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ROTORUA 2024

WEAVING SOIL SCIENCE ACROSS CULTURES & ENVIRONMENT

New Zealand Society of Soil Science

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Joint NZSSS and SSA Conference "Te Kiri o Papatūānuku"

2nd to 5th December 2024, Rotorua Energy Events Centre, NZ

PASTORAL CARE OF ROTORUA FIELD TRIP HANDBOOK

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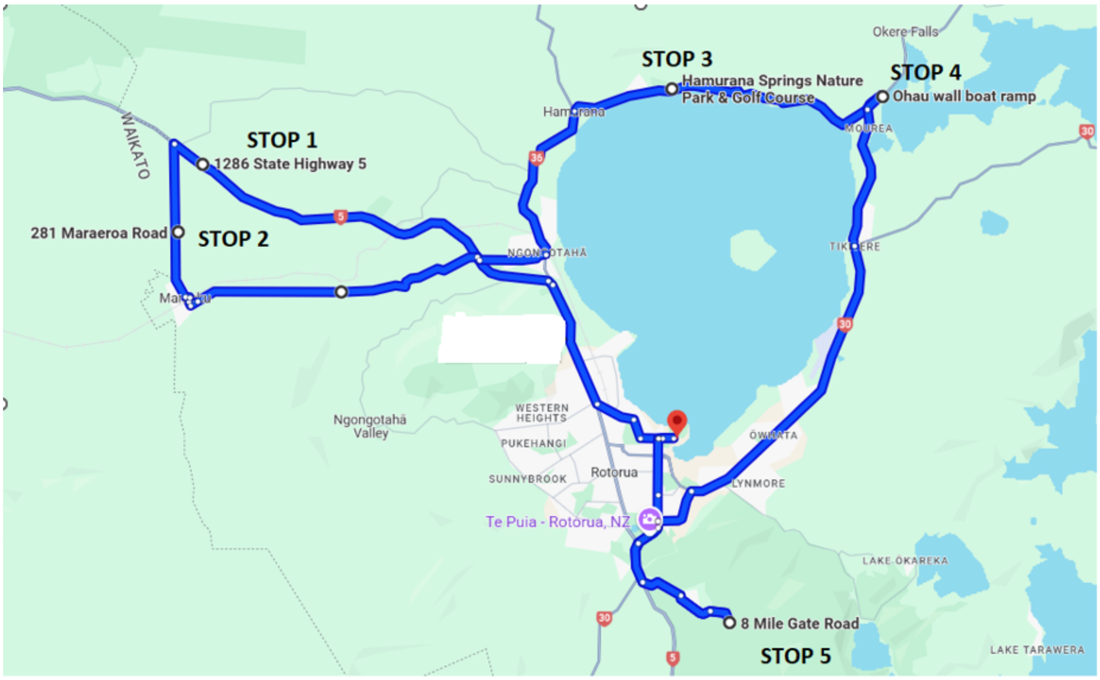
1. Tour Route Map and Site Locations

The Rotorua Lakes district has 14 major lakes with a total area of about 250 km^2, most formed as crater or caldera features following volcanic eruptions. Many of the lakes have unique active geothermal features. The lakes are taonga, valued for their incredibly clear waters, beauty and wildlife and are an important resource for fishing and multi-faceted effort to manage the nutrients entering the lakes, starting about 40 years ago with establishment of the Whakarewarewa effluent irrigation scheme. Our fieldtrip will take you to see some of the water, soil and land management innovations and challenges of living and farming in a catchment where strong rules are being implemented to prevent N and P from impacting the lakes.

Map of proposed route and stops



2. Itinerary

Stop	Time	Location	Topic	Facilitator
8 am Depart Rotorua Energy Events Centre				
1	8.30 am	Farm visit - Steve Holdem	Rotorua landscape – Overview of the geological history of the Rotorua Caldera Discussion around the N problem Overview of rules in Rotorua catchment Overview of the Holdems' farm system and management strategies utilised	Scott Fraser Stewart Ledgard Lee Matherson Steve Holdem
10.40 am Depart Steve Holdem's property				
2	11 am	Soil profile – Maraeroa Road, Mamaku	Soil pit profiles to view & discuss	Scott Fraser *Toilet available*
12.10 pm Depart Soil profile pits				
3	12.30 pm	Hamurana Springs	Lunch and self-guided walk *Tea & coffee and range of cold drinks can be purchased here*	*Toilet's available*
2.00 pm Depart Hamurana Springs				
4	2.20 pm	SH33 rest area – overlooking Ohau channel	Effect of N & P load on Lake Rotorua and mitigation options used	Andy Bruere *Toilet available down the road at boat ramp*
3.00 pm Depart SH33				
5	3.30 pm	Whakarewarewa Forest Park	Overview of the Rotorua wastewater treatment system – benefits and challenges	Alison Lowe
4.45 pm Depart Whakarewarewa Forest Park				

3. Overview of the Rotorua Basin

Presented by Dr. Scott Fraser (Manaaki Whenua, Landcare Research)

3.1 Geological Setting of New Zealand (Adapted from Hewitt, Balks and Lowe 2021, Soils of Aotearoa NZ, Chapter 1).

New Zealand lies on the collisional plate boundary between the Pacific and Australian tectonic plates which are moving towards each other at about 40 mm/year (Figure 1). In the North Island the Pacific plate is being subducted beneath the Australian plate, resulting in current volcanic activity in the central North Island and Taranaki. To the south of the South Island the Australian plate is being subducted beneath the Pacific plate. Through the central part of New Zealand, the boundary of the two plates is marked by the Alpine Fault, a transform or strike-slip fault that passes mainly along the western margin of the Southern Alps. The crumpling, uplift, and lateral movement, are marked by numerous hill and mountain ranges, and fault-lines, in both the North and South Islands.

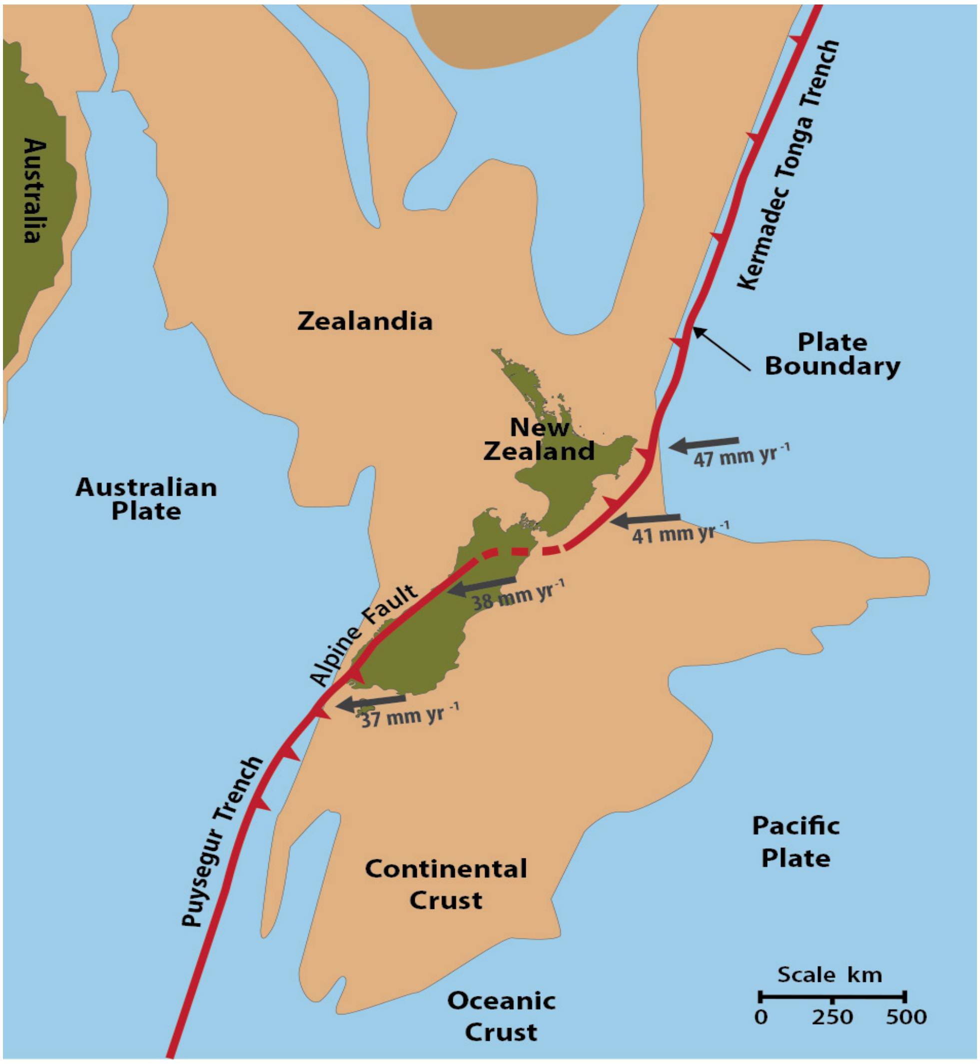


Figure 1: *The Zealandia continent and plate tectonic setting of New Zealand (Adapted from Q-map GNS)*

As the Pacific plate descends into the Earth's hot mantle, the crustal rocks are heated causing magma to form. The magma is mostly made up of materials low in silica called basalt. This evolves into andesite, with intermediate silica content, that erupts to form cone or stratovolcanoes such as Mt Ruapehu. Heat from the basalt magma causes the continental crust (mainly greywacke) to melt, leading to huge rhyolite eruptions, with high silica content, that can result in collapse of the land to form calderas such as those occupied by Lakes Taupo and Rotorua.

