Far North District Council
Te Kaunihera o Tai Tokerau ki te Raki

HE ARA TĀMATA
CREATING GREAT PLACES
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Response to S92 Request for Further Information

Application to renew resource consents for the Opononi Wastewater Treatment Plant.

This document has been prepared in response to a request for further information in relation to the discharge of wastewater to the CMA from the Opononi Omapere WWTP. It also details a request that the application for this consent be publicly notified.

RESPONSE TO QUESTIONS

Question 1

A copy of Met-Ocean Solution's hydrodynamic study report within one week of it being received by the applicant.
Reason: To allow a more complete assessment of the effects of the discharge, particularly any cumulative adverse effects.

Response

- The Far North District Council (FNDC) operates four WWTP that discharge to the Hokianga Harbour; Kaikohe, Rawene, Opononi and Kohukohu. FNDC commissioned MetOcean Solutions to undertake a hydrodynamic modelling study of the wastewater discharges to assess the fate of contaminants discharged from the WWTPs to the Hokianga Harbour. The report is attached as **Appendix 1** and is an updated (for typos) copy of that sent to NRC in March 2020.
- The concentrations of contaminants (e.g., E.coli, Faecal coliforms, Total Suspended Solids, Biological Oxygen Demand, Total Ammoniacal Nitrogen) have been conservatively estimated. For the Opononi WWTP discharge the results show that the dilution factor is about 1 in 25,000 near the discharge for the 50th percentile and about 1 in 1000 for the 95th percentile for both El Nino and La Nina scenarios. The discharge followed the tidal currents and mostly extended toward the entrance of the harbour with a dilution of 1 in 5,000 at about 750m for El Nino and 500m for La Nina. Near the shoreline the dilution is about 1 in 25,000 or more.
- Policy D.4.4 of the Proposed Regional Plan for Northland (PRP) allows for zone of reasonable mixing to be determined on a case-by-case basis. The conclusions of the hydrodynamic study confirm those in section 6.3 of the AEE, where, given the dynamics of the coastal waters at the discharge point, coupled with the discharge on an outgoing tide, it is considered that the receiving environment provides significant dilution of the discharge and that the discharge will not exceed or further exceed water quality standards of the PRP beyond a zone of reasonable mixing that is considered appropriate given the nature of the receiving environment.

Question 2

If the Met-Oceans Solution's hydrodynamic study report shows that the discharge will leave the main channel of the harbour, then the applicant shall identify recreational swimming and food gathering areas that are within the area between where the discharge leaves the channel and the shore. A quantitative microbiological risk assessment of the level of risk to public health shall be undertaken for these identified areas. If there is a quantifiable risk to public health in an area, then the assessment shall recommend mitigation measures to reduce this risk to an acceptable level. This assessment must be completed within three months of the Met-Ocean Solution's report being received by the applicant. Reason: To allow council [NRC] to properly assess the risk to human health from the discharge.

Response

- FNDC commissioned Streamlined Environmental to undertake a Quantitative Microbial Risk Assessment of the discharge from the Opononi WWTP. The QMRA determined the health risk associated with the wastewater discharge by applying the modelled dilution factors at various shellfish and bathing sites against infection response scenarios. A copy of the QMRA was provided to NRC in March 2020, and is attached as **Appendix 2**
- The QMRA uses the MetOcean Solution hydrodynamic model to estimate quantitative distributions of wastewater dilutions at key sites in the receiving environment. In undertaking the assessment each of the four modelled WWTP discharges were 'turned on', so that the public health effects modelled in the report capture the additional effects from the WWTPs upstream of the Opononi WWTP.

Shellfish consumption

- Where a 1-log virus reduction is achieved low individual illness risks are associated with the consumption of raw shellfish potentially polluted by norovirus and enterovirus at all sample sites used in the assessment. The risk associated with consumption of raw shellfish are fractionally above the 1% threshold for NOAL (at 1.40% in a bracket of 1.0-4.99%).
- Where a 2-log reduction in enterovirus and norovirus concentrations is achieved, enteric illness risks among individuals who consume raw shellfish are reduced to below the "no observable adverse effect level" at all sample sites; the risk is >0.1% (the 'no observable adverse effect level' is >0.3%).

Ingestion or inhalation of water

- Where a 1-log virus reduction is achieved the individual illness risk associated with the ingestion or inhalation of water potentially polluted by enterovirus, norovirus and/or adenovirus are reduced below the "no observable adverse effect level" at all sample sites.

WWTP performance

- The QMRA uses the reported virus removal rate for similar WWTP and the faecal indicator bacteria concentration of the receiving environment water samples from both LAWA and NRC recreational bathing water quality sampling to assume that a 2-log reduction occurs at the WWTP. As discussed in the response to questions 4 and 5 below, the preferred upgrade option includes both chemically assisted solids removal and UV treatment which will ensure that at least a 2-log reduction continues to occur at the WWTP.
- The QMRA concludes that, where the virus reduction performance of the WWTP provides a 2-log virus removal, then its performance is sufficient to reduce illness risks associated with recreation or

consumption of harvested raw shellfish below the "no observable adverse effect level". Additionally, the reported risks in the QMRA include a 'worst case scenario' and may be overstated. On that basis it is reasonable to conclude that the adverse effects of the discharge on public health are less than minor.

Question 3

The application acknowledges that:

i. the Hokianga Harbour is a statutory acknowledgement area; and
ii. the discharge of sewage to water is culturally offensive; and
iii. there is Hapu Environmental Management Plan that covers the area of this the area of the discharge.

The application then concludes that the adverse effects on the cultural values of the Hapu are less than minor. The application however does not present any assessment of adverse effects on tangata whenua, and their values and resources, to validate this conclusion. It also does not present any assessment of the effects on the statutory acknowledgment area. It is therefore requested that an assessment be undertaken on the effects on tangata whenua values and resources by the discharge to the CMA. As minimum, this assessment should be undertaken in accordance with criteria of Policy D.1.2 of the Proposed Regional Plan. Reason: This is to allow the council to determine which tangata whenua are adversely affected by the application in accordance with Policy D.1.3 of the Proposed Regional Plan and to provide potential means of mitigation of any adverse cultural effects. It will also allow council when making a decision on this application to meet the requirements of Policy 23(2)(b)(ii) of the New Zealand Coastal Policy Statement which only allows a discharge of treated sewage to coastal water if it is "informed by an understanding of tangata whenua values and the effects on them".

Response

A Cultural Impact Assessment (CIA) has been completed and is attached as **Appendix 3**. The CIA confirms that the discharge to the CMA from the Opononi Wastewater Treatment Plant has significant adverse effects on cultural values, including on the mauri of the Hokianga Harbour, mahinga kai, indigenous biodiversity, areas of significance including the Waiarohia Stream and cumulative effects on the Waiarohia Stream from a number of FNDC assets. The CIA identifies the following affected parties:

- Ngā Hapū o Ngati Korokoro;
- Pakanae Resource Management Committee (representing Ngati Korokoro, Ngati Wharara and Te Pouka);
- Te Hikutu;
- Ngāpuhi;
- Te Rarawa; and
- Te Roroa

Further, the CIA confirms that the discharge affects land that is the subject of both Te Rarawa and Te Roroa statutory acknowledgements, being the Hokianga Harbour and Arai-Te-Uru Recreation Reserve respectively.

Recommended Mitigation

In preparing the CIA, consultation with hapū and iwi representatives resulted in five recommendations for mitigating adverse cultural effects for both the discharge to the Hokianga Harbour and potential/cumulative effects on Waiarohia stream. These five recommendations are addressed as follows:

	Recommendation from CIA	Discussion/Comment
1	*Should the Community Liaison Group remain as part of the Council / Community interface that representation on the Community Liaison Group be increased by two seats to include Nga Hapu o Ngati Korokoro and Te Roroa in the interim until such time that a determination is made via the Treaty Settlement process. It is anticipated that this would also entail a review of the Terms of Reference for the Group.*	The Community Liaison Group (CLG) is a requirement of Condition 21 of the current resource consent. The purpose of this condition is for FNDC staff to provide information about the WWTP (particularly compliance), and to investigate alternative land disposal areas. Now that the investigation into the alternative land disposal areas has been completed the FNDC is not of a mind to continue the CLG for the replacement resource consent. There is no policy direction to require the continuation or establishment of a new CLG, however if a community liaison group is determined by the affected parties to be the most effective way for FNDC to disseminate information and provide some mitigation of the adverse effects cultural values then FNDC will consider volunteering this as a condition of consent. If the continuation or establishment of a new CLG is not a requirement of the new consent, then information about the performance of the WWTP is publicly available and FNDC can provide regular updates of compliance to tangata whenua upon request (this is discussed further in the response to recommendation 4)
2	*Council updates its Contact Database to include Nga Hapu O Ngati Korokoro as an affected party to all matters pertaining to community consultation and engagement in relation to Infrastructure Plans,*	FNDC's Strategic Planning and Policy (SPP) group is responsible for the contact database and for determining who to invite to participate in consultation and engagement in relation to, for example, the Long Term Plan and Infrastructure

	Council's Infrastructure Assessment, Strategies, and resource consent applications.	Strategy. This financial year's LTP (including the Infrastructure Strategy) will be open for consultation in March 2021 and finalised by June 2021. In terms of determining affected parties for resource consent applications this is ultimately the function of the consent authority.
3	*Council take immediate steps to address and rectify the issues non-compliance.*	As discussed in the AEE, rather than compliance limits, Condition 19 of the current resource consent provides trigger value concentrations for contaminants. If the trigger values are exceeded the Consent Holder is required to report to the NRC on the reasons for the exceedance, the actions to correct the exceedance and prevent it from re-occurring. The actions undertaken to address, and correct exceedances are discussed in Section 6.2 of the AEE. Longer term: As discussed in the response to Question 5, FNDC staff have identified a preferred upgrade option that will be included in the in LTP consultation process and if adopted by FNDC, its delivery will be scheduled in the Capital Works programme.
4	Recommendations include a timeframe of actions over twenty years, as below	Ultimately the decision-making authority determines the appropriate consent term. A 35-year consent term has been requested and the reasons that this term is considered appropriate are discussed in the application for consent. FNDC can to discuss a shorter term with affected parties but at this stage offering any shorter term would only be arbitrary.

4.1	**Immediately** • Update Iwi / Hapu Contacts Database • Additional 2 seats on the Community Liaison Group • Review of current Monitoring Program an co-design a program that meets the requirements of both territorial authorities and tangata whenua • Installation of new technologies to improve water quality and manage risks. • FNDC to engage with tangata whenua re: 30 year Infrastructure Management Strategy • FNDC to advocate a comprehensive study of the Hokianga Harbour Catchment be carried • Hokianga Harbour Catchment Management Plan initiated	• The first two bulleted pointed items and input into the Infrastructure Strategy are discussed above. • In terms of the remaining recommendations these are best addressed by the NPS Freshwater Management 2020 and its fundamental concept 'Te Mana o Te Wai', and the 6 principles relating to the roles of tangata whenua and other New Zealanders in the management of freshwater. NRC must engage with communities and tangata whenua to determine how Te Mana o te Wai applies to water bodies and freshwater ecosystems in the region.

4.2	**Within 5 years** • Riparian strip planted along Eastern boundary of WWTP envelop • Monitoring reports provided to tangata whenua along with action taken to mitigate breaches • Initiate Bi-annual Council workshop with tangata whenua reporting	on Capital Works Program for South Hokianga (30-year Infrastructure Strategy milestones and New Accounting Policy, Long Term Plan and Annual Plan. • Rehabilitation of Waiarohia Stream • Hokianga Harbour Catchment Board established • Hokianga Harbour Catchment Management Plan Completed • Transfer Station setback increased at least 30mtres from water body • 1 of the 4 WWTP transferred to land-based disposal • Progress solutions for transfer to land-based disposal for Opononi WWTP	• The funding for the rehabilitation of the Waiarohia Stream will be recommended to Council through the 2021-2031 LTP process and ultimately the recommended stream works can only be undertaken if funding is approved by FNDC. • Compliance reports (including breaches and remedial action taken) are provided to Council's Elected Members and NRC at least monthly and are also public information. This information can be circulated to tangata whenua. Information about the performance of the WWTP is publicly available and FNDC can provide regular updates of compliance to tangata whenua upon request (this is discussed further in the response to recommendation 4) • There are no plans to set-back the Transfer station. • Land-based wastewater discharge can only be undertaken where practicable, and FNDC cannot commit to undertaking this recommendation. If discharge to land was an option for these WWTP the scale of the upgrade is so immense that the recommended timeframes could not be adhered to.

4.3	**Within 10 years** • Continue reticulation improvements • Ongoing Monitoring reports provided to tangata whenua inclusive of any breaches and migration action • Continue Bi-annual Council and tangata whenua workshop on reporting on Capital works Program for South Hokianga (update on 30 year Infrastructure Strategy milestones) • Hokianga Harbour Catchment Project underway • 2 of the 4 WWTP transferred to land-based disposal • Options for Opononi WWTP identified.	• Reticulation improvements are an on-going project for FNDC. • Compliance reports (including breaches and remedial action taken) are provided to Council's Elected Members and NRC at least monthly and are also public information. This information can be circulated to tangata whenua. Information about the performance of the WWTP is publicly available and FNDC can provide regular updates of compliance to tangata whenua upon request • Land-based wastewater discharge can only be undertaken where practicable, and FNDC cannot commit to undertaking this recommendation. If discharge to land was an option for these WWTP the scale of the upgrade is so immense that the recommended timeframes could not be adhered to. • Options for upgrading the Opononi WWTP and options for discharging to land have been assessed during this renewal process.

4.4	**Within 15 years** • Ongoing Monitoring reports provided to tangata whenua inclusive of any breaches and migration action taken • Catchment have covered a significant portion (to be determined) of the catchment area • Continue Bi-annual Council and tangata whenua workshop on reporting on Capital works Program for South Hokianga (30 year Infrastructure Strategy milestones) • 3 of the 4 WWTP transferred to land based disposal • Best Option identified and project plan development started.	• Compliance reports (including breaches and remedial action taken) are provided to Council's Elected Members and NRC at least monthly and are also public information. This information can be circulated to tangata whenua. Information about the performance of the WWTP is publicly available and FNDC can provide regular updates of compliance to tangata whenua upon request • Land-based wastewater discharge can only be undertaken where practicable, and FNDC cannot commit to undertaking this recommendation. If discharge to land was an option for these WWTP the scale of the upgrade is so immense that the recommended timeframes could not be adhered to. • Options for upgrading the Opononi WWTP and options for discharging to land have been assessed during this renewal process.
4.5	**Within 20 years** • Ongoing Monitoring reports provided to tangata whenua inclusive of any breaches and migration action taken • Continue Bi-annual Council and tangata whenua workshop on reporting on Capital works Program for South Hokianga (30 year Infrastructure Strategy milestones) • Catchment has had project works established over much of its area and maintenance of these areas will be ongoing. • RC required for Opononi Omapere WWTP (New Consent or Renewal)	• Compliance reports (including breaches and remedial action taken) are provided to Council's Elected Members and NRC at least monthly and are also public information. This information can be circulated to tangata whenua. Information about the performance of the WWTP is publicly available and FNDC can provide regular updates of compliance to tangata whenua upon request

5	***recommend*** that a coordinated and concerted approach to be taken to manage the revitalisation of Hokianga Harbour. ***recommend*** that a comprehensive study of the harbour catchment including cultural impacts be completed and positive steps be taken to secure appropriate resources to support this process and that a Catchment Management Board be established over the harbour	This recommendation can be addressed with the same comments addressing recommendation 4.1

4. A report on land disposal options for the wastewater which provides details of the cost and viability for each option. This report should provide a decision on whether land disposal is to be undertaken for this discharge and the reasons for that decision.

   Reason: This is to meet Policy D.4.3(b) of the Proposed Regional Plan which states a discharge to water will generally not be granted unless "a discharge to land has been considered and found not to be economically or practicably viable". Policy 23(2)(b)(i) of the New Zealand Coastal Policy Statement also requires that "there has been adequate consideration of alternative methods, sites and routes for undertaking the discharge".

   Response

   - As discussed in Section 7 of the application for this consent, to give effect to Condition 20 of the resource consent two studies into land disposal were completed in 2011 and 2014 both identifying potential areas for the discharge of wastewater to land for some of the year. It was determined by the Community Liaison Group in December 2014 that land disposal options appeared impractical and unaffordable and that treatment options should be investigated more thoroughly.
   - A wastewater issues and options report has been undertaken by Jacobs, and is attached as **Appendix 4**. This report discusses the issues with the current WWTP, options for improvement, and the methodology used to determine the preferred treatment and discharge option. The Jacobs report further considers the parcels of land identified by the 2011 and 2014 reports and discusses the result of a multi-criteria analysis which discusses the reasons that continued discharge to the Hokianga Harbour is preferred over discharge to land.
   - Option 5 of the Jacob's report (optimisation of the current treatment process and discharge of the treated wastewater to land) may be included in the LTP for public consultation alongside Option 4(b). The LTP will be adopted in June 2020 and if Option 5 is included in the adopted LTP then it will require at least five years for scoping and land acquisition so the Option 4b upgrade to ensure a log-2 reduction and resource consent will be required for at least five years.
   - As discussed in the Issues and Options report the multi-criteria analysis used to rank the options places option 5 (discharge to land) as the least preferred option in all weighting scenarios, except in scenario 3, where 'environmental' and 'cultural' criteria are weighted higher than 'economic' criteria. This is because the capital cost of option 5 is $13.090M greater, or 3.65 times more capital cost than option 4b.
   - A preliminary assessment of the capital and operational rates per connection for each upgrade option is set out below. The operational and capital rates for each option are in addiction to the current district-wide operational rates and Opononi WWTP capital rates. This is a preliminary assessment only and is included to illustrate the contrast in the cost of discharge options only. A final version of this table will be available in the LTP consultation document.

OPERATING Rate per connection	Increase in average rate
Option 4A	$5.19
Option 4B	$5.19
Option 5	$5.19
Option 6	$23.58

CAPITAL rate per connection	Option 4A	Option 4B	Option 5	Option 6
Year 1	$-	$-	$-	$-
Year 2	$66.14	$66.14	$56.28	$43.53
Year 3	$410.95	$634.61	$390.37	$500.02
Year 4	$406.55	$627.11	$1,477.00	$738.23
Year 5	$402.15	$619.62	$1,448.73	$ 726.71
Year 6	$397.74	$612.13	$1,420.46	$715.19
Year 7	$393.34	$604.64	$1,392.19	$703.67
Year 8	$388.94	$597.15	$1,363.92	$692.15
Year 9	$384.54	$589.65	$1,335.65	$680.64
Year 10	$380.13	$582.16	$1,307.38	$669.12

5. Where the outcome of questions 1, 2, 3 and/or 4, or a combination thereof, above identify at least a minor adverse effect to the environment because of pathogens in the wastewater discharge, an investigation and report into potential upgrade options for pathogen reduction in the discharge shall be provided. This should include any improvements to the current WWTP that would improve the effectiveness of pathogen reduction in the discharge. The report on this investigation should incorporate the outcomes of the assessments and reports required by questions 1 to 4 above and shall provide a preferred upgrade option for the WWTP.

   Reason: To allow council to assess what methods are available to the applicant to mitigate any adverse effects. This information is also a requirement of Policy 23(2)(b)(i) of the New Zealand Coastal Policy Statement which requires that "there has been adequate consideration of alternative methods, sites and routes for undertaking the discharge".

   Response

   - The Jacobs 'issues and options' assessment identified four upgrade options suitable for the Opononi WWTP that each further treat E.coli, BOD, TSS, and ammonia. As discussed in the report these four options were taken through a multicriteria analysis process and the preferred option, Option 4(b) will be included in the LTP for public consultation.

UPDATED APPLICATION STATUS

The Proposed Regional Plan (appeals version) is now at a stage where the existing outlet pipe in the CMA can be considered a Permitted Activity in accordance with Rule C.1.1.1. The appeal to this rule was made by the Royal Forest & Bird Protection Society and is related to the criteria of the general conditions in C.1.8 of the Proposed Regional Plan and more specifically Significant Bird Areas and deposition of material, which are not of consequence to this application.

NOTIFICATION STATUS

The CIA confirms that there are significant adverse cultural effects as a result of the continued discharge of wastewater to the CMA and therefore the application must be publicly notified in accordance with section 95A of the RMA. Further to this, on 24 September 2020 FNDC resolved to request public notification of this application.

Should there be a hearing for this application, it is requested that independent commissioners are appointed to the hearing panel, including at least one commissioner with an understanding of tikanga Maori and of the perspectives of local iwi or hapu, to be appointed in consultation with the relevant iwi authorities.

It is respectfully requested that this application is publicly notified at the same time as the renewal application for the Kohukohu WWTP (APP.003839.01.03) so that the submission period and hearings for both applications can align. The application to renew the Kohukohu WWTP is likely to be publicly notified under similar circumstances (adverse effects on cultural values and/or at FNDC’s request).

S92 Response - Appendix 1

Hokianga Harbour Hydrodynamic Model

Hokianga Harbour Hydrodynamic Study

Hydrodynamic Study of WasteWater Discharges

Report prepared for Far North District Council

March 2020

MetOcean
SOLUTIONS

Document History

Versions

Version	Revision Date	Summary	Reviewed by
0.1	04/12/19	Initial document created	Berthot
0.2	16/12/19	Draft for internal review	Zyngfogel/Cussioli
0.3	18/12/19	Draft for client review	Berthot
0.4	10/01/20	Draft for internal review	Berthot
0.5	23/01/20	Draft for internal review	Zyngfogel/Goward-Brown
0.6	23/01/20	Draft for Client review	Berthot
0.7	11/03/20	Draft for Client review	Berthot

Distribution

Version	Date	Distribution
1.0	16/09/2020	Far North District Council
2.0	28/09/2020	Far North District Council

Document ID:

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Executive Summary

Far North District Council (FNDC) currently discharges wastewater from four municipal WasteWater Treatment Plants (WWTP) into the Hokianga Harbour and its tributaries (Figure 1). FNDC are in the process of renewing these resource consents. In the community, there is growing concern over the health of the harbour and FNDC requires information about the effects of these discharges in the receiving environment, and/or identify simple ways to minimise the effects.

FNDC has commissioned MetOcean Solutions (MOS) to undertake a hydrodynamic modelling study of the wastewater discharges. The release of pollutants in the oceanic environment through an outfall is a process that is generally continuous over time, but often subject to significant fluctuations in released quantities. The fate of these pollutants can be assessed based on hydrodynamic modelling of historical conditions, thereby allowing estimations of the expected general spatial dispersion.

For this work MOS has partnered with the Cawthron Institute to undertake a data collection campaign; Water level and currents within Hokianga Harbour were measured in order to calibrate and validate the hydrodynamic model. This study will be used to support the required Quantitative microbial Risk Assessment (QMRA).

In addition, the council has a mandate to accelerate the development of a long-term plan for the existing Hokianga ferry and therefore require the acquisition of sub-bottom geophysical survey data in order to ascertain the viability of alternative route options and northern landing locations. For the survey work MetOcean Solutions has partnered with Scantec Ltd; Survey results are presented in a separate report (Appendix A:).

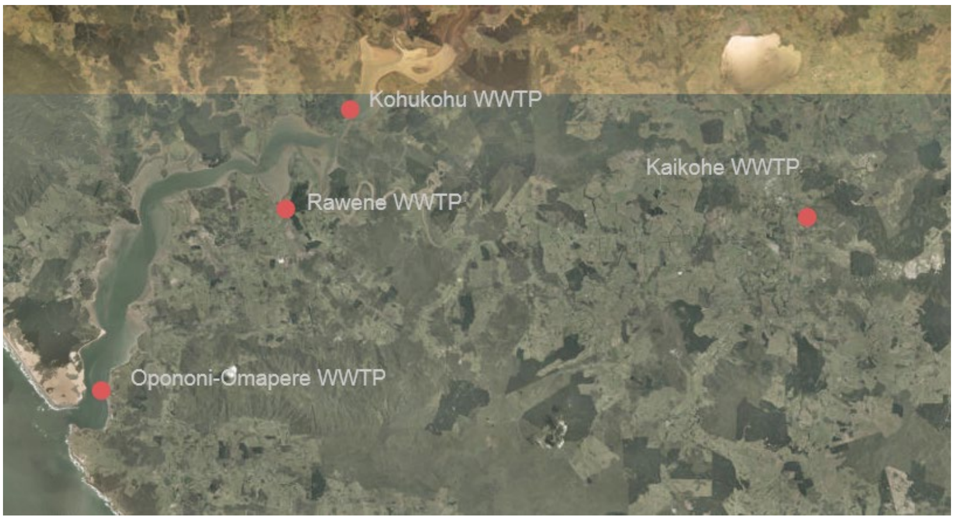

Figure 1:Hokianga Harbour Location (top) - Municipal Wastewater Treatment Plant Discharges in the Catchment of the Hokianga Harbour (bottom).

Field data collection:

A field measurement campaign was undertaken by Cawthron Institute to assist with the characterisation of the hydrodynamic regime within Hokianga Harbour and provide the necessary field data for calibration and validation of the hydrodynamic model. The campaign focused on four locations between the harbour entrance and the Narrows (Figure 2). The measurement period extended from July 2019 to August 2019 and included measurements of water elevation and current velocities.

