Colin Dall

To: Colin Dall

From: Richard Griffiths <richardg@nrc.govt.nz>
Sent: Tuesday, 15 October 2024 5:52 pm
To: Colin Dall <colind@nrc.govt.nz>
Subject: RE: Aluminium monitoring/ testing

Kia ora Colin,

Bad news I am afraid - there was a mix up with the lab, and they haven't analysed the dissolved metal bottles (and these have now been discarded). We can still get the Total Al result, but I don't think there any point to that. This month's run is scheduled for this Thursday, so we will add Dissolved Al and Total Al to that run.

Ngā mihi

Richard Griffiths
Resource Scientist Coastal
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

DDI 09 470 1210 Ext 9255
M 027 7159923

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

P 0800 002 004 » **W** www.nrc.govt.nz

From: Richard Griffiths
Sent: Wednesday, October 9, 2024 9:05 AM
To: Colin Dall <colind@nrc.govt.nz>
Subject: RE: Aluminium monitoring/ testing

Results are not back yet.

From: Colin Dall <colind@nrc.govt.nz>
Sent: Tuesday, October 8, 2024 4:08 PM
To: Richard Griffiths <richardg@nrc.govt.nz>
Subject: RE: Aluminium monitoring/ testing

Thanks for the update. Have we received the results of testing from the last Kaipara Harbour run if we've done it yet?

Colin

From: Richard Griffiths <richardg@nrc.govt.nz>
Sent: Tuesday, October 8, 2024 3:43 PM
To: Colin Dall <colind@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>; Tess Dacre <tessd@nrc.govt.nz>
Cc: Clark Ehlers <clarke@nrc.govt.nz>; Ricky Eyre <rickye@nrc.govt.nz>
Subject: RE: Aluminium monitoring/ testing

Kia ora Colin,

Just took a call from . The biotoxin tests on the snapper with cloudy eyes (zombie snapper) came back negative. Advice from MPI's vets is that it is possible that whatever caused the condition is no longer present in the snapper so biotoxins can't be ruled out. Cataract can be a symptom of kidney or liver damage so biotoxins are still seen as a plausible cause of the symptoms (i.e. biotoxins were present earlier in the year - caused the damage and the fish has been swimming around with the symptoms ever since. MPI are going to put out some media around this shortly and request that people send them any snapper with the cloudy eye condition caught during summer (when biotoxins are more likely to be present in the fish). Rich has asked that this information be treated as confidential until they do their media release.

Ngā mihi
Richie

From: Colin Dall <colind@nrc.govt.nz>
Sent: Thursday, October 3, 2024 6:47 PM
To:
Cc: Richard Griffiths <richardg@nrc.govt.nz>; Jason Donaghy <JasonDo@nrc.govt.nz>; Clark Ehlers <clarke@nrc.govt.nz>; Ricky Eyre <rickye@nrc.govt.nz>; Manas Chakraborty <manasc@nrc.govt.nz>
Subject: RE: Aluminium monitoring/ testing

Kia ora

As I'm away tomorrow, just a quick addition. We have also done some more recent water and sediment testing for Al, albeit mostly in the Kaipara Harbour as part of our routine SOE monitoring of the harbour. Regarding that water testing, the samples were analysed for both total and dissolved Al to help address the "so what" question about the potential adverse effects of high Al concentrations. The first round of that water testing results were:

Determinands	Test method name	109665	109666	109668	109669
		Kaipara Harbour at Wahiwaka Creek	Kaipara Harbour at Te Hoanga Point	Kaipara Harbour at Te Kopua	Kaipara Harbour at K Point
Aluminium Dissolved (g/m3)	Aluminium (Dissolved) by ICP-MS	<0.1 (P)	<0.1 (P)	<0.1 (P)	<0.1 (P)
Aluminium Total (g/m3)	Aluminium (Total) by ICP-MS	0.43 (P)	0.3 (P)	0.31 (P)	0.29 (P)

As you can see, no dissolved Al was detected in any of the samples.

MPI has also tested Snapper (that displayed cataracts etc that the media have described as Zombie fish) for metals (including Al) with test results within normal ranges.

In short, although we have found high Total Al concentrations in some Northland rivers, our evidence to date indicates that they are the result of catchment geology and natural processes rather than human activities, albeit that soil containing naturally high concentrations of Al exposed by human activities may 'exacerbate' the situation. We don't think that the high Al concentrations pose significant risk to humans or aquatic ecology.

Ngā mihi

Colin Dall
Pou Whakaritenga – Group Manager Regulatory Services
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

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M 027 226 8414

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

From: Manas Chakraborty <manasc@nrc.govt.nz>
Sent: Thursday, October 3, 2024 5:08 PM
To:
Cc: Richard Griffiths <richardg@nrc.govt.nz>; Colin Dall <colind@nrc.govt.nz>; Jason Donaghy <JasonDo@nrc.govt.nz>; Clark Ehlers <clarke@nrc.govt.nz>; Ricky Eyre <rickye@nrc.govt.nz>
Subject: RE: Aluminium monitoring/ testing

Kia ora

We had some exceptionally high Aluminium (10-30mg/L Total Al but did not test for dissolved fraction) results between May and June 2023 investigation samples in Northern Wairoa catchments and Victoria River (Far North catchment) mostly coincided with high cumulative rainfalls preceding the sampling events and consequent high suspended sediment concentration (indicated by exceptionally low water clarity and high TSS such as 400-1300 g/m3). However, for all these exceptionally high Al concentrations the pH levels were within normal range (i.e. between 6.5 and 8). It is the acidic pH, and high DOC (i.e. high redox potential) that will determine Al toxicity causing fish kill.

According to Land & Water Science' Physiographic model elevated Al concentrations in Northland's soil and water are expected in those catchments with high overland flow risk (as percentage of effective rainfall) and poorly drained weathered geology dominated with mudstone, sandstone, and peat. So, for Northland lot of it is predominantly influenced by particular soil and geology types and therefore predominantly naturally occurring processes. According to Northland soil specialist Bob Cathcart "*The particular soil types that will be generating the greatest volumes of Al are within one soil suite (a family of soils from the same or very similar parent material). They are the moderately to strongly leached Awapuku, Waimatenui, Mangonui and Awarua soils of the Te Kie Suite. The sediment will certainly be causing turbidity as it has a very high proportion of colloidal clay. One of the features of these soils that once the thin topsoil is lost, you have high Al and high clay subsoil exposed*".

Also, just came across the attached report from Waikato the other day on the influence of Acid Sulphate Soil causing on elevated heavy metal concentrations and consequent fish death, you might have seen that already.

I am forwarding your email to relevant managers in case they want to comment on NRC's further actions regarding this topic.

Thanks.

Ngā mihi

Manas Chakraborty
Resource Scientist - Freshwater
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

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At NRC we value and encourage flexible working and I recognise that my working hours may be different to yours. I'm sending this message at a time that suits me. I don't expect you to read, respond or action it outside of your normal working hours.

Week 1					Week 2				
Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu	Fri
Work from home	At work	At work	At work	Work from home	Work from home	At work	At work	Work from home	Day off

From:
Sent: Thursday, October 3, 2024 9:31 AM
To: Manas Chakraborty <manasc@nrc.govt.nz>; Richard Griffiths <richardg@nrc.govt.nz>
Subject: Aluminium monitoring/ testing

Kia ora Manas and Richie

I am reaching out to see whether you have any updates on the aluminium results that were found the Dargaville area earlier this year. I would be really interested to hear if you are taking any further actions/investigations in this space, and any progress you have made.

On our end, I am looking to progress an envirolink advice grant that will design an investigation attempting to determine natural background concentrations of a range of metals including aluminium.

Kind regards,

Environment Southland *Te Taiao Tonga*

P 03 211 5115 |
Cnr Price St & North Rd, Private Bag 90116, Invercargill 9840

Kathryn Pabirowski

From: Richard Griffiths
Sent: Wednesday, 18 September 2024 5:32 pm
To: Manas Chakraborty; Colin Dall
Cc: Tess Dacre; Cathy Orevich; Ricky Eyre
Subject: RE: Aluminium data from SOE sites 2023-24_11092024.csv

Kia ora

Do we have any fish or macroinvertebrate data for the Mangakahia? That might help with the 'so what' question. If fish and macroinvertebrate communities are healthy and happy then we can stop worrying. Although I am guessing there are other issues in that river (e.g. 3cm viz) that may be impacting fish and macroinvertebrate communities. Are there any IRIS records of dead fish in that river? if not, again good news. Manas out of interest what do freshwater fish do, during these high rainfall, high sediment load events? Are there refuges where they can shelter/escape the high flow sediment laden water?

Kaipara run tomorrow has been postponed due to high wind. It's rescheduled for next week – I will add Al as requested.

Richie

From: Manas Chakraborty <manasc@nrc.govt.nz>
Sent: Wednesday, September 18, 2024 3:23 PM
To: Colin Dall <colind@nrc.govt.nz>; Richard Griffiths <richardg@nrc.govt.nz>
Cc: Tess Dacre <tessd@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>; Ricky Eyre <rickye@nrc.govt.nz>
Subject: RE: Aluminium data from SOE sites 2023-24_11092024.csv

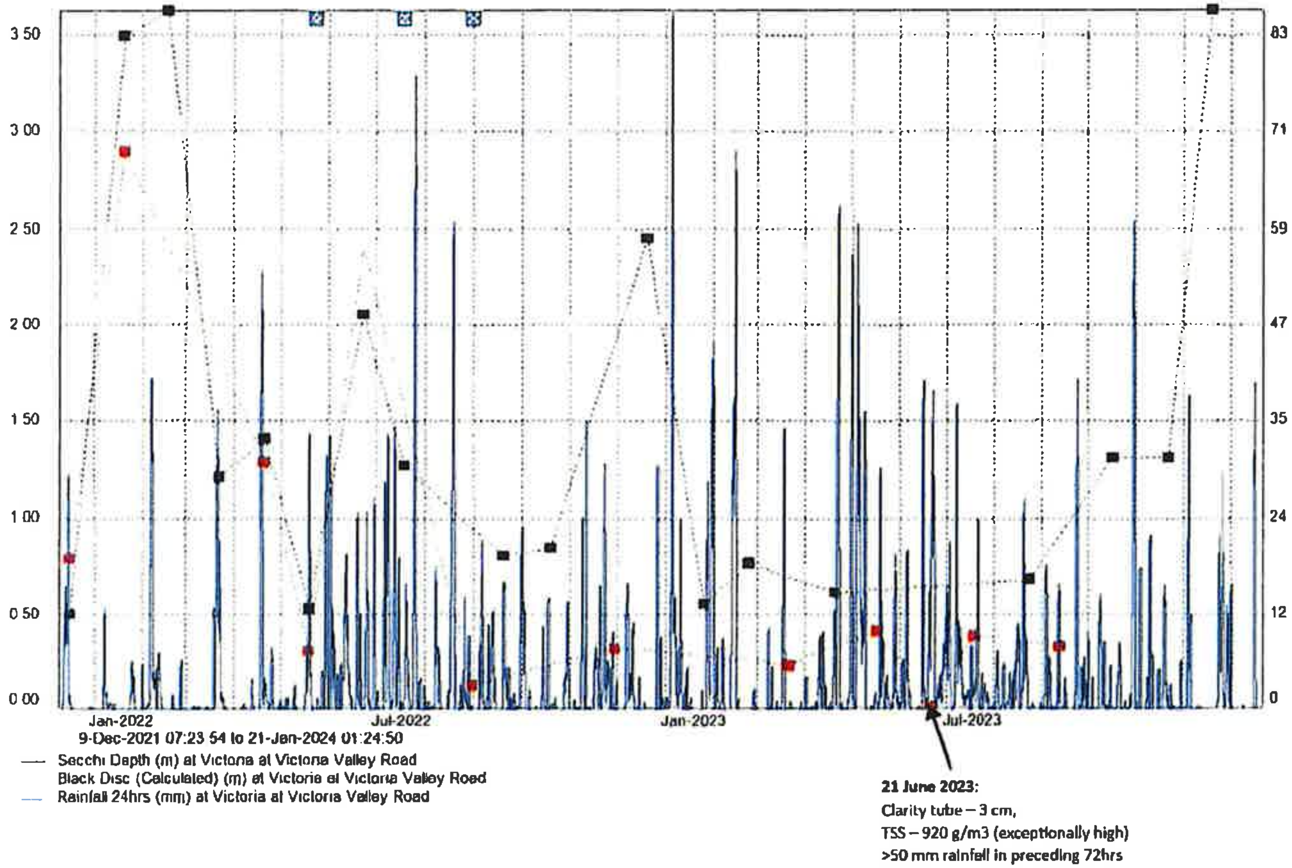
Kia ora Colin,

I would say, the high Aluminium (Al) results between May and June 2023 samples in Northern Wairoa catchments and Victoria River mostly coincided with high cumulative rainfalls preceding the sampling events and consequent high suspended sediment concentration (indicated by exceptionally low water clarity and high TSS). However, for all these exceptionally high Al concentrations the pH levels were within normal range (i.e. between 6.5 and 8). It is the acidic pH, and high DOC (i.e. high redox level) that will determine Al toxicity causing fish kill.

Date	Time	Al (mg/L)	test.description	Lab.name.for.site	TSS (g/m3)	Visual clarity (m)
9/05/2023	11:35:00	15	Aluminium (Total)	Mangakahia at Titoki	428	0.04
9/05/2023	10:50:00	17	Aluminium (Total)	Mangakahia at Twin Bridges	452	0.04
9/05/2023	10:25:00	30	Aluminium (Total)	Opouteke at Suspension Bridge	764	0.03
9/05/2023	9:45:00	34	Aluminium (Total)	Tangowahine at Tangowahine Valley Road	1320	0.02
21/06/2023	9:00:00	9.9	Aluminium (Total)	Victoria at Victoria Valley Road	920	0.03

According to Land & Water Science' Physiographic model elevated Al concentrations in soil are expected in those Northland catchments with high overland flow risk (as percentage of effective rainfall) and poorly drained weathered geology dominated with mudstone, sandstone, and peat.

Going forward, my recommendation will be also to collect DOC (dissolved organic carbon), sulphate and chloride ion (indicator of Acid sulphate soil) side by side dissolved Al and Zn (instead of Total) to predict the potential effect of metal toxicity such as fish death (FYI, first flush following dry summer months are particularly critical). Default ANZECC guideline value for dissolved Al at 95% freshwater species protection level is 0.055 mg/L (there is no freshwater ANZECC guideline value for Total Al).



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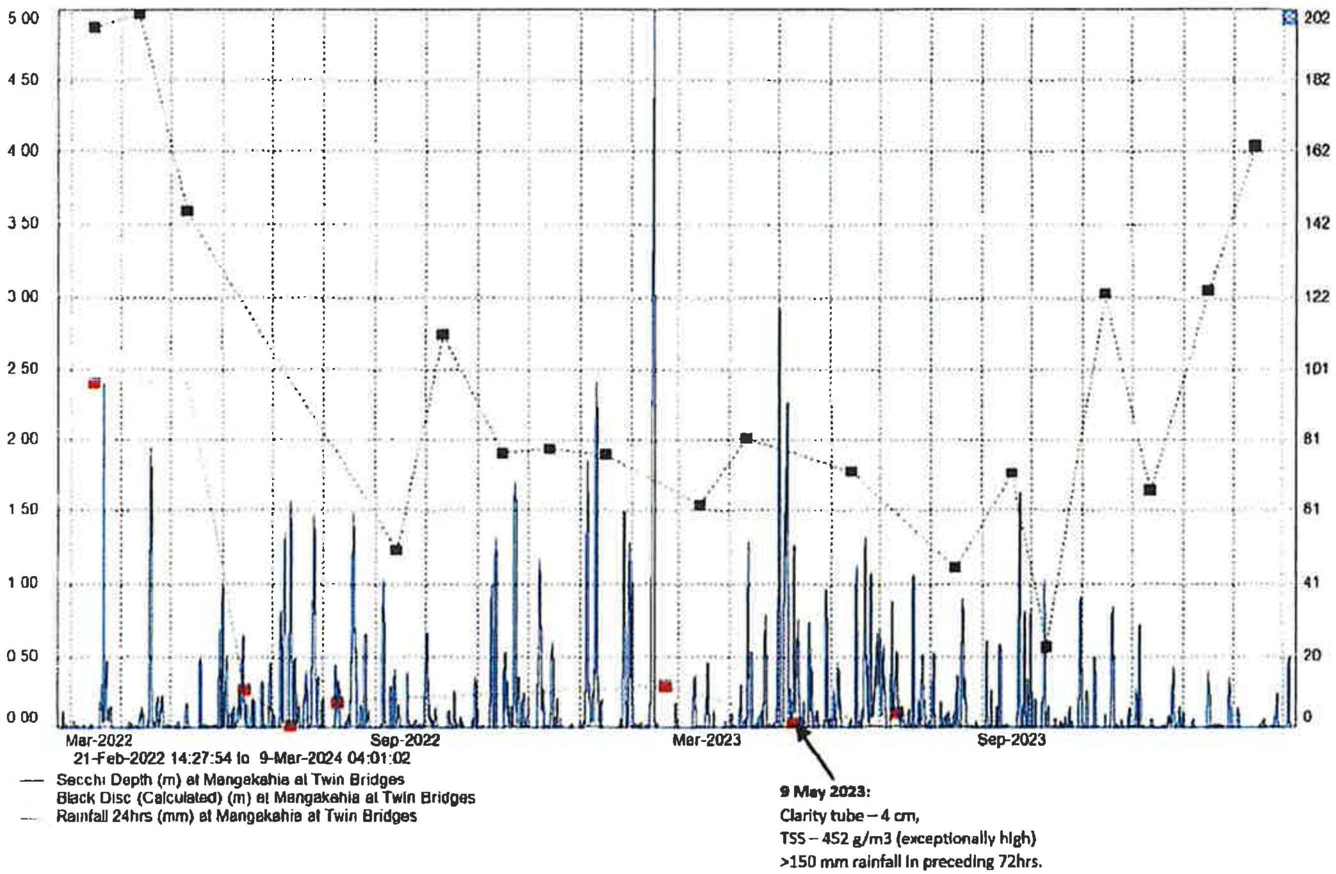
Jul-2023
9-Dec-2021 07:23 54 to 21-Jan-2024 01:24:50
Secchi Depth (m) at Victoria at Victoria Valley Road
Black Disc (Calculated) (m) at Victoria at Victoria Valley Road
Rainfall 24hrs (mm) at Victoria at Victoria Valley Road
21 June 2023:
Clarity tube – 3 cm,
TSS – 920 g/m3 (exceptionally high)
>50 mm rainfall in preceding 72hrs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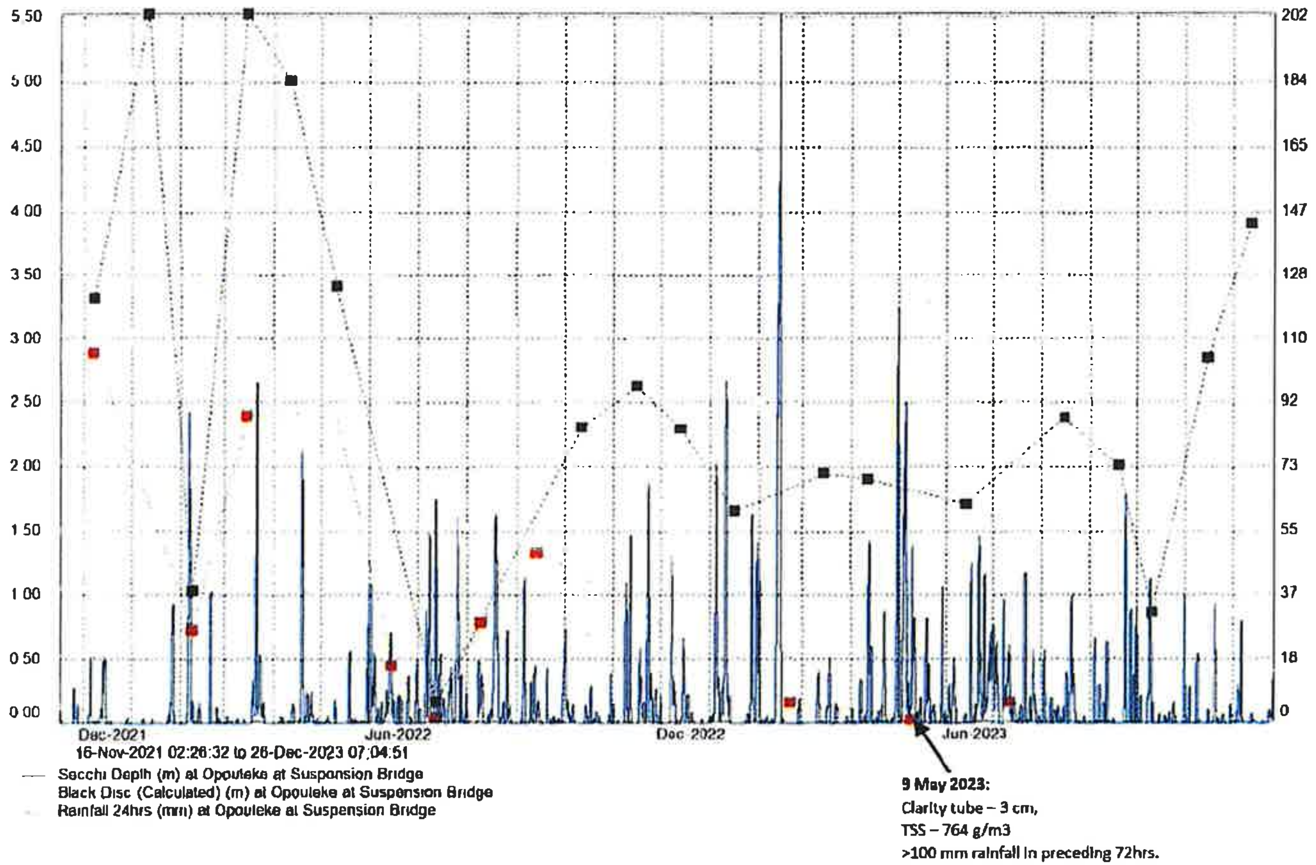
21-Feb-2022 14:27:54 to 9-Mar-2024 04:01:02
Secchi Depth (m) at Mangakahia at Twin Bridges
Black Disc (Calculated) (m) at Mangakahia at Twin Bridges
Rainfall 24hrs (mm) at Mangakahia at Twin Bridges
9 May 2023:
Clarity tube – 4 cm,
TSS – 452 g/m3 (exceptionally high)
>150 mm rainfall in preceding 72hrs.



Ngā mihi

Manas Chakraborty
Resource Scientist - Freshwater
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

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At NRC we value and encourage flexible working and I recognise that my working hours may be different to yours. I'm sending this message at a time that suits me. I don't expect you to read, respond or action it outside of your normal working hours.

Week 1					Week 2				
Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu	Fri
Work from home	At work	At work	At work	Work from home	Work from home	At work	At work	Work from home	Day off

From: Colin Dall <colind@nrc.govt.nz>
Sent: Wednesday, September 18, 2024 10:57 AM
To: Richard Griffiths <richardg@nrc.govt.nz>; Manas Chakraborty <manasc@nrc.govt.nz>
Cc: Tess Dacre <tessd@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>
Subject: RE: Aluminium data from SOE sites 2023-24_11092024.csv

Morena Richie

I think there is value in repeating the Al testing we did last time as it will help with the "so what" question (I rather not rely on one set of dissolved Al testing in the harbour).

Al is tested for in the kumara washwater because it is recycled/reused and to enable this, flocculant (aluminium sulphate) is added in the process (just like drinking water treatment processes).

Thanks
Colin

From: Richard Griffiths <richardg@nrc.govt.nz>
Sent: Wednesday, September 18, 2024 9:57 AM
To: Colin Dall <colind@nrc.govt.nz>; Manas Chakraborty <manasc@nrc.govt.nz>
Cc: Tess Dacre <tessd@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>
Subject: RE: Aluminium data from SOE sites 2023-24_11092024.csv

Some big numbers. Definitely helps us identify the catchment sources. Probably not a massive surprise for anyone that drives the Twin Bridges Road. Not so sure it helps us with the 'so what' question. Manas do you know if that ANZECC freshwater guidelines are for total AL or dissolved? do we have pH for those samples? And how does this tie in with the high numbers from Kaipara Kumera. Are we assuming those high values are from them washing (soil off) their produce? What's the next step - are getting these freshwater samples tested for dissolved Al?

Colin did you want the Al tested again on the coastal run (tomorrow), or are we treating this as a freshwater issue now?

Richie

From: Colin Dall <colind@nrc.govt.nz>
Sent: Tuesday, September 17, 2024 3:52 PM
To: Richard Griffiths <richardg@nrc.govt.nz>; Manas Chakraborty <manasc@nrc.govt.nz>
Cc: Tess Dacre <tessd@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>
Subject: Aluminium data from SOE sites 2023-24_11092024.csv

Kia ora Richie & Manas

Gale has sent me some (early processed) total aluminium results for our river SOE sites. I've highlighted results ≥ 1 mg/L. They "speak for themselves" but support the theory that Al levels are linked to geology (volcanic)/soil type. You will see that there are some eye-watering high results (4^{th} results for Mangakahia at Titoki Mangakahia at Twin Bridges, Opouteke at Suspension Bridge and Tangowahine at Tangowahine Valley Road), which I suspect could also be linked to a high river flow, rainfall event.

Kathryn Pabirowski

From: Richard Griffiths
Sent: Monday, 16 September 2024 9:40 am
To: Colin Dall
Cc: Susie Osbaldiston; Ricky Eyre; Cathy Orevich; Nick Bamford
Subject: RE: Kaipara Al results

Kia ora Colin,

We have another Coastal WQ run scheduled for this week (although may be postponed due to poor weather). Do you want us to test for Aluminium again?

Personally, I think our effort is better spent investigating the catchment source. Plus, because we test for Zn and Cu we can always go back to Watercare later and get the results if we find that we really need them.

Richie

From: Richard Griffiths
Sent: Thursday, September 12, 2024 10:11 AM
To: Colin Dall <colind@nrc.govt.nz>
Cc: Susie Osbaldiston <susieo@nrc.govt.nz>; Ricky Eyre <rickye@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>
Subject: RE: Kaipara Al results

Kia ora Colin,

Yes, I was going to add some explanation and a map. We don't measure pH in the coast because there is very little variation. Personally, I think these results are good news overall and will help alleviate some community concern.

Richie

From: Colin Dall <colind@nrc.govt.nz>
Sent: Thursday, September 12, 2024 9:01 AM
To: Richard Griffiths <richardg@nrc.govt.nz>
Cc: Susie Osbaldiston <susieo@nrc.govt.nz>; Ricky Eyre <rickye@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>
Subject: RE: Kaipara Al results

Morena Richie

I'm okay with passing the data onto AC, Te Uri o Hau and MPI, although it would be preferable to include a map/aerial overlaid with the sampling site locations and to explain that importantly no dissolved Al was detected in any of the samples and so there are unlikely to be any toxicity effects on aquatic life due to presence of Al in the harbour (can we provide the pH results as well?).

Ngā mihi

Colin Dall
Pou Whakaritenga – Group Manager Regulatory Services
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

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Kathryn Pabirowski

From: Richard Griffiths
Sent: Wednesday, 4 September 2024 5:10 pm
To: Colin Dall; Cathy Orevich
Cc: Susie Osbaldiston; Ricky Eyre
Subject: Kaipara Al results
Attachments: FieldAnalysisMonitoringByFieldsheetMethod (7).xlsx

Kia ora,

Wanted to send you this quickly because I am on leave tomorrow. Please see attached the results from last months Kaipara Run (and snip below). In short, Total AL concentration order of magnitude higher at Wairoa River than other sites. Dissolved AL below detection limit at all sites. As you can imagine the TSS concentrations are also an order of magnitude higher at Wairoa compared to the other sites.

Richie

Determinands	Test method name	109665	109666	109668	109669	109670	109671	
		Kaipara Harbour at Wahiwaka Creek	Kaipara Harbour at Te Hoanga Point	Kaipara Harbour at Te Kopua	Kaipara Harbour at Kapua Point	Kaipara Harbour at Burgess Island	Kaipara Harbour at Five Fathom Channel	Kaipar
Aluminium Dissolved (g/m3)	Aluminium (Dissolved) by ICP-MS	<0.1 (P)	<0.1 (P)	<0.1 (P)	<0.1 (P)	<0.1 (P)	<0.1 (P)	
Aluminium Total (g/m3)	Aluminium (Total) by ICP-MS	0.43 (P)	0.3 (P)	0.31 (P)	0.29 (P)	<0.1 (P)	0.32 (P)	

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Northland Regional Council Discharge and Receiving Water Quality Testing Results: 20240684

Sampling Date 22/08/24

Report generated 04/09/24 02:29

Determinands	Test method name	109665	109666	109668	109669	109670	109671	318293
		Kaipara Harbour at Wahiwaka Creek	Kaipara Harbour at Te Hoanga Point	Kaipara Harbour at Te Kopua	Kaipara Harbour at Kapua Point	Kaipara Harbour at Burgess Island	Kaipara Harbour at Five Fathom Channel	Kaipara Harbour at Wairoa River
Aluminium Dissolved (g/m3)	Aluminium (Dissolved) by ICP-MS	<0.1 (P)	<0.1 (P)	<0.1 (P)	<0.1 (P)	<0.1 (P)	<0.1 (P)	<0.05 (P)
Aluminium Total (g/m3)	Aluminium (Total) by ICP-MS	0.43 (P)	0.3 (P)	0.31 (P)	0.29 (P)	<0.1 (P)	0.32 (P)	13 (P)
Ammoniacal Nitrogen (g/m3-N)	Ammonia by FA	<0.005 (P)	0.0064 (P)	0.013 (P)	0.015 (P)	0.048 (P)	0.015 (P)	0.0061 (P)
Chlorophyll a (g/m3)	Chlorophyll by UVVIS	<0.0006 (P)	<0.0006 (P)	0.0013 (P)	0.0012 (P)	<0.0006 (P)	0.00089 (P)	<0.003 (P)
Copper Total (g/m3)	Copper (Total) by ICP-MS	0.0013 (P)	0.0011 (P)	0.0011 (P)	0.0009 (P)	0.0016 (P)	0.0009 (P)	0.0096 (P)
Depth - Boat (m)	Depth - Boat	4.5 (P)	8.3 (P)	16.1 (P)	20 (P)	5.6 (P)	23 (P)	5.6 (P)
Dissolved Reactive Phosphorus (g/m3-P)	Dissolved Reactive Phosphorus by DA	0.029 (P)	0.013 (P)	0.015 (P)	0.016 (P)	0.026 (P)	0.014 (P)	0.025 (P)
Enterococci (MPN/100ml)	Enterococci by Enterolert	10 (P)	<10 (P)	<10 (P)	<10 (P)	20 (P)	<10 (P)	20 (P)
Faecal Coliforms (presumptive) (CFU/100ml)	Faecal coliforms by Membrane Filtration	13 (P)	1.6 (P)	<1.6 (P)	4.9 (P)	36 (P)	3.3 (P)	340 (P)
Nitrite/nitrate nitrogen (g/m3-N)	NO3NO2 by FA	0.0745 (P)	0.0411 (P)	0.0402 (P)	0.0306 (P)	0.198 (P)	0.0604 (P)	0.443 (P)
Dissolved Oxygen (mg/L)	ODO	8.32 (P)	8.59 (P)	8.59 (P)	8.64 (P)	8.57 (P)	8.46 (P)	9.07 (P)
Dissolved Oxygen Percent Saturation (% Sat)	ODO %	92.2 (P)	98 (P)	97.7 (P)	97.6 (P)	93.3 (P)	96.6 (P)	87.7 (P)
Salinity (Field) (ppt)	Salinity	22.75 (P)	26.4 (P)	26.13 (P)	25.07 (P)	20.2 (P)	27.1 (P)	2.07 (P)
Depth of Sample (m)	Sample Depth	0.3 (P)	0.3 (P)	0.3 (P)	0.3 (P)	0.3 (P)	0.3 (P)	0.3 (P)
Secchi Depth - with viewer (m)	Secchi with viewer	0.99 (P)	1.37 (P)	1.27 (P)	1.27 (P)	0.61 (P)	1.19 (P)	0.02 (P)
Total Suspended Solids (g/m3)	Suspended Solids by Gravimetry	15 (P)	10 (P)	11 (P)	12 (P)	34 (P)	15 (P)	240 (P)
Temperature (degC)	Temperature - YSI	13.6 (P)	13.9 (P)	13.9 (P)	13.9 (P)	13.5 (P)	13.7 (P)	13.3 (P)
Total Kjeldahl Nitrogen (g/m3)	TKN by Calculation	0.26 (P)	0.17 (P)	0.17 (P)	0.17 (P)	0.29 (P)	0.17 (P)	0.55 (P)
Total Nitrogen (g/m3-N)	TN by FA NDIGEST	0.34 (P)	0.21 (P)	0.21 (P)	0.21 (P)	0.49 (P)	0.23 (P)	0.99 (P)
Total Phosphorus (g/m3-P)	TP by DA	0.038 (P)	0.018 (P)	0.017 (P)	0.021 (P)	0.04 (P)	0.018 (P)	0.119 (P)

Turbidity (red light) (FNU)	**Turbidity (Red Light) FNU by Nephelometry**	9.7 (P)	5.1 (P)	6.3 (P)	5.5 (P)	18 (P)	5.7 (P)	260 (P)
Zinc Total (g/m3)	**Zinc (Total) by ICP-MS**	0.0026 (P)	0.0025 (P)	0.0033 (P)	0.0027 (P)	0.0042 (P)	0.0022 (P)	0.037 (P)

Methods used: Standard Methods for the Examination of Water and Waste Water. APHA, AWWA, WEF, 1998 20th edition

Ammoniacal Nitrogen	
Dissolved Oxygen Percent Saturation	The capacity of water to absorb oxygen gas. Often expressed as a percentage, the amount of oxygen that can dissolved into water will change depending on a number of parameters, the most important being temperature. Dissolved oxygen saturation is inversely proportion to
Dissolved Reactive Phosphorus	Any species of phosphorous that will pass through a filter with holes no bigger than 10-20 μm in diameter (10-20 thousandths of a millimetre wide) and then reacts with the chemical compound molybdenum blue. Dissolved reactive phosphorous is typically a measure of biologically
Nitrite/nitrate nitrogen	
Temperature	Temperature in degrees Celsius
Total Kjeldahl Nitrogen	
Total Nitrogen	Total nitrogen is the sum of nitrate, nitrite, ammoniacal nitrogen and organic nitrogen measured in a given sample
Total Phosphorus	Total phosphorous is the sum of both dissolved and particulate (non-filterable) phosphorous measured in a given sample.

Kathryn Pabirowski

From: [redacted]
Sent: Wednesday, 4 September 2024 2:40 pm
To: Colin Dall
Subject: RE: Snapper testing from up North

Thanks Colin

Interesting. Mystery continues..

Kind regards
[redacted]

From: Colin Dall <colind@nrc.govt.nz>
Sent: Wednesday, 04 September 2024 1:09 pm
To: [redacted]
Cc: [redacted]; Richard Griffiths <richardg@nrc.govt.nz>; [redacted]
Subject: FW: Snapper testing from up North

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FYI

From: [redacted]
Sent: Wednesday, September 4, 2024 12:28 PM
To: [redacted] Colin Dall <colind@nrc.govt.nz>; Richard Griffiths <richardg@nrc.govt.nz>
Subject: Snapper testing from up North

Hi all,

Just to keep you updated, we currently have Snapper (that displayed cataracts etc that the media have described as Zombie) in for testing with Cawthron for biotoxins having had PCBs and heavy metals (including Aluminium) testing come back to us within normal ranges.

We are still advising that even though we cannot detect anything toxic yet if the fish does not look healthy people should not eat it.

If anyone has [redacted] email address (from the National Public Health Service) can you please forward this to him and Cc me (so I have his email address).

I will update you with the outcome of these analyses when we have them.

Thanks

[redacted]
Ministry for Primary Industries | [redacted] Charles Ferguson Building 38 Bowen Street | PO Box 2526 | Wellington | New Zealand
TE MANA WHAKAMARU ĀHUARANGI/CENTRE FOR CLIMATE ACTION ON AG EMISSIONS
www.mpi.govt.nz

SEEMail

Kathryn Pabirowski

From:	Colin Dall
Sent:	Tuesday, 20 August 2024 4:02 pm
To:	Richard Griffiths; Tess Dacre; Cathy Orevich
Subject:	RE: Test results NW River

Kia ora Richie

Although I share a similar personal view, I think it is important to test/verify our assumptions/views. Talking with [redacted] may reveal/confirm the so-called zombie fish are not a new/recent phenomenon in the harbour, which has "yet to surface" in the media on this issue. If so, he may also have a sense of if it's getting worse, happens periodically etc.

Ngā mihi

Colin Dall
Pou Whakaritenga – Group Manager Regulatory Services
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

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M 027 226 8414

From: Richard Griffiths <richardg@nrc.govt.nz>
Sent: Tuesday, August 20, 2024 3:49 PM
To: Colin Dall <colind@nrc.govt.nz>; Tess Dacre <tessd@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>
Subject: RE: Test results NW River

Kia ora Colin,

Ricky has suggested I talk to [redacted] to get a feel for what is actually happening with the fish in the harbour. He is our [redacted] and long-time commercial fisherman in the Harbour.

Personally, I'd be surprised if there is a link between high Al in Dargaville (where snapper don't even live) and the zombie fish. I see the two issues as unrelated, but I am happy to have a chat to him, if you think there is value in it.

Ngā mihi

Richie

Richard Griffiths

Colin Dall

To: Colin Dall

From: Ricky Eyre <rickye@nrc.govt.nz>
Sent: Tuesday, 20 August 2024 3:17 pm
To: Richard Griffiths <richardg@nrc.govt.nz>
Cc: Jason Donaghy <JasonDo@nrc.govt.nz>
Subject: FW: Zombie fish

Hi Richie.

Do you still have contact details? Could be worth ground truthing what's going on. We've gone from pubic catching 'zombie fish' in Port Albert to this being caused by high Aluminium in Dargaville to needing to "find contaminant source which is driving fish death in Dargaville". Its snowballing a bit without any understanding of what's actually going on with the fish health of the area. I feel this is separate to explaining if Aluminium is high or not, and its source if it is.

Ricky Eyre
Water Quality Field Operations Manager
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

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From: Suha Sanwar <suhas@nrc.govt.nz>
Sent: Tuesday, August 20, 2024 2:42 PM
To: Jason Donaghy <JasonDo@nrc.govt.nz>; Susie Osbaldiston <susieo@nrc.govt.nz>; Manas Chakraborty <manasc@nrc.govt.nz>
Cc: Chantez Connor-Kingi <chantezc@nrc.govt.nz>; Hadyn Butler <hadynb@nrc.govt.nz>; Ricky Eyre <rickye@nrc.govt.nz>
Subject: Re: Zombie fish

Kia ora.

Thanks, Jason, for sharing the report. And thanks, Manas, for summarising it really well.

Adding to that,

1. A potential acid sulphate soil map of Auckland region, on the report, suggests potential high acid sulphate soil occurrence around Kaipara harbour (screenshot below) and likely further up north, around Dargaville.
2. The report provides lists of acid sulphate soil and water qulaity indicators that can be useful in relevant future investigations in Northland.
3. Possible source of acidity, likely responsible for fish death in Waikato, are:
    a. Acid sulphate soil. 1) *Potential acid sulphate soil* is non-threat because the soil is still submerged; but can release acidity once drained (for example, drained wetland/peatland containing iron-sulphide in coastal areas). 2) *Actual acid sulphate soil* which already has been drained, became oxidised and is realising acidity.
    b. Toxic metal release from landfill leachate.
    c. High level of farm fertiliser (ammonium-sulphate) application within the catchment.

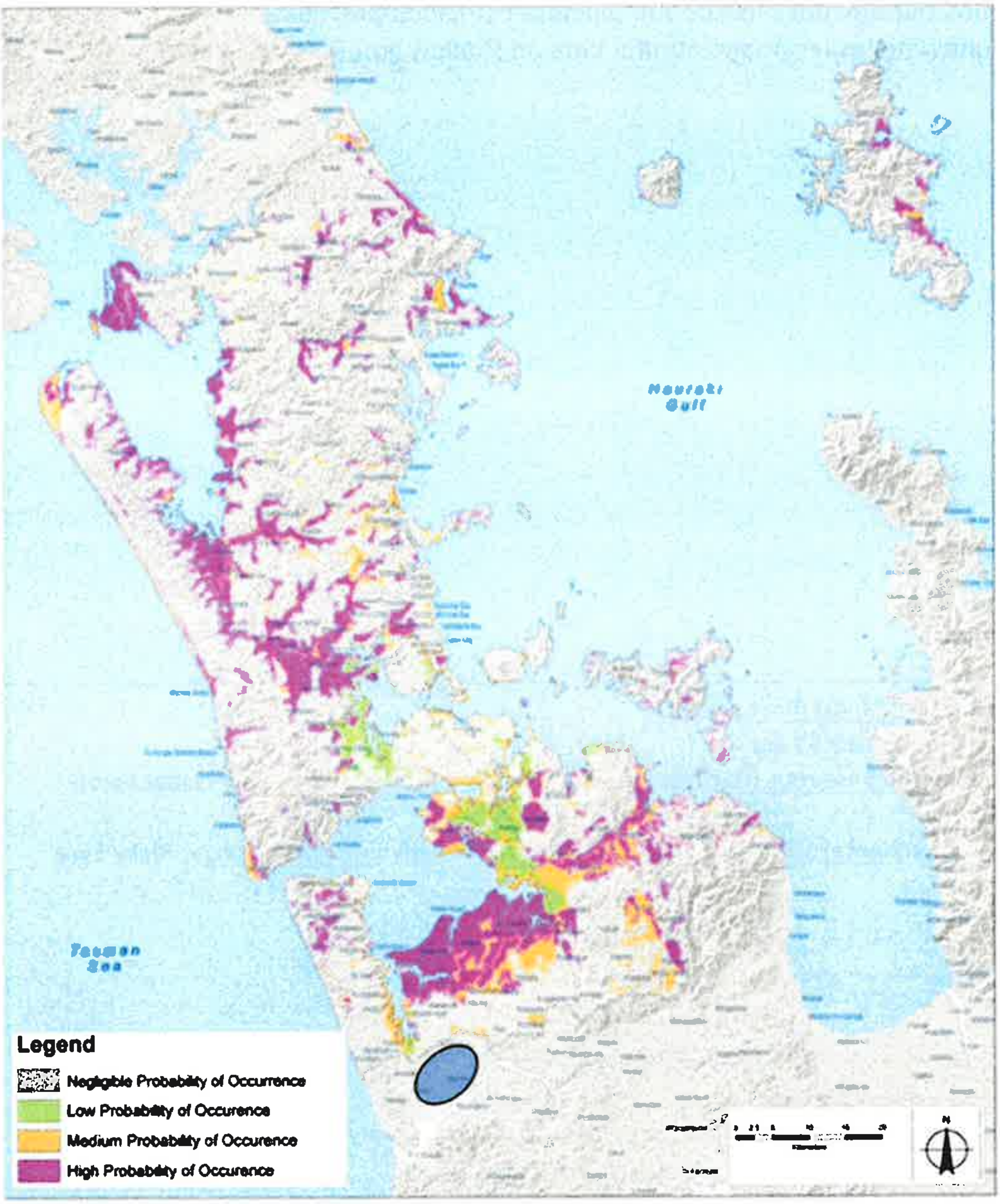

Figure 10 - Preliminary map of the potential for acid sulphate soils in the Auckland Region (Robert and McConchie, 2017).

