AN ASSESSMENT OF THE QUALITY OF PUBLIC, GROUP SCHEME AND PRIVATE GROUNDWATER SUPPLIES IN NORTH COUNTY TIPPERARY
(Draft)

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Glossary of terms and abbreviations used in this report

Chemistry

NO_3	nitrate	*Na*	sodium
HCO_3	bicarbonate	*K*	potassium
SO_4	sulphate	*Mg*	magnesium
Cl	chloride	*Ca*	calcium
		NH_x	ammonium
VOC	Volatile Organic Carbon compounds	*PO_4*	phosphate
BOD	Biochemical Oxygen Demand	*Fe*	Iron
		Mn	Manganese

EU MAC – European Union Maximum Admissible Concentrations
US EPA – United States Environmental Protection Agency

WSS – public water supply scheme
GWS – group water scheme

RPZ – Resource protection zone: 24 RPZs are defined by combining eight aquifer categories, based upon the hydrogeological characteristics and on the value of the resource, with four vulnerability ratings of the source.

An Assessment of the Quality of Public, Group Scheme and Private Groundwater Supplies in North County Tipperary

1: Introduction

1.1 Objectives and Intended Readership

This report aims to provide an overview of the groundwater quality characteristics of public, group scheme and private water supply sources in North County Tipperary. In particular, the objectives of the report are to:

- Compile readily available groundwater quality data for most of the public, group scheme and recently drilled grant-aided private groundwater supply sources in North Tipperary.
- Identify the 'natural' causes of variations in water quality.
- Identify the regional-scale potentially polluting human activities that are considered to have affected water quality across the county.
- Recommend actions with regard to water quality problems or with regard to on-going water quality monitoring programmes.

The report is intended for use by civil engineers, planners, regulators, and hydrogeologists who are considering the regional-scale distribution of water quality across the county. Potential uses of the report include:

- Focussing remedial measures on problem sites;
- Tailoring 'at risk' site monitoring;
- Relating problems to natural aquifer conditions (i.e. resource protection zones, RPZ), anthropogenic pressures, and well construction to guide future planning decisions

Unless augmented by field-based hazard assessments at the supply source(s) in question, this report is not suitable for use in identifying specific issues at individual water supply sources.

1.2 Scope of report

Water quality data (i.e., chemistry and bacteriological data) have been used in this report to enhance the current understanding of:

- The natural groundwater flow regime in the vicinity of the groundwater supply sources.
- The main domestic and agricultural hazards to the regional pattern of groundwater quality.

The data, which are described more fully in section 1.3, come from groundwater sampling rounds of Public (WSS) and Group Water (GWS) Schemes and private boreholes. The main interpretations and conclusions are drawn from analysis of the WSS and GWS data. Results from the analysis of private borehole data are presented primarily to show the difference between the groundwater qualities of the various supply options.

For the purposes of this report, the term 'groundwater quality' relates to both bacteriological and inorganic chemical parameters. Organic chemistry data (e.g. pesticides, petroleum, etc.) are limited and are therefore considered in less detail than inorganic and bacteriological parameters.

Interpretations of the natural groundwater flow regime are based on the 'major ion' chemistry of the samples available. Major ions are the dominant dissolved species in groundwater (Table 1). Study of the 'major ion' chemistry provides a water quality categorisation, or 'chemical signature', for each supply source. This signature can prove useful in the assessment of the overall groundwater flow regime in the aquifers, as well as giving indirect indications of areas of lower groundwater vulnerability. (For example, elevated levels of sodium in relation to calcium can indicate the presence of slow groundwater flow systems and inhibited recharge; such areas will tend to be less vulnerable to groundwater pollution.) Major ion hydrochemistry can also provide valuable information on borehole scaling or well screen corrosion potential, in addition to providing additional information on contamination derived from human activities (e.g. using chloride or nitrate).

Table 1: Major ions occurring in groundwaters.

Positively-charged ions (cations)		**Negatively-charged ions (anions)**	
Ca^{2+}	Calcium	HCO_3^-	Bicarbonate
Mg^{2+}	Magnesium	Cl^-	Chloride
Na^+	Sodium	$SO4^{2-}$	Sulphate
K^+	Potassium	NO_3^-	Nitrate

(Nitrate can occur naturally in groundwater, but generally is an introduced substance)

Interpretations of the main domestic and agricultural influences on groundwater quality in North Tipperary are based on concentration data of the parameters listed in Table 2. These parameters are considered the key indicators of contamination by agricultural activities and domestic wastes (Appendix A, Box A.1).

To assess the data, concentrations of indicator ions/bacteria are compared graphically with European Union Maximum Admissible Concentrations (MACs; Quality of Water Intended for Human Consumption Regulations, 1988 (S.I. No. 81 of 1988)) and with GSI recommended threshold levels. These threshold levels can help to identify sources where significant contamination may be occurring. Levels falling between the threshold and MAC concentrations indicate the presence of contamination, but not, in the strictest sense of the word, ‘pollution’. The distinction between ‘contamination’ and ‘pollution’ is discussed further in Appendix A.

Table 2: Key indicators of groundwater contamination. Summarised from Box A.2 in Appendix A.

Parameter	**Reason for high concentrations to occur**
Nitrate	Inorganic fertiliser or oxidised organic waste.
Chloride	Organic waste source.
Phosphate	Organic waste source.
Ammonia	Source is nearby organic waste. Not from fertilisers.
E.coli / faecal coliforms	Organic waste nearby – usually septic tank system or farmyard.
Potassium and sodium	High potassium concentration indicates organic waste. High K/Na ratio indicates farmyard waste rather than septic tank effluent.
Iron and manganese	Silage or septic tank effluent, milk, landfill leachate or soiled water.

Activities that have pollution potential and are considered likely to influence water quality patterns within North County Tipperary include:

- Landspreading.
- On-site waste disposal systems (e.g. septic tank systems).
- Farmyards.

Landspreading is considered because it is carried out over large areas. The remaining two are considered because, though the areas of individual cases are small, they are widely distributed throughout the county. All three relate to domestic or agricultural activities.

Clearly, there are many other types of potentially polluting activity, such as manufacturing industry and small commercial enterprises, storage tanks, and road runoff. Although individual pollution incidents related to these activities can be serious in terms of public health, they are generally likely to be localised, and will not influence the regional groundwater quality situation across the county. Consequently, such activities are not considered in this report. Furthermore, due to the limited availability of data on organic chemicals (e.g. petroleum products, pesticides, etc.), adequate assessments cannot be made of these activities within the scope of this report.

1.3 Data sources

The inorganic, organic and bacteriological data analysed in this report come from a variety of information sources spanning 1985 to 2001. Sources of data for the Tipperary North Riding area were: the Environmental Protection Agency (EPA), the EU-funded STRIDE Programme, sampling organised by the Geological Survey of Ireland (GSI), and North Tipperary County Council monitoring. The hydrochemical and bacteriological analyses were made on groundwaters coming from Public Water Supply Schemes (WSSs), Group Water Schemes (GWSs) and private sources.

Data were compiled from the sources listed in Table 3. The data have varying degrees of completeness and reliability; issues impacting upon the chemical analyses and their interpretation are discussed in sections 1.4 and 1.5, below.

1.4 Data screening and data accuracy

Public water supply data were screened as follows:

- The results of the EU STRIDE Programme and GSI groundwater monitoring rounds in 1993 and 2000, respectively, are used as the baseline for the standard set of sources and source names.
- The results of the EU STRIDE Programme and GSI groundwater monitoring are used to characterise the natural groundwater signature only if the ion concentrations in the samples are measured with sufficient accuracy. This is determined by checking the sample electroneutrality (or Ionic Balance; see Appendix G). The criterion for acceptance of a sample was that the electroneutrality was within ± 10% of zero (i.e., electrically neutral). All 44 samples conformed to the criterion, with an average ionic balance of –0.1% and standard deviation of 4.2%.
- Faecal coliform and *Escherichia coli* (*E. coli*) data collected by North Tipperary County Council as part of routine monitoring of contaminant indicators (Table 2) are not included if the sample is known to be treated, *unless their presence is positively identified*.
- In cases where treatment of the samples is *unknown*, if levels of faecal coliforms and *E. coli* are non-detectable, the data are not included, and the samples assumed to have been treated. This is because, in treated samples, the absence of bacteria is not of value in determining contamination and contaminant origin unless they are above detection levels.
- Nitrate data reported by the EPA (EPA, in prep.) were in mixed format, since it was a preliminary report (i.e. as mg/l Nitrogen (N) or as mg/l Nitrate (NO_3)). Where it is clear how the nitrate data are presented the data were included in the quality assessment (with the required conversion factors if necessary). Where there were doubts about the units of concentration, the data were omitted.

Group water scheme data screening was as follows:

- GWS samples were measured by the DoELG in 2000-2001. Since the DoELG report is currently in preparation, there is no geographical information about the samples other than the general Townland or Town location. Therefore, they are considered in aggregate and compared with aggregate WSS and private supplies.

Private supply data screening was as follows:

- Private supply data are considered in aggregate and compared with aggregate WSS and GWS data using histograms. The data are assessed ‘as is’; the samples of groundwater are assumed to be untreated.

Table 3: Sources of data for assessing the quality of groundwater supplies in North Tipperary.

All data compiled and used in this report are summarised in Appendices B to K, as indicated in the last column of the Table.

Information source	Analytical laboratory	Analytical parameters			No of samp-les	Ground-water source	Data in Appen-dix
		Inorganic	Organic	Bacterial			
DoELG (Nov 2000 – Jan 2001)	unknown	✓ [3]		✓	129	GWS	E
GSI targeted sampling (Aug 2000)	State Laboratory, Abbotstown, Co. Dublin	✓ [1]		✓	26	WSS	B
EPA (Dec 1999)	EPA, Regional Inspectorate, Butt's Green, Kilkenny		✓ [5]		6	WSS GWS	K
EPA (March 1997 and in prep.)	Compilation of data from different sources	✓ [4]			~300	WSS GWS	-
County Council analyses of Public supplies (1990 – 2000)	State Laboratory, Abbotstown, Co. Dublin	✓ [2]			265	WSS	D
County Council returns from private well-grants (1997 – 2001)	WHB, Public Analyst's Laboratory, University College Hospital, Galway	✓ [3]		✓	262	Private WS	F
EC STRIDE Sub-programme Measure 1 (Sept 1993)	Regional Water Laboratory, Butt's Green, Kilkenny	✓ [2]	✓ [6]	✓	18	WSS GWS	C

Notes:

1. Full suite of ions
2. Major ions and ions indicative of contamination
3. Ions indicative of contamination only (e.g., NO_3, Cl, NH_x, Fe, Mn, Na, K)
4. Nitrates only
5. Pesticides
6. Volatile Organic Carbon (VOC)

1.5 Data limitations

It is not possible for this report to make a full assessment of all the water quality threats posed to the supply sources and aquifers examined. Raw water quality, rather than treated water quality is the main issue under consideration in this report. Additionally, public health issues are not directly considered.

This study relies on existing data, which commonly consists of major ions, total coliforms, and *E. coli* or faecal coliforms. There are a variety of factors that influence the utility and interpretation of the hydrochemistry and water quality data presented in this report. With respect to the different data sources, these include:

Use of existing data

In the majority of cases, sampling protocol and the conditions of sampling (e.g., pumping rate, timing of sampling in the pumping sample) are unknown. For example, some chemical parameters (e.g. iron) can vary in concentration as a function of pumped volume.

Different laboratories may use different methods to establish chemical concentrations. Additionally, older results may have been calculated using less sophisticated and less accurate methods. Sample electrical conductivities (ECs) can be only compared in a semi-quantitative way, since it should be measured at the well head and not in the lab, although they can show that groundwaters from different areas or with different residence times in the aquifer have different characteristics. Likewise, the acidity (pH) measurements that exist for many of the samples have limited value as they are measured in the lab; additionally, limestone groundwaters have a limited and predictable pH range due to the alkalinity of the water.

Mistakes in transcribing data from different sources can occur. Every care has been taken to cross-check the data where possible, but errors may exist.

Lack of physical information

For WSS, GWS and private wells, there is often a lack of data regarding the well construction (e.g., depth, the screened or open interval and the depth to bedrock). This results in ambiguities about which part of the aquifer the groundwater is coming from, the degree of protection afforded by the subsoil cover, and the degree of protection given to the source by good borehole construction and other protection measures.

Table 4: Inventory of Public (WSS) and Group (GWS) Water Scheme groundwater supply sources considered in this report.

See Table 5 and Table 8, respectively, for details of the geological units (bold type) and rock type (italicised) listed in the last column of this table.

Source name used in this report	Source type	GSI well name	Reference from other source [1]	Regional supply scheme	Scheme type	Visited by GSI?	Rate [m^3/d] [2]	Treatment process	Depth hole [m]	Depth to bedrock [m]	Depth lining [m]	Comments	geological unit *rock type*
Aglish	spring	1719SE W062	TN00200 TIN137		WSS	✓	155 MDO	Chlorine	4	~5	n/a	'Eglish' in EC STRIDE	**BK** *LC*
Ballynaclogh	bore		TIN4/5		WSS	✓	341 MDO	None	30.5	u/k	u/k		**LLS** *LM*
Borrisokane	spring	1719SE W061	TN00300 TIN14		WSS	✓	866 MDO	Chlorine, Fluoride	4	~5	n/a		**SV** *LM*
Borrisoleigh	2 bores	2015NW W187/ 188	TN01400 TIN15	Borrisoleigh	WSS	✓	1030 MDO		42, 40.5	12		2 bores pump simul-taneously	**BA** *LM*
Cloghjordan	spring		TN00400 TIN27		WSS	✓	778 MDO	Chlorine	4	u/k	n/a		**WA** *LC*
Clonakenny	bore		TN00700 TIN22		WSS	✓	23 MDO		106.7	u/k	u/k		**LLS/CW** *SS*
Drumbane	bore	2015SW W204	TN01900		WSS		273 YT				u/k	Source closed?	**CA/LLS** *SS*
Holycross	bore		TN02000 TIN37		WSS	✓	350 MDO	Chlorine	34.2	u/k	u/k		**AG** *LM*
Kilcommon	bore		TN01500 TIN38		WSS	✓	218 OT	None	25.9	u/k	u/k		**HF** *MS*
Littleton	bore	2015SE W207	TN02100 TIN47		WSS	✓	170 OT	Chlorine	45.7	u/k	u/k		**AG** *LM*
Lorrha	bore	1719NE W058	TIN48		WSS	✓	280 MDO	Chlorine	16.9	~12.5	u/k		**CDlr** *LM*

[1] **Note:** may be more than one reference if the data source is a compilation.
e.g., TIN001; three-digit EPA plot number used in 'Nitrates in Groundwater, Tipperary (NR)' (EPA 1997).
e.g., TN02200; five-digit reference number in 'EC STRIDE Environment Sub-Programme Measure 1' (Kilkenny Regional Water Lab., 1993) and also for 'Pesticides in Groundwater' (EPA, 1999).
e.g., TN001 to TN041; three-digit sample number in 'Private Group Water Schemes: National Monitoring Project' (DoELG, in prep.)

[2] **MDO** signifies mean daily output computed over one calendar year;
YT signifies rate from yield test;
OT signifies pumping rate derived from other sources.

Source name used in this report	Source type	GSI well name	Reference from other source [1]	Regional supply scheme	Scheme type	Visited by GSI?	Rate $[m^3/d]$ [2]	Treatment process	Depth hole [m]	Depth to bedrock [m]	Depth lining [m]	Comments	geological unit *rock type*
Loughmore	bore	2015NW W156		Templemore								Source closed.	**BA** *LM*
Moycarky – Curraheen	bore		TN02200 TIN50		WSS	✓	180		28.4	u/k	u/k	Not Horse & Jockey	**DW/AG** *LM*
Rathcabban	bore	1719NE W070	TIN59		WSS	✓	100-132 MDO	Yes, but u/k	54.9	u/k	u/k		**CDlr** *LM*
Riverstown	spring	2019NW W118	TN00100 TIN85		WSS	✓	155 [MDO]	Chlorine	2.5	u/k	n/a		**WA** *LC*
Roscrea-Glenbeha	spring		TN00500 TIN64	Roscrea	WSS	✓	1000 [MDO]	Chlorine	u/k	u/k	n/a	Three springs.	**CW** *SS*
Templederry	bore	1715NE W086	TIN68		WSS	✓	82 [MDO]	None	21.3	≥ 10	u/k	Depth 15.9 and dtb 14?? Plans to treat supply	**HF** *MS*
Templemore	2 bores	2017SW W187, W232	TN01000 TIN69	Templemore	WSS	✓	2180[MDO]	Chlorine	72.5, 86	~3		Pumped from each bore alternately	**BA/BAld** *LM*
Templetouhy	2 bores	2017SW W057/ W058	TN00900 TIN70	Templemore	WSS	✓	2182 [YT] 800 [YT]		60 36	3 7	4.5 7	Source closed.	**WA** *LC*
Terryglass	bore	1719NE W067	TIN71		WSS	✓	62 [MDO]	Chlorine	u/k	u/k	u/k	treated sample	**WA/TS** *LC*
Thurles – Creamery	spring		TN01700 TIN132	Thurles UDC	WSS	✓	1400 [MDO]	Chlorine	4	0[3]	n/a	dug into bedrock	**WA** *LC*
Thurles – Lady's Well	spring	2015SW W206	TN01800 TIN75	Thurles UDC	WSS	✓	600 [MDO]	Chlorine	u/k	u/k	n/a	Treated prior to reservoir	**WA** *LC*
Thurles – Tobernaloo	spring	2015SW W195	TN01600 TIN74	Thurles UDC	WSS	✓	900 [MDO]	Chlorine, Fluoride	5	~5	n/a		**WA(do)** *LC*
Toomyvara	spring	1717SE W164	TIN76		WSS	✓	145 [MDO]	Chlorine	n/a	~4.5	n/a		**CW** *SS*
Tullahedy	bore		TIN78		WSS	✓	136	Chlorine	38.1	u/k	u/k		**WA** *LC*
Two-Mile-Borris	bore	2015SE W199	TIN79		WSS	✓	120 [MDO]	Chlorine	28.7	<3	u/k		**AG** *LM*
Upperchurch	bore	1715NE W041	TIN80		WSS	✓	23 [OT]		35.1	u/k	u/k		**HF** *MS*

Group water schemes listed in the following table are a subset of those analysed. Only those for which the GSI holds information are listed here; the full list along with water quality data is included in Appendix E.

Source name used in this report	**Source type**	**GSI well name**	**Reference from other source** [1]	**Regional supply scheme**	**Scheme type**	**Visited by GSI?**	**Rate** $[m^3/d]$ [2]	**Treatment process**	**Depth hole [m]**	**Depth to bedrock [m]**	**Depth lining [m]**	**Comments**	**geological unit** ***rock type***
Ballycasey			TN034		GWS							To be taken over by Co. Co. in 2002.	
Castlecranna	bore	1717SW W071	TN003		GWS		240 [OT]		76.2	u/k			
Curryquinn			TN016	Nenagh	GWS							Source closed.	
Garrynamona			TN015		GWS							Three sources.	
Graigue/ Pouldine	bore	2015SW W205	TN019A		GWS		327						
Killahara			TN014		GWS							Source closed.	
Knock	bore		TN00600 TIN84	Knock	GWS							Not known by Co. Co.	
Lordspark			TN028	Lorrha	GWS							Source closed.	
Tougher	bore		TN00800	Tougher	GWS				17[3]			uncertain depth[3]	

2: Natural groundwater quality and characteristics

2.1 Introduction

Pure water, in a chemical sense, is not found in nature, even in areas remote from development. Natural water contains both dissolved and suspended solids – which may be of organic or inorganic origin – gathered by the water on its way through the atmosphere and from the soil on its way to a stream, river, lake or the water table (EPA, 1999).

This chapter describes the natural characteristics of the groundwaters in North Tipperary. The rock types through which the groundwater flows impart a distinct chemical signature to the groundwater. For example, limestone bedrock and limestone-dominated subsoils are common in Ireland and consequently groundwater is often hard, containing high concentrations of calcium, magnesium and bicarbonate. However in areas where volcanic rocks or granites are present and in many sandstone areas, soft water is normal (Daly, 1994). The hydrochemistry can be further modified naturally by the residence time of the groundwater in the subsurface which, amongst other effects discussed below, influences the amount of rock that dissolves in the groundwater. To assist the interpretation of the natural groundwater characteristics, a brief overview of the geology of North Tipperary is given first (section 2.2), and then followed by a quantitative analysis of the groundwater chemistry (sections 0 to 2.6)

2.2 Overview of the geology of North Tipperary

The geology of North Tipperary, as it relates to controls on the hydrogeology of the county, is described in detail in the North Tipperary Groundwater Protection Scheme Main Report (Hunter Williams, Motherway and Wright, 2002). This section provides a brief summary and tabulates important rock and sediment types that groundwater is abstracted from (Table 5). The rock unit codes in Table 5 are referred to in Table 4.

The rocks of North Tipperary are mainly sedimentary in origin, consisting of limestones, sandstones and shales. The bedrock geology of the area is shown in Figure 1. The landscape reflects the varied underlying geology; where underlain by limestones, the terrain is generally flat to undulating. However, it rises dramatically in areas underlain by Old Red Sandstone and Silurian sediments such as the Slievefelim Mountains, the Arra Mountains, the Silvermine Mountains, the Knockshigowna area and the hills just south of Roscrea.

The rocks range in age from Silurian, through the Devonian Old Red Sandstones (ORS) to rocks deposited during Lower Carboniferous (Table 5). The rocks were folded and faulted in response to two deformation events, which originated to the south of Ireland. The intensity of rock deformation generally decreases northwards throughout the county.

The regional structure of the area has been influenced by two major mountain building events: the Caledonian and Variscan Orogenies. Caledonian deformation affected the Silurian rocks, which are tightly folded in a northwest-southeast direction. The Variscan Orogeny deformed the Devonian and Carboniferous rocks, resulting in large amplitude and wavelength folds. With both the early and late folding, associated tension jointing is found and is most intense at the peaks and troughs of folds. Later faulting occurs along a regional northwest-southeast trend. These faults are generally planar and near vertical and result in many lithologies being compartmentalised or isolated, with the result that the geology in some areas can be very varied or heterogeneous.

Table 5: Summary of geological units in North Tipperary intersected by the WSS boreholes/springs listed in Table 4.

Rock unit code	Aquifer code	Rock unit/ Formation	Geological age	Description
CDlr	Ll	Lorrha Calp	Lower Carboniferous	*Well-bedded limestones with rare thin shales:* medium grained calcarenite with frequent bands and nodules of chert. Beds range from 0.5 to 1m thick. Rare shale beds are 2cm to 20cm in thickness.
AG	Ll	Aghmacart Formation		*Shaly micrite and peloidal limestones, often dolomitised.*
BK	Rf	Borrisokane Calcarenite Formation		*Limestones:* coarse, occasionally medium grained, well-sorted calcarenite. Bedding planes are usually 1m apart and are generally irregular.
SV	Ll	Slevoir Limestone-Shale Formation		*Homogenous clayey limestones and calcareous shales* in equal proportions. Bed thicknesses range from cms-1 m.
TS	Rf	Terryglass Calcarenite Formation		*Limestones:* very well sorted, medium to fine grain carbonate 'sands'. Thickly bedded (0.5-2.0m) with irregular bedding planes.
WA WAdol	Ll Rf	Waulsortian Limestone/ dolomitised WA		*Limestones:* accumulations of massive steep-sided carbonate mud mounds that coalesce into a thick unit surrounded by varied but related limestones. Expressed topographically as abrupt and rounded hills or knolls.
BAld	Lm	Lisduff Oolite Member		*Limestones:* thick, cross-bedded, well-jointed oolite and crinoidal grainstone. Occur especially around Templemore.
BA	Ll	Ballysteen Formation		*Muddy limestones:* well-bedded, ca. 0.5m thick beds. Formation informally subdivided: the upper Ballynash Member, and the lower Lisduff Oolite Member.
LLS	Pl	Lower Limestone Shale		*Grey sandstones, siltstones and shales:* mark the transition from the Old Red Sandstones and the ensuing limestone sequence.
ORS	Ll	Red Sandstones	Devonian	*Purple, red and grey sandstones, siltstones and conglomerates with interbedded mudstones*
CA	Ll	Cappagh White Sandstone Formation		*Coarse conglomerates overlain by red sandstones and interbedded black mudstones*
CW	Rf	Cadamstown Formation		*Medium to coarse grained pale sandstone with siltstones and mudstones*
HF	Pl	Hollyford Formation	Silurian	*Mudstones interbedded with thin siltstones and/or laminated siltstones* predominate in some sections; in others, mudstones and siltstones are interbedded with numerous thin, fine sand-grade sandstones. Coarser and thicker-bedded sandstones appear to be randomly distributed throughout the formation.

younger ← → older

The rock types are listed in order from older rocks (Silurian) at the bottom of the table to the younger rocks (Carboniferous) at the top.

2.3 Aquifer Categories

Also included in Table 2 are the aquifer codes assigned to the different rock types (see Chapter 3 in the Main Report, "North County Tipperary Groundwater Protection Scheme" for details). The aquifer map for North Tipperary is shown in **Error! Reference source not found.**.

The GSI aquifer classification (DoELG/EPA/GSI, 1999) has three main aquifer categories, with each category sub-divided into two or three classes:

Regionally Important (R) Aquifers
- (i) Karstified bedrock aquifers (**Rk**)
- (ii) Fissured bedrock aquifers (**Rf**)
- (iii) Extensive sand/gravel aquifers (**Rg**)

Locally Important (L) Aquifers
- (i) Sand/gravel (**Lg**)
- (ii) Bedrock which is Generally Moderately Productive **(Lm)**
- (iii) Bedrock which is Moderately Productive only in Local Zones **(Ll)**

Poor (P) Aquifers
- (i) Bedrock which is Generally Unproductive except for Local Zones **(Pl)**
- (ii) Bedrock which is Generally Unproductive **(Pu)**

2.4 General natural water quality characteristics

Twenty-six supply sources have a full analysis suite for which the results are acceptably accurate (see section 1.3 and Appendix G for details). Data for these public water scheme supplies, which are listed in Table 4, come from the sampling round conducted by the GSI in August 2000 (Appendix B) and from sampling conducted in 1993 for the EC STRIDE Programme (Appendix C). Sixteen of the 26 supplies were sampled twice or more[3], with the remainder being sampled only once[4]. Therefore, there are a total of 44 groundwater chemical analyses that have been used to interpret the natural groundwater quality characteristics of North County Tipperary.

Groundwater chemical signature

To ascertain the chemical 'signature' of the groundwaters, data from these supplies are presented on a Durov diagram in Figure 3 (see Appendix H for an explanation of the Durov diagram). The data are also included in graphs presented in Figure 6 to Figure 31.

Of the 26 supply sources, 23 have a 'calcium-bicarbonate' chemical signature (Figure 3). Essentially, this means that calcium (Ca) and bicarbonate (HCO_3^-) are the dominant ions dissolved in the groundwater (see Table 1). The presence of such a signature does not aid significantly the interpretation of groundwater flow patterns where limestone is the dominant rock type, as in much of North Tipperary.

However, several of the groundwater supplies are not extracted from limestone bedrock. For example, the sources at Templederry, Kilcommon and Upperchurch extract groundwater from Silurian sandstones, siltstones and mudstones (see Table 5). The likely explanation for the 'limestone' signature of these waters is that the dissolved calcium/magnesium carbonate comes from the overlying Quaternary deposits[5], as recharge to the aquifer passes through the calcareous subsoils. Conductivities in the samples are low, typically ranging between 300 and 400 μS/cm. This suggests that these

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[3] Borrisokane and Littleton were sampled three times.
[4] Sources sampled only once are: Ballynaclogh, Lorrha, Loughmore, Templederry, Terryglass, Toomyvara, Tullahedy, Two-Mile-Borris and Upperchurch (in August 2000), and Drumbane (in 1993).
[5] This material was deposited in the last glaciation and, since limestone is widespread in the country around the Silurian Slieve Felim Mountains, movement of the ice sheets could carry significant amounts of calcareous material onto the uplands.

groundwaters have short residence times and largely contain the more readily-dissolved ions such as calcium and bicarbonate.

The remaining three supplies fall into the more unusual 'calcium-magnesium-bicarbonate' category. Clonakenny WSS (two samples, in 1993 and 2000); Drumbane WSS (sampled in 1993) and Terryglass WSS (sampled in 2000).

At Clonakenny and at Drumbane, this signature is considered to be diagnostic of 'ion exchange' processes in the Lower Limestone Shale and the Cadamstown/Cappagh White Formations, which comprise layered sequences of sandstone, siltstone and mudstone/shale. Evidence of this type of process is relatively rare in Ireland, and usually indicates less vulnerable groundwater with slower, longer flow pathways.

Very low (3 samples) or non-detectable (5 samples) nitrate levels in samples taken at Clonakenny in the period 1993–2000 (Figure 10) also indicate a longer groundwater residence time and slower flow in the aquifer around Clonakenny. Ammonia levels over the same period generally increase, with two samples exceeding the GSI threshold of 0.15mg/l. Significant ammonia concentrations in groundwater at this supply indicate that a source of nitrogen is readily available. The ammonia may not come from human activities but be derived naturally from the shales in the Lower Limestone Shale and the Cadamstown Formation, although the presence of *E. coli* indicates that a pathway(s) from a contamination source(s) exists.

At Drumbane, although faecal coliform and ammonia concentrations are zero or negligible, an average nitrate concentration of 11.7 mg/l indicates that a component of modern (post-1950s) recharge reaches the borehole in addition to the older groundwaters suggested by ion exchange.

In contrast to the sources at Clonakenny and Drumbane, Terryglass WSS apparently extracts water from a Waulsortian Limestone aquifer. However, the relative proportions of calcium and magnesium in the Terryglass water are more similar to groundwaters abstracted from the muddy limestones of the Durrow and Aghmacart Formations at Holycross, Littleton and Moycarky (Curraheen) than to other groundwater samples from Waulsortian Limestone aquifers. The signature is therefore not easy to explain, but may indicate that some of the groundwater is coming from the Slevoir Limestone Shale aquifer that is mapped as occurring about 0.5 km to the north. The well depth and construction are unknown, so further assessment is not possible. The origin of the relatively high sodium concentration in the Terryglass groundwater is also unknown, but could indicate that water is being drawn from deep within the aquifer where groundwater flow is slow, and ion exchange has occurred.

Hardness

Of the 26 supplies fully sampled, waters in about 58% can be described as 'excessively hard', 22% as 'hard', 10% as 'moderately hard', 10% as 'slightly hard' (Table 8, and Figure 4). The hardest groundwaters are found at Loughmore, around Thurles, Lorrha and Templetouhy in both clean and shaly limestones, and the softest groundwaters are abstracted from sandstones and mudstones, at Templederry, Clonakenny and Kilcommon.

Iron and manganese

Iron concentrations range from 1.17 mg/l to undetectable (i.e. less than 0.005 mg/l). Typical concentrations are on the order of 0.01 mg/l, with most samples in the range 0.01 mg/l to 0.1 mg/l. The highest iron concentrations were measured at Borrisokane (1.167 mg/l), Terryglass (1.02 mg/l) and Lorrha (0.79 mg/l). (However, at Borrisokane and Terryglass, all other samples are very low or <MDL.) Elevated iron concentrations are also detected at Roscrea (Glenbeha), Toomyvara and Borrisoleigh.

Concentrations of manganese range from undetectable (less than 0.005 mg/l) to 0.345 mg/l. Manganese concentrations are commonly less than 0.005 mg/l (90% of sources in August 2000, 60% in 1993). Elevated manganese concentrations occur especially in groundwaters at Aglish, Borrisokane and Lorrha WSSs, and also at Rathcabban and Clonakenny.

Both parameters are discussed further below, in section 3.6.

Sulphate and Chloride

Sulphate concentrations range from 3 mg/l to 65 mg/l, but are typically (circa 70%) 10 to 20 mg/l. The highest sulphate concentrations were recorded at Lorrha, Templemore and Templetouhy, and seem to be associated with muddy limestones and some of the Waulsortian Limestone aquifers. Low concentrations occur at Kilcommon, Upperchurch and Templederry, where groundwater comes from the Silurian mudstones and siltstones.

Chloride concentrations range from about 10 mg/l to 35 mg/l, with an average concentration of about 20 mg/l. Many samples (62%) are between 15 and 25 mg/l. Chloride is a constituent of organic wastes and levels higher than 25 mg/l may indicate contamination, and away from coastal areas, concentrations higher than 30 mg/l usually indicate significant contamination. This parameter is discussed further in section 3.3, below.

Other parameters

In all sources sampled, the parameters listed in Table 6 are less than the method detection limit (MDL) or significantly less than the Maximum Admissible Concentration (MAC).

Table 6: Parameters tested for, but either not detected in groundwaters from North County Tipperary WSSs, or significantly less than the MAC level.

Parameter	MDL [mg/l]	MAC [mg/l]	Sample status
Aluminium	<0.02	0.2	< MDL
Antimony	<0.02		< MDL
Arsenic	<0.05		< MDL
Cadmium	<0.005	0.005	< MDL
Chromium	<0.005	0.05	< MDL
Lead	<0.02	0.05	< MDL
Total Phosphorus	<0.25	2.18	< MAC
Selenium	<0.05		< MDL
Silver	<0.005	0.01	< MDL
Boron		2	<< MAC
Copper		3	<< MAC
Nickel		0.05	<< MAC
Zinc		5	<< MAC

However, there are several parameters for which concentrations exceed or closely approach the MAC level in certain sources. These are detailed in Table 7. Implications for health are discussed in section 2.6.

Table 7: Parameters that are present in concentrations that exceed, or closely approach, the MAC level in groundwaters from North County Tipperary WSSs.

Parameter	MAC [mg/l]	Source location(s)	Concentration [mg/l]	Concentration range of remaining samples [mg/l]
Barium	0.5	Clonakenny Roscrea – Glenbeha	1.690 0.495	0.004 – ~0.2
Strontium	no limit set	Clonakenny Templemore Lorrha	1.938 0.577 0.465	0.108 – 0.255
Fluoride	1.0	Lorrha	0.91	<0.25 – 0.34

2.5 Comparison of natural groundwater quality and rock type at selected supply sources

To contextualise the natural groundwater characteristics, the 26 WSS sources sampled have been classified into four broad rock type categories, which are defined on the basis of the bedrock geology. The rock types at each WSS source are also indicated in Table 4:

- **LC:** clean limestone (e.g., Waulsortian [WA], Table 5);
- **LM:** muddy/shaly limestone (e.g., Ballysteen Formation [BA]);
- **SS:** Carboniferous and Devonian layered sandstone/ siltstone/ mudstone sequences (e.g., Lower Limestone Shales [LLS], Cadamstown Formation [CW]).
- **MS:** Silurian layered mudstones and siltstones (i.e. Hollyford Formation [HF]).

In most cases, groundwater is abstracted from a bedrock aquifer. There are sources, however, that are thought to partially derive groundwater from overlying (Quaternary) sand and gravel deposits, for example, Templederry and Borrisoleigh.

A summary of the main water quality characteristics as a function of the local rock type is presented in Table 8.

2.6 Summary of natural groundwater characteristics

Analysis of data from two sampling rounds encompassing 26 WSSs in North Tipperary indicates the following:

- The dominant chemical signature (88%) in the sources under consideration is 'calcium-bicarbonate'. This is typical of Irish groundwaters.
- Median sulphate and chloride concentrations are typical of groundwaters in the Irish Midlands.
- Waters in sources drawing groundwater from limestone aquifers are hard or extremely hard. Sources in layered sandstone, siltstone and mudstone range from slightly hard to hard.
- As expected, calcium, magnesium and bicarbonate concentrations are highest in limestone aquifers. Sulphate is also higher in limestone aquifers than in sandstone or mudstone areas.
- Iron concentrations are higher on average in sandstone aquifers, and probably derives from iron minerals that coat the sand grains.
- Because of their association with groundwater contamination, it is not possible to comment on the relative concentrations with respect to bedrock aquifer type of potassium, chloride and manganese, although manganese does seem to be naturally occurring in the Lorrha Calp and other muddy limestones.

Major and commonly occurring ion concentrations are generally within expected and acceptable ranges in the 26 supply sources. However, there are a number of parameters, such as hardness, iron and manganese, whose presence in groundwaters at significant levels can be a nuisance rather than harmful to health.

- Hard water causes limescale in boilers, kettles and on bathroom fittings. High concentrations of iron and manganese cause mainly aesthetic problems, with water looking 'rusty', and possible 'spotting' of laundry. In some parts of the county, these parameters reach significant concentrations.
- Engineering aspects of high levels of iron and manganese include the potential for biofilm growth in water wells – bacteria use these metal ions to grow. The bacterial colonies, whilst not harmful to humans, can cause blockage of the well screen, leading to decreased efficiency (e.g., Driscoll, 1986). Excessive water hardness can also cause well screen blockage due to the precipitation of calcium carbonate ($CaCO_3$) from solution.

Of particular concern are the concentration levels of minor ions in several of the sources (see Table 7):

- At Clonakenny, the barium concentration exceeds the EU MAC level of 0.5 mg/l, and at nearby Glenbeha (Roscrea), the concentration closely approaches it.
- At Lorrha, fluoride concentrations are close to the EU MAC of 1 mg/l. Whilst this is less than the concentration in artificially fluoridised waters, it is important to know the amount of fluoride in water used by children to which extra fluoride may be added, since excessive fluoride causes mottling of tooth enamel. Teeth can also become brittle due to a decrease in tooth density.

Table 8: Variation in groundwater quality and characteristics as a function of rock type category.

Rock type category	Number of supply sources	Number of supply sources in: Hardness category				Number of supply sources in: Chemical signature category		Median major ion and other commonly-occurring ion concentrations for each rock unit category [mg/l] [4]										
		Excessively hard (>350 mg/l)	**Hard** (251-350 mg/l)	**Moderately hard** (151-250 mg/l)	**Slightly hard** (101-150 mg/l)	**Calcium-bicarbonate**	**Calcium-Magnesium-bicarbonate**	**Ca**	**Mg**	**K**	**Na**	**HCO_3**	**SO_4**	**Cl**	**NH_x**	**Fe**	**Mn**	**EC [µS/cm]**
LC: Clean Carboniferous limestones	9	7.5 *(83%)*	1.5 [1] *(17%)*			8	1	121.5	22.3	3.7	10.7	417.0	12.3	23.6	< 0.015	0.024	0.006	740
LM: Muddy/ shaly Carboniferous limestones	9	8 *(89%)*	1 [2] *(11%)*			9		118.0	22.5	1.7	9.6	417.0	15.2	21.0	< 0.015	0.027	0.030	734.0
SS: Carboniferous/ Devonian layered sand-stone/ siltstone/ mudstone	4		2 *(50%)*	1 *(25%)*	1 *(25%)*	2	2	77.8	10.9	3.7	10.0	314.6	4.1	18.8	< 0.015	0.113	0.05	532.5
MS: Silurian layered mudstones and siltstones	4		1 *(25%)*	1.5 *(37.5 %)*	1.5 [3] *(37.5 %)*	4		54.6	9.0	0.7	8.6	189.0	5.5	11.4	< 0.015	0.05	< 0.005	325.0
Total	26	15.5 *(60%)*	5.5 *(21%)*	2.5 *(9.5%)*	2.5 *(9.5%)*	23 *(88%)*	3 *(12%)*											

Notes:

1) Aglish groundwater analysed three times; on 2 occasions the hardness was 'hard' and once 'excessively hard'. Riverstown sampled twice, with hardness ranging between 'hard' and 'excessively hard'.
2) Groundwater abstracted at Borrisoleigh and Moycarky ranges between 'hard' and 'excessively hard'.
3) Kilcommon water hardness, sampled twice, ranged between moderately hard and hard.
4) Ca: Calcium; Mg: Magnesium; Na: Sodium; K: Potassium; HCO_3: Bicarbonate – alkalinity; SO_4: Sulphate; Cl: Chloride; Fe: Iron; Mn: Manganese; EC: Electrical conductivity.

3: Indicators of groundwater contamination

3.1 Introduction

As human activities have had some impact on a high proportion of groundwater in Ireland, there are few areas where the groundwater is in pristine condition. Consequently, most groundwater is contaminated to some degree, although it is not necessarily polluted (see Appendix A for discussion). In assessing groundwater quality, there is often a tendency to focus only on the EU maximum admissible concentrations (EU MACs). In the view of the GSI, there is a need for an assessment of the degree of contamination of groundwater as well as showing whether the water is polluted or not. This type of assessment can indicate where appreciable impacts are occurring. Consequently, thresholds for certain parameters can be used to help indicate situations where significant contamination, but not pollution, is occurring. The thresholds used by the GSI for assessing water quality are given in Table 9.

Other parameters which can also be useful indicators of contamination include ortho-phosphate (threshold 0.02 mg/l, MAC 5 mg/l as PO_4), manganese (MAC and threshold of 0.05 mg/l) and iron (MAC and threshold of 0.2 mg/l).