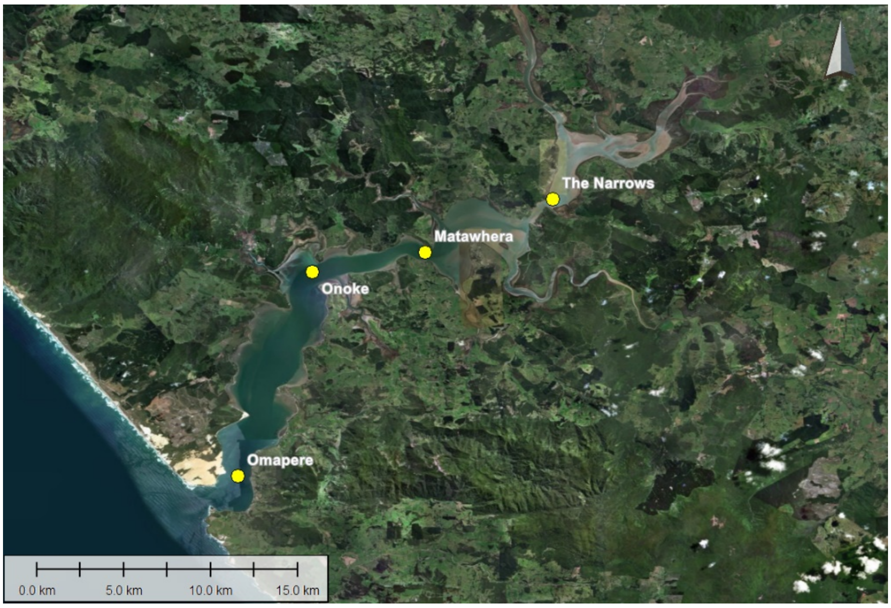

Figure 2:Instruments locations within Hokianga Harbour.

Hydrodynamic Modelling :

A SCHISM hydrodynamic model of Hokianga Harbour was setup for this study. The model resolution was optimised to ensure replication of the salient hydrodynamic processes. The resolution ranged from 90 m at the offshore boundary to 15 m within Hokianga Harbour and near the discharge locations. The model bathymetry was prepared based on the best available datasets for the region. The model was forced by tidal conditions (extracted from MOS greater NZ SCHISM model) and temperature/salinity (HYCOM model) at the offshore boundary, atmospheric data (wind and heat exchange extracted from MOS existing atmospheric models) and river discharges (Discharge report from NIWA for the Waima river (Wairoro-Penakitere-Taheke-Waima River), Waihou River, Orira River and Mangamuka River) forced at the boundary.

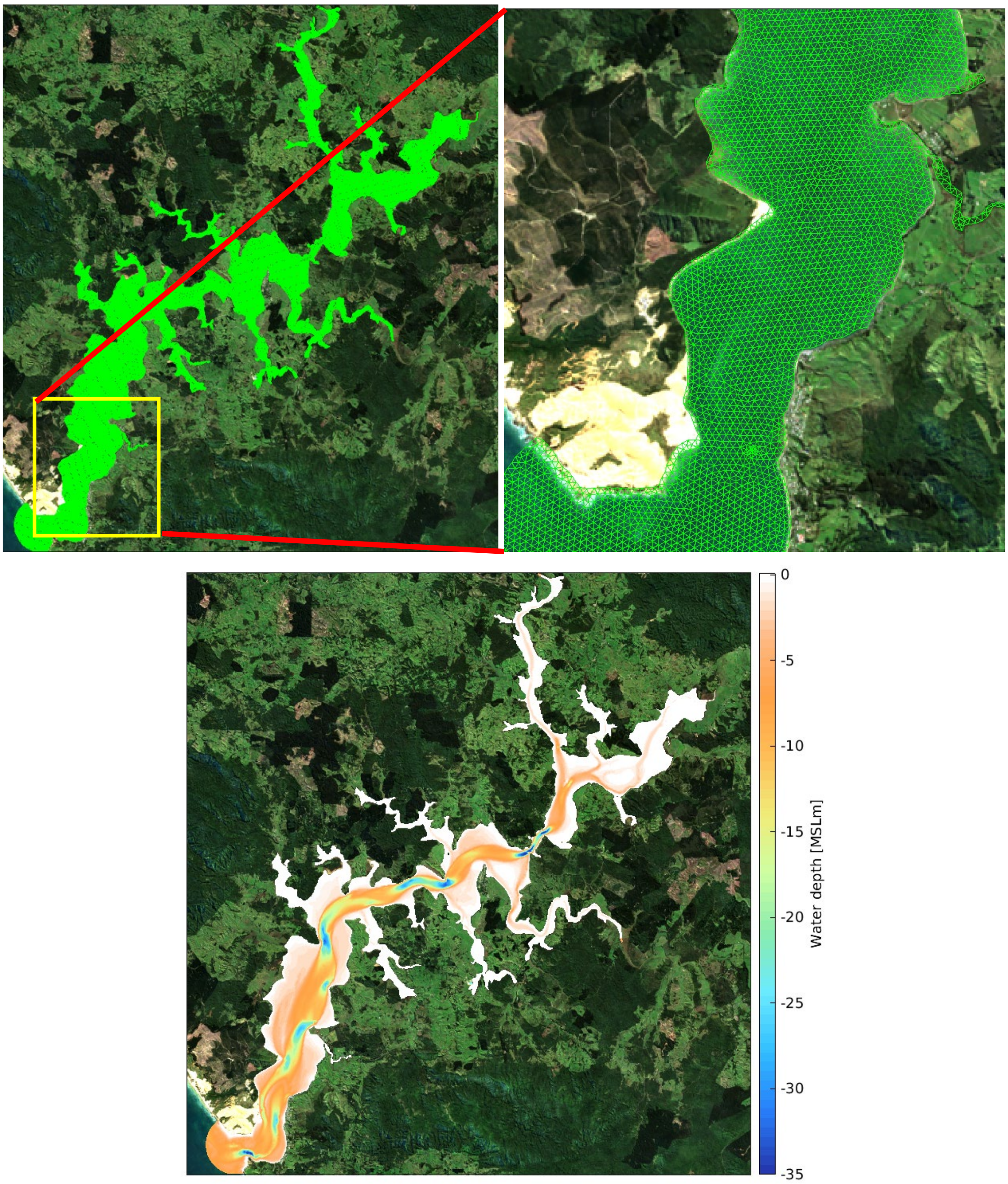

Figure 3:Hydrodynamic model: Bathymetry of model domain showing water depth (left) and triangular model (Center is the whole domain and right show the grid refinement around the Opononi discharge location).

The model was calibrated and validated using the water level and current collected by Cawthron within Hokianga Harbour. Comparisons between the measured and modelled data show that the model successfully reproduces the propagation of the tidal wave inside the harbour, with good agreement in terms of water level, current and temperature patterns.

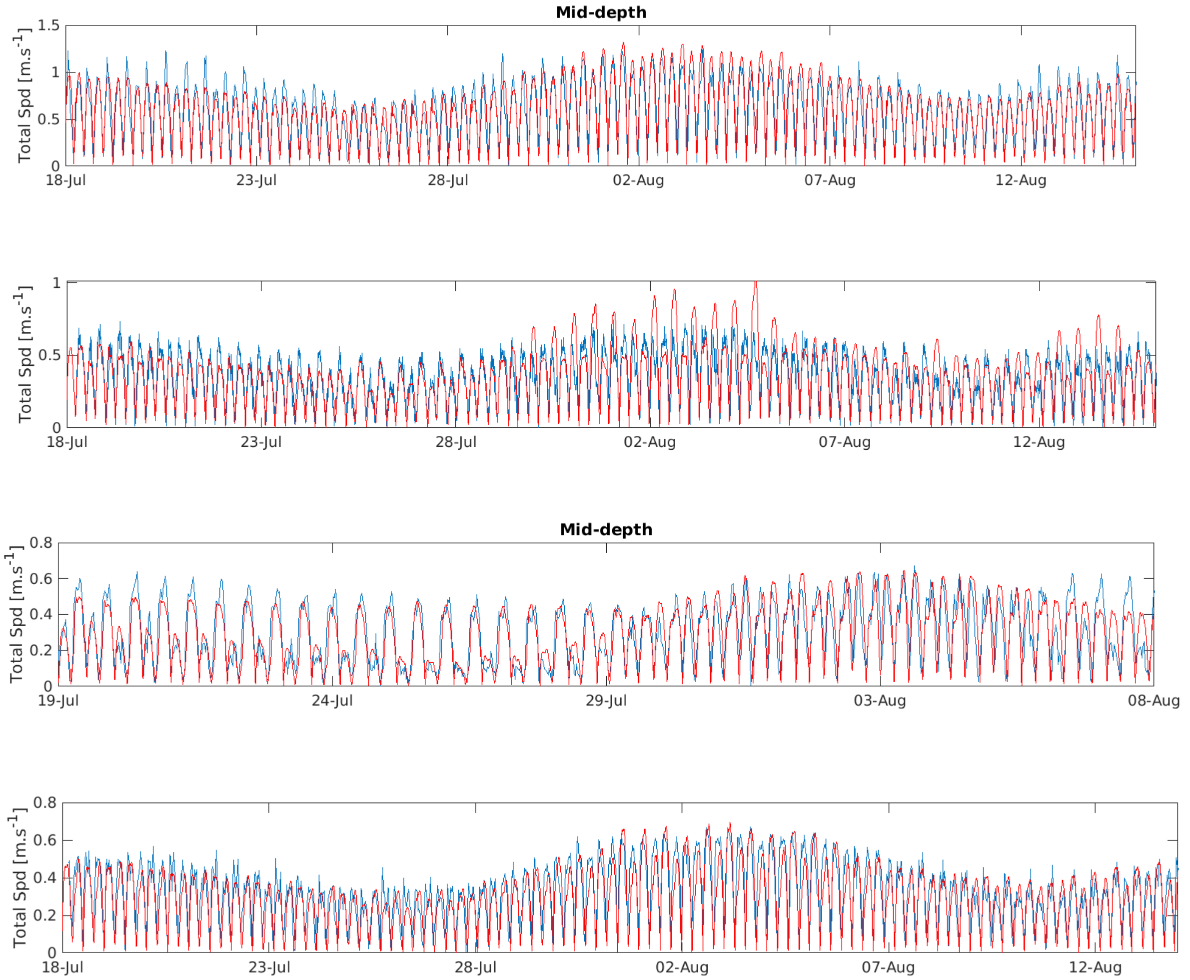

Figure 4:Measured (blue) and modelled (red) current speeds at Omapere ADCP Onoke FSI , Matawhera ADCP The Narrows FSI sites, from July 2019 to August 2019

WWTP Discharge Simulations

In order to model the four WWTP discharges a review of the discharge rate timeseries data was undertaken and a year representative of the variability in the discharge rate as well as a maximum at the proposed resource consent was adopted for each of these four discharges.

Different passive tracers (i.e. a neutrally buoyant pollutant with no decay) were used for each WWTP discharge. A nominated concentration value of 1 mg/L was used so that dilution can be calculated at various distance from the source. Specific contaminant concentration levels can then be determined using concentration ratios and the expected or measured discharge value.

In the present study, the approach consisted of running year-long simulations within two contrasting historical contexts (El Nino / La Niña/El Niño episodes). This allows robust probabilistic estimates of the plume dispersion and dilution patterns to be determined and thus provide some guidance on expected concentration levels associated with the Hokianga Harbour WWTP discharges.

The year-long simulations were extended by two days, and the discharge rate increased to the highest discharge recorded, in order to assess the impact of an extreme isolated event. The model simulations results were processed in terms of dilution factors which were determined by dividing the tracer concentration at any grid point to the discharged concentration. A dilution factor of 1:1000 indicates a contaminant concentration at that location 1000 time smaller than discharged. Specific contaminant concentration levels at environmental receptors will be determined by consultants doing the QMRA, using concentration ratios and the expected or measured discharged value.

Results are presented in terms of 50^{th} and 95^{th} percentiles dilution factor maps and timeseries of dilutions factors at selected locations.

The 50^{th} percentile maps present the dilutions factors expected to be exceeded 50% of the time.

The 95^{th} percentile maps present the dilution factors expected to be exceeded 5% of the time (or not exceeded 95% of the time).

Timeseries of tracer concentration were also extracted at selected locations within Hokianga Harbour and dilution factors were calculated and provided to the consultants undertaking the QMRA.

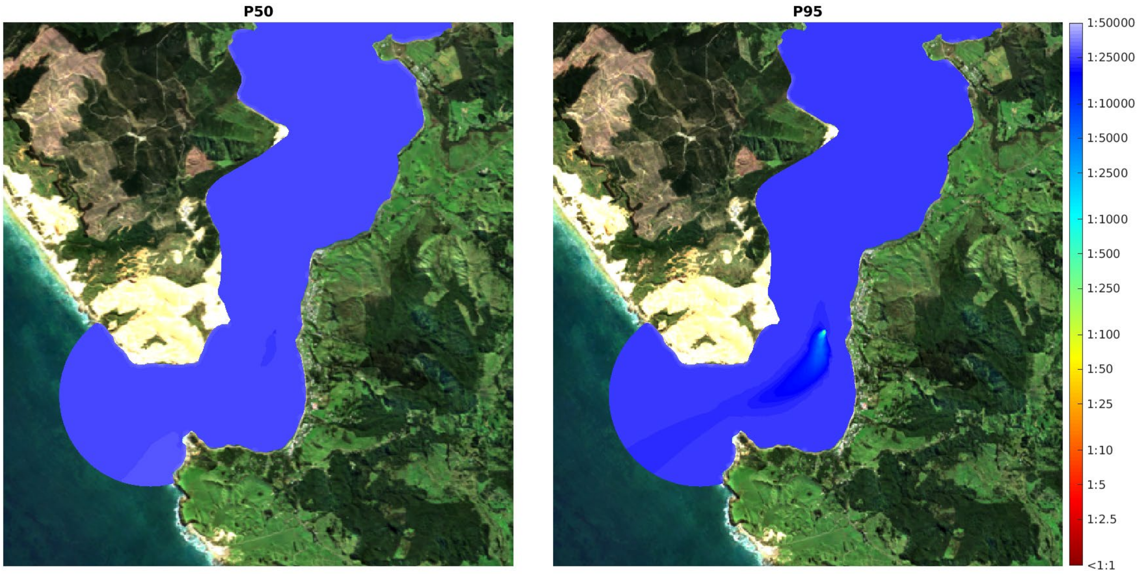

Figure 5:50th Percentile and 95th Percentile Dilution factor for Opononi WWTP during El Nino year.

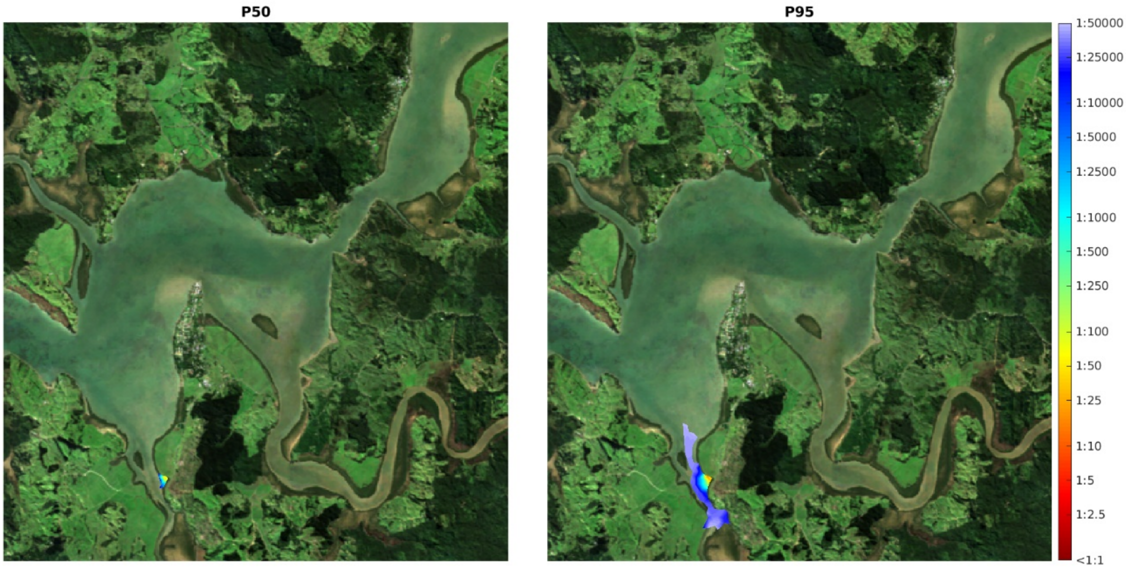

Figure 6:50th Percentile and 95th Percentile Dilution factor for Rawene WWTP during El Nino year.

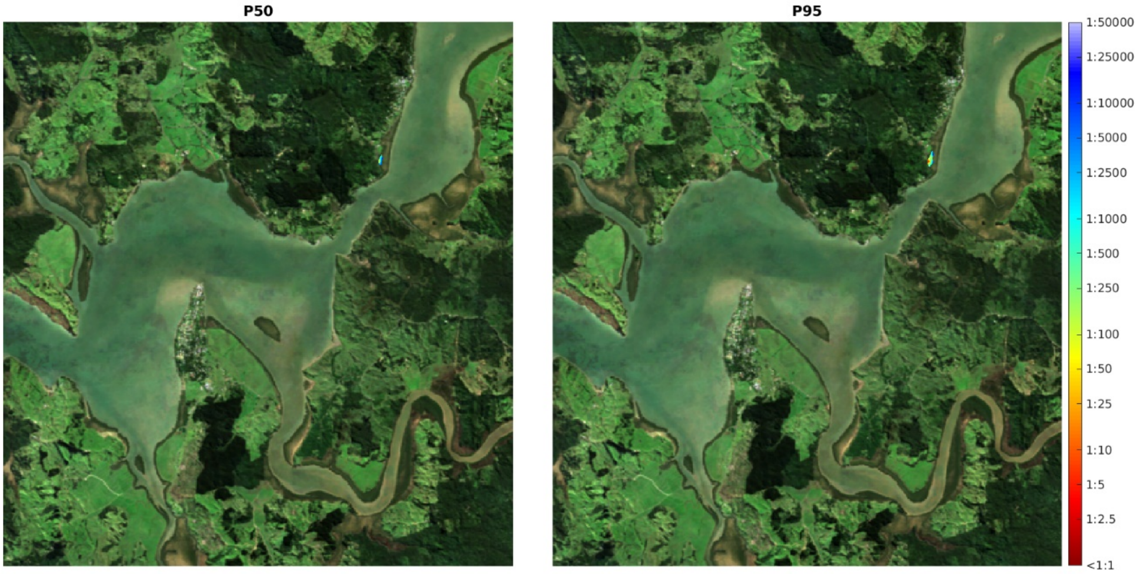

Figure 7:50th Percentile and 95th Percentile Dilution factor for Kohukohu WWTP during El Nino year.

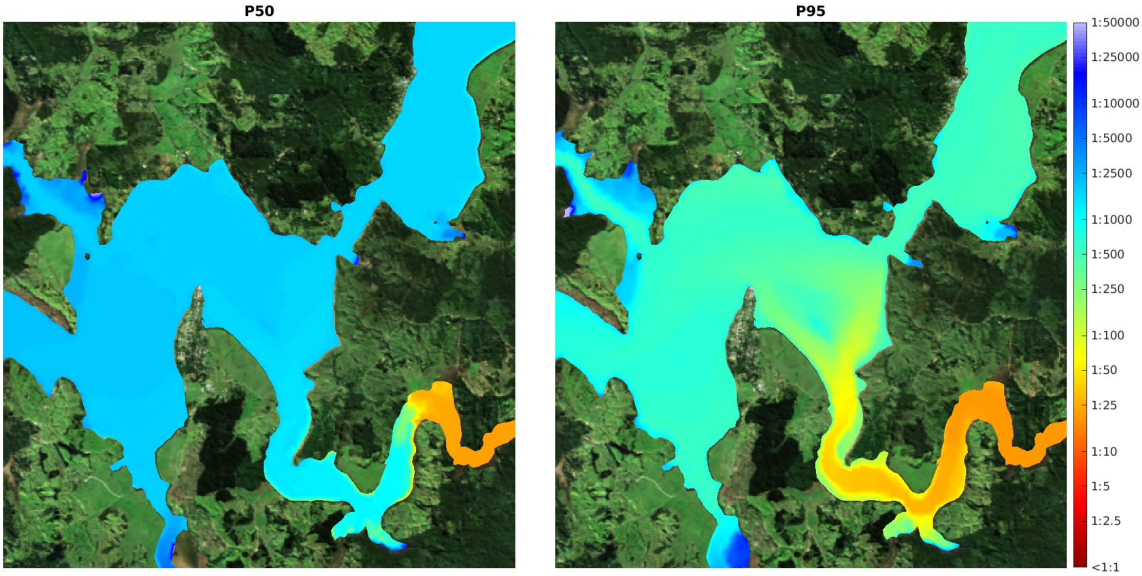

Figure 8:50th Percentile and 95th Percentile Dilution factor for Kaikohe WWTP during El Nino year.

Results shows that each WWTP discharges present very different plume extents due to their location within the harbour and the actual discharge volumes. Some of the key features for each discharge are:

- The Opononi WWTP discharge presents an elongated plume stretching toward the entrance of Hokianga harbour. Dilution factors for the 50th percentile are as high as 1 in 5000 within 100 m of the discharge.

- The Rawene WWTP discharge plume is mostly contained within the Omanaia River and dilution factors for the 50th percentile are about 1 in 5000 at 100 m from the discharge location
- The Kohukohu WWTP discharge plume is mostly confined to the vicinity of the discharge location with a dilution factor of 1 in 50,000 at approx. 50 m for the 50th percentile.
- The Kaikohe WWTP discharge plume present dilution factors of 1 in 25 within the Waima River as far as downstream as the last bend before Motukiore Road. Dilution is about 1 in 1000 to 1 in 2500 within the harbour.

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1.Introduction

Far North District Council (FNDC) currently discharges wastewater from four municipal wastewater treatment plants (WWTP) into the Hokianga Harbour or its tributaries (Figure 1.1). FNDC are in the process of renewing two of these resource consents. In the community, there is growing concern over the health of the harbour and FNDC requires information about the effects of these discharges in the receiving environment, and/or identify simple ways to minimise the effects.

FNDC has commissioned MetOcean Solutions (MOS) to undertake a hydrodynamic modelling study of the wastewater discharge. In order to support the modelling, MOS has partnered with Cawthron Institute to undertake a data collection campaign which includes the measurement of water level and currents within Hokianga Harbour.

In addition, the Council has a mandate to accelerate the development of a long-term plan for the existing Hokianga ferry for which they require the acquisition of sub-bottom geophysical surveys to ascertain the viability of alternative route options and northern landing locations. For the survey work, MetOcean Solutions has partnered with Scantec Ltd; Results from the survey will be presented in a separate report in Appendix A:.

This report is structured as follows: an introduction to the study background and rational is provided in Section 1, while a summary of the available measured data are provided in Section 2. Methods applied, including numerical model definitions are presented in Section 3. Model validation and Results are given in Section 4 and Section 5 respectively. Conclusions are presented in Section 6 and References cited within the text are provided in Section 7.

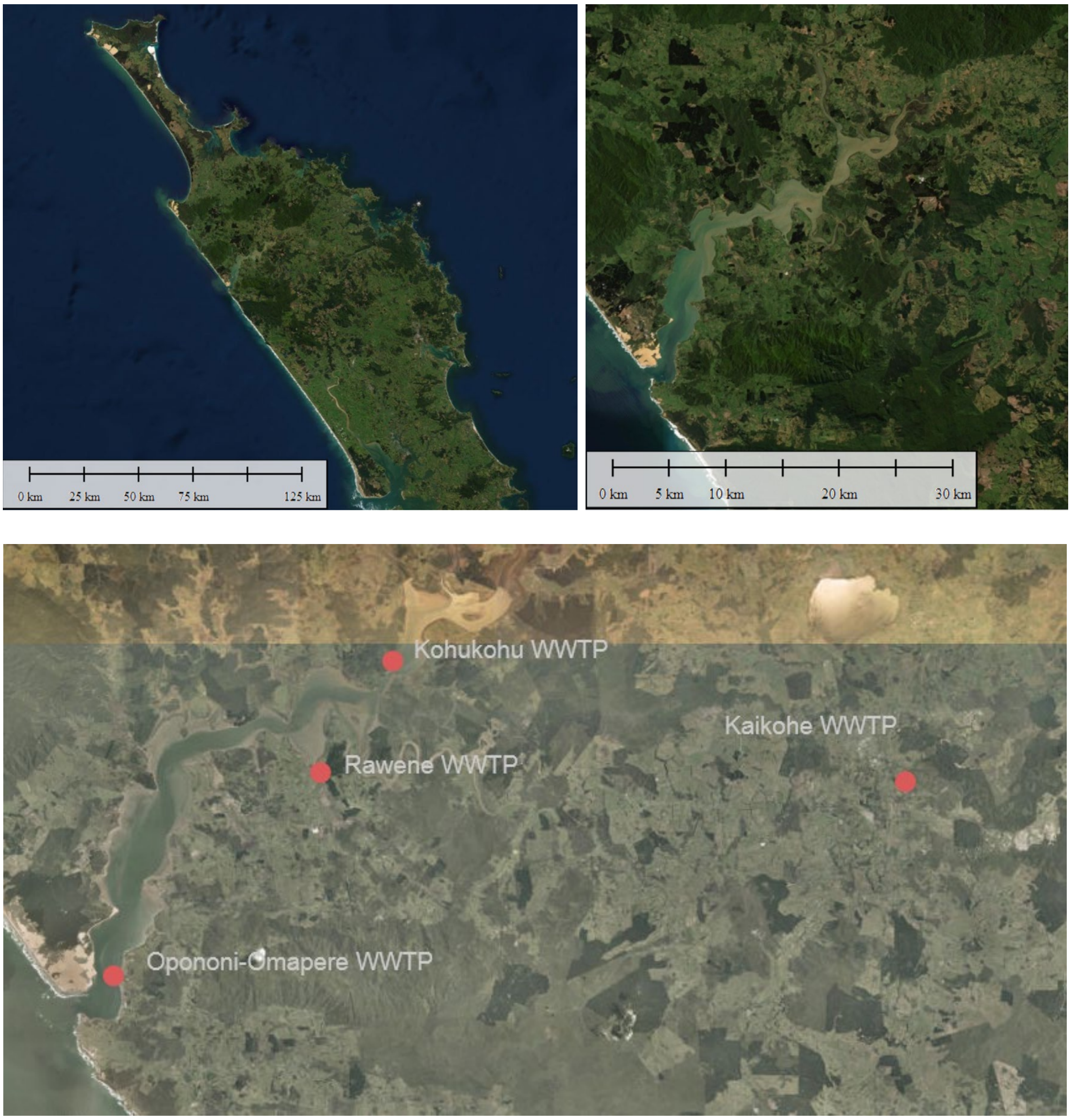

Figure 1.1: Hokianga Harbour Location (top) - Municipal Wastewater Treatment Plant Discharges in the Catchment of the Hokianga Harbour (bottom).

