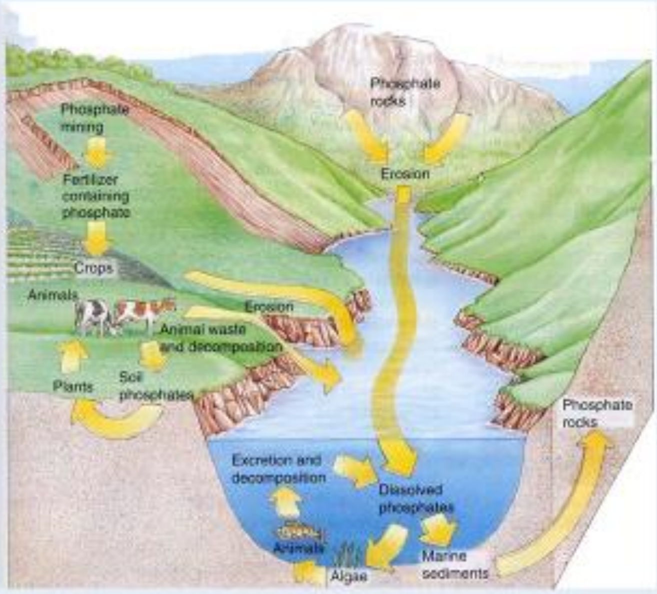
Phosphorus Workshop

3rd November 2016

Rotorua



ROTORUA TE ARAWA LAKES PROGRAMME

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Executive Summary

Lake Rotorua Phosphorus Workshop 3rd Nov 2016

The following summarises workshop findings from three keynote presenters:

Phosphorus Loss Sources in BoP Region (Prof. David Hamilton, University of Waikato)

- To achieve the target TLI for Lake Rotorua both catchment N and P need to be reduced. Sustainable target levels have been set in the BOPRC Policy statement and in the Rotorua/Rotoiti Action Plan.
- The catchment nutrient reduction strategy must have regard for the in-lake N:P ratio. It is acceptable to reduce them concurrently, but the ratio itself should not be reduced below the long-term average of 12:1. A reduction in the N:P ratio could lead to cyanobacteria becoming dominant with some that can potentially fix N from the atmosphere.
- In Lake Rotorua bioassays it has been shown that cyanobacteria increase growth in response to additions of N and P individually, but the response to the addition of both N and P is larger than observed with the addition of only N or P alone.
- The response to additional N or P can vary from season to season depending upon which nutrient is limiting at the time. Sometimes the response is to N or P, but often it's to both simultaneously.
- The Alum dosing programme has reduced available phosphorus in Lake Rotorua. Total P has been reduced to in-lake target levels since about 2012 due to the alum dosing programme. The target level is 20 µgP/L In Lake Rotorua. Alum dosing has resulted in a reduction in cyanobacteria presence since 2010 and there have been no health warnings due to cyanobacteria blooms in recent years.
- When the lake stratifies, most commonly in summer, bottom waters begin to de-oxygenate with consequent release of nutrients from bottom sediments. Alum appears to have had a role in reducing this release. A reduction in nutrients results in a reduction in algal growth, which in turn reduces the volume of decomposing material settling on the lake bed. The injection of alum effectively initiates a positive feedback loop; stream dosing of alum beyond the level required to inactivate phosphorus in the stream helps to create a residual that controls both natural and anthropogenic sources of P in the lake.
- Alum dosing is identified as a short-term intervention to manage P until catchment N and P loads are controlled and approach the sustainable catchment targets. It is expected that alum dosing will be phased out as these targets are realised.
- N and P from land take different pathways through the soil and water. Generally N travels as a soluble phase with water, whereas P attaches readily to soil particles and travels overland, often as the result of erosion. The techniques available to reduce N leaching will mostly not provide a similar magnitude of reduction in the loss of P from the same area of land. There is a

need to address P run-off from land use and transport in streams. The objective should be to increase the retention of P on the land in order to reduce downstream effects.

- Assessment of P inputs to Lake Rotorua from the catchment indicate that around half of the stream and groundwater inputs are from natural geological sources. Anthropogenic inputs which may be able to be managed by land use controls contribute the other half of the P load reaching Lake Rotorua. Hence, any reduction of the P load coming from anthropogenic sources (catchment land use) can only ever address about 50% of the total catchment P load.

- Science advice is that management of algal blooms in Lake Rotorua cannot be achieved by catchment management of P alone unless in-stream/in-lake controls (e.g., alum dosing) are used. Current management of P through the alum dosing programme has resulted in an approximately 50% reduction in P concentrations in the lake, with the alum addressing both natural and anthropogenic sources, including in-lake releases.

- Both diffuse and point-source urban storm water discharge have been identified as potentially significant contributors to in-lake phosphorus.

- Removal of urban storm water P could be greatly enhanced by improved engineering interventions.

P losses and mitigation (Prof. Richard McDowell, Lincoln University)

- There can be a wide seasonal variation in P loss due to climate, soil type, topography and land management. The interaction of these factors with land management and farmer environmental practice has a significant effect on the level of P loss from season to season and from farm to farm. Best management practices are available to minimise P loss from land.

- There is a positive relationship between soil test P (Olsen P) and the P in surface runoff and leaching. In terms of common pastoral farming land uses within the Lake Rotorua catchment dairy farming contributes the greatest N loss; deer farming is likely to have the greatest sediment loss on a per hectare basis. Any land use can contribute P losses depending on soil P, slope, climate,

- There is a need to understand the difference between agronomic optimum and economic optimum for P fertility. The latter is more important for farm profitability, and tends to be lower than agronomic optimum, hence lower P run-off.

- Soil Olsen P levels should be maintained no higher than the agronomic optimum because losses of P are potentially greatest from areas with higher Olsen P. However, these losses only become real where there is a hydrological link to streams .

- Fertilisers, grazing management, and dung are the main sources of P loss within a farm environment.

- The bulk of P loss from farming systems can be attributed critical source areas. It is important to target these areas in addressing mitigation and ensure mitigations are correctly implemented and maintained. Dealing with Critical Source Areas (CSAs) can dramatically increase the cost-effectiveness of mitigation strategies

- P loss mitigations should be specific to the enterprise and match the region, taking account of the key local environmental factors including: critical source areas (small areas that account for most losses), climate, farming and grazing management, fertiliser and effluent management, flow paths, soil types and characteristics.
- Various P mitigation measures can have variable environmental effectiveness. A useful metric is $/kg of nutrient (N or P) retained on-farm
- Farm mitigations that are designed to address N leaching will not necessarily achieve the same level of P mitigation (and vice versa). If changes to both N and P are required then assessment of the efficacy of the mitigation for each nutrient should be understood.
- There is little research measuring the load of N and P from the harvesting of Radiata Pine forest. Hence, losses may be greater or less than predicted using the OVERSEER model predictions within the Rotorua Catchment. The data suggests that sediment loads from harvesting are high; if we assume a set P concentration for this sediment then P losses should also be high
- Key priorities to achieve P reduction: recognise that land management decisions heavily impact P loss; target Critical Source Areas of P loss; assess the cost-effectiveness of mitigations; develop a plan to put the appropriate mitigation options in place.

Nutrient losses from forestry (Dr. Peter Beets, Scion)

- Forestry plantations currently do not typically receive N or P applications to boost production.
- Forest sites converted from pastoral farming can be highly productive. The soil nutrient stores at ex pasture sites are generally much higher than trees actually need. This can result in legacy nutrient loss effects throughout the first rotation, and possibly longer.
- During forest harvesting, the nutrient cycle is interrupted and nutrient export (loss) during the time where the seedlings are establishing can be expected to occur in drainage water.
- N leaching in the first 3 years after planting can be significant. N is produced from decaying organic matter and can be as high as 70kgN/ha/year, prior to attenuation occurring.
- Stream water monitoring is not always a good indicator of losses from the forest operations. Within-stream nutrient processes can be highly variable.
- Sediment runoff during harvest operations is a key source of sediment and associated P loss to water. The management of sediment runoff during harvesting must be a key consideration during forest planting planning. Provide buffer zones that effectively stop runoff during forest harvest and ensure steep slopes that cannot be buffered are not planted for production forestry.

- Current forestry nutrient focus is on matching supply and demand (using modelling) and on live and dead biomass-N pools. First rotation radiata pine initial places a high demand on soil N stores (1000kg/ha removed from mineral soil), however subsequent demands on soil stores decrease appreciably, assuming continued use of conventional stem only harvesting operations.

LAND TECHNICAL ADVISORY GROUP: PHOSPHORUS WORKSHOP

9am-4.30pm, Thurs 3rd Nov 2016, Energy Sigma Room, Energy Events Centre, Rotorua

Chair: Phil Journeaux
Convener: Andy Bruere
Facilitator: Warren Webber

Present: Alastair MacCormick
Chris Sutton
David Burger
David Hamilton
Gretchen Sveda (minutes)
Hamish Dean
Ian Power
John Paterson
Paul Scholes
Peter Beets
Rebecca Burton
Richard McDowell
Rosemary Cross
Stephen Lamb
Stuart Morrison
Warren Webber

Time	Agenda Item	Who	Comment
9.00	1. **Welcome**: Introductions, Workshop Purpose and Format	Andy Bruere	Purpose and Outcomes: to inform BOPRC on (i) P loss rates, mitigation, costs & N interactions; (ii) P priorities for policy, research & extension The outcome will be a statement from the TAG workshop, specifically detailing what we know about P, what data/info gaps are identified and what recommendations for application and research.
9.15	**2. Phosphorus loss sources in BOP region and why is phosphorus an issue for the lakes** a. Lake Rotorua P sensitivity, P sources b. P transport and future loads	David Hamilton	Note L Rotorua co-limitation; more recent P limitation due to alum; summarise P sources (UoW report); particularly note forest P loss and the concern re P loss over the forest cycle.
9.45	c. Bay of Plenty regional overview: P limitation, state and trends	Paul Scholes	A few slides showing % of streams P or co-limited across the region, range of values (DRP and/or TP?); trends – for brevity, perhaps just focus on Kaituna R to illustrate?
10.00	d. Lake Rotorua proposed policy on P	Stephen Lamb	PC10 N Mgt. Plan P requirements; reliance on getting enough P via N; science & policy review method
10.15	e. Lake Rotorua 2032 P 'load' from land	Paul Scholes	2 slides on status quo Vs 2032 P loss using Parsons et al 2015 model scenarios; show high sensitivity to forest P loss rate.
10.30	*Refreshments (30min)*		
11.00	**3. P loss from farms**	Richard McDowell	This is to link to Overseer P loss rates and drivers like Olsen P (show graph of loss vs soil P), stocking rate, rainfall/soil/runoff,

	a. Outline of the sources of P loss b. Quantification of P loss c. Outline of P loss mitigation strategies d. Present the cost-effective method of decreasing P losses: maximising mitigation on critical source areas, are there co-benefits associated with decreasing N losses? e. Other issues: groundwater, lag times.		crop management and Critical Source Areas. Recap from AgR May 2016 slides plus give latest P research e.g. from Clean Water Productive Land and Our Land and Water. This should include P source differentiation within farms. Describe P guidance focusing on P mitigation strategies in actual practice. Discuss efficacy and, if possible, the **quantitative** P reductions to be expected. We would like to see how effective the strategy was in getting P reduction and what methods were most successful in achieving results vs. those that don't achieve.
11.45	**f. Group Discussion (30min)** **- P loss from farms**		
12.15	g. Possible projects to improve knowledge of farm P loss and mitigation	Paul Scholes David Burger Ian Power	Canvass 3 possible projects: (i) Redo P soil sampling to build on BOPRC's soil health data, Redding et al (2006) (ii) Case study to optimise P mitigation on an N-mitigated farm; (iii) liaise with fert companies to assess trends in Olsen P and P fert use, including the L Rotorua catchment. Attendees can discuss and refine project scope with presenter (to be recorded on whiteboard)
12.30	*Lunch (30min)*		
1.00	**4. P and N loss from forestry** a. Why is it important to consider N loss from forestry; changes in N over the forest cycle. b. Research and data on P & N loss rates; harvest risks vs whole cycle; Rotorua applicability c. NuBalM forestry nutrient model; scope to link to OVERSEER	Peter Beets	An overview of forestry P & N loss, including from Baillie & Neary 2015 and Davies 2014 (latter N-focused) and any Rotorua-specific data (still regionally relevant). NuBalM could be demo'd plus explain the hydrology module to improve N/P loss estimates, potential OVERSEER links and timeline for this to occur. We want to cover both N & P due to the synergy and risks identified in 2c/2d above. Why has N has not changed with new OVERSEER outputs? We could agree to a 'resolution' to ask MBIE and Overseer Ltd to expedite NuBalM development and its integration with Overseer
1.30	**d. Group Discussion (60min)** **– P & N loss from forestry**		
2.30	*Refreshments (30min)*		
3.00	**Workshop Recommendations** The aim is to consider the preceding P topics and provide advice to BOPRC	Facilitator: Andy Bruere	Ideally we want some specific direction on (i) how to optimise P mitigation alongside N mitigation; (ii) P monitoring & measurement of gains (iii) N & P loss from forestry

	Identify outcomes. We anticipate a detailed statement from the workshop outlining: 1. What we know about P loss, 2. P and N loss from Forestry, 3. P research and P info and research gaps, 4. Recommendations on the importance of P control and future recommendations for research and information to support BOP land use improvements wrt P		(iv) research priorities and /or leveraging opportunities; (v) develop P good practice or NOT; (vi) anything else the group prioritises e.g. P attenuation.
4.00	**Action Summary**	Phil Journeaux	Recap specific recommendations, follow-up actions

APPENDIX TO AGENDA:

DRAFT Land TAG advice on phosphorus sources and mitigation (from May 2016)

1. The OVERSEER P sub-model was recently reviewed (Gray et al, 2016) and, while there was good prediction of P loss from pastoral systems, multiple potential improvements were identified, including: non-pastoral uses; more comprehensive sediment losses; and spatial and temporal capability e.g. Critical Source Areas.

2. Attenuation of P losses (beyond the source e.g. farm or forest) is highly variable and needs to better understood, including clarity on the 'boundary' of OVERSEER P loss predictions

3. Forestry P losses need to be better understood, both for the more vulnerable harvest window and the long term average.

4. On-farm mitigations that reduce both N and P losses are useful but we do not have good information on what landowners are actually doing. Farm stocking rates and feed budget should be the first focus to reduce both N and P losses before jumping to mitigation options

5. The cost effectiveness hierarchy of P mitigation techniques (e.g. as presented May 2016 by David Houlbrooke) is useful at a generic level but can vary a lot between farms and regions.

6. As with other recommended farm practices, it is important to consider:

a. How to apply learnings via farmer peers and specialist advisors.

b. What happens after advice is provided i.e. auditing is important

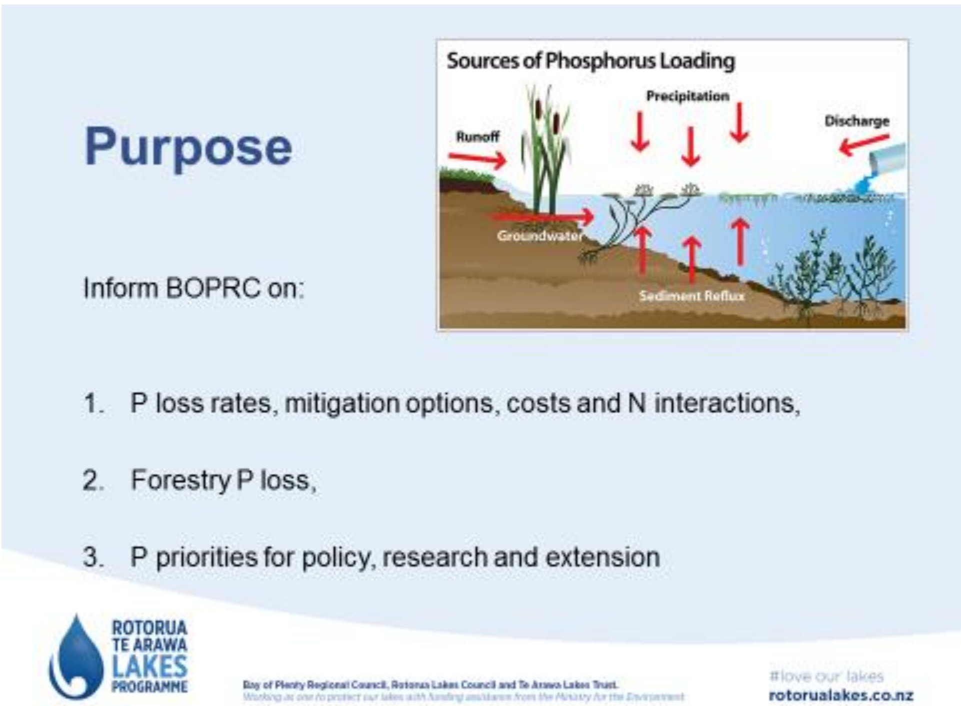
c. Reducing the variety of messages given out there

d. Holistic environmental management plans improves buy-in

e. Farmer catchment groups enable farmers to compare notes and support each other

Welcome: Introductions, workshop purpose and format
Presenter: Andy Bruere

- We want to inform the Regional Council on P loss rates, potential mitigations and the costs of these sorts of options and what sorts of interactions we get between P and N if we take either N or P out of a system
- We're particularly interested in Forestry
- We've been focussing strongly on Lake Rotorua due to Plan Change 10 (PC10) which refers specifically to managing nitrogen within the Lake Rotorua catchment



Background

Lake Rotorua restoration

- Sustainable N target in BOP RPS → 435 t N
- Current load 650 t N → 750 t N
- Temporary interventions such as alum to control P
- Plan Change 10 → long term solution
- Focus on N reductions

- Impact of forestry operations on nutrient losses
- Step change in OVERSEER losses for N from farming but not forestry

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- PC10 is focussed on N, but we're interested in what impact forestry operations have on nutrient losses, because there are many assumptions about the reduction in nutrients reaching the lake as a consequence of conversion to trees

We are not clear on whether Overseer is dealing with the impact of harvest cycles or just the growth stage of forests. In recent Overseer updates there was no step change in losses from forestry – why is attenuation between the root zone and lake is deemed to impact pastoral land but not land in forest/bush/scrub given that there was a clear 80% step change in N leaching from pastoral land uses.

Phosphorus target

- UoW and WQTAG advice → need N and P focus
- P target → 34 – 39 t P
- Current load 49 t

- High natural loads

	Annual loading t P y^{-1}		
	Total	Anthropogenic	Baseline
Dissolved reactive phosphorus	27.7	6.1	21.6
Particulate phosphorus	21.0	17.3	3.7
Total phosphorus	48.7	23.4 (43-64%)	25.3

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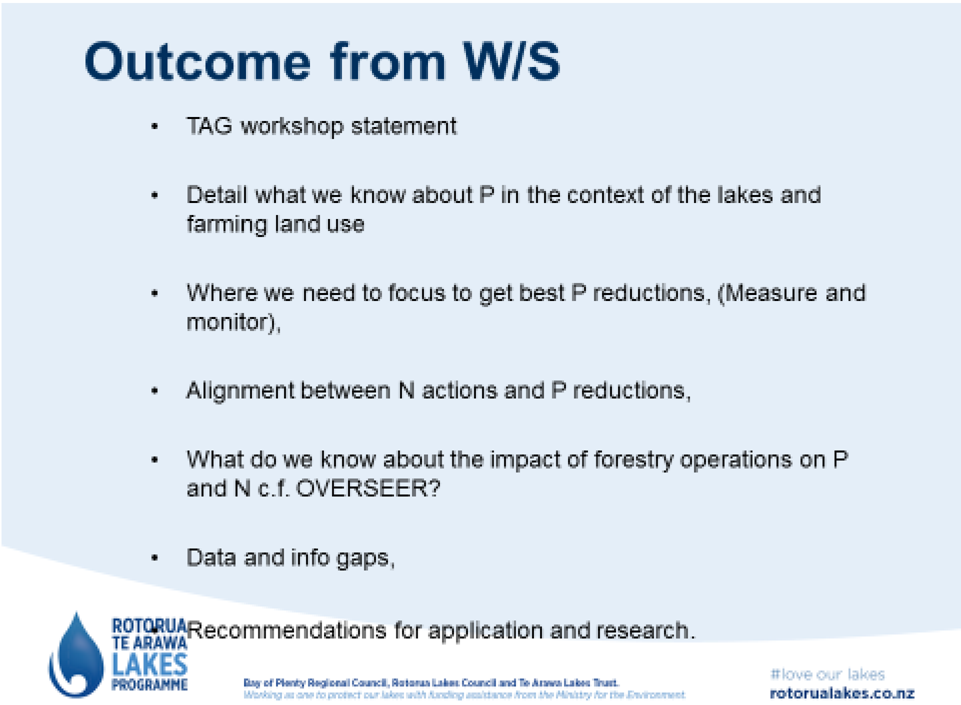
- The University of Waikato and the Water Quality TAG have always said that we need to focus on both N and P
    - current P load is est. at 49tP
    - sustainable load is est. at 34-39tP to the lake
    - hence we have a 10-15tP reduction target, but no regulation in place to this
- The University of Waikato have broken the P load down into anthropogenic and baseline loads. Nearly half is from natural sources. We need to reduce the anthropogenic load by 43-64% to achieve the P reduction target
- Outcomes from this workshop:
    - Detail what we know about P in the context of lakes and farming land use
    - Where we need to focus to get best P reductions – concern is that the numbers that we get from estimates have all sorts of conditions around them as to where the loss might be and how accurate the information is
    - Alignment between N actions and P reductions
    - What we know about the impact of forestry operations on P and N compared to Overseer predictions
    - Data and information gaps
    - Recommendations for application and research



Phosphorus Workshop
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Phosphorus loss sources in BOP region

Why is phosphorus an issue for the lakes?

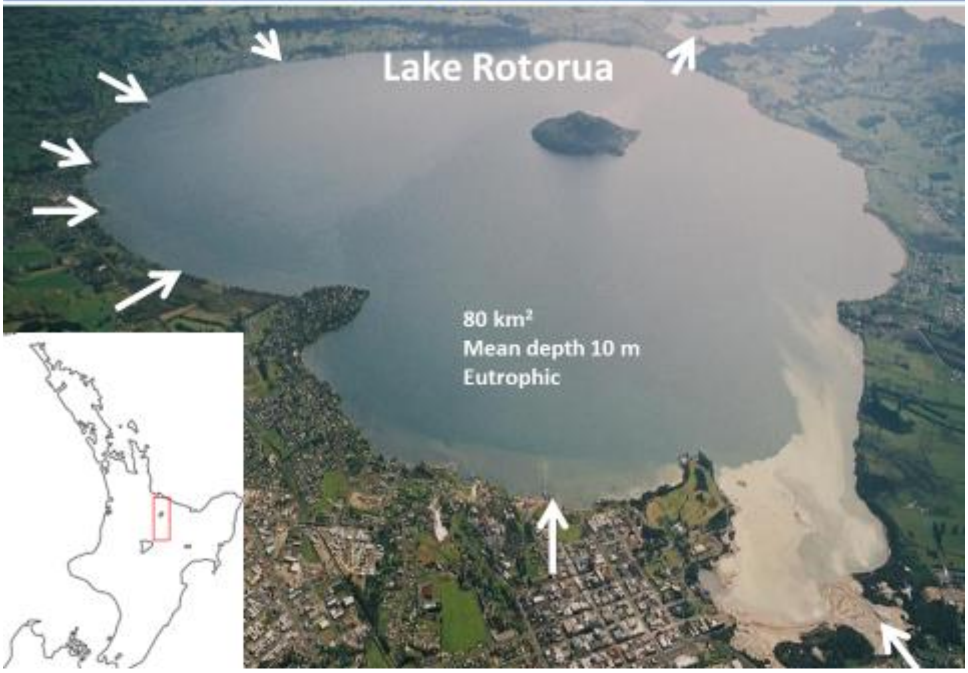
- Lake Rotorua P sensitivity, P sources
- P transport and future loads

David Hamilton
Jonathan Abell, Chris McBride, Grant Tempero, Jamie Peryer-Fursdon

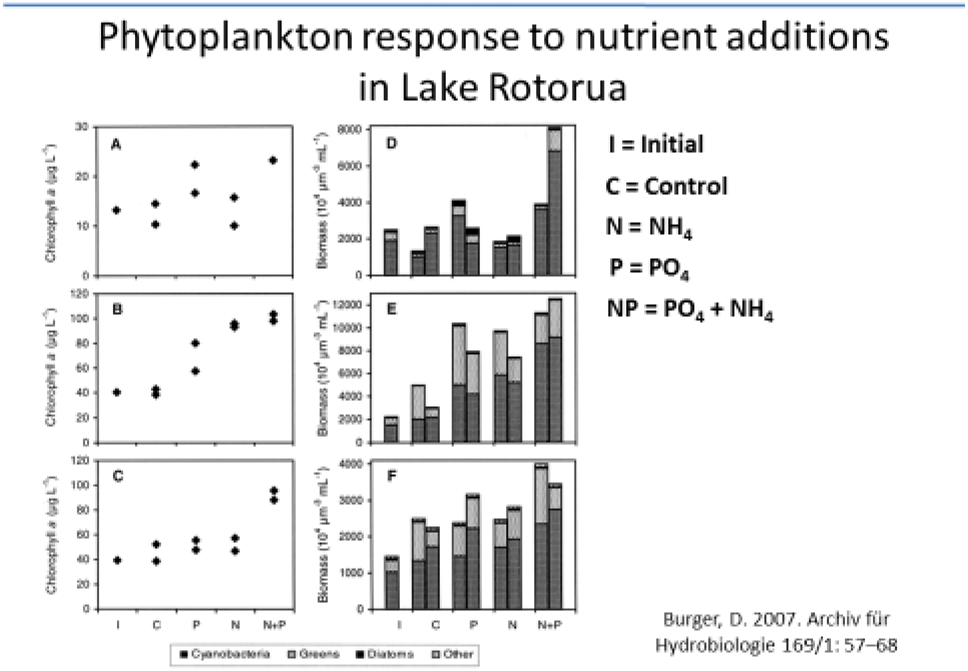
WAIKATO

Outline

- Phytoplankton responses to nutrient additions
- Alum dosing effects
- Phosphorus loads by subcatchment
- P loss from pastoral land use
- P loss from forestry
- Strategies for P control



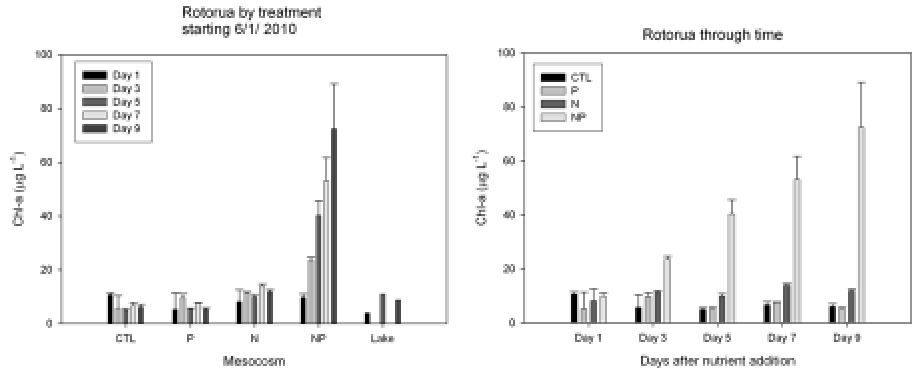
- Rotorua is a complex lake with 9 major inflows, and as many as 20 surface water inflows
- 80 km2, mean depth 10 m, eutrophic
- Alum dosing is done at two sites, Puarenga and Utuhina



- David Burger differentiated different algal groups in response to nutrient additions. Cyanobacteria had the largest response to N and P increases at the same time – the combined response is larger than seen with just N or just P
- Nutrient impact assessments are made by adding a nutrient to a mesocosm within the lake. This protocol is challenged by some - for example, David Schindler contends that nutrient

assessments are valid only when applied on a ‘whole of lake’ basis. Nonetheless, microcosm methodology has acceptance by many in the scientific community.

