AN ASSESSMENT OF GROUNDWATER QUALITY IN SOUTH CORK

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AN ASSESSMENT OF GROUNDWATER QUALITY IN SOUTH CORK

1. Introduction

This report contains an assessment of the readily available groundwater chemistry and quality data for public and private supplies in South Cork. It also gives a number of recommendations for consideration by Cork County Council.

2. Sources of Information

Data on hydrochemistry and water quality were obtained from the following sources:

- Two rounds of chemical analyses (April 1999, September 1999) carried out for the project by Cork County Council Laboratories at Inniscarra, on 19 major public groundwater supplies in South Cork. The analyses on a total of 25 samples in April and 24 samples in September, comprised all major cations and anions, hardness and some trace metals (Tables 1, 2). The County Council also carried out raw water bacteriological analyses during both sampling rounds.
- Chemical and bacteriological analyses for over 95 private groundwater supplies submitted under the Water Supply Improvement Grant Scheme (Table 3) (February 1997 to September 1999).
- Source reports for Grenagh, Coachford, Ballinspittle, Robert's Cove, Minane Bridge and Crookstown Public Water Supplies (GSI, 2000).
- Groundwater Protection Scheme for the Dower Spring, County Cork, unpublished M.Sc. thesis (Gately, 1996, TCD).
- Geological Survey of Ireland water quality and hydrochemistry files.
- Nitrates in Groundwater County Cork (South) (MacCárthaigh, EPA, 1997).
- Report on Nitrate levels in Co. Cork water supplies, (Cork County Council, Water Laboratories, Inniscarra, 1998)

3. Hydrochemistry

The inherent water signature and variations in chemical parameters over space and time were assessed to gain an understanding of the groundwater flow system in the various rock types. The data available for assessment mainly come from Council records from 1991 to 1999, so there is a good database of long term records. However a lot of this data is only from C1 analysis (basic analysis of electrical conductivity, pH, temperature, aluminium, fluoride and coliforms, both total and faecal) so there are few long term data available for nitrates, metals, sodium, potassium etc. Although this does not allow a full overview of the hydrochemistry, it does provide some indication of spatial variations across South Cork. Hydrochemistry data for all major supplies are given in Tables 1 and 2.

3.1 Non-carbonate rock units

Most of South Cork is underlain by non-carbonate rock units, which include all the Old Red Sandstone rocks, as well as the sandstones and mudstones of the Cork Group. Alkalinity ranges from 14 to 310 mg/l (as $CaCO_3$) and hardness ranges from 43 to 224 mg/l (moderately soft to moderately hard).

The Old Red Sandstone formations largely contain calcium bicarbonate type water. This indicates that these groundwaters largely contain the more readily dissolved ions such as calcium and bicarbonate. Conductivities in these units are relatively low ranging from 125 to 600 μS/cm, with an average of 312 μS/cm. Conductivities in the Cork Group rocks are quite similar with an average of 381 μS/cm and a range from 160 to 433 μS/cm.

Cation exchange is occasionally evident in groundwater samples taken from non-carbonate rocks. The most important exchange reactions are the replacements of both calcium and magnesium by sodium which show up in the analyses where total alkalinity is greater than total hardness. A large reservoir of exchangeable sodium (provided chiefly by clay particles in the shales) and sufficient residence time within the aquifer are the main requirements for the process to occur. However, available data do not seem to indicate this process occurring in South Cork, even within the more shaly formations.

Iron (Fe) and manganese (Mn) commonly occur in groundwater derived from sandstone and shale formations, due to the dissolution of Fe and Mn from the sandstone/shale where reducing conditions occur.

3.2 Carbonate Rock Units

A sizeable proportion of South Cork is underlain by carbonate limestone rock, the most important unit being the Waulsortian Limestone, mainly found in East Cork. Also important is the Little Island Formation which is also found in the synclines as far west as Crookstown. The hydrochemistry of the carbonate rocks is dominated by calcium and bicarbonate ions. As a result many of the sources abstracting from the limestones in Cork have similar chemical characteristics. Hardness is in the range 217 to 377 mg/l (as $CaCO_3$), i.e. moderately hard to very hard. Spring waters tend to be softer as throughput is quicker and there is less time for the dissolution of minerals into the groundwater. This is particularly true in karstic limestones.

Groundwater alkalinity is high, ranging from 116 to 306 mg/l ($CaCO_3$). Alkalinity is less than hardness indicating that ion exchange (where calcium or magnesium are replaced by sodium) is not significant. Electrical conductivities range from 384 to 660 µS/cm for Council sources and 250 to 796 µS/cm for private wells. Typical limestone water conductivities are of the order of 500-700 µS/cm. Lower values suggest that the residence times of some of the sources are very short, for example at Killeagh and the Dower Spring where conductivities average 384 and 396 µS/cm respectively. These values reflect karstic systems (in the Waulsortian) with rapid flow velocities.

The magnesium/calcium ratio is used in limestone aquifers to indicate possible dolomitisation where the calcium ions have been replaced by magnesium. A ratio of greater than 0.3 (where parameters are expressed in milliequivalents per litre) indicates dolomitisation, or ion exchange or some form of contamination. However, from the available data for the limestone aquifers, there is no evidence for any dolomitisation within these rocks. This confirms evidence from geological mapping.

3.3 Sand and Gravel Deposits

The hydrochemistry of groundwater in sand and gravel deposits tends to reflect the predominant lithology of the clasts. 'Limestone gravels' for example will have harder groundwater than 'sandstone gravels'. Where a mixed gravel is present the signatures may be variable. Groundwater analyses are available for 4 sources located in gravel deposits namely Minane Bridge, Crookstown, Coolcour (Macroom) and Carrigtohill (Youghal carpets & IDA Estate). Hardness ranges from 56 to 174 mg/l ($CaCO_3$) i.e. moderately soft to moderately hard.

At Minane Bridge the groundwater is slightly to moderately hard (ranging from 140-174 mg/l). The underlying bedrock units at this source are mainly non-calcareous mudstones and sandstones, which is obviously reflected in the water quality. Somewhat lower hardness values are found at Crookstown with a range from 82 to 160 mg/l $CaCO_3$ (moderately soft to slightly hard water). The underlying bedrock at this source is mainly limestones although it appears from the nature of the groundwater quality that there is possibly a mixture of sandstone and limestone clasts. At Coolcour, hardness was only 56 mg/l $CaCO_{3.}$ At Carrigtohill, two boreholes at Youghal Carpets site gave hardnesses of 90 to 124 mg/l $CaCO_{3.}$

Overall, it appears that the gravels are dominated by sandstone material, which tends not to give rise to high hardness. This tends to confirm the findings of the Teagasc subsoil mapping.

Alkalinity ranges from 44 to 269 mg/l (as $CaCO_3$). The range at Minane Bridge is 57 to 90 mg/l $CaCO_3$, and is similar at Crookstown (44-90 mg/l)

Natural iron and manganese levels are occasionally elevated in gravelly deposits where the clasts are largely of sandstone and shale, but this is not evidenced in South Cork. The data available for the Council sources do not highlight any problems with regard to high Fe/Mn levels. However, data from the Grant Scheme records generally lack well logs, so it is not known how many are actually abstracting from bedrock or gravels.

4. Indicators of Groundwater Contamination

4.1 Introduction

In assessing groundwater quality, the GSI distinguishes between the terms ‘contamination’ and ‘pollution’. Groundwater becomes ‘contaminated’ when substances enter it as a result of human activity. The term ‘pollution’ is reserved for situations where contaminant concentrations are sufficiently high to be objectionable i.e. above the maximum admissible concentration (MAC) for drinking water (Irish Drinking Water Regulations, S.I No. 81 of 1988).

As human activities have had some impact on a high proportion of groundwater in Ireland, there are few areas where the groundwater is in pristine condition. Consequently most groundwater is contaminated to some degree although it is not necessarily polluted. In assessing groundwater quality there is often a tendency to focus only on the EU maximum admissible concentrations (MAC). In the view of the GSI, there is a need for assessment of the degree of contamination of groundwater as well as showing whether the water is polluted or not. This type of assessment can indicate where appreciable impacts are occurring and when monitored over time can be helpful in isolating potential sources of contamination before major incidents occur. Consequently, thresholds for certain parameters can be used to help indicate situations where significant contamination but not pollution is occurring. The thresholds for assessing water quality in County Cork are given below and originate from Daly (1996).

Parameter	**Threshold** mg/l	**MAC** mg/l
Nitrate	25	50
Potassium	4	12
Chloride*	25-50	250
Ammonia	0.15	0.3
Faecal bacteria	0	0
K/Na ratio **	0.4	

* Refer to Section 7.
** Refer to Section 8.
Indicators of groundwater contamination are discussed in Appendix 2.

Table 1 Groundwater Quality Classification of Co. Cork (South) Groundwater Supply Sources

Group*	**Supply Source**	**Exceedances by Key Indicators of Contamination[1]**						
		NO_3	**Cl**	**E.coli[2]**	**K**	**K:Na Ratio**	**Fe**	**Mn**
1	.Minane Bridge	**excess MAC**	*Excess threshold*	**excess MAC**	**excess MAC**	*Excess threshold*		
	.Cloyne (Town Parks, Spital)	*Excess threshold*		**excess MAC**	**excess MAC**	*Excess threshold*		
	Berrings	*Excess threshold*	*Excess threshold*	**excess MAC**			**excess MAC**	
	Killeagh 2 (west of N25)	**excess MAC**	*Excess threshold*	**excess MAC**	*Excess threshold*			
	Ballinagree, Robert's Cove (Doonavanig), Ballinspittle Old (Carrigavulleen), Coachford 1 (Fr. Sheehan Place)	**excess MAC**		**excess MAC**				
	Stoneview/Blarney, Aghabullogue, Killeagh 1(east of N25), Cloyne (Lissanly), Cloyne (Farranamannagh),Grenagh (Quarryhall), Carrigadrohid, Kilbrittain, Newcestown, Whitegate Regional (Dower Spring)	*Excess threshold*		**excess MAC**				
	Coachford 2 (Old Railway)	*Approaching threshold*		**excess MAC**				
	Ballinadee	*Excess threshold*					**excess MAC**	
	Clondrohid			**excess MAC**			**excess MAC**	**excess MAC**
	Grenagh (Village Wells)	*Approaching threshold*		**excess MAC**				**excess MAC**
	Belgooly		*Excess threshold*					**excess MAC**
	Garrettstown (Village & Kilmore)						**excess MAC**	
	Donoughmore/Stuake (Stuake Well)			**excess MAC**				
2	Ballymacoda, Ballyshoneen, Coolyhane, Riverstick, Ballincurrig/Lisgoold (Lisgoold well), Coole East, Glenville, Whitechurch/Ryefield (Ryefield well)	*Excess threshold*						
	Kilnamartyra				*Excess threshold*			
3	Ballymakeera, Cloyne (Commons East), Crookstown, Dungourney, Inchigeelagh, Nohoval, Robert's Cove (Britfieldstown)[3]							
4	Rylane.							

