GROUNDWATER STUDY –
THE EIGHT LAKES CATCHMENT

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Paul is a Senior Scientist in groundwater resources at GNS Science and has worked for 37 years in New Zealand groundwater hydrology with current research including: 3D models of geology, groundwater flow and groundwater use, that are developed to inform regional council water allocation policy decisions; land use, groundwater quality and lake water quality; and the economic drivers of groundwater use.

TRANSCRIPT

Thank you very much. This talk is on behalf of my colleagues in GNS Science - Mike Toewes, Conny Tschritter and others, and my colleagues in Bay of Plenty Regional Council - Janine Barber and previously Dougal Gordon.

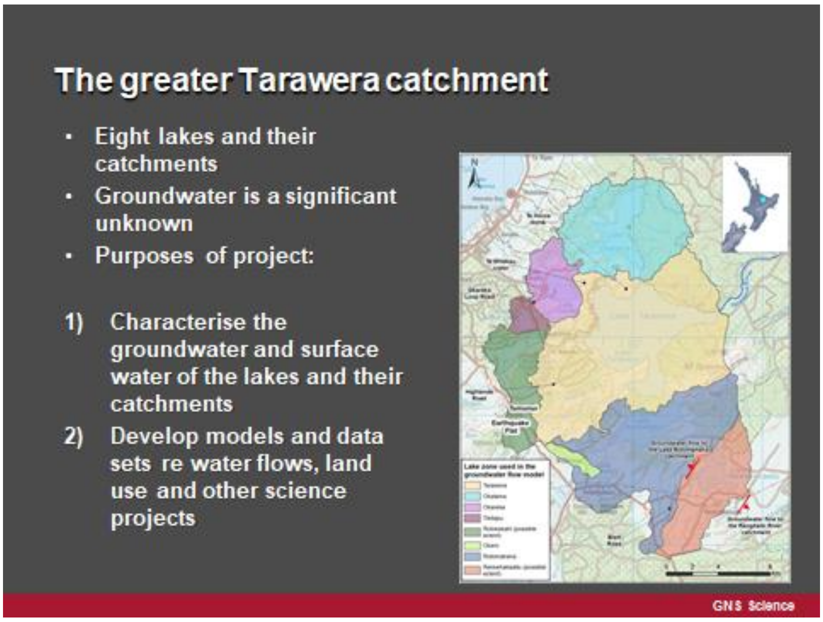
I would like to quickly romp over some of the science we have done since 2002 in the Greater Tarawera catchment, focusing on results. I hope to give people a flavour of what we think is going on in each of the 8 lakes in the catchment:-

- The greater Tarawera catchment
- Purpose of Tarawera project
- Overview of scientific results
    - drilling and some early results
    - geological model
    - catchment hydrology of the 8 lakes
    - groundwater flow
    - nitrogen generation and discharge to lakes and streams
- How results are being used

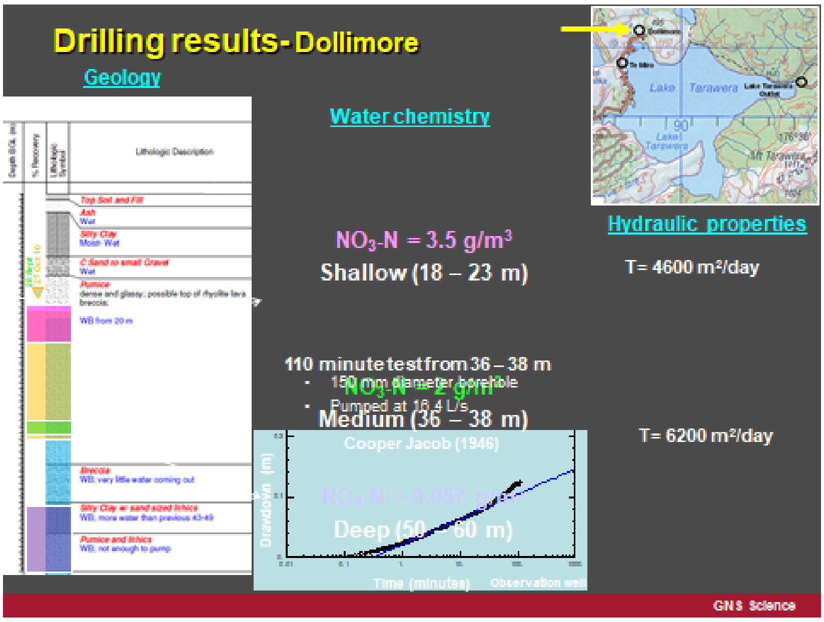
The following slide is the greater Tarawera catchment which includes 8 lakes. Tarawera topographically is at the bottom and rainfall will gradually make its way down to Tarawera from its surrounding area.

