Irish Groundwater Newsletter

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Groundwater Newsletter No. 57 includes the customary mix of groundwater related topics and news from research, data collection, and management perspectives. The first article comprises Donal Daly's reflections on groundwater in Ireland past, present and future and was written in response from a request by the Newsletter editors on the occasion of his retirement from the EPA. (GWNL 56). Two articles are concerned with hydrogeological topics that are relatively neglected in Ireland, at least in the literature. These relate to urban groundwater and to the hydrogeology of sands and gravels. The first of these topics is addressed by Gerry Baker in respect of groundwater levels in the Dublin area and the second by a Geological Survey (GSI) team who provide an update on the on-going collection of data on sand and gravel aquifers in the country. An example of the resulting database is provided for a sand and gravel aquifer on the Meath-Kildare border. A further stage in processing environmental data is demonstrated by Xavier Pellicer and Michael Sheehy (GSI) who explain the new physiographic units map of Ireland which classifies the Irish landscape into physiographic types using part genetic part generic methods. Water management is represented by Pauline Gillard's article on Drinking Water Safety Plans including their rationale, development and implementation with an example being given from a Co. Galway PWS.

The newsletter rounds off with the annual research reports from third level institutions and with items of hydrogeological news.

Geological Survey
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Cover photo: Example of good wellhead protection [Pualine Gillard]

Lessons from the past: looking to the future

Donal Daly

Donal Daly provides reflection, developments and lessons learnt from his 41 year career in hydrogeology and catchment management.

"***You can't connect the dots looking forward; you can only connect them looking backwards***"

Quote from Steve Jobs

David Drew asked me to write 'a reflective piece' for the Newsletter. I imagine that he expected that I would have some profound views after 41 years working in the public sector as a hydrogeologist and catchment scientist. However, I searched and searched my mind, but all that I could find were some simple, rather unoriginal thoughts and debatable views. However, I decided to persist with writing the article for two reasons: I had promised to write it; and because I would like to encourage 'connecting the dots' as often as possible, learning from this and applying the lessons – something to my regret I didn't do sufficiently. And, just to be clear, any lessons here are based on my own mistakes, usually learned later in my life than I would have liked, although I have seen all of them repeated by others. While I have oriented this article towards groundwater and hydrogeology, if you read on, you will see that, for whatever they are worth, some points might be applicable more widely.

In looking for lessons from the past, it is in a context of massive advances in Irish hydrogeology and in our understanding of groundwater in Ireland since the late 1960s. This is not the place to list those advances or the people and institutions that enabled this to happen, except to say that more than the well known names need to be acknowledged, such as those that were 'temporary field assistants' in the Groundwater Section of the GSI, the numerous research students in third level colleges, and the younger hydrogeologists in the public bodies and consultancies; I would like to acknowledge them and thank them and the colleagues who worked with me for their good influence.

In Issue 50 (July 2012) of the Groundwater Newsletter (Available at: https://www.gsi.ie/documents/GWNewsletterNo50.pdf), I wrote an article with "Challenges and Questions for the Future" in the title; I have tried to avoid repeating points here. Interestingly, a lot of progress in some of the areas mentioned then has been made in the last six years.

Lessons from the Past

First Principles Thinking

One of the earliest lessons I learned, thanks to John Lloyd, the former Professor of Hydrogeology in the University of Birmingham, was to the effect 'first get the geology right' or 'understand the geology' as the basis for hydrogeological work. On many occasions I have seen hydrogeologists 'jumping to conclusions' or interpretations – often the more interesting role – as I did as a young hydrogeologist, without first describing and assessing the basic information; for example, describing a subsoil exposure before trying to interpret it. Likewise, there can be a tendency to accept what has always been done or be influenced by a more senior 'expert' without any questioning. Later as I gained my own experience, I associated this with what I regard as 'first principles thinking' or breaking down a complicated issue into basic elements and fundamental concepts and assumptions, and then working it out and reassembling it 'from the ground up'. And all the time asking yourself and others 'why'. In this way, we can build a sound mental model on which to base decision-making. Related to this is the freedom that is worthwhile giving your work colleagues, particularly younger colleagues, to question your views and decisions;

while it can be painful for the ego – I can still remember clearly that minute in time over 20 years ago when a young colleague came into my office, stood in front of my desk, and said correctly and reasonably 'Donal, do you realise that there is no 'I' in team'. So, my advice to managers is: 'surround yourself with people who are strong enough (and able enough) to make you change your mind'. Even though it can be challenging and uncomfortable at times, it can also be interesting and, above all, it is worthwhile.

The story of the mobile phone

During her teenage years, my oldest daughter preferred evening to morning and, at times then, didn't have a high opinion of her father. She loved her mobile phone, particularly speaking on it during the night. So, she was 'requested' to leave her phone outside her bedroom door at night. For months afterwards, as I was going to bed, I was comforted to see the phone where it was supposed to be. But, one night well after midnight, I happened to hear talking from the bedroom. I went over and picked up the phone, only to find that it was an empty phone case! The lessons for us as scientists regarding the importance of effective observation doesn't really need stating here.

The 10 Commandments for Hydrogeologists

In 1998, the Directorate of Hydrogeology, Department of Water Affairs and Forestry, Republic of South Africa published their 10 commandments; at the time I put them as a laminated sheet on my wall as a reminder. Most of these still apply, in my view.

1. Thou shall not assume isotropy, homogeneity, or uniform gradient without field evidence.
2. Thou shall not assume wells or streams to penetrate fully or flow systems to be two-dimensional.
3. Thou shall not use regional data to make site-specific judgements.
4. Thou shall not use colour graphics to enhance lousy science. (My own version is 'GIMGO' – garbage in, multicoloured garbage out.)
5. Thou shall not employ geostatistics to obfuscate poor interpretations or weak conclusions.
6. Thou shall not rely on stochastic methods to disguise insufficient field data.
7. Thou shall not place geochemical interpretations above hydraulic interpretations.
8. Thou shall never regard geophysics as the truth.
9. Thou shall never use a contouring programme to make a water table map. (This is too 'strong' now 20 years later, but it still vital to check the results by drawing contours with paper and pencil.)
10. Thou shall never use more than three significant digits.

While these are aimed at hydrogeologists, it might be a worthwhile exercise for all disciplines to have similar 'commandments'.

'Looking up from the borehole' and 'the straitjacket of …ologies'

The following quotation by James Lovelock (of Gaia Theory fame) – *"Science is broken down into non-communicating disciplines"* is largely true, in my experience. Most hydrogeologists I know 'love' their work; it is interesting, challenging generally, and important in that groundwater is critical for water supply and for ecosystems. For years it was (almost) a passion for me, and still is. For years I didn't realise that the general point made by George Monbiot about specialists in his book Feral **"***Moorland weevil specialists become moorland weevil champions"* applied to me. I was comfortable and happy in my groundwater 'silo'. Last year, after working for 40 years, I wrote the following *"The modern complex world needs the detailed expertise and knowledge of disciplines, and the work of specialist teams. Hydrogeologists can feel comfortable that their expertise has, rightly, become indispensable in a variety of environmental and development areas. But the problems siloes pose must be avoided. By being outward looking, respectful of other disciplines, promoting the role of groundwater only where justifiable, willing to connect with other areas and ensuring that the mental, structural and discipline silos are conquered rather than being conquered by them, hydrogeologists will have a greater impact, which will give both personal and societal benefits."* (Daly,

2017). The challenge goes on. You, the reader, may not agree. However, if you don't, at least 'look in the mirror' (often a difficult but worthwhile exercise I have found) before dismissing the point.

Approaches to environmental management

The approach to environmental management has largely been top down, command and control and involved focusing on compliance of isolated components of an environmental system and end -of-pipe solutions. For instance, enforcement instead of being the ultimate and sometimes necessary 'tool in the tool kit', is too often used as the main one with threats and fear as the weapons, and the means of bringing about behavioural change. While there have been some successes using this approach, understandably it has failed. Thankfully, new approaches combined with the existing ones are starting to be developed and used; for instance, there is an increasing recognition that it is necessary for environmental protection to take firm root in public opinion and consequently have an effect on politics and policy making. This is a challenging objective, and the groundwater community has a role in making this happen.

The joy of understanding via communication and learning from one another

"Every day is a school day" is an often quoted expression. Do we as a hydrogeological community give this sufficient priority? We have monthly Technical Discussion meetings, the Groundwater Newsletter, the Annual Conference in Tullamore and the annual field trip. Yet, how many hydrogeologists really contribute? How many write articles and papers (one of the best ways of learning) and give presentations? Very few, in my experience. How many give up evenings and their own time to attend relevant evening lectures? How many read academic papers? Not enough, I suggest. Also, when reading and reviewing hydrogeological reports, I find that some of the inadequacies are worrying. The older I get, the more I realise how much I don't know and, arguably, need to know. In an increasingly complex and important area, it is vital that we all give priority to continued learning; we have a vibrant hydrogeological community, let us try to learn and benefit as a community to a greater degree than we are now doing. And, by the way, as it is right now, we are far ahead in our efforts than many other disciplines; but …….

We have karst in Ireland!

This is stating the obvious. But how many Irish-based hydrogeologists have training in karst hydrogeology? How many hydrologists, environmental scientists, catchment scientists, environmental or infrastructural engineers, planners, public health specialists, ecologists or environmental regulators know about karst to a degree that decisions they make on developments in karst areas are based on an understanding that is sufficient for successful environmental management. Not enough. I say this as someone trained in the Darcian-flow approach to hydrogeology and who for many years was not sufficiently aware of the high degree of heterogeneity and anisotropy of the limestones that underlie 40% of the Irish landscape, of which half have a significant degree of karstification, with a landscape dominantly of solutional origin and with features such as caves, sinking streams and dry valleys. The solution (!) is ongoing training, research and outreach on this complex (and fascinating) environment. A book 'Karst of Ireland', with David Drew as the main author, will be published by the Geological Survey of Ireland in the Autumn with information that should be essential reading for those undertaking development or environmental protection functions in karst areas.

Analysing and accepting the context for our work

As a younger hydrogeologist, I tended to do (and enjoy) my work without giving thought to or taking account of the context in which I was doing it. So, I wonder now whether, if I did, I would have done it a bit differently, more effectively and more advantageously for the tax payers that paid my wages? As a consequence, was I more concerned about the right processes rather than beneficial environmental outcomes (a

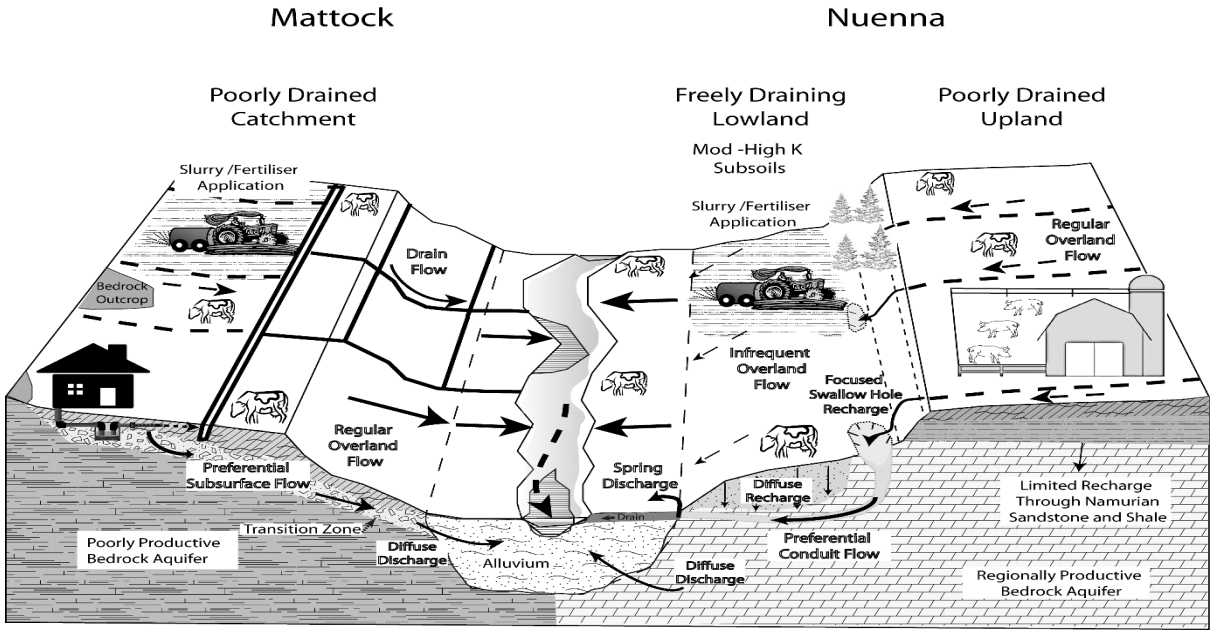

Figure 1: Schematic representation of the contrasting hydro(geo)logical pathways contributing flow and nutrients to the stream in the poorly drained Mattock catchment (left) and freely draining karst catchment (right). The thicker arrows represent a larger relative flow component than the thinner arrows. Dashed arrows represent intermittent flow (Copied from Deakin *et al*., 2016).

major issue in public bodies today, in my view)? Rather than 'worrying' about my past failures, it is worthwhile considering the context in which we work today:

- We have a greater knowledge and understanding of Irish groundwater than ever before.
- Groundwater is seen to be vital to ecosystems.
- The proportion of drinking water in Ireland contributed from groundwater will decrease, in my view.
- As food production is water intensive, Ireland has a big advantage for exporting food and therefore gaining the resulting economic benefits.
- The quality of Ireland's surface water is not improving, as required not only the by the Water Framework Directive but also our own wellbeing, and as needed for marketing Ireland's food exports. For instance, 43% of river water bodies haven't reached their required status, and poor groundwater quality is a contributor to this.
- Water is, arguably, the 'new oil'. "*Many of the wars this century were about oil, but those of the next century will be over water*" according to Ismail Serageldin, World Commission for Water in the 21st Century (1995). There have been water riots and deaths in Pakistan, India and north China in recent years. India has 17% of the world population and 4% of world water. The future situation in Palestine and Egypt is disquieting. (Acknowledgement: The source of this point is a readable book by S. Solomon (2011) Water. The Epic Struggle for Wealth, Power and Civilisation.)
- The world population is increasing rapidly and is projected to grow from 7.6 billion today to 10 billion in 2055.
- As for greenhouse gas emissions and climate change, I don't need to elaborate here, but just think of the likelihood of 'population migration' as a consequence and the suffering that this represents. While the effects on Ireland may be less than in many other countries, mitigation and adaption will be essential.
- Etc, etc.

So what! I suggest that: i) as scientists funded largely by the Irish tax payer, whether in the public or private sectors, we have a responsibility to consider and give priority to the needs of Irish society and the Irish environment in our work; and ii) as scientists in a prosperous country, we have an obligation to take account

of the world situation in our lifestyles and work. How we do this is for each of us as individuals to consider, but those of us who are groundwater specialists are lucky enough to have the knowledge and training to (using the cheesy phrase) 'make a difference'.

Looking to the Future

Many of us as children will have been told on occasions 'learn your lessons' or words to that effect! This never had a positive connotation for me. So, enough of some of the negativity in the previous sections of this article. Many issues could be dealt with here and various points made; I will mention five.

Availability of Geoscience Maps and Data

One of the 'joys' of being an 'oldish' geoscientist is the appreciation of the abundance of information and maps that are now available. This may be a simple point to make and maybe I don't need to make it, but because I believe strongly in it I am going to make it – good characterisation of sites and/or areas and the understanding this provides are the building blocks for effective analysis and decision-making. The easy availability and utilisation of a range of geoscience maps and comprehensive information are key to future progress. For those who do not already do so, can I encourage you to check out the GSI and EPA websites at the following links: https://www.gsi.ie/en-ie/programmes-and-projects/groundwater/Pages/default.aspx, https://gis.epa.ie/EPAMaps/, and www.catchments.ie . For anyone working in the public sector, the WFD Application has a wide range of information on water; permission to access this information can be obtained through the EDEN network (https://wfd.edenireland.ie/). Continued adding to and updating this information will no doubt be a priority for the GSI and EPA, and this will aid research and decision-making.

Seeing the Underground as a Pathway for Water and Contaminants

All hydrogeologists are familiar with groundwater as a receptor in itself, and this is the source of most hydrogeological work. Up until recently, assessments of surface water quality issues tended to be based on a simple but incorrect equation that '**pressure = impact**'. However, there has been an increasing appreciation of the role of the 'geology' of an area – the soils, subsoils and bedrock – as the contributor of the **pathway** and groundwater as a potential transmitting and attenuating medium for pollutants in influencing the impact of human activities on surface water and groundwater dependent ecosystems. The main potential pathways are illustrated in Figure 1, where two contrasting scenarios are shown. But this realisation needs to be extended among all disciplines dealing with water management. Hydrogeologists, as scientists who can 'see' and understand the landscape in 3-D, can help facilitate this and in the process increase their role in water management; a 'win, win' situation.

