Parliamentary Commissioner for the Environment
Te Kaitiaki Taiao a Te Whare Pāremata

Address to the 2018 EDS Conference:

Nutrient transport, water quality and modelling: Joining the dots

Introduction

I have an investigation underway looking at the fitness-for-purpose of OVERSEER as an instrument to be relied on and in some instances mandated in the regulation of diffuse pollution of water quality from agricultural sources. I'm not going to give you a preview of my conclusions – I'm not at that stage. But I can share with you three things relevant to water quality that the investigation has highlighted as needing improvement. They are:

1. A better understanding of nutrient transport in three dimensions across a catchment;
2. A better understanding of what models can and can't do to assist in building that picture;
3. Improved communication of what is happening to water quality

After some of the presentations you have heard, this may seem a rather dry and pedestrian address. But dry, pedestrian things can still cause plenty of trouble!

Developing a better understanding of nutrient transport across a catchment

OVERSEER provides us with useful information about nutrient losses from a range of land uses; however, it stops at the root zone. The model is silent about what happens once those nutrients leave a thin 60cm sliver at the land's surface.

But we know that nutrients translocate. For example, nitrogen follows several flow pathways – travelling down into deep groundwater, travelling laterally through soil closer to the surface (interflow), or travelling via surface water. It may be temporarily stored (e.g., taken up by plants that die back in winter and decay). It may be permanently removed from the water (e.g., denitrification).

Landscape features including climate, topography, hydrology, soils and underlying geology determine which of these processes occur. From an environmental perspective we are concerned when nitrogen makes its way from the farm paddock to aquifers, rivers, estuaries and lakes.

Very high levels of nitrate can make groundwater unsafe to drink and kill some sensitive organisms. But the main impact of excess nutrient in water bodies such as lakes and rivers is the 'over-fertilisation' of aquatic plants, leading to excessive plant growth and algal blooms causing oxygen levels to plummet below that needed to sustain life. The natural characteristics of the water body where nitrogen ends up have a great influence on the impact of the pollutants.

Generally **lakes** and **estuaries** are more vulnerable than rivers. Lakes and estuaries act like sinks, accumulating pollutants that can in turn favour algal blooms and nuisance plant growths.

How much water there is in a **river** or **stream**, how fast it moves, whether it's shallow or wide, and the consistency of its flow will determined its vulnerability.

I can't show you a picture of an **aquifer**! They are, in effect, underground lakes that are fed by water soaking through the ground. Like lakes, aquifers are relatively still and contained, so nitrate accumulates. How vulnerable an aquifer is to dissolved pollutants depends on how accessible it is to water from the surface, and that depends on the subsoil.

But it's not just natural characteristics of water bodies that are important – the ability of soil to attenuate nutrients is another key factor. Nutrient loss estimates can be high for a given land use; however, thanks to a highly attenuating soil, the effect on the water quality in a lake or river can be buffered. However, if the same land use is combined with poorly-attenuating soil, water quality will be compromised. These differences would ideally be taken into account when managing land use and water quality in regional plans – *if* you knew about them.

From our discussions with councils, CRIs and universities we understand there are still big gaps in our understanding of nutrient transport across a catchment. For example, GNS has highlighted that we only understand the properties of about 40% of the aquifers in New Zealand. Soil databases are also patchy in scale, age and quality. S-Map coverage of New Zealand is 30%, although this is 61% of productive land.

There are numerous data sets available that can assist our understanding of nutrient transport across a catchment. Here is my current tally. They represent a major investment by taxpayers over decades. But you will see that they are maintained by a variety of different organisations. They come in various states of comprehensiveness and vintage. Here's just one example – hydrogeology. There is no nationally consistent classification of our aquifers although a couple of attempts have been made by GNS. These datasets are not always accessible or being "joined up" in the most useful way to feed into regional council plan making. If we could do so, we could gain a better understanding of nutrient transport in three dimensions.

The role of models

While the fate of nitrogen beyond the root zone is well understood at a general level, the diffuse nature of nutrient losses from land and the large spatial scale of catchments make actual measurement of nitrogen loss at a catchment scale impossible. In the absence of suitable direct measurements, numerous models of varying levels of complexity have been developed to estimate the fate of nutrients lost from land and the consequent loads on receiving water bodies.

Generally models are 'parameterised' (i.e. 'fitted' or 'calibrated') to observations at sampling sites. Because of the costs involved in sampling, models usually rely on calibration based on a small number of sites. This leads to extrapolation – using models outside the range for which observations are available.

