AN ASSESSMENT OF THE QUALITY OF PUBLIC, GROUP SCHEME, INDUSTRIAL AND PRIVATE GROUNDWATER SUPPLIES IN COUNTY MONAGHAN (DRAFT)

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Table of Contents

FIGURES

TABLES

APPENDICES

1 Introduction

1.1 Objectives and Intended Readership

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

- Compile readily available groundwater quality data for most of the public, group scheme, industrial and recently drilled grant-aided private supply sources in County Monaghan.
- Identify the 'natural' causes of variations in groundwater 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 programs.

The uses of this report are to relate water quality problems to natural conditions, common pressures, and well construction as a means of helping decision makers focus scarce resources on targeted:

- Hazard surveys
- Remedial measures
- Detailed water quality monitoring, where necessary.

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. 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 and Methodology of Assessment

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

- The natural groundwater flow regime around the groundwater supply sources.
- The hazards posing a threat to groundwater quality.

Given the objectives outlined above, this report considers raw water rather than treated water quality. Observations are related to the quality of water as it exists at source and are not directly related to human health issues. Consequently, results of raw water analysis are assessed to try to explain water quality problems in the context of groundwater vulnerability, aquifer classification, typical land use and specific information on the effectiveness of wellhead construction, where available. Definitions and descriptions of groundwater vulnerability and aquifer delineation can be found in Chapters 4 and 5 of the Groundwater Protection Scheme for County Monaghan Main Report (Swartz and Daly, 2002).

1.2.1 Natural groundwater flow regime

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, and are listed in Table 1.1. Study of the major ion chemistry provides a water quality categorisation, or 'chemical signature' for each aquifer. This signature can prove useful in the assessment of the overall groundwater flow regime in 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. chloride or nitrate).

Table 1.1: Major ions occurring in groundwater

Positively-charged ions (cations)		Negatively-charged ions (anions)	
Ca^{2+}	Calcium	HCO_3^-	Bicarbonate
Mg^{2+}	Magnesium	Cl^-	Chloride
Na^+	Sodium	SO_4^{2-}	Sulphate
K^+	Potassium	NO_3^-	Nitrate*
Notes: * Nitrate can occur naturally in groundwater, but is generally an introduced substance.			

1.2.2 Contaminant indicators

Interpretations of the main domestic and agricultural influences on the regional pattern of groundwater quality are based on nitrates, chloride, phosphates, ammonia, *E. coli* and/or faecal coliforms, potassium, sodium, iron and manganese data. These are considered the key indicators of contamination by agricultural activities and domestic wastes. Levels were compared graphically with European Union Maximum Admissible Concentrations (MACs) and with GSI recommended threshold levels. These threshold levels can be used 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 term 'pollution'.

1.2.3 Potentially polluting activities

The main activities considered likely to influence water quality within County Monaghan include:

- Landspreading;
- On-site wastewater treatment systems (e.g. septic tank systems);
- Farmyards.

Landspreading of organic wastes and inorganic fertilisers 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 enterprise. Though individual pollution incidents related to these activities can be serious in terms of public health, they are likely to be localised, and rarely influence the regional groundwater quality situation. Consequently, such activities are not considered in this report. Furthermore, due to limited availability of data on organic parameters (e.g. petroleum hydrocarbons), adequate assessments cannot be made of these activities within the scope of this report.

The data used in this assessment, which are described more fully in Section 1.3, come from groundwater sampling rounds of Public and Group Water Schemes, industrial and private water supplies. The main interpretations and conclusions are drawn from an analysis of the data for Public, Group and industrial water supplies. Results from the analysis of private well data are generally used to provide additional data, and for comparisons between the groundwater quality of the various supply schemes or aquifers.

1.3 Data sources

Water in County Monaghan is largely provided by surface water supplies; only 17% of the water supplies in Monaghan come from groundwater. Of the 17 Public and 13 Group Water Schemes, only seven are supplied from groundwater, including the towns of Monaghan, Clones and Carrickmacross. The groundwater component of these three public supplies have only recently been explored, and are not yet fully in production.

The data used were derived from readily-available data on bacteriological and inorganic chemical analyses from the early 1980s to early 2001 (see Table 1.2). Data were compiled from the following sources:

- EPA bi-annual monitoring carried out between 1996 and 2001 by the EPA Regional Inspectorate (The Glen, Monaghan). Data was supplied by the EPA and all analyses are from raw water samples.
- Monitoring of water quality organised by the Northeastern Health Board and Monaghan County Council.
- Sampling of 15 wells organised and carried out by the GSI in February and August 2001.
- A study on the groundwater resources in the North Eastern Regional Development Organisation (NERDO) region (An Foras Forbartha and GSI, 1981).
- A STRIDE Environment Sub-Programme Measure 1 report, which updated the information presented by the NERDO report using data collected in 1993 (Friel and Quinn, 1994).

Where readily available, data from consultants' reports were also taken into account, primarily for the new public supply wells installed at Scotshouse (Clones), Monaghan and Carrickmacross. As most of these wells are not yet in production, the chemical and bacteriological data from these wells were typically collected during pumping tests of trial and production wells. Where the trial and production wells are adjacent, the data are combined as if coming from the same well.

The data compiled from each source are listed in Table 1.3. These data have varying degrees of completeness and reliability, the implications of this for the chemical analyses and the interpretations are discussed in Section 1.4.

Table 1.2 Sources of data used to assess the quality of groundwater in County Monaghan. (All data used in this report are compiled in Appendices I to VII, as indicated in the last column of the table).

Information Source	Analytical Laboratory	Analytical Parameters		No. of Samples	Type of Source[2]	Raw Data
		Inorganic	Bacterial			
An Foras Forbartha (NERDO)	EPA Regional Inspectorate, Pottery Road, Dun Laoghaire, Co. Dublin	✓	✓	80	PWS, GWS, Indust. private	Appendix I
GSI	State Laboratory, Abbotstown, Co. Dublin	✓	✓	25	PWS, GWS, Indust.	Appendix II
EPA (Nitrate)[1]	EPA Regional Inspectorate, Waterloo Rd, Dublin 4	✓		139	PWS, GWS, Indust.	Appendix III
EPA (Sampling)	EPA Regional Inspectorate, The Glen, Monaghan	✓	✓	52	PWS, GWS, Indust.	Appendix IV
County Council (private well grants, 1997 – 2001)	Microlabs Ltd., Drumillard Little, Monaghan Road, Castleblaney, Co. Monaghan	✓	✓	23	Private	Appendix V
Consultancy Reports (once-off sampling for new wells)	Various Labs Used	✓	✓	27	PWS	Appendix VI
Carrickmacross UDC	EPA Regional Inspectorate, The Glen, Monaghan	✓	✓	4	PWS	Appendix VII

Notes:
1. Nitrate results only
2. PWS – public water supply; GWS – group scheme water supply; Indust. – Industrial water supply; Private – private water supply.

1.4 Data screening and accuracy

All data were screened as follows:

- The results of GSI groundwater monitoring rounds from 2000-1, combined with biannual EPA sampling from 1996 – 2000, were used as the baseline for the standard set of sources and source names.
- Samples were not included if they were taken from water supply schemes fed from more than one water source (e.g. surface and groundwater). This is because it is assumed that the samples taken are of mixed waters which would not be representative of any one source or aquifer, and would reveal very little about water quality patterns.
- Data which was anomalous to the general trend in a given supply source was, where possible, verified with the lab that carried out the analysis. Where verifications were not possible, strongly anomalous data were omitted.
- Ionic balances were only carried out on those samples where all the major ions were analysed.

- Faecal coliform and *E. Coli* data collected by the EPA and GSI as part of routine monitoring of contaminant indicators 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 are assumed to have been treated.
- Nitrate data supplied by the EPA were in mixed format (i.e., as mg/l Nitrogen (N) or as mg/l Nitrate (NO_3)). Where it is clear which unit is used, the data are included in the water quality assessment. If there was any doubt about the units of concentration, the data were omitted.
- The majority of data from private water supplies in Monaghan are considered 'incomplete' as they do not contain analyses of all the major cations and anions (see Table 1.1). The data are assessed 'as is', without consideration of potential treatment prior to sampling.

1.5 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. This study relies on existing data, which commonly consists of major ions, total coliforms, and *E. coli* or faecal coliforms. Heavy metals, hydrocarbons and other organic compounds are rarely analysed for. Consequently, these parameters are not discussed in this report.

In addition, public health issues are not directly considered. Raw water quality, rather than treated water quality is the main issue under consideration in this report.

Table 1.3 Inventory of Public (PWS), Group Scheme (GWS) and Industrial water supply sources used in this report. (See the Groundwater Protection Scheme Main Report for details of aquifer classification, name and geological units shown in this table).

Source Type	**GSI Well Name**	**Scheme Type**	**Visited by GSI?**	**Sampled by / Data source**	**Rate m^3/d**	**Treatment Process**	**Depth hole (m)**	**Depth to rock (m)**	**Depth lining (m)**	**Comments**	**Aquifer Classification / name / geological unit.**
Monaghan PWS Roosky wells	2633SWW081 2633SWW287	PWS	✓	EPA bi-annual sampling	1100	Chlorine	47 N/A	18 N/A	N/A N/A	Raw samples collected from combined port for both wells.	Rf / Monaghan - Clones Aquifer / BA.
Monaghan PWS Lambs Lough (PW1, TW1)	2633SWW252 2633SWW148	PWS	✓	GSI sampling	430	Chlorine	91 91	5 3	6 12	Raw sample	Rf / Monaghan - Clones Aquifer / BS.
Monaghan PWS Mona Co-Op (TW2)	2633SWW149	PWS		KTC sampling	1930	N/A	91	13	13	Raw sample collected during pumping test on trial well	Rf / Monaghan - Clones Aquifer / BS
Monaghan PWS Cappog (PW3, TW3)	2633SWW249 2633SWW142	PWS	✓	KTC	680	N/A	103 91	6 12	10 10	Raw sample collected during pumping test on wells	Rf / Monaghan - Clones Aquifer / BN
Monaghan PWS Ballyalbany (PW4, TW4)	2633SWW254 2633SWW143	PWS	✓	KTC	680	N/A	103 91	6 12	10 10	Raw sample collected during pumping test on wells	Rf / Monaghan - Clones Aquifer / BS
Monaghan PWS Drumbenagh (PW5, TW5)	2633SWW256 2633SWW144	PWS	✓	KTC	680	N/A	84 91	8 30	40 38	Raw sample collected during pumping test on wells	Rf / Monaghan - Clones Aquifer / DA, BN
Monaghan PWS Kilnadreen (PW6, TW6)	2633SWW260 2633SWW145	PWS	✓	KTC	200	NA	91 91	4.3 12.2	8 18	Raw sample collected during pumping test on wells	Rf / Monaghan - Clones Aquifer / DA

Table 1.3 con't. Inventory of Public (PWS), Group Scheme (GWS) and Industrial water supply sources used in this report. (See the Groundwater Protection Scheme Main Report for details of aquifer classification, name and geological units shown in this table).

Source Type	GSI Well Name	Scheme Type	Visited by GSI?	Sampled by / Data source	Rate m^3/d	Treatment Process	Depth hole (m)	Depth to rock (m)	Depth lining (m)	Comments	Aquifer Classification / name / geological unit.
Monaghan PWS Silverstream (PW7, TW7)	2633SWW262 2633SWW145	PWS	✓	KTC	680	N/A	91 91	4.5 12.2	7 18	Raw sample collected during pumping test on wells	Rf / Monaghan - Clones Aquifer / BA
Clones/ Scotshouse PWS (PW1)	2331SEW050	PWS	✓	KTC	360	N/A	70	9.5	12.5	Raw sample collected during pumping test	Rf / Monaghan - Clones Aquifer / CH.
Clones/ Scotshouse PWS (PW2)	2331NEW210	PWS	✓	KTC	540	N/A	70	4.9	7	Raw sample collected during pumping test	Rf / Monaghan – Clones Aquifer / CH
Carrickmacross PWS Nafarty Spring	2629NEW083	PWS	✓	EPA	430 to 2160	Chlorine	Spring	Spring	-	Raw samples collected	Rk / Carrickmacross Aquifer / MF
Carrickmacross PWS Nafarty New Well	2629NEW299	PWS	✓	GSI and Jer Keohane	970	Chlorine	60	10	12	Raw samples collected. One collected during pumping test.	Rk / Carrickmacross Aquifer / MF
Carrickmacross PWS Spring Lake well	2629NEW300	PWS	✓	Jer Keohane	1730	N/A	90	15	18	Raw sample collected during pumping test	Rk / Carrickmacross Aquifer / MF
Carrickmacross PWS Tullyvaragh Lower well	2631SEW133	PWS	✓	Jer Keohane	890	N/A	90	40	48	Raw sample collected during pumping test	Rk / Carrickmacross Aquifer / MF
Carrickmacross PWS Lossets well	2629NEW301	PWS	✓	Jer Keohane	1860	N/A	90	18	24	Raw sample collected during pumping test	Rf / Carrickleck Aquifer / CR
Clontibret PWS (well)	2633SEW012	PWS	✓	GSI	12	Chlorine	92	N/A	N/A	Raw sample collected.	Pl / Lower Palaeozoic Aquifer / RI

Table 1.3 con't. Inventory of Public (PWS), Group Scheme (GWS) and Industrial water supply sources used in this report. (See the Groundwater Protection Scheme Main Report for details of aquifer classification, name and geological units shown in this table).

Source Type	GSI Well Name	Scheme Type	Visited by GSI?	Sampled by / Data source	Rate m^3/d	Treatment Process	Depth hole (m)	Depth to rock (m)	Depth lining (m)	Comments	Aquifer Classification / name / geological unit.
Smithborough well Templetate	2331NEW058	PWS		EPA	650	N/A	45	18	N/A	Raw sample collected.	Rf / Monaghan – Clones Aquifer/ CH
Pullis well	2633NWW226	GWS	✓	GSI	<40	None	N/A	N/A	N/A	Raw sample collected.	Lm / Emyvale Aquifer / MA
Tydavnet Well A	2333NEW009	GWS	✓	GSI	1090	None	64	31	37	Raw sample collected	Rf / Knockatallon-Tydavnet Aquifer / ME
Tydavnet Well B	2333NEW032	GWS	✓	GSI	6550	None	124	37	47	Raw sample collected	Rf / Knockatallon-Tydavnet Aquifer / ME
Tydavnet Well C	2333NEW033	GWS	✓	GSI	1300	None	123	28	46	Raw sample collected	Rf / Knockatallon-Tydavnet Aquifer / DA
Tydavnet Well D	2333NEW034	GWS	✓	GSI	750	None	96	45	47	Raw sample collected	Rf / Knockatallon-Tydavnet Aquifer / DA
Tydavnet Well E	2333SEW095	GWS	✓	GSI	1090	None	92	33.5	N/A	Raw sample collected	Rf / Knockatallon-Tydavnet Aquifer / DA
Bragan Water (well)	2633NWW074	Indust.	✓	EPA	>430	N/A	17	2	N/A	Raw sample collected	Rf / Knockatallon-Tydavnet Aquifer / ME

Table 1.3 con't. Inventory of Public (PWS), Group Scheme (GWS) and Industrial water supply sources used in this report. (See the Groundwater Protection Scheme Main Report for details of aquifer classification, name and geological units shown in this table).

Source Type	GSI Well Name	Scheme Type	Visited by GSI?	Sampled by / Data source	Rate m^3/d	Treatment Process	Depth hole (m)	Depth to rock (m)	Depth lining (m)	Comments	Aquifer Classification / name / geological unit.
Feldhues Meats (well)	2331NEW213	Indust.	✓	EPA	N/A	N/A	N/A	N/A	N/A	Raw sample collected	Rf / Monaghan - Clones Aquifer / DH
Grove Farm (well)	2333SEW102	Indust.		EPA	1050	N/A	N/A	N/A	N/A	Raw sample collected	Rf / Monaghan - Clones Aquifer / BA
Limestone Industries (well)	2629SEW171	Indust.		EPA	10	N/A	N/A	N/A	N/A	Raw sample collected	Rk / Carrickmacross Aquifer / MF
Meadow Meats (well)	2331NEW215	Indust.		EPA	120	N/A	N/A	N/A	N/A	Raw sample collected	Rf / Monaghan - Clones Aquifer / BA
Monaghan Mushrooms Kayebun (well)	2633SWW286	Indust.	✓	GSI	N/A	N/A	N/A	N/A	N/A	Raw sample collected	Pl / Lower Palaeozoic Aquifer / CA
Monaghan Mushrooms Tyholland (well)	2633SWW285	Indust.	✓	GSI	N/A	N/A	N/A	N/A	N/A	Raw sample collected	Rf / Monaghan - Clones Aquifer / BS
Monaghan Co-Op (well)	2633SWW068	Indust.	✓	GSI	720	N/A	36	N/A	N/A	Raw sample collected	Rf / Monaghan - Clones Aquifer / BS
Monaghan Poultry Products (well)	2633SWW277	Indust.	✓	GSI	680	N/A	91	33	48	Raw sample collected	Rf / Monaghan - Clones Aquifer / BS
Rye Valley Foods (well)	2629NEW084	Indust.	✓	GSI	1000	N/A	61	8	N/A	Raw sample collected	Rk / Carrickmacross Aquifer / MF
Silverhill Ducks (well)	2633NWW012	Indust.	✓	GSI	35	N/A	21	6	N/A	Raw sample collected	Rk / Emyvale Aquifer / MA

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 soil, on its way to streams, rivers, lakes or water tables (EPA, 1999).

This chapter describes the natural characteristics of the groundwater in County Monaghan. The rock types through which groundwater flows impart a distinct chemical signature to the groundwater. For example, limestone bedrock and limestone-dominated subsoils are common in Ireland. Consequently, groundwater is often hard and contains high concentrations of calcium, magnesium and bicarbonate. However, in areas where volcanic rocks or granites are present, and also 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.

2.2 Groundwater occurrence in County Monaghan

The vulnerability of the groundwater within an aquifer to contamination, and the flow regimes within that aquifer, both have a strong bearing on the ease with which contaminants can reach a supply source abstracting from it. Chapters 2 and 4 in the Groundwater Protection Scheme for County Monaghan Main Report discuss the geology and consequent aquifer characteristics in the county, while Chapter 5 outlines the vulnerability.

2.3 General natural water quality characteristics

Thirty four supply sources have a full analysis suite for which the results are acceptably accurate, and are used to study the natural water quality characteristics. Data for these water supply sources, which are listed in Table 1.3, come primarily from the two sampling rounds conducted by the GSI in February and August 2001 (Appendix II), and from biannual monitoring of water supplies by the EPA (Appendix IV). Data collected during the NERDO report are included, as are thirteen 'one-off' samples that were collected during pumping tests at new trial and production wells. Twenty-two of the supplies were sampled twice or more, with the remainder sampled only once. Overall, analyses from 78 groundwater chemical are used to interpret the natural groundwater quality characteristics of County Monaghan. This section presents a general overview of the data, linking the chemistry characteristics of individual sources with the aquifers they occur in. These aquifers have been delineated in the County Monaghan Groundwater Protection Scheme Main Report (Chapter 4) and are discussed in Section 2.4.

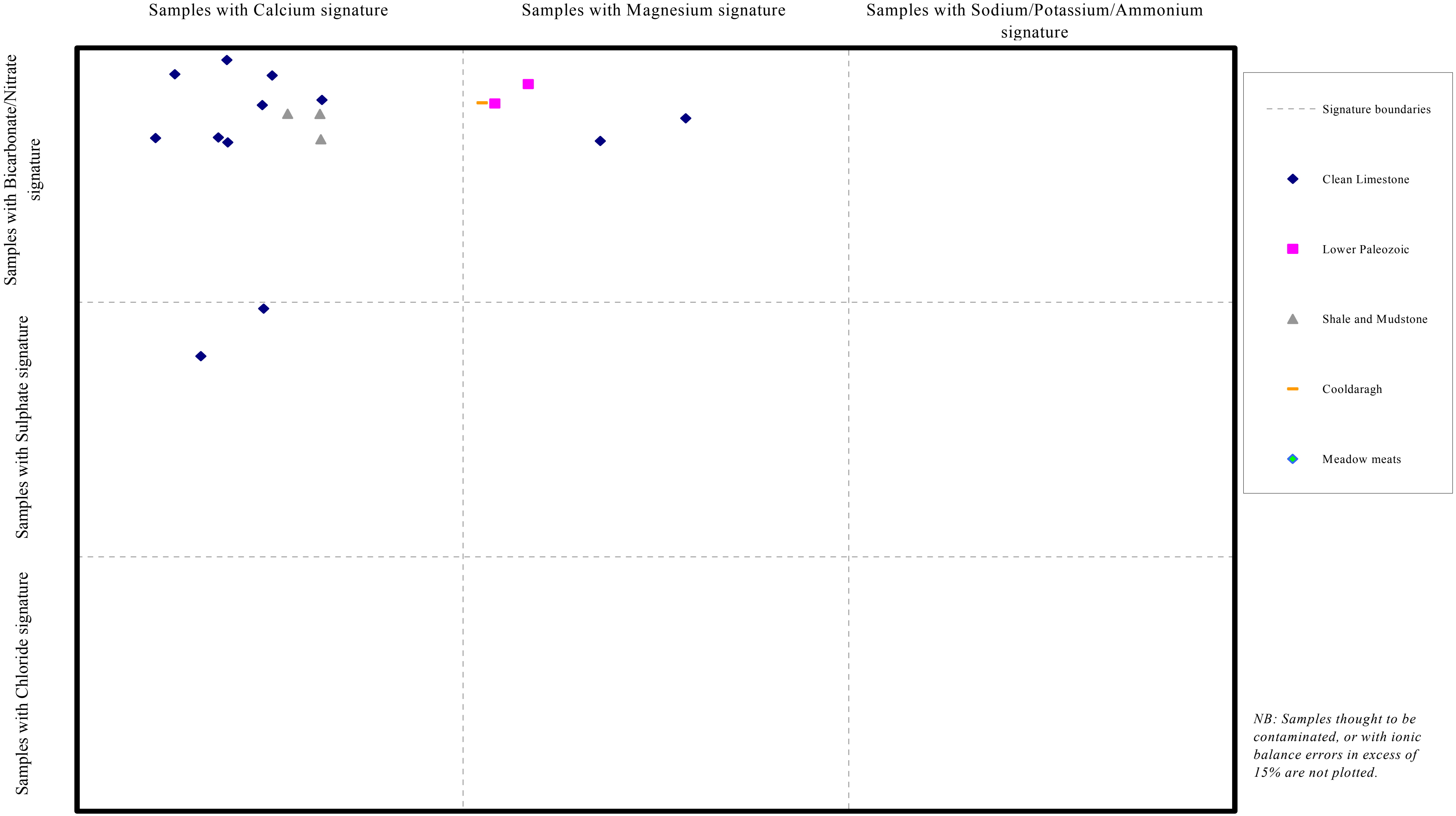
2.3.1 Groundwater chemical signature

To ascertain the chemical 'signature' of the groundwater, data from these supplies are presented on a Durov diagram in Figure 2.1 (see Appendix VIII for original data). Data used are from relatively uncontaminated sites; therefore, samples that have faecal coliforms greater than or equal to 1, or have elevated concentrations of NO_3 or NH_4, are not included in the diagram. Groundwater in Monaghan has three 'signatures', according to the Durov plot.

