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THE GSI GROUNDWATER NEWSLETTER

NUACHTÁN SCREAMHUISCE SGÉ

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IN THIS ISSUE

Are the databases on our natural resources and environment -our soils, rocks, climate, surface water, groundwater, etc. - **adequate for the general planning and development needs of this country? Should data collection have a greater emphasis? Are GIS and numerical modelling techniques being oversold** as a quick, cheap means of providing answers to planning and other scientific and technical issues, in situations where the data is poor and/or a good conceptual model is lacking? Definitive answers to these issues will not be provided in this **Newsletter**, nor is it intended to provide them. However these, and related questions, are regarded as worth discussing in this and future **Newsletters**. Following a mildly contentious view given on page 3, the discussion commences with articles from Krysia Rybaczuk (p. 6) and Michael Bruen (p. 7).

The **environmental impact of landspreading of manures, slurries and organic wastes** is now a major issue facing local authorities and developers. Suggested **guidelines** dealing with the **groundwater aspects** are given on page 13. In the following article, David Ball gives his experience with this issue and convincingly argues for a full understanding of the **groundwater recharge and flow system** on, below and down gradient of proposed landspreading areas.

About 90% of public water supplies in the North Cork Division of the Cork County Council are obtained from **groundwater sources.** An aquifer protection scheme and water level monitoring both play important roles in groundwater resources management in the area. The impressive work of the County Council is described by Pat Walshe on page 9. Eugene Daly provides details on one of the most important aquifers in the country - the **dolomite aquifer**, that extends from Dublin, through Kildare, Laois, Tipperary into Waterford and Wexford - on page 11.

The **Groundwater Newsletter** is intended as a forum for discussion on groundwater issues. Your views on the adequacy of databases, GIS, numerical modelling and the suggested guidelines on the groundwater aspects of the land application of animal wastes would be welcome in future issues of the **Newsletter**.

Editor.

V.L.F. RADIO WAVES AND GROUNDWATER RESOURCES DEVELOPMENT

Since the 1960's geophysics and mineral prospectors have used the distortion of radio waves to search for concealed electrically conductive mineral ore bodies. This technique was pioneered by Vaino Ronka and his company, Geonics of Canada.

Although all radio waves of differing frequencies are affected both in direction and signal strength when encountering a conductor, be it a mineral ore body or a metal ground fence, the most effective radio waves are those termed V.L.F. (Very Low Frequency). Whilst most radio transmissions are in the Megahertz range, V.L.F. radio waves are in the Kilohertz (KHZ) range, usually 15 to 30 KHZ. It is these V.L.F. frequencies that Ronka utilised in his research and subsequent development of a hand-held unit - the Geonics EM-16.

It should be noted at this point that Very Low Frequency provides a depth penetration below the ground surface up to several hundred metres. The V.L.F. transmitter stations operate at high transmitting power, for example the V.L.F. transmitter at Rugby in the English Midlands operates at 750 Kilowatts (KW) and at a frequency of 16.00 KHZ.

During the past two decades, the V.L.F. technique was used extensively to locate buried metal conductors and with further research it was possible to locate linear geological features such as fractures, shear zones and faults. Generally the source of the V.L.F. anomaly was considered to be due to the altered or fractured material in a fault zone being more electrically conductive than the host rock, and also to conductive groundwater or percolating through fault and fracture zones.

In 1985 ABEM, a geophysical instrument manufacturer, introduced a new V.L.F. unit and named it the WADI, said to be an abbreviation for 'Water Diviner'. This new instrument embodied up-to-date electronics and many features such as automatic tuning to V.L.F. stations, storage of field data and computer software for plotting and interpretation of data.

For many engineers in the water resources industry the WADI was of marginal interest but to water well drilling contractors it was of immense interest because of the ability to find deep vertical water bearing structures.

Des Meehan & Co. Ltd. invited the ABEM distributor to demonstrate the instrument and following several surveys in the basalt and sandstone formations of Northern Ireland, the WADI was purchased.

We soon learned to recognise and ignore V.L.F. anomalies due to overhead power lines, buried water pipes and metal fences and to interpret readings that showed fracture zones to depths of 200 metres. Prior to acquiring the WADI, water well exploratory boreholes were sited using local knowledge and published geological information. Besides carrying out WADI surveys for his own drilling operations, a number of surveys have been carried out for other water well contractors and geological consultants on a contract basis.

Des Meehan, Well Driller.

NUMERICAL MODELLING AND GIS: COMPUTER GAMES, TECHNOLOGICAL CONS, TEACHING AIDS OR SOLUTIONS TO THE WORLDS PROBLEMS?

The greatest advance in modern science may well be the advent of the cheap colour plotter. Attach one to a computer with numerical modelling or GIS software and the results can be beautiful, in fact one might often call them works of art. Every third level college, every consulting engineering and hydrogeology firm, every self-respecting scientific institution, such as my own here in the GSI, must have them. Look at some of the benefits - a solution to land-use planning issues, impressed clients, predictions of the flow of millions of gallons of water in aquifers or impacts of pumping wells, groundwater protection zones, etc, all at the finger tips without getting your feet wet, without examining a soil or subsoil profile, without dipping a water level in a well, in fact without hardly any real data. A truly amazing technological and scientific feat!. No wonder the EC and clients are being requested to fund their use; no wonder basic, boring and often expensive data collection has been virtually abandoned.

Donal Daly, Geological Survey of Ireland.

BOTTLED WATER STANDARD

In the Autumn of 1992 a voluntary standard for bottled water(I.S.432:1992) was introduced by the National Standards Authority of Ireland. This was done in conjunction with The Bottled Water Association of Ireland(a group within the Soft Drinks Association) and the relevent Government Agencies.

"This standard is written to provide information on the development of suitable supplies of groundwater, to establish a code of practise for all existing and new bottling plants for bottling groundwater, to define the requirements to assure the safety of bottled groundwater and to give consumers confidence in the industry and its products" (NSAI, 1992).

The standard also contains much useful information for those intending to develop groundwater as the source for large water supplies. It has sections on well construction, pumping and water quality tests and protection and management of well and groundwater catchment areas amongst others. The standard includes contributions from a number of members of the Irish Branch of IAH. In the absence of a standard for well construction in Ireland developers and well drillers will find the information contained in the report to be a useful guide to good design and construction practise.

The standard is available from Eolas, Glasnevin, Dublin 9 at a price of £38.

Eugene Daly, Geological Survey of Ireland.