Hydrogeologists as Catchment Scientists

Catchments are at the core of the newly published River Basin Management Plan 2018-2021 (RBMP) (http://www.housing.gov.ie/sites/default/files/publications/files/rbmp_full_reportweb.pdf) and 'Integrated Catchment Management' (ICM) (see Daly *et al*., 2016 for an explanation) is the new approach that is being used to support the development and implementation of the RBMP. A definition that is broader than the traditional topographically- and hydrologically-based one that captures all the elements, including the people is needed. The following is suggested (Daly, 2017): The catchment is a multi-functional, topographically-based, dynamic, multiple-scale socio-biophysical system; defined by over ground and underground hydrology; connecting land, water, ecosystems and people; and used as the basis for environmental analysis, management and governance.

This ICM approach has led to a need for 'catchment scientists'. So, what is catchment science and what type of person is a catchment scientist? According to Deakin (2018), "*Catchment science is the study of the dynamic interactions between the physical catchment landscape, the ecosystems that sit within that landscape, and the human activities that can cause impacts to ecosystems in that landscape. These three elements are all linked within the source pathway receptor framework. The fourth element in the catchment science and*

management nexus is the identification of efficient and effective mitigation measures based on this catchment science understanding. Understanding all the elements within the framework equally, and more importantly the linkages between them, is essential in carrying out the pressure-impact analysis which is central to identifying 'the right measure in the right place'. As pointed out in the same article "*The ideal catchment scientist has a firm knowledge and understanding of all the source, pathway, receptor elements of catchments, a good grounding in appropriate measures, and most importantly, the capacity to integrate, analyse and synthesise the knowledge to gain new understanding for the purposes of answering relevant catchment science and management questions*". The reality is that there are few 'ideal catchment scientists' as all scientists dealing with water have a background in specialist disciplines such as environmental science, biology, hydrogeology, engineering, agricultural science, etc. and have particular experience in the organisations that they have worked in. A new office, called the Local Authority Support and Advisory Team (LASAT), with 43 staff, supported by the Catchments Unit of the EPA and local authority colleagues, is being set up to undertake what is, in effect, catchment science. So, these are progressive and exciting times in water management in Ireland and groundwater scientists and engineers can and must make a significant contribution.

The 'right measure in the right place' and 'multiple benefits'

The 'right measure in the right place' is a key requirement for protecting and, where necessary, improving water quality. The 'one size fits all measures' such as those in the various regulations are necessary, but it is now recognised that they are not sufficient on their own (see the RBMP 2018-2021). These new measures must take account of the biophysical setting, the critical source areas, the issues causing the water quality problem (e.g. P, N, pesticides, sediment) and the value in achieving multiple benefits (e.g. for biodiversity and greenhouse gas emissions as well as water quality). This is a newly developing area and the continued input of groundwater scientists and engineers is needed to meet this challenge.

Putting People and Communities as well as Science at the Core of Environmental Management

In 'looking to the future', this is perhaps the point I feel most strongly about, but also is one that makes me feel positive about that future of younger readers, and my children and grandchildren, as progress will take time. Three quotes are given below as background.

Making scientific progress is essential for the future, but it won't be enough on its own. Local communities and policy makers are the 'people' referred to in the title. For space reasons, I cannot develop the points adequately here; if you are interested see Daly (2017(a) and 2017 (b)) for more details. I have given below a summary of points that give reasons for optimism:

- There is increasing recognition that the participatory approach based on 'social learning' is key to successful environmental management. There are several definitions of 'social learning' (google the phrase for definitions), but the bottom line is that it requires **all** relevant stakeholders (regulators,

"It is people who save rivers, not plans, reports, websites and newsletters..."
Quote adapted from 'Saving Eden: A Manifesto' www.savetheeden.org

"In order to win a person to your cause, you must first reach their heart, the great high road to their reason. This is the only road to victory."
Quote (slightly amended) from Abraham Lincoln

"***The research suggests that social learning is the key to adaptive processes for tackling water and climate change as part of sustainable communities in Europe for the 21st century. This has resonance in many facets of building a more sustainable Europe, including personal consumption, climate change, energy use and nature protection***." (Ó Cinnéide, 2014).

public servants, farmers, farm advisors, local communities, researchers, industrialists, policy makers, NGOs, etc.) to engage with and learn from one another as, according to O'Cinnéide (2014), 'the building of a shared understanding is a necessary pre-condition for common action'.

- Natural Capital Accounting – a necessary alternative to GDP as a measure of economic activity – is becoming a key approach to making the environment an integral part of the economy in Britain and Northern Ireland. It is absolutely essential that this gets further traction in Ireland if future development is to be truly sustainable. While biologists and economists are two of the main disciplines whose input is required, there is also a role for geologists and hydrogeologists to provide input on the abiotic or geosystem services and catchment services components of natural capital; I ask that all of us, particularly those with the responsibility and power, to provide vision, leadership and input.
- Meaningful stakeholder and public engagement on water quality and water protection (including groundwater) is now feasible through the recently-established Water Forum (An Fóram Uisce) and the 18 staff in the Local Authority Waters and Communities Office (LAWCO) (http://watersandcommunities.ie/). In addition, the formation of new Rivers Trusts is an exciting development (https://www.catchments.ie/development-rivers-trusts-ireland/).
- The Smart Farming initiative, which is led by the Irish Farmers Association (see http://smartfarming.ie/), means that "those with the challenge are leading their response to addressing it". This is a well organised effort by the farming community to raise awareness of the environment on farms, undertake measures to protect/improve it, while at the same time benefiting financially.
- The realisation that increasing farming outputs will threaten both water quality and biodiversity and, in the process, hinder achievement of WFD and sustainability objectives as well as the increased outputs planned by Food Wise 2025 has led to the Dairy Sustainability Initiative – a joint industry/farmer/government forum. Some may be cynical about developments such as this; however, keep in mind that agri-industry needs to demonstrate a good (and in some areas improving) quality environment for marketing food products and, in addition, the EPA will be monitoring the water quality outcomes. And, among many involved with this initiative there is a wish to ensure that farming is genuinely sustainable.
- The environmental NGOs, such as SWAN (http://www.swanireland.ie/), are helping to ensure that environmental concerns are taken into account by public bodies and to increase awareness of the environment and the benefits of environmental protection.

Conclusions

The quotes below sum up some of the points I have tried to make in this article:

1. "We can't solve problems by using the same kind of thinking that created them"; Quote from Albert Einstein.
2. "No man/woman made a greater mistake than he/she who, because he/she could do so little, did nothing"; Quote from Edmund Burke (slightly amended).
3. "Keep it simple, make it fun"; Quote from a presentation by Liam Sheedy (former Tipperary hurling manager) given at the 2018 Smart Farming Conference.

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Groundwater Level Fluctuations in Dublin

Gerry Baker, Arup, Dublin

Exploring the ups and downs of groundwater level monitoring in Dublin

There are currently around 70 cranes operating in Dublin's City Centre according to the Irish Times Crane Count. These city centre developments are now more likely to contain deep basements as the planning restrictions on building height and the limited space available forces developments inevitably downwards. As a hydrogeologist I find I am being called upon by geotechnical engineers to provide estimates of *likely* groundwater level fluctuations and peak groundwater levels to inform geotechnical design criteria.

Unfortunately, the site investigation programme for most building developments will have limited groundwater data available and that will more than likely not include monitoring over a long enough period to determine the local seasonal variation in groundwater levels or its response to extreme events.

A review of the EPA Hydronet website (http://www.epa.ie/hydronet) shows there are no groundwater level monitoring stations currently within the M50. Arup understand that Dublin City Council are planning to formalise their requirements as part of the planning process for the assessment of potential impacts of new basements on, amongst other things, groundwater. However, in the absence of adequate baseline data the confidence in these assessments will be limited.

A review of the available groundwater data shows that the nearest locations monitored by the EPA to the city are on the Carton House Estate near Maynooth, Co. Kildare. The monitoring network at that site are part of the Poorly Productive Aquifer monitoring programme which was commissioned in 2009 and comprise three sets of nested monitoring boreholes along a catchment transect. More information can be found from the EPA/CDM Summary Report of 2009 (https://www.epa.ie/pubs/reports/water/ground/ppa/EPA%20Poorly%20Productive%20Aquifers%20Summary%20Report.pdf).

Virtually live groundwater level data is available for the sites on Hydronet in graphical format and the complete dataset from 2009 is also available for download. Arup recently analysed this data to assess the response of groundwater level to extreme events. The RW1 cluster of boreholes is located at the furthest point up-stream of the 3 clusters, approximately 1.5km from the main river in the catchment, the Ryewater. There are three monitoring wells within the cluster including a transition, shallow and deep hole, which have screened intervals between (EPA 2010):

- Deep - 34.4 to 67.4mBGL,
- Shallow – 9.5 to 30.0mBGL,
- Transition - 2.3 to 3.2mBGL.

Chart 1 shows the entire available record for the three boreholes which illustrates groundwater fluctuates between 1.5m to 3.0m below ground. There are frequent sharp dips in the record which are considered to relate to groundwater level response during purging. Unfortunately, this distorts any summary statistics derived for the data and (having tried) it's a very laborious exercise to try and remove these as they are somewhat random in their timing and scale of displacement. It would be beneficial to the data usage if such artificial troughs were omitted to present a more natural representation of the

ambient groundwater level.

A review of the groundwater level maxima shows a significant spike around 24th October 2011 which relates to a storm event. The nearest met station with hourly data available is Casement Aerodrome. The peak rainfall over this storm event was 18mm per hour and the maximum rainfall over 24 consecutive hours was 75mm. This equates to a return period of approximately 72yrs, based on the OPW FSU Web-app. The groundwater levels in the transition zone and shallow bedrock boreholes show a groundwater level increase of 0.78m and 0.63m respectively with a time lag from the peak rainfall of 2 hours and 16 hours respectively.

The recharge for this groundwater body is assumed to be limited by the infiltration capacity of the subsoil and rock. The infiltration capacity can reasonably be assumed to be equivalent to the permeability once the soil moisture deficit is overcome, which is represented by the lag between the commencement of the rainfall and the start of the rising limb of the groundwater hydrograph.

Adopting a permeability value within the range reported for shallow aquifer at the site by GSI ($1.5x10^{-7}$m/s, typical of Calp limestone) results in an infiltration capacity 0.53mm/hr, which is significantly less than the rainfall intensity (up to 18mm/hr). Chart 3 shows the rainfall hydrograph with the recharge rate shown limited by the infiltration capacity and soil moisture deficit.

Flood forecasting design rainfall events are typically expressed as a rainfall intensity over a given duration i.e. the 1 in 50 year 24hr event. If the rainfall intensity reported for the event is higher than the infiltration capacity the maximum recharge possible over the storm duration will be limited by the infiltration capacity, which in the case of RW1 Shallow is 12.7mm at RW1 (i.e. 0.53 mm x 24 hours). This response will be the same for the 50 year, 100 year or 1,000 year design events irrespective of the actual rainfall total or intensity as the groundwater infiltration capacity remains the same. Similarly, no increase is expect due to climate change as this will not affect the bedrock permeability and infiltration capacity.

The estimated groundwater recharge over the 2011 event (11mm) and the observed groundwater level displacement (0.63m) can be compared to derive a specific yield:

Recharge (mm) = Change in water table elevation (mm) x Specific Yield

The resulting specific yield is 1.7% which is the value recommended by GIS Aquifer Properties Manual (2015) for this aquifer type.

This simple assessment demonstrates that groundwater level fluctuations to extreme events can be limited by infiltration capacity. However, there may be other recharge processes for a specific site which could lead to a different response.

In summary, the available data from the EPA has demonstrated the value of long term groundwater monitoring. Some data cleansing is required to rid the hydrographs of artificial troughs. The response of groundwater to extreme events can be complex and therefore extrapolation from short term on site data is not desirable. Given the scale of development in Dublin and the propensity for deep basements in new developments the need for baseline monitoring and characterisation is clear.

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Chart 1: RW1 Groundwater Levels