2. Field Measurement Campaign

A field measurement campaign was undertaken by the Cawthron Institute to assist with the characterisation of the hydrodynamic regime within Hokianga Harbour and provide the necessary field data for calibration and validation of the hydrodynamic model. The campaign focused on four locations between the harbour entrance and the Narrows (Figure 2.1).

2.1.1 Instrumentation and Deployment

The measurement period extended from July 2019 to August 2019 and included measurements of water elevation and current velocities. Measurements were undertaken using a range of instruments spread between the Hokianga Harbour entrance and the Narrows (Figure 2.1); coordinates of the deployment sites are provided in Table 2.1. Further details on instrument deployment and measured data are provided in the following sections.

The data collection campaign consisted of the collection of water level and ocean current information via four separate moorings in ~5 to 26m (CD) water depths throughout the Hokianga Harbour for 30 days. Two of the moorings included bottom mounted ADCPs with the other two featuring mid-water mounted FSI current meters. All moorings included pressure sensors. Detailed equipment description follows:

- Two sea-bed mounted ADCP instruments to record water level and current velocity profiles.
- Two FSI current meters deployed at mid-water on individual moorings, recording current velocities at a single point.
- Four RBR Solo pressure sensors (supplied by MetOcean Solutions) deployed on individual moorings, recording water levels.

Figure 2.1 shows the locations of the instruments deployed

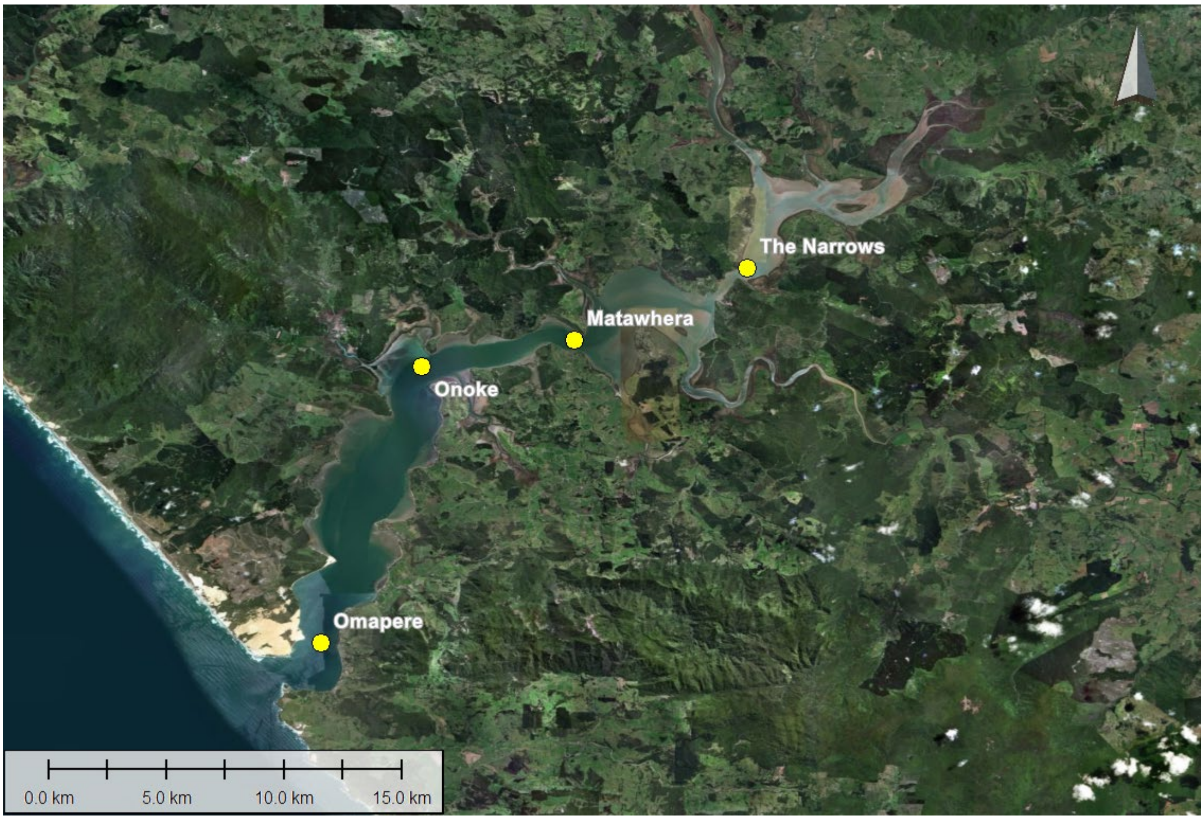

Figure 2.1 Instruments locations within Hokianga Harbour.

Table 2.1 Latitude, longitude, depth and instruments deployed at each mooring location.

Location	Instrument	Latitude/ Longitude	Depth Deployment
Omapere	ADCP	35°31.080'S	16.5 m
	RBR Solo	173°22.850'E	
Onoke	FSI	35°24.739'S	9 m
	RBR Solo	173°25.152'E	
Matawhera	ADCP	-35°24.152'S	25.6 m
	RBR Solo	173°28.652'E	
The Narrows	FSI	-35°22.473'S	5.5 m
	RBR Solo	173°32.673'E	

2.1.2 Data Processing

Data recorded by the pressure sensors were processed in Matlab. The data was checked and any unusable data, such as that collected during the deployment and retrieval of the instrument were removed; Pressure data was converted to water level and saved at 1-minute intervals. Similarly, any data recorded during the deployment and retrieval of the FSI current meters were removed from the dataset. Current magnitude and direction were calculated from U and V velocities and saved at 1-minute intervals.

Native files from the ADCPs were first processed using WinADCP (v 1.14) and various variables (e.g. velocities, depth, pitch, roll, amp, echo) were exported to be processed in Matlab. The instrument was configured with 29 bins (Omapere) and 35 bins (Matawhera), for both ADCPs the bin size was 1.0 m . The blanking depth was 0.50 m for the ADCP deployed at Matawhera and 0.88 m for the Omapere ADCP. In Matlab, bad data was flagged and removed based on threshold values. Bins above the maximum height of the surface layer were removed and the depth was corrected to account for the instrument height of 0.5m.

2.1.3 Water Level Measurements

The pressure sensors recorded during the entire time of deployment and captured well the tidal elevation, including spring and neap cycles (Figure 2.2 to Figure 2.5). Semi-diurnal tides are predominant in this area, with tidal amplitudes displaying variation in elevation between subsequent spring and neap cycles, resulting in some differences in the tidal current magnitudes both within, and between, spring-neap cycles (see next section – Current Measurements).

The deployments at Onoke and The Narrows presented a shift in the pressure data at around the 1st and the 4th of August, respectively. The shift resulted in an increase of 0.5 m in level, from 9 m to 9.5 m at Onoke (Figure 2.3) and from 5.5 to 6 m at The Narrows (Figure 2.5). The dates coincide with the start and the middle of the spring tide. According to data from the field campaign, the instruments did not alter position significantly between deployment and retrieval, therefore, the shift could be a result of the instrument frame sliding slightly along the bed sand/or the anchor weights sinking into the soft sediment.

Tidal amplitude variations (around the mean) for the period of the field campaign were: 3.4 m for Omapere, 4.9 for Onoke, and 3.6 m for Matawhera and The Narrows. Higher amplitudes at Onoke and The Narrows are results of the shift in data described above.

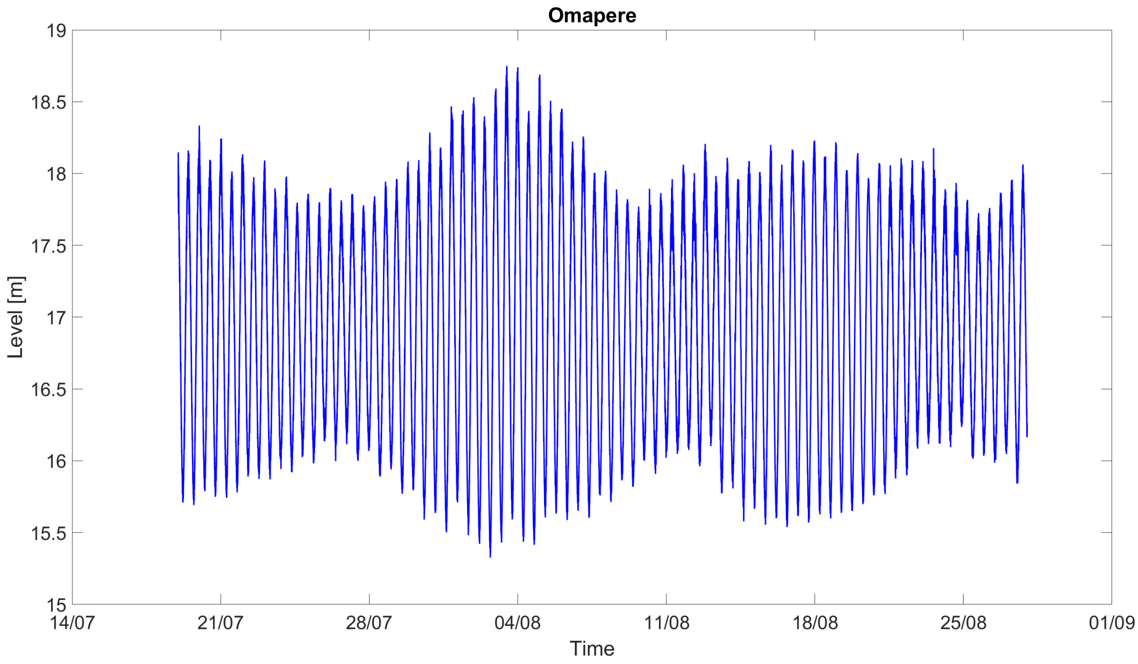

Figure 2.2 Water level at Omapere, calculated from measured pressure using an RBR Solo pressure sensor.

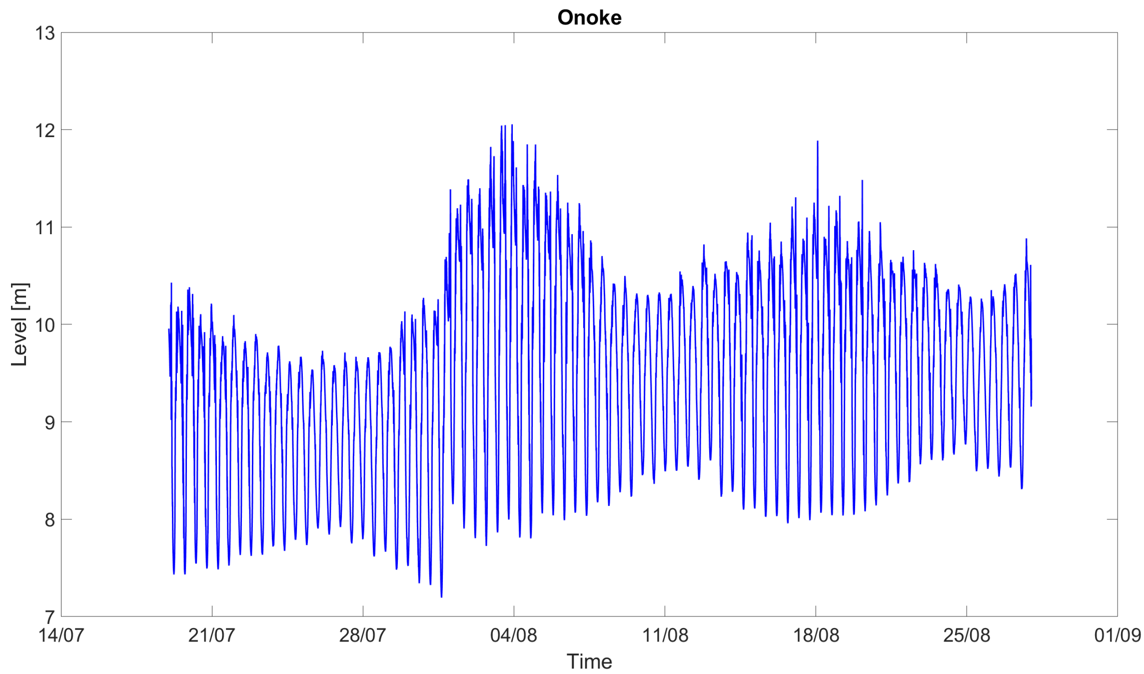

Figure 2.3 Water level at Onoke, calculated from measured pressure using an RBR Solo pressure sensor.

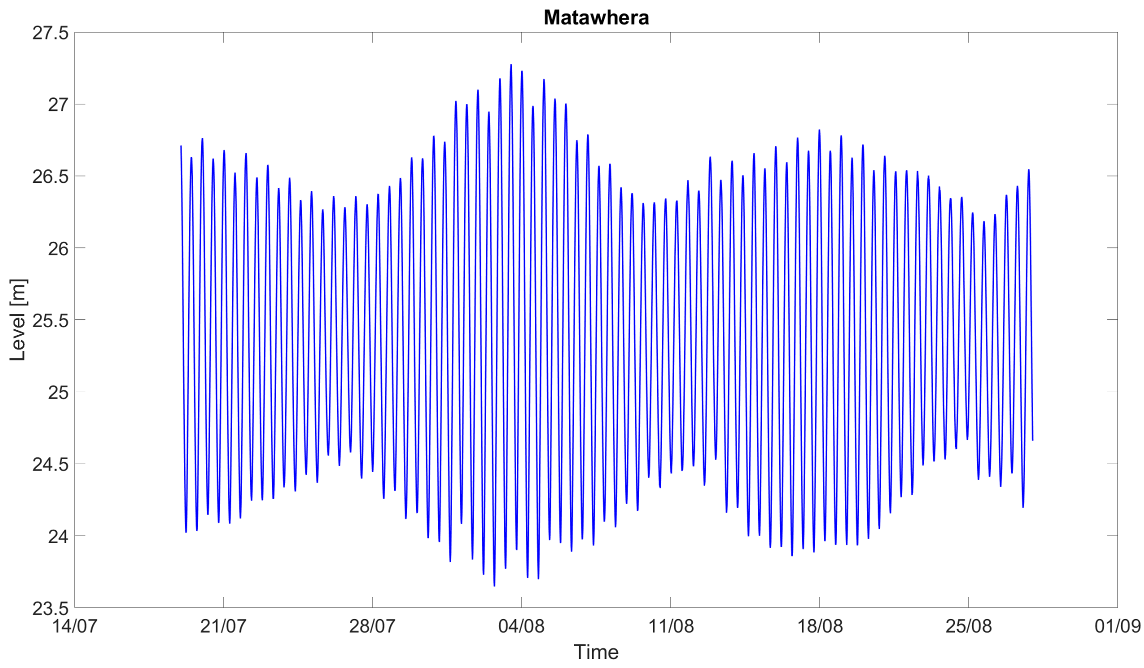

Figure 2.4 Water level at Matawhera, calculated from measured pressure using an RBR Solo pressure sensor.

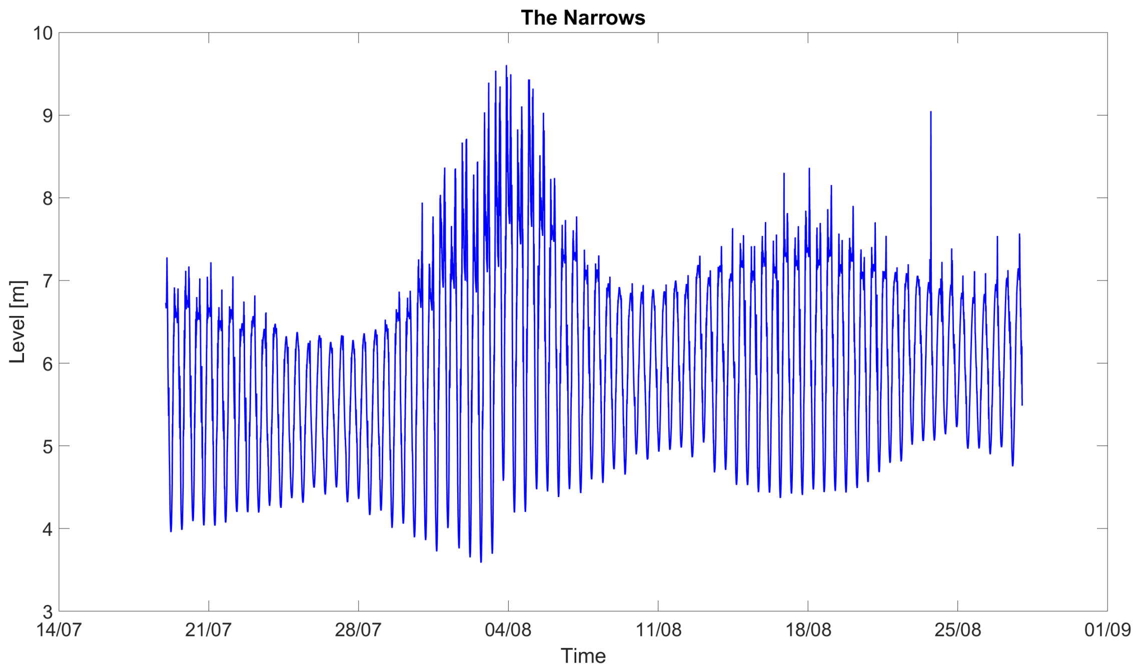

Figure 2.5 Water level at The Narrows, calculated from measured pressure using an RBR Solo pressure sensor.

2.1.4 Current Measurements

Current measurements were carried out using an ADCP at Omapere and Matawhera while an FSI was deployed at Onoke and The Narrows.

The ADCP and FSI current magnitude and direction are presented in Figure 2.6 to Figure 2.9.

For clearer visualisation, a one-week subset of current speed and direction at Omapere is shown in Figure 2.6. Directions of current flow measured at the entrance of the Harbour remained mostly aligned with the N-S axis of the channel throughout the period. Current reversals and magnitudes show a close correlation with tidal elevations, with faster currents at the beginning of the period shown in the subset, which correspond to the end of a spring tide, and slower currents in the following days leading to a neap tide. This indicates the dominant effect of the tide in this area. Mean current speeds over the campaign were 0.5 m s^{-1} and peak speed was 1.4 m s^{-1}.

At Onoke, current direction showed a N-NNE and SW pattern (Figure 2.7) indicating that currents flowing along the west margin of the channel are affected by the significant change in orientation of the main channel from N-S to almost E-W. Mean speed at this location during the field campaign was 0.3 m s^{-1} and the highest speed recorded was 0.7 m s^{-1}.

In contrast, currents at Matawhera typically flowed along the main channel axis, to the east-southeast during flood and to the west-northwest during ebb (Figure 2.8). Mean and maximum speed were 0.3 m s^{-1} and 0.8 m s^{-1}, respectively. The data shows a significant variability in current speed through the water column, with ebb current (WNW) stronger near the surface and flood current (ESE) stronger below mid depth level. This indicates the influence of the freshwater river flowing out to the ocean which tended to reduce the surface current. This pattern mainly occurs in July when the river discharges were much stronger than in August and stratification was likely significant. This is also shown in the validation plots later in this report (Section 5.1.2) with a stronger ebb and weaker flood during the first part of the data collection period.

This pattern is not as pronounced near the entrance where the water is expected to be mixed.

The Narrows was the most upstream, and shallowest, mooring deployment. Flow is predominantly affected by the orientation of the main channel, which can be seen in Figure 2.9 by the predominance of N and WSW current direction. Average and peak current speeds at this location were 0.3 m s^{-1} and 0.8 m s^{-1} respectively, very similar to the values recorded at Onoke and Matawhera.

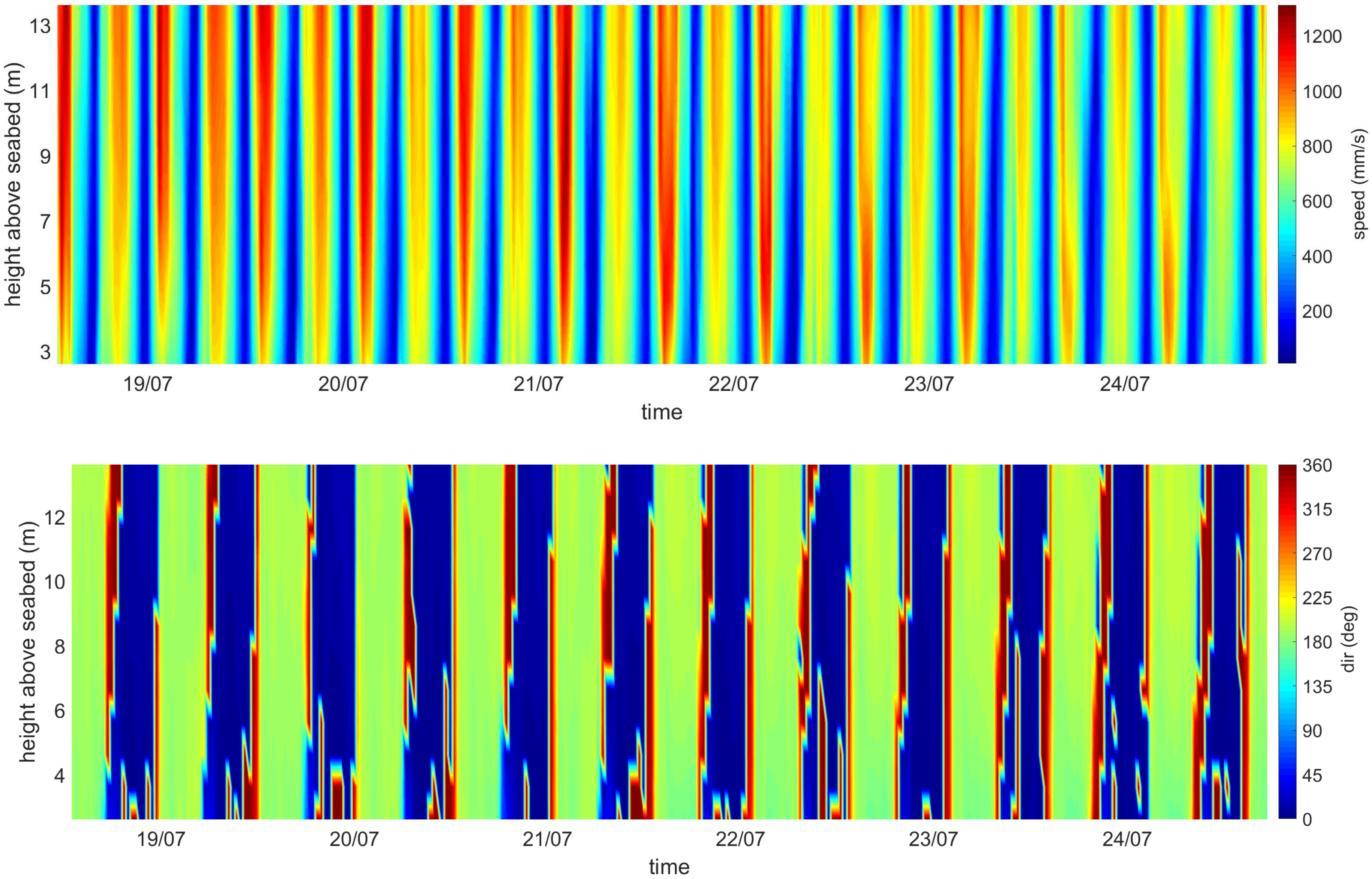

Figure 2.6 Current speed and direction at Omapere, recorded by seabed mounted ADCP. Figure shows a subset of the period recorded for clearer visualization.

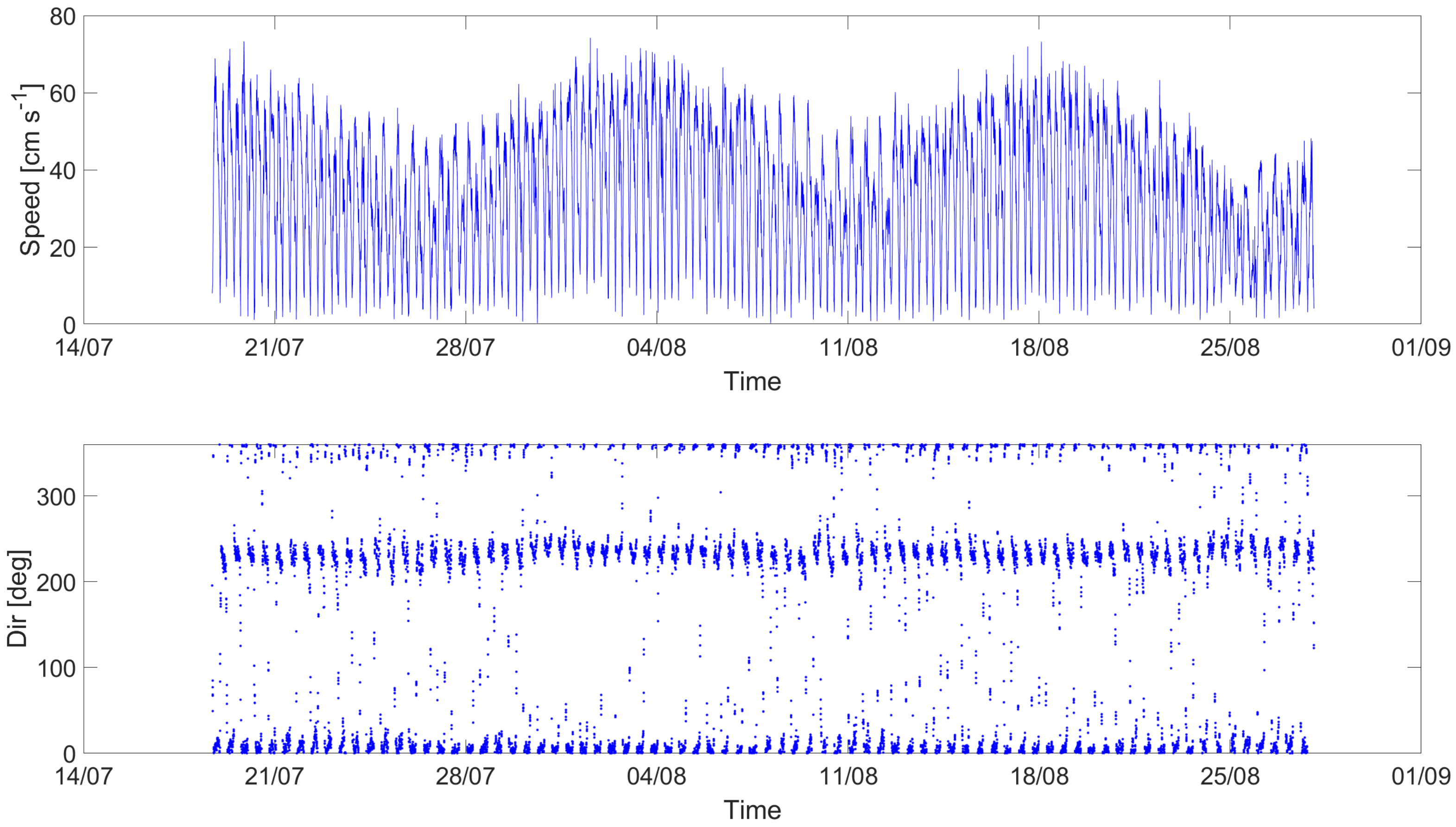

Figure 2.7 Current speed and direction at Onoke, recorded by an FSI current meter.