* Groups explained on next page

[1] NO_3: Nitrate. Cl: Chloride. PO_4: Phosphate. NH_3: Ammonia. K: Potassium. K:Na ratio: potassium:sodium ratio. Fe: Total Iron. Mn : Manganese. NH_3: Ammonia.

[2] These figures represent untreated samples. As such, though useful in terms of identifying contamination sources, they are not necessarily indicative of human health concerns.

[3] Most of these supplies are categorised here due to ambiguous nature of historical data (i.e. it is not clear which samples were raw or treated and bacteriological readings are anomalous)

4.2 General groundwater quality assessment of supply sources

The supply sources were divided into four groups to aid in the water quality assessment. The classification is based on concentrations of key contaminant indicators in relation to the Maximum Admissible Concentration (MAC) and to the GSI threshold levels.

- **Group 1:** Sources in which one or more contaminant indicators in the available data set exceeded the MAC and which are therefore considered to have been polluted at the time of sampling.
- **Group 2:** Sources which show concentrations of the contaminant indicators chloride, nitrate, ortho-phosphate, iron, manganese and potassium:sodium ratio in excess of the GSI threshold levels. Some interpretation is required as levels in excess of these thresholds can reflect natural conditions in some cases (e.g. elevated potassium and/or iron can occur naturally in sandstone groundwaters).
- **Group 3:** Sources with slight anomalies in the analyses which may be naturally induced or indicate some slight contamination. These are, however, inconclusive with the current data set.
- **Group 4:** Sources showing no evidence of contamination from the analyses carried out for the project.

The public supply sources are listed under each of the four groups in Table 1. The assessment has been made on the basis of information from County Council data from 1991 to present and from sampling by the GSI in 1999.

From a study of Table 1, the following points are worth noting:

- 25 supply sources lie within the Group 1 categorisation (59.5 % of the total, from available data).
- Of the 25 Group 1 sources, 8 had at least two contaminant indicators in excess of the MAC and/or at least two contaminant indicators in excess of GSI thresholds. These were Minane Bridge, Cloyne (Town Parks, Spital), Berrings, Killeagh 2, Ballinagree, Robert's Cove (Doonavanig), Ballinspittle Old (Carrigavulleen) and Coachford 1 (Fr. Sheehan Place).
- Group 2 sources constituted 21.5% of the total.
- Group 3 sources constituted 16.5% of the total.
- Group 4 sources constituted 2% of the total.

Each major parameter considered to be an important indication of groundwater contamination is discussed in the following sections, with special attention given to faecal bacteria, nitrates, chloride and the potassium:sodium ratio.

5. Faecal Bacteria

Escherichia coli (*E. coli*) is the parameter tested as an indicator of the presence of faecal bacteria and perhaps viruses: constituents which pose a significant risk to human health. The most common health problem arising from the presence of faecal bacteria in groundwater is diarrhoea, but typhoid fever, infectious hepatitis and gastrointestinal infections can also occur. Although *E. coli* are an excellent indicator of pollution, they can come from different sources - septic tank effluent, farmyard waste, landfill sites, birds.

The natural environment, in particular the soils and subsoils, can be effective in removing bacteria and viruses by predation, filtration and adsorption. There are two high risk situations: (i) where permeable sands and gravels with a shallow water table are present; and (ii) where fractured rock, particularly karstified limestone, is present close to the ground surface. The presence of clayey gravels, tills, and peat will, in many instances, hinder the vertical migration of microbes giving sufficient time for them to die off.

Two rounds of raw water sampling were carried out on over 25 major groundwater supplies in South Cork as part of the South Cork Groundwater Protection Scheme Project (Kelly & Wright, 2000a). In April 1999 8% (2 of 25 samples) of the supplies contained *E. coli* and total coliforms (see Table 1). In

September 1999, 29% (7 of 24 samples) contained *E. coli* and total coliforms (see Table 2). In karst areas where the vulnerability is extreme, rapid recharge and flushing of coliforms from the land surface, septic tank systems and farmyards into groundwater can readily occur. In gravel areas, where the vulnerability will be either high or extreme it is also expected that rapid recharge will occur. Although the gravel aquifers sampled during 1999 by the GSI showed relatively little bacteriological contamination, some history of contamination *does* appear evident in further examination of some of the results and other historical records. The supply at Minane Bridge showed 3 total coliforms in September 1999 and it is unclear whether the sample taken in April (which showed no coliforms at all) was actually a raw water sample. Historical data from this supply do highlight a problem with bacteriological contamination in the past. Council data for the Crookstown supply show no breaches of MAC levels for total or faecal coliforms since 1991. As no treatment system is installed on this supply, it can be said that the bacteriological quality of the water here is very good. The Commons East borehole at the Cloyne/Aghada WS also abstracts from a very local gravel aquifer. Water quality from this borehole is difficult to track as Council records only show data from the Cloyne WS as a whole. Raw water samples in both April and September showed no bacteriological contamination (which was very different to the other 3 boreholes all of which were highly contaminated bacteriologically).

3.2% (3 of 95 samples) of private wells sampled for the well improvement grant scheme contained some general coliforms (usually < 5, although one sample had 23 total coliforms) however no *E. coli* were detected (Table 3). This low level of exceedance may be due to the fact that many of these analyses are from samples taken after treatment systems were installed because the first sample taken did not pass the standards set.

6. Nitrates in Groundwater in South Cork

6.1 Introduction

Nitrate is one of the most common contaminants identified in groundwater. The nitrate ion is not adsorbed on clay or organic matter. It is highly mobile and under wet conditions is easily leached out of the rooting zone and through soil and permeable subsoil. It poses a potential health hazard to babies. Nitrate is found to be a problem in a significant percentage of the Council's public sources in South Cork as shown in Section 6.3.

6.2 Sources of Nitrate

Elevated nitrate levels can be derived from the following sources: septic tank effluent; slurry and soiled water in farmyards; spreading of organic wastes and fertilisers; and spreading of inorganic fertiliser.

Septic tank effluent contains nitrogen concentrations in the range 30–45 mg/l as N. As this nitrogen is usually converted to nitrate, it poses a risk to groundwater and can significantly raise nitrate levels in the vicinity of the septic tank system.

While farmyards contain large volumes of organic wastes, most are landspread and do not cause significant problems. However, infiltration of soiled or dirty water into the ground beneath and in the vicinity of farmyards can increase nitrate levels (and pollution by faecal bacteria). Also the disposal of soiled water by rain guns can raise nitrate levels in underlying groundwater if they are not moved regularly. Many farm wells in Ireland have been contaminated by soiled water.

Inorganic fertilisers are also a hazard, particularly in tillage areas (leaching of nitrates from tillage crops is generally greater than from grassland) and intensive dairying areas.

Drawing conclusions on the source of elevated nitrate levels in any particular well depends not only on assessing the nitrate data, but also the other parameters, in particular faecal bacteria, ammonia, potassium, chloride and the potassium/sodium ratio.

Of these parameters, nitrate has recently been the main focus of attention when assessing domestic and agricultural contamination of groundwater, primarily because:

- it is difficult to treat - bacteria, by comparison, can be treated relatively easily, and are therefore often of less concern to sanitary engineers
- it is the focus of recent European Legislation (the 'Nitrates Directive')
- it occurs in excess of the MAC in many groundwater supply sources in Ireland

Assessing the reasons for elevated nitrate levels also requires some knowledge of the zone of contribution (ZOC) of the well, the vulnerability and potential hazards in the ZOC. Further details on nitrate are given in Appendix 2.

6.3 Appraisal of Nitrate Data

As part of a review of draft county reports on nitrate for the EPA, the GSI have subdivided groundwater sources into four broad categories with respect to nitrate contamination.

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

Analysis of the available data has provided the following results for Co. Cork (Southern Division).

- **Category A:** 4 public supply wells fall into this category.
- **Category B**: 8 public supply wells fall into this category.
- **Category C**: 10 sources are in this category. Nitrate levels at these sources ranged from 20 to 42 mg/l (data from 1990 - 1999).
- **Category D**: 22 public supply wells and 62 out of 95 private supplies are in this category.

Nitrate levels for public supply wells sampled during April and September 1999 are given in Table 2. Out of the 20 wells that were sampled in both rounds, 19 had higher levels of nitrate in the September round.

Table 2: Possible Origin of Nitrate Contamination in Group 1 and Group 2 Water Supply Sources

Group	Nitrates Regularly Exceed GSI Threshold of 25 mg/l				Nitrates Generally less than 25 mg/l
	Supplies Where Only Nitrates Regularly exceed threshold	Supplies Where Compounds in Addition to Nitrate Also Regularly Exceed Threshold.			
		E.coli	K:Na Ratio	BOTH E.coli and Potassium:Sodium	
1.A		Stoneview/Blarney, Ballinagree, Robert's Cove (Doonavanig)		Minane Bridge	
1.B		Aghabullogue, Ballinspittle Old, Coachford 1, Killeagh, Berrings			
1.C	Ballinadee	Killeagh 1, Cloyne (Lissanly & Farrnamnannagh), Grenagh (Quarryhall), Carrigadrohid, Whitegate (Dower)		Cloyne (Town Parks)	
1.D					Kilbrittain, Newcestown, Garrettstown, Stuake, Belgooly, Grenagh (village), Clondrohid, Coachford 2
2.B	Ballymacoda, Coolyhane, Riverstick				
2.C	Ballyshoneen, Lisgoold, Coole East, Glenville, Ryefield				
2.D					Kilnamartyra
Possible Origin of Nitrates	*Landspreading*	*On-site systems*		*Farmyard Point Sources*	*Landspreading <u>unlikely</u> to be a significant source of the contamination levels identified.*

Note: Origin of nitrate levels at individual sources cannot be firmly established without a field-based hazard assessment.

However, if the main nitrate hazards are to be understood, the nitrate data cannot be seen in isolation, but must be reviewed alongside other key indicators of domestic and agricultural contamination outlined in Table 1.

Table 2 above addresses this issue by merging the groupings in Table 1 (based on all the available contaminant indicators) with nitrate categories A to D.

Points to note from Table 2 are as follows:

- Of the 25 Group 1 sources and 9 Group 2 supply sources identified in Table 1, 4 fall into Group 1A. This group requires urgent action in relation to nitrate contamination. This should involve:

  ⇒ Delineation of the Zone of Contribution (ZOC) and Source Protection Zones for each supply.

  ⇒ A field-based hazard assessment within the ZOC of each supply to assess the most likely sources of contamination.

  ⇒ Acquisition of additional water quality data on key indicators of groundwater contamination.

  If point release appears to be an important contributor to the nitrate contamination, measures should be employed to remove these sources. If landspreading appears to be an important contribution, and if additional data supports the existing categorisation of the supply sources, consideration should be given to the delineation of nitrate vulnerable zones around each supply source.

- Of the 25 Group 1 and 9 Group 2 sources/wells identified in Table 1, 8 (Groups 1B and 2B) require a fairly urgent study in relation to nitrate contamination. Essentially, this means that the same measures as those proposed for Group 1A sources are recommended, though at a lower priority and with less frequent monitoring. As with Group 1A supplies, if point sources appear to be an important contribution to the nitrate contamination, measures should be employed to remove these sources. If landspreading appears to provide an important contribution, and if additional data indicate that nitrate concentrations remain close to, or occasionally exceed, the MAC, consideration should be given to the delineation of nitrate vulnerable zones around each supply source.