What areas are we talking about in the greater Tarawera catchment? Rerewhakaaitu and Earthquake Flat have been the subject of debate within our team and the Regional Council as to where water goes on the margins. Earthquake Flat is included in the Waikato Region and we have included it also because there is evidence that water does flow from this area towards the Tarawera catchment and to the Ōkaro catchment.

We have a situation similar to the Rotorua catchment where part of the Lake Rotorua catchment is in the Waikato region. The Bay of Plenty Regional Council and Waikato Regional Council seem to be working well together in having consistent planning rules around the Waikato part of the Rotorua catchment and possibly the same will happen here.



In 2011 we started the Tarawera Project, a drilling programme, as very little was known about the groundwater system of the area. It is important to understand the groundwater systems to these lakes and I will give a lake by lake potted summary in a few minutes.



The purpose of drilling is to understand the geology, what sort of rocks are down there and the properties in relation to water flow. We drilled three wells, the first being on the Dollimore property in 2011/2012. On the left of the slide is a geological log which is produced by a drilling and shows the most common sediment type which is pumice sand.

We do pump tests, pumping the well, the water level goes down in the well and we can analyse for the hydraulic properties of the rocks in terms of water flow. We came up with numbers, called transmissivity. These numbers are about ten times the numbers in the Rotorua catchment. The implication is that groundwater flows faster in the Tarawera catchment than it does in the Rotorua catchment.

Groundwater chemistry. We sampled for all the nutrients and various other bits and bobs from shallow, medium and deep depths. The results in nitrate nitrogen were:-

- 3.5 g/m^3 in the shallow zones, 18 to 23 metres
- 2 g/m^3 in the moderate depths, 36 to 38 metres
- Less than 0.1 g/m^3 in the deep

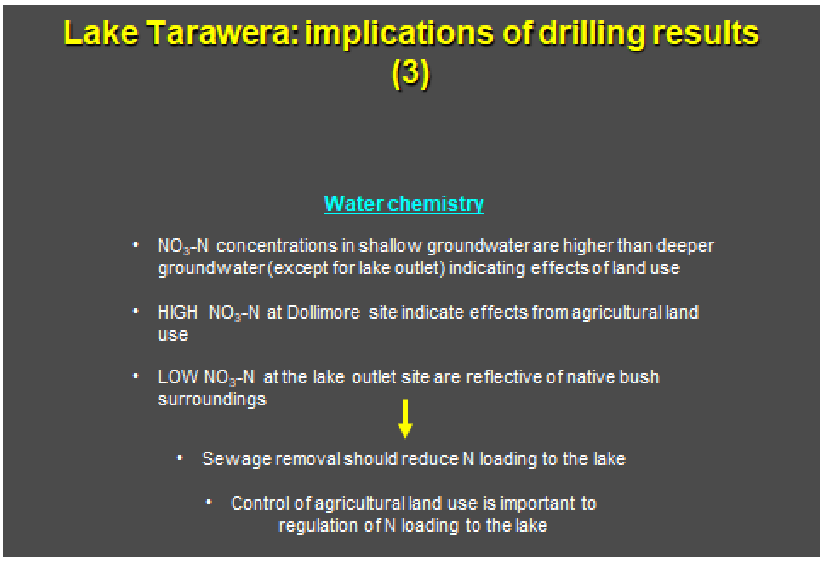
It is very common in groundwater systems to see a decrease of nitrate concentrations in groundwater. Is this number of concern? Yes, it clearly indicates the impact of human activities. That could either be septic tanks or farmland behind the Dollimore well.

