Healthy Rivers | Wai Ora
PLAN FOR CHANGE | HE RAUTAKI WHAKAPAIPAI

Collaborative Stakeholder Group ("CSG") Workshop 13 Notes

(Day one) 2 July 2015, Don Rowlands Centre, Lake Karapiro, 9.30am – 6.45pm

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Attendees:

CSG:	George Moss (Dairy), Gwyneth Verkerk (Community), James Bailey (Sheep and Beef), Phil Journeaux (Rural Professionals), Ruth Bartlett (Industry), Stephen Colson (Energy), James Houghton (Rural Advocacy), Sally Davis (Local Government), Jason Sebastian (Community), Sally Millar (Delegate for Rural Advocacy), Garry Maskill (Water supply takes), Michelle Archer (Env/NGO's), Weo Maag (Māori Interests), Alan Fleming - part (Env/NGO), Charlotte Rutherford (Delegate – Dairy), Garth Wilcox (Horticulture - Delegate), Alamoti Te Pou – part (Māori Interests), Evelyn Forrest (Community), Patricia Fordyce (Forestry) , Gayle Leaf (Community), Graeme Gleeson – part (Sheep and Beef – Delegate), Gina Rangi (Maori Interests), Brian Hanna – part (Community), Chris Keenan – part (Horticulture), Liz Stolwyk – part (Community), Dave Campbell – part (Delegate for ENV/NGO), Don Scarlet (Delegate – Tourism/Recreation)
Other:	Bill Wasley – part (Independent Chair), Helen Ritchie (Facilitator), Janine Hayward (WRC), Jackie Fitchman (WRC), Will Collin (WRC), Janet Amey (WRC), Bruce McAuliffe, Billy Brough (River Iwi Co-ordinator), David Payne – part (MRP)
TLG:	Mike Scarsbrook, Liz Wedderburn, Graeme Doole, Tony Petch - part
Other staff (part):	Alan Campbell (WRC), Vicki Carruthers (WRC), Emma Reed (WRC), Ruth Lourey (WRC), Ben Ormsby (WRC), Justine Young (WRC), Jo Bromley (WRC), Jon Palmer (WRC)

Apologies:

CSG:	Rick Pridmore (Dairy), Matt Makgill (Community), Alastair Calder (Tourism and Recreation), Dr Bryce Cooper (Chair), Dr John Quinn

Item	Time	Description	Action
1.	9.30am	**Opening waiata** The group opened with the waiata himene.	
2.	9.35am	**Intro to CSG13 process** The new Iwi Technical Advisor, Billy Brough was	

		introduced to the CSG. His role is to liaise with River Iwi. Jo introduced some of the Waikato Regional Council staff who were present for the first time at a CSG meeting. Helen provided an overview of the agenda for the two days.	
3.	9.40am	**<u>What to expect from models (DM# 3445650) Graeme Doole</u>** Overview of what the modelling for the project will and won't cover. Key points included: • Importance of the modelling in order to determine potential costs • Solutions to water quality problems lie on the land, with the people. The model tries to integrate the water with the land to understand the impacts. • Management of the land results in profit and pollutant loss. Pollutant loss affects water quality which in turn affects our values. • Profit will be modelled at a farm level and at a wider economic level. • The model will set levels as per the attribute bands CSG chose through the scenarios and work out the potential impacts of scenarios. The goal of the model is to identify the relationship between economic outcomes and reducing contaminants Graeme then talked about the model structure. Inputs to the model will include: • Income and pollutant load relationships • Attenuation information Outputs to the model will include: • Management • Profit • Production • Employment We can't model every farm so representative farm types (developed in collaboration with sectors) will be used for the model. A range of mitigation options for each representative farm type are included in the model. There is a load to come in terms of nitrogen coming in through groundwater. This has been factored in to the model, as well as estimates of attenuation. Discussion on how models should be viewed. Key points: • Modelling is part of the conversation; not the	

		whole conversation • We shouldn't over emphasise the role of modelling • Economics is important but the social and cultural values are important too • Models all have assumptions which limit their effectiveness • An understanding of the assumptions is integral to understanding the limits of the model • Modelling shows one way of achieving your goals but complexity on farm makes things complicated. Water quality limits impact businesses across both space and time. Modelling tries to highlight these impacts. Models can provide: • A set of insights, subject to a number of assumptions • Capacity to test alternative scenarios • Exploration of trade-offs between factors Models cannot provide: • Precision • Perfection • Consensus – will not give answers but will inform the discussions From the economic study you will get: • Understanding the assumptions • Contribution to the Integrated Assessment Framework • A report on the scenarios including tables and spatial effects • Intensive discussions with lots of questions for understanding. • Sensitivity analysis. This can highlight how scenarios would change if some of the assumptions change. <u>Questions:</u> Q – How do non-market values get incorporated into the JEV modelling? A – (Note JEV was an earlier model finished last year) • NMV assesses $ value of water quality improvements • Was done as part of JEV • Shows how people value different parts of the of river by how much they would pay to go there • Difficult to bring into the HRWO model – CSG comes up with the possible improvement to river values. 'These are our aspirations'. Then the model looks at the cost to achieve it.	

		Q –Does the modelling include point source discharges, within sub catchments? A – Yes – as inputs/current loads and as potential for mitigating/ reducing Usually find cost effective gains for point sources have already been done. May be significant locally. Q – When will we get to see an example of the modelling? A – Have to discuss that through TLG. Want to provide full and accurate picture.CSG14 (August 10/11) will have intermediate results and CSG15 August (26/27) will have the full set of results of the 1st round of modelling. Q – Attenuation varies depending on which part of the catchment you are talking about. Does the model assign different rates of attenuation to different parts? A – Yes there is variability spatially throughout the catchment for attenuation – model uses 74 sub-catchments. Q – Catchments, sub catchments and freshwater management units have all been mentioned as different spatial units. Can the model measure them all? A – • Catchment = Waikato / Waipa • FMU – Upper, Mid, Lower and Waipa. • 74 sub catchment s – each has a monitoring station – for water this is the finest scale used. Q – Does the model include any assumptions around climate change? A – No assumptions have been included around climate change. This is due to the difficulty in understanding the relationship between climate change and contaminant effects on water quality. Update on modelling working group Gwyn Verkerk has developed Terms of Reference (ToR) for modelling working group. Anyone from CSG is welcome to join in. Moving forward, Graeme will advise a time to meet in next two weeks. Gwyn to advise other working group members of the timeframe. The Terms of Reference (TOR) are on page 18 of the Agenda Pack.	
	10.15am	**Morning tea**	
4.	10.45am	**Integrated Assessment Framework ("IAF") (DM#3445649) Liz Wedderburn and Graeme Doole** Update on the IAF development. The working group on Integrated Assessment indicators has met and looked at the Integrated Assessment Framework. Thanks to Ruth Bartlett, Charlotte Rutherford, Gwyn Verkerk and Sally Davis who met with	

		Liz Wedderburn. Liz has taken the feedback on board. Discussion on the following points regarding the model and how it will contribute to the IAF. **How can the model inform the Integrated Assessment?** **Positive social/community benefits** Model will tell us: 1. Employment from a social perspective. What happens to the labour/jobs: where do they end up (existing industries)? • By FMU Hard to know what new things will start up from better water quality or under different scenarios 2. Infrastructure: Security of key regional infrastructure is also another key item i.e. waste, water, energy. Affordable (over time) and reliable. Find other ways to get that info – not out of modelling Nothing 3. Access: Nothing 4. Community vitality: types of economic activity **Economic – won't show visitor economy changes** Model will tell us: 1. Jobs created and lost – yes 2. Resilience shows range of land use only in terms of business income and the buffering that provides – other things matter e.g. debt 3. Debt level – is variable – could try – need industry support EFS - yes definitely 4. Industry investing – is this existing or general 5. Retained industry confidence – is this existing or general 6. Change in land value – No Being done in LAWF – is a gap (WRC rating database) 7. Economic opportunity for new business – no e.g. tourism 8. Allow resources to go for high value – yes optimises forestry/ dairy/ horticulture/ dry stock 9. Creation of new industry - no	

		- It was noted that a report on how land has changed over time will be available in six months - this may be helpful to the project. - Consider resilience to farms – not putting eggs in one basket. - The Tourism/Recreation sector advised that they have helped fund a new visitor strategy, with plans to grow the economy. This information to be provided to Liz Wedderburn. - Concern regarding Flood plains – if take out stop banks it will cause problem. The 'flood plains' indicator came out of Values process - This assessment will deal with a range of issues including 'solving one problem and creating another problem regarding access i.e. fencing planting can exclude access.' . - Concern regarding the community indicators - duplication. - Is there an indicator for flexibility – maintain robustness – could fit under resilience. <u>Activity:</u> Which three indicators will be most useful to the CSG to understand the key implications of different modelled outputs/scenarios? Looking at 4 areas of interest: - Cultural/Maori aspirations – we will leave this one until we hear back from Antoine - Economic - Social/community - Wider environmental (beyond water quality) **Specific Indicators – Environmental** Measure proportion / % streams or wetlands protected - Percentage increase in streams fenced (needs more thought – e.g. not feasible for all drystock streams to be fenced % of unique habitats protected - peat lakes - Riverine lakes - Karst Environments - Percentage increase of stock exclusion from wetlands - Measure of % of native species – e.g. fish/ macroinvertebrates/ vegetation/terrestrial and instream. - Use of River going up or down – people days/use/tourism	

3 preferred environmental indicators:

- **Riparian ‘effective for the land use’**
- **Habitat – wetland, unique**
- **Native species – aquatic/ terrestrial**

‘Effective riparian management’ could include

- % including streams fenced (define)
- % unique habitats protected
- % stock exclusion wetlands

Economic/Social Boundary

- Don’t double count but recognise the community/national investment in infrastructure (economic?)
  And the social community benefit/implication of resilient infrastructure
- Relied on by people/communities essential for business
- Ability to afford cost of infrastructure dependent on ratepayer base/investment/reinvestment/population growth/decline (prosperity/ability to pay)
- Ability to afford the service
  Water rates/power bill etc

Social/community

- Employment
  - Types/ diversity of income/jobs leading towards national average income
- Security of infrastructure
  - Reliable and affordable over time while improving
- Enhanced recreational use of the river

3 preferred social/ community indicators:

- **Employment**
  - **Types/diversity and security of jobs**
  - **Average income**
- **Infrastructure secure**
  - **Reliable, affordable to consumers, with investment/reinvestment**
- **Recreational use of river**

  (Vitality and population and ratepayer base will flow from employment and income).

Economic

<table>
<tr><td></td><td></td><td>• Not farm should be land use
• Resilience
  o Not just $ made

We think also need to take into account
  o Adaptability - farm
  - catchment
  o Debt levels (indicator become part of resilience)
  o Change land use and farm management practices to respond to adverse events
  o Industry is actually about economic activity

<u>3 preferred economic indicators</u>

• Employment – total value (no of jobs x income)
• Profitability of land use
• Regional GDP

<u>Process to do the Integrated Assessment:</u>
The CSG were offered 3 options: have an expert panel ‘populate the circles’, have a sub-group of CSG work with experts to do this, or have an extra CSG meeting to do this all together. CSG opted for option 2, a sub-group to work with the panel.

Integrated Assessment subgroup (Liz Wedderburn to convene) –
Sally Davis, Trish Fordyce, Stephen Colson, Jason Sebestian, Gwyn Verkerk, George Moss, Weo Maag, James Bailey, Alastair Calder, James Houghton, Al Fleming. Aim to populate circles by 26/27 August 2015.

Q: River iwi – can they attend and be involved in this sub group? To be discussed further on day 2.</td><td></td></tr>
<tr><td>5.</td><td>12.00pm</td><td><u>Update on approach to lakes (DM#3433691) Mike Scarsbrook</u>

Mike Scarsbrook showed the group a map of lakes in the The CSG have developed and agreed on 5 FMUs. What has been discussed currently with shallow lakes, refers to a subset of lakes in region. There are 62 lakes in catchments (3 of those are geothermal but have been taken out). Only 13 of those lakes are monitored.
WRC usually have representative sampling – different types of lakes have different characteristics etc, dune lakes (at Port Waikato end) there are a large number of peat lakes. Many are very small. Most have catchments that are strongly modified. NOF in NPS provides some bottom lines for attributes – these must be applied to lakes in these catchments.</td><td></td></tr>
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<tr><td></td><td></td><td>Options for CSG to discuss in relation to resolving the issue of lakes currently sitting outside an FMU include:

1. Lakes FMU include only the monitored lakes and their catchments
2. Lakes within the river FMU's
3. One lake FMU for all lakes
4. One lake FMU for monitored lakes that are in D band
5. 4 lake FMU's (1 for each lake type)
6. Lake FMU/s based on management requirements (if that differs from the river FMU they're in)

<u>Lakes questions:</u>
• WRC are reviewing existing monitoring but it is not possible to monitor everywhere for both costs and other reasons.
• NOF attributes don't apply differently to different lake types however, management may be different.
• NPS says all lakes have to be included in an FMU.
• The implications for modelling are that modelling looks mostly at the river. The TLG could do add-ons to give rough estimate for lakes.
• Why were the currently monitored lakes chosen? Most critical, most valued ecologically and most likely to be improved.
• All options would comply with FMU
• Unlikely to get exemptions under NPS.

Action: CSG requests that TLG come back with refined pros and cons and guidance on a preferred option (s).</td><td></td></tr>
<tr><td></td><td>1.15pm</td><td>Lunch</td><td></td></tr>
<tr><td>6.</td><td>1.45pm</td><td><u>Groundwater and Hydrology</u>
<u>David Payne (DM#3433579) and Tony Petch (DM#3445652)</u>

Presentation from David Payne from Mighty River Power (MRP) on Lake Taupo water level, rainfall and flow stations.

Key points:
• There are variations in annual lake level which are due to climatic influences.
By way of example;
• 2004 is considered a wet year and the lake level was above average for the majority of that year.
• 2010 experienced drought for the summer & autumn months, then experienced a flood in September but the annual mean worked out to be an average year.</td><td></td></tr>
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- The level of Lake Taupo must be managed within the minimum and maximum operating levels shown. If the 2010 drought had continued for another 10 days the lake level would have dropped below the minimum operating level. If the lake level drops below the minimum operating level then the flow below Karapiro would constrain many users' ability to abstract water for industrial and public purposes given their current infrastructure.

Modelled dam residence times:
The dam residence times below are based on Opus modelling for the report "*Waikato Catchment Water Quality Model" (2000), Rutherford et al*

- Residence time for a natural catchment from Taupo to the sea is 5 to 6 days
- Residence time for low flows to pass through the hydro system (Taupo to Karapiro) is 30 days, from Taupo to the sea it is 35 days
- Residence time for mean flows to travel from Taupo to the sea is 23 days
- Residence time for high flows to travel from Taupo to the sea is 15 days

Storage:

- Mighty River Power is required to maintain a minimum flow at Karapiro at all times.
- There are times during the year when Lake Taupo storage is used to generate when inflows are lower and at other times of the year when inflows are greater Lake Taupo storage is replenished.
- As a result the Lake Taupo level is restored to approximately the same level each year by the start of the next calendar year
- In dry years inflows into Lake Taupo and the hydro dam catchments can fall below the minimum flow at Karapiro which means the lake level drops.
- The minimum flow from Karapiro ensures that a higher flow than natural is maintained below Karapiro from approximately March onwards during drought events.

