Catchment Action Plan for Lake Ngaroto

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Acknowledgements:
We would like to thank Rebecca Eivers for your unfailing enthusiasm; Paula Reeves for your professional support; all the farmers in the catchment, especially Buck Macky, Darcy Finch and John Smyth who were on our steering committee - thank you; Jenny Charman for your gentle patience; and Natalie Pilcher for enabling us to undertake this work.

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Contents

Executive Summary

This Catchment Action Plan (CAP) is the culmination of a three year Ministry for the Environment (MfE) Community Environment Fund project coordinated by the NZ Landcare Trust in the Lake Ngaroto catchment in the Waikato region.

This Plan has been produced in conjunction with the farming community, local and regional governmental agencies, Iwi representatives and lake users.

During the course of this project, eight farms have completed Whole Farm Plans (WFP), and the Best Management Practices (BMP) currently being carried out on these farms have been recommended as actions for all farmers in the catchment.

For lake edge management recommendations, a scoping study of all the waterways draining into the lake was completed. A number of sites where actions could be taken to reduce suspended sediment and nutrient loads draining to the lake were identified. Recommendations include fencing of watercourses, riparian planting to provide shade and improve bank stability, as well as silt-traps, wetlands and habitat ponds. These can be seen marked on the map below, where the top five sites have been ranked and are listed in the following recommendations.

Map of top five sites for end-of-drain treatment systems

In-lake recommendations were also considered and these ranged from pest fish removal to floating treatment wetlands.

There are many actions that will help to improve the water quality of Lake Ngaroto and prevent it from deteriorating further. Financial considerations will mean not everything can be done at once. Therefore, actions have been prioritised into the top five recommendations we consider more likely to be achievable in the short term. These recommendations are a mixture of actions that can be undertaken by agencies such as Waipa District Council, individual landowners and Iwi/hapu and are listed below:

1. As the resource consent has already been lodged to set the lake level and divert the Lake Ngarotoiti inflow, we recommend this work be undertaken as soon as the consent is granted and weather conditions permit.

2. As the resource consent has already been granted for the demonstration silt trap site, we recommend that the works are undertaken as soon as the weather permits in spring.

3. Continue dialogue with farmers in the catchment to ascertain which Best Management Practices have been carried out since the project started in 2012. Encourage further uptake of these practices within the catchment's farming community.

4. As pest fish will re-suspend sediment, it is recommended to continue to control and expand pest fish control, as finances allow.

5. From the scoping study carried out on 3rd February 2014, the following five sites, in order of priority, would benefit from the installation of the recommended end-of-drain treatment systems:

    1) **Site 10/Ngar-9**
    Excellent potential site for silt-trap wetland and habitat pond:
        - At the time of the study, approximately 80% of the catchment was in maize (a likely source of sediment during ploughing and harvesting);
        - There is a spring and ponds in the upper catchment providing more permanent water levels and possible upstream habitat for migratory fish;
        - A raceway boarding the upper maize paddock is a likely additional source of sediment and nutrients;
        - There are gambusia, rudd and goldfish present in the stream under the bridge.

    2) **Site 7/ Ngar-6**
    Suitable site for silt-trap wetland:
        - At the time of the study, 100% of the upper catchment was in maize (a likely source of sediment during ploughing and harvesting).

    3) **Site 5 / Ngar-4**
    Suitable site for silt-trap wetland:
        - At the time of the study, approximately 95% of the catchment was in maize (a likely source of sediment during ploughing and harvesting);
        - This drain has been a previous silt-trap site;
        - There is a pond in the upper catchment providing possible upstream habitat for migratory fish.

4) **Site 15 / Ngar-13**
   Suitable site for silt-trap wetland and habitat pond:
   - It is likely the water table is shallow, given the water depth of the drain relative to it's short length and lack of flow at the time of the study, providing more permanent water levels;
   - At the time of the study, approximately 50% of the catchment was in maize and 50% in pasture;
   - This drain captures runoff from a raceway in the upper catchment; therefore it is a likely sediment and nutrient "hot spot".

5) **Site 25 / Ngar-18**
   Suitable site for silt-trap wetland and habitat pond:
   - There is a large area in which to create a wetland with additional amenity values;
   - The size of the drainage subcatchment needs to be confirmed.

These recommendations are available as an online interactive map:
https://mapsengine.google.com/map/viewer?mid=zK_2UNjQN0TM.k3EhmJauyR4U

This map enables the viewer to click on the different features around the lake, such as drains and wetlands, and read relevant information including the recommendations that have been made for each site.

Current state of Lake Ngaroto

Lake Ngaroto is located in the Waikato Ecological District and is the largest of the Waipa peat lakes. It is positioned south of Hamilton city and north-west of Te Awamutu.

Lake Ngaroto has poor water quality; however a major effort has been launched by Waipa District Council to return this lake to a more natural state, surrounded by native vegetation[1].

Lake Ngaroto is a shallow lake with a maximum depth of four metres and an average depth less than two metres. The catchment area covers 1846 ha and has 31 farms greater than 20 ha. The land use of the catchment is 1416 ha (77%) dairy pasture, 270 ha (15%) drystock pasture and 60 ha (3%) non-agricultural use (Environment Waikato, 2006).

The lake is a recreation reserve which includes an open water area of around 89 ha, and a considerable wetland margin of 60 ha, giving a total area of 149 ha. The Waipa District Council is responsible for day to day administration and management of the reserve.

Water quality in the lake has been impacted greatly by land use in the catchment resulting in a 'Trophic Level Index' (TLI) classification of 'hypertrophic' (Hamill & Lew 2006). Hypertrophic lakes are fertile and have extremely high levels of phosphorus (P) and nitrogen (N). They are rarely suitable for recreation and habitat for desirable aquatic species is limited[2].

[1] http://www.waikatoregion.govt.nz/Environment/Natural-resources/Water/Lakes/Shallow-lakes-of-the-Waikato-region/Peat-lakes/Lake-Ngaroto/

[2] http://www.lernz.co.nz/index.html

Cultural Importance of Lake Ngaroto

Map of Hingakaka Battle Area. Courtesy of Nga Iwi Toopu o Waipa

After the arrival of Maori on the shores of Kawhia, there began an inland migration circa 1400 - 1500 and Ngaroto was an important settlement area. Tribes and hapu lived here, over the next two to three hundred years, "cultivated their own food, using the nearby forest and lake as a food source (Amess et al. 1978), and as a resource for building materials, medicine, and traditional rituals and ceremony."[3]

Sometime between 1798 and 1808, a significant battle was fought between the Waikato-Maniapoto tribes of the Tainui Waka Tribal region, and a large force of tribes from throughout the middle and lower North Island. The battle took place within and around the area now known as Lake Ngaroto and along slopes of the Te Mangeo hills overlooking the lake.[4]

"The battle of Hingakaka, as it is known, is recognised as one of the largest battles in the Tainui Waka region in which warriors used solely traditional weapons, and was hailed as a great victory for the Waikato-Maniapoto tribes of Tainui.

As a result of this battle, the area around Ngaroto has significant national, historical, customary, cultural and spiritual significance for tangata whenua as kaitiaki of the region, and the descendants of the warriors that fell in the battle."[5]

There is currently a Treaty Claim for the Hingakaka battle site before the Treaty Tribunal by Ngāti Apakura and Lake Ngaroto is considered wāhi tapu (sacred site) by Ngāti Apakura[6].

A glossary of words in Te Reo can also be found at the end of this document.

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[3] Brookes J D and Hamilton D P. (2009) Lakes and Reservoirs of Australia and New Zealand. In: Gene E. Likens, (Editor) Encyclopedia of Inland Waters. Volume 2, pp. 513-523 Oxford: Elsevier.

[4] *Maniapoto, H., Charman, J., Roberts, G. 2006. Hingakaka-Ngaroto Iwi Management Plan. Compiled for Nga Iwi Toopu o Waipa.*

[5] *Ibid*

[6] Personnel communication with Jenny Charman from Ngāti Apakura. 2014

Development of the Catchment Action Plan (CAP)

The project started with setting up a steering group of key stakeholders, many of whom were already working in the catchment. The steering group comprised representatives from: local landowners, Waikato Regional Council, Waipa District Council, Ngā Iwi Toopu o Waipa, DairyNZ, the Sailing Club, the University of Waikato, Fonterra and Headlands[7].

The project was launched with a newsletter delivered to the catchment community, and then a background report on Lake Ngaroto was produced.

A Whole Farm Plan workshop was held at the Sailing Club rooms to provide information about WFPs to local landowners, after which farmers in the catchment were offered the opportunity to have a WFP completed for their farm. Eight WFPs were carried out over the course of the project by Headlands consultants. These plans look at actions that could be undertaken on a farm to optimise economic returns while minimising the impacts of agribusiness on the receiving environment[8]. Many of these actions were developed into Best Management Practice fact sheets which were sent to all landowners in the catchment.

A report on pest fish removal and uses was written in year two of the project and is being used by Waipa District Council to support a three year pest removal project at Lake Ngaroto.

A map of all the restoration work being carried out around Peat Lakes in the Waikato and Waipa districts was also created, using Google Map technology.

A field trip to another peat lake restoration project - in Horsham Downs - was cancelled when the trip date coincided with the drought breaking and farmers understandably reprioritised their time to complete on-farm work. In lieu of the field trip, a farmer phone survey was conducted. Among other things, this survey asked for suggestions for the Catchment Action Plan, and these suggestions were summarised and added to the Plan.