- Of the 8 Group 1B and Group 2B supply sources identified above, none has elevated potassium:sodium ratios. However K:Na ratios are a continuing problem at Minane Bridge (Group 1A) and Cloyne (Town Parks borehole) (Group 1B). As such, farmyard point sources are likely to be at least an important contribution to levels of nitrate contamination. Thus, restrictions on landspreading practices alone at these four supply sources are unlikely to fully alleviate the nitrate problem.

- Of the remaining Group 1 and Group 2 supply sources identified in Table 1, 13 (Groups 1C and 2C) require a regular review of the nitrates and associated data, and 8 (Group 1D) requires no action with regard to nitrate other than the continuation of the current monitoring programme *(is this true for Coachford 2)*.

7. Chloride

Chloride, like nitrate, is a mobile anion i.e. the ions do not get bound up by the soil/subsoil as they infiltrate. In coastal areas, rainwater is enriched with chloride (Cl) due to the presence of seawater in rainfall. Therefore, groundwater in areas close to the coast often contains relatively high concentrations of chloride. Chloride is also a constituent of organic wastes and fertilisers.

The GSI threshold value for chloride is generally taken to be approx. twice the background level. The average background level for chloride for South Cork is 12–15 mg/l, therefore the threshold is taken to be 25–30 mg/l. In more coastal areas however, the threshold level may be greater than 50 mg/l. At some of the public water schemes, chloride levels greater than 30 mg/l were recorded, which would suggest that some form of contamination by organic wastes is occurring, probably seepage from septic tank systems. These included Belgooly (101 and 100 mg/l in April and September respectively), and Minane Bridge (61.9 and 55.5 mg/l, although this source is close to the sea). Levels of around 40 mg/l found at Cloyne could be as a result of organic pollution (especially when taken with the bacteriological results). However this source is also close to the sea and the levels may be just a consequence of this.

8. Potassium:Sodium ratio (K/Na)

The potassium:sodium ratio in most Irish groundwaters is less than 0.4 and often less than 0.3. The K:Na ratio of soiled water and other wastes derived from plant organic matter is considerably greater than 0.4, whereas the ratio in septic tank effluent is usually less than 0.2. Consequently a K:Na ratio greater than 0.4 can be used to indicate contamination by plant organic matter - usually from farmyards and occasionally landfill sites (from the breakdown of paper). However, a K:Na ratio below 0.4 does not indicate that farmyard wastes are not the source of contamination (or that a septic tank is the cause), as K is less mobile than Na. The K:Na ratio for most of the public supply wells sampled in South Cork in April and September 1999 was < 0.4. However, the ratio at Minane Bridge was 0.84 in April and 0.67 in September suggesting some kind of organic contamination at this infiltration gallery. The Town Parks borehole in Cloyne, also seems to have problems with organic contamination with an April value of 0.72 and a September value of 0.51. The borehole at Kilnamartyra (which was only sampled in April) may also have a problem as the ratio of 0.38 is approaching 0.4.

9. Iron and Manganese

The source of iron (Fe) can be iron minerals in the rocks or soils, pollution by organic wastes or occasionally the corrosion of iron fittings in the water system. Manganese (Mn) is frequently associated with Fe although it is less prevalent. Groundwater from certain rock types such as dark muddy limestones, shales and sandstones and from boggy areas may contain high Fe and Mn concentrations. Effluent from the wastes cause deoxygenation in the ground which results in the dissolution of Fe and Mn from the soil, subsoil and bedrock into groundwater. With reoxygenation in the well or water supply system the Fe and Mn precipitate out. The breakdown of high BOD organic wastes from farmyards and other sources can cause the formation of carbon dioxide and oxygen deficient conditions and can bring the Fe and Mn into solution in the groundwater.

High Fe concentrations have been reported in private wells in areas underlain by muddy sandstones and shales, such as the Kinsale Formation as well as in some of the mudstones of the Old Red Sandstone formations such as the Ballytrasna. It was found that 41 % (39 of 94 samples) of the well improvement grant scheme private supplies throughout South Cork had Fe and/or Mn problems in 1998/1999. It is likely that these problems are for the most part natural as there is little evidence of other contamination in the majority of cases (only 7.5% of those sources experiencing Fe/Mn problems showed evidence of bacterial contamination). It has been demonstrated that at low pumping rates water does not reside long enough in the well for oxidation to occur thereby resulting in elevated Fe and Mn in small domestic supplies (Applin *et al*, 1989).

Less than 18% (5 out of 29) of public supply boreholes/springs sampled by the GSI in 1999 had Fe and/or Mn problems. Examples are the borehole at Berrings (of the Berrings/Ballyshoneen W.S.) and the combined boreholes of the Garrettstown supply, all of which had elevated levels of iron. Elevated levels of manganese above MAC are found at the public supplies of Belgooly, Grenagh (the wells in the village), and the Town Parks borehole, Cloyne. In locally important and poor sandstone and shale aquifers large drawdowns in wells are common and can result in Fe and Mn precipitation during pumping. In regionally important limestone aquifers, Fe and Mn problems may occur where surface runoff from non-limestone rocks infiltrates the groundwater system. This problem can be accentuated in karstified limestone where rapid groundwater flow prevents the Fe and Mn precipitating prior to pumping, resulting in elevated Fe/Mn levels. Groundwater in shaley limestones can also contain high Fe and Mn such as in the Ballysteen limestone. However manganese problems, when not associated with a corresponding high level of iron, may be caused by organic contamination, as has been desribed in Section 12.11, which discusses the situation at Belgooly.

10. pH

The hydrogen ion concentration in water is expressed as pH. It ranges from 0 to 14 with a pH of 7 considered as neutral. The MAC value for pH in drinking water is between 6.0 and 9.0. The corrosive effect of low pH waters is a concern (Flanagan, 1990) and is a quite significant problem for distribution systems. It has also been noted that pH values outside the MAC range may also affect the efficiency of chlorine disinfection systems. There are a number of groundwater sources in South Cork where pH values are below 6.0. Many public water sources have pH levels that could cause problems. These have been looked at with regard to the geological unit they are abstracting from.

Those, which are located in the Gortanimill Formation of the Old Red Sandstone, are grouped together. Such sources include Ballinagree (consistently 5.1 to 6.0); Donoughmore (available data ranging from 5.6 to 5.8); Grenagh (village wells) ranging from 5.3 to 6.9; Rylane (consistently 5.7 - 5.8 in recent years) and Whitechurch/Ryefield (levels at the Ryefield well were 5.4 in 1998 and 5.5 in 1999).

The Ballytrasna Formation also has a few public water sources with low pH values, although the problems are not as acute as in the Gortanimill. These sources include Berrings/Ballyshoneen (Berrings borehole; 5.9); Newcestown (only a slight problem with values of 5.9 and 6.1) and Stoneview/Blarney (again only a slight problem at 5.6-6.0).

Data from the sampling rounds did not highlight any major problems with low pH levels in Council sources abstracting from the Cork Group (e.g. the Kinsale, Courtmacsherry, Lispatrick and White Strand Formations). Data from GSI files illustrate that there may be a few low yielding private wells with low pH problems in the Kinsale Formation as well as in the Lispatrick Formation. Values from around the Upton area in this rock type can be around 5.1. The gravels above the Lispatrick Formation also exhibit low pH (e.g. Borehole no. 5 at St. Patrick's, Upton) at 5.9.

Low pH levels are also found in some private wells in South Cork. Data from the wells bored as part of the Well Improvements Grant Scheme (see Table 3) show levels down to 5.4 in a range of different geological formations. There are a few in the Old Red Sandstones of the Gortanimill, Ballytrasna and Caha Mountain Formations with pH ranging from 5.4 to 5.94. Some domestic supplies abstracting from the Cork Group rocks such as the Kinsale Formation also show low pH, ranging from 5.6 to 5.95. A private well in Castlepark, Kinsale (information from a consultant's report; Daly, E.P, (1997)) also showed a low pH value and was abstracting from the Kinsale Formation.

The gravel aquifer at Crookstown also gives low pH waters as is exhibited by the groundwater at the Crookstown public supply, which averages 6.3 but can be as low as 5.7.

11. Turbidity

Turbidity in groundwater arises from the presence of very fine solids which cannot be filtered by routine methods (Flanagan, 1990). The presence of turbidity in groundwater will give rise to a cloudy appearance. Very little data were available for this project on *long-term* turbidity levels at the Council sources. Data from individual samples show that the great majority of public water supplies in South Cork do not have a problem with turbidity levels, even those in the karstic limestones. (Turbidity fluctuations are normally typical of a karst environment with a rapid 'flashy' response to rainfall events and short residence times).

12. Appraisal of groundwater quality in selected sources and areas

12.1 Introduction

The section contains an assessment of the water quality of sources/areas in South Cork for which source reports or groundwater studies were previously carried out. Any water quality problems identified during GSI sampling rounds are also outlined below.

12.2 Minane Bridge

- The public water supply at Minane Bridge consists of an engineered infiltration gallery, about 40 metres long, which underlies a fairly extensive tract of river gravels and alluvium on the northern side of the stream. It is located in Springhill townland just north of the village.
- The bedrock in this area is the Pig's Cove member of the Kinsale Formation and is classified as a Locally Important Aquifer, moderately permeable only in local zones (**Ll**). However the aquifer that the infiltration gallery is abstracting from is the overlying alluvial gravels, which are classified as a Locally Important Gravel Aquifer (**Lg**). The thickness of the gravel is not known, but trial pitting in 1999 and the reported depth of the gallery itself, suggests that it could be between 5 and 10 m thick (Kelly & Wright, 2000f). The groundwater in a large proportion of the catchment for this infiltration gallery is either extremely or highly vulnerable to pollution.
- Groundwater hardness values from this source are moderately hard at around 220 mg/l $CaCO_3$.
- The main water quality problem at this source is the very high levels of nitrate which have been consistently above 40 mg/l NO_3 in the last 10 years and at times up to 100 mg/l. Council records indicate that the maximum levels seem to occur in the winter months which suggests a local source of contamination and a mechanism which sees nitrogenous contaminants entering the shallow aquifer after heavy winter recharge. However, even though levels are lower in the summer months, they still average out at about 40-45 mg/l. There is some evidence for a possible downward trend with average levels falling from close to 70 down to around 50 mg/l. Further frequent monitoring of the nitrate levels at this source are needed to confirm this downward trend.
- Historical records from Cork County Council show that water from this source has quite good bacteriological quality. However, it is thought that a large proportion of these samples were treated and the characteristics of the raw water would not show through. Sampling of this source by the G.S.I. in September 1999 found 3 total coliforms per 100 ml. Samples from October 1993 (3 total per 100 ml) and January 1996 (41 total per 100 ml) also showed bacteriological contamination.
- Potassium/Sodium ratios for this source also seem to indicate some form of organic contamination. The background ratio in most groundwaters is usually less than 0.4. Soiled water and wastes from plant organic matter will have a ratio considerably greater than 0.4 (Cronin and Furey, 1998). Sampling in April and September noted ratios of 0.83 and 0.67 respectively.
- Although this source is quite close to the sea, chloride levels are not in themselves a cause for concern. They are however, slightly elevated at 61.9 mg/l in April 1999 and 55.5 mg/l in September as would be expected for a source close to tidal waters.

