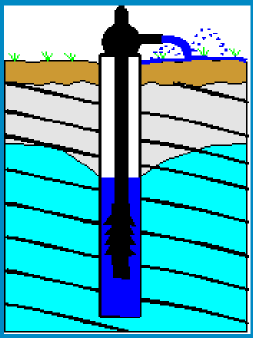

Groundwater Newsletter

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Inside this issue:

The future of the Groundwater Newsletter What do you think?

The Groundwater Newsletter is back after a break, with a new improved format and a move towards email distribution to reduce costs and environmental impacts. The Newsletter has evolved over time and we would be interested in any feedback on the current style and content, and any new ideas you might have. ***Please send us your email address (see back page) to keep receiving the newsletter and tell us what you think.***

Applied groundwater research has benefitted greatly from a wide range of funding opportunities in recent years. This issue focuses on some of the practical outcomes. The new EPA Code of Practice for Wastewater Treatment and Disposal Systems Serving Single Houses (OSWWTs) is one example of where policy has benefitted from specific targeted research. Margaret Keegan takes us through the basics of the code (p. 2) while Lawrence Gill highlights the key aspects of the research that underpins it (p. 4). However, while our policies may be improving, studies by Dundalk IT (p. 20) have shown that a high proportion of OSWWTs are still being installed and operated incorrectly. Donal Daly reports that OSWWTs and farmyards are considered to be approximately equally responsible for pollution of wells and springs in Ireland by microbial pathogens (p. 7). So while the Code is a great step forward, it is clear we still have a long way to go in the practical management of OSWWTs.

Drinking water source protection is a topical issue at the moment, particularly with the recent flooding. Sarah McManus talks about pesticides in groundwater (p. 12); Brian MacDonald provides an insight into the issues facing group water schemes (p. 17); and Siobhán Jordan describes a pilot source protection project which aims to drive source protection and management from the local community level (p. 20).

In other articles, Matthew Craig describes the EPAs groundwater monitoring network (p. 24) and Bruce Misstear shares some thoughts following a recent UK groundwater modelling forum (p. 29). Future IAH events are listed on p. 30.

Finally, we would like to wish all our readers a very happy new year.

Monica Lee, Groundwater Section and Jenny Deakin, Editor

On-Site Wastewater Treatment and Disposal Systems – a new code of practice

The EPA have published a Code of practice in relation to on-site wastewater treatment systems. Important aspects include site suitability assessment, and system selection, installation and maintenance

The 2006 census indicated that around 40% of the population of Ireland lived outside of the main cities and towns. Unlike other more urbanised European countries, around a third of the population of Ireland lives in the open countryside in individual dwellings not connected to a public sewer. The wastewater from such dwellings is treated at or near the dwelling by treatment systems often called on-site systems.

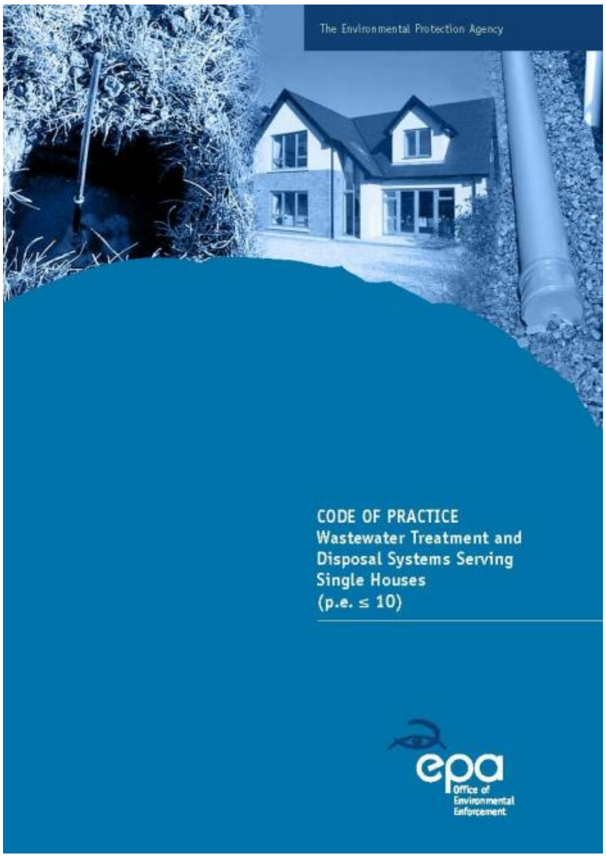
When on-site systems such as septic tanks fail to operate satisfactorily they threaten public health and water quality. When the wastewater is not absorbed by the soil it can form stagnant pools on the ground surface. In such failures, humans can come in contact with the wastewater and be exposed to pathogens. Inadequately treated wastewater may lead to contamination of our groundwaters and surface waters, which in many areas are used as sources of drinking water. It is essential, therefore, that these on-site systems are properly designed, operated and maintained.

The EPA recently published a code of practice in relation to on-site systems for protection of our environment and specifically drinking water.

The code of practice sets out the following:

- An assessment methodology for the determination of site suitability for an on-site wastewater treatment system and identification of the minimum environmental protection requirements.
- A methodology for the selection of a suitable on-site wastewater treatment system for sites in unsewered rural areas.
- Information on the design and installation of conventional septic tank systems, filter systems and mechanical aeration systems.
- Information on tertiary treatment systems.
- Maintenance requirements for the above systems.

It is important that homeowners have the correct on-site system for their home. If not, problems can arise in the future, such as contamination of water supplies, streams and/or ponding on the surface, which may lead to a potential health hazard. It is in the best interest of the environment and the homeowner to install an appropriate system. All new on-site systems should comply with the EPA *Code of Practice for Wastewater Treatment and Disposal Systems Serving Single Houses (2009)*.



The EPA *Code of Practice for Wastewater Treatment and Disposal Systems Serving Single Houses (2009)*

Three important aspects relating to wastewater treatment for homeowners are:

1. Site Suitability Assessment

A site suitability assessment is an assessment of site conditions in relation to the suitability for wastewater treatment and disposal. All sites for proposed single houses in unsewered rural areas will require a site suitability assessment. This needs to be undertaken by a competent person in accordance with the EPA Code of Practice (Consult with the local authority for information on competent persons). A full site suitability assessment report is required to be submitted as part of an application for planning permission and in many cases, including for extensions.

2. Selecting a Wastewater Treatment System

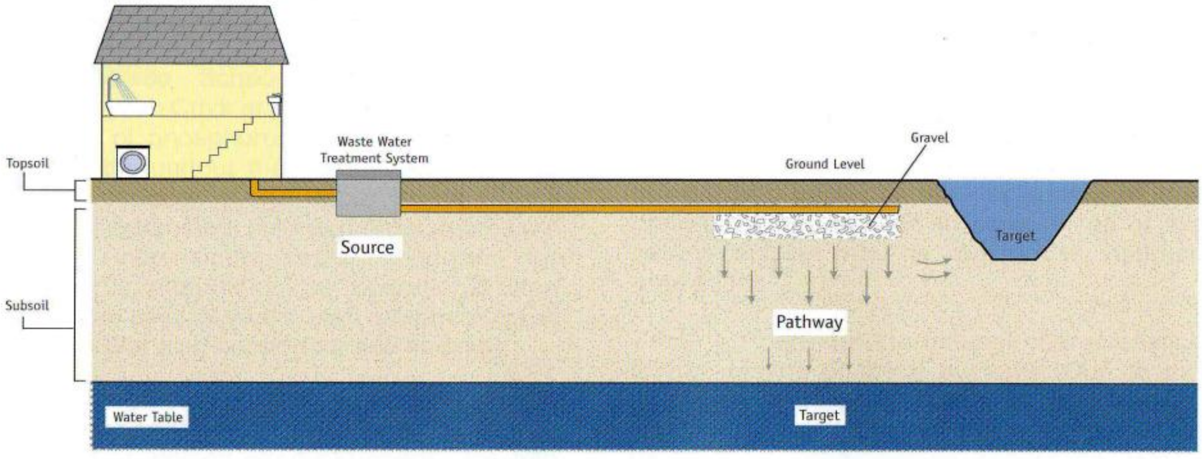
Site conditions, as determined by the site suitability assessment, govern the selection of wastewater treatment system and are site specific. Some sites may not be suitable for wastewater disposal regardless of the type of system used. Unsuitable sites lead to pollution of surface and ground waters and/or pose an unacceptable risk to public health. Any selected system should comply with the EPA Code of Practice, which incorporates the requirements of the *European Standard EN 12566 Small Wastewater Treatment Systems* for up to 50 population total (PT).

3. Installation and Maintenance of Wastewater Treatment Systems

The homeowner is legally responsible for the operation of their wastewater treatment system according to Section 70 of the *Water Services Act 2007* (S.I. No. 30 of 2007). Correct installation and maintenance are critical in ensuring correct operation of all wastewater treatment systems. The homeowner is advised to obtain relevant documentation from the installer/manufacturer in relation to installation and maintenance including costs. It is also essential that maintenance contracts be renewed. Certification by a competent person of installation may be required in planning conditions and should be checked with the local planning authority. Documentation should be retained for future reference.

A copy of the Code of Practice: Wastewater Treatment and Disposal Systems serving Single Houses (population equivalent ≤ 10) may be downloaded from the EPA's website at www.epa.ie. Hard copies are available from: Publications Office, McCumiskey House, Richview, Dublin 14 on 01-2680100.

Margaret Keegan
Environmental Protection Agency
Richview, Dublin 14



The Source — Pathway — Target model used in the risk assessment process to determine site suitability

On-site wastewater treatment research - Trinity College Dublin

Research into on-site wastewater treatment showed that properly constructed septic tanks and percolation areas perform as well as, if not better than, packaged secondary treatment systems

The safe disposal of on-site wastewater is essential for the protection of both groundwater and surface water resources in Ireland particularly due to the rapid rise in the number of one-off developments in unsewered rural areas over the last decade. However, little field research had been carried out into the effectiveness of on-site treatment with respect to groundwater protection. Hence two research projects have been commissioned by the EPA and carried out over the last 8 years involving field trials on seven separate sites.

The aim of the research projects was to carry out a series of rigorous on-site trials in order to test the designs promoted in the EPA Guidelines / Code of Practice; and also to enhance the understanding of the processes involved, and pollutant attenuation performance across a range of Irish subsoil types with varying percolation characteristics.

The first project entitled, **"***An investigation into the performance of subsoils and stratified sand filters for the treatment of wastewater from on-site systems*" (ref. 2001-MS-15) was completed in 2004. This study involved four separate, intensively monitored sites on subsoils with T-values ranging from 15 to 52: two sites receiving effluent from septic tanks, the other two receiving effluent from two secondary treatment peat filters. In addition, the effluent on two of the sites was split, with half directed to percolation trenches and the other half passing to stratified sand filters, in order to provide a direct comparison and evaluation of this treatment option. The four chosen sites were constructed in exact compliance with the EPA 2000 guidelines (trench lengths and widths, pipe gradients, gravel and sand specifications etc) and all surface water was diverted away from the foul network. Each percolation area was intensively studied with soil moisture samples taken at three nominal depths below the invert of the percolation trenches (0.3, 0.6 and 1.0 m) at several different locations across the area to give a three dimensional picture of treatment within the subsoil. Meteorological variables were continuously recorded to calculate recharge and thus dilution of effluent at depth in the percolation area.

