# IESC Explanatory Notes Virtual Masterclass – Assessing groundwater-dependent ecosystems – Video transcript

**Interviewer: Welcome, everyone, to the second of the IESC Masterclass Series on the Explanatory Notes and hopefully, you all know that you’re listening into one today about assessing groundwater-dependent ecosystems or the GDEs. I’m sure that acronym will get used a fair bit today.**

**As we get going, you might remember that this week is Reconciliation Week in Australia. And I would like to start by acknowledging the tradition custodians of all the lands that we’re meeting on today, particularly the Bindal and Wulgurukaba people of Townsville where I’m joining from today, and pay my respects to the elders past, present and emerging.**

**I particularly like to acknowledge their role in land and sea country management particularly of those systems that we’re talking about today. And I’d like to extend that acknowledgment to any Aboriginal and Torres Strait Islander people that are joining in the masterclass today.**

**My name’s Fiona Chandler. My background is in natural resource management. I’m with Alluvium Consulting based in their Townsville office where it’s nice and warm. But today, my role here is as facilitator and moderator and to make sure you get the very best experience from today.**

**But more importantly, we’ve got some other people that will be doing all the hard work this morning. So, just to start with, I’d like to let them do a couple of introductions. So, Andrew, would you like to say hi?**

Interviewee 1: Thanks, Fiona. My name’s Andrew Boulton. I’m a member of the IESC. IESC and I’m affiliated with University of New England but I’m actually in much warmer West Australia at the moment.

**Interviewer: Thanks, Andrew. Peter?**

Interviewee 2: Yeah, I’m Peter Hancock and I work for Eco Logical Australia as a principal groundwater ecologist. I’ve been doing stygofauna work for about 25 years or so and a lot of that’s been in mining areas like the Hunter Valley or Central Queensland.

**Interviewer: Thanks, Peter. Jodie?**

Interviewee 3: Hello, everybody. I’m Jodie Pritchard. I work for CSIRO as a research scientist. I’m located in Adelaide and I’m a hydrogeologist. And I’ve been working in the area of trying to understand surface water and groundwater interactions using isotope geochemistry for about 20 years now.

**Interviewer: Thanks, Jodie. And Peter.**

Interviewee 4: I’m Peter Baker. I’m Director of the Office of Water Science. And I’m -- I and my team have the pleasure of supporting the IESC.

**Interviewer: Thanks, Peter. Okay, here’s just a few tips on how you can get the most out of today’s masterclass and how you importantlycan interact. So there’s a couple of ways for this, there’s something for everyone. The first way to ask a question that you’d like perhaps someone in the panel to respond to is to use the Q&A function. So you’ll just see the little icon Q&A down the bottom. Hopefully, I’ve set it so that you can all see each other’s question. But if you really like someone else’s question and you want it answered as a higher priority, you can actually like that and that will move it to the top of our list. So please use that Q&A at any time. We will make sure that we stop throughout the presentations to stop and, and look at that Q&A and take some time to answer the questions that we can.**

**Also, at any time, please feel free to use that chatroom to make a comment, to say hi, add a reflection or if you particularly maybe like to ask a question.**

**The other way, if you like to ask a personal question, is to raise your hand. There’s a little raise your hand icon down the bottom. And that means that it’s a little sign for me to perhaps mute, unmute you which I do, which I can do at my end. And it means I can let you ask the question verbally. I appreciate that some of these topics are a bit technical or complex in most scenarios perhaps you’re working in and need a bit further explanation.**

**So any one of those three will get our attention and we’ll be monitoring those throughout this morning. Obviously, you’re here to, you know, to learn and to interact. But really, the best way to get the most out of this presentation is to also ask some of those questions.**

**But in case we run out of time for those questions, what we have opted to do is that once the formal part of the, the webinar and the current material is over, what I’d like to do is I’m going to make everyone to join the panel which means you can all share your video and your own connection. And we’re going to have a bit about of an open discussion. There’s no format to it. What we’re just really keen to do, we acknowledge that there’s lots of experienced people in the room today as well and we’re really keen for you to each share some of your own experiences or help out each other with your own tips and tricks. So that’s a really important part today as well.**

**And I’d just like you to note that we are recording this session so that we can make the information available to others as a resource in the future. If you’ve got any concerns with that, just let me know in the chatroom.**

**So, who actually is in the room, apart from the panellists and myself? What I’m going to do is just launch a little poll right now. That will give us a little bit of information about where you’re all from. Thanks to those people who’ve given us a shout out in the chatroom. I’m loving all the people from Townsville, I’ve got to say.**

**So just hopefully up in the screen, there’s three poll questions, if you’d just like to answer those. Interested, just how long you’ve kind of been working in the groundwater kind of area or ecology area? Maybe mining? We’re interested in how familiar you are with this particular Explanatory Note. This just helps the team pitch the right level of information to you.**

**And then the third question there is just perhaps giving us a little bit more information about where you might have been able to apply some of the content or all of the content in this Explanatory Note. And if you’re not from Australia, we’re particularly keen to find out if you’ve applied it somewhere else in the world.**

**Okay, I’m going to end that poll now. And I’ll share the results with you. So hopefully, you can see those results come up there. Jodie, can you see those results on the screen?**

Interviewee 3: Yes, I can. Thank you, Fiona.

**Interviewer: Okay, thank you. So in terms of experience, we’ve got some highly experienced people in the room which is fantastic. We look forward to some of your own reflection throughout the morning. But welcome to those that are new. Hopefully, this will give you a really solid grounding in some of the concepts in the Explanatory Note. We’ve got people that have been using it which is fantastic. And in particular, it looks like most of the application has been in Queensland and New South Wales on the east coast with a smattering elsewhere. And I’m going to look to see where the other is. Did anyone let me know where they applied it other than in Australia? No, okay.**

**So thank you for filling up that poll. We’re going to do that a couple of more times throughout the morning to get some feedback from you.**

**At this point in the morning then I’d really like to reintroduce Andrew back to the team. He’s just going to give us a little introduction to the IESC. So over to you, Andrew.**

Interviewee 1: Thanks, thanks Fiona and I, I smiled at you saying whether I was awake in West Australia by shuffling the name of the notes on question two. It’ll be the GDE one today I reckon.

Look, before we get into the masterclass, I’d like to give just a very quick overview of the Independent Expert Scientific Committee and what we do. Can I get the next slide please, Fiona?

And so very broadly, the Committee itself was established in 2012 underneath the Commonwealth EPBC Act. And our primary responsibility is to provide scientific advice to the government on water-related impacts or potential water-related impacts of coal seam gas and large coal mining development. And there are four states, members of the National Partnership Agreement -- South Australia, New South Wales, Victoria, and Queensland to whom we also provide that advice, if requested.

The other roles that the committee has is to contribute to Bioregional Assessments. We also suggest some various research priorities in the field and support some of those with funding from the Office of Water Science. And then under certain circumstances, the Minister can ask us to provide commentary on other matters.

The Committee, there’s a maximum of eight of us and just running from left to right. You’ve got Craig Simmons who’s a hydrogeologist. Probably a lot of you know him. Our Chair, Chris Pigram. Wendy Timms, geology and hydrogeology. Cath Moore, who sadly has left to head off to New Zealand. She was or is a groundwater hydrologist and has been replaced by Phil Hayes from Queensland CSIRO. Jenny Stauber, ecotoxicology. Rory Nathan, hydrogeology. Jenny Davis and me, both ecologists.

As I said, our prime role there is to provide scientific advice to the Australian government, Environment Minister. And under the water trigger, the Minister is obligated to request our advice on coal seam gas and large coal mining development projects that might have a significant impact on a water resource. And you can see from the table on the right that we’ve already provided guidance on about 137 projects to date.

We consider all potential impacts on water resources. That’s water resources as defined under the Water Act including effects on groundwater and of course, their depend on ecosystems, on surface water, water quality and quantity, ecosystems, ecological processes and anything living in the water.

I think the three key things to note is that our advice is scientific. Eight of us are scientists. We have no decisions about whether the project should or should not go ahead. We make no judgment at all about regulation. Our advice is transparent and is published within 10 business days of being, of our meeting, of being sent to the regulator. And also, completely independent. None of us are affiliated with any of the -- anything else but universities or CSIRO. And so all the advice we provide is scientific, transparent and independent.

Next slide. So jumping into the Information Guidelines and the Explanatory Notes. The Information Guidelines were first produced in 2013 and have been revised a couple of times since. And those revisions were based on feedback from users and folks like yourself. And the prime goal of those guidelines are really to help proponents improve the clarity and outline of what they’re putting together for environmental impact statements.

