Lakeside Te Kauwhata

Private Plan Change Ecological Report
Prepared for Lakeside Developments 2017 Ltd

6 March 2017

Document Quality Assurance

Bibliographic reference for citation: Boffa Miskell 2016. *Lakeside Te Kauwhata: Private Plan Change Ecological Report*. Report prepared by Boffa Miskell for Lakeside Developments Ltd.		
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Status: FINAL	Revision / version: D	Issue date: 6 March 2017

Template revision: 20150331 0000

File ref: 16241

SECTION ONE - CONTEXT

1 Executive Summary

Lakeside Developments 2017 Ltd has contracted to purchase a current dairy farm to the south of Te Kauwhata and converting it into a residential subdivision. While shelter belts and copses of planted exotic trees are present throughout the farm it is largely devoid of native vegetation, with the exception of a narrow riparian fringe on the margins of two lakes that border the farm to the west and east. These are Lakes Waikare and Kopuera. While both of these are highly eutrophic (i.e. nutrient enriched) with degraded water quality and pest fish (koi carp) infestations, they nevertheless represent the key (and only) ecological resources in and around the farm.

The conversion from dairy farm to residential housing will remove a major source of on-going nutrient contamination of the lakes, and so is viewed as a positive ecological outcome. While residential infrastructure such as roads will generate stormwater with vehicular contaminants (PAH, lead, copper and zinc), provided this is treated appropriately in water treatment wetlands the levels of metal contamination of the lakes is unlikely to be of concern.

2 Introduction

Lakeside Developments 2017 Ltd has contracted to purchase a current dairy farm to the south of Te Kauwhata and converting it into a residential subdivision. The only ecological features of any note within the site are stands of mature trees and farm drains that might support eels (and possibly other fish species). Adjacent to the site are two lakes, being Waikare and Kopuera. Where practicable the tall stands of trees should be retained where they also provide an amenity feature, so they may continue to provide resources for native birds (feeding, roosting and nesting).

The two lakes (Waikare and Kopuera) are both shallow and support a narrow edge of riparian woody and sedge vegetation. Several drains feed into the lakes from the surrounding floodplain areas, which are regularly inundated during the wetter months.

3 Waikato Riverine lakes

Lake Waikare and Kopuera are both riverine lakes. Riverine lakes have been formed through fluvial (river) processes as rivers carry and deposit sediments along the river banks. River processes can enlarge existing water bodies, create natural levies that separate and form new waterbodies, or leave a remnant oxbow waterbody when it changes course.

Lake ecosystems associated with large river basin floodplains are highly productive, diverse and interconnected. Their ecology (e.g. nutrient dynamics and biological diversity) is highly dependent upon riverine hydrology and flood frequency, so must be considered within the wider context of river processes.

There are 12 riverine lakes in the Waikato region that are associated with the Waikato. The lakes within the catchment of the lower Waikato River are part of an extensive river floodplain wetland system that includes Lakes Whangape, Waahi, Waikare and the internationally important Whangamarino wetland. Together, these environments create a nationally significant, interconnected system of open water, wetlands and swamp environments that provide important habitat for native plants and animals.

The riverine lakes share common properties with the peat lakes in terms of depth, catchment influences and vulnerability to change. All of the Waikato riverine lakes are naturally shallow (<5m depth) and their higher wind fetch has resulted in increased internal sediment re-suspension and reduced water clarity, especially following collapse of submerged vegetation. This group of lakes contains some of the largest shallow lakes in the region including Waikare (3442 ha).

