ROTORUA TE ARAWA LAKES PROGRAMME

Science Plan 2014

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Document Control

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This approved document will be distributed to the Workstream Leads and Partnership Steering Group.

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1. Introduction and Background

The Rotorua Te Arawa Lakes Programme (RTALP) is a $230M programme of protection and restoration for twelve lakes in the Rotorua District. The programme was initiated in 2000 with the development of the Strategy for the lakes of the Rotorua District. The priorities to date have been the most degraded lakes: Ōkaro, Rotoehu, Rotorua, and Ōkāreka. The focus is now gradually moving to other less degraded lakes; the impact of land use change and defining the science behind some of our successes such as alum dosing.

Science monitoring initially commenced in the early 1960s particularly for lakes Rotorua and Rotoiti, as water quality deterioration was recognised at that time by the community for Lake Rotorua. Since the 1960's, a significant science effort has been undertaken to monitor the quality of the twelve lakes in the district. A step change in water quality for many of the lakes in the 1990 prompted more regular monitoring. The Bay of Plenty Regional Council (BOPRC) has been undertaking intensive monitoring of lakes since 1990 under the regional Natural Environment Regional Monitoring Network (NERMN) Programme.

In 2000, the S*trategy for the Lakes of the Rotorua District* was initiated by BOPRC, Rotorua District Council (RDC), and the Te Arawa Māori Trust Board, as a response to the decline in water quality of many of the lakes. It initiated a programme of coordination and co-operation between the three parties and this is acknowledged in the Te Arawa Lakes Settlement Act (2006). The strategy was reviewed in 2013 with the input of the community, iwi members, and stakeholders. Soon after the development of the 2000 strategy, it was recognised that the Rotorua Te Arawa Lakes Programme (RTALP) would benefit from a focused research effort and an agreement to fund a Chair in Lakes Management and Restoration at the University of Waikato, was signed in 2002. The success of this agreement has resulted in the continuation for a further five (5) year period in 2007, and again in 2012.

A number of other science providers are engaged in the programme, including scientists from BOPRC, Crown Research Institutes and various independent consultants. These providers form the Water Quality Technical Advisory Group (WQTAG), which convenes 3 - 4 times per year to provide science advice, critique, and direction for the programme. Details on this group are provided in section 5, Science Groups. It is of value to note that some of the scientists involved have been associated with the research and advice on the Rotorua lakes since the 1980s and so there is a valuable source of knowledge and continuity since that time.

Although the strategy for the lakes of the Rotorua district was initiated in 2000 in response to declining water quality, the quality of the lakes ranges from very high quality (oligotrophic) to somewhat degraded eutrophic and super-trophic lakes. The objectives of the strategy were not only to improve water quality in degraded lakes but also to halt the decline of those still in a good state. The vision of the strategy is the following:

> ***"The lakes of the Rotorua district and their catchments are preserved and protected for the use and enjoyment of present and future generations, while recognising and providing for the traditional relationship of Te Arawa with their ancestral lakes."***

The vision is an important focus of the science plan. It is considerably more encompassing than simply addressing the quality concerns. It is also of merit to note that various parts of the groups within our community identify different values for the lakes. Initially the focus of the science work has been on the water quality; however, in recognition of these other values, the science focus is widening, to include a larger range of science, monitoring, research, and advice.

The science work now encompasses:

- Lakes water quality, monitoring and restoration
- Ecological monitoring and restoration
- Land use monitoring and restoration

- Water and land modelling and interventions for improvement
- Development of cultural health framework and associated indicators

The quality of the science effort is well demonstrated with results that have been spectacular for the programme. Water quality targets have been defined by the community and reside in the Regional Water and Land Plan. These targets refer to the lakes Trophic Level Index (TLI). The TLI was developed by NIWA as a robust tool that is used on the lakes and is a single number representing water quality in each lake, derived from four water quality parameters: water clarity, chlorophyll-α, total nitrogen and total phosphorus. The use of a single annual indicator number assists in portraying lake restoration progress in a community friendly average. Notably, Lake Rotoiti is now at its target TLI; Lakes Rotorua, Rotoehu, and Tikitapu are very close to their target TLI. Research and work on Lake Ōkaro has a reduced TLI from a peak of 6 to less than 5.5 and for one year, it reached its target of 5.

The science needs and resources are managed by setting priority lakes and projects. As lake restoration has achieved success, attention has moved to the next set of lakes while still protecting the gains made.

2. Science Plan Objective

The objectives of the science plan are:

- To provide science directions for monitoring, research, and advice for the programme for the next 12 months to 5 years;
- To provide an opportunity for team members to identify science gaps within the programme and help set the science direction for the plan; and
- To provide a transparent and visible science plan for the RTALP partners and public, so that science direction and priorities are understood
- To provide science that is a foundation for clear lake restoration and protective action, monitor the progress and identify where action and science needs to adapt in response to the results observed.
- To provide science that will underpin policy and plans required to manage lake catchments sustainably in line with community objectives. The community objectives are for each lake are set as TLIs in the Regional Water and Land Plan.

It should be recognised that although a formal science plan had not been written previously, the science has been most recently directed by the WQTAG and relationship with the University of Waikato (UoW). This has provided a good foundation for the restoration work that has already taken place.

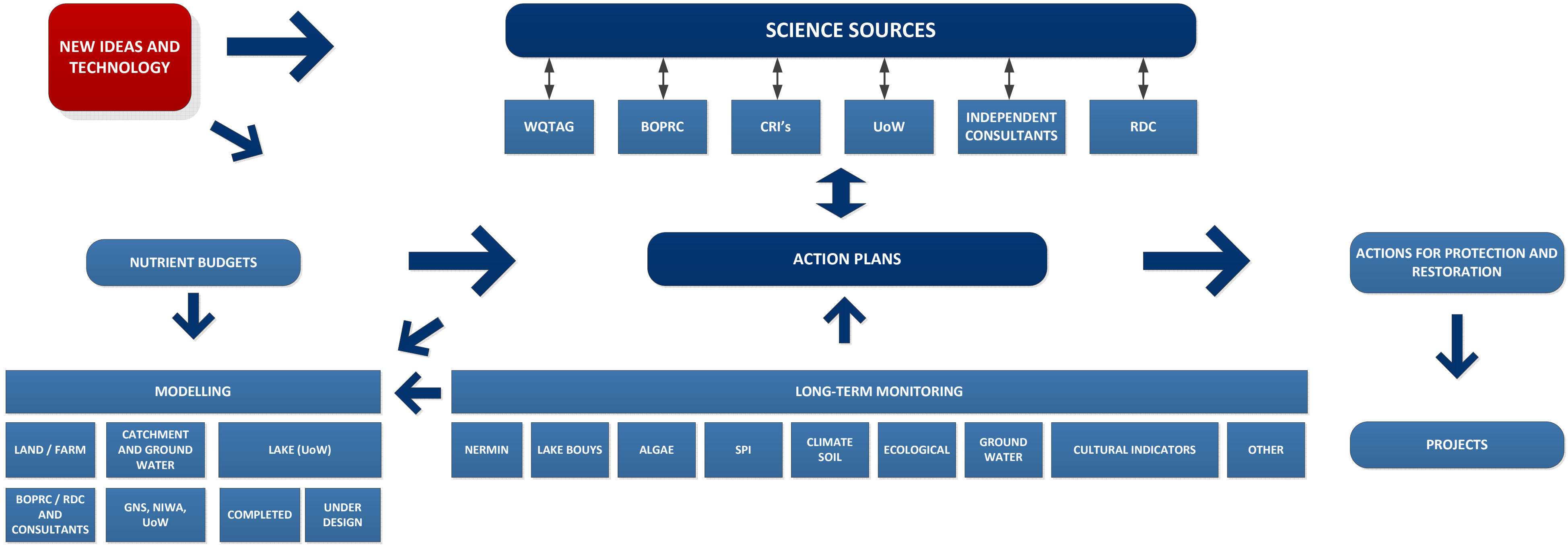
3. Science Structure

Science input is a vital component of the RTALP. It sets the foundation for restoration and management actions by providing monitoring information and advice on potential impacts: including lake and catchment modelling. This advice in turn, helps inform potential solutions and risks and inform planning of lake and catchment parameters pertinent to development of responsive framework, policies, rules and incentives for lake management.