Calcium-bicarbonate

The majority, or 62%, of the samples have a calcium-bicarbonate chemical signature. Essentially, this means that calcium and bicarbonate are the dominant ions dissolved in the groundwater. The presence of such a signature does not significantly aid the interpretation of groundwater flow patterns where

Figure 2.1 Summary of the 'natural' hydrochemical signature of groundwaters in Monaghan (expanded Durov Plot)



NB: Samples thought to be contaminated, or with ionic balance errors in excess of 15% are not plotted.

limestone is the dominant rock type, as in much of northern Monaghan. Three of the samples in this field are from wells in geological units described as 'shale', however, these are carbonate shales and mudstones and so contain a high amount of calcium.

Calcium-magnesium-bicarbonate
Twenty-eight percent of the samples fall into the more unusual 'calcium-magnesium-bicarbonate' category. These samples are from wells at the Tydavnet GWS (Well D), Pullis GWS, Monaghan Mushrooms at Kayebun, Clontibret PWS, Feldhues Meats near Clones and one-off samples collected from the Monaghan PWS trial and production wells at Griggy (PW6).

In the Tydavnet well, and possibly also at the Pullis GWS well, this signature is considered to be diagnostic of ion-exchange processes. As ion-exchange occurs, calcium ions are replaced by magnesium ions, which are in turn replaced by sodium ions and then potassium ions. Evidence of this type of process is relatively rare in Ireland, and usually indicates confined and less vulnerable groundwater with slower, longer flow pathways. Both wells are overlain by more than 10m of low permeability subsoils, giving additional evidence of long and slow groundwater pathways. Further support is given by the low concentrations of ammonia and nitrate in these wells.

The Clontibret PWS well, and the well at Monaghan Mushrooms Kayebun are located in the Red Island and Coronea sandstones respectively. These formations belong to the Lower Palaeozoic Rocks Aquifer. These rocks are comprised of quartz-rich sandstones, which most likely results in the calcium-magnesium-bicarbonate signature.

The Feldhues Meat facility near Clones is located in the Drumgesh Shale unit of the Monaghan-Clones Aquifer. This unit is thought to have zones of higher permeability materials, possibly included dolomite lenses. As magnesium is a major component of dolomite, it is unsurprising that these samples have a calcium-magnesium-bicarbonate signature.

Finally, the samples collected from the new Monaghan PWS well at Griggy are located in the Dartry Limestone in the Monaghan – Clones Aquifer, and may suggest the presence of magnesium-rich dolomite lenses within these rocks.

Calcium-Sulphate
Ten percent of the samples have a calcium-sulphate signature. These samples come from the industrial supply wells at Monaghan Mushrooms Tyholland and the Monaghan Co-Op, and are located in the Ballyshannon and Ballysteen Limestones, respectively. The presence of sulphate is most likely due to naturally occurring conditions within the rocks. While evaporite lenses are associated with the Lower Limestones which lie south of these wells, they are not mapped as occurring in the Ballysteen or Ballyshannon units. The influence of sulphate on the hydrochemical signature is most likely due to the presence of unmapped evaporite deposits in these rock units.

2.3.2 Groundwater Hardness

Eighty-seven supply sources, including private wells, have hardness data. Overall, these indicate that groundwater in 28% are considered 'excessively hard', 48% as 'hard', 18% as 'moderately hard' and 6% as 'slightly hard' (Table 2.1). The moderately and slightly hard waters are found in the Carrickmacross, Knockatallon/Tydavnet and Lower Palaeozoic Rocks aquifers.

Table 2.1 Groundwater hardness in the aquifers of County Monaghan.

Aquifer Name	Number of supply sources within each hardness category			
	Excessively Hard (>350mg/l)	**Hard** (251–350 mg/l)	**Moderately Hard** (151-250 mg/l)	**Slightly Hard** (<150mg/l)
Carrickmacross	3	10	4	
Monaghan – Clones	19	24		
Knockatallon/ Tydavnet		2	5	
Emyvale	2	4		
Lower Palaeozoic Rocks		2	7	5
Total	***24***	***42***	***16***	***5***

These results are discussed in more detail in the following sections, where they are described in the context of individual aquifers.

2.3.3 Iron and Manganese

Iron concentrations range from 25 mg/l to non-detectable (i.e., less than 0.005 mg/l), with most concentrations less than 0.5 mg/l and a median concentration of 0.3 mg/l.

Concentrations of manganese range from non-detectable (less than 0.005 mg/l) to 3 mg/l. Manganese concentrations are commonly less than 0.05 mg/l.

2.3.4 Sulphate and Chloride

Sulphate concentrations range from 2 mg/l to 2400 mg/l, but are typically less than 200 mg/l. Excessive concentrations of sulphate (>500 mg/l), which tend to occur in the Monaghan – Clones Aquifer, are generally associated with deep, high yielding wells and evaporite lenses within the bedrock. This is discussed in more detail in Section 2.4.2.

Chloride concentrations range from about 10 mg/l to around 325 mg/l, with a median concentration of about 17 mg/l. 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).

2.3.5 Fluoride

Fluoride concentrations range from 0.04 – 3.5 mg/l, although most are below 0.3 mg/l. Most high fluoride concentrations are found in the Knockatallon/Tydavnet Aquifer and are associated with evaporite lenses within the bedrock. This is discussed more thoroughly in Section 2.4.4.

2.3.6 Other Parameters

In all sources sampled, the parameters listed in Table 2.2 are less than the Method Detection Limit (MDL) or significantly less than the Maximum Admissible Concentration (MAC). Table 2.3 shows those parameters and occasions where samples exceeded or are near to the MAC.

Table 2.2 Parameters tested which are not detected or are significantly less than the MAC.

Parameter	MDL [mg/l]	MAC [mg/l]	Sample status
Cadmium	<0.005	0.005	~ MDL
Lead	<0.02	0.05	< MDL
Total Phosphorus	<0.25	2.18	> MDL,< MAC
Selenium	<0.05		~ MDL*
Silver	<0.005	0.01	~ MDL**
Boron		2	<< MAC
Copper		3	<< MAC
Barium		0.5	<<MAC

Notes:
* The MDL is <0.05, the highest value was <1.
** The MDL is <0.005, the highest value was <50.

Table 2.3 Parameters where samples exceed or approach the MAC in County Monaghan

Parameter	MAC [mg/l]	Source location(s)	Concentration [mg/l]	Concentration range of remaining samples [mg/l]
Aluminium	0.2	Monaghan PWS Ballyalbany (PW4)	0.43	0.09-0.004
		Clones PWS (TW3)	0.804	
		Bragan Water	1.2	
		Limestone Ind	124.6, 93.4, 55.1	
Antimony	0.01	Clontibret PWS	0.116	0.02-0.0005
Arsenic	0.05	Monaghan PWS - Mona Co Op (TW2)	1.3	0.05-0.00057
		Monaghan PWS Cappog Bridge (TW3)	1.4	
Chromium	0.05	Monaghan PWS Ballyalbany (TW4)	0.12	0.034 -0.001
		Monaghan PWS Cappog Bridge (TW3)	0.16	
Fluoride	1.0	Meadow Meats	1.1, 1.25	<0.8-0.036
		Tydavnet GWS well C	3.04-1.52	
		Pullis GWS	1.19	
		Bragan Water	2	
Nickel	0.05	Monaghan PWS Cappog Bridge (TW3)	0.33	0.004-0.0007
Strontium	no limit set	Monaghan Mushrooms Kayebun	1.817, 1.891	
		Clontibret PWS	0.235	
		Feldhues Meats	2.517, 2.647	
Zinc	5	Monaghan PWS Mona Co Op (TW2)	19	2.09-0.001

2.4 Comparison of the natural groundwater quality for aquifers delineated in County Monaghan

In assessing the groundwater chemistry for the whole county, it is easier to conceptualise the results when viewed with respect to the different aquifers that have been delineated in the county as part of the groundwater protection scheme. This also helps relate data with similar aquifer areas discussed in the NERDO and STRIDE reports. Data are not available for all the aquifers, especially the smaller ones, such as the Kingscourt Gypsum unit in southern Monaghan. However, data are available from most of the larger, more permeable aquifers, which are identified in Table 2.4. A little data are also available for the Lower Palaeozoic Aquifer, which while not considered a particularly permeable aquifer, covers a large part of County Monaghan. These data, while limited, are also discussed in this report. For further information on how the aquifers were delineated, refer to Chapter 4 of the County Monaghan Groundwater Protection Scheme Main Report (Swartz and Daly, 2002).

2.4.1 Carrickmacross Aquifer

The Mullaghfin and Milverton Group limestones comprise the Carrickmacross Aquifer (see Table 2.4), which covers 73 km^2 in southern Monaghan. This is the only karstified aquifer identified in County Monaghan, and is classified by the GSI as a regionally important karstified aquifer (Rk). This aquifer is similarly referred to in the NERDO and STRIDE reports (AFF and GSI, 1981; Friel and Quinn, 1994).

Water quality data from 21 sources, including private wells, are available for this aquifer. This data consists of a total of 10 complete and 67 incomplete samples. The Carrickmacross PWS is located within this aquifer; sample data are available from the spring/lagoon and new borehole that comprise the scheme. Data from two industrial supplies are used in this assessment, as are data from 16 private wells. Once-off data collected during pumping tests are included from public supply trial wells at Spring Lake and Tullyvaragh Lower. The main water quality characteristics for this aquifer are summarised in Tables 2.5 and 2.6.

In general, the major and commonly occurring ion concentrations are within expected and acceptable ranges for this aquifer. The groundwater hardness and chemical signature are representative of a limestone aquifer. Discussion of samples collected from this aquifer for the NERDO and STRIDE reports indicate that the natural groundwater quality is good, with no issues such as elevated iron or manganese levels (AFF and GSI, 1981; Friel and Quinn, 1994).

2.4.2 Monaghan – Clones Aquifer

The Monaghan – Clones Aquifer comprises eight bedrock units: the Fearnaght Sandstone, Cooldaragh Limestone and Mudstone, Ulster Canal Limestone, Ballysteen Limestone, Ballyshannon Limestone, Dartry Limestone, Bundoran Shale and the Drumgesh Shale. The aquifer lies in a band across the county from Monaghan to Clones, covering an area of 132 km^2, and extends westward into County Cavan. The limestones in this aquifer are expected to be a mix of both muddy and clean, and the fine grained shale units are assumed to contain high permeability, clean limestone zones. This aquifer corresponds to the 'Basal Clastics and Lower Limestones' (Area 4) in the NERDO report (AFF and GSI, 1981) and is classified by the GSI as a regionally important fissured aquifer (Rf) (Swartz and Daly, 2002).

Water quality data from this aquifer come from public supplies (Monaghan, Smithborough, and Clones/Scotshouse), industrial and various private well records, representing 46 sources. These data include once-off samples collected during pumping tests for new public supply wells at Monaghan and Clones/Scotshouse. Data from 17 samples with complete chemical analyses and 29 with incomplete analyses are used in this assessment. The main water quality characteristics for this aquifer are summarised in Tables 2.7 and 2.8.

Table 2.4 Summary of Well Productivity Index & Yield Categories for Monaghan Aquifers

Aquifers		***Well Productivity Index***					***Well Yield (m^3/d)***					**Aquifer category**
		I	***II***	***III***	***IV***	***V***	***E (>400)***	***G (400-100)***	***M (100-40)***	***P (<40)***	***F (<2.7)***	
Quaternary deposits (Sand/gravel)		1					1					**None**
Dolerite (D)		No Data					No Data					**Pl**
Kingscourt Sandstone (KS)		No Data					No Data					**Lm**
		1	*1*	*1*			*3*					
Kingscourt Gypsum (KG)							1					**Pl**
Carrickleck Sandstone (CR)		1					1					**Rf**
		1	*3*				*7*	*1*				
	Carrickleck Sandstone Member (CRcg)	1					1				1	
Westphalian Shales (WES)		No Data					No Data					**Pl**
Carnmore Sandstone (MEce)		No Data					No Data					**Lm**
Knockatallon Area:	*Meenymore Formation (ME)*	3					8	3				**Rf**
	Dartry Limestone (DA)	1	1				8					
			1	*1*	*2*	*1*	*1*	*3*	*2*	*1*		
Bellanode Area:	*Benbulben Shale (BB)*			1			2	5				**Ll**
	Mullaghmore Sandstone (MU)	No Data					No Data					
	Bundoran Shale (BN)							4				
Monaghan-Clones Area:	*Drumgesh Shale (DH)*		2				1	4				**Rf**
	Bundoran Shale (BN)	2					2					
	Dartry Limestone (DA)	1	1				2	1				
	Ballyshannon Limestone (BS)	4		1	1		9	4		2		
	Ballysteen Limestone (BA)	2	1	1	2		9	10	1	1	1	
		1				*1*	*1*		*1*	*1*		
	Ulster Canal (UC)	No Data					No Data					
	Cooldaragh Formation (CH)		4	1			6	6		1	1	
	Fearnaght Formation (FT)	No Data						1				
Emyvale Area:	*Maydown Limestone (MA)*	No Data					6	6			1	**Lm**
		No Data					*2*	*3*		*4*		
	Carrickaness Sandstone (CS)	No Data						1				
Carrickmacross Area:	*Mullaghfin Limestone (MF)*	2	4				6	5			1	**Rk**
	Milverton Group Limestones (MLV)	No Data					No Data					
			1	*1*			*2*	*2*				
Fingal Limestone and Shale (FNG)		No Data					No Data					**Lm**
		7	*10*	*11*	*7*	*2*	*23*	*31*	*1*	*3*		
Cruicetown Limestone (CRT)		No Data					No Data					**Pl**
Navan Group (NAV)		No Data					No Data					**Ll**
		1	*4*	*5*	*7*	*3*	*3*	*4*	*11*	*5*		
Ardagh Shale (AD)		No Data					No Data					**Pl**
Lower Palaeozoic rocks					2	7	1	8	1	8	4	**Pl**
		1		*1*	*1*		*1*	*5*	*3*	*4*		

1. The majority of these data are drawn from Co. Monaghan; data shown in italics below the dashed lines are from Counties Cavan, Meath, Louth and Northern Ireland.
2. These statistics may be skewed towards higher yielding sources, mainly Co. Co., group scheme and industrial supplies.
3. Most well records for Co. Monaghan have neither drawdown data (for specific capacities) nor maximum yield

Table 2.5 Groundwater hardness and chemical signature for the Carrickmacross Aquifer

Bedrock Unit	Hardness Category (Number of Supply Sources)				Chemical Signature (Number of Samples)		
	Excessively Hard (>350mg/l)	**Hard** (251–350 mg/l)	**Moderately Hard** (151-250 mg/l)	**Slightly Hard** (<150mg/l)	**Calcium Bicarbonate**	**Calcium Magnesium Bicarbonate**	**Calcium Sulphate**
Carrickmacross Aquifer	3	10	4		2		

Notes:
- No data are available for the Milverton Group Limestone.
- Samples from one industrial source ranges between 'hard' and 'moderately hard'.

Table 2.6 Median major ions and other commonly occurring ion concentrations for the Carrickmacross Aquifer. Results are in mg/l unless otherwise specified.

Bedrock Unit	Ca	Mg	K	Na	HCO_3	SO_4	Cl	NH_4	Fe	Mn	EC µS/cm
Carrickmacross Aquifer	106.4	8.35	3.02	12.8	250	25.7	16.8	0.06	0.09	0.042	622
EU MAC	-	*50*	*12*	*150*	-	*250*	*250*	*0.3*	*0.2*	*0.05*	*1500*

1. No data are available for the Milverton Group Limestone.

Ca: Calcium; Mg: Magnesium; Na: Sodium; K: Potassium; HCO_3: Bicarbonate; NH_4: Alkalinity; SO_4: Sulphate; Cl: Chloride; Fe: Iron; Mn: Manganese; EC: Electrical conductivity

Table 2.7 Groundwater hardness and chemical signature of the Monaghan – Clones Aquifer

Bedrock Unit	Hardness Category (Number of Supply Sources)				Chemical Signature (Number of Samples)		
	Excessively Hard (>350mg/l)	**Hard** (251–350 mg/l)	**Moderately Hard** (151-250 mg/l)	**Slightly Hard** (<150mg/l)	**Calcium Bicarbonate**	**Calcium Magnesium Bicarbonate**	**Calcium Sulphate**
Drumgesh Shale (DH) / Bundoran Shale (BN)		5			3	2	
Dartry Limestone (DA)		2				3	
Ballyshannon Limestone (BS)	5	6			5		2
Ballysteen Limestone (BA)	9[1]	5			1		1
Lower Limestones (UC, CH, FT)	5[2]	6[3,4]			3		
Totals	*19*	*24*	*0*	*0*	*12*	*4*	*3*

Notes:

1 Samples from the wells at Grove Farm, Roosky and Silver Stream range between 'hard' and 'excessively hard'.

2 Samples from a private wells (2331NEW040) range between 'excessively hard' and 'moderately hard'.

3 Samples from the Smithborough PWS (Templetate) well range between 'hard' and 'excessively hard'.

4 Samples from the Clones/Scotshouse PW1 range are primarily 'hard' with occasional 'excessively hard' and 'moderately hard' samples.

Table 2.8 Median major ions and other commonly-occurring ion concentrations in the Monaghan – Clones Aquifer. All units are in mg/l, unless otherwise specified.

Bedrock Unit	Ca	Mg	K	Na	HCO_3	SO_4	Cl	NH_4	Fe	Mn	EC µS/cm
Drumgesh Shale (DH) / Bundoran Shale (BN)	85	22	1.6	16.5	278	19	18	0.11	0.69	0.07	614
Dartry Limestone (DA)	55.5	26.5	1.6	24	282	40	15	0.12	0.34	0.01	558
Ballyshannon Limestone (BS)	90	23	1.6	14.2	308	28	17	0.08	0.47	0.06	733
Ballysteen Limestone (BA)	195	49	2.2	28.4	296	221	20.5	0.29	0.32	0.07	855
Lower Limestones (UC, CH and FT)	141	18.9	2.14	17.3	308	37.5	19	0.03	0.33	0.09	629
EU MAC	-	*50*	*12*	*150*	-	*250*	*250*	*0.3*	*0.2*	*0.05*	*1500*
GSI Threshold	-	-	*4*	-	-		*30*	*0.15*	-	-	-

Ca: Calcium; Mg: Magnesium; Na: Sodium; K: Potassium; HCO_3: Bicarbonate; NH_4: Alkalinity; SO_4: Sulphate; Cl: Chloride; Fe: Iron; Mn: Manganese; EC: Electrical conductivity

In general, major and commonly occurring ion concentrations are within expected and acceptable ranges within this aquifer. However, there are a number of parameters, such as hardness, electrical conductivity, sulphate, chloride, iron and manganese, that are present at significant levels and can be a nuisance rather than harmful to health.

In the Ballyshannon and Ballysteen limestones, electrical conductivity, chloride and sulphate are significantly elevated in some of the samples collected from the larger supply wells, as outlined below:

- Electrical conductivity values from the Monaghan Co-Op industrial supply well and the Roosky public supply well are frequently higher than 1000 µS/cm. Samples from Grove Farm, Meadow Meats and Monaghan Mushroom (Tyholland) regularly exceed the MAC of 1500 µS/cm.
- Chloride concentrations for the Monaghan Mushroom (Tyholland), Grove Farm, and Roosky wells frequently exceed the GSI threshold value of 30 mg/l. In the case of Grove Farm, recorded chloride concentrations can be as high as 326 mg/l.
- At Grove Farm, Meadow Meats, Monaghan Mushroom (Tyholland) and the Monaghan Co-Op wells, sulphate concentrations regularly exceed the MAC (250 mg/l), and often exceed 1000 mg/l.