EC/DOE STRIDE AQUIFER PROTECTION PROJECT

In Issue 21, September, 1992 of the **The GSI Groundwater Newsletter** the start of an EC/DOE funded project dealing with the development of aquifer protection plans for Counties Galway, Mayo and Roscommon and related groundwater projects was reported. Nine months on and halfway through the project is a good time to report on progress.

The project is in four parts:

1. the development of the aquifer protection schemes for the three counties,

2. the assessment of the use of Geographic Information System technologies as a tool for handling and using the hydrogeological data needed to assess groundwater vulnerability,

3. the assessment of the vulnerability of selected sources and the relationship between vulnerability and water quality variability at those sources and,

4. a range of source protection studies at selected sources.

The project as a whole is being directed by a management committee that includes, not just the academic personnel and their research assistants/students, but also representatives from each of the local authorities and the Regional Laboratory involved.

Project 1 above is being undertaken by Cyril Furey in Sligo RTC and in the GSI under the direction of Donal Daly, Willie Warren and Richard Thorn. To date all the data (archive data from the GSI and other sources) for the preparation of the aquifer protection scheme for county Mayo have been compiled (at a scale of 1:25,000 with final map production probably at a scale of 1:100,000) and digitised using AutoCAD software and transferred to TCD for GIS analysis. The data for County Galway have also been compiled and are currently being digitised.

Project 2 is being undertaken by a team in the Environmental Sciences Unit and the Natural Resources Development Centre in TCD comprising Paul Mills, Susan Pipes, Krysia Rybaczuk and Catherine Coxon (Project Co-ordinator). The data that have been transferred from Sligo RTC are currently being analysed using both Arc Info and SPANS GIS software. The preliminary indications are that the technology will work.

Project 3 is being carried out by Malcom Doak in Sligo RTC under the direction of Willie Warren, Donal Daly and Richard Thorn. In this project 13 groundwater sources have been selected for detailed vulnerability assessments involving field mapping, trial pitting and some drilling. The sources that have been selected are Ballyhaunis, Kilkelly, Ballindine and Crossmolina in County Mayo, Athenry, Belmont, Barnaderg-Mid-Galway and New-Inn in County Galway and Ballinagard, Ballinlough, Killeglin, Rockingham and Mount Talbot in County Roscommon. Mapping of the vulnerability of the County Mayo sources has been completed, the data digitised (1:10,000 and 1:25,000 scales) and transferred to TCD for GIS analysis. The vulnerability of the sources in County Roscommon is currently being mapped. In addition to the soil and subsoil mapping a range of hydrological/hydrogeological investigations are being undertaken including water tracing and catchment budget determinations. The Regional Laboratory in Castlebar and the environmental laboratory of Roscommon County Council are collecting water samples on a regular basis. These are being analysed for a range of physico-chemical parameters so as to allow determination of the hydrogeological characteristics and the water quality variability.

Project 4 is based in the Environmental Engineering Department of TCD and is being looked after by Heidi Price under the direction of Paul Johnston (Project Co-ordinator) and with assistance from the GSI. This project is concerned with just four of the sources viz Athenry and New-Inn in County Galway, Ballindine in County Mayo and Rockingham in County Roscommon. At Athenry and New-Inn a series of boreholes have been drilled and a number of pumping tests carried out. The purpose of these investigations is to assess the usefulness of the available approaches for delimiting source protection zones in karstic aquifers. In addition to the approach using drilling and pumping tests, flow recorders have been installed at the two spring sources. Rockingham and Ballindine with a view to undertaking hydrograph analysis.

The project is on schedule for the completion of data collection by the end of the year and the presentation of the final report early in 1994.

Richard Thorn, Sligo, RTC.

NUMERICAL MODELLING AND GIS: USEFUL TOOLS WHEN SUPPORTED WITH ADEQUATE DATA

Is the previous article on page 3 a nonsense or an exaggeration? I suggest the latter.

I am aware from first-hand experience and from hearsay, of both numerical modelling and GIS being used in the decision-making process when they have been based on minimum data and many general assumptions; of being used to impress and pull the wool over engineers' and geologists' eyes by the use of fancy colour maps and obtuse language; of being claimed as the answer to land-use planning questions; of being oversold by numerical modelling and GIS scientists.

I need no convincing of the value of both numerical modelling and GIS. I need no convincing of the value of well illustrated maps and diagrams as a means of effective communication. I have seen the benefits of modelling of groundwater flow in Ireland, for instance in predicting the impact of a proposed mine; I have seen the benefits of GIS, for instance in forest management. I am involved with projects which use both techniques. Numerical modelling as a hydrogeological tool can enable not just predictions at the end of a scientific study, but when used throughout a study can highlight the most appropriate and cost-effective data collection. Also, it can help refine the conceptual model that is the basis for data collection and hydrogeological investigation.

However numerical modelling and GIS are tools that must be used with care. GIMGO (garbage in, multi-coloured garbage out) applies. Good basic data are needed for both. Yet how much data collection is being carried out? How can a useful land-use planning policy be drawn-up if we don't have good soils maps? Regional soils surveying has now ceased and soils maps at a useful scale are not available for many counties! Geological and hydrogeological data collection is proceeding only very slowly. For instance, we don't have large scale maps of gravel deposits in Ireland. We don't have subsoils maps on which to base groundwater vulnerability and pollution risk assessments. Whither land-use planning using GIS? It can be argued that numerical modelling is useful in local studies. Yes, but once again only if the data is adequate to verify the model properly. In groundwater studies this implies drilling and proper pumping tests with transmissivity and specific yield determinations; work which is expensive and time-consuming, and which is removed from the computer terminal.

There is a danger, in my view, that the great benefits of numerical modelling and GIS will not be achieved if sloppy work, based on minimal data, is used in decision-making. So, can I make the following plea to those numerical modelling and GIS scientists that these comments apply to (if the cap doesn't fit ....):

(i) know about the data, collect some data, do some fieldwork, or at least visit the "field";
(ii) give your assumptions clearly and comment on their applicability;
(iii) in the case of numerical modelling, describe the conceptual model for the area/site concerned;
(iv) use user-friendly language;
(v) assess and comment on the adequacy of the data;
(vi) please don't say that remote sensing is <u>the</u> solution to data collection!; and
(vii) don't oversell the technique.

Can I also make a plea to the decision-makers who allocate money for scientific work: that basic data collection on our natural environment - soils, surface water, climate, geology, groundwater etc. - is essential to successful land-use planning, environmental protection and the progress of our society.

The following two articles were written as a response to these points.

Donal Daly, Geological Survey of Ireland.

