Tarawera Lakes Restoration Plan

December 2015

Bay of Plenty Regional Council
Environmental Report 2014/12

5 Quay Street
PO Box 364
Whakatāne 3158
NEW ZEALAND

ISSN: 1175-9372 (Print)
ISSN: 1179-9471 (Online)

Summary

Lake Tarawera's TLI is currently 3.0 and does not meet its target of 2.6. The target TLI was established through a public process and confirmed within the Regional Water and Land Plan.

The main cause of the declining water quality (indicated by a high TLI) is an increase in nitrogen and phosphorus flowing from the catchment. To solve the problem, the level of nutrients entering the lake needs to be reduced to a sustainable load. This involves calculating how many nutrients are flowing to the lake from each source, and estimating the reduction to achieve the target.

The most recent nutrient budget indicates that phosphorus is more of a concern than past nutrient budgets may have signalled. The recommendation is to focus resources on reducing phosphorus, while capping nitrogen, to ensure further water quality decline does not occur.

Therefore, the interim reduction targets are:

- Phosphorus: at least 1,200 kg per year
- Nitrogen: no increase

These targets should be considered the absolute minimum required to improve water quality.

Although the exact proportions of phosphorus loads are still uncertain, approximately 44% of the phosphorus flowing to Lake Tarawera is from the seven surrounding lakes. Any restoration scheme to improve Lake Tarawera must consider these outer lakes as well as the inner catchment.

As the lake is impacted by the surface and groundwater inputs from seven other lakes, the development of the groundwater model is vital in establishing more robust information on water and nutrient inputs and finalising nutrient reduction targets. Until these targets have been developed more thoroughly, the 1,200 kg reduction of phosphorus can be considered the minimum reduction required to stabilise water quality.

In the meantime, the way forward to start reducing phosphorus to the lake is to:

- address known sources of phosphorus
- engage with landowners to gather information and identify voluntary actions
- review nutrient targets once groundwater work is completed.

The key actions are as follows:

1. Reticulation of sewage (reduction of 2,828 kg/year of nitrogen and 283 kg/year of phosphorus)
2. Better management of agricultural land- use (inner catchment)
3. Control of nitrogen fixing plants (reduction of 230 kg/year of nitrogen)
4. Better management of agricultural land-use (outer catchment)
5. Develop a rule to limit land-use changes that increase nutrients in the Tarawera System
6. Groundwater modelling

Contents

Part 1: Background

1 Introduction

1.1 Purpose

The Tarawera Lakes Restoration Plan (the Restoration Plan) seeks to identify actions to cap the total nitrogen and reduce total phosphorus concentrations in Lake Tarawera to improve water quality.

1.2 Scope and approach

Lake Tarawera receives the water from all the lakes in the Ōkataina Caldera. Lakes Ōkāreka, Ōkataina, Rotokakahi, Rotomahana and Tikitapu all drain into Lake Tarawera, either via surface water or groundwater flows. Lake Ōkaro and Lake Rerewhakaaitu drain first to Lake Rotomahana, then to Lake Tarawera.

Because of this interaction between lakes, the catchment of Lake Tarawera (the Tarawera System) is made up of an inner catchment and an outer catchment:

- Inner catchment – includes the land, surface water and groundwater that drain directly to Lake Tarawera.
- Outer catchment – includes the land, surface water and groundwater that drain to the seven other lakes in the Tarawera System before draining to Lake Tarawera.

The approach up until now has been to address each lake in isolation, without consideration of the interaction between lakes[1]. This approach is effective, as a reduction in nutrients in the catchment of any of the outer lakes will benefit both the immediate lake and Lake Tarawera. However, it doesn't consider the interactions between lakes or Lake Tarawera as the final destination of the nutrients.

Work is underway to build a groundwater model of the area, which will provide more information on the interactions between lakes. This work is expected to be completed in about twelve months, at which time a more accurate nutrient budget can be prepared with updated reduction targets.

With so little known about the outer catchment and its contribution to the phosphorus load to Lake Tarawera, the best approach is to reduce phosphorus from known sources while the groundwater model is finalised. In the meantime, discussions with landowners in both the inner and outer catchments will improve our knowledge of the current phosphorus load to the lake from this source, and lead to voluntary reductions.

1.3 Community engagement

In April 2015, the Tarawera Lakes Restoration Working Party (the Working Party) was set up to discuss the draft Tarawera Lakes Restoration Plan.

Representatives from a number of established organisations and groups were specifically invited to be members of the Working Party. Membership was kept open and additional groups and individuals joined as required. Members included iwi and hapū, councillors and staff from the Regional Council and Rotorua Lakes Council, landowners, Rerewhakaaitu Project and the Lake Tarawera Ratepayers Association.

[1] Five lakes in the Tarawera system already have approaches in place (Ōkāreka, Ōkaro, Ōkataina, Rerewhakaaitu, and Tikitapu) and investigations are underway to develop actions for the remaining lakes (Rotokakahi and Rotomahana).

The Working Party discussed the draft Restoration Plan – its approach, science, and actions. Regional Council staff also attended a meeting at Lake Rerewhakaaitu to explain the Restoration Plan and its implications to the outer lakes community.

From May to August 2015 the draft Restoration Plan was released to the public for feedback. The Regional Council received 59 feedback forms, 57 in support of the actions in the Restoration Plan. Two submissions were in opposition, specifically to reticulation of sewage in Action 1.

Following a Working Party meeting in August to discuss community feedback, alterations were made to the Restoration Plan.

2 Background

2.1 A brief history

Unless otherwise referenced, the information in this section was sourced from *Tarawera: The Volcanic Eruption of 10 June 1886*[2].

Before colonisation, the Rotorua lakes provided food, shelter, economic resources and primary transport routes for Te Arawa. The iwi used Mount Tarawera as a burial ground for chiefs and other persons of importance and the mountain is considered tapu.

Te Arawa is made up of iwi and hapū, based predominantly in Rotorua, tracing their ancestry back to the Arawa waka. Presently, Te Arawa has a population of about 35,127[3].

After colonisation, the "Hot Lakes" district attracted tourists from all over the world as stories of the boiling mud, geysers and other geothermal wonders spread. In particular, the Pink and White Terraces (Otukapuarangi and Te Tarata) on the shores of Lake Rotomahana were becoming known as one of the natural wonders of the world. Te Arawa played a major role in developing tourism in Rotorua, and acted as guides for visitors. They kept a significant degree of control over access and transport to the attractions of the area.

Settlers introduced trout and other exotic species into the Rotorua lakes, which depleted indigenous fish stocks and forced a reliance on the introduced species. The introduction of fishing licences led to further hardship for some members of Te Arawa already affected by the reduction of indigenous species.

Over the years, Te Arawa negotiated with the Crown for customary fishing rights, trout fishing licences and burial reserves in the lakes.

Developments in the late nineteenth century led to an increase in nutrients flowing into the lakes from clearing forestry, farming and septic tanks. The environmental degradation of the lakes has affected their mana and wairua[4].

[2] Keam, R. G., 1988 *Tarawera: The Volcanic Eruption of 10 June 1886.*

[3] Statistics New Zealand Census 2006.

[4] The New Zealand Government, 2006 Te Arawa Lakes Settlement Act 2006.

2.1.1 Mount Tarawera eruption

Mount Tarawera has three domes – Wahanga (bursting open), Ruawāhia (the split hole), and Tarawera (the burnt cliff). Prior to its eruption in June 1886, Mount Tarawera was believed to be extinct. At the time, most volcanoes in New Zealand other than White Island (Whakaari) and Tongariro were considered dormant.

Visitors to the Pink and White Terraces started at the town of Te Wairoa, located at Lake Tarawera. A steep track went from Te Wairoa to Rotomahana for those who hired horses, but the preferred travel route was by boat across Lake Tarawera to Te Ariki and then up the Kaiwaka Stream.

About two weeks prior to the eruption, unusual events created unease. Tourists and locals noticed strange surges in lake level, and at the Terraces there was evidence of recently ejected mud from the geysers.

The most unusual event was the sighting of the waka, or "phantom canoe" as it became known. Eyewitnesses in a tourist boat, both Māori and Pakeha, saw a large war canoe with a high prow and stern being paddled on the main body of Lake Tarawera. The day was clear and bright with no clouds, and they could see the waka and the flashing of the paddles clearly. The canoe did not respond to hails and disappeared around a headland. Local Māori regarded the canoe as an apparition, as they had no waka like the one seen on the lake. Spectral appearances such as this indicated calamity.

Mount Tarawera erupted in the very early hours of 10 June 1886. Strong earthquakes were felt in the Rotorua area and lightning was seen around Mount Tarawera. By 2:30 am all three peaks had erupted, sending ash and smoke thousands of metres into the air. A rift tore open the domes of Ruawāhia and Tarawera and a large new crater emerged at Rotomahana. The Rotomahana crater generated a surge of hot scoria, mud pellets, and balls of fire that destroyed Te Wairoa and other surrounding villages. Buildings collapsed and were buried under mud and ash. Approximately 120 people were killed.

Rotomahana and Rotomakariri were now one crater which later filled with water to become the present day Rotomahana. There was no trace of the Pink and White Terraces and they were long believed to be destroyed. In 2011, researchers mapping the bottom of Lake Rotomahana found their remnants[5]. They are now believed to be buried in sediment under the lake, rather than destroyed.

2.1.1 Farming development

In the late 1920s, the land to the south of the lake was identified as third class land, heavily faulted with some steeper contours, bush sickness (cobalt deficiency), and unsuitable for farming. Allen Ford, while hunting on what was then called Run 78 on the Government maps, saw possibilities for the land as sheep and cattle country. After petitioning the Commissioner of Crown Lands to open this area for farming, Allen Ford, in partnership with his father Henry Ford, were granted a lease for part of Run 78.

Despite its contours, Run 78 was fertile volcanic soil, ranging from medium pumice clay to Rotomahana mud and ash from the recent Tarawera eruption. The biggest drawback to the property was the inaccessibility of water. Although the property has high rainfall (1,500 millimetres per year on average) and surface water on two boundaries (Wairua Stream and Rotokakahi) water supply for domestic and stock use had to be pumped 120 m up from the swamp in the lagoon valley, leading to Rotokakahi.

[5] www.gns.cri.nz/Home/News-and-Events/Media-Releases/Scientists-find-part-of-Terraces.

The land was covered in scrub and regenerating forest populated with wild animals, mainly cattle, horses, and deer. The early days of what would become Highlands Station were spent clearing tracks, digging a water reservoir, clearing trees and removing stumps.

