ISSN 0790-7753

# THE GSI GROUNDWATER NEWSLETTER

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

# NUACHTÁN SCREAMHUISCE SGÉ

- *Biscéalaíocht*
- *Bainistíocht*
- *Truailliú*
- *Nuacht idirnáisiúnta*
- *Forbairt*
- *Cáilíocht*
- *Athbhreithniú*
- *Tuairimí*

*Published by the Geological Survey of Ireland, Beggars Bush, Haddington Rd., Dublin 4. Tel: (01) 6707444 Fax: (01) 6681782*

*Edited by: Donal Daly*

*Foilsithe ag an Suirbhéireachta Gheolaíochta Éireann, Tor an Bhacaigh, Bóthar Hadington, Baile Átha Cliath 4. Tel: (01) 6707444 Fax (01) 6681782*

**No. 33 May 1998**

## In This Issue



Information on the properties (porosity, permeability, and transmissivity) of Irish aquifers is generally lacking. This has a detrimental impact on predictions of groundwater and contaminant movement, aquifer definition, and delineation of source protection zones. On page 2, Olga Aslibekian uses data on well yields and specific capacities to enable **transmissivities** of many of our main rock units to be estimated.

**Monitoring of groundwater chemistry and quality** is a growth area. For people not proficient in chemistry or having no experience with groundwater, **assessing a chemical analysis** or a mass of data can be problematic. On page 7, Colette Cronin and Anita Furey present **useful tips** that will help. On page 12, Garrett Kilroy describes an important **research project** that has commenced in TCD on **phosphorus in groundwater**.

**Groundwater flow in Irish bedrock varies along a continuum from fracture- to karst-dominated systems; matrix flow is virtually non-existent.** Therefore, an understanding **of structural geology** and **rock fracturing** is crucial to Irish hydrogeology. Shane O'Neill illustrates the value of these in a useful summary article on page 10. Further on (page 16), he presents details of a newly formed association – **the Geothermal Association of Ireland**.

In other articles, Monica Lee and Melissa Swartz (page 13) outline a joint TCD/GSI research project on **vulnerability mapping**; Donal O'Suilleabháin reviews a "**Handbook of Drinking Water Quality**" (page 14); Bob Aldwell summarises the main points of an interesting **conference in Florida** (page 15) and describes the **on-going contacts between Irish and Russian hydrogeologists** (page 17); Pat O'Connor and Ian Mitchell give details on **a cross-border geosciences project** (page 19); and Geoff Wright provides an up-date on **IAH (Irish Group) news** (page 18).

**Editor**

# Transmissivities of Aquifers in Ireland

## Introduction

Transmissivity (T, $m^2$/day) is the major parameter which characterises rocks as water-conducting strata. Most hydrogeological calculations, including ground water flow modelling, are based on transmissivity data, which makes their availability very important, particularly when hydrogeological expertise is required in Ireland:

1. Use of ground water sources for domestic and industrial water supply is continuously growing in Ireland.
2. Industrial development in the country ultimately increases environmental concern in relation to ground water contamination and hence its prediction and prevention.
3. Hydrogeological expertise is often required in various areas of human activities (prevention of flooding, bog conservation, water table subsidence and rise due to development, etc.).

At the present time the most representative ground water database has been collected in the Geological Survey of Ireland, which includes the following parameters:

- well yield (Q, $m^3$/day);
- specific capacity (q, $m^3$/day/m);
- borehole depth (D, m);
- geographical location and grid references.

A review of these data was given in the GSI Groundwater Newsletter by G.R. Wright (1997).

In the present paper these data are considered as a basis for the calculation of transmissivity values of water-conducting rocks, aimed to facilitate regional assessment of Irish aquifers. Since a pumping test designed to evaluate rock transmissivity is a costly procedure, such analysis of available information is an effective and efficient method of hydrogeological assessment.

## 1. Calculations.

Taking into consideration that initial data include well yield (Q) and specific capacity (q), the following equation was used for transmissivity calculation:

$$T = q.\ln(1/r*\sqrt{(Q/\pi\varepsilon)})/2\pi \qquad (1)$$

where ε is ground water recharge within the area of well influence on ground water flow, r = radius of borehole tube.

The equation (1) was obtained from the two following equations:

$$Q=2\pi sT/\ln(R/r) \qquad (2)$$

$$Q=\pi R^2\varepsilon \qquad (3)$$

where R is the radius of ground water drawdown; s = ground water drawdown.

Some assumptions were applied:

1. Borehole radius was taken as 10cm (8" tubes), which is considered as a common size for boreholes in use. However tubing of other diameters may be used (7.5cm - 6" tubes), therefore an error in the transmissivity calculation might occur. The error was calculated for r=10cm and r=7.5cm: $T_{10}/T_{7.5}$ = $\ln\sqrt{7.5}$ / $\ln\sqrt{10}$ = 1.01 / 1.15. Hence the T error is E(r) = 12.3%.

2. Ground water recharge was taken as $\varepsilon=5*10^{-4}$ m/s/$m^2$ or 183 mm/a. According to this estimation, the ground water recharge of a Midland aquifer is approximately this value (in Northern Tipperary ε=179mm/a, for Galmoy Mine Project ε=161mm/a). In the northeastern region of Ireland (Co. Cavan, Co. Monaghan) ε is 118-206 mm/a (Report, 1981). The error for the ground water recharge value is estimated as E(ε)=11.8 % from the following: $T_{min}$ / $T_{max}$ = $\ln\sqrt{\varepsilon_{max}}$ / $\ln\sqrt{\varepsilon_{min}}$ = 2.93 / 2.59.

The cumulative error in transmissivity values arising from the assumptions is $E = \sqrt{(E(r)^2 + E(\varepsilon)^2)}$ = 17.1%.

To confirm the applicability of equation (1), the result of a pumping test for the Galmoy Mine project was processed: Q = 3230 $m^3$/day, q=Q/S= 190 $m^3$/day/m, and the transmissivity of the local aquifer was estimated as $T_p$= 250 $m^2$/day. On the other hand, the transmissivity value calculated by equation (1) is T = 290±49 $m^2$/day. The agreement between data T and $T_p$ demonstrates that equation (1) may be used for assessment of aquifer transmissivity on the basis of available data, access to which was kindly provided by Geoff Wright during spring 1997.

**2. Data analysis**

The GSI data base includes information on Irish aquifers, occurring in the following rock formations (about 500 data points):

1. ***Carbonate sedimentary rocks:*** northern and southern *Waulsortian*; *CALP* and calp-related rocks (western, central and eastern areas of their occurrence); *Burren* Limestone; Wexford limestone (*WX*).
2. ***Non-carbonate sedimentary rocks:*** *Namurian* sandstones; *Kiltorcan*; Old Red Sandstones (*ORS*); *Cork Group*.
3. ***Granites and Campile Formation (CA).***
4. ***Gravel/sand***.

As all these data were obtained during borehole exploitation, they are associated with most permeable geological strata, where water pumping was possible. Hence the values of transmissivity, considered below, are the highest. Results of the calculations are presented on T distribution histograms and cumulative curves (Figs. 1(a), 1(b)) as well as in Table 1.

**3. Discussion**

Calculation of transmissivity and results analysis allow us not only to obtain T values, but to make more general conclusions on the properties of various aquifers.

1. Generally the transmissivity of water-conducting rocks in Ireland varies widely from $0.1m^2$/day to more than $1000m^2$/day. Nevertheless approximately ***75%*** of rocks (73-82% for different types of rock) are characterised by ***$T<100m^2$/day***, and ***30%*** (23-37%) of rocks have a transmissivity less than ***$T<10m^2$/day***. Hence, half of the tested aquifers may be characterised by transmissivity of limited values between $10m^2$/day and $100m^2$/day.