The volcanoes, and associated geothermal activity, are concentrated in a linear zone, stretching from Ruapehu in the south to Whakaari (White Island) in the north, called the Taupo Volcanic Zone (TVZ) (Figure 2). Large volumes of pyroclastic material, or tephra, have been explosively erupted from volcanoes in the TVZ and deposited over the landscape of the central North Island and beyond. Hence, many soils in the central North Island are formed from tephra deposits which, because of their intermittent deposition, often comprise multiple layers of tephra with buried soil horizons (paleosols) within them. Such soils are said to be formed by "upbuilding pedogenesis" whereby the deposition of tephra on the land surface causes the land to rise. At the same time, top-down soil-forming processes modify and transform the tephra materials to form soil horizons.

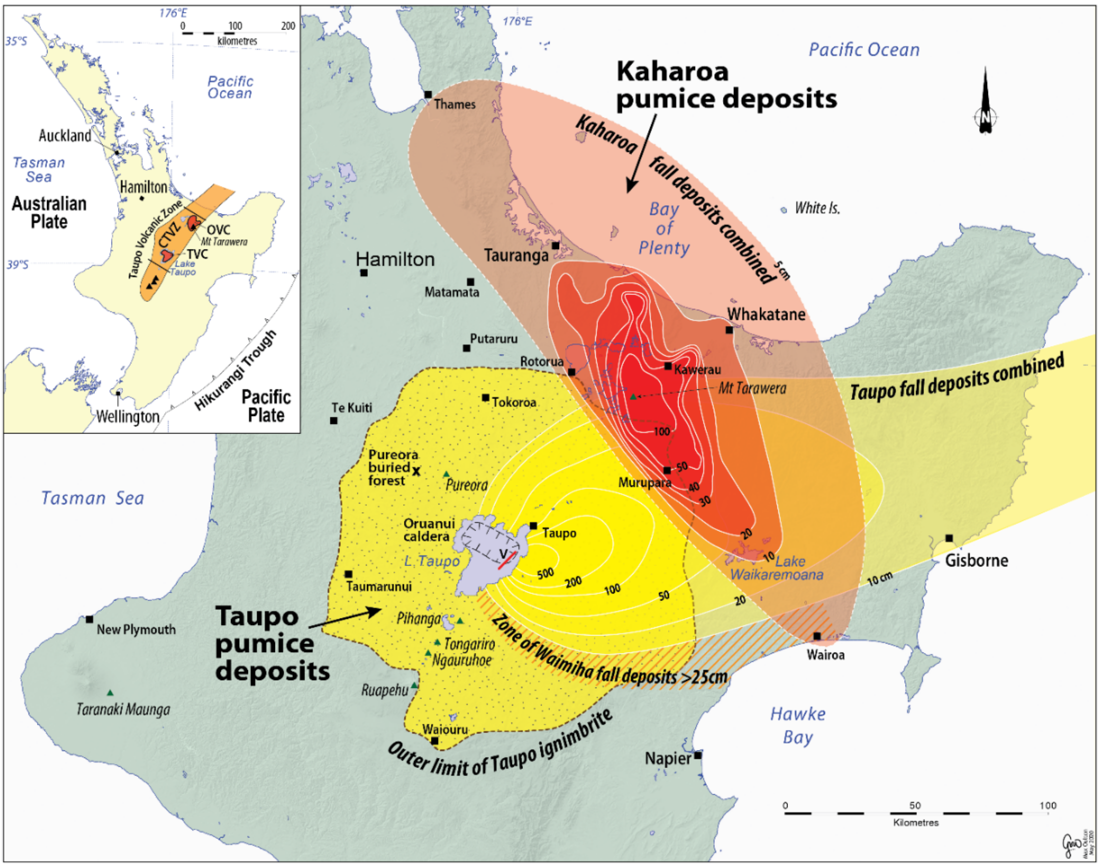


Figure 2: *Taupo volcanic Zone and thickness of deposits from the Taupo (232 AD) and Kaharoa (1314 AD) eruptions. From Hewitt, Balks and Lowe 2021, Chapter 12.*

The Last glaciation, which extended from about 115 000 to 11 700 years ago, with a glacial maximum between about 31 000 and 18000 years ago, had marked impacts on New Zealand. The average temperature in New Zealand was about 6 to 6.5°C colder, and it was about 25% drier, frostier, and windier. Sea level was about 135 m lower than at present. The treeline was lowered by about 800 m, and forest in most places (except Northland) was replaced by grassland or shrublands, or both, except in refugia where small patches of forest remained.

3.2 The Geological history of the Rotorua Basin

There are two major centres of volcanic activity in the Rotorua area, the Rotorua Caldera, which forms the Rotorua Basin, including Lake Rotorua, and the Okataina Caldera, which lies to the east of Rotorua and includes Mt Tarawera and many of the Rotorua Lakes. The first eruptions from the Okataina caldera were about 500 000 years ago. The most recent eruptions from Okataina were the Tarawera eruption in 1884, and the Kaharoa eruption 700 years ago (Figure 2), both from Mt Tarawera, with at least 13 other recognised eruptions in between (Houghton and Scott 2008).

The Rotorua caldera formed 220,000 years ago as a result of vast rhyolitic eruptions that produced the Mamaku Ignimbrite, which outcrops on the Mamaku Plateau (Figure 3). The Mamaku ignimbrite comprises over 200 cubic km of material (enough to bury greater Auckland with a 2 km thick layer of ignimbrite) that erupted as a series of pyroclastic flows, burying the pre-existing landscape to the north and west of Rotorua (Houghton and Scott 2008). It is hard to imagine the size of such an eruption. In this case the explosion flung more than 200 cubic kilometres of molten rock perhaps 25 kms into the air. The molten rock then fell back to earth, blasting out across the landscape like a fiery avalanche (the pyroclastic flow). It destroyed everything in its path, burying the landscape under a layer of ignimbrite (gaseous rhyolitic lava that contains pumice, clasts of the rock through which it erupted, and materials from the preexisting land surface that are caught up in the eruption). When the ignimbrite came to rest, in some places it was hot enough and thick enough (up to 200 m thick in some places) to weld into a hard rock. In other places it was not so strongly welded and so more easily eroded. The Mamaku ignimbrite covered perhaps 400 km^2 to the north, west and south-west of Rotorua and formed the gradually sloping Mamaku Plateau, which State Highway 5 runs through connecting Rotorua with Tirau and Cambridge. Erosion during the last 200,000 years (and particularly during the last glaciation) has gradually cut into the ignimbrite, wearing away the softer parts and leaving a series of harder rocky hillsides and bare rock columns. The ignimbrite erosion remnants are particularly noticeable on State Highway 5 between Tarukenga and Galaxy Roads. The nearly uniform height of the outcrops indicates the thickness of the layer of ignimbrite that smothered the land there so long ago. We will see them at Holdems' farm.

Following the Mamaku Ignimbrite eruption the remaining land collapsed in, forming the Rotorua Caldera. Rhyolite domes, such as Mokoia Island in the middle of Lake Rotorua, were formed from the eruption of more viscous lava associated with ongoing caldera collapse. Mt Ngongotaha is a rhyolite dome that erupted about 65 000 years ago. About the same time as Mt Nongotaha was formed, a large eruption from Okataina (the Rotoiti Breccia) blocked the outlet to Lake Rotorua and the lake level rose to about 80 m above the present lake level. You can see old lake shore terraces on the flanks of Ngongotaha. The lake level has fluctuated since then (in response to blockages and erosion of outlets), dropping rapidly about 21 000 years ago, reaching a level similar to the current level about 9 000 years ago then rising to 13 m above the current level about 7 500 years ago (Houghton and Scott 2008).