Sensitivity of Lake Rotorua phytoplankton biomass to phosphorus concentrations

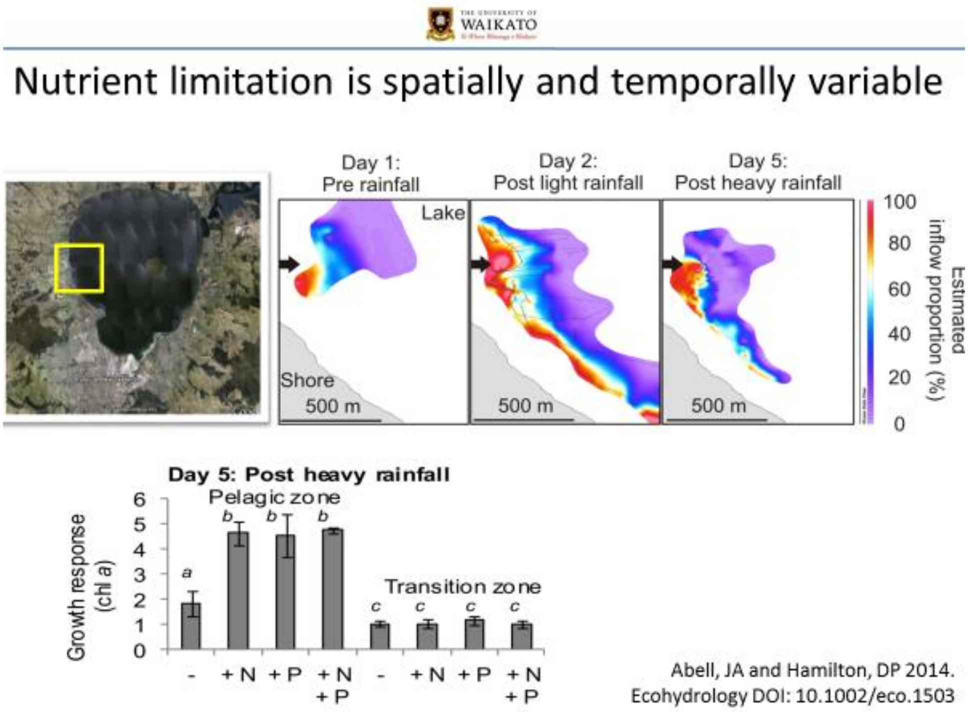


- A student worked on three lakes, added N and P to them and got some great data in L.Rotorua. Adding one or the other caused increases in algal growth, but adding both gave the greatest increases.
- Lake Rotorua has some of the most prolonged sequences of nutrient bioassay research.
- You don’t always get the same responses – sometimes the response is to N or P, but often it’s to both simultaneously

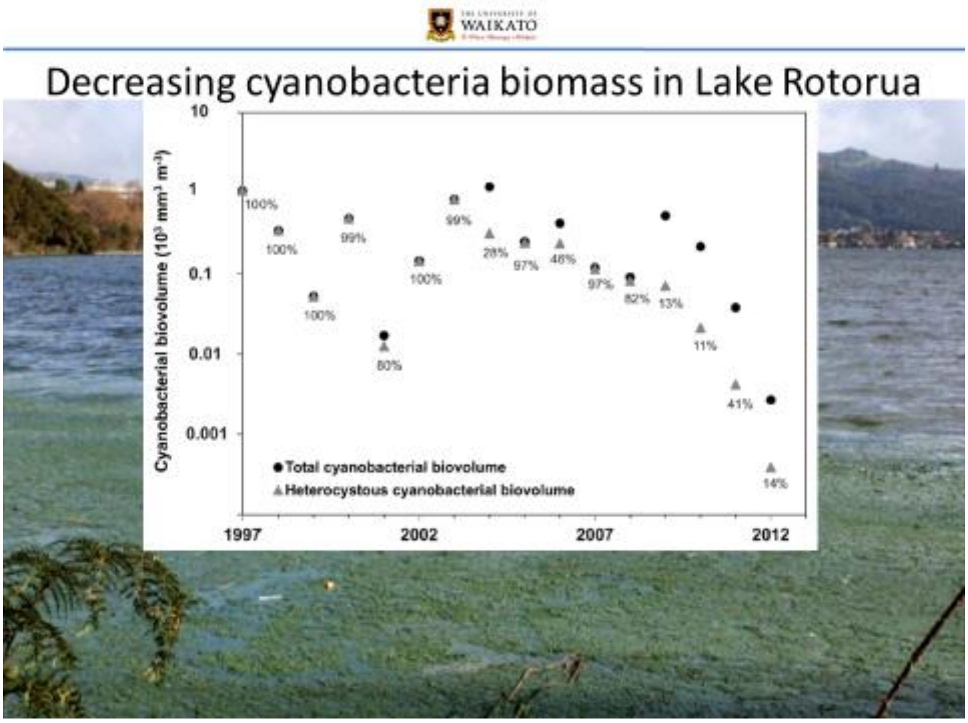
Phytoplankton response to nutrient additions in Lake Rotorua

Experiment organisation level	Observed response		Relative response	Co-limit. response	Incubation/ simulation duration	Study
	+N	+P				
Lab bioassays (0.25 L)	Yes	No			5 d	White and Payne (1978)
Lab bioassays	Yes	No		>N	2 h, 24 h	White et al. (1985)
In situ mesocosm (3 L)	Yes	Yes	P>N	>N, >P	4 d, 6 d	Burger et al. (2007)
In situ mesocosm (1 m^3)	Yes	No		>>N	1-9 d	Meads (unpub. data 2009)
Lab bioassays (1)	No	No		No	1 d	Abell and Hamilton (2015)
Lab bioassays (2)	Yes	No		≈N	1 d	Abell and Hamilton (2015)
Lab bioassays (3)	No	Yes		No	1 d	Abell and Hamilton (2015)
Lab bioassays (4)	Yes	Yes	N≈P	≈N, ≈P	1 d	Abell and Hamilton (2015)
Model simulations	Yes	Yes	N >>P	>N, >>P	5 d	Abell and Hamilton (2015)

- It depends where you are in the lake, what season you're in as to which nutrient is limited Adjacent to an inflow (transition zone) there is no nutrient limitation because the inflowing nutrient alleviates any nutrient limitation

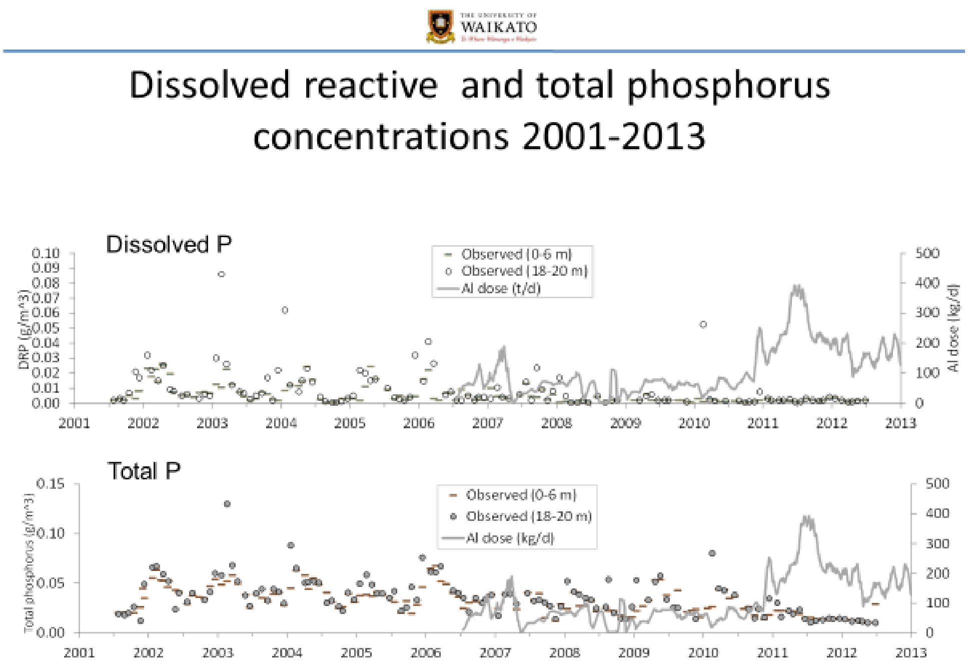


- When you add nutrients to the middle of the lake, there is a marked increase in growth
- In L. Rotorua, there's been an amazing drop in cyanobacteria biomass in recent years – it has decreased markedly

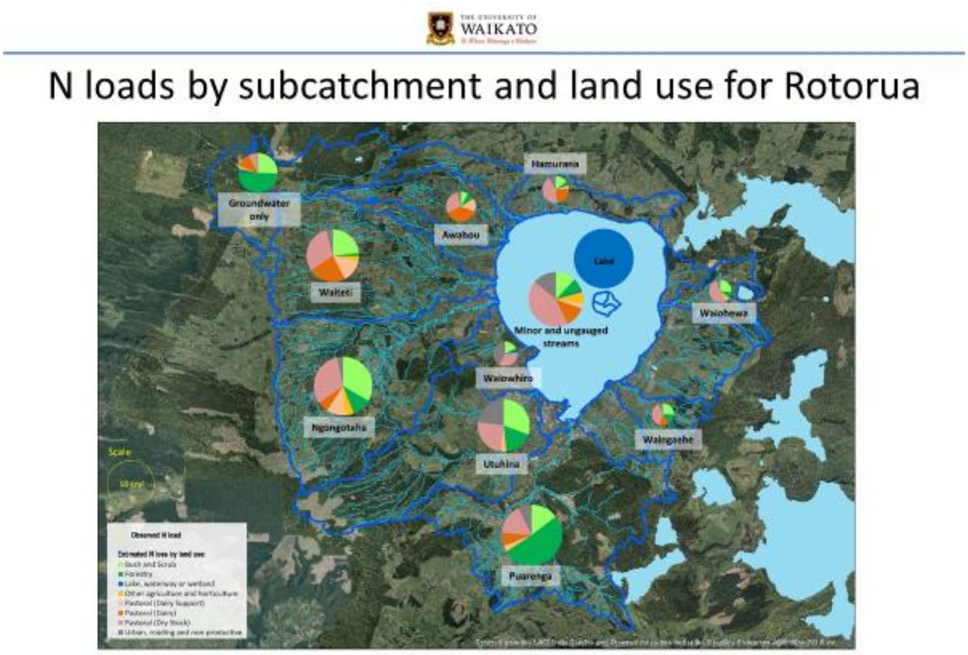


- Recent evidence indicates that Taupo may be shifting to P limitation because of a shift to ongoing increases in nitrogen loading to the lake. Interestingly, none of the calculations have ever built in the potentially important contribution of N-fixing cyanobacteria to nitrogen in the lake.

- Heterocystous cyanobacteria can fix N, and are the dominant type in Lake Taupō, a lake which may have been shown to have switched to P limitation. They have the ability to fix N , so you can drop N but you also have to drop P by a particular ratio to prevent them from potentially becoming dominant
- Alum dosing is knocking out the phosphate in L. Rotorua, and Total P has been dropped down to target levels. Target level is 20ugP/l

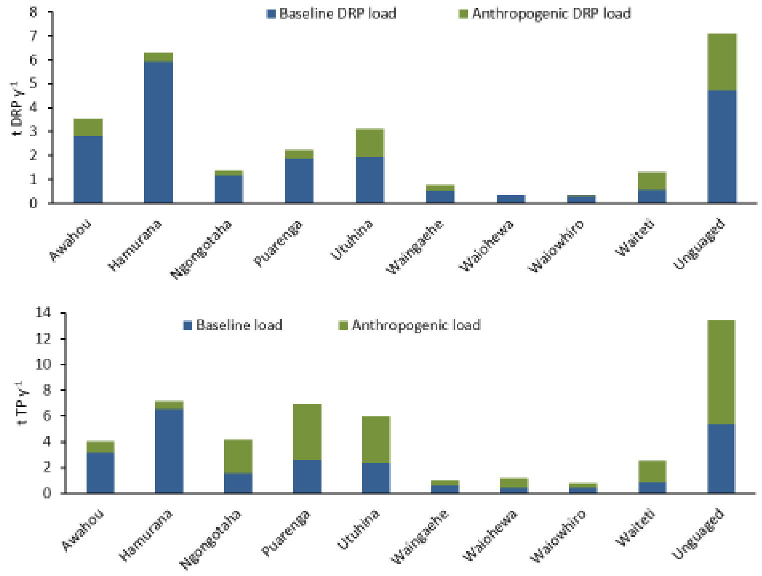


- The alum dosing prevents so much P from being released during stratification events

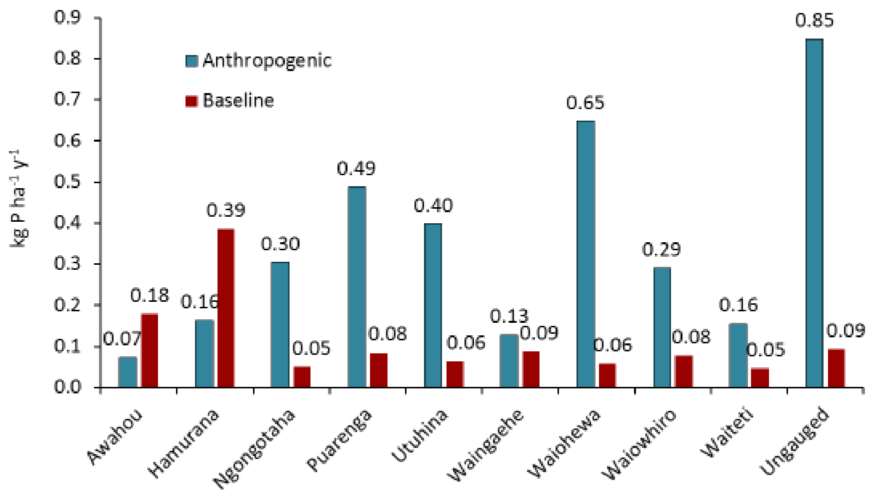


Size of the pie charts is scaled to the area of the corresponding catchment.

P load summary by subcatchment

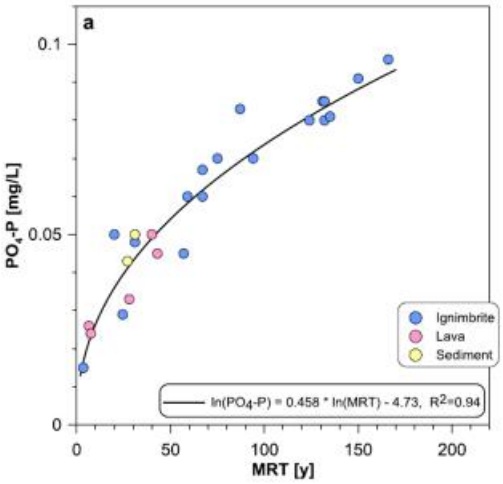


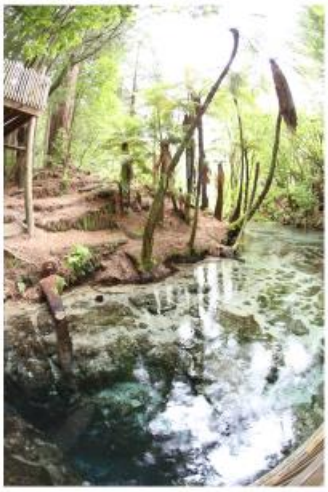
P yield by subcatchment



- Alum dosing has pushed both dissolved and Total P much closer to the baseline
- Ground water that has been in contact with the rhyolitic rock leaches P (phosphate) so there's a strong baseline or natural phosphorus. The Awahou and Hamurana streams are particularly dominated by the 'natural' baseline load, despite these also being significant agricultural catchments
- Diffuse urban runoff and storm flow is 'ungauged' but has been calculated as a significant part of the anthropogenic load
- Anthropogenic load is largely in the form of particulate P. An obvious target for P mitigation.

P concentrations and groundwater residence times





- The P yield has been separated out by anthropogenic and baseline loads. Waiohewa, Utuhina and Puarenga have the highest anthropogenic loads
- The above graph shows that the dissolve P concentration increases in relation to residence time and the consequent exposure to ryolitic rock

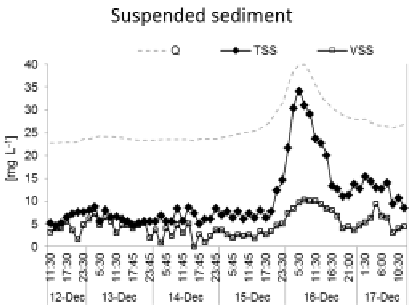
- Blowouts happen less often thanks to the Kaituna catchment control work, but ephemeral water flow is an ongoing issue which John Paterson has been working on. The P runs off the land, through the streams and into the lakebed, where it is released during stratification events when the lower layers of the water are anoxic

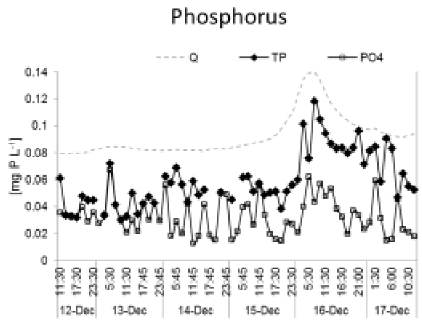
'Blowout' from ephemeral stream leading to large stormflow sediment loads

Source: Bay of Plenty Regional Council

Ephemeral watercourse in the Lake Rotorua catchment

Example of a moderate storm event from a tributary (Ngongotaha Stream) to Lake Rotorua



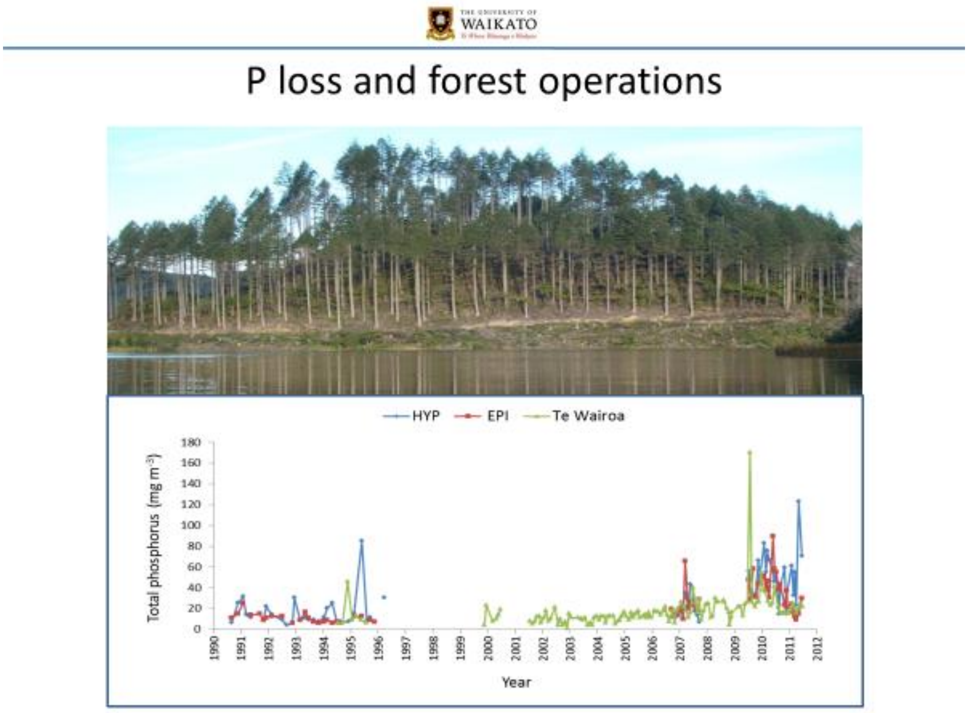


Abell at al. (2013). Environmental Science Processes Impacts. (flood events).

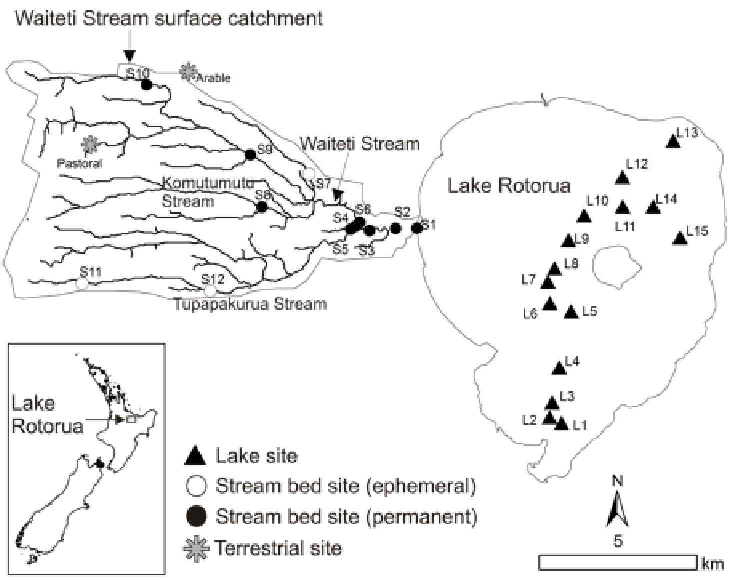
Abell and Hamilton (2013). NZ Journal of Marine and Freshwater Res. (phosphorus transport).

Ephemeral run-off loads are high in particulate phosphate

- The above graph shows a moderate storm event resulting in elevated suspended sediment and particulate P loads

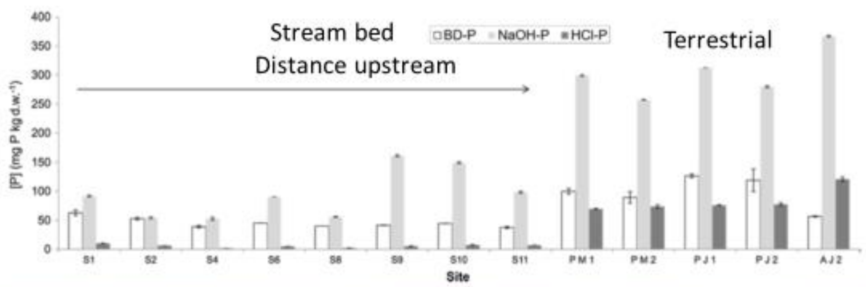


- Lake Rotokakahi (Green Lake) is an example of what can happen at and around harvest time in a predominantly afforested catchment. Harvesting close to the lake margins resulted in water quality declines during the years 2009-2012



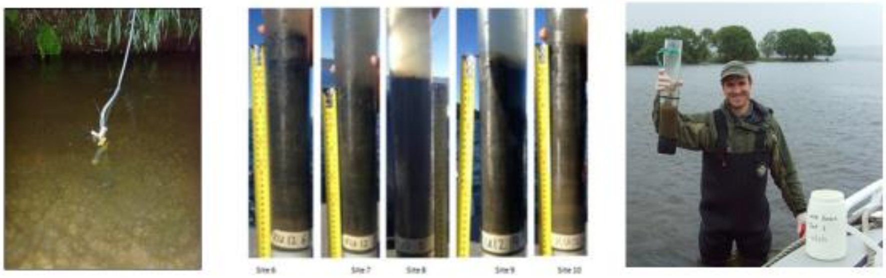
- This figure demonstrates P translocation from terrestial land which is high in P, through stream systems, and thence to the lake. Once in the lake sediments this P contributes to the quantity of P released in stratification events
- There is much to be gained from reducing P run-off to streams
- Need to retain the P on the land

Phosphorus fractionation in terrestrial and stream sediments

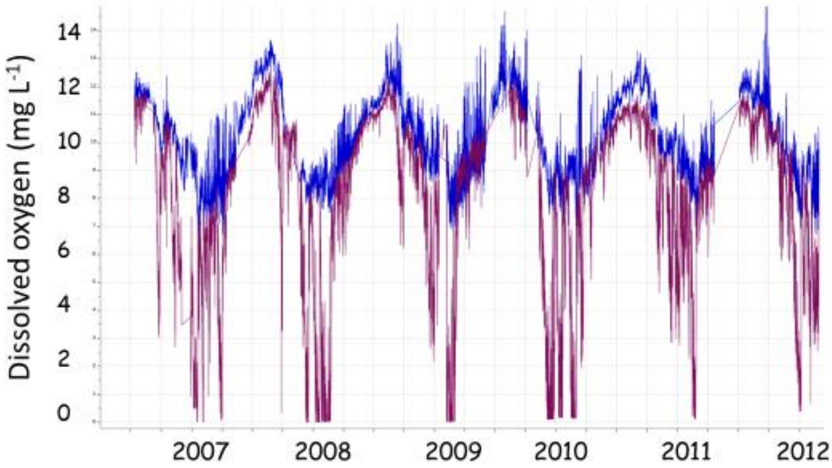


Summary of total phosphorus concentrations in terrestrial, stream and lake sediments

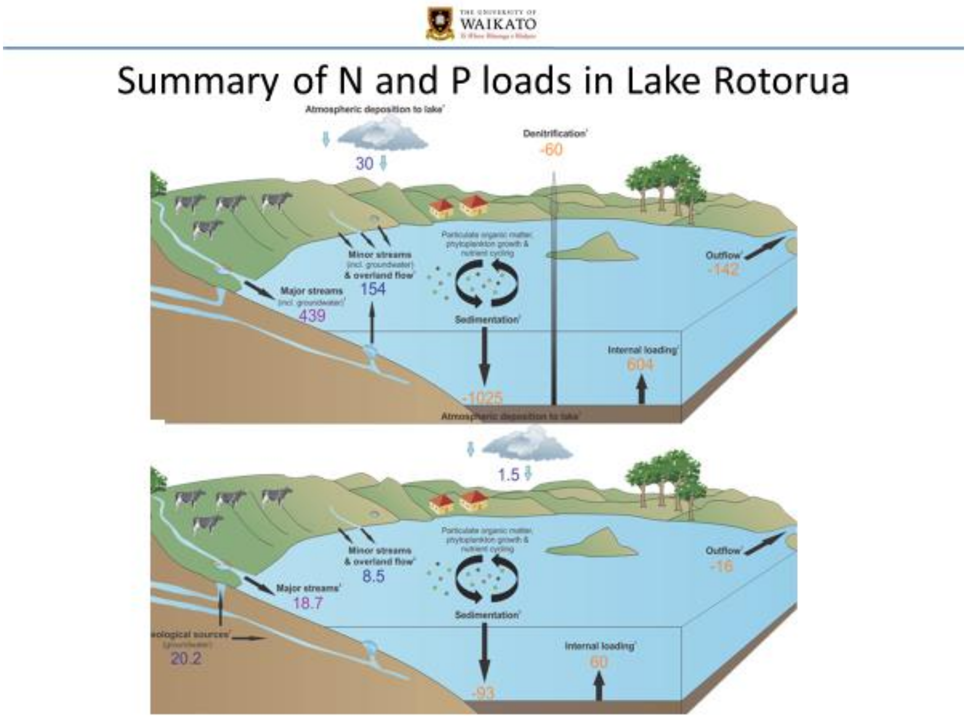
Variable		Terrestrial (n = 14)	Stream (n = 36)	Lake (n = 15)
TP mg (kg dw)$^{-1}$	Median	2157	212	2661
	Min	1204	93	1526
	Max	2727	715	3564



Surface and bottom dissolved oxygen, 2007 to 2012



- When the lake stratifies in summer this causes deoxgenation of bottom waters and a consequent release of nutrient from bottom sediments. Alum has had a significant role in reducing this release. A reduction in nutrients results in a reduction in algal growth, which in turn reduces the volume of decomposing material settling on the lake bed. The injection of alum is effectively initiating a positive feedback loop, Excess stream dosing of alum is helping to control both natural and anthropogenic sources of P.