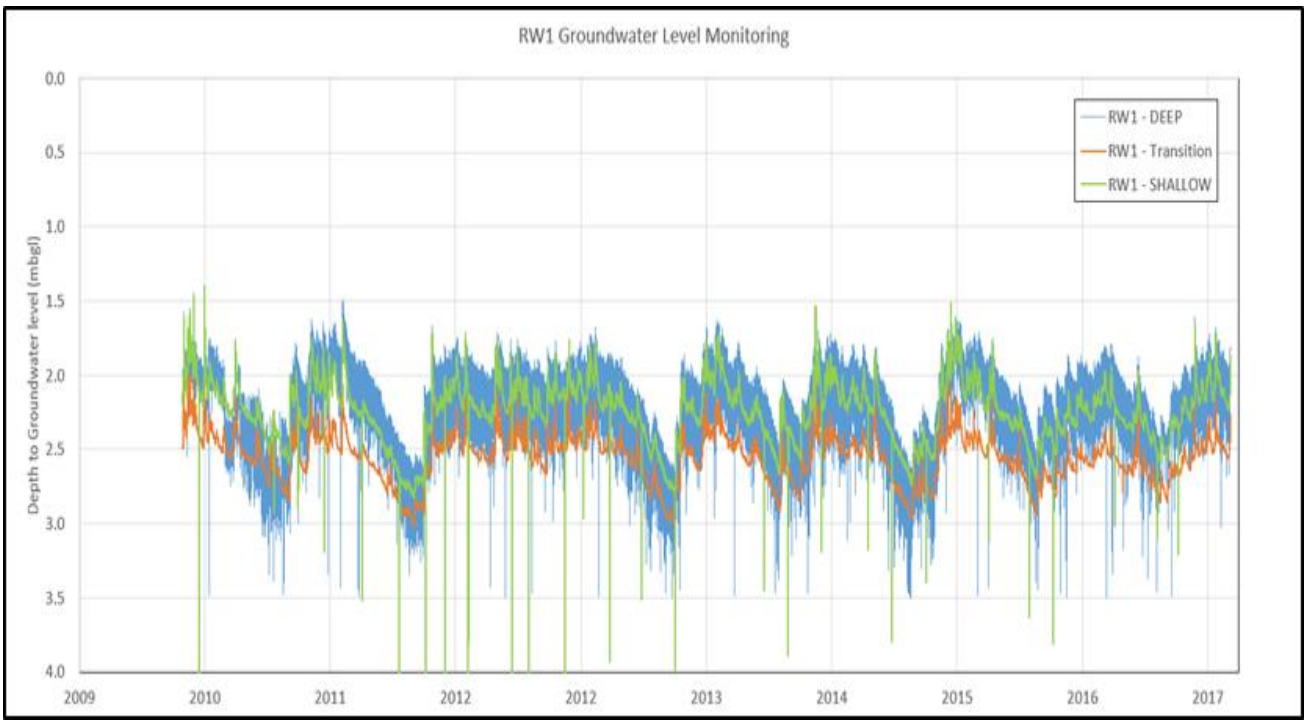


Chart 2: RW1 Groundwater Levels and Recharge

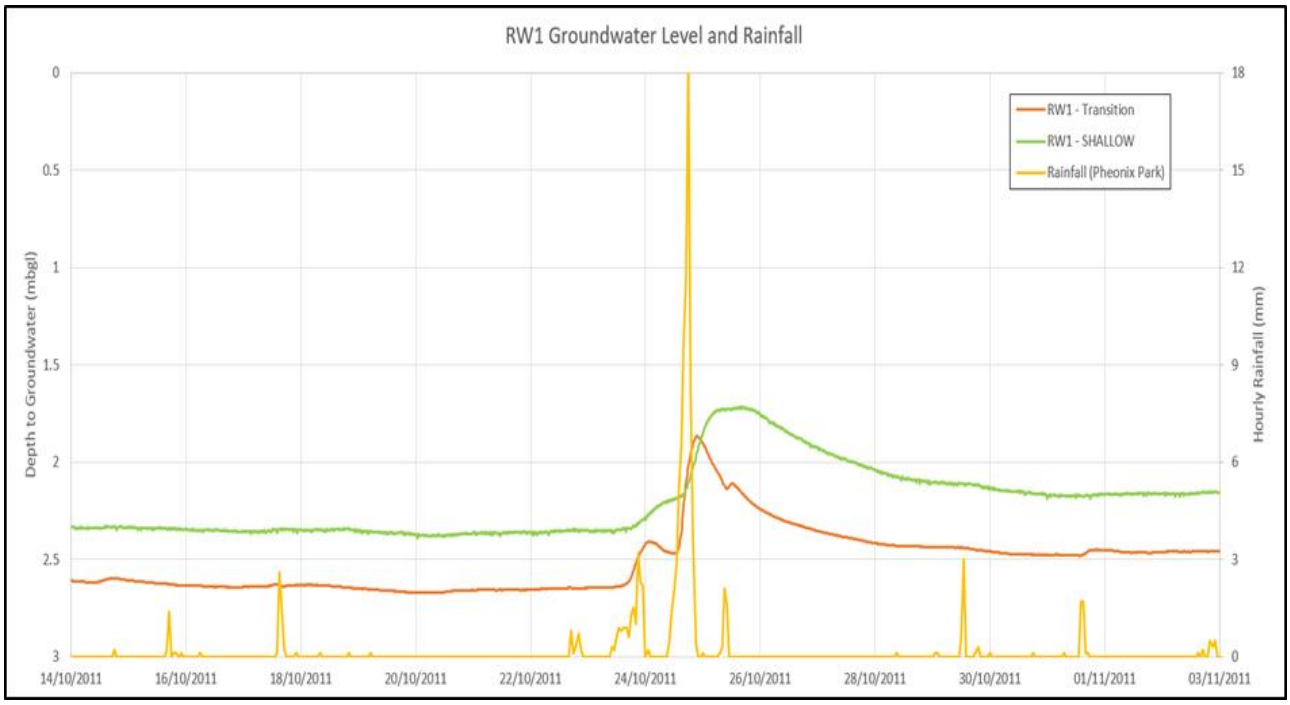
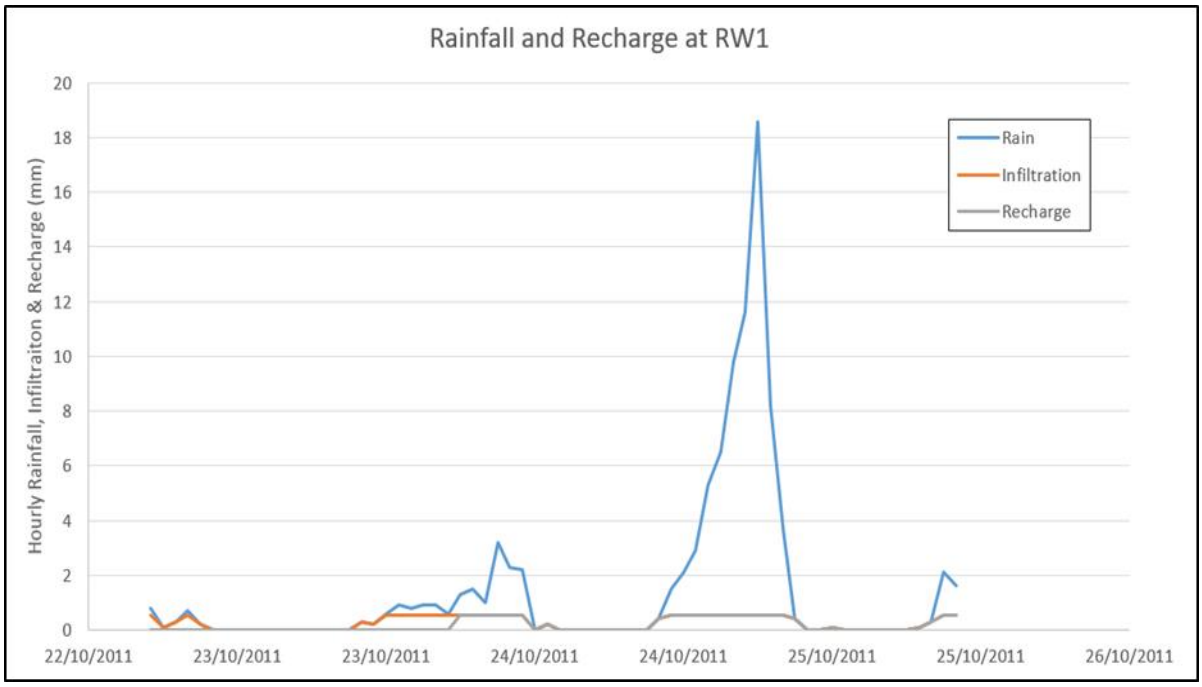


Chart 3: Rainfall and Recharge Estimation for RW1



Drinking Water Safety Plans

Pauline Gillard, EPA.

A tool to provide a risk management framework for secure and safe drinking water.

One of the most challenging and key issues of today is the protection and security of our drinking water resources from pollution.

In Ireland, we have high compliance monitoring that ensures our drinking water is safe at the tap, when it complies with the drinking water quality standards at a certain point in time but how do we ensure that a supply is secure? Compliance monitoring cannot guarantee you that your water supply system continuously delivers safe drinking water. Compliance monitoring is typically done only once or twice a year so therefore it may not reflect drinking water quality between testing dates. Also, the test results will be available only after people have already drunk the water which means that it's too late to prevent people from drinking contaminated water.

Worldwide, the key to protecting our drinking water resources is providing security from source to tap by implementing Drinking Water Safety Plans (DWSP's), which is a multiple level approach as described below. In Ireland 81.5% of drinking water across both public and private water supplies is sourced from surface water (i.e. river and lakes), 18.5% is sourced from groundwater (7% of this being sourced from springs). DWSP's provide a risk management framework to protect the security and safety of a water supply.

The World Health Organisation (WHO) published guidance on the implementation of the DWSP approach in 2009, the document is entitled " *Water Safety Plan Manual: step-by-step Risk Management for Drinking Water Supplies*". The main aim of this approach is to protect human health. If a drinking water supply is contaminated, then many people could be infected and get sick. This approach can be applied irrespective of the type of raw water source used, or the size or the complexity of the drinking water supply. A DWSP provides an initial risk assessment and risk assessment and risk management approach that incorporates all steps in a drinking water supply chain. It provides an assessment of the potential risks to the source, catchment, treatment plant and distribution network through to the consumer's tap. A supply is safe if it meets the water standards by complying with the regulations but a supply is secure when the risks are managed and a plan is in place to deal with any hazardous events. Knowledge of the catchment is key.

The EPA has adopted the World Health Organisation's Water Safety Plan approach. The EPA's Advice Note No. 8 – Developing Drinking Water Safety Plans, provides guidance on the Drinking Water Safety Plan approach and encompasses potential hazardous events from the catchment to the consumer (see EPA Advice Note No 8 (bit.ly/epadwadvice8)). The advice note is intended to give an overview of the steps involved in constructing a Drinking Water Safety Plan and an outline of what it should contain. Drinking Water Safety Plans are also covered in Section 10 of the EPA's 2010 Handbook for Public Water Supplies

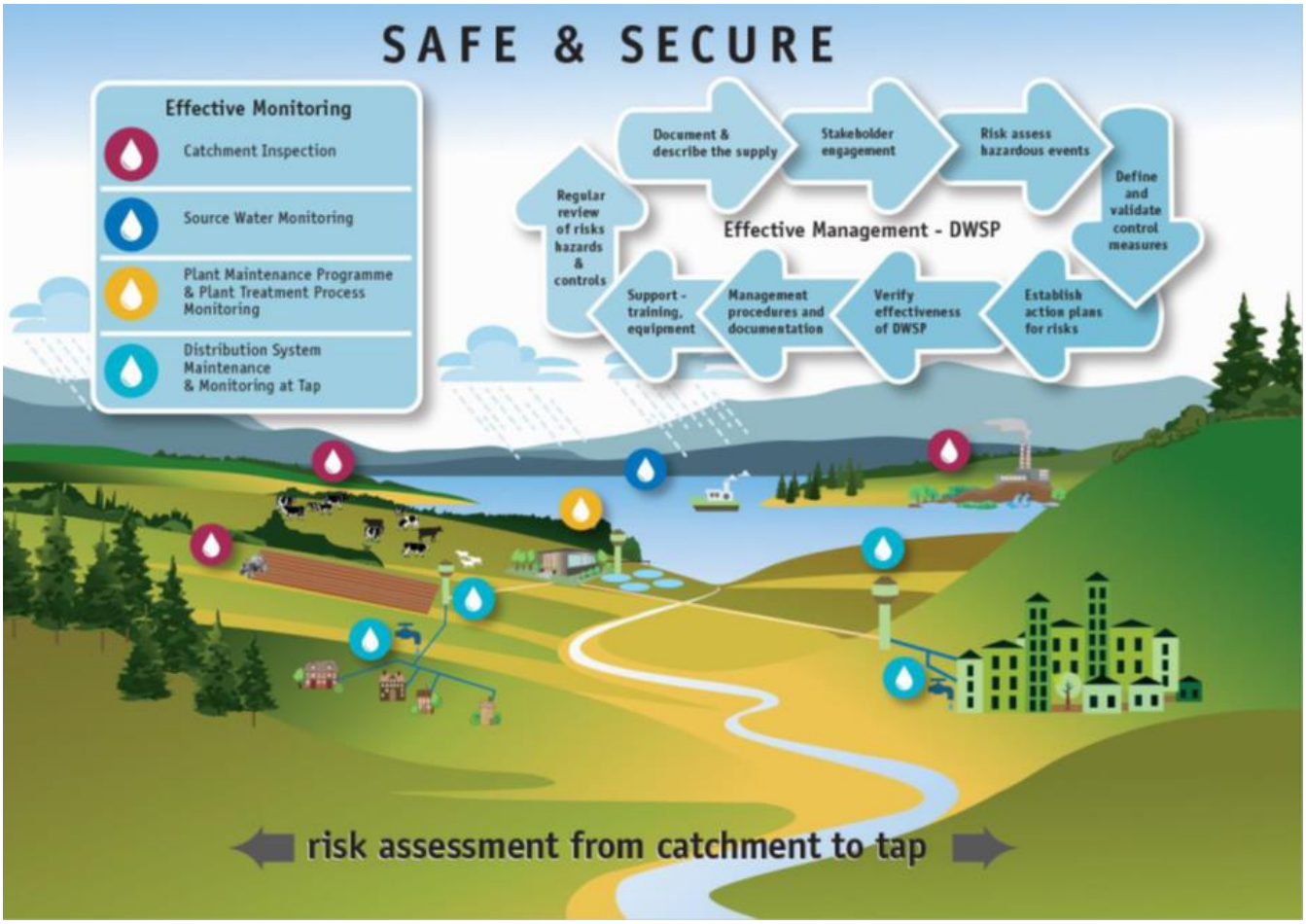


Figure 1: What does a DWSP look like?

(bit.ly/epapublicwaterhandbook).

Security of Public Drinking Water Supplies

How secure are our drinking water supplies? How do we know that our supply remains secure in the intervals between compliance sampling? A DWSP will document all the risks in a supply from source to tap; system assessment and design of the plant, operational monitoring programmes, training, awareness programmes for the catchment and all its users. (See figure 1.) It must be continually reviewed to keep up to date with changes in the catchment.

Responsibility for developing and implementing a DWSP lies with the water supplier. Irish Water implement DWSP's in the public water supplies. The approach allows Irish Water to identify drinking water priorities and to focus resources and investment on the supplies and specific drinking water issues that most need it. Applying DWSP's also provides a technically sound basis for decisions on improvements. The water supplier in many cases is only responsible for part of the water supply system, for example the abstraction, treatment and distribution elements, but the drinking water safety plan team should work with others to ensure that risk assessments are completed for all from catchment to point of use for each water supply system. There must be co-operation from many different parties involved, for example farmers, Local Authorities, government agencies, Waste Water Treatment plants, Licenced facilities, homeowners with septic tanks, and public users of the area. Co-operation and understanding is key to moving for-

Photo 1: Example of good wellhead protection

ward and protecting both the quality and quantity of the future water supply. Successful engagement of such stakeholders will serve a dual role of improving the quality of the raw water source, providing protection of the supply, and assist in meeting Water Framework Directive requirements by maintaining or improving the water quality status.

Case Study

In November 2015, a Boil Water Notice was placed on Kilconnell PWS, Co. Galway following the discovery that the UV disinfection system at the treatment plant was operating outside its validated range. The borehole construction was sub-standard and the corroded steel casing was giving rise to elevated raw water turbidity. Following on from its risk assessment, Irish Water decommissioned the borehole and installed a new alternative existing borehole that provided better raw water quality. The consumers receive adequately disinfected water at all times. The Boil Water Notice was lifted in December 2016.

The alternative borehole source has been demonstrated to have much better raw water quality and is a more stable source than the borehole at the treatment plant. The new wellhead protection works have been completed to a very high standard. (See photo no. 1.) The installation of new UV duty and standby units has resulted in a more robust primary disinfection system. These upgrades have significantly improved the safety and security of the supply. The examples demonstrates how a DWSP establishes a framework to embark on a stepped, investigative approach to find the critical issues and address the in a robust, future-proofing manner, rather than dealing with the 'symptoms' (turbidity) by additional treatment.

Drinking Water Safety Plans and the Water Framework Directive

Article 7 of the Water Framework Directive requires Member States to identify waters used

or to be used for drinking water and provide for their necessary protection (Member States may establish 'Safeguard Zones' for those bodies of water to protect against further deterioration in raw water quality so that, as a minimum, the need for additional water treatment to meet drinking water standards is avoided and ideally the level of treatment can over time be reduced, as shown in the above case study. The delivery of Article 7 objectives will primarily be through measures set out in River Basin Management Plans drawn up for the river basin districts across Ireland under the Water Framework Directive.

The findings from the catchment element of the DWSP risk assessment will be pivotal in identifying Article 7 water supply sources at risk, as the DWSP will identify individual parameters or hazards (e.g. nitrate, pesticides) in the catchment in addition to the identification of generic risks or hazardous events (e.g. agricultural pollution) which introduce those hazards to the water supply. For each unacceptable risk identified, the water supplier will formulate an action plan of short, medium and long term mitigation measures required to reduce the risk to the water supply as part of the DWSP. These mitigation measures can be fed into the Programme of Measures associated with the Water Framework Directives River Basin Management Plans, as they contribute to identifying the 'critical source areas' i.e. where there is both a potential hazard and a likely pathway to the receptor, which in this case would be drinking water supply . All relevant local partners and stakeholders need to engage in the process in identifying long-term sustainable solutions to priority issues that may compromise future water supplies. Whilst there is a specific role for Government, EPA, GSI, Local Authorities and the water supplier it also includes the collaboration of all stakeholders to deliver the necessary improvements, depending on the issues in each catchment. Water suppliers should share the relevant findings on their risk assessments as part of engaging and collaborating with local partners and stakeholders.

Where are we now

The DWSP approach allows Irish Water to identify drinking water priorities and to focus resources and investment on the supplies and specific drinking water issues that most need it. In 2016 Irish Water continued to make progress in the development of DWSPs, increasing the number of assessments from 151 water treatment plants in 2015 to 422 water supplies in 2016. The assessments have ensured high priority issues such as *Cryptosporidium*, lead and THMs are targeted through national programmes, which are putting in place the controls and mitigation measures to address the issues, and to verify their effectiveness. The next steps are to delineate further catchment areas for the surface and groundwater supplies so that the DWPS approach can be applied to those additional catchments.

The Drinking Water Safety Plan approach provides security to the users of the supply, in the quality and quantity of water provided now and for future generations.

Sand and Gravel Aquifer Resource Mapping

Melissa O'Keefe, Sara Raymond, Coran Kelly, Robert Meehan, Damien Doherty, Natalie Duncan, Geological Survey Ireland

Keeping the 3D to the fore of sand and gravel aquifers in Ireland

Background

This article briefly revisits the classification criteria for sand and gravel aquifers in Ireland and outlines the rationale for the current mapping and the mapping methodology. It summarises progress to date in terms of countrywide data collection. The article also includes a prepared report which is based on the GSI Groundwater Body template for one of the recently mapped and delineated aquifers to indicate that for each delineated sand and gravel aquifer there is an associated report documenting the evidence and providing the conceptual model and cross sections.

The field mapping of sand and gravel bodies throughout Ireland, that form both groundwater resources (aquifers) and flow pathways, is one of the priority work tasks being undertaken as part of the 'Groundwater 3D' project of Geological Survey Ireland (Lee *et al.*, 2015; Kelly *et al.*, 2016). The aim of the 'Groundwater 3D' sand and gravel mapping was to consistently delineate sand and gravel aquifers based on available evidence.

Sand and gravel aquifers cover a small percentage of the country. However, they are still a significant resource at a local scale due to the potential for high yielding wells set within them. The presence of these aquifers, particularly in areas where the bedrock aquifer is classified as 'Poor', is significant, as the sand and gravel deposits should be capable of providing higher volumes of groundwater from an alternative source to the bedrock.

