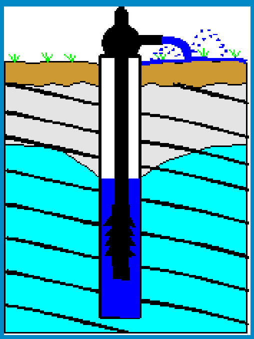

Groundwater Newsletter

Issue 51 ISSN 0790-7753 Oct 2013

Inside this issue:

Integrated catchment management	2
Water-borne diseases: bacteria	7
Impacts of point sources in a river	11
National Inspection Plan for DWWTSs	14
Microbial contamination in a GW fed river (Nuenna)	17
GW flooding	20
Ecosystem services	24
Fracture systems controlling GW flow	28
Flow in poorly productive aquifers	34
New IGI EIS Guidelines	36
IAH Karst field workshop report	40
GWS ZOC project	42
GAI news	45
IAH news	46

Groundwater and catchment management

This year we have had a fairly strong theme of groundwater and catchment management throughout the annual groundwater events, with the Tullamore conference, the IAH field trip, and now the newsletter. The Rural Water News, which is the National Federation of Group Water Schemes magazine, also ran a front page article on integrated catchment management in their Autumn edition. There is a growing awareness in the UK, the USA and Australia that effective water management is best achieved through taking a catchment based approach that tackles all water related issues in an integrated way, in a risk based framework, from the bottom up. As one of our colleagues said in response recently, 'but that's not a new approach… groundwater professionals have been working that way for years', and in many ways, that is true. Groundwater professionals are used to thinking in 3D (or indeed 4D), used to considering groundwater and surface water as the one resource, and used to using the catchment as the unifying water management unit. However, what is new and exciting about integrated catchment management, is that the concept is centered around the people that live and work in the catchment, i.e. in getting their views and ideas on what the issues are and how improvements might be made, and combining that with the catchment science to arrive at an agreed plan for the future. It is only by helping the community learn about and take ownership of their water resources, that meaningful improvements will be made. Donal Daly tells us more on page 2. A follow up article from Donal on ecosystem services is provided on page 26. We learn about a major project to develop ZOC reports for 290 Group Water Scheme (GWS) sources (Page 7), about the types of bacterial contamination that occur in untreated drinking water supplies (Page 9) and about the microbial contamination that was found in a spring fed catchment study (Page 19). The smaller supplies are especially at risk, so it is excellent to see such an investment in the GWS sector. Margaret Keegan gives us an update on the National Inspection Plan for domestic waste water treatment systems (Page 19) which will help protect our groundwater. We have two articles on research into the fracture systems governing groundwater flow (Page 30) and flow in poorly productive aquifers (Page 36) which are greatly advancing our understanding of groundwater flow. We also learn about ongoing work into groundwater flooding and about the new IGI guidelines for writing the soils, geology and hydrogeology sections of an EIS. Finally we have a report on the recent very successful karst course and the regular sections on IAH and GAI news.

Monica Lee, Groundwater Section and Jenny Deakin, Editor

Integrated catchment management (ICM) - a pathway to the future

"Progress and change; change and progress"

Visualising Integrated Catchment Management (ICM)?

In broad terms:

'An organising principle', an 'organising framework' and 'a robust structure for change'[1] are the phrases that I believe are appropriate when considering integrate catchment management (ICM). When I think about water management in any area, I 'see' the area in terms of a catchment (it could be for one or all of a river, lake, estuary or well/spring) in three dimensions (3-D)[2], with a range of people, cultures, histories, issues, concerns, elements, scientific and engineering disciplines, planning and management institutions, and requirements. Mostly, at the moment, these are either not connected or poorly connected, and therefore planning and management for the efficient use and protection of the catchment water, associated ecosystems and geosystems, in many instances, is not feasible. Without a new 'organising principle' and an 'organising framework', we will not achieve the sustainable outcomes that communities in catchments need; nor will we meet the Water Framework Directive (WFD) and Food Harvest 2020 (*FH2020)* objectives. Integrated catchment management can provide the necessary connections, the organising principle and the organising framework. In fact, while the precise details of what it entails needs further consideration, I see it as the only approach that will achieve the desired and required outcomes.

More specifically:

Integrated catchment management (ICM) is based on the concepts of i) catchments as biophysical units in which natural resources use, and ecological and water protection takes place, ii) integration of local community and scientific involvement, and iii) appropriate organisational structures and policy objectives. Specifically, ICM is[3]:

A ***philosophy*** – to foster an organisational culture and associated attitudes that view i) cooperation and collaboration as essential and ii) interactions between natural resources and human activities or responses in a holistic way.

A ***process*** – an overarching planning framework and implementation process that reflects the philosophy of ICM and provides the 'vehicle' through which ICM is delivered. The process needs to provide a flexible, adaptive, on-going and dynamic integrated mechanism, which coordinates the activity of many people, both in the public sector and the community.

An ***outcome*** – the planning and implementation of sustainable resource use practices, which will vary from place to place, depending on conditions and needs, and the achievement of planned environmental outcomes, which are based on environmental, regulatory, economic and social considerations.

Is it a New Concept?

Yes and No!

The ICM approach is being used currently in a small number of countries, such as Australia, and more recently has been instigated in the US and Britain, where it is called the 'catchment based approach' (Defra, 2013). Many elements of ICM have undoubtedly been undertaken in the past in Ireland by various organisations, and there is evidence of some successes although

[1]A phrase from 'Saving Eden: The Next Three Years'. www.savetheeden.org

[2]Earth scientists, particularly hydrogeologists, provide the information and understanding of the underground component of catchments.

[3]This definition is adapted from: Bellamy *et al*., 2002.

they are often on specific issues or in local areas. However, the harsh reality is that more widespread success has been limited mainly because, in my view, we have not encompassed **all** the necessary elements of ICM – see box for reasons why approaches and plans have not achieved and cannot achieve the required outcomes. Einstein is often quoted as saying "*We can't solve problems by using the same kind of thinking we used when we created them*." However, we don't need a complete change in our way of thinking as there have been successes; but we do need a change in philosophy and approach:

- To partnerships with local communities and emphasis on citizen engagement that includes identifying key stakeholders, public awareness and outreach campaigns, identifying issues of concern, and obtaining and taking account of feedback, collectively devising practical solutions to issues raised, and providing assistance to implement measures and change where necessary.
- To genuine integration and learning.
- From the top-down, 'command and control' approach to a combination of bottom-up and top-down.
- From 'restoration' to 'protection/ maintenance' and 'restoration'.
- To systematic communications and social learning between policy, science and operations as a means of dealing with the complexities caused by working cultures, remits and priorities.
- To giving a higher priority to addressing nonpoint (diffuse) sources of pollution and small point sources.
- To linkages, co-operation and networks rather than 'silos', both internally in organisations and between organisations.
- To an emphasis on pollutant pathways, both surface and subsurface, that link pressures with receptors, and enable critical source areas (CSAs) to be delineated.
- To consideration of 'ecosystem goods and services' in a systematic manner, including putting a 'value' on water resources and ecosystems and the potential contribution to

Why have approaches and plans to-date have not achieved the required outcomes?

- Stakeholder involvement and local ownership lacking.
- Regulations, which are often unconnected and focussed on particular pollution sources and pollutants, have not resulted in an integrated environmental approach.
- Most analysis and resulting activities conducted at too generalised (regional or national) a scale.
- River Basin Plan recommendations usually too generalised and based on a 'one size fits all' approach.
- Activities have concentrated largely (and understandably up until now) on the WFD 'restoration' objective, such as 'red dot' river sites (i.e., where there is pollution from a specific major activity, such as sewage discharge).
- Often a focus on means (operation of processes) rather than ends (environmental outcomes).
- Critical pressures and conflicts in the catchments often 'skirted around'.
- Emphasis on pressures and receptors, with no or limited appreciation of the role of the 'pathway' connecting them.
- Catchment based on a 2-D conceptual model, with little or no account taken of roles of the subsurface pathways and groundwater.
- Over-emphasis on 'what' and not enough on 'where'; the critical source area concept not used.
- Main emphasis is on the 'command and control' approach, using inspections and compliance checking rather than seeking behavioural change through stakeholder awareness and involvement.
- Multi-organisational involvement and responsibilities, but with inadequate linkages and collaboration.
- Silo organisational structures, founded on either disciplines or narrowly based processes and objectives, with inadequate linkages and integration.

From: Daly, 2013

the ‘green economy’.

- To a broader range of ‘tools’ in the ‘toolkit’, ranging in a continuum from local participation and partnership to enforcement.
- To an emphasis on benefit to water rather than regulatory lists.
- To enhancement of the local environment for people, businesses & wildlife, while achieving the WFD objectives required by the EC.

What is the ICM Approach?

The elements of ICM, comprising of nine steps, are outlined in Table 1; for success, all of these must be undertaken in an integrated fashion. Only the first step is considered below, but further details can be seen in Harris (2013), USEPA (2008) and Daly (2013).

The First Step – Creating a Vision

"*Where there is no vision, the people perish*" according to Proverbs 29:18. While this is a bit ‘strong’ in the current context, it nevertheless captures the importance of creating and communicating a ‘new’ vision. So, what could that vision include?

The vision is *a healthy, resilient, productive and valued water resource, that supports vibrant communities*. It is based on i) a conceptual model of the catchment as a 3-D entity, ii) integrated catchment science, iii) consideration and integration of all the ‘services’ in a catchment – ecosystem, geosystem and husystem (see article on ecosystem services later in the Newsletter), and iv) involvement of and collaboration with local communities. Effective ‘catchment science’ is based on integrating a wide range of ecosystems and geosystems, of physical and biological factors (such as hydrology, hydrogeology, ecology, hydrochemistry), pressures (such as UWWTPs, DWWTSs, farming, forestry, landfills), IT (such as GIS and recording of inspection details), education and public participation, authorisation of activities, enforcement, etc. Communicating the vision is essential. The connection between people and water is instinctive; however, making this a means of ensuring that water is protected and, where necessary, improved requires creating a greater understanding of water itself, its value and the threats to it from human activities. A ‘*healthy catchments*’ brand, together with an appropriate diagram illustrating water in the landscape, is proposed as a means of marketing ICM. Admittedly, this vision is technical and jargonistic, and is coming from a scientific perspective. To achieve an appropriate vision and language for all participants, we will need to get local community participation; otherwise we will fail.

The Future

We are at a cross-roads, in my view. On the one hand:

- The leading participants (DECLG, EPA, CCMA and SWAN) have expressed the clear view that existing governance arrangements are

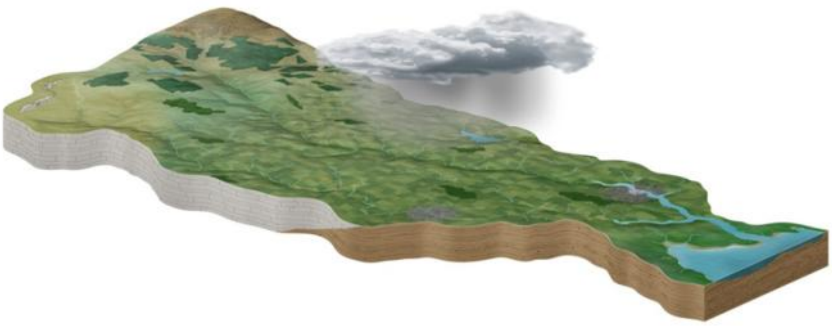

Table 1. Steps in the Integrated Catchment Management Process (adapted from USEPA 2008)

Steps in the Integrated Catchment Management Process

1. **Create and communicate a vision of ICM**
   - A healthy, resilient, productive and valued water resource, that supports vibrant communities.
2. **Build Partnerships**
   - Identify key stakeholders
   - Identify issues of concern
   - Conduct public outreach
3. **Characterise the Catchment**
   - Gather existing data and create a catchment inventory
   - Identify data gaps & collect additional data, if needed
   - Analyse data
   - Identify causes and sources of pollution
   - Estimate pollutant loads
   - Undertake risk assessments
4. **Undertake Further Characterisation**
   - Collect and evaluate local information
   - Locate critical source areas (CSAs)
   - Undertake investigative monitoring
   - Organise catchment walks
5. **Finalise Goals**
   - Set overall goals and management objectives
   - Develop indicators/targets
   - Estimate load reductions needed
6. **Identify & Evaluate Possible Management Strategies**
   - Evaluate existing measures
   - Get stakeholder input
   - Take account of ecosystem services, water value, pollution sources and CSAs
   - Develop management measures to achieve goals
   - Rank the measures
7. **Design an Implementation Programme**
   - Select measures
   - Develop an implementation schedule with milestones
   - Develop the monitoring component
   - Develop information/education component
   - Identify technical & financial assistance needed
8. **Implement the Programme**
   - Prepare a work plan with short- and long-term outcomes
   - Implement the measures
   - Use metrics to track progress
   - Conduct information/education activities
9. **Measure Progress and Make Adjustments**
   - Analyse trends and outcomes
   - Give feedback to stakeholders
   - Make adjustments, if necessary

Characterisation & Analysis Tools

- GIS
- Databases
- Statistical packages
- Numerical models
- Flow estimations
- Load estimations
- Monitoring

River Basin Management Plan

inadequate to achieve effective water/ catchment management.

- We have to-date made virtually no progress in undertaking the 2nd river basin management plans while discussions continue on the resourcing model.
- Our measures, while achieving some progress, are insufficient to achieve WFD objectives.
- *FH2020* is becoming a reality for farmers and agri-industry and will have economic benefits for this country, but it could be constrained by our inability to meet water quality objectives, and therefore will not meet the sustainability requirement that is the basis for marketing our food abroad.

- The silos of knowledge, organisations, processes and disciplines are a hindrance to our future wellbeing.
- Our resources are limited.

On the other hand:

- While it is not universal, there is a desire and momentum for progress and change in water management, with ICM as the answer.
- We now have unparalleled knowledge of our ecosystems and geosystems (biotic and abiotic factors), of the information needed to characterise our catchments and of the measures needed to protect or restore, as appropriate, our water bodies.
- We have sophisticated GIS, informatics and modelling approaches that can assist us.
- It is increasingly acknowledged that the boundaries of our silos, where they are necessary, should be more permeable, and that there needs to be greater integration of all required elements.
- There is an acknowledgement that public participation to-date has been inadequate – this is a crucial first step in the change process. "It is people who save rivers not plans ……."[4].
- We can build on the successes and experiences of the National Federation of Group Water Schemes, as a means of understanding and providing a link with local communities.
- We can build on the successes of local authorities and other public bodies.
- Agri-industry appreciates the necessity for good water quality as the basis for marketing Irish food products – this can be a major incentive to encourage behavioural change where it is required.
- New governance arrangements are close to finalisation and Irish Water is a reality; thereby providing the opportunity to progress ICM.

[4]Quote from 'Saving Eden: A Manifesto'. www.savetheeden.org

However, achieving success will undoubtedly be challenging (or, more truthfully, difficult!). But as Barak Obama would say 'Yes We Can'!

And Finally ……

To quote Mahatma Gandhi, 'we must become the change we wish to see in the world'.

Donal Daly
Environmental Protection Agency

If you have views on the issues raised in this article or ideas for the future, please contact Donal at: d.daly@epa.ie .

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Water-borne Pathogens and Disease: Bacteria

This article is the first of three that describe the different pathogens that can impact on groundwater sources in Ireland. The second (protozoa) and third (viruses) will appear in subsequent editions

Introduction

Groundwater contamination is the introduction of a harmful substance or product into an environment, with the receiving environment in this case being an aquifer on a large scale, or a public or private supply well on a small scale. A wide variety of materials have been identified as groundwater contaminants, an extensive listing of which is presented by Appelo and Postma (2005). The following article, is the first of a series of three that describes the most common water-borne pathogens that are found in groundwater, particularly those most often encountered in rural settings. Their sources, pathways and subsequent potential human health effects are described.

Pathogenic Organisms and Diseases

Pathogens are those organisms that either produce or are involved in the production of a disease, which include bacteria, viruses and protozoa. There are four main categories of water related diseases based on the direct or indirect action of pathogens, as first characterized by Bradley (1974). In Ireland, the majority of water related diseases are thought to be transmitted via the 'water-borne' pathway; therefore, this series of articles will concentrate on this contamination pathway and associated human health implications.

Water-borne diseases are caused by the ingestion of water contaminated by human or animal faeces or urine containing pathogenic organisms. Disease transmission typically occurs when organisms previously excreted by an infected person or animal, make their way into a drinking water source and are subsequently consumed by another person or animal, initiating further infection. Contamination occurs as a result of human or animal waste ingress to groundwater.

Water-washed diseases are most commonly caused by poor personal hygiene and/or skin or eye contact with contaminated water and therefore occur in areas where clean water is scarce. Consequently, they are most commonly associated with tropical areas and include infections of the intestinal tract, the skin and the eyes. *Water-based* diseases are caused by organisms that reside primarily in water, require water or require an intermediate aquatic host for part or all of their life-cycle. The main causes of water-based diseases are parasitic worms, with increased numbers of worms directly affecting the severity of infection. *Water-related* diseases are diseases caused by insects which breed and/or feed adjacent to contaminated waters (Gleick, 2002) and are therefore not usually associated with groundwater.

Bacteria

The kingdom Monera consists of unicellular prokaryotic organisms called bacteria (Stanier *et al.*, 1963). Bacteria are the microbial group of most importance in terms of frequency of isolation in drinking water and the number of reported water-borne disease outbreaks. Table 1 outlines the most commonly reported bacterial pathogens associated with groundwater in temperate climates.