4.

List for fish death investigation at Dargaville

An investigation might be worthwhile to find contaminant source which is driving fish death in Dargaville. The investigation can consider:

1. Mapping GPS Locations of:
   a. fish death occurrence/ sick fish discovery. Is it happening in same area?
   b. Soil types and geology in Dargaville;
   c. Treatment plant/ landfill facilities (if any). Local suggested aluminium used in a local treatment plant on a news report.
   d. Farms and waterways
2. Soil assessment: Soil chemical analysis: iron-sulphate and metal (Al, Cu, Cd, Co, Zn, Fe, Ni) contents
3. Fish death/sick fish catch records: dates and locations; species; numbers (if available)
4. Water quality analysis (if available from around fish incidence reporting): river water – pH, DO, temp, clarity, ammonium and metal concentrations (Al, sulphate, Ni, Zn, Co, Cu, Cd)

5. Rainfall pattern: does fish death/sickness coincides with heavy rainfall/onset of winter?
6. Groundwater assessment: aquifer data on shallow groundwater; connectivity.

Ngā mihi

Suha

027 246 4561

From: Manas Chakraborty <manasc@nrc.govt.nz>
Sent: Tuesday, 20 August 2024 10:53 am
To: Jason Donaghy <JasonDo@nrc.govt.nz>; Suha Sanwar <suhas@nrc.govt.nz>; Susie Osbaldiston <susieo@nrc.govt.nz>
Cc: Chantez Connor-Kingi <chantezc@nrc.govt.nz>; Hadyn Butler <hadynb@nrc.govt.nz>; Ricky Eyre <rickye@nrc.govt.nz>
Subject: FW: Zombie fish

Kia ora Jason

Thank you very much for sharing this report on fish kill investigation in Waikato. The findings are very useful and relevant to Northland.

Key messages from this investigation are as follows:

1. Acid sulphide soils (ASS) in coastal and estuarine areas can make waterways acidic, leading to low pH and the release of toxic heavy metals. This likely caused fish deaths in Waikato streams.

2. Acid leachate from sulphate soils was released due to dry summers (exposure to oxidation) followed by heavy winter rains and seasonal changes in groundwater levels.

3. Even if streams looked healthy with exception clear water and good oxygen levels, low pH, high sulphate, and high metal concentrations (especially Aluminium and Zinc) most likely caused the fish kill.

4. These findings are relevant for lowland waterways in Northland, which are mostly anoxic and vulnerable to extreme weather conditions (e.g. drought followed by flood events) due to climate change.

5. The Waikato study highlights the need to monitor additional water quality parameters (like sulphate, chloride, cation/anions and metals) to better understand water quality processes.

Thanks.

Ngā mihi

Manas Chakraborty

Resource Scientist - Freshwater
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Work from home	At work	At work	At work	Work from home	Work from home	At work	At work	Work from home	Day off

From: Jason Donaghy <JasonDo@nrc.govt.nz>
Sent: Monday, August 19, 2024 3:32 PM
To: Manas Chakraborty <manasc@nrc.govt.nz>; Suha Sanwar <suhas@nrc.govt.nz>
Subject: Fw: Zombie fish

fyi

Ngā mihi

Jason Donaghy

Natural Resources Monitoring Manager
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

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Kathryn Pabirowski

From: Colin Dall
Sent: Friday, 16 August 2024 4:16 pm
To: Nicola Bull
Cc: Cathy Orevich; Tess Dacre; Clark Ehlers; Alexandra Ashkettle
Subject: RE: Zombie fish

Cheers – more information that supports our thinking on the "prime suspect".

From: Nicola Bull <nicolab@nrc.govt.nz>
Sent: Friday, August 16, 2024 4:07 PM
To: Colin Dall <colind@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>; Tess Dacre <tessd@nrc.govt.nz>; Clark Ehlers <clarke@nrc.govt.nz>; Alexandra Ashkettle <alexandraa@nrc.govt.nz>
Subject: Fwd: Zombie fish

FYI.

From: [redacted]
Sent: Friday, August 16, 2024 3:16:10 PM
To: Nicola Bull <nicolab@nrc.govt.nz>
Cc: [redacted]
Subject: Zombie fish

Hi Nicola

[redacted] ust alerted me to your zombie fish issue.

We were just wondering if it could be related to the effects of acid sulfate soils releasing the high concentrations of dissolved aluminium into the river.

We had a series of fish kill events in one of our drainage areas which led us to identify acid sulfate soils as being the cause with dissolved aluminium being a likely cause as it was very elevated. See attached report.

Yesterday's article:
'Zombie fish' highlight Northern Wairoa River pollution concerns - NZ Herald

Have a great weekend

[redacted]

[redacted]
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Waikato Regional Council Internal Series 2020/20

Internal series report on the causes of fish kill in the Aka Aka-Otaua area

www.waikatoregion.govt.nz

Waikato
REGIONAL COUNCIL

Prepared by:
Jonathan Caldwell

For:
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Private Bag 3038
Waikato Mail Centre
HAMILTON 3240

15 September 2020

Document #: 17014876

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Acknowledgement

Alicia Williams from the Environmental Compliance team in ICM is gratefully acknowledged for her initial investigation and reporting of the July 2020 fish kill event. Chris McKinnon from Environmental Monitoring in SAS is also gratefully acknowledged for assisting with collection of water quality samples and deployment of a water quality Sonde.

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Abstract

As a result of a significant fish kill event in July 2020 in the Aka Aka-Otaua drainage area, a detailed assessment of the potential causes of this event and previous similar events has been prepared with some recommendations for further investigation and management.

In July 2020 a large-scale fish kill in the Aka Aka-Otaua drainage area occurred with dead fish in varying stages of decomposition identified within the Awaroa Stream, Otaua Creek and Aka Aka Stream. Subsequent investigations have determined that while dissolved oxygen levels and temperature were within a range unlikely to cause concern to fish, the pH was extremely low across all sites investigated with some sites recording a pH as low as 4.6. Water clarity at all sites was also extremely high which is unusual for this area due to the typically high turbidity.

This event was preceded by a similar fish kill event in June 2014 in the Aka Aka-Otaua drainage area. In this case dead fish were discovered within Mangawhero and McLaren's drains at the eastern side of this drainage area. As for the July 2020 event, subsequent investigations determined normal dissolved oxygen levels and temperature but very low pH and high water clarity.

Two earlier fish kill events in the Aka Aka-Otaua drainage area in late 2012/early 2013 and 2007 had also been recorded by ICM staff with observations of high clarity in drains in both of those cases.

An analysis of Waikato Regional Council's long term water quality monitoring data in addition to water quality data collected from targeted monitoring investigations provides strong evidence that the fish kill events of 2007, 2012/2013, 2014 and 2020 have been caused by seasonal changes in water chemistry as a result of the likely presence of acid sulphate soils.

Acid sulphate soils are naturally occurring soils, sediments and peats that contain iron sulphides. These soils are typically found in low-lying coastal or estuarine areas where land is often water-logged and have been formed during historic sea level rise and inundation of land. These soils have the potential to cause acidic conditions and mobilisation of metals in water and soil when they oxidise which can happen when there is significant seasonal fluctuation of groundwater levels.

A seasonal variation in pH has been observed with the wintertime pH often falling well below 6 pH units which has at times coincided with significant changes in water clarity along with sulphate to chloride ratios increasing above 0.5 during winter and a significant increase in dissolved metal concentrations well above ANZ water quality guidelines. These are all strong indicators that potential acid sulphate soils and actual acid sulphate soils are present and impacting surface water quality in the Aka Aka-Otaua drainage area.

While low pH will be resulting in adverse effects on fish, the extremely elevated concentrations of dissolved aluminium and zinc are the most likely causes of mortality with low pH being an additional causal factor. Potentially, the adverse water quality conditions are occurring for up to three months per year which could explain the observations of dead fish in varying levels of decomposition.

The impacts on water quality are also widespread with impacted water quality identified in the Otaua creek, Awaroa stream, Aka Aka stream, Ten foot drain, Arrowville drain, Eastern drain, McLarens drain and Mangawhero drain. While the biggest fish kill was identified in the Awaroa stream during the 2020 event, the longer-term water quality data suggests that the water quality of the Aka Aka stream is potentially being impacted more significantly.

It is also evident that water quality has been consistently varying from year to year on a seasonal basis with the recorded fish kill events generally aligning with years where there was a very low cumulative summer rainfall of 100mm or less followed by heavy rainfall in the winter months. This supports the theory that acid sulphate soils are being exposed to oxidative conditions when groundwater and surface water levels are low over summertime with subsequent release of acid leachate when levels rise again after heavy rainfall, typically during wintertime.

It is clear from the evidence available that fish kill events will continue in future years, typically during wintertime when pH drops along with associated increase in concentration of dissolved metals in streams and drains within the Aka Aka-Otaua area. If climate change results in a trend towards more extreme climatic conditions, this may increase the frequency of these events.

An investigation to confirm the presence of acid sulphate soils and identify the seasonal fluctuation of shallow groundwater levels in those locations is in preparation. These further investigative works will help inform a more targeted management response including more comprehensive water quality monitoring with an alert system linked to pH levels and water clarity as well as a review of drainage works and how those works might be best optimised to reduce the impacts of acid sulphate soils.

1 Introduction

The purpose of this report is to provide an assessment of the potential causes of a recent large-scale fish kill as well as some earlier fish kills in the Aka Aka-Otaua drainage area just south of Waiuku on the northern catchment of the lower Waikato river (refer to Figure 1). The report also provides recommendations for further investigation and ongoing and extended water quality monitoring in the area as well as informing future management and mitigation actions.

1.1 Background on fish kill events

On the 14 July 2020 ICM received notification from Incident Response (RUD) and Chris Hattingh (Works Supervisor, ICM) that there had been a large-scale fish kill in the Waiuku area. Dead fish were seen within the Awaroa Stream, Otaua Creek and Aka Aka Stream, which included catfish (*Ameiurus nebulosus*), goldfish (*Carrisus auratus*), koi carp (*Cyprinus carpio*) and an estimate of 50 eels (*Anguilla sp.*).

RUD undertook a site visit on the 14 July 2020 to ascertain the locality and severity of the kill. No water samples were taken for analysis at the time due to the assumption that it was likely to have been caused by a "one-off" point source discharge, and that it would have been too late to identify the potential cause from water sample analyses as the fish were discovered in varying stages of decomposition.

Silt removal and vegetation removal had been undertaken by ICM three weeks prior to this notification, at 89 Crouch Rd on the Awaroa Stream, the location where the majority of dead fish had been discovered. Silt removal had also been undertaken by ICM on the Aka Aka Stream three to four weeks prior. Other than these works detailed above, no other works had been recently undertaken by ICM within the Aka Aka-Otaua drainage area.

An initial investigation into the cause of this fish kill event in the Aka Aka-Otaua drainage area was undertaken on 15 July 2020 by Alicia Williams from ICM (refer Doc# 16850672). The key observations made from this initial investigation included:

- The discovery of dead fish in varying levels of decomposition as well as live fish displaying significant stress indicating that exposure to adverse environmental conditions had been occurring over an extended period.
- Water clarity at all sites was extremely high, as the bottom of the stream beds were visible at most sites (unusual for this area due to typically high turbidity).
- Dissolved oxygen within a range indicative of good instream oxygen levels unlikely to cause any severe or life-threatening impacts on aquatic life.
- Temperature was identified as being not of concern to aquatic fish life.
- pH was found to be extremely low across all sites ranging from 4.6 to 6.35 indicating high acidity (note that follow up calibration indicated that the pH was likely to have been around 0.5 pH units lower than recorded in the field indicating a potential range of 4.1 to 5.85). This pH range is likely to cause extensive and significant stress to aquatic life.

A local landowner, Stuart Muir, who has property bounding the Aka Aka stream had also been in communication with ICM for some months prior to the event regarding concerns about overnight changes in the stream's clarity.

The presence of acid sulphate soils in the drainage area was identified as a probable cause of the fish mortality (Williams, 2020). Acid sulphate soils are known to have detrimental impacts on surface and groundwater quality such as low pH and high water clarity in areas known to contain these soil types.

Three similar fish kill events have previously been identified to varying degrees in the Aka Aka Otaua drainage area (refer to Figure 1).

On 20 June 2014 a fish kill came to the attention of ICM staff when they were undertaking monthly pump inspections on the Mangawhero flood pump. However, a local landowner, had reported first seeing fish caught on the screen just after a rain event on the 10 June 2014. Dead fish were discovered within the Mangawhero drain, mainly drawn up against the floodpump screen. The dead fish were predominantly made up of adult grass carp and feral goldfish (possibly goldfish x koi hybrids). A smaller number of large bullhead catfish were also observed along with one large shortfin eel.

Figure 1 - Fish kill areas identified within the Aka Aka Otaua drainage area over the period 2007 to 2020.

Dead fish (mainly eels) were also observed in McLarens drain in June 2014 which runs along Aka Aka Road and flows in an easterly direction. Under most conditions this drain is hydrologically separated from the Mangawhero drain and therefore the discovery of dead fish in this drain as well provided potential evidence of a more widespread issue.

An investigation into the cause of the fish death in this area was undertaken by Mike Lake from ICM on 24 June and 25 June 2014 (refer Doc# 3189712). The key observations made from this initial investigation included:

- The discovery of dead fish as well as live fish displaying significant stress indicating that exposure to adverse environmental conditions had been occurring over an extended period.
- Water clarity was observed to be unusually high.
- Dissolved oxygen levels and oxygen demand did not point to any sustained low oxygen event although could not be eliminated because low DO events can be short-lived and therefore possibly missed by the water quality sampling.
- Temperature was identified as being not of concern to aquatic fish life.
- pH found to be low at 5.0 in the Mangawhero drain and 4.3 in McLarens Drain, at which it is considered likely to cause extensive and significant stress to aquatic life.

Acid-sulphate soils were also proposed by Mike Lake as a potential cause of the large and sustained reduction in pH for this 2014 event.

The Land Drainage Comprehensive Annual Report 2013-2014 (Doc# 3242415) records that no drainage works in the Aka Aka-Otaua drainage system area were undertaken over the July 2013 to June 2014 period.

A fish kill involving grass carp but on a smaller scale to the 2014 event is also known to have occurred in the Mangawhero drain in late 2012/early 2013 according to Peter Cullen (the works supervisor for the area). High clarity was also observed at that time but no specific documentation on this event, including specific dates, could be found apart from reference to it in Mike Lake's File Note (refer Doc# 3189712) and a spreadsheet on PTTS mortality events associated with pump stations by Steve Hall (Doc# 16582635).

The Land Drainage Comprehensive Annual Report 2012-2013 (Doc#2381331) records that no drainage works in the Aka Aka-Otaua drainage system area were undertaken over the July 2012 to June 2013 period.

In investigating the 2014 event, Mike Lake also talked with Adam Daniel (officer with Fish and Game) who recalled a fish kill in the nearby Aka Aka Drain that was reported to him by local land owner, Stuart Muir, sometime around 2007. When investigating the 2007 Aka Aka drain fish kill, Adam Daniel observed that the water was unusually clear and that DO levels were normal until the drainage pump started at which time there was a sharp decrease in oxygen levels. The observation that water was unusually clear is the same as that found in July 2014 fish kill event and is consistent with water of very low pH. As for the 2013 event, no further specific documentation of the event could be found apart from reference to it in Mike Lake's File Note (refer Doc# 3189712) and a spreadsheet on PTTS mortality events associated with pumpstations by Steve Hall (Doc# 16582635).

In addition to the 2014, 2013 and 2007 events, there is a 1984 report[1] by the Fisheries Research Division of MAF which refers to grass carp mortalities in drainage channels of the Aka Aka and Otaua Drainage Board systems during trials being undertaken when they were originally stocked

[1] McDowall, R. M. 1984. Escape of grass carp from the Aka Aka-Otaua drainage system. Fisheries Environmental Report No. 44.

in the early 1980's. However, the mortalities were considered at the time to be due to the poor water quality as a result of effluent runoff. The report did not make any reference to high water clarity or low pH or any mention of acid sulphate soils.

1.2 Acid sulphate soils

Acid sulphate soils (commonly abbreviated to ASS) are naturally occurring soils, sediments and peats that contain iron sulfides, predominantly in the form of pyrite materials. They have the potential to cause acidic conditions in water and soil when they oxidise. In Australia, these soils are commonly found in low-lying land bordering the coast or estuarine and saline wetlands and freshwater groundwater-dependent wetlands throughout Western Australia and Northern and Eastern Australia where effects are usually more severe in warmer climates but are also known to exist and have significant effects in cooler climates such as Tasmania. The presence of Acid Sulphate Soils is well documented overseas but is less well reported in New Zealand (Roberts and McConchie, 2017; WA Department of Environment Regulation, 2015).

Acid sulphate soils are typically formed during historic sea level rise and inundation of land where sulphates in the seawater mix with land sediments containing iron oxides and organic matter. The resulting chemical reaction produced large quantities of iron sulphides in water logged environments (WA Department of Environment Regulation, 2015).

ASS materials are benign when in a waterlogged state. However, when these soils or sediments are drained or excavated, oxygen from the atmosphere reacts with the iron sulphides in the soil resulting in the production of sulphuric acid. This acidity releases elements such as metals and nutrients from the soil profile which can then be mobilised/transported to waterways, wetlands and groundwater systems, often with deleterious environmental and economic impacts including (WA Department of Environment Regulation, 2015):

- fish kills and loss of biodiversity in wetlands and waterways;
- contamination of groundwater resources by acid, arsenic, heavy metals and other contaminants;
- loss of agricultural productivity; and
- corrosion of concrete and steel infrastructure by acidic soil and water.

Some of the types of activities that can cause ASS problems include (WA Department of Environment Regulation, 2015):

- estate and underground infrastructure development (including installation of sewage pipework and pump station infrastructure);
- major infrastructure projects, such as bridges, roads, tunnels, port facilities, flood gates, dams, railways and flood mitigation works;
- compacting saturated soils or sediments;
- drainage works;
- groundwater pumping;
- de-sludging or otherwise cleaning open drains;
- rural drainage which lowers the water table;
- laterally displacing previously saturated sediments, resulting in groundwater extrusion and aeration of ASS;

The impacts of ASS leachate may persist over a long time, or peak seasonally (after dry periods with the first drought-breaking rains). In some areas of Australia, ASS drained 100 years ago is still releasing acid (Sammut, 2000).

The Richmond River in New South Wales, Australia has experienced numerous leaching events of acidified water enriched with metals being discharged from acid sulphate soils. These discharges have been linked to major fish kills and can also lead to sub-lethal effects, such as red spot disease in fish (Corfield, 2000).

2 Investigative findings

2.1 June 2014 event

After the initial fish kill notification on 20 June 2014, a site visit was undertaken by Mike Lake from ICM on 24 and 25 June 2014.

Most of the dead fish observed were found at the Mangawhero flood pump where they had been drawn up against the floodpump screen. A local landowner had been removing them and dumping them near the pump station to keep the screen unblocked. The dead fish were predominantly made up of adult grass carp and feral goldfish (possibly goldfish cross koi hybrids). A smaller number of large bullhead catfish were also observed. The only native fish species found was one large shortfin eel. Grass carp are deliberately stocked in the drain to control aquatic weed, but the goldfish and catfish are exotic pests. One large catfish was found alive but clearly struggling and this was collected for possible toxicological analysis. Gambusia were seen swimming in the shallows but appeared to be stressed with obvious fungal growths on their bodies.

Dead fish were also observed in McLarens drain which runs along Aka Aka Road and flows in an easterly direction. Around five small dead eels were found as well as one small goldfish. One live but struggling goldfish was found next to the floodgate and taken for possible toxicological analysis. A live shortfin eel and one sick goldfish were also observed but not taken. Gambusia were present and also appeared to be stressed and carrying fungal growths.

Under most conditions McLarens drain is hydrologically separated from the Mangawhero Drain by a flapgate located on Aka Aka Road (refer to Figure 2). Water can backflow from Mangawhero into McLarens when water levels in the former are high enough. This would only occur if the Mangawhero pump failed or potentially if the screen became blocked.

The presence of the flapgate was considered important for two reasons:

1. The cause of the fish kill in the Mangawhero drain almost certainly originated there unless the flap-gate was held open for some reason (there is no evidence this occurred and it was observed to be closed during the investigation).
2. The fish kill in McLarens drain could either have originated there (or upstream of the catchment) or from within the Mangawhero Drain, with the latter backflowing into McLarens Drain when water levels rose. This could have occurred when the screen became blocked with dead fish, however all evidence at the time of the event indicated that it was very unlikely that there had been a backflow from the Mangawhero drain to the McLaren's Drain.

Figure 2 - Aerial photo showing location of fish kill, WRC managed drains (blue dashed lines) and Mangawhero Pump. Red arrows show direction of stream flow.

2.1.1 Water quality analysis and field measurements

On the 24 June 2014, field meter measurements of dissolved oxygen (DO), electrical conductivity (EC) and temperature were recorded at sites F1 (Mangawhero drain flood pump station), F2 (Mangawhero drain adjacent to a stockpile of silage) and F3 (McLarens drain flapgate). A grab sample of water was also taken at WQ1 (Mangawhero drain flood pump station) for water quality analysis of a suite of water quality determinands including pH, EC, ammoniacal nitrogen, BOD, and sulphate. Further field measurements of DO, EC and temperature were recorded on 25 June 2020 at sites F4 & F5 (both at the McLarens drain flapgate but before and after the bed sediment was disturbed) and at site F6 (Eastern drain flood pump station). A grab sample of water was also taken at WQ2 (McLarens drain flapgate) and WQ3 (Eastern drain flood pump station) for water quality analysis of a suite of water quality determinands including pH, EC, ammoniacal nitrogen, BOD, and sulphate. The locations of the sampling sites are provided in Figure 3.

Figure 3 - Locations of water quality sampling sites (WQ1-3) and field meter measurement sites (F1-6) during initial investigation on 24 to 25 June 2014.

Field meter results are summarised in Table 1. Electrical conductivity (EC) was elevated at all locations indicating a high concentration of dissolved ions but was still within the range expected for moderately disturbed/ non-pristine waters or waters impacted by limestone geology. Dissolved oxygen levels were normal except where sediment was deliberately disturbed at F4. Water temperatures were similar at all locations and within a narrow range of 13.1 to 14 degrees which is of no concern to aquatic fish life.

Table 1 - Field meter measurements recorded on 24 and 25 June 2014.

Parameter	**F1**	**F2**	**F3**	**F4***	**F5**	**F6**
		24/06/14			**25/06/14**	
DO (mg/L)	7.38	6.47	5.55	2.2	7.96	7.56
DO (%)	70	61.7	52.4	21	77.7	72.8
EC (µS/cm)	719	910	667	818	583	466
Temperature (°C)	13.1	13.5	13.2	13.8	14	13.6

*reading taken after bed sediment disturbed

The laboratory analysis of the three water samples (Table 2) indicated that pH was lowest (high acidity) at the two sites where dead fish had been discovered in the Mangawhero and McLarens drains (WQ1 and WQ2) with pH values of less than 6 which is well below the ANZ Water Quality guideline range of 6.5 to 9.0 indicating that adverse effects on aquatic organisms will be occurring if low pH is maintained over an extended period of time.

Alkalinity was also low at these two locations indicating very limited buffering capacity to control sudden changes in pH.

While ammoniacal nitrogen was higher at WQ1 and WQ2 (Mangawhero and McLarens drains) compared with WQ3, the low pH and low temperature means that the majority of the ammoniacal nitrogen would be in the low toxicity ammonium ion form and would therefore fall well within the Australian and New Zealand Water Quality Guidelines for 95% species protection after correction for temperature and pH. Total Kjeldahl nitrogen was high at all three sites and would be categorised as unsatisfactory with regards to WRC's water quality guidelines and standards and would fall within the C to D band of the NPS for Freshwater attribute states for total nitrogen (NPSFW 2014).

Oxygen demand was low for all three sampling locations which is consistent with the field measurement DO values that were within the normal range for supporting aquatic life.

Sulphate concentrations of 124 to 360 mg/L across the three monitoring sites are all significantly elevated compared to the range that recorded in 2018 to 2019 in streams and rivers across the region (RERIMP) where concentrations were typically well below 10 mg/L except for the Waitoa, Piako and Ohinemuri rivers where annual averages of 20 to 30 mg/L have been identified (from my analysis of unpublished data).

Sulphate itself is not considered to be very toxic to aquatic organisms, and as such, there are no toxicity-based guideline values for sulphate provided in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ 2000). As part of a regional assessment for the Queensland coal industry, a 99% species protection guideline value for sulphate toxicity of 307 mg/L was derived but that was based on a low sensitivity for sulphate that had been verified for local species which may not be relevant to this environment. While direct sulphate toxicity is not a risk, the presence of sulphate in surface waters can lead to the formation of acid sulphate soils in some wetlands which will depend on the sulphate concentration in surface water, amount of bioavailable carbon, and amount of time that the sulphate is in contact with the anaerobic zone in the sediments. For example, for the Ranger Uranium mine in Australia where sulphate discharges were occurring to waterways, it was determined that sustained sulphate levels above 10 mg/L (as annual means) have a high likelihood of generating acid sulphate soils in aquatic ecosystems (Australian Department of the Environment and Energy, 2018).

What this indicates is that ongoing up catchment release of sulphates to waterways and drains from acid sulphate soils could also contribute to the potential for generation of a new source of acid sulphate soils or sediments further downstream should they start accumulating in an anaerobic environment where sulphides start forming with potential for future sulphate formation and acid release on re-oxidation. Anecdotal information indicates that there is a high use of ammonium sulphate fertilisers during winter in this area which could be a contributary source of sulphate release to waterways and drains. Acid leachate impacts from these secondary acid sulphate soils/sediments are likely to be highly susceptible to in-channel works.

Table 2 - Water quality laboratory analysis results for grab samples collected on 24 and 25 June 2014.

Parameter	WQ1 24/6/2014	WQ2 25/06/2014	WQ3
pH	5.0	4.3	7.3
Alkalinity (g/m³ as $CaCO_3$)	2.1	<1	26
EC (µS/cm)	709	812	453
Total Ammoniacal-N (g/m³)	0.26	0.88	0.092
Total Kjeldahl Nitrogen (g/m³)	0.58	1.42	0.94
Chemical Oxygen Demand (g O_2/m³)	11	10	22
Total Biochemical Oxygen Demand (g O_2/m³)	<3*	<2	2
Sulphate (g/m³)	290	360	124

*Results from a repeated analysis from frozen sample. Original results were outside QA acceptance limits

The 2014 investigation by Mike Lake concluded that the results of the water quality analysis indicated that conditions were less favourable for fish life in McLarens Drain than the Mangawhero drain at the time the samples were taken. It also concluded that the results do not support the theory that the fish kill originated in the Mangawhero Drain. However, it was acknowledged that the Mangawhero drain could have recovered more rapidly than the top end of McLarens drain because the former had been flushed through by the pump whereas the top end of McLarens drain would drain much more slowly through the eastern drain network.

The 2014 file note also concluded that it is often difficult to determine the causes of fish kills and this has been made even more difficult in this case due to the time delay between the first fish deaths and the taking of samples. This does not appear to be a simple case of deoxygenation because even low DO tolerant species such as catfish and feral goldfish have been killed and fish were still observed to be dying when oxygen levels are relatively high in the drain (>6mg/L). Oxygen levels and oxygen demand found in the affected drain do not point to any sustained low oxygen event. This possibility cannot be eliminated because low DO events can be short-lived and therefore possibly missed by the water quality sampling. The pH recorded in both the affected drains was sufficiently low to kill most fish species and it is possible the pH was even lower when the first fish were observed dead around three weeks before any water quality samples had been collected.

The absence of any low DO conditions, high ammonia levels and the fact that water was observed to have a high clarity makes it unlikely that point source organic pollution (eg. from silage leachate or effluent ponds) was the cause of the fish kill. The presence of acid sulphate soils was concluded to be the most likely cause of the fish deaths.
Following on from this initial June 2014 investigation, pH and temperature were recorded for the following two years (13 August 2014 to 7 June 2016) at approximately 1 to 2 month intervals at 12 monitoring locations across the Aka Aka-Otaua drainage area as identified in Figures 4 &

5. There is no evidence from a search of the WRC document system that this data has previously been analysed or reported on.

Figure 4 - pH and temperature monitoring sites 1 to 8 from 13 August 2014 to 6 September 2015 (note site 8 was sampled only once over this period).

Figure 5 - pH and temperature monitoring sites 9 to 12 from 13 August 2014 to 6 September 2015.

Temperatures ranged from as low as approximately 11 degrees in June to up to 23 degrees in December (refer to Appendix A for specific values). The pH ranged from as low as 3.06 to as high as 9.38 (refer to Appendix A for specific values). With reference to Figure 6 it is evident that the pH was varying significantly from winter to summer over the two-year period of monitoring within the Mangawhero and MacLarens drains. The lowest pH levels were recorded over the months of June to October with a similar pattern observed in both the Mangawhero and MacLarens drains at various locations along those drains providing additional evidence that the cause is not point source related. Many of the pH recordings fall well below the ANZ Water Quality guideline range of 6.5 to 9.0 (pink shaded band) indicating that adverse effects on aquatic organisms will be occurring over an extended period of time.

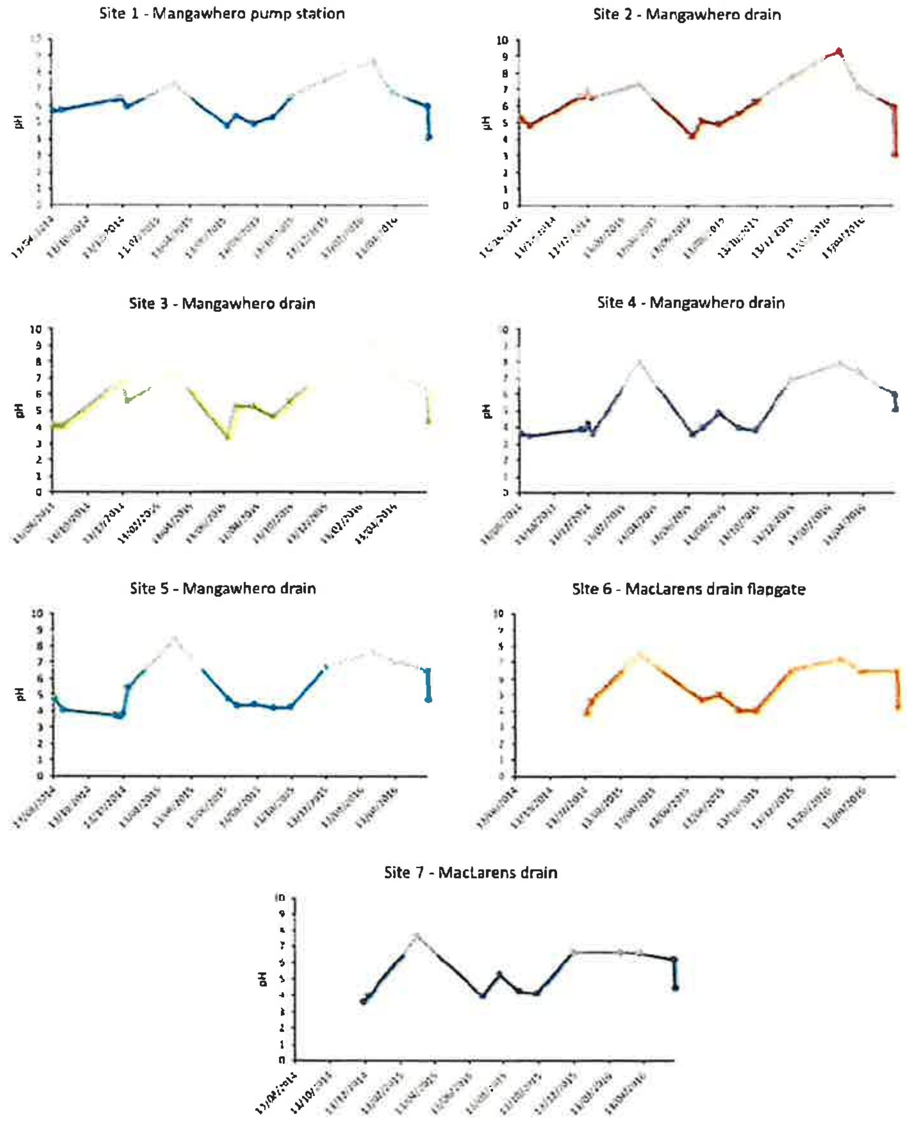

Figure 6 - pH results for sites 1 to 7 recorded August 2014 to June 2016 (Note that no graph is provided for Site 8 – Eastern drain, as only one reading of pH 4.1 was made on 3 July 2015).

The pH results recorded in the Aka Aka stream, Ten foot drain, Awaroa stream and Otaua creek (Figure 7) over the more limited monitoring period of July 2015 to June 2016 also indicate a lower pH over the winter period but with a less severe drop in pH. The pH variation for these sites provides additional evidence that water quality was impacted over an extensive area during this period.

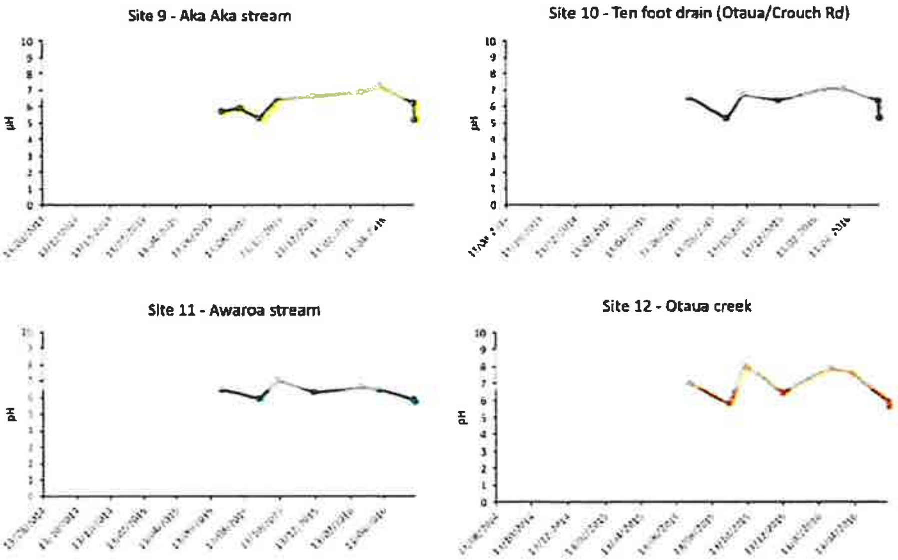

Figure 7 - pH results for sites 8 to 12 recorded August 2014 to June 2016.

2.2 July 2020 event

To understand the cause of the recent fish kill event in the Aka Aka-Otaua drainage area, a site visit was undertaken on 15 July 2020 by Alicia Williams from ICM.

Water quality readings of temperature, dissolved oxygen and pH using a YSI multi meter pro were recorded at multiple locations on each of the three known affected watercourses, namely the Otaua Creek and the Awaroa and Aka Aka streams as well as in the Eastern and Arrowville drains located to the far east of the drainage area (refer to Figure 8).

Water quality samples were also collected for laboratory analysis from sites 1 and 6 (Otaua creek and Aka Aka stream respectively) on the 21 July 2020 and again on the 11 August 2020 at which time a Data Sonde (YSI EXO2) was deployed at site 6 for continuous monitoring of pH, temperature, electrical conductivity, turbidity, dissolved oxygen and chlorophyll (refer to Appendix B for Sonde and probe serial numbers).

Figure 8 - Locations of water quality sampling sites and field meter measurement sites July to August 2020.

Dead fish were observed at five out of the eight sites visited, with the majority of dead fish found at 89 Crouch Rd on the Awaroa Stream (refer to Figure 1). This was likely due to these catchments being tidally influenced and recent rain events increasing flow throughout the catchments, causing fish to either be pulled out into the mainstem of the Waikato River or washed up on the stream banks. Fish at the Awaroa Stream were observed to have varying levels of decomposition, suggesting that this occurrence has been happening over an extended period of time. There were goldfish found still alive with mouths gaping, stuck on top of a macrophyte bed indicating significant stress (Williams, 2020).

Water clarity at all sites was extremely high, with the bottom of the stream bed visible at most sites (Figure 9). This is an extremely uncommon occurrence for this area as streams and drains in this area typically have a high suspended sediment load and high turbidity. Landowners at the sites visited remarked that they had never seen it so clear before (Williams, 2020).

Figure 9 - Water clarity at Otaua Creek (Site 1, top left), dead fish (Awaroa Site 5, top right) and water clarity at Awaroa stream (site 4, bottom).

Field meter results and fish kill observations are summarised in Table 3. Dissolved oxygen was found to range from 57% to 82% throughout the area (6.01 mg/L to 8.88 mg/L), with an average reading of 71.3% (7.5 mg/L) determined across the area. These results are indicative of good instream oxygen levels and are unlikely to cause any severe or life-threatening impacts on aquatic life.

Dean & Richardson (1999) tested the acute tolerances of seven native freshwater fish species to varying levels of dissolved oxygen. Shortfin eels showed no stress or mortality when faced with dissolved oxygen levels of less than 3mg/L, indicating that these species are highly tolerant of low dissolved oxygen levels. Additionally, McNeil & Closs (2007) tested the response of many fish species to progressive hypoxia (low dissolved oxygen levels) and found that goldfish and carp were both highly tolerant of hypoxia under laboratory conditions and that they may be able to survive in habitats with <1mg/L for sustained periods of time.

Effects of dissolved oxygen can be further intensified with high temperatures, however, temperatures remained around 13 degrees throughout the area which is of no concern to aquatic fish life (Williams, 2020). The majority of our native fish have preferences for instream temperatures between 17-23 degrees, in which these waterways were well under, with shortfin eel the most tolerant species of sub-lethal (low) and high temperature extremes (Richardson et al. 1994).

Table 3 - Field meter measurements recorded at seven locations throughout the Aka Aka Otaua drainage area on 15 July 2020.

	Site	Temperature (°C)	Dissolved oxygen (%)	Dissolved oxygen (mg/L)	pH*	Dead fish observed
1	Otaua at Otaua Rd	13.6	73	7.55	5.30	None
2	Otaua at Hoods Landing Rd/Forestry Rd	13.3	76.1	7.94	5.29	1 x shortfin, 2 x koi
3	Otaua at Hoods Landing	13.2	82	8.88	5.84	1 x shortfin, 3 x goldfish
4	Awaroa at Otaua Rd	13.4	76.8	8.01	5.80	1 x goldfish
5	Awaroa at 89 Crouch Rd	13.8	75	7.95	6.35	>40 koi, goldfish, shortfin
6	Aka Aka at Muir Rd	13.5	71	7.30	4.96	1 x goldfish
7	Arrowville Drain at Arrowville Rd	13	59.2	6.05	4.60	None
8	Eastern Drain at Eastern Drain Rd	13.1	57	6.01	5.13	None

*pH monitor was serviced by ENVCO post monitoring, which found a +0.5 unit drift.

pH was found to be extremely low across all sites, ranging from 4.6 to 6.35 indicating high acidity. Native fish prefer pH ranging from 6.5 to 8, which is naturally common in most rivers and streams except for humic rich streams where pH can be lower. A pH value of less than 6 equates to the D band of the National Objectives Framework (NOF, 2013) and is likely to cause extensive and significant stress to aquatic life, possibly leading to death (Williams, 2020).

West et al. (1997) tested the responses of nine different New Zealand native fish species to variable levels of pH. Adult fish showed stronger pH preferences than juveniles and an avoidance of pH below 5 was evident for all species including shortfin and longfin eels. Low pH levels can cause changes in the solubility of different compounds, making toxic chemicals more readily mobile which can lead to increased likelihood of absorption by aquatic life.

A NZ study by Olsson et al., (2006) suggests eels and banded kokopu as potentially having higher tolerance for low pH than introduced trout. There may be some slight site-specific habituation by some species to consistently low pH (as tends to occur for some species with temperature) though this would require regular and consistent exposure (David, 2020).

The laboratory analysis of the water samples collected from Sites 1 and 6 (Otaua creek and Aka Aka stream) on the 21 July 2020 and the 11 August 2020 are presented in Table 4.

Table 4 - Water quality laboratory analysis results for grab samples collected on 21 July 2020 and 11 August 2020.

Parameter (mg/L unless specified)	Otaua (1)	Aka Aka (6)	Otaua (1)	Aka Aka (6)
	21/7/2020		11/08/2020	
pH	6.1	4.6	6.3	4.8
Alkalinity (g/m^3 as $CaCO_3$)	8.1	2.9	10.0	2.6
EC (µS/cm)	517	909	536	576
Total Ammoniacal-N	0.190	0.54	0.195	0.29
Nitrate-N + Nitrite-N	1.59	1.90	1.37	1.08
Total Kjeldahl Nitrogen	0.38	1.21	0.45	0.74
Total nitrogen	1.98	3.1	1.82	1.81
Dissolve reactive phosphorus	<0.004	0.004	<0.004	<0.004
Total phosphorus	0.008	0.040	0.012	0.012
E. coli (cfu / 100 mL)	<10	20	10	50
Turbidity (NTU)	3.8	7.5	4.8	4.3
Absorbance @340nm (AU cm^{-1})	0.008	0.021	0.009	0.018
Absorbance @440nm (AU cm^{-1})	<0.002	<0.002	<0.002	<0.002
Absorbance @780nm (AU cm^{-1})	<0.002	<0.002	<0.002	<0.002
Aluminium (dissolved)	0.30	5.0	0.196	2.2
Aluminium (total)	1.04	5.0	1.20	2.3
Arsenic (dissolved)	<0.0010	<0.0010	<0.0010	<0.0010
Cadmium (dissolved)	0.00023	0.00084	0.00023	0.00031
Chromium (dissolved)	<0.0005	0.0007	<0.0005	0.0005
Lead (dissolved)	<0.00010	<0.00010	<0.00010	<0.00010
Nickel (dissolved)	0.0143	0.037	0.0140	0.028
Selenium (dissolved)	<0.0010	<0.0010	<0.0010	<0.0010
Zinc (dissolved)	0.074	0.22	0.076	0.116
Chloride	45	55	44	31
Sulphate	156	360	161	210

The pH is still low in both streams over a month after the initial fish kill event with low alkalinity indicating very limited buffering capacity to control sudden changes in pH. Electrical conductivity (EC) elevated at both locations and on both dates ranging from around 500 to 900 µS/cm. This indicates a high concentration of dissolved ions but is within the range expected for moderately disturbed/ non-pristine waters or waters impacted by limestone geology. The EC range is also consistent with the EC ranged measured for the 2014 event where ECs ranged from around 450 to 900 µS/cm.

E. coli and other pathogens were all very low and well within the A band of the NPS for Freshwater attribute states (NPSFW, 2014).

While total nitrogen concentrations exceed the national bottom line and fall well within the D band of the NPS for Freshwater attribute states (NPSFW, 2014), the ammoniacal nitrogen concentrations when taking into account the low pH and temperature, would mean that the majority of the ammoniacal nitrogen would be in the low toxicity ammonium ion form and would therefore fall well within the Australian and New Zealand Water Quality Guidelines for 95% species protection after correction for temperature and pH. Nitrate nitrogen is satisfactory, falling within the B band of the NPS for Freshwater attribute states (NPSFW, 2014).

Sulphate concentrations of 156 to 360 mg/L are very similar to the concentrations recorded in 2014 and all are significantly elevated compared to the range of typically less than 10 mg/L recorded in streams and rivers across the region as well as the Waikato river monitoring site at Taukau which is typically around 10 mg/L.