An areal depiction of the mapping schedule is given in Figure 1. The work for each area under examination, in summary, consists of a desk study, extensive hydrogeological field mapping (logging exposures, collecting water level data), making observations and inferences on geometry followed by office-based geotechnical data collection, GIS interpretation, map preparation and reporting.

Classification of sand and gravel aquifers

The classification of sand and gravel aquifers in Ireland is based on assessment of the following criteria (Daly, 1995; DELG *et al.,* 1999; O'Suilleabháin, 2000; Wright, 2001):

- The saturated thickness is at least 5 m, or the depth of sorted sand and gravel sediment has a thickness of at least 10 m if the saturated thickness is unknown.
- The areal extent is greater than 1 km^2 (*i.e.* comprising a Locally Important sand and gravel, **Lg**, aquifer). Some exceptions to this do occur.
- If the areal extent is greater than 10 km^2, and the deposit is well-characterised and understood, then the classification changes from a Locally Important sand and gravel aquifer (**Lg**) to a Regionally Important sand and gravel aquifer (**Rg**).
- Assuming an average annual recharge rate of 400 mm per year, the groundwater 'throughput' or 'flux' is in excess of 1,000 m^3/d for a Locally Important Sand and Gravel aquifer (**Lg**), and greater than 10,000 m^3/d for a Regionally Important Sand and Gravel aquifer (**Rg**). It is envisaged that a small group water scheme could abstract sufficient water from an '**Lg**' aquifer and that a public water supply could get sufficient water from an '**Rg**' aquifer. It provides an indication of the total resource available. However, it does not mean that is the absolute volume readily available for abstraction.
- The particle size range is dominated by grain size distributions with less than 7% fines.
- Permeability in the sediments is generally greater than 10^{-4} m/s.

- Other factors considered include the geometry and continuity within each of the sand and gravel bodies. It is generally considered that, using the criteria above, the body can be essentially considered as one single unit.

Mapping and 3-D modelling

As of 2014, the then-available national sand and gravel aquifer map compiled by GSI was highly variable in terms of the level of empirical information available for within each aquifer body, as different bodies had been delineated in different ways and under different levels of scrutiny, owing to a history of varying mapping programmes and strategies within GSI. As well as this, 'full' Quaternary stratigraphic and sedimentological mapping, showing the three-dimensional extent of these sand and gravel bodies, had not been completed for the majority of these areas across the country at the time of delineation.

Such mapping and subsequent characterisation is required to provide field evidence on the true nature of these deposits (*i.e.* thickness, depth to bedrock, depth to water table, degree of grading and bedding, lateral extent and continuity) in the third dimension. Given that the above mapping procedure involves a traversal of the area under question, as well as mapping the extent and depth of the bodies, the investigations should also consider their hydraulic properties in terms of gathering of data on significant groundwater abstractions, springs, private domestic wells, EISs, stratigraphy as ascertained from gravel pits, *etc.*

This more indepth and consistent mapping approach began in 2015 as one of the strands in the 'Groundwater 3D' project and the field mapping is due to be completed by the end of 2018. The work to date includes newly-delineated sand and gravel aquifers, updated areal extents to previously-mapped sand and gravel aquifers and other sand and gravel bodies, and cross sectional 3D assessments of both the aquifer body and the water level information across those bodies. A further task is the subdivision of areas of 'Extreme' and 'High' groundwater vulnerability across the areal extents of all of the 'updated' sand and gravel aquifer areas. Groundwater vulnerability for sand and gravel aquifers is categorised as 'Extreme' where the water table is within 3 m of the ground surface, and as 'High' where the water table is at depths greater than 3 m from the surface (DELG *et al.,* 1999).

Work progress from 2015 until the end of 2017

The field mapping carried out throughout several months in each of 2015, 2016 and 2017 has thus far recorded and logged 1,412 exposures of sand and gravel. Water levels and other available details were recorded at 1,829 well localities. In total, in excess of 680 km^2 of sand and gravel bodies have been systematically mapped, and this has resulted in the mapping of new sand and gravel aquifers and has improved the conceptual understanding of almost all the known sand and gravel bodies previously recorded. As a result there is a better understanding of our national sand and gravel aquifer resource.

It is planned to publish an updated sand and gravel aquifer map online for the areas delineated in 2015 and 2016, during the summer of 2018. The reports for each delineated aquifer will be made available over the coming year. There is significant information collected and collated for sand and gravel deposits that have not been delineated as an aquifer and it is intended to publish this information also in due course.

In Summary:

- Extensive desk studies and the collection of comprehensive swathes of field point data facilitated detailed analysis and 3D interpretation of sand and gravel bodies which has enabled a significantly improved understanding of the body in 3D dimensions.
- This allowed for revised delineation of the extents of documented sand and gravel aquifers and, importantly, the discovery of previously unknown sand and gravel aquifers.
- The work has also enabled much more accurate delineation of areas of 'Extreme' and 'High' groundwater vulnerability within all of those aquifers.
- The national aquifer and national groundwater vulnerability maps will be updated following the completion of this detailed work.
- The geodatabase information is documented thoroughly and is being incorporated into the Land Mapping (Quaternary) and Groundwater geodatabases.

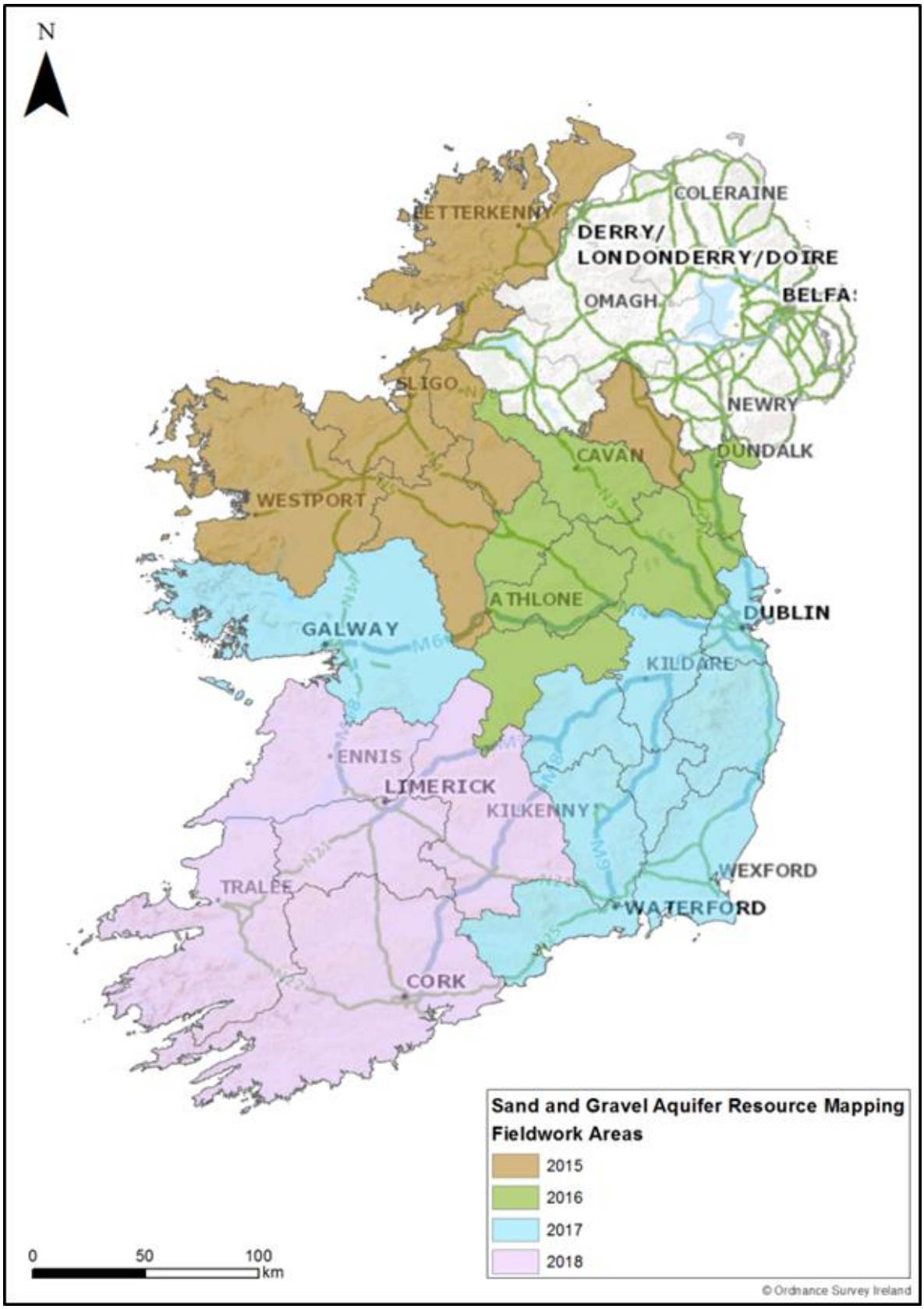


Figure 1. Mapping Schedule

1st Draft Kilmurry Sand and Gravel Aquifer Description March 2017

Kilmurry Sand and Gravel Aquifer: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water features	Associated terrestrial ecosystem(s)	Area (km^2)
07 – Boyne Meath Co. Co. and Kildare Co. Co.	**Rivers;** Blackwater. **Streams;** Togher, Aleckafin. **Lakes;** n/a	Royal Canal NHA	5.38

Topography	This sand and gravel aquifer covers the valley floor of the River Blackwater, along the boundary of southwest County Meath and north County Kildare. The valley is orientated northwest – southeast, and is set among relatively low-lying bedrock-cored ridges at Moyvalley and Newcastle. The ground level across the aquifer extent is situated approximately 30 m beneath the level of outcropping 'Dinantian Upper Impure Limestones' to the northwest at Moyvalley, and 5 - 10 m beneath the level of the 'till derived from Limestones' to the southeast. The sand and gravel body is hummocky, and constitutes a number of wide, flat-topped sub-zones, which coalesce to form the outwash sandur of the deglacial Blackwater River.	
Geology and Aquifers	**Aquifer categories**	There are 12 borehole data points available within the area of this sand and gravel body, with the majority containing geotechnical logs. One borehole records 21 m of sand and gravel with 17 m of this saturated with groundwater. The area of the sand and gravel body which has properties meaning it qualifies as an aquifer occupies approximately just over 5 km^2. Based on its areal extent, inferred thickness, saturated thickness and position in the landscape the deposit is classified as **Locally Important Sand and Gravel Aquifer (Lg)** (DELG/EPA/GSI (1999)).
	Main aquifer lithologies	Glaciofluvial sand and gravels derived from limestone, with some overlying alluvium and lacustrine silts and clays.
	Key structures	n/a
	Key properties	There are 11 water level points available from within the sand and gravel aquifer extent, along with a number of water levels from streams that join with the River Blackwater. The water levels from water wells and boreholes have allowed for inferences to be made on the water levels throughout the body of the sand and gravel aquifer. Particle size analysis plots are available for a number of the boreholes drilled in the body. The percentage of sand and gravel that is greater than 63 µm varies between 50% in the alluvial deposits up to 100% in some sand and gravel samples. Sand and gravel aquifers generally consist of unconsolidated coarse grained material, usually containing less than 8% fines (O'Suilleabháin, 2000).
	Thickness	All of the boreholes indicate that the subsoil thickness is likely to be greater than 10 m over the entire area delibneated as an aquifer.

1st Draft Kilmurry Sand and Gravel Aquifer Description March 2017

Overlying	Lithologies	Mostly sand and gravel at surface, with relatively small portions of land covered with alluvium and lacustrine sediments.
	Thickness	The thicknesses of the alluvium and lacustrine silts and clays are inferred to be less than 2 m.
	% area aquifer near surface	79 % of the aquifer is near the surface with the remaining 21% underneath the alluvium and lacustrine sediments.
	Vulnerability	The groundwater vulnerability of the sand and gravel is 'Extreme' wherever the water table is inferred to be less than 3 m from the ground surface, while in all other areas where the water table is at depths greater than 3 m, the vulnerability is classed as 'High'. With the data outlined above, it is inferred that 81% of the sand and gravel aquifer is "Extreme" in terms of groundwater vulnerability.
Recharge	Main recharge mechanisms	Diffuse recharge occurs *via* rainfall percolating through the unsaturated sand and gravel. Due to the high permeability of sand and gravel, a high proportion of the available recharge will percolate down to the water table.
	Est. recharge rates	The groundwater recharge rate varies between 34 mm/year in the areas covered by alluvium and lacustrine sediments, to 380 mm/year on the sands and gravels themselves.
Discharge	Large springs and large known abstractions (m^3/d)	There are no known large abstractions from this aquifer.
	Main discharge mechanisms	Groundwater is believed to discharge to the River Blackwater and its tributaries that flow through the aquifer.
	Hydrochemical Signature	There are no data readily available to assess the hydrochemistry of this aquifer.
Groundwater Flow Paths		The length of flow paths depend on the extent of the sand and gravel deposit. In general, locally important sand and gravel aquifers are expected to have relatively short flow paths, *i.e.* up to several hundred metres.
Groundwater & Surface water interactions		Groundwater is believed to discharge to the River Blackwater and its tributaries that flow through the aquifer, and in the area where the sand and gravel meets the alluvium, a number of springs are in evidence *e.gKilmorebrannagh.* .
Conceptual model		• The aquifer consists of hummocky sand and gravel deposits and a glacial outwash sandur system. • The deposits stand within the undulating valley floor of the River Blackwater at elevations between 68 m and 81 m AOD. • Sand and gravel thicknesses are inferred to be greater than 10 m over the majority of the body. • Particle size distribution charts prove the aquifer hydraulic properties with some containing 100% of particles greater than 63 µm. • Diffuse recharge occurs *via* rainfall percolating through the unsaturated sand and gravel. • Groundwater is expected to discharge to the River Blackwater and its tributaries, and seems to do so *via* a number of springs.
Attachments		Figure 2: Groundwater vulnerability of the Kilmurry sand and gravel aquifer. Figure 3: 3D conceptual model of the Kilmurry sand and gravel aquifer
Instrumentation		**Stream gauges:** None **EPA Water Level Monitoring boreholes:** None **EPA Representative Monitoring points:** None

1st Draft Kilmurry Sand and Gravel Aquifer Description March 2017

Information Sources	DELG/EPA/GSI (1999) *Groundwater Protection Schemes.* Department of the Environment and Local Government, Environmental Protection Agency and Geological Survey of Ireland. EPA map viewer. http://gis.epa.ie/Envision Geotech Specialists Limited (2000). *N4: Kinnegad-Enfield-Kilcock, Preliminary Site Investigation, Factual Report.* Carried out for Westmeath County Council. NPWS viewer. http://webgis.npws.ie/npwsviewer/ O'Suilleabháin, C., (2000). *Assessing the boundary between high and moderately permeable subsoils.* Unpublished MSc., University of Dublin. Department of Civil, Structural and Environmental Engineering, Trinity College Dublin.
Disclaimer	Note that all calculation and interpretations presented in this report represent estimations and assumptions based on the information sources described above and established hydrogeological formulae. Figures 1 to 4 are used for illustrative purposes only.