2. Higher transmissivity values in the limestone aquifer group are related to Southern Waulsortian $T_{50\%} = 126m^2$/day (3.4 - 4080) and Wexford $T_{50\%} = 200m^2$/day (78 - 515) limestones (Fig. 1-2, 1-4); in sandstone aquifers - Kiltorcan formation $T_{50\%} = 71m^2$/day (7.6 - 790) (Fig. 1-8). Sand/gravel aquifers are characterised by higher transmissivities also ($T_{50\%} = 79m^2$/day (up to 3260)) (Fig. 1-11) (Table 1).

3. Sandstone formations are characterised by more uniform fissure systems than limestone strata. This is reflected on the T data distribution curves: data sets of sandstone aquifers are better sorted, with a clear log-normal type of T distribution* (Maximum of transmissivity distribution is within intervals 3-$10m^2$/day for Namurian and ORS formations and 31.6-$100m^2$/day for Kiltorcan rocks (Figs. 1-5, 1-6, 1-8)), while limestone transmissivity values are usually less well sorted and histograms of T distribution are characterised by two maxima (e.g. $<3m^2$/day and 10-$31.6m^2$/day for transmissivity of the CALP formation) (Fig. 1-3). The latter may result from the different nature of limestone fracture genesis, which is probably related to tectonic discontinuity followed by later weathering processes and karstification.

4. Regional changes in aquifer transmissivity and hence general characteristics of rock permeabilities may be based on T data analysis:
   - Waulsortian limestones are considerably more permeable in the southern region of their occurrence (Table 1);
   - The transmissivity of the CALP formation changes from western (Co. Galway) to eastern (Co. Kildare & Dublin) regions of the country, and the most permeable rocks within the CALP formation are present in the Midlands ($T_{50\%} = 45\ m^2$/day).
   - Although no significant relationship between transmissivity and the depth of occurrence was found, the permeability of water-conducting strata demonstrates a consistent decrease with depth (Fig. 2), which is particularly significant within the first 30m (which in general reflects the depth of most rock weathering (E.P. Daly, 1995).

The applicability of these general conclusions may be illustrated by the following examples:

1. In the case of a pollution event, a front of pollution migration within a limestone aquifer should be expected to be more deformed than in a sandstone aquifer. Due to less uniform fracture systems in limestones, such a front

* Except for the Cork Group, whose transmissivity distribution has two maxima, and the formation includes both carbonate and non-carbonate sedimentary rocks.

may be formed in the shape of a pollution tongue and hence pollutants may migrate further, even if transmissivity values for the particular limestones and sandstones are similar.

2. As it follows from Fig. 2, the aquifer zone of active ground water exchange rate or most permeable zone occurs within the first 30 metres. Therefore within this zone (i) ground water abstraction is most productive; (ii) ground water oxidation potential, as a function of dissolved oxygen concentration, is highest; (iii) sources of pollution occurring below this depth (e.g. abandoned mines) cause low impact on ground water quality within this zone.

**4. Implications of the Results**

An approach to aquifer transmissivity assessment described in this paper may be considered as a tool for regional aquifer characterisation on the basis of the available hydrogeological data, and transmissivity values could provide additional information toward existing Irish aquifer classification.

These data may be used for different regional ground water programmes and planning operations which require rock permeability assessment and approximate hydrogeological estimation, for instance: (i) planning a programme of ground water tests, (ii) approach to environmental impact assessment, (iii) design of ground water monitoring programmes, etc.

In addition, T data may be inserted into an aquifer protection scheme, when in addition to the existing scheme (D. Daly, 1997), the distribution of pollutants within an aquifer might be considered on a regional scale.

**References**

Daly, E.P. (1995) The principal characteristics of the flow regime in Irish aquifers. The role of ground water in sustainable development. Proceedings of IAH Seminar, Portlaoise, p.1-8.

Daly, D. (1997). A summary of the Irish groundwater protection scheme. Irish-Russian Hydrogeological Workshop, 18 September.

An Foras Forbartha & GSI (1981). Ground water resources in the NE Region. Main Report.

Wright, G.R. (1997). QSC graphs – a tool to assist in aquifer classification. The GSI Groundwater Newsletter, No. 32, p11-20.

**Table 1. Transmissivity of aquifers in Ireland**

| Formation | $T_{50\%}/T_{interval}$ m²/day | Formation | $T_{50\%}/T_{interval}$ m²/day |
|---|---|---|---|
| ***Carbonate rocks*** | | ***Non-carbonate sedimentary rocks*** | |
| Burren Limestone | 18 / 0.1-602 | Kiltorcan | 71 / 7.6-790 |
| Wexford Limestone | 200 / 78-515 | ORS | 14 / 0.1-350 |
| Waulsortian | 56 / 0.3-4080 | Namurian | 6 / 0.3-122 |
| Northern Waulsortian | 10 / 0.3-115 | Cork Group | 13 / 0.7-160 |
| Southern Waulsortian | 126 / 3.4-4080 | | |
| | | ***Other formations*** | |
| CALP | 14 / 0.2-427 | Granites | 3 / 0.1-47 |
| Western CALP | 6 / 0.3-0.75 | Campile Formation | 63 / 5.6-318 |
| Midland CALP | 45 / 1.6-427 | Gravel/Sand | 79 / 1.4-3260 |
| Eastern CALP | 11 / 0.3-29 | | |