12.3 Robert's Cove

- The Robert's Cove Public Water Supply consists of two boreholes; a shallow one on the road into Robert's Cove (from Minane Bridge) in the townland of Doonavanig, and a deeper one by the roadside on the other side of the village in the townland of Britfieldstown.
- Both supplies are located in the Cuskinny member of the Kinsale Formation, described as bedded sandstones and mudstones. The well at Doonavanig lies quite close to a fault. This rock type is classified as a Locally Important Aquifer (**Ll**). The groundwater in both of these catchments is considered to be extremely vulnerable to pollution in some parts and highly vulnerable in others (Kelly & Wright, 2000g).
- Groundwater hardness values in these wells average about 280-290 mg/l as $CaCO_3$. This groundwater is therefore classified as 'hard'.
- The main water quality problem in this public supply is the high levels of nitrate in the shallow Doonavanig borehole. Records from 1991 to date indicate a range from near-zero to over 70 mg/l of NO_3. However it appears that the maximum levels occur in the winter months (ranging from 40 to 76 mg/l). This suggests that nitrogenous contaminants are being flushed into the aquifer after times of heavy rainfall. Nitrate levels at the other borehole in Britfieldstown are not known.
- There are no other obvious water quality problems noted in this area. The bacteriological quality of the water is also quite good.

12.4 Ballinspittle / Garrettstown

- The Ballinspittle Water Supply consists of one spring/shallow sump (at Carrigavulleen). The associated Garrettstown Water Supply consists of two boreholes, one in the village of Ballinspittle and the other in Kilmore townland close to the GAA pitch.
- All of these supplies are located in the Kinsale Formation (sandstones and mudstones) which is considered to be a Locally Important Aquifer, (**Ll**). The catchments for all three supplies have areas of land where the groundwater is extremely vulnerable to pollution (***E***). Groundwater in the remaining areas is probably highly vulnerable (Kelly & Wright, 2000b).
- Groundwater hardness values in all of these supplies range from 120 to 185 mg/l of $CaCO_3$, representing slightly to moderately hard water.
- The main water quality problem in the Ballinspittle WSS (at Carrigavulleen) is the high level of nitrates which varies from 30 to almost 60 mg/l of NO_3. The peak values are mainly found in the winter and spring which suggests there is a local source of contamination which is being flushed into the aquifer system after heavy winter rainfall. There is no obvious downward trend over time.
- The water quality in the Garrettstown boreholes is generally good. Samples are taken from a mixed supply at Garrettstown pumphouse so it is difficult to appraise the individual wells. However it can be seen that both these wells have quite high iron levels (a permanganate treatment system is already in place) and up to 6.2 mg/l of iron was found after sampling by G.S.I. in September 1999.
- Bacteriological water quality at the Ballinspittle Water Supply at the spring is also quite poor and it is thought that the relatively shallow groundwater flow which is feeding this spring is very vulnerable to pollution from the farming activities within the groundwater catchment (which is coincident with the surface water catchment). The Garrettstown Water Supply may also have some bacteriological problems. The samples taken during April and September 1999 by the G.S.I. did not show any coliforms although these were not raw samples. Historical records from Council files show that there have been breaches of bacteriological MAC levels at this supply in the past.
- The source of bacteriological contamination in the Carrigavulleen spring is probably from farming activities within the catchment and any septic tanks in the vicinity. These farming activites probably also contribute to the high levels of nitrate at the spring. The high iron levels in the Garrettstown Water Supply are probably due to the inherent nature of the rock type (namely the Kinsale Formation) that these wells are abstracting from. They are mudstones and muddy sandstones, and this, along with the relatively low abstraction rates (when compared with some of the larger public supplies), will restrict the oxidation of the naturally occurring iron and manganese, as explained in Section 9.

12.5 Coachford

- This public water supply consists of two boreholes north of Coachford village. Borehole 1 is quite deep (85 m) and is located close to some council houses. Borehole 2 is not as deep (approximately 30 m) and is located near the old railway terminus.
- Both these boreholes are abstracting from the Ballytrasna Formation which consists of mudstones with subordinate sandstones. This is a Locally Important Aquifer, (**Ll**) moderately permeable only in local zones according to the South Cork Groundwater Protection Scheme (Kelly *et al*, 2002). The groundwater around Borehole 1 is known to be extremely vulnerable in the upper reaches of the catchment to the northwest and highly vulnerable in other parts of the catchment. The groundwater around Borehole 2 is less vulnerable but still receives a high vulnerability rating due to the nature of the subsoils in the area (although they are >8 m thick) (Kelly & Wright, 2000c).
- Groundwater hardness in Borehole 1 ranges from 187 to 212 mg/l as $CaCO_3$ at Borehole 1 and 168 to 175 mg/l at Borehole 2. Groundwater in this area is therefore classified as moderately hard.
- The main water quality problem in this area is the high level of nitrate in both wells. The borehole near the council houses has quite high levels (averaging nearly 50 mg/l and sometimes exceeding it), while the well near the railway has levels which are somewhat lower but still quite close to the G.S.I. threshold level of 25 mg/l. Historical records from Cork County Council are at times from mixed samples and it is difficult to discern any trend in the data for either borehole. However it is

thought that farming activities upgradient of the borehole near the houses may be contributing to the high levels of NO_3.

- Bacteriological water quality in the area is generally quite good. The water at Borehole 1 is bacteriologically clean. However there have been breaches of the MAC at Borehole 2, and levels of total coliforms of 19 per 100 ml and *E.coli* of 1 per 100 ml were recorded in September 1999. The source of these contaminants is unknown but it is thought that septic tanks in the area may be a contributing factor.
- Iron and Manganese levels in both wells are normal and there do not appear to be any other parameters that are out of the ordinary.

12.6 Grenagh

- This public supply, situated approximately 9 km north of Blarney, comprises 3 boreholes. Two are located in the village, at a pumphouse close to some houses. The third is located near Quarryhall crossroads about 1 km south of the village. The village boreholes are 55 and 77 m deep and abstract up to 163.5 m^3/d. The borehole at Quarryhall is shallower at 23 m and abstracts 65 m^3/d.
- All these wells are abstracting from the Gortanimill Formation (of the Old Red Sandstone). This is considered to be a Locally Important Aquifer, (**Ll**) (Kelly *et al*, 2002). A source report has been carried out in this area and the catchment has been classified in vulnerability terms also (Kelly & Wright, 2000e).
- Groundwater hardness values for these boreholes range from 56 to 74 mg/l of CaCO3 at the village wells and 173 to 185 mg/l at the Quarryhall borehole. The water in the village is 'moderately soft' while that at the Quarryhall site is classified as 'moderately hard'.
- Water quality at the Quarryhall borehole is relatively good, apart from slightly elevated nitrate levels which average about 26 mg/l and can be up to 31 mg/l (Council sampling 1991–98 and GSI sampling in 1999). Not enough data are available to pick out any seasonal trend although there may be a slightly *increasing* trend over the 9 years of data. Activities upgradient of the well seem to consist of a meadow immediately above the borehole (used for keeping horses), and some grassland further upgradient. It is assumed that the houses within the catchment have septic tanks which could be a hazard, but whether they are affecting nitrate levels at the borehole is unknown.
- Other causes for concern in the Grenagh WSS can be found at the wells in the village. High manganese (Mn) levels were found during sampling in both wells in both April and September 1999. The 'old' well in the pumphouse had concentrations of 0.11 and 0.10 mg/l Mn in April and September respectively, while the nearby 'new' well outside the pumphouse had concentrations of 0.07 mg/l in both rounds. Iron levels do not seem to be above normal and it is suspected that these wells may be contaminated by organic pollutants of some kind. A sample taken in September also showed *very* high levels of total coliforms (>120 per 100 ml) which again points to local contamination. These wells also have slightly elevated levels of nitrate, averaging 23 mg/l.

12.7 Aghabullogue

- The public water supply at Aghabullogue comprises one bored well located just northeast of the village approx. 100 m from some council houses (St. Olan's estate), in a grassed field.
- The well, although currently abstracting about 40 m^3/d, is capable of 88 m^3/d (from a yield test carried out by Cork County Council in 1975). It is abstracting from the Ballytrasna Formation of the Old Red Sandstone and comprises mudstones with subordinate sandstones. This is a Locally Important Aquifer, (**Ll**) moderately permeable only in local zones according to the Groundwater Protection Scheme for Cork (Southern Division) (Kelly & Wright, 2000a).
- Groundwater hardness values for this borehole are available from historical data and from GSI sampling in April and September 1999. Average values are around 170 - 180 mg/l as $CaCO_3$. This water is therefore classified as moderately hard.
- Nitrate values are notably elevated in this borehole. Although below the MAC of 50 mg/l as NO_3, they average about 40 mg/l (37 mg/l in April 1999, 42.6 mg/l in September). There are insufficient data available to pick out any trends (seasonal or otherwise). Dairy farming takes place upgradient

of the well close to the village, but a detailed study of the catchment area has not been carried out to see if this has an affect on nitrate levels at the well.

- The bacteriological water quality at this borehole is also a problem. There is no chlorination and a sample in September 1998 found 3 total and 2 faecal coliforms per 100 ml. Similarly in September 1999, levels were breached with 11 total and 7 faecal coliforms per 100 ml. A detailed survey of potential pollution sources was not carried out as part of this project, but the houses are directly upgradient of the well and if there are any septic tanks in the vicinity these could cause problems. It was noted by the Council that there is a large septic tank on the opposite side of the field to the well. It is possible that the sewers down to this tank are crossing the field upgradient of the well, and these may be leaking and contaminating the water supply. It is recommended that a treatment system be installed for this well as soon as possible.

12.8 Ballymacoda

- This council supply consists of springs from which is abstracted about 218 m^3/d (48,000 gals/d). No data is available for this report on its construction (or exact location) but it is thought to be abstracting from the limestones in the area.
- Total hardness values for this supply are in the order of 280 mg/l of $CaCO_3$, which represents a hard water source, typical of limestones.
- The only problem with the water quality at this source is the relatively high levels of nitrate found there since 1989. Average values are around 41 mg/l NO_3 with a maximum of 49 mg/l in 1992. Values are consistently high although there are not enough seasonal data to pick out any seasonal trends. There may be a very slight indication of a downward trend over time, but more data are needed.