The elevated conductivity, chloride, and sulphate levels are most likely due to evaporite lenses within the rocks. Although evaporite lenses are not mapped as occurring in the Ballyshannon or Ballysteen limestones, they are mapped in the Cooldaragh unit to the south. Given the thick nature of the subsoil deposits in the area, bedrock mapping is dependent upon scant borehole information. Most likely there are unmapped evaporite deposits within the rocks that are influencing the hydrochemistry. As the high concentrations seem to be in the deep, higher yielding wells, monitoring of the new production wells for both Clones and Monaghan should be carried out, even though evaporite lenses were not identified during the drilling of these wells.

Similar conditions to those described above are also outlined in the NERDO and STRIDE reports, which discuss groundwater quality in Counties Cavan, Louth and Monaghan (AFF and GSI, 1981, Friel and Quinn, 1994). In the NERDO report, a variety of wells (public, industrial and private) were identified as having sulphate concentrations over 100 mg/l. While the NERDO report does not correlate the wells to specific bedrock units (as they were unmapped at the time), it does present six pairs of bored wells located close to each other within this aquifer. The well pairs are located within 1 km of the Lower Carboniferous/ Lower Palaeozoic boundary, and so are presumably within the Lower Limestone rock units, and possibly also the Ballysteen limestone. Samples collected from these wells show that sulphate concentrations vary significantly not just between the well pairs, but also within the well pairs, making it difficult to identify which unit the high sulphates are coming from.

In the more recent STRIDE report, four wells located in the Monaghan – Clones aquifer within Monaghan have elevated sulphate levels and associated high chloride, iron, manganese and conductivity levels. These wells, all of which correspond to well listed above, are deep, high yielding wells (Friel and Quinn, 1994).

The elevated levels of the various ions in these wells are most likely due to the intersection of evaporite lenses within the rocks. Concentrations may also be influenced by the drawdown on the pumping water level below the rockhead within the well, which encourages oxidation of interstitial minerals.

More widespread throughout this aquifer are elevated iron and manganese concentrations. With the exception of the manganese concentrations in the Dartry limestone, iron and manganese are generally above the MACs (0.2 and 0.05 mg/l, respectively) within the aquifer, as shown in Table 2.8. These conditions are probably derived from the bedrock and indicate reducing conditions (although it can indicate pollution).

2.4.3 Emyvale Aquifer

The Emyvale Aquifer is comprised of the Maydown Limestone (MA) and Carrickaness Sandstone (CS) (see Table 2.4), which underlie approximately 105 km^2 of northeast County Monaghan. The Maydown Limestones are described by various sources as consisting of muddy limestones, siltstones and shales (AFF and GSI, 1981; Geraghty, 1997). The Carrickaness Sandstone forms a band of mudstones and clean quartz sandstones within the Maydown Limestone. This aquifer corresponds partly to the 'Calp Sandstone' aquifer (Area 6) in the NERDO and STRIDE reports and is classified as a locally important, generally productive aquifer (Lm) by the GSI (Swartz and Daly, 2002). These reports include limestones found in northwest as part of this aquifer; the GSI has delineated these limestones as a separate aquifer (the Knockatallon/Tydavnet Aquifer), which is discussed in Section 2.4.4.

Little water quality data are available for this aquifer. Six samples with complete analyses are available from one industrial supply, and one 'complete' sample is available from the Pullis Group Water Scheme. Incomplete sample analyses are available for five private wells and the Pullis GWS. In addition, no sample data are available for the Carrickaness Sandstone. The main water quality characteristics of this aquifer are summarised in Tables 2.9 and 2.10.

Table 2.9 Groundwater hardness and chemical signature of the Emyvale Aquifer

Bedrock Unit	Hardness Category (Number of Supply Sources)				Chemical Signature (Number of Samples)		
	Excessively Hard (>350mg/l)	**Hard** (251–350 mg/l)	**Moderately Hard** (151-250 mg/l)	**Slightly Hard** (<150mg/l)	**Calcium Bicarbonate**	**Calcium Magnesium Bicarbonate**	**Calcium Sulphate**
Maydown Limestone[1] (MA)	2	4[2]			1	1	

Notes:
1. No data are available for the Carrickaness Sandstone.
2. One of the six samples from the industrial well is 'excessively hard', while the rest are 'hard'.

Table 2.10 Median major ions and other commonly occurring ion concentrations for the Emyvale Aquifer. Results are in mg/l unless otherwise specified.

Bedrock Unit	**Ca**	**Mg**	**K**	**Na**	**HCO_3**	**SO_4**	**Cl**	**NH_4**	**Fe**	**Mn**	**EC µS/cm**
Maydown Limestone[1] (MA)	143	11.2	4.4	20	340	73.5	25	0.7	0.84	0.18	798
EU MAC	-	*50*	*12*	*150*	-	*250*	*250*	*0.3*	*0.2*	*0.05*	*1500*

1. No data are available for the Carrickaness Sandstone.
Ca: Calcium; Mg: Magnesium; Na: Sodium; K: Potassium; HCO_3: Bicarbonate; NH_4: Alkalinity; SO_4: Sulphate; Cl: Chloride; Fe: Iron; Mn: Manganese; EC: Electrical conductivity

In general, the major and commonly occurring ion concentrations are within expected and acceptable ranges for this aquifer. Parameters such as hardness, iron and manganese are present at significant levels as can be a nuisance rather than harmful to health. Other parameters, such as ammonia and chloride may indicate contamination from organic wastes, and are discussed in Section 3.1.

Only two samples are available for determining the hydrochemical signature of the Emyvale Aquifer. The others have been discounted due to elevated ammonia concentrations. The two useable samples have calcium-bicarbonate and calcium-magnesium-bicarbonate signatures. The latter comes from the Pullis GWS, and was discussed in Section 2.3.1. Overall, this signature suggests that ion-exchange is occurring, indicating long, slow groundwater flowpaths. Given the deep subsoils (>10m) in the area, this result is not surprising.

The elevated levels of iron and manganese found in this aquifer are similar to conditions reported in both the NERDO and STRIDE reports (AFF and GSI, 1981; Friel and Quinn, 1994). These high concentrations are most likely due to the muddy nature of the limestone bedrock, and indicate reducing conditions within the aquifer.

2.4.4 Knockatallon/Tydavnet Aquifer

The Knockatallon/Tydavnet Aquifer consists of two rock units, the Dartry Limestone and the Meenymore, which are expected to be hydraulically connected. Overall, the aquifer covers an area of 80 km^2 and is covered by thick (>20m) subsoil deposits. The Meenymore consists of laminated limestones, mudstones, shales, sandstones and dolomites. This unit also contains evaporite deposits which will influence the hydrochemistry of the aquifer. The Dartry Limestone is a clean, well-bedded unit with occasional chert bands. The location of this aquifer is shown on Map 5. In the NERDO and STRIDE reports, this aquifer is considered part of the 'Calp Sandstones', and so is combined with the Emyvale Aquifer.

Available water quality data for this aquifer are from the Tydavnet Group Water Scheme and Bragan Water, samples of which were collected by the GSI and EPA. Data collected from private wells during the NERDO study are used in this assessment, as are 'once-off' sampling of trial wells drilled for Monaghan UDC. Early data collected from the original Tydavnet supply well at Strathnahincha Bridge are also included.

The Tydavnet GWS consists of five supply wells; two sets of samples with complete analyses are available from each of these wells, with extra data (complete and incomplete) available from Production Well B. Seven complete and nine incomplete samples are available from Bragan Water. Data are also available from three trial wells drilled in the 1980s, and four trial wells drilled in 1996. The main water quality characteristics for this aquifer are summarised in Tables 2.11 and 2.12.

Table 2.11 Groundwater hardness and chemical signature of the Knockatallon/Tydavnet Aquifer

	Hardness Category (Number of Supply Sources)				Chemical Signature (Number of Samples)		
Bedrock Unit	**Excessively Hard** (>350mg/l)	**Hard** (251–350 mg/l)	**Moderately Hard** (151-250 mg/l)	**Slightly Hard** (<150mg/l)	**Calcium Bicarbonate**	**Calcium Magnesium Bicarbonate**	**Calcium Sulphate**
Meenymore (ME)		2[1]	1		3		
Dartry Limestone (DA)			4			1	
Totals	*0*	*2*	*5*	*0*	*3*	*1*	*0*

Notes:
1. Occasional samples from Bragan Water are 'moderately hard'.

Table 2.12 Median major ions and other commonly occurring ion concentrations for the Knockatallon/Tydavnet Aquifer. Results are in mg/l unless otherwise specified.

Bedrock Unit	**Ca**	**Mg**	**K**	**Na**	**HCO_3**	**SO_4**	**Cl**	**NH_4**	**Fe**	**Mn**	**EC µS/cm**	**F**
Knockatallon/Tydavnet Aquifer	48	20.7	3.2	76.6	290	55	11.9	0.22	0.14	0.03	620	1.91
EU MAC	-	*50*	*12*	*150*	-	*250*	*250*	*0.3*	*0.2*	*0.05*	*1500*	*1.0*

Ca: Calcium; Mg: Magnesium; Na: Sodium; K: Potassium; HCO_3: Bicarbonate; NH_4: Alkalinity; SO_4: Sulphate; Cl: Chloride; Fe: Iron; Mn: Manganese; EC: Electrical conductivity; F: Fluoride.

In general, the major and commonly occurring ion concentrations are within expected and acceptable ranges for this aquifer. Fluoride is present at significant levels, and can constitute a health hazard with prolonged exposure, causing dental fluorosis and more seriously skeletal fluorosis (bone deformation and brittle bones) (Kelly, 2001).

Where ion exchange is occurring, it is common to find fresh, meteoric waters near outcrop or recharge areas, with progressive increases in salinity down the groundwater flow system. As ion exchange takes place, calcium is replaced by magnesium, which is replaced by sodium. Ion exchange conditions are observed in this aquifer and influence the hydrochemistry of the groundwater. Groundwater in the Knockatallon/Tydavnet Aquifer is not as hard as those found elsewhere in County Monaghan, which is most likely a result of ion exchange processes.

Ion exchange can also influence the fluoride concentrations within the aquifer, which are consistently high and, in the majority of samples, are above the MAC (1mg/l). The presence of evaporite lenses within the rocks provides a potential source of fluoride, and ion-exchange controls the amount of fluoride that can dissolve into the groundwater. The ability of fluoride to dissolve in water is related to the amount of calcium and magnesium present. In general, there is an inverse relationship between calcium and fluoride: high concentrations of calcium in the water mean little fluoride can be dissolved. However, under ion-exchange conditions, calcium is replaced by magnesium, which reduces the calcium concentration and increases the solubility of fluoride (Kelly, 2001).

2.4.5 Lower Palaeozoic Rocks Aquifer

Numerous bedrock units comprise the Lower Palaeozoic rocks, which cover an area of 817 km^2 across the middle of County Monaghan. Predominantly they are dirty sandstones and shales with minor volcanics. These rock units are considered together as a single aquifer, which is classified by the GSI as a poor aquifer, generally unproductive except for local zones (Pl). This area is considered a 'non-aquifer' in the NERDO and STRIDE reports. Although not discussed in the NERDO report, the STRIDE report discusses samples from five private wells within this region.

Overall, very little hydrochemical data are available for this aquifer. Only two complete sample analyses are available, from the Clontibret PWS and one industrial supply well. Forty incomplete sample analyses from private wells are therefore included in this assessment. The main water quality characteristics for this aquifer are summarised in Tables 2.13 and 2.14.

Table 2.13 Groundwater hardness and chemical signature for the Lower Palaeozoic Rocks Aquifer

Bedrock Unit	Hardness Category (Number of Supply Sources)				Chemical Signature (Number of Samples)		
	Excessively Hard (>350mg/l)	**Hard** (251–350 mg/l)	**Moderately Hard** (151-250 mg/l)	**Slightly Hard** (<150mg/l)	**Calcium Bicarbonate**	**Calcium Magnesium Bicarbonate**	**Calcium Sulphate**
Lower Palaeozoic Rocks[1]		2	7	5		2	

Notes:
1. Numerous rock units of similar age and geology comprise this aquifer.

Table 2.14 Median major ions and other commonly occurring ion concentrations for the Lower Palaeozoic Rocks Aquifer. Results are in mg/l unless otherwise specified.

Bedrock Unit	Ca	Mg	K	Na	HCO_3	SO_4	Cl	NH_4	Fe	Mn	EC µS/cm
Lower Palaeozoic Rocks[1]	68	36.9	1.84	18.4	350	25.7	16.8	0.06	0.17	0.04	478.5
EU MAC	-	*50*	*12*	*150*	-	*250*	*250*	*0.3*	*0.2*	*0.05*	*1500*

1. Numerous rock units of similar age and geology comprise this aquifer.
Ca: Calcium; Mg: Magnesium; Na: Sodium; K: Potassium; HCO_3: Bicarbonate; NH_4: Alkalinity; SO_4: Sulphate; Cl: Chloride; Fe: Iron; Mn: Manganese; EC: Electrical conductivity; F: Fluoride.

In general, the major and commonly occurring ion concentrations are within expected and acceptable ranges for this aquifer. Parameters such as iron and manganese are present at significant levels as can be a nuisance. While the median concentrations of these parameters are not above the MACs, some samples collected from private wells do significantly exceed the MACs. The STRIDE report also reports high iron and manganese in the five wells samples in this aquifer. These elevated concentrations are most likely due to naturally occurring conditions within the bedrock and indicate reducing conditions.

The two complete samples available for this aquifer indicate that the chemical signature is calcium-magnesium-bicarbonate. In addition, groundwater in the aquifer tends to be slightly to moderately hard. These conditions are most likely due to the non-carbonate nature of the rocks.

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. Most groundwater is contaminated to some degree although it is not necessarily polluted. In assessing groundwater quality, there is often a tendency to focus 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. Consequently, thresholds for certain parameters are used to help indicate situations where significant contamination (but not pollution) is occurring. These thresholds are given below in Table 3.1.

Table 3.1 Thresholds used by the GSI for assessing water quality

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	0.35	-
Faecal bacteria	0	0

3.1.1 Faecal Coliforms and *E. Coli*

Background: Faecal coliforms are the most common parameter tested as indicators of faecal bacteria and perhaps viruses, both of which can affect human health. Faecal coliforms are commonly analysed for because they are easily detected and identified, and because they originate in the intestine, along with other pathogenic organisms. The presence of faecal coliforms, and especially *E. coli*, in a water supply is proof that faecal contamination has occurred, and that there is a risk of pathogens being present (Flanagan, 1992). 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. Therefore, the presence of faecal bacteria in samples from groundwater supply sources 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.

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.

The natural environment, in particular soils and subsoils, can be effective in removing bacteria and viruses by predation, filtration and absorption. 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 allow rapid movement and bypassing of the subsoil. Although *E. coli* bacteria are an excellent indicator of pollution, they can come from a wide range of sources, such as on-site system (septic tank) effluent, farmyard waste, landfill sites and birds.

Occurrence: Summary water quality information for each aquifer is presented in Table 4.1. *E. coli* or faecal coliforms were in excess of both the MAC and GSI thresholds in nine of the sources (26%), and three had faecal coliform concentrations higher than 10 counts per 100 ml. These sources are described on an aquifer basis below:

> *Carrickmacross Aquifer*: Of six sources in this aquifer, faecal coliforms were detected in four, including the Nafarty PWS spring and new borehole. Data are available from a total of 10 samples; at least one sample in each of the four sources has more than 10 counts per 100ml.
>
> *Monaghan-Clones Aquifer:* Of 17 sources, faecal coliforms were detected in four. Two of these sources are the public supply wells at Roosky and Templetate; the remaining sources are industrial supply wells. Two of the sources each had one sample with faecal coliforms over 10 counts per 100 ml.
>
> *Knockatallon/Tydavnet Aquifer:* Of the six sources, five of which comprise the Tydavnet GWS, only one sample contained faecal coliforms (at 1 count per 100 ml).
>
> *Emyvale Aquifer:* Data are available from two sources in the Emyvale Aquifer – the Pullis GWS and one industrial supply well. No samples were found to have faecal coliforms above the MAC.
>
> *Lower Palaeozoic Rocks Aquifer:* Data are available from two sources in the Lower Palaeozoic rocks. Faecal coliforms were not detected in any of the samples from this aquifer.

Variations with time: Data are not sufficient for a detailed assessment of the presence of faecal coliforms over time. In addition, coliform analyses were not carried out as part of the NERDO report. Coliforms were found in wells in the Monaghan-Clones and Carrickmacross Aquifers (Friel and Quinn, 1994). Discussions with Monaghan County Council suggest that problems with coliforms regularly occur at the Nafarty supply for Carrickmacross.

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 Carrickmacross spring/lagoon at Nafarty is an uncovered spring and so is susceptible to surface runoff. The Rye Valley Foods and new Nafarty borehole are constructed to proper well standards. No well construction information is available for the Limestone Industries well. However, in view of the karstified nature of the Carrickmacross aquifer, it is not possible to draw definitive conclusions on the source/s of the faecal bacteria.

3.1.2 Nitrate

Background: Nitrate is one of the most common contaminants identified in groundwater, and increasing concentrations have been recorded in many counties. Elevated levels can be derived from on-site systems (septic tanks), slurry and soiled water from farmyards, land spreading of organic wastes and inorganic fertilisers. As the normal concentration in uncontaminated groundwater is low (less that 5 mg/l), nitrate can be a good indicator of contamination by fertilisers and organic waste.

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 subsoils.

Occurrence: Summary water quality information for each supply source is presented in Table 4.1. Of the 33 sources, no samples have nitrate levels in excess of the MAC, and only 3 have samples above the GSI threshold.

> *Carrickmacross Aquifer:* The public supply spring/lagoon at Nafarty has nitrate levels above the GSI threshold.
>
> *Monaghan – Clones Aquifer:* One sample from the Grove Farms well is above the GSI threshold for nitrate. This sample also corresponds with elevated ammonia and a coliform count of 36 in 100 ml, and probably indicates a point contamination source.
>
> *Knockatallon/Tydavnet Aquifer:* No sources in this aquifer have nitrate concentrations above the threshold or MAC.
>
> *Emyvale Aquifer:* No sources in this aquifer have nitrate concentrations above the threshold or MAC.
>
> *Lower Palaeozoic Rocks Aquifer:* One sample from the Clontibret Public supply well is above the GSI threshold for nitrate.

Variations with time: Of the 33 sources examined, 10 have data spanning three or more years. For the majority of the sources, the data show no trend, with nitrate concentrations staying level or showing 'spikes' reflecting possible contamination events. Only the data from Grove Farms show a possible, slight upward trend; however, the last sample tested for nitrate from this source was in 1999.

Relationship between nitrate levels, attenuation potential in the groundwater pathway and well construction: Given the large amount of low permeability and low vulnerability areas in County Monaghan, widespread nitrate contamination is not expected. Nitrate could potentially be an issue in the Carrickmacross Aquifer, which is a karstified aquifer with many areas of extreme and high vulnerability. In addition, point recharge is an issue in this aquifer, with sinking streams and swallow holes providing rapid access to the aquifer. Sample data from the Nafarty, Limestone Industry and

Rye Valley Foods sources, while not always exceeding the GSI threshold, are commonly above 10 mg/l, which is higher than in any other aquifer in County Monaghan, and suggests that human activities are impacting to some degree on groundwater quality in this aquifer. Nitrate concentrations in the Clontibret PWS well, which is located in a poor aquifer, are only occasionally high, suggesting isolated contamination events.

3.1.3 Ammonia

Background: Ammonia concentrations in excess of 0.15 mg/l (as NH_3 or NH_4) are generally indicative of contamination from organic wastes, and consequently may indicate the possible presence of micro-organisms (Flanagan, 1992).

Ammonia has a low mobility in soil and subsoil and its presence at concentrations greater than 0.1 mg/l in groundwater indicates a nearby contaminant hazard, vulnerable conditions, and/or poor well construction.

Occurrence: Summary water quality information for each supply source is presented in Table 4.1. Of the 33 sources, nine have ammonia levels over the GSI threshold and four over the MAC.

> *Carrickmacross Aquifer:* Ammonia levels within the aquifer are generally below the GSI threshold, with only one sample from the new Nafarty borehole having ammonia concentrations above the GSI threshold. (Elevated ammonia concentrations are commonly detected in new boreholes; concentrations usually drop over time with proper development and regular pumping of the well.)
>
> *Monaghan – Clones Aquifer:* Three sources in this aquifer exceed the MAC for ammonia Two are industrial supplies (Grove Farm and Meadow Meats). Ammonia concentrations from Grove Farm are consistently over the GSI threshold, with only occasional samples exceeding the MAC. Samples from Meadow Meats are consistently over the MAC. The new production well at Scotshouse also has ammonia levels above the MAC; however, since this well is not yet in production, the samples were collected during pumping tests. Ammonia is above the GSI Threshold in one sample collected from the Roosky well, and may indicate a contamination event around the time the sample was collected. Elevated ammonia levels were also detected in once-off samples collected from a new trial well for the Monaghan public water supplies (TW2). These elevated levels are most likely associated with the new well, and are likely to reduce over time with regular pumping.
>
> *Knockatallon/Tydavnet Aquifer:* Ammonia concentrations in the Tydavnet group scheme wells are consistently between the GSI threshold and the MAC, with no samples exceeding the MAC.
>
> *Emyvale Aquifer:* Of the two sources in this aquifer, ammonia concentrations in samples from Silverhill Duck are consistently above the MAC.
>
> *Lower Palaeozoic Rocks Aquifer:* Ammonia concentrations above the GSI threshold are detected in one sample from the well at Monaghan Mushrooms Kayebun.