Initially, the programme focused on interventions that would provide rapid improvement in water quality. In some cases, these have been short-term interventions such as the Ōhau Diversion Wall, alum dosing, and weed harvesting. Some longer-term interventions have also been applied, such as sewage reticulation and treatment. It has always been intended to implement long-term sustainable interventions, such as matching catchment land use with sustainable lake loads. Science advice is needed to support these decisions. The restoration effort has generally focused on undertaking actions on the lakes with poorer water quality, leaving the protection work on the better lakes until later. Consequently, as each lake improves, the focus of actions is transitioning from generally short-term interventions to longer-term interventions, such as catchment land use. As a result, there is an increasing demand for land-use science advice for planning decisions as well as for identification of restoration actions. This change in focus is reflected in the science plan, but it must be recognised that the water/lake science underpinning the programme will not be weakened because of an additional element of the science focus.

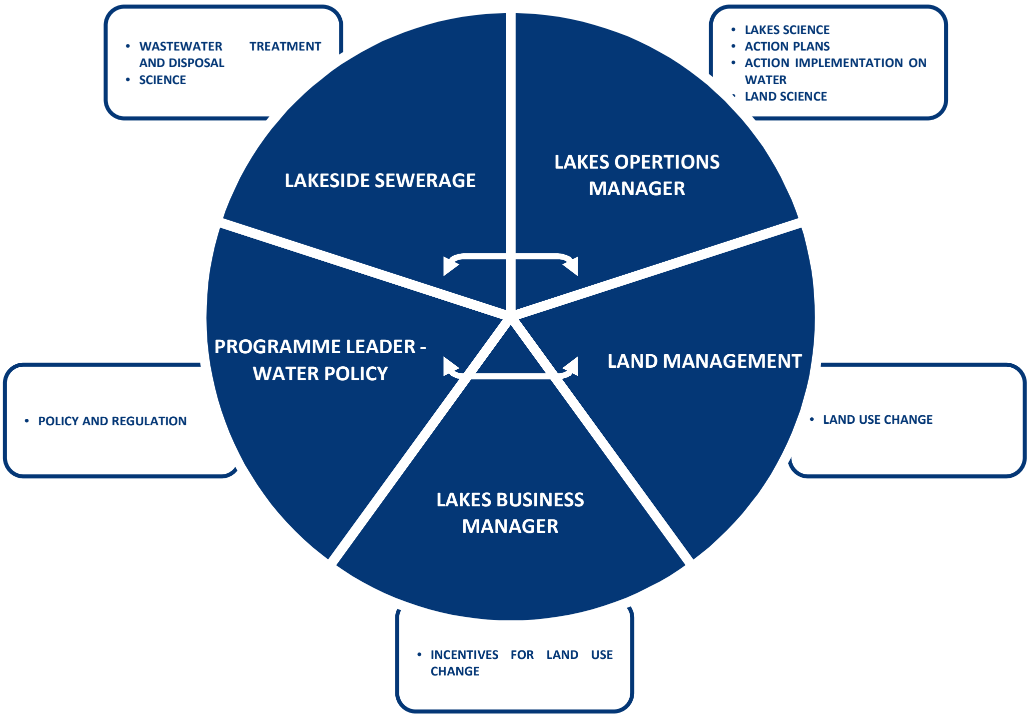
The structure of the science programme is not particularly complicated, but it does have a number of elements working together at any one time that makes precise definition more difficult. In addition, due to the new and innovative approach of the programme, the structure needs flexibility to allow science innovation and application down new paths as they emerge. The science programme for the lakes is the responsibility of the Lakes Operations Manager.

Diagram 1 – Programme Science Structure



The Programme Science Structure diagram is centred on the Action Plans (Diagram 1 – Programme Science Structure). This is a clear signal that the science effort is aimed at actions to restore lakes.

Diagram 2 – Programme Workstream Leads and the Relationship with Science



Generally, our RTALP science advisors initiate lake research opportunities and interventions for in-stream and in-lake restoration in response to BOPRC, the public and the research community. They provide comment commonly through the TAGs. This is then communicated to the RTALP via the Action Plan process where the science advisors and managers advise the community and Rotorua Te Arawa Lakes Strategy Group (RTALSG) about the benefits and disadvantages of a specific intervention or research opportunity. These can then be included in actions in the action plan process and implemented through that process.

The agreement with the UoW enables high level thinking on potential projects and the outcomes to date have been highly successful in closing the gaps in water science. It is recognised that:

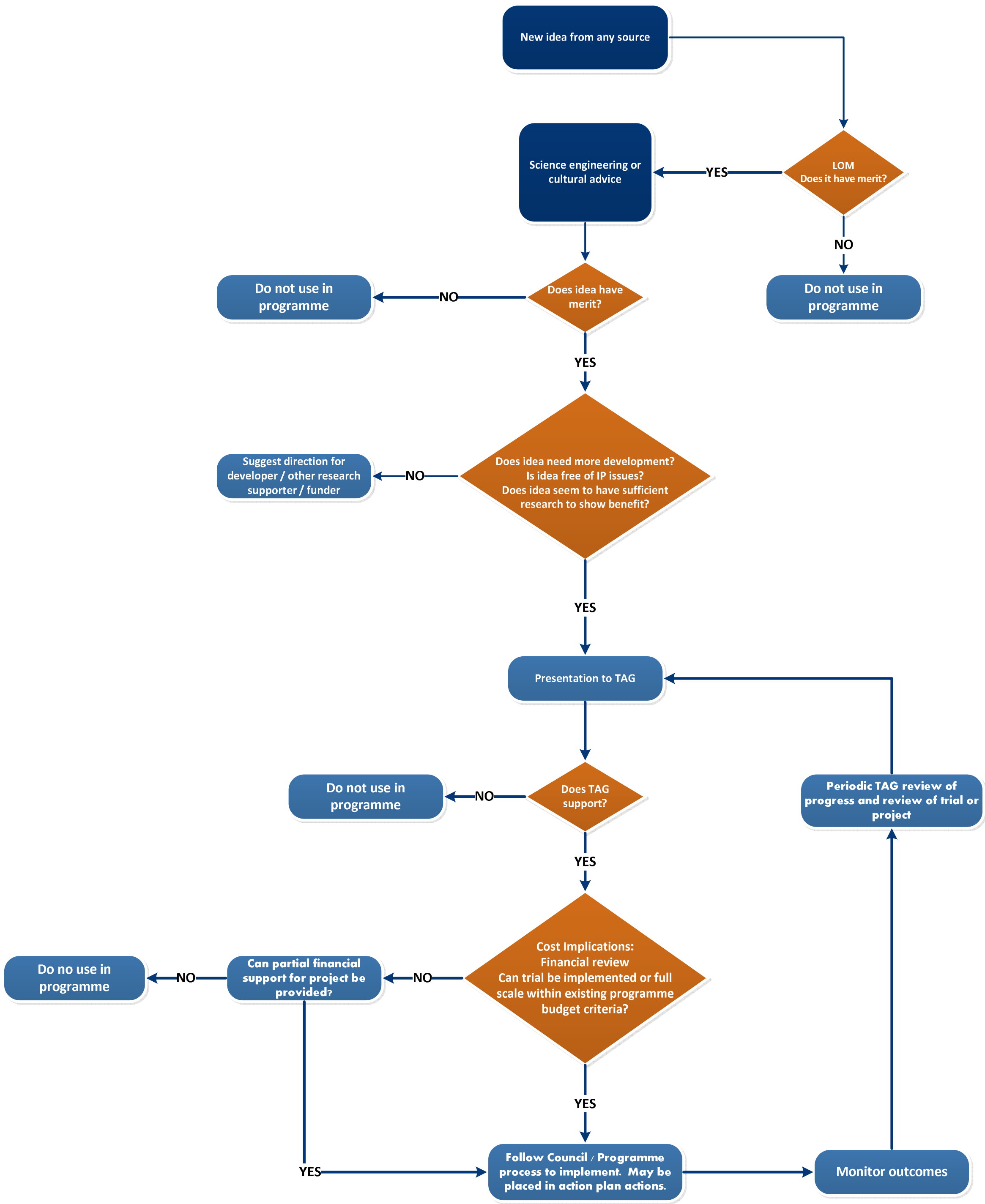
1. Lake hydrology and ecological models will be progressively set up for each lake
2. Catchment nutrient budgets will be prepared as required for each action plan or review process
3. Monitoring and research will accompany lake intervention and the outcomes will be discussed at regular TAG meetings
4. New ideas for research, monitoring, restoration are brought to WQTAG for discussion and decisions are made as to any further action.[1]
5. The Lakes Operations Manager and the Lakes Chair meet regularly to agree on short-term priorities to achieve the outcomes listed above and long-term research needs to be proactive in providing research on potential management strategies prior to their implementation.