A whole of lake nutrient budget has been attempted. Half of the stream and groundwater inputs are from geological sources; this increases the challenge of removing sufficient P from other sources

Inputs	**Nitrogen (tN)**	**Phosphorus (tP)**
Rainfall	30	1.5
Geological	0	20.2
Major streams	439	18.7
Minor streams	154	8.5
Release from sediment	604	60
Total Inputs	**1227**	**109**
Outputs		
Deposition to sediments	1025	93
Denitrification	60	0
Ohau Outflow	142	16
Total Outputs	**1227**	**109**

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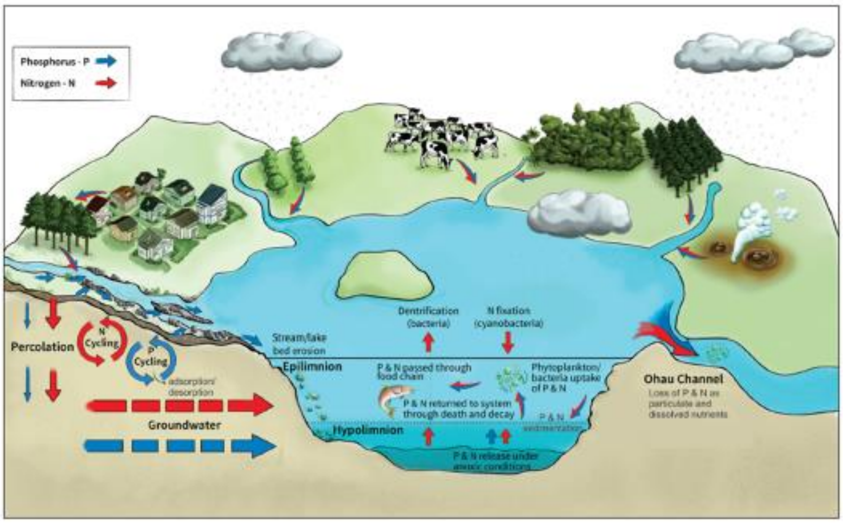
Processes associated with nutrient loadings and responses



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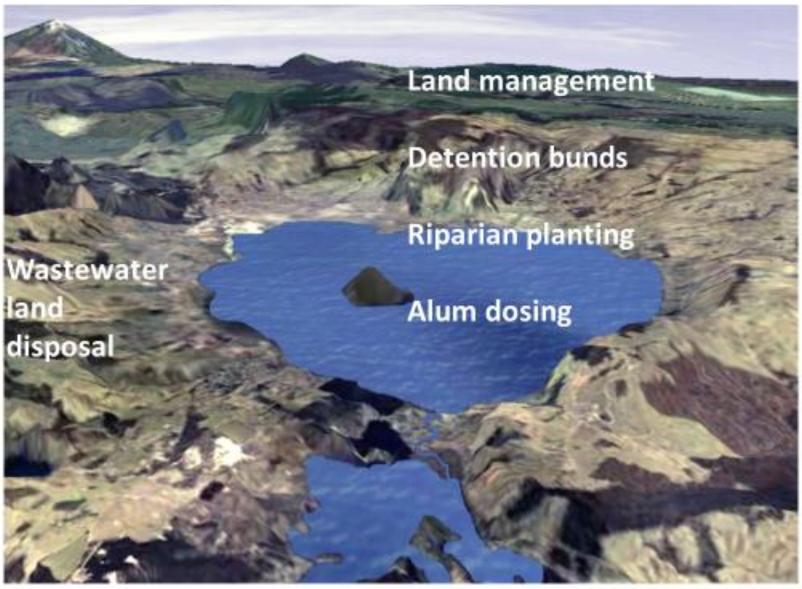
Strategies for managing P in Lake Rotorua



COMMENTS

Hamurana Mitigations

- A possible strategy for L. Rotorua P control is to treat the Hamurana stream inflow via water treatment plant technology; take 80% of the water, put it through a flocculation process to remove the P and put it back in at the same point. There is even potential to reactivate the alum (although not easy, and would require pH manipulation). P in the Hamurana outflow is predominantly dissolved P and is very low in particulate P – this improves the potential effectiveness of flocculation. This strategy differs from in-stream dosing in that the alum is removed rather than dispersed to the lake.

Stormwater Mitigations

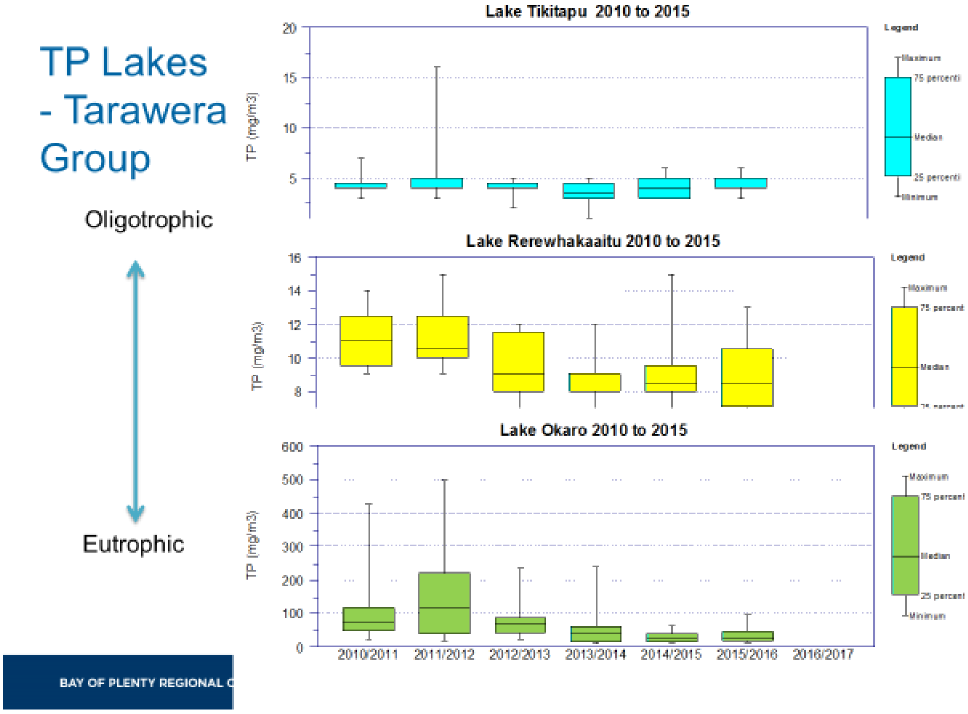
- Both diffuse and point-source urban stormwater discharge are a significant contributor to in-lake Phosphorus
- The effectiveness of stormwater P mitigation could be greatly enhanced by improved engineering interventions

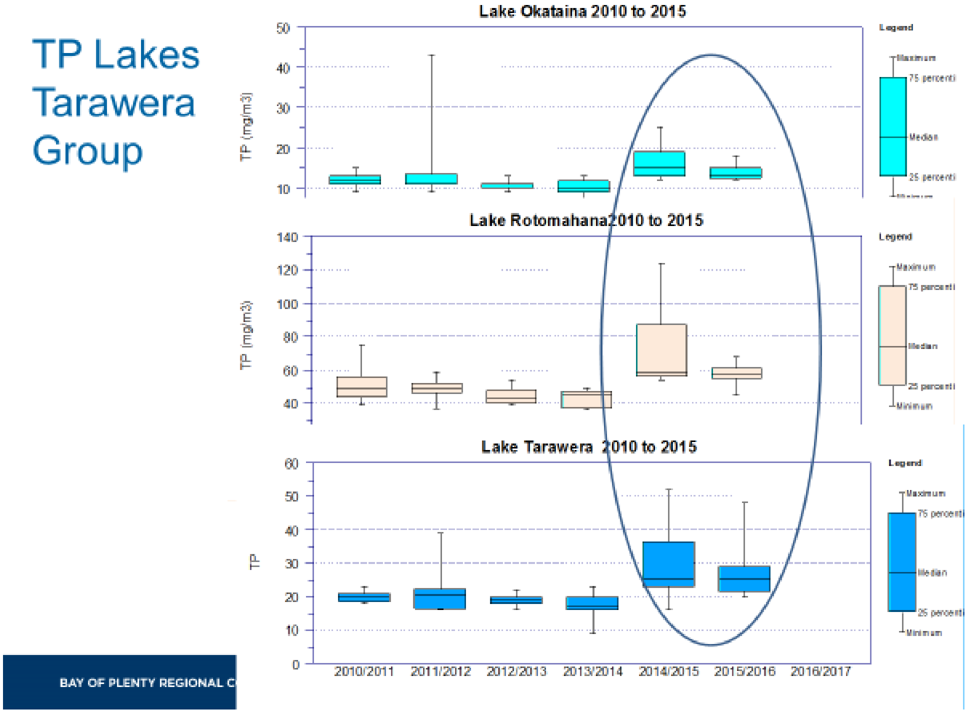
General

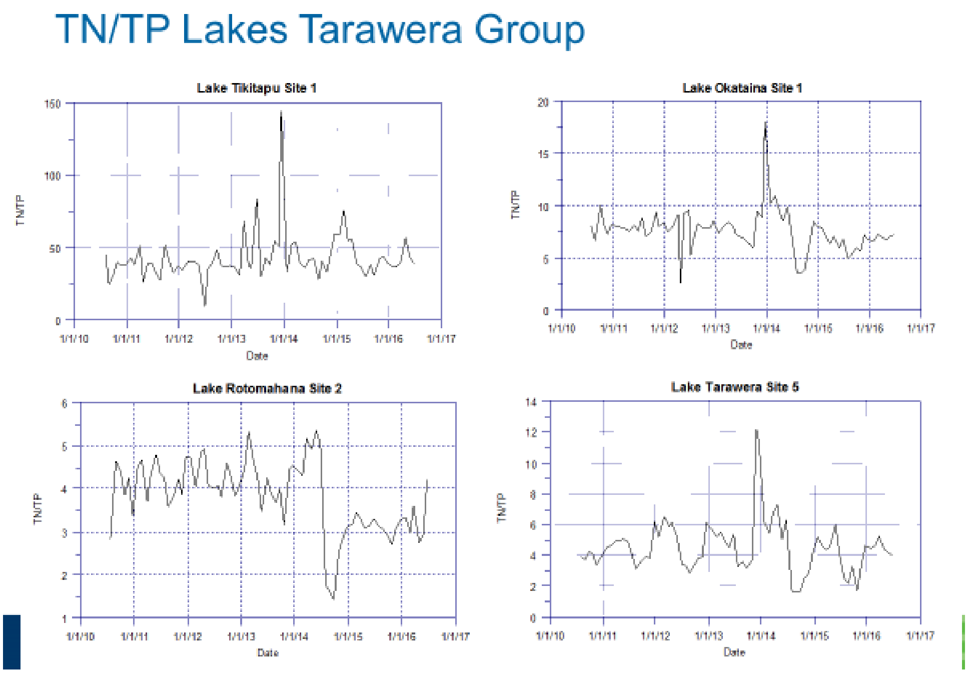
- A question arises whether it is possible to alum dose as long as we need to, perhaps 20-30 more years. It's related to how quickly we get the changes in the catchment, and how quickly they translate into results in lake
- The modelling we've had done by NIWA has shown about 70% of changes can be expected within 35 years
- Here in Rotorua we have a larger groundwater P concentration than in other catchments due to the rock types and high groundwater residence times
- Alum dosing may be relatively effective in the Rotorua catchment because it's constantly being reworked between the bottom sediments and the water column

P loss from farms
Presenter: Paul Scholes

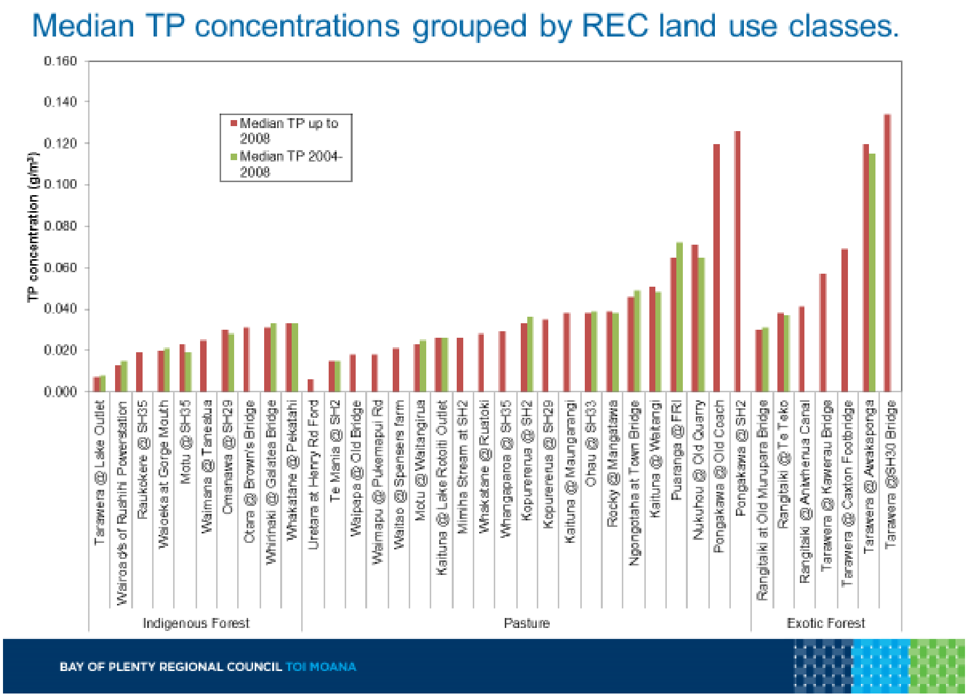
- Quick look at the Tarawera group of lakes – Tikitapu, Rerewhaaaitu and Ōkaro
- Ōkaro is showing improvements with the work being done there
- Ōkataina, Rotomanana and Tarawera and showing a slight increase in P
- The TN/TP ratio of these lakes is quite variable, keep that in mind in terms of targeting P efforts in those systems

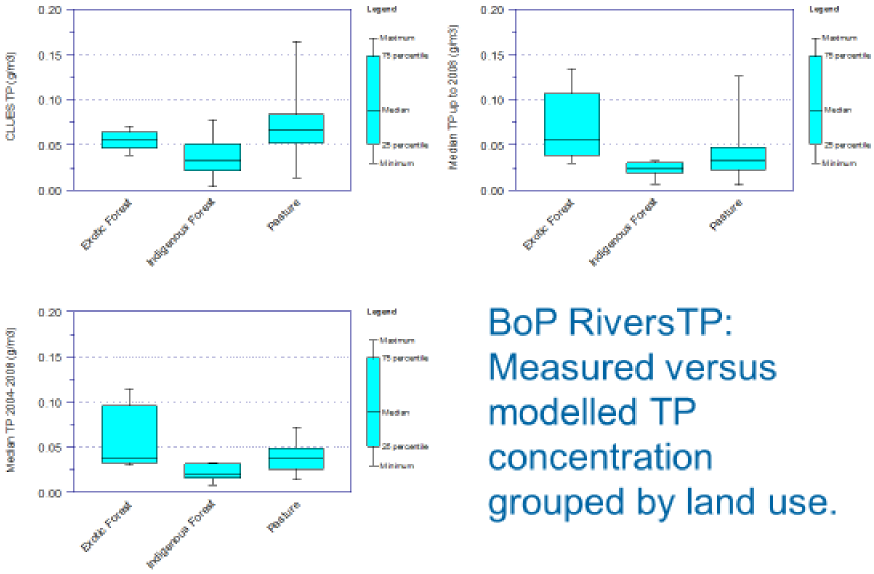






- We monitor a whole range of streams across the BoP region, located in indigenous forest, exotic forest and pasture





BoP RiversTP: Measured versus modelled TP concentration grouped by land use.

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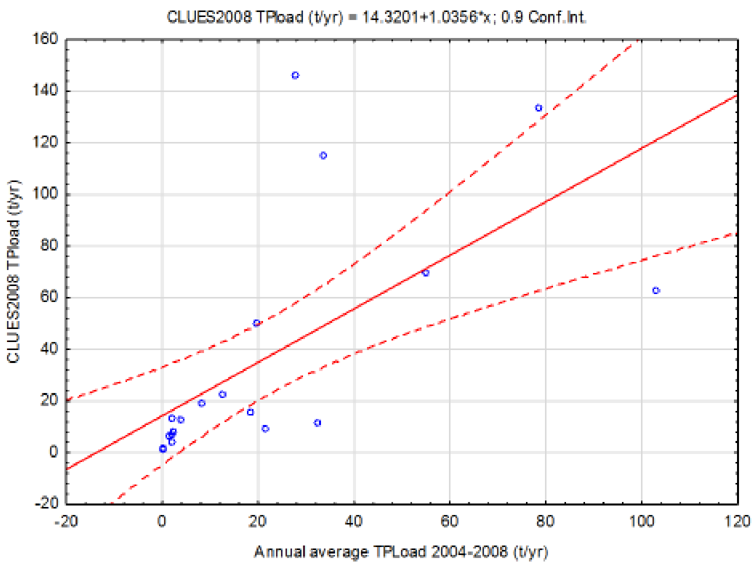
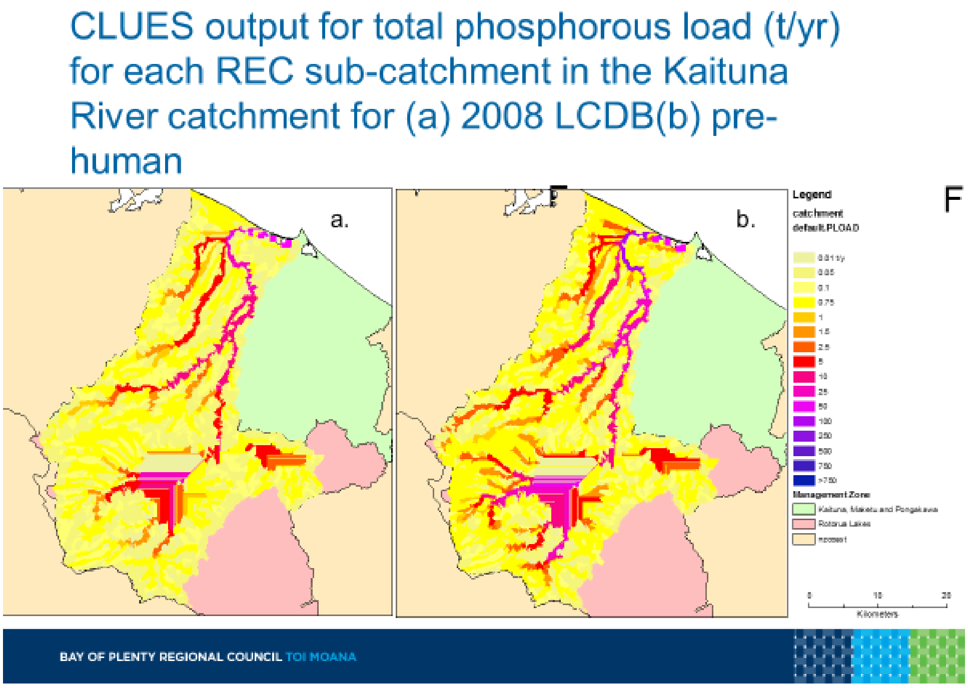
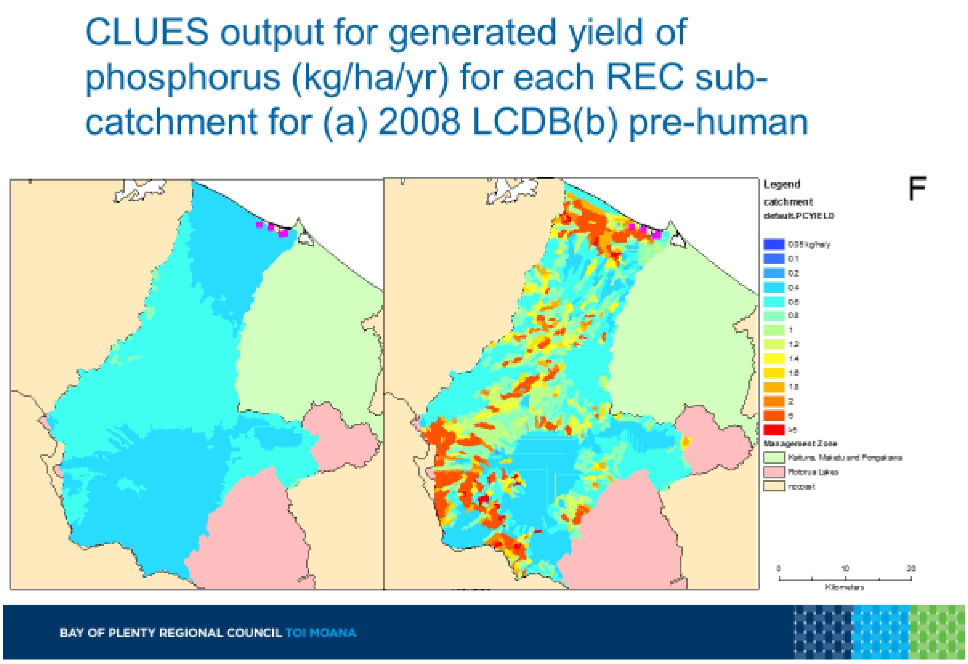


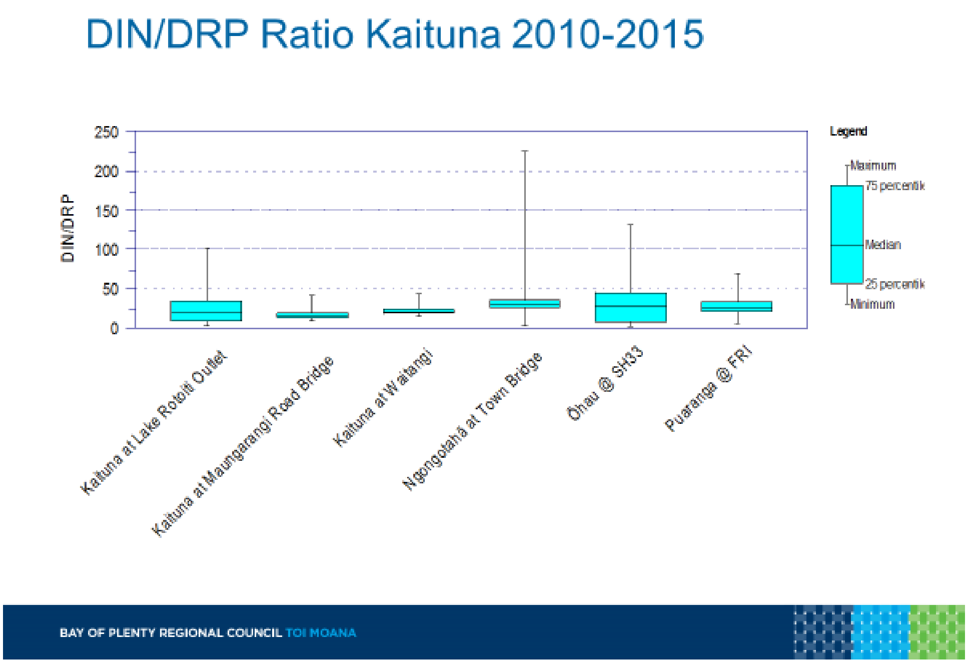
BAY OF PLENTY REGIONAL COUNCIL TOI MOANA

- CLUES is a GIS tool developed by NIWA for determining nutrient loads. Using it, you can see where the hotspots for P load are within the catchment. CLUES generally performs better for N than P.