**Olga Aslibekian, CES, University of Limerick**

**Fig 1(a). Histograms of Transmissivity Distribution for Different Aquifers**

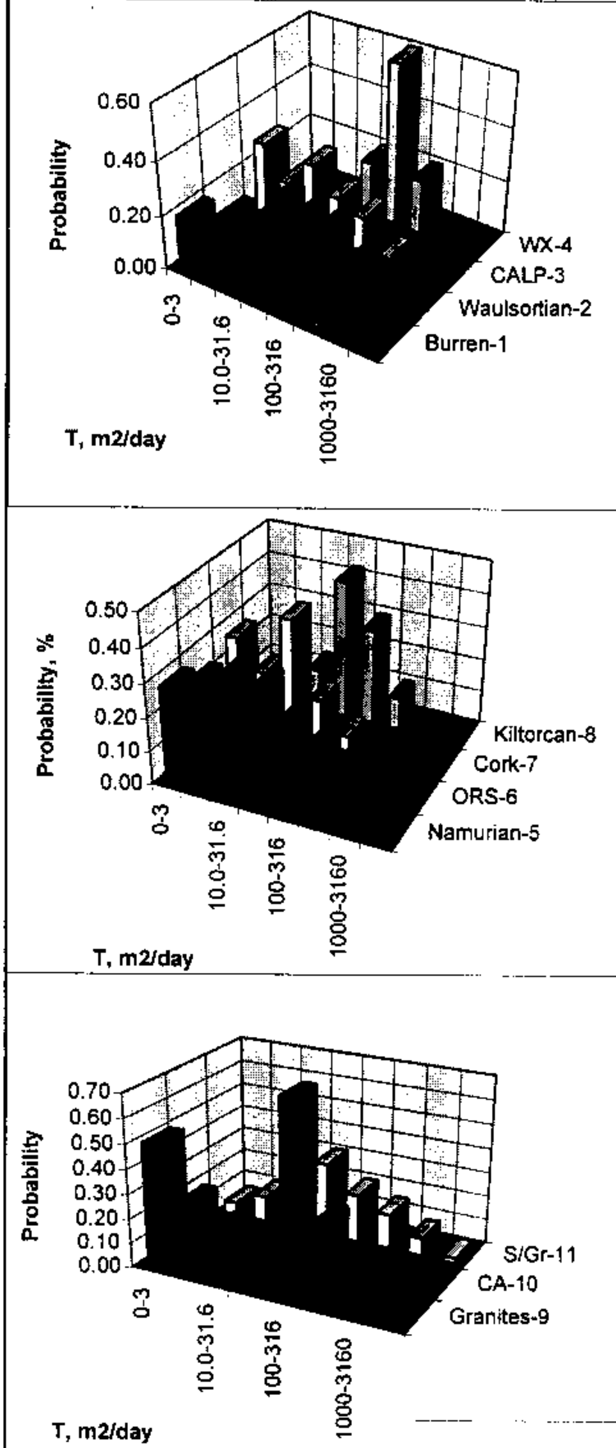
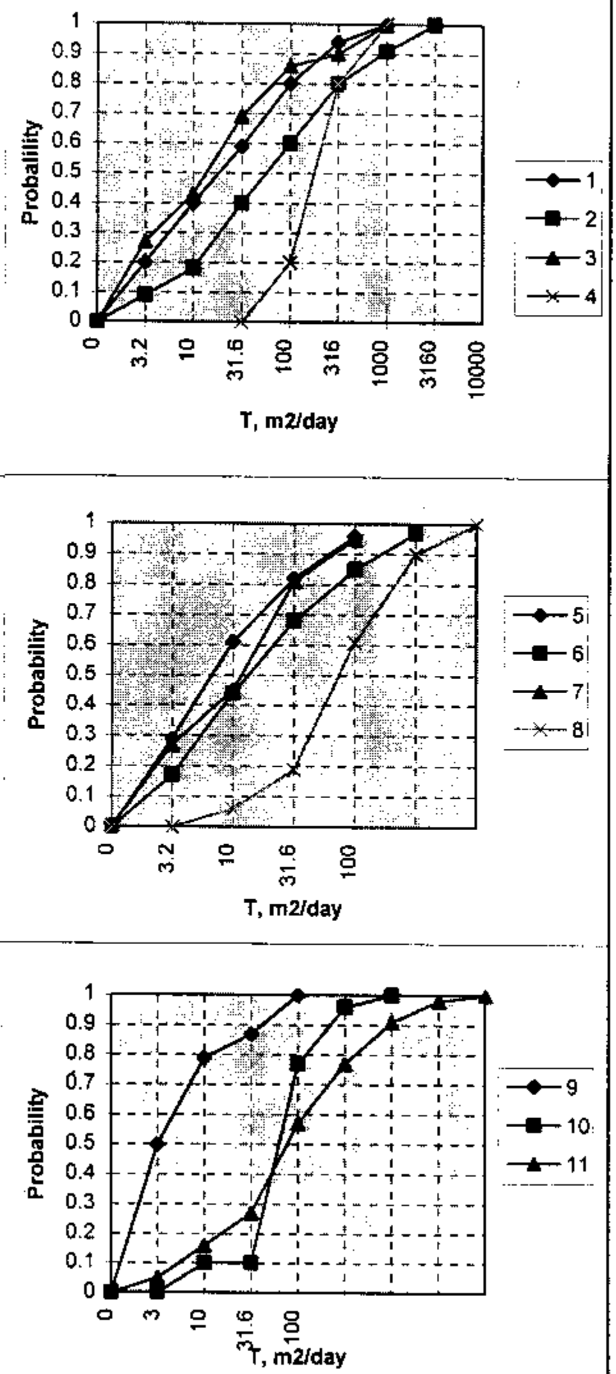



**Fig 1(b). Cumulative Distribution of Transmissivity Data**



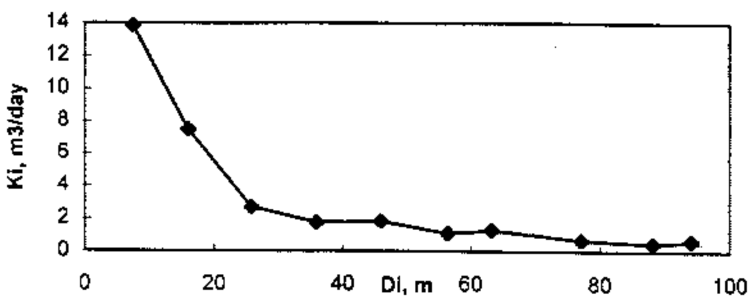




**Fig. 2. Change of Rock Permeability with Depth**

## International Groundwater Standards

Ireland is a member of ISO (International Standards Association) along with the majority of other countries around the globe. ISO is a voluntary body which was formed with the purpose of formulating standards and technical guidelines primarily in the interests removing international barriers and fostering trade. ISO member countries provide their own funding for participation and Ireland's representative body in ISO is the NSAI (National Standards Association of Ireland). ISO standards such as ISO9000 and ISO14000 are commonly recognised in this country along with a host of others. Ireland is currently a p-member (participating member) of several TCs (technical committees) which are currently drafting ISO standards. Examples of interest to those involved in the geological or environmental sciences are ISO TC190 (Soil), ISO TC207 (Environmental auditing), ISOTC146 (Air), and ISOTC147 (Water). Each TC is generally made up of several SCs (Subcommittees) each of which specialises in one aspect of the particular field of concern. For example TC190 SC1 is entitled *Terms & Definitions* and would be expected to assist the subcommittees within TC190 by publishing technical glossaries to accompany the standards being written. The standards themselves are generally drafted by WGs (Working Groups). P-membership of an ISO TC or WG is an option available to any member organisation in ISO which has an interest in the particular field of concern.

Ireland is currently an O-Member (Observation-Member) of ISOTC147 (Water) and it has come to my attention recently that this technical committee is involved with the drafting of groundwater standards which may be of interest to hydrogeologists in Ireland. An example is ISOTC147/SC6/WG4 (Water Quality) which is proposing to develop a technical guidance document entitled *Sampling - Guidance on the sampling of groundwater on potentially-contaminated Sites.* Other WGs in TC147 are concerned with the sampling of sludges/sediments and laboratory analysis of a number of parameters including COD, petroleum hydrocarbons, and trace elements.

Any standard developed within ISO, although not mandatory, will be internationally accepted. For this reason there has been an increasing tendency within CEN, the European Standards Agency, to adopt ISO standards, especially in highly technical fields such as *soil* and *water*. CEN standards are mandatory and it is therefore in Ireland's interest to be aware and to participate in the development of these standards. Unfortunately there is no specific government funding to attend ISO meetings, and individuals or organisations interested in representing Ireland in ISO TCs or WGs must finance their own travel and accommodation. Similarly there is no remuneration for time spent in participation. For this reason participation from outside the larger companies or the civil service can prove prohibitively costly.

Although as a hydrogeologist I currently have an interest in attending TC147/SC6/WG4 meetings, I am already participating in two other similar TCs. Consequently the extra burden would be unacceptable at this time. I would therefore like to hear from individuals or companies who have an interest in the development of this standard and other groundwater standards and who feel that they can provide the necessary experience to participate in this WG.

**Shane Bennet, Contaminant Hydrogeologist**

---

## Assessing Groundwater Analyses: Some Useful Tips

### Introduction

Assuming groundwater sampling has been carried out in accordance with an appropriate sampling protocol, how can the results of a standard chemical analysis be validated and evaluated in terms of groundwater quality?

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

Given these factors, it is important that a level of confidence is reached whereby the data received from the laboratory makes sound chemical sense. Some techniques commonly used to evaluate analytical results are briefly discussed below.

### Ions

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

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

These ions normally make up >95% of the dissolved minerals in groundwater.

### Units

Concentrations of constituents in groundwater are generally reported as mass per unit volume e.g. milligrams per litre (mg/l). These constituents have different atomic masses and charges, therefore concentrations cannot be directly compared using milligrams per litre. The milli-equivalent per litre (meq/l) is the standard unit which takes atomic mass and charge into consideration. To convert from mg/l to meq/l: divide by the Relative Atomic Mass (RAM) and multiply by the charge. The RAM can be obtained from the Periodic Table of any chemistry textbook.

e.g. RAM of $Ca^{2+}$ is 40.08, and the charge of $Ca^{2+}$ is 2.

$$21 mg/l\ Ca^{2+} = \frac{21 \times 2}{40.08} = 1.048\ meq/l\ Ca^{2+}$$

Or more simply, to convert mg/l to meq/l, multiply by the following Conversion Factors (CF):

| Cations | CF | Anions | CF |
|---|---|---|---|
| $Na^+$ | 0.04350 | $CO_3^{2-}$ | 0.03333 |
| $K^+$ | 0.02558 | $HCO_3^-$ | 0.01639 |
| $Ca^{2+}$ | 0.04990 | $SO_4^{2-}$ | 0.02082 |
| $Mg^{2+}$ | 0.08229 | $Cl^-$ | 0.02821 |
| | | $NO_3^-$ | 0.01613 |

### The Ionic Balance

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

$$Ionic\ Balance\ Error\ \% = \frac{\Sigma(+) - \Sigma(-)}{\Sigma(+) + \Sigma(-)} \times 100$$

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

1) The analysis is poor (inaccurate).
2) Other constituents were present that were not used to calculate the balance.