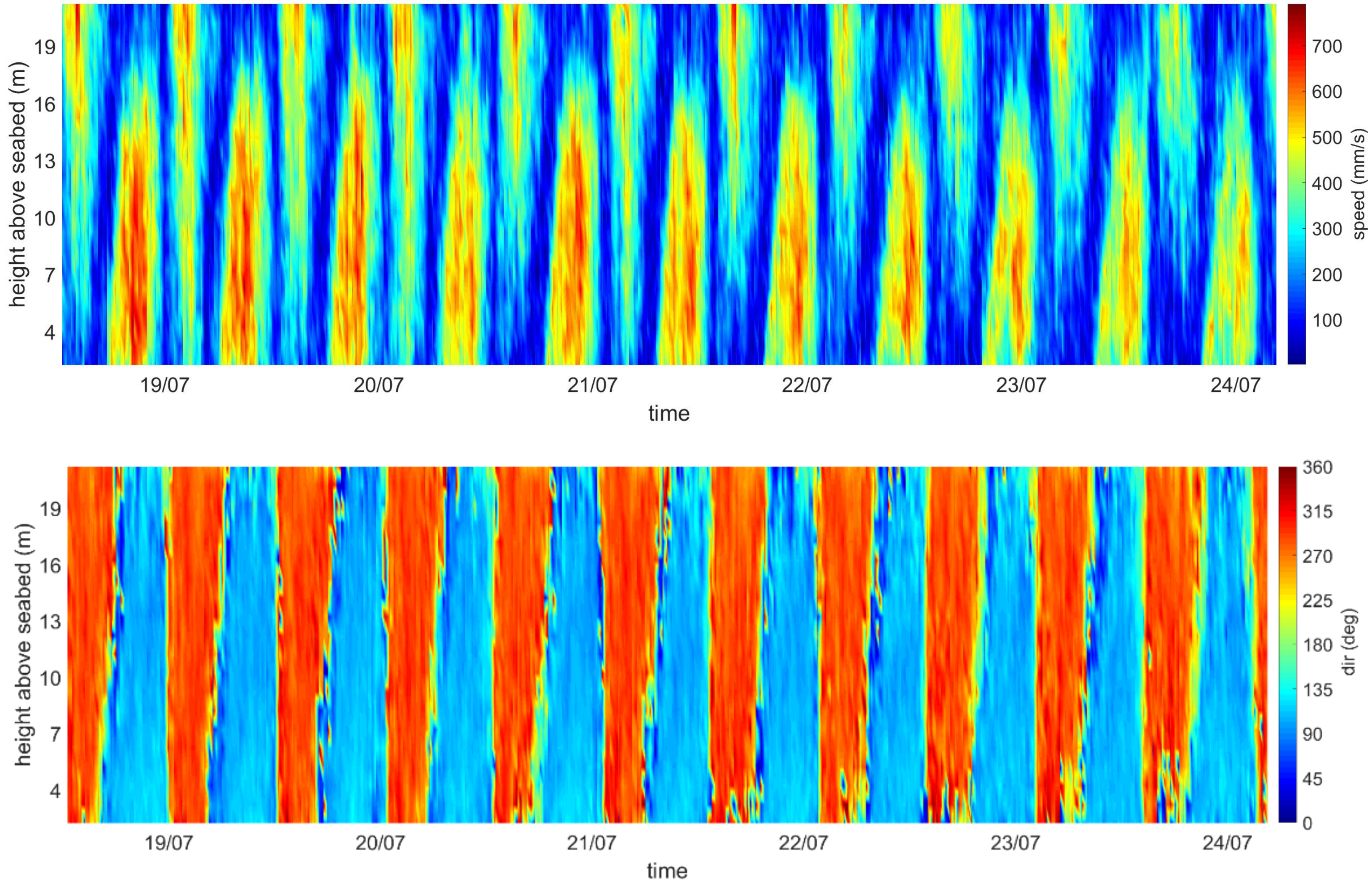

Figure 2.8 Current speed and direction at Matawhera, recorded by seabed mounted ADCP. Figure shows a subset of the period recorded for clearer visualization.

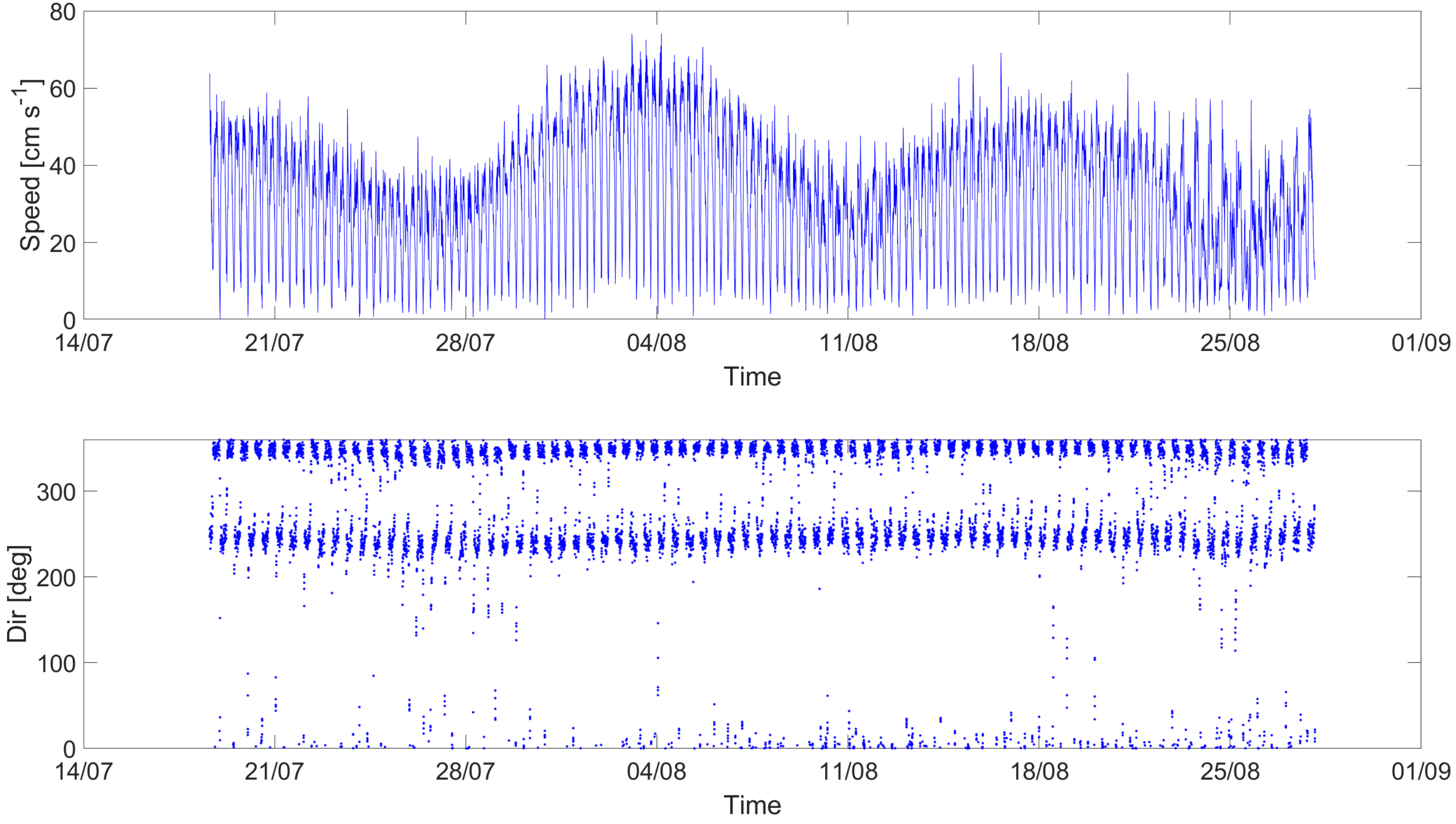

Figure 2.9 Current speed and direction at The Narrows, recorded by an FSI current meter.

3.Sub-Bottom Surveys – Scantec Ltd

The survey scope included measuring general stratigraphy and sediment thickness over bedrock in a triangular area of approx. 1.7 square kilometres. Equipment was mounted on a 5.5m vessel which was launched from the boat ramp at Rawene. A high powered 3.5kHz to 7kHz SBP system was used to penetrate the seabed and obtain reflections from bedrock. A Knudsen 320M 200kHz single beam echosounder was used to collect bathymetric data which needs to be collected as part of the SBP dataset to assist in data processing. The data was processed using seismic processing packages.

The Scantec report is included in Appendix A .

4. Numerical Modelling

4.1 Methodology

The release of pollutants in the oceanic environment through an outfall is a process that is generally continuous over time, but often subject to significant fluctuations in released quantities. The outcome of such releases is inherently non-deterministic and is governed, in part, by random variables such as currents, turbulence, wastewater network use and precipitation, it is therefore difficult to accurately predict.

However, the probability of future oceanic conditions can be assessed from the historical conditions, thereby allowing estimations of the general geographical dispersion expected. In the present study, the approach consisted of running year-long simulations within two contrasting historical contexts (La Niña /El Niño episodes, June 2010-June 2011, and June 2015-June 2016, respectively). This allows robust probabilistic estimates of the plume dispersion and dilution patterns to be determined and thus provide some guidance on expected concentration levels associated with the proposed outfall.

During El Niño conditions, New Zealand typically experiences stronger or more frequent westerly winds during summer. This leads to a greater risk of drier-than-normal conditions in east coast areas and more rain than normal in the west. In winter, colder southerly winds tend to prevail, while in spring and autumn, south-westerlies tend to be stronger or more frequent, bringing a mix of the summer and winter effects.

During La Niña conditions more north–easterly winds are characteristic, which tend to bring moist, rainy conditions to the north–east of the North Island, and reduced rainfall to the south and south–west of the South Island.

By considering both La Niña and El Niño episodes a robust probabilistic estimate of the plume dispersion and dilution patterns is able to be determined and thus provide guidance on expected concentration levels associated with the Hokianga Harbour WWTP discharges.

The discharge of waste-water into Hokianga Harbour has been modelled using a high-resolution local domain hydrodynamic model to characterise the salient hydrodynamics of the environment, while an Eulerian tracer technique has been applied in order to quantify the likely dilution of the discharged waste water.

The following sections detail the hydrodynamic models, including calibration and validation, and Eulerian tracer technique implemented for this specific study; assumptions around the discharge rates are also presented.

4.2 Hydrodynamic Model

4.2.1 Model description

The 2D and 3D baroclinic hydrodynamics of the Hokianga Harbour were modelled using the open-sourced hydrodynamic model SCHISM[1][2]. The benefit of using open-source science models is the full transparency of the code and numerical schemes, and the ability for other researchers to replicate and enhance any previous modelling efforts for a given environment.

SCHISM is a prognostic finite-element unstructured-grid model designed to simulate 3D baroclinic, 3D barotropic or 2D barotropic circulation. The barotropic mode equations employ a semi-implicit finite-element Eulerian-Lagrangian algorithm to solve the shallow-water equations, forced by relevant physical processes (atmospheric, oceanic and fluvial forcing). A detailed description of the SCHISM model formulation, governing equations and numerics, can be found in Zhang and Baptista (2008).

The SCHISM model is physically realistic, in that well-understood laws of motion and mass conservation are implemented. Therefore, water mass is generally conserved within the model, although it can be added or removed at open boundaries (e.g. through tidal motion at the ocean boundaries) and water is redistributed by incorporating aspects of the real-world systems (e.g. bathymetric information, forcing by tides and wind). The model transports water and other constituents (e.g. salt, temperature, turbulence) through the use of triangular volumes (connected 3-D polyhedrons).

The finite-element triangular grid structure used by SCHISM has resolution and scale benefits over other regular or curvilinear based hydrodynamic models. SCHISM is computationally efficient in the way it resolves the shape and complex bathymetry associated with estuaries, and the governing equations are similar to other open-source models such as Delft3D and ROMS. SCHISM has been used extensively within the scientific community[3][4], where it forms the backbone of operational systems used to nowcast and forecast estuarine water levels, storm surges, velocities, water temperature and salinity[5].

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[1] http://ccrm.vims.edu/schism/

[2] http://www.ccrm.vims.edu/w/index.php/Main_Page#SCHISM_WIKI

[3] http://www.stccmop.org/knowledge_transfer/software/selfe/publications

[4] http://ccrm.vims.edu/schism/schism_pubs.html

[5] https://tidesandcurrents.noaa.gov/ofs/creofs/creofs_info.html

4.2.2 Model domain and bathymetry

The model resolution was optimised to ensure replication of the salient hydrodynamic processes. The resolution ranged from 90 m at the boundary to 15 m within Hokianga Harbour and near the discharge locations.

Bathymetry is an essential requirement for coastal and estuaries numerical modelling. MetOcean Solutions has compiled an extensive national and regional bathymetric dataset derived from Electronic Navigation Charts (ENC). GEBCO data (Becker et al. 2009) was also used to characterise the deepest offshore areas. These datasets were updated with available hydrographic surveys for the region.

This included:

- LIDAR data available for parts of the harbour (Opononi-Omapere, Rawene and Kohukohu).
- Hydrographic surveys of the Hokianga Harbour completed by LINZ in 2015 (from the mouth to the upper reaches, see Figure 3).
- Hydrographic surveys of the Hokianga Harbour completed by NRC in 2006 (Motuti, Omapere and lower harbour).

Specialist data manipulation tools have been developed in-house to allow merging, interpolation and QA of raw bathymetric data to establish the numerical model domain (Figure 4.1and Figure 4.2).

The triangular elements of the model domain mesh is shown in Figure 4.3 and associated bathymetry is presented in Figure 4.4.

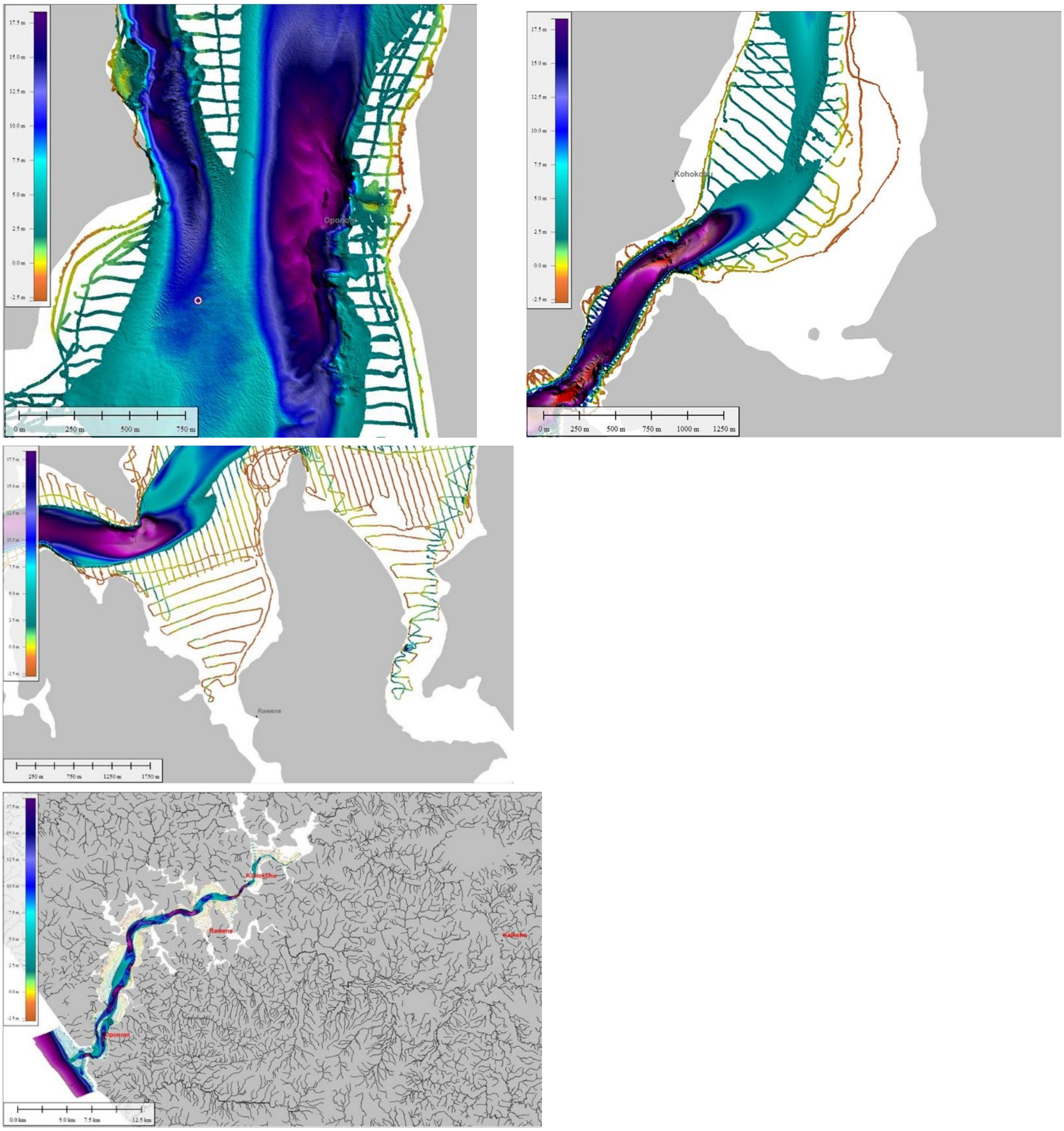

Figure 4.1: Hydrographic Survey for Hokianga Harbour completed by LINZ in 2015 near the WWTP (Top left: Opononi, Top right: Kohokohu, Bottom left: Rawene, Bottom right: Kaikohe)

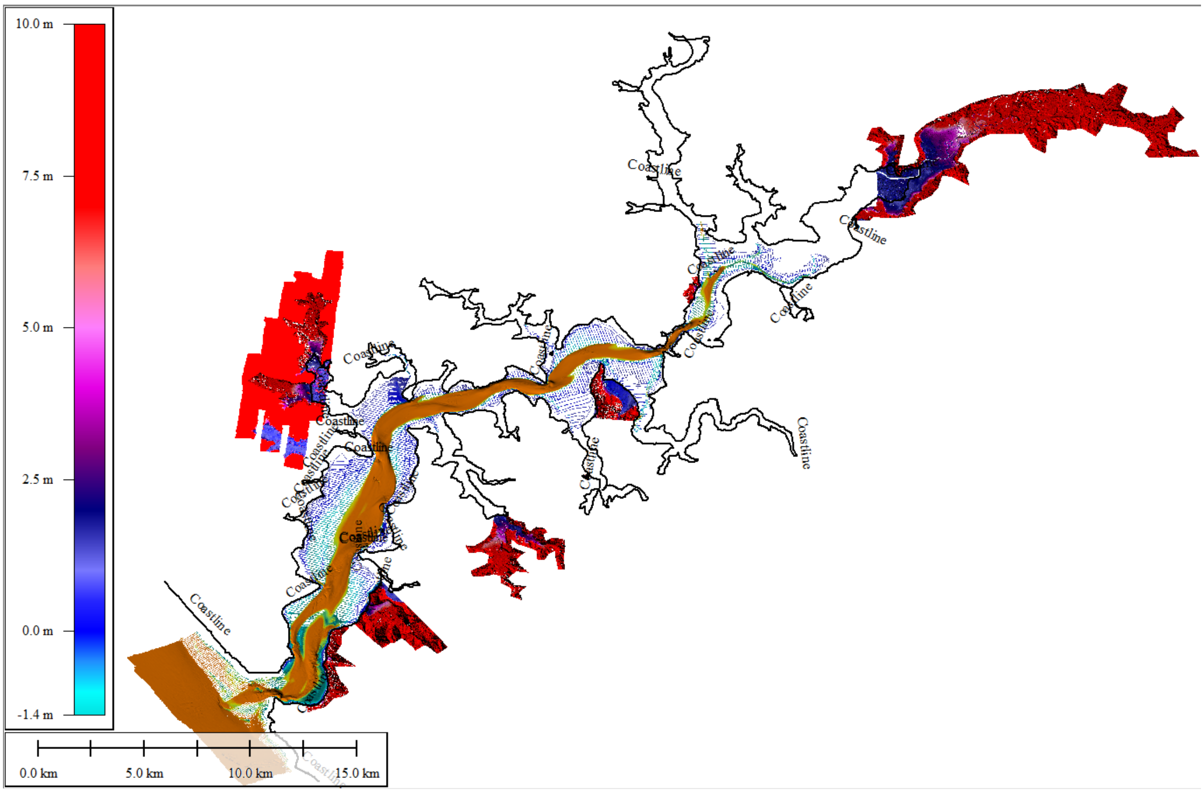

Figure 4.2: Compilation of all bathymetric data used to prepare the hydrodynamic model bathymetry of Hokianga Harbour.

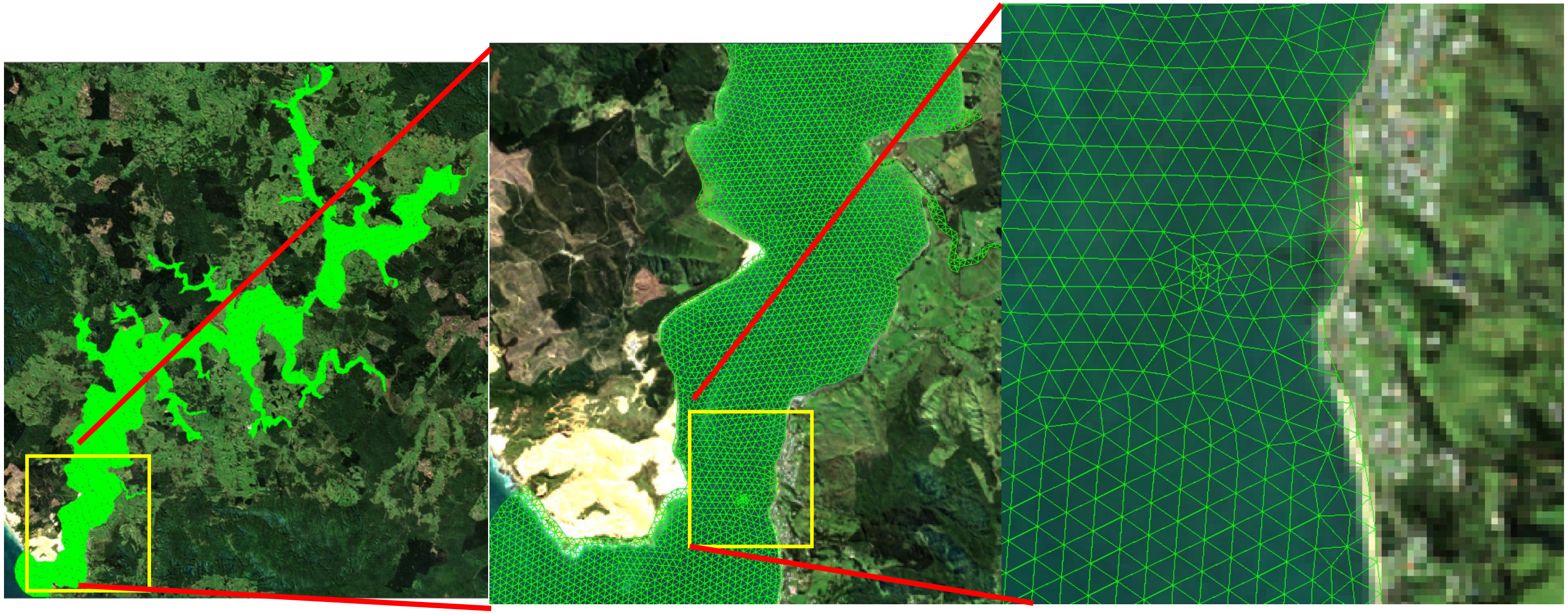

Figure 4.3 Triangular model mesh defined for the Hokianga Harbour. Left is the whole domain and right shows the grid refinement around the Opononi discharge location.