All topdressing and sowing was carried out by hand until 1951 when aerial topdressing was introduced. This was a turning point for hill country farms. The farm was connected to electricity in 1954 which allowed the Ford family to live permanently on the farm.

In the 1950s the Government bought land for settlement by returned servicemen and in the 1960s neighbouring farms were developed. The families of these farms, Travers, Keeling, Doney, Ross, Armer and Lambie have been on the land for generations. For all but one, the families that originally purchased the land from the Government are still farming there today.

Although some dairying was carried out on Highlands Station, the contour of the land was better suited to dry stock and in 1961 dairying ceased and the farm became all sheep and cattle. From 1968 and through to the 2001, deer were added to the stock during the venison and velvet boom.

2.2 Te Arawa Lakes Treaty Settlement

On 18 December 2004, a Deed of Settlement was signed between The Crown and Te Arawa for the cultural, financial and annuity redress and the transfer of 13 lake beds to Te Arawa[6]. These 13 lakes include Lake Tarawera and six other lakes of the Ōkataina Caldera – Ōkataina, Ōkāreka, Rerewhakaaitu, Rotomahana, Tikitapu and Ōkaro. The content of the Deed is enshrined in legislation which was passed in 2006.

The Te Arawa Lakes Settlement Act returns the title of the lakebeds to Te Arawa. This includes the ownership of the lake beds (including plants attached to the lake beds) and the subsoil of the lake. At this stage the water column and the airspace remain in Crown ownership. The water itself is a public asset and continues to be regulated according to the Resource Management Act 1991.

The Settlement Act protects all existing rights, including public access and use of the lakes. Any new structures or modification to existing structures need the consent of both Te Arawa and the Crown.

In 2007, a Memorandum of Understanding (MoU) was signed between the Crown, Te Arawa Lakes Trust, Rotorua District Council and Bay of Plenty Regional Council. The MoU acknowledged, that although the lake beds had been returned to Te Arawa ownership, the water quality was poor and the lakes infested with exotic weeds. It recognised that these legacy issues were created over a long time and that restoration of the lakes would take significant time, effort and financial resources. The MoU also set out the roles for each of the four parties.

2.3 Legislation

In May 2010, the Government released the National Policy Statement for Freshwater Management (the NPS) which was updated in 2014. The policy explicitly requires regional councils to improve the water quality of degraded water bodies and make changes or variations to plans to introduce policies and rules[7] to achieve this.

According to the definition in the NPS, most of the Rotorua Te Arawa Lakes are degraded. The Regional Council has also identified the Rotorua Te Arawa Lakes as at risk in the

[6] The New Zealand Government (2006) *Te Arawa Lakes Settlement Act 2006.*

[7] The New Zealand Government (2011) *National Policy Statement Freshwater Management 2011.*

Regional Policy Statement[8]. The Bay of Plenty Regional Water and Land Plan (the RWLP) contains objectives, policies and methods to specifically address the issue of declining water quality in these lakes.

The Regional Plan for the Tarawera River Catchment (the Tarawera River Plan) has provisions that control activities within the catchments of lakes Ōkaro, Ōkāreka, Ōkataina, Rotokakahi, Rotomahana, Tarawera, Tikitapu and the catchment of the Tarawera River. The main focus of this plan is to control discharges in the lower reaches of the river. Many of the provisions have been superseded by the RWLP. The Tarawera River Plan has been reviewed according to the Resource Management Act (requirements for regional plans). Regional Council resolved to replace the Tarawera River Plan with a new catchment plan. Development of this new plan will start after the community involvement process for this catchment in 2018.[9]

Currently, Te Arawa and Affiliate Te Arawa Iwi and Hapū have statutory acknowledgments in place that cover Lake Tarawera and its catchments[10]. A statutory acknowledgment is a formal acknowledgement by the Crown of the mana of tangata whenua over a specified area. It recognises the particular cultural, spiritual, historical and traditional association of an iwi with the site, which is identified as a statutory area. These statutory acknowledgments require consent authorities, the Environment Court and the Historic Places Trust to have regard to the statutory acknowledgement, to forward summaries of all applications for resource consents to the trustees and enable the trustees and members to cite the statutory acknowledgment as evidence of their association with the statutory area.

2.4 Importance to the community

The community of Lake Tarawera (both permanent residents and visitors) is passionate about the lake and is anxious to keep it in good condition. The aspects of the lake that the community like are:

- Native bush and scenery.
- Water quality good enough to allow fishing, boating and swimming.
- Iconic features like Mount Tarawera and Hot Water Beach.

The community's main concerns are:

- Declining water quality - once water quality has deteriorated it may never recover.
- Number of pests, both aquatic and land-based (pest trees on Mount Tarawera, catfish, hornwort, rats, wattles, possums, swans).

2.5 Importance to tangata whenua

2.5.1 Māori environmental management

The relationship of Māori and their culture and traditions with their ancestral lands, water, sites, waahi tapu and other taonga is recognised as a matter of national importance in the RMA. The concept of kaitiakitanga and the ethic of stewardship are included as other matters to consider when carrying out duties under the RMA.

[8] The Bay of Plenty Regional Council (2010) *Bay of Plenty Regional Policy Statement October 2014.*

[9] The Bay of Plenty Regional Council (2015) *Bay of Plenty Regional Plan for the Tarawera River Catchment Review and Options,* Staff Report to Regional Direction and Deliver Committee, July 2015.

[10] The Bay of Plenty Regional Council *Nga Whakaaetanga-a-Ture ki Te Taiao a Toi – Statutory Acknowledgments in the Bay of Plenty.*

For Māori, water is a taonga, a treasure, and is very highly regarded. Māori identify themselves in terms of their ancestors and their rivers and mountains. Māori consider water bodies to be their ancestor, a part of their family and a part of them. When a freshwater body is mismanaged, it hurts not only the water body itself, but the tangata whenua who identify with it.

In the past when travelling away from the coast, Māori relied heavily on freshwater bodies as a source of food including tuna (eels), kakahi (mussels) and koura (crayfish) as well as edible plants. Māori of today still use freshwater bodies as important food sources as well as for ceremonial purposes. Rivers, lakes and streams are an important part of their cultural heritage and identity.

In Māori environmental management, all resources have mauri (an energy which binds and supports life). The mauri of each water body is a separate entity and cannot be mixed with the mauri of another. This conflicts with the traditional western view that water can be diverted, dammed and used to take away waste. The pollution and alteration of a water body diminishes its mauri and affects its ability to provide food from this source.

Practices, or tikanga, are used to maintain the mauri of resources. The ongoing observation of these tikanga has led to the development of the ethic of kaitiakitanga. Kaitiakitanga is most simply translated as guardianship, but it also includes care, wise management and the use of resource indicators (where resources themselves indicate the state of their own mauri).

The degradation of Lake Tarawera and its surrounding catchments, is of concern to all tangata whenua who are connected to the lake by whakapapa (genealogy) within their rohe. The extent to which the land-use changes and declining water quality has impacted on tangata whenua values is currently unknown. This has been identified in this document as an area for further investigation and action.

2.5.2 Iwi and hapū of Lake Tarawera

This section discusses the issues of the three core iwi and hapū that identify Lake Tarawera as part of their rohe. There are many other iwi and hapū which have an interest in Lake Tarawera who have not been included here.

2.6 Te Arawa

Te Arawa is one of seven Māori Tribes of New Zealand whose rohe extends from Maketū to Tongariro in the central North Island. Te Arawa has a long history with the Rotorua Te Arawa Lakes and Lake Tarawera, as summarised in the sections above.

The Te Arawa Lakes Trust is a partner in the Rotorua Te Arawa Lakes Strategy Group (alongside Rotorua District Council and the Bay of Plenty Regional Council). As a partner, they are committed to ensuring the lake water quality does not decline further, and that action is taken to improve Lake Tarawera.

2.7 Tūhourangi Tribal Authority[11]

Tūhourangi Tribal Authority was established to manage the Treaty of Waitangi settlement benefits relating to the Hapū of Tuhourangi (part of the Te Pumautanga o Te Arawa settlement in 2008).

[11] Tūhourangi Tribal Authority (2011) *Enhanced Iwi Environment Resource Management Plan*.

Their rohe is from Moerangi (including the Whakarewarewa Forest), Haparangi and Horohoro bluffs to the west, south to Kakaramea (Rainbow Mountain) and east to Ruawāhia (Mount Tarawera). Hapū of Tūhourangi also reside in the Te Puke area.

Environmental concerns include the contamination of the Puarenga Basin, the geothermal fields and the health of waterways, including Lake Tarawera and Rotokakahi.

2.8 Ngāti Rangitihii[12]

Ngāti Rangitihi is descended from Rangitihi, the great great grandson of Tametekapua, the commander of Te Arawa Waka. Although he was born at Maketū, he and many of his descendants moved inland to other areas, including Lake Tarawera. They resided at the inland lakes for hundreds of years alongside Tūhourangi and other Te Arawa iwi.

In 1886, the Tarawera eruption caused significant loss of life as well as devastating villages, pā, gardens and the landscape. Whānau gathered at Matatā and travelled inland to look for survivors. The survivors and their whānau settled at Matatā and remain there to this day.

Their rohe covers the Maketū area (the birth place of Rangitihi and the arrival place of Te Arawa waka), the Kaituna River, Lake Tarawera, Tarawera River, Kāingaroa Plains, Rangitaiki River and south to specific places on the Waikato River.

The Ngati Rangitihi Iwi Environmental Management Plan, includes objectives to address the issues of alteration of water bodies and their ability to support fish and bird habitats. The restoration and enhancement of specific water bodies, including Lake Tarawera, is identified as an objective. Other objectives relating to water, concern the issue of the discharge of contaminants and the overuse of finite freshwater resources.

3 Lake characteristics

3.1 The lake today

Lake Tarawera is the second largest lake of the twelve Rotorua lakes managed for water quality by the Bay of Plenty Regional Council (the largest is Lake Rotorua).

At a glance:

- Lake size: 4,138 ha
- Catchment area: 14,472 ha
- Elevation: 298 m
- Average depth: 50 m
- Deepest point: 87.5 m
- Formed: 5,000 years ago
- Outflow: Surface via the Tarawera River

About 391 houses are located at the lake with about 25% occupied all year round by 290 residents. The remaining 75% of houses are used as holiday accommodation. There are anecdotal reports of an emerging trend of bach owners that have been holidaying at the lake for the past few decades, retiring and living at the lake permanently.

