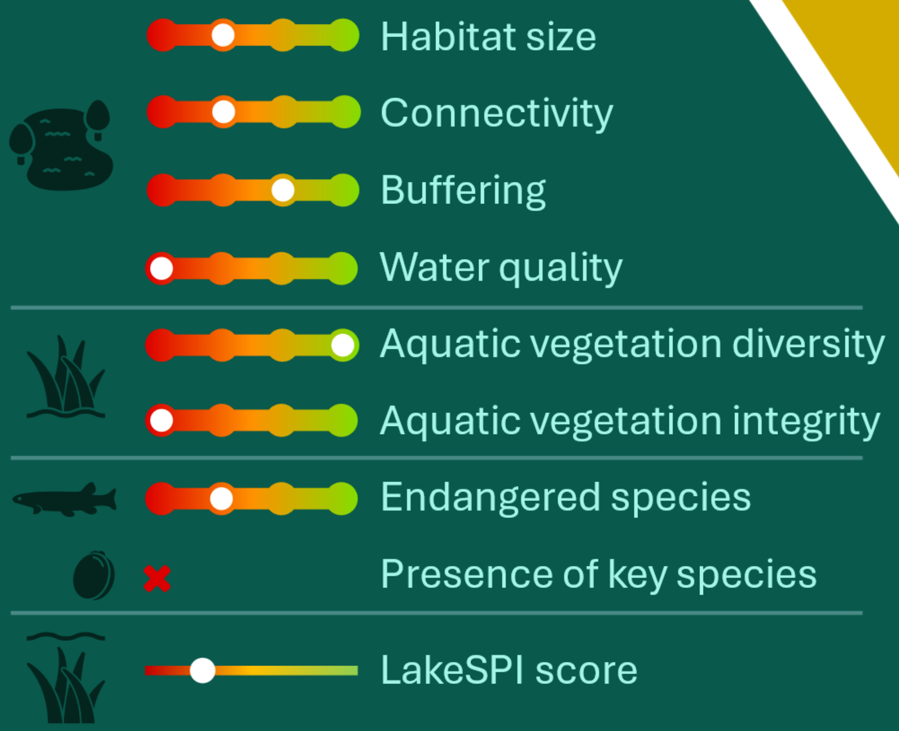
Lake Waiporohita

01/05/2024

NRC Lake Number: 99



ECOLOGICAL VALUE SCORE

8 /20

Overall Rank: High to Moderate

Key impact	Management action
Eutrophication: There are signs of nutrient enrichment from the pasture dominant catchment.	Develop a farm environment plan and use the management tool box for immediate interventions.
Invasive Species: The lake is easy to access so the risk of invasive species introductions is high.	Increase biosecurity awareness and install lake-side signage.
Canadian geese: These birds are adding a lot of nutrients and E. coli to the lake.	Develop and implement a Canadian geese control plan.
Declining state: There are signs of declining lake health.	Routine monitoring including monthly water quality testing as well as 3-5 yearly ecological assessments and invasive species surveillance.

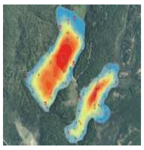
Did you know:

This lake shore is an iron pan covered with sand!

Northland REGIONAL COUNCIL

Te Kaunihera ā rohe o Te Taitokerau

Report card glossary



Habitat size: This score is based on the size and depth of the lake. Large deep lakes are more stable because they have a greater dilution capacity and a larger area to support different habitat types.

Connectivity: This score considers the number of nearby lakes and wetlands. This connectivity is important as several threatened birds travel between waterbodies that form a network of habitats across the landscape.

Buffering: This score is based on the riparian vegetation around the lake and how much native vegetation and wetlands there are in the catchment. This vegetation filters pollutants entering the lake from the surrounding land.

Water quality: This score is based on the nutrient concentrations in the lake. Higher nutrient concentrations typically result in a poor level of ecological health and is often associated with murky water and algal blooms.

Aquatic vegetation diversity: This score is based on how many different species of aquatic plants live in the lake. Lakes with a high diversity of aquatic plants are usually in better ecological condition.

Aquatic vegetation integrity: This score is based on the extent, diversity and condition of native submerged plant. Fully vegetated lakes with a high species diversity are often in the best condition.

Endangered species: This score is based on how many endangered plants and fish live in this lake. Endangered species add value to the ecosystem and are an indicator of good ecological health.

Presence of key species: This score is based on the presence of freshwater mussels (kakahi or torewai). These mussels are important for lake health because they filter the lake and remove algae.

LakeSPI: This score is based on the health, density and extent of native and exotic submerged plants in the lake. This score also integrates the impact of invasive submerged plants.

General description

Lake Waiporohita was assessed during the following years: 2004, 2005, 2006, 2011, 2014, 2017, 2019, 2021, 2022 and 2024.