GIS - ISSUES OF DATA VERSUS TECHNOLOGY

Geographic Information Systems (GIS) are a relatively new tool, which the literature tells us are capable of editing, managing, storing, analysing, inputting and outputting geographic material (in the sense that the data are spatial). However, little, if anything is ever said about the data themselves. For example, to what extent will these operations rely on the quality of the data to produce worthwhile and successful analysis? No vendor of a GIS will point out that there may be a critical point associated with the accuracy or reliability of the data beyond which the functions a GIS performs are no more than the production of expensive wallpaper.

The decision as to whether any environmental or geohydrological analysis is worth pursuing using a GIS should rest not on whether the organisation can afford to purchase the required technology, but whether the problem at hand can be addressed with such tools given the data available. Two important issues which should form part of this assessment are those of quality and scale.

As part of the work of the US Committee for *Digital* Cartographic Data Standards, several issues were highlighted as being important with respect to data quality. Although much of the spatial data that might be required in the Irish context may not be available in digital form, the concepts of assessing data quality are still valid. In the first instance the user should evaluate any data in terms of its fitness for use. That is to say, the onus for verifying the quality of data to be used in any GIS analysis should rest firmly with the user and not with the supplier. As part of this evaluation the user should investigate the lineage of the data. This may involve asking questions along the following lines. Who are the data suppliers? Who collected it? When were the data collected? What kind of sampling tests were carried out? Were the data collected to meet a specific purpose, and does this coincide with the use I want to make of the data? Questions should also be asked with respect to both positional and feature accuracy as well as to the completeness of the data set.

A second issue related to data quality is that of scale. GIS gives the impression of being "scale-free", that is to say it would appear that the data can be entered in at any scale and then reproduced at any scale. This does not hold true. Admittedly there is some interchange, especially if one is going to reduce the scale but assuming that data can be entered into a GIS at a scale of 1:100,000 and then be usefully employed for analysis at a scale of 1:10,000 is wishful thinking. Even working the other way causes problems as graphic representations start to become cluttered and difficult to read. So a vital data check point becomes the scale of the source material. Is it *really* applicable to the problem at hand? Or are you just going to use whatever is available? In this context, something is not necessarily better than nothing.

It is quite common to find that as GIS manuals or training courses are often designed by software suppliers, these issues are rarely addressed, and many projects tend to focus on the technological side of GIS, marvelling at the "tool box" it contains. Users need to be aware that poor data will yield suspect project results. Furthermore, draft EC database legislation proposes that project directors will be legally liable for the consequences of poor decisions made as a consequence of bad data.

To what extent is Ireland adequately supplied with spatial data suitable for GIS analysis? In many respects it isn't. A worrying trend which Donal Daly has highlighted is that investment is being made in GIS technology rather than in the data which will underpin the functionality of such technology. Naturally, we cannot demand a perfect set of digital data sources before we invest in the technology to store and analyse them, otherwise we would wait forever. However, it is vital that the two components of good data and good technology go hand in hand. There is no point in having a technologically impressive GIS if there are no suitable data for it to work on.

A reduction in good primary data collection by National Agencies will inevitably lead to information being collected by private concerns. As this would require heavy investment, it is likely that the owners of such data may wish to charge a commercially profitable rate for the data in order to recover their costs. Alternatively, they may decide to retain the data in order to protect their commercial advantage. Thus in such a scenario data may exist, but its use may be prohibitive in terms of cost, availability or quality. Furthermore, as there would be no storage of such data in the National Archive, there would be no need for such data to meet any National Standard. Needless to say, in the long term this type of situation would do more harm than good to the GIS community.

However, users such as myself writing about the adequacy and importance of data can only generate awareness; we cannot generate better data. Better data can only come from high quality primary data collection and those who are dazzled by the technology should not lose sight of this.

Krysia Rybaczuk, Lecturer in GIS, Trinity College Dublin.

NUMERICAL MODELLING AND GIS: DON'T SHOOT THE MESSENGER

Donal's first piece in this series is certainly an exaggeration, but while not nonsense, it is seriously misdirected. Behind every computer model printout and multicoloured GIS map is a human model-user, at whose door much of Donal's criticism properly belongs. The colour printer can hardly be blamed for printing an inaccurate map. Neither can the GIS program, which basically stores spatial data, be blamed for regurgitating rubbish, if rubbish was its diet. When problems occur, the model-users (I hesitate to give all model-users the title of modeller), and not their tools, should bear the brunt of Donal's criticism. Otherwise it is like blaming car manufacturers for all road accidents, or the television set for bad news. The messenger is not responsible for the message. Once the real culprit is thus identified, much of the hyperbole in Donal's first piece is appropriate, except for the implication that good hydrogeological work cannot be either beautiful or artistic. And while I agree that bad work can be hidden in a model printout, it can equally well be hidden in a mountain of inappropriate data.

In this controversy it is too easy to forget the real nature of the relationship between models and data. They are inextricably linked (except in the Platonic world) and the links go deep into the scientific method. What is a model? It is a set of assumptions about how a small aspect of the real world behaves. Remember how many assumptions are involved even in the simple equations used to analyse pumping test results? Has anyone come across an Irish aquifer which satisfied all those assumptions? To the extent that models are invariably simplifications, they are inherently inaccurate, but this is not so important. What is important is that the model gives results (predictions) sufficiently accurate for the purpose for which it is used. Where then does data come in? Data may be used in verifying the adequacy of the model (model identification), it may also be used in estimating the model's parameters, i.e. fitting the model to a particular instance of the real world (model estimation). Once a model is identified and fitted it may be used to make predictions about the future behaviour of the real world. Data may be gathered to check these predictions and if they are sufficiently accurate they contribute to confidence in the model. If the predictions are not sufficiently accurate the model may be refined, changed or even abandoned and a new one developed. This mirrors the steps of the scientific method, hypothesis (model), prediction, verification (data). Thus data must always be thought of in relation to the model which uses it. And both must be related to the purpose of the study in hand.

A number of important consequences for projects, both research and consultancy, follow:

* It is important that the objectives of the study be clearly set out and understood by all parties before any work is undertaken. If the study is expected to provide specific answers to specific questions then they must be described in detail in the project brief. If this is not done then the different parties may have completely different ideas about what the project is to achieve and much disappointment can follow.

* Once a proper set of objectives can be defined for a project, some measures of performance can be established to assess how well the completed work achieves its objectives. If the objectives of a project are woolly then the results cannot be properly assessed and the project, regardless of its conclusions, cannot be deemed to have failed or be incomplete. How can a project whose brief is "to investigate...." or "to study..." be judged a failure if the executor does "investigate.." or does "study..." the subject in question and produces any kind of report. Quality control can only be enforced if objectives are clearly defined.