In general, the research showed that a properly constructed septic tank and percolation area provided a comparable treatment performance with respect to groundwater protection as a packaged secondary treatment system and percolation area with no discernible differences in treatment performance were found between the sites of different percolation characteristics. However, a notable finding was that the development of a biomat across the percolation areas receiving secondary treated effluent was muted on these sites compared to the sites receiving septic tank effluent, whereby the effluent was shown to have only reached one quarter of the length of each percolation trench after one year. This result is not surprising as the organic load in the wastewater (the food for the micro-organisms in the soil) is significantly removed in the secondary treatment process. The consequence of this is a more concentrated hydraulic loading at the front of the trenches compared to the sites receiving septic tank effluent where the effluent is more evenly spread over the whole percolation area. So, even though the concentrations of organics and micro-organisms were significantly lower in secondary treated effluent, the higher hydraulic loading (and consequential high pollutant mass loadings) resulted in a similar quality of effluent at depths of 0.6m of subsoil beneath the percolation

Installation of one of the monitoring sites

trenches when compared to the sites receiving the septic tank effluent. Another consequence of this was that there were much higher nitrogen loads at the 1.0m sampling plane beneath the secondary treated effluent sites compared to the equivalent septic tank sites. The total nitrogen load is not reduced in the secondary treatment processes, rather it just changes form from ammonia and organic nitrogen into nitrate. This nitrate then percolates down through the subsoil in a relatively concentrated plume without any significant reduction. The processes in the more developed biomats in the percolation gravel and subsoil receiving septic tank effluent, however, appear to be suitable for both nitrification of the effluent and then subsequent denitrification, resulting in a significant reduction in total nitrogen loading.

The stratified sand filters on two sites performed slightly better compared to the percolation areas for both septic tank and secondary treated effluent. However, it was recommended that the loading rate for a sand filter receiving septic tank effluent should be reduced to 30 l/m^2d but kept at 60 l/m^2d for tertiary treatment applications. There were also difficulties sourcing the sand in Ireland according to the specification and so it is recommended that the design in the EPA guidelines should be slightly modified to allow indigenous sand to be used. Finally, it was found that current distribution boxes available on the Irish market do not distribute effluent effectively and a functional design needs to be specified in the EPA guidance manual. The faith in the performance of any correctly designed on-site treatment system is based upon the assumption of an equal loading of effluent across the percolation area, which is obviously not the case if all the effluent is passing down one trench. [*Editors note*: this first project was also reported on in the last edition of the newsletter].

This second project, which was entitled, "*On-site Wastewater Treatment: Investigation of Rapid Percolating Subsoils, Reed Beds and Effluent Distribution*" (ref. 2005-MS-15), has just been completed. This was commissioned to investigate the on-site disposal of effluent into relatively fast percolating subsoils (T-value <5). The project also studied the potential application of the horizontal subsurface flow reed bed process as treatment systems of such effluents. The third area of research was to investigate the efficacy of gravity flow distribution devices, which should be used to split the on-site effluent evenly across a percolation area, following on from the discoveries in the first project.

The project found that the discharge of septic tank effluent or packaged plant secondary treated effluent onto gravity fed percolation areas with subsoils of relatively quick percolation characteristics (T-values down to 3.5) provides a reasonable protection to groundwater, providing there is at least 0.95 m of unsaturated subsoil. The effects of increased percolation in these sites with relatively fast percolation characteristics compared to the previous studies on higher T-value sites was evident – muted biomat development and reduced nitrogen removal on the percolation area receiving septic tank effluent, and isolated incidences of bacterial breakthrough of *E. coli* under trenches receiving both septic tank and secondary treated effluent. Hence, it was recommended that the current lower T-value limit for fast percolating subsoils of T = 1 should be raised to T = 3 on a precautionary basis, which was adopted in the recently released Code of Practice.

As before, the secondary treated effluent discharged into such subsoils resulted in a much reduced biomat with equivalent increases in the hydraulic loading and again seems to promote a higher nitrogen load on the groundwater; there was also evidence of breakthrough of the indicator viruses (bacteriophages) used in targeted trials. Hence, the recommendation is that packaged plants should not be promoted over septic tanks in areas where the reasonable unsaturated subsoil depths and percolation rates exist. Equally, the minimal spread of the biomat on the trenches receiving secondary treated effluent means that consideration should be given on such sites as to how to distribute the effluent over a wider area for percolation, as the majority of the trench in the current design is not being used.

The use of three different bacteriophage tracers on the sites has demonstrated that enteric viruses in on-site effluent should be almost completely removed with 0.95 m of subsoil. However, as small concentrations were still detected after 0.95 m beneath the trenches receiving secondary treated effluent, the trials confirmed the decision to increase the depth of subsoil required in the new Code of Practice from 0.6 to 0.9 m for percolation areas receiving such effluent.

The research also showed that the design criteria given for horizontal flow reed beds in the Code of Practice are appropriate for both secondary and tertiary systems, although the limitations of such systems need to be acknowledged. The effluent from tertiary treatment reed beds will still need to pass through a polishing filter before discharging to groundwater. The existing distribution devices on the market were evaluated both in the controlled laboratory environment using clean water and also out on site under real effluent conditions, and all were found to be unsuitable for use in gravity fed on-site situations without regular maintenance. Indeed, the regular maintenance requirements in general are important for all on-site systems, especially for packaged plants and distribution devices, a message that has been heavily reinforced in the new Code of Practice. Finally, the wastewater production at each site was accurately measured continuously throughout all the trials and was found to be much lower than EPA guideline value of 180 lcd (litres per capita per day). An average value of closer to 120 lcd was found to be more appropriate.

Full reports can be downloaded from the EPA website at http://www.epa.ie/downloads/pubs/research/water/

Other relevant ongoing research being carried out by the TCD group include the following:

- a project funded by Wexford County Council investigating the use of zero-discharge treatment systems using willow evapotranspiration beds in areas where discharge to ground is not possible due to very low subsoil percolation rates (i.e. heavy clays);
- the use of recycled glass as an alternative media for on-site tertiary treatment filters;
- investigation into the fate of Endocrine Disrupting Compounds in on-site treatment processes;
- the impact of on-site treatment for small community developments (cluster systems) on groundwater; and
- the groundwater protection (or otherwise) afforded by old septic tanks with soak pits.

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Groundwater Pollution in Ireland – A Brief Assessment of the Main Causes

The main causes of groundwater pollution are microbial pathogens, caused equally by farmyards and on-site wastewater treatment systems, and nitrate caused by grazing animals and inorganic fertilisers

Introduction

From a public health perspective, the two main widespread pollutants present in groundwater in Ireland are microbial pathogens and nitrate. This article considers the likely sources of each of these pollutants.

Current Situation

Microbial Pathogens

From a human health perspective, microbial pathogens (Verotoxigenic E. Coli in particular and potentially Cryptosporidium) are the most widespread and significant pollutants in groundwater. Between 2007 and 2008, the EPA sampled untreated water from wells and springs as part of the national groundwater monitoring programme. During this reporting period, 67 percent of all EPA monitoring locations had faecal coliforms (see Figure 1) in at least one sample (samples are taken every three months). Approximately 34% of the 2,057 samples taken between 2007 and 2008 tested positively for faecal coliforms and 18% of the samples had greater than 10 faecal coliforms/100 ml. (The drinking water standard is zero.) Private domestic wells in vulnerable areas are particularly prone to pollution by microbial pathogens and, as water from these wells is usually untreated, this poses a health hazard.

Nitrates

Between 2007 and 2008, the mean nitrate concentration exceeded the Irish Threshold Value concentration of 37.5 mg/l NO_3 at approximately 7% of all EPA monitoring locations and exceeded the Drinking Water MAC of 50 mg/l NO_3 at 1% of all EPA monitoring locations. Figure 2 shows that the south east and south of the country has the greater proportion of monitoring locations with elevated nitrate concentrations.

Assessment of Pollution Sources

Farming activities and on-site wastewater treatment systems (OSWTSs) (mostly conventional septic tank systems, but in recent years also 'advanced systems') are commonly regarded as the two main sources of pollution of wells and springs in terms of the number of wells affected. Assessment of the likely source uses a 'weights of evidence' approach and takes into account the following three factors:

1. Source of pollutants

The main sources of microbial pathogens and nitrates in Ireland are organic manure/slurry in farmyards and spread on land; soiled water in farmyards, inorganic fertilizer and effluent from OSWTSs.

2. Presence of, and distance to, nearby receptors

Wells and springs are the abstraction points for drinking water supplies and are therefore important receptors.

3. Pathway between source and receptor

The amount of contamination arriving at a receptor depends on the nature of the pathway from the source. Groundwater vulnerability is a critical factor. This depends on the thickness and permeability of subsoils and the presence of karst features, e.g. sinking streams.

Attenuation, e.g. filtration and die-off of pathogens, and dilution of nitrate, is also important. This is influenced by the soil and subsoil properties, and the aquifer type, e.g. the likelihood of pollution by bacteria is far higher in karstified aquifers than in sand/gravel aquifers, as groundwater velocities are high and there is no filtration.