Lake Waiporohita (34°54'01"S 173°20'52"E) is a shallow (3 m) 6.4 ha lake located on the east coast near Doubtless Bay. The lake is fenced and surrounded by mature riparian vegetation and manuka/kanuka scrub along the majority of the perimeter.

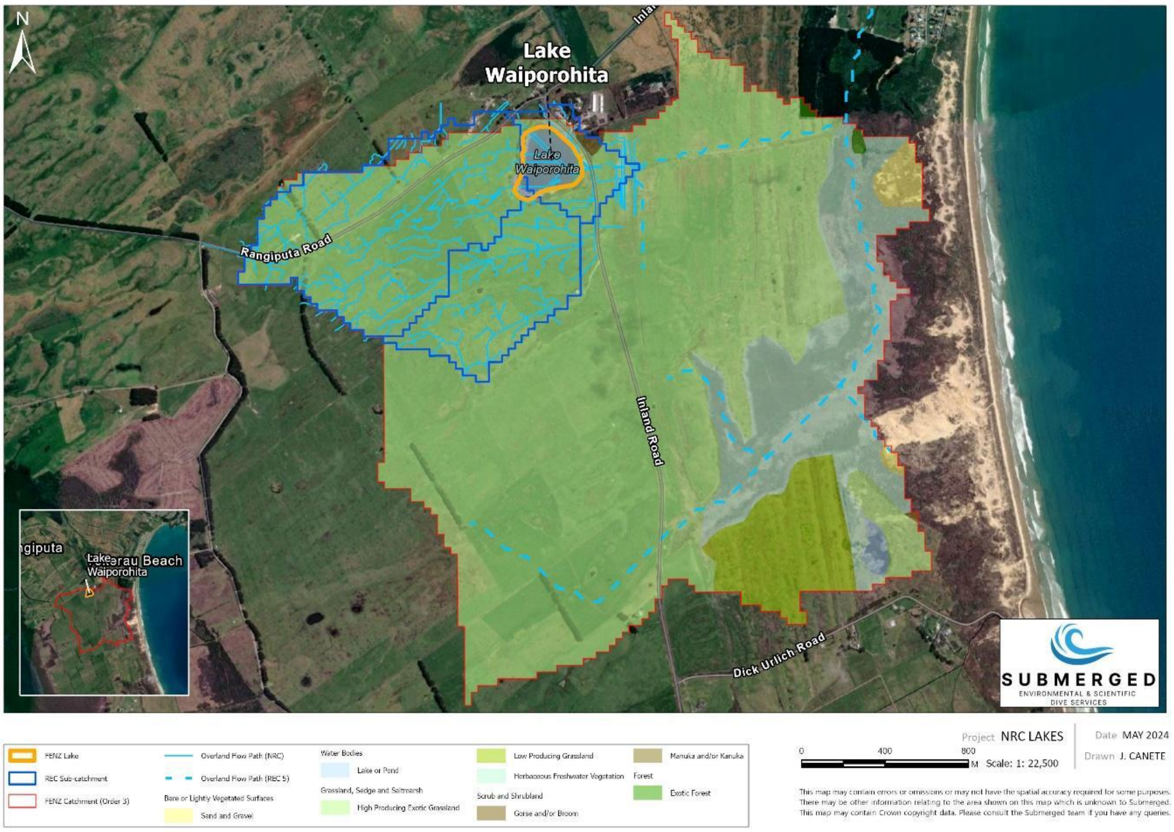
Health warnings were in place at the time of the 2024 site assessment and there was a green surface algal bloom along the eastern bank, which was presumed to be cyanobacteria.

Lake Waiporohita - Western view indicating the emergent riparian margin and Canadian geese

Catchment & sub-catchment description

The wider 562.05-hectare catchment is almost entirely covered by exotic pasture (83% of the total catchment). Fourteen percent of the catchment is classified as wetland; however, this is made up of a single wetland complex southeast of the lake. This wetland complex is not hydrologically connected to the lake via surface flows and is part of a separate main stem stream. The stream drains the wetland and flows past the lake before it drains to the coast. As a result, the wetland does not provide any buffering of contaminant loads entering the lake from the surrounding pasture.

The lake is surrounded by an entirely pastoral sub-catchment that is 131.82 hectares. The lake does not have any defined inflowing streams however, the overland flow tends to drain in a west to east direction which will deliver diffuse contaminant loads to the lake during high rainfall events. The limited sub-catchment buffering and high producing pasture land use directly contribute to the eutrophication of this lake.



Lake Waiporohita catchment land cover and overland flow path network

In-lake description

Divers did not enter the lake due to cyanobacteria blooms, so no in-lake assessments were done.