Figure 3: *Mamaku Ignimbrite, erosion remnant rock columns*

Except where there is ongoing erosion, the ignimbrites are overlain by many tephra layers, erupted from various North Island volcanoes, including Tarawera, and the Taupo, Rotorua and Okataina calderas along with minor inputs from the andesite volcanoes further south, including Ruapehu, Tongariro, and Ngauruhoe. Within the soil profiles there are also layers that have been identified as “tephric loess”, material that was reworked by wind during the last glaciation.

4. Stop 1: Nitrogen and Farming within the Rotorua Catchment

4.1 The problem with Nitrogen

Presented by Dr. Stewart Ledgard (AgResearch)

Farming in the catchment has increased in area and intensity over time. Farming has changed from mainly extensive sheep grazing to intensive beef/sheep and dairy. This change in land use has resulted in more nitrogen leaching (primarily from an increase in animal urine nitrogen deposited). This increase in nitrogen and the pumice soil types has resulted in increased nitrogen in the lake

This excess nitrogen enables increases in algal growth, and algal blooms frequently occurred over summer with health warnings to stay out of the lake water. This mass of algal material then dies and sinks to the bottom of the lake so that in summer, when the lake stratifies, anaerobic conditions result in the death of aquatic life.

The water quality in the 1970s was identified as the water quality aspired to by the community and a sustainable nitrogen load for Lake Rotorua calculated to be 435 t/year in 2010. The modelled nitrogen loss from land use was 755 t/year. This required a massive reduction in nitrogen load of 320 t/year.

4.2 Overview of the Nutrient Management Rules in Rotorua

Presented by Lee Matherson (Perrin Ag)

Consultation with the community on how to achieve this mammoth target resulted in the following breakdown:

- 140 T nitrogen to be removed through rules,
- 100 T nitrogen to be bought out voluntarily from landowners by Council,
- 50 T nitrogen to be removed through engineering works and other interventions by Council.
- 30 T from gorse program

Through the rules framework dairy farmers have to reduce their leached nitrogen, on average, by 30% and drystock farmers, on average, 22%. Each landowner has a leached nitrogen allocation and the total reduction is required to be made by 2032. This is broken down into managed reduction targets to be achieved by 2022 and 2027 to enable the landowner to adjust farming practices to meet their allocation.

4.3 Overview of Holdems' Dairy farm

Presented by Steve & Paula Holdem

Steve and Paula Holdem farm on the Mamaku plateau, overlooking Lake Rotorua (Figure 4). They operate a 265 effective hectare dairy farm, which they bought with Steve's parents, Jeff and Glenys in 2017. The Holdems have been using plantain since they purchased the property, as a key management strategy to meet N targets within the catchment. Plantain helps them run a profitable farm system while caring for the environment and building a sustainable future.

Figure 4: *View from the farm towards Lake Rotorua.*

<u>**Facts and Figures**</u>

Farm size (effective): 265 ha (Figure 6 – Farm map)

Stocking rate: 2.7 cows/effective ha

Contour: Flat to rolling

Soil class: Podzol (well-drained)

Rainfall: 2050 mm/year

Herd size and breed: 700 crossbred

Milksolids production (4-year average): 408 kg MS/cow or 1,087 kg MS/ha

Farm system class: System 3 *(80-89% of total feed is home grown. 11-20% of total feed imported to extend lactation and for wintering dry cows)*

Purchased feed: 35 t DM maize silage and 350 t DM Palm Kernel Extract (PKE)

Pastures: Rye, clover, plantain mix, Currently 21% Ecotain plantain average across the farm. 2 kg Ecotain broadcast in fertiliser annually. Undersewing 25% of the farm with Mohaka hybrid Tetraploid. Re-grassing using a 14 ha Maize crop rotation while nitrogen discharge allows. Trialling Ecotain/Mohaka crop 2 year rotation to help with N leaching/Re-grassing the steeper contour.

Run-off: 90 ha ex-dairy farm in the catchment (Hamurana) For all youngstock. 40 ha out of catchment for 40 carryover cows and for wintering 200 cows.

Dairy infrastructure: 55-a-side Herringbone shed, cup removers, Protrack drafting. 600 cow feedpad. 2 large silage bunkers (1 concrete lined). Covered PKE and fertiliser bunkers. 3 implement/calf sheds. 3 rhyolite quarries used as stand-off pads during winter wet periods (Figure 5).

Effluent management: Storage pond 4120 m^3, Pumps: 1 x Electric + 1 x PTO backup. 1 x travelling and 2 x stationary irrigators. 60 ha of coverage area. Contractors used to pump/cart to maize crop paddocks

Figure 5: *Aerial shot of cowshed and feedpad.*

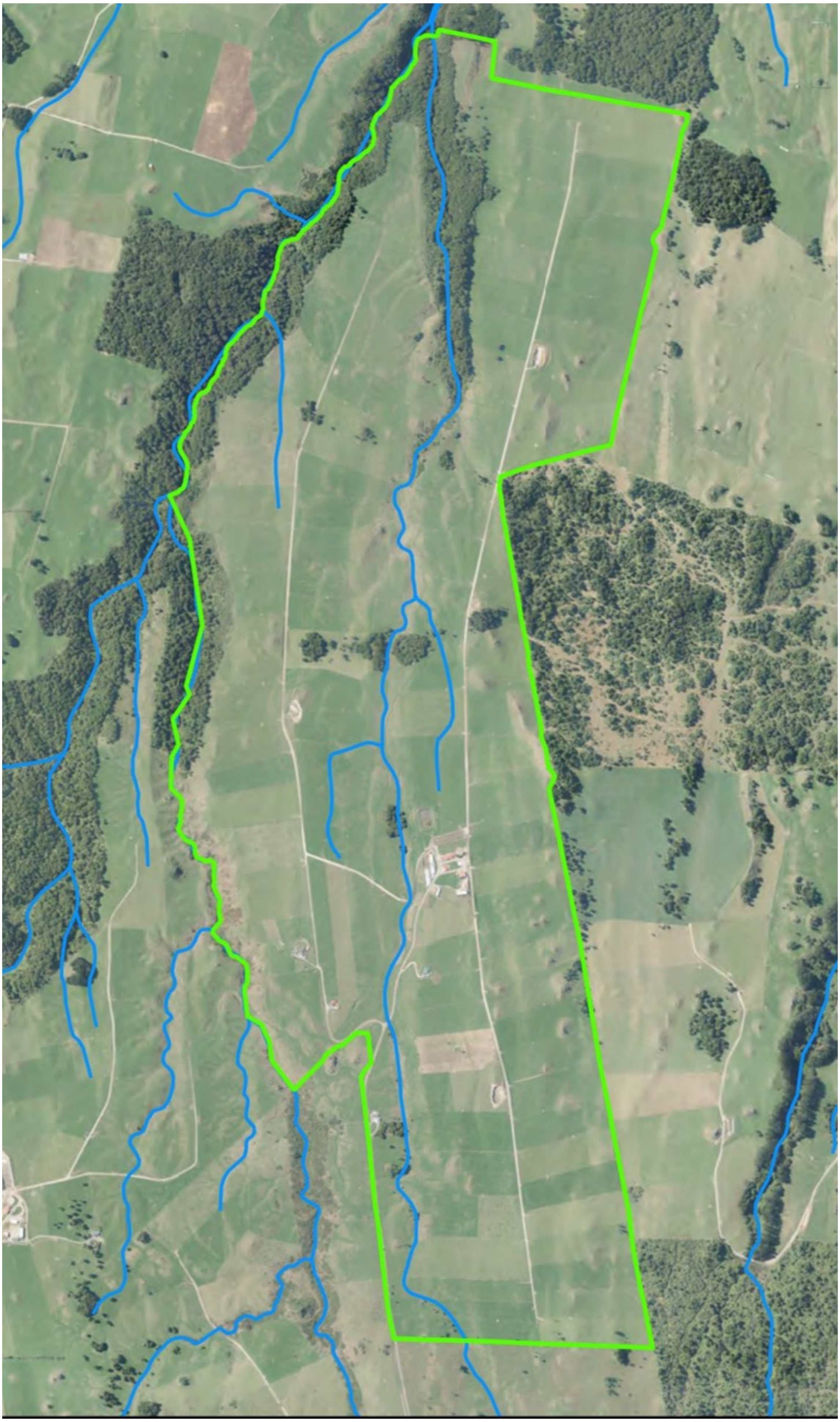


Figure 6: *Holdem Farm Map*

4.4 Management options utilised on the property

Farming in the Lake Rotorua catchment (Figure 7) means meeting challenging N-loss targets. Knowing they had to do their bit for the environment, Steve and Paula Holdem began looking at tools to reduce the N-loss from their farm.