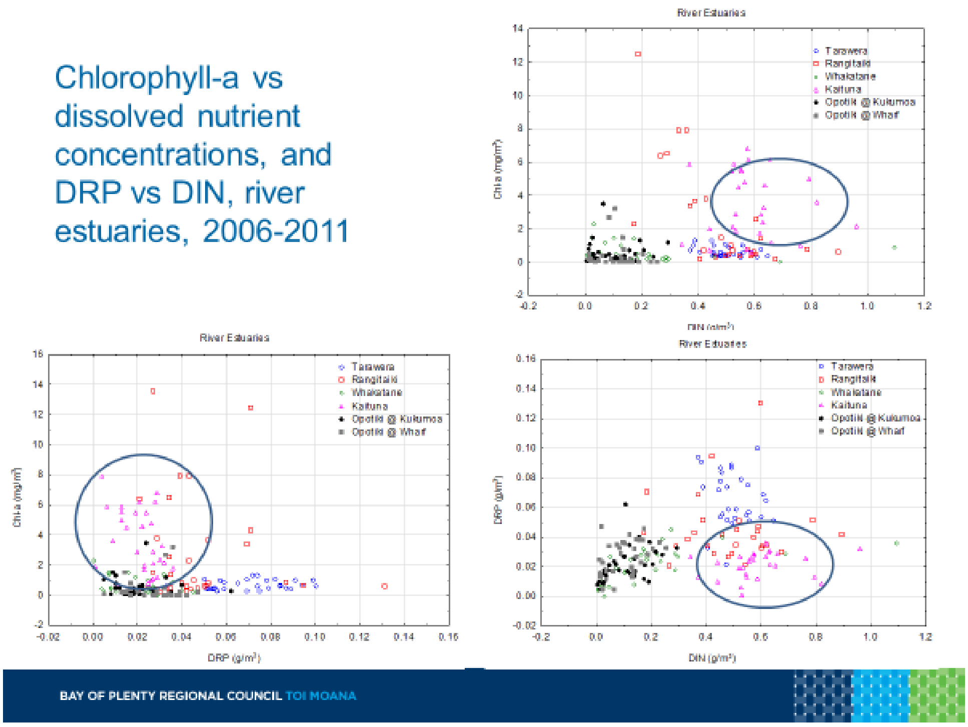


- We're looking at a range of models for our work, and CLUES is just one of them. It may not be suitable for what we're doing due to simplified lookup tables, and data that differs slightly over measured values

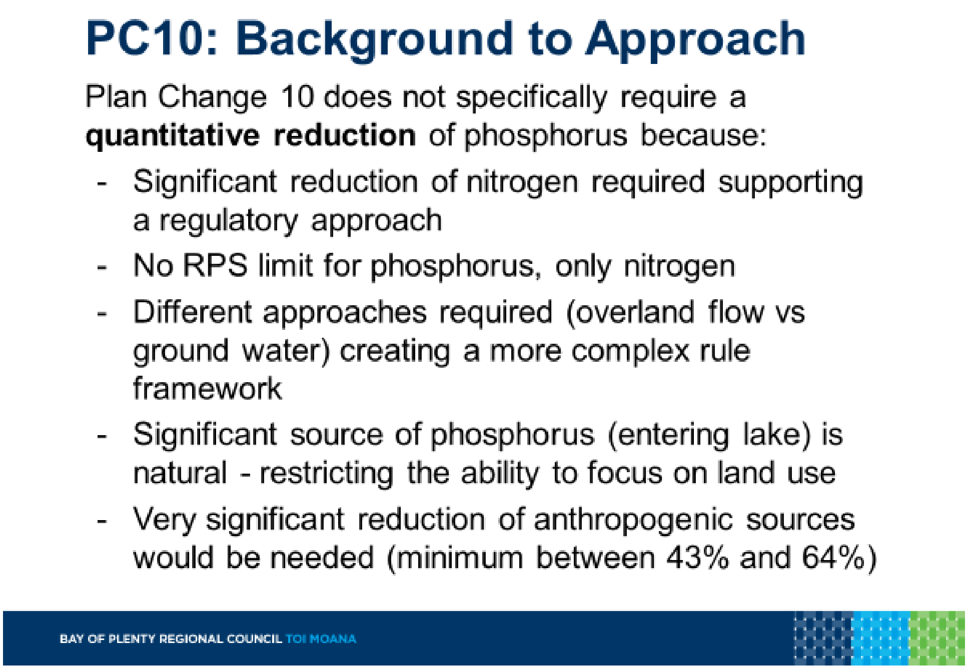




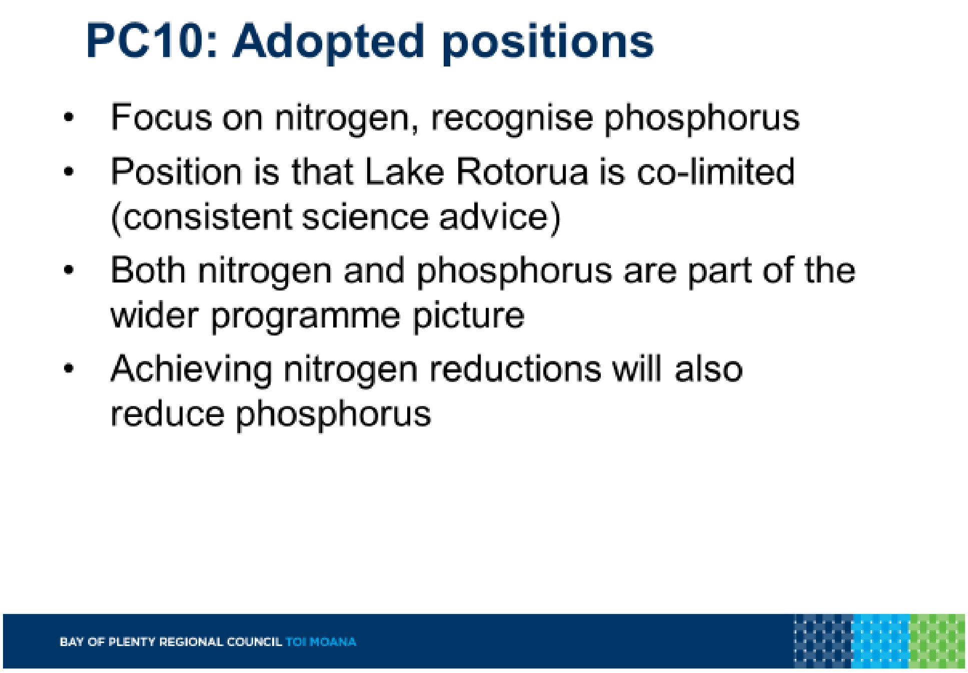
- In the river estuaries, dissolved nutrient concentrations and Chlorophyll *a* is measured, and the lower reaches of the Kaituna appear to be mainly P limited at the moment




P on the move
BAY OF PLENTY REGIONAL COUNCIL TOI MOANA



- PC10 has a nitrogen target (435tN sustainable load), but there isn't a set target for phosphorus due to there not being enough evidence for P at the time the Regional Policy Statement was drafted



The part PC10 has to play

Therefore Plan Change 10:

- Requires nitrogen loss to reduce to meet Nitrogen Discharge Allocations
- Supports use of management practices within Nitrogen Management Plans to manage phosphorus

BAY OF PLENTY REGIONAL COUNCIL TOI MOANA

- The decision was made to focus on N, but we know there's significant load of P from anthropogenic sources
- Our position around P is that the Rules focus on N but they do recognise P
- We continue to work on the basis of the Lake being co-limited. N and P are both part of the wider programme
- Assumption is being made that N reductions will also reduce P. PC10 is built on best science, and we try to use it when we can

PC10: Phosphorus Provisions

Proposed Policy 2:

To manage phosphorus loss through the implementation of management practices that will be detailed in Nitrogen Management Plans prepared for individual properties/farming enterprises.

Proposed Schedule 6(5)(b):

Phosphorus management: To identify the environmental risks associated with phosphorus and sediment loss from the subject property, the significance of those risks and implementation of industry best practice management to avoid or reduce the risks.

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PC10: Adaptive Management

- Plan Change 10 provides for adaptive management to ensure the plan is informed by the most recent up-to-date science.
- Key provision is Method 2 which requires Council to complete science reviews every 5 years.
- Results from the review may require Council to initiate a formal plan change in the future to amend lake loads or include phosphorus reduction.

BAY OF PLENTY REGIONAL COUNCIL TOI MOANA

- There's a science review every 5 years, and results of review may require Council to initiate a formal plan change in the future to amend lake loads or include P reduction
- We try to focus on up to date science as we go

- Method 2 is a key part of the plan change, and this is where P comes in
    - We focus on N but we don't lose sight of P
    - The N specific changes being made on land will include reducing stocking rates and areas of cropping, retiring some land

PC10: Phosphorus in Method 2

Proposed METHOD 2

Regional Council will review and publish the science that determined the limits set in the RPS and the Regional Water and Land Plan for Lake Rotorua on a five yearly basis. These reviews may include:

(a) Review of trends in Lake water quality attributes including nitrogen, phosphorus, Chlorophyll a, algal blooms, clarity, trophic level index2 for in-lake, inflows, and outflow where relevant.

(b) Review of progress towards achieving the RPS Policy WL 6B(c) 2022 catchment nitrogen load target.

(c) Review of the RPS Policy WL 3B(c) catchment nitrogen load, and a nominal phosphorus (external and internal) catchment load of 37 tP/yr3, and any other nitrogen and phosphorus load combinations that catchment modelling shows would meet the Lake Rotorua Trophic Level Index of 4.2. This may necessitate:

(i) a review and rerun of the lake model (or any successor model), including its ability to replicate recent years data;

(ii) a review and rerun of ROTAN (or any successor model), including nitrogen loss rates, groundwater trends and attenuation rates, including OVERSEER® or similar estimates;

(iii) an assessment of the efficacy and risks of alum dosing and an assessment of land-based phosphorus loss mitigation.

(d) Review of relevant New Zealand and international lake water quality remediation science.

(e) Recommendations.

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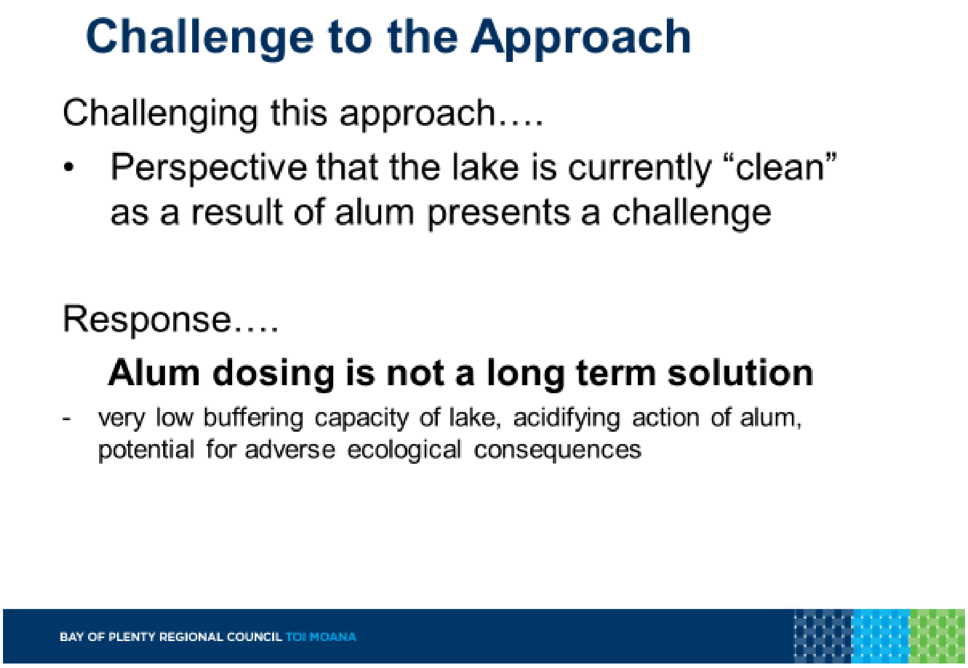
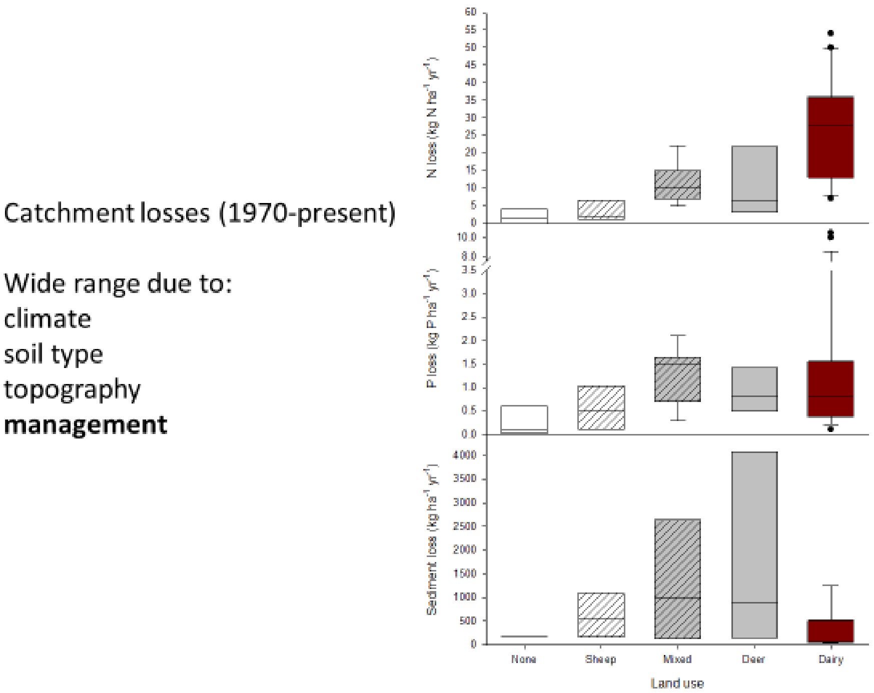


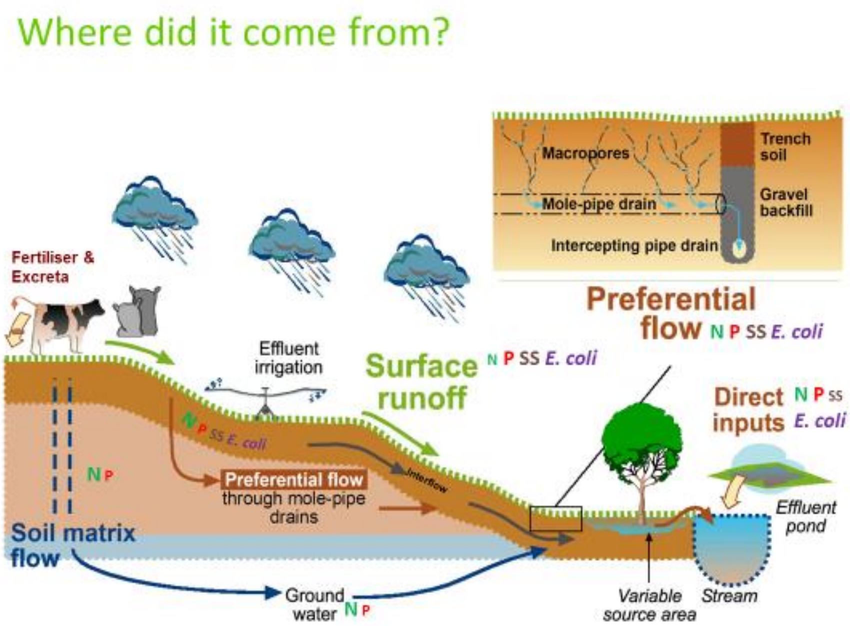
Comments:

- We have three parts to the N reduction programme
  - The rules will bring down N losses
  - $40m allocated to reduce N loss via an Incentives Scheme
  - Additional funding allocated to getting rid of N through gorse conversion (to trees)
- The Council is not targeting P with the rules, but it is still considered

- Catchment scale data from the 70's to now

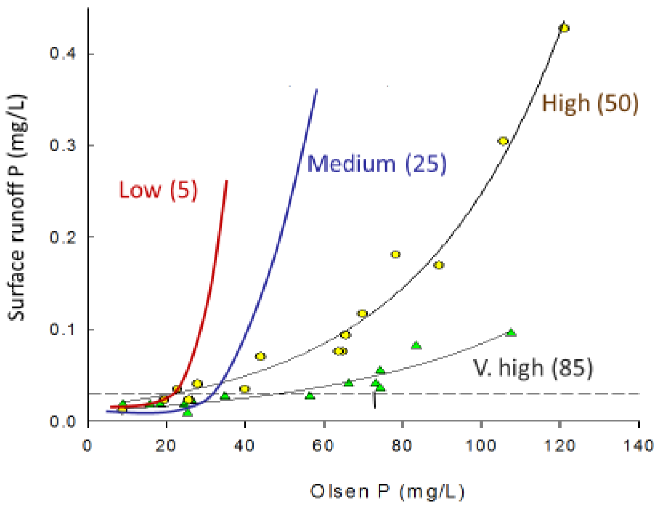


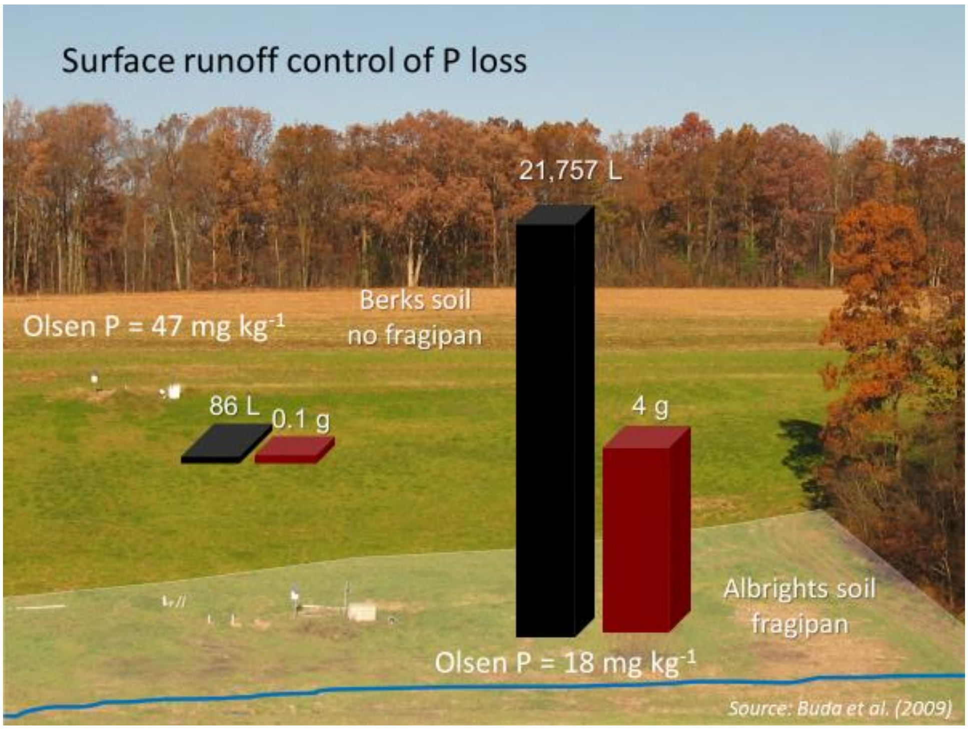
- There is a wide variation due to climate, soil type, topography and land management
- Sources of P – in terms of surface runoff losses, there is a relationship between soil test P (Olsen P) and the P in surface runoff



- Different soils have different anion storage capacity (ASC), so different soils have different propensity for P losses. These losses are also influenced by hydrology

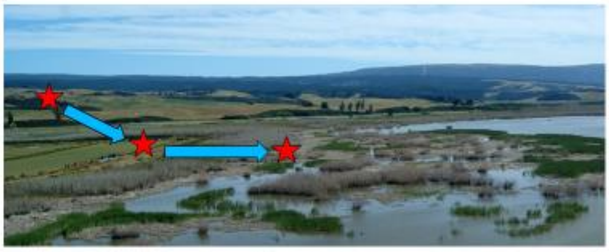
Soil





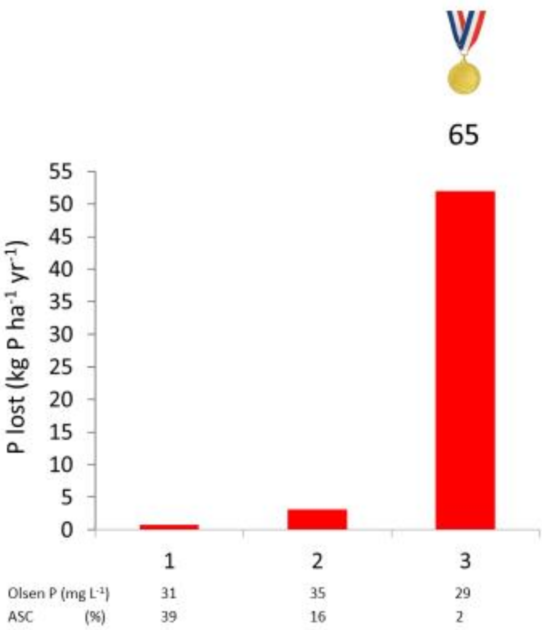
- The same relationship between P loss and soil ASC occurs in sub surface flow

Sub-surface P loss



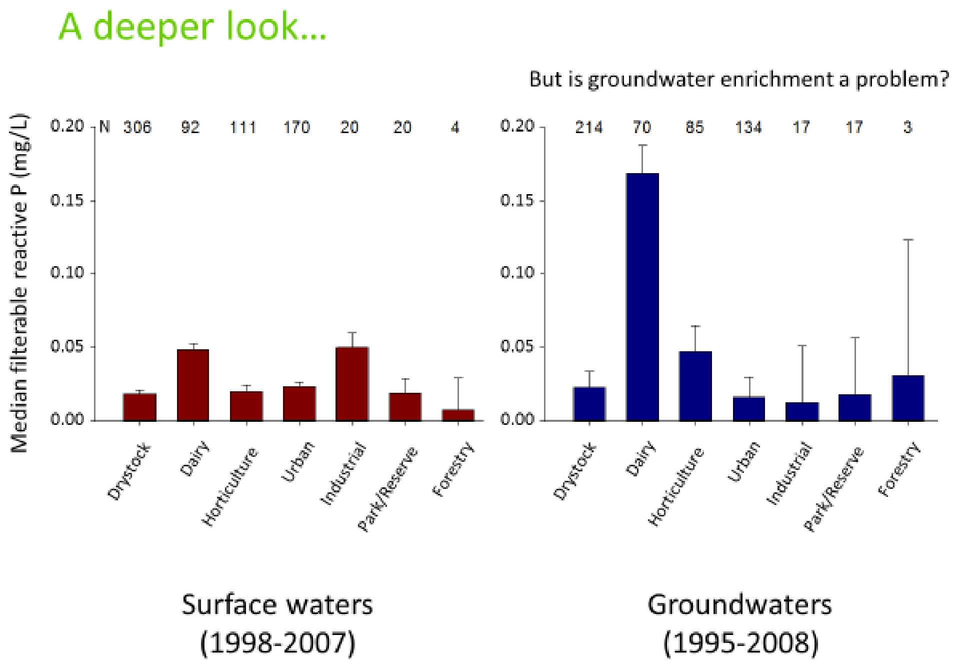
	1	2	3
Olsen P (mg L^{-1})	31	35	29
ASC (%)	**39**	**16**	**2**

Sub-surface P loss

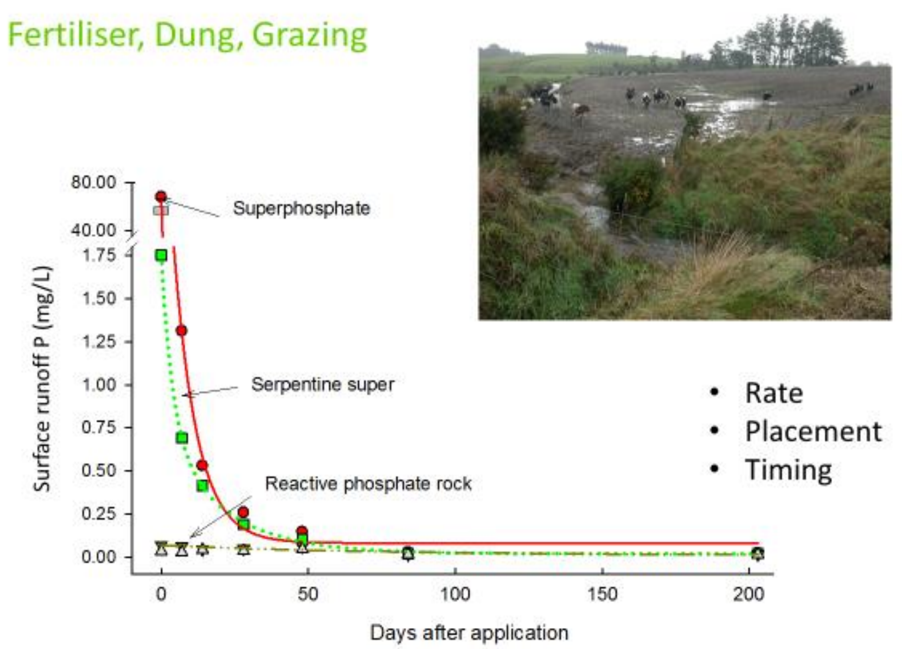


Annual rainfall = 1100mm; drainage = 480 mm

- These losses can reach groundwater

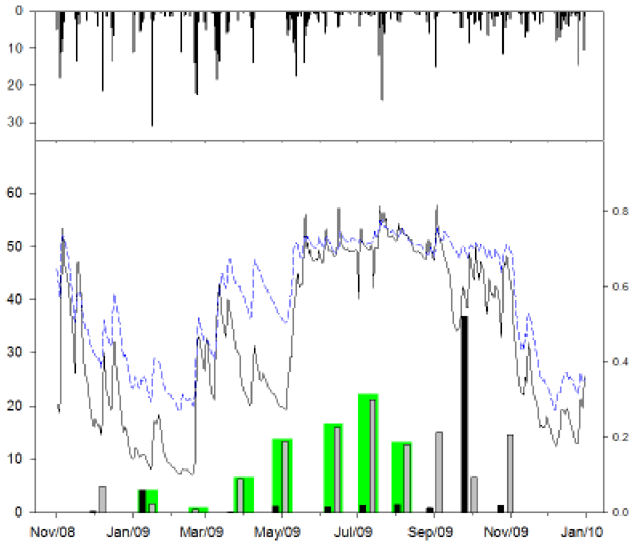


- P-rich aquifers connected to surface water can enrich base flow of the stream.
- Fertilisers, grazing, and dung are the main sources of P loss
- The potential for loss declines quickly with time since deposition
- The degree of initial enrichment can vary quite a lot dependant on solubility
- It's not only the form, it's also the rate and the placement in time that will influence the loss (eg, runoff events)
- Effluent – too much effluent applied at too high a rate can result in ponding which then has the ability to drain into surface water flows and through artificial drainage systems.