* Only when the objectives are clearly established can the type, amount and quality of data necessary to achieve them be determined. Here models help in identifying the type of data which must be used. But they also help in defining the accuracy required of the data. A sensitivity analysis of a model reveals which variables have a strong influence on its predictions, for which very accurate data is required, and which variables do not, for which less accurate data is sufficient. Some projects can be deficient by not measuring a variable which is important for the phenomenon under investigation. However, it is also possible to measure a variable with insufficient accuracy or indeed too accurately (waste of resources) for the project.

* The scale of the problem under investigation has a large bearing on the accuracy of the data needed. Even if the same phenomenon, say infiltration, is investigated at the scale of a single infiltrometer, or of a field, or at catchment scale, or even the huge grid scale of a general circulation model (each of which is actually being done by someone or other) the accuracy, and even the type, of data required to model the phenomenon is quite different for each scale.

Thus models, or expressions of the models in equations, computer programs etc. are an integral part of any study. Data by itself is not necessarily information. Most hydrogeologists must, at some time or another, have had to cope with a lack of data and would agree that in general there is not sufficient basic data. However, how do you specify what additional data should be collected and with what accuracy and frequency? In an ideal world there would be no difficulty, but with limited resources what are the priorities? I contend this question cannot be answered in the abstract, and when answered for particular cases must be in the context of applications and models. Some attempt must be made to predict the future trends in hydrogeological work and in uses of hydrogeological data before this question can be answered.

There is another complication, particularly in certain types of consultancy work. The client may be in a position where he/she must make a decision within a short time frame. Do you say, "sorry I'm not prepared to advise you because I do not have sufficient data, but I'll collect the data and give you the answer in two years." or do you say, "there isn't sufficient data to give you a definitive answer, but the existing data suggests that .... and I'm (not) confident that this reflects the real situation". In reality, many clients need some sort of advice based on existing data and as long as the limitations in data, and model, are explained there is some justification for giving such advice.

Michael Bruen, Civil Engineering Department, University College, Dublin.

GROUNDWATER DEVELOPMENT IN NORTH CORK: SUMMARY OF THE PRESENT SITUATION

Existing Water Supply Sources

The predominant characteristics of the water supply sources in North Cork are

(a) that there are a large number of individual sources; and
(b) that the majority of the sources are from groundwater.

In total, there are 67 separate water sources in use in North Cork to serve a population of 75,000 people in an area of approximately 1,000 sq. miles. Many of these are small supplies serving group and local authority schemes in the rural areas. The twelve larger schemes would account for approximately 50% of the daily usage.

The daily water consumption is approximately 5.4 mgd (24,550 m^3/d). The sources can be classified as follows:
Springs - Over half the daily usage comes from naturally occurring springs (56%). Examples of the bigger springs are Ballinatona spring (5,800 m^3/d), Doneraile/Buttevant supply (1,910 m^3/d), Castletownroche (1,364 m^3/d).
Bored Wells - About 34% of the daily consumption is supplied from bored wells of which the largest are: Charleville (2,300 m^3/d) and Mitchelstown (2,600 m^3/d).
River Abstractions - The remaining 10% of the daily usage is made up of 3 river schemes, the Allow River at Freemount (600 m^3/d), the Clyda River at Mallow (3,000 m^3/d) and the Bride River at Castlelyons (900 m^3/d).

It is worthy of note that the above figures represent only the present usage whilst the yields of many of these sources are far greater thus allowing expansion in the future. For example, the figure for Charleville of 2,300 m^3/d is the present daily flow, whilst the three bored wells in the scheme, have been pump tested to yield a flow of almost 9,100 m^3/d (2 mgd). Thus it can be seen that the figures mentioned above do not represent the great potential for expansion there is in many of the schemes.

There are a few hundred square miles of major aquifers in the North Cork Division, so without a detailed study it is not possible to estimate the vast groundwater potential in the area.

Aquifer Protection Schemes

The Geological Survey of Ireland (GSI) have correctly stressed the importance of protecting the groundwater resources in Ireland from the many types of pollution that can arise. Many of the GSI recommendations have been implemented now for some years by Cork County Council.

Aquifer Protection Zones: All of the bigger supplies in North Cork have had a detailed aquifer protection study performed by a hydrogeologist. Particularly in the limestone aquifers, details of disappearing streams, swallow holes, thin overburden cover, the fissured nature of the rock structure, etc., are all very relevant features which need to be taken into account in protecting the aquifer. Maps showing the source protection areas are kept, not only in the area engineer's office, but also in our central Planning Department Offices where proposed developments are checked against these aquifer zones. In some cases, planning permission has been refused, while in other instances, additional conditions may apply.

Internal Training Courses: Over the last 3 years, a number of "training days" have been held for our own staff, e.g. water curators, etc. in which particular attention is given to the role everybody has to play in protecting our water resources. This vigilance is just as important where there are groundwater sources as with river abstractions because, even though the groundwater is not as vulnerable to pollution, nevertheless if pollution does enter an aquifer, then it can be difficult to clear it. There are probably few instances where the maxim "prevention is better can cure" is more apt.

Sludge Injection: North Cork is located away from the sea, so that disposal at sea was never an option for sludge disposal from either municipal sewage works or from private industry. In order to assist the protection of our aquifers, soil injection of sludge is now being carried out as a means of disposing of the Council sludge. Licensing of industry for the disposal of sludge by soil injection, on previously surveyed farms, is now on-going. This licensing is done under the Waste Regulations.

In the overall context of aquifer protection, it behoves us all to protect the water cycle so that it can be passed on to future generations in the condition we have received it.

Water Level Monitoring

Borehole Water Levels: The winter of 1991/92 was drier than usual and, as a result, the water table actually continued to drop until mid-March during the period when the aquifer would normally be recharging. Weekly dippings have been taken on 6 wells since 1991 and also on another 5 wells fortnightly. This data has been logged on computer and in the relative short history of taking these levels, they have proven very useful.

Rainfall Recording: In the North Cork area, six council employees record rainfall levels daily for the Meteorogical Office. This information is then available to the Council for its own use and is very valuable in predicting the possibility of water shortages, etc.

Combination of Rainfall and Water Level Records: There is much merit in looking at the water cycle as a unit. To that end, a number of internal reports were written in the spring of 1992, analysing rainfall records over the winter and water levels in boreholes. Indeed in April, 1992, the Council informed its elected members that water levels were particularly low at the end of the recharge period and that if the summer ahead was warm and dry that water shortages would be experienced in the autumn. As the summer developed, however, there was 4" of rain in July, 5" in August and 4" in September, so no problem arose.