Good wellhead protection, i.e. sealing around

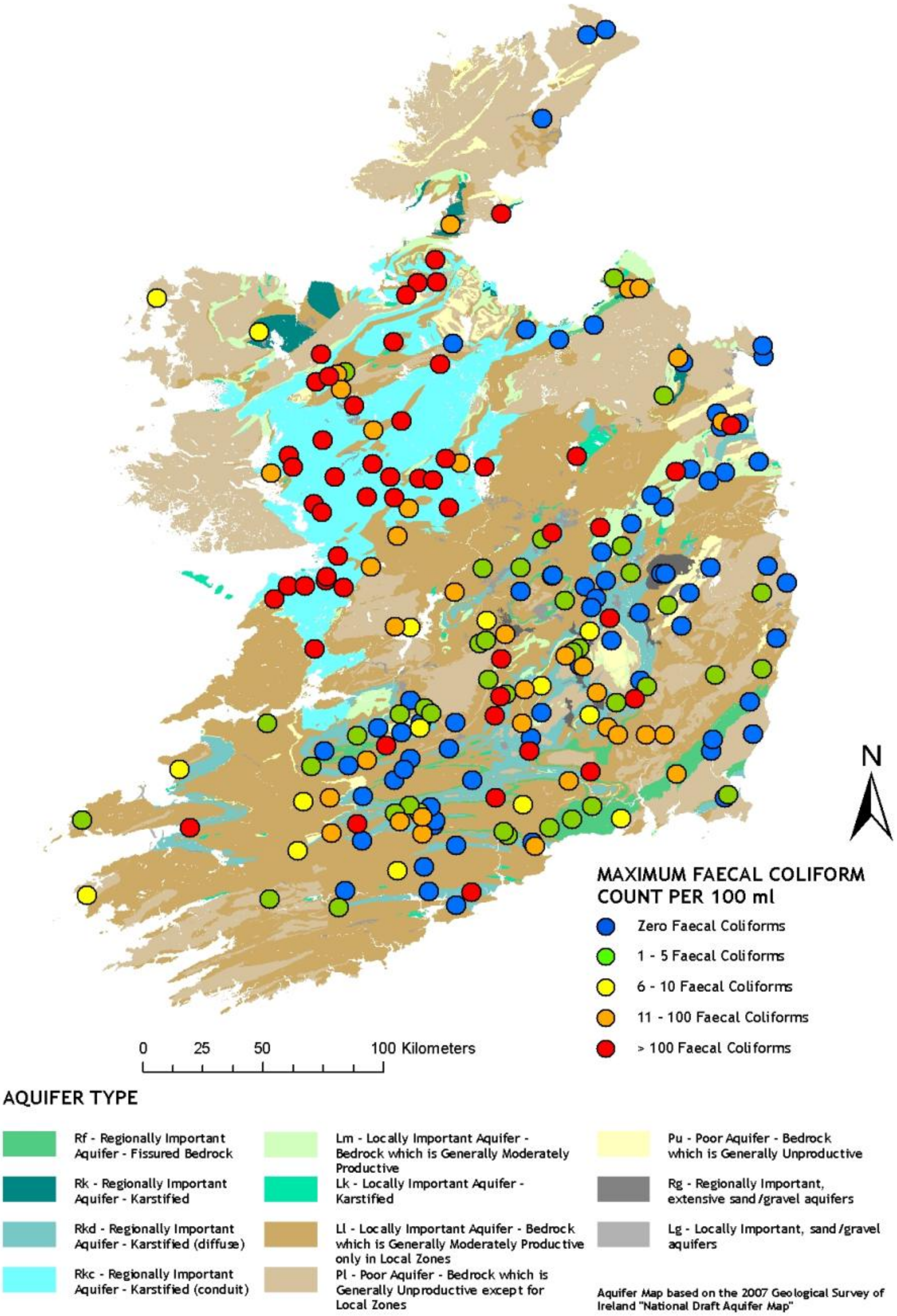

Figure 1. Maximum Faecal Coliform Count / 100 ml in groundwater in 2007 — 2008 (Source EPA)

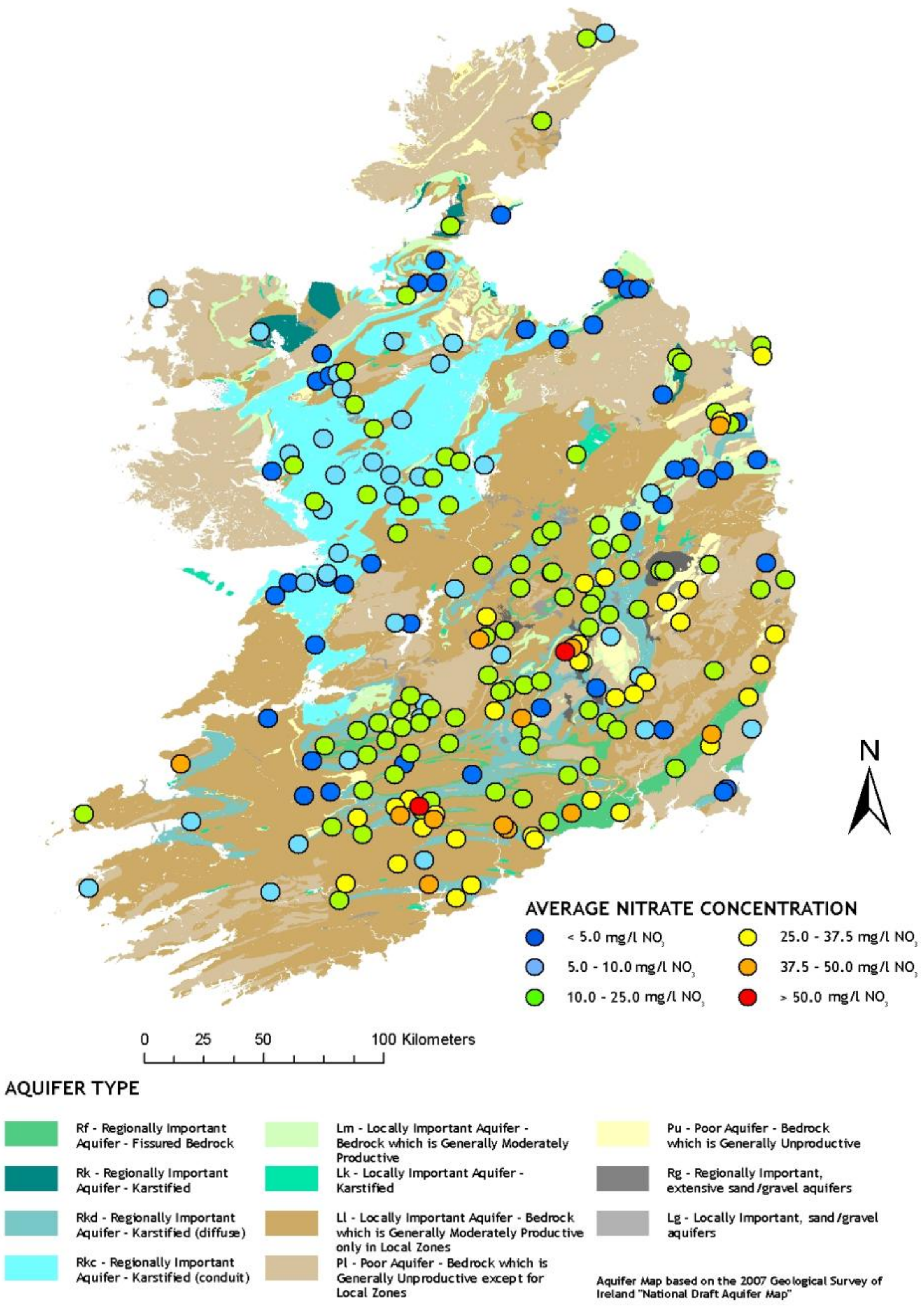

Figure 2. Mean nitrate concentrations in groundwater in 2007 — 2008 (Source EPA)

the outside of the well, plays another important role.

Main Sources of Microbial Pathogens in Wells and Springs

The sources of faecal bacteria are warm blooded animals, such as humans, cattle, sheep, pigs and birds. The presence of faecal bacteria not only reflects the impact of human activities, but also the vulnerable nature of groundwater in some parts of the country. Historically, it is likely that low numbers of faecal coliforms would have been present in groundwater in some of these areas. Determining the precise cause of well and spring pollution is difficult. Tracing between the pollution source and receptor has been previously used but has tended to be limited. In the future, genetic sequencing may also prove useful.

It is considered that OSWTSs and organic manure/slurry/soiled water generated in farmyards are roughly equally responsible overall for pollution of wells and springs by faecal bacteria in Ireland. This view is based on the following:

- Groundwater pollution assessments done by the Geological Survey of Ireland staff over a 40 year period. Evidence was usually a combination of circumstantial (e.g. proximity of the polluted well to the OSWTS and nearby farmyards, taking account of the likely groundwater flow direction) and hydrochemical (e.g. K/Na ratio).

- Well water quality surveys in south Sligo by Sligo RTC in the mid 1980s.

- Research on septic tank systems by Sligo RTC in the early 1990s.

- EPA-funded research undertaken by TCD on OSWTSs (refer to the article on page 4).

Farming is by far the most important ***potential*** source of pollution because it produces large volumes of organic fertilizers (manure and slurry) – about 80% of organic wastes generated in Ireland comes from agriculture, equivalent to that from a human population of over 50 million people based on B.O.D loadings. Approximately 25-35% is stored in slurry pits and manure heaps, where some die-off of pathogens will occur. The remainder is distributed over fields by grazing animals.

Effluent from OSWTSs is also a major potential source of pollution to wells, particularly domestic wells. There are over 400,000 systems in Ireland serving a population of about 1.2 M people and discharging approximately 80 Mm^3 of effluent into the ground annually (or 50 million gallons each day). Wells are located in the vicinity of many of these OSWTSs.

The numbers of microbial pathogens present in OSWTS effluent and manure/slurry/soiled water are both enormous and the drinking water limit is zero, so dilution by unpolluted groundwater is insufficient to mitigate the problem. Pollutant loadings from different sources are also not a useful means of identifying the source.

While farmyard manure/slurry has a greater potential to pollute generally than OSWTSs, this material is recycled onto land. This allows pathogen die-off and filtration in the soil and subsoil (except where the vulnerability is Extreme). OSWTS effluent however, bypasses the topsoil and some or all of the subsoil (depending on the depth to rock and the use of soakage pits), thereby increasing the risk of groundwater pollution. (The soil and subsoil act as a protecting filtering layer over groundwater; once pollutants enter bedrock there is minimal attenuation of pollutants, other than by dilution.) In addition, OSWTSs are far more numerous than farmyards, and polluted wells are more often located closer to OSWTSs than farmyards. However, it is probable that, in instances where 'gross' pollution of wells occurs (a small proportion of polluted wells), farmyards are likely to be the main cause as OSWWTs would seldom be capable of contributing a sufficient pollutant load to groundwater.

Compliance with the new EPA Code of Practice will significantly reduce the likelihood of pollution by OSWTSs in the future. Information on the Code is provided by Margaret Keegan on page 2 of this issue.

Main Sources of Nitrate in Wells and Springs
Nitrate is a 'conservative', mobile contaminant and attenuation occurs only by dilution (an exception is where denitrification occurs.) Unlike microbial pathogens, the relative pollutant loadings from the various sources can be used to identify the source, although only as a crude measure as a high proportion of nitrogen in fertilizers is utilised by crops. The natural background nitrate concentration in groundwater is estimated to be no higher than 9 mg/l NO_3.

Agricultural activities (inorganic fertilizers, and faeces and urine from grazing animals) are considered to be the main nitrate source in groundwater in areas where concentrations are relatively high, for the following reasons:

- The highest concentrations are present in the south, south-east and east where agriculture is most intensive.

- The nitrogen loading from agriculture is far higher than from OSWTSs. While there are no figures for groundwater, the sectoral total nitrogen load to rivers is estimated to be over 70% from agriculture and 3% from single house OSWTSs (from National Summary Characterisation Report prepared under the Water Framework Directive, available on www.wfdireland.ie).

- The results of several research projects undertaken in Ireland, e.g. ERTDI Project LS-2.3 (see www.epa.ie for project reports.)

There are circumstances whereby OSWTSs can be the cause of high nitrate concentrations in groundwater:

- Public, group or farm supplies with a relatively low abstraction rate and a cluster of houses in the Zone of Contribution (ZOC or catchment area). Although uncommon, this situation does arise. In such cases, the cumulative nitrogen load from the OWSTSs is sufficient to cause a significant rise in the nitrate concentrations.