12.9 Killeagh

- The Killeagh public water supply comprises two wells. Killeagh #1 at Lisglasheen is on a road east of the main N25, close to and just southwest of Killeagh village. Killeagh #2 is west of Killeagh on a small road with sharp turns which crosses the old railway twice, before reaching the pumphouse which is also on the side of a road.
- Both boreholes abstract from Carboniferous Limestones. Killeagh #1 appears to be close to a fault zone with Waulsortian Limestones on the east of the fault and Ballysteen and Waulsortian on the west side. The Waulsortian is classified as a Regionally Important Aquifer where karstic flow is dominant (**Rk**). The Ballysteen Limestone is at best a locally important aquifer (**Ll**). Killeagh #2 is located in the Ballysteen Formation, with Waulsortian limestones located south of the borehole.
- Groundwater hardness values for these wells are available from sampling carried out by Cork County Council and the GSI. Average values are about 158 mg/l of $CaCO_3$ for Killeagh #1 and 291 mg/l for Killeagh #2. The groundwater in this area is therefore classified as moderately hard to hard, as would be expected for limestone-derived groundwater.
- Nitrate levels in this public water supply are a cause for concern. According to Cork County Council's 1998 report on Nitrate levels in Cork water supplies, (Cork County Council, 1998) the water from both of these wells is being mixed which brings the levels of NO_3 down to an average of 37 mg/l. However samples from Killeagh 1 at Lisglasheen indicate much higher levels (up to 62 mg/l). Samples taken by GSI in April 1999 show that the level at Lisglasheen, although high at 33.8 mg/l, was not as high as the level at Killeagh 2 which was 58.2 mg/l. It is clear that both bores have nitrate problems which may be due to farming activities within their catchments, which are largely grass dominated with some houses close to each. There are few data from summer months, but a possible pattern of levels peaking in the winter months can be seen.
- Bacteriological water quality at both wells is considered to be relatively good. A sample taken by the Council in April 1998 showed no coliforms, as was the case with the sample taken by GSI a year later.

12.10 Ballinagree

- The public water supply at Ballinagree comprises one bored well (approximately 30 m deep) by the roadside about 9 km north of Macroom.
- It is abstracting from the Gortanimill Formation of the Old Red Sandstone. These rocks are described as medium to fine grained sandstones with some interbedded siltstones. This rock type is considered to be a Locally Important Aquifer, (**Ll**) moderately permeable only in local zones according to the South Cork Groundwater Protection Scheme (Kelly *et al*, 2002). A source report was not carried out for this area and as such vulnerability information is only available for areas where rock is within 3 m of the surface. There is such an area northwest of the well but it is probably outside the catchment.
- Groundwater hardness values for this well are available from 1991 to the present from sampling by the Council (and GSI in April and September 1999). They average about 66 mg/l as $CaCO_3$. This groundwater is therefore considered as moderately soft which is typical of this rock type.
- High nitrate levels are noted at this well and historical data show that the average level is 49 mg/l NO_3. There are not enough available data to pick out any long term or seasonal trends, as most of the samples were taken in the winter months. However, those taken in the summer also have high levels of nitrate (48 mg/l in July 1996 and 51 mg/l in June 1993). It is possible that the nitrate in this public water supply may be getting to the source by a different mechanism than at most of the supplies described above. This may be an aquifer which has high levels of nitrate on quite a large areal scale. A high nitrate level in the summer of 1996 (51 mg/l) was lowered by winter rainfall in early 1997 to 38.7 mg/l. However, with a lack of a good range of data from different seasons it is difficult to prove this hypothesis. More frequent monitoring of this borehole is needed.
- Bacteriological water quality at this supply is generally quite good, considering there is no treatment system in operation. Coliforms have been found in samples in the past (July 1992, October 1995 and September 1998) but levels are not any higher than 4 per 100 ml.

12.11 Belgooly

- This public water supply consists of one well near the bridge just west of Belgooly village. Data from 1987 suggest the well is capable of yielding over 200 m^3/d. It is abstracting from the Courtmacsherry Formation of the Cork Group. These rocks are described as calcareous and non-calcareous nodular mudstones, which may have subsidiary limestones. The more limestone-rich facies is found in this area between Belgooly and Ringabella. The mudstones/limestones are classified as a Locally Important Aquifer, (**Ll**) moderately permeable only in local zones (Kelly & Wright, 2000a).
- Groundwater hardness values for these rocks are in the order of 297 mg/l $CaCO_3$ (April 1999) to 317 mg/l (September 1999). The water is classified as 'hard'. This supports the geological description of more limestone-rich rocks in this area. Nitrate levels at this borehole are not considered to be a problem with levels around 5 mg/l.
- The main water quality problem at this well is the high level of manganese (Mn). Sampling in April and September showed levels of 0.29 and 0.3 mg/l respectively (the MAC is 0.05 mg/l). Other data from Council records show that the level can be lower but the 1999 values are considered to be worryingly high. High iron (Fe) and manganese (Mn) levels can occur naturally in some groundwaters, particularly those of the Cork Group rocks (Section 9). However iron levels at this well seem to be well below the MAC (<0.05 mg/l). High manganese levels are also good indicators of organic contamination and also specifically, silage effluent. It can also be caused by other high BOD wastes such as milk, soiled water and septic tank effluent. A detailed study of all possible pollution sources within the catchment of the well is recommended.
- Chloride levels at this well are also of concern, considering the inland location of this well. Concentrations of 94-100 mg/l are typical at this source, and are much higher than at nearby Riverstick (40 mg/l) and Nohoval (23 mg/l). (Nohoval is actually closer to the sea than Riverstick or Belgooly). Chloride is a constituent of organic wastes such as seepage from septic tanks systems or farmyard wastes (Cronin & Furey, 1998) and once again an assessment of possible pollution sources needs to be carried out.

13. Overall Assessment

♦ The hydrochemistry of groundwater in County Cork is primarily influenced by the nature of the subsoil and bedrock that it passes through. The groundwater in the limestone areas (mainly East Cork) is hard and can be classed as calcium bicarbonate ($Ca(HCO_3)_2$) type water. Softer waters are found in the remaining areas (southern areas around Kinsale etc.; the Cork Group, along with the western areas of the Devonian Old Red Sandstone), where the bedrock comprises mainly sandstones, siltstones and shales.

♦ The main groundwater quality problems in County Cork are:
- high nitrate levels in a lot of major sources
- high iron (Fe) and manganese (Mn)
- bacteriological pollution

♦ The most important groundwater quality issue in County Cork is the presence of high nitrate levels in many of the public supplies as well as in some private supplies.

♦ The high nitrate levels in such a high proportion of groundwater supplies in Cork is due to:
- the 'extremely' vulnerable conditions in areas around the sources, where thin subsoils provide only limited protection
- poorly designed, located and constructed septic tank systems and farmyards
- landspreading of organic wastes
- poor siting and construction of wells

♦ The high iron (Fe) and manganese (Mn) concentrations are caused mainly by the natural conditions in the ground and the natural chemistry of the groundwater. This may occur in areas underlain by peat, muddy limestones, the Old Red Sandstone and the Cork Group rocks, where reducing conditions result in solution of Fe and/or Mn from the geological materials. This causes taste and aesthetic problems. High manganese levels may also occur from pollution by silage effluent.

♦ Another important issue in County Cork is the presence of faecal bacteria in public and private water supplies. A significant proportion of the public groundwater supplies (8 out of 25) contained faecal bacteria during GSI sampling of raw waters. In certain areas, a high proportion of private wells (>50%) are also likely to be polluted, at least intermittently, due to the proximity of local pollution sources such as septic tanks or farmyard wastes. While the presence/absence of faecal bacteria is considered to be the most reliable indicator of microbiological water quality, they are not reflective of the presence/absence of other non bacterial pathogens in a supply.

♦ From Table 1, it can be seen that 25 supply sources lie within the Group 1 categorisation, meaning that they are 'polluted' and that at least one indicator compound is, or has been, in excess of the drinking water MAC. A further 9 supplies showed evidence of contamination (but not pollution). These supplies have the potential to become polluted if corrective or preventative action is not taken.

♦ Groups 1A, 1B and 2B constitute the highest priority in terms of nitrate problems. There are 12 sources in these groupings:

- Minane Bridge
- Stoneview/Blarney
- Ballinagree
- Robert's Cove (Doonavanig)
- Aghabullogue,
- Ballinspittle Old (Carrigavulleen)
- Coachford 1
- Killeagh
- Berrings
- Ballymacoda
- Coolyhane
- Riverstick

Prompt action is required at these supply sources to increase the frequency of monitoring data available and to identify the origin of contamination. The latter requires a delineation of the water catchment for each supply. This has been carried out already at Minane Bridge, Robert's Cove, Ballinspittle and Coachford. An on-site hazard survey would also be very useful within each catchment delineated. This study, and subsequent decisions on alleviation measures, would be greatly enhanced by the delineation of source protection zones within each supply catchment.

- Restrictions on landspreading (such as those identified in the European 'Nitrates Directive') are unlikely to adequately address the nitrate contamination issues in those supply sources where farmyard waste and other point sources are an important contribution to the levels of contamination identified. However, on-site hazards surveys are required to augment these interpretations.

14. Recommendations

- The GSI recommends that a database on the location, groundwater quality and construction details of all water supply sources is constructed to enable an improved and continuing assessment.
- Group 1A, 1B, and 2B supplies require action to identify and remove the source of nitrate contamination. The likely origins of the nitrate contamination at these supply sources cannot be adequately assessed without consideration of other indicator compounds and an on-site survey of potential contamination hazards. Clearly, the nitrate problem at a source cannot be alleviated without adequate consideration of the origin of the problem. Further, the hazards cannot be adequately or efficiently examined without prior consideration of the groundwater catchment for each supply. This is best achieved by commissioning source protection zones studies from the GSI or suitably-qualified consultants, for those sources that do not already have zones delineated.
- All supply sources require analysis of raw water as well as treated water samples on a regular basis. Full analyses (including all major ions) should be carried out on these samples. The frequency of sampling at each supply source should be influenced by the degree of concern at each source. The following is recommended:

Group	Number of supply sources in each group	Recommended sampling frequency
Group 1A	4	At least *fortnightly*, until conclusions can be drawn on the origin of the contamination and appropriate alleviation measures are taken. Then down-grade to Group 3 sampling frequency.
Group 1B	5	At least *monthly*, until conclusions can be drawn on the origin of the contamination and appropriate alleviation measures are taken. Then down-grade to Group 3 sampling frequency.
Group 2B	3	At least *monthly*, until conclusions can be drawn on the origin of the contamination and appropriate alleviation measures are taken. Then down-grade to Group 3 sampling frequency.
Groups 1C, 1D, 2C, 2D.	22	At least *quarterly*, until conclusions can be drawn on the origin of the contamination and appropriate alleviation measures are taken. Then down-grade to Group 3 sampling frequency.
Groups 3 and 4	8	At least twice yearly.

- Indicators of organic compound contamination, including those of petroleum, pesticide, sheep dip and herbicide substances, should be included at least twice yearly. One example is to undertake a 'semi-volatile organic carbon' scan on selected samples. These analyses are relatively cheap and suitably-accredited laboratories should be able to identify indicator compounds of all the above substances from such scans (e.g. certain phenols and permethrin, when found together, can indicate sheep dip contamination). Analyses such as these cannot give the precise concentrations required for drinking water analyses. However, they can identify the indicator compounds, where they occur, to a level comparable with the detection limits specified in drinking water criteria. Once detected in a supply source sample, more specific compounds can be examined. For example, if diesel fuel-related compounds have been detected in a scan, analysis of total petroleum hydrocarbons can be requested for additional samples.
- Groundwater protection zone delineation around public and group scheme supplies, using the GSI guidelines, is recommended for those sources that have not yet been looked at, over the next few

years. After the main supply sources of nitrates concern have been addressed in this manner, Groups 1, 2 and 3 sources should be used in prioritising sources for this work.