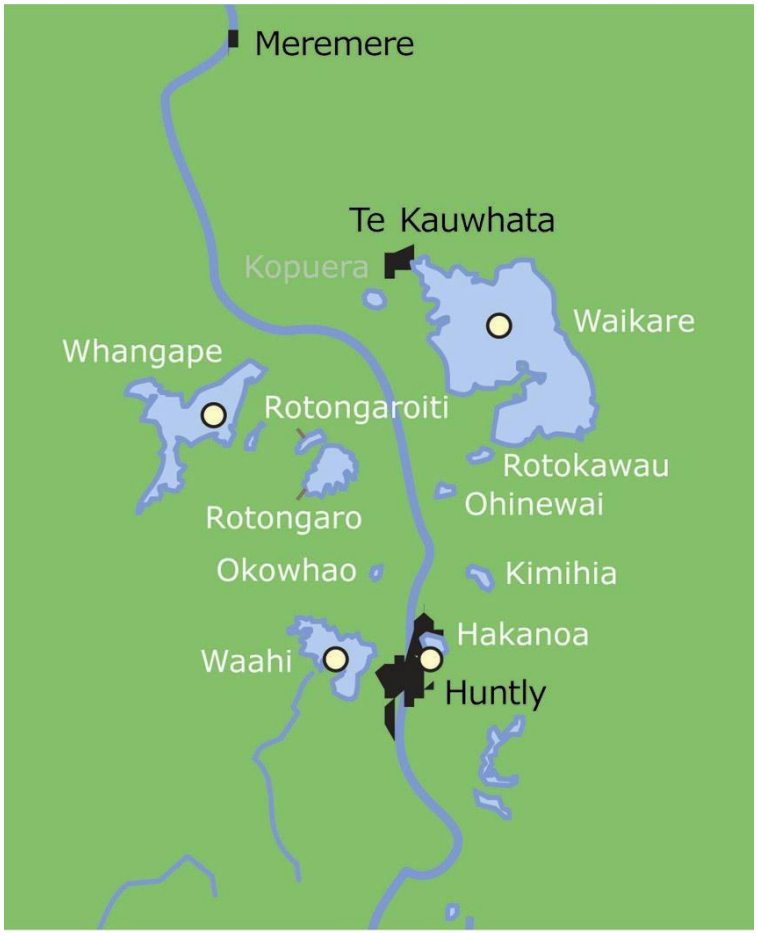

Figure 1 Location of riverine lakes associated with the Waikato River

The large riverine lakes have some of the highest ecological significance scores for shallow lakes. This is because their size generally confers a high diversity of habitats and they tend to have large marginal wetlands that sustain a diversity of species, many of which are threatened.

Ecosystem condition scores are low to moderate for all riverine lakes. All riverine lakes have poor water quality and most experience regular algal blooms. The interconnectedness of the riverine lakes facilitates the spread of pest fish and weeds so that almost all riverine lakes support pest fish and wetland weeds. Their poor condition translates to low vulnerability scores since many of the threats to these lakes have already occurred and are well entrenched.

Potential outcome scores are mostly low, as they recognise the practical difficulties and uncertainties associated with shallow lake resotoration – particularly for the large riverine lakes that have highly modified hydrological regimes and extremely large catchment sizes.

4 Condition of Shallow Lakes

The Waikato region"s shallow lakes make up a large proportion of the 30% of New Zealand lakes that have been categorised as having poor to extremely poor water quality, having undergone substantial declines in ecological condition. Many of these lakes have shifted from a clear-water macrophyte-dominated state to a turbid, phytoplankton-dominated state.

The following factors have been identified as contributing to the ongoing decline of the health and wellbeing of many shallow lakes in the Waikato region:

- High loads of diffuse contaminant inputs of nutrients, sediment and bacteria from catchment run-off and livestock access to the lakes;

- Internal regeneration of nutrients from sediment re-suspension (by wind action or pest fish) and/or release of nutrients as a result of low oxygen events at the lakebed;
- High abundance of pest fish (e.g., koi carp and catfish), and/or aquatic weeds (willow, alligator weed, oxygen weed, hornwort);
- Reduced water depth due to drainage and/or reduced flushing due to water control structures and artificial regimes such as the Lower Waikato Flood Control scheme;
- Past development of large exotic weed beds that create deoxygenation events and often precede a switch to turbid, nutrient enriched conditions; and
- Removal of vegetation filtering potential in the catchment through drainage of marginal wetland vegetation, agricultural development and grazing access.

5 Lake Water Quality

Waikato Regional Council has two main lake monitoring programmes that collect information about the water quality of shallow lakes.

The first is a lake water quality/trophic state monitoring programme that monitors water quality parameters bimonthly in 8 shallow lakes (Lakes Waahi, Whangape, Waikare, Serpentine North, Serpentine East, Maratoto, Rotomanuka, Hakanoa). These lakes have been monitored consistently for between 10 and 17 years, providing valuable information about the inherent variability of lake water quality and long term water quality trends for these sites. The variables monitored include: temperature; dissolved oxygen; dissolved reactive and total phosphorus; dissolved inorganic nitrogen species and total nitrogen; chlorophyll *a*; and suspended solids.

Lake trophic state is assessed using trophic level index (TLI) values that are calculated using commonly measured lake variables, including chlorophyll a (Chla), secchi depth, total phosphorus (TP), total nitrogen (TN), hypolimentic volumetric oxygen depletion rate and phytoplankton species and biomass. TLI values provide a measure of the nutrient status of water bodies and are critical indicators of lake water quality. The following table provides an indication of the lake types, trophic levels and values of the 4 key variables that define the boundaries for different trophic levels.

Lake type	**Trophic level**	**Chl a(mg m-3) (mg m-3)**	**Secchi depth (m)**	**TP (mg P m-3)**	**TN (mg N m-3)**
Ultra-microtrophic	0.0 to 1.0	0.13 - 0.33	31 – 24	0.84 - 1.8	16 - 34
Microtrophic	1.0 to 2.0	0.33 - 0.82	24 - 15	1.8 - 4.1	34 - 73
Oligotrophic	2.0 to 3.0	0.82 - 2.0	15 - 7.8	4.1 - 9.0	73 -157
Mesotrophic	3.0 to 4.0	2.0 - 5.0	7.8 - 3.6	9.0 - 20	157 - 337
Eutrophic	4.0 to 5.0	5.0 - 12	3.6 - 1.6	20 - 43	337 - 725
Supertrophic	5.0 to 6.0	12.0 - 31.0	1.6 - 0.7	43 - 96	725 -1558
Hypertrophic	6.0 to 7.0	>31	<0.7	>96	>1558

Blue-green algae (BGA) levels are also monitored by WRC in five shallow lakes (Lakes Hakanoa, Ngaroto, Waahi, Waikare and Whangape) to assess their suitability for contact recreation.

