Keeping groundwater sustainable under multi-functional pressures

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(incorporating the 2015 NGWA Darcy and IAH Ineson lectures)

Abstracts

Oil, gas and groundwater: a perspective on risks

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There continues to be apprehension about the prospect of developing unconventional sources of oil and gas in the UK. Some have noted the lack of solid, peer reviewed research and the often disputed information that circulates in the public domain. If unconventional sources of hydrocarbons are to be exploited successfully, research needs to show clearly that the real and perceived risks are well understood: a high level of certainty is needed to persuade an increasingly sceptical public that these sources of energy are needed and that the exploitation technologies can be managed safely.

Much of the concern stems from the US, where operations have been linked to environmental impacts. There is an acceptance that groundwater contamination has occurred, but disagreement over sources and mechanisms, and the timing of incidents. Advocates of the industry in the UK point to the lack of baseline data and alleged poor oversight of activities in the US. It is maintained that the more robust regulatory regime in the UK will prevent similar occurrences here.

Many in the UK would argue that the case is yet to be proven. There is a need to establish baseline conditions and to understand the mechanisms for transport of pollutants, as a basis for controlling risks. The development of technically defensible guidance is crucial in demonstrating how operational practice can meet the standards that are demanded. Supporting evidence needs to be based on 'responsible science' and, ideally, a high level of consensus should be sought. Objective articulation of risks and comparison with other industries will help ensure perspective – but without better attempts to engage with an undecided audience, current perceptions may well persist.

Geological Disposal and Groundwater: What we need to know

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This presentation provides an overview of the consideration of groundwater in the siting of facilities for the geological disposal of higher activity radioactive waste. To identify sites where a geological disposal facility (GDF) could be located, the UK Government favours a voluntarist approach based on working with communities that are willing to participate in the siting process.

A GDF is a highly engineered underground facility located deep below ground which isolates radioactive waste within multiple protective barriers. These barriers include the waste form, waste containers, engineered backfill and the geosphere. Therefore a site must have suitable geology to enable us to demonstrate to the regulators that it will be safe. A key aspect of the suitability is ensuring the sustainability of groundwater resources over the very long timescales involved.

In 2014 RWM launched a two-year national geological screening exercise, which aims to provide communities with high level and existing information about the UK geology that is relevant to the long-term safety of a GDF. A public consultation on the national geological screening Guidance was launched on 8 September and will run until 4 December. The Guidance sets out the safety requirements to which the geological environment contributes, the geological attributes that are relevant to meeting these safety requirements and how the information will be assembled and presented.

Later in the GDF siting process, for those communities that come forward, extensive, detailed investigative work will be required to identify and characterise potentially suitable sites to a sufficiently detailed level to support the development of a GDF. The investigations will include non-intrusive aerial and ground-based geophysical surveys as well as borehole drilling and testing. The approach to characterising particularly the hydrogeological aspects of a potential site will focus on the needs of the sustainable engineering design and long-term nuclear safety case.

National Ground Water Association 2015 Darcy lecture

Evaluating the Competitive Use of the Subsurface: The Influence of Energy Storage and Production in Groundwater

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The talk describes how advanced numerical models may be used to analyze and predict the mutual influence of subsurface projects and their impact on groundwater reservoirs, and the increasing need to do so. The subsurface is being increasingly utilized both as a resource and as an energy and waste repository. With increasing exploitation, resource conflicts are becoming increasingly common and complex, such as thermal energy storage and the effects surrounding hydraulic fracturing in both geothermal and shale gas production.

The lecture covers possible utilization conflicts in subsurface systems and how groundwater is affected. The fundamental properties and functions of a compositional multiphase system in a porous medium; basic multiscale and multi-physics concepts are introduced and conservation laws formulated; and how large-scale simulation that shows the general applicability of the modelling concepts of such complicated natural systems, especially the impact on the groundwater of simultaneously using geothermal energy and storing chemical and thermal energy, and how such real large-scale systems provide a good environment for balancing the efficiency potential and possible weaknesses of the approaches discussed.

NAPLs – Here to stay?

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L/DNAPLs - light/dense non-aqueous phase liquids - have proven to be particularly troublesome groundwater contaminants. Examples include degreasing solvents such as the now-notorious TCE (trichloroethene), coal-tar creosotes and hydrocarbon fuels and oils. Whilst hydrocarbons use still remains globally ubiquitous and accidental spillages may still occur, the use of many DNAPLs has been in significant decline. On-going concerns typically then relate to the persistence of slowly dissolving legacy NAPL that may have resided in the subsurface for decades. Particularly difficult and persistent NAPL source zones may be expected to occur where large quantities of NAPL mass exist in discrete layers / pools, where there is poor flushing of low permeability units holding secondary source zone diffused mass, where the intrinsic solubility of the NAPL is low, and where clean-up is challenging (even perhaps nigh impossible), for example, DNAPL lost deep within any of the UK's principal aquifers. "NAPLs – here to stay?" is hence a pertinent question to ask in the longer-term management of sites and the protection and use of wider groundwater resources and, also, the recognition that difficult NAPL problem sources will inevitably pass to the next generation despite sustainability ideals. This question is gently explored amongst a presentation of field- and laboratory-based NAPLs research I became intertwined with and have enjoyed since meeting the 2015 Ineson Lecturer a few years ago.