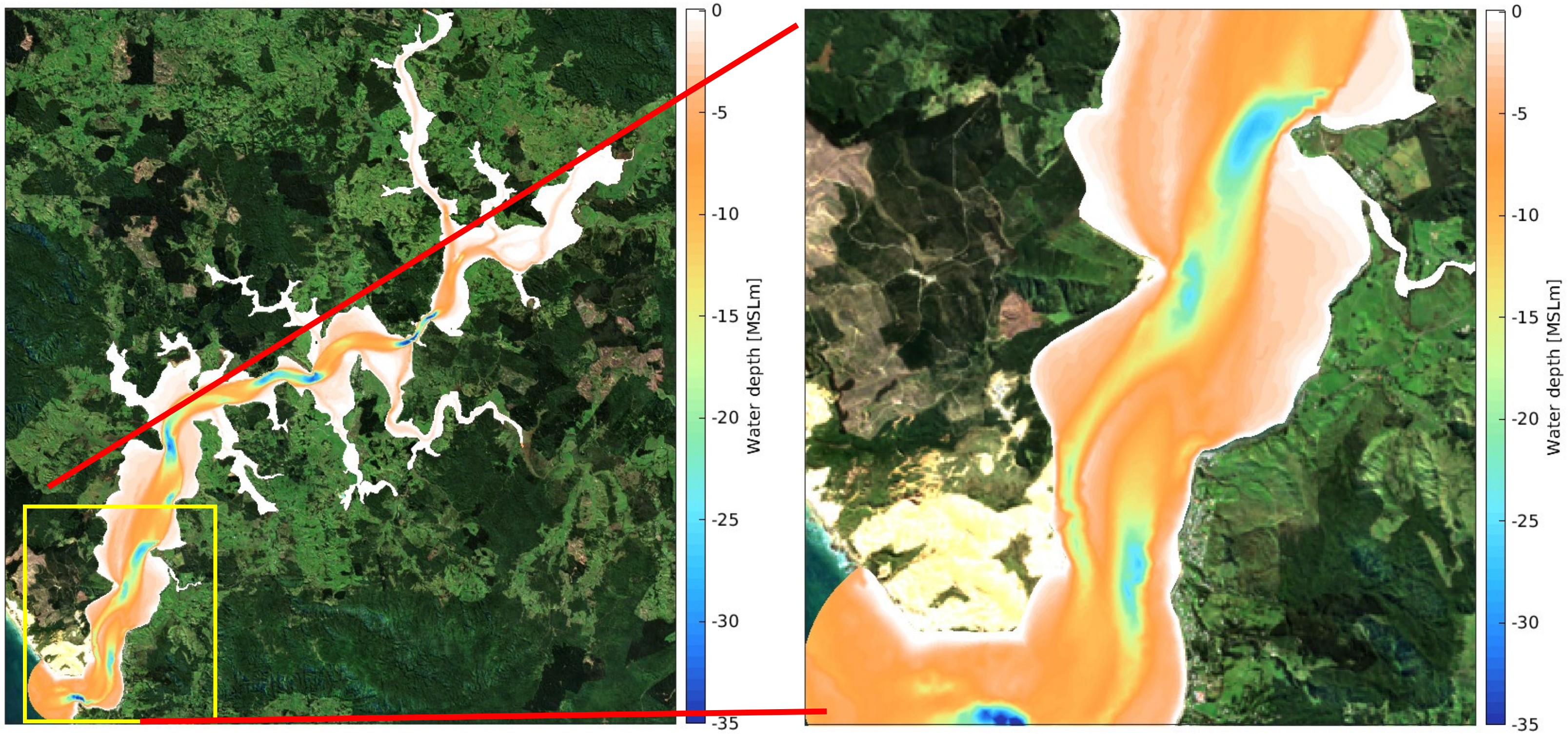

Figure 4.4 Bathymetry of model domain showing the water depth in m below mean sea level. Left is the whole domain and right is a zoom over the Opononi discharge location.

4.2.3 Vertical discretisation

For this model simulations, the vertical discretisation of the water column consisted of a Localized Sigma Coordinate system with Shaved Cell (LSC^2), a type of terrain-following layers as described in Zhang et al. (2014).

The use of this type of vertical grid was dictated by the stratification of the water column as well as the shallows area in the Northern end of the Harbour. The vertical grid is constituted of quadratic terrain-following coordinate with 4 layers near in the shallow area (less than 2m) and 24 layers near the offshore boundary A vertical section showing both the sigma layers and the water depths along a transect is presented in Figure 4.5.

For this study, the model was configured with increased vertical resolution at the surface. The vertical discretisation used in this study is appropriate for investigating the stratified flow regime that is expected within the harbour due to the mixing of the river fresh water and denser marine waters which leads to a concentration of fresh water in the upper levels of the water column.

In order to add more accuracy in the shallow region, the model was setup so that the minimum water depth calculated by the model is 0.001m. In other words, depth less than 1mm is considered dry.

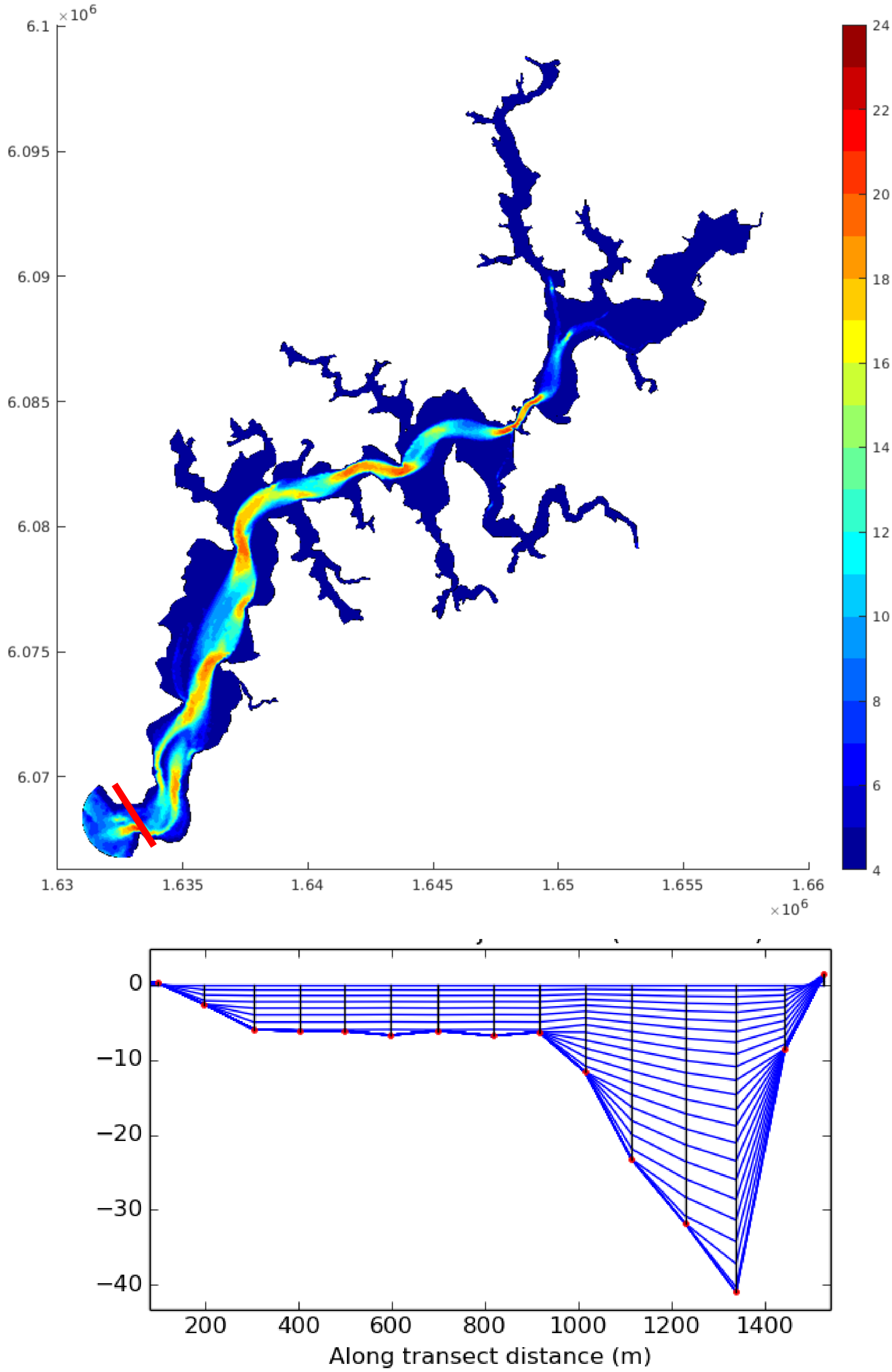

Figure 4.5 Map of Hokianga harbour showing the number of vertical level used in the model (left) and the cross section represented by the black line is shown on the right picture. Note the vertical resolution is increased near the surface to resolve the fresh water forcing.

4.2.4 Vertical mixing / turbulence closure

Vertical mixing was modelled using a *GLS* model with a (Kantha and Clayson 1994) stability function with minimum and maximum diffusivities set to $1x10^{-4}$ and $1x10^{-2}$, respectively, following model validation and calibration. These values were adjusted as part of the model validation and calibration process.

The constant surface mixing length was held to the recommended default of 0.1 (i.e. 10% of the uppermost sigma layer); however, variations of the mixing length were examined during the validating and calibration process.

Frictional stress at the seabed was approximated with a quadratic drag law, with the drag coefficient (*CD*) determined using a manning coefficient of 0.01. Detailed explanations of the determination of the drag coefficient are given in (Zhang Y.L. and Baptista 2008).

4.2.5 Submerged Aquatic Vegetation

In order to include the mangroves ecosystem in the model, the Submerged Aquatic Vegetation (SAV) module was used. By using the SAV module the drag coefficient is increased (a coefficient of 1.13) and therefore affect the flow velocity.

Figure 4.6 Aerial photography of Hokianga Harbour showing in red the mangrove habitat used in the SCHISM model

4.3 Boundary Conditions and Forcing

4.3.1 Atmospherics Forcing

MetOcean Solutions maintains an up-to-date 12 km resolution New Zealand atmospheric hindcast reanalysis from 1979 to 2019 using the Weather and Research Forecasting (WRF) model and deriving boundary conditions from the global CFSR product. The improvement in resolution from the 35 km of CFSR adds accuracy and variability to the atmospheric fields that force the hydrodynamic models, especially over coastal margins where topography is known to substantially change the large-scale wind patterns and local responses. WRF reanalysis prognostic variables such as winds, atmospheric pressure, relative humidity, surface temperature, long and short wave radiation, and precipitation rate were used at hourly intervals to provide air-sea fluxes to force SCHISM in all domains, using a *bulk flux* parameterization (Fairall et al., 2003).

4.3.2 Open Boundary and Tidal Forcing

Tidal constituents were calculated from a greater New Zealand SCHISM domain (Figure 4.7). This New Zealand domain was run in hindcast baroclinic mode for a 10-year period spanning 2000-2009. Depth averaged velocity, elevations, tidal phases and amplitudes for the salient primary and secondary tidal constituents were derived near the Hokianga harbour entrance using harmonic analysis.

Residual surface elevation at the offshore boundary is a combined from multiple factors (Atmospheric pressure, tide and wave). In this study, the inverse barometric effect (IB) was calculated from the WRF mean sea level pressure. The impact of the wave on the offshore boundary was calculated using a basic wave set-up equation from Goda (1985), Where H_o is the wave height and L_o is the wavelength.

Wave setup (Goda 1985): $$\frac{0.01H_o}{\sqrt{\frac{H_o}{L_o}\left(1+\frac{h}{H_o}\right)}}$$ (Eq. 4.1)

The final residual surface elevation is the sum of the IB and the wave setup (Figure 4.8)

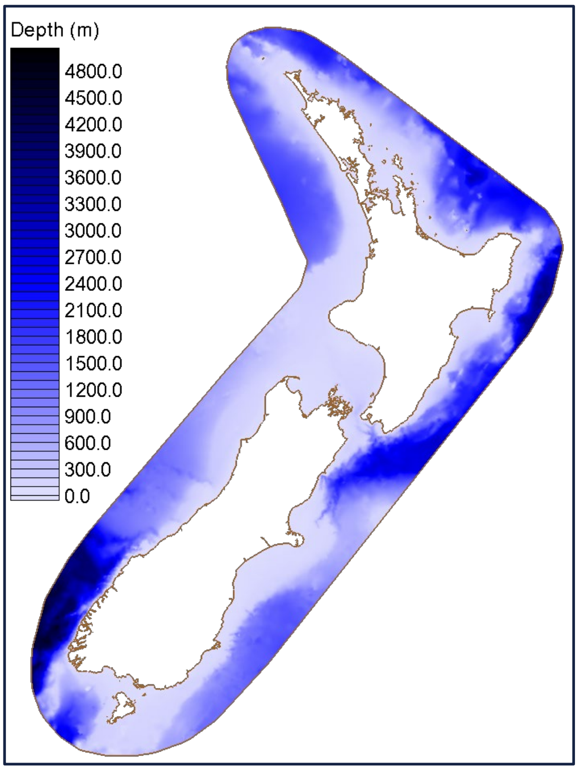

Figure 4.7 Extent of the NZ scale finite element domain used to derive tidal constituents at the Hokianga harbour entrance.

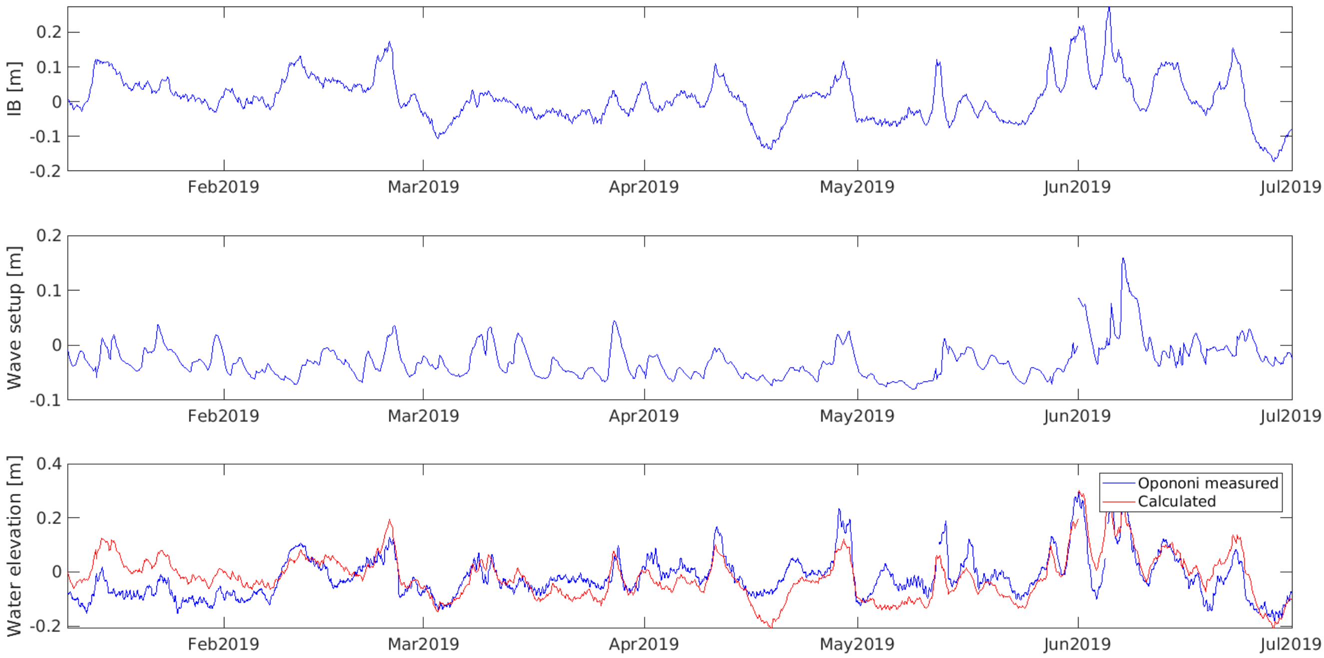

Figure 4.8 Time series of the IB calculated from the mean sea level pressure from WRF model (top).Timeseries of the wave setup calculated from the wave height at the offshore boundary using the equation from Goda 1985.(middle). Comparison of the residual elevation from IB and wave setup with the residual elevation measured at Opononi.

4.3.3 River Discharges

Only four major rivers were included in the model: Waima river, Waihou River, Orira River and the Mangamuka River (Figure 4.10).

Discharge records of Waihou and Waima rivers measured between 1989 and 2019 by NIWA and Northland Regional Council were processed to force the SCHISM domains. Due to the limited available data for Mangamuka River, a time series discharge rates for this river was estimated based on a ratio between the mean discharge rate from the Mangamuka and Waihou Rivers. The discharge from the Orira River was made constant and the mean discharge was used (0.4 m^3/s)

In order to include the runoff from the surrounding streams, the rivers discharge were increased by a percentage calculated during the calibration of the model (Table 4.1).

Table 4.1 Factor used for each of the river in order to account for the run off in Hokianga harbour.

River	Factor
Waihou	1.16
Mangamuka	1.25
Waima	1.10

The time series of the Waima river and Waihou river discharges are presented in Figure 4.9

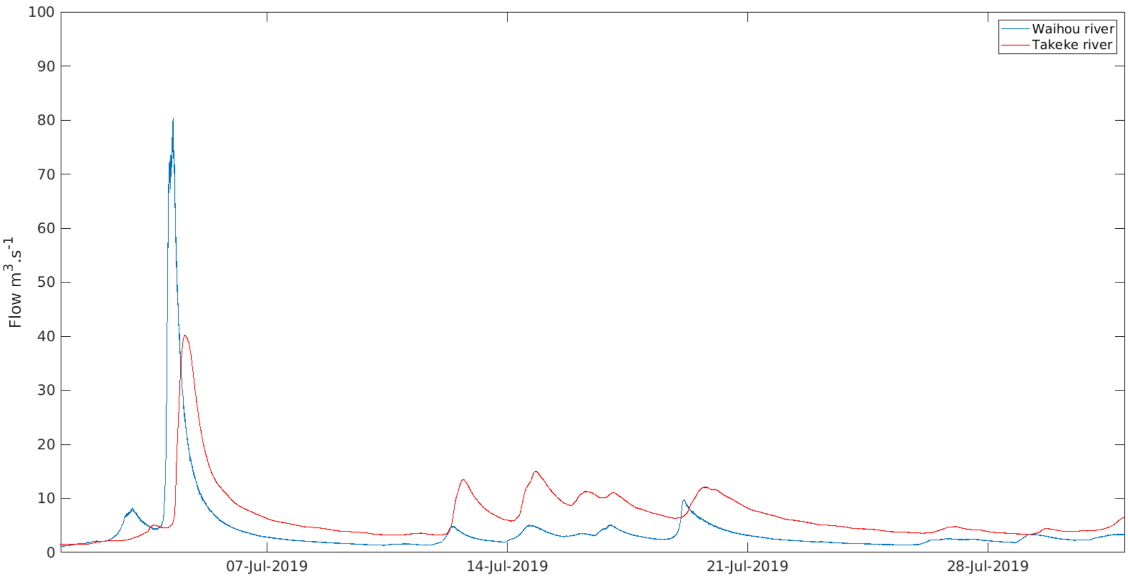

Figure 4.9 Timeseries of the Waihou and Waima river flow used during the validation period of the model.

Figure 4.10 Aerial photography showing in red the four rivers included in the model

4.3.4 Temperature and Salinity

A vertically and horizontally uniform salinity and temperature fields were applied to the open ocean model boundary from the HYCOM model.

River salinity was defined as fresh water (0 PSU), and river temperature was only measured at the Waiapa river (upstream from Waihou river).

The same temperature was used in all rivers. A time series of river temperature is presented in Figure 4.11.

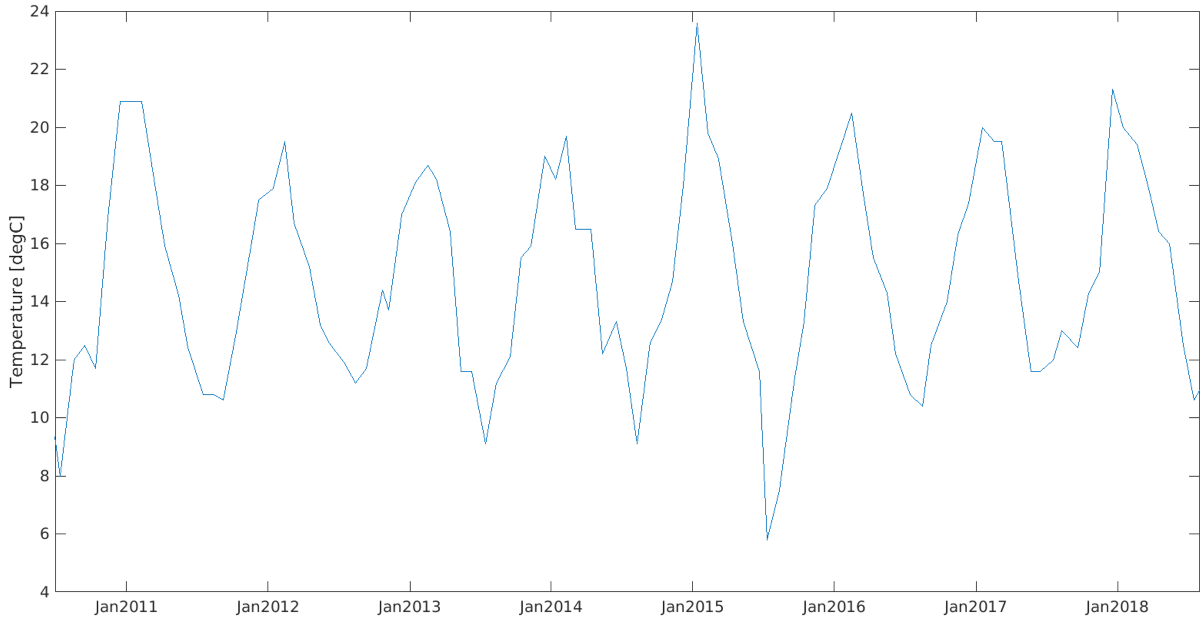

Figure 4.11 Timeseries of river temperature, measured at Waiapa river, used for all the rivers in the Hokianga Harbour model between 2010 and 2018

4.3.5 WWTP Discharges

As presented in the FNDC documents details of the WWTP discharges into Hokianga Harbour are as follows:

Opononi WWTP - 1634768E 6069462N (NZTM 2000)

- Discharged directly into the harbour via outfall pipe.
- Pumped from a holding pond and discharged into the harbour for maximum of 4 hours on an outgoing tide.
- Treated wastewater shall only be discharged to the Harbour for a max. of 3 hours each tidal cycle between one and four hours after high tide.
- Discharge Limit 450m3/day (revised from 685m3 previously)

Kohukohu WWTP – 1648973E 6085591N (NZTM 2000)

- Discharged into unnamed tributary of the Hokianga Harbour (tidal mud flat)
- Continuous gravity discharge. Known to have zero discharge in dry periods.
- Discharge limit 40m3/day (30 days average)

Rawene WWTP - 1645309E 6079915N (NZTM 2000)

- Discharged into Omanaia River (tidal mud flat)
- Continuous gravity discharge from the WWTP but once the discharge enters the drain it is controlled by a flood gate discharging to the Omanaia River. There are other contributors to the drain and therefore the discharge from the floodgate.
- Discharge limit 254m3/day (30 days average)

Kaikohe WWTP (1674845E 6079488N.)

- Discharged into unnamed tributary of the Wairoro Stream
- Continuous gravity discharge into freshwater that runs into the Hokianga Harbour.
- Discharge limit 1710m^3/day (30 days average)

Nearfield:

Each of the four WWTP discharge are occurring either via an outfall pipe or via continuous gravity discharge which therefore did not have any structural design which would lead to complex dilution patterns (diffuser, multiple pipe arrangement…). The nearfield dilution is expected to simply occur as the discharge water mixes with the stream water or the Hokianga Harbour water. The SCHISM model represents the release of the contaminant as a discharge flow (with a tracer concentration [C]) in a model cell similarly to that of a pipe on the seabed (or with gravity discharge on dry land). The near field dilution is then occurring within that model cell .The representation in the numerical model as a discharge source is therefore suitable for assessing the fate and dispersion of the WWTP waters in the harbour.

Discharge Timeseries:

In order to model the four discharges a review of the discharge rate timeseries data was undertaken (see Figure 4.12) and an annual representation of the variability in the discharge rate, as well as a maximum, close to the proposed resource consent was chosen for each of the four discharge locations (Figure 4.13 and Figure 4.14). If needed, the discharge was increased to reach the resource consent limit.

Opononi was set up to only discharge up to four hours following high tide.

The probability of future estuarine conditions can be assessed from the historical conditions, thereby allowing estimations of the general geographical dispersion expected. In the present study, the approach consists in running year-long simulations within two contrasting historical contexts (La Niña /El Niño episodes, June 2010 - June 2011, and June 2015 - June 2016, respectively).

The yearlong run simulation was extended by two days with a discharge rate increased to the highest discharge recorded in order to assess the impact of an extreme isolated event (Figure 4.14).

Different passive Eulerian tracers (i.e. neutrally buoyant , no decay) were used for each WWTP discharge. A nominated concentration value of 1 mg/L was used so that dilution can be calculated at various distance from the source. Specific contaminant concentration levels can then be determined using concentration ratios and the expected, or measured, discharged value.

For the Kaikohe WWTP the discharge occurs more than 30 km upstream of the Waima River connection to Hokianga Harbour. The WWTP contaminant concentration gets diluted as it flows from Kaikohe to the harbour due to the little tributaries joining along the stream. Timeseries of river discharge data are only available further downstream of the discharge and closer to the harbour (i.e. 'Punakitere at Taheke' data from NRC).