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

### pH and Alkalinity

Water molecules comprise hydroxyl ions ($OH^-$) and hydrogen ions ($H^+$). The hydrogen ion concentration in water is expressed as pH.

$$pH = \log_{10} [1/H^+] \quad \textbf{or} \quad pH = -\log_{10} [H^+]$$

pH ranges from 0 to 14, a pH of 7 indicates an equal concentration of $H^+$ and $OH^-$, i.e. has a neutral pH. pH > 7 indicates a basic solution, pH < 7 indicates an acid solution. The Maximum

Admissible Concentration (MAC) value for pH in drinking water is between 6.0 and 9.0.

The alkalinity of groundwater is its ability to neutralise acid. The main ions which contribute to alkalinity are carbonate ($CO_3^{2-}$) and bicarbonate ($HCO_3^-$). Alkalinity is generally expressed as mg/l $CaCO_3$.

Beware of a pH or alkalinity calculated in the lab as they are unstable and will change quickly with exposure to atmospheric conditions. The sampling and transit process will disturb the equilibria between dissolved carbonate, bicarbonate and carbon dioxide. This will cause for example, the release of carbon dioxide to the atmosphere, or the precipitation of carbonates. Such disturbances can bring about changes in pH and alkalinity. The tendency will be for pH to rise and alkalinity to fall. Therefore pH and alkalinity should be measured in the field if at all possible.

**Hardness**

Hardness has been described as the soap consuming capacity, or scale forming capacity of water. Calcium and magnesium are the main constituents of hardness. Total hardness comprises the $Ca^{2+}$ + $Mg^{2+}$ concentration and is expressed as "mg/l $CaCO_3$ equivalent". Hardness varies throughout the country depending on rock type; the following classification is used in the GSI and elsewhere to describe the hardness of groundwater:

| | |
|---|---|
| Soft | < 50 mg/l $CaCO_3$ |
| Moderately Soft | 51 - 100 mg/l $CaCO_3$ |
| Slightly Hard | 101 - 150 mg/l $CaCO_3$ |
| Moderately Hard | 151 - 250 mg/l $CaCO_3$ |
| Hard | 251 - 350 mg/l $CaCO_3$ |
| Very Hard | >350 mg/l $CaCO_3$ |

Total Hardness is equal to the Carbonate Hardness plus the Non Carbonate Hardness. Carbonate hardness is derived from the calcium and magnesium which combine with any bicarbonate or carbonate present (carbonate hardness is equivalent to alkalinity). Carbonate hardness (also known as temporary hardness) can be removed by boiling. This causes the precipitation of calcium and magnesium carbonates, often seen as scale in pipes, kettles etc.

Non carbonate hardness is derived from the calcium and magnesium which combine with sulphates, chlorides and nitrates. Non carbonate hardness (also known as permanent hardness) cannot be removed by boiling.

$$\textit{Total Hardness} - \textit{Alkalinity} = \textit{Non Carbonate Hardness}$$

To check the Total Hardness (TH) figure:

$$2.5 \times Ca^{2+}\ (mg/l) + 4.1 \times Mg^{2+}\ (mg/l) = TH\ (mg/l\ CaCO_3)$$

**Electrical Conductivity**

Electrical conductivity (EC) can be defined as the ability of a substance to conduct an electric current at a specified temperature, usually 20°C or 25°C. EC depends on the amount of dissolved materials and is reported in microsiemens per centimetre (µS/cm). As a rule:

$$EC\ (\mu S/cm) = K \times \sum Cations\ (meq/l) = K \times \sum Anions\ (meq/l)$$

where $K$ is a factor which ranges from 90 - 125. In relatively unpolluted groundwater $K$ is taken as 100.

There is also a relationship between EC and Total Dissolved Solids (TDS):

$$TDS = A \times EC$$

where $A$ is a factor, which lies between 0.55 and 0.96. In relatively unpolluted groundwater $A$ generally lies in the range of 0.65 to 0.7.

**Nitrogen**

Nitrogen (N) is an element that can exist in different states, such as ammonia ($NH_3$), ammonium ($NH_4^+$), nitrite ($NO_2^-$) and nitrate ($NO_3^-$). Decomposition of plant and animal waste products by bacteria and fungi gives rise to the production of ammonia. Ammonia is naturally present in small amounts in groundwater; when present in levels above 0.1 mg/l N, contamination by organic wastes may be indicated. Ammonia is found in its free state as $NH_3$, or in its ionic state, as $NH_4^+$ (Ammonium).

If ammoniacal nitrogen, i.e. nitrogen expressed as ammonia or ammonium, is reported as N mg/l; the exact $NH_3$ or $NH_4^+$ concentration can be determined by the following relationships:

$NH_3$ = *Ammoniacal Nitrogen (mg/l N) x 1.214*
$NH_4^+$ = *Ammoniacal Nitrogen (mg/l N) x 1.285*

Ammonia is first oxidised by bacteria to nitrite and then to nitrate. Heavy contamination of groundwater by nitrate is linked to methemoglobinemia, or blue baby syndrome. This is a blood disorder in which the transport of oxygen in babies or unborn foetuses is impaired.

If Nitrate is reported as $NO_3^-$ mg/l N, the nitrate concentration as $NO_3^-$ can be determined by the following relationship:

$$NO_3^- = NO_3^- \; mg/l \; N \times 4.43.$$

e.g. 11.3 mg/l $NO_3^-$ (mg/l N) is 50 mg/l $NO_3^-$

**Chloride**
In coastal areas, rainwater is enriched with chloride ($Cl^-$) due to the evaporation of seawater. Groundwater in these areas often contains higher concentrations of chloride.

Chloride like nitrate is a mobile anion i.e. these ions do not tend to get bound up by the soil/subsoil as they move toward groundwater. Chloride is also a constituent of organic wastes. Consequently, levels appreciably above background levels (12-15 mg/l in Offaly for instance) are taken to indicate contamination by organic wastes e.g. seepage from septic tank systems or farmyard wastes.

**Iron and Manganese**
Although iron (Fe) and manganese (Mn) can occur under natural conditions in some groundwaters, they can also be good indicators of contamination by organic wastes. 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. 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.

**K:Na ratio**
The background potassium-sodium ratio in most Irish groundwaters is less than 0.4 and often 0.3. The $K^+$:$Na^+$ ratio of soiled water and other wastes derived from plant organic matter is considerably greater than 0.4. Consequently a $K^+$:$Na^+$ ratio greater than 0.4 can be used to indicate contamination by plant organic matter (such as slurry) and occasionally landfill sites (from the breakdown of paper). However a $K^+$:$Na^+$ ratio lower than 0.4 does not necessarily indicate that farmyard wastes are not a source of contamination i.e. a low ratio may reflect the fact that $K^+$ is less mobile than $Na^+$ and therefore is bound up in the soil and subsoil before reaching the groundwater.

**Conclusion**
Before assessing water quality, it is advisable to double check the laboratory results. The above information serves to highlight a few of the common techniques employed when validating and assessing groundwater analyses.

**Bibliography**

Daly, D. 1994. *Chemical Pollutants in groundwater; A Review of the Situation In Ireland.* Proceedings of the Sherkin Island Marine Research Station Conference "Chemicals - A Cause for Concern?"

Domenico P.A. and F.W. Schwartz 1990. *Physical and Chemical Hydrogeology.* John Wiley & Sons.

Driscoll, F.G. 1986. *Groundwater and Wells*, 2nd Edition. Johnson Filtration Systems Inc.