Streams flowing into Lake Elsmere typically have a median nitrate concentration of about 3 ppm so this would definitely cause impacts on the nitrogen loading to the lake. In comparison, from a study we did around Lake Rerewhakaaitu in 2002, nitrate concentrations in groundwater around Lake Rerewhakaaitu are up to about 8 ppm and that reflects the intensive use around this lake.

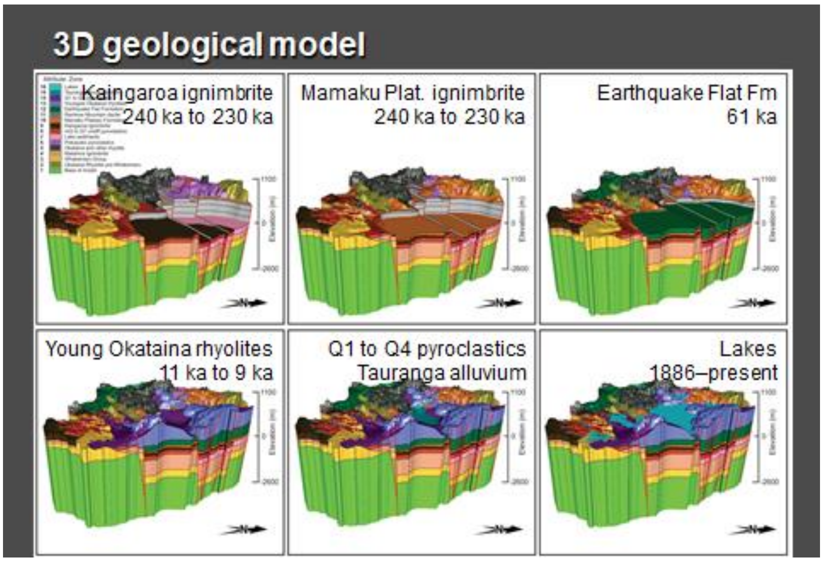
From the geology we found that pumice and ash are the most common lithology, aquifers are mostly unconfined, and confining layers are uncommon. This showed that there is little impediment to groundwater flow and that nitrogen from land use can generally reach lakes. In some of New Zealand's groundwater systems there are denitrifying layers but it seems that these do not occur in the Tarawera catchment and that is because the eruptive products are quite recent.

The hydraulic properties show that the permeability values (K values) range from 14 to 3100 m/day which is typical for volcanic sand and gravels, and they are greater than in the Rotorua catchment. The implications are that nitrogen will respond to land use change and that response may be faster than Lake Rotorua as I mentioned before.

Water chemistry and nitrate nitrogen concentrations in shallow groundwater are higher than deeper groundwater. Sewerage removal should reduce the nitrogen load into the lake. The control of agricultural land uses is important to the regulation of nitrogen loading to the lake.



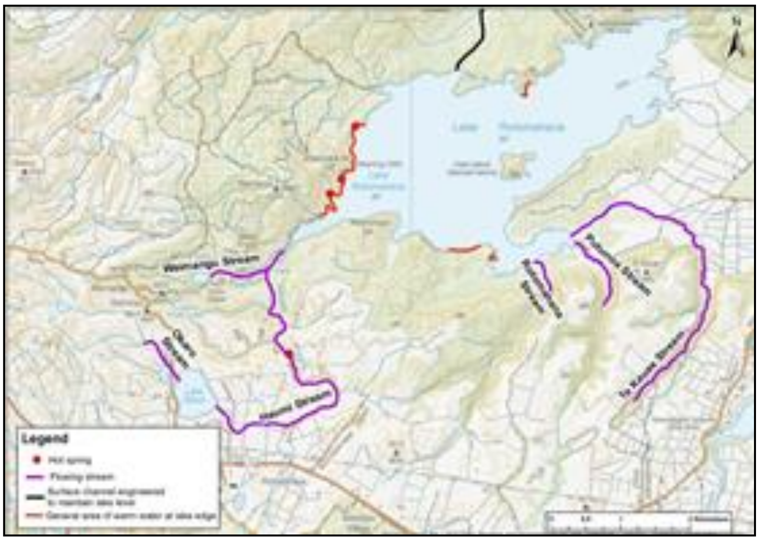
Groundwater can be dated using isotopic methods. We measured the groundwater age to be about 10 to 40 years. For Rotorua the age is about 40 to 180 years. That is consistent with the idea that groundwater is flowing faster in Tarawera than in Rotorua and means that it will respond faster to an increase in nitrate loading from the land and that reductions in taking out nitrate from the catchment will improve lake water quality over shorter timescales.