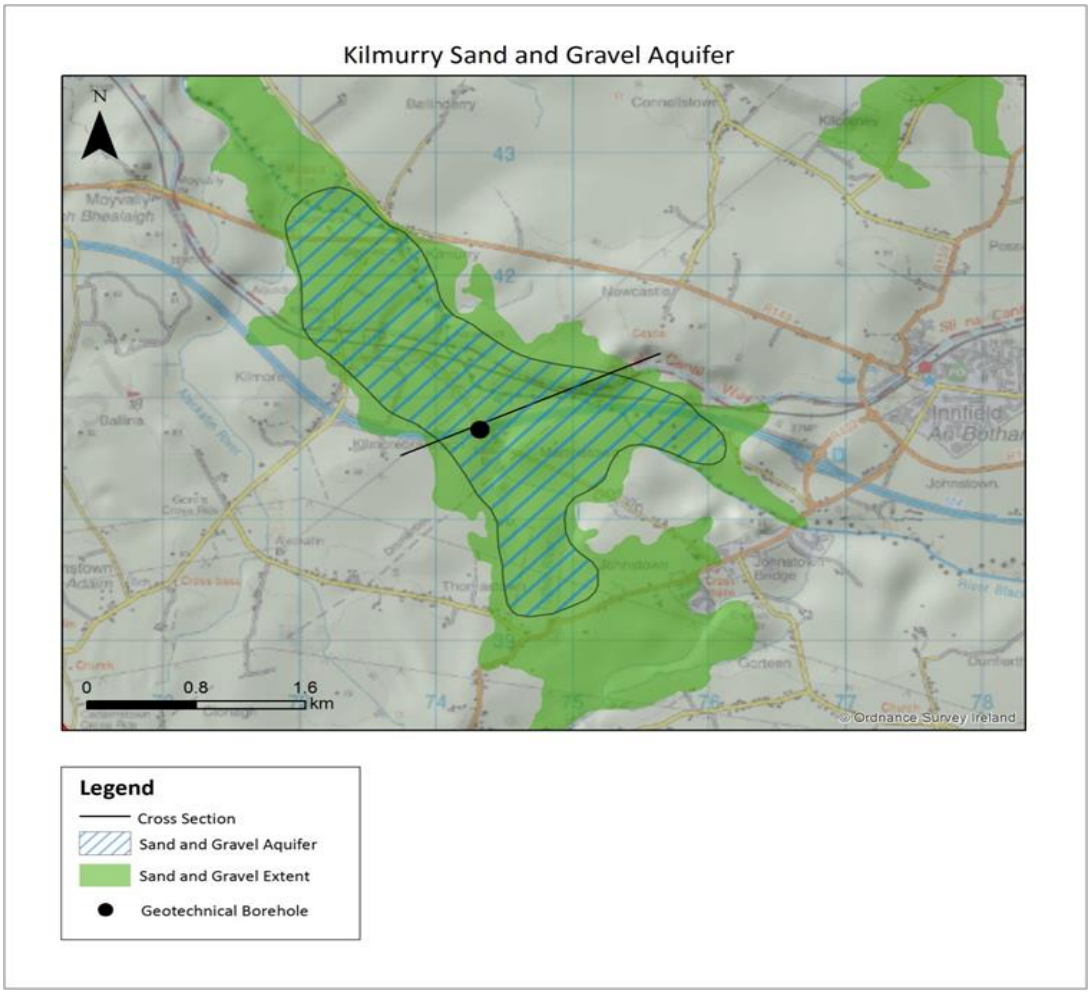


Figure 1: Kilmurry sand and gravel aquifer with cross section location

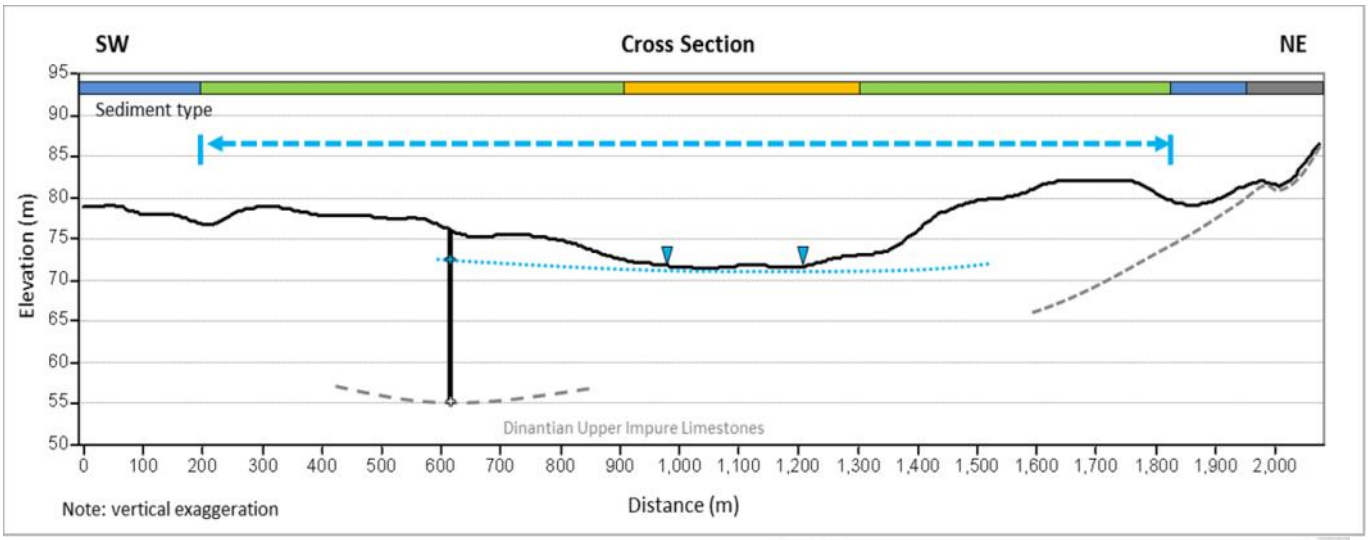
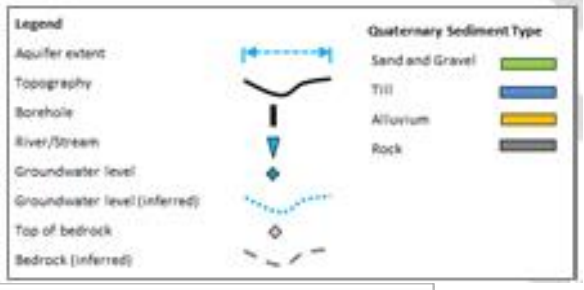


Figure 2: Cross section through the Kilmurry sand and gravel aquifer body



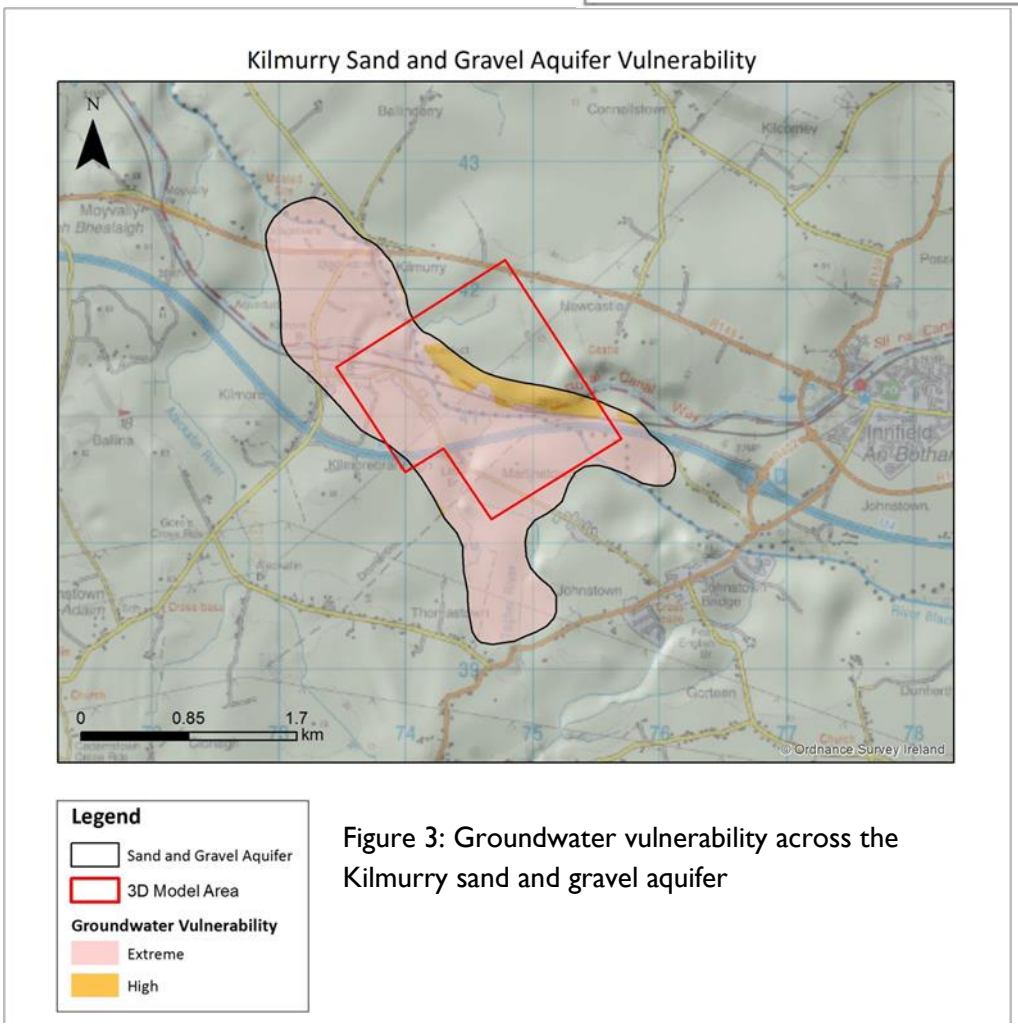


Figure 3: Groundwater vulnerability across the Kilmurry sand and gravel aquifer

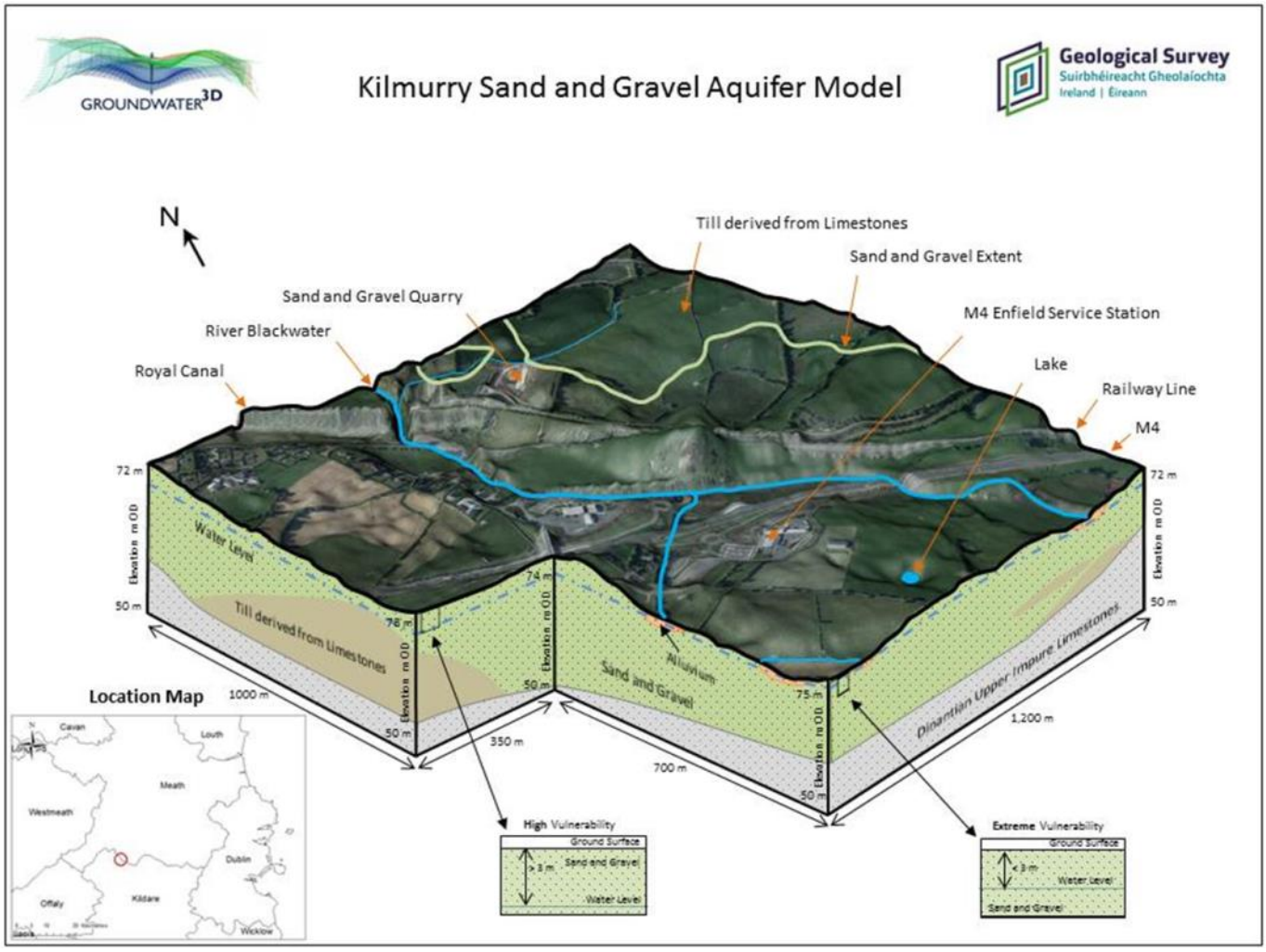


Figure 4: Conceptual 3D Model of the Kilmurry sand and gravel aquifer

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A Standardised Physiographic Units Map for Ireland

Xavier Pellicer and Michael Sheehy, Geological Survey Ireland

An introduction and brief overview of the new national physiograhic units map.

The Geological Survey Ireland's Quaternary Programme has just published Physiographic Units Maps on the Geological Survey's web viewer (https://dcenr.maps.arcgis.com/apps/webappviewer/index.html?id=afa76a420fc54877843aca1bc075c62b)

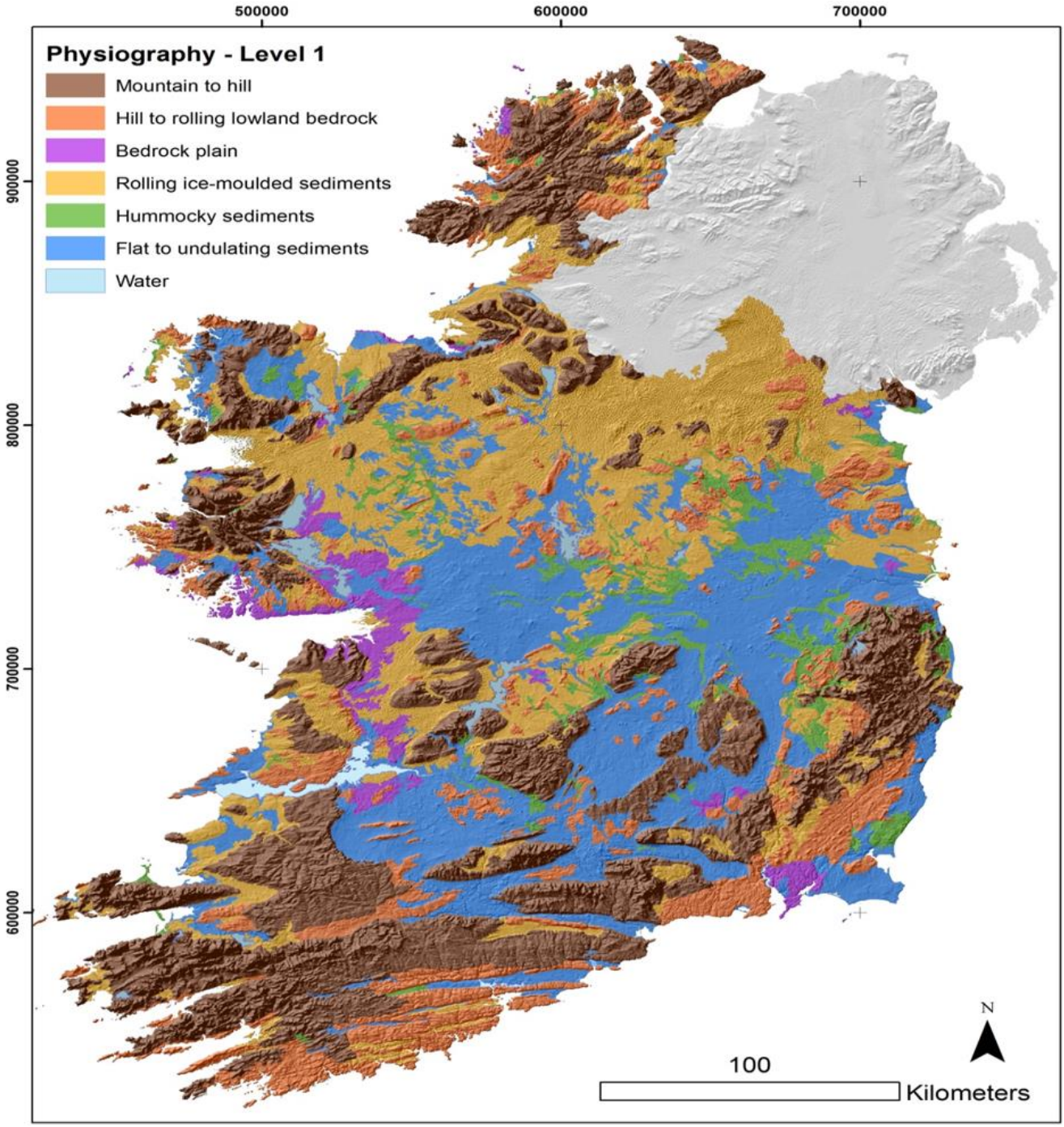
The need for 'landscape unit' type of map has long been recognised and several local and regional scale maps have been developed for specific needs over the years. However, this is the first national, standardised map in Ireland, the catalyst for which