Records for the past winter, 1992/93, now show a similar trend if not indeed worse. The end of March water table levels are equivalent to the early May levels of last year. If this summer ahead is dry, then problems with the effect of pollution, the drying of small springs etc. are likely to occur.

A list of water schemes that could be affected was drawn up in 1992 and a strategy decided even in June as to what measures needed to be taken in the event of shortages. This we feel represents good planning.

Data Recording/Collection - The Future: The value of having groundwater data has been shown clearly to us in the past year. With that in mind, we are now examining options for the use of data loggers for recording water levels and also rainfall. We have had two types of datalogger on trial and indeed used them for a well pumping test recently. We have received quotations for a system and hope to purchase a number of dataloggers this year. Eventually, they will be linked by telemetry to the central Council offices in Mallow. It is estimated that the labour savings on one prolonged pump test would pay for a mobile datalogging unit!

(This article is part of a paper given at the IAH (Irish Group) Seminar in Portlaoise, April 1993).

Pat Walshe, Cork County Council (North Cork Division).

THE DOLOMITE AQUIFER OF THE SOUTHEAST OF IRELAND

Introduction

The dolomitised limestones of the southeastern part of Ireland are one of the most important bedrock aquifers in the country. They are found within an area bounded by southwest County Dublin, Portlaoise, Thurles, Cahir, Clonmel, Waterford and Rosslare but excluding the Leinster Massif. Over the last 20 years the aquifer has been developed as a source of supply for a number of large water schemes in this region. The recently discoverd zinc-lead orebodies at Galmoy and Lisheen are hosted by this aquifer.

Geology

Dolomite($CaMg\{CO_3\}_2$) is a mineral usually found with carbonate rocks. It does not form as a sediment but frequently replaces the calcite and aragonite minerals($CaCO_3$) which form naturally in a marine environment and are the dominant minerals in limestone. Dolomitisation frequently alters the primary carbonates in a number of phases and the intensity of alteration is normally quite variable in distribution. The term "dolomite" is applied to rocks that contain in excess of 90% of the mineral dolomite. From a hydrogeological point of view the most important feature of dolomitisation is that it results in an increase in the porosity and permeability of carbonate rocks and generally renders them more susceptible to jointing, possibly faulting and subsequent karstification and weathering.

In the southeastern part of Ireland there has been extensive dolomitisation of the limestones, especially those in the middle of the Dinantian succession. In this region the alteration generally appears to be greatest in the originally cleaner rocks and in the strata along faults. The thickness of the aquifer varies from a few tens of metres to a few hundred.

In outcrop these rocks are very varied as befits their variable and complex origin. They are severely jointed, friable, weathered and in places have been reduced almost to the consistency of a sand. In core they are typified by crystal-lined vugs, sand filled or solution(open) cavities, shrinkage cracks, veins and fractures.

The strata are folded into a number of synclines and are extensively faulted.

Hydrogeology

In the mid-1970's the true potential of this aquifer was initially detected by geological mapping, well drilling and baseflow analysis of the River Nore. It was subsequently confirmed by the discovery of the large springs through which the aquifer discharges in the Callan-Bennettsbridge Lowlands of Co. Kilkenny and by the completion of successful water supply schemes at Portlaoise and South Wexford.

The aquifer crops out in relatively low-lying ground, with a water table normally within 10m of the surface and an annual fluctuation of less than 5m. Small karst features such as caves, a turlough, highly permeable zones, swallow holes and surface solution are found in parts of this aquifer.

The permeability of these strata is variable and largely unpredictable in distribution. It is found to be greatest in intensly dolomitised areas, along wide fault/fracture zones, within 30m of the surface and at particularly permeable horizons at depth. Dolomitisation is not a near surface phenomenon and hence significant permeability can be anticipated to occur at depth. Permeability and weathering have been shown to exist at depths of over 100m. Core samples from particular horizons give porosity values of 5% down to 10m and over 2% at depths from 30-300m. The results of well tests carried out at a number of localities in the southest are given in Table 1. The permeability is likely to vary from 10^{-2}m/d to 20m/d. The storage coefficient is of the order of 10^{-3}-10^{-4}.

In a large aquifer such as this the hydraulic conditions are bound to be quite variable. In outcrop areas the aquifer is normally unconfined except for relatively small areas where it is confined by till or thick peat. The bulk of groundwater movement in these strata occurs relatively rapidly, at shallow depths, along short flow paths and discharges, frequently via small springs, into the normally effluent (gaining) streams which traverse the aquifer.

AREA	STRAIGRAPHIC HORIZON	WELL YIELD m^3/D	SPECIFIC CAPACITY $m^3/d/m$	TRANS-MISSIVITY m^2/d
Athy	Lr. Aghmacart -> Upr. Ballysteen (Equiv)	1,000- 1,500	50 - 100	100 - 200
Carlow	Crosspatrick -> Lr. Ballysteen (Equiv)	700 - 2,620	40 - 130	80 - 300
Bagenalstown	Lr. Ballysteen	500 - 1,000	40 - 80	60 - 120
Nore River Basin	Lr. Aghmacart -> Upr. Ballysteen	160 - 260	50 - 80	100 - 150
Galmoy (Arcon, 1992)	Waulsortian	310 - 2,850	10 - 260	50 - 600
Portlaoise Laois Co Co	Crosspatrick (Equiv) -> Waulsortian	2,350 - 4,420	180-280	400 - 600
S. Wexford (Cullen, 1978)	Crosspatrick (Equiv.) -> Ballysteen	1,110 - 1,200	40 - 75	50 - 100

Table 1: Pumping test results from boreholes in the areas where the dolomite aquifer has been developed.

The aquifer is confined beneath a considerable thickness of sediment in the synclines. There is a certain amount of evidence to suggest that some groundwater flow does occur in these deeply confined areas. If flow does occur at depth it is likely to be fault controlled.

The boundaries of this aquifer are difficult to delineate owing to the variability of the dolomitising process. They rarely coincide with lithological limits and the contacts are generally gradational.

Groundwater Resources and Aquifer Development

Effective rainfall over the aquifer ranges from around 375-550mm/a and recharge from 200-350mm/a. The aquifer is estimated to cover a total area of over 550km^2 with resources in excess of 90x10^{6}g/d. Less than 10% of the available resources have been developed to-date.

Optimum well yields from this aquifer will be obtained from boreholes drilled into one of the many fault zones and penetrating at least 50-100m of the aquifer. Drilling into this aquifer at depths of over 200m, at favourable locations, has a reasonable prospect of success. Drilling conditions can frequently be very poor owing to the friable, cavernous and weathered nature of the material. Drilling muds or additives are frequently required to get penetration and long casing runs and grouting are necessary to stabilize the large caverns often created underground by the drilling and/or flushing medium.