This 3D geological model represents the layers in the ground from the Kaingaroa plateau deposited from the Reporoa area 240,000 years ago to now. All these layers have different properties. Our drilling programme tries to understand the relevant properties of the key layers in relation to groundwater flow.

Above is a potted summary of some of the lakes, starting off at Lake Rerewhakaaitu. Work we did in 2002 with Dougal Gordon indicated that this lake was perched which answered an issue in terms of the management of that lake. I estimate that this catchment is probably the most intensively farmed in New Zealand. There is a lot of pasture, mostly dairy, and yet the lake is not as poor quality as you would expect if all the nutrients leaked into the lake. It looks like groundwater in the catchment is generally below lake level, which means the lake is perched. So the nitrate from land use seeps down into the ground travels in the directions of the Rangitaiki and Rotohama catchments, and mostly not into Lake Rerewhakaaitu.

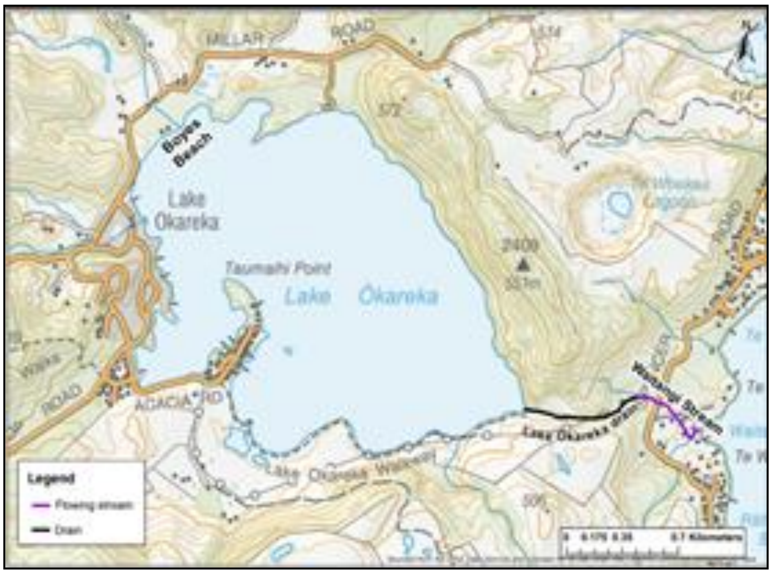
I have spent a lot of time trying to figure out where it does go but it looks like nitrate flow in the groundwater is split between going towards Rangitaiki one way and towards Rotomahana the other way. It is a bit tricky to figure out where the boundary is.



Above is Ōkaro and Rotomahana. The purple streams are permanently flowing and there is one flowing into Ōkaro and the Haumi Stream flows down to Rotomahana. The red colours are geothermal and there is geothermal activity around the lake. The black lines are engineered channels with one going out of Rotomahana. There is another permanent stream on the eastern side which is probably recharged with flow from the Rerewhakaaitu catchment. Ōkaro itself possibly gets groundwater from the Earthquake Flat area.