[12] Te Mana o Ngāti Rangitihi Trust (2011) *Te Mahere a Rohe mo Ngāti Rangitihi – Ngāti Rangitihi Iwi Environmental Management Plan.*

Lake Tarawera is a popular lake, providing a variety of recreational uses for residents and visitors:

- Water activities – kayaking, sailing, water-skiing, ski-biscuiting, jet-skiing, swimming.
- Fishing – Lake Tarawera has a well-stocked trout fishery.
- Walking, tramping and camping – there are several walking and tramping tracks around Lake Tarawera with camping grounds located at The Outlet, Humphries Bay and Hot Water Beach.
- Tourist attractions – the Buried Village of Te Wairoa, Hot Water Beach, trout fishing and an ascent of Mount Tarawera attract visitors to the lake.
- General activities – parks and reserves adjacent to the lake provide public facilities such as boat ramps, playgrounds and public toilets.

Map 1 (page 11) shows the main recreational uses of Lake Tarawera.

The inner catchment includes the land, streams, and groundwater that run directly into Lake Tarawera. Land cover in the inner catchment is mostly native and exotic forest with some pasture as shown in Figure 1 and Map 2 (page 13) (information sourced from the 2012 nutrient budget).

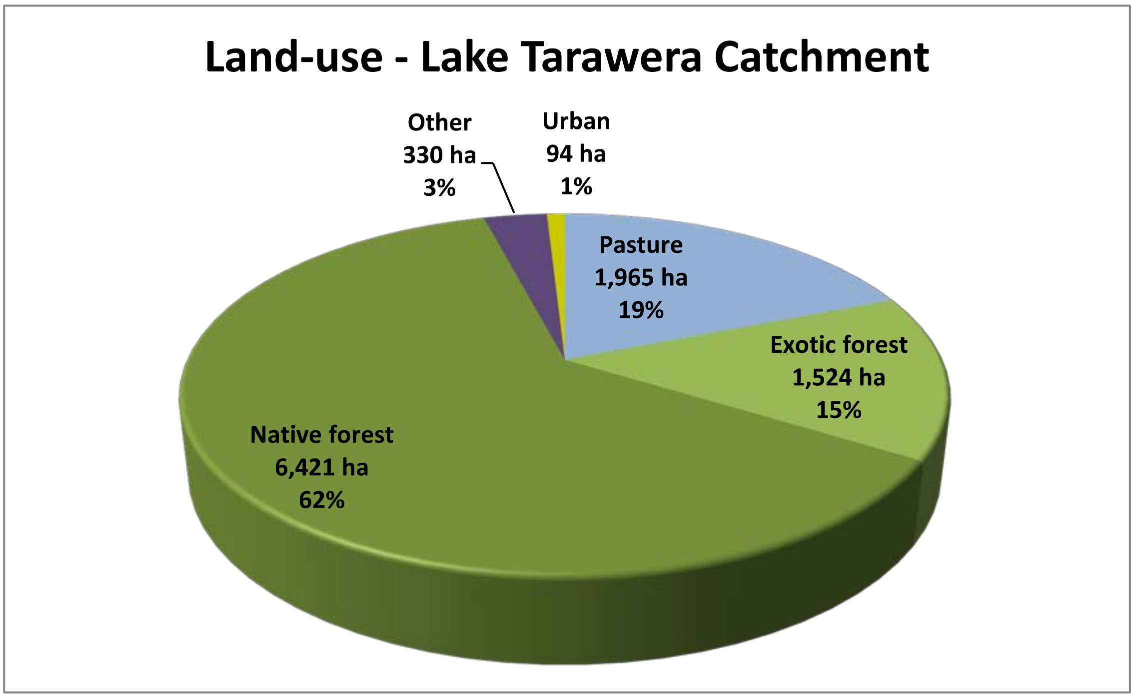
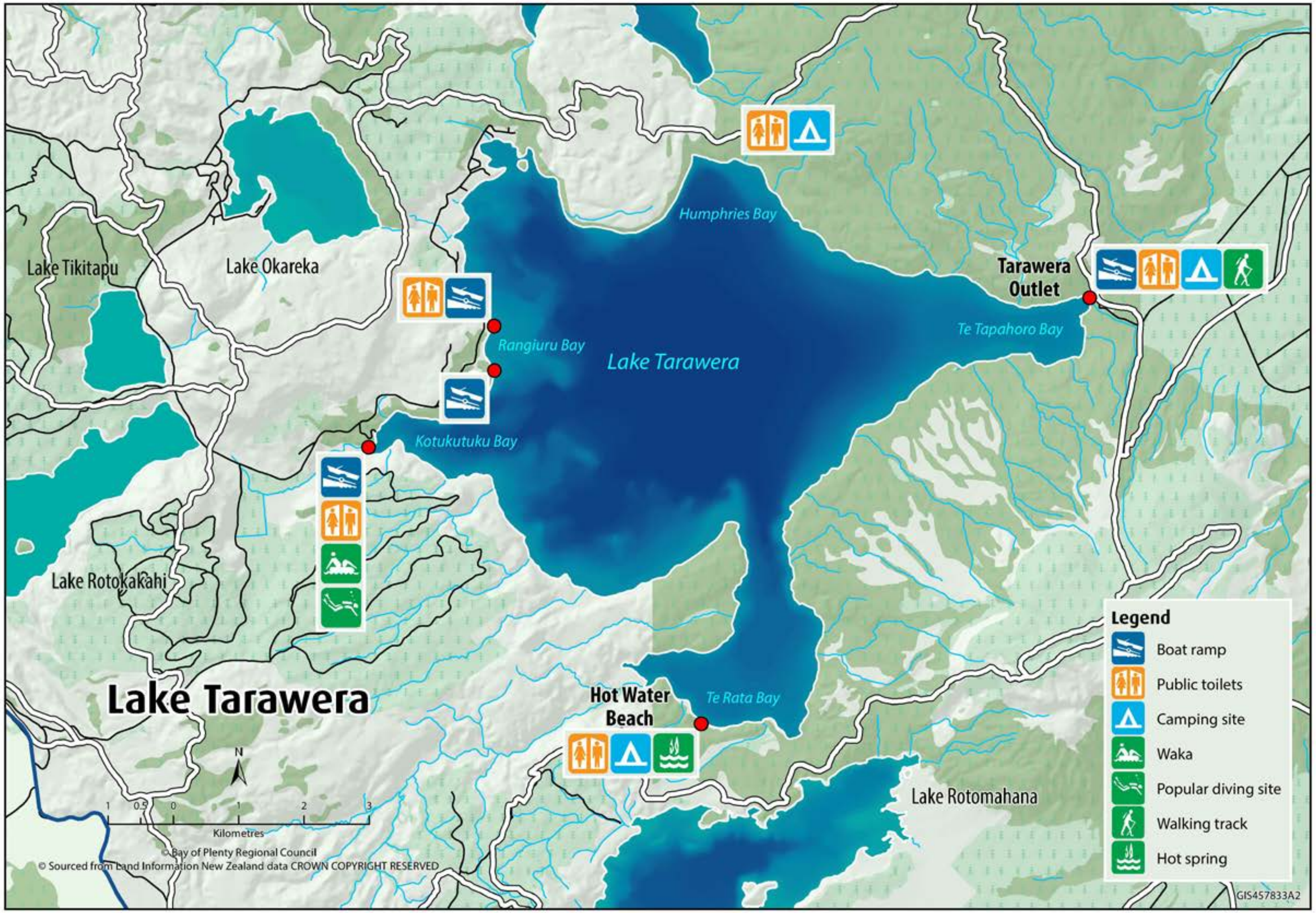


Figure 1 Graph of land cover in the inner catchment of Lake Tarawera



Map 1 Lake Tarawera – Recreational usesLand-use (inner catchment)[13]

[13] McIntosh, J. (2012) *Lake Tarawera Nutrient Budget,* Bay of Plenty Regional Council.

3.2 Inflows

An estimated 20% of the water entering the lake is from rainfall and surface water flows. Groundwater is the dominant source of inflow to Lake Tarawera with 80% of water entering the lake from sources other than streams.

Surface water flows into Lake Tarawera, predominantly from Rotokakahi via Te Wairoa Stream and from Lake Ōkāreka via the Waitangi Stream. A number of minor inflows also contribute freshwater to the lake, with one stream intermittently sourced from Rotomahana when the lake level is high. Sub-surface inflows connect to Lake Tarawera from lakes Tikitapu, Ōkataina and Rotomahana. Lake Ōkaro and Lake Rerewhakaaitu flow to Rotomahana, then to Lake Tarawera via sub-surface flows.