Chloride concentrations of 31 to 55 mg/L are somewhat elevated compared with the typical concentrations recorded in streams and rivers around the region of around 10 to 20 mg/L with the Waikato river at Taukau typically being around 18 mg/L.

Dissolved aluminium ranges from 0.3 to 5.0 mg/L which is around 5 to 90 times higher than the ANZ water quality guideline of 0.055 mg/L for 95% protection at pH >6.5. The toxicity of aluminium increases considerably at low pH and is generally most toxic over the pH range 4.4 to 5.4 which is a similar range to the pH identified in the Aka Aka stream. The ANZ water quality guidelines also provides a low reliability guideline of 0.0008 mg/L for dissolved aluminium when the pH is below 6. It is therefore expected that the aluminium concentrations would have had a significant adverse effect on fish in both streams.

Dissolved zinc is also elevated with concentrations ranging from 0.074 to 0.220 mg/L which is around 9 to 28 times the ANZ 95% protection value which would also be expected to have resulted in significant adverse effects on fish in both streams.

Dissolved nickel and cadmium concentrations were also up to three times and eight times the ANZ 95% protection values respectively which would have also contributed to the overall toxicity effects.

2.3 Evidence for acid sulphate soil impacts

2.3.1 Acid sulphate soils

At the time of preparing this report, the presence of acid sulphate soils has not yet been confirmed. However, an acid sulphate soil investigation by the Land and Soil team, within the Science section, is currently in preparation. This investigation will be undertaken in parallel with the SOE soil monitoring programme that will be undertaken later this year and will require landowner approvals before it can begin.

Limited research has been undertaken into the extent and implications of acid sulphate soils in New Zealand. Key pieces of research include the assessments of acid sulphate soils occurrence in Auckland and other northern parts of New Zealand in the 1970s and 1980s (Dent, 1980, 1986 and Metson et al, 1977).

A joint study based on known geology and soil maps as well as some limited soil investigations was undertaken in 2016 by GHD and Auckland Council to provide information on the likelihood of acid sulphate soils occurring in the Auckland region to inform planners and developers of the potential risks (Roberts and McConchie, 2017).

The following map was produced which provides a spatial probability of acid sulphate soil occurrence in the Auckland region (refer to Figure 10). It is relevant to note that the closest high probability area in the Auckland region is only around 10 km to the north of the Aka Aka-Otaua drainage area (indicated by blue ellipse) with only about 5 km separation from the medium probability area.

Acid sulphate soils have previously been identified in the northern Waikato region at the Hampton Downs Landfill, approximately 30 km southeast of the Aka Aka area. An investigation report was prepared by Fraser Thomas Ltd for Envirowaste in 2007 to assist them with management of this issue (Envirowaste, 2007). Impacted drainage water with a distinctly different signature to landfill leachate was found to have low pH of 5.7 to 5.8, low alkalinity and elevated sulphate and electrical conductivity. The report commented that Whangamarino formation materials were believed to be the principal source of the "acid runoff". Geological maps of the site indicated that these materials were present within the Stage 1 landfill footprint and were likely to have been excavated as part of Stage 1 construction works and hence to have ended up in the gully stockpiles. The Whangamarino formation materials in-situ when undisturbed are likely to be subject to reducing conditions, this being supported by the soil colours and low hydraulic conductivities noted in these soils. Based on the high sulphate values in exposed soils, they have inferred that there are sulphides present in the in-situ soil, which upon exposure to air and water are oxidised to form sulphates and subsequently sulphuric acid.

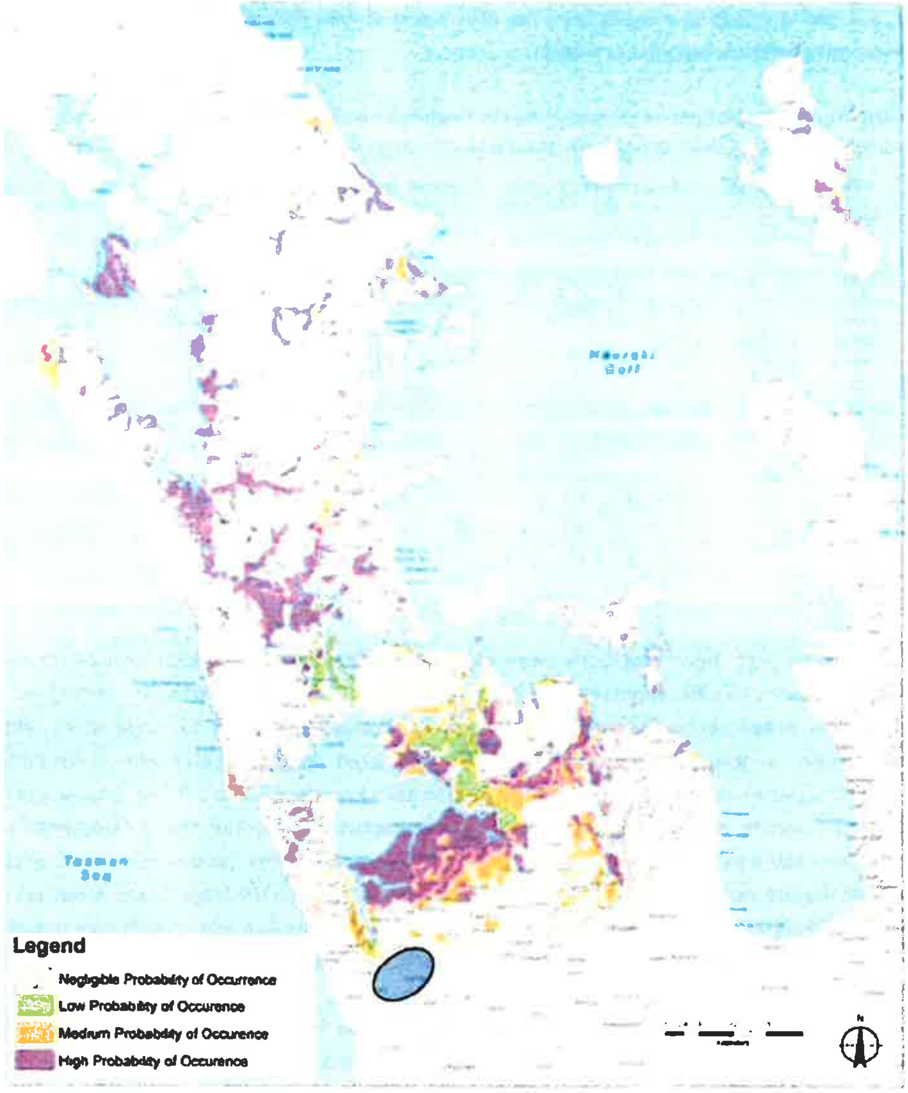

Figure 10 - Preliminary map of the potential for acid sulphate soils in the Auckland Region (Robert and McConchie, 2017).

Acid sulphate soils are classified in to two types (WA Department of Environment Regulation, 2015):

- Potential acid sulphate soils (PASS) are soils or sediments which contain iron sulphides and/or other sulphidic minerals that have not been oxidised. The field pH of these soils in their undisturbed state is more than pH 4 and is commonly neutral to alkaline (pH 7 to pH 9). These soils or sediments are invariably saturated with water in their natural state. The waterlogged layer may be peat, clay, loam, silt, or sand and is usually dark grey and soft but may also be dark brown, or medium to pale grey to white.
- Actual acid sulphate soils (AASS) are soils or sediments which contain iron sulphides and/or other sulphidic minerals that have undergone some oxidation. This results in low pH (i.e. pH <4) and often a yellow and/or red mottling (jarosite/iron oxide) in the soil

profile. AASS commonly also contain residual un-oxidised sulphide minerals (i.e. potential acidity) as well as existing acidity.

A groundwater study undertaken by Waikato Regional Council in 1991 (Cochrane *et al.*, 1991) provides some discussion of soils and geology in the Waiuku/ Aka Aka area.

The soils in the Aka Aka basin are classified as peaty loams which are an intergrade between northern organic soils and gley soils (Orbell, 1977). These soils are impeded by poor drainage and are subject to surface water ponding. Drainage work has improved the soil structure and pasture growth, but most of the basin remains liable to surface flooding from the surrounding hill catchments (MAF, 1983).

In the north, south of Waiuku, soils on the rolling hills are predominantly brown granular loams. Brown loams formed on underlying basalts and intergrades between these and northern yellow brown earths also occur in the area (Orbell, 1977).

The soils of the western hill catchments are yellow brown sands formed on a high dune barrier between the sea and the Aka Aka basin (Gibbs *et al.*, 1968). Vegetation and weathering processes have stablised the dune sands but soils formed on unconsolidated parent material remain vulnerable to soil erosion and are best kept vegetated (Cochrane *et al.*, 1991).

A semi-continuous silt and silty clay layer between 5 and 40 metres thick has been identified as sitting above the underlying Kaawa Formation sediments in the Waiuku area. Swamp and alluvial gravels, sands, silts, clays and interbedded peats are all described in the superficial sediments infilling the Aka Aka basin (Cochrane *et al.*, 1991).

The low-lying nature of the Aka Aka basin and its proximity to the Waikato river mouth and tidal influences has led to the construction of stopbanks, floodgates and numerous pumping stations to maintain the existing, mainly pastoral land use (Cochrane *et al.*, 1991).

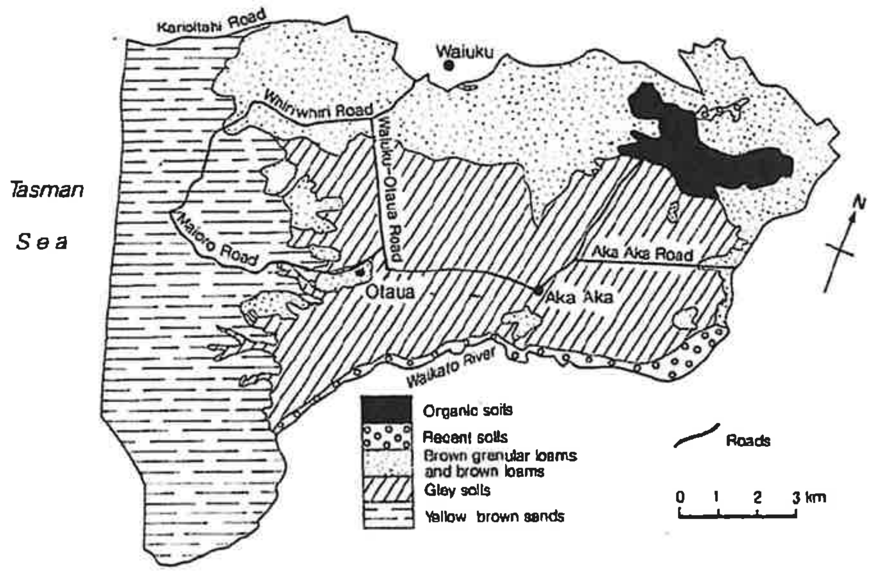

Figure 11 - Distribution of soil groups in the Waiuku area (after Maggs, 1987).

These previous assessments of soils in the Waiuku and Aka Aka basin area indicate some potential for acid sulphate soils to be present in this area.

The Australian National Acid Sulphate Soils Guidance (WQA, 2018) provides some useful information on soil and surface and ground water quality indicators that help provide evidence of the presence of acid sulphate soils.

Investigations should include:

- visual assessment of topography and geomorphology;
- visual assessment of surface water and hydrology;
- visual assessment of prevalent plant communities; and
- examination of surface soils and the soil profile (hand auger sufficient at this stage).

The site investigation should examine the presence of both actual acid sulphate soils (AASS) and potential acid sulphate soils (PASS) materials. Many of the indicators for AASS and PASS are substantially different. Commonly AASS are found overlaying PASS, and both are often covered by non-ASS topsoil layers.

Potential acid sulphate soil (PASS) indicators include:

- soil field pH_F > 4 and commonly neutral
- soil pH_{FOX} < 3, with large unit change from pH_F to pH_{FOX}, together with volcanic reaction to peroxide (note pH_{FOX} is the field pH of the soil after reaction with 30% hydrogen peroxide)
- waterlogged soils—unripe muds (soft, sticky and can be squeezed between fingers, blue grey or dark greenish grey mud with a high water content, silty sands or sands (mid to dark grey) or bottom sediments (dark grey to black for example monosulphidic black oozes) possibly exposed at sides and bottom of drains, cuttings or in boreholes
- peat or peaty soils
- coffee rock horizons, and
- a sulphurous smell for example hydrogen sulphide or 'rotten egg' gas
- surface water pH usually neutral but may be acidic
- surface water may have an oily looking iron bacterial surface scum (the similar appearances of iron bacterial scum and a hydrocarbon slick can be differentiated by disturbing the surface with a stick— bacterial scum will separate if agitated whereas a hydrocarbon slick will adhere to the stick upon removal).

During the 2014 fish kill investigation the top (eastern) end of McLarens drain was observed to have deep deposits of black anoxic sediment that were thigh deep near the flap gate. When disturbed the sediment caused DO levels to drop to very low levels. It is possible that these black sediments could be consistent with the description above of waterlogged soils including unripe muds and bottom sediments as potential acid sulphate soil indicators.

Actual Acid Sulphate Soil (AASS) characteristics include:

- soil field pH_F <4 (when field pH_F >4 but <5 this may indicate some existing acidity and other indicators should be used to confirm presence or absence of AASS
- sulphurous smell e.g. hydrogen sulphide or 'rotten egg' gas
- any jarositic horizons or substantial iron oxide mottling in the surface encrustations or in any material dredged or excavated and left exposed; and

- presence of corroded mollusc shells.

Water characteristics associated with AASS:

- water of pH <5.5 (and particularly below 4.5) in surface water bodies, drains or groundwater (this is not a definitive indicator as organic acids may contribute to low pH in some environments such as Melaleuca swamps)
- unusually clear or milky blue-green water flowing from or within the area (aluminium released by ASS acts as a flocculating agent)
- extensive iron stains on any drain or pond surfaces, or iron-stained water and ochre deposits, and
- oily looking bacterial surface scum.

If soil materials or associated water bodies display one or more of the indicators of ASS materials described above, the presence of ASS materials is likely, but not conclusive.

2.3.2 Surface water chemistry

The analysis of groundwater (and drain water) for $SO_4^{2-}:Cl^-$ ratio has frequently been used as an indicator of ASS. A $SO_4^{2-}:Cl^-$ ratio of greater than 0.5 is a strong indicator of an extra source of sulphate from reduced inorganic sulphate oxidation. However, the utility of the $SO_4^{2-}:Cl^-$ ratio to identify ASS materials diminishes as the salinity of groundwater approaches that of freshwater. (WQA, 2018).

Based on the surface water analyses of samples collected on 21 July 2020 and 11 August 2020 from the Aka Aka stream and Otaua creek (refer Table 4) it is evident that the $SO_4^{2-}:Cl^-$ ratios are much greater than 0.5 ranging from 3.4 to 6.8. A determination of salinity in comparison to typical freshwater salinity concentrations would be useful for providing additional confidence in the applicability of these $SO_4^{2-}:Cl^-$ ratios.

With reference to the Australian National guidance (WQA, 2018) the $SO_4^{2-}:Cl^-$ ratios of >0.5 and pH of 6-8 recorded for the Otaua creek are indicators of the presence of AASS or PASS but with substantial acid neutralising capacity. For the Aka Aka stream, the $SO_4^{2-}:Cl^-$ ratios of >0.5 and pH of <5 are indicators of the presence of AASS or PASS with little or no acid neutralising capacity.

In addition to the water quality monitoring in 2020 within the Aka Aka stream and Otaua creek, there are also long term water quality monitoring results available from WRC's RERIMP monitoring site on the Awaroa stream (Otaua Rd bridge opposite Moseley Rd – Site 41_9). The pH has been monitored at this site on a monthly basis from 1993 to 2020. The pH has ranged from 5.2 to 9.6 over this period (refer to Figure 12). While typically pH has not dropped as low as identified in these more recent fish kill investigations, there is a clear seasonal change from alkaline conditions during summer to acidic conditions over winter with typically 1 to 2 pH unit differences between winter and summer seasons. However, the most significant seasonal pH changes are evident in 1994, 2013, 2015 and 2020 when the pH change was around 3 to over 4 pH units difference with a pH of around 5.2 to 5.4 during the winter of three of those years.

Long term water clarity (measured using the black disk method) has also been recorded over this same period at the Awaroa stream site. Both pH and water clarity are presented over the period 1993 to 2020 in Figure 12. A seasonal variation in water clarity is less obvious (i.e. there has been some summers where clarity was higher than in winter) which may possibly be due to higher sediment runoff during heavy rainfall events in winter. However, while increased water clarity has not always coincided with a drop in pH, the most significant seasonal variations in pH recorded in 1994, 2013, 2015 and 2020 align with the most significant increases in water clarity with 2020 featuring the largest drop in pH over the winter period and the largest increase in water clarity.

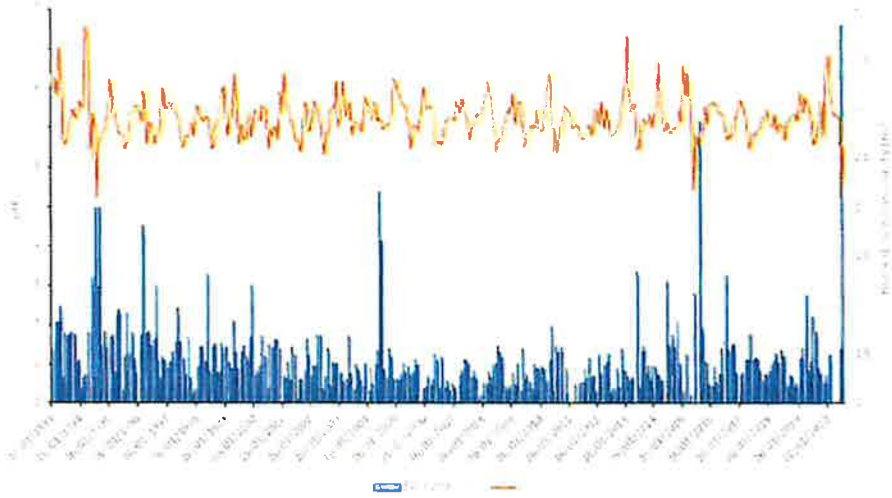

Figure 12 - pH and black disk water clarity levels recorded in the Awaroa stream from 1993 to 2020.

An analysis of sulphate and chloride ions from water samples taken at monthly intervals at the Awaroa stream RERIMP site in 1993, 2005, 2010/2011 and 2016 also provides supporting evidence of the presence of acid sulphate soils. Chloride concentrations ranged from 25 to 72 mg/L with a mean of 41 mg/L and sulphate concentrations ranged from 4.9 to 74 mg/L with a mean of 27.6 mg/L. These concentrations are elevated compared with typical ranges recorded across the region. During the winter/spring months of June to October for these four years the SO_4^{2-}:Cl^- ratio was greater than 0.5 with a pH of 6-8 which is an indicator of the presence of AASS or PASS but with substantial acid neutralising capacity.

Dissolved zinc concentrations analysed from monthly samples collected from the Awaroa stream RERIMP site from August 2009 to June 2011 (refer to Figure 13) ranged from 0.001 to 0.050 mg/L with a mean of 0.007 mg/L. The maximum concentration of 0.050 mg/L exceeds the ANZ water quality guideline for 95% protection by around six times. The zinc concentration also shows a seasonal variation with higher concentrations during the winter months.

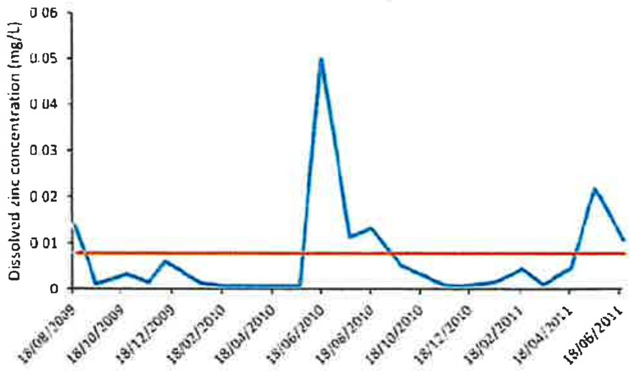

Figure 13 - Dissolved zinc concentrations recorded in the Awaroa stream from 2009 to 2011 (red line indicates the ANZ 95% protection level).

A large suite of dissolved metals was also analysed from samples collected at the Aka Aka stream at Otaua Road bridge from November 2013 to July 2014 as part of a seasonal trace elemental and isotopic study across the lower Waikato catchment with a focus on fish otolith microchemistry aimed at identifying key recruitment origins for native freshwater fish species in the lower Waikato river basin (David, 2016).

Seven metals showed seasonal variation with exceedances of the relevant ANZ water quality guidelines occurring in winter of 2014. As was identified in the Aka Aka stream and Otaua creek in July and August 2020, aluminium and zinc are the metals that are most likely to be resulting in significant adverse effects on fish with very significant exceedances occurring.

Table 5 - Dissolved metal concentrations recorded in the Aka Aka stream (Otaua Road bridge) from 2013 to 2014 (numbers in red indicate ANZ exceedance).

Dissolved metals	Concentration (mg/L)				
	19/11/2013	21/02/2014	12/04/2014	1/07/2014	ANZ water quality guideline
Aluminium	0.028	0.11	0.014	1.94	0.055*
Cadmium	< 0.00005	< 0.00005	< 0.00005	0.00031	0.0002
Cobalt	0.0013	0.0004	0.0047	0.026	0.0014
Copper	0.0029	0.0013	0.0009	0.0018	0.0014
Nickel	0.0038	0.0021	0.009	0.022	0.011
Thallium	< 0.00005	< 0.00005	< 0.00005	0.00009	0.00003
Zinc	0.0028	< 0.001	0.0115	0.105	0.008

*When pH < 6.5 the guideline value is 0.0008.

This seasonal variation in pH which has at times coincided with significant changes in water clarity along with sulphate to chloride ratios increasing above 0.5 during winter and a significant increase in elevated dissolved metal concentrations provides strong evidence of acid sulphate soil impacts in the Aka Aka-Otaua drainage area.

2.3.3 Rainfall analysis

In Australia, the impacts of acid sulphate soil leachate are often known to peak seasonally after dry periods with the first drought-breaking rains (WQA, 2018) which is consistent with the seasonal variations in water chemistry that have been identified in the Aka Aka-Otaua drainage area.

In addition to the evidence of a seasonal impact it is important to note that although oxidation of iron sulphides within potential acid sulphate soils may occur within a localised area, affected water may impact the surrounding areas some distance away from the original site. Acids and metals mobilised in soil leachate are usually transported episodically in concentrated slugs, usually after high rainfall events. As a result, leachate that is normally within acceptable limits may exceed these limits under episodic release conditions (Roberts and McConchie, 2017).

A long-term analysis of rainfall in the Aka Aka-Otaua drainage area is therefore important in identifying what some of the potential climatic conditions might be for these episodic or seasonal changes in water chemistry and fish kill observations.

A 1991 groundwater assessment by Waikato Regional Council for the Aka Aka-Otaua area (Cochrane *et al.*, 1991) provides a detailed analysis of rainfall for the area.

The rainfall analysis was based on rainfall data from the Maioro Forest (just to the west of the drainage area) and Waiuku (just to the north of the drainage area) and is presented in Table 6. A seasonal pattern of monthly rainfall was identified as occurring at both sites, usually with a distinct summer minimum (January) and winter maximum (June). Estimates for the 5 and 10 year recurrence interval summer drought rainfall (December, January and February) show a similar spatial pattern to that for mean annual rainfall.

Table 6 - Annual rainfall statistics for two representative sites in the Waiuku area (Cochrane et al., 1991).

Station	Mean Annual Rainfall (mm)	Extreme annual rainfall statistics for selected recurrence intervals			
		Extreme drought rainfall (mm)		Extreme heavy rainfall (mm)	
		5 y	10 y	5 y	10 y
Waiuku	1402	1195	1070	1520	1690
Maioro Forest	1373	1120	1060	1510	1605

Prolonged high intensity rainfall occurs periodically in the Waiuku area. The heaviest and most persistent rainfall is generally associated with slow moving depressions travelling in a westerly direction. Heavy rainfall runoff from the hill catchments drains towards the Aka Aka basin and extensive surface water ponding occurs periodically in the basin.

The two closest rainfall monitoring sites to the Aka Aka-Otaua drainage area that are currently available include the Pukekohe station (accessed through NIWA's Cliflo database) which is around 12 km northeast and the Wairamarama station (a WRC site) which is around 15 km south in the Kaawa catchment. The annual rainfalls recorded at the Pukekohe station (1994 to 2020) and the Wairamarama station (2007 to 2020) are presented in Figure 14. The mean monthly rainfalls for these two stations are presented in Figure 15.

A mean annual rainfall of 1227 mm calculated for Pukekohe and 1242 mm calculated for Wairamarama are both around 150 mm less than the annual means determined from the 1991 analysis as presented in Table 5. There is insufficient information available to determine whether this reduction in mean annual rainfall in the last 20 years for the area is in fact due to a real change in climate conditions or whether it is an artifact of comparing historic rainfall data collected at slightly different locations compared with the current rainfall station locations. There was also no information provided in Cochrane's 1991 study regarding over what period of time the mean annual values had been derived from.

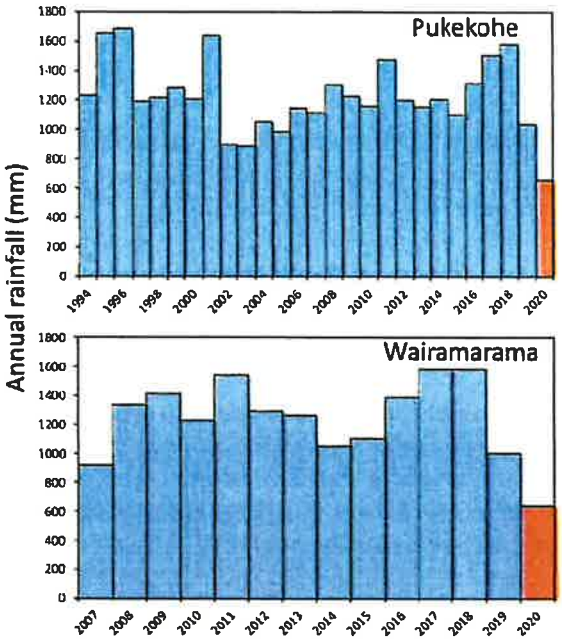

Figure 14 - Annual rainfalls recorded at the Pukekohe and Wairamarama rainfall monitoring stations (2020 total represents year to date to end of August).

The total rainfall of approximately 650 mm for 2020 for the period up to the end of August (orange bar in Figure 13) indicates that the annual total for this year is likely to fall within a low range of 1000 to 1100 mm when the mean monthly rainfalls (refer to Figure 14) for September through to December are added.

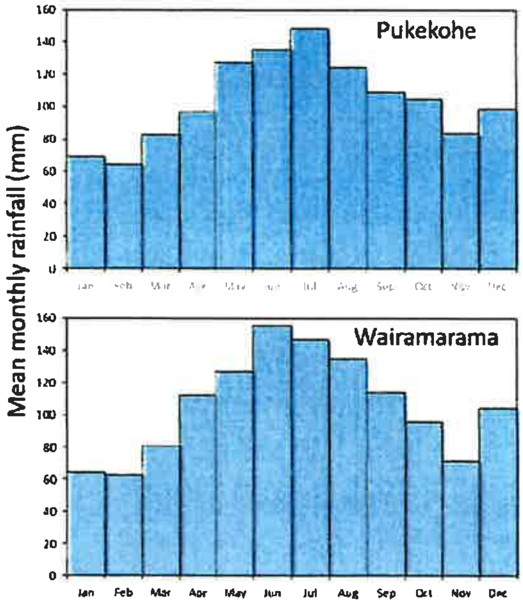

Figure 15 - Mean monthly rainfalls recorded at the Pukekohe and Wairamarama rainfall monitoring stations.

The highest annual rainfalls of 1500 to 1680 mm were recorded in 1995, 1996, 2001, 2011, 2017 and 2018 and are consistent with the 10-year extreme heavy rainfalls presented in Table 5 for the 1991 analysis. The lowest annual rainfalls of 900 to 1100 mm were recorded in 2002, 2003, 2004, 2005, 2007, 2014, 2015 and 2019 and are consistent with and in some years lower than the 10-year extreme drought rainfalls presented in Table 5.

An analysis of summer rainfall totals (January, February and March) compared to winter rainfall totals (June, July and August) is presented in Figure 16. The red arrows indicate the years or approximate periods when there was a large difference between the summer and winter rainfalls which usually coincided with very low summer rainfall. The years 1998, 2008, 2010, 2014, 2015, 2019 and 2020 are the years when summer rainfall was typically around 100 mm or less followed by winter rainfalls of around 400 mm.

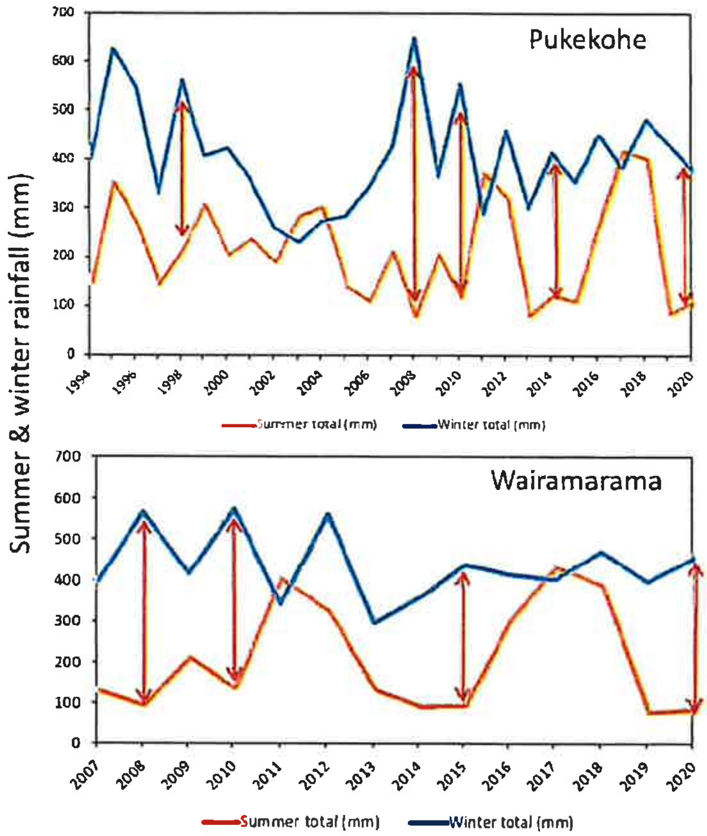

Figure 16 - Comparison of summer rainfall totals (Jan, Feb & Mar) with winter rainfall totals (Jun, Jul & Aug).

2.3.4 Groundwater and surface water flow assessment

There is some limited stream flow data for the Awaroa stream available through WRC's WISKI database. However, the data is only available up to 1988 and therefore it has not been possible to make any updated assessment of flow rates and how this varies seasonally. There is also no recent groundwater assessment for this area.

A groundwater and surface water assessment was undertaken by Waikato Regional Council for the Aka Aka-Otaua area and reported on in 1991 (Cochrane *et al.*, 1991).

The report describes the Waiuku area as covering approximately 142 km^2 and being characterised by the flat low-lying Aka Aka basin containing swamp and alluvial materials adjacent to the Waikato river and rolling to hilly catchments surrounding the basin.

The mean annual specific discharge was reported to vary from 11 to 14 L s^{-1} km^{-2} in most of the sub-catchments in the hill catchment area or near the margin of the Aka Aka basin. Stream flow was described as generally being sustained during periods of drought, especially in the Aka Aka basin where a large component of stream flow is derived from upwelling groundwater. However, seasonal surface water demand reduces stream low flow by at least 15% in the upper Awaroa catchment.

Importantly, it was identified that a close relationship was established between shallow aquifers and streams. Shallow aquifers were identified as being a large source of water contributing 200 mm to annual stream base flow but use of this water would further reduce stream water availability during drought.

Stream flow may be compromised during a prolonged drought when stream flow and ground water are under heavy demand. However, it was concluded that the water demand (as determined at the time of the study) in the Aka Aka basin has minimal impact on stream flow during drought, because stream flow is maintained by shallow ground water.

Piezometric levels showed no long-term trend during the study. In the shallow aquifers, piezometric levels respond closely to net rainfall, but seasonal changes in aquifer storage are relatively small compared with climatic variation.

Approximately 75% of water right abstractions in the study area were identified as being sustained by deep aquifers which do not link directly with local streams. The report recommended that future large abstractions in the hill catchment area be directed towards the deep aquifers thereby minimising the potential for shallow ground water abstractions to interfere with stream flow.

The 1991 study also assessed groundwater quality from samples collected from farm production bores throughout the study area (refer to Figure 17).

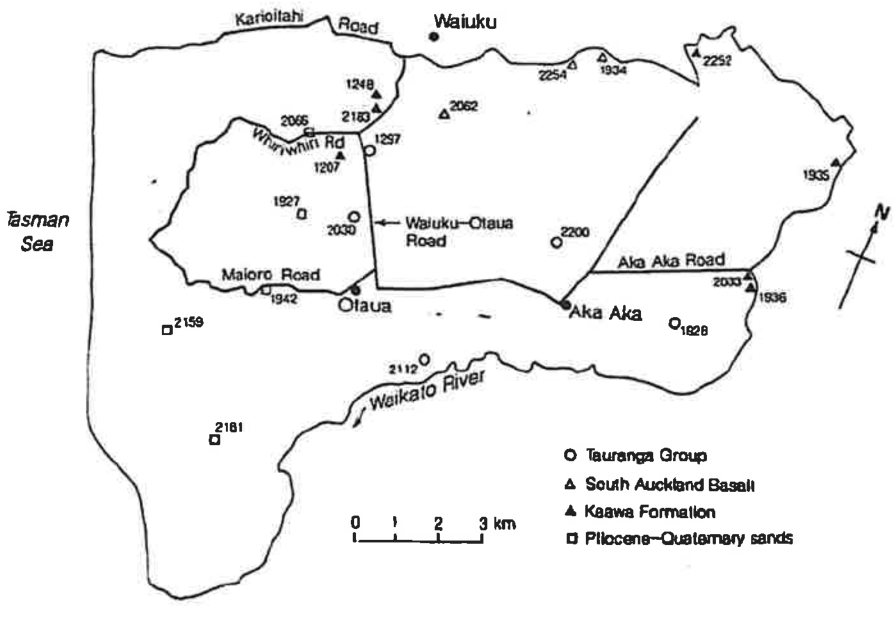

Figure 17 - Location of bores sampled for groundwater chemistry (Cochrane et al., 1991).

While the limited suite of major and minor ions and other water quality parameters analysed did include sulphate and chloride ions and pH, the ratios and pH were not indicative of being impacted by acid sulphate soils or potential acid sulphate soils. This absence of evidence of impact of acid sulphate soils on groundwater is likely because of the significant depth of the groundwater being targeted in this assessment.

No information was provided on individual bore depths that samples were collected from but the report does separate out the various bores in to deep aquifers (>50 metres – mainly the Kaawa formation bores with some Tauranga group bores) and shallow aquifers (<50 metres – all Pliocene-Quaternary sands and basalt bores and most of the Tauranga group bores). However, it is assumed that the groundwater depth of these bores will be all more than 20 metres below ground level. For purposes of investigating the impacts of acid sulphate soils on groundwater, it would be necessary to target very shallow groundwater of less than 10 metres and potentially in the vicinity of 5 metres depth.

For further investigation of the potential impacts of acid sulphate soils in the Aka Aka-Otaua area and for informing how best to reduce the impacts in future, it will be important to establish shallow groundwater depth and how this varies seasonally. It will also be important to monitor the stream and drain levels and flow rates and how levels can be better optimised and controlled to reduce the oxidation and disturbance of acid sulphate soils that are potentially present in the area.

Waikato Regional Council's groundwater scientist, John Hadfield, has recommended that shallow piezometers should be placed within 50 metres of the banks of drains and streams where acid sulphate soils have been identified in order to best determine the seasonal variation of shallow groundwater and how this might be impacting on acid sulphate soil effects.

3 Conclusions

Long term water quality monitoring data from 1994 to 2020 in addition to water quality data collected from targeted monitoring investigations over the period 2014 to 2016 and during 2020 provide strong evidence that the fish kill events of 2007, 2012/2013, 2014 and 2020 have been caused by seasonal changes in water chemistry as a result of the likely presence of potential acid sulphate soils and actual acid sulphate soils.

A seasonal variation in pH has been observed with the wintertime pH often falling well below 6 pH units which has at times coincided with significant changes in water clarity along with sulphate to chloride ratios increasing above 0.5 during winter and a significant increase in elevated dissolved metal concentrations well above ANZ water quality guidelines. These are all strong indicators that potential acid sulphate soils and actual acid sulphate soils are present and impacting surface water quality in the Aka Aka Otaua drainage area.

While low pH will be resulting in adverse effects on fish, the extremely elevated concentrations of dissolved aluminium and zinc are the most likely causes of mortality. However, it is possible that pH may have dropped below 3 to 4 pH units for very short periods and therefore the effect of low pH as a causal factor for the fish mortality cannot be ruled out. Potentially, the adverse water quality conditions are occurring for up to three months per year which could explain the observations of dead fish in varying levels of decomposition.

The impacts on water quality are also widespread with impacted water quality identified in the Otaua creek, Awaroa stream, Aka Aka stream, Ten foot drain, Arrowville drain, Eastern drain, McLarens drain and Mangawhero drain. While the biggest fish kill was identified in the Awaroa stream during the 2020 event, the longer-term water quality data suggests that the water quality of the Aka Aka stream is potentially being impacted more significantly.

While it is unclear whether drainage works by ICM in the Aka Aka and Awaroa streams around three to four weeks prior to the 2020 fish kill event had exacerbated the water quality conditions, it is important to note that there was no evidence of low dissolved oxygen levels or blue-green algal blooms in those two streams which can be indicative of effects caused by silt removal and vegetation removal. In addition to this, fish kills and compromised water quality were identified across multiple waterways within the area where works had not been undertaken.

The previous fish kill events of 2013 and 2014 also do not appear to have occurred immediately following any recorded drainage works. It is also evident that water quality has been consistently varying from year to year on a seasonal basis with the recorded fish kill events generally aligning with years where there was a very low cumulative summer rainfall of 100mm or less followed by heavy rainfall in the winter months. This supports the theory that acid sulphate soils are being exposed to oxidative conditions when groundwater and surface water levels are low over summertime with subsequent release of acid leachate when levels rise again when levels increase again after heavy rainfall, typically during wintertime.

However, it is possible that the control of water levels through some of these drains and floodgates may at times exacerbate the effects on water quality and fish mortality.

It is clear from the evidence available that fish kill events will continue in future years, typically during wintertime when pH drops along with associated increase in concentration of dissolved metals in streams and drains within the Aka Aka-Otaua area. If climate change results in a trend towards more extreme climatic conditions, this may increase the frequency of these events.

4 Recommendations

The following are a series of recommendations for ongoing monitoring and further investigation as well as review and potential amendments to ICM works in that area that could help reduce the impact and frequency of these fish kill events.

1. More widespread and frequent monitoring of water quality across the Aka Aka Otaua area is needed in future. Currently the Awaroa stream is monitored regularly as part of the RERIMP monitoring programme which includes pH, clarity, turbidity and DO. However, it would be important to extend the suite of monitoring parameters to also include, sulphate and chloride ions, alkalinity and a suite of dissolved metals including aluminium and zinc. A Sonde has also been deployed in the Aka Aka stream since 11 August which is monitoring pH, DO, conductivity and turbidity. However, previous monitoring rounds that have occurred in the Aka Aka stream and indicated very elevated dissolved metal concentrations and low pHs, it is recommended that water quality monitoring of this stream is undertaken on a more regular basis with pH, clarity, turbidity, DO, sulphate and chloride ions, alkalinity and a suite of dissolved metals including aluminium and zinc. Consideration may also need to be given to extending this monitoring programme to also include the Mangawhero drain at the eastern end of this area.

2. Set up an alert through the WISKI database for the Awaroa River water quality monitoring site (and any additional site that is set up in this area) that gives ICM/SAS warning that clarity is increasing within the Aka Aka/Otaua area (i.e. over 0.55m, the relative average) and also when pH drops below 6.5 units. This will signify that more intense investigation and observation is required.

3. A comprehensive acid sulphate soil investigation is required to confirm the presence, location and depth of actual acid sulphate soils and potential acid sulphate soils including dredged silts from drains. This investigation should be undertaken in general accordance with the Australian guidance (WA Department of Environment Regulation, 2015; and WQA, 2018).

4. Establish shallow groundwater depth in the areas where acid sulphate soils have been identified and determine how this varies seasonally. It will also be important to monitor the stream and drain levels and flow rates and how these vary seasonally with specific emphasis on those locations closest to acid sulphate soils.

5. Undertake a review of drainage works in the area and how drain levels are maintained in order to establish whether there is an ability to maintain higher levels in drains during periods of drought in order to reduce the potential for acid sulphate soils to become oxidised. This review should also look at how silt/dredgings that are removed from drains are placed and managed as this may also have an impact on water quality.

6. Review other areas in the Waikato region that may be impacted by acid sulphate soils including areas in Hauraki, specifically near to the Piako river mouth where high clarity has been observed in drainage systems that typically have high turbidity and also based on sulphate to chloride ratios of greater than 0.5 and pH less than 6.

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6 Appendices

Appendix A.1

pH and temperature results for sites 1 to 6 recorded August 2014 to June 2016.

Date	Parameter	1	2	3	4	5	6
13/8/14	pH Temp	5.7	5.2	4.1	3.6	4.7	
27/8/14	pH Temp	5.8	4.8	4.1	3.5	4.1	
27/11/14	pH Temp	6.4 17.8	6.6 17.4	6.6 19.2	3.9 16.7	3.8 16.0	
4/12/14	pH Temp	6.5	6.6	6.7	3.9	3.7	
9/12/14	pH Temp	6.5 22.6	6.9 20.0	7.1 20.2	4.2 23.5	3.9 20.2	3.9 20.2
18/12/14	pH Temp	6.0	6.5	5.6	3.6	5.5	4.6
13/3/15	pH Temp	7.3 20.6	7.3 20.3	7.3 20.0	8 18.9	8.4 18.7	7.6 19.4
17/6/15	pH Temp	4.8	4.25	3.4	3.6	4.8	
3/7/15	pH Temp	5.4 13.7	5.1 12.9	5.3 12.7	4.0 12.9	4.4 12.7	4.7 12.8
3/8/15	pH Temp	4.9 16.5	4.92 16.0	5.3 15.5	4.92 14.9	4.47 15.3	5.02 15.5
6/9/15	pH Temp	5.32 15.0	5.57 15.3	4.68 15.4	3.98 14.6	4.26 14.8	4.10 14.9
7/10/15	pH Temp	6.48 19.9	6.28 18.3	5.56 16.1	3.85 15.9	4.30 16.1	4.11 15.3
9/12/15	pH Temp	7.59 23.0	7.77 23.3	7.34 22.3	6.93 21.6	6.74 21.5	6.59 20.0
2/3/16	pH Temp	8.66 21.4	9.38 20.9	8.86 22.1	7.89 22.4	7.66 21.8	7.25 24.2
5/4/16	pH Temp	6.79 19.0	7.13 20.4	7.25 20.4	7.37 20.9	7.10 19.2	6.49 18.6
5/6/16	pH Temp	6.02 12.8	6.00 12.9	6.49 11.9	5.99 12.7	6.52 12.3	6.53 13.4
7/6/16	pH Temp	4.16 10.9	3.06 10.83	4.41 10.7	5.1 11.1	4.71 10.9	4.30 10.9

Appendix A.2

pH and temperature results for sites 7 to 12 recorded August 2014 to June 2016.