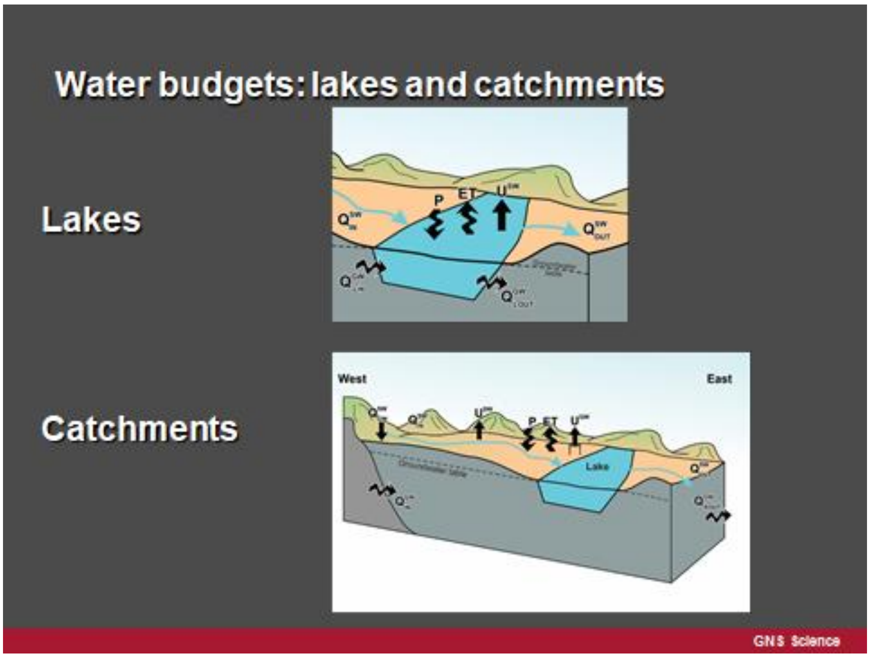
Above is Rotokakahi and Blue Lake. Neither of these lakes have inflowing streams. Therefore rainfall on the catchment all travels into the groundwater system. Generally, 50% of rainfall goes into groundwater. Rainfall in this area may be 1.5 metres, or something like that, per year, that means 700 mm a year goes into the groundwater system. That is a lot of water, aggregated for catchments.

This is Ōkareka which has no permanently inflowing streams and the lake outlet is an engineered structure.



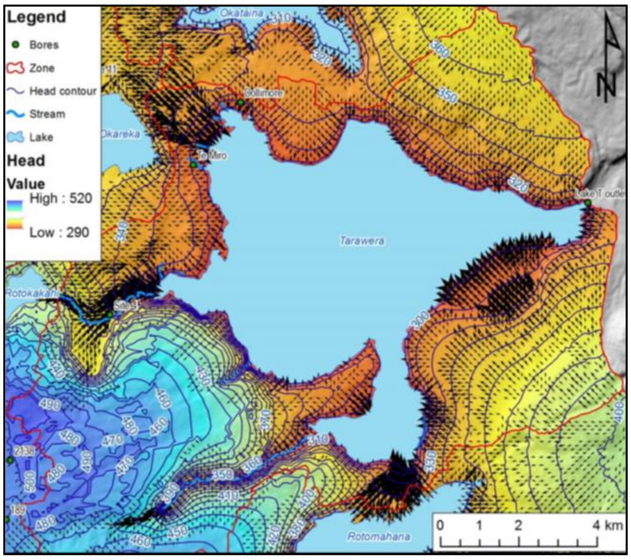
Ōkataina has a couple of little streams in the west and some sign of geothermal activity in the east.

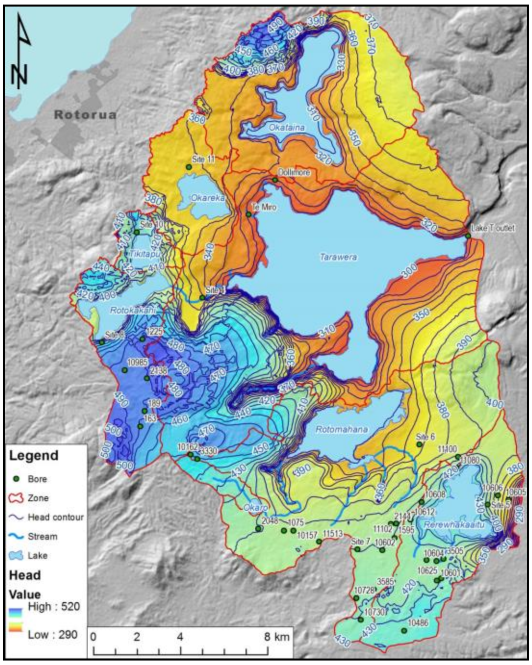
Tarawera is the most complex catchment. There are lots of springs around the lake shore, but not everywhere. For example, few springs are observed between the outlet and opposite Moura Point.