Escherichia coli

The coliform group of bacteria comprises several genera belonging to the family Enterobacter-iaceae. Among the common genera of the group are *Escherichia*, *Citrobacter*, *Enterobacter* and *Klebsiella* (Bonde, 1977). *Escherichia coli* (*E. coli*) were discovered in 1885 by German pediatrician and bacteriologist Theodor Escherich (Feng et al., 2002). *E. coli* are Gram-negative rod-shaped

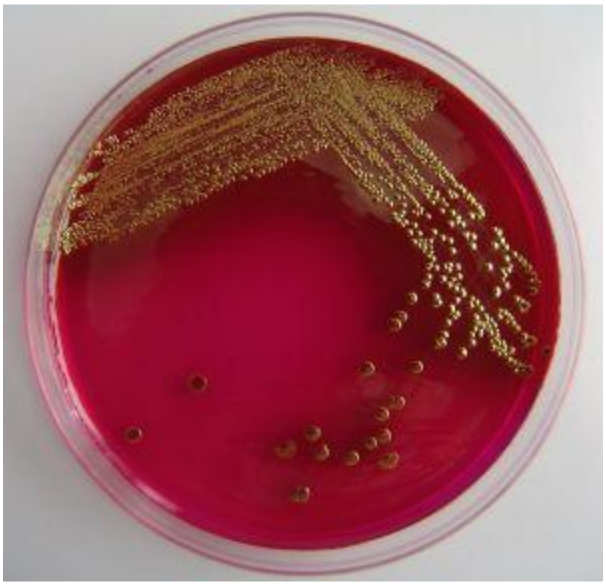
Table 1. Waterborne Bacterial Pathogens

Bacterial Pathogen	Health Effect	Major Reservoirs
Shigella spp.	Shigellosis	Human faeces
Salmonella spp.		
S. Typhimurium	Salmonellosis	Human and animal faeces
S. Typhi	Typhoid fever	Human faeces
S. Paratytyphi	Paratyphoid	Human faeces
Enterotoxigenic		
Escherichia coli	Gastroenteritis	Human feaces
Campylobacter spp.	Gastroenteritis	Human and animal faeces
Vibrio cholera	Gastroenteritis/Cholera	Human faeces
Yersinia enterolitica	Gastroenteritis	Human and animal faeces
Leptospira spp.	Leptospirosis	Human and animal urine
Streptococcus spp.	AGI/Meningitis/Endocarditis	Human and animal faeces
Mycobacteria	Pulmonary illness/TB	Soil and water

Adapted from Ashbolt, 2004; Soller *et al.*, 2010

(bacillus) bacteria, found in the lower intestine of warm blooded animals including humans (Haas *et al*., 1999). *E. coli* are generally non-pathogenic, however, a number of strains are capable of causing infection (virulent). The pathogenic strains are characterized into five main groups or virotypes (Todar, 2007). *E. coli* are ubiquitous in the faecal material of all humans and animals, in varying concentrations (Table 2).

Virulent strains of *E. coli* can cause gastroenteritis, urinary tract infections, and neonatal meningitis, although gastroenteritis is the most prevalent form of illness. Survival of *E. coli* is similar throughout the serotypes and in



Escherichia coli

warm nutrient-rich conditions (e.g. septic tank effluents) they are able to multiply rapidly (Gray, 2004). Approximately 100 organisms are required to cause infection, with gastroenteric symptoms including profuse watery diarrhoea, nausea and dehydration. Typically, the duration of illness ranges from 5-8 days, and is more prevalent in infants, children and elderly consumers, being rarely serious in healthy adults (Haas *et al.,* 1999).

A number of *E. coli* infection outbreaks of varying scales associated with private groundwater supplies are documented in the literature, the majority of which focus on the verotoxin-producing EHEC strain O157:H7. Verotoxigenic *E. coli* (VTEC), including serotype O157:H7, is associated with a wide range of severity of illnesses from mild diarrhoea to haemorrhagic colitis and haemolytic uraemic syndrome (HUS) (Garvey *et al.*, 2010). HUS associated with VTEC is the most common cause of renal failure in children. Approximately 10% of confirmed VTEC cases in Ireland result in HUS and associated renal failure (Garvey *et al.*, 2010). Cattle (and other ruminants) are a primary reservoir due to VTEC occurring naturally in the ruminant gut (Garvey & McKeown, 2008), resulting in this virulent *E. coli* strain's association with rural area outbreaks from private groundwater sources. Drinking troughs and moist mixed cattle rations are sources of VTEC on farms (Hancock *et al.* 2001).

Table 2. The level of *E. coli* found in faecal matter of various species

Species	Faecal production (g/day)	*E. coli*/g faeces	Daily load *E. coli*
Human	150	13×10^6	1.9×10^9
Cow	23,600	0.23×10^6	5.4×10^9
Pig	2,700	3.3×10^6	8.9×10^9
Sheep	1,130	16×10^6	18.1×10^9
Duck	336	33×10^6	11.1×10^9
Chicken	182	1.3×10^6	0.24×10^9

Jones and White, 1984, as cited in Gray, 2004

In 1999 a serious outbreak of *E. coli* affected. A total of 122 cases of *E. coli* O157:H7 were confirmed, 65 people were admitted to hospital and 11 children developed HUS. The source of the infection was a contaminated well at the Washington County Fair. Runoff from cow manure after torrential rain was responsible for the contamination (Charatan, 1999). A study by Schets *et al.* (2005) reported *E. coli* 0157:H7 presence in 2.7% of private groundwater supplies in the Netherlands, with analysis suggesting that cattle were the most probable source. This would seem to correspond with Irish experience, with annual VTEC peaks occurring in late summer, when the majority of livestock are grazing (Garvey *et al.*, 2010). More recently, both Garvey *et al.* (2009) and McKeown *et al.* (2011) have suggested that a rise in VTEC infections in Ireland may be associated with water consumption from untreated private wells in rural areas, with at least 12 VTEC outbreaks in 2009 associated with exposure to a private groundwater supply.

Campylobacter spp.

Campylobacter (meaning 'twisted bacteria') are a genus of Gram-negative spirally shaped bacteria, typically 2000-5000 nm in length (Ryan & Ray, 2004). There are at least 17 known species, with *C. jejuni*, *C. coli*, *C. fetus* and *C. rectus* the most important from a human health perspective (Zia *et al.*, 2003). They are oxidase-positive and reduce nitrates (Gray, 2004).

Campylobacter jejuni and *Campylobacter coli* are amongst the most common bacterial causes of gastroenteritis worldwide (Ashbolt, 2004). In Ireland, campylobacteriosis is the most commonly reported bacterial cause of infectious intestinal disease (HPSC, 2007) with illness characterised by severe diarrhoea and abdominal pain (Humphrey *et al.*, 2007). Symptoms may subside after a number of days or may persist for weeks. Rarely, more severe symptoms may develop such as reactive arthritis, Reiter's syndrome, or HUS, and approximately one in every 1,000 cases leads to a severe neurological disorder called Guillain-Barré Syndrome (HPSC, 2007). Human campylobacter infection became a statutorily notifiable disease in 2004 under the Infectious Diseases (Amendment) Regulations 2003.

Campylobacter species are found in the faeces of humans, livestock and a number of wildlife species, and are therefore common in the environment (Szewzyk *et al*., 2000). The primary routes of transmission are ingestion of contaminated food and untreated water, with *C. jejuni* now recognised as being a major cause of food-borne infection in developed countries (Moore *et al*., 2005). A number of *campylobacter* outbreaks have been positively associated with water-borne transmission routes, particularly in Scandinavian countries (Hänninen *et al*., 2003). Survival in water can be from several weeks up to 3 months provided the temperature is low (Nicholson *et al*. 2005). Chlorination is a highly effective barrier against *Campylobacter* species in water and therefore, where water-borne illness occurs, it is typically associated with untreated private water supplies (Coffey *et al.*, 2007). One water-borne *C. jejuni* outbreak in Denmark in 1995 caused an estimated 2,400 symptomatic infections. The contamination of the water supply was positively traced to contamination of groundwater due to a break in a sewage pipe (Engberg *et al*., 1998).

Shigella spp.

Shigella is a genus of Gram-negative, non-spore forming rod-shaped bacteria closely related to *E. coli* and *Salmonella* (Ryan & Ray, 2004); however, it has a shorter environmental survival rate than both of these organisms (Bitton, 1999). During infection, it typically causes dysentery which is an inflammatory disorder of the intestine, presenting as severe gastroenteritis. *Shigella* species are classified by four serogroups A-D, three of which are the major disease causing species.

S. flexneri is the most frequently isolated species worldwide, accounting for up to 60% of cases in the developing world; *S. sonnei* causes 77% of cases in the developed world, compared to only 15% of cases in the developing world; and *S. dysenteriae* is usually the cause of dysentery epidemics (DuPont, 2010). The disease is characterized by a short period of watery diarrhoea with intestinal cramps and general malaise, followed by emission of bloody stools (Hale & Keusch, 1996).

Alamanos *et al*. (2000) report that a water-borne outbreak of shigellosis occurred in a community in northwestern Greece, in October 1999. Almost 300 inhabitants of the village of Eleoussa, suffered from gastroenteritis, with the peak of the epidemic occurring during the first 3 days. The highest risk of developing gastroenteritis was observed in the age group 0–14 years (41%) and decreased significantly with age. Patients >65 years were more frequently hospitalized than those in other age groups. *S. sonnei* was isolated from both water samples and faeces of patients. Environmental conditions indicated that contamination was caused via groundwater.

Garvey *et al.* (2010) report that there were, on average, about 50 notifications of shigellosis per annum in Ireland during the period 2004-2008, with 11 outbreaks reported during the same period. None of these, however, was directly related to water-borne transmission routes.

Salmonella spp.

Salmonella spp. are a genus of rod-shaped Gram-negative bacteria that inhabit the human intestine during infection. They are aerobic or facultatively anaerobic and as shown in Table 1, are present in both human and animal faeces, causing a range of enteric infections depending on the serotype involved, including gastroenteritis, salmonellosis, typhoid fever and paratyphoid fever. The most common symptoms of *Salmonella* gastroenteritis include diarrhoea, fever, and abdominal cramps.

Salmonella spp. may be found in drinking water from sources that have been contaminated via various pathways including sewage overflows, polluted storm water runoff, and agricultural runoff (Coffey *et al*., 2007). Once infection has taken place, large numbers of organisms are excreted in the faeces (>10^8 g^{-1}) resulting in up to 2,000 organisms per 100 ml in contaminated waters (Feachem *et al*., 1983). Gray (2004) reports that the number of typhoid fever cases in the UK has fallen to <200 per year with the majority (85%) of cases contracted abroad (of which, relatively few are the result of contaminated drinking water). One documented water-borne outbreak of *Salmonella* associated with a groundwater supply occurred in Gideon, Missouri in 1993. Angulo *et al.* (1997) reported that this outbreak affected approximately 650 persons, 15 of whom were hospitalised, with 7 associated deaths. The outbreak was associated with community wells, all of which tested positive for *S. typhimurium*. To date, no water-borne *Salmonella* spp. outbreaks have been reported in Ireland.

Conclusion

There is significant potential for water-borne disease in groundwater supplies. Smaller schemes and private wells are most at risk especially where they are poorly designed, or poorly located close to a source of contaminants. However, there are effective treatment barriers available and a wealth of experienced hydrogeologists to help well owners make the most of their investment.

Paul Hynds, Public Health Agency of Canada

Investigating the influence of point sources on baseflow quality in the Mattock River, Co. Louth/Co. Meath

Longitudinal in-stream profiling in baseflow conditions was found to be a useful tool to isolate the impacts of point sources of contamination. In the Mattock catchment, cumulative impacts of small point sources was found to be an issue

Baseflow constitutes a critical element of river flow. Both the quality and quantity of baseflow can play a critical role in determining the ecological status of a river, particularly during prolonged dry periods when its capacity to dilute contaminant inputs may prove critical in influencing the ability of sensitive aquatic species to survive. Although baseflow is often equated with groundwater discharge, additional inputs may also contribute. These include point sources, such as discharges from sewage treatment systems, livestock access points, and farmyards.

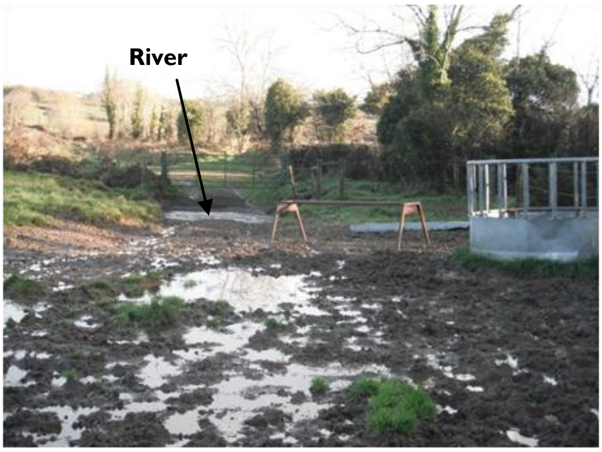
To better understand the impact of point sources on baseflow, researchers from Dundalk Institute of Technology and Queen's University Belfast carried out detailed field hydrochemical profiling in the River Mattock Catchment, spanning the Co. Louth/Co.Meath border. Poorly productive metasedimentary and volcanic aquifers, covered by variable thicknesses of glacial till and alluvium underlie the area. Pressures on river water quality include intensive agricultural practices (pasture with subordinate areas of arable), onsite wastewater treatment systems from single houses and a centralised wastewater treatment plant treating sewage from the town of Collon.

Methods

A catchment-wide survey aimed to examine the variation in field hydrochemistry in space and time along the course of the river during July 2012 and August 2012. Repeated profiling of the River Mattock using a YSI(556) portable water quality multimeter involved recording specific electrical conductivity(SEC), dissolved oxygen, temperature and pH along a 14.6 km stretch of the river and its tributaries, from its head waters to a catchment outflow monitoring point, located approximately 2 km downstream of Collon. In total, over 350 SEC measurements were recorded, including measurements at cattle access points land drains, farmyard discharge pipes and unidentified point sources, with their location recorded using GPS.

Higher than average rainfall recorded during these months made it difficult to conduct surveys during low flow conditions over much of the period. Nonetheless, greater emphasis was placed on surveys carried out during periods of lower flow.

Following an initial walk up the main river and its tributaries, point sources discharging water with high EC values were identified. More focused follow-up surveys aimed to better characterise the sources of the elevated readings. This involved walking up drains, while checking EC periodically to assess variation in field hydrochemistry values. To verify that a potential point source was causing a change in one or more hydrochemical parameters, background



Point sources: cattle access to the river

readings were recorded up gradient from the suspected outlet. Where values decreased significantly above the input to the ditch or drain, that specific source was deemed to be responsible for the elevated readings.

Based on the results of the catchment-wide survey, plotting of results onto GIS-generated maps permitted identification of six point sources for further investigation. Three sites selected were farm/agricultural point sources, while another three were influenced by domestic point sources such as onsite wastewater treatment systems. Samples were also collected along the main river and its tributaries to assess the increases in concentrations of contaminants. Samples were analysed for major ion, nutrient and faecal indicator micro organism content.

Results

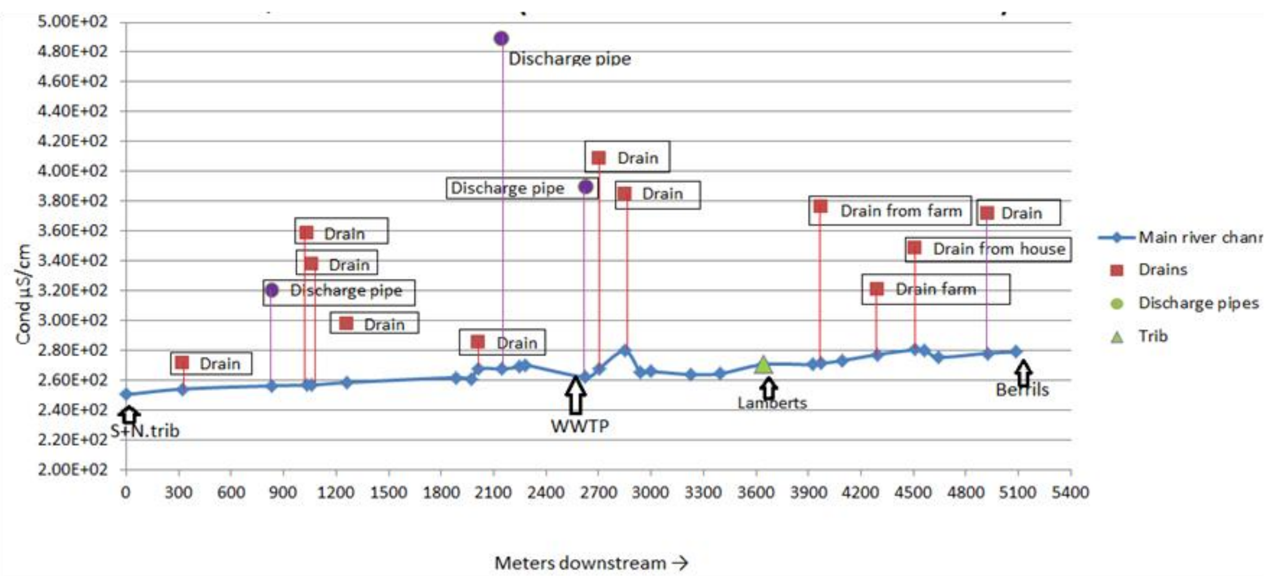
River profiling results display a gradual increase in specific electrical conductivity along the main course of the river between its headwaters and the catchment outflow. Although some sharp increases in conductivity were recorded at the confluence with selected drains, the impact of individual inputs on overall SEC levels in the river proved minimal. Further examination of the origin of the elevated SEC levels in drains identified frequent connections to farmyards or housing as being the principal sources.