Wetland vegetation

The majority of the emergent vegetation was concentrated in a 20 m wide band along the northern portion of the lake. The remainder of the riparian margin had narrower bands of emergent vegetation or was bare.

The dominant riparian species were *Typha orientalis* with an outer fringe of *Eleocharis sphacelata*, with other areas of *Schoenoplectus tabernaemontani*, *Eleocharis acuta* and *Apodasmia similis*. Species colonising the hard iron pan area included annual weeds, *Chenopodium pumilio* and *Conyza parva*, but also indigenous species such as *Alternanthera nahui* and *Centipeda aotearoana*. The first record of *Gratiola pedunculata*, probably a natural introduction from Australia (de Lange 1997), was made at this lake in 1996 and has been commonly found since then in exposed grass/herb land amongst tall emergent vegetation, indicating successful establishment. Other species present were *Alternanthera denticulata*, *Paspalum distichum* and *Centella uniflora*. In 2007, *Alternanthera denticulata* had expanded its range over much of the lake margin growing on the lake side of some emergent vegetation.

A species of rush, *Juncus polyanthemus*, not previously recorded from New Zealand, was recognised growing in the marginal vegetation of Lake Waiporohita in 2009. This plant looked like a robust form of *Juncus usitatus* and was previously overlooked. It is likely to be another Australian vagrant. The first New Zealand record of the minute annual herb *Crassula natans* var. *minus* was also made at Lake Waiporohita in 2011. Since 2014, all four vagrant species were common around the lake and can be regarded as established at this site.

A 2 m^2 patch of alligator weed (*Alternanthera philoxeroides*) was noted in 2005 at the north end access point. This species has increased and was found amongst much of the marginal emergent vegetation. The introduced weed, primrose willow (*Ludwigia peploides* var. *montevidensis*), was also recorded. Both species are now widespread in the margins of Lake Waiporohita.

Submerged vegetation

Divers did not enter the lake due to health concerns, so no updated LakeSPI scores were generated.

The previous survey (2017) describes intact turf communities, consisting of *Glossostigma elatinoides, Lilaeopsis novae-zelandiae, Myriophyllum propinquum, the exotic Ludwigia palustris* and *Gratiola pedunculata,* that extended to 1 m deep followed by dense beds of *Chara australis* and stands of *Potamogeton ochreatus* to a maximum depth of 2.9 m.

In 2004 and 2006, charophytes were typically found at depths of around 1.5 m, but by 2011 and 2014, the lake had significantly improved, with vegetation covering the lakebed up to its deepest point at (3 m). A shift in the charophyte composition was noted, marked by a decline in *Nitella* sp. aff. *cristata* and a corresponding increase in *Chara australis*. *Nitella* sp. aff. *cristata* was last observed in 2011, while *Chara australis* has since formed tall, extensive meadows. Although small amounts of *Utricularia gibba* were observed in shallow areas near the emergent vegetation in 2014, there have been no sightings since.

LakeSPI

Divers did not enter the lake in 2024 due cyanobacteria blooms, so no updated LakeSPI scores were generated. The previous LakeSPI scores of 88 - 94% reflect the extent of the native vegetation, with limited influence of invasive exotic species.

Lake Waiporohita LakeSPI scores as a percentage of the maximum Potential LakeSPI score, Native Condition Index, and Invasive Impact Index

Survey Date	Status	LakeSPI %	Native Condition %	Invasive Impact %
March 2017	Excellent	94	85	0
May 2014	Excellent	90	83	4
March 2011	Excellent	88	83	7
Nov 2004	Excellent	93	83	0

Wetland birds

A high diversity of wetland birds was noted in 2024, with over 250 Canada geese (*Branta canadensis*), large numbers of black swan (*Cygnus atratus*), mallards (*Anas platyrhynchos*) and paradise shelduck (*Tadorna variegata*). Australasian little grebe (*Tachybaptus novaehollandiae*) were present along with shoveler (*Spatula rhynchotis*), grey teal (*Anas gracilis*) and a white-faced heron (*Egretta novaehollandiae*). The large numbers of swans and geese are concerning as they would elevate the nutrient status of the lake.

Several At Risk species including weweia (dabchick) (*Poliocephalus rufopectus*), royal spoonbills (*Platalea regia*), little black shags (*Phalacrocorax sulcirostris*) and black shags (*Phalacrocorax carbo novaehollandiae*) were seen across the lake.

The large areas of wetland and emergent vegetation provides good habitat for many aquatic birds including the following priority conservation species that have been sighted near the lake: weweia (dabchick) (*Poliocephalus rufopectus*), matuku (Australasian bittern) (*Botaurus poiciloptilus*), grey duck (*Anas superciliosa superciliosa*), black shag (*Phalacrocorax carbo novaehollandiae*), white heron (*Ardea alba*), mātātā (fernbird) (*Poodytes punctatus*) and brown teal (*Anas chlorotis*).