Lost urban streams and springs buried beneath our feet – and what to do with them

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Watercourses have been buried in culverts beneath towns and cities around the world to make way for urban development, to tame floodwaters, and to sanitise urban rivers that had often become disease-ridden open sewers. This is a radical change in the water landscapes of our urban areas – streams, rivers and natural springs lost in both a physical and socio-cultural sense, largely forgotten by people who live and work above them.

Some streams and springs were not only buried in culverts, but deliberately converted or diverted into sewer networks. This clean water robs capacity from sewers, increasing the risk of flooding and sewage spills, and increasing the costs of wastewater treatment. This represents another source of clean baseflow into combined sewers that, until now, has not been widely considered by the water industry. Unlike the more widely known infiltration-inflow of groundwater leaking into sewers through pipe cracks and defective joints, this deliberate "capture" brings unique challenges in identifying and removing it.

This talk draws on recent research from a case study in the city of Sheffield, UK, that shows that half the original stream length and hundreds of natural springs have been lost from the surface. New methods have been developed, including hydrochemical water typing, to identify several sites where streams and springs have been captured.

We now understand that the burial of urban watercourses has resulted in numerous negative impacts. Case studies and experience from around the world demonstrate that there are many environmental, social and economic benefits of "daylighting" these lost streams and springs, separating them from sewer networks in cases where they have been captured, and using them to enhance urban space and design our cities to be water resilient.

Getting the buggers to listen – trials, tribulations and success in delivering relevant scientific research

Prof Bob Harris

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Governments tend to present their policies as being 'evidence based' but the reality is somewhat different. Policy approaches often fly in the face of the evidence. Inferences and repercussions that science has been flagging for years may eventually become accepted, but the time lag is sometimes very long. Why is that? "Inconvenient truths' are rarely welcomed by those who already have made up their minds or who want to be seen to be doing something quickly… or popular. But that's only part of the story; why won't they listen?

- They can't understand: you don't make sense.
- They don't want to understand: but they could… if they wanted to.
- They don't need to understand: what you're saying is actually irrelevant.

What we now term 'knowledge exchange', the interchange of ideas and understanding between sectors, is a complex process that we neither resource well nor are particularly skilled at. The links in the chain from producing science to its take-up are several and mostly invisible. It can often rely on developing good personal relationships… that we pretend to no longer have time for.

Some of these issues will be discussed, drawing on successful and not-so-successful examples at the interface between research providers and consumers from Bob's experience such as: the development of the initial groundwater protection policy and practice, establishing a consensus on contaminated land policy and guidance in Europe, and promoting integrated approaches to catchment management and supporting science.

IAH Ineson Lecture 2015

From urban groundwater research to tampons: How did I get here?

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How does a research career develop, and does it make any difference to the world? Serendipity, opportunism and good research students and postdocs have shaped my trajectory. I have moved between quantity and quality and between groundwater and surface water; the constants have been urban and industrial impacts on water. Quite by chance early in my career, I worked on urban groundwater projects and realised that leaking pipes were a source of recharge. This lead to a long running interest in urban water balances. Eventually it became clear that water was missing – the lost streams diverted into sewers – at an aesthetic and ecological cost to cities. The first two PhD students I supported, Mike Rivett and Paul Ashley, worked on groundwater pollution themes and started a second major thread. Should we view the multiple sources of urban pollution as separate points or as a diffuse source? Both views are valid; point sources led to research on remediation and, in my case, natural attenuation. The diffuse perspective led to research on risk assessment for groundwater and nitrate as an urban diffuse pollutant. Linking these issues with the dreaded Water Framework Directive lead me the broader aspects of urban diffuse pollution surface waters including the risks from industrial estates and the frequency and effects of misconnected sewers, which is where the use of (clean) tampons came in and generated the biggest media coverage I've ever had! In the Ineson lecture I will talk about the research content of some of these areas and whether the research has any significant effect.

Poster Abstracts

Posters will be displayed throughout the day in the Main Library

The following poster was the recipient of the IAH British Chapter – 2015 John Day Bursary (£1000) to support students in undertaking hydrogeology-related fieldwork outside Great Britain as part of their postgraduate studies:

Geothermal Energy in East Africa: Menengai Caldera Geothermal Field

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In 2012, Kenya spent $569 million of its domestic resources servicing debt; a third of all its aid received in the same year. The country does not meet the required threshold of the Heavily Indebted Poor Country (HIPC) scheme, yet it still benefits from it.

The Kenyan government has set up Kenya Vision 2030, a national long-term development blue-print. The aim is that by 2030, Kenya will be an industry rich, middle-income nation, with an improved standard of living for its citizens. However, an estimated 84% of Kenyans do not have access to electricity, the lack of which is a major issue when trying to implement Vision 2030. The development of geothermal energy at locations such as Menengai, Ol Karia and Longonot to name a few, means that by 2030, the country should be producing clean electricity, returning a surplus to the national grid, reducing its reliance on hydrocarbons and the need to import expensive power.