I think the key thing to note is that those guidelines are not prescriptive. We’re not saying you must do it this way. But they’re really help proponents see what sort of information would be needed for us as a panel to provide scientific advice and to have a good assessment of the potential impacts of coal mining or coal seam gas.

In 2018, largely to supplement those Information Guidelines, we embarked on a bunch of Explanatory Notes. These are obviously a little bit more detailed than the Information Guidelines. And the topics that they tackle tend to be those topics which are either in rapidly evolving fields or areas where quite a lot of users and proponents have asked for more information.

Again, like the guidelines, they’re guidance. They’re not mandatory requirements and the guidelines, the Explanatory Notes themselves cover a lot of the up-to-date scientific methods, particularly the ones that are judged to be pretty robust. They include a lot of case studies and practical examples. And to date, we’ve produced three lots of Explanatory Notes.

The first lot and a lot of you probably attended the masterclass on this lot last week, is on uncertainty analysis in groundwater modelling. The second one is today’s hot topic and the third one which will be a masterclass on next week, is developing site-specific guidelines for physico-chemical parameters and toxicants. And that introduces the use of a water and sediment quality guiding, management network. And also assists with the design of appropriate monitoring strategy for assessing site-specific guideline values.

Probably the most important point to make just in closing and that is that these guidelines and also the Explanatory Notes rely really heavily on input from folks like yourself. And we’ve really valued the input that’s provided, being provided so far. A fourth guideline on faults, geological faults is out for draft consultation. And it would be terrific if people are interested in that topic to provide some guidance and input on that as well.

Anyway, I, like the rest of you, I’m looking forward to this. I’ll hand back to Fiona and welcome you all to this masterclass. Cheers.

**Interviewer: Thanks very much, Andrew. Would you just have a moment if there’s any burning questions to ask Andrew about the IESC? Andrew will be staying with us for this whole masterclass so there’s certainly other opportunities but don’t forget, you’ve got that Q&A room or the chatroom, if you do have a question.**

**And I can’t see anything now. All right, you’re off the hook for now, Andrew.**

Interviewee 1: Off, off the hook. Thanks, Fiona. Cheers.

**Interviewer: But only for now. Okay, in that case, I’d like to invite Jodie to kick off with the first part around the Explanatory Note? And we’re going to be stopping again at various times to look at the Q&A throughout the presentation. So Jodie, if you just like to take control of the presentation from me?**

Interviewee 3: There we go. I think I have control. Greetings, everybody. It’s really, really pleasing to see so many people interested in groundwater-dependent ecosystems gathered here today. Peter and I are really pleased to be able to share with you some of our learnings. And really excited to open the lines of communication to hear from you and learn from your experiences as well. Our contact details are here on this slide. And we’re really happy for you to contact us outside of this session with whatever questions you may have as well.

Before I go any further, I’d like to acknowledge our co-author on the Information Guidelines Explanatory Note, Tanya Doody. She put in a lot of work to bring it altogether but unfortunately is unavailable to join us here today.

So the plan for our session today is not specifically to run through the GDE Explanatory Note. What we intend to do is provide you with the feedback from the pre-registration questionnaire, discuss the purpose of the GDE Explanatory Note, to give a bit of an overview of what GDEs are and have a look at how the guidelines have been applied, and what challenges that people have had in actually applying the guidelines, and share some case studies and then some tips and hints that we’ve gathered along the way. And hopefully leaving plenty of time for questions and discussion along the way.

Peter and I are really happy for this to be interactive so please do ask questions and Fiona will draw our attention to those as we go through.

So these points are a synthesis of the feedback that some of you provided to us in the preregistration questionnaire. And you told us what you wanted us to include in this masterclass so the purpose of the Explanatory Notes, some hints and tips about how to apply the Explanatory Notes, and provide some case studies that apply to different situations and tell you what a successful application might look like. And my initial response to that is make it as easy as possible as you can for the regulators. Provide them a clear line of sight and also make sure that you explain the degree of groundwater dependency of the ecosystems.

You also told us that you wanted to know what your peers are doing. And you also asked us where to find the science and the data to help with understanding rooting depths, plant condition, seasonal versus decadal trends, and stygofauna distribution. Now, we won’t be able to get to all of these during this particular session just because of the time constraints. But we’ll do our best as we go through to answer a lot of these.

So at this point in time, I mean, to try and address this question, is that there is no central data porthole that provides us all this information. And so, there is no escaping the hard work involved with trawling through the grey literature and scientific literature to find some of these information. But what we can do is also take advantage of expert opinion and advice. So we on the panel are all really happy to be contacted to help. We’re unlikely to have all the answers but we might be able to point you in the direction of other people who may be able to help.

So as part of the questionnaire, you also told us what kind of challenges you are facing. And one of those key ones is bringing your clients along on the journey. Also, how to best pick the, to pick the best approach to understand your groundwater-dependent ecosystems. And also, that there are different rules for different developments and in different states. Another challenge is balancing the time versus the budget versus the data that’s available. And actually, what dataset are available.

So time constraints really don’t necessarily fit with the hydrogeological and the ecological timeframes. So that is, you know, groundwater dependence is more readily observed at the end of prolonged dry periods which doesn’t necessarily fit with project timeframes.

And I’m going to hand over to Peter for the next couple of slides.

Interviewee 2: Thanks, Jodie. Andrew gave a pretty good overview of the IESC guidelines for preparing development proposals. And these Information Guidelines are designed to help proponents meet state and commonwealth legislation guidelines, legislation and guidelines for groundwater-dependent ecosystems. Importantly, they’re also applicable to other types of developments whether they be different types of mining and also large-scale developments that -- such as infrastructure developments.

They’re designed also to incorporate or allow proponents to incorporate the best industry standards which or the most recent methods and they’re adaptable to developing technologies which I’ll talk more about later on. Okay, there we go.

One thing worth talking about is they’re not designed to provide a step-by-step manual for GDE assessments. And one of the reasons for that is there’s a lot of differences with, between different assessments. The states have different requirements and there’s a lot of site-specific variation, both spatially and temporally that need to be considered from when collecting samples and considering the impacts of a development.

They’re also not designed to hinder the development of new methods and the application of new technologies. So we’ve sort of kept them as a frame, to provide a framework rather than an instruction manual for assessing GDEs.

So you will have seen probably this diagram up in the corner in the Explanatory Notes. It outlines the steps in assessing GDEs as part of a development assessment. The first step is to identify an impact area which requires an understanding of the project as well as the anticipated changes to groundwater level. And at right at the start, it can be just a shape on the map outlining the area that you think is going to be impacted.

The next step in that is to work out which GDEs in the impact, where the potential GDEs are in the impact area. A good way to get a really early indication is to have a look at the Groundwater-Dependent Ecosystem Atlas. It’s really important that that’s not the only thing you do because the GDE Atlas doesn’t have a lot of information on some ecosystems particularly stygofauna distribution in aquifer ecosystems. They’re often not included in the Atlas.

So you need to also consider other sources such as groundwater level, aquifer type. And it can also be probably important to take a conservative approach. So if there’s a river or a water body in the area that’s potentially connected to an alluvial aquifer or sometimes it’s, or a karstic aquifer, you consider that as potentially being GDE until you find evidence that it’s not.

The next step is to determine the level of dependence from the list of GDEs you generate in the first step. And that can be done by having a look at potential causal pathways. Those are the pathways linking the aquifer and the changes expected in the aquifer as a result of mining to the ecosystem. And that can also help you identify the types of samples you collect in your survey program and also where those samples are collected from.

And you also need to determine the ecological condition and significance of the GDE so whether it’s a -- it contains endemic species, for example, or conservation significant species or ecosystems. And that information can be difficult to determine. It can be difficult to know what is valued in the ecosystem, for example, whether it’s biodiversity or endemism. And that can be -- you can get that information by discussing in with the experts or the regulators are a good lot of people to talk to if you’ve got questions there. Also, the scientific literature.

So once you’ve got an understanding of the baseline ecological condition and the level of groundwater dependence as well as expected changes from mining, you then need to assess what the potential impacts will be to each of the GDEs in the impact area. And following on from that, come up with options to avoid or mitigate impacts to GDEs and set trigger values that might provide early warning alerts to potential impacts.

You should also establish a monitoring program for any GDEs that are in potentially, are potentially going to be impacted by the development.