Lake water quality has also been monitored as part of WRC's shallow lake health indicators programme. Under this programme up to 17 lakes have been sampled three times per year (December, March and May). Six lakes have been monitored annually from 2006-2012 in this programme with a further 9-11 lakes selected (and varied) annually to extend data coverage, and/or complement other work programmes. No water quality information has been collected by WRC for 50% of shallow lakes in the region.

6 Current condition

Table 1 summarises the nutrient enrichment status of 19 lakes that were monitored between 2006-2010 in WRC"s water quality monitoring programme and in the shallow lake health indicators programme. More than half of these lakes (c. 63%), including all of the riverine and volcanic lakes monitored, had high levels of nutrient enrichment. All of the monitored dune lakes were found to be moderately enriched, whilst no karst lakes have been included in WRC"s water quality monitoring programmes.

Nutrient enrichment levels range from moderate to extremely high in peat lakes, although standard and rotifer inferred trophic level indices may under-estimate the condition of dystrophic peat lakes that have higher humic content and lower algal concentrations than their nutrient (N and P) concentrations might otherwise suggest. Secchi depth readings in these lakes are also reduced due to factors other than primary production.

Table 1 Trophic level index of Lake Waikare

Lake	Lake type	Trophic state (2006-10)		Trophic state (2008-12)	
		TLI (2006-10)	Nutrient enrichment	TLI (2008-12)	Nutrient enrichment
Waikare	Riverine	6.9	Extremely High	6.9	Extremely High

Water quality trends

Water quality data has been analysed for trends and are presented in Table 2. Water quality during the last 20 years has shown periods of decline in Lake Waikare.

Table 2 Trends in nutrient enrichment for Lake Waikare between 1993 and 2012

Lake	Type	1993-2001	1995-2010	2002-2010	2005-2010	1995-2012	2002-2012
Waikare	Riverine	Decline	No Change			No Change	

7 Shallow lake health indicators

Lake Waikare has been visited and sampled in December, March and May each year between 2007 – 2013 as part of the Waikato Region Shallow Lake Monitoring Programme. However, it is noted that lake water quality monitoring is not an effective or efficient way to measure and report upon the health of all lakes within the region over the long term, as water chemistry can change significantly over short periods of time, may not always reflect the ecological values and "health" of lakes, and requires regular and ongoing sampling.

Zooplankton

Lake trophic state has been found to be a major determinant of rotifer (microscopic zooplankton) community composition and distribution in North Island lakes. On this basis, Waikato Regional Council has investigated the use of a rotifer community composition index (Rotifer Trophic Lake Index) as an indicator of lake trophic status. Whilst this method appears promising, rotifer species" distributions can be influenced by a range of other factors, including the presence of cyanobacteria, predatory zooplankton and oxygen depletion. As a result, rotifer TLI scores may not always reflect lake trophic status. Average rotifer inferred TLI scores for 15 Waikato lakes are shown in the table below (from Duggan 2014 *in prep*).

Table 4 : Average rotifer-inferred TLI values from samples collected in December, February & March

Lake	2012/13	2011/12	2010/11	2009/10	2008/09	2007/08
Waikare	4.56	4.78	5.88	5.44	5.89	6.79

Submerged aquatic plant indicators (Lake SPI)

Submerged plants are thought to be effective indicators of lake ecological condition as they are:

- easy to observe and identify and are commonly found in lakes all year round;
- mostly rooted to the bed of lakes, so are non-mobile;
- able to integrate long-term changes in environmental conditions - therefore providing a more stable measure of overall lake condition, rather than responding to seasonal or daily changes in water clarity and chemistry; and
- mostly associated with lake edges/margins (the littoral zone), where there is greatest public interaction and interest – e.g. for recreation.

Lake SPI uses submerged plants as indicators of lake condition. Lake SPI scores are calculated using information about the composition and condition of native plants and the depth to which they grow. Lake SPI also provides a direct measure of the impact by alien invasive weeds that have invaded lakes over the past 150 years, often displacing native species.

Invasive plants often become dominant in lakes prior to vegetation collapse by forming dense mono-specific weed beds that exclude other species. Although invasive species are not favourable in terms of overall lake condition, Lake SPI recognises that the presence of any submerged plant species in a lake is preferable to none, as the plants act to mitigate many of the symptoms of eutrophication (e.g., absorb nutrients, maintain water clarity, stabilise the water column, compete with phytoplankton). Retention and or restoration of submerged plant communities, is therefore a high priority.

In a recent Lake SPI report, Lake Waikare has effectively proceeded to the stage where de-vegetation has occurred and the lake has become turbid and dominated by planktonic algae, with major impacts on other lake biota and lake use.