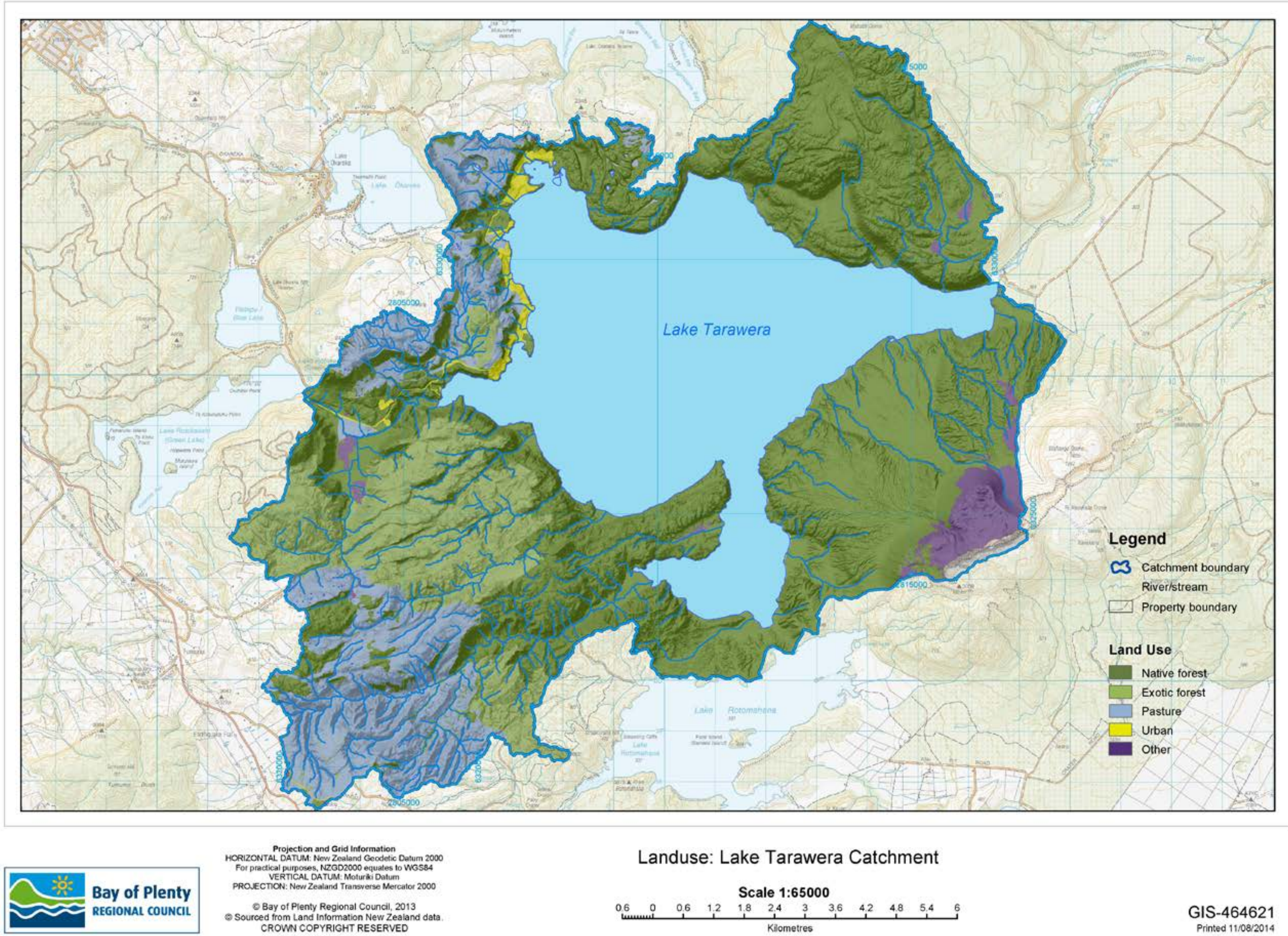
This represents a particular challenge for the lake, as it can take several decades for groundwater to reach the lake. Any changes made within the groundwater catchment to improve water quality will take many years to show a measurable effect. With the main inflow to Lake Tarawera coming from groundwater, the lake will respond slowly to any land-use changes.

Septic tanks are generally closer to the lake edge and their effluent affects the shallow groundwater. The removal of this source would most likely lead to quicker improvements in water quality.

3.3 Lake dynamics and sediments

During spring, the water in deep lakes like Lake Tarawera, stratifies into two layers and remains stratified throughout summer and autumn. The layers remain separate until the surface cools again in June of the each year. The bottom layer of water is isolated from the air and oxygen cannot be replenished for the whole nine months of stratification. During this time the decomposition of dead algal cells in the bottom layer uses up the oxygen. There is a risk that with increased algal concentrations, that the bottom layer oxygen could be used up, releasing nitrogen and phosphorus from the lakebed into the water column.

During winter (July to September) the surface waters cool to the same temperature as the bottom waters. All water mixes from top to bottom and any nutrients that have been released from the lake bed during stratification, may be brought to the surface where they can stimulate algal blooms during the following summer. Increased algal growth in the surface waters results in further deposition of algae on the lake bed, further fuelling the cycle. A diagram of this process is shown in Figure 2 (page 14).



Map 2 Land Cover in the Lake Tarawera Catchment

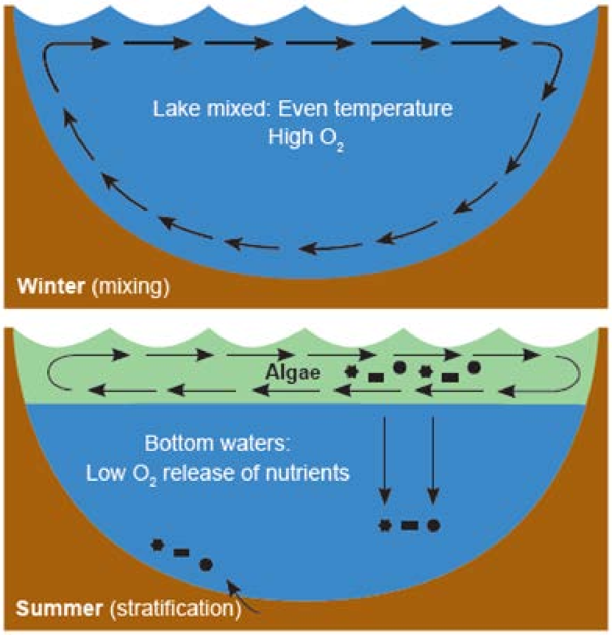


Figure 2 Diagram of lake dynamics during mixing and stratification

Currently in Lake Tarawera, there is insufficient algal matter dropping into the bottom layer to use up all the oxygen. However, if water quality continues to decline and algal matter in the lake increases, there may be enough matter dropping into the bottom layer to use all the oxygen during the stratification months. If this happens, nitrogen and phosphorus in the lake bed is released into the water. This leads to an algal cycle as illustrated in Figure 3 below.

Lake Tarawera has the most phosphorus enriched sediments of any of the Rotorua Te Arawa lakes. If the bottom waters of the lake were to become deoxygenated, this phosphorus would release from the sediment and further contribute to the phosphorus levels.

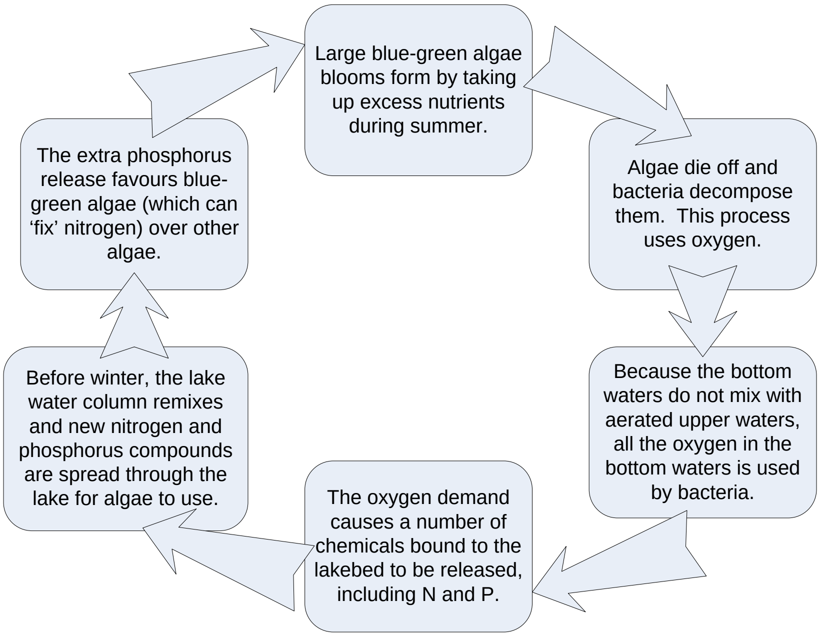


Figure 3 Nutrient cycling within lakes during stratification

3.4 Outer catchment – the interaction between lakes in the Tarawera System

Lake Tarawera is downstream of the eight lakes in the Tarawera System. Lakes Ōkāreka, Ōkataina, Rotokakahi, Rotomahana and Tikitapu all drain directly into Lake Tarawera either via surface or sub-surface flows. Lake Ōkaro and Lake Rerewhakaaitu drain into Rotomahana, then to Lake Tarawera. The outer catchment of Lake Tarawera is estimated at 50,000 ha and the full extent of the groundwater boundary is unknown. A project is currently underway to investigate the groundwater relationships in the Tarawera System. Map 3 (Page 16) shows the ground and surface water flows as they are currently understood.

4 Defining the problem

4.1 The target

The Trophic Level Index (TLI) is the indicator used to indicate the health of lakes. The poorer the water quality, the higher the number. The TLI is calculated using four separate water quality measurements: total nitrogen, total phosphorus, water clarity and chlorophyll-*a*.

- Total nitrogen and total phosphorus are nutrients that plants thrive on. Large amounts of these nutrients in the lakes encourage the growth of algae, which can lead to poor water quality.
- Water clarity is how clear the water in the lake is (measured by secchi disk). Clear water usually means better water quality.
- Chlorophyll-a is the green colour in plants. Knowing how much chlorophyll-a is in a lake gives us a good idea of the concentration of algae in the lake. The greater the concentration of algae, the poorer the water quality.

These four measurements are combined into one number which is the Trophic Level Index.