So taking a step back now, it’s useful to define what the GDE is for the purpose of the Explanatory Notes. We’ve used the 2011 definition from Richardson which is on the slide here. But the main point to emphasise or the main points to emphasise are that groundwater is required to meet some or all of the needs of the ecosystem and it may be needed all or some of the time. So it’s not needed 100% of the time. It may be needed during drought or but the, if there’s no ground or if the groundwater connection is severed or disrupted or the groundwater is made unsuitable for the ecosystem through changes in groundwater quality, then there will be some change in the species present or the ecosystem processes present in that ecosystem.

Now, the GDEs or groundwater for the purpose of the Explanatory Notes includes all water in the saturated zone as well as the capillary fringe. But it doesn’t include the unsaturated zone so the area above the water, above the capillary fringe in the soil.

There are different types of GDEs and they’ve been grouped. This grouping comes from the GDE Atlas because that’s a tool that a lot of people will be familiar with and have used. So we have subterranean GDEs which are karstic and alluvial aquifers, river-based flow systems below the ground, not the aquatic component. And surface expression GDEs which includes the base flow part of the stream or groundwater fed wetlands as well as submarine groundwater discharge areas. And the subsurface expressed GDEs include floodplain vegetation, riparian vegetation and some coastal systems.

Jodie and I, to get an idea of how the GDE assessments have been going over the past few years, we reviewed the comments from or we reviewed 10 projects that the IESC have commented on over the past two years so since 2019. And these, if you’re interested in having a look, they’re a great indicator of what the IESC is looking for and can give you just by looking at them, you can get some sort of sense on what needs to be included in your particular GDE assessment. And I’d recommend having a look at them just to get a, to gauge the essence of what’s needed in an assessment.

So of the 10 we reviewed, six included subterranean ecosystems. Five of those were desktop and field. Two, they didn’t consider subterranean ecosystems but the IESC felt that they probably should have. Another comment from the IESC for subterranean ecosystems was that there often weren’t enough samples collected. I’m not going to go and read through all of this. You can read them on the slide. I’ll just draw out the main points.

You can see for terrestrial veg, more sampling was needed in some of the or in most of the assessments. And that sampling was linked with testing how or testing the level of groundwater dependence basically for a lot of the vegetation ecosystems. A lot of the veg assessments relied only on desktop and not field assessments. And for field assessments for terrestrial veg, that can often mean doing a lot of GIS work. So it’s not necessarily always going out in the field and collecting veg samples or leaf water potential although that helps. That is a good way of determining groundwater dependence.

Interviewee 1: Peter, can I just chip in there perhaps?

Interviewee 2: Yeah.

Interviewee 1: I think Peter’s point is a very, very good one. The value of looking at some of the previous advices from the IESC just to get a feel for what kind of priorities and what kind of comments we make. Those advices, of course, are available on the IESC website. But I think one of the key points, particularly Peter’s observation that the IESC often comments that there’s not enough samples collected or that sampling is needed tends to be where the proponent makes quite a strong claim, you know, there’s nothing to see here, folks or the impacts will be negligible or not too serious. And it’s really just a case of providing that line of sight. And I think Peter and Jodie both sort of highlighted the value of identifying the GDEs early on. And then you’ve almost got to assume they’re important until you can demonstrate they’re not. And that’s often one of the core things that we see coming up again and again. Unsupported claims that these won’t be an impact on the GDE when there’s not enough samples or not enough evidence to support it. So really just, you know, I like this approach of looking at the past projects but it also highlights, you know, some recurrent themes here which I know are going to be covered later on in the masterclass. Just a comment. Thanks for that and cheers.

Interviewee 2: Thanks, Andrew. The other ecosystem was a river-based flow ecosystem that was fairly regularly considered in these 10 ecosystems we reviewed. Again, not -- there was some hydrological modelling done for a lot of these but not a lot of ecological surveys to determine condition or to provide some sort of baseline to measure changes against in the future.

There were only two that had wetlands or springs in them. And these were assessed by field sampling and there was some, the comments were that there was not a lot of baseline sampling collected to back up a lot of the claims.

So there were no submarine groundwater GDEs considered in the documents we reviewed and they’re not very common from what I’ve understand.

So common themes from the projects we had looked at were that there was firstly, not a lot of sampling. But another one that came through was that a lot of the modelling was not detailed enough and it was not at a fine enough scale to provide to be useful for discerning changes in groundwater-dependent ecosystems.

So, and another comment was that there wasn’t, there was a lot of focus on hydrological changes. Changes to water level pressure, that sort of thing but not a lot of consideration given to changes in water chemistry or potential changes in water chemistry resulting from the project.

So just wanting to open up, if there are any questions you have or if anyone has any ecosystems or perhaps sampled any ecosystems that they wanted to talk about, particularly marine?

**Interviewer: I’m just checking the Q&A again there. So don’t forget, that’s an option there or just in the chatroom. If you are putting something to the chatroom, make sure it’s to all panellists and attendees so other people can see your question. But there’s nothing there at the moment, Peter.**

Interviewee 2: Okay.

**Interviewer: So everyone’s happy or sorry. Just one. One’s just coming here so it’s a question around you can probably read it in front of you, Peter.**

Interviewee 2: Yeah.

**Interviewer: But potential impact of GDEs is based on simplified regional scale groundwater models. Would you like to have a pick initially on that one?**

Interviewee 2: Yeah, I’m just reading it now.

Interviewee 1: Peter, I can give a bit of commentary from the IESC perspective, if you like.

Interviewee 2: Okay.

Interviewee 1: But particularly to the last question and it’s a great point to make. You can have these broad models but Claire, I would say, without some ideas of the sort of actual site-specific details and data, or if you’ve got those, and I’m saying this as an ecologist rather then as a hardcore modeller, that information is vital for actually justifying and validating, if you like, the way that the models and the conclusions are drawn. And so, I would emphasise that any chance where you have actual site details and data, if you can use that information to validate and support the broad models and predictions that you’re using, please do that.

Quite often, as a panel, we’ll see some very general models but there are very few data to support the claims. And even if we’re not sure whether a GDE is going to be relevant or not, you have to have some information to rule it out. And so I think the answer to your final question is yes, there is consideration and there’s a strong preference by the IESC to sort of see both the modelling and the data to support the assertions in the model.

Peter, I don’t know. You might have some other comments to add to that.

Interviewee 2: No, that’s along, I agree with that. I’m not, I can’t speak for the IESC. But I agree that site-specific data is often best, if you have it rather than modelling or to complement modelling.

**Interviewer: Thanks, Claire, for that question. If there’s no others, Peter, I might invite you to keep going with some of the challenges that you’ve talked, started talking about.**

Interviewee 2: Okay. Yes, some of the challenges that we’ve seen or faced, that are faced by proponents in assessing GDEs include a level of dependence on groundwater modelling to determine the impact area and the level of the impact. But groundwater impact assessments are often not finalised until later in the project which means that and GDE samples need to be collected early on in the project so you’ve got a bit of a temporal scale in your data. But the earlier GDE samples are often collected only when there’s a rudimentary understanding of the extent and magnitude of the drawdown which is usually okay if you can go back and collect additional samples in the future, if you need to. If modelling once it’s finalised shows that there’s a particular area of drawdown or a particular area of change that you haven’t collected samples in previously then you can always go back and collect that. But it becomes a potential problem if you don’t have the time to go back and collect additional samples, if needed.

The other challenge has been what the criteria are for valuing GDEs. And that can depend on the state. For example, some states consider GDEs, if they’re definitely GDEs then that makes them worthwhile protecting. In others, it can depend on the amount of endemism in a GDE or whether that GDE supports threatened species or threatened communities.

And one way around that is to open an early dialogue with the regulators. If it’s not clearly listed in guidelines or legislation then open up a dialogue with the regulators to see what they value and what, how they think or what information they need to see in the assessment.

The other area of uncertainty is determining the level of dependence and that’s particularly uncertain for a lot of people for groundwater-dependent vegetation because the level of dependence changes through time and even spatially within species, they can use different levels of groundwater. And that’s again another reason why collecting longer-term data or multiple sampling events is important although it can be limited because usually there’s only one or two years’ worth of sampling in the lead up to submitting an EIS.

This one, I think, Jodie was …

Interviewee 3: Yes, I’ll take over here. This is my opportunity to vent a few bugbears I’ve encountered as I’ve gone through. In a draft version of the GDE Explanatory Notes, I included my own personal list of known GDE veg species, just a handful of studies and the ranges in depth to water that groundwater was sourced from. And I’m happy to share my list but it is by no means a fully comprehensive list of species. And if a specific faeces -- species, not faeces, sorry. If a specific species doesn’t feature on my list, it doesn’t mean that it is not a groundwater-dependent species.