These sightings are within 5 - 10 km of the Motutangi and Waihuahua Swamps so it is likely that the lake is used by other wetland birds. Matuku (bittern) were recorded within 2 km south of the lake in 2008, 2009 and 2023. Weweia (dabchick), grey duck, mātātā (fernbird) and black shags were consistently seen using the lake from 2019 to 2023. White heron have been sighted between 2013- 2021 near Spirits Bay and Rangaunu Bay estuary so it is possible that they use wetlands/lakes across the northern tip of the region. Black shags are commonly sighted across freshwater environments in the region and there have been brown teal sightings along Tokerau beach.

Fish

Common bullies (*Gobiomorphus cotidianus*), shortfin eels (*Anguilla australis*) and invasive *Gambusia affinis* have been previously reported.

Aquatic invertebrates

Water boatmen (*Sigara arguta*) were reported to be abundant during the previous survey and leeches (*Richardsonianus mauianus*) were also seen.

There are no records of freshwater mussels in this lake. The poor water quality and frequent cyanobacteria blooms would likely prevent these key species from establishing in the lake.

Endangered species

The Threatened - Nationally Vulnerable grass *Amphibromus fluitans* was collected in 1998 but has not been seen since. This was the only recent record of this species in Northland. It is a cryptic species, superficially similar to other grasses common in this lake but has disappeared from this site.

There are three vagrant species first recorded in New Zealand from this lake; *Gratiola pedunculata, Juncus polyanthemus,* and *Crassula natans* var. *minus*. These are classified as Non-Resident Native - Coloniser by de Lange et al. (2018), naturally spreading here from Australia, but currently have a limited population size. Interestingly, *Crassula natans* var. *minus* is not native to Australia (being a South African species) but has arrived in New Zealand without human transfer.

Several At Risk wetland birds including weweia (dabchick) (*Poliocephalus rufopectus*), royal spoonbills (*Platalea regia*), little black shags (*Phalacrocorax sulcirostris*) and black shags (*Phalacrocorax carbo novaehollandiae*) were seen across the lake.

Lake ecological value

Lake Waiporohita was assessed as having “High to moderate" ecological value with a score of 8 out of 20. This score was based on the high diversity of emergent species in the riparian margins and the presence of three threatened plants.

A large planktonic cyanobacteria bloom prevented any investigation of the submerged ecology in the lake, so no macrophyte assessments were done during the 2024 survey. If the submerged macrophyte data from the 2017 survey is added to the calculations, the overall Lake Ecological Value Score would be an 11 out of 20 (High condition)

Lake Waiporohita is a small (6.4 ha) shallow (3 m) lake, so it scores a 1 out of 3 for the Habitat Size metric. There are several large waterbodies and wetland complexes on the Karikari peninsula north of the lake, there are also several smaller un-named water bodies to the west of the lake and a large wetland immediately south, so it gets an additional point for connectivity to other waterbodies.

The lake scores a 2 out of 3 for the Buffering Metric. Majority (>75%) of the lake perimeter consists of mature emergent vegetation. Large sections of the wider catchment are considered as wetland environments (14%) and native manuka/kanuka scrub (14%) which raises the overall buffer score.

No water quality data is available for the lake, so it is automatically assigned a 0 out of 3. This is done to ensure a standardised approach when scoring unmonitored lakes and is representative of the worst-case scenario. The lake-side health warning and surface cyanobacteria bloom are indications that the lake is likely eutrophic.

The lake supports a rich diversity of wetland plants, and the intact riparian margins have a variety of emergent reeds. Twenty-eight indigenous emergent plant species were recorded, resulting in a 3 out of 3 for the Aquatic Vegetation Diversity Metric.

The Aquatic Vegetation Integrity metric is taken from the LakeSPI Native Condition. No updated LakeSPI scores were generated during the 2024 survey, so the lake receives a default score of 0 for this metric. The 2017 assessment assigned a score of 3 out of 3 for the Aquatic Vegetation Integrity metric, which reflected the extent of the native vegetation and the limited influence of invasive species at the time.

Gratiola pedunculata and *Juncus polyanthemus* were the only endangered plants recorded during the 2024 survey. The presence of these rare species gives the lake a score of 1 out of 3 for the Endangered Species Metric. No endangered fish were seen during the previous surveys however, there are several records of threatened birds utilising the lake. Lake Ohia and the Motutangi and Waihuahua Swamps are less than 10 km away from the lake so it is likely that the lake forms part of a wider habitat for highly mobile threatened species.

No freshwater mussels were recorded during the previous surveys and the current in-lake conditions are unlikely to be able to support this key species.

Threats

The lake is located on the roadside with no fencing which makes access very easy. This significantly increases the risk of invasive species introductions.