Variations with time: Of the 33 sources examined, 10 have data spanning three or more years. Of the sources with ammonia in excess of the MAC or GSI guide levels, long term data are available only from two industrial supplies in the Monaghan – Clones Aquifer. The data for the supply well at

Meadow Meats is variable, with the recent data suggesting a possible slight increase in ammonia over time. Similar conditions are seen at Grove Farms, where the concentrations are fairly level, with the exception of a sharp increase in 1998 (see Appendix IV).

Relationship between ammonia levels, attenuation potential in the groundwater pathway and well construction: Given the large proportion of low permeability and low vulnerability areas in County Monaghan, widespread ammonia contamination is not expected. Proper well construction can greatly reduce the amount of contamination from ammonia. Four sources have levels above the MAC. Three of these are industrial supplies from either large farms or meat-processing facilities. All three industrial sites are located in areas of low vulnerability; and well construction details are not available.

Well construction at the Clones PWS well, which also has ammonia above the MAC, is not thought to be an issue. Thus, the ammonia levels here may indicate contamination events, or may reflect the fact that the samples were collected during pumping tests when the well was new. Elevated ammonia is commonly associated with new wells, and typically drops with regular pumping and development of the well.

Given the low vulnerability and well construction and protection at the Knockatallon/Tydavnet wells, it is likely that the high ammonia concentrations are due to naturally occurring bedrock conditions. However, at Well B, where faecal coliforms have also been detected, it is more likely that the ammonia concentrations indicate a local contamination event.

3.1.4 Chloride

Background: 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 15 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).

Occurrence: Summary water quality information for each supply source is presented in Table 4.1. Of the 33 sources examined, four have chloride levels above the GSI threshold with two of these above the MAC. One source, Rye Valley Foods, is located in the Carrickmacross Aquifer. While only one sample from this source is above the threshold, the other samples are above 25 mg/l.

The other three sources with elevated chloride are located in the Monaghan – Clones Aquifer. All three have associated high levels of sulphate and electrical conductivity, which are related to evaporite lenses within the bedrock. These evaporite lenses are likely to also be influencing the chloride levels in these wells.

Variations with time: Of the 33 sources examined, seven have data spanning five or more years. Of these, no trends are discernible except in the Monaghan public supply well at Roosky, where a very slight upward trend is discernible. Given that, in this well, chloride concentrations are probably due to naturally occurring bedrock conditions, this increase may correspond to an increase in abstraction rate or supply demand put on the well.

Relationship between chloride levels, attenuation potential in the groundwater pathway and well construction: Chloride is a conservative ion, which can move readily through soil and subsoil in a manner similar to water. 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.

3.1.5 Sodium and potassium

Background: The background potassium:sodium ratio in most Irish groundwater is less than 0.4, and often 0.3. The potassium:sodium 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 potassium:sodium ratio greater than 0.4 can be used to indicate contamination by plant organic matter – usually in farmyards, and occasionally landfill sites (from the breakdown of paper). However, a potassium:sodium 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 potassium is less mobile than sodium.

Note that 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, 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: Summary water quality information for each supply is presented in Table 4.1. Of the 33 supply sources examined, only two have potassium:sodium ratios above the threshold. In one source (Limestone Industries), potassium levels are also above the MAC. The other source, Clones PWS (Well 2), potassium levels are also above the threshold. The sample from the source with a potassium:sodium ratio above the threshold also has high ammonia concentrations. While this may suggest contamination from organic wastes, the samples were collected during pumping tests on the new well, and so may not reflect regular pumping conditions.

Four other supply sources have potassium concentrations above the threshold; one of these is also above the MAC. Evaporite lenses within the rocks are thought to cause elevated chloride, electrical conductivity and sulphate concentrations within these wells, and may also contribute to the high potassium levels.

Variations with time: No long term trends are apparent in the available data set.

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 Table 4.2.

3.1.6 Iron and Manganese

Background: Although they are present under natural conditions (groundwater in muddy limestones, shales and boggy area may contain high iron and manganese), iron and manganese can also be good indicators of contamination by organic wastes. Effluent from the wastes cause deoxygenation in the ground which results in dissolution of iron and manganese from the soil, subsoil and bedrock into groundwater. 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).

Occurrence: Summary water quality information for each supply source is presented in Table 4.1. Of the 33 supply sources examined, 27 have either iron or manganese (or both) above the MAC.

Variations with time: Of the 33 supply sources examined, seven have data spanning five or more years. The only apparent long term trend is at Silverhill Ducks, where iron concentrations have decreased between 1996 and 2001.

Relationship between iron and manganese levels, attenuation potential in the groundwater pathway and well construction: Given that 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 bedrock is the primary source of iron and manganese. At three supply sources (Limestone Industries, Meadow Meats and Silverhill Ducks), iron concentrations are considerably higher than the MAC.

At Limestone Industries, which draws water from a clean, karstified aquifer, only occasional samples have excessively high iron concentrations. Faecal coliforms were also detected in these samples, thus indicating groundwater contamination by organic wastes.

At Meadow Meats, which draws water from a muddy limestone, iron concentrations are consistently above the MAC. These samples also correspond with ammonia levels above the MAC, and so possibly indicates contamination by organic wastes. However, this supply source also has elevated chloride, electrical conductivity and sulphate, which are associated with evaporite lenses within the bedrock. These evaporite lenses may also be responsible for at least part of the high iron and manganese levels within this well.

The Silverhill Ducks facility is located in the Emyvale Aquifer, and draws water from a rock unit consisting of limestones, sandstones and shales. The iron concentrations are commonly more than 10 times the MAC and often correspond with high ammonia levels. Chloride levels, while not above the guideline value of 30 mg/l, are often above 22 mg/l. Unfortunately, there is only one sample available for the other source (Pullis GWS) in this aquifer, so background levels for this aquifer are not well constrained. However, given that the iron concentrations are much higher than the MAC, and that they tend to correspond with high concentrations of other parameters, it is likely that the groundwater around this source has been impacted by organic wastes.

3.1.7 Phosphate

Background: The principal significance of phosphate is as a cause of eutrophication in surface water. Sources of phosphate include slurries, dirty water, inorganic fertilisers, farmyard runoff and detergents. Phosphate is strongly adsorbed onto soil but 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 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). Consequently, elevated concentrations in water supplies can also occur if well construction or wellhead protection measures are poor.

Occurrence: Summary water quality information for each supply source is presented in Table 4.1. Of the 33 supply sources examined, nine exceed the GSI guide level of 0.02 mg/l for ortho-phosphate. In half of these, phosphate is above the guide level occasionally; in the other half, elevated concentrations are more common.

Variations with time: No long term trends are apparent in the available data sets.

Relationship between phosphate levels, attenuation potential in the groundwater pathway and well construction: Phosphate was detected above the GSI Guide Level only occasionally at five of the supply sources. In one of these sources (Smithborough PWS), the sample containing high phosphates also contained faecal coliforms, suggesting possible contamination from organic wastes. No obvious correlation is seen in the other supplies with occasional elevated phosphates. Four samples consistently have elevated phosphate levels. Given the potential for phosphate to adsorb within soil materials, levels would be expected to be relatively low in most vulnerability situations. The presence of phosphate levels in excess of 0.01 to 0.02 mg/l PO_4 in all vulnerability types, as with the supply sources studied, suggests that point hazards may be contributing to many of the contamination problems identified in this study.

4 General Groundwater Quality Assessment of Supply Sources

4.1 Introduction

The supply sources are divided into four group to aid in the water quality assessment. The classification is based on concentrations of key contaminant indicators in relation to the European Union Maximum Admissible Concentration (MAC) and to the 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:

1. **Group 1:** Sources in which one or more contaminant indicators in the available data set exceeded 10 counts / 100 ml for *E.coli*, or the EU MAC for the remaining indicators.
2. **Group 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).
3. **Group 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).
4. **Group 4:** Sources showing no evidence of contamination from the analyses carried out for the project.

4.2 Discussion

Table 4.1 provides the results of the grouping exercise based for the different aquifers. Overall, 33% of the 33 supply sources studied occur in Group 1, 3% in Group 2, 12% in Group 3, and 52% in Group 4. Many of the water supplies in Group 4 have naturally derived water quality problems relating to iron and manganese. However, since these are quite common and are most likely derived from bedrock conditions, they are classed as Group 4 to avoid shifting attention from cases where human activities have had an impact.

Four sources (67%) located in the Carrickmacross Aquifer have experienced contamination from human activities and are classed in Group 1. The two sources listed in Group 4 are new wells with only one sample available per well. Given the highly vulnerable, karstified nature of this aquifer which allows groundwater (and contaminants) to travel quickly, contamination within this aquifer may be caused by farmyards, industrial sites, septic tank systems and/or the landspreading of organic waste.

In the Monaghan – Clones Aquifer, six (35%) of the supply sources are in Group 1, three of which are public supply wells. The data suggest that these wells have been impacted by human activities, although not as consistently as supplies in the Carrickmacross Aquifer. The vulnerability of the Monaghan – Clones Aquifer is more mixed and has large areas of low vulnerability. However, the

Table 4.1 Groundwater quality classification of County Monaghan Groundwater Supply Sources

Group	Supply Source	RPZ[6]	Exceedences by Key Indicators of Contamination[1]								
			NO3	Cl	PO$_4$	NHx	Faecal coli.[2]	K	K:Na	Fe	Mn
Carrickmacross Aquifer (Rk):											
1	Carrickmacross PWS – old spring/lagoon	Rk/H	*Excess threshold*		*Excess threshold*		**Excess 10**			**Excess MAC[3]**	**Excess MAC[3]**
	Carrickmacross PWS – new Nafarty well	Rk/H				*Excess theshold[5]*	**Excess 10**			**Excess MAC[3]**	
	Limestone Industries	Rk/H			*Excess threshold*		**Excess 10**	**Excess MAC**	*Excess threshold*	**Excess MAC**	**Excess MAC[3]**
	Rye Valley Foods	Rk/H		*Excess threshold*			**Excess 10**				**Excess MAC[3]**
2	No supply sources in this category										
3	No supply sources in this category										
4	Carrickmacross PWS – Spring Lake well	Rk/M								**Excess MAC[3]**	
	Carrickmacross PWS – Tullyvaragh well	Rk/L								**Excess MAC[3]**	**Excess MAC[3]**
Monaghan – Clones Aquifer (Rf):											
1	Monaghan PWS – Roosky well	Rf/L		*Excess threshold[4]*	*Excess threshold*	*Excess threshold*	**Excess 10**	*Excess threshold*		**Excess MAC[3]**	**Excess MAC[3]**
	Clones/Scotshouse PWS – PW2	Rf/M			*Excess threshold*	**Excess MAC**		*Excess threshold*	Excess threshold	**Excess MAC[3]**	**Excess MAC[3]**
	Smithborough PWS	Rf/H			*Excess threshold*		**Excess 0**	*Excess MAC*		**Excess MAC[3]**	**Excess MAC[3]**
	Grove Farm	Rf/H	*Excess threshold*	*Excess threshold[4]*	*Excess threshold*	**Excess MAC**	**Excess 10**	*Excess threshold*		**Excess MAC[3]**	**Excess MAC[3]**
	Monaghan Poultry Products	Rf/L		*Excess threshold[4]*			**Excess 0**				**Excess MAC[3]**
	Meadow Meats	Rf/M				**Excess MAC**		*Excess threshold*		**Excess MAC**	**Excess MAC[3]**
2	No supply sources is this category										
3	Monaghan PWS – TW2 (Co-op)	Rf/M				*Excess theshold[5]*				**Excess MAC[3]**	**Excess MAC[3]**
4	Monaghan PWS – Lambs Lough (PW1)	Rf/H								**Excess MAC[3]**	**Excess MAC[3]**
	Monaghan PWS – Cappog (PW3)	Rf/H								**Excess MAC[3]**	**Excess MAC[3]**
	Monaghan PWS – Ballyalbany (PW4)	Rf/M								**Excess MAC[3]**	**Excess MAC[3]**
	Monaghan PWS – Drumbenagh (PW5)	Rf/H								**Excess MAC[3]**	**Excess MAC[3]**
	Monaghan PWS – Kilnadreen (PW6)	Rf/M								**Excess MAC[3]**	
	Monaghan PWS – Silverstream (PW7)	Rf/H									**Excess MAC[3]**
	Clones/Scotshouse PWS – PW1	Rf/L			*Excess threshold*					**Excess MAC[3]**	**Excess MAC[3]**
	Feldhues Meats	Rf/H									**Excess MAC[3]**
	Monaghan Mushrooms Tyholland	Rf/L								**Excess MAC[3]**	**Excess MAC[3]**
	Monaghan Co-Op	Rf/M									**Excess MAC[3]**

Notes:
1. NO$_3$: Nitrate; Cl: Chloride; NH$_x$: Ammonia; K: Potassium; K:Na: Potassium – sodium ratio; Fe: Iron; Mn: Manganese.
2. These figures 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.
3. Excess iron and manganese concentrations are most likely due to naturally occurring conditions in the bedrock.
4. Excess chloride concentrations are most likely due to naturally occurring conditions in the bedrock.
5. Ammonia concentrations are often high in new wells and typically drop with regular pumping.
6. Aquifer type / Groundwater vulnerability. Codes described in Maps 5 and 6.

Table 4.1. con't Groundwater quality classification of County Monaghan Groundwater Supply Sources

Group	Supply Source	RPZ[6]	Exceedences by Key Indicators of Contamination[1]								
			NO3	Cl	PO_4	NHx	Faecal coli.[2]	K	K:Na	Fe	Mn
Knockatallon/Tydavnet Aquifer (Rf):											
1	No supply sources in this category										
2	Tydavnet GWS – Well B	Rf/L				*Excess threshold*	**Excess 0**	*Excess threshold*		**Excess MAC[3]**	
3	Bragan Water	Rf/L			*Excess threshold*			*Excess MAC**			**Excess MAC[3]**
4	Tydavnet GWS – Well A	Rf/L				*Excess threshold[5]*					
	Tydavnet GWS – Well C	Rf/L				*Excess threshol5[4]*				**Excess MAC[3]**	
	Tydavnet GWS – Well D	Rf/L				*Excess threshold[5]*					
	Tydavnet GWS – Well E	Rf/L				*Excess threshold[5]*					
Emyvale Aquifer (Lm):											
1	Silverhill Ducks	Lm/M			*Excess threshold*	**Excess MAC**		*Excess threshold*		**Excess MAC**	**Excess MAC[3]**
2	No supply sources in this category										
3	No supply sources in this category										
4	Pullis GWS	Lm/L									
Lower Palaeozoic Rocks Aquifer (Pl):											
1	No supply sources in this category										
2	No supply sources in this category										
3	Monaghan Mushrooms Kayebun	Pl/M				*Excess threshold*					
	Clontibret PWS	Pl/H	*Excess threshold*								
4	No supply sources in this category										

Notes:
1. NO_3: Nitrate; Cl: Chloride; NH_x: Ammonia; K: Potassium; K:Na: Potassium – sodium ratio; Fe: Iron; Mn: Manganese.
2. These figures 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.
3. Excess iron and manganese concentrations are most likely due to naturally occurring conditions in the bedrock.
4. Excess chloride concentrations are most likely due to naturally occurring conditions in the bedrock.
5. Ammonia concentrations are often high in new wells and typically drop with regular pumping.
6. Aquifer type / Groundwater vulnerability. Codes described in Maps 5 and 6.

aquifer is very permeable, which allows groundwater and contaminants to travel quickly. The sources in Groups 3 and 4 are dominated by new public supply wells for Monaghan and Clones/ Scotshouse. In general, few samples are available from these wells, and none span a long period of time. Three of the supplies in Group 4 are industrial wells and, while having naturally derived high iron and manganese concentrations, show no evidence of contamination from human activities.

No supply sources in the Knockatallon/Tydavnet Aquifer are classed as Group 1. One supply in each class is in Groups 2 and 3, with the remaining four supplies in Group 4. Tydavnet GWS Well B, which is in Group 2, has been impacted by faecal coliforms. Potassium levels are also elevated in this well, although given the nature of the bedrock, it is difficult to tell whether this is naturally occurring or not. All of the Tydavnet GWS well have elevated ammonia levels. Given the low vulnerability of the area around these wells and the good well construction and well head protection, it is unlikely the ammonia is derived from human activities. As the levels of potassium and phosphate are only occasionally high in the Bragan Water supply, and may reflect natural rock conditions, this source is considered to be in Group 3.

Of the two supply sources in the Emyvale Aquifer, only the Silverhill Ducks supply shows possible evidence of contamination from human activities.

The two supply sources located in the Lower Palaeozoic Rocks Aquifer are both in Group 3, as occasional samples have exceeded MACs for nitrate and ammonia.

4.3 Appraisal of Water Quality Issues at Specific Supply Sources

As discussed in Section 1.1, no field hazard surveys have been undertaken as part of this report. Assessments have been made on the basis of water quality data and cannot be used to link quality problems with specific enterprises unless they are accompanied by field hazard surveys. Nevertheless, in order to provide some initial guidance, the combination of contaminant indicators at each supply has been assessed in the context of generic hazard types. Results are presented in Table 4.2.

Table 4.2 Generic Hazard Types Influencing Selected Groundwater Supplies in County Monaghan

Releases of domestic or agricultural wastes likely to have influenced groundwater quality		
Evidence of point releases		Releases may be point and / or diffuse
Elevated K:Na ratios	*Combination of indicators such as E.coli and ammonia in high, moderate or low groundwater vulnerability settings*	*The origin cannot be discerned using quality data & vulnerability mapping alone*
Possible farmyard hazard nearby	*Possible hazards include nearby septic systems and/or sewerage pipes and/or farmyard hazards.*	
Limestone Industries, Clones/Scotshouse PW2.	Carrickmacross – Nafarty, Monaghan PWS – Roosky Well, Grove Farm, Tydavnet – Well B.	Carrickmacross PWS – Lagoon, Rye Valley Foods, Smithborough – Templetate, Monaghan Poultry Products, Meadow Meats, Silverhill Ducks.

4.4 Conclusions

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

- The dominant hydrochemical signature of the groundwater in County Monaghan is calcium-bicarbonate, with some samples having a calcium-magnesium-bicarbonate signature, and even fewer samples having a calcium-sulphate signature.
- Twenty-eight percent of the supply sources in County Monaghan have 'excessively hard' groundwater, with 48% having 'hard' water, 18% 'moderately hard' and 6% 'slightly hard' groundwater. The moderately and slightly hard waters are found in the Carrickmacross, Knockatallon/Tydavnet and Lower Palaeozoic Rocks aquifers.
- High levels of iron and manganese, often in excess of the EU MAC, are widespread, and in most cases are a consequence of natural geological conditions.
- Evaporite lenses are thought to influence the hydrochemistry of the Monaghan – Clones Aquifer, especially the higher yielding, deeper wells. Sources effected by the evaporites tend to have high electrical conductivity, chloride, and sulphate.
- Fluoride concentrations above the MAC are found in the Knockatallon/Tydavnet Aquifer, and result from natural geological conditions.
- Faecal coliforms are in excess of 0 counts per 100 ml in nine (26%) of the supply sources. Of these, six are in excess of 10 counts per 100 ml.
- Nitrate contamination is not a widespread issue in County Monaghan, with no supply sources having nitrate concentrations above the MAC. Three sources (9%) have nitrates above the GSI threshold (25 mg/l). Nitrate levels, which not necessarily above the threshold, are generally more elevated in the Carrickmacross Aquifer than anywhere else in Monaghan, reflecting the highly vulnerable, karstified nature of this aquifer.
- Ammonia is in excess of the GSI threshold in 9 (26%) supply sources; four (12%) of the sources are above the MAC.
- Chloride is in excess of the GSI threshold in four (12%) of the supply sources, with two of these over the MAC.
- The potassium:sodium ratio exceeds the GSI threshold in two supply sources.
- Excessively high levels of iron and/or manganese at three supply sources may indicate contamination by organic wastes.
- Phosphate is in excess of the EPA guide level of 0.02 mg/l in nine (27%) of the supply sources. Consequently, landspreading of slurries, manures and inorganic fertilisers may be contributing to the elevated phosphate levels, especially in areas with thin subsoils.
- Thirty-three percent of the groundwater supplies studied are in Group 1, which are the most contaminated supplies in County Monaghan. Only 3% are in Group 2, comprising those supplies where there is evidence that the discharge have been significantly contaminated by human activities. Twelve percent of supplies are in Group 3, comprising those supplies where there is some slight evidence impact by human activities. Finally, 52% of the supplies are in Group 4, showing no evidence of human-induced water quality problems.
- Faecal coliforms and ammonia are the most common contaminant indicators identified in the available samples, and are commonly seen in samples from sources in Group 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 County Monaghan.