All of the aforementioned documents are available for download from the NZ Landcare Trust website: http://www.landcare.org.nz/Regional-Focus/Hamilton-Office/Lake-Ngaroto

A silt trap information day was held at Lake Ngaroto to introduce how silt traps can work to capture sediment transported via drains in runoff from farms, thereby preventing or minimising the quantity of sediment entering the lake. Andrew Hayes, a dairy farmer from Horsham Downs, came and shared what he and his family and others have done to improve two (previously) degraded lakes which their farm surrounds while operating a profitable farm business. Rebecca Eivers, a PhD student studying effective remediation measures to mitigate sediment and nutrient inputs from agricultural catchments to Waikato peat lakes, gave a presentation on the wetlands and silt traps she has been studying as well as the new ones she has created with Andrew Hayes. From this workshop, it was decided that installing a demonstration silt trap in the catchment - that local farmers could go and see - would be a good way to show the benefits of these end of drain treatment systems.

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[7] http://www.headlandsenviro.co.nz/

[8] http://www.headlandsenviro.co.nz/whole-farm-planning/

In year three, a scoping study was carried out, which included mapping all the drains running into the lake and a plan outlining recommendations for each site.

The CAP itself is broadly divided into three sections:

- Catchment level actions, such as on-farm mitigation measures;
- Lake edge actions, such as riparian management and end of drain treatment systems; and
- In lake actions, such as pest fish removal.

Sitting alongside are actions from some of the recreational users of the lake.

Overarching this entire project is Mātauranga Māori. "Mātauranga Māori can be defined as 'the knowledge, comprehension, or understanding of everything visible and invisible existing in the universe', and is often used synonymously with wisdom. In the contemporary world, the definition is usually extended to include present–day, historic, local, and traditional knowledge; systems of knowledge transfer and storage; and the goals, aspirations and issues from an indigenous perspective".[9]

[9] http://www.landcareresearch.co.nz/about/sustainability/voices/matauranga-maori/what-is-matauranga-maori

CAP Outcomes

Farmers' Perspectives

A phone survey of farmers in the Lake Ngaroto Catchment was conducted in April 2013 to gain further ideas and direction for the Catchment Action Plan. These have been summarised below.

Flooding of the lake is a major issue for some farmers and comments ranged from "Council should purchase flood prone land"* to "sensitive places in the catchment should be retired from farming". Water quality issues were also raised, including the problem of pest fish, algal blooms and in-lake sediment.

*Waipa District Council are aware of flooding issues and have offered to buy flood prone land on the lake margin but none of the adjoining landowners have taken up this offer to date.

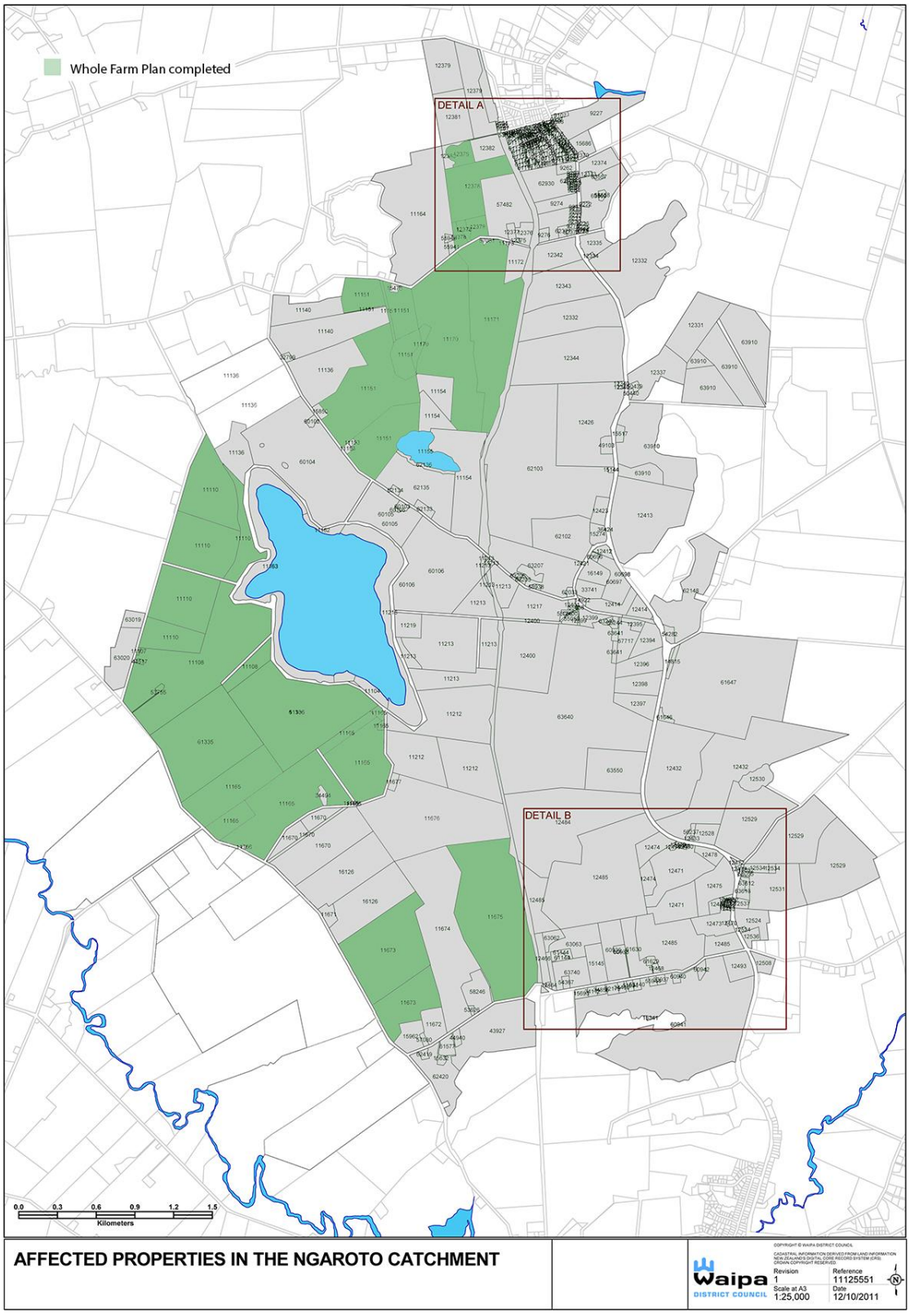
Ideas to improve the lake water quality ranged from "Testing the water in farm drains, before it comes into and after it comes out of the farm", to "Dredging a channel in the right place (in the lake) to flush the stuff out during flood events". Some people thought diverting the drain from Ngaroto-iti would be negative for Lake Ngaroto-iti and others thought it would be beneficial for Lake Ngaroto.

Ideas for improvement in the lake catchment included reducing N and P inputs on farms in the catchment, setting fences back from drains, and more weed control around the lake margin.

On-Farm Recommendations

Actions highlighted from Whole Farm Plans

During the first and second years of the project, eight WFPs were carried out on farms surrounding the lake and a map showing the participating farms within the catchment is on the following page:



The WFPs were subsequently used to determine what actions farmers could take to reduce the negative impact of some farming practices on the downstream receiving environment.

The summarised list of the Best Management Practices is given in the table below (in no particular order). Implementing these BMPs on all the farms in the lake catchment would make a positive difference to the water quality of the lake.

Action on Farm	Benefit to Environment
Strategic use of fertiliser.	Low use of synthetic N and soluble P reduces amount lost to environment.
Good water use efficiency achieved through recycling.	Reduced water take.
Upgrade of races on farm.	Runoff from races diverted into paddocks, avoiding direct runoff to waterways.
All waterways and drains fenced.	Stock excluded from waterways reduces faecal matter in the water and erosion of soil from the land and reduces nutrients and pathogens entering the lake.
Staff trained in the application of fertiliser.	No urea spread directly into waterways.
Monitoring soil fertility levels with regular soil testing and applying accordingly.	Reduces over-application of soluble N & P fertiliser.
Planting deep rooting summer active species (Chicory and Plantain).	Improves nutrient efficiency, helps cow productivity and draws nutrients from deep in the soil.
Animal shelter, with sealed base, for wintering cows.	Reduced pugging and pathogen loss in high risk months, soil protection and reduced runoff.
Feeding cereals to improve dietary balance.	Reduces the protein load for the cows which reduces urea load in urine, thus reducing nitrate leaching losses to groundwater.
Retiring and planting areas that are wet and swampy.	Grazing the wet/swampy areas causes significant soil disturbance resulting in P loss through soil erosion. Retiring wetlands would be a major benefit to Lake Ngaroto as it reduces the P loads in the drains leaving the farm, and enhances the denitrification potential of the wetlands helping to reduce N loads to the lake.
Effluent is applied to >30% of the farm and there is adequate storage. Manual storm water diversion is available.	This results in better N conversion efficiency and utilisation of a valuable nutrient resource. All cowshed and feed pad effluent is captured and pumped from the effluent pond. The large pond is then emptied going into winter.
Feed pad is used for stand-off during wetter months.	Some pugging is avoided and soil loss is reduced.
No winter cropping is done.	Reduces soil and P loss via runoff that occurs during winter high rainfall events.
Converting pine plantations to a more diverse selection of trees, including natives.	Provides a sustainable wood resource for the future. Supports natural biodiversity and improves long term aesthetic value of the property.
Planting steep sidlings and retiring and planting wet seeps in hillsides.	Reduction of soil erosion and nutrient losses, improves carbon sequestration and will also support biodiversity.
Wetland restoration (see Infiltration Wetlands below).	Runoff from farms is filtered through the wetland. Vulnerable areas are protected from stock whilst simultaneously protecting stock from misadventure. Planting native wetland species can provide nesting sites, food and shelter for wildlife as well as improving the natural character of the area.
Low stocking rate with high pasture harvest.	Very low nutrient loss risk. Aids soil protection. Is a low cost and resilient farm system.
Low rate application for effluent using LARRALL system.	Low rate applications and good effluent storage means there is the ability to plan applications for when soil moisture levels are suitable, enhancing nutrient efficiency and lowering risk to receiving environment.