Date	Parameter	7	8	9	10	11	12
13/8/14	pH Temp						
27/8/14	pH Temp						
27/11/14	pH Temp						
4/12/14	pH Temp						
9/12/14	pH Temp	3.6 23.5					
18/12/14	pH Temp	4.0					
13/3/15	pH Temp	7.6 21.0					
17/6/15	pH Temp						
3/7/15	pH Temp	4.0 13.2	4.1 12.8	5.7 13.1	6.5 12.3	6.5 13.1	7.0 13.1
3/8/15	pH Temp	5.3 15.3		5.9 15.4			
6/9/15	pH Temp	4.28 14.3		5.29 18.4	5.28 14.2	5.98 13.8	5.82 13.7
7/10/15	pH Temp	4.14 16.6		6.46 18.0	6.71 16.6	7.06 16.9	8.03 17.9
9/12/15	pH Temp	6.65 22.2		6.66 22.7	6.35 22.9	6.35 22.0	6.47 21.9
2/3/16	pH Temp	6.66 22.2		6.91 22.6	7.10 21.4	6.66 22.7	7.90 24.1
5/4/16	pH Temp	6.62 18.2		7.25 22.1	7.10 17.6	6.50 19.9	7.61 22.4
5/6/16	pH Temp	6.24 11.9		6.22 12.1	6.34 12.4	5.93 12.6	6.01 12.5
7/6/16	pH Temp	4.51 10.8		5.20 11.3	5.32 11.3	5.73 11.5	5.63 11.8

Appendix B

YSI EXO2 Sonde deployed in the Aka Aka stream at site 11_5 at Otaua Road bridge on 11 August 2020 at 13.30.

Date	Sonde	Temp/Cond	DO	pH	Turbidity	Chlorophyll	Wiper
11/08/2020	15J101533	15G101435	18E100508	15F104692	16C103410	16C103741	15H102693

Colin Dall

To: Colin Dall

From:
Sent: Thursday, 15 August 2024 5:10 pm
To: Richard Griffiths <richardg@nrc.govt.nz>; Colin Dall <colind@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>
Subject: RE: Snapper testing

Richie,

Snapper were caught from Whangarei harbour that externally appeared to show the same symptoms – I have yet to have official confirmation that these were the same symptoms when examined more thoroughly.

So feel free to recommend anything that you think could potentially be causative from the harbour (that might also potentially be causative on the other coast as well), noting we have had samples showing the same symptoms from Paekakariki to the Kaipara Harbour, but we believe there is little to no effective mixing from West to East coast.

Ministry for Primary Industries | | Charles Ferguson Building 38 Bowen Street |
PO Box 2526 | Wellington | New Zealand
TE MANA WHAKAMARU ĀHUARANGI/CENTRE FOR CLIMATE ACTION ON AG EMISSIONS
www.mpi.govt.nz
SEEMail

From: Richard Griffiths <richardg@nrc.govt.nz>
Sent: Thursday, August 15, 2024 4:48 PM
To: Richard Ford (Rich Ford) <Richard.Ford@mpi.govt.nz>; Colin Dall <colind@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>
Subject: RE: Snapper testing

Kia ora Rich,

Thanks for sending this to me. We will have a look and get back to you. I have included Colin Dall on this email, our GM for regulatory services, who is co-ordinating our response, and Cathy our compliance monitoring manager. When you spoke to me last week you indicated that 'zombie' fish had also been caught off the Whangārei coast. Are you able to share these locations with us please? That may help with our decision making.

Ngā mihi
,
Richie

Richard Griffiths
Resource Scientist - Coastal
M 027 715 9923

Northland
REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

From:
Sent: Thursday, August 15, 2024 4:35 PM
To: Richard Griffiths <richardg@nrc.govt.nz>
Subject: Snapper testing

Hi Richie,

That report is taking longer to get right than I had hoped.

But see the attached for what we have tested for thus far in these Snapper.

I would be interested to hear if there are other substances NRC might recommend we test for as well (feel free to recommend broadly we would rather cast the net wide at this stage)?

We can identify a number of heavy metals known/likely to impact marine life in NZ = Aluminium, Cu, Pb, Zn, Arsenic, Chromium, Cadmium, Nickel from the document at www.mpi.govt.nz/dmsdocument/51694-Chapter-15-Land-based-effects-on-the-coastal-environment, some of these have already been tested for, we will recommend testing the rest as a next step, are there any others on the radar of NRS?

Are there any other specific PCBs, or compounds from herbicides or insecticides that NRC suggest we should test for?

Please don't circulate these beyond NRC currently without permission.
We are also making other external enquiries about what we should be testing for.

Thanks in advance

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TE MANA WHAKAMARU ĀHUARANGI/CENTRE FOR CLIMATE ACTION ON AG EMISSIONS
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---

CAWTHRON

Certificate of Analysis: Final

Cawthron Contract Number: 60632

Project Number: **C65201**

Ministry for Primary Industries
PO Box 2526
WELLINGTON

Attention: Marc Griffiths

Customer Ref: Contract No: SEA2023-19, Investigation 360907, Cost Centre 1572
Email Recipients: Marc Griffiths
Date Project Started: 14/06/2024 14:04

Sample Details

Laboratory ID: C65201-1 **Sample Type:** Fish **Date Sampled:** 07/06/2024 00:00
Description: Snapper **Date Received:** 11/06/2024 16:30
Site Description: Kaipara Harbour - caught at the mouth of Oruawharo River
Customer ID: Fish wgt: 3757g
Note: *Please see report attached for results of subcontracted test/s.*

Analysis	Result	Units	Method
E.coli	Not Detected	per gram	Compendium 5th Edn 2015 Ch 9.93 (modified)
Aerobic Plate Count at 30°C	2.6×10^5	cfu/g	Compendium 5th Edn 2015 Ch 8
Vibrio species	Not Detected	per 25g	FDA BAM On Line (modified)
Arsenic	0.78	mg/kg	In-house digestion / ICP-MS (APHA 3125B)
Cadmium	<0.01	mg/kg	In-house digestion / ICP-MS (APHA 3125B)
Mercury	0.48	mg/kg	In-house digestion / ICP-MS (APHA 3125B)
Lead	<0.01	mg/kg	In-house digestion / ICP-MS (APHA 3125B)

Sample Details

Laboratory ID: C65201-2 **Sample Type:** Fish **Date Sampled:** 07/06/2024 00:00
Description: Snapper **Date Received:** 11/06/2024 16:30
Site Description: Kaipara Harbour - caught at the mouth of Oruawharo River
Customer ID: Fish wgt: 737g
Note: *Please see report attached for results of subcontracted test/s.*

Analysis	Result	Units	Method
E.coli	Not Detected	per gram	Compendium 5th Edn 2015 Ch 9.93 (modified)
Aerobic Plate Count at 30°C	9.9×10^7	cfu/g	Compendium 5th Edn 2015 Ch 8
Vibrio species	Not Detected	per 25g	FDA BAM On Line (modified)
Arsenic	0.63	mg/kg	In-house digestion / ICP-MS (APHA 3125B)
Cadmium	<0.01	mg/kg	In-house digestion / ICP-MS (APHA 3125B)
Mercury	0.07	mg/kg	In-house digestion / ICP-MS (APHA 3125B)
Lead	<0.01	mg/kg	In-house digestion / ICP-MS (APHA 3125B)

Nelson Laboratory: 98 Halifax Street East, Nelson 7010. Private Bag 2, Nelson 7042
Auckland Laboratory: 78 Ascot Road, Māngere, Auckland 2022
(+64) 03 548 2839 | lab@cawthron.org.nz | www.cawthron.org.nz

Sample Details

Laboratory ID:	C65201-3	**Sample Type:**	Fish	**Date Sampled:**	07/06/2024 00:00
Description:	Snapper			**Date Received:**	11/06/2024 16:30
Site Description:	Kaipara Harbour - caught at the mouth of Oruawharo River				
Customer ID:	Fish wgt: 658g				
Note:	*Please see report attached for results of subcontracted test/s.*				

Analysis	Result	Units	Method
E.coli	Not Detected	per gram	Compendium 5th Edn 2015 Ch 9.93 (modified)
Aerobic Plate Count at 30°C	8.5×10^7	cfu/g	Compendium 5th Edn 2015 Ch 8
Vibrio species	Not Detected	per 25g	FDA BAM On Line (modified)
Arsenic	0.59	mg/kg	In-house digestion / ICP-MS (APHA 3125B)
Cadmium	<0.01	mg/kg	In-house digestion / ICP-MS (APHA 3125B)
Mercury	0.08	mg/kg	In-house digestion / ICP-MS (APHA 3125B)
Lead	<0.01	mg/kg	In-house digestion / ICP-MS (APHA 3125B)

Results apply to samples as received unless otherwise specified.

Microbiological counts less than the limit of quantification should be regarded as estimates. Limits of quantification are available from the laboratory on request.

Our routine detection limits for chemical testing relate to samples with a clean matrix.
Reported detection limits may be higher for individual samples if there is insufficient sample or the matrix is complex.

< means less than, > means greater than

Date Generated: 5/7/24

Authorised by: Sarbjit Singh
Position: Key Technical Person
Signature:

Authorised by: David Lewis
Position: Key Technical Person
Signature:

Test results indicated as not accredited are outside the scope of the laboratory's accreditation

Report Number: 1062736
Project Number: C65201

Nelson Laboratory: 98 Halifax Street East, Nelson 7010. Private Bag 2, Nelson 7042
Auckland Laboratory: 78 Ascot Road, Māngere, Auckland 2022
(+64) 03 548 2839 | lab@cawthron.org.nz | www.cawthron.org.nz

AsureQuality Kaitiaki Kai

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Certificate of Analysis

Submission Reference: C65201
Final Report

Cawthron Lab
Cawthron Institute
Private Bag 2
Nelson 7042
New Zealand

PO Number: 67094 (AQ)

Report Issued: 04-Jul-2024 **AsureQuality Reference:** 24-169631 **Sample(s) Received:** 20-Jun-2024 08:50

Testing Period: 20-Jun-2024 to 04-Jul-2024
Date of analysis is available on request.

Comments

The results for Sum of 7 Indicator PCBs (PCBs 28, 52, 101, 118, 138, 153 and 180) are given below: 24-52567-1 = 1.1 ng/g (Upperbound value) 24-52567-2 = 1.3 ng/g (Upperbound value)

Results

The tests were performed on the samples as received.

Customer Sample Name: 3757g Snapper - Kaipara Harbour **Lab ID:** 24-169631-1

Sample Description: C65201-1

Sample Condition: Acceptable **Sampled Date:** 07-Jun-2024

Test	Result	Unit	Method Reference
Dioxin-Like and Indicator Polychlorinated Biphenyls (PCBs) - Fish Tissue			
Dioxin-Like PCBs			
PCB 77	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 81	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 105	26	pg/g	AsureQuality Method (GC-MS/MS)
PCB 114	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 118	130	pg/g	AsureQuality Method (GC-MS/MS)
PCB 123	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 126	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 156	20	pg/g	AsureQuality Method (GC-MS/MS)
PCB 157	5.1	pg/g	AsureQuality Method (GC-MS/MS)
PCB 167	16	pg/g	AsureQuality Method (GC-MS/MS)
PCB 169	<5.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 189	3.3	pg/g	AsureQuality Method (GC-MS/MS)
Total PCB WHO-TEQ - Lowerbound	0.0060	pg/g	AsureQuality Method (GC-MS/MS)
Total PCB WHO-TEQ - Mediumbound	0.18	pg/g	AsureQuality Method (GC-MS/MS)
Total PCB WHO-TEQ - Upperbound	0.36	pg/g	AsureQuality Method (GC-MS/MS)
Indicator PCBs			
PCB 28	<0.025	ng/g	AsureQuality Method (GC-MS/MS)
PCB 52	<0.025	ng/g	AsureQuality Method (GC-MS/MS)
PCB 101	0.050	ng/g	AsureQuality Method (GC-MS/MS)
PCB 138	0.23	ng/g	AsureQuality Method (GC-MS/MS)
PCB 153	0.47	ng/g	AsureQuality Method (GC-MS/MS)

Test	Result	Unit	Method Reference
PCB 180	0.14	ng/g	AsureQuality Method (GC-MS/MS)
Sum of 6 Indicator PCBs - Lowerbound	0.89	ng/g	AsureQuality Method (GC-MS/MS)
Sum of 6 Indicator PCBs - Mediumbound	0.92	ng/g	AsureQuality Method (GC-MS/MS)
Sum of 6 Indicator PCBs - Upperbound	0.94	ng/g	AsureQuality Method (GC-MS/MS)
Environmental Tissue Sample Clean/Gut/Prep/Composite.			
status *	Complete		AsureQuality Method

Customer Sample Name: 737g Snapper - Kaipara Harbour **Lab ID:** 24-169631-2

Sample Description: C65201-2

Sample Condition: Acceptable **Sampled Date**: 07-Jun-2024

Test	Result	Unit	Method Reference
Dioxin-Like and Indicator Polychlorinated Biphenyls (PCBs) - Fish Tissue			
Dioxin-Like PCBs			
PCB 77	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 81	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 105	4.7	pg/g	AsureQuality Method (GC-MS/MS)
PCB 114	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 118	26	pg/g	AsureQuality Method (GC-MS/MS)
PCB 123	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 126	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 156	2.9	pg/g	AsureQuality Method (GC-MS/MS)
PCB 157	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 167	2.7	pg/g	AsureQuality Method (GC-MS/MS)
PCB 169	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 189	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
Total PCB WHO-TEQ - Lowerbound	0.0011	pg/g	AsureQuality Method (GC-MS/MS)
Total PCB WHO-TEQ - Mediumbound	0.13	pg/g	AsureQuality Method (GC-MS/MS)
Total PCB WHO-TEQ - Upperbound	0.26	pg/g	AsureQuality Method (GC-MS/MS)
Indicator PCBs			
PCB 28	<0.025	ng/g	AsureQuality Method (GC-MS/MS)
PCB 52	<0.025	ng/g	AsureQuality Method (GC-MS/MS)
PCB 101	<0.025	ng/g	AsureQuality Method (GC-MS/MS)
PCB 138	0.048	ng/g	AsureQuality Method (GC-MS/MS)
PCB 153	0.097	ng/g	AsureQuality Method (GC-MS/MS)
PCB 180	<0.025	ng/g	AsureQuality Method (GC-MS/MS)
Sum of 6 Indicator PCBs - Lowerbound	0.14	ng/g	AsureQuality Method (GC-MS/MS)
Sum of 6 Indicator PCBs - Mediumbound	0.20	ng/g	AsureQuality Method (GC-MS/MS)
Sum of 6 Indicator PCBs - Upperbound	0.24	ng/g	AsureQuality Method (GC-MS/MS)
Environmental Tissue Sample Clean/Gut/Prep/Composite.			
status *	Complete		AsureQuality Method

Customer Sample Name: 658g Snapper - Kaipara Harbour **Lab ID:** 24-169631-3

Sample Description: C65201-3

Sample Condition: Acceptable **Sampled Date**: 07-Jun-2024

Test	Result	Unit	Method Reference
Dioxin-Like and Indicator Polychlorinated Biphenyls (PCBs) - Fish Tissue			
Dioxin-Like PCBs			
PCB 77	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 81	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 105	3.5	pg/g	AsureQuality Method (GC-MS/MS)
PCB 114	<2.0	pg/g	AsureQuality Method (GC-MS/MS)

Test	Result	Unit	Method Reference
PCB 118	17	pg/g	AsureQuality Method (GC-MS/MS)
PCB 123	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 126	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 156	2.3	pg/g	AsureQuality Method (GC-MS/MS)
PCB 157	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 167	2.4	pg/g	AsureQuality Method (GC-MS/MS)
PCB 169	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
PCB 189	<2.0	pg/g	AsureQuality Method (GC-MS/MS)
Total PCB WHO-TEQ - Lowerbound	0.00076	pg/g	AsureQuality Method (GC-MS/MS)
Total PCB WHO-TEQ - Mediumbound	0.13	pg/g	AsureQuality Method (GC-MS/MS)
Total PCB WHO-TEQ - Upperbound	0.26	pg/g	AsureQuality Method (GC-MS/MS)
Indicator PCBs			
PCB 28	<0.025	ng/g	AsureQuality Method (GC-MS/MS)
PCB 52	<0.025	ng/g	AsureQuality Method (GC-MS/MS)
PCB 101	<0.025	ng/g	AsureQuality Method (GC-MS/MS)
PCB 138	0.036	ng/g	AsureQuality Method (GC-MS/MS)
PCB 153	0.079	ng/g	AsureQuality Method (GC-MS/MS)
PCB 180	<0.025	ng/g	AsureQuality Method (GC-MS/MS)
Sum of 6 Indicator PCBs - Lowerbound	0.12	ng/g	AsureQuality Method (GC-MS/MS)
Sum of 6 Indicator PCBs - Mediumbound	0.16	ng/g	AsureQuality Method (GC-MS/MS)
Sum of 6 Indicator PCBs - Upperbound	0.22	ng/g	AsureQuality Method (GC-MS/MS)
Environmental Tissue Sample Clean/Gut/Prep/Composite.			
status *	Complete		AsureQuality Method

Analysis Summary

Wellington Laboratory

Analysis	Method	Accreditation	Authorised by
Dioxin-Like and Indicator Polychlorinated Biphenyls (PCBs) - Fish Tissue			
DX-PCBS09, 02-FISH_TISSUE	AsureQuality Method (GC-MS/MS)	IANZ	Johan Viaene
The total toxic equivalence (WHO-TEQ) is calculated for each sample using WHO toxic equivalency factors (WHO-TEFs; Van den Berg et al., 2005).			
Environmental Tissue Sample Clean/Gut/Prep/Composite.			
DX-PREP01, 01-DEFAULT	AsureQuality Method	Not Accredited	Phil Bridgen

Any tests marked with * are not accredited for specific matrices or analytes.

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.

Phil Bridgen
Senior Scientist

Johan Viaene
Senior Scientist

Accreditation

Appendix

Analyte LOR Summary

Dioxin-Like and Indicator Polychlorinated Biphenyls (PCBs) - Fish Tissue - AsureQuality Method (GC-MS/MS)

Analyte	LOR
Dioxin-Like PCBs	
PCB 77	2.0 pg/g
PCB 81	2.0 pg/g
PCB 105	2.0 pg/g
PCB 114	2.0 pg/g
PCB 118	12 pg/g
PCB 123	2.0 pg/g
PCB 126	2.0 pg/g
PCB 156	2.0 pg/g
PCB 157	2.0 pg/g
PCB 167	2.0 pg/g
PCB 169	2.0 pg/g
PCB 189	2.0 pg/g
Indicator PCBs	
PCB 28	0.025 ng/g
PCB 52	0.025 ng/g
PCB 101	0.025 ng/g
PCB 138	0.025 ng/g
PCB 153	0.025 ng/g
PCB 180	0.025 ng/g

Analyte Definitions

Dioxin-Like and Indicator Polychlorinated Biphenyls (PCBs) - Fish Tissue - AsureQuality Method (GC-MS/MS)

Analyte	Full Name
Dioxin-Like PCBs	
PCB 77	3,3',4,4'-Tetrachlorobiphenyl
PCB 81	3,4,4',5-Tetrachlorobiphenyl
PCB 105	2,3,3',4,4'-Pentachlorobiphenyl
PCB 114	2,3,4,4',5-Pentachlorobiphenyl
PCB 118	2,3',4,4',5-Pentachlorobiphenyl
PCB 123	2',3,4,4',5-Pentachlorobiphenyl
PCB 126	3,3',4,4',5-Pentachlorobiphenyl
PCB 156	2,3,3',4,4',5-Hexachlorobiphenyl
PCB 157	2,3,3',4,4',5'-Hexachlorobiphenyl
PCB 167	2,3',4,4',5,5'-Hexachlorobiphenyl
PCB 169	3,3',4,4',5,5'-Hexachlorobiphenyl
PCB 189	2,3,3',4,4',5,5'-Heptachlorobiphenyl
Indicator PCBs	
PCB 28	2,4,4'-Trichlorobiphenyl
PCB 52	2,2',5,5'-Tetrachlorobiphenyl
PCB 101	2,2',4,5,5'-Pentachlorobiphenyl
PCB 138	2,2',3,4,4',5'-Hexachlorobiphenyl
PCB 153	2,2',4,4',5,5'-Hexachlorobiphenyl
PCB 180	2,2',3,4,4',5,5'-Heptachlorobiphenyl

Any tests marked with * are not accredited for specific matrices or analytes.

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

Kathryn Pabirowski

From: Ricky Eyre
Sent: Tuesday, 13 August 2024 3:00 pm
To: Richard Griffiths
Subject: FW: Aluminium data for Northland
Attachments: REQ.621736_Aluminium data Northland.csv

Ricky Eyre
Water Quality Field Operations Manager
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

P 09 470 1258
M 0274 767 981

Week 1					Week 2				
M	T	W	T	F	M	T	W	T	F

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

P 0800 002 004 » **W** www.nrc.govt.nz

From: Gail Townsend <GailT@nrc.govt.nz>
Sent: Monday, August 12, 2024 5:51 PM
To: Ricky Eyre <rickye@nrc.govt.nz>; Colin Dall <colind@nrc.govt.nz>
Subject: Aluminium data for Northland

Hi Ricky and Colin, here is the aluminium total and aluminium total sediment data we have for Northland.

This should be everything. We have figured out the Hilltop issue and logged a bug for investigation.

Ricky – if you need to do any data exports from Hilltop in the meantime please make sure there are no duplicate sites in your site list. Hilltop allows it but then does not export correctly. Hopefully Hills will resolve this quickly.

Ngā mihi

Gail Townsend
Senior Environmental Data Analyst
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

DDI 09 470 1210 ext 9128
M 027 438 4008

Northland REGIONAL COUNCIL
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P 0800 002 004 » **W** www.nrc.govt.nz

Week 1					Week 2				
M	T	W	T	F	M	T	W	T	F

SiteNumbe	DateTime	Run Name	Run Numbe	Run Type	SampleID	Comment	QA Comme	Aluminium	Aluminium Total Sediment (mg/kg)
100305	########	REQ.62133	20240738	Complianc	20244000			1.4	
101556	########	FNDC - KAI	20050105		20050272			0.182	
101556	########	FNDC - KAI	20060384		20061906			0.186	
101556	########	FNDC - KAI	20070433		20072136			0.157	
101556	########	FNDC - KAI	20080461		20082358			0.16	
101556	########	0750301 S(	20100501		20102805			0.39	
101556	########	750301	20111398		20114918			0.13	
101556	########	750301	20121292		20125999			0.23	
101727	########	REQ.62133	20240738	Complianc	20244003				18000
101727	########	REQ.62133	20240738	Complianc	20244002			4.2	
102475	########	3652001	20150966		20155068			13	
102475	########	3652001	20160644		20163096			64	
102475	########	3652001	20170407		20172171			34	
102475	########	3652001	20170407		20172172			33	
102475	########	3652001	20170407		20172173			42	
102475	########	3652001	20170407		20172174			7.2	
102475	########	3652001	20170407		20172175			34	
102475	########	3652001	20170407		20172176			29	
102475	########	3652001	20170407		20172177			13	
102475	########	3652001	20170407		20172178			4.3	
102475	########	3652001	20170407		20172179			12	
102475	########	3652001	20170407		20172180	Composite sample		18	
102475	########	3652001	20181091		20185237			9.6	
102475	########	3652001	20191473		20196671			8.6	
102475	########	3652001	20200517		20203110	Taken from treatment p		0.66	
102494	########		20070897		20073830			0.26	
103998	########	KAIPARA PI	20050467		20052046			0.82	
103998	########	395301	20051192		20054422			0.627	
103998	########	REG.00395	20200774		20204901			8.6	
103998	########	REG.00395	20210707		20214485			14	
103998	########	REG.00395	20221095		20225367	sample taken prior to d		2.1	
103998	########	REG.00395	20231148	Complianc	20234766			12	
103998	########	REG.00395	20240544	Complianc	20242188			0.97	
105126	########		19970514		19972374			85	
105593	########	FNDC - KAI	20060384		20061907			0.098	
105609	########		19960719		19963256			0.4	
105609	########		19960719		19963257			0.3	
105609	########		19960719		19963258			2.4	
105609	########		19960719		19963259			1.8	
105636	########		19960764		19963478			0.1	
105636	########		19960764		19963479			0.3	
105642	########	KAIPARA PI	20050467		20052048			0.4	
105642	########	395301	20051192		20054420			0.59	
105642	########	REG.00395	20200774		20204902			4.3	
105642	########	REG.00395	20210707		20214486			8.4	
105642	########	REG.00395	20231148	Complianc	20234767			10	
105776	########	REG.00366	20240735	Complianc	20243992			0.2	
105897	########	FNDC RUS!	20081451		20086388			0.12	
106046	########		19990433		19992087			0.71	
106101	########	795801	20140277		20141486			0.44	
106101	########	795801	20150454		20152300			0.28	
106101	########	795801	20180338		20181726			5.4	
106101	########	795801	20190406		20192273			0.15	
106101	########	795801	20191325		20195964			0.28	
106101	########	REG.00795	20211242		20215717	After flood gate		<0.1	
106101	########	REG.00795	20230693	Complianc	20233778	Flowing		0.29	
106101	########	REG.00795	20240722	Complianc	20243949	Cows in paddock		1.1	
106102	########	795801	20140362		20141845				3300
106102	########	795801	20140277		20141487			1.5	
106102	########	795801	20150455		20152304				6600

106102	########	795801	20150454		20152301			0.94	
106102	########	795801	20151142		20155372				4500
106102	########	795801	20180338		20181727			9.7	
106102	########	795801	20180339		20181730				7000
106102	########	795801	20190407		20192277	Running creek			3300
106102	########	795801	20190406		20192274			1.3	
106102	########	795801	20191325		20195965			0.3	
106102	########	795801	20191239		20195724				10000
106102	########	REG.00795	20200922		20205341				3400
106102	########	REG.00795	20211242		20215718			0.76	
106102	########	REG.00795	20230693	Complianc	20233780			0.72	
106102	########	REG.00795	20240722	Complianc	20243951			1.1	
106103	########	795801	20140277		20141488			0.42	
106103	########	795801	20150454		20152302			0.26	
106103	########	795801	20180338		20181728			9.8	
106103	########	795801	20190406		20192275			1.8	
106103	########	795801	20191325		20195966			0.67	
106103	########	REG.00795	20211242		20215719	10m from		2	
106103	########	REG.00795	20230693	Complianc	20233779			0.15	
106103	########	REG.00795	20240722	Complianc	20243950			1	
106193	########	KDC HAKAI	20020840		20023640			0.1	
106193	########	KDC HAKAI	20030523		20032217			0.07	
106193	########	KDC HAKAI	20050095		20050226			0.021	
106193	########	KDC HAKAI	20060391		20061927			0.056	
106193	########	KDC HAKAI	20070284		20071539			0.797	
106193	########	KDC HAKAI	20080553		20083129			0.13	
106193	########	KDC HAKAI	20090721		20093750			0.024	
106193	########	756201	20101023		20104874			0.041	
106193	########	756201	20111639		20116491	Transfer ststion closed		0.18	
106197	########	KDC HAKAI	20020840		20023641			0.03	
106197	########	KDC HAKAI	20030523		20032216			0.035	
106197	########	KDC HAKAI	20050095		20050223			<0.006	
106197	########	KDC HAKAI	20060391		20061924			0.027	
106197	########	KDC HAKAI	20070284		20071536			0.011	
106197	########	KDC HAKAI	20080553		20083126			0.16	
106197	########	KDC HAKAI	20090721		20093747			0.016	
106197	########	756201	20101023		20104876			0.011	
106921	########	KDC HAKAI	20020840		20023637			1.84	
106921	########	KDC HAKAI	20050095		20050222			0.077	
106921	########	KDC HAKAI	20060391		20061923			0.017	
106921	########	KDC HAKAI	20070284		20071535			0.017	
106921	########	KDC HAKAI	20080553		20083125			0.7	
106921	########	KDC HAKAI	20090721		20093746			0.78	
106921	########	756201	20101023		20104875			0.64	
106922	########	KDC HAKAI	20020840		20023638			0.16	
106922	########	KDC HAKAI	20050095		20050224			0.006	
106922	########	KDC HAKAI	20060391		20061925			0.043	
106922	########	KDC HAKAI	20070284		20071537			0.005	
106922	########	KDC HAKAI	20080553		20083127			0.65	
106922	########	KDC HAKAI	20090721		20093748			0.05	
106923	########	KDC HAKAI	20020840		20023639			0.17	
106923	########	KDC HAKAI	20050095		20050226			0.112	
106923	########	KDC HAKAI	20060391		20061926			0.867	
106923	########	KDC HAKAI	20070284		20071538			2.73	
106923	########	KDC HAKAI	20080553		20083128			3.2	
106923	########	KDC HAKAI	20090721		20093749			0.36	
108142	########	KAIPARA PI	20050467		20052047			0.6	
108142	########	395301	20051192		20054421			0.544	
108142	########	REG.00395	20200774		20204903			7.2	
108142	########	REG.00395	20210707		20214487			6.8	
108142	########	REG.00395	20231148	Complianc	20234768		Conductivi	10	

108711	########		20070481		20072331		0.754	
108711	########	INCIDENTS	20080622		20083470		3.8	
108711	########	INCIDENTS	20080622		20083469		5.2	
108711	########	INCIDENTS	20080622		20083471		0.91	
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109631	########	WDC POHE	20081432		20086306		0.19	
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110612	########	795801	20150455		20152306			5900
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110612	########	795801	20180339		20181732			12000
110612	########	795801	20190407		20192279	Still		5300
110612	########	795801	20191239		20195726			7900
110612	########	REG.00795	20200922		20205343			3900
110612	########	REG.00795	20211243		20215722			8500
110612	########	REG.00795	20230576	Complianc	20232381			12000
110613	########	795801	20140277		20141489		0.45	
110613	########	795801	20150454		20152303		0.38	
110613	########	795801	20180338		20181729		8.5	
110613	########	795801	20190406		20192276		2.7	
110613	########	795801	20191325		20195967		0.093	
110613	########	REG.00795	20211242		20215720	Before flood gate	<0.1	
110613	########	REG.00795	20230693	Complianc	20233777	No flow	0.16	
110613	########	REG.00795	20231289	Complianc	20235235	Stagnant not flowing	0.75	
110613	########	REG.00795	20240722	Complianc	20243948	Cows in paddock	0.26	
305351	########	795801	20140362		20141846			7300
305351	########	795801	20150455		20152305			6000
305351	########	795801	20151142		20155373			5100
305351	########	795801	20180339		20181731			11000
305351	########	795801	20190407		20192278	Running creek		9100
305351	########	795801	20191239		20195725			6500
305351	########	REG.00795	20200922		20205342			5000
305351	########	REG.00795	20211243		20215721			8000
305351	########	REG.00795	20230576	Complianc	20232382	gravelly		5600
316345	########	3135101	20171024		20175218		1.6	
329516	########	ICE 7719	20210649		20214228		1.3	
330987	########	REG.00795	20211243		20215723			13000
330987	########	REG.00795	20230576	Complianc	20232383			12000
339278	########	REQ.62133	20240738	Complianc	20244007	Foam at rivers edge near site.		20000
339278	########	REQ.62133	20240738	Complianc	20244006	Foam at rivers edge nea	9.1	
339279	########	REQ.62133	20240738	Complianc	20244008		3.4	
339279	########	REQ.62133	20240738	Complianc	20244009	Sediment sample taken from mout		19000
339280	########	REQ.62133	20240738	Complianc	20244010		4.2	
339281	########	REQ.62133	20240738	Complianc	20244012		5.2	
339282	########	REQ.62133	20240738	Complianc	20244014		4.6	

Colin Dall

From: Colin Dall
Sent: Friday, 15 November 2024 12:50 pm
To: Colin Dall
Subject: RE: Kaipara Coastal water quality montioring

From: Richard Griffiths <richardg@nrc.govt.nz>
Sent: Monday, 12 August 2024 10:46 am
To:
Cc:
Subject: RE: Kaipara Coastal water quality montioring

Kia ora

Thanks form your responses. That's helpful to know what data you have. We still haven't decided what to do with our historical samples, but likely to get the 2014 and 2022 sediment results for aluminium. We are also due to undertake our soe sediment sampling in the harbour on Friday so we will add aluminium to that run. May also add aluminium to the next coastal water quality run. Will keep you in the loop.

Ngā mihi

Richie

Richard Griffiths
Resource Scientist - Coastal
M 027 715 9923

Northland
REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

From:
Sent: Friday, August 9, 2024 11:41 AM
To:
Cc:
Subject: RE: Kaipara Coastal water quality montioring

Kia ora all,

We have taken marine sediment samples for metal analysis twice in the southern Kaipara – in 2009 and 2019. Samples were collected from 5 of our harbour ecology monitoring sites. Unfortunately we don't include aluminium in the suite of analytes (typically it's Cu, Pb, Zn, As and Hg). Concentrations at all sites were low and had remained fairly stable. We have archived sediment from these rounds of analysis and sites are visited several times a year for ecology monitoring. Interested to see updates on this as things progress Richie.

Table 4-5. Kaipara Harbour Environmental Response Criteria (ERC) state for sites sampled in 2019 and analysed in 2020.

Site	MRA	Programme	Status Cu Pb Zn only	Mud Content % <63 um	Total Recoverable metals, mg/kg <500 µm Cu	Pb	Zn	As	Hg
Haratahi Creek	Kaipara	Ecology		0.5	2.2	2.3	25	6.8	0.002
Kaipara Flats	Kaipara	Ecology		0.3	1.1	1.5	17	5.1	0.001
Kaipara Bank	Kaipara	Ecology		26.7	3.7	3.6	35.3	8.5	0.006
Kakarai Flats	Kaipara	Ecology		4.8	2.5	2.4	28.3	6.1	0.004
Te Ngaio Point	Kaipara	Ecology		0.6	0.9	0.9	8.3	4.2	0.001

Table 4-6. Kaipara Harbour Environmental Response Criteria (ERC) state for sites sampled and analysed in 2009.

Site	MRA	Programme	Status Cu Pb Zn only	Mud Content % <63 um	Total Recoverable metals, mg/kg <500 µm Cu	Pb	Zn	As	Hg
Haratahi Creek	Kaipara	Ecology		0.3	3.2	2.5	25.5	6.1	0.031
Kaipara Flats	Kaipara	Ecology		0.2	2.1	1.7	19.6	4.9	0.018
Kaipara River	Kaipara	Ecology		6.8	5.4	3.4	33.5	6.8	0.057
Kakarai Flats	Kaipara	Ecology		4.4	3.1	2.6	28.5	5.5	0.057
Tapora Bank	Kaipara	Ecology		0.5	1.8	1.3	13	3.9	0.02

Ngā mihi

Air, Land & Biodiversity | Environmental Evaluation & Monitoring Unit
Engineering, Assets & Technical Advisory

Te Kaunihera o Tāmaki Makaurau | Auckland Council, Level 16, 135 Albert Street, Auckland 1010

Visit our website: www.aucklandcouncil.govt.nz
View Environmental Data online at: Environmental Data Online

From:
Sent: Friday, August 9, 2024 9:33 AM
To: Richard Griffiths <richardg@nrc.govt.nz>;
Cc:
Subject: RE: Kaipara Coastal water quality montioring

Kia ora Richie,

Yes we heard about the aluminium issue. We do not test for metals in our usual costal water quality SOE, so unfortunately don't have any data in the southern Kaipara Harbor that we could include in that.

I have cc-ed my colleagues in as they may have samples from coastal sediments of freshwater that may be of interest.

What are your thoughts on the source of the high aluminum so far? Have you tested further south in the Harbour?
Yes, please keep us in the loop.

Ngā mihi

From: Richard Griffiths <richardg@nrc.govt.nz>
Sent: Thursday, August 8, 2024 10:35 AM
To:
Subject: RE: Kaipara Coastal water quality montioring

Kia ora

Thanks. I have another related question. We have been dealing with concerns about elevated aluminium levels around Dargaville. Some people are also trying to draw a link to the zombie fish.

https://www.nzherald.co.nz/northern-advocate/news/alarmingly-high-levels-of-aluminium-found-in-northern-wairoa-near-dargaville/G6EV2Q3M3NDCVFU7ZB2NE2GMCI/

Have you done any testing for Aluminium? Freshwater or coastal. We have obviously done some recent testing in response to this and one option we are looking at is getting Watercare to release some Al results from our historic samples (when you test for one metal i.e. Cu, they also have the results for the entire metal suite). We collect metal data on our monthly coastal water quality run and also sampled metals from 40 odd sites around the harbour in 2014, so we have quite a lot of historic samples that we could get results from. Do you have any interest getting metal results for any historic metal samples?

I will keep you updated with what our investigation turns up

Ngā mihi

Richie

Richard Griffiths
Resource Scientist - Coastal
M 027 715 9923

Northland
REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

Colin Dall

From: Colin Dall
Sent: Friday, 15 November 2024 12:37 pm
To: Colin Dall
Subject: RE: Aluminium levels in the Enviornment

From: Richard Griffiths <richardg@nrc.govt.nz>
Sent: Thursday, 8 August 2024 4:40 pm
To:
Subject: RE: Aluminium levels in the Enviornment

Kia ora

Thanks for your time earlier. I Just spoke to my GM and don't worry about getting that report or a statement released tomorrow. But we will get follow up enquiries so when that report and the data is publicly available, please let us know as it will be very useful. Thanks again.

Snip below shows Dargaville.

Ngā mihi

Richie

Richard Griffiths
Resource Scientist - Coastal
M 027 715 9923

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

From: Richard Griffiths
Sent: Wednesday, August 7, 2024 4:42 PM
To:
Cc:
Subject: RE: Aluminium levels in the Enviornment

Kia ora

Thank you very much for sending this report, it is very helpful. Firstly, is this public information? and are you happy for us to reference your results, for comparisons purposes, when we communicate our data? I note there is a comment in the pdf document, so I am not sure if this is a draft or internal memo? Is there a finalised version?

Also, the memo talks about 'the detection of elevated aluminium during a water quality investigation'. Are you able to share the findings from this early investigation?

And if you have any more info or references on environmental effects of aluminium in the environment (including the coastal environment), that would be helpful.

I think that our results are being finalised, but preliminary results are high. I will send you the data once the numbers are confirmed. Samples so far are from freshwater, but I will collect some coastal sediment samples later this month. I can share that data too if you are interested.

Ngā mihi

Richie

Richard Griffiths
Resource Scientist - Coastal
M 027 715 9923

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

From:
Sent: Tuesday, August 6, 2024 1:13 PM
To:
Cc:
Subject: RE: Aluminium levels in the Enviornment

Kia ora Richie

Thanks for getting in touch.

Just over a year ago, some investigation sampling recorded high aluminium concentrations in one of our rivers down here. As a result of this, we did an investigation where we tested Al at three sites in the mainstem of the Mataura River for twelve months with our routine SOE monitoring. We also did a wider survey of metals at a selection of our SOE sites to give a picture across the region, which was done once in dry weather conditions and once in wet weather conditions. From this, it doesn't appear that the elevated total Al is unusual, at least for Southland.

I have attached a memo that was recently completed following the twelve months of sampling that should give you a bit of an overview of our findings.

I am currently scoping our next steps on this, which is going to include looking at how we might determine natural background concentrations of Al in Southland rivers.

Happy to talk through any of this further if that would help.

It would also be great if you could keep me in the loop with your findings – it would be really interesting to see if Northland finds similar observations.

Ngā mihi,

Environment Southland *Te Taiao Tonga*

P 03 211 5115 |
Cnr Price St & North Rd, Private Bag 90116, Invercargill 9840

From:
Sent: Monday, August 5, 2024 4:18 PM
To: Richard Griffiths <richardg@nrc.govt.nz>;
Cc:
Subject: RE: Aluminium levels in the Enviornment

Kia ora Richie,

We have actually spent the last year doing some investigations into Al in our rivers and streams so this is a timely enquiry. has lead this work in conjunction with our Compliance team, so I will leave her to get in touch with the details.

I'd be interested to know how you get on and if you are seeing similar things to what we've observed.

Kind regards,

From: Richard Griffiths <richardg@nrc.govt.nz>
Sent: Monday, August 5, 2024 3:48 PM
To:
Subject: Aluminium levels in the Enviornment

Tēnā Koutou,

, I hope you are both well. , I am not sure if we have met? I apologise if we have, my memory is fading. I hope you are well too. I am emailing about a recent incident we have had with high levels of aluminium reported in the Wairoa River. We were wondering if you are able to help with any information you may have about Al levels in the environment given the location of the Tiwai Point Aluminium smelter. Any information you have about natural levels in the environment, impacts on aquatic organisms and trigger values or levels at which concentrations are of concern would be greatly imprecated. Any help much appreciated.

https://www.nzherald.co.nz/northern-advocate/news/alarmingly-high-levels-of-aluminium-found-in-northern-wairoa-near-dargaville/G6EV2Q3M3NDCVFU7ZB2NE2GMCI/#google_vignette

Ngā mihi

Richie

Richard Griffiths
Resource scientist - Coastal
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

M 0277159923

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P 0800 002 004 » **W** www.nrc.govt.nz

environment
SOUTHLAND
REGIONAL COUNCIL
Te Taiao Tonga

Memorandum

For Your Information

To:	
From:	
Date:	Thursday, 11 July 2024
File Reference:	A1118407
Subject:	***Mataura River aluminium monitoring***

Message:
This memorandum summarises the results of additional physicochemical testing in the Mataura River during routine SOE monitoring in 2023-2024 following the detection of elevated aluminium during a water quality investigation.

Background:
Aluminium is a naturally occurring metal that is abundant in the earth's crust. It is typically found as aluminium silicates and aluminium oxides. Weathering processes can release aluminium from rocks. Aluminium can be found in the water column in a number of forms including free aluminium ions, dissolved complexes, or in association with suspended particles. The forms of aluminium are dependent on water quality parameters such as pH and dissolved organic carbon. Aluminium is least soluble at circumneutral pH. In New Zealand, river water is typically of circumneutral pH, and monitoring data confirms that this is the case in the Mataura River.

Aluminium toxicity occurs in fish by disruption of either ionoregulatory processes or respiration. The mechanism for toxicity is dependent on pH. At circumneutral pH, aluminium hydroxide precipitates can form at the gill surface, which can lead to hypoxia. For invertebrates, respiratory effects are less common than for fish.

During the previous analysis, subject matter experts at NIWA provided advice that the ANZECC (2000) guidelines are in need of updating. The Canadian federal environment quality guideline (FEQG)[1] was recommended for use over the USEPA guidelines as the approach used by the Canadian guidelines is more similar to the approach typically used in New Zealand and Australia (Jennifer Gadd, NIWA, pers. comm.). In this analysis the use of the Canadian FEQG in preference to the ANZECC (2000) guideline has continued.

Mataura River Aluminium Results:
As a result of the samples collected during the water quality investigation, three sites in the mainstem of the Mataura River have been tested for aluminium concentrations (total and dissolved) in conjunction with routine SOE monitoring in the 2023-2024 year. Twelve months of results are now available and summary statistics are provided in Table 1.

