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Groundwater-dependent ecosystems: GDEs – just another acronym or do we really need to know?

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I have to apologise, I'm not an ecologist, I'm a geologist by trade and then got into groundwater. I worked for the Department at Epsom for eight or so years. I did my PhD on springs and degradation of springs. We didn't call them groundwater-dependent ecosystems back then. One of the findings of the PhD was that these springs had always been there and are a natural part of the landscape - and that's how I got into this idea of GDEs.

If you look in literature before 1998 you won't find a report or a book with "groundwater-dependent ecosystems" - those three words together. It's an acronym that's got a lot of popularity and there's a reason for it: trying to get them onto the map, so to speak. We've never really understood groundwater because we can't see it. But we have an idea of ecosystems.

One issue is that policy around ground water is governed by "climate". I'm old enough now to have gone through the rise and fall of "climate". In the 70s and 80s, water tables were rising, we sold Telstra, the whole world was going to get flooded with dryland salinity. So that water was generally a "threat" across the landscape – and part of my job was addressing this "threat". Then we had a whacking drought and groundwater levels fell. In hydrographic groundwater level maps, time series have shown we had about a 6-9 metre fall in groundwater levels and we started seeing acid sulphate soils within rivers.

But we were worried about stream refuges, we were worried about the ecological impact of groundwater, and the acronym of groundwater-dependent ecosystems jumped on board. It's actually where I first met Nick Bond. We were using satellite imagery to try and map where there were remnant pools. Nick was doing his ecology. Then we had a flood and everything was okay, it's all good, no issue at all. One thing you'll notice though is that the incredible wet years only replenished groundwater levels by about 30 or 40%.

What are groundwater-dependent ecosystems?

I was involved in a national project for two years of my life called a Groundwater-Dependent Ecosystem Atlas. And we had to define what a GDE is. It's interesting that in the project there's no set definition of groundwater by the way. Every single state has got a different definition of groundwater and it makes it really difficult when you're trying to define what a groundwater-dependent ecosystem is. So I think we need to get rid of states.

Any part of the lifecycle of anything that has groundwater in it is a GDE, that's the definition we went with. It seems very broad but I'll explain why that's really important. In the past, goundwater-dependent ecosystems policy was driven by Great Artesian Basin (GAB) plans relating to the big mound springs. The states (New South Wales) got a bit involved in the late 90s-early 2000s, and in 2004 we had a National Water Initiative where they started putting money towards GDEs in response to the drought.

And then we built the GDE Atlas. It was the first national definition of GDE and it's on the BOM website where all the mapping of GDEs is being collated over time. It gets updated every year. We've even got to the point where Victoria has Ministerial guidelines on how and when to manage GDEs. So we've gone from something that didn't exist 20 years ago as an acronym to something that's actually under Ministerial protection.

There's three general types of GDEs. There's cave and aquifer GDEs with little critters that live in the ground (you actually go fishing for them by digging a hole and putting a net down). In porous rock like basalt, you will have little critters that live down in the ground - the stygofauna. They're sometimes really complex. The stygofauna in Tasmania includes the largest kind of yabby there is that lives in springs – and they taste good but they're endangered.

The loggerhead turtle is a great example where only a small part of its lifecycle comes in touch with groundwater. Remember when you were a little kid on the beach and you're making a sand castle, you've got to have the right amount of moisture. When loggerheads dig their cavities in the dunes, the groundwater keeps the moisture above the water table and actually keeps the cavity of the egg chamber open. But they found that, inland of some nests, there was some groundwater extraction. This had dried out the dunes and, lo and behold, the egg chambers collapsed. So that turtle only once in its life really has something to do with groundwater, but if you remove the groundwater, it's in a lot of trouble.

I grew up north of Clunes and a little swamp near where I grew up never changed level in my life. I was on a farm and we used to fish little blackfish there and shoot spotted ducks, because there was always life there. So GDEs, they aren't always big springs and they don't always have really, really obvious critters.