- Private wells where an OSWTS is up-gradient and within the ZOC. In this instance, direct recycling of the effluent could occur and the resulting nitrate concentration could be >100 mg/l NO_3.

However, the number of wells with high nitrate concentrations due to the presence of nearby OSWTSs is likely to be a small fraction of those caused by organic and inorganic fertilizers.

Conclusions

1. Microbial pathogens and nitrate are the two main pollutants present in groundwater in Ireland from a public health perspective.

2. Farmyard activities and OSWTSs are considered to be approximately equally responsible for pollution of wells and springs by microbial pathogens. Compliance with the new EPA Code of Practice will significantly reduce pollution of groundwater in the future.

3. Faeces and urine from grazing animals and landspreading of inorganic fertilizers are considered to be the main source of nitrates in groundwater.

Donal Daly
Hydrometric and Groundwater Section, EPA

Pesticide Occurrence in Irish Groundwaters

A new project is underway to investigate the poorly understood issue of pesticides in groundwater and to validate risk assessment models used to indentify groundwater bodies at risk

Introduction

Nearly 4 million hectares of land in Ireland had some form of agricultural pesticide product applied in 2004. This equates to 55% of Ireland's total land area. To date there has been little research conducted in Ireland on pesticide transport to groundwater and this information is urgently required. Water Framework Directive (2000/60/EC) implementation has highlighted the need for further data on agricultural pesticides which may act as diffuse sources of groundwater contamination in Ireland.

A new collaborative research project between TCD and Teagasc began in October 2008 to investigate pesticide occurrence in a range of hydrogeological settings predominantly under tillage but with one grassland site on a karst aquifer. A selection of 36 common pesticide products and metabolites will be quantified on a monthly basis. The research is being undertaken as a Ph.D project by Sarah McManus, supervised by Catherine Coxon and Karl Richards. This project forms part of a wider interdisciplinary project led by UCD, entitled *"Assessment of the vulnerability of groundwater to pesticide inputs from Irish agriculture"*, which involves three other Ph.D projects. The other projects involve developing a ranking procedure for pesticides of environmental and toxicological concern, the quantification of adsorption and desorption isotherms of pesticides and parameterising the pesticide component of the preferential flow model MACRO, modelling of pesticide movement to groundwater under Irish site conditions, and the development of a groundwater vulnerability / risk assessment map for pesticides. The data generated from this part of the project will be used for risk assessment model validation to aid in identifying the groundwater bodies at risk from pesticides and contribute towards achieving the Water Framework Directives objectives of good status for all waters. This research will also assist Ireland in evaluating the impact of the proposed changes to Council Directive 91/414/EEC (placing of plant protection products on the market) to enable increased awareness of pesticide control and protection of groundwater.

Site selection

The role that site properties play in controlling the mobility of agricultural chemicals through soils to groundwater is essential in the risk assessment of their environmental fate (Worral *et al*, 2002). Sites were chosen with contrasting

Table 1. List of sites for groundwater pesticide quantification

Site	***Subsoil thickness/permeability***	***Aquifer type/rock type***
Castledockrell, Wexford	7m of till derived from lower Palaeozoic sandstones & shales	Ll (Ordovician metasediments)
Ballycanew 1, Wexford	12m of Irish sea till	Rf (Ordovician volcanics)
Ballycanew 2, Wexford	<3m of subsoil with exposed bedrock outcrops	Rf (Ordovician volcanics)
Nuenna, Co. Kilkenny	<3m of subsoil with karstified bedrock outcrops	Rkd (Dinantian pure bedded limestones)
Oak Park, Co. Carlow	6m of gravels derived from limestones	Sand & Gravel, Rkd (Dinantian pure bedded limestones)
Cregduff, Co. Mayo	<3m of subsoil with karstified bedrock outcrops	Rkc (Dinantian pure bedded limestones)

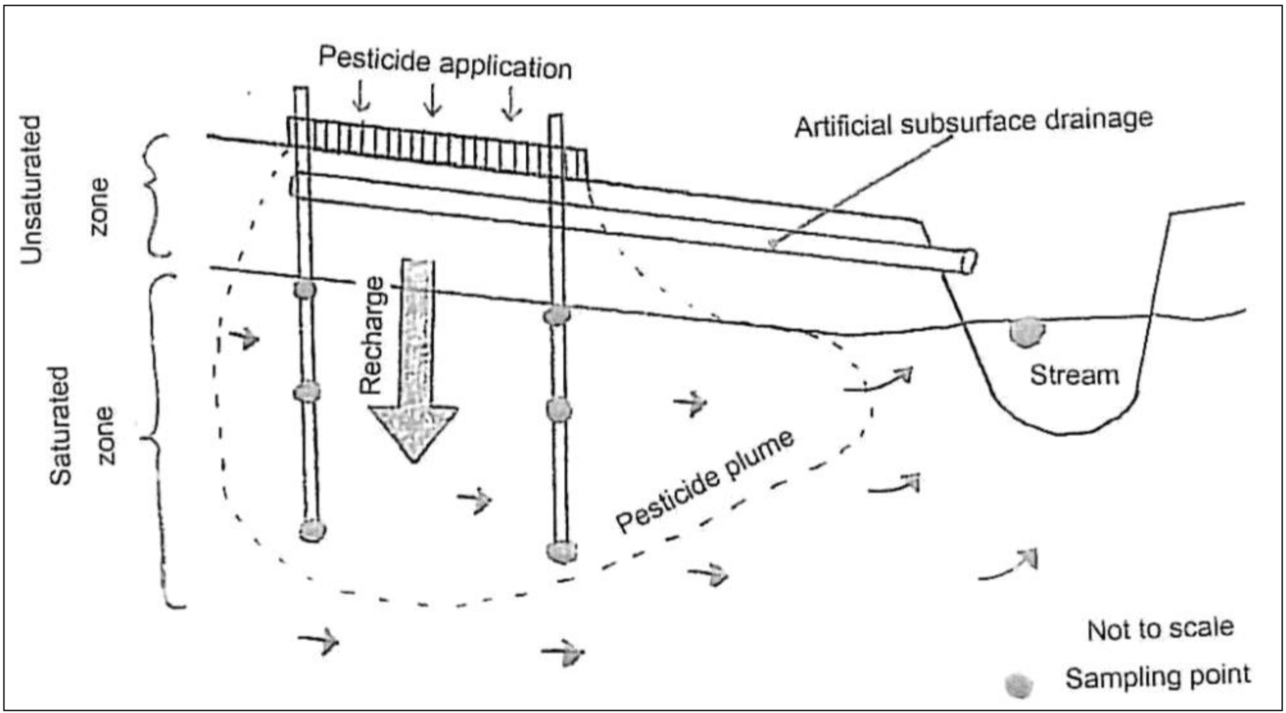

Figure 1. Hydrogeological conceptual model and groundwater sampling strategy. Samples will also be taken from artificial subsurface drainage (where present)

soil, subsoils and bedrock geology and aquifer type. ArcGIS 9.3 was used to locate areas with these differing characteristics. Depth of soil and subsoil, and unsaturated zone thickness has also been taken into consideration using archived records of exploratory boreholes supplied by the Geological Survey of Ireland. The research will focus on tillage farming with similar crops and pesticide usage, to allow comparisons to be made between each site. Comparisons will also be made with tillage (Nuenna) and grassland (Cregduff) land uses over karst aquifers. Table 1 summarises each sampling location.

Methods

Figure 1 presents the hydrogeological conceptual model and the groundwater sampling strategy. In October 2009 multilevel piezometers were installed, in single borehole constructions drilled using the Symmetrix drilling system on each site. Groundwater samples at varying depths will be taken recurrently and event based samples shall also be taken. Interestingly when drilling at Ballycanew 1, Co. Wexford we installed a piezometer at the interface between the Ordovician volcanics and the overlying Irish Sea till at a depth of 12 m bgl, where we encountered a confined aquifer with a minimum head of 6m above ground level and a flow rate of c. 150 l/minute (Figure 2).

Samples from nearby streams and field drains shall also be taken from lower permeability sites. Sampling will occur for 18 months and include two drainage seasons. Collected groundwater

Figure 2. Confined aquifer encountered below Irish Sea till at a depth of 12m in Ballycanew. Minimum piezometric surface was 6 m above ground with a flow rate of c. 150 l/minute

samples will be extracted using derivitization techniques, solid phase extraction and solid phase micro extraction prior to analysis using gas chromatography (GC/ECD & GC/MS) in Teagasc, Johnstown Castle. Four methods have been adopted to include analysis of 28 pesticide products and 8 pesticide metabolites or degradates to 0.005 μgl^{-1} detection limits.

Expected outcomes

This project will improve the national dataset on pesticide occurrence in Ireland as well as improving our understanding of pesticide partitioning through different flow paths (subsurface drainage, shallow groundwater, deep groundwater and surface water) which will improve our hydrogeological understanding of pesticide transport in Irish groundwater systems. The data will also be used in a wider interdisciplinary project for risk assessment model validation to aid identifying the groundwater bodies at risk from pesticides and contribute towards achieving the objective of good status for all waters.

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Acknowledgements

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Extensive survey of Dublin Soils Commences
Dublin SURGE Project – Soil Urban Geochemistry

The Geological Survey of Ireland (GSI), in conjunction with the Geological Survey of Norway, is carrying out a geochemical survey of topsoil around Dublin city and county. It involves taking samples of soil from areas that are publicly accessible (e.g. public parks and school grounds). The aim of the survey is to acquire important information about Dublin soils that will help better assess and manage our urban environment. The results of the survey will be publicly available towards the end of 2010.

This is a significant project for Ireland since there is currently no significant baseline geochemical information for Irish urban environments. The study will have benefits in the following areas:

1) Baselines for environmental monitoring;
2) Identification of city areas possibly in need of remediation;
3) Assist authorities in setting soil environmental standards for Irish cities;
4) Contribute to more informed urban planning for both brownfield redevelopment of inner city areas and suburban development;
5) Assist compliance with EU Directives (Soil and Water) and legislation protecting groundwater, soils, habitats etc.

Further information at: www.gsi.ie/surge

Investigating subsoil and groundwater denitrification in Ireland

Research at Teagasc is underway into potential rates of denitrification in a range of hydrogeological settings, including the organisms responsible. Methods for enhancing denitrification will be investigated

Teagasc research focuses on the improvement of nutrient efficiency on farms through soil specific agronomic research to maximise the utilisation of nutrients and thereby reduce farmers' costs and reduce losses to the environment. Nitrogen loss by leaching as nitrate (NO_3^-) contributes to eutrophication of surface waters and may cause breaches of drinking water standards, while gaseous loss from soil to the atmosphere as nitrous oxide (N_2O), mainly through denitrification, is a major source of greenhouse gas. Not all losses of nitrogen to the environment are bad; di-nitrogen (N_2) is an environmentally benign gas and it comprises nearly 79% of the air we breathe and it is the ultimate end product of complete denitrification. In certain circumstances, completely eliminating nitrogen loss to the environment is not possible, so what can we do about this? Research on subsurface denitrification is currently being undertaken in Teagasc Johnstown Castle to increase process-based and quantitative understanding of the importance of denitrification as a pathway for the control of NO_3^- and N_2O emissions from agriculture.