David Payne stated that "I recently commissioned ENVCO to undertake flow velocity measurements for the calibration of our Forecast Inflow model for the WHS (Taupo to Karapiro). Based on the velocity measurements attained the travel time worked out to be 9 to 11 days for water to pass through the hydro system which differs from the modelled residence time of 30 days. It was noted that only two or three velocity measurements were taken at each dam so further

		measurements may be required to verify the difference in travel time between actual measured and modelled velocities". The CSG were prompted to read Ed Brown's presentation as it provides base information on hydrology. (DM Ref# 3426929) Discussion on how climate change could increase the amount of rainfall in the area – would that have an impact on the river and in Taupo? It is unpredictable and hard to pick a trend. Huntly Power Station has a monitoring site and a resource consent to keep water at certain temperature. The maximum temperature is 25 degrees. In summer this is hard to maintain as the ambient river temperature can get up to 25 degrees. It is also shallow there. Genesis Energy can't discharge any heat during that time. **<u>Tony Petch – Presentation (DM#3445652)</u>** **See Appendix 1 - Summary document Interim summary of ground water information for consideration by the Collaborative Stakeholder Group DM#3433606** In October 2014 the TLG gathered together six groundwater experts to understand more about ground water. A gap analysis was carried out – what we need to know in 6 months, 1 year and 2 years? This started a range of investigations. Groundwater investigations- Waikato and Waipa Catchments: • Short term field investigations of groundwater • Groundwater resource characterisations • Estimation of lag time of water and nitrate flow through the unsaturated zone • Predicting the denitrification status of ground water • Steady-state catchment model • How has land use changed over time? Discussion points: • Of the total water flowing out at Port Waikato each year, about 75% comes from groundwater • In the Waikato we are generally not losing groundwater to neighbouring catchments. • After centuries, groundwater will extend into the long-term flow paths. • Impacts of that will take time to be expressed in	

water and streams.

- Geology of the Upper Waikato is highly permeable.
- Waipa has old basement terrain. This is from old marine sediments. Volcanics overlaid such as Pirongia and Hauapuka. The geology is like a bathtub – once it's full, it flows out.
- Middle and Lower Waikato has moderately permeable soils.

Discussion on chemistry and the groundwater lag times.

- Total travel times
  - < 10 years for low lying areas and low hills in lower and middle Waikato and Waipa and Reporoa area
  - 10 – 30 years for rolling land above 100 m asl
  - longest travel times (50 – 100+ years) under ranges and elevated terrain
- Mixing in the upper aquifer zone
  - 2.5 – 6 years (mean 17 per cent of total travel time)

Water age (Waikato and Waipa):
Surface water

- Stream water <15 years (average 10 years) in lower, middle Waikato and Waipa
- Stream water older (average 52 years) in upper Waikato
- Waikato River main stem water is younger (12 years) because of inflow from Taupo

Ground water

- Ground water age much older than surface water
- No clear relationship with depth
- Age highly variable – depends on hydraulic properties, flow paths, fracturing
- Very shallow lowland ground water 1-2 years
- Upper Waikato springs 11 to 60 years
- Deeper ground water 150 to 250+ years

Q: Why were the nitrogen lags not increasing in the Upper Waikato bores that were sampled?
A: Data is episodic – might have only one of two observations over 12 months. There are bores in some parts of Upper Waikato that some show increased nitrogen – some don't.

Impacts from the original reduction of forests may not have been seen yet (due to very long lag times).

Denitrification: Waikato and Waipa

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<td>This is a process where nitrate as it enters the ground water converts into nitrogen gas under reducing conditions (no oxygen).
No strong regional pattern in where reducing conditions occur.

Implications for the CSG to consider:

Groundwater quality
Impacted by land-generated N – N especially in shallow aquifers
Lag time and water age

Stream water quality not in equilibrium with land use yet
Upper Waikato stream water not yet impacted by conversions
Other areas showing slow increase in groundwater N
Deep ground water not yet affected but this can take centuries

Denitrification
Exists but is spatially variable: consistent patterns hard to establish at a property scale

Discussion points:

There is not any mapping of hot spots of nitrate levels. It is fair to say that younger water in the Hamilton basin carried higher levels of nitrogen that older ones.
Thinking about land use change over time and the loads that are applying to groundwater and streams. Historical land use data is from 1972. A lot of forestry was planted in the 1920s.
Shallow 0 -10 meters, deep 200 metres down. Water over 100m classed as deep.
The two reports from Aqualink have been referenced by other reports Tony Petch has written. Aqualink were part of groundwater panel.

Q: Climate change question for Ed Brown. Clarify difference of IPO and climate change

<u>Where to next:</u>

Summary report for phase one.
Tony Petch is managing the groundwater work.
Action: The CSG would be interested to know information on how groundwater influences the operation of the model. This will help with messaging to HRWO and stakeholders.
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<td>7.</td>
<td>2.30pm</td>
<td><u>Nutrients (DM#3445653) Mike Scarsbrook</u>

The results of the expert review on nutrients were presented by acting independent chair of the TLG Mike Scarsbrook. The report was written by TLG member Dr</td>
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John Quinn.

Key points:

- A number of studies have been done in this area and we are now at a point where there is a good picture of nutrient limiting dynamics
- From the monitoring site information we know that where there is a strong correlation between both TN and TP and Chlorophyll A [indicator for phytoplankton]
- One piece of analysis asked does increasing TP and increasing TN always lead to an increase in Chlorophyll A? The answer was yes for TP but not for TN.
- Bioassay work was done [multiple studies]. The different studies showed different outcomes. At times N was more important than P and at other times P was more important than N, in regards to algal growth.
- This suggests that variation both temporally and spatially occurs in regards to which nutrient is limiting.

<u>Conclusions</u>

- The evidence suggests that phosphorus is more important than nitrogen in controlling the annual median phytoplankton biomass in the Waikato at present
- However, nitrogen is likely to exert limitation of phytoplankton biomass at times.
- Therefore efforts to control phytoplankton biomass should be primarily focussed on phosphorus, but still have a secondary focus on nitrogen.
- Controlling nitrogen would also be prudent for a precautionary approach as a large weather event could result in an influx of phosphorus [leading to algal growth if the river was P limited]

<u>Questions:</u>

Q – What are the wider implications of the TN and TP attributes beyond phytoplankton?
A – TN and TP are primarily a concern in regards to algae. Phytoplankton has affects on water clarity which affects swimming. TN and TP are required attributes for ecosystem health too under the NOF for lakes and lake-fed rivers.

Q – If P is the more important nutrient to focus on, as we manage P down it will still be important look at N. How do we find the balance, e.g. if there is a flood of P etc?
A – The thinking the CSG has done around the attribute bands will address this. Chlorophyll A, N and P are all being looked at together through the scenarios.

Q – Why would you not include TN and TP in the Waipa? The effect is seen in lake fed rivers as algae have time to grow there but the Waipa is not impounded so there is no retention time for algae to grow. There are also mixing and light issues in the Waipa that make it difficult for algae to grow.

Q - Has P gone down in recent trends?
A –In the latest report P has trended down in a number of sites.

Q – Why has P improved at many sites?
A – NO – hypotheses are: better effluent point source control, riparian, erosion control, climate variability – but we can't know
. Reducing sediment run off certainly helps to reduce P. Improving effluent management also reduces P inputs.

Q – Is there any increase in P solubility as N increases? (If N rises will it at some point release more P?)
A - P bound to sediment can be released under some chemical conditions. It would be worth investigating this further.

Action: (Question for TLG) Can increases in N lead to more release of P from sediment? If so, will this influence the nutrient limiting of N/P?

Q – The CSG still hasn't seen the bioassay reports. Can this happen?

Action – Follow up on when CSG can get bioassay reports.

Q – Is coastal/ estuary environment a risk at Port Waikato/ Waikato River?

> A - It's a general view that coast and estuarine areas are more at risk of N than freshwater. Could look at specific effects for Waikato.

Q; Climatic effects – wouldn't the P bound to sediment be trapped in the dams in a dry climatic event?
A - Relates more to anoxic phases during stratification of water in a dry period, when P is released from bottom sediments

Q: Is there a report showing what percentage of the P load is manageable? (Vs already in bed sediments)
A - Bill Vant may have done this – need to check

Q – Would phytoplankton still occur naturally? (Without human activity?)
A – Yes still would be phytoplankton in a natural river,

even a river without dams. But to grow lots, time and nutrients are required

Q - How do we deal with groundwater delay factor?
A - Will go into model. Critical info is historical land use. Will provide projections, over time as things head for equilibrium. Some work to predict this is underway

Q - Is one bioassay in Autumn sufficient?
A - Other bioassays were done; showed response to N and P. Use word ‘precautionary.’ If N can be limiting at times, need to think about what activities might be going on at that time that affect N

Q - Could there be sediment accumulation sites at stream mouths, not just dams?
A - Possibly

Q - Do we know enough about what is happening in the whole water column during stratification times?
A – it is largely theoretical - little evidence of any stratification in Karapiro.
.
Q – If you improve clarity by removing sediment, will effects of N change? If you drive the system to P – limitation by removing sediment
A -

- Algae might grow more due to light
- You might still have dissolved P (not attached to sediment)
- You could still get macrophytes (because they draw P from bed sediment)
- More macrophytes might provide more habitat, but might also reduce Dissolved Oxygen and impact ecology and reduce quality for swimming.

Important point – if we improve clarity, what are the impacts for other attributes

Action: (Question for TLG) If water clarity improves due to reduced sediment; will this lead to more phytoplankton due to increased light climate? How would the nutrient limiting dynamics be affected by this, either positively or negatively?

Q – How can test the robustness of studies to ensure that when we build in this information for policy development we can justify it?
A –In general the TLG is keen to have independent peer review for sensitive work.

- Expert caucusing on first two reports
- Publishing detailed experimental work
- 2 additional pieces of work
- Independent peer review ramped up

		o Need to document this process Q - Will CSG see S32 material and backing reports. A -Yes	
	3.15pm	**Afternoon Tea**	
8.	3.45pm	**<u>Point and non-point source mitigations – microbes and nutrients (DM#3433551) Mike Scarsbrook</u>** Report (DM#3433551) pre circulated to CSG. Mike Scarsbrook gave a verbal update on DNA sourcing work – early results show no human contamination in samples. Ruminant animals (sheep, cattle), and water fowl were the main sources. The CSG then completed a workshop session to draw on experience of CSG members. Three stations were set up for N, P and microbes. The TLG interacted with the group. Workshopping notes **<u>E. coli</u>** **Where does it come from?** • Sheep/cows/other livestock • Birds/waterfowl – pukeko, ducks etc • Possums/land-based animals • Septic tanks (? groundwater factor?) • Farm effluent (discharges of untreated material to land) • Point sources - ? o 2 pond systems discharging to water • Storm water run-off • Sewage – urban discharges (if processing incomplete) **How does it get into water?** • Overland flows to streams etc • Animals (stock and birds) directly to water • Groundwater flows – re-emerging. NB - general view they only last for 5 days • Point – source pipes **What can be done to reduce it?** • Sunlight • * Matching LUC to stock class • * Riparian margin (width important) • * Fencing to exclude stock • Fewer cows/cattle/stock/manage better base flow • No deer wallows that lead to watercourse • Waste water treatment • Wild fowl control!! (eliminate)	

- Effluent disposal by spray irrigation
- Pest control
- Compulsory doggie bags (pooper scoopers)
- * Retention areas/wetland – depends on topography

How effective is this (what does it depend on)
- Disinfection
- Reducing overland flows and direct input
- Not effective forestry (riparian margin)
- Grass better than trees
- Depends on level of financial investment re bells and whistles or low cost approach
- Storm water control
- Irrigation management
- Locally highly significant at base flow (effluent disposal by spray irrigation)
- Bunds along streams
- Unintended consequences, creates dams
- Issue large area land and storage needed – Rotorua discharge to Whaka forest is to be discontinued (effluent disposal by spray irrigation)

N

Where does it come from?

- Urine
- Direct from animals to ground (pee)
  - sheep, cattle, deer, pigs
  - birds, wildlife
- Run off to streams
- Drain into ground water
- Dairy effluent e.g. wastewater, irrigation
- Wastewater treatment plants
- Industry point source discharges e.g. dairy factories
  - pigs
  - industry fertiliser ponds e.g. Kinleith
- Mineralisation following cultivation (e.g. cropping on pastoral farmland)
- Stormwater
- Fertiliser aerial/runoff
- Native trees
- Forestry, gorse, N-fixers
- Lightning
- Compost, silage

How does it get into water?

- Leach through ground water
- Surface runoff
- Discharge from poo ponds to watercourse

- Direct from stock to waterways
- Pumped out
- Point source discharges
- Leaching
- Runoff

What can be done to reduce it?

- Reduce urbanisation on cropping land
- Improved N-efficiency through grazing, genetics etc
- No till
- Maintain organic matter
- Band and incorporate fertiliser not broadcast - cropping

(a) Reduce runoff to streams (lower effectiveness than (b))
Riparian planting
Stopbanks, sediment ponds
Prevent stock entry to waterways
Reduce or have appropriate stocking rates
Appropriate fertiliser applications
Use effluent storage pond and contents to capture N
Fertiliser with effluent at appropriate rates rather than discharge to streams
Shoot/poison birds

LUC to stock class
Timing/rate of fertiliser – important for hort
Winter cropping/fodder crop management (high N loss if grazed in situ)

(b) Nutrient management on farm
Use low protein feeds
Effective use of stand-off pads
Use liners for storage of N-rich materials e.g. compost/silage
Off pasture systems
Low impact systems, less intensity = lower N
Use DCDs (currently banned)
Moratorium on conversions
Use of wetland plantings/wetland construction/protection
Grow watercress
Wastewater treatment all point sources – 6%
Maize
Soil additives – gibberelic acid
Gorse control
Improved pasture species

How effective is this? (What does it depend on)

(a) Yes. Use appropriate species, width. Not effective for forestry.
(b) Yes. Lower intensity. Effective until production system becomes uneconomic

Depends on level of treatment.
Ponds → Carbon dosing → barriers/fillers

<u>**P**</u>

Where does it come from?

- Sediment and erosion
- Earthworks
- Overland water flow
- Fertiliser use
- Point source and non point
- Sewerage
- Natural/background
- Animal excretion
- Supplementary feed
- Compost piles
- Dissolved Phosphorous eg anoxic sediment at base of dams
- Forestry harvesting
- Dishwashing powder

How does it get into water?

- Erosion
- Stock in waterways
- Stream bank erosion
- Need to consider lag effect of P
- Overland flow sediment
- Overland flow from exposed soil/pugging
- Stormwater
- Point source discharges

What can be done to reduce it?

