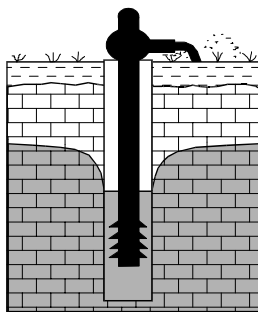


THE GSI GROUNDWATER NEWSLETTER

- Exploration
- Management
- Pollution
- News from abroad
- Development
- Quality
- Reviews
- Opinion Forum



NUACHTÁN SCREAMHUISCE SGÉ

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Fifteen years ago I would not have considered **faecal bacteria**, **viruses** or other **microbes** to be significant pollutants in Irish groundwaters. Then, the more ‘glamorous’ pollutants were nitrates, trace metals and trace organics, which were the topics for much of the research being carried out in Britain, US and continental Europe. But by focusing on the issues of concern abroad and assuming that the same situation applied here, I was missing the evidence of the most significant (in my view) issue for well water in Ireland – the presence of *E. coli*, particularly in **private wells**, either as an indicator of possible problems or as a problem in itself. Since the mid 1980s, the GSI and researchers such as Catherine Coxon, Paul Johnston and Richard Thorn, have drawn attention to the **critical role of subsoils in attenuating pollutants** and the importance of **septic tank systems** and **farmyards** as sources of pollution. In his article on page 3, David Ball follows up on this and highlights two **pathogens**, called **Cryptosporidium** and *E. coli* 0157. He summarises **recent illnesses** caused by these pathogens, **describes their characteristics** and **draws conclusions** for hydrogeologists and water supply engineers. At the moment there is a lot of emphasis on **landspreading of organic wastes**; this article emphasises the need to take into account **the type and depth of subsoil over bedrock**.

The **classification of aquifers** is crucial not only to the **production of groundwater protection schemes**, but also to the **development of groundwater**. The most commonly available data are **on well yields and specific capacities**. How can this information be used to help classify aquifers? Geoff Wright presents a compilation of data for 860 wells on page 11 and answers this question.

Other articles include a description of **The David Burdon Library** by Gillian Misstear (page 6); **initial verification of the use of the GSI vulnerability guidelines** (page 9); **IAH News** (page 21); and **News from Abroad** by Victoria Conlon (page 22). Information on future **IAH Technical Discussion Meetings** is given on page 21; **note talk** by Michael Bruen on 2nd December.

Editor

Bibliography of Urban Hydrogeology - A Free Database on the Internet

The bibliography of Urban Hydrogeology was initiated by the Commission on Groundwater in Urban Areas (CGUA), a Commission within the International Association of Hydrogeologists (IAH).

The setting-up of the Bibliography database was carried out at Chalmers University of Technology, with personnel from the Department of Geology and from Chalmers University Library. The Department of Geology has many years of experience from research within the field of Urban Hydrogeology.

This work was made possible by the financial support from the Swedish Environmental Protection Agency (SNV), the Swedish Council for Building Research (BFR), and the Swedish Water and Wastewater Works Association (VA-forsk).

General Information on the Bibliography

The Bibliography of Urban Hydrogeology is created to yield information in the growing field of Urban Hydrogeology. It is meant to contain references to literature in this field. To keep the Bibliography up-to-date, the participation of the users is important. If you have references to literature that you feel should be in the database, please do submit your information; "Spread the word" of your own work, or of the work of your institution.

Areas of interest are:

- ◆ Urban hydrogeology in general
- ◆ Stormwater treatment
- ◆ Hydrogeological properties of urban geology
- ◆ Geochemical properties of urban waters, as related to pollution, effects on constructions, etc.

- ◆ Clean-up of polluted waters in urban areas
- ◆ Urban expansion effects on hydrogeology

Contributions to the Bibliography

We should appreciate it if you would contribute to the Bibliography. The future of the Bibliography depends on input and actuality. The start was sponsored for a base collection. Now we need help to expand the database as we have no extra financial support for this.

If you want to add only a small number of records, you can send them via e-mail or fax to any of the two addresses below. When you send your own texts as contributions we would like to also get the abstracts (via e-mail or diskfiles, we prefer txt-files).

To make the handling of submitted information comprehensive, we would appreciate if you use the format shown in the format example (on a separate sheet).

If you have other suggestions, questions or comments on the Bibliography, please use the addresses below.

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Information supplied by the IAH Commission on Groundwater in Urban Areas

Cryptosporidium and *E. coli* 0157

The objective of this article is to raise awareness of two pathogens in groundwater. There is probably a greater general awareness of the bacterium *E. coli* 0157 as a result of multiple deaths in Scotland last autumn. *Cryptosporidium* has been known for much longer in the water industry in Europe and the United States but there appears to be little general awareness of it amongst hydrogeologists in Ireland. Hydrogeologists need to be aware of these two pathogens because they both can survive and remain viable for a long period in groundwater, they are present in livestock in Ireland (especially in very young animals) and they lead to human infections that are serious. There is an economic reason for awareness; both of these pathogens can contaminate food and could undermine the quality and reputation of Irish products.

Cryptosporidium parvum

Reasons for Raising Awareness

- ◆ In March 1997 Three Valleys Water Co. in Hertfordshire asked 300,000 consumers to boil water.
- ◆ The outbreak was thought to have arisen from manure seeping down deep cracks in the overburden and then being flushed down fractures in the chalk or down the borehole annulus. Many parts of south east Britain have had a drought for over 2 years, and the protection afforded by the overburden is being short circuited.
- ◆ The source was never isolated though several water supply boreholes in the Chalk aquifer between St Albans and Bushey contained the pathogen.
- ◆ 30 people were hospitalised for severe diarrhoea. Three schools and Hertford University were closed.
- ◆ *Cryptosporidium* has emerged since the 1980's as a common cause of gastro-enteritis in otherwise healthy people.
- ◆ *Cryptosporidium* is lethal to those who are immuno-compromised - children, elderly people, people convalescing, people taking immunosuppressant drugs
- ◆ In the UK there are 5,000 - 10,000 cases of cryptosporidiosis every year - most are not linked to water supplies - farm animals, food, and human-human contact in swimming pools or school play groups are other sources of infection - though cryptosporidiosis is an increasing occurrence in water sports participants in lakes in Britain. The incubation period is 1-12 days
- ◆ In 1995 one child was hospitalised in Crumlin Hospital for several days, and several others suffered severe diarrhoea after a school visit to a children's farm in Co. Kildare.