Flanagan, P.J. 1990. *Parameters of Water Quality, Interpretation and Standards*, 2nd Edition. Environmental Research Unit.

Hem, J.D. 1985. *Study and Interpretation of Chemical Characteristics of Natural Water*, 3rd Edition. USGS Water Supply Paper No. 2234.

Hounslow, A.W. 1995. *Water Quality Data; Analysis and Interpretation.* CRC Press, Inc.

Kotz, R.C. and R.F. Purcell. 1987. *Chemistry and Chemical Reactivity*, CBS College Publishing.

Silsoe College, Cranfield University, 1998. Notes for short course on *Groundwater Data; Presentation and Interpretation.*



**Colette Cronin, Geological Survey of Ireland and Anita Furey, K.T.Cullen & Co. Ltd.**


------------------

## The Use of Structural Geology, Fracture Analysis and Stochastic Fracture Flow Modelling in Ground Water Exploration and Development

The study area and the wellfield of interest lies on the boundary between the Waulsortian Mudbank Limestone and the bedded Middle Limestones of late Dinantian age in south west Limerick, Ireland. There is regional E-W to ENE folding and cleavage but while the fold style varies, the local strain does not. The deformation style is controlled by the lithology and there is a regional increase in strain towards the south and towards the Fergus Shear Zone to the north. N-S fractures are dominant but tend to become rotated and modified by transcurrent faults and shear zones. The prolonged N-S compression, accompanied by a component of dextral shear, indicates an overall transpressive regime. The dextral transpression produced dilation zones at bends, terminations and intersections of fault and shear zones which control secondary permeability.

The Newcastle West region was deformed during the Variscan Orogeny. The area is about 35km north of the Variscan Thrust Front and has undergone significant deformation. The area is located in the hinge region of a large open anticline. The hinge region has several large second order folds resulting in three periclinal inliers of Old Red Sandstone. The outer arcs are tensional zones resulting in open brittle fractures. Cross faults are also more common in the periclines.

No major faults are seen in the Newcastle West Anticlinorium although minor faults have been seen. Shear veins and slickensides are not seen on any fault surface indicating low pore pressures at the time of faulting which would have resulted in wide brecciated and fractured zones enhancing the secondary permeability. The Waulsortian would have behaved in a brittle manner during deformation. A North-South trending extensional fault, perpendicular to the fold axis is inferred to be running through the wellfield area along the contact between the Waulsortian Mudbank Limestones and the Middle Limestones.

Cleavage is either poorly developed or absent in the area as it is north of the Variscan front. This lack of cleavage supports the contention that deformation occurred under a low pore pressure regime. Jointing is most developed in the Waulsortian. There is a well developed north-south subvertical joint system throughout the area. There are secondary joints developed that trend between $100^0$ to $120^0$.

Karstification of the Courceyan rocks has resulted in the development of secondary permeabilities. Karstification is considered to be either palaeokarst or recent karst. The Quaternary glaciations reduced mean sea levels by about 70 to 100m. The elevation of the wellfield is between 55 and 60m so circulation through karst systems would have been possible down to about 150 to 160m below ground level.

The majority of the warm springs in Munster and Leinster are associated with the Waulsortian Mudbank complexes. This indicates that deeply circulating groundwater is possible through the Waulsortian. The Waulsortian complexes are known to be preferentially dolomitised along joints and faults which resulted in increased secondary permeabilities at depth in the Waulsortian.

There are models that apply a continuum and equivalent porous medium approach or there are models that apply a discrete fracture approach to groundwater flow modelling. The collection of fracture data can be used to demonstrate that a fractured aquifer is or is not an equivalent porous medium above a certain scale. The data can also be used as the basic input to a fracture flow model. The permeability of fractured rocks is affected by the fracture density. There is a critical fracture density below which the overall permeability of a fractured rock mass is zero. Above the critical fracture density, permeability increases linearly with fracture density. The permeability of fractured rocks is controlled by the connectivity of fractures which in turn is related to fracture density.

Power law or negative exponential equations were fitted to all the fracture aperture and fracture length plots. Such data through which a straight-line could be drawn were defined as being fractal or power law distributions. A linear curve, of the form a+bx, could be fitted to all the cumulative fracture spacing plots. The sum of all the apertures was averaged and cumulated to give a mass function plot. The mean horizontal fracture density is $0.44m/m^2$, the mean vertical fracture density is $0.24m/m^2$ and the mean total fracture density is $0.34m/m^2$. Fractures with apertures greater than 20mm were the only class to have a significant anticluster value of 0.7. The coefficients of variation indicated that 50% of the fractures for all sizes are evenly distributed and 41% are significantly clustered.

The mean fracture spacing is between 0.42m to 2.79m depending on the orientation. Therefore the model domain must be at least between 420m and 2790m in length. The fracture density is classified as medium. The fracture orientation is not uniform while the calculation of the coefficient of variation values for fracture apertures indicates an uniform distribution. Finally the volume of rock tested was large. All the criteria for approximating the study area to an equivalent porous medium, with the exception of density, are fully met. The aquifer could therefore be assumed as being an equivalent porous medium. There is potentially a water bearing fracture every 1.11m in both the x and z directions.

The type of porosity seen in the study area is secondary solution enlargement resulting in meso- to megapore sized non fabric selective fractures, channels, vugs and caverns. It can be shown that the average areal porosity is equal to the volumetric porosity. The range of values is from 1.83% to 7.89% with an average porosity in the horizontal direction of 4.34% and an average of 3.23% in the vertical direction. An average of 3.79% was calculated for all the sections.

Values for Umin and Umax range between 16.0 and 26.0m for the most part. The REV (representative elementary volume) chosen is 19m in the horizontal and 19m in the vertical or some multiple thereof. This means that the minimum cell size for any model should be 19m in the x, y and z directions in order to satisfy the assumption that the domain is a continuos porous medium. The REV can increase in multiples of 19m in all directions to a maximum value of 57m. A REV greater than that will start to be affected by the macroscopic heterogeneities of the domain. A conceptual model based on the results of the fracture analyses is given.

The permeability calculations demonstrate the anisotropy of the system based on the orientation of the sampled section. There is variation in all three directions. All the vertical permeabilities are lower than the horizontal permeabilities by one order of magnitude.

MODFLOW was implemented for the modelling of the well field and the surrounding area. The grid was set up using the criteria of the REV and porous equivalent media approximation. A steady state model was developed. A good approximation of head distributions was achieved. The model was used to develop an aquifer protection programme.

A stochastic discrete fracture flow model, FRACMAN (Golder Associates), was developed of just the well field. A steady state model was developed initially and then a transient model. The results of both runs gave acceptable calibration results. The FRACMAN model was used to estimate time of travel for particles through the well field. Finally FRACMAN was used to calculate the optimum borehole orientation to provide the highest probability of success for a high yielding well.

**Shane O'Neill, O'Neill Ground Water Engineering,**

--------------------

## Phosphorus in Irish Aquifers: Implications for Input to Surface Waters

Phosphorus (P) is a frequently neglected parameter in studies of groundwater chemistry and quality, because the maximum admissible concentration for drinking waters (5 mg/l $P_2O_5$, = 2.2 mg/l P) is rarely approached, except in areas of gross localised contamination. In surface waters, however, the concern with phosphorus is at much lower levels: a concentration of only 0.02 mg/l P may trigger eutrophication. Entry of P from agricultural sources to surface waters is currently receiving considerable attention both internationally and within Ireland. The primary concern of Irish researchers is with overland flow on low permeability soils, but current research on this has highlighted the current lack of knowledge on the proportion of P reaching rivers and lakes from different routes, and the need to quantify inputs from aquifers. Conventional wisdom is that most phosphorus is retained in the soil zone by adsorption and by precipitation as hydroxyapatite; however, in some situations (e.g. non-calcareous aquifers or high permeability fissured and karstified aquifers), this may not provide complete attenuation. Furthermore, groundwater contributions of P to surface water are greatest (as a proportion of total P loading) in the summer, when the risk of eutrophication is highest, so the effect of groundwater P loading may be substantial.