Another point of confusion that I’ve come across is the definition of obligate versus facultative groundwater-dependent ecosystems. I’ve seen it stated that obligate GDEs are continuously have access to groundwater. And I’ve seen also facultative GDEs referred to as systems that have intermittent access to groundwater or are opportunistic in their use of groundwater and can essentially survive if groundwater, their access to groundwater is severed.

So I personally think this terminology is confusing and we’re better off avoiding it. What obligate, what an obligate GDE is really meant to represent is a species that will only exist where it can have access to groundwater, whether that be continuously, annually at the end of the dry season or you know, only once in 10 years. But it only exists where it has, can have the access to groundwater. Where as a facultative GDE is a species that can exist in areas where it does have access to groundwater but then it can also exist in areas where it never has access to groundwater, where the soil moisture store provides efficient water to satisfy all of its water requirements.

So another point of confusion that I’ve come across is in the use of the GDE Atlas. And Peter has made reference to this. It’s, I’ve seen that, you know, in some studies that if a GDE isn’t identified within the GDE Atlas, that it’s been assumed that there are no GDEs present. Whereas in actual fact, there are large information gaps in the Atlas and the scale of information isn’t necessarily compatible with the size of GDEs that may exist. So there is always a need to investigate site-specific information to identify the presence of GDEs.

Another point I’d also like to reiterate here is that whilst the GDE Explanatory Notes were developed for the coal mining sector, their guidelines are not exclusive to coal mining. They are relevant to other mining sectors as well.

And I’ll pass that to you, Peter.

Interviewee 2: Thanks, Jodie again. So the first step once you’ve determined what GDEs are in your potential impact area and you’ve determined that they are groundwater dependent its’ working what is valued in the ecosystem and what can change as a result of the development. And that can help you determine your sampling regime, what samples to collect, how frequently, where your site should be if you have the opportunity to choose different sites. And these can be determined, like I mentioned earlier, from the legislation or discussions with the regulator as well as with expert, discussion with experts and reviewing the scientific literature.

Occasionally, there will be some pre-existing information. For example, there might be a coal mine next door that has included some of the sites in their assessment previously and you might be able to get access to that if they search information sharing or if that information has been published. And that can help get an idea of what types of GDEs there are but also what the diversity might be or whether there are likely to be a different species in that ecosystem.

The next step is to identify the causal pathways which are the pathways connecting the CSG activity or the mining activity to the groundwater-dependent ecosystem. And this can be done by looking at aquifers that currently support GDEs and determining how the conditions in those aquifers can change or are expected to change as a result of the development, keeping in mind that one aspect of the mining development may affect multiple GDEs, for example, aquifer depressurisation might affect stygofauna communities as well as vegetation in river-based flows.

To recap the GDE assessment or as a recap of GDE assessments before we go into assessing some of the specific GDE types separately, I will just run through this diagram. First step is to define the project and the project impact area. And then within that impact area, you need to identify what GDEs are present and that can rely on, that can be determined by using resources like the GDE Atlas. But also, looking at what groundwater information is available, whether that be data or whether it be a report such as an impact assessment, groundwater impact assessment for a nearby area, just to get an idea of the aquifer type, the water quality, the groundwater level, things that are going to assist in recognising whether an ecosystem is likely to be receiving groundwater or using groundwater at some period.

Then once you’ve identified the potential GDEs in the area, you need to work out what condition they’re in, ecological condition and also work out what is valued in that ecosystem.

Then once you have an understanding of how the groundwater can change and where as a result of mining, you can use the ecological information to determine how the impact is likely to affect the GDE, then come up with some avoidance or mitigation measures. It’s often best to avoid impacts to GDEs rather than try and mitigate them because there is often not proven mitigation measures that will work.

And then, you need to as part of the monitoring plan, you need to also set trigger values that can indicate whether an impact is likely. So it’s often best to set trigger values that are linked with groundwater rather than the ecosystem. So looking at water level changes or water chemistry changes somewhere along the causal pathway between the impact and the GDE or the change from mining and the GDE, I mean to say. But it is also important to have some sort of ecological monitoring to assess the condition of the ecosystem as the mining project develops.

Let me see. Okay, any questions on that one?

**Interviewer: Just before we go to Claire’s question there, I’ll let you just let the panel read that one. I just wanted to bring people’s attention to one that was also asked around the Atlas being updated. And that was, so Jodie said that was last updated in 2017. Is it every few years or is it kind of more than as-needs basis?**

Interviewee 3: Well, that’s the first time it’s been updated since its inception. And I don’t know when there is a plan to update it again, I’m afraid.

**Interviewer: All right, so we’ve got another question there from Claire around the Atlas. Jodie, did you want to answer that one as well?**

Interviewee 3: Sorry, I haven’t seen that question yet. What is that question?

**Interviewer: One in the Q&A, are there any plans to update the GDE Atlas based on vegetation mapping and refined by site studies from all of the impact assessments conducted that could help really inform where those GDEs are.**

Interviewee 3: I think that’s most definitely on the wish list but as to whether it’s being funded is another question.

**Interviewer: Okay. And another one from Claire. Thanks for your interaction, Claire. She said she’s noticed the GDE Atlas differs based on how you download it by the catchment regions or by bioregional assessment. Which do you believe is the best version to use?**

Interviewee 3: Look, I don’t have an answer to that one at the moment. We might have to take that one on notice and actually, maybe we can put it to everybody who’s here from their experience what works best.

**Interviewer: Absolutely! Feel free to chuck a response to that in the chatroom if you can help Claire out on that one. For sure, okay. Oh, Claire, another one. GDB download versus the shapefiles. Yeah, okay, so in terms of the data. We might hold on to that one, Claire, and see if we can maybe move that to the open discussion and I’ll let you perhaps talk through that one later on as well. So let’s not lose that one.**

**Another question from Tim here. Panels so in New South Wales GDEs are gazetted in water-sharing plans. Is there a general requirement to assess potential GDEs that are not gazetted? Who’d like to start with that one.**

Interviewee 1: I could probably have a go at that one from the IESC. It’s a good point, Tim, because in many cases, proponents will look at the water-sharing plans and then if there are GDEs mentioned in those, you know, I think there’s an assumption that the WSPs are already covering those. If there are potential GDEs and particularly in the impact areas as Peter was describing, you would need to identify those. And even if you needed to say, look this is not a GDE because we went out and sampled and showed that there was no groundwater dependence, then that’s also a key aspect of it.

So the short answer is yes, there is a general requirement to assess potential GDEs that are not gazetted. But also, more importantly, to show that they are not GDEs if you know what I mean. So in other words, you want to be able to rule them out.

We, as a panel, as the IESC often have no idea based on the information whether or not these systems could be using groundwater. And it’s really up to the proponent to reassure us particularly if there is an impact expected on groundwater and it’s likely to be a valued vegetation system, we expect the proponent to be able to provide convincing evidence that it’s not a GDE, it’s not reliant on groundwater or if it is, that groundwater removal will be within the capacity of the GDE to bounce back.

Great, great question, though, thanks.

**Interviewer: Thanks, Andrew. Peter or Jodie, did you want to add anything to that or you … okay. It was just a quick slide here on the resources but then we’re going to do a quick poll as well. So I’ll hand back over to you.**

Interviewee 3: Back to me. And so, there are a range of national-scaled tools that have been developed to help in the approach for assessing GDEs. And we’ve spoken about most of these already. What we havn’t spoken about is the GDE Toolbox. This was updated in 2010 and it includes a framework and a collation of desktop and field evaluation tools for investigating GDEs.

The GDE Atlas was co-developed with the Toolbox and here, as someone has already asked it, was updated in 2017. It includes information about the locations of known but not, unknown GDEs. It does not include aquifer ecosystems nor does it include marine ecosystems.

What it does include is an inflow-dependent ecosystem layer which was generated from remote sensing information and it indicates where evapotranspiration is higher than rainfall, that there is potential for what they call inflow-dependent ecosystems. So a source of water in addition to the rainfall that is incident to that area.

What else do we have? So the IESC Explanatory Note, which came out in 2019, provides links to national datasets and state and territory datasets. And these are kind of semi-hidden in the appendices. There’s a wealth of information that you can access from the appendices in the GDE Explanatory Note.

So and also, expert opinion. I think we keep coming back to this. You know, please ask questions and you know, we will do what we can to direct you to people who can help.