Our research project, which is due for completion in March 2011, focuses on understanding and quantifying denitrification in the unsaturated and saturated zones. The research, co-funded by the Department of Agriculture Fisheries and Food, involves a small team of soil scientists in Teagasc, microbiologists in NUI Galway and hydrogeologists in TCD. Our goal is to quantify subsurface denitrification, to understand the drivers of complete denitrification and if possible identify strategies to enhance complete denitrification for the abatement of NO_3^- leaching and N_2O loss to the atmosphere. The research will help to identify if denitrification is an important process influencing NO_3^- levels in groundwater and rivers or if it is a significant source of N_2O emissions.

Unsaturated Zone

In this part of the research project we are investigating the importance of denitrification in subsoils for reducing NO_3^- concentrations in recharge as it is transported through the unsaturated zone. Subsoil denitrification has been investigated under controlled laboratory conditions, enabling us to quantify the end products of denitrification and thus identify if the NO_3^- is reduced to N_2 or N_2O. Initial results from these experiments indicate that the rate of subsoil denitrification is about 40% lower than in topsoils (Figure 1). But importantly of the c. 25% of the added N that was denitrified in the subsoil, 86-94% is reduced to N_2 compared with 58% in topsoils. A remaining experiment is planned to examine in-situ denitrification capacity of subsoils.

Saturated zone

Saturated zone monitoring sites have been established on three grassland farms and one tillage farm, representing a range of soils and hydrogeological settings, to quantify

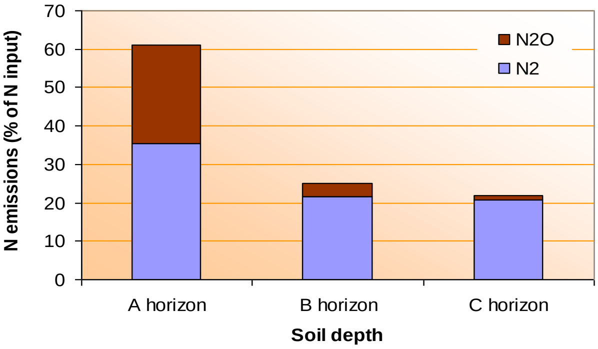


Figure 1. Proportion of N_2 and N_2O emitted as a percentage of the nitrogen applied. Each horizon separately received 90 mg NO_3^--N and 150 mg glucose-C, per kg of soil, under laboratory conditions

denitrification changes in the landscape and at different depths in the aquifers (Figure 2). We have targeted the saturated zone in the subsoil, the subsoil/bedrock interface and within the bedrock with multilevel 2” piezometers installed in a single borehole construction using the Symmetrix drilling system. Our hypothesis is that groundwater NO_3^- is related to the residence time in an aquifer; under the favourable conditions of low redox/oxygen and with sufficient carbon the slower groundwater moves in an aquifer, the greater the time for denitrification to occur and potentially more is converted to N_2. Our monitoring programme concentrates on measuring physio-chemical properties, NO_3^- and dissolved gases in groundwater (N_2/Ar ratio, N_2O, O_2, CO_2 and CH_4).

Monthly saturated zone monitoring began in late 2008 by M. Jahangir and P. Johnston in TCD. The initial results indicate that there are major contrasts between the sites investigated, with higher dissolved gas and lower NO_3^- concentrations in the less productive aquifers compared to the productive karst aquifers. Interestingly the karst aquifers appear to have elevated N_2O concentrations and this will be subject to further investigation. To complete the saturated zone denitrification capacity investigations, a final series of experiments will be conducted using the push-pull technique where ^{15}N-labelled NO_3^- will be injected into the groundwater and the labelled N_2, N_2O and NO_3^- will be measured to determine actual rates of denitrification.

Figure 2. Drilling boreholes to investigate the ground-water denitrification capacity at a range of depths on a tillage farm

Environmental Microbiology

The final piece in our research denitrification jigsaw is to try to look at the organisms responsible for denitrification. We know that denitrification is mainly a microbial process that occurs under low oxygen conditions. The subsoil and groundwater studies are investigating the occurrence of the optimal conditions for denitrification and the microbiological investigations are quantifying denitrifiers in these studies to help identify which ingredient is limiting denitrification. Our collaborators M Barrett and V. O’Flaherty at the Dept. Microbiology NUI Galway are using advanced molecular microbiological tools to quantify the number of organisms related to the emission of N_2 and N_2O and to identify where they are located in subsoil and groundwater. Preliminary results to date have indicated that the abundance of denitrifiers decreases with soil depth and this could be the driver to explain why denitrification rates were lower in the sub-soil experiments above. Denitrifier DNA has been observed in the groundwater at all monitoring sites including the Karst limestone. It still remains to compare the abundance of denitrifier DNA with the actual rates of denitrification being observed across our monitoring network.

By the end of this project we will have a reasonable idea as to the potential rates of denitrification in a range of Irish hydrogeological settings. We have developed a capacity to further investigate denitrification and, potentially, methods to enhance denitrification using remediation technologies.

K. Richards[1], M. Khalil[1], O. Fenton[1], M. Barrett[1,2], M. Jahangir[1,3], P. Johnson[3], C. Coxon[3] and V. O’Flaherty[2]

[1]Teagasc Johnstown Castle; [2]NUI Galway; [3]Trinity College Dublin

Ireland's Group Water Schemes: focusing on the source

The majority of Group Water Schemes extract from groundwater and operators are being advised to develop groundwater source protection plans to enable better water management

Described as 'The Quiet Revolution', rural electrification addressed one of the great infrastructural challenges of mid 20th century Ireland. By the late 1950s, however, another (and arguably more important) infrastructural challenge remained: the provision of a piped water supply network to rural homes.

For householders outside of the main towns, the reality of life meant daily visits to a spring well or (from the 1930s) to one of the pumps constructed above shallow wells in villages and on country roadsides. The advent of the first group water schemes at Oldcourt and then Manor Kilbride in County Wicklow in the late 1950s provided a solution to this infrastructural headache. By pooling the individual well grants that were available to households, communities could abstract water from a single source and distribute it through a common network.

All that was required were determined individuals (like Fr Joe Collins who spearheaded the West Wicklow initiative) to head a local committee.

This committee would liaise with the Department and County Council Engineers for technical support and advice and, in addition to raising a local contribution from those wishing to join the scheme, would organise teams of locals to provide direct labour. It was community activism at it best.

Most early schemes were in the east of the country and like Oldcourt, depended on mountain springs for their supply. Water was collected in a holding tank and gravity-fed to homes, farms and businesses in the locality. In less hilly areas, direct pumping systems were installed.

By the early 1960s deeper wells were being sunk at places like Tullyallen, near Drogheda, while schemes without a readily available groundwater source were content to take their supply from a mountain stream or lake.

The schemes were usually vested in trusteeships and were run by the committees that established them. Apart from maintaining pumps and fixing leaks, these voluntary committees raised whatever funds were required to keep things ticking over. State funding ended as soon as the scheme was completed and, in most instances, little thought was given to the need for capital reserves.

The benefits of rural piped water networks were so glaringly obvious that little consideration was given to any potential downside, even as farmers began to hose down dairies and farmyards and householders rushed to install indoor plumbing with bathrooms, toilets and a variety of water-using devices.

Water consumption naturally soared in home and farm and wastewater levels rose in tandem with this. Most passed untreated into a sheugh or into crudely-built septic tank systems. And even as treatment systems improved, little thought was given percolation. Out of sight is out of mind. And so, households dotted across Ireland contributed to the contamination of water bodies to an extent that was unimaginable in previous generations.

By the early 1980s there were thousands of group water schemes, ranging from just two houses to some on surface water supplies that had well over 1,000 households, in addition to field connections, community facilities etc.

Treatment was unheard of in the early days, but schemes established in the 1970s tended to have disinfection (chlorination), while a minority had slow sand filters installed.

As the quality of raw water deteriorated through the late 70s and 80s, the chickens came home to roost for all water suppliers, public and privately-sourced. The absence of adequate treatment meant that the GWS sector (unlike most public supplies) was unable to respond effectively to the deterioration.

True, the problems were most acute on those schemes that relied on increasingly eutrophic lakes or sometimes heavily coloured mountain streams and springs that were now also contaminated by the faeces of thousands of sheep populating our uplands. However, even in the majority of schemes (some 70%) relying on groundwater sources, the need for radical change was evident, a point borne out by the damning results of successive EPA drinking water quality reports since the early 1990s.

Pressure from Europe meant that the health of consumers was the main priority. As a result, since 1998, the focus of the Rural Water Programme has been to provide adequate treatment on GWS supplies.

This meant the decommissioning of more problematic sources through the amalgamation of smaller schemes (particularly west of the Shannon) and the search for new and better sources that could meet the needs of larger populations. Based on raw water analysis of these, appropriate treatment is provided.

In spring 2010 the final phase of this major infrastructural investment programme will begin as scores of treatment plants begin construction across Counties Galway and Roscommon.

Even before this milestone will have been reached, there is growing understanding in the rural water sector that while water treatment is essential, it should not be seen as a substitute for the restoration of drinking water sources to good (if not pristine) status. If nothing else, GWS operators are keenly aware that a deteriorating source has direct implications in terms of the cost of running their schemes.

The Quality Assurance system being introduced on group water schemes since November 2007 makes the point that water treatment, of itself, cannot guarantee a quality drinking water supply. Apart from management of a treated water supply in the distribution network, the main focus of the QA system is in protecting the source.

On those group water schemes that rely on surface water supplies, the case is easily made and the solutions are fairly obvious. Stop animals standing in the water (through fencing, if necessary), prevent run-off from septic tanks or farm activity entering your water supply, liaise with Coillte during planting or felling of forestry and so on.

We make the point that even if all of these measures are implemented in full in the morning, the levels of phosphorous in the beds of our lakes means that it will be decades before we see a major improvement. The curse of eutrophication and the dreaded blue-green algae will be around to haunt at least another generation!

But what do we tell the vast majority of schemes that are abstracting their water supplies from groundwater sources. Unlike surface waters that have an obvious beginning and end (even if they are fed by aquifers along the way), groundwaters are tricky.

No doubt the threats are similar, but the paths of contamination are likely to be a lot more complicated. We have no idea how long it might take for a source protection measure to take effect, but from the success of Tullyallen GWS in reducing its nitrate contamination problem we

Kilriffith:Kilmore Group Water Scheme near Nenagh, Co. Tipperary. Discussion on improvements to the spring source that supplies 120 households as well as farms in the locality.

know that groundwater contamination may also take years to fully resolve.

Truth be told, most GWS activists know precious little about their groundwater source. Yes, they can tell you the volume of water produced and they may have some knowledge about quality issues, particularly if they have been getting nitrates failures in their drinking water tests. Sin a bhfuil!

Most have no idea of the extent of their aquifer, where it originates, what direction it flows. Without this basic information, developing a source protection strategy is simply shooting in the dark. Worse than that, it means being constrained by the blunt instrument that is the Nitrates Directive.