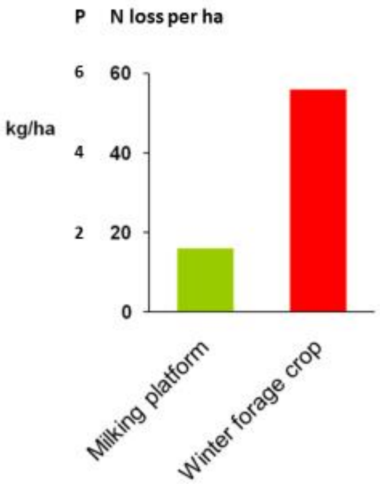
- There are times when there are no storm events (green bars), but effluent is still making it into the streams. This could only be effluent lost via artificial drainage or ponding
- Forage crop grazing is another source – the take home message is that although they occupy less than 10-15% of the land area, they are relatively high emitters so they do occupy a relatively high percentage of the farm footprint (perhaps 30-40%)

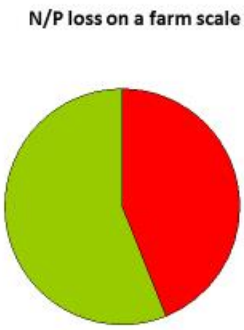
Effluent



22% P, 42% NH_4-N, 58% *E. coli* load via direct losses

Forage Crop Grazing



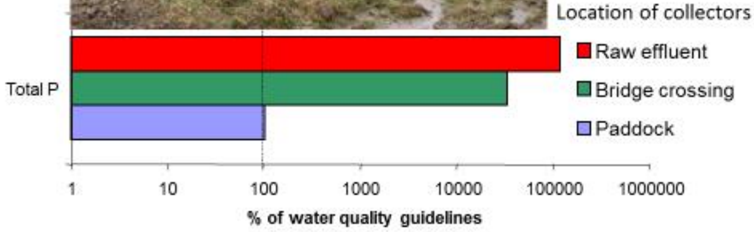


- Tracks and lanes are used daily, and the runoff from them has the P concentration of raw effluent. This is a concern if the runoff from these areas can go directly into waterways

TRACKS AND LANES

Used each day

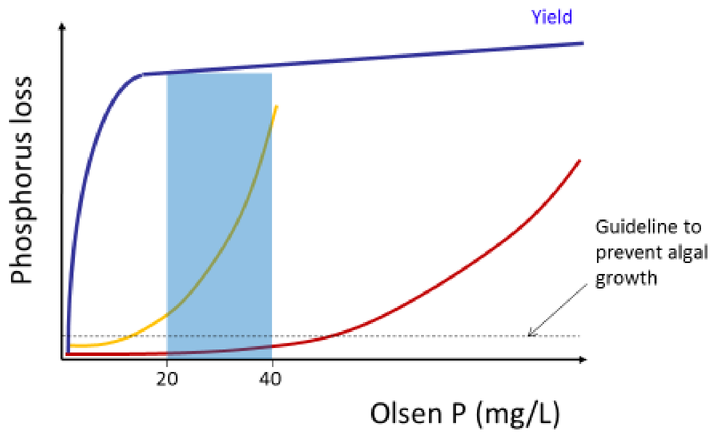
Concentrated source of faecal deposits



- What can we do about it?

What can we do about it?

Optimum Soil Test P



- The recommendation is to remain as close to the agronomic optimum as possible

Fertilisers

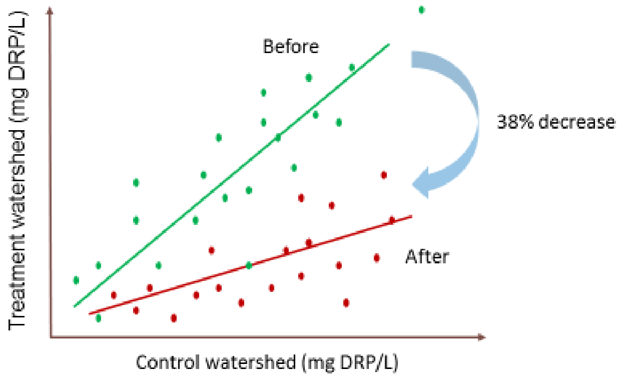
- Timing
- Placement
- Solubility

P loss from application of 30 kg P/ha/yr (± 0.02)

Application date	Superphosphate	RPR
2002		
June	0.24	0.01
December	0.04	0.01
2003		
June	0.23	0.01
December	0.09	0.01

- Fertilisers (timing, placement, solubility): applications of super phosphate in a wet period (e.g. June) lead to greater concentrations being lost than applications in dry periods (e.g. Dec).
- To mitigate the flush of water soluble P into the soil solution and potential loss of this P should a runoff event occur, use a less water-soluble P fertilizer

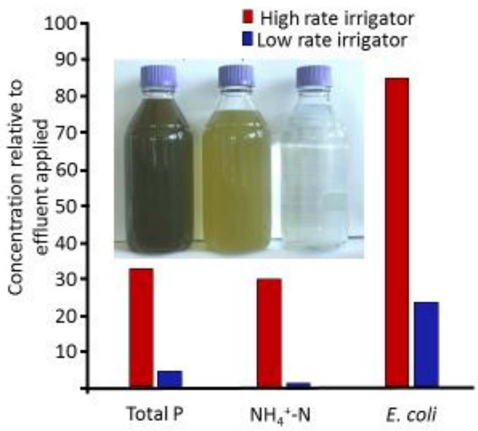
Low Water Soluble P Fertilisers



If reactive phosphate rock, productivity can only be maintain if:
soil pH < 6.0
rainfall > 800 mm/yr

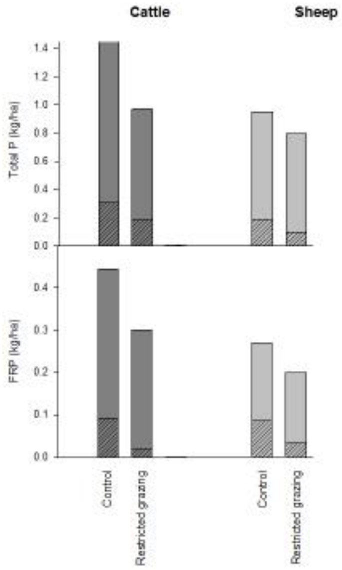
- At a catchment scale, two catchments were treated the same (P applied in winter) but one was treated exclusively with RPR (low water soluble P fertiliser) and there was a 38% decrease
- The mitigation for effluent is to use a low rate application, which is also low depth. This results in drainage or leachate that's significantly lower in nutrients and E. coli.

USE LOW RATE EFFLUENT APPLICATION



- Restricted grazing: during winter, only allow stock to have maintenance feed for 3 – 4 hours, preferably on an area where effluent is collected ie. a feedpad. The lesser quantity of excreta results in approx. 30% lower losses

Restricted Grazing



Pasture or winter forage crop

3-4 hrs maintenance only
fewer dung pats
less treading/soil disturbance

Labour intensive

- Drains – artificial drains can be augmented with a backfill that has P retention (P-sorbing) rather than greywacke

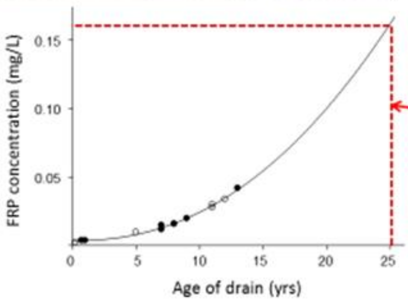
Tile Drains

Backfill is P-sorbing material not greywacke

High-flow

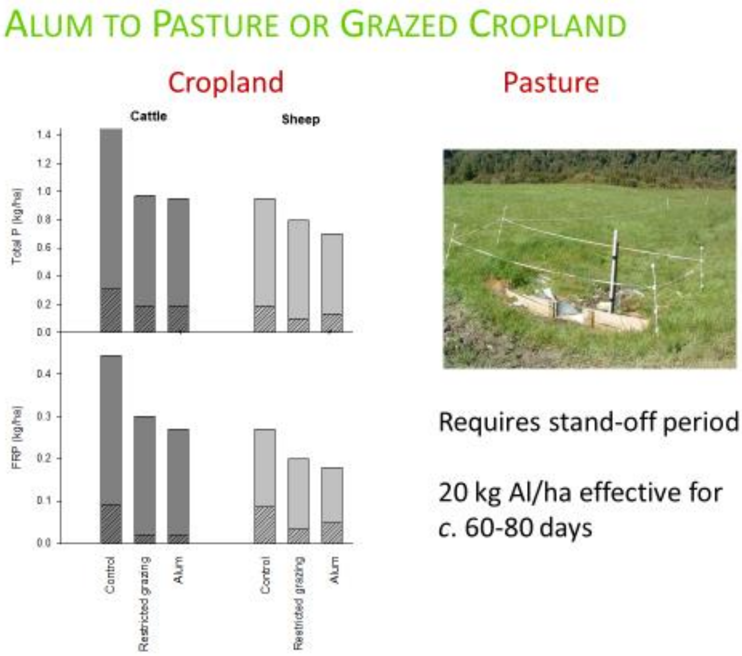
Sediment retention

Life-span c. 20 yrs

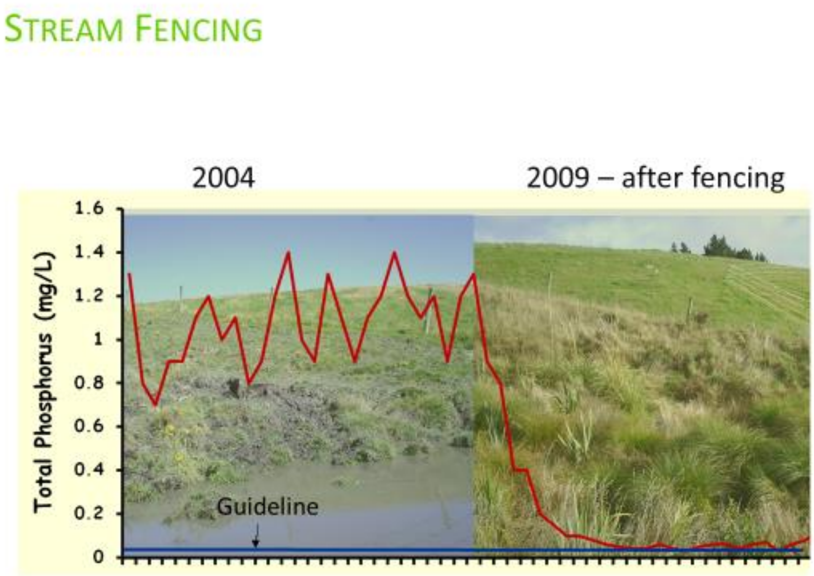


Concentration in control (greywacke) drain

- Alum (aluminium sulphate) can be used on topsoil and will also decrease P loss. Can result in approx. 30% reduction in losses. It's very expensive, so only useful in select locations like tracks or lanes



- Stream fencing. Often a mandatory requirement.



- Sorbents in and near streams – steel smelter slag is heavy, a good P-sorber and non-toxic. It's a short-term fix because it has to be replenished

SORBENTS IN AND NEAR STREAMS

93% DRP
95% TP
99% Sediment
86% *E. coli*

Steel melter slag (heavy, good P sorber, non-toxic)
performance flow dependant
uptake at flow rates < 20 L/s
potential to clog in silt-dominated beds

- Natural and constructed wetlands. Good for nitrogen, but not necessarily for P as the process that removes P via anaerobic conditions will dissolve P from sediment. This is made worse in wetlands that have a high sediment load. Detention bunds might decrease this sediment load before flow reaches a wetland.

NATURAL AND CONSTRUCTED WETLANDS

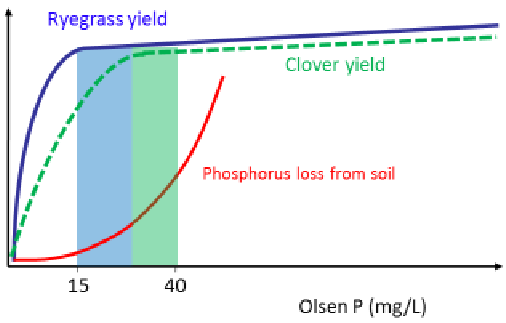
- Optimal location
  focal point
- Size vs. production
- Longevity
- Alternatives?
  advanced pond system

- Split grass-clover – Clover has greatest P demand. Split the sward into monocultures and have the P-efficient ryegrass in low-P areas with runoff (e.g. along area that floods during runoff events), and the P inefficient clover in high-P areas that have less chance of runoff (eg away from ephemeral waterways). To make low-P areas, conventionally till the soil to invert the P rich topsoil and reduce a 30 Olsen P soil to 15 Olsen P instantly, then re-sow with ryegrass. Clover sward (maintained at 30-40 OP) is able to express itself better, and in this trial resulted in a 10% increase in milksolids and 45% dissolved reactive P (DRP)
- Negligible impact on N

Split grass-clover to mitigate P loss

Example:

Ryegrass produces well at low soil test P. However, higher soil test P (and loss?) is required to maintain clover.



Split grass-clover to mitigate P loss

Answer:

Place clover in areas of a catchment unlikely to contribute runoff to the stream.

When selecting mitigations

- Make sure they are specific to your enterprise and region.
  - Is there better information to tailor the mitigation according to likely flowpaths or seasonality?
- Consider the cost-effectiveness of the mitigation.
  - Be objective (use $ / kg nutrient retained on farm).
  - Take into account any likely lag time.
  - Consider co-benefits.
- Ensure mitigations are correctly implemented and maintained.

The above mitigations represent only about 50% of those available.

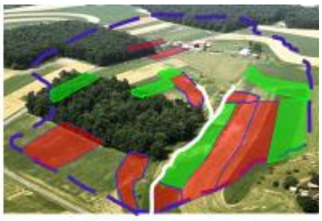
- Mitigations should be specific to your enterprise and matched to your region – climate, flow paths, soil etc
- Main take home message is to always have regard to the cost effectiveness of measures, and be objective. A useful metric is $/kg of nutrient (N or P) retained on-farm
- Take account of lag time, but for most P mitigations this is not significant (within a season)
- Ensure mitigations are correctly implemented and maintained – target the right mitigations at the right place and right time. Dealing with Critical Source Areas (CSAs) can dramatically increase cost-effectiveness of mitigation strategies

Generalised vs Targeted Mitigations

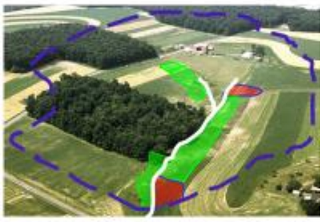
- Targeted = execute specific strategies which may mean higher cost

Targeting the right mitigations at the right place and right time

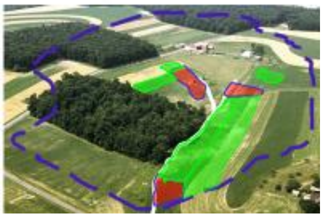
Risk
Low
(clear)
Medium
High



Source +



Transport = risk



The majority (e.g. 80%) of contaminant losses come from a minority (e.g. 20%) of a paddock, farm or catchment's area.

Well call these Critical Source Areas

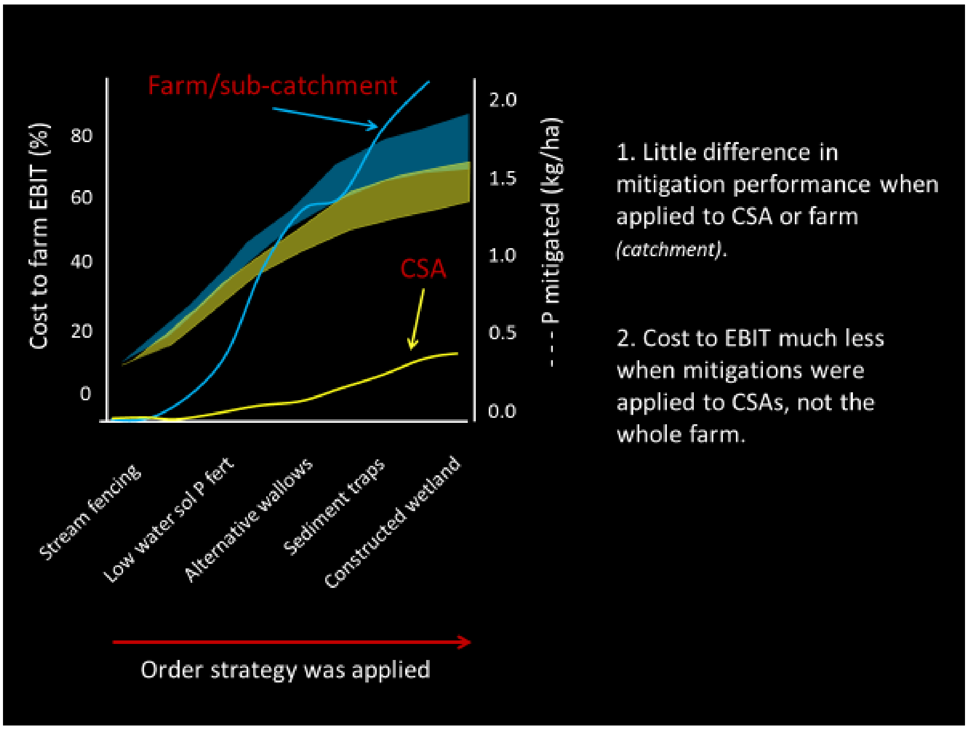
Targeting N and P mitigations to CSAs or not

Apply strategies in order of most **cost-effective** first

to:

Critical Source Areas, or

Across the whole farm/sub-catchment?



Targeting cost-effectiveness of mitigations to CSAs

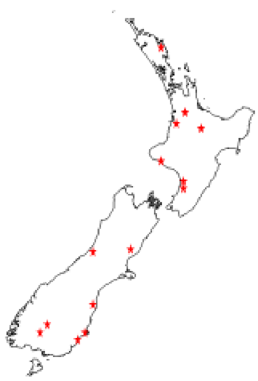
Mean percentage change in EBIT or P mitigated after four strategies implemented across 14 farms/sub-catchments

Critical source areas only		Whole farm/sub-catchment	
ΔEBIT	ΔP loss	ΔEBIT	ΔP loss
-2%	-40%	-12%	-48%

Focusing mitigation strategies on critical source areas:

1) Has a similar mitigation potential, but

2) Costs much less.



A generalised approach sees easy low cost – highly efficient strategies implemented first before those that require more resources (moderate) or even infrastructure (hard) changes. This approach also includes co-benefits for reductions of other water pollutants such as sediment and faecal microorganisms

Generalised or targeted mitigation of N and P to CSAs

Generalised: cost-effective mitigations consecutively implemented for a region starting with those that are easy to implement, through to those requiring infrastructure and system changes.

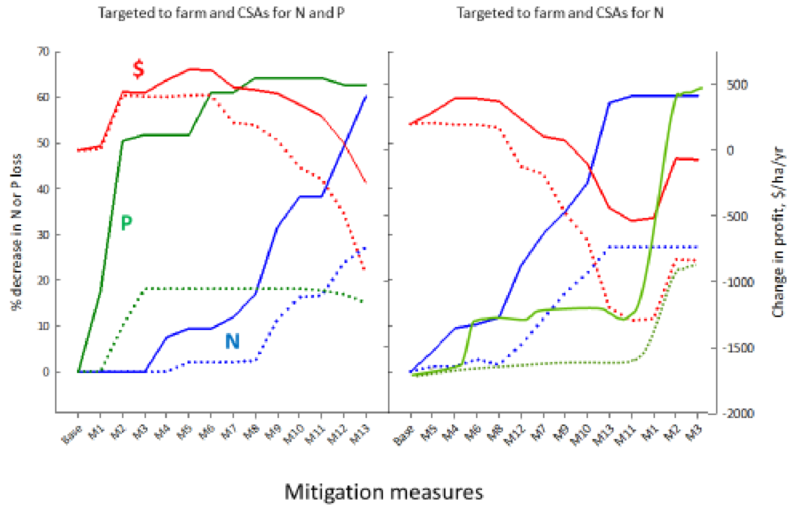
Targeted: mitigations for N or P implemented on the specific cost-effectiveness for the region from best to worst to achieve fast decreases at least cost – irrespective of the need for management or farm system changes.

Can P mitigations be cost-effectively achieved when focusing on N?

MITIGATION BUNDLES

Ease of Implementation		N or P focus
Easy	M1. Optimum Olsen P	P
	M2. Low-P near stream areas and efficient pastures	P
	M3. Low solubility P fertiliser	P
	M4. Increased effluent application area	N P
	M5. Reduce N inputs	N
Moderate	M6. Strategic grazing of winter forage crops	N P
	M7. Better irrigation management	N P
	M8. Deferred irrigation (pond storage)	N P
Hard	M9. Constructed/Facilitated wetland	N P
	M10. Decrease stocking rate	N
	M11. Change supplementary feed to Low N feed	N
	M12. Restricted grazing over winter	N P
	M13. Restricted grazing over winter and autumn	N P

Generalised v. Targeted



- The above graph attempts to show the differences between focussing on either N alone, or on both N & P. This is reflected in the X-axis for each graph; the graph on the RHS applies the various mitigation strategies in a different order to the graph on the LHS. There is also an attempt to take into account both cost-effectiveness and the "can I be arsed" factor
- A focus on both N & P results in rapid gains for P mitigation and slower gains for N, and some impact on farm profitability
- Focussing only on N gives more rapid gains for N mitigation, and a similar impact on farm profitability. **A singular focus on N will not bring significant reductions in P loss.** There are sufficient differences in the flow pathways and loss mechanisms of N and P that when the question is posed "Are there significant gains in P mitigation when the focus is on N?", the answer is "No".

Effectiveness of P mitigation when focusing on N

Fewer and less costly measures to mitigate P than N

Targeting measures for one nutrient over another will mitigate the targeted nutrient quicker and with fewer measures than a generalised approach

Advantages of a generalised approach include:

- protection against both N and P losses,
- consideration of the ease of implementation of measures and
- co-benefits for reductions of other water pollutants such as sediment and faecal microorganisms

<u>Questions and Discussion</u>

(Note: audio quality of recording was often too poor to capture all of the following discussion)

JP: What is the influence on N and P mitigation from land use change to forestry?

- A model has been supplied to EBOP showing the relationship between percentage pasture (and by difference forestry) and median P concentrations for a river environment class. The losses are lower. However, if harvest coincides with a period of significant runoff I would imagine the difference could be small. These perturbations are not accounted for in Overseer – being an annualised long-term average.
- The load from the harvesting of Radiata Pine is probably greater than we thought, but there is little data.

AB: Does production forestry have a similar nutrient footprint to native forest in Overseer?

- Yes. The exception is during harvest (as noted above).

CS: Is the impact of a winter or summer forage crop averaged in Overseer over a year?

- Yes. The high initial losses are diluted by lower losses during the rest of the year.

AB: The forestry context can be quite variable (eg. Lake Rotokakahi where much of the harvest impact is on a single catchment, versus a forest block on the Canterbury Plains, or the Central Plateau)

- It should be a quick and simple fix within Overseer to better capture extreme temporal variations caused by the impact of harvest, assuming that data is available which defines this in relation to soil, slope, climate. If not, stream sediment records could be used as a proxy calibration.

SL: Going back to the impact on P resulting from a focus on N. How much can be gained from a focus on N?

- If you focus on N mitigations only (lower stocking rate, low N feed, low N fertilizer inputs), you are doing something that is counter-intuitive if you want to focus on both N & P

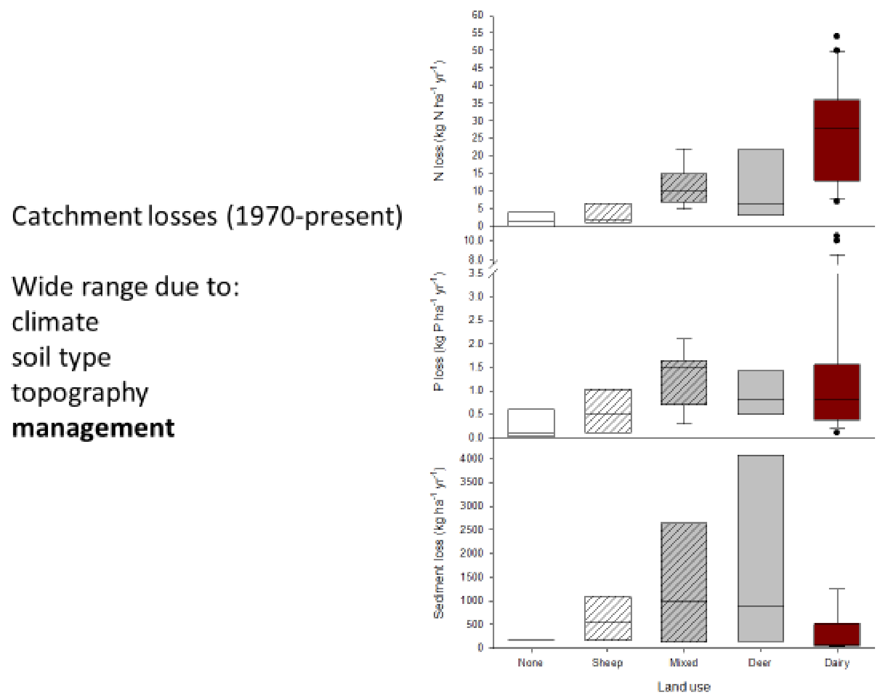
SL: Surely if you take a dairy farm and convert it to forestry, or decrease the intensity of farming by conversion to a less intense land use, there must be an impact on P?