[1] https://www.canada.ca/en/environment-climate-change/services/evaluating-existing-substances/federal-environmental-quality-guidelines-aluminium.html

Table 1: Aluminium summary statistics from sampling in the Mataura River (includes SOE water quality and investigation samples)

Site	n	Total Aluminium (g/m³)				Dissolved Aluminium (g/m³)			
		Minimum	Median	Mean	Maximum	Minimum	Median	Mean	Maximum
Mataura River at Gore	14	0.030	0.077	0.096	0.182	0.005	0.010	0.016	0.047
Mataura River 200m d/s Mataura Bridge	12	0.032	0.087	0.118	0.250	0.008	0.014	0.018	0.048
Mataura River at Mataura Island	12	0.033	0.092	0.122	0.250	0.015	0.022	0.025	0.055

Aluminium concentrations showed variation throughout the year, particularly for total aluminium. The Canadian FEQG has been calculated individually for each sample (based on sample pH, hardness and DOC). Episodic exceedances have occurred relatively frequently, and exceedances of this guideline have occurred together at all three monitored sites (Figure 1).

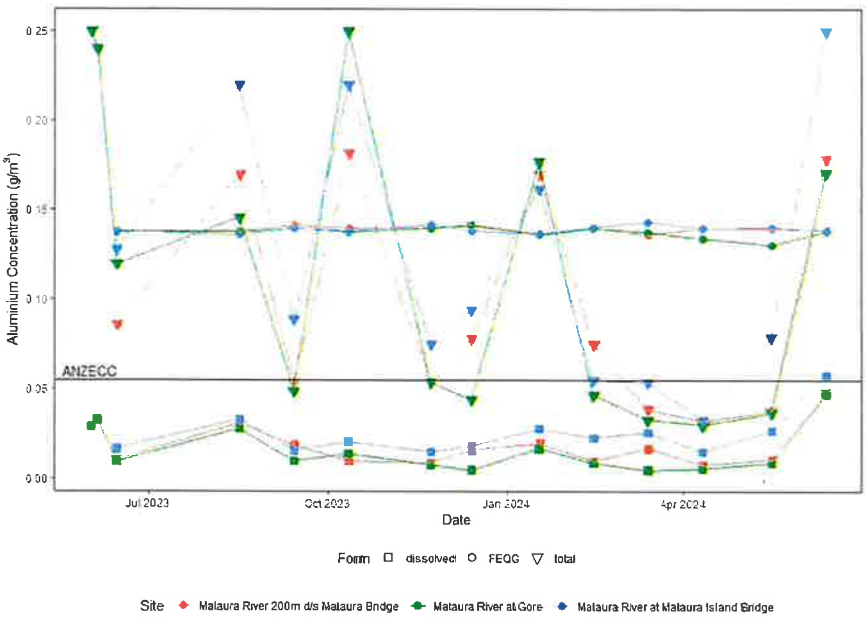

Figure 1: Aluminium concentrations (dissolved aluminium=squares, total aluminium=triangles) and calculated Canadian FEQG (circles) thresholds in the Mataura River. The guideline value is exceeded when the total aluminium is greater than the FEQG. The ANZECC (2000) aluminium guideline is represented by the black line.

Visual inspection of the data shows some relationship between flow and total aluminium concentrations (Figure 2). It should be noted that the flow data is not necessarily measured at the same location as the water quality samples are collected, with sites being up to 1.4km distant in the case of Seaward Downs and Mataura Island. Further analysis shows moderately strong positive relationships between flow and total Al across the three sites (Figure 3).

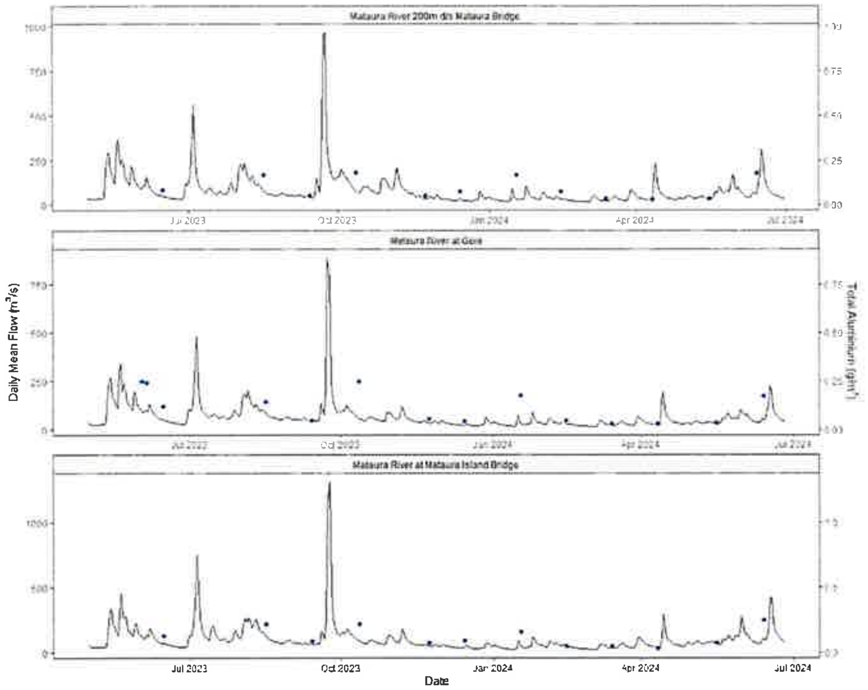

Figure 2: Daily mean flow (left axis) and total aluminium concentrations (right axis) for monitored sites on the Mataura River, May 2023 – June 2024.

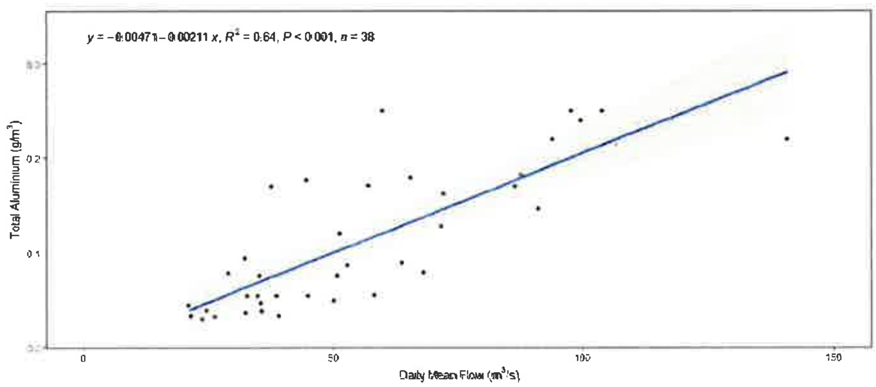

Figure 3: Linear relationship between total aluminium and daily mean flow for the three monitored sites on the Mataura River

Total aluminium is generally associated with sediment, and strong, statistically significant positive correlations between total aluminium and both turbidity and suspended sediment concentrations are observed. Similarly, there is a moderately strong negative relationship between clarity and total aluminium. These are illustrated in Figure 4. A relationship with volatile suspended sediment concentrations was not able to be assessed due to a high proportion of censored data. It should be noted that the water quality samples with measured aluminium concentrations cover a relatively small range of suspended sediment concentrations and turbidity values (SSC range <2-11 g/m³; turbidity range 0.75-10.2 FNU). Targeted monitoring during elevated flow events may be helpful to assess whether the correlations across the mid to high range of suspended sediment loads continue to display the same correlations.

Relationships between total aluminium concentrations and other physicochemical variables were also considered. While some statistically significant relationships were detected, the correlations between the variables were generally weak, as determined by R^2 values (<0.25). Furthermore, the stronger relationships were between variables were expected, and mechanism for the correlation can be explained. This includes other variables known to have strong correlation with sediment (total phosphorus, $R^2 = 0.43$) or which are known to modify the toxicity of aluminium (DNPOC, R^2=0.34). Therefore, these variables are not considered further.

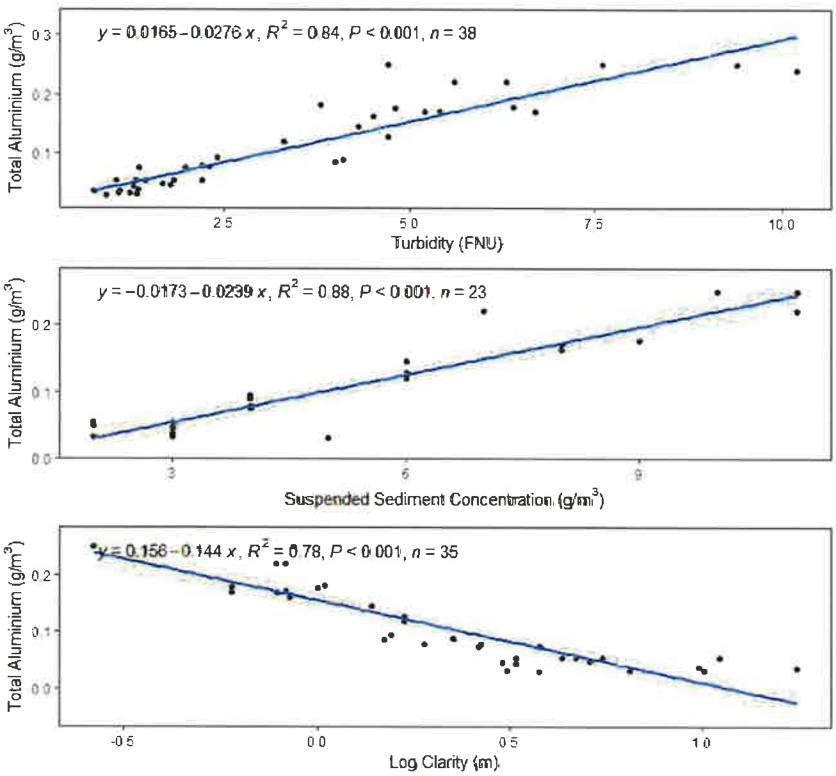

Figure 4: Statistically significant relationships between total aluminium and sediment-related variables at monitored sites in the Mataura River. Note that suspended sediment concentrations are measured at only 2 of 3 sites.

Results from other sites:

In addition to the additional testing in the Mataura River reported in this memo, a further action was to undertake metals testing at a range of SOE sites in conjunction with routine monitoring. This was undertaken in June 2023 under dry weather conditions[2] and was to be repeated during wet weather conditions. In the past year, suitable flow conditions have coincided with SOE sampling only in the Waiau catchment and this sampling remains to be completed for the remaining catchments. Data from this sampling round is presented for

[2] Environment Southland memorandum. Metals results from selected River Water Quality sites. July 2023.

comparison in Table 2. Exceedances of the Canadian FEQG occurred under preceding wet weather conditions at all three sites. The Waiau River at Tuatapere recorded total aluminium of 3.36 g/m^3, similar to the 4.08 g/m^3 recorded in the Mataura River in the May 2023 investigation. This demonstrates that the elevated aluminium concentrations are not limited to the Mataura River catchment and are likely to be a regional issue. Furthermore, the dry weather sampling results from these sites did not exceed the FEQG, suggesting that exceedances are linked to elevated flow and/or elevated suspended sediment concentrations.

Table 2: Aluminium and other relevant results from additional SOE sites during high flow conditions on 12 April 2024. The Canadian FEQG has been calculated for each sample and exceedances of this guideline are in bold.

	Total Al (g/m^3)	Dissolved Al (g/m^3)	Suspended Sediment Concentration (g/m^3)	Turbidity (FNU)	Flow (daily mean; cumecs)	pH	DNPOC (g/m^3)	Hardness (g/m^3 as $CaCO_3$)	FEQG
Orauea River at Orawia Pukemaori Road	**1.49**	0.263	N/A	50.1	79	7.3	7.8	43.7	0.795
Waiau River at Sunnyside	**1.39**	0.182	N/A	25.1	218	7.3	6.9	16.86	0.617
Waiau River at Tuatapere	**3.36**	0.192	129	61.1	474	7.3	7.9	24.2	0.719

Discussion:

Although aluminium guidelines are based on total aluminium concentrations, some literature suggests that total aluminium may overestimate the bioavailable aluminium (and therefore toxicity) because of extraction of mineralised forms from suspended solids[3]. To compensate for this, a method has been developed to assess bioavailable aluminium via extraction at pH 4. The Canadian FEQG suggests that this or other methods may be considered where false-positive exceedances of the guidelines are suspected (ie. where the guidelines are exceeded but do not cause toxicity effects). However, this method has not been fully validated.

Commented [ER1]: Any comments on concentrations in other regions? I suspect not solely a Southland issue
Possibly sampling smaller "natural state" tribs to get a feel for natural background (covered in your last sentence I guess.)

Prior to the water quality investigation in May 2023, aluminium had not been routinely monitored in rivers in the Southland region. While concentrations in exceedance of the FEQG have been recorded at times in this investigation, there is no reason to believe that the elevated concentrations are a recent change in water chemistry. Additionally, it is unclear whether the observed results present actual ecological risk or whether they are 'false-positive' exceedances. Therefore, it is suggested to seek further advice around the observed aluminium concentrations in the Mataura River. This advice should address whether development of site-specific thresholds or a regional threshold for aluminium toxicity would be appropriate for the Mataura River and/or the wider Southland region; or consider any alternative methods that may allow determination of the ecological effects of the observed aluminium concentrations. If appropriate, the advice should address methods and data requirements to assess background aluminium concentrations in the Southland region to inform the development of any required thresholds.

Recommendations:

1. Consider targeted sampling to assess the relationship between aluminium and suspended sediment concentrations at moderate to high suspended sediment concentrations.
2. Prioritise sampling of the SOE RWQ sites to be tested for metals under wet weather conditions, when conditions permit. This may need to be undertaken separately from routine SOE RWQ sampling when the appropriate weather conditions occur.
3. Consider whether geographical expansion of any further sampling is warranted.
4. Seek expert advice regarding the observed aluminium levels, addressing the points described in the discussion above.

[3] Rodriguez, P.H., Arbidula, J.J., Villavicencio, G., Urrestarazu, P., Opazo, M., Cardwell, A.S., Stubblefield, W., Nordheim, E., Adams, W. 2019. Determination of Bioavailable Aluminium in Natural Waters in the Presence of Suspended Solids. *Environmental Toxicology and Chemistry* 38(8): 1668-1681.

Colin Dall

From: Colin Dall
Sent: Friday, 15 November 2024 12:41 pm
To: Colin Dall

From:
Sent: Tuesday, 6 August 2024 11:07 am
To: Richard Griffiths <richardg@nrc.govt.nz>
Subject: RE: Voice message

Richie,

I suspect you've seen this already?

[Fish so sick they are called zombies found from Paekākāriki to Northland - NZ Herald]

Still waiting on some details before I send you an update

Thanks

Ministry for Primary Industries | | Charles Ferguson Building 38 Bowen Street |
PO Box 2526 | Wellington | New Zealand
TE MANA WHAKAMARU ĀHUARANGI/CENTRE FOR CLIMATE ACTION ON AG EMISSIONS
www.mpi.govt.nz
SEEMail

From: Richard Griffiths <richardg@nrc.govt.nz>
Sent: Monday, August 5, 2024 11:36 AM
To:
Subject: Voice message

Kia ora Rich,

I got your voice message but couldn't get your contact details. What's your phone number please? or give me a call on the number below. I am in the office today but on leave tomorrow.

Ngā mihi

Richie

Richard Griffiths
Resource Scientist - Coastal
M 027 715 9923

Northland
REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

Disclaimer

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Kathryn Pabirowski

From: Richard Griffiths
Sent: Monday, 5 August 2024 12:30 pm
To: Colin Dall
Cc: Tess Dacre; Cathy Orevich; Ricky Eyre
Subject: RE: High aluminium results Northern Wairoa

Kia ora Colin,

We rarely test pH in any coastal sampling as pH is so stable because of the carbonate buffer system. Even when we do test (the allied concrete incident & Busck compliance monitoring, pH is high in the discharge but returns to range quickly). We can test for pH if you want. Sea water is slightly alkaline (~8.2) and seem like Aluminium's bioavailability is greatest in alkaline solutions.

For the sediment sampling, we collect the surface 2cm – it would be pretty unusual for the sediment to be anoxic at this depth (it would need a layer of organic material or debris sitting on the seabed). We normally make notes on the colouration of the sediment and take photographs of the grab sample. It will be pretty obvious if the surface sediment is anoxic. I will make sure we make good notes.

Regarding the 'so what' question - there doesn't seem to be a guideline value for Aluminium (either marine water or marine sediment). I will see if I can find any interventional trigger values.

Ngā mihi

Richie

Richard Griffiths
Resource Scientist - Coastal
M 027 715 9923

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

From: Colin Dall <colind@nrc.govt.nz>
Sent: Monday, August 5, 2024 11:41 AM
To: Richard Griffiths <richardg@nrc.govt.nz>
Cc: Tess Dacre <tessd@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>; Ricky Eyre <rickye@nrc.govt.nz>
Subject: RE: High aluminium results Northern Wairoa

Thanks Richie.

I don't think we need to do extensive sampling as the results will vary depending on the soils in the 'contributing' catchments. My thinking is we need to address the "so what" question regarding high Al levels and putting them in question. For sediment samples, will you be doing pH and, if we can, determine if the sediment is anoxic/anaerobic?

Regards
Colin

From: Richard Griffiths <richardg@nrc.govt.nz>
Sent: Monday, August 5, 2024 11:20 AM
To: Colin Dall <colind@nrc.govt.nz>
Cc: Tess Dacre <tessd@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>; Ricky Eyre <rickye@nrc.govt.nz>
Subject: RE: High aluminium results Northern Wairoa

Kia ora Colin,

The Kaipara testing was going to be seabed sediment. We test heavy metals in coastal sediments every two years from sites throughout northland (Cu, Zn, Pb, Cd, Ni and Cr). That run is scheduled for August 16. I have added Al to all 7 sites on Cathy's request. Note we won't have Al data for other sites in Northland to compare the Kaipara data against (as these have all been collected already).

We do a monthly water quality sampling. We can add Al (total and dissolved) if you want? We currently sample for Zn and Cu (Total). Next run is August 22. We could also add Al to other coastal water quality runs if you want to compare results to other areas?

Ngā mihi

Richie

Richard Griffiths
Resource Scientist - Coastal
M 027 715 9923

Northland
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From: Colin Dall <colind@nrc.govt.nz>
Sent: Monday, August 5, 2024 10:02 AM
To: Richard Griffiths <richardg@nrc.govt.nz>
Cc: Tess Dacre <tessd@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>; Ricky Eyre <rickye@nrc.govt.nz>
Subject: FW: High aluminium results Northern Wairoa

Morena Richie

I understand you will be adding Al testing in the next Kaipara Harbour SOE water quality round. To date we have only tested for total Al. Can you ensure we also test for other forms of Al (dissolved Al).

Thanks
Colin

From: Bob Cathcart <bob.cathcart@agfirst.co.nz>
Sent: Friday, August 2, 2024 9:37 PM

To: Tess Dacre <tessd@nrc.govt.nz>
Subject: RE: High aluminium results Northern Wairoa

Good evening Tess

I saw the article in the Northern Advocate and immediately sent off an email question to John Ballinger, but he was on leave.

My first question is whether the aluminium you are detecting in river sediments is in a soluble form or is it fixed, inert aluminium? The soils formed on Tangihua volcanics and on the andesitic rocks from the Maunganui Bluff stratovolcano, a monster, are naturally high in aluminium, particularly in the subsoil clays. At low pH, the aluminium can be 'free aluminium', that is aluminium ions which totally fix phosphorus and many other plant nutrients, making them totally unavailable to plants and soil biota. High concentrations of aluminium are also toxic to plant roots, meaning that plants tend to be shallow-rooted.

There are extensive areas of Waimatenui soils within the catchments of the north-bank tributaries of the N. Wairoa River – Kaihu, Awakino, Tangowahine, Mangakahia and Kaikou Rivers. I have attached an old, unpublished DSIR Soil Bureau Report, and from page 12 onwards there is an explanation of the Waimatenui and Awarua soils, the deeply weathered soils on Tangihua volcanics and the presence of aluminium. You will also find info on Al and Fe content of Waimatenui soils in DSIR Soil Bureau publication Bulletin 29, Part 3, Soils of New Zealand, which has a detailed analysis of this soil type. The Council had a copy of this publication when it had a library, with hard-copy books on shelves. Just in case you can't find a one, I can bring one in.

I suspect what you are dealing with is aluminium in sediment from, in particular, the Mangakahia River catchment. It is most probably inert, except in anaerobic and/or acidic conditions. It could well be sediment dislodged from Waimatenui soils hundreds or even thousands of years ago, which has worked its way down the catchment, settling out and then being re-eroded by streambank erosion, time and time again. That is, the presence of Al may not reflect in any way on current land use within the catchment, it may just be an accumulation of high Al sediment over millennia. It is most probably inert unless the pH drops below about 5.0. So, what you need to determine is whether you are dealing with inert aluminium compounds or 'active' Al ions. Waimatenui soils are very deeply weathered with a high proportion of colloidal clays, material that itis so fine that it remains in suspension/doesn't settle out. Given that this soil type has in excess of 80% clay in the subsoil, a little bit can go a long way. That explains high turbidity without high volumes of sediment. [Your 'control' on this inquiry could be the Waipoua River, within the Waipoua Forest sanctuary where land use is almost totally pristine indigenous forest. I know the water quality in this river frequently fails to meet national standards because national WQ standards are based on hard-rock catchments, not catchments with deeply weathered, colloidal clay catchments.]

Give me a call when you have some time this coming week, 5 to 9 August and I will come in. Lets talk about what we already know before we talk about further work or payment.

Regards

AGFIRST

Bob Cathcart
Land & Environmental
Management Consultant

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W

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SOILS OF NORTHLAND
2. AWARUA SOILS

A.D. Wilson, W.S. McDonald

REPORT KK2

NZ Soil Bureau Northland District Office
DSIR
Kaikohe

N.Z. SOIL BUREAU DISTRICT OFFICE REPORT KK2
DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH, NEW ZEALAND 1987

Preface

The soil survey of North Auckland was carried out by N.H. Taylor, C.F. Sutherland and A.C.S. Wright between 1937-51. The resultant 1:63360 scale provisional soil maps made a significant contribution to agricultural and forestry development during and subsequent to that period.

The soil maps and legend were recompiled by J.E. Cox and published between 1981-85 at 1:100 000 scale as part of the N Z Land Inventory Survey of Northland.

The soil survey of Northland was at a reconnaissance level, with a soil map resolution of about 20 ha. Soil map units frequently comprised associations of soils, but were designed to emphasize similarities in properties commensurate with the purpose of the survey.

We intend to produce a series of reports on the soils of Northland using the soil map unit framework of the published survey. These will be compiled from current work and supplemented by unpublished file information. The aim of these reports is to describe the variation in soils within map units and to document those soil properties which are important to crop production and management.

District Office Reports are produced as a means of making available interim results of small surveys, and results of detailed investigations into particular small areas. They are not subject to scientific referring, correlation or editorial scrutiny, and should not be regarded as formal publications of the New Zealand Soil Bureau. Information in this report may not be cited or quoted without permission from the Director, New Zealand Soil Bureau, DSIR Lower Hutt, New Zealand.

CONTENTS

Summary

This report describes the soils of the Awarau map unit and their chemical and physical properties. Information is also applicable to similar Rangiuru soils.

The Awarua soil map unit is an association of very strongly leached Brown Granular Clays (Orthoxic and Epiaquic Palehumults) and Gleyed Brown Granular Clays (Epiaquic and Typic Paleaquults) developed in the clayey, kaolinite weathering products of deeply weathered basalts and dolerites. Smaller areas of Typic Haplohumults occur on slopes above drainage lines. Six soil classes are defined and described. Their typical distribution and relationships with landforms is outlined.

Soils are strongly weathered and strongly acid with low activity clay properties in the subsoil. Effective cation exchange capacities in the subsoils are less than 12me/100g clay and denote low activity clay properties. Soil are strongly acid with aluminium saturation exceeding 50%. Root extension and function in the subsoil may be limited by aluminium toxicity. The possibility of manganese toxicity suggests further work. Reserves of P, K, Mg and Ca are low..

Soil physical properties are related to mineralogical properties and the presence of tightly packed lower subsoils. Available water (mm water) is medium, but readily available water is low. Soil resistance to penetration in tightly packed subsoils below about 60cm is in excess of values commonly considered to limit root extension. Similarily the permeability of these horizons is slow, causing perching of water on gently sloping sites during wet periods. Such soils are susceptible to trampling damage by livestock. Many soils within the Awarua set tend to crack during dry periods, allowing insect damage to pastures. Uneven rewetting of soils after dry periods is related to preferential flow down planar channels, and to moderately water repellent topsoils. Marked changes in soil strength and consistence with relatively small changes in water content may give cultivation problems. Cultivation characteristics are weakly buffered against weather.

Introduction

Awarua soils are mapped in the Awarua and Waimamakau Valleys (Soil Map Sheets 006/07, P06/05; Sutherland et al. 1981). Cox et al. (1983) assigned these soils to the Te Kie Suite (shattered dolerite, breccia and tuff parent rocks), and classified them as strongly to very strongly leached Brown Granular Clays. Sutherland (1960) described the soil parent materials as deeply and strongly weathered andesitic basalt and noted a range in soils within the map unit.

The Awarua map unit is delineated on rolling to easy rolling land with a mean annual rainfall of about 1550-1800mm. Awarua soils are geographically associated with Waimatenui hill and Te Kie steepland map units which occur on adjacent ranges.

Sutherland (1960) suggested the former presence of a kauri-podocarp forest cover on Awarua soils. Most of the area was converted to proved grassland with remnants of fire-induced manuku-lycapodium-kumarahou-wiwi rush scrub. Large tung oil plantations were established in the Awarua valley in the 1940's and 1950's, but later ceased operations. Since the 1970's P. radiata forestry has become increasingly prominant.

Awarua soils have been traditionally regarded as problem soils due to both soil chemical and physical limitations. Sutherland (1960) recorded poor persistance of improved pasture species, rapid reversion to low fertility species, and low pasture dry matter production on these soils. Even today, grassland agriculture is generally extensive in character.

This report gives information on soils of the Awarua map unit based on recent work in the Awarua Valley, and supplemented by unpublished data from Sutherland (1960). Information is also applicable to Rangiuru soils which are considered similar. The local name for Awarua, Rangiuru and related soils is semi-volcanic soils. Awarua and Rangiuru map units cover about 22 500ha in Northland.

(1) soil variation and distribution within the Awarua map unit is described from a representative area. (Fig 1)
(2) soil physical and chemical properties which are significant to land use and management are discussed.

Methods

Soils were described along transects which were designed to encompass the facets of characteristically rolling landforms. Sampling intervals varied from 5m to 100m to allow characterisation of soil variation and construction of a soil-landscape model relevant to detailed soil mapping.

Soil description methods are given in Taylor and Pohlen (1979), except for soil consistence and horizon nomenclature which are according to FAO (1974).

Soil individuals were grouped at soil series level according to profile form. The descriptions of the representative profiles of the Awarua set in Soil Bureau(1955) and the Awarua map unit in Sutherland (1960) were deemed to fall within the Awarua series. Other profile forms defined in present work have soil series status, but have been provisionally named as variants of the Awarua series, until formal soil correlation is completed.

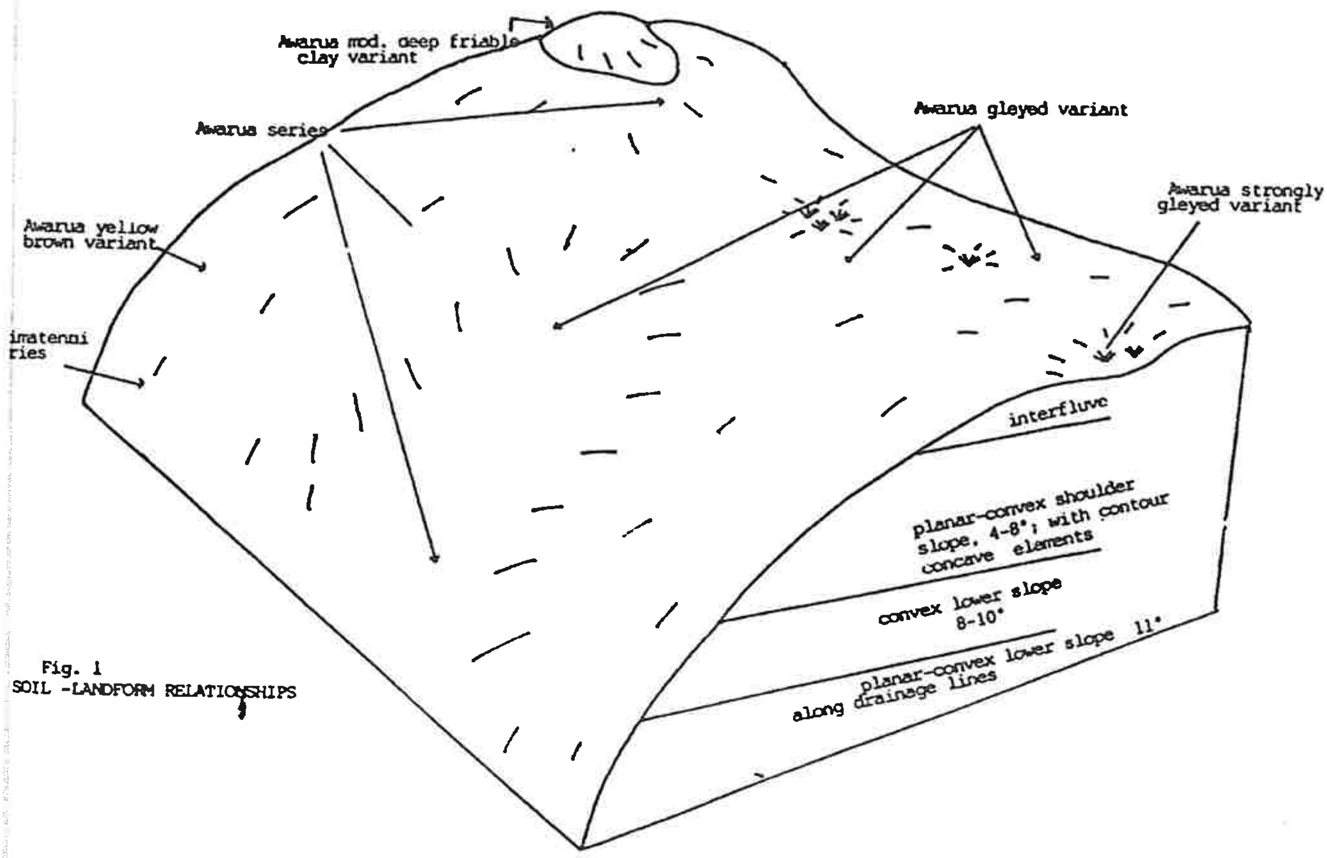

Fig. 1
SOIL -LANDFORM RELATIONSHIPS

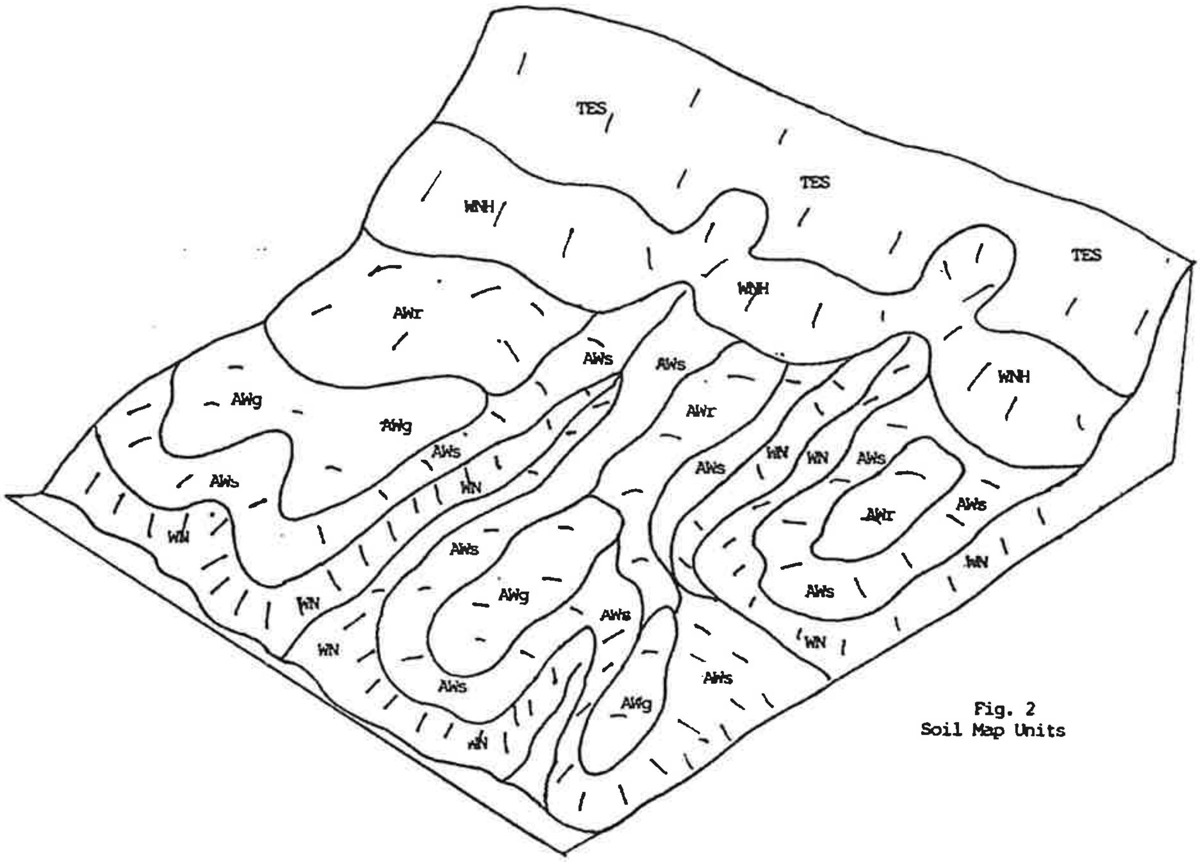

Fig. 2
Soil Map Units

Soil Map Unit		Landform Position	Map Unit Composition	
Ar	Awarua	sloping ridges and interfluves <5°	Awarua series	>50%
			Awarua yellowish brown var.	>30<50%
			Awarua gleyed variant	15-30%
			Awarua mod.deep friable var.	<5%
Ag	Awarua gleyed	broad, gently sloping interfluves <3	Awarua gleyed variant	>55
			Awarua strongly gleyed var.	<25
			Awarua series	20-30%
As	Awarua moderately sloping	moderately sloping side slopes; 6-10°	Awarua series	>50%
			Awarua yellowish brown var.	15-30%
			Awarua gleyed variant	<15%
			Waimatenui series	<10%
WN	Waimatenui strongly sloping	short, planar-convex slopes >12° along drainage lines	Waimatenui series	>75%
			Waimatenui mod.deep var.	<15%
			Awarua yellowish brown var	<10%

WNH Waimatenui hill soils on adjacent hill land.

TES Te Kie steepland soils from dolerite and andesite on adjacent steep hill land: not described in this report.

1 SOIL DISTRIBUTION AND SOIL CLASSES

1.1 Soil Distribution

Fig 1 shows the distribution of soil classes over a representative segment of the landscape. Topography is rolling to easy rolling, and comprises broad, convex, undulating (1-4′) interfluves with moderately sloping sideslopes and moderately steep to steep (10-20′) slopes along gully sides. Fig. 2 lists soil map units according to soil class composition and landscape position. These map units have a resolution of about 1ha. They describe the likely range in soil class over a 1ha area on recognisable facets of the landscape.

Soil parent materials are kaolinite clays derived from basalts and dolerites of Cretaceous to late Tertiary Tangihua Volcanics (Thompson, 1961). Clays are red weathered below about 1m depth. Clayey slope deposits occur on moderately steep slopes. The depth to weathered basalt generally exceeds 3m over most of the area.

The Awarua soil set encompasses a range of clayey, clay-enriched soils developed in a deeply weathered basalt and dolerite substrate which is generally "red-weathered" below about 1m depth. Soil classes were distinguished by first, the presence/absence and depth-continuity of features indicative of seasonal wetness and chemical reduction; and second, by the consistence of subsoil materials. Differences between soil classes are related to the denudational history of the landscape and its effect on soil hydrological processes.

Soils of the Awarua series are recognised by a clayey A horizon overlying a yellowish brown, weakly mottled clayey Bt(g) horizon with few manganiferrous concretions. This horizon overlies a brownish yellow tightly packed, clayey Bt horizon on red to reddish brown, very tightly packed clay below about 1m depth. Soils of this class typically occur on sloping interfluves and adjacent convex, shedding upper side slopes.

A yellowish brown variant of the Awarua series typically occurs on shedding sites and on moderately sloping convex-planar sideslopes. This class lacks characteristics of wetness in the upper Bt(g) horizon.

Awarua gleyed variant soils are characterised by a low chroma dominant (greyish) clayey Btg horizon below the Ap grading to brownish yellow and red clays with depth. The low chroma Btg horizon indicates seasonal wetness and chemical reduction above slowly permeable lower horizons. Soils of this class typically occur on gently sloping interfluves, and on receiving sites on side slopes.

Awarua strongly gleyed variant soils are recognised by grey, low chroma dominant Btg horizons to at least 60cm and typically more than 90cm depth. These soils occur on flat receiving sites on gently sloping interfluves and are associated with Awarua gleyed variant soils.

Awarua moderately deep friable clay variant soils are recognised by a strong brown, friable clay subsoil with weathered basalt within 90cm depth. This class is of limited occurrence, and restricted to a few indistinct resistant knobs on the crests of rolling interfluves.

Soils of the Waimatenui series occur on moderately steep slopes which bound drainge lines. These soils have yellowish brown to strong brown, nut structured clayey Bt horizons, commonly grading to a reddish clay with depth.

1.2 Soil Class Descriptions

AWARUA SERIES

Parent Materials
Kaolinite clay weathering products of deeply weathered basalts and dolerites. Clays are red weathered below 1m soil depth.

Typical Landscape Position
Gently sloping (<5′) interfluves, and shedding convex upper slopes.

Soil Class Definition
Strongly acid Brown Granular Clay soils with a nut structured cutanic horizon, a clayey (>60% clay) particle size class and a kaolinitic mineralogy class; with

- a clayey, fine nut structured Ap horizon on
- a yellowish brown to light olive brown clayey Bt(g) horizon with more than 2% ferruginous and /or low chroma <3 mottles, and a rough faced, fine nut structure on
- a brownish yellow, tightly packed, clayey Bt horizon with a smooth faced, fitted nut structure on
- a red, very tightly packed, clay with a smooth faced, fitted nut structure

Characteristic Profile Features

Ap 0-7/14cm	dark greyish brown to very greyish brown (10YR3/2-4/2) O-silty clay; 3-10mm nut structure; moderately weak moist and very firm dry soil and ped strength; brittle to semi-deformable unconfined moist failure; slightly sticky; plastic; many roots; indistinct boundary
Bt(g) 7/14- 40/90cm	yellowish brown (10YR5/4) to light olive brown (2.5Y5/4) clay with 2-5% strong brown (7.5YR4/6) and few light grey (2.5Y6/1) mottles, 1-2% black manganiferrous concretions 1-2mm size; 5-15mm rough faced, fitted nut structure with weally developed vertical planar voids; moderately firm moist soil strength; firm in situ; brittle unconfined moist failure; moderately sticky; plastic; light olive brown (2.5Y5/3) clay coatings on less than 5% ped faces; few roots; indistinct boundary
Bt 40/60- 80/105cm	brownish yellow (10YR6/6-7.5YR5/6-6/6) clay; 10-25mm smooth faced, fitted nut structure; moderately firm moist soil strength; very firm in situ; tightly packed; semi-deformable moist unconfined failure; moderately sticky; very plastic; light olive brown clay coatings on 5-10% of ped faces; indistinct boundary

CBt 80/105cm+ red (2.5YR5/6 - 5YR5/6-8) or redder) clay; 20-50mm smooth faced, nut structure with massive tendency; very firm soil strength; very tightly packed; brittle to semi-deformable unconfined moist failure; 15-30% thin discontinuous 7.5YR/10YR5/4 clay coatings.

Similar Soils
Awarua yellowish brown variant: no mottles in Bt horizon.
Awarua gleyed variant: low chroma dominant (greyish brown) Btg horizons below the A horizon.

Soil Drainage Class
Moderately well drained

Soil Classification
NZ Genetic Classification: strongly leached, weakly gleyed, clay illuvial Brown Granular Clay.
Soil Taxonomy: (Epiaquic) Orthoxic Palehumult, very fine, kaolinitic, thermic, acid.

AWARUA YELLOWISH BROWN VARIANT

Parent Materials
Kaolinite clay weathering products of deeply weathered basalts and dolerites. Clays are red weathered below 1m soil depth.

Typical Landscape Position
Shedding convex upper slopes (<5'), convex-planar side slopes (<8').

Soil Class Definition
Strongly acid Brown Granular Clay soils with a nut structured cutanic horizon, a clayey (>60% clay) particle size class, a kaolinitic mineralogy class, and with
- a clayey, fine nut structured Ap horizon on
- a yellowish brown, clayey Bt horizonn with less than 2% ferruginous mottles, and a rough faced, fine nut structure on
- a brownish yellow, clayey, tightly packed, Bt horizon with smooth faced, fitted nut structure on
- a red to reddish brown, very tightly packed clay below 1m depth

Characteristic Profile Features
- as for Awarua series but with less than 2% ferruginous or low chroma mottles in the Bt horizon underlying the Ap horizon.

Similar Soils
Awarua series: >2% ferruginouus and/or low chroma mottles in the Bt(g) horizon underlying the A horizon.
Awarua moderately deep friable clay variant: strong brown friable Bo horizon with weathered basalt within 90cm depth.
Waimatenui series: strong brown (10YR5/6-7.5YR5/6) Bt horizons.

Soil Drainage Class
Well drained

Soil Classification

NZ Genetic: strongly leached, clay illuvial Brown Granular Clay Soil
Taxonomy: Orthoxic Palehumult, very fine, kaolinitic, acid, thermic

AWARUA GLEYED VARIANT

Parent Materials
Kaolinite clay weathering products from deeply weathered basalts and dolerites. Clays are red weathered below about 1m soil depth.

Typical Landscape Position
Very gently sloping (<4') interfluves, ridges and contour concave upper sideslopes.