Results of laboratory analyses of samples collected in targeted sampling locations showed increased concentrations of nutrients such as nitrate, ammonia and phosphate, as well as indicator parameters such as chloride, sulphate, potassium and sodium. Increases in indicator micro organisms were also observed.

Discussion and Conclusion

Study results show that specific electrical conductivity profiling provided a useful screening tool for identifying the sources and pathways of aquatic contamination within the Mattock catchment. The close correspondence between elevated SEC values and high concentrations of more conventional water quality parameters used to identify pollution proved it to be useful in rapidly and inexpensively identifying potential sources of contamination entering the river. Conversely it could also be used to identify discharges/drains which may have less of an impact on river water quality.

Despite non ideal base-flow conditions within



Conductivity profile along the main channel of the River Mattock starting approximately 2km downstream of the catchment headwaters to catchment outflow

Point sources: farmyard runoff

the catchment during the time of the survey, the conductivity profiling method permitted preliminary identification of a number of point sources that contributed to pollutant fluxes in the river. In follow-up sampling, many of these point sources were shown to be responsible for elevated nutrient and fecal indicator bacteria levels. Although no one source could be identified as adversely affecting the water quality, the gradual rise in SEC moving downstream, and, a corresponding increase in pollutant concentrations reflected a gradual deterioration in water quality, despite the increased flow rates that could contribute to its dilution. Moreover, the low levels of nutrients and faecal indicator organisms analysed in groundwater samples collected in EPA monitoring wells close to the catchment outlet

Point sources: septic tanks

suggest that the increase in nutrient levels is largely derived from sources closer to the surface. This is consistent with the concept of multiple point sources making a significant contribution to overall pollutant fluxes in the Mattock River during low flow periods.

Ideally the survey should have been conducted during a prolonged period of little to no rainfall to best evaluate the contribution of point sources to baseflow. Nonetheless, the SEC profiling method was demonstrated to be a useful initial screening tool for use in identifying point sources of contamination within the catchment prior to the implementation of a more targeted sampling regime. Given the close correlation between SEC and many of the pollutants analysed in this study, the method shows considerable potential for wider application in field work by environmental professionals and hydro-geologists in other catchments with comparable pressures.

Acknowledgements
The authors wish to acknowledge the assistance of Agri-food and Bioscience Institute (AFBI) Newforge Lane Belfast for the provision of microbiological analyses. John Finn's research was funded by the Environmental Protection Agency's STRIVE funded *Pathways Project* research programme. Patrick Rafferty's research was funded by a student grant provided by the Irish branch of the International Association of Hydrogeologists.

Patrick Rafferty*, John Finn** and Raymond Flynn*

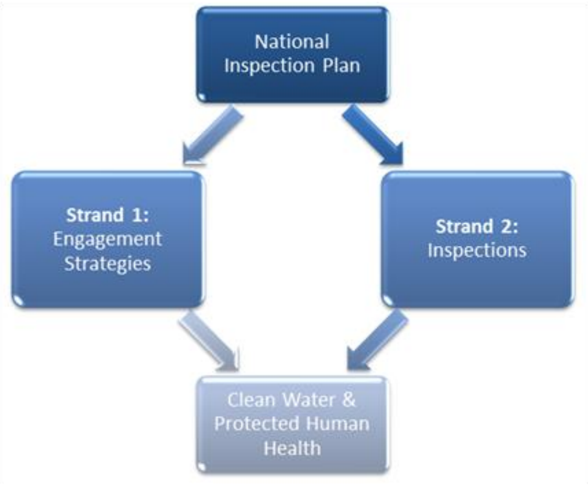
****Dundalk Institute of Technology***
*****The Queens University of Belfast***

The National Inspection Plan: Domestic Waste Water Treatment Systems
What is it and what does it mean for me?

The Water Services (Amendment) Act 2012 requires the EPA to produce a National Inspection Plan, which was published in February 2013 and is available on the following website: http://www.epa.ie/water/wastewater/nip/
The Plan sets out a two strand approach, focusing on raising owner awareness and responsibility, and on the inspection process for domestic waste water treatment systems (DWWTSs) including septic tanks.

Through the mechanisms of citizen engagement strategies and DWWTS inspections, the overall aim of the Plan is to move to a situation where homeowners with domestic wastewater treatment systems know what to do to ensure that their systems are well operated and maintained, and act voluntarily to achieve this, thus protecting human health and the environment.

An Engagement Strategy Working Group, chaired by the Local Authorities and including membership from Department of the Environment, Community and Local Government (DoECLG), Health Services Executive (HSE) and the EPA, has been established. The Group have published a series of leaflets (available from www.protectourwater.ie or your local authority) aimed at assisting homeowners on the following



topics:

- Is your well at risk from your septic tank?
- What to expect from a septic tank inspection
- What you need to know about your septic tank

Inspections are being carried out to ensure that DWWTSs do not pose a risk to human health or the environment. Owners of DWWTSs are obliged to properly operate and maintain their systems as required under the *Water Services Act, 2007* and *Water Services (Amendment) Act 2012*. There are 'things you can do' to make sure that your system is working properly – check with your local authority or www.epa.ie.

A scientific evidence based document "A Risk-Based Methodology to Assist in the Regulation of Domestic Waste Water Treatment Systems" has been developed to identify and prioritise inspection of DWWTSs which pose the highest risk to the environment and human health. Consequently, inspections will be focused on susceptible environmental receptors in highly sensitive waters such as to maximise the environmental outcome. The inspections will check that DWWTSs do not pose a risk to human health or the environment.

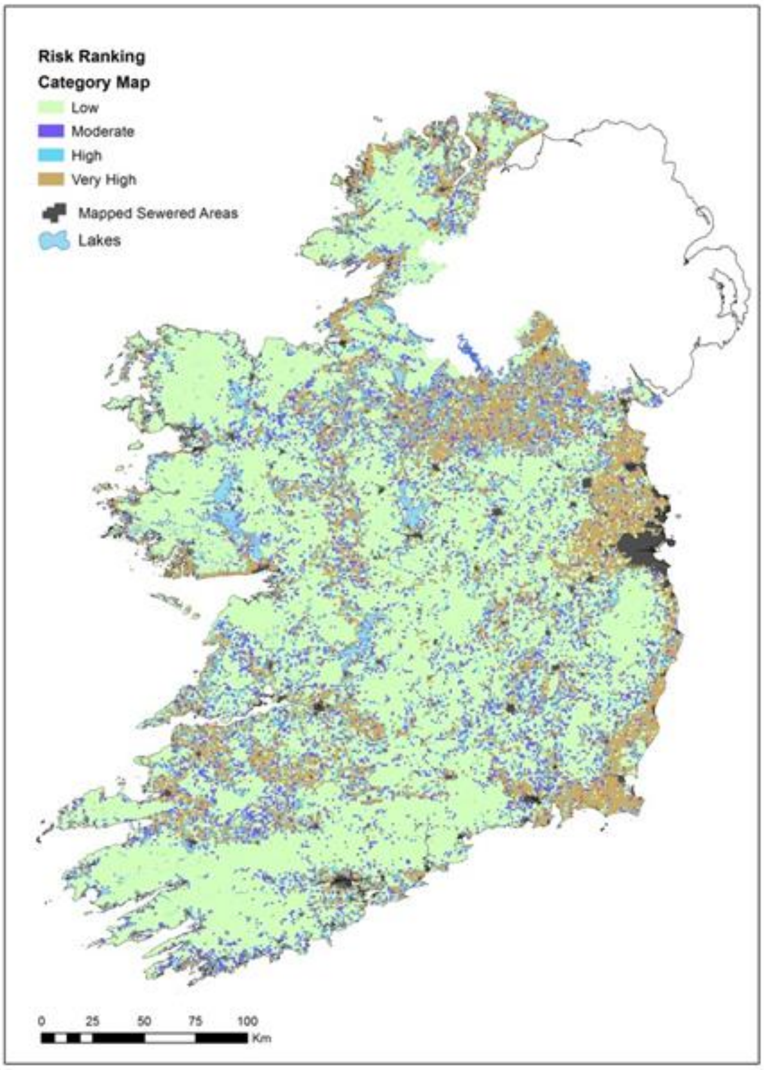
Local authorities are initially required to carry out a minimum of 1,000 inspections of DWWTSs across the whole country from July 2013 to July

2014 so not everyone will be inspected immediately. Local authorities will determine the areas where inspections will be carried out on a local basis. They will use risk information and locations of sensitive receptors such as bathing waters and drinking water supplies to prioritise the areas of inspection. If you want to know the risk category for your area you can access the EPA's ENVISON GIS maps: http://gis.epa.ie/Envision/.

Inspectors are local authority employees appointed by the EPA in accordance with the criteria set out in the legislation. Inspectors have been appropriately trained by the Local Authority National Training Services Group (LANTSG). Inspectors have powers to enter and inspect DWWTS as directed by a local authority: conduct monitoring, sampling, photographs, survey, excavate, request information regarding maintenance, & servicing/operation of DWWTSs.

The local authority will provide 10 days written notice in advance of any inspection. You cannot request an inspection by the local authority. There is no fee for the first inspection carried out by the local authority.

The inspections are intended to find out if your DWWTS pose a risk to you and your family's health and the environment. They consist of a visual check to make sure that the DWWTS is not leaking nor has an unauthorised discharge, that it is properly operated and maintained and that



Risk ranking areas combined with areas of special interest map

it has been emptied of excess sludge when required. Our animated video talks you through an inspection:
http://www.epa.ie/water/wastewater/nip/

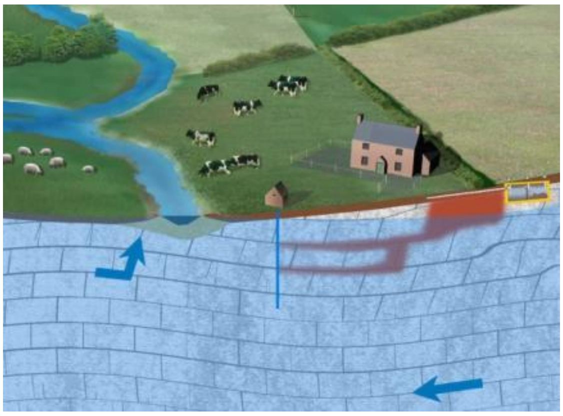
If your DWWTS fails the inspection you will be notified immediately by the Inspector, a copy of the inspection report will issue to you within 21 days and it will be accompanied by an Advisory Notice, which sets out the reason for the failure and advises what next steps you need to take.

If you are not satisfied with the inspection report you may request a re-inspection using the form in *S.I. No. 189 of 2013* and by paying the €20.00 re-inspection fee – http://www.environ.ie/en/Legislation/Environment/Water/FileDownLoad,33444,en.pdf

The upgrade or remediation of any domestic waste water treatment system required following an inspection is a matter for the local authority and the homeowner. Where remediation is required it is recommended that the homeowner procure the services of a competent wastewater professional to work with the local authority in agreeing a remediation strategy. For more advice on remediation works please see information note on the EPA's website.
http://www.epa.ie/water/wastewater/guidance/remed/

The Minister of Environment, Community and Local Government (DECLG) has announced a grant scheme. Grants are available for the carrying out of remediation, repair or upgrading works to, or replacement of, a domestic waste water treatment system (DWWTS), where such remediation, repair, upgrading or replacement arises directly from an inspection and subsequent issue of an Advisory Notice under the *Water Services (Amendment) Act 2012*.

At a minimum the DWWTS requiring remediation must have been registered by the owner of the premises connected to it by the prescribed date of 1st February 2013. There are also income limits relating to the availability of the grant. More details are available from the DECLG. http://www.environ.ie/en/Publications/Environment/Water/FileDownLoad,33607,en.pdf.



The Plan forms part of the 'programme of measures' under the EU Water Framework Directive (2000/60/EC)(WFD). It is just one part of the effort to improve and protect our waters in line with the objectives of the WFD.

The successful implementation of the Plan requires significant commitment from government, local authorities and rural communities; however, the resultant clean, healthy and well protected waters will assist in maintaining viable and vibrant communities across Ireland.

Margaret Keegan
EPA

For more information please contact Margaret at m.keegan@epa.ie

Assessment of the occurrence and pathways for transport of microbial contaminants in an Irish groundwater dominated catchment

A recent study in the Nuenna groundwater catchment found that microbial contamination from faecal matter was present in the stream and springs and that concentrations increased with rainfall suggesting an overland flow pathway

This project investigated faecal indicator organism (FIO) occurrence and transport in the Nuenna River catchment in Co. Kilkenny. The study catchment is underlain by a karst limestone aquifer which feeds the majority of flow in the Nuenna River via large springs. Nine sample locations (S1-S9), including seven springs, were sampled on seven separate occasions (E1-E7) from February to July 2012. Parameters for the investigation included FIOs (E. coli, faecal streptococci), total coliforms, TSS, nutrients (nitrate, ammonium), EC and temperature. Parameter results were used with recorded field measurements of discharges, along with rainfall data and flow data for the catchment, in an attempt to delineate the main pathways of transport of faecal contamination and to identify the most probable sources.

The investigation was carried out as part of the *Pathways Project*, a research consortium

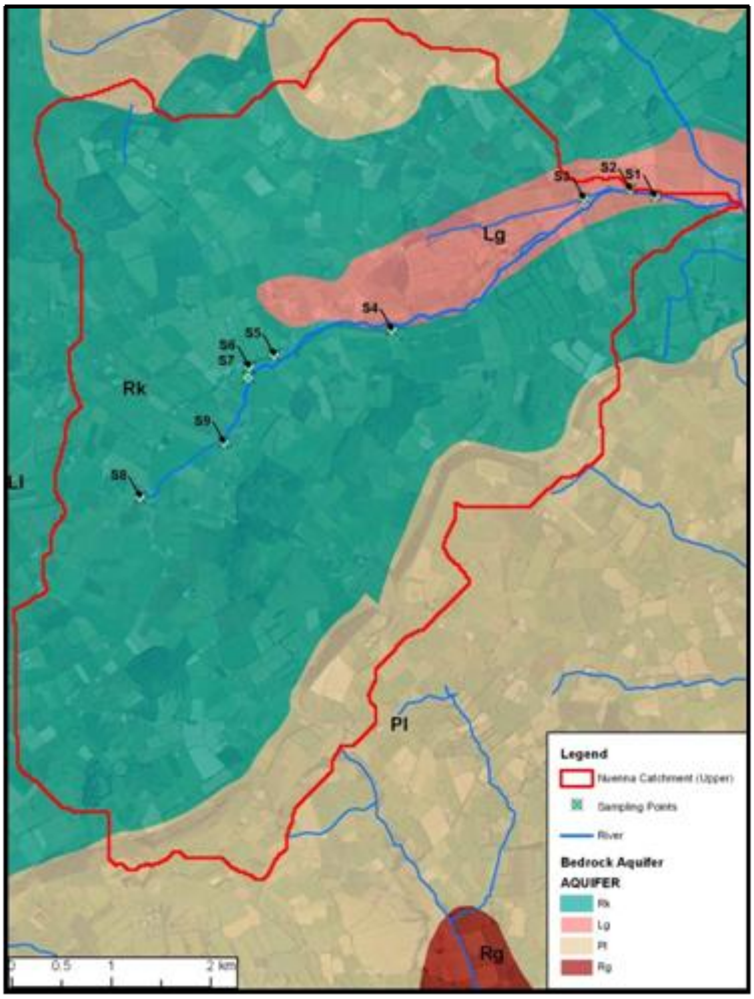


Figure 1. Nuenna catchment bedrock aquifers and sampling points

involving QUB, UCD and TCD, which is funded by the EPA STRIVE programme. Its main objective is to develop a Catchment Management Tool (CMT) to assist the EPA and River Basin District managers in achieving 'good status' in all water bodies by 2015, as directed by the Water Framework Directive. The pathways project is working towards a greater degree of understanding of hydrological processes and interactions in the environment, and includes investigations on selected water-borne contaminant occurrence, transport and subsequent impact on aquatic ecosystems in Irish catchments.

The study catchment is characterised by elevated hill areas at the northern and southern boundaries and by a gently sloping west to east gradient along the central valley (Figure 1). The Nuenna River generally runs west to east along the landscape from the source at Magoo's spring (S8) to Monument Weir (S1), the study catchment outlet, and carries onto its confluence with the River Nore east of Freshford village. The entire catchment has a High to Extreme vulnerability rating for pollution to groundwater, and there is a high proportion of rock outcrops in the upper catchment and recharge zones. Overland flow, direct recharge, and indirect recharge via sinking streams from the Namurian shales at the extremities of the catchment, are the most likely cause of faecal contamination.