Pest Fish

Many of the Waikato lakes have serious pest fish infestations, including Lake Waikare which has an abundance of koi carp. To combat this an invasive fish trap/cage has been installed on the fish pass at the outlet of Lake Waikare to capture and remove invasive fish species that migrate into Lake Waikare from the Waikato River. Fish are trapped in the cage and minced flesh is digested in a low energy protein digestion process to produce a dry product that is suitable for a range of uses, including plant fertiliser. The commercial potential of this system is currently being evaluated. It is envisaged that this type of technology could be applied at various sites within the lower Waikato River system to coincide with dispersal and seasonal migration events.

SECTION TWO – TE KAUWHATA LAKES

8 Lake Waikare

Depth	1.8 m
TA	Waikato District Council
WRC zone	Lower Waikato
Land tenure	Lake bed administered by Waikato-Tainui
Lake area	3442 ha
Estimated catchment area	21,055 ha
Catchment land use	Dairy/drystock
Percent native vegetation cover in catchment	7.58%
Applicable joint agency accord/MOA	Waikato Lakes & Freshwater Wetlands Memorandum of Agreement
Lake level in WRP	□Yes
Identified as significant wetland (WRP Rule 3.7.7)	□Yes
Identified as Priority 1 stock exclusion	□Yes

Lake biodiversity ranking

Regional (71)	District (33)	Lake type (15)	WRC zone (29)
24	10	6	10
Figures in brackets indicate the total number of lakes included in assessment.			

Lake Waikare is the largest lake in the lower Waikato catchment. The lakebed was previously administered by LINZ but has now been transferred to Waikato-Tainui through the Waikato River Settlement Act (2011) process. It is located to the south-east of Te Kauwhata Township, and is connected to the Whangamarino wetland by the Pungarehu canal. The lake receives water from an extremely large catchment and discharges to the Whangamarino River and thenceforth to the Waikato River, via the artificial Pungarehu Canal. The lake is managed under a strict seasonal fluctuation regime of approximately 0.3 metres. Geothermal activity occurs on the eastern side of the lake, in and around Punikanae Rock.

Lake Waikare operates as a flood storage reservoir within the Lower Waikato Waipa Flood Control Scheme (LWWCS). Prior to the completion of the LWWCS in1965, Lake Waikare was part of an extensive hydraulically linked lake-wetland system that included lakes Kopuera, Ohinewai and Rotokawau, the Waikato River, and the Whangamarino wetland. During normal conditions water flowed from lake Waikare into the Waikato River through the Te Onetea Stream, although reverse flow occurred during flood events when the lake received water from the river via the Te Onetea and Rangiriri Streams and overland flow. High lake levels caused water to discharge from the lake into the Whangamarino wetland over the Te Kauwhata-Waerenga Road.

As part of the LWWCS, an outlet canal (with a radial flood gate) was constructed at the northern end of the lake (Northern Outlet) to convey water into the Whangamarino wetland. The Te Onetea and Rangiriri Streams were also blocked to prevent interchange between the lake and the Waikato River during normal flows. A culvert on the Te Onetea Stream is now opened to allow the Waikato River to flow into Lake Waikare.

As a result of these works, the average lake level was lowered by c.1m, and the lake level fluctuation range was reduced from 2.71m to 0.35m. Elimination of the natural seasonal fluctuation in water levels resulted in the loss of c.840ha of seasonally inundated wetland that had previously linked lakes Waikare and Rotokawau, which was subsequently cleared and converted to pasture. It is estimated that the wetlands surrounding the shores of Lake Waikare have been reduced by 67% since 1963.

Water quality monitoring was initiated by the WVA in 1982, and Waikato Regional Council has monitored the water quality of Lake Waikare every second month between 1996 – 2012. The lake was also sampled by Waikato Regional Council during the summers between 2007/08 – 2011/12 as part of a project investigating indicators of shallow lake health. Analysis of recent data indicates that between 2006 and 2010 there has been no significant change in the hypertrophic state of Lake Waikare which is extremely nutrient enriched (WRC 2012). Water quality information for Lake Waikare is summarised below:

	Mean SD (m)	**Mean Chl *a* (mg m^{-3})**	**Mean TN (mg m^{-3})**	**Mean TP (mg m^{-3})**	**Estimated TLI**	**pH**	**Turbidity (NTU)**
1982[a]	0.07 - 0.3	34.6		189.5		7.8	
1994-1997[b]	0.15	30.5	1202	161.8	6.28		
1998-2001	0.12	43.8	1436	245.3	6.62		
2002-2005	0.13	103	2414	371.3	7.19		
2006-2008	0.31	124	2836	209.3	6.90		
2003-2007[c]	0.3	100	2500	290			
2006-2010[d]					6.9		
2007/2008[e]	0.13	260	4851	400	7.7	8.75	150
2008/2009[f]	0.22	97.7	3649	203	6.99	9	69.7
2009/2010[f]	0.22	96.3	3268	167	6.88	8.1	68
2010/2011[f]	0.5	71	3001	113	6.44	8.63	48.1
2011/2012[f]	0.16	86	2315	161	6.8	8.1	57
2012/2013[f]	0.20	90.3	2601	128	6.73		