Table 9: GSI thresholds and EU MACs for selected analytes

Parameter	GSI Threshold [mg/l]	EU MAC [mg/l]
Nitrate	25	50
Potassium	4	12
Chloride	30	250
Ammonia	0.15	0.4
K/Na ratio	0.3	–
Faecal bacteria	0	0

The key indicators of domestic and agricultural contamination for each supply source are plotted graphically (Figure 6 to Figure 31), along with the corresponding MAC and GSI threshold levels. All available data from 1985 to 2001 for the 26 supply sources listed in Table 4 were used in this assessment, subject to the screening criteria detailed in section 1.4. Concentrations in North County Tipperary of the various contamination indicators are reported in sections 3.2 to 3.6, below, together with an overview of the significance of the contaminant. Some of the text is adapted from the EPA report "Water Quality in Ireland 1995-1997" (1999). Further information on the use of these parameters in assessing groundwater quality is given in Appendix A.

3.2 Microbiological contaminants

From the perspective of human use and consumption of groundwaters, the most important consideration is the absence of pathogenic organisms, i.e. those organisms capable of infecting, or of transmitting diseases to, humans. The most common health problem arising from the presence of faecal bacteria or other pathogens in groundwater is diarrhoea, but typhoid fever, infectious hepatitis and gastrointestinal infections can also occur. The universal indicator organisms for the presence or absence of pathogens originating in sewage are the coliforms, specifically *E. coli*. These bacteria are of definite faecal origin (human and animal). Their presence in samples from groundwater supply sources is proof that faecal contamination has occurred and indicates that either:

- Organic wastes have entered the groundwater from a nearby hazard which is in an area where groundwater vulnerability is extreme or,

- A nearby point hazard exists, where the point of release of contamination is several metres underground, or,
- Contaminated surface washings have entered the spring or well directly.

The absence of faecal coliforms must be demonstrated as an assurance of the minimisation of this potential. The natural environment, in particular the soils and subsoils, is effective in removing bacteria and viruses by predation, filtration and absorption. However, bacteria can move considerable distances in the subsurface, given the right conditions. In a sand and gravel aquifer, coliform bacteria were isolated 100 ft from the pollution source 35 hours after the sewage was introduced (Hagedorn, 1983). They can rapidly travel several kilometres in karstic aquifers. There are three high risk situations: (i) where permeable sands and gravels with a shallow water table are present; (ii) where fractured rock, particularly limestone, is present close to the ground surface; and (iii) where poor sanitary construction allows direct ingress of contaminated surface water to the well or spring. The presence of clayey gravels, tills, and peat will, in many instances, hinder the vertical migration of microbes, although preferential flow paths, such as cracks in clayey materials, can also allow rapid movement by bypassing the subsoil.

Occurrence in WSSs

Levels of contamination by coliforms of faecal origin at individual WSS sources are shown in Figure 6 to Figure 31. These data are from every raw sample taken, and from treated samples in which the coliform count is greater than zero.

Figure 32 shows the results of two sampling rounds on WSSs carried out for faecal coliforms in untreated groundwater samples in September 1993 (for the EC Stride project) and in August 2000 (by the GSI). In 1993, of 17 sources sampled, 53% had no faecal coliforms. The remaining 9 samples had coliforms of faecal origin in concentrations ranging from 1 to 13 per 100 ml. The GSI sampling round sampled 25 sources at which non-treated samples were obtainable. Of these, 64% (16 samples) were uncontaminated. In the remaining 36% of samples, faecal coliform concentrations ranged from 1 to 30 coliforms per 100 ml.

Seventeen of the 26 WSSs sampled are boreholes, and nine are springs. The results of the two sampling rounds show that, in November 1993 and August 2000,

- Five of the 17 boreholes were contaminated by faecal bacteria at least once. All five boreholes (Borrisokane, Holycross, Littleton, Loughmore, Templemore) extract water from muddy limestones (LM) classified as Ll or Lm aquifers.
- Five of the nine springs were contaminated at least once – four of the springs (Aglish, Riverstown, Thurles – Creamery, Thurles – Lady's Well) are fed by groundwater from clean limestone Ll/Rf bedrock aquifers, with the remaining spring (Roscrea – Glenbeha,) sourced from a layered sandstone Rf aquifer.
- No borehole sources in clean limestone (LC) or Carboniferous sandstone (SS) aquifers were contaminated; one of the two springs in sandstone aquifers was uncontaminated, as were two of the six springs in clean limestone aquifers, and the one spring emerging from muddy limestone Ll aquifer.
- No contamination was detected in the four WSS boreholes (at Ballynaclogh, Kilcommon, Templederry and Upperchurch) located in fractured Silurian siltstone and mudstone (MS) Pl aquifers.

Available *E. coli* results, although mainly relating to treated samples, indicate that in addition to the sources found to be contaminated by faecal coliforms, the boreholes at Clonakenny, Drumbane (both sandstone/ siltstone Pl aquifers) and Terryglass (clean limestone Ll aquifer) are also vulnerable to contamination by a source of definite faecal origin.

Considering all available samples and not just those in the baseline EU Stride and GSI sampling rounds of 1993 and 2000, sixteen of the 26 sources have been contaminated (Table 6), and six sources had faecal coliform concentrations higher than 10 counts per 100 ml, which is described as ‘gross contamination' by the EPA (reference needed). These sources are Aglish, Borrisoleigh, Riverstown, Roscrea (Glenbeha), Toomyvara and Two-Mile-Borris. Excepting Riverstown, where 30 counts per 100 ml were recorded in August 2000, all the other 'gross contamination' incidents were recorded before July 1995. Summary data are included in Table 10.

Variation with time

Data are generally not sufficient enough for a detailed assessment of the variation of faecal coliforms over time. However, apparent downward trends can be tentatively determined at Aglish, Borrisokane, Borrisoleigh, Clonakenny, Roscrea (Glenbeha), Templemore, Toomyvara, and Two-Mile-Borris. An increase in time of coliforms of faecal origin *may* be occurring at Riverstown.

Relationship between faecal coliform levels, attenuation potential in the groundwater pathway and well construction

As described above, conditions favourable to the entry of faecal coliforms to water supplies relate to the groundwater pathway (vulnerability and aquifer type), but also to poor well construction and well protection measures. The latter are more significant for faecal coliforms than for other common contaminants because the dilution effect of surface washings entering a volume of groundwater in a well will be insufficient to reduce faecal coliforms to acceptable levels.

Well details other than the depth to rock are not available for most of the wells. The springs at Aglish, Borrisokane, Toomyvara and Riverstown are all chambered in concrete and apparently well-protected. Many springs are situated in low-lying boggy ground, with depths to rock of around 5-10 m, and surrounded by grazing or farmland. The springs at Riverstown and Thurles Creamery are in less rural areas. Riverstown WSS is near to a sewage pumping station and also considered susceptible to road runoff; hazards noted at the Creamery WSS include the creamery and a nearby dump. Boreholes that are constructed to proper well standards (e.g., Borrisoleigh and College Hill) have also been contaminated in the past, showing that surface water ingress is not the only contaminant pathway to the borehole. Point hazards (e.g., septic tanks) or diffuse sources (e.g., manure) are the most likely origin in the sources listed of the faecal coliforms, which travel quickly through the fractured aquifers.

The results discussed above are presented in the context of aquifer type (e.g., fissured bedrock aquifer) and aquifer vulnerability in Table 10 and Chapter 4:.

Comparison of coliform contamination levels in WSSs with GWSs and private supplies

To make a general assessment and comparison of the degree of contamination in WSSs, GWSs and private water supplies, coliform concentrations (*E. coli*, faecal and Total coliforms) in all samples (subject to screening, see section 1.4) are shown graphically in Figure 33. Figure 34 shows the total coliform count.

The results indicate that the private grant-funded wells are less often contaminated than WSSs. *E. Coli* were detected in only 8.8% (9/102) of private wells that were sampled. This figure compares with 50% (13) of WSSs testing positive at least once for either *E. coli* or faecal coliforms. However, private wells were sampled only once (potentially resulting in missed contamination episodes), and the grossest level of contamination was found in a private well, with an *E. coli* count of 2420/100 ml measured at Carrig near Birr.

40% (10/25) of WSSs have been contaminated at least once by faecal coliforms (16/26, 62% by either *E. coli* or faecal coliforms) in comparison with 58% (22/38) of GWSs. More extreme levels of contamination are detected in WSS sources, however.

Total coliform levels give an indication of the *general* level of microbiological contamination of groundwater at a source, since not all coliform organisms are of faecal origin. The graph on Figure 34 shows that the most extreme general coliform counts have been encountered in WSS and private wells.

3.3 Chloride

The principle source of chloride in uncontaminated groundwater is rainfall. In any region, depending on the distance from the sea and evapotranspiration, chloride levels in uncontaminated groundwater will be fairly constant (generally below 30 mg/l in central Ireland). Chloride, like nitrate, is a mobile cation. It is a constituent of organic wastes and levels appreciably above background levels (say in excess of 30 mg/l) have been taken to indicate contamination by organic wastes such as on-site systems (septic tanks). It is worth noting that chloride can also be derived from potassium fertilisers (Sherwood, 1991).

Concentrations of chloride in groundwater vary and what is important is not the absolute level, but rather the relative levels from one sampling period to the next. A high level or a significant increase may give rise to suspicions of pollution from sewage. Under EU regulations, the MAC value for chloride is 250 mg/l Cl.

Occurrence in WSSs

The average chloride concentration in North Tipperary groundwaters is about 22 mg/l (standard deviation 6.5 mg/l), with concentrations ranging between 10.4 mg/l and 35 mg/l.

Summary water quality information for each supply source is presented in Table 10. Of the 26 sources examined, four have chloride levels above the GSI threshold. WSS sources at which concentrations are greater than 30 mg/l, or which vary significantly are: Aglish, Borrisokane, Cloghjordan, Riverstown, Templemore, Templetouhy, Terryglass and Loughmore. Six of these sources have also shown *E. Coli* or faecal coliform contamination at least once (Table 10).

Variation with time

All[6] the sources listed above show a decrease in groundwater chloride concentration between 1993 and 2000, and no chloride concentrations above 30 mg/l were measured in August 2000, indicating that possible aquifer contamination may be decreasing with time at some sources.

Relationship between chloride levels, attenuation potential in the groundwater pathway and well construction

Chloride is a conservative ion, and levels are not expected to be influenced by groundwater vulnerability or aquifer type. Further, chloride in itself is not a contaminant of concern and is mainly studied in combination with the other contaminants to help identify possible hazards. Consequently, individual considerations of the relationship between chloride levels, attenuation potential in the groundwater pathway and well construction are not regarded as relevant. Chloride concentrations in the context of the identification of contaminant hazards are discussed in Chapter 4.

Comparison of chloride levels in WSSs with GWSs and private supplies

Chloride concentrations are not routinely sampled during standard water quality testing undertaken by County Councils and regulatory bodies, therefore no chloride concentration data were obtainable for GWS and private sources.

3.4 Sodium and Potassium

The background potassium-sodium (K:Na) ratio in most Irish groundwaters is less than 0.4 and often less than 0.3. The K:Na ratio of soiled water and other wastes derived from plant organic matter is considerably greater than 0.4, whereas the ratio in septic tank effluent is less than 0.2. Consequently a K:Na ratio greater than 0.4 can be used to indicate contamination by plant organic matter (such as slurry in farmyards) and occasionally landfill sites (from the breakdown of paper). However a K:Na ratio lower than 0.4 does **not** necessarily indicate that farmyard wastes are not a source of contamination (or that a septic tank is the cause) because potassium is less mobile than sodium and therefore is bound up in the soil and subsoil before reaching the groundwater.

[6] Loughmore and Terryglass sampled only once.

As potassium is relatively immobile in soil and subsoil, the spreading of manure, slurry and inorganic fertilisers is unlikely to significantly increase the potassium concentrations in groundwater. In most areas in Ireland, the background potassium levels in groundwater are less than 3.0 mg/l. Higher concentrations are found occasionally where the rock contains potassium e.g. certain granites, sandstones and mudstones.

Occurrence in WSSs

K:Na ratios in North Tipperary groundwaters are below 0.3 in 15 of the 26 sources (57.7%), averaging 0.26 across all available samples. The spread of values is large, however, ranging from 0.043 to 0.778. None of the samples has potassium concentrations greater than the MAC, although at Aglish, Clonakenny, Loughmore, Templetouhy and Cloghjordan the concentration was above the GSI threshold.

Four of 26 sources (15.4%) have K:Na ratios greater than 0.4 (in order of increasing ratio): Roscrea (Glenbeha), Cloghjordan, Loughmore and Templetouhy. Six sources of 26 (23%) have sample K:Na ratios between 0.3 and 0.4: Aglish, Borrisokane, Borrisoleigh, Riverstown, and the Creamery and Lady's Well at Thurles. In eight of these cases, significant *E. coli* or faecal coliform contamination has occurred at the source (not necessarily at the same sampling time).

Variation with time

Apart from Drumbane and Loughmore, which were sampled only once, the K:Na ratio at each source listed in this section increases, to varying extents but usually only slightly, with time.

Relationship between the potassium:sodium ratio, attenuation potential of the groundwater pathway and well construction:

The potassium:sodium ratio in itself is not of concern and is mainly studied in combination with other contaminants to help identify possible hazards. Consequently, individual considerations of the relationship between the potassium:sodium ratio, attenuation potential in the groundwater pathway and well construction are not regarded as relevant. Potassium:sodium ratios in the context of the identification of contaminant hazards are discussed in Chapter 4.

Comparison of potassium:sodium ratios in WSSs with GWSs and private supplies

Sodium and potassium concentrations are not routinely measured during standard water quality testing undertaken by County Councils and regulatory bodies, therefore no potassium:sodium ratios could be calculated for GWS and private sources.

3.5 Nitrate, Nitrite and Ammonia

Nitrate is one of the most common contaminants identified in groundwater, and increasing concentrations have been recorded in many counties. Under natural conditions, nitrate occurs only in low concentrations – normally in the range 5-9 mg/l. Most nitrate found in natural waters relates to human activities and comes from organic and inorganic sources. The former includes waste discharges (on-site septic tank systems, slurry and soiled water from farmyards, spreading of organic wastes); the latter chiefly comprises artificial fertilisers. Septic tank effluent contains nitrogen concentrations in the range 130-200 mg/l as NO_3. Inorganic fertilisers are also a hazard, particularly in the tillage areas (leaching of nitrates from tillage crops is generally greater than from grassland) and intensive dairy farming areas. The presence of nitrates in groundwater is cause for suspicion of remote sewage pollution or of excess levels of fertilisers or manure slurries spread on land. In addition, there are health risks associated with excess nitrate consumption in the human diet, which include blue baby syndrome (methaemo-globinaemia) and potential carcinogenic hazards for the general population (Conway & Pretty, 1991). Normal drinking water treatment does not remove nitrate.

Ammonia is generally present in natural waters, though in very small amounts, as a result of microbiological activity which causes the reduction of nitrogen-containing compounds (Flanagan, 1992). It has a low mobility in soil and subsoil and its presence in groundwater much above 0.1 mg/l (as NH_3 or NH_4) is generally indicative a nearby contaminant hazard, vulnerable conditions, and/or poor well construction. From the viewpoint of human health, significant concentrations of ammonia can indicate the possibility of sewage pollution and the consequent possible presence of pathogenic micro-organisms.

Nitrite is an intermediate compound in the oxidation of ammonia to nitrate and not likely to accumulate. Therefore, high nitrite levels would indicate more recent pollution and a highly vulnerable aquifer, and be regarded as being of highly questionable quality. Levels in unpolluted waters are normally low, below 0.01 mg/l. The EU MAC for nitrate is 0.1 mg/l as NO_2.

The nitrate ion is not adsorbed onto clay or organic matter. It is highly mobile, and under wet conditions is easily leached out of the rooting zone and through soil and permeable subsoils. Consequently, groundwater nitrate concentrations are more influenced by dilution and less influenced by groundwater vulnerability than concentrations of parameters such as *E. coli*, ammonia or nitrite.

Nitrate

In considering nitrate data, the GSI subdivides groundwater supply sources into four broad categories:

Category A: Nitrate levels regularly exceed 50 mg/l.

Category B: Average nitrate levels exceed 25mg/l and peaks regularly approach or exceed 50 mg/l.

Category C: Average nitrate levels exceed 25 mg/l, peaks rarely approach 50 mg/l but give cause for concern.

Category D: Average nitrate levels are <25 mg/l and peaks do not give cause for concern.

Occurrence in WSSs

Summary water quality information for each supply source is presented in Table 10 and in Appendix J. Of the 26 sources, four WSSs (15%) have nitrate levels in excess of the MAC on one or two occasions (out of more than 10 samples). Fifteen of the sources (58%) have had nitrate concentrations greater than the GSI threshold during the sampling period. Analysis of the available data provides the following results for North Tipperary WSSs, which are summarised in Figure 35:

Category A: No public supply wells fall into this category.

Category B: Two of 26 WSS sources (7.7%) are in this category: Cloghjordan (Figure 11) and Templetouhy (Figure 23).

The data are tabulated in Appendix J.1.

Category C: Four of 26 WSS sources (15.4%) are in this category: Borrisokane (Figure 8), Thurles Creamery and Thurles Lady's Well (Figure 25 and Figure 26) and Two-Mile-Borris (Figure 30).

The data are tabulated in Appendix J.2.

Category D: The remaining twenty WSS sources (76.9%) belong to Category D. These sources and average nitrate concentrations are summarised in Appendix J.3

Variation with time

At most sources, although there may be more or less variability about a mean value at different sources, there are no apparent trends. The exceptions are at Aglish, and possibly Two-Mile-Borris WSSs, where there is an apparent decrease in nitrate concentrations with time, and at Ballynaclogh and Borrisokane WSSs, where nitrate levels appear to increase with time.

Comparison of nitrate concentrations in WSSs with GWSs and private supplies

Group Water Scheme nitrate concentrations measured by the DoELG (in prep.) are treated in aggregate. Nitrate concentrations vary slightly with time (Figure 36.a), with groundwater at more sources falling below the GSI threshold in December 2000 (58%) than in November 2000 and January 2001 (47% both months). None of the samples has nitrate levels greater than 50 mg/l (Categories A or B). Averaged over the three sampling rounds (Figure 36.b):

- 45% of the 38 GWS sources have nitrate levels less than the GSI threshold of 25 mg/l. (Category D).
- 55% (21) of the GWS sources fall within Category C (average nitrate levels greater than the GSI threshold).

The vast majority of private supplies are sampled only once hence no assessment about the 'average' properties of the groundwater can be made. Instead, the data are considered with respect to the GSI threshold and MAC level (Figure 37). Of 262 samples:

- 2% of private wells were above the EU MAC (50 mg/l).
- 77% of private wells were below the GSI threshold (25 mg/l).
- 21% of private wells were above the GSI threshold, but below the MAC.

The data indicate that public supply sources have better nitrate status than group water schemes. From limited data for private wells, the distribution of source nitrate status across nitrate categories is similar to WSSs. The number of sources falling within each category for each source type is shown in Figure 38.

Ammonia

Occurrence in WSSs

Summary water quality information for each supply source is presented in Table 10. Compared with the nitrate levels at the 26 sources, no WSS samples had ammonium levels in excess of the MAC, and only three had concentrations above the GSI threshold (these were Clonakenny, Rathcabban and Terryglass in 1998-1999). At Clonakenny and Rathcabban WSSs, nitrate concentrations are very low.

Variation with time

Many sources have insufficient data to determine trends in ammonium concentrations with time. Where sufficient data exist, at most sources, there is no trend apparent. Exceptions are noted at Borrisoleigh, Lorrha, Terryglass and Roscrea (Glenbeha) WSSs, where there appears to be a decrease in ammonium levels over time. Only at Clonakenny does there appear to be an upward trend in ammonium concentrations.

Comparison of ammonium concentrations in WSSs with GWSs and private supplies

Group Water Scheme ammonium concentrations measured by the DoELG (in prep.) during the period November 2000 – January 2001 were all less than the MDL of <0.01 mg/l.

Ammonium concentrations in groundwater from private wells range between <MDL and 9.6 mg/l. The data are considered with respect to the GSI threshold and EU MAC. Of 262 private well groundwater samples:

- 2% were above the EU MAC (0.4 mg/l).
- 4% were above the GSI threshold (0.15 mg/l).
- 40% were above the MDL.

In terms of ammonium concentrations, GWS sources had the best quality groundwater. Private water supply sources have the worst ammonium problems. WSSs ammonium levels fall between the two. In the 84 private supplies that had both ammonium and faecal coliform measurements, there was no general correlation between high ammonium levels and positive faecal coliform tests. There is only one measurement per source, however, so bacterial contamination could have been missed.

Nitrite

Occurrence in WSSs

The source at Borrisokane is the only WSS source that had nitrate levels in excess of the MAC (0.1 mg/l), and this was once out of six samples. Only three WSSs had concentrations above 0.05 mg/l (these were Terryglass, Toomyvara and Borrisokane).

Comparison of nitrite concentrations in WSSs with GWSs and private supplies

Group Water Scheme nitrite concentrations measured by the DoELG (in prep.) during the period November 2000 – January 2001 were all less than the MAC of <0.1 mg/l. Concentrations ranged between 0.01 – 0.05 mg/l.

Nitrite concentrations in groundwater from private wells range between 0.03 and 3.8 mg/l. Of 85 samples,

- 62 (73%) were below the MDL of 0.02 mg/l.
- 3 (3.5%) were above the EU MAC (0.1 mg/l).
- 11 (13%) were above 0.05 mg/l, of which 8 (9.4%) were below the MAC.

GWSs have the best water quality in terms of nitrite concentrations. Private water supplies have the worst levels, but show a similar pattern with respect to nitrite levels in different sources to WSSs.

Relationship between nitrate, ammonia and nitrite concentrations, attenuation potential of the groundwater pathway and well construction at WSSs

Given the fairly large amount (about 33%) of extreme vulnerability areas in North County Tipperary, widespread nitrate, ammonium and nitrite contamination is not unexpected. Nitrate will most likely be an issue in the limestone lowlands north of Nenagh, where patches of extreme vulnerability occur over fractured limestone aquifers that are classified as Ll to Rf. Areas of extreme vulnerability also occur aligned with ridges formed by the Rf Cadamstown aquifer south of Roscrea. The karstified and dolomitised aquifers in the Suir River basin are protected by moderate thicknesses of subsoil, but are still vulnerable.

Sources at which high nitrate concentrations were measured occur in urban, suburban and rural settings. The source at Templetouhy, which falls within the GSI nitrate Category B, is in the centre of the town. At Cloghjordan spring, also Category B, the surrounding land is agricultural, and boggy. At both sources, nitrate levels vary widely with time, indicating both high nitrate loading and quick pathways to highly vulnerable aquifers. From the available data it is not possible to determine any seasonal pattern in the varying concentrations. Of the Category C nitrate levels, the source at Two-Mile-Borris is extremely vulnerable, and situated in the centre of the village; the surrounding land is suburban and pastureland?. In the immediate vicinity of the Borrisokane spring, the land is used for grazing cattle. Uphill of the source, the land use is agricultural and there are several farms. At the Creamery WSS, there is a creamery industry and also a dump nearby. The land use around Lady's Well is not known.

Very high ammonium concentrations are less commonly seen in North County Tipperary. Three sources have levels above the GSI threshold. Two of these are thought to be related to contamination by organic wastes. At Rathcabban, it is thought that there is a natural source for the ammonia, probably from the shaly layers in the Lorrha Calp limestones. Shales and mudstones in the Lower Limestone Shale may contribute to elevated ammonium levels at Clonakenny, but it is thought that contamination may contribute to ammonium through the reduction of nitrate, since organic waste contamination is evidenced by positive faecal coliforms. Since the groundwater signature at Clonakenny is indicative of long residence times, it maybe that contamination is entering the source at the spring chamber. At Terryglass where abstraction is from a clean limestone Ll aquifer, nitrate averages around 15 mg/l, indicating that ammonium is a contaminant. All three sources are located in areas of 'high-low' vulnerability. Well/spring chamber construction details are not available. Proper well construction can greatly reduce the amount of contamination from ammonium

Drawing conclusions on the source of elevated nitrate levels in any particular well depends not only on assessing the nitrate data, but also the other parameters indicative of contamination. In particular, faecal bacteria, ammonia, chloride, potassium, and the potassium:sodium ratio are useful. Also required is some knowledge of the zone of contribution (ZOC) of the well, the vulnerability, and potential hazards in the ZOC. The categorisation of nitrate concentrations is considered together with the other parameters in Chapter 4:.

3.6 Iron and Manganese

Iron and manganese are present in significant amounts in soils and rocks (e.g. muddy limestones and shales) principally in insoluble forms. They may be present in solution in groundwaters due to reducing conditions (e.g. in boggy areas), and many naturally occurring reactions can give rise to more soluble forms of iron or manganese. Background levels vary considerably depending on the rock type. Since pollution by organic effluents can lead to serious deoxygenation of groundwaters and provide the necessary reducing conditions to bring the two metals into solution, marked increases in levels of iron and manganese can, therefore, be considered indicative of such pollution. With reoxygenation in the well or water supply system, the iron and manganese precipitate. High manganese concentrations can be a good indicator of pollution by silage effluent. However, they can also be caused by other high BOD wastes such as milk, landfill leachates and possibly soiled water and septic tank effluent (Daly, 1994).

Excessive concentrations of iron do not cause health problems but are of concern for aesthetic and taste reasons. The principal objection to the presence of relatively large concentrations of manganese in drinking waters is, again, aesthetic due to turbidity and taste, there being little significance for health. It may also cause staining of fabrics.

Occurrence in WSSs

Five out of 26 WSSs (19%) had iron concentrations above the MAC (0.2 mg/l) in at least one sample, and four of the 26 WSSs (15.4%) had manganese concentrations above the MAC (0.05 mg/l). These metals occurred in tandem at significant levels at Borrisokane, Terryglass and Lorrha. Iron alone exceeded the MAC at Roscrea – Glenbeha and Toomyvara, whilst at Aglish, manganese (but not iron) exceeded the MAC. Summary water quality information for each supply source is presented in Table 10.

Variation with time

Of the 26 supply sources examined, 17 have manganese data spanning five or more years and sufficient data to infer a trend. At most sources, the data are below the MDL. The only trends apparent are a general upwards increase at Lorrha around quite variable concentrations, and a smooth, slight decrease with time at Roscrea (Glenbeha). At Lorrha, manganese is probably derived from the calp bedrock aquifer. The general upwards increase may be a consequence of long-term abstraction from the source, as concentrations of other contaminant indicators are very low. At the Glenbeha spring fed by Cadamstown Sandstone, the manganese concentration decreases slightly with time along with faecal coliform counts, suggesting elevated manganese levels are associated with contamination of the aquifer by organic effluents. In contrast to upwards concentration trends of manganese at Lorrha (and at Aglish), iron concentrations seem to be decreasing. At Borrisoleigh, Clonakenny and Rathcabban, the iron concentration trend is downwards.

Relationship between iron and manganese concentrations, attenuation potential in the groundwater pathway and well construction

Since iron and manganese are mobilised from subsoil and bedrock as a result of chemical reactions within waters contaminated by organic effluent, considerations of well construction and attenuation potential within the groundwater pathway are not relevant. While some of the supply sources with iron and manganese concentrations above the MAC correspond with elevated nitrate, faecal coliforms or chloride levels, many do not, suggesting that the nature of the bedrock and the low DO groundwater (indicating low vulnerability) is the primary source of iron and manganese.

County Council personnel report that Aglish WSS has elevated manganese concentrations during dry summers, which is interpreted as being due to the pumped spring drawing water from the bog immediately adjacent to the source. The variation of manganese concentration at this source is 'spiky'.

The variation of manganese with time is also quite variable at Lorrha; The sample interval at this source doesn't allow possible seasonality in the data to be assessed (most measurements were taken in February/March), although the bedrock composition and overall upward trend indicates that elevated manganese levels are due purely to groundwater movement through the Calp aquifer.

At five supply sources (Aglish, Lorrha, Borrisokane, Terryglass and Clonakenny), average manganese concentrations are above the MAC and are also considerably higher than the rest of the WSSs North Tipperary. Iron concentrations are generally more variable, but Glenbeha, Lorrha and Clonakenny have relatively high average iron concentrations (about 0.11 to 0.16 mg/l) in more than 60% of samples. In combination with geological considerations, iron and manganese data indicate that Clonakenny and Glenbeha, and possibly Borrisokane and Terryglass, are being contaminated by organic materials, whereas at Aglish and Lorrha elevated levels are related to the bedrock material and natural groundwater flowpaths in the area.

Comparison of iron and manganese concentrations in WSSs with GWSs and private supplies

Two Group Water Scheme supplies (5.3%) had iron concentrations in excess of the MAC; the average concentration of all 38 supplies is 0.04 mg/l, ranging from below the MDL (0.005 mg/l) to 0.94 mg/l. No GWS sources had manganese concentrations in excess of the MAC. Average concentrations above the MDL were 0.013 mg/l, and ranged from below the MDL (0.005 mg/l) to 0.042 mg/l.

Manganese problems are more frequent in private wells than iron concentrations in excess of the MAC. Of 261 sources, 38 (14.6%) had manganese concentrations greater than 0.05 mg/l. Concentrations range from below the MDL up to 2.21 mg/l. Eleven of 262 private sources (4.2%) had iron concentrations greater than 0.2 mg/l, with the greatest concentration reaching 55.5 mg/l.

The histograms in Figure 39 shows how iron and manganese concentrations vary per source in public, group and private supplies.

3.7 Phosphate

Concentrations

The principal significance of phosphate is as a cause of eutrophication in surface water, due to the growth of algae and other plants leading to blooms. Phosphorus occurs widely in nature in plants, in micro-organisms and in animal wastes. Other common sources of phosphate include slurries, dirty water, inorganic fertilizers, farmyard runoff and detergents. Phosphorus has not generally been regarded as a problem in groundwaters as it is considered to be retained in the soil zone and unlikely to penetrate to groundwaters. However, although it is strongly adsorbed onto soil, it can show enhanced leaching to groundwater in coarse subsoils, thin subsoils, and areas with a shallow watertable, amongst others (Kilroy et al, 1999). Consequently, elevated levels in groundwater generally only occur if the vulnerability is extreme or if point sources of phosphate are present. Concentrations are considered elevated if they are in excess of a few milligrams per litre of ortho-phosphate (i.e. parts per billion). In this respect, if there are potential pathways from the subsoil to a surface water body via the aquifer (e.g., through fractures, fissures, thin soil cover, high water table) this parameter should be monitored.

Occurrence in WSSs

Summary water quality information for each supply source is presented in Table 3.2. Of the 26 supply sources examined, 12 (46%) exceeded the EPA guide level of 0.02 mg/l for ortho-phosphate, with these concentrations ranging between 0.03–0.15 mg/l. At these sources, only one out of the two samples per source (taken in 1993 for the STRIDE report) exceeds the threshold, except at Borrisokane, which was above the EPA guide level both times.

At Aglish, Clonakenny, Kilcommon, Littleton, Riverstown, Roscrea (Glenbeha) and Templemore, the measured PO_4 concentration was 0.03 mg/l. At Borrisokane, Cloghjordan, Drumbane, Templetouhy and the Thurles Creamery WSSs, PO_4 concentrations range between 0.03 and 0.15 mg/l.

Variation with time

The data are insufficiently frequently measured to allow an assessment of the variation of ortho-phosphate with time.

Relationship between phosphate levels, attenuation potential in the groundwater pathway and well construction

At Borrisokane, faecal coliforms have been measured along with high nitrate levels and high K:Na ratios, indicating an organic waste origin for the PO_4. The spring is very well chambered in an area with about 5 m depth to rock, indicating a point source of contamination, which could be related to grazing cows drinking from the River Crotta.

Three sources that have significantly elevated phosphate levels in the range 0.1–0.15 mg/l PO_4 (Drumbane, Templetouhy and the Thurles Creamery WSSs) occur in all vulnerability type areas, but are all in urban/village settings. This suggests that underground point hazards are contributing to many of the contamination problems identified in this study. The origin of the PO_4 at Templetouhy may be the graveyard adjacent to the source. The proximity of the Creamery well to a potential milk waste source may contribute at this source. Detergents from leaking drains may contribute at any of the urban/ suburban sources.

The remaining sources, with ‘lower’ PO_4 concentrations (still in excess of the EPA guideline) all occur in a range of vulnerability statuses, spanning Extreme to High-Low, and also are situated in urban and rural settings.

Comparison of ortho-phosphate concentrations in WSSs with GWSs and private supplies

Ortho-phosphate concentrations are not routinely measured as part of the standard parameter suite during normal water quality testing undertaken by County Councils and regulatory bodies, therefore no ortho-phosphate concentrations were readily available for GWS and private sources.

3.8 Trace Organics

Limited sampling of various pesticides and other organic parameters has been conducted on groundwaters from North County Tipperary. The information sources are listed in Table 3. The Drinking Water Directives (80/778/EEC and 98/83/EC) set a limit of 0.1 μg/l for individual pesticides and 0.5 μg/l total pesticides in drinking water. The limits for organic (e.g. hydrocarbon) contaminants vary depending upon the substance.

Pesticides

The EPA (1999) conducted a survey in County Tipperary (North and South) of pesticides in groundwaters. They took 23 samples, of which six were in North Tipperary. These supplies, which are listed in Appendix J extract groundwater from both limestone and sandstone/mudstone aquifers. Seventeen pesticides were tested for, and are also listed in Appendix J.

Each water supply was tested only once. The EPA (1999) consider that, whilst this does not give an indication of short-term effects of pollution, it does give a good indication of the long-term state of groundwaters.

No sample had pesticides above the MDL. Therefore, the results show no evidence of any background, long-term pollution in any of the groundwaters sampled.

Volatile organic carbon (VOC)

Fifty-four unspecified VOCs were tested for in groundwaters sampled for the EC STRIDE Programme in 1994. The 17 sources tested are listed in Appendix C.

No sample had significant levels of VOC detected.

Notes accompanying Table 10 (overleaf):

- NO_3: Nitrate; Cl: Chloride; NH_x: Ammonia; K: Potassium; K:Na: Potassium – sodium ratio; Fe: Iron; Mn: Manganese.
- Coliform data represent untreated samples and treated samples where e.coli or faecal coliforms were detected. Though useful in terms of identifying contamination sources, they are not necessarily indicative of human health concerns.

Fluoride was detected above the detection limit in a sample from Lorrha. Strontium was detected above the MAC at Clonakenny and at Roscrea (Glenbeha). These compounds, though important in human health considerations, are not major factors in assessing sources of agricultural or domestic contamination. As such, these results have not been used in assessing groupings outlined above.

Table 10: Groundwater quality classification of North County Tipperary WSS groundwater supply sources (1)

Cate-gory	Supply source	Aquifer type	Vulner-ability	Exceedance of Key Contaminant Indicator								
				NO_3	Cl	PO_4	NH_x	E/F coli	K	K:Na	Fe	Mn
1	Aglish	Rf (BK)	H-L	> T $(^{1}/_{6})$	> T $(^{2}/_{3})$	> T $(^{1}/_{2})$	•	>>MAC	> T $(^{1}/_{2})$	> T $(^{1}/_{2})$	•	>MAC $(^{2}/_{5})$
1	Borrisokane	Ll (SV)	E/ H-L	> T $(^{15}/_{25})$	> T	> T $(^{2}/_{2})$	•	>MAC	•	> T $(^{2}/_{3})$	>MAC	>MAC
1	Borrisoleigh	Ll (BA)	H-L	> T $(^{2}/_{35})$	•	> T $(^{2}/_{2})$	•	>>MAC	•	> T $(^{1}/_{2})$	•	•
1	Clonakenny	Pl/Rf (LLS/ CW)	H-L	•	•	•	> T $(^{2}/_{4})$	>>MAC	>> T $(^{2}/_{2})$	•	•	
1	Riverstown	Ll (WA)	E/ H-L	> T $(^{3}/_{9})$	> T	> T $(^{1}/_{2})$	•	>>MAC	•	> T $(^{2}/_{2})$	•	•
1	Roscrea – Glenbeha	Rf (CW)	H-L/ E	>MAC $(^{1}/_{13})$ >T$(^{2}/_{13})$	•	> T $(^{1}/_{2})$	•	>MAC	> T $(^{1}/_{2})$	> T $(^{2}/_{2})$	>MAC $(^{1}/_{7})$	•
1	Templetouhy	Ll (WA)	H-L ?E	>MAC $(^{3}/_{15})$ >T $(^{12}/_{13})$	> T	>>T $(^{1}/_{2})$	•	•	>> T $(^{2}/_{2})$	> T $(^{2}/_{2})$	•	•
1	Terryglass	Ll/Rf (WA/ TS)	H-L	> T $(^{2}/_{14})$	> T	•	> T $(^{1}/_{5})$	>MAC	•	•	>MAC $(^{1}/_{6})$	>MAC $(^{1}/_{6})$
1	Toomyvara	Rf (CW)	H-L/ E	> T $(^{5}/_{14})$	•	•	•	>>MAC	•	•	>MAC $(^{1}/_{8})$	•
1	Two-Mile-Borris	Ll (AG)	E	>MAC $(^{1}/_{11})$ >T$(^{9}/_{11})$	•	•	•	>>MAC	•	•	•	•
1	Cloghjordan	Ll (WA)	E	>MAC $(^{1}/_{21})$ >T $(^{18}/_{21})$	> T	> T $(^{1}/_{2})$	•	•	>>T $(^{2}/_{2})$	>> T $(^{1}/_{2})$	•	•
2	Drumbane			•	•	> T $(^{1}/_{1})$	•	>MAC		•	•	•
2	Holycross	Ll (AG)	H-L	> T $(^{5}/_{10})$	•	•	•	>MAC	•	•	•	•
2	Littleton	Ll (AG)	H-L	> T $(^{4}/_{16})$	•	> T $(^{2}/_{2})$	•	>MAC	•	•	•	•
2	Loughmore	Ll (BA)	H-L	•	> T	•	•	>MAC	> T $(^{1}/_{1})$	> T $(^{1}/_{1})$	•	•
2	Templemore	Ll/Lm (BA/ BAld)	E/ H-L	> T $(^{2}/_{31})$	> T	> T $(^{1}/_{2})$	•	>MAC	•	•	•	•
2	Thurles – Creamery	Ll (WA)	H-L/ E	> T $(^{23}/_{54})$	•	>>T $(^{1}/_{2})$	•	>MAC	•	> T $(^{2}/_{2})$	•	•
2	Thurles - Lady's Well	Ll (WA)	H-L/ E	> T $(^{8}/_{8})$	•	•	•	>MAC	•	> T $(^{1}/_{2})$	•	•
2	Thurles – Tobernaloo	Rf (WAdo)	H-L/ E	> T $(^{2}/_{7})$	•	•	•	•	•	•	•	•
2	Ballynaclogh	Pl (HF)	H-L	> T $(^{1}/_{24})$	•	•	•	•	•	•	•	•
3	Tullahedy	Ll (WA)	E	> T $(^{1}/_{30})$	•	•	•	•	•	•	•	•
3	Kilcommon	PL (HF)	E	> T $(^{1}/_{14})$	•	> T $(^{2}/_{2})$	•	•	•	•	•	•
4	Lorrha	Ll (CDlr)	E	•	•	•	•	•	•	•	>MAC $(^{1}/_{17})$	>MAC $(^{12}/_{17})$
4	Moycarky	Ll (DW/ AG)	H-L	•	•	•	•	•	•	•	•	•
4	Templederry	Pl (HF)	H/ H-L	•	•	•	•	•	•	•	•	•
4	Upperchurch	Pl (HF)	H-L/ ?E	•	•	•	•	•	•	•	•	•

4: General groundwater quality assessment of supply sources in North Tipperary

To aid the water quality assessment, the supply sources are assigned to one of four categories that are defined on the basis of concentrations of key contaminant indicators. The classification is based on concentrations of key contaminant indicators in relation to EU MACs and to GSI threshold levels. The grouping is intended to help categorise supply sources in the context of potential contaminant hazards, and to help prioritise sources for the purpose of recommending remedial action. The four groups are described as follows:

Category 1: Sources in which one or more contaminant indicators in the available data set exceed the MAC (or 10 counts per 100 ml for faecal coliforms).

Category 2: Sources which show concentrations of the contaminant indicators chloride, nitrate, ortho-phosphate, iron, manganese and potassium:sodium ratio GENERALLY in excess of the GSI threshold levels (or more than 0 faecal coliforms in any one sample). Some interpretation is required as levels in excess of these thresholds can reflect naturally occurring conditions (e.g. elevated potassium and/or iron in certain rock types).

Category 3: Sources with slight anomalies in the analyses which may be naturally induced or indicative of some slight contamination (i.e. indicator levels OCCASIONALLY in excess of the GSI threshold levels).

Category 4: Sources showing no evidence of contamination from the analyses carried out for the project.

4.1 Discussion

Table 11 provides the results of the grouping exercise based on aquifer type, and uses the combination of contaminants found in each supply source to draw inferences on the potential origin of the contamination. Overall, 42% of the 26 supply sources studied occur in Category 1, 35% in Category 2, 7.5% in Category 3, and 15.5% in Category 4. One of the water supplies in Category 4 has natural water quality problems relating to iron and manganese. However, since these are quite common and are most likely derived from bedrock conditions, it is classed as Category 4 to avoid shifting attention from cases where human activities have had an impact.