**Interviewer: Thanks, Jodie. So while you might be thinking about some other questions here. Before we move into the next section, we’re keen to find out a little bit more information from you. So here’s a couple of questions that we’re going to use the poll tool on while you’re thinking about some other questions. So I’m just about to put them up on the screen now, if you’d like to answer them. And I love these because we’re just trying to find out a little bit more about the individual GDEs that you have worked on and any that you might feel guilty about. I love that word, Jodie, on that one. So if you could just respond to those survey questions. There’s just two that had popped up.**

Interviewee 1: Jodie, while people are doing that, do you want to just explain the aspect of guilt that we ought to be feeling? Is it just that it might be an understudied or poorly-known GDE or is it one where you’ve done the assessment and you’re thinking, maybe it wasn’t as reliable as I hoped or over time, I looked at this. I guess, to put it a bit into context, the IESC often thinks about when an assessment was done in relation to when the last drought or heavy rain was. And sometimes, as you well know, that gives you quite an insight into how much groundwater dependence there might be.

And so, you’ll see proponents using data collected from a long time back when there might have been an awful lot more rainfall than there had been say straight after the Millennium Drought. And so, that could influence your suspicion as to whether or just check there to these comments. But that just might influence your suspicions as to whether you have a GDE or not. So what’s guilty?

Interviewee 3: So I guess what I was thinking in that respect was what are we neglecting? What do we think we should be looking at and we’re not because we don’t know how to approach it or if it’s there, that kind of thing. But you know, everyone has a different perception of guilt. So …

Interviewee 1: It depends on our religious upbringing, I reckon.

**Interviewer: We got a flurry of responses now that you’ve clarified the guilt question for us, Jodie. Oh, oh. Give people, thirty more seconds to complete those two. I’m just going to share those with you now. So it looks like, as you might suspect, the veg and the rivers are certainly some of the most common but there’s a pretty good spread as well across those. And in terms of guilt, it looks like stygofauna is winning that one. But again, it’s pretty close across all of that which at least in those freshwater systems perhaps. Interesting.**

Interviewee 1: I guess just an early observation. I’m actually impressed with the relatively low levels of guilt. I mean, like I feel good about that.

**Interviewer: And we will talk about at the end an opportunity to always be providing feedback to the IESC on other areas you think that might be needed in future updates. So we’ll come back to that at the end as well.**

**Okay, so let’s keep going. Who’s going to keep, continue us off?**

Interviewee 3: This is over to me, Fiona. So up until this point, the information provided has been relevant to all GDEs. But once the GDE types have been identified, there’s a need to delve down deeper into GDE type specific studies. So this next section is about groundwater-dependent vegetation. And then we’ll have another section that Peter will talk about, stygofauna and then another section where we’ll have a look at surface water systems that have some dependence on groundwater.

So initially, for groundwater-dependent vegetation, it is essential to characterise the depths to groundwater, the water quality and the gradients across the landscape. Looking also to soil and aquifer characteristics including also vegetation condition, vegetation type, landscape position and to develop a conceptual understanding of how the system works seasonally or at its extremes of water availability.

So this diagram here provides a conceptual understanding of where groundwater-dependent vegetation exists in the landscape. So we’ve got some through here. I don’t know if you can see my arrow. I hope you can. And how the groundwater levels change seasonally and then how the groundwater source interacts with the other water sources. So here, depicted as being disconnected from the more regional groundwater system.

So this conceptualisation can be in the form of an infographic like this or it can be, you know, a box and arrow diagram to indicate the likely causal pathways. But it really does need to pick up those likely causal pathways.

So once we have a reasonable conceptual understanding of how the ecosystem works or how the system works, it can be tested and refined using a range of field-based or remote sensing tools. So an ideal evaluation would use multiple lines of evidence to test and refine the conceptual understanding. So for example here, we have an example of the use of the stable isotopes of water which can be used to identify the sources of water used by vegetation and also soil water and plant water potentials to identify where in the soil process a soil profile that vegetation is accessing water from. So in this example here, we have the soil water potential as it changes with depth in the soil profile and also, the oxygen 18 signature as it changes with depth in the soil profile.

And up here we have the ranges of values of the leaf water potential and leaf or sorry, plant oxygen 18 signature that correspond to those sites. And you can see quite clearly here that there is one species here, the C.clarksoniana which is accessing water from deeper in the profile, from the saturated area of the profile. And that’s evidenced by both the water isotopes and soil and leaf water potentials. Whereas these other species quite clearly look like they’re accessing water from the shallower unsaturated zones of the soils.

So this example shows how leaf water potential can change in respond to stress. So on the top part of the diagram, we have rainfall over time. And this bottom part is how groundwater levels have changed over time. And in the middle here, we have the leaf water potentials at predawn and compared to midday for two species. So we have a Melaleuca here in red and a coolabah here in blue.

And what I want you to take particular note of here is that there was, like I said, a failure in the wet season in 2007 which resulted in this drop in groundwater level of about 10 metres. And you can see that both of these vegetation types are feeling quite stressed. They’re having to exert a lot more water potential to extract water. And that can be due to a complicated array of different properties. So it can be due to differences in soil salinity, sorry, soil water salinity so overcoming an osmotic potential. It can be related to soil texture. So if you imagine it’s harder to draw water up from a clay than it is from a sand. And also, depth to water which I think is probably the case in this example where water levels have dropped to an extent where they’re having to draw it from deeper in the soil profile or perhaps not, perhaps losing contact with groundwater altogether.

And so, of particular interest here is also this Melaleuca. It’s suffering quite an extreme stress because it is not equilibrating with the soil profile overnight so that there is no difference here between the midday and the predawn leaf for the potential shine that it’s suffering extreme stress. But then we come to the following wet season and all the plants kind of rebound and they’re happily using water again.

But what we don’t know from this is how frequently vegetation can rebound from a stress like this and what the duration of the stress that they can withstand? And whether or not, you know, during that period of extreme stress whether they were actually performing all their essential ecosystem services, so providing a suitable habitat for fauna, whether they could flower and seed and reap fruit.

So yes, so I think that was the key point I wanted to take from here. So we do have some longer-term data and we’re looking at stresses but we still don’t know the extremes of those stresses that these species can withstand.

Okay, so another method for understanding where groundwater use occurs and trying to quantify what that groundwater use is, is by using a water balance approach. And so, this picture that we have here is a field setup that Tanya had for monitoring water use by willow. And so what we have here is this is a soil lysimeter to monitor evaporation. We have this throughflow troughs to monitor interception of the leaf canopy. And then, installed in the trees are some sap flow loggers that monitor water use.

And when we have a look at the difference between the rainfall and the total evapotranspiration, we can see that there’s quite a strong difference and it can be inferred that that difference is potential groundwater use. Okay, so yeah, a knowledge of plant rooting depth and morphology compared to groundwater levels can give an indication of where vegetation is likely to use groundwater.

So this is my table that I spoke about earlier. It’s my personal list of species that have been identified as being groundwater-dependent and the depths that they were accessing groundwater from. And I just need to reiterate that this is not an exhaustive list. And you’re absolutely welcome to use it and it would be fantastic if, you know, this could be live and we can all just add to it and share it. I think that would be brilliant. But you know, if a species isn’t on the list right now, it doesn’t mean that it’s not groundwater-dependent. It just means that I haven’t looked at a study about it at this point in time.

Okay, so the rate of groundwater uptake by trees varies between species and depending on the climatic regime and the depth to groundwater and the groundwater quality and the soil texture. So you can have one species in two different locations and in one location, it would use groundwater and in another location, it won’t because it has sufficient water coming from rainfall that’s been stored in a soil profile that’s deep enough and exhaustive enough that it has enough water there at all times.

Okay, so remote sensing has a lot of potential to tell us where groundwater-dependent ecosystems or groundwater-dependent vegetation specifically exist within the landscape. So NDVI which is the normalised difference vegetation index is quite frequently used to look at where vegetation retains more vigour at the end of the dry season or prolonged dry period to indicate that it has access to a more permanent source of water and infer that it could be groundwater-dependent.

But what I actually want to talk about here is SAR which is the synthetic aperture radar. And this wasn’t featured in the GDE Explanatory Note. It’s a new emerging technology. And so, this figure that we have here is a comparison between the SAR GDE index and the groundwater-dependent ecosystems mapped in the GDE Atlas. So the ones in the GDE Atlas are outlined in black whereas in the SAR index, you know, the reds and oranges are more indicative of where ecosystems are likely to be groundwater-dependent.

And I just zoomed in on this little bit here. We can see that that’s come out quite red and it’s not in the GDE Atlas. And that’s because this is a plantation and they weren’t included in the GDE Atlas.

So I don’t want to talk about this in great detail because there is a great resource online and the link is just here of a webinar that Tanya Doody put together about SAR. So if you’re interested in the new emerging technologies, I would direct you to that link to find out more information about it.