[1] Preliminary screening of new ideas precedes any information presented to WQTAG to avoid irrelevant proposals being presented.

4. New Ideas and Innovation

Frequently, external sources request opportunity to present new ideas and innovations of lake restoration prototypes. The BOPRC is pleased to receive ideas and innovations; however, these presentations are not always supported by science research suitable to demonstrate applicability to the programme. To allow new ideas to progress into our programme, while avoiding resources being wasted, all submitted ideas follow the process set out in the flowchart below (Diagram 3 – New Ideas and Innovation Flowchart) to assess the ideas viability for the programme.

Diagram 3 – New Ideas and Innovation Flowchart



Note: The process for initiation of action to undertake new science work is detailed above. The areas identified are:

1. New technical ideas that may have anecdotal evidence of success,
2. New technical ideas that have research results to support them, or
3. New technical ideas that have been applied in other environments, but not in the programme.

The Lake Operations Manager undertakes a preliminary review of new ideas, often with advice from one or more scientists. Frequently, the proponents are looking for research support and funding to prove their ideas. These types of projects typically would not be discussed at TAG. It is likely the applicants would be referred to alternative national funding sources.

Note: A similar flow diagram will be required to assess land research innovation once a decision on a Land TAG is made.

5. Science Groups within Programme

GROUP	Function	Frequency	BOPRC / Facilitator
WQTAG **(Water Quality Technical Advisory Group)**	Provide science advice and critique for the RTALP. See Terms of Reference for WQTAG (Appendix 1 – Final Terms of Reference (ToR) Lakes Technical Advisory Group)	3 - 4 times Annually	Lakes Operations Manager
UoW / LERNZ **(University of Waikato) and (Lake Ecosystem Restoration New Zealand)**	To develop a strategy for applied original research to support some of the key knowledge gaps relevant to management, politics, and regulation for the lakes. A series of projects that aim to restore indigenous biodiversity in lakes.	Monthly or as required Bi-Annually	Lakes Operations Manager Professor David Hamilton
APCG **(Aquatic Pests Coordination Group)**	To coordinate a number of different agencies' work on aquatic pests. (Appendix 3 – Terms of Reference (ToR) Aquatic Pest Co-Ordination Group)	3 times Annually	Senior Land Management Officer
SAG **(Sediment Advisory Group)**	To advise on lake sediment research and remediation, reports to WQTAG. Appendix 2 - Terms of Reference (ToR) Sediment Advisory Group (SAG)	3 - 4 times Annually or as requested	Professor David Hamilton

6. Science Providers

ORGANISATON OR GROUP	AREA OF EXPERTISE	RELATIONSHIPS	CURRENT PROJECTS
BOPRC	Water Quality Monitoring New techniques Research Lake restoration prototype Modelling for lakes Ecology Project Monitoring	Science Team Lakes Operations Land Management Pollution Prevention Team Environmental Data Services Team	RTLAP Support in all areas NERMN Summer cyanobacteria Lake bathing
UoW	Water Quality Monitoring New techniques Research Lake restoration prototypes Modelling for lakes catchment and lakes modelling Ecology	Contract Chair Post Doc Technical Support PhD and Masters projects Other providers e.g. Nick Ling and Brendan Hicks	Lake Monitoring Buoys Puarenga Catchment Modelling-sewerage Catchment Modelling- Lake Tikitapu Sediment Survey-Lake Rotorua Lake Rotoehu destratification Integrated Ecosystem- Lake Ōkataina Catchment and lake Modelling of Ōkaro Detainment Bunds for mitigating diffuse-source losses Nutrient Concentrations in Puarenga Catchment Greenhouse gas emissions in Rotorua lakes Socio-economic contexts and tools for more efficient policies and regulation of diffuse nutrient loads to lakes Dependence of phytoplankton succession on lake hydrodynamics Remote sensing of water quality in lakes Lake bathymetry Rotomā, Ōkataina and Ōkaro.
NIWA	Sediment Water Quality Catchment land use Ecology Project monitoring	TAG contract Max Gibbs Chris Palliser	Catchment boundaries Catchment modelling Ecotoxic study Sediment releases

ORGANISATON OR GROUP	AREA OF EXPERTISE	RELATIONSHIPS	CURRENT PROJECTS
GNS	Groundwater Monitoring Modelling	Paul White	Tarawera Model Catchment boundaries
NIWA/UoW	Fisheries expert	Ian Kusabs, PhD study	Koura in a context of matauranga Maori
Private Consultants	Fisheries Biology Ecologists Cultural Knowledge Fisheries Management	Ian Kusabs Joe Butterworth TALT Iwi / hapū Schools	Tau Koura Kakahi modelling Intervention monitoring

7. Research Funding Support

Through the process of assessment, the BOPRC needs to determine its involvement and local funding. Ultimately, this is reliant on agreement from the RTALSG and subject to some general guidelines:

1. The restoration or research process is transparent and the BOPRC will have access to the technology without an unreasonable additional cost (e.g. royalties or fees for IP etc.)
2. There is sufficient evidence to suggest the project is technically feasible and likely to have the environmental outcomes that are claimed and "in sync" with the programme objectives.
3. That WQTAG supports the project.
4. The level of funding support and BOPRC involvement in the project will depend on the potential benefit to the RTALP and the perceived responsibility within the project area. Typically, in-lake and in-stream interventions will be led by BOPRC, as the council has clear RMA responsibilities in that area of the environment. Conversely, land catchment interventions are more likely to be led by other organisations or individuals. However, BOPRC may be a collaborator, including part-funder.
5. Where BOPRC is a collaborator or part-funder, without direct control of the project, a clear business case for support must be provided before any funding decision will be made.
6. Generally two (2) types of projects will be considered:
    a) New science / technical ideas (not applied elsewhere)
    b) Existing science / technical applications that have worked elsewhere but need to be tested within the programme and the local Rotorua environment.
7. Each project will be assessed against general iwi and community expectations and aspirations. Long-term applications require a robust application and that requires the support of iwi and alignment with community expectations. Funding may not be allocated to proposals that do not align with iwi and community expectations.

8. Current Science Plan

Science is undertaken as a part of a structured programme of research, monitoring, and interventions that have delivered lake restoration outcomes over the past 13 years. Some specific case studies are attached in Appendix 5 – Case Studies, to demonstrate how these have worked.