A research project is currently being undertaken by Garrett Kilroy at the Environmental Sciences Unit (ESU), Trinity College Dublin, and is funded by a Forbairt Basic Research Grant. Dr. Catherine Coxon, is the principal supervisor for this project, dealing with groundwater aspects; the project also involves a limnologist (Dr. Norman Allott) and a GIS specialist (Dr. Krysia Rybaczuk). This project aims to examine phosphorus levels in a range of Irish hydrogeological situations, both to fill this gap in basic scientific knowledge, and to determine the circumstances in which concentrations likely to trigger eutrophication are likely to arise.

The possibility of naturally elevated levels due to natural geological sources (e.g. bands of phosphatic shale within aquifers) will be investigated, but the main focus will be on determining the hydrogeological factors which allow phosphorus from anthropogenic sources (including inorganic fertilizer, animal manure and sewage) to enter the saturated zone and pass through the aquifer, discharging at springs and as river baseflow.

- A national groundwater P spatial database will be compiled from existing data. These data will be overlaid with information on aquifer locations and characteristics, to determine if these exert a significant control on P levels. Comparison will also be made with the national soil P desorption model being developed for the EPA.
- Phosphorus data from surface water will be examined in relation to aquifer distribution, and hydrograph analysis will be carried out, to identify rivers and lakes with elevated P which have a significant groundwater input. Temporal variations in river P will be examined in conjunction with hydrographs, and situations where there is evidence of significant P in river baseflow will be identified.
- Situations worthy of detailed field research will be identified. Investigations will involve monitoring of groundwater and surface water P, determining sources of phosphorus (both diffuse and localised), determining groundwater vulnerability from soil type and Quaternary geology, and determining aquifer characteristics. Where possible, the focus will be on areas already subject to hydrogeological investigation, in order to build on existing knowledge.

From all the above approaches, the chief controls of phosphorus levels in aquifers will be identified, and areas where groundwater P is a potential source of eutrophication of surface water bodies will be identified.

Any comments or elucidations pertaining to this project would be very welcome.

**Garrett Kilroy, Environmental Sciences Unit, Trinity College Dublin**

-----------------

## Improving the Groundwater Vulnerability Concept

Groundwater protection schemes aim to minimise the risk to groundwater from potentially polluting activities such as septic tank systems, agricultural wastes and landfill sites. Application of a conventional *source - pathway - target* model of environmental management indicates the potential risk of contamination to groundwater. In these models, the vulnerability of groundwater to contamination characterises the pathway, and is considered to be one of the most significant factors in influencing groundwater quality in Ireland. Due to the increase in demand for, and reliance on, groundwater protection schemes for planning purposes, it is important that we increase our knowledge of groundwater vulnerability in Ireland.

### The Vulnerability Concept

In Ireland, the assessment of groundwater vulnerability is based mainly on the thickness and permeability of the subsoil which lies between the topsoil and bedrock: a thick, low permeability, clayey subsoil, for example, generally provides better protection to underlying groundwater than a thin layer of coarse grained sandy subsoil. Since natural attenuation of pollutants occurs mainly in subsoils above the groundwater in bedrock and sand and gravel aquifers, knowing the thickness and permeability of the subsoils is of utmost importance in making land use planning decisions.

As there are little quantitative data available regarding the permeability of tills in Ireland, vulnerability maps are based on qualitative assessments of permeability. These include grain size analyses, till matrix descriptions, and till boundaries based on clast lithology. In addition, relatively little is known about other potential indicators of groundwater vulnerability, especially the relationships between vegetation, surface drainage density, groundwater recharge and subsoil permeability.

To further research these issues, two projects are currently under way at the Department of Civil, Structural and Environmental Engineering at Trinity College Dublin (TCD) and the GSI. The first project involves assessing and mapping the permeability of subsoils using geotechnical and hydrogeological techniques. The second project investigates surface hydrology and land use as indicators of permeability and recharge acceptance. Both projects are outlined below in more detail.

### Project One: Permeabilities of Subsoils

The primary motivation for this project is to quantify permeability values for the different till types and the vulnerability ranges using a variety of field and laboratory tests. Other relationships, such as those between permeability and grain size distribution, percentage of silt and clay, till genesis, and till lithology are also being explored.

In order to investigate these relationships, we propose to drill boreholes at four to six locations in County Meath this summer. Sites in counties Laois and Clare are likely to be investigated this coming autumn. The current scope of field work includes using a shell and auger drill rig to install piezometers, and to collect undisturbed samples for laboratory permeability tests. Bulk samples will also be collected for grain size analyses. The performance of at least two falling head and rising head tests at each site over extended time periods will help to minimise error. We will also use TCD's Cone Penetrometer Testing (CPT) equipment to explore relationships between the measured permeabilities, pore water dissipation, and subsoil resistivity. If necessary, and where applicable, we will perform infiltrometer tests and Guelph permeameter tests for additional information. Laboratory tests, including grain size analyses, permeability tests, and consolidation tests will be carried out on collected samples at TCD's Civil Engineering laboratory.

In order to augment data from the above mentioned permeability tests, the GSI is currently looking for the results of any permeability tests and corresponding grain size analyses that have been performed in glacial tills in Ireland. Any relevant data that readers may have, and are willing to share, would be greatly appreciated; please contact Melissa Swartz (01-6041408 or swartzm@tec.irlgov.ie) in the Groundwater Section of the GSI if you have such information. Please note that the results of this research will be made public upon completion of the project, but that specific data sources may be kept confidential if requested.

**Project Two: Surface Indicators of Permeability**

The main objective of this project is to assess the relationships between surface runoff, drainage characteristics and vegetation, with respect to measured and assumed permeabilities. A variety of techniques are being employed to investigate the links between surficial features and recharge capacity.

In order to understand how underlying till and/or bedrock types influence catchment characteristics, we are researching correlations between stream lengths, catchment areas, stream junctions and the underlying materials. We will also investigate links between vulnerability classes and catchment characteristics. In addition, low flow river data from the Flood Studies Report (1975) will be analysed to investigate whether baseflows are indicative of the recharge capacity, and hence permeability, of the subsoils. These relationships will also be investigated using soils maps, published by An Foras Talúntais, and CORINE land use data.

Work to be conducted at specific sites includes vegetation mapping and drainage density (including field drains) analyses. This mapping may result in the identification of vegetative indicator species and drainage densities for different subsoil vulnerability classes. Ultimately, the use of surface indicators of recharge, and hence permeability, will enhance the mapping of vulnerability boundaries, especially in areas where more specific data are not available.

**Monica Lee and Melissa Swartz, Trinity College Dublin and the Geological Survey of Ireland**

----------------

## Review

### Handbook of Drinking Water Quality (2nd Ed.) by John De Zuane. Published by Van Nostrand Reinhold. (£55.00)

This 575 page book was originally published in 1990 and this edition was updated in 1997 to deal with the changes in water quality control over the intervening period. The book is intended to provide a quick reference and technical support regarding water quality control.

Chapter 1 acts as an introduction to water consumption and potability. Chapter 2 deals with general or physical parameters, their determination, public health aspects and standards. Chapter 3 deals with inorganic chemicals and each is evaluated on the basis of chemistry, environmental exposure, health effects, standards, analysis and removal. Chapter 4 deals with the inorganic chemicals, their occurrence in the environment and health effects, with standards and lab determination methods being listed for each parameter. Microbiological parameters are examined in Chapter 5 and radionuclei in Chapter 6. Chapter 7 briefly reviews carcinogenic substances and, although the relevant parameters have been dealt with in the preceding chapters, risk assessment and drinking water standards are reviewed here. Chapter 8 deals with the application of standards, particularly sampling and monitoring procedures and laboratory analyses. Chapter 9 is on public health regulation while Chapter 10 deals with water works and water treatment. Chapter 11 deals with federal regulation for surface water supplies.