- Maintain soil organic matter *hort
- Stock out of waterways *dairy
- Farm planning → target hotspots *hort, sheep, beef
- No effluent pond discharge to water *dairy
- Riparian strips
    - Set backs site specific
- Encouraging wetlands retirement retention dams/sediment traps
- Erosion management

		- Trees on hills e.g. - retire steep land *sheep and beef • Tracks and races - management → run off All earthworks, cultivation, setback from perennial streams * forestry earthwork controls • Precision application of fertiliser and timing • Managing Olsen P * if high (soil dependent) – dairy • Limits on strip grazing of stock • Good management - Buffers - Direction of strip • Dose waterways with alum • Timing and type of fertiliser • Hard stand pads *hort • Matching LUC to stock class *sheep and beef Wastewater treatment Subject to the technology used: • Ponds • Mechanical dosing with allum • Filters barriers **How effective is this? (What does it depend on)** • Set back/class of stock • Permanent or temporary fence • Ease of fencing/hill country → sheep options • Problem what mean by riparian? should be setback from top bank • Slope/type of vegetation • Depth of riparian strip • Very – provided it's maintained (Encouraging wetlands retirement retention dams/sediment traps) • Earth bunds/ interception drains *hort Day 2 will look at how we encourage people how to do these practices.	
9.	5.15pm	**<u>Feedback from our networks (DM#3080587)</u>** Written feedback was provided from Rural professionals, Community, Env/NGO and Sheep and Beef sectors.	**Action: CSG members to complete the feedback template**
10.	5.30pm	**<u>Approvals and updates session</u>** **1. Confirm CSG12 workshop notes** **The workshop notes were confirmed by the CSG:** **Stephen Colson/ George Moss**	**Action: Availability of the technical reports – TLG to create a programme of release of**

		Carried **2. Receive research update** **The TLG update report was received by the CSG.** **George Moss/Sally Davis** **Carried** **3. Further discussion/ confirm attributes** Bill Wasley outlined that feedback from the Sheep and Beef sector and ENV/NGO sector had been received. The intention for this session is to confirm the attributes. Once confirmed, the attributes will go to HRWO Committee for endorsement. The Sheep and Beef sector representative has had further discussions with TLG and the issues stated have now been resolved. Sheep and Beef sector key points: • Part of the role of the members of the CSG is to provide confidence in the process of setting limits to their respective sectors. The drystock sector wanted time to explore the reasons and implications for adopting attributes and site selection • The choice of attributes is more than just a benchmarking or a reporting mechanism. • Choice of sites to report on progress or compliance is important because this will influence modelling and public perception. • Drystock sector have critical role to play in improving water quality. • Large scale land use change to production forestry from sheep and beef not considered a legitimate N loss reduction mitigation. • Release and reference to Beef + Lamb New Zealand principles for the allocation of nutrients. • Develop a scenario that does not involve regulated wide scale land usechange and models adoption of known on farm good management practice for N and P. Env/NGO sector provided a paper on “MCI as an attribute in the Waikato and Waipa River Catchments.” (DM#3458720) • Extra information provided to CSG as to why MCI should be an attribute. Prior to last workshop the Env/NGO sector had meeting and endorsed this position. • The TLG recommended that MCI not be an attribute. • The CSG was asked by the Env/NGO rep to	**technical reports that provide basis of decisions to be made.** **Action – Justine Young to provide DO info to TLG.** **Can increases in N lead to more release of P from sediment? If so, will this influence the nutrient limiting of N/P? TLG/Vicki Carruthers** **If water clarity improves due to reduced sediment, will this lead to more phytoplankto n due to increased light climate? How would the nutrient limiting dynamics be affected by this, either positively or negatively? TLG/Vicki Carruthers** **What is the difference between effects on rainfall from Pacific Oscillation and climate**

		reconsider if MCI be an attribute An excerpt from the above paper is noted below to show reasons for MCI as an attribute: **1 Support for including the MCI as an attribute in NOF** 1. Contrary to the TLG's recommendation there is large support for inclusion of the MCI as a compulsory attribute in the National Objectives Framework for Freshwater Management (NOF). This support comes from scientists, environmental groups and various other parties. 2. The New Zealand Freshwater Sciences Society (NZFSS) states in their 2014 submission to the "Proposed amendments to the NPS for Freshwater" that: "The MCI was developed as an index of pollution tolerance and has been shown in numerous studies to respond in a predictable way to land use **and nutrient enrichment**". 3. The NZFFS recommended that MCI be adopted as a NOF attribute and provided an attribute table that included banding and associated limits. 4. Various other scientific reports support the use of MCI as an attribute to assess ecosystem health including "Collier et al 2014. A macroinvertebrate attribute to assess ecosystem health for New Zealand waterways for the national objectives framework – Issues and options. Environmental Research Institute report 36, University of Waikato, Hamilton." 5. This report was prepared for the Ministry for the Environment and includes an assessment of whether a MCI attribute would satisfy the guiding principles for NOF attribute development. These principles are similar to the list of principles used by the TLG in their assessment and subsequent recommendation that MCI should not be an attribute. 6. The recently released report by the Parliamentary Commissioner for the Environment (PCE) entitled "Managing Water Quality – Examining the 2014 National Policy Statement" recommends: "The Minister for the Environment amends the NPS to include MCI as a compulsory attribute for measuring ecosystem health." 7. Stark JD 2014 states:	**change? Ed Brown**

> "... In this report the focus is on the use of the Macroinvertebrate Community Index (MCI) developed by Stark (1985, 1993, 1998) because of its long history of use in New Zealand and in Taranaki, proven strong negative responses to increasing enrichment (such as nitrogen, periphyton chlorophyll 'a' and ash free dry weight), **sedimentation,** and changes in land-use along the native bush – agricultural – urban gradient ..."

Further discussion within the CSG.

The Decision Making Framework (DM#3436809) was handed out to CSG.

1) Has there been robust discussion? Yes
2) Test for unanimous discussion: No (Env/NGO and Horticulture sector not agree)

Further discussion from CSG:

<u>Attributes</u>

- Concern if MCI monitoring resources reduce. Is there a way to ensure that it gets its due weight?
  - want to see this secure
  - part of what we recommend.
- What can we manage vs measure?
- Manage nutrient enrichment
- NOF didn't land this – should we wait until its resolved there?
- Can it apply to mainstem/ soft-beds (there is a version that can)
- Concern of process - bringing in science that's counter to TLG
- Share sentiment of concern for mahinga kai, mauri and MCI as an indicator of healthy ecosystems and natural environments - also important to visitors
- Important to keep 'looking up' into the tributaries

<u>Possible resolution – MCI</u>

- CSG sees MCI as an important indicator of ecosystem health and want to see it given weight in the wider policy process and monitoring regime.
- It is included in SOE monitoring
- It could come into the Integrated Assessment and Anticipated Environmental Results for HRWO.
- WRP review can take into account any changes in NOF from 2016 review.

<u>TN/TP – 2 alternative wording suggestions</u>

- TN/ TP in tributaries to

1: be set as
2: be reconsidered as

		attributes once modelling results are available **Proposed wording - CSG to revisit/reconsider tomorrow.** <u>Dissolved Oxygen</u> • TLG has assumed this was already monitored below point source discharges – this is not currently the case • Is not fully in scope of 4 contaminants (not a robust cause –effect link) • TLG yet to consider this • NOF requires continuous monitoring for 7 days • Consent process provides for discharges to present evidence etc – makes sense to let individual consent holders work through this process. • Might not be relevant to these 4 contaminants but WRC would still have to pick it up in some way as a compulsory NOF attribute. **Dissolved Oxygen (DO)** • **Request the TLG to come back to CSG with a report on DO as an attribute related to cause and effect link with 4 contaminants.** **Ruth Bartlett/George Moss** **Carried. Note Rural Professionals disagree.** **(Reason: Do not want to delay the decision).** Agenda items: Plan template working group and Information release are deferred until Day 2. Further discussion on Attributes on Day 2.	
	7.15pm	**Workshop closed. Dinner**	

Collaborative Stakeholder Group ("CSG") Workshop 13 Notes

(Day two) 3 July 2015, Don Rowland Centre, Lake Karapiro 8.30am – 4pm

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Attendees:

CSG:	Alan Fleming (Env/NGO), Garry Maskill (Water supply takes), George Moss (Dairy), Gwyneth Verkerk (Community), Phil Journeaux (Rural Professionals), Ruth Bartlett (Industry), Stephen Colson (Energy), Garth Wilcox (Delegate – Horticulture), Patricia Fordyce (Forestry), Sally Davis (Local Government), Michelle Archer (Env/NGO's), Weo Maag (Māori Interests), Charlotte Rutherford (Delegate – Dairy), Sally Millar (Delegate – Rural Advocacy), James Houghton (Rural Advocacy), Evelyn Forrest (Community), James Bailey (Sheep and Beef) Liz Stolwyk (Community) Gayle Leaf (Community), Graeme Gleeson (Delegate – Sheep and Beef), Brian Hanna (Community), Chris Keenan (Horticulture), Dave Campbell – part (Delegate – ENV/NGO's), Don Scarlet (Delegate – Tourism/Recreation), Gina Rangi (Māori Interests)
Other:	Bill Wasley (Independent Chair), Helen Ritchie (Facilitator), Janine Hayward (WRC), Will Collin (WRC), Jackie Fitchman (WRC), Justine Young (WRC), Janet Amey (WRC), Vicki Carruthers (WRC), Alan Campbell (WRC), Jon Palmer (WRC), Bruce McAuliffe (WRC), Ben Ormsby (WRC), Tony Quickfall (WRC), Emma Reed (WRC), Jonathan Cowie (WRC), Patrick Lynch (WRC)
TLG:	Mike Scarsbrook, Tony Petch
Other (part):	Tracey May (WRC), Alan Livingston (HRWO Co-chair), Lakimini Karunathilake (TARIT), Ngaroma Maika (TARIT), Grant Kettle (Raukawa), Simon Barsdell (MMTB), Tim Manukau (Tainui), Billy Brough (Iwi Co-ordinator) Jacqui Henry (WRC) Jo Bromley (WRC),

Apologies:

CSG:	Matt Makgill (Community), Alamoti Te Pou (Māori Interests), Jason Sebastian (Community), Rick Pridmore (Dairy), Alastair Calder (Tourism and Recreation), Roger Pikia (HRWO Co-chair), Bryce Cooper (TLG), John Quinn (TLG)

Item		Description	Action
	8.30am	Waiata	
11.	8.35am	**CSG-only time – Reflect**	

12.	9.15am	**<u>Policy options – nutrients and microbes (DM#3425911)</u>** **Policy Options – Nutrients and Microbes** For this session, the CSG were asked to keep in mind: • the policy selection criteria (think about options). • the Vision & Strategy (to give effect to this as well as the RMA). **Key questions:** If you are thinking about a performance or effects based method (like a property cap) • Can you measure the amount of microbes/nutrient from a property (or from a point source)? • Can you measure it directly or use a model (and what issues come with each of those options) If you are thinking about asking for specific practices or mitigations: • What matters for effectiveness? • Can you observe the practice? • What are the implications for wide-scale implementation? **Recap sediment policy options** Policy A Rule – CSG have set this aside for now Policy B – Rules-some activities specified that apply everywhere (e.g. earthworks restricted on steep slopes – existing) Staff are looking at options from last CSG to bring back • Cattle and deer exclusion from water • Steep slopes/waterbody setback for heavy stock • Sediment traps (e.g. As seen at Bill Garland's farm) • Setback for strip grazing from waterbodies in wet periods Policy C – Subsidies - money or expert help available to undertake activities • Could also do things like run competitive tender or par more for certain things (Policy E & F) Policy D – Rules – activities that suit each specific property, as set out in property plan • Range of CSG views about whether every property must have a plan and a timeline for achieving • Could have an industry approved plan with WRC regulatory backstop **CSG feedback themes so far:** • Need to know the size of the change required before we can nail down which options • The end package will probably have aspects from a few	

of these options.

Ideas for microbes policy options

- Same as sediment options
- PLUS detail about which practices are promoted or required
    1. Continue to control point sources
    2. Stock exclusion/setbacks to prevent runoff of microbes into water (sheep matter as well as cattle for microbes)
    3. Ways to manage farm effluent – ponds and irrigation
    4. Attenuation options – die off of microbes

Ideas for phosphorous policy options

Same as sediment options PLUS

- Detail about which practices are promoted or required e.g. Track/road design on slopes
- Soil or input limits on P
  e.g. could have a rule: permitted if soil test results supplied showing Olsen P doesn't exceed limit for different soil types
  Market instrument: tax on P fertiliser – not considered feasible at a regional scale

Ideas for N policy options

Same as sediment options PLUS

- Detail about which practices are promoted or required eg. Could include promoting attenuation using boggy areas, wetlands
- Market instrument: tax on N fertiliser – not considered feasible at a regional level
- Rule: property level limit of root zone nitrogen OVERSEER model in background to determine the limit or within rule and used in monitoring/compliance
- Rule: property level limit on main N inputs eg. Amount of brought-in feed, fertiliser

There is a trade off between going for simple, easy to understand, option and an option that has greater flexibility and information.

A key question is - what does it take to implement these?

Jon Palmer then talked about the WRC experience of Variation 5 (V5) in the Lake Taupo catchment.

Key points from Jon's presentation included:

- For V5 they used OVERSEER to set a Nitrogen cap and trade scheme.
- Farms have nitrogen management plans and every year farms supply data to ensure compliance.
- A lot of work was done to ensure the implementability of V5. It needed to be enforceable and to give the ability to defend a case in court; otherwise there was no point in

having rules.

- 80 N cap consents have been granted to date.
- The work in Taupo started with a lot of education and relationship building.
- An independent third party (AgResearch) did the benchmarking of farmers. The data was also taken back to the farmers to check on the ground.
- They created a database of farms but when things changed on farms this created complexity.
- To use the OVERSEER model protocols were needed, for example what should be entered for soils, what to do when there was missing information etc.
- Took 3.5 years to benchmark all the farms in the catchment but to start N trading they had to do the benchmarking first.
- They use a set version of OVERSEER (5.4.3). Farmers like certainty and this helped people to be able to go forward and make changes on their land.
- Monitoring of farms used to take a very long time but nowadays most farms get monitored in 2-3 hrs and it costs farmers a lot less than it used to.

Alan Campbell then talked about the results of a pilot study that was conducted in the Little Waipa and Waipapa in the Integrated Catchment Management project.

Key points from Alan's presentation included:

- A key purpose of the pilot study was to understand what can be achieved in terms of change on land.
- There are ~100 farms in the two pilot catchments.
- The study worked with all the willing farmers (60 farms) in those catchments to see how they could reduce their nutrient discharges.
- The study used OVERSEER to determine what N leaching was occurring. They then ran scenarios using OVERSEER to see what options would lead to lower N leeching.
- N was a key focus of the pilot study but other contaminants were included too.
- Some practices that farmers readily undertook included:
  - improving effluent systems
  - stopping winter N leeching
  - dealing with hot spots.
- Some practices that there was lack of uptake from farmers included:
  - installing stand-off pads
  - reducing stocking rates
  - reducing Olsen P levels

<u>Summary</u>
Farmers tended to favour easy to integrate practices; practices that were affordable and provide financial benefit, and practices that were supported by strong evidence.