4.5 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 Group 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 1 km upslope and 30 m downslope for boreholes. For springs, recommended upslope and downslope distances are 1 km and 50 m, respectively. However, these distances are somewhat arbitrary, and are largely dependent on the abstraction rate. Thus, 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:

Group	No. Supply Sources in Each Group	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 Group 3 sampling frequency.
2	1	At least *quarterly*, until conclusions can be drawn on the origin of the contamination and appropriate alleviation measures are taken.
3	4	At least *quarterly*.
4	17	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.

4.6 Acknowledgements

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

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4.7 References

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Appendix I - Laboratory analytical results from An Foras Forbartha (NERDO).

WELL NAME	DATA SOURCE/Name	AQUIFER NAME	SAMPLE DATE	SAMPLE COMPANY	ALKALINITY (mg/l)	bicarbonate (hco3)	AMMONIA TOTAL(mg/l)	CA HARDNESS (mg/l)	CALCIUM (mg/l)	CHLORIDE (mg/l)	E_COLI (count/100ml)	F_COLI (count/100ml)	IRON_TOTAL (mg/l)	MAGNESIUM (mg/l)	MANGANESE (mg/l)
2629NEW003	Private well	Carrickmacross	22-Aug-79	NERDO	212	258.64		163		34			0.067		0.072
2629NEW006	Private well	Carrickmacross	22-Aug-79	NERDO	472	575.84		436		71			0.08		0.02
2629NEW016	Private well	Carrickmacross	10-Apr-79	NERDO	240	292.8		290		45			N.A.		N.A.
2629NEW016	Private well	Carrickmacross	14-May-79	NERDO	300	366		370		59			0.48		0.08
2629NEW043	Private well	Carrickmacross	22-Aug-79	NERDO	248	302.56		248		19			N.D.		0.1
2629NEW044	Private well	Carrickmacross	22-Aug-79	NERDO	173	211.06		130		13			0.04		0.05
2629NEW045	Private well	Carrickmacross	22-Aug-79	NERDO	194	236.68		199		19			0.02		0.043
2629NEW046	Private well	Carrickmacross	22-Aug-79	NERDO	274	334.28		314		23			N.D.		0.024
2629NEW070	Private well	Carrickmacross	10-Apr-79	NERDO	204	248.88		136		18			0.035		0.11
2629NEW070	Private well	Carrickmacross	14-May-79	NERDO	198	241.56		128		17			0.13		N.A.
2629NEW070	Private well	Carrickmacross	22-Aug-79	NERDO	214	261.08		142		17			0.76		0.02
2629NEW077	Private well	Carrickmacross	10-Apr-79	NERDO	306	373.32		282		25			0.02		N.D.
2629NEW077	Private well	Carrickmacross	14-May-79	NERDO	310	378.2		278		24			0.16		0.07
2629SEW105	Private well	Carrickmacross	22-Aug-79	NERDO	408	497.76		336		25			0.012		0.008
2629SEW106	Private well	Carrickmacross	22-Aug-79	NERDO	312	380.64		316		32			0.02		0.004
2629SEW109	Private well	Carrickmacross	22-Aug-79	NERDO	208	253.76		212		89			0.05		0.241
2629SEW118	Private well	Carrickmacross	22-Aug-79	NERDO	182	222.04		136		22			0.07		0.065
2633NWW013	Private well	Emyvale	20-Aug-79	NERDO	444	541.68		312		20			0.015		0.035
2633NWW075	Private well	Emyvale	30-Aug-76	NERDO						29			1.6		
2633NWW075	Private well	Emyvale	29-Sep-78	NERDO	390	475.8		165		29			1.15		N.D,
2633NWW106	Private well	Emyvale	no date	NERDO	340	414.8				28			0.1		
2633NWW106	Private well	Emyvale	30-Jul-72	NERDO	340	414.8				28			0.1		n.d.
2633NWW217	Private well	Emyvale	9-Nov-79	NERDO	402	490.44		248		18			0.44		0.18
2633NWW217	Private well	Emyvale	14-May-79	NERDO	324	395.28		202		17			0.18		0.169
2331NEW061	Private well	Lower Palaeozoic	26-Mar-79	NERDO	74	90.28		109		30			0.39		
2331NEW067	Private well	Lower Palaeozoic	26-Mar-79	NERDO	350	427		224		13			1		0.43
2331NEW179	Private well	Lower Palaeozoic	14-Dec-98	NERDO		0	0					0	0.05		0.038
2331NEW183	Private well	Lower Palaeozoic	7-Jan-98	NERDO		0	0.05						0		0
2331NEW184	Private well	Lower Palaeozoic	20-Nov-99	NERDO		0	0.02						0.12		0.025
2331NEW193	Private well	Lower Palaeozoic	26-Feb-98	NERDO		0	0						0.65		0.403
Ardaghey	Private well	Lower Palaeozoic	10-Mar-66	NERDO		0				16			8.4		
Carrickagarvan, Castleblaney	Private well	Lower Palaeozoic	10-Sep-78	NERDO		0				14			2.2		2.25
Castleblaney	Private well	Lower Palaeozoic	16-Oct-78	NERDO		0				23			3.6		2.6
Skerrick West, Scotshouse	private well	Lower Palaeozoic	25/5/65	NERDO		0				19			15.9		
Tattygare	private well	Lower Palaeozoic	30/9/69	NERDO		0				40			25		
Tullyyard	private well	Lower Palaeozoic	9-Sep-74	NERDO		0				16			0.5		
Castleshane		Lower Palaeozoic	26/11/73	NERDO											
Clontibret, Nat'l School		Lower Palaeozoic	29/6/66	NERDO						13					
Derryvalley		Lower Palaeozoic	9-Jan-70	NERDO						18			17.6		
2633SWW086	Patton's Mill	Mona-Clones	no date	NERDO	334	407.48		272		15			0.43		N.A.
2331NEW064	Private well	Mona-Clones	26-Mar-79	NERDO	344	419.68		273		74			0.09		0.01
2331NEW094	Private well	Mona-Clones	26-Mar-79	NERDO	296	361.12		200		17			0.16		N.D.
2331NEW097	Private well	Mona-Clones	26-Mar-79	NERDO	264	322.08		156		14			1.77		0.94
2331NEW117	Private well	Mona-Clones	26-Mar-79	NERDO	278	339.16		184		20			0.65		0.004
2331NEW180	Private well	Mona-Clones	13-Dec-97	NERDO			0						0.45		0.2
2331NEW181	Private well	Mona-Clones	18-Jan-00	NERDO			0.02						0.03		0.06
2331NEW182	Private well	Mona-Clones	27-Jul-98	NERDO			0.25						0.18		0.04
2331NEW187	Private well	Mona-Clones	2-Jun-71	NERDO	296	361.12									
2331NEW187	Private well	Mona-Clones	20-Oct-69	NERDO	278	339.16							0.1		
2331NEW187	Private well	Mona-Clones	13-Oct-69	NERDO									trace		
2331NEW188	Private well	Mona-Clones	29-Jun-71	NERDO											
2331NEW188	Private well	Mona-Clones	2-Jun-71	NERDO	296	361.12							neg		
2331NEW188	Private well	Mona-Clones	20-Oct-69	NERDO	290	353.8							0.4		
2331NEW194	Private well	Mona-Clones	26-Mar-79	NERDO	320	390.4		121		78			0.06		N.D.
2333SEW021	Private well	Mona-Clones	20-Aug-79	NERDO	328	400.16		280		14			0.38		0.07
2333SEW038	Private well	Mona-Clones	26-Mar-79	NERDO	316	385.52		242		13			0.35		0.11
2633SWW086	Private well	Mona-Clones	no date	NERDO	330	402.6		272		17			0.43		
2633SWW097	Private well	Mona-Clones	30-Jul-72	NERDO	308	375.76		202					0.2		
2633SWW097	Private well	Mona-Clones	no date	NERDO	308	375.76		202					0.2		
2633SWW139	Private well	Mona-Clones	15-Jun-71	NERDO	306	373.32							0.5		
2633SWW140	Private well	Mona-Clones	9-Mar-70	NERDO							0		0.3		
2633SWW140	Private well	Mona-Clones	21-Jul-69	NERDO	306	373.32							0		
2633SWW103	Private well	Mona-Clones	21-Aug-79	NERDO	296	361.12		242		24			0.18		0.44
2633SWW246	Private well	Mona-Clones	1-May-78	NERDO						17			1		
2331NEW035	Private well	Mona-Clones	26-Mar-79	NERDO	248	302.56		428		19			0.28		0.009
2331NEW040	Private well	Mona-Clones	9-Apr-79	NERDO	306	373.32		266		17			0.32		N.D.
2331NEW040	Private well	Mona-Clones	26-Mar-79	NERDO	264	322.08		166		14			0.26		0.33
2331NEW041	Private well	Mona-Clones	no date	NERDO	416	507.52		516		55			0.53		0.07
2331NEW052	Private well	Mona-Clones	14-May-79	NERDO	288	351.36		236		17			0.34		0.08
2331NEW053	Private well	Mona-Clones	no date	NERDO	278	339.16		198		14			0.08		0.29
2331NEW055	Private well	Mona-Clones	26-Mar-79	NERDO	294	358.68		208		18			1.86		N.D.
2633SWW109	Private? Cortlovin Bridge	Mona-Clones	3-Oct-72	NERDO	304	370.88		676		21			0.57		n.d.
2633SWW109	Private? Cortlovin Bridge	Mona-Clones	2-Nov-72	NERDO	290	353.8		320		21			0.65		n.d.

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WELL NAME	DATA SOURCE/Name	AQUIFER NAME	SAMPLE DATE	SAMPLE COMPANY	ALKALINITY (mg/l)	bicarbonate (hco3)	AMMONIA TOTAL(mg/l)	CA HARDNESS (mg/l)	CALCIUM (mg/l)	CHLORIDE (mg/l)	E_COLI (count/100ml)	F_COLI (count/100ml)	IRON_TOTAL (mg/l)	MAGNESIUM (mg/l)	MANGANESE (mg/l)
2633SWW034	Private well	not sure	no date	NERDO		0				29			1.6		
2633SWW014	Private well	not sure	30-Jul-72	NERDO	428	522.16		340					10		
2633SWW014	Private well	not sure	no date	NERDO	428	522.16		340					10		
2633SWW137	Private well	not sure	23-Oct-67	NERDO	312	380.64	0.42		246	15			0.25	48	0.5
2633SWW137	Private well	not sure	16-Oct-67	NERDO		0					0		0.8		
2633SWW137	Private well	not sure	2-Jun-67	NERDO	312	380.64									
2633SWW245	Private well	not sure	30-Jul-72	NERDO	320	390.4		402					N.D.		
2633SWW245	Private well	not sure	no date	NERDO	320	390.4		402					NEGLIGIBLE		
2331NEW058	Public Smithborough PWS - Templetate prod well	Mona-Clones	10/10/1979 / top of well	AFF				292		24					
2331NEW058	Public Smithborough PWS - Templetate prod well	Mona-Clones	10/10/1979 / bottom of well	AFF				172		15					
2331NEW058	Public Smithborough PWS - Templetate prod well	Mona-Clones	9/11/1979 @ 12.00	AFF	312	380.64		274		20					
2331NEW058	Public Smithborough PWS - Templetate prod well	Mona-Clones	9/11/1979 @ 16.40	AFF	314	383.08		270		19					
2331NEW058	Public Smithborough PWS - Templetate prod well	Mona-Clones	4-Jan-80	AFF	320	390.4		278		22			1.04		0.068
2331NEW058	Public Smithborough PWS - Templetate prod well	Mona-Clones	2/4/1980 @10.00	AFF	336	409.92		260					0.798		0.047
2331NEW058	Public Smithborough PWS - Templetate prod well	Mona-Clones	2/4/80 @ 19.00	AFF	310	378.2		268		21			0.734		0.053
2331NEW059	Public Smithborough PWS - Templetate prod well	Mona-Clones	no date	AFF	296	361.12		220		15					

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WELL NAME	NITRATE (mg/lNO3)	NITRITE (mg/l)	O_PHOSPHATE (mg/l)	ODOUR	PH	PHOSPHORUS (mg/l)	POTASSIUM (mg/l)	SODIUM (mg/l)	SULPHATE (mg/l)	TDS(mg/l)	TEMP(°C)	TON(mg/l_N)	TOTAL_HARDNESS (mg/l)	TURBIDITY	SAMPLETIME
2629NEW003					7.4		3.82	11.6	36	402		2.8	260		
2629NEW006					7		3.41	12.8	37	785		8.41	500		
2629NEW016					7.1				15	439		10.7	316		
2629NEW016	14.6				7		0.89	28.7	22	657			378		
2629NEW043					7.3		3	8.3	16	370		2.77	272		
2629NEW044					7.7		0.72	10.8	5	215		0.53	166		
2629NEW045					7.5		0.55	10.7	14	292		1.32	218		
2629NEW046	4+				7.3		3.02	9.6	20	437			332		
2629NEW070					7.6		6.5	18.2	29	275		0.79	200		
2629NEW070					7.5		3.09		48	301		0.05	210		
2629NEW070					7.6		3.48	16.8	35	296		0.06	236		
2629NEW077					7.3		1.7	7.3	7	450		6.66	344		
2629NEW077					7.3		7.62	11.6	11	480		6.4	334		
2629SEW105					7.2		3.2	13	41	607		3.12	442		
2629SEW106					7.1		3.3	14.6	30	501		3.2	356		
2629SEW109					7.5		1.9	22.2	110	532		0.05	328		
2629SEW118					7.6		1.7	10.6	26	277		0.1	216		
2633NWW013					7.1		4.85	10	29	480		1.66	468		
2633NWW075					7.5				118			0.001	344		
2633NWW075					7.4				78	610		N.D.	332		
2633NWW106					7.1					462		1.1	384		
2633NWW106					7.1							1.1	384		
2633NWW217					7.2		6.52	6.8	75	569		1.93	344		
2633NWW217	0.13				7.2		5.62	6.77	68	561			278		
2331NEW061					6.9		0.58	12.7	14	292		5.63	143		
2331NEW067					7.5		1.84	18.4	2	370		TRACE	322		
2331NEW179	0	0		0	7.3						6				9:00
2331NEW183	3	0.006		0	6.9						10			0	8:55
2331NEW184	3	0.04		1	7.2										
2331NEW193	4.4	0.04			6.8						7				
Ardaghey					6.5				Trace			0.002	85		
Carrickagarvan, Castleblaney					7.1				16			0.48	166		
Castleblaney					6.8				33			0.23	162		
Skerrick West, Scotshouse					6.6				14.3			0.01	100		
Tattygare					6.8				23.7			0.002	207		
Tullyyard					6.8				49			3.04	64		
Castleshane													105		
Clontibret, Nat'l School					7.3				16			2.23	173		
Derryvalley					7.1				Trace			0.001	195		
2633SWW086					7.2		2.2		28	445		0.03	332		
2331NEW064					7.1		7.87	40	38	560		2.46	364		
2331NEW094					7.5		2.07	16.5	2	375		0.47	284		
2331NEW097					7.5		1.4	29	2	285		0.01	216		
2331NEW117					7.5		2.2	23	40	396		0.02	290		
2331NEW180	3.9	0.33		0	6.6						11				9:00
2331NEW181	3.4	0.02			7										
2331NEW182	11	0.1		1	7.1						13			1	6:00
2331NEW187					7.05								344		
2331NEW187				0	7.05								282		
2331NEW187				0	7.35										
2331NEW188															11:30
2331NEW188				0									344		
2331NEW188				0	7								304		
2331NEW194					7.3		17.8	27	61	627		6.47	416		
2333SEW021					7.4		2.6?	15.6	92	640		0.4	484		
2333SEW038					7.5		1.7	12.4	12	399		0.03	282		
2633SWW086					7.3		2.2		28	409		0.01	360		
2633SWW097					7.25								294		
2633SWW097					7.25								294		
2633SWW139					7.2								338		5:30
2633SWW140				NONE	7.3										
2633SWW140				NONE	7.45								293		
2633SWW103					7.4		1.3	12.8	26	377		TRACE	300		
2633SWW246					7.4					600		0.23	444		
2331NEW035					7.3		2.4	20	395	936		TRACE	612		
2331NEW040					7.4		2.01	19.3	120	556		1.13	412		
2331NEW040					7.5		1.8	29	17	357		0.02	240		
2331NEW041					7.1		2.14	24.2	269	1083		0.41	688		
2331NEW052					7.3		1.4	9.5	37	430		0.55	314		
2331NEW053					7.2		1.91	20	23	316		0.14	256		
2331NEW055					7.5		2.2	17.1	10	315		0.01	276		
2633SWW109					7.25				751				1060		
2633SWW109					7.6				245	744		1.16	510		

Appendix I - Laboratory analytical results from An Foras Forbartha (NERDO).

WELL NAME	NITRATE (mg/lNO3)	NITRITE (mg/l)	O_PHOSPHATE (mg/l)	ODOUR	PH	PHOSPHORUS (mg/l)	POTASSIUM (mg/l)	SODIUM (mg/l)	SULPHATE (mg/l)	TDS(mg/l)	TEMP(°C)	TON(mg/l_N)	TOTAL_HARDNESS (mg/l)	TURBIDITY	SAMPLETIME
2633SWW034					7.5				118			TRACE	344		
2633SWW014					7.1								432		
2633SWW014					7.15								432		
2633SWW137	0.45			NONE	7.45					398			294	FAINT	
2633SWW137				NONE	7.2									TURBID	
2633SWW137													294		
2633SWW245					7								420		
2633SWW245					7								420		
2331NEW058													352		
2331NEW058													294		
2331NEW058					7.6				36	430		0.42	340		
2331NEW058					7.6				36	411		0.38	334		
2331NEW058					7.4		1.53	10.28	34			2.77	356		
2331NEW058					7.35		1.54	10.7	35			2.41	348		
2331NEW058					7.5		1.55	10.7	34			2.51	343		
2331NEW059					7.5				30	366		0.03	320		

Appendix II: Laboratory analytical results from the Geological Survey of Ireland

WELL NAME	DATA SOURCE/Name	AQUIFER NAME	SAMPLE DATE	SAMPLE COMPANY	ALKALINITY (mg/l)	bicarbonate (hco3)	AMMONIA TOTAL(mg/l)	CA HARDNESS (mg/l)	CALCIUM (mg/l)	CHLORIDE (mg/l)	E_COLI (count/100ml)	F_COLI (count/100ml)	IRON_TOTAL (mg/l)
2629NEW299	Public Naffarty PWS new borehole	Carrickmacross	14-Aug-01	GSI MONA7	251	306.22	0.027	251.2	87.39	15.2		46	0.008
2629NEW299	Public Naffarty PWS new borehole	Carrickmacross	15-Feb-01	GSI MONA7	258	314.76	0.168		91.48	13.6		2	0.009
2629NEW084	Rye Valley Foods	Carrickmacross	14-Aug-01	GSI MONA11	251	306.22	<0.019		94.5	60			0.01
2629NEW084	Rye Valley Foods	Carrickmacross	15-Feb-01	GSI MONA11	302	368.44	0.057		117.56	29			<0.005
2633NWW226	Group Pullis GWS	Emyvale	13-Aug-01	GSI MONA12	308	375.76	0.121		63.04	26.6		0	0.08
2333NEW009	Group Tydavnet well A	Knockatallon-Tydavnet	15-Feb-01	GSI MONA3	284	346.48	0.337		39.92	11.8		0	0.094
2333NEW009	Group Tydavnet well A	Knockatallon-Tydavnet	13-Aug-01	GSI MONA3	296	361.12	0.21		44.3	13.3		0	0.093
2333NEW032	Group Tydavnet well B	Knockatallon-Tydavnet	15-Feb-01	GSI MONA4	352	429.44	0.375		55.63	9.2		0	0.246
2333NEW032	Group Tydavnet well B	Knockatallon-Tydavnet	13-Aug-01	GSI MONA4	363	442.86	0.27		59.32	8.7		1	0.348
2333NEW033	Group Tydavnet well C	Knockatallon-Tydavnet	15-Feb-01	GSI MONA5	298	363.56	0.396		31.75	13.3		0	0.138
2333NEW033	Group Tydavnet well C	Knockatallon-Tydavnet	13-Aug-01	GSI MONA5	306	373.32	0.31		32.04	13.5		0	0.27
2333NEW034	Group Tydavnet well D	Knockatallon-Tydavnet	15-Feb-01	GSI MONA2	276	336.72	0.217		43.61	10.5		0	0.123
2333NEW034	Group Tydavnet well D	Knockatallon-Tydavnet	13-Aug-01	GSI MONA2	282	344.04	0.147		44.13	11.1		0	0.108
2333SEW095	Group Tydavnet well E	Knockatallon-Tydavnet	15-Feb-01	GSI MONA1	246	300.12	0.375		29.24	9.4		0	0.098
2333SEW095	Group Tydavnet well E	Knockatallon-Tydavnet	13-Aug-01	GSI MONA1	252	307.44	0.22	164.3	29.19	9.6		0	0.096
2633SWW286	Mona Mushrooms Kayebun	Lower Palaeozoic	14-Feb-00	GSI MONA10	362	441.64	0.275		68.01	13		0	0.016
2633SWW286	Mona Mushrooms Kayebun	Lower Palaeozoic	15-Aug-01	GSI MONA10	370	451.4	0.059		70.45	13.8		0	0.061
2633SEW012	Public Clontibret PWS	Lower Palaeozoic	15-Aug-01	GSI MONA15	214	261.08	<0.019		49.11	17.5		0	0.021
2331NEW213	Feldhues Meats	Mona-Clones	14-Feb-01	GSI MONA6	276	336.72	0.141		64.08	14.3		0	0.168
2331NEW213	Feldhues Meats	Mona-Clones	14-Aug-01	GSI MONA6	285	347.7	0.069		68.11	19.6		0	0.129
2633SWW285	Mona Mushrooms Tyholland	Mona-Clones	13-Aug-01	GSI MONA9	260	317.2	<0.019		430.04	27.7		0	0.405
2633SWW285	Mona Mushrooms Tyholland	Mona-Clones	14-Feb-00	GSI MONA9	280	341.6	0.081		329.54	21.9		0	0.551
2633SWW068	Monaghan Co Op	Mona-Clones	15-Aug-01	GSI MONA13	296	361.12	<0.019		148.72	18.6			0.197
2633SWW277	Monaghan Poultry Products	Mona-Clones	14-Aug-01	GSI MONA14	370	451.4	<0.019		99.06	41.7		1	0.008
2633SWW252	Public Mona PWS Lambs Lough (PW1)	Mona-Clones	13-Aug-01	GSI MONA8	296	361.12	<0.019		81.12	15.2		0	0.313
2633SWW252	Public Mona PWS Lambs Lough (PW1)	Mona-Clones	14-Feb-01	GSI MONA8	314	383.08	0.071		88.9	14.4		0	0.532