Summary characteristics of *Cryptosporidium*

- ◆ *Cryptosporidium* is a coccidian protozoan; it is not a bacterium.
- ◆ *Cryptosporidium* is a parasite that grows only within an appropriate host animal.
- ◆ *Cryptosporidium* is a parasite that attaches to the intestine and produces a virulent toxin.
- ◆ *Cryptosporidium* has a complex life cycle but survives as a hardy oocyst that is excreted in faeces.
- ◆ There are several species of *Cryptosporidium* affecting different groups of animals
- ◆ *Cryptosporidium parvum* infects man and his livestock. Sheep are a very common and potent source. There is a very high level of cryptosporidia in the excreta of young lambs and calves.
- ◆ The precise number of *Cryptosporidium* oocysts needed to cause infection in healthy adults is not known but is thought to be small, probably <10 viable oocysts.
- ◆ *Cryptosporidium* oocysts are resistant to disinfectants such as chlorine at current levels in treated water supplies.
- ◆ A chlorine treatment may remove *E. coli* and other bacterial indicators of pollution but the *Cryptosporidium* oocysts remain viable and unaffected.
- ◆ *E. coli* die off with time in a groundwater system; *Cryptosporidium* oocysts are hardy and can persist for longer periods.
- ◆ *Cryptosporidium* oocysts are identified by a complex time consuming process that confirms numbers but does not determine viability.

Conclusions for hydrogeologists in Ireland

1. *Cryptosporidium* is here in Ireland.
2. We do not consider it in terms of water quality because we do not appear to be aware of it.
3. Increased sheep stocking rates on shallow soil pastures over karst limestone aquifers in the west, are likely to increase the *Cryptosporidium* levels in the groundwater.

4. We should look at any groundwater indicators of pollution from faeces carefully, and inform the owner of the water source whenever we consider there is a high risk of Cryptosporidium in the aquifer recharge.
5. We should inform the County Council and the Health Board of our findings.
6. We should follow research on different treatment methods to disinfect water supplies.
7. We need to draw attention to the risk of Cryptosporidium being in groundwater when we work for the food industry. Groundwater may appear to be good quality but may still, periodically, contain pathogens that are not included in standard water analyses.
8. We should get funding for a research project to assess the Cryptosporidium levels in groundwater. At the moment there appears to be no background information on Cryptosporidium levels in Irish groundwaters.

***Escherichia coli* 0157**

Reasons for Raising Awareness

- ◆ *E. coli* 0157 was first detected in the USA in 1980 and in Ireland in 1993. The first outbreak occurred in 1995.
- ◆ The first fatality occurred in Ireland in 1997 when a three year old child died in Kildare.
- ◆ *E. coli* 0157 caused the deaths of 18 people in Scotland last winter.
- ◆ The infective dose is very low. The dose is a total of 50 bacteria or less. It may be as low as just 10 organisms. It is important to stress that this dose is not a concentration of 10 organisms per ml. in a sample. It is the total number of bacteria ingested, from say a glass of water or a meal, that will cause an infection. Most of us are aware of the risks from Salmonella. We take precautions to avoid Salmonella poisoning. To put the infective dose of *E. coli* 0157 in context; the infective dose for Salmonella is 50,000 organisms.
- ◆ Death is from the bacteria releasing verotoxins that break down the wall of the large intestine in humans, with resultant haemorrhaging.
- ◆ *E. coli* 0157 is in the national cattle herd.

Summary characteristics of *E. coli* 0157

- ◆ *E. coli* 0157 is a bacterium and is excreted in faeces.
- ◆ Recent research in Ireland has found that *E. coli* 0157 can remain viable on grass in the open for over 70 days.

- ◆ *E. coli* 0157 has been found in 2% of the cattle in Britain. It is known to be present in the Irish herd but actual percentage has not been determined. It is also found in sheep.
- ◆ It appears that the amount of *E. coli* 0157 in cattle excreta increases in summer. The reason is not known.
- ◆ Fortunately *E. coli* 0157 can be removed by disinfection of water, or cooking meats, right through, to a temperature higher than 68°C for 10 minutes.

Conclusions for hydrogeologists in Ireland

1. Many, if not most of the water supplies for farms and rural households outside village group water schemes, are cheaply constructed boreholes, wells and shallow springs. Almost all these supplies are not disinfected, and many are close to, or in, cattle pastures. In other words Ireland's least protected water supplies are in the areas where the bacteria is most prevalent.
2. Areas with a fractured rock or karst weathered limestone aquifer below a thin soil and subsoil cover and pasture are particularly vulnerable. Domestic and farm water supplies in these areas often come, without treatment, from these aquifers.
3. Though only a small percentage of the cattle are excreting *E. coli* 0157 this does not necessarily mean there is a low, and/or even distribution of carriers of the pathogen across the country. As *E. coli* 0157 remains viable on the grass for long periods it is assumed that other animals in a herd can be infected and that several animals in one place could be carriers. There could be pockets or concentrations of carriers. Faecal swabs from cattle in abattoirs have found that ten to fifteen percent of animals from one source are carrying *E. coli* 0157. The epidemiology is complex, and requires further research because the genetic characteristics of the *E. coli* 0157 indicate there are several strains of *E. coli* 0157 in the same herd. The purpose of giving this detail is to be open about current uncertainties, but also to alert hydrogeologists to expect point source as well as diffuse source pollution containing *E. coli* 0157.
4. The increased *E. coli* 0157 content in summer excreta is worrying because coincidentally, in summer, the protection afforded by the soil and subsoil to shallow water table aquifers, is often short circuited. The soil and subsoil under pasture is often deeply cracked in summer, and a short, intense rainfall shower can wash cattle faeces rapidly down the cracks straight to the water table. Preferential flow paths developed in the top 1-2 metres of soil and subsoil from either cracking in

summer or the holes created by old tree roots and burrows, remain as conduits for rapid recharge throughout the year. Therefore, spreading of slurry or fresh dung containing *E. coli* 0157 continues the risk of pollution and disease at times when the animals are not grazing the pasture.

5. *E. coli* 0157 can exist in groundwater for long periods in the same way as 'ordinary' *E. coli*. In the groundwater system the bacteria are protected from UV radiation, kept at a constant temperature and kept moist. *E. coli* 0157 would still be expected to be viable in groundwater 2 -3 months after reaching the aquifer.

6. Experiments during a current European research programme has found that if 1,000 *E. coli* 0157 are inoculated into a bottle of drinking water, the bacteria still form an infectious dose for up to seventy days later.