Five out of six sources located in or partly in a regionally important fractured bedrock aquifer (Rf) have experienced contamination from human activities and are classed in Category 1. Of these five, two sources have extreme vulnerability. The remaining source in a Rf aquifer (Tobernaloo) is classed in Category 2. Given the highly fractured and sometimes karstified nature of this aquifer, groundwater (and contaminants) will be able to travel quickly. Contamination within this aquifer type may be caused by farmyards, septic tanks, landspreading of organic waste and/or animal grazing.

Of the 14 WSS sources considered in this report that occur in bedrock aquifers that are "moderately productive only in local zones" (Ll), six of the supply sources (43%) are in Category 1. The sources comprise boreholes and springs, and both new and old sources. The vulnerability of the Lm aquifer type is mixed and has large areas of extreme vulnerability and large areas of high-low vulnerability. However, the aquifer is highly productive and very permeable in local zones (e.g., Borrisoleigh, Two-Mile-Borris), which allows groundwater and contaminants to travel quickly. The sources in Category 2, 3 and 4 again span the range of vulnerabilities, with the most extremely vulnerable sources falling in Category 3 and 4.

Only one WSS is sited in a "bedrock aquifer that is generally moderately productive". This source is at Templemore (College Hill), and it is located along a fault zone that juxtaposes Lm and Ll aquifer types. Consideration of the contaminant indicators places the Templemore source into Category 2. It is an extremely vulnerable site, but as the wells are finished to the very highest standard, the organic waste pollution must come from subsurface point sources.

The four supply sources located in the Silurian siltstone/mudstone bedrock aquifer that is "generally unproductive except for local zones" (Pl) span Categories 2 to 4. The main contamination problems in these sources are occasional high nitrate concentrations that have exceeded the GSI threshold. Due to the resistance of the mudstones and sandstones to erosion by the glaciers, the depth to rock is small. Hence, the vulnerability of the Pl aquifers is extreme for much of their extent. Despite this, these aquifers are less polluted than the higher permeability limestone aquifers. This is partly due to their lower permeability, allowing less ingress of pollutants into the aquifer, and partly due to the demography of North County Tipperary, where most people live in the limestone lowlands rather than on the Silurian Silvermine Mountain range.

The groundwater quality from GWS and private sources generally is very good. The traditional perception may be that WSS sources are far more 'hygienic' and better constructed than non-council wells. With the advent of grant awards to group water schemes and well grants for rural domestic wells, the standards of privately owned and operated wells may increase substantially.

4.2 Appraisal of Water Quality Issues at Specific Supply Sources

Detailed hazard surveys at problem supply sources are beyond the scope of this project. Table 11 briefly outlines the main issues of concern for each supply source, and, on the basis of water quality analysis, suggests a likely source for the contamination. However, the origin of some contaminants at individual sources can not be firmly established without a field-based hazard assessment.

4.3 Conclusions

The main natural and human-induced water quality issues are outlined below:

- The dominant hydrochemical signature of the groundwater in North County Tipperary is calcium-bicarbonate, with some samples having a calcium-magnesium-bicarbonate signature.
- Fifty-nine percent of the WSS sources in North Tipperary have 'excessively hard' groundwater, with 21% having 'hard' water, 10% 'moderately hard' and 10% 'slightly hard' groundwater. The hardest groundwaters are found at Loughmore, around Thurles, Lorrha and Templetouhy. The softest waters are abstracted from sandstones and mudstones, at Templederry, Clonakenny and Kilcommon.
- High levels of iron and manganese, often in excess of the EU MAC, are widespread, and in most cases originate from natural geological conditions, although the situation is exacerbated by organic waste pollution causing mobilisation of these ions.
- Fluoride concentrations above the MAC are found in parts of the Lorrha Calp aquifer (Ll), and result from natural geological conditions.
- High barium and strontium are found collectively at Clonakenny, Templemore, Roscrea (Glenbeha) and Lorrha. These elements probably occur as a result of low-grade mineralisation and may relate to remobilisation of Sr and Ba from limestones. The occurrence is in the Cadamstown Formation south of Roscrea, and across the northern part of the County.
- Faecal coliforms are in excess of 0 counts per 100 ml in 16 (62%) of the WSS supply sources. For GWS, this figure is 60%, and for private supply sources, about 9%.
- Coliforms of a definite faecal origin are in excess of the EPA threshold for 'gross contamination' (>10 counts per 100 ml) at six of the public supply sources (23%).
- Nitrate contamination is a widespread issue in North County Tipperary although generally concentrations are less than the GSI threshold of 25 mg/l. Two of 26 WSS sources (7.7%) are in Category B, four in Category C, and the remaining 77% in Category D. The distribution for private wells is very similar. GWSs have less extreme nitrate concentrations but, on average, the contamination of these supply sources is worse, with 55% of sources in Category C.

- Ammonium is in excess of the GSI threshold in three (12%) public water supply sources. Ammonium was not detected in GWS sources. Private water supply sources have the worst ammonium problems.
- Chloride is in excess of the GSI threshold in four (15%) of the supply sources; none of these is over the MAC. Eight of the WSS supplies (31%) have chloride concentrations that vary significantly and/or exceed the GSI threshold.

Table 11: Groundwater quality classification of North Tipperary WSS sources (2)

Cate-gory	Supply source	Aquifer type	Vulner-ability	Exceedance of Key Contaminant Indicator
1	Aglish	Rf (BK)	H-L	High faecal coliforms, K:Na, chloride, PO4 suggest contamination from organic wastes. Vulnerability setting indicates 'point' hazard, prob. from grazing cattle. Mn from natural source (bog). Spring chamber construction and site security poss. an issue.
1	Roscrea – Glenbeha	Rf (CW)	H-L/ E	High faecal coliforms, NO3, K:Na, PO4 indicates contamination from an organic, farmyard, source. Mn decreases along with faecal coliforms. Vulnerability setting indicates a possibly diffuse hazard. Well construction unknown, poss this is a factor.
1	Toomyvara	Rf (CW)	H-L/ E	High faecal coliforms, Fe, NO3, NO2 indicates recent contamination from organic waste, poss septic tank. Vulnerability setting indicates point hazard.
1	Terryglass	Ll/Rf (WA/ TS)	H-L	Faecal coliforms, NO3, NO2, NH4, Fe, Mn indicate recent contamination by nearby organic wastes. Vulnerability setting indicates point source of contamination. Well construction and protection unknown.
1	Clonakenny	Pl/Rf (LLS/ CW)	H-L	High faecal coliforms, NH4, PO4 indicating organic wastes. Vulnerability setting indicates a point hazard. K could relate to organic waste or come from the rock minerals. Site out of town off small road..
1	Borrisokane	Ll (SV)	E/ H-L	Consistently high NO3, high faecal coliforms, high K:Na, Fe, Mn, NO2, PO4, varying Chloride, indicating recent contamination from organic wastes. Vulnerability setting indicates 'point' hazard, probably grazing cows along stream that soaks into aquifer.
1	Two-Mile-Borris	Ll (AG)	E	V. high NO3 and variable faecal coliforms, indicate contamination by organic wastes, probably septic tanks/sewage pipes. Extreme vulnerability but paved surfaces, so subsurface point hazards. Evidence of contamination after heavy rains may suggest well protection inadequate; supports theory of leaking drains.
1	Cloghjordan	Ll (WA)	E	Very high NO3, K:Na, K, PO4 and variable Chloride indicate contamination by organic wastes and possibly inorganic fertiliser. Vulnerability setting indicates diffuse hazard – poss landspreading and/or fertiliser application.
1	Borrisoleigh	Ll (BA)	H-L	High faecal coliforms, K:Na ratio indicates organic waste source. Vulnerability setting suggests 'point' source, probably grazing cattle uphill along stream that soaks into aquifer. Surroundings of well could be an issue – water and potential spills soak away very rapidly around wells.
1	Riverstown	Ll (WA)	E/ H-L	High faecal coliforms, K:Na, PO4, variable chloride suggest contamination from organic wastes, possibly sewage. Vulnerability setting indicates 'point' hazard, probably local source. Contamination indicators have upward trend.
1	Templetouhy	Ll (WA)	H-L ?E	V. high NO3, K, K:Na, PO4. Faecal coliforms not measured. Located in centre of town, which suggests inorganic fertiliser not hazard. Source near church– possible local source of contamination.
2	Thurles – Tobernaloo	Rf (WAdo)	H-L/ E	NO3 occasionally > threshold, may suggest contamination from local organic wastes or inorganic fertiliser. Karstic setting in H-L vulnerability area could indicate point or diffuse hazard
2	Templemore	Ll/Lm (BA/ BAld)	E/ H-L	High faecal coliforms, NO3 and PO4, Chloride varying indicates pollution from organic wastes. Extreme vulnerability setting indicates diffuse hazards, although potential local point hazards comprise septic tanks and farmyards.
2	Holycross	Ll (AG)	H-L	High faecal coliforms and NO3 indicate contamination from organic wastes. Town centre and vulnerability setting indicate subsurface point hazard.
2	Littleton	Ll (AG)	H-L	High faecal coliforms and NO3 indicate contamination from organic wastes. Town centre and vulnerability setting indicate subsurface point hazard.
2	Loughmore	Ll (BA)	H-L	High faecal coliform and K:Na ratio indicates contamination from organic waste of farm origin.
2	Thurles – Creamery	Ll (WA)	H-L/ E	NO3 consistently high, K:Na, PO4 high, faecal coliforms suggest organic wastes, poss point hazard is milk wastes. Karstic setting in H-L vulnerability area could indicate point or diffuse hazard
2	Thurles - Lady's Well	Ll (WA)	H-L/ E	NO3, K:Na high, faecal coliforms high, indicates contamination by organic wastes. Karstic setting in H-L vulnerability area could indicate point or diffuse hazard. Well construction unknown.
2	Drumbane			High phosphate and faecal coliforms may indicate contamination from bird droppings. No vulnerability or well construction details available.
2	Ballynaclogh	Pl (HF)	H-L	NO3 > threshold occasionally. Inorganic or organic source of contamination.

Table 11 Continued/

Cate-gory	Supply source	Aquifer type	Vulner-ability	Exceedance of Key Contaminant Indicator
3	Tullahedy	**Ll (WA)**	**E**	NO_3 > threshold indicates slight contamination by organic or inorganic fertiliser. Vulnerability setting indicates a diffuse hazard.
3	Kilcommon	**PL (HF)**	**E**	NO_3 and PO_4 > threshold indicates slight contamination by organic or inorganic fertiliser. Vulnerability setting indicates a diffuse hazard.
4	Lorrha	**Ll (CDlr)**	**E**	High Mn and Fe almost certainly due to natural aquifer and flow conditions
4	Moycarky	**Ll (DW/ AG)**	**H-L**	No indication of contamination
4	Templederry	**Pl (HF)**	**H/ H-L**	No indication of contamination
4	Upperchurch	**Pl (HF)**	**H-L/ ?E**	No indication of contamination.

- The potassium:sodium ratio exceeds the GSI threshold in four (15%) of the public water supply sources.
- Excessively high levels of iron and/or manganese at four (15%) public supply sources may indicate contamination by organic wastes. Many of the WSS, GWS and private supplies will have naturally elevated iron and manganese concentrations.
- Phosphate is in excess of the EPA guide level of 0.02 mg/l in 12 (46%) of the supply sources. Landspreading of slurries, manures and inorganic fertilizers may be contributing to the elevated phosphate levels, especially in areas with thin subsoils. However, three of these sources are in urban settings, indicating other, point, sources of pollution.
- Forty-two percent of the public groundwater supply schemes studied are in Category 1; these comprise the most contaminated supplies. Thirty-five percent are in Category 2, comprising those supplies where there is evidence that the discharge have been significantly contaminated by human activities. Seven and a half percent of supplies are in Category 3, comprising those supplies where there is some evidence of contamination from human activities. Finally, 15.5% of the supplies are in Category 4, having no evidence of human-induced water quality problems.
- Faecal coliforms, nitrate, ortho-phosphate and elevated potassium:sodium ratios are the most common contaminant indicators identified in the available samples, and are commonly seen in samples from sources in Category 1.
- The combination of contaminant indicator parameters suggest that all three of the human activities considered in this report (septic tanks, landspreading and farmyards) are contributing to groundwater contamination in North County Tipperary.

4.4 Recommendations

- In order to try and minimise the potential for contamination, new supplies would ideally comprise boreholes drawing water from confined aquifers or from moderate to low vulnerability groundwater. These boreholes should preferably be constructed to seal off shallow water strikes close to the top of the rock and to eliminate the potential for surface water ingress to the well. The bottle water standards produced by the Irish Standards Authority give guidance as to the correct procedure for well production and maintenance (EOLAS, 1992).
- Hazard surveys are recommended for Category 1 and 2 sources to remove or improve contaminant hazards. For public supplies, these surveys should be conducted within the delineated source protection areas. Priority surveys might first concentrate within the inner source protection areas (SI) of each supply. For group scheme and industrial supplies where no source protection areas have been delineated, surveys might be best concentrated within 300 to 500 m up-slope and 100 m down-slope for boreholes. For springs, recommended up-slope and down-slope distances are 1 km 100 m, respectively. However, these figures are arbitrary, and source protection area delineation for all group schemes planned for long-term use is recommended.
- Sampling of raw water as well as treated water is recommended for all sources on a regular basis. Full analysis (including major ions) should be carried out on these samples. The frequency of sampling is best determined by the degree of concern at each supply. The following is recommended:

Cate-gory	No. Supply Sources in Each Category	Recommended Sampling Frequency
1	11	At least *monthly*, until conclusions can be drawn on the origin of the contamination and appropriate alleviation measures are taken. Then downgrade to Category 3 sampling frequency.
2	9	At least *quarterly*, until conclusions can be drawn on the origin of the contamination and appropriate alleviation measures taken.
3	2	At least *quarterly*.
4	4	At least *twice yearly*.

In addition to the usual analytes, indicators of petroleum, sheep dip, pesticides and herbicides should also be examined, perhaps on a less frequent basis (e.g. twice yearly).

- In this region where iron and manganese concentrations can naturally be high, avoidance of iron biofouling problems can be achieved by minimising the factors that enhance the process. This can largely be achieved by attention to borehole design and construction and operating schedules, which minimise high velocities and oxygenation of the groundwater in the borehole system and the immediate aquifer environment.

5: Acknowledgements

The following people contributed time and/or information to this report:

- EPA Regional Inspectorate Tipperary.
- DoELG
- North Tipperary County Council.
- State Laboratory Staff.
- Vincent Fitzsimons, Melissa Swartz, Orla McAlister, MMA and Ulrika Forsberg, GSI Groundwater Section.

6: References

CEC (Council of the European Communities) (1998) Council directive of 3 November 1998 on the quality of water intended for human consumption. *Official Journal of the European Communities*, No. L 300/32.

Conway, G.R. and Pretty, J.N. (1991) *Unwelcome harvest: agriculture and pollution*. Earthscan, London.

Daly, D. (1994) *Chemical Pollutants in Groundwater: A review of the Situation in Ireland*. Geological Survey of Ireland, Beggars Bush, Dublin 4.

DoE (in preparation) *Private Group Water Schemes: National Monitoring Project.*

Driscoll, F.G. (1986) *Groundwater and Wells* (2^{nd} edition). Johnson Filtration Systems Inc, Minnesota, USA, 1089 pp.

E.C. STRIDE Environment sub-programme Measure I: The establishment of a database for groundwater in the South East region of Ireland. The Regional Water Laboratory, Kilkenny (1993).

EC *Quality of Water Intended for Human Consumption Regulations*, 1988 (S.I. No. 81 of 1988)

EPA (????) definition of 'gross contamination' of sources by faecal bacteria > 10/ 100 ml.

EPA (1997) *Nitrates in Groundwater County Tipperary (NR)*. EPA, Regional Inspectorate, Dublin (March 1997 and in preparation).

Freeze, R.A. and Cherry, J.A. (1979) *Groundwater*. Prentice-Hall, New York.

Hagedorn, C. (1983)

Hunter Williams, N.H., Motherway, K. and Wright, G.R. (2002) *North County Tipperary Groundwater Protection Scheme: Main Report.* Geological Survey of Ireland, Dublin.

Kilroy et al (1999) phosphates

NSAI, 1992. *Bottled water. Irish Standard I.S. 432 : 1992*. National Standards Authority of Ireland. 54pp.

Pesticides in Groundwater: A report to Tipperary North Riding County Council and Tipperary South Riding County Council. EPA, Regional Inspectorate, Butt's Green, Kilkenny (1999).

Tyrrel, S.F. & Howsam, P. (1994). Field observations of iron biofouling in water supply boreholes. *Biofouling* 8, pp.65-69

Water Quality in Ireland 1995-1997. EPA (1999).

Figures

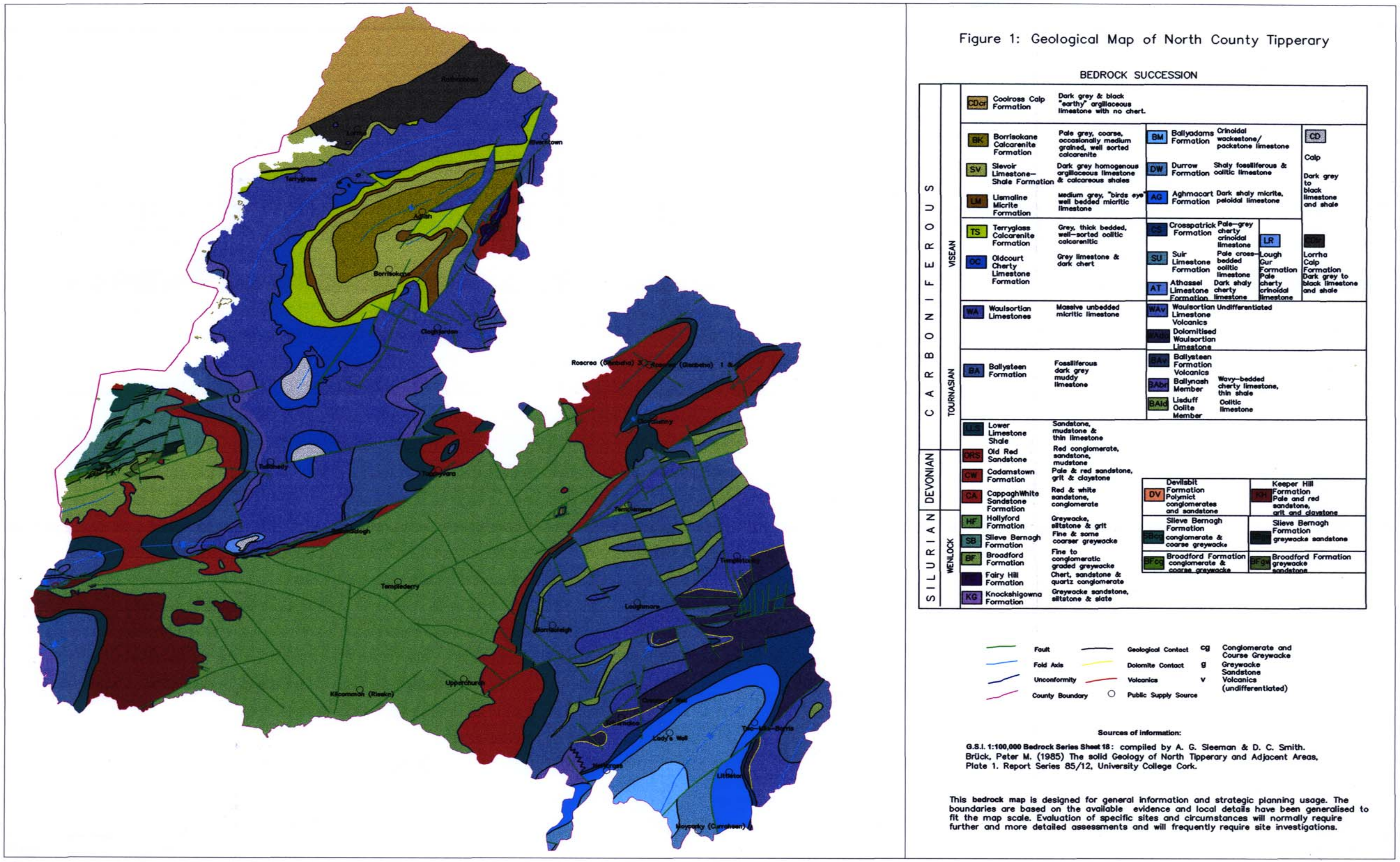


Figure 1 Geological Map of North County Tipperary

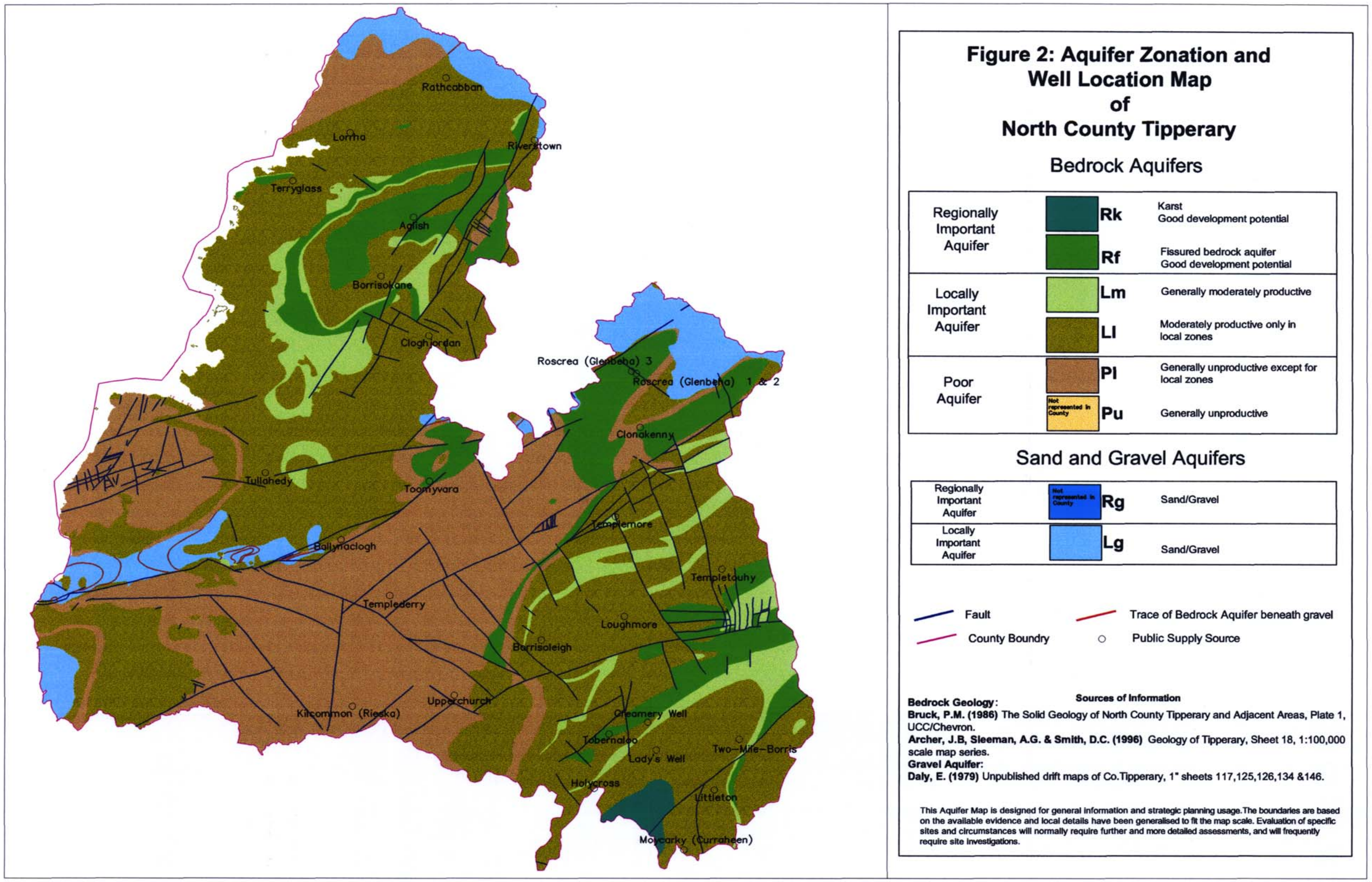


Figure 2 Aquifer Zonation and Well Location Map of North County Tipperary

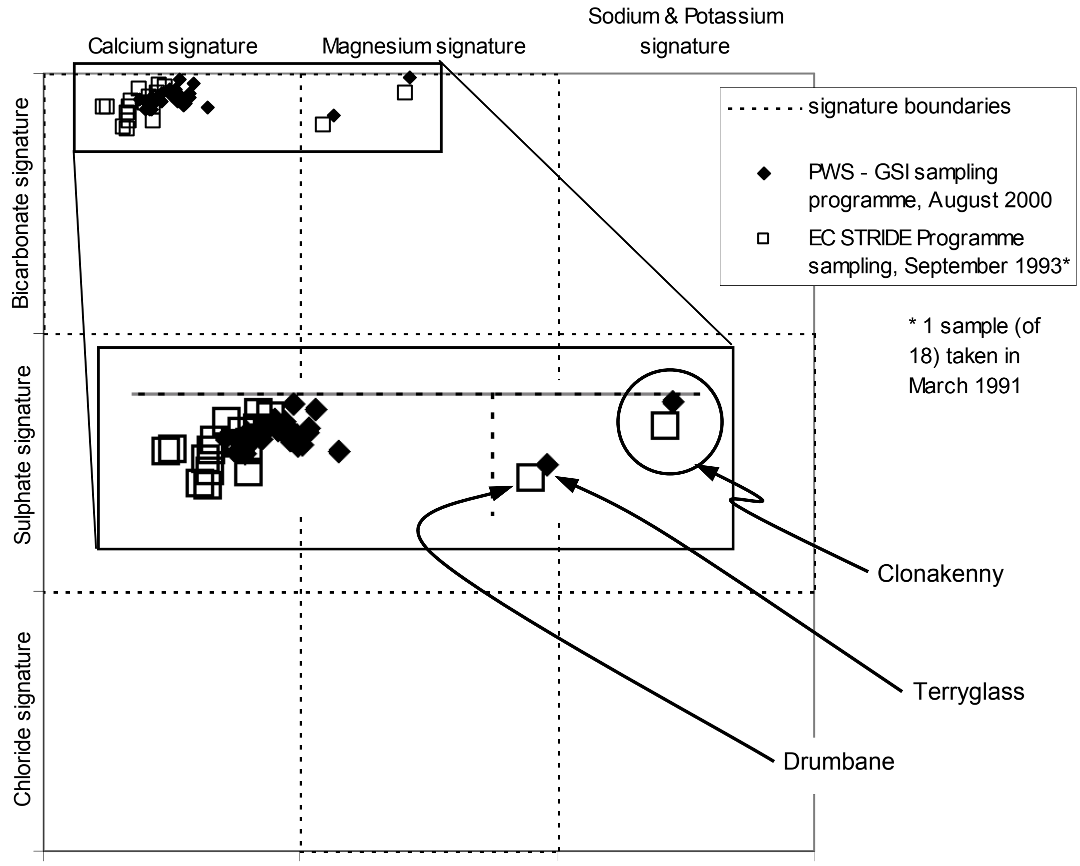


Figure 3: Hydrochemical signature of groundwater in Co. Tipperary (NR) determined on the Durov diagram.

The inset shows at increased magnification the position of the samples. The "outliers" with magnesium–bicarbonate signatures were samples measured at Clonakenny (two samples), at Drumbane and at Terryglass (one sample each). Nitrate, ammonium, iron and manganese were not included in the calculation of the signature for this plot. This does not affect the signatures of the groundwater samples significantly. Groundwater samples from Public Water Schemes taken in August 2000 by the GSI in at 25 of 26 sources, and by North Tipperary County Council in March 1991 (1 sample) and September 1993 (17 samples).

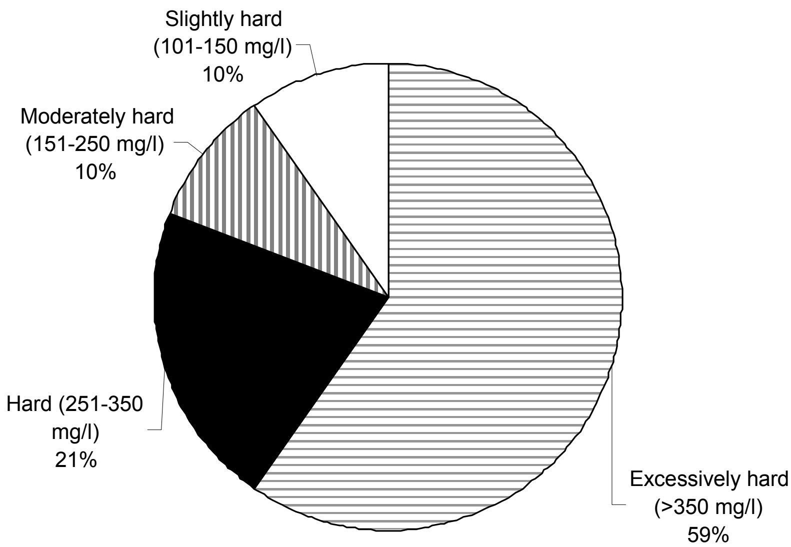


Figure 4: Pie chart showing the number of WSS *sources* falling within each hardness category in North County Tipperary.

Number of sources, 26. Number of samples: 45. Data are from the GSI sampling round (Appendix B), the EU STRIDE Programme (Appendix C) and North Tipperary County Council monitoring (Appendix D, Aglish WSS only). Note that some sources were sampled more than once.

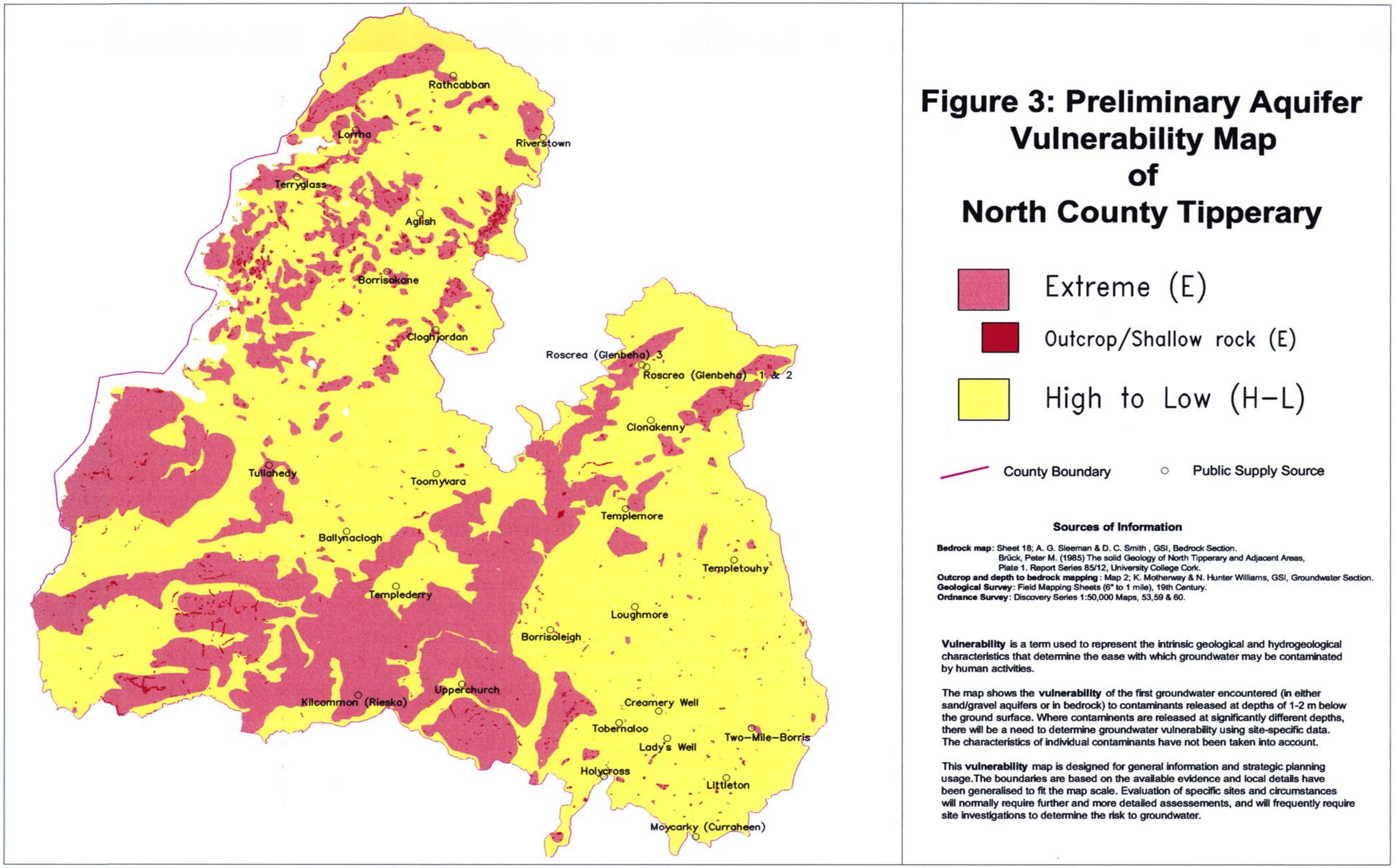


Figure 5 Preliminary Aquifer Vulnerability Map of North County Tipperary

Figure 6: Aglish WSS – Key indicators of agricultural and domestic groundwater contamination

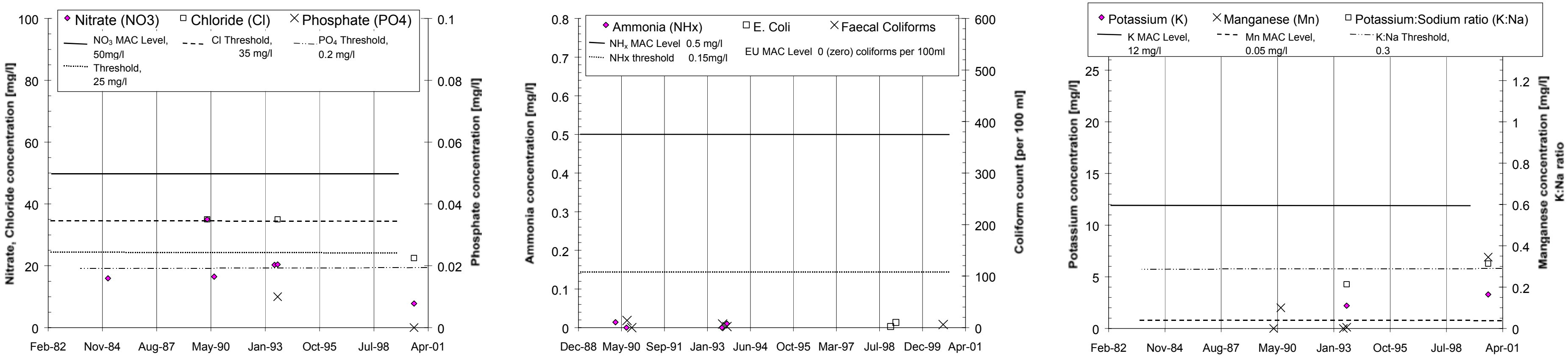


Figure 7: Ballynaclogh WSS – Key indicators of agricultural and domestic groundwater contamination

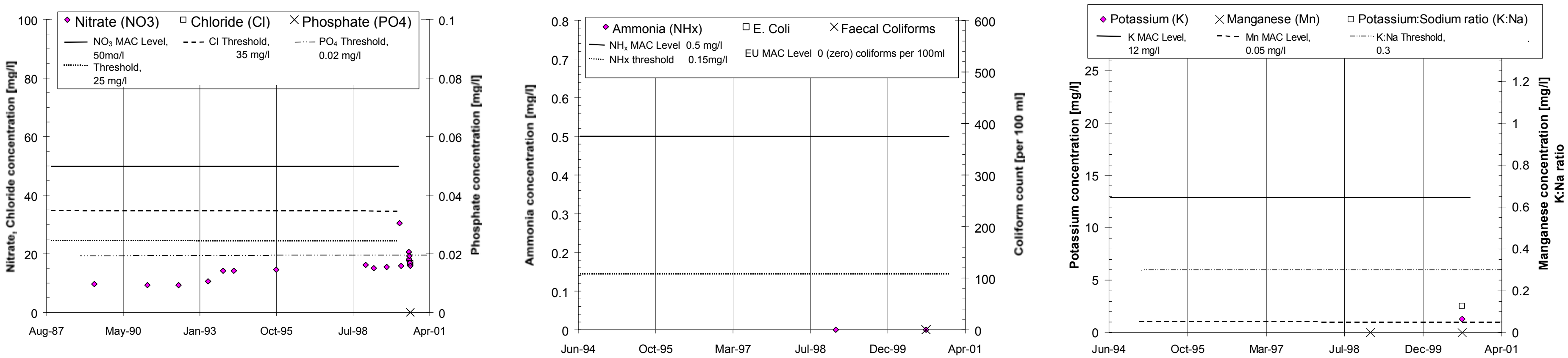


Figure 8: Borrisokane WSS – Key indicators of agricultural and domestic groundwater contamination

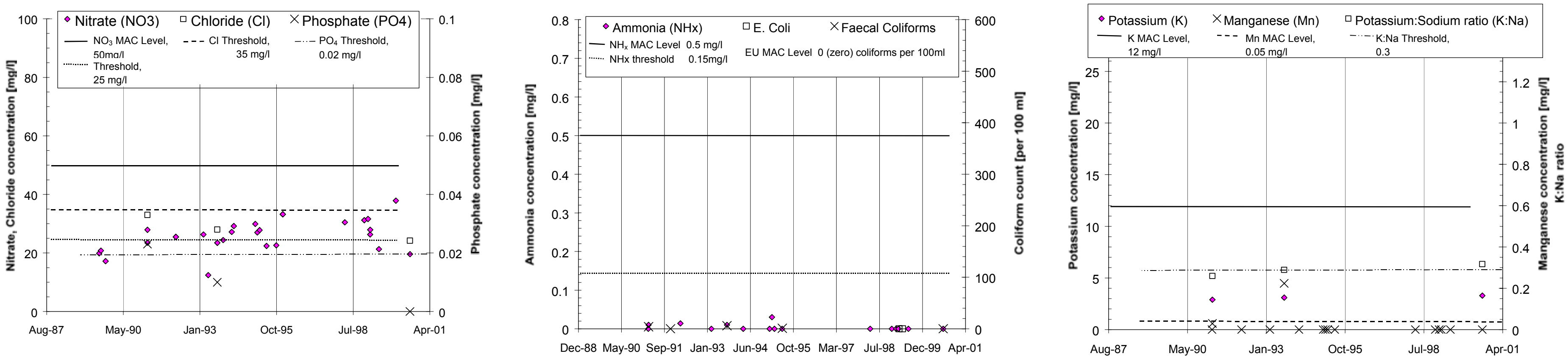


Figure 9: Borrisoleigh WSS – Key indicators of agricultural and domestic groundwater contamination

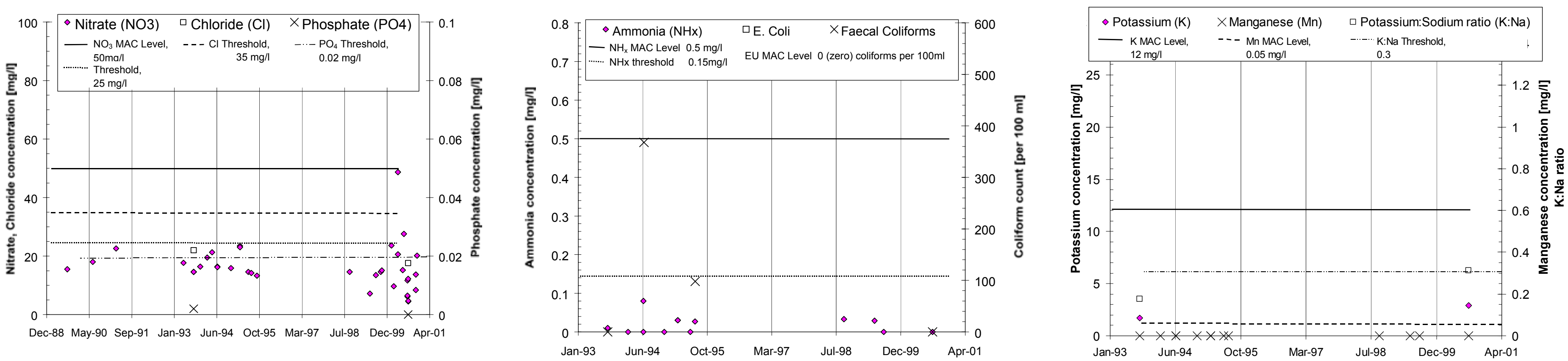


Figure 10: Clonakenny WSS – Key indicators of agricultural and domestic groundwater contamination