Appendix II: Laboratory analytical results from the Geological Survey of Ireland

WELL NAME	MAGNESIUM (mg/l)	MANGANESE (mg/l)	NITRATE (mg/lNO3)	NITRITE (mg/l)	ODOUR	PH	PHOSPHORUS (mg/l)	POTASSIUM (mg/l)	SODIUM (mg/l)	SULPHATE (mg/l)	TEMP(°C)	TOTAL_HARDNESS (mg/l)	SAMPLETIME
2629NEW299	8	<0.005	12.82	<0.10		5.84	<0.25	1.4	11.37	13.7	14.6		8:45
2629NEW299	7.2	<0.005	13.91	<0.10			<0.02	1.4	14.01	16	10	258.1	8:40
2629NEW084	11.6	0.288	8.91	<0.10		5.86	<0.25	2.9	28.84	24.6	17	283.7	9:00
2629NEW084	9	0.027	13.55	<0.10		6.04	<0.25	2.4	16.95	49.1	10.7	330.6	
2633NWW226	39.5	<0.005	<0.10	<0.10	some smell	5.96	<0.25	3.3	49.37	105.3	18.8	320.1	11:45
2333NEW009	20.7	0.012	<0.1	<0.10			0.28	3.1	73.91	63	9	177.4	
2333NEW009	24.1	0.028	1.77	<0.10		5.99	0.39	3.6	76.6	73.3	13.4	209.9	13:30
2333NEW032	31	0.021	<0.1	<0.10			0.31	5.1	101.77	171.9	8	266.6	12:15
2333NEW032	33	0.024	<0.10	<0.10		6.02	0.31	5.3	109.79	168.7	15.5	284	13:45
2333NEW033	19.6	0.01	<0.1	<0.10			<0.25	3.1	86.89	64.3	9	160	
2333NEW033	20.5	0.013	<0.10	<0.10		6.03	<0.25	3.2	96.84	60.4	16.7	164.4	14:00
2333NEW034	22.1	0.014	<0.1	<0.10			<0.25	3.1	63.89	75	9	199.9	
2333NEW034	22.9	0.015	<0.1	<0.10		5.98	0.26	3.2	65.4	73.8	16.6	204.5	13:00
2333SEW095	20.9	0.011	<0.1	<0.10			0.29	3.1	56.29	44	8	159.1	
2333SEW095	22.2	0.009	<0.10	<0.10		5.98	0.3	3.1	62.71	46.4	17.7		12:30
2633SWW286	36.9	0.012	<0.1	<0.10		6.01	<0.25	2.2	24.32	71.6	11.3	321.8	
2633SWW286	38.3	0.014	<0.1	<0.10		5.81	<0.25	2.3	23.81	27.7	17.2	333.6	10:00
2633SEW012	27.8	0.005	2.33	<0.10		5.84	<0.25	1.1	13.92	51.6	13.6	237.1	9:00
2331NEW213	25.6	0.055	<0.1	<0.10		5.64	<0.25	1.7	22.74	38.8	11.2	265.4	
2331NEW213	27.2	0.062	<0.1	<0.10		5.93	<0.25	1.8	19.85	38.1	16.8	282.1	11:45
2633SWW285	55.8	0.028	<0.10	<0.10		5.99	<0.25	2.4	27.97	1259	14.8	1303.6	16:30
2633SWW285	39.4	0.016	<0.1	<0.10		5.89	<0.25	1.9	22.32	906	11.2	985.1	
2633SWW068	42.1	0.063	1.68	<0.10		5.78	<0.25	1.7	22.6	306	16.6	544.7	10:45
2633SWW277	39.9	0.151	3.86	<0.10		5.86	<0.25	1.8	49.18	77.5	18.1	409.2	13:15
2633SWW252	21.7	0.056	2.01	<0.10		5.99	<0.25	1.6	12.53	22.5	13.7	291.9	16:45
2633SWW252	22.3	0.064	1.84	<0.10		5.72	<0.25	1.6	15.46	44.6	9.9	313.8	

Appendix III: Laboratory analytical results from the Environmental Protection Agency (nitrate only)

AQUIFER NAME	SAMPLE DATE	SAMPLE COMPANY	NITRATE (mg/lNO3)
Carrickmacross	2-Jan-99	EPA Nitrate Data	11.9
Carrickmacross	23-Mar-92	EPA Nitrate Data	4.35 / 28.08
Carrickmacross	29-Jun-92	EPA Nitrate Data	0.32 / 10.83 / 18.74
Carrickmacross	7-Sep-92	EPA Nitrate Data	2.2 / 19.8
Carrickmacross	2-Nov-92	EPA Nitrate Data	0.35 / 35.12
Carrickmacross	9-Nov-92	EPA Nitrate Data	21.43
Carrickmacross	18-Jan-93	EPA Nitrate Data	4.23 / 25.6
Carrickmacross	1-Mar-93	EPA Nitrate Data	8.41 / 45.26
Carrickmacross	29-Mar-93	EPA Nitrate Data	4.4
Carrickmacross	26-Apr-93	EPA Nitrate Data	3.37
Carrickmacross	3-May-93	EPA Nitrate Data	3.19 / 22.89
Carrickmacross	17-May-93	EPA Nitrate Data	24.59
Carrickmacross	1-Jun-93	EPA Nitrate Data	0.94 / 23.9
Carrickmacross	21-Jun-93	EPA Nitrate Data	2.21
Carrickmacross	18-Aug-93	EPA Nitrate Data	21.56
Carrickmacross	6-Sep-93	EPA Nitrate Data	0.89 / 18.52
Carrickmacross	4-Oct-93	EPA Nitrate Data	16.83
Carrickmacross	28-Oct-93	EPA Nitrate Data	25.37
Carrickmacross	11-Nov-93	EPA Nitrate Data	1.68
Carrickmacross	15-Nov-93	EPA Nitrate Data	1.51 / 20.47
Carrickmacross	23-Nov-93	EPA Nitrate Data	19
Carrickmacross	10-Jan-94	EPA Nitrate Data	17.7
Carrickmacross	7-Feb-94	EPA Nitrate Data	3.5
Carrickmacross	14-Mar-94	EPA Nitrate Data	5.32
Carrickmacross	18-Apr-94	EPA Nitrate Data	10.81
Carrickmacross	3-May-94	EPA Nitrate Data	1.86 / 5.18 / 19.85
Carrickmacross	4-Jul-94	EPA Nitrate Data	7.58
Carrickmacross	16-Aug-94	EPA Nitrate Data	0.8
Carrickmacross	17-Aug-94	EPA Nitrate Data	16.81
Carrickmacross	5-Sep-94	EPA Nitrate Data	0.58
Carrickmacross	4-Oct-94	EPA Nitrate Data	8.86
Carrickmacross	25-Oct-94	EPA Nitrate Data	1.37
Carrickmacross	16-Jan-95	EPA Nitrate Data	2.44 / 23.66
Carrickmacross	6-Mar-95	EPA Nitrate Data	5.07 / 21.26
Carrickmacross	8-May-95	EPA Nitrate Data	3.81 / 18.74
Carrickmacross	4-Sep-95	EPA Nitrate Data	0.66 / 11.34
Carrickmacross	31-Oct-95	EPA Nitrate Data	12.01
Carrickmacross	6-Nov-95	EPA Nitrate Data	0.75
Carrickmacross	1-May-85	EPA Nitrate Data	19.26
Emyvale	11-Sep-95	EPA Nitrate Data	0.04
Emyvale	21-Nov-95	EPA Nitrate Data	4.47
Emyvale	29-Oct-97	EPA Nitrate Data	0.44
Emyvale	2-Mar-99	EPA Nitrate Data	0.9
Knockatallon-Tydavnet	16-Aug-93	EPA Nitrate Data	0.04
Knockatallon-Tydavnet	6-Oct-93	EPA Nitrate Data	0.04
Knockatallon-Tydavnet	1-Nov-93	EPA Nitrate Data	0.04
Knockatallon-Tydavnet	24-Nov-93	EPA Nitrate Data	0.04
Knockatallon-Tydavnet	29-Oct-97	EPA Nitrate Data	0.04
Knockatallon-Tydavnet	25-Jan-99	EPA Nitrate Data	<0.04
Knockatallon-Tydavnet	22-Feb-00	EPA Nitrate Data	nda
Lower Palaeozoic	7-Jan-91	EPA Nitrate Data	3.6
Lower Palaeozoic	6-Jul-92	EPA Nitrate Data	0.73
Lower Palaeozoic	11-Jan-93	EPA Nitrate Data	3.83
Lower Palaeozoic	5-Apr-93	EPA Nitrate Data	1.55
Lower Palaeozoic	5-Jul-93	EPA Nitrate Data	2.17
Lower Palaeozoic	15-Nov-93	EPA Nitrate Data	0.31
Lower Palaeozoic	10-Jan-94	EPA Nitrate Data	11.87
Lower Palaeozoic	18-Apr-94	EPA Nitrate Data	3.06
Lower Palaeozoic	4-Jul-94	EPA Nitrate Data	0.56
Lower Palaeozoic	26-Sep-94	EPA Nitrate Data	0.18
Lower Palaeozoic	16-Jan-95	EPA Nitrate Data	2.7
Lower Palaeozoic	3-Jul-95	EPA Nitrate Data	0.04
Lower Palaeozoic	6-Nov-95	EPA Nitrate Data	0.35
Lower Palaeozoic	11-Jan-99	EPA Nitrate Data	35.291
Lower Palaeozoic	12-Apr-99	EPA Nitrate Data	18.819
Lower Palaeozoic	10-Apr-00	EPA Nitrate Data	3.808
Mona-Clones	29-Mar-93	EPA Nitrate Data	0.22
Mona-Clones	18-Aug-93	EPA Nitrate Data	0.22
Mona-Clones	6-Oct-93	EPA Nitrate Data	0.22
Mona-Clones	1-Nov-93	EPA Nitrate Data	0.09
Mona-Clones	24-Nov-93	EPA Nitrate Data	0.18
Mona-Clones	29-Oct-97	EPA Nitrate Data	0.04
Mona-Clones	25-Feb-99	EPA Nitrate Data	11.73
Mona-Clones	22-Feb-00	EPA Nitrate Data	nda
Mona-Clones	19-Apr-93	EPA Nitrate Data	0.09
Mona-Clones	18-Aug-93	EPA Nitrate Data	0.04
Mona-Clones	6-Oct-93	EPA Nitrate Data	0.07
Mona-Clones	1-Nov-93	EPA Nitrate Data	0.12
Mona-Clones	24-Nov-93	EPA Nitrate Data	0.11
Mona-Clones	29-Oct-97	EPA Nitrate Data	0.04
Mona-Clones	14-Jan-98	EPA Nitrate Data	0.09
Mona-Clones	27-Jan-99	EPA Nitrate Data	<0.04
Mona-Clones	16-Sep-99	EPA Nitrate Data	0.04
Mona-Clones	22-Mar-00	EPA Nitrate Data	0.04*
Mona-Clones	14-Apr-93	EPA Nitrate Data	0.22 / 20.68
Mona-Clones	16-Aug-93	EPA Nitrate Data	5.98
Mona-Clones	29-Sep-93	EPA Nitrate Data	0.27 / 3.94
Mona-Clones	26-Oct-93	EPA Nitrate Data	0.09 / 3.5

AQUIFER NAME	SAMPLE DATE	SAMPLE COMPANY	NITRATE (mg/lNO3)
Mona-Clones	29-Sep-93	EPA Nitrate Data	1.9
Mona-Clones	26-Oct-93	EPA Nitrate Data	2.75
Mona-Clones	17-Nov-93	EPA Nitrate Data	199
Mona-Clones	16-Aug-96	EPA Nitrate Data	2.48
Mona-Clones	21-Aug-79	EPA Nitrate Data	0.13
Mona-Clones	14-Apr-93	EPA Nitrate Data	3.01
Mona-Clones	13-Jan-90	EPA Nitrate Data	1.03
Mona-Clones	28-Jan-90	EPA Nitrate Data	0.02
Mona-Clones	30-Jul-90	EPA Nitrate Data	3.1
Mona-Clones	13-Feb-91	EPA Nitrate Data	0.74 / 9.69 / 9.89
Mona-Clones	6-Apr-92	EPA Nitrate Data	0.71 / 4.46 / 4.75 / 4.9
Mona-Clones	27-Jul-92	EPA Nitrate Data	0.00 / 0.01 / 0.16 / 0.16
Mona-Clones	28-Sep-92	EPA Nitrate Data	0.01 / 0.8
Mona-Clones	1-Feb-93	EPA Nitrate Data	2.7
Mona-Clones	8-Feb-93	EPA Nitrate Data	0.06 / 4.01 / 4.31 / 4.39
Mona-Clones	26-Apr-93	EPA Nitrate Data	0.5 / 0.56 / 2.08 / 2.88
Mona-Clones	19-Jul-93	EPA Nitrate Data	0.04
Mona-Clones	16-Aug-93	EPA Nitrate Data	0.04
Mona-Clones	29-Sep-93	EPA Nitrate Data	0.04
Mona-Clones	17-Nov-93	EPA Nitrate Data	0.04
Mona-Clones	6-Dec-93	EPA Nitrate Data	0.75 / 1.51
Mona-Clones	13-Mar-95	EPA Nitrate Data	0.53 / 1.87 / 2.1 / 2.26
Mona-Clones	10-Jul-95	EPA Nitrate Data	0.58
Mona-Clones	24-Jul-95	EPA Nitrate Data	0.13 / 0.22 / 0.04 / 0.44
Mona-Clones	26-Sep-95	EPA Nitrate Data	0.1
Mona-Clones	2-Oct-95	EPA Nitrate Data	0.04 / 0.04
Mona-Clones	3-Oct-95	EPA Nitrate Data	0.04 / 1.46
Mona-Clones	5-Dec-95	EPA Nitrate Data	0.27 / 14.04
Mona-Clones	11-Dec-95	EPA Nitrate Data	0.40 / 0.53
Mona-Clones	7-May-90	EPA Nitrate Data	12.2
Mona-Clones	5-Nov-90	EPA Nitrate Data	16.7
Mona-Clones	6-Apr-92	EPA Nitrate Data	16.75
Mona-Clones	4-May-92	EPA Nitrate Data	15.5
Mona-Clones	20-Jul-92	EPA Nitrate Data	5.09
Mona-Clones	10-Aug-92	EPA Nitrate Data	6.31
Mona-Clones	7-Sep-92	EPA Nitrate Data	15.8
Mona-Clones	5-Oct-92	EPA Nitrate Data	13.08 / 13.29
Mona-Clones	9-Nov-92	EPA Nitrate Data	14.81
Mona-Clones	18-Jan-93	EPA Nitrate Data	14.83
Mona-Clones	5-Apr-93	EPA Nitrate Data	14.5
Mona-Clones	3-May-93	EPA Nitrate Data	15.3
Mona-Clones	12-Jul-93	EPA Nitrate Data	12.85 / 12.85
Mona-Clones	30-Aug-93	EPA Nitrate Data	10.01
Mona-Clones	18-Oct-93	EPA Nitrate Data	11.92
Mona-Clones	3-Apr-95	EPA Nitrate Data	9.29
Mona-Clones	8-May-95	EPA Nitrate Data	6.69
Mona-Clones	29-Oct-97	EPA Nitrate Data	12.49
Mona-Clones	26-Oct-99	EPA Nitrate Data	0.1328*
Mona-Clones	22-Mar-00	EPA Nitrate Data	14.83*

Mona-Clones	17-Nov-93	EPA Nitrate Data	0.09
Mona-Clones	29-Oct-92	EPA Nitrate Data	1.42
Mona-Clones	14-Apr-93	EPA Nitrate Data	2.79

Appendix IV: Laboratory analytical results from the Environmental Protection Agency (full analysis)

WELL NAME	DATA SOURCE/Name	AQUIFER NAME	SAMPLE DATE	SAMPLE COMPANY	ALKALINITY (mg/l)	bicarbonate (hco3)	ALUMINIUM(mg/l)	AMMONIA TOTAL(mg/l)	ANTIMONY(mg/l)
2331NEW058	Public Smithborough PWS - Templetate prod well	Mona-Clones	6-Aug-96	EPA sampling/EPA Nitrate Data	334	407.48		0.05	
2331NEW058	Public Smithborough PWS - Templetate prod well	Mona-Clones	29-Jan-97	EPA sampling	388	473.36		0.01	
2331NEW058	Public Smithborough PWS - Templetate prod well	Mona-Clones	8-Sep-97	EPA sampling/EPA Nitrate Data	304	370.88		0.01	
2331NEW058	Public Smithborough PWS - Templetate prod well	Mona-Clones	22-Jan-98	EPA sampling/EPA Nitrate Data	324	395.28		0.01	
2331NEW058	Public Smithborough PWS - Templetate prod well	Mona-Clones	19-Aug-98	EPA sampling	206	251.32		0.01	
2331NEW058	Public Smithborough PWS - Templetate prod well	Mona-Clones	11-Oct-99	EPA sampling/EPA Nitrate Data	360	439.2		<0.01	
2331NEW058	Public Smithborough PWS - Templetate prod well	Mona-Clones	21-Mar-00	EPA sampling	216	263.52	<0.02	<0.01	<0.0005
2633NWW074	Bragan Water	Knockatallon-Tydavnet	6-Aug-96	EPA sampling/EPA Nitrate Data	324	395.28		0.05	
2633NWW074	Bragan Water	Knockatallon-Tydavnet	29-Jan-97	EPA sampling	344	419.68		0.01	
2633NWW074	Bragan Water	Knockatallon-Tydavnet	8-Sep-97	EPA sampling/EPA Nitrate Data	310	378.2		0.01	
2633NWW074	Bragan Water	Knockatallon-Tydavnet	22-Jan-98	EPA sampling/EPA Nitrate Data	282	344.04		0.01	
2633NWW074	Bragan Water	Knockatallon-Tydavnet	22-Sep-99	EPA sampling/EPA Nitrate Data	306	373.32		<0.01	
2633NWW074	Bragan Water	Knockatallon-Tydavnet	21-Feb-00	EPA sampling	338	412.36	1.2	<0.01	<0.0005
2633NWW074	Bragan Water	Knockatallon-Tydavnet	10-Jan-01	EPA sampling	293	357.46	<50	<0.04	<0.001
2633NWW102	Silverhill Duckling	Emyvale	6-Aug-96	EPA sampling/EPA Nitrate Data	240	292.8		1.09	
2633NWW102	Silverhill Duckling	Emyvale	29-Jan-97	EPA sampling	356	434.32		0.94	
2633NWW102	Silverhill Duckling	Emyvale	8-Sep-97	EPA sampling/EPA Nitrate Data	316	385.52		0.72	
2633NWW102	Silverhill Duckling	Emyvale	11-Feb-98	EPA sampling/EPA Nitrate Data	356	434.32		0.01	
2633NWW102	Silverhill Duckling	Emyvale	11-Oct-00	EPA sampling	384	468.48	<50	0.68	<0.001
2633NWW102	Silverhill Duckling	Emyvale	10-Jan-01	EPA sampling	368	448.96	<50	0.68	<0.001
2633SWW081	Public Mona PWS - Roosky	Mona-Clones	6-Aug-96	EPA sampling/EPA Nitrate Data	308	375.76		0.14	
2633SWW081	Public Mona PWS - Roosky	Mona-Clones	29-Jan-97	EPA sampling	352	429.44		0.01	
2633SWW081	Public Mona PWS - Roosky	Mona-Clones	23-Sep-97	EPA sampling/EPA Nitrate Data	320	390.4		0.17	
2633SWW081	Public Mona PWS - Roosky	Mona-Clones	22-Jan-98	EPA sampling/EPA Nitrate Data	292	356.24		0.03	
2633SWW081	Public Mona PWS - Roosky	Mona-Clones	22-Sep-99	EPA sampling/EPA Nitrate Data	320	390.4		0.04	
2633SWW083	Public Mona PWS - Roosky	Mona-Clones	11-Oct-00	EPA sampling	300	366	<50	0.08	<0.001
2633SWW084	Public Mona PWS - Roosky	Mona-Clones	11-Jan-01	EPA sampling	323	394.06	<50	0.08	<0.001
Drummond GWS	Drummond GWS		4-Aug-99	EPA sampling	62			<0.013	
Drummond GWS	Drummond GWS		22-Feb-00	EPA sampling	78		<0.02	<0.013	<0.0005
Drummond GWS	Drummond GWS		7-Feb-01	EPA sampling	70		<0.05	<0.04	<0.001
Grove Farm	Grove Farm	Mona-Clones	6-Aug-96	EPA sampling/EPA Nitrate Data	300	366		0.37	
Grove Farm	Grove Farm	Mona-Clones	29-Jan-97	EPA sampling	348	424.56		0.13	
Grove Farm	Grove Farm	Mona-Clones	8-Sep-97	EPA sampling/EPA Nitrate Data	324	395.28		0.13	
Grove Farm	Grove Farm	Mona-Clones	22-Jan-98	EPA sampling/EPA Nitrate Data	292	356.24		0.81	
Grove Farm	Grove Farm	Mona-Clones	11-Aug-98	EPA sampling/EPA Nitrate Data	272	331.84		1.03	
Grove Farm	Grove Farm	Mona-Clones	11-Oct-99	EPA sampling/EPA Nitrate Data	304	370.88		0.28	
Grove Farm	Grove Farm	Mona-Clones	21-Feb-00	EPA sampling	410	500.2	<20	0.31	<0.0005
Grove Farm	Grove Farm	Mona-Clones	11-Oct-00	EPA sampling	300	366	<50	0.36	<0.001
Grove Farm	Grove Farm	Mona-Clones	10-Jan-01	EPA sampling	305	372.1	<50	0.35	<0.001
Limestone Ind.	Limestone Ind.	Carrickmacross	14-Aug-96	EPA sampling/EPA Nitrate Data	288	351.36		0.14	
Limestone Ind.	Limestone Ind.	Carrickmacross	15-Jan-97	EPA sampling/EPA Nitrate Data	296	361.12		0.03	
Limestone Ind.	Limestone Ind.	Carrickmacross	27-Jan-98	EPA sampling/EPA Nitrate Data	236	287.92		0.01	
Limestone Ind.	Limestone Ind.	Carrickmacross	24-Aug-98	EPA sampling/EPA Nitrate Data	270	329.4		0.01	
Limestone Ind.	Limestone Ind.	Carrickmacross	4-Aug-99	EPA sampling/EPA Nitrate Data	280	341.6		<0.001	
Limestone Ind.	Limestone Ind.	Carrickmacross	22-Feb-00	EPA sampling	354	431.88	93.4	0.01	<0.0005
Limestone Ind.	Limestone Ind.	Carrickmacross	4-Oct-00	EPA sampling	210	256.2	55.1	<0.04	<0.001
Limestone Ind.	Limestone Ind.	Carrickmacross	7-Feb-01	EPA sampling	276	336.72	124.6	<0.04	<0.001
Meadow Meats	Meadow Meats	Mona-Clones	6-Aug-96	EPA sampling/EPA Nitrate Data	240	292.8		0.64	
Meadow Meats	Meadow Meats	Mona-Clones	29-Jan-97	EPA sampling	440	536.8		0.41	
Meadow Meats	Meadow Meats	Mona-Clones	8-Sep-97	EPA sampling/EPA Nitrate Data	250	305		0.27	
Meadow Meats	Meadow Meats	Mona-Clones	2-Sep-99	EPA sampling/EPA Nitrate Data	448	546.56		0.41	
Meadow Meats	Meadow Meats	Mona-Clones	11-Oct-99	EPA sampling/EPA Nitrate Data	220	268.4		0.42	
Meadow Meats	Meadow Meats	Mona-Clones	21-Mar-00	EPA sampling	124	151.28	<20	0.42	<0.0005
Meadow Meats	Meadow Meats	Mona-Clones	9-Oct-00	EPA sampling	200	244	<50	0.54	<0.01