The issue of GDEs is really complicated. I came across a gate in Queensland and we spoke to the farmer, he said "I asked my son to fix the gate and he used gates to fix it and I don't know

where the gates came from". A GDE is a bit like the gate - where do you open from it and where do you start.

The issue is that, in an ecological sense, GDEs are ecotones. You've got groundwater and you've got surface water coming in. They're a bit like estuaries. And that's probably why they're so rich in life. The other issue about it is that, from a policy point of view, you've got a different department managing the groundwater and a different department managing the surface water. And that's really, really problematic.

The other point is that, because groundwater comes to the surface even in dry times, that is often where the only water is. The vast majority of GDEs are actually high valued ecosystems because they persist through time.

Risks to groundwater dependent ecosystems

What are the risks to groundwater-dependent ecosystems? We've got groundwater extraction. But it's a really small world, and the connection between frogs and urbanisation and GDEs means that it's not just groundwater extraction lowering the water table that impacts on them. I do a lot of work for Melbourne Water and the impact of change in land use on GDEs. Changes in surface water management and urbanisation cause changes in runoff and changes in quality, and these have impacts on GDEs. I'll give some examples.

What we had in the Millennium drought was the perfect storm. We compared the flow along the Loddon River with the cumulative deviation of rainfall (so when it's rising it's getting wet and when it's coming down it's getting dry) and levels in a groundwater bore right beside the river. During wet times, groundwater is flowing into the river for long periods of time. But then we get this period where, through climate change and also groundwater pumping, the groundwater levels fall below the river, so there is no groundwater flowing into the river.

If you have a swamp (photo is not the Loddon) and you change the surface water flow and lower the groundwater, you have a massive acid sulphate soil kill. One very large swamp was completely annihilated after they had put a big drain around it. In this case, what we had was a situation where surface water management and groundwater management weren't really talking to each other, and you have quite a consequence for the environment.

But it's not just the obvious threats that are really important. We're doing a project in the upper Merri Creek that Nick was talking about. It's an area with growling grass frogs. We were mapping groundwater discharge zones for Melbourne Water and, when we were in the Melbourne Water offices, quite by accident we found a meeting nearby of frog ecologists. They were talking about this fungus and they were trying to find the linkage about why this fungus was persisting. And it's persisting because of the increased temperature and possibly increased salinity, and it persisted in groundwater discharge zones, because groundwater is warmer than surface water and it has a higher salinity. The reason that's so significant is that, in the upper Merri catchment, groundwater flow lines

run from the west side of the catchment to discharge zones along the creek and its populations of growling grass frogs. There was going to be a big development in the headwaters and the way of treating the surface water, the excess runoff, was to dump it all into the Merri Creek. Everybody thought that's not a bad idea. But that was going to make the creek colder and actually decrease its salinity, and therefore impact the growling grass frog1. So the management understanding of these things, it is complicated and you don't always see those relationships until you literally stumble across them.

The other example is in another urban landscape. At one site in the Hallam area (near corner of Hallam Rd and O'Grady Rd) is a drain with melaleucas. And there were galaxia fish persisting in the drain. It hadn't been recorded for a while, but the water level was dropping. And this was not groundwater pumping, it was urbanisation. We did some modelling to try and work out what might be going on. Using a particle flow analysis model where we back-model from the drain that's been getting fed by groundwater and we work out the groundwater capture zone. In the model, all the groundwater is flowing south (red lines on 2nd map) to the drain. What's occurred over the last five-ten years is that a big industrial estate has occurred and completely reduced the recharge. So the water level in that little drain was dropping. And the fish weren't too happy about that. Once again, when we look at these landscapes, we might think it's all about groundwater pumping. But it's actually land use change – urbanisation - that's impacted some of these ecosystems.