The flow patterns of fluid and heat within potential geothermal reservoirs are as yet poorly understood, though it is already clear that faults are a major control on these. Within Menengai caldera (0.2°S, 36.07°E), the location of faults and more importantly, faults and fractures actively used as conduits, are yet to be identified. In addition to such identification, the isotopic composition of the fluids and gases associated with them provide the means of discriminating between magmatic (e.g. $\delta^{13}C\text{-}CO_2$ and ^3He / ^4He) and meteoric (e.g. $\delta D\text{-}H_2O$, $\delta^{18}O\text{-}H_2O$ and $\delta^{13}CH_4$) fractions, as well as determining the equilibration temperature and subsequent fluid history.

Fieldwork completed during 2014 allowed for the development of a detailed geological map of the caldera, data that until this point, was absent from the caldera database. This will be complemented by the information that is starting to arise from the 2015 field season where data was collected on soil gases, efflux rates, structures, surface temperatures, fumaroles, ground penetrating radar and transient electromagnetics.

Multiphase flow modelling of shale gas and brine leakage from faulty well casing

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Potential natural gas leakage into shallow overlying aquifers from shale gas extraction activities becomes a public concern, as a recent study in USA show CH4 concentration in groundwater within the active extraction areas are systematically higher than those within the non-active areas at Marcellus Shale play. However, the migration pathways of the fugitive CH4 and impact of the rock heterogeneity on CH4 plume development in subsurface conditions are poorly understood. This makes it difficult to design the groundwater monitor programme in the event of a shale gas leakage. We construct a hypothetical shale gas leakage case within a Sherwood sandstone aquifer using the data from a Bowland Shale gas exploration in Lancaster. Multiphase flow simulation show that the upward CH4 flux dominates within the sandstone aquifer due to the buoyancy effect and high permeability of the aquifer. However, a horizontal CH4 plume up to few hundred meters was found within the low permeability of the overlying Mercia Mudstone formation. The results suggest that the permeability of the rock formation has strong impact on CH4 plume development. This study provided new insights into the design of groundwater monitoring programme in the event of a shale gas leakage.

Keeping groundwater sustainable – Is it always worth it?

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Brownfield development, particularly for housing, requires investigation of soil and groundwater contamination. Where groundwater is contaminated, assessment of the significance, sensitivity and potential future use of groundwater resources in the area is essential to identify if significant remediation is required in order to maintain a sustainable resource. Through the creation of detailed and accurate conceptual site models, using site specific data as far as possible, including detailed geology, hydrogeology and contaminant loading, the sensitivity of and risks to the groundwater resource can be defined. The conceptual model needs to account for any risks to human health and aquatic ecosystems from existing groundwater contamination. At sites where these risks are significant or can be mitigated effectively and sustainably, addressing the groundwater contamination becomes the main driver for remediation. However, where the underlying aquifer is already impacted by historical contamination, is of low productivity and is unlikely to be used for any future downgradient abstractions, then maintaining a sustainable resource may not always be worthwhile. The key issues are illustrated with relevant examples of sites with persistent contaminants.

Sustainability Reductions: To Be or Not to Be?

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This study demonstrates the impact of Sustainability Reductions on the Water Resources Planning cycle and compares the perceived versus the real benefits to chalk stream flows. Affinity Water have agreed to reduce their groundwater abstraction in environmentally sensitive catchments by 42 megalitres per day by 2020, with further reductions of 27 megalitres per day being implemented by 2024. These reductions are aiming to alleviate low flow issues in chalk streams especially under low groundwater level conditions (i.e. droughts). However, the anticipated benefit of these reductions may not be always realized, as demonstrated by a case study on the River Ver in Hertfordshire. In order to understand the causes and effects, baseline monitoring for at least a full hydrological cycle is key to better define the catchment's responses due to reductions in abstraction versus natural fluctuations.

An assessment of micro-organic pollutants in groundwater across England and Wales

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Multi-functional pressures on the groundwater lead to a diverse and growing number of sources and pathways as the number of potential contaminants increase. With the increased use of the subsurface necessary to meet the growing needs for various purposes from waste disposal to development of secure energy supply the number of potential sources for contamination of the groundwater resources is likely to increase as is the risk of contamination taking place. In the last few decades there has been a growing interest in the occurrence of micro-organic (MO) contaminants in the terrestrial and aquatic environment, and in their environmental fate and potential toxicity. A large variety of MOs are used in huge quantities for a range of purposes including arable agriculture, industrial manufacturing processes, as well as human and animal healthcare. Improvements in analytical techniques have allowed identification of organic compounds at low concentrations previously undetected in the aqueous environment.

The contamination of groundwater resources by MOs is a growing concern and relatively poorly understood compared to other freshwater resources. Of particular concern are newly 'emerging contaminants' such as pharmaceuticals and life-style compounds, particularly those with potential endocrine disrupting properties.

This study provides the first national scale assessment of micro-organic compounds in groundwater in England and Wales by analysing a national dataset to determine the relative occurrence and detected concentrations of different groups of compounds and aims to determine relationships with different land-use, aquifer type s and groundwater vulnerability.