- ♦ A programme of checking the sanitary protection at each well and spring site (i.e. on Council property immediately around the source) would help to ensure that shallow groundwater and surface water, and accidental spillages, do not contaminate the source.
- ♦ All group scheme water supplies should be disinfected adequately.

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April 1999																				
Source	**NO_3**	**Ca**	**Mg**	**K**	**Na**	**Cl**	**NO_2**	**SO_4**	**Alk**	**Hard**	**E.C.**	**pH**	**Fe**	**Mn**	**NH_4**	**Cu**	**PO_4**	**Zn**	**TC**	**E.coli**
Stoneview/Blarney	32.9[a]	20.4	7.9	1.2	14.3	20.9	<0.013	16.6		83	227	6.1	<0.05	<0.05	<0.026	<0.04	0.032	<0.05	0	0
Ryefield	25.3[a]	8.1	7.5	0.7	12	18.7	<0.013	7.9		51	152	5.5[b]	<0.05	<0.05	<0.026	<0.04		<0.05	0	0
Grenagh Old	23.1	16.8	7.3	1	14.8	25.8[a]	<0.013	8.8		72	200	5.8[b]	<0.05	0.11[b]	<0.026	<0.04	0.047	<0.05	0	0
Grenagh 'New'	23.5	8.4	8.5	1.1	15.1	29.2[a]	<0.013	11.1		56	181	5.4[b]	<0.05	0.07[b]	<0.026	<0.04	0.038	<0.05	0	0
Quarryhall (Grenagh)	31.1[a]	51.6	10.8	2	15	27[a]	<0.013	10		173	365	6.6	<0.05	<0.05	<0.026	<0.04	0.025	<0.05	***1***[b]	***1***[b]
Glenville	17.2	16.5	5.6	2.6	16.5	29[a]	<0.013	5.4		64	195	6.1	<0.05	<0.05	<0.026	<0.04	0.08	<0.05	0	0
Donoughmore (Stuake)	19	10.9	3.9	0.4	8.1	15	<0.013	11.1		43	125	5.3[b]	<0.05	<0.05	<0.026	<0.04	0.015	<0.05	0	0
Rylane (village)	13.8	13.6	5.7	0.7	10.1	15.9	<0.013	7.5		57	142	5.8[b]	<0.05	<0.05	<0.026	<0.04	0.013	<0.05	0	0
Rylane (NW of village)	13.3	13.3	4.4	0.8	8.8	13.3	<0.013	8.9		51	142	5.8[b]	<0.05	<0.05	<0.026	<0.04		<0.05	0	0
Aghabullogue	37.3[a]	56.4	7.4	1.1	13.4	21	<0.013	7.5		171	350	7.1	<0.05	<0.05	<0.026	<0.04	0.03	<0.05	0	0
Coachford Bore 2	23.5	39.7	16.8	1.2	14.5	24	<0.013	11.7		168	341	7	<0.05	<0.05	<0.026	<0.04	0.021	<0.05	***1***[b]	0
Coachford Bore 1	48.4[a]	47.6	16.5	1.7	14.3	28.2[a]	<0.013	15.6		187	397	7	<0.05	<0.05	<0.026	<0.04	0.02	<0.05	0	0
Killeagh Bore 1	33.8[a]	43.8	11.9	3.6	16.7	29.2[a]	<0.013	11.7		158	355	6.8	<0.05	<0.05	<0.026	<0.04	0.131	<0.05	0	0
Killeagh Bore 2	58.2[b]	96.9	12	4.9[a]	17.8	37.8[a]	<0.013	16		291	585	7.2	<0.05	<0.05	<0.026	<0.04		<0.05	0	0
Cloyne (Commons East)	19.1	107	7.6	1.6	18.2	35.7[a]	<0.013	16		299	581	7.4	<0.05	<0.05	<0.026	<0.04	0.025	<0.05	0	0
Cloyne (Town Park)	26.2[a]	112	9.6	17[b]	23.2	37.5[a]	<0.013	27.7		319	637	7.3	<0.05	<0.05	<0.026	<0.04	0.027	<0.05	***20***[b]	***3***[b]
Cloyne (Lissanly)	34.2[a]	118	8.1	1.6	18.4	40.4[a]	<0.013	16.1		329	606	7.3	<0.05	<0.05	<0.026	<0.04		<0.05	0	0
Cloyne (Farranamannagh)	30.7[a]	102	12.7	2.2	19.5	42.3[a]	<0.013	17.9		307	588	7.3	<0.05	<0.05	<0.026	<0.04		<0.05	0	0
Garrettstown WS (@ p/house)	1.78	43.9	18.4	2.5	27.9	36.8[a]	<0.013	32.7		185	433	6.7	<0.05	<0.05	<0.026	<0.04	0.094	<0.05	0	0
Belgooly	5.1	95.3	14.4	1.2	58.1	101.5[a]	<0.013	48.8		297	732	7.3	<0.05	0.29[b]	<0.026	<0.04	0.017	<0.05	0	0
Minane Bridge	43.1[a]	33.7	13.5	25[a]	29.8	61.9	<0.013	29.2		140	445	6.4	<0.05	<0.05	<0.026	<0.04	0.026	<0.05	0	0
Robert's Cove (Doonavanig)	48.6[a]	97	12.7	1.7	24.5	47.3[a]	<0.013	19.8		295	598	6.9	<0.05	<0.05	<0.026	<0.04		<0.05	0	0
Ballinagree	51.1[b]	13	6.5	0.7	9.2	16.2	<0.013	4.3		59	168	5.1[b]	<0.05	<0.05	<0.026	<0.04		<0.05	0	0
Coolyhane	47.1[a]	62	16.1	0.9	15.3	24.2	<0.013	6.2		221	427	7.1	<0.05	<0.05	<0.026	<0.04	0.013	<0.05	0	0
Kilnamartyra	12	37.6	10.7	5[a]	13	18.8	<0.013	11.5		138	294	6.8	<0.005	<0.05	<0.026	<0.04	0.025	<0.05	0	0

Table 1: Hydrochemical and Bacteriological Analyses for Groundwater Sources in South Cork (sampled in April 1999)

x[a] denotes levels higher than GSI threshold levels.

x[b] denote MAC exceedances.

All units for chemical parameters are mg/l; TC and EColi are numbers/100 ml.

All chemical analyses were carried out by Cork County Council Laboratories at Inniscarra.

September 1999																		
Source	NO_3	Ca	Mg	K	Na	Cl	NO_2	SO_4	Alk	Hard	E.C.	pH	Fe	Mn	Cu	PO_4	Zn	TC	E.coli
Stoneview Blarney	38.8[a]	23.4	9.0	1.2	14	19.7	<0.013	19.4	41	95.4	23	6	<0.1	<0.05	0.08	<0.01	<0.05	***1***[b]	0
Glenville	15.7	18.9	5.9	1.6	17.4	26.6[a]	<0.013	7.4	45	71.4	200	6.1	<0.1	<0.05	<0.02	0.139	0.08	0	0
Aghabullogue	42.6[a]	58.1	7.8	1.1	13.7	10.8	<0.013	10.7	131	176.7	365	6.8	<0.1	<0.05	<0.02	<0.01	<0.05	***11***[b]	***7***[b]
Crookstown	21.2	31.6	6.4	3.1	12.6	19.8	<0.013	15.9	70	105.2	343	6.4	<0.1	<0.05	<0.02	<0.01	<0.05	0	0
Coachford Bore 2	23.7	41.4	17.6	1.3	15.3	22.6	<0.013	15.4	125	175.1	346	6.9	<0.1	<0.05	0.05	0.08	0.14	***19***[b]	***1***[b]
Coachford Bore 1	50.4[b]	53.6	19.2	1.8	16.2	27.2[a]	<0.013	18.3	133	212.2	420	7.1	<0.1	<0.05	<0.02	<0.01	<0.05	0	0
Belgooly	5	102	15.6	1.2	59.4	100[a]	0.03	48	219	317.3	728	7.3	<0.1	0.3[b]	<0.02	<0.01	<0.05	0	0
Ryefield	27.7[a]	7.8	7.6	0.8	12.1	18.5	<0.013	11.1	17	50.7	152	5.3[b]	<0.1	<0.05	0.02	<0.01	0.05	0	0
Grenagh 'Old'	24.3	16.8	7.84	1.1	16	24.9	<0.013	12.4	37	74.0	201	5.8[b]	<0.1	0.1[b]	<0.02	<0.01	0.08	***120***[b]	0
Grenagh 'New'	27.1[a]	8.65	9.1	1.1	17	28.1[a]	<0.013	14.7	17	58.9	187	5.3[b]	<0.1	0.07[b]	<0.02	<0.01	0.06	0	0
Quarryhall (Grenagh)	31.7[a]	55.3	11.5	2	16.8	27.2[a]	<0.013	13.2	128	184.7	372	6.6	<0.1	<0.05	<0.02	<0.01	<0.05	0	0
Donoughmore (Stuake)	20.9	11.7	3.9	0.4	8.9	15.5	<0.013	9.4	19	45.0	132	5.5[b]	0.14	<0.05	<0.02	<0.01	<0.05	***38***[b]	***25***[b]
Rylane (village)	15.9	13.4	5.9	0.7	10.2	16.3	<0.013	10.3	36	57.6	154	5.8[b]	<0.1	<0.05	<0.02	<0.01	<0.05	0	0
Rylane (NW of village)	15.5	13.9	5.1	0.7	9.52	15.3	<0.013	11.6	33	55.8	148	5.8[b]	<0.1	<0.05	<0.02	<0.01	<0.05	0	0
Ballinagree	53.6[b]	14	7.45	0.7	10.1	17.6	<0.013	7.3	14	65.5	174	5.3[b]	<0.1	<0.05	<0.02	<0.01	<0.05	0	0
Minane Bridge	44.3[a]	36.2	15.6	22[b]	31.9	55.5	<0.013	31.9	80	154.6	445	6.4	<0.1	<0.05	<0.02	<0.01	0.07	***3***[b]	0
Ballinspittle (Carrigavulleen)	49.8[a]	42.7	9.5	3	22.8	38.5[a]	<0.013	15.9	78	145.4	365	6.5	<0.1	<0.05	<0.02	<0.01	<0.05	0	0
Garrettstown	<1.78	28.1	12.1	1.3	24.8	37.5[a]	<0.013	(81?)	86	119.9	606	6.6	6.2	<0.05	<0.02	<0.01	<0.05	0	0
Cloyne (Town Parks)	28.3[a]	117	11	13[b]	25.5	35.3[a]	<0.013	31.4	270	337.4	659	7.5	<0.1	0.06[b]	<0.02	<0.01	<0.05	***120***[b]	***79***[b]
Cloyne (Lissanly)	38.2[a]	123	9.85	2	19.5	37.4[a]	<0.013	19	268	347.3	644	7.3	<0.1	<0.05	<0.02	<0.01	<0.05	***22***[b]	***8***[b]
Cloyne (Farranamannagh)	31.4[a]	106	13.9	2.4	20.6	39[a]	<0.013	20.7	241	321.8	605	7.4	<0.1	<0.05	<0.02	<0.01	<0.05	***29***	***18***
Cloyne (Commons East)	20.9	114	8.2	1.7	19.3	33.4[a]	<0.013	18.8	248	317.7	596	7.4	0.16	<0.05	<0.02	<0.01	<0.05	0	0
Berrings	45[a]	22.1	13.3	2	23.8	27.4[a]	<0.013	38.1	41	109.6	293	5.9[b]	0.61	<0.05	<0.02	0.076	<0.05	***30***[b]	***14***[b]
Ballyshoneen	44[a]	54.8	10.8	2.3	19.2	19.9	<0.013	20.2	126	180.8	374	6.8	<0.1	<0.05	<0.02	<0.01	<0.05	0	0