Infiltration Wetlands

Infiltration wetlands can be retrofitted to shallow, ephemeral drains, especially at points where springs or seeps meet the surface. They can be used to capture fine sediment and reduce nutrients transported downstream. Particulate P (that which is adsorbed onto soil particles) can be filtered from the water by the wetland plants, while N can be denitrified and released into the atmosphere as N_2 gas, or used by wetland plants for growth (Kadlec & Wallace, 2008). Infiltration wetlands are best suited to sites with low flows and a low gradient, where there are natural depressions in the landscape and in areas with a shallow water table. These wetlands are better placed higher up the catchment on individual farms, rather than at the bottom of the catchment on the lake margin. Infiltration wetlands will be site-specific, and will most likely need specialist input and advice, and possibly a resource consent - check with the Regional Council. Ideally these wetlands will include a variety of plants ranging from wetland species such as rushes, sedges and *Carex* species, to riparian species such as flaxes, native shrubs and trees. Riparian plants, particularly trees, should be planted on one side, preferably the northern side, to shade the watercourse.

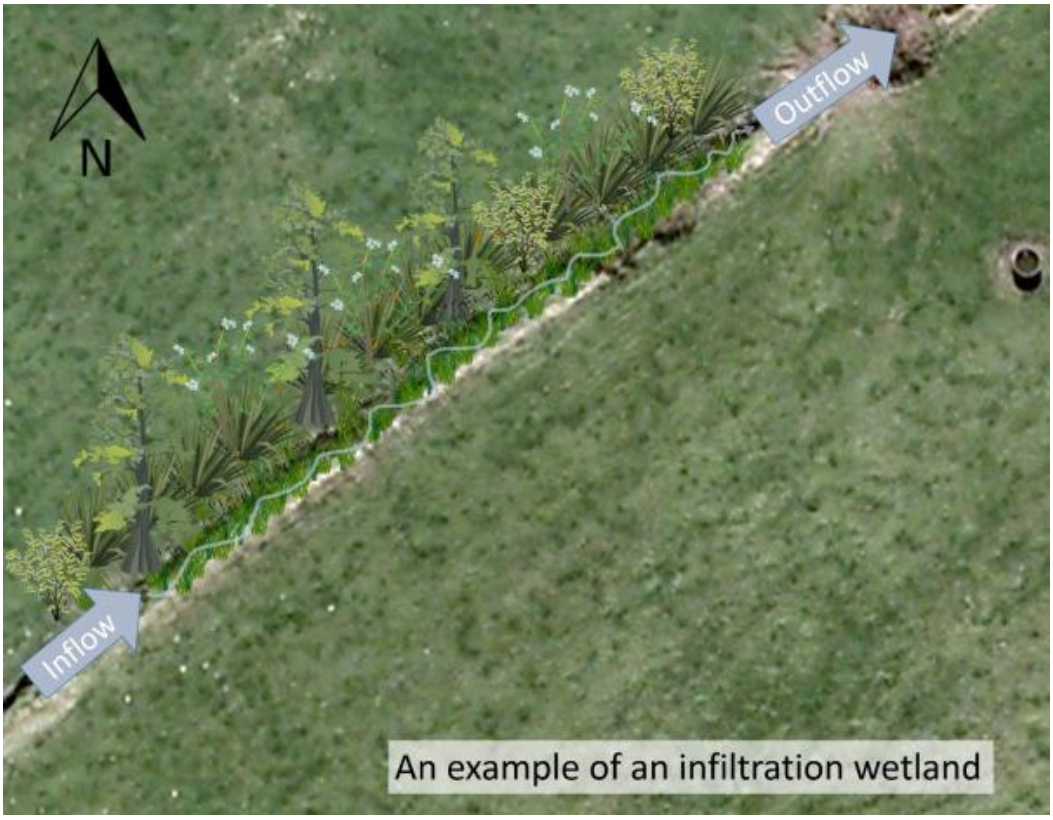


Image courtesy of Rebecca Eivers

Support from Waipa District Council

Landowners within peat lake catchments who make positive changes on their farms via a WFP that will benefit peat lakes can apply for an environmental benefit lot under the Proposed District Plan. Contact Waipa District Council for further information.

Lake Edge Management Recommendations

Waipa District Council actions

Waipa District Council has received funding from the Waikato River Authority (WRA) Clean-Up Fund to restore the lake margin over three years (2014-2017).

In the 1990's a great deal of effort was expended fencing the lake margin and planting the pioneer species manuka by the Waipa District Council. This was a ground breaking restoration project at the time and transformed the lake margin. Over time, manuka stands have been affected by citrus borer, which has led to the gradual collapse of these stands around the lake.

Photo showing die back of stands of manuka around the riparian area of Lake Ngaroto and the subsequent vegetation gaps being invaded by weed species (Photo credit: Waipa District Council)

As manuka collapses, it opens up areas for weeds to establish. There is now a considerable need to remove these weeds and to replant with more diverse native species to create the type of forest ecosystem that would have been present around the lake before the land was cleared for farming.

Richard Paul, a local volunteer, has been working tirelessly to clear weeds in the worst affected areas and replant with native species. The WRA funded project will further Richard's work around other parts of the riparian area of the lake. The aim is to replant approximately 60% of the lake margin by the end of 2017.

Pā sites

The Waipa District Council and Ngāti Apakura will work together to fence off a grazed historic pā site and remove exotic plant species from the sides of the pā.

Scoping Study

A scoping study of Lake Ngaroto was completed by PhD Researcher Rebecca Eivers in May, 2014. Rebecca assessed and mapped all the waterways draining into the lake on the 3rd

February 2014, (from the lake reserve) and measured their physical characteristics (length, width, depths and flows) as well as giving a brief description about each site.

The scoping survey identified a number of sites where actions could be taken to reduce suspended sediment and nutrient loads draining to the lake. Recommendations include fencing off watercourses; riparian planting to provide shade and improve bank stability; and the installation of silt-traps, wetlands and habitat ponds.

Recommended actions for each of the sites are summarised in Table 1.

Table 1 *– Summary of Recommendations for the drains going into Lake Ngaroto. Superscript numbers (1-5) refer to the order of preference for the suggested silt-trap wetlands. TRB: True Right Bank of watercourse; TLB: True Left Bank of watercourse*

Site	Fencing required	Recommendations	Distance to lake edge (m)
1	No	Floating wetland raft(s)	30
2	No	Riparian planting	70
3	No	Riparian planting; silt-trap	85
4	One-side, TRB	Riparian planting	78
5	No	Silt-trap wetland[3]	80
6	One-side, TLB	Riparian planting	85
7	No	Silt-trap wetland[2]	100
8	One-side, TLB	Riparian planting	110
9	One-side, TRB	Silt-trap	115
10	No	Silt-trap wetland[1]; riparian planting; habitat pond	115
11	Yes	Retire from pasture	80
12	No	Silt-trap; riparian planting	125
13	Yes	Weed management	60
14	No	Silt-trap; riparian planting; weed management	150
15	No	Silt-trap wetland[4]; riparian planting; habitat pond	90
16	Yes	Retire from pasture	70
17	Yes	Retire from pasture	100
18	No	Riparian planting	250
19	One-side, TRB	None	100
20	No	Weed management; riparian planting	50
21	Yes	Riparian planting	70
22	One-side, TLB	Riparian planting	85
23	Yes	Riparian planting	100
24	One-side, TLB	Silt-trap; riparian planting	150
25	No	Silt-trap wetland[5]; habitat pond	200

A map giving the locations of each site is also provided on following page.