7. Hydrogeologists need to shed a certain complacency concerning *E. coli*. Though the drinking water standard requires zero *E. coli* per ml in a water supply, we are all aware that a low count of 'ordinary' *E. coli* is not likely to cause an infection particularly in farmers and other people habitually handling livestock. The infective dose for 'ordinary' *E. coli* is similar to Salmonella. Now that we are aware that there is a much smaller infective dose for *E. coli* 0157, we need to insist that any groundwater source showing signs of contamination from animal faeces should be disinfected. This could lead to big change in rural water supplies.

8. The rural food industry is at risk. For example high quality and high value organic crops, salads, vegetables or fruit for the local or export market, washed in raw water could introduce the 10 - 50 bacteria needed to cause infection. Commercial water cress cultivation using hydroponics was a source of a recent *E. coli* 0157 outbreak in Japan.

9. The tourism industry is also at risk. For a long time we have been fortunate that foreign visitors have not realised, or advertised back home, the

uncertain quality of the untreated drinking water in some rural B&B's and small hotels and hostels. The old joke of coach drivers and tour guides that 'the brown water in the hotel basin is just nature's Guinness' will not suffice if a coach party of 48 visitors become seriously ill.

An obvious question is: why have we not heard of more cases of illness, if these pathogens are so virulent? There is no straight forward answer. *E. coli* 0157 has been noticed only in the last few years and we are fortunate that there has been only one fatality. Cryptosporidium on the other hand has been around for a long time. However healthy people with the symptoms of severe diarrhoea sometimes do not go to doctors. If they do require medical attention there is no requirement for the doctor to notify a Health Authority. It is probable that Cryptosporidiosis is more common than is shown by our medical statistics. I believe that making gastro-enteritis a notifiable disease would make our work as hydrogeologists concerned with water quality in rural areas much easier. Maps showing the location of cases of gastro-enteritis would be an interesting corollary to our maps showing potential groundwater vulnerability and source protection zones.

I am interested in communicating with others who are working on Cryptosporidium, Campylobacter, Brucella or *E. coli* 0157 in groundwater.

Though I am responsible for the form and content of this article, would like to acknowledge generous assistance from Dr Geraldine Duffy and Dr Margaret Fitzgerald, Research Officers with Teagasc, National Food Centre, Castlenock; Eileen Loughman, Senior Environmental Health Officer, Eastern Health Board, Naas; John Geoghegan, Veterinary Inspector, Central Meat Control Laboratory, Abbotstown, and Margaret Murphy, Public Analysts Laboratory, Dublin.

David Ball, Consulting Hydrogeologist

The David Burdon Library

Next time you visit the Geological Survey of Ireland library take time to glance to your left. In a glass-fronted cabinet are held some of the treasures of the library collection donated to the Geological Survey and the Irish branch of the International Association of Hydrogeologists by the family of the late Dr. David Burdon (1914-1987). The collection reflects Dr. Burdon's huge enthusiasm for many aspects of geology and also of the history of his beloved Buttevant where he lived and worked for his last years on the family farm. Here he built a library especially to house the papers and books which now form this invaluable collection which will be of great interest to all geologists and especially to hydrogeologists.

David Burdon had a varied and distinguished career, graduating in geology and engineering from UCD and the Camborne School of Mines in Cornwall. His first job was in the Kolar Goldfield in southern India, where he co-wrote a paper on the effect of mine dust and mining methods on the health of the mine workers.

His interest in the geology of Ireland was reflected in his PhD thesis on the Leinster Granite, completed at Imperial College London in 1949. It was after this that he began his long career in hydrogeology, a word not at all familiar at that time. He joined the colonial service in Cyprus as water engineer and geologist, and in 1952 was recruited by the Food and Agriculture Organisation of the United Nations, based in Rome.

From 1952 to 1974 David Burdon travelled widely for the FAO, mainly in the Mediterranean and Middle East. During this time he built up a series of yearbooks - bound volumes of his notes and photographs as well as his published papers. These volumes cover Greece, Syria, Jordan, Lebanon and many other areas where he worked. They are fascinating even to the uninitiated and will provide invaluable reference material to hydrogeologists working in those areas. During this time David Burdon published his Handbook of

the Geology of Jordan and the original typescripts are in the collection.

Other areas covered in great detail in David Burdon's papers and books are the Arabian Peninsula, South East Asia and various parts of Africa, especially North Africa. He had a particular interest in the arid zones and published and collected a large number of papers and books on this topic. Other interests reflected in his library are geothermal energy, including many studies in Ireland, karst hydrology, springs, salinity problems and the use of remote sensing in hydrogeological mapping.

After 'retiring' and returning to Ireland, David Burdon became a consultant to the FAO and also to the Geological Survey, as well as a director of Minerex Ltd. He was a founder member of the IAH and is gratefully remembered by Irish hydrogeologists for his great enthusiasm and encouragement to them. He was always to be seen with a notebook and pencil in his hand and it can now be understood where all of those copious notes ended up.

I have spent two short periods over the last two years listing and cataloguing the collection. At present the material in the library is ordered and numbered by area or topic covered. It is shelved in two locked cabinets, one to the left at the entrance to the library and the other behind the librarian's desk. There is still a huge number of papers, as well as textbooks and runs of journals, stored in the rock store, awaiting shelf space in the library.

The printed catalogue orders all of the material by subject matter, first listing all papers on that subject by David Burdon, then papers by other authors. The location in the library or store is indicated so that material can be gathered together relatively easily.

A copy of the catalogue will be available at the librarian's desk in the Geological Survey library on application to the librarian and is well worth a browse.

Gillian Misstear, Librarian (now Dublin Public Libraries)

Protection of Wells : Where Dilution is not the Solution to Point Source Pollution!

Introduction

In most rural areas, chemical contamination (e.g. by nitrates, chlorides, sulphates, potassium) of large public and group scheme groundwater supplies by point sources (farmyards and septic tank systems) is not usually too significant. The reason for this is that dilution is sufficient to keep concentrations well below EU limits. (Keep in mind that this point does not apply to bacteria and viruses, where dilution will seldom be sufficient. Here the issue is vulnerability and time of travel and not dilution. Also, it would not apply to trace organics, such as pesticides and solvents). We wish in this article to highlight two situations where dilution is not sufficient to prevent significant chemical contamination.

Situation 1: Public and Group Scheme Wells with a Low Abstraction Rate

Setting

An area in the midlands, with relatively intensive grassland agriculture and free-draining, sandy subsoils. There are four public groundwater supplies in the area; three large and one small.