Table 2 Hydrochemical and Bacteriological Analyses for Groundwater Sources in South Cork (sampled in September 1999)

x^a denotes levels higher than GSI Guidelevels.
All units for chemical parameters are mg/l; TC and E. coli are numbers/100 ml

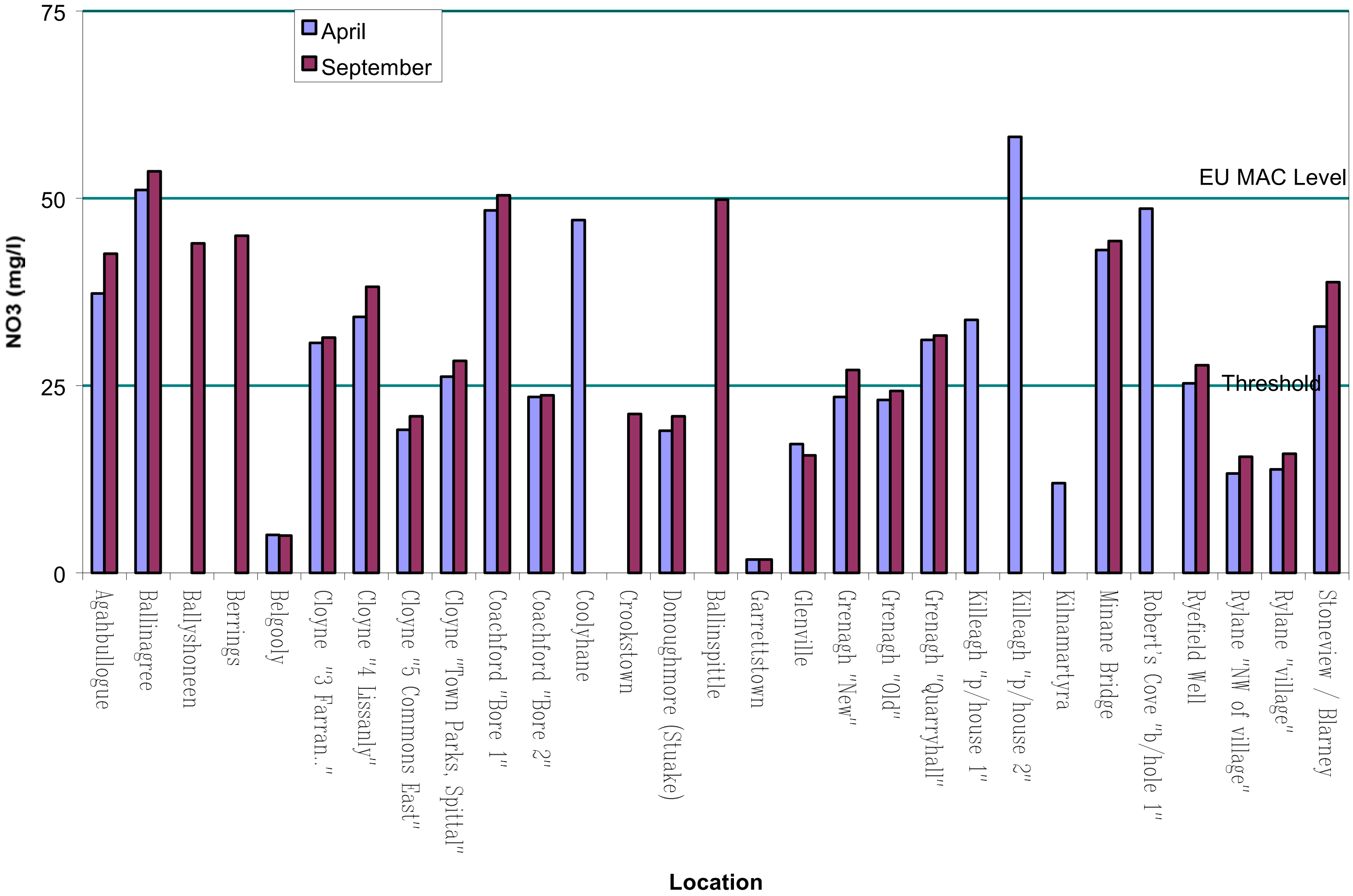
x^b denote MAC exceedances.
All chemical analyses were carried out by Cork County Council Laboratories at Inniscarra.

Location	Rock Type	NO_3	pH	Fe	Mn	Coliforms	E. C.
							μS/cm
Creighmore, Youghal	Carb. Limestones (Little Island)	24	7.31	<0.04	0.18 [b]	0	796
Creighmore, Youghal	Carb. Limestones (Little Island)	34 [a]	7.29	<0.04	<0.02	0	781
Ballinascartha, Midleton	Carb. Limestones (Waulsortian or Ballysteen)	18.0	5.85 [b]	2.7 [b]	0.059 [b]	0	250
Lispatrick, Old Head	Cork Group (Courtmacsherry)	4.8	6.3	0.167	0.005	0	634
Ballinamona, Dunderrow	Cork Group (Courtmacsherry)	25.1 [a]	6.77	0.022	0.001	0	365
Tracton, Minane Bridge	Cork Group (Courtmacsherry)	4.4	6.88	6.1 [b]	1	0	310
Whitegate, Midleton	Cork Group (Kinsale Cuskinny or Old Head)	29.92 [a]	6.2	0.151	<0.001	0	280
Ballyvorane, Minane Bridge	Cork Group (Kinsale Cuskinny)	39.16 [a]	5.61 [b]	0.15	0.4 [b]	0	
Ballinacourtha, Belgooly	Cork Group (Kinsale Cuskinny)	×	5.6 [b]	0.056	0.026	0	1500 [b]
Dunbogey, Nohoval	Cork Group (Kinsale Narrow Cove)	0.4	6.2	1.4 [b]	0.6 [b]	0	290
Ballymacredmond	Cork Group (Kinsale Narrow Cove)	17.6	5.9 [b]	0.067	0.019	0	270
Dunbogey, Nohoval	Cork Group (Kinsale Narrow Cove)	×	5.8 [b]	0.187	0.02	0	170
Oysterhaven, Kinsale	Cork Group (Kinsale Narrow Cove)	24.64	6.25	0.024	0.004	0	300
Knocknabinny, Kinsale	Cork Group (Kinsale Pig's Cove)	14.5	6.3	0.265 [b]	0.09 [b]	0	290
Knocknabinny, Kinsale	Cork Group (Kinsale Pig's Cove)	1	5.9 [b]	0.015	0.052 [b]	0	270
Knocknacurra, Bandon	Cork Group (Kinsale)	×	6.7	0.143	0.343 [b]	0	340
Ballycatteen, Ballinspittle	Cork Group (Kinsale)	32.12 [a]	6.54	0.024	0.364 [b]	0	280
Knocksmall, Dunderrow	Cork Group (Kinsale)	6.6	6.1	0.138	0.059 [b]	0	160
Kilmacsimon, Bandon	Cork Group (Kinsale)	11.44	6.96	0.006	0.254 [b]	0	380
Killountain, Bandon	Cork Group (Kinsale)	13	5.82	0.41	0.357	0	198
Clancoolbeg, Bandon	Cork Group (Old Head)	34.75 [a]	×	0.156	0.34 [b]	0	×
Coolatooder, Ballinhassig	Cork Group (Old Head)	×	5.1 [b]	0.018	0.008	0	×
Clancoolbeg, Bandon	Cork Group (Old Head)	4.84	5.95 [b]	0.05	0.06	0	335
Tullyglass, Enniskeane	Cork Group (Old Head)	17	6.2	0.07	0.006	0	169
Meadstown, Carrigaline	Cork Group (White Strand)	14.1	6.02	0.023	0.009	0	400
Coolavokig	ORS	11.8	6.5	0.11	0.001	0	280
Caherbaroule, Macroom	ORS (Ballytrasna or Gortanimill)	13.64	6.26	0.408 [b]	0.015	0	220
Ballyandreen, Ballycotton	ORS (Ballytrasna)	10.56	×	0.021	0.086 [b]	×	640
Ballinvriskig, White's Cross	ORS (Ballytrasna)	×	5.7 [b]	0.016	0.017	0	330
Ballinvriskig, White's Cross	ORS (Ballytrasna)	30.0 [a]	6.97	<0.04	×	×	507
Killeen, Aghabullogue	ORS (Ballytrasna)	26.4 [a]	5.94 [b]	0.011	0.011	0	215
Monavarnogue, Killeagh	ORS (Ballytrasna)	39.16 [a]	×	0.179	0.105 [b]	23 Total [b]	×
Drishane, Killeagh	ORS (Ballytrasna)	25.1 [a]	6.57	0.022	0.02	0	340
Shanakill, Macroom	ORS (Ballytrasna)	29.0 [a]	6.99	0.181	0.203 [b]	0	580
Gort, Vicarstown	ORS (Ballytrasna)	×	7.2	<0.02	0.015	0	390
Ballyregan, Churchtown	ORS (Ballytrasna)	26.4 [a]	6.23	0.047	0.087 [b]	4 Total [b]	540
Ballynacrusha, Cobh	ORS (Ballytrasna)	43.56 [a]	6.71	0.07	0.138 [b]	0	×
Pluckanes North	ORS (Ballytrasna)	21.12	6.86	0.123	0.07 [b]	0	×
Knockmalavogue, Spur Hill	ORS (Ballytrasna)	×	6.3	0.15	0.029	0	210
Drishane, Killeagh	ORS (Ballytrasna)	19.4	6	0.321 [b]	0.008	0	410
Ballinahina, White's Cross	ORS (Ballytrasna)	28.16 [a]	6.22	0.054	0.002	0	260
Ballincrokig, White's Cross	ORS (Ballytrasna)	66 [b]	5.5 [b]	0.227 [b]	×	0	230
Lahardane, White's Cross	ORS (Ballytrasna)	15	5.9 [b]	0.016	<0.02	0	810
Ballincurrig, Leamlara	ORS (Ballytrasna)	17.6	5.4 [b]	0.035	0.043	0	458
Ballincolly, Ballyvourney	ORS (Ballytrasna)	8.8	6.8	0.013	0.204 [b]	0	240
Belmount Lwr, Crookstown	ORS (Ballytrasna)	22	6.22	0.04	0.002	0	300
Ballincolly, Ballyvolane	ORS (Ballytrasna)	7.7	6.6	0.06	0.019	0	200