a Town (1982b) weekly water quality sampling undertaken by WVA between January - March 1982 b Average of samples taken between January 1993 and 2001- Barnes (2002a) – WRC data

c 2003-2007 WRC data reported in Hamilton et al (2009)

d 2006-2010 W R C shallow lakes water quality monitoring programme – bi-monthly samples. Data taken from Nutrient enrichment of shallow lakes State of the Environment Indicator: WRC (2012)

e WRC shallow lake health indicators programme (December/March) Neilson & Hamer (2008)

f WRC shallow lake health indicators programme (average of December, March, May samples)

Lake Waikare has extremely high levels of suspended inorganic sediment that reduce light penetration into the water column. Aerial photographs from the 1940"s indicate that the lake experienced increased turbidity during a time of extensive land clearance in the Matahuru catchment. Anecdotal information suggests that this turbidity declined whenever the Waikato River flooded, indicating that the turbidity was locally derived and that inflowing Waikato River water had a flushing effect. However, the construction of the LWWCS prevented flushing, and the c.1m water level reduction would have increased wave velocities, thereby increasing sediment entrainment and turbidity within the water column.

In 1982, the lake had high TP concentrations but relatively low chlorophyll *a* concentrations, indicating that algal production was limited by light availability or phosphorous absorption onto clay particles. Results between February 1993 and December 2001 demonstrated that the lake had become eutrophic and that restoration would be problematic. Water quality monitoring since 2002 indicates that concentrations of phosphorus, nitrogen, and chlorophyll *a*, have further increased with a corresponding reduction in water clarity.

The lake is presently hypertrophic, and blue-green algal blooms have become abundant in recent years. The Lake Waikare Steering Group (2007) reported that algal blooms are usually confined to isolated bays due to the influence of strong winds. Between 2010-2012, 90% of the 10 samples taken annually from Lake Waikare exceeded recreational guideline levels for blue green algae.

Recently Lake Waikare has experienced a red algal bloom which has been caused by a non-toxic microscopic algae, *Monoraphidium*. Cells have been present since May 2013, but reached considerable levels in June 2014 and became a source of considerable public concern.

An assessment of inflows indicates that the Matahuru catchment is the main source of lake nutrients and sediment, contributing an estimated 60% of TN, 53% of TP, and c.75% of the annual sediment load44 of the lake. The Te Kauwhata Sewage Treatment Plant discharge was estimated to contribute 6-10% of the lake"s phosphorus load and 1% of the lake"s nitrogen load46 before it was upgraded in 2006 (Lake Waikare Steering Group 2007).

The most recent lake SPI survey was conducted by NIWA in 2008 which confirmed that Lake Waikare remains de-vegetated. The lake has been in this condition since the collapse of its submerged aquatic vegetation in the late 1970's. Historically, Lake Waikare supported a range of aquatic plants, although submerged aquatic plants were comparatively less abundant in Lake Waikare than in other lakes in the lower Waikato region. Between the late 1960"s and 1977/78, substantial areas of Lake Waikare were covered in submerged vegetation, including *Egeria densa* (dominant) *and Myriophyllum triphyllum*. Since the collapse of submerged vegetation (documented by Williams) only sparse, low-growing plants have been recorded from restricted (sheltered) sites.

Submerged vegetation is likely to have gradually declined since the 1940"s due to decreased light penetration arising from increased turbidity and nutrient enrichment associated with land clearance, lake level reduction, and modification of wetland margins (including grazing). A phytoplankton bloom around 1977/78 is thought to have precipitated the final collapse of the (already stressed) submerged aquatic vegetation in the lake.

Regeneration of submerged vegetation is limited by a range of factors, including low water clarity due to the re-suspension of bottom sediments, and a high level of wind exposure that create an unsuitable environment for submerged plant regeneration. Recent studies indicate that it would be difficult to increase water clarity due to the presence of (strongly light attenuating) fine clay particles that are unlikely to settle out of the water column naturally and high concentrations of algae and dissolved humic matter that also attenuate light and limit the depth extent of submerged vegetation. The re-establishment of submerged vegetation is further impeded presence of plant damaging fish, a lack of plant inocula and blue-green algal scums (Reeves et al. 2002).

In recent years, DOC and Waikato Regional Council have undertaken weed control work for yellow flag iris and alligator weed in the vicinity of Lake Waikare under the provisions of the Biosecurity Act

Prior to 1965, a range of fish species were known from Lake Waikare, including eels, mullet, smelt, galaxiid species (including inanga and banded kokopu), bullies, shrimp, grey mullet, lamprey, and brown trout (Davenport 1980; McLea 1986). Nine species of fish were caught from the Lake Waikare catchment by McLea (1986) during surveys in 1983/84, including four native species (longfin eel, shortfin eel, smelt, common bully), and five introduced species (catfish, goldfish, mosquito fish, rainbow trout and rudd). Black mudfish and banded kokopu have also been caught infrequently. Black mudfish and fernbird are still known to occur within marginal wetlands, and freshwater mussels *Echyridella menziesii* were reported from the lake in 2013.