Water quality

In the three sources with large abstractions, groundwater quality is good. Nitrate levels are about 20 mg/l; this level represents the general background in the area and is due to both diffuse and point sources. In contrast, groundwater quality in the low yielding well is poor. Nitrate levels are usually greater than 30 mg/l, with a highest level over 50 mg/l. Chloride is about 25 mg/l - significantly higher than the general background level of about 15 mg/l.

Why the difference?

The area required to supply the three large abstractions (or combined areas of the three zones of contribution (ZOCs)) is about 300 ha. The number of houses and farmyards is not exceptional, and so a combination of relatively good farming practices (in particular, no badly managed farmyards with exceptional losses of

nutrients to groundwater) together with dilution maintains nitrate levels below the EU guide level of 25 mg/l. In contrast, the estimated recharge area or ZOC for the well with the low abstraction rate is only 6 ha. Unfortunately, there is an exceptional density of point sources of pollution in the ZOC - six septic tank systems which by design input contaminants into the ground and groundwater, and two farmyards where some soiled water is infiltrating. These can readily bring the general or background nitrate levels of 20 mg/l to above 35-40 mg/l and create the possibility of occasional peaks above 50 mg/l. There is insufficient dilution in the ZOC to keep the nitrate levels below 25 mg/l. While it might be possible for the local authority to encourage/enforce a reduction in the infiltration of soiled water from the farmyards, little can be done to reduce the inputs from the septic tank systems.

Lesson

It is essential that Planning and Environmental Sections in local authorities take account of the density of developments in the vicinity of small public and group scheme groundwater sources, and in particular in the ZOCs of these sources. It is also essential that local authorities take groundwater flow direction into account when giving planning permission to houses that have private wells, so that the likelihood of a septic tank system being in the ZOC of the well is minimised. (Keep in mind that virtually all the water pumped out of a private well is recharged back to groundwater through a percolation area 30-40 m away as highly polluting effluent. A 6-10 fold dilution is necessary to bring the nitrate level below the EU guide level, assuming no denitrification. If the septic tank system or a neighbour's septic tank system is in the ZOC of the well, achieving this dilution is unlikely.) This example also highlights the need to discourage intensive landspreading of organic wastes in the ZOC of both public and private wells.

Situation 2: Public and Group Scheme Wells in Esker Gravels

Setting

Eskers are long, narrow, sinuous ridges of sand/gravel that typically formed in subglacial river channels during the Ice Age. They vary in height from 5 to 50 m, and the normal width is 15 to 250 m. They are very common in the midlands – Offaly, Westmeath, Meath, Roscommon and Galway. They are often bounded by raised bogs and therefore they form the only high and dry ground in many areas. As a consequence, eskers were used as routeways through the midlands since ancient times. The Eiscir Riada, which stretches from Meath through Westmeath, Offaly, Roscommon and Galway and which is mentioned in the Annals of the Four Masters, is the best known Irish esker.

In the area under consideration in this article: the bedrock has a low permeability; an esker ridge is present bounded on one side by a bog, with till (boulder clay) on the other; a high yielding well is located in the esker sand/gravel; a road runs along the esker ridge.

Water Quality

Whilst inorganic parameters such as nitrate and chloride indicate dilute pollution (20 - 40 mg/l for both parameters), there is no analytical evidence to date that faecal bacteria are reaching the source. The sands and gravels appear to be filtering the bacteria. The raw water is not chlorinated. It is possible that the periodic monitoring does not show the full picture, and that at certain times the water may be polluted by bacteria. There is a sense of uncertainty and insecurity concerning the source. The hydrogeological assessment of the area is frustrating. The only good aquifer in the area is the esker. However ribbon development of houses has been permitted

along the esker between the adjacent villages. New houses have filled in the gaps between isolated older farms and occasional cottages with a result that roughly every 50 -100 metres along the crest of the aquifer there is a septic tank. Some of these septic tanks are new and probably comply with regulations, others will be basic 'soakaways'.

The Lesson

The esker sands and gravels are an excellent aquifer and extend for 1-3 miles on either side of the village. There is no alternative aquifer and there is no alternative reliable surface water source. There also appears to be no obvious alternative site for a new borehole source in the esker aquifer because a ribbon and infill development of houses has been allowed along the road on the crest of the aquifer. There is no significant section along the aquifer which does not have potential house, farm or agri-business point source pollution.

Rural communities are expecting high quality water supplies. Consumption of water is increasing with increasing prosperity, yet ironically this prosperity is also leading to new housing that is in turn blocking the development of better quality water supplies.

The lesson in general is that eskers may form the best, and in some cases, only source of good quality water for large water supply abstractions in the Midlands. It is suggested that local authority planners and engineers should take into consideration the present and future water supplies when considering planning applications along or adjacent to eskers. Nuclear villages rather than ribbon villages are sustainable on eskers.

Donal Daly, Geological Survey of Ireland and David Ball, Consulting Hydrogeologist

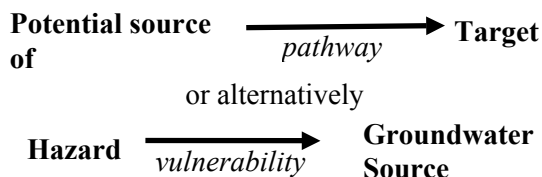
Verifying the GSI Groundwater Vulnerability Ratings : An Assessment of the Relationship Between Water Quality and Vulnerability

Introduction

The GSI is currently producing vulnerability maps as part of groundwater protection schemes. These maps show areas with extreme, high, moderate and low vulnerability. The vulnerability of groundwater, as defined by the GSI, is a natural intrinsic characteristic which dictates the likelihood of contamination reaching groundwater if a hazard or contaminant source exists at or close to the ground surface. It depends on the type, permeability and thickness of subsoils overlying groundwater in bedrock and sand/gravel aquifers, and on the presence or absence of karst features. Thick, low permeability subsoils such as clayey till are assumed to provide better protection to underlying groundwater than thin units of, for example, coarse grained high permeability sand/gravel. It follows, therefore, that areas with a low vulnerability should have better quality groundwater, in general, than those with extreme or high vulnerability. Is this the case in practice? This article looks at the evidence in one county by examining the groundwater quality at public supply sources and the relationship with the vulnerability mapped around the sources.

Risk and Risk Assessment : The Framework for Protection Schemes

The groundwater protection schemes are based on the concepts of groundwater contamination risk and risk management. The conventional source-pathway-target model for environmental management can be applied to groundwater risk management.