The hypothesis of the source-pathway-receptor conceptual model in the catchment for faecal contamination is that grazing livestock expel waste onto the land surface and during periods of rainfall the faecal bacteria in the waste are mobilised. They can then enter directly into the soil, subsoil and aquifer, or be transported via overland flow. Direct infiltration into the

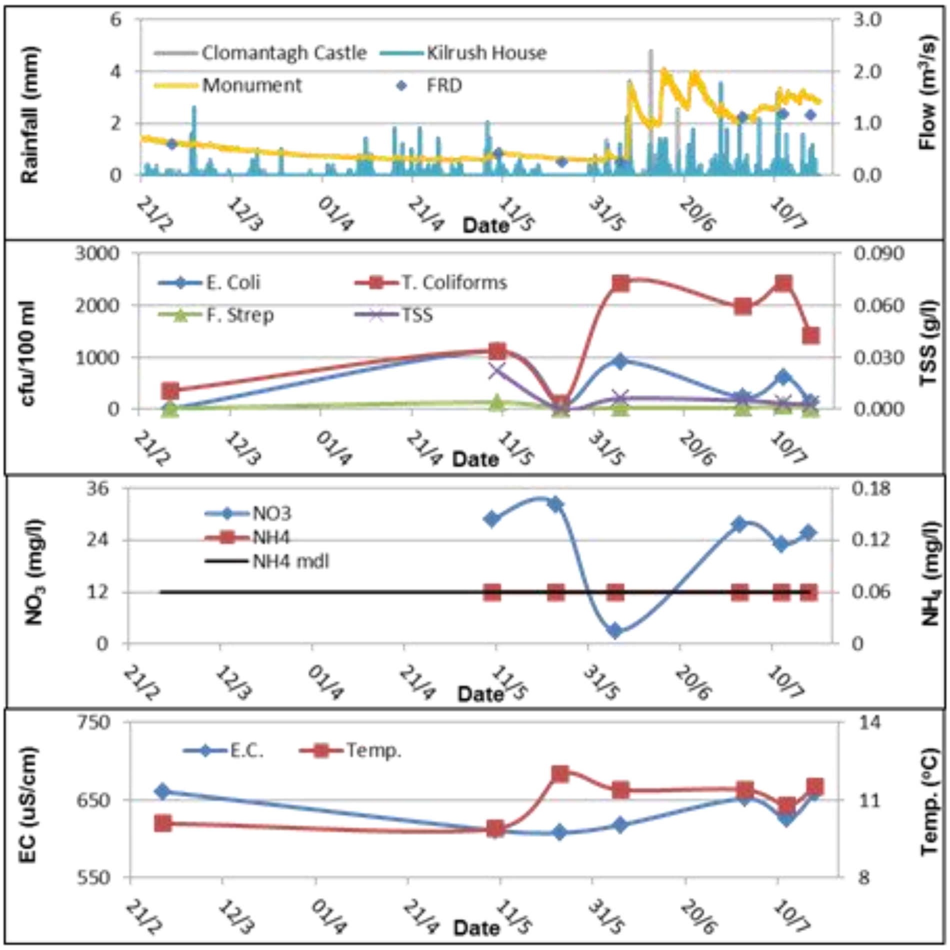


Figure 2. Results for Magoos spring (S8) for the 7 sampling events

karstified aquifer as well as overland flow will result in little or no attenuation of the faecal bacteria concentrations entering the aquifer, whereas infiltration through the soil and subsoil will reduce faecal concentrations.

The project results indicated that the occurrence of faecal indicators varied both at the different sampling locations and for the different sampling events that were undertaken. Figure 2 shows the results for Magoo's spring for the study period; its results are also representative of the trends of the majority of the springs in the catchment.

Rainfall appears to be the driving force behind elevated microbial concentrations at the majority of locations investigated. In general, the drier sampling events (E1, E3) show the lowest concentrations of faecal contamination. 'Wet' sampling events, most notably E4–E6, generally have higher microbial contamination. This indicates that rainfall events trigger an increase in faecal contamination in the catchment (Figure 3) and suggests that overland flow adjacent to the river, and potentially from the Namurian shales via the sinking streams is a likely pathway.

The main source of contamination is thought to be from the dominant agricultural pasture land use in the catchment. Figure 4 at Kilrush showing a direct source of faecal contamination to the surface water.

Dónal O'Keeffe, previously with Trinity College

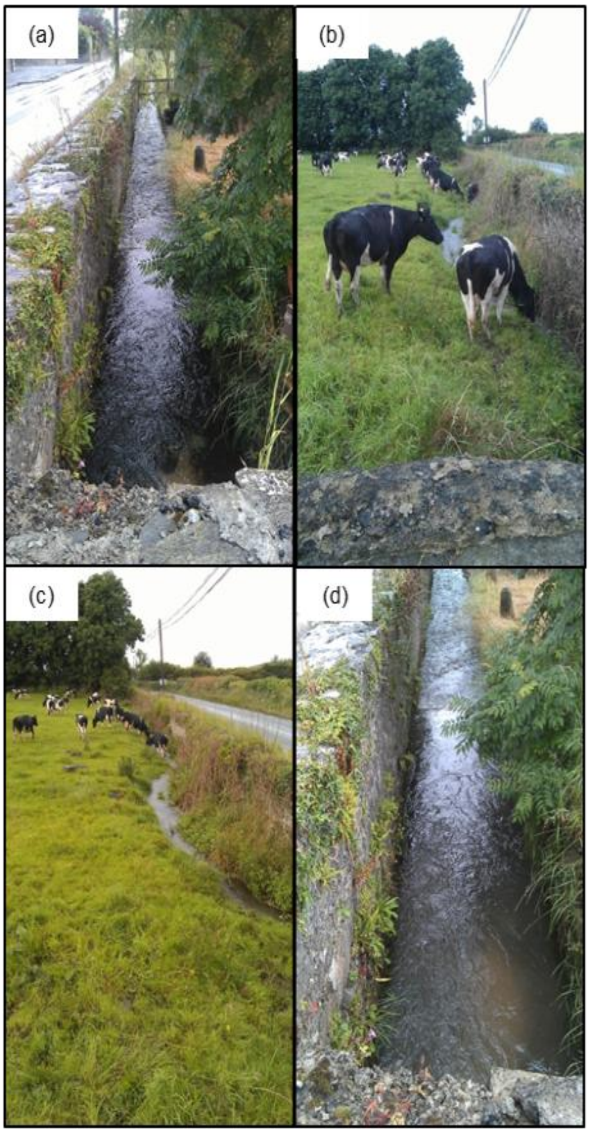


Figure 4. Photo montage during the E7 sampling at Kilrush tributary; (a) tributary prior to cattle entering (clear water); (b,c) cattle enter tributary upstream of sampling point; (d) land drain post cattle entering (turbid water).

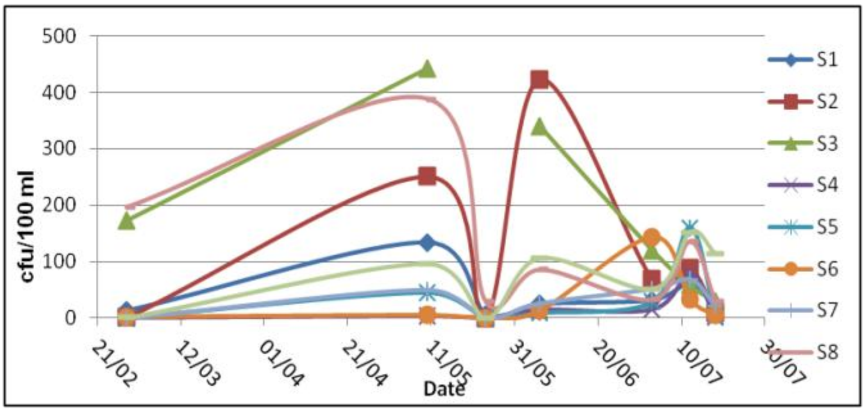


Figure 3. Faecal streptococci results for all sample locations

Acknowledgements

I would like to thank my supervisor Bruce Misstear as well as Ronan O' Brien and Jenny Deakin who assisted me on many occasions during this project. I would also like to thank the IAH for their financial support (bursary).

An Overview of Groundwater Flooding in Ireland

Groundwater flooding is common in Ireland in the karstified limestones in the west of the country. Flood hazard and flood risk maps are currently under development as required under the Floods Directive

Flood risk management in Ireland

Floods are natural phenomena which cannot be completely prevented; they have the potential to cause fatalities, damage property and infrastructure, and compromise economic development (Directive 2007/60/EC). The extensive flooding in November 2009 is one such example, which caused widespread damage throughout much of Munster, Connaught and the midlands and had an estimated insurance cost of €244 million (IIF, 2009). There is a pressing need to improve our understanding of the factors and mechanisms which cause flooding, in order to ensure efficient flood prevention and mitigation in future. This is addressed within the aims of the recent EU Directive on the assessment and management of flood risks (2007/60/EC), or the "Floods" Directive. The Floods Directive was transposed into Irish Law in 2010, with the Office of Public Works (OPW) the authority responsible for its implementation. The Floods Directive requires member states to consider all forms of flood hazard, such as fluvial, pluvial, coastal, and groundwater, in the assessment and management of flood risk. The three main requirements of the Directive are:

- Undertake a Preliminary Flood Risk Assessment (PFRA) by December 2011
- Development of flood hazard and risk maps by December 2013
- Produce Flood Risk Management Plans by December 2015

The first phase of the Directive implementation, the Preliminary Flood Risk Assessment (PFRA), was essentially a screening process which used available and readily derivable information to identify areas where the risks associated with flooding were potentially significant. The current phase requires the development of flood hazard and flood risk maps for areas identified during the PFRA. Flood hazard maps show geographical areas which could be flooded under a range of low, medium and high probability scenarios. Flood risk maps combine the probability of a flood event occurring with the adverse consequences of the event, using standardised vulnerability classifications. One of the unique challenges in flood risk management for Ireland identified during the PFRA, and subsequent flood mapping, was the assessment of risks posed by groundwater flooding.

Groundwater flooding in Ireland

Groundwater flooding is defined as flooding caused by the emergence of water originating from sub-surface permeable strata induced by exceptional and/or prolonged recharge (Morris *et al.*, 2007). In Ireland, groundwater flooding is prevalent in the extensive Carboniferous limestones of the western lowlands, which extend from the River Fergus in Co. Clare in the south, to the areas east of Lough Mask and Corrib in Co. Galway and southern Co. Mayo (Mott McDonald, 2010). These limestone formations have undergone significant karstification and are characterised by relatively low storage, high transmissivity, shallow depth to groundwater and a high level of interaction between ground and surface waters, which leaves them susceptible to groundwater flooding. The groundwater PFRA found that the principal form of extensive, recurrent groundwater flooding in Ireland originated in turloughs (Mott McDonald, 2010), a common Irish karst feature which will already be familiar to many readers (e.g. GSI Newsletter Issue 49).

The spatial heterogeneity of groundwater flow

Figure 1. Widespread groundwater flooding near Gort, Co. Galway, November 2009

within karst systems poses unique difficulties in evaluating likely flood occurrence. Unlike fluvial or coastal flooding, where the general flood locations are relatively simple to identify as they are concentrated along the river network or coastline, zones of groundwater flooding can be much harder to determine. Groundwater flooding can occur in a discontinuous manner across a wide geographical area (Figure 1). As this type of flooding predominantly occurs in rural areas, flood receptors tend to be similarly dispersed. This raises difficulties in the implementation of flood prevention schemes, as the scale and cost of such measures required to reduce the flood risk frequently outweighs the economic benefit. The groundwater flooding mechanism can also vary depending on local hydrogeological conditions. This complexity is acknowledged within the Floods Directive, which states that for areas where flooding is from groundwater sources, the preparation of flood hazard maps can be limited to floods with a low probability or extreme events.

Groundwater flooding generally requires sustained rainfall over relatively longer durations than other types of flooding; the groundwater aquifer acts as a filter that is sensitive to rainfall fluctuations over a relatively long, sometimes even multi-year, timescale (Pinault *et al*., 2005). Accumulated recharge causes a rise in the groundwater table until it breaches the surface, which can cause a significant flood hazard during extreme events. As a result groundwater flooding, unlike fluvial (river) flooding, rarely poses a risk to life but instead can cause prolonged damage and disruption due to the relatively long flood duration. In terms of response times to rainfall, there are two end members in the groundwater flooding spectrum;

- Flash flooding involving rapid groundwater surges caused by short-duration (hours to weeks) intensive rainfall events (Bonacci *et al*., 2006)
- Long-duration flooding as a result of the

cumulative effect of sustained high levels of rainfall over successive years (Finch *et al.*,2004)

The well-developed secondary porosity characteristic of Irish karst results in a relatively short system 'memory', with maximum groundwater levels in one year having little or no impact on the following year. At a shorter timescale, the nature of Irish groundwater flooding is diverse; groundwater systems show a continuum of response times ranging from days to months (Naughton *et al.*, 2012). At one end of the flooding continuum are rapidly responding systems in which water level or discharge increases in response to short-duration rainfall events (Figure 2B). At the other flooding extreme lie systems which show a seasonal flood pattern, where flood peaks are a cumulative response to rainfall over a number of months (Figure 2D).

Groundwater flooding in karst areas can manifest itself in a variety of ways and via a range of different mechanisms, often in combination with fluvial, pluvial and coastal flooding. Excess diffuse recharge can overwhelm the storage of an epikarstic aquifer, causing rapid rises in the unconfined water table and consequent flooding. This may occur either in the vadose zone (epikarst), which is analogous to pluvial flooding, or deeper in the saturated zone (Najib *et. al.*, 2008). Excess point recharge (such as sinking rivers) may inundate sinks and swallow-holes capable of accommodating recharge under normal conditions. Such cases would clearly have a strong fluvial component. The nature of flooding associated with this mechanism may be backwater flooding of the area upstream of the sink, or overland flow into adjacent areas due to overtopping of the topographic depression containing the sink (Figure 3). Groundwater

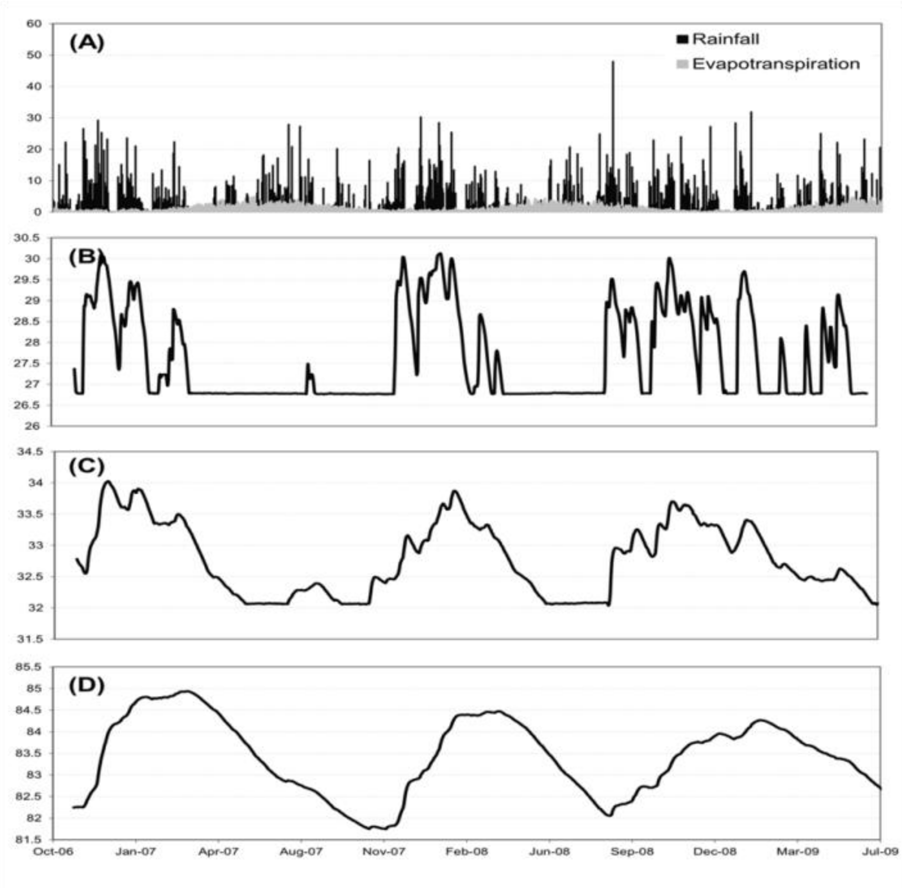


Figure 2. (a) Daily Rainfall and evapotranspiration for monitoring period from 2006 to 2009, and water level time series plot for (b) Turloughmore, (c) Skealoghan and (d) Coolcam (from Naughton *et al.*, 2012).

Figure 3. Flooding across the N18 National Road at Kiltartan (left) and L4506 Local Road at Corker (right) in November 1009. (Images supplied by Galway County Council)

springs and risings can exceed normal discharge levels and cause localised flooding around and downstream of the resurgence (groundwater-induced flooding). Epikarst features, such as shallow conduits and springs, may become active at exceptionally high groundwater levels and facilitate transfer of groundwater to adjacent topographic depressions.