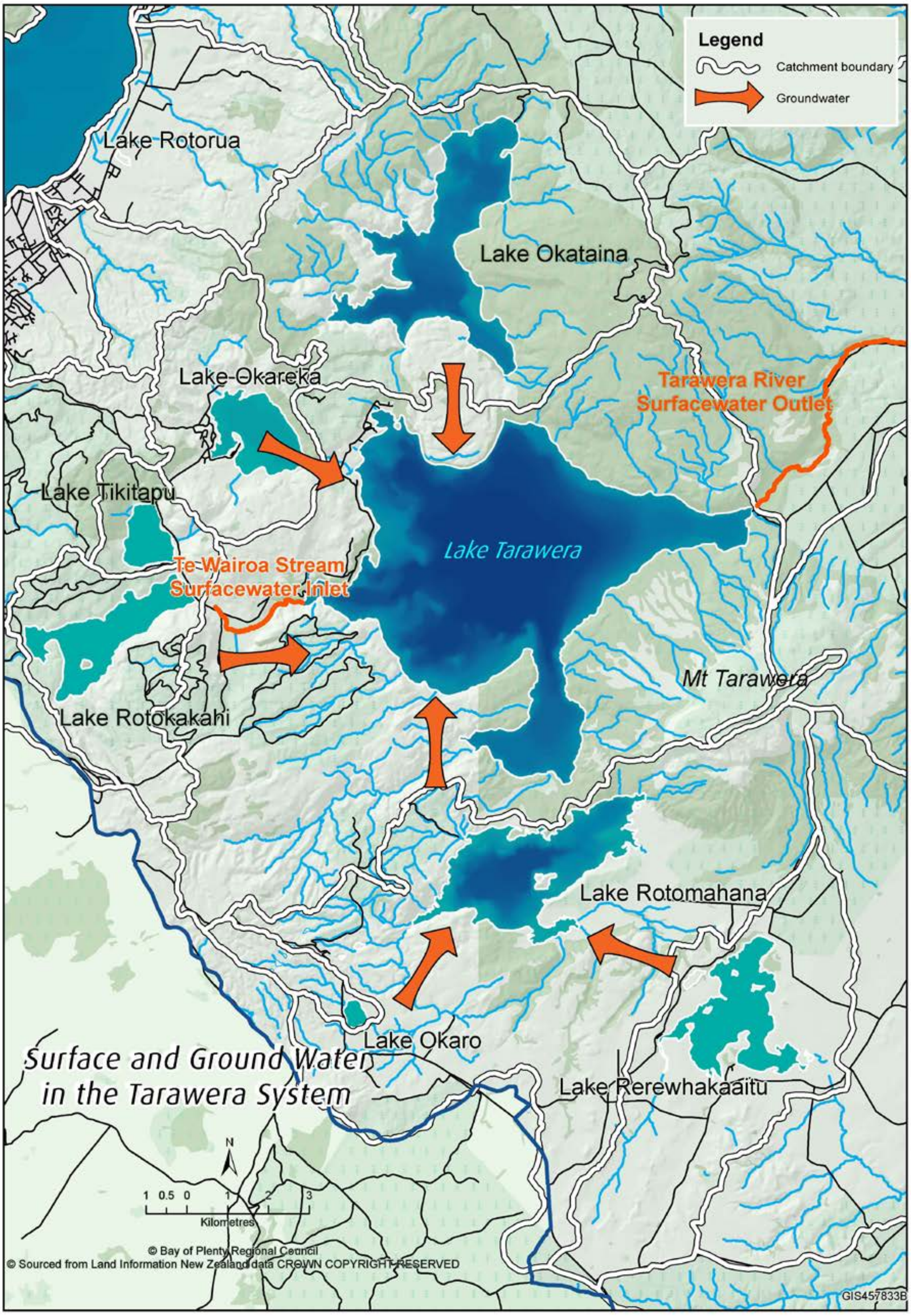
During development of the Bay of Plenty Regional Water and Land Plan (RWLP), the community set target TLIs for each of the Rotorua Te Arawa Lakes and the RWLP contains objectives, policies and methods, to specifically address the issue of declining water quality in these lakes.

Objective 11 of the RWLP is to maintain or improve water quality in the Rotorua Te Arawa Lakes to meet the TLI for each lake. If the TLI is not met, Method 41 of the plan requires the development and implementation of an action plan to maintain or improve lake water quality to meet the three year average index.[14] The target TLI for Lake Tarawera is 2.6. The current TLI is 3.0. Table 1 summarises the most recent TLIs.

Table 1 Summary of TLIs for Lake Tarawera

TLI	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Three-year average TLI	2.9	2.9	2.8	2.8	2.9	3.0	3.0	3.0
Annual TLI	2.9	2.9	2.6	3.0	3.0	3.0	3.0	3.1

[14] Environment Bay of Plenty (2008) The Bay of Plenty Regional Water and Land Plan.



Map 3 Ground and surface water flows to Lake Tarawera

An increasing trend of phosphorus and nitrogen concentrations was recorded from 1994 to 2008. Since 2009, nitrogen concentration fell, but the phosphorus concentration remains high and is increasing[15].

The main cause of the increasing TLI (indicating declining water quality) in Lake Tarawera is the increase in nitrogen and phosphorus flowing to the lake. This is caused by changes in land-use within both the inner and outer catchment of Lake Tarawera. This increase, combined with the characteristics of Lake Tarawera, has the potential to lead to an increase in algal blooms.

Nutrients can take several years to reach the lake through groundwater and surface water. Developments and activities that occurred decades ago have caused the state of the lake that we are measuring today. This means that if no action is taken, and/or further land-use change occurs that increases the nutrients going to the lake, then the lake will not improve or further water quality degradation may occur over the coming decades.

4.2 Nutrient sources

The following sources contribute to the total nutrient load of the lake.

4.2.1 Pasture

Sheep and beef farming is the main land-use (after native bush) in the Lake Tarawera inner catchment. Nutrient loss comes from a number of sources:

- Erosion and sediment run-off – phosphorus attached to the soil flows to the lake.
- Urine patches and dung – the nitrogen concentration in a patch of urine or dung is far greater than what the grass can use.
- Fertiliser spray drift – application of fertiliser when the soil is waterlogged and excessive fertiliser application, can all cause nitrogen and phosphorus leaching and run-off.

There are four main agricultural land-uses in the Lake Tarawera Catchment; mixed scrub/pasture, mixed sheep/beef/deer, beef, and horse/lifestyle grazing. The outer catchment, particularly the land around Lake Rerewhakaaitu, is used for dairy farming. Dairy farming has a much higher rate of nutrient loss than sheep and beef.

4.2.2 Urban

The predominant source of urban nutrients are septic tanks. The Lake Tarawera community in the inner catchment is the only urban community in the greater catchment that still uses septic tanks.

Most of the homes within the Lake Tarawera Catchments discharge their wastewater to conventional septic tanks. These effectively break down organic matter and filter bacteria as the fluid passes through the ground, but do not remove nitrogen and phosphorus.

The nutrient load from septic tanks is difficult to estimate due to the large proportion of holiday homes at the lake. The average occupancy has been estimated as 775. This amount takes into account the permanent population of 291 and an additional annual visitor load of 484. This number differs from Rotorua District Council’s estimates which are derived from the anticipated maximum load.

[15] Scholes, P. (2011) 2010/2011 Rotorua Lakes TLI Update Environmental Publication 2011/1 Bay of Plenty Regional Council.

The urban area also increases stormwater run-off from the impermeable surfaces such as roofs and roads into the lake, carrying nutrients (and other contaminants like heavy metals) with it.

4.2.3 Native and exotic forest

Nutrient loss from native bush and scrub reflects nutrient loss to the lake before human activity. Lakes Tarawera, Tikitapu, Ōkataina and Ōkāreka have large proportions of their catchments in native forest.

Exotic forest includes commercial plantations of trees that are harvested approximately every 30 years. All lakes in the Tarawera System have some proportion of their catchment in exotic forest. Rotokakahi has the highest proportion, with 50% of its catchment in exotic forestry.

4.2.4 Sewage disposal field in Whakarewarewa Forest

The Rotorua District Council discharges effluent from the wastewater treatment plant to a spray irrigation field in Whakarewarewa Forest. This reduced the nitrogen load to Lake Rotorua from 100 t to about 30-40 t per year.

However, when water quality in Rotokakahi declined, the Whakarewarewa Forest sewage disposal field was identified as a possible source. To investigate this, a bore located between the disposal field and the lake was proposed. Groundwater testing from this bore would have been able to determine whether water from the irrigation field was contaminating Rotokakahi.

Unfortunately, construction of this bore did not go ahead. Instead, the Regional Council commissioned GNS Science to investigate the groundwater from the existing bores in the area, to determine whether effluent from the disposal fields was flowing through groundwater to Rotokakahi.

The study investigated the geology, surface water data, and hydrogeologic data of the area. The findings were:

- Modelled groundwater flows are consistent with the surface water catchments. Water discharged to the Whakarewarewa Forest flows into the Waipa Catchment.
- Most (94%) of the disposal fields are below 394 m, the elevation of Rotokakahi.
- A small proportion (6%) of disposal fields are between 394 and 415 metres. At this height, groundwater is significantly lower than ground level and is lower than 394 m. These discharges have since ceased.

The investigation concluded that due to topography and groundwater levels, it is highly unlikely that the treated wastewater from the Whakarewarewa Forest disposal field flows into Rotokakahi.

4.2.5 Other sources

Other sources of nutrients include rainfall on lake, bare land (Mount Tarawera) and recreation/other grass. Rainfall adds nitrogen and phosphorus directly to the lake from dissolved gases in the air.

4.3 Nutrient loads – inner catchment

The most recent nutrient budget for Lake Tarawera was prepared in 2014[16]. The nutrient budget calculated nutrient inflows to the lake from the inner catchment as shown in Table 2 and in Figures 4 and 5 (page 20).

Table 2 Summary of nutrient sources and loads from the inner catchment

Land-use		Rate of loss (kg/ha/year)		Total load (kg/year)	
	Area (ha)	**Phosphorus**	**Nitrogen**	**Phosphorus**	**Nitrogen**
Pasture					
Mixed scrub/pasture	137	0.5	5	68	683
Mixed sheep/beef/deer	1,726	1	10	1,726	17,259
Beef	81	1	15	81	1,217
Horse/lifestyle grazing	21	0.8	8	17	169
Total pasture	**1,965**			**1,892 (42%)**	**19,328 (29%)**
Total exotic forest	**1,524**	**0.18**	**2.81**	**274 (6%)**	**4,283 (6%)**
Total native forest	**6,421**	**0.12**	**3.67**	**771 (17%)**	**23,565 (35%)**
Other sources					
Bare ground	280	1	5	280	1,398
Rainfall on lake	4,139	0.17	3.5	704	14,486
Recreation/other grass	50	0.3	4	14	200
Total other sources	**4,469**			**1,183 (27%)**	**16,583 (25%)**
Urban					
Urban (stormwater)	93.5	0.7	3	66	281
Urban (septic tanks)	775 (people)			283	2,829
Total urban	**94**			**348 (8%)**	**3,109 (5%)**
Total nutrient sources	**14,473**			**4,469 kg/year**	**66,868 (kg/year)**

[16] Hamilton, D. (2014) Memo: Nutrient Budget for Lake Tarawera.