The probability of contaminated groundwater arriving at a local authority's public drinking water abstraction points depends on three elements: (a) the hazards, or the potential sources of contamination within the catchment areas (or zones of contribution) of the public supplies; (b) the vulnerability, or the likelihood of contaminants reaching groundwater; and (c) management of the hazards. Obviously, if there are no hazards in the zone of contribution, or they are managed well (e.g. minimising generation of soiled water at

farmyards, together with proper collection and disposal of soiled water), irrespective of the vulnerability, the groundwater quality will be good. However, in areas where there are significant hazards, the vulnerability is assumed to be a very significant factor in influencing groundwater quality.

Groundwater Quality in Public Supplies

Using the GSI guidelines for mapping vulnerability, the inferred catchment areas of 44 public supplies in the west of Ireland were classified into each of the four vulnerability categories: *extreme (E)*, *high (H)*, *moderate (M)* and *low (L)*. In many of the catchment areas, more than one vulnerability category was represented: in these cases, the most representative vulnerability rating was applied giving preference where appropriate, to the category found within the inner source protection zone where groundwater was expected to take less than 100 days to travel to the well.

Water quality data for the 44 supplies were compiled from the following sources: comprehensive raw water analyses carried out by the State Laboratory for two sample rounds, Sept 1993 and April 1994; the C1, C2 and C3 drinking water returns carried out by the County Council for the years 1991–93 inclusive; the C2 drinking water returns for 1993 carried out by the Health Board; and the 1997 EPA Nitrate report. The untreated groundwater quality at each of the supplies was classified into the following four water quality groups:

Group 1: Supplies at which one or more of the water quality parameters exceeded the EU maximum admissible concentration (MAC) for drinking water and which are therefore considered to have been polluted at the time of sampling.

Group 2: Supplies with elevated concentrations of the contaminant indicators chloride, nitrate and potassium. Although none of these parameters is over the EU MAC for drinking water, when present in concentrations greater than a threshold of approximately two to three times the background level, they are evidence of significant contamination and serve as a warning that pollution may be occurring at times other than when the samples were taken, or may occur in the future.

Group 3: Supplies with slight anomalies in the analyses which may be naturally induced or indicative of some slight contamination. These are, however, inconclusive on the basis of the given data set.

Group 4: Supplies showing no evidence of contamination.

The vulnerability ratings were then compared with the water quality groups for each public supply, to check whether the protection afforded by the subsoils, as determined by the vulnerability rating, was reflected in the groundwater quality.

The relationship of water quality and vulnerability at 44 public groundwater supplies in the west of Ireland.

Water quality group	Vulnerability rating						Total
	E	E/H*	H	H/M*	M	L	
Group 1 (polluted)	4	2	1	0	0	0	7
Group 2 (contaminated)	5	2	2	0	0	0	9
Group 3 (inconclusive)	3	3	6	1	0	2	15
Group 4 (clean)	3	2	4	1	0	3	13

Values given are numbers of supplies.

*Catchments are dominated by areas of both vulnerability categories.

Conclusions

- ◆ In general, the groundwater quality in the public supply wells is good. Only 7 of 44 supplies (16%) did not comply with EC drinking water regulations (Group 1) while a further 9 fell into Group 2 (20%). It was recommended to the local authority that regular monitoring take place at all supplies and that the sources of contamination at Group 1 and 2 wells be investigated.
- ◆ All of the supplies considered to be polluted or contaminated at the time of sampling (Groups 1 and 2) occur in areas of extreme and high vulnerability.
- ◆ All supplies located in areas of moderate and low vulnerability were of good quality, i.e. falling into Groups 3 and 4.
- ◆ Quite a high proportion of the good water quality supplies are also located in areas of extreme and high vulnerability. However, of these, 14 (67%) are located in areas where there is little or no development, hence no contaminant loading and therefore no hazard. Six (29%) are deep boreholes located in areas with interbedded rock units of variable permeability where the main aquifer is likely to be confined and hence ultimately protected by the overlying lower permeability rock units. The remaining supply is a shallow well which may be recharged by the nearby stream.

- ◆ The risk concept is considered to be useful to prioritise the supplies in terms of groundwater protection: if there is no hazard, or source of contamination, then there is minimal risk; supplies with low groundwater vulnerability ratings in their catchment areas are at less at risk than those with extreme or high vulnerability, assuming the same hazard applied at both.
- ◆ As groundwater vulnerability is assigned in a relative, rather than an absolute sense, and as the area mapped to date in Ireland is relatively small, verification is difficult. While this study does not provide a comprehensive evaluation of the general approach, it nevertheless provides initial supportive evidence. Further research is planned, which could involve, for example, developing a 'source vulnerability index' which would incorporate appropriate 'weightings' given for vulnerability in inner and outer source protection areas; and would consider all vulnerability ratings over the entire catchment areas rather than representative classifications. By including contaminant loading, a 'source risk index' can then be developed, which would be of value to local authorities. This index could be related to the groundwater quality.

Jenny Deakin*, Catherine Coxon and Donal Daly***

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QSC Graphs - A Tool to Assist in Aquifer Classification

The classification of aquifers is crucial to the production of groundwater protection schemes. Because hydrogeological data are scarce and patchy, various criteria are used, including lithology, structural setting, karstification, occurrence/size of springs, baseflow separation, drainage density, etc. However, where data are available on borehole yield and specific capacity, these will normally be the main evidence whereby an aquifer is classified.

A spreadsheet has been compiled summarising the availability of data on well yields and specific capacities for more than 860 boreholes in Ireland. The data come from four main sources:

- County Council data for public supply sources, mostly for higher-yielding boreholes, and mainly from counties where specific studies have been carried out.
- Irish Land Commission boreholes, mainly for single farms or small group schemes. Test rates are generally low ($<100 \text{ m}^3/\text{d}$), and boreholes generally not deep. Records are numerous for certain counties, and sparse for others.
- K.T. Cullen & Co.'s well records, normally quite deep boreholes and high yields.
- GSI records, including boreholes drilled for GSI projects, e.g. Nore Basin.

From the data, I have prepared graphs for 15 particular "formations", such as the Namurian, the

Old Red Sandstone, and the Calp Limestone. The graphs are termed "QSC Graphs" because they plot "Q" (well 'yield') against Specific Capacity (SC or Q/s).

Hitherto, aquifer classification has taken account of the relative occurrence of 'excellent', 'good', 'moderate' and 'poor' wells, based on their recorded yields (>400 , $<400>100$, $<100>40$, and $<40 \text{ m}^3/\text{d}$). Specific capacities were also taken into account, but there was no simple or consistent way to do this. The QSC graphs allow the available yield and specific capacity data to be viewed simultaneously and in the context of similar data from other aquifers.