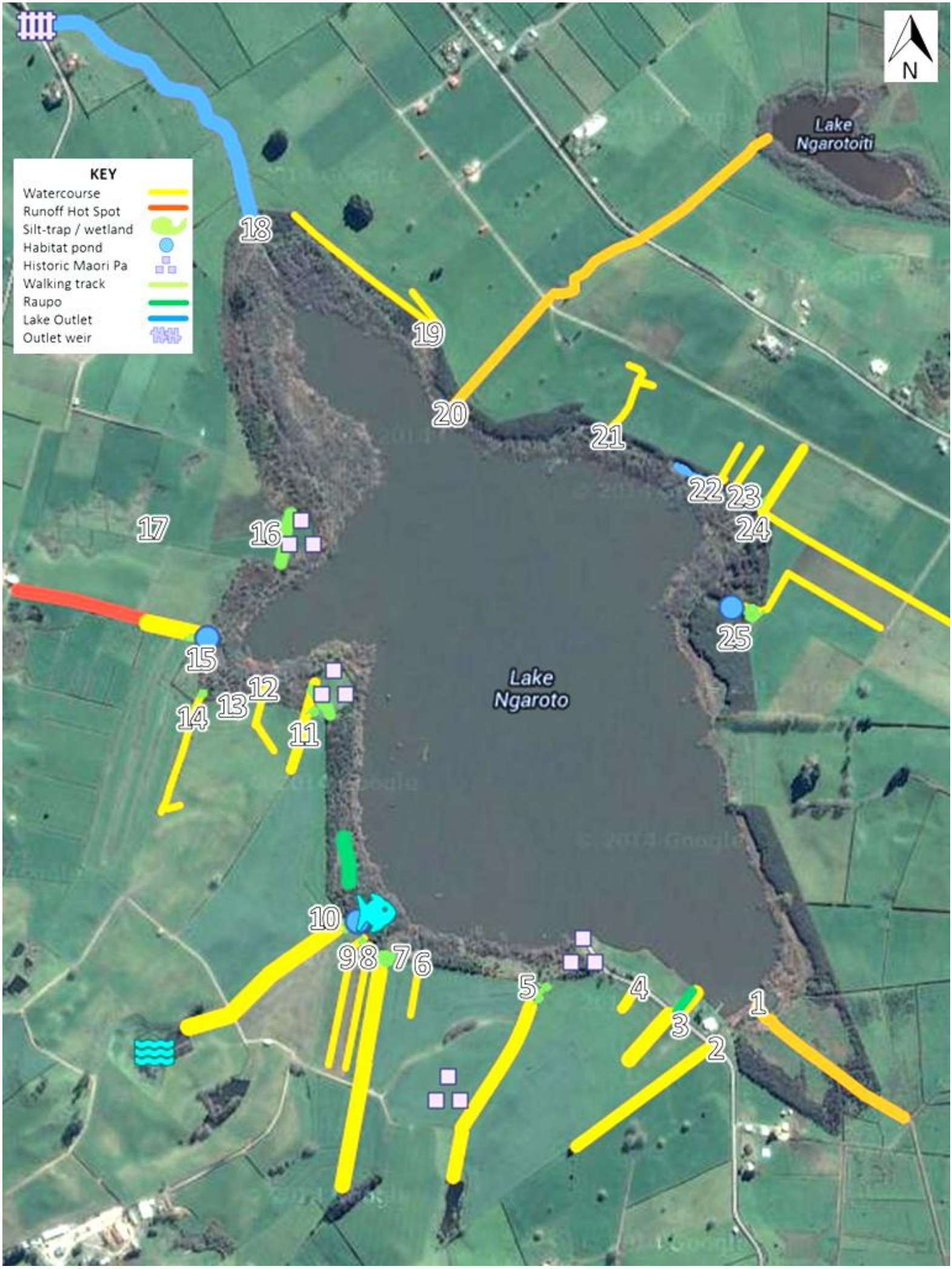


Image courtesy of Rebecca Eivers

As part of the scoping study, an interactive map has been created. The map enables the viewer to click on the different features around the lake, such as drains and wetlands, and to read information about the feature including finding out what recommendations have been made for the site. This map is available online at: https://mapsengine.google.com/map/viewer?mid=zK_2UNjQN0TM.k3EhmJauyR4U

Reducing sediment and nutrients into the lake

Soil and nutrients are best utilised on the land, so reducing their run-off is beneficial for the landowner and the lake. Many of the BMPs listed in the "On-farm recommendations" (see page 13) will help to minimise erosion and nutrient losses.

There are additional management options for reducing sediment and nutrient loss to waterways, which include the following:

Silt-traps are treatment systems designed to capture suspended sediment in drains carrying agricultural runoff thereby reducing sediment accumulation in downstream lake ecosystems. Sediment accumulated in lakes can reduce depths and exacerbate water quality issues as a source of stored phosphorus. Silt-traps can benefit both the aquatic environment and the land owner, as sediment captured in silt-traps can be used as a source of fertiliser on the farm when the silt-traps are cleaned out.

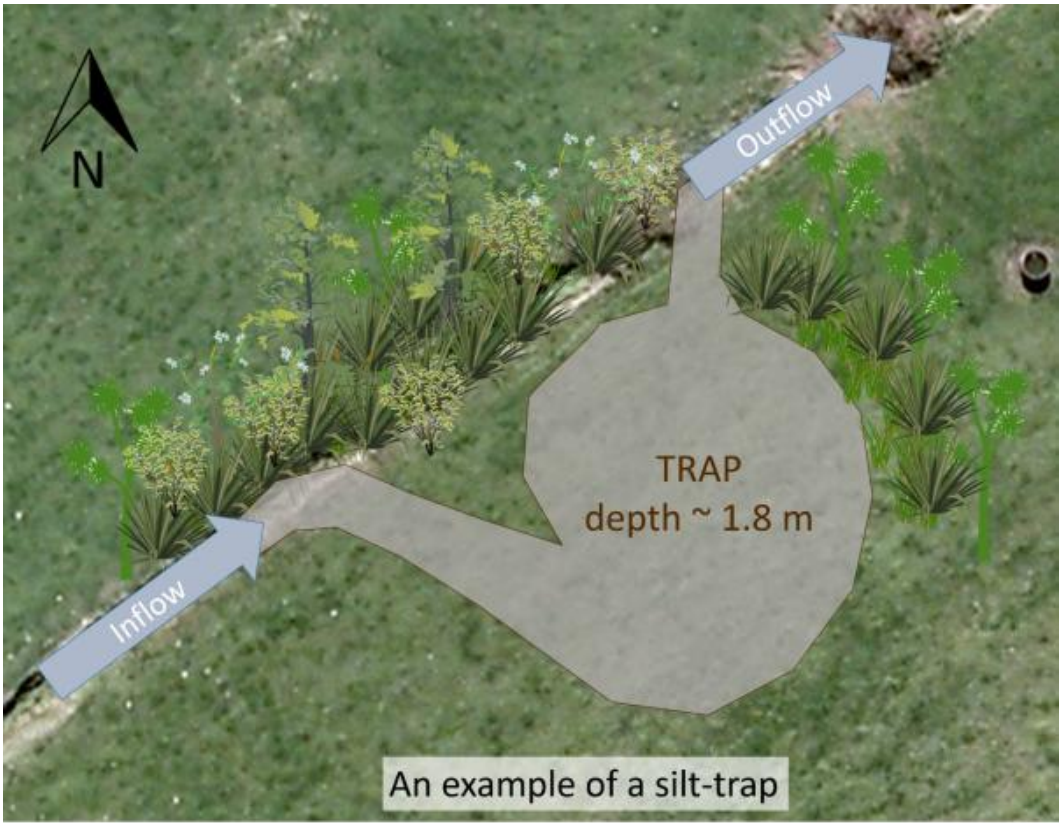


Image courtesy of Rebecca Eivers

Silt-trap wetlands are treatment systems designed to capture suspended sediment *and* nutrients including nitrogen and phosphorus. Wetland plants and aquatic communities use the nutrients in the water for growth therefore reducing the amount of nutrients flowing downstream into the lake.

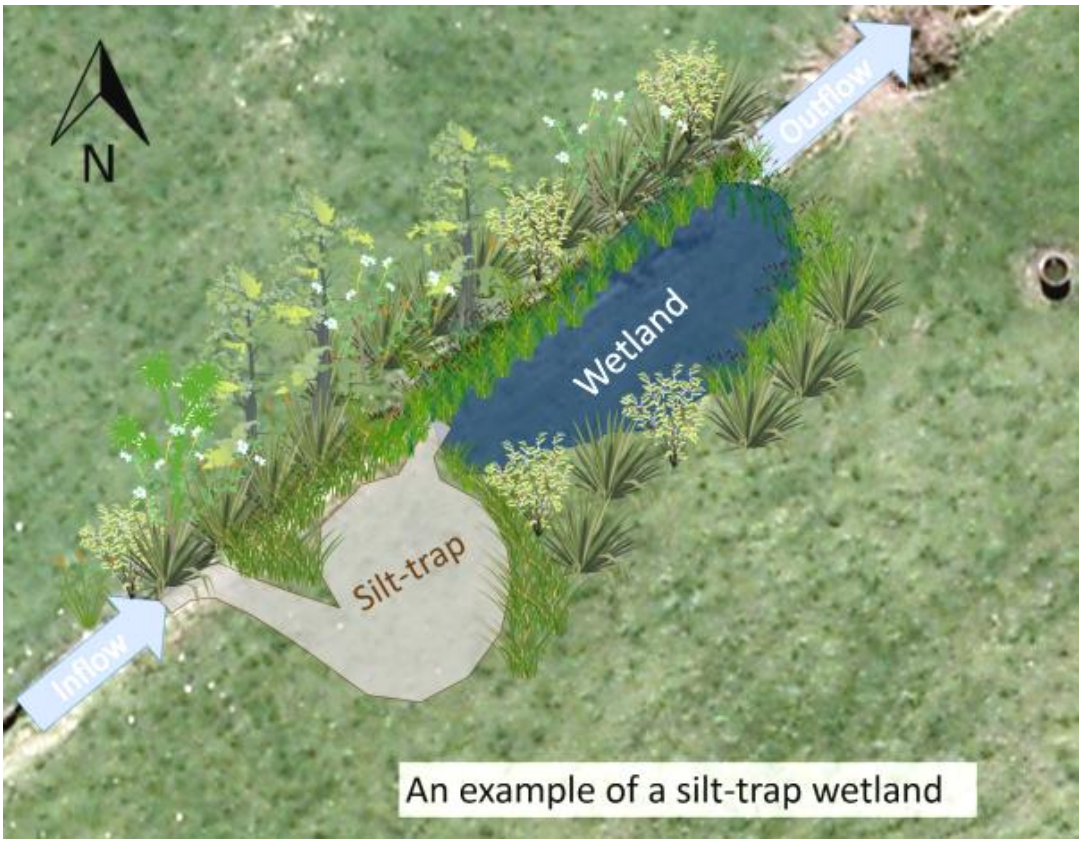


Image courtesy of Rebecca Eivers

Demonstration Silt trap

A resource consent application was lodged with Waikato Regional Council in early 2014, to install a demonstration silt trap on private land near the southern end of Lake Ngaroto. The aim is that farmers within the catchment will be able to easily view how a silt trap functions. The following diagram illustrates the silt trap and the native plants to be planted.

