Taranaki Regional Council

AGENDA
Policy & Planning

Tuesday 4 February 2020, 10.30am

Taranaki Regional Council

AGENDA
Policy & Planning

Date: Tuesday 4 February 2020, 10.30am

Venue: Taranaki Regional Council chambers, 47 Cloten Road, Stratford

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Members	Councillor C L Littlewood	(Committee Chairperson)
	Councillor N W Walker	(Committee Deputy Chairperson)
	Councillor M G Davey	
	Councillor M J McDonald	
	Councillor D H McIntyre	
	Councillor C S Williamson	
	Councillor E D Van Der Leden	
	Councillor D N MacLeod	(ex officio)
	Councillor M P Joyce	(ex officio)
Representative Members	Councillor Stacey Hitchcock	(NPDC)
	Councillor Grant Boyde	(SDC)
	Councillor Chris Young	(STDC)
	My Phill Muir	(Federated Farmers)
	Iwi representative members have not yet been appointed.	

Apologies

Notification of Late Items

Taranaki Regional Council

AGENDA Policy & Planning

Purpose of Policy and Planning Committee meeting

This committee attends to all matters of policy developed either in-house or by third parties.

Responsibilities

Prepare and review regional policy statements, plans and strategies and convene as a Hearing Committee as and when required for the hearing of submissions.

Monitor plan and policy implementation.

Develop biosecurity policy.

Advocate, as appropriate, for the Taranaki region.

Other policy initiatives.

Endorse submissions prepared in response to the policy initiatives of organisations.

Membership of Policy and Planning Committee

Councillor C L Littlewood (Chairperson)	Councillor N W Walker (Deputy Chairperson)
Councillor M G Davey	Councillor M J McDonald
Councillor D H McIntyre	Councillor C S Williamson
Councillor E D Van Der Leden	Councillor D N MacLeod (ex officio)
Councillor M P Joyce (ex officio)	Councillor S Hitchcock (NPDC)
Councillor C Young (STDC)	Councillor G Boyde (SDC)

Health and Safety Message

Emergency Procedure

In the event of an emergency, please exit through the emergency door in the committee room by the kitchen.

If you require assistance to exit please see a staff member.

Once you reach the bottom of the stairs make your way to the assembly point at the birdcage. Staff will guide you to an alternative route if necessary.

Earthquake

If there is an earthquake - drop, cover and hold where possible.

Please remain where you are until further instruction is given.

MEMORANDUM
Policy & Planning

Date 4 February 2020

Subject: Confirmation of Minutes - Tuesday 19 November 2019

Approved by: A D McLay, Director - Resource Management

B G Chamberlain, Chief Executive

Document: 2407765

Resolve

That the Policy and Planning Committee of the Taranaki Regional Council:

a) takes as read and confirms the minutes of the Policy and Planning Committee meeting of the Taranaki Regional Council held in the Taranaki Regional Council chambers, 47 Cloten Road, Stratford, Tuesday 19 November 2019 at 10.30am

b) notes the recommendations therein were adopted by the Taranaki Regional Council on Tuesday 10 December 2019

Matters Arising

Appendices/Attachments

Document 2371362: Policy and Planning Meeting Minutes - Tuesday 19 November 2019

MINUTES
Policy & Planning

Taranaki Regional Council

Date	19 November 2019, 10.30am
Venue:	Taranaki Regional Council chambers, 47 Cloten Road, Stratford
Document:	2371362

Members	Councillors	C L Littlewood	(Committee Chairperson)
		N W Walker	
		D H McIntyre	
		C S Williamson	
		E D Van Der Leden	
		D N MacLeod	(ex officio)
		M P Joyce	(ex officio)

Representative Members

Representative Members have not yet been appointed.

Attending	Messrs	B G Chamberlain	(Chief Executive)
		G K Bedford	(Director-Environment Quality)
		M J Neild	(Director – Corporate Services)
		A D McLay	(Director – Resource Management)
		S R Hall	(Director- Operations)
		G Severinsen	(Manager Policy & Strategy)
		S Tamarapa	(Iwi Communications Officer)
		R Phipps	(Science Manager)
	Mrs	H Gerrard	(Science Manager)
	Mrs	V McKay	(Science Manager)
	Mr	S Ellis	(Environment Services Manager) (from 11 am)
	Mr	T Shanley	(Project Manager - Towards Predator Free Taranaki) (from 11 am)
	Ms	J Mack	(Committee Administrator)
	Mr	J Clough	(Wrightson Consulting)
	Mr	C Young	(South Taranaki District Council)
	Mr	G Boyde	(Stratford District Council)
	Ms	S Hitchcock	(New Plymouth District Council)

One member of the media and four further members of staff.

Apologies

The apologies from Councillors M G Davey and M J McDonald were received and sustained.

Notification of Late Items

Councillor Walker had previously circulated an email to Councillors regarding the climate change bill, which will be discussed in general business.

1. Confirmation of Minutes – Tuesday 3 September 2019

Resolved

THAT the Policy and Planning Committee of the Taranaki Regional Council

a) takes as read and confirms the minutes of the Policy and Planning Committee meeting of the Taranaki Regional Council held in the Taranaki Regional Council chambers, 47 Cloten Road, Stratford, on Tuesday 3 September 2019 at 10.30am

b) notes that the minutes of the Policy and Planning Committee Meeting of the Taranaki Regional Council held in the Taranaki Regional Council chambers, 47 Cloten Road, Stratford, on Tuesday 3 September 2019, at 10.30am were authenticated by the Committee Chairperson, N W Walker, and the Taranaki Regional Council Chief Executive, B G Chamberlain, pursuant to Model Standing Orders.

McIntyre/Walker

Matters Arising

There were no matters arising.

2. Submission on Proposed Priority Products and Priority Product Stewardship Scheme Guidelines

2.1 Mrs H Gerrard, Science Manager, spoke to the memorandum to introduce a submission that has been made to the Ministry for the Environment on a consultation document, Proposed Priority Products and Priority Product Stewardship Scheme Guidelines and to recommend its endorsement by the Council.

Recommended

That the Taranaki Regional Council:

a) receives and notes the submission sent to the Ministry for the Environment on the Proposed Priority Products and Priority Product Stewardship Scheme Guidelines by the due date of 4 October 2019

b) endorses the submission on the Proposed Priority Products and Priority Product Stewardship Scheme Guidelines.

MacLeod/Williamson

3. Submission on a Proposed National Policy Statement on Highly Productive Land

3.1 Mr G Severinsen, Manager Policy & Strategy, spoke to the memorandum to introduce a submission made by Officers of the Council to a proposed National Policy Statement on Highly Productive Land and to recommend that it be endorsed by the Council.

Recommended

That the Taranaki Regional Council:

a) receives the memorandum 'Submission on a proposed National Policy Statement on Highly Productive Land'

b) endorses the submission.

McIntyre/Walker

4. Submission on Proposed National Policy Statement on Urban Development

4.1 Mr C Spurdle, Planning Manager, spoke to the memorandum to introduce a submission made to the Ministry for the Environment and Ministry of Housing and Urban Development on a proposed National Policy Statement on Urban Development, and to recommend its endorsement by the Council.

Recommended

That the Taranaki Regional Council:

a) receives and notes the submission sent to the Ministry for the Environment on the proposed National Policy Statement on Urban Development by the due date of 10 October 2019

b) endorses the submission on the proposed National Policy Statement on Urban Development, subject to any changes suggested by Members.

Williamson/Joyce

5. Controller and Auditor-General's report: *Managing freshwater quality: Challenges and opportunities*

5.1 Mr G K Bedford, Director – Environment Quality, spoke to the memorandum to introduce a report by the Office of the Controller and Auditor-General entitled *'Managing freshwater quality: Challenges and opportunities'.*

Recommended

That the Taranaki Regional Council:

a) receives the memorandum *'Controller and Auditor-General's report: managing freshwater quality: Challenges and opportunities'.*

MacLeod/Williamson

6. Annual report on the Progressive Implementation Programme: National Policy Statement for Freshwater Management

6.1 Mr C Spurdle, Planning Manager, spoke to the memorandum presenting for Members' information the annual report on the implementation programme for the National Policy Statement for Freshwater Management 2014 (NPS-FM) for the 2018/2019 financial year.

Recommended

That the Taranaki Regional Council:

a) receives the memorandum '*Annual report on the Progressive Implementation Programme: National Policy Statement for Freshwater Management'*

b) notes the progress on the implementation of the NPS-FM for the 2018/2019 financial year.

Van Der Leden/Walker

7. Update on Towards Predator-Free Taranaki Project

7.1 Mr S R Hall, Director - Operations, introduced Mr S Ellis, Manager Environmental Services, and Mr T Shanley, Project Manager – Towards Predator Free Taranaki, who spoke to the memorandum to present for Members' information a quarterly update on the progress of the Towards Predator-Free Taranaki project.

Recommended

That the Taranaki Regional Council:

a) receives this memorandum *Update on Towards Predator-Free Taranaki project*

b) notes the progress and milestones achieved in respect of the urban and rural predator control and the zero density possum projects of the Towards Predator-Free Taranaki project.

McIntyre/Walker

8. Proposal for New Zealand's Next Biodiversity Strategy

8.1 Mr S R Hall, Director - Operations, spoke to the memorandum to present for Members' information a Government proposal for a revised New Zealand Biodiversity Strategy (NZBS) and the Local Government New Zealand submission in response to that proposal.

Recommended

That the Taranaki Regional Council:

a) receives this memorandum entitled *Proposal for New Zealand's next Biodiversity Strategy* and the attached regional sector submission.

Joyce/MacLeod

9. *Our Marine Environment 2019:* MfE and Stats NZ report

9.1 Mr G Severinsen, Manager Policy & Strategy, spoke to the memorandum to introduce and briefly discuss 'Our marine environment 2019', the latest report in New Zealand's environmental reporting series prepared by the Ministry for the Environment and Stats NZ.

Recommended

That the Taranaki Regional Council:

a) receives the memorandum *'Our marine environment 2019: MfE and Stats NZ report'.*

Williamson/Van Der Leden

10. Submission on Resource Management Bill 2019

10.1 Mr C Spurdle, Planning Manager, spoke to the memorandum to introduce a submission made by officers of the Council to the Resource Management Bill 2019 (the Bill).

Recommended

That the Taranaki Regional Council:

a) receives the memorandum *Submission on the Resource Management Bill*

b) endorses the submission.

MacLeod/Williamson

11. Report from the Parliamentary Commissioner for the Environment: *'Focusing Aotearoa New Zealand's environmental reporting system'*

11.1 Mr GK Bedford, Director – Environment Quality, spoke to the memorandum to introduce a report prepared by the Parliamentary Commissioner for the Environment (PCE) and released on 7 November 2019, entitled 'Focusing Aotearoa New Zealand's environmental reporting system'.

Recommended

That the Taranaki Regional Council:

a) receives the memorandum *'Report from the Parliamentary Commissioner for the Environment: Focusing Aotearoa New Zealand's environmental reporting system'.*

Williamson/Walker

12. Late item – Climate Change Response Emissions Trading Reform Amendments Bill 2019

12.1 Councillor N W Walker proposed that a submission to the Bill be made, this would potentially send a positive message to the landowners and the community involved in the activity.

12.2 Mr B G Chamberlain, Chief Executive, responded that a submission be drafted on the Bill and brought before members for their consideration.

Closing Karakia Mr S Tamarapa (Iwi Communications Officer) gave the closing Karakia to the Policy and Planning Committee and Karakia for kai (lunch).

There being no further business, the Committee Chairperson, Councillor C L Littlewood, declared the meeting of the Policy and Planning Committee meeting closed at 12.10pm.

Confirmed

Policy and Planning
Chairperson: ______________________________

C L Littlewood

Tuesday 4 February 2020

AGENDA
Policy & Planning

Date	4 February 2020
Subject:	**National Survey of Pesticides and Emerging Organic Contaminants (EOCs) in Groundwater 2018**
Approved by:	G K Bedford, Director - Environment Quality
	B G Chamberlain, Chief Executive
Document:	2409795

Purpose

1. The purpose of this memorandum is to present the results of the National Survey of Pesticides and Emerging Organic contaminants (EOCs) in Groundwater 2018, in which the Taranaki Regional Council participated, and to discuss their significance.

Executive summary

2. The Council's *Regional Freshwater Plan for Taranaki* identifies the use of pesticides as an activity that requires appropriate management to avoid adverse effects on the region's groundwater quality, and to safeguard the ecological health of the region's waterways and the health of those who rely on them, including through municipal water supplies.
3. The Council routinely monitors for the presence of pesticides in groundwater through participation in the national survey of pesticides in groundwater (the survey). The survey is coordinated by the Institute of Environmental Science and Research Ltd (ESR) who also interpret and report on the results. Regional councils are given the opportunity to participate in the survey by undertaking the collection of groundwater samples in the field and covering the cost of sample analyses.
4. The Survey has been carried out every four years since 1990 with 2018 being the eighth consecutive survey. Fourteen of the regional and unitary authorities with groundwater management responsibilities participated in the 2018 survey. A total of 279 wells were sampled across the country.
5. Samples taken as part of the survey are analysed by AsureQuality Ltd for a comprehensive suite of pesticides. Improvements in analytical techniques mean that the concentrations at which pesticide residues can be detected have significantly reduced over time. This means that the potential for the number of detections is higher than during earlier surveys (even though residual concentrations may actually be reducing) and that detections can now be made well below concentrations that may be of health and/or ecological concern.

6. The 2018 survey was unique in that, for the first time, it included the opportunity for councils to elect to have additional screening of samples for emerging organic contaminants (EOCs). EOCs are a broad group of organic compounds that are commonly found in personal care products (e.g. shampoos, insect repellents, and sunscreen) antibiotics and other pharmaceuticals, recreational compounds such as caffeine and nicotine, industrial compounds and compounds from plastic packaging. Samples were analysed for EOCs by Northcott Research Consultants Ltd. The Council elected to participate in this component of 2018 survey, as did 11 other regional and unitary authorities. Nationally, 121 groundwater wells were sampled for EOC analysis.
7. In collaboration with ESR, eight groundwater wells were selected for both pesticide and EOC analysis in Taranaki as part of the 2018 survey. The well selection process was based on a range of criteria that prioritised sites most vulnerable to contamination with pesticides (and EOCs) given their location, depth, past or present land use and known past or present pesticide usage. The sampling locations were therefore biased to higher risk sites, rather than being a representative subset of the regional groundwater resource, in that significantly reduced risk of contamination by these residues likely exists elsewhere. A subset of sites sampled during previous surveys was retained in the 2018 survey to provide for temporal comparison.
8. The findings of the survey are reported within this memorandum, both from a national and Taranaki specific perspective. This memo focuses on reporting the results from local wells sampled, but a summary of national results is presented for information and to provide context to local results. Results for pesticides are assessed against the relevant health based standards for consumptive use set by the Ministry of Health (MoH) and/or the World Health Organisation (WHO). Currently there are no health-based standards set for concentrations of various EOCs in water, nor are their potential impacts on ecological systems well understood.
9. In Taranaki, a single pesticide residue was detected, in one of the eight wells sampled (13%). The concentration of the pesticide detected was only slightly above the limit of detection for the specific compound (Terbuthylazine) and less than 1% of its maximum acceptable value (MAV) as set out in the Drinking Water Standards for New Zealand (DWSNZ). Nationally, detections were made in 68 of 279 wells sampled (24%), but no concentrations of any pesticide were found to exceed safe limits for consumptive use as set out in the applicable health standards. Terbuthylazine (as detected in Taranaki) was the most widely detected pesticide nationally, being found at 13% of all sites. Terbuthylazine is a selective herbicide used to control a wide range of perennial and broadleaf weeds.
10. The 2018 survey also included an additional option for councils to have samples analysed for glyphosate (trade name Roundup), a very widely used and long-established herbicide that has more recently become controversial because of alleged and disputed adverse effects upon human and/or environmental health. Glyphosate is unlikely to leach through soils under normal conditions and degrades quickly. As a result, glyphosate is unlikely to be detected in groundwater under most circumstances. The results of the survey support this assessment. No glyphosate was detected in any well sampled in Taranaki and only one detection was made across all sites sampled nationally. It is though that the detection of glyphosate at this site (in Otago) was a result of poor wellhead construction and contamination from the containers and activities occurring around the well, rather than being a result of residues leaching to groundwater following surface application.

11. EOCs were detected at five of the eight Taranaki wells sampled during the 2018 survey. The rate of EOC detection in Taranaki (63%) was similar to that seen nationally (70%). There was also a high degree of commonality in the substances detected. There are no MAVs for non-pesticide EOCs in New Zealand, so no health relates risk assessment is possible, nor are the environmental or ecological impacts of most EOCs well understood.
12. This survey and its results provide some reassurance to the Council and the regional community that the provisions of the *RFWP* and the implementation of good practices around the usage of pesticides are proving effective for the protection of the region's groundwater resources and their associated values and uses. The survey has also provided a useful first screening and benchmark for the presence of EOCs in Taranaki groundwater and officers will continue to monitor research developments in this evolving field of water quality science.

Recommendations

That the Taranaki Regional Council:

a) receives the memorandum *National Survey of Pesticides and Emerging Contaminants in Groundwater 2018*
b) notes the results of the survey, that pesticides are virtually undetectable in the Taranaki groundwater or when present, are far below levels of concern for either environmental or human health
c) notes the detection of various EOCs in groundwater in Taranaki (and nationally) and that officers will continue to closely monitor research developments in this evolving field of water quality science

Background

13. Pesticides, which include insecticides, fungicides, herbicides and plant growth regulators, are commonly used in New Zealand to control insects, diseases and weeds in primary industries such as horticulture, agricultural farming, and forestry. The horticultural sector is the most intensive user of pesticides on a land area basis, followed by arable, forestry and pastoral sectors. They are also used in urban areas e.g. domestic vegetable gardens and lawns, and through roadside and recreational reserve spraying for weed control.
14. Pesticide contamination of water is a subject potentially of national importance because of the need to safeguard catchments used for municipal water supply (whether groundwater or surface water), to provide for safe recreational contact uses of water bodies, and more generally to recognise and mitigate against potential adverse effects of pesticides on aquatic ecosystems and their component communities. Note that an additional item on today's meeting agenda will provide details of a recent survey by the Council on pesticide concentrations in surface water.
15. The analysis of EOCs as part of the 2018 survey is the first widespread survey of EOCs in groundwater undertaken in New Zealand. EOCs can arise from sewage treatment plants, industrial effluents, leaking sewage networks, runoff from agricultural, storm-water and urban sources, application of effluents to land, and septic tank soakage fields. Many of these sources are associated with urban environments. The study of the

distribution of EOCs and their potential health and ecological impacts is a developing field of research and is not well understood currently.

16. Under the Resource Management Act (1991), regional councils have the responsibility to maintain and enhance the quality of regional water resources. The Council recognises that pesticide application to land is a potential point and diffuse source contaminant of freshwater. The *Regional Fresh Water Plan for Taranaki* (RFWP) identified as an issue for the region, adverse effects upon groundwater (and surface water) from the discharge of contaminants to land and water, if these discharges are not managed properly and with consideration of receiving water quality requirements. Objective 6.5.2 of the RFWP is *'to promote the sustainable management of groundwater while avoiding, remedying or mitigating adverse effects on groundwater quality from the discharge of contaminants'*. Policy 6.5.3 is that *'The Taranaki Regional Council will manage the discharge of contaminants to land and water such that any actual or potential adverse effects on groundwater quality are avoided, remedied or mitigated'*.

17. Surface water is likewise addressed. Objective 6.2.1 of the RFWP is *'to maintain and enhance the quality of the surface water resources of Taranaki by avoiding, remedying or mitigating adverse effects of contaminants discharged to land and water from point sources'*, while Objective 6.3.1 applies in similar vein to diffuse discharges. Policies 6.2.1-6.2.4, 6.2.7, and 6.3.1 provide a suite of considerations that the Council applies when assessing discharges to land or water, including the values of the water body and the extent to which these might be impacted. Policy 6.3.1 states explicitly that *'Land use practices which avoid, remedy or mitigate adverse effects on water quality will be encouraged and promoted including…the careful use of agrichemicals'*.

18. The application of agrichemicals in Taranaki is controlled in the current RFWP (eg Rules 32, 33, 34, 43) and *Regional Air Quality Plan* (Rules 56-58 and Appendices VI and VII). The Council promotes the careful use of such chemicals in accordance with these rules and the manufacturers' instructions, thus safeguarding off-target or secondary receiving environments.

19. Section 10.3 of the RFWP sets out the Council's commitment to undertake relevant monitoring, either on its own account or by participation in monitoring and research programmes conducted by other agencies. To ascertain the effectiveness of the controls discussed above, and to confirm the ongoing state of the environment of Taranaki, the Council routinely monitors the attaining of these objectives through its State of the Environment groundwater (and surface water) monitoring programmes. This includes the sampling of groundwater for pesticides in a collaborative nationwide programme administered by ESR. This programme is undertaken on a cycle of about 4 years. Surveys have been undertaken in 1990, 1994, 1995 (Taranaki-specific), 1998, 2002, 2006, 2010, 2014 and 2018. Traces of pesticides have been occasionally found in a few individual monitoring wells in Taranaki during earlier surveys.

20. The *National Environmental Standard for Sources of Human Drinking Water* (2008; currently under review) is a regulation made under the *Resource Management Act*. It imposes requirements for protecting sources of human drinking water from becoming contaminated. It does not apply to catchments not used for municipal supply, nor to waters used to supply other consumptive purposes (eg stock drinking supply), nor to ecological considerations. Specifically, it requires regional councils to be satisfied that activities permitted in regional plans will not pose unacceptable risks to the quality of community-scale drinking water supplies. The Government has noted that changes to the intensity or composition of land-use activities in a catchment can introduce new contaminants or increase the concentration of existing contaminants in the source

waters. A review of regional council performance in implementing the NES undertaken by MfE last year found that this Council was one of 7, out of 16, that had a 'high' level of implementation of the drinking water NES when considering resource consent applications, and as with almost all regional councils this Council had a 'medium' level of implementation of the NES provisions within its regional freshwater plan. MfE's ratings for implementation of the NES within regional plans focused on the extent to which plans had specific provisions applying to drinking water supply catchments. It should be noted that the shaping and publication of the Council's RFWP pre-dates the NES; the NES does not require councils to retrospectively amend existing plans; and in any case the Council is currently reviewing its plan and will incorporate the requirements of the NES as the latter stand at the time (given that the NES is now under review with a view to amendment).

Discussion

Programme design

21. In collaboration with ESR, eight groundwater wells were selected for both pesticide and EOC analysis in Taranaki as part of the 2018 survey. The well selection process was based on a range of criteria that prioritised sites most vulnerable to contamination with pesticides (and EOCs) given their location, depth, past or present land use and known past or present pesticide usage.

22. The eight wells selected for inclusion in the programme in Taranaki broadly covered the region's most extensive shallow groundwater system (the Taranaki Volcanics) and our predominant water supply aquifer (the Whenuakura aquifer). Site locations included urban wastewater treatment sites, current and former nursery sites and pastoral farming areas. The sampling network was therefore biased to higher risk sites, rather than being a representative subset of the regional groundwater resource, in that significantly reduced risk of contamination by these residues likely exists elsewhere.

23. A subset of sites sampled during previous surveys was retained in the 2018 survey to provide for temporal comparison.

24. Samples were collected according to the ESR procedures for sampling pesticides and EOCs, and purging procedures based on "A National Protocol for State of the Environment Groundwater Sampling in New Zealand" (Daughney et al., 2006). Samples were collected as close to the well head as possible using portable or in-situ pumps. In most cases field measurements of pH, dissolved oxygen, conductivity and temperature were recorded and a water sample only taken when these parameters had stabilised. For each well sampled a field sheet was filled out and returned to ESR. Sample bottles were supplied by analysing laboratories.

25. All samples for the pesticide analysis suites were sent to AsureQuality Ltd in Wellington and analysed for acidic herbicides and a suite of organo-chlorine, organo-phosphorus and organonitrogen pesticides. Samples from 7% of wells were collected in duplicate for quality control purposes. The limits of detection achieved by the laboratory were far below (by many orders of magnitude) relevant human health standards.

26. The 2018 survey was unique in that, for the first time, it included the opportunity for councils to elect to have additional screening of samples for EOCs. The Council elected to participate in the EOCs component of 2018 survey, as did 11 other regional and unitary authorities. EOCs are a broad group of organic compounds that are commonly found in personal care products (e.g. shampoos, insect repellents and sunscreen),

antibiotics and other pharmaceuticals, recreational compounds such as caffeine and nicotine, industrial compounds and compounds from plastic packaging. Samples were analysed by Northcott Research Consultants Ltd. Blind duplicate samples from five wells (4%) were submitted to the laboratory as an additional quality control measure for EOC analysis.

27. Nationally, the 2018 survey comprised of 279 wells sampled for pesticides and 121 wells sampled for EOCs. The regions were sampling was undertaken and the individual locations of sampled wells is set out in Figure 1 (pesticides) and Figure 2 (EOCs).

Results

28. Pesticides were detected in 68 of the 279 wells sampled nationally (24%). Herbicides were the most frequently detected pesticide group with 98 detections (88% of all pesticides detected) of 17 different herbicides and their metabolites, with seven insecticides and one fungicide detected in the sampled wells. There were 80 detections (71%) of triazine herbicides with terbuthylazine being the most frequently detected pesticide (36 detections). No concentration of detected pesticides exceeded any MAV for drinking water at any site sampled. The highest detection as a percentage of the MAV was dieldrin, detected at a concentration of 0.025 µg/L, which was 62.5% of the MAV of 0.04 µg/L. The next highest detections relative to the MAV were for total atrazine and metabolites at 16.5% of the MAV, hydroxyatrazine (another atrazine metabolite) at 11% of MAV assuming the same MAV as for atrazine, then terbacil at 9.5% of the MAV. The remainder of pesticide detections were less than 5% of the MAV.

29. In Taranaki, a pesticide was detected in one of eight wells sampled (13%) (Figure 1). This rate of detection is approximately half that found nationally (24%). The organic herbicide terbuthylazine was detected at an extremely low concentration (0.029 µg/L) at site GND2515, a shallow monitoring well located within the boundary of the New Plymouth Wastewater Treatment plant. The well is located away from the treatment plant itself, on land occasionally used for stock grazing. The concentration of terbuthylazine detected was only slightly above the limit of analytical detection and less than 1% of the MAV set out in the DWSNZ (8 µg/L). As discussed above, terbuthylazine (as detected in Taranaki) was the most widely detected pesticide nationally, being found at 13% of all sites sampled.

30. Terbuthylazine is a selective herbicide used to control a wide range of perennial and broadleaf weeds. The sources of this herbicide at site GND2515 could be localised weed control within the site itself or from the adjacent New Plymouth Golf Club. At the concentrations detected, the presence of terbuthylazine at this site is of no health or ecological concern and no additional investigations into the source are warranted.

31. Nation-wide, there was only one detection of glyphosate in the 135 wells sampled for this substance (0.7%). The well was located in Otago and had a range of other pesticides that were also detected in the sample, including atrazine and its metabolites, diazinon and DDT. Glyphosate was detected at a concentration of 2.1 µg/L. The well has been sampled on four previous surveys and has had pesticides detected during three of those. An investigation carried out in 2019 found the wellhead at this site to be in poor condition and chemical containers being stored in close proximity to the well, meaning that ingress of chemicals from the surface was a high possibility. No MAV has been established for glyphosate in drinking water in New Zealand. The WHO does have a Health Based Value for glyphosate of 900 µg/L (WHO 2017). The concentration detected at the site remained far below this value.

32. No glyphosate was detected in any well sampled in Taranaki.
33. There is no evidence of any temporal trends in pesticide detection rates nationally, or within Taranaki.

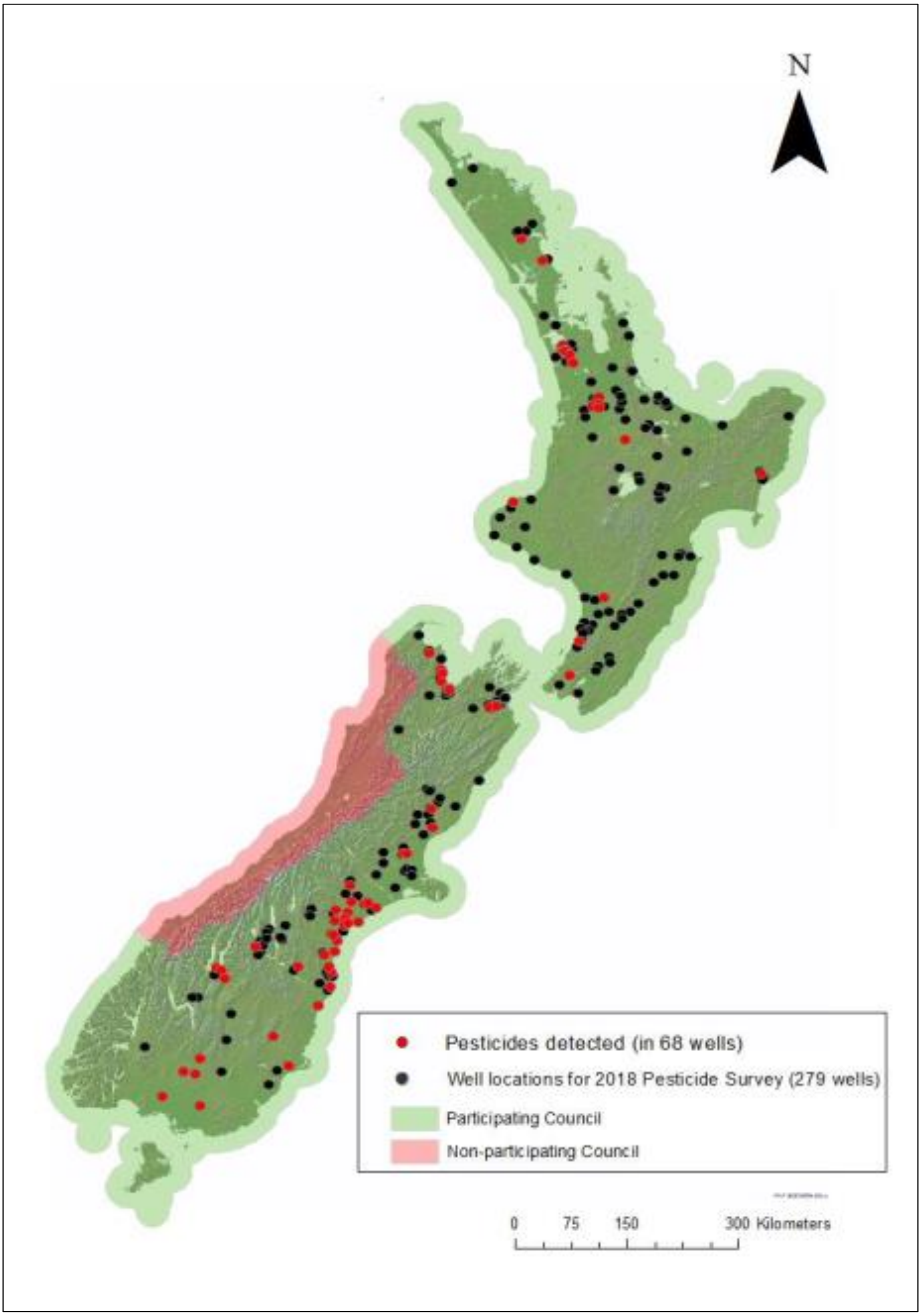

Figure 1: sampling sites for survey of pesticides in groundwater

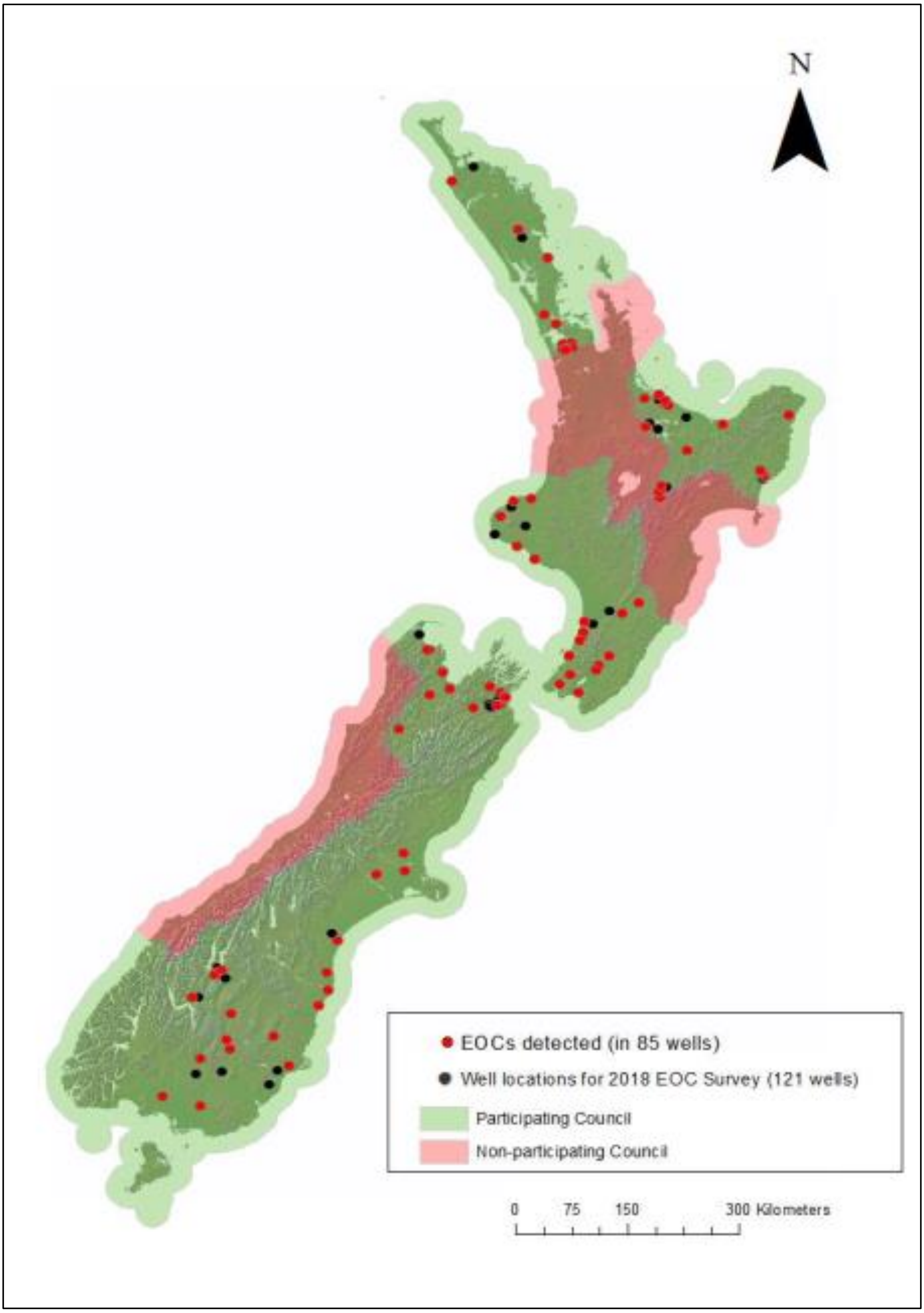

Figure 2: sampling sites for survey of EOCs in groundwater

34. EOCs were detected at 85 of the 121 wells sampled across the country as part of the 2018 survey (70%). Most of the EOCs detected in this study originate through human body metabolisms such as caffeine, sucralose, ibuprofen, or steroidal hormones, or are applied to skin for protection against ultraviolet rays. Other EOCs such as BPA are widely used in packaging and plastic products or in the case of parabens, as food preservatives. It is considered that these substances are likely to exhibit low toxicity to humans. There are no drinking water MAVs for non-pesticide EOCs in New Zealand and any environmental or ecological impacts of most EOCs are largely unknown.
35. EOCs were detected at five of the eight Taranaki wells sampled during the 2018 survey (Figure 2). The rate of EOC detection in Taranaki (63%) was similar to that seen nationally (70%). There was also commonality in the substances detected.
36. Certificates of results from the analysing laboratories are available from Council officers upon request.

Conclusions

37. The Council has continued to monitor for the presence of pesticides in groundwater through participation in the National Survey of Pesticides and Emerging Organic Contaminants 2018, which was coordinated by ESR. The Council's ongoing participation in the national surveys, which take place at four yearly intervals, is in response to the commitments and obligations of the Council as set out in its RFWP and various statutes and regulations. It provides robust data for any discussion around the effect of pesticide usage in the region and the appropriateness of current controls, and thus can inform the shaping of the next Regional Land and Water Plan for Taranaki (in development).
38. The survey found no concentrations of pesticides in groundwater above any relevant health standard in Taranaki, or nationally. The report prepared by ESR summarising the results of the 2018 survey states that most groundwater in New Zealand should be considered safe to drink with respect to pesticides. This conclusion is particularly valid for Taranaki, where the rate of pesticide detections in groundwater was well below that found nationally during the 2018 survey.
39. The rate of EOC detection in Taranaki was similar to that seen nationally. There was also commonality in the substances detected. Given there are no MAVs for drinking water for non-pesticide EOCs in New Zealand, and that the environmental or ecological impacts of most EOCs are largely unknown, a detailed interpretation of these results is not possible. It is nonetheless a useful first screening of Taranaki groundwater for the presence of EOCs, and establishes a benchmark for future reference. Officers will continue to monitor research and interpretation developments in this evolving field of water quality science.
40. The results of the survey of pesticide residues in groundwater provide reassurance to the Council and the regional community that the provisions of the RFWP and the implementation of good practices around the usage of pesticides are proving effective for the protection of the region’s groundwater and its uses.

Decision-making considerations

41. Part 6 (Planning, decision-making and accountability) of the *Local Government Act 2002* has been considered and documented in the preparation of this agenda item. The recommendations made in this item comply with the decision-making obligations of the *Act*.

Financial considerations—LTP/Annual Plan

42. This memorandum and the associated recommendations are consistent with the Council's adopted Long-Term Plan and estimates. Any financial information included in this memorandum has been prepared in accordance with generally accepted accounting practice.

Policy considerations

43. This memorandum and the associated recommendations are consistent with the policy documents and positions adopted by this Council under various legislative frameworks including, but not restricted to, the *Local Government Act 2002*, the *Resource Management Act 1991* and the *Local Government Official Information and Meetings Act 1987*.

Iwi considerations

44. This memorandum and the associated recommendations are consistent with the Council's policy for the development of Māori capacity to contribute to decision-making processes (schedule 10 of the *Local Government Act 2002*) as outlined in the adopted long-term plan and/or annual plan. Similarly, iwi involvement in adopted work programmes has been recognised in the preparation of this memorandum.

Legal considerations

45. This memorandum and the associated recommendations comply with the appropriate statutory requirements imposed upon the Council.

Appendices/Attachments

Document 2342829: National Survey of Pesticides and Emerging Organic Contaminants (EOCs) in Groundwater 2018

Science for Communities

National Survey of Pesticides and Emerging Organic Contaminants (EOCs) in Groundwater 2018

September 2019

Prepared by:

Murray Close and Bronwyn Humphries

PREPARED FOR:	**Regional Councils**
CLIENT REPORT No:	**CSC19016**
REVIEWED BY:	**Liping Pang**

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Manager	Peer reviewer	Authors
Wim Nijhof	**Liping Pang**	**Bronwyn Humphries**
Group Leader, Human & Ecological Health, Health & Environment	Science Leader	Scientist
		Murray Close
		Senior Science Leader

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EXECUTIVE SUMMARY

In 2018 ESR coordinated a survey of pesticides in groundwater throughout New Zealand. The survey has been completed every four years since 1990 with 2018 being the eighth consecutive survey. Regional and Unitary Authorities carried out the well sampling and the 2018 survey was the first time that glyphosate, glufosinate and their metabolites, and a suite of Emerging Organic Contaminants (EOCs) were included. The pesticide and glyphosate analyses were carried out by AsureQuality and samples were analysed for acidic herbicides and a suite of organochlorine, organophosphorus and organonitrogen pesticides, and for glyphosate and three of its metabolites. The EOCs were analysed by Northcott Research Consultants Ltd. ESR's role was to coordinate the survey, advise on well selection as needed, collate and interpret the results and provide a national summary report.

Wells were selected based on the importance of an aquifer to a region, known application and storage of pesticides in the area, and the vulnerability of the aquifer to contamination. If possible, where a well had been sampled during previous surveys, it was included in the current survey to give a temporal comparison. The majority of the selected wells were from unconfined aquifers, recognising that shallower, unconfined aquifers would be more at risk than deeper aquifers.

Two regional councils provided pesticide results that were sampled outside of this survey. The Waikato Regional Council provided results for an additional 41 wells that had been sampled as part of a regional survey in December 2016. Environment Canterbury also provided results for an additional 71 wells that had been sampled in late 2018. Both these datasets have been included in this report to give a national perspective.

There were a total of 279 wells sampled and analysed for the pesticide suites, including the 41 wells from Waikato Regional Council and the additional 71 wells from Environment Canterbury. There were 68 wells (24.4%) with pesticides detected, with 28 of these wells having two or more pesticides detected. The maximum number of pesticides detected in one well was six. Herbicides were the most frequently detected pesticide group with 98 detections (88%) of 17 different herbicides and their metabolites. There were three pesticide detections exceeding 1 μg/L with none of the sampled wells exceeding the Maximum Acceptable Value (MAV) for drinking water. The highest detection as a percentage of the MAV was dieldrin, which was detected at a concentration of 0.025 μg/L that was 62.5% of the MAV of 0.04 μg/L

(Ministry of Health 2018). Most pesticide detections were less than 0.5% of the MAV. Note that μg/L = mg m^{-3} = ppb.

A total of 135 wells were analysed for glyphosate, glufosinate and their principal metabolites. There was only one detection of glyphosate at a concentration of 2.1 μg/L. This well showed evidence of poor well-head protection and the contamination likely came from containers that were stored near the well. No MAV for glyphosate in drinking water has been set in New Zealand. New Zealand follows WHO guidelines when setting its MAVs but there is currently no WHO guideline; however, WHO does have a Health Based Value for glyphosate of 900 μg/L (WHO 2017). The detected level of 2.1 μg/L is far below this value.

121 wells were sampled and analysed for a suite of EOCs, with a total of 227 EOCs detected in the 85 wells (70%). All regions that had samples analysed for EOCs had at least three wells with EOCs present. There were 29 different EOCs in the analytical suite and 25 different EOCs were detected in at least one well with the maximum number of EOCs detected in a single well being 13. Most EOCs are used extensively by people or are produced by people (eg estrogenic steroid hormones) and most do not have significant human toxicity when used under normal conditions. There are no MAVs for drinking water associated with these EOCs. However, some of these compounds have shown some endocrine disrupting effects in surface waters and the main concerns with these EOCs are environmental or ecological impacts. There are no or very few guideline values for EOCs regarding ecological impacts as the relevant studies are sparse. Some EOCs, such as sucralose and caffeine, can act as tracers of the presence of human activities or wastewater impacts in the groundwater system.

The most commonly detected EOC was bisphenol-A (BPA) that was detected in 40 wells, with the UV filter compounds, OMC and BP3 next most common with 33 and 24 detections, respectively. Sucralose, an artificial sweetener, was next most common with 18 detections. The highest concentration measured was 655 ng/L for sucralose.

These results indicate that EOCs, sourced from either animal or human effluents/activities, are making their way into shallow groundwater systems and can be detected at low concentrations. Currently there is a lack of knowledge of the fate and effects of many EOCs and whether the levels measured in this study are likely to have impacts for ecological systems. We recommend that monitoring of EOCs in groundwater resources is extended and that research is carried out to quantify the likely risks for the EOCs most frequently detected in this study.

There is limited discussion in this report about temporal variation of pesticides in groundwater with time, the correlation of pesticide detections with parameters such as well depth and groundwater chemistry, and the occurrence of different classes of EOCs that were detected in the groundwater survey. It was felt that it was more important to provide the actual results of the survey of pesticide and EOC concentrations in groundwater to the regional councils as soon as possible. Further analysis of the data is continuing and more extensive discussion will be provided in a journal paper that will be prepared for publication and sent to all the councils as soon as it is ready.

1. INTRODUCTION

When this series of surveys began in 1990, groundwater was, and it continues to be, an important source of drinking water in New Zealand. Around 40% of the community drinking water supplies around New Zealand utilise groundwater (Davies 2001). In addition, many individual rural households rely on groundwater for their drinking water needs. In the majority of regions throughout New Zealand the volume of abstracted groundwater is increasing due to increased demand from the agricultural (irrigation) and industry sectors as well as from drinking water use. Groundwater quality, however, in some urban and rural areas has been steadily degrading and is increasingly under pressure as land use intensifies (MfE & StatsNZ, 2019).

Regional councils are responsible for the management of our water resources and carry out regular monitoring programmes to assess their quality. There is interest from the community about whether pesticides, Emerging Organic Contaminants (EOCs) and in particular if glyphosate is reaching the groundwater systems. In an increasingly globalised world the consumers of our export products value and demand traceability as well as ensuring that our agricultural systems are environmentally responsible (Ministry for Primary Industries, 2019). Pesticides, which include insecticides, fungicides, herbicides and plant growth regulators, are commonly used in New Zealand to control insects, diseases and weeds in primary industries such as agricultural farming, forestry and horticulture (Manktelow et al., 2005). The horticultural sector is the most intensive user of pesticides on a land area basis (13.2 kg active ingredient/ha) followed by arable, forestry and pastoral sectors (Manktelow et al., 2005).

Glyphosate (common name Roundup) is widely used in New Zealand and other countries as a general purpose herbicide. It binds to soil and is readily degraded and therefore is not expected to leach to groundwater. It is commonly found in surface waters. However, a recent study in the USA (Battaglin et al., 2014) compiled data from a range of sources including groundwater, that had been analysed using an improved analytical method with a reporting limit of 0.02 μg/L (Note that μg/L = mg m^{-3} = ppb). They found low levels of glyphosate in 5.8% of samples from groundwater and similarly low levels of its metabolite, aminomethylphosphonic acid (AMPA) in 14.3% of groundwater samples. In early 2017 Environment Waikato analysed 40 wells for glyphosate and AMPA (Hadfield, 2017). The samples were analysed at AsureQuality with a detection limit of 1 μg/L. No glyphosate was detected in any of the samples but AMPA was detected in one well at a concentration of 1.9 μg/L. There is no Maximum Acceptable Value (MAV) for glyphosate or its metabolites with respect to drinking water and the US Environmental Protection Agency has stated that glyphosate is no more than slightly toxic to birds, fish, and aquatic invertebrates and exhibits low oral and dermal toxicity to humans (USEPA 1993).

Glyphosate and AMPA was analysed using a separate extraction and LC-MS/MS detection. Glufosinate and one of its metabolites, MMPA, are also detected using this method. Glufosinate is a naturally occurring broad-spectrum systemic herbicide produced by several species of Streptomyces soil bacteria. The compound irreversibly inhibits glutamine synthetase, an enzyme necessary for the production of glutamine and for ammonia detoxification, giving it antibacterial, antifungal and herbicidal properties. Application of glufosinate to plants leads to reduced glutamine and elevated ammonia levels in tissues, halting photosynthesis, resulting in plant death (Wikipedia, accessed June 2017). While their spectrum of control is comparable for several weed species, glufosinate tends to be more effective on annual broadleaf weeds than annual grasses, while glyphosate is more effective on grasses. Glufosinate is a "contact" herbicide, in contrast to glyphosate being extensively translocated within the plant.

For the first time EOCs have been included to determine their prevalence in groundwater. There are a wide range of organic compounds that are used widely in the domestic, industrial and agricultural sectors. Some of these compounds have been detected in freshwater systems and are known as emerging contaminants. Some of these compounds are more likely to be transported into surface water systems rather than groundwater depending on their mobility and persistence characteristics. EOCs include personal care products, for example, shampoos, insect repellants, and sun screens, anti-biotics and other pharmaceuticals, estrogens, recreational compounds such as caffeine and nicotine, industrial compounds and compounds from plastic packaging (bisphenol A). There are a few studies on their leaching properties that have been carried out for some of these compounds and there is work being carried out on their presence in wastewaters. However, we know little about most of their transport characteristics and almost nothing about their occurrence in New Zealand groundwater systems. Two regional studies have been recently carried out looking for EOCs in groundwater. A MSc study looked for a suite of 25 EOCs in Canterbury groundwater (van der Krogt, 2018) and found at least one EOC in 26 out of 33 samples taken from 18 wells. The five most commonly detected EOCs were BPA, octyl phenol (industrial compounds), BP3 (UV filter), methyl paraben and propyl paraben (preservatives). A regional study has been carried out in the Waikato region using a wide-screening approach (723 compounds) for EOCs in groundwater (Moreau et al., 2019). They sampled 61 wells and found EOCs in 91% of the baseline sites (51 wells) in 2018. Most of the EOCs detected (75%) were pesticides, with pharmaceutical and industrial chemicals being the next most common groups.

National surveys of pesticides in groundwater have been carried out at four yearly intervals since 1990 with this current survey being the eighth consecutive survey. Previous national and regional groundwater surveys in New Zealand have shown low levels of pesticides in some groundwater systems, particularly those shallow unconfined systems that are vulnerable to contamination. While the concentrations of detected pesticides have generally been less than 1% of the respective MAV, there have been occasional exceedances of the MAVs. Triazine pesticides, which are commonly used to kill weeds, are the group of pesticides most commonly detected. Further details of previous surveys are summarised in Close and Humphries (2015), Close and Skinner (2011), Gaw et al., (2008), Close and Flintoff (2004), Close and Rosen (2001), Close (1996) and Close (1993). In addition to the national surveys some regions have also undertaken their own more intensive monitoring programmes (Hadfield and Smith, 1999; Taranaki Regional Council, 1995; Hadfield, 2013).

The seventh national survey in 2014 sampled 165 wells from regions throughout New Zealand, including the additional 40 wells sampled by Waikato Regional Council (Close and Humphries, 2016). There were 28 wells (17%) with pesticides detected, with 10 wells having two or more pesticides detected. There were one or more wells with pesticides detected in six of the 13 regions. Pesticides were not detected in wells from the Hawke’s Bay, Taranaki, Horizons (Manawatu-Wanganui), Greater Wellington, Marlborough, Canterbury and Otago regions. There was one well in the 2014 survey with a pesticide concentration greater than the MAV for drinking water (Ministry of Health, 2008). There were a total of 21 different pesticides detected in the 2014 survey. Herbicides were the most common pesticide group detected followed by insecticides and fungicides. There were a total of 51 pesticide detections and of these detections, 44 (86%) were herbicides. There were 31 detections of triazine herbicides. Levels of only four of the 51 pesticide detections exceeded 1 μg/L.

This report gives the results from the eighth national survey. The sampling for this survey was carried out in late 2018, mostly between September and November. The Waikato Regional council provided results for an additional 41 wells that had been sampled in late 2016 as part of their regional survey. Environment Canterbury also provided additional results for 71 wells that had been sampled in late 2018. Both these datasets have been included in this report to give a national perspective.

There is limited discussion in this report about temporal variation of pesticides in groundwater with time, the correlation of pesticide detections with parameters such as well depth and groundwater chemistry, and the occurrence of different classes of EOCs that were detected in the groundwater survey. It was felt that it was more important to provide the actual results of the survey of pesticide and EOC concentrations in groundwater to the regional councils as soon as possible. Further analysis of the data is continuing and more extensive discussion will be provided in a journal paper that will be prepared for publication and sent to all the councils as soon as it is ready.

2. METHODOLOGY

2.1 WELL SELECTION

In collaboration with ESR wells were selected by each participating council using the following criteria:

- shallow, unconfined and vulnerable aquifers
- significant and important aquifers
- past or present land use
- known or suspected pesticide storage and use

If possible, where a well had been sampled during previous surveys it was also included in the 2018 survey to provide a temporal comparison. Wells were also selected in areas that were under-represented or not sampled in previous surveys. For each well the following information was requested from the council: well location, water level, depth of the well screen, the type of aquifer, and the general land use in the area. A balance was sought between selecting wells that were most vulnerable to contamination (shallow and screened near the water table) and wells that reflected the general usage of the aquifer. Most of the selected wells were from unconfined aquifers.

Fourteen of the Regional and Unitary Authorities with groundwater management responsibilities participated in the 2018 survey. The West Coast Regional Council did not participate in the 2018 survey. The Waikato Regional Council carried out their own regional survey in 2016 as did Environment Canterbury in late 2018. The results from 41 wells from the Waikato Region and the additional 71 wells from the Canterbury region were included in this survey (Figure 1). The number of wells sampled in each region depended on the usage of pesticides in the region, the importance of groundwater resources to the region, and whether the council had recently carried out regional monitoring of pesticides.

A total of 121 wells were selected and sampled from 12 regions and analysed for a suite of EOCs. The Waikato Regional Council had participated in a regional survey of EOCs earlier in 2018 (Moreau et al., 2019) so did not take part in this survey. The distribution of wells sampled for EOCs in shown in Figure 2.

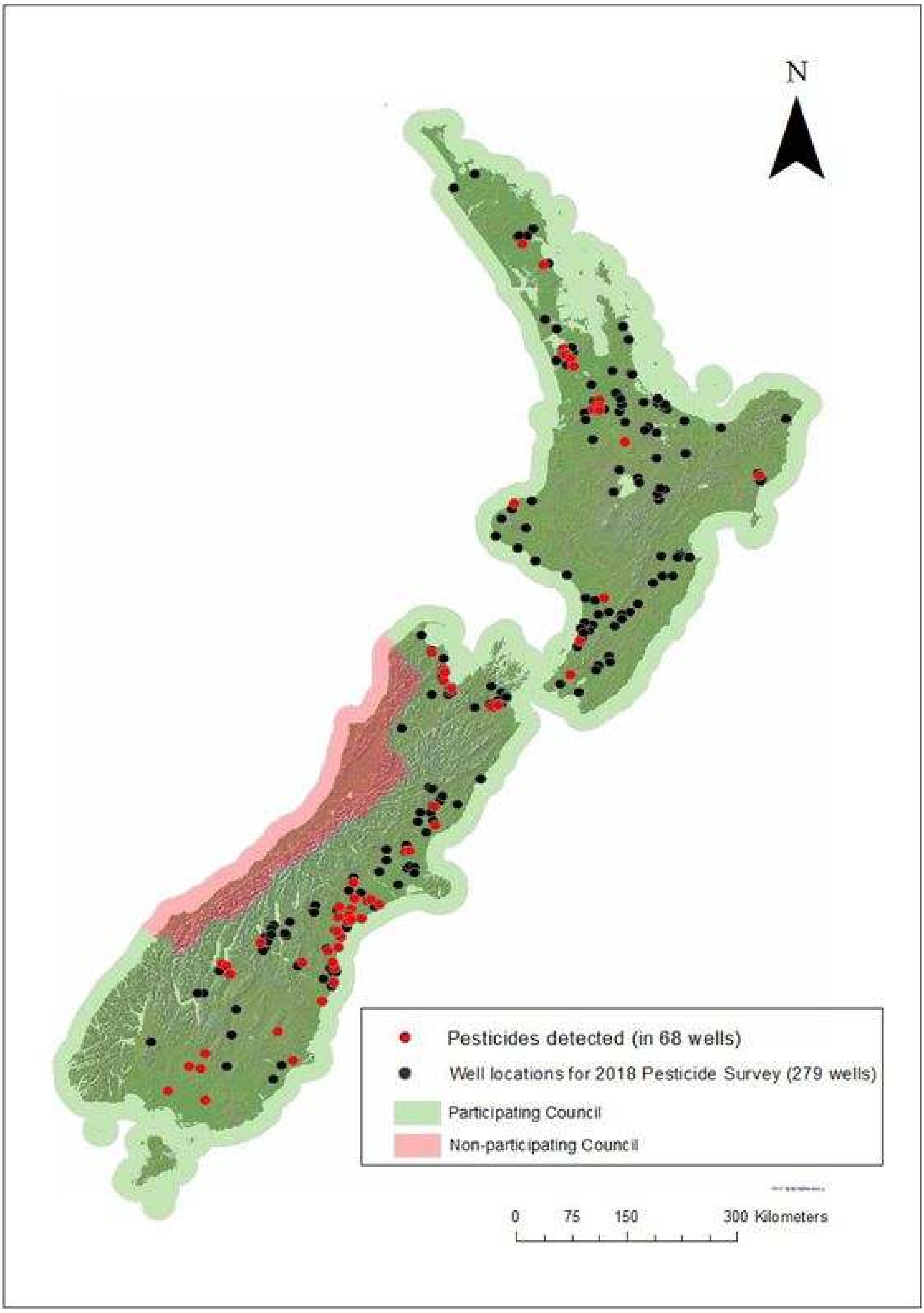

Figure 1: Regions and sampling locations for the 2018 survey of pesticides in groundwater.

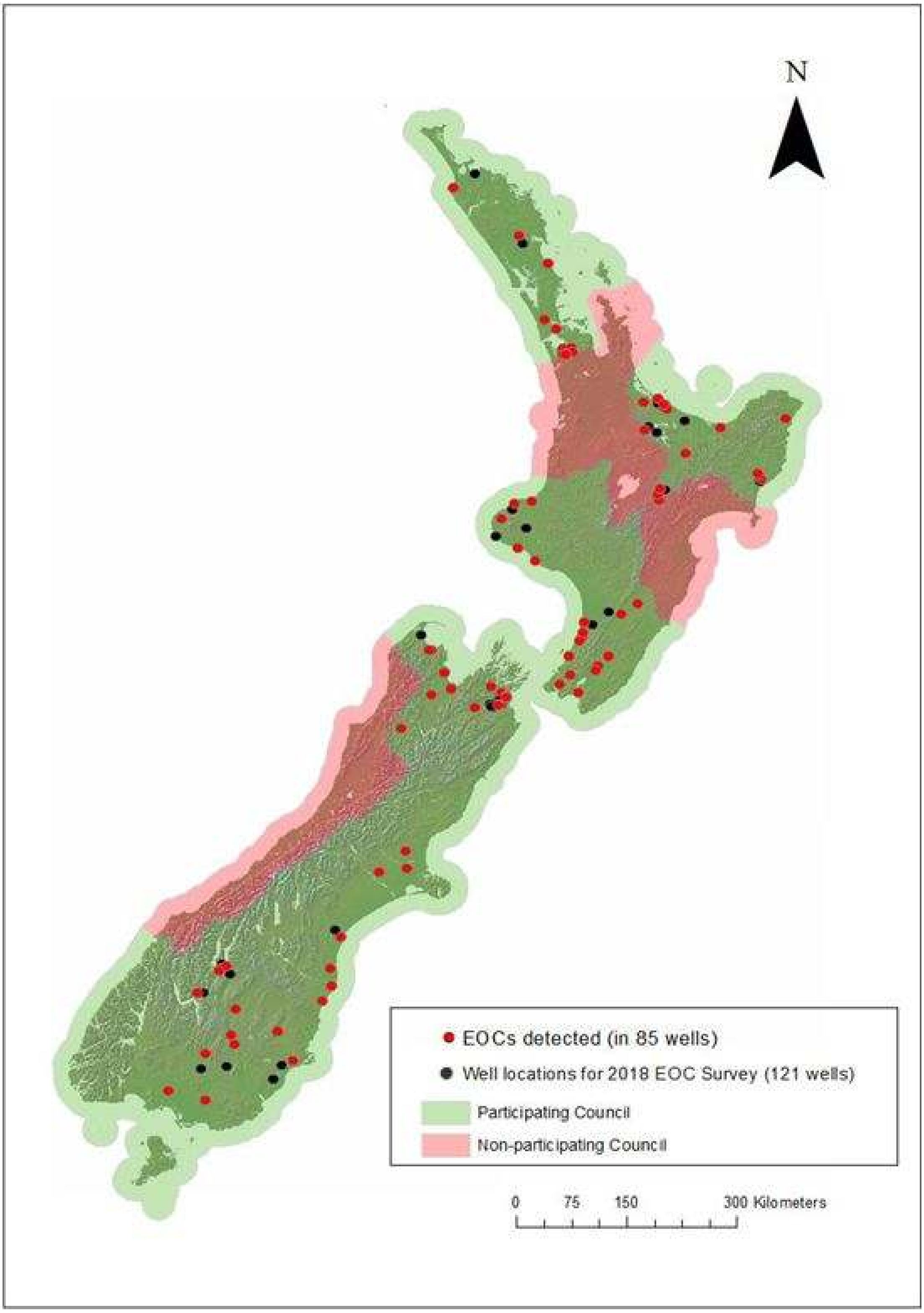

Figure 2: Regions and sampling locations for the 2018 survey of EOCs in groundwater.

2.2 SAMPLING

Samples were collected according to the ESR procedures for sampling pesticides and EOCs (Appendix A) with purging procedures based on *"A National protocol for State of the Environment Groundwater Sampling in New Zealand"* (Daughney et al., 2006). According to these procedures each council was asked to purge three well volumes where possible before sampling. Samples were collected by either portable pumps or in-situ pumps as close to the well head as possible. In most cases field measurements of pH, dissolved oxygen, conductivity and temperature were recorded and a water sample only taken when these parameters had stabilised. For each well sampled a field sheet was filled out and returned to ESR (Appendix B). Bottles for pesticide and glyphosate analysis were supplied by AsureQuality and bottles for EOC analysis were supplied by Northcott Research Consultants Ltd.

2.3 LABORATORY ANALYSIS

2.3.1 Pesticide analysis

All samples for the pesticide analysis suites were sent to AsureQuality in Wellington and analysed for acidic herbicides and a suite of organo-chlorine, organo-phosphorus and organo-nitrogen pesticides (OC/OP/ON) using gas chromatography with a mass spectrometry detector (GC-MS). The acid herbicide analysis involved solid phase extraction and derivatisation of the extract with diazomethane followed by GC-MS analysis using single ion monitoring. The OC/ON/OP pesticide analysis involved extraction with dichloromethane and a pre-concentration step followed by GC-MS analysis in scan mode. Samples from 7% of wells were collected in duplicate as blind duplicate samples for quality control purposes.

The pesticides assayed and their detection limits are provided in Appendix C. The detection limits for this survey were similar to 1998, 2002, 2006, 2010, and 2014 surveys but significantly lower than the limits for the 1994 and 1990 national surveys by a factor of between 5 and 10. The groundwater samples for Waikato Regional Council and Environment Canterbury were analysed by Hill Laboratories which had similar methods but slightly lower detection limits.

2.3.2 Glyphosate and Glufosinate analysis

The samples for the pesticide analysis suites were sent to AsureQuality in Wellington and analysed for glyphosate, glufosinate and their principal metabolites, AMPA (from glyphosate) and MPPA (from glufosinate). The analysis used liquid chromatography with a tandem mass spectrometry detector (LC-MS/MS). The pesticides assayed and their detection limits are provided in Appendix C.

2.3.3 Emerging Organic Contaminants (EOCs)

Upon receipt by NRC Ltd at Plant and Food Research in Hamilton the bottles of groundwater samples were checked for damage, correlated against the supplied inventory and sampling details, and immediately transferred into a walk-in chiller and stored in the dark at 4^{o}C.

Particular care was taken to avoid potential contamination of the groundwater and Quality Assurance (QA) samples with EOCs during all steps of the preparatory, extraction and purification process. Laboratory personnel undertaking these tasks were required to avoid drinking coffee and tea for a period of 16 hours proceeding, and for the duration when working with the samples. These same personnel were similarly asked to refrain from applying cosmetics and skin moisturisers and were required to where nitrile gloves when handling the samples.

Sample preparation

The bottles of groundwater samples were removed from storage at 4^{o}C and the pH adjusted to <2.5 by the addition of 6M sulphuric acid. The aqueous samples were filtered through a glass microfiber filter (47 mm, Labservice) topped with diatomaceous earth filter aid media (Hyflo SuperCel) to remove particulate material. The sample filtrate was collected in pre-cleaned 2L Glass Schott bottles.

The filtered groundwater samples extracted for the analysis of EOCs excluding pharmaceutical compounds were spiked with a solution of carbon-13 labelled analogues of target EOCs for use as surrogate recovery compounds. Filtered groundwater samples being extracted for pharmaceuticals were spiked with the acidic herbicides dichlorprop, flamprop and MCPB, and the plant growth regulator naphthalene acetic acid for use as surrogate recovery compounds

Sample extraction and purification

Emerging organic contaminants (EOCs) in the filtered groundwater samples (dissolved phase) were extracted by solid-phase extraction (SPE). Neutral and phenolic EOCs were extracted by SPE using Waters Oasis HLB cartridges and pharmaceuticals using Waters Oasis MCX cartridges. The EOC sample extract was split into two equal portions- one for analysis of neutral EOCs and the other for polar EOCs requiring chemical derivatisation for analysis by gas chromatography mass-spectrometry (GCMS). The portions of split sample extract were transferred into vials, capped and sealed and stored under refrigeration for analysis. One half of the EOC sample extract was exchanged into acetone, deuterated internal standards added, and transferred into GC vials for the analysis of non-polar neutral EOCs.

Sample extract derivatisation

A solution of deuterated polar internal standards was added to the second portion of the EOC sample extracts and the polar EOCs (steroid hormones, phenolic antimicrobials, paraben preservatives, UV filters, succralose) were derivatised to their respective trimethylsilyl ethers using a catalytic mixture of N-methyl-N-(trimethylsilyl)trifluoroacetamide (MSTFA), ammonium iodide, and mercaptoethanol.

An internal standard mixed solution containing deuterated monocarboxylic phthalate acid esters and ibuprofen-d3 was added to the pharmaceutical sample extracts which were evaporated to dryness and converted to their respective tertiary-butyl dimethyl silyl esters by reaction with N-tert-butyldimethyl- silyl-N-methyltrifluoroacetamide (MTBSTFA) with 1% t-butyldimethylsilyl chloride (TBDMSCl).

Instrumental analysis of EOCs

The analysis of the different classes of EOCs required the use of different GCMS instruments and instrumental analysis methods. Paraben preservatives, phenolic antimicrobials and UV filters were analysed using an Agilent 6890N gas chromatograph coupled to a 5975 mass spectrometer operating in single ion monitoring mode. Quantitation of target EOCs was achieved by internal standard quantitation using Agilent Chemstation MS software. Steroid hormones, neutral EOCs, BPA and acidic pharmaceuticals were analysed using an Agilent 7000 series triple quadrupole GCMS operating in MS/MS mode. Quantitation of target EOCs was achieved by internal standard quantitation using Agilent Mass Hunter Quantitative Analysis software.

Quality assurance procedures

Each individual sample was spiked with a mixed solution of surrogate recovery standards at a concentration of 50 ng/L (parts per trillion) and 25 ng/L, respectively for neutral and polar EOCs and pharmaceuticals. Quality Assurance (QA) samples incorporated into the analysis of ground water samples included blank SPE cartridges, Milli-Q water blank samples, Milli-Q water samples spiked with target analytes. The QA Milli-Q water spike samples were spiked with mixtures of the target analytes at an equivalent concentration of 50 ng/L and 25 ng/L respectively for neutral and polar EOCs and pharmaceuticals.

Comparative standards, comprising the same volume of each individual QA spike solution incorporated into each batch of extracted samples, were prepared by dispensing aliquots of the individual QA spike solutions into labelled vials at the same time they were added to each batch of samples. The percentage recovery of surrogate and target compound spikes was determined by directly comparing the concentration of analytes measured in QA and sediment samples against that measured in the corresponding comparative standard(s).

Background concentration of EOCs

Residues of three EOCs, namely Bisphenol-A (BPA), octinoxate and oxybenzone were detected in SPE cartridge blanks and Milli-Q water blanks at mean equivalent concentrations of 2.33, 2.15 and 2.19 ng/L respectively. No residues of pharmaceutical compounds were detected in any of the QA blank samples.

The results reported for BPA, octinoxate and oxybenzone were corrected against the blank concentration measured in each batch of extracted samples.

Method detection limits

Method detection limits (MDLs) for individual EOCs were calculated using a signal-to-noise ratio of 3:1 and by assessment of the mean concentration of target EOCs detected in the QA blank samples. The higher of these two values was adopted as the MDL for each individual compound. The resulting confirmed MDLs obtained for the target analytes are listed in Table 7. The final MDLs obtained for seven target EOCs were higher than initially estimated. The final MDLs obtained for bisphenol-A, octinoxate and oxybenzone increased because of their presence as background contaminants in the QA SPE and Milli-Q water blanks. The MDLs for the stimulants caffeine, 1,7-dimethylxanthine, nicotine and cotinine increased above initial estimates due to the relatively low intensity of their respective mass ions combined with increased background contributions of these low mass ions impacting on the sensitivity of mass detection.

3. RESULTS

A total of 167 wells were sampled and the groundwater samples sent to AsureQuality in Wellington. The Waikato Regional Council provided results for an additional 41 wells that had been sampled as part of their regional survey in December 2016 and were sent to Hill Laboratories. Environment Canterbury also provided results for an additional 71 wells that were sampled as part of a regional survey and were analysed by Hill Laboratories. Both these additional datasets were included in this report to give a national perspective, giving a total of 279 wells for the pesticide suites. Glyphosate, Glufosinate and their metabolites were analysed on samples from 135 wells and the EOC suite was analysed on samples from 121 wells.

3.1 ASSESSMENT OF SURVEY METHODOLOGY

3.1.1 Pesticides

Blind duplicate samples from 12 wells (7 %) were submitted to the analytical laboratory as a quality control measure. Most of the blind duplicate samples did not have detectable pesticides present and there was very good agreement for 11 of the 12 duplicate analyses (Table 1). Well 7428105 from Auckland had 2,4-DB detected in one duplicate and bentazone detected in the other duplicate sample, both at concentrations just above the detection limits. All of the blind duplicate samples had no detections for Glyphosate as there was only one detection from all the sampled wells and that particular well was not sampled as one of the blind duplicates.

3.1.2 Emerging Organic Contaminants

Blind duplicate samples from 5 wells (4%) were submitted to the analytical laboratory as an additional quality control measure. There was very good agreement for four of the five duplicate analyses (Table 2), with well GND2515 having 9 different EOCs detected in both duplicates with reasonably similar concentrations in each sample. There were differences in the samples from well 362397, with one sample having detections of caffeine and octinoxate (OMC) and the other sample having no detections of any EOC.

Table 1: Comparison of Blind Duplicate samples for pesticides suite.
(ND, not detected)

Council	Well ID (Blind duplicate)	Pesticide Concentration (μg/L)	
Northland Regional Council	1355 (Blind Duplicate)		ND (ND)
Auckland Council	7428105 (Blind Duplicate)	2,4-DB Bentazone	0.11 (<0.1) <0.1 (0.11)
Bay of Plenty Regional Council	1001289 (Blind Duplicate)		ND (ND)
	1001290 (Blind Duplicate)		ND (ND)
Hawkes Bay Regional Council	16095 (Blind Duplicate)		ND (ND)
Taranaki Regional Council	GND2515 (Blind Duplicate)	Terbuthylazine	0.028 (0.030)
Horizons Regional Council	315027 (Blind Duplicate)	Bentazone	0.13 (0.14)
	338005 (Blind Duplicate)		ND (ND)
	372136 (Blind Duplicate)		ND (ND)
Tasman District Council	524 (Blind Duplicate)	Bentazone	0.35 (0.36)
	6342 (Blind Duplicate)		ND (ND)
Otago Regional Council	G41/0045 (Blind Duplicate)		ND (ND)

Surrogate standard recovery for EOCs

The results obtained from quality assurance procedures met or exceeded accepted standards for laboratories undertaking trace analysis of organic contaminants and pesticides.

The recovery of surrogate standards spiked into all of the analysed ground water, and Milli-Q water blank and spiked QA fell within the accepted range of 70% to 130 % (Table 3). The relatively narrow 95% confidence intervals for the mean recovery of surrogate standards reflects in part the high total number of ground water and QA samples from which this data was derived (N = 147). Regardless, the recovery data obtained of the surrogate spike compounds demonstrates good overall reproducibility of the sample extraction and analysis method.

Table 2: Comparison of Blind Duplicate samples for EOC suite.
(ND, not detected)

Council	Well ID (Blind duplicate)	Pesticide Concentration (ng/L)	
Horizons Regional Council	362397 (Blind Duplicate)	Caffeine	ND (3.12)
		Octinoxate	ND (13.2)
Taranaki Regional Council	GND2515 (Blind Duplicate)	Bisphenol-A	5.05 (5.55)
		Caffeine	7.08 (4.39)
		Carbamazepine	73.1 (72.1)
		Diclofenac	89 (107)
		4-methylbenzylidene camphor	11.8 (12.7)
		Octinoxate	7.85 (10.7)
		o-phenylphenol	7.31 (4.93)
		Oxybenzone	26.5 (24.3)
		Sucralose	266 (1043)
Otago Regional Council	F40/0045 (Blind Duplicate)	Bisphenol-A	55.1 (42.6)

Table 3: Recovery of surrogate standards spiked into groundwater and quality assurance samples.

Recovery compound	95% confidence interval for mean % recovery [A]	Range (min-max)
Bisphenol-A-13C6	89.5 ± 1.7	78.5 - 102.7
Butyl paraben-13C6	102.5± 2.2	75.4 – 124.1
Caffeine-13C3	76.6 ± 2.5	70.3 – 123.1
17β-estradiol-13C6	92.5 ± 1.7	75.6 – 122.7
Estrone-13C6	92.6 ± 1.9	74.6 – 107.3
Methyl paraben-13C6	89.5 ± 1.5	82.8 – 104.8
4n-nonylphenol-13C6	82.0 ± 1.5	71.2- 90.5
Oxybenzone-13C6	112.6 ± 6.1	86.5 – 127.2
o-phenylphenol-13C6	76.9 ± 2.1	70.6 – 110.8
Triclosan-13C6	96.2 ± 2.1	86.5 – 120.8
Dichlorprop[B]	108.9 ± 1.8	89.9 – 115.3
Flamprop[B]	97.1 ± 2.8	72.2 – 123.9
MCPB[B]	117 ± 0.8	99.0 – 127.0
NAA[BC]	98.2 ± 0.7	83.9- 106.1

[A] N=147; [B]surrogate for acidic pharmaceuticals; [C]napthalene acetic acid

Target analyte recovery for EOCs

The mean percentage recovery of target analytes spiked into the Quality Assurance Mill-Q water spike recovery samples similarly largely fell within the accepted range of 70% to 130 %. Recoveries of <70% were occasionally obtained for a limited number of target EOCs, principally the more volatile chemicals (Caffeine, nicotine etc) and the highly polar and water soluble sucralose. Despite the occasional recovery of <70% being obtained the corresponding mean recovery for these EOCs were above 70%. Overall, the mean and 95% confidence intervals calculated for the recovery of target EOCs from the QA spike samples demonstrated an acceptable and consistent recovery.

The combined results obtained for the recovery of surrogate compounds and target analyte EOCs from the individual analysed samples and quality assurance spike samples demonstrates the robustness of the employed methodologies.

3.2 SURVEY RESULTS

3.2.1 Pesticides

With the addition of the 41 wells from the Waikato Regional Council and the 71 additional wells from Environment Canterbury, there were a total of 279 wells sampled with 68 wells (24.4%) having pesticides detected. The additional wells from Waikato had the same detection frequency (24.4%) while the additional wells from Canterbury had a slightly higher detection frequency (32%) compared to the national detection frequency. There were one or more wells with pesticides detected in 6 of the 13 participating regions (Table 4), with regional detection rates varying from 0 to 83% (note that the higher rates were for a small number of sampled wells). Pesticides were not detected in sampled wells from Bay of Plenty (25 wells) and Hawkes Bay (14 wells). In 28 of these wells (10%) two or more pesticides were detected (Table 4). The maximum number of pesticides detected in one well was six. Twenty-five different pesticides, including metabolites, were detected in the sampled wells (Table 5).

Herbicides were the most frequently detected pesticide group with 98 detections (88%) of 17 different herbicides and their metabolites, with seven insecticides and one fungicide detected in the sampled wells. There were 80 detections (71%) of triazine herbicides with terbuthylazine being the most frequently detected pesticide (36 detections). There were three pesticide detections exceeding 1 μg/L with none of the sampled wells exceeding the MAV for drinking water. The highest detection as a percentage of the MAV was dieldrin which was detected at a concentration of 0.025 μg/L which was 62.5% of the MAV of 0.04 μg/L (Ministry of Health 2018). The next highest detections relative to the MAV were for total atrazine and metabolites at 16.5% of the MAV, hydroxyatrazine (another atrazine metabolite) at 11% of MAV assuming the same MAV as for atrazine, then terbacil at 9.5% of the MAV. The remainder of pesticide detections were less than 5% of the MAV.

There was only one detection of glyphosate in the 135 wells (0.7%) that were sampled. This well also had a range of other pesticides detected in the sample including atrazine and its metabolites, diazinon and DDT. This well is a reasonably shallow, large diameter well (depth = 20 m; diameter = 1.0 m). It has been sampled on four previous surveys and has had pesticides detected for three of those surveys. On investigation in 2019 it was found that the condition of this wellhead was poor and there were chemical containers stored close to the well, meaning that ingress of chemicals from the surface was a high possibility.

No MAV for glyphosate in drinking water has been set in New Zealand. New Zealand follows WHO guidelines when setting its MAVs but there is currently no WHO guideline; however, WHO does have a Health Based Value for glyphosate of 900 μg/L (WHO 2017). The detected level of 2.1 μg/L is far below this value.

The range of concentrations found, MAV values, groundwater ubiquity scores (GUS), and the mobility and degradation characteristics of each pesticide are given in Table 5. The mobility and degradation values come from the National Pesticide Information Centre, which hosts several pesticide properties databases (http://npic.orst.edu/) as at September 2019, unless otherwise noted. The selected value listed in this database, plus the range of values in the literature, are given in Table 5. The mobility is represented by the soil organic carbon sorption coefficient (K_{oc}). K_{oc} is calculated by measuring the ratio, Kd, of sorbed to solution pesticide concentrations after equilibrium of a pesticide in a water/soil slurry and then dividing by the weight fraction of organic carbon present in the soil. High K_{oc} values indicate compounds with high absorption to soils and low mobility. The soil half-life is the time it would take for half the amount of pesticide to degrade in soil, assuming a first order degradation process. The GUS scores are a simplified assessment of whether a pesticide is likely to leach or not (Gustafson, 1989) and are calculated as:

$$GUS = \log_{10}(\text{soil half-life}) \times (4-\log_{10}(K_{oc}))$$

GUS value greater than 2.8 indicates that the compound would leach relatively readily and a GUS score of less than 1.8 indicates a ‘non-leacher’. There is a transitional zone between 1.8 and 2.8 where pesticides could leach under favourable conditions. In this report a wider transitional zone was used. The GUS values suggested by Primi et al., (1994) of 1.5 and 3.0 were used to differentiate leachers and non-leachers.

Table 4: Summary of results from the 2018 pesticides in groundwater survey detailing 112 detections in 68 wells out of a total of 279 wells sampled.

Note that µg/L = mg m^{-3} = ppb. DET = desethyl terbuthylazine=terbuthylazine desethyl; DEA = desethyl atrazine = atrazine-desethyl; and DIA = desisopropyl atrazine = atrazine-desisopropyl; p,p'-DDT = 4,4'-DDT.

Council Region (# detections / # wells sampled)	Well ID	Pesticide Detected	Concentration (µg/L)
Northland Regional Council (2/11)	7244	Hexazinone	0.05
	9851	Terbuthylazine	0.041
Auckland Regional Council (4/8)	43915	Bentazone	0.17
		Metolachlor	0.025
	7419127	Bentazone	0.14
	7428031	Bentazone	0.2
	7428105	Bentazone	0.08
		2,4-DB	0.08
Waikato Regional Council (10/41)	61-54	Dieldrin	0.02
		Propazine	0.04
	61-93	Metolachlor	0.05
	61-113	Metalaxyl	0.06
		Propazine	0.03
		Terbuthylazine	0.03
	61-230	Dieldrin	0.025
	62-5	DET	0.05
	67-4	Hexazinone	0.11
	69-19	Terbuthylazine	0.02
	69-97	Terbuthylazine	0.02
	69-295	Bromacil	0.88
		Endosulfan II	0.061
		Terbacil	3.8
	70-22	Endosulfan I	0.016
		Endosulfan II	0.033
		Endosulfan sulphate	0.068
		Terbacil	0.4
		Terbuthylazine	0.09
		DET	0.39
Bay of Plenty Regional Council (0/25)			
Gisborne District Council (1/5)	GPF032	2-Hydroxyatrazine	0.22
Hawkes Bay Regional Council (0/13)			
Taranaki Regional Council (1/8)	GND2515	Terbuthylazine	0.029
Horizons (2/20)	315027	Bentazone	0.14

Council Region (# detections / # wells sampled)	Well ID	Pesticide Detected	Concentration (µg/L)
	372034	Alachlor	0.59
		Metalaxyl	0.024
Greater Wellington Regional Council (1/8)	R27/1137	Terbuthylazine	0.054
Tasman District Council (8/22)	285	Simazine	0.041
		Terbuthylazine	0.011
	524	Bentazone	0.36
	3115	Terbuthylazine	0.031
	4096	Simazine	0.016
		Terbuthylazine	0.034
	4140	Terbuthylazine	0.038
	6601	Simazine	0.02
	8036	Hexazinone	0.095
		Terbuthylazine	0.014
	23604	Terbuthylazine	0.018
Marlborough District Council (2/19)	P28w/3069	Terbuthylazine	0.064
	P28w/3222	Terbuthylazine	0.016
Environment Canterbury (26/77)	J38/0242	Simazine	0.019
		Terbuthylazine	0.019
	K39/0033	Simazine	0.019
		Terbuthylazine	0.17
	M35/8567	Terbuthylazine	0.013
	BY20/0148	Hexazinone	0.01
	CA15/5009	Bromacil	2.0
	CA17/0008	DEA	0.015
	CA18/0020	Hexazinone	0.018
	J37/0012	Bentazone	0.22
	J38/0004	DET	0.027
	J38/0169	Terbuthylazine	0.04
		DET	0.199
		Simazine	0.011
		DIA	0.02
	J39/0135	DET	0.015
		Atrazine	0.021
	J40/0286	Terbuthylazine	0.037
		DET	0.06
		Hexazinone	0.013
	J40/0333	DEA	0.011

Council Region (# detections / # wells sampled)	Well ID	Pesticide Detected	Concentration (µg/L)
		DET	0.023
	J41/0018	Terbuthylazine	0.006
		DET	0.011
	K36/0033	Terbuthylazine	0.35
		DET	0.175
		4,4'-DDE	0.0025
		4,4'-DDT	0.0018
	K37/0147	Terbuthylazine	0.019
		DET	0.021
	K37/0216	DEA	0.015
	K38/0148	Terbuthylazine	0.005
	K38/0404	Atrazine	0.011
	K38/1017	DET	0.011
	K38/2200	Terbuthylazine	0.005
	L37/0297	4,4'-DDE	0.0007
	L37/0439	DET	0.014
		Terbuthylazine	0.022
	M35/6295	DET	0.027
		Terbuthylazine	0.01
	N33/0064	DET	0.03
		Terbuthylazine	0.006
	N33/0212	DET	0.021
		Terbuthylazine	0.01
Otago Regional Council (6/16)	F40/0206	Simazine	0.03
	G40/0367	Picloram	0.4
	G40/0411	Terbuthylazine	0.022
	H43/0132	Picloram	0.91
		Terbuthylazine	0.16
	I44/0821	Hexazinone	0.15
	J41/0008	Atrazine	0.032
		Total Atrazine and Metabolites (max)	0.33
		Diazinon	0.01
		Glyphosate	2.1
		4,4'-DDT	0.02
Environment Southland (5/6)	E44/0036	Terbuthylazine	0.089
	E46/0093	Simazine	0.019
		Terbuthylazine	0.025

Council Region (# detections / # wells sampled)	Well ID	Pesticide Detected	Concentration (µg/L)
	F44/0484	Simazine	0.053
		Terbuthylazine	0.3
	F45/0792	Terbuthylazine	0.021
	F46/0239	Hexazinone	0.024
		Propazine	0.062
		Simazine	0.067
		Terbuthylazine	0.15
	68 wells		**112 detections**

Table 5: Characteristics of detected pesticides.

Field half-lives and Koc values are from the National Pesticide Information Centre database (http://npic.orst.edu/): selected value with range in parentheses. GUS classes: L = leacher; N = non-leacher; T = transitional. NA = not available. MAV = maximum acceptable value.

Pesticide	FAO Classification	Field half-life (days)	Koc (ml g^{-1})	GUS score	No. of Wells	Range (µg/L)	MAV (µg/L)
Herbicides							
2,4-DB	Phenoxy hormones	5	440	0.95 N	1	0.08	100
2-Hydroxyatrazine	Triazine				1	0.22	2
Alachlor	Amide	15	170	2.08 T	1	0.59	20
Atrazine	Triazine	60	100	3.56 L	3	0.011 - 0.032	2
DEA	Triazine	†	†		3	0.011 – 0.015	2
DIA	Triazine	†	†		1	0.02	2
Bentazone	Other herbicide	27 (7–98)	35	3.52 L	7	0.08 – 0.36	
Bromacil	Uracil	60	32	4.44 L	2	0.88 – 2.0	400
Glyphosate	Phosphonyl	47	24,000	-0.64 N	1	2.1	900
Hexazinone	Triazine	90	54	4.43 L	8	0.01 – 0.15	400
Metolachlor	Amide	90	200	3.32 L	2	0.025 – 0.05	10
Picloram	Other hormone type	90	16	5.46 L	2	0.4 – 0.91	200
Propazine	Triazine	135	154	3.86 L	3	0.03 – 0.062	70
Simazine	Triazine	60	130	3.35 L	10	0.011 – 0.067	2
Terbacil	Uracil	120	55	4.70 L	2	0.4 – 3.8	40
Terbuthylazine	Triazine	86 (34–193)*	110 (42–575)*	3.79 L	36	0.005 – 0.35	8
DET	Triazine	#	#		15	0.011	0.39

Pesticide	FAO Classification	Field half-life (days)	Koc (ml g^{-1})	GUS score	No. of Wells	Range (µg/L)	MAV (µg/L)
Insecticide							
4,4'-DDE	Organochlorine	1000	50,000	-2.10 N	2	0.0007 – 0.0025	1
4,4'-DDT	Organochlorine	2000	2,000,000	-7.60 N	2	0.0018 – 0.02	1
Diazinon	Organophosphate	40	1000	1.60 T	1	0.01	
Dieldrin	Organochlorine	1000	12000	-0.24 N	2	0.02 – 0.025	0.04
Endosulfan I	Other insecticide	50	12,400	-0.17 N	1	0.016	
Endosulfan II	Other insecticide	‡	‡		2	0.033 – 0.061	
Endosulfan sulphate	Other insecticide	‡	‡		1	0.068	
Fungicides							
Metalaxyl	Other fungicide	70	50	3.33 L	2	0.024 – 0.06	100

† values assumed similar to Atrazine; * values for Terbuthylazine taken from Close et al., (2008); # values assumed similar to Terbuthylazine; ‡ values assumed similar to Endosulfan I; DET = desethyl terbuthylazine=terbuthylazine desethyl; DEA = desethyl atrazine = atrazine-desethyl; and DIA = desisopropyl atrazine = atrazine-desisopropyl; p,p'-DDT = 4,4'-DDT.

3.2.2 Emerging Organic Contaminants (EOCs)

There were a total of 227 EOCs detected in the 85 wells (70%) from the 121 wells that were sampled (Table 6), and all regions that had samples analysed for EOCs had at least three wells with EOCs present. There were 29 different EOCs in the analytical suite and 25 different EOCs were detected in at least one well (Table 7). The maximum number of EOCs detected in a single well was 13.

The EOCs were grouped into six categories that reflected their source and usage (Table 7). Most EOCs are used extensively by people or are produced by people (eg estrogenic steroid hormones) and most do not have significant human toxicity when used under normal conditions, such as use of sun screens or anti-inflammatories such as diclofenac (voltaren). There are no MAVs for drinking water associated with these EOCs. However, some of these compounds have shown some endocrine disrupting effects in surface waters (Sellin et al., 2009; Tremblay et al., 2018) and the main concerns with these EOCs are environmental or ecological impacts. However, there are no or very few guideline values for EOCs regarding ecological impacts as the required studies are sparse (Lapworth et al., 2012). Some EOCs, such as sucralose and caffeine, can act as tracers of the presence of human activities or wastewater impacts in the groundwater system (Table 7).

The most commonly detected EOC was bisphenol-A (BPA) which was detected in 40 wells, with the UV filter compounds, OMC and BP3 next most common with 33 and 24 detections, respectively (Table 7). Sucralose, an artificial sweetener, was next most common with 18 detections. The highest concentration measured was 655 ng/L for sucralose (Table 7).

Table 6: Summary of results from the 2018 Emerging Organic Contaminants (EOCs) in groundwater survey detailing 227 detections in 85 wells.