This book provides a very comprehensive review of drinking water quality and a wide range of parameters are covered in chapters 2 to 7. Understandably the book tends to focus on US standards and regulations although the WHO guidelines and the European Drinking Water Directives are included in the Appendices. However, despite its volume, the book is well written and does allow quick and easy reference.

**Donal O'Suilleabháin, B.J. Murphy & Associates**

------------------

## Report on American Institute of Hydrology (AIH) - International Conference on Advances on Groundwater Hydrology, Tampa, Florida, November 1997.

This conference was one of a series held each decade since the inaugural such meeting in San Francisco in 1967. The others were in Chicago (1976) and Tampa (1988). The current meeting was co-hosted by AIH, Southwest Florida Management District and the UG Geological Survey (USGS). The stated objectives of these conferences are :

- To review the most important advances made in groundwater hydrology in the USA and abroad during the past decade;
- To inform the hydrological community about recent results of research and practical applications in groundwater hydrology;
- To discuss the needs for research and practical application and possible trends in groundwater hydrology.

The programme comprised :
- A one day short course
- Three days of technical papers
- A one day field workshop
- A poster session
- Technical exhibition.

The attendance was about 300. The 362 page advance proceedings consisted of about half papers and half abstracts only. There was a special international session with invited papers from eight European countries, including Ireland.

The themes were :
Groundwater cleanup vs containment:
3 abstracts
Groundwater contamination and remediation;
7 papers, 4 abstracts
Groundwater flow/solute transport analyses;
3 papers, 4 abstracts
Groundwater in fractured rock and karst;
1 paper, 7 abstracts
Groundwater modelling;
8 papers, 6 abstracts
Groundwater protection and management;
6 papers, 3 abstracts
Hydrogeologic studies and aquifer tests;
7 papers, 2 abstracts
Techniques and methods;
5 papers, 8 abstracts
Trends in groundwater hydrological research;
3 papers. 3 abstracts.

### Selected Points

**General**
- Goal of hydrogeology is to obtain the maximum quantity of water, of a given quality at minimum cost.
- Drop in number of hydrogeologists employed in USA due to less emphasis on cleanup.
- Changing world for consultants - unhappy clients who come not to have a problem solved but to meet regulatory requirements.
- Insufficient progress in understanding processes.
- Hydrogeologists need to provide scientific data and knowledge to politicians and the media.

**Water Management**
- Increased emphasis on the conjunctive use of all water resources.
- Redirection of funds towards sustainability.
- Regard to aquifers as reservoirs and thus manage what comes in and what goes out.
- Movement towards regional co-operation in water supplies.
- Acceptable change due to groundwater abstraction defined in Florida as "up to level at which significant harm will occur".
- New West-Central Florida multi-agency water management master plan up to year 2015 includes aggressive conservation methods, conjunctive use, allowance for climatic variation and lowest possible costs.

**Protection and Water Treatment**
- Role for both cleanup and containment of contamination but trend in USA in 1990s is away from cleanup and towards containment, including doing nothing.
- Intermediate alternatives for groundwater contamination include in-situ treatment and natural attenuation.
- In UK, solvents and sprays seen as main threat to groundwater rather than landfills.
- US Federal Super Fund now seen as a good idea taken to extremes.

**Research**
- Two major paths of research in hydrogeology in past 50 years, that of the engineer and that of the hydrogeologist.

- Need for better and more reliable geostatistical data.
- 1989 Danish review identified the main issues for soil and groundwater as strengthened basic research and increased research into organics.
- In Denmark future research is seen to include the development of a national 3D numerical groundwater model together with emphasis on pesticides, groundwater recharge and heterogeneous systems.

**Methodologies**

- Re-emphasis of USGS geological mapping programme around groundwater resources.
- Use of new geophysical methods in hydrogeology such as Transient Electromagnetic Sounding (TEM). and the Pulley Array continuous Electrical Profiling Method.
- Vulnerability maps as good as the information and methods put into them.
- In Norway in hard rocks, amount of isostatic uplift considered an important factor in determining openness of fractures and thus size of yield.

A copy of the Conference proceedings is available for viewing in the GSI library.

**Bob Aldwell, Geological Survey of Ireland**

--------------------

## Geothermal Association of Ireland

The inaugural meeting of the Geothermal Association of Ireland was held at the Energy Agency Office in Spa House, Mallow, Co. Cork on January 16th, 1998. The meeting was convened by Mr. Pat Walsh, Cork County Council Project engineer, who runs the Energy Office.

The objective of the Association is to promote an awareness of geothermal energy in Ireland, to act as a focus for the collation and compilation of data on all aspects of geothermal energy and to be a conduit for the dissemination of that and other related information to the general public. The promotion of spas and associated waters will also be included in the remit of the Association.

The Geothermal Association of Ireland will be publishing a quarterly newsletter on all aspects of geothermal energy both here in Ireland and abroad. There will be quarterly meetings of the Association at various geographical locations throughout the country. Anyone interested in receiving the newsletter or attending future meetings should contact the secretariat in Mallow.

Elections were held among the thirteen people present for various administrative positions within the Association. The following were elected:

1. Chairperson
Michael O'Brien, Cork Corporation;
2. Vice Chairperson
Bob Aldwell, Geological Survey of Ireland;
3. Secretary
Ger Barry, Energy Office, Mallow;
4. PRO/Development
Shane O'Neill, O'Neill Ground Water Engineering;
5. EU Co-ordinator
Brian Connor, Brian P. Connor and Associates Ltd.

The first objective of the Geothermal Association of Ireland is to encourage anyone involved in the exploitation of ground water to send in information on ground water temperatures to the secretariat in Mallow.

The second meeting of the Association was held during the two day annual IAH groundwater seminar held at the Killeshin Hotel, Portlaoise on April 21st and 22nd, 1998.

**Shane O'Neill, PRO/Development Officer.**

-------------------

## Irish Group of IAH Further Develop Contacts with Russian Hydrogeologists in St Petersburg.

Following on from the 1995 visit to Ireland of Professor Arkady Voronov of St Petersburg University and the 1996 visit to Russia of an eight person delegation from the Irish IAH, it was decided to further develop these contacts in 1997. An Irish IAH Group subcommittee composed of Bob Aldwell, Olga Aslibekian, David Ball and David Drew was set up to organise arrangements on the Irish side. The initial objective was to make use of the opportunity provided by the recent opening up of Russia to contacts with the West to become familiar with the situation in hydrogeology and related topics in each other's countries. It was decided to do this by a series of initiatives involving Russian hydrogeologists coming to Ireland and becoming more involved with the IAH at an international level and a number of Irish IAH members going to St Petersburg to lecture and to discuss matters of mutual interest with their Russian colleagues.

Discussions with the Irish Ambassador in Moscow, Ronan Murphy and the Department of Foreign Affairs in Dublin showed strong support for the initiatives and was backed by some funding. Approaches were made to a number of Irish organisations for additional support as well as to the British IAH to facilitate the attendance of some of the Russians at the IAH Congress on urban hydrogeology held in Nottingham in September 1997.

The outcome was :

- The Irish IAH agreed to sponsor five young Russian hydrogeologists as members of the IAH for five years.
- Two young Russian graduates came to Ireland for three months work experience (to ESBI and GSI).
- Six other Russian hydrogeologists visited Ireland in September. They participated in a nine day series of meetings, workshops and field visits. The Irish organisations they met were Ballygowan, Bord na Mona, ENFO, EPA, ESBI, GSI, Kevin Cullen & Co, Teagasc, TCD, UCG and Wexford County Council.
- Five of the Russians were taken to the IAH Congress in Nottingham.
- Three other Russians remained for the second week in Ireland hosted by individual Irish IAH Group members.
- Shane O'Neill attended a three day international workshop on "The Quality of Drinking and Mineral Waters of the St Petersburg Region and their Bottling", held in St Petersburg University in July.
- David Ball and Bruce Misstear spent a week lecturing to the staff and students of the Department of Hydrogeology of St Petersburg University in October. Two seminars were run - "Groundwater Protection" and "Working as a Hydrogeological Consultant".