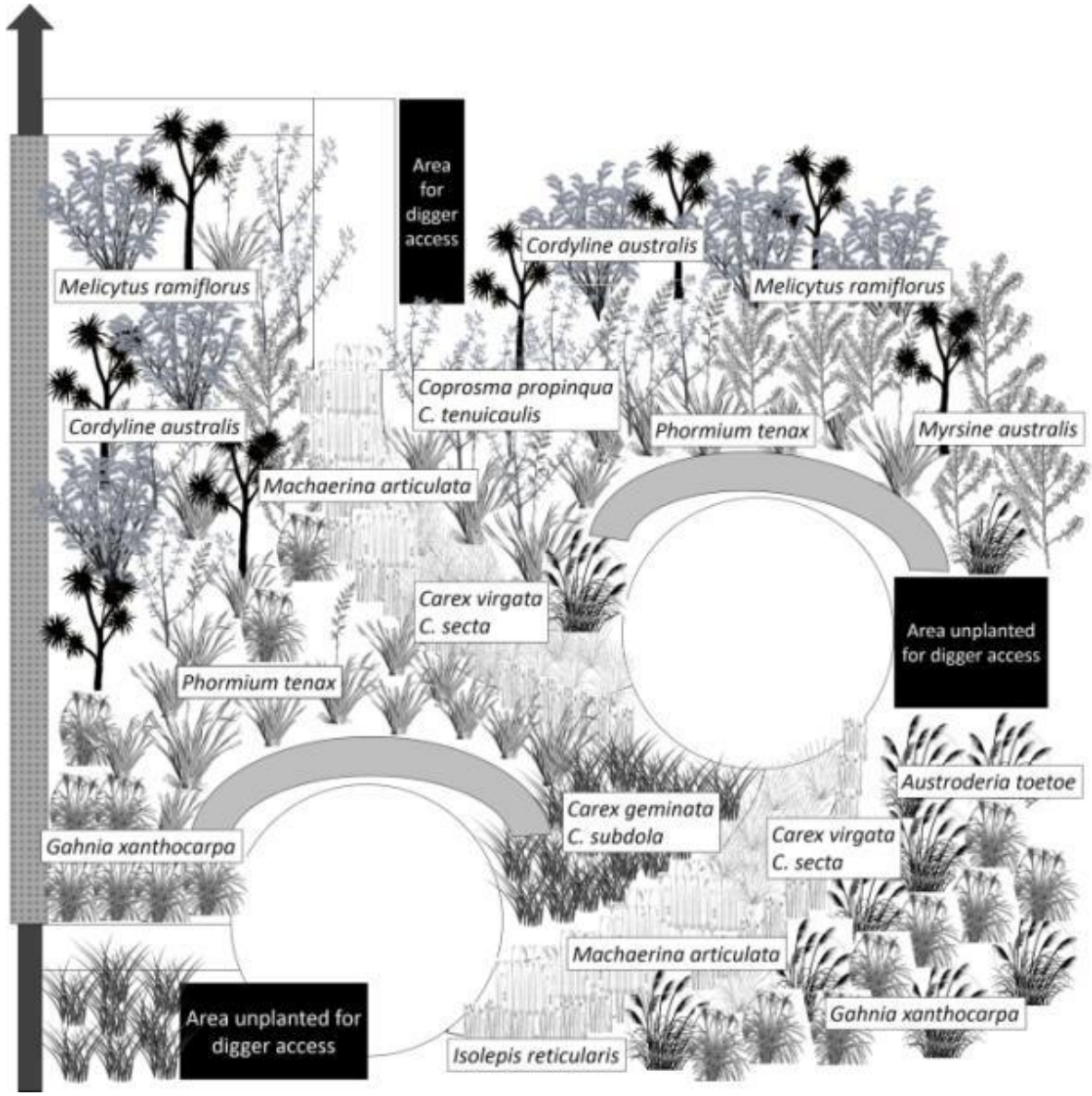


Image courtesy of Rebecca Eivers

Enhancing Habitats around the lake

Habitat ponds can be created to provide areas of refuge for aquatic communities such as plankton, invertebrates and native fish. These recreated aquatic habitats can also provide important amenity values for recreational users of the lakes' walkway. Exclusion of exotic pest fish using appropriate fish barriers can allow native aquatic communities to re-establish more successfully than in the lake.

An example of where this has happened can be seen in the habitat ponds developed around the margins of lakes Kainui and Kaituna in Horsham Downs. Native black mudfish were reintroduced into a number of habitat ponds around the margin of Lake Kaituna (McDonald, A., 2007) and are now believed to have established a self-sustaining population.

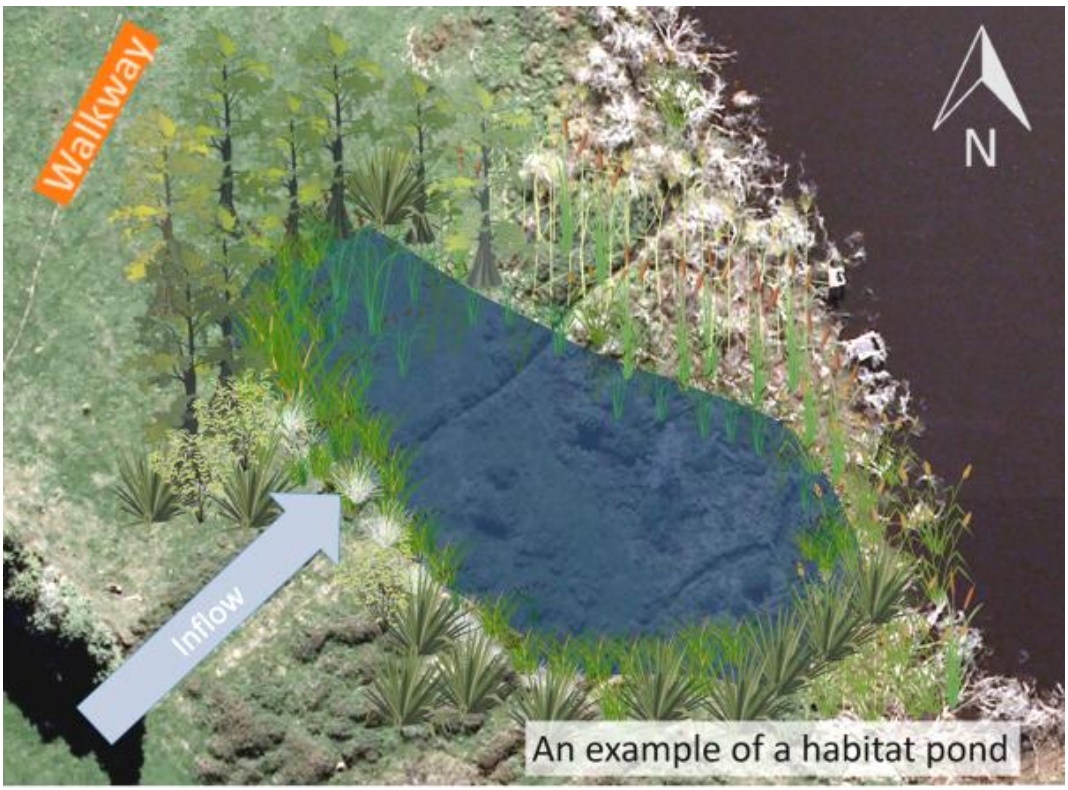


Image courtesy of Rebecca Eivers

Sand Beach

The Sailing Club would like to see a sand beach in front of the Club rooms for ease of launching and beaching boats.

Pest Control

There will certainly be animal pests such as rats, stoats, hedgehogs and possums around Lake Ngaroto. As Waipa District Council is continuing with its revegetation plan, it may be worth considering an animal pest control programme in the long term. Before starting a pest control program it is useful to consider:

- which native plants and animals are present
- which pests are present
- the levels to which pests have to be reduced to (and for how long) to make a difference
- sustainability questions
- what monitoring needs to be done in order to determine if the pest control is working and the desired results are being achieved
- ripple effects or side effects that might occur, and how to minimise these.

Side-effects include direct impacts, e.g. the accumulation of toxins in the environment and the trapping of non-target species. Ripple effects are undesirable biological responses to pest control such as the increase in rat numbers once stoats are controlled, which in turn could lead to increased predation of insects and seeds. Where possible, try to implement an integrated pest management programme targeting all serious biodiversity pests and potential problem species.