An important observation from the science monitoring and implementation programme over the past 13 years is that some new ideas have had spectacular outcomes; some have been lake specific only and implementation has enabled identification of issues related to success or failure. In addition, in deciding upon science projects, simple analyses such as "lowest cost" are not likely appropriate, as many interventions have been implemented mainly due to community and hapū/iwi support and not just economics per se.

9. Current Workstreams

1. Provide science on state of each lake:
   a) Maintain a monitoring programme for N&P, Secchi disc, deoxygenation and chlorophyll-a
   b) Communicate TLI changes annually in August of each year
   c) Lake Submerged Plant Index (SPI)
   d) Stream water quality and flow monitoring
   e) Meteorology
   f) Lake buoys
2. Support Action Plan Development:
   a) Lake nutrient budgets
   b) Provide information on in-lake and in-stream interventions
   c) Monitor specific projects
3. Support management and planning of the RTALP:
   a) Support science to assist implementation of Action Plans e.g. nutrient budgets, groundwater models, monitoring etc…
   b) Modelling of land use and lakes:
      i) On farm
      ii) Catchment
      iii) Progress lake models for each lake
      iv) Specific modelling e.g. in Puarenga catchment in Lake Rotorua
      v) Support the testing of projects for deed funding or other funding e.g. aeration trials for Lake Rotoehu
4. Support ecological monitoring and restoration projects:
   a) Koaro
   b) Kakahi (Rotokakahi)
   c) Kakahi and koura (Ōhau Diversion Wall)
   d) Trout fishing and associated smelt and migration issues – Ōhau Diversion Wall
   e) Floating wetlands (all lakes)
5. Provide other lake science as needed:
   a) Ōhau Diversion Wall - impact of adjusting Okere control gate flows
   b) Ōhau Diversion Wall - impact of removal if Lake Rotorua reaches TLI 4.2 and associated risks
6. Land use science:
   a) Identify opportunities for nutrient footprint reduction e.g. P-Project and engagement opportunities, e.g. gorse
   b) Identify opportunities for collaboration and possible joint funding

10. Key Issues

The following is an identification of potential key science issues that could pose significant risk to the RTALP if the prior work streams are not maintained:

1. Specific science monitoring and assessment of alum use in lakes: Alum dosing has now become a key part of the lakes programme, with two alum dosing plants on Lake Rotorua streams, Puarenga and Utuhina; one dosing plant on the Lake Rotoehu geothermal stream and periodic alum dosing directly into Lake Ōkaro. Monitoring involves the following:

   a) Alum plant management and dose rate

   b) Water quality monitoring, specifically Al and P

   c) In-stream and in-lake ecological monitoring annually

   d) Lake sediment monitoring – every three years

   e) Targeted ecological monitoring as necessary, previously undertaken by NIWA of UoW.

   Alum dosing has proven to be a successful strategy in the restoration of Lake Rotorua. Until land use changes come into effect and a reduction in nutrient inputs is achieved (reaching the lake), then alum dosing is likely to be necessary. A major risk is that any reduction in monitoring here could reduce the ability to assess the environmental safety of alum dosing. An important question is whether recent improvements can be maintained if alum dosing is phased out and whether the land use changes required are being successfully implemented.

2. Many of the lake projects and wastewater disposal are subject to RMA and resource consents. Science monitoring is necessary to ensure legal compliance with resource consent conditions. Performance and environmental monitoring are also necessary to support the resource consent application process in the future, as consents expire and need to be replaced.

   This applies to the alum dosing plants as described above, but is also critical for projects such as the Ōhau Diversion Wall.

   The Ōhau Diversion Wall consent expires in October 2017. It is anticipated that a resource consent replacement will be required. Monitoring of the wall includes:

   - Water quality
   - Water flows and velocity
   - Native and introduced fish species
   - Avifauna
   - Structural integrity of the wall
   - Sediment movement and disposition
   - Modelling of hydrodynamic and ecological impacts

3. There is significant value in long-term continuous monitoring records, for determining lake water quality trends and changes. In the past, where monitoring records have been stopped due to lack of resources or redirection of resources, this has made understanding water quality changes more challenging. Prior to ceasing any long-term monitoring, an assessment of the long-term needs and potential risks need to be undertaken by appropriate science advisors. . Needs of the RTALP require alignment with BOPRC overall science strategy and resourcing, and where gaps are identified; develop methodologies on how these will be resolved.

4. The programme will be active in identifying new monitoring techniques that can be integrated with monitoring outcomes and understanding. Some examples of this type of innovation are high-frequency monitoring buoys, satellite images, and DNA sequencing for identification of algae species. In these types of applications, there can be multiple advantages and potential to lower costs. For example, recent implementation of the pH-monitoring buoy in Lake Ōkaro is now able to identify times suitable for alum dosing applications.

5. Modelling: identifying science requirements to support present and future environmental modelling; identifying uncertainty in models; usefulness of model in the future – will models be resourced for future iterations and uses.

11. Programme Gaps

A workshop was held in November 2013 to review current work and identify science gaps within the current Programme. Three specific areas were identified:

1. Current lake water science (including cultural indicators of lake health)
2. Land use science
3. Wastewater science

The workshop attendees were selected to provide feedback from scientists and end users (Programme Workstream Leads) and to help identify programme science gaps (Appendix 4 – Science Workshop Attendees).

12. General Water Science Gaps

1. Groundwater for Lakes Rotoiti, Rotoehu, Rotorua
2. Cultural Framework / indicators / mahinga kai /matauranga
3. Other lake health indices (in particular specific monitoring of native fauna in lakes for example extension of the koura monitoring programme)
4. Mechanisms to get ideas into Science Programme
5. Mechanisms for Action Plan change / review
6. In-lake contaminants / environmental health risks
7. Science succession for Programme
8. Loss of native flora / native fisheries
9. Floating wetlands- benefits
10. Regular science forum, extension of student presentations
11. Modelling of scenarios
12. Story of TLI and other targets to communities
13. Local and Māori student involvement
14. Storage of information - access to public and scientists, other volume of data now being generated.
15. Wastewater disposal science

13. Land Use Science Gaps

The following categories have been identified as the general land use science gaps. A more detailed description of how there will be addressed is outlined in Section 14.2.

1. Focused identification and monitoring of sources (sediments and nutrients)
    a. Knowledge
    b. Research
    c. Application
2. Best Management Practice in land use
3. Social science to reduce barriers to implementation
4. Farm scale modelling – validation
    a. Scenarios for different farming types
5. Catchment scale modelling
6. Soil science (no expert employed by Council)
7. N and P losses, delivery times and attenuation

14. Addressing the Gaps

Addressing the gaps s broken into the two component parts:

14.1 Gaps in Water Science

Definition of Gap	Potential Solution	Resource Need High/Moderate/Low
Groundwater for Lakes Rotoiti, Rotoehu and Rotorua	Monitoring bores and model development	High
Cultural Framework / Indicators - mahinga kai, matauranga	Develop framework of Framework, being led by TALT	High
End User Needs	Community engagement	TBC
Other Lake Health Indices	Community input and related to cultural framework	High
Mechanisms to get ideas into Science Programme	Community engagement, science forums, OBI, UoW study opportunities.	Moderate
Mechanisms for Action Plan Change / Review	Science review of intervention success	High
In-lake Contaminants / Risks	Science review and safety mechanisms	High
Science succession for Programme		
Loss of Native Flora	Research on native species and impact of environmental changes	High
Floating Wetlands	Habitat value for native species and others	Moderate
Regular Science Forum, extension of student presentation	Programming of science presentations, field trips and discussions	Low
Modelling of Scenarios	Implementation of Land TAG	High
Lake in-flows	Especially the greater Tarawera catchment, awaiting GW model to progress	High
Quality of Data		
Story of TLI and other Targets to Communities	Identify best ways of reaching interested community members	Low