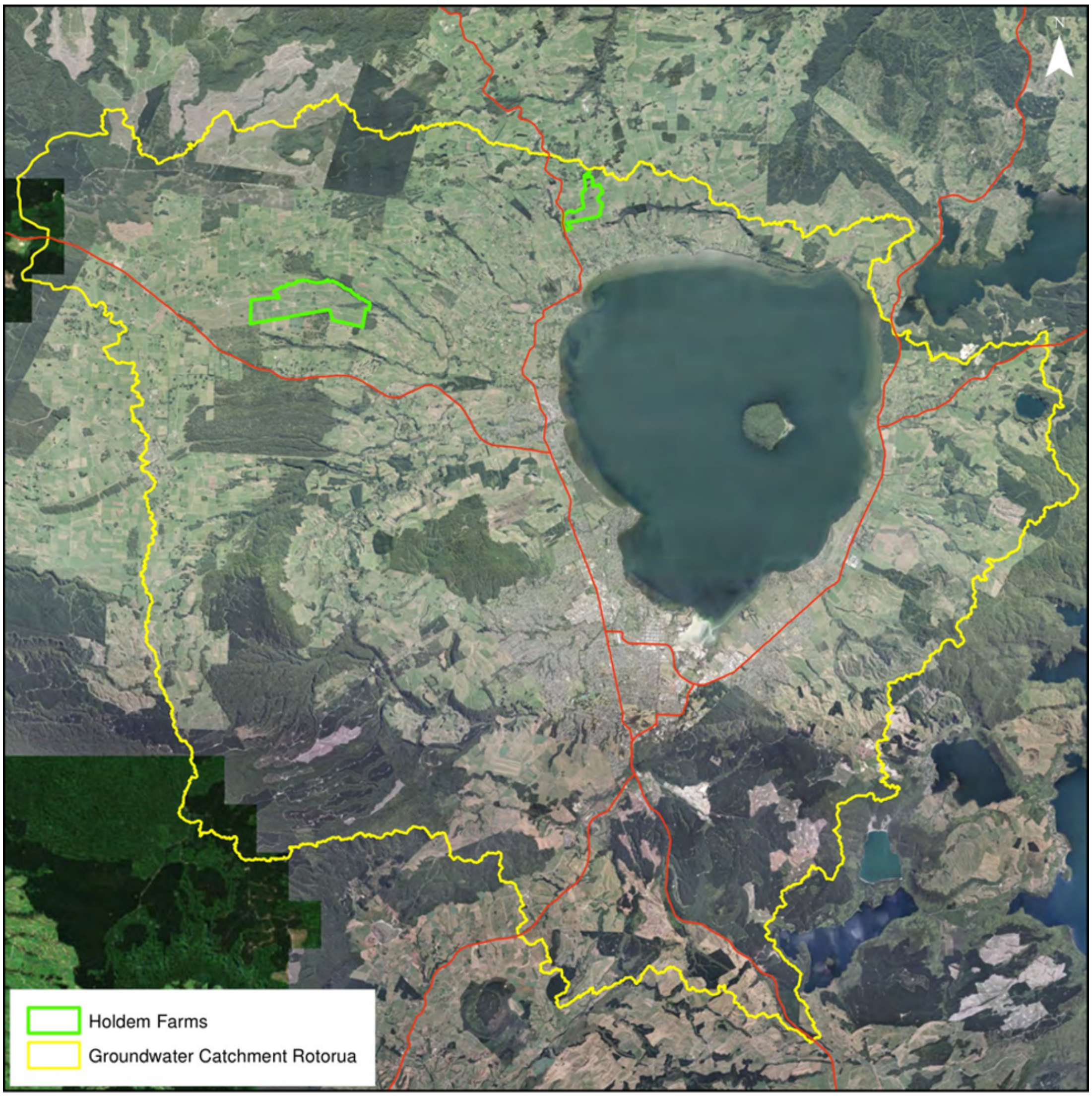


Figure 7: *Green section is the Holdem Farm and where it sits within the Lake Rotorua Catchment.*

4.4.1 Nitrogen-loss goal:

Holdem Farm falls under the regional council rules for the Lake Rotorua catchment. Steve and Paula are required to achieve a 29% N-loss reduction by 2032, down to 41 kg N/ha/year. The average N-loss reduction required for the Lake Rotorua catchment is 35%.

As part of the partner farm project with DairyNZ, three scenarios were modelled that achieve the target N-loss for Holdem Farm (Table 1). The base farm model included young stock and cows wintered within the system and no plantain use.

Scenario 1: Plantain +

- Including 30% plantain content in pastures
- 300 cows wintered off-farm, earlier autumn culling
- 7% less autumn N fertiliser use
- 7% lower stocking rate and 37% less imported feed

Scenario 2: Fewer cows & no plantain

- 31% lower stocking rate, no imported feed and surplus silage sold
- 300 cows wintered off-farm, earlier autumn culling
- 7% less autumn N fertiliser use

Scenario 3: Stand-off pad & no plantain

- Stand-off pad added and used in autumn and winter, increased effluent area
- 30 ha of less productive land converted to forestry
- 27% less autumn N fertiliser use
- 5% lower stocking rate, earlier autumn culling

Table 1. *Modelled N-loss scenarios for Holdem Farm*

	Base (2021/22 season)	**Scenario 1 (plantain)**	**Scenario 2 (fewer cows)**	**Scenaro 3 (stand-off pad)**
Production (kg MS/year)	299,552	267,702	205,296	275,764
Stocking rate (cows/ha)	2.1	2.1	1.9	1.4
N fertiliser to pasture (kg/ha)	99	92	92	76
Pasture conserved (t DM/year)	146	315	1096	222
Total N loss (kg N/year)	23,271	15,912	16,031	16,077
N leached (kg/ha/year)	**60**	**41**	**41**	**41**
N surplus (kg/ha/year)	174	148	111	146
Purchased N surplus (kg/ha/year)	73	41	-2	24
Operating profit ($/ha)	$4,109	$3,864 (-4%)	$3,631 (-10%)	$3,354 (-17%)
Methane (t CO_2 eq./ha)	6.26	6.44	4.99	5.96
Nitrous oxide (t CO_2 eq./ha)	1.86	1.59	1.41	1.47

*Modelled in Overseer and Farmax, based on DairyBase data

4.4.2 Plantain:

In 2018 they started incorporating plantain into their farm system. By 2023, there was plantain present across 92% of the milking platform of Holdem Farm. The Holdems have successfully incorporated plantain across the majority of their farm by broadcasting seed with their fertiliser. They started off by doing this at a rate of 8 kg/ha (4 kg/ha equivalent bare seed), with 100 ha of the farm broadcast with Ecotain seed in 2018/19. Over the following year, plantain was broadcast across the rest of the farm and some areas were undersown with 2 kg/ha of bare Ecotain seed. Over time the Holdems saw plantain content decrease across their farm. To maintain plantain, the Holdems now broadcast 4 kg of coated Ecotain seed per hectare with their fertiliser. This has allowed the Holdems to achieve plantain presence across 92% of their platform. The Holdems have found plantain grows better in less fertile areas.

Using plantain has allowed the Holdems to run 2.7 cows per hectare and meet their regional rules for N-loss. Without plantain they would have to drop to 1.9 cows per hectare with associated negative impacts on production and profit. The Holdems have found plantain grows easily on their farm, and while they haven't faced any challenges when using plantain, they have noted that it generally takes a full season for the plantain to appear after broadcasting.

Using plantain is an attractive N-loss mitigation tool for the Holdems when compared with the effects that reducing their herd by 200 cows would have on their business. They have reduced their N-loss by 12% in OverseerFM through using plantain, while increasing their milk production, achieving over 300,000 kg MS in the 2020/21 season.

5. Stop 2: Soil Profiles

Information provided as a separate hand-out on the soil profiles.

6. Stop 3: Lunch at Hamurana Springs

Hamurana Springs is a taonga (treasure) to the people of Ngāti Rangiwewehi, whose association with this land goes back to the mid 1300's (Figures 8 & 9). The rock surrounding the springs is volcanic in origin. The spring water travels down from the Mamaku plateau through undergound aquifers. This journey takes 70 years. From the springs, the water flows into the Kaikaitahuna River, into Lake Rotorua then through the Ohau Channel into Lake Rotoiti.