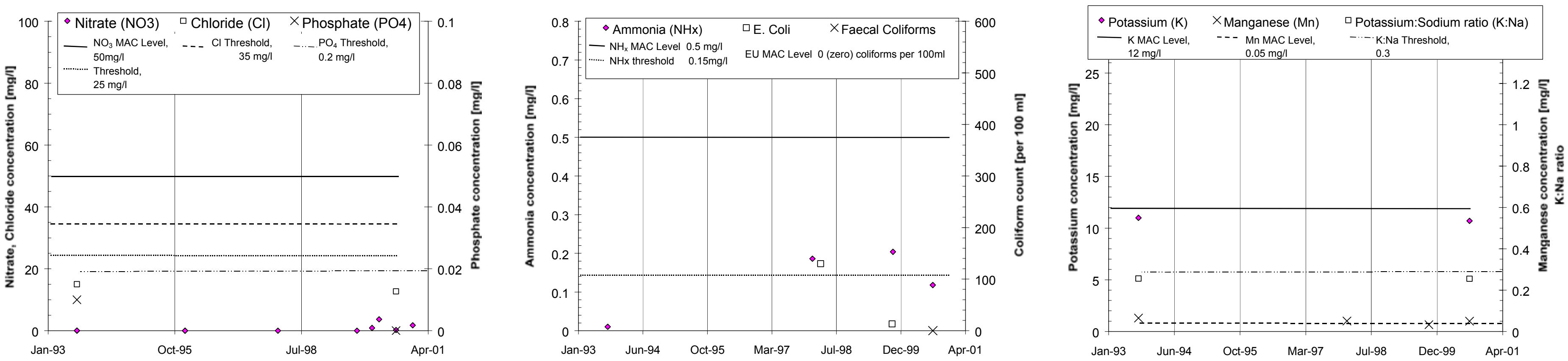


Figure 11: Cloghjordan WSS – Key indicators of agricultural and domestic groundwater contamination

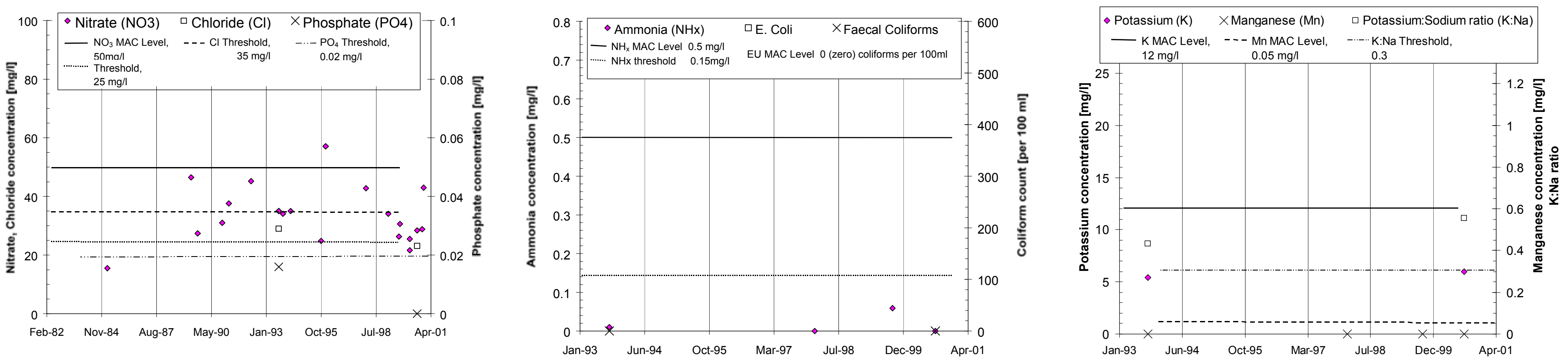


Figure 12: Drumbane WSS – Key indicators of agricultural and domestic groundwater contamination

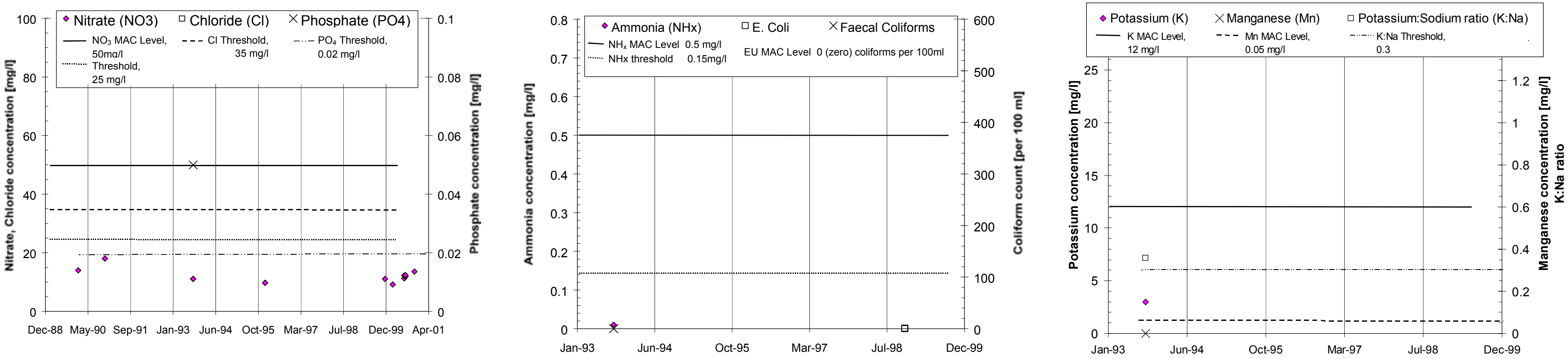


Figure 13: Holycross WSS – Key indicators of agricultural and domestic groundwater contamination

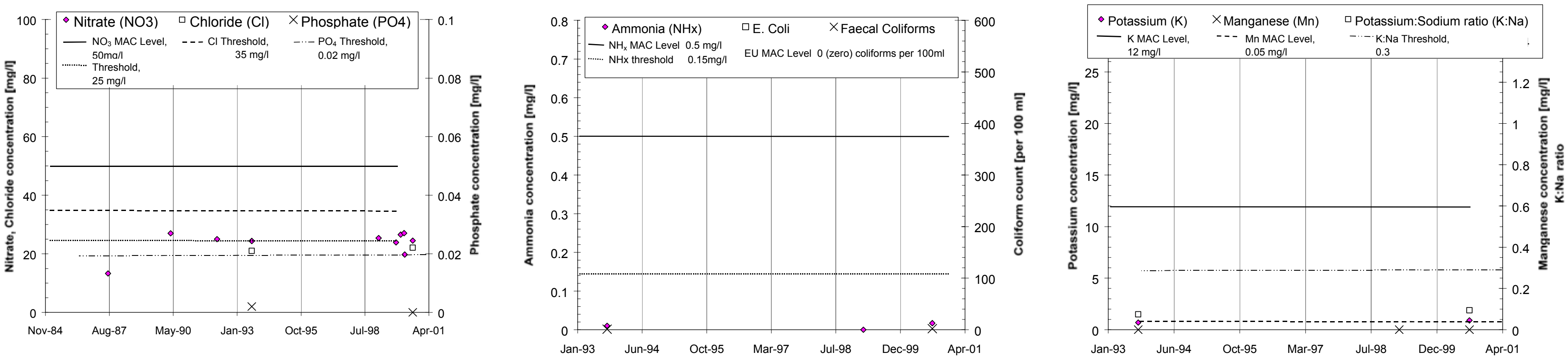


Figure 14: Kilcommon WSS – Key indicators of agricultural and domestic groundwater contamination

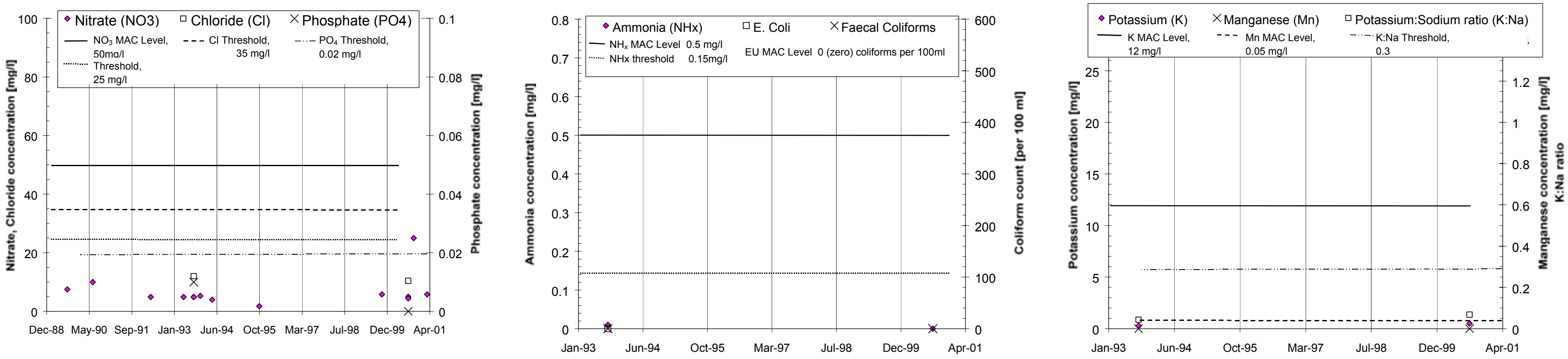


Figure 15: Littleton WSS – Key indicators of agricultural and domestic groundwater contamination

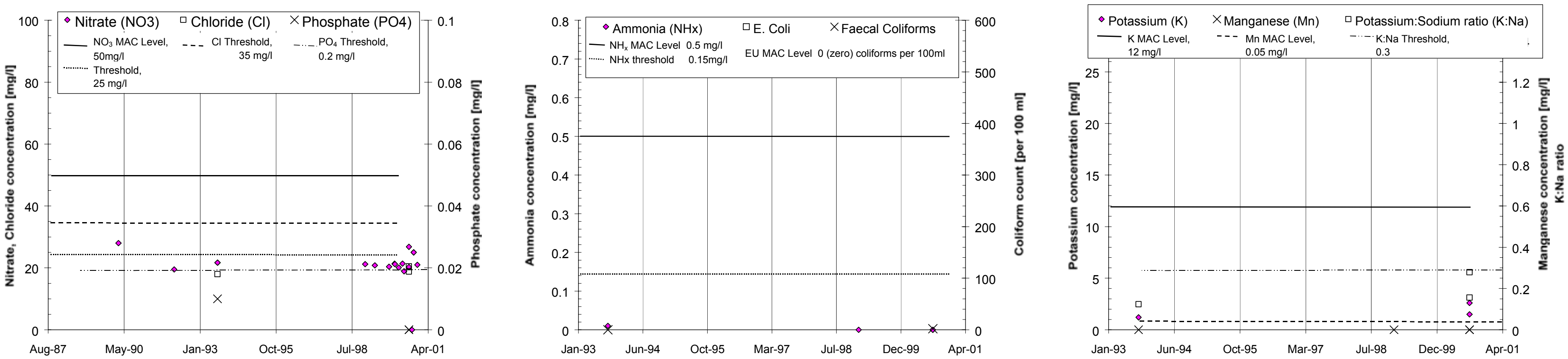


Figure 16: Lorrha WSS – Key indicators of agricultural and domestic groundwater contamination

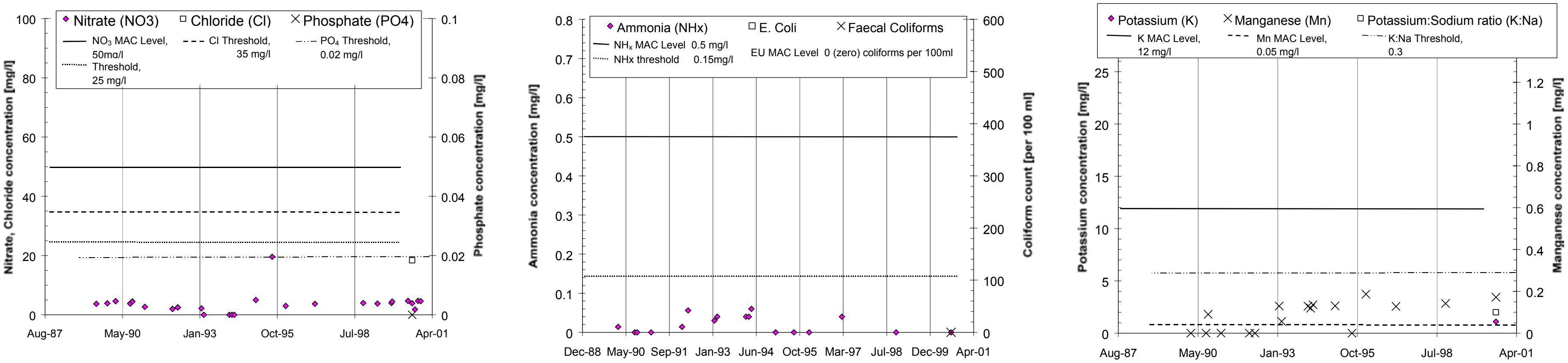


Figure 17: Loughmore WSS – Key indicators of agricultural and domestic groundwater contamination

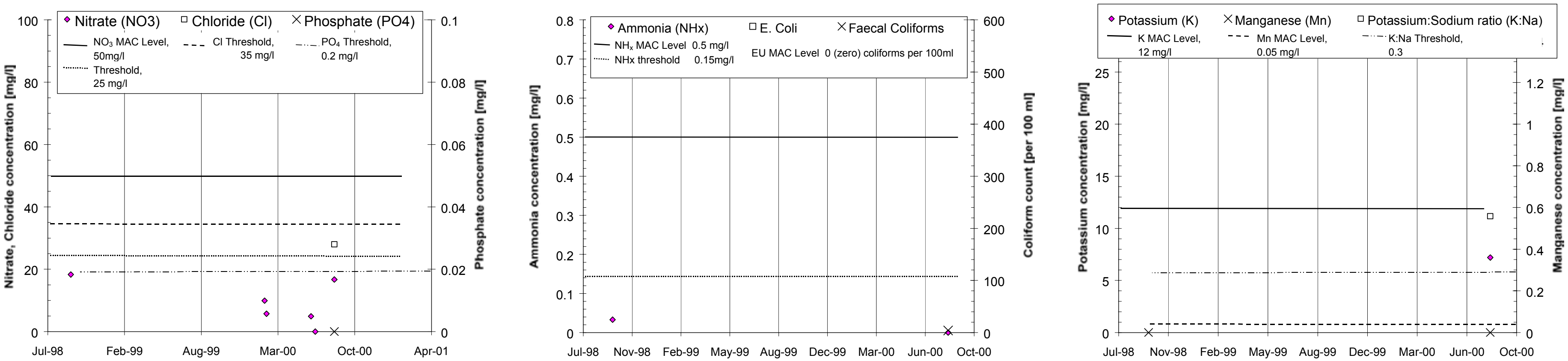


Figure 18: Moycarky WSS – Key indicators of agricultural and domestic groundwater contamination

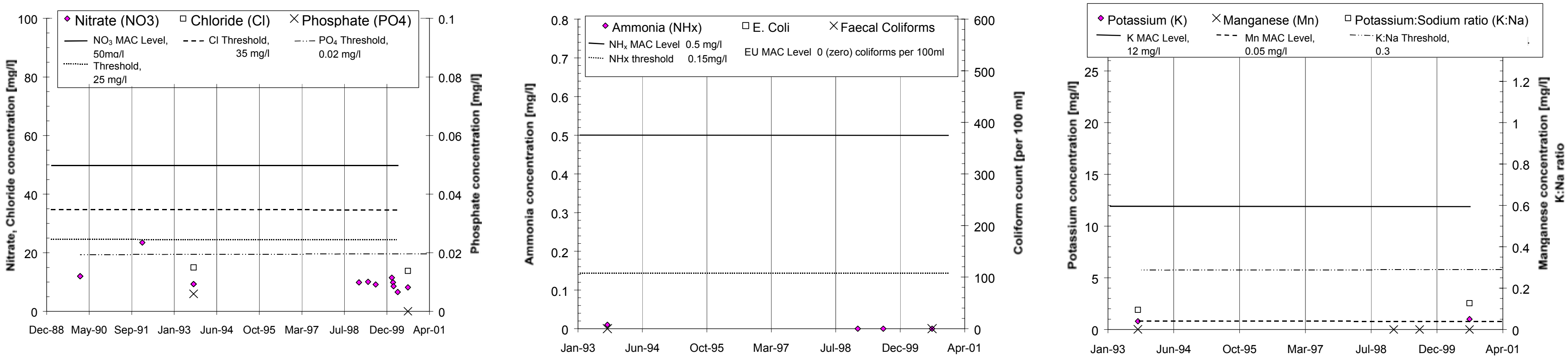


Figure 19: Riverstown WSS – Key indicators of agricultural and domestic groundwater contamination

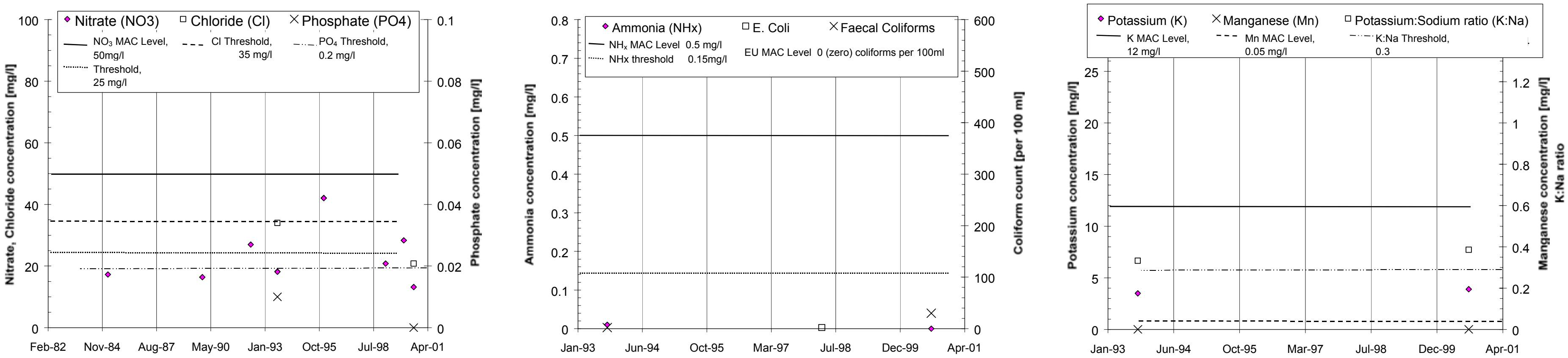


Figure 20: Roscrea – Glenbeha WSS – Key indicators of agricultural and domestic groundwater contamination

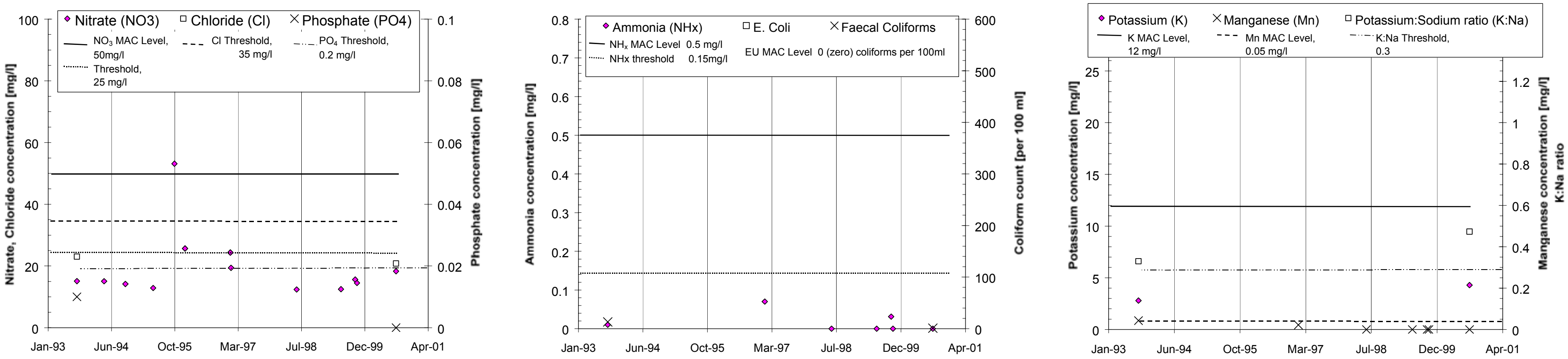


Figure 21: Templederry WSS – Key indicators of agricultural and domestic groundwater contamination

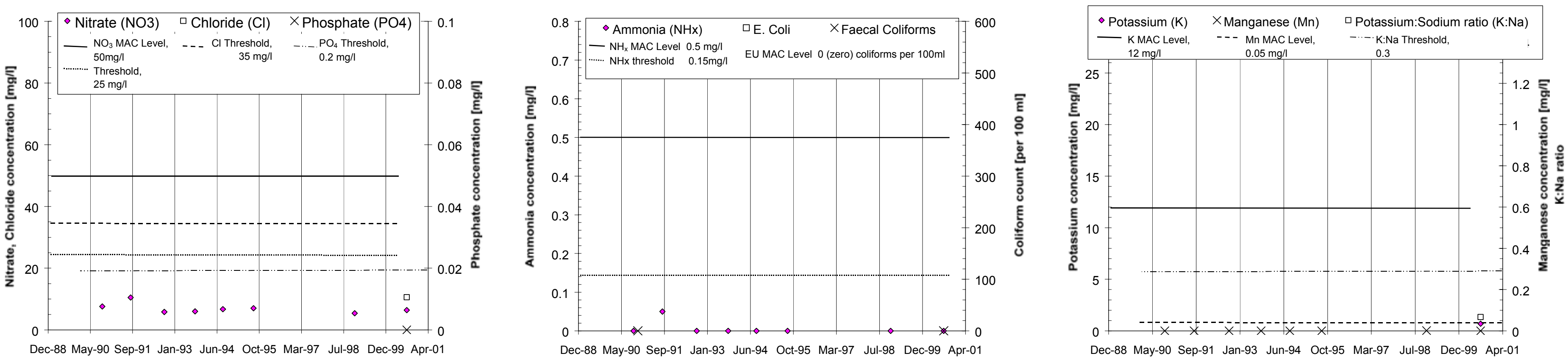


Figure 22: Templemore WSS – Key indicators of agricultural and domestic groundwater contamination

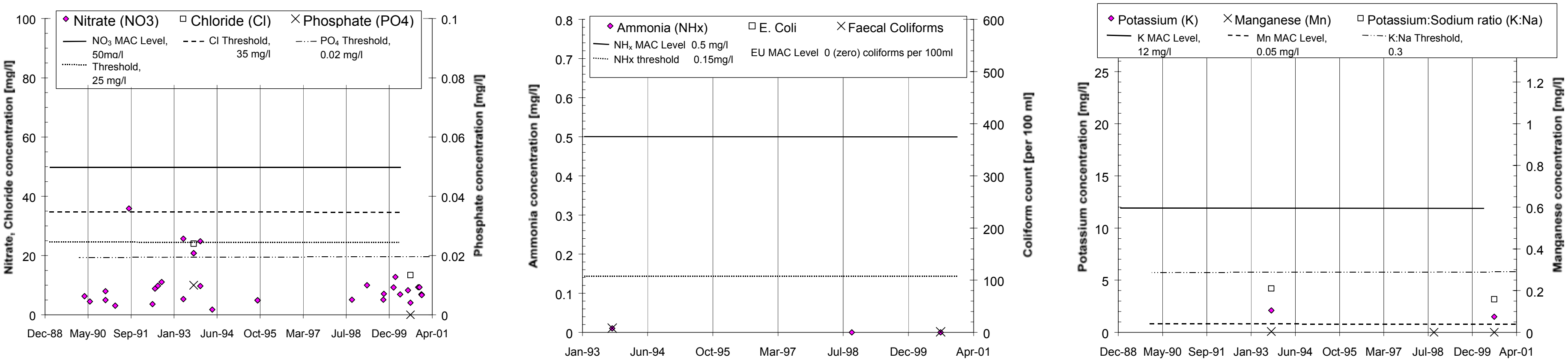


Figure 23: Templetouhy WSS – Key indicators of agricultural and domestic groundwater contamination

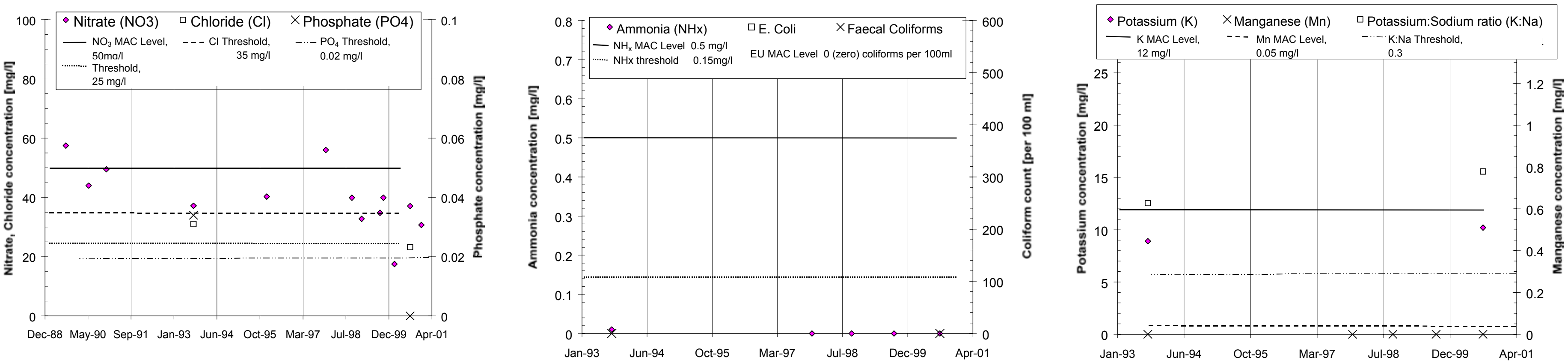


Figure 24: Terryglass WSS – Key indicators of agricultural and domestic groundwater contamination

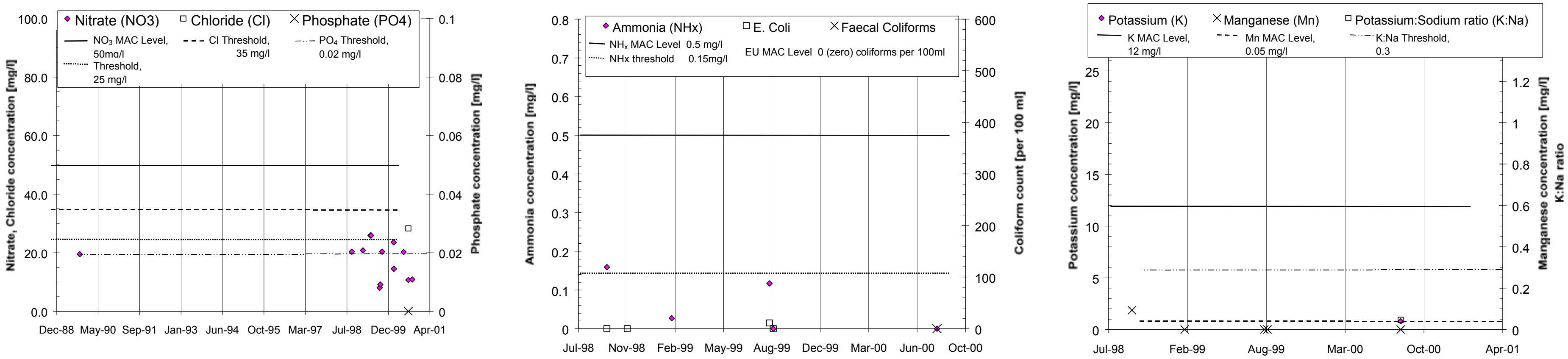


Figure 25: Thurles Creamery WSS – Key indicators of agricultural and domestic groundwater contamination

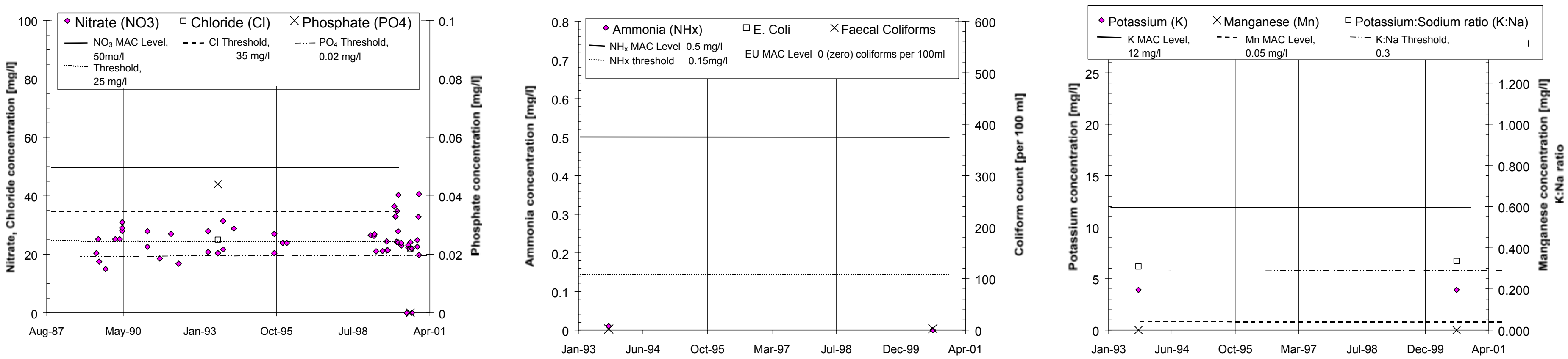


Figure 26: Thurles Lady's Well WSS – Key indicators of agricultural and domestic groundwater contamination

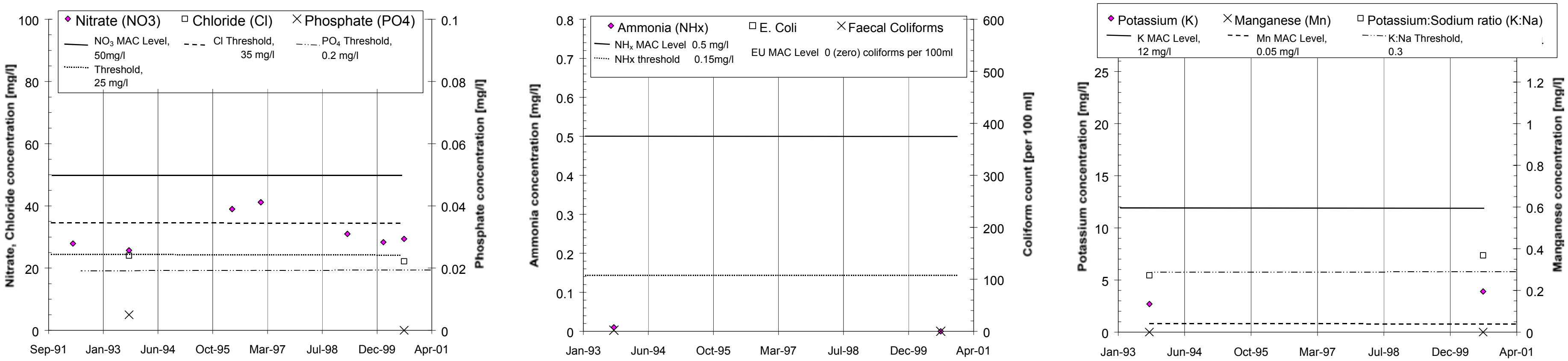


Figure 27: Thurles Tobernaloo WSS – Key indicators of agricultural and domestic groundwater contamination

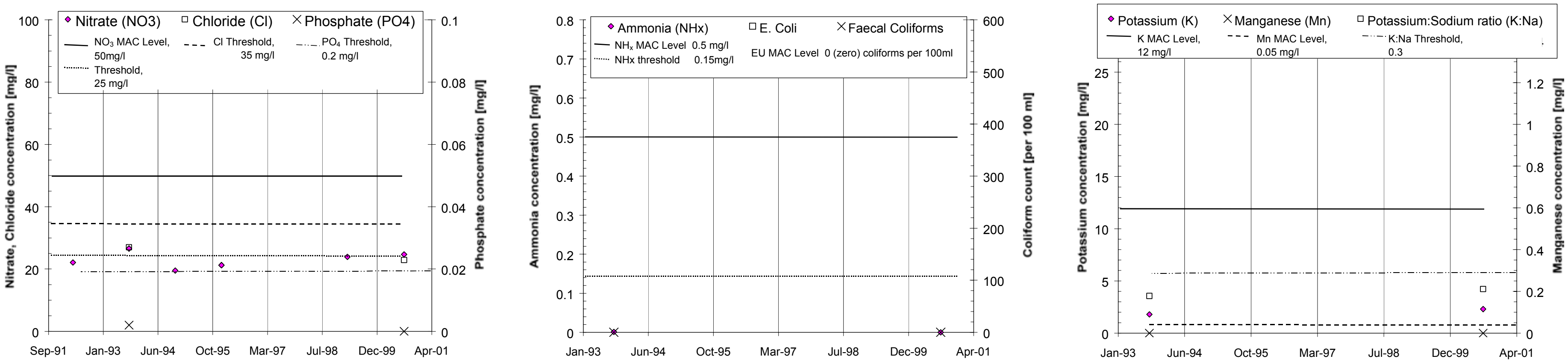


Figure 28: Toomyvara WSS – Key indicators of agricultural and domestic groundwater contamination

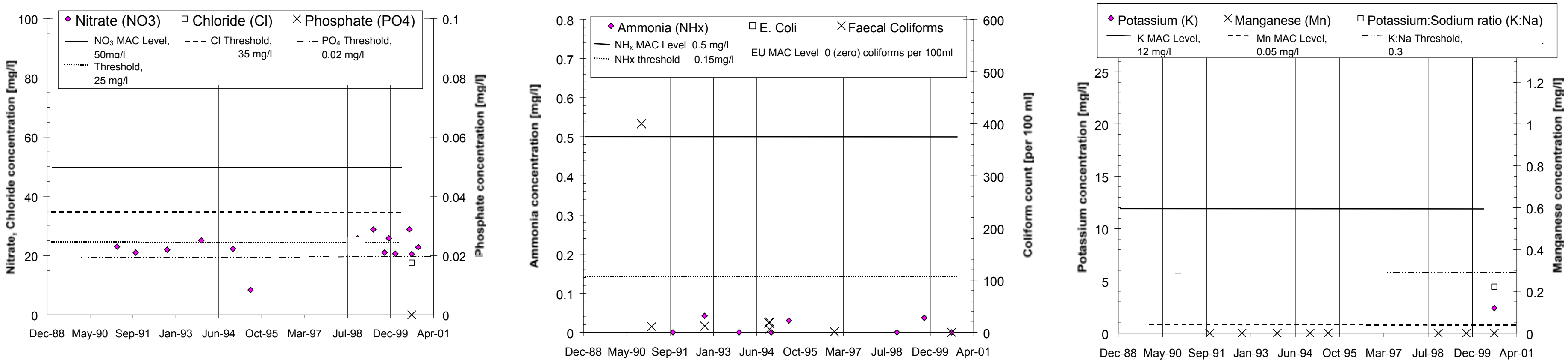


Figure 29: Tullahedy WSS – Key indicators of agricultural and domestic groundwater contamination

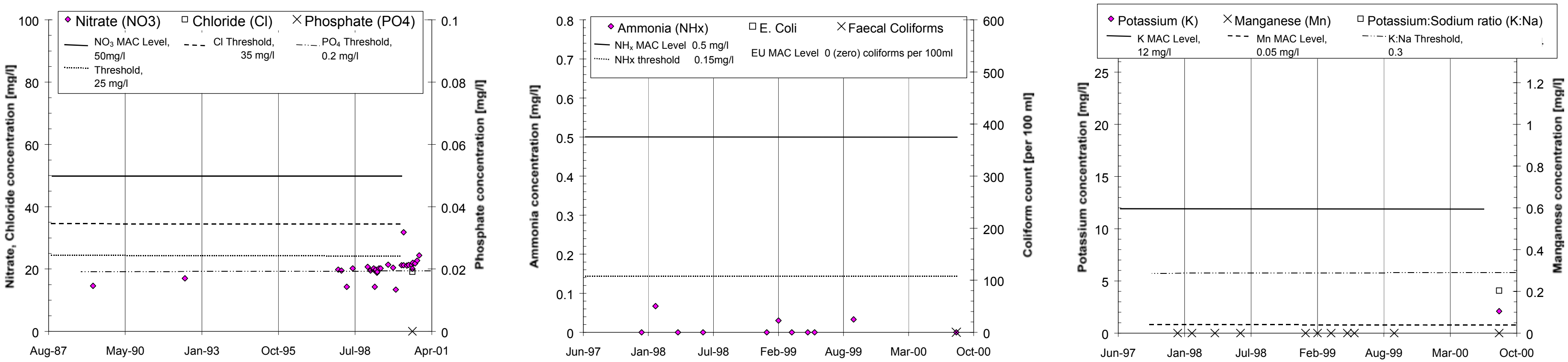


Figure 30: Two-Mile-Borris WSS – Key indicators of agricultural and domestic groundwater contamination

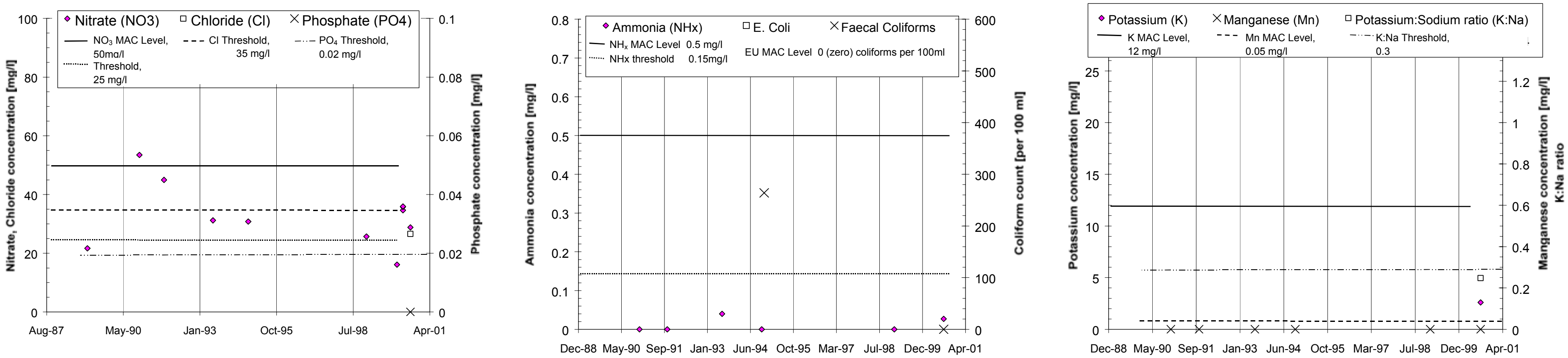
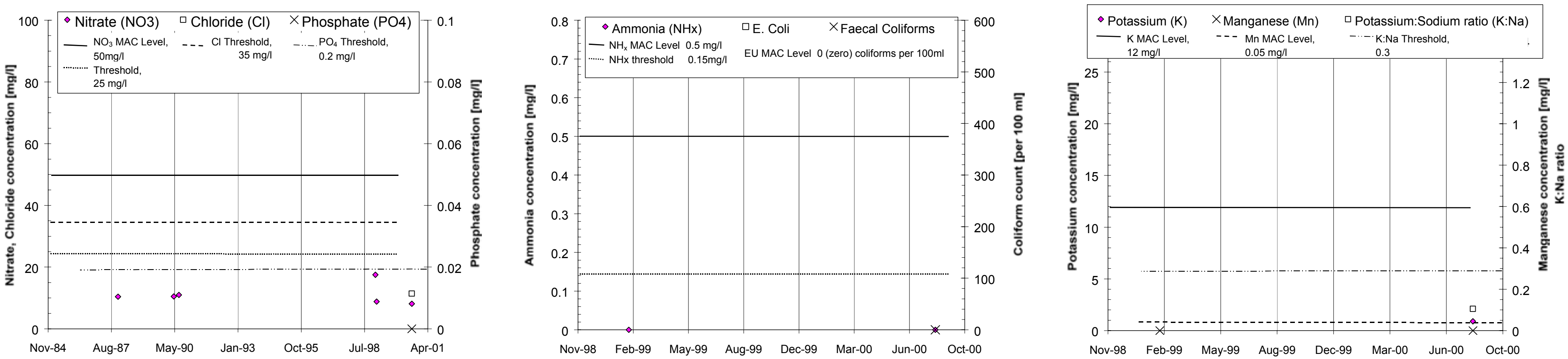


Figure 31: Upperchurch WSS – Key indicators of agricultural and domestic groundwater contamination



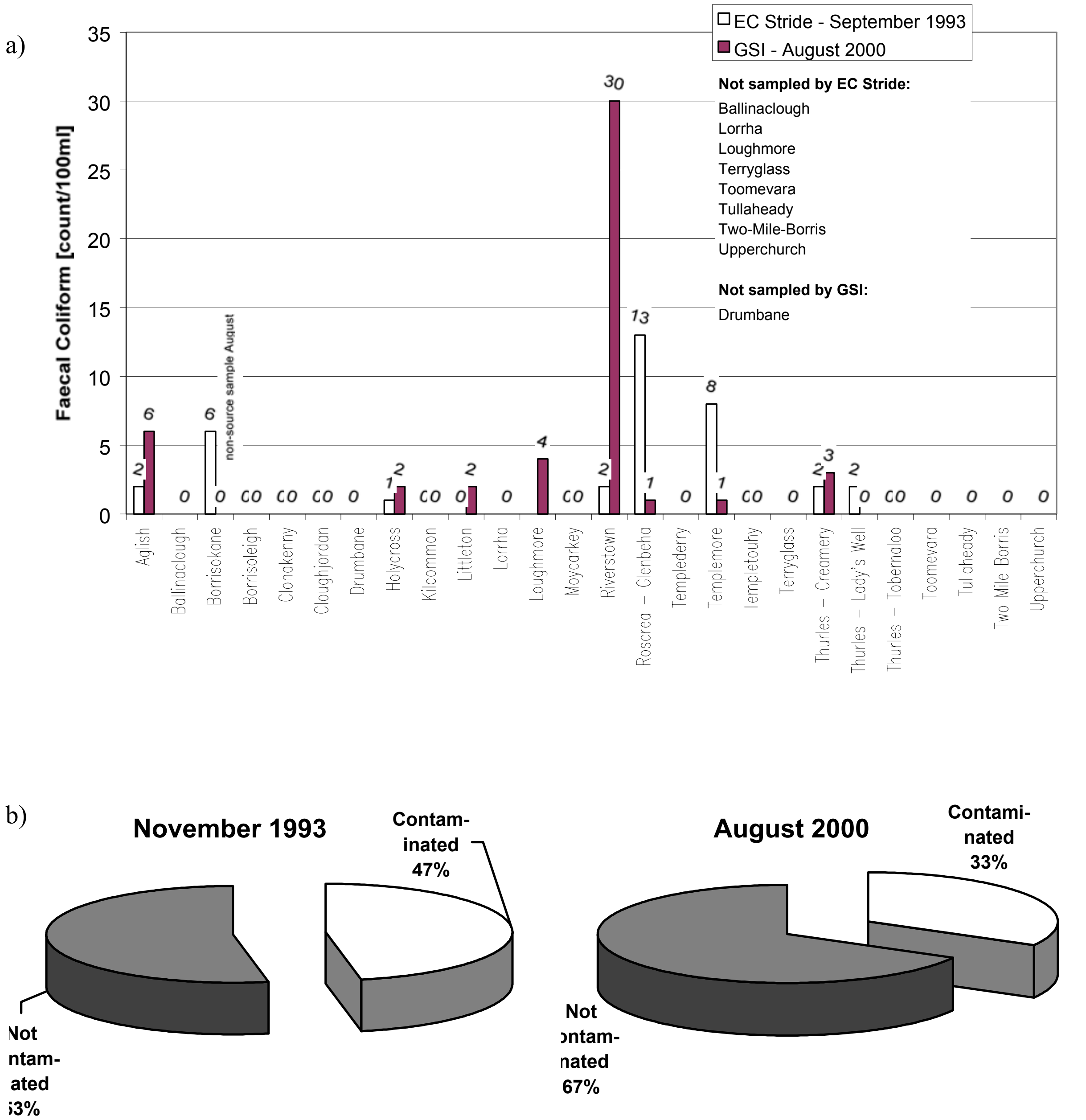
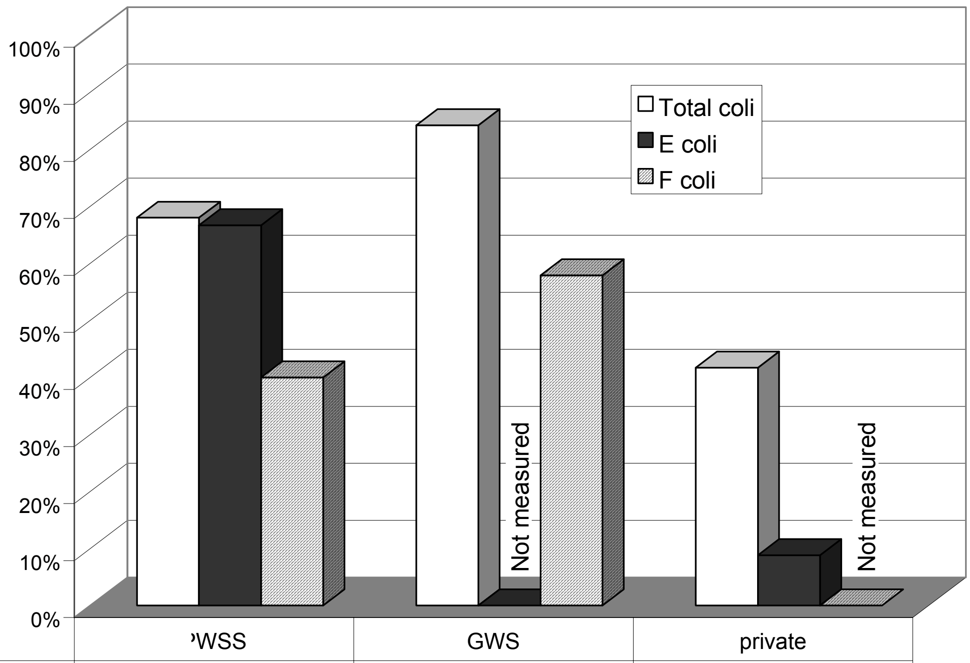


Figure 32: Faecal coliform concentrations measured in two sampling rounds of 26 WSSs in North Tipperary.