Besides the generous support from the Department of Foreign Affairs, the Irish organisers also express their thanks to

Aer Lingus
Aer Rianta
Ballygowan
GSI
IAH (British and Irish Groups)
Walsh Western International
University College Galway.

Bord na Mona, ENFO, EPA, TCD, Teagasc are all thanked for their hospitality to our visitors.

**Bob Aldwell, Geological Survey of Ireland**

------------------

## IAH News

At the IAH (Irish Group) Annual General Meeting last November, the following committee was elected:

| | |
|---|---|
| President: | Geoff Wright (GSI) |
| Secretary: | Bruce Misstear (TCD) |
| Treasurer: | Margaret Keegan (EPA) |
| Seminar Secretary: | Shane Bennet |
| Field Trip Secretary: | Richard Church |

*****

**18th Annual Groundwater Seminar, Portlaoise: *"Hydrogeology and Waste Management"*, April 21-22.**

Those who attended can testify that our annual IAH highlight was again very successful, and our congratulations and thanks go particularly to Shane Bennet and his team for the smooth organisation. Attendance was a record 167, and the standard of presentations was well up to our customary high standards.

*****

***Copies of the IAH Irish Group Directory are still available for £5 each, from Geoff Wright at GSI or Margaret Keegan at the EPA in Wexford.***

*****

**Exchange Visits with French IAH Group**

The Irish IAH Group has been approached by our French counterparts with a view to organising a visit by French hydrogeologists around May 1999, with the prospect of a corresponding visit by us to France the following year. Pierre Thonon, representing the French Group, visited here in March and a provisional itinerary was drawn up, as follows:

Day 1 (Saturday): Morning arrival at Cork (in Coach): drive through Cork and Limerick to Clare, visiting sites of interest.

Day 2 (Sunday) Burren & Galway karst

Days 3 to 6 Possible places to visit include additional karst sites in Galway/Mayo/Roscommon, Offaly bogs, Galmoy or Lisheen Mine (subject to the companies approval) .........returning to Cork at the end of the week.

We hope to get a good turnout of IAH members, at least for the first weekend of the trip. Further information will be issued in due course. Meanwhile, the Committee would be interested to hear from any members with suggestions for the itinerary, offers to lead parts of the trip, or particular interest in taking part. We would also be glad to receive ideas for our prospective itinerary in France in 2000. We hope members will warmly welcome this initiative by our French colleagues, which could mark the start of a wider programme of exchange visits with European hydrogeologists.

*****

**Geoff Wright, IAH (Irish Group) President**

-----------------

## Cross-border Co-operation in Geosciences

In recent years, the Geological Survey of Ireland (GSI) and the Geological Survey of Northern Ireland (GSNI) have sought opportunities to increase the level of co-operation between the two organisations in the interests of the customers they serve and, more generally, in the interests of geoscience in Ireland. A catalyst was provided in late 1994 when the International Fund for Ireland provided funds to support a joint GSI/GSNI pilot study of the minerals development potential and geotourism opportunities of the Cavan-Fermanagh area.

The project delivered a wealth of information in the form of detailed geological maps, reports and digital databases (on CD ROM) to the local authorities of both counties. The data presented will assist planners, engineers and developers to make informed decisions about responsible development of the region's earth resources into the next millennium.

A suite of popular illustrated guides describing the scenic landscapes and rocks of the region was published and distributed to local tourist centres and retail outlets. A brief marketing survey highlighted the region's potential in attracting overseas educational tours, particularly from Britain.

The success of the Cavan-Fermanagh pilot project encouraged both GSI and GSNI to formulate a much more ambitious 12-county proposal - *Developing green tourism: the landscape and rocks of Northern Ireland.* The proposal received financial support from EU Structural Funds (INTERREG II Programme; Special Support Programme for Peace and Reconciliation) and from most of the councils in the 12-County Region Northern Ireland & six border counties in the Republic of Ireland.

The new cross-border project started in 1997 and will run for three years. A team of three or more geoscientists and a marketing specialist will be employed to assess and market the opportunities for earth resource tourism in the region.

In a parallel study, aspects of the mineral potential of the region will also be evaluated.

Both GSI and GSNI are eager to succeed in this new joint venture in the spirit of scientific co-operation between both organisations.

**Pat O'Connor, Geological Survey of Ireland & Ian Mitchell, Geological Survey of Northern Ireland**

----------------

## Irish Speleology 16

The most recent volume of the Journal of the Irish Speleological Union of Ireland has been published. Included in this 52 page volume are papers on: Poll an Chaisc, a new swallet cave in the Burren by Colin Bunce; Caddis fly larval tubes in Polltalloon also by Colin Bunce; the karst landforms and hydrology of the Co. Westmeath 'Lakeland' area by David Drew; the caves at Ballagh in Co. Tipperary; Oweynagat, an archaeological/mythological cave near Rathcroghan, in Roscommon with unusual (?) karst features adjacent to it. Also of interest may be two papers on caves within Quaternary deposits in Galway and Dublin City centre. The journal also contains a preliminary listing of references in the Karst Reference Database, compiled by Morgan Burke in the GSI and available for consultation. Over 1100 articles and books on Irish karst are included, and already, since the publication, some additional data and corrections of details have been forthcoming. I have entered these on the Karst Reference Database but any further information will be most welcome.

The Journal is available from the Editor, Dr Matthew Parkes, 3 Fontenoy St., Dublin 7. It costs £5.00 plus 50p p&p. Please make cheques payable to SUI or Speleological Union of Ireland.

**Matthew Parkes, Geological Survey of Ireland**

----------------

### and lastly, fresh off the INTERNET via Jenny Deakin

## Common Highway Runoff Constituents and Their Primary Sources

- - Particulates from pavement wear, vehicles, atmosphere, highway maintenance
- - Nitrogen, phosphorus from atmosphere, roadside fertilizer application
- - Lead from leaded gasoline (auto exhaust), tire wear (lead oxide filler material), lubricating oil and grease, bearing wear
- - Zinc from tire wear (filler material), motor oil (stabilizing additive), grease
- - Iron from auto body rust, steel highway structures (guardrails, bridges, etc.), moving engine parts

- - Copper from metal plating, bearing and bushing wear; moving engine parts; brake lining wear
- - fungicides and insecticides (from roadside maintenance operations)
- - Cadmium from tire wear (filler material), insecticides
- - Chromium from metal plating, moving engine parts, brake lining wear
- - Nickel from diesel fuel gasoline (exhaust) and lubricating oil, metal plating, bushing wear, brake lining wear, asphalt paving
- - Manganese from moving engine parts
- - Bromide from auto exhaust
- - Cyanide from anticake compound (ferric ferrocyanide, etc.) used to keep deicing salt granular
- - Chloride from deicing salts
- - Sulphate from roadway beds, fuel, deicing salts
- - Petroleum from spills, leaks, or blow-by of motor lubricants; antifreeze, and hydraulic fluids, asphalt surface leachate
- - Polychlorinated biphenyls (PCBs), synthetic pesticides from spraying of highway right-of-ways, background atmospheric deposition, PCB catalyst in tires
- - Pathogenic bacteria (indicators) from Soil, litter, bird droppings, trucks hauling livestock and stockyard waste
- - Rubber from Tire wear
- - Asbestos from Clutch and brake lining wear

**U.S. Department of Transportation, Federal Highway Administration. 1984. Sources and migration of highway runoff pollutants, Vol. III. Research report. Pub.
No. FHWA/RD-84/059. McLean, VA. Cited in EPA/625/R-95/003, National Conference on Urban Runoff Management, which can be downloaded from http://www.epa.gov/ttbnrmrl/625/R-95/003.htm**

---

## 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 2-3 times each year.

Your contribution to the dialogue would be welcome. **Contributions for the next issue should arrive before 1st October 1998.**

Editor,
The GSI Groundwater Newsletter,
Geological Survey of Ireland,
Beggars Bush,
Haddington Road,
Dublin 4.

---