This has had major implications for schemes in some counties where farmers have refused to allow the development of potentially good sources on their land because it will restrict their farming activities in a 200-metre radius of the borewell/spring.

The NFGWS is telling schemes that the way to overcome such restrictions is to develop a source protection plan that will point to actual zones of vulnerability, thereby replacing blanket bans within a pre-determined area.

Our advice to each scheme is that it pulls together all of the available information about its groundwater supply so that a preliminary source protection plan can be formulated. A model plan has already been developed through the National Source Protection Pilot Project and schemes are invited either to avail of this as a starting point or to procure professional assistance.

We point out that the professional services of hydrogeologists will be required for a more detailed source protection plan. Or schemes might like to help fund post-graduate research on their aquifer!

We are greatly encouraged by the co-operation and advice we have been getting from the GWS, the Groundwater Section of the GSI and the EPA. The ongoing studies into some 240 boreholes and springs, as well as the database accumulated by the GSI over many decades, means that we are not starting from scratch.

In return, we think that group water schemes can contribute to the further development of that database. Again, as part of the Quality Assurance system, schemes are installing raw water sampling points and through local approved laboratories will be testing for a range of parameters that will best indicate if there is contamination. They are also being encouraged to begin depth testing of their wells.

Our intention is that all of this data will be forwarded to the GSI and the EPA so that together we begin the process of restoring water quality in all of our water bodies.

B. MacDonald
National Federation of Group Water Schemes

Protecting water at source

Pilot study commenced to take a community driven, catchment wide approach to identifying and remediating the deterioration in water quality used for drinking water purposes

The protection of water quality at source is the first of line of defence for ensuring the quality of drinking water supplies. Typically, this involves identification of the major sources of pollutants and the pathways by which they reach water supplies. Actions and strategies are then implemented to address these issues on a catchment wide basis. The National Source Protection Pilot Project is a unique project, with a strong scientific component but deeply rooted in the local community. The Project is based in Churchill and Oram north of Castleblayney, Co. Monaghan. Milltown Lake, the source of drinking water for the local Group Water Scheme, lies at the bottom of the 34 km^2 catchment. This lake has a trophic status (mesotrophic – eutrophic); it has been enriched by nutrients that normally limit nuisance levels of plant growth in surface waters. Contamination by pathogens can also arise when faeces from humans or animals enter the water resource. Measures adopted through this study aim to co-ordinate efforts to monitor and assess water quality within the catchment, identify reasons for its deterioration, and to implement community-led and low-cost remediation measures to restore and maintain the quality of raw water in the catchment.

The main sources of nutrients are small point sources, like septic tanks and farmyards, and more diffuse sources due to agricultural and management practices in the catchment. In an effort to reduce the diffuse nutrient losses within the study area, soil nutrient management plans have been devised and are being implemented by landowners. The plans should reduce the effect of nutrient runoff from soils to nearby watercourses. As part of the pilot management initiatives being trialled in the Milltown Lake catchment, the entire tributary of the Milltown Lake river network was fenced-off to prevent livestock accessing the stream and river systems. The aims of this programme were to eliminate contamination of surface waters by livestock faeces and urine and to reduce the loading of dissolved and particulate nutrients to streams. It is anticipated that by excluding cattle access from waterways, water quality will gradually improve due to a reduction in bank-side erosion and restoration of riverbed habitats. Grass buffer strips were established between the fencing and the river bank to filter out and trap nutrients entering the nearby watercourse, especially from steeply sloping drumlins.

Furthermore, in an attempt to identify point contaminant sources and assess their contributions to nutrient loadings of surrounding waterbodies, detailed risk assessments of farmyards and on-site wastewater treatment systems (OSWTS) were conducted. Of the 126 farmyards surveyed, 36% presented a medium to high risk of pollution to nearby watercourses, with the most common issue being the lack of guttering on outhouses that permitted the mixing of clean rainwater and effluent on the farmyard. Lack of slurry storage was also problematic, as was the out-wintering of cattle, resulting in serious soil poaching and erosion of poorly structured soils and therefore high potential runoff.

The risks associated with on-site wastewater systems were more complex. Work began in 2006 investigating the extent of their risk to surface water quality. A two-phase approach to the study was taken, in which a door-to-door survey of households within the catchment was carried out to establish the number, age and type of OSWTS. This was followed up by a visual inspection of a subset of these systems to establish the materials used in the construction

Sampling at Milltown Lake

of the system, the type of effluent dispersal unit and the overall condition of the site.

A total of 154 households cooperated in the survey in 2006. The majority of the households questioned (>90%) had a conventional septic tank. Over half of these systems were installed before 1991 (prior to SR6:1991 Wastewater, Treatment Systems for Single Houses), and consequently might not comply with existing standards although they may have conformed with the standards current at the time of their installation. Of those surveyed 27% had never desludged their systems. Periodic desludging of the system (i.e. once a year to once every two years, depending on the household size and capacity of the tank) is recommended to ensure proper system performance.

A subset of 42 of the systems within the catchment were visually inspected. Of these, 83% were conventional septic tanks and the remainder were proprietary systems. A majority (64%) of the septic tanks inspected were single-chambered tanks and would, therefore, be considered sub-standard when compared to current standards. All of the proprietary systems inspected had been installed within the previous ten years, and all apart from one were still under maintenance contracts including annual desludging. Nevertheless, it was found that 43% of these proprietary systems were not operating correctly at the time of inspection and had either malfunctioned in someway or were not switched on. The type of effluent dispersal unit was also inspected: 45% were found to have percolation areas, whereas 38% relied on soakaways (i.e. pits filled with stone) and 17% were found to have direct discharge to a nearby ditch or water course, 2 of which had no settlement tank at all.

These observations pointed towards a possible risk to surface water associated with the OSWTS within the catchment. Work was therefore extended to include intrusive surveys at five sites. These investigations aim to measure the contribution of OSWTS to organic pollution within the catchment. At each of the five sites, monitoring wells were installed down gradient of the system at regular intervals between it and the nearest water course. Since June 2008, samples of sub-surface water have been collected and analysed once every two weeks from each of the monitoring wells and this will continue until June 2010. This project will provide valuable data on nutrient loading from OSWTS and an increased understanding of the risk posed by OSWTS to water quality.

Although, this research is ongoing, it is evident that a multi-barrier approach towards source protection must be adopted in Ireland. Potential benefits are not only public health protection, but lower treatment costs and community ownership in managing their water resources. It is anticipated that this project will eventually lead to the development of policies and strategies to prevent and/or minimise contamination of the water system. This initiative will rely on the effective participation of local communities, private stakeholders, government and local authorities.

S. Jordan, V. McCarthy, E. Jennings and S. Linnane, National Centre for Freshwater Studies, Dundalk IT

Groundwater or Ground Water?

Those of us of a certain age remember the debates in the 1970s concerning the correct spelling of the liquid substance of our profession - "groundwater" or "ground water"? On the far side of the Atlantic, the hydrogeological community favoured the two-word spelling – as in the journal of that name – whereas the rest of the world generally came down on the side of the single word spelling.

Well, there has now been a shift by our North American cousins. The US Geological Survey decided to adopt the one-word spelling in March of this year and the journal *Ground Water* announced in its September-October issue that it will use "groundwater" in articles published in future editions of the journal.

That's not quite the end of the matter, however, since the National Ground Water Association (which publishes *Ground Water*) is retaining the two-word spelling for both the name of the organisation and the journal.

For those of you interested in a more lengthy discourse on the topic, I suggest you read the article by Vicki Kretsinger Grabert in the July-August 2009 issue of *Ground Water*, in which she suggests that increasing use of the one-word spelling reflects increased public awareness of groundwater as a resource.

Bruce Misstear
Trinity College Dublin

Caoimhe Hickey wins an international award

Caoimhe Hickey (GSI) recently won one of three inaugural Young Karst Researcher Prizes for presentations made at an international karst conference. More than 150 delegates attended the conference from all over the world.

Caoimhe attended the Sustainability of the Karst Environment conference in Croatia, and presented a paper on the extensive research she carried out as part of her PhD thesis. The award is presented by the IAH Karst Commission at international conferences.

This award is not only an outstanding personal achievement for Caoimhe, but also promotes her as an expert on Irish karst in the international IAH community. A summary of her research and her presentation will be published in the next edition of the Groundwater Newsletter. Congratulations Caoimhe!

Caoimhe and the 2 other inaugural recipients of the Young Karst Researcher Prize receiving their awards from Nico Goldsheider, the Chairman of the IAH Karst Commission

Coastal Groundwater Research
Griffith Geoscience Programme – Earth and Ocean Sciences, NUIG

The 2007 Griffiths Geoscience Award Programme granted €3.1 million to support two linked projects at Earth & Ocean Sciences at NUI Galway (*Principal Investigator* Dr. Colin Brown), one on seabed habitat mapping and the other on coastal groundwater research. The Groundwater project is being co-ordinated by Rachel Cave (impacts on marine waters), Eve Daly (geophysical investigation) and Tiernan Henry (hydrogeological investigation). The required baseline survey work is largely completed, and the integration of results from the hydrogeology, geophysics and oceanography strands is beginning.

Detailed well surveying has been followed by the selection of a smaller number of wells to be used for monitoring purposes; wells known or likely to be impacted by saline intrusion have been selected initially for recording detailed time-series, dedicated loggers are recording water level changes, water temperature and electrical conductivity in these wells. Extensive sampling and analysis of water from these and other wells is underway. This work is being coordinated and organized by Barbara Petrunic. Barbara is also completing work on assessing the oxygen isotope ratios in groundwater samples. Some of the data will be used by Marie Perriquet who is focusing on establishing the necessary parameters to begin modelling of the fluxes of water in the system.

Marine resistivity survey, Bell Harbour, 2009

Aisling Smith is doing detailed work in the coastal zone, monitoring nutrient levels and fluxes in the estuarine environments resulting from submarine groundwater discharges (SGD). Her work is targeting zones that are heavily influenced by SGD and dovetails with the terrestrial components of the project. Detailed geophysical surveying was completed in Bell Harbour this year and initial analysis of the data by Catherine Elder is proving extremely valuable in understanding the nature of the SGD in the area and in understanding the nature of the mixing of salt and fresh waters. Catherine has also completed a land trial of the geophysical equipment (detailed separately).

Liam Morrison's work will focus on understanding the biological impacts in the coastal zone of the influxes of groundwater (frequently nutrient rich) and saline water, in the overall context of the geology and the hydrogeology of the system.

Collaborative work on the use of radium and radon isotopes is being carried out in conjunction with Michael Schubert and Kay Knöller from the Helmholtz Centre for Environmental Research-Ufz in Leipzig, on oxygen isotopes with Florian Einseidl at the University of Copenhagen, and on trace metals with Matt Charette at the Woods Hole Oceanographic Institution in the USA.

This is a strongly inter- and multi-disciplinary project where the continual integration of the results from each team member helps to drive forward the next phase of research.

Tiernan Henry, Earth and Ocean Sciences, NUIG.