Council Region (# detections / # well sampled)	Well ID	EOC Detected	GCMS Concentration (ng L^{-1})
Northland Regional Council (3/5)	1002	Bisphenol-A	31.4
		Octinoxate	31.4
	5044	Acetominophen	1.18
		Bisphenol-A	16.7
		Carbamazepine	5.49
		Diclofenac	12.8
		2,4-dihydroxybenzophenone	3.18
		Ibuprofen	5.66
		Naproxen	4.83
	8287	Oxybenzone	10.8
Auckland Council (4/8)	43915	Caffeine	45.0
		17α-estradiol	0.95
	6475015	Bisphenol-A	27.0
		Ibuprofen	30.8
	6487015	Bisphenol-A	6.73
		Estrone	0.57
		Sucralose	50.5
	7419009	Acetominophen	94.0
		Bisphenol-A	3.29
		Carbamazepine	59.8
		Diclofenac	68
		2,4-dihydroxybenzophenone	2.12
		Estrone	1.06
		4-hydroxybenzophenone	2.08
		Ibuprofen	63.9
		Methyl-Triclosan	1.81
		Naproxen	57.3
	7419126	Acetominophen	13.6
		Bisphenol-A	2.36
		Carbamazepine	5.77
		Diclofenac	7.84
		Ibuprofen	5.33

Council Region (# detections / # well sampled)	Well ID	EOC Detected	GCMS Concentration (ng L^{-1})
		Mestranol	6.78
		Naproxen	3.99
	7419127	Octinoxate	7.19
	7428031	Bisphenol-A	9.92
		Octinoxate	7.4
	7428105	Caffeine	9.25
		17α-estradiol	5.15
		Sucralose	265
Bay of Plenty Regional Council (13/25)	915	Bisphenol-A	5.26
	1561	Bisphenol-A	7.95
	1670	Bisphenol-A	4.44
		Methyl paraben	1.43
		Propyl paraben	0.5
	2822	Bisphenol-A	4.68
	3036	Bisphenol-A	5.79
		Caffeine	2.21
	100106	Octinoxate	11.4
	170049	Bisphenol-A	7.59
	1001058	Bisphenol-A	423
		Octinoxate	5.95
	1001239	2,4-dihydroxybenzophenone	0.65
		Oxybenzone	15.6
	1001241	Oxybenzone	7.32
	1001249	Bisphenol-A	4.7
		Propyl paraben	0.69
	1001289	Caffeine	2.34
	Waitapu Spring	Caffeine	1.87
Gisborne District Council (4/5)	GPB099	Acetominophen	5.33
		Bisphenol-A	56.0
		4-methylbenzylidene camphor	40.1
		Octinoxate	13.9
		Sucralose	202
	GPF032	Octinoxate	25
	GPG019	Sucralose	20.3
	R SPRING	Acetominophen	2.99

Council Region (# detections / # well sampled)	**Well ID**	**EOC Detected**	**GCMS Concentration (ng L^{-1})**
		Diclofenac	1.97
		Octinoxate	21.1
		Oxybenzone	7.65
Taranaki Regional Council (5/8)	GND0076	Oxybenzone	9.06
		2,2',4,4'-tetrahydroxybenzophenone	0.44
	GND0809	4-hydroxybenzophenone	2.08
	GND0827	Methyl paraben	1.77
	GND1718	2,4-dihydroxybenzophenone	0.87
	GND2515	Bisphenol-A	5.30
		Caffeine	5.74
		Carbamazepine	72.6
		Diclofenac	98
		4-methylbenzylidene camphor	12.3
		Octinoxate	9.28
		o-phenylphenol	6.12
		Oxybenzone	25.4
		Sucralose	655
Horizons (6/8)	338005	2,4-dihydroxybenzophenone	1.77
		4-hydroxybenzophenone	2.00
		Methyl paraben	2.2
		Propyl paraben	1.26
		Sucralose	31.8
		2,2',4,4'-tetrahydroxybenzophenone	5.53
	342051	Ibuprofen	175
	362397	Caffeine	1.81
		Octinoxate	6.6
	362801	Caffeine	4.25
	372034	Bisphenol-A	6.49
		Octinoxate	14.4
	421001	Caffeine	2.25
		2,4-dihydroxybenzophenone	2.07
		Estrone	0.85
		Methyl paraben	2.72
		Methyl-Triclosan	5.07
		Octinoxate	15.6
		Oxybenzone	11.0

Council Region (# detections / # well sampled)	Well ID	EOC Detected	GCMS Concentration (ng L^{-1})
		Propyl paraben	2.13
		Sucralose	39.4
		2,2',4,4'-tetrahydroxybenzophenone	1.69
Greater Wellington Regional Council (7/7)	R26/6587	Octinoxate	5.33
	R27/1137	Bisphenol-A	1.28
		Sucralose	22.5
	R27/1182	Bisphenol-A	2.51
		2,4-dihydroxybenzophenone	0.95
		Estriol	1.08
		Sucralose	88.8
		2,2',4,4'-tetrahydroxybenzophenone	2.85
	S26/0117	Acetominophen	96.8
		Bisphenol-A	1.97
		Carbamazepine	61.4
		Diclofenac	63.7
		Ibuprofen	63.8
		Naproxen	57.1
		Octinoxate	25.7
		Oxybenzone	2.47
	S26/0457	Triclosan	2.03
	S27/0588	Methyl-Triclosan	3.03
		Oxybenzone	14.3
		Triclosan	1.94
	T26/0259	Acetominophen	13.3
		Carbamazepine	5.91
		Diclofenac	7.64
		Ibuprofen	5.3
		Naproxen	3.98
Tasman District Council (8/10)	524	Oxybenzone	12.3
		Sucralose	1.21
	4096	4-methylbenzylidene camphor	63.8
		Octinoxate	63.8
		Oxybenzone	19.7
	6342	Bisphenol-A	8.66
		Methyl-Triclosan	1.18
		Octinoxate	36.2

Council Region (# detections / # well sampled)	Well ID	EOC Detected	GCMS Concentration (ng L^{-1})
		Oxybenzone	10.7
	23604	Bisphenol-A	5.73
		Caffeine	5.77
		2,4-dihydroxybenzophenone	4.66
		17α-estradiol	1.50
		17α-Ethinylestradiol	1.48
		Estriol	3.10
		Estrone	1.49
		Mestranol	1.94
		Methyl paraben	5.45
		o-phenylphenol	4.08
		Propyl paraben	5.95
		Sucralose	162
		2,2',4,4'-tetrahydroxybenzophenone	8.35
	23658	Octinoxate	31.3
	23759	2,4-dihydroxybenzophenone	2.76
	23806	Estrone	0.85
		Methyl-Triclosan	5.07
		Sucralose	1.50
	Pupu springs - Main spring	Octinoxate	41.2
		Oxybenzone	19.6
Marlborough District Council (12/19)	10542	Bisphenol-A	8.46
		Oxybenzone	5.51
	O28w/0015	Methyl paraben	8.91
		Propyl paraben	1.8
	P27w/0448	Chloroxylenol	0.50
		Propyl paraben	0.77
	P28w/0124	Methyl paraben	26.0
		Propyl paraben	5.70
	P28w/0610	Bisphenol-A	5.05
		2,4-dihydroxybenzophenone	0.81
		Oxybenzone	10.8
	P28w/0647	Octinoxate	11.5
	P28w/1634	Bisphenol-A	9.3
	P28w/2993	Bisphenol-A	34.3

Council Region (# detections / # well sampled)	Well ID	EOC Detected	GCMS Concentration (ng L^{-1})
		Oxybenzone	6.81
	P28w/3222	Oxybenzone	6.91
	P28W/3668	Octinoxate	9.37
	P28W/3711	Bisphenol-A	2.78
		Octinoxate	5.13
		Sucralose	118
	P28W/6037	Bisphenol-A	56.8
Environment Canterbury (5/6)	J40/0256	Bisphenol-A	5.71
	K39/0033	Octinoxate	14.7
		Oxybenzone	14.7
		Sucralose	51.3
	L36/0003	Bisphenol-A	5.49
		Octinoxate	14.4
	M35/5918	Ibuprofen	7.71
	M35/8567	Bisphenol-A	20.1
		Octinoxate	17.9
		Sucralose	36.4
Otago Regional Council (11/16)	F40/0045	Bisphenol-A	48.9
	F41/0203	Bisphenol-A	50.0
		2,4-dihydroxybenzophenone	1.17
		Methyl paraben	1.75
		Methyl-Triclosan	0.66
		Octinoxate	12.8
		Sucralose	7.94
	F41/0437	Bisphenol-A	9.84
		2,4-dihydroxybenzophenone	0.95
		Methyl paraben	2.16
		Octinoxate	14.3
		Oxybenzone	7.66
	G40/0367	Oxybenzone	6.91
	G42/0290	Bisphenol-A	34.3
		Octinoxate	20.5
		Oxybenzone	6.81
	G43/0072	Bisphenol-A	5.05
		2,4-dihydroxybenzophenone	0.81
		Octinoxate	6.61

Council Region (# detections / # well sampled)	**Well ID**	**EOC Detected**	**GCMS Concentration (ng L^{-1})**
		Oxybenzone	10.8
	G43/0224b	Bisphenol-A	8.46
		Octinoxate	40.3
		Oxybenzone	5.51
	H43/0132	Methyl paraben	1.49
		Octinoxate	35.3
		Oxybenzone	10.4
	I44/0821	Bisphenol-A	56.8
		Octinoxate	7.99
	J41/0008	Bisphenol-A	12.4
		Methyl paraben	1.59
	J41/0317	Estrone	6.24
		Octinoxate	30.8
Environment Southland (3/4)	E46/0093	Octinoxate	13.4
	F44/0484	Sucralose	36.5
	F46/0239	Methyl-Triclosan	1.73
		Sucralose	11.0

Table 7: Summary of EOC detections, method detection limits (MDL), and concentrations (ng/L).

EOC	# detects	Mean	Min	Max	MDL	Detailed type
Anti microbial/Preservative						
Chloroxylenol	1	0.5	0.5	0.5	0.05	
Methyl paraben	11	5.0	1.43	26	0.05	preservative
Methyl-Triclosan	7	2.7	0.66	5.07	0.05	Triclosan metabolite
o-phenylphenol	2	5.1	4.08	6.12	0.10	
Propyl paraben	8	2.4	0.5	5.95	0.05	preservative
Triclosan	2	2.0	1.94	2.03	0.10	Antimicrobial
Estrogenic steroid hormones						
17α-estradiol (17αE2)	3	2.5	0.95	5.15	0.05	All but mainly dairy
17β-estradiol (17βE2)	0				0.05	All but mainly human
Estriol (E3)	2	2.1	1.08	3.1	0.05	pregnant women
Estrone (E1)	6	1.8	0.57	6.24	0.05	dairy and swine effluent
17α-Ethinylestradiol (EE2)	1	1.5	1.48	1.48	0.05	contraceptive pill
Mestranol (17α-Ethinylestradiol 3-methyl ether)	2	4.4	1.94	6.78	0.05	contraceptive pill
Human Wastewater tracer						
Caffeine	10	8.1	1.81	45	5.0	stimulant
Cotinene	0				5.0	Stimulant – nicotine metabolite
1,7-dimethylxanthine	0				5.0	stimulant -caffeine metabolite
Nicotine	0				5.0	stimulant
Sucralose	18	100.1	1.21	655	1.0	Artificial sweetener
Industrial						
Bisphenol-A (BPA)	40	26.1	1.28	423	0.62	Plasticiser

EOC	# detects	Mean	Min	Max	MDL	Detailed type
Pharmaceuticals						
Acetominophen	7	32.5	1.18	96.8	0.10	NSAID
Carbamazepine	6	35.12	5.49	72.6	0.10	Epilepsy & mental health treatment
Diclofenac	7	37.1	1.97	98	0.10	NSAID
Ibuprofen	8	44.7	5.3	175	0.10	NSAID
Naproxen	5	25.4	3.98	57.3	0.10	NSAID -Aleve, Naprosyn
UV filter/stabiliser						
2,4-dihydroxybenzophenone (BP1)	13	1.78	0.65	4.66	0.10	
4-hydroxybenzophenone	3	2.1	2	2.08	0.10	
4-methylbenzylidene camphor (4-MBC)	3	38.7	12.3	63.8	0.10	
Octinoxate (OMC)	33	19.0	5.13	63.8	2.15	
Oxybenzone (BP3)	24	10.8	2.47	25.4	1.21	
2,2',4,4'-tetrahydroxybenzophenone (BP2)	5	3.8	0.44	8.35	0.10	

4. DISCUSSION

4.1 PESTICIDES

There were three pesticide detections exceeding 1 μg/L with none of the sampled wells exceeding the MAV for drinking water. The highest detection as a percentage of the MAV was dieldrin which was detected at a concentration of 0.025 μg/L which was 62.5% of the MAV of 0.04 μg/L (Ministry of Health 2018). The next highest detections relative to the MAV were for total atrazine and metabolites at 16.5% of the MAV, hydroxyatrazine (another atrazine metabolite) at 11% of MAV assuming the same MAV as for atrazine, then terbacil at 9.5% of the MAV (Table 6). The remainder of pesticide detections were less than 5% of the MAV with the median of the pesticide detections being below 0.5% of the MAV. These results indicate that there should be little significant health risk based on the pesticides analysed from drinking the groundwater sampled from the wells included in this survey.

Dieldrin has been detected occasionally in previous surveys at concentrations above the MAV (Close & Humphries 2016; Close & Skinner 2012). Dieldrin was widely used in New Zealand primarily for the government-required control of ectoparasities on sheep in the 1960’s. Most livestock farms in New Zealand would probably have had a sheep or cattle dip site. Even though dieldrin has not been used for this purpose since the mid 1960’s, its long persistence means that it can be detected in the soil where the dip site wastewater was disposed of and occasionally in the underlying groundwater. Hadfield & Smith (1999) carried out an investigation into dieldrin in groundwater in the Waikato region. Their results indicated that dieldrin contamination in soils near sheep dip sites could be widespread and that concentrations in shallow groundwater (about 5 m below ground level) could increase in certain conditions, even though usage had ceased 30-40 years previously. The low MAV for dieldrin (0.04 μg/L) means that even low concentrations in groundwater can easily exceed the MAV for drinking water.

Terbuthylazine was the most commonly detected pesticide, being found in 36 wells (16%) at levels ranging from 0.005 – 0.35 μg/L (Table 6), with the next most common pesticide being desethyl terbuthylazine (a metabolite of terbuthylazine) with 15 detections. Simazine was detected in 10 wells.

Herbicides were the most frequently detected pesticide group with seven insecticides and only one fungicide detected in the sampled wells. There were 80 out of the total of 112 detections (71%) of triazine herbicides. The high detection rate for herbicides is consistent with estimates that herbicides comprise at least 60% of the total amount of pesticides sold in New Zealand annually (Manktelow et al., 2005). The high frequency of triazine detections is consistent with previous surveys of pesticides in groundwater (Table 8).

Of the 25 pesticides detected that had data available for soil half-life and Koc, GUS values indicated that 13 were leachers, 2 were transitional, and 6 were non-leachers (Table 5). Most of the detections were for pesticides classed as leachers (Table 5). One of the non-leacher pesticides was the glyphosate detection that was probably the results of poor well-head protection and ingress of contamination directly from the surface into the well, as discussed above. DDT and DDE are non-leacher pesticides that are extremely persistent and were detected in samples from Waikato and Canterbury by Hill laboratories using lower detection limits. Two other non-leacher pesticides were dieldrin, which was widely used and very persistent as discussed above, and endosulfan. Endosulfan is an organochlorine but not nearly as persistent as dieldrin (Table 5). It was used in New Zealand from the 1960s onwards to control insects in crops such as potatoes, citrus and berry fruit crops, and on turf for earthworm control. Its use had been declining from the mid-1990s to mid 2000s and it was de-registered by ERMA in December 2008. The mix of leaching properties indicates that normal leaching processes are mostly responsible for the presence of the detected pesticides in the groundwater but other pathways, such as spills, ingress from the surface via poor well-head protection or preferential flow, may also occur. Leaching of extremely persistent pesticides, such as DDT and its metabolites and dieldrin, can also occur over long time periods to shallow groundwater.

The significant decrease in detection limits for many pesticides for groundwater surveys undertaken since 1998, compared to the two earlier surveys in 1990 and 1994, needs to be considered before assessing temporal trends. If the detection limits for the 1990 and 1994 surveys were applied to the 2018 survey then there would only be a total of 21 wells (8%) with detectable pesticides instead of 68 wells (Table 8). Table 8 shows that there has been a similar level of pesticides detected over the past 4 surveys using the more sensitive detection limits. In 1998 35% of wells had pesticides detected but from 2002 to 2018 the percentage of wells with detectable pesticides varied from 17 to 24%. If the earlier less sensitive detection limits were applied then the percentage of wells with detectable pesticides has varied from 7 to 14%

over the eight surveys from 1990 to 2018. In all surveys there have been a very small number of wells (between 2 and 4) where pesticides have been detected at concentrations greater than 1 μg/L. There has been a maximum of one pesticide detected at a concentration greater than the MAV in five out of the eight surveys, with the other three surveys having no pesticides detected at a concentration greater than the MAV (Table 8). As these surveys have been focused on shallow unconfined groundwater systems, which are most at risk of pesticide contamination, this indicates that most groundwater in New Zealand should be considered safe to drink with respect to pesticides.

4.2 GLYPHOSATE

Reviews of the mobility and likely leaching of glyphosate to groundwater have been carried out (Vereecken 2005; Borggaard & Gimsing 2008) and indicate that under normal conditions leaching of glyphosate through the soil to groundwater should be very limited due to strong sorption to soil and relatively fast degradation (Borggaard & Gimsing 2008). There is the possibility that transport processes with high recharge (intense rainfall or heavy irrigation) combined with structured soils containing macropores or cracks may bypass much of the soil profile and enable even strongly sorbing pesticides to leach into groundwater (Vereecken 2005).

There has been little monitoring of glyphosate and its metabolites (principally AMPA) in groundwater until the last 5 years. Battaglin et al., (2014) developed an extremely sensitive method for the measurement of glyphosate and AMPA (DL = 0.02 μg/L) and analysed 1171 groundwater samples as well as a further 2500 samples from surface waters, drains and rainfall. They found extensive contamination of surface waters by glyphosate (30 – 70% of samples) and 5.8% of groundwater samples having detectable glyphosate. The median and maximum concentrations of glyphosate found in groundwater were < 0.02 and 2.03 μg/L, respectively. AMPA was found in 14.3% of groundwater samples with median and maximum concentrations of < 0.02 and 4.88 μg/L, respectively.

In New Zealand John Hadfield collected samples from 40 wells in the Waikato region that were selected as having higher potential for pesticide contamination and had the samples analysed for glyphosate and AMPA by AsureQuality (Hadfield, 2017). The detection limit was 1 μg/L which was the same as for this study. He found one detection of AMPA at a concentration of 1.9 μg/L. The landowners indicated that a herbicide, and most likely roundup, had been used on the property in the months before sampling took place.

The investigations on the well in this study where glyphosate was detected indicated that this detection was likely caused by poor well head protection and contamination from the containers and activities occurring around the well. The detection of other pesticides such as DDT, diazinon and atrazine, which have very different leaching characteristics (Table 6) support contamination of the well from surface sources rather than widespread groundwater contamination. The very low frequency of glyphosate and AMPA detections in both the national and Waikato surveys imply that there is little risk of glyphosate reaching groundwaters in New Zealand. The detected levels of 2.1 μg/L for glyphosate in this survey (probably from surface contamination) and 1.9 μg/L for AMPA found in the Waikato survey, are far below the WHO Health Based Value for glyphosate of 900 μg/L (WHO 2017) indicating a very low risk from glyphosate for drinking water purposes in New Zealand.

4.3 EMERGING ORGANIC CONTAMINANTS

EOCs can arise from sewage treatment plants, industrial effluents, leaking sewage networks, runoff from agricultural, storm-water and urban sources, application of effluents to land and septic tanks. Many of these sources are associated with urban environments. In New Zealand, where most of the large cities are located on the coast, there should be limited opportunity for these municipal discharges to impact groundwater. Some compounds can arise from farming activities such as dairy shed effluent and animal manures (estrogens associated with dairy cows: E1, 17α-E2 – Table 7). Many EOC detections are likely to be associated with the widespread use of septic tank systems in the rural environment from which the majority of the groundwater samples in this study originated. The high rate of EOC detections, albeit at low concentrations, indicates that effluents from small towns, septic tank systems and farming activities are probably the sources for the detections of EOCs in groundwater in this study.

Schaider et al., (2016) evaluated whether septic tanks are a likely source of EOCs in groundwater. They tested 20 domestic drinking water wells in a sand and gravel aquifer on Cape Cod, Massachusetts, USA, for 117 EOCs and detected 27 compounds, including 12 pharmaceuticals, four organophosphate flame retardants, and an artificial sweetener (acesulfame). These wells were all located in areas served exclusively by onsite wastewater treatment systems, which are likely the main source of the EOCs in these wells, although landfill leachate may also be a source. Their results suggest that current regulations to protect domestic wells from pathogens in septic system discharges do not prevent EOCs from reaching domestic wells.

Overall detection frequencies are often difficult to compare between studies as different combinations of EOCs are measured, sometimes with differing detection limits. Nevertheless, the detection frequencies and levels of EOCs found in this national survey are broadly similar to studies in other countries. Focazio et al., (2008) carried out a national study in the USA in untreated drinking water sources, which included 25 groundwater wells and analysed the samples for 100 EOCs. The most commonly detected compounds in their study were tetrachloroethylene (24%, solvent), carbamazepine (20%, pharmaceutical), bisphenol-A (20%, plasticizer), and 1,7-dimethylxanthine (16%, caffeine metabolite). Of these compounds we didn't analyse for tetrachloroethylene but detected carbamazepine and bisphenol-A in 5% and 33% of samples, respectively. Loos et al., (2010) carried out a study of EOCs in European groundwater and analysed 164 samples from 23 countries for 59 selected EOCs. The non-pesticide compounds that were common to the New Zealand national survey, in terms of frequency of detection and maximum concentrations detected, were caffeine (83%; 189 ng/L), carbamazepine (42%; 390 ng/L), and bisphenol A (40%; 2.3 mg/L). Jurado et al., (2012) reviewed the detection of EOCs in groundwater in Spain and found a wide range of compounds had been detected with maximum concentrations generally above the levels in the rest of Europe found by Loos et al., (2010). They noted that none of the studied estrogens have been found in Spanish aquifers but some of them have been detected in groundwater from the rest of Europe at low concentrations (up to 10 ng/L). They concluded that most EOCs are usually detected at low ng/L concentrations or not detected at all in groundwater throughout Europe. Lapworth et al., (2012) has carried out a comprehensive review of the sources and occurrence of EOCs in groundwater and noted the occurrence and detected concentrations for 10 of the 29 EOCs analysed for in the New Zealand survey, namely carbamazepine, ibuprofen, diclofenac, paracetamol, triclosan, caffeine, cotinine, bisphenol A, estrone, and 17β-estradiol.

The regional study of EOCs in Waikato groundwater detected EOCs in 91% of the sites (Moreau et al., 2019) although this included a large number of pesticides that were the most frequently detected category of EOC in that study. Of the non-pesticide EOCs, they detected BPA, triclosan, diclofenac, and sucralose in common with this national survey. The Canterbury groundwater study detected BPA, various paraben compounds (preservatives), Estriol (E3), and 4 UV filter compounds – BP1, BP2, BP3 and OMC in common with this national study (van der Krogt et al., 2018).

Most of the EOCs detected in this study originate through human body metabolisms such as caffeine, sucralose, ibuprofen, or steroidal hormones, or are applied to our skin to protect us from the UV from the sun. Other EOCs such as BPA are used widely in packaging and plastic products or in the case of parabens, as food preservatives. The compounds tend to be used in milligram and gram quantities in such applications and most compounds are likely to exhibit low toxicity to humans. There are no MAVs for drinking water for these non-pesticide EOCs in New Zealand. However, the environmental or ecological impacts of most EOCs are largely unknown or the concentration at which effects begin to exhibit are unknown (Tremblay et al., 2018). Some compounds such as BPA are known to have endocrine disrupting properties (Rochester 2013).

These results indicate that EOCs, sourced from either animal or human effluents or activities, are making their way into shallow groundwater systems and can be detected at low concentrations in groundwater. Currently there is a lack of knowledge of the fate and effects of many EOCs and whether the concentrations measured in this study are likely to have impacts for ecological systems. We recommend that monitoring of EOCs in groundwater resources is extended and that research is carried out to quantify the potential risks to ecosystems for the EOCs most frequently detected in this study.

Table 8: Summary statistics for the eight national surveys of pesticides in groundwater in New Zealand.

	Year of survey							
	1990	1994	1998	2002	2006	2010	2014	2018
	Close 1993	Close 1996	Close & Rosen 2001	Close & Flintoft, 2004	Gaw et al. 2008	Close & Skinner 2012	Close & Humphries 2015	This study
No. of wells in survey	82	118	95	133	163	162	165	279
No. of regions	6	13	15	15	14	14	13	14
No. of regions with pesticides detected	4	8	11	9	11	9	6	12
No. of pesticides detected	7	10	22	21	19	22	21	28
% of wells with pesticides detected > DL = 0.1 μg/L	7%	14%	11%	9%	8%	7%	10%	8%
% of wells with pesticides detected > DL = 0.01 μg/L	-	-	35%	21%	19%	24%	17%	24%
No. of wells with pesticides >1 μg/L	2	3	3	3	2	3	4	3
No of pesticides detected > MAV	1	0	1	0	1	1	1	0
% of detections that were herbicides	50%	95%	92%	92%	74%	91%	86%	88%
% of detections that were triazines	13%	65%	76%	67%	50%	61%	61%	71%

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APPENDIX A: ESR 2018 PROCEDURES FOR SAMPLING PESTICIDES AND EOCS

E/S/R
Science for Communities

National Survey of Pesticides in Groundwater 2018 - Sampling Procedures

To: The Regional or Unitary Authority

Thank you for participating in the National Survey of Pesticides in Groundwater 2018. The survey has occurred every four years since 1990 with this year being the 8th survey.

This document contains details of the required sampling procedures for this year's survey. Three organisations are involved in the survey, ESR, AsureQuality and Northcott Research Consultants Ltd, with details of their role and what support and services you will receive from them below:

ESR:

- Management of the nationwide survey and full technical support
- Field sampling form
- Analysis of the results and a final report

AsureQuality *(Pesticide and Glyphosate analysis laboratory)*

- x1 1L amber glass bottle which has been preserved with sodium thiosulphate
- x1 500ml amber glass sample bottle which has been preserved with sodium thiosulphate
- x1 250mL amber glass bottle (no preservative)
- x1 250ml plastic (HDPE, no preservative) sample bottle for Glyphosate analysis if chosen.
- **NOTE: For all Assure Quality (AQ) samples, there are holding time requirements that must be met. Samples must be refrigerated after collection and received at AQ-Wellington within 3 calendar days of collection. Samples should not arrive at the laboratory on a Friday due to sample extraction requirements.**
- Sample submission form
- Polystyrene boxes, ice packs and packing material for the return trip (i.e. bubble wrap)

Northcott Research Consultants *(Emerging Organic Contaminants (EOCs) analysis laboratory)*

- x1 4L amber glass sample bottle
- Sample submission form
- Polystyrene boxes, ice packs and packing material for the return trip (i.e. bubble wrap)

GEAR LIST

- Council Health and Safety Form, first aid kit and cell phone
- Personal Protection Equipment (PPE)
- Sampling gloves (nitrile)
- Sample bottles (x5 bottles for each well)
- Chilly bins, ice packs and packing material (i.e. bubble wrap)
- Portable pump (i.e. Grundfos MP1 or SuperTwister) and power source
- Courier tickets and address information for AsureQuality and Northcott Research Consultants Ltd.

SOME IMPORTANT THINGS TO REMEMBER WHEN SAMPLING

1. Please do not sample on a Thursday or Friday. If it is unavoidable then please send samples with a weekend delivery ticket or refrigerate until Monday. If at all possible, please sample on Monday to Wednesday and then send the samples back to AsureQuality and Northcott Research Consultants immediately via courier.
2. **NOTE: For all AQ samples, there are holding time requirements that must be met. Samples must be refrigerated after collection and received at AQ-Wellington within 3 calendar days of collection.**
3. Field staff please strictly avoid the following on the day of sampling if sampling for EOCs :
- Spray deodorants
- Perfume
- Insect repellent
- Smoking
- Coffee and other caffeine containing drinks such as tea, V, coke, pepsi, etc. (no drinking of these caffeine containing drinks on the day of sampling as caffeine is exuded in breath and will influence the results for nicotine and cotinine)
- Sunscreen
- Makeup/cosmetics (these products contain UV filters that are being analysed and will affect the results)

4. Please try to avoid sampling in the pouring rain so that the risk of contamination is minimised.

WELL SAMPLING PROCEDURE

1) Collect the **static water level** within the well, this information can be very important during the process of interpreting the results. The static water level is to be taken from a known or historical council recorded measuring point (i.e. typically the top of the well casing).

2) Make sure that **x3 times the casing volume of water** has been purged from the well before a sample is taken. This is to ensure that a representative sample is taken from the surrounding aquifer and not from the stagnant water within the well casing.

3) If the well is a domestic/agricultural water supply fitted with a submersible pump, make sure the pump is running and allow it to run so that x3 well volumes are removed from the well. Take your

sample as close to the well head as possible before it enters into a pressure tank or storage tank (**NEVER sample down gradient of a pressure tank or storage tank**).

4) If you are using your own pump for sampling (i.e. Grundfos MP1 or SuperTwister pump) while you are purging the well (x3 well volumes) ensure that any water within the entire length of the hosing is purged between wells. This will also ensure that the pump itself is adequately rinsed between wells.

5) If you have a multi-parameter water meter (i.e. pH, temperature, conductivity, dissolved oxygen etc) make sure that these **readings have stabilised** before taking the sample.

6) Clearly label the bottles before you get your hands or the bottles wet with the date, time and well ID number.

7) Make sure your hands are clean and once the lid is off do not touch the top of the sample bottle or the inside of the lid.

8) **AsureQuality bottles:** The glass sample bottles have been washed and rinsed according to a strict protocol. It is important that the samples are collected directly into the bottles and not into a bucket or other container before filling the sample bottles. **DO NOT RINSE THE BOTTLES AS THERE ARE PRESERVATIVES INSIDE EACH BOTTLE.**

a) Fill the bottles to just below the cap thread as each bottle contains a preservative, Sodium Thiosulphate and there may be some expansion on warming.

9) **Northcott Research Consultants bottles:** The glass 4L bottles need to be pre-rinsed twice with approximately 0.5 L of sample before filling with the collected sample. It is important that the samples are collected directly into the bottles and not into a bucket or other container before filling the sample bottles.

10) Make sure that you fill the correct number of bottles for each well that is sampled. If your council has opted to sample everything (i.e. Pesticides, Glyphosate and Emerging Organic Contaminants) there will be a total of x5 bottles to fill

11) Once your samples have been collected immediately store them in a chilly bin with ice packs (keep them stored at approx. 4°C) in preparation for transportation to the labs. **DO NOT FREEZE THE BOTTLES, OTHERWISE THEY WILL BREAK.**

BLIND DUPLICATES

For councils that are sampling more than 7 wells, there is an additional set of sample bottles. This is for the collection of blind duplicate samples, which is a quality control measure for the laboratory analysis. There is no additional cost for the collection of the blind duplicate sample. Please collect the blind duplicate samples as an extra sample from one of the wells at the same time as collecting the normal sample. Instructions are below:

- Pick at random which well will be chosen to provide the blind duplicate sample.
- The blind duplicate sample should be labelled the same as the well sample but the well ID number on the bottle should be **fictitious** and the time should be omitted. On the ESR sampling sheet identify the well ID number that is associated with the fictitious blind duplicate well number. **On the AsureQuality chain of custody form do not indicate which sample is the blind duplicate sample.**

- For example, if you are sampling 8 wells then only 1 blind duplicate sample is required. If you are sampling 15 wells then 2 blind duplicate samples are required. If you are sampling 22 wells then 3 blind duplicate samples are required and so on.
- When you are sampling the well collect the water for the sample and the blind duplicate as outlined below. This will ensure that the sample and the blind duplicate are representative of the whole sampling period when both samples are being taken.

  - 1st 1L glass bottle for the well sample
  - 1st 1L glass bottle for the Blind Duplicate
  - 2nd 500mL glass bottle for the well sample
  - 2nd 500 mL glass bottle for the Blind Duplicate
  - 3rd 250ml glass bottle for the well sample
  - 3rd 250ml glass bottle for the Blind Duplicate
  - 4th 250ml plastic for the well sample
  - 4th 250ml plastic for the Blind Duplicate
  - 5th 4L bottle for the well sample
  - 5th 4L bottle for the Blind Duplicate

FORMS

Please fill in the forms for each well sampled:

- **ESR Field Sampling form** (i.e. the well details and parameters). Record if there has been a blind duplicate sample taken and record the fictitious well ID number along with what well the blind duplicate belongs to.

- **AsureQuality Environmental sample submission form** (please place the form in a waterproof plastic bag inside the chilly bin)

- **Northcott Research Consultants Ltd sample submission form** (please place the form in a waterproof plastic bag inside the chilly bin)

Scan and email copies of the ESR Field Sampling forms to Bronwyn Humphries: bronwyn.humphries@esr.cri.nz, copy to Murray Close, murray.close@esr.cri.nz

COURIERING SAMPLES

The glass bottles should be packed in the chilly bins and packaging received in, and couriered to AsureQuality and Northcott Research Consultants Ltd (addresses are provided at the end of this document).

Please advise AsureQuality of any breakages at GracefieldSR@asurequality.com and Environmental.wgtn@asurequality.com so that replacement bottles can be sent.

Please advise Northcott Research Consultants Ltd of any breakages nrcltd@hotmail.co.nz or 021 2268474 so that replacement bottles can be sent.

If you have any questions about sampling or if the procedures conflict with your current sampling protocols, please do not hesitate to contact us and we can try to resolve the issues as quickly as possible.

Thanks for participating in the programme; it could not exist without your support. Any questions or comments are welcome.

APPENDIX B: ESR PESTICIDE SAMPLING FIELD SHEET

Field Sampling Form: 2018 National Survey of Pesticides in Groundwater

(please use one form per well)

ESR Science for Communities

Regional/District Council:		
Person collecting sample:		
Grid reference (NZTM):		
Council well number/ID:		
Well owners name:		
Address:		
Weather:		
Surrounding land use:		
Well use:		
Well diameter (mm):		
Well depth (m):		
Screened interval (m):		
Pumped (circle one):	*YES / NO*	
Sampling point description:		
Water level (m):		
Date and time of sampling:	*Date:*	*Time:*
Time of pumping before sampling:		
Well volume removed:		
Field measurements:	*DO (mg/L)*	
	Conductivity	
	Temperature	
	pH	
Type of aquifer:		
Name of aquifer (if any):		
Comments:		

APPENDIX C: LIST OF PESTICIDES AND LIMITS OF DETECTION

Units are µg/L (ppb).

(1) Pesticide Screen

(i) Organochlorine pesticides:

aldrin	0.01
α-chlordane	0.01
γ-chlordane	0.01
p,p'-DDE (also *o, p'*)	0.01
p,p'-DDD (also *o, p'*)	0.01
p,p'-DDT (also *o, p'*)	0.01
dieldrin	0.01
endosulfan I	0.02
endosulfan II	0.04
endosulfan sulphate	0.02
endrin	0.02
endrin aldehyde	0.04
endrin ketone	0.04
α-HCH	0.01
β-HCH	0.01
γ-HCH (Lindane)	0.01
heptachlor	0.01
heptachlor epoxide	0.03
hexachlorobenzene	0.1
methoxychlor	0.02
cis permethrin	0.01
trans permethrin	0.01
procymidone	0.02
vinclozin	0.02

(ii) Organophosphorus pesticides:

azinphos methyl	0.6
chlorpyrifos	0.02
diazinon	0.01
dimethoate	0.4
pirimiphos methyl	0.02

(iii) Organonitrogen herbicides:

acetochlor	0.02
alachlor	0.02
aldicarb	0.1
atrazine	0.02
bromacil	0.03
carbofuran	0.9
chlorotoluron	0.04
cyanazine	0.02
desethyl atrazine	0.01
desethyl terbuthylazine	0.01
desisopropyl atrazine	0.1
diuron	0.04
hexazinone	0.01
2-hydroxyatrazine	0.1
isoproturon	0.04
linuron	0.1
metalaxyl	0.02
metolachlor	0.02
metribuzin	0.02
molinate	0.01
norflurazon	0.1
oryzalin	2.0
oxadiazon	0.01
pendimethalin	0.02
primisulfuron-methyl	0.1
propanil	0.06
propazine	0.01
pyriproxyfen	0.5
simazine	0.01
terbacil	0.02
terbuthylazine	0.01
thiabendazole	0.1
trifluralin	0.02
total atrazine & metabolites	0.32

(iv) Acid herbicides

2,4-D	0.1
2,4-DB	0.1
2,4,5-T	0.1
2,4,6-trichlorophenol	0.12
3,5-dichlorobenzoic acid	0.1
acifluorfen	0.4
bentazone	0.1
bromoxynil	0.1
dicamba	0.1
dichlorprop	0.1
dinoseb	0.1
fenoprop	0.1
MCPA	0.1
MCPB	0.1
mecoprop	0.1
pentachlorophenol	0.1
picloram	0.1
triclopyr	0.1

2/ Glyphosate suite

AMPA	1
glyphosate	1
glufosinate	5
MPPA	5

E/S/R
Science for Communities

INSTITUTE OF ENVIRONMENTAL
SCIENCE AND RESEARCH LIMITED

Kenepuru Science Centre
34 Kenepuru Drive, Kenepuru, Porirua 5022
PO Box 50348, Porirua 5240
New Zealand
T: +64 4 914 0700 F: +64 4 914 0770

Mt Albert Science Centre
120 Mt Albert Road, Sandringham, Auckland 1025
Private Bag 92021, Auckland 1142
New Zealand
T: +64 9 815 3670 F: +64 9 849 6046

NCBID – Wallaceville
66 Ward Street, Wallaceville, Upper Hutt 5018
PO Box 40158, Upper Hutt 5140
New Zealand
T: +64 4 529 0600 F: +64 4 529 0601

Christchurch Science Centre
27 Creyke Road, Ilam, Christchurch 8041
PO Box 29181, Christchurch 8540
New Zealand
T: +64 3 351 6019 F: +64 3 351 0010

www.esr.cri.nz

Taranaki Regional Council

AGENDA Policy & Planning

Date	4 February 2020
Subject:	**Pesticides in Surface Water Survey**
Approved by:	G K Bedford, Director - Environment Quality
	B G Chamberlain, Chief Executive
Document:	2409096

Purpose

1. The purpose of this memorandum is to present the results, together with a discussion of their significance, of a survey undertaken by Council officers in order to determine whether there is any consequent environmental or human health issue due to pesticides in surface waters in Taranaki.

Executive summary

2. The Council's *Regional Freshwater Plan for Taranaki* identifies the use of pesticides as an activity that needs to be appropriately managed in order to safeguard the ecological health of the region's waterways and the health of those who rely on them, including through municipal water supplies. Also, the *National Environmental Standard for Sources of Human Drinking Water* requires regional councils to take steps to ensure catchments used for municipal water supply do not become contaminated beyond the capability of treatment plants to provide safe water supplies. The Council's ongoing programme for monitoring for the presence of pesticides in groundwater, together with the responsibilities of the Ministry of Health and water supply authorities to ensure the wholesome quality of community water for human consumption, already provides some degree of assurance in this regard, but Council officers deemed it worthwhile to undertake a survey of surface waters around the region to ascertain whether pesticide residues were present and if so, whether concentrations might be significant from an environmental or human health perspective.

3. The findings of the survey are reported within this memorandum. Samples were collected from lower river reaches in catchments considered to have a relatively higher usage of pesticides due to land uses. Each sample was tested for around 200 different pesticide compounds, generating a total of around 1,800 analytical results. Analytical methods had limits to detectability far below criteria for ecological or consumptive protection. From 1,800 results, there were only two detections, at concentrations barely above the laboratory detection limit. These were for two organochlorine compounds, which are highly persistent and widely distributed in the environment. They were detected in a catchment where market gardening and plant nurseries have been long-

established activities. Given the very low concentrations and the fact that the compounds in question were banned from sale and withdrawn from use three decades ago, no follow-up action is practical or beneficial.

4. The survey included analyses for glyphosate (trade name Roundup), a very widely used and long-established herbicide that has more recently become controversial because of alleged and disputed adverse effects upon human and/or environmental health. Glyphosate is considered more likely to be transported via surface water rather than ground water. No glyphosate was detected in any survey sample, despite the extremely low limits of detection used in analysis.
5. This survey and its results provide some reassurance to the Council and the regional community that the provisions of the *RFWP* and the implementation of good practices around the usage of pesticides are proving effective for the protection of the region's waterways and their associated values and uses.

Recommendations

That the Taranaki Regional Council:

a) receives the memorandum *Pesticides in surface water in Taranaki*

b) notes the results of the survey, that pesticides are virtually undetectable in the surface waters of Taranaki, or when present, are far below levels of concern for either environmental or human health

c) notes that these findings will inform the provisions of the next *Regional Land and Water Plan for Taranaki*

Background

6. Pesticides, which include insecticides, fungicides, herbicides and plant growth regulators, are commonly used in New Zealand to control insects, diseases and weeds in primary industries such as horticulture, agricultural farming, and forestry. The horticultural sector is the most intensive user of pesticides on a land area basis, followed by arable, forestry and pastoral sectors. They are also used in urban areas e.g. domestic vegetable gardens and lawns, and roadside and recreational reserve spraying for weed control.
7. Pesticide contamination of water is a subject potentially of national importance because of the need to safeguard catchments used for municipal water supply (whether groundwater or surface water), to provide for safe recreational contact uses of water bodies, and more generally to recognise and mitigate against potential adverse effects of pesticides on aquatic ecosystems and their component communities.
8. Under the Resource Management Act (1991), regional councils have the responsibility to maintain and enhance the quality of regional water resources. The Council recognises that pesticide application to land is a potential point and diffuse source contaminant of freshwater. The *Regional Fresh Water Plan for Taranaki* (RFWP) identified as an issue for the region, adverse effects upon surface and ground water from the discharge of contaminants to land and water, if these discharges are not managed properly and with consideration of receiving water quality requirements. Objective 6.2.1 of the RFWP is *'to maintain and enhance the quality of the surface water resources of Taranaki by avoiding, remedying or mitigating adverse effects of contaminants discharged to land and water from point sources'*, while Objective 6.3.1 applies in similar vein to diffuse discharges. Policies 6.2.1-

6.2.4, 6.2.7, and 6.3.1 provide a suite of considerations that the Council applies when assessing discharges to land or water, including the values of the water body and the extent to which these might be impacted. Policy 6.3.1 states explicitly that *'Land use practices which avoid, remedy or mitigate adverse effects on water quality will be encouraged and promoted including…the careful use of agrichemicals'*.

9. Groundwater is likewise addressed. Objective 6.5.2 is *'to promote the sustainable management of groundwater while avoiding, remedying or mitigating adverse effects on groundwater quality from the discharge of contaminants'*. Policy 6.5.3 is that *'The Taranaki Regional Council will manage the discharge of contaminants to land and water such that any actual or potential adverse effects on groundwater quality are avoided, remedied or mitigated'*.

10. The application of agrichemicals in Taranaki is controlled in the current RFWP (eg Rules 32, 33, 34, 43) and *Regional Air Quality Plan* (Rules 56-58 and Appendices VI and VII). The Council promotes the careful use of such chemicals in accordance with these rules and the manufacturers' instructions, thus safeguarding off-target or secondary receiving environments.

11. Section 10.3 of the RFWP sets out the Council's commitment to undertake relevant monitoring, either on its own account or by participation in monitoring and research programmes conducted by other agencies. To ascertain the effectiveness of the controls discussed above, and to confirm the ongoing state of the environment of Taranaki, the Taranaki Regional Council routinely monitors the attaining of these objectives through its State of the Environment surface and groundwater monitoring programmes, which include sampling groundwater for pesticides in a collaborative nationwide programme administered by the Institute of Environmental and Scientific Research Ltd (ESR). This programme is undertaken on a cycle of about 4 years. Surveys have been undertaken in 1990, 1994, 1995 (Taranaki-specific), 1998, 2002, 2006, 2010, 2014 and 2018. Traces of pesticides have been occasionally found in a few individual monitoring wells in Taranaki during the earlier surveys. In the latest survey, a trace of one pesticide, at levels non-significant for human health, was found in one well in Taranaki; otherwise, the last detection of pesticides in groundwater in Taranaki was in 1998. The results of the latest ESR groundwater survey are reported more fully elsewhere in today's agenda.

12. There is no equivalent national programme surveying pesticides in surface water. Through New Zealand's Drinking Water Standards (2000), the Ministry for Health and municipal water supply authorities (usually district councils) are together responsible for ensuring that municipal water supplies are routinely analysed for pesticides, amongst a range of other potential contaminants that may affect public health or the aesthetic quality of water supplies.

13. The *National Environmental Standard for Sources of Human Drinking Water* (2008; currently under review) is a regulation made under the *Resource Management Act*. It imposes requirements for protecting sources of human drinking water from becoming contaminated. It does not apply to catchments not used for municipal supply, nor to waters used to supply other consumptive purposes (eg stock drinking supply), nor to ecological considerations. Specifically, it requires regional councils to be satisfied that activities permitted in regional plans will not pose unacceptable risks to the quality of community-scale drinking water supplies. The Government has noted that changes to the intensity or composition of land-use activities in a catchment can introduce new contaminants or increase the concentration of existing contaminants in the source waters. A review of regional council performance in implementing the NES undertaken by MfE last year found that this Council was one of 7, out of 16, that had a 'high' level of implementation of the drinking water NES when considering resource consent

applications, and as with almost all regional councils this Council had a 'medium' level of implementation of the NES provisions within its regional freshwater plan. MfE's ratings for implementation of the NES within regional plans focused on the extent to which plans had specific provisions applying to drinking water supply catchments. It should be noted that the shaping and publication of the Council's RFWP pre-dates the NES; the NES does not require councils to retrospectively amend existing plans; and in any case the Council is currently reviewing its plan and will incorporate the requirements of the NES as the latter stand at the time (given that the NES is now under review with a view to amendment).

Discussion

Programme design

14. There are 16 surface water catchments in Taranaki used for municipal or community water supply. Notwithstanding that MoH monitoring of water supply quality might therefore be considered to already offer a fair coverage of representative pesticide concentrations in surface water catchments in the region, and that the Council's participation in the ongoing national groundwater survey is a monitoring programme that offers by implication significant information on the (absence of any) presence and effects of pesticide usage, this Council deemed it worthwhile to undertake its own survey of agrichemical concentrations in surface waters by targeting sites in rivers that were likely to be the most impacted by pesticide usage, at a time of year when agrichemical usage (whether herbicide or pesticide) was relatively high.
15. It is noted that while it is expected there would be overall similar patterns in pesticides in groundwater and surface water respectively, there would also be differences- the different routes of transportation (horizontal overland flow vs infiltration) would mean different attenuation and degradation pathways due to the varying exposures to sunlight and temperature; different microbial communities and levels of metabolic activity; soil and vegetation adsorption; different times of travel to receptors; and extent of relative dilution and dispersion. Surface water systems are much more likely to show time-dependant variation in concentrations, due to the presence of peaks immediately following usage and run-off, or alternatively the flushing away and removal of any residues, compared to the persistent reservoirs of agrichemicals within long-retention groundwater systems.
16. Council officers considered that in Taranaki, agrichemical contamination of surface water is most likely to occur in areas where there are commercial horticultural activities (plant nurseries, market gardens etc) or below areas of intensive urban and agricultural land use, including recreational areas where agrichemical usage might be high (eg golf courses). Advice from industry and supply representatives was that peak usage tends to be in spring-early summer. Nine regionally representative sites were selected, located in the lower reaches of the Waitara River, Waiongana River, Waiwhakaiho River, Te Henui Stream, Huatoki Stream, Oakura River, Waimoku Stream, Timaru River, and Waingongoro River. Sampling was undertaken in November 2019, with the sampling run timed to avoid wet weather and any consequent dilution of agrichemicals by high river flows, and to avoid or minimise any seawater mixing in estuarine sites that might likewise dilute pesticide concentrations if present.
17. Samples were analysed for comprehensive suites of acidic herbicides (22 compounds eg 2,4D, 2,4,5-T, MCPA, MCPB), organochlorine pesticides (24 compounds eg aldrin, DDT, dieldrin, heptachlor), organophosphorus and organonitrogen pesticides (89 compounds

eg atrazine, captan, chlorpyrifos, diazinon, malathion, simazine), glyphosate/AMPA herbicide (AMPA is a breakdown product from glyphosate), and a multi-residue analysis for 64 other pesticides (eg bromophos-ethyl, methiocarb, phorate). A certificate of analysis for the Waitara River and Waiongana River sites is attached to this memorandum as an example. The full laboratory certificates for all sites are available from Council officers upon request.

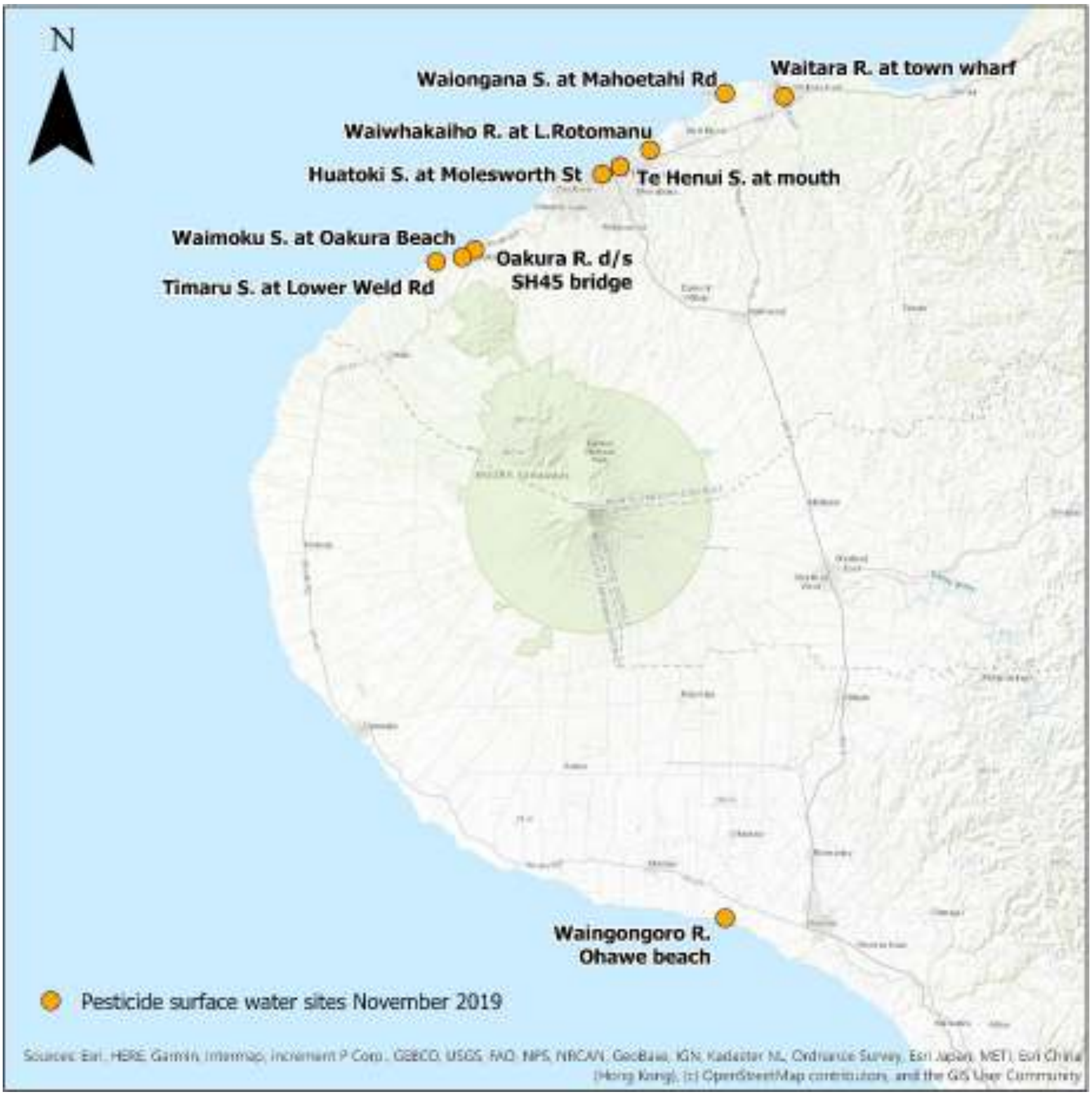

Figure 1: sampling sites for survey of pesticides in surface water

18. Limits of detection achieved by the laboratories were far below (by many orders of magnitude) the standards (human health standards) or guideline values (aesthetic quality) for drinking water. The limits of detection were also generally at least about the trigger values used by the Australian and New Zealand Environment and Conservation Council (ANZECC) to ensure protection of at least 95% of all freshwater species, and for some groups of pesticides the limits of laboratory detection were lower than even the trigger levels for 99% protection. The suites of pesticide residues analysed on behalf of

the Council were similar to and in some cases broader than those used by ESR in the latter's national groundwater surveys.

Results

19. Out of some 200 individual analytical results available for each of nine sites- about 1,800 results altogether- there were only two detections of individual pesticides. That is, there was a detection rate of 0.1%. No pesticides were detected in 99.9% of all analyses.

20. Both aldrin and heptachlor were detected in the sample collected from the Waiongana River. These chemicals are part of the family of organochlorines that were banned several decades ago. Both compounds were present at a concentration of 0.000 006 g/m^3, or 6 parts of a millionth of a millionth. Both results were barely above the detection threshold of 0.000 005 g/m^3. To put these results into perspective, the New Zealand Drinking Water Standard for aldrin and dieldrin combined is 0.000 03 g/m^3, so the aldrin concentration in the Waiongana River sample is 5 times lower than the drinking water standard; the drinking water standard for heptachlor and heptachlor epoxide combined is 0.000 04 g/m^3, so the heptachlor result in the Waiongana River sample is 7 times lower than the drinking water standard. (Note that neither dieldrin nor heptachlor epoxide were detected in the sample, even at limits of detection 30 times below the relevant drinking water standards).

21. The ANZECC aquatic ecological guidelines do not provide a trigger value for further investigation for aldrin, as there was insufficient data available to derive defensible trigger values. For heptachlor, the trigger value for protection of 99% of species (the most stringent ecological protection value provided within the ANZECC guidelines) is 0.000 01 g/m^3, so the result for the Waiongana River is half that which is to be applied for the most stringent level of protection; the trigger value for protection of 95% of species (the recommended level of protection for communities desiring a good level of ecological health in slightly modified freshwater systems) is 0.000 09 g/m^3, so the result for the Waiongana River is 15 times lower than the level of protection most relevant for waterways in a developed landscape.

22. Organochlorines were historically used as insecticides. They are highly persistent within the environment, and widely dispersed, typically through adsorption onto particles of soil which subsequently become mobilised. While their use was banned more than 30 years ago, it is not surprising, given the power of modern analytical techniques, that residues can still be detected in some environments. In the case of the Waiongana River, it is noted that market gardening is a historical activity within the catchment, along with very large plant nurseries. Such activities might well have used organochlorine insecticides while they were legal for application. During the 1990s and the first decade of the current millennium, this Council undertook a number of collections of hazardous substances throughout the region. Over 40 tonnes of substances were gathered and appropriately disposed of, including over 5 tonnes of organochlorine pesticides. Given the number and success of collection programmes the Council has delivered, with associated intensive publicity campaigns, the Council is confident that at most there are only very small stockpiles or holdings of organochlorines left in the region, and thus negligible potential for ongoing fresh releases of organochlorines into the environment.

Conclusions

23. The survey of the presence and concentrations of pesticides in surface waters in Taranaki is in response to the commitments and obligations of the Council as set out in its RFWP and various statutes and regulations. It provides robust data for any

discussion around the effect of pesticide usage in the region and the appropriateness of current controls, and thus can inform the shaping of the next Regional Land and Water Plan for Taranaki (in development). The survey's findings, that pesticide residues in surface waters are negligible, provide some reassurance to the Council and the regional community that the provisions of the RFWP and the implementation of good practices around the usage of pesticides are proving effective for the protection of the region's waterways and their associated values and uses.

Decision-making considerations

24. Part 6 (Planning, decision-making and accountability) of the *Local Government Act 2002* has been considered and documented in the preparation of this agenda item. The recommendations made in this item comply with the decision-making obligations of the *Act*.

Financial considerations—LTP/Annual Plan

25. This memorandum and the associated recommendations are consistent with the Council's adopted Long-Term Plan and estimates. Any financial information included in this memorandum has been prepared in accordance with generally accepted accounting practice.

Policy considerations

26. This memorandum and the associated recommendations are consistent with the policy documents and positions adopted by this Council under various legislative frameworks including, but not restricted to, the *Local Government Act 2002*, the *Resource Management Act 1991* and the *Local Government Official Information and Meetings Act 1987*.

Iwi considerations

27. This memorandum and the associated recommendations are consistent with the Council's policy for the development of Māori capacity to contribute to decision-making processes (schedule 10 of the *Local Government Act 2002*) as outlined in the adopted long-term plan and/or annual plan. Similarly, iwi involvement in adopted work programmes has been recognised in the preparation of this memorandum.

Legal considerations

28. This memorandum and the associated recommendations comply with the appropriate statutory requirements imposed upon the Council.

Appendices/Attachments

Document 2386582: Certificate of analysis for survey of agrichemicals in surface waters: Waitara and Waiongana river sites

Hill Laboratories
TRIED, TESTED AND TRUSTED

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Client:	Taranaki Regional Council	**Lab No:**	2280407 POPv1
Contact:	J Kitto	**Date Received:**	23-Nov-2019
	C/- Taranaki Regional Council	**Date Reported:**	02-Dec-2019
	Private Bag 713	**Quote No:**	100151
	Stratford 4352	**Order No:**	72831
		Client Reference:	#5498 - Bacto A: NORTH
		Submitted By:	Jonti Owen

Sample Type: Saline

Sample Name:		TRC194165 (WTR000922) 22-Nov-2019 11:25 am				
Lab Number:		2280407.1				
OrganoNitrogen & Phosphorus pesticides, trace, liq/liq GCMS						
Analytes Detected:		None				
Acid Herbicides Screen in Water by LCMSMS						
Analytes Detected:		None				
Multiresidue Extra Pesticides Trace in Water samples by Liq/liq						
Analytes Detected:		None				
Organochlorine Pesticides Trace in water, By Liq/Liq						
Analytes Detected:		None				
Individual Tests						
Glyphosate		See attached report	-	-	-	-

Please refer to the detection limits table for the list of analytes screened and their detection limits.

Sample Type: Aqueous

Sample Name:		TRC194167 (WGA000495) 22-Nov-2019 12:40 pm				
Lab Number:		2280407.2				
OrganoNitrogen & Phosphorus pesticides, trace, liq/liq GCMS						
Analytes Detected:		None				
Acid Herbicides Screen in Water by LCMSMS						
Analytes Detected:		None				
Multiresidue Extra Pesticides Trace in Water samples by Liq/liq						
Analytes Detected:		None				
Organochlorine Pesticides Trace in water, By Liq/Liq						
Analytes Detected:		2				
Aldrin	g/m^3	0.000006				
Heptachlor	g/m^3	0.000006				
Individual Tests						
Glyphosate		See attached report	-	-	-	-

Please refer to the detection limits table for the list of analytes screened and their detection limits.

Analyst's Comments

2280407.1 was spiked with target compounds as part of the in-house QC procedure for Acidic Herbicides analysis. It showed lower than expected recoveries for bentazone and clopyralid (51% and 56% respectively). The corresponding sample result was accepted because the Laboratory Control Sample (LCS) spike recovery was within the expected ranges (91% and 92% respectively). This indicates that the low sample spike recovery was due to the matrix of the samples that were spiked. The detection limits reported for these compounds have been raised for this reason.

Appendix No.1 - AsureQuality Report

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Individual Tests			
Glyphosate (Sub AQ)	Subcontracted to AsureQuality, Lower Hutt.	-	1-2
Acid Herbicides Screen in Water by LCMSMS	Direct injection LCMSMS	0.0003 - 0.0006 g/m³	1-2
Multiresidue Pesticides Trace in Water by Liq/liq GCMS	Liquid/liquid extraction, GPC (if required), GC-MS analysis	-	1-2
Multiresidue Extra Pesticides Trace in Water samples by Liq/liq			
Bendiocarb*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Benodanil*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00008 g/m³	1-2
Bifenthrin*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00002 g/m³	1-2
Bromophos-ethyl*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Bupirimate*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Buprofezin*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Captafol*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.0002 g/m³	1-2
Carboxin*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Chlorfenvinphos*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Chlorpropham*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00008 g/m³	1-2
Chlozolinate*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Coumaphos*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00008 g/m³	1-2
Cyproconazole*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Cyprodinil*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Demeton-S-methyl*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00008 g/m³	1-2
Dichlobenil*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Dichlofenthion*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Dicofol*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.0002 g/m³	1-2
Dicrotophos*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Dinocap*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.0003 g/m³	1-2
Disulfoton*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
EPN*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Esfenvalerate*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Ethion*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Etrimfos*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Famphur*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Fenamiphos*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Fenarimol*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Fenitrothion*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Fenpropathrin*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Fensulfothion*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Fenthion*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Fenvalerate*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Folpet*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00008 g/m³	1-2
Hexythiazox*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.0002 g/m³	1-2
Imazalil*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.0002 g/m³	1-2
Indoxacarb*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Iodofenphos*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Isazophos*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Isofenphos*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00002 g/m³	1-2
Leptophos*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Methacrifos*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Methidathion*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Methiocarb*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Mevinphos*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00008 g/m³	1-2
Nitrofen*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00008 g/m³	1-2
Nitrothal-isopropyl*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Oxychlordane*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00002 g/m³	1-2
Penconazole*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Phorate*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00008 g/m³	1-2
Phosmet*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Phosphamidon*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Propetamphos*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00006 g/m³	1-2
Propham*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Prothiofos*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Pyrazophos*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2
Pyrifenox*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m³	1-2

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Pyrimethanil*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m^3	1-2
Quintozene*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00008 g/m^3	1-2
Sulfotep*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m^3	1-2
Tebufenpyrad*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00002 g/m^3	1-2
Tetrachlorvinphos*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m^3	1-2
Thiometon*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00008 g/m^3	1-2
Triadimefon*	Liquid / liquid extraction, GPC (if required), GC-MS SIM analysis. Roos et al (modified).	0.00004 g/m^3	1-2

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental

Detection Limits

Analytes	Detection Limit
OrganoNitrogen & Phosphorus pesticides, trace, liq/liq GCMS	
Sample Number(s):	1-2
Acetochlor*	0.00004 g/m³
Alachlor*	0.00004 g/m³
Atrazine*	0.00004 g/m³
Atrazine-desethyl*	0.00004 g/m³
Atrazine-desisopropyl*	0.00008 g/m³
Azaconazole*	0.00002 g/m³
Azinphos-methyl*	0.00008 g/m³
Benalaxyl*	0.00002 g/m³
Bitertanol*	0.00008 g/m³
Bromacil*	0.00004 g/m³
Bromopropylate*	0.00004 g/m³
Butachlor*	0.00004 g/m³
Captan*	0.00008 g/m³
Carbaryl*	0.00004 g/m³
Carbofenothion*	0.00004 g/m³
Carbofuran*	0.00004 g/m³
Chlorfluazuron*	0.00004 g/m³
Chlorothalonil*	0.00004 g/m³
Chlorpyrifos*	0.00004 g/m³
Chlorpyrifos-methyl*	0.00004 g/m³
Chlortoluron*	0.00008 g/m³
Cyanazine*	0.00004 g/m³
Cyfluthrin*	0.00004 g/m³
Cyhalothrin*	0.00004 g/m³
Cypermethrin*	0.00008 g/m³
Deltamethrin (including Tralomethrin)*	0.00006 g/m³
Diazinon*	0.00002 g/m³
Dichlofluanid*	0.00004 g/m³
Dichloran*	0.0002 g/m³
Dichlorvos*	0.00008 g/m³
Difenoconazole*	0.00008 g/m³
Dimethoate*	0.00008 g/m³
Diphenylamine*	0.00008 g/m³
Diuron*	0.00004 g/m³
Fenpropimorph*	0.00004 g/m³
Fluazifop-butyl*	0.00004 g/m³
Fluometuron*	0.00004 g/m³
Flusilazole*	0.00004 g/m³
Fluvalinate*	0.00004 g/m³
Furalaxyl*	0.00002 g/m³
Haloxyfop-methyl*	0.00004 g/m³
Hexaconazole*	0.00004 g/m³
Hexazinone*	0.00002 g/m³
IPBC (3-Iodo-2-propynyl-n-butylcarbamate)*	0.0002 g/m³
Kresoxim-methyl*	0.00002 g/m³
Linuron*	0.00005 g/m³
Malathion*	0.00004 g/m³
Metalaxyl*	0.00004 g/m³
Metolachlor*	0.00004 g/m³
Metribuzin*	0.00004 g/m³
Molinate*	0.00008 g/m³
Myclobutanil*	0.00004 g/m³
Naled*	0.0002 g/m³
Norflurazon*	0.00008 g/m³
Oxadiazon*	0.00004 g/m³
Oxyfluorfen*	0.00002 g/m³
Paclobutrazol*	0.00004 g/m³
Parathion-ethyl*	0.00004 g/m³
Parathion-methyl*	0.00004 g/m³
Pendimethalin*	0.00004 g/m³
Permethrin*	0.00002 g/m³
Pirimicarb*	0.00004 g/m³
Pirimiphos-methyl*	0.00004 g/m³
Prochloraz*	0.0002 g/m³
Procymidone*	0.00004 g/m³
Prometryn*	0.00002 g/m³
Propachlor*	0.00004 g/m³
Propanil*	0.0002 g/m³
Propazine*	0.00002 g/m³
Propiconazole*	0.00004 g/m³
Pyriproxyfen*	0.00004 g/m³
Quizalofop-ethyl*	0.00004 g/m³
Simazine*	0.00004 g/m³
Simetryn*	0.00004 g/m³
Sulfentrazone*	0.0002 g/m³
TCMTB [2-(thiocyanomethylthio) benzothiazole,Busan]*	0.00008 g/m³
Tebuconazole*	0.00004 g/m³
Terbacil*	0.00004 g/m³
Terbufos*	0.00004 g/m³
Terbumeton*	0.00004 g/m³
Terbuthylazine*	0.00002 g/m³
Terbuthylazine-desethyl*	0.00004 g/m³
Terbutryn*	0.00004 g/m³
Thiabendazole*	0.0002 g/m³
Thiobencarb*	0.00004 g/m³
Tolylfluanid*	0.00002 g/m³
Triazophos*	0.00004 g/m³
Trifluralin*	0.00004 g/m³
Vinclozolin*	0.00004 g/m³

Analytes	Detection Limit
Acid Herbicides Screen in Water by LCMSMS	
Sample Number(s):	1
Bentazone	0.0008 g/m³
Clopyralid	0.0008 g/m³
Sample Number(s):	1-2
Acifluorfen	0.0004 g/m³
Bromoxynil	0.0004 g/m³
2,4-Dichlorophenoxyacetic acid (24D)	0.0004 g/m³
2,4-Dichlorophenoxybutyric acid (24DB)	0.0006 g/m³
Dicamba	0.0006 g/m³
Dichlorprop	0.0004 g/m³
Fluazifop	0.0004 g/m³
Fluroxypyr	0.0004 g/m³
Haloxyfop	0.0004 g/m³
2-methyl-4-chlorophenoxyacetic acid (MCPA)	0.0004 g/m³
2-methyl-4-chlorophenoxybutanoic acid (MCPB)	0.0004 g/m³
Mecoprop	0.0004 g/m³
Oryzalin	0.0011 g/m³
2,3,4,6-Tetrachlorophenol (TCP)	0.0004 g/m³
2,4,5-trichlorophenoxypropionic acid (245TP,Fenoprop, Silvex)	0.0004 g/m³
2,4,5-Trichlorophenoxyacetic acid (245T)	0.0004 g/m³
Pentachlorophenol (PCP)	0.0004 g/m³
Picloram	0.0004 g/m³
Quizalofop	0.0004 g/m³
Triclopyr	0.0004 g/m³
Sample Number(s):	2
Bentazone	0.0004 g/m³
Clopyralid	0.0004 g/m³

Analytes	Detection Limit
Multiresidue Extra Pesticides Trace in Water samples by Liq/liq	
Sample Number(s):	1-2
Bendiocarb*	0.00004 g/m³
Benodanil*	0.00008 g/m³
Bifenthrin*	0.00002 g/m³
Bromophos-ethyl*	0.00004 g/m³
Bupirimate*	0.00004 g/m³
Buprofezin*	0.00004 g/m³
Captafol*	0.0002 g/m³
Carbofenothion*	0.00004 g/m³
Carboxin*	0.00004 g/m³
Chlorfenvinphos*	0.00004 g/m³
Chlorpropham*	0.00008 g/m³
Chlozolinate*	0.00004 g/m³
Coumaphos*	0.00008 g/m³
Cyproconazole*	0.00004 g/m³
Cyprodinil*	0.00004 g/m³
Demeton-S-methyl*	0.00008 g/m³
Dichlobenil*	0.00004 g/m³
Dichlofenthion*	0.00004 g/m³
Dicofol*	0.0002 g/m³
Dicrotophos*	0.00004 g/m³
Dinocap*	0.0003 g/m³
Disulfoton*	0.00004 g/m³
EPN*	0.00004 g/m³
Esfenvalerate*	0.00004 g/m³
Ethion*	0.00004 g/m³
Etrimfos*	0.00004 g/m³
Famphur*	0.00004 g/m³
Fenamiphos*	0.00004 g/m³
Fenarimol*	0.00004 g/m³
Fenitrothion*	0.00004 g/m³
Fenpropathrin*	0.00004 g/m³
Fensulfothion*	0.00004 g/m³
Fenthion*	0.00004 g/m³
Fenvalerate*	0.00004 g/m³
Folpet*	0.00008 g/m³
Hexythiazox*	0.0002 g/m³
Imazalil*	0.0002 g/m³
Indoxacarb*	0.00004 g/m³
Iodofenphos*	0.00004 g/m³
Isazophos*	0.00004 g/m³

Analytes	Detection Limit
Multiresidue Extra Pesticides Trace in Water samples by Liq/liq	
Sample Number(s):	1-2
Isofenphos*	0.00002 g/m³
Leptophos*	0.00004 g/m³
Methacrifos*	0.00004 g/m³
Methidathion*	0.00004 g/m³
Methiocarb*	0.00004 g/m³
Mevinphos*	0.00008 g/m³
Nitrofen*	0.00008 g/m³
Nitrothal-Isopropyl*	0.00004 g/m³
Oxychlordane*	0.00002 g/m³
Penconazole*	0.00004 g/m³
Phorate*	0.00008 g/m³
Phosmet*	0.00004 g/m³
Phosphamidon*	0.00004 g/m³
Propetamphos*	0.00006 g/m³
Propham*	0.00004 g/m³
Prothiofos*	0.00004 g/m³
Pyrazophos*	0.00004 g/m³
Pyrifenox*	0.00004 g/m³
Pyrimethanil*	0.00004 g/m³
Quintozene*	0.00008 g/m³
Sulfotep*	0.00004 g/m³
Tebufenpyrad*	0.00002 g/m³
Tetrachlorvinphos*	0.00004 g/m³
Thiometon*	0.00008 g/m³
Triadimefon*	0.00004 g/m³
Organochlorine Pesticides Trace in water, By Liq/Liq	
Sample Number(s):	1-2
Aldrin*	0.000005 g/m³
alpha-BHC*	0.000010 g/m³
beta-BHC*	0.000010 g/m³
delta-BHC*	0.000010 g/m³
gamma-BHC (Lindane)*	0.000010 g/m³
cis-Chlordane*	0.000005 g/m³
trans-Chlordane*	0.000005 g/m³
2,4'-DDD*	0.000010 g/m³
4,4'-DDD*	0.000010 g/m³
2,4'-DDE*	0.000010 g/m³
4,4'-DDE*	0.000010 g/m³
2,4'-DDT*	0.000010 g/m³
4,4'-DDT*	0.000010 g/m³
Total DDT Isomers*	0.00006 g/m³
Dieldrin*	0.000005 g/m³
Endosulfan I*	0.000010 g/m³

Analytes	Detection Limit
Endosulfan II*	0.000010 g/m³
Endosulfan sulfate*	0.000010 g/m³
Endrin*	0.000005 g/m³
Endrin aldehyde*	0.000005 g/m³
Endrin ketone*	0.000010 g/m³
Heptachlor*	0.000005 g/m³
Heptachlor epoxide*	0.000005 g/m³
Hexachlorobenzene*	0.00004 g/m³
Methoxychlor*	0.000005 g/m³
Total Chlordane [(cis+trans)* 100/42]*	0.00002 g/m³

AsureQuality Limited | 1C Quadrant Drive | Waiwhetu | Lower Hutt 5010 | Wellington | New Zealand
PO Box 31242 | Lower Hutt 5040 | Wellington | New Zealand
t. +64 4 570 8800 | e. cswellington@asurequality.com | w. www.asurequality.com
Global Experts in Food Assurance

Certificate of Analysis

Submission Reference: EnvSubAQ_LH 249
Final Report

Environment Client Service Managers
Hill Laboratories - Hamilton
Private Bag 3205
Hamilton 3240
New Zealand

PO Number: 152895

Report Issued: 29-Nov-2019 **AsureQuality Reference:** 19-271948 **Sample(s) Received:** 26-Nov-2019 07:30

Testing Period: 26-Nov-2019 to 29-Nov-2019

Results

The tests were performed on the samples as received.

Customer Sample Name: 2280407.1 **Lab ID:** 19-271948-1

Sample Description: Saline

Sample Condition: Acceptable **Sampled Date**: 23-Nov-2019

Test	Result	Unit	Method Reference
Glyphosate and AMPA in Potable and Non-Potable Water			
AMPA	<0.0010	mg/kg	AsureQuality Method (LC-MS/MS)
Glyphosate	<0.0010	mg/kg	AsureQuality Method (LC-MS/MS)

Customer Sample Name: 2280407.2 **Lab ID:** 19-271948-2

Sample Condition: Acceptable **Sampled Date**: 23-Nov-2019

Test	Result	Unit	Method Reference
Glyphosate and AMPA in Potable and Non-Potable Water			
AMPA	<0.0010	mg/kg	AsureQuality Method (LC-MS/MS)
Glyphosate	<0.0010	mg/kg	AsureQuality Method (LC-MS/MS)

Analysis Summary

Wellington Laboratory

Analysis	Method	Accreditation	Authorised by
Glyphosate and AMPA in Potable and Non-Potable Water			
DX-GLYP01, 01-DEFAULT	AsureQuality Method (LC-MS/MS)	IANZ	Joanne Fry

Results that are prefixed with '<' indicate the lowest level at which the analyte can be reported, and that in this case the analyte was not observed above this limit.

Joanne Fry
Scientist

Accreditation

ilac-MRA IANZ ACCREDITED LABORATORY

Appendix

Analyte LOR Summary

Glyphosate and AMPA in Potable and Non-Potable Water - AsureQuality Method (LC-MS/MS)

Analyte	LOR
AMPA	0.0010 mg/kg
Glyphosate	0.0010 mg/kg

Analyte Definitions

Glyphosate and AMPA in Potable and Non-Potable Water - AsureQuality Method (LC-MS/MS)

Analyte	Full Name
AMPA	Aminomethylphosphonic acid

LOR = Limit of Reporting LOD = Limit of Detection NR = Not Reportable

Taranaki Regional Council

MEMORANDUM
Policy & Planning

Date 4 February 2020

Subject: **Summary of the Freshwater Improvement Fund (FIF) Project 'Transforming Taranaki' for year 1 (2018-19)**

Approved by: S R Hall, Director - Operations

B G Chamberlain, Chief Executive

Document: 2409209

Purpose

1. The purpose of this memorandum is to update Members on the progress of the freshwater improvement fund project 'transforming Taranaki', following completion of year one of this project, and an update on the riparian programme with reference to the development of the approaching auditing regime.
2. A brief presentation on the item will be given.

Executive summary

3. The Freshwater Improvement Fund (FIF) is a government led initiative managed by the Ministry for the Environment (MfE) aimed at helping to improve and protect New Zealand's fresh water resources. The Taranaki Regional Council (the Council) made a successful application to the fund in mid-2017. The project focused on accelerating the riparian programme with a particular emphasis on rewarding those that either have completed their plans or have shown good progress towards finishing by 2020.
4. Ministry for the Environment funding totalled $2 million and distributed over a two-year period with a total of $1 million spent in each year of the project. Of this, $500,000 was assigned to maintenance and weed control projects on existing riparian margins in Taranaki. Another $500,000 assigned to subsidising plants for further riparian planting in the region. Year one of the project completed on 30 September 2019 with $977,430 of audited works completed. Planning and operations for year two are well under way and scheduled to finish by 30 September 2020.
5. The riparian management programme has seen a healthy increase in implementation rates in recent times and partly attributed to the FIF project. With a pending shift towards more regulatory measures for the riparian programme, the land management team are developing a strategy for auditing existing riparian plans in the region to accurately gauge the completed and remaining works.

Recommendations

That the Taranaki Regional Council:

a) receives this memorandum Summary of the Freshwater Improvement Fund Project 'Transforming Taranaki' for year 1 (2018-19); and

b) notes the approach to delivery and progress made to date.

Fund performance

6. The Freshwater Improvement Fund (FIF) is a $100 million fund over 10 years; MfE oversees the fund for projects larger than $400,000. The fund was launched in 2017 and to date the Government have committed $47 million to 34 projects across New Zealand.
7. The Taranaki Regional Council made four applications to the fund in mid-2017. These projects were: accelerating the riparian programme; improving water quality in the Waitōtara catchment; improving water quality in the Waitara catchment; and a constructed wetland at the lower end of the Mangatī catchment. Of these projects, the riparian project was the only one approved.
8. The riparian project focuses on rewarding those that either have completed their plans or have shown good progress towards finishing by 2020. The Council has received funding of $2 million over two years (2018-2020). Riparian Management Plans with high original proposed works, high works implemented and are complete, take priority for FIF maintenance funding. Allocation of funds for both the maintenance of existing riparian areas and contribution towards completion of planting were made. The following will be achieved over the 2 years:
   - $1 million allocated to riparian maintenance;
   - $1 million allocated to riparian completion planting;
   - 1,000 plan holders to receive funding for maintenance and/or planting ; and
   - Planting 250 km of stream bank with 250,000 native plants.
9. To achieve the above, maintenance works and planting is to take place on up to 500 selected Riparian Management Plans per year to the value of $2,000 each. Contractors are used to deliver the work; landowners will contribute one dollar per plant.
10. At the conclusion of year one of the project a total of $977,430 has been spent on both maintenance and plant funded projects.
11. A total of $497,934 has been spent on subsidising plants and planting costs while $479,496 has been spent on maintenance works. This has encompassed 519 properties in total with 259 receiving FIF plant funding and 260 receiving FIF maintenance funding, respectively.
12. The Council exceeded the target of 500 properties to receive the funding in year one, however total expenditure was under the targeted $1 million. This is because not all projects met the $2,000 limit per property.
13. Physical works undertaken under the FIF planting option involved advertising a planting tender contract, securing a signed plant order, plant pick-up from one of our five depots along with spot spraying and planting the plants. Plan holders could enter into the tender system, seek their own contractor, or plant themselves. Expenditure at 30

September 2019 for FIF planting totalled $497,934.81, which accounts for 256 plant orders ($362,693) and 204 planting ($135,241) rebates processed. A total of 176,952 plants were sold through the FIF plant funding option.

14. Physical works undertaken under the FIF maintenance option involved advertising a weed control tender contract where contractors undertook work that involved hand releasing, spraying, and cut and paste methods. It also involved plan holders being able to order up to 200 plants for infill blanking of their riparian margins where they could enter into the tender system, seek their own contractor, or plant themselves. Expenditure at 30 September 2019 for FIF maintenance totalled $479,496, which accounts for 233 weed control jobs ($358,710), 122 plant orders ($75,348) and 110 planting ($45,437) rebates processed. A total of 23,355 plants were sold under the FIF maintenance funding option.
15. There were 200,307 native riparian plants sold and planted in year one of the FIF project. This was a significant contribution to the total 539,000 plants sold in the riparian scheme in 2018-19. Year two of the project is now well under way with operational processes in full swing and the contract tender for maintenance works complete. Maintenance works have commenced on the ground and will carry on through to the end of April 2020. Land Management Officers (LMOs) are also scoping and confirming FIF plant funding projects as they work through annual monitoring and will be confirmed by May 2020. The total budget for expenditure for 2019-20 is $1,022,569.

Riparian Programme – Progress and audit

16. The Council's riparian management programme is progressing well with all Riparian Management Plans undergoing a full audit over the next couple of years to provide plan holders with clarity on what is required to achieve compliance. It is important to note the Government freshwater proposals recently released are likely to be in place at some point this year. Whilst there is still much uncertainty around where these will finally land, it is hoped that the Council's riparian requirements, which are the most comprehensive and advanced in the country, will more than meet anything the Government requires.
17. In the 2018-19 financial year, some 539,000 native plants were supplied and sold through the programme, with 296 km of fencing and 321 km of planting completed. This takes the total implementation to 87.1% fenced and 75.2% vegetated (where recommended) in the region.
18. Year to date progress for the 2019-20 financial year sees some 112.5 km of fencing and 221.7 km of planting already completed. Trends suggest that this is a significant increase in implementation in this early stage of the year.
19. The Land Management team have been developing a mobile application over the last 12 months to carry out full farm riparian audits. Development of this app is nearing completion with office based and field testing now being carried out. The aim is to have a fully functional product ready to go live by early this year. Once the app is up and running, auditing of riparian works will be more efficient and will ramp up considerably over the next year. These audits will provide an accurate assessment of works completed, works remaining, and will generate the monitoring regimes of individual riparian management plans moving forward.

Decision-making considerations

20. Part 6 (Planning, decision-making and accountability) of the *Local Government Act 2002* has been considered and documented in the preparation of this agenda item. The recommendations made in this item comply with the decision-making obligations of the Act.

Financial considerations—LTP/Annual Plan

21. This memorandum and the associated recommendations are consistent with the Councils adopted *Long-Term Plan* and estimates. Any financial information included in this memorandum has been prepared in accordance with generally accepted accounting practice.

Policy considerations

22. This memorandum and the associated recommendations are consistent with the policy documents and positions adopted by this Council under various legislative frameworks including, but not restricted to, the *Local Government Act 2002*, the *Resource Management Act 1991* and the *Local Government Official Information and Meetings Act 1987*.

Iwi considerations

23. This memorandum and the associated recommendations are consistent with the Council's policy for the development of Māori capacity to contribute to decision-making processes (schedule 10 of the *Local Government Act 2002*) as outlined in the adopted *Long-Term Plan* and/or *Annual Plan*. Similarly, Iwi involvement in adopted work programmes is recognised in the preparation of this memorandum.

Legal considerations

24. This memorandum and the associated recommendations comply with the appropriate statutory requirements imposed upon the Council.

Taranaki Regional Council

MEMORANDUM

Policy & Planning

Date	4 February 2020
Subject:	**Update on Proposed Coastal Plan for Taranaki: Appeals**
Approved by:	A D McLay, Director - Resource Management B G Chamberlain, Chief Executive
Document:	2408708

Purpose

1. The purpose of this memorandum is to update Members on appeals lodged with the Environment Court on the *Proposed Coastal Plan for Taranaki* (the Proposed Plan).

Executive summary

2. The Coastal Plan review has involved a comprehensive consultative and engagement process, including the extra steps of consulting on the Draft Proposed Coastal Plan and undertaking extensive pre-hearing engagement with submitters on the publicly notified Proposed Plan.
3. The Proposed Plan was publicly notified on 24 February 2018. Sixty-one initial submissions were received on the Proposed Plan, with a further 25 submissions received in support or opposition of the initial submissions. A hearing of submissions was held over August and September 2018.
4. After its Ordinary meeting of 1 October 2019, Council considered and adopted the hearing panel’s report and recommendations, which included many changes to give effect to relief’s sought by submitters. In accordance with the *Resource Management Act 1991* (RMA), the Council’s decisions on submissions were publicly notified with submitters having 30 working days from receipt of the Council’s decisions in which to lodge appeals to the Environment Court.
5. Ten appeals have been lodged with the Environment Court involving largely non-government organisations, one iwi, and two Government departments.
6. Nineteen parties have subsequently lodged with the Environment Court that they wish to be a party to any proceedings before the Environment Court pursuant to section 274 of the RMA. As a section 274 party, these parties must state whether they support or oppose the proceedings and have an opportunity to participate in any Environment Court mediation or other dispute resolution of the proceedings, and/or appear and call evidence at any Environment Court hearing.

7. Of note, a number of new parties that have not previously submitted on the Proposed Plan have entered the process given some of the matters that are the subject of the appeal, i.e. the Fishing Industries Parties and the Ministry for Fisheries.
8. Issues raised by the appellants predominantly relate to relief sought in relation to how the Proposed Plan regulates hydrocarbon exploration and production activities, protects significant indigenous biodiversity, and recognises tangata whenua values.
9. With the lodgement of the appeals, proceedings are now largely dependant upon Environment Court processes. Where possible, the Environment Court will encourage settlement by negotiation or the use of alternative dispute resolution processes (principally mediation) under section 268 of the RMA. Some matters raised are likely to be resolved by mutual agreement with submitters. However, it is anticipated that not all matters are likely to be resolved and there will need to have a hearing of the Environment Court.
10. After hearing appeals before the Environment Court, the court may direct Council to make changes to the Proposed Plan pursuant to section 293 of the RMA.

Recommendations

That the Taranaki Regional Council:

a) receives this memorandum entitled *Update on Proposed Coastal Plan for Taranaki: Appeals;* and

b) notes that ten appeals to the Proposed Plan have been lodged with the Environment Court.

Background

11. As Members are aware, the Council is reviewing its current *Regional Coastal Plan for Taranaki* under the *Resource Management Act 1991* (the RMA). A Proposed Plan, which was the culmination of a comprehensive consultative and engagement process including consultation on the Draft Proposed Coastal Plan, was publicly notified on 24 February 2018.
12. Sixty-one initial submissions were received on the Proposed Plan, with a further 25 submissions received in support or opposition of the initial submissions.
13. Members may recall that the Council, acting under section 34A of the RMA, appointed three experienced hearing commissioners to hear, consider and make recommendations to it on the submissions on the Proposed Plan. The Council delegated to the Hearing Panel all its functions, powers and duties to hear and consider submissions on the Proposed Plan, including requiring and receiving reports under section 42A and exercising powers conferred by sections 41B and 41C of the RMA.
14. On Wednesday 24 July and Thursday 1 August 2019, a Hearing Panel heard submissions made to the Proposed Plan. The three accredited hearing commissioners appointed to the Hearing Panel, were Cr Michael Joyce (as Chair), Cr Neil Walker, and Rawiri Faulkner (an independent hearing commissioner with plan hearing and tikanga Māori expertise).
15. Fifteen submitters were heard in support of their submissions at the Hearing, with a further six submitters tabling correspondence to be considered by the Hearing Panel. During the course of the hearing, the Hearing Panel considered the submissions, heard

all written submissions on the Proposed Plan, the outcome of pre-hearing consultation with all submitters, the officer recommendations on submissions and the further evidence and submissions tabled at the Hearing. The Hearing Panel reached decisions on all submissions and instructed officers to prepare a report setting out the Panel's deliberations and its recommendations to the full Council on those submissions.

16. The Policy and Planning Committee considered and adopted its report and recommendations on submissions at its meeting on 3 September 2019. The Hearing Panel's recommendations were incorporated into the Council's decisions report with that report and an amended version of the Proposed Plan being adopted at the Ordinary meeting of 1 October 2019.

17. The Council's decisions were publicly notify with submitters individually notified on the 4th of October. Clause 14(1) of the first schedule of the RMA reads as follows:

    "… a person who made a submission on a proposed policy statement or plan may appeal to the Environment Court in respect of—

    a) a provision included in the proposed policy statement or plan; or

    b) a provision that the decision on submissions proposes to include in the policy statement or plan; or

    c) a matter excluded from the proposed policy statement or plan; or

    d) a provision that the decision on submissions proposes to exclude from the policy statement or plan."

18. Any appeals must relate to matters raised in submissions. The deadline for submitters to lodge an appeal against the Council's decision was 18 November. Given the extensive engagement undertaken it was hoped there would be no appeals. However, this did not eventuate.

Appeals against the Proposed Plan

19. Pursuant to Clause 14(1) of the first schedule of the RMA, Council has been advised by the Environment Court that 10 submitters have lodged to appeal the Proposed Plan, these being:

    - Climate Justice Taranaki
    - Department of Conservation
    - Fonterra
    - Ngāruahine
    - New Zealand Defence Force
    - Petroleum Exploration and Production Association of NZ
    - Royal Forest and Bird Society
    - Taranaki Energy Watch
    - Transpower

20. Issues raised by the appellants may be broadly grouped under the following matters/themes:

    - Further controls and restrictions on hydrocarbon and exploration activities (Climate Justice Taranaki, Taranaki Energy Watch)

- Further recognition for regionally important infrastructure, industries and/or network utilities (Transpower, Fonterra)
- Further provision for the protection of biodiversity (Department of Conservation, Royal Forest and Bird Society) or opposed to Council's decisions in relation to biodiversity (PEPANZ)
- Further provision for spatial planning for the protection of cultural heritage (Grant Knuckey, Ngāruahine)
- Revised provisions for noise (New Zealand Defence Force).

Section 274 parties

21. In accordance with section 274(1) of the RMA, other persons may also be a party to any proceedings before the Environment Court where they have an interest in the proceedings greater than the public generally.
22. As a section 274 party, these parties must state whether they support or oppose the proceedings and have an opportunity to participate in any Environment Court mediation or other dispute resolution of the proceedings, and/or appear and call evidence at any Environment Court hearing.
23. The Council has been given notice that the following are a party to proceedings under section 274 of the RMA:
    - Department of Conservation
    - Fonterra
    - New Zealand Defence Force
    - Petroleum Exploration and Production Association of NZ
    - Royal Forest and Bird Society
    - Taranaki Energy Watch
    - Greenpeace
    - Kiwis Against Seabed Mining
    - Transpower
    - Powerco
    - Oil Companies (Z Energy Ltd, BP Oil New Zealand Ltd and Mobil Oil New Zealand Ltd)
    - Spark New Zealand Limited
    - Port Taranaki Ltd
    - Trans-Tasman Resources Ltd
    - Te Kaahui o Rauru
    - Federated Farmers
    - South Taranaki District Council
    - Fishing Industry Parties (Fisheries Inshore New Zealand, NZ Rock Lobster Industry Council and Pāua Industry Council)

- Minister of Fisheries.