Soil Class Definition
Strongly acid Brown Granular Clay soils with a clayey, gleyed cutanic horizon below the A horizon or 25cm depth overlying a slowly permeable clayey subsoil; a clayey (>60% clay) particle size class, a kaolinitic mineralogy class; and with . a clayey, fine nut structured Ap horizon on . a clayey ,low chroma dominant (chromas <=3 in hues of 2.5Y or
yellower) Btg horizon with rough faced, fitted nut structure with vertical planar channels on
. a brownish yellow Bt horizon on a red (5YR or redder) very tightly packed clay

Characteristic Profile Features

Ap 0-10/15cm	very dark greyish brown-dark greyish brown (2.5Y-10YR3/2 to 4/2) silty clay; 3-10mm nut structure; moderately weak soil and ped strength; brittle to semi-deformable unconfined moist failure; sticky; plastic; many roots; indistinct boundary
Btg 10/15- 40/60cm	greyish brown (2.5Y5/2)-light olive brown (2.5Y5/3) clay with 2-10% strong brown (7.5YR5/2) mottles and 1-2% hard black 1-2mm manganiferous concretions; 10-25mm fitted, rough irregular faced nut structure within weakly developed coarse prismatic structure; moderately firm soil and ped strength; firm in situ; brittle to semi-deformable unconfined moist failure; sticky; plastic; light olive brown (2.5Y5/3) clay coatings on less than 5% ped faces; few roots; indistinct boundary
Bt(g) 40/60- 60/70cm	brownish yellow (10YR6/6) and greyish brown (2.5Y5/3) clay; gradational horizon with structure and consistence properties as for Btg, common cutans.
Bt 60/70- 85/105cm	brownish yellow (10YR6/6-7.5YR5/6-6/6) clay with domains of red flecking towards base; moderately firm soil strength; 15-30mm smooth faced, fitted nut structure with weak prismatic tendency; moderately firm soil and ped strength; very firm in situ; tightly packed; brittle to semi- deformable unconfined moist failure; sticky; very plastic; light olive brown clay coatings on less than 10% ped faces; indistinct boundary
CBt	yellowish red (5YR5/6), red (2.5YR5/6) or redder clay;

85/115cm 25-50mm smooth faced, fitted nut structure with massive tendency; very firm soil strength; very firm in situ; very tightly packed; brittle to semi-deformable unconfined moist failure; sticky; very plastic; common thin discontinuous cutans.

Similar Soils
Awarua strongly gleyed variant: olive grey Btr horizon below the Ap horizon, extending to at least 60cm soil depth. Awarua series: yellowish brown Bt or Bt(g) horizon below the Ap horizon, overlying brownish yellow and red clayey lower horizons.

Soil Drainage Class
Poorly drained

Soil Classification
NZ Genetic: strongly leached, clay illuvial Gleyed Brown Granular Clay. Soil Taxonomy: (Epiaquic) Paleaquult, very fine, kaolinitic, acid, thermic.

AWARUA STRONGLY GLEYED CLAY

Parent Materials
Kaolinite clay weathering products of deeply weathered basalts and dolerites.

Typical Landscape Position
Receiving sites and flat slopes on gently sloping interfluves, commonly adjacent to natural drainage ways.

Soil Class Definition
Strongly acid, gleyed Brown Granular Clay soils with clayey, gleyed (>50% chromas <2 in hues of 2.5Y or yellower) cutanic horizon below the A horizon or 25cm depth, extending to more than 90cm depth; a clayey (>60% clay) particle size class, and a kaolinitic mineralogy class.

Characteristic Profile Features

Apg 0-10/15cm dark greyish brown (2.5Y4/2-10YR4/3) silty clay with 0-2% fine strong brown (7.5YR4/6) mottles along root channels; sticky; plastic; moderately weak moist soil and ped strength, very firm dry ped strength; semi-deformable to brittle moist unconfined failure; 5-10mm nut structure; many roots; indistinct boundary.

Btr1 10/15-35/50cm grey (5Y5/1-2 to 2.5Y5/1-5/2) clay with less than 5% ochreous mottles and 0-2% small, black manganiferrous concretions; sticky; plastic; moderately firm moist soil and ped strength; very firm dry strength; firm in situ strength; brittle moist unconfined failure; compound 10-25mm rough faced, fitted nut structure within coarse prismatic structure; light olive brown clay coatings on less than 10% ped faces; few roots; indistinct boundary

Btr 2 35/50-80/100cm	light grey (5Y6/1-2, 2.5Y6/1-2) clay; very sticky; very plastic; firm soil strength; very firm in situ strength semi-deformable to deformable moist unconfined failure; 20-30mm smooth faced, fitted nut and block structure within coarse prismatic structure; light olive brown clay coatings on less than 10% ped faces; indistinct boundary
BCtr 80/100cm+	light grey (5Y6/1-2, 2.5Y6/1-2) clay; sticky; very plastic; very firm soil strength; very firm in situ; semi-deformable to deformable moist unconfined failure; 50mm smooth faced, fitted block and nut structure with massive tendency; few discontinuous clay coatings

Similar Soils

Awarua gleyed variant: olive grey Btg horizon with more than 2% ferruginous mottles below the Ap on a brownish yellow to strong brown Bt horizon within 60cm depth.

Soil Drainage Class

Poorly drained

Soil Classification

NZ Genetic: strongly leached, clay illuvial Gleyed Brown Granular Clay.

Soil Taxonomy: Typic Paleaquult, very fine, kaolinitic, acid , thermic

AWARUA MODERATELY DEEP FRIABLE CLAY VARIANT

Parent Material

Red-weathered basalt and dolerite.

Typical Position

Small knobs on some ridge crests. In extensive soil class.

Soil Class Definition

Brown Loam soils with a clayey oxidic B horizon, weathered rock fragments within 90cm soil depth, and a clayey particle size class

Characteristic Profile Features

Ap 0-12cm	dark brown (7.5YR3/3) to very dark greyish brown (10YR3/2 silty clay; 3-5mm nut structure breaking to less than 3mm nut and granular structure; moderately weak soil and ped strength; very friable unconfined moist failure; slightly sticky; slightly plastic; many roots; indistinct boundary
Bo1 12-34/40cm	strong brown (7.5YR4/6-5/8) silty clay, 0-5% weathered basalt fragments; 3-5mm rough faced nut structure; moderately weak soil and ped strength; friable unconfine moist failure; slightly sticky; slightly plastic; common roots; indistinct boundary
Bo2 34/40-57/60cm	strong brown to yellowish red (7.5YR5/6-5YR5/6) clay; 1-20% weathered basalt fragments; 3-10mm nut structure, moderately weak to moderately firm soil and ped strength friable, or friable-brittle unconfined moist failure; slightly sticky; moderately plastic; few roots;

indistinct boundary

on yellowish red (5YR4/6) or redder clay with 5-25% weathered basalt fragments.

Similar Soils
Awarua series: yellowish brown Bt horizons which lack friability.

Soil Drainage Class
Well drained

Soil Classification
NZ Genetic: Brown Loam

WAIMATENUI SERIES

Parent Materials
Kaolinite clay weathering products of basalts and dolerites. Clays are commonly red weathered below about 0.8-1.0m. Depth to basalt saprolite varies from 1-2m.

Typical Landscape Position
Planar locally steeply sloping (>11') side slopes and steep gully slopes of rolling land.

Soil Class Definition
Strongly acid, Brown Granular Clay soils with a clayey, nut structured cutanic Bt horizon, a clayey particle size, and a kaolinitic mineralogy class; with
- a clayey, fine nut structured Ap horizon on
- a yellowish brown (10YR5/6-5/8) Bt horizon with tightly packed fitted nut structure on
- a strong brown (7.5YR5/6-6/8) tightly packed Bt horizon on
- a red (5YR or redder) very tightly packed clay.

Three soil classes have been described, two on hillslopes (Waimatenui clay, Waimatenui moderately deep clay) and one on sloping footslope benches (Waimatenui variant) above incised streams.

Characteristic Profile Features
Waimatenui clay

Ap 0-7/12cm	dark greyish brown (10YR3/2-3) silty clay; 3-10mm nut structure; moderately weak moist soil and ped strength; friable unconfined moist failure; slightly sticky; plastic; many roots; indistinct boundary
Bt1 7/12- 35/45cm	yellowish brown (10YR4/6-5/6) clay; 5-20mm fitted, rough faced nut structure; moderately firm moist strength, brittle moist unconfined failure; tightly packed; sticky; plastic; few thin discontinous cutans; 0-2% 1-2mm black manganiferrous concretions; few roots; indistinct boundary
Bt2 35/45-	strong brown (7.5YR5/6-6/8) clay; 10-25mm smooth faced, fitted nut structure; moderately firm moist strength;

72/90cm	brittle unconfined moist failure; tightly packed; sticky, very plastic, common thin discontinous cutans; few roots; indistinct boundary
BCt 72/90cm+	reddish brown (5YR5/5) or redder clay; 25->50mm smooth faced, fitted nut structure with massive tendency; moderately firm moist strength; very tighly packed, brittle unconfined moist failure; common thin discontinuous cutans.

Waimatenui moderately deep clay
Similar to Waimatenui clay, but 50-100cm to weathered basalt. A minor soil class which occcurs over small areas on steep slopes with occasssional surface boulders.

Waimatenui clay variant
Bt1 horizon has a friable rather than brittle failure with 5-10mm partially fitted nut structure below the Ap within 50cm soil depth. The BCt horizon has common weathered basalt fragments. This profile form occurs on small footslope benches above shallow, incised stream.

Similar Soils

Awarua series:	yellowish brown to light olive brown Bt(g) horizon with ferruginous mottle below the Ap horizon and 10YR6/6 Bt2 horizon.

Soil Drainage Class
Well drained

Soil Classification
NZ Genetic: strongly leached, clay illuvial Brown Granular Clay.
Soil Taxonomy: Typic (Orthoxic) Haplohumult, thermic, very fine, kaolinite, acid.

1.3 Soil Map Units

The Awarua map unit in the regional soil map of Sutherland et al. (1981) is an association of strongly leached Brown Granular Clays (Orthoxic and Epiaquic Palehumults) and Gleyed Brown Granular Clays (Typic and Aeric Paleaquults) with smaller inclusions of Brown Granular Clays (Orthoxic Haplohumults) on slopes above drainage lines.
The average composition of the map units is

	% Frequency
Awarua series	46
Awarua yellowish brown variant	8
Awarua gleyed variant	39
Awarua strongly gleyed variant	8
Awarua mod. deep friable clay variant	<1
Waimatenui series	9

Soil-Landscape Units

The design of the Awarua map unit was dictated by map scale. We have tried to identify those repetitative association of soils which occur on recognisable parts of the landscape as an aid to land management. These we call soil-landscape units. Their typical occurrence is shown in Fig 1.

Awarua ridge

Landform Element: narrow (<50m) shedding, easy rolling higher ridges and interfluves

Soil Class	% Frequency	Typical Position
Awarua series	>53	sloping interfluves
Awarua yellowish brown var.	>30>50	shedding sites
Awarua gleyed var.	>15	very gentle slopes and receiving sites
Awarua mod. deep friable var.	>2	infrequent knobs

Awarua Gleyed

Landform Element: broad, gently sloping interfluves, and concave benches/receiving sites on side slopes

Soil Class	% Frequency	
Awarua gleyed var.	>55	gently sloping sites
Awarua st. gleyed var.	25	flat and receiving sites
Awarua series	>20	shedding shoulder slopes

Awarua moderately sloping

Landform Element: moderately sloping side slopes

Soil Class	% Frequency	
Awarua yellowish brown var.	30	main side slopes
Awarua series	45	oversteepened slopes
Awarua gleyed	<15	contour concave receiving slopes
Waimatenui series	<10	gully slopes

Waimatenui strongly sloping

Landform Element: moderately steeply sloping hill slopes along drainage lines

Soil Class	% Frequency	
Waimatenui series	>75	main slopes
Waimatenui mod. deep	<15	oversteepened slopes
Awarua	<10	locally moderately sloping

2. SOIL CHEMISTRY AND MINERALOGY

Soil mineralogical and chemical data (Table 1) are given for representive profiles of the Awarua series, Awarua yellowish brown variant and Awarua gleyed variant. Data for the Waimatenui series is extra polated from the Waimatenui reference profile in the adjacent valley.

Summary

Soils have a kaolinite-crystalline iron oxide mineralogy which confers low activity clay properties (low effective cation exchange capacity) in subsoils. Subsoils therefore have a limited ability to retain cations. Topsoils, however, are strongly buffered. Subsoils are strongly acid with large concentrations of extractable aluminium and less than 1me exchangeable calcium. Exchangeable potassium is low. Low reserves of phosphorus and phosphorus fixation properties signify relatively large fertiliser requirements. Reserves of potassium and magnesium are low.

2.3.1 Soil Mineralogy

Mineralogical analysis shows a kaolinite clay mineralogy with 15-24% crystalline Fe oxyhdroxides thought to be mainly goethite. Crystalline iron oxide contents were calculated from dithionite-extractable Fe minus acid oxalate-extractable Fe and expressed as Fe2O3 on a whole soil basis. The transition between brown upper horizons and red lower horizons is thought to reflect the replacement of haemitite by goethite.

The sand fraction comprises less than 10% of the whole soil and is characterised by a relatively large heavy mineral concentration (25-55%) and a quartz dominat light fraction. Ilmenite and magnetite are the dominant heavy minerals. Sand size goethite occurs in upper horizons, and sand size kaolinite occurs in the red clay layers. Weatherable mineral concentrations exceed 10% in topsoils and upper B horizons but rapidlly decrease to trace concentrations with depth. The depth-continuity of weatherable hornblende, feldspars, pyroxene, and rhyolitic volcanic glass suggests wind-blown accession from both distant sources in the Central Volcanic Plateau and nearby sources. The occurrence of cummingtonite hornblende is commonly interpreted as denoting the presence of Rotoehu ash (35000 yrs BP) from the Okataina centre. In which case, interfluves and side slopes have been stable for > 35000 yrs.

2.2 Soil Chemistry

Awarua soils are strongly acid below limed topsoils while the Waimatenui soil is moderately acid. All soils have large concentrations of KCl-extractable Al below the topsoil. Al saturation of the cation exchange complex exceeds 50%. The dominant Al species at prevailing pH and Al concentration is probably toxic, monomeric Al^{3+}. Al toxicity in subsoils is therefore a limitation to root extension and function, and an important cause of the shallow rooting habit of Al sensitive plants in these soils.

The presence of manganese concretions especially in the upper B horizon in Awarua series and gleyed variants which are periodical reduced, also suggests the possibility of large concentrations of We would therefore flag the possibility of Mn toxicity.

Cation exchange capacities close to field pH (ECEC)) are relati large in topsoils but decrease to low values in subsoils. ECEC/1 clay is less than 12me and these soils show low activity clay properties in the subsoil. Low activity clay properties stem fro variable charge ("pH-dependent CEC") kaolinite-iron oxide mineral Subsoils therefore have a limited ability to retain cations and a relatively weakly buffered against cation concentration changes i the soil solution. Conversely, low activity clay soils, have a comparative advantage in that soil solution cation concentrations be manipulated with lower inputs and more effectively than in hig activity clay soils. For example, subsoil acidity may be correct to greater depth by calcium based fertilisers more soluble than l The difficulty in these soils, however, is the presence of an overlying strongly buffered topsoil with a relatively large lime requirement.

Exchangeable K values are low, and exchangeable Ca concentratio are less than 1me% below the topsoil in all soils.

Phosphorus fractionation analyses for the Waimatenui profile sh low concentrations of 0.5MH2SO4-P and total P, low 0.5MH2SO4-P/ inorganic P ratios, and high P retention %. Similar trends are expected in Awarua soils. These trends are typical of strongly weathered soils with a kaolinite-crystalline iron oxide mineralog We conclude that inorganic reserves of P (0.5MH2SO4-P) are very l P retention value in combination with 0.5MH2SO4-P/ inoragnic P ra indicate P fixation process. P maintenance requiremnts therefore tend to be large. Where phosphate fertiliers are withheld, P availability is largely dependant on release from organically-bou sources rather than inorganic reserves.

Acid-extractable reserves of K and Mg (Kc and Mgr) are very low the Waimatenui profile. We would expect similar or lower values Awarua soils. Such low values are a consequence of strong weathe processes and a low density of K specfic sorption sites. All soi have a potassium fertilier requirement. Magnesium fertilisers ma required for Mg demanding crops.

3. SOIL PHYSICAL PROPERTIES

A number of soil properties which are important to crop production and management are given in Table 2.

3.1 Soil Resistance to Penetration

Soil resistance to penetration (SPR) was measured by penetrometer at sites representative of the Awarua series and Awarua gleyed variant (McDonald and Wilson 1986, SWIG 1987). Measurements were made at soil water contents close to "field capacity". SPR is then a measure of the bulk resistance likely to be encountered by actively growing roots in moist conditions.

SPR values of 1500-2500 kPa were measured below the topsoil in upper B horizons above dense, tightly packed lower horizons below about 60cm depth. We have also noted that relatively small decreases in water content from field capacity result in large increases in SPR. SPR values >3000kPa have been measured at matric potentials of 30-50kPa. Root extension is therefore mainly restricted to voids between aggregates.

3.2 Hydraulic Conductivity

Measurements of saturated hydraulic conductivity (Ksat) and hydraulic conductitiy at a matric potential of 40mm (K-40) were made at a representative site for the Awarua series. For the other soils listed, assessments were made from morphological properties following the procedures of Griffiths (1986 and pers. comm.) and given as a permeability class.

Nearly all soils have a moderately slow or slower profile permeability due to tightly packed, slowly permeable horizons below about 50-60cm depth. Permeabilities in upper horizons are moderate to moderately rapid. Water movement in wetting-up phases is mainly preferential along planar voids which bound weakly defined prisms and larger blocky aggregrates. The presence of slowly permeable subsoil horizons causes ponding of water in upper horizons. Soil water movement on sloping land probably occurs as interflow through more permeable upper and middle horizons. On gentle slopes and on receiving sites, water ponds above slowly permeable horizons resulting in varying durations of saturation, and chemical reduction during wet winter and spring periods. The soil distribution over the area reflects soil hydrological characteristics.

Ksat measurements on the Awarau series reference site shows moderate to moderately rapid values in Ap and upper Bt(g) horizons. Ksat decreases to values of <2mm/h in slowly permeable brownish yellow and reddish brown horizons. K-40 is the conductivity through pores <0.075mm diameter. This is important to the maintainance of non-saturated conditions during irrigation and is also a measure of the surface infiltration rate when macropores have collapsed due to structured damage as under high stocking rates. The difference between Ksat and K-40 is a measure of the large pore volume available for aeration. Upper horizons have a relatively large aeration porosity. Slowly permeable lower horizons have a very small aeration porosity.

3.3 Water Repellency

Water repellency characteristics were determined by the methods of Letey et al (1975). These methods measure first, the resistance to initial wetting, and second, the persistance of repellency. Topsoils of Awarua series and Awarua gleyed variant soils are moderately repellent. A moderate repellency is also associated with organic clay coatings bounding planar voids in subsoils. Other soils are essentially non- or weakly repellent.

Water repellency is therefore a factor in the characteristic slow re-wetting of some of these soils.

3.4 Soil Drainage

Soil drainage classes are given to allow correlation with those in Cox et al.(1981) and Cox (1972). The overall drainage of the soil under prevailing conditions indicates the rate at which water is removed from the soil and the duration for which the soil is wet or above 'field capacity'.

Most soil classes show evidence (ie low chroma colours, ferruginous mottles, concretions) of impeded drainage above tightly packed clayey slowly permeable horizons. As a result, soil water contents within the root zone are wet or above field capacity for varying periods during wet winter and spring periods.

3.5 Available and Readily Available Water

Available water is here defined as the volume of water (mm) retained between field capacity and wilting point (-1500kPa tension) over an abritrary root depth of 60cm. Field capacity was measured on a Awarua series site in late winter 1986 (McDonald and Wilson 1986). Values lay between -10 and -20kPa pressure potential within 60cm soil depth. A value of -10kPa was assumed. Readily available water is calculated as the water content difference between -10kPa and -100kPa over a 60cm PRD. Soils have moderate available water, and low readily available water. Soils retain large amounts of water at tensions larger than 100kPa and especially 1500kPa. This is typical of strongly leached Brown Granular Clays.

3.6 Soil Aggregate Stability

The aggregate stability of topsoils was determined by the dispersibility/slaking test of McQueen (1982).

Negligible dispersion or slaking was recorded in most soils. Aggregate stability is rated as high in all soils with the exception of moderate values in Awarua gleyed and strongly gleyed variants.

4. SOIL CHARACTERISTICS IN RELATION TO CROP PRODUCTION AND SOIL MANAGEMENT

Assessments of some primary soil characteristics which directly influence crop production and management are given in Table 4. These assessments are derived by combining soil properties, often with climatic data.

4.1 Soil Water Deficits (Fig 3)

Soil water deficits for 10,20,40 50 percentile rainfalls were calculated for gently sloping sites using climatic data (NZ Meteorological Service, 1983) and a readily available water storage of 30mm. Water balance calculations and assumptions are given in Giltrap (1986).

Calculations suggest small deficits in late summer in most years, and large deficits in 1 in 10 and 1 in 5 dry years. The duration of water deficits is likely to be longer than that calculated due to slc rewetting of dry soils.

Soil water deficits are likely to have a marked effect on the growth of crops which are sensitive to water stress during the perioc of deficit. For example, pasture dry matter production and P. radiat growth rates will be less than optimum in most years.

4.2 Potential Root Volume (PRV)

PRV is assessed from the trend of soil penetration resistance with depth, and also the size, porosity and packing of soil aggregates. This characteristic describes the soil volume as a mediu for root extension and subsequent exploitation of soil water and nutrient reserves. On a soil physical basis, the potential rooting depth in most of these soils is about 60cm. Relatively large penetration resistances however, occur below the topsoil, and aggregates show only small amounts of macropores. The PRV is therefore rated as low-moderate as roots will be largely confined to inter-aggregate pores.

In practice, however, the effective root volume will be low for many crops being largely confined to surface horizons by Al-toxic subsoils. The possibilities of overcoming Al-toxicity problems and increasing PRV are discussed later.

4.3 Soil Aeration

Soil aeration characteristics of the root zone were assessed from air capacity and morphological data. Oxygen deficiency and chemical reduction due to impeded drainage and small air capacity values periodically occur in Awarua series profiles and frequently in gleyed and strongly gleyed variants during wet winter and spring periods .

Periodic oxidation-reduction processes may have feed-back effects on pH, nitrogen cycling, P transformations, and Mn accumulation.

4.4 Soil Fertility

Soil nutrient levels are transient. Fertiliser requirements depend on antecedent management, time of year, crop type as well as soil type. The assessment of soil fertility given here is in terms of soil processes which are important to fertiliser needs and subsequent nutrient transformations.

All soils are rated as being of low fertility on the basis of soil acidity, Al-toxicity, low long-term K and Mg supply rates, sma concentrations of non-occluded P with medium P retentions, and larg molybdenum sorption capacities.
Soils have phosphorus, potassium and molybdenum fertiliser requirements, with magnesium likely for demanding crops. Aluminium and possible manganese toxicity in subsoils may be corrected to increase potential rooting depth by liming materials more soluble than $CaCO_3$. The presence of low activity clay properties is regarde as an advantage in increasing the depth-effectiveness of liming materials.

4.5 Susceptibility to Animal Treading

Most soils are rated as being moderately to highly susceptible to animal treading damage during wet periods with likely losses in pasture production.

During wet periods, soils of the Awarua series and in particular gleyed variants, drain by a process of arrested drainage which maintains near-wet water states in upper horizons. Such wate contents are close to the plastic limit. Strength loss with resulta deformation under animal treading therefore occurs. Susceptibility treading damage, however, is less than on gumland soils.
The severity of animal treading damage is highly dependant on bot animal (sheep or cattle) and stocking intensity. Where severe dama occurs early in the winter, topsoil macroporosity is reduced, givin subsequent problems for the rest of the wet season. Animal treadin damage can be a significant limitation to winter and spring pasture production. Where a wetter-than-average winter/spring is followed b a dry summer, then the effective growing season is very short.

4.6 Trafficability by Off-Road Vehicles

Trafficability by off-road vehicles, as in forest logging operations, is likely to be constrained for extended periods during wet winter and spring periods on most soils. Similar principles to those outlined above apply, with the additional limitation of slope

4.7 Susceptibility to Cracking

An ancillary effect of water deficits in soils with a significant shrinkage potential is cracking and subsequent pasture damage by insects. Awarua series and in particular gleyed/strongly gleyed variants are moderately to highly susceptible to cracking, while Waimatenui series is slightly-moderately susceptible. Measurements of cracking in the early summer of 1986, indicate that cracks are initiated at water contents equivalent to a matric potential of about 60kPa in topsoils and 40kPa in upper subsoils. A highly susceptible class would be reserved for soils with large shrinkage potential and which crack to considerable depths every ye eg. limited area of Vertisols in South Island.

4.8 Cultivation Charateristics

The workability of gently to moderately sloping Awarua series and gleyed variant soils will be limited by physical properties and the frequency of rain-days in spring. These soils drain by a process o arrested drainage over an extended period after rainfall. The frequency of days when topsoils are at a suitable water content for cultivation and seed-bed preparations is then likely to be limited : early spring. Also, rainfall is highly variable, with water defici occuring in late spring in some years. Soil strength increases rapidly above field capacity, and is therfore likely to affect workability in some years.

4.9 Erosion Risk

The NWASCO Land Inventary Worksheets (NWASCO) record slight sheet and gully erosion on soils of the Awarua map unit.

Table 1a: Sand Mineralogy(%)

Soil Class	Horz.	Depth (cm)	Q	F	G	K	Total Heavy Mins.	H	P	M	I	G
Awarua series (IS73)	Ap	0-8	45	12	3	0	25	12	27	0	45	8
	Bt(g)	8-42	55	7	2	0	35	15	5	0	60	20
	Bt1	42-64	55	5	1	0	40	10	0	0	65	25
	Bt2	64-80	25	2	0.2	20	50	5	0	45	25	25
	CBt	80-100	12	0	0	35	55	0	0	85	3	12
Awarua gleyed	Btg	30-40	70	2	1	0	25	5	0	0	80	15
	Bt2	80-100	60	0	0.5	15	20	3	0	0	80	15

Q quartz F feldspar G volcanic glass K kandite
H hornblend (mainly cummingtonite and oxyhornblend
P orthopyroxene and clinopyroxene
M magnetite I ilmenite G goethite

Table 1b: Clay Mineralogy(%)

Soil Class	Horz.	Depth (cm)	Kaolinite	Vermic.	Quartz
Awarua series (IS73)	Ap	0-8	90	5	6
	Bt(g)	8-42	85	5	8
	Bt1	42-64	90	4	6
	Bt2	64-80	90	3	5
	CBt	80-100	95	0	4
Awarua gleyed	Btg	30-40	90	2	9
	Bt2	80-100	90	2	6
Waimatenui clay SB7640	Ap	0-10	90	-	-
	Bt1	17-48	86	-	-
	Bt2	48-70	82	2	-
	C	85-108	100	-	-

Table 1c: Soil Chemical Properties

Depth (cm)	pH	C%	CEC (me%)	BS%	Exch.Cations(me%) Ca	Mg	K	Na	KCl -Al	ECEC (me%)	Pret	Pmg-0.5M H2SO4
Awarua series (IS 73)												
0-8	nd	nd	33.0	60	14.8	3.7	0.91	0.3	0.2	20.0	61	nd
8-42	4.9	"	16.4	29	2.8	1.5	0.33	0.2	2.2	7.0	66	"
42-64	4.8	"	12.2	14	0.8	0.5	0.20	0.1	4.7	6.4	62	"
64-80	4.8	"	12.5	12	0.7	0.4	0.22	0.1	6.7	8.2	63	"
80-100	4.8	"	13.4	10	0.5	0.4	0.25	0.1	8.7	10.0	66	"
Awarua yellow brown variant (SB7676)												
0-10	5.1	6.2	23.0	30	3.7	2.5	0.45	0.3	nd	nd	60	5
10-23	5.0	4.1	16.9	13	0.8	1.0	0.15	0.2	"	"	65	3
23-45	4.7	2.7	12.8	5	0.1	0.4	0.05	0.1	"	"	60	2
45-68	4.6	1.7	12.1	5	0.1	0.4	0.05	0.1	"	"	nd	2
83-95	4.8	0.7	11.1	8	0.1	0.4	0.05	0.3	"	"	"	1
Awarua gleyed variant (IS 75)												
30-40	4.7	nd	10.1	40	2.5	1.2	0.14	0.1	1.1	5.2	50	nd
80-100	4.8	"	10.5	14	0.8	0.5	0.07	0.1	4.5	6.0	49	"
Waimatenui clay (SB 7640)												
0-10	5.4	7.8	33.2	41	6.7	6.4	0.77	0.3	nd	nd	71	13
10-17	5.3	5.4	25.3	16	1.8	2.6	0.4	0.5	nd	nd	nd	nd
17-48	5.1	2.8	16.2	3	0.3	0.7	0.06	0.2	5.3	6.5	74	3
48-70	5.2	1.7	15.0	1	0.2	0.5	0.05	0.2	5.2	6.2	77	4
70-85	5.3	0.9	15.0	1	0.2	0.4	0.05	0.2	nd	nd	nd	nd
85-108	5.2	0.5	19.2	0	0.6	0.5	0.07	0.3	nd	nd	79	4

Table 2c (continued)

Depth (cm)	Pyrophos.-ext. Fe%	Al%	Dithionite-ext Fe%	Al%	Kc	Mgr (me%)	Phos.-ext S (mg%)
Awarua series (IS 73)							
0-10	0.83	0.37	6.5	1.2	nd	nd	nd
10-23	0.84	0.34	8.2	1.5	"	"	"
23-45	0.29	0.18	7.8	1.3	"	"	"
45-68	0.09	0.15	9.8	1.3	"	"	"
83-95	0.02	0.15	7.6	0.83	"	"	"
Awarua gleyed variant (IS 75)							
30-40	0.29	0.13	7.1	0.82	nd	nd	nd
80-100	0.13	0.13	7.1	1.0	"	"	"
Waimatenui clay (SB 7640)							
0-10	nd	nd	nd	nd	0.06	2.6	4
17-48	"	"	7.2	1.3	nd	2.1	17
48-70	"	"	9.6	1.6	nd	3.5	33

Table 2: Soil Physical Properties

Soil Class	Soil Drainage Class	Soil Permeability Class	Available Water (mm) 0-60cm	Readily Available 0-60cm	Air Capacity % Ap	Air Capacity % B	Topsoil Aggregate Stability	Water Repellency	Subsoil Soil Penetration Resistance (kPa)
Awarua series	moderately well drained	moderate; slow below 60cm	80-90	30-35	10-12	4-7	high	slight	2000-3000
Awarua yellowish brown variant	moderately drained well	moderate; slow below 60cm	80-90	30-35	10-12	5-8	high	slight	2000-3000
Awarua gleyed variant	imperfectly drained	slow	80-90	30-35	10-12	3-5	med.-high	mod	2000-3000
Awarua strongly gleyed variant	poorly drained	v.slow	80-90	30-35	5-12	3-5	med.-high	mod	2000-3000
Awarua mod. deep friable clay variant	well drained	moderate	70-90	30-35	>15	>10	high	non	nd.
Waimatenui series	well drained	moderate	90-100	30-35	10-15	5-8	high	slight	2000-3000

Table 3: Soil Management-related Characteristics

Soil Class	Susceptibility to Livestock Trampling	Trafficability	Cultivation Characteristics	Susceptibility to Cracking	Erosion Risk	Root Zone Aeration
Awarua series	moderate	limited-winter wetness	fair	moderate	moderate sheet and rill erosion	moderate
Awarua yellowish brown variant	moderate	limited-winter wetness	fair	moderate	moderate sheet and rill erosion	good
Awarua gleyed variant	high	limited-winter spring wetness	limited	severe	slight sheet	limited in winter/spring
Awarua strongly gleyed variant	high	limited-winter spring wetness	limited	severe	slight sheet	limited in winter/spring
Awarua mod. deep friable var.	slight	slight limitations in winter	good	negligible	negligible	good
Waimatenui series	moderate	limited-steep slopes and winter wetness	n.a	slight -moderate	moderate sheet and medium slip	moderate

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Kathryn Pabirowski

From: Colin Dall
Sent: Monday, 5 August 2024 2:36 pm
To: Bob Cathcart
Subject: RE: High aluminium results Northern Wairoa
Attachments: LC3600_Soil contract report.pdf

FYI – when this first came up, I did wonder if the soils in the area could be a source of Al/contain high Al levels. After a quick Google search, I found the attached report which you are probably aware of. Page 10 of the report (immediately below) confirmed this.

Table 4. Subsoil pH 'alert' list of soils in the Kaipara District Council region

Soil names and symbols	Subsoil pH observations
Parore peaty sandy loam (PZ)	The organic material to a depth of 60 cm from the soil surface, or to its base if shallower, has pH of 4.5 or less throughout the major part
Otonga peaty clay loam (OG) Waiotira series (YC, YCe, YCeH, YCH) Waipu series (YU, YUy) Takahiwai clay (TC)	pH of 4.8 or less in some part between 20 and 60 cm from the mineral soil surface, or, a horizon within 60 cm of the mineral soil surface with pH less than 4.8
Rangiuru series (RU, RUH) Waipoua series (WP, WPH)	pH of less than 5.1 in the major part of the B horizon to 60 cm from the mineral soil surface
Tutamoe friable clay (TO) Aranga clay (AR)	pH of less than 5.1 in some part of the B horizon to 60 cm from the mineral soil surface
Waipu clay (YU) Kara series (KR, KRa, KRe, KRp)	pH of less than 5.5 in some part from the base of the A horizon to 60 cm from the mineral soil surface
Hukerenui series (HK, HKa, HKgH, HKH, HKr) Wharekohe series (WK, WKa, WKap, WKfp) Aponga series (AP, APH) Rangiora series (RA, RAH) Okaka series (OA, OAH) Waikare series (YK, YKH) Puketitoi series (PD, PDH) Riponui series (RP, RPa) Tangitiki series (TT, TTH) Omu series (PM, OMH) Pukemanu series (PM, PMH) Red Hill series (RLa, RLaH) Mata clay (MA) Rockvale series (RV, RVe) Wairiki clay loam & silt loam (YR) Puhoi series (PBuH) Rockvale series (RV) Warkworth series (WA, WAH) Pukekaroro series (POS) Otaika series (OP, OPH) Mahurangi series (MV, MVH) Whangaripo series (WR, WRe, WRH, WReH) Maungarei series (ME, MEH, MEbH) Piroa series (PFH) Tanoa series (TNH)	All soils belonging to the Ultic Soil Order are on 'pH alert', because an accessory property of the Order is that KCl-extractable aluminium levels in B horizons are usually more than 1 cmol (+)/kg and Al-toxicity is possible.
Te Kopuru series (TEK) Tinopai series (TP) One Tree Point series (OT)	In Podzols, KCl-extractable-aluminium levels are high, and aluminium in soil solution may be toxic to some plants.

Manaaki Whenua
Landcare Research

Soils and soil data – Kaipara District Council Region Topo-climate Study

Prepared for: NIWA

September 2019

Soils and soil data – Kaipara District Council Region Topo-climate Study

Contract Report: LC3600

Malcolm McLeod

Manaaki Whenua – Landcare Research

Reviewed by:	*Approved for release by:*
Gerard Grealish	Sam Carrick
Scientist	Portfolio Leader – Characterising Land Resources
Manaaki Whenua – Landcare Research	Manaaki Whenua – Landcare Research

Contents

1 Introduction

Manaaki Whenua – Landcare Research is subcontracted to NIWA to provide soil and land information for the Kaipara District Council region topo-climate study.

2 Background

Manaaki Whenua – Landcare Research's soil and NZ Land Resource Inventory data can be used to produce maps for areas of crop suitability and inform the Topo-climate report.

3 Objectives

- Provide information on soils and soil data in the Kaipara District Council region study area.
- Write a section on soil variation in the Kaipara District Council region study area.

4 Methods

New Kaipara District Council region-specific data were generated by updating relevant fundamental soil datasets and relevant NZ Land Resource Inventory data for the Kaipara District Council region study area.

5 Results

5.1 Description of the soil maps

This section describes the soil maps produced for the Kaipara District Council area. Fieldwork to generate the soil maps used in this study was undertaken in the mid-1950s with soils developed in similar rocks aggregated into 'soil suites'. It is unlikely we would use the same methods today as soils within the soil suites can show considerable variation in properties such as drainage class. The region is not covered by Manaaki Whenua – Landcare Research's more recent S-map product and associated soil information. Table 1 lists all the soil maps and derivatives generated for this study and gives them identifier numbers, which will be referred to in this section. The maps are in Appendix 1.

Table 1. List of soil maps produced for the Kaipara District Council region

Map identifier	Map description
1	Soil terrains
2	Soil series, types and phases (the soil name)
3	Slope class
4	Subsoil acidity
5	Potential rooting depth
6	Soil drainage classes
7	Profile total available water

5.2 Soil Terrains

Nine soil terrains are depicted in the Atlas of Soil Information, and each terrain represents a broad division of the landscape according to the general type of soil parent material and slope. Sloping land is divided into land with slopes less than 15° (flat to rolling) and land with slopes greater than 16° (strongly rolling to steepland). Soil terrains give a spatial framework to the soil and climate-related themes. There are over 120 soil types in the project area, with a little over half the area being sand country, flood plains or downland terrains. (Map 1).

The following soil terrains are recorded:

1 Sand country (655 km^2, 21%)

2 Flood plains (379 km^2, 12%)

3 Peatland (61 km^2, 2%)

4 Downland from sedimentary rocks – most slopes <16° (475 km^2, 15%)

5 Downland from volcanic rocks – most slopes <16° (134 km^2, 4%)

6 Hill country from weathered sedimentary rocks (444 km^2, 14%)

7 Hill country from mixed crushed & sheared rocks (410 km^2, 13%)

8 Hill country and occasional steepland from volcanic rocks (483 km^2, 16%)

9 Hill country and steepland from greywacke and argillite (18 km^2, 1%).

5.3 Soil Series, Types and Phases (the Soil Name)

The soil series, type and phase provide a link to soil attributes that require consideration when investigating land-use opportunities and management requirements. The attributes (such as potential plant rooting depth) can be represented spatially because their values have been attached to soil map units. The mapped soils and names are listed in Table 2. For improved understanding of these soils, it is essential to refer to the published legend of soils (Cox et al. 1983), where soil series, type, and phase are set out in suites according to parent material, and further arranged into leaching regimes.

Soils are grouped into *series* of similar soil profiles, similar temperature, moisture regime and parent material. The series is frequently given the name of a locality where it is well developed. *Soil types* within a series are defined by topsoil texture, and so textural terms are placed after the series name. *Soil phases* are an informal subdivision of soil types to reflect a soil property of potential importance to land use and management.

Soils according to soil terrains

Sand country: Sand country soils often include those mapped as Bare Rock and occur all the way up the west coast of the study area (Map 1). Sand country soils become older and more weathered away from the coast (Map 1). The sequence begins seaward with areas of sand dunes which show minimal soil development being delineated as Bare Rock followed by soils with very weak soil development–Pinaki soils (86 km^2, 3%). Red Hill soils (93 km^2, 3%) generally occur inland from Pinaki soils. Red Hill soils have enough soil development to provide one of the better opportunities for land-use intensification, although subsoil acidity would need checking that it is not too low (Map 4). Tangitiki soils (225 km^2, 7%) are slightly older and show high variability over short distances, with some sites strongly podzolised ('egg cup podzols' where large kauri trees once grew). This variability would make general crop predictions unreliable at a broad scale. Podzols named Te Kopuru soils (128 km^2, 4%) occur furthest inland on the oldest dunes. These soils are uniformly poor in many attributes, affecting the growth of deeper rooting and soil water sensitive crops.

Flood plains: About 12% of the project land area comprises flood plains (Map 1) and these may be well suited to some high value land uses. The poorly drained clays and peaty clays of the Kaipara soil suite (207 km^2, 7%) are already well understood and widely used for kumara growing – with highly specialised management. The narrower flood plains of the hill country are generally not used for cropping. Whakapara soils from alluvium derived from sedimentary rocks occur in valleys throughout the study area (81 km^2, 3%), whereas Mangakahia soils from alluvium derived from volcanic terrains are generally mapped in valleys north of Dargaville (63 km^2, 2%). Although both soils are well supplied with plant nutrients, they can be imperfectly drained (Map 6) and may also be subject to flooding. Careful site assessments are required when considering soil water sensitive crops.

Peatland: About 50 km^2 of Parore peaty sandy loam occurs in small valleys in the sand country of the west coast and smaller areas of Otonga peaty loam in backswamp positions (Map 2). While these soils are generally very poorly drained (Map 6), with shallow rooting depth (Map 5), they may provide growing environments for a limited range of crops.

Downland from sedimentary rocks (most slopes <16°): The easy slopes in this soil terrain make it a potential area for land-use intensification or diversification. The terrain is scattered throughout the study area (Map 1). The terrain is dominated by Aponga and Waikare soils developed in claystone, mudstone or shale. Potential plant rooting depth (Map 5) is generally about 90–120 cm for Aponga soils (71 km^2, 2%) and slightly less (60–90 cm) in Waikare soils (78 km^2, 2%). Arapohue and Rockvale soils from argillaceous limestone have heavy clayey subsoils. The potential plant rooting depth (Map 5) is about

60–90 cm in Rockvale soils (35 km^2, 1%), but is shallow (25–45 cm) in Arapohue soils (46 km^2, 1%). Most soils in this terrain are imperfectly drained, suggesting some impediment to soil water sensitive plants.

Downland from volcanic rocks (most slopes <16°): generally, this terrain occurs near Tutamoe and north of Lake Taharoa. Rolling slopes on andesitic and basaltic volcanics, together with terraces from redeposited volcanic material, offer good opportunities for crop production. Soils are naturally well supplied with plant nutrients and have good structure. While upper subsoils can be firm and plant rooting slightly restricted (Map 5), the soils do not become firmer with increasing depth (unlike soils of the sedimentary downlands). Tutamoe, Whatoro, Aranga, Katui, Waimatenui, Rangiuru, and Kohumaru soils at least appear to provide an opportunity for land-use intensification, (together, covering 106 km^2, 3%; Map 2). Some of the soils, especially those in higher rainfall areas or receiving drainage water, contain a localised iron pan, while others are imperfectly drained, so detailed site investigation is recommended.

Hill country from weathered sedimentary rocks (most slopes 16–25°): In the study area, contiguous areas generally occur south west of Dargaville. This soil terrain is underlain by stable rocks (not crushed or sheared), and they are mostly sandstones. The main soil series is Waiotira. On rolling slopes, the soils are imperfectly drained but on hilly slopes the drainage may improve, and the soils are moderately well drained (Map 6). They have few root restrictions above about 60 cm depth (Map 5) but may need checking for subsoil pH (Map 4). Slope generally precludes arable land uses (Map 3).

Hill country from mixed crushed and sheared rocks (most slopes 16–25°): While this terrain occurs throughout the study area, larger contiguous areas occur south west and north east of Dargaville. This soil terrain is underlain by tectonically disturbed and finer grained sedimentary rocks (Map 1). The rock masses are mixed and unpredictable, and often subject to earthflow and gully erosion. Soils likewise form complex patterns. While this land has limited cropping potential (too hilly, erodible, infertile, etc.) small, low slope-angle areas of Waiotira should not be discounted where soil water sensitive plants are not considered (Map 2).

Hill country and steepland from volcanic rocks (most slopes16–35°): Very large contiguous areas of Tangihua Volcanics and Waipoua Basalts exist in the north of the project area (Map 1). Where the land is steep and rocky it is often scrub-covered, with limited productive potential beyond environmental protection and biodiversity preservation.

Hill country and steepland from greywacke/argillite (most slopes16–35°): Greywacke covers just 18 km^2 (<1%), and generally lies along the foothills north of Mangawhai Heads (Map 1). Soils are predominantly Te Ranga steepland soils (10 km^2) where slope steepness (Map 3) constrains land-use options, and the hilly Marua soils (4 km^2, Map 3). Marua soils are versatile but some show evidence of short periods of waterlogging in the upper part of the subsoil. Plant rooting depth (Map 5) is very deep (to about 90–120 cm). Rangiora soils (3 km^2) are less versatile, being more strongly weathered on the easier slopes, imperfectly drained (Map 6), and have more restricted plant rooting (although still moderately deep at 60–89 cm, Map 6).

