What to do when probabilities are hard to believe: impact assessment using causal networks

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The use of probabilistic risk assessment is becoming ubiquitous in environmental impact assessment. The likelihood of an undesirable outcome is inferred through a combination of expert knowledge and historical data, often based on Bayes Law. This strong theoretical underpinning makes probabilistic risk assessment well suited to supporting scientifically robust decision-making.

However, a significant drawback to probabilistic risk assessment is that estimated probabilities are vulnerable to critique; the assessment is only as strong as its knowledge base. Estimating the probability of an unwanted outcome invariably and unavoidably requires a series of assumptions, such as the set of scenarios to include, the conceptualisation of the system, prior distributions of parameters and likelihood functions for Bayesian inference. For probabilistic risk assessment to be robust and trusted by decision makers and stakeholders, each assumption not only needs to be transparently justified, they also need to be clearly communicated as an integral part of the assessment.

For greenfield development situations, the existing knowledge base and historical information is often insufficient for a reliable probabilistic risk assessment. In the Geological and Bioregional Assessment (GBA) program, assessing potential impacts from unconventional gas development in the Cooper and Beetaloo GBA regions, we developed an alternative impact assessment methodology that focuses on possibilities, rather than probabilities.

The first step in the assessment is to develop a causal network that explicitly and systematically identifies all possible causal relationships between unconventional gas development activities and the environmental assessment endpoints. The causal network allows us to address the first question in the assessment:

1. *Is it **possible** that a change in state A will cause a change in state B?*

When there is no causal link between state A and state B in the causal network, the answer is ‘no’ and the causal chain to impact can be ruled out from the assessment. However, if we only considered the first question, the impact assessment would only consider a worst-case scenario. The second question we examine, for each cause –> effect pairs that are considered possible, is:

2. *Is it possible that a change in state A will **not** cause a change state B?*

The answer to this question is only positive when the change is unavoidable. In that case, the impact assessment focusses on estimating what the change in state B can look like. When it is possible to avoid a change in state B, the next question for the assessment is:

3. *Under what **conditions** will a change in state A cause a change in state B that exceeds threshold X?*

This question changes the impact assessment from a bottom-up approach, starting at the activity, to a top down scenario exploration, starting at the assessment endpoint. Spatially comparing the required conditions with the physical system and established control mechanisms allows the causal network to be refined and to prioritise causal pathways in informing decision makers.

To illustrate this workflow, we present a worked example of the potential impact of unconventional gas development in the Cooper GBA region on groundwater pressures and quality in deep aquifers.