Appendix IV: Laboratory analytical results from the Environmental Protection Agency (full analysis)

WELL NAME	ARSENIC(mg/l)	BARIUM(mg/l)	BORON(mg/l)	CADMIUM(mg/l)	CALCIUM (mg/l)	CHLORIDE (mg/l)	F_COLI (count/100ml)	IRON_TOTAL (mg/l)	MAGNESIUM (mg/l)	MANGANESE (mg/l)	NITRATE (mg/lNO3)
2331NEW058				<0.0002	139.7	21	1	<0.05	18.85	<0.00020	15.54
2331NEW058				<0.0002	152.4	23	0	<0.05	17.74	<0.00020	
2331NEW058				<0.0002	168.4	21	0	<0.05	9.23	<0.00020	15.99
2331NEW058				<0.0002	138.6	24	0	0.15	23.29	0.03	17.84
2331NEW058				<0.0002	140.9	20	5	<0.05	15.9	<0.00020	
2331NEW058				<0.00005	141.2	19	0	<0.02	23.88	<0.0005	15.63*
2331NEW058	<0.0005	0.377	<0.02	<0.00005	95.06	22	0	<0.02	17.06	<0.0005	
2633NWW074				<0.0002	102.3	11	0	<0.005	11.89	0.22	0.22
2633NWW074				<0.0002	113.1	11	0	0.07	10.69	0.23	
2633NWW074				<0.0002	122.1	11	0	0.06	5.62	0.21	0.4
2633NWW074				<0.0002	129.5	11	0	<0.005	10.42	0.22	0.04
2633NWW074	<0.0005	0.1911	0.0879	<0.00005	106.13	12	0	0.0112	14.12	0.1663	0.04*
2633NWW074	<0.0005	0.1671	0.0428	<0.00005	98.24	11	0	<0.005	9.77	0.2135	
2633NWW074	<0.001	0.1534	0.0893	<0.00010	108.57	10	0	<0.005	11.82	0.2147	
2633NWW102				<0.0002	157.44	23	0	7.43	11.6	0.28	0.04
2633NWW102				<0.0002	144.4	27	0	8.48	10.7	1.19	
2633NWW102				<0.0002	114	22	0	3.36	10.79	0.18	0.53
2633NWW102				<0.0002	142	25	0	2.64	8.91	0.21	3.68
2633NWW102	<0.001	0.0909	0.2691	<0.00010	71.91	20	0	0.5363	12.38	0.1306	
2633NWW102	<0.001	0.0756	0.431	<0.00010	78.63	20	0	0.3889	18.89	0.12	
2633SWW081				<0.0002	162.8	41	31	0.44	39.3	0.28	0.18
2633SWW081				<0.0002	151	38	0	0.25	46.1	0.3	
2633SWW081				<0.0002	194.8	48	0	<0.005	33.58	0.261	0.53
2633SWW081				<0.0002	152.1	47	0	0.34	52.25	0.3	0.13
2633SWW081	<0.005	<0.1	0.2689	<0.0005	161.54	55	1	<0.100	53.89	0.2432	0.09*
2633SWW083	<0.001	0.1088	0.084	<0.00010	143.71	69	0	0.1973	29.19	0.2708	
2633SWW084	<0.001	0.0961	0.1405	<0.00010	172.59	70	0	0.1906	209.89	0.2911	
Drummond GWS	<0.005	0.012	<0.05	<0.0005	36.09	17	0	<0.05	5.76	0.0451	
Drummond GWS	0.00061	<0.02	<0.02	<0.0005	37.54	17	0	<0.02	4.78	0.0493	
Drummond GWS	<0.001	<0.05	<0.05	<0.00010	36.72	31	0	<0.05	6.07	0.0504	
Grove Farm				<0.0002	189.5	174	36	0.07	53.36	<0.02	25.95
Grove Farm				<0.0002	29.32	46	0	0.66	109.8	0.03	
Grove Farm				<0.0002	336.4	137	9	0.12	33.76	0.03	7.35
Grove Farm				<0.0002	187.6		0	0.08	42.7	0.1	5.05
Grove Farm				<0.0002	235.4	326	0	0.05	43.1	0.04	2.08
Grove Farm	<0.005	<0.1	0.6644	<0.0005	233.21	63	0	0.412	114.17	0.0199	<0.04*
Grove Farm	<0.0005	0.0773	0.1654	<0.00005	216.73	73	0	0.1009	75.54	0.0295	
Grove Farm	<0.001	0.0659	0.1817	<0.00010	210.10	75	4	0.7539	50.28	0.0308	
Grove Farm	<0.001	0.0644	0.2931	<0.00010	233.77	89	0	0.8112	311.57	0.0428	
Limestone Ind.				<0.0002	113.6	14	188	4.35	7.84	0.17	17.76
Limestone Ind.				<0.0002	121.8	14.3	0	0.58	7.6	0.03	16.21
Limestone Ind.				<0.0002	124	12		0.18	6.87	<0.020	13.24
Limestone Ind.				<0.0002	100.7	13	3	0.41	7.1	<0.020	14.39
Limestone Ind.	<0.005	<0.05	<0.050	<0.0005	120.01	16	4	0.3017	9.95	0.0474	14.52*
Limestone Ind.	<0.0005	0.0491	<0.02	0.0003	111.66	14	0	0.0983	7.39	0.0194	nda
Limestone Ind.	<0.001	<0.05	<0.050	<0.1	101.14	14	0	0.0752	6.77	0.0171	0
Limestone Ind.	<0.001	<0.05	<0.050	<0.0002	131.10	12	0	0.0986	8.69	0.0232	0
Meadow Meats				<0.0002	399	25	0	3.09	117.9	0.06	0.04
Meadow Meats				<0.0002	474	26	0	1.11	159.24	0.07	
Meadow Meats				<0.0002	337.2	20	0	0.72	28.6	0.04	0.04
Meadow Meats	0.00057	<0.01	0.5348	<0.00005	515.45	25	0	1.3088	125.59	0.0585	0.04*
Meadow Meats	<0.005	<0.1	1.5934	<0.0005	574.02	26	0	1.0597	200.28	0.0483	0.04*
Meadow Meats	<0.0005	<0.02	0.5882	<0.00005	354.43	25	0	1.1272	131.44	0.0852	
Meadow Meats	<0.01	<0.05	0.5706	<0.00010	477.88	26	0	1.3289	80.79	0.0606	

Appendix IV: Laboratory analytical results from the Environmental Protection Agency (full analysis)

WELL NAME	NITRITE (mg/l)	O_PHOSPHATE(mg/l)	PH	POTASSIUM (mg/l)	SODIUM (mg/l)	SULPHATE (mg/l)		TEMP(°C)	TOC(mg/l)	TON(mg/l_N)	TOTAL_HARDNESS (mg/l)	ZINC(mg/l)
2331NEW058	0.002	0.04	7.4	1.76	11.13	34				3.51	360	0.01
2331NEW058	0.001	0.01	7.29	2.57	12.3	27				2.82	440	<0.01
2331NEW058	0.001	0.02	7.4	2.29	10.56	44			3.8	3.61	332	<0.01
2331NEW058	0.001	0.01	7.19	4.99	29.25	39				4.03	388	
2331NEW058	0.001	0.01	7.55	1.9	10.8	40			1.1	4.75	270	
2331NEW058	<0.002	0.01	7.2	2.46	18.42	39	512		5.0	3.53	420	0.0144
2331NEW058	<0.002	<0.01	7.1	2.31	12.35	40			4.3	3.35	380	0.008
2633NWW074	0.002	0.04	7.42	1.41	13.83	14				0.05	252	<10
2633NWW074	0.001	0.01	7.45	2.01	14.1	12				0.01	340	<10
2633NWW074	0.001	0.02	7.41	1.47	13.29	14			4.2	0.09	210	<10
2633NWW074	0.002	0.02	7.49	5.54	38.23	8				0.01	288	
2633NWW074	<0.002	<0.01	7.4	1.65	20.68	16		nm	1.8	0.01	292	0.0016
2633NWW074	nm	<0.01	7.2	1.51	13.60	15		9	3.0	<0.01	304	0.0021
2633NWW074	<0.002	<0.02	7.2	<1	23.00	16		9	1.4	<0.03	292	0.0051
2633NWW102	0.029	0.07	7.31	2.13	18.67	100				0.01	332	0.01
2633NWW102	0.03	0.04	7.32	2.62	20.02	42				0.1	432	<10
2633NWW102	0.01	0.04	7.37	4.36	27.22	72			7.3	0.12	280	0.03
2633NWW102	0.009	0.01	7.5	8.11	30.51	46			4.2	0.83	300	
2633NWW102	0.003	<0.02	7.3	5.42	93.31	61		11	nm	<0.03	280	0.0305
2633NWW102	<0.002	<0.02	7.2	6.69	128.51	77		10	3.9	<0.03	276	0.041
2633SWW081	0.001	0.04	7.22	1.42	17.14	140				0.04	436	0.01
2633SWW081	0.001	0.01	7.2	2	18.53	12				0.01	588	<10
2633SWW081	0.001	0.05	7.16	1.42	19.08	225			3.3	0.12	540	<10
2633SWW081	0.001	0.02	7.18	4.47	50.72	93				0.03	516	
2633SWW081	<0.002	0.01	7.1	1.73	34.22	270		nm	1.1	0.02	562	0.0718
2633SWW083	<0.002	<0.02	7.2	1.97	26.18	202		12	nm	<0.03	560	0.016
2633SWW084	<0.002	<0.02	7.1	<1	42.52	217		11	1.4	<0.03	505	0.0253
Drummond GWS	<0.005	0.51	6.5	1.70	12.88	44	211		0.2	2.43	99	0.0469
Drummond GWS	nm	0.48	6.5	1.97	12.46	35	nm		2.2	2.17	106	0.0948
Drummond GWS	<0.002	0.51	6.7	2.22	16.00	38	161		1.0	2.25	106	0.0344
Grove Farm	0.018	0.05	7.17	3.13	111.6	310				5.86	592	0.02
Grove Farm	0.002	0.01	7.18	2.81	27.86	15				0.01	832	0.02
Grove Farm	0.004	0.01	7.11	3.16	82.6	440			4.6	1.66	660	<10
Grove Farm	0.004	0.02	7.15	7.2	231.3	118				1.14	520	
Grove Farm	0.006	0.03	7.13	3.6	177					0.47	344	
Grove Farm	<0.002	0.02	7.1	2.64	61.68	410		nm	3.0	<0.01	980	0.0773
Grove Farm	nm	<0.01	7.1	2.55	43.53	588		29	4.7	<0.01	940	0.0202
Grove Farm	0.004	<0.02	7.2	2.60	47.41	618		12	nm	<0.03	920	0.029
Grove Farm	<0.002	<0.02	7.1	1.96	81.46	474		11	1.7	<0.03	703	0.0451
Limestone Ind.	0.055	0.39	7.29	14.9	13.1	16				4.01	277	0.15
Limestone Ind.	0.008	0.03	7.51	23.43	16.54	16				3.66	285	0.05
Limestone Ind.	0.001	0.02	7.39	26.52	31.11	21			2.6	2.99	292	
Limestone Ind.	0.006	0.05	7.4	18.8	16.5	21			0.9	3.25	252	
Limestone Ind.	0.016	0.06	7.1	16.93	20.81	32		nm	0.3	3.28	292	0.1681
Limestone Ind.	nm	0.02	7.1	15.98	14.34	24		7	54.5	3.72	336	0.5737
Limestone Ind.	0.005	<0.02	7.2	15.75	19.89	28		11	nm	2.94	314	0.169
Limestone Ind.	0.008	<0.02	7.2	15.56	16.58	25		9	1.9	3.39	320	0.2567
Meadow Meats	0.011	0.01	7.29	2.93	42.28	2400				0.01	1180	0.01
Meadow Meats	0.005	0.01	7.28	4.1	57	14				0.01	1408	<10
Meadow Meats	0.005	0.02	7.36	2.22	22.56	440			3.4	0.01	640	<10
Meadow Meats	0.004	0.02	7.2	3.91	46.87	1700		nm	1.7	0.01	1940	0.0512
Meadow Meats	0.003	0.02	7.0	4.28	81.20	300		nm	1.0	0.01	1900	0.056
Meadow Meats	<0.002	0.01	6.9	3.69	49.99	>1000		12	3.0	0.01	1680	0.0379
Meadow Meats	0.002	<0.02	7.0	3.57	45.95	1610		12	nm	<0.03	1800	0.0648

Appendix V: Laboratory analytical results from Monaghan County Council

WELL NAME	DATA SOURCE/Name	AQUIFER NAME	SAMPLE DATE	SAMPLE COMPANY	ALKALINITY (mg/l)	bicarbonate (hco3)	AMMONIA TOTAL(mg/l)	CA HARDNESS (mg/l)	CALCIUM (mg/l)	CHLORIDE (mg/l)	E_COLI (count/100ml)	F_COLI (count/100ml)
2333SEW042	Public Smithborough PWS - Mulladuf	Mona-Clones	7-Feb-78	Co Co (Mulladuff - Smithboro?)	256	312.32		206		19		
2633SEW002	Private well	Carrickmacross	2-Dec-00	well grant?			0.03					0
2631NEW093	Private well	Lower Palaeozoic	23-Apr-98	well grant?		0						
2631NEW096	Private well	Lower Palaeozoic	30-Sep-99	well grant?		0	0.02					
2631NEW098	Private well	Lower Palaeozoic	9-Oct-98	well grant?		0	0					
2631NEW101	Private well	Lower Palaeozoic	8-Nov-99	well grant?		0	0.1					
2631NEW102	Private well	Lower Palaeozoic	21-Dec-97	well grant?		0	0.09					
2631NEW104	Private well	Lower Palaeozoic	25-Nov-00	well grant?		0	0.02					0
2631SWW099	Private well	Lower Palaeozoic	21-Dec-97	well grant?		0	0					
2631NEW100	Private well	Lower Palaeozoic	10-Dec-97	well grant?		0	0.01					
2633SWW131	Private well	Lower Palaeozoic	11-Mar-98	well grant?		0	0.65					
2633SWW133	Private well	Lower Palaeozoic	16-Jan-98	well grant?		0	0					
2633SWW134	Private well	Lower Palaeozoic	no date	well grant?		0						
2633SWW135	Private well	Lower Palaeozoic	13-Dec-97	well grant?		0	0					
2633SEW001	Private well	Lower Palaeozoic	24-Dec-97	well grant?		0	0					
2633SEW002	Private well	Lower Palaeozoic	18-Jun-99	well grant?		0						
2631SEW118	Private well	Lower Palaeozoic	24-Nov-99	well grant?		0	0.11					
2631NEW097	Private well	Lower Palaeozoic	16-Jul-98	well grant?		0						
2631NEW099	Private well	Lower Palaeozoic	9-Jul-98	well grant?		0	0.1					
2631NEW105	Private well	Lower Palaeozoic	1-Aug-00	well grant?		0	0.01					0
2631NWW118	Private well	Lower Palaeozoic	18-May-99	well grant?		0	0.26					
2631SEW117	Private well	Lower Palaeozoic	20-May-99	well grant?		0	0.04					
2633SEW012	Public Clontibret PWS	Lower Palaeozoic	16-Dec-98	Mona Co Co								0
2633SEW012	Public Clontibret PWS	Lower Palaeozoic	18-May-00	Mona Co Co								0
2633SEW012	Public Clontibret PWS	Lower Palaeozoic	4-Sep-00	Mona Co Co								0

Appendix V: Laboratory analytical results from Monaghan County Council

WELL NAME	IRON_TOTAL (mg/l)	MAGNESIUM (mg/l)	MANGANESE (mg/l)	NITRATE (mg/lNO3)	NITRITE (mg/l)	ODOUR	PH	SULPHATE (mg/l)	TEMP(°C)	TOTAL_HARDNESS (mg/l)	SAMPLETIME
2333SEW042	1.1						7.6	42		280	
2633SEW002	0.1		0.04	9	0.02		6.6				
2631NEW093	0.2		0.05	50	0.1				25		13:25
2631NEW096	0.01		0.033	7.2	0.01		7.1				
2631NEW098	0.09		0.024	13.64	0.04		7.2		10		5:00
2631NEW101	0.15		0.035	2	0.03		6.9				
2631NEW102	0		0.045	8.8	0.1		7.2		9		10:00
2631NEW104	0.38		0.09	4	0.02		7.5				
2631SWW099	0		0.012	3.08	0.1		6.39		10		11:00
2631NEW100	0.02		0.003	2.1	0.002		6.8		8		10:30
2633SWW131	0.01		0	3.2	0.06		7.1		10		5:30
2633SWW133	0		0	21.3	0.06	NONE	6.9		10		9:00
2633SWW134					0.09						
2633SWW135	0.26		0.5	12.8	0.08		6.6		11		10:30
2633SEW001	0		0.05	3.5	0.1	NONE	7.1		9		1:15
2633SEW002											
2631SEW118	0.17		0.032	4	0.06		7		11		
2631NEW097	0.012		0								9:00
2631NEW099	0.05		0.035	0	0		7.3		12		9:00
2631NEW105	0.17		0.043	0.3	0.02		7				
2631NWW118	0.1		0.011	3.75	0.01		7.1				9:00
2631SEW117	0.18		0.02	12.4	0.02		6.9		11		
2633SEW012											
2633SEW012											
2633SEW012											