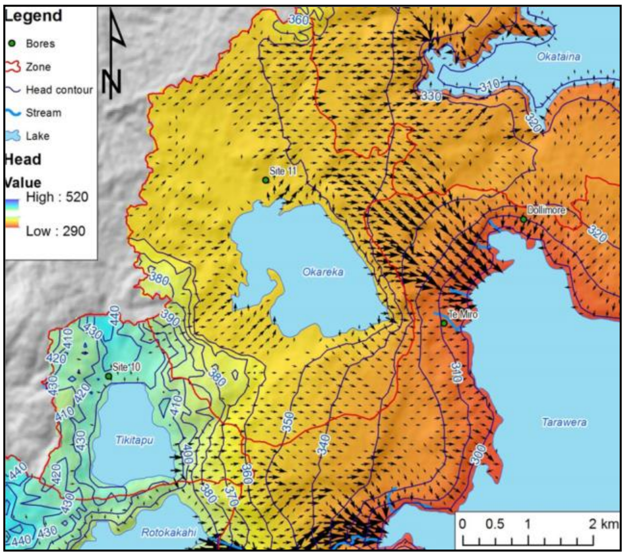


We did water budgets of the lakes to understand the inflows and outflows of each individual lake and the catchments. It is a bit tricky to figure out. One of the first things we did was to estimate properties of groundwater flows for setting up a groundwater flow model.

The next three slides are groundwater flow models. These contours are elevations of the water table. Like any contour map the groundwater table can be represented as an elevation map and we can figure out where the water is going. We can also understand how groundwater interacts with surface water, e.g. the spring-fed stream that crosses Spencer Road takes groundwater from the area between Tarawera and Okareka.