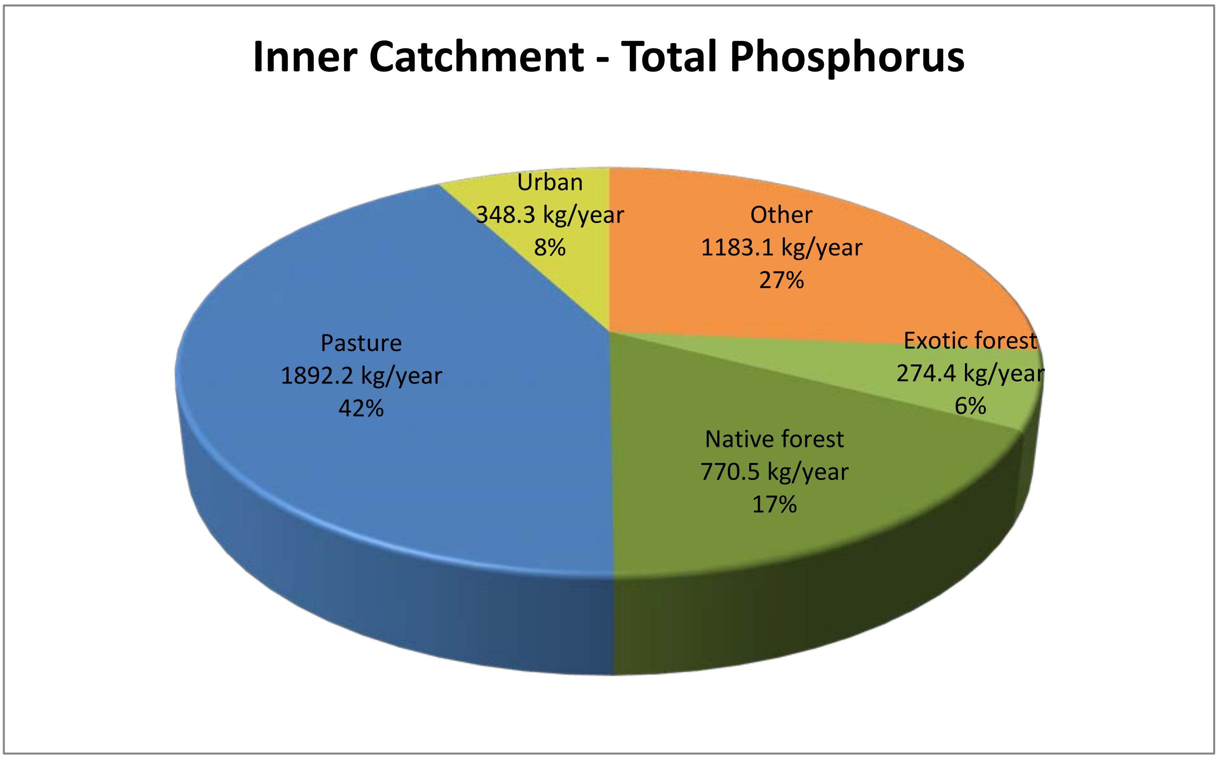


Figure 4 *Graph of total phosphorus load from land-use in the Lake Tarawera Catchment*

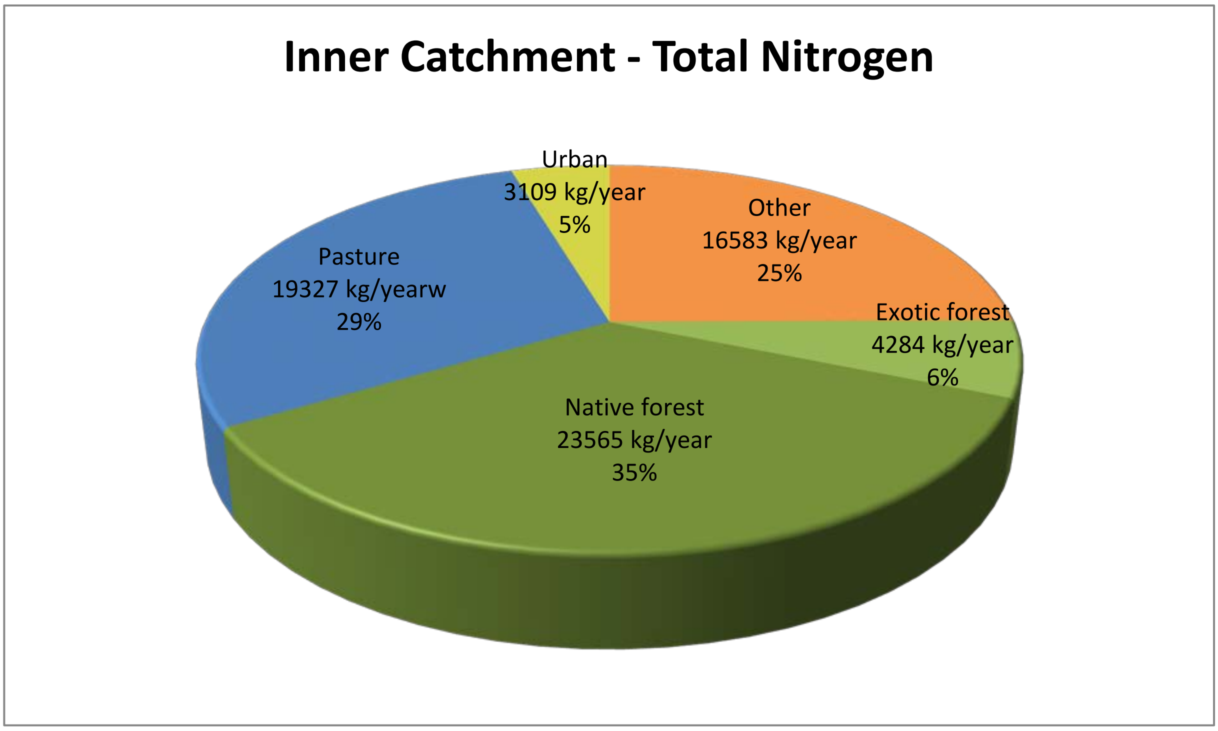


Figure 5 *Graph of total nitrogen load from land-use in the Lake Tarawera Catchment*

4.4 Nutrient loads – outer catchment

Although information on the outer catchment is still incomplete, it is possible to estimate the contribution of nutrients from the lakes that flow to Lake Tarawera as shown in Table 3.

Table 3 Summary of nutrient sources and loads from the outer catchment

Lake	Total load (kg/year)	
	Phosphorus	**Nitrogen**
Tarawera (inner catchment)	4,470	66,870
Rotomahana (also includes loads from lakes Ōkaro and Rerewhakaaitu)	1,270	9,100
Ōkataina	320	5,250
Rotokakahi	190	3,500
Ōkāreka	110	3,400
Tikitapu	10	250
Buried Village septic tank	20	180
Geothermal (estimated)	*5,000*	*6,300*
Total	**kg/year 11,390**	**kg/year 94,850**

As Table 3 demonstrates, the Lake Tarawera Inner Catchment contributes most of the nutrients to the lake. However, a significant proportion comes from the outer lakes, particularly Lake Rotomahana (which, in turn, receives water and nutrients from lakes Ōkaro and Rerewhakaaitu). Map 4 shows the inner and outer catchments of the Tarawera Lakes System.

The additional 5,000 kilograms of phosphorus from geothermal sources is an estimate only.

5 Solving the problem

The solution is to determine the sustainable load for the lake and reduce the inflow of nutrients from sources until the sustainable load is reached.

The 2012 nutrient budget estimated reduction targets for Lake Tarawera as 1,200 kg of phosphorus per year and 12,000 kg of nitrogen per year.[17]

However, a review of all nutrient budgets indicates that these targets require further review.[18] In particular, a greater focus on phosphorus may be necessary than is signalled by these targets. The recommendations were to focus the majority of resources on reducing phosphorus while capping nitrogen to ensure that further water quality decline does not occur as a result of an increase in total nitrogen.

Recent monitoring data show that phosphorus levels are highly elevated relative to nitrogen, water clarity and levels of chlorophyll-*a* and the levels are higher than previously estimated.

[17] McIntosh, J. (2012) Lake Tarawera Nutrient Budget.
[18] Hamilton, D. (2014) Memo: Nutrient Budget for Lake Tarawera.

Contributions from the lakes in the outer catchment represent a substantial portion of the total nutrient load to the lake and need to be considered in the Tarawera nutrient budget and targets.

The high background load from geothermal sources also increases the level of phosphorus in Lake Tarawera. This reinforces the importance of effectively targeting manageable sources of phosphorus to the lake (e.g. septic systems, best management practices on low-intensity farmland), concurrently with ensuring that increases in nitrogen, which could drive further water quality decline, do not occur.

Therefore, the interim reduction targets based on the best information currently available are:

- Phosphorus: at least 1,200 kg per year
- Nitrogen: no increase

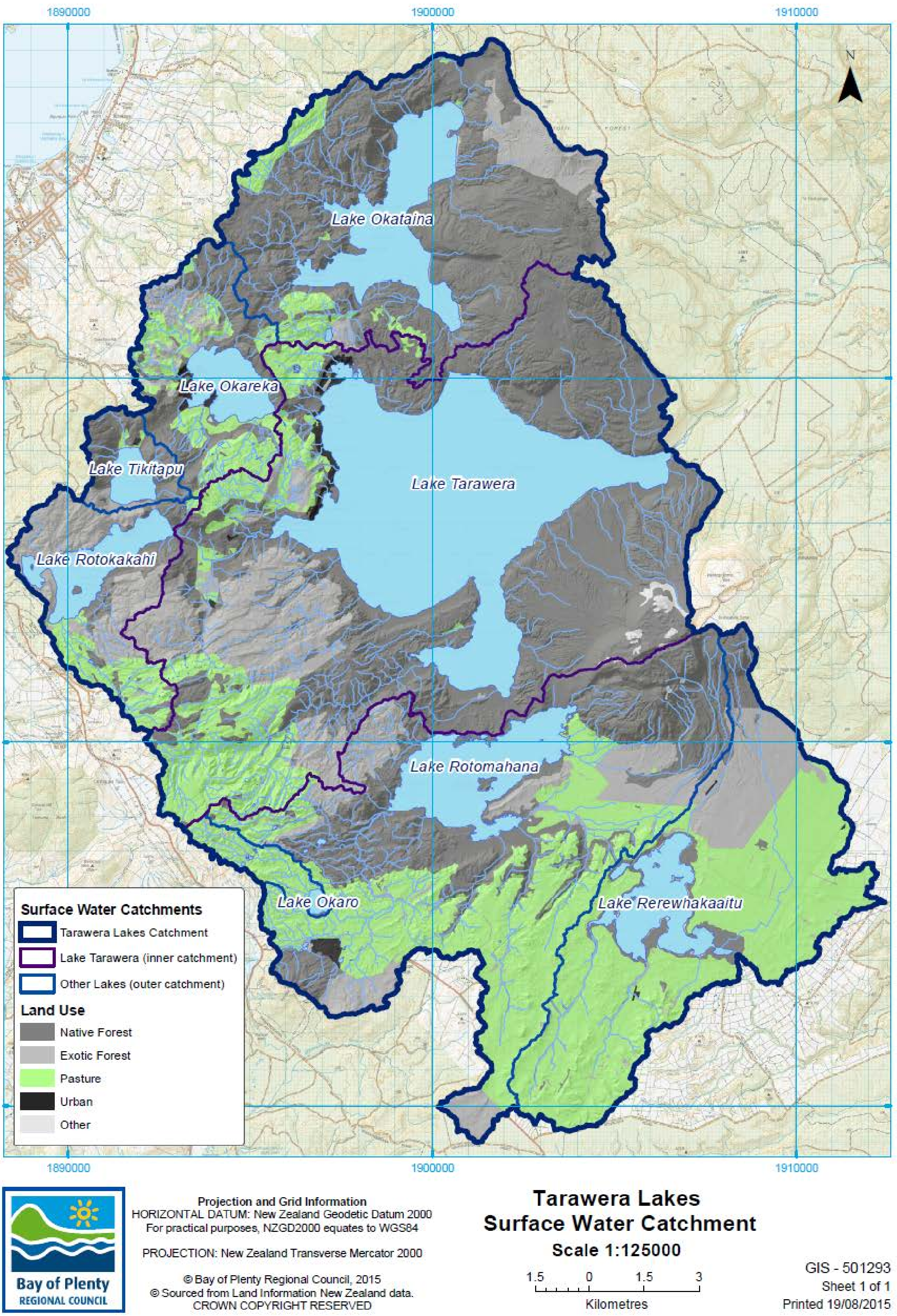
These targets will change when further science is available.