Groundwater Flooding: Future Challenges

The climate in Ireland is changing in line with global and regional trends and this change is expected to continue in the coming decades (Desmond *et al*., 2009). Mean annual temperatures have risen by 0.7 ^{0}C over the last century and there is a further predicted rise of 1.4–1.8^{0}C by 2050 (McElwaine & Sweeney, 2007; Sweeney *et al*., 2008). The distribution of rainfall is also changing, with precipitation increasing in the north and west of the country (McElwaine & Sweeney, 2007). It has been suggested that there will be an amplification of the seasonal hydrological cycle in response to the altered seasonal precipitation and an increased occurrence of extreme precipitation events (Steele-Dunne *et al*., 2008). These changes, if they occur, are likely to have a significant impact on groundwater flooding given the strong connection between short- to medium term rainfall and groundwater flooding response in Irish karst flow systems. Higher cumulative rainfall over the winter period could see the frequency of extreme regional flood events, such as occurred during the winter of 2009, increase significantly over the coming decades. While substantial progress has been made in elucidating the main groundwater flooding processes and drivers prevalent in Ireland, major challenges remain in terms of flood prediction which must be addressed in order to enable effective future groundwater flood management.

Acknowledgements

This research was jointly funded and supported by the Office of Public Works and the Irish Research Council. The author would like to thank Paul Johnston (Trinity College Dublin), and Mark Adamson and Richael Duffy of the Office of Public Works for their assistance.

Owen Naughton, TCD

The 'ecosystems services' concept – progress or a new constraining 'silo'?! A discussion

Ecosystem services is an important concept to help us recognize the value we get from earth's resources. The concept needs to include ecosystem, geosystem and husystem services

Introduction

'Ecosystem services' is a core concept for Action 5 of the EU Biodiversity Strategy to 2020, which requires '*Member States to map and assess the state of ecosystems and their services in their national territory by 2014, assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020*'. It is now emerging as a means of supporting the achievement of WFD objectives, particularly as an approach that helps prioritisation of financial resources for integrated water management programmes. This article discusses the role that the ecosystem services approach (ESA) can provide in Water Framework Directive (WFD) implementation and, more particularly, in successful integrated catchment management (ICM).

Ecosystem services – what are they?

Fisher, *et al.* (2009) define ecosystem services (ES) as '*the aspects of ecosystems utilised (actively or passively) to produce human well-being*'. Walker & Salt (2006) define them as '*the combined actions of the species in an ecosystem that performs functions of value to society (pollination, water purification, flood control, etc*.' Maes *et al*. (2013) describe three categories of ES:

- **Provisioning**, such as biomass (cultivated crops, reared animals, wild plants and animals), surface water and groundwater for drinking, and fibres and wood.

- **Regulation and maintenance**, such as mediation of waste, toxics by biotas and ecosystems, mediation of flows, flood protection, atmospheric composition and climate regulation.

- **Cultural**, such as physical and experiential interactions with biota and ecosystems, spiritual, either symbolic or religious.

Benefits of the ecosystem services approach (ESA)

The WFD is essentially an ecologically-driven directive. Until recently, in my view, ecosystems as components of river basins have not been given adequate priority in water management. In addition, the associated disciplines of biology and ecology have been unable to contribute sufficiently[1]. Utilisation of ESA is now a means of ensuring that the role of ecosystems gets the required priority in river basin/catchment planning and management.

But, is the ecosystem services approach enough?

No!

On the one hand, the ES concept has drawn attention to the value of ecosystems and their benefits to society. This is timely and now provides a means of taking them into account in a structured manner in catchment management and, by giving ecosystems a value, ensures they influence the prioritisation of investment. On the other hand, ecosystems are just one component of a catchment. An over-emphasis on them could create a 'silo', both in terms of the elements included in ES and in the associated disciplines – biology and ecology.

[1]It could be argued that the dominance of the engineering profession in dealing with water management issues has led to inadequate input from other relevant disciplines, such as ecology and environmental science, but as this point tends to evoke a defensive reaction and is not associated with 'positivity', I won't make it!

Ecosystem services: pollination by bees

The need for an organising framework

In an earlier article in this Newsletter on integrated catchment management (ICM), it is, for instance, argued that:

- A new approach, philosophy and process is needed to achieve successful catchment management.
- Genuine integration of components, disciplines and attitudes is required.
- Catchment management will need to be undertaken in partnership with local communities to be successful.
- The ICM approach/philosophy/process provides the 'organising framework' that can enable successful catchment management.

The limitations of our 'mental models'

I worry about 'the knowledge I need to know, but don't know, and the knowledge I don't know that I need to know', and no doubt this applies to all of us, even if we don't admit it. In my view, we are all constrained by our mental images of the world around us; images that are based largely on the knowledge that arises from our areas of expertise and to the particular experiences each of us have. This is one of the reasons we are comfortable in the silos created by our disciplines, particularly those of us with a scientific background, or in process-oriented work units.

Imagine how a householder in a local community 'sees' the surrounding landscape; in simple technical language, it would be a mosaic of physical, ecological, cultural and infrastructural features and functions, probably with no significant mental boundaries between them. Water would be just one element in this vision of an area. In the context that involvement and 'buy-in' is required from members of local communities, what are the implications of this for those of us in the scientific and engineering communities working to achieve successful catchment management and WFD objectives? While there are several, such as the need for greater public education and awareness, I will deal with just one issue in this article – the need to use the integrated catchment concept as a coherent means of connecting all the relevant elements; by relevant, I mean to local communities, as well as to scientists, engineers and regulators.

Why a catchment as the organising landscape feature?

The main reason, from my perspective, is that it relates to an area of land that is the basic unit for water management. From a scientific perspective, the water in a catchment is in continuous connection, over ground and underground, from highest areas along the topographic catchment divide to the lowest areas alongside the river. In addition, it is a coherent topographically-based feature, which can encompass all the activities, past and present, and all the functions and services needed in an area; by functions and services, I mean employment, water supply, food production, maintenance/improvement of biodiversity, energy production, recreation, historical buildings, etc. Stoate (2010) in an inspiring book on the Eye Brook catchment in England states '*In practice, a multi-functional landscape is likely to be the most acceptable and most resilient to future uncertainties*'. Therefore, in my view, by taking account of and linking all the components and services provided by a

Geosystem services: quarrying

catchment, it can achieve the following:

- help reconnect people back to both our natural and cultural environments (as I believe that this is being lost in this modern era);
- increase the likelihood of successfully maintaining or restoring, as appropriate, the status of our water bodies, and of managing our water resources;
- increase the likelihood of achieving our biodiversity requirements;
- enable sustainable food production and achievement of the *FH2020* objectives;
- create a local sense of 'ownership' of **all** the goods/services in the catchment, particularly those depending on our natural environment.

What services are provided in a catchment area?

In broad terms, there are three classes of services comprising the total system:

- **Ecosystem services**: crops, farm animals, both terrestrial and aquatic wild plants and animals, pollination, influences on the landscape by ecosystems, constructed wetlands and riparian zones for water purification, soil ecosystems for attenuating pollutants and increasing crop production, cultural values attached to wildlife and ecosystems, etc.
- **Geosystem services**: landscape geomorphology and geology, bedrock and sand/gravel, groundwater for drinking water and for ecosystems maintenance, soils and subsoils as chemical and physical attenuating media for pollutants, energy production, such as geothermal, hydropower and wind, cultural values associated with landscape features, etc. *[I notice a tendency in some papers on ecosystem services to claim some of these services as ecosystem services. This is not advisable, in my view, because firstly, they provide a service that is not related to ecosystems and secondly, in the minds of most people, ecosystems are associated with living organisms such as sphagnum moss, fish, macroinvertebrates, trees, etc., rather than the abiotic factors].*
- **Husystem[2] services:** housing, farming both intensive and extensive, mining, quarrying, wind mills, water abstraction facilities, roads, cultural values associated with historical features and buildings such as ring forts, castles and holy wells, landfills, industries, recreational facilities, etc.

The value of using these three subdivisions of services within the concept of ICM are as follows:

- It helps ensure that all relevant services are considered.
- It encourages an integrated approach.
- It encourages linkages between water management and biodiversity objectives. For instance, high nature value farming (HNV) (see http://www.efncp.org/policy/ for further information on this) is one way to help achieve both objectives, but needs the linking mechanism that ICM can provide.
- From the perspective of local communities, it is comprehensive and includes the complete mosaic of physical, ecological, cultural and infrastructural features and functions,

[2] I couldn't find a better term for 'human system' than this in the literature. No doubt there is one.

Husystem services: nature recreation

thereby giving a sense of comfort that no one area is dominating and that the needs of local communities are taken into account. discourages emphasis on more than just agriculture and therefore is likely to encourage the participation of the farming community.

Conclusions

1. Ecosystem services as a concept is a vital one for successful WFD implementation. However, if it is not combined with the other services – geosystem and husystem – there is a danger that it could become a constraining 'silo'.
2. Scientists, engineers and policy makers working to implement the WFD successfully need to ensure that there is input from local communities in analysing and implementing measures designed to achieve successful water management.
3. We have to deal with what Bossel (2001) calls 'a complex set of interacting and self-organising natural and human systems'. The integrated catchment management approach provides the 'organising principles' and the 'organising framework' that connects all the relevant aspects and systems.
4. ICM enables and encourages a focus on all relevant issues in a holistic manner; this discourages emphasis on more than just agriculture and therefore is likely to encourage the participation of the farming community.
5. Successful ICM requires the integration of inputs from a wide range of disciplines; in addition to water scientists and engineers, there is a need for the involvement of historical geographers to enable an understanding of the cultural landscape, biodiversity experts, agricultural advisors, social scientists, communications experts, and experts in facilitating dialogue between scientists and local communities.
6. 'ICM is the future'; we need to work together to achieve this future.

Donal Daly, EPA

If you have views on the issues raised in this article or ideas for the future, please contact Donal at: d.daly@epa.ie .

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Analysis of fracture systems and their impact on flow pathways in Irish bedrock aquifers

A number of different fracture systems have been mapped in Irish rocks, some of which are permeable while others are sealed and act as barriers to flow. Near surface joints, N-NNW trending Variscan veins and NNW- and NE-trending Tertiary strike-slip faults are often the most important for groundwater flow

Introduction

Fault and fracture systems are the most important store and pathway for groundwater in Ireland's bedrock aquifers, either directly as conductive flow structures, or indirectly as the locus for the development of dolomitised limestone and karst (e.g. Daly, 1995; Fitzsimons et al., 2005; Ball, 2007). This article presents the preliminary results of a study involving the quantitative analysis of fault and fracture systems in the broad range of Irish bedrock types and a consideration of their impact on groundwater flow. The principal aims of the project are to develop generic conceptual models for different fault/fracture systems in different lithologies and at different depths, and to link them to observed groundwater behaviour. Here we briefly describe the geometrical characteristics of the main post-Devonian fault/fracture systems controlling groundwater flow from field observations at outcrops, quarries and mines. The structures range from Lower Carboniferous normal faults through to Variscan-related faults and veins, with the most recent structures including Tertiary strike-slip faults and ubiquitous uplift-related joint systems. The geometrical characteristics of different fault/fracture systems combined with observations of groundwater behaviour in both quarry and mine localities, can be linked to general flow and transport conceptualisations of Irish fractured bedrock. Most importantly they also provide a basis for relating groundwater flow to particular fault/ fracture systems and their expression with depth and within different lithological sequences, as well as their regional variability.

Field characterisation of structures

Much of our work to date has involved the characterisation of post-Devonian faults and fracture systems from field work at more than 60 outcrop, quarry and mine localities and

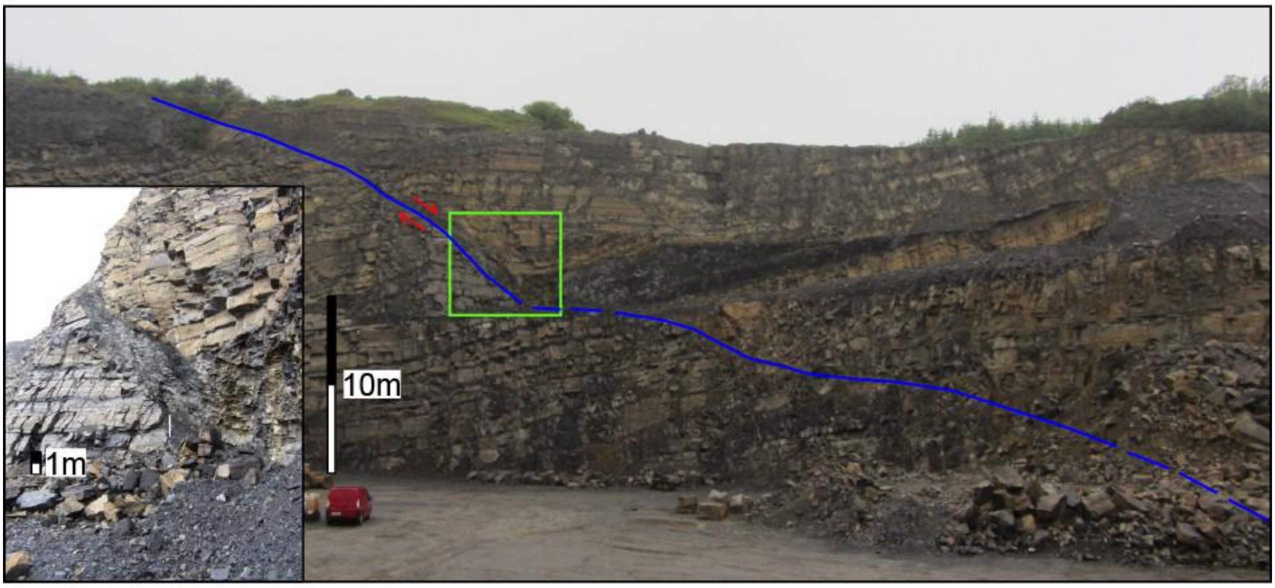


Figure 1. Normal fault (blue line) in a Carboniferous limestone/shale sequence which downthrows the sequence on the right hand side by 30 m to the north. The fault zone contains shaley fault rock (i.e. gouge) along its entire length and sometimes up to 2 m thick: see inset, the location of which is shown by the green box (the boxes do not have the same shape because of differing perspectives). Dunaree Quarry, Fermanagh.

linking them to observed groundwater behaviour. The main structures in general chronological order, as defined by cross-cutting relationships, are:

- Carboniferous normal faults (Figure 1)
- Variscan fold-related structures (Figure 2)
- Variscan reverse and thrust faults (Figure 3)
- Variscan NNW and NE conjugate veins (Figure 3 and 4)
- Variscan dextral ENE strike-slip faults
- Tertiary strike-slip faults (Figure 5)
- Joints (Figure 3).

The basic geometry and nature of each of these types of structure are illustrated schematically in Figure 6. Here we briefly outline some of the attributes of the main structures and make reference to their potential impact on groundwater flow and storage.

Carboniferous normal faults

Lower Carboniferous normal faults are generally between NE- and E-trending with relatively steep dips (60-80^0). They can have displacements of cm- to km-scale, with mapped lengths on m- to 10s km-scale. Larger faults can control the distribution of minor Carboniferous Basins and associated lithological changes. Although some of these faults were the flow conduits responsible for the formation of Zn-Pb mineral deposits (Johnston 1999; Fusciardi *et al*. 2004), today they are generally sealed by veins, shaley fault rock (gouge) and restite (post-dissolution clays). Nevertheless, they can still control groundwater flow within karstified limestones, with significant cavities forming particularly where they intersect other structures (in particular, later N-NNW veins and Tertiary strike-slip faults).

Variscan fold and thrust-related structures

The Variscan Orogeny towards the end of the Carboniferous is responsible for N-S compression and the generation of related folds and thrusts (Figure 3). Folding is important in terms of groundwater flow insofar as it controls the basic geometry of bedding and associated aquitards, including clay-dominated wayboards. Our study has highlighted the presence of other bedding-parallel structures which also affect groundwater flow.

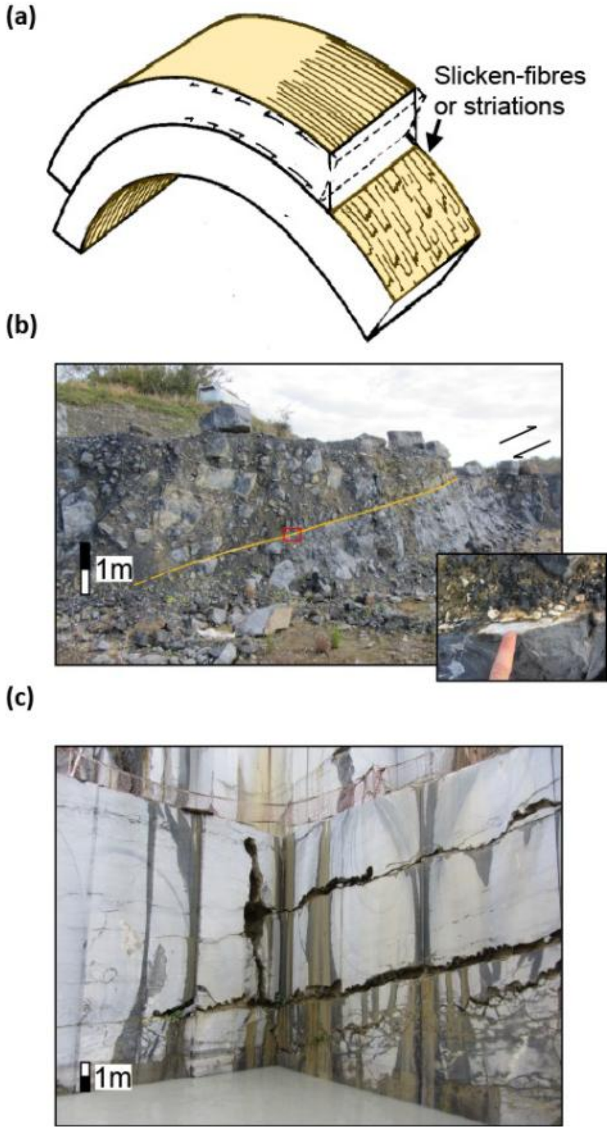


Figure 2. (a) Schematic diagram showing how flexural slip and associated veining occurs where there is folding of thicker and stronger layers, with intervening low cohesion material. (b) Flexural slip surface in a bedded limestone sequence and a slickensided bedding surface (inset photo). Moymore Quarry, Clare. (c) Bedding parallel and inclined stylolites forming a linked vertical and lateral flow system. Holdensrath Quarry, Killkenny.