24. With the appeals, many submitters have decided to re-enter the process. However, two new parties, that have not previously submitted on the Proposed Plan, have also entered the process given some of the matters that are the subject of the appeal, namely the Fishing Industries Parties and the Ministry for Fisheries.

Where to from here

25. With the lodgement of the appeals, proceedings are now largely dependent upon Environment Court processes. Where possible, the Environment Court will encourage settlement by negotiation or the use of alternative dispute resolution processes (principally mediation) under section 268 of the RMA.
26. While the lodgement of the appeals and subsequent delay in making the Proposed Plan operative is frustrating (particularly given the effort put in to resolving issues with submitters), staff have a good measure of confidence that many of the matters raised can be resolved by mutual agreement with submitters and this will be progressed over the coming months. However, it is anticipated that not all matters are likely to be resolved or settled with some submitters and there will be a need to have a hearing at the Environment Court.
27. After hearing appeals before the Environment Court, the court may direct Council to make changes to the Proposed Plan pursuant to section 293 of the RMA. Officers will regularly update Members through this part of the process.

Decision-making considerations

28. Part 6 (Planning, decision-making and accountability) of the *Local Government Act 2002* has been considered and documented in the preparation of this agenda item. The recommendations made in this item comply with the decision-making obligations of the *Act*.

Financial considerations—LTP/Annual Plan

29. This memorandum and the associated recommendations are consistent with the Council's adopted Long-Term Plan and estimates. Any financial information included in this memorandum has been prepared in accordance with generally accepted accounting practice.

Policy considerations

30. This memorandum and the associated recommendations are consistent with the policy documents and positions adopted by this Council under various legislative frameworks including, but not restricted to, the *Local Government Act 2002*, the *Resource Management Act 1991* and the *Local Government Official Information and Meetings Act 1987*.

Iwi considerations

31. This memorandum and the associated recommendations are consistent with the Council's policy for the development of Māori capacity to contribute to decision-making processes (schedule 10 of the *Local Government Act 2002*) as outlined in the adopted long-

term plan and/or annual plan. Similarly, iwi involvement in adopted work programmes has been recognised in the preparation of this memorandum.

Legal considerations

32. This memorandum and the associated recommendations comply with the appropriate statutory requirements imposed upon the Council.

Taranaki Regional Council

MEMORANDUM
Policy & Planning

Date	4 February 2020
Subject:	**Taranaki Estuarine Vulnerability Assessment - consultant report**
Approved by:	G K Bedford, Director - Environment Quality B G Chamberlain, Chief Executive
Document:	2409900

Purpose

1. The purpose of this memorandum is to introduce the report produced by Dr Ben Robertson (Robertson Environmental Ltd.), *Taranaki Regional Estuaries - Ecological Vulnerability Assessment*. The report has been prepared to provide baseline information on the region's estuaries and to inform monitoring priorities for the Council's State of the Environment Estuaries Monitoring Programme.
2. Staff will make a presentation to the Committee on the report.

Executive summary

3. A soft shore (estuarine) SEM programme was in place at the Taranaki Regional Council (the Council) from 1996 until 2013, at which time it was deemed to be no longer fit for purpose and was discontinued.
4. A review of the estuarine SEM programme was completed in 2016, which recommended that a region-wide synoptic baseline survey was undertaken, in the form of an Estuarine Vulnerability Assessment (EVA).
5. The recommendation for an EVA was made as it would provide valuable baseline information on the estuaries in Taranaki, particularly in terms of their sedimentation and eutrophication status. This information could then be used for defensibly prioritising ongoing State of the Environment Monitoring effort (ensuring that monitoring was prioritised at the estuaries that were most susceptible to the effects of sedimentation and eutrophication).
6. In early 2019, the Council commissioned Dr Ben Robertson (Robertson Environmental Ltd) to undertake an EVA for 20 estuaries (tidal river mouths) in Taranaki.
7. The EVA produced three main outputs for each estuary: habitat maps, vulnerability ratings (including condition assessments), and monitoring recommendations.
8. Habitat maps were produced during field surveys at each estuary to document the dominant estuary features (e.g. substratum, vegetation, etc.). These maps provide a

baseline against which broad scale changes in the future can be measured. The information recorded in this survey was also used to inform the estuarine condition assessments (described in the next paragraph).

9. An overall vulnerability rating was assigned, by assessing the susceptibility and current condition of each estuary with respect to sedimentation and eutrophication state and potential. The susceptibility to sedimentation (muddiness) and eutrophication was assessed using catchment and land use information, as well as physical and hydrological attributes of the estuary. The current condition of each estuary was determined through field surveys, where relevant synoptic variables were measured in order to determine the estuary's sedimentation and eutrophication status at that point in time. Together, these assessments produced an overall vulnerability rating for each estuary.

10. The vulnerability rating was used to inform future monitoring recommendations. Where an estuary's overall vulnerability was minimal to moderate, it was recommended that synoptic (screening level) monitoring be completed only every 10 years. Where an estuary's overall vulnerability was moderate to high, more intensive monitoring was deemed appropriate. This monitoring would entail five yearly 'broad-scale' (habitat mapping) surveys which focus on changes in dominant estuary features or habitats. Three years of annual 'fine-scale' surveys, which assess the baseline condition of intertidal sediment through various physical, chemical and biological indicators, were also recommended for the moderate to highly vulnerable estuaries. Where eutrophication symptoms were present, or highly likely to occur, eutrophication targeted monitoring was recommended, consisting of monthly water sample collection through the summer period when eutrophication risk was greatest.

11. Assessment results found that sedimentation susceptibility was moderate to high at seven of 20 estuaries. Condition assessments undertaken during the field visits supported this finding, with the same seven estuaries (35%) rating 'very high' with regards to current sedimentation levels.

12. In terms of eutrophication, susceptibility ratings varied from high to very high at five of 20 estuaries, however, the condition assessments only discovered eutrophication symptoms at two (10%).

13. For 11 of the estuaries (55%), the condition ratings for both sedimentation and eutrophication ranged from minimal to moderate.

14. The EVA monitoring recommendations were as follows:

15. Synoptic monitoring every ten years was recommended for the Onaero, Waiongana, Waiwhakaiho, Te Henui, Tapuae, Timaru, Kauopokonui, Waingongoro, Tangahoe and Manawapou Estuaries

16. Broad and fine scale monitoring was recommended for the Mohakatino, Tongaporutu, Mimi, Urenui, Waitara, Patea and Waitotara Estuaries (broad-scale five yearly, fine-scale annual for 3 years, then review).

17. Eutrophication-centred water quality monitoring was recommended for the Oakura, Katikara and Whenuakura Estuaries (once a month for one summer, then review).

18. Council Officers plan to use the majority of the recommendations in this report to inform ongoing monitoring priorities.

Recommendations

That the Taranaki Regional Council:

a) receives the report *Taranaki Regional Estuaries - Ecological Vulnerability Assessment;*

b) notes the results of EVA

c) notes that the recommendations within the report will be used to inform an ongoing State of the Environment Estuaries Monitoring Programme.

Background

19. The Resource Management Act 1991 (the RMA) established requirements for local authorities to undertake environmental monitoring. Section 35 of the RMA requires local authorities to monitor, among other things, the state of the environment for their region or district, to the extent that is appropriate to enable them to effectively carry out their functions under the Act.

20. To this effect, the Taranaki Regional Council (the Council) has established a State of the Environment Monitoring (SEM) programme for the region. This programme is outlined in the Council's "State of the Environment Monitoring Procedures Document", which was prepared in 1997. The monitoring programme is based on the significant resource management issues that were identified in the Council's Regional Policy Statement for Taranaki (1994).

21. Historically, the coastal component of the SEM programme involved bathing beach water quality and coastal marine ecology. Coastal marine ecology was assessed by monitoring intertidal rocky reefs (hard-shore) and estuarine (soft-shore) habitats.

22. The estuarine health SEM component ran from 1996 until 2013, at which time it was deemed to be no longer fit for purpose and was discontinued.

23. A review of the estuarine SEM programme was completed in 2016, which recommended that a baseline survey of the region's estuaries be undertaken. The purpose of this recommendation was to gather information on all of the region's estuaries and, subsequently, inform where ongoing monitoring was most needed.

24. An Estuarine Vulnerability Assessment (EVA), offered by Robertson Environmental Limited was identified as a baseline survey methodology that would provide the information necessary to inform an ongoing Estuarine SEM programme.

25. Father and son, Dr Barry and Dr Ben Robertson, are the two directors at Robertson Environmental Limited. They have both been involved in similar vulnerability assessments in the Southland, Greater Wellington, Tasman, Manawatu-Whanganui and Nelson regions, and have developed the NZ Estuary Trophic Index (ETI) toolbox.

26. It was not feasible for the EVA to cover all of the region's coastal water bodies (hydrosystems) given that there are 217 parent catchments in Taranaki. Therefore, a shortlist of 20 sites was formulated, including all of the region's estuaries and a selection of regionally representative stream mouths where tidal intrusion was limited but may occasionally occur.

27. Robertson Environmental Limited were subsequently commissioned to undertake an EVA covering the 20 selected sites with the field work component taking place between 26 February and 4 March 2019.

28. The EVA report was finalised in August 2019.

Discussion

29. An estuary can be defined as a semi enclosed body of water which may be always open to the sea (or intermittently open) and within which there are variations in salinity due to the interactions between seawater and freshwater (Robertson et al. 2002, Pritchard 1967).
30. There are a number of small estuaries (<500ha) at the mouths of Taranaki's larger rivers. Due to the gradient and geology of the ring plain, this stretch of the coast lacks any extensive estuarine environments, instead the region's larger estuaries are located further north and south. These estuaries are well flushed, with a high freshwater input/ area ratio and relatively little diversity in the way of intertidal and subtidal habitats.
31. Under the New Zealand Coastal Hydrosystem Typography (Hume et al., 2016), the estuaries in Taranaki are all classified as tidal river mouths. The remaining coastal hydrosystems found around the Taranaki coastline largely consist of freshwater river mouths and beach stream mouths.
32. The scope of the EVA was to include the tidal river mouths within the Taranaki region. To achieve this, an initial survey was carried out to formulate a list of sites to be included in the assessment.
33. In the end, the final 20 sites that were put forward for the EVA not only included the region's larger estuaries located north and south of the ring plain, but also a number of smaller stream mouths where tidal intrusion was limited but may occasionally occur. Including this wide range of estuaries allowed the assessment to better represent the region. The estuaries included in the EVA, listed in descending order of catchment size, are as follows: Waitotara, Waitara, Patea, Whenuakura, Tangahoe, Tongaporutu, Waingongoro, Waiongana, Kaupokonui, Waiwhakaiho, Mimi, Urenui, Mohakatino, Manawapou, Onaero, Oakura, Tapuae, Timaru, Te Henui, Katikara.
34. The EVA focused on two major issues facing New Zealand estuaries, sedimentation and eutrophication. Increased sedimentation (deposition of terrestrial sediment) in estuaries can lead to significant adverse impacts on their ecology and amenity. These effects include, but are not limited to, the loss of natural estuarine habitats and a shift in benthic infaunal communities (to the detriment of important kai moana species). Eutrophication refers to the adverse consequences of increased growth of phytoplankton and/or macroalgal species driven by increased nutrient availability. Eutrophic conditions interfere with natural ecological processes in estuaries by significantly affecting sediment and water quality. Eutrophication can also detract from the amenity of estuaries due to visual effects and odour issues.
35. The EVA produced three main outputs for each estuary: a habitat map, a vulnerability rating (including a condition assessment), and monitoring recommendations.
36. Habitat maps were produced during field surveys at each estuary to document the dominant estuary features (e.g. substratum, vegetation, etc.). These maps provide a baseline to measure broad scale changes against in the future. The information recorded in this survey is also used to inform the estuarine condition assessments (described in the next paragraph). Following these field surveys, all 20 estuaries were classed as Shallow, Short Residence Time Tidal River Estuaries (SSRTREs) based on ETI Tool 1 (Robertson et al. 2016).
37. An overall vulnerability rating was assigned, by assessing the susceptibility and current condition of each estuary with respect to sedimentation and eutrophication state and

potential. The susceptibility to sedimentation and eutrophication was assessed using catchment and land use information, as well as physical and hydrological attributes of the estuary. The current condition of each estuary was determined with the field surveys, where relevant synoptic variables were measured in order to determine the estuary's sedimentation and eutrophication status at that point in time. Together, these assessments produced an overall vulnerability rating for the estuary.

38. The vulnerability rating was used to inform future monitoring recommendations. Where an estuary's overall vulnerability was minimal to moderate, it was recommended that synoptic (screening level) monitoring be completed only every 10 years. Where an estuary's overall vulnerability was found to be moderate to high, more intensive monitoring was deemed appropriate. This monitoring would entail five yearly 'broad-scale' (habitat mapping) surveys which focus on changes in dominant estuary features or habitats. Three years of annual 'fine-scale' surveys, which assess the baseline condition of intertidal sediment through various physical, chemical and biological indicators, were also recommended for the moderate to highly vulnerable estuaries. Where eutrophication symptoms were present, or highly likely to occur, eutrophication targeted monitoring was recommended, consisting of monthly water sample collection through the summer period when eutrophication risk is greatest.

39. The field component of the EVA was carried out between 26 February and 4 March 2019 and the final report was produced in August 2019. The key findings of the assessment are discussed below.

40. Where the vulnerability of an estuary was moderate to high, this was largely due to the effects of sedimentation rather than eutrophication. This was the case for seven of the 20 estuaries included in the assessment (i.e. Mohakatino, Tongaporutu, Urenui, Mimi, Waitara, Patea and Waitotara). Vulnerability to sedimentation was generally attributed to high sediment loads, and the high areal coverage of soft mud in the estuary recorded during the condition assessment. On the contrary, eutrophication was considered less of an issue in these estuaries due to them being well flushed, with no primary symptoms being identified during the condition assessments (i.e. macroalgae and/or phytoplankton blooms).

41. Two estuaries, Oakura and Katikara, were rated moderate to highly vulnerable to eutrophication effects. These were the only two estuaries where symptoms of eutrophication, in the form of phytoplankton blooms, were recorded. It should be noted that these observations were made during worst case conditions (i.e. low river flows, restricted stream mouths). Other estuaries were considered susceptible to eutrophication where they had large intertidal areas (to facilitate macroalgal blooms), high catchment nutrient loads, and where they were poorly flushed or restricted at the mouth.

42. Out of the 20 estuaries that were assessed, the EVA recommended that 10 receive synoptic monitoring only, seven receive broad and fine scale monitoring, and three receive monitoring targeting the potential water quality drivers of eutrophication for three years, followed by a review.

43. Synoptic monitoring was recommended for the Onaero, Waiongana, Waiwhakaiho, Te Henui, Tapuae, Timaru, Kauopokonui, Waingongoro, Tangahoe and Manawapou Estuaries.

44. Broad and fine scale monitoring was recommended for the Mohakatino, Tongaporutu, Mimi, Urenui, Waitara, Patea and Waitotara Estuaries.

45. Eutrophication targeted monitoring was recommended for the Oakura, Katikara and Whenuakura Estuaries.

46. It should be noted that catchment land use, nutrient and sediment load, and hydrological models have been factored into this assessment to determine estuary susceptibility to sedimentation and eutrophication. These models are associated with varying degrees of accuracy. Furthermore, the condition assessments involved discrete sampling measurements and observations that were representative of a single point in time. For these reasons, this EVA should not be interpreted as a complete and comprehensive assessment of the issues facing Taranaki estuaries. Instead, the purpose of the EVA was to screen the estuaries to identify which ones were susceptible to, or are currently experiencing issues related to sedimentation and/or eutrophication. Ongoing SEM monitoring will provide a more detailed assessment of estuarine health going forward.

47. When reviewing the results of this assessment, it is also important to consider what the natural (pre-human) state of these estuaries would have looked like. Although the EVA incorporates catchment information and nutrient and sediment loads, which represent changes from the pre-human era, it does not deduce what the condition of each estuary once was, nor what it should or could be. It is generally understood that following the geological formation of an estuary, it begins to infill with terrestrial sediment. Depending on the age and physical attributes of the estuary, and the adjacent coastal and catchment processes, it will contain a varying proportion of marine and terrestrial sediments. Given this, it may be possible for estuaries in catchments with highly erodible terrain and geology, to have a muddier pre-human baseline state, than estuaries in catchments with contrasting attributes. In Taranaki, eastern hill country catchments are typified by their erodible terrain and geology, therefore, these estuaries potentially contained an elevated level of sediment before human arrival and intervention (e.g. land clearance). There are methods available to investigate historical sedimentation rates in estuaries (e.g. Hunt 2019), and it may be worth doing so. This is because it is important to understand what the natural state of these ecosystems may have looked like, especially within the context of what the estuarine ecosystem values are that the community would like to maintain or enhance, and what outcomes are possible with policy interventions.

48. Finally, it was outside of the scope of the EVA to consider the effects of nutrient and sediment loads on the near shore coastal environment adjacent to these estuaries. This is another line of enquiry to investigate in the future, given the value of near shore coastal water quality and habitats in Taranaki.

49. It may be noted that Council officers are currently in discussions with academic researchers over a possible major reef and near-shore research proposal, which would shed light on these additional questions.

Decision-making considerations

50. Part 6 (Planning, decision-making and accountability) of the *Local Government Act 2002* has been considered and documented in the preparation of this agenda item. The recommendations made in this item comply with the decision-making obligations of the *Act*.

Financial considerations—LTP/Annual Plan

51. This memorandum and the associated recommendations are consistent with the Council's adopted Long-Term Plan and estimates. Any financial information included in this memorandum has been prepared in accordance with generally accepted accounting practice.

Policy considerations

52. This memorandum and the associated recommendations are consistent with the policy documents and positions adopted by this Council under various legislative frameworks including, but not restricted to, the *Local Government Act 2002*, the *Resource Management Act 1991* and the *Local Government Official Information and Meetings Act 1987*.

Iwi considerations

53. This memorandum and the associated recommendations are consistent with the Council's policy for the development of Māori capacity to contribute to decision-making processes (schedule 10 of the *Local Government Act 2002*) as outlined in the adopted long-term plan and/or annual plan. Similarly, iwi involvement in adopted work programmes has been recognised in the preparation of this memorandum.

Legal considerations

54. This memorandum and the associated recommendations comply with the appropriate statutory requirements imposed upon the Council.

Appendices/Attachments

Document 2347096: Taranaki Regional Estuaries - Ecological Vulnerability Assessment

Hume, T., Gerbeaux, P., Hart, D. E., Kettles, H., & Neale, D. (2016). A classification of New Zealand's coastal hydrosystems.

Hunt, S. (2019). Summary of historic estuarine sedimentation measurements in the Waikato region and formulation of a historic baseline sedimentation rate. Waikato Regional Council Technical Report 2019/08.

Robertson, B. M., Gillespie, P. A., & Asher, R. A. (2002). Estuarine environmental assessment and monitoring: a national protocol. Cawthron Institute.

Robertson, B.M., Stevens, L.M., Robertson, B.P., Zeldis, J., Green, M., Madarasz-Smith, A., Plew, D., Storey, R., Hume, T. and Oliver, M. 2016a. NZ Estuary Trophic Index. Screening Tool 1. Determining eutrophication susceptibility using physical and nutrient load data. Prepared for Envirolink Tools Project: Estuarine Trophic Index MBIE/NIWA Contract No: C01X1420. 47p.

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Taranaki Regional Estuaries

Ecological Vulnerability Assessment

For Taranaki Regional Council

July 2019

REPORT INFORMATION & QUALITY CONTROL

Prepared for:	Taranaki Regional Council C/- Thomas McElroy, Environmental Scientist - Marine Biology

Authors:	Dr Ben Robertson Principal Consultant, Director
Internal Reviewer:	Dr Barry Robertson Technical Advisor, Director

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- **Ben Robertson** (Principal Consultant, Director)
  BSc (Hons), PhD
- **Jodie Robertson** (Senior Consultant, GIS Tech)
  BSc, PG Dip, MSc
- **Barry Robertson** (Technical Advisor, Director)
  BSc, Dip Sci, PhD
- **Julian Goulding** (Technical Officer, Skipper)
  BComm, Master 3000 Gross Tonnes

151 Awa Awa Road
Tasman 7173
Phone: +64 27 823 8665
robertsonenvironmental.co.nz

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Executive Summary

Robertson Environmental Limited has been engaged by Taranaki Regional Council (TRC) to undertake the vulnerability assessment of twenty estuaries in the Taranaki Region in relation to the key coastal issues of eutrophication (excessive nutrients) and sedimentation (excessive muddiness), and to use the resulting information to inform long-term estuary monitoring recommendations.

The purpose of the assessment was to characterise each estuary's current ecological condition in relation to eutrophication and sedimentation, and compare the findings with relevant national standards (NZ Estuary Trophic Index, NZ ETI), to provide recommendations regarding future monitoring priorities at a regional scale. The fieldwork was undertaken in February 26th - 4th March 2019, and the results, overall vulnerability ratings, and monitoring recommendations are outlined below (see summary table on next page).

Estuary Vulnerability to Eutrophication and Sedimentation

As is characteristic of estuaries on the West Coast of NZ, all twenty of the Taranaki Region estuaries assessed were shallow, short residence time, tidal river estuaries (SSRTREs), each variable in size and partially separated from the sea by a range of physical features. The results showed that each estuary fits into one of four sub-types (based on physical attributes and freshwater inflows), each with different vulnerabilities to nutrients and fine sediment and therefore long-term monitoring requirements, as follows:

Estuary Type 1. Short length, low flow SSRTREs - <1 km long, beach located, low freshwater inflows (<1 m^3 s^{-1}), mouth sometimes restricted/closed. Taranaki Region estuaries that fit into this sub-group included Tapuae, Timaru, Te Henui, and Katikara Estuaries.

- **Physical characteristics:** Very short length, often beach located SSRTREs consist of relatively narrow channels situated between the upper edge of the beach and the tidal level. In some situations the channel meanders along the back of the beach for a small distance before entering the sea, whereas in others the discharge path is more direct. A few expand into small lagoons around the upper high water area. In very high tides and storm surges, saline water enters the stream inland of the beach for a small distance. At times the mouth is often restricted and can sometimes close for short periods, during which time the upper beach lagoon may expand and show eutrophication/sedimentation symptoms.
- **Overall vulnerability:** With the exception of Katikara Estuary, which was shown to be highly vulnerable to eutrophication impacts, Type 1 estuaries were the least vulnerable of the Taranaki Region estuaries to eutrophication and sedimentation. The main reason for this was their small size, comparatively low ecological diversity, and regular periods of high flushing (even though some examples experience periodic mouth closure/restriction). Consequently, although estimated nutrient and sediment loads to the estuaries were generally large, they are unlikely to be subjected to prolonged periods of eutrophication and muddiness. Synoptic surveys of this estuary type in Feb/March 2019 confirmed the absence of symptoms of eutrophication (i.e. opportunistic macroalgal and/or phytoplankton blooms) or sedimentation (extensive areas of soft muddy sediments), while Katikara Estuary had phytoplankton issues as indicated by highly elevated chlorophyll *a* concentrations throughout the subtidal channel habitat.

Estuary Type 2. Moderate length, low flow SSRTREs - 1-3 km long, low freshwater inflows (<2 m^3 s^{-1}), mouth sometimes restricted/closed. Taranaki Region estuaries that fit into this sub-group included Waiongana, Mimi, Manawapou, Onaero, Waingongoro, Kaupokonui, and Oakura Estuaries.

- **Physical characteristics:** Moderate length SSRTREs consist of relatively narrow channels situated between the tidal level and approximately 1-3 km inland. In some situations the channel meanders along the back of the beach for a distance before entering the sea, whereas in others the discharge path is more direct. A few expand into small lagoons around the upper high water area. The estuary mouth is generally open to the sea but in others it is often closed (e.g. Onaero Estuary).

Summary of NZ ETI-based susceptibility, current condition and overall vulnerability ratings, and monitoring recommendations, for twenty Taranaki Region estuaries, 2019. * See further details in 'Estuary Monitoring Recommendations' below.

Sub-Type[1]	Estuary	Coastal Stressor				Overall Vulner-ability	Recommended Monitoring*	Monitoring Frequency
		Sedimentation		Eutrophication				
		Suscepti-bility	Current Condition (2019)	Suscepti-bility	Current Condition (2019)			
SSRTRE Type 1	Tapuae	Moderate	Moderate	Minimal	Minimal	Moderate	Synoptic monitoring only	10-yearly
	Timaru	Moderate	Moderate	Minimal	Minimal	Moderate		
	Te Henui	Moderate	Moderate	Minimal	Minimal	Moderate		
	Katikara	Moderate	Moderate	Moderate	High	Mod-High	Eutrophication-targeted monitoring	Annually
SSRTRE Type 2	Waiongana	Moderate	Moderate	Minimal	Minimal	Moderate	Synoptic monitoring only	10-yearly
	Mimi	Mod-High	Very High	Very High	Moderate	High	Broad- & fine-scale monitoring	3-year baseline, 5-yearly
	Manawapou	Moderate	Moderate	Minimal	Minimal	Moderate	Synoptic monitoring only	10-yearly
	Onaero	Moderate	Moderate	Minimal	Moderate	Moderate		
	Waingongoro	Moderate	Minimal	Minimal	Minimal	Minimal		
	Kaupokonui	Moderate	Moderate	Minimal	Minimal	Moderate		
	Oakura	Moderate	Moderate	Moderate	High	Mod-High	Eutrophication-targeted monitoring	Annually
SSRTRE Type 3	Tangahoe	Moderate	Moderate	Minimal	Minimal	Moderate	Synoptic monitoring only	10-yearly
	Urenui	Mod-High	Very High	Very High	Moderate	High	Broad- & fine-scale monitoring	3-year baseline, 5-yearly
	Mōhakatino	Mod-High	Very High	Moderate	Moderate	High		
SSRTRE Type 4	Waitotara	Mod-High	Very High	Minimal	Minimal	Mod-High		
	Waitara	Mod-High	Very High	Minimal	Moderate	Mod-High		
	Patea	Mod-High	Very High	Very High	Moderate	High		
	Whenuakura	Moderate	Moderate	Very High	Minimal	Mod-High	Eutrophication-targeted monitoring	Annually
	Tongaporutu	Mod-High	Very High	High	Moderate	High	Broad- & fine-scale monitoring	3-year baseline, 5-yearly
	Waiwhakaiho	Moderate	Moderate	Minimal	Minimal	Moderate	Synoptic monitoring only	10-yearly

- **Overall vulnerability:** Type 2 estuaries which had excessive nutrient/sediment loads and whose mouths were mostly closed (and therefore very poorly flushed) were identified as moderately to highly vulnerable. Those that had excessive nutrient/sediment loads but were mostly open to the sea were rated as moderately vulnerable. When nutrient/sediment loads were low and estuaries were open to the sea, estuaries had minimal vulnerability. Characteristic symptoms of eutrophication were opportunistic macroalgal blooms and/or elevated chlorophyll *a* symptomatic of phytoplankton blooms, with symptoms of sedimentation being extensive areas of soft fine muddy sediments. The expression of such symptoms was variable because of the flushing regime - being highly flushed during high flow events, and poorly flushed during summer low flows when their mouths become restricted and the upstream waters stratify. This meant that under high nutrient/sediment loads, the estuaries were likely to exhibit eutrophication and muddiness symptoms only during periods of mouth constriction and/or poor flushing.

Estuary Type 3. Long length, moderate flow SSRTREs - 3-12 km long, moderate freshwater inflows (4-6 $m^3 s^{-1}$), mouth always open. Taranaki Region estuaries that fit into this sub-group included Tangahoe, Urenui, and Mōhakatino Estuaries.

- **Physical characteristics**: Long SSRTREs, with moderate freshwater inflows and mouths always open, consist of a relatively narrow channel that extends inland for approximately 3-12 km. In some situations the channel meanders along the back of the beach for a distance before entering the sea, whereas in others the discharge path is more direct.
- **Overall vulnerability**: Type 3 estuaries all had moderate-high vulnerability (apart from Tangahoe Estuary), primarily reflecting their high sediment loads and soft mud habitat. The main reason for the moderate eutrophication rating was that, for estuaries where the nutrient load was excessive, the estuary was likely to oscillate between low and moderate-high levels of eutrophication; i.e. low levels of eutrophication and sedimentation in winter, and immediately during and following high flow events in the warmer months, and moderately eutrophic conditions with some sedimentation during summer base-flow conditions. This latter situation arises from the extensive estuary length and moderate freshwater inflow, which means that the residence time for water and nutrients is sufficient to allow for phytoplankton blooms under baseflow conditions (given that the time taken for a parcel of water to travel the length of the estuary under baseflow is ~1-3 days for these estuaries).

Estuary Type 4. Long length, high flow SSRTREs - 3-12 km long, high freshwater inflows (7-220 $m^3 s^{-1}$), mouth always open. Taranaki Region estuaries that fit into this sub-group included Waitotara, Waitara, Patea, Whenuakura, Tongaporutu, and Waiwhakaiho Estuaries.

- **Physical characteristics**: Long SSRTREs, with high freshwater inflows and mouths always open, consist of relatively narrow channels situated between the tidal level and approximately 3-12 km inland. In some smaller estuaries the channel meanders along the back of the beach for a distance before entering the sea, whereas in others the discharge path is more direct. Some of the smaller estuaries expand into lagoons around the upper high water area. In the larger examples (e.g. Tongaporutu, Waitara and Patea Estuaries), significant areas of intertidal flats are found in the mid-lower estuary.
- **Overall vulnerability**: Most of the Type 4 estuaries had high overall vulnerability. This rating reflects their high nutrient/sediment loads and, in most cases, significant intertidal habitat already affected by sedimentation (extensive areas of soft muddy sediments), despite the fact that flushing in these estuaries was found to be high, even during summer low flows (a consequence of the high freshwater inflows, extensive tidal intrusion, mouths always open and narrow channels). Although synoptic surveys of each estuary in March 2019 generally indicated the absence of symptoms of eutrophication (i.e. opportunistic macroalgal and/or phytoplankton blooms), eutrophic susceptibilities remain high for several of these long length/high flow systems. It is also noted that the vulnerability of the inshore coastal habitats from the river plumes of these large estuaries has not been assessed in this report, given it was outside the study brief.

We note that field survey results of conditions within Mimi, Urenui, Patea and Whenuakura estuaries ranged from minimal to moderate with respect to eutrophication status. However, these condition ratings did not reflect their very high susceptibility ratings (based on catchment nutrient loading and specified physical attributes), despite the survey being carried out towards the end of summer following a sustained period of warm weather and low river flows, i.e. during a high risk period for eutrophication to occur. The prevention of primary eutrophication symptoms in these very highly susceptible estuaries was likely attributable to other less well-understood factors (discussed further in the body of this report). Therefore further fine scale monitoring is recommended to better understand, characterise and manage these systems in relation to eutrophication (and sedimentation) impacts.

Finally, catchment land use and hydrological models have been factored into this assessment which are associated with varying degrees of accuracy. For this reason and others listed in Section 7, the work presented here should not be interpreted as a complete and comprehensive assessment of the issues facing Taranaki estuaries. Rather, this is a screening level assessment for the purpose of identifying estuaries which are vulnerable to, or are currently experiencing, issues related to sedimentation and/or eutrophication. Recommendations for future monitoring are made within this report which allow for more detailed assessments of the state and trend of estuarine health in the region.

Estuary Monitoring Recommendations

To maintain the value of the twenty surveyed Taranaki Region estuaries, and to ensure sufficient information is available to manage each in relation to the identified vulnerability to eutrophication and sedimentation, long-term monitoring is recommended for each estuary below.

For Tongaporutu, Mimi, Urenui, Mōhakatino, Waitotara, Waitara and Patea Estuaries, all with significant intertidal and subtidal habitat comprising poorly flushed/muddy substrata, moderate-high nutrient/sediment loads and high human use and cultural/ecological values, the following four components are recommended:

- **Broad scale habitat mapping** to document dominant estuary features (e.g. substratum, seagrass, saltmarsh, macroalgae) and monitor changes over time. It is typically repeated at 5-yearly intervals;
- **Fine scale monitoring** measures the condition of representative intertidal sediments (usually the dominant substrata type as well as deposition zones where sedimentation and eutrophication symptoms are more likely to be expressed) and subtidal channel habitat using a suite of physical, chemical and biological indicators. It is undertaken once annually for three consecutive years during the period Nov-March (usually at 2 intertidal and 3-4 subtidal sites), and thereafter at 5-yearly intervals;
- **Annual sedimentation rate (including grain size) monitoring** measures sedimentation trends within the estuary over time. Sediment plates should be deployed and monitored annually as per Hunt (2019);
- **High level data on dominant changes in catchment landuse** to track changes in high risk activities (e.g. land disturbance, point source discharges), and facilitate estimates of changes to naturally occurring catchment inputs of sediment, nutrients and other stressors (e.g. pathogens) likely from human influenced land disturbance.

For Katikara, Oakura and Whenuakura Estuaries, where overall eutrophication vulnerability is high, it is recommended that:

- **Annual monitoring of targeted eutrophication indicators** (intertidal and subtidal channel) be undertaken to provide data on long-term trophic state trends. To address potential for eutrophication, it is recommended that relevant water column and sediment-based indicators be monitored monthly during the period Nov-March each year at 1-2 sites representative of general conditions (e.g. mid-upper estuary) and at the same time, intertidal/shallow subtidal

- macroalgal cover be assessed throughout the intertidal/shallow subtidal estuary. This monitoring may cease if, after 1-2 years, eutrophication is not found to be a persistent issue in the estuaries. Because these estuaries are generally flushed regularly by high flow events, it is recommended that long-term monitoring for sedimentation be limited to low frequency (5-yearly), broad scale, screening level assessments only.

For Tapuae, Timaru, Te Henui, Waiongana, Manawapou, Onaero, Waingongoro, Kaupokonui, Tangahoe and Waiwhakaiho Estuaries, all of which had very low overall vulnerabilities to both sedimentation and eutrophication, we recommend:

- **Low frequency, screening level monitoring only**. To address the low potential for eutrophication/sedimentation issues (including both benthic and water column effects), it is recommended that low frequency (once every 10 years), screening level (synoptic) monitoring be undertaken to confirm that these low risk estuaries have not changed their vulnerability ratings.

The monitoring proposed, based on the NEMP framework, has been successfully applied to establish estuary monitoring priorities throughout NZ, and underpins the NZ ETI. Adopting a nationally consistent approach ensures the TRC benefit directly from work undertaken in other regions, as well as from established tools and existing national data, indicators and thresholds.

1 Introduction

1.1 Project Brief and Scope

Gathering information to inform the assessment of effects on the coastal environment is implicit in New Zealand's legislation for sustainable management. A key mechanism in this process is to undertake estuary vulnerability assessments, which are designed to consistently and transparently assess the vulnerability of estuaries in the region to major coastal issues (see Appendix A), to identify appropriate monitoring design, and guide management.

Recently, Taranaki Regional Council (TRC) contracted Robertson Environmental Limited to identify the habitat vulnerability and monitoring priorities associated with the key estuarine issues of eutrophication (excessive nutrients) and sedimentation (excessive muddiness) for estuarine ecological resources in the Taranaki Region using a similar approach to that recently used in the coastal vulnerability assessments in the Southland, Greater Wellington, Tasman, Manawatu-Wanganui and Nelson regions (Robertson and Stevens 2007a, 2007b, 2007c, 2008, 2012, 2016, 2017) and in the NZ Estuary Trophic Index (ETI) toolbox (Robertson et al. 2016a,b). The following report targets 20 estuaries in the Taranaki Region (Figure 1) and includes three main components which produce the following outputs:

- Estuarine Habitat Maps: An ArcMap GIS dataset depicting current broad-scale habitat and substrata types within each estuary, using aerial photographs and ground truthing techniques (e.g. Robertson 2019). Habitat and substrata maps for 20 estuaries are presented in the main document (also provided to TRC as electronic GIS files).
- Vulnerability Assessments: An assessment of the "vulnerability" and "existing condition" of the estuarine habitats to key estuarine issues of eutrophication and sedimentation using the recently developed NZ Estuary Trophic Index (ETI) toolbox (Robertson et al. 2016a,b).
- Monitoring Priorities: A recommended monitoring programme designed to track long-term changes in estuary condition and guide appropriate management in relation to these key issues in a stageable, cost effective and defensible manner.

1.2 Report Structure

The current report presents a brief overview of the scope and structure of the study (Section 1.1), methods used for the habitat mapping, vulnerability assessments and for identifying monitoring recommendations (Section 2), summary detail for each estuary, including their characteristics, values and uses, vulnerabilities to eutrophication and sedimentation, existing condition and recommended monitoring (Section 3), and an estuary-specific overview of the vulnerability assessment results (Section 4) and monitoring recommendations (Section 5).

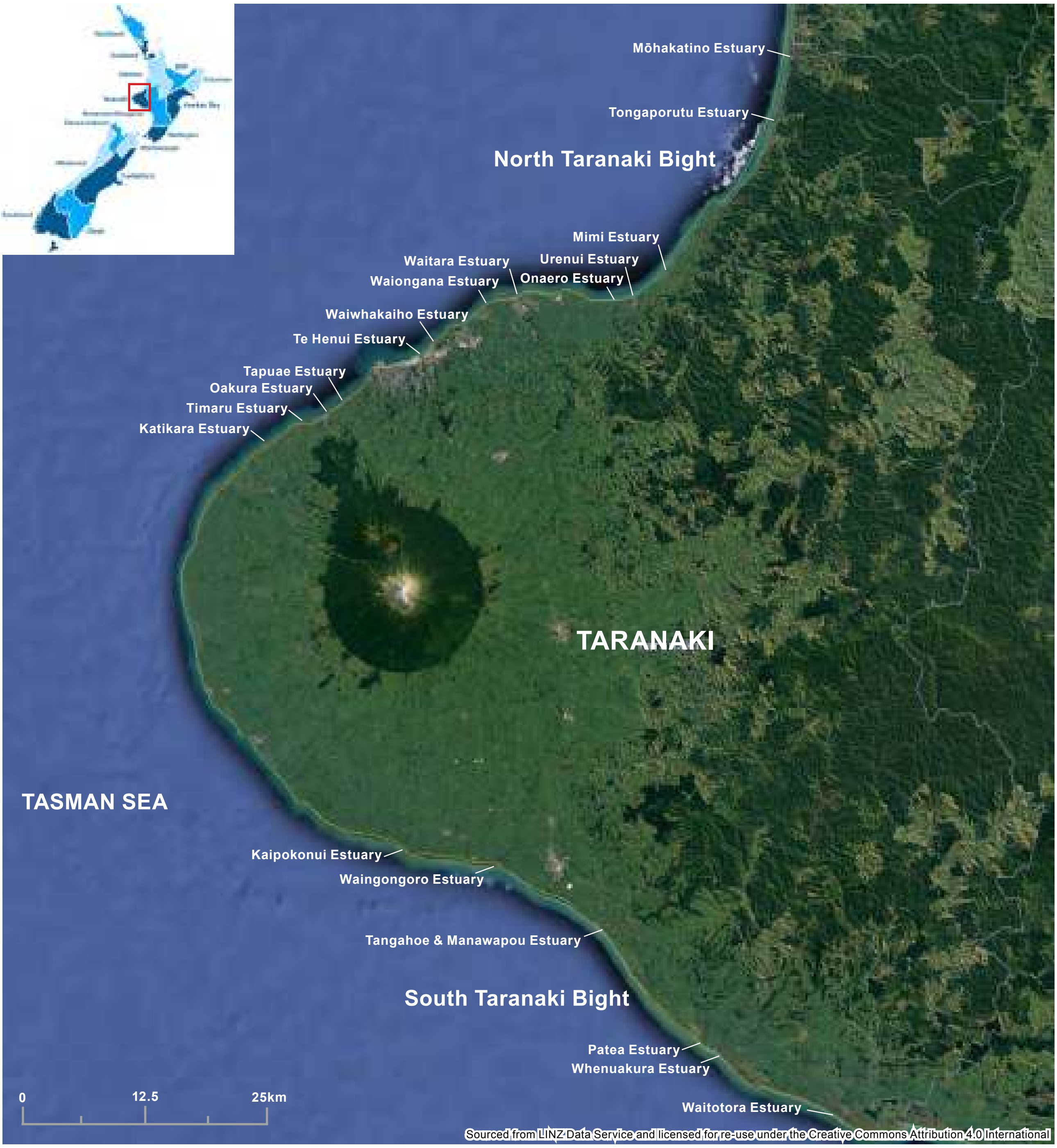


Figure 1. Taranaki Region, including locations of 20 estuaries assessed in the present study.

2 Assessment Methodology

2.1 Vulnerability Assessments and Monitoring Recommendations

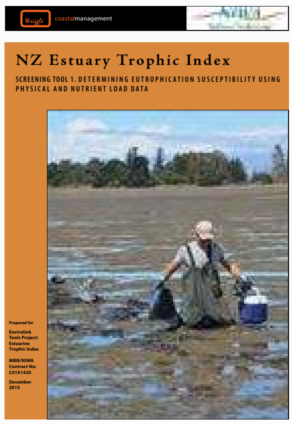
The Taranaki Region Estuary Vulnerability Assessment (EVA) follows the NZ Estuary Trophic Index (ETI) approach (Robertson et al. 2016a,b) (see summary inset below), which is designed to be used by experts to represent how estuarine ecosystems are likely to react to the effects of excessive nutrients and fine sediment, and how to monitor and assess their existing level of eutrophication and sedimentation. A summary outline of the approach used for the Taranaki Region EVA is presented in Figure 2, with a detailed step-wise outline of the methods presented in Section 2.2. For each estuary, a final matrix used for recording the findings for each of the key steps is presented in Appendix C.

Summary of NZ Estuary Trophic Index (ETI) Tool

The NZ ETI is a stand-alone, hard-copy methodology that includes two sets of tools that provide screening guidance for assessing where an estuary sits in the eutrophication (and associated sedimentation) gradient, what is required to shift it to a different location in the gradient, and which indicators are required for monitoring. Each tool is presented in a separate report with supporting appendices. Although the ETI focuses on the issue of eutrophication, it includes relevant thresholds for determining the influence of fine sediments on estuary condition, in particular, sedimentation rate and area (spatial extent) of soft muds.

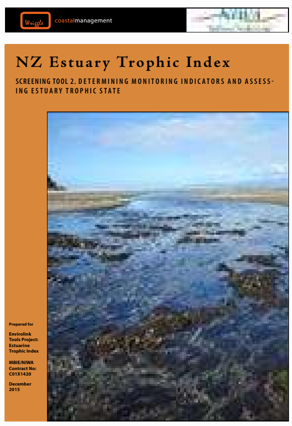
Screening Tool 1. Physical and Nutrient Susceptibility Tool

This method is designed to provide a relatively robust and cost effective approach to enable the prioritisation of estuaries for more rigorous monitoring and management. It applies a desktop susceptibility approach that is based on estuary physical characteristics, and nutrient input load/estuary response relationships for key NZ estuary types. The tool produces a single physical susceptibility score that can be used to classify either the physical susceptibility (i.e. very high, high, moderate, low susceptibility), and/or be combined with nutrient load data to produce a combined physical and nutrient load susceptibility rating. Nutrient areal load/trophic state bands for each estuary eutrophication type will be developed as a long-term goal, with data currently available for some estuary types, but not all as yet. This section also provides guidance on the use of a simple load/response model tool provided in the ETI toolbox, and recommendations for the use of more robust approaches for setting load limits. [*Note recent extensions to Tool 1 (Plew et al. under review) have also been employed to determine estuary eutrophic susceptibility in this report*].



Screening Tool 2. Trophic Condition Assessment Tool

This tool is a monitoring approach that characterises the ecological gradient of estuary trophic condition for relevant ecological response indicators (e.g. macroalgal biomass, dissolved oxygen), and provides a means of translating these ratings into an overall estuary trophic condition rating/score (the ETI). It provides guidance on which condition indicators to use for monitoring the various estuary types (and why they have been chosen), and on assessing the trophic state based on the indicator monitoring results and their comparison to numeric impairment bands (e.g. very high, high, moderate, low). The latter involves measurement of the expression of both primary (direct) eutrophication symptoms (e.g. macroalgae phytoplankton) and supporting indicators for secondary (indirect) symptoms of trophic state.



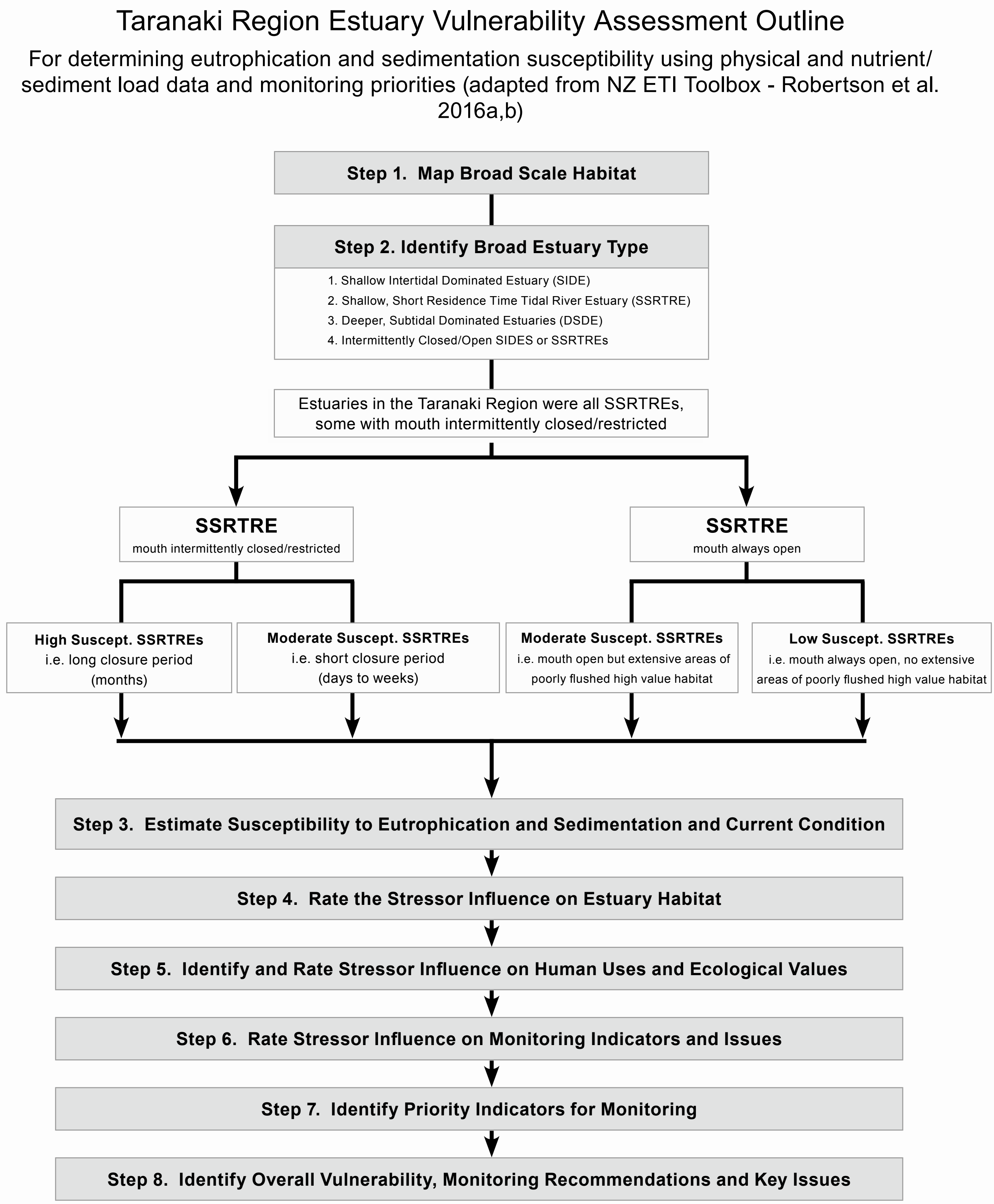


Figure 2. Flow diagram outlining the procedure used to assess the eutrophic and sedimentation susceptibility of estuaries and provide monitoring recommendations in the present report. Note: estuary-specific vulnerability matrices (including NZ ETI Tool 1 & Tool 2 outputs) are presented in Appendix C.

2.2 Summary of the steps used in the Taranaki Region Estuary Vulnerability Assessment

Step 1: Generate Broad Scale Estuary Habitat Maps

In order to identify habitats in Taranaki Region estuaries, broad scale mapping based on the National Estuarine Monitoring Protocol - NEMP (Robertson et al. 2002) was used to record the primary habitat features at a structural class level e.g. vegetation: saltmarsh, seagrass, macroalgae, and substrata: mud, sand, cobble, rock. Features were ground-truthed on 1:2,000, 0.3 m pixel^{-1}, colour aerials flown in summer 2016-18 and provided by LINZ (http://data.linz.govt.nz/layer/99140) and digitised into ArcMap 10.5 to produce GIS maps of dominant intertidal substrata, saltmarsh, and seagrass (*Zostera* spp. or *Ruppia* spp.).

Estuaries were mapped from a 120^{o} angle from the low tide channel entering the sea to the upper extent of saline intrusion (directly measured or where inaccessible estimated based on the presence of salt intolerant plants).

Appendix D lists the class definitions used to classify estuarine substrata and vegetation. Substrata were mapped separately, with the total area of soft mud used as a primary indicator of fine sedimentation impacts, and seagrass and macroalgae were assessed using measures of biomass and percentage cover, as described in the ETI (Robertson et al. 2016a,b) and elsewhere (e.g. Robertson 2019). Broad scale habitat features were digitised into ArcMap 10.5 shapefiles, and combined with field notes and georeferenced photographs to produce habitat maps showing the dominant cover of: substrata (e.g. mud, sand, cobble, rock), macroalgae (e.g. *Ulva* spp., *Gracilaria* spp.), seagrass, and saltmarsh vegetation. These broad scale results are summarised in Section 3, with the supporting GIS files (supplied as a separate electronic file) providing a more detailed data set designed for easy interrogation to address specific monitoring and management questions.

Step 2: Identify Estuary Type

Susceptibility to eutrophication and sedimentation in estuaries is influenced by specific physical modifying characteristics including dilution, flushing, residence time, depth and intertidal extent.

The ETI adopted a simple four category typology (described further in Table 1) specifically suited to the assessment of estuarine eutrophication susceptibility in NZ (an adaptation of the more detailed New Zealand Coastal Hydrosystems Typology, Hume 2016), as follows:

1. Shallow intertidal dominated estuaries (SIDEs);
2. Shallow, short residence time tidal river and tidal river with adjoining lagoon estuaries (SSRTREs);
3. Deeper subtidal dominated, longer residence time estuaries (DSDEs);
4. The ETI classed SIDEs and SSRTREs whose mouths intermittently close for short or long periods as ICOLLs (intermittently closed/open lakes and lagoons estuaries), but ICOLLs are more accurately sub types of SIDEs and SSRTREs.

The results of the broad scale assessment indicated that all the Taranaki Region estuaries assessed were SSRTREs, some of which have intermittently open/closed mouths, and that they could be grouped in the following four sub-types (further details in Appendix B):

- **Type 1**: Short length, low flow SSRTREs: <1 km long, beach located, low freshwater inflows (<1 m^{3} s^{-1}), mouth sometimes restricted/closed;
- **Type 2**: Moderate length, low flow SSRTREs: 1-3 km long, low freshwater inflows (<2 m^{3} s^{-1}), mouth sometimes restricted/closed;
- **Type 3**: Long length, moderate flow SSRTREs: 3-12 km long, moderate freshwater inflows (4-6 m^{3} s^{-1}), mouth always open;
- **Type 4**: Long length, high flow SSRTREs: 3-12 km long, high freshwater inflows (7-220 m^{3} s^{-1}), mouth always open.

Because freshwater inflow is considered a stronger determinant of an estuary's vulnerability to catchment sediment and nutrient loads than its length (e.g. Plew et al. 2018), the sub-typing of estuaries was weighted towards freshwater inflow.

Step 3: Assess Key Stressor Influence Based on Magnitude, Existing Condition and Susceptibility

Eutrophication of shallow SSRTREs in NZ is a process driven by the enrichment of water by nutrients, especially compounds of nitrogen (N) and, to a lesser extent, phosphorus (P), whereas sedimentation is a process driven by the enrichment of water by sediments, especially fine sediments (i.e. muds). Because fine sediments often contain elevated nutrients, the two issues of eutrophication and sedimentation are generally interlinked. Catchment inputs are the primary source of nutrients and fine sediments and, if individually present in excess, they result in ecological degradation, which is exacerbated when they occur together (e.g. muddy, nutrient-rich sediments leads to lower pore water exchange, increased sediment bound nutrients, increased organic matter, reduced sediment oxygenation, elevated toxic sulphide levels; e.g. Robertson 2018). In this section, the likely influence of the key stressors of nutrients and fine sediment on the ecological condition of Taranaki Region estuaries is assessed as follows (and includes the use of detailed estuary data presented in Appendices B and C):

Susceptibility to Eutrophication	Based on a modification of the ETI, nutrient load thresholds for SSRTREs are recommended as follows: 1. High susceptibility SSRTREs i.e. with long periods of mouth closure or restriction (months). Eutrophic conditions unlikely at estimated areal TN load <35 mg m^{-2} d^{-1} 2. Moderate susceptibility SSRTRE i.e short periods of mouth closure or restriction (days to weeks), or with extensive poorly flushed high value habitat i.e. estuaries with long water column residence time. Eutrophic conditions unlikely at estimated areal TN load <100-250 mg m^{-2} d^{-1} 3. Low susceptibility SSRTRE i.e mouth always open or mouth generally open with short periods of mouth closure or restriction (days to weeks) and no significant areas of poorly flushed high value habitat i.e. a well flushed water column. Eutrophic conditions unlikely at estimated areal TN load <2000 mg m^{-2} d^{-1} Areal N load = TN estuary load (mg N d^{-1})/estuary area (m^2). For the Taranaki Region estuaries, TN load estimates were derived using the NIWA CLUES model (Version 10.5, released June 2017) default setting using REC2 and LCBB3 (2008/2009) land cover).
Current Eutrophication Condition	The current trophic state of the Taranaki Region estuaries was assessed using the ETI Tool 2 approach, including recent extensions (Plew et al. *under review*). This approach requires data or expert opinion for at least one primary indicator and one supporting indicator. For the Taranaki Region estuaries, measured chlorophyll *a* and macroalgal cover data or expert opinion was used for the primary indicator and redox potential for the supporting indicator to develop an ETI trophic state score (note that other indicator data is also presented where available in order to provide additional support).
Susceptibility to Sedimentation (Muddiness)	The susceptibility of estuaries to the accumulation of fine sediments is related both to the suspended sediment input load and the physical (sediment trapping) characteristics of each estuary. Currently, there is insufficient information to identify robust sedimentation susceptibility thresholds for NZ estuaries, but for screening level purposes it is appropriate to use the Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio as a means of identifying catchments with excessive sediment loads. For the Taranaki Region estuaries, the chosen CSSL/NSSL ratio thresholds were as follows: low 1-1.1, moderate 1.1-2, high 2-5, very high >5. Catchment sediment load estimates were derived from the NIWA's CLUES model (Version 10.5, released June 2017)[1]. The load threshold ratings were then combined (using the matrix below) with ratings for the likelihood of sediment trapping based on the assumption that high susceptibility SSRTRE estuaries are physically susceptible to fine sediment accumulation. [1]CSSL estimated using CLUES (default setting of REC2 and LCBB3 (2008/2009) land cover), NSSL estimated by setting CLUES land cover to native forest, with a further 50% reduction applied to account for high expected sediment retention in wetlands in the catchment under natural state (Kreiling et al., 2013, McKergow et al. 2007, Tanner et al. 2010, Kadlec & Wallace 2009; Mitsch & Grosslink 2007, and International BMP Database 2007 as presented in Semadeni-Davies 2009).

Estuary Category	**Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL)**			
	CSSL = 1 to 1.1 x NSSL	CSSL = 1.1 to 2 x NSSL	CSSL = 2 to 5 x NSSL	CSSL > 5 x NSSL
SSRTREs with extensive areas of poorly flushed habitat	Minimal Susceptibility	Moderate Susceptibility	High Susceptibility	Very High Susceptibility
SSRTREs with no extensive areas of poorly flushed habitat	Minimal Susceptibility	Minimal Susceptibility	Minimal Susceptibility	Moderate Susceptibility

Current Sedimentation Condition	The current ETI thresholds for % estuary area dominated by soft mud substrata (i.e. sediment mud content >25%) were used to assess the current sedimentation (or muddiness) of the Taranaki Region estuaries as follows: low 1%, moderate 1-5%, high 5-15%, very high >15%.
Determine Overall Vulnerability	This step combines the susceptibility and current condition ratings to get an overall vulnerability rating. If the estuary was assessed for condition during reasonable worst case times, then the existing condition rating is used as the final rating. However, if there is considerable uncertainty around the condition rating, then the more conservative susceptibility rating (or combination) is used.

Step 4: Rate the Stressor Influence on Habitat

The influence of key stressors on the ecological condition of each listed estuarine habitat type is rated based on the results of Steps 1-3.

Step 5: Identify and Rate Stressor Influence on Human Uses and Ecological Values

Human uses and ecological values were identified and their presence assessed using four broad rating categories (Very Low, Low, Moderate, High) based on a UNESCO (2000) methodology. Expert judgement is used to provide an overall rating for stressor influence on each use as follows:

1. Human Uses and Values. The information used to rate human uses and values of coastal habitat is based on local knowledge and available information (Schedule 5B of the Proposed Coastal Plan for Taranaki - Schedule 5B of the Proposed Coastal Plan for Taranaki “Sites of significance to Māori and associated values”). We note that amenity values can be informed from the results of a recent recreational water use survey carried out by TRC. The results generally indicate that the most popular water based activity in Taranaki estuaries is swimming, and the three next most popular activities in varying order were fishing, whitebaiting and kayaking (TRC 2019, pers. comm).

   The estimated number of people involved are used to guide the rating:

   - Very Low: <10 per year;
   - Low: 10 to 50 per year (<30 per day in summer);
   - Moderate: >30 per day (may be only in summer) but <200 per day;
   - High: >200 per day (any time during year).

2. Ecological Values (Richness). Ecological value defines an ecosystem’s natural riches (generally interpreted as habitat diversity and biodiversity). It can be supposed that the richer and more diversified an ecosystem is, the greater the losses will be in the event of a disruption. The ecological richness component is divided into four subcategories; birds, vegetation, fish, and other biota. The information used to rate the ecological value will be drawn from local knowledge, available reports and information (Taranaki Regional Council 2015 - https://www.trc.govt.nz/assets/Documents/Environment/Coast/reg-landscape-study-of-naki-coastal-enviro.pdf), and expert opinion.

Step 6: Rate the Stressor Influence on Monitoring Indicators and Issues

Monitoring indicators that can be used to assess the influence of stressors are identified. For each, a rating is applied based on the extent that each monitoring indicator is likely to be affected by the stressor influence that was estimated in Step 3. Because each monitoring indicator is assigned into an appropriate issue category, then it is straightforward to assess which issues are likely to arise and what should be monitored. In this section, the overall stressor influence rating for each indicator is also determined using an appropriate weighting for each stressor.

Step 7: Identify Priority Indicators for Monitoring

Combine the results of Steps 4 and 6 to determine the priority indicators for monitoring.

Step 8. Identify Overall Vulnerability, Key Issues, Monitoring Recommendations

Finally, determine overall vulnerability by combining total stressor influence, total human use rating and total ecological values rating, identify key issues for monitoring, and make monitoring recommendations based on priority monitoring indicators.

Table 1. Main estuary categories used in susceptibility analysis

1. Shallow, Intertidal Dominated Estuaries (SIDEs)	
For NZ's dominant estuary types (i.e. shallow, short residence time (<3 days), and predominantly intertidal, tidal lagoon estuaries and parts of other estuary types where extensive tidal flats exist e.g. Firth of Thames, Kaipara Harbour, Freshwater Estuary - Stewart Island), flushing is too strong for significant retention of dissolved nutrients. Nevertheless, retention can still be sufficient to allow for retention of fine sediment and nutrients (particularly if these are excessive), deleterious for healthy growths of seagrass and saltmarsh, and nuisance growths of macroalgae in at-risk habitat. In these latter estuary types, assessment of the susceptibility to eutrophication must focus on the quantification of at-risk habitat (generally upper estuary tidal flats), based on the assumption that the risk of eutrophication symptoms increases as the habitat that is vulnerable to eutrophication symptoms expands. Nitrogen has been identified as the element most limiting to algal production in most estuaries in the temperate zone and is therefore the preferred target for eutrophication management in these estuaries (Howarth and Marino 2006). ***Susceptibility to Nutrient Loads: Moderate to High; Major Primary Producers: Macroalgae.***	 Freshwater Estuary (Stewart Island): high susceptibility pristine estuary
2. Shallow, Short Residence Time Tidal River, and Tidal River with Adjoining Lagoon, Estuaries (SSRTREs)	
NZ also has a number of shallow, short residence time (<3 days) tidal river estuaries (including those that exit via a very well-flushed small lagoon) that have such a large flushing potential (freshwater inflow/estuary volume ratio >0.16) that the majority of fine sediment and nutrients are exported to the sea. Tidal Rivers with mouth restrictions or closure periods of days rather than months and high freshwater inflows (e.g. Lake Onoke) can also fit in this category. In general, these estuary types have extremely low susceptibilities and can often tolerate nutrient loads an order of magnitude greater than shallow, intertidal dominated estuaries. These shallow estuary types are generally N limited. ***Susceptibility to Nutrient Loads: Low to Very Low; Major Primary Producers: Macroalgae, but low production, especially if freshwater inflow high.***	 Waimatuku Estuary (Southland)
3. Deeper, Subtidal Dominated, Estuaries (DSDEs)	
Mainly subtidal, moderately deep (>3 m to 15 m mean depth) coastal embayments (e.g. Firth of Thames) and tidal lagoon estuaries (e.g. Otago Harbour) with moderate residence times >7 to 60 days, can exhibit both sustained phytoplankton blooms, and nuisance growths of opportunistic macroalgae (especially *Ulva* spp. and *Gracilaria* spp.) if nutrient loads are excessive. The latter are usually evident particularly on muddy intertidal flats near river mouths and in the water column where water clarity allows. Deeper, long residence time embayments and fiords are primarily phytoplankton dominated if nutrient loads are excessive. Outer reaches of such systems which sustain vertical density stratification can be susceptible to oxygen depletion and low pH effects (Sunda and Cai 2012, Zeldis et al. 2015). In both cases, it is expected that the US ASSETS approach will adequately predict their trophic state susceptibility. These deeper estuary types are generally N limited. ***Susceptibility to Nutrient Loads: Moderate to Low; Major Primary Producers: Macroalgae (moderately deep) and phytoplankton (deeper sections).***	 Pelorus Sound (Marlborough)
4. Intermittently Closed/Open Estuaries (SIDEs and SSRTREs)	
Shallow tidal lagoon and tidal river type estuaries (<3 m deep) that experience periodical mouth closure or constriction have the highest susceptibility to nutrient retention and eutrophication, with the most susceptible being those with closure periods of months (e.g. Waituna Lagoon, Southland) rather than days (e.g. Lake Onoke, Wellington). In general, the tidal rivers have shorter periods of mouth closure (unless they are very small) than the more buffered tidal lagoons. The high susceptibility arises from reduced dilution (absence of tidal exchange at times) and increased retention (through both enhanced plant uptake and sediment deposition). Excessive phytoplankton and macroalgal growths and reduced macrophyte growth are characteristic symptoms of eutrophication in mouth restricted or closed estuaries. In such situations, which vary between marine and close to freshwater salinities, a co-limiting situation between N and P is expected, and as a consequence nutrient load/estuary response relationships should consider both N and P. ***Susceptibility to Nutrient Loads: Very High; Major Primary Producers: Both Macroalgae and Phytoplankton.***	 Waituna Lagoon (Southland): high susceptibility intermittently open/closed estuary

3 Results and Discussion

Mōhakatino Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Mod-High	Very High
Eutrophication	Moderate	Moderate

The Mōhakatino Estuary is a long length, shallow tidal river estuary whose mouth is predominantly open. It has a moderate freshwater inflow and is located ~3 km south of Mokau. Intertidal sediments are characterised by soft muds (4.6 ha, 34% unvegetated intertidal area) and sands and include some relatively sparse saltmarsh dominated by rushland (*Apodasmia similis* - Jointed wirerush, *Juncus krausii* - Searush, *Plagianthus divaricatus* - Saltmarsh ribbonwood) and to a lesser extent sedgeland (*Scheonoplectus pungens* - Three-square) and herbfield (*Sarcocornia quinqueflora* - Glasswort) vegetation limited to the mid-upper reaches. The estuary catchment is dominated by mixed native forest, and includes exotic forest and sheep and beef farming (see summary information overleaf).

Human use, ecological and cultural values: Recognised as a "Key Native Ecosystem" (KNE) with good access, the estuary is valued for its spiritual and aesthetic appeal, bathing, biodiversity, food harvesting and mahinga kai. The estuary is significant to Ngāti Tama as it is here where the Tokomaru waka landed. The river was abundant with tuna, īnanga, and mātaitai especially kutae (mussel) which was gathered at the mouth and the surrounding coastal reefs. Ecologically, habitat diversity is moderate-high with some of its intertidal vegetation, saltmarsh (in this case rushland, and some sedgeland and herbfield) intact, and contains breeding areas for native fish and supports whitebait, flounder and shellfish. However, there is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed for grazing and roading infrastructure.

Eutrophication status: The estuary is moderately (NZ ETI Tool 1, Band B) susceptible to macroalgal-based eutrophication at times based on (1) its relatively high proportion (>40%) of intertidal habitat, and (2) its relatively high nutrient load (the current estimated N areal loading of 457.5 mg TN m^{-2} d^{-1} exceeds the tentative guideline for moderate susceptibility SSRTREs of ~250 mg TN m^{-2} d^{-1}).

The 2019 field survey confirmed the absence of nuisance opportunistic macroalgae from all parts of the estuary, resulting in an NZ ETI (Tool 2) condition rating of moderate. Their absence was most likely related to turbidity-induced light limitation (during hightide) and/or flushing (tidal/during flood periods). In addition, the main subtidal channel waters (surface and bottom) had an absence of nuisance phytoplankton blooms (very low [chl *a*]), again reflecting light limitation and/or flushing in that part of the system. However, on occasions during low flows when the estuary is stratified and turbidity is low, nuisance algal/macrophyte growth may occur.

It is important to note that because mud-impacted systems are generally more susceptible to eutrophication impacts, nuisance growths could quickly expand and estuary conditions deteriorate in the short-medium term, particularly if the mouth becomes constricted.

Sedimentation (muddiness) status: The estuary is rated as mod-highly vulnerable to muddiness issues based on the fact that, although the estimated current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL) and excess sediments are likely to be flushed to the sea during high flows, the catchment is naturally erosion prone (Suspended Sediment Yield map of sediment delivery to rivers and stream [https://www.niwa.co.nz/freshwater/management-tools/sediment-tools/suspended-sediment-yield-estimator]) and the synoptic survey which showed that the estuary is dominated by muddy sediments in the less well flushed mid-upper (intertidal and subtidal) reaches. Ecologically, the overall high mud extent fits the NZ ETI Band D (very high muddiness) condition rating.

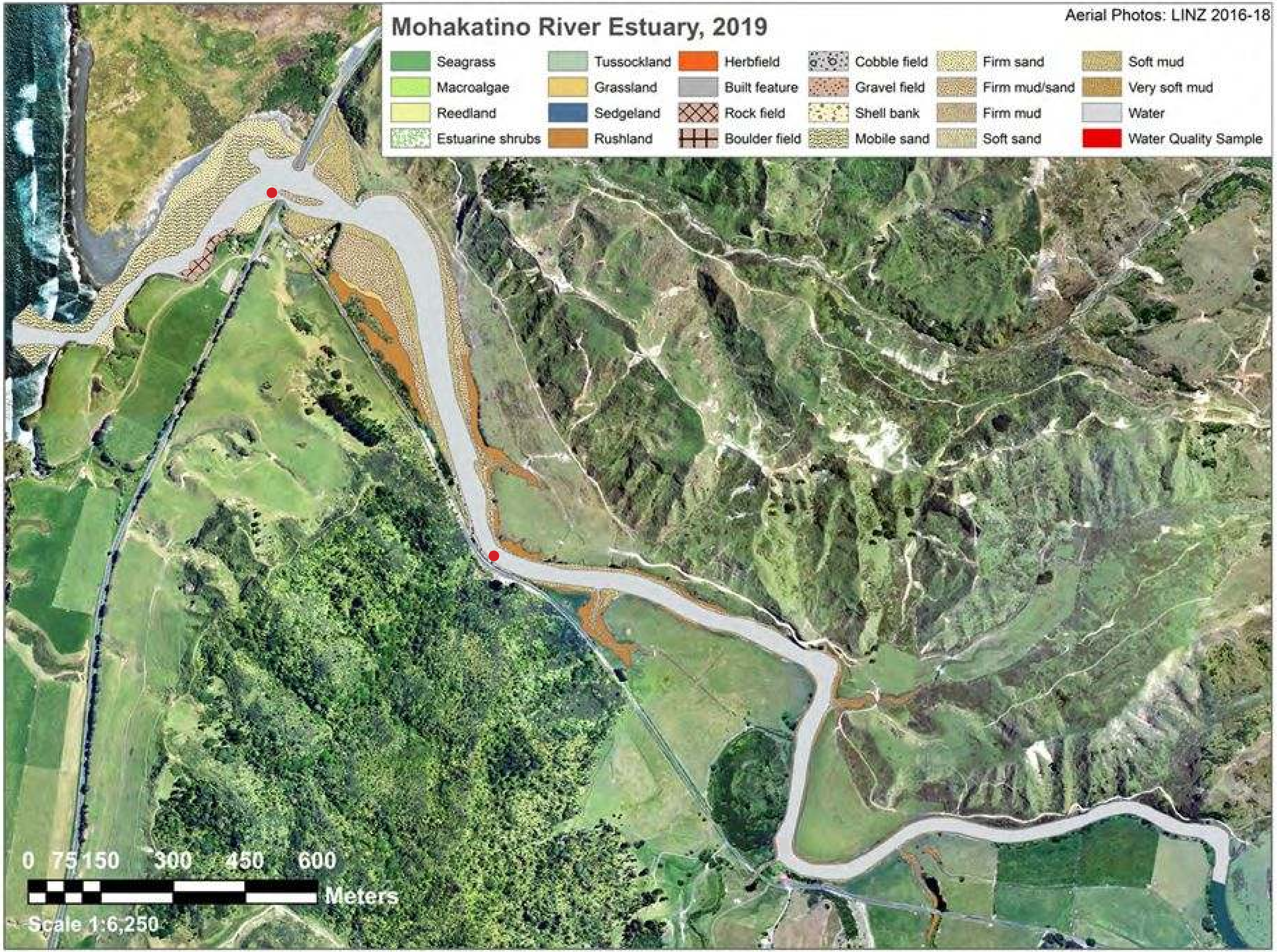


Figure 3. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sampling locations, Mōhakatino Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at each site.

Mōhakatino River Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 3, 32.1 ha
	Intertidal/Subtidal	52% intertidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	2-3 m, 4 km (salt wedge extent)
	Freshwater Inflow	Mean annual 5.0 m^3 s^{-1}*
	Saltmarsh, Seagrass	3.3 ha saltmarsh, no seagrass
	Soft Mud	4.6 ha (34% unvegetated intertidal area)
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Very Low**
	[Dissolved oxygen] (subtidal channel)	Low-Mod**
Catchment	Catchment size	120.6 km^2
	Max Dairy Cows Permitted	0
	Suspended Sediment Loading	172.6 kt yr^{-1}
	Total Nitrogen Loading	53.6 t yr^{-1} (457.5 mg TN m^{-2} d^{-1})
	Total Phosphorus Loading	20.3 t yr^{-1}
	Dominant Landuse	80% native forest, 0.4% exotic forest, 0% dairy, 19% sheep/beef.
	Dominant Toprock Geology	Alluvial 7%, mudstone 6%, massive sand-stone 87%.

*Estimated mean flow at river mouth from NIWA's NZ River Maps software tool.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 2 representative subtidal channel sites (see locations in Figure 3). Sampled values in Appendix B.

Monitoring and Investigations

For "moderate-length (mouth sometimes closed or restricted) SSRTREs" with very significant intertidal and subtidal habitat characterised by extensive poorly flush/muddy substrata, moderate-high nutrient/sediment loads and high human use and cultural/ecological values, it is recommended that both broad scale habitat mapping and fine scale monitoring be undertaken on a long-term basis to assess trends in estuary ecological condition using the National Estuary Monitoring Protocol (Robertson et al. 2002), plus subsequent improvements (Robertson 2018; Plew et al. *under review*). Outputs should be compared against relevant national standards (i.e. NZ ETI; Robertson et al. 2016a,b) to gauge overall estuary condition. In addition, sedimentation plates, which, over the long-term, will help provide an indicative measure of the rate of sedimentation in the estuary, should be deployed and monitored annually as per Hunt (2019).

Broad scale habitat mapping documents the key habitats within the estuary, and changes to these habitats over time. It is typically repeated at 5-yearly intervals. Fine scale monitoring measures the condition of the high susceptibility intertidal and subtidal habitat through physical, chemical and biological indicators. It is undertaken once annually for three consecutive years during the period Nov-March (usually at 2 intertidal and 3-4 subtidal sites), and thereafter at 5-yearly intervals. Both components have not yet been measured in this estuary.

Tongaporutu Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Mod-High	Very High
Eutrophication	High	Moderate

The Tongaporutu Estuary, one of the few places where indigenous coastal forest adjoins the coastal marine area, is a long length, predominantly shallow, often poorly-flushed tidal river estuary whose mouth is predominantly open. It has a high freshwater inflow and is located close to the settlement of Tongaporutu, 15 km south of Mokau. Sediments are dominated by coarse/muddy sands in the expansive intertidal flats in lower estuary, but soft muds (7.8 ha, 23% non-vegetated intertidal flats) dominate the mid-upper estuary channel margins. Mid-estuary saltmarsh comprises *Apodasmia similis* (Jointed wirerush), *Juncus krausii* (Searush) and *Plagianthus divaricatus* (Saltmarsh ribbonwood). The estuary mouth is mostly open to the sea but may become restricted during periods of lowflow, limiting tidal mixing, and consequently the estuary waters can become brackish. The estuary catchment is mixed native forest (highly dominant, 82%), exotic forest, sheep and beef farming (see summary information overleaf).

Human use, ecological and cultural values: Recognised as a “Key Native Ecosystem” (KNE) with good access, the Tongaporutu Estuary is valued for its spiritual/aesthetic appeal, bathing, biodiversity, food harvesting and mahinga kai. It is also significant for Ngāti Tama with a number of pā sites along its river banks. This estuary channel was abundant with fish and mātaitai was gathered form the mouth and the surrounding reefs. Ecologically, habitat diversity is moderate-high with some of its intertidal vegetation, saltmarsh (in this case rushland and to a much lesser extent herbfield) intact. The estuary also contains important breeding areas for native fish as well as abundant shellfish with high species diversity. However, there is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed for grazing and a small area of urban use.

Eutrophication status: The estuary is highly (NZ ETI Tool 1, Band C) susceptible to macroalgal-based eutrophication at times based on (1) its relatively high proportion (>40%) of intertidal habitat, and (2) its moderate nutrient load (the current estimated N areal loading of 630 mg TN m^{-2} d^{-1} does not exceed the tentative guideline for low susceptibility SSRTREs of ~2,000 mg TN m^{-2} d^{-1}).

Despite the high rating, the 2019 field survey showed minimal signs of nuisance opportunistic macroalgal growth, resulting in an NZ ETI (Tool 2) condition rating of moderate. Their low incidence was most likely related to turbidity-induced light limitation (during hightide) and flushing during flood periods. Synoptic (one-off) sampling of the main subtidal channel waters (surface and bottom), indicated an absence of nuisance phytoplankton blooms (very low [chl *a*]), again reflecting light limitation and/or flushing in that part of the system. However, on occasions during low flows when the estuary is stratified and turbidity is low, nuisance algal/macrophyte growth may occur.

In addition, such a mud-impacted estuary (in this case in its mid-upper reaches) generally is more susceptible to eutrophication impacts, so the present survey results must be viewed in that context, and the potential for rapid ecological decline accounted for in any long-term monitoring programme.

Sedimentation (muddiness) status: The estuary is rated as highly vulnerable to muddiness issues based on the fact that, although the estimated current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL) and excess sediments are likely to be flushed to the sea during high flows, the catchment is naturally erosion prone (Suspended Sediment Yield map of sediment delivery to rivers and stream [NIWA]) and the synoptic survey showed that the estuary is dominated by muddy sediments in the less well flushed mid-upper (intertidal and subtidal) reaches. Ecologically, the overall high extent fits the NZ ETI Band D (very high) condition rating.

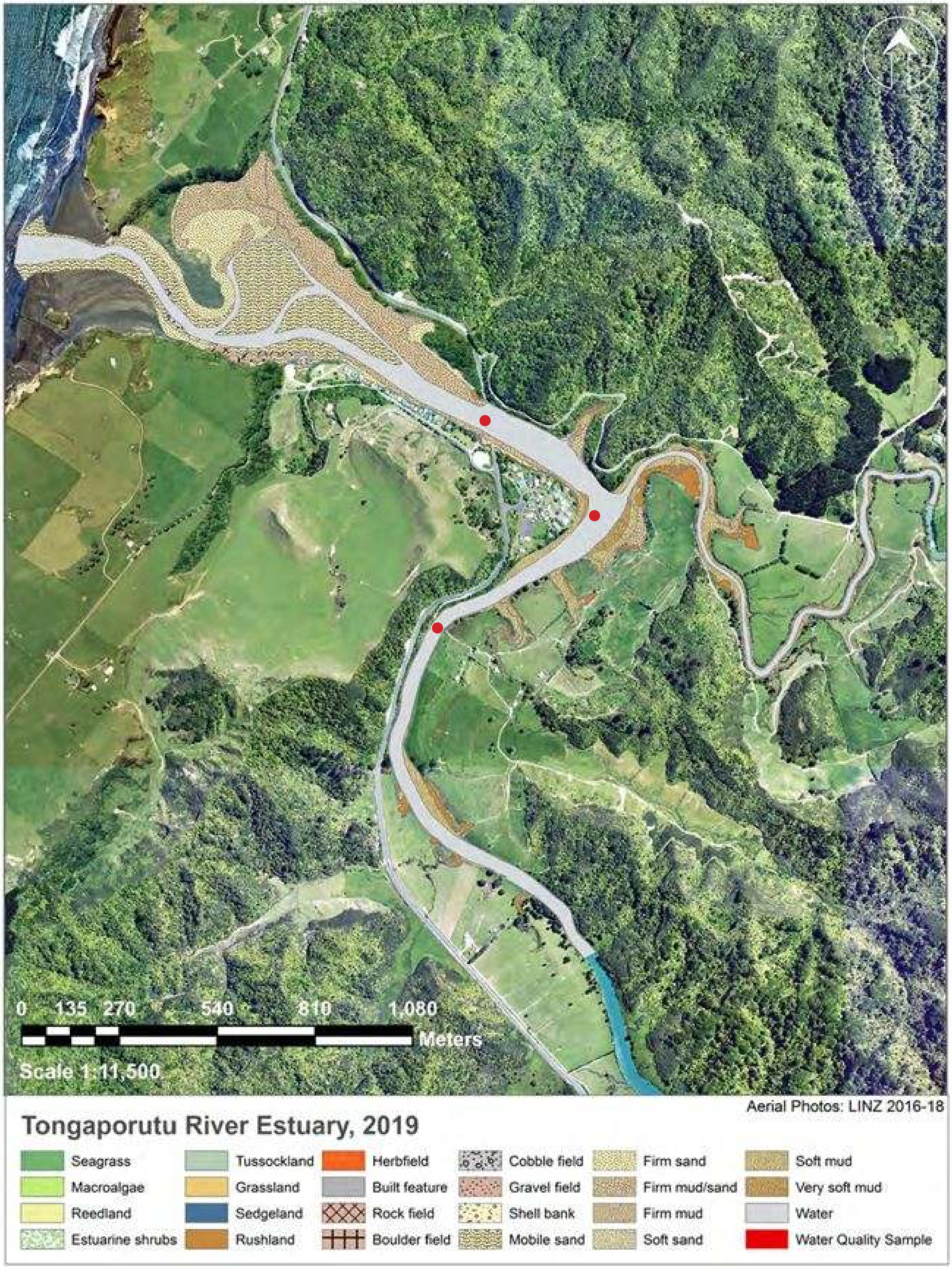


Figure 4. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Tongaporutu Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at each site.

Tongaporutu Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 4, 58.2 ha
	Intertidal/Subtidal	63% intertidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	1-2 m, 6 km (salt wedge extent)
	Freshwater Inflow	Mean annual 9.3 m^3 s^{-1}*
	Saltmarsh, Seagrass	2.8 ha saltmarsh, no seagrass
	Soft Mud	7.8 ha (23% unvegetated intertidal area)
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Very Low**
	[Dissolved oxygen] (subtidal channel)	Low**
Catchment	Catchment size	270.4 km^2
	Max Dairy Cows Permitted	665
	Suspended Sediment Loading	362.4 kt yr^{-1}
	Total Nitrogen Loading	133.9 t yr^{-1} (630 mg TN m^{-2} d^{-1})
	Total Phosphorus Loading	48.1 t yr^{-1}
	Dominant Landuse	82% native forest, 2% exotic forest, 0% dairy, 16% sheep/beef.
	Dominant Toprock Geology	Alluvial 3%, massive mudstone 12%, peat 2%, massive sandstone 85%.

*Estimated mean flow at river mouth from NIWA's NZ River Maps software tool.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 3 representative subtidal channel sites (see locations in Figure 4). Sampled values in Appendix B.

Monitoring and Investigations

For "long-length (mouth sometimes closed or restricted) SSRTREs" with significant intertidal and subtidal habitat comprising poorly flushed/muddy substrata, moderate-high nutrient/sediment loads and high human use and cultural/ecological values, it is recommended that both broad scale habitat mapping and fine scale monitoring be undertaken on a long-term basis to assess trends in estuary ecological condition using the National Estuary Monitoring Protocol (Robertson et al. 2002), plus subsequent improvements (Robertson 2018). Outputs should be compared against relevant national standards (i.e. NZ ETI; Robertson et al. 2016a,b). In addition, sedimentation plates, which, over the long-term, will help provide an indicative measure of the rate of sedimentation in the estuary, should be deployed and monitored annually as per Hunt (2019).

Broad scale habitat mapping documents the key habitats within the estuary, and changes to these habitats over time. It is typically repeated at 5-yearly intervals. Fine scale monitoring measures the condition of the high susceptibility intertidal and subtidal habitat through physical, chemical and biological indicators. It is undertaken once annually for three consecutive years during the period Nov-March (usually at 2 intertidal and 3-4 subtidal sites), and thereafter at 5-yearly intervals. Both components have not yet been measured in this estuary.

Mimi Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Mod-High	Very High
Eutrophication	Very High	Moderate

The Mimi Estuary is a relatively small, long, shallow, moderately-highly flushed tidal river estuary (SSRTRE) that has a moderate-high freshwater inflow, extends approximately 3 km inland, and is located approximately 25 km northeast of Urenui. The estuary mouth is mostly open to the sea, but at times it migrates and can be semi-restricted, which means the estuary is often brackish.

Sediments are dominated by muds and sands in the middle to upper estuary and sands in the lower reaches. The middle estuary includes several small pockets of saltmarsh including *Juncus krausii* (Searush) and *Apodasmia similis* (Jointed wirerush) and to a much lesser extent reedland (*Typha orientalis,* Raupo) and herbfield (*Triglochin striata*, Arrow-grass) vegetation.

The estuary catchment is mixed native forest, exotic forest (including consented forestry), dairy and sheep and beef farming (see summary information below).

Human use, ecological and cultural values: The estuary is recognised as an important nursery area for marine and freshwater fish (including diverse and regionally distinctive native species) and birds (e.g. the 'Threatened (Nationally Vulnerable)' Northern New Zealand dotterel (*Charadrius obscurus aquilonius*), Caspian tern (*Hydroprogne caspia*) and red-billed gull (*Larus novaehollandiae scopulinus*). With a high degree of natural character, it is considered a "Key Native Ecosystem" (KNE), and habitat diversity is moderate with some of its intertidal saltmarsh intact, although there is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed primarily for grazing. The full name of this estuary is Mimitangiatua, and it is significant to Ngati Mutunga for many reasons. Historically, the river has been used for food gathering and there are a number of pā and kāinga located along its banks. Human activity is minimal associated with low key recreation use, and the visiting experience maintains a sense of remoteness and high scenic associations.

Eutrophication status: The estuary is 'very highly' (NZ ETI Tool 1, Band D) susceptible to macroalgal-based eutrophication at times based on:

1. its relatively high proportion of intertidal habitat (>40%); and,
2. its high nutrient load (the current estimated N areal loading of 2,429 mg TN m^{-2} d^{-1} exceeds the tentative guideline for moderate susceptibility SSRTREs of ~250 mg TN m^{-2} d^{-1}).

In terms of current conditions, the field survey (2019) showed an absence of nuisance opportunistic macroalgae, fitting the 'moderate' (NZ ETI Tool 2, Band B) condition category. Their low incidence was most likely related to turbidity-induced light limitation (during hightide) and flushing during flood periods.

Synoptic (one-off) sampling of the main subtidal channel waters (surface and bottom) showed no signs of nuisance phytoplankton blooms (very low [chl *a*]), with light limitation and/or flushing in that part of the system the most plausible explanation. However, on occasions during low flows when the estuary is stratified and turbidity is low, nuisance algal/macrophyte growth may occur.

Sedimentation (muddiness) status: The estuary is rated as moderate-highly vulnerable to muddiness issues based on the facts that, while the estimated current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL), and excess sediments are likely to be flushed to the sea during high flows, the catchment is naturally erosion prone (Suspended Sediment Yield map of sediment delivery to rivers and stream [NIWA]) and the synoptic survey showed that the estuary is impacted by muddy sediments (26% intertidal area) in the less well flushed mid-upper (intertidal and subtidal) reaches. Ecologically, the overall relatively high mud extent fits the NZ ETI Band D (very high) condition rating.

Figure 5. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sampling locations, Mimi River Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at each site.

Mimi Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 2, 10.3 ha
	Intertidal/Subtidal	49% intertidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	0.5-1.0 m, ~2 km (salt wedge extent)
	Freshwater Inflow	Mean annual 3.6 $m^3 s^{-1}$*
	Saltmarsh, Seagrass	0.9 ha saltmarsh, No intertidal seagrass
	Soft Mud	1.2 ha (26% intertidal area)
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Very Low**
	[Dissolved oxygen] (subtidal channel)	Low-Moderate**
Catchment	Catchment size	133.4 km^2
	Max Dairy Cows Permitted	1735
	Suspended Sediment Loading	186.1 kt yr^{-1}
	Total Nitrogen Loading	91.3 t yr^{-1} (2,429 mg TN $m^{-2} d^{-1}$)
	Total Phosphorus Loading	42.7 t yr^{-1}
	Dominant Landuse	Native forest 56%, Exotic forest 4%, Dairy 7%, Sheep/beef 32%.
	Dominant Toprock Geology	Alluvial 9%, Massive mudstone 20%, Ash (older than Taupo ash) 22%, Massive sandstone 50%.

*Estimated mean flow at river mouth from NIWA's NZ River Maps software tool.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 3 representative subtidal channel sites (see locations in Figure 5). Sampled values in Appendix B.

Monitoring and Investigations

For "moderate-length (mouth sometimes closed or restricted) SSRTREs" with significant intertidal and subtidal habitat comprising relatively extensive poorly flushed/muddy substrata, moderate-high nutrient/sediment loads and high human use and very high cultural/ecological values, it is recommended that both broad scale habitat mapping and fine scale (intertidal and subtidal) monitoring be undertaken on a long-term basis to assess trends in estuary ecological condition using the National Estuary Monitoring Protocol (Robertson et al. 2002), plus subsequent improvements (Robertson 2018; Robertson and Robertson 2018). Outputs should be compared against relevant national standards (i.e. NZ ETI; Robertson et al. 2016a,b). In addition, sedimentation plates, which, over the long-term, will help provide an indicative measure of the rate of sedimentation in the estuary, should be deployed and monitored annually as per Hunt (2019).

Broad scale habitat mapping documents the key habitats within the estuary, and changes to these habitats over time. It is typically repeated at 5-yearly intervals. Fine scale monitoring measures the condition of the high susceptibility intertidal and subtidal habitat through physical, chemical and biological indicators. It is undertaken once annually for three consecutive years during the period Nov-March (usually at 2 intertidal and 3-4 subtidal sites), and thereafter at 5-yearly intervals. Both components have not yet been measured in this estuary.

Urenui Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Mod-High	Very High
Eutrophication	Very High	Moderate

The Urenui Estuary is a moderate length, shallow, often poorly-flushed tidal river estuary. It has a moderate freshwater inflow and is located at Urenui township. Intertidally, sediments are characterised by soft muds (5.7 ha, 39.2% non-vegetated intertidal flats) and sands and include a significant area of high tide saltmarsh dominated by *Juncus krausii* (Searush) and *Apodasmia similis* (Jointed wirerush) and to a lesser extent herbfield (*Triglochin striata*, Arrow-grass) vegetation. The middle estuary also comprises a small band of variably sized mangrove (*Avicennia marina var. resinfera*) shrubs, the distribution of which appears to be expanding towards the main channel. The estuary mouth is mostly open to the sea but may become restricted during periods of low-flow, limiting tidal mixing, and consequently the estuary waters can become brackish. The estuary catchment is mixed native forest, exotic forest (including consented forestry), dairy and sheep and beef farming (see summary information overleaf).