A modelled discharge point closer to the harbour was therefore implemented. A dilution factor of 1/18.4 between the Kaikohe discharge location and the point where the modelled Waima river discharges into the harbour was adopted. Comparing the volume of water from the NIWA river maps service (https://shiny.niwa.co.nz/nzrivermaps/) data, at these two locations allow us to consider all the fresh water input from all the small tributaries between the WWTP discharge point and the modelled discharge point in the harbour. The mean flow value extracted from the NIWA site where 0.768m3/s near the Kaikohe discharge location and 14.1m3/s near the modelled Waima river point, this leas to a ratio of 18.4.It is noted that based on the available data (mean flow, mean annual low flow, 1 in 5-year low flow) this dilution ratio can vary between approximately 1/16 to 1/23.

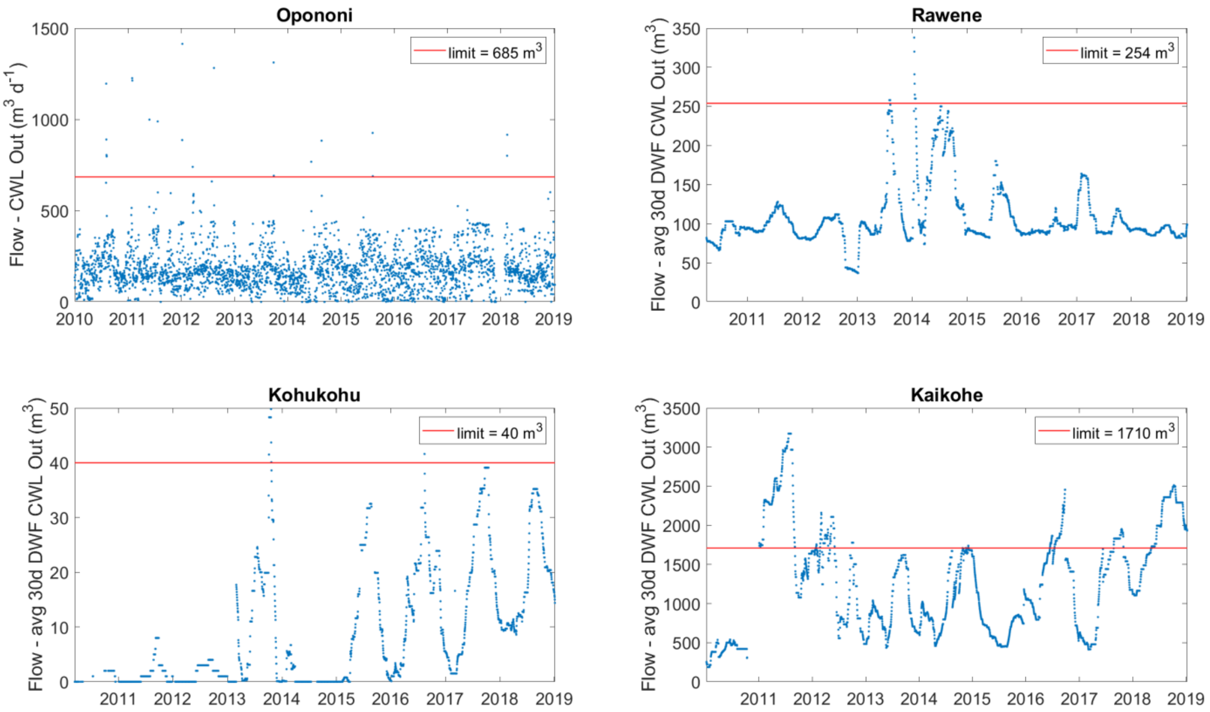

Figure 4.12 Discharge timeseries (blue) and council limits (red) from the four locations

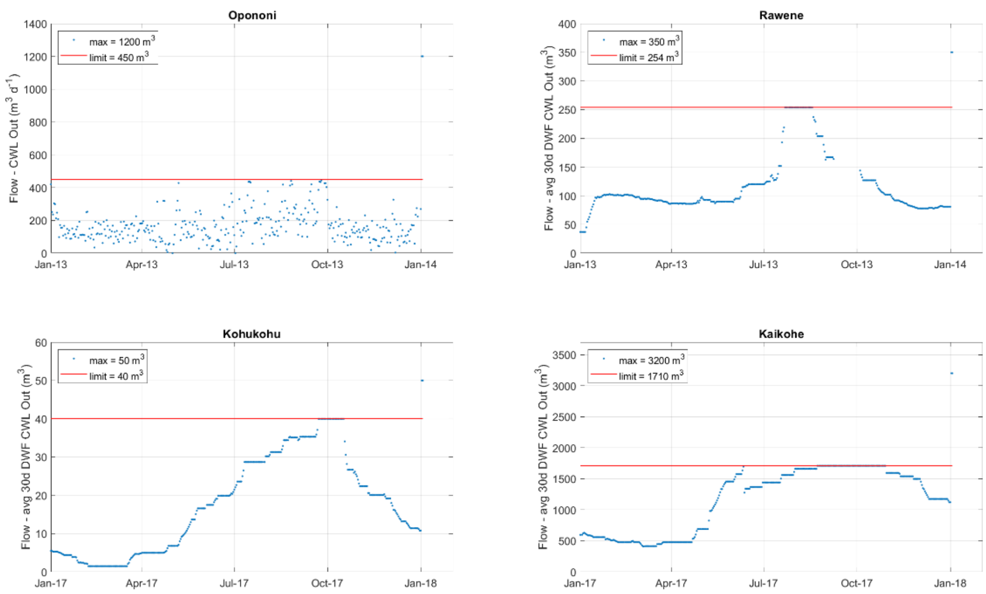

Figure 4.13 Discharge timeseries (blue) and council limits (red) from the four locations selected for use in the modelling

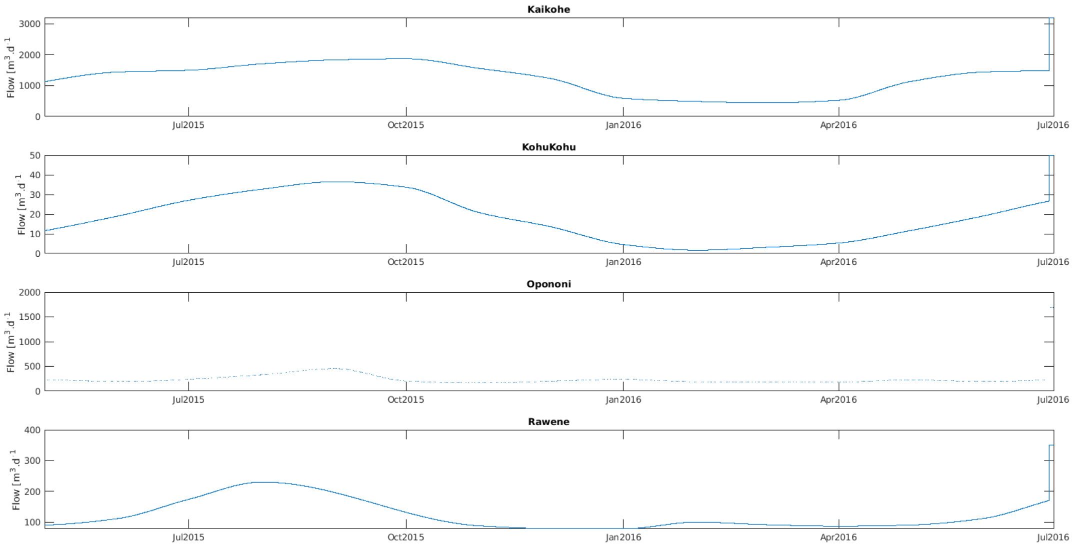

Figure 4.14 Modelled timeseries of discharge rate (in m3/day) from the four discharge locations. Note Opononi was only released during the first four hour of the ebb tide.

5. Results

5.1 Model validation

5.1.1 Elevation

Time series of measured water elevations have been processed and the residual elevations are separated from the tidal elevations.

The amplitudes and phases from M2, S2, N2, K2, K1 and L2 tidal constituents extracted from all data collection sites are shown from Table 5.1 to Table 5.6. Time series of total elevations are shown in Figure 5.1. Residual time series are presented in Figure 5.2.

Comparisons show that the model successfully reproduces the propagation of the tidal wave inside the harbour, with good agreement between both amplitudes and phases of the principal tidal constituents. The misalignment in the time series of the measured and modelled water level at Onoke and The Narrows are due to the movement of the instrument which occurred during the deployment as discussed in Section 2.1.3, nevertheless the water level variations are in good agreement.

Table 5.1 Comparison of measured and modelled amplitude and phase for the M2 constituent at all sites.

M2 constituent	Amplitude [m]		Phase [deg]	
Site name	**Measured**	**Modelled**	**Measured**	**Modelled**
Omapere	0.98	1.01	291.28	289.23
Onoke	1.11	1.08	293.48	296.86
Matawhera	1.14	1.10	302.13	301.65
The Narrows	1.24	1.10	307.76	311.17

Table 5.2 Comparison of measured and modelled amplitude and phase for the S2 constituent at all sites

S2 constituent	**Amplitude [m]**		**Phase [deg]**	
Site name	**Measured**	**Modelled**	**Measured**	**Modelled**
Omapere	0.25	0.25	322.28	316.62
Onoke	0.30	0.29	326.00	322.83
Matawhera	0.28	0.31	336.87	326.98
The Narrows	0.30	0.32	339.20	335.93

Table 5.3 Comparison of measured and modelled amplitude and phase for the N2 constituent at all sites

N2 constituent	**Amplitude [m]**		**Phase [deg]**	
Site name	**Measured**	**Modelled**	**Measured**	**Modelled**
Omapere	0.21	0.19	286.87	276.65
Onoke	0.24	0.20	292.74	286.25
Matawhera	0.24	0.20	299.92	291.98
The Narrows	0.26	0.20	306.89	301.51

Table 5.4 Comparison of measured and modelled amplitude and phase for the K2 constituent at all sites

K2 constituent	**Amplitude [m]**		**Phase [deg]**	
Site name	**Measured**	**Modelled**	**Measured**	**Modelled**
Omapere	0.08	0.08	320.89	322.66
Onoke	0.12	0.12	321.54	338.78
Matawhera	0.09	0.14	327.36	344.99
The Narrows	0.12	0.16	308.89	356.66

Table 5.5 Comparison of measured and modelled amplitude and phase for the K1 constituent at all sites

K1 constituent	**Amplitude [m]**		**Phase [deg]**	
Site name	**Measured**	**Modelled**	**Measured**	**Modelled**
Omapere	0.06	0.07	34.14	33.88
Onoke	0.08	0.07	41.38	38.59
Matawhera	0.07	0.07	41.31	41.17
The Narrows	0.09	0.07	32.81	46.16

Table 5.6 Comparison of measured and modelled amplitude and phase for the L2 constituent at all sites

L2 constituent	**Amplitude [m]**		**Phase [deg]**	
Site name	**Measured**	**Modelled**	**Measured**	**Modelled**
Omapere	0.05	0.01	283.54	232.30
Onoke	0.06	0.03	250.81	253.33
Matawhera	0.08	0.04	284.07	259.66
The Narrows	0.04	0.04	271.83	270.39

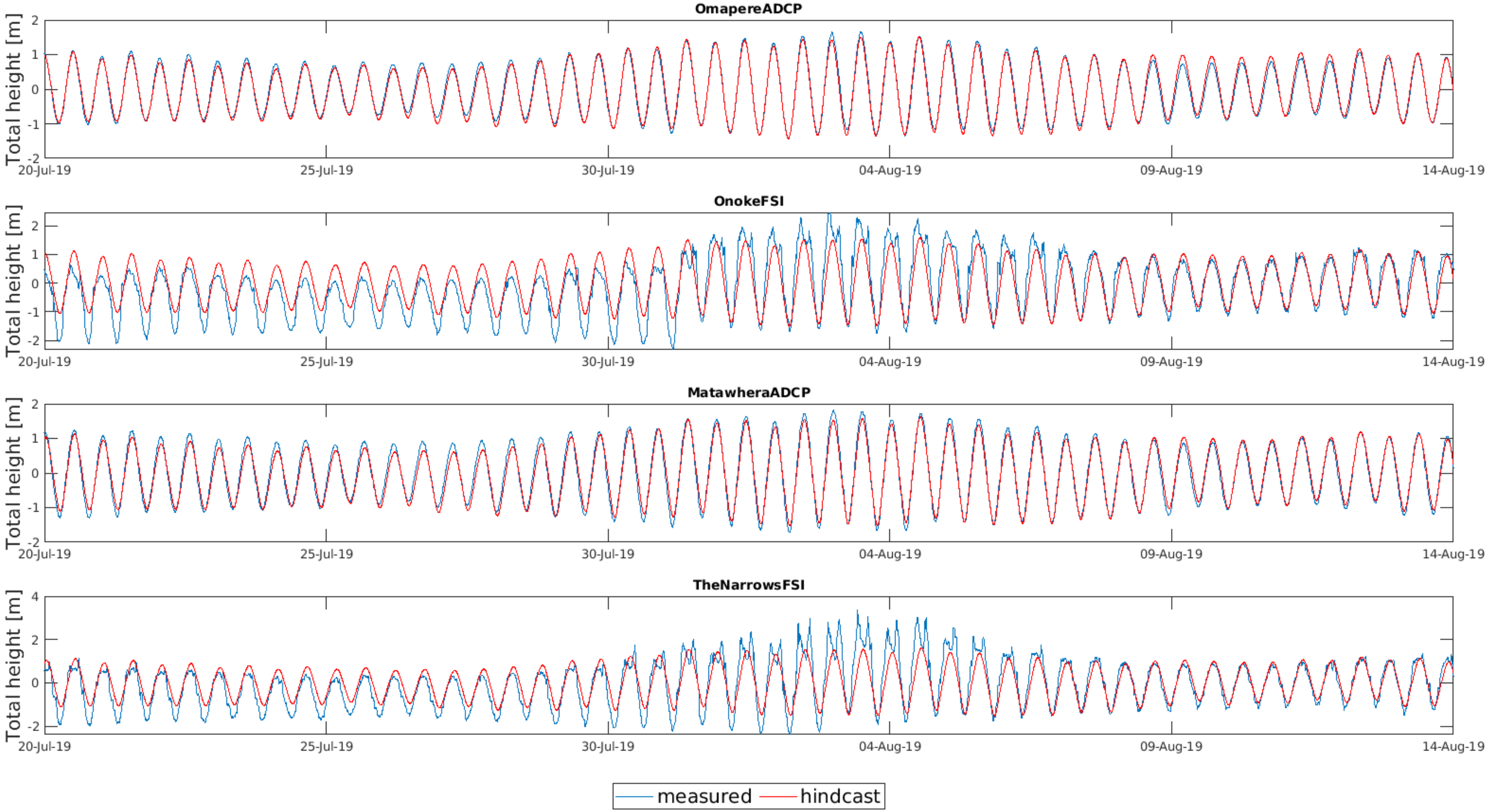

Figure 5.1 Timeseries of water elevation measured at the four sites (blue) and modelled (red) between July 2019 and August 2019. Note: the two FSIs have moved positioned during the measurement period.

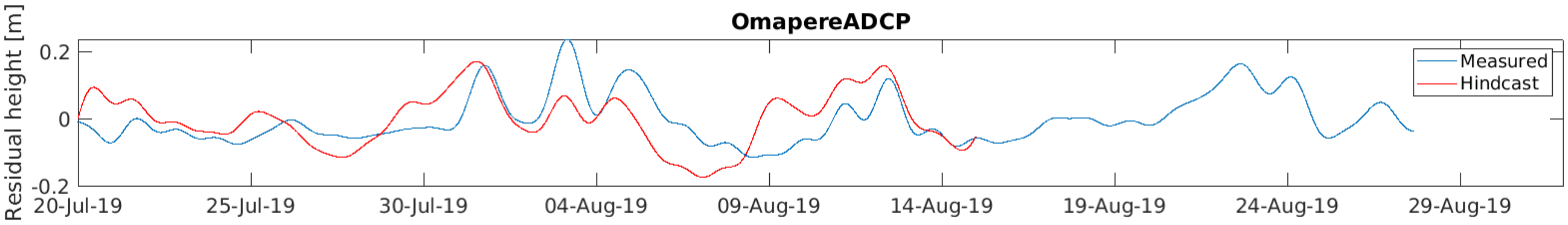

Figure 5.2 Timeseries of residual water elevation measured at Opononi sites (blue) and modelled (red) between July 2019 and August 2019

5.1.2 Velocities

The comparison of the total current speeds and directions at three levels in the water column at the Omapere ADCP site are presented in Figure 5.3 and Figure 5.4 respectively. Tidal signal was removed from the velocities, and currents were rotated in the channel axes. The resultant velocities are presented in Figure 5.5.

Comparison of current speeds and direction at Onoke and The Narrows are presented in Figure 5.6 and Figure 5.10 respectively. For both FSI sites, the extraction of the tidal signal was not possible due to the shift of the instrument during the deployment.

The comparison of the total current speeds and directions at three levels in the water column at the Matawhera ADCP site are presented in Figure 5.7 and Figure 5.8 respectively. Tidal signal was removed from the velocities, and currents were rotated in the channel axes. The resultant velocities are presented in Figure 5.9.

At all sites, the model reproduces well the tidal signal in the entire water column. More precisely, the amplitude difference between the ebb and flood current is modelled correctly especially at the Matawhera site (Figure 5.7).

The model tends to reproduce the current more accurately toward the end of the deployment (in August). This could be due to the freshwater influence on the environment. Higher precipitation rate and higher discharge from the river were observed between the 14th and 20th of July 2019 (Figure 4.9).

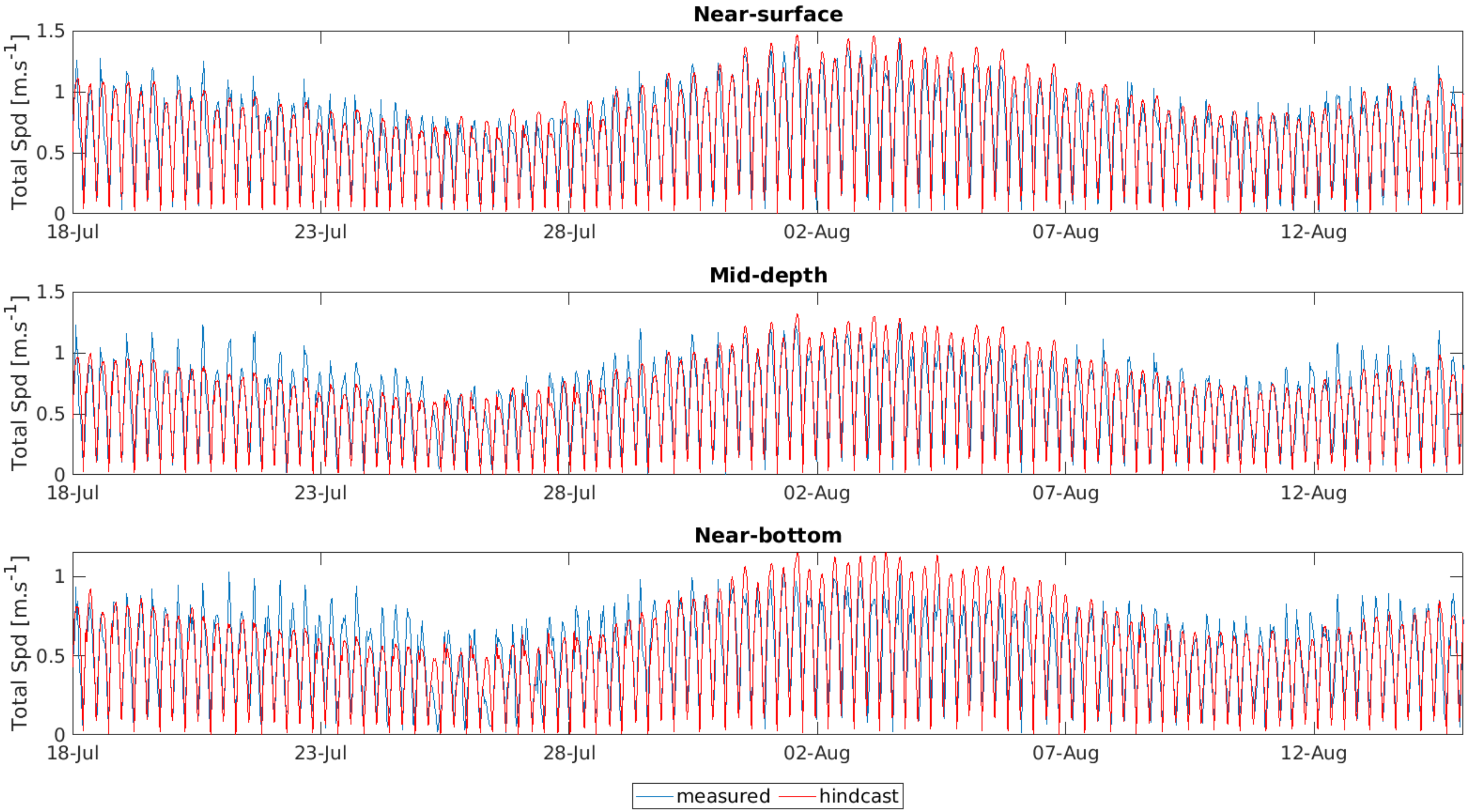

Figure 5.3 Measured (blue) and modelled (red) total near-surface (top), mid-depth (middle), and near-bottom (bottom),current speeds at Omapere ADCP site from July 2019 to August 2019.

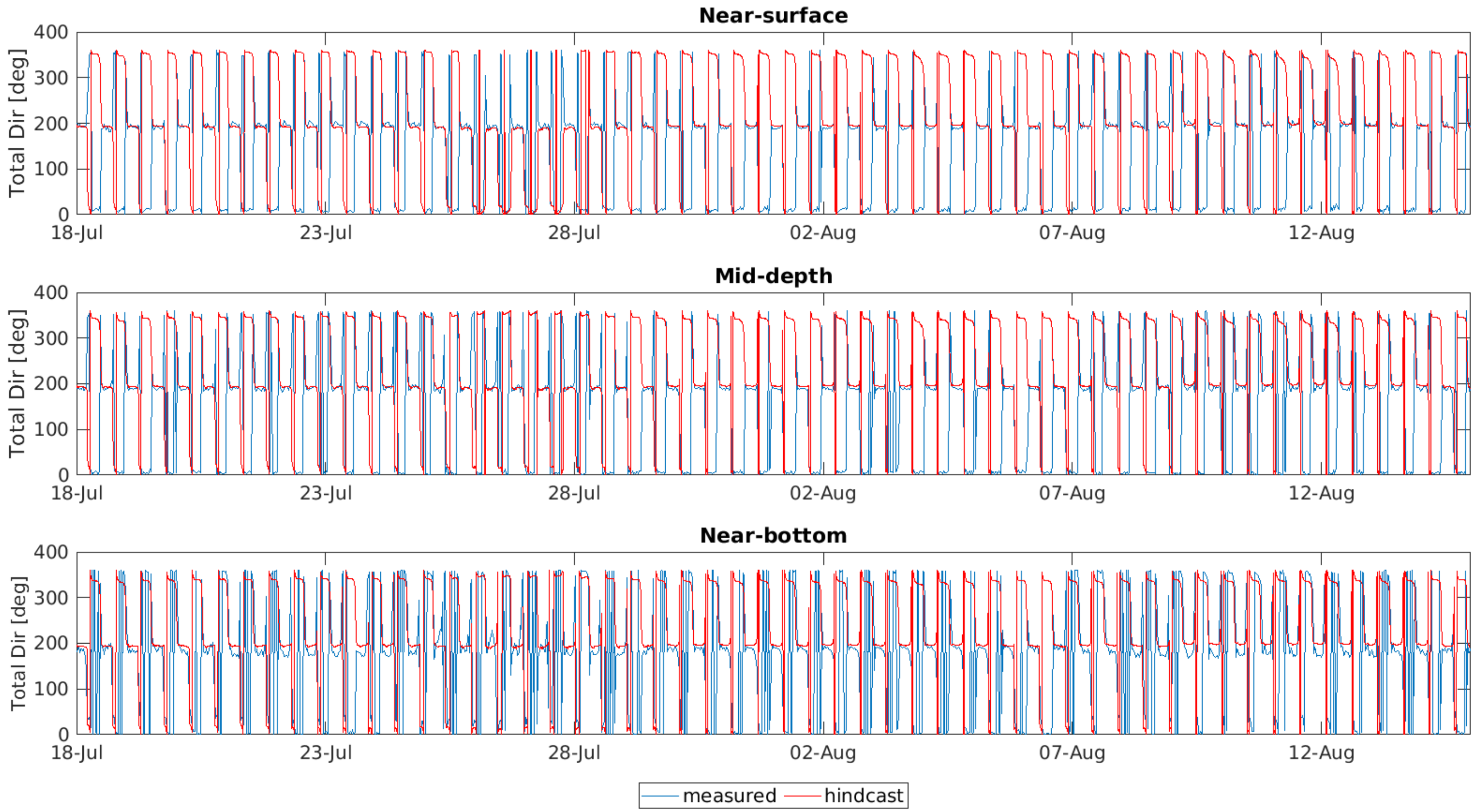

Figure 5.4 Measured (blue) and modelled (red) total near-surface (top), mid-depth (middle), and near-bottom (bottom),current direction at Omapere ADCP site from July 2019 to August 2019

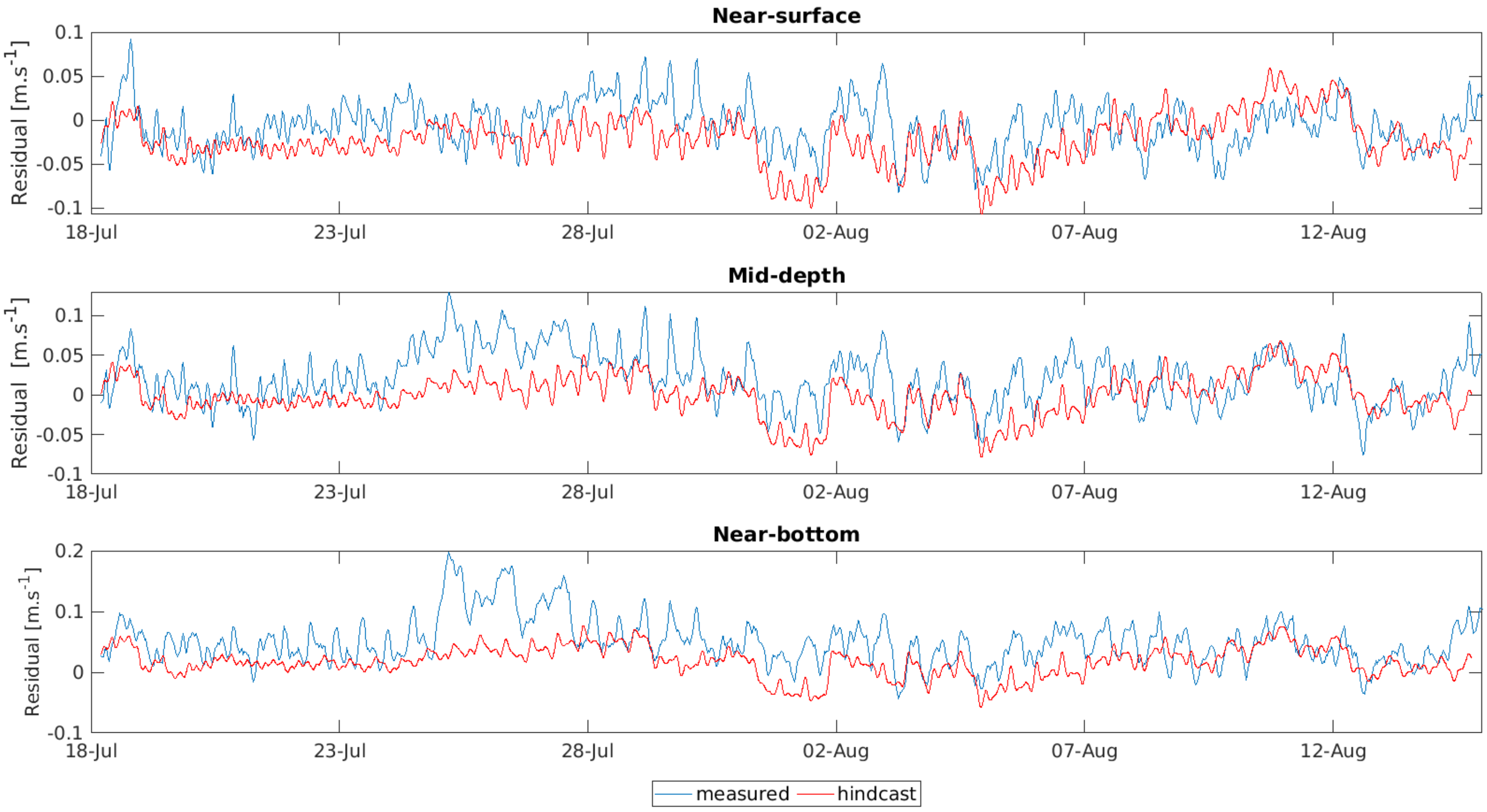

Figure 5.5 Measured (blue) and modelled (red) total near-surface (top), mid-depth (middle), and near-bottom (bottom),Residual velocities at Omapere ADCP site from July 2019 to August 2019. Note the current were rotated to be aligned with the main channel.