Groundwater Flow and Transport in Poorly-Productive Aquifers
Griffith Geoscience Programme – Queens University Belfast

New research will better characterize the hydrogeology of Poorly Productive Aquifers. Initial results show that groundwater contributes more to baseflow in upland areas than previously assumed

Measures introduced to ensure compliance with the Water Framework Directive have led to a renewed emphasis on monitoring and protecting groundwater resources, on elucidating the complex interactions between groundwater and surface water systems, and on the role played by groundwater in influencing the health of aquatic ecosystems.

In Ireland, approximately 65% of the land surface is underlain by low productivity bedrock units that are of limited hydrogeological significance on a regional scale, but can prove important at a local level. Groundwater flow and mass transport in poorly-productive aquifers (PPAs) is believed to occur in fractures close to the bedrock / subsoil interface. There has been little research in Ireland into these aquifers however, and they remain poorly understood.

A new research initiative undertaken at the Queen's University of Belfast, in collaboration with the Irish Environmental Protection Agency (EPA), the Geological Survey of Ireland (GSI) and the Geological Survey of Northern Ireland (GSNI)/Northern Ireland Rivers Agency (NIRA) will focus on better characterising the hydrogeology and groundwater flow regimes of PPAs. Funded under the Irish Governments Griffith's Geoscience Research Initiative, this research programme aims to develop a methodology to provide reliable information on the structure and connectivity of PPAs at the catchment scale. This will allow more realistic numerical models of groundwater flow and mass transport in catchments underlain by PPAs to be developed, which can be used as management tools to evaluate future climatic and human impacts on the wider hydrological cycle.

Studies completed elsewhere in similar geological settings suggest that highly variable structural heterogeneity in PPAs is important in controlling flow regimes and contaminant transport pathways. Understanding flow and transport in such complex geological settings is one of the most challenging and exciting aspects of this research programme. Tackling this issue requires a multi-scale and multi-disciplinary approach employing geological, geophysical, hydrogeological and hydrochemical techniques to provide a reliable basis for the development of conceptual hydrogeological models. These models will then provide the foundation for mathematical models that will utilise techniques commonly applied to heterogeneous aquifers and in hydrocarbon reservoir characterisation, an approach not widely used in Ireland.

Five catchments with contrasting bedrock hydrogeology, have been instrumented (see below), courtesy of the EPA , GSI and GSNI/NIRA.

Mount Stewart, Co. Down; Ordovician/Silurian Greywackes
Gortinlieve, Co. Donegal; Dalradian Metasediments
Oughterard, Co. Galway; Granite
Belmullet, Co. Mayo; High Grade Metasediments
Mattock, Co. Louth; Ordovician/Silurian Greywackes

Investigations are currently focusing on multi-scale catchment characterisation using geophysical techniques, fracture mapping, pumping tests and hydrochemical investigations. Preliminary results from the west of Ireland suggest that groundwater plays a more significant role in baseflow in streams in upland areas than previously assumed.

J.C. Comte, R. Cassidy and R. Flynn
Groundwater Research Group, QUB

Groundwater Monitoring in Ireland

An extensive network of wells and springs is being monitored for levels and flows, and groundwater quality, under the national groundwater monitoring programme. Data are freely available on request

Until recently, groundwater monitoring has mainly focused on its use for drinking water supply; with about 75% of EU residents and 25% of Irish residents depending on groundwater for their water supply. However, groundwater plays an essential role in the hydrological cycle and is critical for maintaining wetlands, river flows and surface water ecosystems. In most rivers in Ireland, more than 30 percent of the annual average flow is derived from groundwater. In low flow periods, this figure can rise to more than 90 percent. Therefore, reductions in groundwater input, particularly in dry weather periods, or deterioration in groundwater quality may directly affect related surface water and terrestrial ecosystems.

The introduction of the EU Water Framework Directive (WFD) and the recent EU Directive on "the Protection of Groundwater Against Pollution and Deterioration" (Groundwater Directive) adopt a more holistic view of water resources, establishing links between groundwater and associated surface water and ecological receptors. Therefore, as well as considering groundwater in terms of water supply, groundwater monitoring networks have been developed to improve knowledge of, and the links between, groundwater and the ecological health of associated receptors.

The responsibility for the development of a National Groundwater Monitoring Programme has been placed on the Environmental Protection Agency, supported by local authorities and the National Parks and Wildlife Service. This monitoring is used to assess the general state of groundwater quality and groundwater levels/flows in Ireland. The National Groundwater Monitoring Programme became operational on 22nd December 2006.

Regular reviews of the monitoring network will be undertaken to assess the adequacy of the network and ensure the requirements of the WFD are being met.

National Groundwater Monitoring Programme

Article 8 of the WFD requires the establishment of groundwater monitoring programmes. These programmes are needed to assess:

- Groundwater quality;
- Groundwater levels and flows;
- Drinking Water and Habitats Protected Area objectives.

The groundwater monitoring programmes primarily focus on providing information that can be used to assess the environmental status of groundwater bodies. They will also provide information to assess whether the other environmental and management objectives of the WFD are being met.

Groundwater Level Monitoring

The groundwater level monitoring network is designed to primarily focus on groundwater bodies where over-abstraction is causing falling groundwater levels (e.g. see Figure 1), or is impacting on surface water ecology by reducing the flow of water to rivers or wetlands.

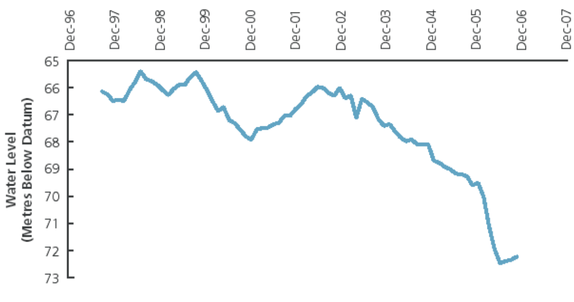


Figure 1. Falling water levels and water level recovery at Tydavnet GWS, Monaghan (EPA, 2008)

The monitoring network is comprised of both wells and springs. Water levels in wells are measured using a combination of groundwater level recording data loggers and manual dipping. Spring flow discharge is measured using traditional water level/flow rating curve relationships and through the use of flow measuring devices. Data loggers have been installed on 155 wells and springs, with water level readings recorded at 15 minute intervals.

Groundwater Quality Monitoring

The design of the monitoring network is based on a conceptual understanding of the hydrogeological system and pressures, with monitoring data used to test or validate this understanding.

Monitoring points have been selected by assessing the requirements for achieving a network that is representative of the variations in hydrogeology and pressure across a groundwater body or group of bodies. A representative monitoring network is achieved when the hydrogeology and pressure variations impacting upon a combined network of monitoring points is similar to the combined hydrogeology and pressure variations over the whole groundwater body or bodies in which the monitoring points are located, i.e. the average concentrations of diffuse pollutants from a representative network of monitoring points reflect the average concentrations for those pollutants across the whole groundwater body or group of bodies.

Monitoring points with large ZOCs are preferred because localised pressures are likely to have less of an impact on the water quality at that monitoring point. In this regard, monitoring locations with daily abstraction rates greater than 100 m^3 per day have been prioritised for the monitoring network. Large springs have also been prioritised because the spring water quality effectively integrates the combined pressures from within the ZOC of the spring. Springs are an important feature in Ireland, particularly in karstified limestone areas. Over 50 springs have been included in the network. Weirs or other flow measurement structures have been installed at half of these springs (e.g. see Figure 2), thereby enabling a comprehensive assessment and understanding of pollutant movement in the underground environment.

Figure 2. Weir installation at Caltra GWS, County Galway

Whilst it was possible to identify suitable monitoring points in the productive aquifers, very few suitable monitoring points exist in the poorly productive aquifers (which underlie about two thirds of the country), as these aquifers, by their nature, are generally unable to yield significant quantities of groundwater for abstraction. In addition, groundwater flow paths are generally short in these aquifers, and consequently water level monitoring is probably only representative of a small area in the vicinity of the monitoring point. Consequently, the monitoring network in poorly productive aquifers is focused on monitoring three scenarios:

1. Groundwater bodies where rivers and wetlands are "at risk" from abstraction;
2. Major fault zones;
3. A number of newly installed monitoring wells in different poorly productive settings across

Figure 3. Newly installed monitoring wells near Glencastle, County Mayo

Table 1. Water quality determinands monitored by the EPA

Monitoring suite	Determinands
Standard suite	E-Coli, Total & Faecal Coliforms, pH, Temperature, Conductivity, DO, Redox Potential, Colour, Alkalinity, Total Hardness, Nitrate, Ammonium, Nitrite, Total Phosphate, Molybdate Reactive Phosphorus, Silica, Iron, Manganese, Sodium, Potassium, Chloride, Calcium, Sulphate, Cadmium, Arsenic, Zinc, Mercury, Lead, Magnesium, Copper, Boron, Aluminium, Nickel, Chromium, Total Organic Carbon, Fluoride, Barium, Molybdenum, Silver, Cobalt, Strontium, Beryllium, Antimony, Turbidity & Uranium
Additional determinands	Pesticides (Atrazine, MCPA, 2,4-D, IPU, Mecoprop, Chlortoluron, Glyphosate, Bentazone, Cypermethrin, Dieldrin, DDT, Lindane and Diuron); selected VOC's & Hydrocarbons

Ireland, e.g. In the Galway granites.

The purpose of these newly installed wells (e.g. see Figure 3), is to assess variability in groundwater quality **and** level at different locations in a catchment, with wells installed in the upper regions of a catchment (recharge areas), the middle of the catchment and the lower areas of the catchment by a river (discharge area).

At present, the water quality network consists of 275 wells (refer to D Daly's article for map, this issue), with samples taken every three months.

Water Quality Determinands

In addition to a standard suite of determinands (see Table 1), the EPA monitor additional determinands, e.g. selected pesticides, VOC's and hydrocarbons, on a case-by-case basis.

Monitoring Data

The WFD requires the use of monitoring data to assess the status of groundwater bodies and establish the presence of significant upward trends in pollution. These data will also be used to determine the success of action programmes that are introduced to prevent or limit the inputs of pollutants and prevent deterioration of the status of groundwater. The national water quality monitoring networks will contribute significantly to the assessment of these programmes, and are supplemented with compliance monitoring data, e.g. from IPPC licensed activities.

The monitoring data are being made available to all local authorities, to assist them in their drinking water supply management, and are freely available to consultants and the general public on request.

References

Environmental Protection Agency (2008) *Ireland's Environment 2008.* EPA, Wexford.