- It is a common misconception that if you decrease your stocking rate you will also decrease P. Not true. This only happens with N because of the overwhelming effect of N loss by urine patches. Urine patches do not drive P losses, so reducing stocking rates will not make a huge difference to P loss – whether its' a mob of 200 or a mob of 150 it makes little difference to P.
- The potential for runoff, slope and soil type (viz ASC) are the main factors influencing P losses.
- Mob grazing of small areas will increase P loss.

AB: So it's a matter of changing management to significantly reduce the high per ha stocking rates created by strip grazing?

- Absolutely

AB: Let's go back to the slide which addresses P loads coming from different land uses



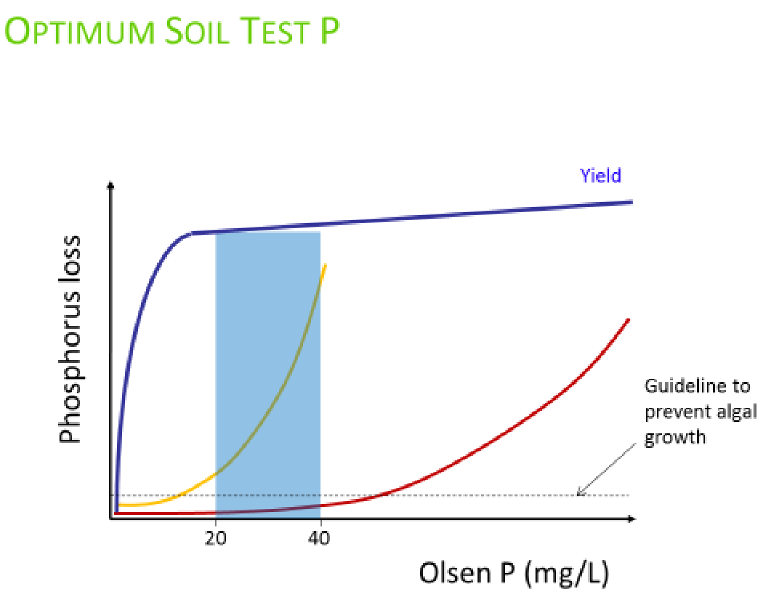
- Salient point is that it is context sensitive. Can't change soil type and this can be a significant influence. A deer farm with many wallows may generate 4/6/8t/ha of sediment, but it's only coming from the 1% in wallows. Knock out the wallows and you knock out the problem.

AB: Why in the above slide with sediment loss so high with deer, is the P loss not also high?

- Wallows can look very muddy, but in terms of P, most will be coming from excreta via direct deposition not from the soil, which can be very low P sub-soil.

In regard to the benefits of reducing Olsen P, surely if you reduce stocking rate there will be less need for a high Olsen P, so there should be an indirect benefit that accrues to reduced stocking?

- However, you will probably not go below the agronomic optimum so depending on the soil type this may or may not decrease soil P losses (compare the yellow and red soil P loss lines below. There remain all the other factors and sources of P loss.



PJ: Perhaps we are better off talking about the Olsen P which provides an economic optimum, rather than to focus on the agronomic optimum?

- This is probably true, but the problem is that there is considerable variation in the economic optimum for different regions, soil types and contour. For that reason we tend to focus on an agronomic optimum for Olsen P
- However, in regard to P loss the far more important focus should be on Critical Source Areas (CSAs). CSA's are influenced most by hydrology, before considerations of slope, soil type, anion storage capacity and Olsen P. Where you are in the catchment in relation to streams has a huge influence on CSA's
- It is then a matter of deciding strategies for CSAs and non-CSAs

- Consideration of Olsen P has it's place farm-wide, but greater gains are made by mitigating P losses from CSAs

AB: What is the reliability of quantifying nutrient loss?

- If Overseer is blocked correctly so that the majority of factors that influence P loss are captured, the relationship between modelled loads and measured loads is approx. 80%. This is similar for N.
- Discrepancies come when Overseer is not properly blocked e.g. missing important factors that describe CSAs. Overseer does have a tick box for deer wallows. However, people tend to block according to farm management not P losses. Hence, the 10% of a block that might have most of the CSAs is diluted by inclusion in a non-representative block.
- MitAgator (Ballance Agri-Nutrient) does a reasonable job of capturing CSAs

AB: are there other means of monitoring and measurement of P gains?

- Lookup tables for different farm typologies are available, but that would be stepping backwards from what you could do with Overseer because you are going for even more of an average. However, at a catchment scale tables could be fine for estimating gross changes – e.g. if change went from 30% through to 15% of a land use, how much on average would it change; you could have confidence intervals about that but they would be quite large; these would narrow depending on how many farm typologies you had and the representativeness of those typologies to the management within that catchment. If you had 50 different farm typologies you could get a reasonable answer which is close to Overseer, but why not just use Overseer and put the effort into getting the blocking as accurate as possible.

AB: What would be your advice around the development of good practice guidelines for P management?

- Apply strategies that are suitable to your farm, applied them to critical source areas (assessed objectively, perhaps via MitAgator, or Farm Environment Plan) applied according to cost-effectiveness and with the "can't be arsed" factor taken into account (ease of implementation)

AB: You have given us your thoughts on P losses associated with forestry

- Advocate for a "simple fix" in Overseer to capture the perturbations associated with harvest. This assumes we have data of sufficient temporal resolution to capture the perturbations associated with harvest.

AB: Any research priorities with forestry?

- Ensuring that the data above is available, otherwise the result from Overseer will not be as good as it could be. That would probably be a priority in the Rotorua lakes catchments, but may not be the priority in other parts of the country

AB: We talk a lot about attenuation with N. What about attenuation with P? You have said that if you have good block setups in Overseer then you could get approx. 20% attenuation for P.

- Many people use attenuation to mean decreases associated with uptake between the source of the loss and the site of impact
- With N we commonly say 50% gets knocked out as it goes through
- With P it will vary dependent upon flow regime and the sediment. If you have a highly reactive form of P (e.g. DRP) you will get a higher attenuation in the base flow because it will get sucked up into sediment. Conversely, if you have frequently flushed streams there will be minimal attenuation
- The good thing though is that the attenuation factor for P is taken into account and is reasonably well modelled within CLUES

PJ: Can you expand on the movement of P to groundwater

- The enrichment of streams associated with the influx of P through groundwater occurs where there is a coincidence of high Olsen P soil, soils that have relatively low anion storage capacity, are relatively free draining, and coupled with an aquifer with low anion storage capacity that feeds into surface flow. These findings were based on a 10 year time frame of data collection and P movement to streams. Meaning it still could happen.
- There has been some data locally to suggest that there is some movement of P through the soil profile, but insufficient data to be statistically robust.

AB: Even though we have free draining soils locally, perhaps the anion storage capacity is too high for there to be significant P movement through the soil?

- Much of the data has been collected over a 10 year time frame. It is possible that in a 20/30/50 year timeframe even high anion storage soils can leach P if enough P is being added to it
- With peat soils in the Waituna you see P in the streams within a day on a very small surface area
- A soil in Central Otago which might have an anion storage capacity of 18-20% we saw enrichment at 1.5m within a year
- Lincoln University Dairy Farm has an anion storage capacity of 25%. Interestingly, instead of leaching 0.3kgP/ha/yr, after 13 years it is leaching 1.5kgP/ha/yr

AB: With the local WWTP Irrigation System P retention was assessed at 80-100 years

- This would be to complete saturation and significant P would move well before that is reached. Even high anion storage capacity soils will leach P if you add enough to it
- Of course P retention does not affect loss by surface runoff.

AB: What should be our priorities?

- Know your Critical Source Areas of P loss
- Understand the cost-effectiveness of mitigations
- Have a plan to put the appropriate mitigation options in place. Management is the most important thing.
- Ensure monitoring is in place for the assessment of efficacy and compliance

Improving our knowledge of farm P loss –
Presenters: Paul Scholes, David Burger and Ian Power

Paul Scholes

- Looking at projects repeating the work of Redding *et al*, to see where the P baselines are at now

Possible projects

Sampling based on Redding et al., 2006

- Studied P leaching at 28 sites around the Rotorua Lakes using 150 cm deep boreholes
- Found in 2006, over 2/3 of sites had P concentrations >45 ml/L
- Couple with BOPRC NERMN data for a "decade later" snapshot of P loss from farms after a decade of N mitigation strategies
- *Difficulties: Obtaining the exact locations of sites, land use changes, potential access issues*

BAY OF PLENTY REGIONAL COUNCIL TOI MOANA

- Also looking at working with fert companies to look at their info on fertiliser distribution in the catchment. Ballance may be willing to contribute

Possible projects

Fertiliser company collaboration

- Liaise with fertiliser companies to obtain information based on their client farms
- Elaborate data to show Rotorua Lakes and wider regional trends
- Initial discussions with Ballance indicate they are willing to collaborate – Dani Guinto is our contact and understands our needs
- *Difficulties: Low spatial resolution due to privacy concerns, data possibly not in the form we would need (i.e., trends only)*

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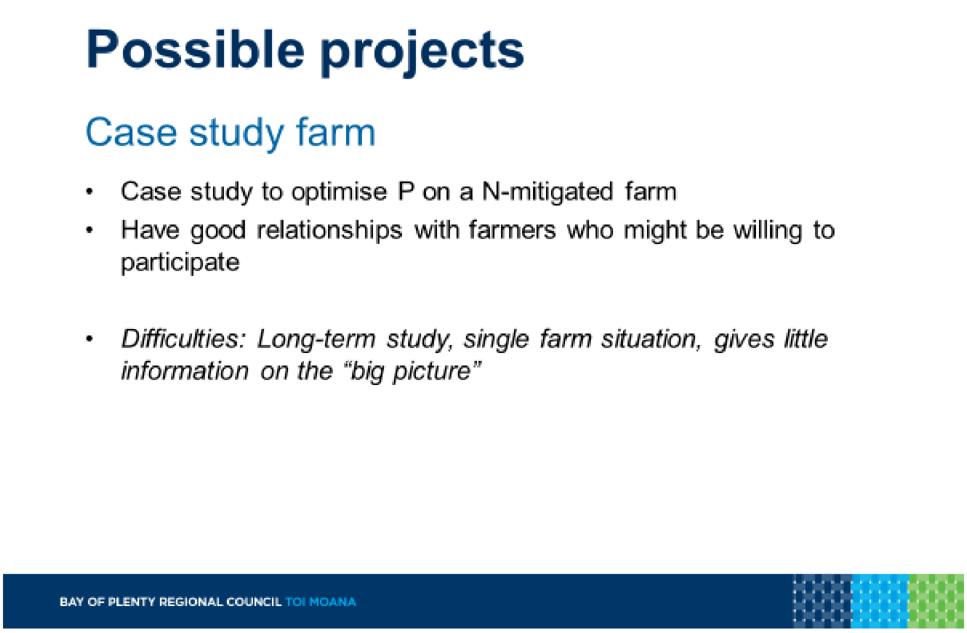
- Case study farm to optimise P on an N mitigated farm – good relationships with some farmers who may be willing to participate



David Burger (oral presentation, no graphics)

- Interested in looking at LiDAR and hydrological paths. Looking at test cases
- Opportunities for adding detainment bunds and coming up with targets
- 5-6 case study farms and profiling flow paths on them
- Sub catchment groups working together
- Controlled drainage (similar to detention bunds but involving culverts) is used extensively in Scandinavian forestry so they can manage harvesting on the peaty soil, and it does have quite a significant mitigation effect
- work is going into modelling the best places to put detainment bunds based on ephemeral flow paths
- Planning riparian buffers is also important

Ian Power

- Olsen P survey done over 7 years, and soil test categories used for dairy and dry stock soils
- Statistics still being analysed
- Some years no samples were taken, and the number of soil tests varied
- Some tests were repeated on the same property but different blocks
- More farms were in the optimum, above optimum and high categories across the BoP region
- Most reliable data from ash and pumice soils for both dairy and drystock
- No data for Drystock peat soils
- The proportion of farms with high Olsen p does seem to be declining
- Gaps in data still need to be filled

Olsen P status of Bay of Plenty and Rotorua Soils 2009-2015 (Preliminary results)

Danilo F. Guinto
Ian Power
Ballance Agri-Nutrients
Tauranga
November 2016

Methods

- Soil test categories with appropriate ranges for each soil type were used. These classes are:
  - low, below optimum, optimum, above optimum and high
- Optimal soil test category ranges based on
  - Morton and Roberts (2009)
  - Roberts and Morton (2009)
  - Anonymous (2016)
- For each year, the percentage or proportion of farms within each soil test category was calculated
- Statistics still being analysed

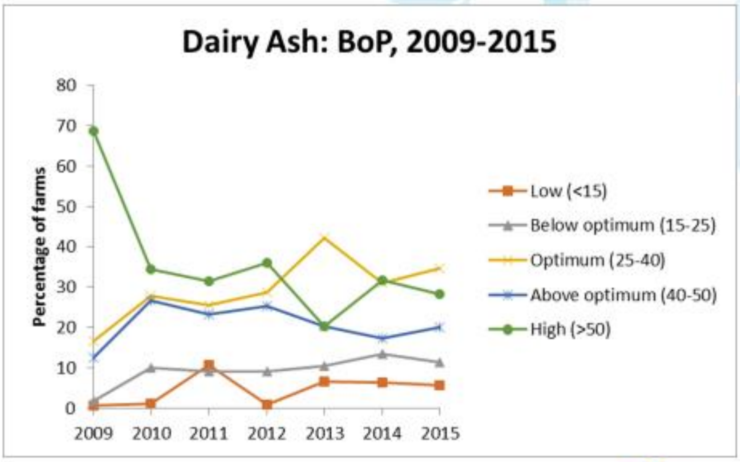
Soil test categories used for dairy and dry stock soils

Soil test category	Olsen P (mg/kg)
Sedimentary and Ash soils	
Low	<15
Below optimum	15-25
Optimum	25-40
Above optimum	40-50
High	>50
Pumice and Peat soils	
Low	<25
Below optimum	25-35
Optimum	35-50
Above optimum	50-60
High	>60

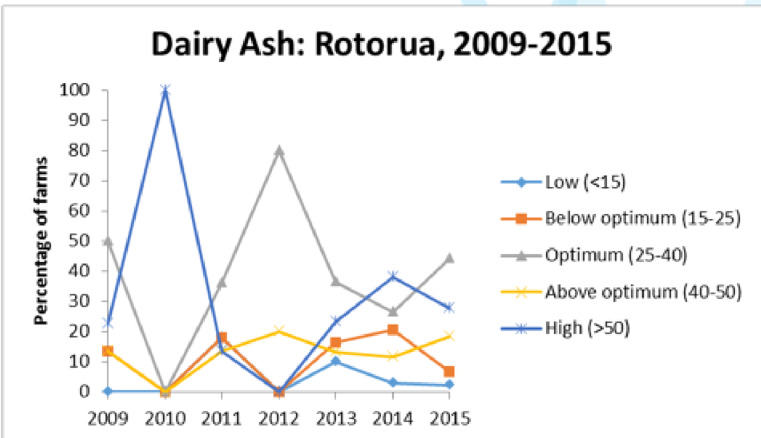
Data

- Covered a 7-year period (2009-2015)
- Within each year;
  - the number of soil tests varied
  - some tests were repeat analysis from the same property but on different blocks
  - some farms weren't sampled every year but some were
  - some years there were no samples taken