Table 1. Physiographic Units Hierarchical Scheme

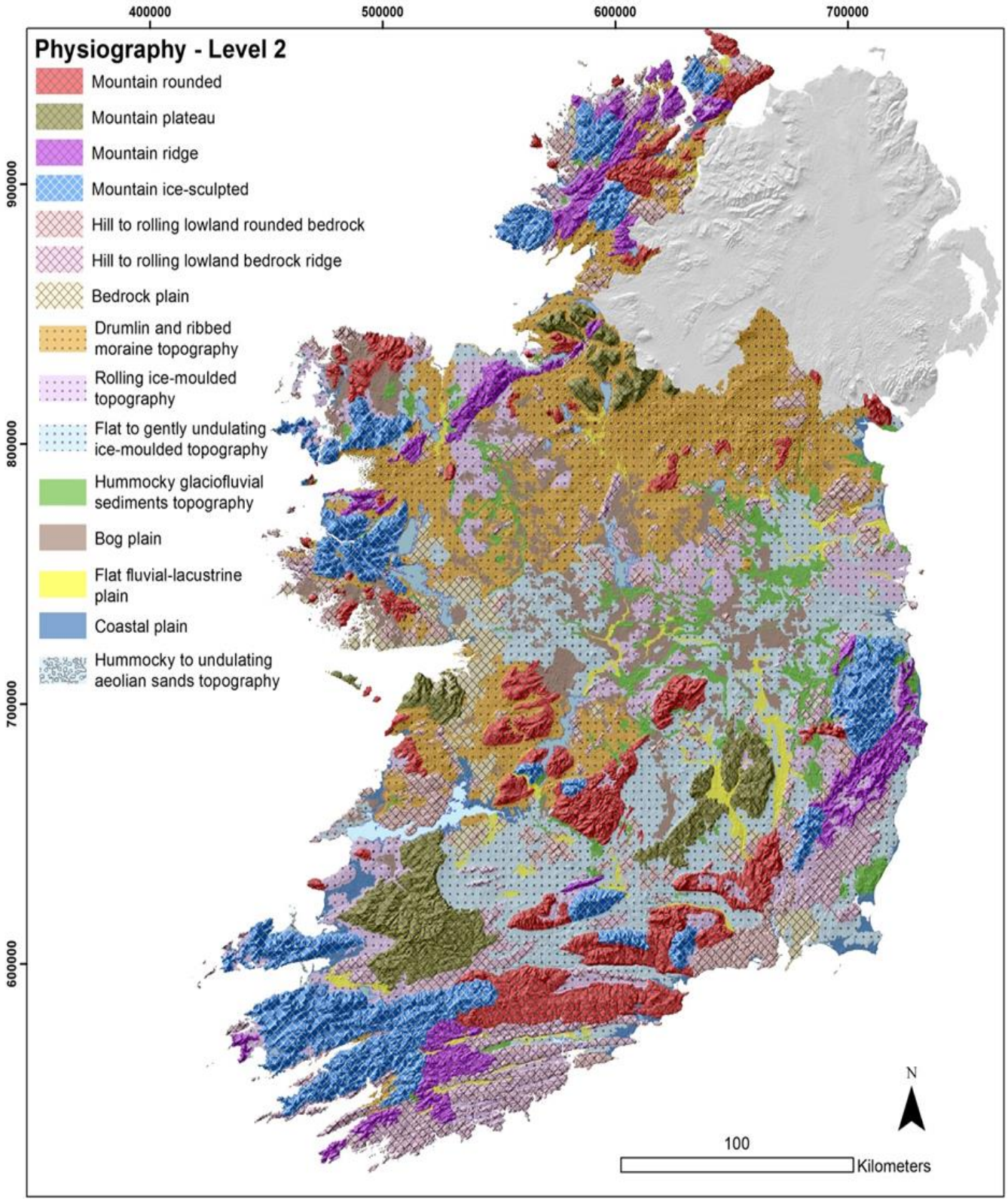
	LEVEL 1	LEVEL 2	LEVEL 3
Bedrock dominated landscape	Mountain to hill	Mountain rounded	Mountain rounded
			Mountain streamlined rounded
		Mountain plateau	Mountain plateau
			Mountain streamlined plateau
		Mountain ridge	Mountain ridge
			Mountain streamlined ridge
		Mountain ice-sculpted	Mountain ice-sculpted ridge
			Mountain ice-sculpted U-shaped valley
	Hill to rolling lowland bedrock	Hill to rolling lowland rounded bedrock	Hill to rolling lowland rounded bedrock
			Hill to rolling lowland rounded streamlined bedrock
		Hill to rolling lowland bedrock ridge	Hill to rolling lowland bedrock ridge
			Hill to rolling lowland bedrock streamlined ridge
	Bedrock plain	Bedrock plain	Bedrock plain
			Bedrock streamlined plain
Sediments dominated landscape	Rolling ice-moulded sediments	Drumlin and ribbed moraine topography	Ribbed moraine
			Drumlinised ribbed moraine
			Drumlins
		gently rolling ice-moulded topography	Megascale lineations
			Gently rolling landscape
	Hummocky sediments	Hummocky glaciofluvial sediments	Esker ridge and associated landforms
			Hummocky ice-marginal sediments
		Hummocky postglacial sediments	Hummocky to undulating aeolian sands
	Undulating to flat sediments	Flat to gently undulating ice-moulded topography	Flat to gently undulating glacial sediments
		Flat (glacio)fluvial-lacustrine plain	Flat alluvial-glaciofluvial plain
			Flat alluvial-lacustrine plain
		Coastal plain	Coastal plain
		Bog plain	Raised bog
			Atlantic blanket bog

Articles

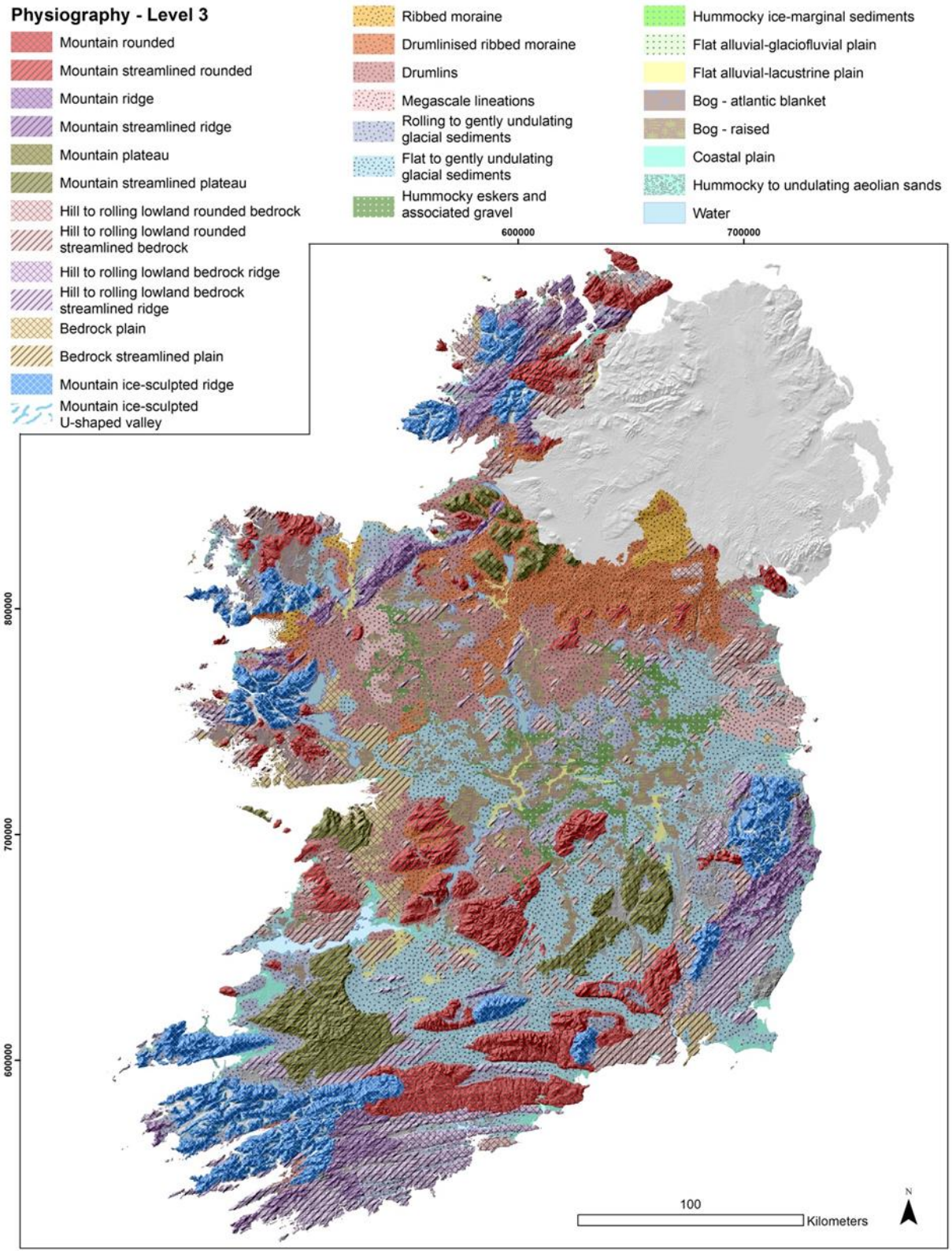
was the Water Framework directive's requirement for Hydromorphological assessments (which use landscape units in their methodology. The Physiographic Units Maps delineate broad-scale, physical landscape units that are based on geomorphological and geological influences. There are three maps representing a three-tier, hierarchical, landscape classification schemes (Table 1). Level 1 (Map 1) is the more basic level, identifying 6 different physiographic categories. This expands to Level 2 (15 categories: Map 2) and then the more complex Level 3 (28 categories: Map 3). By providing different levels of complexity in the three maps, this product can be used by a wide range of end users depending on the level of detail required. The units were mapped at 1:100,000 scale in order to be represented as a cartographic digital map at 1:250,000 scale.



Map 1 – Physiographic units map of Ireland illustrated with Level 1 classification scheme.



Map 2 – Physiographic units map of Ireland illustrated with Level 2 classification scheme.



Map 3 – Physiographic units map of Ireland illustrated with level 3 classification scheme.

New Research in Hydrogeology

This section of the Irish Groundwater Newsletter contains summary reports on hydrogeological research being carried out in Ireland. Due to the multi-institutional nature of many of the projects there is an inevitable overlap between some of the reports. Many thanks to the individuals who coordinated the reports from each institution. If you know of research which should be included please contact the editors at groundwaternewsletter@gsi.ie.

Current research areas related to groundwater in Earth and Ocean Sciences (EOS) at NUI Galway can be grouped under four headings: metals in groundwater; engineering aspects of shallow karst; groundwater in coastal dune systems; and, stakeholder engagement in the integrated catchment management process.

Metals in Groundwater

Ellen McGrory (supervised by Liam Morrison) is completing her Griffiths-funded PhD which is focused on arsenic concentration, distribution and species in the Clew Bay and North Louth areas. Alex Russell (iCRAG PhD student supervised in UCD by Frank McDermott) presented at IGRM2018 on a GSI-short call funded project working on arsenic occurrence in cores recovered in the Louth project area (Tiernan Henry and Liam Morrison are co-PI's on Alex's project).

Tiernan Henry and John Murray are co-PIs (along with Frank McDermott) on another iCRAG project that started in September 2016. Seán Wheeler is looking at the chemistry of historic mine-water makes, initially at Lisheen and Galmoy. Seán is exploring the gross chemistry and will be assessing more subtle relationships between metals to better understand the pathways and sources of these formation waters (he presented his initial work at this year's IGRM in UCC). He will be starting isotope work on samples recovered at different depths from Tara to consider the relationships between groundwater ages and chemical makeup.

Engineering Aspects of Shallow Karst

Megan Dolan started an iCRAG-funded MSc in December 2017. Her project is focused on considering a buried, shallow valley that was uncovered during the site investigation phase for the Galway City bypass. The valley is several hundred metres long, about 100m deep and about 100m wide and is completely infilled with a mix of fine and coarse sediments. Megan will be logging recovered core in detail, assessing paleoenvironments and – if possible – ageing the various infill layers. She will also be completing a series assessments of rock properties, and contextualising the location from a hydrogeological perspective. Megan's project is co-supervised by Tiernan Henry, John Murray and Eve Daly (from EOS) along with Bryan McCabe (Civil Engineering). Megan presented a poster outlining her project at IGRM2018 in UCC.

In a related area, recent PhD graduate (funded by Griffiths) Yvonne O'Connell has recently published a paper on the use of marine and terrestrial geophysical techniques in coastal karst aquifers.

Groundwater in coastal dune systems

Tiernan Henry is part of an EPA-funded (2014-CCRP-MS.22) research project (headed up by Eugene Farrell in NUI Galway Geography) looking at the response and recovery of coastal catchment ecosystems to the impacts of large storms. The study area is Doogort on the north side of Achill island. Tiernan has installed a number of loggers in piezometer tubes across the dune complex to assess groundwater flow direction, and response to terrestrial drainage and seawater inflows. The project is now in write-up

stage. O'Connell, Y., Brown, C., Henry, T. & Daly, E. (2018). Terrestrial and marine electrical resistivity to identify groundwater pathways in coastal karst aquifers. *Near Surface Geophysics, 16, 2, pp 1-12. DOI: 10.3997/1873-0604.2017062*

Stakeholder engagement in the integrated catchment management process

The catchment-mapping project funded by the Burren and Cliffs of Moher UNESCO Geopark through EU Life is now completed. This community based research project focused on catchment mapping with TY secondary school students from Lisdoonvarna. Grainne Barron taught the TY students to use QGIS and they have been compiling catchment maps of the Aille River (their catchment). The students presented their work to the 2017 European Geopark Network conference were joint winners in the (Senior) Water section of the 2017 ECO-UNESCO Young Environmentalist Awards held in the Mansion House. Tiernan Henry was awarded funding under the SFI Discover programme to develop the project into a broader mapping programme that could be completed independently in any secondary school. Grainne Barron is now working as an RA on this project, developing a toolkit for teachers and students, class plans and support materials.

General

Over the past year a more collaborative and iterative approach has developed among the various iCRAG researchers and students based in TCD (in Engineering and Geography) and those in NUIG, along with other EOS staff (Rachel Cave, Triona McGrath and Clynt Gregory in particular). Data and outputs from the Griffiths project related to the coastal zone along south Galway Bay are now being built on by iCRAG projects, and the various aspects of coastal karst are being explored in a coherent and collegiate way. A number of the recent EOS graduates are completing groundwater MSc programmes in Strathclyde, Newcastle and Birmingham, and EOS graduates worked on the TELLUS data collection programme.

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

The Schools of Natural Sciences and Engineering in Trinity College continue as a major partner in the SFI funded Irish Centre for Research in Applied Geosciences - iCRAG. This is funding 5 ongoing groundwater related PhD research projects and one postdoctoral researcher led by TCD, supervised by Catherine Coxon, Laurence Gill, Bruce Misstear, and Carlos Rocha (see details below), on the subjects of flow pathways through karst aquifers, groundwater terrestrial dependent ecosystems, contamination of karst springs by on-site wastewater, submarine groundwater discharge and 3-D modelling (see: http://icrag-centre.org/).

Two new GSI Short Call research grants were awarded towards the end of 2017, one on tracing from Poll Gonzo cave on the Burren, the other on identifying human contaminants in karst systems (details below).

A new EPA research project on groundwater dependent ecosystems has been awarded to TCD (PI Laurence Gill) entitled EcoMetrics.

A team from TCD is competing in the international Karst Modelling Challenge which was set up by Pierre-Yves Jeannin (SISKA) with the aim of identifying the most effective approach for modelling karst aquifers in different situations (details below).

A karst modelling workshop was held in TCD (28th February to 1st March 2017) given by Neven Kresic and Sorab Panday which covered problems and solutions in numeric modeling of karst aquifers, using Modflow USG (UnStructuredGrids) with Connected Linear Networks (CLNs).

Bruce Misstear continues as the Secretary General of IAH. He is working to increase outreach activities between IAH and other organisations involved in water science, policy and manage-

ment.