Matthew Craig,
Hydrometric & Groundwater Section
EPA

SNIFFER Launch New Hydrogeological Images on WFDVisual Website

www.wfdvisual.com/storyboard/index.html

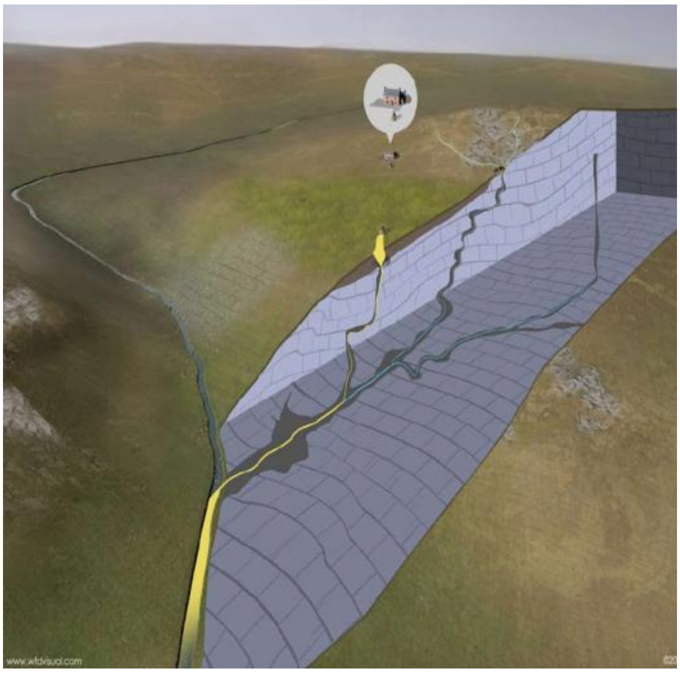
The recently developed WFDVisual website www.wfdvisual.com provides specialists and non-specialists with access to thousands of images depicting different groundwater pressures within varying topographic and geological settings. The images have been developed to help communicate the complex processes underpinning the water environment, including groundwater, and its management under the Water Framework Directive (WFD).

The website has been developed by SNIFFER (Scotland & Northern Ireland Forum for Environmental Research) in partnership with the Environment Agency (England and Wales), the Geological Survey of Ireland, the Environmental Protection Agency (Republic of Ireland) and the Scottish Environment Protection Agency.

In November 2009, SNIFFER added a new suite of images for karst, floodplain, fluvial and coastal settings to its WFDVisual website. There are over 70 new images grouped together into storyboards to convey some commonly encountered hydrogeological scenarios. Each storyboard starts with an overview of the landscape; the landscape is then cut-away to help explain the hydrogeological processes (Figure 1). As the user moves through the images, the descriptive text helps to explain the evolving conditions. Through these visuals, users can quickly and easily understand the way water interacts with various elements within the British and Irish landscapes. The jpeg images, which are accompanied by descriptive text, can be downloaded as a storyboard or individually. The new storyboard images were developed for SNIFFER by the designers Freeman-Christie Ltd and hydrological consultant Steve Fletcher.

SNIFFER intends that the images should be used by a broad audience to help convey the importance of hydrogeological processes in managing the water environment. To that end, all images on this website are freely available to the public for non-commercial, not-for-profit use.

Please contact info@sniffer.org.uk with any enquiries about WFDVisual.



The suite of karst images show how pollutants can find their way into river-beds via multiple routes and potentially avoid detection.

This image shows a general view of a karst upland scene. There is an upland farm, a limestone pavement and a number of dolines. A spring is situated near the river, at the bottom of an underground cave system. There are streams at the top of the hills which are feeding into an active doline. The area below the farm is underlain by a raised mire or peat giving a low vulnerability area shown in green - but there is a doline developed in the area next to the farm. The doline gives direct access to the well developed conduit system through the normally protective clay layer. It enables a pollution incident to pollute the stream very quickly.

Figure 1. Example image from the new WFDVisual storyboard collection

The UK Groundwater Modelling Forum

The UK Groundwater Modelling Forum held in Birmingham on 19th November 2009 was attended by hydrogeologists from a mixture of backgrounds including the Environment Agency, water companies, academics and consultants (the keynote speaker, Mary Anderson, from the University of Wisconsin, pointed out that it would be rare for the latter group to attend a similar seminar in the USA). The purpose of this year's meeting was to give speakers the opportunity to present - and get feedback on - papers which are to be published in a forthcoming Geological Society Special Publication *Regional Groundwater Modelling in the UK: Past, Present and Future*.

Ken Rushton (Professor Emeritus, University of Birmingham) kicked matters off with a short presentation on questions and challenges. Ken, as many readers will be aware, is one of the pioneers of groundwater modelling (and author of the excellent text *Groundwater Hydrology: Conceptual and Computation Models*). His presentation was typically thought provoking; he asked modellers to consider questions such as: did the conceptual model improve during the modelling exercise? Did this inform other models? Is the model output in a sensible format for the stakeholders? How was uncertainty represented? And, balm to my ears, he asked people to avoid modelling pitfalls such as springs covering tops of hills! Ken emphasised that the book will be about the process of 'development and continuous improvement in modelling', not just about modelling.

Keith Seymour of the Environment Agency gave a useful overview of regional groundwater modelling in England and Wales. Regional models are mainly used for catchment management strategies, abstraction licensing, water availability forecasts and reviews of consents under the Habitats Directive. He emphasised that stand-alone models are not sustainable and therefore that modelling carried out in the Agency's regions now follows a national modelling framework (he referred to the Agency's *Groundwater Resources Modelling: Guidance Notes and Template Project Brief* http://publications.environment-agency.gov.uk/pdf/GEHO0505BJEN-e-e.pdf). One of the interesting ongoing developments is the creation of a National Groundwater Modelling System for England and Wales (NGMS). The NGMS, described in a later presentation by the Agency's Mark Whiteman, is 'a map-based, client-server system for holding groundwater and recharge models and supporting documentation.'

Mary Anderson (whose name will be familiar to many readers, both as editor of *Ground Water* journal and co-author of *Applied Groundwater Modeling*) focused on MODFLOW. She argued that MODFLOW has evolved from its beginnings as a groundwater model in the late 1960s to its current position as an integrated watershed model, through the incorporation of packages for rivers, lakes, evapotranspiration, the unsaturated zone and, most recently, conduit flow (karst), plus links to contaminant transport models such as MT3D and RT3D. She presented a detailed case study in which MODFLOW, with some of its associated packages, was applied to an area of Wisconsin containing many groundwater-fed lakes.

Following the opening plenary talks, the forum broke into parallel sessions, with session themes presumably corresponding to proposed topics in the book: Chalk; Sandstone; Other aquifers; Groundwater quality applications; River flow and wetland impact applications (which I chaired); Recharge; Review, delivery and use; Optimisation and future look. With parallel sessions, of course, it is only possible to sample a selection of the talks.

Several speakers followed up on Keith Seymour's point about the non-sustainability of stand-alone models, giving examples of how models for site specific investigations can be linked into the Agency's regional models. The perceived result is a reduction in conflict, as the site specific model should tie in with the accepted conceptual framework of the regional model. Although most of the talks I heard contained rather too much detail for the time allotted – authors were attempting to summarise their full book contributions – there was a lot of interesting material and I expect the upcoming book to be a very useful resource for practising hydrogeologists – here as well as in the UK.

A final reflection arising from my attendance both at this forum and at the National Hydrology seminar in Tullamore the previous week. Hydrogeologists tend to focus on the application of distributed groundwater models, and over the years have strived to increase the utility of these models by incorporating greater model sophistication at and near the land surface: a bottom-up view, one might say. Hydrologists, on the other hand, beginning with simple rainfall-runoff models, have developed more sophisticated models in terms of surface processes (including channel routing, evapotranspiration and soil infiltration characteristics), but often with a rather limited representation of the groundwater system: a top-down view, if you will. It seems to me that there is still scope to combine these different world views into fully integrated catchment models, with a particular need to produce models that are not too data hungry. Or is this asking too much?

Bruce Misstear, Trinity College Dublin
(with input from Anthony Mannix, Environmental Protection Agency)

IAH (Irish Group) events in early 2010

Date	Title	Details
12 Jan 2010	Joint Geotechnical Society of Ireland/ IAH (IrishGroup) TDM*	The national EPA groundwater monitoring network in poorly productive bedrock *See back page for details*
2 Feb 2010	The Younger Hydrogeologists Forum TDM	3 presentations on topical issues.
Mar 2010	The David Burdon lecture TDM	Richard Carter, WaterAid. *Date and title to be confirmed*
20-21 Apr 2010	30th Annual IAH (Irish Group) conference	*See below for details*
4 May 2010	Joint Geothermal Association of Ireland/ IAH (Irish Group) lecture	*Speaker and title to be confirmed*

*The IAH technical discussion meetings (TDMs) are held on the first Tuesday of every month, in the lecture theatre in the basement of the Geological Survey. The meetings are free and run from 18:00 to 19:30, with tea and coffee available from 17:30. Non-members very welcome. **See www.iah-ireland.org for updates to the schedule.**

The **30th Annual IAH (Irish Group) conference** is to be held on 20–21 April 2010 in the Tullamore Court hotel. The theme of the conference will be "Groundwater in the hydrological cycle: pressures and protection". Sessions may include recharge, discharge, flow, pressures and groundwater dependent ecosystems. Climate change impacts and the recent flooding will also be incorporated.

www.iah-ireland.org for more details

Previous issues available at www.gsi.ie

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IAH News — New committee

The IAH (Irish Group) held its AGM on 3rd November 2009. After three dedicated years Paul Johnston stepped down as President. The position of incoming President was gracefully accepted by Teri Hayes. Pamela Bartley and Ulrich Ofterdinger also completed their respective terms of office as Conference Secretary and Education & Publicity Officer. Shane Herlihy was voted in as new Conference Secretary and Suzanne Tynan will be the new Education & Publicity Officer. Michael Gill also stepped down from his position on the conference subcommittee. The IAH would like to take this opportunity to thank Paul, Pam, Ulrich and Michael for all their work and we wish the incoming officers every success in their roles. The current committee now comprises:

President:	Teri Hayes (teri.hayes@wyg.com)
Secretary:	Morgan Burke (morgan.burke@greenstar.ie)
Treasurer:	Orla McAlister (orla.mcalister@tobin.ie)
Conference Secretary:	Shane Herlihy (shane.herlihy@rpsgroup.com)
Fieldtrip Secretary:	Peter McConvey (peter.mcconvey@mclorinanconsulting.com)
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Northern Ireland Secretary:	Peter McConvey
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Conference Subcommittee:	Niall Mitchell (niall.mitchell@rpsgroup.com)
	Caoimhe Hickey (caoimhe.hickey@gsi.ie)
	Matthew Craig (m.craig@epa.ie)
	Pat Groves (pgroves@eircom.net)

Next IAH Technical Discussion meeting

12th January 2010

Joint Geotechnical Society of Ireland/IAH (Irish Group) Lecture

"The newly installed national EPA groundwater monitoring network in poorly productive bedrock – drilling, installation, hydraulic testing, geophysics, applied research and monitoring"

Speakers: Henning Moe (CDM), Padraig Briody (Aquadrill), Ray Flynn (QUB), Matthew Craig (EPA) and Donal Daly (EPA)

6 pm at the Geological Survey of Ireland (tea/coffee from 5.30 pm)

Contributions for the next issue of the Groundwater Newsletter

should arrive by 31 May 2010 to:

groundwaternewsletter@gsi.ie