The cultural connection

We think we know a lot, and then when we go down the track and realise we're thinking about things that people have been thinking about for a very long time. We do a lot of work on stream refuges that are connected to groundwater and the importance for the ecology during dry periods. I came across a great little bit of information about the cultural connection to all this. Well before we rocked up, there was an understanding among Aboriginal groups of the importance of stream refuges around ecology. The local mobs had rules and appreciation of groundwater that I thought was pretty amazing - there was already a lot of knowledge that actually existed around groundwater. I've worked in Northern Australia with these guys. When they do groundwater mapping of the different aquifers up there, they actually take on the cultural values. They'll put a waterhole on a map and there will be a reason why the waterhole might be there. It might be because there's a fault with groundwater flowing through it. But what they actually do, which I think is really cool about GDEs and connection with water, is that they actually link the story, the Dreamtime story into that modern style map. And they treat that knowledge equally. They don't say one is more positive or better than the other. And there's actually people that hold the knowledge. There's a guy, Frank, who's allowed to talk about these waterholes and how he believes they formed. So when they do the mapping, they actually combine the two together which I think is a really, really lovely way of discussing the importance of groundwater and ecosystems.

Mapping GDEs

So why the acronym? Why don't we call rivers "water-dependent ecosystems"? But we just call them rivers. So why do we have this thing called GDEs? I spent ten years working on GDEs but really it's just water management. I went to an International Association of Hydrologists conference about 18 months ago. One of the guest speakers there was a hydrogeologist who said "GDEs were easy to manage until somebody made a map". Because they weren't there in the landscape. I do work on impacts of mines, coal seam gas, etc. and 10-15 years ago, there was nothing to look at. We now have a GDE atlas and a national website.

You can Google the GDE Atlas (here). It's not perfect - it's the first map. A famous early Australian geologist made a quote that "you can't drown until you step out of the boat". And it's a bit like "you can't fix things until you make the first map". The mapping was a two year project of bringing all the information we knew together. It gets updated, and there's a working committee in each of the states on that. The map and website are updated regularly when they get new mapping or new knowledge in different themes.

When someone builds a new development - a road or a mine - and they're doing an Environmental Impact Statement, they actually have to go to the maps and say if there is a GDE in the area. And then they have to go and prove that the map's wrong or they actually have to go through the process of mitigation around that ecosystem.

So we've come a long way from the acronym not existing in 1998. We now have national legislation and a national website that's dedicated to groundwater-dependent ecosystems.

Q&A

Q (Paul Foreman) I've been doing spring soak type work as an ecologist for the last few years which has been fantastic and there's a lot more to do. But I noticed that your map or that map covers large parts of Central Victoria. And yet a lot of the large organisations involved in land use change and management still don't seem to be doing the requisite work to find out exactly where those areas are and appropriately protect and conserve them. So does more higher resolution mapping need to be done?

JF The miners have to do it because they're told they have to do it, so therefore they go to the maps. Scale is a massive issue. All the mineral springs are actually on this - the mineral springs at Hepburn have been mapped, and Queensland has been really active on this so nearly all their springs are on the map. There's a lot more to map and it will only get better. This is like the first iteration. They had the first update only last year, where everybody got together, with representatives from each state. And two weeks' time is the next meeting. I'm part of the working group on the GDE Atlas. So getting that information up is really important.

Making people use that information is a bit more problematic. At that site at Hallam, the reason that the developer had to do some work was because it existed on the GDE Atlas.

It was a registered high value ecosystem. I don't know if anybody actually knows that there's Ministerial guidelines on GDEs but every single new groundwater licence has to take account of high value GDEs. So the management is getting there, but the mapping has got to go a long way.

The maps are actually based on uncertainty as well. Some areas have a high likelihood, for example, that that bunch of trees is a GDE, and some areas are low likelihood that they could be. But it's not black and white and we need lots more mapping.

Q I'm a bit confused how you define a GDE versus a swamp, for example? So how would one know what is a GDE versus a swamp?