Definition of Gap	Potential Solution	Resource Need High/Moderate/Low
Local and Maori Student involvement	Identify projects and students and attempt to connect	Moderate
Storage of Information- access to Public and Scientists	Some work being undertaken by UoW and BOPRC developing new data application	High

14.2 Gaps in Current Land Use

Although there is a need for additional land use advice from science, the extent of the programme partners in providing that advice is not clear. In addition, the Science Programme currently has inputs to land use science in the following areas:

1. Connection of catchment land use and lake models for specific lakes. In particular, the subject of a range of scenarios for Lake Rotorua. Refinement of N and P losses, delivery times, and attenuation may be required.
2. Some specific land use interventions that have been researched and led by BOPRC. This includes gorse N leaching and P-detention bunds.
3. Focused reports have been commissioned on land use impacts of farming and also on mitigation measures and their effectiveness
4. BOPRC is a co-funder of a number of land use research projects in the region, including the Parekarangi SFF Project

The question has been raised whether a specific land TAG should be convened, similar to the WQTAG. It appears there is some expectation of this, from comments from the Stakeholder Advisory Group (StAG). It would appear BOPRC's mandate or responsibility to fund such a group is not clear together with the land use questions being considered as science or technical questions requiring specialist technical advice. If a second TAG focused on land use were to be formed, then there would need to be integration with the WQTAG as much of the long-term work to improve water quality in the lakes is reliant on long-term land use change.

An alternative approach would be to expand the Terms of Reference (ToR) and functions of the WQTAG to encompass the areas of land use to provide the necessary advice on land use science. Some distinct advantages can be leveraged from this approach:

- One all-encompassing advisory TAG
- Much of the current UoW and past NIWA modelling work relates to land use change scenarios, and so additional brain power there will provide more robust results
- Identifying the full range of land use mitigation practices and options is beyond the scope of the Programme partners, so BOPRC should be careful to avoid being too influential in the options chosen, but focus on providing an environment that encourages the industry to identify options. The TAG could then provide advice, where necessary, to confirm the science around the option(s) identified and highlight any information gaps.
- The mass balance model used in the action plans can be maintained and refined for each lake on a continuing basis; as it is a transparent method and a useful policy tool depending on how catchment policies may be framed in the future.

14.3 Proposal

The decision to form a Land Use TAG or to increase the scope of the current TAG requires further specific assessment and consideration. This will be managed over the next six months via a separate process. Once established this science plan will be reviewed to reflect how this group interacts with the RTALP.

15. Appendix 1 – Final Terms of Reference (ToR) Lakes Technical Advisory Group (21 May 2012)

1. Purpose of the Lakes TAG

To provide technical advice on lake science and management to BOPRC, RDC and TALT in order to improve the water quality of the 12 Te Arawa Rotorua lakes. The purpose of the Lakes TAG is to operate as an informal forum of experts on lake water quality problems, causes, and solutions.

2. Membership

The membership comprises representatives from the following core organisations: BOPRC, RDC, TALT, NIWA, UoW, GNS, and SCION. Lakes TAG membership can be fluid, reflecting changes to priority issues, the evolving research and operational programmes, staff roles and availability. At the discretion of the Lakes TAG convenor, additional people can be invited to participate on a short or long-term basis.

3. Scope of Work

The Lakes TAG will make considerations of, provide coordination and guidance to, and make recommendations on, the following matters relating to **the water quality of the 12 Te Arawa Rotorua lakes**:

a) Lake, aquifer, catchment and ecological research linked to lake water quality status, trends and potential water quality solutions, including:

   i) Current and future lake nutrient loads and water quality response

   ii) Sediment nutrient release and management options, taking into account advice from the Sediment TAG

   iii) Nutrient load reductions necessary to achieve the water quality targets and other matters relating to water quality as identified in statutory planning documents

   iv) Current and future risks to lake water quality, including climate and land use risks,

   v) Hydrology (surface and groundwater) and land use.

b) Operational matters, including current and proposed in-lake and in-stream mitigation actions

c) Monitoring regimes, results and analysis

d) Input to the development and review of non-statutory documents, including Lake Action Plans.

The lake TAG is not expected to provide technical guidance on practical aspects of land use and land management change except as they impact on overall lake nutrient loads. The Lakes TAG can identify land use knowledge gaps that may be an impediment to progress on achieving water quality targets.

4. Meetings, Reporting, Confidentiality and Financial Support

a) The lakes TAG will meet 3 to 4 times per year and operate by consensus.

b) The lakes TAG convenor is BOPRC's Lake Operations Manager, Andy Bruere, who is responsible for circulating agendas and minutes to all TAG members.

c) Formal reporting of lakes TAG advice is via the convenor of the Rotorua Te Arawa Lakes Strategy Group, and Regional Council, Rotorua District Council and Te Arawa Lakes Trust by their representatives as appropriate. Minutes of the TAG meeting are public documents. Some aspects of items raised at the TAG meeting in confidence, to aid free and frank discussion, may be excluded from the minutes by agreement at the time of the meeting.

d) The lakes TAG does not have authority to initiate projects or incur costs beyond meeting-related costs, with such projects subject to the external approval processes of BOPRC, RDC and other agencies.

16. Appendix 2 - Terms of Reference (ToR) Sediment Advisory Group (SAG)

A Sub-Group of the Rotorua Lakes Water Quality Technical Advisory Group (WQTAG)

1. *Purpose of the SAG:*

To provide scientific advice and operational direction on how to reduce internal lake nutrient loads via lakebed sediment management techniques.

2. *SAG Membership:*

- Prof David Hamilton (Convenor)
- John McIntosh
- Max Gibbs
- Andy Bruere

Plus co-opted experts as required, including specific postgraduate students and staff from the University of Waikato, NIWA, and SCION scientists, and private sector experts with relevant expertise, products, and systems.

3. *Scope of SAG's work*

a) Provide advice on all relevant remediation methods, and potential for ecological and human health effects, of lake bed sediment flux measurement, including, but not limited to:

  - Sediment capping materials
  - Hypolimnetic dosing materials, e.g. with alum
  - Oxygenation and de-stratification
  - Dredging

b) Formulate criteria for recommending research into any particular product or technique.

c) Review sediment treatment proposals and trials brought to WQTAG and BOPRC and make recommendations.

d) Provide input to other related Rotorua lakes research initiatives, including the in-lake modelling of sediment nutrient dynamics and the response of lakes to interventions and climate change effects.

e) The SAG does not have authority to initiate projects or incur costs beyond meeting-related costs. As such, projects/costs will need to go through the normal project approval processes of BOPRC and other agencies. The SAG can, however, recommend projects for approval to BOPRC or make recommendations through the WQTAG (see below).

4. *Meetings, Reporting and Support*

a) Aim to meet 3 to 4 times per year and to operate by consensus.

b) Report to WQTAG as part of WQTAG regular meetings.

c) Financial support will be provided by BOPRC for the actual and reasonable meeting costs of SAG members.

d) Meeting agendas and minutes will be documented and circulated to all SAG members.

17. Appendix 3 – Terms of Reference (ToR) Aquatic Pest Co-Ordination Group

1. Purpose

The purpose of the Aquatic Pest Co-ordination Group (APCG) is for those agencies with a role in the management of aquatic pests to effectively network, pool resources where possible and share information to achieve the integrated planning and management of aquatic pests in the Rotorua Lakes.

This will be achieved through the objectives of the Group set out below.