(a) Bar chart of faecal coliform concentrations at each source in 1993 and 2000. (b) Percentage of sources sampled that were contaminated or not contaminated by faecal coliforms in 1993 and 2000.

Sampling by EC Stride (1993) and GSI (August 2000) on the sources listed in Table 4. Note that some sources were sampled only once.



	'WSS	GWS	private
Total coli	68.0%	84.2%	41.7%
E coli	66.7%		8.8%
F coli	40.0%	57.9%	

Figure 33: Percentage of WSS, GWS and private groundwater supply sources that were contaminated at the time of measurement in at least one sample by general coliform organisms (Total), *E. coli* or faecal coliforms.

E. coli were not measured in the GWS groundwater quality assessment by the DoELG; faecal coliforms are not routinely measured in the assessment of private supplies.

***E Coli* concentrations**

Number of sources sampled: **Number of samples:**
WSSs: 6 11
(Aglish, Clonakenny, Drumbane, Riverstown – non-source positive samples
Kilcommon, Terryglass – source sample)
Private: 102 102 (unscreened samples)
(see Appendix F)

Faecal Coli

Number of sources sampled: **Number of samples:** (raw or positive non-
WSSs: 25 55 non-source samples)
(all WSS sources listed in Table 4 but not Drumbane)
GWS: 38 122 (unscreened samples)
(3 sampling rounds – listed in Appendix E, but not (November 2000): Graige/Pouldine, Abbeyville, Ballinderry, Scraggeen; or (December 2000): Barnane, Scrageen, Toher).

Total Coli

Number of sources sampled: **Number of samples:**
WSS: 25 71 raw samples and all non-source samples with detectable coliforms
(all WSS sources listed in Table 4 but not Drumbane)
GWS: 38 122 (unscreened samples)
(3 sampling rounds – listed in Appendix E, but not (November 2000): Graigue/Pouldine, Abbeyville, Ballinderry, Scraggeen; or (December 2000): Barnane, Scrageen, Toher).
Private: 247 247

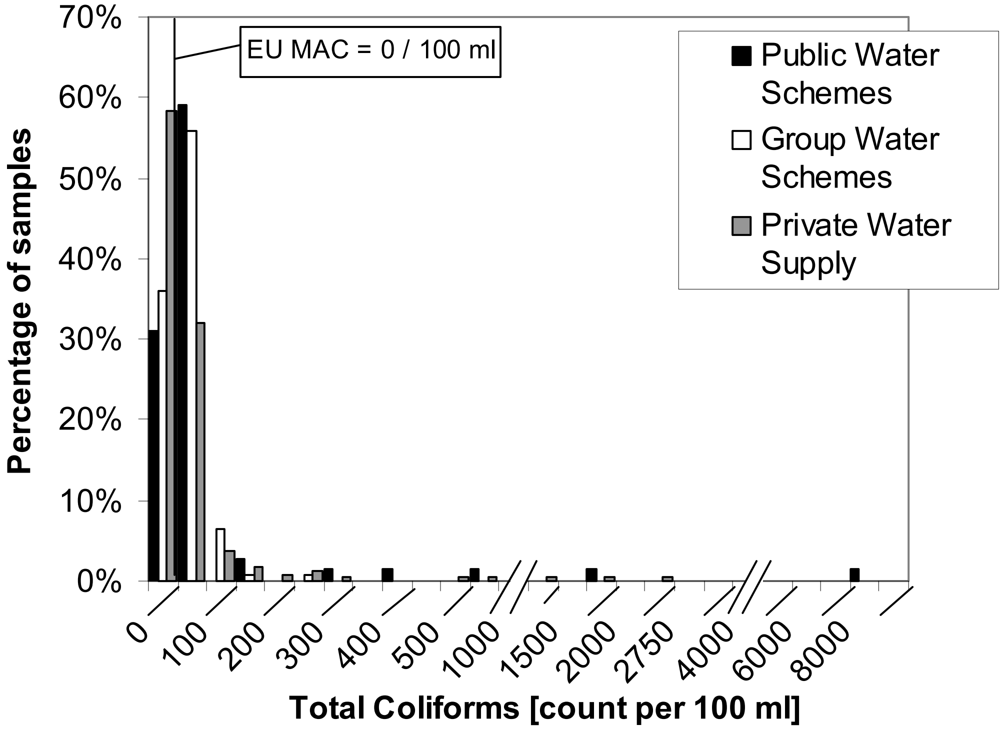


Figure 34: Frequency of occurrence as a percentage of all samples within each source type of Total Coliform concentrations in WSS, GWS and private water supplies.

An analysis for total coliforms gives an indication of the general level of microbiological contamination of a water, since not all coliform organisms (or organisms which respond to the test conditions) are of faecal origin, some types being able to grow in soil. Note that private water supplies tend to have higher coliform counts than GWS and WSS, although the good quality of private supplies compared with WSS and GWS at zero and less than 100 per 100 ml is surprising.

Number of sources sampled:	**Number of samples:**	
WSS: 25	71	raw samples and all non-source samples with detectable coliforms

(all WSS sources listed in Table 4 but not Drumbane)

GWS: 38	122	(unscreened samples)

(3 sampling rounds – listed in Appendix E, but not (November 2000): Graigue/Pouldine, Abbeyville, Ballinderry, Scraggeen; or (December 2000): Barnane, Scrageen, Toher).

Private: 247	247

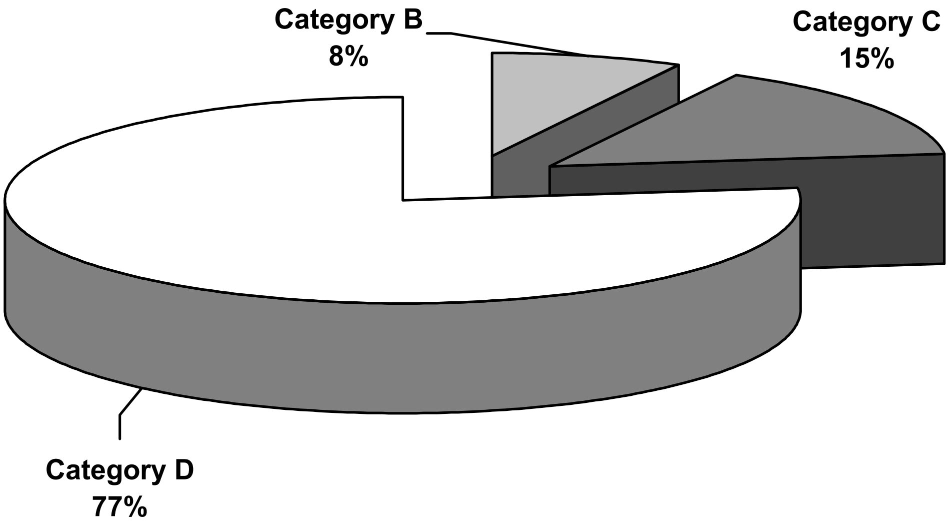
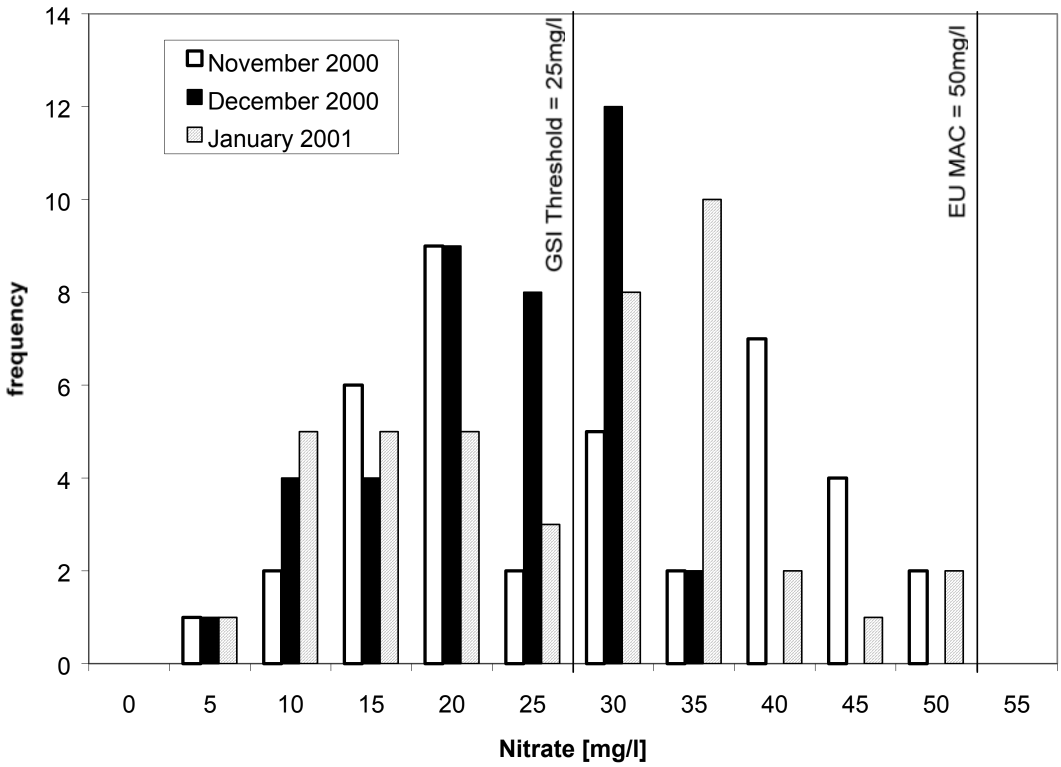


Figure 35: Percentage of WSSs that fall within each GSI nitrate category.

Twenty-six sources; the number of samples averaged at each source is variable. See Appendices B, C and D for raw data, and Figure 6 to Figure 31 for graphs of nitrate data at each source.

Category B: Average nitrate levels exceed 25mg/l and peaks regularly approach or exceed 50 mg/l; **Category C:** Average nitrate levels exceed 25 mg/l, peaks rarely approach 50 mg/l but give cause for concern; **Category D:** Average nitrate levels are <25 mg/l and peaks do not give cause for concern.

a)



b)

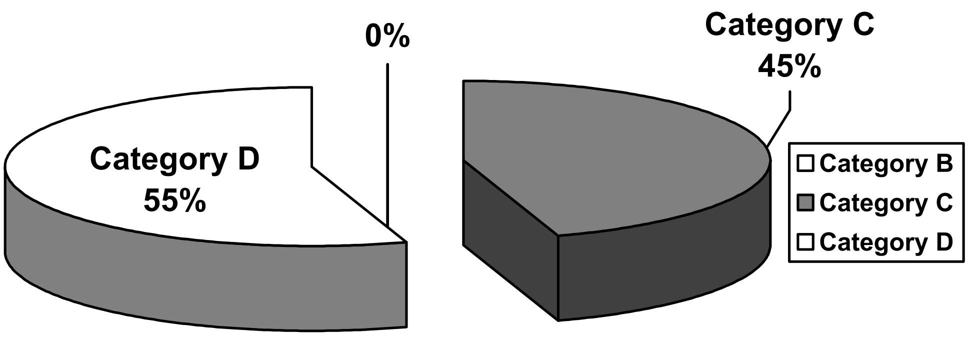


Figure 36: (a) Histogram of nitrate concentrations in 38 GWS sources sampled by the DoELG in November 2000 – January 2001 (see Appendix E for the raw data). **(b)** Percentage of sources within each GSI nitrate category (38 sources, data at each source averaged over 3 samples).

Category B: Average nitrate levels exceed 25mg/l and peaks regularly approach or exceed 50 mg/l; **Category C:** Average nitrate levels exceed 25 mg/l, peaks rarely approach 50 mg/l but give cause for concern; **Category D:** Average nitrate levels are <25 mg/l and peaks do not give cause for concern.

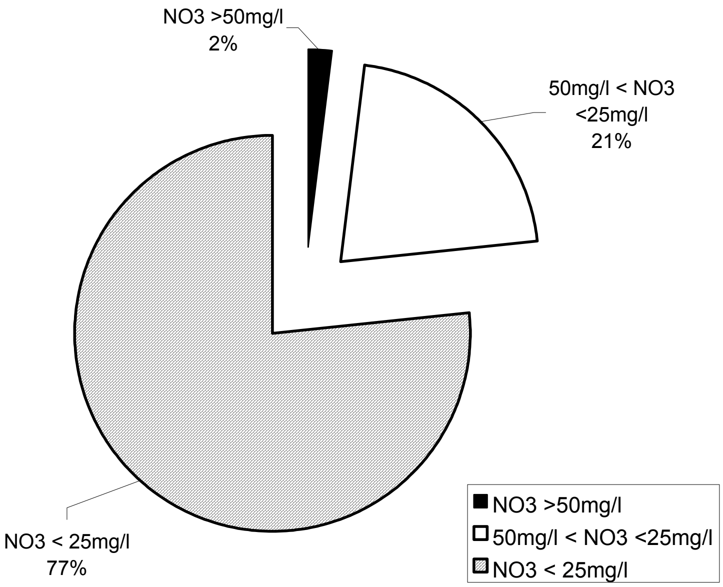


Figure 37: Nitrate levels in private water supplies, assessed with respect to the GSI threshold of 25 mg/l and the EU MAC of 50 mg/l.

Number of samples 262.

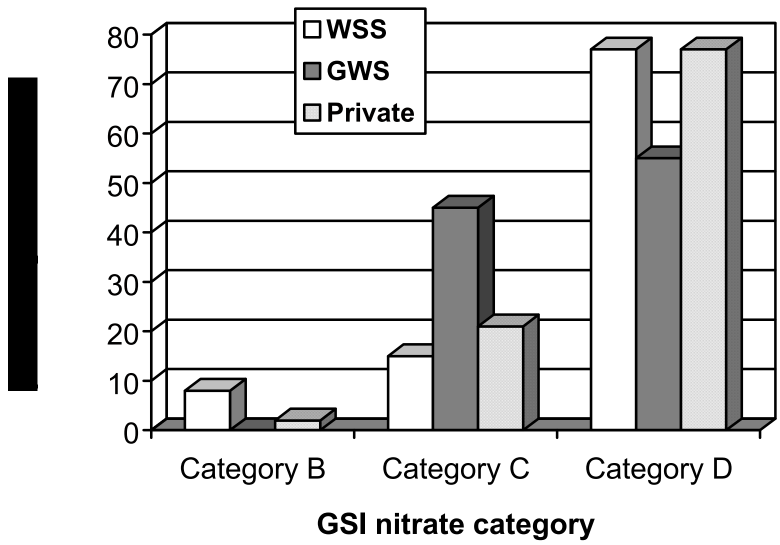
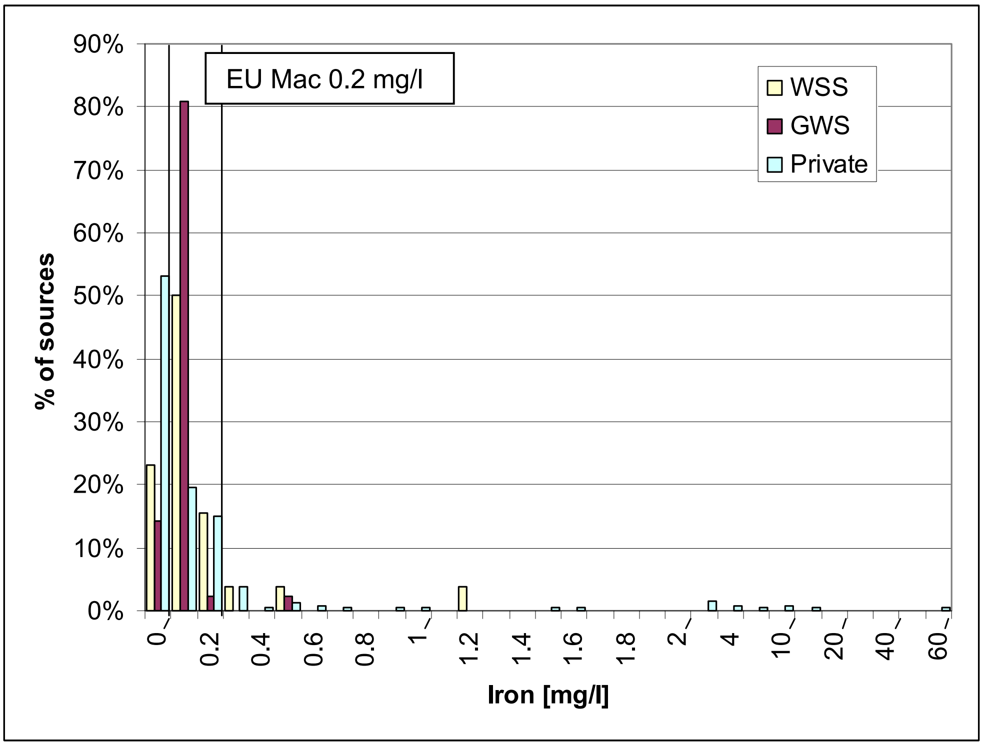


Figure 38: Percentage of WSS, GWS and private supply sources falling within the GSI nitrate categories.

Category B: Average nitrate levels exceed 25mg/l and peaks regularly approach or exceed 50 mg/l; **Category C:** Average nitrate levels exceed 25 mg/l, peaks rarely approach 50 mg/l but give cause for concern; **Category D:** Average nitrate levels are <25 mg/l and peaks do not give cause for concern.

a)



b)

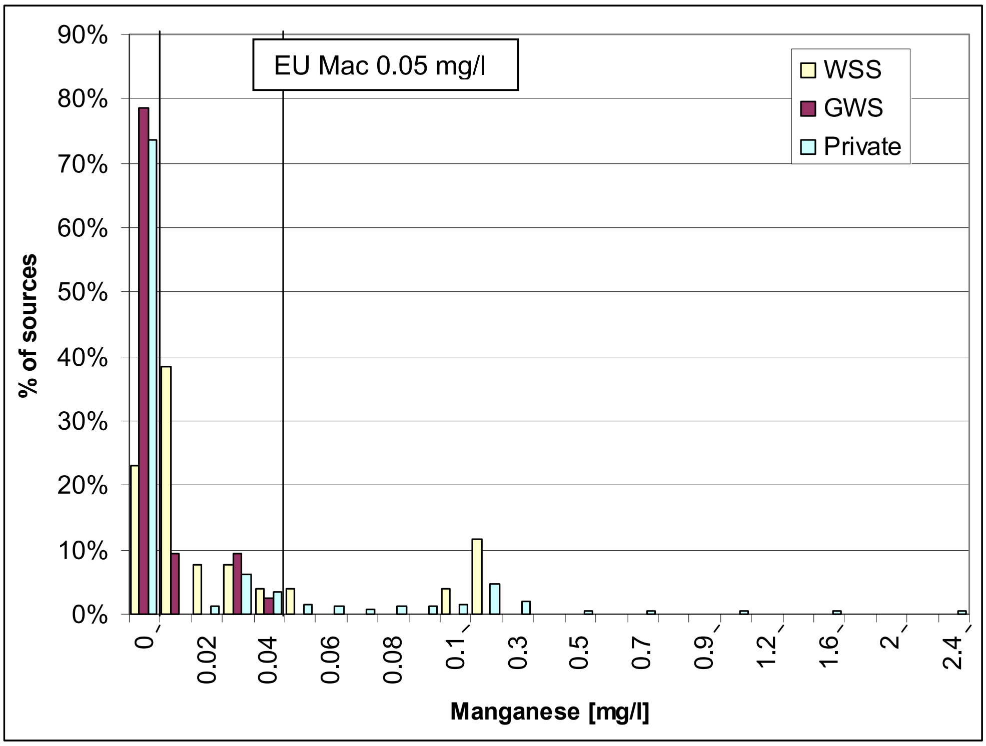


Figure 39: Histogram of (a) iron and (b) manganese concentration at each source in groundwater samples from WSS, GWS and private supply schemes.

Number of sources: WWS – 26, GWS – 42; Private – 242. Where more than one sample per source (e.g., WWS and GWS), values averaged. Note the variable scale on the concentration axes.

Appendices

Appendix A: Discussion of the key indicators of domestic and agricultural contamination of groundwater

(adapted from Daly, 1996)

A.1 Introduction

There has been a tendency in analysing groundwater samples to test for a limited number of constituents. A "full" or "complete" analysis, which includes all the major anions and cations, is generally recommended for routine monitoring and for assessing pollution incidents. This enables (i) a check on the reliability of the analysis (by doing an ionic balance), (ii) a proper assessment of the water chemistry and quality and (iii) a possible indication of the source of contamination. A listing of recommended and optional parameters are given in Table A1. It is also important that the water samples taken for analysis have not been chlorinated – this is a difficulty with some local authority sources where water take-off points prior to chlorination have not been installed.

The following parameters are good contamination indicators: *E.coli*, nitrate, ammonia, potassium, chloride, iron, manganese and trace organics.

TABLE A1

Recommended Parameters		
Appearance	Calcium (Ca)	Nitrate (NO_3)*
Sediment	Magnesium (Mg)	Ammonia ($NH_4$and NH_3)*
pH (lab)	Sodium (Na)	Iron (Fe)*
Electrical Conductivity (EC)*	Potassium (K)*	Manganese (Mn)*
Total Hardness	Chloride (Cl)*	
General coliform	Sulphate ($S0_4$)*	
E. coli *	Alkalinity	
Optional Parameters (depending on local circumstances or reasons for sampling)		
Fluoride (F)	Fatty acids *	Zinc (Zn)
Orthophosphate	Trace organics *	Copper (Cu)
Nitrite (NO_2)*	TOC *	Lead (Pb)
B.O.D.*	Boron (B) *	Other metals
Dissolved Oxygen *	Cadmium (Cd)	
*** good indicators of contamination**		

A.2 Faecal Bacteria and Viruses

For assessment of the microbiological quality of water, it is the faecal coliform count that is the primary indicator of pollution of faecal origin in the water. While there is no absolute correlation between the coliform presence and other bacterial pathogens due to the variable and unpredictable behaviour of pathogens, the underlying principle of the test for faecal coliforms is that its presence in waters indicates the potential presence of pathogens. The usefulness of the test as indicators of protozoan or viral contamination is limited. The most common health problems arising from the presence of microbial agents include diarrhoea, gastro-enteritis, giardiasis, cryptospiridiosis and hepatitis. Sources of *E. coli* include septic tank effluent, farmyard waste, landfill sites and birds. There is no reliable method to distinguish between animal and human waste sources. Establishing water quality criteria for viruses and protozoan pathogens is difficult as the infective dose for all strains is generally unknown. In addition, they can persist longer in natural waters than faecal coliforms and are more resistant to water treatment processes. As not all coliform organisms (or organisms which respond to the test conditions) are of faecal origin, some types being able to grow in soil, a second analysis is carried out for the presence of total coliforms, giving an indication of the general level of microbiological contamination of a water. The latter is a confirmatory test.

E. coli is the parameter tested as an indicator of the presence of faecal bacteria and perhaps viruses; constituents which pose a significant risk to human health. The most common health problem arising from the presence of faecal bacteria in groundwater is diarrhoea, but typhoid fever, infectious hepatitis and gastrointestinal infections can also occur. Although E. coli bacteria are an excellent indicator of pollution, they can come from different sources - septic tank effluent, farmyard waste, landfill sites, birds. The faecal coliform:faecal streptococci ratio has been suggested as a tentative indicator to distinguish between animal and human waste sources (Henry *et al*., 1987). However, researchers in Virginia Tech (Reneau, 1996) cautioned against the use of this technique.

Viruses are a particular cause for concern as they survive longer in groundwater than indicator bacteria (Gerba and Bitton, 1984).

The published data on elimination of bacteria and viruses in groundwater has been compiled by Pekdeger and Matthess (1983), who show that in different investigations 99.9% elimination of *E. coli* occurred after 10-15 days. The mean of the evaluated investigations was 25 days. They show that 99.9% elimination of various viruses occurred after 16-120 days, with a mean of 35 days for Polio-, Hepatitis, and Enteroviruses. According to Armon and Kott (1994), pathogenic bacteria can survive for more than ten days under adverse conditions and up to 100 days under favourable conditions; entertoviruses can survive from about 25 days up to 170 days in soils.

Bacteria can move considerable distances in the subsurface, given the right conditions. In a sand and gravel aquifer, coliform bacteria were isolated 100 ft from the source 35 hours after the sewage was introduced (Hagedorn, 1983). They can travel several kilometres in karstic aquifers. In Ireland, research at Sligo RTC involved examining in detail the impact of septic tank systems at three locations with different site conditions (Henry, 1990; summarised in Daly, Thorn and Henry, 1993). Piezometers were installed down-gradient; the distances of the furthest piezometers were 8 m,10 m and 9.5 m, respectively. Unsurprisingly, high faecal bacteria counts were obtained in the piezometers at the two sites with soakage pits, one with limestone bedrock at a shallow depth where the highest count (max. 14 000 cfu's per 1000 ml) and the second where sand/gravel over limestone was present (max 3 000 cfu's per 100 ml). At the third site, a percolation area was installed at 1.0 m b.g.l; the subsoils between the percolation pipes and the fractured bedrock consisted of 1.5 m sandy loam over 3.5 m of poorly sorted gravel; the water table was 3.5 m b.g.l. (So this site would satisfy the water table and depth to rock requirements of S.R.6:1991, and most likely the percolation test requirement.) Yet, the maximum faecal coliform bacteria count was 300 cfus per 100 ml. Faecal streptocci were present in all three piezometers. It is highly likely that wells located 30 m down gradient of the drainage fields would be polluted by faecal bacteria.

As viruses are smaller than bacteria, they are not readily filtered out as effluent moves through the ground. The main means of attenuation is by adsorption on clay particles. Viruses can travel considerable distances underground, depths as great as 67 m and horizontal migrations as far as 400 m have been reported (Keswick and Gerba, 1980; as reported in US EPA, 1987). The possible presence of viruses in groundwater as a result of pollution by septic tank systems is a matter of concern because of their mobility and the fact that indicator bacteria such faecal coliforms have been found not to correlate with the presence of viruses in groundwater samples (US EPA, 1987).

The natural environment, in particular the soils and subsoils, can be effective in removing bacteria and viruses by predation, filtration and absorption. There are two high risk situations: (i) where permeable sands and gravels with a shallow water table are present; and (ii) where fractured rock, particularly limestone, is present close to the ground surface. The presence of clayey gravels, tills, and peat will, in many instances, hinder the vertical migration of microbes, although preferential flow paths, such as cracks in clayey materials, can allow rapid movement and bypassing of the subsoil.

A.3 Parasitic Protozoans and viruses

During the last 20-30 years many outbreaks of waterborne giardiasis and cryptospiridosis have been reported with high frequency in USA, UK and Canada. In Britain, cryptosporidium is the fourth most common cause of water borne related diarrhoea. Detailed information about different Cryptosporidium species, together with their occurrence, viability and infectivity is currently scarce. Cryptosporidia oocysts have been found in faecal material from pigs, cattle, rabbits, sheep and many birds. There is a strong body of evidence that there are identifiable "strains" of cryptosporidium and that one such "strain" appears to be restricted to humans. Current detection methods are not specific to species which are viable or pathogenic to humans. Infection by Cryptosporidium parvum causes self limiting gastroenteritis of approximately two to three weeks duration in immuno-compromised hosts. In immuno-suppressed hosts the disease is much more severe. The infective dose for humans is not known with any confidence but is thought to be quite low. As yet there is no specific treatment. There is always a low level of cryptosporidiosis in the community and it is unlikely that drinking water is the major cause of this background. Infection is initiated by ingestion of the oocyst with subsequent excystation and release of the organism , usually on exposure to bile salts. The organism completes its lifecycle within the host and produces oocysts which are excreted in the faeces. The oocyst is environmentally robust and can survive routine water treatment, which will normally remove bacterial pathogens.

A.4 Nitrate

Nitrate is one of the most common contaminants identified in groundwater and increasing concentrations have been recorded in many developed countries. The consumption of nitrate-rich water by young children may give rise to a condition known as methaemoglobinaemia (‘blue baby syndrome’). The formation of carcinogenic nitrosamines is also a possible health hazard and epidemiological studies have indicated a positive correlation between nitrate consumption in drinking water and the incidence of gastric cancer. However, the correlation is not proven according to some experts (Wild & Cameron, 1980). The EC MAC for drinking water is 50mg/l.

The nitrate ion is not adsorbed on clay or organic matter. It is highly mobile and under wet conditions is easily leached out of the rooting zone and through soil and permeable subsoil. As the normal concentrations in uncontaminated groundwater is low (less than 5 mg/l), nitrate can be a good indicator of contamination by fertilisers and waste organic matter.

In the past there has been a tendency in Ireland to assume that the presence of high nitrates in well water indicated an impact by inorganic fertilisers. This assumption has frequently been wrong, as examination of other constituents in the water showed that organic wastes - usually farmyard waste, probably soiled water - were the source. The nitrate concentrations in wells with a low abstraction rate - domestic and farm wells - can readily be influenced by soiled water seeping underground in the vicinity of the farmyard or from the spraying of soiled water on adjoining land. Even septic tank effluent can raise the nitrate levels; if a septic tank system is in the zone of contribution of a well, a four-fold dilution of the nitrogen in the effluent is needed to bring the concentration of nitrate below the EU MAC. (The EU limit is 50 mg/l as NO_3 or 11.3 mg/l as N and assuming that the N concentration in septic tank effluent is 45 mg/l).

The recently produced draft county reports by the EPA on nitrate in groundwater (EPA in prep.) show high levels of nitrate in a significant number of public and group scheme supplies, particularly in south and southern counties and in counties with intensive agriculture, such as Carlow and Louth. This suggests that diffuse sources – landspreading of fertilisers – are having an impact on groundwater.

To counteract the threat posed to health and the environment by rising nitrate levels, the EC issued a directive to control inputs of nitrate from agricultural sources to water (Thorn & Coxon, 1992). This ‘Nitrates Directive’ (Commission of the European Communities, 1991) allows for the designation of "vulnerable zones", which are areas of land that drain into surface or groundwaters which are intended for the abstraction of drinking water and which could contain more than 50mg/l nitrate if protective action is not taken.

In assessing regional groundwater quality and, in particular the nitrate levels in groundwater, it is important that:

(i) conclusions should not be drawn using data only from private wells, which are frequently located near potential point pollution sources and from which only a small quantity of groundwater is abstracted;

(ii) account should be taken of the complete chemistry of the sample and not just nitrate, as well as the presence of *E. coli*.;

(iii) account should be taken of not only the land-use in the area but also the location of point pollution sources;

(iv) account should be taken of the regional hydrogeology and the relationship of this to the well itself. For instance, shallow wells generally show higher nitrate concentrations than deeper wells, low permeability sediments can cause denitrification, knowledge of the groundwater flow direction is needed to assess the influence of land-use.

Giving a balanced view of the nitrate situation in Irish groundwater is not easy as the data availability is poor. On the one hand, many of the wells with relatively high nitrate levels examined by the GSI are being contaminated by organic waste and not inorganic fertilisers. On the other hand, inorganic fertilisers have increased the background nitrate levels significantly in some of the intensive agricultural areas - the Barrow valley, for instance.

A.5 Ammonia

Ammonia has a low mobility in soil and subsoil and its presence in concentrations above 0.1 mg/l in groundwater indicates a nearby waste source and/or vulnerable conditions. The EU MAC is 0.3 mg/l.

A.6 Potassium

Potassium (K) is relatively immobile in soil and subsoil. Consequently the spreading of manure, slurry and inorganic fertilisers is unlikely to significantly increase the potassium concentrations in groundwater. In most areas in Ireland, background potassium levels in groundwater are less than 3.0 mg/l. Higher concentrations are found occasionally where the rock contains potassium e.g. certain granites and sandstones. The background potassium:sodium ratio in most Irish groundwaters is less than 0.4 and often 0.3. The K:Na ratio of soiled water and other wastes derived from plant organic matter is considerably greater than 0.4, whereas the ratio in septic tank effluent is less than 0.2. Consequently a K:Na ratio greater than 0.4 can be used to indicate contamination by plant organic matter - usually in farmyards, occasionally landfill sites (from the breakdown of paper). However, a K:Na ratio lower than 0.4 does not indicate that farmyard wastes are **not** the source of contamination (or that a septic tank is the cause), as K is less mobile than Na.

A.7 Chloride

The principal source of chloride in uncontaminated groundwater is rainfall and so in any region, depending on the distance from the sea and evapotranspiration, chloride levels in groundwater will be fairly constant. Chloride, like nitrate, is a mobile anion. Also, it is a constituent of organic wastes. Consequently, levels appreciably above background levels (12-15 mg/l in Co. Offaly, for instance) have been taken to indicate contamination by organic wastes such as septic tank systems. While this is probably broadly correct, Sherwood (1991) has pointed out that chloride can also be derived from potassium fertilisers.

A.8 Iron and manganese

Although they are present under natural conditions in groundwater in some areas, iron (Fe) and manganese (Mn) can also be good indicators of contamination by organic wastes. Effluent from wastes cause deoxygenation in the ground which results in dissolution of Fe and Mn from the soil, subsoil and bedrock into groundwater. With reoxygenation in the well or water supply system the Fe and Mn precipitate. High Mn concentrations can be a good indicator of pollution by silage effluent.

However, it can also be caused by other high BOD wastes such as milk, landfill leachate and perhaps soiled water and septic tank effluent.

A.9 Phosphorus

Phosphorus is a significant contaminant and cause for eutrophication in surface water in Ireland. It is not generally a problem in groundwater and is not likely to be in the future. There are two reasons for this:

- the orthophosphate anion, which is the plant-available form of phosphorus, precipitates quickly to either calcium or iron or aluminium phosphate, depending on the nature of the soil;
- the maximum admissible concentration for drinking water (5000 μg/l P_2O_5) = 2200 μg/l P) is rarely approached except in areas of gross contamination.

However, in surface waters phosphorus causes concern at much lower levels; total phosphorus concentrations in excess of only 20 μg/l P may trigger eutrophication. Recent research at the Environmental Sciences Unit, TCD, has pointed out that in certain hydrogeological situations, concentrations greater than this may occur in groundwater, e.g. where groundwater is extremely or highly vulnerable to contamination, particularly where fissured bedrock is at or close to the ground surface and where soils and subsoils are sandy. There may also be leaching from soils and subsoils that are saturated with phosphorus.

In conclusion, P does not generally present a problem for groundwater; however, groundwater can provide a pathway for P to reach targets such as lakes, streams and wetlands.

Box A1 Warning/trigger Levels for Certain Contaminants

As human activities have had some impact on a high proportion of the groundwater in Ireland, there are few areas where the groundwater is in a pristine, completely natural condition. Consequently, most groundwater is contaminated to some degree although it is usually not polluted. To-date there has been a tendency to focus only on the EU maximum admissible concentrations (MAC). In the view of the GSI, there is a need for assessment of the degree of contamination of groundwater as well as showing whether the water is polluted or not. This type of assessment can indicate where appreciable impacts are occurring. It can act as a warning that either the situation could worsen and so needs regular monitoring and careful land-use planning, or that there may be periods when the source is polluted and poses a risk to human health and as a consequence needs regular monitoring. Consequently, thresholds for certain parameters can be used to help indicate situations where significant contamination but not pollution is occurring. *So if you have to assess groundwater quality data when considering the location of a potentially polluting activity, see if the thresholds given below are of use.*

Parameter	**Threshold** mg/l	**EU MAC** mg/l
Nitrate	25	50
Potassium	4	12
Chloride	30 (except near sea)	250
Ammonia	0.15	0.3
K/Na ratio	0.3-0.4	
Faecal bacteria	0	0

Box A2 Summary : Assessing a Problem Area
Let us assume that you are examining an area with potential groundwater contamination problems and that you have taken samples in nearby wells. How can the analyses be assessed?
E. coli present ⇨ organic waste source nearby (except in karst areas), usually either a septic tank system or farmyard. ***E. coli absent*** ⇨ either not polluted by organic waste or bacteria have not survived due to attenuation or time of travel to well greater than 100 days. ***Nitrate > 25 mg/l*** ⇨ either inorganic fertiliser or organic waste source; check other parameters. ***Ammonia > 0.15 mg/l*** ⇨ source is nearby organic waste; fertiliser is not an issue. ***Potassium (K) > 5.0 mg/l*** ⇨ source is probably organic waste. ***K/Na ratio > 0.4 (0.3, in many areas)*** ⇨ Farmyard waste rather than septic tank effluent is the source. If < 0.3, no conclusion is possible. ***Chloride > 30 mg/l*** ⇨ organic waste source. However this does not apply in the vicinity of the coast (within 20 km at least).
In conclusion, faecal bacteria, nitrate, ammonia, high K/Na ratio and chloride indicate contamination by organic waste. However, only the high K/Na helps distinguish between septic tank effluent and farmyard wastes. So in many instances, while the analyses can show potential problems, other information is needed to complete the assessment.