Nitrogen is still an issue for the lake, therefore, some actions are proposed that target nitrogen reductions, but the majority of actions focus on phosphorus.

As the lake is impacted by the surface and groundwater inputs from seven other lakes, the development of the groundwater model is vital in establishing more robust information on water and nutrient inputs and finalising nutrient reduction targets. Until these targets have been developed more thoroughly, the 1,200 kg reduction of phosphorus can be considered the minimum reduction required to stabilise water quality.

Therefore the way forward to start reducing phosphorus to the lake is to:

- Address known sources of phosphorus
- Engage with landowners to gather information and identify voluntary actions
- Review nutrient targets once groundwater work is completed



Map 4 Inner and outer catchment of Tarawera Lakes System

Part 2: Initial actions

1 Target reductions

- Phosphorus: at least 1,200 kg per year
- Nitrogen: no increase

One single intervention focussed on one nutrient source will not achieve the required reduction. To ensure the target is met and that costs are shared across the community, a range of actions have been selected for this document. The estimated cost of each intervention has been included in the key action areas, but where the costs may fall for each intervention has not yet been established. The initial actions have been developed to ensure that reductions in nutrient sources are started. A further review of the necessary actions will take place in 2016 once the groundwater model is available and the source of nutrients to Lake Tarawera is more certain from a revised nutrient budget.

2 Inner catchment

Land-use in the inner catchment is responsible for approximately 57% of the phosphorus input to Lake Tarawera. The two main sources of phosphorus in the inner catchment are urban wastewater and run-off from pasture.

The best option to remove phosphorus from urban wastewater is to reticulate (see discussion below) which will remove 283 kg of phosphorus.

2.1 Action 1 – Wastewater management

Reticulate houses in the Lake Tarawera urban community and upgrade conventional septic tanks outside the future reticulation zone.

Ensure that existing septic tanks are maintained regularly while options for reticulation are investigated.

- Phosphorus removed: 283 kg
- Nitrogen removed: 2,829 kg

2.1.1 Background

At present, the 391 houses in the Lake Tarawera community rely on conventional septic tanks to process their wastewater. This community is the only remaining lakeside community out of the eight lakes in the Tarawera System that relies on septic tanks to treat human sewage.

Septic tanks are a source of both nitrogen and phosphorus. The total discharge is 283 kg of phosphorus and 2,829 kg of nitrogen, based on estimated population of 291 permanent residents and 484 visitors.

The preferred option to remove nutrients from this source is to reticulate sewage from all developed properties along the north-western shore of the lake and remove it for treatment at the wastewater treatment plant in Rotorua. This will permanently remove phosphorus and nitrogen from this source.

A steering group, coordinated by the Rotorua Lakes Council is being set up to discuss options for reticulation. The steering group will assess the various reticulation methods and associated costs, as well as investigating funding options.

This work is expected to take several years. With the expectation that reticulation will go ahead, maintenance of septic tanks may not be occurring as required for optimum performance. This is likely leading to increased discharges to the lake and health risks. Therefore, an action to ensure that septic tanks continue to be maintained while reticulation options are investigated.

The option to upgrade properties to advanced on-site treatment systems will not remove phosphorus from this source, and therefore is not a viable option to achieve the target. In addition, these systems require 400 m^2 of undeveloped or hard surfaced land for a soakage field and reserve field. On that basis, about half of all sections at the lake would not be able to install these systems[19].

2.1.2 Benefits and risks

Reticulation will remove the health issues associated with bacteria and other pathogens that may cause illness being discharged to land near the lake. It also removes the issue of shock loading – when septic tanks left dormant for long periods of time suddenly become active again (e.g. during holidays), sewage may not be treated properly before discharging to the water table.

If reticulation goes ahead, it is likely that the wastewater will be treated at the wastewater treatment plant in Rotorua. Despite the issues associated with transferring the nutrients from one at-risk catchment to another, treating the waste at a modern plant is preferable to partial treatment on individual sites.

2.1.3 Financial cost

Although reticulation is the only feasible method to remove phosphorus from this source, it comes at a high cost. A feasibility study carried out by Rotorua District Council indicates that the total cost will be $12.4 m (plus GST). This equates to $24,453 per house.

The Rotorua District Council or the Regional Council are currently consulting with the community about how and when this will be funded through the Long-Term Plan.

2.2 Action 2 – Agricultural land management (inner catchment)

All agricultural properties within the Lake Tarawera Inner Catchment to have voluntary environmental management plans.

An environmental management plan is an agreement between the landowner and the Regional Council on what is the ideal nutrient discharge from the property, and sets out a pathway to achieve the required reductions. The environmental management plan must set out how phosphorus reductions will be achieved.

Environmental management plans may include actions such as:

- Riparian protection – streambanks fenced and planted.
- Land retirement in steep areas.
- Sediment retention structures.
- Phosphorus reduction plan.

[19] Pers comm, Terry Long, October 2012.

This list of actions is not exhaustive and some actions may not be suitable for some farms within the catchment. The Regional Council will work directly with farmers to discuss options for environmental management plans.

The basic plans should contain as a minimum, a map of the farm with an explanation of any restoration work carried out and a plan of what work may be carried out in the future. At this stage, the plans will not require Overseer®.

2.2.1 Background

A third of all nutrients leaching to Lake Tarawera from the inner catchment come from agricultural land-use which includes sheep, beef and deer. The Regional Council will work with farmers on voluntary actions to minimise phosphorus run-off from their properties. This builds on actions that farmers have already carried at their own expense, such as fencing and planting of streams, retirement of pasture to native bush, and detention dams in steep gullies.

2.2.2 Benefits and risks

Other Council programmes have benefited from one on one relationships with stakeholders. These relationships are particularly effective when there are small numbers of stakeholders committed to solving the problem.

Environmental management plans follow this same method of designing a tailored approach for each farm. This allows landowners to choose which nutrient management and reduction options will work best for them and help achieve the overall goal. It builds trust and respect between parties.

However, any reductions in environmental management plans are will not have regulatory support at this stage.

The cost of employing a consultant to discuss options with landowners and assist with farm nutrient plans is estimated to cost $60,000.

2.3 Action 3 – Control of nitrogen fixing plants

Control nitrogen fixing pest plants in the Lake Tarawera Inner Catchment.

- Nitrogen removed: 230 kg

The Regional Council will work with landowners to target approximately 46 ha of silver wattle over a three year programme. Initial treatment is by stem injection with herbicide. This is followed up after two years to treat re-emergent plants.

2.3.1 Background

Nitrogen fixing plants come from the family of Fabaceae or legumes. These plants use the process of nitrogen fixation to take nitrogen from the air and convert it to a form that is used by the plant. Excess nitrogen is leached into the groundwater so these plants are an additional source of nitrogen.

The current land-cover of silver wattle is estimated at 230 ha throughout the southern part of the catchment. This is estimated to be leaching 1,150 kg of nitrogen per year. The full 230 ha would cost an estimated $805,000 to remove over a three year programme. At this stage, resources are best spent on phosphorus removal. Therefore, only 20% of the 230 ha will be targeted for this phase.

2.3.2 Benefits and risks

The total cost of removing 46 ha is $161,000.

Removing these plants will also have a beneficial effect on the amenity value of the area. There is little risk in a three year programme to control silver wattle. This is a non-native plant that has little to no amenity value for the area. Provided that landowners are in agreement for its removal, controlling wattle will have more benefits than risks.

3 Outer catchment

Land-use in the outer catchment is responsible for an estimated 43% of the phosphorus input to Lake Tarawera. This does not include the unknown proportion from geothermal sources.

The main source of phosphorus in the outer catchment is from pastoral land-use. Farms range from dry stock (beef, deer and sheep) to dairy support and dairying.

3.1 Action 4 – Agricultural land management (outer catchment)

All agricultural properties within the Lake Tarawera Outer Catchment to have environmental management plans by 1 December 2020.

The environmental management plans in this action should follow the same process as those developed for the inner catchment.

3.1.1 Background

Nutrients leach to Lake Tarawera from the outer catchment from agricultural land-use which includes sheep, beef, deer, and dairy. The Regional Council will work with farmers on voluntary actions to minimise phosphorus run-off from their properties.

3.1.2 Benefits and risks

This action has the same benefits and risks as Action 2 (above). The cost of employing a consultant to discuss options with landowners and assist with farm nutrient plans for the outer catchment is estimated to cost $120,000.

4 Whole catchment

4.1 Action 5 – Limit on land-use change

Develop a rule to limit land-use changes that increase nutrients in the Tarawera System.

Currently, land-use change in the catchments of any lake in the Tarawera System (except Ōkaro) is a permitted activity under Rule 12 of the Regional Water and Land Plan. A change of ownership and/or economic pressures may drive land-use change. This places the lakes at risk of increased nutrient loading, if land is converted from a low impact activity to a high impact activity. The impact of these higher nutrient activities could completely negate all other actions completed at high cost.

Research and development of these rules has already commenced. Once drafted, the rules will be included in a change to the Regional Water and Land Plan. Any change to a Regional Plan requires full public consultation and input under the Resource Management Act. The change, when prepared, will be notified to the community for submissions.