All TCD-based research projects within the SFI funded Irish Centre for Research in Applied Geosciences (iCRAG) are ongoing since last year, as follows:

Characterisation of diffuse recharge into karst aquifers using chemical and numerical modeling techniques

[PhD student: Philip Schuler (schulerp@tcd.ie) Supervisors: Laurence Gill (laurence.gill@tcd.ie) Paul Johnston (pjhnston@tcd.ie)]

The project aims to differentiate between diffuse and conduit flow pathways into a karst network using both chemical (isotopic and trace element water quality) and spring hydrograph source separation techniques. The aim is then to develop numerical models of different karst networks with a focus on characterising the fissure flow more accurately as well as linking this to contaminant transport. Fieldwork is being carried out on the Bell Harbour catchment in the Burren in which some significant findings with respect to multi-level submarine discharge from the catchment have been hypothesised, in addition to the Ballindine spring catchment (Co. Mayo) with slower more diffuse autogenic input and the Manorhamilton catchment (Co. Leitrim).

A Geological Survey Ireland (GSI) Research Short Call 2017 has also been awarded to Laurence Gill and Philip Schuler linked to this project entitled Submarine groundwater discharge from the Burren plateau into Galway Bay. This is focused on carrying out tracer studies from the Poll Gonzo cave system near Carran and the nearby newly discovered Deelin pot.

Impacts of changing climate on groundwater recharge in low storativity fractured-rock aquifers

[PhD student: Èlia Cantoni (cantonil@tcd.ie) Supervisor: Bruce Misstear (bmisster@tcd.ie)]

The aim is to investigate the effects of forecast changes in climate parameters on groundwater recharge. The project objectives are to investigate:

1. How bedrock properties affect the response of Irish aquifers to present and future recharge.
2. How climate change impacts on our regional groundwater resources.
3. How climate change impacts on dependent wetlands (GWDTEs).
4. How climate change impacts on Source Protection Areas (SPAs).

Work to date has focussed on catchment selection and then sensitivity analysis of impacts of changing climatic and hydrogeological parameters on groundwater recharge using a GIS platform.

Emerging organic contaminants arising in rural environments: investigations in karst and fractured bedrock aquifers

[PhD student: Damien Mooney (mooneyd2@tcd.ie) Supervisor: Catherine Coxon (cecoxon@tcd.ie), Co-supervisors: Karl Richards & Per-Erik Mellander (Teagasc Johnstown Castle), Martin Danaher (Teagasc Ashtown), Laurence Gill (TCD)]

This project is investigating the occurrence of agro-chemicals in Irish karst and fractured bedrock aquifers, focussing on veterinary pharmaceuticals. Following the pilot sampling for anthelmintic drugs in autumn 2016, a fuller spatial investigation was undertaken in March – April 2017, with collection of 122 samples from 106 sites (88 groundwater sites and 18 surface water sites). Sixteen out of 40 anthelmintic compounds tested for were detected, at concentrations of 1-41 ng/l, with detections at 18% of groundwater sites and 39% of surface water sites. Monthly sampling of karst springs for anthelmintics is currently under way. Method development for a second group of veterinary pharmaceuticals, anticoccidials (primarily used in poultry production) is nearing completion, and sampling for these compounds will be undertaken in 2018.

The impact of on-site wastewater effluent on karst springs

[PhD student: Luka Vucinic (vucinicl@tcd.ie)

Supervisors: Laurence Gill (laurence.gill@tcd.ie) & Catherine Coxon (cecoxon@tcd.ie)]

This research aims to characterise the diffuse recharge from DWTS effluent in order to develop a better understanding of risk of the groundwater pollutant contamination and linked risks to human health from such sanitation systems. To date 8 karst springs, across a range of different catchment scale and karstic network geomorphologies are being sampled on a monthly basis over a range of hydrological events to determine contribution of on-site effluent contaminants by chemical biochemical and microbiological fingerprinting methodologies. In addition, a Geological Survey Ireland (GSI) Research Short Call 2017 has been awarded to David O'Connell (TCD) and Luka Vucinic, entitled Fluorescence-based tracking of particles from domestic wastewater treatment system plumes discharging to springs in karst aquifer systems, which complements this project.

Ecosystem services provided by groundwater dependent wetlands in karst areas

[PhD student: Fabio Delle Grazie (dellegrf@tcd.ie) Supervisors: Laurence Gill (laurence.gill@tcd.ie) & Owen Naughton (naughto@tcd.ie)]

This research aims to identify and quantify the ecosystem services associated with turloughs, particularly in relation to the need for habitat conservation in the face of external pressures associated with agriculture, road drainage schemes, water supply and wastewater disposal. The primary aim of the research will be to develop a framework that outlines the methodology and actions to be undertaken when attempting to assess damage from external pressures. Research to date has focused on quantifying the soil as well as water quality parameters of a suite of around 20 turloughs.

Effects of Groundwater-Surface water Interactions (GSI) on the biogeochemistry of coastal areas hosting aquaculture activities

[PhD student: Maxime Savatier (savatiem@tcd.ie) Supervisor: Carlos Rocha (rochac@tcd.ie)]

This research continues and aims to refine the developed approaches to incorporate the biogeochemical role of aquaculture in mitigating N pollution from land and quantify its potential value as a component of natural capital. Fieldwork is being carried out in Kinvara Bay (south Galway) and Killary fjord.

Visualisation of flow and contaminant transport through karst aquifers

[Postdoctoral researcher: Lea Duran (duranl@tcd.ie) Supervisor: Laurence Gill (laurence.gill@tcd.ie)]

This research project aims to develop a state of the art modelling methodology in order to make the groundwater flow and contaminant transport through karst aquifers more understandable by means of visual 3D models. This is being applied to a number of Irish karstic catchments in order to shed light on their hydrologic operation. To date 3D models are being developed of Ballindine and Manorhamilton spring catchments using Modflow USG (UnStructuredGrids) with Connected Linear Networks (CLNs). These are being compared to semi-distributed pipe network models of the karst aquifer system built on the Infoworks modelling software.

Karst Modelling Challenge

[Contact Laurence Gill (laurence.gill@tcd.ie), Lea Duran (duranl@tcd.ie) & Philip Schuler (schulerp@tcd.ie)].

A team from TCD is competing in the the Karst Modelling Challenge which was set up by Pierre-Yves Jeannin of the Swiss Institute for Speleology and Karst Studies (SISKA) with the aim of identifying the most effective approach for modelling karst aquifers in different situations. As such, competing teams have been given access to the same rainfall-discharge measurements from the Milandre cave stream catchment in Switzerland and asked to model the aquifer behaviour using their own preferred approach. The TCD team's approach has been to develop a hydraulic / hydrological semi-distributed pipe network model of the karst aquifer system. The first round of results will be presented at the *Eurokarst 2018* conference in Besancon, France.

Other groundwater research projects (i.e. non-iCRAG)

The Environmental Engineering research group has completed the EPA funded project (ref. 2012 -W-MS-12) to quantify the impact of on-site wastewater effluent on rivers and wells with the final report now in press. This project focused on studying private wells across four different areas, two characterised as Low vulnerability (in Counties Wexford and Cavan) and two characterised as Extreme vulnerability (in Counties Wexford and Kilkenny). 216 wells were sampled for contamination as well as surveyed for pollutant source susceptibility. 24 wells of these wells have been sampled once per month since September 2016 to build up a temporal picture. The research has also identified appropriate chemical and/or microbiological fingerprinting methods (in collaboration with the Dept. of Microbiology in NUIG) for on-site effluent contaminants in both surface water and groundwater environments. Final report due out in next two months. Contact: Chris Fennell (fennelca@tcd.ie), Bruce Misstear (bmisster@tcd.ie), Laurence Gill (laurence.gill@tcd.ie), Donata Dubber (dubberd@tcd.ie).

The Geological Survey of Ireland under the Department of Communications, Climate Action and Environment continues to partner with the Environmental Engineering research group on a 3 year project to establish a groundwater flood monitoring and modelling programme for Ireland. This project is focussed on monitoring the flooding regime of turloughs in the west of Ireland as well as the development of numerical models which can be used to provide the fundamental technical knowledge and information necessary to enable the development of appropriate groundwater flood mitigation measures, and allow for informed flood assessments to be made in future. Work is ongoing on the development of a 2D model of the south Galway lowland karst system which will be used to compare different flood alleviation options, as well as prediction of and remote sensing of turlough delineation. Contact Ted McCormack (mccormte@gsi.ie), Owen Naughton (naughto@tcd.ie), Patrick Morrissey (morrispj@tcd.ie) and Laurence Gill (laurence.gill@tcd.ie).

An EPA funded project entitled *EcoMetrics - environmental supporting conditions for Groundwater Dependent Terrestrial Ecosystems* started in April 2017 led by the Environmental Engineering research group and School of Natural Sciences in Trinity College. The aim of the research is to define appropriate metrics for the different GWDTEs - fens, raised bogs and turloughs. To date, the research has started to apply Remote Sensing data to characterise different ecotopes across raised bogs, as well as starting fieldwork on four calcareous fen sites in order to establish the nutrient and/or drainage pressures on them.

Contact, Laurence Gill (laurence.gill@tcd.ie), Shane Regan (regans@tcd.ie) and PhD researchers Ella Bijkerk (bijkerke@tcd.ie) and Saheba Bhatnagar (sbhatnag@tcd.ie)

Finally, research by the Environmental Engineering group also continues into the transport and attenuation of on-site effluent contaminants with a new project in collaboration with the Dept. of Mathematics in Limerick to develop numerical models of pollutant transport from on-site systems to groundwater. Two instrumented field sites in County Limerick in different soil types are being continuously monitored to determine vadose zone contaminant transport and attenuation with an additional field site in north County Dublin recently constructed and instrumented. Contacts Laurence Gill (laurence.gill@tcd.ie), Jan Knappe: (jan.knappe@tcd.ie), Andrew Fowler (andrew.fowler@ul.ie

iCRAG
IRISH CENTRE FOR RESEARCH IN APPLIED GEOSCIENCES

ICRAG (Frank McDermott and John Walsh)

The new Irish Centre for Research in Applied Geosciences (iCRAG) was established in 2015 by Science Foundation Ireland (SFI) with funding of €18m along with an additional €8m from industry partners: the Science Foundation Ireland Re-

search Centres Programme is co-funded under the European Regional Development Fund. The overall aim of iCRAG is to transform applied geoscience research in Ireland, delivering economic impact for a broad range of application areas and industries.

The iCRAG research programme spans a spectrum of application areas linked to Applied Geosciences. Research 'spokes' in Raw Materials, Marine, Groundwater and Hydrocarbons are built around four enabling 'platforms' within the iCRAG Hub, including Geophysics, Geochemistry, 3D Model datasets and Public Perception/ Understanding (see Figure 1). A new Geohazards and Geotechnical Engineering spoke broadened the scope of our research from 2017, with funding of ca €1.2M jointly supported by SFI, GSI and industry. Spokes were selected to build on demonstrable islands of scientific excellence and to leverage the maximum economic impact for Ireland. The groundwater research spoke is being led by Laurence Gill (TCD) and Frank McDermott (UCD), with other Principal Investigators being Bruce Misstear (TCD), Catherine Coxon (TCD), Carlos Rocha (TCD), John Walsh (UCD), Tiernan Henry (NUIG) and Karl Richards (Teagasc): our research is mainly conducted in the context of PhD projects started within the last 2 years. This research programme has been devised to provide innovative methodologies, measurements and models to improve our understanding of ongoing and future threats to groundwater quantity and quality. This will allow improved forecasting of the impacts of contemporary environmental challenges such as land-use change (e.g. agricultural intensification) and climate change.

Our research focusses on the hydrogeology of fractured/fissured aquifers in order to characterise both flow and contaminant transport processes more accurately. Related research on karst imaging and characterisation is also performed in our Geohazards and Geotechnical Engineering spoke. In addition, we hope to initiate a PhD Programme on Environmental Geosciences by the end of 2018, with ca 8 PhD students jointly funded by SFI and GSI. The overall Groundwater research programme has been sub-divided into two generic topics relating to the quantity and quality of water, which umbrella several individual research projects, as follows:

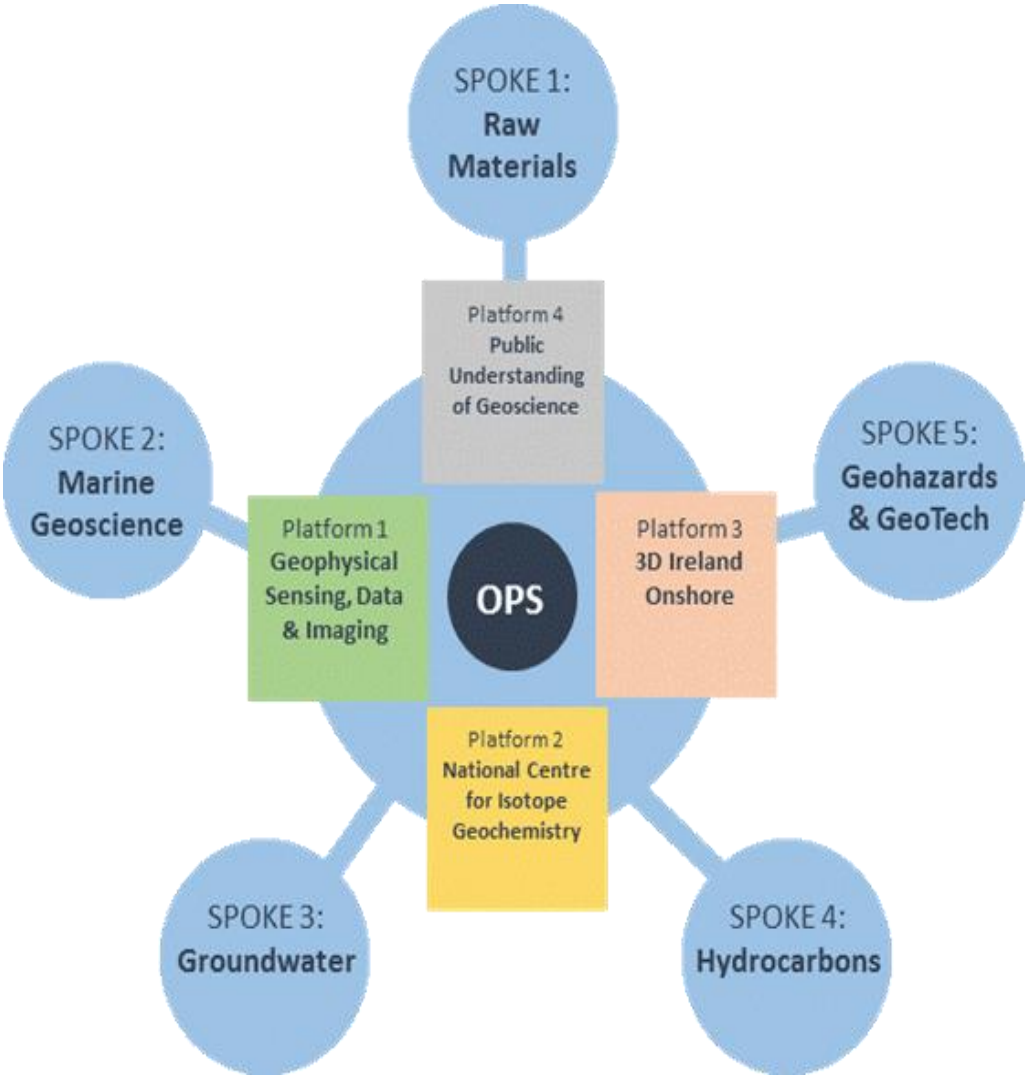
Geological & Climate Change Impacts on Groundwater Quantity

- Characterisation of diffuse recharge into karst aquifers using chemical and numerical modeling techniques [Philip Schuler; Laurence Gill]
- Impacts of changing climate on groundwater recharge in low storativity fractured-rock aquifers [Elia Cantoni; Bruce Misstear]
- Ecosystem services provided by groundwater dependent wetlands in karst areas [Fabio Delle Gracie; Laurence Gill]
- Quantification of the flow and recharge characteristics of potential geothermal system. [Sarah Blake; John Walsh]
- Quantitative assessment of the impact of faults and related karst networks on groundwater flow [John Walsh
- Visualisation of flow and contaminant transport through karst aquifers [Lea Duran; Laurence Gill]

Land-use & Climate Change Impacts on Groundwater Quality

- Emerging organic contaminants arising in rural environments: investigations in karst and fractured bedrock aquifers [Damien Mooney; Catherine Coxon & Karl Richards]
- An investigation of arsenic sources, speciation and mobilization processes in selected Irish aquifers [Alex Russell; Frank McDermott]
- An investigation of uranium occurrence, sources and mobilization processes in selected Irish groundwaters [Fani Papageorgiou; Frank McDermott]
- The impact of on-site wastewater effluent on karst springs [Luca Vucinic; Laurence Gill]

- An investigation of metal occurrence, sources and mobilization processes in selected Irish groundwaters associated with mines [Sean Wheeler; Tiernan Henry]
- Effects of Groundwater-Surface water Interactions (GSI) on the biogeochemistry of coastal areas hosting aquaculture activities [Mariateresa Guerra; Carlos Rocha]
- Contribution of Submarine Groundwater Discharge (SGD) to the marine carbonate biogeochemistry of western Irish coastal seas. [Maxime Savatier; Carlos Rocha]
- Linked laboratory and field investigate of engineered nanomaterial (ENM) behaviour in selected soils and groundwaters. [Frank McDermott]



Hydrogeological News

This section of the newsletter contains news of interest to hydrogeologists in Ireland. It includes short reports on the recent activities of the IAH Irish Chapter as well as the IAH International. It also includes other groundwater related material such as new publications that may be of interest and where groundwater has featured in the media. If you are involved in, or aware of, any items which may be of relevance for this section of the newsletter please contact the editors at groundwaternewsletter@gsi.ie

Irish landscape revealed by 3D laser mapping technology

Launch of Open Topographical Data Viewer: Geological Survey Ireland, National Monument Service, National Parks and Wildlife Service and Discovery Programme

Geological Survey Ireland has built Ireland's first Open Topographic Data Viewer. The viewer was launched by Seán Kyne, Minister for Natural Resources, on the 24th April at the annual meeting of the International Association of Hydrogeologists (Irish Branch), Tullamore.