A.10 References

Ashley, R.P. & Misstear, B.D.R., 1990. Industrial development: the threat to groundwater quality. Paper presented to Institution of Water and Environmental Management, East Anglia Branch.

Callery, P., 1988. Groundwater for public supply. In: Proceedings of International Association of Hydrogeologists (Irish Group) Seminar, Portlaoise.

Clark, L.,1990. Lecture to IAH (Irish Group) Technical Discussion Meeting

Commission of the European Community, 1991. Council Directive concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC). Official Journal of the European Communities, No. L375/1-8.

Coxon, C., 1987. Nitrate problems in domestic water supplies. GSI Groundwater Newsletter, No. 5, p 10.

Daly, E.P. 1994. Groundwater resources of the Nore River Basin. Geological Survey of Ireland, Internal Report.

Daly, D., 1986. Groundwater in County Galway, with particular reference to its protection from pollution. Geological Survey of Ireland, Report to Galway County Council, 98pp.

Daly, D. 1996. Groundwater in Ireland. Course notes for Higher Diploma in Environmental Engineering, UCC.

Daly, D. & Warren, W.P. 1994. Mapping groundwater vulnerability to pollution: GSI guidelines. GSI Groundwater Newsletter, No. 21, p 10-15.

Sherwood, M. 1991.

Thorn, R. & Coxon, C. 1992.

US EPA, 1987.

Wild & Cameron, 1980.

Appendix B: Results of GSI sampling (Aug 2000) of groundwaters from WSSs – Major ions and species indicating contamination

Source location name	Sample date	Source type	Grid location [1]	GSI location accuracy	Coliforms [count/ 100ml] Total	Coliforms [count/ 100ml] Faecal	Conductivity EC [µS/cm]	Calcium Ca [mg/l]	Magnesium Mg [mg/l]	Potassium K [mg/l]	Sodium Na [mg/l]	Chloride Cl [mg/l]	Sulphate SO_4 [mg/l]	Nitrate NO_3 [mg/l]	Alkalinity [mg/l $CaCO_3$]	Total hardness [mg/l $CaCO_3$]	K:Na ratio	Aluminium Al [mg/l]	Total Iron Fe [mg/l]	Manganese Mn [mg/l]	Ammonium NH_x [mg/l]	Nitrite NO_2 [mg/l]	Electroneutrality [%]
Aglish	03/08/2000	spring	19571, 19724	1	46	6	752	115.73	13.8	3.3	10.5	22.5	11.4	7.8	354	346.21	0.314	<0.02	0.013	0.345		<0.1	-3.99
Ballynaclogh	09/08/2000	bore	19043, 17295	3	0	0	521	86.29	12.9	1.3	10.3	16.8	9.6	15.9	264	268.90	0.126	<0.02	<0.005	<0.005	<0.015	<0.1	-2.96
Borrisokane	03/08/2000	bore	19334, 19279	1	0	0	772	118.63	13.7	3.3	10.4	24.2	18.9	19.6	342	353.05	0.317	<0.02	<0.005	<0.005	<0.015	<0.1	-4.06
Borrisoleigh [2]	09/08/2000	bore	20510, 16542	1	0	0	607	99.36	17.5	2.9	9.3	17.6	11.7	12.2	322	320.54	0.312	<0.02	<0.005	<0.005	<0.015	<0.1	-3.47
Clonakenny	09/08/2000	bore	21233, 18141	3	0	0	468	38.61	15.7	10.7	41.9	12.7	3.2	0.2	258	161.25	0.255	<0.02	0.07	0.05	0.118	<0.1	-2.46
Cloghjordan	09/08/2000	spring	19684, 18830	3	0	0	687	131.44	11.9	6.0	10.8	23.1	22.1	28.4	330	377.66	0.556	<0.02	<0.005	<0.005	<0.015	<0.1	-0.01
Holycross	09/08/2000	bore	20899, 15423	3	2	2	662	95.90	27.3	0.9	9.6	22.1	12.5	24.5	342	352.29	0.094	<0.02	<0.005	<0.005	0.017	<0.1	-4.10
Kilcommon	09/08/2000	bore	19128, 16043	3	0	0	286	44.11	7.4	0.5	7.3	10.4	3.1	4.4	140	140.78	0.068	<0.02	0.008	<0.005	<0.015	<0.1	-1.35
Littleton	09/08/2000	bore	21780, 15414	3	2	2	656	93.71	27.8	2.6	9.3	20.5	16.1	26.8	328	348.88	0.280	<0.02	<0.005	<0.005	<0.015	<0.1	-3.03
Littleton	09/08/2000	bore	21780, 15414	3			698	95.27	31.6	1.5	9.6	18.8	15.2	20.3	376	368.44	0.156	<0.02	<0.005	<0.005	<0.015	<0.1	-5.31
Lorrha	03/08/2000	bore	19107, 20360	1	0	0	845	134.90	14.9	1.1	11.0	18.4	65.4	3.9	370	398.67	0.100	<0.02	0.013	0.172	<0.015	<0.1	-4.90
Loughmore	09/08/2000		21118, 16718	5	5	4	787	148.07	8.8	7.2	12.9	28.0	23.7	16.7	406	406.45	0.558	<0.02	<0.005	<0.005	<0.015	<0.1	-4.35
Moycarky	09/08/2000	bore	21559, 14962	3	0	0	560	84.59	22.5	1.0	7.9	13.8	7.1	8.2	312	304.23	0.127	<0.02	<0.005	<0.005	<0.015	<0.1	-3.46
Riverstown	03/08/2000	spring	20456, 20300	3	35	30	741	117.57	12.0	3.9	10.1	20.8	12.7	13.2	332	343.39	0.386	<0.02	0.019	0.008	<0.015	<0.1	-2.02
Roscrea-Glenbeha	09/08/2000	spring	21203, 18546	3	1	1	588	114.65	4.8	4.3	9.1	20.8	8.6	18.3	292	306.41	0.473	<0.02	<0.005	<0.005	<0.015	<0.1	-2.02
Templederry	09/08/2000	bore	19399, 16875	1	0	0	289	41.01	8.1	0.7	10.4	10.6	5.5	6.4	138	135.92	0.067	<0.02	<0.005	<0.005	<0.015	<0.1	-1.41
Templemore [2]	09/08/2000	bore	21052, 17468	1	3	1	691	126.34	14.9	1.5	9.4	13.4	55.2	4.1	350	377.27	0.160	<0.02	0.008	<0.005	<0.015	<0.1	-3.68
Templetouhy	09/08/2000	bore	21835, 17075	5	0	0	747	113.33	23.2	10.2	13.1	23.2	30.6	37.1	364	378.97	0.779	<0.02	<0.005	<0.005	<0.015	<0.1	-4.37
Terryglass	03/08/2000	bore	18685, 19999	3	0	0	704	79.67	27.4	0.8	17.2	28.3	14.5	10.7	308	312.13	0.047	<0.02	<0.005	<0.005	<0.015	<0.1	-2.97
Thurles - Creamery	09/08/2000	spring	21292, 15922	3	3	3	690	106.21	23.4	3.9	11.6	21.8	22.7	24.1	348	361.99	0.336	<0.02	<0.005	<0.005	<0.015	<0.1	-3.69
Thurles - Lady's Well	09/08/2000	spring	21354, 15714	3	0	0	664	129.42	18.0	3.9	10.6	22.2	11.9	29.4	332	397.75	0.368	<0.02	<0.005	<0.005	<0.015	<0.1	3.15
Thurles – Tobernaloo	09/08/2000	spring	21006, 15832	1	0	0	700	112.31	22.2	2.3	10.9	22.9	15.7	24.7	358	372.29	0.211	<0.02	<0.005	<0.005	<0.015	<0.1	-3.40
Toomyvara	09/08/2000	spring	19689, 17736	1	0	0	513	92.63	5.7	2.4	10.8	17.6	11.1	20.5	242	255.07	0.222	<0.02	<0.005	<0.005	<0.015	<0.1	-2.35
Tullahedy	09/08/2000	bore	18484, 17800	3	3	0	658	103.73	22.3	2.1	10.3	19.1	9.9	20.1	342	351.26	0.204	<0.02	<0.005	<0.005	<0.015	<0.1	-2.53
Two-Mile-Borris	09/08/2000	bore	21962, 15793	1	0	0	709	112.37	22.5	2.6	10.5	26.6	15.7	28.8	356	373.68	0.248	<0.02	<0.005	<0.005	0.027	<0.1	-4.04
Upperchurch	09/08/2000	bore	19874, 16127	3	0	0	357	54.56	10.3	0.9	8.6	11.4	7.5	8.1	170	178.86	0.105	<0.02	<0.005	<0.005	<0.015	<0.1	-0.48

1 Locations from Co. Co. and GSI field visits
2 2 boreholes

Appendix B cont/d.: Results of GSI sampling (Aug 2000) of groundwaters from WSSs – minor ions

Source location name	Sample date	Source type	Grid location	GSI location accuracy	Strontium Sr [mg/l]	Barium Ba [mg/l]	Selenium Se [mg/l]	Chromium Cr [mg/l]	Nickel Ni [mg/l]	Copper Cu [mg/l]	Silver Ag [mg/l]	Zinc Zn [mg/l]	Cadmium Cd [mg/l]	Boron B [mg/l]	Lead Pb [mg/l]	Fluoride F [mg/l]	Total Phosphorus P [mg/l]	Arsenic As [mg/l]	Antimony Sb [mg/l]
Aglish	03/08/2000	spring	19571, 19724	1	0.224	0.049	*<0.05*	*<0.005*	*<0.01*	0.028	*<0.005*	0.027	*<0.005*	0.022	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Ballynaclogh	09/08/2000	bore	19043, 17295	3	0.157	0.197	*<0.05*	*<0.005*	*<0.01*	*<0.005*	*<0.005*	0.023	*<0.005*	0.018	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Borrisokane	03/08/2000	bore	19334, 19279	1	0.198	0.020	*<0.05*	*<0.005*	*<0.01*	0.011	*<0.005*	0.015	*<0.005*	0.026	*<0.02*	1.03	*<0.25*	*<0.05*	*<0.02*
Borrisoleigh	09/08/2000	bore	20510, 16542	1	0.122	0.048	*<0.05*	*<0.005*	*<0.01*	*<0.005*	*<0.005*	0.029	*<0.005*	0.020	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Clonakenny	09/08/2000	bore	21233, 18141	3	1.938	1.690	*<0.05*	*<0.005*	*<0.01*	*<0.005*	*<0.005*	0.018	*<0.005*	0.180	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Cloghjordan	09/08/2000	spring	19684, 18830	3	0.185	0.017	*<0.05*	*<0.005*	*<0.01*	*<0.005*	*<0.005*	0.020	*<0.005*	0.033	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Holycross	09/08/2000	bore	20899, 15423	3	0.110	0.085	*<0.05*	*<0.005*	*<0.01*	0.005	*<0.005*	0.022	*<0.005*	0.017	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Kilcommon	09/08/2000	bore	19128, 16043	3	0.131	0.005	*<0.05*	*<0.005*	*<0.01*	0.007	*<0.005*	0.019	*<0.005*	0.010	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Littleton	09/08/2000	bore	21780, 15414	3	0.135	0.161	*<0.05*	*<0.005*	*<0.01*	*<0.005*	*<0.005*	0.078	*<0.005*	0.029	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Littleton	09/08/2000	bore	21780, 15414	3	0.126	0.202	*<0.05*	*<0.005*	*<0.01*	*<0.005*	*<0.005*	0.018	*<0.005*	0.031	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Lorrha	03/08/2000	bore	19107, 20360	1	0.465	0.031	*<0.05*	*<0.005*	0.0153	0.012	*<0.005*	0.058	*<0.005*	0.031	*<0.02*	0.34	*<0.25*	*<0.05*	*<0.02*
Loughmore	09/08/2000		21118, 16718	5	0.197	0.173	*<0.05*	*<0.005*	*<0.01*	0.013		0.022	*<0.005*	0.038	*<0.02*	*<0.25*	*<0.25*	*<0.05*	
Moycarky	09/08/2000	bore	21559, 14962	3	0.146	0.144	*<0.05*	*<0.005*	*<0.01*	*<0.005*	*<0.005*	0.022	*<0.005*	0.018	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Riverstown	03/08/2000	spring	20456, 20300	3	0.255	0.023	*<0.05*	*<0.005*	*<0.01*	*<0.005*	*<0.005*	0.013	*<0.005*	0.023	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Roscrea-Glenbeha	09/08/2000	spring	21203, 18546	3	0.147	0.495	*<0.05*	*<0.005*	*<0.01*	*<0.005*	*<0.005*	0.021	*<0.005*	0.018	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Templederry	09/08/2000	bore	19399, 16875	1	0.108	0.005	*<0.05*	*<0.005*	*<0.01*	0.005		0.044	*<0.005*	0.013	*<0.02*	*<0.25*	*<0.25*	*<0.05*	
Templemore	09/08/2000	bore	21052, 17468	1	0.577	0.123	*<0.05*	*<0.005*	*<0.01*	0.008	*<0.005*	0.020	*<0.005*	0.053	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Templetouhy	09/08/2000	bore	21835, 17075	5	0.139	0.125	*<0.05*	*<0.005*	*<0.01*	0.009	*<0.005*	0.028	*<0.005*	0.060	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Terryglass	03/08/2000	bore	18685, 19999	3	0.216	0.004	*<0.05*	*<0.005*	*<0.01*	*<0.005*	*<0.005*	0.039	*<0.005*	0.019	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Thurles - Creamery	09/08/2000	spring	21292, 15922	3	0.143	0.179	*<0.05*	*<0.005*	*<0.01*	*<0.005*	*<0.005*	0.015	*<0.005*	0.027	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Thurles - Lady's Well	09/08/2000	spring	21354, 15714	3	0.171	0.200	*<0.05*	*<0.005*	*<0.01*	*<0.005*	*<0.005*	0.016	*<0.005*	0.031	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Thurles – tobernaloo	09/08/2000	spring	21006, 15832	1	0.149	0.199	*<0.05*	*<0.005*	*<0.01*	*<0.005*	*<0.005*	0.019	*<0.005*	0.048	*<0.02*	0.91	*<0.25*	*<0.05*	*<0.02*
Toomyvara	09/08/2000	spring	19689, 17736	1	0.139	0.144	*<0.05*	*<0.005*	*<0.01*	*<0.005*	*<0.005*	0.015	*<0.005*	0.036	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Tullahedy	09/08/2000	bore	18484, 17800	3	0.132	0.043	*<0.05*	*<0.005*	*<0.01*	0.005	*<0.005*	0.037	*<0.005*	0.020	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Two-Mile-Borris	09/08/2000	bore	21962, 15793	1	0.130	0.100	*<0.05*	*<0.005*	*<0.01*	0.006	*<0.005*	0.017	*<0.005*	0.052	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*
Upperchurch	09/08/2000	bore	19874, 16127	3	0.117	0.066	*<0.05*	*<0.005*	*<0.01*	*<0.005*	*<0.005*	0.028	*<0.005*	0.019	*<0.02*	*<0.25*	*<0.25*	*<0.05*	*<0.02*

Appendix C Summary of results from EC STRIDE Sub-Programme (1993) assessing WSS water quality

see Appendix B, first Table, for source type, grid reference and location ‘accuracy’

	Source location name	Sample date	Coliforms [count/ 100ml]		Conductivity	Colour	Turbidity	pH	Calcium	Magnesium	Potassium	Sodium	Chloride	Sulphate	Nitrate	Alkalinity	Total hardness	K:Na ratio	Total Iron	Manganese	Ammonium	Nitrite	Total Phosphorous	Zinc	Electroneutrality [%]
			Total	Faecal	EC [µS/cm]	Hazen	NTU		Ca [mg/l]	Mg [mg/l]	K [mg/l]	Na [mg/l]	Cl [mg/l]	SO_4 [mg/l]	NO_3 [mg/l]	[mg/l $CaCO_3$]	[mg/l $CaCO_3$]		Fe [mg/l]	Mn [mg/l]	NH_x [mg/l]	NO_2 [mg/l]	P [mg/l]	Zn [mg/l]	
	Aglish	15/09/1993	2	2	711	5	0.15	7.4	122	19	2.2	10.3	35	*<1*	20.4	296	384.17	0.214	0.019	0.006	0.01	0.001	0.010	0.065	6.01
	Borrisokane	15/09/1993	11	6	766	5	0.20	7.4	131	19	3.1	10.7	28	*<1*	23.5	339	406.67	0.289	1.167	0.224	0.01	0.001	0.010	0.205	3.20
	Borrisoleigh	16/09/1993	15	0	740	5	0.25	7.8	122	30	1.7	9.6	22	7	14.6	373	430.00	0.177	0.035	0.007	0.01	0.001	0.002	0.043	4.24
*	Clonakenny	15/09/1993	0	0	538	5	0.35	7.8	48	22	11.0	43.0	15	1	0.0	273	211.67	0.256	0.156	0.065	0.01	0.001	0.010	0.037	3.22
	Cloghjordan	15/09/1993	0	0	802	5	0.15	7.3	140	15	5.4	12.5	29	9	35.0	397	412.50	0.432	0.024	0.006	0.01	0.001	0.016	0.013	3.74
*	Drumbane	23/09/1993	1	0	527	5	0.30	7.8	63	35	3.0	8.4	20	2	11.1	226	303.30	0.357	0.004	<0.001	0.01	0.001	0.050	0.045	-3.26
	Holycross	16/09/1993	23	1	734	5	0.10	7.4	114	36	0.7	9.4	21	*<1*	24.4	367	435.00	0.075	0.027	0.004	0.01	0.001	0.002	0.031	9.90
	Kilcommon	16/09/1993	0	0	325	5	0.15	7.6	59	9	0.3	6.9	12	1	4.9	144	185.00	0.043	0.018	0.001	0.01	0.001	0.010	0.041	9.26
	Littleton	16/09/1993	9	0	786	5	0.15	7.4	118	41	1.2	9.7	18	10	21.7	411	465.80	0.124	0.013	0.002	0.01	0.001	0.010	0.061	2.30
	Moycarky	16/09/1993	0	0	631	5	0.20	7.5	99	30	0.8	8.4	15	1	9.3	336	372.50	0.095	0.032	0.017	0.01	0.002	0.006	0.026	3.23
	Riverstown	15/09/1993	9	2	739	5	0.20	7.3	134	16	3.5	10.5	34	*<1*	18.2	344	401.67	0.333	0.052	0.008	0.01	0.001	0.010	0.047	2.54
	Roscrea-Glenbeha	15/09/1993	14	13	632	5	0.15	7.7	126	6	2.8	8.5	23	5	15.1	287	340.00	0.330	0.365	0.043	0.01	0.004	0.010	0.010	3.52
*	Templemore	16/09/1993	12	8	797	5	0.15	7.3	162	13	2.3	10.0	24	18	20.8	375	459.17	0.210	0.016	0.004	0.01	0.001	0.010	0.060	4.14
	Templetouhy	16/09/1993	0	0	864	5	0.20	7.3	142	28	8.9	14.2	31	15	37.2	399	471.67	0.627	0.004	0.004	0.01	0.001	0.034	0.024	2.38
+	Thurles – Creamery	23/09/1993	24	2	777	5	0.45	7.3	121	33	3.9	12.6	25	14	20.4	330	440.00	0.309	0.104	0.013	0.01	0.001	0.044	0.265	8.56
	Thurles - Lady's Well	23/09/1993	13	2	767	5	0.15	7.4	138	23	2.7	9.9	24	8	25.7		440.80	0.273	0.030	0.001	0.01	0.001	0.005	0.144	
	Thurles - Tobernaloo	23/09/1993	0	0	792	5	0.40	7.5	131	30	1.8	10.1	27	8	26.6	377	452.50	0.178	0.027	0.003	0.001	0.001	0.002	0.094	3.27
⌘	Borrisokane	19/03/91	8	4	746	5	0.10	7.8	128	13.6	2.9	11	33	16	6.3	310	376.00	0.26	0.06	0.03	0.01	0.001	0.023	0.01	

⌘ Sample, like the EC STRIDE Programme samples, analysed by the Regional Water Lab, Kilkenny, but taken as part of another sample collection.
\+ Suspended solids and a detectable odour were discerned in this sample.
* Non-source sample.

Appendix D: Summary of results from North Tipperary County Council water quality monitoring of WSSs (1990-2000)

See Appendix B, first Table, for source type, grid reference and location ‘accuracy’. **‘Sample status’: NS –** Non-source; **S** – Source; **blank** or **?NS:** – unsure of sample treatment.

Source location name	Sample date	Coliforms [count/ 100ml]			Conductivity	Colour	Turbidity	pH	Chloride	Sulphate	Nitrate	Alkalinity	Total hardness	Total Iron	Manganese	Ammonium	Nitrite	Cadmium	Copper	Lead	Zinc	Sample status
		Total	E. Coli	Faecal	EC [µS/cm]	Hazen	NTU		Cl [mg/l]	SO_4 [mg/l]	NO_3 [mg/l]	[mg/l $CaCO_3$]	[mg/l $CaCO_3$]	Fe [mg/l]	Mn [mg/l]	NH_x [mg/l]	NO_2 [mg/l]	Cd [mg/l]	Cu [mg/l]	Pb [mg/l]	Zn [mg/l]	
Aglish	26/02/1990					*<5*	1	7.4	35	22	35.0	292	335.0	0.1	*<0.020*	0.014	*<0.004*	*<0.005*	0.07	*<0.020*	*<0.02*	
Aglish	04/07/1990				736	*<5*	0.5	7.7			16.5			*<0.05*	0.1	*<0.014*	*<0.004*					
Aglish	11/07/1990	14		14																		NS
Aglish	24/07/1990	0	0	0																		?NS
Aglish	04/09/1990	0		0																		S
Aglish	19/07/1993				740	6	0.43	7.07			20.3			*<0.050*	*<0.020*	*<0.025*	*<0.02*					
Aglish	27/07/1993	7		7																		?NS
Aglish	03/08/1994	8																				S
Aglish	19/04/1995	0																				NS
Aglish	01/12/1998	6	2																			NS
Aglish	01/02/1999	11	10																			NS
Aglish	09/02/1999	0	0																			NS
Ballynaclogh	04/01/1999				575	*<2*	*<0.2*	7.6			16.2			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Ballynaclogh	04/01/1999	0	0																			NS
Ballynaclogh	24/01/1995	8																				NS
Ballynaclogh	27/04/1999	0	0																			NS
Borrisokane	26/03/1990	0																				NS
Borrisokane	14/08/1990			0																		?NS
Borrisokane	15/03/1991				725	*<5*	0.28	7.6						*<0.1*	*<0.025*	*<0.014*	*<0.004*					
Borrisokane	19/03/1991	600																				?NS
Borrisokane	18/04/1991	0																				NS
Borrisokane	29/11/1991	50		0																		?NS
Borrisokane	23/03/1992				704	*<5*	0.3	7.7			25.5			*<0.1*	*<0.05*	0.014	*<0.004*					
Borrisokane	24/03/1992	0																				NS
Borrisokane	18/03/1993				758	*<2*	*<0.2*	7.53			26.3			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Borrisokane	19/03/1993	0																				NS

Source location name	Sample date	Coliforms [count/ 100ml] Total	Coliforms E. Coli	Coliforms Faecal	Conductivity EC [µS/cm]	Colour Hazen	Turbidity NTU	pH	Chloride Cl [mg/l]	Sulphate SO_4 [mg/l]	Nitrate NO_3 [mg/l]	Alkalinity [mg/l $CaCO_3$]	Total hardness [mg/l $CaCO_3$]	Total Iron Fe [mg/l]	Manganese Mn [mg/l]	Ammonium NH_x [mg/l]	Nitrite NO_2 [mg/l]	Cadmium Cd [mg/l]	Copper Cu [mg/l]	Lead Pb [mg/l]	Zinc Zn [mg/l]	Sample status
Borrisokane	02/11/1993	0																				NS
Borrisokane	22/03/1994				747	<2	<0.2	7.6			27.2			<0.05	<0.02	<0.025	<0.02					
Borrisokane	24/03/1994	0																				NS
Borrisokane	05/07/1994	0																				NS
Borrisokane	23/01/1995				739	<5	<0.2	7.7			29.9			<0.05	<0.02	<0.025	<0.02					
Borrisokane	24/01/1995	0																				NS
Borrisokane	20/02/1995				736	<2	<0.2	7.7			27.0			<0.05	<0.02	0.03	<0.02					
Borrisokane	21/02/1995	0																				NS
Borrisokane	21/03/1995				763	2.7	<0.2	7.6			27.8			<0.05	<0.02	<0.025	<0.02					
Borrisokane	26/04/1995	0																				NS
Borrisokane	19/06/1995				750	<2	<0.2	7.8			22.4			0.057	<0.02	<0.025	<0.02					
Borrisokane	20/06/1995	0		1																		NS
Borrisokane	06/04/1998				756	<2	0.2	7.7			30.5			<0.05	<0.02	<0.025	<0.02					
Borrisokane	15/12/1998				768	3.4	0.3	7.8			31.2			<0.05	<0.02	<0.025	<0.02					
Borrisokane	02/02/1999				760	5.5	0.6	7.7			31.6			<0.05	<0.02	<0.025	<0.02					
Borrisokane	02/03/1999				767	5.6	0.6	7.8			26.3			<0.05	<0.02	<0.025	<0.02					
Borrisokane	09/03/1999	0	0																			NS
Borrisokane	19/04/1999	0	0																			NS
Borrisokane	25/06/1999				757	2.7	< 0.2	7.7			21.3			<0.05	<0.02	<0.025	<0.02					
Borrisoleigh	21/02/1994				584	<2	<0.2	7.62			4.4			0.2	<0.020	<0.025	<0.02					
Borrisoleigh	20/06/1994				666	<2	<0.2	7.25			16.4			<0.05	<0.020	<0.025	<0.02					
Borrisoleigh	20/06/1994				730	<2	<0.2	7.3			16.2			<0.05	<0.020	0.08	<0.02					
Borrisoleigh	24/06/1994	368		368																		NS
Borrisoleigh	24/06/1994	0																				NS
Borrisoleigh	24/06/1994	0																				NS
Borrisoleigh	28/11/1994				764	<2	<0.2	7.2			15.9			<0.05	<0.020	<0.025	<0.02					
Borrisoleigh	01/12/1994	0																				?NS
Borrisoleigh	13/03/1995				551	<2	<0.2	7.7			5.3			0.031	<0.020	0.03	0.028					
Borrisoleigh	13/03/1995				554	<2	<0.2	7.7			5.2			0.023	<0.020	0.03	0.02					
Borrisoleigh	19/06/1995				741	<2	<0.2	7.1			14.6			0.054	<0.020	<0.025	<0.02					
Borrisoleigh	21/06/1995	0																				?NS
Borrisoleigh	25/07/1995				727	<5	0.55	7.1			14.2			<0.05	<0.020	0.027	<0.02					

Source location name	Sample date	Coliforms [count/ 100ml]			Conductivity	Colour	Turbidity	pH	Chloride	Sulphate	Nitrate	Alkalinity	Total hardness	Total Iron	Manganese	Ammonium	Nitrite	Cadmium	Copper	Lead	Zinc	Sample status
		Total	E. Coli	Faecal	EC [µS/cm]	Hazen	NTU		Cl [mg/l]	SO_4 [mg/l]	NO_3 [mg/l]	[mg/l $CaCO_3$]	[mg/l $CaCO_3$]	Fe [mg/l]	Mn [mg/l]	NH_x [mg/l]	NO_2 [mg/l]	Cd [mg/l]	Cu [mg/l]	Pb [mg/l]	Zn [mg/l]	
Borrisoleigh	26/07/1995	124		98																		?NS
Borrisoleigh	26/07/1995	0																				S
Borrisoleigh	22/09/1998				677	2.6	0.3	7.2			14.6			*<0.05*	<0.020	0.033	*<0.02*					
Borrisoleigh	22/09/1998	0	0																			NS
Borrisoleigh	20/04/1999	10	0																			NS
Borrisoleigh	30/04/1999	0	0																			NS
Borrisoleigh	17/05/1999				501	3.8	0.49	7.7			7.2			*<0.05*	*<0.020*	0.029	0.026					
Borrisoleigh	27/07/1999				697	*<2*	0.8	7.5			13.5			0.078	*<0.020*	*<0.025*	*<0.02*					
Borrisoleigh	30/07/1999	0	0																			NS
Clonakenny	19/01/1998				515	*<2*	<0.2	7.8			*<2.5*			*<0.05*	0.051	0.186	*<0.02*					
Clonakenny	19/01/1998	0																				NS
Clonakenny	24/03/1998	130	130																			NS
Clonakenny	07/04/1998	0																				NS
Clonakenny	20/04/1998	0																				NS
Clonakenny	28/09/1999	13	13																			NS
Clonakenny	05/10/1999				514	3.6	0.36	7.9			*<2.5*			0.094	0.033	0.204	0.026					
Clonakenny	05/10/1999	0	0																			NS
Cloghjordan	20/01/1998				792	2.4	0.3	8.4			42.8			*<0.050*	*<0.020*	*<0.025*	*<0.02*					
Cloghjordan	20/01/1998	0																				NS
Cloghjordan	19/05/1998	0																				NS
Cloghjordan	29/09/1998	0																				NS
Cloghjordan	01/06/1999	0																				NS
Cloghjordan	13/09/1999				788	3.5	0.2	7.5			26.3			*<0.05*	*<0.02*	*0.059*	*<0.02*					
Cloghjordan	13/09/1999	0																				?NS
Drumbane	16/11/1998	24	1																			NS
Drumbane	16/11/1998	1	0																			NS
Holycross	22/02/1999	0																				?NS
Holycross	22/02/1999				731	2.7	0.58	7.5			25.4			*<0.050*	*<0.020*	*<0.025*	*<0.02*					
Kilcommon	18/05/1999	0																				NS
Littleton	19/05/1998	0	0																			?NS
Littleton	12/01/1999				777	*<2*	0.34	7.2			21.2			*<0.050*	*<0.020*	*<0.025*	*<0.02*					

Source location name	Sample date	Coliforms [count/ 100ml]			Conductivity	Colour	Turbidity	pH	Chloride	Sulphate	Nitrate	Alkalinity	Total hardness	Total Iron	Manganese	Ammonium	Nitrite	Cadmium	Copper	Lead	Zinc	Sample status
		Total	E. Coli	Faecal	EC [µS/cm]	Hazen	NTU		Cl [mg/l]	SO_4 [mg/l]	NO_3 [mg/l]	[mg/l $CaCO_3$]	[mg/l $CaCO_3$]	Fe [mg/l]	Mn [mg/l]	NH_x [mg/l]	NO_2 [mg/l]	Cd [mg/l]	Cu [mg/l]	Pb [mg/l]	Zn [mg/l]	
Lorrha	07/02/1990				700	*<5*	0.6	7.1			4.6			0.15	*<0.05*	0.014	*<0.004*					
Lorrha	09/02/1990	0																				?NS
Lorrha	16/08/1990				753	*<5*	3.4	7.3			3.8			0.79	*<0.050*	*<0.014*	*<0.004*					
Lorrha	17/08/1990	0																				NS
Lorrha	12/09/1990				725	*<5*	0.6	7.2			4.5			0.1	0.09	*<0.014*	*<0.004*					
Lorrha	21/02/1991				739	*<5*	0.58	7.2			2.7			*<0.100*	*<0.025*	*<0.014*	*<0.004*					
Lorrha	22/02/1991	0																				NS
Lorrha	12/02/1992				736	*<5*	0.25	7.3			2			*<0.100*	*<0.050*	0.014	*<0.004*					
Lorrha	13/02/1992	0																				NS
Lorrha	21/04/1992				728	*<5*	0.6	7.5			2.5			*<0.100*	*<0.050*	0.056	*<0.004*					
Lorrha	22/04/1992	0																				NS
Lorrha	29/09/1992	0																				NS
Lorrha	19/02/1993				737	5	3.5	7.4			2.2			0.05	0.13	0.03	*<0.02*					
Lorrha	22/02/1993	0																				?NS
Lorrha	22/03/1993				761	*<2*	*<0.2*	6.97			*<2.5*			*<0.050*	0.056	0.04	*<0.02*					
Lorrha	23/03/1993	0																				NS
Lorrha	16/02/1994				769	*<2*	*<0.2*	7.25			*<2.5*			0.151	0.129	0.04	*<0.02*					
Lorrha	17/02/1994	0																				NS
Lorrha	21/03/1994				752	*<2*	*<0.2*	7.15			*<2.5*			0.059	0.12	0.04	*<0.02*					
Lorrha	23/03/1994	0																				NS
Lorrha	20/04/1994				759	*<5*	0.23	7.3			*<2.5*			0.064	0.136	0.06	*<0.02*					
Lorrha	25/04/1994	0																				?NS
Lorrha	23/01/1995				764	*<5*	*<0.2*	7.2			5.0			0.068	0.131	*<0.025*	*<0.02*					
Lorrha	24/01/1995	0																				NS
Lorrha	22/08/1995				755	*<2*	*<0.2*	7.4			19.6			*<0.050*	*<0.020*	*<0.025*	*<0.02*					
Lorrha	23/08/1995	0																				NS
Lorrha	13/02/1996				797	*<2*	*<0.2*	7.2			3.0			*<0.050*	0.187	*<0.025*	*<0.02*					
Lorrha	24/02/1997				786	*<2*	*<0.2*	7.1			3.7			0.062	0.128	0.04	*<0.02*					
Lorrha	29/09/1998	0	0																			NS
Lorrha	09/11/1998				824	*<2*	0.6	7.1			4.0			*<0.05*	0.142	*<0.025*	*<0.02*					
Lorrha	09/11/1998	0	0																			NS
Lorrha	11/01/2000	0	0																			NS

Source location name	Sample date	Coliforms [count/ 100ml]			Conductivity	Colour	Turbidity	pH	Chloride	Sulphate	Nitrate	Alkalinity	Total hardness	Total Iron	Manganese	Ammonium	Nitrite	Cadmium	Copper	Lead	Zinc	Sample status
		Total	E. Coli	Faecal	EC [µS/cm]	Hazen	NTU		Cl [mg/l]	SO_4 [mg/l]	NO_3 [mg/l]	[mg/l $CaCO_3$]	[mg/l $CaCO_3$]	Fe [mg/l]	Mn [mg/l]	NH_x [mg/l]	NO_2 [mg/l]	Cd [mg/l]	Cu [mg/l]	Pb [mg/l]	Zn [mg/l]	
Loughmore	22/09/1998				844	5	0.2	7.2			18.3			*<0.05*	*<0.02*	0.033	*<0.02*					
Loughmore	22/09/1998	0	0																			NS
Loughmore	14/09/1999	0	0																			NS
Moycarky	11/01/1999				637	*<2*	0.42	7.3			9.9			*<0.050*	*<0.020*	*<0.025*	*<0.02*					
Moycarky	27/07/1999				629	*<2*	0.21	7.3			9.2			*<0.050*	*<0.020*	*<0.025*	*<0.02*					
Moycarky	19/08/1999	0																				NS
Rathcabban	21/03/1994				765	*<2*	*<0.2*	7.5			*<2.5*			*<0.050*	0.089	*<0.025*	0.026					
Rathcabban	18/11/1998				781	4.1	2.76	7.3			4.5			0.069	0.093	0.063	0.029					
Rathcabban	09/08/1999				582	*<2*	1.3	7.7			6.4			0.118	*<0.02*	0.185	0.046					
Rathcabban	09/08/1999	0	0																			NS
Riverstown	07/04/1998	8	2																			NS
Riverstown	20/04/1998	0	0																			NS
Riverstown	29/09/1998	0	0																			NS
Riverstown	11/01/2000	0	0																			NS
Roscrea-Glenbeha	14/01/1997				601	*<2.0*	2.8	7.5			19.4			0.083	0.022	0.07	*<0.02*					
Roscrea-Glenbeha	14/01/1998	0	0																			NS
Roscrea-Glenbeha	15/06/1998	0	0																			NS
Roscrea-Glenbeha	16/06/1998				664	6.8	0.3	7.7			12.4			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Roscrea-Glenbeha	18/08/1998	0	0																			NS
Roscrea-Glenbeha	28/08/1998	0	0																			NS
Roscrea-Glenbeha	01/12/1998	0	0																			NS
Roscrea-Glenbeha	01/06/1999				673	6.3	0.9	7.5			12.5			0.138	*<0.02*	*<0.025*	0.02					
Roscrea-Glenbeha	01/06/1999	0	0																			NS
Roscrea-Glenbeha	23/08/1999	0	0																			NS
Roscrea-Glenbeha	21/09/1999				653	4.3	0.38	7.6			15.6			*<0.05*	*<0.02*	0.031	*<0.02*					
Roscrea-Glenbeha	21/09/1999	0	0																			NS
Roscrea-Glenbeha	05/10/1999				623	7.9	0.31	7.5			14.5			0.065	*<0.02*	*<0.02*	*<0.02*					

Source location name	Sample date	Coliforms [count/ 100ml]			Conductivity	Colour	Turbidity	pH	Chloride	Sulphate	Nitrate	Alkalinity	Total hardness	Total Iron	Manganese	Ammonium	Nitrite	Cadmium	Copper	Lead	Zinc	Sample status
		Total	E. Coli	Faecal	EC [µS/cm]	Hazen	NTU		Cl [mg/l]	SO_4 [mg/l]	NO_3 [mg/l]	[mg/l $CaCO_3$]	[mg/l $CaCO_3$]	Fe [mg/l]	Mn [mg/l]	NH_x [mg/l]	NO_2 [mg/l]	Cd [mg/l]	Cu [mg/l]	Pb [mg/l]	Zn [mg/l]	
Roscrea-Glenbeha	05/01/2000	0	0																			NS
Templederry	03/01/1990	0																				NS
Templederry	04/04/1990	0																				NS
Templederry	25/09/1990				312	*<5*	0.25	7.4			7.6			*<0.05*	*<0.05*	*<0.014*	*<0.004*					
Templederry	14/11/1990	13		0																		?NS
Templederry	26/08/1991				318	*<5*	0.6	7.4			10.5			*<0.1*	*<0.05*	*0.05*	*<0.004*					
Templederry	27/08/1991	0																				?NS
Templederry	19/11/1991	0		0																		?NS
Templederry	18/08/1992	1																				?NS
Templederry	01/09/1992	0																				?NS
Templederry	28/09/1992				311	*<5*	0.4	7.6			5.8			*<0.1*	*<0.05*	*<0.014*	*<0.004*					
Templederry	24/08/1993	0																				?NS
Templederry	28/09/1993				317	*<2*	*<0.2*	7.6			6.0			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Templederry	23/08/1994				317	*<5*		7.8			6.7			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Templederry	24/08/1994	0																				NS
Templederry	21/08/1995				417	*<5*	*<0.2*	7.8			7.0			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Templederry	19/05/1998	0	0																			NS
Templederry	01/12/1998				315	2.6	0.35	7.7			5.4			*<0.05*	*0.025*	*<0.025*	*<0.02*					
Templederry	27/04/1999	0	0																			NS
Templemore	23/08/1995	0																				NS
Templemore	23/03/1998	1	0																			NS
Templemore	18/08/1998	0	0																			?NS
Templemore	28/08/1998	0	0																			NS
Templemore	28/09/1998				873	3.3	0.73	7.4			5.1			*<0.050*	*<0.02*	*<0.025*	*<0.02*					
Templetouhy	02/12/1997				841	2.6	0.5	7.6			56.0			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Templetouhy	02/10/1998				866	2.2	0.32	7.1			39.9			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Templetouhy	02/10/1998	0	0																			?NS
Templetouhy	23/08/1999				859	*<2*	0.23	7.3			34.8			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Terryglass	21/09/1998				715	3.5	90.9	7.5			4.6			1.02	0.093	0.159	0.072					
Terryglass	21/09/1998	7200	0																			S
Terryglass	02/11/1998	2	0																			S