JF A GDE is a swamp, a GDE is a river, a GDE is a group of red gums. So GDE is a sub-classification of ecosystems really. There are existing maps for riparian vegetation, existing maps of wetlands, and if we have enough information to say the groundwater at some part interacted with that wetland, we call it a GDE. And this interaction only has to be in a part of its lifecycle, like the loggerhead turtle that only comes into contact with groundwater once in its life. So any mapped landscape that we believe had a connection with groundwater is labelled a GDE.

In the future it will be great that we don't have a definition of a GDE, we just have proper management rules where we actually manage groundwater and surface water together. So we don't actually have to have a groundwater-dependent ecosystem atlas, we just have water-dependent ecosystems. And hopefully the acronym will disappear into the future.

The other thing we did was to try to get common terminology across Australia on what a wetland is. Western Australia has a completely different definition to Victoria and so it was really difficult to actually define, to get a consensus across Australia what definitions were. As I said before, different states have different definitions of groundwater which I find quite peculiar but that's what it is.

Q [Unclear]

JF With the environmental flow and regulated releases that Nick's involved in, we do projects with environmental flow teams around the groundwater component of environmental flow. But in some situations around release of water, there's not a lot of work occurring. One of the things in terms of the impact of urbanisation is trying to encourage new developments in both the east and western parts of Melbourne to build infiltration banks to actually stop water flows – to really encourage groundwater recharge and reduce the surface water flow. The issue is that you've got to get in really early in the development, because once it's built it's built. Developers aren't too keen on spending money on doing it.

Q [Unclear].

JF The solution to reduced recharge is to increase the recharge, by recapturing the storm water and making sure the groundwater flows. It is a design issue. And it's really complicated. I've never seen anyone find a solution to it. All I've really done is identified where the issue is. But there is a CRC for Water Sensitive Cities that is trying to develop some of those integrated water management ideas. But I think progress is pretty slow.

Q On the GDE map of Australia, the difference between New South Wales and Queensland border seems to indicate something significant.

JF It's just extraordinary the difference in mapping between states. At the Queensland border, all of a sudden the landscape stops. That's a great example of the difference in definition between two states. We need to get rid of state governments because they all map things to different scales. Queensland has a very different definition of wetlands than New South Wales. I'd love to get rid of this and just have a consistent GDE map because it's really odd. We've got a completely national consistent approach to mapping for soils and geology.

Q I've got one question: how connected are these systems underground? If you impact and extract a lot of water in one area could you be impacting systems elsewhere? Do we know much about this?

JF Yes, we do. What you're talking about is groundwater flow systems. So if you take a volcanic cone with a really local groundwater flow system, the water goes into the top and you get springs at the bottom. So we might have different systems like the basalt plains, where you've got a lot of these wetlands and a lot of the discharge zones are actually at the very edge of basalt flows. We have an idea of that contained flow system from the recharge to the discharge. There are areas where that's mapped quite well. Again, it's all a scale thing. The hills will have lots of little local flow systems. And when you come off the hard rock and down to the scree slope, you'll find little soaks and springs that will change with the topography.

And those flow systems get bigger and bigger until you get to the Great Artesian Basin where water lands on the ground along the ranges around Rockhampton, it goes into the ground to about 5 kilometres deep, maybe a bit more, and keeps on going south east underneath New South Wales and comes out at Lake Eyre. That's on a massive regional scale where that water flow path is millions of years old. By the way there's no groundwater from New Guinea coming into Australia, not true.

There's a website called Visualising Victoria's Groundwater (http://www.vvg.org.au/) that has information on aquifers and groundwater bores. It's run out of Federation Uni and it's a growing website. I really recommend people look at VVG for groundwater information and its linking reports. On the website, you can put a dot somewhere and it will tell you if there is a groundwater flow systems map or is there a groundwater flow system report. And

you can then go and get that information. The information on groundwater is getting better. It's still all witchcraft because we can't see it, but it's getting better.

Notes:

Editor: Increasing the salinity of water has been demonstrated as a way to limit the impact of the chitrid fungus on frog populations (for example, see here).