Take this example from modelling done by NIWA for the national environmental reporting run by Statistics NZ and MfE. On your left, we have 10-year median macroinvertebrate community index (MCI) scores from sites around the North Island. MCI is a measure of the health of a waterway – the higher the number the better. Using data on the MCI score for a site and the physical and hydrological characteristics, it is possible to predict the MCI score at other, unsampled sites. The results of this model are shown on your right.

As you would expect, the MCI scores are higher, and the water quality better in forested upland catchments. The reverse is true for developed lowland catchments. But there are big holes in the coverage; there is almost an entire region in the middle of the island that appears to have no data. This makes it harder to calibrate the model. As a result, the accuracy of the model suffers. In this case, the model can only accurately predict MCI scores at 70% of the sites.

But even where predictions are made by a "calibrated model" they can be accompanied by large uncertainties.

Let's take, for example, the movement of nitrogen through groundwater. A model might assume that attenuation of nitrogen is uniform across a sub-catchment. However we know from studies that land can be highly heterogeneous. Differences even metres apart can cause attenuation to differ significantly.

For example, Massey University research showed that nitrogen attenuation varied from 30 to over 70% in 15 sub-catchments in the Tararua groundwater management zone. This means that the amount of nitrogen attenuated between leaching from the root zone and reaching the river varies between 30% and 70%. That is significant by any standard.

Dealing with uncertainty is a formidable technical challenge. We will never be able to eliminate uncertainty when modelling complex biological / physical systems. What we can change are the questions we ask of a model before we consider it appropriate for use in decision making.

One of the questions to ask is: "How closely does the model approximate the real system of interest?" To answer this, decision makers and modellers need to understand the uncertainties underlying the model. One of the fundamental tools to establish this is an uncertainty analysis. An uncertainty analysis investigates how a model might be affected by a lack of knowledge about the real value of model parameters.

Identifying those uncertainties that significantly influence model outcomes and communicating their importance is key to using models in decision making process. This doesn't just apply to catchment scale models, but it applies to all models. With this in mind let me share one observation about OVERSEER.

A formal uncertainty analysis of OVERSEER has never been carried out. There have been informal analyses but some of these are very old. A 25 - 30% model uncertainty is often quoted but it is derived from a look at just the nitrogen sub-model and dates back 17 years. This means those using OVERSEER to support decision making may lack important information on what the model can and can't help them with in a policy or regulatory context.

Communicating water quality information

Finally, we need to do a better job communicating information more generally about water quality status.

We could be doing more to assist the community and policy makers understand whether a lake, river or estuary is healthy.

To do this, we need to use the most useful indicators to hand. Ideally, we want to use direct indicators of ecosystem health and function, like the macroinvertebrate community index. This index uses direct evidence of small animals like snails, worms and crustaceans to indicate stream health.

Proxies for health and function of freshwater ecosystems make the next best sort of indicator. An example is dissolved oxygen. Fish, invertebrates, bacteria and plants need dissolved oxygen. Its level will decrease when nutrient levels rise, promoting excessive plant and algae growth. Despite this being an important proxy for health and function of freshwater ecosystems – it is still missing from the national objectives framework, except on rivers below point sources. This means there is no obligation to measure it, or any obligation to ensure the levels are such as to ensure ecosystem health.

Finally, parameters that affect health and function tell us the least – for example nitrate concentrations. Now here's the point: when it comes to indicators, we have more of the least valuable indicators and the greatest scarcity of the most valuable indicators. This is a reflection of data availability which in turn is probably a reflection on how difficult or costly it is to gather.

As a result, direct indicators of stream health are not always available. And even when they are, the data is analysed and displayed in different ways by different organisations. All of which leaves a concerned member of the community none the wiser about what is actually going on.

Let me give you an example from Southland. The Mataura River catchment is the region's second largest. It extends from the southern tip of Lake Wakatipu to the Toetoes Estuary, east of Invercargill. The sampling site I've chosen is Gore which is in a lowland reach of the river.

The LAWA website (a collaboration between New Zealand's regional councils, with analysis done by Cawthron Institute) shows a "fair" MCI rating for Mataura River at Gore. The national level dataset maintained by Statistics NZ and MfE provides no MCI data at this site. This probably results from different time periods being used by the two collecting consortia. Hopefully, MCI state and trend data should improve since macroinvertebrate monitoring has been compulsory for councils since last year.

If we look at nitrate, the LAWA website shows an indeterminate trend for nitrate. At the same site, Statistics NZ and MfE show a worsening trend. We also see that LAWA analyses the trend between 2006 and 2017, while Statistics NZ and MfE analyse the trend between 2004 and 2013. So we are not quite sure what is going on at this site.

So let me summarise:

1. We need a better understanding of nutrient transport in three dimensions across a catchment;
2. We need to understand what models can and can't do to assist in building that picture;
3. We need to improve our communication of what is happening to water quality.

Thank you.