Okay, so each of these tools helps to build an understanding of groundwater use by vegetation. But what we really need is to understand what the long-term response to change is. We need to understand what ecosystem thresholds we want to monitor for. Is it just tree survival we’re interested in or is there a specific ecosystem function we need to monitor for? So unless there is recruitment, there will end up being a shift in ecosystem type.

So we need to know how the ecosystem thresholds relate to groundwater. Is there a maximum groundwater drawdown or change in water quality that can be withstood? Or is the rate of the change or the frequency in the duration of the change more important? And this is all really complicated by the fact that there are lags in eco-response, in ecosystem response to changes in the water regime.

But we really need to have an early warning monitoring system that can tell us before we see that ecosystem response to change. And I guess we’re pinning our hopes on monitoring groundwater to be able to have that early intervention. I might have to add that we don’t, I haven’t lost control.

So I have here an example of a modelling response to groundwater change. So this is the WINDS model that was applied on the Murray floodplain and it takes information about layers of groundwater salinity, groundwater depth, soil type, water source, flooding and rainfall and vegetation type to generate layers about soil salinity, water availability. And then from that, come up with a vegetation tree health index.

And so this top map here is a part of the Murray floodplain. And this was the status quo of red indicating where the vegetation was dead, orange where it was in poor health, and green where it was in relatively good health. And down here, the lower figure shows a modelled scenario of where something like 15,000 megalitres was released down the river and into the anabranches. And what 20 years later, what the response is in vegetation health and you can see that there are some areas of improvement close to the river channels.

And so I just wanted to point out here that modelling does have the potential to show scenarios of how changes in the groundwater and surface water system can be used to have a look at how vegetation health might change in response to that. And that might be a good point to look at some questions.

**Interviewer: Thanks very much, Jodie. In fact, we’ve just got one. Would you be able to copy the link to that water school remote sensing presentation into the chatroom for me, just to drop in the website maybe?**

Interviewee 3: Yeah. I will do that.

**Interviewer: And we do have a couple of questions here. Claire, we haven’t forgotten yours but we’ll come back to them. So we’ve got another question around how important is the assessment of bounce back or GDE recovery after the development? Should there be consideration between permanent and temporary impacts? It could be one for Andrew as well as yourself.**

Interviewee 1: Yeah, I can give a little bit of insight on that. I mean, I think that assessment is crucial because very often, mining projects, as you know, will extend, you know, 10, 20, 50 years and there might be quite a long time afterwards. And quite a lot of of groundwater models will often show some sort of recovery of water tables, not necessarily back to pre-impact levels but those recovery or that recovery of water table levels may extend, you know, over 20 to 50 or sometimes 100 years. If the GDE is unlikely to be around in 20 to 50 years and on top of climate change and all the other things, those observations are really important for the proponent to make particularly if there’s a situation where you can say, well, maybe the GDE will bounce back but it’ll take 50 years to do it and by that time, they could be a very, very different sort of situation.

In terms of the consideration between permanent and temporary impacts, that’s super important. You need to specify the time scale. So when you say a temporary impact, are you meaning on the cessation of mining or do you mean that okay, that might happen during one phase of the operations but before there’s irreparable damage to the GDE, it will bounce back.

In quite a lot of cases, we know that there are some GDEs that will never bounce back so peat swamps, for example, if you crack their base or they drain dry, if they don’t burn first, often end up becoming, you know, no longer a GDE and there’s no bounce back whatsoever. And so, I think that’s where you would have to identify that there would be a permanent impact and it was Peter’s point earlier about, you know, the fact that you now have a situation where the GDE no longer exists and there’s no mitigation or remediation option.

**Interviewer: Thanks, Andrew.**

Interviewee 1: Peter or Jodie, I don’t know if you wanted to add anymore to that answer?

Interviewee 3: That was great. Thank you, Andrew.

**Interviewer: Tim I can unmute you later on if you’d like to explain that one a little bit more in answer to the scenario that Andrew was posing there. We do have another one around for Jodie. Might have missed it but did your list of rooting depths include Canadell, excuse that if it’s all right, in 1996, maximum rooting depth to veg types at global scale?**

Interviewee 3: Look, I do have that data. Thank you, Hugh, for bringing that to my attention. But that’s not included in that table because they were not necessarily groundwater-dependent tree species and there wasn’t information about depth to water where those tree roots might be accessing water from. But yes, that is a very useful use resource for just having an idea of what kind of depths those specific species can grow to and whether that’s in range of the groundwater. So thank you for that, Hugh.

**Interviewer: So let’s move on into the fascinating world of stygofauna. And Peter, I suspect this is you on this one. So if you’d like to take over and we’ll move on to this next section. But keep those questions coming, we’ll certainly get back to them.**

Interviewee 2: Okay, this is looking at aquifer ecosystems and stygofauna surveys in particular. There was a bit of uncertainty about stygofauna so I’ve gone into probably the steps involved and the things that you need as part of a stygofauna assessment.

And the first thing is to have a good map that clearly delineates the area of interest and also shows the different aquifer types and their extent. And to help with choosing sampling locations, a list of or the location of bores in the area as well as a bit of information on which aquifer the bores sample from and any water quality information. In particular, one of the most useful indicators is electrical conductivity or salinity. The lower it is generally the better. If it’s below 10 or 5000 then it’s -- oh, if it’s below a 1000 or you know, between or 5000, it can be a good indicator that there may be stygofauna there.

We’re also looking for water table depth because most stygofauna rely on surface-derived organic matter. The deeper they are below, the deeper the water table is below the ground level, the less chance there is that there’ll be sufficient organic matter reaching them to fuel them, although there are exceptions because you have preferential flow paths that can deliver organic matter from the surface to relatively deep areas.

As far as aquifer characteristics go, the aquifer type, the hydraulic conductivity, that higher hydraulic conductivity is generally useful. Very compact aquifers are unlikely to have stygofauna so unless they’re fractured and connected to either the surface or a sedimentary or karstic aquifer.

Also at the start of the assessment, you need to have an understanding of what impacts may occur and where they’re likely to occur. So you know, where the drawdown is likely to be most extensive and roughly how far the drawdown is likely to occur.

Now the GDE Atlas is of limited value. When it was updated in 2017, they put some information on aquifer ecosystems in for Queensland but none of the other states have that information. So you often rely on the grey literature or the scientific literature to provide information on how diverse the aquifer is likely to be in your impact area.

It has, over the past 10 or 15 years, there’s been a quite a few developments in the coal fields of Queensland and New South Wales. They have required stygofauna sampling so there is generally a bit of an indication of where the stygofauna are likely. But if there’s a large alluvial aquifer and there’s no information then it’s often better to assume that stygofauna will be in the aquifer and then to proceed to a sampling program.

In the early 2000s, a lot of work was done in Western Australia particularly in the Pilbara, to work at, to determine the optimum number of samples or the optimum number of bores and the number of survey rounds for assessing impacts to mining. And for practical reasons, the researchers settled on two survey rounds of 20 bores roughly each survey round inside an impact area as well as another 20 outside the impact area to give reference conditions because not a lot of that was known of stygofauna distribution back then. And this is generally how things have continued today although a lot of the times, it’s better to get more than two survey rounds, if you can. And that’s because stygofauna distribution in aquifers is fairly patchy and they can be hard to get.

Stygofauna sampling relies on pumping like you see in this photo, or from nets drawn up and down the bore. And they each have inherent limitations on the stygofauna they can collect. For example, with pumping, you’re pumping water in from the aquifer through a sand or gravel medium which can act as a filter and prevent stygofauna from being sucked into the pipe and then transferred through to the bucket. So having more than one survey round and particularly having more than or having two or three, can increase your chance of collecting stygofauna from a particular bore.

When you’re designing your sampling plan, you should focus on mainly the alluvial and karstic aquifers because they’re the ones most likely to have good diversity and good stygofauna communities. But it’s also important to include a subset of any rock or sedimentary aquifers that may -- any fractured rock aquifers may be connected to these karstic or alluvial aquifers just because they can be some sort of connection between them and stygofauna do move into rock or rock aquifers, if the fracturing is enough.

They should have a fairly low salinity, as I’ve mentioned before. And it’s also important to include bores from outside of the expected impact area just to act as reference sites for monitoring as the development progresses.

Once you’ve selected your bores then you can either sample traditionally with nets and pumps to collect fauna or recently, there’s been a few projects that have used environmental DNA where they collect, they pump water, filter the water through fine paper and then they analyse the DNA on that paper to determine what species live in the water.