Transmissivity (T) estimates from pumping tests, would, of course, be desirable but there are currently too few of these for any given aquifer, and often only a range of values can be suggested.

The QSC graph for all boreholes (Figure 1) covers a range of several orders of magnitude for both parameters, showing an obvious general trend within a broad 'envelope' of data points. The upper boundary of the envelope is very fuzzy, but the lower boundary is sharper and is controlled by two main factors, one artificial and one natural: (a) borehole depths limit the available drawdown, and (b) permeability tends to decrease with depth.

In general, a data point close to the lower boundary indicates a deep borehole which is being pumped near its maximum rate (most available drawdown

has been used). Conversely, a data point in the upper part of the envelope indicates a borehole which could be pumped at a much higher rate than indicated (or a shallow borehole with little available drawdown).

The QSC graph can also be used to plot data from multiple tests from the same borehole (e.g. step tests), in which case the points will normally plot along a line which falls from left to right, i.e. showing that as the pumping rate increases the specific capacity decreases (Figure 2). The rate of fall will normally be quite shallow until a critical point is reached, after which the fall may be very sharp. This critical point is effectively the maximum yield of the borehole.

If we could predict the general slope of such curves from individual boreholes in a given aquifer, it would be possible to extrapolate from a single data point on a QSC graph in order to predict (approximately) the ultimate maximum yield of a given borehole. However, it should be borne in mind that step tests would give different curves at different times of year.

By plotting the Q/SC data points for a given "formation" one can attempt an aquifer classification. In some cases, e.g. the 'Calp' Limestone, it is clear that no single classification applies in all regions, and the data must be examined to see if a regional or stratigraphic-lithologic sub-division (or both) is valid, i.e. is the wide spread of data due to lithological variations within the "formation" or due to regional (perhaps

structural) variations, or both?

Too much attention must not be paid to any single data point, because the data quality may be suspect. The validity of any conclusions depends on the totality of the data, and therefore depends on having enough data points, so that occasional extreme values can be discounted. Among the factors which detract from the data quality:

- Data collection by untrained personnel, accuracy of measurements may be low.
- Pumping tests of variable length, sometimes too short. In some cases it is possible to extrapolate drawdown to, say, one week.
- In many cases, pumping rates were not constant.
- In some cases, drawdown may not have stabilised.
- Pumping tests may have been carried out at a time of relatively high water table, thus giving an unduly high SC. This may be particularly important in the poorer aquifers.
- The aquifer may not have been identified/inferred correctly.
- Borehole depths are very variable. (Graphs plotting depth against yield show virtually no correlation, but in individual boreholes the depth will often be significant.)
- Borehole construction is very variable and may adversely affect yields in some cases.

The data highlight the difficulties of using well yield categories (poor, moderate, good and excellent), because these categories include wells with a very wide range of SC, and, by inference, a



wide range of transmissivities.

It seems that the yields of wells in Ireland are, in general, better than we once thought. In my QSC spreadsheet there are about 250 wells with measured yields over 400 m³/d and many more (c. 140) capable of such yields if pumped harder.

Well Productivity

To supplement the the four existing well yield categories, I have used the QSC graphs to create another index (“**Productivity**”) with four categories: A (highest), B, C, and D (lowest), with boundaries as shown on Figure 3. Wells in a Regionally Important Aquifer should plot largely within the ‘A’ and ‘B’ categories, and in a Poor Aquifer should plot predominantly within the ‘C’ & ‘D’ categories.

Comments on QSC graphs and productivity charts for particular formations or lithologies (Table 1 and Figures 4 to 24 and 4a to 24a):

1. **Granites/Metamorphics:** 27 data points, clustered in the lower half of the total range, and mostly in the lower third. Some SCs look surprisingly high, but probably derive from pumping tests at high water tables. Median yield is about 33 m³/d (300 gph). These data can be taken as characteristic of a ‘Pu’ aquifer.
2. **Lower Paleozoic rocks (excluding Campile Formation):** 65 data points. The spread is

surprising, Q ranging up to over 1000 m³/d but mostly under 100, and a median of about 55 m³/d. Median SC is about 7 m³/d/m. The data need further examination for regional or lithological factors, but a general classification of ‘Pu’ or ‘Pl’ is supported, with some ‘LI’.

3. **Campile Formation (Ordovician volcanics in Wexford/Waterford):** 31 data points. This is a fairly compact data set, and even the few lower yielding wells have rather high SCs, indicating much higher ultimate yields. This formation is classified ‘Rf’.
4. **Old Red Sandstone (excluding Kiltorcan Sandstone):** 46 data points, spread widely through the range, except at the very top and bottom. Median Q is 70-80 m³/d and median SC is about 13 m³/d/m. A general classification of ‘LI’ is supported, but there is evidence that the coarser formations (conglomerates/coarse sandstones) are more productive and may justify ‘Lm’, whereas finer-grained formations (siltstones, etc.) may be ‘Pl’.
5. **Kiltorcan Sandstone:** 33 data points, almost all in the upper half, and most in the upper third. A classification of ‘Rf’ is supported.
6. **‘Cork Group’:** 22 data points, generally in the middle third of the envelope, suggesting a classification of ‘LI’.
7. **ABL/Ballysteen Limestone:** 53 data points, over a wide range, but with few yields over

400 m³/d. Median Q is about 60 m³/d, and median SC about 8 m³/d/m. The data need further study to distinguish regional (structural) and lithological (clean/muddy/dolomitised) variations. Higher yields (e.g. in Kilkenny/Tipperary) are probably from cleaner oolitic and/or dolomitised members. In general, a classification of 'LI' is supported.

8. **Lower Limestones (Northeastern region - Cavan, Louth, Monaghan, Meath):** Only 13 data points, mostly in the upper part of the range, justifying a rating of 'Rf' or 'Rk'.

9. **Waulsortian Limestone (including dolomitised Waulsortian):** 70 data points, over a wide range, but mostly in the upper half. A marked regional contrast is evident. In the south (Cork, Kilkenny, Limerick, Tipperary, and Waterford) a classification of 'Rk' is justified. Elsewhere it could be 'LI' or 'PI'. Further investigation may extend the 'Rk' region.