Human use, ecological and cultural values: Recognised as a “Key Native Ecosystem” (KNE) with good access, the Urenui Estuary is valued for its aesthetic appeal, bathing, biodiversity, and food harvesting. Ecologically, habitat diversity is moderate-high with some of its intertidal vegetation, saltmarsh (in this case rushland, mangrove and herbfield) intact. However, there is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed for grazing and urban use. The estuary is recognised as an important nursery area for marine and freshwater fish and birds. Culturally, this estuary is significant to Ngati Mutunga, with a large number of pā located along its banks. The mouth of the river provided a plentiful supply of pipi, pūpū, pātiki kahawai and other fish.

Eutrophication status: The estuary is very highly (NZ ETI Tool 1, Band D) susceptible to macroalgal-based eutrophication at times based on (1) its relatively high proportion (>40%) of intertidal habitat, and (2) its very high nutrient load (the current estimated N areal loading of 1102.4 mg TN m^{-2} d^{-1} exceeds the tentative guideline for moderate susceptibility SSRTREs of ~250 mg TN m^{-2} d^{-1}). Despite the very high rating, the 2019 field survey showed very limited nuisance opportunistic macroalgal growth, resulting in an NZ ETI (Tool 2, Band B) condition rating of moderate. Nuisance macroalgae were present as only a single low density (20-30% cover, biomass ~100 g wet weight m^{-2}) patch of *Ulva intestinalis* in shallow margin areas of the middle estuary (i.e. the only Taranaki Region estuary assessed with any macroalgae at all). Their low incidence was most likely related to turbidity-induced light limitation (during hightide) and flushing during flood periods. Synoptic (one-off) sampling of the main subtidal channel waters (surface and bottom) indicated an absence of nuisance phytoplankton blooms (very low [chl *a*]), again reflecting light limitation and/or flushing in that part of the system. However, on occasions during low flows when the estuary is stratified and turbidity is low, nuisance algal/macrophyte growth may occur.

It is important to note that because mud-dominated systems are generally more susceptible to eutrophication impacts, nuisance growths could quickly expand and estuary conditions deteriorate in the short-medium term, particularly if the mouth becomes constricted.

Sedimentation (muddiness) status: The estuary is rated as highly vulnerable to muddiness issues based on the fact that, although the estimated current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL) and excess sediments are likely to be flushed to the sea during high flows, the catchment is naturally erosion prone (Suspended Sediment Yield map of sediment delivery to rivers and stream [NIWA]) and the synoptic survey showed that the estuary is dominated by muddy sediments in the less well flushed mid-upper (intertidal and subtidal) reaches. Ecologically, the overall high mud extent fits the NZ ETI Band D (very high) condition rating.

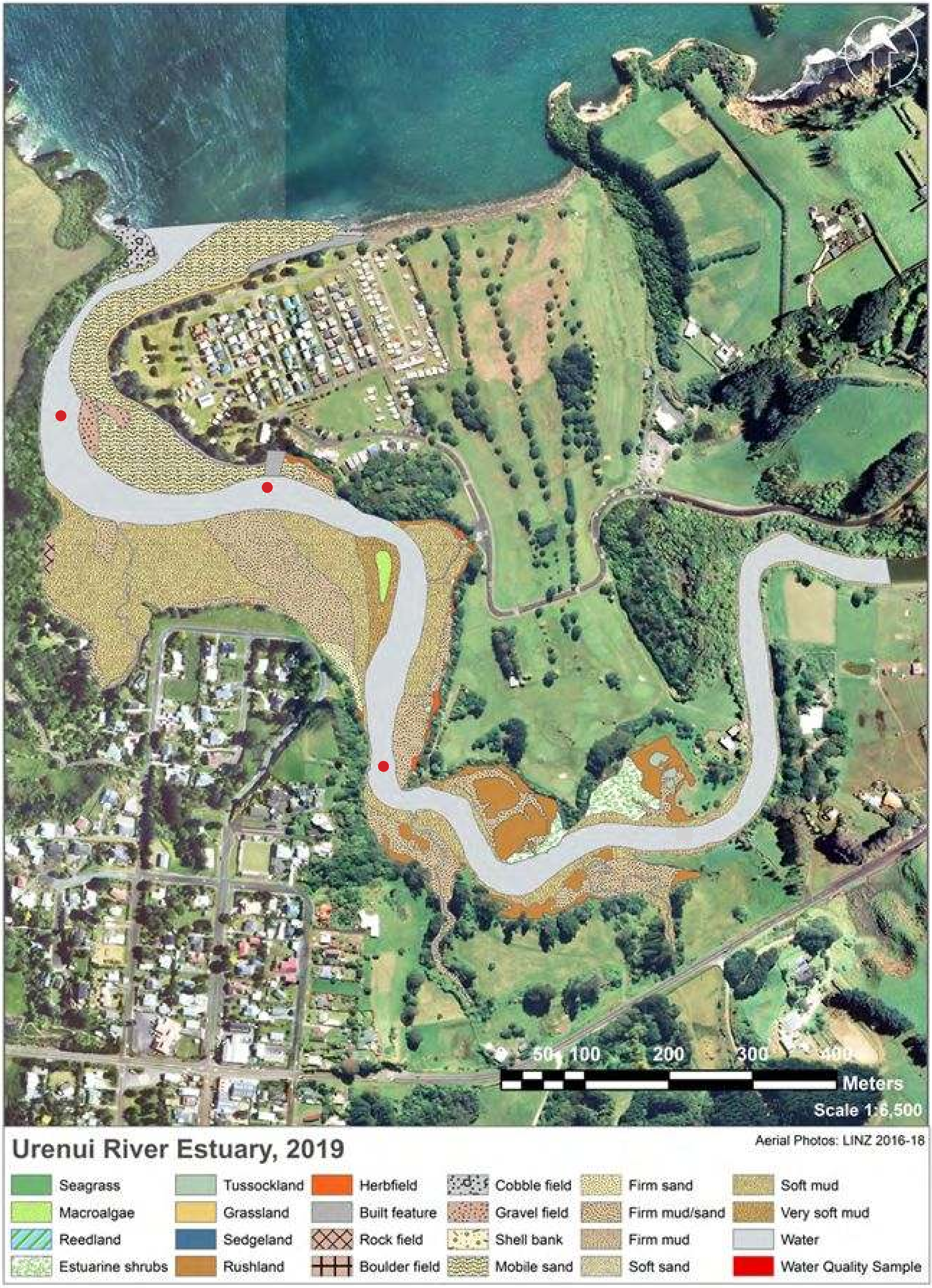


Figure 6. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Urenui Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at each site.

Urenui Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 3, 21.2 ha
	Intertidal/Subtidal	31% subtidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	0.5-1.0 m, ~3 km (salt wedge extent)
	Freshwater Inflow	Mean annual 4.4 $m^3 s^{-1}$*
	Saltmarsh, Seagrass	1.9 ha saltmarsh, No intertidal seagrass
	Soft Mud	5.7 ha (39.2% intertidal area)
	Macroalgae	0.08 ha (20-30% cover, ~100 g ww m^{-2})
	[Chlorophyll *a*] (subtidal channel)	Very Low**
	[Dissolved oxygen] (subtidal channel)	Low-Moderate**
Catchment	Catchment size	132.8 km^2
	Max Dairy Cows Permitted	745
	Suspended Sediment Loading	149.4 kt yr^{-1}
	Total Nitrogen Loading	85.3 t yr^{-1} (1102.4 mg TN m^{-2} d^{-1})
	Total Phosphorus Loading	66.3 t yr^{-1}
	Dominant Landuse	Native forest 66%, Exotic forest 3%, Dairy 9%, Sheep/beef 22%.
	Dominant Toprock Geology	Massive mudstone 54%, ash (older than Taupo ash) 17%, massive sandstone 24%.

*Estimated mean flow at river mouth from NIWA's NZ River Maps software tool.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 3 representative subtidal channel sites (see locations in Figure 6). Sampled values in Appendix B.

Monitoring and Investigations

For "moderate-length (mouth sometimes closed or restricted) SSRTREs" with very significant intertidal and subtidal habitat characterised by extensive poorly flush/muddy substrata, moderate-high nutrient/sediment loads and high human use and cultural/ecological values, it is recommended that both broad scale habitat mapping and fine scale monitoring be undertaken on a long-term basis to assess trends in estuary ecological condition using the National Estuary Monitoring Protocol (Robertson et al. 2002), plus subsequent improvements (Robertson 2018). Outputs should be compared against relevant national standards (i.e. NZ ETI; Robertson et al. 2016a,b). In addition, sedimentation plates, which, over the long-term, will help provide an indicative measure of the rate of sedimentation in the estuary, should be deployed and monitored annually as per Hunt (2019).

Broad scale habitat mapping documents the key habitats within the estuary, and changes to these habitats over time. It is typically repeated at 5-yearly intervals. Fine scale monitoring measures the condition of the high susceptibility intertidal and subtidal habitat through physical, chemical and biological indicators. It is undertaken once annually for three consecutive years during the period Nov-March (usually at 2 intertidal and 3-4 subtidal sites), and thereafter at 5-yearly intervals. Both components have not yet been measured in this estuary.

Onaero Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Moderate	Moderate
Eutrophication	Minimal	Moderate

The Onaero Estuary is a moderate length, shallow, tidal river estuary. It has a low freshwater inflow and is located 2 km west of the Urenui township. The main subtidal channel (10-20 m wide) comprises 63% of the estuary, with intertidal sediments largely dominated by sands and there is a narrow strip of saltmarsh (*Cyperus ustulatus* - Giant umbrella sedge) vegetation within the middle reaches. The estuary mouth fluctuates between an open and closed state (time frame unknown), and when restricted/closed, tidal mixing is limited and estuary waters become brackish. The estuary catchment is mixed native forest, exotic forest (including consented forestry), dairy and sheep and beef farming (see summary information overleaf).

Human use, ecological and cultural values: The estuary is valued for its spiritual/aesthetic appeal, bathing, biodiversity, and food harvesting. It is significant to Ngati Mutunga, with a number of pā located in close proximity. The mouth of the river provided a plentiful supply of pipi, pūpū, pātiki kahawai and other fish. Ecologically, habitat diversity is low-moderate with a very limited area of intertidal saltmarsh vegetation (in this case a strip of rushland) intact. There is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed primarily for grazing.

Eutrophication status: Despite its very high nutrient load (the current estimated catchment N areal loading of 7,302.4 mg TN m^{-2} d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2000 mg TN m^{-2} d^{-1}, Robertson et al. 2016), the estuary has minimal susceptibility to eutrophication (NZ ETI Tool 1, Band A). This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with very few poorly flushed areas, and has adequate freshwater inflow.

The (one-off) synoptic survey in 2019, confirmed the absence of opportunistic macroalgal and phytoplankton blooms throughout the intertidal and subtidal estuary, but with low-moderate chlorophyll *a* and dissolved oxygen concentrations in subtidal channel waters, an NZ ETI (Tool 2) condition rating of 'moderate' (Band B) for eutrophication impacts was allocated.

We note that, while periodic (short-term) changes in eutrophic susceptibility are expected (particularly if the mouth becomes constricted), given the low degree of eutrophic symptoms on the day of sampling when flushing was low (i.e. baseflow conditions), the low susceptibility rating is considered appropriate.

Sedimentation (muddiness) status: Despite emptying a catchment naturally prone to erosion (Suspended Sediment Yield map of sediment delivery to rivers and stream [NIWA]), the estuary has moderate vulnerability to muddiness issues based on the facts that the current suspended sediment load (CSSL) is 2-5 times the estimated natural state SS load (NSSL), but with some subtidal muds, and the mouth may be occasionally restricted. Currently, the overall moderate mud extent fits the NZ ETI Band B (moderate muddiness) condition rating.

Figure 7. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Onaero Estuary, 2019. Water quality sampling involved assessment of conditions in bottom (0.5 m from bottom) waters only at each site.

Onaero Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 2, 2.6 ha
	Intertidal/Subtidal	63% subtidal
	Mouth Status (on day of survey)	Closed
	Mean Depth, Length	0.5-1 m, 1 km (salt wedge extent)
	Freshwater Inflow	Mean annual 2.4 m^3 s^{-1}*
	Saltmarsh, Seagrass	0.4 ha saltmarsh, no seagrass
	Soft Mud	No intertidal soft mud
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Low**
	[Dissolved oxygen] (subtidal channel)	Mod-High**
Catchment	Catchment size	89.8 km^2
	Max Dairy Cows Permitted	1085
	Suspended Sediment Loading	75.1 kt yr^{-1}
	Total Nitrogen Loading	69.3 t yr^{-1} (7,302.4 mg TN m^{-2} d^{-1})
	Total Phosphorus Loading	36 t yr^{-1}
	Dominant Landuse	43% native forest, 3% exotic forest, 31% dairy, 24% sheep/beef.
	Dominant Toprock Geology	Alluvial 5%, ash (older than Taupo ash) 45%, massive mudstone 38%, massive sandstone 12%.

*Estimated mean flow at river mouth from NIWA's NZ River Maps software tool.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 2 representative subtidal channel sites (see locations in Figure 7). Sampled values in Appendix B.

Monitoring and Investigations

The low rating for both eutrophication and sedimentation in this estuary signifies a requirement for low frequency, screening level monitoring only.

To address the low potential for eutrophication/sedimentation issues (including both benthic and water column effects), it is recommended that low frequency (once every 10 years), screening level (synoptic) monitoring be undertaken to confirm that this low risk estuary has not changed its risk rating.

Waitara Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Mod-High	Very High
Eutrophication	Minimal	Moderate

The Waitara Estuary, located at the coastal town of Waitara, is one of the region's most significant long length, shallow, well-flushed tidal river estuary whose mouth (flanked either side by man-made boulder/rock wall) is always open. It has a very high freshwater inflow and is dominated by a relatively wide (30-40 m) subtidal channel (73% of estuary). Intertidal habitat is characterised by soft muds (2.7 ha, 26% unvegetated intertidal flats) and sands and include some saltmarsh comprising rushland (*Juncus kraussii* - Searush, *Apodasmia similis* - Jointed wirerush, *Isolepis nodosa* - Knobby clubrush) and to a lesser extent reedland (*Typha orientalis* - Raupo) and sedgeland (*Schoenoplectus pungens* - Three-square) vegetation. The estuary catchment is dominated by native forest, dairy and sheep/beef farming and exotic forest (including consented forestry) - see further summary information overleaf.

Human use, ecological and cultural values: With its good access and close proximity to the Waitara township, the estuary is valued for its aesthetic/spiritual appeal, bathing, biodiversity, and food harvesting. It is significant to Te Atiawa as it was one of the first areas to be settled in Aotearoa. The river provided an abundance of fish, īnanga, tuna/eel, piharau, kahawai, yellow eyed mullet, flounder, herrings, kōkopu, weka, pukeko and ducks. Ecologically, habitat diversity is moderate with some of its regionally significant intertidal vegetation (in this case rushland) intact. However, there is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed for grazing, flood protection and urban use.

Eutrophication status: Despite its very high nutrient load (the current estimated catchment N areal loading of 9,807 mg TN m^{-2} d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2000 mg TN m^{-2} d^{-1}, Robertson et al. 2016), the estuary has minimal susceptibility to eutrophication. This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with very few poorly flushed areas, has high freshwater inflow, is strongly affected by tidal currents. The overall eutrophic susceptibility of the estuary is minimal (NZ ETI Tool 1, Band A).

The synoptic survey in 2019 indicated a general absence of primary symptoms (i.e. no opportunistic macroalgal and phytoplankton blooms) from all areas of the estuary and generally clear waters in the lower and middle estuary, resulting in an NZ ETI (Tool 2) Band B (moderate eutrophication) condition rating.

However, it is important to note that such mud-impacted estuaries generally are more susceptible to eutrophication impacts, so the present survey results must be viewed in that context, and the potential for rapid ecological decline accounted for in any long-term monitoring programme.

Sedimentation (muddiness) status: The estuary is rated as moderate-highly vulnerable to muddiness issues based on the fact that, although the estimated current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL) and excess sediments are likely to be flushed to the sea during high flows, the catchment is naturally erosion prone (Suspended Sediment Yield map of sediment delivery to rivers and stream [NIWA]) and the synoptic survey showed that the estuary is impacted by muddy sediments in the less well flushed mid-lower (intertidal and subtidal) reaches. Ecologically, the overall high proportion of muds in 2019, possibly a result of recent flood activity, fits the NZ ETI Band D (very high) condition rating.

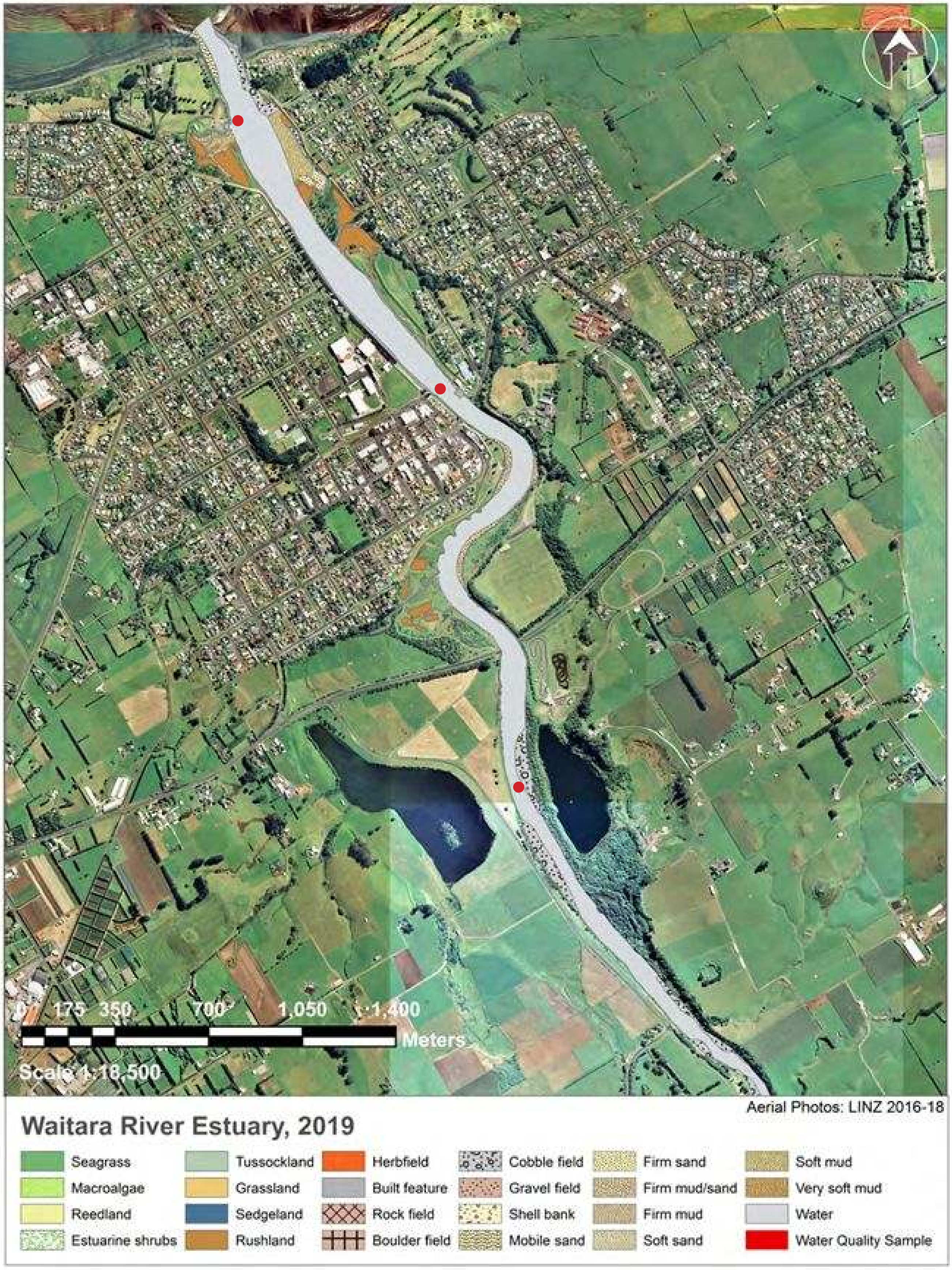


Figure 8. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Waitara Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at each site.

Waitara Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 4, 56.7 ha
	Intertidal/Subtidal	73% subtidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	2-3 m, 5 km (salt wedge extent)
	Freshwater Inflow	Mean annual 57.3 m^3 s^{-1}*
	Saltmarsh, Seagrass	4.6 ha saltmarsh, no seagrass
	Soft Mud	2.7 ha (26% unvegetated intertidal area)
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Very Low**
	[Dissolved oxygen] (subtidal channel)	Very Low-Low**
Catchment	Catchment size	1135.7 km^2
	Max Dairy Cows Permitted	51,515
	Suspended Sediment Loading	1109 kt yr^{-1}
	Total Nitrogen Loading	2030 t yr^{-1} (9,807 mg TN m^{-2} d^{-1})
	Total Phosphorus Loading	272.4 t yr^{-1}
	Dominant Landuse	38% native forest, 5% exotic forest, 30% dairy, 26% sheep/beef.
	Dominant Toprock Geology	Alluvial 2%, mudstone 2%, massive mudstone 2%, ash (older than Taupo ash) 46%, massive sandstone 42%.

*Mean flow measured at Waitara at Bertrand Rd, and includes Motukawa HEP (consented to take max 5,650 l s^{-1}, but can discharge up to 7,787 l s^{-1}) and 2x Methanex Consents.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 3 representative subtidal channel sites (see locations in Figure 8). Sampled values in Appendix B.

Monitoring and Investigations

For “long-length (mouth sometimes closed or restricted) SSRTREs” with significant areas of intertidal and subtidal habitat comprising poorly flushed/muddy substrata, moderate-high nutrient/sediment loads and high human use and cultural/ecological values, it is recommended that both broad scale habitat mapping and fine scale monitoring be undertaken on a long-term basis to assess trends in estuary ecological condition using the National Estuary Monitoring Protocol (Robertson et al. 2002), plus subsequent improvements (Robertson 2018). Outputs should be compared against relevant national standards (i.e. NZ ETI; Robertson et al. 2016a,b). In addition, sedimentation plates, which, over the long-term, will help provide an indicative measure of the rate of sedimentation in the estuary, should be deployed and monitored annually as per Hunt (2019).

Broad scale habitat mapping documents the key habitats within the estuary, and changes to these habitats over time. It is typically repeated at 5-yearly intervals. Fine scale monitoring measures the condition of the high susceptibility intertidal and subtidal habitat through physical, chemical and biological indicators. It is undertaken once annually for three consecutive years during the period Nov-March (usually at 2 intertidal and 3-4 subtidal sites), and thereafter at 5-yearly intervals. Both components have not yet been measured in this estuary.

Waiongana Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Moderate	Moderate
Eutrophication	Minimal	Minimal

The Waiongana Estuary is a moderate length, shallow, often poorly-flushed tidal river estuary whose mouth is predominantly open. It has a moderate freshwater inflow and is located directly northeast of New Plymouth Airport. Intertidal sediments are sand and cobble dominated and include limited saltmarsh (*Schoenoplectus pungens* - Three-square, *Cyperus ustulatus* - Giant umbrella sedge) vegetation. The estuary mouth is mostly open to the sea but may become restricted during periods of lowflow, limiting tidal mixing, and consequently the estuary waters can become brackish. The estuary catchment is predominantly dairy farming but includes some mixed native forest and exotic forest (see summary information overleaf).

Human use, ecological and cultural values: The estuary is valued for its aesthetic and spiritual appeal, bathing and biodiversity. It is significant to Te Atiawa, with various foods and resources historically gathered from the river itself, its banks and the coastal reefs at the river mouth. Ecologically, habitat diversity is low-moderate with very little intertidal vegetation, saltmarsh (in this case a small pocket of rushland) intact, and the estuary contains significant habitat for native and migratory birds. There is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed primarily for grazing.

Eutrophication status: Despite its very high nutrient load (the current estimated catchment N areal loading of 16,955 mg TN m^{-2} d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2,000 mg TN m^{-2} d^{-1}, Robertson et al. 2016), the estuary has minimal susceptibility to eutrophication (NZ ETI Tool 1, Band A). This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with very few poorly flushed areas, and has adequate freshwater inflow.

The (one-off) synoptic survey in 2019, confirmed the absence of opportunistic macroalgal and phytoplankton blooms throughout the intertidal and subtidal estuary. The absence of primary eutrophication symptoms placed the estuary in very good (NZ ETI, Tool 2, Band A) condition with regard to eutrophication impacts.

We note that, while periodic (short-term) changes in eutrophic susceptibility are expected (particularly if the mouth becomes constricted), given the complete absence of eutrophic symptoms on the day of sampling when flushing was low (i.e. baseflow conditions), the low susceptibility rating is considered appropriate.

Sedimentation (muddiness) status: The estuary has moderate vulnerability to muddiness issues based on the facts that the current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL), the estuary is dominated by sands, but the mouth may be occasionally restricted. Ecologically, the overall moderate mud content fits the NZ ETI Band B (moderate muddiness) condition rating.

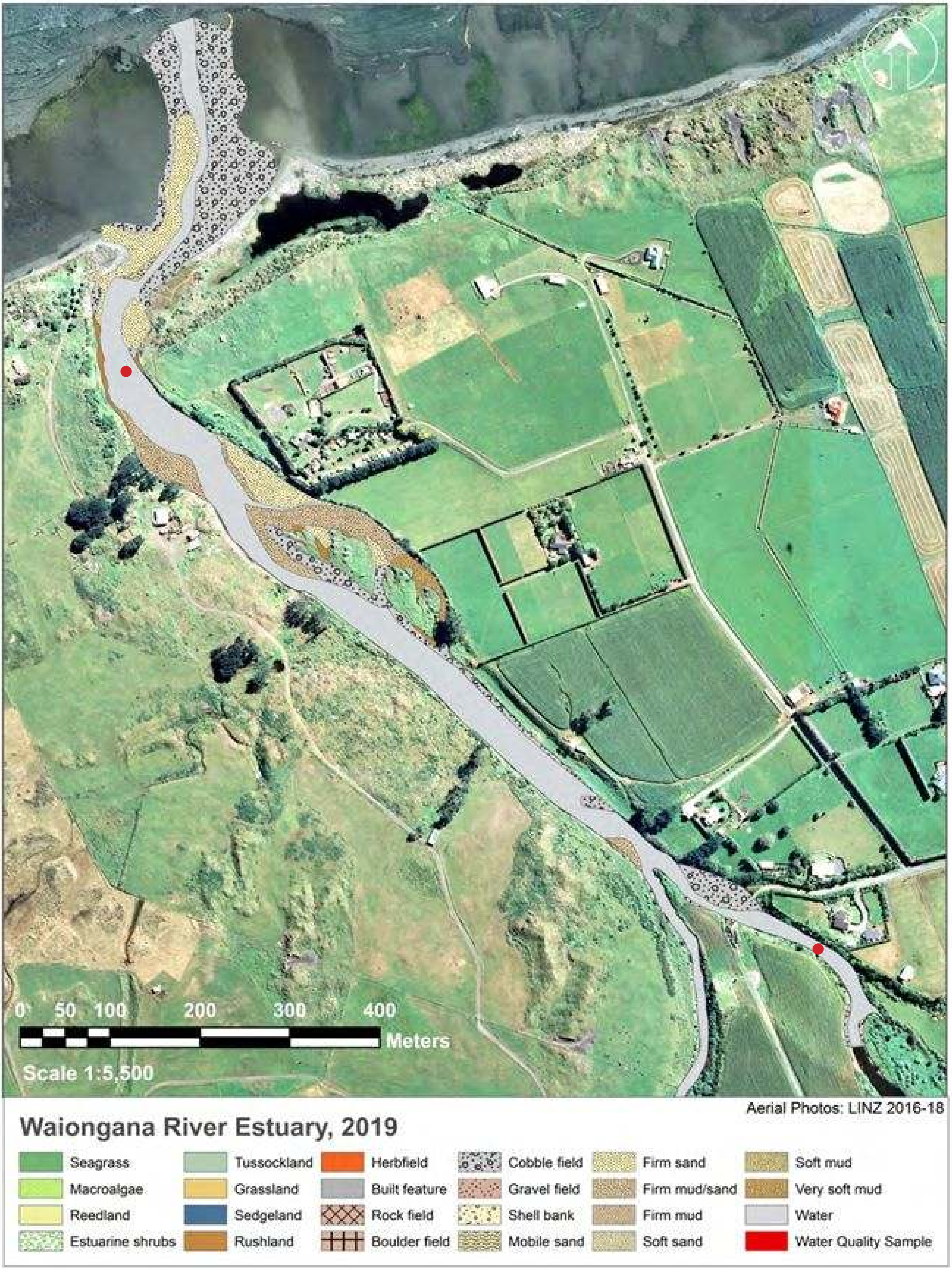


Figure 9. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Waiongana Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at each site.

Waiongana Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 2, 9 ha
	Intertidal/Subtidal	53% intertidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	0.5-1 m, 2 km (salt wedge extent)
	Freshwater Inflow	Mean annual 4.8 m^3 s^{-1}*
	Saltmarsh, Seagrass	0.1 ha saltmarsh, no seagrass
	Soft Mud	0.1 ha (2% unvegetated intertidal area)
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Very Low**
	[Dissolved oxygen] (subtidal channel)	Low-Mod**
Catchment	Catchment size	158.8 km^2
	Max Dairy Cows Permitted	20,930
	Suspended Sediment Loading	16 kt yr^{-1}
	Total Nitrogen Loading	557 t yr^{-1} (16,955 mg TN m^{-2} d^{-1})
	Total Phosphorus Loading	12.9 t yr^{-1}
	Dominant Landuse	5% native forest, 4% exotic forest, 88% dairy, 0% sheep/beef.
	Dominant Toprock Geology	Mudstone 96%, peat 1%.

*Mean flow based on combined flow from two recorder sites (Waiongana at SH3A and Mangaoraka at Corbett Rd.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 2 representative subtidal channel sites (see locations in Figure 9). Sampled values in Appendix B.

Monitoring and Investigations

The low rating for both eutrophication and sedimentation in this estuary signifies a requirement for low frequency, screening level monitoring only.

To address the low potential for eutrophication/sedimentation issues (including both benthic and water column effects), it is recommended that low frequency (once every 10 years), screening level (synoptic) monitoring be undertaken to confirm that this low risk estuary has not changed its risk rating.

Waiwhakaiho Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Moderate	Moderate
Eutrophication	Minimal	Minimal

The Waiwhakaiho Estuary is a moderate length, shallow, tidal river estuary that extends from the sea to approximately 1 km inland. It has a high freshwater inflow and is located close to the New Plymouth suburb of Fitzroy. Intertidal sediments are cobble-dominated with some sands at the mouth, and include areas of saltmarsh (*Juncus kraussii* - Searush, *Cytisus scoparius* - Broom, *Baumea juncea* - Bare twig rush, *Typha orientalis* - Raupo) vegetation confined to several physically constricted zones of the estuary. The estuary mouth is mostly open to the sea, and is flanked to the south by man-made boulder wall. The estuary catchment is predominantly dairy farming and mixed native forest but includes some exotic forest (see summary information overleaf), and has been subject to recent significant flood activity.

Human use, ecological and cultural values: Culturally, the estuary provided various resources for the people of Te Atiawa. Ecologically, habitat diversity is low-moderate with some of its intertidal vegetation, saltmarsh (in this case small pockets of rushland) intact, although there is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed for grazing and urban use. The estuary is valued for its aesthetic and spiritual appeal, bathing, biodiversity.

Eutrophication status: Despite its high nutrient load (the current estimated catchment N areal loading of 10,408 mg TN m^{-2} d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2,000 mg TN m^{-2} d^{-1}, Robertson et al. 2016), the estuary has minimal susceptibility to eutrophication (NZ ETI Tool 1, Band A). This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with very few poorly flushed areas (exposed to elevated nutrients), dominated by cobble substrata rather than high susceptibility muds, and has high freshwater inflow and is often turbid.

The (one-off) synoptic survey in 2019, confirmed the absence of opportunistic macroalgal and phytoplankton blooms throughout the intertidal and subtidal estuary. The absence of primary eutrophication symptoms placed the estuary in very good (NZ ETI, Tool 2, Band A) condition with regard to eutrophication impacts.

We note that, while periodic (short-term) changes in eutrophic susceptibility are expected (particularly if the mouth becomes constricted), given the complete absence of eutrophic symptoms on the day of sampling when flushing was low (i.e. baseflow conditions), the low susceptibility rating is considered appropriate.

Sedimentation (muddiness) status: The estuary has moderate vulnerability to muddiness issues based on the facts that the current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL), the estuary is dominated by sands/cobbles, but muds in several small, physically constricted regions of the lower estuary, and the mouth may be occasionally restricted. Ecologically, the overall moderate mud content fits the NZ ETI Band B (moderate muddiness) condition rating.

Figure 10. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sampling locations, Waiwhakaiho River Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2m) and bottom (0.5m from bottom) waters at each site.

Waiwhakaiho Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 4 (moderate length), 10.6 ha
	Intertidal/Subtidal	61% intertidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	0.5-1 m, 1.2 km (salt wedge extent)
	Freshwater Inflow	Mean annual 12.1 $m^3 s^{-1}$*
	Saltmarsh, Seagrass	0.3 ha saltmarsh, no seagrass
	Soft Mud	0.05 ha (1% unvegetated intertidal area)
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Very Low**
	[Dissolved oxygen] (subtidal channel)	Very Low**
Catchment	Catchment size	145.3 km^2
	Max Dairy Cows Permitted	12,210
	Suspended Sediment Loading	26 kt yr^{-1}
	Total Nitrogen Loading	402.7 t yr^{-1} (10,408 mg TN $m^{-2} d^{-1}$)
	Total Phosphorus Loading	21 t yr^{-1}
	Dominant Landuse	32% native forest, 4% exotic forest, 57% dairy, 0.1% sheep/beef.
	Dominant Toprock Geology	Alluvial 4%, mudstone 78%, Alluvial gravels 7%, Lahar deposits 3%, Tow 3%, Lavas & welded ignimbrites 3%.

*Mean flow measured at Rimu St. This does not include Mangorei HEP or other discharges (e.g. to lake) below this sampling station.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 1 representative subtidal channel site (see location in Figure 10). Sampled values in Appendix B.

Monitoring and Investigations

The low rating for both eutrophication and sedimentation in this estuary signifies a requirement for low frequency, screening level monitoring only.

To address the low potential for eutrophication/sedimentation issues (including both benthic and water column effects), it is recommended that low frequency (once every 10 years), screening level (synoptic) monitoring be undertaken to confirm that this low risk estuary has not changed its risk rating.

Te Henui Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Moderate	Moderate
Eutrophication	Minimal	Minimal

The Te Henui Estuary is a short length, predominantly shallow, often poorly-flushed tidal river estuary. It has a low freshwater inflow and is located in East End Reserve, New Plymouth. Intertidal sediments in the lower estuary are characterised by coarse sand and cobble. The estuary mouth, flanked either side by man-made rockwall, is mostly open to the sea but may become restricted during periods of lowflow, limiting tidal mixing, and consequently the estuary waters can become brackish. The estuary catchment is predominantly dairy farming and includes mixed native forest, exotic forest and sheep and beef farming (see further summary information overleaf).

Human use, ecological and cultural values: The estuary is a focal part of the Te Henui Coastal Walkway and is valued for its aesthetic and spiritual appeal, bathing and biodiversity. This river mouth is a culturally significant site for Te Atiawa. Ecologically, habitat diversity is relatively low with no estuarine vegetation intact, largely due to its heavily modified (hardened for flood/storm surge protection) and naturally steep margins. There is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed for recreation/urban use.

Eutrophication status: Despite its very high nutrient load (the current estimated catchment N areal loading of 11,732 mg TN m^{-2} d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2,000 mg TN m^{-2} d^{-1}, Robertson et al. 2016), the estuary has minimal susceptibility to eutrophication (NZ ETI Tool 1, Band A). This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with very few poorly flushed areas, and has adequate freshwater inflow.

The (one-off) synoptic survey in 2019, confirmed the absence of opportunistic macroalgal and phytoplankton blooms throughout the intertidal and subtidal estuary. The absence of primary eutrophication symptoms placed the estuary in very good (NZ ETI, Tool 2, Band A) condition with regard to eutrophication impacts.

We note that, while periodic (short-term) changes in eutrophic susceptibility are expected (particularly if the mouth becomes constricted), given the complete absence of eutrophic symptoms on the day of sampling when flushing was low (i.e. baseflow conditions), the low susceptibility rating is considered appropriate.

Sedimentation (muddiness) status: The estuary has moderate vulnerability to muddiness issues based on the facts that the current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL), the estuary is dominated by intertidal sands, but with some subtidal muds, and the mouth may be occasionally restricted. Ecologically, the overall moderate mud content fits the NZ ETI Band B (moderate muddiness) condition rating.

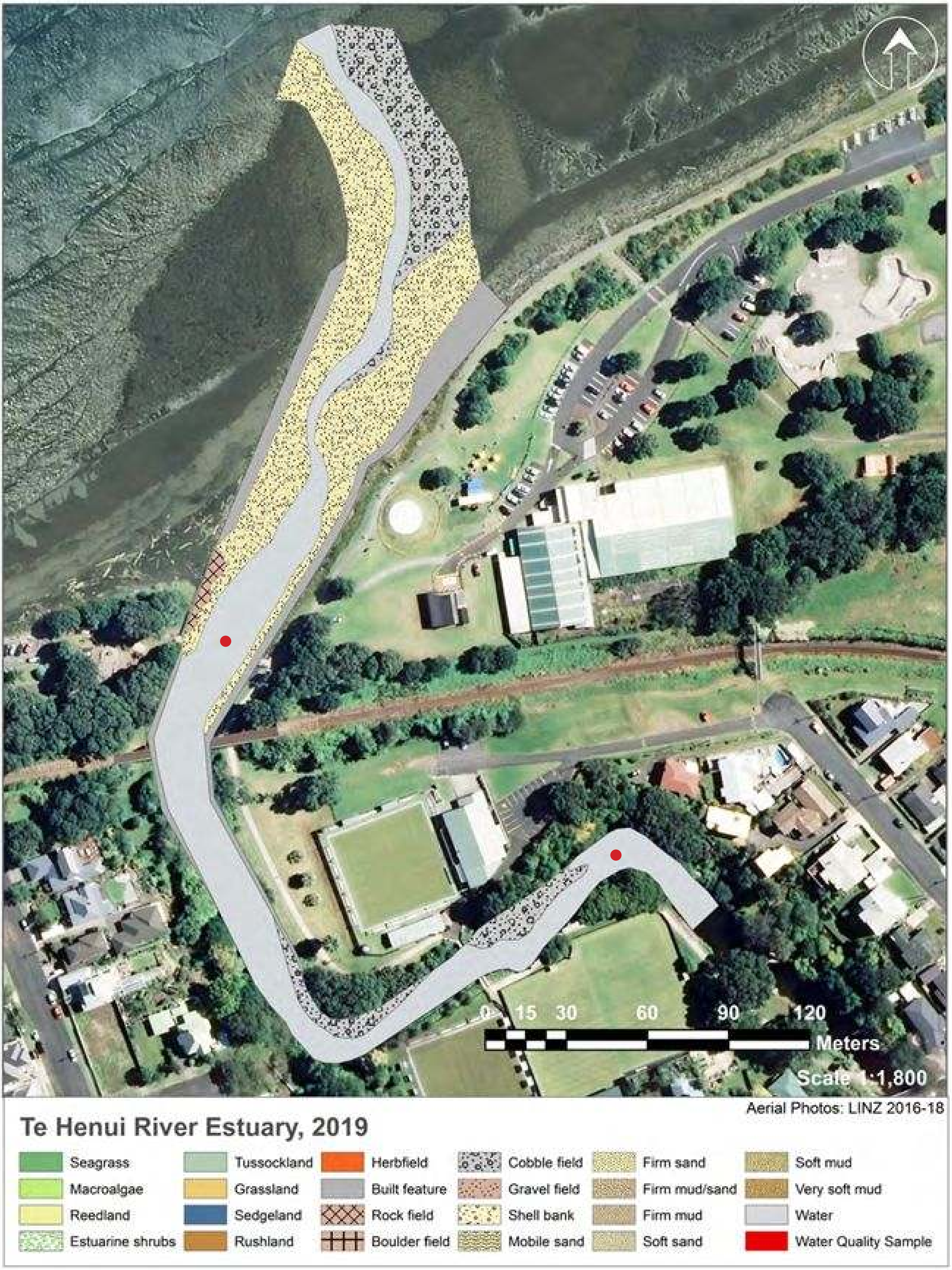


Figure 11. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Te Henui Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at lower site, but bottom (0.5 m from bottom) waters only in upper site.

Te Henui Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 2, 1.7 ha
	Intertidal/Subtidal	51% subtidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	0.5-1 m, 800 m (salt wedge extent)
	Freshwater Inflow	Mean annual 1.2 m^3 s^{-1}*
	Saltmarsh, Seagrass	No saltmarsh, no seagrass
	Soft Mud	No intertidal soft mud
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Very Low**
	[Dissolved oxygen] (subtidal channel)	Low**
Catchment	Catchment size	28.4 km^2
	Max Dairy Cows Permitted	1,275
	Suspended Sediment Loading	3.7 kt yr^{-1}
	Total Nitrogen Loading	72.8 t yr^{-1} (11,732 mg TN m^{-2} d^{-1})
	Total Phosphorus Loading	2.2 t yr^{-1}
	Dominant Landuse	28% native forest, 1% exotic forest, 54% dairy, 0.1% sheep/beef.
	Dominant Toprock Geology	Ash (older than Taupo ash) 88%.

*Estimated mean flow at river mouth from NIWA's NZ River Maps software tool.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 2 representative subtidal channel sites (see locations in Figure 11). Sampled values in Appendix B.

Monitoring and Investigations

The low rating for both eutrophication and sedimentation in this estuary signifies a requirement for low frequency, screening level monitoring only.

To address the low potential for eutrophication/sedimentation issues (including both benthic and water column effects), it is recommended that low frequency (once every 10 years), screening level (synoptic) monitoring be undertaken to confirm that this low risk estuary has not changed its risk rating.

Tapuae Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Moderate	Moderate
Eutrophication	Minimal	Minimal

The Tapuae Estuary, which marks the boundary of the Tapuae Marine Reserve, is a short length, shallow, often poorly-flushed tidal river estuary. It has a low freshwater inflow and is located between Oakura and New Plymouth. Intertidal habitat is sand dominated and there is a narrow band of high tide saltmarsh (*Baumea juncea* - Bare twig rush) vegetation. The estuary mouth is mostly open to the sea but may become restricted during periods of lowflow, limiting tidal mixing, and consequently the estuary waters can become brackish. The estuary catchment is predominantly dairy farming but includes some mixed native forest and exotic forest (see summary information overleaf).

Human use, ecological and cultural values: The estuary is valued for its aesthetic and spiritual appeal, bathing and biodiversity. This stream mouth is a culturally significant site for Taranaki Iwi. Ecologically, habitat diversity is low-moderate with very little estuarine vegetation (in this case a small pocket of rushland and grassland) intact. There is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed primarily for grazing. The adjacent Tapuae coastal marine area is of high importance as it contains a number of significant pā and kainga, including tauranga waka and pūkāwa (reefs).

Eutrophication status: Despite its very high nutrient load (the current estimated catchment N areal loading of 32,054 mg TN m^{-2} d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2,000 mg TN m^{-2} d^{-1}, Robertson et al. 2016), the estuary has minimal susceptibility to eutrophication (NZ ETI Tool 1, Band A). This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with very few poorly flushed areas, and has adequate freshwater inflow.

The (one-off) synoptic survey in 2019, confirmed the absence of opportunistic macroalgal and phytoplankton blooms throughout the intertidal and subtidal estuary. The absence of primary eutrophication symptoms placed the estuary in very good (NZ ETI, Tool 2, Band A) condition with regard to eutrophication impacts.

We note that, while periodic (short-term) changes in eutrophic susceptibility are expected (particularly if the mouth becomes constricted), given the complete absence of eutrophic symptoms on the day of sampling when flushing was low (i.e. baseflow conditions), the low susceptibility rating is considered appropriate.

Sedimentation (muddiness) status: The estuary has moderate vulnerability to muddiness issues based on the facts that the current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL), the estuary is dominated by intertidal sands (with limited subtidal muds), but the mouth may be occasionally restricted. Ecologically, the overall moderate mud extent fits the NZ ETI Band B (moderate muddiness) condition rating.

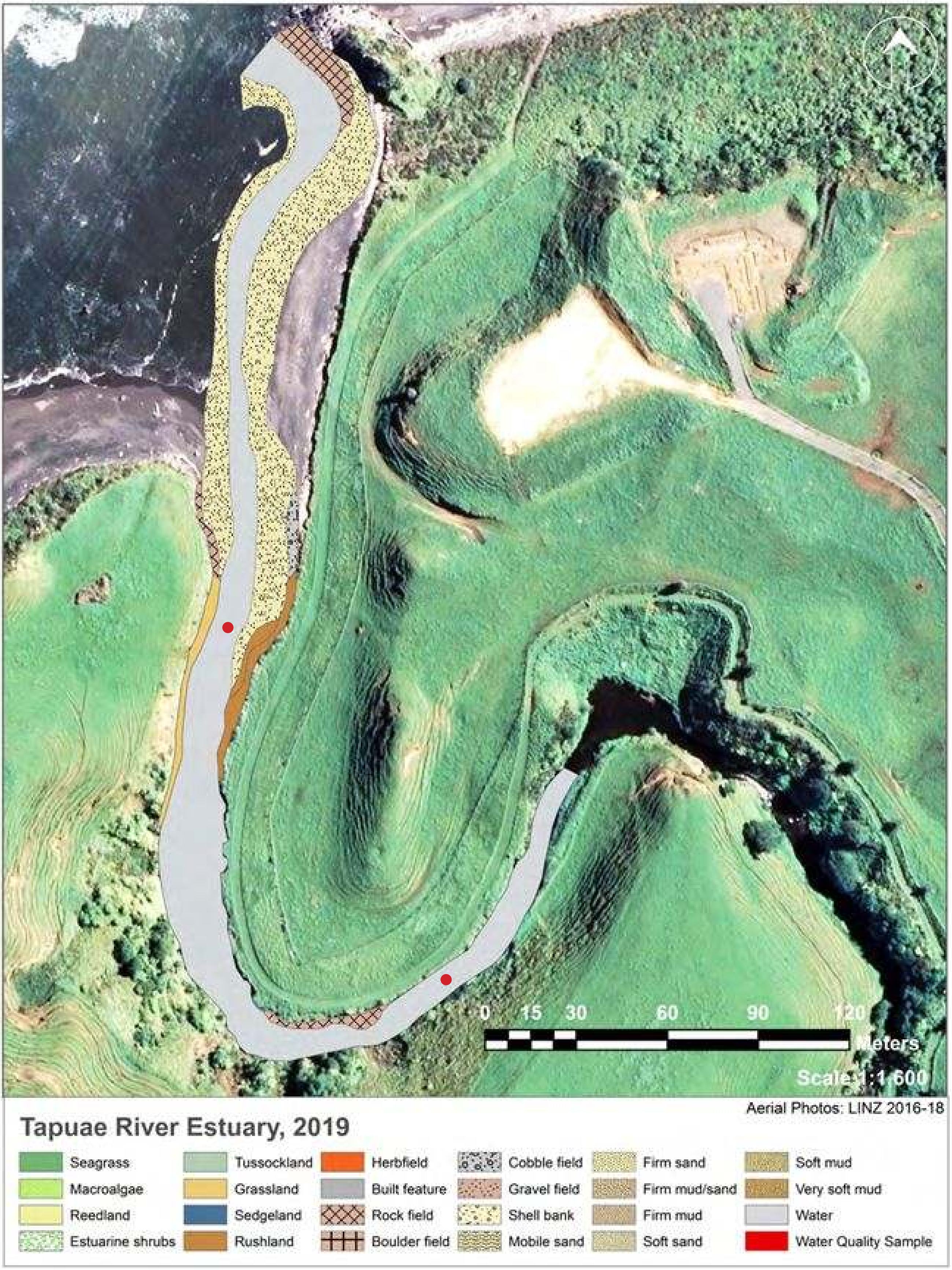


Figure 12. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Tapuae Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at each site.

Tapuae Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 1, 1.0 ha
	Intertidal/Subtidal	56% subtidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	0.5-1 m, 500 m (salt wedge extent)
	Freshwater Inflow	Mean annual 1.2 $m^3 s^{-1}$*
	Saltmarsh, Seagrass	0.05 ha saltmarsh, no seagrass
	Soft Mud	No intertidal soft mud
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Low**
	[Dissolved oxygen] (subtidal channel)	Very Low**
Catchment	Catchment size	31.9 km^2
	Max Dairy Cows Permitted	4,095
	Suspended Sediment Loading	4.1 kt yr^{-1}
	Total Nitrogen Loading	117 t yr^{-1} (32,054 mg TN m^{-2} d^{-1})
	Total Phosphorus Loading	2 t yr^{-1}
	Dominant Landuse	6% native forest, 3% exotic forest, 91% dairy.
	Dominant Toprock Geology	Ash (older than Taupo ash) 100%.

*Estimated mean flow at river mouth, NIWA's NZ River Maps software tool.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 2 representative subtidal channel sites (see locations in Figure 12). Sampled values in Appendix B.

Monitoring and Investigations

The low rating for both eutrophication and sedimentation in this estuary signifies a requirement for low frequency, screening level monitoring only.

To address the low potential for eutrophication/sedimentation issues (including both benthic and water column effects), it is recommended that low frequency (once every 10 years), screening level (synoptic) monitoring be undertaken to confirm that this low risk estuary has not changed its risk rating.

Oakura Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Moderate	Moderate
Eutrophication	Moderate	High

The Oakura Estuary is a relatively long, shallow, often poorly-flushed tidal river estuary (SSRTRE) that has a low freshwater inflow, extends approximately 1 km inland, and is located at the Oakura township. The middle estuary includes a 200 m long poorly flushed, deep (2-3 m) subtidal channel, and there is a 400 m long poorly flushed, shallow arm to the north that predominantly empties at low tide. Sediments are dominated by muddy sands in the mid-upper estuary and coarse sands in the lower. A small area of high tide saltmarsh (*Festuca arundinacea* - Tall fescue and *Plagianthus divaricatus* - Saltmarsh ribbonwood) vegetation occurs in the middle reaches. Beach duneland vegetation, primarily marram grass (*Ammophila arenaria*), dominates the terrestrial margins near the beach. The estuary mouth is mostly open to the sea, but at times it migrates along the beach and can be semi-restricted, which means the estuary is often brackish. A main feature of the estuary is that the majority of its area is located on the beach where tidal exposure is high. The estuary catchment is mixed native forest, dairy farming, and exotic forest (see summary information below).

Human use, ecological and cultural values: The estuary is valued for its aesthetic and spiritual appeal, bathing and biodiversity. This river mouth is a culturally significant site for Taranaki Iwi. Ecologically, habitat diversity is relatively low with very limited intertidal saltmarsh vegetation (in this case a narrow strip of glassland) intact, largely due to steep cliffs lining most of the mid-upper estuary margins. There is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed for recreation/urban use.

Eutrophication status: The estuary is moderately susceptible to eutrophication (both macroalgal- and phytoplankton-based) impacts based on the following:

- The estuary, although relatively small in size, has significant intertidal (48%) and subtidal (52%) habitat;
- It receives a high catchment-derived nutrient load (the current estimated catchment N areal loading of 7,692 mg TN m^{-2} d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2,000 mg TN m^{-2} d^{-1}, Robertson et al. 2016); and,
- It is often not well flushed, particularly its significant subtidal channel habitat, and has low freshwater inflow and is often turbid.

The (one-off) synoptic survey in 2019, confirmed the presence of nuisance phytoplankton blooms (highly elevated chlorophyll *a* coupled with super-saturated DO concentrations) throughout the entire subtidal channel, while macroalgae was absent from the intertidal reaches. The presence of primary eutrophication symptoms in the channel waters, despite the mouth being open on the day of sampling, placed the estuary in highly eutrophic (NZ ETI, Tool 2, Band C) condition. Notably, the persistence of such degraded conditions through time is likely regulated by (1) available intertidal area (i.e. influenced by mouth position), and (2) a combination of river inflow and tidal mixing, with mouth closure events reflecting a worst-case scenario in that regard. This latter point should be accounted for in any long-term estuary monitoring programme.

Sedimentation (muddiness) status: The estuary has moderate vulnerability to muddiness issues based on the facts that the current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL), the estuary is dominated by sands, but the mouth may be occasionally restricted. Ecologically, the overall moderate mud extent fits the NZ ETI Band B (moderate muddiness) condition rating.

Figure 13. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Oakura Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at each site.

Oakura Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 2, 2.6 ha
	Intertidal/Subtidal	52% intertidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	1-2 m, 1 km (salt wedge extent)
	Freshwater Inflow	Mean annual 2.7 m^3 s^{-1}*
	Saltmarsh, Seagrass	0.02 ha saltmarsh, no seagrass
	Soft Mud	No intertidal soft mud
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	High**
	[Dissolved oxygen] (subtidal channel)	Very Low**
Catchment	Catchment size	44.1 km^2
	Max Dairy Cows Permitted	1,495
	Suspended Sediment Loading	8.7 kt yr^{-1}
	Total Nitrogen Loading	73 t yr^{-1} (7,692 mg TN m^{-2} d^{-1})
	Total Phosphorus Loading	4.7 t yr^{-1}
	Dominant Landuse	60% native forest, 4% exotic forest, 34% dairy.
	Dominant Toprock Geology	Ash (older than Taupo ash) 96%, lavas & welded ignimbrites 3%.

*Estimated mean flow at river mouth, NIWA's NZ River Maps software tool.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 2 representative subtidal channel sites (see locations in Figure 13). Sampled values in Appendix B.

Monitoring and Investigations

For the Oakura Estuary it is recommended that annual monitoring of targeted eutrophication indicators (intertidal and subtidal channel) be undertaken to provide data on long-term trophic state trends.

To address potential for eutrophication, it is recommended that relevant water column and sediment-based indicators be monitored monthly during the period Nov-March each year at 1-2 sites representative of general conditions (e.g. mid-upper estuary) and at the same time, intertidal/ shallow subtidal macroalgal cover be assessed throughout the intertidal/shallow subtidal estuary. If, after 1-2 years, eutrophication is not found to be a persistent issue, this monitoring may cease.

Because this estuary is generally flushed regularly by high flow events, it is recommended that long-term monitoring for sedimentation be limited to low frequency (5-yearly), broad scale, screening level assessments only.

Timaru Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Moderate	Moderate
Eutrophication	Minimal	Minimal

The Timaru Estuary is a short length, predominatly shallow, often poorly-flushed tidal river estuary. It has a low freshwater inflow and is located to the southeast of Oakura township. Intertidal sediments are coarse sand and there are several relatively small pockets of high tide saltmarsh (*Phormium tenax* - NZ flax, *Baumea juncea* - Bare twig rush) vegetation in the mid-upper reaches. The estuary mouth is mostly open to the sea but may become restricted during periods of lowflow, limiting tidal mixing, and consequently the estuary waters can become brackish. The surrounding catchment comprises an almost equal proportion of dairy farming and mixed native forest (see further summary information overleaf).

Human use, ecological and cultural values: The estuary is valued for its aesthetic and spiritual appeal, bathing and biodiversity. It is a culturally significant site for Taranaki Iwi. Ecologically, habitat diversity is low-moderate with very little estuarine vegetation (in this case small pockets of rushland) intact. There is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed for grazing.

Eutrophication status: Despite its very high nutrient load (the current estimated catchment N areal loading of 8,421 mg TN m^{-2} d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2,000 mg TN m^{-2} d^{-1}, Robertson et al. 2016), the estuary has minimal susceptibility to eutrophication (NZ ETI Tool 1, Band A). This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with very few poorly flushed areas, and has adequate freshwater inflow.

The (one-off) synoptic survey in 2019, confirmed the absence of opportunistic macroalgal and phytoplankton blooms throughout the intertidal and subtidal estuary. The absence of primary eutrophication symptoms placed the estuary in very good (NZ ETI, Tool 2, Band A) condition with regard to eutrophication impacts.

We note that, while periodic (short-term) changes in eutrophic susceptibility are expected (particularly if the mouth becomes constricted), given the complete absence of eutrophic symptoms on the day of sampling when flushing was low (i.e. baseflow conditions), the low susceptibility rating is considered appropriate.

Sedimentation (muddiness) status: The estuary has moderate vulnerability to muddiness issues based on the facts that the current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL), the estuary is dominated by intertidal sands and subtidal muds, but the mouth may be occasionally restricted. Ecologically, the overall moderate mud content fits the NZ ETI Band B (moderate muddiness) condition rating.

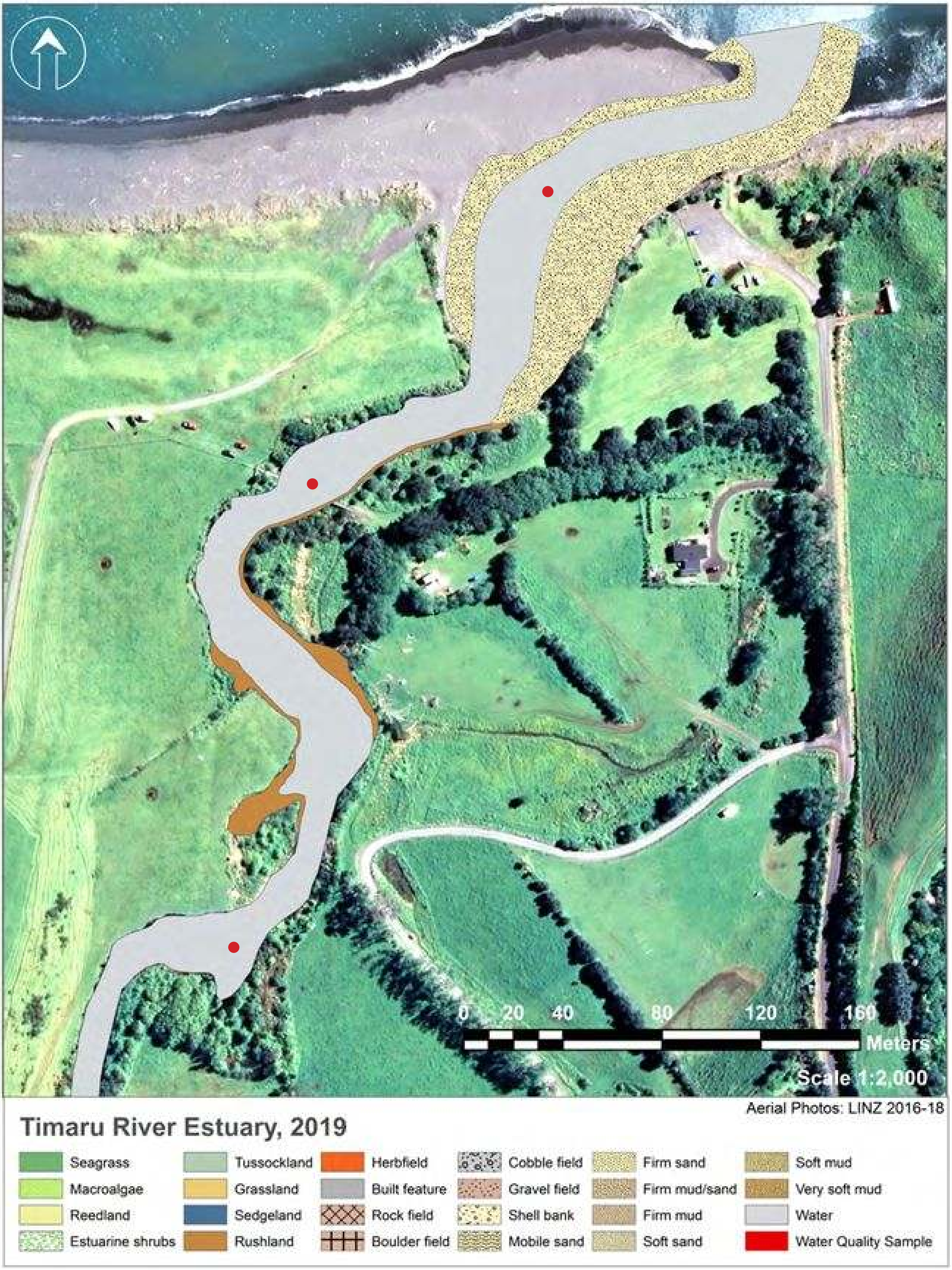


Figure 14. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Timaru Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2m) and bottom (0.5m from bottom) waters at each site.

Timaru Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 1, 1.9 ha
	Intertidal/Subtidal	64% subtidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	0.5-1 m, 800 m (salt wedge extent)
	Freshwater Inflow	Mean annual 1.8 $m^3 s^{-1}$*
	Saltmarsh, Seagrass	0.1 ha saltmarsh, no seagrass
	Soft Mud	No intertidal soft mud
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Low**
	[Dissolved oxygen] (subtidal channel)	Very Low**
Catchment	Catchment size	31.4 km^2
	Max Dairy Cows Permitted	1,690
	Suspended Sediment Loading	5.2 kt yr^{-1}
	Total Nitrogen Loading	58.4 t yr^{-1} (8,421 mg TN $m^{-2} d^{-1}$)
	Total Phosphorus Loading	2.5 t yr^{-1}
	Dominant Landuse	56% native forest, 43% dairy.
	Dominant Toprock Geology	Ash (older than Taupo ash) 98%.

*Mean flow as measured at Tataraimaka (SH45).
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 3 (*n*=5, as only bottom waters sampled at lower site) representative subtidal channel sites (see locations in Figure 14). Sampled values in Appendix B.

Monitoring and Investigations

The low rating for both eutrophication and sedimentation in this estuary signifies a requirement for low frequency, screening level monitoring only.

To address the low potential for eutrophication/sedimentation issues (including both benthic and water column effects), it is recommended that low frequency (once every 10 years), screening level (synoptic) monitoring be undertaken to confirm that this low risk estuary has not changed its risk rating.

Katikara Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Moderate	Moderate
Eutrophication	Moderate	High

The Katikara Estuary is a short, shallow, often poorly-flushed tidal river estuary (SSRTRE) that has a low freshwater inflow, extends approximately 700 m inland, and is located 6 km southeast of Oakura township. The mid-upper estuary includes a 300 m long poorly flushed, deep (1-2 m) subtidal channel, and there is a 200 m long well flushed, shallow arm to the north that predominantly empties at low tide. Sediments are dominated by muds in the subtidal mid-upper estuary and coarse sands in the lower intertidal reaches. A narrow band of high tide saltmarsh (*Isolepis nodosa* - Knobby clubrush, *Phormium tenax* - NZ Flax) vegetation occurs in the mid-upper reaches. The estuary mouth is mostly open to the sea, but at times it migrates along the beach and can be semi-restricted, which means the estuary is often brackish. The estuary catchment is predominantly dairy farming and includes mixed native forest, exotic forest and sheep and beef farming (see summary information overleaf).

Human use, ecological and cultural values: The estuary is located within the rohe of Taranaki Iwi, and is valued for its aesthetic and spiritual appeal, bathing and biodiversity. Ecologically, habitat diversity is relatively low-moderate with limited estuary vegetation (in this case a narrow strip of rushland/grassland) intact. There is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed for grazing.

Eutrophication status: The estuary has moderate susceptibility (NZ ETI Tool 1, Band B) to eutrophication impacts (primarily phytoplankton-based expression), based on the following:

- The estuary, although relatively small in size, has significant intertidal (56%) and subtidal (44%) habitat;
- It receives a high catchment-derived nutrient load (the current estimated catchment N areal loading of 10,736 mg TN m^{-2} d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2,000 mg TN m^{-2} d^{-1}, Robertson et al. 2016); and,
- It is often not well flushed, particularly its significant subtidal channel habitat, and has low freshwater inflow and is often turbid.

The (one-off) synoptic survey in 2019, confirmed the presence of nuisance phytoplankton blooms (highly elevated chl *a* coupled with super-saturated DO concentrations) throughout the entire subtidal channel, although macroalgae were absent from the intertidal reaches. The presence of primary eutrophication symptoms in the channel waters, despite the mouth being open on the day of sampling, placed the estuary in highly eutrophic (NZ ETI, Tool 2, Band C) condition. Notably, the persistence of such degraded conditions through time is likely regulated by a combination of river inflow and tidal mixing, with mouth closure events reflecting a worst-case scenario in that regard. This latter point should be accounted for in any long-term estuary monitoring programme.

Sedimentation (muddiness) status: The estuary has very minimal vulnerability to muddiness issues based on the facts that the current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL), the intertidal estuary is dominated by sands, but with some subtidal muds, and the mouth may be occasionally restricted. Ecologically, the overall moderate mud content fits the NZ ETI Band B (moderate muddiness) condition rating.

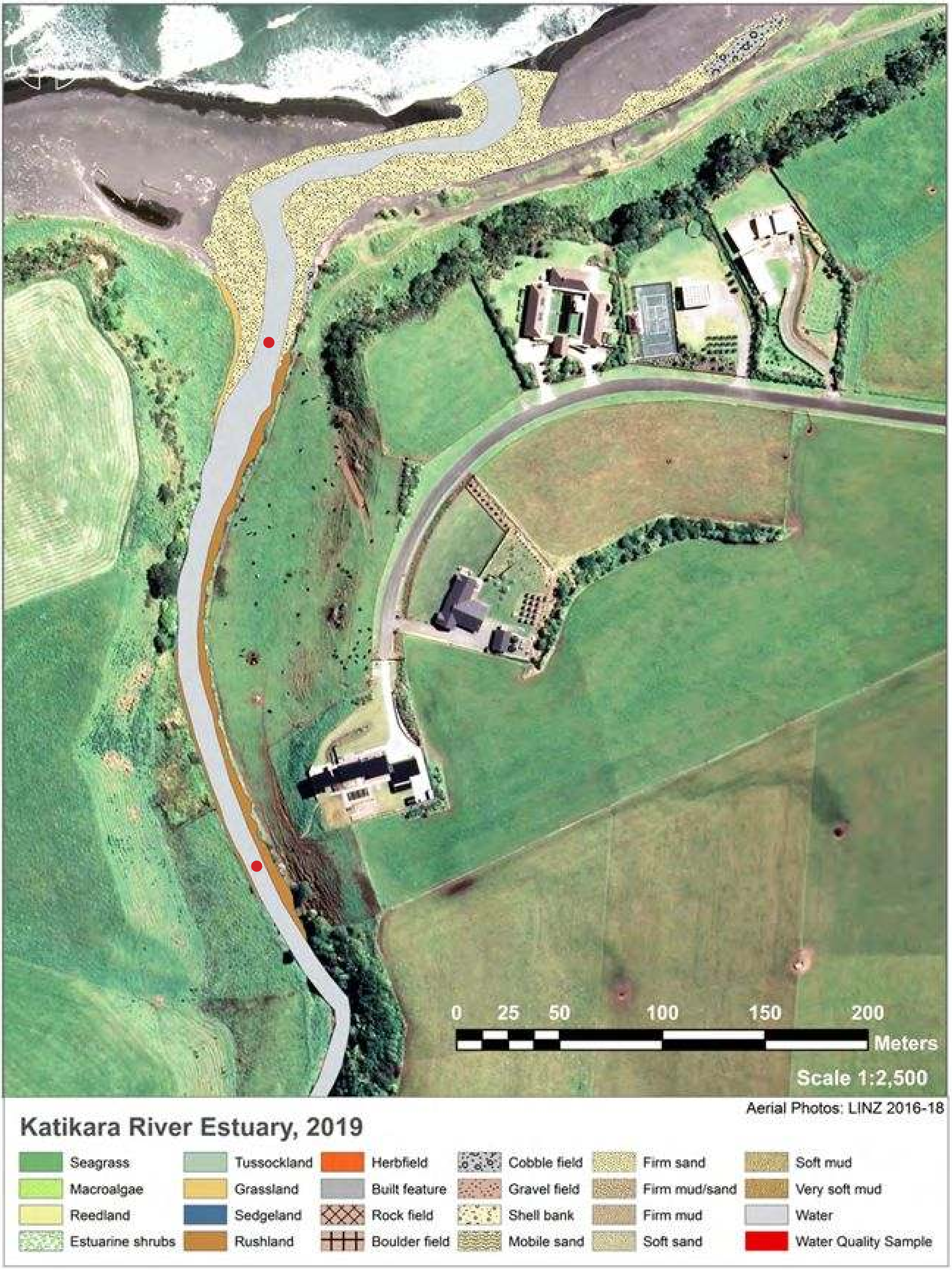


Figure 15. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Katikara Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at each site.

Katikara Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 1, 1.6 ha
	Intertidal/Subtidal	56% intertidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	0.5-1 m, 700 m (salt wedge extent)
	Freshwater Inflow	Mean annual 1.0 $m^3 s^{-1}$*
	Saltmarsh, Seagrass	0.15 ha saltmarsh, no seagrass
	Soft Mud	No intertidal soft mud
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	High**
	[Dissolved oxygen] (subtidal channel)	Very Low**
Catchment	Catchment size	22 km^2
	Max Dairy Cows Permitted	2,250
	Suspended Sediment Loading	2.5 kt yr^{-1}
	Total Nitrogen Loading	62.7 t yr^{-1} (10,736 mg TN $m^{-2} d^{-1}$)
	Total Phosphorus Loading	1.5 t yr^{-1}
	Dominant Landuse	26% native forest, 2% exotic forest, 71% dairy, 0.5% sheep/beef.
	Dominant Toprock Geology	Ash (older than Taupo ash) 99%.

*Estimated mean flow at river mouth from NIWA's NZ River Maps software tool.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 2 representative subtidal channel sites (see locations in Figure 15). Sampled values in Appendix B.

Monitoring and Investigations

For the Katikara Estuary it is recommended that annual monitoring of targeted eutrophication indicators (intertidal and subtidal channel) be undertaken to provide data on long-term trophic state trends.

To address potential for eutrophication, it is recommended that relevant water column and sediment-based indicators be monitored monthly during the period Nov-March each year at 1-2 sites representative of general conditions (e.g. mid-upper estuary) and at the same time, intertidal/ shallow subtidal macroalgal cover be assessed throughout the intertidal/shallow subtidal estuary. If, after 1-2 years, eutrophication is not found to be a persistent issue, this monitoring may cease.

Because this estuary is generally flushed regularly by high flow events, it is recommended that long-term monitoring for sedimentation be limited to low frequency (5-yearly), broad scale, screening level assessments only.

Kaupokonui Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Moderate	Moderate
Eutrophication	Minimal	Minimal

The Kaupokonui Estuary is a small, short length, shallow, tidal river estuary that extends from the sea to approximately 700 m inland. It has a high freshwater inflow and is located 5 km west of Hawera. Intertidal sediments are mostly cobbles with some coarse sands near the mouth, which is predominantly open to the sea. There is duneland on the northern margin but no estuarine vegetation, primarily due to lack of space with steep banks and rockwall lining the margins. The estuary mouth is mostly open to the sea but may become restricted during periods of lowflow, limiting tidal mixing, and consequently the estuary waters can become brackish. The estuary catchment is predominantly dairy farming but includes some mixed native forest, exotic forest, sheep and beef farming (see summary information overleaf).

Human use, ecological and cultural values: Although small in size and inland extent, the estuary and landscape is highly valued by locals and tourists for camping, swimming, fishing and surfing. Kaupokonui is commonly cited as the 'jewel of South Taranaki' in terms of amenity values. Ecologically, habitat diversity is low with no estuarine vegetation, steep cliffs either side, and much of the immediate natural vegetated margin has been lost and is now developed for grazing. The estuary and associated coast has significant scientific values including the remains of several species of moa and other extinct birds, includes threatened, at risk and regionally distinctive flora species, and inanga spawning sites. This estuary is particularly significant to Ngā Ruahine Iwi, and was abundant with tunaheke, piharau, kahawai, īnanga, pakotea and kōkopu.

Eutrophication status: Despite its very high nutrient load (the current estimated catchment N areal loading of 42,033 mg TN m^{-2} d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2,000 mg TN m^{-2} d^{-1}, Robertson et al. 2016), the estuary has minimal susceptibility to eutrophication (NZ ETI Tool 1, Band A). This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with no poorly flushed areas, and has high freshwater inflow.

The (one-off) synoptic survey in 2019, confirmed the absence of opportunistic macroalgal and phytoplankton blooms throughout the intertidal and subtidal estuary, and an NZ ETI (Tool 2) condition rating of 'minimal' (Band A) for eutrophication.

We also note that, while toxic algal blooms (e.g. benthic cyanobacteria) have been reported in the estuary in the past, often leading to public closure (e.g. November, 2018), such conditions are likely driven by short periods of mouth closure coincident with prolonged low river inflows and therefore highly ephemeral. The present survey was undertaken during baseflows and no such algal blooms were observed, so the overall low susceptibility rating is considered appropriate.

Sedimentation (muddiness) status: The estuary has moderate vulnerability to muddiness issues based on the facts that the current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL), the estuary is dominated by cobble/sand, but the mouth may be occasionally restricted. Ecologically, the overall moderate mud extent fits the NZ ETI Band B (moderate muddiness) condition rating.

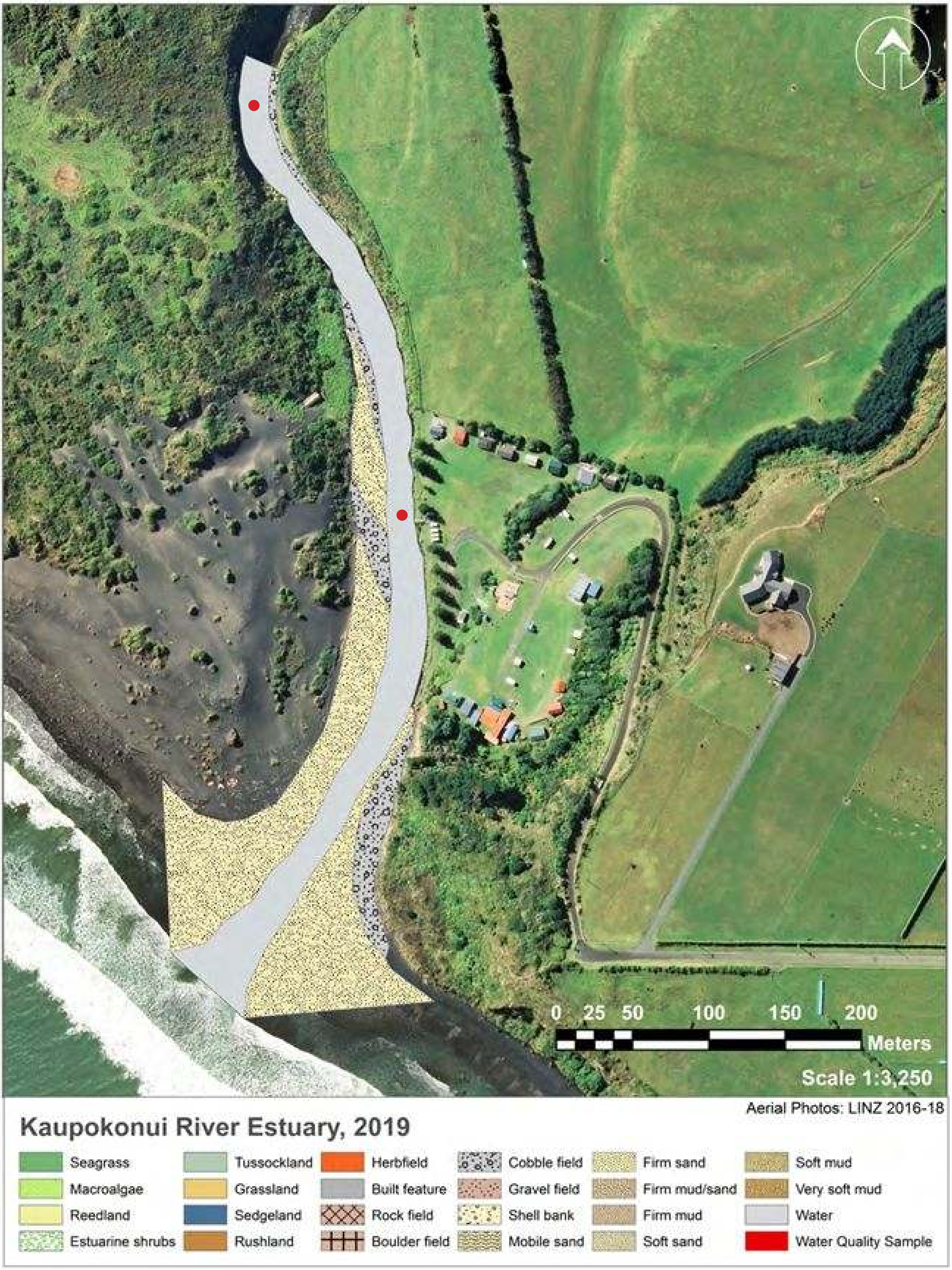


Figure 16. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Kaupokonui Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at each site.

Kaupokonui Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 4 (short length), 3.8 ha
	Intertidal/Subtidal	60% intertidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	0.5-1 m, 700 m (salt wedge extent)
	Freshwater Inflow	Mean annual 7.14 m^3 s^{-1}*
	Saltmarsh, Seagrass	No saltmarsh, no seagrass
	Soft Mud	No intertidal soft mud
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Very Low**
	[Dissolved oxygen] (subtidal channel)	Very Low**
Catchment	Catchment size	146.9 km^2
	Max Dairy Cows Permitted	27,025
	Suspended Sediment Loading	15.2 kt yr^{-1}
	Total Nitrogen Loading	583 t yr^{-1} (42,033 mg TN m^{-2} d^{-1})
	Total Phosphorus Loading	14.1 t yr^{-1}
	Dominant Landuse	20% native forest, 2% exotic forest, 76% dairy, 0.4% sheep/beef.
	Dominant Toprock Geology	Ash (older than Taupo ash) 75%, lavas & welded ignimbrites 5%, Taupo & Kaharaoa breccias (older than Taupo breccia) 6%, lahar deposits 3%.

*Estimated mean flow at river mouth from NIWA's NZ River Maps software tool.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 2 (*n*=3, as only bottom waters sampled at lower site) representative subtidal channel sites (see locations in Figure 16). Sampled values in Appendix B.

Monitoring and Investigations

The low rating for both eutrophication and sedimentation in this estuary signifies a requirement for low frequency, screening level monitoring only.

To address the low potential for eutrophication/sedimentation issues (including both benthic and water column effects), it is recommended that low frequency (once every 10 years), screening level (synoptic) monitoring be undertaken to confirm that this low risk estuary has not changed its risk rating.

Waingongoro Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Moderate	Minimal
Eutrophication	Minimal	Minimal

The Waingongoro Estuary is a small, short length, shallow, tidal river estuary that extends from the sea to approximately 500 m inland. It is slightly perched at the high water zone, has a high freshwater inflow and is located 5 km west of Hawera. Intertidal sediments are mostly cobbles with some coarse sands near the mouth, which is predominantly open to the sea. There is no estuarine vegetation, primarily due to lack of space with steep cliffs at the margins. The estuary mouth is mostly open to the sea but may become restricted during periods of lowflow, limiting tidal mixing, and consequently the estuary waters can become brackish. The estuary catchment is predominantly dairy farming but includes some mixed native forest, exotic forest, sheep and beef farming (see summary information overleaf).

Human use, ecological and cultural values: Although small in size and inland extent, the estuary is valued for its aesthetic and spiritual appeal, bathing and biodiversity. It is also significant to Ngāruahine, and was abundant with tunaheke, piharau, īnanga, pakotea and kōkopu. Ecologically, habitat diversity is low with no estuarine vegetation, steep cliffs either side, and much of the immediate natural vegetated margin has been lost and is now developed for grazing.

Eutrophication status: Despite its very high nutrient load (the current estimated catchment N areal loading of 147,808 mg TN m^{-2} d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2,000 mg TN m^{-2} d^{-1}, Robertson et al. 2016), the estuary has minimal susceptibility to eutrophication (NZ ETI Tool 1, Band A). This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with no poorly flushed areas, and has high freshwater inflow.

The (one-off) synoptic survey in 2019, confirmed the absence of opportunistic macroalgal and phytoplankton blooms throughout the intertidal and subtidal estuary, and an NZ ETI (Tool 2) condition rating of 'minimal' (Band A) for eutrophication.

We note that, while periodic (short-term) changes in eutrophic susceptibility are expected (particularly if the mouth becomes constricted), given the complete absence of eutrophic symptoms on the day of sampling when flushing was low (i.e. baseflow conditions), the low susceptibility rating is considered appropriate.

Sedimentation (muddiness) status: The estuary has moderate vulnerability to muddiness issues based on the facts that the current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL), the estuary is dominated by cobble/sand, but the mouth may be occasionally restricted. Ecologically, the overall very low mud extent fits the NZ ETI Band A (minimal muddiness) condition rating.

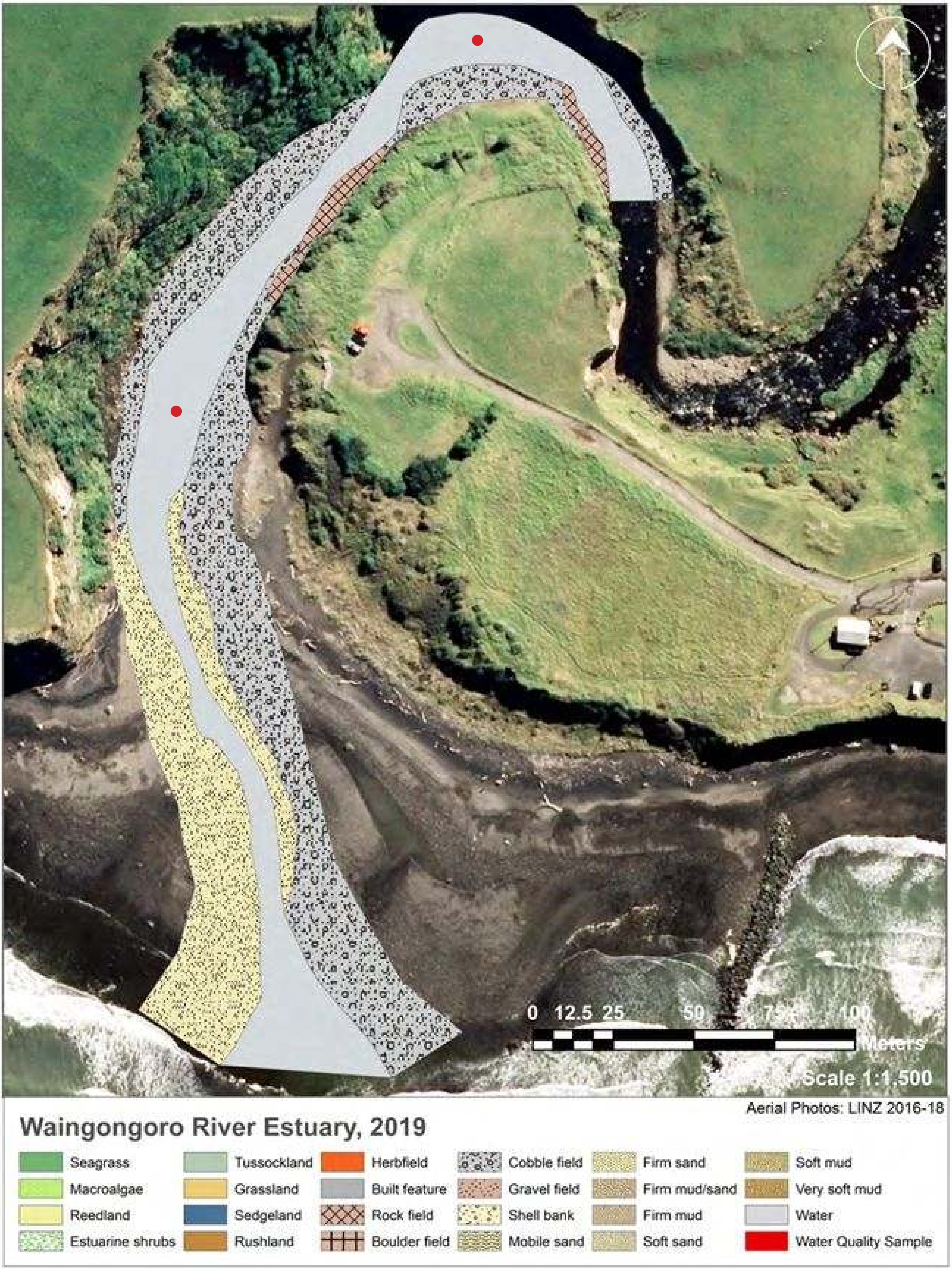


Figure 17. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Waingongoro Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at each site.

Waingongoro Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 2 (short length), 1.6 ha
	Intertidal/Subtidal	65% intertidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	0.5-1 m, 500 m (salt wedge extent)
	Freshwater Inflow	Mean annual 7.2 $m^3 s^{-1}$*
	Saltmarsh, Seagrass	No saltmarsh, no seagrass
	Soft Mud	No intertidal soft mud
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Very Low**
	[Dissolved oxygen] (subtidal channel)	Very Low**
Catchment	Catchment size	219.1 km^2
	Max Dairy Cows Permitted	49,259
	Suspended Sediment Loading	16.2 kt yr^{-1}
	Total Nitrogen Loading	863.2 t yr^{-1} (147,808 mg TN $m^{-2} d^{-1}$)
	Total Phosphorus Loading	27.4 t yr^{-1}
	Dominant Landuse	7% native forest, 1% exotic forest, 91% dairy, 0.1% sheep/beef.
	Dominant Toprock Geology	Ash (older than Taupo ash) 90%, lavas & welded ignimbrites 1%, peat 5%.

*Mean flow measured at SH45.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 2 representative subtidal channel sites (see locations in Figure 17). Sampled values in Appendix B.

Monitoring and Investigations

The low rating for both eutrophication and sedimentation in this estuary signifies a requirement for low frequency, screening level monitoring only.

To address the low potential for eutrophication/sedimentation issues (including both benthic and water column effects), it is recommended that low frequency (once every 10 years), screening level (synoptic) monitoring be undertaken to confirm that this low risk estuary has not changed its risk rating.

Tangahoe Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Moderate	Moderate
Eutrophication	Minimal	Minimal

The Tangahoe Estuary is a short length, shallow, tidal river estuary that extends from the sea to approximately 1 km inland. It is perched at the high water zone, has a moderate freshwater inflow and is located in the South Taranaki Bight (5 km southeast of Hawera). Intertidal sediments are sand-dominated and include a small area of saltmarsh (*Sarcocornia quinqueflora* - Glasswort, *Juncus kraussii* - Searush, *Juncus articulatus* - Jointed rush) vegetation. The estuary mouth is mostly open to the sea but may become restricted during periods of lowflow, limiting tidal mixing, and consequently the estuary waters can become brackish. The estuary catchment is predominantly dairy farming but includes some mixed native forest, exotic forest (including consented forestry), sheep and beef farming (see summary information overleaf).

Human use, ecological and cultural values: The estuary is valued for its aesthetic and spiritual appeal, bathing and biodiversity. It is significant to Ngāti Ruanui, with piharau, kokopu, tunaheke, patiki, and shelfish previously abundant within the estuary and on the coastal reefs at the river mouth. Ecologically, habitat diversity is low-moderate with some of its intertidal vegetation, saltmarsh (in this case small pockets of rushland and herbfield) intact, although there is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed for grazing.

Eutrophication status: Despite its very high nutrient load (the current estimated catchment N areal loading of 16,757 mg TN m^{-2} d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2,000 mg TN m^{-2} d^{-1}, Robertson et al. 2016), the estuary has minimal susceptibility to eutrophication (NZ ETI Tool 1, Band A). This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with very few poorly flushed areas, and has adequate freshwater inflow.

The (one-off) synoptic survey in 2019, confirmed the absence of opportunistic macroalgal and phytoplankton blooms throughout the intertidal and subtidal estuary, and an NZ ETI (Tool 2) condition rating of ‘minimal’ (Band A) for eutrophication.

We note that, while periodic (short-term) changes in eutrophic susceptibility are expected (particularly if the mouth becomes constricted), given the complete absence of eutrophic symptoms on the day of sampling when flushing was low (i.e. baseflow conditions), the low susceptibility rating is considered appropriate.

Sedimentation (muddiness) status: The estuary has moderate vulnerability to muddiness issues based on the facts that the current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL), the estuary is dominated by sands, but with some subtidal muds, and the mouth may be occasionally restricted. Ecologically, the overall moderate mud extent fits the NZ ETI Band A (moderate muddiness) condition rating.