The Open Topographic Data Viewer project is a collaboration between Geological Survey Ireland (GSI), the Department of Culture, Heritage and Gaeltacht's National Monuments Service (NMS) and National Parks and Wildlife Service (NPWS) and The Discovery Programme: Centre for Archaeology and Innovation Ireland within the remit of the Heritage Council.

These organisations are keen to make all of their high resolution topographic data freely available. The datasets are in the form of Digital Terrain Models and Digital Surface Models, which have been processed from LiDAR (light detecting and ranging) data.

The main aim is to host LiDAR from all interested government and non-government organisations and to build up a mosaic of available data across the country. Therefore, the launch of the viewer actually highlights the beginning of this project. LiDAR data are expensive and sometime difficult to acquire as it is remotely sensed from an aircraft, which can be affected by poor weather conditions. Organisations will generally commission data collection campaigns over very focused areas for a specific project. Therefore, a large part of this programme will be to continue to promote the benefits of the viewer. This will require an on-going and sustained effort but should be very worthwhile.

The benefit of LiDAR data and its derived high resolution topographic data are already nationally and internationally recognised with uses including highly detailed mapping of natural and man-made surface features; field-scale changes in slopes, which support agricultural practice, infrastructure planning and development, and flood assessments; habitat mapping and forestry resource assessments.

Michael MacDonagh, Chief Archaeologist in the Department of Culture, Heritage and the Gaeltacht welcomed the collaboration and the access to this new mapping data – "The benefits of LiDAR imagery to survey, management and protection of archaeological sites is already well established. This new access to such high resolution imagery at a country-wide scale is a very exciting development. The mapping resource will be of significant benefit to archaeological research across the 3rd level sector and other organisations and heralds a new period of exciting archaeological exploration and mapping. It will assist greatly in the protection of our archaeological resource and provide accurate survey information for infrastructural providers to allow them to plan projects sustainably, complementing the various open-access archaeological survey platforms already managed by the Department."

"Mapping our diverse and precious habitats and ecosystems, especially where they are at risk, has become more and more important," noted Dr. Ciaran O'Keeffe from the National Parks and Wildlife Service. "This will help to ensure that we can look after the environment that supports many vital species, such as pollinators, and that enriches our own lives on a daily basis. For example, the National Parks and Wildlife Service use LiDAR data to design the restoration works

to repair the hydrological balance on raised bogs, and this makes efficient project budgeting, scheduling and implementation possible. It also helps us to explain to our stakeholders what we are doing, and allay any fears in relation to potential changes in the water table in adjacent lands."

Shane Carey, GSI's LiDAR data manager, highlighted that "Geological Survey Ireland use LiDAR data specifically to map geological features, which are not only interesting and feed into our publically available maps, but also provide important planning information to reduce the risk of certain hazards occurring – building houses over areas of possible geological collapse for example". The maps are also used to identify possible flood extents around turloughs, which are a karst feature almost unique to Ireland.

The overarching benefits of the viewer were summed up by Koen Verbruggen, Director of the Geological Survey: "These high quality topographic maps are not only fascinating to look at, but making them freely available will definitely stimulate new research and improve existing mapping, products and techniques. Another important point is that having all of the data displayed at one location will prevent costly duplication of LiDAR data collection, which has already occurred in some locations".

The topographic data from The Discovery Programme, which includes data donated by the Heritage Council and Meath County Council, Geological Survey Ireland, National Monuments Service and National Parks and Wildlife Service are now freely available to download from this online portal, which is hosted on Geological Survey Ireland's website (https://tinyurl.com/opentopographicdataviewer). A number of other organisations have expressed their interest in making their data available through the web viewer and the next update is already being planned.

www.gsi.ie

www.discoveryprogramme.ie

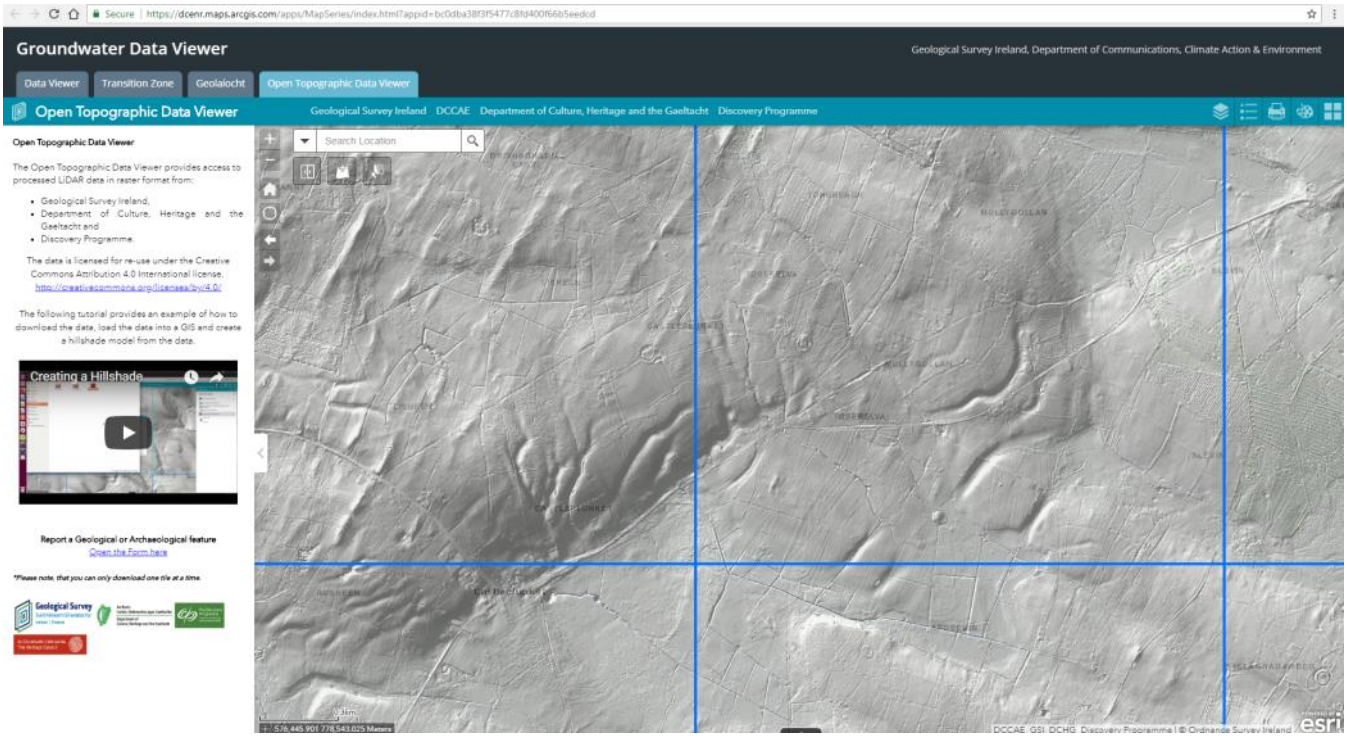
www.heritagecouncil.ie

www.chg.gov.ie/heritage/national-monuments-service

www.archaeology.ie

www.chg.gov.ie/heritage/national-parks-wildlife

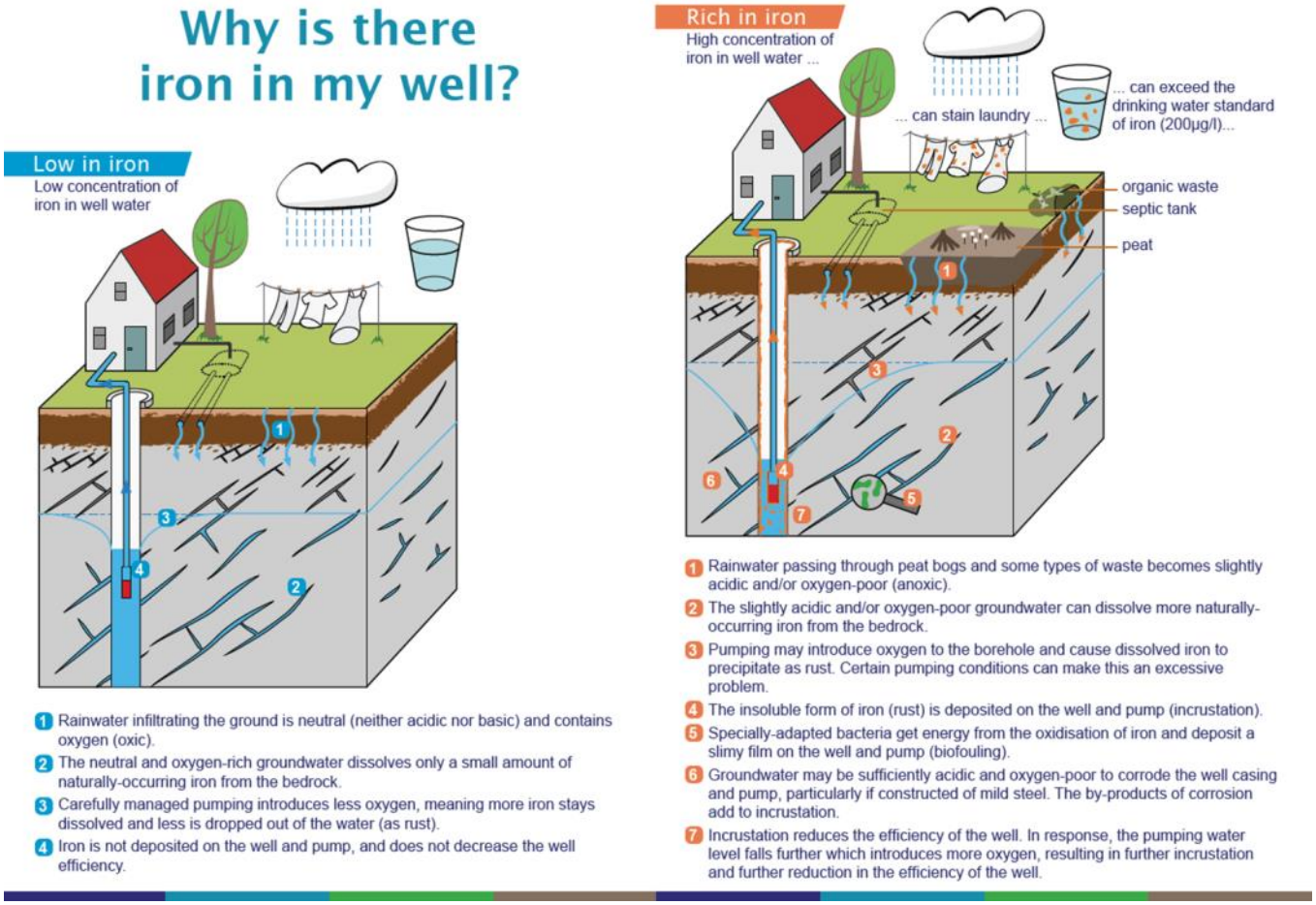
www.npws.ie/about-npws



GSI information leaflet on Iron in Groundwater

Geological Survey Ireland has prepared an information leaflet for well owners whose wells have excessive iron concentrations. The Iron leaflet explains the presence of iron in groundwater, the issues it can raise and ways to manage iron rich groundwater supplies. This is a useful guide for private well owners managing their groundwater supply.

The information leaflet may be found on the GSI website:
https://www.gsi.ie/en-ie/programmes-and-projects/groundwater/Pages/default.aspx



Forthcoming book on the karst of Ireland

Following a prolonged gestation a book entitled Karst of Ireland: Landscape - Hydrogeology - Methods is due to be published by GSI this summer. The book is intended to reflect the importance of karst in Ireland, not simply in terms of the widespread occurrence of karst aquifers but also in terms of the relationships between karst waters, surface water and ecosystems and in geotechnical investigations in karst terrains. Unlike for most other aquifer types, karst hydrogeology cannot be fully understood apart from its geomorphological framework and therefore the book encompasses both the hydrogeology and geomorphology of karsts. There is also a summary of the methods of investigation into karst hydrogeology that have proved to be most effective under Irish conditions. The idea for the book came from Donal Daly during his time at the E.P.A, (see his remarks on page 5 of this Newsletter) and was subsequently taken up by GSI.

It is hoped to launch the book in the autumn, possibly at the TDM held jointly with the Geotechnical Society.

Irish Group

IAH (Irish Group) update

Barry Sexton - Secretary

The 2017 AGM was held on the 14th of November in the GSI. It was well attended despite the fact that the Irish soccer team were in a crucial world cup playoff with Denmark at the same time. As part of the AGM new members were elected to the committee. John Dillon (Tobin) was elected as the treasurer and Sonja Masterson was elected to position of educational and publicity secretary. Alison Orr and Orla Murphy (ARUP) were elected to the Conference Sub-Committee and Damian Doherty (GSI) was elected the educational and publicity sub-committee.

The newly elected committee members were elected to fill the vacancies left by the departure of Orla O'Connell, Dominica Baird and Sara Casey who had reached the end of their terms.

The committee would like to express their sincere thanks for the level of commitment, support and hard work from the three departing members over the last three to four years.

There was great discussion at the AGM relating to several issues including IAH Outreach, Themes for the 2018 Conference, Irish Water and the proposed IT Carlow Drilling Course.

As ever we are trying to increase the level of outreach between the IAH and the public, local authorities, Irish Water and Policy Makers. If there are any members that may have suggestions or ideas relating to this please let us know by contacting the education and publicity secretary educationandpublicity@iah-ireland.org

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.

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If you are involved in an event which you would like to be advertised in the groundwater newsletter please email details to groundwaternewsletter@gsi.ie

Upcoming Events

2018

20-21 Jun 2018	**EPA national water event** "Pathways to progress" - Galway Bay hotel http://www.epa.ie/pubs/reports/other/events/oee/nationalwaterevent2018/Water%20Conference%20Programme%202018%20revised.pdf
18-22 June 2018	26th **International Karstological School** "Classical Karst" http://iks.zrc-sazu.si/en/
2-6 Jul 2018	**EuroKarst 2018** conference, Besancon, France, 2-6th July http://www.eurokarst.org/
18-20 Sep 2018	**National Ploughing Championships** - Screggan, Offaly http://www.npa.ie/wp-content/uploads/2018/03/Rates-INDOOR-Exibition-2018.pdf
9-14 Sep 2018	**IAH congress** - Groundwater and Life: Science and Technology into Action –Daejeon, Korea http://iah2017.org/
TBC Oct 2018	**IAH Irish Group** programme of monthly **Technical Discussion Meetings** www.iah-ireland.org or @iah_ireland for further information Email tdm@iah-ireland.org to be added to TDM mailing list
TBC Oct 2018	**IAH Irish group** fieldtrip Contact Robbie Meehan fieldtrip@iah-ireland.org for more information
TBC Nov 2018	**Geoscience Conference** - Dublin Castle https://www.gsi.ie/en-ie/events-and-news/annual-events/Pages/Geoscience-Conference.aspx
20th Nov 2018	**National Hydrology Conference, Midlands (venue to be confirmed)** http://hydrologyireland.ie/

The editors welcome feedback on the contents of the newsletter, as well as suggestions for contributions to the next issue.

Please contact: Groundwaternewsletter@gsi.ie

Contributions for the next issue should arrive before **24 Jan 2019.**