Submerged weed species and pest fish would significantly impact the lake by outcompeting native species and, in part, contributing to the poor water quality. Alligator weed and primrose willow have now spread throughout the marginal vegetation but do not seem to be having a major impact on other marginal species.

Large flocs of Canadian geese are often seen on the lake. They feed on the surrounding pasture and introduce nutrients into the lake via faeces. The wide shoreline encourages water fowl to reside in the lake and it is likely that the associated nutrient inputs are a key driver of eutrophication.

The lake was previously improving in clarity and plant health, but dense cyanobacteria blooms are commonly encountered. These blooms pose a threat to human health and the drivers of these events need to be managed.

Management recommendations

New invasive species incursions and algal blooms associated with eutrophication are the primary threats that need to be managed. The following management actions are recommended:

Pathways assessment & biosecurity control plan

High-risk invasive species (e.g., *Ceratophyllum demersum*, *Egeria densa* & *Lagarosiphon major*) occur in several waterbodies across the region, so it is essential that the incursion pathways are identified, and a plan is developed to limit new incursions. Direct communications with the iwi, landowners, local hunters/fishermen, and wider engagement with industry bodies (Fish & Game, local hunting and fishing clubs) is recommended as a first step. Installing signage at the lake could help raise awareness of the impacts of invasive species.

Land/farm management plan

The impacts from the surrounding pasture can be better managed through an effective land/farm management plan. An initial assessment should be done to identify intermittent/ephemeral waterways entering the lake, key areas of diffuse overland flow, critical source areas for contaminants, and land use activities that do not follow best practices. Management interventions can then be selected from the Management tool box section to minimise the impacts from the catchment.

Geese control

The lake supports large populations of Canadian geese that add to the bioload in the lake. Considering how shallow the lake is, this increased bioload will likely have significant contributions to the in-lake nutrient concentrations. Controlling the geese numbers will help reduce the nutrient and *E. coli* levels in the lake. Due to the public nature of the lake geese control will be difficult however, subtle control methods such as egg addling could be employed.

Routine monitoring

Lake Waiporohita is a dynamic lake and is prone to new invasive species incursions and the impacts of eutrophication. It is recommended that routine monitoring includes monthly water quality sampling as well as 3 – 5 yearly ecological assessments and invasive species surveillance. Scheduling the in-lake surveys for winter, when the algal blooms have dissipated, could minimise the human health risk associated with diving in this lake. Alternatively, grapnel sampling or acoustic surveys could be used to assess the submerged vegetation. Diver surveys are preferred as they are more comprehensive and are directly comparable to previous surveys.

Management tool box

The interventions are grouped in tables (tool box) according to the contaminant they manage. Phosphorus, nitrogen, sediment, and *E. coli* were identified as the primary contaminants that drive deteriorating lake health.

The management interventions in the tool boxes are listed in order of efficacy and cost effectiveness e.g., the first option in the table is the most efficient and/or cost-effective way to manage that specific contaminant whereas, the last option is the least efficient and/or most costly intervention. The actual costs and efficiency will differ between farms as it depends on the specific land use activity, scale of the activity/issue, level of existing infrastructure, existing interventions, underlying topography and expected outcomes. For this reason, all interventions should be considered when drafting an environmental management plan.

Management Interventions for Phosphorus			
Intervention	**Description**	**Co-benefit**	**Comments**
Stock exclusion/ Fencing	Preventing livestock access to the lake, decreases bank damage, reduces sediment inputs via bank erosion and prevents direct deposition of faces. All of which reduce *E. coli*, N and P loads.	Allows riparian vegetation to establish which provides filtration capacity, shading, habitat, and organic matter input.	Excluding stock from the stream network reduces impacts to the downstream receiving environment. Most cost-effective intervention considering the wide range of co-benefits.
Tile drain amendments	Use of P-sorbing Ca, Al and Fe materials as backfill for artificial drainage systems. This	Additional filtration of sediment and faecal bacteria.	This is a potentially costly intervention but is very effective. It should be considered if there is a lot of overland flow