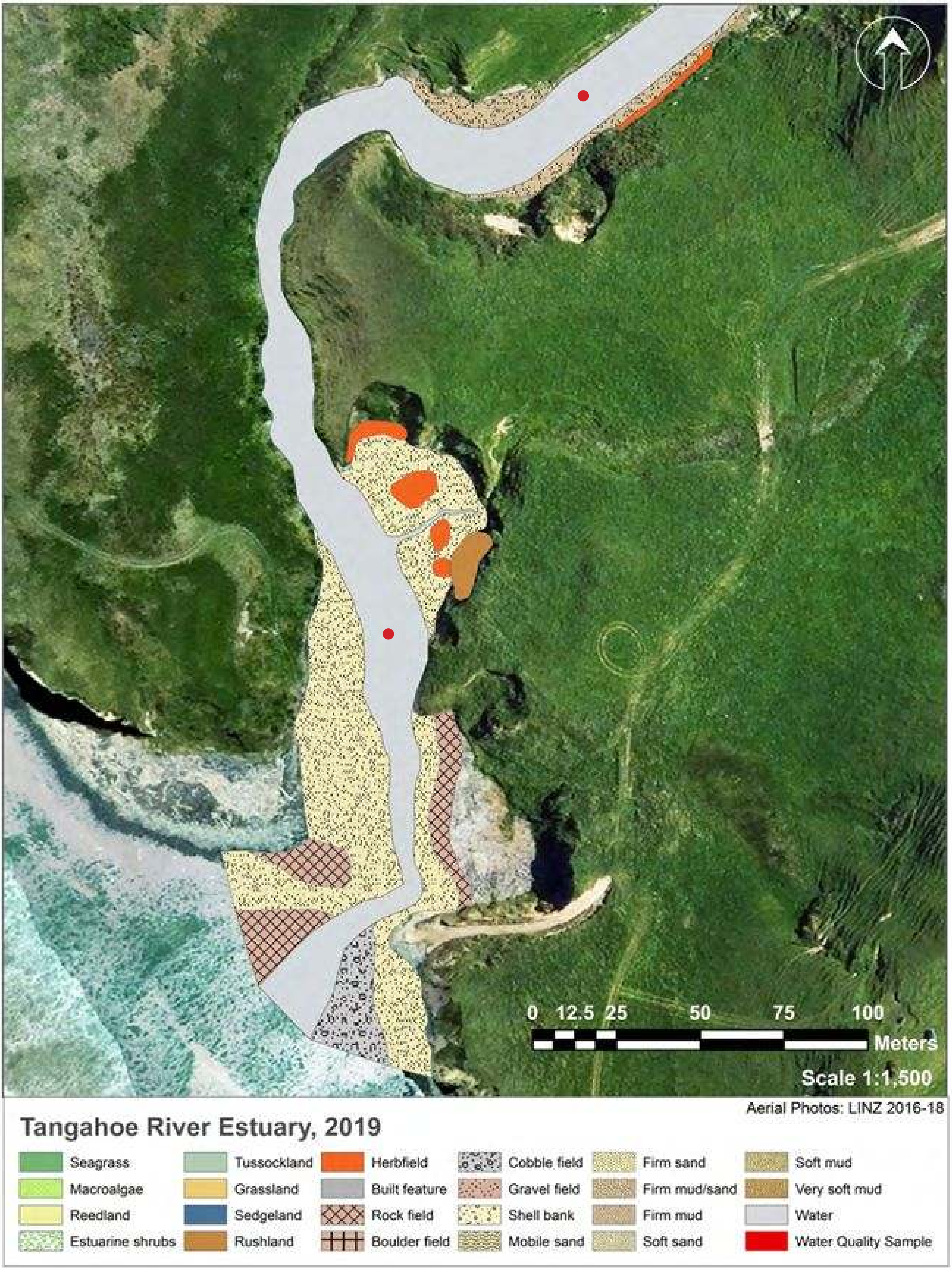


Figure 18. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Tangahoe Estuary, March 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at each site.

Tangahoe Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 3 (short length), 1.8 ha
	Intertidal/Subtidal	57% intertidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	0.5-1 m, 900 m (salt wedge extent)
	Freshwater Inflow	Mean annual 6.7 m^3 s^{-1}*
	Saltmarsh, Seagrass	0.1 ha saltmarsh, no seagrass
	Soft Mud	No intertidal soft mud
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Very Low**
	[Dissolved oxygen] (subtidal channel)	Low-Mod**
Catchment	Catchment size	297.6 km^2
	Max Dairy Cows Permitted	24,440
	Suspended Sediment Loading	52.5 kt yr^1
	Total Nitrogen Loading	110.1 t yr^1 (16,757 mg TN m^{-2} d^{-1})
	Total Phosphorus Loading	15.5 t yr^1
	Dominant Landuse	10% native forest, 13% exotic forest, 57% dairy, 18% sheep/beef.
	Dominant Toprock Geology	Alluvial 2%, mudstone 3%, massive mudstone 55%, peat 2%, massive sandstone 33%.

*Estimated mean flow at river mouth from NIWA's NZ River Maps software tool.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 2 (*n*=3, as only bottom waters sampled at lower site) representative subtidal channel sites (see locations in Figure 18). Sampled values in Appendix B.

Monitoring and Investigations

The low rating for both eutrophication and sedimentation in this estuary signifies a requirement for low frequency, screening level monitoring only.

To address the low potential for eutrophication/sedimentation issues (including both benthic and water column effects), it is recommended that low frequency (once every 10 years), screening level (synoptic) monitoring be undertaken to confirm that this low risk estuary has not changed its risk rating.

Manawapou Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Moderate	Moderate
Eutrophication	Minimal	Minimal

The Manawapou Estuary is a moderate length, shallow tidal river estuary, has low freshwater inflow, and is located in the South Taranaki Bight between Hawera and Patea. Intertidal sediments are dominated by sands and include several small pockets of saltmarsh (*Juncus krausii* - Searush, and *Apodasmia similis* - Jointed wirerush) and herbfield (*Sarcocornia quinqueflora* - Glasswort) vegetation which is limited to the upper reaches. The estuary mouth is mostly open to the sea but may become restricted during periods of lowflow, limiting tidal mixing, and consequently the estuary waters can become brackish. The estuary catchment is mixed native forest, exotic forest (including consented forestry), dairy and sheep and beef farming (see summary information overleaf).

Human use, ecological and cultural values: The estuary, located within the rohe of Ngāti Ruanui, is valued for its spiritual/aesthetic appeal, bathing and biodiversity. Ecologically, habitat diversity is low-moderate with some of its intertidal vegetation, saltmarsh (in this case small pockets of rushland and herbfield) intact. However, there is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed primarily for grazing.

Eutrophication status: Despite its very high nutrient load (the current estimated catchment N areal loading of 16,758 mg TN m^{-2} d^{-1} exceeds the guideline for low susceptibility tidal river estuaries of ~2,000 mg TN m^{-2} d^{-1}, Robertson et al. 2016), the estuary has minimal susceptibility to eutrophication (NZ ETI Tool 1, Band A). This is primarily because of its highly flushed nature, given that it is predominantly strongly channelised with very few poorly flushed areas, and has adequate freshwater inflow.

The (one-off) synoptic survey in 2019, confirmed the absence of opportunistic macroalgal and phytoplankton blooms throughout the intertidal and subtidal estuary, and an NZ ETI (Tool 2) condition rating of 'minimal' (Band A) for eutrophication impacts.

Sedimentation (muddiness) status: The estuary has moderate vulnerability to muddiness issues based on the facts that the current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL), the estuary is dominated by sands, but the mouth may be occasionally restricted. Ecologically, the overall moderate mud extent fits the NZ ETI Band B (moderate muddiness) condition rating.

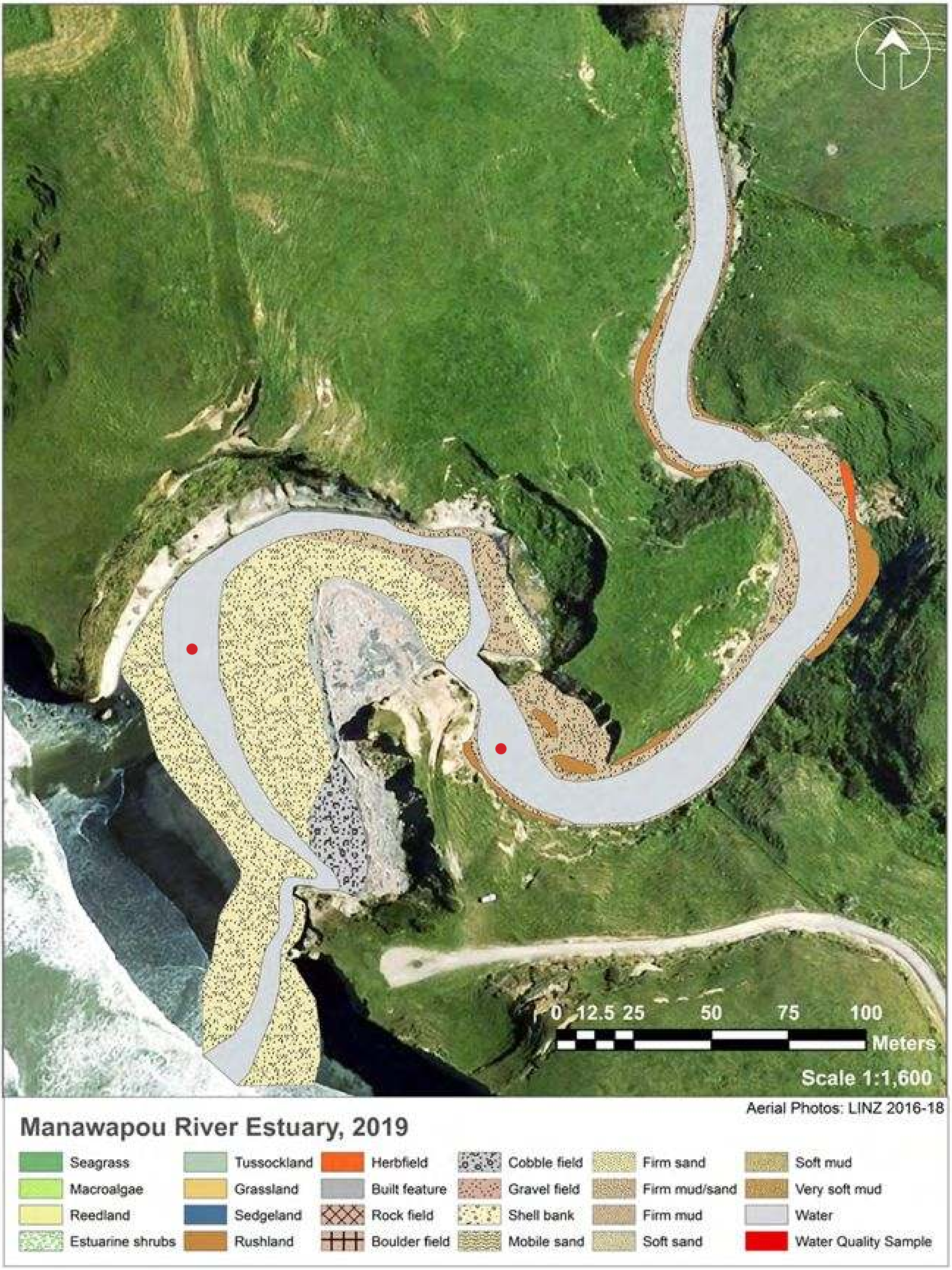


Figure 19. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Manawapou Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2m) and bottom (0.5m from bottom) waters at each site.

Manawapou Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 2, 1.8 ha
	Intertidal/Subtidal	57% intertidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	0.5-1 m, 1 km (salt wedge extent)
	Freshwater Inflow	Mean annual 2.9 m^3 s^{-1}*
	Saltmarsh, Seagrass	0.1 ha saltmarsh, no seagrass
	Soft Mud	No intertidal soft mud
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Very Low**
	[Dissolved oxygen] (subtidal channel)	Low-Mod**
Catchment	Catchment size	122.3 km^2
	Max Dairy Cows Permitted	9,000
	Suspended Sediment Loading	52.5 kt yr^{-1}
	Total Nitrogen Loading	110.1 t yr^{-1} (16,758 mg TN m^{-2} d^{-1})
	Total Phosphorus Loading	15.5 t yr^{-1}
	Dominant Landuse	32% native forest, 7% exotic forest, 43% dairy, 17.8% sheep/beef.
	Dominant Toprock Geology	Alluvial 2%, mudstone 54%, massive sand-stone 37%, unconsolidated gravels/sands 6%.

*Estimated mean flow at river mouth from NIWA's NZ River Maps software tool.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 2 (*n*=3, as only bottom waters sampled at lower site) representative subtidal channel sites (see locations in Figure 19). Sampled values in Appendix B.

Monitoring and Investigations

The low rating for both eutrophication and sedimentation in this estuary signifies a requirement for low frequency, screening level monitoring only.

To address the low potential for eutrophication/sedimentation issues (including both benthic and water column effects), it is recommended that low frequency (once every 10 years), screening level (synoptic) monitoring be undertaken to confirm that this low risk estuary has not changed its risk rating.

Patea Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Mod-High	Very High
Eutrophication	Very High	Moderate

The Patea Estuary is a highly modified, long length, shallow, well-flushed tidal river estuary located in the South Taranaki Bight near the town of Patea. It has a high freshwater inflow (regulated somewhat by upriver hydro-schemes), an always open mouth, and is dominated by a relatively wide (~30 m) subtidal channel (63% of estuary).

Intertidal habitat is characterised by soft muds (3.4 ha, 23% unvegetated intertidal area) and sands and include some saltmarsh dominated by rushland (*Juncus kraussii* - Searush, *Apodasmia similis* - Jointed wirerush, *Isolepis cernua* - Slender clubrush) and to a lesser extent herbfield (*Sarcocornia quinqueflora* - Glasswort) vegetation.

The estuary catchment is dominated by native forest, dairy and sheep/beef farming and, to a much lesser extent, exotic forest (including consented forestry) - see summary information overleaf.

Human use, ecological and cultural values: The estuary has good access and is valued for its spiritual value, aesthetic appeal, bathing and biodiversity. It is significant to the people of both Ngāti Ruanui and Ngaa Rauru Kiitahi. Food sources, gathered from the entire length of this river, included kaakahi, kuku, tuna, kanae, piharau, whitebait, smelt, flounder, place, sole, kahawai, taamure, shark and stingray. Ecologically, habitat diversity is moderate-high with some of its intertidal vegetation, saltmarsh (in this case rushland and herbfield) intact. However, there is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed for grazing and urban use.

Eutrophication status: The estuary is very highly (NZ ETI Tool 1, Band D) susceptible to macroalgal-based eutrophication at times based on (1) its relatively high proportion (>37%) of intertidal habitat, including two physically constricted arms in the middle estuary, and (2) its very high nutrient load (the current estimated N areal loading of 7,020 mg TN m^{-2} d^{-1} exceeds the tentative guideline for low susceptibility SSRTREs of ~2000 mg TN m^{-2} d^{-1}).

Despite the very high rating, the 2019 field survey resulted in an NZ ETI (Tool 2) condition rating of moderate (Band B), with minimal sign of primary eutrophication symptoms (nuisance opportunistic macroalgae). Their absence was most likely related to turbidity-induced light limitation (during hightide) and/or flushing during flood periods. In addition, synoptic (one-off) sampling of the main subtidal channel waters (surface and bottom) indicated an absence of nuisance phytoplankton blooms (very low [chl *a*]), again reflecting light limitation and/or flushing in that part of the system. However, on occasions during low flows when the estuary is stratified and turbidity is low, nuisance algal/macrophyte growth may occur.

We note that such mud-impacted estuaries generally are more susceptible to eutrophication impacts, so the present survey results must be viewed in that context, and the potential for rapid ecological decline accounted for in any long-term monitoring programme.

Sedimentation (muddiness) status: The estuary is rated as moderate-highly vulnerable to muddiness issues based on the fact that, although the estimated current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL) and excess sediments are likely to be flushed to the sea during high flows, the catchment is naturally erosion prone (Suspended Sediment Yield map of sediment delivery to rivers and stream [NIWA]) and the synoptic survey showed that the estuary is dominated by muddy sediments in the less well flushed mid-upper (intertidal and subtidal) reaches. Ecologically, the overall high mud content fits the NZ ETI Band D (very high) condition rating.

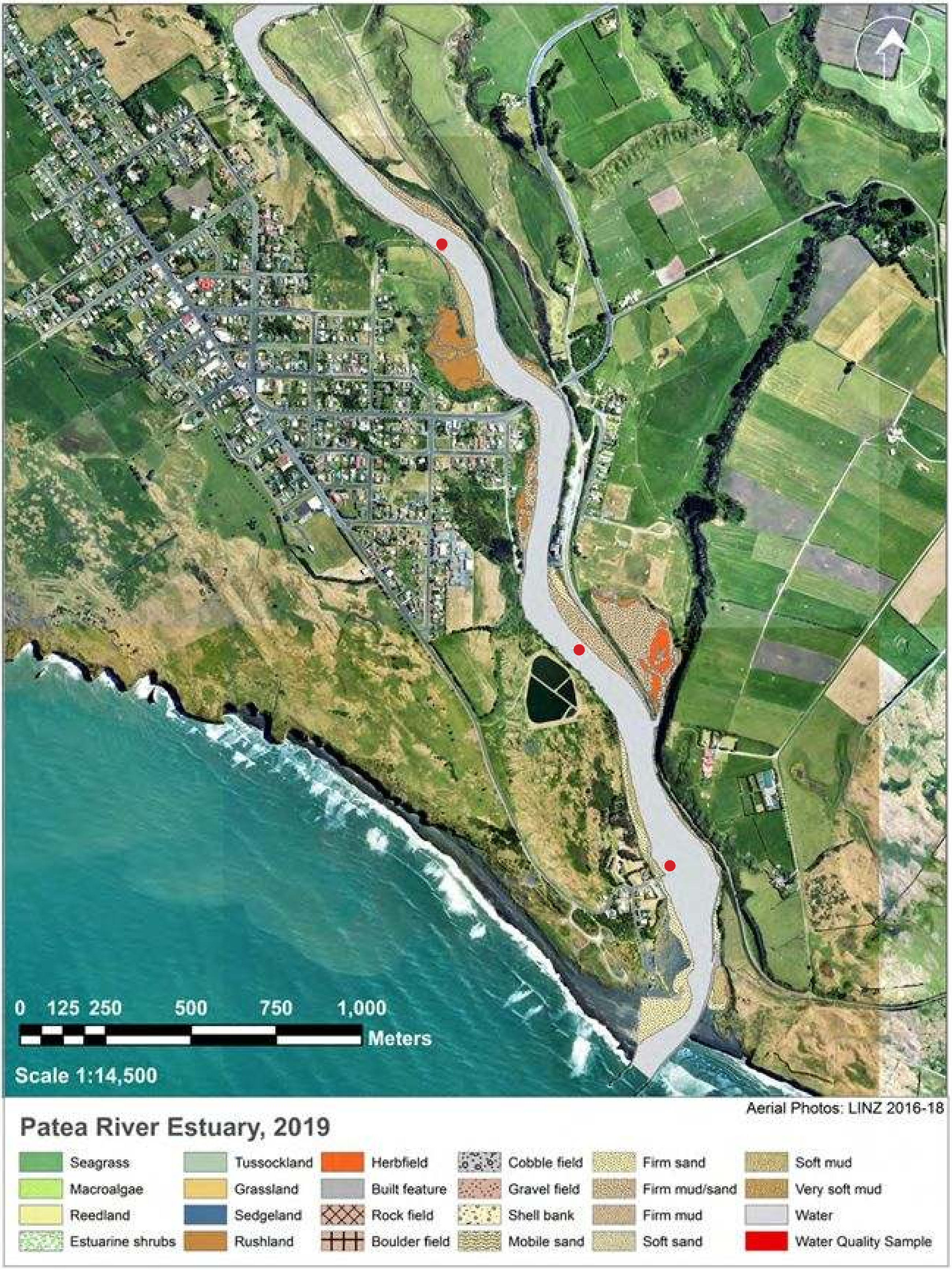


Figure 20. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Patea Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at each site.

Patea Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 4, 49.1 ha
	Intertidal/Subtidal	63% subtidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	2.0-3.0 m, 4 km (salt wedge extent)
	Freshwater Inflow	Mean annual 29.5 m^3 s^{-1}*
	Saltmarsh, Seagrass	3.7 ha saltmarsh, no seagrass
	Soft Mud	3.4 ha (23% unvegetated intertidal area)
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Very Low**
	[Dissolved oxygen] (subtidal channel)	Low-Mod**
Catchment	Catchment size	1045.8 km^2
	Max Dairy Cows Permitted	49,291
	Suspended Sediment Loading	469.6 kt yr^{-1}
	Total Nitrogen Loading	1258 t yr^{-1} (7,020 mg TN m^{-2} d^{-1})
	Total Phosphorus Loading	123.5 t yr^{-1}
	Dominant Landuse	35% native forest, 7% exotic forest, 27% dairy, 31% sheep/beef.
	Dominant Toprock Geology	Alluvial 5%, ash (older than Taupo ash) 36%, peat 1%, massive sandstone 56%.

*Mean flow measured at Patea at McColls Bridge and does not include Patea HEP (Lake Rotorangi), but they on average discharge at 29 m3 s^{-1} or 2,505,946 m^3 d^{-1}.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 3 representative subtidal channel sites (see locations in Figure 20). Sampled values in Appendix B.

Monitoring and Investigations

For "long-length (mouth sometimes closed or restricted) SSRTREs" with significant intertidal and subtidal habitat comprising poorly flushed/muddy substrata, moderate-high nutrient/sediment loads and high human use and cultural/ecological values, it is recommended that both broad scale habitat mapping and fine scale monitoring be undertaken on a long-term basis to assess trends in estuary ecological condition using the National Estuary Monitoring Protocol (Robertson et al. 2002), plus subsequent improvements (Robertson 2018). Outputs should be compared against relevant national standards (i.e. NZ ETI; Robertson et al. 2016a,b). In addition, sedimentation plates, which, over the long-term, will help provide an indicative measure of the rate of sedimentation in the estuary, should be deployed and monitored annually as per Hunt (2019).

Broad scale habitat mapping documents the key habitats within the estuary, and changes to these habitats over time. It is typically repeated at 5-yearly intervals. Fine scale monitoring measures the condition of the high susceptibility intertidal and subtidal habitat through physical, chemical and biological indicators. It is undertaken once annually for three consecutive years during the period Nov-March (usually at 2 intertidal and 3-4 subtidal sites), and thereafter at 5-yearly intervals. Both components have not yet been measured in this estuary.

Whenuakura Estuary Issue	Susceptibility	Condition Rating (2019)
Sedimentation	Moderate	Moderate
Eutrophication	Very High	Minimal

The Whenuakura River Estuary is a large, shallow, generally well-flushed, tidal river estuary (SSRTRE) that is located southeast of Patea and extends approximately 5 km inland. It has a high freshwater inflow which, along with tidal inflow, is expected to flush most of the catchment-derived nutrients and sediment from the estuary. Intertidal substrata are dominated by sand, are generally well oxygenated and comprise small areas of saltmarsh. The estuary includes areas of high tide saltmarsh (*Typha orientalis* - Raupo, *Schoenoplectus pungens* - Three-square, *Apodasmia similis* - Jointed wirerush) and herbfield (*Sarcocornia quinqueflora* - Glasswort) vegetation. The estuary mouth is mostly open to the sea but may become restricted during periods of lowflow, limiting tidal mixing, and consequently the estuary waters can become brackish. The estuary catchment is mostly native forest, but also developed predominantly for sheep, beef and dairy farming and smaller areas of consented exotic forest (see summary information overleaf).

Human use, ecological and cultural values: The estuary is recognised as a “Key Native Ecosystem” (KNE) with relatively good access, it is valued for its spiritual/aesthetic appeal, bathing and biodiversity. It is also significant to the people of both Ngāti Ruanui and Ngaa Rauru Kiitahi. Food sources, gathered from the entire length of this river, included tuna, whitebait, smelt, flounder, and sole. In terms of ecological value, habitat diversity is moderate-high with some of its intertidal vegetation, saltmarsh (in this case rushland and herbfield) intact. However, there is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed for farming. The estuary is recognized as an important nursery area for birds including the ‘Threatened (Nationally Vulnerable)’ Caspian tern (*Sterna caspia*), northern New Zealand dotterel (*Charadrius obscurus aquilonius*) and banded do terel (*Charadrius bicinctus*) and the ‘At Risk’ (Declining) New Zealand pipit (*Anthus novaeseelandiae*), and is included in the migratory route of several bird species including the variable oystercatcher (*Haematopus unicolor*) and royal spoonbill (*Platalea regia*).

Eutrophication status: The estuary has very high (NZ ETI Tool 1, Band D) susceptibility to macroalgal-based eutrophication, reflecting its relatively high proportion (>40%) of intertidal habitat and high nutrient load (the current estimated N areal loading of 2,207 mg TN m^{-2} d^{-1} exceeds the tentative guideline for low susceptibility SSRTREs of ~2000 mg TN m^{-2} d^{-1}).

Despite the very high rating, the 2019 field survey of intertidal and subtidal habitat showed no signs of primary eutrophication symptoms. This result was likely driven by the estuary’s highly flushed nature, given that it is predominantly strongly channelised with very few poorly flushed areas, has high freshwater inflow, is strongly affected by tidal currents and is often turbid. The absence of primary eutrophication symptoms on the day of sampling placed the estuary in very good (NZ ETI, Tool 2, Band A) condition with regard to eutrophication impacts.

However, on occasions during low flows when the estuary is stratified and turbidity is low, nuisance algal/macrophyte growth may occur within intertidal and/or subtidal habitat, particularly if the mouth becomes constricted, hence the very high eutrophic susceptibility rating is considered appropriate.

Sedimentation (muddiness) status: The estuary has moderate vulnerability to muddiness issues based on the facts that estimated current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL), the estuary is dominated by coarse sediments (NZ ETI, Band A), but some subtidal muds, and the mouth may be occasionally restricted. Ecologically, the overall moderate mud content fits the NZ ETI Band B (moderate muddiness) condition rating.

Figure 21. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sites, Whenuakura Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at each site.

Whenuakura Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 4, 32.2 ha
	Intertidal/Subtidal	54% intertidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	1.0-2.0, 5 km (salt wedge extent)
	Freshwater Inflow	Mean annual 10.2 $m^3 s^{-1}$*
	Saltmarsh, Seagrass	5 ha saltmarsh, no seagrass
	Soft Mud	0.2 ha (2% unvegetated intertidal area)
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Very Low**
	[Dissolved oxygen] (subtidal channel)	Low-Mod**
Catchment	Catchment size	468.6 km^2
	Max Dairy Cows Permitted	15,100
	Suspended Sediment Loading	326 kt yr^{-1}
	Total Nitrogen Loading	260 t yr^{-1} (2,207 mg TN $m^{-2} d^{-1}$)
	Total Phosphorus Loading	67 t yr^{-1}
	Dominant Landuse	66% native forest, 4% exotic forest, 16% dairy, 13% sheep/beef.
	Dominant Toprock Geology	Alluvial 1%, massive mudstone 21%, massive sandstone 77%.

*Mean flow measured at Whenuakura at Nicholson Rd.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 3 representative subtidal channel sites (see locations in Figure 21). Sampled values in Appendix B.

Monitoring and Investigations

For the Whenuakura Estuary it is recommended that annual monitoring of targeted eutrophication indicators (intertidal and subtidal channel) be undertaken to provide data on long-term trophic state trends.

To address potential for eutrophication, it is recommended that relevant water column and sediment-based indicators be monitored monthly during the period Nov-March each year at 1-2 sites representative of general conditions (e.g. mid-upper estuary) and at the same time, intertidal/ shallow subtidal macroalgal cover be assessed throughout the intertidal/shallow subtidal estuary. If, after 1-2 years, eutrophication is not found to be a persistent issue, this monitoring may cease.

Because this estuary is generally flushed regularly by high flow events, it is recommended that long-term monitoring for sedimentation be limited to low frequency (5-yearly), broad scale, screening level assessments only.

Waitotara Estuary	Issue	Susceptibility	Condition Rating (2019)
	Sedimentation	Mod-High	Very High
	Eutrophication	Minimal	Minimal

The Waitotara Estuary is a long length, shallow tidal river estuary whose mouth is predominantly open. It has a high freshwater inflow and is located on the South Taranaki Bight. Intertidally, sediments are characterised by soft muds (14.5 ha, 34% non-vegetated intertidal flats) and sands and include saltmarsh comprising herbfield (*Sarcocornia quinqueflora* - Glasswort) and to a lesser extent rushland (*Isolepis nodosa* - Knobby clubrush, *Juncus articulatus* - Jointed rush, *Isolepis cernua* - Slender clubrush, and *Schoenoplectus pungens* - Three-square) vegetation. While the estuary mouth is mostly open to the sea, it may become restricted during periods of lowflow, limiting tidal mixing, and consequently the estuary waters can become brackish. The estuary catchment is dominated by dairy farming and to a much lesser extent mixed native forest, exotic forest (including consented forestry) - see summary information overleaf.

Human use, ecological and cultural values: The estuary is valued for its aesthetic appeal, spiritual values, bathing and biodiversity. It is significant to Ngaa Rauru Kiitahi, with many hapū located along or near the river. Food sources, gathered from its entire length, included kaakahi, tuna, whitebait, smelt, kahawai, flounder, and sole. A piliocene section along bank of Waitotara River together with fossilised totara stumps and ventifacts provides high scientific and educational interest. Ecologically, habitat diversity is moderate-high with some of its intertidal vegetation, saltmarsh (in this case rushland, sedgeland and herbfield) intact. However, there is no high-value seagrass (intertidal or subtidal) habitat and much of the natural vegetated margin has been lost and is now developed for grazing. The wider reserve also provides habitat for coastal and migratory birds and is occasionally visited by the ‘ Threatened (Nationally Critical)’ kotuku or white heron (*Ardea modesta*). Human activity is minimal associated with low key recreation use, and the visitor experience maintains a high sense of wildness and remoteness retained along the coastal edge.

Eutrophication status: The overall eutrophic susceptibility of the estuary is minimal (NZ ETI Tool 1, Band A) based on (1) its well flushed nature (mouth not often restricted), and (2) its relatively low nutrient load (the current estimated N areal loading of 1,228 mg TN m^{-2} d^{-1} does not exceed the tentative guideline for low susceptibility SSRTREs of ~2000 mg TN m^{-2} $d^{-1;}$ Robertson et al. 2016).

The synoptic (one-off) survey in 2019 confirmed the absence of opportunistic macroalgae in all areas of the intertidal estuary and generally clear subtidal waters in the lower and middle estuary with very low phytoplankton (chl *a*) and dissolved oxygen concentrations. Overall, the estuary fits the NZ ETI (Tool 2) condition rating of ‘minimal’ (Band A) in terms of eutrophication.

Although periodic (short-term) changes in eutrophic susceptibility are expected (particularly if the mouth becomes constricted), given the general lack of primary symptoms on the day of sampling when flushing was low (i.e. baseflow conditions), the low susceptibility rating is considered appropriate. However, it is important to note mud-impacted estuaries generally are more susceptible to eutrophication impacts, so the present survey results must be viewed in that context, and the potential for rapid ecological decline accounted for in any long-term monitoring programme.

Sedimentation (muddiness) status: The estuary is rated as highly vulnerable to muddiness issues based on the fact that, although the estimated current suspended sediment load (CSSL) is <5 times the estimated natural state SS load (NSSL) and excess sediments are likely to be flushed to the sea during high flows, the catchment is naturally erosion prone (Suspended Sediment Yield map of sediment delivery to rivers and stream [NIWA]) and the synoptic survey showed that the estuary is dominated by muddy sediments in the less well flushed mid-upper (intertidal and subtidal) reaches. Ecologically, the overall high extent of muds fits the NZ ETI Band D (very high) condition rating.

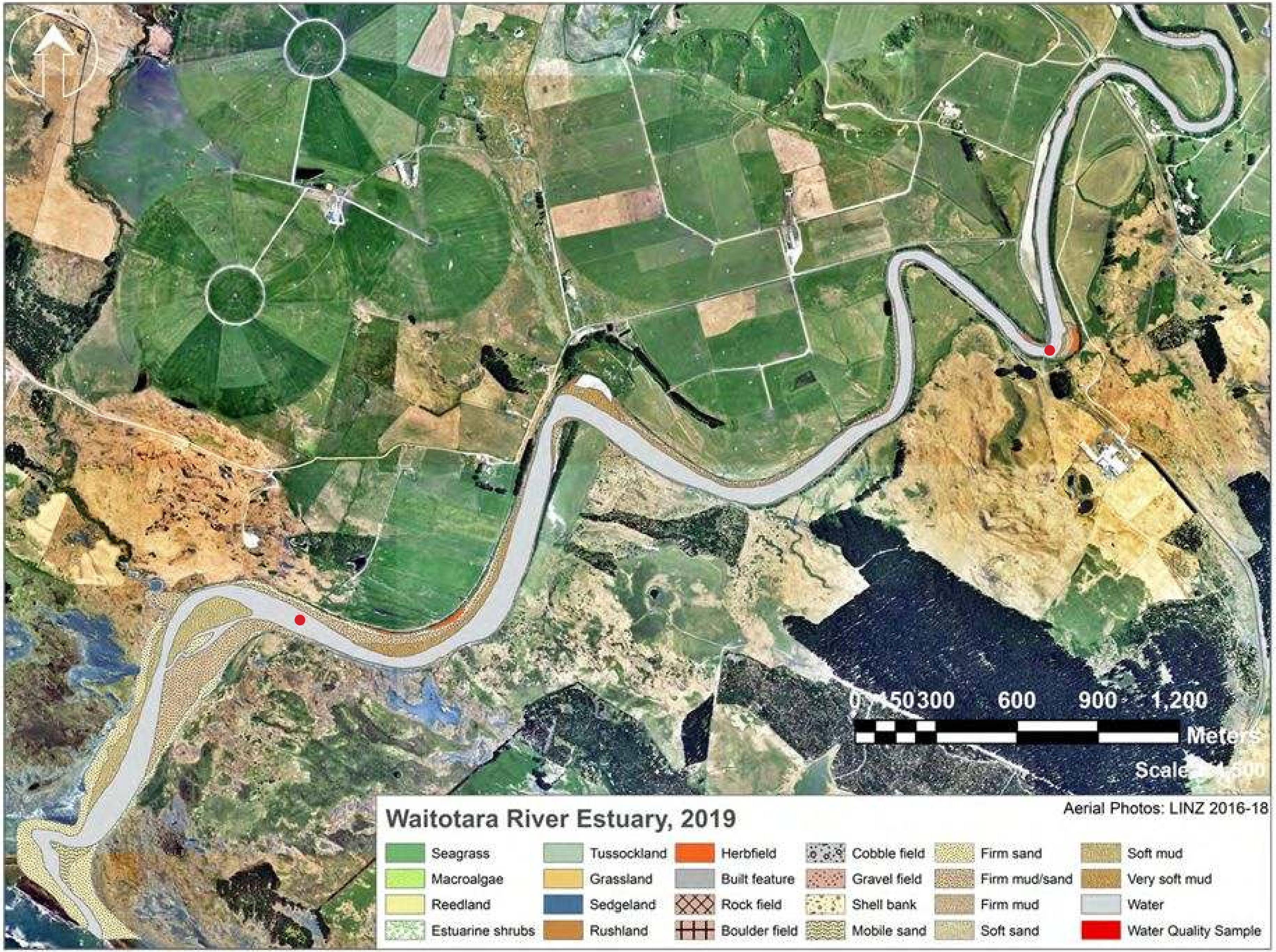


Figure 22. Distribution of intertidal substrata, macrophyte and saltmarsh, and water quality sampling locations, Waitotara River Estuary, 2019. Water quality sampling involved assessment of conditions in both surface (0.2 m) and bottom (0.5 m from bottom) waters at each site.

Waitotara Estuary - Summary Data		
Estuarine	Estuary Type/Area	SSRTRE Type 4, 98 ha
	Intertidal/Subtidal	45% intertidal
	Mouth Status (on day of survey)	Open
	Mean Depth, Length	0.5-1.0 m, 5 km (salt wedge extent)
	Freshwater Inflow	Mean annual 44.3 m^3 s^{-1}*
	Saltmarsh, Seagrass	1.4 ha saltmarsh, no seagrass
	Soft Mud	14.5 ha (34% unvegetated intertidal area)
	Macroalgae	No intertidal macroalgae
	[Chlorophyll *a*] (subtidal channel)	Very Low**
	[Dissolved oxygen] (subtidal channel)	Low-Mod**
Catchment	Catchment size	1183 km^2
	Max Dairy Cows Permitted	10820
	Suspended Sediment Loading	1131.7 kt yr^{-1}
	Total Nitrogen Loading	439.2 t yr^{-1} (1,228 mg TN m^{-2} d^{-1})
	Total Phosphorus Loading	139.1 t yr^{-1}
	Dominant Landuse	68% native forest, 7% exotic forest, 5% dairy, 20% sheep/beef.
	Dominant Toprock Geology	Alluvial 3%, mudstone 1%, massive mudstone 1%, ash (older than Taupo ash) 9%, massive sandstone 82%, windblown sand 3%.

*Estimated mean flow at river mouth from NIWA's NZ River Maps software tool.
**NZ ETI (Tool 2) condition bandings based on discrete (bottom and surface) water quality samples obtained from 3 representative subtidal channel sites (see locations in Figure 22 - note uppermost site not within map view). Sampled values in Appendix B.

Monitoring and Investigations

For "long-length (mouth sometimes closed or restricted) SSRTREs" with significant intertidal and subtidal habitat comprising poorly flushed/muddy substrata, low nutrient but high sediment loads and high human use and cultural/ecological values, it is recommended that both broad scale habitat mapping and fine scale monitoring be undertaken on a long-term basis to assess trends in estuary ecological condition using the National Estuary Monitoring Protocol (Robertson et al. 2002), plus subsequent improvements (Robertson 2018). Outputs should be compared against relevant national standards (i.e. NZ ETI; Robertson et al. 2016a,b). In addition, sedimentation plates, which, over the long-term, will help provide an indicative measure of the rate of sedimentation in the estuary, should be deployed and monitored annually as per Hunt (2019).

Broad scale habitat mapping documents the key habitats within the estuary, and changes to these habitats over time. It is typically repeated at 5-yearly intervals. Fine scale monitoring measures the condition of the high susceptibility intertidal and subtidal habitat through physical, chemical and biological indicators. It is undertaken once annually for three consecutive years during the period Nov-March (usually at 2 intertidal and 3-4 subtidal sites), and thereafter at 5-yearly intervals. Both components have not yet been measured in this estuary.

4 Summary

Intertidal habitat mapping and associated sampling undertaken in Feb-March 2019, combined with NZ ETI-based estuary typing and condition ratings, have been used to evaluate overall vulnerability of twenty estuaries in the Taranaki Region to sedimentation and eutrophication impacts, and also inform future monitoring recommendations (Section 5).

Estuary Vulnerability to Eutrophication and Sedimentation

As is characteristic of estuaries on the West Coast of NZ, all twenty of the Taranaki Region estuaries assessed were shallow, short residence time, tidal river estuaries (SSRTREs), each variable in size and partially separated from the sea by a range of physical features. The results showed that each estuary fits into one of four sub-types (based on physical attributes and freshwater inflow), each with different vulnerabilities to nutrients and fine sediment and therefore long-term monitoring requirements, as follows:

Estuary Type 1. Short length, low flow SSRTREs - <1 km long, beach located, low freshwater inflows (<1 m^3 s^{-1}), mouth sometimes restricted/closed. Taranaki Region estuaries that fit into this sub-group included Tapuae, Timaru, Te Henui, and Katikara Estuaries.

- **Physical characteristics:** Very short length, predominantly beach located SSRTREs consist of relatively narrow channels situated between the upper edge of the beach and the tidal level. In some situations the channel meanders along the back of the beach for a small distance before entering the sea, whereas in others the discharge path is more direct. A few expand into small lagoons around the upper high water area. In very high tides and storm surges, saline water enters the stream inland of the beach for a small distance. At times the mouth is often restricted and can sometimes close for short periods, during which time the upper beach lagoon may expand and show eutrophication/sedimentation symptoms. Of the 20 Taranaki Region estuaries included in this EVA, four were very small Type 1 systems.
- **Overall vulnerability:** With the exception of Katikara Estuary, which was shown to be highly vulnerable to eutrophication impacts, Type 1 estuaries were the least vulnerable of the Taranaki Region estuaries to eutrophication and sedimentation. The main reason for this was their small size, comparatively low ecological diversity, and regular periods of high flushing (even though some examples experience periodic mouth closure/restriction). Consequently, although estimated nutrient and sediment loads to the estuaries were generally large, they are unlikely to be subjected to prolonged periods of eutrophication and muddiness. Synoptic surveys of this estuary type in March 2019 confirmed the absence of symptoms of eutrophication (i.e. opportunistic macroalgal and/or phytoplankton blooms) or sedimentation (extensive areas of soft muddy sediments), while Katikara Estuary had phytoplankton issues as indicated by highly elevated chlorophyll *a* concentrations throughout the subtidal channel habitat.

Estuary Type 2. Moderate length, low flow SSRTREs - 1-3 km long, low freshwater inflows (<2 m^3 s^{-1}), mouth sometimes restricted/closed. Taranaki Region estuaries that fit into this sub-group included Waiongana, Mimi, Manawapou, Onaero, Waingongoro, Kaupokonui, Oakura Estuaries.

- **Physical characteristics:** Moderate length SSRTREs consist of relatively narrow channels situated between the tidal level and approximately 1-3 km inland. In some situations the channel meanders along the back of the beach for a distance before entering the sea, whereas in others the discharge path is more direct. A few expand into small lagoons around the upper high water area. The estuary mouth is generally open to the sea but in others it is often closed (e.g. Onaero Estuary).
- **Overall vulnerability:** Type 2 estuaries which had excessive nutrient/sediment loads and whose mouths were mostly closed (and therefore very poorly flushed) were identified as moderately to highly vulnerable. Those that had excessive nutrient/sediment loads, but were mostly open to the sea were rated as moderately vulnerable. When nutrient/sediment loads were low and estuaries were open to the sea, estuaries had minimal vulnerability.

- Characteristic symptoms of eutrophication were opportunistic macroalgal blooms and/or elevated chlorophyll *a* symptomatic of phytoplankton blooms, with symptoms of sedimentation being extensive areas of soft fine muddy sediments. The expression of such symptoms was variable because of the flushing regime - being highly flushed during high flow events, and poorly flushed during summer low flows when their mouths become restricted and the upstream waters stratify. This meant that under high nutrient/sediment loads, the estuaries were likely to exhibit eutrophication and muddiness symptoms only during periods of mouth constriction and/or poor flushing.

Estuary Type 3. Long length, moderate flow SSRTREs - 3-12 km long, moderate freshwater inflows (4-6 m^3 s^{-1}), mouth always open. Taranaki Region estuaries that fit into this sub-group included Tangahoe, Urenui, and Mōhakatino Estuaries.

- **Physical characteristics**: Long SSRTREs, with moderate freshwater inflows and mouths always open, consist of a relatively narrow channel that extends inland for approximately 3-12 km. In some situations the channel meanders along the back of the beach for a distance before entering the sea, whereas in others the discharge path is more direct.
- **Overall vulnerability**: Type 3 estuaries all had moderate-high vulnerability (apart from Tangahoe Estuary), primarily reflecting their high sediment loads and soft mud habitat. The main reason for the moderate eutrophication rating was that, for estuaries where the nutrient load was excessive, the estuary was likely to oscillate between low and moderate-high levels of eutrophication; i.e. low levels of eutrophication and sedimentation in winter, and immediately during and following high flow events in the warmer months, and moderately eutrophic conditions with some sedimentation during summer base-flow conditions. This latter situation arises from the extensive estuary length and moderate freshwater inflow, which means that the residence time for water and nutrients is sufficient to allow for phytoplankton blooms under baseflow conditions (given that the time taken for a parcel of water to travel the length of the estuary under baseflow is ~1-3 days for these estuaries).

Estuary Type 4. Long length, high flow SSRTREs - 3-12 km long, high freshwater inflows (7-220 m^3 s^{-1}), mouth always open. Taranaki Region estuaries that fit into this sub-group included Waitotara, Waitara, Patea, Whenuakura, Tongaporutu, and Waiwhakaiho Estuaries.

- **Physical characteristics**: Long SSRTREs, with high freshwater inflows and mouths always open, consist of relatively narrow channels situated between the tidal level and approximately 3-12 km inland. In some smaller estuaries the channel meanders along the back of the beach for a distance before entering the sea, whereas in others the discharge path is more direct. Some of the smaller estuaries expand into lagoons around the upper high water area. In the larger examples (e.g. Tongaporutu, Waitara and Patea Estuaries), significant areas of intertidal flats are found in the mid-lower estuary.
- **Overall vulnerability**: Most of the Type 4 estuaries had high overall vulnerability. This rating reflects their high nutrient/sediment loads and, in most cases, significant intertidal habitat already affected by sedimentation (extensive areas of soft muddy sediments), despite the fact that flushing in these estuaries was found to be high, even during summer low flows (a consequence of the high freshwater inflows, extensive tidal intrusion, mouths always open and narrow channels). Although synoptic surveys of each estuary in March 2019 generally indicated the absence of symptoms of eutrophication (i.e. opportunistic macroalgal and/or phytoplankton blooms), eutrophic susceptibilities remain high for several of these long length/high flow systems. It is also noted that the vulnerability of the inshore coastal habitats from the river plumes of these large estuaries has not been assessed in this report, given it was outside the study brief.

5 Monitoring Recommendations

To maintain the value of the twenty surveyed Taranaki Region estuaries, and to ensure sufficient information is available to manage each in relation to the identified vulnerability to eutrophication and sedimentation, long-term monitoring is recommended for each estuary below and summarised in Table 2.

For Tongaporutu, Mimi, Urenui, Mōhakatino, Waitotara, Waitara and Patea Estuaries, all with significant intertidal and subtidal habitat comprising poorly flushed/muddy substrata, moderate-high nutrient/sediment loads and high human use and cultural/ecological values, the following four components are recommended:

- **Broad scale habitat mapping** to document dominant estuary features (e.g. substratum, seagrass, saltmarsh, macroalgae) and monitor changes over time. It is typically repeated at 5-yearly intervals;
- **Fine scale monitoring** measures the condition of representative intertidal sediments (usually the dominant substrata type as well as deposition zones where sedimentation and eutrophication symptoms are more likely to be expressed) and subtidal channel habitat using a suite of physical, chemical and biological indicators. It is undertaken once annually for three consecutive years during the period Nov-March (usually at 2 intertidal and 3-4 subtidal sites), and thereafter at 5-yearly intervals;
- **Annual sedimentation rate (including grain size) monitoring** measures sedimentation trends within the estuary over time. Sediment plates should be deployed and monitored annually as per Hunt (2019);
- **High level data on dominant changes in catchment landuse** to track changes in high risk activities (e.g. land disturbance, point source discharges), and facilitate estimates of changes to naturally occurring catchment inputs of sediment, nutrients and other stressors (e.g. pathogens) likely from human influenced land disturbance.

For Katikara, Oakura and Whenuakura Estuaries, where overall eutrophication vulnerability is high, it is recommended that:

- **Annual monitoring of targeted eutrophication indicators** (intertidal and subtidal channel) be undertaken to provide data on long-term trophic state trends. To address potential for eutrophication, it is recommended that relevant water column and sediment-based indicators be monitored monthly during the period Nov-March each year at 1-2 sites representative of general conditions (e.g. mid-upper estuary) and at the same time, intertidal/shallow subtidal macroalgal cover be assessed throughout the intertidal/shallow subtidal estuary. This monitoring may cease if, after 1-2 years, eutrophication is not found to be a persistent issue in the estuaries. Because these estuaries are generally flushed regularly by high flow events, it is recommended that long-term monitoring for sedimentation be limited to low frequency (5-yearly), broad scale, screening level assessments only.

For Tapuae, Timaru, Te Henui, Waiongana, Manawapou, Onaero, Waingongoro, Kaupokonui, Tangahoe and Waiwhakaiho Estuaries, all of which had very low overall vulnerabilities to both sedimentation and eutrophication, we recommend:

- **Low frequency, screening level monitoring only**. To address the low potential for eutrophication/sedimentation issues (including both benthic and water column effects), it is recommended that low frequency (once every 10 years), screening level (synoptic) monitoring be undertaken to confirm that these low risk estuaries have not changed their vulnerability ratings.

The monitoring proposed, based on the NEMP framework, has been successfully applied to establish estuary monitoring priorities throughout NZ, and underpins the NZ ETI. Adopting a nationally consistent approach ensures the TRC benefit directly from work undertaken in other regions, as well as from established tools and existing national data, indicators and thresholds.

Table 2. Summary of NZ ETI-based susceptibility, current condition and overall vulnerability ratings, and monitoring recommendations, for twenty Taranaki Region estuaries, 2019. * See further details in 'Estuary Monitoring Recommendations' (Section 4.2).

Sub-Type[1]	Estuary	Coastal Stressor				Overall Vulner-ability	Recommended Monitoring*	Monitoring Frequency
		Sedimentation		Eutrophication				
		Suscepti-bility	Current Condition (2019)	Suscepti-bility	Current Condition (2019)			
SSRTRE Type 1	Tapuae	Moderate	Moderate	Minimal	Minimal	Moderate	Synoptic monitoring only	10-yearly
	Timaru	Moderate	Moderate	Minimal	Minimal	Moderate		
	Te Henui	Moderate	Moderate	Minimal	Minimal	Moderate		
	Katikara	Moderate	Moderate	Moderate	High	Mod-High	Eutrophication-targeted monitoring	Annually
SSRTRE Type 2	Waiongana	Moderate	Moderate	Minimal	Minimal	Moderate	Synoptic monitoring only	10-yearly
	Mimi	Mod-High	Very High	Very High	Moderate	High	Broad- & fine-scale monitoring	3-year baseline, 5-yearly
	Manawapou	Moderate	Moderate	Minimal	Minimal	Moderate	Synoptic monitoring only	10-yearly
	Onaero	Moderate	Moderate	Minimal	Moderate	Moderate		
	Waingongoro	Moderate	Minimal	Minimal	Minimal	Minimal		
	Kaupokonui	Moderate	Moderate	Minimal	Minimal	Moderate		
	Oakura	Moderate	Moderate	Moderate	High	Mod-High	Eutrophication-targeted monitoring	Annually
SSRTRE Type 3	Tangahoe	Moderate	Moderate	Minimal	Minimal	Moderate	Synoptic monitoring only	10-yearly
	Urenui	Mod-High	Very High	Very High	Moderate	High	Broad- & fine-scale monitoring	3-year baseline, 5-yearly
	Mōhakatino	Mod-High	Very High	Moderate	Moderate	High		
SSRTRE Type 4	Waitotara	Mod-High	Very High	Minimal	Minimal	Mod-High		
	Waitara	Mod-High	Very High	Minimal	Moderate	Mod-High		
	Patea	Mod-High	Very High	Very High	Moderate	High		
	Whenuakura	Moderate	Moderate	Very High	Minimal	Mod-High	Eutrophication-targeted monitoring	Annually
	Tongaporutu	Mod-High	Very High	High	Moderate	High	Broad- & fine-scale monitoring	3-year baseline, 5-yearly
	Waiwhakaiho	Moderate	Moderate	Minimal	Minimal	Moderate	Synoptic monitoring only	10-yearly

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7 Limitations

This document does not include any comprehensive assessment or consideration of ecological conditions within the subtidal benthic environment of the Taranaki Region estuaries assessed, and water quality sampling was carried out at a site-specific scale and represent a single point in time only. Regarding the latter, from a technical perspective, the overlying water environment outside of areas sampled may present substantial uncertainty. It is a changeable, heterogeneous, complex environment, in which small changes in environmental conditions can have substantial impacts on associated physicochemical conditions and biology. We also note that the vulnerability of the inshore coastal habitats from the river plume has not been assessed in this report, given it was outside the study brief. Robertson Environmental's professional opinions are based on its professional judgement, experience, and training. These opinions are also based upon data derived from the monitoring and analysis described in this document, with the support of relevant national standards (e.g. NZ ETI; Robertson et al. 2016a,b). It is possible that additional testing and analyses might produce different results and/or different opinions. Should additional information become available, this report should be updated accordingly. Robertson Environmental Limited has relied upon information provided by the Client to inform parts of this document, some of which has not been fully verified by Robertson Environmental Limited. This document may be transmitted, reproduced or disseminated only in its entirety.

Appendix A:

Major Issues Facing NZ Estuaries

Eutrophication is a process that adversely affects the high value biological components of an estuary, in particular through the increased growth, primary production and biomass of phytoplankton, macroalgae (or both); loss of seagrass, changes in the balance of organisms; and water quality degradation. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of goods and services (Ferriera et al. 2011). Susceptibility of an estuary to eutrophication is controlled by factors related to hydrodynamics, physical conditions and biological processes (National Research Council, 2000) and hence is generally estuary-type specific. However, the general consensus is that, subject to available light, excessive nutrient input causes growth and accumulation of opportunistic fast growing primary producers (i.e. phytoplankton and opportunistic red or green macroalgae and/or epiphytes - Painting et al. 2007). In nutrient-rich estuaries, the relative abundance of each of these primary producer groups is largely dependent on flushing, proximity to the nutrient source, and light availability. Notably, phytoplankton blooms are generally not a major problem in well flushed estuaries (Valiela et al. 1997), and hence are not common in the majority of NZ estuaries. Of greater concern are the mass blooms of green and red macroalgae, mainly of the genera *Cladophora, Ulva, and Gracilaria* which are now widespread on intertidal flats and shallow subtidal areas of nutrient-enriched New Zealand estuaries. They present a significant nuisance problem, especially when loose mats accumulate on shorelines and decompose, both within the estuary and adjacent coastal areas. Blooms also have major ecological impacts on water and sediment quality (e.g. reduced clarity, physical smothering, lack of oxygen), affecting or displacing the animals that live there (Anderson et al. 2002, Valiela et al. 1997).

Recommended Indicators	Method
Macroalgal Cover/Biomass	Broad scale mapping - macroalgal cover/biomass over time.
Phytoplankton (water column)	Chlorophyll *a* concentration (water column).
Sediment Organic and Nutrient Enrichment	Chemical analysis of sediment total nitrogen, total phosphorus, and total organic carbon concentrations.
Water Column Nutrients	Chemical analysis of various forms of N and P (water column).
Redox Profile	Redox potential discontinuity profile (RPD) using visual method (i.e. apparent Redox Potential Depth - aRPD) and/or redox probe. Note: Total Sulphur is also a robust indicator of benthic trophic status.
Biodiversity of Bottom Dwelling Animals	Type and number of animals living in the upper 15 cm of sediments (infauna in 0.0133 m^2 replicate cores), and on the sediment surface (epifauna in 0.25 m^2 replicate quadrats).

Sedimentary changes influence the ecology of estuaries. Because they are a sink for sediments, their natural cycle is to slowly infill with fine muds and clays. Prior to European settlement they were most likely dominated by sandy sediments and had low sedimentation rates (e.g. <1 mm/year). In the last 150 years, with catchment clearance, wetland drainage, and land development for agriculture and settlements, NZ's estuaries have begun to infill rapidly with fine sediments. Today, average sedimentation rates in our estuaries are typically 10 times or more higher than before humans arrived (e.g. see Abrahim 2005, Gibb and Cox 2009, Robertson and Stevens 2007a, 2010b, and Swales and Hume 1995). Soil erosion and sedimentation can also contribute to turbid conditions and poor water quality, particularly in shallow, wind-exposed estuaries where re-suspension is common. These changes to water and sediment result in negative impacts to estuarine ecology that are difficult to reverse. They include:

- habitat loss such as the infilling of saltmarsh and tidal flats;
- prevention of sunlight from reaching aquatic vegetation such as seagrass meadows;
- increased toxicity and eutrophication by binding toxic contaminants (e.g. heavy metals and hydrocarbons) and nutrients;
- a shift towards mud-tolerant benthic organisms which often means a loss of sensitive shellfish (e.g. pipi) and other filter feeders;
- making the water unappealing to swimmers.

Recommended Indicators	Method
Soft Mud Area	GIS Based Broad scale mapping - estimates the area and change in soft mud habitat over time.
Seagrass Area/Biomass	GIS Based Broad scale mapping - estimates the area and change in seagrass habitat over time.
Saltmarsh Area	GIS Based Broad scale mapping - estimates the area and change in saltmarsh habitat over time.
Mud Content	Grain size - estimates the % mud content of sediment.
Water Clarity/Turbidity	Secchi disc water clarity or turbidity.
Sediment Toxicants	Sediment heavy metal concentrations (see toxicity section).
Sedimentation Rate	Fine scale measurement of sediment infilling rate (e.g. using sediment plates).
Biodiversity of Bottom Dwelling Animals	Type and number of animals living in the upper 15 cm of sediments (infauna in 0.0133 m^2 replicate cores), and on the sediment surface (epifauna in 0.25 m^2 replicate quadrats).

Habitat Loss impacts estuaries and their many different types of high value habitats including shellfish beds, seagrass meadows, saltmarshes (rushlands, herbfields, reedlands etc.), tidal flats, forested wetlands, beaches, river deltas, and rocky shores. The continued health and biodiversity of estuarine systems depends on the maintenance of high-quality habitat. Loss of such habitat negatively affects fisheries, animal populations, filtering of water pollutants, and the ability of shorelines to resist storm-related erosion. Within New Zealand, habitat degradation or loss is common-place with the major causes being sea level rise, population pressures on margins, dredging, drainage, reclamation, pest and weed invasion, reduced flows (damming and irrigation), over-fishing, polluted runoff, and wastewater discharges (IPCC 2007 and 2013, Kennish 2002).

Recommended Indicators	Method
Saltmarsh Area	Broad scale mapping - estimates the area and change in saltmarsh habitat over time.
Seagrass Area	Broad scale mapping - estimates the area and change in seagrass habitat over time.
Vegetated Terrestrial Buffer	Broad scale mapping - estimates the area and change in buffer habitat over time.
Shellfish Area	Broad scale mapping - estimates the area and change in shellfish habitat over time.
Unvegetated Habitat Area	Broad scale mapping - estimates the area and change in unvegetated habitat over time, broken down into the different substrata types.
Sea level	Measure sea level change.
Others e.g. Freshwater Inflows, Fish Surveys, Floodgates, Wastewater Discharges	Various survey types.

Toxic Contamination has become an issue in the last 60 years, as NZ has seen a huge range of synthetic chemicals introduced to the coastal environment through urban and agricultural stormwater runoff, groundwater contamination, industrial discharges, oil spills, antifouling agents, leaching from boat hulls, and air pollution. Many of them are toxic even in minute concentrations, and of particular concern are polycyclic aromatic hydrocarbons (PAHs), heavy metals, polychlorinated biphenyls (PCBs), endocrine disrupting compounds, and pesticides. When they enter estuaries these chemicals collect in sediments and bio-accumulate in fish and shellfish, causing health risks to marine life and humans. In addition, natural toxins can be released by macroalgae and phytoplankton, often causing mass closures of shellfish beds, potentially hindering the supply of food resources, as well as introducing economic implications for people depending on various shellfish stocks for their income. For example, in 1993, a nationwide closure of shellfish harvesting was instigated in NZ after 180 cases of human illness following the consumption of various shellfish contaminated by a toxic dinoflagellate, which also lead to wide-spread fish and shellfish deaths (de Salas et al. 2005). Decay of organic matter in estuaries (e.g. macroalgal blooms) can also cause the production of sulphides and ammonia at concentrations exceeding ecotoxicity thresholds.

Recommended Indicators	Method
Shellfish and Bathing Water faecal coliforms, viruses, protozoa etc.	Bathing water and shellfish disease risk monitoring. Note disease risk indicators on the Marlborough coast are assessed separately in MDC's recreational water quality monitoring programme.
Biota Contaminants	Chemical analysis of suspected contaminants in body of at-risk biota (e.g. fish, shellfish).
Biodiversity of Bottom Dwelling Animals	Type and number of animals living in the upper 15 cm of sediments (infauna in 0.0133 m^2 replicate cores), and on the sediment surface (epifauna in 0.25 m^2 replicate quadrats).

Appendix B:

Detailed Data Taranaki Region Estuaries

Estimated catchment-derived TN, TP, TSS loading rates[1] (under natural and current landuse) for the 20 Taranaki Region Estuaries assessed.

Estuary	SSRTRE SUBTYPE	HW estuary Area (km²)	Natural State Loads[2]			Current State Loads				
			Total Nitrogen	Total Phosphorus	Total Suspended Sediment	Total Nitrogen	Total Phosphorus	Total Suspended Sediment	Areal Total Nitrogen	Current State Sediment Load / Natural State Sediment Load ratio (CSSL/NSSL ratio)[2]
			t yr^{-1}		kt yr^{-1}	t yr^{-1}		kt yr^{-1}	mg m^{-2} d^{-1}	
Mōhakatino	3	0.321	47	17	131	54	20	173	457	2.6
Tongaporutu	4	0.582	98	38	280	134	48	362	630	2.6
Mimi	2	0.103	50	31	106	91	43	186	2429	3.5
Urenui	3	0.212	52	56	92	85	66	149	1102	3.2
Onaero	2	0.026	34	26	36	69	36	75	7302	4.2
Waitara	4	0.567	519	198	561	2030	272	1109	9807	4.0
Waiongana	2	0.09	72	9	5	557	13	16	16956	6.4
Waiwhakaiho	4	0.106	97	19	13	403	21	26	10408	3.9
Te Henui	1	0.017	16	2	2	73	2	4	11732	4.1
Tapuae	1	0.01	18	2	1	117	2	4	32055	6.3
Oakura	2	0.026	22	4	5	73	5	9	7692	3.5
Timaru	1	0.019	16	2	3	58	3	5	8421	3.1
Katikara	1	0.016	13	1	1	63	2	3	10736	4.5
Kaupokonui	2	0.038	83	10	6	583	14	15	42033	5.2
Waingongoro	2	0.016	116	27	5	863	27	16	147808	6.5
Tangahoe	3	0.018	43	5	31	110	16	52	16758	3.4
Manawapou	2	0.018	41	5	30	110	16	53	16758	3.5
Patea	4	0.491	375	65	241	1258	124	469	7020	3.9
Whenuakura	4	0.323	155	51	259	260	66	326	2207	2.5
Waitotara	4	0.98	356	94	812	439	139	1132	1228	2.8

[1] Estimates sourced from NIWA's CLUES - REC2 default setting (current loads) and all landuse set to native forest cover (natural state loads).
[2] 50% reduction applied to natural state component to account for expected nutrient uptake and retention in wetlands present under natural state.

Input data for NZ ETI Tool 1: Determining susceptibility of estuaries to eutrophication. Detailed metadata descriptions available at https://shiny.niwa.co.nz/Estuaries-Screening-Tool-1/. Field data was used to inform parameter values (V, P, Intertidal, est_area_m2, mean_depth) as appropriate.

Est_name	ETI_ class	Qf[2]	TN river	TP river	V	P	b	A[1]	B[1]	R_ NO3	R_ DRP	Ocean-Salinity_ mean	N Ocean	P Ocean	Inter-tidal	TI	est_ area_ m2	mean_ depth	tidal_ height
Waitotara	SSRTRE	44.3	439	139	1960000	1372000	NA	-0.466876	164.38	0.7	0.7	35	16.6	7.3	45.0	NA	980000	2.0	1.4
Waitara	SSRTRE	57.3	2030	272	1701000	1190700	NA	-0.504925	172.42	0.7	0.7	35	18.6	7.1	27.0	NA	567000	3.0	2.1
Patea	SSRTRE	29.5	1258	124	1473000	1031100	NA	-0.507392	196.82	0.7	0.7	35	16.2	7.3	37.0	NA	491000	3.0	2.1
Whenuakura	SSRTRE	10.2	260	66	646000	452200	NA	-0.517324	161.16	0.7	0.7	35	16.2	7.3	54.0	NA	323000	2.0	1.4
Tangahoe	SSRTRE	6.7	110	16	27000	18900	NA	-0.495041	179.46	0.7	0.7	35	18.7	7.2	57.0	NA	18000	1.5	1.1
Tongaporutu	SSRTRE	9.3	134	48	1164000	814800	NA	-0.518357	171.02	0.7	0.7	35	21.1	7.1	63.0	NA	582000	2.0	1.4
Waiongana	SSRTRE	4.8	557	13	135000	94500	NA	-0.451837	184.75	0.7	0.8	35	18.3	7.1	53.0	NA	90000	1.5	1.1
Waiwhakaiho	SSRTRE	12.1	403	21	15900	11130	NA	-0.501954	182.35	0.7	0.7	35	18.7	7.2	61.0	NA	10600	1.5	1.1
Mimi River	SSRTRE	3.6	91	43	257500	180250	NA	-0.538245	174.16	0.6	0.7	35	20.2	7.1	49.0	NA	103000	2.5	1.8
Urenui River	SSRTRE	4.4	85	66	530000	371000	NA	-0.440671	171.69	0.5	0.7	35	20.0	7.1	69.0	NA	212000	2.5	1.8
Mōhakatino	SSRTRE	5.0	54	20	963000	674100	NA	-0.496849	228.30	0.7	0.7	35	21.2	7.1	52.0	NA	321000	3.0	2.1
Manawapou	SSRTRE	2.9	110	16	27000	18900	NA	-0.495041	179.46	0.7	0.7	35	18.7	7.2	57.0	NA	18000	1.5	1.1
Onaero	SSRTRE	2.4	69	36	39000	27300	NA	-0.495041	179.46	0.7	0.7	35	18.7	7.2	37.0	NA	26000	1.5	1.1
Waingongoro	SSRTRE	7.2	863	27	24000	16800	NA	-0.495041	179.46	0.7	0.7	35	18.7	7.2	65.0	NA	16000	1.5	1.1
Kaupokonui	SSRTRE	3.1	583	14	57000	39900	NA	-0.495041	179.46	0.7	0.7	35	18.7	7.2	60.0	NA	38000	1.5	1.1
Oakura	SSRTRE	2.7	73	5	65000	45500	NA	-0.495041	179.46	0.7	0.7	35	18.7	7.2	52.0	NA	26000	2.5	1.8
Tapuae	SSRTRE	1.2	117	2	15000	10500	NA	-0.495041	179.46	0.7	0.7	35	18.7	7.2	44.0	NA	10000	1.5	1.1
Timaru	SSRTRE	1.8	58	3	19000	13300	NA	-0.495041	179.46	0.7	0.7	35	18.7	7.2	36.0	NA	19000	1.0	0.7
Te Henui	SSRTRE	1.2	73	2	25500	17850	NA	-0.495041	179.46	0.7	0.7	35	18.7	7.2	49.0	NA	17000	1.5	1.1
Katikara	SSRTRE	1.0	63	2	24000	16800	NA	-0.495041	179.46	0.7	0.7	35	18.7	7.2	56.0	NA	16000	1.5	1.1

[1] Estimated based on Taranaki Region SSRTREs with comparable physical properties and freshwater inflows.
[2] Supplied by Taranaki Region Council.

Input data for NZ ETI Tool 2: ETI Tool 2: Assessing estuary trophic state using measured trophic indicators. Detailed metadata descriptions available at https://shiny.niwa.co.nz/Estuaries-Screening-Tool-2/.

estuary_name	CHLA[1]	macroal-gae_GNA_ha	macroal-gae_GNA_percent	macroal-gae_EQR	DO[1]	REDOX	TOC	TN	AMBI	soft_mud	estuary_type
Urenui	3.49	0	0	0.97	6.12	-50	NA	NA	NA	0.392	SSRTRE
Mimi	3.28	0	0	1	5.97	-47	NA	NA	NA	0.229	SSRTRE
Waitotara	3.02	0	0	1	7.84	-61	NA	NA	NA	0.34	SSRTRE
Waitara	2.42	0	0	1	9.22	-70	NA	NA	NA	0.26	SSRTRE
Patea	1.95	0	0	1	7.77	-41	NA	NA	NA	0.23	SSRTRE
Whenuakura	2.47	0	0	1	7.36	-34	NA	NA	NA	0.02	SSRTRE
Tangahoe	2.65	0	0	1	8.25	-23	NA	NA	NA	0	SSRTRE
Tongaporutu	1.32	0	0	1	6.06	-69	NA	NA	NA	0.23	SSRTRE
Waiongana	2.25	0	0	1	7.77	-41	NA	NA	NA	0.02	SSRTRE
Waiwhakaiho	1.68	0	0	1	10.96	-46	NA	NA	NA	0.01	SSRTRE
Mōhakatino	3.88	0	0	1	7.15	-54	NA	NA	NA	0.34	SSRTRE
Manawapou	2.67	0	0	1	8.06	-43	NA	NA	NA	0	SSRTRE
Onaero	8.28	0	0	1	5.41	-35	NA	NA	NA	0	SSRTRE
Waingongoro	2.3	0	0	1	11.37	34	NA	NA	NA	0	SSRTRE
Kaupokonui	1.58	0	0	1	8.18	-22	NA	NA	NA	0	SSRTRE
Oakura	20.33	0	0	1	9.27	-9	NA	NA	NA	0	SSRTRE
Tapuae	9.95	0	0	1	13.95	-21	NA	NA	NA	0	SSRTRE
Timaru	8.03	0	0	1	8.81	-14	NA	NA	NA	0	SSRTRE
Te Henui	2.48	0	0	1	9.35	-39	NA	NA	NA	0	SSRTRE
Katikara	21.53	0	0	1	13.9	-10	NA	NA	NA	0	SSRTRE

[1] 1-day mean based on measurement of surface and bottom waters within subtidal channel habitat, March 2019.

Summary of geology in catchments surrounding the Taranaki Region estuaries assessed[1].							
		Area (km²)				Area (km²)	
Urenui	Catchment	132.7	% catchment	Waiongana	Catchment	158.9	% catchment
	Massive mudstone	71.8	54%		Mudstone	152.1	96%
	Ash (older than Taupo ash)	22.0	17%		Peat	1.0	1%
	Massive sandstone	32.5	24%	Waiwhakaiho	Catchment	145.1	% catchment
Mimi	Catchment	133.4	% catchment		Alluvial / Gravels	5.3	11%
	Alluvial	11.3	9%		Mudstone	112.6	78%
	Massive mudstone	26.7	20%		Lahar deposits	1.3	3%
	Ash (older than Taupo ash)	28.8	22%	Mōhakatino	Catchment	122.6	% catchment
	Massive sandstone	66.5	50%		Alluvial	8.5	7%
Waitotora	Catchment	1185.0	% catchment		Mudstone	7.4	6%
	Alluvial	30.8	3%		Massive sand-stone	106.7	87%
	Loess	4.3	0%	Manawapou	Catchment	122.3	% catchment
	Mudstone	14.3	1%		Alluvial	1.9	2%
	Massive mudstone	15.4	1%		Mudstone	66.6	54%
	Ash (older than Taupo ash)	111.7	9%		Massive sand-stone	45.8	37%
	Peat	0.9	0%		Unconsolidated gravels and sands	7.7	6%
	Massive sandstone	973.8	82%	Onaero	Catchment	89.8	% catchment
	Windblown sand	31.6	3%		Alluvial	4.4	5%
Waitara	Catchment	1139.3	% catchment		Massive mudstone	34.1	38%
	Alluvial	26.4	2%		Massive sand-stone	11.0	12%
	Mudstone	27.8	2%		Ash (older than Taupo ash)	40.3	45%
	Massive mudstone	22.5	2%	Waingongoro	Catchment	219.1	% catchment
	Ash (older than Taupo ash)	528.2	46%		Ash (older than Taupo ash)	196.3	90%
	Massive sandstone	474.2	42%		Lavas & welded ignimbrites	2.9	1%
Patea	Catchment	1046.3	% catchment		Peat	10.2	5%
	Alluvial	48.3	5%	Kaupokonui	Catchment	146.9	% catchment
	Mudstone	0.0	0%		Ash (older than Taupo ash)	110.4	75%
	Massive mudstone	3.3	0%		Lavas & welded ignimbrites	6.9	5%
	Ash (older than Taupo ash)	373.8	36%		Taupo & Kaha-raoa breccias older than Taupo breccia	8.6	6%
	Peat	14.6	1%		Lahar deposits	4.7	3%
	Massive sandstone	591.1	56%				

[1] Data provided by Taranaki Regional Council.

Summary of geology in catchments surrounding the Taranaki Region estuaries assessed[1].							
		Area (km²)				**Area (km²)**	
Whenu-akura	Catchment	468.6	% catchment	Oakura	Catchment	44.1	% catchment
	Alluvial	7.0	1%		Ash (older than Taupo ash)	42.2	96%
	Massive mudstone	98.6	21%		Lavas & welded ignimbrites	1.4	3%
	Massive sandstone	359.5	77%	Tapuae	Catchment	31.9	% catchment
Tangahoe	Catchment	297.6	% catchment		Ash (older than Taupo ash)	31.8	100%
	Alluvial	4.8	2%		Lavas & welded ignimbrites	0.1	0.3%
	Mudstone	9.0	3%	Timaru	Catchment	31.4	% catchment
	Massive mudstone	164.9	55%		Ash (older than Taupo ash)	30.7	98%
	Peat	6.7	2%		Lavas & welded ignimbrites	0.5	2%
	Massive sandstone	99.1	33%	Te Henui	Catchment	28.4	% catchment
Tonga-porutu	Catchment	271.3	% catchment		Ash (older than Taupo ash)	24.9	88%
	Alluvial	8.5	3%		Massive sand-stone	3.5	12%
	Mudstone	0.3	0%	Katikara	Catchment	22.0	% catchment
	Massive mudstone	32.9	12%		Ash (older than Taupo ash)	21.9	99%
	Peat	0.0	0%		Massive sand-stone	0.1	1%
	Massive sandstone	229.7	85%				

[1] Data provided by Taranaki Regional Council.

Summary of subtidal water quality data[1].						
Estuary	Site	Parameter	Water Column Position		Location	
			Bottom	Surface	NZTM North	NZTM East
Urenui	Low Estuary	Depth (m)	0.6	0.2	1720484	5683261
		Temp (°C)	20.4	-		
		DO (%)	106.8	-		
		DO (mg m^{-3})	7.8	-		
		Salinity (ppt)	30.6	-		
		PC RFU	0.0	-		
		Chla (ug l^{-1})	1.5	-		
	Middle Estuary	Depth (m)	1.3	0.2	1720484	5683259
		Temp (°C)	20.5	20.5		
		DO (%)	106.6	107.1		
		DO (mg m^{-3})	7.8	7.8		
		Salinity (ppt)	30.7	5.9		
		PC RFU	0.0	0.0		
		Chla (ug l^{-1})	1.2	1.4		
	Upper Estuary	Depth (m)	2.3	0.2	1722523	5682929
		Temp (°C)	20.3	22.3		
		DO (%)	80.3	91.0		
		DO (mg m^{-3})	6.1	7.6		
		Salinity (ppt)	28.2	2.7		
		PC RFU	0.1	0.3		
		Chla (ug l^{-1})	4.2	6.3		
Mimi	Low Estuary	Depth (m)	2.0	0.2	1724812	5686241
		Temp (°C)	19.2	18.5		
		DO (%)	93.4	86.9		
		DO (mg m^{-3})	7.2	7.7		
		Salinity (ppt)	35.2	10.8		
		PC RFU	0.1	0.1		
		Chla (ug l^{-1})	1.8	2.1		
	Middle Estuary	Depth (m)	1.2	0.2	1725022	5686348
		Temp (°C)	19.5	18.7		
		DO (%)	90.1	85.9		
		DO (mg m^{-3})	6.8	7.6		
		Salinity (ppt)	30.2	10.5		
		PC RFU	0.1	0.2		
		Chla (ug l^{-1})	3.3	3.3		
	Upper Estuary	Depth (m)	2.3	0.2	1725634	5686117
		Temp (°C)	19.5	17.6		
		DO (%)	79.1	79.1		
		DO (mg m^{-3})	6.0	7.4		
		Salinity (ppt)	30.7	4.5		
		PC RFU	0.1	0.2		
		Chla (ug l^{-1})	3.0	3.5		

[1] All sampling undertaken at mid-low tide using an EXO1 (Sonde 15F103960; Serial Number: 15F103960; Firmware Version: 1.0.73), Feb 26th - March 4th 2019, Taranaki.

Summary of subtidal water quality data[1].

Estuary	Site	Parameter	Water Column Position		Location	
			Bottom	Surface	NZTM North	NZTM East
Waitotara	Low Estuary	Depth (m)	2.0	0.2	1744999	5588387
Waitotara	Low Estuary	Temp (°C)	19.4	20.7	1744999	5588387
Waitotara	Low Estuary	DO (%)	86.7	91.2	1744999	5588387
Waitotara	Low Estuary	DO (mg m^{-3})	7.1	7.6	1744999	5588387
Waitotara	Low Estuary	Salinity (ppt)	19.4	10.8	1744999	5588387
Waitotara	Low Estuary	PC RFU	0.1	0.4	1744999	5588387
Waitotara	Low Estuary	Chla (ug l^{-1})	2.5	5.2	1744999	5588387
Waitotara	Middle Estuary	Depth (m)	2.2	0.2	1747836	5589260
Waitotara	Middle Estuary	Temp (°C)	20.4	20.2	1747836	5589260
Waitotara	Middle Estuary	DO (%)	84.3	83.2	1747836	5589260
Waitotara	Middle Estuary	DO (mg m^{-3})	7.6	7.5	1747836	5589260
Waitotara	Middle Estuary	Salinity (ppt)	0.2	0.3	1747836	5589260
Waitotara	Middle Estuary	PC RFU	0.3	0.5	1747836	5589260
Waitotara	Middle Estuary	Chla (ug l^{-1})	3.2	4.4	1747836	5589260
Waitotara	Upper Estuary	Depth (m)	2.0	0.2	1748593	5592321
Waitotara	Upper Estuary	Temp (°C)	20.1	20.1	1748593	5592321
Waitotara	Upper Estuary	DO (%)	95.1	94.6	1748593	5592321
Waitotara	Upper Estuary	DO (mg m^{-3})	8.6	8.6	1748593	5592321
Waitotara	Upper Estuary	Salinity (ppt)	0.2	0.2	1748593	5592321
Waitotara	Upper Estuary	PC RFU	0.1	0.0	1748593	5592321
Waitotara	Upper Estuary	Chla (ug l^{-1})	1.4	1.4	1748593	5592321
Waitara	Low Estuary	Depth (m)	4.0	0.2	1706451	5683599
Waitara	Low Estuary	Temp (°C)	19.3	20.5	1706451	5683599
Waitara	Low Estuary	DO (%)	106.6	104.1	1706451	5683599
Waitara	Low Estuary	DO (mg m^{-3})	8.0	9.2	1706451	5683599
Waitara	Low Estuary	Salinity (ppt)	35.2	3.8	1706451	5683599
Waitara	Low Estuary	PC RFU	0.2	0.1	1706451	5683599
Waitara	Low Estuary	Chla (ug l^{-1})	2.5	2.1	1706451	5683599
Waitara	Middle Estuary	Depth (m)	2.2	0.2	1707200	5682576
Waitara	Middle Estuary	Temp (°C)	20.4	20.5	1707200	5682576
Waitara	Middle Estuary	DO (%)	111.7	110.3	1707200	5682576
Waitara	Middle Estuary	DO (mg m^{-3})	9.5	9.7	1707200	5682576
Waitara	Middle Estuary	Salinity (ppt)	10.1	10.0	1707200	5682576
Waitara	Middle Estuary	PC RFU	0.1	0.1	1707200	5682576
Waitara	Middle Estuary	Chla (ug l^{-1})	2.4	2.5	1707200	5682576
Waitara	Upper Estuary	Depth (m)	2.0	0.2	1707493	5681336
Waitara	Upper Estuary	Temp (°C)	19.1	19.1	1707493	5681336
Waitara	Upper Estuary	DO (%)	103.1	104.7	1707493	5681336
Waitara	Upper Estuary	DO (mg m^{-3})	9.4	9.6	1707493	5681336
Waitara	Upper Estuary	Salinity (ppt)	2.2	2.3	1707493	5681336
Waitara	Upper Estuary	PC RFU	0.1	0.1	1707493	5681336
Waitara	Upper Estuary	Chla (ug l^{-1})	2.4	2.6	1707493	5681336

[1] All sampling undertaken at mid-low tide using an EXO1 (Sonde 15F103960; Serial Number: 15F103960; Firmware Version: 1.0.73), Feb 26th - March 4th 2019, Taranaki.

Summary of subtidal water quality data[1].

Estuary	Site	Parameter	Water Column Position		Location	
			Bottom	Surface	NZTM North	NZTM East
Patea	Low Estuary	Depth (m)	4.0	0.2	1727540	5596823
		Temp (°C)	19.6	20.4		
		DO (%)	94.2	95.9		
		DO (mg m^{-3})	7.7	7.8		
		Salinity (ppt)	34.6	17.7		
		PC RFU	0.1	0.1		
		Chla (ug l^{-1})	1.9	1.9		
	Middle Estuary	Depth (m)	5.0	0.2	1727262	5597497
		Temp (°C)	19.7	20.3		
		DO (%)	94.2	95.9		
		DO (mg m^{-3})	7.7	7.8		
		Salinity (ppt)	17.7	17.7		
		PC RFU	0.1	0.1		
		Chla (ug l^{-1})	1.9	1.9		
	Upper Estuary	Depth (m)	2.0	0.2	1726837	5598645
		Temp (°C)	19.8	19.6		
		DO (%)	95.1	94.0		
		DO (mg m^{-3})	8.0	7.6		
		Salinity (ppt)	12.8	16.1		
		PC RFU	0.1	0.1		
		Chla (ug l^{-1})	1.6	2.5		
Whenuakura	Low Estuary	Depth (m)	2.0	0.2	1729461	5595530
		Temp (°C)	19.2	18.5		
		DO (%)	93.4	86.9		
		DO (mg m^{-3})	7.2	7.7		
		Salinity (ppt)	35.2	10.8		
		PC RFU	0.1	0.1		
		Chla (ug l^{-1})	1.8	2.1		
	Middle Estuary	Depth (m)	3.0	0.2	1730317	5595794
		Temp (°C)	18.3	20.7		
		DO (%)	95.3	97.9		
		DO (mg m^{-3})	7.3	8.6		
		Salinity (ppt)	34.8	3.5		
		PC RFU	0.2	0.2		
		Chla (ug l^{-1})	4.1	1.6		
	Upper Estuary	Depth (m)	3.0	0.2	1730222	5596645
		Temp (°C)	19.5	17.6		
		DO (%)	79.1	79.1		
		DO (mg m^{-3})	6.0	7.4		
		Salinity (ppt)	30.7	4.5		
		PC RFU	0.1	0.2		
		Chla (ug l^{-1})	4.0	1.2		

[1] All sampling undertaken at mid-low tide using an EXO1 (Sonde 15F103960; Serial Number: 15F103960; Firmware Version: 1.0.73), Feb 26th - March 4th 2019, Taranaki.

Summary of subtidal water quality data[1].

Estuary	Site	Parameter	Water Column Position		Location	
			Bottom	Surface	NZTM North	NZTM East
		Depth (m)	0.2			
		Temp (°C)	16.2			
		DO (%)	110.7			
	Low Estuary	DO (mg m^{-3})	10.9		1715938	5609523
		Salinity (ppt)	0.2			
		PC RFU	0.1			
		Chla (ug l^{-1})	1.7			
		Depth (m)	1.5	0.2		
		Temp (°C)	15.9	15.0		
		DO (%)	110.0	113.7		
Tangahoe	Middle Estuary	DO (mg m^{-3})	10.9	11.2	1715965	5609607
		Salinity (ppt)	0.2	0.2		
		PC RFU	0.2	0.2		
		Chla (ug l^{-1})	5.7	3.2		
		Depth (m)				
		Temp (°C)				
		DO (%)				
	Upper Estuary	DO (mg m^{-3})				
		Salinity (ppt)				
		PC RFU				
		Chla (ug l^{-1})				
		Depth (m)	0.2			
		Temp (°C)	19.2			
		DO (%)	99.4			
	Low Estuary	DO (mg m^{-3})	7.3		1738684	57021128
		Salinity (ppt)	35.2			
		PC RFU	0.0			
		Chla (ug l^{-1})	0.9			
		Depth (m)	3.0	0.2		
		Temp (°C)	20.5	20.4		
		DO (%)	99.4	99.4		
Tongaporutu	Middle Estuary	DO (mg m^{-3})	7.3	7.3	1738586	5701588
		Salinity (ppt)	34.2	33.1		
		PC RFU	0.0	0.0		
		Chla (ug l^{-1})	1.1	1.2		
		Depth (m)	3.0	0.2		
		Temp (°C)	18.9	19.9		
		DO (%)	90.1	89.3		
	Upper Estuary	DO (mg m^{-3})	7.0	7.5	1738890	5699500
		Salinity (ppt)	28.4	14.9		
		PC RFU	0.1	0.1		
		Chla (ug l^{-1})	2.3	2.4		

[1] All sampling undertaken at mid-low tide using an EXO1 (Sonde 15F103960; Serial Number: 15F103960; Firmware Version: 1.0.73), Feb 26th - March 4th 2019, Taranaki.

Summary of subtidal water quality data[1].

Estuary	Site	Parameter	Water Column Position		Location	
			Bottom	Surface	NZTM North	NZTM East
Waiongana	Low Estuary	Depth (m)	0.2		1702464	5682884
		Temp (°C)	20.0			
		DO (%)	119.2			
		DO (mg m^{-3})	10.5			
		Salinity (ppt)	4.7			
		PC RFU	0.2			
		Chla (ug l^{-1})	3.8			
	Middle Estuary	Depth (m)	3.0	0.2	1703188	5682285
		Temp (°C)	17.9	18.3		
		DO (%)	108.1	106.0		
		DO (mg m^{-3})	10.2	9.9		
		Salinity (ppt)	0.1	0.1		
		PC RFU	0.2	0.2		
		Chla (ug l^{-1})	3.7	1.5		
	Upper Estuary	Depth (m)				
		Temp (°C)				
		DO (%)				
		DO (mg m^{-3})				
		Salinity (ppt)				
		PC RFU				
		Chla (ug l^{-1})				
Waiwhakaiho	Low Estuary	Depth (m)	2.0	0.2	1696403	5678453
		Temp (°C)	19.8	21.5		
		DO (%)	120.9	123.9		
		DO (mg m^{-3})	11.0	10.9		
		Salinity (ppt)	0.1	0.1		
		PC RFU	0.1	0.5		
		Chla (ug l^{-1})	1.5	1.8		
	Middle Estuary	Depth (m)				
		Temp (°C)				
		DO (%)				
		DO (mg m^{-3})				
		Salinity (ppt)				
		PC RFU				
		Chla (ug l^{-1})				
	Upper Estuary	Depth (m)				
		Temp (°C)				
		DO (%)				
		DO (mg m^{-3})				
		Salinity (ppt)				
		PC RFU				
		Chla (ug l^{-1})				

[1] All sampling undertaken at mid-low tide using an EXO1 (Sonde 15F103960; Serial Number: 15F103960; Firmware Version: 1.0.73), Feb 26th - March 4th 2019, Taranaki.

Summary of subtidal water quality data[1].

Estuary	Site	Parameter	Water Column Position		Location	
			Bottom	Surface	NZTM North	NZTM East
Mōhakatino	Low Estuary	Depth (m)	1.0	0.2	1740302	5711749
		Temp (°C)	19.1	19.1		
		DO (%)	93.1	93.0		
		DO (mg m^{-3})	7.1	7.1		
		Salinity (ppt)	32.0	32.0		
		PC RFU	0.2	0.2		
		Chla (ug l^{-1})	5.5	4.8		
	Middle Estuary	Depth (m)	2.0	0.2	1740739	5710974
		Temp (°C)	17.9	17.9		
		DO (%)	93.7	93.8		
		DO (mg m^{-3})	7.2	7.2		
		Salinity (ppt)	35.3	35.1		
		PC RFU	0.1	0.2		
		Chla (ug l^{-1})	2.1	3.1		
	Upper Estuary	Depth (m)				
		Temp (°C)				
		DO (%)				
		DO (mg m^{-3})				
		Salinity (ppt)				
		PC RFU				
		Chla (ug l^{-1})				
Manawapou	Low Estuary	Depth (m)	1.0		1715938	5609524
		Temp (°C)	16.0			
		DO (%)	110.5			
		DO (mg m^{-3})	10.1			
		Salinity (ppt)	0.1			
		PC RFU	0.1			
		Chla (ug l^{-1})	1.7			
	Middle Estuary	Depth (m)	2.0	0.2	1715968	5609607
		Temp (°C)	15.9	15.0		
		DO (%)	110.6	113.7		
		DO (mg m^{-3})	10.9	11.2		
		Salinity (ppt)	0.1	0.1		
		PC RFU	0.3	0.2		
		Chla (ug l^{-1})	5.8	3.2		
	Upper Estuary	Depth (m)				
		Temp (°C)				
		DO (%)				
		DO (mg m^{-3})				
		Salinity (ppt)				
		PC RFU				
		Chla (ug l^{-1})				

[1] All sampling undertaken at mid-low tide using an EXO1 (Sonde 15F103960; Serial Number: 15F103960; Firmware Version: 1.0.73), Feb 26th - March 4th 2019, Taranaki.

Summary of subtidal water quality data[1].

Estuary	Site	Parameter	Water Column Position		Location	
			Bottom	Surface	NZTM North	NZTM East
Onaero	Low Estuary	Depth (m)	0.5		1718288	5682899
		Temp (°C)	22.0			
		DO (%)	54.5			
		DO (mg m^{-3})	3.9			
		Salinity (ppt)	33.1			
		PC RFU	0.3			
		Chla (ug l^{-1})	8.1			
	Middle Estuary	Depth (m)	0.5		1718300	5682691
		Temp (°C)	21.7			
		DO (%)	81.2			
		DO (mg m^{-3})	6.9			
		Salinity (ppt)	26.9			
		PC RFU	0.5			
		Chla (ug l^{-1})	8.5			
	Upper Estuary	Depth (m)				
		Temp (°C)				
		DO (%)				
		DO (mg m^{-3})				
		Salinity (ppt)				
		PC RFU				
		Chla (ug l^{-1})				
Waingongoro	Low Estuary	Depth (m)	2.0	0.2	1702391	5617525
		Temp (°C)	16.3	16.4		
		DO (%)	110.7	114.9		
		DO (mg m^{-3})	10.9	11.2		
		Salinity (ppt)	0.1	0.1		
		PC RFU	0.1	0.1		
		Chla (ug l^{-1})	1.7	2.4		
	Middle Estuary	Depth (m)	2.5	0.2	1702469	5617650
		Temp (°C)	17.2	16.5		
		DO (%)	126.2	114.2		
		DO (mg m^{-3})	12.3	11.1		
		Salinity (ppt)	0.1	0.1		
		PC RFU	0.2	0.2		
		Chla (ug l^{-1})	2.9	2.2		
	Upper Estuary	Depth (m)				
		Temp (°C)				
		DO (%)				
		DO (mg m^{-3})				
		Salinity (ppt)				
		PC RFU				
		Chla (ug l^{-1})				

[1] All sampling undertaken at mid-low tide using an EXO1 (Sonde 15F103960; Serial Number: 15F103960; Firmware Version: 1.0.73), Feb 26th - March 4th 2019, Taranaki.