Table 2. List of soil names and their area in the Kaipara District Council region

Soil code	Soil series	Soil type	Soil phase	Area (km^2) of series
Water bodies				32
Town				5
Bare rock (sand dune)				120
AK	Awapuku	clay loam		2
AKH	Awapuku	clay loam	hill	11
AP	Aponga	clay		100
APH	Aponga	clay	hill	39
AR	Aranga	clay		21
AU	Arapohue	clay		36
AUd	Arapohue	clay	deep	16
AUH	Arapohue	clay	hill	36
C1	C1 complex			3
C4	C4 complex			<1
C8	C8 complex			15
HI	Hihi	clay		2
HK	Hukerenui	silt loam		6
HKa	Hukerenui	sandy loam		1
HKH	Hukerenui	silt loam	hill	3
KB	Kiripaka	silt loam	bouldery	3
KBe	Kiripaka	boulder silt loam	bouldery	1
KBH	Kiripaka	silt loam	hill	<1
KM	Kohumaru	clay		12
KN	Konoti	clay		15
KNH	Konoti	clay loam	hill	2
KNr	Konoti	clay		11
KNrH	Konoti	clay	hill	2
KO	Kamo	clay loam		3
KP	Kaipara	clay loam		188
KPy	Kaipara	peaty clay loam		20
KR	Kara	silt loam		20
KRa	Kara	sandy loam		2
KRe	Kara	clay		2
KT	Katui	clay loam		16
KTH	Katui	clay loam		31
MA	Mata	clay loam		5
ME	Maungarei	clay		3

Soil code	Soil series	Soil type	Soil phase	Area (km^2) of series
MEH	Maungarei	clay	hill	1
MF	Mangakahia	clay		19
MFm	Mangakahia	clay loam		44
MO	Maungatoroto	clay		16
MRH	Marua	clay loam	hill	4
MRuH	Marua	clay loam	hill	<1
MT	Motatau	clay		14
MV	Mahurangi	fine sandy loam		63
MVH	Mahurangi	fine sandy loam	hill	14
OA	Okaka	clay		24
OAH	Okaka		hill	28
OG	Otonga	peaty clay loam		4
OM	Omu	clay loam		15
OMH	Omu	clay loam	hill	50
ON	Omanaia	clay loam		4
OPH	Otaika	silt loam	hill	<1
OT	One tree point	peaty sand		7
PBuH	Puhoi	light brown clay loam	hill	8
PC	Pakòtai	clay		2
PD	Puketitoi	sandy loam		1
PES	Parakiore	stony clay loam	steep	4
PFH	Piroa	clay	hill	12
PM	Pukenamu	silt loam		1
PN	Pinaki	sand		46
PNH	Pinaki	sand	hill	39
POS	Pukekaoro	clay loam	steep	15
PZ	Parore	peaty sandy loam		50
RA	Rangiora	clay		2
RAH	Rangiora		hill	<1
RAI	Rangiora	silty clay loam		<1
RL	Red Hill	sandy loam		19
RLa	Red Hill	sandy clay loam		48
RLaH	Red Hill	sandy clay loam	hill	6
RLH	Red Hill	sandy loam	hill	20
RP	Riponui	clay		20
RPa	Riponui	silty clay loam		6
RPaH	Riponui	silty clay loam	hill	5
RPH	Riponui	clay	hill	4

Soil code	Soil series	Soil type	Soil phase	Area (km²) of series
RU	Rangiuru	clay		18
RUH	Rangiuru	clay	hill	10
RV	Rockvale	clay		98
RVe	Rockvale	clay	coarse subsoil	10
TC	Takahiwai	clay		4
TCa	Takahiwai	sand		<1
TEK	Te Kopuru	sand		128
TErS	Te Kie	reddish clay loam		61
TES	Te Kie	clay loam		75
TN	Tanoa	sandy clay loam		2
TNaH	Tanoa	sandy loam		6
TNH	Tanoa	sandy clay loam	hill	9
TO	Tutamoe	clay		70
TP	Tinopai	sandy loam		5
TRS	Te Ranga	clay loam	steep	11
TT	Tangitiki	sandy loam		56
TTH	Tangitiki		hill	170
TU	Takitu	clay loam	gravelly	5
TUH	Takitu	gravelly clay loam	hill	39
WA	Warkworth	clay, sandy clay loam		8
WAH	Warkworth	clay, sandy clay loam	hill	24
WCS	White cone	sandy clay loam	steep	6
WE	Waitemata	silt loam		2
WF	Whakapara	sand		11
WFm	Whakapara	clay	mottled	70
WK	Wharekohe	silt loam		8
WKa	Wharekohe	sandy loam		1
WNH	Whirinaki	clay loam	hill	2
WO	Whaeora	clay loam		4
WR	Whangaripo	clay loam		4
WRe	Whangaripo	clay		3
WReH	Whangaripo	clay	hill	26
WRH	Whangaripo	clay loam	hill	15
WT	Whatoro	clay		27
WTH	Whatoro	clay	hill	23
WU	Waipuna	clay		8
YC	Waiotira	clay loam		77
YCe	Waiotira	clay		38

Soil code	Soil series	Soil type	Soil phase	Area (km²) of series
YCeH	Waiotira	clay	hill	35
YCgH	Waiotira	gravelly sandy loam	hill	3
YCH	Waiotira	clay loam		253
YCr	Waiotira	brownish clay loam		<1
YCrH	Waiotira	brownish clay loam	hill	<1
YK	Waikare	silt loam		103
YKH	Waikare	silt loam	hill	20
YN	Waimatenui	clay		24
YNH	Waimatenui	clay	hill	107
YP	Waipoua	clay		2
YPH	Waipoua	clay	hill	13
YR	Wairiki	clay loam		1
YU	Waipu	clay		3
YUy	Waipu	peaty silt and clay		2

5.4 Slope Class

Slopes of New Zealand Land Resource Inventory (NZLRI) polygons are recorded as one or a complex of two slope classes defined by an upper and lower slope angle and expressed in degrees of slope: A (0–3°), B (4–7°), C (8–15°), D (16–20°), E (21–25°), F (26–35°), G (>35°). Each class is important for particular aspects of land management, for example, the use of wheeled vehicles is appropriate up to and including slope C; hill country that can be cultivated using tracked or four wheel drive tractors lies in class D; hill country that cannot be cultivated using tracked or four wheel drive tractors is in class E. Cultivation for cropping is not feasible for E slopes and steeper. Consideration of slope underpins almost every land-use and management decision.

Slopes are generally subdued (<20°), in the study area (Map 3). The only significantly steep and very steep country is where Tangihua Volcanics form craggy mountain slopes to the west of Pukehuia. Other areas of steepland slopes are scattered throughout the study area but cover only 5% of the area. Over seventy percent of the area has slopes of less than 20°, and these can be cultivated, although with a significant risk of erosion and soil loss on slopes greater than about 12°.

5.5 Subsoil Acidity (minimum pH over the depth range 0.2–0.6 m)

Soil acidity is a measure of whether the soil solution is acid, neutral or alkaline, and is expressed in pH units (Table 3). Where solutions contain equal concentrations of H^+ and OH^- ions, pH 7 is neutral; pH values <7 indicate acidity, and pH >7 indicate alkaline conditions. Because the pH scale is logarithmic, pH 6 is 10 times more acid than pH 7, and so on. Classes are given for the 20–60 cm soil depth range, because adverse pH can have a significant effect on root growth at these depths and pH is very difficult to alter below the topsoil. The pH affects plant growth largely through its influence on nutrient availability, the presence of toxic ions, and soil biological composition, including the amount and type of bacteria present. For example, several essential elements such as iron, manganese, and zinc tend to become less available as the pH is raised to >7.5. Molybdenum availability, on the other hand, is higher at the higher pH levels. At pH values below 5.0 to 5.5, aluminium, iron, and manganese may be soluble in sufficient quantities to be toxic to the growth of some plants. Although most plants tolerate a wide range of pH, each has a narrower range for optimum growth, and pH is not the same for all soils.

Subsoil pH over much of the project area is moderately low to very low (over nearly 70% of the land area, Map 4). Amelioration of low subsoil pH is usually impractical, so taking account of existing subsoil pH becomes important when crop/soil matching. Soils with a high cation exchange capacity, such as those rich in clay (as are many soils in Northland) or organic matter, have greater reserves of acidity or alkalinity than do soils with lower cation exchange capacity such as sandy soils. Consequently, their pH values are less easily changed and are said to be 'well buffered'. Such soils would therefore require significant additions of lime to raise pH levels.

A review of soils of the project area according to the New Zealand soil Classification (Hewitt 1998) reveals a 'pH alert' list (Table 4) of soils with likely low or very low pH in some part of their subsoils. The list is comprehensive, but not necessarily exhaustive.

Table 3. pH classes and their area for soils in Kaipara District Council region

pH class	Range of min pH	Description	Notes on plant growth relationships	Project area (km^2, %)
1	7.6–8.3	High	May seriously interfere with plant growth	0, 0
2	6.5–7.5	Moderately high	May depress growth, possible deficiencies of some nutrients may be induced	0, 0
3	5.8–6.4	Near neutral	Satisfactory pH for many plants.	615, 20
4	5.5–5.7	Moderately low	Earthworm numbers, microbial activity, and nutrient cycling may be restricted	1183, 38
5	4.9–5.4	Low	Al often toxic and probably limits growth	724, 23
6	4.5–4.8	Very low	Both Al and Mn are likely to be toxic	416, 13
7	2.5–4.4	Extremely low	Both Al and Mn are probably toxic	0, 0
B		Not rated (bare sand)		158, 5

Table 4. Subsoil pH 'alert' list of soils in the Kaipara District Council region

Soil names and symbols	Subsoil pH observations
Parore peaty sandy loam (PZ)	The organic material to a depth of 60 cm from the soil surface, or to its base if shallower, has pH of 4.5 or less throughout the major part
Otonga peaty clay loam (OG) Waiotira series (YC, YCe, YCeH, YCH) Waipu series (YU, YUy) Takahiwai clay (TC)	pH of 4.8 or less in some part between 20 and 60 cm from the mineral soil surface, or, a horizon within 60 cm of the mineral soil surface with pH less than 4.8
Rangiuru series (RU, RUH) Waipoua series (WP, WPH)	pH of less than 5.1 in the major part of the B horizon to 60 cm from the mineral soil surface
Tutamoe friable clay (TO) Aranga clay (AR)	pH of less than 5.1 in some part of the B horizon to 60 cm from the mineral soil surface
Waipu clay (YU) Kara series (KR, KRa, KRe, KRp)	pH of less than 5.5 in some part from the base of the A horizon to 60 cm from the mineral soil surface
Hukerenui series (HK, HKa, HKgH, HKH, HKr) Wharekohe series (WK, WKa, WKap, WKfp) Aponga series (AP, APH) Rangiora series (RA, RAH) Okaka series (OA, OAH) Waikare series (YK, YKH) Puketitoi series (PD, PDH) Riponui series (RP, RPa) Tangitiki series (TT, TTH) Omu series (PM, OMH) Pukemanu series (PM, PMH) Red Hill series (RLa, RLaH) Mata clay (MA) Rockvale series (RV, RVe) Wairiki clay loam & silt loam (YR) Puhoi series (PBuH) Rockvale series (RV) Warkworth series (WA, WAH) Pukekaroro series (POS) Otaika series (OP, OPH) Mahurangi series (MV, MVH) Whangaripo series (WR, WRe, WRH, WReH) Maungarei series (ME, MEH, MEbH) Piroa series (PFH) Tanoa series (TNH)	All soils belonging to the Ultic Soil Order are on 'pH alert', because an accessory property of the Order is that KCl-extractable aluminium levels in B horizons are usually more than 1 cmol (+)/kg and Al-toxicity is possible.
Te Kopuru series (TEK) Tinopai series (TP) One Tree Point series (OT)	In Podzols, KCl-extractable-aluminium levels are high, and aluminium in soil solution may be toxic to some plants.

5.6 Potential Rooting Depth

Potential rooting depth (PRD) is the depth to a layer that may physically or chemically impede root extension. It is the depth of soil that can be potentially exploited by the rooting systems of most common crops, providing a medium for root development, water and nutrient uptake. The presence of toxic chemicals, such as high levels of aluminium, may also limit root depth, and chemical criteria can be used to determine PRD when critical limits of the chemical species are known (such as using pH values below 5.5). Soil physical characteristics known to influence root development are penetration resistance, aeration, water retention, sharp contrasts in soil properties including pans, waterlogged horizons, stiff and slowly permeable clays, and stony horizons with few or no fines <2 mm. PRD can be assessed by measurements of penetration resistance or by packing density estimates. A penetration resistance of >3000 kPa (Taylor et al. 1966) and a packing density critical limit of 1.85 Mg m^{-3} define the potential rooting depth (Jones 1983).

Plant root penetration is seriously restricted in Kaipara soils, Otonga soils (because of poor drainage), Te Kopuru soils (because of subsoil pans and poor drainage), some Arapohue soils and Konoti soils (rock at shallow depth) with root extension being limited to the soil volume above 45 cm (Map 5). These soils account for most of the shallow to very shallow rooting soils. Soils in class 4 (17% of the land area) may restrict root extension in some tree crops, and a large area (classes 1, 2, and 3—61%) is not limited by this soil attribute (Table 5).

Table 5. Potential rooting depth and area of soils in Kaipara District Council region

PRD Class	PRD Class range (m)	Description	Project area (km^2, %)
1	1.20–1.50	Very deep	195, 6
2	0.90–1.19	Deep	498, 16
3	0.60–0.89	Moderately deep	1206, 39
4	0.45–0.59	Slightly deep	534, 17
5	0.25–0.44	Shallow	378, 12
6	0.15–0.24	Very shallow	128, 5
B	Bare sand – not rated		120, 5

5.7 Soil Drainage Classes

Soil drainage classes (Table 6) provide a qualitative indication of the likely wetness status of the soil and its seasonal aeration constraints. Drainage classes are visually assessed from the presence or absence of grey soil matrix colours, the colour, size and percentage of mottles (blotches of greyish or reddish colour), and the position of the water table. Grey colours are generally reliable indicators of oxygen-deficient conditions. Waterlogging of pores markedly reduces gas exchange rates and induces seasonal anaerobic or partially anaerobic conditions. The classes may also be used to understand water availability, drainage requirements and trafficability/workability constraints.

Well- and moderately well-drained soils provide favourable environments for plant roots. Imperfectly drained soils present some problems for soil water sensitive crops. Poorly drained and very poorly drained soils present serious problems to most crop plants.

Table 6. Drainage classes and their area for soils in the Kaipara District Council region

Drainage class	Description	Project area (km^2, %)
1	Very poor	194, 6
2	Poor	372, 12
3	Imperfect	1455, 47
4	Moderately well	442, 14
5	Well	475, 15
B	Bare sand – not rated	120, 4

Nearly half the project area has imperfectly drained soils (Map 6), which this is not unusual for Northland soil environments because of the clayey subsoil conditions. Imperfect or poor drainage of soils is a normal condition for almost all flood plains in the region. A further fifth of the area is more poorly drained. Poorly drained Kaipara soils occur on the wide Wairoa River flood plain, Mangahakia mottled clay loams occur in narrow river valleys in the study area, and Whakapara mottled clay loams occur in narrow rivers valleys draining the non-volcanic hill country of Kaipara. Imperfectly drained soils also occur on strongly weathered sedimentary rock terrains, and in the older inland dunelands where Tangitiki and very poorly drained Te Kopuru soils are recorded. Better drainage status occurs with Pinaki and Red Hill soils in the younger coastal dunelands, and soils associated with volcanic material.

5.8 Profile Total Available Water

Profile total available water (PAW) is the total amount of water available to plant roots within the potential rooting depth, or to a depth of 0.9 m, whichever is shallower, expressed as mm of water. It is water that occurs between the field capacity and wilting point and, as such, is estimated as the difference in volumetric water content between −10 kPa (the pressure level at field capacity) and −1500 kPa (the pressure level at wilting point). Only a portion of the PAW is considered to be readily available. Readily available water is the difference in volumetric water content between −10 kPa and −100 kPa. Much of the PAW is held more tightly in the soil micropores at suctions greater than −100 kPa and becomes more difficult for plants to absorb the closer the soil water potential moves towards wilting point. As a result, while plants do not wilt, plant growth becomes increasingly restricted because the soil water held at lower potentials is not readily available for plant use. For most clayey soils of the project area, readily available water would be about one quarter of the PAW.

Eighty-nine percent of the project area has soils with moderate to high levels of PAW (Map 7).

Table 7. Profile Available Water (PAW) classes and their area for soils in the Kaipara District Council region

PAW class	PAW class range (mm)	Description	Project area (km2, %)
1	250–350	Very high	0, 0
2	150–249	High	106, 3
3	90–149	Moderately high	1216, 39
4	60–89	Moderate	1470, 47
5	30–59	Low	123, 4
6	0–29	Very low	4, <1
B	Bare sand – not rated		121, 4

5.9 Water Options Report

The Water Options Report (Mawer et al. 2019) develops a desktop analysis of potential water supplies capable of supporting small-scale horticultural development. It was not contracted to identify soil and land suitability for horticulture but can be used in conjunction with such assessments. When climate/crop interaction information is combined with soil and land information and potential water supplies, a powerful dataset can be created and options for intensifying land use identified.

6 Conclusions

Relevant soil and land data have been extracted from Manaaki Whenua – Landcare Research's Fundamental Soils Layer and NZ Land Resource Inventory databases, described and maps of the layers for the Kaipara District Council region generated.

7 Recommendations

Where climatic data suggests land use could be intensified, more detailed soil assessment including field site assessment by a qualified soil surveyor is required to ascertain soil variability within the soil map unit and the suitability of the soil for the proposed land use.

Fieldwork to generate the soil maps used in this study was undertaken in the mid-1950s with soils developed in similar rocks aggregated into 'soil suites'. It is unlikely we would use the same methods today as soils within the soil suites can show considerable variation in properties such as drainage class.

8 Soil references and further reading

Cox JE, Taylor NH, Sutherland CF, Wright ACS 1983. Northland Peninsula soil legends: A Legend of soil mapping units arranged physiographically. B. Legend of Taxonomic units arranged pedologically. C. Suite chart – Legend of soil mapping units arranged by parent materials and in genetic group sequences. Lower Hutt, NZ: Soil Bureau, DSIR. 1 Sheet.

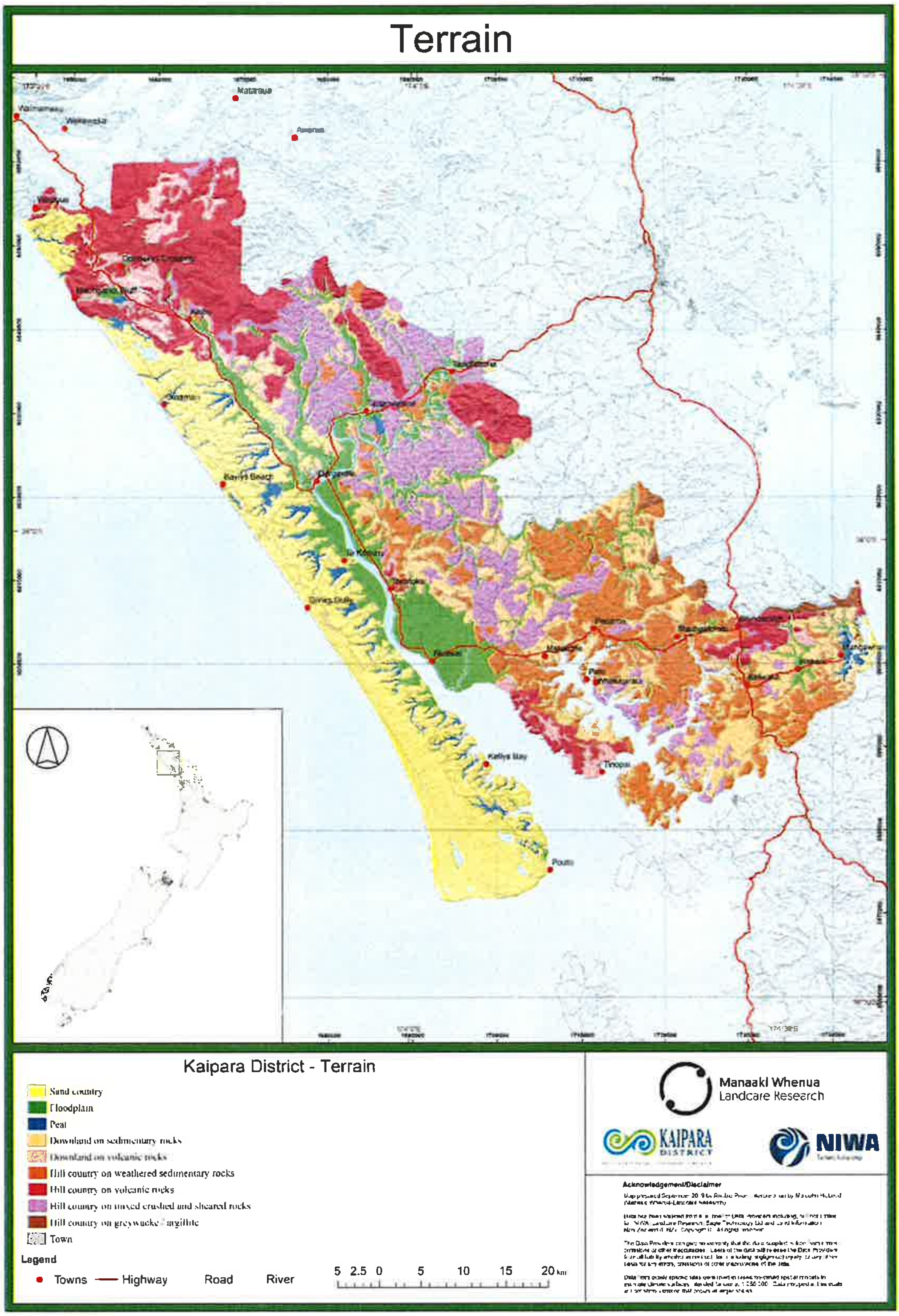
Hewitt AE 1998. New Zealand Soil Classification. *Landcare Research Science Series* 1, 2nd edn. Lincoln: Manaaki Whenua Press. 133 p.

Jones CA 1983. Effect of soil texture on critical bulk densities root growth. Soil Science Society of America Journal 47: 1208–1211.

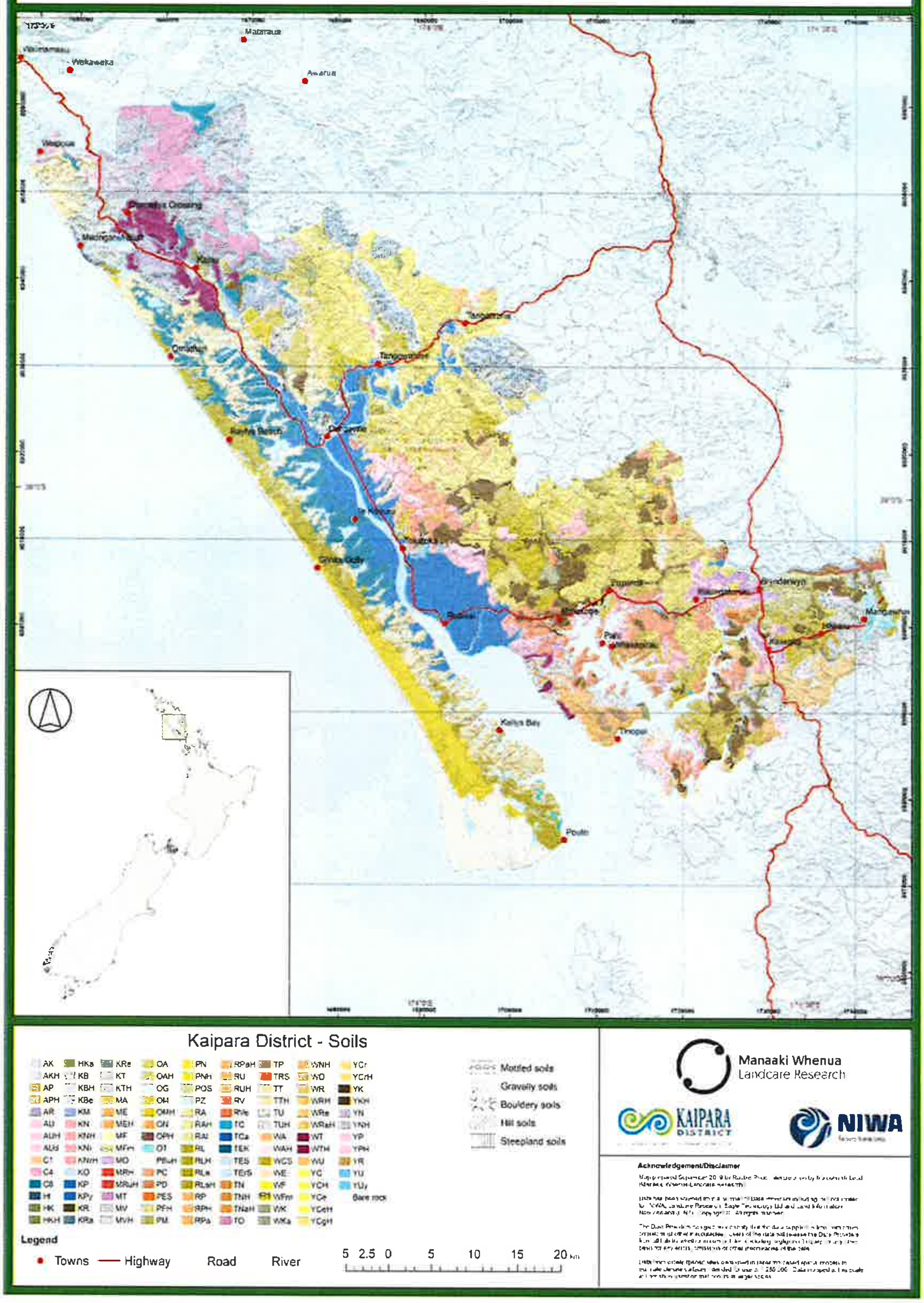
Taylor HM, Robertson GM, Parker JJ 1966. Soil strength-root penetration relations to medium to coarse textured soil materials. Soil Science 102: 18–22.

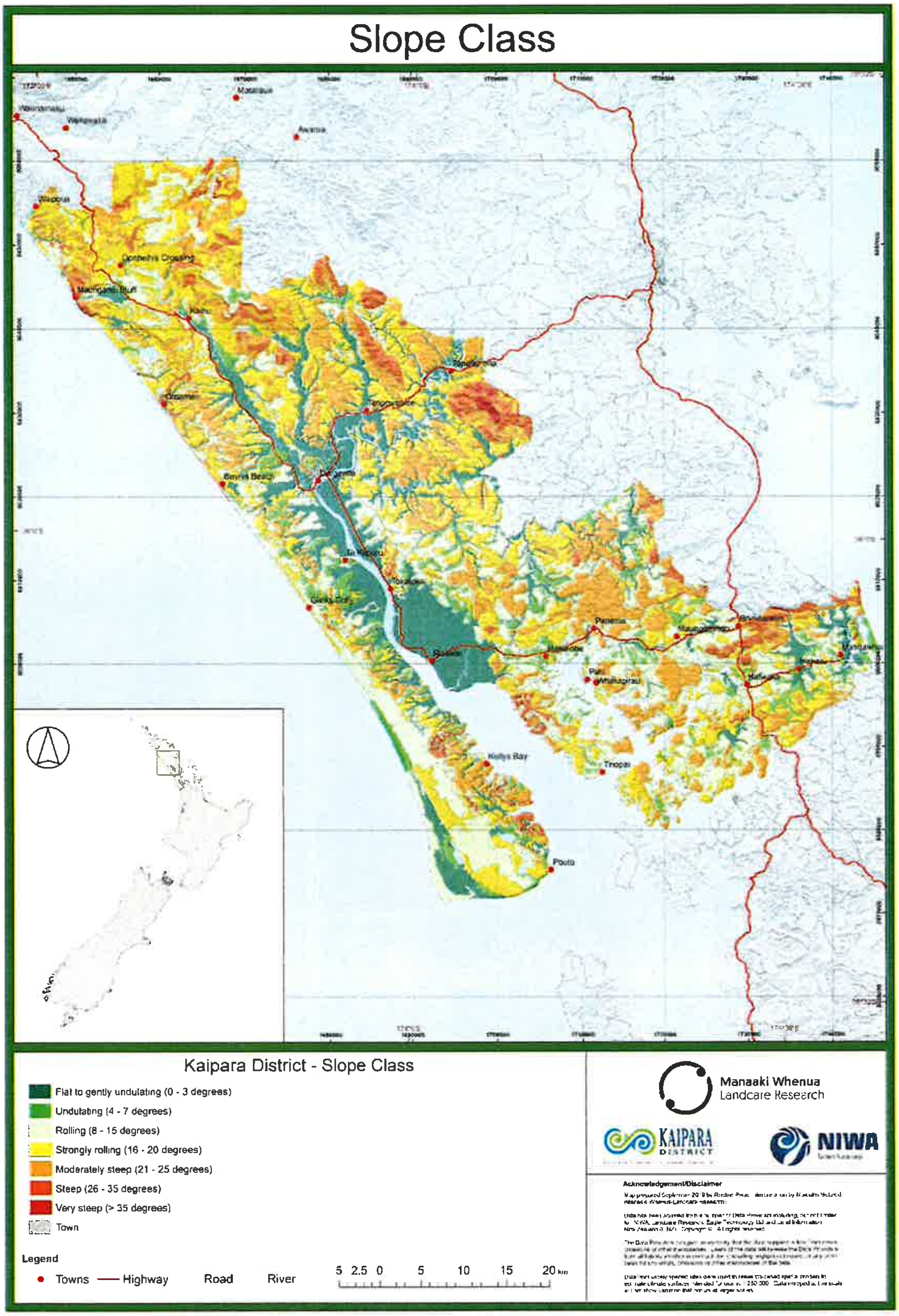
Mawer J, Soltau L, Scheberg J 2019. Kai For Kaipara – water resource assessment. Williamson Water & Land Advisory contract report WWLA0158 Rev. 1 prepared for Kaipara District Council. 41 p.

Appendix 1 – Soil and land maps

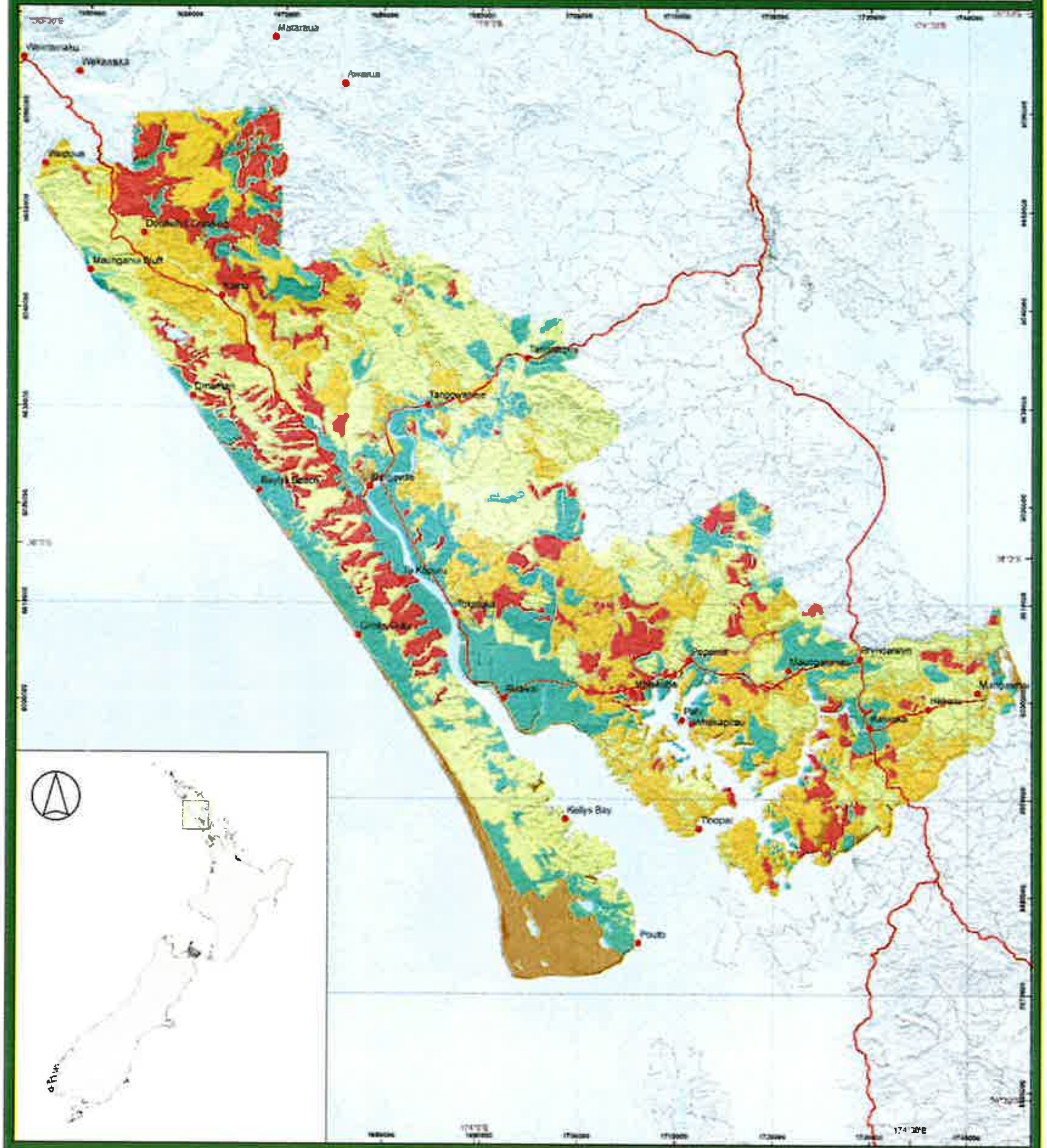


Soil


Wekaweka
Kaihu
Kellys Bay
Pouto
Tinopai
Brynderwyn
Kaiwaka
Kaipara District - Soils
AK AKH AP APH AR AU AUH AUi C1 C4 C8 H HK HKH
HKa KB KBH KBe KM KN KNH KNi KNrH KO KP KPy KR KRa
KRe KT KTH MA ME MEH MF MFm MO MRH MRuH MT MV MVH
OA OAH OG OH OMH ON OPH OT PEuH PC PD PES PFH PM
PN PNH POS PZ RA RAH RAi RL RLH RLe RLsH RP RPH RPa
RPaH RU RUH RV RVe TC TCa TEK TES TEtS TN TNH TNaH TO
TP TRS TT TTH TU TUH WA WAH WCS WE WF WFm WK WKa
WNH WO WR WRH WRe WRaH WT WTH WU YC YCH YCe YCeH YCgH
YCr YCrH YK YKH YN YNH YP YPH YR YU YUy Bare rock
Mottled soils
Gravelly soils
Bouldery soils
Hill soils
Steepland soils
Legend
Towns
Highway
Road
River
5 2.5 0 5 10 15 20 km
Manaaki Whenua
Landcare Research
KAIPARA DISTRICT
NIWA
Acknowledgement/Disclaimer


Slope Class
Kellys Bay
Tinopai
Pouto
Kaipara District - Slope Class
Flat to gently undulating (0 - 3 degrees)
Undulating (4 - 7 degrees)
Rolling (8 - 15 degrees)
Strongly rolling (16 - 20 degrees)
Moderately steep (21 - 25 degrees)
Steep (26 - 35 degrees)
Very steep (> 35 degrees)
Town
Legend
Towns
Highway
Road
River
5 2.5 0 5 10 15 20 km
Manaaki Whenua
Landcare Research
KAIPARA DISTRICT
NIWA
Acknowledgement/Disclaimer

Subsoil Acidity (Minimum pH 0.2 - 0.6 m)



Kaipara District - Subsoil Acidity

- Near neutral (5.8 - 6.4)
- Moderately low (5.5 - 5.7)
- Low (4.9 - 5.4)
- Very low (4.5 - 4.8)
- Not Rated

Manaaki Whenua Landcare Research

KAIPARA DISTRICT

NIWA

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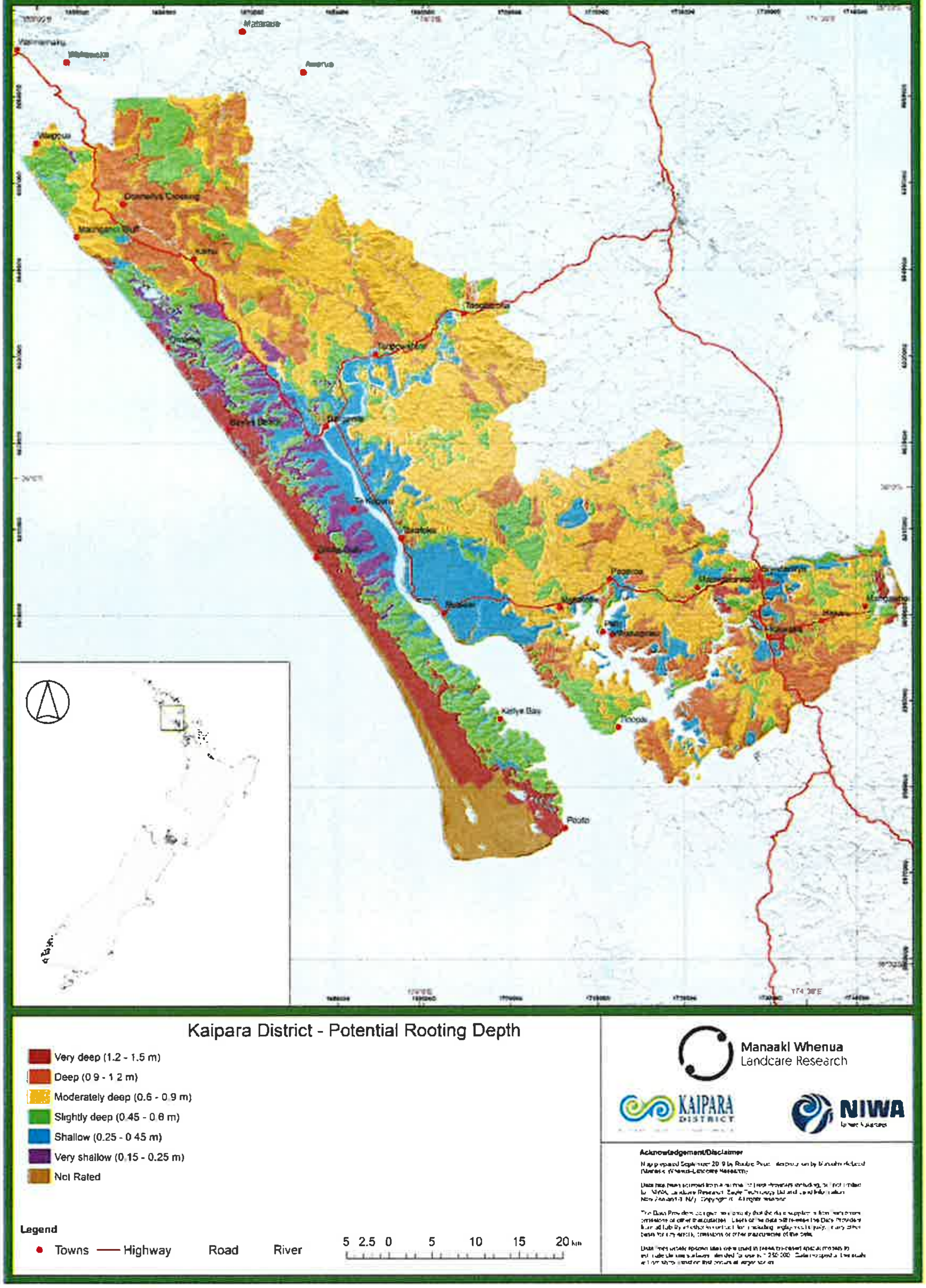
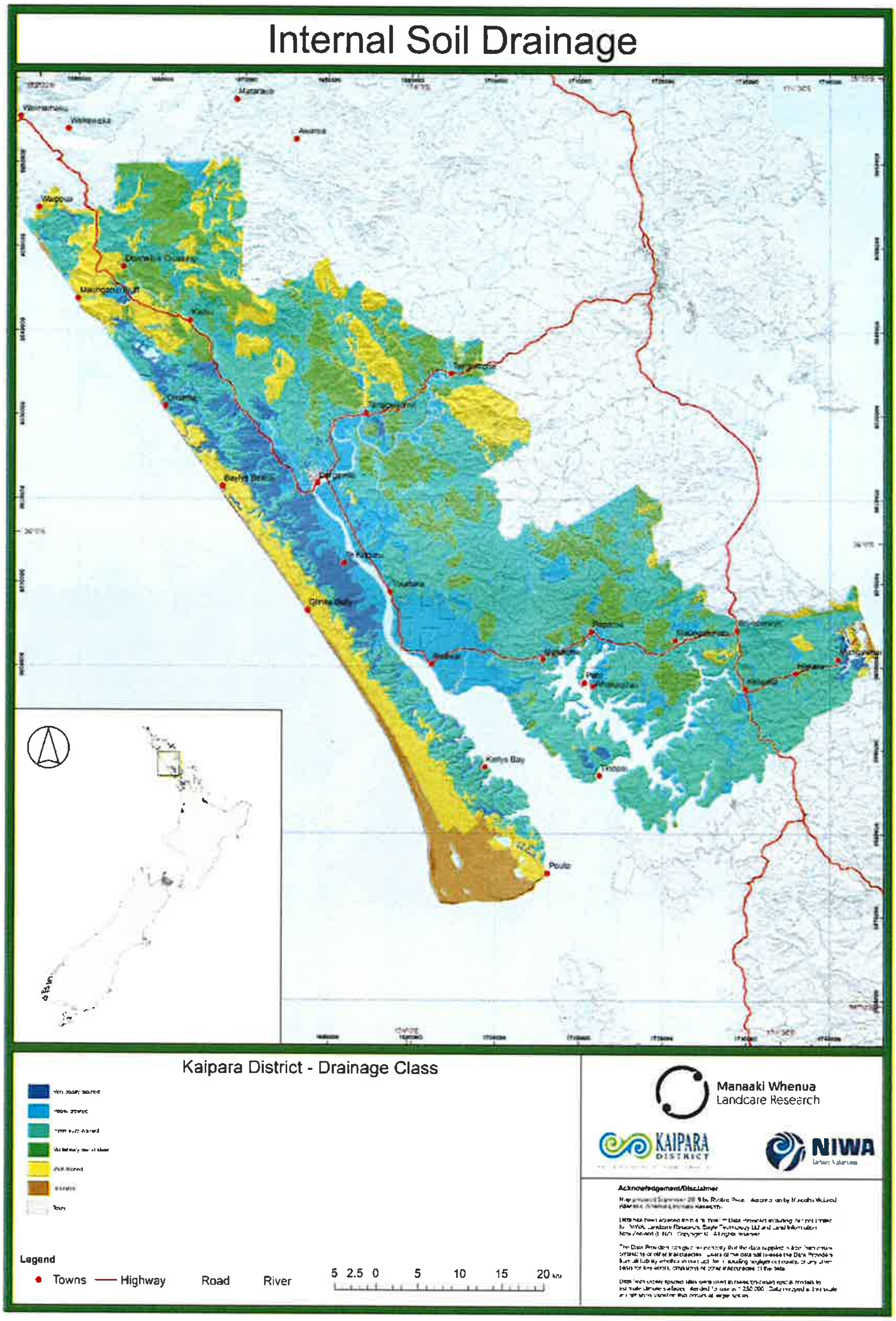
Legend

• Towns — Highway Road River

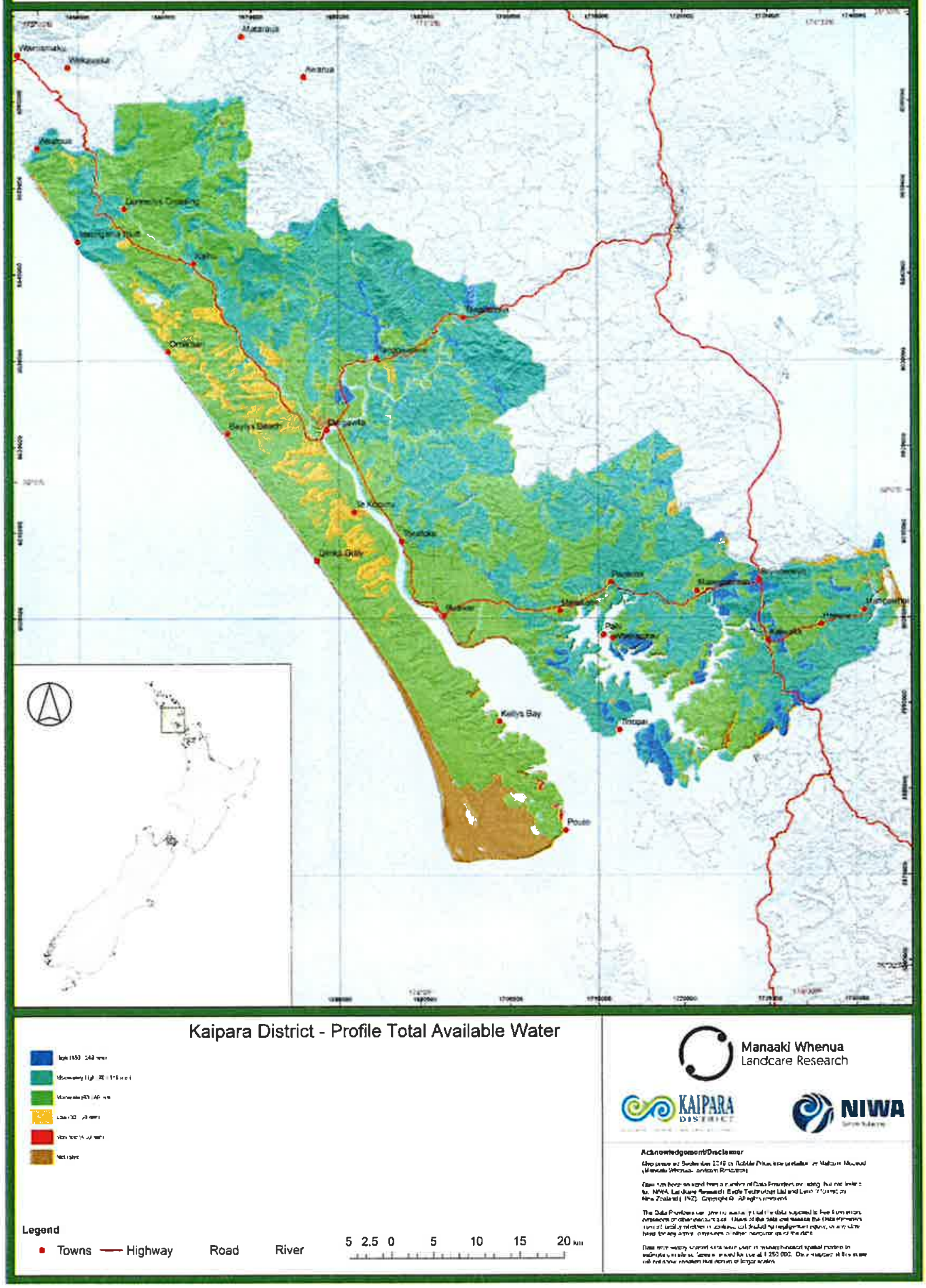
5 2.5 0 5 10 15 20 km

Potential Rooting Depth




Internal Soil Drainage
Kaipara District - Drainage Class
Legend
Towns
Highway
Road
River
5 2.5 0 5 10 15 20
Kellys Bay
Pouto
Manaaki Whenua
Landcare Research
KAIPARA
DISTRICT
NIWA
Acknowledgement/Disclaimer

Profile Total Available Water



Kathryn Pabirowski

From:	Colin Dall
Sent:	Wednesday, 7 August 2024 3:37 pm
To:	Richard Griffiths
Subject:	FW: Dargaville aluminium investigation map & sample results....
Attachments:	Dargavilla_aluminum_investigation.pdf; REQ.621338 Sample results.xlsx

FYI

From: Cathy Orevich <cathyo@nrc.govt.nz>
Sent: Friday, August 2, 2024 10:48 AM
To: Colin Dall <colind@nrc.govt.nz>
Cc: Tess Dacre <tessd@nrc.govt.nz>
Subject: Dargaville aluminium investigation map & sample results....