		Conclusions: • Farmers will make voluntary changes, when they are given support and advice • Voluntary agreements alone are unlikely to lead to significant nutrient reductions • On farm changes were limited by the uncertain policy environment It was noted that more recent work has been undertaken by industry and farmer groups, e.g. Sustainable Milk Plans. Members were asked if the same conclusions largely hold and they confirmed this and also made the following comments: • Decisions made by farmers that rely on models have a trust component associated with them. • For the pilot study they didn't explain the Vision and Strategy to farmers [wasn't in law at the time of the study]. Once you explain to the community what you are trying to achieve you get much greater buy in. • People have a much greater understanding of their nutrient contributions nowadays then they did before.	
	10.00am	**Morning tea**	
13.	10.30am	**Workshop nutrient and microbe policy options** **Part I:** 1. Can we have an in-stream measure for nutrients or microbes to attribute back to a source/ property? 2. Is there a robust model for attributing property-level contributions? 3. Alternative to a model is to limit or cap key 'proxy' measures (more like an activity rule). **Small group notes – Group 1** 1. Yes – but it is difficult and expensive o What property o Renewal or existing 2. No for microbes Yes for N & P But depends what you do with the 'number' so the question is 'is it robust enough for the end use' Hard number enforcement or productivity change or increase or a trend over time e.g. 10% over 10 years 3. Proxy or input controls not first choice for N o could work for P + dairy **Small group notes – Group 2** • Overseer has some limitation but is best tool we have at moment • Confidence will grow as model accuracy improves • Could work in Overseer bands to test relative changes:	**Sub group of Forestry, Horticulture, Sheep and Beef and Dairy CSG reps to work with policy workstream and WRC enforcement/extension staff to look at the feedback from CSG nutrient workshop and farm plans.**

		- Getting better - Getting worse • How would the Overseer bands then relate to WQ bands? Microbes/P Looking for critical sources **Summary Workshop Part 1** **1. Instream measure** No – <u>fraught</u> Can DNA test microbe sources P + source – can be monitored at discharge/mixing regime **2. Robust model** **Microbes** – no **P** – Overseer + Mitigator – (a farm tool developed by Ballance – will become public) – keep on the table for now – Better for some sectors/only certain practices entered – Limited (Overseer) – 'Robust' depends on end use i.e. 'hard' number – tricky trend over time – more robust for dairy, for P are you better to use 'proxy' changes? **N** models – Yes • Overseer limited – depends on use (number vs trend) • Issues with variable years – shouldn't be used year by year • Use as a 'drafting gate' to identify risk/bands or direction of change • To help a catchment meet a limit (in-stream measure) • Only tool that gives a degree of information • Need ability to be flexible - move with science - issue with locking in 1 version • Consider it to create 'headroom' flexibility for new entrants **3. Proxies** Restrict innovation potentially, for P, for dairy (focus on key farm practices) • Opposed to input controls • Not for N	

- Over simplify

Microbe/nutrient workshop – Part II

- Are there any practices that might lend themselves to rules that apply generally (all of catchment/ all of FMU/ high risk areas/ certain stock types)?

Summary in large group – Part 2: General Rules

- Remove rules that inhibit good practice eg cleaning out and creating sediment traps
- No more pond direct discharges
    - Might be targeted to catchments
- Stocking rate cap to limit intensification
    - Issue is it stifles innovation
    - How do you define it?
    - Won't stop conversions
    - Farmers work round it – per cow production
- Need to reconsider when we have set the limits
- Winter cropping? – or just use model that takes this into account
- Direct discharges N + P
- Require farm plan and record keeping
    - cost and scale issues – who pays?
- 'Enterprise Rules' – treating blocks that are the same together
- Nutrient user groups
    - collective management of nutrients within a catchment
- Need to consider small blocks/other landowners
- Need to consider enforcement
- Third party auditing – is there a legal option for it under RMA?
- Is in some plans – states that auditor must be approved by CE of the RC

<u>**Follow up on Attributes (DM# 3458965)**</u>

Mike Scarsbrook provided further information on attributes. This helped clarify what CSG is recommending regarding TN/TP bands and use of bands.

A map was provided to the group, showing P and bands provided in catchments. The concentration you see in tributaries is only part of the story. It's about the loads e.g. Mangamihi – high TN and TP but small river, so small load contribution. Monitored sites are a subset of total tributaries. The TN and TP attributes in the NOF have been developed for lakes and lake-fed rivers. A graph was displayed, showing TN/ TP in streams – everything would be D band according to those.

<u>**Recommendations re attributes:**</u>

- **Request the TLG to come back to CSG with a report on DO as an attribute related to cause and effect**

link with 4 contaminants.

Ruth Bartlett/George Moss. <u>Unanimous Agreement</u>

<u>The CSG confirmed the following list of attributes:</u>

Value	Attribute	Explanation
Human Health	*E.coli*	
	Clarity	Include with modified A-B threshold
	Cyanobacteria (planktonic)	Include in Shallow Lakes FMU only
Ecosystem Health	Phyoplankton (lakes and lake fed rivers)	
	TN TP	1. Apply proposed TN/TP bands at mainstem sites 2. Do not apply A-D bands on TN/TP concentrations at tributary sites 3. Loads of TN/TP from tributaries are accounted for in the catchment model and individual land users can still be held responsible via various policy options
	Nitrate	
	Ammonia	
Mahinga Kai	*E.coli*	
	Cyanobacteria (planktonic)	Apply as for human health (above)

Phil Journeaux/Brian Hanna.
Dave C stood aside. Alan F was against the proposal. The chairperson Bill W determined there was sufficient agreement in order to proceed with the proposal. <u>Agreement.</u>

<u>Macroinvertebrate Community Index (MCI) recommendations</u>:

- **CSG sees MCI as an important indicator of ecosystem health and want to see it given weight in the wider policy process and monitoring regime.**
- **That it be included in SOE monitoring**
- **That it be ~~considered~~ included as part of the Integrated Assessment and Anticipated Environmental Results for HRWO.**
- **It is noted the Waikato Regional Plan review can take into account any changes in NOF from 2016 review.**

Sally Davis/Chris Keenan. A motion was made to use the word 'included' instead of 'considered' in bullet point 3 above.
George Moss/Chris Keenan. <u>Unanimous Agreement.</u>

<u>TN/TP recommendation:</u>

- **Recommendation that TN and TP in tributaries to be reconsidered as attributes once modelling results are available.**

		Chris Keenan/Brian Hanna. **Alan Fleming was against the proposal, preferring the word ‘set’ rather than ‘reconsidered’.** **The chairperson Bill Wasley determined there was sufficient agreement in order to proceed with the proposal. <u>Agreement.</u>**	
	1.15pm	**Lunch**	
14.	1.30pm	**<u>Update on Values (DM#3421947)</u>** Discussion points: • Clarification sought on what ‘protection and security’ meant on page 231. TARIT can’t provide answer today but Chris from TARIT can. TARIT are trying to map up all the info over several years to visually see fishing and cultural sites. Looking at ‘what is your history, what did you like to do?’ but does not capture ‘what would you like to do in future, what do you want to see in future?’ Oral history picks up on cultural associations and memories – include a statement in ‘hononga’ value? TARIT is working with Antoine Coffin on this. • ‘Sense of place’ - making clear that it is part of values – suggest layout change to include it within the table. • Redrafted section on primary industry focuses on economics: failed to recognise what stems out of that i.e. food production. Wider value to that i.e. community, generations, connection with land. Value production for high quality safe food. Pride and culture for those communities. • Hard to connect mauri with this document. Past present and future. • CSG have been through this process, taken the list back to community. • Ecosystem health – flood plains – where does it fit in? Would have to take out stop banks. Al-wetlands and flood plains serve those purposes – Whangamarino wetland etc bunding along Waikato river. Maybe in future need to reinstate flood plains? Whitebait laying eggs in grass - areas that flood. Stop banks have a place in existing environment. Agreed to leave this in. • Do we acknowledge flood protection? Whole extra – value? Change water supply to water infrastructure and add under that? • Include TPS flows as part of river value • Natural form and character – the rivers are a corridor. Want changed to ‘river as a corridor’	**Values actions:** **Make the overarching value ‘Hononga ki te wai, Hononga ki te whenua’ more obvious as a value.** **Liaise with Antoine re values gaps identified from TARIT plan [Chris - TARIT]** **Change water supply wording to water infrastructure in values list**

		have ecological corridors….. concept of 'river corridor' have concern with. Agreed to take out word 'corridor' and leave just 'river.' • Sense of place – still feel it needs an addition. About an emotional historical connection/ can be personal, groups, families, organisations with connection to a place. • Human health for recreation – first bullet point has lots of active stuff – don't need to active to be near river. Agreed to add in place 'to relax' • River iwi– feedback o direction. Tim Manukau – Acknowledge the work that has been done. River iwi have a level of comfort with this new version. • The Electricity value is too detailed - synthesise. Energy sector rep to work with staff on wording • Community member Gayle Leaf to come up with ideas on her views and how to incorporate. • Change water supply wording 'The catchment surface and subsurface water is of a quality'. <u>It was noted that the feedback would be considered and reported back to the next CSG</u>	
15.		**<u>River Iwi input on Vision and Strategy</u>** Deferred to CSG14.	
16.	2.45pm	**<u>Scoping community engagement (DM#3431526 and DM#3445648 presentation) Will Collin</u>** There are only two CSG workshops between now and when the CSG start engaging with sectors and the community. CSG's engagement plan has had some minor amendments as noted in presentation. Highlighted in yellow in DM #3411909 Outline of the breakdown of the 2nd Intensive Engagement Period: Key engagement period dates were highlighted during this time including tight timeframe for turning feedback around. Part 1: 7 Sept– 21 Sept 2015 Part 2: 12 Oct– 16 Oct 2015 **Resolutions:** 1. That the report "New Amended Community Engagement Plan and the 2nd Intensive Engagement Period" (Doc 3431526 dated 19 June 2015) be received for information. 2. That the Collaborative Stakeholder Group agrees upon and approves a finalised new amended Community Engagement Plan which will be provided to the Healthy Rivers Wai Ora committee, subject to any agreed further amendments being made, and agree that the website version of the Community Engagement Plan	**Jackie F to craft a presentation on the story so far.** **Gina Rangi and Jacqui Henry to communicate regarding iwi engagement.**

can be replaced with the new amended version.

3. That the Collaborative Stakeholder Group confirms the date for the next large stakeholder workshop as being 13 October 2015.
4. That the Collaborative Stakeholder Group consider the questions posed by council staff and provide responses to the questions marked ‘needing an answer to proceed’.

Items 1 -3

George Moss/ Sally Davis

Carried

Discussion on the four proposed engagement event types

- Large Stakeholder Workshop
- ‘Out and about’ days
- Community workshop
- Online survey

Jackie Fitchman (WRC Communications) provided the CSG with ideas on how to reach the public and the objectives:

1. Awareness/interest
   Increase awareness of and interest in the project.
2. Information
   Provide background and context to enable people to engage.
3. Involvement
   Promote attendance and involvement in engagement activities.

Discussion points:

- CSG to get ideas/comments to Jackie Fitchman directly.
- Parallel iwi engagement. Concern re community / iwi expectations – potential risk. Jacqui Henry (WRC) is liaising with iwi in rohe. Gina and Jacqui to discuss further.
- CSG requested a generic power point presentation that CSG can all utilise with timeline.
- Need materials for out and about days
- CSG requested more information regarding out and about days. See Stakeholder Engagement Strategy.

<u>Community Engagement</u>

- Include a story of how we got to here e.g. attributes etc and relate it to V & S and NPS/NOF.
- First model run results – can’t commit to that until we see results.
- Warm people up to model – how it works

		• Have to all do the same • Dairy prefer to go with first results • Busy time – horticulture, sheep and beef sectors. <u>Still to discuss with CSG:</u> 1) Maori interests – do they want their own sector day? 2) Learnings meetings 3) Pilot review as per last online survey	
		<u>Approvals session – follow up</u> **<u>Plan change template – Sally Millar ((DM#3435649)</u>Resolutions:** 1. That the report be received by the Collaborative Stakeholder Group and 2. That the Collaborative Stakeholder Group agrees to the amended headings for the Plan Change Template. **Chris Keenan/Charlotte Rutherford** **Carried** **<u>Public release of documents from the CSG portal – workshop notes and summary section (DM#3431167):</u>** A - Documents marked with A – suitable to make public now B – Need more work – check with author C – Not suitable to be made public now. The CSG supported public release of documents but noted that anything relating to the CSG only session, draft items, iterative documents (uncompleted and works in progress), internal discussions and brain dump notes were not to be released. **Action: CSG members to send in their queries regarding documents to Healthy Rivers Inbox** **Action: Bill Wasley to work with staff to address those matters outlined above and that subject to this the documents be released.** **Resolutions:** 1. That the CGS approves the release of documents deemed suitable for proactive release (refer to Attachment 1) as per criteria outlined above and with approval of the Chair 2. That all PowerPoint presentations are converted to PDF files containing only slides, with the notes removed. 3. That where multiple iterations of documents exist, the final version of the documents are proactively made public (if not already public). 4. That where documents are already publicly available	

		(see part 3 of Attachment 1) a link to the source location of the document is provided on the CSG website. **Don Scarlet/Chris Keenan** **Carried** **Feedback from networks to be discussed at CSG14.**	
16.	3.15pm	**<u>HRWO Co-chairs update and Feedback from Project Sponsor (Tracey May) (DM#3444359)</u>** Alan Livingston and Deputy Co-Chair Kataraina Hodge present. Apologies from Roger Pikia. HRWO Co-Chair Alan Livingston provided an update on the HRWO meeting held Friday 26 June 2015. • Alan acknowledged those who attended: George Moss, Stephen Colson, James Bailey, Bill Wasley, Matt Makgill and Alastair Calder. • Members had a workshop prior to the meeting. This was a valuable exercise. HRWO Committee will now meet monthly and also have a workshop prior to each meeting to cover a specific subject. • It is anticipated that some CSG members can represent the group at these workshops and give HRWO committee members a level of understanding of what they are doing. • If there are any recommendations – please note any dissentions. • Acknowledge and appreciate Billy Brough (Iwi Co-ordinator) coming on board to co-ordinate the five river iwi. This is an important role for the project. • The HRWO Committee minutes have been provided to CSG. These outline the concerns raised regarding the PSC for CSG to consider. The suggestion of having workshops prior to the committee meetings is the chance to have things aired and considered so there are no hold ups. Discussion on the CSG decision making process. The CSG make a decision, this then goes to HRWO and then to Council for approval. HRWO are urging councillors that aren't on HRWO Committee to come to workshops to learn along the way. **<u>Tracey May – Project Sponsor</u>** • Acknowledge those who attended last HRWO workshop and the work that has been done to date. The councillors valued and appreciated the free and frank discussion and would like this to continue going forward. • MfE visited WRC this week. There is interest in what are we doing to implement NPS FM. WRC were able to	**Janine H to circulate further dates for HRWO committee and workshops**

		talk through the different things that council are doing. There was a heavy focus on the CSG and what they have achieved to date and some of key challenges. Feedback provided on evaluation report. An offer was extended to MfE to sit in on a CSG workshop. • Tracey has been invited to a WRA Board meeting next week to provide an update on the Healthy Rivers Project. Alan Livingston and Weo Maag are board members. • Information flow between parties in project needs to be co-ordinated better. Billy Brough will step into this role.	
17.	3.30pm	**<u>Wrap up session</u>** • The group was referred to the 'Milestones and Focus' document (DM# 3394155) on page 243 which outlines what will be discussed at CSG14. • Allocation principles to be discussed at the CSG14. • Note that Beef and Lamb NZ have a list of 'Principles for the Allocation of Nutrients' in this agenda pack. Do any other sectors have documents that they can circulate? Dairy and horticulture do. • PSC needs to be reviewed • Allocation is large topic – need more information • Helpful to have allocation discussions with policy ideas talked about today. • **Defer CSG13 feedback from networks to the next workshop** • **PSC agenda item for next meeting regarding HRWO concerns re PSC** • **HRWO committee members and MFE attendance discussion deferred to CSG-only session at next workshop**	**Allocation actions:** **Chris K to look into allocation principles work from LAWF.** **WRC staff to look at how allocation has been done elsewhere.** **CSG will look at policy options in light of the allocation principles developed.**
18.	3.55pm	**<u>Chairperson closing reflections</u>** • Bill referenced the items raised regarding Attributes. • Acknowledgement and appreciation to Mike Scarsbrook for stepping in while Bryce Cooper away. • The timing of the agenda approvals session to be reviewed (allowing more time /not evening)	
	4pm	**Meeting closed with karakia by Helen Ritchie at 4.15pm.**	

Interim summary of ground water information for consideration by the Collaborative Stakeholder Group

Collaborative Stakeholder Group

Healthy Rivers: Wai Ora Project

20 June 2015

Technical Leaders Group report for discussion at a CSG workshop

Disclaimer

This report has been prepared by the Technical Leaders Group for the use of Collaborative Stakeholder Group Healthy Rivers: Wai Ora Project as a reference document and as such does not constitute Council policy

Memo

File No:	2015 06 21
Date:	21 June 2015
To:	Chairman, Technical leaders Group
From:	Tony Petch, Tony Petch Consulting Limited
Subject:	**Interim summary of phase 1 ground water investigations commissioned to support the Healthy Rivers - Plan for Change: Waiora He Rautaki Whakapaipai project.**

Introduction

The Healthy Rivers programme requires information on ground water resources of the Waikato and Waipa catchments to help understand how ground water is impacted by contaminant discharges from land use, especially nitrogen. Important factors to understand are: how nitrogen is transformed as it passes through the aquifers, the travel times (lags) for water and nitrogen to pass through the aquifers to rivers and streams, and the structural relationships and interactions between ground water and surface water resources. This information helps understand the extent to which the water quality observed in rivers and streams is in equilibrium with current land use: and, if it is not in equilibrium, the amount of nitrogen load to come as a consequence of today's land use.