2629NEW286	Private well	Carrickmacross	14-Dec-01					0.3				
2629NEW084	Rye Valley Foods	Carrickmacross	16-Jan-02	KTC?	263	320.86	0.09					
2333SEW002	Tydavnet National School	Knockatallon-Tydavnet	28-Mar-85	Tydavnet Group Scheme	292	356.24						
2633SWW136	Private well	Lower Palaeozoic	5-Aug-02	EAMON LAVELLE		0		0				
Knocknamaddy		Lower Palaeozoic	23/Jun6/70									
2331NEW190	Clonagore? - check	Mona-Clones	12-Apr-99	KT Cullens	154	187.88		2.73				
2331SEW049	Clones PWS (TW3)	Mona-Clones	2-Jul-00	KTC /Mo Co Co	320	390.4	0.804	0.22				
2331NEW209	Clones PWS - Anlore	Mona-Clones	2-Nov-99	KTC/ Monaghan Co Co	332	405.04		0.01				
2331NEW208	Clones PWS - Old Convent	Mona-Clones	2-Nov-99	KTC / Monaghan Co Co	208	253.76		0.33				
2633SWW277	Monaghan Poultry Products	Mona-Clones	25-May-89	?	348	424.56		<0.10				
2331SEW048	Public Clones PWS (OB1)	Mona-Clones	2-Jul-00	KTC/Monaghan Co. Co	336	409.92	<0.016	0.03				
2331SEW050	Public Clones PWS (PW1)	Mona-Clones	6-May-02	KTC / Mo Co Co	151.7	185.074		0.01				
2331SEW050	Public Clones PWS (PW1)	Mona-Clones	21-Apr-02	KTC/ Monaghan Co Co	168.1	205.082	0.02	0.03				
2331SEW050	Public Clones PWS (PW1)	Mona-Clones	28-Apr-02	KTC/ Monaghan Co Co	146	178.12		0.03				
2331SEW050	Public Clones PWS (PW1)	Mona-Clones	15-May-02	KTC/ Monaghan Co Co	365	445.3		0.01				
2331SEW050	Public Clones PWS (PW1)	Mona-Clones	16-May-02	KTC/ Monaghan Co Co	290	353.8		<0.05				
2331NEW210	Public Clones PWS (PW2)	Mona-Clones	21-Apr-02	KTC/ MO CO CO	202.6	247.172	<0.02	0.58				
2331NEW210	Public Clones PWS (PW2)	Mona-Clones	28-Apr-02	KTC/ MO CO CO	190.3	232.166		0.57				
2331NEW210	Public Clones PWS (PW2)	Mona-Clones	6-May-02	KTC/ MO CO CO	200.1	244.122		0.5				
2331NEW210	Public Clones PWS (PW2)	Mona-Clones	15-May-02	KTC/ MO CO CO	182.1	222.162		0.46				
2331NEW210	Public Clones PWS (PW2)	Mona-Clones	16-May-02	ktc/ mo co co	365	445.3		0.46				
2633SWW254	Public Mona PWS Ballyalbany (PW4)	Mona-Clones	12-Nov-01	KT Cullen	320	390.4	0.43					
2633SWW143	Public Mona PWS Ballyalbany (TW4)	Mona-Clones	2-Jan-01	KT Cullen			0.008	0.013	<0.003	<1	0.179	0.179
2633SWW249	Public Mona PWS Cappog Bridge (PW3)	Mona-Clones	12-Nov-01	KT Cullen	280	341.6	<0.05					
2633SWW142	Public Mona PWS Cappog Bridge (TW3)	Mona-Clones	2-Jan-01	KT Cullen			0.13	0.013	<0.003	1.4	0.102	0.102
2633SWW260	Public Mona PWS Griggy, N2 (PW6)	Mona-Clones	20-Dec-01	KT Cullen	282	344.04	<0.05					
2633SWW145	Public Mona PWS Griggy, N2 (TW6)	Mona-Clones	2-Jan-01	KT Cullen	295	359.9	<0.004	0.116	<0.003	<1.0	0.09	0.09
2633SWW252	Public Mona PWS Lambs Lough (PW1)	Mona-Clones	19-Nov-01	KTC sampling	306	373.32	<0.05					
2633SWW148	Public Mona PWS Lambs Lough (TW1)	Mona-Clones	2-Jan-01	KT Cullen	332	405.04	0.007	0.129	<0.003	<1	0.194	0.194
2633SWW149	Public Mona PWS Mona Co Op (TW2)	Mona-Clones	2-Jan-01	KT Cullen	324	395.28	0.004	0.36	<0.003	1.3	0.088	0.088
2633SWW256	Public Mona PWS Rafeenan Bridge (PW5)	Mona-Clones	12-Nov-01	KT Cullen	298	363.56	<0.05					
2633SWW144	Public Mona PWS Rafeenan Bridge (TW5)	Mona-Clones	2-Jan-01	KT Cullen	262	319.64	0.036	0.013	<0.003	<1	0.14	0.14
2633SWW262	Public Mona PWS Silverstream (PW7)	Mona-Clones	12-Dec-01	KT Cullen	250	305	<0.05					
2633SWW146	Public Mona PWS Silverstream (TW7)	Mona-Clones	2-Jan-01	KT Cullen	271	330.62	<0.004	0.103	<0.003	<1.0	0.06	0.06
2331NEW058	Public Smithborough PWS - Templetate prod well	Mona-Clones	5-Feb-84	EHB								

Appendix VI: Laboratory analytical results used in Durov diagram

2629NEW286						0				703			0.05	
2629NEW084			105	24		>100			23	590			0.05	0.16
2333SEW002		<0.005		20			<5	0.1						
2633SWW136						0	CLEAR			301			0	
Knocknamaddy				18									0.2	
2331NEW190			104	14		0	17		0	631			2.15	0.166
2331SEW049	390			54		5			1	769		0.2	0.48	
2331NEW209				17		nil	8		nil	746		0.16	0.092	
2331NEW208				17			1		nil	629	nil	3.51	<0.05	
2633SWW277			104	36		0	<5.0	<0.10	0	720			0.2	0.06
2331SEW048	280			16		Nil	5		Nil	673		0.166	0.46	0.00
2331SEW050				16			6		nil	710	nil		0.225	
2331SEW050				16		nil	6	<0.010	nil	680		0.29	0.319	
2331SEW050				16		nil	9		nil	692		0.098	0.22	
2331SEW050				16			11		nil	710	nil			
2331SEW050			85	13		Nil	<5	<0.01	nil	640	nil		0.23	0.08
2331NEW210				18		NIL	6	<0.01	NIL	848		0.29	0.978	
2331NEW210				17		nil	9		nil	893		0.111	0.97	
2331NEW210				18		1	6		NIL	911			0.856	
2331NEW210				18		nil	11		nil	889				
2331NEW210			155	16		nil	<5	<0.01	nil	800	nil		0.75	0.41
2633SWW254			115	17		Nil	<5	<0.01	Nil	605	Nil		1.8	0.126
2633SWW143		<0.01	85	13.9	0.12	Nil	9	<0.1	Nil	530	Nil	0.42	1.34	0.123
2633SWW249			80	16			<5	<0.01		525		0.52	0.79	0.077
2633SWW142		<0.001	85	13.3	0.16	Nil	6	<0.1	Nil	505	Nil	0.42	0.509	0.093
2633SWW260			50	13		Nil	<5	<0.01	Nil	555	Nil	0.8	0.04	0.057
2633SWW145		<0.01	61	15	<0.05	Nil	4	0.62	Nil	561	Nil	0.57	0.34	0.08
2633SWW252			90	18		Nil	<5	<0.01	Nil	570	Nil	0.42	0.95	0.108
2633SWW148		<0.01	87	14.7	<0.05	Nil	7	<0.1	Nil	591	Nil	0.33	1.08	0.118
2633SWW149		<0.01	110	26.5	<0.05	Nil	2	<0.1	Nil	691	Nil	0.25	0.196	0.0863
2633SWW256			85	15		Nil	<5	<0.01	Nil	550	Nil	0.47	0.75	0.1
2633SWW144		<0.01	89	15	<0.05	Nil	<2	<0.1	Nil	649	Nil	0.5	0.608	0.106
2633SWW262			105	18		Nil	<5	<0.01	Nil	680	Nil	0.21	0.13	0.143
2633SWW146		<0.01	98	16.7	<0.05	1	7	<0.1	Nil	668	Nil	0.21	0.188	0.121
2331NEW058				24									0.32	

Appendix VI: Laboratory analytical results used in Durov diagram

2629NEW286			0.005			44	0.09			6.5						
2629NEW084		10	0.02			16	0.03			7.1		2.2			14	32
2333SEW002	0.7		<0.02			0.006			none	8						47
2633SWW136			0			46.2	0.006		NONE	7.3						
Knocknamaddy										8						32
2331NEW190		11.79	0.082			0.04	0.039			7.1	0.069	1.31	9		7.91	2
2331SEW049			1.87			0.22	0.033			7.51			6		18.55	22
2331NEW209			<0.02			1.29		0.01		7.3						30
2331NEW208			<0.02			0.02		0.06		7.67						39
2633SWW277		29	0.5			0.4	<0.01			7.1		1.1			17	30.5
2331SEW048			0.12			0.35	0.007			7.39			0		16.14	26
2331SEW050			0.18			0.04	0.01	0.023		7.17			4			60
2331SEW050	0.0017		0.12			0.04	0.003	0.016		7.27			9			36
2331SEW050			0.14			0.09	0.003	0.06		7.21			1			50
2331SEW050						0.04	0.003	0.023		7.34						
2331SEW050		37	0.18			<0.5	0.01			7.3		1.5			20	87
2331NEW210	<0.0008		0.08			0.09	0.01	0.016		7.08			3			57
2331NEW210			0.09			0.05	0.007	0.06		7.01			3			64
2331NEW210			0.088			0.04	0.016			6.95			6			90
2331NEW210						0.04	0.003		Sulphide	7.16						
2331NEW210		24	0.1			<0.5	<0.01			7.1		4.5			11	104
2633SWW254		12	0.14			0.5	<0.01			7.2		1.2			9.5	21
2633SWW143	<0.2	18	0.153	0.0011	<0.3	0.09	0.023	0.005		7.3		1.6		0.002	13	6
2633SWW249		22	0.04			<0.5	<0.01			7.4		1.3			17	14
2633SWW142	<0.2	18	9.7	<0.0008	0.33	0.8	0.076	<0.002		7.4		1.3		0.001	14	11
2633SWW260		33	0.01			<0.05	<0.01			7.5		1.6			28	40
2633SWW145	<0.2	20	0.01	<0.0008	<0.3	0.7	0.007	0.004		8.37		1.6		<0.001	20	24
2633SWW252		25	0.06			<0.5	<0.01			7.6		1.3			12	24
2633SWW148	<0.2	23	0.06	<0.0008	<0.3	0.74	<0.007	0.005		8.37		1.3		<0.001	11	18
2633SWW149	<0.02	22	0.25	<0.0008	<0.3	<0.22	<0.007	0.02		7.97		1.9		<0.001	22	80
2633SWW256		22	0.19			<0.5	<0.01			7.4		1.5			15	19
2633SWW144	<0.2	25	0.282	<0.0008	<0.3	<0.22	0.007	0.009		7.2		1.7		<0.001	16	23
2633SWW262		27	0.07			4.8	0.02			7.4		2			14	128
2633SWW146	<0.2	25	0.068	<0.0008	<0.3	8.46	0.02	0.011		8.08		1.7		<0.001	14	87
2331NEW058			0.07							6.9						33

2629NEW286		11						12:20
2629NEW084					303	4.4		
2333SEW002					184	3.5	0.09	
2633SWW136		12				NONE		5:00
Knocknamaddy				0.02	200			
2331NEW190					308	29		
2331SEW049					312			
2331NEW209					372	1		12:00
2331NEW208						0		12:00
2633SWW277		10.5			380		0	
2331SEW048						3		
2331SEW050					340	0		
2331SEW050					315	3		
2331SEW050					347.5	1		
2331SEW050					151.7	0		
2331SEW050			<0.2		365	1.4		
2331NEW210					390	10		12:00
2331NEW210					487.5	6		12:00
2331NEW210					520	0		12:00
2331NEW210					475	7		12:00
2331NEW210			2.4		486	5.7		12:00
2633SWW254					336	40		
2633SWW143				0.58	285	12.3	0.34	
2633SWW249					290	5		
2633SWW142				0.42	287	8.6	0.81	
2633SWW260					261	0.3		
2633SWW145	0.041			0.29	274	1.4	2.09	
2633SWW252					328	2.7		
2633SWW148					312	14.1		
2633SWW149				0.51	367	2.3	19	
2633SWW256					303	9.2		
2633SWW144				4.73	324	0.4	0.57	
2633SWW262					373	0.95		
2633SWW146				0.1	347	2.4	1.7	
2331NEW058				2.73	333			

Appendix VII: Laboratory analytical results from Carrickmacross UDC

WELL NAME	DATA SOURCE/Name	AQUIFER NAME	SAMPLEDATE	SAMPLE_COMPANY	ALKALINITY(mg/l)	bicarbonate (hco3)	ALUMINIUM(mg/l)	AMMONIA_TOTAL(mg/l)	ANTIMONY(mg/l)	ARSENIC(mg/l)	BARIUM(mg/l)	BOD(mg/l)
2629NEW301	Public Carrick PWS - Lossets	Carrickleck	26-Sep-00	Carrickmacross UDC		0	<0.04	<0.1		<0.01	0.16	
2631SEW133	Carrick PWS - Tullyvaragh Lower	Carrickmacross	21-Sep-00	Carrickmacross UDC			<0.04	<0.01		<0.01	<0.01	
2629NEW300	Public Carrick PWS - Spring Lake	Carrickmacross	22-Sep-00	Carrickmacross UDC			0.09	<0.1		<0.01	0.07	
2629NEW299	Public Naffarty PWS new borehole	Carrickmacross	20-Sep-00	Jer Keohane/ Carrick UDC			<0.04	<0.1		<0.01	<0.01	

BORON(mg/l)	CA_HARDNESS(mg/l)	CADMIUM(mg/l)	CALCIUM(mg/l)	CHLORIDE(mg/l)	E_COLI(count/100ml)	F_COLI(count/100ml)	IRON_TOTAL(mg/l)	MAGNESIUM(mg/l)	MANGANESE(mg/l)	NITRATE(mg/lNO3)	NITRITE(mg/l)	O_PHOSPHATE(mg/l)
0.16		<0.004	83	22		0	0.24	30	0.5	<0.5	<0.5	
<0.07		<0.004	59	12		0	0.48	15	0.06	4	<0.05	
<0.07		<0.004	97	14		0	1.01	19	<0.05	22	<0.5	
<0.07		<0.004	86	15	0		0.22	8	<0.05	13	<.5	

PH	PHOSPHORUS_TOTAL(mg/l)	POTASSIUM(mg/l)	SODIUM(mg/l)	STRONTIUM(mg/l)	SULPHATE(mg/l)	SULPHIDE(mg/l)	TDS(mg/l)	TEMPFIELD(°C)	TOC(mg/l)	TON(mg/l_N)	TOTAL_HARDNESS(mg/l)	TOTAL_SVOC(mg/l)
6.8		4	16		74							
6.7			10		9							
7.2			9		12							
6			11			11						

TPH(mg/l)	TURBIDITY	ZINC(mg/l)	SAMPLETIME
		0.02	
		0.02	
		0.02	
		<0.02	

Appendix VIII: Laboratory analytical results used in Durov diagram

Sample No./Name	Ca	Mg	Na	K	NH4	Fe	Mn	HCO3	NO3	SO4	CL	pH	F.Coli	T.Coli
2633SWW252	81.12	21.7	12.53	1.6	0.019	0.313	0.056	332	2.01	22.5	15.2	5.99	0	0
2633SWW252	88.9	22.3	15.46	1.6	0.071	0.532	0.064	296	1.84	44.6	14.4	5.72	0	0
2633SWW277	99.06	39.9	49.18	1.8	0.019	0.008	0.151	348	3.86	77.5	41.7	5.86	2	1
2633SWW285	329.54	39.4	22.32	1.9	0.081	0.551	0.016	260	<0.1	906	21.9	5.89	0	0
Grove Farm	336.4	33.76	82.6	3.16	0.13	0.12	0.03	348	7.35	440	137	7.11	31	9
Grove Farm	233.21	114.17	61.68	2.64	0.28	0.412	0.0199	272	<0.04*	410	63	7.1	0	0
2633SWW081	194.8	33.58	19.08	1.42	0.17	<0.005	0.261	352	0.53	225	48	7.16	0	0
2633SWW081	152.1	52.25	50.72	4.47	0.03	0.34	0.3	320	0.13	93	47	7.18	0	0
2633SWW146	98	25	14	1.7	0.103	18.8	6.84	306	8.46	87	16.7	8.08	1	0
2633SWW149	110	22	22	1.9	0.36	19.6	25.3	271	<0.22	80	26.5	7.97	0	0
Meadow Meats	399	117.9	42.28	2.93	0.64	3.09	0.06	250	0.04	2400	25	7.29	0	0
Meadow Meats	337.2	28.6	22.56	2.22	0.27	0.72	0.04	440	0.04	440	20	7.36	0	0
Meadow Meats	515.45	125.59	46.87	3.91	0.41	1.3088	0.0585	250	0.04	1700	25	7.2	0	0
Meadow Meats	574.02	200.28	81.2	4.28	0.42	1.0597	0.0483	448	0.04	300	26	7.0	0	0
2331NEW058	139.7	18.85	11.13	1.76	0.05	<0.05	<0.00020	278	15.54	34	21	7.4	0	1
2331NEW058	168.4	9.23	10.56	2.29	0.01	<0.05	<0.00020	388	15.99	44	21	7.4	2	0
2331NEW058	138.6	23.29	29.25	4.99	0.01	0.15	0.03	304	17.84	39	24	7.19	0	0
2331NEW058	141.2	23.88	18.42	2.46	<0.01	<0.02	<0.0005	206	15.63	39	19	7.2	4	0
2331NEW210	155	24	11	4.5	0.46	0.75	0.1	182.1	<0.5	104	16	7.1	0	0
2331SEW050	85	37	20	1.5	<0.05	0.23	0.18	365	<0.5	87	13	7.3	0	0
2333NEW033	32.04	20.5	96.84	3.2	0.31	0.27	0.013	298	<0.10	60.4	13.5	6.03	0	0
2333NEW034	44.13	22.9	65.4	3.2	0.147	0.108	0.015	276	<0.1	73.8	11.1	5.98	0	0
2333SEW095	29.19	22.2	62.71	3.1	0.22	0.096	0.009	246	<0.10	46.4	9.6	5.98	0	0
2633SWW145	61	20	20	1.6	0.116	0.34	1.44	252	0.7	24	14.9	8.37	0	0
2633NWW102	157.44	11.6	18.67	2.13	1.09	7.43	0.28	390	0.04	100	23	7.31	0	0
2633NWW102	114	10.79	27.22	4.36	0.72	3.36	0.18	356	0.53	72	22	7.37	0	0
2633NWW102	142	8.91	30.51	8.11	0.01	2.64	0.21	316	3.68	46	25	7.5	0	0
2633NWW226	63.04	39.5	49.37	3.3	0.121	0.08	<0.005	324	<0.10	105.3	26.6	5.96	0	0
2333NEW009	44.3	24.1	76.6	3.6	0.21	0.093	0.028	284	1.77	73.3	13.3	5.99	1	0
2333NEW032	59.32	33	109.79	5.3	0.27	0.348	0.024	352	<0.10	168.7	8.7	6.02	4	1
2633NWW074	102.3	11.89	13.83	1.41	0.05	<0.005	0.22	363	0.22	14	11	7.42	0	0
2633NWW074	122.1	5.62	13.29	1.47	0.01	0.06	0.21	344	0.4	14	11	7.41	0	0
2633NWW074	129.5	10.42	38.23	5.54	0.01	<0.005	0.22	310	0.04	8	11	7.49	0	0
2633NWW074	106.13	14.12	20.68	1.65	<0.01	0.0112	0.1663	192	0.04	16	12	7.4	0	0
Limestone Ind.	121.8	7.6	16.54	23.43	0.03	0.58	0.03	288	16.21	16	14.3	7.51	4	0
Limestone Ind.	100.7	7.1	16.5	18.8	0.01	0.41	<0.020	236	14.39	21	13	7.4	6	3
Limestone Ind.	120.01	9.95	20.81	16.93	<0.001	0.3017	0.0474	270	14.52	32	16	7.1	8	4
Limestone Ind.	111.66	7.39	14.34	15.98	0.01	0.0983	0.0194	280	nda	24	14	7.1	0	0
2633SWW142	85	18	14	1.3	0.013	50.9	9.7	312	0.8	11	13.3	7.4	0	0
2633SWW144	89	25	16	1.7	0.013	60.8	28.2	280	<0.22	23	15	7.2	0	0
2331NEW213	64.08	25.6	22.74	1.7	0.141	0.168	0.055	208	<0.1	38.8	14.3	5.64	0	0
2331NEW213	68.11	27.2	19.85	1.8	0.069	0.129	0.062	276	<0.1	38.1	19.6	5.93	0	0
2633SWW286	70.45	38.3	23.81	2.3	0.059	0.061	0.014	362	<0.1	27.7	13.8	5.81	0	0
2633SWW068	148.72	42.1	22.6	1.7	<0.019	0.197	0.063	296	1.68	306	18.6	5.78	0	0
2633SEW012	49.11	27.8	13.92	1.1	<0.019	0.021	0.005	261.08	2.33	51.6	17.5	5.84	0	0
2633SWW260	50	33	28	1.6		0.04	0.01	344.04	<0.05	40	13	7.5	0	0