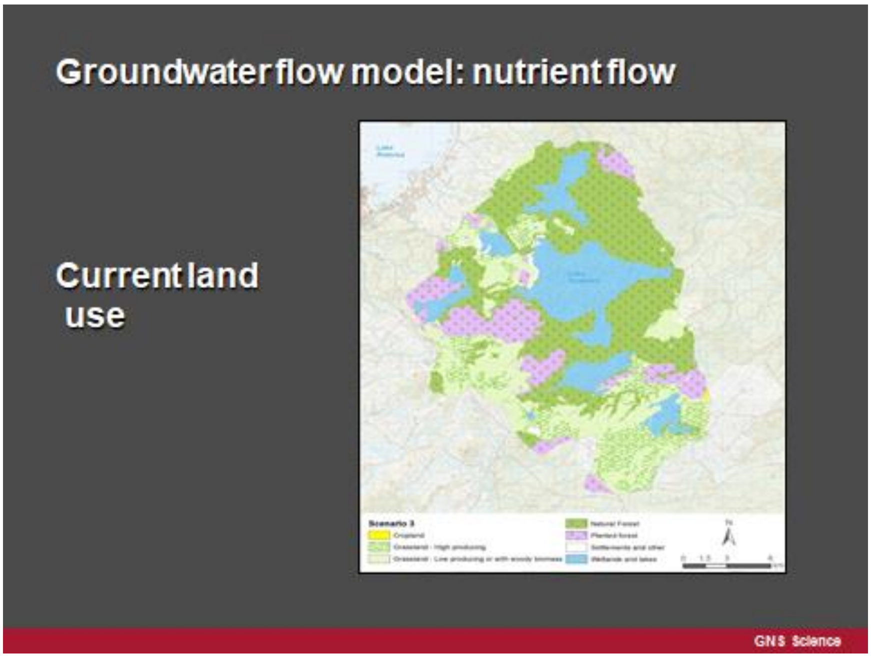






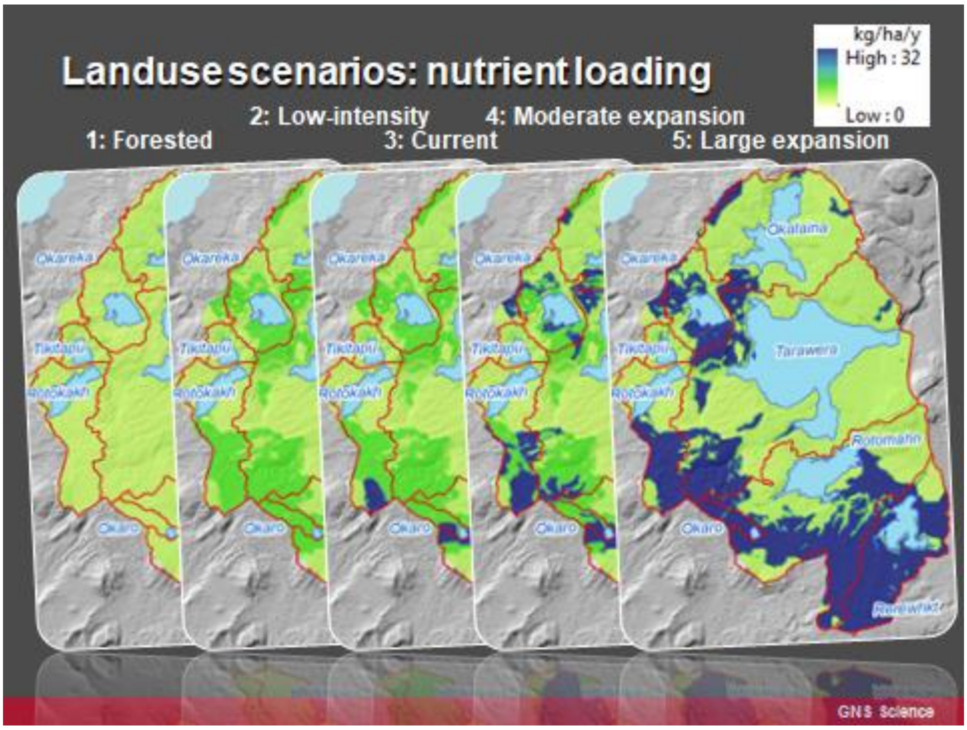
The Dollimore well is on the right slightly above centre of the slide

The computer can work out flow directions. You cannot quite see these details but these are all little arrows. The little arrows are then interpreted to figure out where groundwater is flowing to. The Dollimore well had quite high nitrates in the shallow part of the well. My interpretation of the cause of those would be land use in the area of the craters between Tarawera and Okareka. The arrows are swinging around and then coming down to the lake, so water would be recharged from back up this area. These maps are really important because they make the link between land parcels (and land use in the parcels) and receiving water bodies. We want to know, for instance, if groundwater is flowing directly to the lake or it is flowing to a spring fed stream and then to the lake.