	reduces the nutrient load entering the lake.		paths draining into the lake.
Controlled release fertiliser	Use low-water-soluble P fertiliser. Less fertiliser-P is lost in runoff due to the low water solubility of products such as reactive phosphate rock resulting in increased P use efficiency.	Increases efficiency and P retention which lowers the overall amount of fertiliser required, resulting in large cost savings.	These types of fertilisers are not appropriate for soil pH < 6.0 or rainfall > 800 mm. Also, cannot be used for capital applications and must gradually replace highly-water soluble P applications at a rate of one-third per year.
Dams and water recycling	Recycling systems that divert irrigation outwash for use in others part of the farm reduces nutrient loads/discharges to the lake.	More efficient use of flood irrigation water and increased nutrient recycling.	Could require a change in irrigation infrastructure so should only be considered if water loss/discharges are a significant impact.
Precision/variable rate application of fertiliser	Precision fertiliser application using remote sensing of the nutrient status of the land to determine where & what nutrients should be targeted. This reduces the overall mobile nutrient load in the catchment and prevents excess nutrient loads entering the lake.	Reduction in the amount of fertiliser required, resulting in large cost saving.	Requires a change to the fertiliser application strategy and can present a higher initial implementation cost. Costs should reduce once the system is in place as less fertiliser will be required.
Precision irrigation	Use sensors to automate irrigation and nutrient inputs and optimises crop utilisation at fine scale.	Reduces the overall water and nutrient requirements, optimised applications result in better yields.	The initial infrastructure can be costly and requires active monitoring to ensure the process is optimised effectively.
Strategic grazing of pasture/crops within critical source areas	Identify the critical source areas of phosphorus and avoid grazing those areas during wet seasons.	Allows high P areas to be utilised for arable crops and allows a maximum yield from the land.	Requires more regular stock movement and an assessment of critical source areas.
Refurbish and widen flood irrigation bays	Water exiting flood irrigation bays as outwash represents about 20-50% of that applied. Re-contouring irrigation bays, and/or preventing outwash/wipe-off from accessing the stream network decreases P loads to the lake.	Recycling the water for use elsewhere on the farm reduces overall water consumption and nutrient requirements.	Recontouring can be costly and may result in a minor loss in yield.
Apply aluminium sulphate to pasture,	P-sorbing aluminium sulphate (alum) sprayed onto a winter forage crop	Reduces overall catchment phosphorus load.	Presents an additional annual cost.

forage cropland or crops in critical source areas	just after grazing, or sprayed onto pasture a week before grazing, will prevent surface runoff losses of P and reduce nutrient loads to the lake.		
Restrict grazing of winter forage crops	Restrict grazing of forage crops in winter to reduce deposition of faeces and surface erosion. This limits the amount of phosphorus entering the lake during the wet season.	Better conditions for stock and less pasture damage.	Requires active stock movement and planning. Must be accompanied by a stand-off area that has no connection to a waterway.
Cover/ catch crop	Grow cover/catch crops on the same field in the same year, often used after the main crop or grass has been grazed or machinery has exposed the soil. This reduces nutrient and sediment loads to the lake.	Enhances soil health, prevents erosion, reduces nutrient leaching, and improves yield.	This will improve the year-round use of the pasture and can be designed in a way to maximise yields.
In-stream sorbents	Use of P sorbing material textile bags and place them on the stream bed to remove P from baseflow. This reduces the amount of P entering the lake from overland flow paths.	Additional filtration of other contaminants and reduces the catchment contaminant load.	Installation might require in-stream works. The focus should be on streams that flow into the lake and/or drain high impact land use.
Phosphorus matching to crop requirements	Matching soil Olsen P concentrations to pasture and forage crop requirements avoids excessive soil P concentrations and reduces the P load to the lakes and stream network.	An agronomic optimum phosphorus dosing reduces the amount of fertiliser required and the overall annual cost.	Will require targeted soil investigations but the analysis is low cost and can be coupled with other soil health tests.
Vegetated buffers/planting below critical source areas	Vegetated buffer below critical source areas and at the base of steep sloped pastures work to decrease contaminant loss in surface runoff by a combination of filtration, deposition, and improving infiltration.	Stabilises land, provides habitat for fauna and helps create wildlife corridors across the landscape.	Choose vegetation types based on the outcomes and site details. Use different planting mixes for erosion protection than for nutrient attenuation.
Constructed/natural seepage wetlands	Modification of landscape features such as depressions and gullies to form wetlands creates additional catchment	Enhanced flood attenuation and increased habitat and biodiversity values.	These wetland features need to be fenced and restored to a good ecological condition for them to provide a high

	buffering. Restoring natural seepage wetlands at the heads and sides of streams will reduce the contaminant load entering the stream/lake network.		level of ecosystem services.
Sediment traps/retention ponds/bunds	In-stream sediment traps and retention ponds will allow coarse sized sediment and associated N and P to settle out. Bunds constructed along paddock edges creates ponds of water at the bottom of fields where sediment settles out which prevent excess contaminants from entering the lake.	Potential to buffer storm events and downstream flooding.	Typically, only effective on cropping land with slope greater than 3 degrees.