The construction of the northern control gates as part of the LWWCS created a barrier to fish passage, although a small pipe system was created for climbing species (e.g. elvers). In 2003, a new rock-ramp fish pass was constructed to bypass the Lake Waikare control gate that provided for fish movement between Lake Waikare and the Pungarehu canal. During monitoring in 2003/04, twelve fish species were captured moving through the fish pass, including native and pest fish species. The presence and dominance of exotic fish (particularly koi carp, rudd and catfish) in Lake Waikare is of concern as these species are known to browse aquatic plants, disturb sediments and dislodge aquatic plants during feeding. Because they occur in such high densities within Lake Waikare, pest fish removal methods have been the focus of recent research and management initiatives.

In conjunction with other agencies and stakeholders, Waikato Regional Council has installed a permanent carp cage trap at the outlet of Lake Waikare in conjunction with the existing fish pass. The trap has been very successful to date and has removed 20-30 tonnes of fish over the last 2 years. Once trapped, the pest fish are transferred into a bacterial digestor plant that is used to process the flesh of the fish into a dry granulated powder. Waikato Regional Council is investigating the use of this powder for plant fertiliser and other uses and considering options to install traps in a strategic manner within the lower Waikato basin.

Lake Waikare was historically regarded as the most important lake eel fishery in the Waikato, returning up to 85 tonnes per annum. The eel fishery declined as a result of the hydrological changes associated with the LWWCS, but eventually stabilised at a new level that reflected reduced levels of recruitment and habitat/food availability. The fishery is mostly focussed on shortfinned eels, particularly migratory shortfinned eels that exit the lake to sea during February–April.

Lake Waikare is a significant area for water birds, although its habitat value has declined markedly since the collapse of submerged aquatic vegetation and the construction of the LWWFCS. In particular, major reductions in the abundance of black swans and large black shags were observed as a result of habitat changes and reduced food supplies. Mallard numbers have remained high as the lake provides a daytime refuge for this species. A number of species of conservation significance have been reported from the lake including white heron, Australasian bittern, and NZ dabchick.

Lake Waikare is identified as a priority 1 waterbody for stock exclusion in the WRP, but is not yet fully fenced, and a number of the existing fences are not positioned on legal boundaries. It is estimated that up to 20km of fencing may be required to fully protect the lake margin from stock access.

Work has recently been undertaken on Waikato Regional Council scheme land around Lake Waikare (on the northern side of the lake) as part of the Council"s drainage consent mitigation requirements. This work has involved wetland creation and fencing of seeps.

In 1980, the WVA established an operating regime for Lake Waikare that provided for:
(i) The Te Onetea gate to be opened to facilitate flow from the Waikato River; and (ii) seasonal operating water levels for Lake Waikare of:

- 5.50 m (Moturiki datum) for the period of 1 April – 30 September
- 5.65 m (Moturiki datum) for the period of 1 October – 31 December
- 5.60 m (Moturiki datum) for the period of 1 January – 31 March.

The most recent (2002) resource consents for the operation of the Lower Waikato Waipa Flood Control Scheme adopted these levels but provided for an operating range of ±0.1m around these levels. This flexibility recognises the control limitations associated with the use of the Northern control gates in the context of the size of the lake and its inflows, and the rate of water level changes that can occur. The sediment management conditions of the discharge consent associated with the operation of the LWWCS are currently being reviewed due to concerns about the sediment levels associated with the discharge, that are subsequently deposited in the internationally significant Whangamarino wetland.

The degraded condition of Lake Waikare is a result of hydrological modification associated with the ongoing operation of the LWWCS, point source discharges, non- point source agricultural discharges from the lake"s wider catchment, and invasion by plant and animal pests. These issues occur at a large scale and combine to create a very complex restoration scenario. However, significant efforts have been made over the last 10 years to improve the condition of the lake. Waikato-Tainui has recently indicated that Lake Waikare will be their highest priority for future restoration and rehabilitation works.

As part of the resource consent and associated agreements for the ongoing operation of the LWWFCS, Waikato Regional Council was required to fence c.20km of the Matahuru Stream to reduce sediment inputs, and assess management options for the lake. A steering group was formed to oversee this work, and over $180,000 was allocated between 2002-2004 for riparian management, and research and monitoring projects associated with the lake. A lake care group was established for Lake Waikare in 2007.