Facts and figures:

- The height of the springs above sea level is 280 metres
- The depth of the springs is about 15 metres
- The temperature is a constant 10 degrees
- Around 450,000 L of water flow out of the springs each hour – that's enough to fill two Olympic-sized swimming pools.

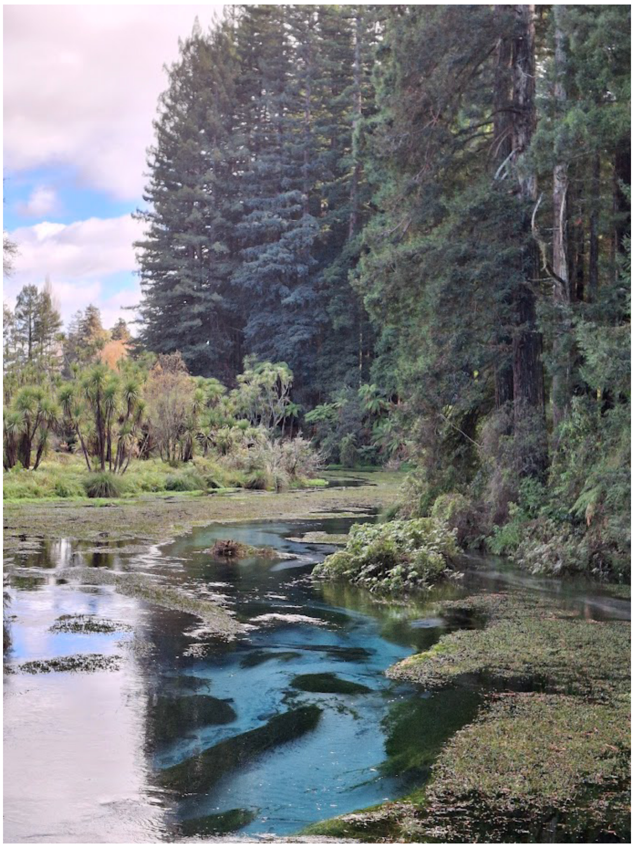


Figure 8: *View from the Hamurana springs walk*

Figure 9: *View from the Hamurana springs walk*

7. Stop 4: N & P load in Lake Rotorua and Management Strategies

Presented by Andy Bruere (Bay of Plenty Regional Council)

The water quality for all our lakes is summarised in our annual lake health report: [Rotorua Te Arawa Lakes Summary 2023/2024 (shinyapps.io)](). Our main water quality targets are based on annual and three-year trophic level indices (TLI), summarised below (Table 2). The Lake Rotorua catchment has significantly more intensive farming and land use than the Rotoiti catchment, with Rotorua having 24 dairy farms, for example, and Rotoiti having no dairying. The inflows to Rotoiti from Lake Rotorua were bringing nitrogen (N) and phosphorus (P) contaminaition along with seeding cyanobacterial blooms.

Table 2: *Annual and three year trophic level indices*

Lake	Trophic Level Index[2]	
	TLI 2023/24 (TLI Target)	TLI 3 Year Average
Ōkāreka	3.1 (3.0)	3.1
Okaro	4.4 (5.0)	4.6
Ōkataina	2.8 (2.6)	2.6
Rerewhakaaitu	4.1 (3.6)	3.6
Rotoehu	4.6 (3.9)	4.4
Rotoiti	3.8 (3.5)	3.7
Rotokakahi	*N/A[1] (3.1)*	*N/A[1]*
Rotomā	2.7 (2.3)	2.4
Rotomahana	3.8 (3.9)	3.8
Rotorua	4.4 (4.2)	4.3
Tarawera	2.9 (2.6)	2.8
Tikitapu	3.0 (2.7)	2.8

Rapid improvement in Rotorua water quality has been achieved by in-stream alum dosing, targeting P removal. However, the key strategy has been to improve land use in the Rotorua catchment, but the slow plume of nutrients in ground water make this improvement an intergenerational challenge. Land-use change impacts are predicted to take more than 35 years to show up in catchment improvements due to old-age ground water, which has been estimated to have an average age of about 60 years. To prevent the on-going contamination of Lake Rotoiti by water flowing in from Lake Rotorua a diversion wall was commissioned in 2008 to divert water directly down the Kaituna River.

The Ohau Diversion wall is a 1300m steel sheet pile wall (Figure 10). Constructed in 2007/08. Formed by driving king piles into the bedrock and filling the gap between each king pile with 2 sheet piles. The king piles go down up to 70 m while the sheet piles are only driven down into the sediment at 6 to 8 m.

Figure 10: *Aerial image of Ohau diversion wall*

The wall has been successful, and the performance of the wall in improving Lake Rotoiti water quality is detailed in the recent 7-year review. (See the two reports: 1970 (rotorualakes.co.nz) and ERI Report Template (rotorualakes.co.nz))

The following table from the review sumarises the water quality analysis using a range of analytical approaches:

Table 3: *Summary of findings for the water quality data analysis*

Approach				**Outcomes**		
	TL1	**TN**	**TP**	**Chlorophyll a**	**Secchi depth (SD)**	**Overall impact in Rotoiti WQ**
Descriptive statistics	N/A	Improvement	Improvement	Improvement	Improvement	Improvement in all variables post-wall
Correclation analysis	N/A	No improvement	No improvement	No improvement	Significant improvement	Significant change post-wall in SD only
Intervention analysis	Significant improvement (down 0.59 units)	Significant improvements (down 203 ppb)	No improvement	No improvement	Significant improvements (up 2.5 m)	Significant step change post-wall in TLI, TN & SD

The review also involved water quality modelling for a range of scenarios with and without the wall. These are summarised in Table 4. Bay of Plenty Regional Council also doses alum into two streams contributing to Lake Rotorua as a short term solution to algal blooms. This partially mitigates effects on the Kaituna River. Sewage reticulation of lake-side communities also forms part of the long-term strategy of water improvement.

Table 4: *Summary of findings for the water quality lake system modelling wall-out scenarios*

Wall-out scenario (c.f. wall-in scenario), as Ōhau Channel inflow water quality	Outcome (8-years post wall removal)					
	TLI	TLn	TLp	TLc	Overall impact in Rotoiti WQ*	Does Rotoiti meet TLI target of 3.5
Simulated scenario						
Wall-out with max TLI of 4.41 (i.e., as measured)	Increase of 0.02	Increase of 0.08	Decrease of 0.09	Increase of 0.07	Small decline (TLI = 3.96)	No
Wall-out with max TLI of 4.2 (i.e., as a 15.5% reduction in WQ parameters)	Decrease of 0.02	Increase of 0.02	Decrease of 0.12	Increase of 0.04	Small improvement (TLI = 3.92)	No
Wall-out with max TLI of 3.8 (i.e., as a 39% reduction in WQ parameters)	Decrease of 0.08	Decrease of 0.07	Decrease of 0.16	Decrease of 0.02	Improvement (TLI = 3.86)	No
Inferred scenario						
Wall-out with max TLI of 4.3	Expected hold	Expected hold	Expected decrease	Expected increase	Expected hold in TLI, but not all of TLn, TLp, & TLc	No
Wall-out with max TLI of 4.0	Expected decrease	Expected decrease	Expected decrease	Expected hold	Expected hold in TLI, & each of TLn, TLp, & TLc	No

* Modelled TLI, thus to be interpreted relative to equivalent modelled 'wall-in' scenario TLI of 3.94.

Note 1: Key conclusion: To meet Rotoiti TLI target 3.5 without the wall, more interventions are required in Rotorua and Rotoiti. Rotorua may need to reach a TLI of 3.8, quite a substantial improvement on current water quality and target.

Note 2: Green font = positive impact while red font = negative impact on water quality WRT target TLI.