A ground water experts panels was convened in October 2014 to define the work required to support Collaborative Stakeholder Group deliberations on policies to restore and protect and restore the Waikato and Waipa Rivers. Given the time available, the experts' panel recommended a staged approach to providing additional information; comprising work required within the first six months, one year and two years.

Initial ground water investigations – information required within six months

The first tranche of ground water investigations comprised:

1) **Study 1: Short term field investigation of ground water resources in the Waikato and Waipa river catchments**
   Knowledge of the ground water resources of the Waikato and Waipa river catchments is highly variable: detailed knowledge is available where specific investigations of ground water resources have been completed; elsewhere little is known but for scattered observations of ground water chemistry, water levels and aquifer hydraulic properties.

   These 'short-term' investigations of ground water resources were aimed to 'fill in' gaps in knowledge of the Waikato regional ground water systems. Comprehensive ground water investigations are notoriously expensive and, since the mid-1980s, have been rarely undertaken.

2) **Study 2: Ground water resource characterisation in the Waikato River catchment for the Healthy Rivers Project**
A synthesis of ground water resources in 74 Healthy River Project catchment's including summaries of: the general distribution of aquifers; their hydraulic properties, catchment water budgets, including ground water inflows and outflows, stream flow components (base flow - sourced from ground water: and quick flow - involving more rapid surface run off during and post rainfall), and ground water chemistry with emphasis on nitrogen *E. coli*, and other chemical characteristics affecting the suitability of the ground water quality for use.

3) **Study 3: Estimation of lag time of water and nitrate flow through the Vadose Zone: Waikato and Waipa River catchments**
This study examines the overall lag time between land use changes and associated surface water quality impacts. The report presents results for predicting the time taken for nitrate-nitrogen to travel from the land surface through the unsaturated (vadose) zone into shallow ground water.

4) **Study 4: Predicting the Redox Status of Ground Water on a regional scale.**
Environmental Science Research was undertaking a MBIE[1] funded study on Redox status of ground water in the Reporoa area of the Upper Waikato catchment and in the Canterbury Plains. An extension of this work was contracted to ESR for the Waikato and Waipa catchments and Hauraki catchments. This study examines the conditions for denitrification to occur and the extent these conditions exist in the Waikato and Waipa catchments.

5) **Study 5: Incorporating this information into a steady-state ground water model**
NIWA developed a steady-state catchment model[2] for the Economic Joint Venture Initiative (EJVI) for the upper Waikato catchment. The scope of this model was increased to cover the middle and lower Waikato catchments and the Waipa catchment by specifically modelling 74 Healthy Rivers' sub-catchments where there was adequate data to provide estimates of nitrate-nitrogen, phosphorus, sediment and *E. coli* loads to each catchment. The output of the NIWA model is then passed to the economic optimisation model being developed for the Healthy Rivers Project to estimate the costs of meeting a range of scenarios determined by the Collaborative Stakeholder Group to restore and protect the Waikato and Waipa Rivers.

Discussion

All this work was targeted to provide a general understanding of regional ground water resources and particularly ground water age and nitrogen attenuation processes in the catchments. Nitrogen load to come was shown as the main determinant of the cost of maintaining water quality in the Waikato river in the EJVI because the nitrate-nitrogen loads in rivers and streams are not yet in equilibrium with catchment land use. Given the time available to complete the work the experts' panel agreed this work would be used as input to the steady-state catchment model used in the EJVI. The year one and two studies would involve additional studies (if required) and development of time varying (transient) ground water models that could provide a more resolved understanding of the catchment's ground water resources and the timing of nitrogen transport to rivers and streams.

The first tranche of work has been completed and draft reports are being received. This report provides an interim summary of the investigations and the main conclusions of the work to date.

[1] Ministry of Business, Innovation and Employment
[2] Elliott S *et al.*, 2013. Catchment models for nutrients and microbial indicators – Modelling application to the Upper Waikato Catchment. Client report for the Ministry for the Environment. NIWA client report Ham 2013-103.

Study 1: Short term field investigation of ground water resources in the Waikato and Waipa river catchments

The scale of this study and the short time within which to complete this study required it to be broken into two segments: investigations in the Waipa catchment were completed over the 2015 summer by GNS science[3]; and investigations in the upper, middle and lower Waikato catchments were completed over the same period by Waikato Regional Council ground water staff and a contractor (WildImpacts Ltd).

The field investigations in the Waipa comprised:

- collection of 48 samples for analysis of chemistry (23 chemical species or properties including nitrate, iron, manganese, reactive silica, pH, ammoniacal-N and other parameters influencing the suitability of the ground water for a range of uses);
- collection of nine water samples for the dating of ground water;
- the recording of static water levels in 27 bores; and
- nine tests of aquifer hydraulic properties.

The field investigations in the upper, middle and lower Waikato comprised:

- collection of 68 samples for analysis of chemistry (23 chemical species or properties including nitrate, iron, manganese, reactive silica, pH, ammoniacal-N and other parameters influencing the suitability of the ground water for a range of uses);
- the recording of static water levels in about 50 bores;
- a survey of radon concentrations to identify longitudinal ground water inflows in the Poikaiwhenua and Little Waipa streams; and
- sampling to determine the depth to the redoxycline in selected location in the catchments (note the costs for drilling were funded by other agencies).

In addition, three other separate field investigations were completed over the 2015 summer throughout the Waikato and Waipa catchments:

- surface and ground water age sampling including 21 surface water sites and ground water for dating by analysis of tritium, CFC and SF6[4];
- a flow confirmation survey on selected streams (484 sites) in the Waipa and middle and lower Waikato catchment to determine the distribution of low flows (predominately ground water discharge). This survey included locating stream heads and their elevations for piezometric surface (ground water level) analysis and for future ground water modelling.
- Low flow gaugings were completed throughout the Waipa and Waikato catchments to determine discharges for the areas gauged. One hundred and seventy gaugings, including 31 in the Waipa catchment, 68 in the Reporoa area, five on the Pokaiwhenua stream and 66 in the lower Waikato catchment. Some of this work involved simultaneous linear gaugings to determine the longitudinal gain in in flow downstream and hence the spatial distribution of ground water discharge along these streams.

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[3] Rawlinson Z *et al* 2015. Short term field investigation of groundwater resources in the Waipa Catchment: January – April 2015. GNS Science Consultancy Report 2015/54.

[4] Tritium, chlorofluorocarbon (CFC) and sulphur hexafluoride (SF6) are particularly useful for dating ground waters less than 100 years old. Tritium (3H) was introduced into the atmosphere by nuclear testing and has a half-life of 12.4 years. Atmospheric tritium concentrations reached a peak in the 1960s. Ground water dating with CFCs and SF6 is possible because concentrations have been building up in the atmosphere at a known rate since the late 1930s and early 1970s respectively and because the dissolved concentrations in rainfall maintain a unique signature of the atmosphere at that particular time, thereby providing a date from which to age ground water.

Summary and findings - Waipa

The results of these field investigations have been incorporated in the hydrogeological models described in Study 2 and are consistent with previous work undertaken in the catchments. Nevertheless the additional data obtained provide greater spatial resolution to the general understanding of ground water resources in the catchments.

Water chemistry

About 50 per cent of bores showed levels of nitrogen that are elevated compared with background levels (i.e. >1 mg/l), most probably relating to land use activities. These results are consistent with other New Zealand studies[5]. The remainder showed no elevation from back ground levels or were associated with strong reducing conditions. Nitrate contamination was not strongly related with depth with similar proportions of shallow and deep bores with elevated nitrate concentrations.

Water level

Water levels for bores located in shallow aquifers (0-27 m deep) have water ground water levels of between 4 and 10 m below ground. Deeper bores (40 - 90 m below surface) have water levels between 15 and 50 m below ground. The water level gradients observed in adjacent bores (shallow and deep) at lower ground surface elevations indicate ground water recharge is occurring. At higher elevations, the greater depth to water, combined with the greater elevation of ground water surface indicates flow away from upland areas to lower lying terrain and the streams incised within valleys.

Hydraulic properties

The results show the expected trends observed in previous studies: with low permeabilities found in fine grained sediments and greater permeabilities in sands and gravels located near river channels and in fractured, indurated sandstones and limestone material. There is little evidence of strong spatial trends in hydraulic properties because of the complex geology within the catchments.

Summary and findings – upper, middle and lower Waikato

As in the Waipa catchment, the results of these field investigations have been incorporated in the hydrogeological models described in Study 2. The results are consistent with previous work undertaken in the catchments but provide greater spatial resolution to the general understanding of ground water resources in the catchments.

Groundwater chemistry

About 38 per cent of all wells sampled this summer show some contamination of nitrate-N probably related to land-use activities (i.e. > 1 mg/l). The ground water sampling in the Reporoa area showed the nitrate-nitrogen concentration was highly variable ranging from non-detectable to above MAV[6] with a mean of 2.5 and median of 0.75 mg/l. Aerobic conditions, were indicated

[5] Morgenstern U and Doughney CJ 2012. Groundwater age for identification of baseline groundwater quality and impacts of land-use intensification – The National Groundwater Monitoring Programme of New Zealand. Journal of Hydrology. V 456-457, pp 79-93.

[6] MAV – Maximum acceptable value. The New Zealand MAV for nitrate-nitrogen concentration in drinking water is 11.3 mg/l. This level is based on the World Health Organisation Guideline Value (GV), established to protect infants from a condition known as "blue baby syndrome". Affected infants have an abnormally high amount of methaemoglobin in their blood, hence the condition - *methaemoglobinaemia*. Unlike haemoglobin, *met*haemoglobin cannot transport oxygen in blood. In the 1950s, infant methaemoglobinaemia was reported regularly in the United States but today it is rare despite increasing exposure to high-nitrate drinking water. Explanations for this anomaly are higher standards of well construction and greater awareness of the importance of avoiding microbial contamination common in shallow ground water. This also explains why the incidence of

at about 36 per cent of the sites and anaerobic conditions (indicating reducing conditions and potential for denitrification) were observed at about 32 per cent of the sites. The potential for denitrification could not be determined at the remainder of the sites.

Water levels

Static water levels were measured at about 50 bores. This information was forwarded to GNS Science for constructing the piezometric surfaces (Study 2). Depth to ground water varies depending on the location of the bore within the catchments. Ground water level is deeper in upland areas and nearer (within a few metres) the surface in low lying areas.

Radon

The sampling for radon along the Pokaiwhenua and Little Waipa streams showed the discrete input of ground water at specific locations (springs) indicating the importance of ground water flow through fractures in these upper Waikato catchments. Ground water flow through fractures can be inferred in much of the upper Waikato where fractured volcanic rocks are present (refer Study 2 Figure 1). Fractures allow the more rapid transmission of ground water and nutrients in aquifers and reduce the opportunities for denitrification if the potential exists.

Oxidising and reducing conditions

Cores from bore holes drilled at 22 sites in Hamilton Basin and adjacent to the Waikato hydro lakes during the summer were tested for the occurrence of anaerobic conditions. The opportunity was taken to test water chemistry, the presence or absence of anaerobic conditions and the occurrence of nitrogen at these locations. Although the depth to anaerobic conditions below the water table was highly variable, spatially and vertically (ranging from a few metres up to 50 m), it occurred at almost half the sites within five metres of the surface indicating the presence of conditions suitable for denitrification.

Summary and findings – field studies completed in both the Waipa and Waikato Catchments

Water age

Surface water

The age of surface water in the Waipa and middle and lower Waikato catchments (expressed as MRT[7]) during summer base flows is usually less than 15 years and average about 10 years.

In contrast, the age of surface waters in the Upper Waikato sub-catchment streams are older with an average MRT of about 52 years (median 35 years; flow weighted mean of about 47 years). The water age of the Waikato River above Karapiro is younger (about 12 years at Karapiro) due to the influence of Lake Taupo, which provides two thirds of the flow.

Ground water

The age of ground water is highly variable throughout the study area. Mean residence times are often much older than surface waters (MRT from latest survey is about 150 years). The MRT is older than suggested by previous investigations (MRT 67 years (n=113)). Initial analysis of the data obtained recently suggests there is no clear relationship between depth of ground water and its mean residence time. Some shallow wells (between 2 and 10m deep) in the middle and lower Waikato catchments and the Waipa catchment, which intersect very shallow ground water, show consistently younger ground water (1 to 2 years MRT). These ages may indicate

infant methaemoglobinaemia in most developed countries (including New Zealand) is now very low, whereas in developing countries it is relatively common.

[7] MRT – mean residence time in years

shallow, more rapid flow in the active surface zone in the aquifers. The age of ground water in three springs measured in the upper Waikato catchment vary between 11 and 60 years MRT. The age of deeper ground water is consistently older but appears unrelated to depth. This observation may reflect the different sediments from which the ground water was obtained, the degree of fracturing of the aquifers intercepted by the bores and the general variability of the aquifers sampled. Generally, age increases with depth in areas of recharge.

Low flows and stream head elevations

The information from the low flow gauging programme and investigation of stream head elevations was provided to GNS Science for inclusion in the water budgets and piezometric surfaces (Study 2 below).

Study 2: Ground water resource characterisation in the Waikato River catchment for the Healthy Rivers Project

The report and accompanying appendices identify a range of features for each of the Healthy River catchments: the upper Waikato above Karapiro; the Waipa Catchment; and the middle and lower Waikato river[8].

Summary and findings - Upper Waikato

Geology

This catchment has a complex geology dominated by large faults characteristic of the Taupo volcanic zone which has influenced the distribution of sediments and the extent of aquifers in the catchment (Figure 1). The basement[9] rock has large offsets associated with faults and calderas. The Whakamaru Group ignimbrites[10] infill the basement structures, as do a sequence of lake sediments from the ancestral Lake Huka (an important aquiclude), and the Oruanui formation, derived from the Lake Taupo eruption, as do the modern day surface alluvial sediments of the Tauranga group. The Whakamaru group form important aquifers as do the Tauranga group which supplies much of the low volume rural domestic and stock water supplies. A suite of volcanos have formed to the west comprising Pureora, Titiraupenga and Maungatautiri. Ignimbrites of the Pakaumanu Group, from the Mangakino Caldera, are common at the ground surface in the centre and west of the catchment. Eruptions from the Whakamaru Caldera deposited large volumes of ignimbrite in the middle sections of the catchment. The Mamaku Plateau formation[11] is exposed at the ground surface to the north of the catchment and also provides an important source of ground water.