The benefits and risks of rules will be considered as part of the assessment requirements for plan changes under the Resource Management Act 1991.

4.2 Action 6 – Groundwater modelling

Build a model of the Lake Tarawera groundwater system.

The Regional Council will continue with its groundwater investigations to identify relative sources of nutrients from all sources within the Tarawera System.

Drilling and monitoring of the groundwater system of Lake Tarawera has been ongoing for several years. The drilling and testing of groundwater to determine the depth, origin, age and nutrient level of the aquifers in the caldera is completed.

The next phase is to build a model of the groundwater system of the area. This model can then be used to simulate land-use scenarios to determine the potential effect of different land-use changes on Lake Tarawera, and to identify how actions throughout the outer and inner catchments will contribute to the water quality of Lake Tarawera. This information will take some time to process and we can expect a good scientific understanding of the groundwater system by early 2016.

This work is already substantially complete, therefore, an assessment of benefits and risks is unnecessary.

4.3 Action 7 – Cultural health assessment

Carry out a cultural health assessment of the Tarawera System.

Māori have a distinctive world view that is not necessarily reflected or measured by modern scientific techniques. For generations, Māori have been concerned with the degradation of the waterways within their rohe and have been seeking greater recognition of their cultural beliefs, values and practices.

In 2003, the Ministry for the Environment (the Ministry) developed a model to carry out cultural health index assessments that collected data specific to Māori culture, such as mauri, mahinga kai, wahi tapu and wahi taonga[20]. A recent assessment on the Puarenga River was carried out by tangata whenua. This assessment adapted the Ministry's model to assess the cultural health of the river. The report provides an opportunity for the views of the tangata whenua to be heard and recorded, and is an extension of mana whenua and kaitiakitanga.[21]

A cultural health assessment carried out for Lake Tarawera and its surrounding areas, would provide valuable information on the effects of land-use changes and declining water quality on values. This assessment will also take into account values that are important to Pākehā.

Estimated cost to carry out this investigation is $60,000.

[20] Tipa. G, Teirney, L (2003) *A Cultural Health Index for Streams and Waterways –Indicators for recognising and expressing Māori values*, Ministry for the Environment.

[21] Tangata whenua (2012) *Cultural Impact Assessment – Adverse environmental effects on hapū communities*, Tūhourangi Tribal Authority.

4.4 Action 8 – Geothermal source investigation

Investigate geothermal inputs into Lake Tarawera.

Early estimations of geothermal inputs into Lake Tarawera did not consider them to be a significant source of nutrients[22]. However, recent evidence suggests that the concentration could be much higher.

Geothermal loads are difficult to quantify because flows may be sub-surface, and geothermal waters also flow to Lake Tarawera from Lake Rotomahana. In 2004, a study by the Department of Chemistry at the University of Waikato, used sodium concentrations to infer the contribution of water sources and concluded that 5-10% of the hydraulic load was from geothermal sources.

Estimated geothermal loads for nitrogen and phosphorus can be calculated by multiplying the observed concentrations with estimated flow. Monitoring of Tarawera inflows found high concentrations of both nitrogen and phosphorus. For example, average concentrations at the geothermal inflow to Hot Water Beach of 0.4 g/m^3 of phosphorus and 0.5 g/m^3 of nitrogen. All geothermal inflows contribute an estimated 5 tonnes/year of phosphorus and 6.3 tonnes/year of nitrogen.[23]

This is a significant phosphorus load to the lake. One way of addressing this source is to use engineering methods such as dosing, to reduce the phosphorus. There are a number of issues with this approach. First, this is only effective if the sources can be located and if they are not diffused. Sources are easier to treat if they can be identified as coming from a single point.

Another issue is the effects that chemical dosing can have on the lake. It is currently uncertain whether there is a long term effect of this type treatment and investigations are ongoing. There is also the issue of using a chemical treatment to reduce phosphorus while anthropogenic sources continue unchanged.

These implications are currently being explored and will be considered when further information is available.

4.5 Action 9 – Consolidation of science

Summarise science around minor nutrient sources.

The community raised a number of concerns with additional sources that could be contributing nutrients to the lake. These include pine pollen, swans and recreational boating.

The current science around these issues is scattered. This action would investigate and consolidate the science to give the community a clear explanation of minor sources that contribute to the lake.

Estimated cost to carry out this investigation is $10,000.

[22] Hamilton, D., Hamilton, M., McBride, C. (2006) *Nutrient and Water Budget for Lake Tarawera,* University of Waikato
[23] Hamilton, D. (2014) Memo: Nutrient Budget for Lake Tarawera.

4.6 Action 10 – Informed community

Keep community informed (in plain English) of science updates and reports when available.

The numbers included in this restoration plan are all interim figures until the groundwater model in Action 6 is completed. Once the groundwater model is available, the target reductions to improve lake water quality will be re-looked at. Current information suggests that further reductions will be required.

The uncertainty around the science leads to concern in the community. Particularly for the farming sector who will be the most affected by any further reductions required. This action keeps the community informed about updates to scientific information when it is available, and in a form easily understandable by most of the community.

5 Contingency actions

Of the several interventions assessed for inclusion in this document, some options were not considered suitable for inclusion. For example, as water quality in the lake is generally good, chemical intervention is unsuitable at this stage.

However, this document was prepared with a number of assumptions including the sewage reticulation project going ahead. If this situation were to change, additional actions may need to be investigated further.

5.1 Engineering solutions

This includes treatment of inflows, sediment capping of the lake bed. These types of interventions have been successful in lakes where water quality was extremely poor, algal blooms common, and rapid intervention necessary (e.g. lakes Rotorua, Rotoiti, Rotoehu). These lakes have improved in a short time due to this type of intervention, and this allows time to develop the long term, sustainable solutions.

However, scientists are unsure about the longevity of these treatments, but information is growing as the Regional Council's programme progresses. For a lake such as Lake Tarawera that is generally still in good condition, chemical intervention within the lake is a less preferred option. It may be a suitable option for treatment of geothermal inputs once the investigation in Action 8 is completed, but this will be reassessed at that time.

If monitoring shows that Lake Tarawera is approaching a condition where these actions become more appropriate, they will be investigated further.

5.2 Weed removal

Weed removal targets nitrogen which is not a current concern for Lake Tarawera. It is also not a viable option as the hornwort beds are not of a suitable size or location. Accessing these beds on a regular basis using current technology makes their removal expensive and less effective.

If technology improves and nitrogen removal becomes necessary, weed removal may become a more viable option and can be re-investigated.

5.3 Residential stormwater management

Residential stormwater has been highlighted by the community as an area of concern. This is not a significant source of nutrients to the lake and on its own is not a targeted area for action.

6 The Tarawera Lakes approach

Most lakes in the Tarawera System had action plans completed or substantially underway when this document was first drafted. These include:

- Lake Ōkāreka (2004)
- Lake Ōkaro (2006)
- Lake Tikitapu (2011)
- Lake Rerewhakaaitu (implemented by landowners in the catchment)
- Lake Ōkataina (2013)

These action plans were prepared by assessing each lake in isolation and did not consider the interactions between the lakes, or the impact on Lake Tarawera. This approach is suitable at this scale, as each lake must meet its own water quality target.

However, the development process for this Restoration Scheme has shown, that in order to select appropriate actions to improve water quality in Lake Tarawera, all nutrients from the outer catchment must be considered, particularly phosphorus.

Once the groundwater science is complete, this may provide an opportunity to review the action plans for all lakes in the Tarawera System and potentially consolidate them into a single Tarawera Lakes Action Plan. The Tarawera Lakes Action Plan would:

- Assess current water quality and trends for each lake.
- Reassess nutrient budgets and targets.
- Track progress of actions completed and reductions achieved.
- Assess any further actions necessary to ensure each lake achieves its target.
- Assess actions necessary to ensure Lake Tarawera achieves its target, taking into account all inputs, including surface and groundwater from the other lakes in the system.
- Consolidate all action plans in the Tarawera System into one document.

In the meantime the Regional Council will continue to implement actions currently included in the lakes' action plans and will complete action plan development for the remaining lakes (Rotokakahi and Rotomahana). These action plans will be designed, taking into account the Tarawera Lakes approach.

7 Summary of actions

All actions included in the document including expected reductions and estimated costs are summarised in Table 5.

Table 5 Summary of all actions

Actions to reduce nutrients				
Action	**Nitrogen reduction kg/year**	**Phosphorus reduction kg/year**	**Cost**	**Cost per kgN and kgP**
Action 1 – Reticulate houses in the Lake Tarawera urban community and upgrade conventional septic tanks outside the future reticulation zone.	2,829	283	$12,400,000 (+GST)	$43,816 /kgP $4,383 /kgN
Action 3 – Control nitrogen fixing pest plants in the Lake Tarawera Catchment.	230	n/a	$161,000	$700 /kgN

Actions with no reductions		
Action	**Outcome**	**Cost**
Action 2 – All agricultural properties within the Lake Tarawera Inner Catchment to have environmental management plans.	Voluntary reductions in phosphorus from agricultural land in the inner catchment.	$60,000 (Includes cost of consultant only. Does not include cost of any nutrient reduction actions)
Action 4 – All agricultural properties within the Lake Tarawera Outer Catchment to have environmental management plans by 1 December 2020.	Voluntary reductions in phosphorus from agricultural land in the outer catchment.	$120,000 (Includes cost of consultant only. Does not include cost of any nutrient reduction actions)
Action 5 – Develop a rule to limit land-use changes that increase nutrients in the Tarawera System.	Cap on total nutrients in the catchment will safeguard the lake from increased nutrient loading.	Costs met by other Council work streams or projects.
Action 6 – Build a model of the Lake Tarawera groundwater system.	Better understanding of the land-uses that contribute to water quality in Lake Tarawera.	Costs met by other Council work streams or projects.
Action 7 – Carry out a Cultural Health Assessment of the Lake Tarawera Catchment.	Better understanding of the interrelationship between lake water quality and tangata whenua values.	$60,000 (Includes cost of consultant only. Does not include cost of any nutrient reduction actions)
Action 8 – Investigate geothermal inputs into Lake Tarawera.	Better understanding of the geothermal inputs into Lake Tarawera.	Costs met by other Council work streams or projects.
Action 9 – Summarise science around minor nutrient sources.	Consolidated science around minor sources of nutrients in Lake Tarawera.	$10,000
Action 10 – Keep community informed (in Plain English) of science updates and reports when available.	Well informed and engaged community.	No cost