Conclusion

The dolomitised limestones in the southeast of Ireland are an extensive aquifer, contain large groundwater resources and make a substantial contribution to baseflow in rivers. They have been successfully developed at a number of locations and are capable of yielding large quantities of good quality groundwater.

(This article is based on a lecture given at the IAH Seminar in Portlaoise in April '93. A full copy of the lecture is available from the Public Office in the Geological Survey).

Eugene Daly, Geological Survey of Ireland

SUGGESTED GUIDELINES FOR LAND APPLICATION OF ANIMAL WASTES: GROUNDWATER ASPECTS.

The land application of animal wastes poses a significant risk to groundwater. The main groundwater contaminants that can result are: nitrate, iron, manganese, faecal bacteria and viruses. The risk to groundwater will depend not only on the management practices and pollution loading but on the geology and hydrogeology of the land spreading area.

The soil and subsoil are excellent and cost-effective media for treating and attenuating contaminants provided they are not overloaded either hydraulically or with nutrients. Consequently, in many areas land spreading can not only be an important source of nutrients for crops but can be a recommended practice from an environmental viewpoint. However, once contaminants reach bedrock in Ireland there is generally little attenuation other than by limited dilution. Consequently, in assessing the impact of a land application development, information on the geology and hydrogeology is needed. Also, in order to reduce the risk of pollution, landspreading should not be allowed in specific situations where groundwater is very vulnerable to pollution. Monitoring is always needed to ensure that pollution is not occurring.

The following guidelines outline i) the information required on the geological and groundwater aspects, ii) restrictions on spreading to reduce the risk of groundwater pollution and iii) monitoring requirements.

Information Needs

In assessing the possible impact on groundwater from piggeries and other major developments involving land application of waste, the following information is required, in my view.

A. Piggery Structure/Building.

i) A site investigation including trial pits and perhaps a borehole. This should provide information on depth to water table (if shallow), depth to rock (if shallow), subsoil and bedrock type and permeability, assessment of groundwater vulnerability.

ii) Details on all private wells within 200m and all public/group scheme wells within 1km.

iii) Assessment of impact of structure on groundwater. (I regard the wastes in/at the structure as posing a greater risk to groundwater than the land spreading).

B. Landspreading Areas.

i) Map showing all private wells within 200m of landspreading area and all public/group scheme wells within 300m. (In areas where groundwater is vulnerable, greater distances are recommended). Basic information on all wells should be given i.e. depth, depth to water table, depth to bedrock, yield, drawdown (if known) etc.

ii) Types of subsoils and bedrock.

iii) Bedrock outcrops (if present) and depth to bedrock information.

v) Direction/s of groundwater flow.

vi) Qualitative assessment of permeability of subsoil and bedrock.

vii) Aquifer category.

viii) Presence or absence of karst features - caves, swallow holes etc. - if bedrock is limestone.

ix) Groundwater vulnerability assessment.

x) Baseline information on groundwater quality.

xi) Assessment of overall groundwater regime.

xii) Assessment of the impact of landspreading on groundwater.

Consequently a site investigation is essential. The main work required is to dig trial pits to check i) the subsoil, ii) that the depth of subsoil is not less than 2m and iii) that in gravel subsoils, the depth to the water table is not less than 1m. The density of trial pits required will vary from 1/1-20ha, depending on the available existing information on the geology and hydrogeology of the site and on the groundwater vulnerability. One borehole somewhere on the farm is advisable to check the depth to rock, depth to watertable, type of subsoil and bedrock, permeability of bedrock, etc.

The geoscience databases in the Geological Survey of Ireland hold information on geology and groundwater, although the level of information varies from area to area. Access to these databases can be obtained by prior arrangement.

I believe that in major developments involving land application of organic wastes, a hydrogeological consultant should be employed by the developer.

Restrictions on Spreading

In order to reduce the risk of groundwater pollution, animal slurries should not be applied:

i) on exposed bedrock;
ii) within 15m of exposed cavernous (karstified) limestone or of karst features such as swallow holes and collapse features;
iii) within 50m of domestic wells;
iv) within 300m of public supply sources, unless the developer can provide evidence that landspreading will not put the source at risk;
v) where permeable rocks, such as pure limestones, are overlain by shallow (less than 2m) free-draining subsoils such as sands, gravels and sandy tills; and
vi) on gravel aquifers, where the water table is within 1m of the surface.

Monitoring

A groundwater quality monitoring scheme will normally be required. Existing boreholes may be used, although frequently specially drilled boreholes may be required; perhaps 3 in number in situations where a large contiguous block of land is used for spreading, one up-gradient and two down-gradient.

(Acknowledgement: This article is influenced by discussions which have taken place as part of a technical sub-committee of the Regional Water Laboratory Kilkenny on "Landspreading of Organic wastes". This sub-committee has now produced general guidelines which I would recommend to local authorities. They can be obtained from Mr. Billy Moore, Tipperary (SR) County Council, who chaired the sub-committee).

Donal Daly, Geological Survey of Ireland.

THE VULNERABILITY OF GROUNDWATER RESOURCES TO CONTAMINATION BY ANIMAL FAECES AND URINE

Groundwater contamination by the spreading of animal wastes is a difficult subject to deal with in a short article. Part of the problem is that there has been little specific groundwater research on this subject in Ireland. Most of the hydrogeological evidence on the vulnerability of groundwater systems has come from detailed work for other purposes. There is a clear need for detailed research into groundwater recharge through soils in Ireland particularly in spring, summer and early autumn (the present slurry spreading seasons).

Donal Daly's article approaches the problem by giving guidelines on the information needed, restrictions on spreading and the need for monitoring. I support this approach because the publishing of guidelines gives everyone something to work from, and helps the dialogue between hydrogeologists and the farming community.

The purpose of my article is to present my observations on groundwater vulnerability and summer recharge mechanisms, and also deal with some of the broader issues that underpin the need for guidelines. The discussion of some of these broader issues will perhaps encourage a renewed look at the whole subject of intensive animal husbandry and waste spreading.

My starting point on groundwater vulnerability is that I assume all groundwater in Ireland is vulnerable to contamination until it is proved otherwise. There are several reasons for this perspective.

First; most of the groundwater that concerns us, and is exploited by domestic, industrial, agricultural and urban users in Ireland, is relatively shallow or near the surface. It appears to be young water, sometimes less than a few days, weeks or months old. This near surface water is in a transient state. It can be looked upon as water that started as rain and percolated through the soil into the rock, is currently moving through the rock and in the near future will leak out of the rock into streams, rivers, lakes and the sea. It is a part of a process that is dynamic.