Bedding parallel veins formed in response to flexural slip along bedding planes (Figure 2a & b) or thrusting along either bedding or shallow dipping thrusts (Figure 3), can have the same

Figure 3. (a) Variscan ramp and flat thrusts (purple lines) dipping to the SE, and the main clusters of Variscan N-NNW veins (red lines) both offset by later Tertiary strike-slip faults (blue lines). (b) Inset photo (green box in (a)) showing that later joints often increase in frequency towards the surface. Laffansbridge Quarry, Tipperary.

effect as wayboards and, within limestones, can also be the locus for immediately overlying karstification to provide groundwater pathways.

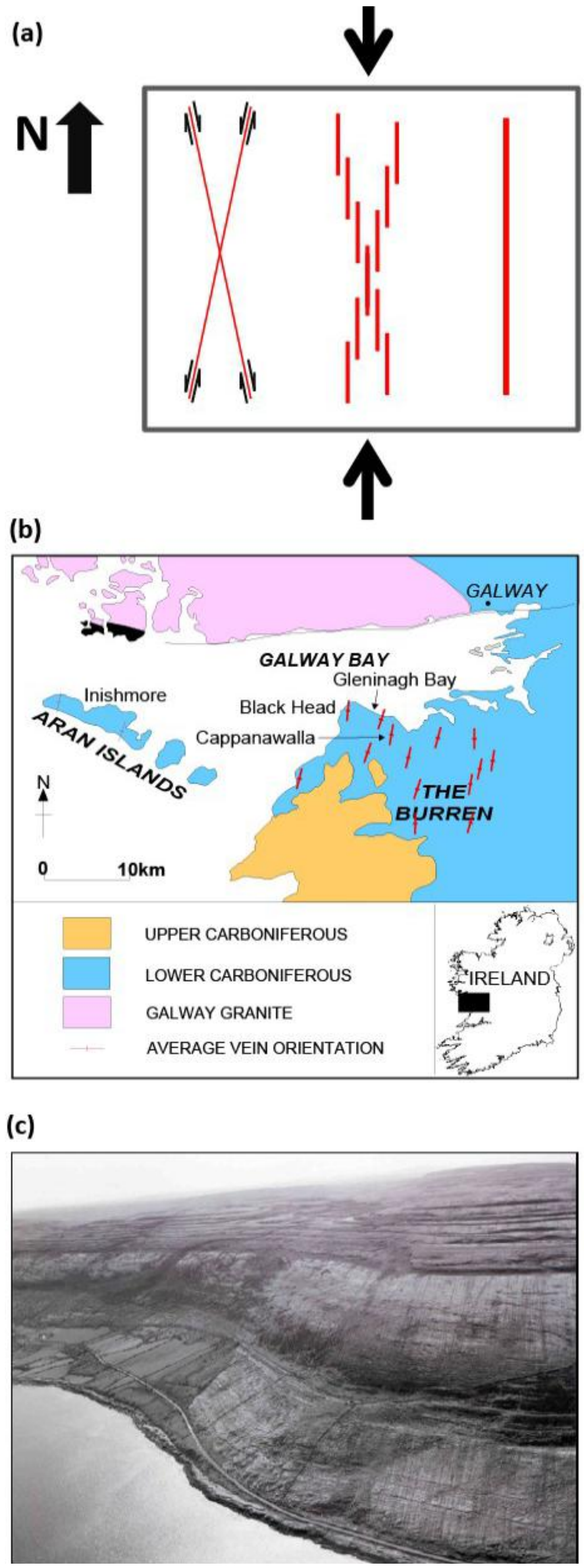
Stylolites formed from limestone dissolution are generally bedding-parallel structures but can also be inclined or vertical. They are believed to have formed before and during the Variscan Orogeny. Associated clay restite (i.e. the clays remaining after dissolution) means that stylolites can also act as barriers to flow, in a similar manner to wayboards, but again within limestones they can be the locus of adjacent karstification and associated groundwater pathways (Figure 2c).

Variscan N-NNW trending veins

Variscan N-NNW trending veins, together with a much more subordinate NE-trending conjugate set, are steeply dipping, mainly calcite, veins which are a very common feature of the Carboniferous rocks of Ireland. They occur in strongly clustered vein arrays attributed to Variscan N-S compression and high fluid pressures at depth (Figure 3 & 4a): cross-cutting relationships suggest that they are sometimes synchronous with, and other times pre-date, Variscan folding. The fluid pressure regime is reflected in the predominance of veins rather than faults, the formation of which in response to N-S compression is shown schematically in Figure 4a. High fluid pressures results in (i) conjugate NNW and NNE veins, which have a component of right lateral (dextral) and left lateral (sinistral) shear (i.e. lateral displacement of the vein walls) and can be en-echelon, and (ii) N-S trending tensile veins, characterised by perpendicular opening with no lateral shear of the vein walls. These vein arrays are vertically and laterally persistent, characteristics which mean that when they are karstified they can represent regional scale and highly directional groundwater flow conduits. Pervasive N-NNW veins control the cave orientations and valleys in the Burren limestones (Figure 4; Gillespie *et al.*, (2001); MacSharry, (2006)) and are considered to have a major impact on groundwater flow in other areas.

Variscan dextral ENE strike-slip faults

Variscan deformation is dominantly due to N-S tectonic compression but with a component of dextral deformation known as dextral transpression (Graham, 2001 and references therein). This deformation is sometimes manifested as ENE dextral strike-slip faults in areas of more intense Variscan deformation, such as in Munster and adjacent to pre-existing Carboniferous normal faults (Collar, 1984; Taylor and Andrew, 1978; Moore, 1975). These structures are often sealed by low permeability fault rock (shale smears or gouge) and can therefore be barriers to flow. Nevertheless, immediately adjacent karstification can occur, particularly where they intersect other cross-cutting structures. The precise temporal relationship between these faults and Variscan veins and folding has yet to be defined, though



previous work suggests that they may be contemporaneous (Coller 1984).

Tertiary strike-slip faults

Near vertical NNW- and NE-trending strike-slip faults, offsetting all other structures, apart from joints, are attributed to N-S Alpine compression. They form fault zones which have anastomosing slip surfaces in both plan and cross-sectional view, geometries which lead to complex extensional and compressional deformation of adjacent host rocks. Associated tensile veins have calcite or pink dolomite infills which are sometimes vuggy. Their formation at relatively low confining pressures (i.e. those exposed at surface will often have formed within 1 km of the contemporary surface), combined with their irregular geometries means that they often represent conduits for localised fluid flow (at bends, for example: Figure 5), behaviour which is commonly observed in quarries and mines. These can be amongst the most transmissive structures in Ireland: in Lisheen Mine (Co. Tipperary), one such fault, with a lateral displacement of less than 10 m (Carboni *et al.,* 2003; Fusciardi *et al.*, 2004), yielded groundwater flow rates of ca 30,000 m^3/d in the first 6 months (i.e. equivalent to ca 10 % of Dublin's daily water usage).

Joints

Joints are the youngest observed structures and their formation is attributed to uplift-related unloading (both erosional and post-glacial) and near surface weathering. They are often contained within individual beds or packages of beds and are, in that sense, strata-bound structures. Whilst joint spacing often scales with bed thickness, this relationship can be obscured by a general upward increase in the frequency and connectivity of joints at shallower depths

Figure 4. (a) Schematic diagram showing how different fault/vein geometries can result from N-S compression. In deformation conditions characterized by low differential stress (i.e. low maximum to minimum stress ratio) and high fluid pressures, conjugate vein arrays and tensile veins are preferred to conjugate faults. See text for details. (b) Simplified geological map of The Burren showing the orientations of Variscan N-NNW veins (red). (c) Cliffs at Gleninagh Bay in the north of The Burren (see (b) for location), highlighting the vertical persistence of veins, a feature which has a profound impact on groundwater flow in the region. (b) and (c) are from Gillespie et al. (2001).

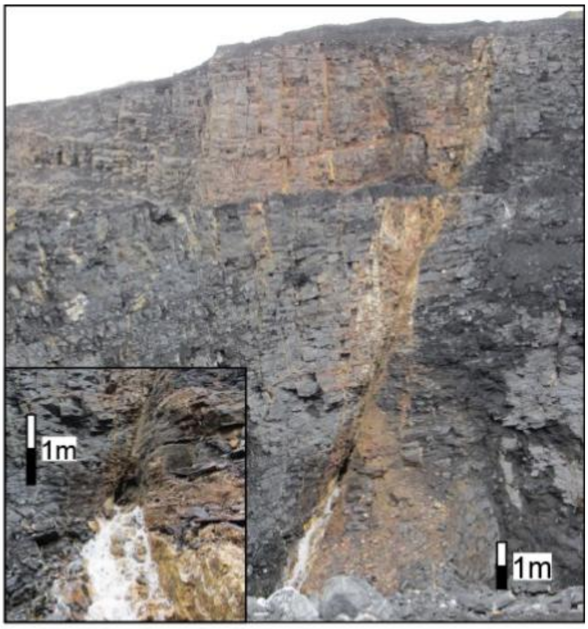


Figure 5. Significant groundwater discharge (max ca. 7,000m^3/d) from a cavity located above a vertical and lateral bend on a Tertiary dextral strike-slip fault (inset shows an enlarged photo of cavity). Huntstown Quarry, Dublin.

and their sometimes weathered and karstified nature, means that they can provide significant groundwater storage and, when saturated, contribute to significant bulk permeability development and groundwater throughput (Fitzsimons *et al*., 2005).

Conclusions and future work

A generic conceptual model of post-Devonian fault and fracture systems and their impact on groundwater flow can be defined from the analysis performed in this study (Figure 6). The principal characteristics of the conceptual model are the following:

- The main Post-Devonian fault and fracture systems have different impacts on groundwater flow in Ireland.
- The most important structures in terms of flow volumes regionally appear to be N-NNW trending Variscan veins and NNW- and NE-trending Tertiary strike-slip faults. These structures are most susceptible to karstification because they are vertically persistent structures which are not clay rich and are often dilational – they therefore often provide open pathways to the surface.
- Normal faults and Variscan reverse faults, thrusts and ENE dextral strike-slip faults are barriers to flow where sealed and unaffected by solution, but can be significant conduits where karstified, particularly at intersections with other flow conduits, such as N-NNW veins and Tertiary strike-slip faults.
- Structurally controlled flexural-slip or stylolite structures can have the same barrier effect on vertical groundwater flow as wayboards, arising from their low permeability infill, such as restite or vein material. Their groundwater flow properties can, nevertheless, lead to karstification of immediately overlying limestones.
- Joints increase in frequency within shallow bedrock (< ca 10 m depth), and can be more weathered and karstified, to provide highly transmissive zones.
- Lithology and lithological sequences have an important control on the precise nature of fault and fracture geometries, and their impact on groundwater flow and pathway connectivity, issues which have not been explored in this article.

Future work will concentrate on further quantification of fault and fracture system attributes and fluid flow on different scales, and on examining lithological & regional variations in structure and related groundwater flow.

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Acknowledgements

We gratefully acknowledge financial support from the EPA STRIVE Programme and thank the EPA and the Department of Environment, Community and Local Government (DECLG) for their support under the National Development Plan 2007-2013. We are very grateful to many people for technical discussions, in particular David Ball, Donal Daly, Taly Hunter-Williams, Tom Manzocchi, Bruce Misstear and Ulrich

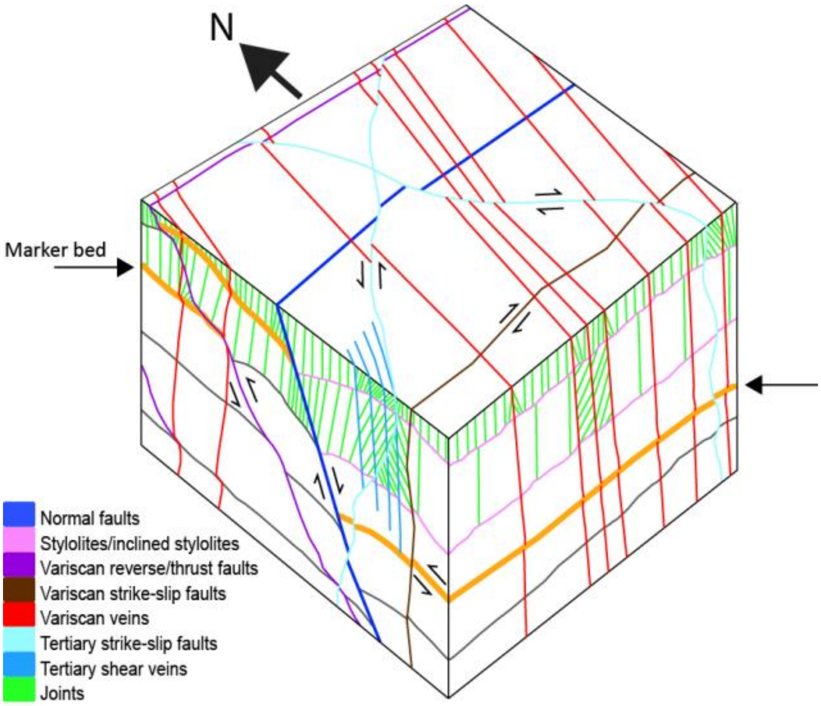

Figure 6. Schematic diagram showing the main post-Devonian fault and fracture systems controlling groundwater flow in Ireland.

Ofterdinger. Thanks also to the numerous quarry/mine operators for providing access and assistance throughout our study.

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Recent advances in the conceptualisation of groundwater flow in Irish poorly productive aquifers – Griffith Geoscience Programme

Approximately 65% of Ireland is immediately underlain by granitic, metamorphic and Lower Palaeozoic sedimentary bedrock units. These units are considered as poorly productive aquifers (PPAs), having low average porosity and permeability. Groundwater flow in PPAs occurs predominantly through fractures, whose productivity is often related to tectonic and weathering history. Detailed hydrogeological investigations completed in comparable geological settings to those encountered in Ireland have shown rock structural fabric (fractures and bedding planes) and weathering patterns to be highly heterogeneous, from the cm-scale to the km-scale. This has lead to high spatial variability in hydraulic properties over many orders of magnitude.

Historically, the complexity and limited productivity of Irish PPAs has meant they have attracted limited attention from hydrogeologists. This has made their *in situ* characterisation extremely challenging. More recently the implementation of the Water Framework Directive (WFD) across Ireland has required regulatory agencies to better understand the role played by groundwater in catchments underlain by PPAs and its impact on the wider hydrological cycle. This has prompted the EPA and GSNI to instrument and monitor test sites in the Republic of Ireland and Northern Ireland to further investigate the hydrogeology of these units. The Groundwater Research Group at Queen's University Belfast, funded by the Griffith Geoscience Research Programme, has built on this through multi-disciplinary research into characterising PPAs and the key drivers controlling groundwater flow in these units.

To date, **c**haracterisation has mainly focussed on three representative metamorphic and Lower Palaeozoic (low grade meta-) sedimentary bedrock catchments in the northern half of Ireland: (1) Mount Stewart in Co. Down, underlain by low-grade metasediments; (2) Gortinlieve in Co. Donegal, underlain by medium-grade micaschists and (3) Glencastle in Co. Mayo, underlain by higher-grade gneisses, schists and quartzites. EPA catchments (2-3) contain depth-specific boreholes that allow characterisation of both vertical and lateral variations of hydrogeo-logical properties (Moe *et al.*, 2010). A combination of mulit-scale geological, geophysical, hydraulic, geochemical, hydro-chemical, isotope and petrophysical research is being applied to further investigate these spatial variations.

Geological and geophysical investigations confirm the high levels of structural complexity and heterogeneity anticipated at catchment scale (Comte *et al*., 2012). Encountered bedrock commonly contains a variety of geological units that display contrasting sensitivities to weathering, which vary depending on the rock-type and bedrock structure. Some regional lineaments (e.g. major faults zones) have been shown to enhance weathering, while small-scale fracture mapping of outcrops, and in boreholes, has shown high variability in fracture density, orientation and hydraulic activity, related to the deformation history and tectonic events that have affected the Irish landmass since the Precambrian.

Results of hydraulic testing have proven consistent with wider structural trends and further demonstrate that aquifer hydraulic properties are controlled by lithology, geological structure and weathering history. Notably, it was observed that at all sites the majority of hydraulically active fractures display orientations that are mainly related to the recent (Alpine) tectonic framework, resulting in hydrogeological anisotropy where permeabilities tend to be higher along Alpine orientations.