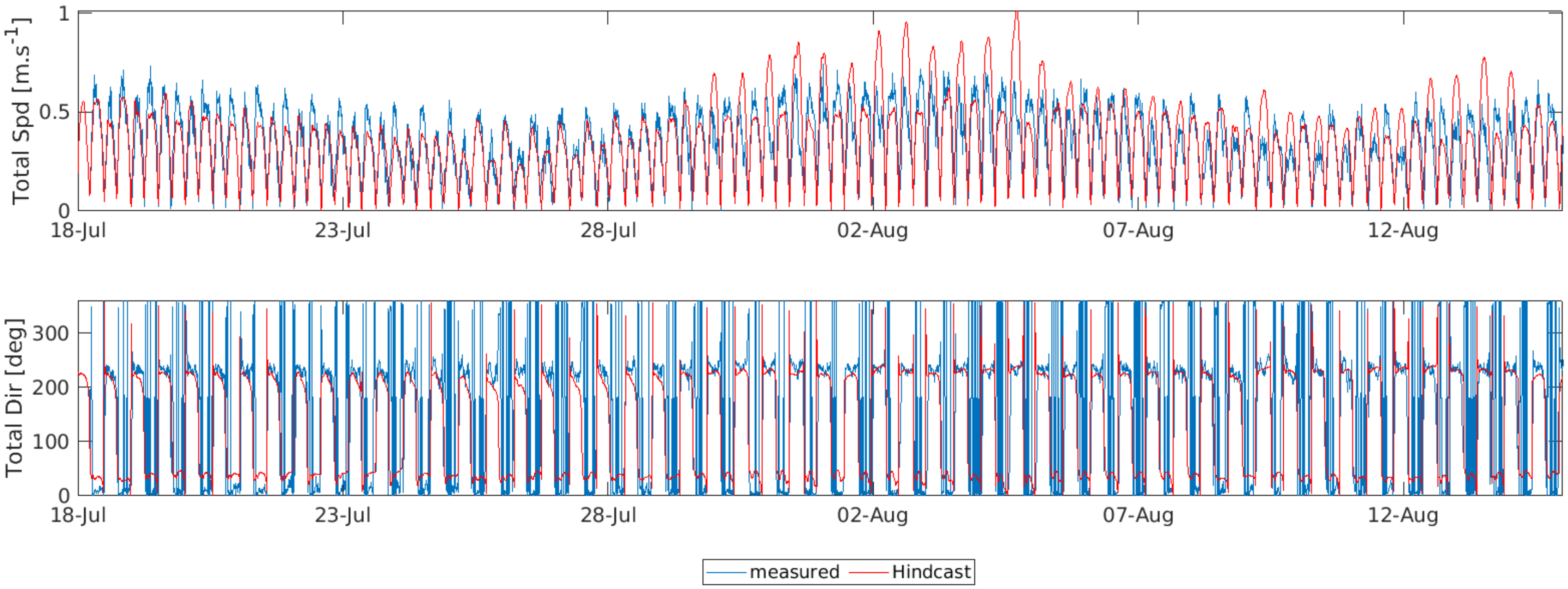

Figure 5.6 Measured (blue) and modelled (red) total mid-depth current speeds (top) and direction (bottom) at Onoke FSI site from July 2019 to August 2019

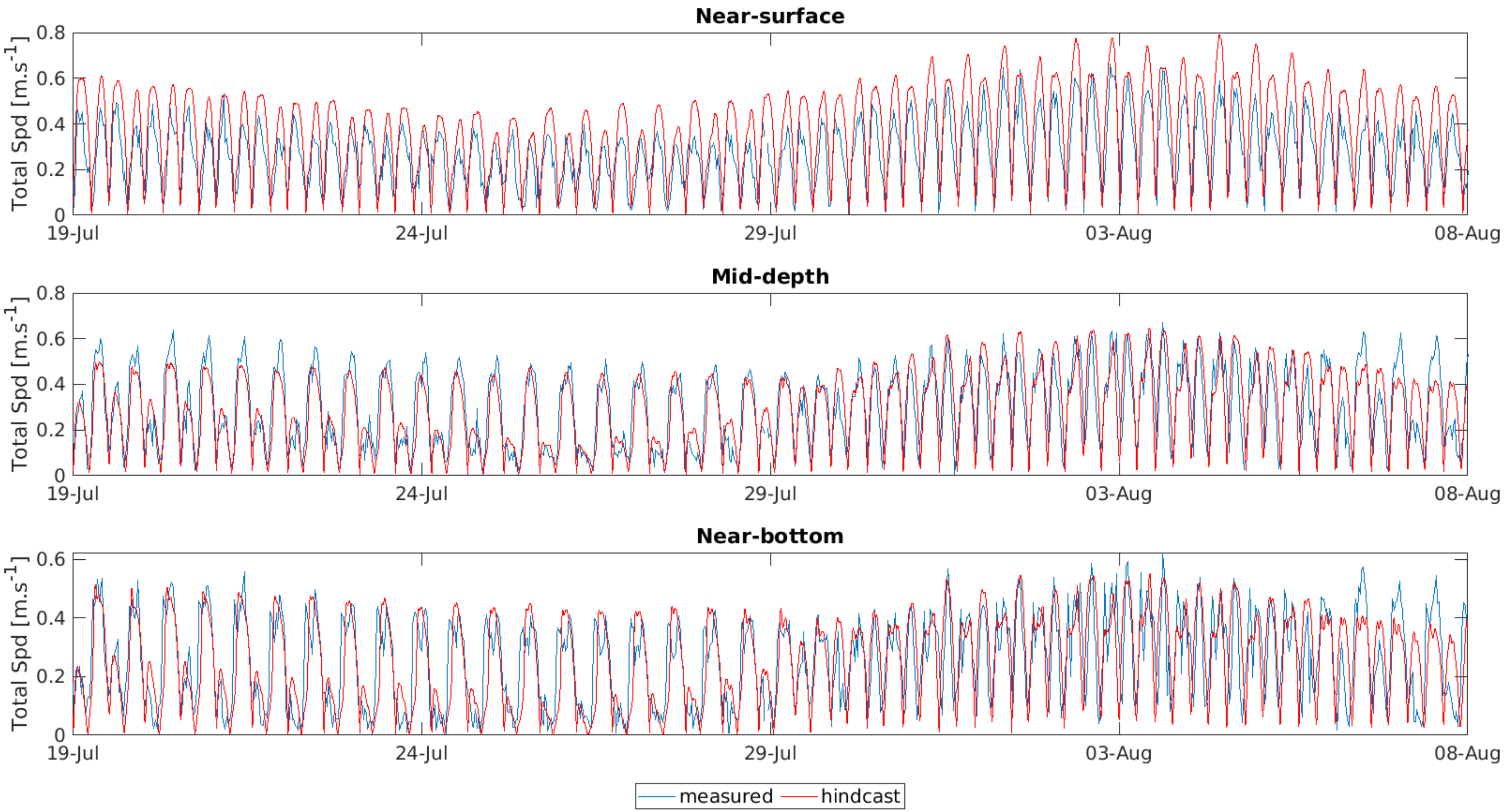

Figure 5.7 Measured (blue) and modelled (red) total near-surface (top), mid-depth (middle), and near-bottom (bottom),current speed at Matawhera ADCP site from July 2019 to August 2019

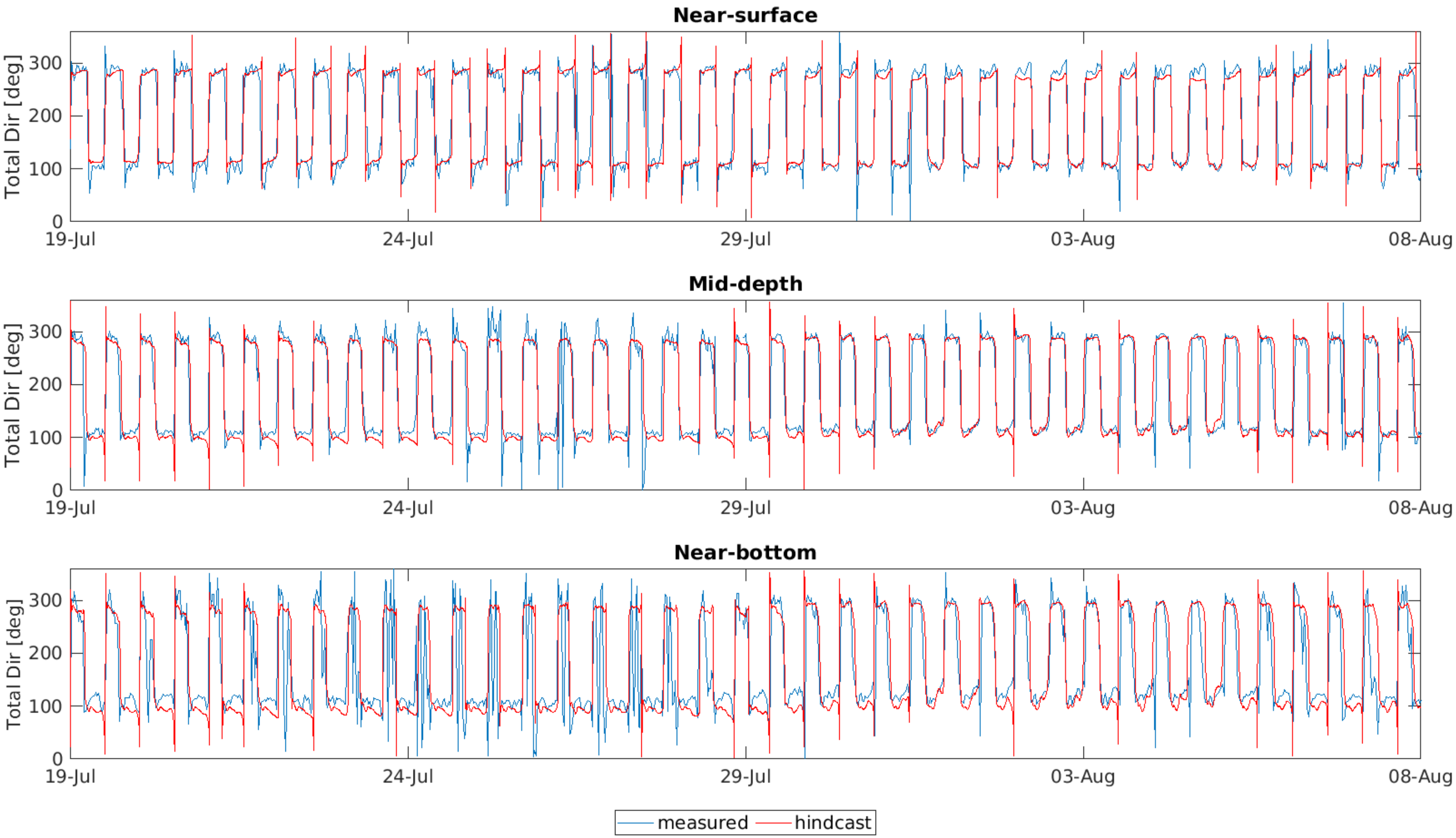

Figure 5.8 Measured (blue) and modelled (red) total near-surface (top), mid-depth (middle), and near-bottom (bottom),current direction at Matawhera ADCP site from July 2019 to August 2019

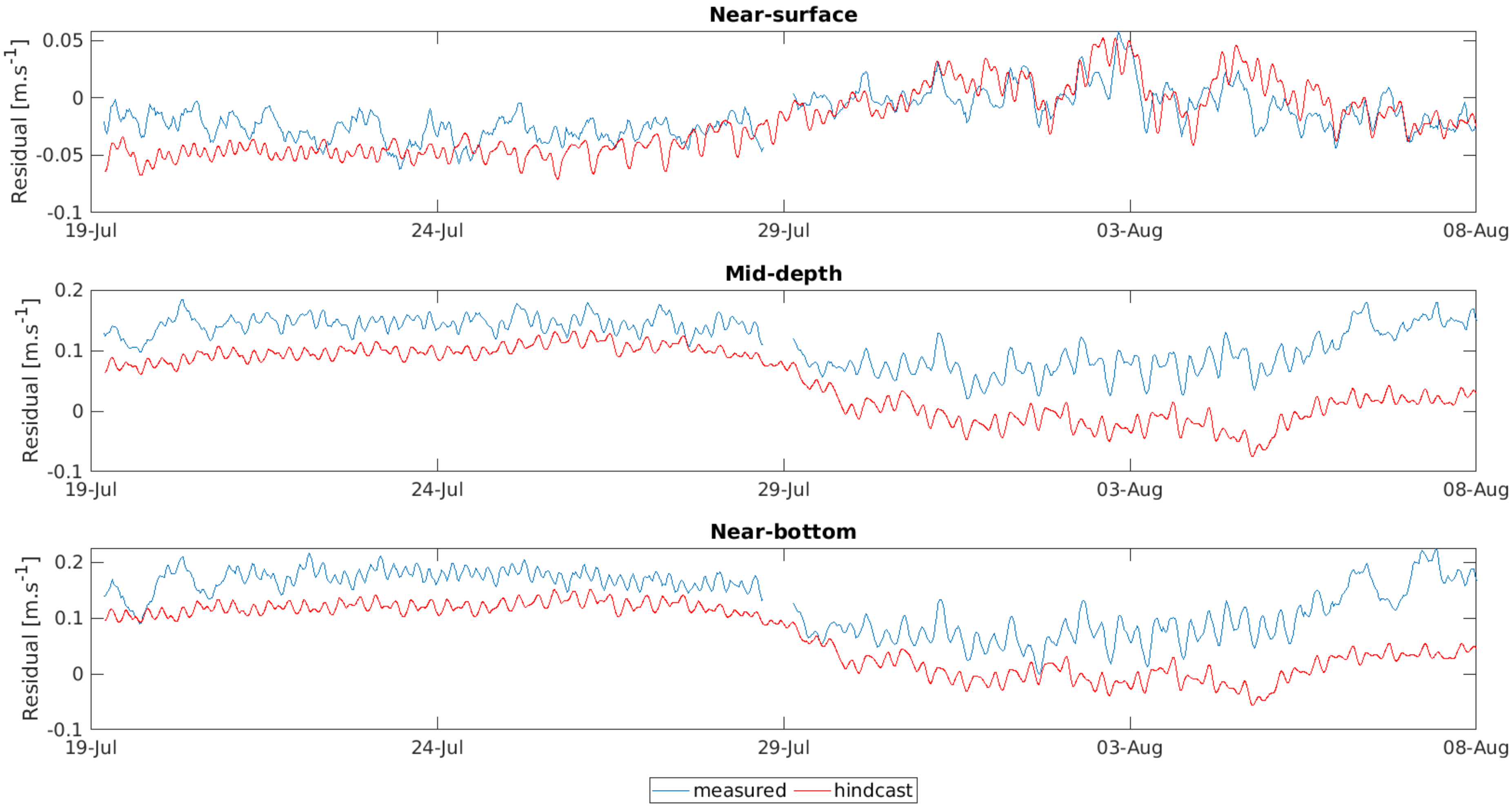

Figure 5.9 Measured (blue) and modelled (red) total near-surface (top), mid-depth (middle), and near-bottom (bottom),Residual velocities at Matawhera ADCP site from July 2019 to August 2019. Note the current were rotated to be aligned with the main channel

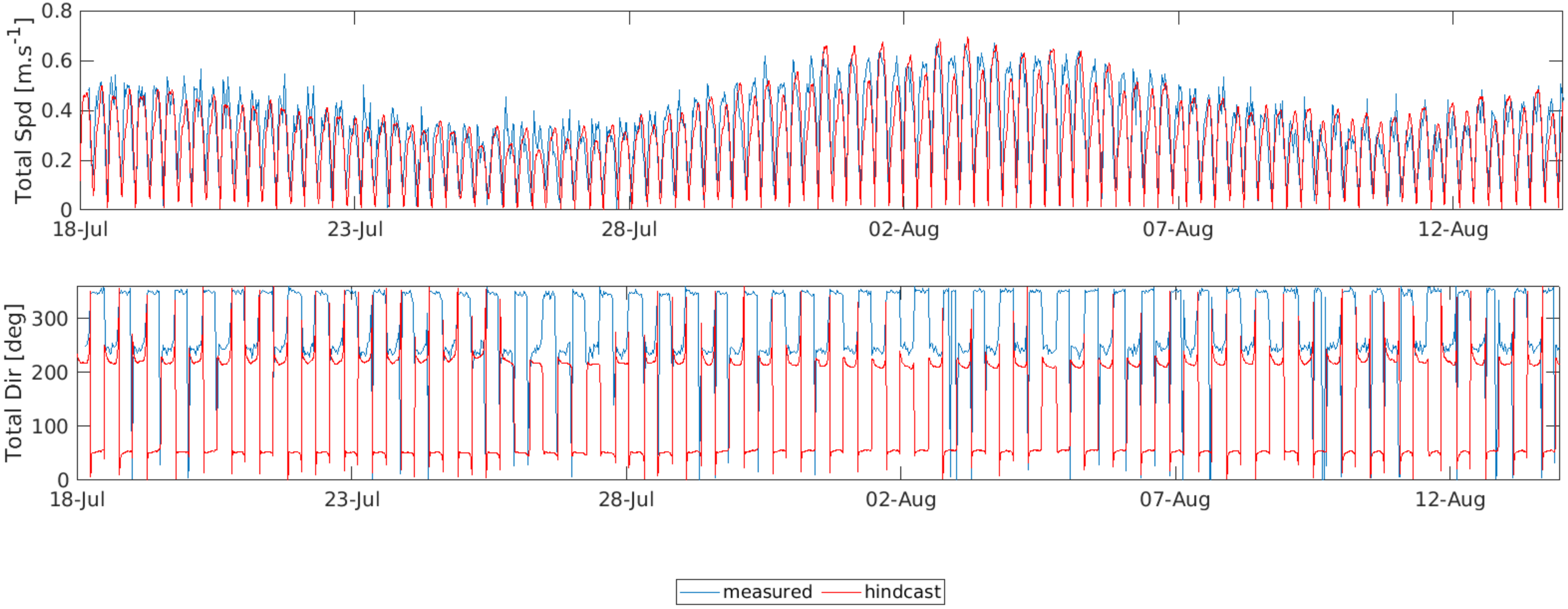

Figure 5.10 Measured (blue) and modelled (red) total mid-depth current speeds (top) and direction (bottom) at The Narrows FSI site from July 2019 to August 2019

5.1.3 Temperature and salinity

Timeseries of near-bottom temperature at all sites are presented in Figure 5.11. The temperature at the entrance of the harbour is modelled more accurately than the northern part of Hokianga Harbour.

Comparisons of mid-depth salinities are presented in Figure 5.12.

The variation and trend in temperature and salinity over the measurement period is well described by the model. Difference in the absolute temperature and salinity values are observed, however these are mostly related to the minimal information available to setup the initial conditions in the model .

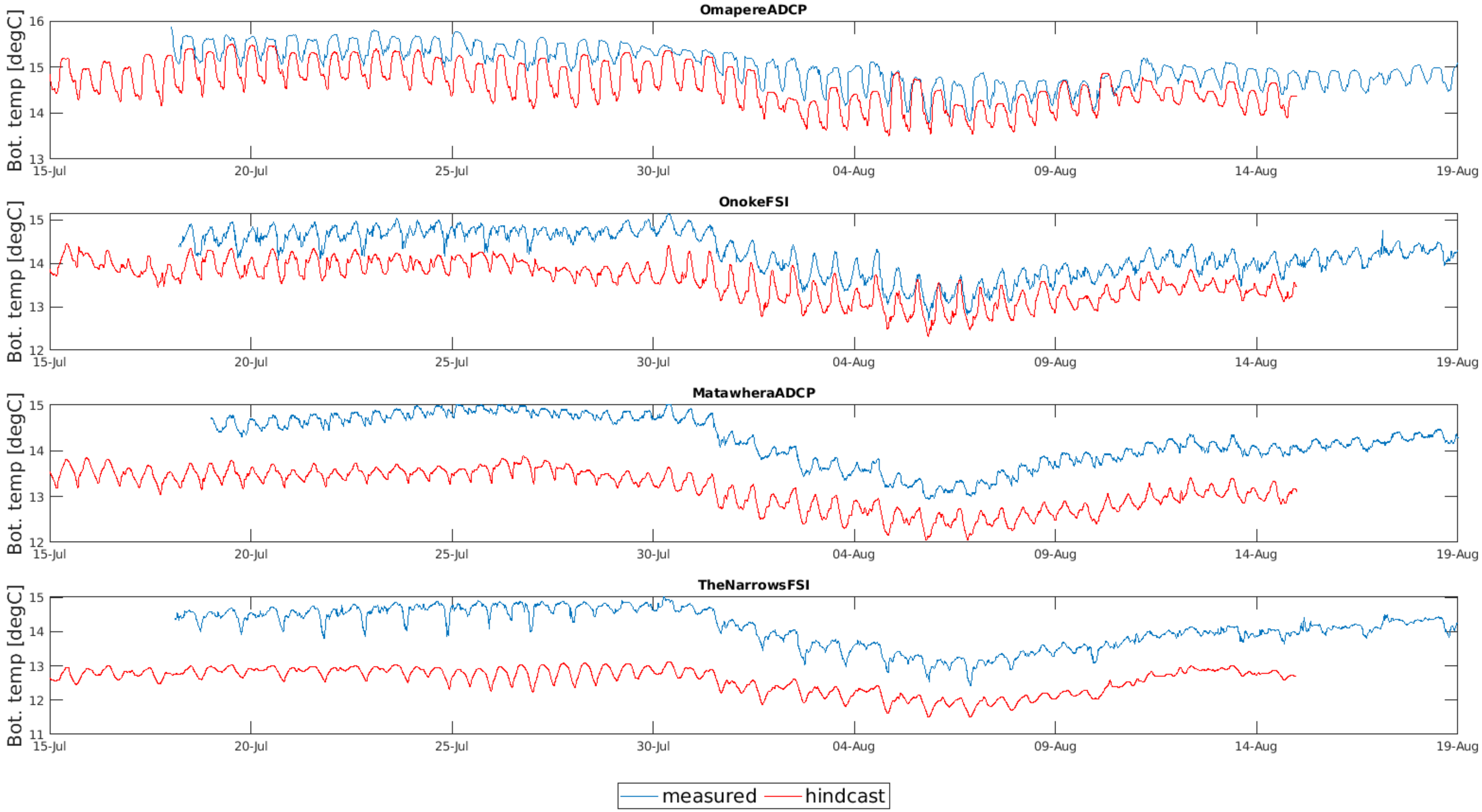

Figure 5.11 Comparison of bottom temperature measured (blue) and modelled (red) at all sites by the FSI and ADCP sensors during July 2019 to August 2019.