10. **SHU/SHL/Burren Limestones:** 137 data points (Galway 83, Roscommon 21, Mayo 10, Longford 7, Offaly 6, Cavan 3, Laois 3, Meath 3, Leitrim 1) covering almost the whole range. The 'north-central' region (Roscommon/Cavan/Leitrim/Longford/Meath) shows higher values than Galway/Mayo. Yields from Lanesborough, Co. Longford, were especially high. Classifications range from 'PI' through 'LI' or 'Lm' to 'Rf'/'Rk'.

11. **Ballyadams/Cullahill Limestone:** 19 points, over quite a wide range. The region is fairly limited (Carlow, Laois, Kilkenny, South Tipperary), so further regional analysis is difficult. Generally 'Rk', but in places 'Lm' might be more appropriate.

12. **'Calp' Limestones:** 98 data points, over a very wide range. Median Q is about 100 m³/d, and median SC about 12 m³/d/m. The data show substantial regional variations. In Meath Q and SC are fairly high, justifying an 'Lm' rating. In Galway values are low ('PI' or 'Pu'). Values in

Offaly/Westmeath/Dublin/Kildare are intermediate, justifying an 'LI' rating.

13. **Wexford Formation (Limestone):** Only 16 data points, but with good data. This is our most compact data set, with a relatively small range of both yield (600-3000 m³/d) and SC (15-350 m³/d/m), and can be taken as characteristic of a regionally important aquifer. Most wells plot near the lower boundary of the QSC envelope, indicating that they have been tested near their maximum yield.

14. **Namurian:** 31 data points, over a surprisingly wide range, but the highest values mainly come from the upper Namurian in NW Meath/Monaghan/Cavan, where it appears to be at least 'Lm' if not 'Rf'. Over most of the country, the upper Namurian is absent and yields and SC are usually low. The data support a general classification of 'Pu' (?shale-dominant) or 'PI' (?sandstone-dominant), but locally higher.

15. **Westphalian sandstones:** Only 7 data points, supporting a classification of 'Lm'.

16. **Quaternary Sands & Gravels:** 87 data points. As expected, both Q and SC are generally high, and many data points indicate higher ultimate well yields. Lower values are probably from very thin deposits, from boreholes in till, or from poorly constructed wells. Classification is normally 'Lg' or 'Rg', depending on aquifer extent.

Note: The above 15 lithologies/formations include about 750 of the 860+ wells in the spreadsheet. The remaining 110 wells either have not been attributed to a particular formation or have been attributed to a formation which has not been grouped with any of the main types listed above.

Comments and additional Q/SC data would be welcomed.

Geoff Wright, Geological Survey of Ireland

IAH (Irish Group) News

IAH Fieldtrip to Northern Ireland

The weekend fieldtrip in October has now become a well attended annual event. This year's trip was to Northern Ireland and the IAH were guests of the Department of Civil Engineering at Queen's University Belfast.

To initiate the weekend on the Friday evening an Open Forum was held in the Canada Room at Queen's on general issues of hydrogeology in Northern Ireland. A keynote talk was presented by Warren Wood of the United States Geological Survey on key research areas within the USGS. The area of interest was then brought closer to home by Des Lyness of the Department of the Environment in Northern Ireland who outlined its work and Peter Bennett of Hydrogeological and Environmental Services who explained the general hydrogeological features of interest in Northern Ireland. Donal Daly then concluded the talks by raising issues relevant to the whole of Ireland, after which an open discussion was held. The Department of Civil Engineering kindly sponsored a cheese and wine reception after the forum.

Saturday morning was spent visiting the disused quarry site at Magheramorne, Co. Antrim. This site has recently had a landfill proposal rejected on ecological grounds and Peter Bennett outlined the hydrogeological investigation conducted for the environmental impact statement of the planning application. The fieldtrip continued up the Antrim coastline via some outcrops at Larne to lunch at Carnlough. During the afternoon, research work on the karstic flow systems through to several chalk springs was outlined by Stephen Barnes of QUB and the impressive blocked sink system at Loughareema was visited before the trip finished up at Ballycastle.

After an enjoyable dinner on the Saturday evening close to QUB, Sunday was spent visiting the Strangford Lough area southeast of Belfast. The potential for saline intrusion through the Sherwood sandstone underlying the area was outlined by Bob Kalin. This could have disastrous consequences for groundwater supplies currently being heavily used at Newtownards. The evidence of subsidence due to the pumping was visited before the morning finished up at Scrabo Tower where the Sherwood

Sandstone and overlying Dolerite units can be clearly seen.

The weekend gave hydrogeologists from both sides of the border a chance to meet in an informal and enjoyable environment. For many it was a fresh look at aquifer systems not seen in southern Ireland in some very beautiful areas.

The IAH (Irish Group) would like to thank Bob Kalin and the Department of Civil Engineering at Queen's University Belfast for hosting the fieldtrip; also Peter Bennett, Mark Cooper and Stephen Barnes for their invaluable contributions.

Richard Church, IAH Fieldtrip Secretary

Future IAH Technical Discussion Meetings

2nd December **Internet Resources in Hydrology and Hydrogeology** by Michael Bruen, Department of Civil Engineering, UCD. (This will be followed by social activities in Rumm's pub!)

6th January **The IAH Nottingham Congress "Groundwater in the Urban Environment"**
Reviewed by Eugene Daly and Bruce Misstear.

4th February **The Burdon Lecture** by Michael Price who runs the MSC course in Hydrogeology and Groundwater Chemistry at Reading University and who is author of the well known book "Introducing Groundwater".

4th March **Younger Hydrogeologists' Forum**

The Meetings are held in the GSI. They start promptly at 18.00 hrs, finish at 19.30 hrs and are preceded by tea/coffee from 17.30 hrs. For further information, contact either Kevin Cullen (☎ 01-2941717) or Donal Daly (☎ 01-6041490).

18th Annual IAH Groundwater Seminar

The annual seminar will be held in the Killeslin Hotel on Tuesday 21st and Wednesday 22nd April 1998. The theme is "**Hydrogeology and Waste Management**".

One Day Course on Protection of Public Groundwater Sources First Notice

Introduction

The recent Nenagh pollution incident has highlighted the need to protect public supply sources. How should this be done? A draft national groundwater protection scheme was proposed by the GSI and has been in use for the last few years. Now this scheme is being up-dated by a joint committee of representatives of the DoE, EPA and GSI, and will be published in the near future. The scheme includes details on the delineation of source protection zones. To-date, the GSI has prepared source protection zone reports for over 30 public supply wells and springs. In the future, while the GSI will continue to complete a small number of these reports, most will be prepared by hydrogeological consultants. This course provides the opportunity to learn about the national guidelines, to become familiar with the techniques used in delineating groundwater source protection zones and to learn from the experience of the GSI and others.