The quality of groundwater, in terms of its chemistry and microbiology, reflects the dynamism of the process, the stable and unstable chemistry of the material through which the water passes and the changes in the surface environment from whence the water has come.

Routine daily monitoring of groundwater quality from boreholes drawing upon the near surface groundwater system show that significant changes can take place within a matter of hours as well as days. In addition there are changes that take place on a seasonal cycle that reflect the change in natural conditions and the seasonal cycle of activities controlled by humans at the surface.

Neither groundwater quality nor the vulnerability of a groundwater system can be assumed to be constant.

Second; supporting this view are the results of work I have been involved in on the movement of the water table and changes in groundwater bacteria levels during the summer in Ireland. At the IAH Seminar in 1992 I gave the following example of the correlation between near surface groundwater microbiology and summer rainfall events.

The aquifer is a fractured limestone below 3 to 5 metres of clay with a well developed soil horizon supporting unimproved pasture. The summer water table was 4 metres or more below ground surface. Within 24 hours of intense isolated showers in June and August there was a rise in the water table of 1-3 centimetres. Such a fluctuation of deviation from the summer groundwater hydrograph recession curve is normally thought to be inconsequential, and would be seldom noticed. The significance of the summer recharge was seen in the corresponding daily microbiology analyses. These showed a sudden jump in values for TVC @ 22°C from close to zero to over 25,000 colonies per 100 ml over the same period. The results show that there are mechanisms by which summer rainfall can bypass the soil moisture deficit and recharge the groundwater system. More importantly this recharge is also bypassing the capacity of the soil and clay overburden to filter out or hold back soil bacteria.

It is worth noting that a recent planning permission for an intensive piggery permits the spreading of slurry between the beginning of March and the end of October each year. As this year has showed there can be intense rainfall and groundwater recharge in the spring.

Third; my inspections of soils and overburden do not give me confidence that the permeability of these materials is dominated by horizontal layering and intergranular porosity. I am also not confident that infiltration tests give results that can be adequately interpreted or extrapolated. Soils and overburden are not materials laid down to an engineering specification. They are natural materials that have a considerable history. Many soils are over 5,000 years old. They have been frozen and thawed, dried out and saturated repeatedly. Even in our present climate I find summer cracks in fields of untilled pastureland down which I can push a 2 metre long ranging rod. The roots of large trees have also driven long tubular holes vertically through the material often to 4 to 5 metres depth. Though the roots have died the hollow cast of the root or even the outer shell can remain for hundreds of years. The top zone of the soil and subsoil is also full of the burrows of small and large animals.

My experience so far indicates that the vertical structures in the soil and overburden act as conduits for the rapid movement of fluids from the surface to the water table. In effect there are two forms of overburden permeability; intergranular permeability and vertical linear or fracture permeability. The former is influenced by the soil moisture deficit, whereas the latter provides a mechanism by which the influence of the soil moisture deficit can be bypassed. The linear permeability is significant in terms of groundwater vulnerability to surface applications in the summer.

How significant is this recharge mechanism to the land spreading of animal faeces and urine? I think it is significant because first we have no quick, reliable and inexpensive way of determining the abundance and openness of vertical conduits in the soil-overburden, and second because of the scale of slurry production and the management of slurry spreading.

It is difficult to grasp the scale of the slurry produced by the agribusinesses concerned. For example, an intensive piggery is often described in "Sow-Units". The application for permission to spread slurry from a 500 sow unit is difficult to imagine when those terms are used. A 500 sow unit actually means 4,000 to 5,000 pigs in the piggery at any one time. Teagasc estimate that such a piggery produces 128,000 litres of neat excreta (just urine and faeces) per week. This is either stored below slatted floors in the pig houses or in separate storage tanks. In order to try and give an idea of what these volumes equate to; an adult human produces about 2.5 litres of urine and 100-200 ccs of faeces per day. Children produce less. The equivalent excreta production of a 500 sow unit in human terms would be a town of roughly 10,000 men, women and children; a town about the size of Mullingar.

Slurry spreading needs to be managed within the context of the strengths and weakness of the natural and agricultural environment which is being harnessed for waste disposal.

I think that the only way of fully understanding the true vulnerability of the groundwater below an area proposed for slurry spreading is to focus on understanding the groundwater recharge and flow system on, below and down gradient of the proposed landspreading areas. This is a large undertaking. It involves trial boreholes, properly constructed monitoring boreholes and a detailed programme of rainfall, surface water and groundwater level monitoring, and water chemistry and microbiology sampling over a full year. The results need to be interpreted and published as a part of an environmental impact study. But more than that; I would suggest that the results need to be in a form that can be appreciated by the owners, developers or operators of any facility that produces slurry.

Slurry is produced by serious, commercial, professional businesses. It is their waste problem and they are responsible for their waste. It is not the responsibility of the local community or the county council or the government to manage their problem. Therefore the owners and operators of, say a piggery, need to be able to understand the changing state of the environment and the dynamic processes that they intend to utilise. The safe disposal of waste cannot be managed if it is not understood.

I conclude that landspreading of animal faeces and urine (and blood and offal) will continue. I agree that the soil and subsoil can be an excellent media for treating this waste, but we, as a groundwater community, need to know more about the processes involved. Also we need to take positive steps to communicate our understanding to the slurry producers so that their operators can take responsibility for managing their waste disposal. Sanitary engineers have put a lot of effort into finding safe ways of treating human wastes. I feel we should join with the agricultural community in similarly finding and ensuring the safe disposal of animal wastes.

David Ball, Consultant Hydrogeologist.

REVIEW

"Septic Tank Systems and Groundwater in Ireland"

by D. Daly, R. Thorn, & H. Henry. A Joint Sligo RTC/GSI Report. Published by the Geological Survey of Ireland.

This Report comprises of a 3 page summary, 18 pages of main text and 12 pages of appendices. Technical staff of local authorities, health boards and architectural and engineering consultants will find much useful information in the body of the document while the extended summary will generally meet the needs of public representatives and other lay persons.

Its publication serves as a useful reminder of the 1991 revision of S.R.6 and it provides valuable background information showing why it is important to use the new standard in dealing with sewage treatment for one-off houses. Perhaps more importantly, it warns that even with good subsoil conditions groundwater pollution can occur and that it is essential to position the percolation area correctly and to follow all the design recommendations carefully if problems are to be minimised. It is interesting to note that it recommends a minimum of 1.0m of unsaturated subsoil beneath the percolation pipes whereas under S.R.6:1991 a depth of only 0.5m can be considered acceptable. Based on the test results presented it would appear that the 1.0m requirement is a much safer criterion.