Summary of subtidal water quality data[1].

Estuary	Site	Parameter	Water Column Position		Location	
			Bottom	Surface	NZTM North	NZTM East
Kaupokonui	Low Estuary	Depth (m)	2.0	0.2	1691152	5619874
		Temp (°C)	15.9	15.7		
		DO (%)	108.1	111.0		
		DO (mg m^{-3})	10.7	11.0		
		Salinity (ppt)	0.1	0.1		
		PC RFU	0.2	0.1		
		Chla (ug l^{-1})	3.1	1.2		
	Middle Estuary	Depth (m)	0.5	-	1691145	5620002
		Temp (°C)	15.7			
		DO (%)	112.0			
		DO (mg m^{-3})	11.0			
		Salinity (ppt)	0.1			
		PC RFU	0.2			
		Chla (ug l^{-1})	2.0			
	Upper Estuary	Depth (m)				
		Temp (°C)				
		DO (%)				
		DO (mg m^{-3})				
		Salinity (ppt)				
		PC RFU				
		Chla (ug l^{-1})				
Oakura	Low Estuary	Depth (m)	1.5	0.2	1682702	5670485
		Temp (°C)	21.0	19.9		
		DO (%)	>150	122.0		
		DO (mg m^{-3})	>15.0	11.1		
		Salinity (ppt)	19.9	0.1		
		PC RFU	2.1	0.1		
		Chla (ug l^{-1})	30.7	1.9		
	Middle Estuary	Depth (m)	2.0	0.2	1682779	5670404
		Temp (°C)	21.0	19.6		
		DO (%)	100.5	107.5		
		DO (mg m^{-3})	8.1	9.8		
		Salinity (ppt)	17.2	171.8		
		PC RFU	3.0	0.1		
		Chla (ug l^{-1})	47.7	1.0		
	Upper Estuary	Depth (m)				
		Temp (°C)				
		DO (%)				
		DO (mg m^{-3})				
		Salinity (ppt)				
		PC RFU				
		Chla (ug l^{-1})				

[1] All sampling undertaken at mid-low tide using an EXO1 (Sonde 15F103960; Serial Number: 15F103960; Firmware Version: 1.0.73), Feb 26th - March 4th 2019, Taranaki.

Summary of subtidal water quality data[1].

Estuary	Site	Parameter	Water Column Position		Location	
			Bottom	Surface	NZTM North	NZTM East
Tapuae	Low Estuary	Depth (m)	1.5	0.2	1684537	5671624
		Temp (°C)	20.5	20.6		
		DO (%)	109.3	104.3		
		DO (mg m^{-3})	7.2	6.7		
		Salinity (ppt)	0.1	0.1		
		PC RFU	0.1	0.1		
		Chla (ug l^{-1})	1.9	1.7		
	Middle Estuary	Depth (m)	1.0	0.2	1684558	5671501
		Temp (°C)	22.0	20.7		
		DO (%)	>150	132.0		
		DO (mg m^{-3})	30.1	11.8		
		Salinity (ppt)	15.2	0.1		
		PC RFU	1.4	0.1		
		Chla (ug l^{-1})	35.0	1.2		
	Upper Estuary	Depth (m)				
		Temp (°C)				
		DO (%)				
		DO (mg m^{-3})				
		Salinity (ppt)				
		PC RFU				
		Chla (ug l^{-1})				
Te Henui	Low Estuary	Depth (m)	0.5		1694204	5676999
		Temp (°C)	17.7			
		DO (%)	96.6			
		DO (mg m^{-3})	9.2			
		Salinity (ppt)	0.1			
		PC RFU	0.2			
		Chla (ug l^{-1})	3.3			
	Middle Estuary	Depth (m)	2.0	0.2	1694363	5676943
		Temp (°C)	17.4	17.8		
		DO (%)	96.2	99.8		
		DO (mg m^{-3})	9.2	9.5		
		Salinity (ppt)	165.5	135.9		
		PC RFU	0.2	0.1		
		Chla (ug l^{-1})	4.8	0.9		
	Upper Estuary	Depth (m)				
		Temp (°C)				
		DO (%)				
		DO (mg m^{-3})				
		Salinity (ppt)				
		PC RFU				
		Chla (ug l^{-1})				

[1] All sampling undertaken at mid-low tide using an EXO1 (Sonde 15F103960; Serial Number: 15F103960; Firmware Version: 1.0.73), Feb 26th - March 4th 2019, Taranaki.

Summary of subtidal water quality data[1].

Estuary	Site	Parameter	Water Column Position		Location	
			Bottom	Surface	NZTM North	NZTM East
Katikara	Low Estuary	Depth (m)	1.5	0.2	1676574	5667865
		Temp (^{o}C)	22.0	19.6		
		DO (%)	>150	107.2		
		DO (mg m^{-3})	17.6	9.8		
		Salinity (ppt)	4.5	0.1		
		PC RFU	1.3	0.2		
		Chla (ug l^{-1})	37.3	2.9		
	Middle Estuary	Depth (m)	1.0	0.2	1676534	5667773
		Temp (^{o}C)	22.0	18.4		
		DO (%)	>150	125.4		
		DO (mg m^{-3})	16.5	11.7		
		Salinity (ppt)	12.5	0.1		
		PC RFU	1.3	0.1		
		Chla (ug l^{-1})	42.8	3.1		
	Upper Estuary	Depth (m)				
		Temp (^{o}C)				
		DO (%)				
		DO (mg m^{-3})				
		Salinity (ppt)				
		PC RFU				
		Chla (ug l^{-1})				
Timaru	Low Estuary	Depth (m)	0.5		1679659	5669540
		Temp (^{o}C)	17.9			
		DO (%)	100.8			
		DO (mg m^{-3})	9.5			
		Salinity (ppt)	0.05			
		PC RFU	0.05			
		Chla (ug l^{-1})	1.02			
	Middle Estuary	Depth (m)	3	0.2	1679592	5669461
		Temp (^{o}C)	21.4	18.3		
		DO (%)	67.1	98.9		
		DO (mg m^{-3})	4.9	9.2		
		Salinity (ppt)	29.8	0.05		
		PC RFU	0.3	0.02		
		Chla (ug l^{-1})	18.9	0.38		
	Upper Estuary	Depth (m)	2	0.2	1679597	5669299
		Temp (^{o}C)	21.5	19.5		
		DO (%)	142	104		
		DO (mg m^{-3})	11	9.1		
		Salinity (ppt)	21.3	0.05		
		PC RFU	0.5	0.1		
		Chla (ug l^{-1})	26.5	0.8		

[1] All sampling undertaken at mid-low tide using an EXO1 (Sonde 15F103960; Serial Number: 15F103960; Firmware Version: 1.0.73), Feb 26th - March 4th 2019, Taranaki.

Appendix C:

Vulnerability Matrices
Taranaki Region Estuaries (Section 2.2)

MŌHAKATINO ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: MŌHAKATINO ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS			
Minimal		High	
Moderate		Very High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility:	Minimal
Macroalgal susceptibility:	Moderate
Overall Susceptibility to Eutrophication Rating	Moderate (Band B)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 2 subtidal sites, n=4) = 3.88 ug l^{-1} - indicative value only	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 2 subtidal sites, n=4) = 7.15 mg l^{-1} - indicative value only	Moderate
Macroalgae (EQR)	Very low throughout estuary	Moderate
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -54 mV	Moderate
Sediment % Mud	34% of unvegetated intertidal estuary was soft mud	Very High
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 60% of estuary	
Overall Existing Condition Eutrophication Rating		Moderate (Band B)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	2.6	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - poorly flushed at low flows.	High
Overall Sedimentation Susceptibility Rating		Mod-High

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	34% of unvegetated intertidal estuary and approximately 50-60% of subtidal area was soft muds.	Very High
Overall Sedimentation Existing Condition Rating		Very High

STRESSOR	Susceptibility	Existing Condition	Total Stressor Influence	STRESSOR INFLUENCE ON HABITAT: Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	STRESSOR INFLUENCE ON USES AND VALUES – HUMAN USES: Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	ECOL. VALUES: Saltmarsh	Seagrass	Birds	Fish	Other Biota	STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES – EUTROPHICATION: Chlorophyll-*a* in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	SEDIMENTATION: Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

TONGAPORUTU ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: TONGAPORUTU ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS		
	Minimal	High
	Moderate	Very High

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility:	Minimal
Macroalgal susceptibility:	High
Overall Susceptibility to Eutrophication Rating	High (Band C)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 3 subtidal sites, n=5) = 1.32 ug l^{-1} - indicative value only	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 3 subtidal sites, n=5) = 6.06 mg l^{-1} - indicative value only	Moderate
Macroalgae (EQR)	Very low throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -69 mV	Moderate
Sediment % Mud	23% of unvegetated intertidal estuary soft mud	Very High
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 60% of estuary	Not Used
Overall Existing Condition Eutrophication Rating		Moderate (Band B)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	2.6	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - mid-upper intertidal regions poorly flushed at low flows.	Mod-High
Overall Sedimentation Susceptibility Rating		Mod-High

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	23% of unvegetated intertidal estuary and approximately 30-40% of subtidal area was soft muds.	Very High
Overall Sedimentation Existing Condition Rating		Very High

STRESSOR	Susceptibility	Existing Condition	Total Stressor Influence
Nutrients (Eut.)	High	Moderate	High
Fine Sediment	High	Very High	Very High

STRESSOR INFLUENCE ON HABITAT	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths
Nutrients (Eut.)	High	High	High	Minimal	Minimal	Minimal	Minimal
Fine Sediment	Very High	Very High	Very High	Minimal	Minimal	Minimal	Minimal
Priorities For Monitoring	High	Very High	Moderate	Minimal	Minimal	Minimal	Minimal

STRESSOR INFLUENCE ON USES AND VALUES	HUMAN USES: Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	ECOL. VALUES: Saltmarsh	Seagrass	Birds	Fish	Other Biota
Nutrients (Eut.)	High	High	High	High	Minimal	Moderate	High	High	High	High
Fine Sediment	High	High	Very High	High	Minimal	Moderate	Very High	Very High	Very High	Very High

STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES – EUTROPHICATION	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos
Nutrients (Eut.)	Minimal	High	Minimal	Minimal	High	High	High	Minimal	High	High
Fine Sediment										
Priorities For Monitoring	Moderate	High	Minimal	Moderate	High	High	High	Minimal	High	High

STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES – SEDIMENTATION	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)						
Fine Sediment	Very High	Very High	Very High	Very High	Very High	Very High
Priorities For Monitoring	Very High	Very High	High	Minimal	Very High	Very High

MIMI ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: MIMI ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS				
	Minimal		High	
	Moderate		Very High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility:	Minimal
Macroalgal susceptibility:	Very High
Overall Susceptibility to Eutrophication Rating	Very High

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 3 subtidal sites, n=6) = 2.38 ug l^{-1}	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 3 subtidal sites, n=6) = 7.1 mg l^{-1} - indicative value only	Moderate
Macroalgae (EQR)	Very low throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -47 mV	Moderate
Sediment % Mud	26% of unvegetated intertidal estuary was soft mud	Very High
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 40% of estuary	Not Used
Overall Existing Condition Eutrophication Rating		Moderate

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	3.5	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - poorly flushed at low flows.	High
Overall Sedimentation Susceptibility Rating		Mod-High

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	26% of unvegetated intertidal estuary and approximately 50-60% of subtidal area was soft muds.	Very High
Overall Sedimentation Existing Condition Rating		Very High

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES: HUMAN USES					ECOL. VALUES					STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES: EUTROPHICATION										SEDIMENTATION						
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-*a* in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

URENUI ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: URENUI ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS				
	Minimal	(light grey-blue)	High	(yellow)
	Moderate	(dark grey-blue)	Very High	(orange)

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility:	Minimal
Macroalgal susceptibility:	Very High
Overall Susceptibility to Eutrophication Rating	Very High (Band D)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 3 subtidal sites, n=5) = 3.08 ug l^{-1} - indicative value only	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 3 subtidal sites, n=5) = 7.5 mg l^{-1} - indicative value only	Moderate
Macroalgae (EQR)	Localised patches, but very low throughout estuary	Moderate
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -50 mV	Moderate
Sediment % Mud	39.2% of unvegetated intertidal estuary soft mud	Very High
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 60% of estuary	Not Used
Overall Existing Condition Eutrophication Rating		Moderate

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	3.2	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - poorly flushed at low flows.	High
Overall Sedimentation Susceptibility Rating		Mod-High

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	39.2% of unvegetated intertidal estuary and approximately 50-60% of subtidal area was soft muds. Local residents indicated that the estuary had got muddier in recent years. But sandy in lower estuary.	Very High
Overall Sedimentation Existing Condition Rating		Very High

STRESSOR	Susceptibility	Existing Condition	Total Stressor Influence
Nutrients (Eut.)	Very High	Moderate	High
Fine Sediment	Very High	Very High	Very High
Priorities For Monitoring			

STRESSOR	STRESSOR INFLUENCE ON HABITAT: Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths
Nutrients (Eut.)	Very High	Very High	Very High	Minimal	Minimal	Minimal	Minimal
Fine Sediment	Very High	Very High	Very High	Minimal	Minimal	Minimal	Minimal
Priorities For Monitoring	High	Very High	Moderate	Minimal	Minimal	Minimal	Minimal

STRESSOR	STRESSOR INFLUENCE ON USES AND VALUES – HUMAN USES: Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	ECOL. VALUES: Saltmarsh	Seagrass	Birds	Fish	Other Biota
Nutrients (Eut.)	High	High	High	High	Minimal	Moderate	High	High	High	High
Fine Sediment	High	High	Very High	High	Minimal	Moderate	Very High	Very High	Very High	Very High
Priorities For Monitoring										

STRESSOR	STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES – EUTROPHICATION: Chlorophyll-*a* in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos
Nutrients (Eut.)	Moderate	Moderate	Minimal	Minimal	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Fine Sediment										
Priorities For Monitoring	Moderate	Very High	Minimal	Moderate	Very High	Very High	Very High	Minimal	Very High	Very High

STRESSOR	SEDIMENTATION: Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)						
Fine Sediment	Very High	Very High	Very High	Very High	Very High	Very High
Priorities For Monitoring	Very High	Very High	High	Minimal	Very High	Very High

ONAERO ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: ONAERO ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS				
	Minimal		High	
	Moderate		Very High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility:	Minimal
Macroalgal susceptibility:	Minimal
Overall Susceptibility to Eutrophication Rating	Minimal (Band A)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (bottom water - @0.5 m - at 2 subtidal sites, n=2) = 8.28 ug l^{-1} - indicative value only	Moderate
Dissolved Oxygen	1-day mean (bottom water - @0.5 m - at 2 subtidal sites, n=2) = 5.41 mg l^{-1} - indicative value only	Moderate
Macroalgae (EQR)	Very low throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -35 mV	Minimal
Sediment % Mud	No intertidal soft mud	Minimal
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 40% of estuary	Not Used
Overall Existing Condition Eutrophication Rating		Moderate (Band B)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	4.2	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - possibly poorly flushed at low flows.	Moderate
Overall Sedimentation Susceptibility Rating		Moderate

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	No intertidal soft mud, but approximately 20-30% subtidal benthos in soft muds.	Moderate
Overall Sedimentation Existing Condition Rating		Moderate

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES: HUMAN USES					STRESSOR INFLUENCE ON USES AND VALUES: ECOL. VALUES					STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES: EUTROPHICATION										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES: SEDIMENTATION					
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-*a* in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

WAITARA ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: WAITARA ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS				
	Minimal		High	
	Moderate		Very High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility:	Minimal
Macroalgal susceptibility:	Minimal
Overall Susceptibility to Eutrophication Rating	Minimal (Band A)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 3 subtidal sites, n=6) = 2.42 ug l^{-1} - indicative value only	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 3 subtidal sites, n=6) = 9.22 mg l^{-1} - indicative value only	Moderate
Macroalgae (EQR)	Very low throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -70 mV	Moderate
Sediment % Mud	26% of unvegetated intertidal estuary was soft mud	Very High
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 60% of estuary	Not Used
Overall Existing Condition Eutrophication Rating		Moderate (Band B)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	4.0	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - intertidal regions poorly flushed at low flows.	Mod-High
Overall Sedimentation Susceptibility Rating		Mod-High

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	26% of unvegetated intertidal estuary and approximately 20-30% of subtidal area was soft muds.	Very High
Overall Sedimentation Existing Condition Rating		Very High

STRESSOR	Susceptibility	Existing Condition	Total Stressor Influence	STRESSOR INFLUENCE ON HABITAT: Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	STRESSOR INFLUENCE ON USES AND VALUES – HUMAN USES: Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	ECOL. VALUES: Saltmarsh	Seagrass	Birds	Fish	Other Biota	STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES – EUTROPHICATION: Chlorophyll-*a* in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	SEDIMENTATION: Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

WAIONGANA ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: WAIONGANA ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS			
Minimal	(light blue-grey)	High	(yellow)
Moderate	(dark blue-grey)	Very High	(orange)

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility	Minimal
Macroalgal susceptibility	Minimal
Overall Susceptibility to Eutrophication Rating	Minimal (Band A)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 2 subtidal sites, n=3) = 2.25 ug l^{-1} - indicative value only	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 2 subtidal sites, n=3) = 7.66 mg l^{-1} - indicative value only	Moderate
Macroalgae (EQR)	Very low (cover/biomass) throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -41 mV	Minimal
Sediment % Mud	2% intertidal estuary in soft mud	Minimal
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 40% of estuary	Not Used
Overall Existing Condition Eutrophication Rating		Minimal (Band A)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	6.4	Very High
Presence of Poorly Flushed Habitat	Well flushed during flood periods - possibly poorly flushed at low flows	Minimal
Overall Sedimentation Susceptibility Rating		Moderate

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	2% intertidal and approximately 30-40% subtidal benthos (mid-upper estuary) in soft muds	Moderate
Overall Sedimentation Existing Condition Rating		Moderate

STRESSOR	Susceptibility	Existing Condition	Total Stressor Influence	STRESSOR INFLUENCE ON HABITAT: Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths
Nutrients (Eut.)	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal
Fine Sediment	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Minimal	Minimal	Minimal	Minimal
Priorities For Monitoring				Moderate	Moderate	Minimal	Minimal	Minimal	Minimal	Minimal

STRESSOR	STRESSOR INFLUENCE ON USES AND VALUES – HUMAN USES: Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	ECOL. VALUES: Saltmarsh	Seagrass	Birds	Fish	Other Biota
Nutrients (Eut.)	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal
Fine Sediment	Minimal	Minimal	Moderate	Minimal	Minimal	Minimal	Moderate	Moderate	Moderate	Moderate
Priorities For Monitoring										

STRESSOR	STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES – EUTROPHICATION: Chlorophyll-*a* in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	SEDIMENTATION: Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal	Minimal						
Fine Sediment											Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Priorities For Monitoring	Moderate	Moderate	Minimal	Minimal	Moderate	Moderate	Moderate	Minimal	Moderate	Moderate	Moderate	Moderate	Moderate	Minimal	Moderate	Moderate

WAIWHAKAIHO ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: WAIWHAKAIHO ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS				
	Minimal		High	
	Moderate		Very High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility	Minimal
Macroalgal susceptibility	Minimal
Overall Susceptibility to Eutrophication Rating	Minimal (Band A)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 1 subtidal sites, n=2) = 1.68 ug l^{-1} - indicative value only	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 1 subtidal sites, n=2) = 10.96 mg l^{-1} - indicative value only	Moderate
Macroalgae (EQR)	Very low (cover/biomass) throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -46 mV	Minimal
Sediment % Mud	1% intertidal estuary in soft mud	Minimal
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 40% of estuary	Not Used
Overall Existing Condition Eutrophication Rating		Minimal (Band A)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	3.9	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - possibly poorly flushed at low flows	Minimal
Overall Sedimentation Susceptibility Rating		Moderate

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	1% intertidal area and approximately 10-20% subtidal benthos (constricted arm in lower estuary) in soft muds	Moderate
Overall Sedimentation Existing Condition Rating		Moderate

STRESSOR | STRESSOR INFLUENCE ON HABITAT | STRESSOR INFLUENCE ON USES AND VALUES (HUMAN USES; ECOL. VALUES) | STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES (EUTROPHICATION; SEDIMENTATION)

STRESSOR	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

TE HENUI ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: TE HENUI ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS				
	Minimal		High	
	Moderate		Very High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility:	Minimal
Macroalgal susceptibility:	Minimal
Overall Susceptibility to Eutrophication Rating	Minimal (Band A)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 2 subtidal sites, n=3) = 2.48 ug l^{-1} - indicative value only	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 2 subtidal sites, n=3) = 9.35 mg l^{-1} - indicative value only	Moderate
Macroalgae (EQR)	Very low (cover/biomass) throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -39 mV	Minimal
Sediment % Mud	No intertidal soft mud	Minimal
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 40% of estuary	Not Used
Overall Existing Condition Eutrophication Rating		Minimal (Band A)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	4.1	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - possibly poorly flushed at low flows.	Moderate
Overall Sedimentation Susceptibility Rating		Moderate

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	No intertidal soft mud, but approximately 30-40% subtidal benthos (mid-upper estuary) in soft muds.	Moderate
Overall Sedimentation Existing Condition Rating		Moderate

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES															
											HUMAN USES					ECOL. VALUES					EUTROPHICATION										SEDIMENTATION					
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

TAPUAE ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: TAPUAE ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS				
	Minimal		High	
	Moderate		Very High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility:	Minimal
Macroalgal susceptibility:	Minimal
Overall Susceptibility to Eutrophication Rating	Minimal (Band A)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 2 subtidal sites, n=4) = 9.95 ug l[-1] - indicative value only	Moderate
Dissolved Oxygen	1-day mean (surface and bottom water at 2 subtidal sites, n=4) = 13.95 mg l[-1] - indicative value only	Moderate
Macroalgae (EQR)	Very low (cover/biomass) throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -21 mV	Minimal
Sediment % Mud	No intertidal soft mud	Minimal
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 40% of estuary	Not Used
Overall Existing Condition Eutrophication Rating		Minimal (Band A)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	3.2	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - possibly poorly flushed at low flows.	Moderate
Overall Sedimentation Susceptibility Rating		Moderate

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	No intertidal soft mud, but approximately 30-40% subtidal benthos (mid-upper estuary) in soft muds.	Moderate
Overall Sedimentation Existing Condition Rating		Moderate

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES: HUMAN USES					ECOL. VALUES					STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES: EUTROPHICATION										SEDIMENTATION					
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

OAKURA ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: OAKURA ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS				
	Minimal		High	
	Moderate		Very High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility:	Moderate
Macroalgal susceptibility:	Moderate
Overall Susceptibility to Eutrophication Rating	Moderate (Band B)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 2 subtidal sites, n=4) = 20.33 ug l^{-1} - indicative value only	High
Dissolved Oxygen	1-day mean (surface and bottom water at 2 subtidal sites, n=4) = 9.27 mg l^{-1} - indicative value only	Minimal
Macroalgae (EQR)	Very low throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -9 mV	Minimal
Sediment % Mud	No intertidal soft mud	Minimal
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 40% of estuary	Not Used
Overall Existing Condition Eutrophication Rating		High (Band C)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	3.5	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - possibly poorly flushed at low flows.	Moderate
Overall Sedimentation Susceptibility Rating		Moderate

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	No intertidal soft mud, but approximately 30-40% subtidal benthos in soft muds.	Moderate
Overall Sedimentation Existing Condition Rating		Moderate

STRESSOR	Susceptibility	Existing Condition	Total Stressor Influence	STRESSOR INFLUENCE ON HABITAT: Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths
Nutrients (Eut.)										
Fine Sediment										
Priorities For Monitoring										

STRESSOR	STRESSOR INFLUENCE ON USES AND VALUES – HUMAN USES: Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	ECOL. VALUES: Saltmarsh	Seagrass	Birds	Fish	Other Biota
Nutrients (Eut.)										
Fine Sediment										
Priorities For Monitoring										

STRESSOR	STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES – EUTROPHICATION: Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos
Nutrients (Eut.)										
Fine Sediment										
Priorities For Monitoring										

STRESSOR	SEDIMENTATION: Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)						
Fine Sediment						
Priorities For Monitoring						

TIMARU ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: TIMARU ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS				
	Minimal		High	
	Moderate		Very High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility	Minimal
Macroalgal susceptibility	Minimal
Overall Susceptibility to Eutrophication Rating	Minimal (Band A)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 3 subtidal sites, n=5) = 8.03 ug l^{-1} - indicative value only	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 3 subtidal sites, n=5) = 8.81 mg l^{-1} - indicative value only	Moderate
Macroalgae (EQR)	Very low (cover/biomass) throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -14 mV	Minimal
Sediment % Mud	No intertidal soft mud	Minimal
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 40% of estuary	
Overall Existing Condition Eutrophication Rating		Minimal (Band A)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	3.1	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - possibly poorly flushed at low flows	Moderate
Overall Sedimentation Susceptibility Rating		Moderate

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	No intertidal soft mud, but approximately 30-40% subtidal benthos (mid-upper estuary) in soft muds	Moderate
Overall Sedimentation Existing Condition Rating		Moderate

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES															
											HUMAN USES					ECOL. VALUES					EUTROPHICATION										SEDIMENTATION					
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

KATIKARA ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: KATIKARA ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS				
	Minimal		High	
	Moderate		Very High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility:	Moderate
Macroalgal susceptibility:	Minimal
Overall Susceptibility to Eutrophication Rating	Moderate (Band B)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 2 subtidal sites, n=4) = 21.53 ug l^{-1} - indicative value only	High
Dissolved Oxygen	1-day mean (surface and bottom water at 2 subtidal sites, n=4) = 13.9 mg l^{-1} - indicative value only	Minimal
Macroalgae (EQR)	Very low throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -10 mV	Minimal
Sediment % Mud	No intertidal soft mud	Minimal
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 40% of estuary	Not Used
Overall Existing Condition Eutrophication Rating		High (Band C)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	4.5	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - possibly poorly flushed at low flows.	Moderate
Overall Sedimentation Susceptibility Rating		Moderate

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	No intertidal soft mud, but approximately 30-40% subtidal benthos in soft muds.	Moderate
Overall Sedimentation Existing Condition Rating		Moderate

STRESSOR	Susceptibility	Existing Condition	Total Stressor Influence	STRESSOR INFLUENCE ON HABITAT: Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	STRESSOR INFLUENCE ON USES AND VALUES – HUMAN USES: Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	ECOL. VALUES: Saltmarsh	Seagrass	Birds	Fish	Other Biota	STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES – EUTROPHICATION: Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	SEDIMENTATION: Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

KOUPOKONUI ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: KAUPOKONUI ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS				
	Minimal		High	
	Moderate		Very High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility:	Minimal
Macroalgal susceptibility:	Minimal
Overall Susceptibility to Eutrophication Rating	Minimal (Band A)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 2 subtidal sites, n=3) = 1.58 ug l^{-1} - indicative value only	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 2 subtidal sites, n=3) = 8.18 mg l^{-1} - indicative value only	Minimal
Macroalgae (EQR)	Very low (cover/biomass) throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -22 mV	Minimal
Sediment % Mud	No intertidal soft mud	Minimal
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 40% of estuary	Not Used
Overall Existing Condition Eutrophication Rating		Minimal (Band A)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	5.2	Very High
Presence of Poorly Flushed Habitat	Well flushed during flood periods - possibly poorly flushed at low flows.	Moderate
Overall Sedimentation Susceptibility Rating		Moderate

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	No intertidal soft mud, but approximately 30-40% subtidal benthos in soft muds.	Moderate
Overall Sedimentation Existing Condition Rating		Moderate

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES: HUMAN USES					ECOL. VALUES					STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES: EUTROPHICATION										SEDIMENTATION					
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

WAINGONGORO ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: WAINGONGORO ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS				
	Minimal		High	
	Moderate		Very High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility	Minimal
Macroalgal susceptibility	Minimal
Overall Susceptibility to Eutrophication Rating	Minimal (Band A)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 2 subtidal sites, n=4) = 2.30 ug l^{-1} - indicative value only	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 2 subtidal sites, n=4) = 11.37 mg l^{-1} - indicative value only	Moderate
Macroalgae (EQR)	Very low (cover/biomass) throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = +34 mV (coarse sands)	Minimal
Sediment % Mud	No intertidal soft mud	Minimal
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 40% of estuary	
Overall Existing Condition Eutrophication Rating		Minimal (Band A)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	6.5	Very High
Presence of Poorly Flushed Habitat	Very well flushed during flood periods - possibly poorly flushed at low flows	Minimal
Overall Sedimentation Susceptibility Rating		Moderate

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	No intertidal or subtidal soft muds	Minimal
Overall Sedimentation Existing Condition Rating		Minimal

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES: HUMAN USES					STRESSOR INFLUENCE ON USES AND VALUES: ECOL. VALUES					STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES: EUTROPHICATION										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES: SEDIMENTATION					
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

TANGAHOE ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: TANGAHOE ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS			
Minimal		High	
Moderate		Very High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS	
Phytoplankton susceptibility:	Minimal
Macroalgal susceptibility:	Minimal
Overall Susceptibility to Eutrophication Rating	Minimal (Band A)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION		
Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 2 subtidal sites, n=3) = 2.65 ug l^{-1} - indicative value only	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 2 subtidal sites, n=3) = 8.25 mg l^{-1} - indicative value only	Moderate
Macroalgae (EQR)	Very low (cover/biomass) throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -23 mV	Minimal
Sediment % Mud	No intertidal soft mud	Minimal
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 40% of estuary	Not Used
Overall Existing Condition Eutrophication Rating		Minimal (Band A)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS		
Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	3.4	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - possibly poorly flushed at low flows.	Moderate
Overall Sedimentation Susceptibility Rating		Moderate

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION		
Percentage of estuary with soft mud (~>25% sediment mud content)	No intertidal soft mud, but approximately 30-40% subtidal benthos (mid-upper estuary) in soft muds.	Moderate
Overall Sedimentation Existing Condition Rating		Moderate

STRESSOR	Susceptibility	Existing Condition	Total Stressor Influence	STRESSOR INFLUENCE ON HABITAT: Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	STRESSOR INFLUENCE ON USES AND VALUES – HUMAN USES: Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	ECOL. VALUES: Saltmarsh	Seagrass	Birds	Fish	Other Biota	STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES – EUTROPHICATION: Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	SEDIMENTATION: Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

MANAWAPOU ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: MANAWAPOU ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS				
	Minimal		High	
	Moderate		Very High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility:	Minimal
Macroalgal susceptibility:	Minimal
Overall Susceptibility to Eutrophication Rating	Minimal (Band A)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 2 subtidal sites, n=3) = 2.67 ug l^{-1} - indicative value only	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 2 subtidal sites, n=3) = 8.06 mg l^{-1} - indicative value only	Moderate
Macroalgae (EQR)	Very low (cover/biomass) throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -43 mV	Minimal
Sediment % Mud	No intertidal soft mud	Minimal
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 40% of estuary	Not Used
Overall Existing Condition Eutrophication Rating		Minimal (Band A)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	3.5	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - possibly poorly flushed at low flows.	Minimal
Overall Sedimentation Susceptibility Rating		Moderate

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	No intertidal soft mud, but approximately 30-40% subtidal benthos in soft muds.	Moderate
Overall Sedimentation Existing Condition Rating		Moderate

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES										STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES															
											HUMAN USES					ECOL. VALUES					EUTROPHICATION										SEDIMENTATION					
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

PATEA ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: PATEA ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS				
	Minimal	(light blue)	High	(yellow)
	Moderate	(dark blue)	Very High	(orange)

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility:	Minimal
Macroalgal susceptibility:	Very High
Overall Susceptibility to Eutrophication Rating	Very High (Band D)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 3 subtidal sites, n=6) = 1.95 ug l^{-1} - indicative value only	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 3 subtidal sites, n=6) = 7.77 mg l^{-1} - indicative value only	Moderate
Macroalgae (EQR)	Very low throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -41 mV	Moderate
Sediment % Mud	23% of unvegetated intertidal estuary soft mud	Very High
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 60% of estuary	
Overall Existing Condition Eutrophication Rating		Moderate

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	3.9	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - poorly flushed at low flows.	High
Overall Sedimentation Susceptibility Rating		Mod-High

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	23% of unvegetated intertidal estuary and approximately 50-60% of subtidal area was soft muds.	Very High
Overall Sedimentation Existing Condition Rating		Very High

STRESSOR	Susceptibility	Existing Condition	Total Stressor Influence
Nutrients (Eut.)	Very High	Moderate	High
Fine Sediment	High	Very High	Very High

STRESSOR INFLUENCE ON HABITAT	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths
Nutrients (Eut.)	High	High	High	Minimal	Minimal	Minimal	Minimal
Fine Sediment	Very High	Very High	Very High	Minimal	Minimal	Minimal	Minimal
Priorities For Monitoring	High	Very High	Moderate	Minimal	Minimal	Minimal	Minimal

STRESSOR INFLUENCE ON USES AND VALUES	HUMAN USES: Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	ECOL. VALUES: Saltmarsh	Seagrass	Birds	Fish	Other Biota
Nutrients (Eut.)	High	High	High	High	Minimal	Moderate	High	High	High	High
Fine Sediment	High	High	Very High	High	Minimal	Moderate	Very High	Very High	Very High	Very High
Priorities For Monitoring										

STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES (EUTROPHICATION)	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos
Nutrients (Eut.)	Minimal	High	Minimal	Minimal	High	High	High	Minimal	High	High
Fine Sediment										
Priorities For Monitoring	Moderate	High	Minimal	Moderate	High	High	High	Minimal	High	High

STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES (SEDIMENTATION)	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)						
Fine Sediment	Very High	Very High	Very High	Very High	Very High	Very High
Priorities For Monitoring	Very High	Very High	High	Minimal	Very High	Very High

WHENUAKURA ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: WHENUAKURA ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS				
	Minimal	(light blue-grey)	High	(yellow)
	Moderate	(dark blue-grey)	Very High	(orange)

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility	Minimal
Macroalgal susceptibility	Very High
Overall Susceptibility to Eutrophication Rating	Very High (Band D)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 3 subtidal sites, n=6) = 2.47 ug l^{-1} - indicative value only	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 3 subtidal sites, n=6) = 7.36 mg l^{-1} - indicative value only	Min-Moderate
Macroalgae (EQR)	Very low (cover/biomass) throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -34 mV	Minimal
Sediment % Mud	2% intertidal estuary in soft mud	Minimal
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 40% of estuary	
Overall Existing Condition Eutrophication Rating		Minimal (Band A)

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	2.5	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - possibly poorly flushed at low flows	Moderate
Overall Sedimentation Susceptibility Rating		Moderate

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	2% intertidal area and approximately 30-40% subtidal benthos in soft muds	Moderate
Overall Sedimentation Existing Condition Rating		Moderate

STRESSOR

STRESSOR	Susceptibility	Existing Condition	Total Stressor Influence
Nutrients (Eut.)	Very High	Minimal	High
Fine Sediment	Moderate	Moderate	Moderate

STRESSOR INFLUENCE ON HABITAT

STRESSOR	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths
Nutrients (Eut.)	High	High	High	Minimal	Minimal	Minimal	Minimal
Fine Sediment	Moderate	Moderate	Moderate	Minimal	Minimal	Minimal	Minimal
Priorities For Monitoring	High	High	Moderate	Minimal	Minimal	Minimal	Minimal

STRESSOR INFLUENCE ON USES AND VALUES

STRESSOR	HUMAN USES: Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	ECOL. VALUES: Saltmarsh	Seagrass	Birds	Fish	Other Biota
Nutrients (Eut.)	High	High	High	High	Minimal	Moderate	High	High	High	High
Fine Sediment	Minimal	Minimal	Moderate	Minimal	Minimal	Minimal	Moderate	Moderate	Moderate	Moderate

STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES

STRESSOR	EUTROPHICATION: Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	SEDIMENTATION: Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)	High	High	Minimal	High	High	High	High	High	High	High						
Fine Sediment											Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Priorities For Monitoring	High	High	Minimal	High	High	High	High	Minimal	High	High	Moderate	Moderate	Moderate	Minimal	Moderate	Moderate

WAITOTARA ESTUARY - VULNERABILITY TO EUTROPHICATION AND SEDIMENTATION DETAILS

SITE: WAITOTARA ESTUARY
DATE: (MARCH 2019)

KEY FOR NZ ETI-BASED RATINGS			
Minimal		High	
Moderate		Very High	

SUSCEPTIBILITY AND EXISTING CONDITION RATINGS

1. NZ ETI (TOOL 1) EUTROPHICATION RATINGS BASED ON SUSCEPTIBILITY TO NUTRIENT LOADS AND PHYSICAL CHARACTERISTICS

Phytoplankton susceptibility:	Minimal
Macroalgal susceptibility:	Minimal
Overall Susceptibility to Eutrophication Rating	Minimal (Band A)

2. NZ ETI (TOOL 2) EUTROPHICATION RATINGS BASED ON EXISTING CONDITION

Primary Indicators		
Chlorophyll *a*	1-day mean (surface and bottom water at 3 subtidal sites, n=6) = 3.02 ug l^{-1} - indicative value only	Minimal
Dissolved Oxygen	1-day mean (surface and bottom water at 3 subtidal sites, n=6) = 7.84 mg l^{-1} - indicative value only	Moderate
Macroalgae (EQR)	Very low throughout estuary	Minimal
Supporting Indicators		
Redox Potential	Mean of measured RP at 1 cm depth (representative the most impacted sediments in at least 10% of estuary area) = -61 mV	Minimal
Sediment % Mud	34% of unvegetated intertidal estuary was soft mud	Very High
Seagrass	No seagrass in estuary	Not Used
Clarity (SD, cm)	SD not visible on bed over 60% of estuary	Not Used
Overall Existing Condition Eutrophication Rating		Minimal

3. SUSCEPTIBILITY TO SEDIMENTATION RATINGS BASED ON SEDIMENT LOADS AND PHYSICAL CHARACTERISTICS

Current State Sediment Load (CSSL)/Natural State Sediment Load (NSSL) ratio	2.8	Moderate
Presence of Poorly Flushed Habitat	Well flushed during flood periods - poorly flushed at low flows.	High
Overall Sedimentation Susceptibility Rating		Mod-High

4. SEDIMENTATION RATINGS BASED ON EXISTING CONDITION

Percentage of estuary with soft mud (~>25% sediment mud content)	34% of unvegetated intertidal estuary and approximately 50-60% of subtidal area was soft muds.	Very High
Overall Sedimentation Existing Condition Rating		Very High

STRESSOR				STRESSOR INFLUENCE ON HABITAT							STRESSOR INFLUENCE ON USES AND VALUES: HUMAN USES					ECOL. VALUES					STRESSOR INFLUENCE ON MONITORING INDICATORS/ISSUES: EUTROPHICATION										SEDIMENTATION					
	Susceptibility	Existing Condition	Total Stressor Influence	Estuary Water	Estuary Unvegetated Substrate	Aquatic Macrophytes	Biogenic (living) Structures	Saltmarsh	Terrestrial Margin	Stream & River Mouths	Bathing	Natural Character	Shellfish Collection	Fishing/Hunting	Waste Assimilation	Saltmarsh	Seagrass	Birds	Fish	Other Biota	Chlorophyll-a in Water	Macroalgal Rating (% cover)	Epiphyte abundance	Dissolved Oxygen in Water	Redox Potential Sediment	Sediment Nutrients	Sediment Organic Carbon (TOC)	Seagrass Loss	Macroinvertebrates AMBI	Phytoplankton Taxa/Nos	Muddiness (% soft mud)	Sedimentation rate	Clarity	Macrophyte Loss	Sediment Grain Size	Macroinvertebrates AMBI
Nutrients (Eut.)																																				
Fine Sediment																																				
Priorities For Monitoring																																				

Appendix D:

Broad Scale Habitat Classifications

Vegetation was classified using an interpretation of the Atkinson (1985) system, whereby dominant plant species were coded by using the two first letters of their Latin genus and species names e.g. marram grass, *Ammophila arenaria*, was coded as Amar. An indication of dominance is provided by the use of ( ) to distinguish subdominant species e.g. Amar(Caed) indicates that marram grass was dominant over ice plant (*Carpobrotus edulis*). The use of ( ) is not always based on percentage cover, but the subjective observation of which vegetation is the dominant or subdominant species within the patch. A measure of vegetation height can be derived from its structural class (e.g. rushland, scrub, forest).

Vegetation (mapped separately to the substrata they overlie):

Forest: Woody vegetation in which the cover of trees and shrubs in the canopy is >80% and in which tree cover exceeds that of shrubs. Trees are woody plants ≥10 cm diameter at breast height (dbh). Tree ferns ≥10 cm dbh are treated as trees. Commonly sub-grouped into native, exotic or mixed forest.

Treeland: Cover of trees in the canopy is 20-80%. Trees are woody plants >10 cm dbh. Commonly sub-grouped into native, exotic or mixed treeland.

Scrub: Cover of shrubs and trees in the canopy is >80% and in which shrub cover exceeds that of trees (c.f. FOREST). Shrubs are woody plants <10 cm dbh. Commonly sub-grouped into native, exotic or mixed scrub.

Shrubland: Cover of shrubs in the canopy is 20-80%. Shrubs are woody plants <10 cm dbh. Commonly sub-grouped into native, exotic or mixed shrubland.

Tussockland: Vegetation in which the cover of tussock in the canopy is 20-100% and in which the tussock cover exceeds that of any other growth form or bare ground. Tussock includes all grasses, sedges, rushes, and other herbaceous plants with linear leaves (or linear non-woody stems) that are densely clumped and >100 cm height. Examples of the growth form occur in all species of *Cortaderia, Gahnia*, and *Phormium*, and in some species of *Chionochloa, Poa, Festuca, Rytidosperma, Cyperus, Carex, Uncinia, Juncus, Astelia, Aciphylla*, and *Celmisia* spp..

Duneland: Vegetated sand dunes in which the cover of vegetation in the canopy (commonly *Spinifex*, *Pingao* or Marram grass) is 20-100% and in which the vegetation cover exceeds that of any other growth form or bare ground.

Grassland: Vegetation in which the cover of grass (excluding tussock-grasses) in the canopy is 20-100%, and in which the grass cover exceeds that of any other growth form or bare ground.

Sedgeland: Vegetation in which the cover of sedges (excluding tussock-sedges and reed-forming sedges) in the canopy is 20-100% and in which the sedge cover exceeds that of any other growth form or bare ground. Sedges vary from grass by feeling the stem. If the stem is flat or rounded, it's probably a grass or a reed, if the stem is clearly triangular, it's a sedge. Sedges include many species of *Carex, Uncinia*, and *Scirpus*.

Rushland: Vegetation in which the cover of rushes (excluding tussock-rushes) in the canopy is 20-100% and where rush cover exceeds that of any other growth form or bare ground. A tall grasslike, often hollow-stemmed plant, included in rushland are some species of *Juncus* and all species of *Leptocarpus*.

Reedland: Vegetation in which the cover of reeds in the canopy is 20-100% and in which the reed cover exceeds that of any other growth form or open water. Reeds are herbaceous plants growing in standing or slowly-running water that have tall, slender, erect, unbranched leaves or culms that are either round and hollow – somewhat like a soda straw, or have a very spongy pith. Unlike grasses or sedges, reed flowers will each bear six tiny petal-like structures. Examples include *Typha, Bolboschoenus, Scirpus lacutris, Eleocharis sphacelata*, and *Baumea articulata*.

Cushionfield: Vegetation in which the cover of cushion plants in the canopy is 20-100% and in which the cushion-plant cover exceeds that of any other growth form or bare ground. Cushion plants include herbaceous, semi-woody and woody plants with short densely packed branches and closely spaced leaves that together form dense hemispherical cushions.

Herbfield: Vegetation in which the cover of herbs in the canopy is 20-100% and where herb cover exceeds that of any other growth form or bare ground. Herbs include all herbaceous and low-growing semi-woody plants that are not separated as ferns, tussocks, grasses, sedges, rushes, reeds, cushion plants, mosses or lichens.

Lichenfield: Vegetation in which the cover of lichens in the canopy is 20-100% and where lichen cover exceeds that of any other growth form or bare ground.

Introduced weeds: Vegetation in which the cover of introduced weeds in the canopy is 20-100% and in which the weed cover exceeds that of any other growth form or bare ground.

Seagrass meadows: Seagrasses are the sole marine representatives of the Angiospermae. They all belong to the order Helobiae, in two families: Potamogetonaceae and Hydrocharitaceae. Although they may occasionally be exposed to the air, they are predominantly submerged, and their flowers are usually pollinated underwater. A notable feature of all seagrass plants is the extensive underground root/rhizome system which anchors them to their substrata. Seagrasses are commonly found in shallow coastal marine locations, salt-marshes and estuaries and are mapped separately to the substrata they overlie.

Macroalgal bed: Algae are relatively simple plants that live in freshwater or saltwater environments. In the marine environment, they are often called seaweeds. Although they contain cholorophyll, they differ from many other plants by their lack of vascular tissues (roots, stems, and leaves). Many familiar algae fall into three major divisions: Chlorophyta (green algae), Rhodophyta (red algae), and Phaeophyta (brown algae). Macroalgae are algae observable without using a microscope. Macroalgal density, biomass and entrainment are classified and mapped separately to the substrata they overlie.

Substrata (physical and biogenic habitat):

Artificial structures: Introduced natural or man-made materials that modify the environment. Includes rip-rap, rock walls, wharf piles, bridge supports, walkways, boat ramps, sand replenishment, groynes, flood control banks, stopgates.

Cliff: A steep face of land which exceeds the area covered by any one class of plant growth-form. Cliffs are named from the dominant substrata type when unvegetated or the leading plant species when plant cover is ≥1%.

Rock field: Land in which the area of residual rock exceeds the area covered by any one class of plant growth-form. They are named from the leading plant species when plant cover is ≥1%.

Boulder field: Land in which the area of unconsolidated boulders (>200 mm diam.) exceeds the area covered by any one class of plant growth-form. Boulder fields are named from the leading plant species when plant cover is ≥1%.

Cobble field: Land in which the area of unconsolidated cobbles (20-200 mm diam.) exceeds the area covered by any one class of plant growth-form. Cobble fields are named from the leading plant species when plant cover is ≥1%.

Gravel field: Land in which the area of unconsolidated gravel (2-20 mm diameter) exceeds the area covered by any one class of plant growth-form. Gravel fields are named from the leading plant species when plant cover is ≥1%.

Mobile sand: Granular beach sand characterised by a rippled surface layer from strong tidal or wind-generated currents. Often forms bars and beaches.

Firm or soft sand: Sand flats may be mud-like in appearance but are granular when rubbed between the fingers and no conspicuous fines are evident when sediment is disturbed e.g. a mud content <1%. Classified as firm sand if an adult sinks <2 cm or soft sand if an adult sinks >2 cm.

Firm muddy sand: A sand/mud mixture dominated by sand with a moderate mud fraction (e.g. 1-10%), the mud fraction conspicuous only when sediment is mixed in water. The sediment appears brown, and may have a black anaerobic layer below. From a distance appears visually similar to firm sandy mud, firm or soft mud, and very soft mud. When walking you'll sink 0-2 cm. Granular when rubbed between the fingers.

Firm sandy mud: A sand/mud mixture dominated by sand with an elevated mud fraction (e.g. 10-25%), the mud fraction visually conspicuous when walking on it. The surface appears brown, and may have a black anaerobic layer below. From a distance appears visually similar to firm muddy sand, firm or soft mud, and very soft mud. When walking you'll sink 0-2 cm. Granular when rubbed between the fingers, but with a smoother consistency than firm muddy sand.

Firm or soft mud: A mixture of mud and sand where mud is a major component (e.g. >25% mud). Sediment rubbed between the fingers retains a granular component but is primarily smooth/silken. The surface appears grey or brown, and may have a black anaerobic layer below. From a distance appears visually similar to firm muddy sand, firm sandy mud, and very soft mud. Classified as firm mud if an adult sinks <5 cm (usually if sediments are dried out or another component e.g. gravel prevents sinking) or soft mud if an adult sinks >5 cm.

Very soft mud: A mixture of mud and sand where mud is the major component (e.g. >50% mud), the surface appears brown, and may have a black anaerobic layer below. When walking you'll sink >5 cm unless another component e.g. gravel prevents sinking. From a distance appears visually similar to firm muddy sand, firm sandy mud, and firm or soft mud. Sediment rubbed between the fingers may retain a slight granular component but is primarily smooth/silken.

Cockle bed/Mussel reef/Oyster reef: Area that is dominated by both live and dead cockle shells, or one or more mussel or oyster species respectively.

Sabellid field: Area that is dominated by raised beds of sabellid polychaete tubes.

Shell bank: Area that is dominated by dead shells.

Appendix E:

Field Photographs

Mohakatino Estuary

Tongaporutu Estuary

Mimi Estuary

Urenui Estuary

Onaero Estuary






Waitara Estuary

Waiongana Estuary

Waiwhakaiho Estuary

Te Henui Estuary

Tapuae Estuary

Oakura Estuary






Timaru Estuary

Katikara Estuary






Kaupokonui Estuary

Waingongoro Estuary

Tangahoe Estuary

Manawapou Estuary






Patea Estuary






Whenuakura Estuary






Waitotara Estuary






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MEMORANDUM
Policy & Planning

Date	4 February 2020
Subject:	**Review of the Navigation Bylaws for Port Taranaki and its Approaches**
Approved by:	A D McLay, Director - Resource Management B G Chamberlain, Chief Executive
Document:	2408750

Purpose

1. The purpose of this memorandum is to seek Members' agreement to commence a review of the *Navigation Bylaws for Port Taranaki and its Approaches 2009* in accordance with the requirements of the *Local Government Act 2002* (LGA).
2. A copy of the project brief and an officer's report investigating the scope of the navigation and safety bylaws in Taranaki are attached to this item.

Executive summary

3. Responsibility for navigation and safety in Taranaki waters is largely shared between Maritime New Zealand (MNZ) and the Taranaki Regional Council (the Council) with some responsibility also undertaken by district councils.
4. Under the *Maritime Transport Act 1994*, the Minister of Transport make maritime rules for a wide range of matters, including rules prescribing safe navigational requirements. Navigation and safety bylaws made by regional councils must be consistent with maritime rules.
5. Under the *Maritime Transport Act* and LGA, the Council has the optional responsibility for the regulation and control of navigation safety in relation to all waters within its region, including inland waters and coastal waters out to 12 nautical miles. To date, the Council has determined that its bylaws and resources will apply where the risks are greatest (Port Taranaki and its approaches) with MNZ retaining responsibilities for other areas.
6. The current *Navigation Bylaws for Port Taranaki and its Approaches* were made operative in late 2009. In accordance with the LGA, the Council must commence a review of these bylaws. Accordingly attached for Members' consideration is a project brief to undertake that exercise.
7. As part of the review of the *Navigation Bylaws for Port Taranaki and its Approaches* to date, officers have undertaken a preliminary exercise of reviewing the jurisdictional and

spatial extent of the bylaws (e.g. retain bylaws for Port Taranaki harbour limits only, extend bylaws to the coastal waters, or extend the bylaws to both coastal and inland waters). The outcomes of that exercise and its recommendations are summarised in the attached report. Of note, the report recommends retaining the status quo in terms of retaining bylaws for Port Taranaki and its approaches only. However, it is recommended that the coverage of the bylaws be amended and widen to address emerging navigational issues occurring on the outer reaches of the harbour limits.

8. After considering matters of risk, jurisdiction, and applicability of rules to inland waters it is concluded that the current approach has worked well and it is recommended that no substantial change in the jurisdiction extent is required. Notwithstanding that, changes are likely to be required to update the bylaws, including reviewing the spatial extent of the Port Taranaki approaches to ensure safe navigational passage and taking into account potential change factors over the 'life' of the current bylaws.

9. While extending Council bylaws to all waters could simplify who controls navigation and safety in Taranaki, this would be taking on the statutory responsibilities currently exercised in the region by MNZ. Furthermore, it would come at a resourcing cost that the Council has not contemplated in its long term planning. The status quo, which is working well, is therefore recommended through the review of the bylaws.

Recommendations

That the Taranaki Regional Council:

a) receives this memorandum entitled *Review of the Navigation Bylaws for Port Taranaki and its Approaches*

b) notes that the Council is required by the LGA to commence a review of the *Navigation Bylaws for Port Taranaki and its Approaches 2009* in the 2019/2020 financial year;

c) agrees that the Council proceed to commence a review of the existing *Navigation and Safety Bylaws for Port Taranaki and its Approaches 2003* in accordance with the attached project brief; and

d) agrees to restrict the scope of the review to the areas where the risk is greatest (i.e. within the area of Port Taranaki and its approaches).

Background

10. Navigation safety is about ensuring that different users can safely use and share waterbodies. It is regulated through the adoption of navigation safety by laws under the Maritime Transport Act 1994 using the LGA provisions for community consultation. Responsibility for navigation and safety in the waters of the region is shared between MNZ and the Council, with some responsibility also undertaken by district councils.

11. Under the Maritime Transport Act, the principal objective of MNZ is to: *"…undertake its safety, security, marine protection, and other functions in a way that contributes to the aim of achieving an integrated, safe, responsive, and sustainable transport system."* Under section 431 of that Act, MNZ also has the following functions:

    a) to promote maritime safety and security, and protection of the marine environment in New Zealand;

    b) to promote maritime safety and security, and protection of the marine environment beyond New Zealand in accordance with New Zealand's international obligations;

c) to ensure the provision of appropriate distress and safety radio communication systems and navigational aids for shipping;
d) to ensure New Zealand's preparedness for, and ability to respond to, marine oil pollution spills;
e) to license ships, their operation, and their crews;
f) to investigate and review maritime transport accidents and incidents, and maritime security breaches and incidents;
g) to maintain the New Zealand Register of Ships;
h) to maintain and preserve records and documents relating to the Authority's functions;
i) to advise the Minister on technical maritime safety policy; and
j) to perform such other functions as are conferred on it by this Act or any other Act.

12. MNZ is also responsible for the management of all navigational aids on or near the coasts of New Zealand and the adjacent seas and islands.

13. The Minister of Transport may also make maritime rules for a wide range of matters relating to maritime transport including rules prescribing safe navigational requirements. MNZ administers and enforces the Maritime Rules. *Maritime Rule Part 91 'Navigation Safety Rules'* came into force on 21 March 2003, replacing the *Water Recreation Regulations 1974*. These rules set out detailed operating requirements for a wide range of vessels, recreational and pleasure craft used in navigation. The rules make it compulsory for personal flotation devices to be carried on board all recreational craft, and for them to be worn at times of heightened risk. They also set out the age for operating power driven vessels, and rules relating to speed, water skiing, access lanes, anchoring and distances to keep from vessels displaying either 'danger' flags or 'diver below' flags. Navigation and safety bylaws made by regional councils must be consistent with maritime rules.

14. Under the *Maritime Transport Act*, the Council has the optional responsibility for the regulation and control of navigation safety in relation to all waters within its region, including inland waters and coastal waters out to 12 nautical miles. The Council continues to have the power to make bylaws for navigation safety. Such bylaws must be made using the special consultative procedure of the LGA.

15. The Council's navigation and safety bylaws were originally prepared in 1993 under the former *Harbours Act 1950*. Subsequent bylaws were later prepared and adopted in 2003 and 2009 (currently operative) under the *Local Government Act 1974*.

16. The current navigation bylaws for Taranaki are limited to Port Taranaki and its approaches out to 2.5 nautical miles from trig Moturoa (Figure 1). No other navigation and safety bylaws are administered by this Council. As a consequence, outside the Port, navigation and safety responsibilities are currently delivered by MNZ. The primary regulatory tool used by MNZ to carry out its responsibilities is Maritime Rule 91, which applies to all waters in New Zealand.

17. The Council and MNZ have successfully managed navigation in Taranaki waters for the last 10 years under the current framework. However, it is timely to carry out a review of the navigation bylaws.

Schedule 1 Harbour limits

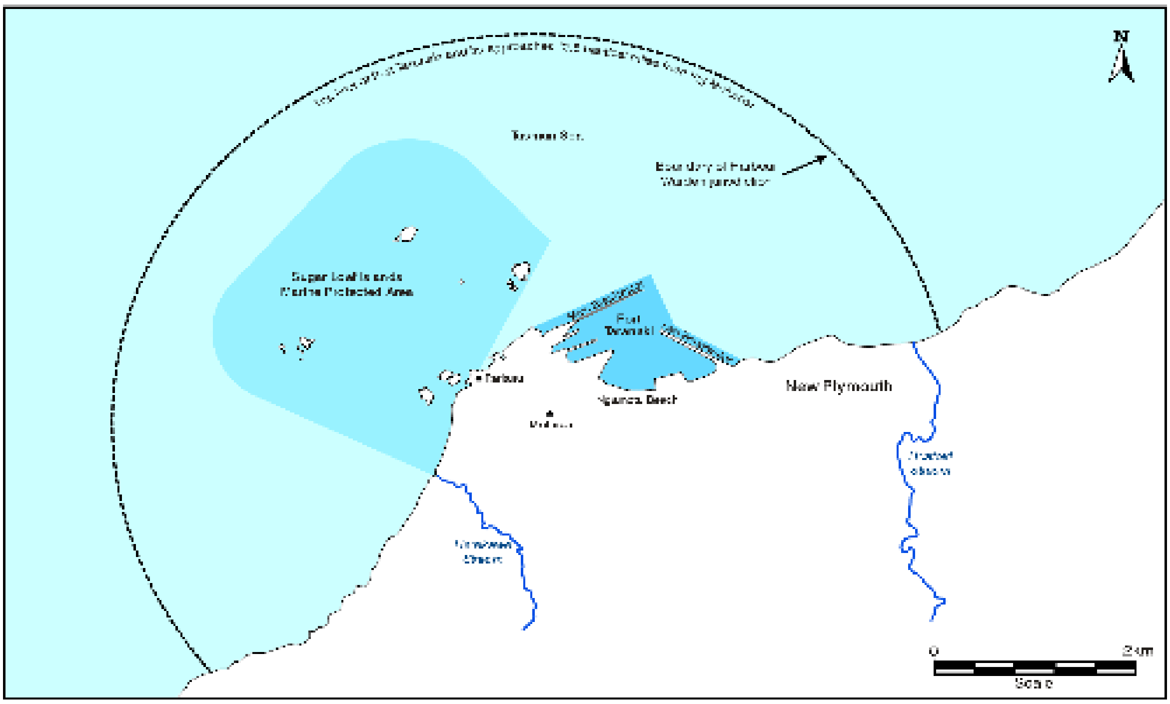

Figure 1: Spatial extent of Port Taranaki and its approaches bylaws

Review of Navigation Bylaws

18. Pursuant to section 160A of the LGA, the Council is required to review bylaws prepared under that Act or the Maritime Transport Act every ten years. The Navigation Bylaws for Port Taranaki and its Approaches, which were adopted in late 2009, are therefore required to be reviewed this financial year.[1]

19. Attached separate to this item is a project brief for carrying out the review. In brief, the objective of the review is to update existing navigation safety bylaws to ensure they remain 'fit for purpose'. As part of that review, Council will make any changes necessary to promote alignment with the requirements of the Maritime Transport Act, maritime rules and other national regulation; remove controls that are no longer relevant or required; ensure adequate health and safety practices; promote inter-regional consistency in bylaw provisions, and recognise and provide for changing uses and demands in Taranaki.

20. Previous Crown Law advice notes that powers in the Local Government Act 1974[2] do not impose an absolute obligation on regional councils to make bylaws in respect of navigation safety in its water or to appoint a harbourmaster or exercise its powers in relation to wrecks.

21. However, Crown Law was of the view that in relation to those powers, a regional council has an implied statutory duty to 'consider (and thereby to decide) from time to time whether to make (or to amend etc) bylaws for navigation safety within its region

1 In accordance with Section 160A of the LGA 2002, any bylaws under that Act will be revoked if not reviewed two years after the date on which the bylaws should have been reviewed.

2 The current bylaw was prepared under the LGA 1974. However, in 2013 that Act with relevant maritime provisions was incorporated into the MTA. Those amendments do not affect the findings of the legal opinion.

(or to any part of it)'. The review of the bylaws provides the Council the opportunity to do just that.

22. Officers have prepared the attached report entitled *Review of navigational responsibilities for Taranaki 2019/2020* to review the jurisdictional and spatial extent of the navigation bylaws.

23. The attached report concludes that the current approach of restricting the bylaws to the areas where the risks are greatest (i.e. Port Taranaki) has worked well from the Council's perspective. Notwithstanding that, there are three broad policy options that Council could consider. The three options are as follows:

    - *status quo*: Spatial extent and geographical coverage of the bylaws to be confined to Port Taranaki and its approaches;
    - all coastal waters: Spatial extent and geographical coverage of the bylaws is extended to include all Taranaki coastal waters out to 12 nautical miles; and
    - all Taranaki coastal and fresh waters: Spatial extent and geographical coverage of the bylaws is extended to include all Taranaki coastal waters out to 12 nautical miles plus all inland waters.

24. In examining which option is preferable, the attached report considered a number of matters, including:

    - navigational jurisdiction and responsibilities of MNZ, the Council, and the district councils;
    - current rules and restrictions relating to navigation and safety for inland waters;
    - the level of pressure and navigation risks across Taranaki; and
    - different approaches adopted by other Councils.

25. In line with previous review, the attached report concludes that the current approach of restricting the bylaws to the areas where the risks are greatest has worked well from the Council's perspective. It involves the Council applying resources where the risks are greatest with MNZ assuming the role in the other areas.

26. While extending Council bylaws to all waters could simplify who controls navigation and safety in Taranaki waters, this would be taking on the statutory responsibilities and obligations currently exercised in the region by MNZ. It would also come at a resourcing cost that the Council has not contemplated in its Long Term Plan. Furthermore, there is not the same level of pressure or risk elsewhere in the region requiring a tailor-made bylaw as has been necessary in the Port.

27. The attached report (and a recommendation in this item) therefore recommends that the Council maintain the status quo in that the extent or geographical coverage of the bylaws should target Port Taranaki and its approaches only.

28. Notwithstanding that, this review has identified some emerging navigational issues occurring on the outer reaches of the harbour limits with the larger number of commercial vessels coming into Port Taranaki but requiring anchorage until access to the Port is granted. In particular, there is potential in this area for vessels to drag anchors or run aground in poor conditions. It is therefore recommended that the spatial extent of Port Taranaki and the approaches be extended to cover this area.

Where to from here

29. If Members agree, officers will work with the Port Taranaki Harbourmaster to immediately review and begin to update revised Port Taranaki Navigation Bylaws.

30. As appropriate, and as part of the drafting of the revised bylaws, Council officers will liaise and undertake initial informal discussions with key stakeholders, primarily, Port Taranaki Ltd, Maritime New Zealand and New Plymouth District Council but also potentially including other commercial and recreational user groups of Port Taranaki and its Approaches where applicable.
31. Around mid-2020, Members can expect to receive a final draft for their consideration prior to commencing formal consultation as required under the special consultative procedure of the LGA.
32. Pursuant to section 157 of the LGA, the revised bylaws will then be publicly notify and submissions called for. If submissions are received that cannot be resolved then these will be considered in a hearing by the Council or a Committee.

Decision-making considerations

33. Part 6 (Planning, decision-making and accountability) of the *Local Government Act 2002* has been considered and documented in the preparation of this agenda item. The recommendations made in this item comply with the decision-making obligations of the *Act*.

Financial considerations—LTP/Annual Plan

34. This memorandum and the associated recommendations are consistent with the Council's adopted Long-Term Plan and estimates. Any financial information included in this memorandum has been prepared in accordance with generally accepted accounting practice.

Policy considerations

35. This memorandum and the associated recommendations are consistent with the policy documents and positions adopted by this Council under various legislative frameworks including, but not restricted to, the *Local Government Act 2002*, the *Resource Management Act 1991* and the *Local Government Official Information and Meetings Act 1987*.

Iwi considerations

36. This memorandum and the associated recommendations are consistent with the Council's policy for the development of Māori capacity to contribute to decision-making processes (schedule 10 of the *Local Government Act 2002*) as outlined in the adopted long-term plan and/or annual plan. Similarly, iwi involvement in adopted work programmes has been recognised in the preparation of this memorandum.

Legal considerations

37. This memorandum and the associated recommendations comply with the appropriate statutory requirements imposed upon the Council.

Appendices/Attachments

Document 2359340: Draft Project brief for the review of the Navigation Bylaws for Port Taranaki and its Approaches.

Document 2396466: Review of navigational responsibilities for Taranaki 2019/2020

Project Concept Brief: (Review of the Navigation Bylaws for Port Taranaki and its Approaches)

Project Description

To review the *Navigation Bylaws for Port Taranaki and its Approaches 2009* (Port Taranaki Navigation Bylaws).

The review will identify and incorporate changes to the Port Taranaki Bylaws in order to better recognise and provide for the activities taking place at Port Taranaki and its approaches.

The project will follow the process for bylaw reviews set out in the *Local Government Act 2002* (the Act). The review will determine whether the bylaws should be amended, revoked, revoked and replaced or whether they should continue without amendment.

The project will follow the consultation requirements of the *Local Government Act 2002* (section 156) when making, amending or revoking the Navigation Bylaws for Port Taranaki and its Approaches.

Reason(s) for the Project

The *Local Government Act 2002*, requires review of bylaws every ten years.

The last review of the Navigation Bylaws for Port Taranaki and its Approaches occurred in in 2009. A review is now due in accordance with the Act.

Benefits

Review of the Navigation Bylaws for Port Taranaki and its Approaches will have the following benefits:

- ensure that the bylaws are fit for the current uses and take into account any changes in use over the last ten years;
- ensure that the bylaws are consistent with changes to legislation;
- ensure marine/maritime safety requirements are adequate for users of the Port and its approaches; and
- provide opportunity for national alignment where appropriate.

Key Dates

Forecast Start Date: 31/10/2019

Forecast End Date: 30/06/2020

Resources

People: C Spurdle, F McLay, B Pope, T Parr, G Marcroft, GIS, K Mischefski, C Musgrave (Harbour Warden).

In Scope

- Port Taranaki and its approaches
- Local Government Act 2002
- Maritime Transport Act 1994
- New Zealand Bill of Rights Act 1990
- Navigation bylaws across New Zealand (Appendix 2)
- New Zealand Port and Harbour Marine Safety Code
- Maritime Rules

Out of Scope

- Navigation bylaws outside New Zealand

- Health and Safety
- TRC Coastal Plan

Project Method

Set out below are the key stages and methodology of the review.

1. Review the extent of the bylaws and scope of review by undertaking a review of use and risk in Taranaki waters by considering:
   - the level of pressure and risk;
   - current rules for inland waters;
   - jurisdiction and responsibility of MNZ; and
   - approach adopted by other councils.

   Report to be attached to Agenda memorandum for the Policy and Planning Committee.

2. In consultation with the Port Taranaki Harbour Master, undertake a desktop study to:
   - review and analyse Port Navigation bylaws across New Zealand and compare against current Port Taranaki Navigation Bylaws;
   - determine if current Port Taranaki Navigation Bylaws meet current legislative and regulatory requirements;
   - determine if the current Port Taranaki Navigation Bylaws are operationally;
   - determine if the current Port Taranaki Navigation Bylaws meet sector health and safety expectations/requirements; and
   - identify whether the current Port Taranaki Navigation Bylaws remain relevant, efficient and effective under the *Local Government Act 2002* section 155.

   As appropriate identify potential amendments.

3. In liaison with the wider project team, draft updated and revised Port Taranaki Navigation Bylaws to incorporate any amendments identified in stage 2 plus any other amendments necessary to meet requirements of section 155 of the Local Government Act 2002 and the Maritime Transport Act 1994.

4. In conjunction with stage 3, undertake initial informal discussions with key stakeholders, primarily, Port Taranaki Ltd, Maritime New Zealand and New Plymouth District Council but also potentially including other commercial and recreational user groups of Port Taranaki and its Approaches where applicable.

5. Undertake consultation as required under the special consultative procedure of the *Local Government Act 2002* sections 156 and 82 where applicable.

6. Publicly notify the bylaws in accordance with the *Local Government Act 2002* sections 157.

7. If submissions are received that cannot be resolved then these will be considered by the Policy and Planning Committee.

Note: Relevant sections of the *Local Government Act 2002*, relating to review of the bylaw, are appended to this document (Appendix 1).

Approval:

The following indicates that approval has been obtained for the project concept:

Project Owner ______________________________

Project Owner

Date ______________________________

Document number: 2359340

Appendix 1 - Relevant sections of the Local Government Act 2002

155 Determination whether bylaw [made under this Act] is appropriate

(1AA) This section applies to a bylaw only if it is made under this Act or the Maritime Transport Act 1994.

(1) A local authority must, before commencing the process for making a bylaw, determine whether a bylaw is the most appropriate way of addressing the perceived problem.

(2) If a local authority has determined that a bylaw is the most appropriate way of addressing the perceived problem, it must, before making the bylaw, determine whether the proposed bylaw—

(a) is the most appropriate form of bylaw; and

(b) gives rise to any implications under the New Zealand Bill of Rights Act 1990.

(3) No bylaw may be made which is inconsistent with the New Zealand Bill of Rights Act 1990, notwithstanding section 4 of that Act.

156 Consultation requirements when making, amending, or revoking bylaws made under this Act

(1) When making a bylaw under this Act or amending or revoking a bylaw made under this Act, a local authority must—

(a) use the special consultative procedure (as modified by section 86) if—

(i) the bylaw concerns a matter identified in the local authority's policy under section 76AA as being of significant interest to the public; or

(ii) the local authority considers that there is, or is likely to be, a significant impact on the public due to the proposed bylaw or changes to, or revocation of, the bylaw; and

(b) in any case in which paragraph (a) does not apply, consult in a manner that gives effect to the requirements of section 82.

(2) Despite subsection (1), a local authority may, by resolution publicly notified,—

(a) make minor changes to, or correct errors in, a bylaw, but only if the changes or corrections do not affect—

(i) an existing right, interest, title, immunity, or duty of any person to whom the bylaw applies; or

(ii) an existing status or capacity of any person to whom the bylaw applies:

(b) convert an imperial weight or measure specified in a bylaw into its metric equivalent or near metric equivalent.

157 Public notice of bylaws and availability of copies

(1) As soon as practicable after a bylaw is made, the local authority must give public notice of the making of the bylaw, stating—

(a) the date on which the bylaw will come into operation; and

(b) that copies of the bylaw may be inspected and obtained at the office of the local authority on payment of a specified amount.

(2) A local authority must—

(a) keep copies of all its bylaws at the office of the local authority; and

(b) make its bylaws available for public inspection, without fee, at reasonable hours at the office of the authority; and

(c) supply to any person, on request and on payment of a reasonable charge, a copy of any of its bylaws.

158 Review of bylaws made under this Act or the Local Government Act 1974

(1) A local authority must review a bylaw made by it under this Act or the Maritime Transport Act 1994 (other than a bylaw deemed to be made under this Act by section 293) no later than 5 years after the date on which the bylaw was made.

(2) A local authority must review a bylaw made by it under the Local Government Act 1974 (other than a bylaw deemed to be made under this Act by section 293)—

(a) no later than 1 July 2008, if the bylaw was made before 1 July 2003; and

(b) no later than 5 years after the bylaw was made, if the bylaw was made after 1 July 2003.**]**

159 Further reviews of bylaws every 10 years

A local authority must review a bylaw made by it under this Act, the Maritime Transport Act 1994, or the Local Government Act 1974 no later than 10 years after it was last reviewed as required by section 158 or this section.

160 Procedure for and nature of review

(1) A local authority must review a bylaw to which section 158 or 159 applies by making the determinations required by section 155.

(2) For the purposes of subsection (1), section 155 applies with all necessary modifications.

(3) If, after the review, the local authority considers that the bylaw—

(a) should be amended, revoked, or revoked and replaced, it must act under section 156:

(b) should continue without amendment, it must—

(i) consult on the proposal using the special consultative procedure if—

(A) the bylaw concerns a matter identified in the local authority's policy under section 76AA as being of significant interest to the public; or

(B) the local authority considers that there is, or is likely to be, a significant impact on the public due to the proposed continuation of the bylaw; and

(ii) in any other case, consult on the proposed continuation of the bylaw in a manner that gives effect to the requirements of section 82.

(4) For the purpose of the consultation required under subsection (3)(b), the local authority must make available—

(a) a copy of the bylaw to be continued; and

(b) the reasons for the proposal; and

(c) a report of any relevant determinations by the local authority under section 155.

(5) This section does not apply to any bylaw to which section 10AA of the Dog Control Act 1996 applies.

76AA Significance and engagement policy

(1) Every local authority must adopt a policy setting out—

(a) that local authority's general approach to determining the significance of proposals and decisions in relation to issues, assets, and other matters; and

(b) any criteria or procedures that are to be used by the local authority in assessing the extent to which issues, proposals, assets, decisions, or activities are significant or may have significant consequences; and

(c) how the local authority will respond to community preferences about engagement on decisions relating to specific issues, assets, or other matters, including the form of consultation that may be desirable; and

(d) how the local authority will engage with communities on other matters.

(2) The purpose of the policy is—

(a) to enable the local authority and its communities to identify the degree of significance attached to particular issues, proposals, assets, decisions, and activities; and

(b) to provide clarity about how and when communities can expect to be engaged in decisions about different issues, assets, or other matters; and

(c) to inform the local authority from the beginning of a decision-making process about—

(i) the extent of any public engagement that is expected before a particular decision is made; and

(ii) the form or type of engagement required.

(3) The policy adopted under subsection (1) must list the assets considered by the local authority to be strategic assets.

(4) A policy adopted under subsection (1) may be amended from time to time.

(5) When adopting or amending a policy under this section, the local authority must consult in accordance with section 82 unless it considers on reasonable grounds that it has sufficient information about community interests and preferences to enable the purpose of the policy to be achieved.

(6) To avoid doubt, section 80 applies when a local authority deviates from this policy.

82 Principles of consultation

(1) Consultation that a local authority undertakes in relation to any decision or other matter must be undertaken, subject to subsections (3) to (5), in accordance with the following principles:

(a) that persons who will or may be affected by, or have an interest in, the decision or matter should be provided by the local authority with reasonable access to relevant information in a manner and format that is appropriate to the preferences and needs of those persons:

(b) that persons who will or may be affected by, or have an interest in, the decision or matter should be encouraged by the local authority to present their views to the local authority:

(c) that persons who are invited or encouraged to present their views to the local authority should be given clear information by the local authority concerning the purpose of the consultation and the scope of the decisions to be taken following the consideration of views presented:

(d) that persons who wish to have their views on the decision or matter considered by the local authority should be provided by the local authority with a reasonable opportunity to present those views to the local authority in a manner and format that is appropriate to the preferences and needs of those persons:

(e) that the views presented to the local authority should be received by the local authority with an open mind and should be given by the local authority, in making a decision, due consideration:

(f) that persons who present views to the local authority should have access to a clear record or description of relevant decisions made by the local authority and explanatory material relating to the decisions, which may include, for example, reports relating to the matter that were considered before the decisions were made.

(2) A local authority must ensure that it has in place processes for consulting with Maori in accordance with subsection (1).

(3) The principles set out in subsection (1) are, subject to subsections (4) and (5), to be observed by a local authority in such manner as the local authority considers, in its discretion, to be appropriate in any particular instance.

(4) A local authority must, in exercising its discretion under subsection (3), have regard to—

(a) the requirements of section 78; and

(b) the extent to which the current views and preferences of persons who will or may be affected by, or have an interest in, the decision or matter are known to the local authority; and

(c) the nature and significance of the decision or matter, including its likely impact from the perspective of the persons who will or may be affected by, or have an interest in, the decision or matter; and

(d) the provisions of Part 1 of the Local Government Official Information and Meetings Act 1987 (which Part, among other things, sets out the circumstances in which there is good reason for withholding local authority information); and

(e) the costs and benefits of any consultation process or procedure.

(5) Where a local authority is authorised or required by this Act or any other enactment to undertake consultation in relation to any decision or matter and the procedure in respect of that consultation is prescribed by this Act or any other enactment, such of the provisions of the principles set out in subsection (1) as are inconsistent with specific requirements of the procedure so prescribed are not to be observed by the local authority in respect of that consultation.

83 Special consultative procedure

(1) Where this Act or any other enactment requires a local authority to use or adopt the special consultative procedure, that local authority must—

(a) prepare and adopt—

(i) a statement of proposal; and

(ii) if the local authority considers on reasonable grounds that it is necessary to enable public understanding of the proposal, a summary of the information contained in the statement of proposal (which summary must comply with section 83AA); and

(b) ensure that the following is publicly available:

(i) the statement of proposal; and

(ii) a description of how the local authority will provide persons interested in the proposal with an opportunity to present their views to the local authority in accordance with section 82(1)(d); and

(iii) a statement of the period within which views on the proposal may be provided to the local authority (the period being not less than 1 month from the date the statement is issued); and

(c) make the summary of the information contained in the statement of proposal prepared in accordance with paragraph (a)(ii) (or the statement of proposal, if a summary is not prepared) as widely available as is reasonably practicable as a basis for consultation; and

(d) provide an opportunity for persons to present their views to the local authority in a manner that enables spoken (or New Zealand sign language) interaction between the person and the local authority, or any representatives to whom an appropriate delegation has been made in accordance with Schedule 7; and

(e) ensure that any person who wishes to present his or her views to the local authority or its representatives as described in paragraph (d)—

(i) is given a reasonable opportunity to do so; and

(ii) is informed about how and when he or she may take up that opportunity.

(2) For the purpose of, but without limiting, subsection (1)(d), a local authority may allow any person to present his or her views to the local authority by way of audio link or audiovisual link.

(3) This section does not prevent a local authority from requesting or considering, before making a decision, comment or advice from an officer of the local authority or any other person in respect of the proposal or any views on the proposal, or both.

83AA Summary of information

A summary of the information contained in a statement of proposal must—

(a) be a fair representation of the major matters in the statement of proposal; and

(b) be in a form determined by the local authority; and

(c) indicate where the statement of proposal is available; and

(d) state the period within which persons interested in the proposal may present their views to the local authority.

86 Use of special consultative procedure in relation to making, amending, or revoking bylaws

(1) This section applies if, in accordance with section 156(1)(a), the special consultative procedure is required to be used in relation to the making, amending, or revoking of a bylaw.

(2) The statement of proposal referred to in section 83(1)(a) must include,—

(a) as the case may be,—

(i) a draft of the bylaw as proposed to be made or amended; or

(ii) a statement that the bylaw is to be revoked; and

(b) the reasons for the proposal; and

(c) a report on any relevant determinations by the local authority under section 155.

Appendix 2 – Other Council navigation Bylaws

Council	Year	Extent	URL
Northland Regional Council	2017	All CMA but not inland waters	https://www.nrc.govt.nz/media/11058/navigationsafetybylaw2017finalweb.pdf
Auckland Regional Council	2014	All navigable waters (including inland lakes)	https://www.aucklandcouncil.govt.nz/plans-projects-policies-reports-bylaws/bylaws/Documents/navsafetybylawcontrols2014.pdf
Environment Waikato	2013	All navigable waters (excluding Lake Taupō)	http://www.waikatoregion.govt.nz/assets/WRC/Services/regional-services/maritime-services/Nav-Safety-2013-bylaw-web.pdf
Gisborne District	2012	Bylaws only cover specific areas – Poverty Bay, Tolaga Bay and Tatapouri channel.	http://www.gdc.govt.nz/bylaws/
Bay of Plenty Regional Council	2017	All waters (including inland lakes)	https://cdn.boprc.govt.nz/media/651889/navigation-safety-bylaw-book-2017-web-final.pdf
Hawkes Bay	2018	All waters (excluding Lake Waikaremoana and Lake Waikareiti)	https://www.hbrc.govt.nz/assets/Document-Library/Plans/NavSafetyBylaws2018-Interactive.pdf
Taranaki	2009	Bylaws only cover Port Taranaki and its approaches	https://www.trc.govt.nz/assets/Documents/Environment/Coast/navigation-bylaws-port-taranaki-09.pdf
Wellington	2009	All waters	http://www.gw.govt.nz/assets/Our-Environment/Harbours/Bylaws-A4-format-for-website-with-contents2011.pdf
Horizons	2010	Bylaws only cover the Manawatu River and tributaries	https://www.horizons.govt.nz/CMSPages/GetFile.aspx?guid=ba94446a-d8d3-4be0-afa4-5ac1d0840d0c
Marlborough	2017 (proposed)	Bylaws only cover the harbour limits – including all the sounds	https://www.marlborough.govt.nz/repository/libraries/id:1w1mps0ir17q9sgxanf9/hierarchy/Documents/Your%20Council/Proposed%20Navigation%20Bylaw%20List/2_Proposed_Navigation_Bylaw_2017.pdf
Buller District	2008	Westport Harbour and Westport Bar	http://bullerdc.govt.nz/wp-content/uploads/2013/09/Navigation-and-Safety.pdf
Canterbury Regional Council	2016	All navigable waters (including inland lakes)	https://www.ecan.govt.nz/do-it-online/harbourmasters-office/recreational-boating/
Otago	2019	All navigable waters (excluding navigable waters in the Queenstown Lakes District Council area, Lake Dunstan and Kawarau River)	https://www.orc.govt.nz/media/6781/orc-navigational-safety-bylaw_2019-05-09_forweb.pdf
Southland	2015	All navigable waters (including inland lakes)	https://www.es.govt.nz/repository/libraries/id:26gi9ayo517q9stt81sd/hierarchy/about-us/plans-and-strategies/bylaws/navigation%20safety%20bylaws/documents/navigation_safety_bylaws.pdf

Memorandum

To	B G Chamberlain, Chief Executive
	Fred McLay, Director - Resource Management
From	Chris Spurdle, Planning Manager
	Grace Marcroft, Policy Analyst
Document	2396466
Date	31 January 2020

Review of navigational responsibilities for Taranaki 2019/2020

Purpose

The purpose of this memorandum is to review the jurisdictional scope and spatial coverage of the *Navigation Bylaws for Port Taranaki and its Approaches 2009* as part of the review of those bylaws.

Recommendation(s)

That Taranaki Regional Council officers:

1. receives this memorandum
2. agrees to retain the *status quo* in terms of retaining bylaws for Port Taranaki and its approaches only
3. agrees that the coverage of the bylaws be amended and widen to address emerging navigational issues occurring on the outer reaches of the harbour limits.

Background

Pursuant to section 160A of the *Local Government Act 2002* (LGA), the Council is required to review bylaws prepared under that Act, the *Maritime Transport Act 1994* (MTA), or the *Local Government Act 1974* every ten years. The *Navigation Bylaws for Port Taranaki and its Approaches* are therefore required to be reviewed this financial year.

As part of that review, Council is considering any changes necessary to promote alignment with the requirements of the MTA, maritime rules and other national regulation; remove controls that are no longer relevant or required; ensure adequate health and safety practices; promote inter-regional consistency in bylaw provisions; and recognise and provide for changing uses and demands in Taranaki. This also includes Council considering the spatial extent of its current bylaws jurisdiction.

Advice from the Crown Law Office sought by Maritime New Zealand (MNZ) in 2004 highlighted that the powers in the *Local Government Act 1974*[1] do not impose an absolute obligation on regional councils to make bylaws in respect of navigation safety in its water or to appoint a harbourmaster or exercise its powers in relation to wrecks.

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[1] *The current bylaw was prepared under the LGA 1974. However, in 2013 that Act relevant provisions were amended with relevant provisions being incorporated into the MTA. Those amendment do not change the findings of the legal opinion.*

However, Crown Law was of the view that in relation to those powers, a regional council has an implied statutory duty to 'consider (and thereby to decide) from time to time whether to make (or to amend etc) bylaws for navigation safety within its region (or to any part of it)'. The review of the bylaws provides the Council the opportunity to do just that.

Section 155 of the LGA also requires the Council to determine whether a bylaw is the most appropriate way of addressing a perceived problem.

Accordingly, given the Council is progressing a review of its navigation and safety bylaws, it is timely to undertake a review of the spatial extent of its bylaws jurisdiction. This is consistent with the approach adopted in previous bylaw reviews (carried out in 2009).

This memorandum examines whether it is appropriate to retain bylaws for Port Taranaki harbour limits only (but allowing for changes to existing boundaries if appropriate), extend bylaws to the coastal waters, or extend the bylaws to both coastal and inland waters.

The options for the scope of the review are presented in Figures 1 to 3 with the green shaded area representing the spatial extent of the bylaw jurisdiction. The options are as follows:

- ***Status quo***: Spatial extent and geographical coverage of the bylaws to be confined to Port Taranaki and its approaches (Figure 1).
- **Coastal waters:** Spatial extent and geographical coverage of the bylaws is extended to include all Taranaki coastal waters out to 12 nautical miles (Figure 2).
- **All Taranaki coastal and fresh waters:** Spatial extent and geographical coverage of the bylaws is extended to include all Taranaki coastal waters out to 12 nautical miles plus all inland waters (Figure 3 overleaf).

In relation to the aforementioned options, and to inform discussions in relation to the preferred option, this memorandum examines:

- jurisdiction and statutory responsibilities of parties for navigation safety (i.e. who should do it);

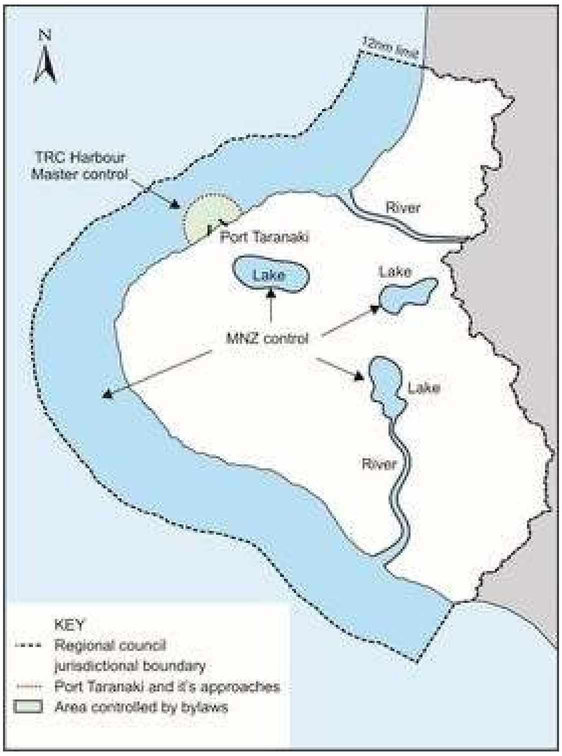

Figure 1: Status quo

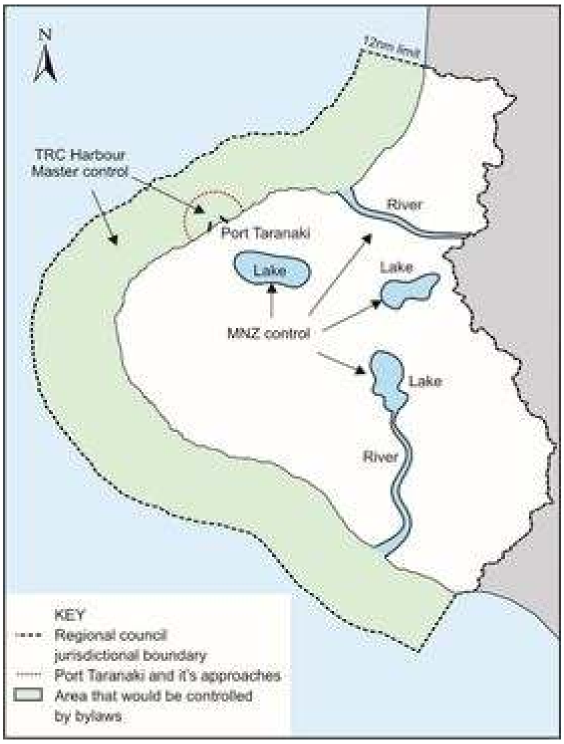

Figure 2: Coastal waters option

- the level of pressure and risk;
- current rules for inland waters; and
- approaches adopted by other Councils.

Refer to the discussion below.

Jurisdiction and responsibilities

A number of agencies have potential statutory roles and responsibilities for navigation safety. However, MNZ is identified as having the main statutory responsibility for ensuring navigational responsibilities, while the Council and territorial authorities have optional statutory responsibilities (should they choose).

Outlined below is a summary of the mandated roles of MNZ, the Council and territorial authorities explaining their functions listed in legislation or from the programmes that they implement.