2. Objectives

2.1 To facilitate communication and liaison regarding aquatic pest issues between the representative organisations.

2.2 To act as a forum to promote further discussion and input on technical issues from relevant organisations.

2.3 To plan, implement and report on operational activities in regard to aquatic pests within the Rotorua Lakes.

2.4 To raise awareness and understanding of aquatic pest issues in the Rotorua Lakes.

2.5 To promote consistency of policy and strategic direction between agencies for the management of aquatic pests within the Rotorua Lakes.

2.6 Regularly review these objectives, how they will be achieved, and the overall effectiveness of the group

3. How the Objectives will be Achieved

3.1 APCG will prepare an annual plan for Rotorua Lakes aquatic pest management by the 1st of July each year. The plan must take into consideration the roles and responsibilities of each organisation and the resources available for aquatic pest management.

3.2 APCG member agencies will implement parts of the annual plan that apply to them and report back to APCG.

3.3 APCG will prepare an annual report on Aquatic pest operational activities carried out by 30th June each year.

3.4 Each member agency will contribute resources as appropriate within their mandate to help achieve the purpose and objectives of the Group. This will include:

- Contributing to issue based working groups where relevant.
- Contributing to planning and policy processes where relevant
- Committing to undertake actions agreed at meetings in the defined timeframe.

3.5 Each member agency will provide a representative at Group meetings at a level sufficient to represent the strategic direction of their organisation. This representative will have the role of disseminating information from the group within their organisations. Agencies may provide other additional representatives as appropriate.

3.6 All agencies will facilitate information sharing and coordination of information where appropriate and relevant. An important principle is maintaining the confidentiality of information shared unless that information is specifically stated as being public.

3.7 The Group will act as an interface for consultation on issues associated with aquatic pest management policy.

3.8 The Group will develop a coordinated approach to community engagement for Aquatic Pest awareness in the Rotorua Lakes.

3.9 The Bay of Plenty Regional Council will provide administrative support to the group.

3.10 Chairing and convening meetings will be by mutual agreement between the member organisations.

Membership

The Aquatic Pest Co-ordination Group members are:

- Department of Conservation
- Eastern Region Fish and Game Council
- Bay of Plenty Regional Council
- Rotorua District Council
- Te Arawa Lakes Trust
- Land Information New Zealand
- National Institute of Water and Atmospheric (Advisory)

18. Appendix 4 – Science Workshop Attendees

BOPRC	Andy Bruere Gloria Zamora Anna Grayling Alastair MacCormick Rob Donald Paul Scholes Alastair Suren Sarah Omundsen Ian Morton John Paterson Niroy Sumeran John McIntosh
RDC	Alison Lowe
TALT	Hera Smith
UoW	Prof David Hamilton

19. Appendix 5 – Case Studies

Lake Okaro

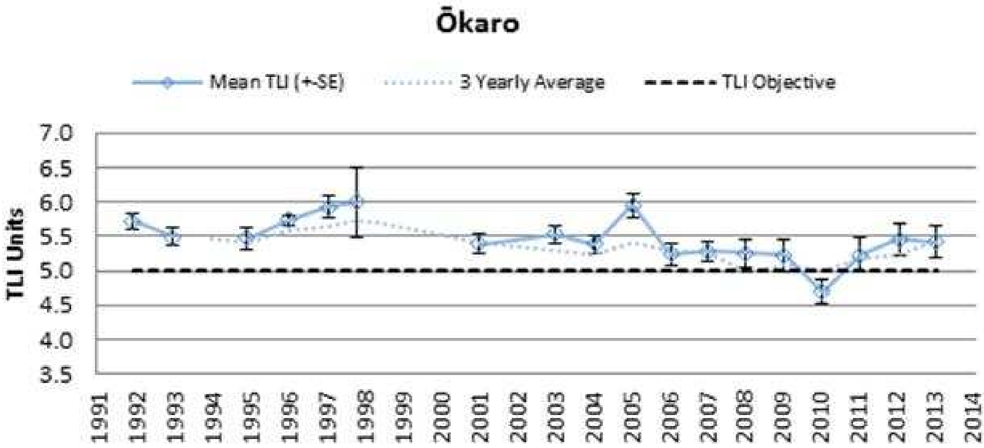
Introduction

Lake Okaro is a small lake situated just to the north of Rainbow Mountain on the Rotorua to Taupō highway. The surface area of the lake is 31 ha and 367 ha of predominantly farmed catchment drains to the lake. The average depth is 12.5m and the deepest part of the lake is 18m. The catchment soils have a high natural fertility due the Rotomahana Mud component spread over the area from old Lake Rotomahana and its surrounds during the 1886 Tarawera eruption. The stream flowing to the lake has a very high background phosphorus concentration because of this.

As part of the Te Arawa Rotorua Lakes Protection and Restoration Programme, an Action Plan was formulated with the community with the primary purpose of reaching the Water and Land Plan trophic level index (TLI) objective of 5.0 TLI units. Okaro had the worst quality of the 12 major lakes of the Te Arawa group. It was unusual in that the internal load was of similar magnitude to the external (catchment) load. This is because the accumulation of organic matter in the lake sediments released more nitrogen and about as much phosphorus into the lake water on an annual basis as flowed into the lake from the land. The internal load of phosphorus could theoretically be reduced by locking with alum or other products but the internal load of nitrogen could only be gradually reduced over time by controlling the outflow of nitrogen from the catchment.

In the Action Plan, the TLI objective was to be achieved by reducing nitrogen by 3.3 Tonne/yr and phosphorus by 0.38 Tonne/yr. Of this, 0.9 Tonne/yr of nitrogen and 0.02 Tonne/yr phosphorus were targeted for reduction from the catchment inflows.

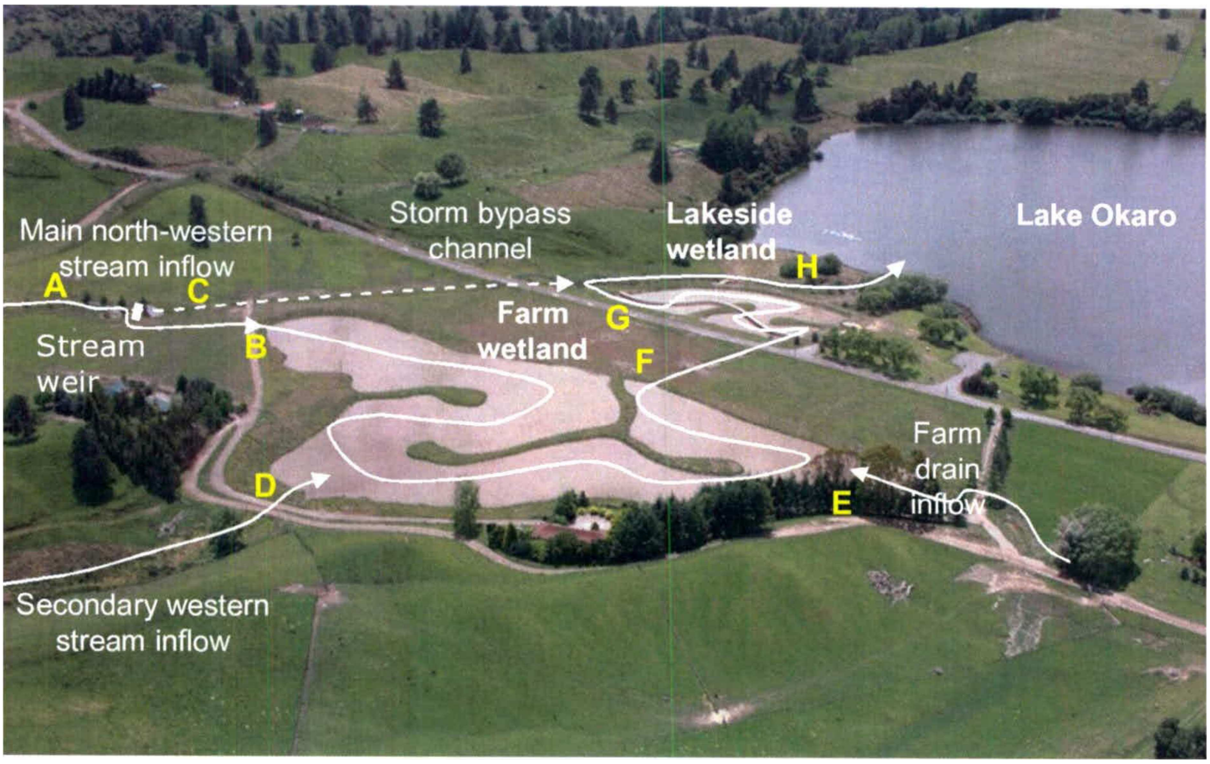
To achieve the objective a range of actions have been undertaken since the Action Plan was put in place in 2006.