In several areas the document overlaps with S.R.6 but it reinforces many important aspects, e.g. site assessment, site location, tank design, maintenance, etc. It then goes further by recommending better promotion of the correct application of the modern septic tank system; the idea of an explanatory leaflet to be issued to all people proposing to build one-off houses is introduced. The extent of groundwater problems identified as of septic tank origin is referred to but details are not given on what areas are affected. It would have been interesting to know the portion of the 300,000 existing systems which are of the soakage pit type and the estimated number of these which are creating problems for either groundwater or surface water, but perhaps these data are not yet available.

Overall, this is a worthwhile read and a handy reference document for all concerned with protecting water resources; it should increase knowledge and awareness in this important area and act as a catalyst initiating further steps to improve the situation.

Ronan Flynn, Central Fisheries Board.

COAL GASIFICATION SITES - A POTENTIAL HAZARD?

Prior to the availability of natural gas for industrial and domestic consumption in Ireland, gas produced from coal was in widespread use. Such gas was produced by the thermal treatment of coal itself at a number of sites around the country located in or close to urban centres. Substantial volumes of coal tar were produced by these coal gasification plants as residue from the thermal process. This coal tar was usually disposed of locally after available space on the site itself was used up.

Coal tar is predominantly comprised of polynuclear aromatic hydrocarbons (PAHs) such as anthracene, crysene, fluoranthene, napthalene, nitrobenzene, phthalates, pyrene, etc. These multiple ring compounds have a low water solubility, are highly toxic and persistent. Many are bioaccumulative, carcinogenic, teratagenic, mutagenic, or have other undesirable properties. The PAHs bind to soil and can migrate in groundwater having a low solubility (e.g. 31-34 mg/l for napthalene).

Coal gasification sites are close to the top of the hazardous site ranking lists in the UK, US and Germany and as such receive priority with regard to investigation and remediation. Large scale production of coal gas continued until recently in Magdeburg, Germany with the consequences of uncontrolled coal tar disposal being very much in evidence in the area. In Ireland production effectively ceased in the early seventies with the advent of natural gas from the Kinsale gasfield. However the coal tar residues remain where disposed of. They are currently being investigated at two locations in Ireland - Derry and Dublin - but, because of the environmental risks involved, it is important to identify, assess, and prioritise all the other former coal gas production and coal tar disposal sites in this country.

Shane M. Bennet, K.T. Cullen & Co. Ltd.

NEWS FROM ABROAD

U.S.: Herbicides in Landfill Leachates

Researchers at the Colorado School of Mines unexpectedly found the herbicide mecoprop in a landfill leachate sample. Follow-up work showed the presence of 2, 4 - DP, silvex and 2, 4 - DB. These compounds persisted during two to three years in the landfill while significant depletion of total organic carbon and low molecular- weight carboxylie acids were observed. This lack of degradation was unexpected and poses concern for groundwater, according to the researchers. The disposal of small quantities of herbicides in household waste or of plant materials containing the herbicides are considered to be the sources. The researchers concluded that the chlorinated 2 - phenoxypropionic herbicides, particularly mecoprop, are ubiquitors in U.S. municipal landfill leachates.

Source: The Groundwater Newsletter of the Water Information Centre, Inc., Vol. 21, No. 5, 1992.

Britain: Sheep Dip Chemicals Cause Concern.

Recent studies have highlighted the pollution risk from spent sheep dip. According to a news item in the ENDS Report No 218, a study by Grampian Regional Council "of an apparently well sited soakaway some 300 - 400 metres from a stream found that sheep dip compounds appeared in the watercourse only two hours after disposal. Chemicals were also found in a pool by a broken field drain 600 - 700 metres from the soakaway shortly afterwards". Research by the NRA detected organophosphates beneath and 20m away from a soakaway in chalk groundwaters in Sussex. The NRA is not only concerned about disposal of spent sheep dip in soakaways but also that many farmers cannot dispose safely of dip by spreading, as many upland farms do not have suitable land which is level and remote from streams.

It would now appear that the 1980 EC Groundwater Directive is being regularly breached. As a consequence, the ENDS Report states that "new environmental quality standards (EQS) for sheep dip chemicals in water are likely to be proposed later this year". These will bring about tighter controls on sheep dip disposal practices.

Source: The ENDS Report No. 218 March 1993. Published by Environmental Data Services Ltd.

Texas: Citizen Participation in Groundwater Protection

According to a Texas Water Commission (TWC) spokesperson, protecting groundwater supplies is the responsibility of local communities, and citizens should be encouraged to find local solutions. Citizen involvement in local groundwater protection programmes has been successful in more than 150 communities. The TWC recommend that after the state has delineated wellhead protection areas, local task forces that represent all interests in the community should be formed. These can help in implementing best management practices, assessing potential pollution sources and educating people about groundwater protection.

Source: The Groundwater Newsletter of Water Information Centre Inc., Vol. 22, No. 7, 1993.

U.S. Landfill Siting - the Role of Groundwater Hydraulics.

According to Professor Henk Hartjema, School of Public and Environmental Affairs at Indiana University, the landfill siting process should focus on exploiting hydraulic principles rather than barrier construction and monitoring for protection from pollution. He recommends landfill design criteria based on negative hydraulic gradient underneath the landfill. This would mean constructing leachate collection systems below the average groundwater table or potentiometric surface of the underlying aquifer. Although groundwater may be forced into the landfill, leachate could never leak into the underlying aquifer. Monitoring to ensure that the negative gradient is maintained would be required.

Source: The Groundwater Newsletter of the Water Information Centre, Inc., Vol. 21, No 7, 1992.

Britain: Levy on Petrol Sales Proposed for Contamination Clean-up.

The General Manager of Shell UK's Retail Division has proposed a levy on petrol sales to pay for the clean-up of contaminated soil and groundwater beneath petrol stations. Research by Shell has shown that one-third of its 1,100 sites are contaminated "to a greater or lesser extent". Leaks from section lines and single-skin tanks and the absence of spillage detection and overspill prevention systems are the main factors in causing contamination. Solving the problem is costly - one small site cost Shell £0.25 million for a survey and clean-up.

Source: The ENDS Report. Published by Environmental Data Services Ltd. No. 219, April 1993.

CONTRIBUTIONS FOR THE NEXT ISSUE OF THE NEWSLETTER

The **GSI Newsletter** aims to improve communication among the many scientists and engineers involved in groundwater. It includes news, developments, reviews and opinions on all aspects of groundwater - exploration, development, water quality, pollution and energy. It is published at four montly intervals.

Your contribution to the dialogue would be welcome. These should reach the Geological Survey before 30th September.