Loughleigh, Carrigadrohid	ORS (Ballytrasna)	5.1	6.66	0.03	0.164	0	×
Location	**Rock Type**	**NO_3**	**pH**	**Fe**	**Mn**	**Coliforms**	**E. C.**
Carrigadrohid, Macroom	ORS (Ballytrasna)	32.0 [a]	6.89	<0.04	<0.02	0	362
Leades, Coachford	ORS (Ballytrasna)	8.8	6.76	0.068	0.033	0	310
Knocknahorgan, Glanmire	ORS (Ballytrasna)	5.0	6.45	<0.1	<0.1	0	600
Berrings (P.O.)	ORS (Ballytrasna)	29.0 [a]	6.15	0.049	0.002	0	240
South Berrings	ORS (Ballytrasna)	25.0 [a]	7.66	0.012	0.001	0	310
Aghavrin, Coachford	ORS (Ballytrasna)	15.4	6.27	0.057	0.076 [b]	0	240
Spur Hill, Doughcloyne	ORS (Ballytrasna)	14.0	7.49	0.024	0.016	0	369
Ovens, Ballincollig	ORS (Ballytrasna)	58.96 [b]	6.36	0.056	0.07 [b]	0	385
Barraghaurin, Donoughmore	ORS (Ballytrasna)	4.84	6.65	0.111	0.053 [b]	0	240
Ballydonagh, Dungourney	ORS (Ballytrasna)	13.64	6.05	0.04	0.011	0	200
Derryroe, Macroom	ORS (Ballytrasna)	5.9	6.06	0.04	0.062 [b]	0	×
Lyravarrig, Glenville	ORS (Ballytrasna)	14.85	5.3	0.06	0.11	0	160
Couragh, Dungourney	ORS (Ballytrasna)	46.64	6.31	0.02	0.024	0	350
Barnaviddane, Inch	ORS (Ballytrasna)	20.24	6.23	0.53	0.008	0	180
Carhoo Lower, Coachford	ORS (Ballytrasna)	10.125	6.2	<0.05	0.02	0	190
Clohina, Kilnamartyra	ORS (Bird Hill)	3.96	6.38	0.084	0.001	0	220
Renaniree, Macroom	ORS (Bird Hill)	7.04	6.93	0.224 [b]	0.056 [b]	0	310
Cahirvereen, Kilnamartyra	ORS (Bird Hill)	11.88	7.4	0.007	0.004	0	400
Carrigahine, Macroom	ORS (Caha Mountain or Gortanimill)		7.31	0.05	0.07 [b]	0	529
Coolavokig, Macroom	ORS (Caha Mountain or Gortanimill)	2.9	7.0	<0.03	<0.005	0	×
Candromay, Kilamartyra	ORS (Caha Mountain or Gortanimill)	2.2	6.86	0.368 [b]	0.78 [b]	0	300
Coolea, Macroom	ORS (Caha Mountain)	3.5	5.72 [b]	<0.02	<0.01	0	×
Droumdubh, Macroom	ORS (Caha Mountain)		6.3	0.054	0.064 [b]	0	190
Dirrees, Coolea	ORS (CH or Bird Hill)	3.52	6.6	0.051	1.55 [b]	0	275
Ballymartin, Grenagh	ORS (Gortanimill)	2.3	6.96	0.06	<0.02	0	×
Drumgarriffe, Whitechurch	ORS (Gortanimill)	13.64	5.71 [b]	0.066	0.057 [b]	0	135
Bawnmore, Macroom	ORS (Gortanimill)	4.47	6.7	0.01	0.105 [b]	0	390
Rathduff, Grenagh	ORS (Gortanimill)	59.84 [a]	6.93	0.226 [b]	0.048	0	1000
Derrananig, Reinarree	ORS (Gortanimill)	3.05	7.6	<0.05	0.04	0	170
Togher, Ballymakeera	ORS (Gortanimill)	3.0	7.18	0.21	0.02	0	372
Coolnacageragh, Lissacresig	ORS (Gortanimill)	<1	7.2	0.092	0.018	0	280
Coolea, Macroom	ORS (Gun Point or Caha Mountain)	10.12	6.12	0.01	0.005	0	175
Milleens, Coolea	ORS (Gun Point or Caha Mountain)	0.88	6.81	0.068	0.053 [b]	0	280
Derrinasaggart, Ballyvourney	ORS (Gun Point)	8.36	7.5	0.1	0.466 [b]	0	280
Bardinchy, Coolea	ORS (Gun Point)	5.28	7.1	0.185	0.044	0	350
Ballymakeera	ORS (Gun Point)	11	6.84	0.09	0.136 [b]	0	319
Coolea, Macroom	ORS (Gun Point)	1.02	7.0	<0.1	0.39 [b]	0	290
Boycestown	ORS (Gyleen (bn))	4.0	7.3	0.12	0	0	×
Barrakilla, Rostellan	ORS (Gyleen (bn))	63.8 [b]	×	0.128	0.018	0	×
Ballyrussell, Midleton	ORS (Gyleen (bn))	9.68	6.78	0.016	0.009	0	370
Raffeen Hill, Monstown	ORS (Gyleen or Ballytrasna)	18.48	6.47	0.029	0.01	0	280
Ballyvatta, Leamlara	ORS (Gyleen or Ballytrasna)	36.0 [a]	6.16	<0.04	0.07 [b]	0	242
Ballybrasil, Cobh	ORS (Gyleen)	44 [a]	7.1	0.017	0.009	0	370
Templemartin, Bandon	ORS (Gyleen)	19.36	6.93	0.017	0.007	0	320
Lackeragh, Lissarda	ORS (Toe Head)	1.76	7.43	0.23 [b]	0.1 [b]	4 Total [b]	380

Table 3: Well Improvement Grant Scheme Data (1997 - 1999)

Nitrate Values for County Council Sources sampled in April and September 1999



APPENDIX
Indicators of Groundwater Contamination: A Discussion
(from Daly, 1996)

A1 Introduction

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

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

TABLE A1

Recommended Parameters		
Appearance	Calcium (Ca)	Nitrate ($N0_3$)*
Sediment	Magnesium (Mg)	Ammonia (NH_3)*
pH (lab)	Sodium (Na)	Iron (Fe)*
Electrical Conductivity (EC)*	Potassium (K)*	Manganese (Mn)*
Total Hardness	Chloride (Cl)*	
General coliform	Sulphate ($S0_4$)*	
E. coli *	Alkalinity	
Optional Parameters (depending on local circumstances or reasons for sampling)		
Fluoride (F)	Fatty acids *	Zinc (Zn)
Orthophosphate	Trace organics *	Copper (Cu)
Nitrite ($N0_2$)*	TOC *	Lead (Pb)
B.O.D.*	Boron (B) *	Other metals
Dissolved Oxygen *	Cadmium (Cd)	
*** good indicators of contamination**		

A2 Faecal Bacteria and Other Pathogens

For assessment of the microbiological quality of water, it is the faecal coliform count which is the primary indicator of pollution of faecal origin in the water. While there is no absolute correlation between the coliform presence and other bacterial pathogens due to the variable and unpredictable behaviour of pathogens, the underlying principle of the test for faecal coliforms is that its presence in waters indicates the potential presence of pathogens. The usefulness of the test as indicators of protozoan or viral contamination is limited. The most common health problems arising from the presence of microbial agents include diarrhoea, gastro-enteritis, giardiasis, cryptospiridiosis and hepatitis. Sources of *E. coli* include septic tank effluent, farmyard waste, landfill sites and birds. There is no reliable method to distinguish between animal and human waste sources. Establishing water quality criteria for viruses and protozoan pathogens is difficult as the infective dose for all strains is generally unknown. In addition, they can persist longer in natural waters than faecal coliforms and are more resistant to water treatment processes.

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

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

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

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

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

A3 Parasitic Protozoans and viruses

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

A4 Nitrate

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

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

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

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

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

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

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

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

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

Giving a balanced view of the nitrate situation in Irish groundwater is not easy as the data availability is poor. On the one hand, many of the wells with relatively high nitrate levels examined by the GSI are being contaminated by organic waste and not inorganic fertilizers. It is essential that "nitrate vulnerable areas" under the Nitrates Directive are not delineated without the proper evidence, as this would restrict farming in these areas unnecessarily. On the other hand, inorganic fertilizers have increased the background nitrate levels significantly in some of the intensive agricultural areas - the Barrow valley, for instance.

A5 Iron and Manganese

Although they are present under natural conditions in groundwater in some areas, they 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 (Fe) and manganese (Mn) from the soil, subsoil and bedrock into groundwater. With reoxygenation in the well or water supply system the Fe and Mn precipitate. High Mn concentrations can be a good indicator of pollution by silage effluent. However, it can also be caused by other high BOD wastes such as milk, landfill leachate and perhaps soiled water and septic tank effluent.

A6 Chloride

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

A7 Ammonia

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 waste source and/or vulnerable conditions. The MAC is 0.3 mg/l.

A8 Potassium

Potassium (K) is relatively immobile in soil and subsoil. Consequently the spreading of manure, slurry and inorganic fertilizers 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 and sandstones.

A9 Phosphorus

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

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

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

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

A10 Hydrogen Sulphide

Hydrogen sulphide is a gas that is recognisable by its 'rotten egg' smell. It is present only in deoxygenated water, from rocks such as black clayey limestones or shales that contain pyrite, or from evaporite beds. It is often associated with iron problems and is common.

Box A1 Summary : Assessing a Problem Area
Let us assume that you are examining an area with potential groundwater contamination problems and that you have taken samples in nearby wells. How can the analyses be assessed? ***E. coli present*** ⇨ organic waste source nearby (except in karst areas), usually either a septic tank system or farmyard. ***E.coli absent*** ⇨ either not polluted by organic waste or bacteria have not survived due to attenuation or time of travel to well greater than 100 days. ***Nitrate > 25 mg/l*** ⇨ either inorganic fertilizer or organic waste source; check other parameters. ***Ammonia > 0.15 mg/l*** ⇨ source is nearby organic waste; fertilizer is not an issue. ***Potassium (K) > 5.0 mg/l*** ⇨ source is probably organic waste. ***K/Na ratio > 0.4 (0.3, in many areas)*** ⇨ Farmyard waste rather than septic tank effluent is the source. If < 0.3, no conclusion is possible. ***Chloride > 30 mg/l*** ⇨ organic waste source. However this does not apply in the vicinity of the coast (within 20 km at least). In conclusion, faecal bacteria, nitrate, ammonia, high K/Na ratio and chloride indicate contamination by organic waste. However, only the high K/Na helps distinguish between septic tank effluent and farmyard wastes. So in many instances, while the analyses can show potential problems, other information is needed to complete the assessment.