Water budgets

The water budgets and the associated estimates of base flow and quick flow show the ground water system is hugely important to the hydrology of the upper Waikato. Most (94 per cent) of the net rainfall recharge infilters to ground water and reappears later as flow in rivers and streams. Very little runoff occurs as quick flow during and after storms. Hence stream beds are usually dry except during storms. Most stream flow is generated from springs located further downstream where ground water intersects the ground surface; often at the base of scarps or other structural features. Most ground water flow is intercepted by streams and, in the very few catchments where this may not occur, there is evidence that the ground water flow is ultimately intercepted by the incised Waikato River. Effectively, the hydrogeological system is closed - the underlying basement is virtually impermeable - and all net rainfall in the upper Waikato ultimately appears as flow in the Waikato River.

Piezometric surface

The piezometric surface lies between 20 and 100 m below surface in elevated terrain to between 2 and 20 m below the surface on more subdued terrain and nearer streams. The stream elevations represent the local ground water surface. Springs, common in the incised terrain typical in the upper Waikato, represent a focussing of ground water outflows often aggregated through local fractures in the surface sediments.

Ground water flow is driven by topographic gradients and is down slope to local streams in almost all catchments. The topographic divide (catchment boundary) therefore reflects the

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[8] White PA *et al*, 2015. Groundwater resource characterisation on the Waikato River catchment for the Healthy Rivers Project. GNS Science Consultancy report 2015/95

[9] The ‘basement’ in the North Island generally comprises low grade indurated ‘greywacke’ of Jurassic age (200 to 145 million years ago)

[10] Widespread plateau forming ignimbrite sheets erupted between 320 and 240 thousand years ago

[11] Ignimbrite sheets erupted from the Rotorua Caldera about 240 thousand years ago

ground water divide. The only potential exception is the boundary on the elevated but flat terrain of the Kaingaroa Plateau to the north east of the upper Waikato: there is no evidence available to clarify the ground water boundary in this areas but this is of little consequence given the large forestry blocks on the area.

Ground water chemistry

Ground water chemistry in the upper Waikato is derived from 21 monitored bores. Nitrate-nitrogen is commonly higher than maximum acceptable values for drinking water (11.3 mg/l) or between half of MAV and MAV[12]. This indicates land use activities are impacting on ground water quality. The trend in nitrate concentrations is varying slowly suggesting recent land use intensification has not yet further impacted ground water quality. Manganese (Mn) and Iron (Fe) concentrations indicate the presence of anoxic conditions in ground water.

Summary and findings - Waipa

Geology

The geology of the Waipa catchment is underlain by basement rocks, of low permeability, and of limited use as an aquifer (Figure 2). The basement rocks form a basin bounded by up-thrown basement material. The basement is overlain by sediments of the Te Kuiti group[13]. These sediments provide limited water sources from discrete fractured and limestone aquifers. Fine grained, relatively impermeable, Miocene[14] marine sediments lie above the Te Kuiti group and form the effective hydrogeological of the Waipa catchment. Above the Miocene sediments lie the Alexandra volcanics[15] forming the mountains of Te Kawa, Kakepuku and Pirongia. Ground water supplies are often plentiful from these sediments as they are strongly fractured. The Pakaumanu group, comprise ignimbrites from the Mangakino caldera and form much of the surface sediments in the east of the Waipa catchment. These sediments form both fractured and porous aquifers. The surface sediments, the Tauranga group[16] and more recent Holocene[17] sediments are the main aquifers used in the Waipa catchment although water quality is often unsuitable for use untreated. These sediments are up to 200 m thick in the north, thinning to a few metres in the south where they cover the underlying sediments.

Water budgets

The water budget for the Waipa shows the importance of ground water in the catchment. Seventy-seven per cent of the net rainfall infiltrates the land surface and passes through aquifers to discharge to streams and rivers. Base flow predominates in the head water catchments draining the Te Kuiti group sediments. Further downstream about 60 per cent of net rainfall is transported via ground water to the streams and rivers. Springs commonly occur in head water catchments where the sloping terrain intersects the shallow, lower permeability Tauranga group sediments.

Piezometric surface

Ground water elevations follow the topography although the surface is relatively subdued in the Lower Waipa catchment. In the lowland plains, the ground water surface is usually between 2 and 5 metres below the ground surface except in shallow depressions where wetlands (now

[12] Thirty per cent of catchments have median ground water nitrate-nitrogen concentrations above MAV and another 32 per cent of catchments have median ground water nitrate-nitrogen concentrations between half of MAV and MAV

[13] A sequence of coals measures, and calcareous marine siltstone, sandstones and limestone laid down between 56 and 20 million years ago

[14] A period of deposition between occurring between 23 and 5 million years ago

[15] Volcanic sediments laid down about 2.5 million years ago

[16] Alluvial sediments laid down between 2 million year ago to about 11 thousand years ago

[17] A period less than 11,700 years ago

mostly drained) and small lakes occur. In the uplands, the piezometric surface lies between 10 and 50 metres below ground. As in the upper Waikato, stream elevations define the local ground water surface. Springs are common in incised gullies draining to the Waipa river.

Ground water chemistry

Ground water chemistry is defined by 22 bores monitored by the Waikato Regional Council. Nitrate-nitrogen is occasionally higher than MAV or between half of MAV to MAV[18]. Moderately high levels of nitrate-nitrogen are common in ground water in the Waipa catchment and are rising slowly, indicating that intensifying land use and conversions to more intensive farm systems are impacting ground water nitrate concentrations. Manganese and iron concentrations are above MAV and guidelines in wells especially in low lying areas.

Summary and findings - Middle and Lower Waikato

Geology

The middle and lower Waikato basins are underlain by a complex surface of basement Mesozoic rocks (Figure 3). These are of low permeability and limited use as aquifers. The basins formed by the basement are complex and faulted. The basement is deepest in the Hamilton Basin (-1300 amsl) yet is at the surface between Hamilton and Cambridge, and forms the Hakiramata and Taupiri range, the Hapuakohe range and the lower hills in east of Lake Waikare and northward to the Hunua range. The basement is -800 m amsl in the Aka Area. A sequence of younger sediments have infilled these basins, starting first with the Te Kuiti group sediments. These sediments are between 700 m thick in the lower Waikato basin and 200 m thick in the Hamilton basin. The Te Kuiti group comprise fine grained marine sediments and are usually unsuitable as aquifers except where fractured. Younger (Miocene) sediments over lie the Te Kuiti group and are used as a source of ground water, although their hydraulic properties restrict extensive water use. The Kaawa formation, comprising marine sands and shell lag deposits, occurs mainly in the Pukekohe and Waiuku area and provides the lower Waikato's most productive aquifers. The Pakaumanu Group comprises ignimbrites from the Mangakino caldera. These sediments provide fractured and porous aquifers. The surface aquifers are found in the Tauranga group, which forms most of the low lying surfaces in the middle and lower Waikato basins. The Tauranga group aquifers are important as water supplies but are usually only moderately productive and limited for domestic and stock use by water chemistry. Volcanic sediments occur to the east of the Hamilton basin and to the north of the lower Waikato basin where they form numerous low- angle volcanic cones and tuff rings at Pukekohe, Pukekawa, Onewhero and Mercer

Water budgets

The water budget for the middle and lower Waikato show the importance of ground water in the catchment. Like the upper Waikato more than 80 per cent of the net rainfall appears as base flow having entered streams and rivers via ground water. The Hamilton basin is effectively a closed ground water system underlain by very poorly permeable basement sediments.

Piezometric surface

Ground water elevations follow the local topography. Ground water in both basins is toward the incised Waikato river. In the lowland plains, the ground water surface is usually between 2 and 5 metres of the ground surface except in shallow depressions where wetlands (now drained) and numerous small shallow peat lakes occur. Drainage is common in the lower Waikato basin

[18] Six per cent of catchments have median ground water nitrate-nitrogen concentrations above MAV and another 10 per cent of catchments have median ground water nitrate-nitrogen concentrations between half of MAV and MAV. Six per cent of the catchments have median nitrate-nitrogen concentrations increasing at > 0.1 mg/l per decade.

because the low lying surface sediments are often saturated by artesian ground water discharges driven by the elevated terrain surrounding the area.

Ground water chemistry

Ground water chemistry is defined by 29 bores monitored by the Waikato Regional Council. Ground water chemistry shows land use is impacting ground water quality in the basins. Nitrate-nitrogen is commonly higher than MAV and between half of MAV to MAV[19]. Nitrate-nitrogen is increasing over time in a few wells at rates of 0.27 to 0.42 mg/l per decade[20]. Also, the ground water in these basins is the most likely of all healthy rivers catchments showing concentrations of *E. coli* that exceed MAV and that are rising.

[19] Thirty-four per cent of catchments have median ground water nitrate-nitrogen concentrations above MAV and another 14 per cent of catchments have median ground water nitrate-nitrogen concentrations between half of MAV and MAV.

[20] Seventeen per cent of the catchments have median nitrate-nitrogen concentrations increasing at > 0.1 mg/l per decade.