Source location name	Sample date	Coliforms [count/ 100ml]			Conductivity	Colour	Turbidity	pH	Chloride	Sulphate	Nitrate	Alkalinity	Total hardness	Total Iron	Manganese	Ammonium	Nitrite	Cadmium	Copper	Lead	Zinc	Sample status
		Total	E. Coli	Faecal	EC [μS/cm]	Hazen	NTU		Cl [mg/l]	SO_4 [mg/l]	NO_3 [mg/l]	[mg/l $CaCO_3$]	[mg/l $CaCO_3$]	Fe [mg/l]	Mn [mg/l]	NH_x [mg/l]	NO_2 [mg/l]	Cd [mg/l]	Cu [mg/l]	Pb [mg/l]	Zn [mg/l]	
Terryglass	02/02/1999				751	6.1	0.9	7.2			20.8			*<0.05*	*<0.02*	0.027	0.022					
Terryglass	02/02/1999	0	0																			NS
Terryglass	23/08/1999				623	*<2*	3.9	7.4			8.1			*<0.05*	*<0.02*	0.117	*<0.02*					
Terryglass	23/08/1999	11	11																			S
Terryglass	31/08/1999				629	*<2*	0.49	7.5			9.2			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Terryglass	31/08/1999	21	0																			S
Thurles	15/12/1997					4.2	0.25	8.3			25.2			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Thurles	19/05/1998	0	0																			NS
Thurles	16/06/1998					*<2*	0.3	7.3			26.7			*<0.05*	*<0.02*	*<0.025*	0.038					
Thurles	11/08/1998	0	0																			NS
Thurles	05/01/1999	0	0																			NS
Thurles	02/02/1999					6	1.85	7.2			25.6			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Thurles	30/04/1999	0	0																			NS
Thurles	04/08/1999	0	0																			NS
Thurles	14/09/1999	0	0																			NS
Toomyvara	06/03/1990	0																				NS
Toomyvara	31/07/1990	0																				?NS
Toomyvara	17/10/1990	1600																				?NS
Toomyvara	24/10/1990			400																		?NS
Toomyvara	06/11/1990	0																				NS
Toomyvara	19/02/1991			11																		NS
Toomyvara	08/03/1991	0																				?NS
Toomyvara	22/10/1991				542	*<5*	0.5	7.8			21.0			*<0.1*	*<0.05*	*<0.014*	*<0.0004*					
Toomyvara	24/10/1991	0																				?NS
Toomyvara	21/11/1991	2		0																		?NS
Toomyvara	09/06/1992	0																				NS
Toomyvara	06/10/1992	0																				?NS
Toomyvara	21/10/1992				566	*<5*	0.17	7.7			22.0			*<0.1*	*<0.05*	0.042	0.007					
Toomyvara	22/10/1992			12																		NS
Toomyvara	23/11/1993				611	*<5*	*<0.2*	7.5			25.1			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Toomyvara	24/11/1993	0																				NS
Toomyvara	02/11/1994			18																		NS

Source location name	Sample date	Coliforms [count/ 100ml]			Conductivity	Colour	Turbidity	pH	Chloride	Sulphate	Nitrate	Alkalinity	Total hardness	Total Iron	Manganese	Ammonium	Nitrite	Cadmium	Copper	Lead	Zinc	Sample status
		Total	E. Coli	Faecal	EC [μS/cm]	Hazen	NTU		Cl [mg/l]	SO_4 [mg/l]	NO_3 [mg/l]	[mg/l $CaCO_3$]	[mg/l $CaCO_3$]	Fe [mg/l]	Mn [mg/l]	NH_x [mg/l]	NO_2 [mg/l]	Cd [mg/l]	Cu [mg/l]	Pb [mg/l]	Zn [mg/l]	
Toomyvara	02/11/1994	0																				NS
Toomyvara	09/11/1994			20																		NS
Toomyvara	09/11/1994	6		6																		NS
Toomyvara	16/11/1994	0																				NS
Toomyvara	16/11/1994	18																				NS
Toomyvara	28/11/1994				596	4	*<0.2*	7.4			22.3			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Toomyvara	29/11/1994	0	0																			NS
Toomyvara	20/06/1995				391	11.5	2.15	8.6			8.4			0.273	0.021	0.03	0.086					
Toomyvara	26/11/1996			1																		NS
Toomyvara	19/05/1998	0	0																			NS
Toomyvara	17/11/1998				598	*<2*	0.68	7.1			25.8			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Toomyvara	17/11/1998	0	0																			NS
Toomyvara	28/09/1999				589	2.4	0	7.3			21.0			*<0.05*	*<0.02*	0.037	*<0.02*					
Toomyvara	28/09/1999	0	0				28															NS
Tullahedy	15/12/1997				717	*<2*	*<0.2*	8			19.8			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Tullahedy	15/12/1997	0																				NS
Tullahedy	27/01/1998				711	*<2*	*<0.2*	7.6			19.5			*<0.05*	*<0.02*	0.067	*<0.02*					
Tullahedy	27/01/1998	0																				NS
Tullahedy	23/03/1998	0																				NS
Tullahedy	06/04/1998				675	*<2*	*<0.2*	7.9			14.3			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Tullahedy	05/05/1998	0																				NS
Tullahedy	22/06/1998				726	<2	0.82	7.2			20.2			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Tullahedy	22/06/1998	0																				NS
Tullahedy	11/08/1998	0																				NS
Tullahedy	12/10/1998	0																				NS
Tullahedy																						
Tullahedy	04/01/1999	0																				NS
Tullahedy	09/02/1999				732	4.5	0.5	7.5			19.5			*<0.05*	*<0.02*	0.03	*<0.02*					
Tullahedy	09/02/1999	0																				NS
Tullahedy	22/03/1999				719	*<2*	*<0.2*	7.4			19.8			*<0.05*	*<0.02*	*<0.025*	*<0.02*					

Source location name	Sample date	Coliforms [count/ 100ml] Total	E. Coli	Faecal	Conductivity EC [μS/cm]	Colour Hazen	Turbidity NTU	pH	Chloride Cl [mg/l]	Sulphate SO_4 [mg/l]	Nitrate NO_3 [mg/l]	Alkalinity [mg/l $CaCO_3$]	Total hardness [mg/l $CaCO_3$]	Total Iron Fe [mg/l]	Manganese Mn [mg/l]	Ammonium NH_x [mg/l]	Nitrite NO_2 [mg/l]	Cadmium Cd [mg/l]	Copper Cu [mg/l]	Lead Pb [mg/l]	Zinc Zn [mg/l]	Sample status
Tullahedy	12/04/1999	0																				NS
Tullahedy	10/05/1999				724	2	0.35	7.4			19.1			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Tullahedy	31/05/1999				726	*<2*	0.4	7.6			20.2			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Tullahedy	31/05/1999	0																				NS
Tullahedy	26/07/1999	0																				NS
Tullahedy	28/09/1999				735	*<2*	0.91	7.4			21.4			*<0.05*	*<0.02*	0.033	*<0.02*					
Tullahedy	28/09/1999	0	0																			NS
Two-Mile-Borris	05/01/1990	0																				?NS
Two-Mile-Borris	27/11/1990	0																				NS
Two-Mile-Borris	27/11/1990	6																				S
Two-Mile-Borris	03/12/1990				791	*<5*	0.38	7.3			53.5			0.05	*<0.05*	*<0.014*	0.4					
Two-Mile-Borris	06/12/1990	0																				?NS
Two-Mile-Borris	11/12/1990	0																				?NS
Two-Mile-Borris	21/10/1991				796	*<5*	0.7	7.6			45.0			*<0.1*	*<0.05*	*<0.014*	*<0.004*					
Two-Mile-Borris	28/11/1991	8		0																		?NS
Two-Mile-Borris	05/11/1992	18																				NS
Two-Mile-Borris	02/07/1993	0																				?NS
Two-Mile-Borris	20/07/1993				927	*<2*	*<0.2*	7.1			31.2			*<0.05*	*<0.02*	0.04	*<0.02*					
Two-Mile-Borris	24/10/1994				789	*<2*	*<0.2*	7.2			30.8			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Two-Mile-Borris	02/11/1994	2																				?NS
Two-Mile-Borris	22/11/1994	280		264																		NS
Two-Mile-Borris	12/01/1999				1006	2.4	0.38	7.1			25.7			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Upperchurch	01/02/1999				401	2.5	1.06	7.7			8.8			*<0.05*	*<0.02*	*<0.025*	*<0.02*					
Upperchurch	11/02/1999	0	0																			NS

Appendix E: Summary of analyses of groundwater from GWSs conducted by DoELG (November 2000 – January 2001)

Source Location name	Sampling point	DoELG sample number	Sample date	Total Coliforms	Faecal Coliforms	Conductivity [uS/cm2]	Colour [Hazen]	Turbidity [NTU]	pH	Nitrate [mg/l]	Aluminium [mg/l]	Total Iron [mg/l]	Manganese [mg/l]	Ammonium [mg/l]	Nitrite [mg/l]
Abbeyville, Lorrha	Abbeyville, Lorrha, Nenagh	TN030	Dec - 00	1	1	873	<5	0.43	7.20	19.85	<0.004	<0.005	<0.006	<0.01	0.005
		TN030	Jan - 01	5	5	770	<5	0.42	7.16	27.07	0.007	0.029	<0.006	<0.01	0.00
Ardcroney	Ardcroney, Nenagh	TN021	Nov - 00	14	8	730	<5	0.53	7.22	36.50	0.013	0.007	0.009	<0.01	0.008
		TN021	Dec - 00	13	11	781	<5	1.03	7.24	28.57	0.013	0.028	0.007	<0.01	0.004
		TN021	Jan - 01	26	7	710	<5	0.41	7.30	29.59	0.007	0.028	<0.006	<0.01	0.01
Ashill	Knockanuss, Horse & Jockey	TN025	Nov - 00	1	0	843	<5	0.27	7.19	14.40	<0.004	<0.005	<0.006	<0.01	0.008
		TN025	Dec - 00	1	0	832	<5	0.17	7.47	11.92	0.062	<0.005	<0.006	<0.01	0.007
		TN025	Jan - 01	1	0	781	<5	0.27	7.33	15.02	<0.004	<0.005	<0.006	<0.01	0.00
Ballinderry	Ballinderry, Nenagh	TN035A	Nov - 00	18	13	681	<5	0.50	7.38	31.90	0.006	0.005	<0.006	<0.01	0.009
		TN035B	Nov - 00												
		TN035A	Dec - 00	7	4	688	<5	0.39	7.26	25.07	<0.004	<0.005	<0.006	<0.01	0.006
		TN035B	Dec - 00	0	0	688	<5	0.20	7.19	23.12	<0.004	0.005	<0.006	<0.01	0.004
		TN035A	Jan - 01	1	0	732	<5	0.36	7.31	26.85	<0.004	0.009	<0.006	<0.01	0.01
		TN035B	Jan - 01	0	0	756	<5	0.23	7.19	30.35	<0.004	<0.005	<0.006	<0.01	0.01
Ballycasey	Derrinvohill, Borrisokane	TN034	Nov - 00	73	16	842	<5	0.43	7.20	40.71	<0.004	0.012	<0.006	<0.01	0.009
		TN034	Dec - 00	31	18	816	<5	0.57	7.27	24.37	0.025	0.006	<0.006	<0.01	0.006
		TN034	Jan - 01	8	1	814	<5	0.28	7.27	30.92	0.009	0.008	<0.006	<0.01	0.01
Barnane	Barnane, Templemore	TN008	Nov - 00	16	6	712	<5	0.45	7.60	6.87	<0.004	<0.005	<0.006	<0.01	0.006
		TN008	Dec - 00												
		TN008	Jan - 01	2	1	657	<5	0.26	7.69	6.73	0.006	0.005	<0.006	<0.01	0.01
Castlecranna	Castelcranna, Carraigatohoer	TN003	Nov - 00	0	0	578	<5	1.07	8.06	0.35	<0.004	0.080	0.019	<0.01	0.006
		TN003	Dec - 00	1	0	560	<5	0.90	7.63	1.06	0.004	0.094	0.024	<0.01	0.006
		TN003	Jan - 01	0	0	526	<5	1.13	7.73	0.71	0.010	0.103	0.024	<0.01	0.01
Castleiney	Kilcuree, Castleiney, Templemore	TN0012	Nov - 00	10	1	868	<5	0.31	7.11	45.19	<0.004	<0.005	<0.006	<0.01	0.008
		TN0012	Dec - 00	3	0	816	<5	0.19	7.03	27.24	<0.004	<0.005	<0.006	<0.01	0.004
		TN0012	Jan - 01	1	0	811	<5	0.26	7.44	31.32	0.052	<0.005	<0.006	<0.01	0.01
Castleiney B	Laha, Castleiney, Templemore	TN029	Nov - 00	88	64	909	<5	0.67	7.03	31.81	0.004	0.009	<0.006	<0.01	0.007
		TN029	Dec - 00	20	4	856	<5	0.28	7.11	21.09	<0.004	<0.005	<0.006	<0.01	0.007
		TN029	Jan - 01	4	0	836	<5	0.18	7.47	31.05	<0.004	<0.005	<0.006	<0.01	0.01
Clareen	Clareen, Moyaliffe, Thurles	TN026	Nov - 00	0	0	514	<5	0.20	7.40	14.84	0.015	<0.005	<0.006	<0.01	0.010
		TN026	Dec - 00	0	0	494	<5	0.21	7.37	12.36	0.006	0.010	<0.006	<0.01	0.005
		TN026	Jan - 01	0	0	202	<5	0.85	7.25	6.20	0.275	0.055	0.007	<0.01	0.01

Source Location name	Sampling point	DoELG sample number	Sample date	Total Coliforms	Faecal Coliforms	Conductivity [uS/cm2]	Colour [Hazen]	Turbidity [NTU]	pH	Nitrate [mg/l]	Aluminium [mg/l]	Total Iron [mg/l]	Manganese [mg/l]	Ammonium [mg/l]	Nitrite [mg/l]
Clobanna	Clobanna, Thurles	TN036	Nov - 00	0	0	870	<5	0.68	7.21	28.93	0.018	0.011	<0.006	<0.01	0.007
		TN036	Dec - 00	0	0	909	<5	0.37	7.18	15.77	<0.004	<0.005	<0.006	<0.01	0.005
		TN036	Jan - 01	0	0	865	<5	0.37	7.43	12.23	0.025	0.101	<0.006	<0.01	0.01
Couraguneen	Gurtderrybeg, Roscrea	TN027	Nov - 00	0	0	570	<5	0.18	7.68	9.83	<0.004	0.012	<0.006	<0.01	0.002
		TN027	Dec - 00	0	0	832	<5	0.22	7.83	7.49	<0.004	<0.005	<0.006	<0.01	0.005
		TN027	Jan - 01	0	0	535	<5	0.17	7.94	10.90	0.011	0.066	<0.006	<0.01	0.01
Cunnahunt	Cunnahurt, Nenagh	TN011	Nov - 00	31	5	848	<5	0.33	7.07	36.95	<0.004	<0.005	<0.006	<0.01	0.007
		TN011	Dec - 00	88	82	818	<5	1.19	7.14	26.58	0.005	<0.005	0.025	<0.01	.008
		TN011	Jan - 01	4	2	846	<5	0.22	7.56	46.52	0.009	<0.005	<0.006	<0.01	0.01
Curryquinn	Mountisland, Dolla, Nenagh	TN016	Nov - 00	0	0	634	<5	0.26	7.27	19.58	<0.004	<0.005	<0.006	<0.01	0.006
		TN016	Dec - 00	134	128	616	<5	0.36	7.32	16.83	<0.004	<0.005	<0.006	<0.01	0.005
		TN016	Jan - 01	0	0	601	<5	0.36	7.52	23.21	<0.004	0.013	<0.006	<0.01	0.01
Drombane	Gorthacoola, Drombane, Thurles	TN037	Dec - 00	2	0	580	<5	0.21	7.65	9.21	<0.004	<0.005	<0.006	<0.01	0.005
		TN037	Jan - 01	0	0	506	<5	0.21	7.87	13.42	0.014	0.016	<0.006	<0.01	0.02
Drombane A		TN037A	Nov - 00	0	0	544	<5	0.23	7.50	13.69	<0.004	<0.005	<0.006	<0.01	0.006
Drombane B		TN037B	Nov - 00	0	0	708	<5	0.17	7.13	26.14	<0.004	0.017	<0.006	<0.01	0.009
Elmhill	Toureigh, Ballymackey, Nenagh	TN033	Nov - 00	0	0	829	<5	0.46	7.20	36.50	<0.004	0.013	<0.006	<0.01	0.008
		TN033	Dec - 00	0	0	845	<5	0.32	7.10	27.55	<0.004	<0.005	0.023	<0.01	0.006
		TN033	Jan - 01	0	0	535	<5	0.23	7.51	35.57	0.014	0.006	<0.006	<0.01	0.01
Fantane	Fantane, Borrisoleigh	TN017	Nov - 00	4	3	468	<5	0.46	7.39	19.67	0.024	0.107	<0.006	<0.01	0.008
		TN017	Dec - 00	12	10	443	<5	0.39	7.00	18.34	0.006	0.008	<0.006	<0.01	0.004
		TN017	Jan - 01	2	2	472	<5	0.36	6.71	25.47	<0.004	0.013	<0.006	<0.01	0.01
Frolic	Frolic, Carney, Nenagh	TN020	Nov - 00	10	10	746	<5	0.43	7.16	35.75	<0.004	<0.005	<0.006	<0.01	0.005
		TN020	Dec - 00	25	0	772	<5	0.31	7.29	29.28	0.007	<0.005	<0.006	<0.01	0.005
		TN020	Jan - 01	4	2	742	<5	0.23	7.17	32.52	0.004	<0.005	<0.006	<0.01	0.01
Garrynamona	Tobins Cross, Holycross	TN015	Nov - 00	0	0	972	<5	0.22	7.16	41.33	<0.004	<0.005	<0.006	<0.01	0.004
		TN015	Dec - 00	1	0	923	<5	0.26	7.27	29.77	<0.004	<0.005	<0.006	<0.01	0.005
		TN015	Jan - 01	0	0	788	<5	0.33	7.22	40.14	0.006	0.025	0.007	<0.01	0.01
Graigue/ Pouldine	Graigue, Thurles	TN019A	Nov - 00	66	48	743	<5	0.48	7.92	39.25	<0.004	0.008	<0.006	<0.01	0.007
		TN019B	Nov - 00												
		TN019A		100	100	671	<5	0.86	7.25	26.80	0.018	0.008	<0.006	<0.01	0.004
		TN019B	Dec - 00	4	1	796	<5	1.01	7.23	29.06	<0.004	0.028	<0.006	<0.01	0.004
		TN019B	Jan - 01	22	5	865	<5	0.51	7.56	27.11	<0.004	<0.005	<0.006	<0.01	0.01

Source Location name	Sampling point	DoELG sample number	Sample date	Total Coliforms	Faecal Coliforms	Conductivity [uS/cm2]	Colour [Hazen]	Turbidity [NTU]	pH	Nitrate [mg/l]	Aluminium [mg/l]	Total Iron [mg/l]	Manganese [mg/l]	Ammonium [mg/l]	Nitrite [mg/l]
Gurtagarry	Gurtagarry, Toomevara, Nenagh	TN023	Nov - 00	4	0	448	<5	0.16	7.50	18.25	0.004	<0.005	<0.006	<0.01	0.006
		TN023	Dec - 00	5	0	400	<5	0.15	7.55	15.95	<0.004	<0.005	<0.006	<0.01	0.004
		TN023	Jan - 01	4	0	348	<5	0.26	8.06	19.89	<0.004	<0.005	<0.006	<0.01	0.01
Kilbarron	Carraigagown, Carney, Nenagh Nenagh	TN032	Nov - 00	53	40	704	<5	0.21	7.35	26.23	0.017	<0.005	<0.006	<0.01	0.008
		TN032	Dec - 00	0	4	803	<5	0.27	7.36	20.42	<0.004	<0.005	<0.006	<0.01	0.006
		TN032	Jan - 01	1	0	739	<5	0.22	7.36	27.42	<0.004	0.011	<0.006	<0.01	0.01
Kilbillier	Kilbilier, Collbawn,	TN010	Nov - 00	21	0	706	<5	0.20	7.12	17.99	0.006	0.006	<0.006	<0.01	0.005
		TN010	Dec - 00	36	0	795	<5	0.29	7.27	13.95	0.013	<0.005	<0.006	<0.01	0.007
		TN010	Jan - 01	7	0	748	<5	0.24	7.21	17.81	0.034	0.007	<0.006	<0.01	0.01
Killahara	Leugh, Thurles	TN014	Nov - 00	5	1	923	<5	1.07	7.03	11.34	0.028	0.200	0.035	<0.01	0.004
		TN014	Dec - 00	7	0	1003	<5	0.65	7.20	6.47	<0.004	0.068	0.042	<0.01	0.008
		TN014	Jan - 01	2	0	892	<5	0.78	7.56	13.73	0.174	0.940	0.041	<0.01	0.01
Killeen A	Nora Kennedy, Killen, Nenagh	TN002a	Nov - 00	3	0	348	<5	0.57	6.85	10.45	0.005	0.008	<0.006	<0.01	0.006
		TN002a	Dec - 00	1	0	380	<5	0.24	6.73	9.21	<0.004	<0.005	<0.006	<0.01	0.007
		TN002a	Jan - 01	0	0	398	<5	0.12	7.23	10.45	0.008	0.015	<0.006	<0.01	0.01
Killeen B	Nora Kennedy, Killen, Nenagh	TN002B	Nov - 00	0	0	335	<5	0.24	7.66	19.05	<0.004	<0.005	<0.006	<0.01	0.005
		TN002B	Dec - 00	0	0	350	<5	0.17	7.58	17.63	<0.004	<0.005	<0.006	<0.01	0.005
		TN002B	Jan - 01	0	0	333	<5	1.27	7.86	18.47	0.039	0.039	<0.006	<0.01	0.01
Kilriffith/ Kilmore	Kilriffith, Dolla, Nenagh	TN022	Nov - 00	>100	>100	773	<5	0.30	7.03	19.67	<0.004	<0.005	<0.006	<0.01	0.005
		TN022	Dec - 00	40	3	718	<5	0.38	7.03	15.95	<0.004	0.010	<0.006	<0.01	0.007
		TN022	Jan - 01	11	7	676	<5	0.37	7.68	17.14	0.010	<0.005	<0.006	<0.01	0.01
Lacka	Carrig, Birr	TN031	Nov - 00	5	3	739	<5	0.35	7.32	38.01	0.032	<0.005	<0.006	<0.01	0.007
		TN031	Dec - 00	0	0	812	<5	0.32	7.30	22.06	0.000	0.007	<0.006	<0.01	0.008
		TN031	Jan - 01	0	0	792	<5	0.22	7.19	31.36	<0.004	0.005	<0.006	<0.01	0.01
Lisheenacloonta	Rodger Ryan, Ballyphilip, Nenagh	TN001	Nov - 00	0	0	840	<5	0.40	7.19	29.24	<0.004	<0.005	<0.006	<0.01	0.007
		TN001	Dec - 00	0	0	800	<5	0.31	7.12	23.48	<0.004	0.007	<0.006	<0.01	0.007
		TN001	Jan - 01	0	0	802	<5	0.23	7.56	27.20	<0.004	0.010	<0.006	<0.01	0.01
Lordspark	Lordspark, Rathcabbin, Roscrea	TN028	Nov - 00	46	4	782	<5	0.37	7.13	42.71	0.010	0.014	<0.006	<0.01	0.009
		TN028	Dec - 00	208	192	881	<5	0.48	7.13	32.29	<0.004	0.009	<0.006	<0.01	0.006
		TN028	Jan - 01	8	0	734	<5	0.30	7.17	31.85	0.033	0.010	<0.006	<0.01	0.01
Milford	Slevoir, Toomevara, Nenagh	TN024	Nov - 00	0	0	750	<5	0.15	7.30	23.70	0.043	<0.005	<0.006	<0.01	0.010
		TN024	Dec - 00	5	0	827	<5	0.31	7.25	34.95	<0.004	<0.005	<0.006	<0.01	0.005
		TN024	Jan - 01	0	0	698	<5	0.30	7.43	21.93	0.000	0.000	0.000	<0.01	0.00

Source Location name	Sampling point	DoELG sample number	Sample date	Total Coliforms	Faecal Coliforms	Conductivity [uS/cm2]	Colour [Hazen]	Turbidity [NTU]	pH	Nitrate [mg/l]	Aluminium [mg/l]	Total Iron [mg/l]	Manganese [mg/l]	Ammonium [mg/l]	Nitrite [mg/l]
Moyne	Moyne, Thurles	TN004	Nov - 00	14	6	859	<5	0.60	8.07	26.00	<0.004	0.005	<0.006	0.000	0.003
		TN004	Dec - 00	4	1	832	<5	0.54	7.84	18.78	0.006	<0.005	<0.006	<0.01	0.006
		TN004	Jan - 01	10	1	767	<5	0.59	7.20	34.29	0.012	0.029	<0.006	<0.01	0.01
Newhill/Leigh A	Noard, Two-Mile-Boris, Thurles	TN018A	Nov - 00	0	0	876	<5	1.90	7.24	16.75	0.024	0.011	<0.006	<0.01	0.005
		TN018A	Dec - 00	5	0	842	<5	1.06	7.30	24.68	0.030	0.027	<0.006	<0.01	0.007
		TN018A	Jan - 01	0	0	796	<5	0.74	7.42	30.30	0.006	0.014	<0.006	<0.01	0.01
Newhill/Leigh B	Noard, Two-Mile-Boris, Thurles	TN018B	Nov - 00	0	0	914	<5	0.26	7.48	19.27	<0.004	0.005	<0.006	<0.01	0.007
		TN018B	Dec - 00	1	0	880	<5	0.14	7.45	29.28	<0.004	<0.005	<0.006	<0.01	0.007
		TN018B	Jan - 01	0	0	828	<5	0.24	7.59	38.50	<0.004	0.009	<0.006	<0.01	0.01
Patrickswell A	Patrickswell, Nenagh	TN007A	Nov - 00	42	12	404	<5	0.42	7.35	37.61	<0.004	0.009	<0.006	<0.01	0.006
		TN007A	Dec - 00	9	8	430	<5	0.31	6.69	20.42	<0.004	<0.005	<0.006	<0.01	0.005
		TN007A	Jan - 01	4	3	342	<5	0.89	6.74	30.92	<0.004	0.005	<0.006	<0.01	0.01
Patrickswell B	Patrickswell, Nenagh	TN007B	Nov - 00	24	6	466	<5	0.20	7.41	42.09	<0.004	0.007	0.006	<0.01	0.007
		TN007B	Dec - 00	7	7	404	<5	0.21	6.60	25.07	<0.004	<0.005	<0.006	<0.01	0.002
		TN007B	Jan - 01	3	3	375	<5	0.55	6.73	25.25	0.014	<0.005	<0.006	<0.01	0.00
Rahealty	Rahealty, Thurles	TN009	Nov - 00	3	0	845	<5	0.24	7.86	17.54	<0.004	<0.005	<0.006	<0.01	0.006
		TN009	Dec - 00	0	0	816	<5	0.20	7.21	27.24	<0.004	<0.005	<0.006	<0.01	0.004
		TN009	Jan - 01	10	4	889	<5	0.22	7.54	7.22	0.005	0.024	<0.006	<0.01	0.01
Scraggeen	Scraggeen, Newport	TN039	Nov - 00												
		TN039	Dec - 00												
		TN039	Jan - 01	0	0	438	<5	0.29	7.63	8.37	0.011	0.031	<0.006	<0.01	0.01
Shalee	Kiltyrome, Capparoe, Nenagh	TN040	Nov - 00	1	0	620	<5	0.34	7.37	11.03	0.012	0.095	<0.006	<0.01	0.006
		TN040	Dec - 00	0	0	640	<5	0.18	7.37	10.23	0.007	0.015	<0.006	<0.01	0.005
		TN040	Jan - 01	0	0	623	<5	0.40	7.50	9.66	<0.004	0.093	<0.006	<0.01	0.01
The Pike	The Pike, Ballingarry, Roscrea	TN006	Nov - 00	3	0	678	<5	0.84	7.51	24.05	<0.004	0.018	<0.006	<0.01	0.008
		TN006	Dec - 00	1	0	760	<5	0.49	7.74	19.49	<0.004	<0.005	0.030	<0.01	0.007
		TN006	Jan - 01	0	0	610	<5	0.23	7.61	22.42	0.004	0.014	<0.006	<0.01	0.01
Toher	Toher, Templetuohy	TN041	Nov - 00	54	50	842	<5	1.30	7.89	45.63	0.005	0.207	0.006	<0.01	0.005
		TN041	Dec - 00												
		TN041	Jan - 01	1	0	809	<5	0.16	7.50	47.40	<0.004	0.010	<0.006	<0.01	0.01

Appendix F: Analyses of groundwater from Rural Water Scheme private boreholes in North County Tipperary

Sample Ref. No.	Sample date	x coords	y coords	Pumping rate m^3/d	Total Coli-forms	Faecal Coli-forms	comments	Odour	EC [uS/cm]	Colour [mg/l Pt-Co]	Turbidity [NTU]	pH	Nitrate [mg/l]	Total Iron [mg/l]	Manganese [mg/l]	Ammonium [mg/l]	Nitrite [mg/l]
PW001	23/09/97	19569	16122	-	1	0	retested 10/3, nilnil	none	413	<2.0	0.56	7.4	<2.5	<0.05	0.192	<0.025	0.039
PW002	13/10/98	21548	16874	22		0	nil 3/6/98nil	none	877	2.7	0.9	7.2	<2.5	0.114	0.04	0.053	<0.02
PW007	05/12/98	20227	16762	33	0	0		none	513	<2.0	0.35	7.6	2.9	<0.05	0.025	0.04	<0.02
PW008	16/2/99	17914	17147	-	0	0		none	469	2.9	1.83	7.7	<2.5	0.152	0.065	<0.025	<0.02
PW009	16/6/98	19493	15819	-	1	0	bact2/2	none	219	<2.0	2.4	6.9	7.6	0.204	0.027	<0.025	<0.02
PW010	05/05/98	19113	18381	-	0	0		none	693	3.1	0.2	7.2	23.2	0.134	0.021	<0..025	<0.02
PW012	02/03/98	21784	15893	-	55	0		none	915	<2.0	<0.2	7.1	36.2	<0.05	<0.02	<0.025	<0.02
PW015	16/3/98	19445	16648	-	0			none	338	<2.0	0.27	7	50.2	<0.05	<0.02	0.05	<0.02
PW016	11/10/97	19504	17200	11	1			none	542	<2.0	0.6	7.4	94.4	<0.05	0.06	<0.025	0.021
PW017	16/11/98	19004	16919	44	0			none	473	<2.0	0.57	7.6	2.7	<0.05	<0.02	<0.025	0.087
PW019	18/11/97	19874	17055	-	0		bact2/12/97	none	300	3.6	0.8	7	25.9	0.056	<0.02	<0.025	<0.02
PW020	18/11/97	21337	17990	-	4	0	bact28/10. Retested13/1/98,nil,nil	none	704	<2.0	0.25	7.2	nil	<0.05	<0.02	nil	nil
PW021	02/10/98	21664	15636	-	0	0	ch retested 4/8/98with Fe<50	none	770	<2.0	15.6	7.4	39.05	2.028	0.03	0.14	0.096
PW023	16/3/98	19149	17275	44	0	0		none	617	<2.0	<0.2	7.2	27.1	<0.05	<0.02	0.04	<0.02
PW027	20/4/98	17833	17514	-	130		bact10/2/98	none	253	<2.0	0.84	6.7	37.5	0.138	<0.02	<0.0254	<0.02
PW030	27/4/98	17990	17467	44	1200	0		none	364	6.2	1.24	7.5	13.6	<0.05	<0.02	0.03	<0.02
PW031	02/02/98	18336	17396	38	1		bact21/4	none	647	7.6	1.4	8	39.2	0.137	<0.02	<0.025	<0.02
PW033	22/2/99	18080	17186	36	0	0		Cl	729	<2.0	1.22	7.4	<2.5	0.101	<0.02	<0.025	<0.02
PW034	24/08/98	18079	16872	-	0			none	422	<2.0	344	7.9	<2.5	0.527	0.034	<0.025	<0.02
PW036	23/2/98	17793	17388	-	2	0		none	331	<2.0	0.42	6.8	41.3	<0.05	<0.02	<0.025	<0.02
PW037	23/2/98	21026	17819	87	4	0		none	514	4.6	1.66	7.4	16.9	0.097	0.037	0.07	<0.02
PW038	18/3/98	17825	17406	-	0	0		none	324	<2.0	0.43	7.1	18.6	<0.05	<0.02	0.04	<0.02
PW039	-	17754	17280	-	0	0		none	378	<2.0	0.4	7.5	10.6	<0.05	<0.02	<0.025	<0.02
PW040	-	17818	17411	-	0			none	280	<2.0	3.6	6.9	18.6	0.1	<0.02	<0.025	0.021
PW041	-	21697	16075	-	8	0		none	825	4.5	1.4	7.3	24.3	<20	0	96.00	<0.025
PW042	-	21761	15854	-	60	0		none	819	<2.0	1.1	7.1	16.3	0.096	<0.02	<0.025	<0.02
PW043	-	18308	19743	n/a	0	0		musty	804	7	0.46	7.3	5.6	0.063	0.096	0.05	0.084
PW044	-	20234	15904	-	2			none	512	<2.0	2.67	7.3	10.4	0.204	0.025	0.08	0.024
PW045	-	21354	17833	16	0			none	585	3.2	1.1	7.8	<2.5	0.064	<0.02	0.09	<0.02

Sample Ref. No.	Sample date	x coords	y coords	Pumping rate m^3/d	Total Coli-forms	Faecal Coli-forms	comments	Odour	EC [uS/cm]	Colour [mg/l Pt-Co]	Turbidity [NTU]	pH	Nitrate [mg/l]	Total Iron [mg/l]	Manganese [mg/l]	Ammonium [mg/l]	Nitrite [mg/l]
PW047	-	19655	15984	-	0	0		none	428	<2.0	1.71	8.1	<2.5	<0.05	<0.02	<0.025	<0.02
PW050	-	20742	15077	55	2			none	760	<2.0	1.2	7.3	50.5	0.12	<0.02	<0.025	<0.02
PW052	-	21395	17504	-	8			none	947	2.8	0.92	7.2	16.9	<0.05	0.034	<0.025	<0.02
PW053	-	18665	19690	-	0			none	761	<2.0	1.1	7.6	23.5	0.054	<0.02	0.14	0.095
PW054	-	21553	17776	16	0	0		none	645	<2.0	1.07	7.6	<2.5	<0.05	<0.02	0.04	0.076
PW055	-	19072	20853	-	n/a	0		Cl	1639	2.3	27.3	8	<2.5	2.358	<0.02	<0.025	0.029
PW058	-	21435	16082	-	0			none	973	4.6	0.9	7.4	32	<0.05	<0.02	<0.025	<0.02
PW061	-	21749	15908	-	0			none	651	<2.0	0.6	7.7	<2.5	0.053	<0.02	0.04	0.036
PW063	-	20077	16259	-	2	0		none	434	<2.0	1.02	7.5	8.2	<0.05	0.033	<0.025	0.09
PW064	-	19255	21065	-	0	0		none	895	2.3	0.52	8.1	3.5	<0.05	0.044	0.03	<0.02
PW065	02/11/98	21540	17329	16	0	0		foul	737	<2.0	29.1	7.2	<2.5	3.23	0.299	0.09	<0.02
PW067	28/01/98	20706	17528	33	18	0		none	431	<2.0	0.6	7.9	<2.5	0.07	<0.02	0.09	<0.02
PW069	20/05/98	19619	16912	22	0			musty	418	2.2	1.49	7.5	11.9	0.058	0.082	<0.025	0.029
PW071	28/01/98	17752	17355	-	0	87		none	364	<2.0	2	7.5	18.85	0.329	<0.02	0.05	<0.02
PW073	23/03/00	21714	18568	44	n/a	0		none	476	<2.0	0.59	7.9	<2.5	0.066	<0.02	<0.025	<0.02
PW074	16/12/97	20184	19910	-	0			none	686	<2.0	0.5	7.8	21.5	<0.05	<0.02	<0.025	<0.02
PW076	13/01/99	17783	17321	-	n/a			none	337	<2.0	0.7	7.1	33.9	0.112	<0.02	<0.025	<0.02
PW077	02/03/98	21762	15863	-	2	0		none	783	<2.0	<0.2	7.2	22.2	0.069	<0.02	<0.025	<0.02
PW078	02/09/98	17294	16935	34	0	0		none	434	<2.0	7.3	7.6	<2.5	2.362	0.123	0.03	<0.02
PW079	27/05/98	17795	17388	-	0	0		none	316	<2.0	0.29	7.1	30.7	<0.05	<0.02	<0.025	<0.02
PW080	02/02/98	20235	15902	-	0	1		none	279	<2.0	0.7	6.6	2.5	0.074	0.076	<0.025	<0.02
PW081	28/09/98	20803	17702	-	1			none	360	<2.0	2.6	6.9	6	0.164	<0.02	<0.025	<0.02
PW082	25/03/98		no map	49	1	0		none	751	<2.0	<0.2	7.3	25.2	<0.05	<0.02	0.05	<0.02
PW083	23/02/99	20797	17005	-	0			none	834	2.2	0.38	7.2	30.5	<0.05	<0.02	0.03	<0.02
PW085	01/12/98	19710	16168	109	1	0		none	539	<2.0	0.5	7.3	17.5	<0.05	<0.02	0.07	<0.02
PW087	09/01/98	17293	17429	-	0	0		none	308	6.8	20.8	6.8	5.02	7.445	<0.02	<0.025	<0.02
PW088	22/06/98	18913	16841	33	0	0		none	334	<2.0	1.48	8	<2.5	<20	nil	<50	<0.025
PW090	21/04/98	19844	16520	-	0	0		none	383	<2.0	1.76	7.3	15.8	<0.05	<0.02	<0.025	0.049
PW091	13/07/98	21295	17253	-	0			none	1292	<2.0	0.5	6	<2.5	<0.05	<0.02	0.11	<0.02
PW092	19/10/98	19431	15839	-	n/a	n/a		none	397	<2.0	0.5	7.4	4.7	0.205	0.02	<0.025	<0.02
PW094	24/11/98	17990	18406	-	0			none	592	2	0.91	7.7	<2.5	<0.05	<0.02	0.09	<0.02
PW097	23/06/98	20088	19440	98	1	0		none	581	,2.0	0.2	7.3	19	<0.05	<0.02	<0.025	<0.02
PW098	25/08/98	17465	16553	-	5	102		none	649	2.4	0.59	7.2	5.9	<0.05	<50	<0.025	<0.02
PW100	27/01/98	19528	19509	n/a	0	0		none	803	<2.0	0.7	7.7	30.7	0.065	<0.02	0.04	<0.02
PW101	01/11/99	21523	15991	-	n/a			none	739	<2.0	0.34	7.2	17.6	<0.05	<0.02	<0.025	<0.02