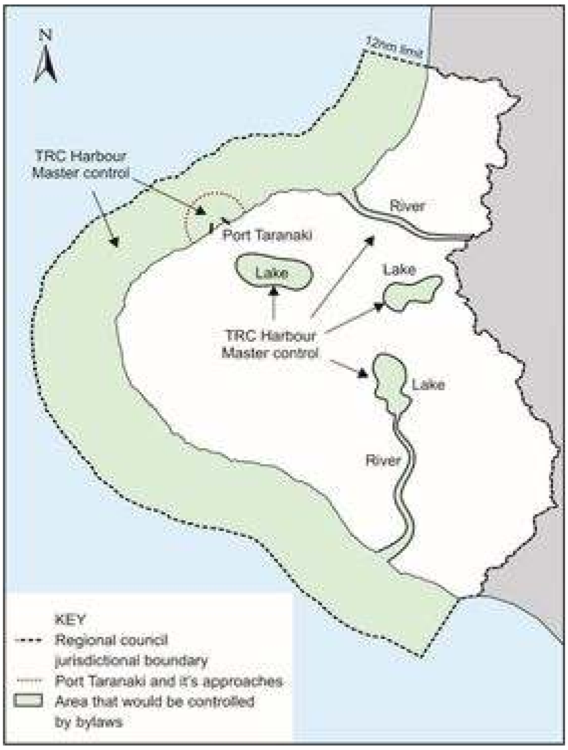

Figure 3: All Taranaki waters option

Maritime New Zealand (MNZ)

MNZ has explicit functions and responsibilities for navigation and safety under the MTA. Pursuant to section 430 of the MTA, the principal objective of MNZ is to "…*undertake its safety, security, marine protection, and other functions in a way that contributes to the aim of achieving an integrated, safe, responsive, and sustainable transport system*".

Under section 431 of that Act, MNZ has the following functions:

(a) to promote maritime safety and security, and protection of the marine environment in New Zealand;

(b) to promote maritime safety and security, and protection of the marine environment beyond New Zealand in accordance with New Zealand's international obligations;

(c) to ensure the provision of appropriate distress and safety radio communication systems and navigational aids for shipping;

(d) to ensure New Zealand's preparedness for, and ability to respond to, marine oil pollution spills;

(e) to license ships, their operation, and their crews;

(f) to investigate and review maritime transport accidents and incidents [and maritime security breaches and incidents;

(g) to maintain the New Zealand Register of Ships;

(h) to maintain and preserve records and documents relating to the Authority's functions;

(i) to advise the Minister on technical maritime safety policy; and

(j) to perform such other functions as are conferred on it by this Act or any other Act.

MNZ is also responsible for the management of all navigational aids on or near the coasts of New Zealand and the adjacent seas and islands.

MNZ administers and enforces the Maritime Rules. *Maritime Rule Part 91 'Navigation Safety Rules'* is of particular import and came into force on 21 March 2003, replacing the *Water Recreation Regulations 1974*. These rules set out detailed operating requirements for a wide range of vessels, recreational and pleasure craft used in navigation. The rules make it compulsory for personal flotation devices to be carried on board all recreational craft, and for them to be worn at times of heightened risk. They also set out the age for operating power driven vessels, and rules relating to speed, water skiing, access lanes, anchoring and distances to keep from vessels displaying either 'danger' flags or 'diver below' flags.

These rules apply to all New Zealand waters, including inland waters and the territorial sea. Although Part 91 sets out operating requirements for all New Zealand waters, the Rules themselves provide for regional council bylaws to identify and mark reserved areas for particular activities, define and mark access lanes and uplift speed restrictions set out in Part 91.
Other Maritime Rules include *Part 22 – Collusion Prevention* which sets out rules relating to steering and sailing, visibility, give way rules, sound and light signals etc.

Regional councils

For the purpose of ensuring maritime safety in their regions, regional councils may regulate the ports, harbours, and waters in their regions, and maritime-related activities in their regions pursuant to section 33C of the MTA.

Section 33M(1) of the MTA specifies that a regional council may, in consultation with the Director of MNZ, make bylaws under the Act to do all or any of the following things in relation to waters within its region:

(a) regulate and control the use and management of ships;

(b) regulate the placing and maintenance of moorings and maritime facilities;

(c) prevent nuisances arising from the use of ships and seaplanes;

(d) prevent nuisances arising from the actions of persons and things on or in the water;

(e) reserve the use of any waters for specified persons, ships, or seaplanes;

(f) in relation to boat races, swimming races, or similar events, prohibit or regulate the use of ships, or regulate, or authorise the organisers of an event to regulate, the admission of persons to specified areas;

(g) regulate and control the use of anchorages;

(h) prescribe ship traffic separation and management schemes;

(i) specify requirements for the carriage and use of personal flotation devices and buoyancy aids on pleasure craft; and

(j) require the marking and identification of personal water craft.

Navigation bylaws made under subsection (1) may not—

- limit or affect the ability of a port company or an operator of a commercial port to manage its operations within areas owned or controlled by it, except to the extent the regional council considers necessary in the interests of maritime safety; or
- be inconsistent with regulations or rules made under the Act, or the *Resource Management Act 1991* (RMA).

The MTA gives regional councils access to powers in relation to navigation safety, but without any mandatory function or duties. When determining which relevant statutory powers to exercise under the MTA (or indeed any decision not to exercise them) a council would look to the purpose and role of local authorities under the LGA. A local authority's role under this Act is to give effect to the purpose of promoting the social, economic, environmental, and cultural well-being of communities of its region and performing duties and exercising rights conferred on it by any statute. Under the Act a council must, in making a decision, seek to identify all reasonably practicable options for achieving the objective of a decision.[2]

District councils

Pursuant to the LGA or RMA, district councils may also have a role to play in navigation and safety. District councils can also include rules relating to the use of boats etc on lakes for reserves they manage. For example, South Taranaki District Council's management plan for Lake Rotokare (2007) includes a policy that limits the use of motor boats and water skiers to certain times of year, in certain places within the lake and sets out operating requirements such as the direction around the lake power boats and water skiers are permitted to travel.

The New Plymouth District Council has a bylaw for public places under the LGA that restricts people from operating a boat within a council reserve (such as Lake Rotomanu) in a way that would endanger the safety of the boat or cause annoyance to anyone else.[3] Neither South Taranaki District, nor Stratford District has bylaws relating to the use of surface water in their bylaws under the LGA. Stratford District Council does not have any navigable waterways aside from the Whanganui River which is not in the Taranaki region.

District councils can also include rules relating to activities on the surface of rivers and lakes in district plans made under the RMA. The only district council in Taranaki to include such rules is South Taranaki District Council in the current District Plan (2004). In their district plan, activities on surface of rivers and lakes are permitted if they meet a number of standards including the following:

- No activity shall be operated and no vessel shall be navigated in a manner that contravenes nominated speed restrictions on any identified water surface. no activity shall be operated and no vessel shall be navigated in a manner that contravenes nominated speed restrictions on any identified water surface;
- no activity shall be operated or be permitted to operate in restricted areas;
- provision of moored accommodation on the surface of rivers and lakes will only be permitted in circumstances where onshore disposal of effluent can be achieved;
- all vessels and craft used on the surface of rivers and lakes shall comply with all relevant national statutes and regulations governing the operation of such vessels and craft.

However, the Proposed District Plan does not include such rules.

Current restrictions

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[2] *Regional councils may appoint harbourmasters and enforcement officers (including honorary enforcement officers) and/or delegate to a port operator any functions, duties, or powers (other than power to make bylaws) relating to navigation safety.*
[3] *Bylaw 2008: Part 5 Public Places was amended and readopted September 2014. Refer* https://www.newplymouthnz.com/Council/Council-Documents/Bylaws.

As noted above, various navigation restrictions on coastal and inland water in Taranaki (Table 1) apply across Taranaki. The default position is that MTA are responsible unless the Council and territorial authorities promulgate their own regulations under either the MTA, LGA or RMA. In Taranaki, this only applies to Port Taranaki and a small number of inland areas. In relation to maritime areas, Council enforces the *Port Taranaki and Approaches Bylaws*. In relation to inland water, two territorial authorities (South Taranaki and New Plymouth districts) have adopted bylaws with provisions addressing navigational safety.

Table 1: Navigational jurisdictional responsibilities across Taranaki

Coastal or inland waters	Jurisdictional responsibility	Discussion
Port Taranaki	Taranaki Regional Council	Pursuant to *Port Taranaki and Approaches Bylaws* under the LGA
Lake Rotakare	South Taranaki District Council	Pursuant to Lake Rotokare Reserve management plan
Lakes and rivers in public reserves	New Plymouth District Council	Pursuant to *Public Places Bylaw* under the LGA
Remaining coastal and inland waters	MNZ	Pursuant to MTA and Rule 91. All coastal and inland waters excluding the aforementioned specified areas

MTA administers and enforces Rule 91. Under Rule 91, no person may propel a vessel at a speed of more than 5 knots within 200 metres of the shore or of any structure. This in effect prohibits any jet boating or jet ski use of any of Taranaki's small lakes or navigable rivers (excluding those listed in Table 2).

Under Rule 91, speed restrictions can be 'uplifted' through either notices that were carried over into the current regulations or on gazette notices, initiated by the community through MNZ. The following table identifies those areas in Taranaki used by jet boats, and where different MNZ speed rules or upliftings apply.

Table 2: MNZ speed rules or upliftings

Coastal or inland waters	MNZ rules or uplifings
Lake Opunake	5 knot restriction within 200 m of shore uplifted by gazette notice in 2005 but only between sunrise and sunset on Sundays, Mondays and Thursdays
Waitara River	Special speed restrictions under the *Water Recreation (Waitara River) Notice 1985* still apply, which seems to allow speeds greater than 5 knots in certain areas. The general agreement is that jet skiers, wake boarders and water skiers occupy the area north of the town bridge upstream to the state highway bridge
Lake Rotorangi	The *Water Recreation (Patea River and Mangaehu Stream) Notice 1980* lifting speed restrictions for the whole Patea River from the sea to the confluence with the Mangaehu Stream, and all the waters of the Mangaehu Stream. However, the notice specifies that no one can travel faster than 5 knots in a manner likely to endanger or unduly annoy any person who is using the water or fishing or undertaking any recreational activity.
Fitzroy beach	The *Water Recreation (Fitzroy/Waiwhakaiho Beach) Notice 1994* establishes an area designated for the use of jet skis, wet bikes or personal water craft.
Tongaporutu River	The *Motor Launch (Tongaporutu River) Notice 1971* is still in force. This establishes a reserve area where there are no speed restrictions for motor launches and water skiers, bathers and fishing are prohibited within the reserve area.

A number of lakes, notably Lake Ratapiko and Rotomanu, are used for jet skiing (thus contravening Rule 91). However, so far, this has not come to the attention of MNZ as warranting attention and New Plymouth District Council's bylaw restricts people from operating a boat in a manner that would cause annoyance in their reserves.

Level of pressure and risk

For the purposes of this review, Council officers consulted with the Taranaki Harbour Master in determining the levels of pressure and risk to public health and safety arising from navigational issues across the region.

The Harbour Master provided advice regarding navigable waters which would be the focus of the assessment. Thirteen sites in total were identified, these sites of interest are displayed in Figure 4 below and include sites popular for water skiing, jet skiing as well as other recreational activities such as fishing, kayaking and swimming as well as sites that include commercial uses. Initial findings from the 2019/2020 recreational use survey of coast, rivers and lakes in Taranaki[4] (in prep) further confirmed the areas considered in this analysis based on usage over the month of December 2019.

'Risk' is a factor of the hazards to navigation minus any mitigation measures in place. Hazards may be natural, such as bar crossings, shallow rocks, tidal or weather factors, or anthropogenic hazards may be cause by submerged structures, levels of use and conflicting types of use. Mitigation of hazards may include signage, speed restrictions, or channel markers.

For the purposes of this review, officers assessed a number of sources to gauge navigation safety risks across Taranaki. These sources included the Harbour Masters records, Port Taranaki Ltd's current hazard profile[5], incident reports from the New Zealand Coastguard[6], consultation with boat clubs, and the findings from the Council's recreation survey for the identified sites[5.] A discussion of navigation safety risks in Taranaki follows.

Within Port Taranaki, navigation safety risks are assessed as high.

Port Taranaki Ltd provided the Council with their Risk Profiles, including incidents logged since 2016. The data supported the Council's previous assessment (last undertaken in 2009) that the major hazards result from the direct activities of the Port and its proximity to popular recreational areas such as Ngamotu Beach. The Risk Profiles identified a small but regularly occurring number of incidents of recreational use within restricted areas of the Port and recreational users not abiding by MNZ rules regarding giving way to larger vessels.

The Risk Profiles also highlighted that Port operations may also produce hazards inside the Port, particularly during the loading and unloading of cargo with potential for pollution from hazardous cargo or producing obstructions to navigation with the accidental spillage of logs or other objects into the port area.

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[4] FRODO #2363355 Recreational Use Survey of Coast, Rivers and Lakes in Taranaki 2019 – methodology for observational counts – results in prep.
[5] FRODO #2412154 Port Taranaki Ltd incidents data
[6] FRODO #2409006 Coastguard statistics 2016 - 2019

Figure 4: Locations of sites for the assessment of navigational pressures and risks in the Taranaki region.

Outside the Port, the Risk Profiles highlighted an emerging issue. Port operations, or activities associated with the Port, may also represent a risk in the navigational approaches to the Port. To avoid congestion of vessels in Port Taranaki, it is common for vessels to be temporarily anchored in an area from Port Taranaki from 3 to 5 nautical miles off the coast (referred to in the remainder of this report as the 'Port Taranaki anchorage area' or 'PTL anchorage') until wharf space becomes available. Several vessels may use the Port Taranaki anchorage area at any one time. Anchorage at this location has been utilized by shipping due to its proximity to the Port, water depths and reasonable anchor holding ground; however, risks associated with this activity increase when weather conditions are unfavourable. Recent incidents associated with this anchorage area are:

- MV LAKE TRIVIEW grounding 24 May 2014[7]; and
- MV XING JING HAI anchor dragged in close proximity to Waitara foreshore 26 September 2019.

The coastguard's information from 2016 from Oakura through to Mokau (Table 3) identified that recreational boat use of the area is high with around 2,500 trips occurring in each year. However, calls for assistance are low with an average of 10 per year.

Table 3: Summary of coastguard's statistics (2016 – 2019) Oakura to Mokau.

	Dec 2019	2019/2020 (Y.T.D)	2018/2019	2017/2018	2016/2017
Radio calls logged	1242	4444	4998	5300	3481
Approximate trips recorded (based on 2 calls to coast guard per trip)	621	2222	2499	2650	1741
Coast Guards - Calls for assistance	0	2	15	8	17

Coastguard statistics reveal that, in comparison with the Port, other coastal and freshwater areas do not have high volumes of traffic. There is no other requirement for commercial and recreational vessels to co-exist in a confined space.

In other coastal and fresh waters, navigational safety risks are assessed as low, the exception being the PTL anchorage area which is considered medium. MNZ do not have any records of any incidents. Nevertheless, officers endeavoured to contact boating clubs, the coastguard and undertook a visual survey of navigation risks and mitigation measures on the 17th January. The outcomes of these has been collated in Table 4.

[7] FRODO #1560535 Vessel monitoring report

Table 4: High level assessment of navigation risks in Taranaki

Coastal or inland waters	Navigation and safety hazards	Level of risk and mitigation measures	Assessment (relative risk)
Tongaporutu Estuary	Estuary generally too shallow for safe boating but is used over the summer months.	Non-motorised boats in general use	Low
Waitara Estuary	Bar is a hazard but deeper water than Urenui estuary. Standing waves and naturally occurring flotsam and jetsam may occur during floods events but generally not at a time the area is in use. Issues with submerged logs. Some reported conflicting uses with swimmers and kayakers around jet boats and other vessels not abiding to speed restrictions.	High recreational use and some commercial (one off seismic vessel use). Signage at boat ramp which includes navigation zones within Waitara River and Estuary and safety zones around and entering the Pohokura Platform B and 500m either side of the subsea pipeline from Pohokura Platform B to shore. Local boat clubs aware of navigation hazards.	Medium-Low
Anchorage off Port Taranaki	North Taranaki bight used by commercial vessels entering Port Taranaki but requiring anchorage until access to Port is granted. Has experienced more frequent use over 10 years. Potential for vessels to drag anchor or run aground in poor conditions or in the event of mechanical failure.	Activity is overseen by PTL who offer anchorage advice on request from a ship's Master. This advice does not have to be complied with.	Medium
Port Taranaki	High number of commercial and recreational vessels co-existing in confined space. Hazardous cargos and pollution potential and risk to people if major incidents occur. High number of users of Ngamotu Beach for recreation and organized events.	Taranaki is only commercial port (1,200 vessel movements/year) and has highest recreational use (est. 4,000 vessel movements/year and about 30 times next highest area). Area covered by Part 90 and Council's bylaws. Aids to Navigation and PTL pilotage SOPs and direction in place. Harbour Master monitors and administers both commercial and recreational use of the port and approaches.	Highest navigation safety risk
Cape Egmont Beach	Only a 'calm' sea berth. Submerged rocks a hazard.	Good boat ramp. Channel markers leading in to the boat ramp provide navigational aid for vessels entering and leaving. Local Coastguard active for registering trip reports (VHF Ch62). Local boat clubs aware of navigation hazards.	Low
Opunake Beach	Large breaking waves and submerged rocks.	Limited local use and very weather dependent. Access to boat ramp may prove difficult for some vehicles. Narrow boat ramp. Breakwater provides shelter directly at the boat ramp. No signage.	Low
Ohawe Beach	Large breaking waves and moving sand.	Limited local use and very weather dependent. Submerged rocks have been cleared in one area to provide safe access channel. Beach access only (no boat ramp). Signage indicates submarine cable and pipeline protection zone for Kupe Pipeline. Coastguard number openly displayed and trip logging encouraged.	Low

Coastal or inland waters	Navigation and safety hazards	Level of risk and mitigation measures	Assessment (relative risk)
Patea Estuary	Bar and river training structures the major hazards.	Mainly recreational use with a number of boats overturned. Good signage and boat ramp. Signage shows Navigation Zones, Maritime Rules. Coastguard number openly displayed and trip logging encouraged. Local boat clubs aware of navigation hazards.	Low
Lake Opunake	Small hydro lake used locally for water skiing and jet skiing. Users have limited space at times. Lake can silt up at head waters.	Generally local community use who are aware of hazards. Access by boat ramp. No signage.	Low (MNZ restrictions on use of lake to allow jet and water skiers to coexist)
Lake Rotorangi	Long sinuous hydro lake accessed at three locations (road/boat ramp). Submerged stumps and logs maybe a hazard for boating.	High recreational use in summer and holidays. Signage shows maritime safety rules, boat safety check, and hazards. Local users aware of hazards.	Low
Lake Rotokare	Small lake in scenic reserve.	Recreational use only during open season (Dec 1st – April 30th). Limited to four powered vessels on the lake at one time and rules on direction and proximity with other vessels.	Low
Lake Ratapiko	21 hectare hydro reserve for the Motukawa Power station. Depth around 2.5 m. Limited space for users, potential for collision.	Jet skiing most popular use. Good access boat ramp. Only open on select dates (gates closed other days).	Low
Lake Rotomanu	Small artificial lake used mainly by water skiers and surrounded by NPDC reserve. Main hazard potential for collision.	Signage in place.	Low

Approach adopted by other regional councils

For the purposes of this review, officers also did a desktop study to examine the approach taken by other councils in relation to the scope and spatial extent of their navigation bylaws. Table 4 provides a summary of that review and sets out the spatial extent adopted by regional councils for their navigation and safety bylaws:

Table 5: Comparison with other regional councils – Extent of navigation and safety bylaws

Regional council	Extent of navigation and safety bylaws
Northland	Bylaws cover coastal waters but not fresh waters
Auckland	Bylaws cover coastal and fresh waters
Waikato	Bylaws cover coastal and fresh waters (excluding Lake Taupo)
Gisborne	Bylaws cover specific areas – Poverty Bay, Tolaga Bay and Tatapouri channel.
Bay of Plenty	Bylaws cover coastal and fresh waters
Hawkes Bay	Bylaws cover coastal waters and several rivers (but not Lake Waikaremoana or Lake Waikareiti)

Regional council	Extent of navigation and safety bylaws
Taranaki	Bylaws cover specific areas – Port Taranaki and its approaches
Wellington	Bylaws cover coastal and fresh waters
Horizons	Bylaws cover specific areas – Manawatu River and tributaries
Marlborough	Bylaws cover specific areas – harbour limits and the sounds
Nelson	Bylaws cover coastal and fresh waters
Tasman	Bylaws cover coastal and fresh waters
West Coast	No navigation or safety bylaws
Canterbury	Bylaws cover coastal and fresh waters
Otago	Bylaws cover coastal and fresh waters (excluding navigable waters in the Queenstown Lakes District Council area, Lake Dunstan and Kawarau River)
Southland	Bylaws cover coastal and fresh waters

Table 5 demonstrates that councils have 'tailored' a number of approaches in relation to adopting navigation and safety responsibilities in their bylaws. Presumably this reflects local issues and risks experienced in their region. Seven (out of 16) councils have applied navigation and safety bylaws to cover all navigable waters (coastal and fresh water) in their region. Other approaches range from focusing on all navigable water with some exceptions, to targeting specific areas only, to having no bylaws at all. Of note, regions where there are lower recreational pressures on navigable waters (including, Taranaki, Horizons and Otago) generally targeted their bylaws to specific areas.[8]

Conclusion – A preferred approach for the Taranaki region

The review of navigation and safety in the region is required as part of the bylaw review process. This report has not identified any change in jurisdictional responsibilities and in the levels of risk factors that warrant a change in navigational responsibilities in Taranaki. In line with previous reviews, officers believe that the current approach of restricting the bylaws to the areas where the risks are greatest has worked well from the Council's perspective. It involves Council applying resources where the risks are greatest with MNZ assuming the role in the other areas.

While extending Council bylaws to all navigable waters could simplify who controls navigation and safety in Taranaki waters, this is not considered appropriate or necessary. First, this would not be appropriate, as it would be taking on the statutory responsibilities and obligations currently exercised in the region by MNZ. It would also come at a resourcing cost that the Council has not contemplated in its Long Term Plan. Second, it is not necessary, as there is not the same level of pressure or risk elsewhere in the region requiring a tailor-made bylaw (as has been necessary for the Port) and associated compliance regime.

[8] *Taranaki has fewer risks and pressures associated with navigation and safety compared to other regions. For example, in the Waikato region there are 100 major lakes, 20 major rivers and 1,150 km of coast. Environment Waikato therefore has seven harbour masters.*

This report therefore recommends largely retaining the *status quo* in terms of the Council having bylaws for Port Taranaki and its approaches only. Bylaws for Port Taranaki and the approaches remain necessary to manage high vessel traffic and the requirement for commercial and recreational vessels to co-exist in a confined space.

However, this report identifies the need to extend the geographical coverage of the bylaws so that they apply from the approaches to the Port and into the North Taranaki Bight, currently outside the coverage of the bylaws. In so doing, the amended bylaws could be applied to manage the need for vessels waiting to enter Port Taranaki to anchor and the associated navigation risks.

Pursuant to the MTA, navigation bylaws may specify the boundaries of any port, harbour, or waters to which the bylaws relate. Where action is necessary in the interests of navigation safety, this Council may reserve specified waters for use, regulate or prohibit the use of those waters by other ships or persons, and regulate admission etc to areas on the occasion of boat races and such events.

This Council may also regulate and control the use of any anchorage, as well as put in place ship traffic separation and management schemes. The spatial extent of the expanded Port Taranaki approaches and other navigation and safety matters will be confirmed through the public consultation process.

MEMORANDUM
Policy & Planning

Taranaki Regional Council

Date 4 February 2020

Subject: Draft National Policy Statement for Indigenous Biodiversity

Approved by: S R Hall, Director – Operations

B G Chamberlain, Chief Executive

Document: 2407804

Purpose

1. The purpose of this memorandum is to introduce for Members' consideration a draft submission on the consultation document for a *National Policy Statement for Indigenous Biodiversity* (NPS-IB).
2. The draft submission is attached to this memorandum.

Executive summary

3. The Government is looking at ways to reverse the decline of indigenous biodiversity in New Zealand.
4. On 25 November 2019, the Government released its consultation document.
5. The consultation document provides information about the proposed new NPS-IB. Through the NPS-IB the Government is seeking to provide clear direction to councils on their responsibilities for identifying, protecting, managing and restoring indigenous biodiversity under the *Resource Management Act 1991* (RMA).
6. If left unchanged, some of the NPS-IB are likely to result in unwarranted cost shifting to councils. Officers, on behalf of the Council, have therefore prepared the attached draft submission.
7. In general, the draft submission is largely supportive of the intent of the draft NPS-IB and many aspects of the document. However, officers are seeking changes to the draft NPS-IB to address a number of issues and concerns with current provisions and/or realise opportunities to improve on the NPS-IB. Key issues identified include:
   - Need for the Government to support the implementation of the NPS-IB by assuming a stronger leadership role that extends beyond just policy development.
   - Requirement to map or describe the location of "ecosystems" identified as taonga could be overly onerous in the absence of comprehensive timely Government

guidance and direction to support the interpretation and application of that part of the NPS-IB.

- NPS-IB requirements to survey and map "highly mobile fauna" should be undertaken by central government to ensure a nationally consistent approach and to give effect to national priorities for maintaining and enhancing indigenous biodiversity, particularly given that Government departments such as the Department of Conservation (DOC) have a stronger mandate and expertise to undertake such work.
- NPS-IB requirements to survey, map and differentiate between high-value and medium-value "Significant Natural Areas" (SNAs) add an unnecessarily complex and subjective element to the management of SNAs with consequential risks of additional legal challenges and costs arising during RMA processes when making those decisions.
- Question the legality, practicalities and policy intent of NPS-IB requirements that councils meet a 10% restoration target for urban vegetation cover and separate indigenous vegetation targets for non-urban areas.
- Note the potential for conflict with other national directions such as the *National Policy Statement for Urban Development* and note that some land uses are treated differently, e.g. forestry.
- Question requirements for mandatory regional biodiversity strategies.
- Seek that the Government better support active management and the implementation of the NPS-IB, including the development of national datasets, available to councils, that map indigenous biodiversity features required by the NPS-IB.

8. Consultation on the NPS-IB closes on 14 March 2020 at 5pm.

Recommendations

That the Taranaki Regional Council:

a) receives this memorandum entitled *Draft National Policy Statement for Indigenous Biodiversity;* and

b) adopts the submission with any changes recommended by the Committee.

Background

9. On 25 November 2019, the Government released the consultation document *He kura koiora i hokia: a discussion document on a proposed National Policy Statement for Indigenous Biodiversity*. The consultation document can be viewed at https://www.mfe.govt.nz/sites/default/files/media/Biodiversity/he-kura-koiora-i-hokia-discussion-document.pdf.

10. The consultation document includes a draft NPS-IB that represents a nationally coordinated response addressing the decline in New Zealand's indigenous biodiversity that threatens the existence of many species and ecosystems. The aim of the NPS-IB is to resolve purported uncertainty and under-valuing of indigenous biodiversity under the RMA. Pursuant to Section 6(c) of the RMA the protection of "…*areas of significant vegetation and habitats of indigenous fauna*" is a matter of national importance that councils

must recognise and provide for when exercising their functions and powers under the Act. Pursuant to sections 30(1)(ga) and section 31(1)(b)(iii) councils have further responsibilities for the maintenance of indigenous biodiversity.

11. Under section 30(1)(ga) of the RMA, regional councils are responsible for the "*…establishment, implementation and review of objectives, policies and methods for maintaining indigenous biological diversity*".

12. Under section 31(1)(b)(iii) of the RMA, district councils are responsible for the "*…the control of any actual or potential effects of the use and development, or protection of land, including for the purpose of … the maintenance of indigenous biological diversity*".

13. The draft NPS-IB seeks a step change in management and protection of indigenous biodiversity. It follows on from the work of The Biodiversity Collaborative Group, a stakeholder-led group funded by the Ministry for the Environment (MfE) to develop national-level policy for indigenous biodiversity in New Zealand. The Group worked to develop a recommended draft national policy statement and reported to the Government in October 2018. As the chair of the Bio-managers Group Mr S Hall, from this Council, participated in the collaborative group.

14. The NPS-IB applies to terrestrial indigenous biodiversity throughout New Zealand, including wetlands. Indigenous biodiversity in the coastal marine area (CMA) and freshwater will continue (with some exceptions) to be managed under the *New Zealand Coastal Policy Statement* (NZCPS) and the *National Policy Statement for Freshwater Management*. It also covers all types of land, including public, private and Maori land.

15. The fundamental framework adopted in the NPS-IB to achieve an integrated and holistic approach to maintaining indigenous biodiversity is Hutia Te Rito. This framework recognises that the health and wellbeing of our terrestrial environment, its ecosystems and unique indigenous vegetation and fauna, is vital for the health and wellbeing of the wider environment and communities. The NPS-IB requires Hutia Te Rito to be "*recognised and provided for*".

16. The NPS-IB also has a strong emphasis on the recognition of tangata whenua as kaitiaki. For example, local authorities must provide opportunities for tangata whenua to be involved in the development of their plans, policies and strategies that give effect to the NPS-IB, and the NPS-IB sets out requirements for identifying and managing taonga species or ecosystems. Most, but not all, NPS-IB requirements fall on territorial authorities.

Key features of the draft NPS-IB

17. A key feature of the draft NPS-IB is that it requires territorial authorities to identify areas with significant vegetation and habitats of indigenous fauna, with a likely contentious requirement being to distinguish between high and medium value Significant Natural Areas (SNAs). The draft NPS-IB sets out principles to follow in the process of identifying SNAs, as well as the ecological criteria for identifying and mapping them. The aim is to make the identification of SNAs more consistent across New Zealand, and the NPS-IB currently proposes an onerous requirement for territorial authorities to review SNA schedules every two years.

18. The effect and costs of implementing the NPS-IB will depend upon the provisions (and wording) ultimately adopted in the final NPS-IB. Significantly, many types of development within or affecting SNAs will be constrained, as the draft NPS-IB requires that such development "*avoid*":

- loss of ecosystem representation and extent;
- disruption to sequences, mosaics or ecosystem function;
- fragmentation or loss of buffering or connectivity within the SNA and between other indigenous habitats and ecosystems; and
- any reduction in population size or occupancy of threatened species using the SNA for any part of their life cycle.

19. The "*effects management hierarchy*" set out in the NPS-IB must be applied to "*other effects*". This hierarchy requires consideration of, in descending order of priority, avoidance, remediation, mitigation, and then offsetting and compensation of residual effects.
20. There are some limited exceptions to the requirement to avoid effects, including exemptions relating to nationally significant infrastructure, Māori land, and development on existing lots within SNAs. In relation to areas used for pastoral farming and plantation forests the NPS-IB has provisions that allow those uses to continue, even if they are within areas that are identified as SNAs. The identification of high and medium value SNAs also allows for different types of activities.
21. Of note the exceptions may not apply in the coastal environment (excluding the CMA which is not covered by the NPS-IB) as the NZCPS will prevail over the NPS-IB in the event of any conflict. Of note, the NZCPS has a stronger 'avoid' requirement in relation to particular types of vegetation and ecosystems. Officers also note some inconsistencies between the NZCPS and NPS-IB in relation to adopted criteria identifying significant indigenous biodiversity.
22. Councils will be required to take steps to maintain indigenous biodiversity outside of SNAs. Specifically, regional policy statements and district plans will be required to:
    - specify where, how and when controls on subdivision, use and development in areas outside SNAs are necessary to maintain indigenous biodiversity; and
    - apply the effects management hierarchy to adverse effects, except that biodiversity compensation may be considered as an alternative to biodiversity offsetting (and not only when biodiversity offsetting is not demonstrably achievable).
23. In some instances, areas that are not identified as SNAs will be required to be assessed to determine if they should be treated as an SNA. This continues an existing approach often applied in planning frameworks, where it is accepted that it is sometimes practically or ecologically not possible to identify every single area of significant vegetation and habitats of indigenous fauna in a district. Where that is the case, effects on those areas are to be managed as it they were SNAs.
24. Significantly, councils will be required to take active steps to increase indigenous vegetation cover to at least 10% in urban areas. Councils will also be required to have more general targets for increasing indigenous vegetation cover across the region.
25. The NPS-IB also contains principles regarding biodiversity offsetting and compensation and requires councils to promote the resilience of indigenous biodiversity to climate change.

The draft submission

26. In brief, the draft submission is supportive of the general intent of the NPS-IB. The draft submission highlights some of the more important programmes and interventions already being implemented by this Council in its efforts to maintain and enhance

indigenous biodiversity in the region and would support further national and local initiatives that complement and build on our efforts.

27. Notwithstanding the above, if left unchanged, some of the NPS-IB are likely to result in significant cost shifting to councils. The draft submission urges the Government to assume a stronger leadership role across the biodiversity systems that extends beyond just policy development but includes meaningful actions and resourcing to support the implementation of the NPS-IB. A summary of key points made in the draft submission is as follows:

   - Question the costs and practicalities of NPS-IB requirements to survey, map and differentiate between high-value and medium-value “Significant Natural Areas” noting the subjectivity of the exercise and the significant risk of legal challenges likely to arise during RMA processes when making those decisions.
   - Support NPS-IB requirements to map or describe the location of indigenous species that are taonga but questions extending that requirement to mapping or describing the location of “ecosystems” identified as taonga. The draft submission notes that if the NPS-IB requirements relating to taonga species and ecosystems remain unchanged, Council seeks comprehensive Government guidance and direction to support the interpretation and application of that part of the NPS-IB.
   - Question the costs and fairness of NPS-IB requirements to survey and map “highly mobile fauna” when arguably Government departments such as DOC have a stronger mandate to do such work and provide the nationally consistent approach sought by the Government.
   - Question the legality, practicalities and policy intent of NPS-IB requirements that councils meet a 10% restoration target for urban vegetation cover and separate indigenous vegetation targets for non-urban areas. Of note the section 30 and 31 functions of the RMA only require councils to maintain (and not enhance) indigenous biodiversity, while the urban restoration target has the potential for conflict with other national directions such as the National Policy Statement for Urban Development.
   - Question requirements for mandatory regional biodiversity strategies.
   - Seek that the Government better support active management and the implementation of the NPS-IB, including the development of national datasets, available to councils, that map indigenous biodiversity features required by the NPS-IB. The submission suggest that such datasets could then be made available to councils for them to be adopted and inserted into their plans as appropriate, e.g. similar in concept to the Government’s Erosion Susceptibility Classification maps released to support the implementation of the *National Environmental Standards for Plantation Forestry*.

28. Of note preparation of the draft submission has been informed by discussions with officers from the three local district councils and, separately, with MfE and DOC officials as part of a regional workshop held on the 28th January.

Where to from here?

29. Consultation on the NPS-IB ends early March 2020 with the Government expected to make their final decisions and gazetting the NPS by mid 2020.

30. Based upon current proposals, by 2023 this Council is required to start producing a biodiversity strategy in collaboration with district councils, tangata whenua, communities and other stakeholders in accordance with Appendix 5 of the NPS-IB.

31. By 2026, district councils must have identified, mapped and notified all SNAs and all regional councils must have a biodiversity strategy that is compliant with the NPS-IB.

32. By 2028, the NPS-IB must be fully implemented.

33. Considerable work for land owners and councils is also expected from the freshwater policy review currently underway by Government. More clarity on this is expected mid-year. Care is needed to ensure there is not excessive workloads on councils and communities arising from the combination of freshwater and biodiversity central government policy initiatives.

Decision-making considerations

34. Part 6 (Planning, decision-making and accountability) of the *Local Government Act 2002* has been considered and documented in the preparation of this agenda item. The recommendations made in this item comply with the decision-making obligations of the *Act*.

Financial considerations—LTP/Annual Plan

35. This memorandum and the associated recommendations are consistent with the Council's adopted Long-Term Plan and estimates. Any financial information included in this memorandum has been prepared in accordance with generally accepted accounting practice.

Policy considerations

36. This memorandum and the associated recommendations are consistent with the policy documents and positions adopted by this Council under various legislative frameworks including, but not restricted to, the *Local Government Act 2002*, the *Resource Management Act 1991* and the *Local Government Official Information and Meetings Act 1987* and *the Biosecurity Act 1993.*

Iwi considerations

37. This memorandum and the associated recommendations are consistent with the Council's policy for the development of Māori capacity to contribute to decision-making processes (schedule 10 of the *Local Government Act 2002*) as outlined in the adopted long-term plan and/or annual plan. Similarly, iwi involvement in adopted work programmes has been recognised in the preparation of this memorandum.

Legal considerations

38. This memorandum and the associated recommendations comply with the appropriate statutory requirements imposed upon the Council.

Appendices/Attachments

Document 2385312: Submission on a proposed National Statement for Indigenous Biodiversity

4 February 2020

Document: 2385312

Ministry for the Environment
PO Box 10362
Wellington 6143

Submission on a proposed National Policy Statement for Indigenous Biodiversity

Introduction

1. The Taranaki Regional Council (the Council) thanks the Ministry for the Environment (MfE) for the opportunity to make a submission on a proposed *National Policy Statement for Indigenous Biodiversity* (NPS-IB).

2. The Council makes this submission in recognition of its:
   - functions and responsibilities for indigenous biodiversity under the *Resource Management Act 1991* (RMA), *Biosecurity Act 1993* (BSA), and *Local Government Act 2002* (LGA);
   - the environmental regulator functions, responsibilities and costs to be incurred by the Council to implement the NPS-IB;
   - regional advocacy responsibilities whereby the Council represents the Taranaki region on matters of regional significance or concern; and
   - experience in implementing regulatory and non-regulatory programmes maintaining and enhancing indigenous biodiversity in the Taranaki region.

3. The Council has also been guided by its Mission Statement '*To work for a thriving and prosperous Taranaki*' across all of its various functions, roles and responsibilities, in making this submission.

4. The Council continues to work closely with district councils in the region in the interests of promoting the maintenance of indigenous biodiversity and has consulted with district councils in the region in making this submission.

Structure of submission

5. In making this submission on the NPS-IB the Council notes it is not starting with a 'blank canvas'. The submission first outlines current programmes and interventions being implemented by Council in its efforts to maintain and enhance indigenous biodiversity in the region.

6. The submission then comments on specific provisions of the NPS-IB that Council supports or where Council is seeking amendment (or the adoption of an alternative approach) as a means to achieve better biodiversity outcomes.

7. First, the submission notes Council support for the Government's objective to maintain and enhance indigenous biodiversity across New Zealand. However, the submission urges that Government assume a stronger leadership role across biodiversity systems that is more than just policy development and a reliance on regulatory interventions.

8. Second, are comments on NPS-IB provisions relating to the identification and management of Significant Natural Areas (SNAs).

9. Third, are comments on clause 3.14 and requirements for regional councils to identify and map or describe the location of taonga species and ecosystems.

10. Fourth, are comments on clause 3.15 and requirements for councils to survey and map "highly mobile fauna" – when arguably Government departments, such as the Department of Conservation (DOC), have a stronger mandate to do such work and provide the nationally consistent approach sought by the Government.

11. Fifth, are comments on the legality, practicalities and policy intent of clause 3.17 and requirements that councils meet a 10% restoration target for urban vegetation cover and separate indigenous vegetation targets for non-urban areas.

12. Sixth, are comments on clause 3.18 around mandatorily requiring regional councils to prepare regional biodiversity strategies under the NPS-IB.

13. Seventh, are general comments advocating for the Government to invest in non-regulatory interventions, including greater investment in active management and the development and maintenance of national datasets that map the indigenous biodiversity required by the NPS-IB.

Taranaki context

14. The Council agrees that urgent action is needed to halt the decline in indigenous biodiversity across New Zealand. Hence, this Council has for the last two decades been implementing significant meaningful intervention programmes that are delivering the biodiversity outcomes sought by the proposed NPS-IB.

15. The Taranaki region is approximately 723,610 ha in size of which 40% is native forest or shrubland. Of the area covered by native vegetation approximately half lies in the public conservation estate, with the remainder being on privately owned land.

16. The Council notes that pursuant to its RMA responsibilities for controlling use and development of the coast, fresh water, air and land for soil conservation purposes, it has adopted objectives, policies, rules and other methods relating to its section 30(1)(ga) [biodiversity] functions in a suite of regional coastal, freshwater, soil and air plans.

17. In addition to RMA policy statement and plans, a suite of other policy documents have been adopted by this Council that contribute to the maintenance and enhancement of indigenous biodiversity in the region. They include a regional pest management plan containing rules relating to the eradication and sustained management of environmental pests that were prepared and reviewed under the *Biosecurity Act 1993*. They include the *Taranaki Biodiversity Forum Accord* prepared by the Council on behalf of the Taranaki Biodiversity Forum and its successor Wild for Taranaki. They include the *Biodiversity Strategy for the Taranaki Regional Council*, which was first adopted in 2008 and subsequently reviewed and amended in 2017.

18. The *Biodiversity Strategy for the Taranaki Regional Council* is of particular relevance. The Strategy is a non-regulatory document that has been prepared by the Council as part of a 'whole of council approach' for biodiversity in the Taranaki region. The Strategy assists the Council to implement the biodiversity objectives, policies and methods of the *Regional Policy Statement for Taranaki*. However, the Strategy sets out 157 work programmes across all sections of the Council and across all legislative responsibilities – not just the RMA but also the BSA and LGA. In so doing, it addresses Council aspirations and responsibilities for indigenous biodiversity on land, in fresh water, and within the coastal environment, including offshore.

19. As previously noted, 'on the ground' the Council has invested significant resources into landscape-scaled programmes supported by other significant programmes targeting 'at risk' ecosystems that are being prioritised for active protection. It is this Council's view that passive protection such as regulation (including the NPS-IB) will not be sufficient to reverse the decline in indigenous biodiversity. Active protection by working with land occupiers to restore degraded ecosystems, to address pest and weed threats, and the exclusion of livestock, is essential.

20. Notable Council programmes include but are not limited to:

- The Key Native Ecosystems Programme: This advocacy and extension programme primarily involves working with private land occupiers to protect sites identified as having regionally significant indigenous biodiversity values. It involves Council preparing and supporting the implementation of property-specific biodiversity plans, including ongoing advice and assistance to the land occupier to protect those values. Currently, the programme covers 157 privately owned sites and actively manages 5,539 hectares of private land and 134 hectares of public land.
- The Taranaki Riparian Programme: This advocacy and extension programme encourages private land occupiers to transform the Taranaki landscape by creating ecological corridors, from the Taranaki mounga to the sea. It involves the implementation of property-specific property plans to fence and plant every waterway and wetland on the intensively farmed ring plain and coastal terraces. Currently, the programme covers 2,900 properties totalling 230,000 hectares. To date, over 5.6 million native riparian plants have been sold by the Council to plan holders as part of the programme.
- The Self-help Possum Control Programme: This advocacy and extension programme involves the use of rules requiring possums to be maintained at very low levels (generally below 5% residual trap catch) on participating properties. The programme has been incrementally applied across the ring plain and coastal

terrace landscapes and now covers a total of 4,086 properties totalling 240,200 hectares, including 9,278 hectares of largely acutely threatened indigenous vegetation.

- The Toward Predator-free Taranaki programme: Another landscape-scale programme, this advocacy and extension programme is supported by Predator Free 2050 Ltd and is incrementally being applied across urban and rural areas on the Taranaki ring plain and coastal terraces. The programme's ultimate aim is to eradicate stoats, rats, and possums across the region by 2050. Only launched 18 months ago, sustained predator control has been achieved over 14,000 hectares between Taranaki mounga and New Plymouth.

21. While the Council regularly liaises and works with others, one-on-one, on biodiversity projects of mutual interest, it has also established, supported and funded the establishment and operation of Wild for Taranaki[1], which brings together a collaboration of over 40 local organisations dedicated to working together to efficiently carry out conservation works to achieve a shared vision to protect and enhance the region's unique native plants and animals, and their ecosystems.

22. It is estimated that Council direct funding for biodiversity related programmes (Biodiversity, Biosecurity, Land Management and Enhancement Grants) is in the order of $11,785,000 per annum. This is a conservative estimate and does not take into account other Council programmes and services that are indirectly contributing to biodiversity outcomes such as policy and planning, consents, compliance, pollution incidents and response, state of environment monitoring, and resource investigations and projects (another $9,000,000 per annum). However, the costs borne by the wider community is an order of magnitude much greater. The interest by private land occupiers in Taranaki to protect indigenous biodiversity has been growing exponentially – as demonstrated by the number of private land occupiers seeking to QEII covenant their land (in 2018/2019, 22 open space covenants were approved in the region, which was the highest number for any region in the country that year).

Overall strategic direction

23. In general, the Council strongly supports the Government's objective to maintain and enhance indigenous biodiversity across New Zealand. The 1997 State of the Environment Report for New Zealand identified biodiversity loss or decline as "*New Zealand's most pervasive environmental issue*". However, despite a raft of initiatives aimed at New Zealand lifting its game, biodiversity loss and decline is still occurring.

24. Notwithstanding the above support, the Council does not believe that promulgation of the NPS-IB and the Government's reliance on others (namely councils) to do things (in the form of rules) is going to reverse the decline of indigenous biodiversity in New Zealand.

25. The Council urges the Government to 'get the system' right. The Council refers MfE to the regional sector 'think-piece' – *Addressing New Zealand's Biodiversity Challenge*, which

[1] *Wild for Taranaki is New Zealand's first regional biodiversity trust and was created in 2015 to advocate for environmental groups working within Taranaki to protect and enhance our region's unique native plants, animals, and ecosystems.*

was prepared and forwarded to the Minister for the Environment and MfE officials in 2017. The think-piece's findings are acknowledged and identified in section 4.1.1 of the Section 32 report, which identified five key shifts recommended to achieve improved outcomes for New Zealand's biodiversity. Of most urgency is the need to address the currently fragmented and inconsistent approach to biodiversity management and leadership across New Zealand (not just that part of the system covered by the RMA).

26. Getting the system right means ensuring there are clear roles and responsibilities, that there is strong governance, leadership and accountability, and that there is effective coordination between central and local government plus other participants. The Council is concerned that the NPS-IB relies solely on local government to deliver national policy directions.

27. It is the Council's view that Government writing policy and simply directing others to take action and 'passing on' associated costs associated with protecting indigenous biodiversity does not constitute real leadership. The Council strongly believes that a package of interventions, both regulatory and non-regulatory, are required to address the challenges. The Council notes that the NPS-IB is but a singular tool that addresses only one part of the biodiversity system. The Council strongly urges the Government to address other aspects of the system while also providing meaningful support for the implementation of the NPS-IB, such as resourcing and undertaking the development of national datasets that map indigenous biodiversity. Further details on this point are made below.

<u>Relief sought:</u>

a) Support the Government's aim to maintain and enhance indigenous biodiversity across New Zealand.
b) Seek that the Government commit to a range of intervention measures, both regulatory and non-regulatory, including the resourcing the development of national datasets that map indigenous biodiversity to support the implementation of the NPS-IB.

Managing adverse effects on significant natural areas

28. The Council supports the criteria in Appendix 1 if the NPS-IB for identifying SNAs and believe it will promote greater consistency across district plans in relation to their identification. However, Council does note its reservations around NPS-IB requirements for territorial authorities to survey and map 'high-value' and 'medium-value' SNAs. While Appendix 1 provides criteria for identifying SNAs it contains no criteria directing territorial authorities on how to differentiate between high and medium values. In the absence of such direction, there is likely to be a continuation of legal challenges over council decisions made in district planning processes under the RMA. The Council seeks amendment to the NPS-IB to include criteria for differentiating between high-value and medium-value SNAs.

29. The Council supports the use of the effects management hierarchy set out in clause 3.9 of the NPS-IB and suggests that the hierarchical approach should promote better more consistent management of adverse effects on biodiversity within SNAs.

Relief sought:

c) Support the inclusion of criteria in Appendix 1 of the NPS-IB for identifying SNAs.
d) Seek amendment to the NPS-IB to include criteria for differentiating between high-value and medium-value SNAs.
e) Support the use of the effects management hierarchy set out in the NPS-IB.

Mapping and managing taonga species

30. The Council notes that in accordance with clause 3.14 of the NPS-IB, there are requirements on regional councils to work with territorial authorities (and tangata whenua) to map or describe the location of indigenous species and ecosystems that are taonga. Territorial authorities must then make or change their district plans to include the description or map of their locations.

31. The Council supports the need to map or describe the location of indigenous species that are taonga but seek that the Government lead this process.

32. Of note the Council has already identified taonga species for its *Proposed Coastal Plan for Taranaki* (2020). However, the Council questions extending this concept to mapping or describing the location of "ecosystems" that are taonga.

33. The NPS-IB defines ecosystem as "*…means the complexes of organisms and their associated physical environment within an area (and comprise: a biotic complex, an abiotic environment or complex, the interactions between the biotic and abiotic complexes and a physical space in which these operate)*." This is a very broad definition and there is likely to be considerable inter-regional variability in relation to what ecosystems are likely to be identified as taonga. Indeed, even within a region, at the iwi and hapū level, there is likely to be considerable variability as to what ecosystems might be identified as taonga. The Council notes that at different times, throughout its plan review processes, the Taranaki mounga, all wetlands, and all rivers and streams have been referred to as taonga.

34. The Council seeks that Government prepare comprehensive guidance and direction to support council and tangata whenua interpretation of clause 3.14 of the NPS-IB. The preparation of comprehensive and timely advice is particularly pertinent should current requirements to map or describe the location of ecosystems identified as taonga be retained.

Relief sought:

f) Support NPS-IB requirements to map or describe the location of indigenous species that are taonga.
g) Opposes NPS-IB requirements to map or describe the location of ecosystems identified as taonga be deleted.
h) Seek the preparation of comprehensive timely Government guidance and direction to support the interpretation and application of clause 3.14, including the development and maintenance of a national dataset that maps NPS-IB requirements for taonga species.

Mapping highly mobile fauna areas

35. The Council notes that in accordance with clause 3.15 of the NPS-IB, regional councils must also survey and record areas outside SNAs where highly mobile fauna have been, or are likely to be, sometimes present. There are a number of issues with this as currently written.

36. First, is the uncertainly relating to what constitutes the term "*highly mobile fauna*"? That is, what is the list of species? The Council notes the definition of highly mobile fauna means species that, for the purposes of the NPS-IB, includes only threatened or at-risk species. However, given the regularity and frequency of reviews and amendments to New Zealand's threat classification, the Council is concerned that the exercise of identifying all "highly mobile fauna areas", for all highly mobile fauna species, will be a large, complex and never-ending exercise.

37. Second, is the wording in clause 2.15(1) of the NPS-IB whereby councils must survey and record all areas outside SNAs "…*where highly mobile fauna <u>have been</u>* [emphasis added] *or are likely to be, sometimes present*". This arguably captures the whole region if you have to take into account historical rather than just current species distribution.

38. Third, is that the very issue of which organisation is best placed to survey and map highly mobile fauna. It is the Council's strong view that the Crown and, in particular, DOC has the statutory responsibilities and is better placed to undertake the exercise of surveying and mapping of highly mobile fauna areas across New Zealand.

39. As noted in section 3.4 of the section 32 report, DOC is the lead central government agency for conservation. DOC is the administering agency for the *Conservation Act 1987*, which is an Act to promote the conservation of New Zealand's natural and historic resources. DOC is also the administering agency for the *Wildlife Act 1953*. Under that Act, the Minister has the explicit powers to "… *prepare and carry out wildlife surveys*" (section 41(a)), "…*coordinate the policies and activities of departments of state, local authorities and public bodies in relation to the protection…and conservation of wildlife*" (section 41(c)) and "…*conduct wildlife research work, and collect and disseminate wildlife information*" (section 41(d)). It is noted that DOC already maintain significant information on highly mobile fauna, they have the capacity and experience in assessing and identifying highly mobile fauna, plus the work of identifying and updating highly mobile fauna areas can be more easily incorporated and/or aligned with DOC's review of the threat classification of highly mobile fauna species.

40. Rather than devolving mapping responsibilities to councils, and the associated risks of inter-regional inconsistencies and overlap with DOC's role and responsibilities, the Council seeks that the Government, take ownership of this issue and resource the generation of a national robust and consistent dataset of highly mobile fauna areas (plus other biodiversity related information) across New Zealand that councils can then adopt and put into their plans.

<u>Relief sought:</u>

i) That the NPS-IB be amended to delete requirements in clause 3.15 of the NPS-IB that councils "…*survey and record areas outside SNAs where highly mobile fauna have* *been identified, or are likely to be sometimes present*."

j) That the Government prepare a national dataset describing and mapping 'highly mobile fauna areas'.

Restoration targets

41. The Council suggests that protection should be our first priority before restoration. The Council does not question the concept and desirability of restoration. As a concept, this Council is already working with land occupiers, community groups, territorial authorities, tangata whenua and others to create and/or restore degraded indigenous habitats and ecosystems. The Taranaki riparian, wetland and Key Native Ecosystems are a case in point. However, the Council questions the legality, practicalities and policy intent of NPS-IB requirements that councils meet an 10% restoration target for urban vegetation cover and separate indigenous vegetation targets for non-urban areas (as set out in clause 3.17).

42. First, the Council notes that section 30 and 31 functions of the RMA only require councils to maintain (and not enhance) indigenous biodiversity. It is the Council's contention that clause 3.17 of the NPS-IB is imposing a statutory requirement on councils that extends beyond what currently exists in the RMA.

43. Second, the Council notes that the urban restoration target has the potential to conflict with other national directions, particularly the *National Policy Statement for Urban Development 2020* where the focus is on making land available for urban development. Although a wider issue than what can be addressed under this process, the Council strongly urges better alignment by Government between their national policy statements and national environmental standards and, as far as is practicable, avoid the differing treatment of different land uses simply because they are covered by a different national policy instrument (e.g. *National Policy Statement for Urban Development* and the *National Environmental Standard for Plantation Forestry*).

44. Third, the Council seeks a priority-based staged implementation approach to the NPS-IB that focusses on where protection is needed most. The Council does not believe that clause 3.17, as currently written, addresses the underpinning rationale or policy intent behind the regulation. Page 68 of the discussion document of the NPS-IB states that "*…maintaining indigenous biodiversity requires more than protecting what is left*" and then goes on to highlight threatened or rare ecosystems that are at risk of collapse. However, it is noted that clause 3.17 does not focus on threatened or rare ecosystems (or degraded SNAs), instead the restoration targets relate to indigenous vegetation cover generally.

45. Fourth, the Council is unclear as to what is an acceptable target for non-urban areas (what is the end point when a council may stop transforming the landscape by increasing indigenous vegetation cover?).

<u>Relief sought:</u>

k) Seeks that NPS-IB restoration targets for increasing indigenous vegetation cover in urban and non-urban areas be removed.

l) Should NPS-IB requirements to set restoration targets remain, seek that clause 3.17 be amended to focus on threatened or rare ecosystems and/or degraded SNAs.

Mandatory regional biodiversity strategies

46. It is noted that, for regional councils, under the RMA, the only mandatory policy documents are a regional policy statement and a coastal plan. The Council therefore questions the proliferation of strategies and plans that councils are mandatorily now required to prepare through the promulgation of national policy statements and national environmental standards.

47. This Council notes that it has already prepared a biodiversity strategy. The *Biodiversity Strategy for the Taranaki Regional Council* is a non-regulatory document that has been prepared by the Council as part of a 'whole of council approach' for biodiversity in the Taranaki region. The Strategy contains a vision and sets out, across all legislative responsibilities, four priorities and almost 160 work Council programmes to maintain and enhance indigenous biodiversity in the region – not just the RMA but also the LGA, and the BSA. The Biodiversity Strategy includes a range of regulatory and non-regulatory interventions. In addition, this region has prepared and is implementing the *Taranaki Biodiversity Forum Accord*, which was prepared by the Council on behalf of the Taranaki Biodiversity Forum and its successor Wild for Taranaki. This Strategy is also a non-regulatory document jointly prepared by signatories comprising of agencies, community groups and individuals that have an interest in biodiversity. It includes an agreed vision, outcomes and plan of action for maintaining and enhancing biodiversity in the region.

48. The Council therefore is not opposed to the concept of regional biodiversity strategies but is opposed to the NPS-IB mandatorily requiring regional biodiversity strategies to be prepared in a prescribed (and limited) form and prescribed manner set out in clause 3.18 and Appendix 5 of the NPS-IB. For example, clause 3.18(1) of the NPS-IB states that "*…regional councils must prepare a regional biodiversity strategy in <u>collaboration</u> [emphasis added] with territorial authorities, tangata whenua, communities, and other stakeholders*." Collaboration infers more than consultation. There is a risk that the outcome of collaborative decision making processes could impose unbudgeted costs on councils to give effect to priorities demanded by external parties that have not been vetted through LGA planning processes and where those parties do not have to directly bear the costs or consequences of their demands. If this risk is too great, it is likely to derogate from the Council's current system-wide approach with new strategies focusing only on the mandatory RMA requirements.

49. The Council seeks that the preparation of regional biodiversity strategies not be a mandatory requirement but instead be encouraged through the *New Zealand Biodiversity Strategy*. This would allow councils to retain control of their form and content.

<u>Relief sought:</u>

m) Seek that the preparation of regional biodiversity strategies not be a mandatory requirement of the NPS-IB.

Implementation and monitoring

50. Reliance on regulation such as the NPS-IB will not reverse the decline in indigenous biodiversity occurring nationally. A package of interventions is required to address the biodiversity challenge, both regulatory and non-regulatory, and there must be a greater focus by the Government on actively managing the threats associated with biodiversity decline. Active management almost always requires working alongside people, whether they're individual landowners or communities. It means taking proactive and positive measures, such as fencing, pest and weed control or planting, to protect and enhance indigenous biodiversity.

51. When you get people involved with biodiversity management, they invariably expand their knowledge about our native flora and fauna, and value it more highly. There is much research to suggest that working alongside people gets more effective results than forcing behavioural change through regulations, which at best can only ever achieve passive protection of biodiversity. The Council therefore seeks that the Government place more emphasis on non-regulatory interventions (i.e. fund a package of support, grants and incentives).

52. This Council understands the concept of active management well. We are leaders in this area, with a long history of developing and implementing work programmes whose success rests on community buy-in. However, the Council is concerned that the NPS-IB and associated regulation, without appropriate and complementary non-regulatory measures, will cut across and cause harm to the good work being done by landowners on the ground. If the Government is serious about actually halting the decline then much more thought is required here.

53. NPS-IB implementation will be difficult and costly for councils, especially in the wider context of other national direction that will need to be implemented over the next five years. Like the recent Essential Freshwater package, Council is concerned about implementation costs associated with the NPS-IB. This includes both the social and economic costs to our communities and the costs imposed on this Council to implement the NPS-IB. When looking at the bigger picture and across all the national direction that needs to be implemented in the near future, stronger and more meaningful support is required from Government to offset some of the costs to the sector of implementing the NPS-IB.

54. It is the Council's contention that mapping requirements are one area where the Government would be better-off taking a lead (with councils taking the lead in administering and monitoring the NPS-IB).

55. For territorial authorities, there are requirements to evaluate, identify and map (clauses 3.8(1), (2) and (3), NPS-IB) significant natural areas using suitably qualified ecologists. They must also differentiate between 'high value' and 'medium value' SNAs. Territorial authorities must also make or change their district plans to include maps or a description of the location of indigenous species and ecosystems that are taonga (clause 3.14(3), NPS-IB).

56. For regional councils, there are requirements to determine the process for mapping or describing the location of indigenous species and ecosystems that are taonga (clause

3.14(1)(c), NPS-IB), and to map habitat areas for highly mobile species (clause 3.15, NPS-IB). Also of note are requirements under the proposed *National Policy Statement for Freshwater Management* to identify and map inland natural wetlands.

57. The Council strongly seeks that the Government develop and maintain national datasets that map indigenous biodiversity across New Zealand. The Council would suggest that such datasets could then be made available to councils for them to be adopted and inserted into their plans as appropriate, e.g. similar in concept to the Government's Erosion Susceptibility Classification maps released to support the implementation of the *National Environmental Standards for Plantation Forestry*.

58. This would be equitable as this represents national information to give effect to national direction and to address a national issue. It also represents an opportunity for Government to show they are a partner in the implementation of the NPS-IB.

59. This would be efficient in that it is likely to be less costly than devolving this task to a large number of councils around New Zealand to individually undertake the exercise – despite their variable size, expertise and capacity to undertake the exercise and/or the cost and capacity of the consultancy sector to support the exercise.

60. This would also be more reliable in that it would ensure national alignment across New Zealand and avoid local variations in the identification of SNAs etc.

61. One added attraction of councils adopting a nationally authorised dataset is that it will reduce the challenges and costs incurred by councils when identifying and incorporating mapped areas in their plans. Despite assertions in the section 32 evaluation report to the contrary, our experiences of district and regional planning processes under the RMA are that proposed plans and the identification of SNAs are regularly and frequently challenged through the schedule 1 RMA planning process in relation to arguments over the implementation of national policy directions with significant added costs incurred by all parties. These costs can be avoided if the Government has gone through an agreed, robust and rigorous exercise to the satisfaction of the Biodiversity Collaborative Group.

Relief sought:

n) Seek a commitment from the Government to a significant investment in non-regulatory interventions that include a package of support, grants and incentives to support the active management and protection of indigenous biodiversity on privately-owned land.
o) Seek that the Government develop and maintain national datasets that map indigenous biodiversity as required by the NPS-IB.

Conclusion

62. The Council again thanks MfE for the opportunity to comment on proposals for a national policy statement on indigenous biodiversity.

63. The Council believes that much more work is required by Government itself to arrest

the decline of biodiversity. The Council strongly submits that the Government needs to 'own' the problem and take the lead in addressing gaps in knowledge and information. The option of central government itself completing a comprehensive risk assessment and mapping exercise to identify significant indigenous biodiversity before embarking on a nation-wide national policy statement should be given serious consideration.

64. Through the NPS-IB, the Government is imposing significant added costs onto councils, particularly in relation to the additional planning and mapping requirements, and this comes on top of other unbudgeted work being directed to local government by central government. As highlighted in this submission, this Council and the wider Taranaki community have no issue with investing in bespoke planning, implementation and monitoring for biodiversity. However, the NPS-IB needs to ensure that its provisions do not derogate from such programmes and/or add unnecessary costs without environmental gain.

65. This situation requires attention by central government as a matter of urgency.

Yours faithfully

S R Hall
Director – Operations

MEMORANDUM
Policy & Planning

Date	4 February 2020
Subject:	***Transitioning Taranaki to a Volcanic Future* - a research programme**
Approved by:	G K Bedford, Director - Environment Quality
	B G Chamberlain, Chief Executive
Document:	2409932

Purpose

1. The purpose of this memorandum is to present the Committee with information concerning a major collaborative research project to be undertaken within and concerning Taranaki over the next few years. The project is to explore and evaluate the consequences and implications for Taranaki and for New Zealand of ongoing volcanic activity from Mt Taranaki.
2. There will be a presentation to the Committee from one of the project leaders.

Executive summary

3. The common view of natural disasters is that they are single and transient events (perhaps with a 'tail' of disruption, such as with after-shocks from an earthquake), and the typical sequence envisaged by authorities and communities is of 'normal life-> disruptive event-> immediate response-> disaster relief-> recovery-> return to previous normality'. However, study of Mt Taranaki's previous eruptive events has shown that they are not single episodes, but rather comprise ongoing periods of continuous or continual cycles of seismic activity, eruptions, ash falls, lahars, cone collapses, and other volcanic phenomena, that continue for decades or longer (centuries).
4. The project *'Transitioning Taranaki to a volcanic future'* has been approved for Endeavour Fund resourcing by the Ministry of Business, Innovation and Enterprise. It is focused on the reality of a long duration, evolving volcanic disruption that will have great national scale consequences and that essentially shifts the Taranaki region and New Zealand as a whole into a new paradigm that is at least semi-permanent. The likelihood of Mt Taranaki beginning an eruptive sequence is currently estimated at 50% within 50 years- that is, it is more likely than not that the region will face this situation within the next 50 years. The current dormant period has lasted longer than usual.
5. The scale of physical impact from volcanic activity by Mt Taranaki will encompass most of the North Island (a researcher has noted that there is more Taranaki ash across Auckland than there is Auckland volcanic ash), while social and economic impacts

include partial or complete ongoing loss of gas supply, electricity, farming, primary exports, municipal water supplies, tourism, and domestic air, road, and rail travel and transport (goods and passengers), on inter-regional and national scales. The social and human consequences of living in and trying to adjust to a permanently heightened level of risk and uncertainty, while coping with fatigue and diminishing resources, could be significant if not over-whelming.

6. The project will explore not only specific resilience and response strategies, but also the adaptive, strategic, forecasting and modelling, and decision-making processes that will be necessary to help Taranaki and New Zealand transition to coping in an environment of dynamic and constantly shifting and cascading impacts, effects, decisions, outcomes, and needs for new capabilities. It is a large-scale five year project aimed at:
   - better understanding how the volcano works,
   - developing a detailed economic impact model from an array of eruption types and lengths,
   - developing an eruption forecasting tool that will help socio-economic decision making, and
   - working within the Mātauranga Maori model to inform and shape the outputs and outcomes.
7. The value of the funded work is $13.6 million over five years.

Recommendations

That the Taranaki Regional Council:

a) receives the memorandum describing the research programme *'Transitioning Taranaki to a volcanic future'*

b) notes the engagement of the Council as a participant in the research programme.

Background

8. The government has a strategic priority to identify risks to NZ's intergenerational wellbeing. Natural disasters are among the most important risks to the country's financial, physical, and human resources. The *National Disaster Resilience Strategy* identifies the need to address, not only specific hazards and risks, but enhancement of generic resilience. The research team have identified an eruptive sequence from Mt Taranaki as a highly disruptive trigger that will force a radical re-think and re-orientation of disaster risk management in New Zealand.

Discussion

9. The project team has identified that Taranaki is the most likely New Zealand volcano to cause national-scale impacts over our lifetimes. A partial economic analysis of such impacts suggests the scale of economic disruption to be in the order of $2-4 billion per year even over only a brief period.
10. The research will build and test the geological, engineering and socio-economic knowledge, tools, and information management essential for the New Zealand economy to transition through such an unprecedented level of on-going disruption, by developing new methods of mathematical and economic simulation, experimentation, planning,

decision-making, and adaptation in the face of rapidly evolving uncertainty and with multiple stakeholders.

11. The international project team consists of over 40 researchers across geology, economics, statistics, mathematics, and Mātauranga Māori. It is led by Dr Shane Cronin (volcanic researcher) and Garry McDonald (economics), and brings together five universities, several Crown Research Institutes, and commercial research agencies. There is a heavy emphasis upon co-creation and collaboration (researchers working with end users to design and deliver the project). Stakeholders and end-users already engaged in the project include the Taranaki Regional Council, Taranaki CDEM Group, district councils, Department of Conservation, Venture Taranaki, DairyNZ, Dept. Prime Minister and Cabinet – National Risk Unit, Ministry of Civil Defence and Emergency Management, Dept. Internal Affairs – Central Government-Local Government Partnerships Group, NZ Treasury, NZ Transport Agency, Ministry of Transport, Civil Aviation Authority, and the Ministry of Business Innovation and Employment – Petroleum and Minerals and Energy Markets.

12. The project will draw heavily on Mātauranga Māori, recognising that in the face of disruption, robust business and community decisions will require partnerships and collaboration, and can draw on whakaoranga processes. The project team recognises that Māori knowledge of volcanic landscapes, hazard and risk is part of an enduring relationship connecting land, people and place over many centuries, and that Maunga Taranaki – a personification of an ancestor - and the waterways flowing from him are deeply entrenched in whakapapa and identity for the eight iwi of Taranaki. Appreciation of this relationship is seen as critical by the team, in order to create appropriate pathways towards adaptation to an active volcanic future. The project brief notes that Mātauranga-ā-iwi (tribal knowledge) regarding Maunga Taranaki has endured through resource and environmental change, and iwi have survived through past eruptions. Furthermore, iwi have major investments in land, marae, schools and business, especially within the agriculture, culture and tourism sectors of the research.

13. It is envisaged that the outcomes of this work will also help New Zealand learn to adapt and transform to other rapid or permanent changes, such as those threatening from climate/environmental change or technological events.

Decision-making considerations

14. Part 6 (Planning, decision-making and accountability) of the *Local Government Act 2002* has been considered and documented in the preparation of this agenda item. The recommendations made in this item comply with the decision-making obligations of the *Act*.

Financial considerations—LTP/Annual Plan

15. This memorandum and the associated recommendations are consistent with the Council's adopted Long-Term Plan and estimates. Any financial information included in this memorandum has been prepared in accordance with generally accepted accounting practice.

Policy considerations

16. This memorandum and the associated recommendations are consistent with the policy documents and positions adopted by this Council under various legislative frameworks

including, but not restricted to, the *Local Government Act 2002*, the *Resource Management Act 1991*, the *Civil Defence Emergency Management Act 2002*, and the *Local Government Official Information and Meetings Act 1987*.

Iwi considerations

17. This memorandum and the associated recommendations are consistent with the Council's policy for the development of Māori capacity to contribute to decision-making processes (schedule 10 of the *Local Government Act 2002*) as outlined in the adopted long-term plan and/or annual plan. Similarly, iwi involvement in adopted work programmes has been recognised in the preparation of this memorandum.

Legal considerations

18. This memorandum and the associated recommendations comply with the appropriate statutory requirements imposed upon the Council.

Appendices/Attachments

Document 2361602: Transitioning Taranaki to a Volcanic Future- application to the 2019 Endeavour Fund

Proposal overview

Proposal information

Investment area: 2019 Endeavour Fund - Research Programmes

Contracting organisation: University of Auckland

New Zealand Business Number (NZBN):
9429041925300

Registration number:

Year 1 funding requested:

$2,735,357.00 GST excl. amount	$410,303.55 GST amount	$3,145,660.55 Total amount

Total funding requested:

$13,676,785.00 GST excl. amount	$2,051,517.75 GST amount	$15,728,302.75 Total amount

Title:
Transitioning Taranaki to a Volcanic Future

Investment mechanism:
Research Programmes

Number of years' funding requested:
5

Fund objective:
- (●) Economic
- ( ) Environmental
- ( ) Social

General signals

High potential impact in areas of future value, growth or critical need for New Zealand

Leverage wider investment and knowledge in New Zealand and overseas

Gives effect to Vision Mātauranga

Take account of broader Government policy and strategy documents

Future growth or critical needs

Creating & growing knowledge-intensive industries

Supporting the transition to a low-emissions economy

Explain this selection (200 words)

The government has a strategic priority to identify risks to NZ's intergenerational wellbeing, with natural disasters indicated as among the most important to financial/physical/human capitals. Our proposed research will build the knowledge and tools to support NZ to adapt and transform to such threats, including an inevitable long-term eruption of Mt. Taranaki (50% chance/next 50 years) presenting wide risks to the central-upper North Island. In line with the draft National Disaster Resilience Strategy, we focus not only on active management for specific risks/assets, but also on generic resilience adaptations. The project also draws heavily on Mātauranga Māori, recognising that in the face of disruption, robust business and community decisions require partnerships and collaboration, and can draw on whakaoranga processes. The government is also committed towards regional development and the draft tourism strategy recognises opportunities afforded by Māori culture and provision of unique visitor experiences. In Taranaki, with recent settlements and investment priorities signalled around mountain tourism, there is now a priority-need to build volcanic/risk capabilities and inform the region's strategic vision. We will lever international knowledge and practice through comparative studies in Italy, Indonesia, Mexico and the USA, where communities are similarly preparing for, or living through long-term volcanic disruption.

Impact category

Protect & Add Value

Explain this alignment (200 words)

New Zealand's risk management and resilience-building practices have been strongly shaped by a paradigm of static hazards and disaster cycles that are sequential and orderly (i.e. planning/risk reduction-event-response-recovery). Our project will force a radical re-think of this approach. We tackle not only a dynamically evolving hazard, where data captured during an unfolding event will trigger new risk conclusions, but also eruption episodes that are potentially decadal or longer, with elements of the disaster cycle becoming disordered and merged. In the Taranaki situation the regional economy, and those downwind in a fallout zone from Auckland to the Central North Island, will face daily-weekly disruptions of transport and energy sectors, poisoning of waterways, drinking water and pasture/crops, along with fatigue and fear. *W*e will protect economic growth by providing the tools and capabilities for sectors (including in agriculture, tourism and infrastructure) and governance practices to transition in this context. This will enable is to make timely decisions and adapt practices to evolving risks and never-before-presented information from volcanic-hazard forecasting tools. The outcomes of this work will help New Zealand to learn to adapt and transform to other rapid or permanent changes, such as those threatening from climate/environmental change or technological events.

Keywords

- Volcanic hazard mitigation
- Economic development
- Disaster risk reduction
- Disaster recovery
- Hazard science
- Economic benefits/cost saving
- Tourism
- Agriculture
- Volcanic risk
- Risk and uncertainty
- probabilistic hazard assessment
- Volcanism
- Taranaki
- transition pathways
- robust decision making

Contact people

Primary Contact

Contact name
Mrs Mandy Brown

Contact telephone
(09) 9232735

Contact email
mandy.brown@auckland.ac.nz

Secondary Contact

Contact name
Miss Chloe Chapman

Contact telephone

Contact email
c.chapman@auckland.ac.nz

Proposal summary and Eligibility

Proposal summary

Taranaki is the most likely New Zealand volcano to cause national-scale impacts over our lifetimes. Positioned upwind from our most populous regions of Auckland, Waikato and Bay of Plenty, all Taranaki eruptions will disrupt air and surface transport, tourism, farming, power and water supplies. This volcano has a 50% probability of erupting over the next 50 years. Yet the dormancy since Taranaki's last eruption (~AD1790) is one of its longest. Thus we have no modern experience of its typically very long eruptions. Past research shows that once Mt. Taranaki starts erupting, it continues for years, decades, or centuries. A recent estimate of the net losses in economic activity from a brief Mt. Taranaki eruption (considering only a subset of potential impacts) is crudely estimated at ~NZ$1.7-4.0 billion of GDP per year, or ~NZ$13-26 billion, for a decade of volcanism. Our research will build and test the geological, engineering and socio-economic knowledge essential for the New Zealand economy to transition through such an unprecedented level of on-going disruption. Using a novel integration of volcanic scientific knowledge, experimentation and advanced mathematical and economic simulation, we aim to radically cut down uncertainty that hinders decisive hazard and mitigation planning for transitioning to a new state of ongoing hazard. We will demonstrate how robust decisions can be made across space, through time, for multiple stakeholders. In this way we will also discover how to transform New Zealand in the face of continuous change. This requires developing an integrated quantitative understanding of volcanism in order to confidently forecast the volcanic impacts over timeframes suited to socio-economic decision-making.

Please confirm that your application meets the eligibility criteria

Yes

If you are unsure whether your proposal meets these criteria please explain why:

Executive summary (560 words)

The hazard and risk management paradigm of New Zealand is focussed on isolated and finite events. Even with several events (e.g., Canterbury Earthquake Sequence), our response and recovery all assume that a hazard episode will finish, and all infrastructure, communities and economies can be recovered to “normality”. Here we address the problem of: **What if a hazard event started and never stopped?** In this case **we need new adaptive or transformative capacity to address long-term hazard disruption,** specifically under conditions of deep uncertainty. We hypothesise that by researching how to transform New Zealand through a **likely nationally devastating scenario of volcanic reawakening at Mt. Taranaki**, we can fast-track development of new knowledge into adaptation and transformation of our communities and economy through any type of uncertain future disruption case. There is a 50% chance of Mt. Taranaki erupting over the next 50 years and once reawakened, eruptions will continue for decades. Long term Taranaki volcanism will impact all sectors of our economy throughout the entire North Island, with especially devastating consequences for transport, airports (especially Auckland), the oil, gas and electricity sector, along with agriculture and tourism.

Science Excellence and research plan

We will develop new science in five areas: (RA1.1) co-creation of new decision-support processes for adaptation to ongoing disruption under deep uncertainty; (RA1.2) development of an agile new multiscale spatially and temporally socioeconomic modelling toolkit to continually forecast local, regional and national impacts considering ongoing changes in hazard/consequence state and adaptation strategy; (RA1.3) revive and build on to Mātauranga Māori/Mātauranga-ā-iwi knowledge to support Māori business and community adaptation; (RA1.4) construct new probabilistic statistical frameworks that integrate multi-volcanic hazard and apply predictive volcanic potential variables during dynamic, long-term hazard episodes, and (RA1.5) address a fundamental scientific weakness in the globally evaluation of volcanic hazards, by discovering specific geochemical or geophysical indicators that have predictive power of volcanic potential on a time cycle relevant for communities and business.

Team Excellence

We have built an inter-disciplinary team of >40 emerging to seasoned researchers spanning specialities in geology, statistics/mathematics, Mātauranga Māori and economics, under the proven science leadership of the outgoing Director of the Resilience NSC (Resilience to Nature’s Challenges National Science Challenge), Prof Shane Cronin and co-leader Dr Garry McDonald, who has led a series of innovations in New Zealand’s economic decision support knowledge through many MBIE and commercial research programmes. We have assembled the national front-runners in volcano and hazard science from five universities, GNS Science and commercial research providers, alongside strategic international partners (USA/Italy/Australia) that open doors to vast analogue experience and analytical equipment.

Benefit to New Zealand

Our work will transform volcano hazard forecasting tools for hazard management authorities and communities with new mathematical hazard approaches that can be applied worldwide, and a new agile socio-economic decision framework to support just decision-making during ongoing disruption for local and national government agencies, infrastructure/lifeline agencies, iwi-authorities and iwi-led businesses. The socioeconomic tool will allow the impacts of adaptation/mitigation decisions and changes in hazard state to be forecast and updated through constant challenging operating conditions and deeply uncertain futures of long-term disruption.

Implementation Pathway

We apply iterative, co-creation processes throughout with, with end-user-led research wānanga (workshops) throughout. Involving leaders of the successful Resilience National Science Challenge team, we bring together a core team of proven collaborators and scientists that can readily bring research to real world impact.

Vision Mātauranga

Is Vision Mātauranga relevant to this proposal?

Yes

Provide the rationale that substantiates this position (200 words)

Māori knowledge of volcanic landscapes, hazard and risk is part of an enduring relationship built with land, people and place over many centuries. Maunga Taranaki – a personification of an ancestor - and the waterways flowing from him are deeply entrenched in whakapapa and identity for the 8 iwi of Taranaki. This relationship is critical to recognise and understand in order to create appropriate pathways to adapt for an active volcanic future. Mātauranga-ā-iwi (tribal knowledge) regarding Maunga Taranaki have endured resource and environmental change, and iwi have survived through past eruptions. Furthermore, iwi have major investments in land, marae, schools and business, especially the agriculture, culture and tourism foci of our research. We see Mātauranga-ā-iwi guiding this research programme as a future adaptive store of indigenous innovation for contemporary and new taiao, strategies and practices for adaptation to ongoing disruption. Māori researchers with whakapapa links to the Taranaki and downwind regions are key researchers (Procter, Sciascia, McCallion) and will help co-create appropriate frameworks, methods, tikanga and socio-economic modelling paradigms tailored to iwi communities and businesses. Knowledge and strategies generated from the research will be transformational and be disseminated to iwi and international partners in ways that are functional (wānanga).

Excellence

Science Excellence (1120 words)

Societal Issue

Taranaki is the most likely NZ volcano to cause national-scale impacts over our lifetimes, with a 50% chance of erupting over the next 50 years (Turner et al., 2008c; Damaschke et al., 2018). Due to its location and prevailing westerly winds, any eruption will affect cities, all transport, tourism, farming, power and water supplies across the North Island (Shane, 2005; Bebbington et al., 2008; Torres-Orozsco, 2018). Auckland is particularly vulnerable, with the probability for impact from a Taranaki ash fall 2 to 7 times higher than from any other volcano, including a local eruption (Shane and Hoverd, 2002; Shane, 2005). Taranaki's last eruption was ~AD1780-90 (Platz et al., 2012; Lerner et al., 2019), making its present dormancy one of the longest known (cf., Damaschke et al., 2017). Most Taranaki eruptions occur in clusters, with activity lasting years to decades (Platz et al., 2007; Turner et al., 2008a; Torres-Orozco et al., 2017a, 2017b, 2018). Long lived-eruptions are common around the world at analogue volcanoes: e.g., Merapi (Indonesia) since 1822 (Thouret et al., 2000); Semeru (Indonesia) since 1818 (Thouret et al., 2007; Doyle et al., 2010); and Colima (Mexico) for >200 years (Massaro et al., 2018). No risk reduction, response or recovery plans have any contingency for a decade-long eruption. Only *Tangata Whenua*in the Taranaki area have experienced this (cf., Platz et al., 2007; Lerner et al., in review).

Science Challenge

We must integrate new socio-economic tools, statistical hazard estimation and quantitative volcano-magma systems parameters into holistic and agile decision support tools to steer us through periods of long-term volcanic hazard disruption. This build a national capacity to thrive under any kind of ongoing national-scale disruption under deep uncertainty.

Hypotheses

- Novel socio-economic models of adaptation and long-term transition will best prepare us for the short-and-long term reduction of risk during enduring volcanic eruptions, or other states of long-term disruption.
- New robust statistical emulation of eruption scenarios and an integrated hazard-to-impact typology will greatly reduce uncertainty around assessing socio-economic impacts of complex volcanic events and long-lived volcanic hazard states.

- The consequences of volcanism at Taranaki can be better forecast by creating new volcanic potential indicators for rates and types of magma processes.

Approach, novelty and effectiveness

1. **Effectiveness through co-creation**. We will apply an action research approach that iteratively develops predictive volcanic indicators from concept to constraint and test their predictive power and usefulness during an agile development process that enables rapid-prototyping. This will involve working collaboratively in a co-creation processes with our end-users.
2. **Socio-economic decision support tools for ongoing disruption**. We will extend from the current approach for simulating socio-economic hazard consequence (based on comparative, or counter-factual studies), by developing new dynamic analysis frameworks that that trace adaptive responses. This will reduce uncertainty and support more robust decisions around adaptation of investment/business operation and risk-avoidance strategies throughout NZ. Our extensional science will incorporate event tree approaches, based on Bayesian networks that capture multiple triggers for socio-economic change and adaptation, including looped and interacting consequences. Furthermore, we will track emerging decision-making processes that underpin robust adaptation to disruption under conditions of deep uncertainty.
3. **Mātauranga Māori and volcanism**: Mātauranga-ā-iwi (tribal knowledge) and tikanga (practices) related to volcano, alpine, river, and coastal hazards is identified and recorded. Iwi/hapū and volcanic researchers develop a shared understanding about the permanence or transience of landscape features – such as river catchments/landslides – and potential impacts on values including Te Mana o te Wai. Mātauranga-ā-iwi is leveraged for use in the transition modelling toolkits.
4. **Mathematical hazard-impact typology**: We will integrate volcanic hazards on an all-of-NZ basis by developing new mathematical science through a 'test-bed' of the forecasting power of volcanic potential indicators, iteratively refining these with volcano-process scientists, before integrating into new-generation forecasting tools. This extends from eruption-pattern-recognition (Damaschke et al., 2017) into a unique world-first simulation model of a stratovolcano. We will leverage a range of existing process-based models of volcanic phenomena (ashfall/pyroclastic flow/lahar/debris avalanche/gas) to create mathematical bridging functions to quantify impacts on built infrastructure, and probabilities for socio-economic consequences, including tracking uncertainties
5. **Volcanic potential indicators**: Complex models of stratovolcanoes invoke networks of stores and processing of magmas before eruption (e.g., Turner et al., 2004; Price et al., 1999; Cassidy et al., 2018). Forecasting eruption outcomes remains a grand scientific challenge, as recently expressed by Cassidy et al. (2018) in Nature Communications. To tackle our overarching science challenge, we must provide robust indicators of a magma system state, distilling decades of petrological and geochemical research into a set of quantitative parameters with forecasting power. Targeted investigations for this are reliant on an existing exceptionally high-resolution record of volcanic events (Turner et al., 2008c; 2011a; Damaschke et al., 2017). We have seen time-variant hazard properties of this system, including a cyclic variation in eruption frequency (Turner et al., 2008a; 2008b; 2011) possibly related to magma composition (Turner et al. 2008b; Green et al., 2013). These features must be built into statistical models currently blind to physical and chemical processes. Our research focuses on targeting the most significant processes and timescales, such as detecting magma recharge and gas-content (explosivity).

Benefits

- By creating new volcanic science, experimentation and advanced mathematical and socio-economic simulation, we can radically cut down uncertainty that hinders decisive natural hazard and mitigation planning.
- We will discover how to transform NZ in the face of continuous hazard by integrating our understanding of volcanic disruptions over timeframes suited to socio-economic decision-making.
- *Additional benefits*: We will create an exemplar of how to manage a much broader range of disruptive events (natural or anthropogenic) through time, across space, for multi-stakeholders, reporting multiscale capital and intergenerational well-being impacts (Forgie and McDonald, 2013) – creating a wider benefit than just volcanic hazard mitigation (e.g., Zero Carbon Act, Climate Change adaptation).

Leveraging knowledge and facilities through collaboration

Our team spans geological, economic, Mātauranga-ā-iwiand mathematical researchers from throughout NZ and overseas. We have levered an extremely important connection with Italian researchers that are working on an analogue problem at Vesuvius volcano, located within the massive Neapolitan metropolitan area. To support our work, we have built a team of highly specialised geochemical and geophysical researchers enabling access to world-leading laboratory and experimental facilities in the USA, Australia and Europe.

Opportunities for Māori knowledge

Māori knowledge has ensured their endurance and survival through eruptions in Taranaki's past. While not current knowledge, these inherent resilient relationships will be a key to identifying practices for the future. Furthermore, traditional indicators of environmental and volcanic change will be integrated into volcanic forecast indicators. Adapting to ongoing volcanic system change will involve Taranaki Māori communities and Iwi authorities re-evaluating current modes of investment to protect their assets for future generations.

Team Excellence (560 words)

Prof Cronin and Dr McDonald will co-lead our research. Cronin is the current Director of the Resilience NSC, where he has built a highly successful collaboration with >200 inter-disciplinary end-users/researchers that have produced >80 peer-reviewed research outputs (achieving a field weighted citation factor of >1.5). He previously led Volcanic Risk Solutions (Massey University) receiving MBIE, Marsden and commercial funding >$17m. He has co-authored >200 papers with >5,900 citations. McDonald has extensive corporate experience (as a founding-Director of ME with >1,600 projects, >$70m) and science leadership (>15 MBIE-funded research programmes, >$30m).

Delivery of our research requires the following skills/knowledge:

- **Co-creation processes**. A/Prof Wilson and Mr Fairclough have exemplary skills in the design and implementation of collaborative stakeholder processes. Wilson leads the Resilience NSC' Rural toolbox, and Fairclough (currently chair of the National Lifelines Council) has led numerous government/business/community stakeholder processes.
- **Socio-economic modelling**. Drs Smith/Harvey and A/Prof Wreford bring world-leading skills in development of integrated decision-support tools and robust decision-making processes that enable evidence-based assessment of socio-economic impacts (e.g. MERIT) across space, through time, for multiple stakeholders.
- **Mātauranga Māori.** A/Prof Procter, Dr Sciascia and Mr McCallion all have whakapapa links to the Taranaki region and a wide diversity of leadership experience in Mātauranga Māori research focused on hazards, environment, cultural and social issues. Procter currently leads the Mātauranga Māori workstream of the Resilience NSC, and Sciascia will take over that role in mid-2019.
- **Geo-statistics**. Prof Bebbington and Drs Wang/Mead have specialist statistical skills in hazard estimation and forecasting, stochastic modelling, computational analysis and uncertainty estimation. These skills will integrate predictive indicators of the volcanic-event chain.
- **Volcanology**: We have assembled a world-class team of volcanologists from NZ/Australia/US/Italy/Germany. They include emerging researchers to the most highly cited geoscientists (Turner/Baker/Cronin/Sulpizio). This includes key specialists in diverse fields (geochemistry/magma properties/mantle/crust geology/experimentation). They are coordinated by Dr Brenna and A/Prof Ukstins, providing leadership opportunities and an international best-practice view.

Partnerships

Within team: Cronin/McDonald/Bebbington/Wilson/Proctor/Sciascia are all part of the leadership team of the Resilience NSC. They have also completed aligned MBIE-funded programmes (>10) including: Understanding and Being Resilient to Super-volcanoes, Towards Robust Decision-Making, Living with Volcanic Risk and the Taranaki-focused Better Recovery through MRCGE.

International: Our team has exemplary international partnerships, including in the US (Ukstins), Australia (Turner/Rushmer), who bring in core capabilities not available in NZ – such as high-resolution isotope geochemistry and Secondary Ion Mass Spectrometry. We also have targeted collaboration with three Italian voclanologists (Sulpizio/Lucchi/Giordano) who lead Italy's response to re-awakening volcanism in Vesuvius, Italy. Our colleagues at the University of Munich, Germany (Scheu/Montanaro) also facilitate our access to the most famous experimental volcanology laboratory in the world.

Māori: Our team has enduring collaborative relationships with all the Taranaki-iwi, along with several Māori land trusts, and Māori businesses in the region. Sciascia comes from (and was raised in) Te Ati Awa, Ngāti Ruanui and Ngāruahine Rangi and has worked alongside all 8 iwi in iwi-governance roles.

People risk management

We mix a healthy gender balance along with a diverse group of well-established through to mid-career and emerging researchers in all areas of our research, minimising people risks. Through monthly research meetings we will maintain a risk register and adopt risk-management strategies including broad-scanning of workplans, proactive adaptive management, and agile face-to-face engagement. We have a co-leadership model (ensuring availability), an Advisory Group (sounding-board for strategies), and world-leading international advisors (reducing technical risk).

Impact

Describe how your research will deliver Benefit to New Zealand (1120 words)

The problem

Of all volcanic hazards, Taranaki is the most likely to cause national scale impacts over our lifetimes. Although >200 years since the last eruption, this dormancy is atypical, with the probability of an event in the next 50 years exceedingly high (50%). Formidable disruptions to air-and-surface transport, tourism, farming, power and water supplies will likely extend well beyond the local region, with the populous and economic 'power-house' regions of Auckland, Waikato and Bay of Plenty positioned down-wind. Even more pivotal than its geographic extend is the potential temporal extent. Evidence suggests that once Taranaki starts erupting, it continues for years even decades. A suitable analogy is Mt Merapi, Indonesia – in an active state since c1930, producing thousands of casualties including >380 in 2010. NZ clearly has no modern experience of such episodes, and at no scale of governance has there been practice and conditioning for dealing with long-term ongoing disruptions. The prevailing disaster management paradigm is of static hazards and disaster cycles that are sequential and orderly (planning/risk reduction-event-response-recovery). A radical re-think is required. Our research will build the knowledge, tools and preparedness to support NZ to make timely decisions and adapt practices under an evolving threat, where elements of the disaster cycle are disordered and merged, and new information is periodically presented from novel volcanic-hazard forecasting tools.