The Lake Waikare Steering Group assessed a range of management options that were considered to be infeasible, ineffective or cost-prohibitive - including lake water level drawdown, dredging, mussel biofiltration and flocculent treatment. However, the steering group recommended the following management actions and indicated that the proposed Waikato Lakes & Freshwater Wetlands Memorandum of Agreement Group could be a key vehicle for their implementation:

- improved riparian management (fencing of lake margins, reducing sediment inflows from Matahuru Stream, creation of wetlands around the lake margin);
- consideration of reserve designation for Lake Waikare;
- cessation of the sewage discharge into Lake Waikare;
- review the costs and benefits of a range of lake levels; and
- researching the following management options:

    - increased inflows from the Waikato River (through Te Onetea Stream);
    - trial management of the sheltered Western Bays using wave barriers to reduce wave action and encourage regeneration of submerged macrophytes;
    - reducing koi carp density; and
    - lake flushing.

In 2012, potential mitigation options for reducing sediment inputs to Lake Waikare and Whangamarino wetland were identified and assessed against a range of criteria. All of the mitigation options had significant drawbacks (e.g. extremely high costs, high uncertainty of outcomes, unacceptable to key stakeholders) and none of the options offered a single solution. The highest scoring option was to reduce sediment inputs from farms in the Matahuru and Waerenga catchments, followed by reducing peak flows from Lake Waikare and constructing a treatment wetland between Waikare and Whangamarino. The review identified critical gaps in knowledge including better quantification of (i) sediment and nutrient inputs and outputs, (ii) the extent of surface flooding at Whangamarino Wetland and (iii) the contribution pest fish make to suspended sediment levels in both Lake Waikare and Whangamarino Wetland.

Options for management and acquisition of information include:

- develop a multi-agency catchment management plan for the catchments of Lake Waikare and the Whangamarino wetland, including: upper catchment management (including fencing and soil conservation); riparian management; invasive fish control; weed management, and research trials for in-lake management and restoration
- continue to monitor water quality and shallow lake health indicators in Lake Waikare
- work with landowners within the catchment of Lake Waikare to inspect and maintain existing fences funded by WRC under land owner agreements
- re-survey submerged aquatic vegetation in Lake Waikare using Lake SPI if submerged plants show any indication of recovery
- work with MOA members to implement the recommendations of the Lake Waikare Steering Group and future catchment management plans
- continue to support initiatives to reduce point and non-point source discharges into Lake Waikare
- continue existing work programmes to prevent koi carp and other invasive fish from entering Lake Waikare during peak migration times, and investigate options to produce commercial products from the carp digestor at Lake Waikare
- work with members of the MOA and others to assess and prioritise the lake"s future management requirements.

9 Lake Kopuera (Rangiriri)

Depth	1.5 m
TA	Waikato District Council
WRC zone	Lower Waikato
Land tenure	Waikato-Tainui (formerly Wildlife management reserve administered by Department of Conservation)
Lake area	52 ha
Estimated catchment area	250 ha
Catchment land use	Dairy/drystock
Percent native vegetation cover in catchment	24.5%
Applicable joint agency accord/MOA	Waikato Lakes & Freshwater Wetlands Memorandum of Agreement
Lake level in WRP	drains into Lake Waikare
Identified as significant wetland (WRP Rule 3.7.7)	Yes
Identified as Priority 1 stock exclusion	Yes

Lake biodiversity ranking

Regional (71)	District (33)	Lake type (15)	WRC zone (29)
36=	15	7	14
Figures in brackets indicate the total number of lakes included in assessment.			

Lake Kopuera is situated south of Te Kauwhata township in close proximity to Lake Waikare. The lake bed was formerly administered by the Department of Conservation as a Wildlife Management Reserve, but has been transferred to Waikato-Tainui as part of the Waikato River Settlement Act (2010). The lake has high cultural significance.

Lake Kopuera drains into Lake Waikare, and was lowered in 1965 as part of works associated with the creation of the Lower Waikato River Flood Control Scheme. There are no direct inflows into Lake Kopuera, and the lake outflow has been modified so that it now drains into Lake Waikare.

Waikato Regional Council holds no recent water quality information for Lake Kopuera. Town (1982) reports water quality results from 10 sampling visits to Lake Kopuera undertaken between 5 January -10 March 1982. At that time, the lake was described to be a very turbid green colour. The lake"s poor water condition was attributed to direct inputs of cowshed effluent and/or the effects of lake level changes.

	Mean SD (m)	Mean Chl *a* (mg m^{-3})	Mean TN (mg m^{-3})	Mean TP (mg m^{-3})	Estimated TLI	pH	Turbidity
1982[a]	0.05-0.2	292.8		383.4		9.4	
a :weekly water quality sampling undertaken by WVA between January - March 1982							

No submerged macrophytes were observed in Lake Kopuera in 1982, during water quality sampling. Submerged plant surveys in 1991 confirmed that plants were still absent from the lake, which was attributed to extremely poor water clarity.

The margin of Lake Kopuera is partially fenced, and it is estimated that approximately 2,500 m fencing would be required to completely fence the entire lake margin. To date, WRC has contributed to the costs of 2.1km of fencing around the margin of Lake Kopuera.

Because Lake Kopuera is identified as a significant wetland in s. 3.7.7 of the WRP, a resource consent is required to create new drains or deepen existing drains within 200m of the legal property boundary.