Management Interventions for Nitrogen			
Intervention	**Description**	**Co-benefit**	**Comments**
Stock exclusion/ Fencing	Preventing livestock access to the lake, decreases bank damage, reduces sediment inputs via bank erosion and prevents direct deposition of faces. All of which reduce *E. coli*, N and P loads.	Allows riparian vegetation to establish which provides filtration capacity, shading, habitat, and organic matter input.	Excluding stock from the stream network reduces impacts to the downstream receiving environment. Most cost-effective intervention considering the wide range of co-benefits.
Change animal type	Animal type influences nitrogen leaching due to differences in the spread of urinary nitrogen. Nitrogen leaching from sheep and deer is approximately half that from beef cows at the same level of feed intake.	Also leads to decreased N_2O emissions.	Careful consideration of the animal type is required as some species exacerbate other contaminant issues e.g., a change to deer may lead to greater sediment and P loss.
Constructed/natural seepage wetlands	Modification of landscape features such as depressions and gullies to form wetlands creates additional catchment buffering. Restoring natural seepage wetlands at the heads and sides of streams will reduce the contaminant	Enhanced flood attenuation and increased habitat and biodiversity values.	These wetland features need to be fenced and restored to a good ecological condition for them to provide a high level of ecosystem services.

	load entering the stream/lake network.		
Cover/ catch crop	Grow cover/catch crops on the same field in the same year, often used after the main crop or grass has been grazed or machinery has exposed the soil. This reduces nutrient and sediment loads to the lake.	Enhances soil health, prevents erosion, reduces nutrient leaching, and improves yield.	This will improve the year-round use of the pasture and can be designed in a way to maximise yields.
Reduce nitrogen in critical source areas	Reduced use of nitrogen fertiliser on winter forage crops coming out of long-term pasture and avoid excessive nitrogen inputs to effluent blocks. This reduces the nitrogen load entering the lakes during high rainfall events.	Decrease emissions of greenhouse gases, reduce overall fertiliser requirements and an improvement in energy use.	Will require targeted soil investigations to ensure an accurate soil nitrogen profile.
Strategic grazing of pasture/crops within critical source areas	Identify the critical source areas of nitrogen and avoid grazing those areas during wet seasons.	Allows high nitrogen areas to be utilised for arable crops and allows a maximum yield from the land.	Requires more regular stock movement and an assessment of critical source areas.
Precision/variable rate application of fertiliser	Precision fertiliser application using remote sensing of the nutrient status of the land to determine where & what nutrients should be targeted. This reduces the overall mobile nutrient load in the catchment and prevents excess nutrient loads entering the lake.	Reduction in the amount of fertiliser required, resulting in large cost saving.	Requires a change to the fertiliser application strategy and can present a higher initial implementation cost. Costs should reduce once the system is in place as less fertiliser will be required.
Precision irrigation	Use sensors to automate irrigation and nutrient inputs and optimises crop utilisation at fine scale.	Reduces the overall water and nutrient requirements, optimised applications result in better yields.	The initial infrastructure can be costly and requires active monitoring to ensure the process is optimised effectively.
Controlled release fertiliser	Use slow-release nitrogen fertiliser. Less mobile nitrogen is lost in runoff due to the low water solubility and slow release resulting in increased nitrogen use efficiency.	Increases efficiency and nitrogen retention which lowers the overall amount of fertiliser required, resulting in large cost savings.	These types of fertilisers may result in a lower initial yield and might not be as effective in cold dry soil.

Denitrification beds	Large containers filled with woodchips that intercept drain flow and denitrify nitrate in water to nitrogen gas which is released to the atmosphere. These reduce the concentrations of bioavailable nitrogen entering the lake.	Provides additional filtration of other contaminants.	Suitable for tile/sub-surface drains or small surface drains. Can create hydrological blockages in larger channels.
Restrict grazing of winter forage crops	Restrict grazing of forage crops in winter to reduce deposition of faeces and surface erosion. This limits the amount of phosphorus entering the lake during the wet season.	Better conditions for stock and less pasture damage.	Requires active stock movement and planning. Must be accompanied by a stand-off area that has no connection to a waterway.

Management Interventions for Sediment			
Intervention	**Description**	**Co-benefit**	**Comments**
Stock exclusion/ Fencing	Preventing livestock access to the lake, decreases bank damage, reduces sediment inputs via bank erosion, and stabilises the stream network.	Allows riparian vegetation to establish which provides filtration capacity, shading, habitat, and organic matter input. Prevents direct deposition of faces and reduces *E. coli*, N and P loads.	Excluding stock from the stream network reduces impacts to the downstream receiving environment. Most cost-effective intervention considering the wide range of co-benefits.
Cover/ catch crop	Grow cover/catch crops on the same field in the same year, often used after the main crop or grass has been grazed or machinery has exposed the soil. This reduces nutrient and sediment loads to the lake.	Enhances soil health, prevents erosion, reduces nutrient leaching, and improves yield.	This will improve the year-round use of the pasture and can be designed in a way to maximise yields.
Contour cultivation	Cultivation along contours of cropping land with slopes greater than 3 degrees reduces the speed and eroding power of runoff water.	Stabilises slopes and prevents slips. Increases yield by farming steep areas. Reduces nutrient loads from highly mobile soils during high rainfall events.	Requires new techniques and earthworks. This practice should be combined with detention ponds/bunds at the base of the slopes to further enhance contaminant attenuation.
Restrict grazing of winter forage crops	Restrict grazing of forage crops in winter to reduce surface erosion. This	Better conditions for stock and less pasture damage.	Requires active stock movement and planning. Must be accompanied by