That has some limitations that I’ll discuss a bit later on. But the traditional method is just either to use nets or pumps to collect the fauna then sort them under a microscope, picking out the stygofauna and identifying them as well as you can based on morphology. And the best way to get them, because the taxonomy of a lot of stygofauna groups has not been developed, that there aren’t keys to species. Often, there aren’t even keys to families. And in most areas you survey, you’ll come across one or two potentially new species that haven’t been described yet.

So the best way to get a species level identification and to see where these particular animals fit in the network of other stygofauna, is to get them identified using their DNA. And that requires you might send them off to a lab. And once the specimen has been sequenced then the research that you can put the DNA sequence into a database such as GenBank which has a repository of almost all the other stygofauna that have been identified using DNA. So you can get to see whether that species has been collected previously or whether it’s a closely-related species to an already known species or whether that species is endemic.

Most of the work, most of the DNA database currently has information on Western Australian species because they’ve been doing DNA work on stygofauna for almost a decade and a half. And that’s the other advantage. The database, the DNA database is one of the strengths of using DNA because with morphological identification, the specimens are often may be identified to species by a particular consultant or researcher. But that information then doesn’t become publicly available. So you don’t know, for example, if the species you are collecting are the same species as another researcher has collected two years ago. So DNA is, I think, the best way to identify stygofauna. It also builds up the database and allows for application of environmental DNA sampling. So as the DNA database builds up and environmental DNA sampling processes become more and more sensitive, you’ll be able to rather than use a net to collect your sample, you’ll be able to pump water, filter it, run it through the database and see whether the species living in your aquifer are new or whether they’ve been collected previously.

So environmental DNA isn’t currently used widely. But it has been used on a few projects, one linked with coal seam gas and another one as a biodiversity assessment. And the Christmas Island biodiversity assessment used eDNA to sample caves, springs, a whole heap of groundwater-dependent ecosystems. And they came across, just by looking at the eDNA. They were able to identify 71 families. They didn’t, because of the broad scale of the project, they didn’t resolve identifications to species level. But they were able to get a good indication of how many fish species, also the number of microcrustaceans such as Harpacticoids and Cladocera which are, Harpacticoids are traditionally what you know, encounter in aquifer ecosystems in alluvium as well as karstic situations.

They also used the eDNA to demonstrate connectivity between different cave systems and between springs and cave systems that they previously didn’t know were connected.

The other example is the Beetaloo gas project in the Northern Territory. It’s a broad spatial, it was a broad spatial survey that looked at stygofauna as well as groundwater bacteria. And it used direct traditional sampling with nets then followed by DNA identification of the specimens collected with the net. And then also looking at environmental DNA collected from bores at a broader scale. So they were able to determine that the stygofauna – so the stygofauna collected with the nets only occurred in a subset of the bores sampled but through eDNA, they were able to show that they had a broader distribution. So we were getting, all the researches we’re getting, environmental DNA from species, you know, several kilometres away from they were collected or hundreds of kilometres away from where they were collected in the bores. It, eDNA had varying success, it didn’t always indicate a presence but it was useful for sampling when there were things like taps or pumps attached to a bore and you couldn’t get a net down.

So the interpretation of the results, it depends a lot on what’s valued. So whether you’re looking for endemism or whether the species are restricted only to one particular aquifer, that was the main concern in Western Australia in the early 2000s when looking at iron ore projects where stygofauna were found to be restricted to only particular aquifers.

The other alternative indicator of value is whether there’s a high diversity in the ecosystem. And generally, the more stygofauna species you collect, the higher value the ecosystem is. But generally, because of the difficulties or the patchiness of stygofauna and the difficulties in collecting large numbers of specimens, if there are any stygofauna in an aquifer, impacts to the aquifer, significant impacts to the aquifer should be avoided because you know, you might only find two species or two taxa in your survey but there’s likely to be a greater number of species present.

As I mentioned there, there are no proven ways to mitigate impacts to stygofauna. There was early talk about collecting stygofauna, keeping them in you know, mesocosm and then reintroducing them into aquifers. But that is unlikely to work and the research into that sort of didn’t or with stygofauna, didn’t last long in mesh cottons basically. So it was not a very successful program.

So avoiding impact is the best option either through redesigning the mine layout or changing the dewatering.

In establishing monitoring plans, trigger values are important in indicating when potential for impact to stygofauna communities are likely to occur. And these can be often properly based on groundwater level and changes in groundwater level and groundwater chemistry. And they need to have the ability to be revised early and regularly as knowledge changes. But ecological monitoring of communities is still important because it increases the local knowledge of stygofauna communities, what their tolerances are for water chemistry and water level, and also how they change through time seasonally. And so that information can be then used to feedback into establishing trigger values. So if you find that, for example, stygofauna numbers decline once the water level reaches a certain depth below ground then you can put that in your trigger value determination. But monitoring of stygofauna communities and other GDEs shouldn’t be used as an indicator of impact because once there is significant change in the community, the impact has already occurred, and it may be too late to do anything about that.

So some of the concerns in stygofauna assessment from comments from the IESC and also other areas are that there are not enough samples collected to adequately indicate the diversity of an aquifer. This can be a problem because stygofauna sampling is often dependent on the number of bores available in that aquifer and whether those bores are operational and the condition of those bores. But generally, the more samples you get, the better indication of diversity you have. And also, when you collect environmental data along with the stygofauna, you have an indication of conditions that those stygofauna are living under. So you have more information to feed into the trigger values.

Another problem that often occurs is misclassification of stygofauna. So just because an invertebrate is collected from a bore, it doesn’t necessarily mean it’s stygofauna. There are all sorts of other areas that invertebrates can come from. Ants can fall into the aquifer through the bore casing. You can get cross contamination from the soil invertebrates. Soil invertebrates are often a big confusing point. And there also can be things like if the bore casing is not sealed properly and there’s a bit of rainfall, you can get leakage of surface-dwelling invertebrates down into the casing.

So it’s important to get the stygofauna identified properly but also to understand the context of each particular bore. The closer a bore is to say a river or a surface water body, or if the bore is surrounded by an ephemeral wetland, there’s a chance that you can get surface invertebrates in the bore. And that surface contamination often will occur too if there’s a uncased bore or you’re using a well to sample.

Other concerns, taxonomy for most groups is not complete which I have mentioned earlier. So the best option there is to use environment or to use DNA identification. And for a lot of regions, there’s not a lot of regional context. The Hunter Valley has got a lot of sampling, has had a lot of sampling done to it over the past 20 years as have the Central Queensland coal fields. But the Southern New South Wales coal fields, there’s not a lot of information from that region.

Again, DNA identification can help link the specimens collected from new areas to either general or families collected from other areas.

And the final problem is that a lot of the data, there’s no central repository for stygofauna data that has information such as the species or morphospecies present as well as the environmental conditions they were collected under.

**Interviewer: Ask you to hold questions, we’re going to just keep moving on with the next section. So on to the surface water.**

Interviewee 3: Hi there, everyone. I’m going to try and skim over this as quickly as possible. So we’re looking at surface water expressions of groundwater and these can be springs, rivers, wetlands, submarine groundwater discharge areas. Similarly to vegetation, we need to have a good understanding of surface water and groundwater elevations, their changes in quality and their gradients across the landscape. We need to have a good understanding of soil and aquifer characteristics to then develop a conceptual understanding of how the system works, how it operates. And it’s also really important to identify whether there are any conservation significant species or ecosystems. And then once you’ve built up that kind of understanding, I’m not going to explain this diagram because I would just move on to the next one, need to bring in multiple lines of evidence to understand how the surface waters and groundwaters are interacting.

And so I have a specific example here of where radon has been monitored. Radon activity has been monitored in a river system at regular intervals along the river system to build up an understanding of where groundwater discharge is occurring.

If I do a couple of quick clicks, we have an indication of where there are spikes in radon activity which show points of groundwater discharge along the river system. And this can be modelled to come up with a semiquantitative volume of what those groundwater discharges are. And I won’t say any more than that other than to point you to a reference where you can find further information about that.

I’ll skip to another example of where environmental tracers have been used to understand where groundwater sources are to a thermal spring. So they’re a range of field parameters, major ions, metals and stable isotopes of water and strontium isotopes that were used to get an understanding of the recharge environment and the aquifer systems that water reside in. And then also, tritium and carbon isotopes were used to get an understanding of the residence times of water in those different systems.