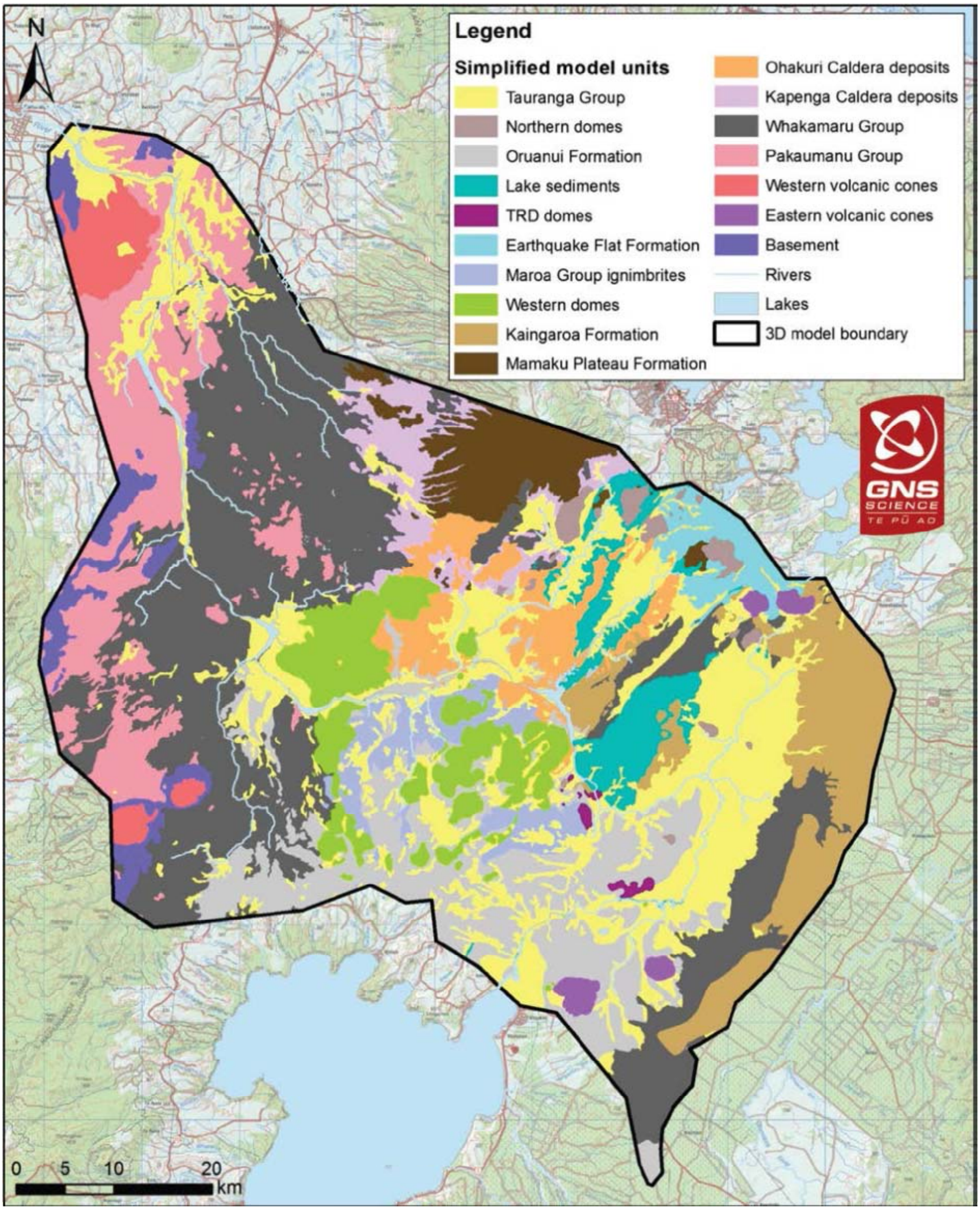


Figure 1: Surface geology of the Upper Waikato catchment

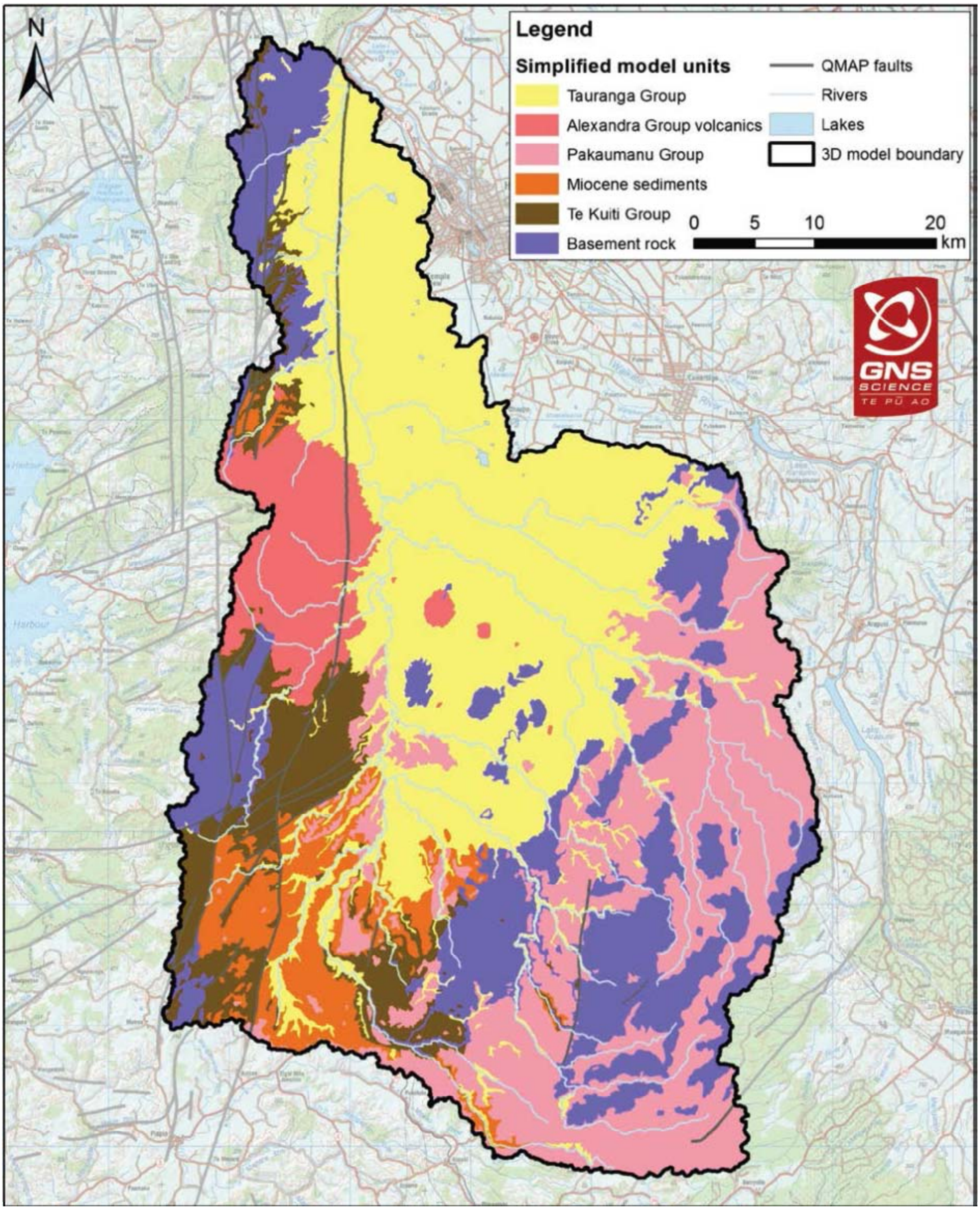


Figure 2: Surface geology of the Waipa Catchment

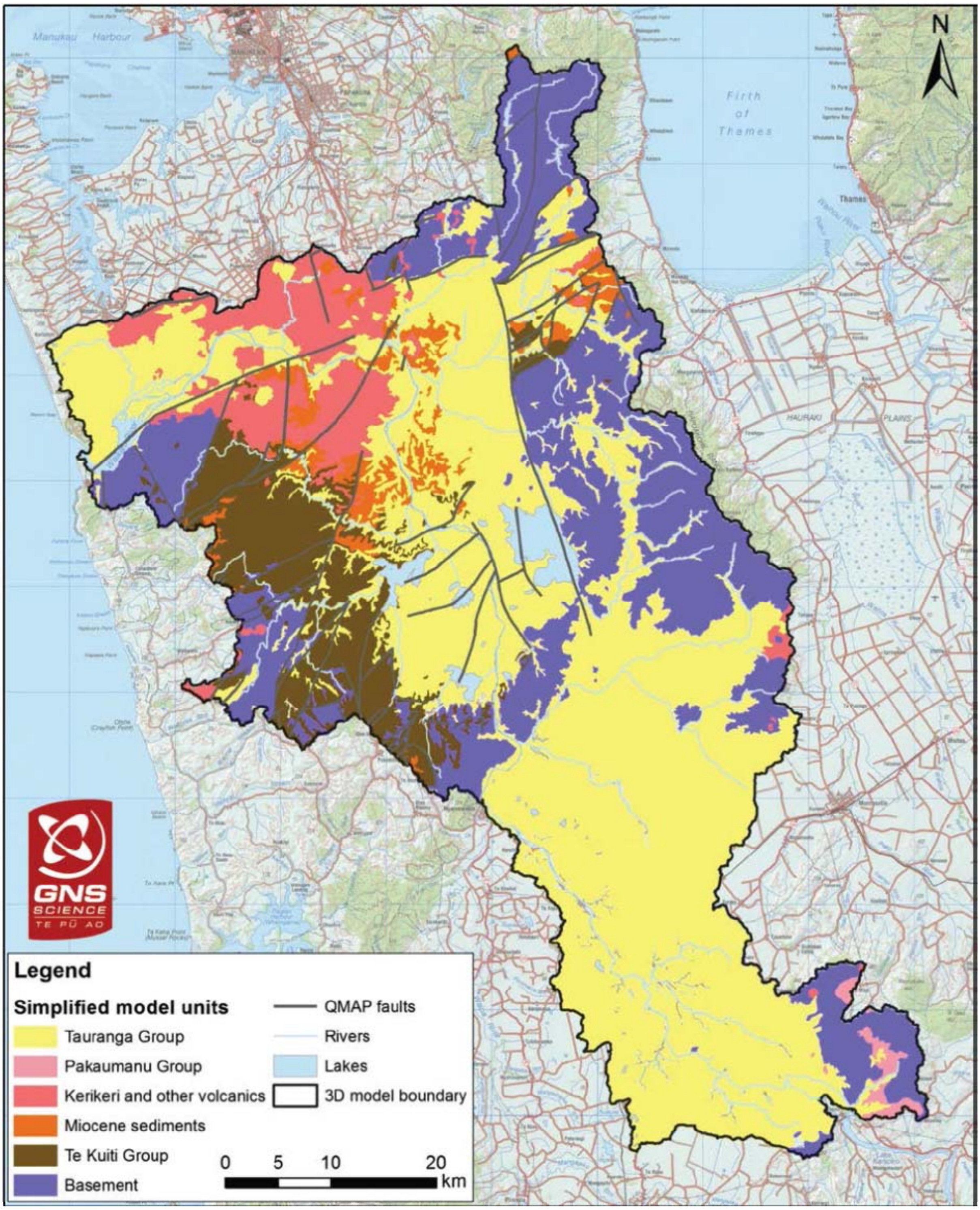


Figure 3: Surface geology of the Lower and middle Waikato catchment

Study 3: Estimation of lag time of water and nitrate flow through the Vadose Zone: Waikato and Waipa River catchments

Travel time through the unsaturated zone is important in determining the overall lag time between land use intensification (often through rapid land use change) and the associated impacts on surface water quality. This report presents results of a modelling study for predicting the time taken for nitrate-nitrogen to travel from the land surface through the unsaturated zone and into shallow ground water[21]. The process of modelling these lag times involves the estimation of land surface recharge; estimation of the time taken to travel through the vadose zone and an estimation of the time taken for water and nitrate to penetrate the uppermost aquifer layer. Input data for these estimations has been sourced from available climate, soil, geological and hydrological databases.

Findings

Total travel times[22] are less than 10 years for most of the lower Waikato, Hamilton and Waipa basins, particularly for the shallow, low angle basin floors and low hills with elevations less than 100 m amsl[23]. Longer travel times of 10 to 30 years are estimated for the land surfaces above 100m amsl (Figure 4).

The longest travel times are estimated beneath and near volcanoes and ranges: mainly as a function of the greater depths to water in these areas. However, there is greater uncertainty in these estimates for these areas because there is only sparse information on depth to water (few bores are drilled at the tops of hills to intersect ground water). The estimates of the total travel times comprise two components: the vadose travel times and the time for water and nitrate-nitrogen to penetrate the more active upper part of the aquifer. The time taken for water to mix in the upper part of the aquifer ranges from 2.5 to 6 years which is between 10 and 40 per cent (average 17 per cent) of the total travel time.

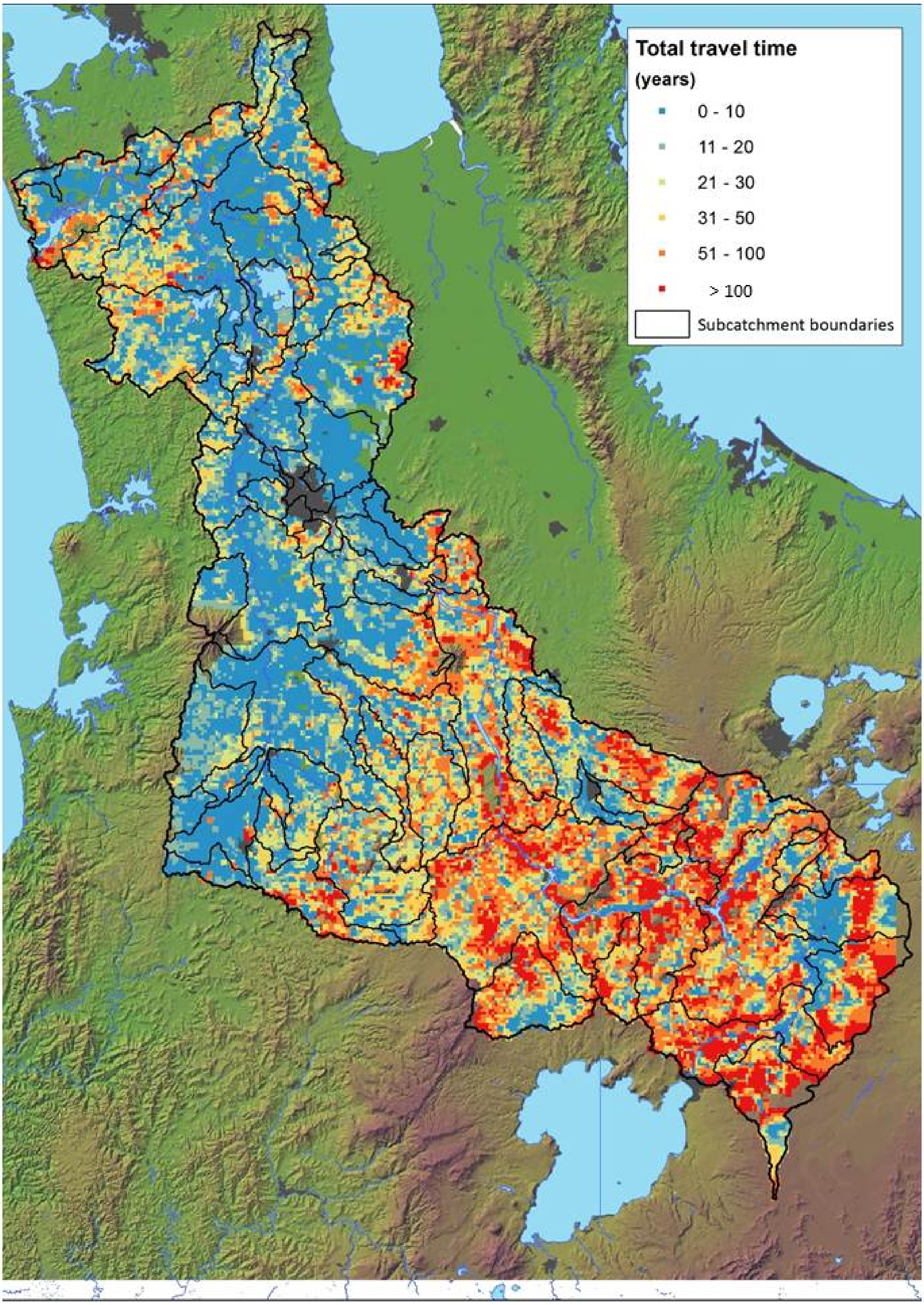
Model predictions compare favourably with reported mean residence times from ground water ages determined from tritium concentrations. The model accounts for 75 per cent of the variation in the tritium mean residence times.

[21] Wilson S, Shokri A 2015. Estimation of lag time of water and nitrate flow through the Vadose Zone: Waikato and Waipa River Catchments. Lincoln Agritech Ltd Report 1058-9-R1.

[22] Total travel time includes travel time through the unsaturated zone and the time taken for water and nitrate-nitrogen to penetrate the upper active parts of the aquifer

[23] Amsl – above mean sea level

Figure 4: Total travel time of water and nitrate flow through the unsaturated (vadose) zone



Study 4: Predicting the Redox Status of Ground Water on a regional scale.

Reducing conditions are necessary for denitrification to occur and thus the attenuation of nitrate-nitrogen as it passes through aquifers. Thus the ground water redox status can be used to identify ground water zones where potentially significant reduction of nitrate-nitrogen can occur. This study relates redox[24] status from 554 ground water bores throughout the Waikato and Waipa catchments with other mapable factors such as subsurface geology, topography and soils characteristics[25]. The more detailed examination of redox status completed in study one shows the extreme variability of redox potential that occurs on a micro scale.

Findings

In the Waikato (including the Hauraki catchment with similar soils and sediments) 56 per cent of the wells indicate oxic conditions, 22 per cent indicate reducing conditions and 22 per cent indicate a mixed condition (sometimes oxic: sometimes anaerobic). The analysis was completed for three different bore depths (<25 m, 25 to 100m and >100 m). The percentage of oxidised ground water decreases with increasing bore depth. The average agreement between predicted and measured redox status was 62 per cent for the Waikato region. The models were incorporated into a GIS model and the prediction of redox status extended over the whole region including steep land. The study therefore estimates the spatial distribution of reducing ground water zones and, when combined with ground water flow paths, improves estimates of where denitrification occurs.

Figure 5 show the oxidising and reducing zone in the shallow ground water (<25m) where most of the rapid ground water flow occurs. Reducing conditions are suggested for much of the low lying poorly drained areas in the lower and middle Waikato basins and in the Waipa catchment. Oxidising conditions are suggested for the elevated terrain forming the ranges in the middle and lower Waikato and Waipa catchments. The pattern of oxidising and reducing conditions in the upper Waikato appears less obvious but may relate to certain lithologies that promote reducing conditions; the Kaingaroa Formation, the Whakamaru group, the Ohakuri Caldera deposits and the Mamakau Plateau formation.

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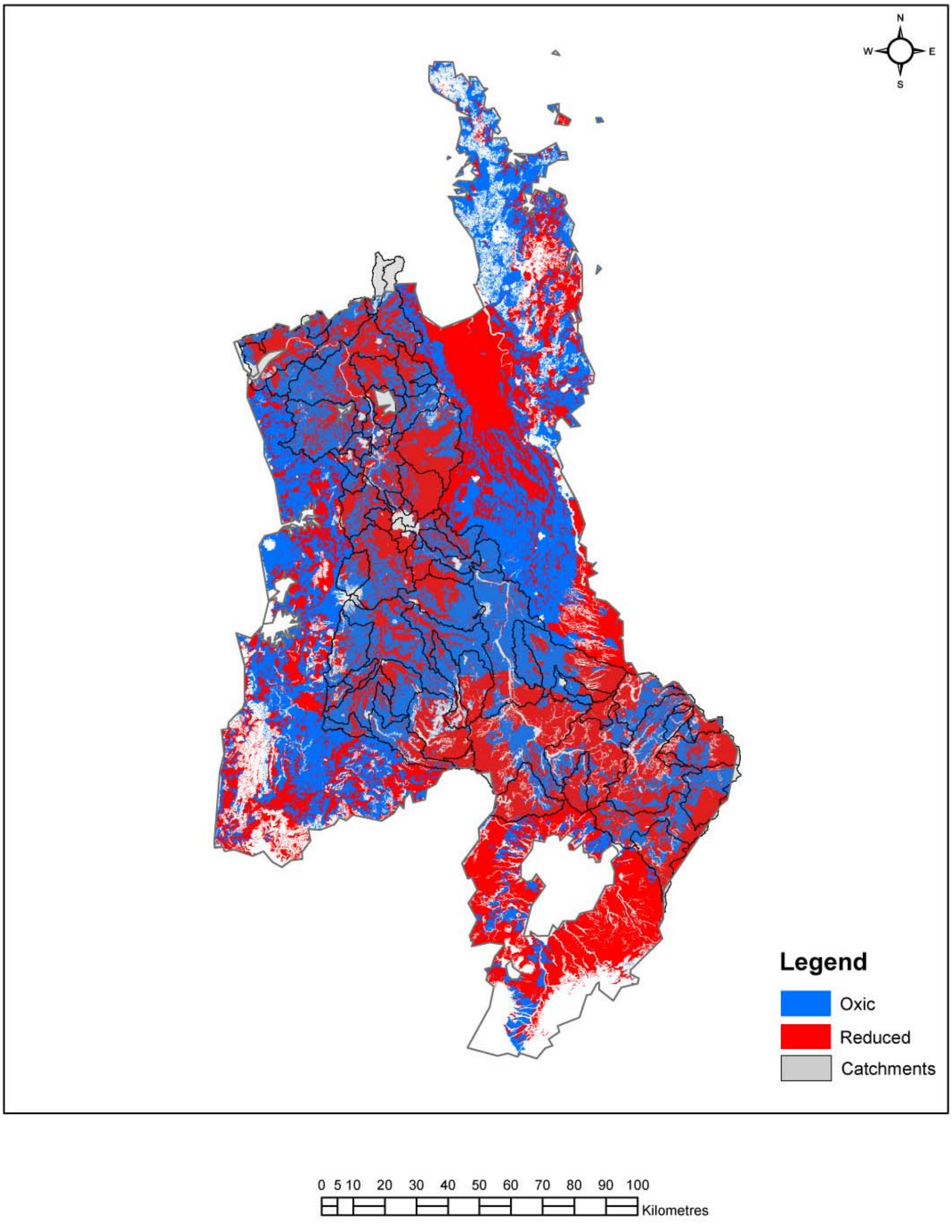
[24] Redox reactions include all chemical reactions in which atoms have their oxidation state changed usually involving transfers of electrons between chemical species. The term 'redox' comes from two concepts of electron transfer; reduction and oxidation. Oxidation is the loss of electrons or an increase in oxidation state by a molecule, atom or ion. Reduction is the gain of electrons or a decrease in oxidation state by a molecule, atom or ion.