	limits the amount of sediment entering the lake during the wet season.		a stand-off area that has no connection to a waterway.
Sediment traps/retention ponds/bunds	In-stream sediment traps and retention ponds will allow coarse sized sediment to settle out. Bunds constructed along paddock edges creates ponds of water at the bottom of fields where sediment settles out which prevent excess contaminants from entering the lake.	Potential to buffer storm events and downstream flooding.	Typically, only effective on cropping land with slope greater than 3 degrees.
Constructed/natural seepage wetlands	Modification of landscape features such as depressions and gullies to form wetlands creates additional catchment sediment buffering. Restoring natural seepage wetlands at the heads and sides of streams will reduce the sediment load entering the stream/lake network.	Enhanced flood attenuation and increased habitat and biodiversity values.	These wetland features need to be fenced and restored to a good ecological condition for them to provide a high level of ecosystem services.
Vegetated buffers/planting below critical source areas	Vegetated buffer below critical source areas and at the base of steep sloped pastures work to decrease sediment loss in surface runoff by a combination of filtration, deposition, and improving infiltration.	Stabilises land, provides habitat for fauna and helps create wildlife corridors across the landscape.	Choose vegetation types based on the outcomes and site details. Use different planting mixes for erosion protection than for nutrient attenuation.
Strategic grazing of pasture/crops within critical source areas	Identify the critical source areas of sediment and avoid grazing those areas during wet seasons.	Allows high sediment areas to be utilised for arable crops and allows a maximum yield from the land.	Requires more regular stock movement and an assessment of critical source areas.
Minimum tillage/ direct drilling of seed	Direct drilling of seed into stubble or pasture reduces the proportion of time that land is bare and erodible during the growing cycle. This greatly reduces the sediment loads entering the lakes/streams.	Enhanced soil condition and stability. Less erosional issues and increased productivity.	May not be suitable for all crop types.
Increasing forested area/ windbreaks	Combination of retirement and pole planting on highly erodible land.	Stabilises slopes and prevents slips. Increases yield by farming steep areas. Reduces nutrient	This intervention should be planed with other re-vegetation interventions to create blue-green

	Introduction of tree roots to soil regolith protects soil on steep slopes from mass movement erosion.	loads from highly mobile soils during high rainfall events.	networks and wildlife corridors across the landscape.

Management Interventions for *E. coli*			
Intervention	**Description**	**Co-benefit**	**Comments**
Stock exclusion/ Fencing	Preventing livestock access to stream and lake banks reduce stream bank damage and stops the direct deposition of excreta (*E. coli*) into the waterways.	Allows riparian vegetation to establish which provides filtration capacity, shading, habitat, and organic matter input. Prevents direct deposition of faces and reduces *E. coli*, N and P loads.	Excluding stock from the stream network reduces impacts to the downstream receiving environment. Most cost-effective intervention considering the wide range of co-benefits.
Strategic grazing of pasture/crops within critical source areas	Identify the critical source areas near waterways and avoid grazing those areas during wet seasons.	Allows these areas to be utilised for arable crops and allows a maximum yield from the land.	Requires more regular stock movement and an assessment of critical source areas.
Restrict grazing of winter forage crops	Restrict grazing of forage crops in winter to reduce the amount of deposited excreta during the wet season. This limits the amount of *E. coli* entering the lake during high rainfall events.	Better conditions for stock and less pasture damage.	Requires active stock movement and planning. Must be accompanied by a stand-off area that has no connection to a waterway.
Sediment traps/retention ponds/bunds	In-stream sediment traps and retention ponds will allow faeces settle out. Bunds constructed along paddock edges creates ponds of water at the bottom of fields where excreta accumulate. This prevents excess *E. coli* from entering the lake.	Potential to buffer storm events and downstream flooding.	Typically, only effective on cropping land with slope greater than 3 degrees.
Vegetated buffers/planting below critical source areas	Vegetated buffer below critical source areas and at the base of steep sloped pastures work to decrease excreta (*E. coli*) loss in surface runoff by a combination of filtration, deposition, and improving infiltration.	Stabilises land, provides habitat for fauna and helps create wildlife corridors across the landscape.	Choose vegetation types based on the outcomes and site details. Use different planting mixes for erosion protection than for nutrient attenuation.