The timing and duration of pest control also needs to be considered. For example, if the recovery of seedlings, lizards and invertebrates is an objective, some level of rat control will be needed throughout the year.[10]

Enhancing Amenities and Education Values

There are between 20 000 and 25 000 visitors to Lake Ngaroto annually[11], many of whom walk around the lake. Suggestions for improving the 'experience' for these visitors include:

- Creating bird hides (areas where people can be screened to watch birds). Although hides were once built chiefly as hunting aids, they are now commonly found in parks and wetlands for the use of bird watchers, ornithologists and other observers who do not want to disturb wildlife as it is being observed[12];
- Seating around the lake at strategic, yet to be determined, points; and
- Further display/information boards describing, for example:
  - the significance of the lake for tangata whenua
  - historic pā sites
  - the ecological significance of flora and fauna.

[10] Pest Control Guidelines, 2012. NZ Landcare Trust.

[11] Personal Communication with Tony Roxburgh (2011)

[12] http://en.wikipedia.org/wiki/Bird_hide

In-lake Recommendations

Pest fish removal

Waipa District Council has received funding from the WRA Clean-Up Fund to remove pest fish from Lake Ngaroto for three years beginning in 2014. Pest fish present in the lake include bullhead catfish, rudd, goldfish, koi carp and gambusia. It is estimated that up to 8.9 tonnes of pest fish are present in the lake. The fish will be having a detrimental effect on water quality, lake marginal habitat and native fish species (Hicks et al. 2010).

Waipa District Council is proposing to carry out intensive netting to capture as many pest fish as possible from the lake over 16 catch nights per year. This will not eradicate pest fish from the lake but should decrease the total volume of pest fish and may contribute to an improvement in water quality. A monitoring buoy present on the lake is being used by the University of Waikato to monitor improvements in water quality and data can be requested from Waipa District Council.

The current weir site on Sing Road could potentially be retrofitted with a koi carp barrier which will allow adult koi carp to leave the lake, but not get back in again. An example of a koi carp barrier can be seen at Lake Ohinewai. Extra funding and a resource consent would be required for this barrier.

Koi carp barrier being lifted into place at Lake Ohinewai. This will enable adult koi to leave the lake, but not return. (Photo credit: J Gumbley, DOC)

The cumulative effect of a koi carp barrier and continual pest fish removal would, over time, help reduce the pest fish problem in the lake.

In addition, the feasibility of preventing the spawning of koi carp, during high flood events on low lying land to further reduce the koi carp population in the lake, should be investigated. After preventing access of adults to the lake, controlling spawning is important to minimise the ongoing impacts of pest fish.

The following would be useful to take into consideration if a feasibility study was to be undertaken:

- behavioural control[13] - manipulating some aspect of koi carp spawning behaviour to either aggregate the fish for control, prevent them spawning entirely, or to "collect" their eggs on structures so they can be removed and destroyed;
- chemical control[14] - using biodegradable products, although these require skill and are difficult to target to pest species (e.g. native fish are removed by electric-fishing prior to treatment, then replaced);
- physical control - preventing fish access to spawning sites by some kind of barrier. For example, bubble curtains[15] are being trialled in North America and early indications are that they effectively deter adult carp from spawning hot spots. Physical approaches, if practical, are usually preferable to chemical control especially if they are relatively passive and require minimum maintenance once installed.

Other things to consider include trapping the fish in baited traps, such as pod traps, that target pest fish species.

Events to raise public awareness about the problems caused by pest fish could also be held, similar to the koi carp classic event where bow hunters come and shoot koi carp in the lake - an event that we hope will require increasing skill levels as koi numbers decline! Koi carp could be made into berley (fish-bait) on-site, and given away to the attending public.

Over time, a small biodigester for the lake - similar to the one operating at Lake Waikare - could be installed as an alternative way of processing the pest fish that are caught, although the economic viability of this would need to be assessed.

Floating Treatment Wetlands

Floating treatment wetlands (FTW) could be installed in Lake Ngaroto as an in-lake restoration measure. FTWs consist of floating rafts through which aquatic or wetland plants grow, their roots emerging beneath the raft in the water (Tanner et al. 2011). FTWs remove nutrients and fine particles from the water by entrapment and uptake via the plants root systems, as well as through bacterial and algal biofilms on the root hairs and the matrix of the floating raft. FTWs provide shade which helps to cool the water and provide shelter for aquatic fauna. Trout and koura have been observed using FTWs as habitat in a number of lakes where they have been trialled in the Bay of Plenty (Rotorua-Lakes, 2014).

FTWs decrease water turbulence which may help to reduce sediment re-suspension in shallow lakes due to wave action and subsequently minimise the release of sediment bound phosphorus into the water column, helping to supress algal blooms. FTWs may be used to protect selected areas around the lake margin from wave disturbance thereby providing

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[13] Personal communications with Sue Clearwater and Cindy Baker NIWA, 2014

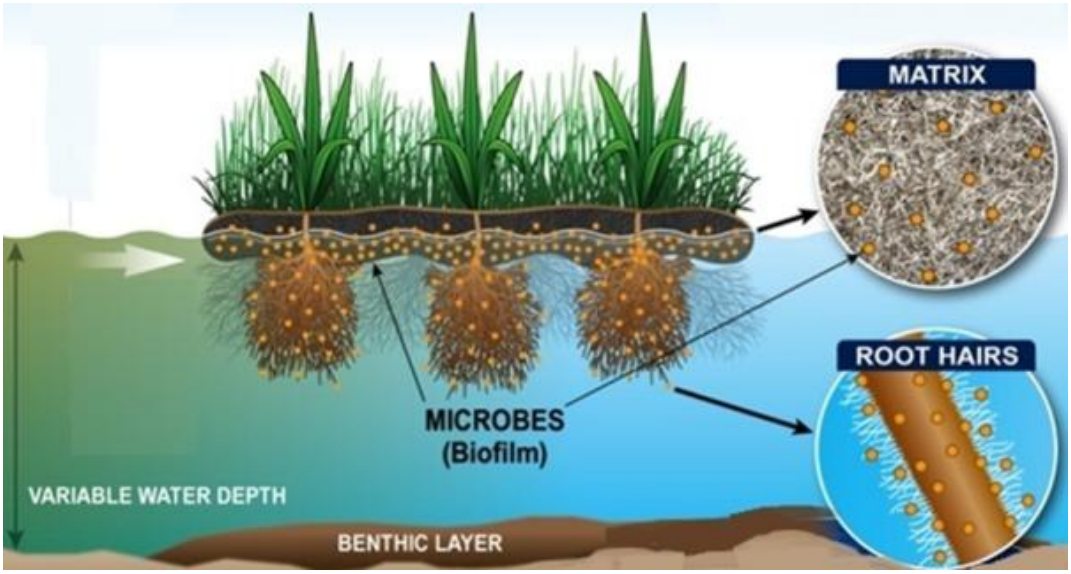
[14] Clearwater et al (2008). Overview of potential piscicides and molluscicides for controlling aquatic pest species in New Zealand. Science for Conservation 283, 74 pp. http://www.doc.govt.nz/publications/science-and-technical/

[15] http://en.wikipedia.org/wiki/Bubble_curtain

more favourable conditions for re-establishment of native macrophytes and charophyte meadows[16] on the lake bed.

Careful consideration of water depths and flows will be necessary to avoid creating stagnant areas. Still, warm water can cause anoxic sediment conditions during which phosphorus can be released into the water column and lead to algal blooms.

Further research and trials of floating wetlands in shallow lakes in the Waikato would enhance our knowledge of the efficacy of FTWs as in-lake restoration tools for targeting water quality, ecosystem health and biodiversity problems.



Schematic diagram of a floating wetland, courtesy of Rebecca Eivers

Algal Harvest

The Lake Ngaroto Sailing Club is often prevented from sailing on the lake during the summer due to potentially toxic cyanobacterial (blue-green algal) blooms. February would normally be an ideal sailing time otherwise. The Sailing Club would like to see a feasibility study done on the possibility of harvesting the algae/cyanobacteria from the surface of the lake, either by an automated boom or using a boat to skim the cyanobacteria/algae from the surface to reduce biomass in the lake.

A "proof of concept" trial was carried out in the Lake Rotorua/Ōhau Channel Algal Harvesting Project in 2010[17] indicated the harvesting of wild algae from a water body could be successfully achieved by the Aquaflow harvest method. As this was only a short term trial, further investigation would be required to ascertain if this could be an option for Lake Ngaroto.

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[16] http://www.landcareresearch.co.nz/resources/identification/algae/identification-guide/identify/guide/descriptions/charophytes

[17] http://www.boprc.govt.nz/media/99806/2010_20_lake_rotorua_ohau_channel_algae_harvest_project.pdf

For members of the Sailing Club, "it would be a shame to miss good sailing days just because the Chlorophyll A counts are high but the toxin levels are low or to expose ourselves to high levels of toxin just because it looks benign".[18]

In early 2010 the Ministry for the Environment released new guidelines for measuring and assessing levels of blue-green algae in waterbodies. Warning levels now take into account both the number of cells and their size. This is referred to as the "biovolume" of blue-green algae.[19]

Waikato Regional Council collect algae samples (but not toxin levels) from Lake Ngaroto ten months of the year, with the blue/green algae results published on their website here: http://www.waikatoregion.govt.nz/Environment/Natural-resources/Water/Rivers/Waikato-River/Algal-Blooms-in-the-Waikato-region/

The summary of blue-green algal blooms in Lake Ngaroto during 2010-2012 can be seen here: http://www.waikatoregion.govt.nz/Environment/Environmental-information/Environmental-indicators/Freshwater/Lakes/lake4-keypoints/
This shows that over half the samples exceeded recommended health levels.