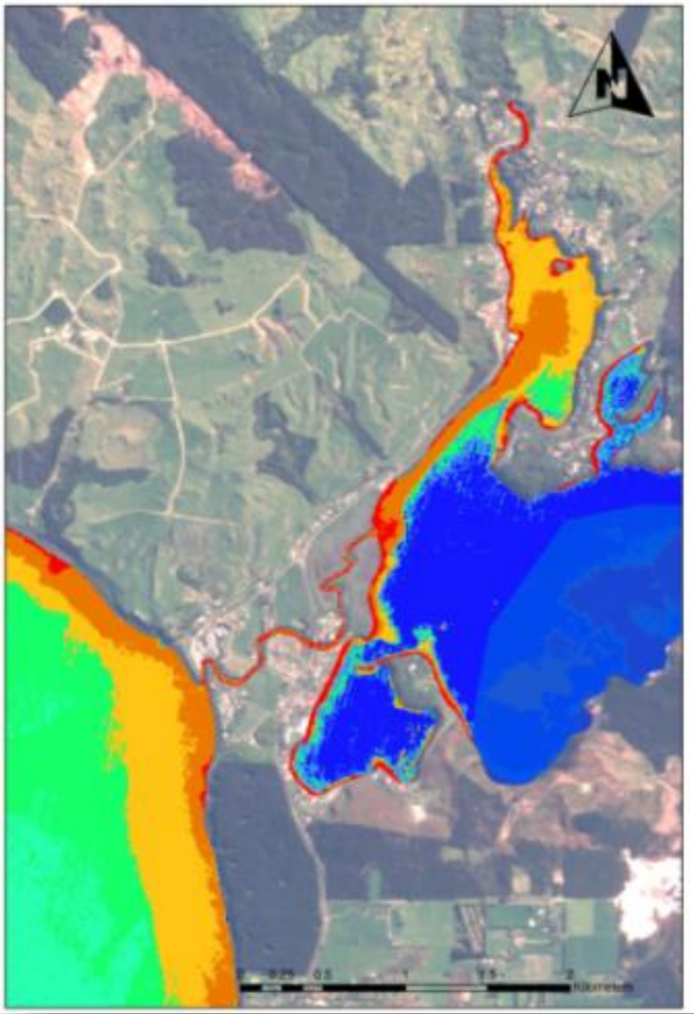


Figure 11: *Satelite image of Ōhau Channel and the effect of the diversion wall on water flows. (Image is enhanced to show cyanobacterial concentrations.).*

8. Stop 5: Rotorua Wastewater Treatment Plant

Presented by Alison Lowe (Rotorua District Council)

8.1 Wastewater Treatment Plant (WWTP)

- Rotorua has one Wastewater Treatment Plant serving the main urban area
- 1970s - Lake Rotorua water quality deteriorating from surrounding agricultural land use and increased urbanisation (Rutherford et al 1989, Donald et al 1991).
- 1973 – WWTP upgrade to strip P prior to discharging to lake (1973-1990)
- 1988 – WWTP upgrade to 5-stage Bardenpho, first full biological N and P removal process for municipal wastewater in NZ
- 1991 – Commissioned the Land Treatment System
- 2005 – WWTP upgrade to allow for a population of 70,000, upgraded RAS pumps, extended Bardenpho, upgraded aeration system, carbon dosing to remove additional N
- 2012 – WWTP upgrade added a MBR (membrane bioreactor) to take 1/3 of flow for additional secondary treatment and membrane filtration
- Exceeding consent limit around 2012 and Environment Court-mediated outcome was to investigate alternative discharge locations
- 2013-2015 stakeholder process agreed on a WWTP upgrade to first and foremost restore the mauri of the water to the extent possible before returning to the receiving environment – this is underway
- 2024 – Current upgrade to increase peak capacity from 44,000 to 72,000 m^3/d, remove P, full-membrane filtration, UV
- Annual average flow 20,000 m^3/d (range 17,000 - 23,000 m^3/d)
- The treatment plant removes approx 90% of N and 50% of P from sewage
- Treated water is irrigated to a land treatment site in Whakarewarewa Forest
- Biosolids, historically composted and/or landfilled, for last decade have been trucked to Kawerau, mixed with pulp fibre and vermicomposted (contract).
- Vermicast is blended with bark and other organic material and the compost is applied to land.

8.2 Land Treatment Site

- Within 433 ha of Whakarewarewa Forest - commercial Pinus radiata (Figure 12).
- Includes approx. 47 ha of wetlands scattered throughout the site.
- Effective irrigated area 220 ha
- Three soil series predominate: Haparangi, Whakarewarewa and Ngakuru.
- They are all developed on layers of tephra resulting in deep, free-draining profiles and differ from each other with the presence or absence of Rotomahana mud and the thickness of Taupo tephra in the upper part of the profile (Lowe and Jones, 2006).
- Rotorua Tephra is particularly thick (2-3m in places) and usually coarse-grained and the allophanic clay content and P retention are high. The coarse texture of the soil means it has a moderate to rapid infiltration rate, which allows water to readily move through the soil profile.
- Annual rainfall range 1300-2200 mm/y and thecatchment discharges to Lake Rotorua

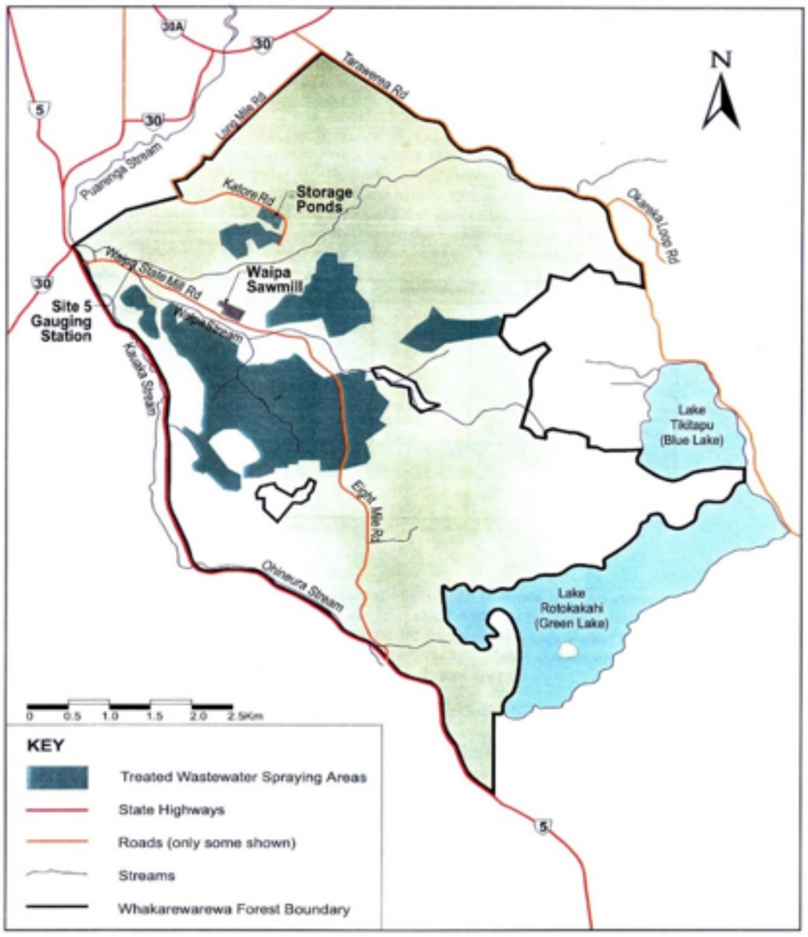
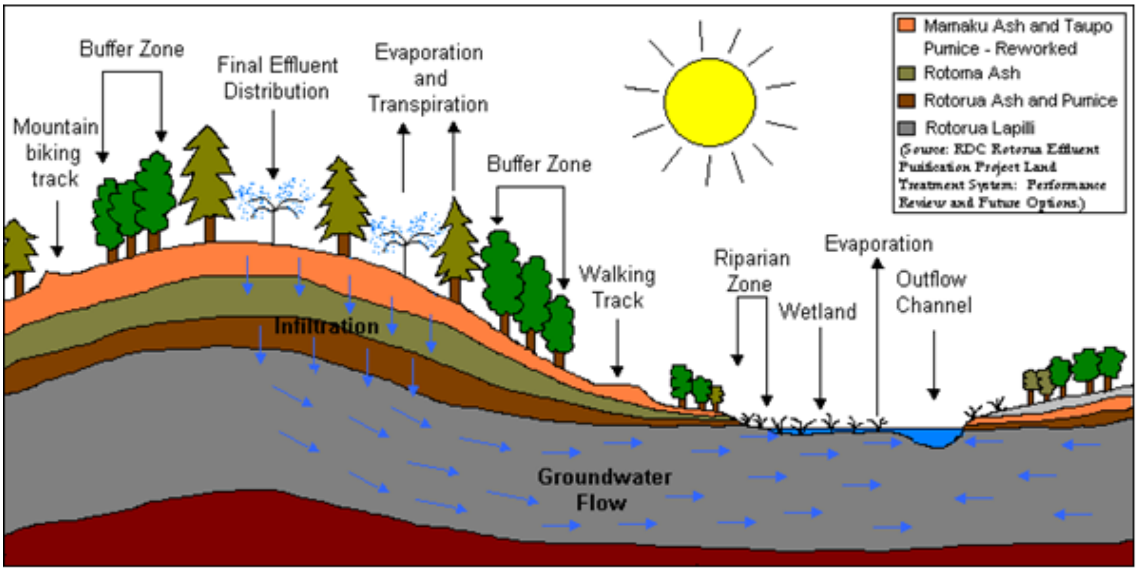


Figure 11: *Land treatment site in the Whakarewarewa forest*

8.3 Land Treatment System

- Treated effluent is pumped from ponds at the WWTP through a 3.3 km long pipeline (66 cm diameter) rising 120 m vertically to holding ponds in the forest that balance continuous treatment at the WWTP with intermittent spray irrigation.
- Pumps distribute the treated effluent through 24 km of underground pipes, then a 120 km network of over-ground pipes in 16 blocks.
- Of the 16 blocks, 14 are used at any one time (193 ha).
- Treated effluent is applied at 5 mm/hr through above-ground sprinklers
- The above ground pipework is easy to remove and reinstate when trees are felled, and there is around 2 years stand-down time around harvest.