At catchment scale, aquifer permeability decreases strongly with depth, while increasing down-gradient from catchment divides, typically by between 10^{-1} m/d and 10^{-3} m/d. Variation with depth can be approximated by a power law, specific to rock-types (Fig. 1). Four bedrock types with typical signatures have been identified: the quartzitic metasediments of Mount Stewart; the micaschists of Gortinlieve, the pelitic schists of Glencastle and the gneiss and mixed units of Glencastle.

Overall, investigation results for Irish PPAs have proven consistent with the findings from studies completed elsewhere in comparable hydrogeological settings, and demonstrate that understanding groundwater flow in such complex aquifers requires a multi-scale spatial understanding of both the nature and structure of the geological formations. Beyond the advances in better understanding the hydrogeology of the Irish PPAs, recent findings also have direct implications for groundwater development, management and protection.

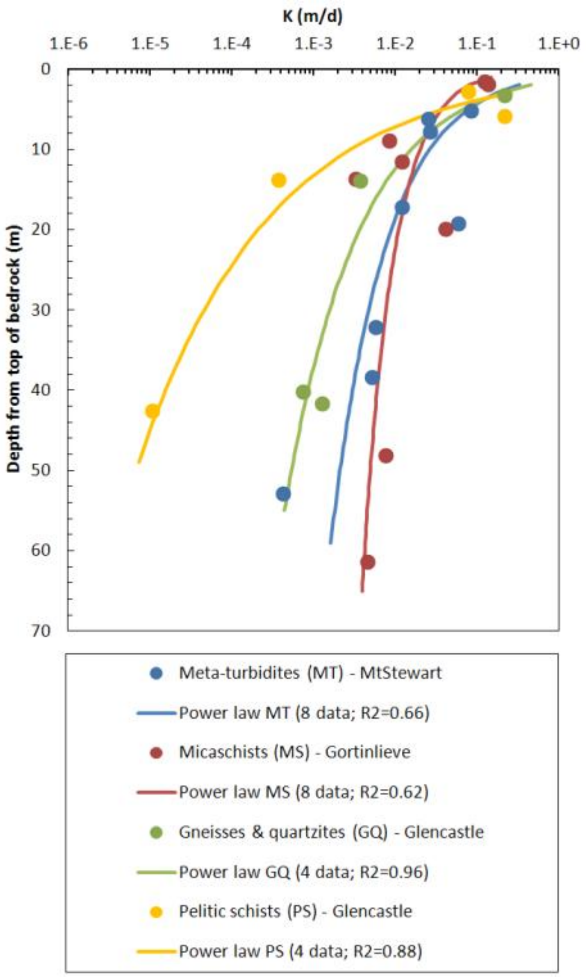

Figure 1: Variations of the bedrock hydraulic conductivities with depth as a function of the rock type, implying very rapid decrease of aquifer productivity with depth (adapted from Comte *et al*., 2012).

Overall, quantification of the decrease in aquifer productivity with depth suggests that, approximately 50% of groundwater flow in PPAs occurs in the uppermost 5 m (the transition zone), 75% in the uppermost 10 m, and more than 90% in the uppermost 20 m, although specific depth intervals can vary depending on the rock-type and more importantly, with the existence of localized structures such as fractures zones. Moreover, study findings have assisted in targeting optimum screening depths for both hydraulically and economically efficient water supply boreholes, where over-drilling and over-casing must be avoided to prevent a significant loss of well productivity (Misstear, 2012). Findings also confirm the crucial role played by the uppermost parts of the bedrock (Transition Zone) in sustaining surface water (rivers, lakes and wetlands), and the ecosystems they support. Understanding these issues will prove important in implementing the programmes of measures that are required in river basin districts by the WFD.

J.-C. Comte, R. Cassidy, U. Ofterdinger and R. Flynn - Groundwater Research Group, Queen's University Belfast

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IGI guidelines for the preparation of soils, geology and hydrogeology chapters of an EIS

Introduction

The Institute of Geologists of Ireland (IGI) convened a Working Group in 2012 to review the Institutes' earlier 2002 Guidelines on the preparation of Environmental Impact Statements (EISs). The revised Guidelines reflect legislative changes and members' experiences in the production of EIS chapters on soils, geology and hydrogeology since the 2002 Guidelines were produced.

The IGI publication is entitled *'Guidelines for the Preparation of Soils, Geology and Hydrogeological Chapters of Environmental Impact Statements, 2013.'* The Guidelines provide a methodology for the assessment of potential impacts which proposed developments may have on soil, geological and hydrogeological environments. The recommended procedure outlined in the Guidelines requires that the information provided in an EIS should reflect the vulnerability of the receiving geological and hydrogeological environments to activities associated with the construction and/or the operation of a development.

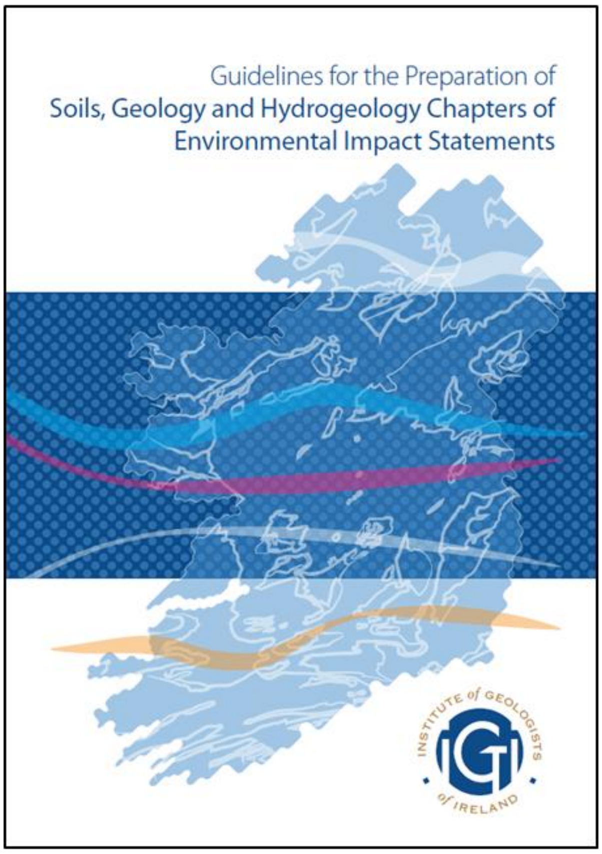
The document includes a consideration of relevant national legislation and guidelines, interactions with other disciplines and recommended consultees. This article describes the principle components of the IGI Guidelines. Information on the availability of the published document is provided at www.igi.ie

Recommended Procedure

Many developments which require an EIS will have no significant impact on the geological/ hydrogeological environment, such as developments which are removed from areas of geological heritage and which are connected to services. On the other hand, developments such as mines, quarries, significant groundwater abstractions and discharges to groundwater would naturally impact on subsurface resources. It is important therefore to identify at the outset the:

- Relative scale of the development;
- Range of activities associated with the development;
- Type of the receiving geological/hydro-geological environment
- Vulnerability of the receiving geological/ hydrogeological environment;
- Interaction/relationship between the development site and nearby protected environments.

By compiling the above information, and where necessary with appropriate site investigations and studies, it should then be possible to determine;



- Whether the development has the potential to impact on the receiving geological/ hydrogeological environment;
- The significance, type, duration and quality of any potential impacts;
- Mitigation measures;
- The significance, type, duration and quality of any residual Impact.

The IGI recommended procedure is described in a flow chart (Figure 1) and consists of 4 elements subdivided into 13 steps which are described in the following sections.

Element 1: Initial assessment (Steps 1 to 5)

The objective of Element 1 is to compile the available and relevant information which, together with a site visit, would allow for the

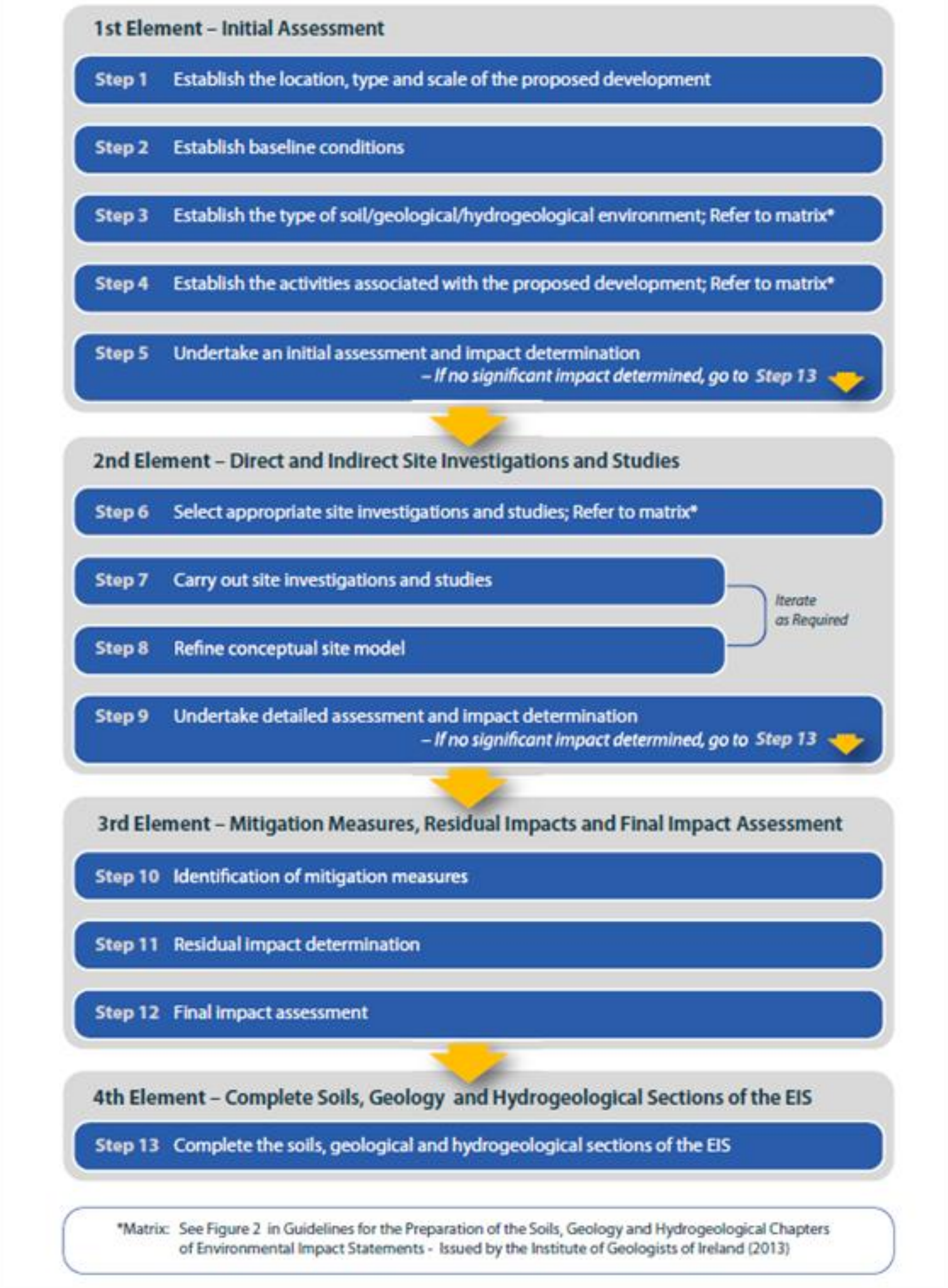


Figure 1: IGI recommended procedure outlining the four elements of work

determination of the type and scale of the proposed development, the range of related activities and the type and vulnerability of the receiving geological/hydrogeological environment. The compilation of the available geological and hydrogeological information into a preliminary conceptual site model (CSM) for the development site and its environs is central to establishing baseline conditions.

An accompanying matrix (Figure 2) aligns the investigations to be carried out with the type of geological/hydrogeological environment and the potential activities which may be undertaken on the development. This ensures that the level of investigation undertaken considers both the nature and vulnerability of the receiving subsurface environment and the development's characteristics.

The matrix provides a useful basis on which to select a suitable range of direct and indirect site investigations and hydrogeological studies that could be carried out to further develop the CSM. A key aspect of the matrix is that the scope of the recommended works and studies increases both in variety and complexity as the receiving environment becomes more vulnerable to potential impacts. A range of generic geological/ hydrogeological environments has been assembled in the matrix to describe and encompass the variety of subsurface environments likely to be found in Ireland.

The generic types of geological/hydrogeological environments classified in the matrix are:

- **Type A**: Passive hydrogeological environments e.g. areas of thick low permeability subsoil, areas underlain by poor aquifers, recharge areas, historically stable geological environments;
- **Type B**: Naturally dynamic hydrogeological environments e.g. groundwater discharge areas, areas underlain by regionally important aquifers, nearby spring rises, areas underlain by permeable subsoils;
- **Type C:** Man-made dynamic hydrogeological environments e.g. nearby groundwater abstractions, nearby quarrying or mining activities below the water table, nearby waste water discharges to ground, nearby geothermal systems;
- **Type D**: Sensitive geological / hydrogeological environments e.g. potentially unstable geological environments, groundwater source protection zones, karst;
- **Type E:** Groundwater dependent ecosystems e.g. wetlands, nearby rivers with a high groundwater component of base flow.

A range of generic activities which could impact on the geological/hydrogeological environment

Activities

	Earthworks	Storage / transmission of leachable and/or hazardous materials	Lowering of groundwater levels by pumping or drainage	Discharges to ground	Excavation of materials above the water table	Excavation of materials below the water table	Land-spreading	Abstraction / Discharge of energy (heat) from/to the ground
Type A	Invasive site works to characterise nature[1] and thickness of soil and subsoil e.g. trial pits or augering.	Establish nature and quantity of leachable materials.	Establish details of borehole /spring construction or drainage system structure details (as appropriate).	Complete a Risk Assessment as per EPA (2011) Guidance on the Authorisation of Discharges to Groundwater[2]; Apply Tier 1, 2 or 3 Assessment as appropriate	Site works to characterise nature[1], thickness, permeability and stratification of soils and subsoils e.g. trial pits, augering.	Site works to characterise nature[1], thickness, permeability and stratification of soils and subsoils e.g. trial pits, augering.	Establish the type of waste to be landspread.	Provide details of type of system (open/closed, shallow/deep). The site works required and described below will reflect the design parameters of the system being installed.
		Site works to characterise nature[1], thickness, permeability and stratification of soils, subsoils and bedrock geology e.g. trial pits, boreholes.	Establish sustainable yield and proposed daily abstraction rate or drainage system invert levels (as appropriate).		Site works to fully characterise the bedrock geology and in order to to define the resource volume/weight according to The PERC Reporting Standard[3] e.g. trenching, drilling, geophysics.	Site works to fully characterise the bedrock geology and in order to to define the resource volume/weight according to The PERC Reporting Standard[3] e.g. trenching, drilling, geophysics.	Undertake a walkover survey of the site.	Site works to characterise nature[1], thickness, permeability and stratification of soils, subsoils and bedrock geology.
		Works to determine groundwater level, e.g.mapping, monitoring in stand pipes, piezometers, or boreholes.	Works to determine summer level of the water table, annual actual recharge and proposed maximum drawdown. Measurement of effects of change in water level on nearby abstractions.		Works to determine groundwater level, flow direction and gradient; e.g.monitoring in stand pipes, piezometers, or boreholes.	Works to determine groundwater level, flow direction and gradient; e.g.monitoring in stand pipes, piezometers, or boreholes. Characterisation of groundwater chemistry and quality. If lowering of groundwater levels is required, then proceed also as for activity Lowering of water levels by pumping of drainage.	Review Groundwater Protection Responses for Landspreading[4], and apply Departmental[5] and Regularory[6] guidelines and best practice. Assign a response category.	Design parameters for the system will be required to be collected, however these are out of the remit of this document - although any information gathered for design purposes should be used in the EIS.

Figure 2. Activities/environments matrix. Note the matrix is intended for production at A3 size. An extract is presented here by way of illustration. Readers are referred to the published Guidelines.

has been assembled in the matrix. The generic activities identified are outlined below;

- Earthworks;
- Storage/transmission of leachable or hazardous materials;
- Lowering of groundwater levels by pumping or drainage;
- Discharges to ground;
- Excavations of materials above the water table;
- Excavations of materials below the water table;
- Landspreading;
- Abstraction/discharge of energy (heat) from or to the ground.

The matrix is produced at A3 in the published Guidelines and is unsuitable for publication in this newsletter. An extract from the matrix is produced here by way of example only and the reader is referred to the published Guidelines to access the entire matrix.

An initial assessment and impact determination should be prepared that summarizes the information compiled so far and is then reviewed to determine whether the proposed development would result in any impact on the receiving geological/hydrogeological environment. The significance of the impact should be defined using terminology consistent with national guidelines. Based on the results of this assessment, it will be necessary to proceed to element 2 or to proceed directly to element 4.

Element 2: Direct and indirect site investigation and hydrogeological studies (Steps 6 to 9)

While the matrix suggests the minimum amount of work which may be needed, professional judgement will be required to select the appropriate range of direct and indirect site investigations and studies. This work will further inform the CSM and quantify the impact of the proposed development on the receiving geological/hydrogeological environment. The range and scope of the planned investigations must reflect;

- the scale of the proposed development,
- the range of activities likely to occur during the construction and operation of the development and
- the type and vulnerability of the receiving geological/hydrogeological environment

Based on the results of these additional investigations, the CSM should be refined and updated and the potential impacts defined.