Sample Ref. No.	Sample date	x coords	y coords	Pumping rate m^3/d	Total Coli-forms	Faecal Coli-forms	comments	Odour	EC [uS/cm]	Colour [mg/l Pt-Co]	Turbidity [NTU]	pH	Nitrate [mg/l]	Total Iron [mg/l]	Manganese [mg/l]	Ammonium [mg/l]	Nitrite [mg/l]
PW104	25/01/00	21371	16789	87	7			none	743	4.4	0.8	7.3	18.8	0.05	0.026	<0.025	<0.02
PW108	07/12/99	21537	15936	-	0			none	737	<2.0	1.14	7.2	9.1	<0.05	<0.02	0.07	<0.02
PW109	26/01/99	21188	15438	-	n/a			none	811	8.4	5.35	7.3	42	0.102	<0.02	<0.025	0.131
PW112	01/12/98	19578	16232	-	5			none	189	<2.0	0.99	7.1	9.1	<0.05	<0.02	0.07	<0.02
PW113	01/12/98	20150	15905	-	0	0		none	446	<2.0	1.28	7.7	5.04	0.09	<0.02	0.07	0.027
PW117	27/04/98	17860	17718	-	1	0	retested2/6/98 ok	none	313	2.4	1.16	6.5	21.9	<0.05	<34	<0.025	0.029
PW118	25/11/97	17426	18104	-	7			none	341	<2.0	0.25	7.7	17.7	0.062	<0.02	0.03	0.023
PW119 (018)	26/11/98	19551	17162	38		0		none	478	<2.0	0.3	6.7	50	<0.05	0.023	<0.025	<0.02
PW120	02/02/98	20689	16718	-	4			none	692	<2.0	0.2	7.3	33.4	<0.05	<0.02	0.06	<0.02
PW121	19/10/98	18254	18843	-	n/a			none	675	<2.0	2.3	7.3	26.8	<0.05	<0.02	<0.025	<0.02
PW122	08/04/98	17790	17385	-	0			none	305	4	0.84	6.7	35.8	<0.05	<0.02	<0.025	0.024
PW125	01/12/99	21748	17420	-	0		high turb and Fe	none	981	5.5	7.89	6.9	21.7	0.488	<0.02	<0.025	<0.02
PW129	21/04/98	22407	15997	-	2	0	retested bact 28/04, nil, nil	none	842	2.5	0.44	7.2	2.8	0.061	0.289	0.04	0.052
PW130	19/01/98	22174	18545	-	60	0	restested 10/2, nil, nil	none	768	<2.0	<0.2	7.5	46.6	<0.05	<0.02	<0.025	<0.02
PW133	08/11/98	19905	15668	-	0	0		none	451	<2.0	0.87	7.3	4.3	0.105	0.031	<0.025	<0.02
PW134	06/02/98	20822	16559	-	0	0		none	762	<2.0	0.27	7.2	30.3	<0.05	<0.02	<0.025	<0.02
PW135	21/09/98	19649	17260	9	0			Cl	579	<2.0	0.4	8	<2.5	<0.05	<0.02	<0.025	<0.02
PW136	22/03/99	19529	17405	33	0			none	556	2	2.1	7.3	22.3	0.109	<0.02	<0.025	<0.02
PW137	08/03/99	21066	16856	-	0	0		none	818	<2.0	<0.2	7.4	4.5	<0.05	0.1	<0.025	<0.02
PW138	09/09/98	-	no map	-	3	0		none	512	3.1	1.9	7.5	<2.5	0.112	<0.02	<0.025	0.036
PW139	16/11/99	21089	16215	-	0			none	819	<2.0	0.62	7.1	12	<0.05	<0.02	0.03	<0.02
PW140	28/07/99	20431	16216	-	38	0		none	524	2.6	0.2	7.6	23.6	<0.05	<0.02	<0.025	<0.02
PW142	08/04/98	22473	16029	-	0			none	847	3.8	0.24	7.1	<2.5	<0.05	<0.02	2.81	<0.02
PW143	27/01/98	20463	17514	196	1	0		none	292	<2.0	0.25	7.1	16.1	<0.05	<0.02	0.07	<0.02
PW145	11/09/98	21049	16144	-	0	0		none	798	7.7	0.4	7	3.4	<0.05	<0.02	<0.025	0.031
PW146	05/12/98	20286	15744	273	0	0		none	534	<2.0	<0.2	7.7	5.9	<0.05	<0.02	<0.025	<0.02
PW148	28/04/98	-	no map	n/a	3	0	restested29/05/98,nil,nil	none	283	2.6	0.29	6.8	25.5	0.05	<0.02	0.05	<0.02
PW149	17/11/98	17197	16789	44	0			none	462	3.4	1.53	7.1	13.4	<0.05	0.1	<0.025	<0.02
PW150	05/12/98	-	no map	436	0	0	30/3bact	none	947	3.6	<0.2	7.8	47	<0.05	<0.02	<0.025	<0.02
PW152	19/10/98	19638	15765	-	133	0	3	none	476	<2.0	0.7	7.4	nil	0.000034	0.081	<0.02	3.8
PW154	27/4/98	-	no map	-	0	0		musty	656	3.2	0.7	6.9	30.1	0.053	<0.02	<0.025	<0.02
PW155	04/06/98	-	no map	65	0	0		none	414	<2.0	<0.2	7.6	18.8	<0.05	<0.02	<0.025	<0.02
PW158	11/08/99	21897	18472		0	0		none	719	<2.0	0.45	7.1	14.5	<0.05	<0.02	<0.025	<0.02

Sample Ref. No.	Sample date	x coords	y coords	Pumping rate m^3/d	Total Coli-forms	Faecal Coli-forms	comments	Odour	EC [uS/cm]	Colour [mg/l Pt-Co]	Turbidity [NTU]	pH	Nitrate [mg/l]	Total Iron [mg/l]	Manganese [mg/l]	Ammonium [mg/l]	Nitrite [mg/l]
PW159	09/07/98	17437	18073	-	0			none	343	<2.0	0.5	6.6	23.7	0.125	<0.02	<0.025	<0.02
PW160	09/01/98	-	no map	22	12		bact1/7/98 retested 19/10,nil,nil	none	531	<2.0	1	7.7	<2.5	0.089	0.023	<0.025	0.095
PW161	15/6/99	21507	17804	-	0			none	694	<2.0	<0.2	7.4	<2.5	<0.05	0.111	0.12	<0.02
PW162	03/10/98	-	no map	-	0	0		none	481	<2.0	0.9	7.8	17.3	<0.05	<0.02	<0.025	0.063
PW163	18/2/98	18006	17450	-	100	0	bact17/11/98. ch retested 4/3/99,Mn <MAC	none	478	4.7	0.35	6.7	<2.5	<0.05	0.166	0.03	<0.025
PW166	12/01/98	19291	16693	11	10	0		none	452	<2.0	0.41	7.8	2.7	<0.05	<0.02	<0.025	<0.02
PW167	31/8/99	17830	17409	-	0			none	313	<2.0	0.44	6.8	34.7	<0.05	<0.02	<0.025	<0.02
PW169	28/7/98	19776	15894	27	>200		bact retested17/08, 15,nil	none	239	<2.0	1.05	6.8	<2.5	<0.05	<0.02	<0.025	<0.02
PW170	21/9/98	-	no map	38	7		ch. Retested after unit installed, Fe, Mn <MAC	none	411	3.6	2.3	7.3	<2.5	0.262	1.514	0.035	<0.02
PW171	12/01/98	20833	16101	-	21			none	334	4.5	0.38	7.8	<2.5	0.183	0.057	1.51	0.025
PW172	20/9/00	21137	18701	-	0			none	629	<2.0	0.28	7.1	<2.5	<0.05	0.19	0.03	<0.02
PW174	01/12/99	20086	17493	29	0	0	ch retested11/02, all below MAC	none	590	<2.0	4.1	7.6	5.2	0.19	0.1	0.069	0.083
PW175	11/02/98	18763	18356	65	4			none	694	<2.0	0.89	7.3	20.1	0.285	<0.02	0.092	0.092
PW177	19/10/98	21194	16989	22	0	0		none	659	4.6	6.9	7.3	2.6	0.16	0.021	<0.025	<0.02
PW178	18/8/98	17158	17481	-	1	0	ch retested 18/8, below MAC	none	806	2.4	0.49	7.1	30.1	0.122	0.055	<0.025	0.442
PW179	11/09/99	17607	17968	-	0			none	402	2.5	0.79	7.6	2.7	<0.05	<0.02	0.066	0.05
PW180	20/7/98	17474	17474	55	0	0		none	348	7.3	0.3	7.6	4	0.056	<0.02	<0.025	0.049
PW183	15/6/99	20435	20582	55	11		bact retested 3,nil	none	997	2.4	0.3	n/a	49.1	<0.05	,20	,0.025	<0.02
PW184	28/9/99	21669	15985	44	16		bact retested 26/10/99 nil,nil	none	674	2	1	7.4	10	0.066	<0.02	0.026	<0.02
PW185	27/4/98	21749	15964	-	0	96		none	852	<2.0	1.96	7.2	17.7	0.128	0.072	0.035	0.02
PW188	25/1/99	-	no map	-	0	0		none	307	6.1	1.63	7.2	4.3	0.072	<0.02	,0.025	<0.02
PW189	28/4/98	-	no map	-	0			none	526	<2.0	0.2	7.4	26.6	nil	nil	<0.025	<0.02
PW190	22/2/99	-	no map	-	0			none	531	2.8	0.57	7.6	3.6	<0.05	<0.02	<0.025	<0.02
PW192	19/5/98	17488	16485	-	0	2		none	578	2.4	1.04	7.7	5.1	0.165	0.022	<0.025	<0.02
PW193	23/2/98	-	no map	109	0			none	556	2.5	0.64	7.5	<2.5	<0.05	<0.02	<0.025	0.028
PW194	08/09/99	17209	17641	49	0			none	253	<2.0	0.24	7.4	14.1	<0.05	<0.02	<0.025	,0.02

Sample Ref. No.	Sample date	x coords	y coords	Pumping rate m^3/d	Total Coli-forms	Faecal Coli-forms	comments	Odour	EC [uS/cm]	Colour [mg/l Pt-Co]	Turbidity [NTU]	pH	Nitrate [mg/l]	Total Iron [mg/l]	Manganese [mg/l]	Ammonium [mg/l]	Nitrite [mg/l]
PW197	28/7/98	19950	16719	-	10	0	bact retested, nil,nil	none	325	>2.0	0.6	7	19.3	<0.05	<0.02	<0.025	<0.02
PW200	06/02/98	-	no map	-	0			none	890	2.2	<0.2	7.1	99	<0.05	<0.02	0.088	<0.02
PW201	02/06/01	20219	19999	-	0	111		none	847	<2.0	<0.2	7.6	<2.5	<0.05	<0.02	0.029	<0.02
PW202	20/7/98	-	no map	-	0	0	bact 15/2/99	none	497	10.6	1.23	7.3	25.9	0.058	0.02	0.026	<0.02
PW203	08/04/98	-	no map	-	0			none	440	2.6	0.62	7.7	<2.5	0.14	<0.02	<0.025	<0.02
PW204	03/01/99	21299	16445	44	0		ch retested,all <MAC	foul	890	2.4	5.4	7.3	30.5	0.932	<0.02	0.046	0.47
PW205	28/7/98	21204	15363	-	0		ch retested Fe<MAC	Cl	796	2.3	183	7.4	7.4	0.631	<0.02	<0.025	<0.02
PW209	08/04/98	-	no map	-	0			none	761	4.3	0.55	7.2	34.4	<0.05	<0.02	0.063	0.0053
PW211	12/01/98	-	no map	22	0			none	409	<2.0	3.96	7.5	3.3	0.163	0.027	0.03	0.025
PW213	24/11/98	20093	17270	22	0		bact24/11/98	none	466	2.3	1.95	7.7	5.6	<0.05	<0.02	<0.025	0.054
PW217	09/12/00	-	no map	44	17	0	retested1/11/00 ok	none	418	<2.0	1.44	7	8.3	0.076	<0.02	<0.025	<0.02
PW220	10/05/98	-	no map	-	0			none	653	<2.0	1.09	7.4	9.2	0.168	<0.02	<0.025	0.021
PW221	03/02/99	19491	16538	44	0	n/a		none	394	<2.0	1.4	7.2	12.2	0.136	<0.02	<0.025	<0.02
PW224	09/01/98	-	no map	87	0			none	328	<2.0	0.6	7.7	4.3	0.111	<0.02	<0.025	<0.02
PW226	10/08/97	20784	16649	55	48			n/a	685	n/a	n/a	7.3	n/a	0.00228	0.00004	0.04	n/a
PW227	24/11/98	-	no map	-	0			none	499	<2.0	0.44	7.1	27.4	<0.05	<0.02	0.03	<0.02
PW230	09/08/98	-	no map	-	5			none	848	<2.0	0.2	7.2	27.1	<0.05	<0.02	<0.025	<0.02
PW232	01/01/99	-	no map	78	10	>2419	retested 25/5 ok	none	827	3.8	0.4	7.2	37.4	<0.05	<0.02	0,036	0.023
PW234	10/02/98	21672	15554	-	12			none	752	<2.0	0.97	7.2	23.5	<0.05	<0.02	<0.025	<0.02
PW236	11/10/98	-	no map	-	1	11		none	373	<2.0	0.85	7.7	<2.5	0.083	0.04	<0.025	0.04
PW238	18/8/98	20853	17045	-	31			none	859	6.9	0.25	6.9	35.2	<0.05	<0.02	0.03	<0.02
PW239	13/10/98	-	no map	-	1		ch retested,below MAC	none	383	<2.0	1.6	7.5	<2.5	0.146	0.028	<0.025	0.26
PW241	13/10/98	-	no map	55	0		ch retested after unit added,<MACs	none	454	<2.0	176	7.1	3.8	14	0.028	0.06	<0.02
PW242	09/07/98	20984	17534	71	0	0		none	504	<2.0	5.7	7.6	<2.5	0.808	<0.02	0.131	<0.02
PW243	04/06/99	-	no map	70	0	0		n	501	<2.0	1.3	7.4	14.4	0.055	<0.02	<0.025	<0.02
PW245	05/04/99	-	no map	-	0	0	ch retested,all<MAC	none	781	<2.0	4.34	7.4	5.8	0.257	0.024	<0.025	<0.02
PW247	22/9/98	20246	16392	-	0		bact 17/5	none	509	2.8	<0.2	7.8	12.8	<0.05	<0.02	<0.025	<0.02
PW250	21/9/98	17510	16514	-	>200			none	729	2.5	0.2	7.1	8.3	<0.05	<0.02	0.03	<0.02
PW251	123/11/98	-	no map	-	0		bact 19/7/99	none	725	7.4	0.86	7.1	10.5	<0.05	<0.02	0.048	<0.02
PW253	29/9/98	-	no map	-	4		retested nov ok	none	424	<2.0	0.29	7.6	5.8	<0.05	<0.02	<0.025	<0.02
PW255	16/11/98	-	no map	-	7			none	356	<2.0	0.43	6.6	34	0.08	<0.02	<0.025	<0.02

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PW257	30/11/98	22417	15905	7	0	0	retested twice, and all<MACs	Cl	959	<2.0	16.2	7.3	30.8	0.203	<0.02	<0.025	<0.02
PW258	19/10/98	21414	18550	-	0			none	658	3.4	0.8	7.2	14.4	0.104	<0.02	<0.025	0.04
PW262	05/10/99	-	no map	-	0	0	ch retested, <MACs	n	566	<2.0	1.05	7.6	<2.5	0.053	0.105	<0.065	<0.02
PW263	21/9/98	-	no map	-	0	0		none	658	3.3	28.9	7.4	21.3	3.995	0.14	0.105	0.602
PW264	26/1/99	17103	17762	22	0			none	253	3.8	0.83	6.5	25	<0.05	<0.02	<0.025	<0.02
PW265	30/11/98	-	no map	-	110			none	787	2.5	0.32	7.1	25.8	<0.05	<0.02	0.027	<0.02
PW267	30/11/98	-	no map	-	0			none	787	<2.0	0.9	7.3	41	0.149	<0.02	0.041	0.02
PW271	11/09/98	-	no map	-	1			none	790	2.2	0.45	7.1	16.1	<0.05	<0.02	<0.025	<0.02
PW272	06/06/00	-	no map	-	0			none	746	4.8	3.09	7	17	0.479	0.035	0.098	0.059
PW273	22/0399	-	no map	-	0			none	509	5.9	0.3	8	13.2	<0.05	<0.02	<0.025	<0.02
PW282	29/2/00	18105	18307	-	4			musty	689	<2.0	93.8	7.4	<2.5	5.787	0.3	0.029	<0.02
PW283	20/7/99	20631	17335	60	0		bact 17/8/99	none	451	<2.0	1.1	7.6	<2.5	0.127	0.025	0.044	0.06
PW284	13/07/99	-	no map	38	40			none	665	2	3.55	7.4	<2.5	0.418	0.2	0.024	0.048
PW285	05/02/00	21748	15632	87	18			none	659	<2.0	0.85	7.2	<2.5	0.084	<0.02	<0.025	<0.02
PW286	01/01/99	-	no map	-	0			none	1131	3.8	1.56	7.1	21.3	0.145	<0.02	0.101	0.052
PW289	03/09/99	-	no map	-	0			nion	745	<2.0	0.3	7.2	6.5	<0.05	<0.02	<0.025	<0.02
PW292	20/7/99	20871	16963	-	1			none	819	3.8	1	7.6	20.2	<0.05	<0.02	0.048	0.021
PW295	29/3/99	22	19	-	0			none	441	<2.0	1.2	7.2	10.9	0.165	<0.02	<0.025	<0.02
PW296	25/1/00	2256	1601	87	3			none	740	2.6	3.6	7.3	14.9	0.098	<0.02	0.037	<0.02
PW297	26/10/00	-	no map	-	38			none	797	<2.0	1.2	7.6	20.3	0.079	<0.02	<0.025	0.026
PW298	26/4/99	20778	17461	-	0			none	415	3.7	1.39	7.7	4.9	0.088	<0.02	<0.025	<0.02
PW301	31/8/99	17484	16467	44	0			none	599	<2.0	1.2	7.2	5.8	<0.05	<0.02	0.031	0.071
PW303	02/01/00	203	1771	28	0			none	416	<2.0	0.5	7.6	<2.5	<0.05	<0.02	<0.025	<0.02
PW304	14/9/99	20936	15721	55	0			none	625	<2.0	0.39	7.5	6.9	<0.05	<0.02	<0.025	<0.02
PW308	05/04/99	21043	16039	-	0			none	695	24.4	0.4	7.9	3.4	<0.05	<0.02	<0.025	<0.02
PW312	10/03/00	21583	15339	-	0			none	701	<2.0	2.47	7.16	41.6	0.267	<0.02	0.059	0.157
PW313	05/03/00	20361	16798	-	0			none	424	<2.0	0.33	7.6	<2.5	<0.05	0.288	<0.025	<0.02
PW314	13/7/99	20750	17176	44	0			none	587	2.3	11.6	7.6	<2.5	0.283	0.063	0.062	<0.02
PW320	07/11/00	19522	15776	-	1			none	973	2.5	0.26	7	28.2	<0.05	<0.02	0.151	?<0.02
PW321	08/09/99	19102	18370	11	13			none	1072	3.2	1.1	7	30.8	0.071	<0.02	0.615	0.52
PW322	09/06/99	21306	17240	65	36			none	956	3.7	3.4	7.1	<2.5	0.579	0.079	<0.025	0.03
PW323	09/06/99	18860	17960	-	0			none	777	<2.0	3.1	7.3	43.4	0.102	<0.02	<0.025	0.029
PW325	20/7/99	21562	16896	-	0			none	817	4.5	0.2	7.1	23.7	<0.05	<0.02	0.056	<0.02
PW327	12/07/99	-	no map	27	11			none	442	<2.0	0.98	7.7	8.9	<0.05	0.456	0.027	0.024

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PW328	08/04/99	20908	16139	-	200		bact retested and ok	none	840	3	0.48	7.1	23.1	<0.05	<0.02	<0.025	<0.02
PW329	07/07/99	-	no map	-	0			none	382	<2.0	0.3	6.9	15.6	<0.05	<0.02	0.026	<0.02
PW330	26/9/00	21698	16620	-	0			none	901	<2.0	<0.2	7.1	49.4	<0.05	<0.02	0.226	0.047
PW333	21/3/00	19921	18091	76	5			<2.0	586	<2.0	0.85	7.3	22.8	<0.05	<0.02	<0.025	<0.02
PW334	16/11/99	21292	17244	41	0			none	761	<2.0	2.03	7.1	<2.5	0.1	0.206	<0.025	0.036
PW335	14/9/99	21694	16405	-	0			none	778	<2.0	0.49	7.6	<2.5	<0.05	<0.02	<0.025	<0.02
PW336	13/9/99	21363	18335	-	120		bact later tested ok	none	829	2.6	<0.2	7.1	20.4	<0.05	<0.02	<0.025	,0.02
PW338	25/1/00	-	no map	174	0			none	729	2.7	2.2	7.3	15.6	<0.05	<0.02	<0.025	<0.02
PW342	01/10/00	19905	15975	38	3			none	329	<2.0	0.73	7.3	3.4	<0.05	0.043	<0.025	0.039
PW343	14/2/00	19108	18373	-	1			none	694	5	1.58	7.3	36.8	0.064	<0.02	<0.025	<0.02
PW344	16/5/00	19627	16625	14	0			none	365	<2.0	0.91	7.3	14.2	0.058	<0.02	<0.025	0.025
PW345	27/03/01	19412	17501	13	0			none	783	<2.0	1.6	7.4	<2.5	<0.05	<0.02	0.05	<0.02
PW353	18/7/00	21441	16376	44	0			none	679	<2.0	<0.2	7.4	10.9	<0.05	<0.02	<0.025	0.024
PW354	22/2/00	21723	15894	-	0			none	789	<2.0	1.08	7.1	39.5	<0.05	<0.02	0.025	<0.02
PW355	11/07/00	-	no map	-	68			none	564	2.5	2.07	7	40.1	0.000158	<0.025	40.1	0.158
PW356	12/07/99	18242	18327	-	0			none	827	<2.0	0.95	7.2	<2.5	0.117	<0.02	0.041	<0.02
PW357	23/11/99	21528	16185	-	17			none	486	<2.0	0.29	7.4	18.1	<0.05	<0.02	0.084	<0.2
PW359	23/11/99	1724	178	33	0			none	261	<2.0	0.31	6.6	13.8	<0.05	0.133	<0.025	<0.02
PW361	14/1/299	21831	16033	-	0			none	859	<2.0	0.53	7.2	16.9	<0.05	<0.02	0.065	<0.02
PW366	12/07/99	20458	17238	-	38			none	162	<2.0	0.47	6.2	3.6	<0.05	<0.02	0.034	<0.02
PW368	03/07/00	19449	17554	-	4			none	938	2.5	0.6	7	35.7	<0.05	<0.02	<0.025	0.042
PW369	21/3/00	19908	20521	22	n/a			none	77	<2.0	0.25	6.8	<2.5	<0.05	<0.02	0.078	<0.02
PW370	02/01/00	19238	17159	-	260			none	494	<2.0	3.6	6.8	44.2	0.114	<0.02	0.054	<0.02
PW372	26/9/00	17230	17868	-	5			none	409	<2.0	1.06	7.59	15.4	<0.05	<0.02	0.06	0.034
PW374	12/07/99	20213	16657	-	13			none	287	4	0.33	6.6	9	<0.05	<0.02	0.028	<0.02
PW380	19/9/00	21579	16012	-	0			none	820	<2.0	0.24	6.9	15.8	<0.05	<0.02	<0.025	<0.02
PW381	15/2/00	21706	15493	-	0			none	856	2.8	1.52	7.1	20.4	<0.05	<0.02	<0.025	<0.02
PW383	13/3/00	-	no map	-	0			none	748	<2.0	0.6	7.2	<2.5	0.067	0.185	<0.025	<0.02
PW384	30/8/99	-	no map	-	0			none	812	<2.0	0.24	7.3	39.6	<0.05	<0.02	<0.025	<0.02
PW387	17/1/00	21227	17672	-	0			none	648	5.3	0.24	7.1	19.1	<0.05	<0.02	0.033	0.056
PW388	24/1/00	-	no map	-	0			none	873	3.1	<0.2	7.1	3.1	<0.05	<0.02	<0.025	<0.02
PW390	10./1/00	21165	18149	-	3			none	627	<2.0	0.45	7.3	11	<0.05	<0.02	<0.025	<0.02
PW392	27/3/00	21179	17809	-	0			none	771	<2.0	2	7	13.9	0.108	<0.02	<0.025	0.119
PW396	3/4/00	21900	16115	-	0			none	548	<2.0	0.23	7.4	<2.5	0.091	<0.02	0.278	<0.02
PW397	15/2/00	19145	17911	-	47			none	799	3	1	7.2	32.7	0.077	<0.02	<0.025	<0.02

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PW398	16/5/00	21144	16033	-	0			none	780	<2.0	1.66	7.3	33.8	0.053	<0.02	<0.025	<0.02
PW400	14/3/00	20282	15913	-	0			none	510	2	0.31	7.1	8.1	<0.05	<0.02	<0.025	<0.02
PW401	12/3/00	20666	16936	-	1			none	1389	<2.0	0.81	77.1	24.7	0.056	<0.02	<0.025	<0.02
PW402	11/11/00	19068	18345	-	0			none	882	<2.0	1.95	7.1	81.6	<0.05	<0.02	<0.025	<0.02
PW403	27/3/00	21253	17847	-	nl			none	922	7.2	17.7	6.9	<2.5	4.788	0.669	0.108	<0.02
PW404	22/8/00	-	no map	-	0			none	274	<2.0	2.52	7.1	9.5	<0.05	<0.02	,0.025	<0.02
PW409	may8th00	20910	18303	-	1			none	331	<2.0	0.33	6.8	9.9	<0.05	<0.02	<0.025	<0.02
PW410	mar3rd00	21442	15572	-	0			none	647	<2.0	1.08	7.2	6.1	<0.05	<0.02	0.042	<0.02
PW411	30/5/00	17814	17299	-	0			none	546	<2.0	11	7.6	<2.5	1.441	0.111	<0.025	<0.02
PW417	18/5/00	21455	17405	-	155			none	781	2.3	0.86	7.2	5.21	<0.05	<0.02	<0.025	0.027
PW420	june6th00	17222	17143	-	54			none	253	<2.0	0.39	6.4	14.8	<0.05	<0.02	<0.025	<0.02
PW422	12/7/00	19126	17820	-	461			none	806	<20	0.32	7.2	43.4	<0.05	<0.02	<0.025	<0.02
PW425	jan3rd00	18313	16153	55	78			none	528	3.5	2.4	7.9	<2.5	0.124	0.05	<0.025	<0.02
PW430	feb3rd00	20971	17702	-	236		bact retested &ok	none	517	6.2	0.5	7.4	19.9	<0.05	<0.02	<0.025	<0.02
PW432	13/6/00	18406	15824	-	6			none	416	<2.0	0.28	7.1	10.7	<0.05	<0.02	<0.025	<0.020
PW435	jan23rd00	18394	19384	-	5			none	722	<2.0	0.5	8.1	22.1	<0.05	<0.02	<0.025	<0.02
PW436	apr18th00	20234	19856	-	1553			none	728	2.7	0.9	7.2	19.2	0.05	0.12	<0.025	<0.02
PW439	27/6/00	19947	16691	-	0			none	407	<2.0	0.55	7.5	7.3	<0.05	<0.02	<0.025	<0.02
PW441	19/9/00	20083	16904	-	649		retested, & ok	none	477	<2.0	0.93	7.7	<2.5	0.064	<0.02	0.076	<0.02
PW442	31/10/00	17740	17327	-	0			none	380	<2.0	<0.2	7.7	10.1	<0.05	<0.02	<0.025	<0.02
PW454	oct10th00	21457	16459	-	8			none	727	<2.0	<0.2	7.36	17.8	<0.05	<0.02	0.042	<0.02
PW456	27/11/00	22138	18626	-	n/a			none	588	<2.0	15.2	7.3	<2.5	55.445	0.081	0.049	<0.02
PW465	aug8th00	21664	17897	-	>2419			foul	814	4.5	1.1	7.1	31.5	0.099	0.953	0.391	0.667
PW470	19/9/00	17234	17899	-	66			none	286	<2.0	2.39	6.5	11	0.173	0.02	,0.025	<0.02
PW471	nov1st00	19776	15706	-	59		retested, bact ok	none	295	4	0.57	7.1	10.6	<0.05	<0.02	<0.025	<0.02
PW475	21/11/00	18638	17038	32	7			none	483	<2.0	1.87	7.7	<2.5	0.065	<0.02	0.031	<0.02
PW476	12/12/00	21044	16048	-	0			none	809	<2.0	0.65	7.2	40.1	<0.05	,20	<0.025	<0.02
PW478	oct3rd00	18252	18774	-	46			none	804	<2.0	0.2	7.33	19.1	<0.05	<0.02	0.108	<0.02
PW490	jan11th01	19979	16072	38	0			none	407	<2.0	1.9	8.3	2.6	0.148	0.022	0.051	0,079
PW491	14/11/00	17427	18001	33	0			none	256	<2.0	1.15	6.7	7.8	0.072	0.045	0.029	<0.02
PW493	jan11th01	19304	20042	-	0			none	730	<2.0	0.7	8	9.9	0.095	<0.02	0.194	<0.02
PW497	21/03/01	-	no map	-	0			none	277	<2.0	<0.2	7.5	15.6	<0.05	<0.02	0.046	<0.02
PW509	jan23rd01	-	no map	-	25			none	543	<2.0	0.3	8.2	12	0.054	<0.02	<0.025	<0.02
PW116	19/05/98	21958	15598	-		0		none	792	<2.0	0.2	7.4	24.7	<0.05	<0.02	<0.025	<0.02

Sample Ref. No.	Sample date	x coords	y coords	Pumping rate m^3/d	Total Coli-forms	Faecal Coli-forms	comments	Odour	EC [uS/cm]	Colour [mg/l Pt-Co]	Turbidity [NTU]	pH	Nitrate [mg/l]	Total Iron [mg/l]	Manganese [mg/l]	Ammonium [mg/l]	Nitrite [mg/l]
PW274	16/2/99	-	no map	-	0		ch retested, all<MACs	none	777	3.5	2.55	7.5	<2.5	0.255	2.21	0.035	<0.02
PW347	14/9/99	20374	16199	-	5			none	964	<2.0	0.21	7.2	37.35	1.324	<0.02	0.048	<0.02
PW349	15/11/99	21222	15271	-	n/a			none	860	<2.0	0.37	7.2	24.8	<0.05	<0.02	<0.025	<0.02
PW482	apr4th01	20838	17037	-	11			none	867	<2.0	<0.2	7.2	33.3	<0.05	<0.02	<0.025	<0.02
PW099	10/06/98	18954	17035	-	n/a	0		none	472	<2.0	0.39	7.9	10.3	<0.05	<0.02	<0.025	0.088

Appendix G: Calculation of sample electroneutrality

This Appendix is summarised from Cronin & Furey (1998).

Inaccuracies and errors can arise in the laboratory from a range of processes such as: calibration of the instrument (several types of standards are available); interference during the analysis (caused by certain chemical and physical properties of the sample); unsuitable methodologies and human error.

Given these factors, it is important that a level of confidence is reached whereby the data received from the laboratory makes sound chemical sense. One technique commonly used to evaluate analytical results is to make sure that the dissolved solids (ions) measured in the groundwater sample are electrically neutral. This is known as the ionic balance method, or checking for electroneutrality.

G.1 Ions

A wide range of substances soluble in water dissociate into positively charged ions (cations) and negatively charged ions (anions). The most commonly reported ions are listed below.

Table G.1: Major ionic species in groundwaters

(These normally make up more than 95% of the dissolved minerals in groundwater)

Major Cations		Major Anions	
Sodium	Na^+	Carbonate	CO_3^{2-}
Potassium	K^+	Bicarbonate	HCO_3^-
Calcium	Ca^{2+}	Sulphate	SO_4^{2-}
Magnesium	Mg^{2+}	Chloride	Cl^-
		Nitrate	NO_3^-

G.2 Units of concentration

Concentrations of constituents in groundwater are generally reported as mass per unit volume e.g. milligrams per litre (mg/l). Since elements have different atomic masses and charges, concentrations cannot be directly compared using mg/l. Values in milli-equivalents per litre (meq/l) take account of atomic mass and charge. To convert from mg/l to meq/l, divide by the Relative Atomic Mass (RAM - obtained from the Periodic Table of any chemistry textbook) and multiply by the charge.

For example, the RAM of Ca^{2+} is 40.08, and the charge of Ca^{2+} is 2. Thus, *21mg/l* Ca^{2+} = *(21 x 2)/40.08 = 1.048 meq/l* Ca^{2+}

G.3 Electroneutrality (the Ionic Balance)

The ionic balance is one of the commonest ways to check for analytical errors. Water is electronically neutral, so the sum of the cations $\Sigma(+)$ in meq/l should equal the sum of the anions $\Sigma(-)$ in meq/l.

$$\text{Electroneutrality Error \%} = \frac{(\Sigma(+) - \Sigma(-))}{(\Sigma(+) + \Sigma(-))} \times 100\%$$

$$\text{or, in words} = \frac{(\text{sum cations + sum anions})}{(\text{sum cations – sum anions})} \times 100\%$$

The ionic balance error should be less than 15% for leachate and less than 5% for groundwater. If the error is much greater than 5% then:

- The analysis is poor (inaccurate).
- Other constituents were present that were omitted from the balance.

But beware of the perfect balance - if the balance is exactly 0% it is likely that the SO_4^{2-}, and/or Na^+ or $Na^+ + K^+$ were determined by difference; this is common in analyses carried out before 1980.

Reference: Colette Cronin & Anita Furey, 1998. Assessing groundwater analyses: some useful tips. *GSI Groundwater Newsletter* No. 33 May 1998. ISSN 0790-7753;
http://www.gsi.ie/workgsi/groundwater/newslet/news_intro_txt.htm

Appendix H: Explanation of the Durov diagram

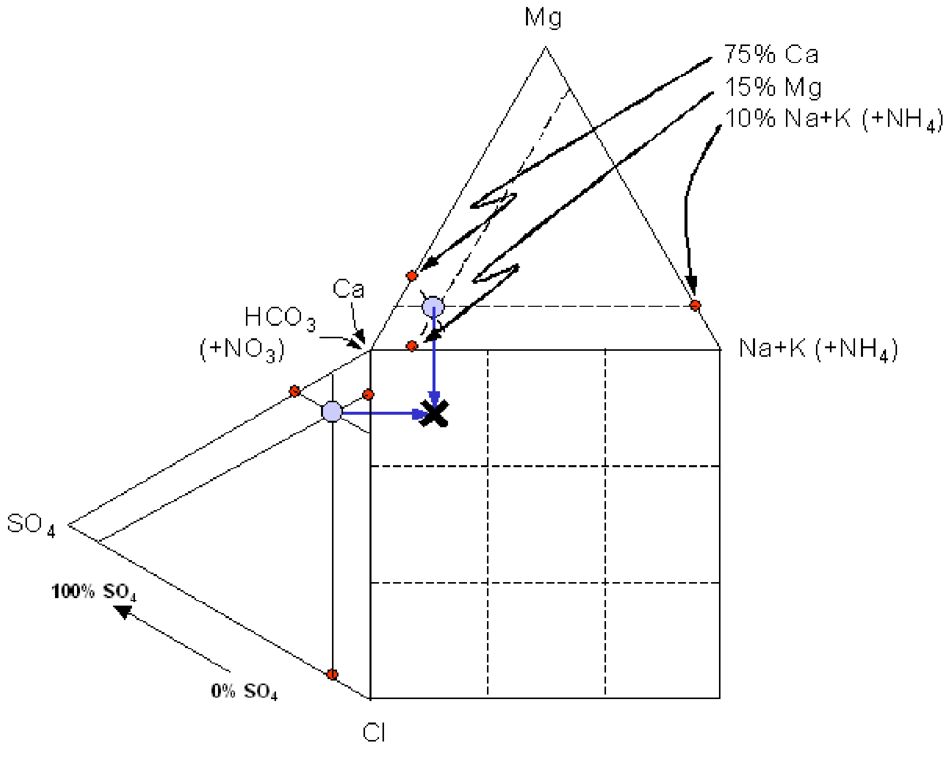
The main purpose of the Durov diagram is to show clustering of data points to indicate samples that have similar compositions. This plot reveals useful properties and relationships between samples for large sample groups.

On the Durov diagram the concentrations of the major ions dissolved in the groundwater, as percentages, are plotted in two base triangles (Figure). Concentrations are expressed in milliequivalents per litre (meq/l), rather than the more conventional milligrams per litre (mg/l). Using milliequivalents allows the relative masses of the ions (i.e., lead is heavier than aluminium) and also the electric charge of the ions to be taken into account (see **Error! Reference source not found.**2).

The total cations (positive electric charge) and the total anions (negative electric charge) are set equal to 100% and the data points in the two triangles are projected onto a square grid that lies perpendicular to the third axis in each triangle.

Figure H.1: Construction of a Durov diagram.

Points are plotted on the two triangles whose corners are defined by the major cations and anions, and then projected onto the square.



Appendix I: Alkalinity

Alkalinity refers to the capability of water to neutralise acid. This is really an expression of buffering capacity. A buffer is a solution to which an acid can be added without changing the pH appreciably. In most natural water bodies in Ireland the buffering system is carbonate-bicarbonate (CO_2 HCO_3 CO_3^{2-}). The presence of calcium carbonate or other compounds such as magnesium carbonate contribute carbonate ions to the buffering system.

Alkalinity is often related to hardness because the main source of alkalinity is usually from carbonate rocks (limestone) which are mostly calcium carbonate – $CaCO_3$. *If $CaCO_3$ actually accounts for most of the alkalinity, hardness in $CaCO_3$ is equal to alkalinity.* Since hard water contains metal carbonates (mostly $CaCO_3$) it is high in alkalinity. Conversely, unless carbonate is associated with sodium or potassium, which don't contribute to hardness, soft water usually has low alkalinity and little buffering capacity. So, generally, soft water is much more susceptible to fluctuations in pH from acid rains or acid contamination.

Alkalinity is expressed as mg/l of $CaCO_3$ even though $MgCO_3$, Na_2CO_3 or K_2CO_3 may actually contribute to part of the alkalinity.

In most natural waters, total alkalinity can be expressed as bicarbonate concentration. CO_3^{2-} only becomes an important component of DIC above pH 8.5. Other bases can act as proton acceptors, and so alkalinity is defined as:

$$\text{Alkalinity} = m\text{HCO}_3^- + m\text{CO}_3^{2-} + m\text{H}_3\text{SiO}_4^- + m\text{H}_2\text{BO}_3^- + m\text{HS}^- + m\text{OH}^-$$

A variety of organic compounds and colloids can also contribute to alkalinity, although HCO_3^- remains the major contributor in most natural waters.

Reference:

http://water.nr.state.ky.us/ww/ramp/rmalk.htm

Appendix J: GSI Nitrate Categories in North County Tipperary

Table J.1: Category B samples: Average nitrate levels exceed 25mg/l and peaks regularly approach or exceed 50 mg/l.

source	number of samples NO_3 > MAC	NO_3 > GSI threshold	sampling period	average [mg/l]	standard deviation [mg/l]	median [mg/l]	range [mg/l]	Cv
Templetouhy	**3/13** (08/89, 12/90, 12/97)	92%	1989-2000	39.8	10.6	39.9	40.0	0.27
Cloghjordan	**1/21** (01/96)	86%	1985-2000	33.6	9.5	34.1	41.6	0.28

Table J.2: Category C samples: Average nitrate levels exceed 25 mg/l, peaks rarely approach 50 mg/l but give cause for concern.

source	number of samples NO_3 > MAC	NO_3 > GSI threshold	sampling period	average [mg/l]	standard deviation [mg/l]	median [mg/l]	range [mg/l]	cv
Two-Mile-Borris	**1/11** (12/90)	82%	1990-2000	32.7	10.4	31.2	37.4	0.32
Thurles – Lady's Well	0/8	100%	1992-2000	31.0	5.9	28.87	15.5	0.19
Borrisokane	0/15	60%	1989-2000	25.7	5.5	26.3	25.5	0.21
Thurles – Creamery	0/54	43%	1989-2000	25.2	5.4	24.1	25.6	0.21

Table J.3: Category D samples: Average nitrate levels are <25 mg/l and peaks do not give cause for concern.

source	number of samples NO_3 > MAC	NO_3 > GSI threshold	sampling period	average [mg/l]	standard deviation [mg/l]	median [mg/l]	range [mg/l]	cv
Holycross	0/10	50%	1987-2000	23.7	4.2	24.8	13.8	0.18
Thurles – Tobernaloo	0/7	29%	1993-2000	23.5	2.7	23.9	7.1	0.11
Toomyvara	0/14	36%	1991-2000	22.6	5.0	22.6	20.4	0.22
Riverstown	0/9	30%	1985-2000	22.4	8.9	18.2	28.9	0.40
Littleton	0/16	25%	1990-2000	22.0	2.7	21.2	9.1	0.12
Tullahedy	0/30	3%	1989-2000	20.1	3.4	20.2	18.4	0.17
Roscrea – Glenbeha	**1/13** (10/95)	15%	1994-2000	19.5	11.0	15.1	40.7	0.56
Aglish	0/6	17%	1985-2000	19.3	8.9	18.4	27.2	0.46
Terryglass	0/14	14%	1989-2000	17.5	6.1	19.9	17.8	0.35
Ballynaclogh	0/24	4%	1989-2000	16.4	4.5	16.3	21.2	0.27
Borrisoleigh	0/35	6%	1989-2000	15.9	7.9	15.1	44.2	0.50
Loughmore	0/3	0%	1998-2000	15.0	4.5	16.7	8.4	0.30
Drumbane	0/12	0%	1990-2000	12.2	2.3	12.0	8.8	0.19
Upperchurch	0/6	0%	1987-2000	11.1	3.3	10.5	9.4	0.30
Moycarky	0/11	0%	1990-2000	10.8	4.5	9.9	16.9	0.41
Templemore	0/31	6%	1990-2000	9.6	7.5	7.1	34.1	0.78
Templederry	0/8	0%	1990-2000	6.9	1.6	6.6	5.1	0.23
Kilcommon	0/14	7%	1989-2001	6.7	5.6	4.95	23.2	0.83
Lorrha	0/22	0%	1989-2000	4.4	3.5	3.9	17.8	0.80
Clonakenny	0/10	0%	1993-2000	1.1	1.4	0.6	3.7	1.27

Appendix K: Pesticides tested for by the EPA (1999)

Table K.1: Pesticides tested for by the EPA in groundwaters from County Tipperary.
Method detection limits (MDL) are also given.

Pesticide	MDL (μg/l)	Pesticide	MDL (μg/l)
α-BHC	0.02	Endrin	0.05
β-BHC	0.02	Endosulphan 2	0.10
χ-BHC (Lindane)	0.02	p,p' – DDD	0.02
δ-BHC	0.02	Endrin Aldehyde	0.10
Heptachlor	0.03	Endosulphan Sulphate	0.10
Aldrin	0.02	p,p' – DDT	0.05
Heptachlor Epoxide	0.05	Endrin Ketone	0.10
Endosulphan 1	0.05	Methoxychlor	0.05
p,p' – DDE	0.02		

These pesticides were tested for in samples from:

1) Drumbane WSS
2) Littleton WSS
3) Holycross WSS
4) Templetouhy
5) Templemore GWS
6) Roscrea – Glenbeha WSS