The TLI may be lower on average in the last decade than in the 1990s but has only reached the W&LP target once. That may be due to the drought year of 2009 reducing the catchment inflows of nutrients.

Constructed Wetland

The constructed wetland was completed in May 2005 but plants were not fully established for another year and complete flow through from all the waterways was held off for one more year. Wetlands work principally in reducing nitrogen levels through the process of de-nitrification. Some settlement of phosphorus may occur and initially there may be some plant uptake. In the 1970s, cowshed effluent was discharged in the lake catchment but that was diverted to a pond out of the catchment, however, storm flows washed drainage from the cowshed race towards the lake through a planted detention basin until that was diverted to the constructed wetland.



The wetland fluctuates in effectiveness depending on rainfall and in high rainfall years, a large quantity of water passes untreated along the by-pass channel. A NIWA study has recorded a nitrogen reduction to Lake Okaro of 150 - 600 kg/y and a 30 - 300 kg/y in phosphorus as the streams flow through the wetland.

Catchment Management Change

The Okaro Catchment Lake Restoration Group (OCLRG) was established with an objective of establishing farm and environmental accountability. They obtained Sustainable Farming Fund financial support and support from the Bay of Plenty Regional Council and have carried out the following mitigation methods: altering stocking levels and stock classes, altering stocking policies, altering the sheep : cattle ratio, strategic use of fertilisers, retirement of land from grazing, managing critical source areas where nutrient runoff can be high, and installation of a storm water detainment capability to an existing dam to buffer peak flows during run-off events. Between 2008 and 2010, nitrogen loss remained steady but phosphorus loss was reduced by an estimated 34%.

A formalised compliance programme carried out by a specified scientific method remains to be set up and implemented. This would enable the nutrient load discharged from farming properties to be audited.

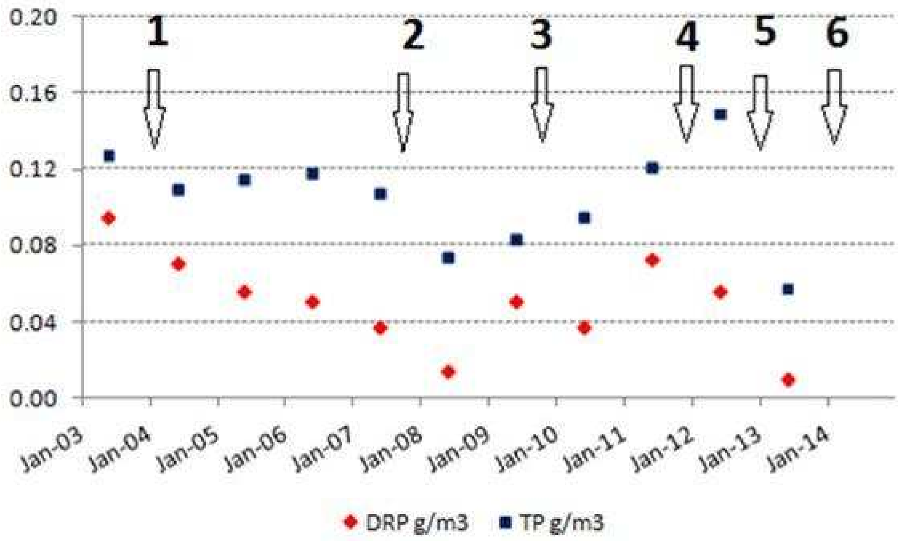
Detainment Bund

A detainment bund (3.9m high and 16,000 m^3) has been constructed (April 2014) to control storm flows in the major portion of the catchment so that the storm water can be channelled through the wetland. Suspended sediment will settle out in the bund removing some nutrients and the delay and attenuation of the storm peak will allow more water to receive additional treatment in the wetland. Storm water by pass of the wetland will be reduced and probably avoided.

Phosphorus Locking

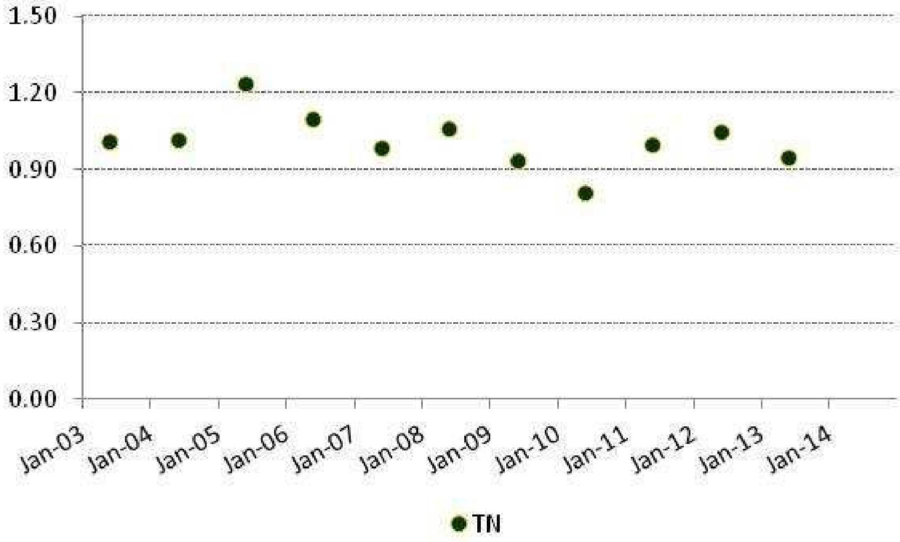
Within the Action Plan the majority of the phosphorus reduction to reach the TLI objective of 5.0, was to be achieved by locking the phosphorus that was re-cycled annually from the bottom sediments of the lake. Two products have been used on Lake Okaro after being trialled either in overseas studies or in New Zealand. Aluminium sulphate (alum) has been used and a locally made zeolite material amended with alum. Alum has been used in recent applications because of cost effectiveness. A resource consent has been obtained for an annual application of 15 tonne of either product.

In June when the lake is completely mixed the phosphorus concentration (g/m^3) is an indicator of the overall nutrient status of the lake.



1: 10 tonne alum, 2: 112 tonne Aqual P, 3: 44 t Aqual P, 4: 5 t Aqual P, 5: 22.6 t alum, 6: 10 t alum

Phosphorus locking has been effective in reducing the in-lake phosphorus concentration (g/m^3) *eg* the 112 T Aqual P drove the concentration down and the after the alum application in 2012 the phosphorus concentration was at its lowest recorded level.



In contrast to the June phosphorus concentration the June nitrogen concentration (g/m^3) has varied around an average of about 1 g/m^3 but has not changed significantly over the last decade.