Leverage wider investment and knowledge in New Zealand and overseas

The main collaborative benefits we will gain through our international partnership is access to a pool of specialised, state-of-the-art knowledge, practice and experimental/analytical facilities. Specifically, comparative studies on Vesuvius volcano in Italy by our colleagues will help us parallel-test approaches ranging from volcanology through to innovations in evaluating societal impact and adaptation pathways. They are more advanced than us in detailed event response planning and decision-making tools, with also areas of advance in volcano-impact knowledge from more recent eruption events and intense archaeological volcanological studies in the area. Access to an international pool of expertise on magma-isotopic studies brings an intellectual and laboratory capability not possible within NZ. Prof Turner and A/Prof Rushmer lead one of the best-equipped (Thermo-fisher demonstration) laboratories in the world and bring decades of experience in applying a range of isotopic systems to bear on reawakening and active volcanoes. Turner has applied isotopic methods to understanding the gas-state, explosivity potential and timescales of magma movement during ongoing long eruption episodes in Montserrat (Caribbean), Indonesia, and Tonga. Other collaborators bring in wider analytical skill sets and laboratory facilities that we cannot replicate in NZ (Ukstins with Ion-probe and other specialist analytical tools; Sheu/Montanaro with explosion/experimental laboratories).

Leveraging of existing research investment our socio-economic modelling extends cutting-edge work undertaken within the Resilience NSC, QuakeCoRE, NHRP (Faster Rebuilds with MRCGE, Towards Robust Decision Making: Uncertainty Quantification for RiskScape-MERIT Modelling) (McDonald et al., 2017a; 2018) and MBIE Endeavour/Targeted Research (several gold-star rated) Economics of Resilient Infrastructure, Sustainable Aquifer Management, Learning to Live with Volcanic Risk, Living with Volcanic Risk and Facing the Challenge of Auckland's Volcanism programmes.

Scale of potential benefits

To illustrate the scale of potential benefits from this programme, a recent estimate of net losses in economic activity over a year from a brief Taranaki eruption is crudely estimated at ~NZ$1.7-4.0 billion of GDP (McDonald et al., 2017b). Taking an average of $2.6 billion, and assuming conservatively that the next Taranaki event extends over just a decade (with probability of commencement of 1% annually, discount rate 6%) we find that even the expected (i.e. probability-adjusted) gains from reducing losses by just 5% will exceed $150 million over the next 50 years, but could be nearly $1 billion if the eruption occurs imminently. And remarkably these calculations only consider a subset of the potential benefits achievable. For one, the above initial loss estimates were based largely just on key local impacts, omitting ceased operation of industrial plants outside of Taranaki, the implications for aviation, and threats to distant drinking water, pasture, crops. Also not considered were potential losses to machinery and infrastructure (e.g. water supply), of which the financial burden of repair and replacement could last decades. Using a novel integration of volcanic scientific knowledge, experimentation, socio-economic and advanced statistical/mathematical simulation/modelling, we will radically cut down uncertainty so that businesses and infrastructure providers from across the broad economic spectrum can seek more strategic outcomes from operations and investment planning, both in anticipation and during an event. Against all this the research programme clearly presents an opportunity for very high impact in areas of future value/growth and is a critical need for NZ. Furthermore, the outcomes of this work will also help NZ to learn how to adapt and transform to other rapid or permanent changes, such as those threatening from climate/environmental change or technological events.

Government policy and strategy documents

The urgency for this research stems not only from the high risk posed, but also the local governance context, i.e. recent treaty settlements and government/iwi investment priorities signalled around mountain tourism and authentic cultural experiences (MBIE, 2018). Clearly the time to act is now to strategically inform the region's vision. The programme also strongly supports Treasury in its stated intent, which prioritises identification of risks to NZ's intergenerational well-being, with natural disasters indicated as among the most important risks (Treasury, 2018a). Our proposed public decision-support tools will themselves also be structured in line with Treasury's Living Standard's framework (Treasury, 2018b), which recognises the need to monitor changes in wealth across multi-capitals, and that what matters to New Zealanders cannot be measured by standard economic measures alone (Smith, 2018). But also, consistent with the draft National Disaster Resilience Strategy (NDRS), we focus not only on active management for the specific Taranaki risk, but also on generic resilience adaptations (CDEM, 2018). The process of preparing and conditioning for the types of risks posed by Taranaki will be a key benefit of the programme.

Mātauranga Māori benefits

As is also recognised in the NDRS, Māori are natural kaitiaki (guardians) of the environment – this stems from a deep whakapapa connection to the land and waterways that are not only identity markers, but are pillars of cultural significance for Māori communities and iwi within Taranaki. We see this programme supporting the active role of kaitiakitanga by Taranaki iwi to understanding hazards and risk in the context of Maunga Taranaki and developing strategies and practice for adaptation that is culturally meaningful and appropriate.

Describe your Implementation Pathway/s and how they will deliver benefit to New Zealand (1120 words)

Key initiatives, timing and pathway

Over the last 18 months we have **co-designed a research agenda** with our key stakeholders during workshops and one-on-one meetings (Taranaki CDEM Group, Taranaki Regional and District Councils, Department of Conservation, Venture Taranaki, DairyNZ, Dept. Prime Minister and Cabinet – National Risk Unit, Ministry of Civil Defence and Emergency Management, Dept. Internal Affairs – Central Government Local Government Partnerships Group, NZ Treasury, NZ Transport Agency, Ministry of Transport, Civil Aviation Authority, Ministry of Business Innovation and Employment – Petroleum and Minerals and Energy Markets). Our work will sit alongside the Taranaki 2050 Transition Roadmap process and can feed into this outcomes around managing uncertainty and change during long-term economic transition. We also have freedom to operate within Taranaki with full support and aligned resources of our partners (e.g., Taranaki CDEM Group has an aligned application to ours with the Ministry of Civil Defence Resilience Capability fund). Further to this, we have also developed key relationships with other research organisations, including alignment and coordination between the Mātauranga Māori, Rural, Volcanic and Multihazards risk streams of the 2019-2014 Resilience National Science Challenge.

Our implementation process is centred on direct resource into co-creation (RA1.1) where we develop enduring partnerships with end users, initially through a Terms of Reference, we build toward levering delivery partners (stakeholders) and Advisory Group members to achieve additional science impact. Our co-creation processes will involve regular stakeholder/iwi-led face-to-face workshops to ensure our technical workstreams (RAs1.2&1.4) are fit-for-purpose, and also that we are managing risk, thoroughly testing assumptions and removing barriers to long-term uptake. Our programme has at least 14 co-creation workshops (≥10 stakeholder/iwi-led in Yrs2-4) spread evenly (≥4 in Yr1, ≥5 in Yrs2&3, ≥5 in Yr4), and two annual Advisory Group Meetings chaired by our group of research-to-practice interlocuters, including Roger Fairclough (Chair of the National Lifelines Council and Resilience NSC Infrastructure Advisory Board) Brad Scot (GNS Science), Aaron Mckellion (Waka Digital) and locally Teresa Gordon (Taranaki CDEM Group).

Our **implementation pathway specification** is designed so that co-creation workshops are efficient and adaptive. Initial workshops (Yr1) are focused on establishing process, building relationships and shared understandings, as well as developing metrics for evaluation. Subsequent workshops (Yrs2-4) are all stakeholder/iwi-led and aligned with decision-making processes, sharpening the delivery of our high-quality science. Importantly, outputs from our socio-economic, Mātauranga-ā-iwi (tribal knowledge), statistical/simulation modelling and geochemical tool-chest will be available for use from Yr1 onwards; and will be continuously and seamlessly updated with science added progressively. Our stakeholder/iwi delivery partners will thus have the cutting-edge science at their fingertips, in each workshop, enabling stress-testing of our work on-the-fly.

Considering, identifying and responding to the needs, opportunities or contribution from Māori knowledge

Partnerships are established between iwi/hapū, researchers and other stakeholders. Iwi-led co-creation wānanga (workshops) set Mātauranga-ā-iwi (tribal knowledge) practices alongside scientific knowledge. Dialogues on volcanic state and landscape state are held/recorded as appropriate (oral recording/video), and a shared understanding developed about the landscape (e.g., river catchments) and important values such as Te Mana o te Wai. An iwi-volcano PhD researcher and a team of iwi-researchers will help build Mātauranga-ā-iwi.

Strength of current relationships

Our team has strong current relationships with all our key stakeholders. This includes the agencies listed above alongside Auckland/Waikato/Bay of Plenty/Hawkes Bay/Hamilton Councils, the 8 Taranaki iwi, industry organisations, critical infrastructure providers (National Lifelines Council), and financial businesses (AIG/AoN/BNZ). We will enhance and extend these relationships through stakeholder-led workshops in our co-creation processes, our Advisory Group, and aligned networks (National Lifelines Council, Resilience NSC Infrastructure Advisory Group).

Track record

Our team has an excellent track record in the delivery of integrated decision support tools for forecasting and assessing the socio-economic impacts associated with disruption events, through time and space for multiple stakeholders. Under the Wellington Resilience Project (Smith et al., 2018), senior executives of 18 infrastructure providers (covering transport, electricity, telecommunications, water, gas and petrochemical sectors) applied RiskScape-MERIT (McDonald et al., 2018) modelling to create an integrated all-of-infrastructure value case for resilience building in Wellington. The Auckland, Waikato, Bay of Plenty, Wellington and Canterbury Regional Councils have all adopted our socio-economic toolkit as one of their key strategic planning tools. The ability of our team to deliver user-friendly tools is evidenced by the strong uptake of their work within NZ, and adoption for assessing disruption in Australia (Infrastructure Australia) and Indonesia (Bappenas). Benefits delivered from our past volcanic hazard work include the implementation of successful response plans to the 2007 eruptions and the 2007 lake-breakout lahar from Mt. Ruapehu, as well as the 2012 eruption of Te Maari, Tongariro. This work included evaluating infrastructure risk mitigation strategies and protection structures, designing monitoring/warning systems and providing scientific advice throughout readiness, response and recovery phases of these events, with industry, community and government partners.

Uptake by other end or next users

We have exemplary relationships to all likely next-users including all CDEM organisations, critical infrastructure lifeline providers, Regional Councils, Territorial Authorities, central government ministries, departments and agencies as evidenced by our role in provision of strategic research and commercial services under the Resilience NSC (Rural co-creation laboratory, Hazard/Economics toolboxes and Infrastructure Advisory Group), QuakeCoRE, National Policy Statements (>25 studies) along with pivotal information provisioning for asset management planning purposes (e.g. Waikato Local Authority Shared-Services Agreement covering *all* 14 Waikato local authorities where our MBIE-funded W/ISE (Rutledge et al., 2008), and NPS-UDC work underpins *all* Council-related infrastructure investments). Our proposed socio-economic work will have significant spill-over benefits for these processes, enabling them to consider multiple future baselines, assess a full range of multi-capital and well-being impacts under conditions of uncertainty for alternative transition pathways.

Our proposed research will also **deliver wider benefits** to NZ by meeting requirements under the Local Government Act 2002 (e.g. infrastructure asset management and investment planning and information provision for the NPS-UDC), Resource Management Act 1991 (under S.6, adding strategic tools for risk-based management of hazards), Civil Defence Emergency Management Act 2002 and the proposed NDRS (managing risk and enabling/empowering/supporting community resilience). This research however goes significantly further, recognising that disruptive events are increasingly becoming the norm, rather than the exception. Our research is applicable to any form of on-going disruption (geo-political/environmental/hazard) providing us with decision-support tools that enable us to better navigate through complex transitions. Through our commercial partners, we will seek opportunities to leverage our research for wider benefit both within NZ and elsewhere.

Partnering arrangements

An Advisory Group will be established at the onset of the programme consisting of representatives from councils (Taranaki RC, Taranaki CDEM, New Plymouth, Stratford and South Taranaki), business (Venture Taranaki/AIG/Aon/BNZ), Taranaki-iwi, industry organisations (DairyNZ/PEPANZ), and government (MCDEM/DPMC/Treasury/ MBIE Petroleum and Minerals-Energy Markets/DIA/NZTA/CAA). The group will meet at least annually to review existing workplans, comment on future workplans, and aid in risk management.

Describe the impact track record of your team (560 words)

Our research is **distinguished by collaboration** across university researchers, Crown Research Institutes, independent research providers, international research leaders, stakeholders and iwi. We have assembled a world-class team of scientists with the right mix of skills and track records to be effective and impactful. In particular our team is experienced in transdisciplinary and applied research that is used in processes and commercial outcomes by our end-users. Our team builds on core partnerships formed over the last decade through the National Hazards Research Platform, the Resilience NSC, and many other joint research initiatives. We have added a raft of new collaborators, particularly early and mid-career researchers, eight PhD students and three Post-Doc fellows to further build NZ research capability.

Our team includes researchers across **Auckland, Massey, Canterbury and Lincoln universities, along with GNS Science, Market Economics**, Macquarie University (Australia), University of Iowa (USA), University of Bari, Bologna and Roma Tre (Italy). Our researchers include those who have successfully **delivered the largest-scale science research programmes offered globally**, including the Resilience NSC (Cronin, Proctor, McDonald, T. Wilson), >11 Marsden fund projects (Cronin, Baker, White, C. Wilson, Kennedy, Wang, Jolly), >20 MBIE (or ministry-equivalent) programmes (McDonald, Cronin, Proctor), an Earthquake Commission/Auckland Council project on Auckland Volcanic hazard (Lindsay, DEVORA), major NASA and US National Science Foundation grants (Ukstins) and large Australian Research Council grants (Turner, Rushmer). Furthermore, our team includes many high-performing emerging and early to mid-career researchers for whom we are providing leadership mentorship opportunities (Smith, Brenna, Wang, Sciascia, Harvey), and key roles within critical steps of the programme (Wreford, Scott, Rowe, Kilgour, Shane, Werner). We include key national leaders in Mātauranga Māori research and Māori engagement (Sciascia, Procter, McCallion).

Our past research in this area includes excellent/gold-star rated stakeholder engagement (e.g., Economics of Resilient Infrastructure, Learning to Live with Volcanic Risk, Living with Volcanic Risk, Facing the Challenge of Auckland's Volcanism). We have also conducted significant commercial research, with McDonald/Smith/Harvey and colleagues having undertaken >$70m of **research-based consultancy work** covering >1,600 projects. Working closely with end-users, they have co-developed several extensively applied integrated socio-economic decision-support tools (ISE/MERIT) that embed science directly into policy, decision-making (including **>200 successful expert witness appearances** on strategic regional/national investment issues in the Environment/High/Appeal/Supreme Courts. The MERIT model is an exemplar **spin-off commercial** product that is jointly administered under a MoU by GNS Science, ME and Resilient Organisations. Core team members have also worked collaboratively with MCDEM/NZTA/MoT/Treasury and local authorities, contributing to the National Disaster Resilience Strategy, **post-event decision-support** (1995-96 and 2007 Ruapehu eruptions; 2012 Tongariro eruption; 2016 Kaikoura earthquakes, 2010-11 Canterbury earthquakes), civil defence training exercises (2018 Alpine Fault Magnitude 8; Volcanic Exercises Pahu (2013), Ruaumoko and Billow (2008)), as well as **developing business investment cases** for resilience (2018 Wellington Resilience Project (18 public/private infrastructure providers)/2018-19 MBIE Fuel Security).

Our implementation strategy will draw on **high-calibre engagement skills** of Mr Fairclough (National Lifelines Chair, strategic government advisor), Māori business leader Mr McCallion (Waka Digital, for Iwi and Māori land/investment trusts), volcano-science communicator Mr Scott (GNS Science), as well as our community partners at Taranaki CDEM, Taranaki RC, and an Advisory Group of key parties. We have held numerous workshops with stakeholders over the last 18-months to build the framework for this research with our whole team.

Post-contract outcomes for New Zealand (280 words)

2 Years: NZ local and national government agencies and key industry sectors (agriculture/energy/tourism) are aware of the planning needs of long-term volcanic eruption scenarios from Mt. Taranaki and have considered planning options to reduce risk and adapt practice. In particular, the paradigm of evacuation and closedown of businesses/services has been reconsidered, with ongoing operation through long-term events considered as the most likely viable option for reduced economic impact. New hazard scenarios and probabilities of occurrence are available to inform planning and there are a series of new volcanic state indicators that reduce the uncertainty in volcanic hazard forecasts.

5 Years: NZ agencies (government and industry) have innovative socio-economic planning tools to manage adaptation to any future volcanic crises from Mt. Taranaki. The socio-economic tools are underpinned by a new generation of robust probabilistic models that reflect underlying volcanic process and state information. New probabilistic approaches to hazard evaluation at Mt. Taranaki are being applied in adapted forms to other volcano hazard evaluations in NZ and worldwide. A robust series of volcanic hazard state/potential indicators are tested and applied to inform more reliable probabilistic forecasts and manage long-term complex volcanic crises.

10 Years: NZ agencies (government and industry) regularly apply adaptive socio-economic planning tools to plan, track and evaluate adaptation strategies for a range of natural and technological hazards/issues facing the country. For volcanic scenarios at most NZ volcanoes, magmatic system indicators are well-established and feed robust hazard forecasting. Volcanic response and recovery planning, as well as long-term adaptation planning for permanent volcanic change, are fully integrated into the National Disaster Resilience Strategy and promulgated through the investment strategies of regional and national government, communities and businesses throughout NZ.

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Project plan

Work programme/Impact Statements

Sequence	Short title	Type	Start date	End date	Realisation date
1	Multiscale decision support tools that enable communities, farming/industry/business, iwi and government to create robust socio-economic transition pathways through ongoing disruption.	Impact statement	01/10/2019	30/09/2024	
1.1	Co-creation processes deep uncertainty	Research aim	01/10/2019	30/09/2024	
1.1.1	Affirm stakeholder and advisory groups	Critical step	01/10/2019	31/12/2019	
1.1.2	Agreed multiscale metrics and baselines	Critical step	01/01/2020	31/10/2020	
1.1.3	Review and refine prototype modelling	Critical step	01/11/2020	31/07/2022	
1.1.4	Stress-test robust decision-making	Critical step	01/08/2022	31/01/2024	
1.1.5	Co-creation processes, findings, and reflections	Critical step	01/02/2024	30/09/2024	
1.2	Decision support for dynamic transition	Research aim	01/10/2019	31/07/2024	
1.2.1	Creation of hazard-to-impact systems map	Critical step	01/10/2019	31/07/2021	
1.2.2	Hotspot identification	Critical step	01/01/2020	31/07/2021	
1.2.3	Bespoke sector modelling	Critical step	01/10/2020	31/10/2022	
1.2.4	Whole-of-economy modelling	Critical step	01/02/2022	31/10/2023	
1.2.5	Model simplification and distillation	Critical step	01/02/2022	31/07/2024	
1.3	Leveraging Mātauranga-ā-iwi	Research aim	01/10/2019	31/07/2024	
1.3.1	Building partnerships	Critical step	01/10/2019	31/10/2020	

1.3.2	Building Mātauranga-ā-iwi	Critical step	01/11/2020	31/07/2021	
1.3.3	Building dialogue on volcanic state/landscape	Critical step	01/08/2021	30/04/2022	
1.3.4	Traditional indicators and sites of unrest	Critical step	01/05/2022	31/01/2023	
1.3.5	Mātauranga-ā-iwi knowledge and practices	Critical step	01/02/2023	31/10/2023	
1.3.6	Mātauranga-ā-iwi alongside modelling	Critical step	01/11/2023	31/07/2024	
1.4	Simulating on-going and disruptive volcanism	Research aim	01/10/2019	31/07/2024	
1.4.1	Multiscale modelling of volcano dynamics	Critical step	01/10/2019	31/10/2022	
1.4.2	Statistical modelling of pre-/syn-eruptives	Critical step	01/10/2019	31/10/2023	
1.4.3	Statistical model of volcanic products	Critical step	01/10/2019	31/10/2023	
1.4.4	Weather-modulated susceptibility	Critical step	01/10/2019	31/10/2023	
1.4.5	Statistical emulators	Critical step	01/10/2019	31/10/2023	
1.4.6	Ash impacts modelling	Critical step	01/10/2019	31/10/2023	
1.4.7	Physical impacts for significant infrastructure	Critical step	01/05/2021	31/10/2023	
1.4.8	Visualisation tools	Critical step	01/11/2023	31/07/2024	
1.5	Geochemical tool chest for hazard forecasting	Research aim	01/10/2019	31/07/2024	
1.5.1	Pre-eruption diagnostic indicators	Critical step	01/10/2019	31/10/2022	
1.5.2	Magma pathways	Critical step	01/10/2019	31/10/2022	
1.5.3	Eruption pathways	Critical step	01/10/2019	31/10/2023	
1.5.4	Explosive potential	Critical step	01/10/2019	31/10/2023	
1.5.5	Realtime assessment	Critical step	01/05/2021	31/07/2024	

Impact statement 1

Impact statement 1

Impact statement title

Multiscale decision support tools that enable communities, farming/industry/business, iwi and government to create robust socio-economic transition pathways through ongoing disruption.

Impact statement (140 words)

Communities, businesses, Māori organisations and iwi/hapū, along with local and national government agencies of New Zealand are applying co-created, multiscale (spatially and temporally) socio-economic toolkits to adapt to severe ongoing disruption of daily life in response to long-term hazard events involving deep uncertainty. In particular, New Zealand is prepared to thrive alongside the high probability case of long-term future volcanic unrest at Mt. Taranaki alongside other similar national-scale environmental or technological hazards (such as climate change impacts and resource limitations). Agile adaptation and proactive planning are supported by quantitative testing and recasting of future socio-economic strategies under constantly-changing threats. This capability is underpinned by an integrated mathematical hazard engine, which translates fundamental system properties (in this case, volcano-magmatic systems) through a federated suite of specific hazard-simulations (e.g., ashfall, mass flow), incorporating a range of stress-tested volcanic 'potential' indicators.

Start date:
01/10/2019

End date:
30/09/2024

Impact statement leader:
Joel Baker
The University of Auckland
Mark Bebbington
Nicola Smith
Thomas Wilson
Ting Wang
The University of Otago

Impact statement 1 > Research aim 1.1

Research aim title

Co-creation processes deep uncertainty

Research aim statement (140 words)

Co-creation laboratories will assess transition pathways for multiple stakeholders at local-to-national scales. Using a collaborative and iterative approach our stakeholders will help design, refine and stress-test our decision-support tools to create robust socio-economic transition pathways through *ex-ante* simulations of ongoing disruption volcanic activity at Mt. Taranaki. These pathways will be evaluated through the use of multi-capital and intergenerational wellbeing metrics through space (community/district/region/nation) and across time (quarterly time-steps) over a 30-year horizon.

Start date:
01/10/2019

End date:
30/09/2024

Impact statement 1 > Research aim 1.1 > Critical step 1.1.1

Critical step title
Affirm stakeholder and advisory groups

Critical step statement (140 words)
The final set of stakeholders for our co-creation processes is affirmed. Over the last 18-months we have co-designed our proposal with many stakeholders (through workshops hosted by Taranaki CDEM, strategic central government meetings, and ongoing discussions with key industry/business/iwi groups). Within this step we will bring together representatives of these organisations, reflect on whether additional organisations are necessary, and contact any new additions.

Similarly, the Advisory Group for this programme is affirmed. The preliminary group is a leverage of the Infrastructure Advisory Group established under the Resilience National Science Challenge. Roger Fairclough, current chair of the National Lifelines Council, will chair this group.

Start date:
01/10/2019

End date:
31/12/2019

Impact statement 1 > Research aim 1.1 > Critical step 1.1.2

Critical step title
Agreed multiscale metrics and baselines

Critical step statement (140 words)
Co-designed multiscale metrics and baselines are produced. Through at least 4 stakeholder co-creation wānanga (workshops) we will have co-designed: a) multiscale socio-economic metrics, capturing various societal values, for assessing our transitions pathways against. They will cover multiple scales (community, district, region, nation), multiple capitals (natural, human, social, physical/financial), and intergenerational wellbeing (including distributional breakdowns). Where possible, they will be aligned with Treasury's Living Standards Framework and prototype Living Standards Analysis Model; and b) a set of baseline/counterfactual scenarios of social and economic growth to measure transition against. These growth scenarios will go beyond 'business-as-usual', acknowledging that a range of plausible futures exist for Taranaki and New Zealand.

Start date:
01/01/2020

End date:
31/10/2020

Impact statement 1 > Research aim 1.1 > Critical step 1.1.3

Critical step title
Review and refine prototype modelling

Critical step statement (140 words)
At least 4 stakeholder co-creation wānanga (workshops) are completed. These wānanga have reviewed and refined the prototype outputs from the socio-economic, probabilistic event-tree modelling, and volcanic streams to ensure that they are appropriate for inclusion in decision-making processes. The form of the outputs from the prototype modelling is finalised, and preliminary sets of outputs are produced to aid stakeholder/iwi leading the next set of wānanga for CS1.1.4. A dynamic typology of the direct geophysical and socio-economic impacts (as developed in collaboration with RAs1.2-4) has been produced.

Start date:
01/11/2020

End date:
31/07/2022

Impact statement 1 > Research aim 1.1 > Critical step 1.1.4

Critical step title
Stress-test robust decision-making

Critical step statement (140 words)
At least 6 co-creation wānanga (workshops) have been completed to stress-test and develop transition pathways through ex ante simulation of ongoing disruption at Mt. Taranaki. These wānanga were stakeholder/iwi-led.

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Start date:
01/08/2022

End date:
31/01/2024

Impact statement 1 > Research aim 1.1 > Critical step 1.1.5

Critical step title
Co-creation processes, findings, and reflections

Critical step statement (140 words)
Collaboratively developed joint guidelines for policy, planning and decision-making purposes have been produced. These will be an exemplar for aiding stakeholder groups in transition through on-going volcanic disruption. A final 'reflective learning' wananga was held and documentation of our co-creation process, findings and reflections has been developed.

Start date:
01/02/2024

End date:
30/09/2024

Impact statement 1 > Research aim 1.2

Research aim title
Decision support for dynamic transition

Research aim statement (140 words)
Develops decision support tools for just economic transition pathways through ongoing disruption, under deep uncertainty.

Start date:
01/10/2019

End date:
31/07/2024

Impact statement 1 > Research aim 1.2 > Critical step 1.2.1

Critical step title
Creation of hazard-to-impact systems map

Critical step statement (140 words)
A full hazard-to-impact systems map is produced. Created out of literature reviews, historic event analysis and expert elicitation, this map systematically describes the cause-effect sequences from an initial triggering (volcanic) event through to impacts across a broad range of potential wellbeing categories (i.e. as informed by Living Standards Framework). The mapping (influence diagrams/Bayesian-network approach) is sufficiently broad and generic to cover wide spatial, temporal, and intensity variations in triggering events, but also is adaptive enough to enable the incorporation of new knowledge as it emerges.

Start date:
01/10/2019

End date:
31/07/2021

Impact statement 1 > Research aim 1.2 > Critical step 1.2.2

Critical step title
Hotspot identification

Critical step statement (140 words)
Using the relationships defined in the systems map, along with a set of test scenarios capturing variation in the triggering event, network topology measures and indicators have been developed. These enable the identification of system components that are most important in amplifying disruption impacts through a socioeconomic system. Insights from this analysis have provided key insights to stakeholders on important 'hotspots' and 'leverage points'.

Start date:
01/01/2020

End date:
31/07/2021

Impact statement 1 > Research aim 1.2 > Critical step 1.2.3

Critical step title
Bespoke sector modelling

Critical step statement (140 words)
Bespoke sectoral decision-support tools are completed for selected sectors. These tools were co-created with sectoral stakeholders (food, transport, energy and tourism) utilising, as appropriate, the most advanced frameworks and methods for decision-making under uncertainty (i.e. real options analysis, dynamic adaptive pathways, robust decision-making). Within the development process these tools were stress-tested across multiple events, providing stakeholders with practise in: agile decision-making under long-term and unfolding disruptions; early identification of key decision points for each sector; and identification of strategies that are robust for alternative contexts.

Start date:
01/10/2020

End date:
31/10/2022

Impact statement 1 > Research aim 1.2 > Critical step 1.2.4

Critical step title
Whole-of-economy modelling

Critical step statement (140 words)
The sectoral models developed in CS1.2.3 are integrated into the dynamic whole-of-economy model i.e. a top-down stock-and-flow model, incorporating an open economy general-equilibrium structure. The outcomes of implementing a set of resilience and 'just transitioning' strategies, co-designed with stakeholders, have been evaluated using this whole-of-economy model. Reporting capabilities have been extended, so that rather than just reporting aggregate measures of economic performance (e.g. GDP, employment), they provide a more nuanced lens to interpret impact, consistent with Treasury's National Living Standards Framework.

Start date:
01/02/2022

End date:
31/10/2023

Impact statement 1 > Research aim 1.2 > Critical step 1.2.5

Critical step title
Model simplification and distillation

Critical step statement (140 words)
The socio-economic models have been distilled and simplified. This enables them to now be run very quickly without the need for high performance computing. This distillation and simplification included replacing existing complex linkages with emulators (such as neural networks trained on model dynamics) where possible, sensitivity analysis to identify unnecessary or redundant elements. Using machine learning techniques to elucidate emergent relationships, enabled gains in performance through bypassing complex model coupling or chaining.

Start date:
01/02/2022

End date:
31/07/2024

Impact statement 1 > Research aim 1.3

Research aim title
Leveraging Mātauranga-ā-iwi

Research aim statement (140 words)
Creates transition pathways for Iwi/hapū and Māori land trusts under on-going volcanic disruption, by applying new knowledge of volcanic behaviour and novel robust probabilistic forecasts and integrating Mātauranga-ā-iwi traditional knowledge of volcanic warning and hazard response. Using co-creating processes alongside iwi to ensure that their māturanga is interwoven into key decision making processes.

Start date:
01/10/2019

End date:
31/07/2024

Impact statement 1 > Research aim 1.3 > Critical step 1.3.1

Critical step title
Building partnerships

Critical step statement (140 words)
Partnerships have been established between iwi/hapū and volcano researchers, building a shared sense of involvement and investment in the research programme's aims and values. These partnerships are fundamental to enable both traditional and western science knowledge to be developed and communicated when considering impacts and decisions for responses to volcanic disruptions. An iwi-volcano researcher and communication network now exists in the Taranaki region.

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Start date:
01/10/2019

End date:
31/10/2020

Impact statement 1 > Research aim 1.3 > Critical step 1.3.2

Critical step title
Building Mātauranga-ā-iwi

Critical step statement (140 words)
Ongoing dialogue through a series of hui and wānanga (more than 4) has contributed to iwi/hapū understanding on Mātauranga-ā-iwi of the volcano and natural resources. This knowledge has been recorded as appropriate (e.g. oral recording, video, report). Collaboratively, through the partnerships built in CS1.3.1, researchers and local iwi/hapū have determined where it would be appropriate (and possible) to leverage Mātauranga-ā-iwi for use in the programme's modelling toolkits.

Start date:
01/11/2020

End date:
31/07/2021

Impact statement 1 > Research aim 1.3 > Critical step 1.3.3

Critical step title
Building dialogue on volcanic state/landscape

Critical step statement (140 words)
Brokered dialogues between iwi/hapū and volcanic researchers on volcanic state and landscape state have been held, and recorded as appropriate (e.g. oral recording, video, report). These dialogues were focused on the permanence or transience of landscape features – such as river catchments/landslides – and the potential impact on important values including Te Mana o te Wai.

Start date:
01/08/2021

End date:
30/04/2022

Impact statement 1 > Research aim 1.3 > Critical step 1.3.4

Critical step title
Traditional indicators and sites of unrest

Critical step statement (140 words)
Traditional indicators and sites of volcanic unrest (kokowai, springs, vents, warm ground) have been identified. This knowledge is stored in text, GIS (spatial), audio recordings, or other data formats, as appropriate.

Start date:
01/05/2022

End date:
31/01/2023

Impact statement 1 > Research aim 1.3 > Critical step 1.3.5

Critical step title
Mātauranga-ā-iwi knowledge and practices

Critical step statement (140 words)
Traditional Mātauranga-ā-iwi knowledge and practices (tikanga) specifically relating to volcano, alpine, river, and coastal hazards are identified and documented as appropriate (e.g. oral recording, video, report).

Start date:
01/02/2023

End date:
31/10/2023

Impact statement 1 > Research aim 1.3 > Critical step 1.3.6

Critical step title
Mātauranga-ā-iwi alongside modelling

Critical step statement (140 words)
Iwi-led wānanga have been completed that interweave Mātauranga-ā-iwi and practices alongside new scientific knowledge. Dissemination of our work, via our project website, is in Te Reo Māori along with English.

Start date:
01/11/2023

End date:
31/07/2024

Impact statement 1 > Research aim 1.4

Research aim title
Simulating on-going and disruptive volcanism

Research aim statement (140 words)
Develops a novel mathematical typology for integrating volcanic hazard on an all-of-NZ basis by a) developing new mathematical science through a 'test-bed' of the forecasting power of geochemical indicators; b) integrating these indicators into a novel probabilistic forecast tool for Taranaki. This will extend existing eruption history/pattern recognition approaches enabling a unique mechanical model of Taranaki to be created; c) taking a range of process-based models of volcanic phenomena (ashfall, pyroclastic flow, lahar, debris avalanche, gas) and creating mathematical relationships that describe geo-physical impacts on built (horizontal/vertical) infrastructure; and d) collates this information for estimation of hazard probabilities for societal consequences, including tracking uncertainties.

Start date:
01/10/2019

End date:
31/07/2024

Impact statement 1 > Research aim 1.4 > Critical step 1.4.1

Critical step title
Multiscale modelling of volcano dynamics

Critical step statement (140 words)
Bayesian hierarchical models (with uncertainty) have been used to quantify the timescales of magma ascent, magma and gas flux. A multiscale hierarchical model of internal volcano dynamics (geochemistry/petrology) has been developed.

Start date:
01/10/2019

End date:
31/10/2022

Impact statement 1 > Research aim 1.4 > Critical step 1.4.2

Critical step title

Statistical modelling of pre-/syn-eruptives

Critical step statement (140 words)

Links between geochemistry/petrology and the long-term eruption record (recurrence and style) have been thoroughly investigated to determine the forecasting power of different indicators. Findings from this investigation led to the formulation and testing of a simulation procedure based on geochemical observations from past events at Taranaki and/or analogue volcanoes.

Start date:

01/10/2019

End date:

31/10/2023

Impact statement 1 > Research aim 1.4 > Critical step 1.4.3

Critical step title

Statistical model of volcanic products

Critical step statement (140 words)

An efficient statistical model for generating estimates of different volcanic products (what ends up where) at a daily scale has been created. This model simulates eruptions using a mixture of tephra fall and collapses and daily weather conditions. The model has been tested and documented.

Start date:

01/10/2019

End date:

31/10/2023

Impact statement 1 > Research aim 1.4 > Critical step 1.4.4

Critical step title

Weather-modulated susceptibility

Critical step statement (140 words)

The model from CS1.4.3 has been extended by incorporating a synthetic synoptic weather stream along with a stochastic triggering condition, so that lahar initiation can be simulated. This extension has been added to the model documentation.

Start date:

01/10/2019

End date:

31/10/2023

Impact statement 1 > Research aim 1.4 > Critical step 1.4.5

Critical step title
Statistical emulators

Critical step statement (140 words)
Statistical emulators of geo-physical impacts have been constructed by running existing numerical flow models, under a statistical experimental design in parameter space. These statistical emulators simulate flows (ashfall, pyroclastic flow, lahar, debris avalanche, gas) incredibly fast and efficiently.

Start date:
01/10/2019

End date:
31/10/2023

Impact statement 1 > Research aim 1.4 > Critical step 1.4.6

Critical step title
Ash impacts modelling

Critical step statement (140 words)
An ash impacts model is completed and documented. This model uses a fast, efficient procedure to simulate both atmospheric densities (for air travel impacts) and deposition of ash across the North Island and beyond (for infrastructure impacts), on a day-to-day schedule incorporating the synthetic synoptic weather stream.

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Start date:
01/10/2019

End date:
31/10/2023

Impact statement 1 > Research aim 1.4 > Critical step 1.4.7

Critical step title
Physical impacts for significant infrastructure

Critical step statement (140 words)
The dynamic volcano (CS1.4.2/1.4.3), flow susceptibility (CS1.4.4), emulators (CS1.4.5), and the ash impact (CS1.4.6) models have been combined to produce spatio-temporal estimates of geo-physical impacts, including uncertainties. To simulate the hazard impacts on the built environment, these geo-physical impacts have been linked to nationally significant infrastructure using mathematical vulnerability and susceptibility relationships.

Start date:
01/05/2021

End date:
31/10/2023

Impact statement 1 > Research aim 1.4 > Critical step 1.4.8

Critical step title
Visualisation tools

Critical step statement (140 words)
A suite of visualisation tools has been assembled and published on the website, where appropriate. These tools link volcano behaviour right through to monitoring/ impact observation and have been developed and adapted through engagement with stakeholders including local iwi/hapū.

Start date:
01/11/2023

End date:
31/07/2024

Impact statement 1 > Research aim 1.5

Research aim title
Geochemical tool chest for hazard forecasting

Research aim statement (140 words)
Develops new volcanic science to discover parameters that reliably indicate volcanic state and hazard potential, and apply these in relation to magma processes that govern specific eruption outcomes for Taranaki. This includes developing new chemical and physical approaches and experimental targets to parametrise settings for deep to surface processes.

Start date:
01/10/2019

End date:
31/07/2024

Impact statement 1 > Research aim 1.5 > Critical step 1.5.1

Critical step title
Pre-eruption diagnostic indicators

Critical step statement (140 words)
Geochemical and geophysical indicators have been developed from the record of past volcanism that: a) more robustly indicate the time to the next eruption; b) link chemical and geophysical properties to eruption volume/magnitude; and c) reliably forecast the likely duration of an eruption.

Start date:
01/10/2019

End date:
31/10/2022

Impact statement 1 > Research aim 1.5 > Critical step 1.5.2

Critical step title
Magma pathways

Critical step statement (140 words)
A model of crustal structure and magma source/processing is completed. This informs new scenarios of magma assembly and rise, including timescales and warning periods from geophysical detection of unrest to eruption. Environmental, chemical, and physical indicators of unrest are identified and codified, including traditional Māori knowledge (from RA1.3). Critical thresholds are established to indicate a shift to a new episode of activity.

Start date:
01/10/2019

End date:
31/10/2022

Impact statement 1 > Research aim 1.5 > Critical step 1.5.3

Critical step title
Eruption pathways

Critical step statement (140 words)
A quantitative framework of the environmental and conduit factors that lead to diverse eruption outcomes is complete, based on detailed textural and experimental studies on Taranaki eruption products. A suite of paleo-eruption scenarios for Taranaki are complete, informed and expanded by targeted knowledge of analogue volcanic systems at Vesuvius, Merapi and Colima. A library of indicators for the starting phases of specific eruption scenarios has been compiled from the first erupted products of scenarios built.

Start date:
01/10/2019

End date:
31/10/2023

Impact statement 1 > Research aim 1.5 > Critical step 1.5.4

Critical step title
Explosive potential

Critical step statement (140 words)
Short-lived isotopes (uranium decay series) have been used to quantify the partitioning of magma and gas and the transport of magmatic gas to eruption, based on Taranaki and analogue volcanoes. A framework of gas-pathways and eruption outcomes at Taranaki has been constructed from studies of melt inclusions and chemical diffusion in erupted minerals. The chemical and isotopic study results are integrated into a series of indicators that predict eruption explosivity.

Start date:
01/10/2019

End date:
31/10/2023

Impact statement 1 > Research aim 1.5 > Critical step 1.5.5

Critical step title
Realtime assessment

Critical step statement (140 words)
A quantitative assessment framework has been developed that enables the rapid updating of forecasts of the next events during an eruption sequence. Forecasts are updated based on rapid analysis of new eruption products, chemical and geophysical signals, and a library of highly detailed paleo-eruption scenarios.

Start date:
01/05/2021

End date:
31/07/2024

Research plan, methods & specialist resources

Research plan (560 words)

We seek to build much-needed capacity for New Zealand to adapt/transform under ***long duration and evolving natural hazard disruptions***, by focusing on a high-probability volcanic-disruption case posing great national-scale consequences. During such events, the nature of impacts and risks shift rapidly. To achieve this objective, we will: (1) build the science to better predict 'what-comes-next' during a disruption, including advancing our ability to capitalise on new information as it emerges (RAs1.3-1.5); and (2) create the tools, processes and experience that enables decision-makers to select robust strategies for transformation (RAs1.1-1.3). We demonstrate this approach through a major Taranaki volcanic scenario, anticipated by geological knowledge, but not yet experienced during European history.

Our research comprises five research aims (Fig. 1), with interconnected critical steps (see Gantt Chart). **RA1.1 (Co-creation processes; Wilson/Fairclough)** forms our foundation. For the Taranaki context, co-creation involves successive workshops/wānanga where stakeholders stress-test the utility of new decision-support tools (from RA1.2), define criteria to select robust strategies, and practice formulating and selecting strategies, all in a collaborative process that favours learning across multiple worldviews. **RA1.2 (Decision-support for dynamic transition; Smith/Wreford)** delivers the tools that enable stakeholders to *ex ante* identification of key risks, decision points and robust strategies. Defining features will be system-wide consideration of impacts, multi-scale applicability, adaptation to new information (from RA1.4), rapid deployment, and stakeholder-led co-design (from RA1.1). **RA1.3 (Leveraging Mātauranga Māori; Procter/Sciascia)** creates transition pathways for Iwi/hapū communities and businesses impact-based investment cases, by applying new robust probabilistic forecasts and knowledge of volcano behaviour (from RAs1.4-1.5) and leveraging decision-support tools (from RA1.2). It also establishes Mātauranga-ā-iwi knowledge of volcanic warning and hazard response. Under **RA1.4 (Simulating on-going & disruptive volcanism; Bebbington/Wang),** the forecasting power of quantitative indicators of volcanic potential (from RA1.5) are tested and refined, then incorporated into novel probabilistic forecasting models for Taranaki volcano. These will encompass a time-varying long-term view, alongside short-term changes during event sequences. By leveraging a range of process-based models of volcanic phenomena, forecasts are also extended to full simulations of geophysical impacts on society/economy, while continually tracking uncertainties. In **RA1.5 (Geochemical tool-chest for hazard forecasting; Brenna/Ukstins),** new volcanic science discovers parameters that reliably indicate volcanic state and hazard potential, based on magma processes that govern specific eruption outcomes at Taranaki. This includes developing new chemical and physical approaches and experiments to parametrise processes from deep-to-surface settings.

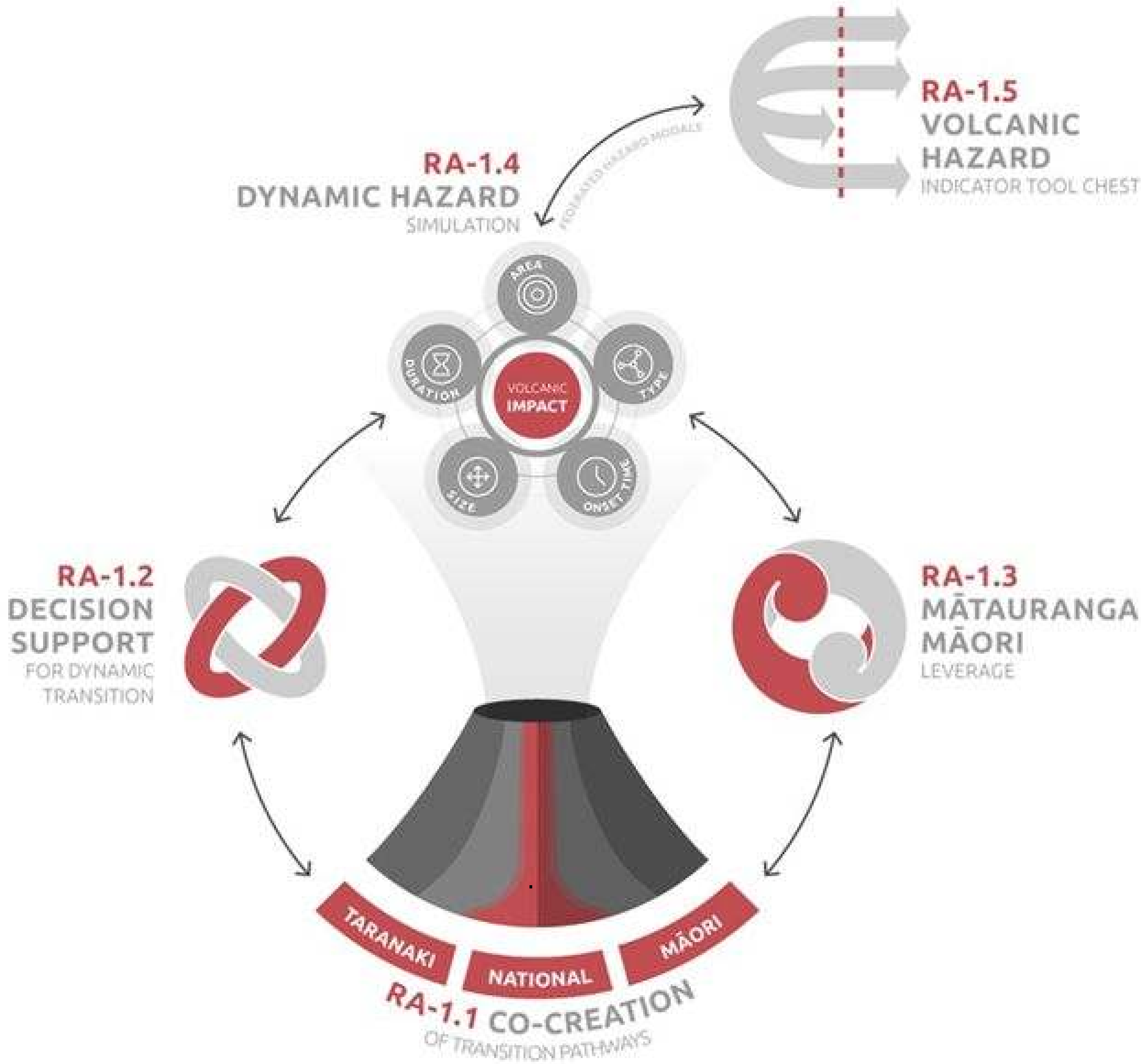
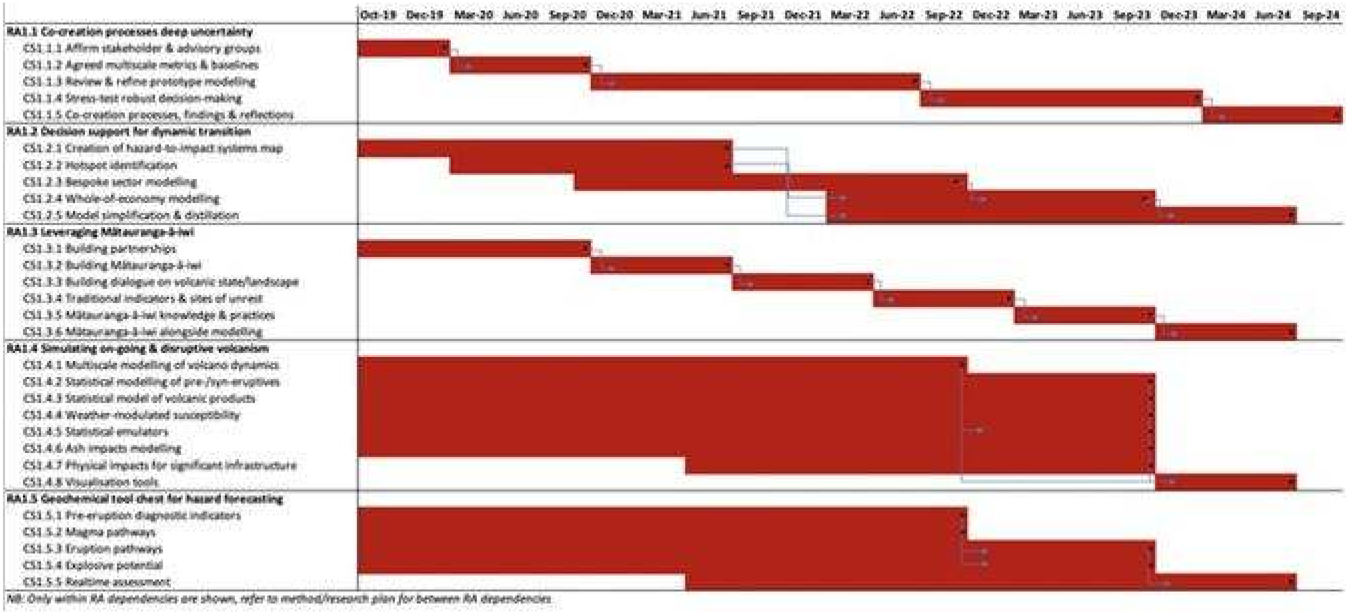


Figure 1: Project design and Research Aims (RA).

Regular monthly **project management** meetings between the science/RA co-leads will track progress and ensure ongoing iteration between all workstreams. An annual full-team meeting will be held in June/July of each year to highlight findings, track performance, and refine research directions for the following year.

To **manage technical risk**, our team (particularly RA1.2/RA1.4) will adopt best practice in software engineering. Specifically, we will apply agile processes that: a) continually deliver working prototypes using an incremental and modular design that adds science progressively; b) use collaborative co-design with stakeholders (leveraging Mātauranga-ā-iwi) to refine and stress-test working prototypes through regular face-to-face workshops (as per RA1.1); c) uniquely test volcanism indicators for predictive suitability, replacing/updating/adapting them on-the-fly as the research progresses; d) pay constant attention to technical excellence and good design through agile continuous iterative feedback between RAs (e.g. RA1.1 to/from RA1.2, RA1.2 to/from RA1.4, and RA1.4 to/from RA1.5); and e) use cloud-based services for **managing data and model** version (Git/GitHub) control.

Gantt Chart



Methods (1680 words)

Programme rationale and key research question: NZ is faced with several socio-economic risks including geo-political changes, environmental challenges (climate change, biodiversity loss, exposure to natural hazards) and technological disruption. We urgently require decision-making frameworks (tools/processes/practices) that answer: "*How best can communities, businesses, iwi and government transition through socio-economic disruption that is on-going and continuous*?" We address this dilemma through an *ex-ante*, but highly plausible, exemplar of volcanic unrest at Mt. Taranaki. **Our choice of Mt. Taranaki as a case study** is because it is the most likely NZ volcano to cause national-scale impacts over our lifetimes, with a 50% chance of erupting over the next 50 years (Damaschke et al., 2015). Moreover, once erupting Taranaki's activity is likely to continue for decades disrupting almost every aspect of society and economy.

How we will perform our research: We use an iterative co-creation process, that significantly leverages existing investments in the Resilience NSC, and progressively adds cutting-edge science in a global-first end-to-end assessment framework that significantly reduces uncertainty for decision-making as we transition through long-term volcanic unrest. Our research has five inter-linked Research Aims (NB: RA=Research Aim, CS=Critical Step (in **bold**), connections between RAs are made explicit (in *italics*), **rationale** for each is RA is provided following its title, and all **data/models are managed** by agile processes using cloud-computing services (Git for version control, GitHub for data/model storage).

RA1.1 Co-creation processes under uncertainty (Wilson and Fairclough)

Co-creation design will assess transition pathways for multiple stakeholders at local-to-national scales. Using an iterative approach, our stakeholders will help design, refine and stress-test our decision-support tools to create robust socio-economic transition pathways via *ex-ante* simulations under ongoing volcanic unrest. These pathways will be evaluated using multi-capital and intergenerational well-being metrics through space (community/district/region/nation) and across time (quarterly time-steps) over a 30-year horizon.

Key steps: a) Affirm stakeholder and advisory groups (**CS1.1.1**) – involves establishing a Terms of Reference for the groups and review group membership (current TaranakiCDEM/Taranaki RC/National Lifelines Council/DairyNZ/DoC/iwi/ResilienceNSC Infrastructure Advisory Group) and addition of new members as deemed necessary; b) Agreed multiscale metrics and baselines – involves co-designing with RA1.2 multiscale socio-economic metrics to measure transition, aligned with Treasury's National Living Standards Framework (Treasury, 2018b) (**CS1.1.2**), c) Review and refine prototype impact modelling (**CS1.1.3**) – involves collaboration with RA1.2 and RA1.4; d) Stress-test robust decision-making with RA1.2 (**CS1.1.4**) – requires **stakeholder/iwi-led** wānanga/workshops that create and record transitions pathways through the on-going volcanic disruption; and e) Co-creation processes, findings and reflections – wider dissemination of research findings/processes/modelling and record 'reflective learning' for future researchers (**CS1.1.5**).

RA1.2 Decision support for dynamic transition (Smith and Wreford)

To best protect the functioning of NZ's socio-economic system, we require science to support decision-making for the sectors that are most likely to be critically disrupted. Additionally, we require science to understand how the wider community may change, including enabling, incentivising or restricting behaviours, and the collection and distribution of resources to support those in need. Robust decision-support tools require a 'whole-of-system' understanding of the pathways through which physical impacts of an unfolding volcanic event, and resulting human responses, will instigate changes in well-being. For decision-support tools to be useful they must be deployed in a timely fashion, which will be aided here by pre-crisis testing, development and implementation.

Key steps: a) Creation of hazard-to-impact systems diagram (**CS1.2.1**) – easily updated cause-effect sequences (multiscale influence diagrams/Bayesian-network approaches/fault-tree analysis) propagating from trigger event through consequential hazard chain, to impact across multiple well-beings (aligned to Treasury's Living Standards Framework (King et al., 2018)); b) Hotspot identification (**CS1.2.2**) – network topology identifying key system components whose compromise amplifies (or whose addition dampens) disruption impacts; c) Sectoral modelling (**CS1.2.3**) – we co-design with our delivery partners (food/transport/energy/tourism) (contributes to *RA1.1, CS1.1.2&3*) **novel bespoke decision-support tools** (real options analysis/dynamic adaptive pathways/robust decision making), stress-test these tools under dynamically unfolding volcanic events, and develop robust adaptive strategies for action; d) Whole-of-economy modelling (**CS1.2.4**) – integrates the sectoral (**CS1.2.3**) with cutting-edge top-down stock-flow socio-economic (computable general equilibrium) models and, in turn, evaluates a set of resilience 'just transition' strategies reporting across multiple well-beings **under deep uncertainty** (contributes to *RA1.1, CS1.1.2-4*); e) Model simplification/distillation (**CS1.2.5**) – of our integrated complex socio-economic systems model using emulators (trained neural networks by-passing complex model coupling/chaining) enabling rapid deployment, including **for other types of disruptive events**.

RA1.3 Leveraging Mātauranga Māori (Procter and Ṡciascia)

It is imperative that we understand how people culturally-locked to locations of intense and continual disruption, make a transition through it. By leveraging Mātauranga-ā-iwi we will understand how people have previously adapted under volcanic unrest, identifying traditional indicators and sites of volcanic state through co-creating processes alongside iwi to ensure that their māturanga is interwoven into key decision-making processes. The latter includes stress-testing robust decision-support tools for 'stay and defend' approaches to Maori business (Tourism/Agriculture) during ongoing (semi-permanent) disruption conditions with rapid change and evolving risks. Dissemination of our work, via our project website, will be in Te Reo Māori along with English and we are committed to returning this knowledge to the communities and iwi through a series of wānanga.

Key steps: a) Build partnerships and an iwi-volcano researcher and communication network in the Taranaki region (**CS1.3.1**), b) Build dialogue and understanding on Mātauranga-ā-iwi of the volcano, its natural resources, and how we may leverage that knowledge in development of our decision-support toolkits (**CS1.3.2**) – contributes to *RAs 1.1 (CS1.1.2)* and *1.2 (CS1.2.3&4)*; c) Build engagement and dialogue on volcanic state and landscape, brokering dialogues about the permanence or transience of landscape features including landslides/river catchments (including Te Mana o te Wai) (**CS1.3.3**) – contributes to *RA1.4 (CS1.4.4)*; d) identify traditional indicators and sites of volcanic unrest (kokowai/springs/vents/warm ground) (**CS1.3.4**) – contributes to *RA1.4 (CS1.4.2)*; e) identify traditional Mātauranga-ā-iwi and tikanga (protocols/practices) of volcano/alpine/river/coastal hazards in the Taranaki region (**CS1.3.5**); and f) integrates scientific knowledge alongside new Mātauranga-ā-iwi practices (**CS1.3.6**) – contributes to *RA1.1 (CS1.1.4)*, creating transition pathways for iwi/hapū and Māori land trusts by applying Mātauranga-ā-iwi traditional and new knowledge into our decision support tools, including for impact-based investing.

RA1.4 Simulating on-going & disruptive volcanism (Bebbington and Wang)

Develops a novel statistical/mathematical methodology for integrating volcanic hazards on an all-of-NZ basis by a) developing new statistical science through a 'test-bed' of the forecasting power of volcanic potential indicators (derived from *RA.15, CS1.5-5*); b) integrating these indicators into a novel probabilistic forecast tool for Taranaki that includes precursory behaviour and dynamically updates through activity cycles. This extends the static eruption history/pattern recognition approaches creating a unique computational/mechanical model of Taranaki; c) leveraging a range of existing process-based models of volcanic phenomena, including ashfall (Turner et al., 2014); pyroclastic flow (Procter et al., 2010; Lube et al., 2015); lahar (Procter et al., 2012); debris avalanche (Roverato et al., 2104; Tost et al., 2014)); acid gas/leachates (Cronin et al., 2003; 2014), and creating statistical relationships that describe physical impacts on built infrastructure; and d) collates this information for estimation of impact hazard probabilities for the socio-economic consequences modelling (*RA1.2, CS1.2.3&4*), including tracking uncertainties. Overall, this RA develops a **world-first test-bed** for rapidly evaluating and selecting indicators, from empirical geochemistry/petrology studies based on their predictive power in determining key characteristics of volcanism (magnitude/onset time/eruption style/duration). Indicator selection is an iterative process involving selection/statistical testing/adoption/discarding – thus, an indicator may initially be adopted, but later replaced supplemented as better indicators become available.

Key steps: a) Multiscale hierarchical model of internal volcano dynamics developed (**CS1.4.1**) – quantifies the evolution of geochemical and petrological states using Bayesian hierarchical models (with uncertainty); b) Statistical model of pre- and syn-eruptive indicators are developed – links geochemistry foundations to existing long-term record, using point-process models with geochemical data as co-variants, and analogues to calibrate geochemistry/geophysics linkages. False alarms/stalled eruptions are included (**CS1.4.2**); c) simulates eruptions using mixture of tephra fall and collapses, establishing an efficient model for predicting distribution (**CS1.4.3**); d) weather-modulated susceptibility for post-eruptive flow-events/lahars determined (**CS1.4.4**); e) Statistical emulators constructed, permitting fast efficient simulation of flows – this represents a significant advance over existing numerical flow models, which run slowly, making their use in nimble syn-event simulations difficult (**CS1.4.5**); f) Ash impacts model (incorporating weather) created – simulates atmospheric densities (for air travel) and deposition of ash across North Island and beyond (**CS1.4.6**); g) regional impacts determined for national significant infrastructure – combines **CS1.4.2-6** to determine physical infrastructure damage spatio-temporally (contributes to *RA1.2, CS1.2.3&4*) (**CS1.4.7**); and h) Suite of visualization tools assembled (**CS1.4.8**).

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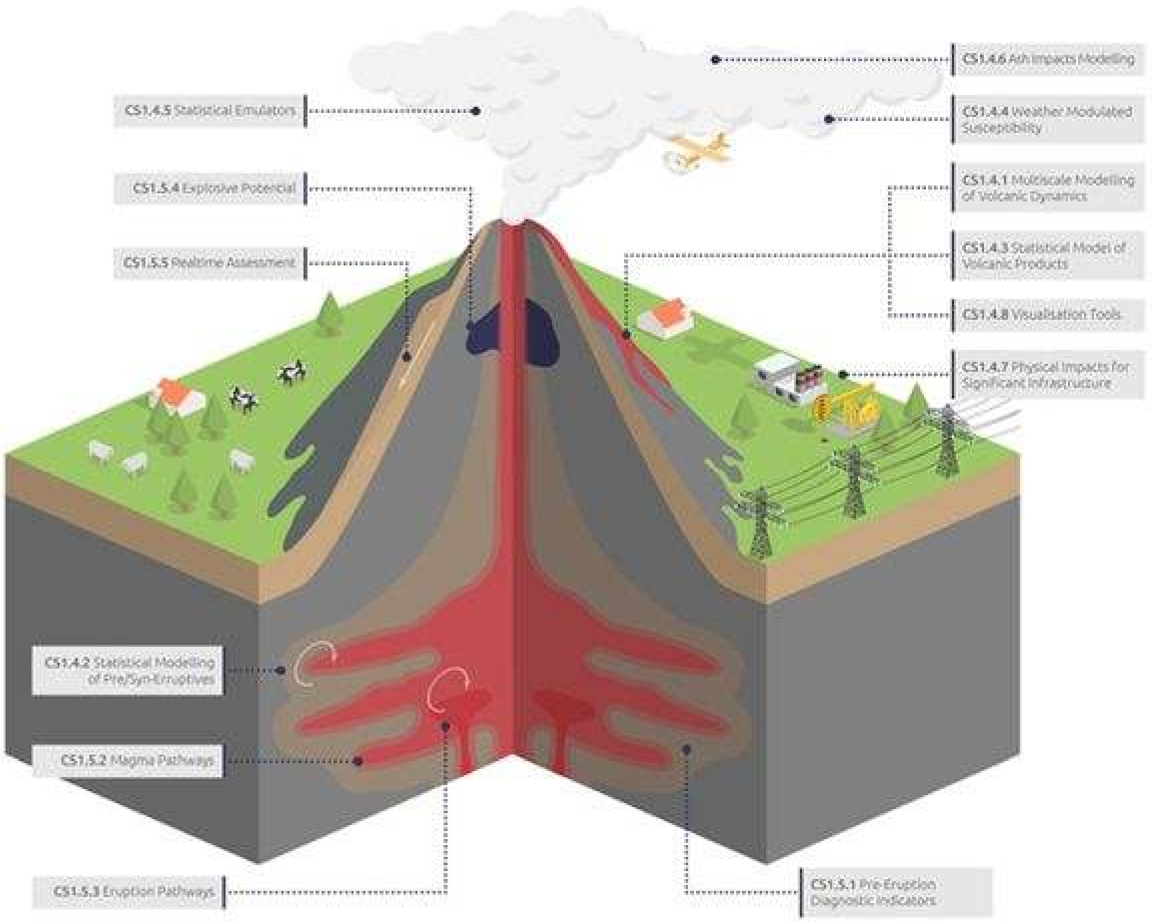

Figure 2 Volcanic potential indicators, from RA1.4 and RA1.5

RA1.5 Geochemical tool chest for hazard forecasting (Brenna and Ukstins)

Developing new volcanic science to discover parameters that reliably indicate volcanic state, hazard potential, as well as specific eruption outcomes. This includes developing new chemical and physical approaches and experimental targets to parametrise settings for deep-to-surface volcanic processes (Fig. 2). Output indicators from this research streams are continuously tested through *RA1.4*'s statistical test-bed.

Key steps: a) Pre-eruption diagnostic indicators geochemical and geo-physical indicators are created from records of past volcanism that more robustly indicate time to the next eruption and better link chemical and geophysical properties to eruption volume/magnitude (**CS1.5.1**); b) New scenarios of magma assembly and rise are generated that provide timescales and warning periods from geophysical detection-of-unrest to eruption, identification and coding of chemical and physical indicators of unrest (including from Māori observation and knowledge), and critical thresholds are established of 'shifts' to new episodes of activity (**CS1.5.2**); c) A quantitative framework of environment and conduit factors leading to diverse eruption outcomes is generated along with a library of paleo-eruption scenarios, based on detailed textual and experimental studies of Taranaki (also analogue volcanic systems e.g. Vesuvius/Merapi/Colima) eruption products (**CS1.5.3**); d) Short-lived isotopes (Uranium decay series) are used to quantify the partitioning of magma/gas, the transport of magmatic gas to eruption based on Taranaki (and analogue systems), and to predict eruption explosivity (**CS1.5.4**); and e) a quantitative framework is established that enables rapid update (real-time assessment) of forecasts of the next events during an eruptive sequence, based on the rapid analysis of new eruptive productions, chemical and geophysical signals and the library of paleo-eruption scenarios as per *CS1.5.3* (**CS1.5.5**).

Specialist resources (560 words)

Analytical equipment

We have arranged reciprocal access for critical instrumentation with our key international collaborators. There are other alternative back-up laboratories for the main instruments. The resources we need include:

1. Electron Microprobe Analysis – for analysing crystal histories and compositional zonation, and compositions of melt-inclusions. We can access a standard instrument at Victoria University ($500/day), a more-sensitive instrument for mapping and trace element analysis at the University of Iowa through A.Prof. Ukstins ($US600/day), and an ultra-high resolution (Field-emission Electron Microprobe) instrument currently being purchased/installed at University of Auckland ($800/day)
2. Laser-Ablation Inductively-Coupled Mass-Spectrometry Analysis (LA-ICP-MS), or solution ICP-MS. Trace-elemental analysis of single-crystals and zonation of crystals will be carried out at University of Auckland (standard LA-ICP-MS $600/day), with a higher resolution multi-collector mass-spectrometer for in-crystal strontium isotopic analysis at University of Otago ($1500/day).
3. Secondary Ion Mass Spectrometry (SIMS or Ion microprobe) – to analyse light elemental diffusion (e.g., Li in feldspar), and water/volatile content of melt inclusions within minerals. This is available via collaborative arrangements with A.Prof. Ukstins at the Arizona State University ($US1000/day)
4. Fourier Transform Infrared Analysis (FTIR), to analyse carbon dioxide and water content within glasses and melt inclusions. Standard instruments are at Massey, Canterbury and Auckland universities ($250/day), with higher resolution and mapping capabilities at the Australian Synchrotron (Schipper, Cronin, Ukstins, Brenna and Kennedy are expert users and our international collaborator Prof. Rushmer sits on the Australian Synchrotron steering committee).
5. Isotopic clean laboratories, U-Series isotopic processing lines and high-resolution multi-collector mass spectrometers for U-series, Pb, Sr, Nd, Re-Os isotopic systems as well as U-Series dating. These facilities are available via a new Thermo-Analytical demonstration lab at Macquarie University managed by our international collaborator Prof. Turner ($AU1000-3000/day depending on analytical methods).
6. Micro-Computed Tomography – for analysis of magma-vesiculation/bubble textures and the determination of explosivity of eruptions. This is available at University of Auckland and via the Imaging and Medical Beamline of the Australian Synchrotron (Schipper, Cronin and Kennedy are expert users). In addition, via collaborators of Cronin, specialised high-resolution microtomography systems can be accessed at other synchrotrons around the world (e.g., UK and Berkeley)
7. High-precision Argon-Argon radiometric dating – for age analysis of key deposits. Can be obtained via a long-term collaborator at Oregon State University ($US700/determination).

Experimental equipment

1. Physical explosion experimental equipment and laboratory at Ludwigs Maximillian University, Munich, Germany, which enables the pressurisation and explosion of Taranaki samples to simulate conduit and ejection conditions. This facility is available to expert users Cronin and Kennedy via our international partners Dr Scheu and Prof. Dingwell ($NZ20-30k per experimental season – 2-3 months' work).
2. High-temperature, high-pressure experimental melt/crystallisation laboratory at University of Rome – for calibration of crystallisation histories and rise conditions for Taranaki magmas. This facility is available for expert user Brenna for nominal costs ($NZ5k per series of experiments).
3. High-temperature magma viscosity experimental laboratory at University of Canterbury. This is available via Kennedy (~$300/day).

Computing/modelling equipment

All computing, modelling and virtual-reality simulation resources are available within Massey University, Market Economics, and especially via pre-arranged time on the NeSI high performance computing system in New Zealand, for which Procter, Mead and McDonald are expert users. In addition, Procter has long-standing collaborative arrangements with the supercomputer centre of the State University of New York in Buffalo, USA and Mead with CSIRO, Australia.

Funding requested

Impact statement funding

Multiscale decision support tools that enable communities, farming/industry/business, iwi and government to create robust socio-economic transition pathways through ongoing disruption.

Start date	Months	Funding			Total annual funding
01/10/2019	12	$2,735,357.00 GST excl. amount	$410,303.55 GST amount	$3,145,660.55 Total amount	$3,145,660.55
01/10/2020	12	$2,735,357.00 GST excl. amount	$410,303.55 GST amount	$3,145,660.55 Total amount	$3,145,660.55
01/10/2021	12	$2,735,357.00 GST excl. amount	$410,303.55 GST amount	$3,145,660.55 Total amount	$3,145,660.55
01/10/2022	12	$2,735,357.00 GST excl. amount	$410,303.55 GST amount	$3,145,660.55 Total amount	$3,145,660.55
01/10/2023	12	$2,735,357.00 GST excl. amount	$410,303.55 GST amount	$3,145,660.55 Total amount	$3,145,660.55
	Total:	$13,676,785.00 GST excl. amount	$2,051,517.75 GST amount	$15,728,302.75 Total amount	**$15,728,302.75**

Project budget

Personnel:	292,608.00
General operating expenses:	649,081.00
Building depreciation/rental:	0.00
Equipment depreciation/rental:	0.00
Overheads:	314,001.00
Subcontracting:	1,479,668.00
Other expenditure:	0.00
Average annual budget:	**2,735,358.00**

Additional budget information

Project team

Year 1 FTE figures

Name	Organisation	Role	Include CV in print	ORCID
Shane Cronin	The University of Auckland	Key researcher, Science leader	✔	https://orcid.org/0000-0001-7499-603X
Thomas Wilson	University of Canterbury	Key researcher, Leader	✔	https://orcid.org/0000-0002-8816-0708
Marco Brenna	University of Otago	Key researcher	✔	https://orcid.org/0000-0001-6096-6999
James Scott	University of Otago	Other		https://orcid.org/0000-0001-5185-6261
James White	University of Otago	Other		Not invited
Tracy Rushmer	Macquarie University	Key researcher	✔	https://orcid.org/0000-0003-0192-2384
Postdoctoral (TBN)	The University of Auckland	Post-doctoral researcher		Not invited
Postdoctoral TBN	Market Economics Ltd	Post-doctoral researcher		Not invited
Mark Bebbington	Massey University	Key researcher, Leader	✔	https://orcid.org/0000-0003-3504-7418
Garry McDonald	Market Economics Ltd/Director	Key researcher, Science leader	✔	Invitation sent

Nicola Smith	Market Economics	Key researcher, Leader	✔	Invitation sent
Emily Harvey	Market Economics	Key researcher	✔	https://orcid.org/0000-0002-8134-3843
Simon Turner	Macquarie University	Key researcher	✔	https://orcid.org/0000-0002-6426-6495
Michael Rowe	The University of Auckland	Other		https://orcid.org/0000-0002-8052-2882
Ben Kennedy	The University of Canterbury	Key researcher	✔	https://orcid.org/0000-0001-7235-6493
Rita Bento-Allpress	The University of Auckland	Contract manager		Not invited
Aaron McCallion	Waka Digital Ltd	Key researcher	✔	Invitation sent
Ting Wang	The University of Otago	Key researcher, Leader	✔	https://orcid.org/0000-0002-4767-3777
Colin Wilson	Victoria University of Wellington	Other		Not invited
Joel Baker	The University of Auckland	Key researcher, Leader	✔	Invitation sent
Jonathon Procter	Massey University	Key researcher	✔	Invitation sent
Jan Lindsay	The University of Auckland	Other		Not invited
Gert Lube	Massey University	Other		Invitation sent
George Perry	The University of Auckland	Other		Not invited

Phil Shane	University of Auckland	Other		https://orcid.org/0000-0002-7824-1184
Arthur Jolly	GNS Science	Key researcher	✔	https://orcid.org/0000-0003-1020-9062
Sigrun Hreinsdottir	GNS Science	Other		https://orcid.org/0000-0003-0143-1251
Brad Scott	GNS Science	Other		https://orcid.org/0000-0003-3560-0287
Geoff Kilgour	GNS	Key researcher	✔	https://orcid.org/0000-0003-0361-1555
Dave Rogers	Department of Conservation	Other		Invitation sent
Teresa Gordon	Taranaki Regional Council	Other		https://orcid.org/0000-0002-9499-1188
Anita Wreford	Lincoln University	Key researcher	✔	https://orcid.org/0000-0002-9546-4080
Roger Fairclough	Neo Leaf Global Ltd	Other		https://orcid.org/0000-0003-0387-1859
Stuart Mead	Massey University	Key researcher	✔	Invitation sent
Kirsty Lee Thomas	GNS Science	Other		Not invited
Ingrid Ukstins	Iowa State University	Key researcher	✔	https://orcid.org/0000-0002-2315-9626
Christina Magill	Macquarie University	Key researcher	✔	https://orcid.org/0000-0001-8872-1678

GUIDO GIORDANO	Università Roma Tre	Other		https://orcid.org/0000-0002-5819-443X
Mary Jo Vergara	Market Economics Ltd	Other		Not invited
Acushla Sciascia	Massey University	Key researcher	✔	Invitation sent
Ian Schipper	Victoria University Wellington	Key researcher	✔	Invitation sent
Natalia Pardo	University de Las Andes	Key researcher	✔	https://orcid.org/0000-0002-8247-4116
Roberto Sulpizio		Key researcher	✔	https://orcid.org/0000-0002-3930-5421
Postdoctoral (TBN)	The University of Canterbury	Post-doctoral researcher		Not invited
Postdoctoral University	Massey University	Post-doctoral researcher		Not invited
Cynthia Werner		Key researcher	✔	Invitation sent
Federico Lucchi		Other		Invitation sent

Key relationships

End users

Impact statements in your application

Number	Title
IS 1	Multiscale decision support tools that enable communities, farming/industry/business, iwi and government to create robust socio-economic transition pathways through ongoing disruption.

Organisation	IS 1
Civil Aviation Authority	✔
Earthquake Commission (EQC)	✔
New Zealand Airports Association	✔
AIG	✔
MBIE - Energy Markets	✔
Ministry for the Environment	✔
New Zealand Treasury - National Infrastructure Unit	✔
New Plymouth District Council	✔
Local Government New Zealand	✔
Ministry of Business Innovation & Employment	✔
Aon	✔
Petroleum Exploration and Production Association of New Zealand	✔
MPI	✔
Taranaki Regional Council	✔
DoC	✔
DairyNZ	✔
Taranaki CDEM	✔
New Zealand Transport Agency	✔
New Zealand Lifelines Council	✔
Department of Prime Minister & Cabinet - Ministry of Civil Defence & Emergency Management	✔
Ministry of Transport	✔
Department of Prime Minister & Cabinet - National Risk Unit	✔
Ministry of Civil Defence and Emergency Management (MCDEM)	✔
Department of Internal Affairs - Central Government Local Government Partnerships Group	✔
MBIE - Petroleum and Minerals	✔

International collaborations/partnerships

Organisation	Organisation country:	Researcher/project name:
Università degli studi di Bari Aldo Moro	Italy	Prof. Roberto Sulpizio
Università di Bologna	Italy	A.Prof. Federico Lucchi
Università Roma Tre	Italy	Prof. Guido Giordano
Macquarie University	Australia	Prof. Simon Turner
Macquarie University	Australia	A.Prof. Tracy Rushmer
The University of Iowa	United States of America (the)	A.Prof. Ingrid Ukstins
Ludwig-Maximillan Universitat	Germany	Dr Bettina Scheu
Ludwig-Maximillan Universitat	Germany	Dr Cristian Montanaro
Universidad de Las Andes	Colombia	A.Prof Natalia Pardo

International collaboration

Our project will be assisted by world-renowned scientists with compelling international track-records. Based in Europe, Australia and the USA, our collaborators bring internationally-recognised mentorship to the programme, a sounding-board for managing technical risks, and strong established collaborative relationships with the research team, including joint research.

Italian volcanologists, Prof. Roberto Sulpizio, A.Prof. Federico Lucchi, Prof. Guido Giordano

Our three Italian colleagues are existing collaborators of Cronin and all are specialists on re-awakening stratovolcanoes, with experience around the world. The leverage that they bring lies in decades of experience on managing the risks of stratovolcanoes at Etna, Stromboli, Vulcano and Vesuvius. Vesuvius poses an equivalent problem to Mt. Taranaki, with its last eruption occurring during 1944, but there is an expectation of enduring activity that will force a major transformation of the mega-city of Naples. Vulcano is a major touristic centre, with its last eruption in 1888. Both Stromboli and Etna have been in a semi-permanent eruptive state for centuries, with large explosive eruptions on a semi-regular basis, posing ongoing adaptation and economic transformation challenges. Sulpizio is a specialist in understanding hazard processes and eruptive scenarios from deposit sequences and will form part of the teams working on CS1.5.3 and CS1.5.5. Lucchi is a specialist in volcanic collapse, mass-flow deposits and complex volcanic transitions. His expertise will help translate the steps from eruption events into the multi-hazards that follow them, including lahars, enduring changes to catchments, and major periods of erosion. Flank-collapse and major volcanic landslides are the greatest hazards anticipated at Mt. Taranaki and will induce fundamental changes to the landscape, including changes to river/water supply catchments and the possible complete abandonment of land buried by tens of metres of volcanic debris. Lucchi will be a key resource to help us interpret the pre-conditions for volcanic collapse in CS1.5.1. Giordano specialises in chemical-volcanic processes, pre-explosive magmatic conditions and also the temperature properties of volcanic flows, especially pyroclastic flows. His work will contribute to the aims of CS1.5.4.

Australian geochemists, Prof. Simon Turner, A.Prof. Tracy Rushmer

Our work on the rise rates of magmas, the detection of gas-state and explosive potential of magmas, and the understanding of the overall structure of the magma system beneath Mt. Taranaki, is contingent upon a range of detailed trace elemental and especially isotopic analyses. Turner is the leader of a major new geochemical laboratory facility, the southern Hemisphere demonstration laboratory for Thermo Scientific at Macquarie University. He is also the world leader in application of U-Series isotopic techniques to understand the timescales of magma assembly and rise and to thereby understand the gas content that magmas bring to the surface. He will apply these techniques to Taranaki and analogue systems in order to better achieve CS1.5.4 and build rapid assessment tools to track ongoing changes in eruptions for CS1.5.5. Rushmer is a specialist on the application of synchrotron x-ray methods to understand magmatic processes, as well as experimental magma-studies. Her experimental approaches will form a major support to CS1.5.1 and CS1.5.2. Both Turner and Rushmer facilitate access to unique geochemical facilities that are not available in New Zealand.

US volcanologist/geochemist, A.Prof. Ingrid Ukstins

Ukstins is a specialist in the micro-scale analysis of crystals and volatiles in magmas, with an emphasis on evaluating explosive vs. effusive volcanism and understanding from petrological techniques the rise rates of magmas to eruption. She also runs a high-precision electron microprobe laboratory at the University of Iowa and is an expert of other microanalytical techniques such as Secondary Ion Mass Spectrometry. Her access to these resources will make her a key participant in achievement of RA1.5. She, along with Dr Marco Brenna are ideally placed to lead the RA1.5, with both having a complementary range of background skills. Ukstins has worked in large igneous provinces of China and Arabia, as well as in ongoing erupting areas in Iceland and Chile. Her wide experience in a range of analytical techniques means that she provides a broad overview needed to co-manage RA1.5.

German experimental laboratories collaborators: Dr Bettina Scheu and Dr Cristian Montanaro

The experimental volcanology laboratory at Ludwigs Maximillian University of Munich is world renowned and unique. Here we can carry out a range of high-pressure explosion experiments to understand magma fragmentation, conduit flow and eruption column steadiness. The latter is crucial for determining if eruption columns will produce stable tephra falls or collapse to produce deadly pyroclastic flows. They also enable us to understand the stability of lava domes rapidly during a crisis, as well as to simulate a range of magma-hydrothermal interactions and explosive eruptions. Scheu and Montanaro will contribute most strongly to CS1.5.3 and CS1.5.5.

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Subcontracting

Impact statement

Multiscale decision support tools that enable communities, farming/industry/business, iwi and government to create robust socio-economic transition pathways through ongoing disruption.

Subcontracting organisation:	Subcontracting status:	Year 1	Year 2	Year 3	Year 4	Year 5
Market Economics Ltd	Letter of Intent	$424,925.00	$424,925.00	$424,925.00	$424,925.00	$424,925.00
Cynthia Werner	Letter of Intent	$57,779.45	$57,779.45	$57,779.45	$57,779.45	$57,779.45
Waka Digital Ltd	Letter of Intent	$54,050.00	$54,050.00	$54,050.00	$54,050.00	$54,050.00
Neoleaf Global Ltd	Letter of Intent	$65,952.50	$65,952.50	$65,952.50	$65,952.50	$65,952.50
Massey University	Letter of Intent	$370,116.00	$370,116.00	$370,116.00	$370,116.00	$370,116.00
The University of Otago	Letter of Intent	$125,314.35	$125,314.35	$125,314.35	$125,314.35	$125,314.35
The University of Canterbury	Letter of Intent	$387,046.30	$387,046.30	$387,046.30	$387,046.30	$387,046.30
Victoria University of Wellington	Letter of Intent	$37,660.20	$37,660.20	$37,660.20	$37,660.20	$37,660.20
Lincoln University	Letter of Intent	$45,634.30	$45,634.30	$45,634.30	$45,634.30	$45,634.30
GNS Science	Letter of Intent	$133,137.80	$133,137.80	$133,137.80	$133,137.80	$133,137.80
	Total	**$1,701,615.90**	**$1,701,615.90**	**$1,701,615.90**	**$1,701,615.90**	**$1,701,615.90**

Supporting information

Intellectual property management

Intellectual property management (560 words)

Intellectual Property (IP) Management Team

An IP Management Team will be established to deal with IP. We will have one representative from each participating organisation including partnership end-user/iwi if they desire. The IP management team will be responsible for all IP generated during our programme. The IP management team representatives (and/or their appointed specialist IP support representatives) will meet at least once a year.

Guidelines for IP Management

All IP arrangements will be recorded through subcontracts and in Terms of Reference for co-creation processes in alignment with the following broad-level guidelines:

1. *Existing IP*: The existing IP owned by a party will remain with that party, but each party will make their existing IP available, for the purpose of this research programme.
2. *Indigenous IP:* Mātauranga Māori is a living taonga and is subject to the rights in the Treaty of Waitangi. In recognition of this, processes around indigenous IP and data will be thoroughly discussed with all iwi end-users at the beginning of the programme, in conjunction with the Te Mana Raraunga (Māori Data Sovereignty Network), and we will be reviewed at our annual (or as required) IP Management Team meetings.
3. *Freedom to operate*: We will have access to all existing IP made available for the programme. We will continually check our freedom to operate with all end-users including iwi.
4. *New IP availability*: A key principle of our IP management is that any IP generated be made available in order to achieve the goals of our research programme, including potentially development of freely available CDEM guidelines for transitioning under the ongoing disruption of a Taranaki/NZ volcanic event. In this regard, there is no need to protect the vast majority of IP within NZ, but due management of the process of information release will be required.
5. *New IP protection*: It is possible that the programme may result in new commercial products or services requiring legal protection. The IP Management Team through their annual review process (or as required) will work with all participating organisations to ensure that new commercial products or services are identified to all participating organisations. Ownership of any such IP will rest with the contributing organisation/s to the programme undertaking that area of research.

Protection of IP

If key participating organisations/end-users require certain data to be held confidentially, this will be dealt with by ‘ring fencing’ activity associated with that data and agreeing that outputs that are available to the wider team to ensure the programme may operate.

Special ethical and regulatory requirements

Special ethical and regulatory requirements (280 words)

There are no specialist ethical or regulatory approvals required to undertake the proposed research.

Proposal Glossary

Word/acronym/ abbreviation/te reo Māori	Full description/translation
CAA	Civil Aviation Authority
CDEM	Civil Defence and Emergency Management
Co-creation	Research conducted jointly between practitioners or the community and academics, with equal relationships, to empower people to become agents of change
CS	Critical Step
DIA	Department of Internal Affairs
DPMC	Department of the Prime Minister and Cabinet
Hapū	*Te Reo Māori*: primary governance unit. Clusters of whanau (extended families) that form a social grouping with a shared territory. The word is often interpreted as 'sub-tribe'.
Hui	*Te Reo Māori*: gathering or meeting
Iwi	*Te Reo Māori:* largest social/economic/political units in Māori society, linked by descent from a common ancestor or ancestors (shared whakapapa). The word is often interpreted as 'tribe'.
Kaitiaki	*Te Reo Māori:* guardians, custodians, caregivers
Kaitiakitanga	*Te Reo Māori:* guardianship, stewardship, trusteeship
Lahar	A violent mudflow or debris flow composed of a slurry of pyroclastic material, rocky debris and water, formed on volcanoes
Magma	Molten rock beneath the Earth's surface, consisting of a mixture of melt and crystals in any relative proportion
Mātauranga-ā-iwi	*Te Reo Māori:* Iwi knowledge - defined as the relationship between the tribe and its land base. Mātauranga-a-iwi is knowledge specific to an iwi and its rohe (tribal area).
Mātauranga Māori	*Te Reo Māori:* Māori knowledge - the body of knowledge originating from Māori ancestors, including the Māori world view and perspectives, Māori creativity and cultural practices.
ME	Market Economics
MED	Ministry of Economic Development
MERIT	Measuring the Economic Resilience of Infrastructure Tool (McDonald et al., 2018; Smith et al., 2017; 2018)
MBIE	Ministry for Business Innovation and Employment
MCDEM	Ministry of Civil Defence and Emergency Management
NDRS	Proposed *National Disaster Resilience Strategy* currently under consideration in the House.
NHRP	National Hazard Resilience Platform
NPS-UDC	National Policy Statement on Urban Development Capacity
NZTA	New Zealand Transport Authority
PEPANZ	Petroleum Exploration & Production New Zealand
Pre- and syn-eruptive	Before and at the time of an eruption
Pyroclastic flow	A ground-hugging, high-velocity and superheated gas-particle flow that travels at high speeds outwards from volcanoes to destroy everything in their path.
RA	Research Aim
RAID	Risk, Assumptions, Issues, Dependencies: a common analysis used in risk assessment.
RC	Regional Council
Resilience NSC	Resilience to Nature's Challenges National Science Challenge
RiskScape	Joint venture with NIWA and GNS Science to provide a modular framework to estimate impacts and losses for assets exposed to natural hazards.
SAM	Smart models for Aquifer Management: MBIE funded-research programme, 2014-2018.
Stratovolcano	A conical volcano built up by many layers (strata) of hardened lava, tephra, pumice and ash. These volcanoes are characterised by a steep profile and periodic, explosive eruptions.
Taiao	*Te Reo Māori:* the natural world or environment
Taonga	*Te Reo Māori:* property possession, treasure, anything prized - applied to anything considered to be of value including socially or culturally valuable objects, resources, phenomenon, ideas and techniques.

Tangata Whenua	*Te Reo Māori:* the people of the land, i.e. the iwi or hapū which have mana whenua (customary authority) over a particular area.
Te Mauri o Te Wai	*Te Reo Māori:* The life supporting capacity, life force of water
Tikanga	*Te Reo Māori:* correct procedure, custom, lore, method, meaning, protocol. The customary system of values and practices that have developed over time and are deeply embedded in a cultural context.
Wānanga	*Te Reo Māori:* conference, forum, meeting of ideas, seminar.
Whakaoranga	*Te Reo Māori: r*esilience - the capacity of whānau to overcome adversity, flourish and enjoy better health and wellbeing.
Whakapapa	*Te Reo Māori:* genealogy, ancestral lineage– including not just human ancestors but all living things, the earth and sky, and the creation of the universe.
Whānau	*Te Reo Māori:* extended family grouping. Basic social unit of Māori society.
W/ISE	Waikato Integrated Scenario Explorer/(Auckland) Integrated Scenario Explorer (Rutledge et al., 2008)

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Classifications

ANZSRC

Impact statements in your application

Number	Title
IS 1	Transitioning Taranaki to a Volcanic Future

Research Classification - ANZSRC FOR

Anzsrc For	**IS 1%**	
There are no matching results		

Research Classification - ANZSRC SEO

Anzsrc Seo	**IS 1%**	
There are no matching results		

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Whakataka te hau

Karakia to open and close meetings

Whakataka te hau ki te uru	Cease the winds from the west
Whakataka te hau ki tonga	Cease the winds from the south
Kia mākinakina ki uta	Let the breeze blow over the land
Kia mātaratara ki tai	Let the breeze blow over the ocean
Kia hī ake ana te atakura	Let the red-tipped dawn come with a sharpened air
He tio, he huka, he hauhu	A touch of frost, a promise of glorious day
Tūturu o whiti whakamaua kia tina.	Let there be certainty
Tina!	Secure it!
Hui ē! Tāiki ē!	Draw together! Affirm!

Nau mai e ngā hua

Karakia for kai

Nau mai e ngā hua	Welcome the gifts of food
o te wao	from the sacred forests
o te ngakina	from the cultivated gardens
o te wai tai	from the sea
o te wai Māori	from the fresh waters
Nā Tāne	The food of Tāne
Nā Rongo	of Rongo
Nā Tangaroa	of Tangaroa
Nā Maru	of Maru
Ko Ranginui e tū iho nei	I acknowledge Ranginui above and
Ko Papatūānuku e takoto ake nei	Papatūānuku below
Tūturu o whiti whakamaua kia	Let there be certainty
tina	Secure it!
Tina! Hui e! Taiki e!	Draw together! Affirm!