Kia ora

I have added the tidal state to each sample on the attached spreadsheet.

As there are a lot of staff who have been involved with this it might be an idea to put something on Aotahi if there is going to be a message going out about our sampling.

Ngā mihi

Cathy Orevich
Compliance Monitoring Manager - General
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

M 027 488 1925

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

P 0800 002 004 » **W** www.nrc.govt.nz

From: Neihana Umuroa <neihanau@nrc.govt.nz>
Sent: Friday, August 2, 2024 10:45 AM
To: Cathy Orevich <cathyo@nrc.govt.nz>
Subject: FW: Dargaville aluminium investigation map

Updated with correct sites! 👍👍

Ngā mihi

Neihana Umuroa
Monitoring Technician
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

M 027 601 4449

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

At NRC we value and encourage flexible working and I recognise that my working hours may be different to yours. I'm sending this message at a time that suits me. I don't expect you to read, respond or action it outside of your normal working hours.

From: Neihana Umuroa
Sent: Friday, August 2, 2024 10:18 AM
To: Cathy Orevich <cathyo@nrc.govt.nz>
Subject: FW: Dargaville aluminium investigation map

Updated with locations 👍

Ngā mihi

Neihana Umuroa
Monitoring Technician
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

M 027 601 4449

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

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Disclaimer
Users are reminded that Northland Regional Council data is provided in good faith and is valid at the date of publication. However, data may change as additional information becomes available. For this reason, information provided here is intended for short-term use only. Users are advised
to check figures are still valid for any future projects and should carefully consider the accuracy/quality of information provided before using it for decisions that concern personal or public safety. Similar caution should be applied for the conduct of business that involves monetary or opera-
tional consequences. The Northland Regional Council, its employees and external suppliers of data, while providing this information in good faith, accept no responsibility for any loss, damage, injury in value to any person, service or otherwise resulting from its use. All data provided is in NZ
Standard Time. During daylight saving, data is one hour behind NZ Daylight Time.

From: Neihana Umuroa
Sent: Friday, August 2, 2024 9:25 AM
To: Cathy Orevich <cathyo@nrc.govt.nz>
Subject: Dargaville aluminium investigation map

Hi Cathy

Will this work? 😊

Ngā mihi

Neihana Umuroa
Monitoring Technician
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

M 027 601 4449

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau
P 0800 002 004 » **W** www.nrc.govt.nz

At NRC we value and encourage flexible working and I recognise that my working hours may be different to yours. I'm sending this message at a time that suits me. I don't expect you to read, respond or action it outside of your normal working hours.

Week 1					Week 2				
M	T	W	T	F	M	T	W	T	F

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

Dargaville Aluminium investigation sample points

NORTHLAND REGIONAL COUNCIL

Report for Field Sheet Number 20240738

Wairoa River 3666 at Below storm water discharge

Report generated 02/08/24 10:19

Sample ID = 20244000	**Date Collected 24/07/2024**	**Time 14:10**		**TIDE: Flooding**
Site 100305	**Wairoa River 3666 at Below storm water**			
Measurement	**Method**	**Value**	**Units**	
Aluminium Total	Aluminium (Total) by ICP-MS	1.4	g/m3	
Arsenic Total	Arsenic (Total) by ICP-MS	0.0003	g/m3	
Cadmium Total	Cadmium (Total) by ICP-MS	<0.0005	g/m3	
Chromium Total	Chromium (Total) by ICP-MS	0.0011	g/m3	
Conductivity at 25 deg C (uS/cm)	SPC (field meter)	172.1	us/cm	
Copper Total	Copper (Total) by ICP-MS	0.0032	g/m3	
Dissolved Oxygen	ODO	8.31	mg/L	
Dissolved Oxygen Percent Saturation	ODO %	78.7	% Sat	
Lead Total	Lead (Total) by ICP-MS	<0.0003	g/m3	
Nickel Total	Nickel (Total) by ICP-MS	0.0025	g/m3	
pH	pH (field meter)	6.81	pH	
Salinity (Field)	Salinity	0.08	ppt	
Temperature	Temperature - YSI	12.9	degC	
Zinc Total	Zinc (Total) by ICP-MS	0.022	g/m3	

Sample ID = 20244002	**Date Collected 24/07/2024**	**Time 10:51**		**TIDE: Flooding**
Site 101727	**Wairoa River at Ramp (town bank)**			
Measurement	**Method**	**Value**	**Units**	
Aluminium Total	Aluminium (Total) by ICP-MS	4.2	g/m3	
Arsenic Total	Arsenic (Total) by ICP-MS	0.0019	g/m3	
Cadmium Total	Cadmium (Total) by ICP-MS	<0.0005	g/m3	
Chromium Total	Chromium (Total) by ICP-MS	0.0051	g/m3	
Conductivity at 25 deg C (uS/cm)	SPC (field meter)	531	us/cm	
Copper Total	Copper (Total) by ICP-MS	0.0055	g/m3	

Dissolved Oxygen	ODO	8.51	mg/L	
Dissolved Oxygen Percent Saturation	ODO %	80.7	% Sat	
Lead Total	Lead (Total) by ICP-MS	0.002	g/m3	
Nickel Total	Nickel (Total) by ICP-MS	0.005	g/m3	
pH	pH (field meter)	7.23	pH	
Salinity (Field)	Salinity	0.26	ppt	
Temperature	Temperature - YSI	12.9	degC	
Zinc Total	Zinc (Total) by ICP-MS	0.017	g/m3	

Sample ID = 20244003	**Date Collected 24/07/2024**	**Time 10:50**		**TIDE: Flooding**
Site 101727	**Wairoa River at Ramp (town bank)**			
Measurement	**Method**	**Value**	**Units**	
Aluminium Total Sediment	Aluminium (Recoverable Dry Wt.) by ICP-MS	18000	mg/kg	
Arsenic Total - sediments	Arsenic (Recoverable Dry Wt) by ICP-MS	10	mg/kg	
Cadmium Total - Sediment	Cadmium (Recoverable Dry Wt.) by ICP-MS	0.11	mg/kg	
Chromium Total sediment	Chromium (Recoverable Dry Wt.) by ICP-MS	35	mg/kg	
Copper Total - sediments	Copper (Recoverable Dry Wt.) by ICP-MS	24	mg/kg	
Lead Total sediment	Lead (Recoverable Dry Wt) by ICP-MS	22	mg/kg	
Nickel total sediment	Nickel (Recoverable Dry Wt.) by ICP-MS	19	mg/kg	
Zinc Total sediment	Zinc (Recoverable Dry Wt) by ICP-MS	97	mg/kg	

Sample ID = 20244006	**Date Collected 24/07/2024**	**Time 10:21**		**TIDE: Slack**
Site 339278	**Northern Wairoa at 50m US of Awakino**			
Measurement	**Method**	**Value**	**Units**	
Aluminium Total	Aluminium (Total) by ICP-MS	9.1	g/m3	
Arsenic Total	Arsenic (Total) by ICP-MS	0.0041	g/m3	
Cadmium Total	Cadmium (Total) by ICP-MS	<0.0005	g/m3	
Chromium Total	Chromium (Total) by ICP-MS	0.012	g/m3	
Conductivity at 25 deg C (uS/cm)	SPC (field meter)	520	us/cm	
Copper Total	Copper (Total) by ICP-MS	0.0094	g/m3	

Dissolved Oxygen	ODO	8	mg/L	
Dissolved Oxygen Percent Saturation	ODO %	76.2	% Sat	
Lead Total	Lead (Total) by ICP-MS	0.0038	g/m3	
Nickel Total	Nickel (Total) by ICP-MS	0.0092	g/m3	
pH	pH (field meter)	7.09	pH	
Salinity (Field)	Salinity	0.25	ppt	
Temperature	Temperature - YSI	13.1	degC	
Zinc Total	Zinc (Total) by ICP-MS	0.033	g/m3	

Sample ID = 20244007	**Date Collected 24/07/2024**	**Time 10:20**		**TIDE: Slack**
Site 339278	**Northern Wairoa at 50m US of Awakino**			
Measurement	**Method**	**Value**	**Units**	
Aluminium Total Sediment	Aluminium (Recoverable Dry Wt.) by ICP-MS	20000	mg/kg	
Arsenic Total - sediments	Arsenic (Recoverable Dry Wt) by ICP-MS	11	mg/kg	
Cadmium Total - Sediment	Cadmium (Recoverable Dry Wt.) by ICP-MS	0.09	mg/kg	
Chromium Total sediment	Chromium (Recoverable Dry Wt.) by ICP-MS	31	mg/kg	
Copper Total - sediments	Copper (Recoverable Dry Wt.) by ICP-MS	21	mg/kg	
Lead Total sediment	Lead (Recoverable Dry Wt) by ICP-MS	9.3	mg/kg	
Nickel total sediment	Nickel (Recoverable Dry Wt.) by ICP-MS	20	mg/kg	
Zinc Total sediment	Zinc (Recoverable Dry Wt) by ICP-MS	95	mg/kg	

Sample ID = 20244008	**Date Collected 24/07/2024**	**Time 11:30**		**TIDE: Flooding**
Site 339279	**Northern Wairoa at Northern Wairoa**			
Measurement	**Method**	**Value**	**Units**	
Aluminium Total	Aluminium (Total) by ICP-MS	3.4	g/m3	
Arsenic Total	Arsenic (Total) by ICP-MS	0.0014	g/m3	
Cadmium Total	Cadmium (Total) by ICP-MS	<0.0005	g/m3	
Chromium Total	Chromium (Total) by ICP-MS	0.0039	g/m3	
Conductivity at 25 deg C (uS/cm)	SPC (field meter)	158.3	us/cm	
Copper Total	Copper (Total) by ICP-MS	0.0049	g/m3	

Dissolved Oxygen	ODO	8.43	mg/L	
Dissolved Oxygen Percent Saturation	ODO %	80	% Sat	
Lead Total	Lead (Total) by ICP-MS	0.0013	g/m3	
Nickel Total	Nickel (Total) by ICP-MS	0.0048	g/m3	
pH	pH (field meter)	6.94	pH	
Salinity (Field)	Salinity	0.07	ppt	
Temperature	Temperature - YSI	13	degC	
Zinc Total	Zinc (Total) by ICP-MS	0.018	g/m3	

Sample ID = 20244009	**Date Collected 24/07/2024**	**Time 11:31**		**TIDE: Flooding**
Site 339279	**Northern Wairoa at Northern Wairoa**			
Measurement	**Method**	**Value**	**Units**	
Aluminium Total Sediment	Aluminium (Recoverable Dry Wt.) by ICP-MS	19000	mg/kg	
Arsenic Total - sediments	Arsenic (Recoverable Dry Wt) by ICP-MS	11	mg/kg	
Cadmium Total - Sediment	Cadmium (Recoverable Dry Wt.) by ICP-MS	0.094	mg/kg	
Chromium Total sediment	Chromium (Recoverable Dry Wt.) by ICP-MS	34	mg/kg	
Copper Total - sediments	Copper (Recoverable Dry Wt.) by ICP-MS	26	mg/kg	
Lead Total sediment	Lead (Recoverable Dry Wt) by ICP-MS	10	mg/kg	
Nickel total sediment	Nickel (Recoverable Dry Wt.) by ICP-MS	20	mg/kg	
Zinc Total sediment	Zinc (Recoverable Dry Wt) by ICP-MS	97	mg/kg	

Sample ID = 20244010	**Date Collected 24/07/2024**	**Time 11:50**		**TIDE: Flooding**
Site 339280	**Northern Wairoa at Parenga St Wharf**			
Measurement	**Method**	**Value**	**Units**	
Aluminium Total	Aluminium (Total) by ICP-MS	4.2	g/m3	
Arsenic Total	Arsenic (Total) by ICP-MS	0.0016	g/m3	
Cadmium Total	Cadmium (Total) by ICP-MS	<0.0005	g/m3	
Chromium Total	Chromium (Total) by ICP-MS	0.0049	g/m3	
Conductivity at 25 deg C (uS/cm)	SPC (field meter)	155.3	us/cm	
Copper Total	Copper (Total) by ICP-MS	0.0054	g/m3	

Dissolved Oxygen	ODO	8.39	mg/L	
Dissolved Oxygen Percent Saturation	ODO %	79.5	% Sat	
Lead Total	Lead (Total) by ICP-MS	0.0016	g/m3	
Nickel Total	Nickel (Total) by ICP-MS	0.0047	g/m3	
pH	pH (field meter)	6.82	pH	
Salinity (Field)	Salinity	0.07	ppt	
Temperature	Temperature - YSI	12.9	degC	
Zinc Total	Zinc (Total) by ICP-MS	0.016	g/m3	

Sample ID = 20244012	**Date Collected 24/07/2024**	**Time 12:20**		**TIDE: Flooding**
Site 339281	**Northern Wairua at 20m DS of Kaihu River**			
Measurement	**Method**	**Value**	**Units**	
Aluminium Total	Aluminium (Total) by ICP-MS	5.2	g/m3	
Arsenic Total	Arsenic (Total) by ICP-MS	0.0028	g/m3	
Cadmium Total	Cadmium (Total) by ICP-MS	<0.0005	g/m3	
Chromium Total	Chromium (Total) by ICP-MS	0.0078	g/m3	
Conductivity at 25 deg C (uS/cm)	SPC (field meter)	158.3	us/cm	
Copper Total	Copper (Total) by ICP-MS	0.0074	g/m3	
Dissolved Oxygen	ODO	8.43	mg/L	
Dissolved Oxygen Percent Saturation	ODO %	80	% Sat	
Lead Total	Lead (Total) by ICP-MS	0.002	g/m3	
Nickel Total	Nickel (Total) by ICP-MS	0.0067	g/m3	
pH	pH (field meter)	6.94	pH	
Salinity (Field)	Salinity	0.07	ppt	
Temperature	Temperature - YSI	13	degC	
Zinc Total	Zinc (Total) by ICP-MS	0.025	g/m3	

Sample ID = 20244014	**Date Collected 24/07/2024**	**Time 12:30**		**TIDE: Flooding**
Site 339282	**Northern Wairoa at Bassett St**			
Measurement	**Method**	**Value**	**Units**	
Aluminium Total	Aluminium (Total) by ICP-MS	4.6	g/m3	
Arsenic Total	Arsenic (Total) by ICP-MS	0.0018	g/m3	
Cadmium Total	Cadmium (Total) by ICP-MS	<0.0005	g/m3	

Chromium Total	Chromium (Total) by ICP-MS	0.0056	g/m3	
Conductivity at 25 deg C (uS/cm)	SPC (field meter)	163.2	us/cm	
Copper Total	Copper (Total) by ICP-MS	0.0059	g/m3	
Dissolved Oxygen	ODO	8.24	mg/L	
Dissolved Oxygen Percent Saturation	ODO %	78.4	% Sat	
Lead Total	Lead (Total) by ICP-MS	0.0018	g/m3	
Nickel Total	Nickel (Total) by ICP-MS	0.0053	g/m3	
pH	pH (field meter)	6.87	pH	
Salinity (Field)	Salinity	0.08	ppt	
Temperature	Temperature - YSI	13	degC	
Zinc Total	Zinc (Total) by ICP-MS	0.016	g/m3	

Methods used: Standard Methods for the Examination of Water and Waste Water. APHA, AWWA, WEF, 1998 20th edition

Colin Dall

From: Colin Dall
Sent: Friday, 15 November 2024 12:23 pm
To: Colin Dall
Subject: RE: New test required....

From: Colin Dall
Sent: Wednesday, 14 August 2024 4:27 pm
To: Richard Griffiths <richardg@nrc.govt.nz>
Cc: Susie Osbaldiston <susieo@nrc.govt.nz>; Ricky Eyre <rickye@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>; Tess Dacre <tessd@nrc.govt.nz>
Subject: RE: New test required....

Quick answer – the Dargaville WTP filter backwash water is no longer discharged to a drain that flows into the Kaihu River and is now discharged to the sewer/Dargaville WTTP, which is why the sampling ceased in 2020.

Also, please included Al (total and dissolved) in the next SOE sampling run.

Thanks
Colin

From: Richard Griffiths <richardg@nrc.govt.nz>
Sent: Tuesday, August 13, 2024 4:31 PM
To: Ricky Eyre <rickye@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>; Colin Dall <colind@nrc.govt.nz>; Tess Dacre <tessd@nrc.govt.nz>
Cc: Susie Osbaldiston <susieo@nrc.govt.nz>
Subject: RE: New test required....

Umm, take a look at the results for LOC.102475 (Dargaville water treatment plant at B/W discharge). The concentrations are high. What does B/W stand for? Is that backwash water? We were sampling annually but seemed to have stopped in 2020. And not sure why we would have collected 10 samples there on the same day back in 2017?

Results from LOC.103998 and LOC.105642 (Kaipara kumara – discharge of kumara process water and truck wash) also high.

The other high really high result – $85g/m^3$ was collected from LOC.105126 (Kaitaia water treatment plant at discharge vat) back in 1997 but hasn't been sampled since.

And then the Bell block samples. LOC.106103 & LOC.106102 for disposal of wastewater sludge are also high. I think it was Mark Pointer that identified high Aluminum in the wastewater sludge. Ricky or Stacey may know more of the history for that.

Ngā mihi
Richie

From: Ricky Eyre <rickye@nrc.govt.nz>
Sent: Tuesday, August 13, 2024 3:26 PM
To: Richard Griffiths <richardg@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>; Colin Dall <colind@nrc.govt.nz>; Tess Dacre <tessd@nrc.govt.nz>

Cc: Susie Osbaldiston <susieo@nrc.govt.nz>
Subject: RE: New test required....

Hi Richie.

Cheers for that. I have attached the data from Gail with my workings. I've copied it below but will leave you could bring it into Arcmap. As per yesterday I've done site average, number of samples, and vlookup for x,y.

IRIS ID	Site Number	Average of Aluminium Total (g/m3)2	Count of Aluminium Total (g/m3)	Average of Aluminium Total Sediment (mg/kg)	Count of Aluminium Total Sediment (mg/kg)	x	y
LOC.100305	100305	1.4	1			1678301	6021919
LOC.101556	101556	0.205	7			1672878	6080977
LOC.101727	101727	4.2	1	18000	1	1678882	6022341
LOC.102475	102475	21.49067	15			1676961	6023294
LOC.102494	102494	0.26	1			1672811	6083754
LOC.103998	103998	5.588143	7			1691854	6000548
LOC.105126	105126	85	1			1623956	6113307
LOC.105593	105593	0.098	1			1672658	6080863
LOC.105609	105609	1.225	4			1715214	6011332
LOC.105636	105636	0.2	2			1704869	6071444
LOC.105642	105642	4.738	5			1691789	6000467
LOC.105776	105776	0.2	1			1680787	6023279
LOC.105897	105897	0.12	1			1703257	6096618
LOC.106046	106046	0.71	1			1693347	6084326
LOC.106101	106101	1.134286	8			1722104	6045218
LOC.106102	106102	2.04	8	5442.857	7	1722096	6045268
LOC.106103	106103	2.0125	8			1722060	6045235
LOC.106193	106193	0.157667	9			1735313	5998563
LOC.106197	106197	0.041429	8			1735065	5999174
LOC.106921	106921	0.581571	7			1735065	5999285
LOC.106922	106922	0.152333	6			1735124	5999082
LOC.106923	106923	1.239833	6			1735251	5998978
LOC.108142	108142	5.0288	5			1691760	6000470
LOC.108711	108711	2.666	4			1720882	6047113
LOC.109072	109072	0.1	1			1672854	6083371
LOC.109631	109631	0.19	1			1721266	6044842
LOC.110612	110612			7388.889	9	1722083	6045238
LOC.110613	110613	1.661625	9			1722118	6045192
LOC.305351	305351			7066.667	9	1722062	6045229
LOC.316345	316345	1.6	1			1683203	6102687
LOC.329516	329516	1.3	1			1674775	6083285
LOC.330987	330987			12500	2	1722097	6045264
LOC.339278	339278	9.1	1	20000	1	1681162	6023313
LOC.339279	339279	3.4	1	19000	1	1678723	6022258
LOC.339280	339280	4.2	1			1678489	6022088
LOC.339281	339281	5.2	1			1678206	6021709
LOC.339282	339282	4.6	1			1678008	6020921

Ricky Eyre
Water Quality Field Operations Manager
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

P 09 470 1258
M 0274 767 981

Week 1					Week 2				
M	T	W	T	F	M	T	W	T	F

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Te Kaunihera ā rohe o Te Taitokerau

P 0800 002 004 » **W** www.nrc.govt.nz

From: Richard Griffiths <richardg@nrc.govt.nz>
Sent: Tuesday, August 13, 2024 2:58 PM
To: Cathy Orevich <cathyo@nrc.govt.nz>; Colin Dall <colind@nrc.govt.nz>; Tess Dacre <tessd@nrc.govt.nz>
Cc: Ricky Eyre <rickye@nrc.govt.nz>; Susie Osbaldiston <susieo@nrc.govt.nz>
Subject: RE: New test required....

Here you go. Pretty basic map (I can make it look nice pretty if needed). Circles are proportional (so bigger circle = higher concentration of Al).

Unless you are getting more pressure from media/Rose, I suggest we wait until we have the results from the sediment sampling on Friday, which will be contemporary with the samples Cathy's team collected and fill in some of the gaps on the map below giving us a good overall spatial spread.

Do you want us to collect Al on the next water quality run? That's happening on the 22nd

Richie

Ngā mihi

Richie

Richard Griffiths
Resource Scientist - Coastal
M 027 715 9923

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

From: Richard Griffiths
Sent: Tuesday, August 13, 2024 2:00 PM
To: Cathy Orevich <cathyo@nrc.govt.nz>; Colin Dall <colind@nrc.govt.nz>; Tess Dacre <tessd@nrc.govt.nz>
Subject: RE: New test required....

Only had a quick look over that. Most of the concentrations are a lot lower than the concentrations you found in Dargaville (<5000mg/kg vs 20,000) but there are a couple of high values. The two highest values are in the upper reaches of Oruawharo River. I will create a map so you can get an idea of the spread. Cathy did you get the 2019 sediment results?

Ngā mihi

Richie

Richard Griffiths
Resource Scientist - Coastal
M 027 715 9923

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

From: Cathy Orevich <cathyo@nrc.govt.nz>
Sent: Friday, August 9, 2024 3:29 PM
To: Richard Griffiths <richardg@nrc.govt.nz>; Colin Dall <colind@nrc.govt.nz>; Tess Dacre <tessd@nrc.govt.nz>
Subject: Fwd: New test required....

I haven't looked at these yet. Will hopefully have a chance on Monday!
Get Outlook for Android

From:
Sent: Friday, August 9, 2024 3:05:06 PM
To: Cathy Orevich <cathyo@nrc.govt.nz>
Subject: RE: New test required....

We could only provide 20 results and they are all from 2014 and the same sampling event it seems, hope they are helpful in your investigation!

Will process the invoice next week and let you know its reference.

Have a nice weekend,

Watercare Laboratory Services

Ph: 0800 522 365
W: www.watercarelabs.co.nz
Address:
52 Aintree Ave, Airport Oaks
Auckland 2022
New Zealand

From: Cathy Orevich <cathyo@nrc.govt.nz>
Sent: Friday, August 9, 2024 9:33 AM
To:
Subject: RE: New test required....

Thanks for this we owe you coffee, chocolates and pastries!!

Ngā mihi

Cathy Orevich
Compliance Monitoring Manager - General
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

M 027 488 1925

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

P 0800 002 004 » **W** www.nrc.govt.nz

From:
Sent: Friday, August 9, 2024 9:24 AM
To: Cathy Orevich <cathyo@nrc.govt.nz>
Subject: RE: New test required....

No worries,

Sean said he would extract them for me today, it will be in our standard CSV format so you might have to do some data manipulation to pop it into your data base.

Will keep you posted on our progress 😊

Kind Regards,

Watercare
Laboratory Services

Ph: 0800 522 365
W: www.watercarelabs.co.nz
Address:
52 Aintree Ave, Airport Oaks
Auckland 2022
New Zealand

From: Cathy Orevich <cathyo@nrc.govt.nz>
Sent: Thursday, August 8, 2024 2:19 PM
To:
Subject: RE: New test required....

Kia ora

Sorry to be a pain!

I have attached an updated spreadsheet with two tabs. I have marked the ones in yellow or red from your spreadsheet that I could find. If you could please give us the results of the ones on the spreadsheet (there are two different runs, one from 2014 and the other from 2022).

If you could use the cost centre REQ.621338 for the invoice thanks.

Ngā mihi

Cathy Orevich
Compliance Monitoring Manager - General
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

M 027 488 1925

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Te Kaunihera ā rohe o Te Taitokerau

P 0800 002 004 » **W** www.nrc.govt.nz

From:
Sent: Wednesday, August 7, 2024 3:15 PM
To: Cathy Orevich <cathyo@nrc.govt.nz>
Subject: RE: New test required....

Thanks Cathy,

See attached in yellow highlight are the ones I likely can dig up a result for, some may not have passed QA/QC so won't be reported but without opening them all individually I cant tell immediately. I did some spot checks and there is a lot available. I couldn't quite go back to 1989 sadly ☹

188 Samples total
Aluminium cost would be ~$7.73 per result so if I can provide them all total would be maximum $1453.99

Let me know which ones you might be keen on and I can get the team to make them reportable and issue them in a CSV back to you.

Kind Regards,

Watercare Laboratory Services

Ph: 0800 522 365
W: www.watercarelabs.co.nz
Address:
52 Aintree Ave, Airport Oaks
Auckland 2022
New Zealand

From: Cathy Orevich <cathyo@nrc.govt.nz>
Sent: Wednesday, August 7, 2024 12:54 PM
To:
Subject: RE: New test required....

Kia ora

Here's a list with site ids in the first column. The ones further down are newer sites and some will be the ones that we recently set up to test for aluminium!

Any information or help would be appreciated!

Ngā mihi

Cathy Orevich
Compliance Monitoring Manager - General
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

M 027 488 1925

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P 0800 002 004 » **W** www.nrc.govt.nz

From:
Sent: Monday, August 5, 2024 1:20 PM
To: Cathy Orevich <cathyo@nrc.govt.nz>; Lab Sales <LabSales@water.co.nz>
Subject: RE: New test required....

No guarantees as the QC had to pass at the time, but worth having a look at if you know which sampling locations to look at.

Kind Regards,

Watercare
Laboratory Services

Ph: 0800 522 365
W: www.watercarelabs.co.nz
Address:
52 Aintree Ave, Airport Oaks
Auckland 2022
New Zealand

From: Cathy Orevich <cathyo@nrc.govt.nz>
Sent: Monday, August 5, 2024 1:14 PM
To: Lab Sales <LabSales@water.co.nz>
Subject: RE: New test required....

This is exciting we will have a look and get back to you!

Ngā mihi

Cathy Orevich
Compliance Monitoring Manager - General
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

M 027 488 1925

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P 0800 002 004 » **W** www.nrc.govt.nz

From:
Sent: Monday, August 5, 2024 12:22 PM
To: Cathy Orevich <cathyo@nrc.govt.nz>; Lab Sales <LabSales@water.co.nz>
Subject: RE: New test required....

If you have the sampling point and we have done metals in the past on it (not particularly aluminium), I may have historical data to share. Let me know if that will be helpful.

Kind Regards,

Watercare Laboratory Services

Ph: 0800 522 365
W: www.watercarelabs.co.nz
Address:
52 Aintree Ave, Airport Oaks
Auckland 2022
New Zealand

From: Cathy Orevich <cathyo@nrc.govt.nz>
Sent: Monday, August 5, 2024 11:26 AM
To: Lab Sales <LabSales@water.co.nz>
Subject: RE: New test required....

Lots of discussions going on! There is a run scheduled for Friday with the SOE team for the Kaipara Harbour, and they have added Aluminium tests for sediment to their run, will see if they want to take water samples. They are also thinking of adding it to the monthly catchment runs, so will keep you posted!

Ngā mihi

Cathy Orevich
Compliance Monitoring Manager - General
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

M 027 488 1925

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P 0800 002 004 » **W** www.nrc.govt.nz

From:
Sent: Monday, August 5, 2024 11:22 AM
To: Cathy Orevich <cathyo@nrc.govt.nz>
Subject: RE: New test required....

Haha I bet.. hopefully it is all sorted soon 😊 are we expecting more samples at all?

Kind Regards,

Watercare
Laboratory Services

Ph: 0800 522 365
W: www.watercarelabs.co.nz
Address:
52 Aintree Ave, Airport Oaks
Auckland 2022
New Zealand

From: Cathy Orevich <cathyo@nrc.govt.nz>
Sent: Monday, August 5, 2024 11:20 AM
To: Lab Sales <LabSales@water.co.nz>
Subject: RE: New test required....

I'm pretty much over aluminium chat! Very wet weekend up here!

Thanks for the fast reply we will note to do salinity when taking samples!

Ngā mihi

Cathy Orevich
Compliance Monitoring Manager - General
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

M 027 488 1925

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From:
Sent: Monday, August 5, 2024 11:18 AM
To: Cathy Orevich <cathyo@nrc.govt.nz>; Lab Sales <LabSales@water.co.nz>
Cc: labcertificates <labcertificates@nrc.govt.nz>; Richard Griffiths <richardg@nrc.govt.nz>; EMO General <emogeneral@nrc.govt.nz>
Subject: RE: New test required....

Good Morning,

Hope you had a nice weekend,

You will need to set up both of these one is for saline samples the other is for fresh waters. Let me know if you need anything else.

ANALYSIS.NAME	ANALYSIS.DESCRIPTION	REPORTED_DESC
METAL_WA_DI_MS05_T	Dissolved Metals on Liquids by ICPMS (Lab Filtered)—Trace Level	Dissolved Metals by ICP-MS–Trace
METAL_WS_DI_MS05_T	Dissolved Metals on Liquids (Saline) by ICPMS—Trace Level	Dissolved Metals by ICP-MS–Trace

Kind Regards,

Watercare
Laboratory Services

Ph: 0800 522 365
W: www.watercarelabs.co.nz
Address:
52 Aintree Ave, Airport Oaks
Auckland 2022
New Zealand

From: Cathy Orevich <cathyo@nrc.govt.nz>
Sent: Monday, August 5, 2024 11:12 AM
To: Lab Sales <LabSales@water.co.nz>
Cc: labcertificates <labcertificates@nrc.govt.nz>; Richard Griffiths <richardg@nrc.govt.nz>; EMO General <emogeneral@nrc.govt.nz>
Subject: New test required....

Kia ora

We will need to set up a new test for 'Aluminium Dissolved'. Would you please advise what the method will be and the lab test code.

Thanks in advance!

Ngā mihi

Cathy Orevich
Compliance Monitoring Manager - General
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

M 027 488 1925

Northland REGIONAL COUNCIL
Te Kaunihera ā rohe o Te Taitokerau

P 0800 002 004 » **W** www.nrc.govt.nz

Kathryn Pabirowski

From: Richard Griffiths
Sent: Wednesday, 17 July 2024 2:37 pm
To: Jason Donaghy
Subject: RE: Elevated aluminum levels Northern Wairoa @ Dargaville

Do you know where are they disposing of the sewage sludge?

Ngā mihi

Richie

Richard Griffiths
Resource Scientist - Coastal
M 027 715 9923

Northland
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From: Jason Donaghy <JasonDo@nrc.govt.nz>
Sent: Wednesday, July 17, 2024 11:11 AM
To: Richard Griffiths <richardg@nrc.govt.nz>
Subject: Re: Elevated aluminum levels Northern Wairoa @ Dargaville

Yeah I had a chat to Stu about the flocking process re the wwtp , its up the Kaihu river, he thought it was too far to travel.

Ngā mihi

Jason Donaghy

Natural Resources Monitoring Manager
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

P 027 2168 426 » **W** www.nrc.govt.nz

At NRC we value and encourage flexible working and I recognise that my working hours may be different to yours. I'm sending this message at a time that suits me. I don't expect you to read, respond or action it outside of your normal working hours.

Week 1					Week 2				
M	T	W	T	F	M	T	W	T	F

From: Richard Griffiths <richardg@nrc.govt.nz>
Sent: Wednesday, July 17, 2024 11:09 AM
To: Jason Donaghy <JasonDo@nrc.govt.nz>
Subject: RE: Elevated aluminum levels Northern Wairoa @ Dargaville

We don't sample for aluminium in the coast as its not normally an issue. My understanding is that aluminium can be used in wastewater treatment to settle out contaminants. Maybe check with Cathy or Stuart if this is true.

Ngā mihi

Richie

Richard Griffiths
Resource Scientist - Coastal
M 027 715 9923

Northland
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From: Jason Donaghy <JasonDo@nrc.govt.nz>
Sent: Wednesday, July 17, 2024 10:51 AM
To: Richard Griffiths <richardg@nrc.govt.nz>
Subject: Fw: Elevated aluminum levels Northern Wairoa @ Dargaville

Do you recall any historic aluminium issues in Kaipara/ Dargaville?, Cr Crawford & Blackwell are attending a meeting tonight, that alleged high sample result is is on the agenda.

Ngā mihi

Jason Donaghy

Natural Resources Monitoring Manager
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

P 027 2168 426 » **W** www.nrc.govt.nz

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Week 1					Week 2				
M	T	W	T	F	M	T	W	T	F

From: Manas Chakraborty <manasc@nrc.govt.nz>
Sent: Wednesday, July 17, 2024 10:20 AM
To: Colin Dall <colind@nrc.govt.nz>; Bruce Howse <bruceh@nrc.govt.nz>
Cc: Cathy Orevich <cathyo@nrc.govt.nz>; Ricky Eyre <rickye@nrc.govt.nz>; Susie Osbaldiston <susieo@nrc.govt.nz>; Jason Donaghy <JasonDo@nrc.govt.nz>
Subject: RE: Elevated aluminum levels Northern Wairoa @ Dargaville

Hi Colin,

To my knowledge I am unaware of any historic SOE water quality results related to dissolved Aluminium in Wairoa River around Dargaville. As I mentioned to our Comms team during this media release, Aluminium is not one of the major water quality concerns in Northland and therefore does not constitute the routine SOE suite of water quality tests.

I have copied Ricky here if he can think of anything else.

Thanks.

Ngā mihi

Manas Chakraborty
Resource Scientist - Freshwater
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

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Week 1					Week 2				
Mon	Tue	Wed	Thu	Fri	Mon	Tue	Wed	Thu	Fri
Work from home	At work	At work	At work	Work from home	Work from home	At work	At work	Work from home	Day off

From: Colin Dall <colind@nrc.govt.nz>
Sent: Wednesday, July 17, 2024 8:35 AM
To: Bruce Howse <bruceh@nrc.govt.nz>
Cc: Manas Chakraborty <manasc@nrc.govt.nz>
Subject: RE: Elevated aluminum levels Northern Wairoa @ Dargaville

Unlikely regarding Al testing. I understand that Cathy and Manus helped with the initial media response and so I assume we've already checked for any relevant historical data. It's Cathy's RDO and so Manas, can you confirm this?

Regards
Colin

From: Bruce Howse <bruceh@nrc.govt.nz>
Sent: Wednesday, July 17, 2024 8:15 AM
To: Colin Dall <colind@nrc.govt.nz>
Subject: FW: Elevated aluminum levels Northern Wairoa @ Dargaville

Hi Colin,

Do we have any previous / historic water quality / sediment results or reports for this area that we could provide?

Ngā mihi

Bruce Howse
Pou Taumatua - Group Manager Corporate Services
Deputy Chief Executive Officer
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

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Standard Time. During daylight saving, data is one hour behind NZ Daylight Time.

From: Geoff Crawford <geoff.crawford@nrc.govt.nz>
Sent: Tuesday, July 16, 2024 6:10 PM
To: Colin Dall <colind@nrc.govt.nz>; Bruce Howse <bruceh@nrc.govt.nz>
Cc: Jason Donaghy <JasonDo@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>; Tess Dacre <tessd@nrc.govt.nz>; John Blackwell <john.blackwell@nrc.govt.nz>; Jonathan Gibbard <jong@nrc.govt.nz>
Subject: RE: Elevated aluminum levels Northern Wairoa @ Dargaville

Hi Colin
Both John and I are going to river meeting tomorrow at 5.3pm in Dargaville if any data is available for support

Ngā mihi

Geoff Crawford
Chair/Heamana
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

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From: Colin Dall <colind@nrc.govt.nz>
Sent: Tuesday, July 16, 2024 11:29 AM
To: Bruce Howse <bruceh@nrc.govt.nz>
Cc: Jason Donaghy <JasonDo@nrc.govt.nz>; Cathy Orevich <cathyo@nrc.govt.nz>; Tess Dacre <tessd@nrc.govt.nz>; John Blackwell <john.blackwell@nrc.govt.nz>; Geoff Crawford <geoff.crawford@nrc.govt.nz>; Jonathan Gibbard <jong@nrc.govt.nz>
Subject: RE: Elevated aluminum levels Northern Wairoa @ Dargaville

Morena Bruce

We have:

- Logged the alleged high aluminium results in the Northern Wairoa as an environmental incident which Compliance Monitoring is investigating.
- Requested and are awaiting details on the sample location and method/ results from the Ratepayers Association to guide the investigation. If the details are not provided, we still undertake some follow-up sampling from potential sources based on the locations mentioned in the media item. Our thinking at this stage is to include sampling of sediment by stormwater outlets near those locations to identify if there is evidence of any long-term accumulation of Al in the sediment at those sites to provide a better indication of any contamination, and because undertaking water sampling alone may be "hit and miss".

I will keep Cr Blackwell in the loop. Including sediment sampling means that we don't expect to report back on sampling results for at least two weeks.

Ngā mihi

Jason Donaghy

Natural Resources Monitoring Manager
Northland Regional Council » Te Kaunihera ā rohe o Te Taitokerau

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Week 1					Week 2				
M	T	W	T	F	M	T	W	T	F

From: Bruce Howse <bruceh@nrc.govt.nz>
Sent: Monday, July 15, 2024 4:24 PM
To: Colin Dall <colind@nrc.govt.nz>; Jason Donaghy <JasonDo@nrc.govt.nz>
Cc: John Blackwell <john.blackwell@nrc.govt.nz>; Geoff Crawford <geoff.crawford@nrc.govt.nz>; Jonathan Gibbard <jong@nrc.govt.nz>
Subject: Elevated aluminum levels Northern Wairoa @ Dargaville

Hi Jason,

As discussed can you please get the science team to follow up and also take some samples to assess this issue.

Apparently elevated aluminium levels were recorded in the NW River at Dargaville, whilst results at Ruawai were not elevated. May pay to track down the initial sample results / sampler to confirm testing locations and protocols etc.

Colin, Jason will have a chat with you about this.

Can you please keep myself and Cr Blackwell updated on timeframes and progress.

Ngā mihi

Bruce Howse

Pou Taumatua - Group Manager Corporate Services

Deputy Chief Executive Officer

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