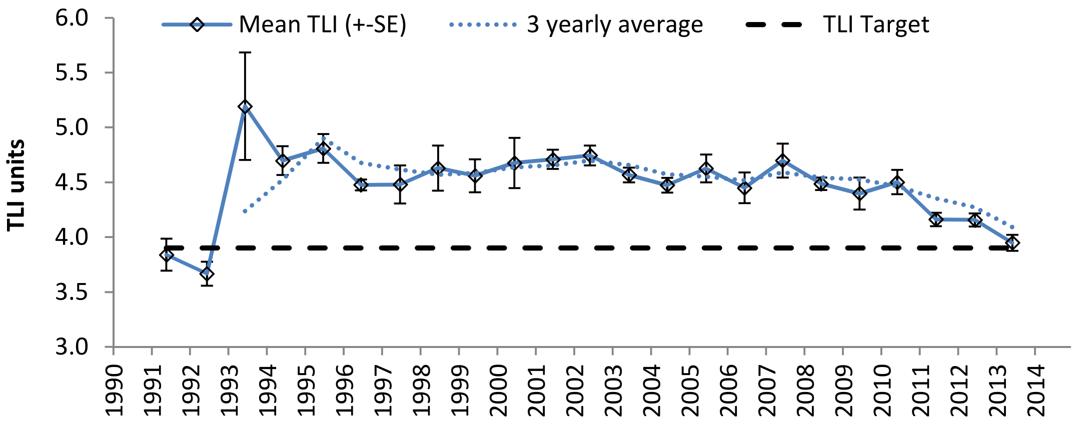
The Action Plan requires a reduction in catchment nitrogen input to Lake Okaro to reduce the in-lake nitrogen concentration and to reduce the internal load of nitrogen, whereas, a reduction in catchment phosphorus input is required but the internal phosphorus load can also be reduced by phosphorus locking.

Lake Rotoehu

Introduction

Formed by lava damming a river valley and surrounded equally by a mix of pasture, exotic and indigenous forestry, Lake Rotoehu water severely declined in the 1990's and has also been impacted by the introduction of the invasive macrophyte *Ceratophyllum demersum* (Hornwort).

As part of the RTALP an Action Plan was formulated with the community with the primary target of reaching the Regional Water and Land Plan trophic level index (TLI) objective of 3.9 TLI units. This would be achieved by reducing nitrogen by 8.88 T/yr and phosphorus by 0.708 T/yr. To achieve this a range of actions have been undertaken since the Action Plan was put in place in 2007 which have seen the TLI, a measure of lake water quality, indicating a marked improvement in lake water quality in recent years. A number of restorative actions have driven this improvement and these are described below.



Science underpins determining not only the extent and potential of many of the restorative actions but also is critical in determining their success.

De-stratifier

Lake science classification defines Lake Rotoehu as a polymictic lake, meaning the lake is too shallow to develop seasonal stratification. Like Lake Rotorua, Lake Rotoehu can intermittently stratify and when the bottom water reach near anoxic conditions phosphorus can be released. De-stratification is a technique that has been employed in other lakes and reservoirs to stop bottom water going anoxic hence preventing phosphorus release, which can fuel toxic algal blooms.

A unique design was proposed for a de-stratifier capitalising on the lessons learnt from other machines with the aim of preventing the lake stratifying. In 2012 two machines were built and installed. An intensive monitoring programme is underway to assess the performance and impact of these machines and will also help in determining the impacts of other restorative actions. Monitoring includes: two (2) live water quality monitoring buoys; zooplankton and phytoplankton monitoring; koura monitoring; monthly water quality monitoring including profiling and longitudinal surveys; current surveys, sediment surveys; and hydrological-ecological lake modelling.

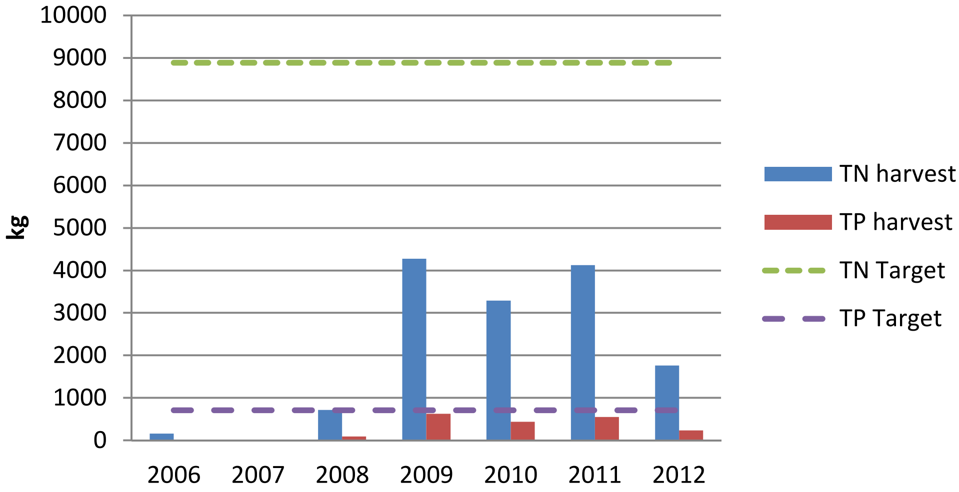
Figure 1: Part of a de-stratification machine being towed into the lake.

Floating Wetlands

Two small floating wetland island were initially trialled on Lake Rotoehu in 2008. Made from buoyant recycled plastic matting and planted with native sedges, the initial success of the wetland islands created the confidence to create a 3000 m^2 floating wetland. To establish the nutrient removal rate from the floating wetland nutrient loads in a tank being treated by a floating wetland were measured. Nutrient removal rates were approximated annually at ~460 kg TN ha^{-1} yr^{-1} and ~73 kg TP ha^{-1} yr^{-1}. Further work and research into the ecological and nutrient reduction benefits of the floating wetlands is ongoing.

Weed Harvesting

Hornwort (*Ceratophyllum demersum*) infestation of Lake Rotoehu likely occurred in the early 2000's, manifesting into large dense surface reaching beds in the southern end of the lake by 2004. Hornwort has been harvested from Lake Rotoehu in large quantities for the last five years after an initial trial began in 2006. The figure below displays the approximate nitrogen and phosphorous removal from the lake over that time in relation to annual lake removal targets. Removal of Hornwort to vermiculture and landfill has achieved almost half of the Rotoehu Action Plan nutrient target for nitrogen in the previous three years of harvesting.



Alum Treatment

The phosphorus load flowing into Lake Rotoehu from Waitangi soda springs is naturally high due to inputs from geothermal springs, which have high levels of phosphorus of geological origin. To address the imbalance of nitrogen to phosphorus in the lake which has occurred due to mans impact on the landscape, an aluminium sulphate (alum) treatment plant doses into the spring waters just before it enters the lake. Alum binds phosphorus, flocculating and settling in the lake sediments removing phosphorus from biological uptake. There is an indication that the present dosing regime may be helping to work towards the TLI target for Lake Rotoehu by providing a strong degree of 'phosphorus locking'. The aim was to remove 0.7 tonne TP yr-1, but like Lake Rotorua there is likely to be further phosphorus locking benefits in the lake waters.

Bio-Treatment

Biodegradation technology has been employed for many years in the wastewater sector. Utilising synergized blends of scientifically selected and adapted bacteria, enzymes, and nutrients, wastes associated with domestic, municipal, commercial, and industrial waste systems are readily transformed to waters of an acceptable standard to be put back into the natural environment. Treatment of Lake Rotoehu with non-pathogenic bacteria and enzymes will help to augment and accelerate nature's own biodegradation process, potentially resulting in the reduction of blue-green algae and improved water quality.

To see if such a technology is applicable to lake restoration problems, BOPRC is trialling this technology in a limited capacity in Otautu Bay, Lake Rotoehu. Initial shock dosing occurred at the end of 2011 and this has been followed up by regular maintenance dosing. Monitoring of sediment-sludge, sediment organic matter, invertebrates and sediment nutrients as well as lake water quality will evaluate the success of this trial. Initial results show that sediment-sludge has reduced in the bay.