And so what we have here is a conceptual understanding of the geology of the region. We have sedimentary aquifers and volcanic systems. And here, this is where the thermal springs are and these are various conceptual flow pathways of where water could potentially be coming from to discharge to that particular spring. So what we have here is strontium isotope versus an inverse strontium concentration plot and here we have the thermal springs plotting out here in red. And what we can see from this is that they are quite different from the other surface water signatures. So these are from other springs and rivers and pools in the area which are more indicative of water originating from silicate aquifer systems. And they’re also quite different from some basalt and sedimentary systems. But what they are most similar to are these other volcanic kind of aquifer systems.

So this particular study wasn’t conclusive because we weren’t able to monitor enough points in the groundwater system to have a look at all potential sources of water to those springs but it did give us an indication of what kind of aquifer they might have come from and definitely what type they didn’t come from.

I’ll move on to the next slide. So look, I’m going to skip over the introduced traces and numerical groundwater modelling and perhaps in the discussion session, if you have any good examples, perhaps you can bring that up. So what I’ll skip straight to is the remote sensing.

So there is an example that I refer to here which uses the normalised difference water index, NDWI. Oops, I might have skipped too far. Can we go back one? Who’s taken control. So that one, so where it’s been used to look for where permanent pools exist in the landscape. So I’ll direct you to that.

What I want to talk about more so is this particular example I have pictured here because this isn’t, this is just something I’ve been playing with. It’s not published anywhere and so, what I have here are a couple of images from the Sentinel Satellite. This shows the land and this shows the sea so we’re looking at a coastline here in Northern Queensland. This is an index of normalised difference chlorophyll index. You can see some black splodges across the frame and they’re actually where the cloud had obscured the view of what, the satellite imagery. So nothing to interpret here.

So the idea of this chlorophyll index is that where groundwater discharges into the near coastal zone, it carries with it elevated nutrients that then stimulates primary productivity and you could get an increase in chlorophyll A in those areas. And in this particular zone here, this is an area where we know from traditional knowledge that there are groundwater discharges into coastal zone. And we can see here where it’s kind of, the index is kind of yellow that there is some kind of indication that groundwater discharge there is heightening the chlorophyll A or so if there is some kind of index there that is picking up that groundwater discharge.

We also see, you know, yellow spots up the coast and you know, we haven’t, we don’t know what’s going on there but they could be points to start having a closer look to see if there is also groundwater discharge occurring in those areas.

This lower figure is the normalised difference vegetation index. So the idea with this was looking at where coastal vegetation might have been more vigorous toward the end of a dry season to indicate that there was potentially access to groundwater, a shallow groundwater system that then could also potentially be discharging to the coast.

And so we can see here in that known area of groundwater discharge that there is an area of more vigorous vegetation that could be indicative of that shallower water table that probably a lot more interpretation required for the rest of the image. But I just wanted to flag that with you so that you’re becoming more aware of some imaging technologies in this area.

I’ll hand over to Peter at this point to talk about the ecological indicators.

Interviewee 2: Okay.

**Interviewer: Can I just jump in before you do that because we are actually out of time for the original masterclass, I’m hoping people can hang on both for these last couple of slides on tips and tricks but also then the open discussion. So if you can hang in there, that would be great. If not, thank you for your time and we’ll be in touch and contact the IESC secretariat if you would like that information from today’s masterclass or copies of the slides. So thanks, Peter. We’ll just see how fast we can get through these last slides.**

Interviewee 2: I’ll just touch on this quickly. Ecological indicators are at for finer scales resolution of whether a stretch of stream might be groundwater fed or not. And by sampling the fauna living in the gravel bed of the river, you sometimes will collect stygofauna as well as surface water invertebrates. And the presence of stygofauna in the shallow sediments of a riverbed can indicate a groundwater connection. And this is somewhere also potentially where environmental DNA once it becomes a bit more sensitive in the future, can be used. So you can detect, you will be able to detect stygofauna DNA in the shallow stream area indicating a groundwater connection.

Interviewee 3: Okay, so this was the last slide that we had to talk about surface water expressions of groundwater. And it’s just bringing everything together so once we have that conceptual understanding of how groundwater and surface water interact in that environment, I guess what we’re still needing to build on there is understanding what that long-term response to change is and what exactly the ecological thresholds are that we’re looking at. So whether it’s the change in flow regime that is important so a cease to flow days or what else do we have? The degree of fragmentation along the system or is it the species abundance or diversity that might show the best change in response to changes in the groundwater regime. And then we have to match our groundwater thresholds to understand that ecological system. So are we looking at maximum drawdown or depressurisation or changes in water quality or is it that the frequency and the duration of those changes?

Okay, and again, you know, it’s all complicated by that lag in ecosystem response to change. And so the need to have that early warning in the water monitoring to be able to flag when ecosystems may be challenged by the changes in water regime.

**Interviewer: Thanks, Jodie. We might just, you’ve got some great tips and hints there which I don’t want people to miss out on. So would you like to continue, you or Peter, just to touch on those and then I’m going to go back to some of the Q&A.**

Interviewee 2: Okay, well, I’ll start on this. One of the main tips is to get the ecological sampling started as soon as you can. That gives you a bigger timeframe and bigger temporal scale to work out the significance of the GDE and the ecological condition and with stygofauna to determine, to get a better indication of diversity of the aquifer.

The other important thing to start early is a discussion about the conceptual models linking hydrology and ecology to assist the groundwater or the hydrogeologists in developing their groundwater models. So it’s often good to open up a dialogue between the groundwater modellers and the ecologists so that there’s good feedback. So the ecologists can get information on where drawdowns likely to occur and when, and the groundwater modellers can get an appreciation of what scale is useful to have in their models and also any other aspects of ecology that might be useful to feed into the modelling.

It’s also important to start talking to regulators to make sure that the assessment is moving in a direction that they want, or they need it to move in to satisfy the legislation.

Another tip is to have some strong evidence for setting threshold values, whether that be water quality or water level or some sort of ecological indicator. And base your assessments on multiple lines of evidence, particularly if there is some sort of -- some level of uncertainty, for example, in groundwater dependence in vegetation communities.

But it’s also important to acknowledge any challenges that you face. So if you, if there is a bit of uncertainty about whether the assessment wasn’t able to get a particular piece of information that it needed then it’s important to acknowledge that up front.

Another good tip is to have a look at past IESC comments and see if there’s any information, in there that might guide your assessment.

And also keep in mind that technology and assessment protocols are continuing to develop. So it’s important to be open to using those as they become available. So as environmental DNA becomes more useful, the cost of applying it will come down and it will be a great way of assessing stygofauna, for example.

Jodie, did you have anything more to add?

Interviewee 3: That’s great. Thank you, Peter.

Interviewee 2: Yeah, okay. Okay, that’s just a list of references from our presentation.

**Interviewer: What I might suggest is if people do want a copy of these slides and these references in particular, I suspect that some of them will be in the Explanatory Note but we’ll just put the address for the IESC secretariat into the chatroom there which you can pick up and email them. I’m sure they’ll be happy to send you a copy of this reference list and other slides from today.**

**What I’d like to do is just before we wrap up and we’ll go to the -- allot some of the other questions, just a reminder that we’ve got the third and last masterclass next Wednesday. It’s on the deriving site-specific guideline values for physico-chemical parameters and toxicants. So it’s not too late to register for that one. Again, just email the IESC if you want the details to register.**

**And just before I open up and giving everyone the videos and we can have a chat and we’ll go through some of the questions including one from Brooke in the Q&A is I just want to invite people to just answer another little poll for us just to give us some feedback on today. So I’m just launching that now. If you can do that before you have to run away, that would be great. And just again, think of any questions now that you’d like to ask in person or in just again, through that Q&A. And what I’m going to do is invite you all to come to the screen and I’ll stop sharing in a second. But your feedback is really important to us.**

**So I’ll just give you a moment to do that and let Peter and Jodie take a breath and perhaps just review a couple of those questions in the Q&A while we do this poll.**

Interviewee 2: While doing that, I’ll just apologise to Tim. I skilfully answered his message to all panellists instead of everyone. Thanks, Fiona for forwarding it. I’m great with the GDEs, not so great with the technology. I thank you.

**Interviewer: And here I was trying to sound intelligent by answering the question.**

Interviewee 2: Oh sorry, I’ve blown your cover.

**Interviewer: I nearly had Tim fooled. All right, just one last couple of seconds, okay. Last chance so I’m just going to end that now. And look at the feedback is much appreciated. I’ll just flick things up pretty quickly. Virtual is not always the best way. You don’t get the chance to chat around the water cooler or the coffee pot but thanks for that feedback. It looks like we’ve certainly done what we set out to do which was still convey information about the Explanatory Notes and give you a chance to meet the IESC and some of the authors.**

**(Music)**

END OF TRANSCRIPT