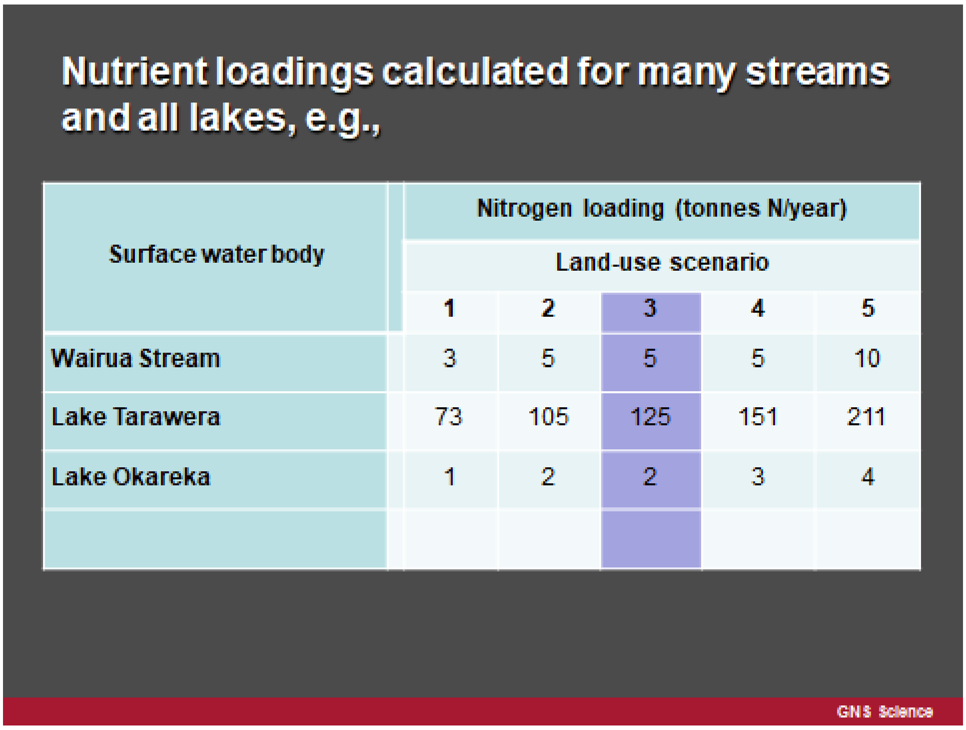


With Alastair McCormack of the Bay of Plenty Regional Council (above) we looked at land use and nutrient flows, particularly nitrogen. The map from Landcare Land Resource Inventory (LRI) data set indicates native forest, exotic forest and pasture in different colours. We looked at what nitrogen could be generated from these land parcels and what the springs and lakes would receive. We looked at current land use, pre-development, pre-human, and a scenario of the likely future intensification. That is not dairy cows everywhere as it is infeasible to think of dairy cows on top of Tarawera. But what if the existing pasture areas were intensified a bit more?

The next slide is actually 5 different scenarios showing the nutrient loading maps translating land use into nutrient loading. Different land uses have different loadings, forest has less than sheep and beef, and others have less than dairy which has less than market gardens for instance. They show a whole lot of zones that we defined around the lake catchments and the green colour goes into blue as the land use becomes more intensified. From forested land use on the left to the current one on the right showing a large expansion in the intensification of farming in the whole catchment.



Following on from that in the slide underneath we looked at nitrogen loading from streams and lakes to understand whether streams are spring fed. In other words are they impacted by land use, particularly nitrogen, or are they not? For the Wairua Stream flowing into Lake Tarawera (Scenario 1, pre-development) we think about 3 tonnes a year was going into there. For Wairua Stream, (Scenario 3, current land use) it has about 5 tonnes of nitrogen per year flowing into the stream with groundwater. Scenario 5 (the most intensified land use) has this discharge increasing to 10 tonnes of nitrogen per year. Therefore, we would have to predict there would be significant water quality effects with such an increase.



Surface water body	Nitrogen loading (tonnes N/year)				
	Land-use scenario				
	1	2	3	4	5
Wairua Stream	3	5	5	5	10
Lake Tarawera	73	105	125	151	211
Lake Okareka	1	2	2	3	4

The Lake Tarawera Scenario 1 (i.e. all forested) about 70 tonnes a year is going into the lake. Nitrogen discharge with Scenario 3 (i.e. current land use) is about 125 tonnes a year, but at its most intensified land use Scenario 5 is about 211 tonnes a year.

In comparison, Lake Rerewhakaaitu shows a very small increase in nitrogen loading from groundwater between Scenario 3 and Scenario 5. This is because the lake is mostly perched.

Chris McBride takes numbers like these and the flows that we calculate and estimates water quality impacts of land use intensification with his lake water quality models.

There are a few more uses as well. We have been looking at the potential effects of land use intensification on spring fed streams. There is a paper on Lake Rerewhakaaitu in the final stages of completion with a student of David Hamilton's and myself. Other lake models are progressing; Chris McBride is going to talk about these models next.

Thank you.