Cyanobacteria can produce or contain toxins regardless of where they are in the water column.[20]

Cyanobacteria can produce a range of other toxins that can cause skin irritations and respiratory problems – thus even if none of the known cyanotoxins (including microcystins) are detected it does not mean there is no health risk. Contact with the water should be avoided when the total cyanobacterial biovolume is above the thresholds recommended in the New Zealand Guidelines for Cyanobacteria in Recreational Fresh Waters: https://www.mfe.govt.nz/publications/water/guidelines-for-cyanobacteria/. This document also provides background information on cyanobacteria and toxins.

Some cyanobacteria produce toxins which can pose a health risk to humans and animals. Toxin levels could be measured from a water sample. AgResearch can test for microcystins (the most common toxin produced by planktonic cyanobacteria in New Zealand) for approximately $100 per sample or the Cawthron Institute also test for toxins at about $350 per sample (Cawthron Institute use a different method which provides more information about which toxins are present). Also available, is the Abraxis Microcystin Strip Test Kit. This is a rapid 35 minute test for the qualitative screening of microcystins and nodularins levels in recreational water and can be purchased from Point View Laboratories Ltd in Auckland.[21] This test is designed for field testing, requiring no instrumentation or other equipment, power source or refrigeration. It can easily be used by lay people for toxin testing of water used for recreational purposes. Test results are read visually with interpretation of results up to 10 parts per billion. (See Appendix One).

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[18] Personal Communication with Robbie Price, member of Ngaroto Sailing Club (2014).

[19] http://www.waikatoregion.govt.nz/Environment/Natural-resources/Water/Rivers/Waikato-River/Algal-Blooms-in-the-Waikato-region/

[20] Personal Communication with Susie Wood, Cawthron Institute, (2014).

[21] Personal Communication with David Bunker, Point View Laboratories, Auckland (2014).

Lake Level Management

Lake Ngaroto Weir

A consent application to build a new weir at Lake Ngaroto was lodged with Waikato Regional Council on 28/02/14. The purpose of the new weir is to introduce a minimum level 34.34 m Moturiki Datum (see website in footnote for explanation of this unit)[22] for the lake all year round. It is proposed this will benefit the ecology of the lake by returning the lake to a more natural water level regime. The new minimum depth will also benefit recreational users of the lake for water sports, particularly yachting which would be possible year round with the higher water level. The present weir under the bridge on Sings Rd controls the lake level which is set at 34.34 m MD during the summer months (1 Oct-1 May) and is dropped to 33.89 m MD for the rest of the year.

The new timber board weir will be built within the reserve near the outlet of the lake (see map below) and will provide passage for people and bikes on top and for native fish beneath. Part of this project involves upgrading the circuit track around the lake. The track will be widened and more of it will be converted to boardwalk so it can be used all year round and accommodate pushchairs and bikes.

Image courtesy of Waipa District Council

[22] Moturiki Datum http://www.linz.govt.nz/geodetic/datums-projections-heights/vertical-datums/mean-sea-level-datums

Diversion of the Ngarotoiti inflow

One of the concerns of adjoining landowners in regards to changing the water level regime of Lake Ngaroto is the effect it may have on the water table outside of the reserve during the winter months, possibly increasing the likelihood of flooding. To minimise this effect the consent application for the weir additionally includes a proposal to divert the Lake Ngarotoiti inflow around the edge of the reserve (see map above). This will result in less water entering the lake (by about 30%) which will reduce the length of time land above 34.6 m MD (i.e. most of the adjoining land) will be flooded during the winter months. The diversion has been designed to trap silt and remove excess nutrients which will improve the quality of water reaching the Mangaotoma Stream. There may also be some improvements in water quality of Lake Ngaroto as a result of the diversion, as it will no longer receive sediment and nutrient inputs from Lake Ngarotoiti and its large catchment (*c.* 400 ha).

The Lake Ngarotoiti diversion will include the construction of a raised walking track on the lake side of the diversion as well as restoration of the wetland area between the track and the lake margin to improve habitat for native flora and fauna.

Photo courtesy of John Greenwood

Mātauranga Māori

"Mātauranga Māori can be defined as 'the knowledge, comprehension, or understanding of everything visible and invisible existing in the universe', and is often used synonymously with wisdom. In the contemporary world, the definition is usually extended to include present–day, historic, local, and traditional knowledge; systems of knowledge transfer and storage; and the goals, aspirations and issues from an indigenous perspective" (Landcare Research)[23]

By the 1800's various hapū of Ngāti Apakura had established mana whenua over lands which extended from Kāwhia along the coast and into the interior. Ngāti Apakura, Ngāti Hinetū and others established pā at Kakepuku, Pirongia, Waipā and Ngāroto.
The different lands which Ngāti Apakura held mana whenua over reflect what has been identified as a "fluid and complex" world in which hapū lived prior to the 1850's.[24]
Ngāroto is the site of the pā, Taurangamirumiru. The lake was very big and the ancestors were involved in aquaculture as well as farming of ducks and weka. Freshwater crayfish (koura), native fish and eels (tuna) were all harvested from the lake. "There were three pā that were floating pā, they did not just stay at Taurangamirumiru, there were about 200 people residing on those pā, floating on the lake."[25]

Some of the work proposed by Ngāti Apakura and Waipa District Council is to enhance two historic pā sites (Site 11 and 16 on the catchment map), by fencing out stock, and removing exotic plant species from the sides of the pā. Interpretation panels could also be installed. Enhancing these pā sites will help the general public to become more aware of the mana whenua of Ngāti Apakura over the lake and develop an appreciation of the historical significance of the lake.

Other suggestions include establishing a rongoa garden (traditional Māori medicinal garden) and/or a native plant nursery as well as monitoring the health of the lake using a Cultural Health Index (CHI) incorporating Mātauranga Māori principles (Robb, M.J. 2014).
The differences between a scientific and Mātauranga Māori approach are listed below[26]:

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[23] http://www.landcareresearch.co.nz/about/sustainability/voices/matauranga-maori/what-is-matauranga-maori

[24] Meredith, P, Nankivel, R, Joseph, R, 'Scoping Report for Ngāti Apakura Oral and Traditional History Report; (Crown Forestry Research Trust, 2010).

[25] Tom Roa, Te Rohe Pōtae Nga Korero Tuku Iho Manuscript, (Unpublished, Waipapa Marae, Kawhia, 29 - 30 March 2010)

[26] Robb, M.J. (2014). When Two Worlds Collide: Mātauranga Māori, Science and Health of the Toreparu Wetland. Master of Science, University of Waikato, Hamilton.

Scientific	Mātauranga Māori
• Generally quantitative and as objective as possible • Does not specifically encompass cultural values for Māori • Uses biotic and abiotic indicators • Often requires specialist training and equipment • A variety of tools, such as WETMAK, Handbook for Wetland Monitoring, DOC, Regional Council methods and Standard Operating Procedures (SOPs)	• Generally qualitative and subjective • Encompasses te ao Māori. The physical and spiritual domains • Indicators are developed by tangata whenua, for tangata whenua. E.g. Monitoring hapū goals and aspirations for a wetland • Requires historical knowledge and connection of tangata whenua to their tribal area/environment • Use site specific values/ priorities to develop indicators • A variety of tools such as CHI for wetlands, estuaries, rivers/streams, cultural flow assessment and the mauri model

Working with Ngāti Apakura, cultural indicators could be developed to monitor the lake. "Māori indicators are a tohu or marker in time, used to assess how Māori see their environment changing. Establishing a cultural health index provides methods that Māori organisations can use themselves to assess environmental change and prepare state-of-the-environment reports, or generate results that can be passed onto tangata whenua, iwi, hapu, local and central government".[27]

[27] Coordinated Monitoring of New Zealand Wetlands, Phase Two, Goal 2: Maori environmental performance indicators for wetland condition and tread. Ministry for the Environment SMF Funded project No. 5105. By Garth Harmsworth, Landcare Research. 2002

Lake Ngaroto Sailing Club

The Sailing Club's main issue is the poor water quality of Lake Ngaroto. The Club find it difficult to attract new members or junior sailors when there are signs and public notices advising to avoid contact with water due to high algae levels. They would like to see:

- A constant water level;
- Remediation measures to reduce the erosion of the foreshore in front of the Club rooms; and
- Management of raupō (native bullrush, *Typha orientalis*) to ensure it does not take over the lake and foreshore.

The Disabled Sailing Trust would like to start using Lake Ngaroto for its disabled sailing programme, and an extended jetty for ease of launch would be beneficial.

Lake Ngaroto Rowing Club

The Rowing Club has similar ideals to the Sailing Club. They would like to see a constant water level, management of the poor water quality and management of the raupō.

The club supports the installation of a weir which will ensure a more constant water level in the lake.

Since the club was established in 1963 the water quality of the lake has declined to the point where the club is now only just viable, due to members leaving because of the degraded water quality and algal blooms.

A few years back the club fundraised for a pontoon which has improved the ease of launching the rowing skiffs, but launching the coach boats does prove difficult at times. With a constant water level, a more permanent solution could be put in place i.e. sanded area for ease of launching.

Stakes in the lake are of concern too. The duck shooters put stakes in the lake each season for their decoys, but at the end of the season these stakes are not always removed. As the water levels drop, sometimes stakes appear, or even worse, do not appear and cannot be seen under the water level. During training boats pass over these stakes, which can cause major damage to the vessels. The coaches do look out for the stakes and mark them if they can.[28]

Photo courtesy of Te Awamutu Museum

[28] Personal Communications with Wendy Reynolds and Shane Swinerd, Ngaroto Rowing Club committee members (2014).