Lake Kopuera still supported a relatively intact narrow marginal fringe when it was surveyed in 1990, despite having been invaded by grey and crack willow. Lake level fluctuations associated with the flood control scheme may have allowed willows to colonise almost to the lake edge at the expense of emergent vegetation. An unusual and undescribed form of *Baumea* was observed at the lake, which is thought to be either a hybrid or new species.

The wetland associated with the lake comprises manuka scrub with *Coprosma tenuicaulis* that grades into willow forest on the margins. Damage to the understorey from stock grazing is obvious.

The lake and adjoining areas offer good habitat for a range of waterfowl including grey duck, fernbird, bittern, and spotless crake, which are of conservation significance. Catfish, eels, *Gambusia*, common bullies, goldfish, koi carp and rudd are known to occur in the lake.

Options for management and acquisition of information:

- seek approval to visit Lake Kopuera and survey lake health indicators
- work with Waikato-Tainui and other MOA members and interested parties to assess the lake and its future management requirements
- advocate and support Waikato-Tainui where possible, to improve the management of the lake margins (including fencing, willow control and planting)
- work with landowners in the lake catchment to encourage best management practices on farms to reduce nutrient and sediment inputs.

Restoration & management opportunities

In addition to the above, restoration and management opportunities exist at the Lakeside subdivision to improve lake values (eg cultural, historic, recreation, wildlife, water quality) and uses (eg swimming, hunting, fishing, water source). Opportunities associated with the Lakeside Te Kauwhata project include the following:

- riparian retirement (including fencing);
- enhancement of marginal habitat, including re-vegetation and weed control;
- reduction of nutrient and sediment inputs; and
- improving access to the sites for recreation and management purposes;

Riparian retirement and fencing

Riparian retirement, fencing and planting is an important aspect of lake restoration - particularly in pastoral catchments and is often the first step in lake restoration programmes. Riparian zones and wetland margins act as "buffer" zones between land and water, provide important habitat for native species, and serve to slow and filter runoff, thereby reducing nutrient and sediment loads entering the lakes from surrounding land.

Waikato Regional Council has worked with a number of landowners and other agencies to help exclude stock from Priority 1 stock exclusion lakes and wetlands. Financial assistance and advice has been provided to fence, plant, and extend riparian margins at priority lakes, and similar support could be sought for both Lake Waikare and Kopuera.

Whilst stock exclusion is the minimum requirement of the WRP, permanent 5 wire fencing (with 2 electric), and wire post and batten are becoming the minimum acceptable fencing standards for excluding cattle and sheep, respectively.

Enhancement of marginal habitat

Most shallow lakes are situated within pastoral catchments with narrow riparian margins, and small adjoining wetlands. Historically, these areas would have been far more substantial, and would have provided important habitat for terrestrial and aquatic species and wildlife. As well as their biodiversity value, these areas would also have played a critical role in maintaining water levels (and reducing flood peaks), and filtering contaminants from runoff and groundwater. It is therefore a high priority to protect and/or restore lake margins, associated wetlands and other native vegetation within the catchments of shallow lakes.

WRC has assisted private landowners to prepare and/or implement restoration plans for privately owned wetlands and lake margins that adjoin some lakes, and some substantial wetland restoration projects have been undertaken at certain lakes. Restoration options have also been assessed for some of the larger riverine lakes, including Lake Waikare.

Reduction of nutrient and sediment inputs

The conversion from dairy farm to residential housing will remove a major source of on-going nutrient contamination of the lakes, and so is viewed as a positive ecological outcome. While residential infrastructure such as roads will generate stormwater with vehicular contaminants (PAH, lead, copper and zinc), provided this is treated appropriately in water treatment wetlands the levels of metal contamination of the lakes is unlikely to be of concern.

Reducing external nutrient and sediment inputs to water bodies is a key focus, since many of the lakes receive large nutrient and sediment loads arising from intensive use of their surrounding catchments. The most commonly used methods to manage point source or diffuse pollution have involved wetland construction/enhancement, riparian planting, stock exclusion (via fencing) and the installation of silt traps. WRC has relied primarily on non-regulatory methods (education and incentives) to date and has offered financial subsidies for landowners to fence and plant riparian areas through the Clean Streams and Catchment New Works Programmes, and through external funding.

WRC have also supported the testing and development of constructed wetlands and silt traps to reduce sediment and nutrient inflows to lakes. Recent studies have focused on the design of these structures to maximise nutrient and sediment removals, with a view to developing best practice guidelines for application at shallow lakes within the regions.

Access to lakes

Physical access to shallow lakes is essential for their management and monitoring, and is a key aspect of shallow lake management and restoration projects. In Appendix G of its District Plan, Waikato District Council has identified Esplanade Priority Areas where it wishes to secure public access (as part of subdivision processes) to and along waterbodies and to the coast, including access to boat ramp sites at Lake Waikare via Gill Road – however, the Lakeside subdivision may provide attractive alternatives.