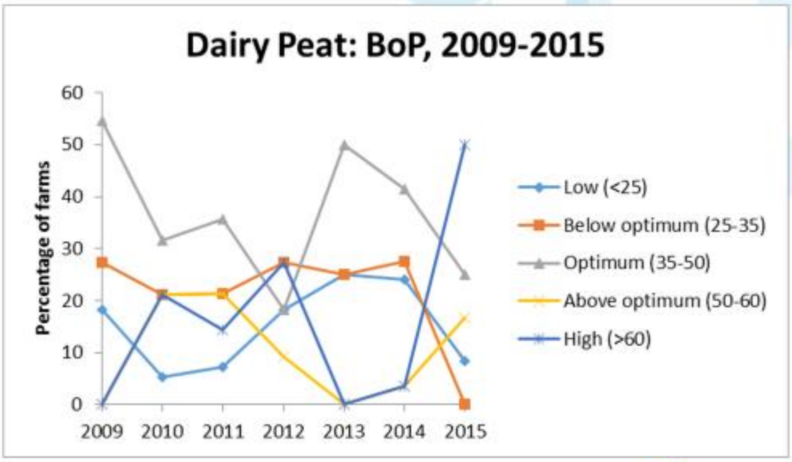
Dairy soils



Dairy soils

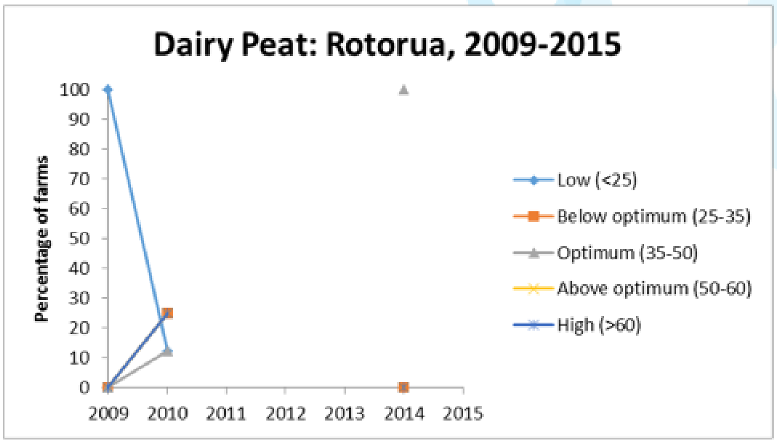


Dairy soils

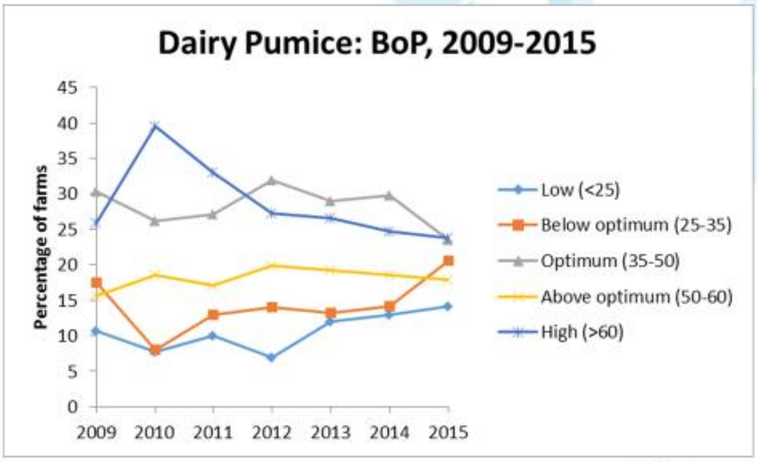


Dairy soils

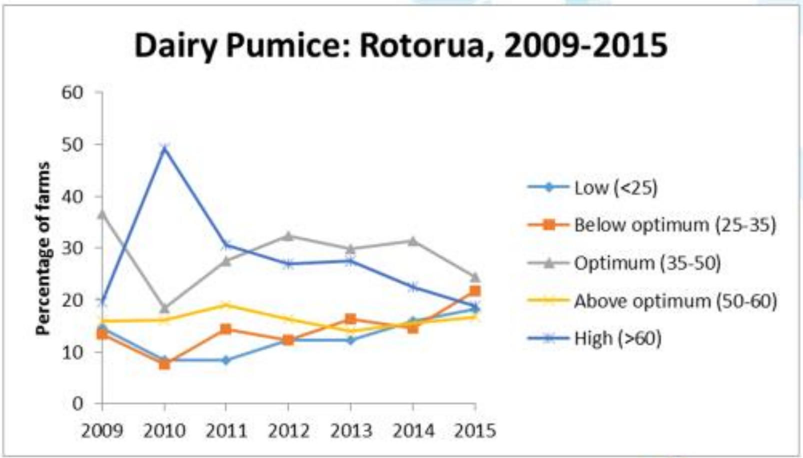
Note: Gaps mean no data for those years



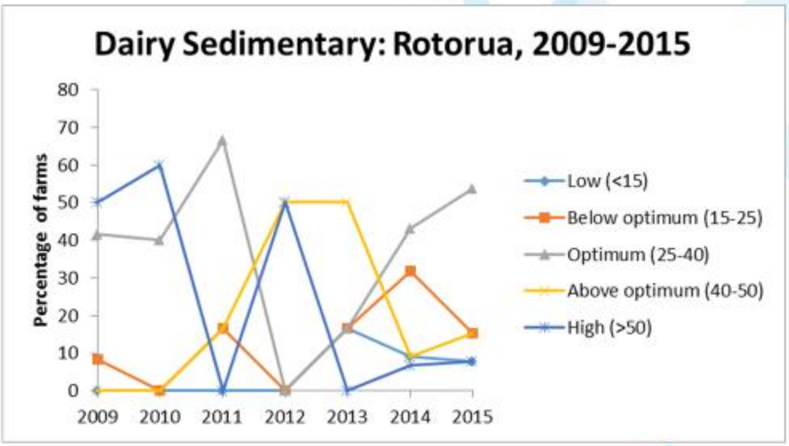
Dairy soils



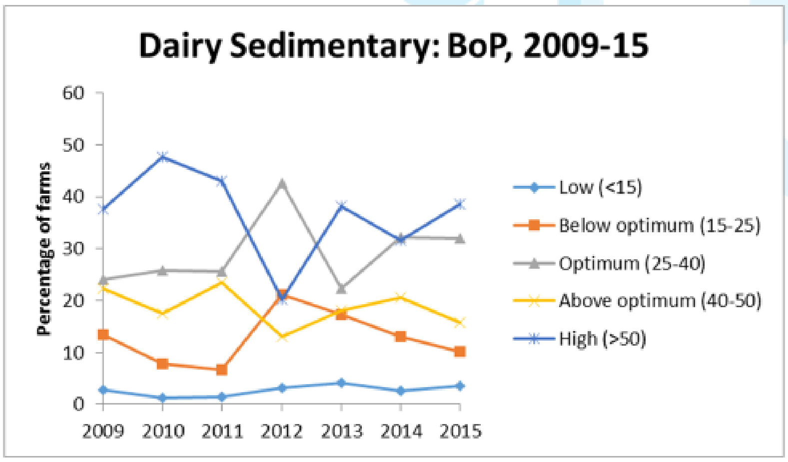
Dairy soils



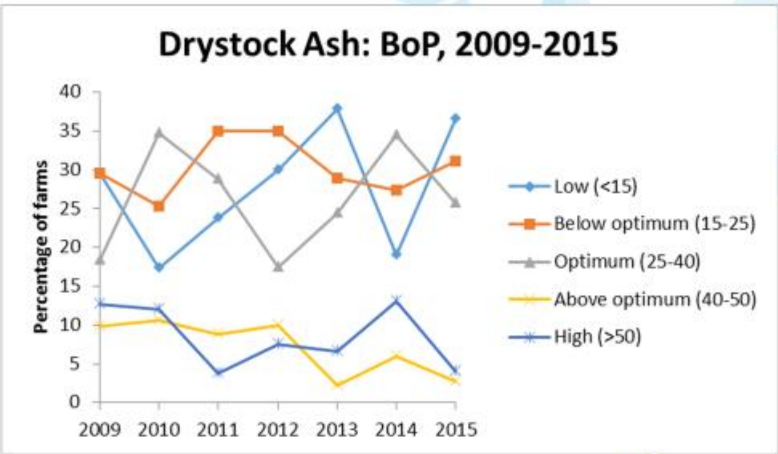
Dairy soils



Dairy soils

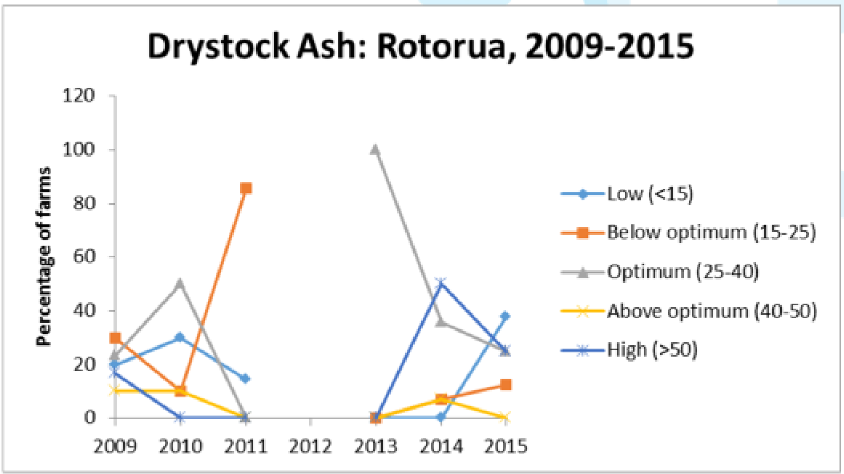


Dry stock soils

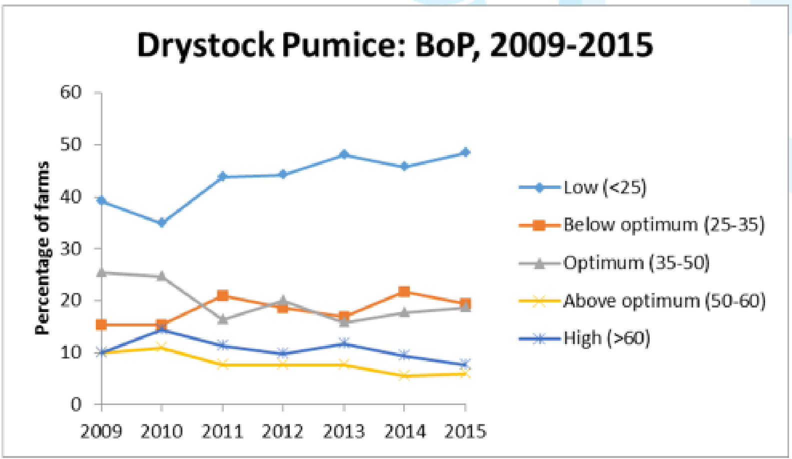


Dry stock soils

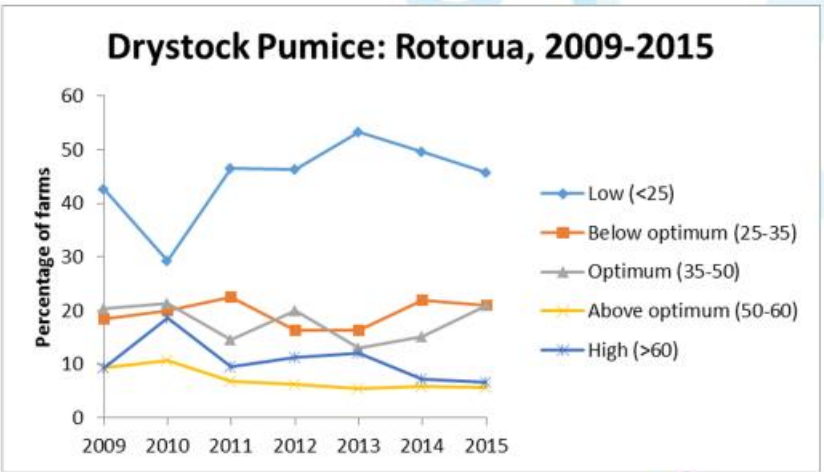
Note: gap means no data for that year



Dry stock soils

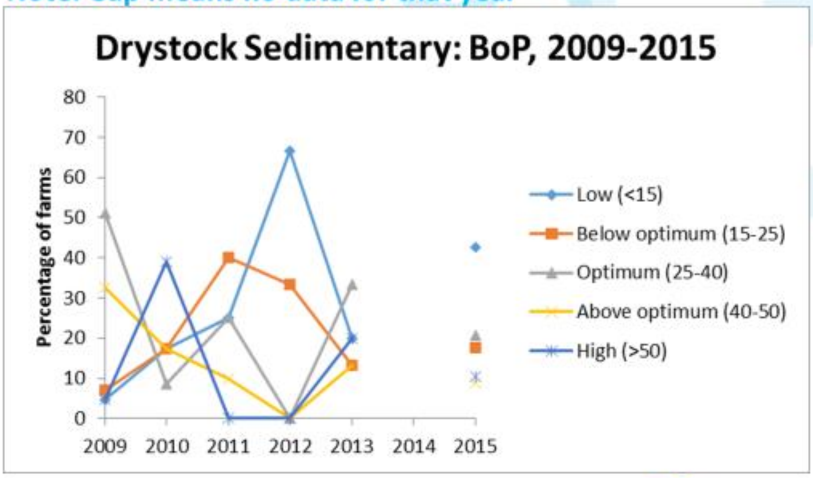


Dry stock soils



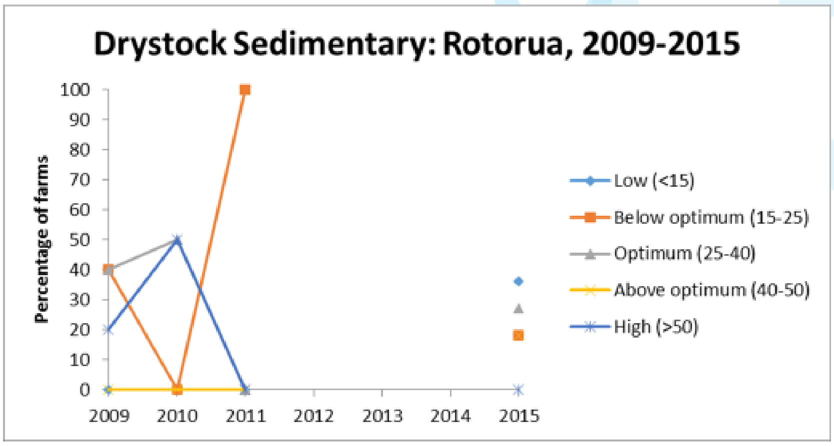
Dry stock soils

Note: Gap means no data for that year



Dry stock soils

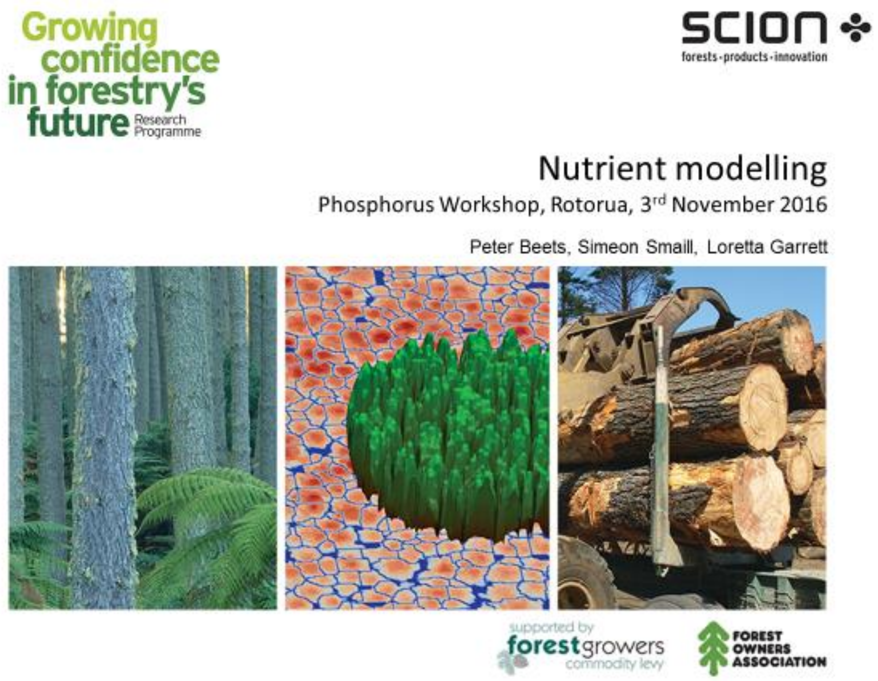
Note: Gaps mean no data for those years



Summary

- Most reliable data come from Ash and Pumice soils for both dairy and dry stock
- Dairy: Proportion of farms with high Olsen P generally declining
- Dairy: Proportion of farms with optimum Olsen P quite good but fluctuating
- Dry stock: Proportion of farms with low Olsen P are high and generally increasing
- Need to fill the gaps of missing data

Nutrient Modelling
Presenter: Peter Beets (Scion)



- Nutrient cycling – forests are thought of in terms of being closed, the reason is that when you grow a plantation forest you don't fertilise the soil if you want it to grow faster, you fertilise the trees
- The crop is there for 2-3 decades, cycling the nutrients so the idea is to get the nutrients into the cycle as quickly as possible. Both N & P can be limiting. Unless you get these nutrients into the organic cycle, it starts to cost.

Forest nitrogen and phosphorus losses (streams) – overview (Davis 2014, Baillie & Neary 2015)

Nutrient cycle in planted forest is relatively closed

- Harvesting/weed control is ephemeral interruption, less ET so more flow, some overland, (sediment export), less nutrient uptake (with weed control), more nutrient to stream
- Closed stands – less flow, more subsurface flow, high nutrient uptake by trees so less nutrient in ground water, soil processing of phosphate, reduced export via streams
- Stream water – flux of NO_3 from groundwater is attenuated by denitrification and within-stream processing into organic forms N for export. More tree shading reduces within-stream processing – depends on stream size etc
- P attenuated by sediment storage on land (important during forest harvesting) and stream channels (riparian zones, woody debris in stream). Depends on stream size

Fertiliser effect (low producing sites):

- Negligible loss of inorganic forms of N and P in streams, unless directly applied to surface water and stream margins

Land use history effect:

- Special case ex-pasture sites (fertilising ceases after planting) – PO_4-P and TP stream exports from 1st rotation pine initially reflect pasture (legacy effect) which diminishes 4-5yrs after planting so overall reduction relative to pasture sites). NO_3-N more complex.

Native veg. history & fertilised – pine N & P loss to ground water

Knight and Will (1977) lysimeter drainage water, Kaingaroa Forest, Pumice soil)

Parameter (loss kg/ha/year)	Age 1-3 years after harvesting	Age 6-12 years	Age 14 years (2nd year after fertiliser)
NO_3 – N	4.8	0.0	0.006
NH_4 - N	0.0	0.0	0.005
PO_4 - P	0.096	0.007	0.0

200kg/ha of ^{15}N labelled urea applied at age 13years:

- NH_4 – soil elevated in week 1 (maximum in week 4)
- NO_3 – soil elevated in week 2 (persisted for 3 years)
- Week 1 - 90% of N recovered in forest floor/soil to 10cm
- Week 2 to 4 - 40% of N not in floor/soil (tree uptake!)
- Virtually no N leached/volatilised 3 years after fert. applied

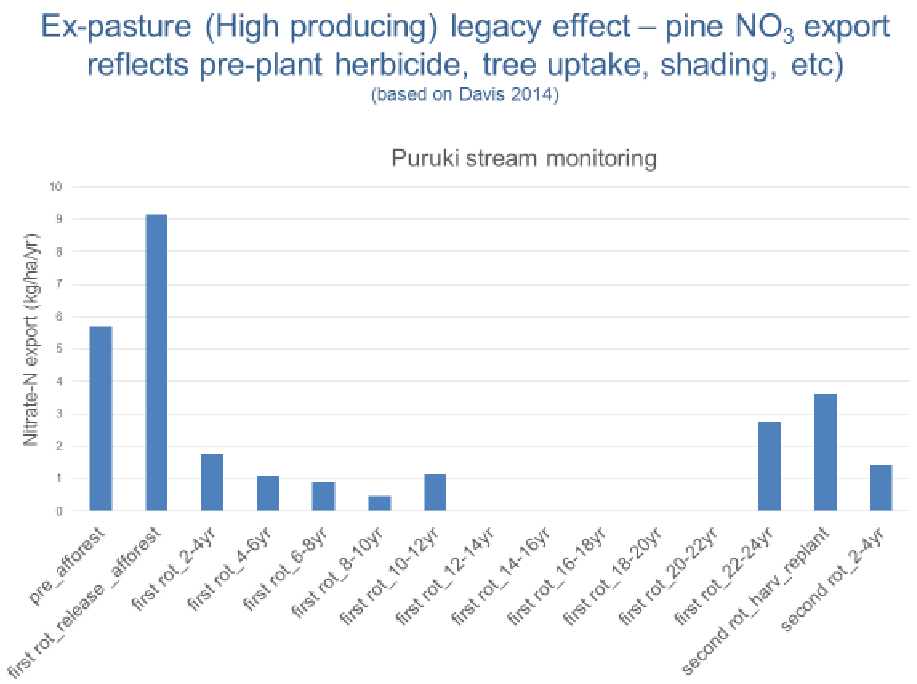
(urea fertiliser results in Warsnop and Will 1980)

- Forestry is all about getting nutrients into the trees and keeping them there. Trees are good at that, and most sites work very well so there's only a few sites where you need to compensate and give a boost of N or P, for example on sand dunes
- When we harvest, we then do weed control and that's something we need to look at more seriously
    - It's cheaper to do a blanket weed control than it is to do spot-spray
    - Weeds take up nutrients just as trees and grass do, so weed control is something we need to consider

Attenuation - soil water versus stream export (1984 with 11yr old pine) of N and P for high prod. pasture/pine at Purukohukohu (Taupo pumice)

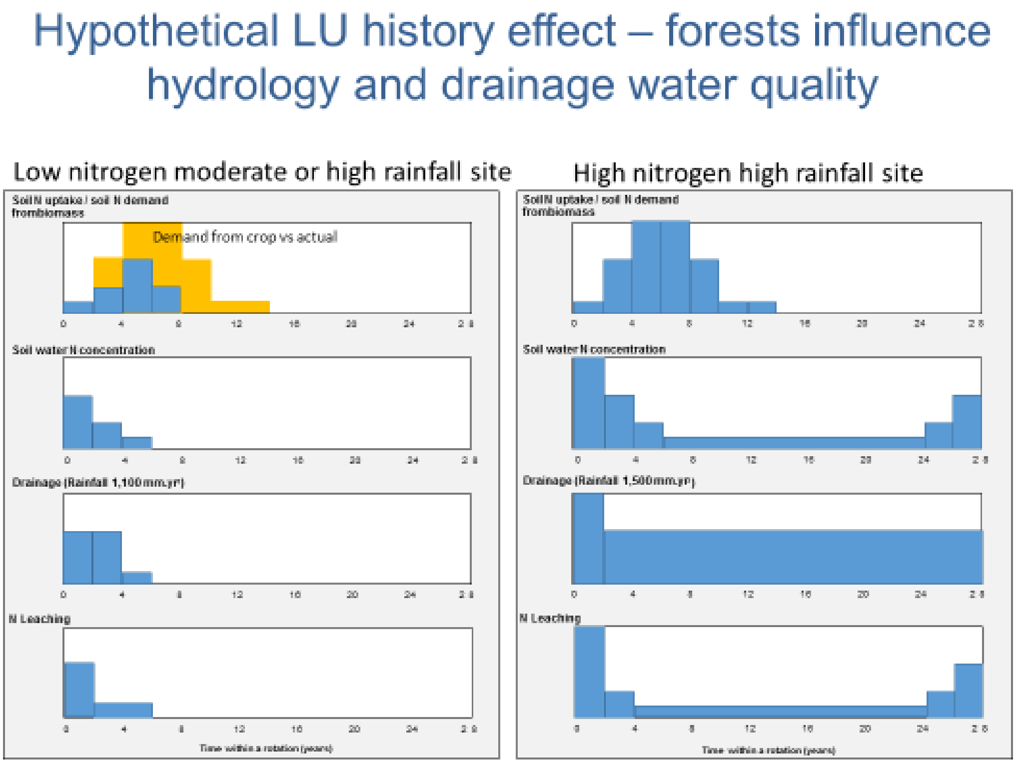
(from Cooper and Thomsen 1988)

Land use	Parameter	Soil loss (in springs) kg/ha	Stream loss (catchment baseflow) (kg/ha)	Stream loss (catchment total flow) (kg/ha)
Pasture	NO_3 - N	8.1	0.29	1.19
	DKN	0.15	0.72	2.62
	Total N		1.15	11.95
	DRP	0.13	0.037	0.37
	Total P		0.122	1.67
	TN/TP	63.5	9.4	7.2
Pine forest	NO_3 – N	1.23	0.4	0.55
	DKN	0.43	0.19	0.52
	Total N		0.63	1.31
	DRP	0.07	0.017	0.036
	Total P		0.038	0.095
	TN/TP	23.7	16.6	13.8



- When the harvest occurs, you interrupt the nutrient cycle and you get nutrient export during the time where the seedlings are planted again since they don't have much uptake
- Overland flow starts again in the absence of trees, and that's what moves the sediment
- Forestry has come a long way from bulldozing as they used to do, to now when they try to maintain the organic matter pools from the slash onsite and windrow etc
- If foresters are careful, there's no need for them to purchase or add fertilisers
- You're not going to be doing a lot of fertilisation on forestry, and none at all on ex-pasture sites
- You don't really have overland flow, and the soils tend to become more permeable over time and what was originally maybe not infiltrating, will begin to once you have a forest on there
  - As a result of trees growing in a stand in a forest, you get more uptake of nutrients so less nutrient export
  - Native forests don't take up as much nutrients as plantation forest. Pines have a much bigger requirement for N than native trees
  - In theory, planted forests should be able to hold nutrients better than natives because you're periodically exporting some of the nutrients in logs
- The main loss of nutrients from plantation forests is sediment runoff during harvests
- Stream water is a poor indicator of what's going on in the forest – there's within-stream processing which is highly variable, and there are lag effects. Better to deal with groundwater
- If you plant an area which is excessively high in nutrients, eventually the trees have had enough and there is no net uptake from the soil
- Trees change the shading in a waterway, the vegetation growing in those areas will be shaded out so there are several impacts – no in-stream processing, the stream will also start to change due to sediment runoff where the stream channel vegetation has disappeared from areas previously vegetated by under-storey species or pasture
- Sediment comes from intact forests, especially afterdisturbances (eg harvesting, windblow, excessive rain). It's a natural process

- Sediment will be greater in previously pastured sites, and it takes at least a rotation to shift this ephemerally stored sediment.
- The impact of sediment in forests with no streams (eg. Kaingaroa) is negligible because it's just moving to a different part of the forest
- If you can't build a physical barrier to intercept sediment to the waterway, the forestry operation shouldn't be on the steep slope down to a stream. Grow it further back would be better, but how would we convince foresters to do that?



- Kāingaroa is growing at approximately 80% of possible rate because it's N limited, but they don't want to lose any applied nutrients so they're looking at ways of optimising nutrient use
- Ex-pasture sites are high producing sites – they have way more nutrient available for uptake than trees actually need. The legacy effect of farming lasts for the first rotation
    - After a harvest, you get N loss of 5kg per hectare on average, for the first 1-3 years afterwards. This is because 1-3 year old trees don't take up as much nutrients as mature trees, and decaying slash/organic matter will still be present, and there is also more drainage occurring owing to the reduced pine leaf area index following harvesting
- 6-12 years, the trees are closed canopy and intercepting more water
- If you've got an inherently low nutrient status site, it doesn't produce much nutrient export. There's a little window in the first three years after harvest, but after that nothing to speak of
- When urea (200kg/ha) was added at age 14yrs, ammonia in soil went up after a week and peaked at 4 wks, nitrate went up after two weeks and persisted for at least 3 yrs
- After the 1st week 90% of the N was still detectable in the first 10cms of soil

- After 3 weeks, 40% of N had been taken up by the trees. Trees have potential to take up 100-200kgN/ha in one year
- So virtually no leaching
- There are going to be poor nutrient sites, sites that are rich, and some that are in between
- Current focus is on matching supply and demand (NuBalM model) and on live and dead biomass-N pools
- Future developments focus on soil processes
- Developed parameters that reflect the potential for the site
- After 30 years, there's about 1000kg/ha of N in the stand

The early development of NuBalM

- Stands for **Nu**trient **Bal**ance **M**odel
- Evolved from a model developed in the 1990's to optimise the timing of fertiliser application across radiata plantations
  - Take projections of biomass growth in a given year
  - Calculate the N mass required to support this growth
  - Project site nitrogen supply in a given year
  - Compare annual supply and demand to determine if fertiliser application will provide any benefit in that year

- Next steps for NuBalM (next two years)

Expansion of the capabilities of NuBalM

- Model was redesigned into a DSS tool to predict impacts on nitrogen dynamics and site productivity resulting from management
- Features included ability to predict the impacts of:
  - Site preparation
  - Fertiliser application
  - Stand management
  - Harvest intensity

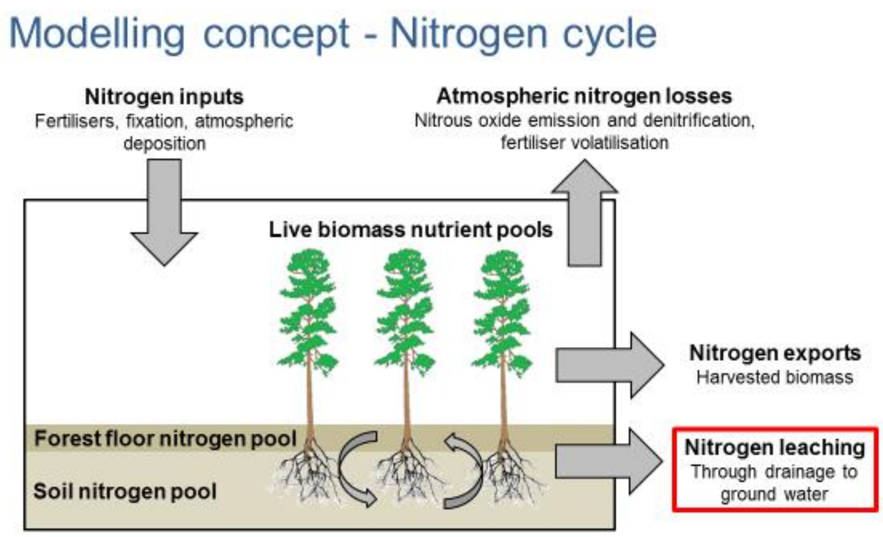
Smaill et al., Forest Ecology and Management 262, 270–277

- Quantifying nutrient pools now, and the model to be run against those in order to calibrate and tune it
- Ensuring that it's accurate and working
- Identify soil parameters that determine stand productivity
- The forestry sector sees NuBalM as a useful tool for the future nutritional management of forests
- Forestry companies are very interested to find out what their current numbers are
- Concerns include leaching and growth rates

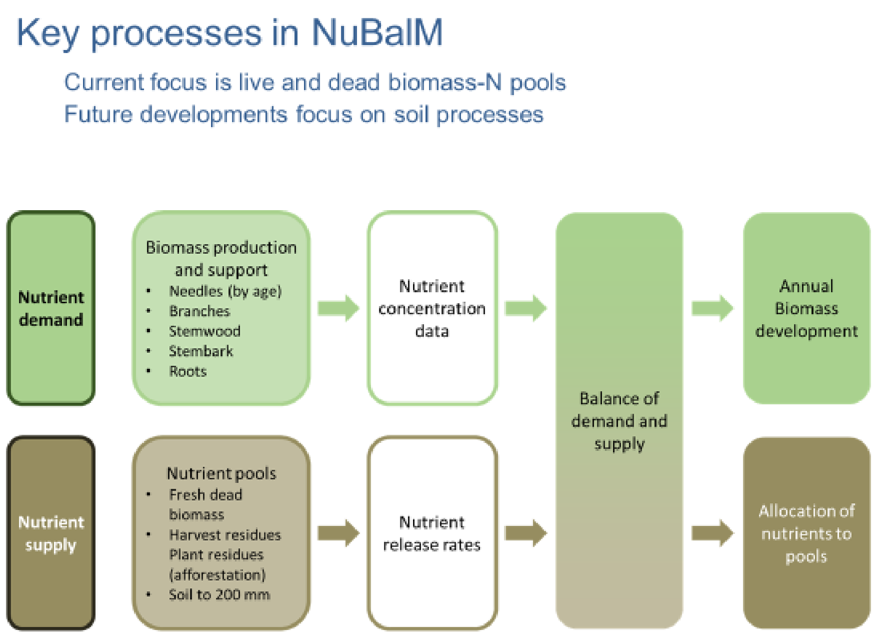
Refinement of NuBalM

- The Growing Confidence in Forestry's Future programme has allowed the following improvements. The additional FGLT funding will allow further development and testing of NuBalM over the next two year.
- Improvements include:
  - linked to C_Change/300 Index
  - Nutrient module includes improved nitrogen and phosphorus parameters
  - Included in Forecaster with three fertility settings: low, medium and high
  - Water balance model developed but not in Forecaster yet

- Trying now to improve predictions with reference to soil properties
- Pasture systems with enough rainfall, will transpire about the same as forests do
- Interception is leaf area driven, not atmospheric



- Excess nutrients will leach because the trees don't need all of it – it's more than they can use, hence the interest in matching nutrient inputs with crop potential demand
- Peter is eager to hear about environmental monitoring studies to improve estimation of nutrient leaching loss under different forest growing conditions and treatments



- Unless physical barriers can be put in place to trap sediment, the only real way to stop sediment runoff during harvest is to stop planting so close to waterways. It's simple, but foresters are getting mixed messages from councils about whether to replant those areas
- Pine species left behind and never logged will eventually be replaced by natives
- If they just leave the trees on the very steep slope without logging it, eventually it'll turn back into native forest – this would essentially result in a riparian zone but the foresters are unlikely to go for that as with farmers they prefer to use all the land available to them

Nutrient module

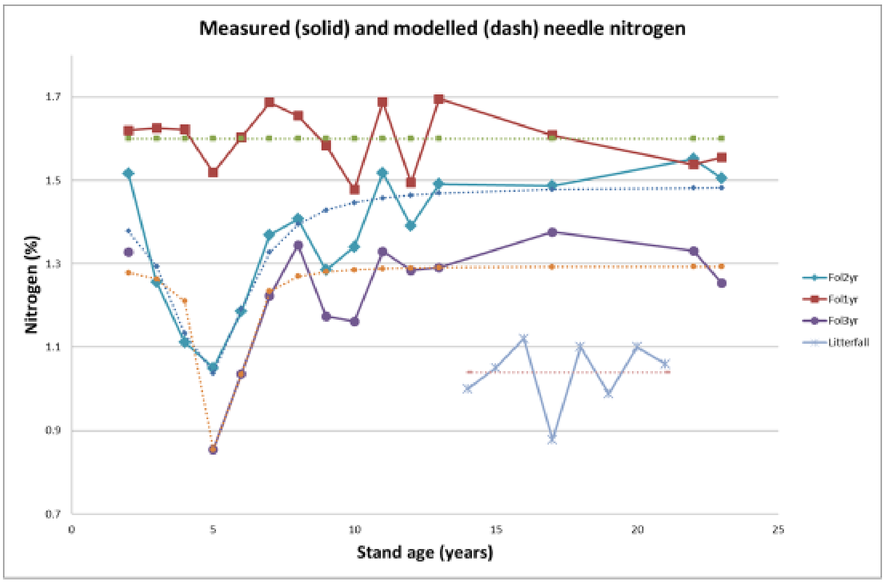
Annual demand (N & P) reflects:

- stand productivity settings (300Index) and tending regime
- C_Change for dry mass of live and dead components
- Component nutrient concentrations
- Nutrient cycling through forest floor.

Component N% & P% parameters developed for high fertile site. Off-sets are applied for medium and low fertility sites.

Other non-crop vegetation currently excluded.