- Spray areas have 15-30 m wide vegetated buffer zone bordering forestry roads and public walking tracks to reduce spray drift and to provide a visual and physical barrier to the irrigation areas.
- Prior to Jan 2002, each block was irrigated for 1 day per week with a recovery time of 6 days. Subsequent to this, each block has been irrigated for approximately 2 hours, 9-10 mm per day.
- Currently, irrigation is scheduled to minimise environmental impact, to meet forest operational and harvesting requirements, and to comply with the resource consent requirements.
- The LTS was designed for soil, plant and wetland components of the landscape to remove nutrients before the groundwater drains to Waipa Stream, and Lake Rotorua.



8.4 Monitoring & Performance

Monitoring commenced in 1991

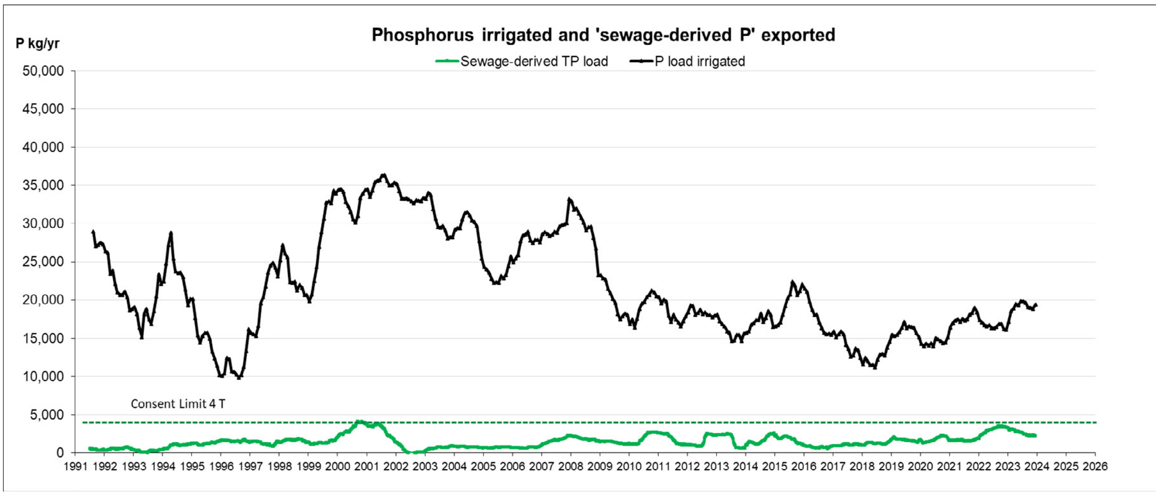
Discharge	• Daily discharge volume to each spray-block. • Weekly effluent composite sample - Cl TN NH4-N Tox-N TP DRP • Weekly effluent grab sample - E Coli
Streams	• Monthly streams - TP DRP Tox-N NH4-N TN Cl SS E. coli • Streamflows were determined using calibrated height gauges for the first 10 years
Wetlands	• Monthly wetlands first 10 years - DRP Tox-N NH4-N Cl
Soils and forest	• Sampled and analysed periodically for research projects
Downstream (export)	• Waipa Stream flow data collected continuously • Weekly flow-proportional composite sample TP DRP Tox-N NH4-N TN Cl pH SS • Weekly grab sample – E. Coli

Discharged to the LTS

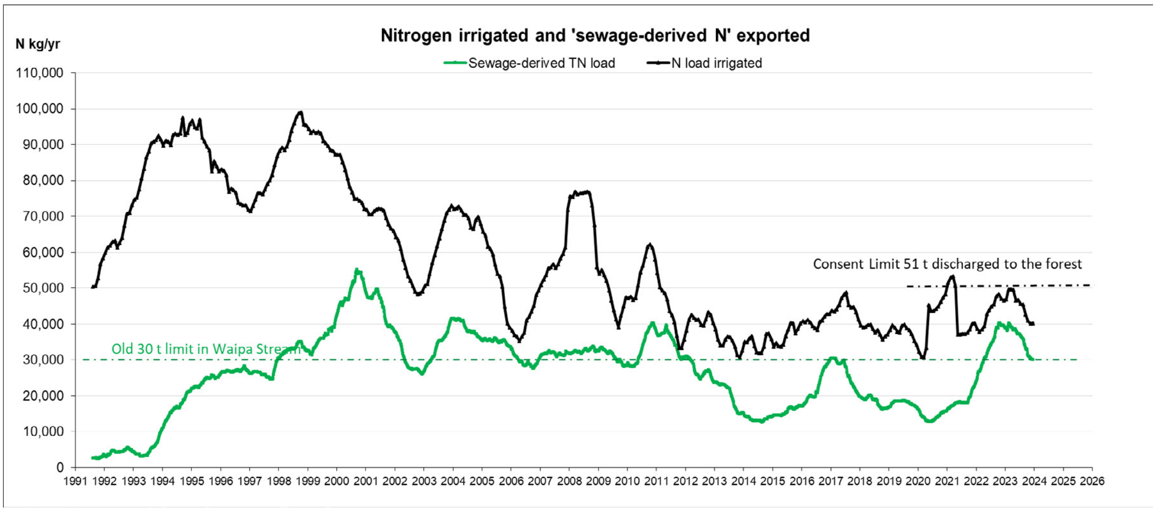
	Raw sewage (g/m³)	Treated effluent 1991-2005 (g/m³)	Treated effluent 2023-2024 (g/m³)	Load 2023-24 (kg/ha/yr)
Total N	47	10.6	6.3	238
Oxidised N	<0.5	6.5	3.6	136
Ammonium N	31	2.6	0.3	11
Total P	8	3.6	2.7	102
DRP	6	3.3	2.3	87

load based on total irrigated area of 193 ha

- The LTS continues to retain the applied P
- Together the treatment plant and land treatment system remove 37 t P from Rotorua's wastewater each year
- The residual 3 t P enters Lake Rotorua



- Together the treatment plant and land treatment system remove 330 t N from Rotorua's wastewater each year
- Residual 30 t N enters Lake Rotorua
- Nitrogen leaching is highly related to rainfall and nitrate concentration



Gielen (2006) pulled together results from various studies to show the distribution of effluent applied nitrogen within the LTS.