Prioritising of Actions and Recommendations

As summarised in this Catchment Action Plan, there are many actions that will help to improve the water quality of Lake Ngaroto and prevent it from deteriorating further, although financial considerations mean not everything can be done at once. Therefore, actions have been prioritised into the top five recommendations we consider more likely to be achievable in the short term. These recommendations are a mixture of actions that can be undertaken by agencies such as Waipa District Council, individual landowners and Iwi/hapu and are listed below:

1. As the resource consent has already been lodged to set the lake level and divert the Lake Ngarotoiti inflow, we recommend this work be undertaken as soon as the consent is granted and weather conditions permit.
2. As the resource consent has already been granted for the demonstration silt trap site, we recommend that the works are undertaken as soon as the weather permits in spring.
3. Continue dialogue with farmers in the catchment to ascertain what Best Management Practices are being carried out since the project started. Encourage further uptake of BMPs within the farming community.
4. As pest fish will re-suspend sediment, it is recommended to continue to control and expand pest fish control, as finances allow.
5. From the scoping study, conducted on the 3rd February 2014, the following five sites, in order of priority, would benefit from the installation of the recommended end-of-drain treatment systems:

    6) **Site 10/Ngar-9**
    Excellent potential site for silt-trap wetland and habitat pond:
    - At the time of the study, approximately 80% of the catchment was in maize (a likely source of sediment during ploughing and harvesting);
    - There is a spring and ponds in the upper catchment providing more permanent water levels and possible upstream habitat for migratory fish;
    - A raceway boarding the upper maize paddock is a likely additional source of sediment and nutrients;
    - There are gambusia, rudd and goldfish present in the stream under the bridge.

    7) **Site 7/ Ngar-6**
    Suitable site for silt-trap wetland:
    - At the time of the study, 100% of the upper catchment was in maize (a likely source of sediment during ploughing and harvesting).

    8) **Site 5 / Ngar-4**
    Suitable site for silt-trap wetland:
    - At the time of the study, approximately 95% of the catchment was in maize (a likely source of sediment during ploughing and harvesting);
    - This drain has been a previous silt-trap site;
    - There is a pond in the upper catchment providing possible upstream habitat for migratory fish.

9) **Site 15 / Ngar-13**
Suitable site for silt-trap wetland and habitat pond:
- It is likely the water table is shallow, given the water depth of the drain relative to it's short length and lack of flow at the time of the study, providing more permanent water levels;
- At the time of the study, approximately 50% of the catchment was in maize and 50% in pasture;
- This drain captures runoff from a raceway in the upper catchment; therefore it is a likely sediment and nutrient "hot spot".

10) **Site 25 / Ngar-18**
Suitable site for silt-trap wetland and habitat pond:
- There is a large area in which to create a wetland with additional amenity values;
- The size of the drainage subcatchment needs to be confirmed.

These actions are the ones we consider will assist to improve the water quality of Lake Ngaroto over time, and are more likely to be achievable in the short term. However, we consider this CAP to be a living document and the other actions within this document should also be considered as finances and time allow.

In the future, others actions not currently included could be added to this document and recorded on the interactive map:
https://mapsengine.google.com/map/viewer?mid=zK_2UNjQN0TM.k3EhmJauyR4U

Review

This CAP should be reviewed annually by Waipa District Council, and assisted by those parties that have an interest in the on-going management of Lake Ngaroto, such as Ngāti Apakura and Nga Iwi Toopu o Waipa, Waikato Regional Council, the Sailing and Rowing Club, University of Waikato, as well as individual landowners in the catchment.

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Glossary[29]

hapū	sub-tribe, extended whānau
iwi	tribe
iwi authority	the authority that represents an iwi and which is recognised by that iwi as having authority to do so
kaitiakitanga	the exercise of guardianship
kaumātua	a respected elder within the tribe
mahinga kai	food and other resources and the areas from which they are sourced
mana whenua	those who hold rangatiratanga for a particular area or district
matauranga maori	the knowledge, comprehension, or understanding of everything visible and invisible existing in the universe', and is often used synonymously with wisdom. In the contemporary world, the definition is usually extended to include present–day, historic, local, and traditional knowledge; systems of knowledge transfer and storage; and the goals, aspirations and issues from an indigenous perspective.[30]
mauri	the essential life force or principle; a metaphysical quality inherent in all things, both animate and inanimate
rangatiratanga	chiefly authority
rohe	area
rongoa	traditional Māori medicine. It includes herbal medicine made from plants, physical techniques like massage, and spiritual healing[31]
rūnanga	local representative groups or community system of organisation
takiwā	area, region, district
tangata whenua	the iwi or hapū that holds mana whenua in a particular area
taonga	all things highly prized including treasures, property, a resource or resources or even a person
tapu	sacred
Te Ao Māori	literally means *"the Māori world".* This includes Te Reo (the language and dialects), Tikanga (the processes and practices), Marae (the community focal point), Waahi Tapu (sites of importance) and access to whānau, hapū and iwi.[32]
wāhi tapu	sacred places
whānau	family

[29] Taken from "A Cultural Health Index for Streams and Waterways: A tool for nationwide use" A report prepared for the Ministry for the Environment by Gail Tipa and Laurel Teirney (2006)

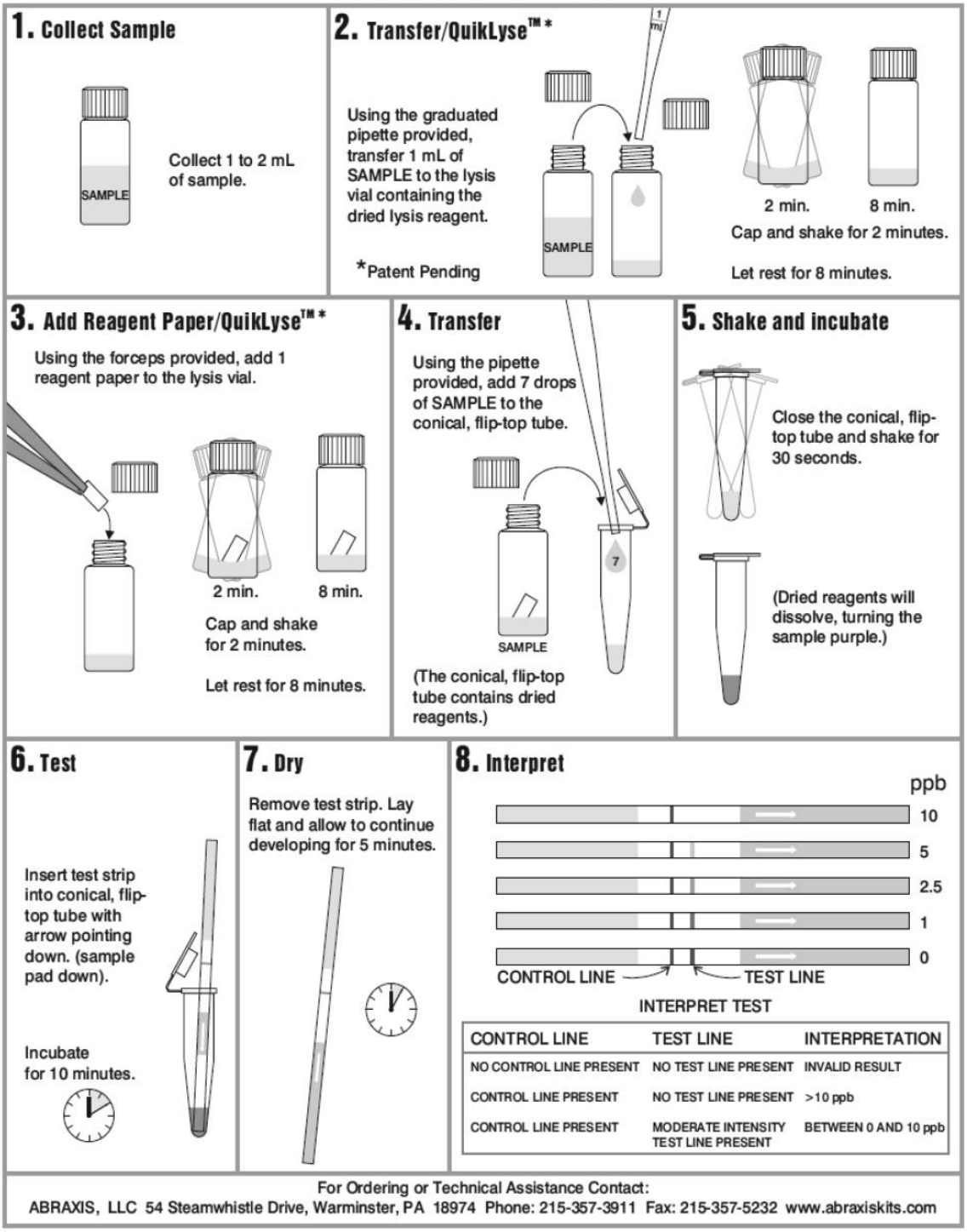
[30] http://www.landcareresearch.co.nz/about/sustainability/voices/matauranga-maori/what-is-matauranga-maori

[31] http://www.teara.govt.nz/en/rongoa-medicinal-use-of-plants

[32] http://en.wikipedia.org/wiki/Te_Ao_M%C4%81ori

Appendix One

Algal Toxin Strip Test (Microcystins) Recreational Water



ABRAXIS

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