Element 3: Mitigation measures and residual impacts (Steps 10 to 12)

The 3rd element of the recommended procedure builds on the outcome of the preceding two elements, by identifying mitigation measures to address potential impacts and then assessing the significance of any residual impacts.

Element 4: Complete the EIS (Step 13)

The EIS should be completed based on the information compiled in previous sections. The CSM should be updated with all available information, impact identified, mitigation measures developed and residual impacts determined. The significance of any residual impact should be determined with particular reference to national guidance documents based on the importance of the feature to be protected and the magnitude of the impact on the receiving geological/hydrogeological environment.

Non-technical summary

In Ireland, a non-technical summary (NTS) is required to accompany the EIS. The NTS should include, in layman's language, a brief summary of the geological and hydrogeological environments present and the activities associated with the proposed project that could impact on these environments.

EurGeol Kevin T. Cullen PGeo. Hydrogeological Consultant, Dublin

EurGeol Catherine Buckley PGeo, ARUP, Dublin

On behalf of the Institute of Geologists of Ireland EIS Guidelines Working Group.

IAH two-day residential karst workshop, Co. Clare, 2013
Course report

In May 2013, the International Association of Hydrogeologists (IAH) Irish Group, funded a two-day course on the fundamentals of karst. This course was organised and led by David Drew and Caoimhe Hickey, with guest lectures. The course took place on Thursday the 16th and Friday the 17th of May and consisted of two half days of lectures and two half days of fieldtrips. The venue was Clare's Rock Hostel in Carron Village, in the Burren, Co. Clare, which was also where the participants stayed.

The course was fully booked with 30 participants in attendance. The lectures on Thursday morning were given by David Drew and started with an introduction to karst and karst landforms and then moved on to look at Irish karsts. This was followed by a short coffee break and some delicious home cooked scones and jam, provided by the hostel. We then learnt about fracture patterns in Irish limestones by John Paul Moore of UCD. The rest of the early afternoon was spent learning about karst hydrogeology with David Drew. After a tasty lunch in the local pub, the group split into two groups for the first field element of the course.

One group went underground into Polldubh Cave, where they learnt at first-hand about subsurface karst landforms and hydrology by following the course of an underground stream for some 500 m. The other group stayed above ground and saw examples of surface karst landforms including enclosed depressions (both large and small), turloughs, springs, limestone pavements and swallow holes. There was a practical element to the surface fieldtrip with participants calculating the volume of water sinking at a swallow hole using a current meter and conducting a dye tracing experiment consisting of both injection of the dye and recovering it at a spring.

Day 2 focused on the methods used to investigate karst. It was opened with an introduction by David Drew. This was following by a presentation on karst landform mapping and dye tracing techniques by Caoimhe Hickey. Laurence Gill of TCD then presented on modelling in karst and gave an example of his model of the turlough network in the western Irish lowlands.

David Drew and James Lalor deep in discussion at the entrance to Polldubh Cave (Photo source: P. Groves)

Some of the participants learning about the vein patterns in the limestones of Co. Clare

Karst course participants measuring stream flow with current meters

Karst course participants measuring stream flow with current meters

More on methods in karst followed a short break with Caoimhe Hickey presenting a paper written by Yvonne O'Connell of NUIG reviewing the different types of geophysical techniques that are useful in karst. David Ball then presented an interesting paper on drilling and developing water resources in karst and the challenges that karst environments pose. The last paper of the course was presented by Coran Kelly of Tobin Consulting Engineers and addressed some of the challenges of investigations in karst terrains, especially with limited resources.

The group then split back into the two field groups with each group participating in the field excursion that they had not done the day before.

The feedback from the participants was very positive and people felt like they had gained very practical and useful knowledge. It is hoped that this course will be run again in the near future. If you are interested in doing this course please contact either David Drew (ddrew@tcd.ie) or Caoimhe Hickey (Caoimhe.Hickey@gsi.ie).

Caoimhe Hickey, GSI

Five year GSI / NFGWS drinking water source catchment project for Group Water Schemes is underway

The project is developing 290 zone of contribution reports for the Group Water Scheme wells across the country. The reports will help the scheme personnel to better understand and protect their source.

A five-year programme started in July this year to delineate zones of contribution (ZOC) for approximately 290 groundwater supplied group water schemes (GWS). This programme is being jointly managed by the GSI and the National Federation of Group Water Schemes (NFGWS), and is funded through the Rural Water Programme by the Department of the Environment, Community and Local Government.

The funding has been awarded due to the success of a joint GSI/NFGWS pilot project initiated in late 2010[1], and also specifically in response to the case made by the NFGWS, through the National Rural Water Services Committee, *that accurate catchment mapping is a vital first step in formulating targeted and effective source protection strategies*.

The main *output* of the pilot project was to delineate the ZOC and highlight the groundwater vulnerability within the ZOC. This enables the decisions in relation to possible protective measures and future planning. Given the generally small abstraction volumes and likely funding that would be available, full Source Protection Zone (SPZ) reports was considered neither appropriate nor affordable. Therefore, each individual GWS ZOC project includes:

- a site/catchment visit;
- discussion with the GWS personnel and other parties;
- a desk study of all available data, including any hydrochemistry;
- hydrogeological interpretation of that information to delineate a ZOC.

Another of GSI/NFGWS's fundamental aims of the project was to engage with the GWS personnel so that they would fully understand the concepts and data behind the reports, and why certain data were requested or collected (e.g. hydrochemistry, borehole logs, water levels etc.). In discussions with the pilot GWS personnel, it seemed that an increased understanding would enable the GWSs to have

[1]The pilot project was in two phases: 1) 2010/2011, six schemes in Cork and Limerick; and 2) 2012, four schemes in Louth and one in Meath.

greater ownership of their supply and the decisions made about it.

From this premise, reports were tailored to be GWS-friendly: short and standardised; use easy-to-understand, schematic diagrams, including cross sections; use non-technical language; and include a 'sky to supply' description of the conception model, which is supported by the available data[2]. Where appropriate and feasible, the GWS personnel aided with data collation and other tasks, such as dipping of wells. This not only provided additional data but also encouraged the GWSs to get involved with the process, have a greater understanding of the information and therefore be in a better position to take ownership of their supply and related data.

The final element of the project was to present the information and discuss the conceptual model, recommendations and any management implications with the GWSs.

The funding is in the form of grant aid -: 85% of up to a maximum cost of €3,000 can be drawn down by each GWS towards the professional assessment and report. This means that the outlay for a GWS should be a maximum of €450. Although this falls a little short of the costs proposed by the NFGWS, it is thought that a ZOC can be delineated for most of the GWSs, and that within the scope of this project, relatively simple catchments may not require the maximum funding.

After the 2013 funding was secured, the GSI formed a panel of 10 hydrogeological consultants to undertake the proposed work for this year, which constitutes assessments for 46 GWSs across five counties.

Onsite meeting with representatives from the Barna -Kilrush Group Water Scheme in Co. Kilkenny

The GSI and NFGWS have an on-going role in organising the work, liaising with the GWSs, collating information, providing support to the consultants and reviewing the reports from the panel of hydrogeologists, that are completing the work. Besides ensuring that a consistent approach is adopted, this will assist the hydrogeologists involved by providing them with a clear reporting framework and maximising the use of their time input. For example, the NFGWS development officers are collating as much source information as possible in advance of site visits and the GSI are providing report formats, all data layers and help with site visits where possible.

There are, of course, teething problems – delays in funding approval has resulted in a year's work being squeezed into less than six months, some of the data have not been immediately available, and, fundamentally, its takes time to get to grips with entire process and reports. However, it is clear that the hydrogeologists have been pulling the stops out to meet the extremely tough deadlines, in order to make this first year a success, which will pave the way for continued funding. With the first draft reports now being submitted, preparations are underway to gather data for next year's GWS projects.

In addition to groundwater sources, source protection for some surface water supplies is

[2]To suit the needs of the GWSs and work within tight financial constraints, the GSI and NFGWS developed a draft report format that took elements from the GSI SPZ reports and EPA 'site folders'. The reports were amended based on feedback from the GWSs during the pilot phase. Further adaptations may follow, as the project progresses.

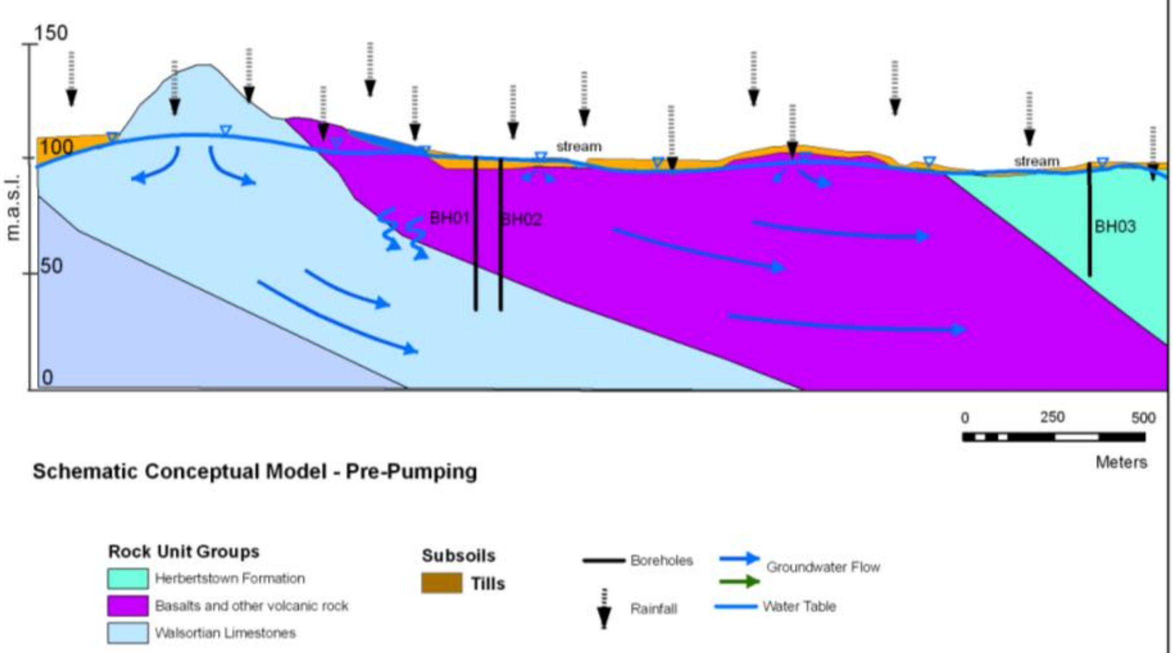
Members of the GSI and Ballinguyroe and Tankardstown Group Water Scheme, Co. Cork during the pilot project, 2010.

also being examined using the previous pilot completed through Centre for Freshwater Studies at Dundalk Institute of Technology. Both the groundwater and surface water projects use some of the concepts of successful catchment management. In this case, there is a focus on good science in the hands of the local community, so that they have input, ownership and ultimately responsibility of management.

We are extremely lucky that the NFGWS have already built a very solid foundation with the GWSs for us to work from. It is also envisaged that not only will the GWS personnel/managers have a greater understanding of their supplies, but that they will have a greater insight into the reasons why they should be working with a hydrogeologist, as well as making a specific professional contact for future work.

Welcoming the provision of financial support for ZOC delineation, the GSI echo the NFGWS chairperson and member of the National Rural Water Services Committee, Brendan O'Mahony, who described it as 'undoubtedly a very important source protection initiative' for the group water scheme sector. Applauding the vision of the Minister and his Department in sanctioning this funding in what is a very difficult economic climate, he added that it is a 'valuable and enlightened investment', that will provide group water schemes with 'a solid basis upon which to build sensible and defensible source protection strategies'.

Caoimhe Hickey, Monica Lee (GSI) and Brian MacDomhnaill (NFGWS)



Simplified schematic cross section

Geothermal Association of Ireland (GAI) news

3rd Geothermal Conference 13th November 2013, Kilkenny

The Geothermal Association of Ireland (GAI) is holding its 3rd Conference in Kilkenny next month. Full details and registration forms are available from the GAI website: www.geothermalassociation.ie/events.html.

The presentations, delivered by both local and overseas specialists, will cover academic research, proven project excellence, developing standards, training and education, environmental assessment and international initiatives. The winners of the Brecan Mooney Ground Source Heat Installation of the Year competition for non-domestic projects will be announced. There is also a poster competition for the best geothermal research posters.

GSI Shallow Geothermal/Ground Source Heat Project

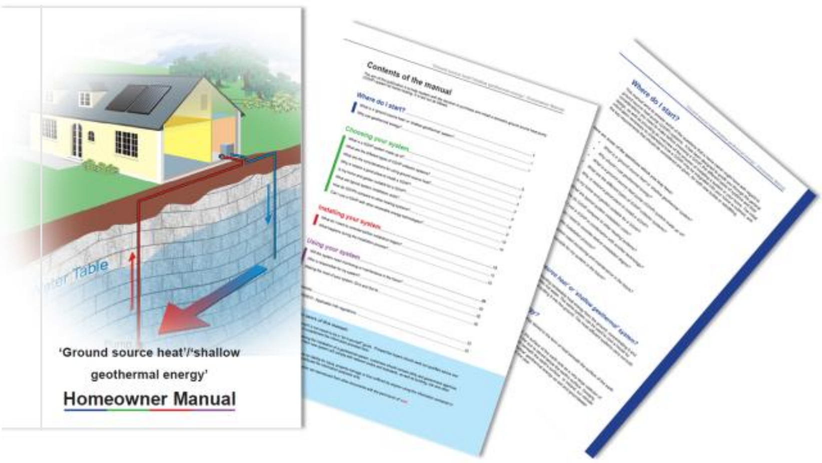
The GSI Shallow Geothermal/Ground Source Heat project (GSHP) is progressing well.

Homeowner Guidelines

The non-technical Homeowner Guidelines are designed to inform end users about shallow geothermal energy, ground source heat pumps, system options and costs. The project team (GSI, with SLR/Arup/GeoServ) will be circulating the draft document for consultation with key stakeholders very soon, with publication following on from this.

GSHP suitability maps

At the forthcoming GAI conference (13th November; Kilkenny), draft 'suitability' maps for closed loop horizontal, closed loop vertical, and open loop GSHP installations will be presented as posters. The project team will be seeking comments and discussion on the maps, their component data and utility, during the course of the day. In addition to completing the map suite and accompanying technical and user guides, from this point on the attention of the project team will be focussed the other elements of the project – namely the installations database and the technical guidance.



GSHP installation database

Whilst initial responses from installers to the database have been positive, the data returns were limited. The project will focus on working with installers, drillers and engineers to acquire and process data on GSHP installations in Ireland. The database will be important in helping to build up a picture of the number of GSHP installations, their distribution, and in what geological setting different types of GSHP installation are successful.

Technical guidelines

In addition to the Homeowner Manual for GSHP systems, the project team are preparing technical best practice guidelines for GSHP installation. These are based on international best practice documents, and will be circulated to key stakeholders for consultation in early 2014.

If you would like to be kept informed about the project results, please email: shallowgeothermal@gsi.ie.

Previous issues available at www.gsi.ie

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

Contributions for the next issue of the Newsletter should arrive by 31 Jan 2014 to: Groundwater newsletter @gsi.ie (*no spaces*)

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Published by the:
Geological Survey of Ireland
Beggars Bush Buildings
Haddington Road
Dublin 4

Foilsithe ag an:
Suirbhéireachta Gheolaíochta Éireann
Tor an Bhacaigh
Bothar Hadington
Baile Átha Cliath 4

IAH News

The IAH AGM was held on 1st October this year in the Geological Survey of Ireland (GSI). This year we used internet technology to also have a remote centre of IAH members in Belfast join us. The remote access hook up to Belfast had been trialled throughout the year during the monthly technical discussion meetings and is proving to be a great success. Testing has been carried out to have a second remote centre in Galway link in as well and this will commence shortly. In due course we would hope to extend this to other centres around the country as demand dictates. Members at the AGM supported the idea of investing in the appropriate equipment so that this can become a permanent arrangement and can help more members outside Dublin to get a greater return for their investment in membership.

There has been an emphasis over the last two years on running technical training courses for members. So far we have had a course on pumping tests, a professional development seminar for hydrogeologists, a WASH (Water supply, sanitation and hygiene) course to help people hoping to work in developing countries, and a two day residential workshop in Co. Clare on karst (see the course report earlier in this edition). We have also trialled investing in the very professionally run webinar series run by Midwest Geosciences in the US. The first webinar was a double session on the hydrogeology of aquitards which was presented by Ken Bradbury and a colleague. Some members may remember Ken who had a month's sabbatical here in the GSI in the 1990s. The webinar was excellent and we have committed to accessing their archives on a regular basis in the future. All training courses are largely free, or at token cost to members, so there has never been a better time to join IAH. Membership is open to all.

Several members from last year's Committee have completed their 3-year terms and so there are some new faces on the Committee this year which is fantastic. The new Committee is listed below. The conference sub-committee will be finalised shortly.

President	David Drew
Secretary	Katie Tedd
Treasurer	Dominica Baird
Education and publicity	Shane Regan and Orla O'Connell
Field trip Secretary	Aisling Whelan
Conference Secretary	Colin O'Reilly
Burdon Secretary	Morgan Burke

I'd to take this opportunity to welcome the new Committee members and wish them all the best in their terms. I would also like to thank the outgoing Committee for their support over the last 3 years in my term as Secretary.

Jenny Deakin

Irish Group