Course Teachers

The course will be given jointly by the **Groundwater Section, GSI, and the Department of Civil, Structural and**

Environmental Engineering, TCD. The speakers will include Colette Cronin, Donal Daly, Jenny Deakin, Paul Johnston, Bruce Misstear and Geoff Wright.

Course Content

The course will cover the following topics: overview of groundwater protection; vulnerability mapping, delineating the catchment areas (or zones of contribution) of wells and springs; delineating the 100-day ToT (time of travel) areas; sanitary protection of wells; use of numerical models; and importance of hydrogeological mapping.

Course Venue and Date

Geological Survey of Ireland; May 1998 (precise date to be confirmed).

Registration Information

The tuition fee for the course is £150.00. The fee covers all instructional costs, lecture notes and lunch.

Further Information

Contact Donal Daly (☎ 01-6041490) or Bruce Misstear (☎ 01-6082212). More information will be circulated in early 1998.

Donal Daly, Geological Survey of Ireland.

News from Abroad

Britain: Government Says No to Water Saving Trust

Dissatisfaction with the private Water Companies' management of water resources looks set to continue in Britain. The Parliament has rejected a call from the House of Commons Environment Committee to set up an independent Water Saving Trust. The intended objectives of the Trust were to promote sustainable use of water and to help prevent shortages in supply such as those experienced in Yorkshire during the summer of

1995. Other proposals put forward by the Committee were:

- 1) punitive charges to the Water Companies for abstracting during times of drought;
- 2) the setting of targets for the reduction of leakage from mains pipes;
- 3) a review of abstraction licences;
- 4) a reduction of 6 litres in the volume of water used in flushing toilets;
- 5) free servicing of customers' pipes by the Water Companies.

The UK Round Table on Sustainable Development has added to the debate by suggesting selective metering schemes for households in the absence of a universal scheme. Other issues raised by the UK Round Table deal with freshwater resources in general, most notably damage caused by acid mine drainage. The rejection of the proposal for the Water Saving Trust, according to the ENDS Report, shows the reluctance of the Government to place environmental issues ahead of economic considerations.

Source: The ENDS Report, No. 265, February 1997.

England: Eutrophication – A Problem According to English Nature

English Nature (EN), a conservation agency in England, has called for a large-scale investigation programme into eutrophication of aquatic environments. In English rivers phosphate is the chief cause of worry. In parts of the country, levels 10 times higher than normal have been measured. Some of these areas are Sites of Special Scientific Interest (SSSIs) which makes the problem more immediate. In order to tackle the problem, which is believed to be caused by sewage discharge into rivers, EN are calling for one of two solutions:

- 1) removal of phosphate at the sewage plant using scrubbing;
- 2) discharge of the sewage into less sensitive waters.

So far EN's pleas have largely been ignored by the Water Regulator (Ofwat), the Government and the Environment Agency. The Government has also reneged on its promise to set statutory water quality objectives (SWQOs) which would set maximum permissible levels for the major ionic constituents and also for nutrients. According to EN the maximum acceptable level of phosphate in a mature lowland river system is approximately 0.1 mg/litre. In the River Thames the value is roughly 1.1mg/litre: approximately 11 times greater than the target value.

Source: The ENDS Report, No. 266, March 1997

Compiled by Victoria Conlon, Geological Survey of Ireland.

England and Wales: Local Authorities fail to reach recycling targets

As a result of the slow progress of many English and Welsh local authorities towards the 25% recycling target by the year 2000, the DoE has issued guidelines to local authorities in England and Wales. Studies show that only 1 in 10 councils have reached the 10% mark, while other councils have management plans which contain no specific objectives or are based on insufficient data. The guidelines hope to promote a more integrated approach to waste management, with closer ties between the collector and disposer. Councils are urged to set targets which are realistic and achievable. To help with this, advice is given on different waste management options and their economic feasibility. Councils are also encouraged to liaise with packaging companies in order to consider options for reducing the amount of waste produced in the first place.

Source: The ENDS Report, No. 266, March 1997.

England: Pesticides Standards Introduced At Last

Water quality standards for 8 'red list' chemicals were issued in March 1997 by the DoE, a full 6 years after they were first proposed. Proposals for 22 other chemicals, mostly pesticides, are due soon. Chemicals make the list if they are considered toxic enough and if they persist over a long enough period of time. This approach militates against pesticides which may peak at high levels for only short periods of time before being attenuated. This is worrying as it has been noted recently that pesticides can move through soil over large areas, via preferential pathways, and can give rise to short-lived high levels of pollution. These short bursts can be just as harmful to aquatic life as the long-lived emissions. An example of one such chemical is the pesticide, cypermethrin, which is used in sheep dip and is known to be responsible for a number of fish kills.

The ENDS Report, No. 266, March 1997.

European Geological Surveys Develop an Electronic Information Exchange System

The primary source of public domain geological information in the European Union lies in the databanks of its fifteen national geological surveys. However these databanks have not delivered their full competitive advantage to customers because of language difficulties and the lack of a standardised approach. The newly proposed Geological Electronic Information Exchange System (GEIXS) aims to redress this and turn them into a readily accessible European resource.

All fifteen EU national geological surveys, as well as Eurogeosurveys, are participating in an Accompanying Measure for two years up to March 1999 with a total budget of 1 million ECU. 50% of the funding has been provided by the EU ESPRIT programme of DGIII (Industry). The industrial technology provider is MATRA Datavision of France.

When complete, GEIXS will provide EU industry and the public with on-line access to information on the type and location of the available geoscientific data for any European Union country. This project will also facilitate the customer in contacting the geological survey that holds the relevant data. It will harmonise geological information at meta-data level. Its software applications will use existing multi-lingual lexicons to translate the index-level data into any of the eleven EU languages.

It is expected that, when operating, GEIXS will provide considerable savings to the geological surveys, their customers and EU decision-makers.

For further information contact Mary Carter at GSI (☎ 01-6041476).

CONTRIBUTIONS FOR THE NEXT ISSUE OF THE NEWSLETTER

The GSI Groundwater Newsletter aims to improve communication among scientists and engineers involved in groundwater. It includes news, developments, reviews and opinions on all aspects of groundwater - exploration, development, management, water quality, pollution and energy. It is published three times each year.

Your contribution to the dialogue would be welcome. **Contributions should arrive before 1st February 1998.**

Editor,
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**The contributors are responsible for the content of the material in this Newsletter.
The views expressed are not necessarily those of the
Geological Survey of Ireland.**