Needle component N%: fertile (Puruki) volcanic soil



- The above graph shows how the quantity of N in the needles declines with increasing needle age and is recycled for reuse prior to litterfall. The needles in 1st year are drawing on the biomass nitrogen of needles from the previous cycle.
- Litter is about 1%, but the concentration of N in the forest floor is double that (2%), during organic matter decay, before N becomes available for tree reuse

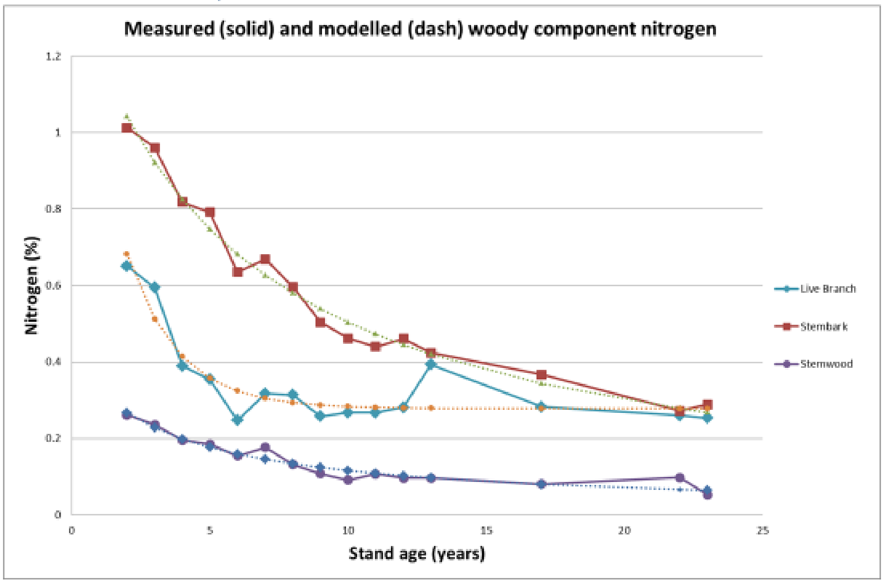
Litter component N%:fertile (Puruki) volcanic soil.

- Needlefall measured 1987-1994.
- Forest floor measured 1995 (to determine decay rate).
- N turnover rate expressed relative to dry matter turnover rate.
- Woody decay examined by Garrett et al. (2008, 2010, 2012)

Puruki Subcatchment	Forest floor (LFH) pool at age 22 years (excl. dead branch)			Average annual needle fall from age 14 – 21 years			Turnover rate		
	DM (t/ha)	N (kg/ha)	N (%)	DM (t/ha/yr)	N (kg/ha/yr)	N (%)	DM	N	Ratio N:DM
Plant 2200 sph, unthinned	35.9	762	2.12	6.33	70.8	1.12	0.18	0.093	0.53
Planted 2200, thin to 575 sph	23.5	509	2.17	5.15	53.4	1.04	0.22	0.105	0.48
Average									0.50

- Stem and branch dead matter is also recycled to the forest floor and is available for reuse

Stem and branch component N%: fertile (Puruki) volcanic soil, cont.



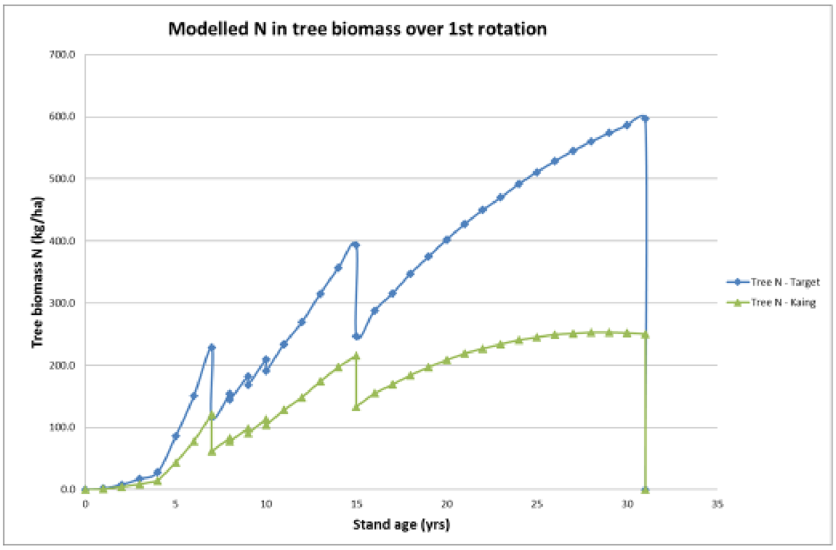
Model output

Given a productivity (300 Index) level and silvicultural regime, the model provides annual predictions of:

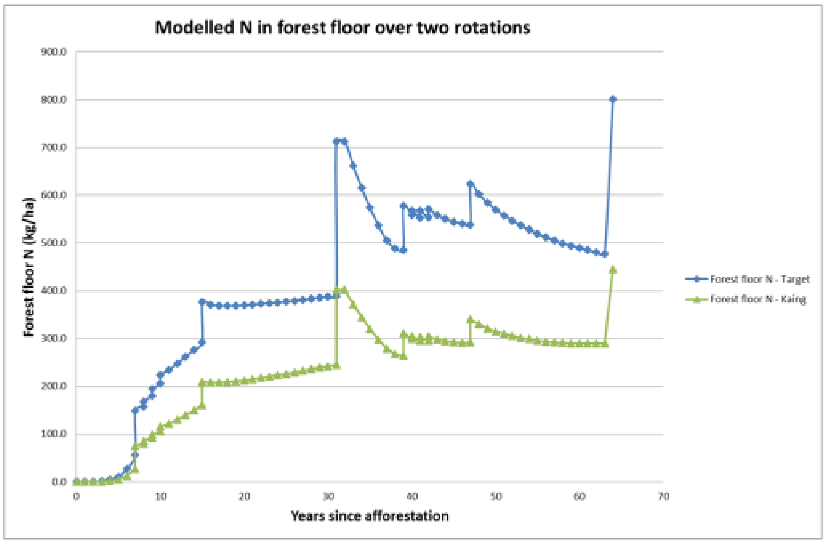
- N and P stocks in live biomass pools
- N and P stock in dead organic matter pools
- N and P uptake requirements

Requirements to be met (i.e. from soil reserves, N-fixation, atmospheric inputs, fertiliser, weed control. These are currently not included in the Forecaster version of NuBalM).

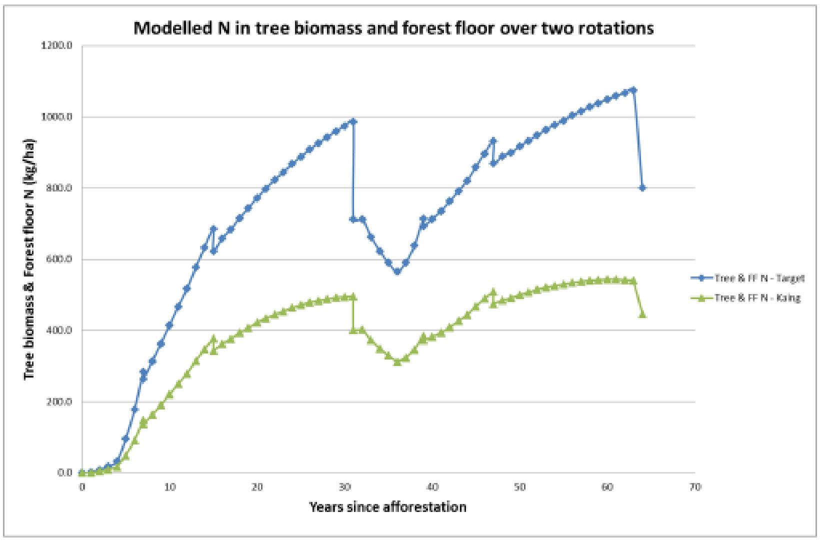
NuBalM output



NuBalM output

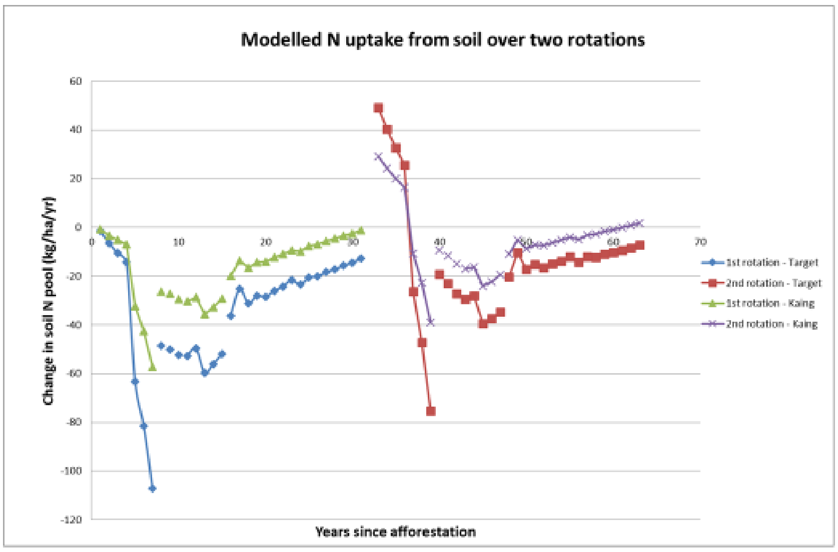


NuBalM output

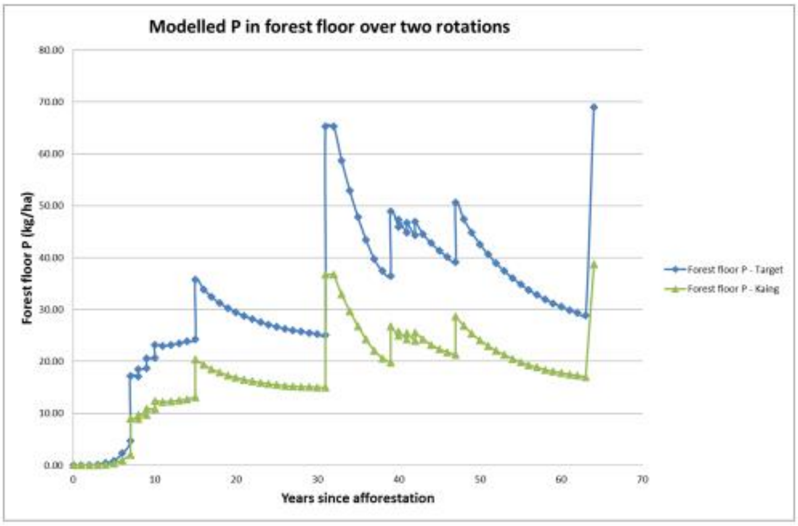


- By the end of the 1st cycle you have accumulated about 1000kgN. This remains at a similar level in the next rotation.
- If you can get enough N into the trees in the first rotation there is a good chance that will be maintained in subsequent rotations, so long as the organic matter pools are maintained.
- Only about 200kg/ha N goes off in logs and there is approx. 1000kg/ha N available
- When you see N leaching in the first 3 years it is coming from slash and decaying organic matter at approx. 70kgN/ha. There is simply too much for the young trees to handle at first (can use about 20-30kgN/ha)

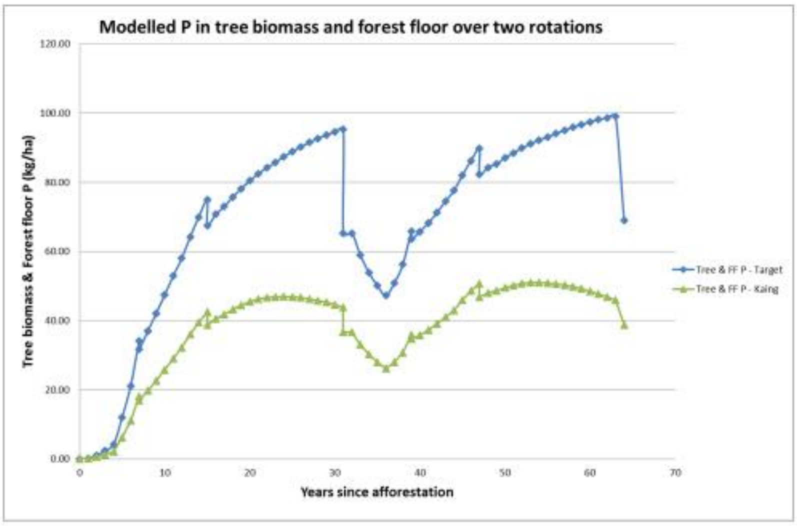
NuBalM output



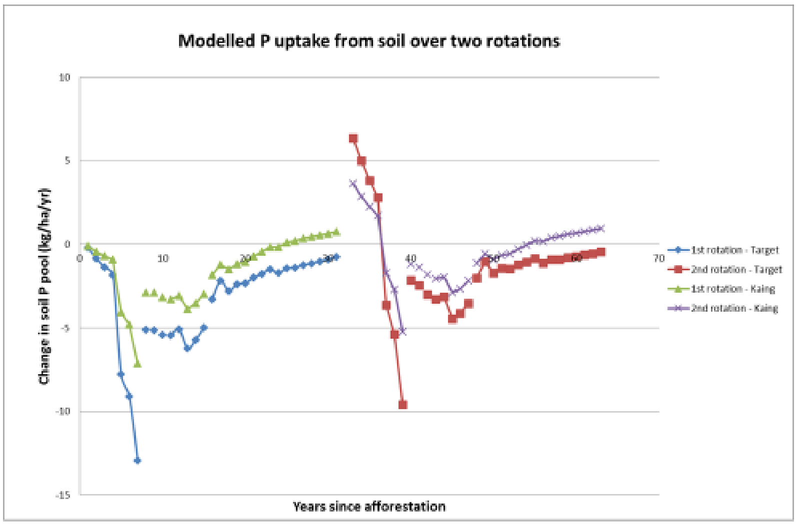
NuBalM output



NuBalM output



NuBalM output



Next steps for NuBalM

1) GCFF funded: testing the model with time series data from long-term sustainability trials (LTSP1 trials)

- The LTSP1 intensive harvesting trials are located at Woodhill, Kinleith, Tarawera, Golden Downs, Berwick, and Burnham)

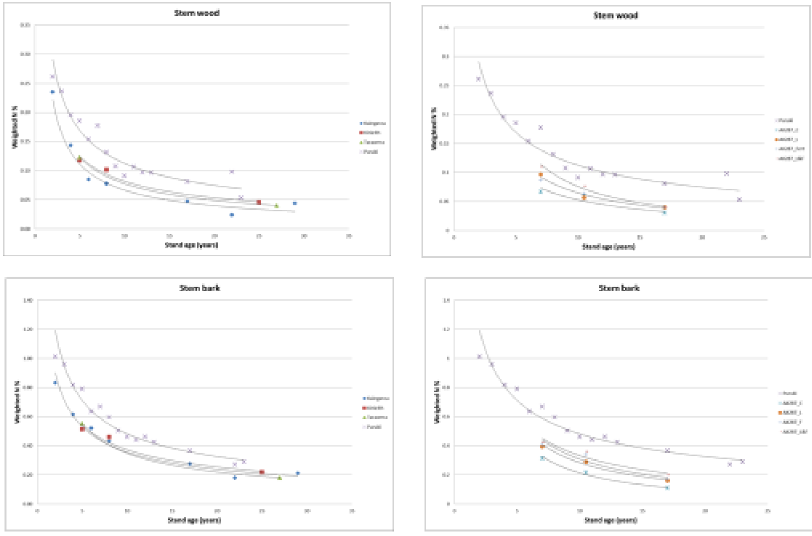
2) FGLT funded: Development plan for NuBalM

- Extending the “off-set approach” to allow for differences in site fertility (LTSP3 trials, 15 sites around NZ)
- Identify soil parameters that determine stand productivity

Next steps – Compare N% parameters for LTSP1 sites with Puruki data and develop off-sets

Medium fertility site - volcanic soil

Low fertility site - Pinaki sand, Woodhill



NuBalM Development Plan

- The forestry sector sees NuBalM as a useful tool for the future nutritional management of forests
- Priority topics for research
  1. Biomass & FF sampling at range of sites (LTSP3), and relate to soil information
  2. Improve predictions of growth response to nitrogenous fertiliser application
  3. Enable projections of the impacts of weeds and other plants (e.g. N-fixers) on nutrition and growth
  4. Enhance growth within environmental limits

NuBalM Water Balance Module

- Addressing leaching requires knowledge of nutrient concentrations in soil water and drainage to ground water
- Leaching can be an issue at sites where drainage occurs (i.e. where rainfall exceeds potential Evapo-Transpiration)
- Addition of a water balance module to NuBalM will determine if rainfall is sufficient, given the leaf area index, to permit drainage
- Considerations when including a water balance module in NuBalM?

- The difference between a pasture and an afforested site is the water that is intercepted by the trees and never reaches the ground
- After harvest this interception is removed and rainfall reaches the ground, and dramatically impacts drainage rates
- Trees can access soil nutrients at considerable depth (3-5m) if root systems are unimpeded

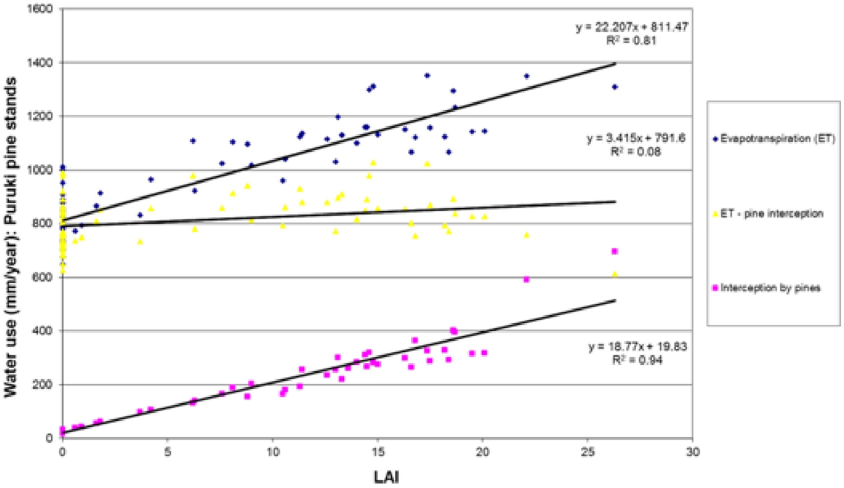
Initial considerations – Soil properties

- Criteria considered for including soil properties
    - Rooting depth – FSL documents soil properties to 1m depth, however, available water requires assumptions around soil properties below 1m depth.
    - Available water content can be treated as a single layer for deep rooted trees.

Initial considerations – Tree water use

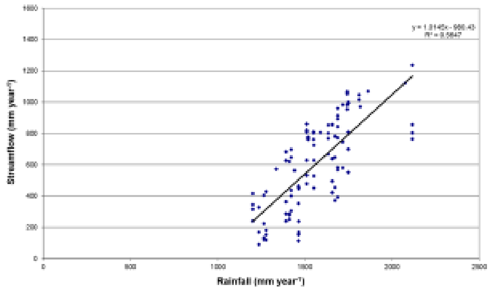
- Drainage model approach:
    - Water use as a function of LAI (C_Change output) and rainfall
    - Option to extend drainage model with a soil component in future, based on test results

Testing phase – ET and radiata pine interception losses, given the rainfall

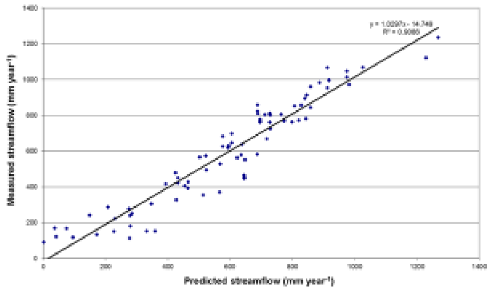


Testing phase – effect of LAI and rainfall on annual streamflow

- Streamflow in relation to rainfall (Puruki)

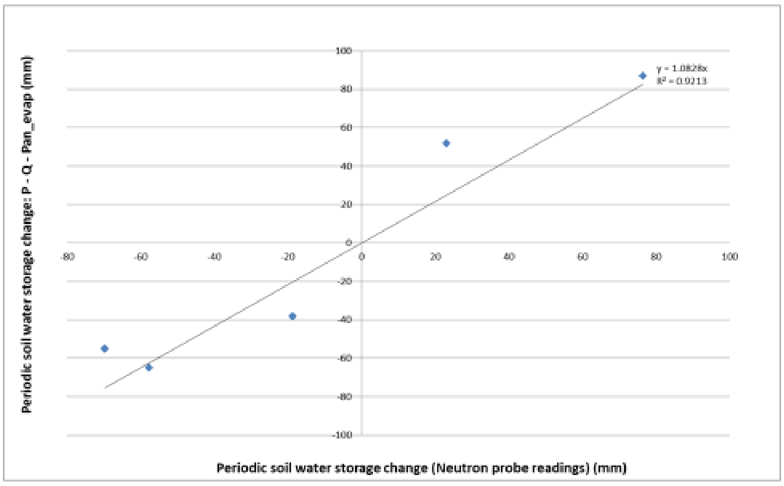


- Streamflow as a function of modelled LAI and rainfall (Puruki)



Soil water storage changes (not in NuBalM)

(approx. monthly at Puruki to 2m depth) – drainage to groundwater may occur for 6-8 months (May – Nov) of the year, depending on rainfall



Future developments

Next step:

- Potential to improve NuBalM by incorporating soil properties, water storage variation (which sites are well measured?), and soil depth (shallow soils have limited capacity to store water)
- Investigate variation in transpiration nationally based on other forest models (e.g. Dean Meason/Cabala model)
- Link with environmental monitoring studies (where?) to improve estimation of nutrient leaching loss under different forest growing conditions and treatments (drainage model)

http://research.nzfoa.org.nz/
www.scionresearch.com/nds

Peter Beets
Principal Scientist
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3rd November 2016

Workshop Conclusions and Recommendations - Group

Importance of P control

- It's what the Water Quality TAG group came up with about ten years ago – a statement about the importance of nitrogen and phosphorus. Even if you look at that again now it would still be relevant (version 2 recently revisited)
- Alum dosing – in-lake mitigation, benefits/risks and other options
- Alternatives to alum
- If you concentrate on N and ignore P, you're not going to make the progress you expect
- Fixation on N only, means that you may result in a cyanobacteria bloom. P must be looked at as well
- More detail around the likelihood that we can turn alum dosing off eventually, and still be able to manage the levels
- We could probably just about put some numbers around the internal anthropogenic P load 10 years ago versus now to work out the current budget
- Alum releases under high pH (8.6) and low pH (below 6) so there's a risk factor there, which is why it hasn't been as effective at Ōkaro
- If you manage to completely reset the lake with alum which stops the blooms, less biomass falls to the lake bed, so you effectively switch the lake into another cycle. But the question is, if you stop alum dosing, will that new cycle continue or will it change back?
- Lake model report executive summary for background
- We have local stream accumulations of aluminium but there's no indication of any impacts on the fauna of any type (fish, mussels etc) and we're continuing to monitor. There's no particular indication that alum bioaccumulates – it gets excreted in similar doses to what's taken up
- What are the unintended consequences of using alum?

What we know about P loss

- N&P interactions
- Olsen P optimum. Need to understand the difference between agronomic optimum and economic optimum. The latter is more important for farm profitability, and tends to be lower than agronomic optimum, hence lower run-off.
- A statement for the lay-public about Olsen P is and what it means. It's not a definitive metric. Relationship with N, and why we need to look at both together
- Dominant factor is always management – strong social element, and how farmers manage their environmental practices is fundamentally important
- The biophysical aspects of the soil are important, but the crucial thing that affects nutrient loss is the management practice. How do we get past the 'can't be arsed factor?' (ease of implementation) and the willingness to engage and implement
- Mitigation strategies – refer Rich McDowell report from a couple of years ago
- Certainty about what is required is a risk, because it could change down the track. Strategies for N are not the same as those for P
- Applies to all land types/uses, not just dairy and forestry

- In terms of calculating the reduction in P achievable on N mitigated farms, we can compare numbers (Rosemary)
- Most of the strategies targeting P are not represented in Overseer
- We need a strategy that doesn't reduce the N:P ratio in the lake. It might reduce them concurrently, but not the ratio itself
- Association of P loss with hydrology – critical source areas, slope, fertility and the ways that water moves around on and below the surface. Ephemeral flow paths and detainment bunds
- Technologies and informed management that can be brought to this – some of that is around analysis of soil fertility but you have a whole suite of mitigations and management
- Need a statement with a recommendation from the group – P loss has major implications for upcoming rule changes
- Two key messages – the information can inform nutrient management plans that are being evolved, and this is the start of the process of science review – it may lead to subtle tweaks to the rules along the track
- To date we haven't put sufficient emphasis on the P part of the equation, and we need to
- We know the position with P and Lake Rotorua, and we want to give the 'powers that be' that information as it might be the start of some of the science work that's being reviewed
- Looking at P has a direct co-benefit in terms of sediment and bacteria
- Climate change risk – the big risk is the length of stratification in the lake – the longer periods occurring, and erosion from high rainfall events
- Monitoring urban inputs

Forest management and N/P loss

- Predicting loss Overseer, NuBalM
- Planting areas/harvest mgmt.
- P&N flux – soil history – understanding that there could be significant differences that we need to understand
- Nobody is saying overseer is bad, but we might have something better coming along in the future
- Duration of high fertility (2 rotations), and impact
- Short rotation crops on farms – quickly grow, then take whole lot off. That will make a difference and draw the N and P away from the land
- Changing land use from gorse/pasture to forestry isn't going to fix things overnight. There will still be legacy N leaching (lag phase) but we need to understand that it's going to happen and manage people's expectations
- Management options – bmp and guidelines that impact nutrients eg weed control- broom and other nitrogen fixers growing under the trees will continue to produce for a while until it's shaded out
- Overseer is dependent on block mapping being done well/accurately
- How can we supplement Overseer with new tools that are becoming available/available now, and how does it deal with extreme events

Research and information gaps

- What is the best management practice that Overseer uses?
- Need to incorporate more P mitigation practices within Overseer
- Need to establish the difference between agronomic optimal P levels versus economic optimums
- Management plans and social decisions
- Education – management etc – uptake of information e.g. sediment management is key/obvious
- Information targeted to users – right audience, at a level that they understand and can build on
- Treatment and measurement of anthropogenic P, how can we quantify the P losses and manage them (eg urban/ungauged)
- David H – maybe we need to alum dose a lake and demonstrate the resulting imbalance of N. For example Tutira has degraded over the last couple of years with an increase in N.
- N:P ratio in Lake Tarawera
- Other options – Hamurana – other natural sources
- Catchment model P with N - see if target can be met
- Is there a need for a P Strategy for RC Programme
- New options – e.g. detention ponds
- Need to upgrade the forestry component of Overseer