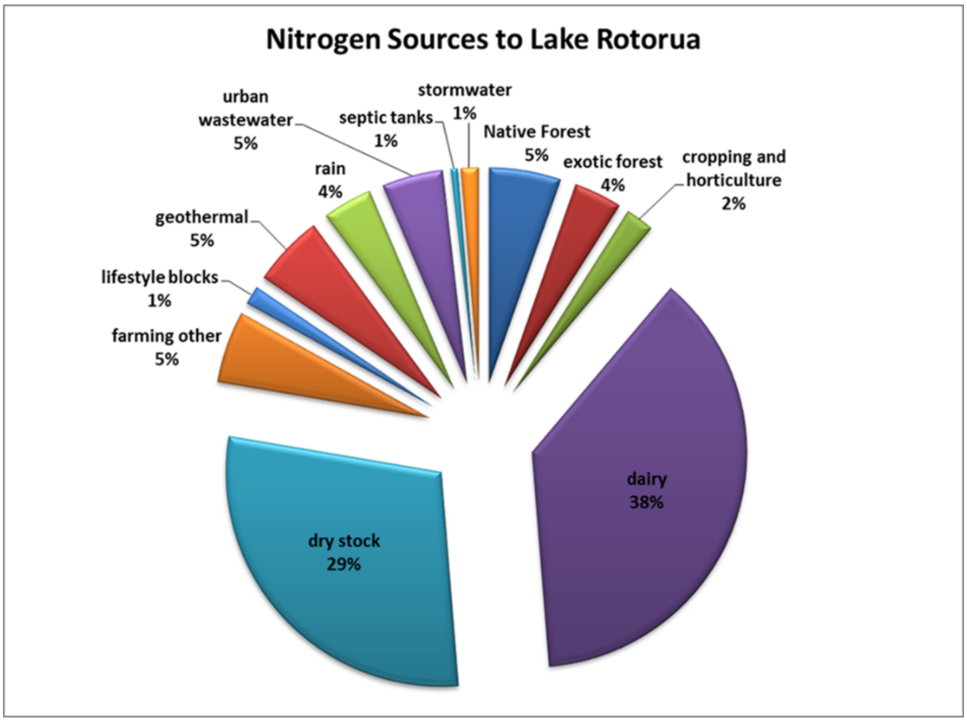
N-flux pathway & reference	Relative magnitude (% applied N)	Duration of study (years)
Soil storage		
McLay *et al.* 2000	43 %	4
Tozer *et al.* 2005	50 %	11
Wetland storage		
Tozer *et al.* 2005	13 %	11
Upland soil denitrification		
Barton *et al.* 2000	< 1 %	1
Wetland denitrification		
Tozer *et al.* 2005	3 %	11
Peacock *et al.* 1998	minimal	0.25 (12 weeks)
Tree uptake		
Tomer *et al.* 2000	8 %	5
Tozer *et al.* 2005	13 %	11
Understory		
Tozer *et al.* 2005	1.5 %	11
Soil leaching		
Gielen *et al.* 2000	39 %	5
Stream export		
Tomer *et al.* 2000	32 %	6
Tozer et al. 2005	29 %	11

- Approx 2/3 of the nitrogen applied in the first 11 years was stored in the system, predominantly in the soil.
- Two studies have found wetland denitrification to be minimal despite an estimated high denitrification potential.
- Tozer et al (2005) sampled the ecosystem after 11 years' operation, and using δ15N analysis to determine the fraction of nitrogen attributable to effluent,

estimated that only 3% of the effluent applied to this site over 11 years had been denitrified.

- Peacock et al. (1998) found that a substantial amount of the groundwater from beneath the irrigated forest was 'short circuiting' to above-ground seepages, and effectively flowing over, rather than through, the organic-rich margins. And this surface water was found to travel the length of the wetland within 24-hours, providing limited contact time with organic substrates.

8.5 Sewage-derived nutrient loads relative to other loads to the lake



Lake Rotorua nutrient inputs (t/y)

	1965	1976-77	1981-82	1984-85	2007	PC10 N target 2032
Phosphorus						
Treated sewage	5	8	21	34	1.5	
Streams	34	34	34	34	**34**	
Nitrogen						
Treated sewage	20	73	134	150	32	
Streams	455	485	420	415	**660**	
Septic tanks	50	80	15	10		
N TARGET						**435**

Council continues to work with stakeholders on alternative discharge locations. Numerous options have considered but no decision yet.

FAQs | Rotorua Wastewater Treatment Plant Upgrade | Let's talk | Kōrero mai

9. References and Related Papers

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Hazard Management Plan

Field trip: NZSSS Pastoral Care of Rotorua
Date: Tuesday 3rd December 2024
Field trip supervisors and contact details: Natalie Watkins (027 260 7667), Sharon Morrell (027 206 7879)
Home base emergency contact person: On Cue: Lea Boodee 021 117 0916
First Aid: An appropriate first aid kit will be carried on each bus and one qualified first-aider will be on each bus.
Please note: No smoking in vehicles or within 20 m of other field trip participants at stops.
Sites to be visited:

1. Steve & Paula's Holdem's Dairy Farm
2. Soil profiles on David Beuth Dairy Farm
3. Hamurana Springs
4. Ohau wall diversion
5. Whakarewarewa Forest

Transport arrangements: Bus depart and return to the Energy Events Centre
Leave Time: 8.00 am
Return Time: 5.00 pm approximately
Emergency Plan: Field trip supervisors provide first aid and seek emergency help via 111. Follow instructions of staff at their sites regarding emergency assembly or evacuation.
Local emergency agency: Police, Fire, Ambulance
Local emergency contact phone/call sign: 111

Alcohol and Drugs

"All persons engaged in field activities have a responsibility to ensure that they are not, through the consumption of alcohol or a drug, in a state that may endanger themselves or any other person."

Smoking

No smoking in vehicles or buildings during the field trip and smoking outdoors should be limited to areas where non-smokers are unaffected. Care must be taken to ensure that wild-fires are not started in dry vegetation. Please do not leave cigarette butts in the environment.

Make hazards clear to field trip attendees: e.g.

- Dehydration, sunburn, cold
- Machinery hazards
- Traffic hazards

A list of fieldtrip attendees including their emergency contact slip (at the end of this document) are to be given to the field trip supervisor's and names to checked off to confirm attendance and signed emergency contact slip.

A list of supervisors, their contact details, relevant qualifications, skills and medical conditions is to be left with the home base emergency contact person to be provided to Police/SAR in case of emergency.

Please help us protect farmers' places from pests, weeds, and diseases by coming in clean footwear. We will also provide disinfection gear for use between stops.

Stop 1: Steve & Paula Holdem's Dairy Farm
Hazard: Farm machinery, livestock, electric fence, uneven ground and cattle stops
Mitigation: Farm staff will be made aware of our presence on the farm and we will stay together as a group.
Stop 2: Soil profile (David Beuth Dairy Farm)
Hazard: Exiting & Entering bus on the side of the road
Mitigation: Bus will be parked on the left hand-side of the road on a clear stretch of road, participants will exit the bus promptly and head straight into the paddock.

Stop 2:Soil profile (David Beauth Dairy Farm)
Hazard: Farm machinery, livestock, electric fence, uneven ground and cattle stops
Mitigation: Farm staff will be made aware of our presence on the farm and we will stay together as a group. Animals will not be located in the paddocks where the soil profiles are, nor the paddocks we need to walk through to get to the soil profiles.

Stop 3:Hamurana Springs
Hazard: Water body
Mitigation: Well maintained tourist attraction, participants to remain on dedicated walkways around the springs.

Stop 4:Ohau Wall
Hazard: Water body
Mitigation: Participants to remain on the rest area to view the wall construction

Stop 4:Ohau Wall
Hazard: Traffic
Mitigation: Bus will be parked in a rest area. Participants to be mindful of other traffic and do not linger on or near the road.

Stop 5:Whakarewarewa Forest
Hazard: Traffic, Mountain bikers
Mitigation: Participants to not wander off into the forest or along the road.

Field Trip Emergency Contact Slip

Personal copy

My name:	Date:
My mobile Phone Number:	
Emergency Contact Name:	
Emergency Contact Relationship to Me:	
Emergency Contact Phone Number:	
Please advise any medical conditions which we should be aware of:	

Waiver: **I agree and acknowledge that:**

- ☐ I agree to hold the NZ Society of Soil Science or OnCue Conference and Events Ltd harmless, and to waive any rights to make a claim against NZSSS or OnCue or any of its members and/or guests involved with the planning or running of this field trip, with respect to any injury or loss suffered through my involvement with any field trips.

- ☐ I recognise and assume all risks and responsibility with respect to my own safety and the safety of any others involved with, at, or in this field trip.

I have been advised about the physical and safety requirements and the hazards and their mitigations of this field trip and have been given the opportunity to advise the field trip organisers of any special requirements I have. Under the Privacy Act 1993, I agree to The NZSSS collecting and maintaining this information for the purposes of ensuring that information necessary for Health & Safety in an emergency is available.

Signed:

Field Trip Emergency Contact Slip

Field trip supervisors copy

My name:	Date:
My mobile Phone Number:	
Emergency Contact Name:	
Emergency Contact Relationship to Me:	
Emergency Contact Phone Number:	
Please advise any medical conditions which we should be aware of:	

Waiver: **I agree and acknowledge that:**

- ☐ I agree to hold the NZ Society of Soil Science or OnCue Conference and Events Ltd harmless, and to waive any rights to make a claim against NZSSS or OnCue or any of its members and/or guests involved with the planning or running of this field trip, with respect to any injury or loss suffered through my involvement with any field trips.

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Signed:

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