Therefore for a redox reaction to occur there must be an electron donor and an electron acceptor. The most common electron donor in ground water is dissolved and particulate organic carbon although minerals such as Pyrite (FeS_2) and glauconite (iron rich clays) may act as electron donors. The most common electron acceptors are dissolved oxygen (O_2), nitrate (NO_3^+), manganese (Mn^{4+}) and ferric iron (Fe^{3+}). Ground water redox reactions are largely driven by bacteria that use organic material as a source of energy to transfer electrons to electron acceptors. Once O_2 has been depleted from ground water the bacteria move on to the next most energy favourable electron acceptor - nitrate (NO_3^+) followed by manganese and iron. Where NO_3 is introduced to a reduced ground water system, microbes will quickly utilise the nitrate and convert it to nitrogen gas (N_2) or gaseous nitrous oxides (N_2O). This process is called denitrification and effectively reduces the concentration of nitrate from ground water and may prevent it from subsequently reaching surface water. However, if the ground water is oxic (contains abundant dissolved oxygen) nitrate will accumulate in ground water and be available for transport to surface water.

[25] Close ME, *et al in prep*. Prediction of the Redox Status of Groundwater on a Regional Scale using linear Discriminant Analysis.

Figure 5: Oxidising and reducing zones in shallow aquifers (< 25 m depth) in the Waikato Region (inc Hauraki and Taupo)



Study 5: Incorporating this information into a steady-state catchment model

The information from studies 1-4 (above) has been incorporated into a simple steady-state catchment model developed by NIWA[26] for the upper Waikato river catchment but extended to cover all the 74 catchments in the Healthy Rivers Project. Improvements to the original model have been incorporated for this project. The information for input to the modelled catchments from all ground water studies was agreed by caucusing among the ground water experts and the modellers. This approach was used to ensure the best interpretation of the ground water information was available to the modellers and to ensure consensus for catchments where there was little information available. Note the main focus was on providing plausible estimates of the nitrogen load to come, the potential for denitrification and nature of the ground water flow processes in each catchment.

The catchment model

The catchment model estimates total nitrogen and total phosphorus loads for the outlets of the 74 healthy River's catchments. The model takes source loadings of nutrients from pasture and other land uses, adds known point source loadings including geothermal sources of nitrogen, accounts for the accumulations and decay between the source, streams and reservoirs, and in ground water. The loads are routed and accumulated downstream. The model predicts mean annual nutrient loads for each catchment. The model is incorporated into an economic optimisation model[27] being developed to determine the land use and mitigation options and estimate costs to meet the rehabilitation scenarios for the Waikato and Waipa Rivers considered by the Healthy Rivers Project Collaborative Stakeholder Group.

Information provided to the catchment model

The information provided from the ground water studies was summarised for each catchment. As an example the following descriptions for two catchments are provided.

> *Pokaiwhenua Stream: NZ Reach 3023849*
>
> *Surface flow is dominated by base flow and ground water outflow from the catchment is likely. The water table is typically in the Whakamaru Group. Water tables are typically deeper than 3 m. Spring-fed streams drain the Mamaku Plateau across the catchment. Ground water ages are highly variable 17-255+ years. Baseflow dominated, large storage capacities. Little seasonality evident. Drains Mamaku plateau north of Tokoroa, through an area being converted from forest. TN concentrations increasing post 2000 from a moderately high base concentration, reflecting an increase in pasture area by about 50%. Anticipate increased concentration rise due to some of the long response times to recent conversion. Good ground water information around Lichfield. Oxidising conditions are suggested at medium ground water depth, with some evidence of reducing conditions in shallow ground water. Low denitrification potential in medium ground water but possible denitrification in shallow ground water. Overall low-medium attenuation, a fast ground water response component but with some load to come. Median ground water age in the Pokaiwhenua stream 31 years.*

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[26] Elliott S *et al.*, 2013. Catchment models for nutrients and microbial indicators – Modelling application to the Upper Waikato Catchment. Client report for the Ministry for the Environment. NIWA client report Ham 2013-103.

[27] Doole GJ, 2013. Evaluation of policies for water quality improvement in the Upper Waikato catchment. University of Waikato Client Report for the Ministry for the Environment.

Waitawhiriwhiri Stream: NZ Reach 3017487
Base flow and quick flow are both important to surface flow and ground water outflow from the catchment is likely. The water table is typically in the Tauranga Group. Water tables are typically deeper than 3 m. Tauranga Group sediments include: the Hinuera Formation where infiltration is relatively rapid; and drained peats, where infiltration is slow. No water age information exists for this sub-catchment. The hydrogeology setting suggests the lag is likely to be moderately short. This streams drains through Hamilton and is subject to increasing urbanisation, along with associated storm water and tradewaste control (Lake Rotoroa/Hamilton catchment). Information suggests shallow and deep ground water are potential reducing zones. About 50% of the catchment is urban (excluded from the reducing zone assessment model). Attenuation is likely to be moderate to high. N Load to come is likely to be low.

This type of information is used by the modellers to categorise the catchment in terms of nitrogen load to come the importance of ground water contributions to stream flow and the potential for denitrification. The Pokaiwhenua catchment has long term water quality monitoring and this site can be used to calibrate the model.

Summary of ground water studies

A series for studies have been completed to improve understanding the regional hydrogeology, how nitrogen is transformed as it passes through the aquifers, the travel times (lags) for water and nitrogen to pass through the aquifers to rivers and streams, and the structural relationships and interactions between ground water and surface water resources. This report provides an interim summary only of these investigations: some reports are still in draft form: most the ground water dating information has just been received – results for some samples are yet to come; and this is the first attempt of integrating the findings from the investigations commissioned. The focus of all investigators has been to provide the main findings as soon as possible to support the modelling required for the Healthy Rivers Project.

The paragraphs below summarise the general findings to date. Some of the points made are illustrated in a schematic (Figure 6).

1. The geological and hydrogeological evidence suggests the hydrogeological systems are closed: all parts of the Waikato and Waipa catchments are underlain by very slowly permeable sediments. Basins formed in the basement by structural faulting have been infilled with a sequence of sedimentary, volcanic and alluvial sediments. These sediments form aquifers of differing hydraulic performance and some provide ground water of useable quantities and quality. The closed nature of the Waikato hydrogeological systems means that all net rainfall arriving on the land surface either: runs off during rainfall or shortly after (interflow); or infiltrates the soil to enter ground water and travels by various pathways (some shallow: some deeper; Figure 6 #1) to emerge in the Waikato and Waipa rivers and discharge ultimately to the sea (Figure 6 #2).

2. Ground water levels vary from a few metres below ground in flat low-lying terrain to between 20 to 50 metres below ground in elevated terrain. Ground water flow paths (driven by peizometric surfaces) indicate spatial patterns of ground water flow are determined strongly by local ground elevation. This pattern is more subdued in deeper aquifers. Ground water flows from higher terrain (where ground water tables are often deeper) to the low points in the hydrological systems determined by the stream and river network (Figure 6 #3). The ground water is at the surface in many low lying areas adjacent to streams, in wetlands and in poorly drained soils. In most parts of the Waikato and Waipa catchments the ground water divide closely follows the catchment divide (Figure 6 #4): there is little evidence of inter-catchment transfers of ground water. Possible, but unproven, exceptions to this may occur on the elevated, flat terrain of the Kaingaroa plateau and in some low angle catchments in the Waikato lowlands.

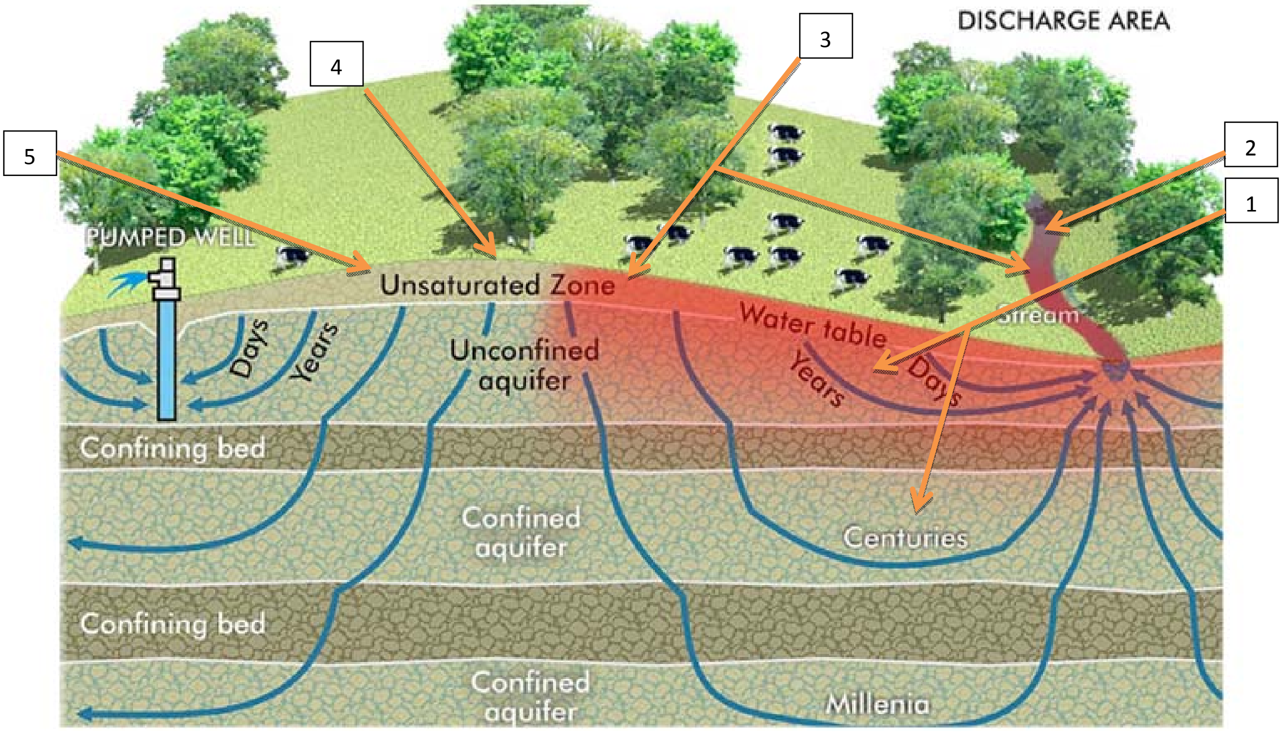
3. Ground water nitrogen in the upper Waikato is commonly higher than MAV or between half MAV and MAV, suggesting land use is impacting on use ground water quality. This finding is consistent with other studies linking land use and ground water quality. Nitrate concentrations are varying slowly suggesting recent land use intensification has not yet full impacted ground water quality.

   Ground water nitrogen in the Waipa is sometimes higher than MAV or between half MAV. Ground water nitrate levels are rising slowly indicating that intensifying land use is impacting ground water.

   Ground water nitrogen in the lower and middle Waikato is commonly higher than MAV or between half MAV and MAV and is increasing in 17 percent of catchments.

   Throughout the Waipa and Waikato catchments there is no simple relationship between age and nitrate-nitrogen concentration in ground water. Typically there is a wedge-shaped distribution showing that ground water older than the recent development of farm land is low in nitrogen, whereas younger ground water ranges in concentration depending on land-use, potential attenuation and flow pathways, particularly the presence of fracturing (Figure 6: graduated red shaded area).

Figure 6 shows a schematic of a ground water system illustrating some of the points in this summary.



4. Travel time through the unsaturated zone is important in determining the overall lag time between land use intensification (often through rapid land use change) and the associated impacts on surface water quality. Total travel times through the unsaturated zone (Figure 6 #5) are less than 10 years for most of the lower Waikato, Hamilton and Waipa basins, particularly for the shallow, low angle basin floors and low hills with elevations less than 100 m amsl. Longer travel times of 10 to 30 years are estimated for the land surfaces above 100m amsl. Substantially longer travel times (50 to more than 100 years) are estimated for the elevated terrain in the Upper Waikato and in the ranges in other parts of the Waikato and Waipa catchments. These observations are consistent with the observed ages for ground water.

5. The age of surface water in the Waipa and middle and lower Waikato catchments (expressed as MRT) are generally less than 15 years and average about 10 years.

   The age of surface waters in the Upper Waikato sub-catchment streams are older with an average MRT of about 52 years (median 35 years; flow weighted mean of about 47 years).

   The water age of the Waikato River above Karapiro is younger (about 12 years at Karapiro) due to the influence of Lake Taupo which provides two thirds of the flow.

The age of ground water is highly variable throughout the study area. Mean residence times often much older than surface waters (mean residence time from the latest surveys is about 150 years). The mean residence time is older than suggested by previous investigations (mean residence time 67 years (n=113)).

Initial analysis of the data obtained recently suggests there is no clear relationship between depth of ground water and its mean residence time. Some shallow wells (between 2 and 10m deep) in the middle and lower Waikato catchments and the Waipa catchment, which intersect very shallow ground water, show consistently younger ground water (1 to 2 years MRT). These ages may indicate shallow, more rapid flow in the active surface zone in the aquifers. The age of ground water in three springs measured in the upper Waikato catchment vary between 11 and 60 years MRT. The age of deeper ground water is consistently older but appears unrelated to depth. This observation may reflect the different sediments from which the ground water was obtained, the degree of fracturing of the aquifers intercepted by the bores, and the general variability of the aquifers sampled. Generally, age increases with depth in areas of recharge (Figure 6).

6. The potential for nitrogen attenuation was examined by estimates of where denitrification is likely to occur in the Waikato and Waipa catchments. Reducing conditions are suggested for much of the low lying poorly drained areas in the lower and middle Waikato basins and in the Waipa catchment. Oxidising conditions are suggested for the elevated terrain forming the ranges in the middle and lower Waikato and Waipa catchments. In the Upper Waikato the pattern of oxidising and reducing conditions appears less obvious but may relate to certain sediments that promote reducing conditions: e.g. the Kaingaroa Formation, the Whakamaru group, the Ohakuri Caldera deposits and the Mamakau Plateau formation. Other studies of oxidising and reducing conditions completed for this project show the occurrence of these conditions is highly variable, spatially and with depth - most likely because of the special conditions required for their occurrence.

7. Information from these investigations has been forwarded to the developers of a catchment model that estimates the mean annual loads of nitrogen from each catchment. The estimates of nitrogen loads (and other water quality parameters) will be passed to an economic optimisation model being developed to incorporate land use and mitigation options and to estimate costs to meet the rehabilitation scenarios for the Waikato and Waipa Rivers considered by the Healthy Rivers Project Collaborative Stakeholder group.