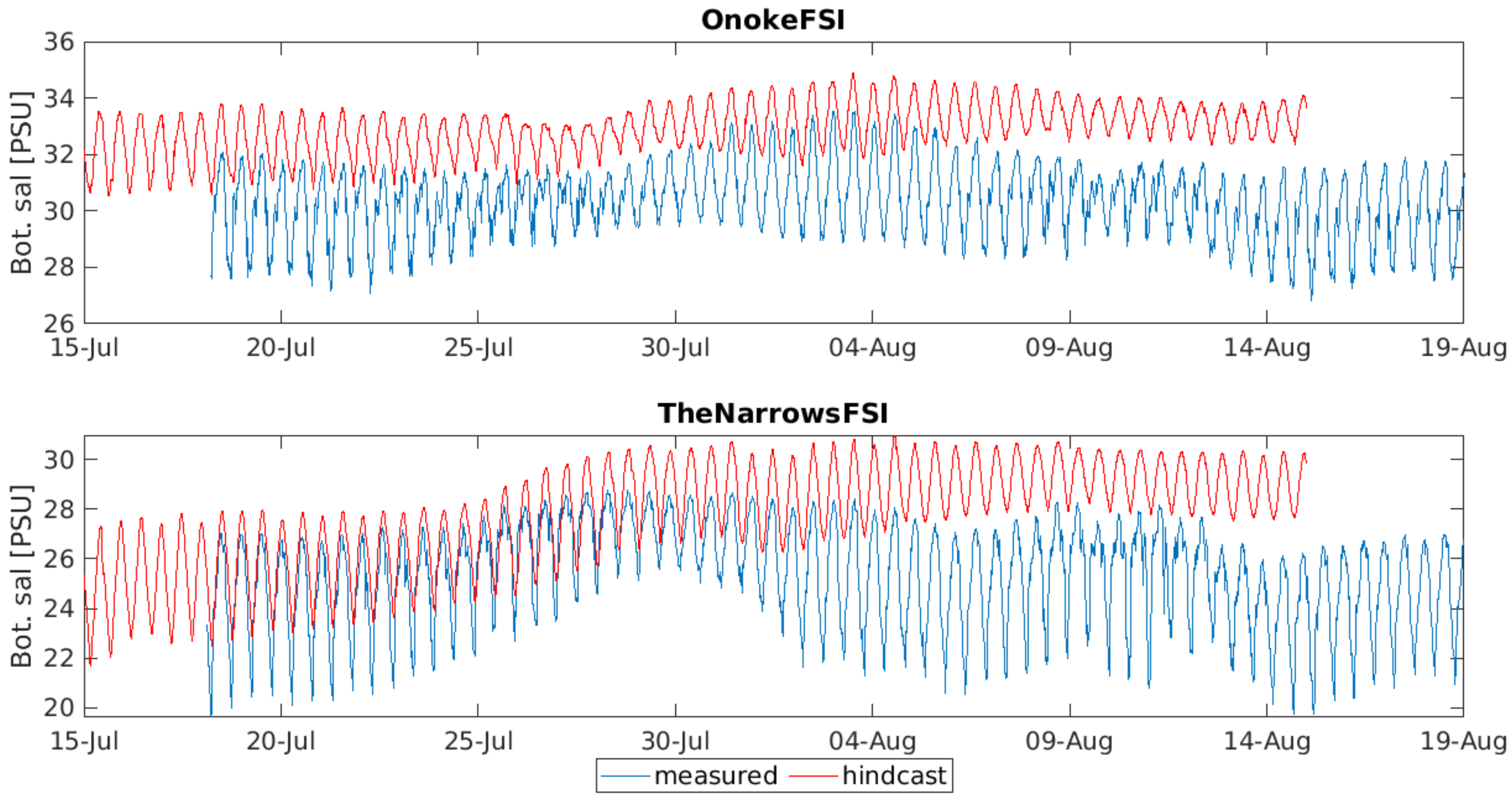

Figure 5.12 Comparison of bottom temperature measured (blue) and modelled (red) at Onoke and The Narrows sites by the FSI sensors during July 2019 to August 2019

5.2 Model results

Surface and bottom velocities in Hokianga harbour are represented in Figure 5.13 and Figure 5.14 during ebb and flood tide. The strong difference of flow between the two tides can be seen at the surface and the bottom of the Harbour.

The horizontal temperature and salinity are shown in Figure 5.15.

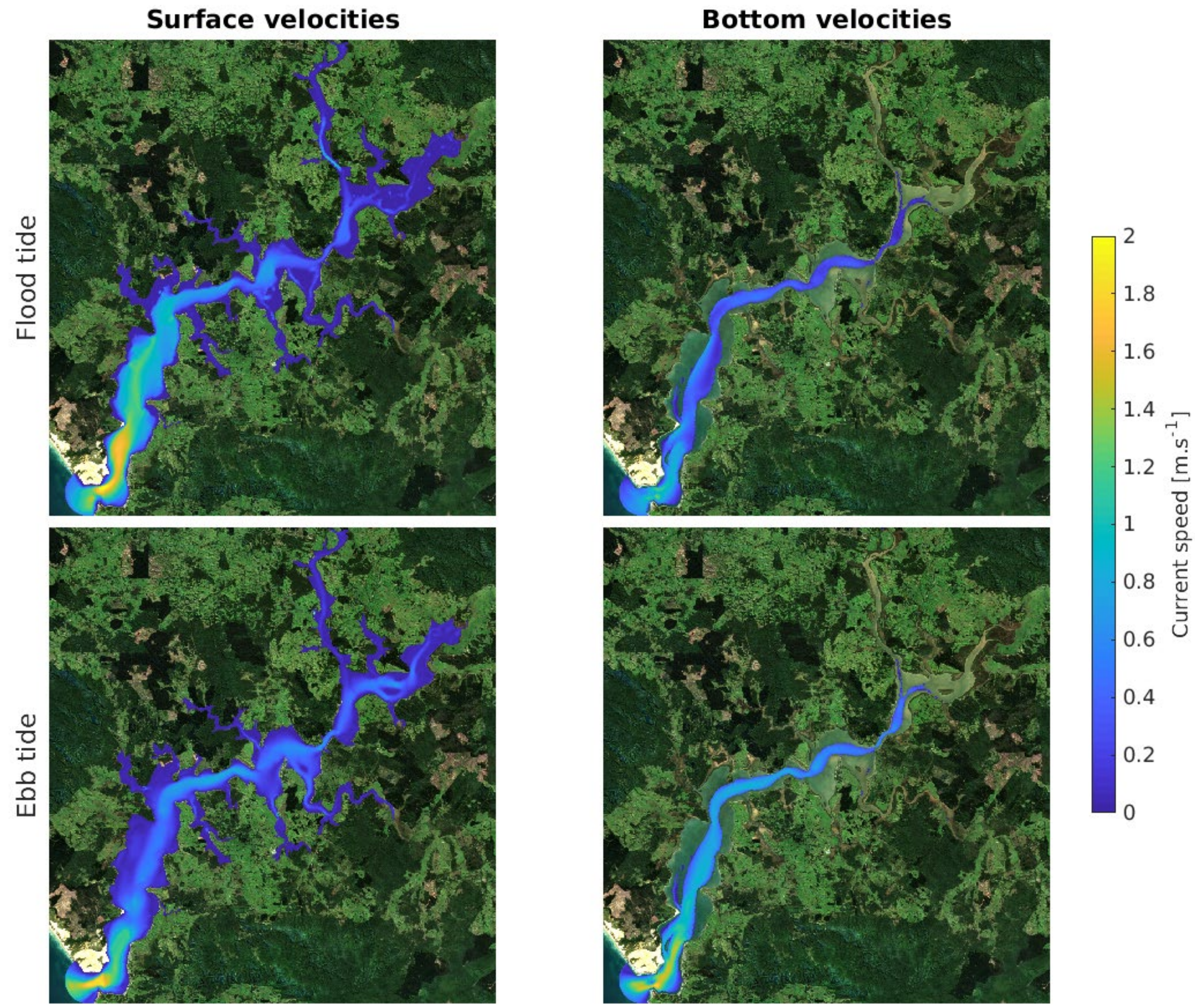

Figure 5.13 Aerial image from Hokianga harbour showing the peak surface (left) and bottom (right) velocities during the flood tide (top) and ebb tide (bottom).

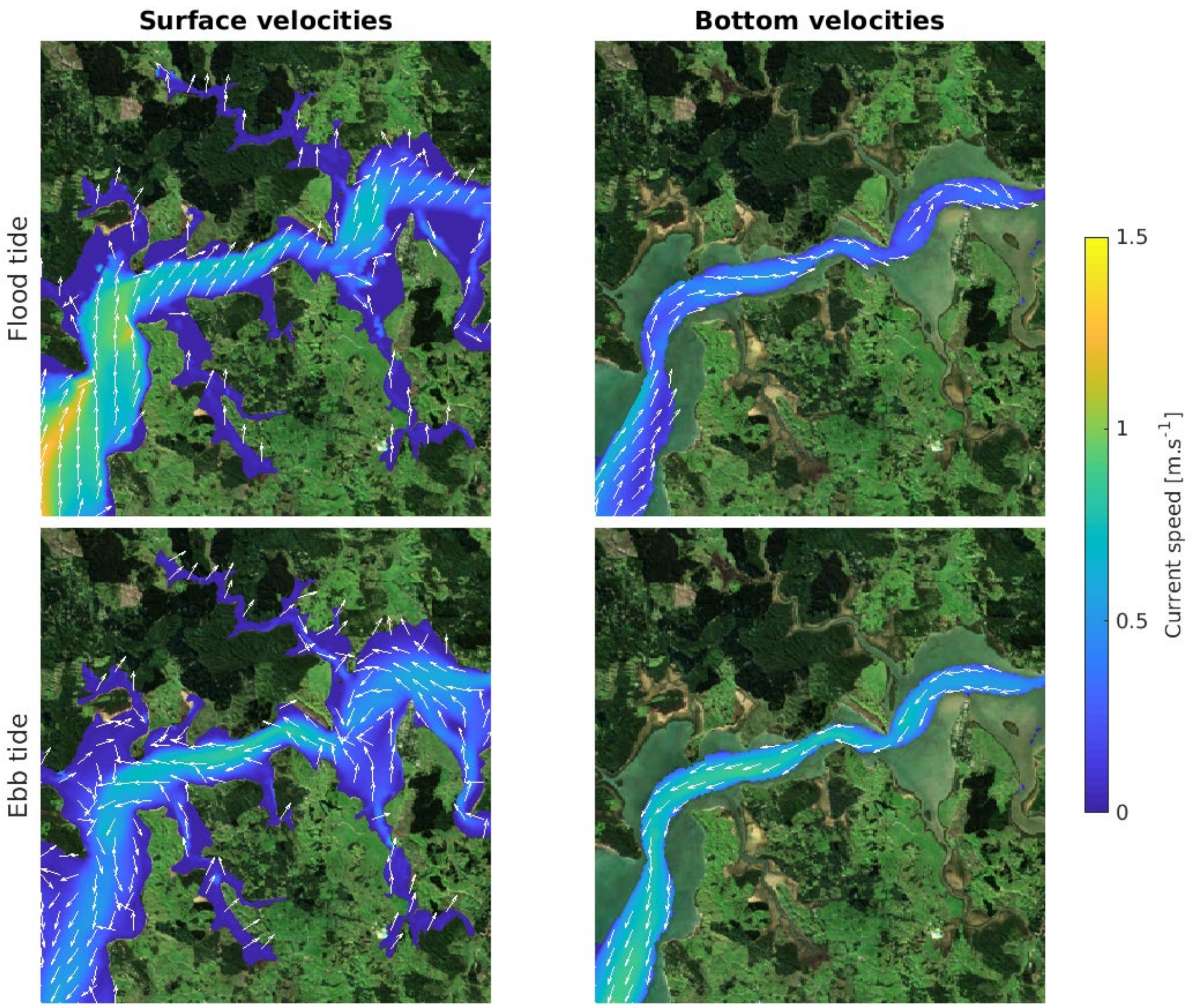

Figure 5.14 Aerial image zoom over Matawhera showing the peak surface (left) and bottom (right) velocities during the flood tide (top) and ebb tide (bottom).

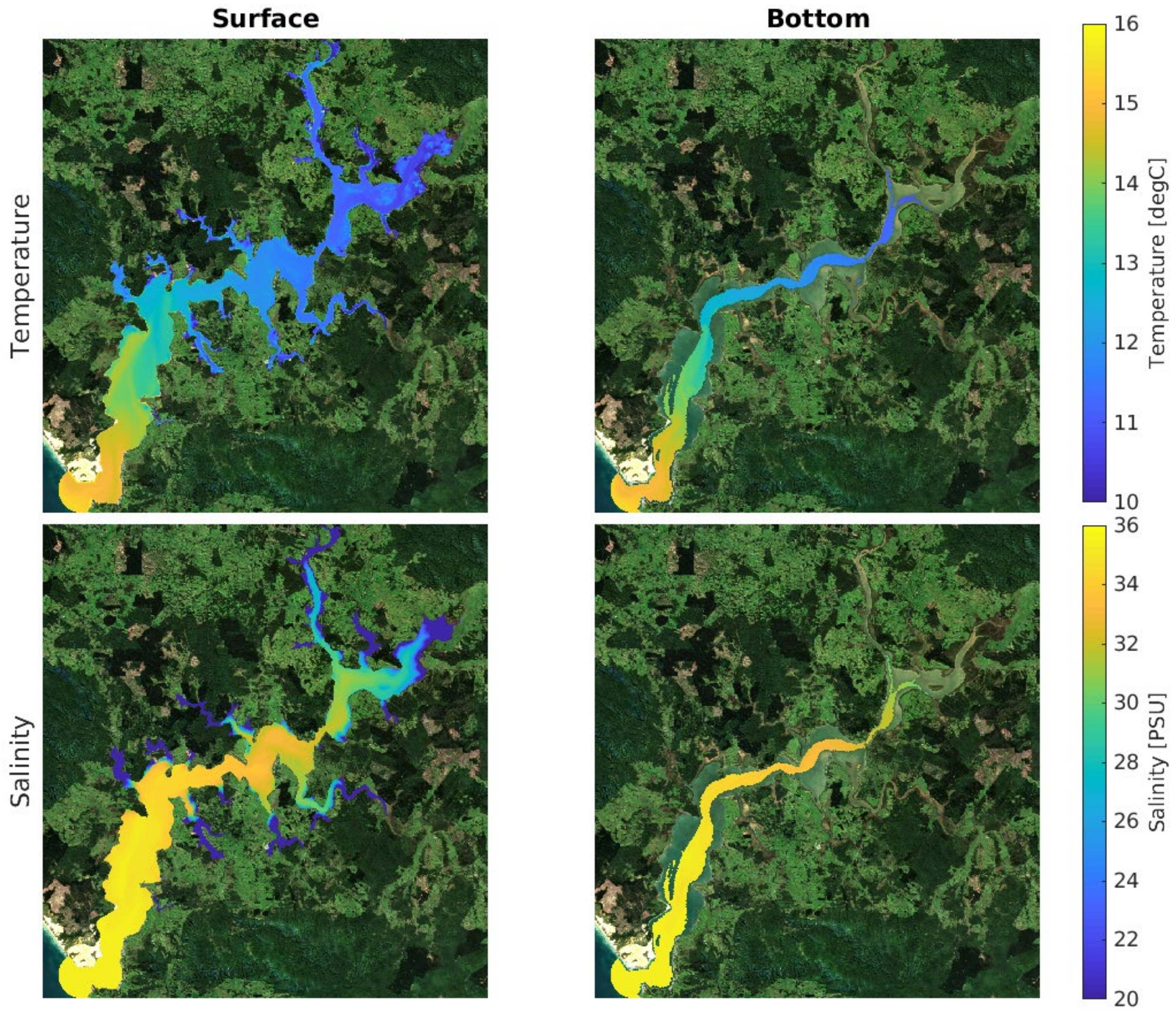

Figure 5.15 Aerial image from Hokianga harbour showing the surface (left) and bottom (right) temperature (top) and salinity (bottom) in July 2015.

5.3 WWTP Discharge Simulations

Simulations were undertaken for a full El Nino (July 2015-June 2016) and La Nina (July 2010 to June 2011) years. The WWTP discharges timeseries presented in Figure 4.14 were used together with a nominated tracer concentration of 1mg/L for each WWTP discharge. The model simulations results were processed in term of dilution factors which were determined by dividing the tracer concentration at any grid point to the discharged concentration. A dilution factor of 1:1000 therefore indicates the contaminant concentration (e.g. Ammoniacal Nitrogen, Total Suspended Solids, Biological Oxygen Demand.) at that location is 1000 times smaller than discharged at the WWTP. Specific contaminant concentration levels at environmental receptors will be determined by consultants doing the QMRA, using concentration ratios and the expected or measured discharged value.

5.3.1 50th Percentile and 95th Percentile Maps

Results are presented in Figure 5.16 to Figure 5.23, in terms of 50th and 95th percentile maps of dilution factor and tracer concentration in mg/L (based on a 1mg/L concentration at the discharge point) . The percentiles were calculated using the hourly output from the model over the full year.

The 50th percentile maps present the dilutions factors and concentration (in mg/L) expected to be exceed 50% of the time.

The 95th percentile maps present the dilution factors and concentration (in mg/L) expected to be exceeded 5% of the time (or not exceeded for 95% of the time).

The 50th and 90th percentile dispersion for each contaminant (e.g. E.coli / Faecal coliforms, Total Suspended Solids, Biological Oxygen Demand, Total Ammoniacal Nitrogen) can be visually estimated by multiplying the concentration seen on the maps by the expected concentration to be discharged or the Consent limit. However, it should be noted that the contaminants estimate may be conservative as no decay was considered for the passive tracer used in the simulations.

The results show dilution factors for the combination of all the four discharges together, which illustrate the potential cumulative effects of all discharges (Note: They assume that the same tracer concentration is being released simultaneously at each WWTP). The 50th and 95th percentile maps of dilution factor and tracer concentration in mg/L (based on a 1mg/L concentration at the discharge point) for the four WWTP combined are presented in Figure 5.24 and Figure 5.25.

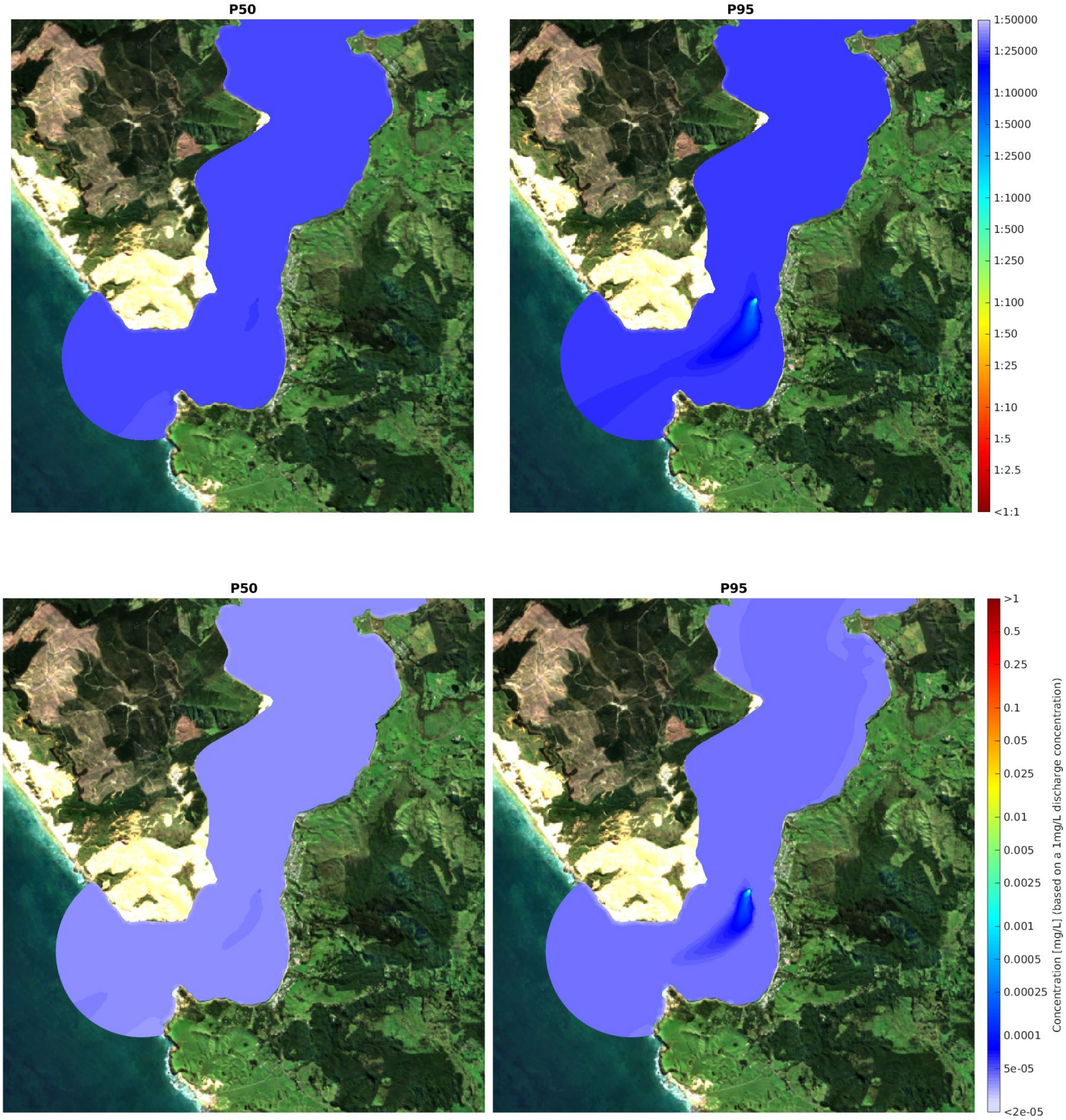

Figure 5.16 50^{th} Percentile and 95^{th} Percentile Dilution factor (top) and tracer concentration in mg/L (bottom) for Opononi WWTP during El Nino year

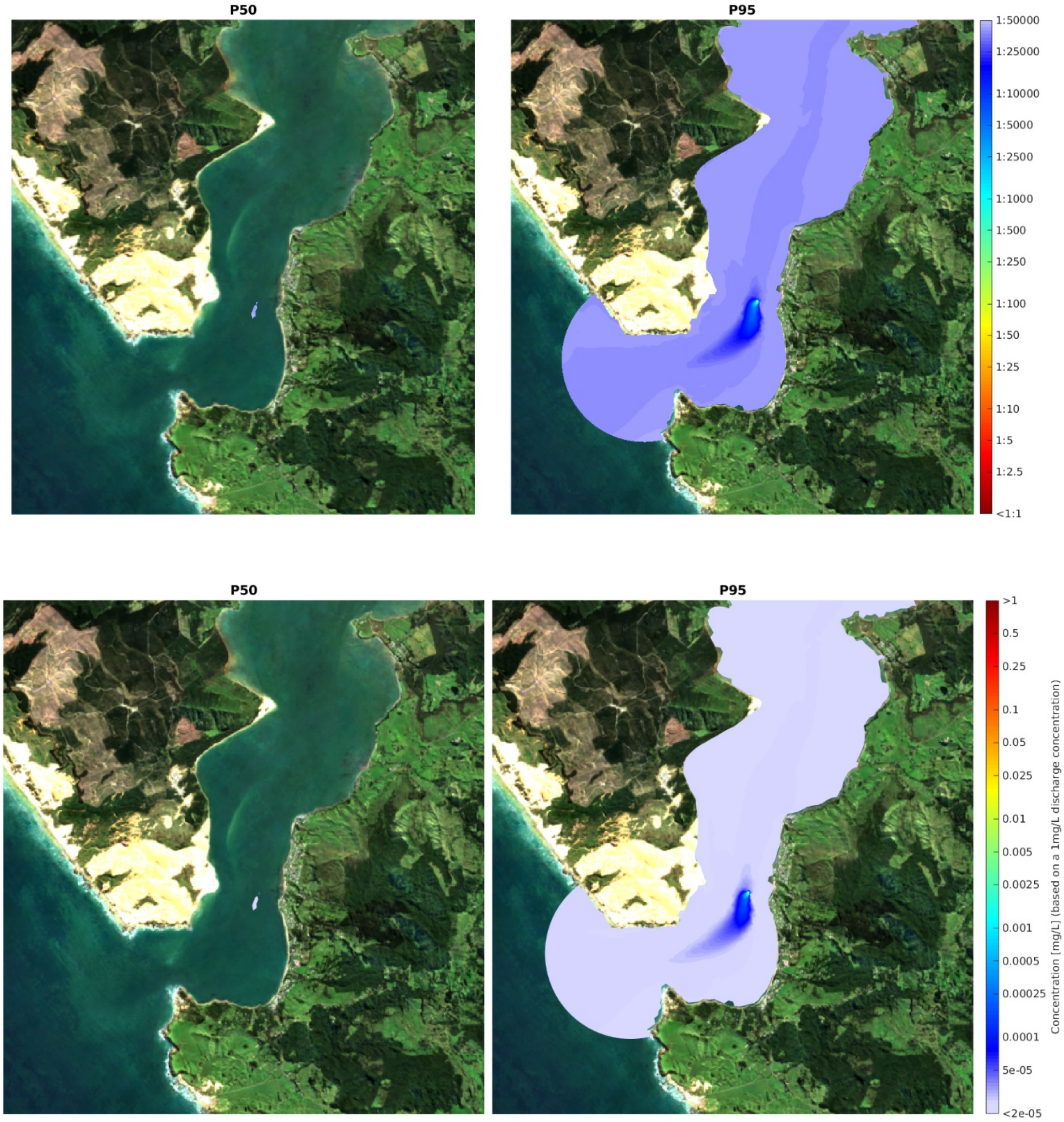

Figure 5.17 50th Percentile and 95th Percentile Dilution factor (top) and tracer concentration in mg/L (bottom) for Opononi WWTP during La Nina year.

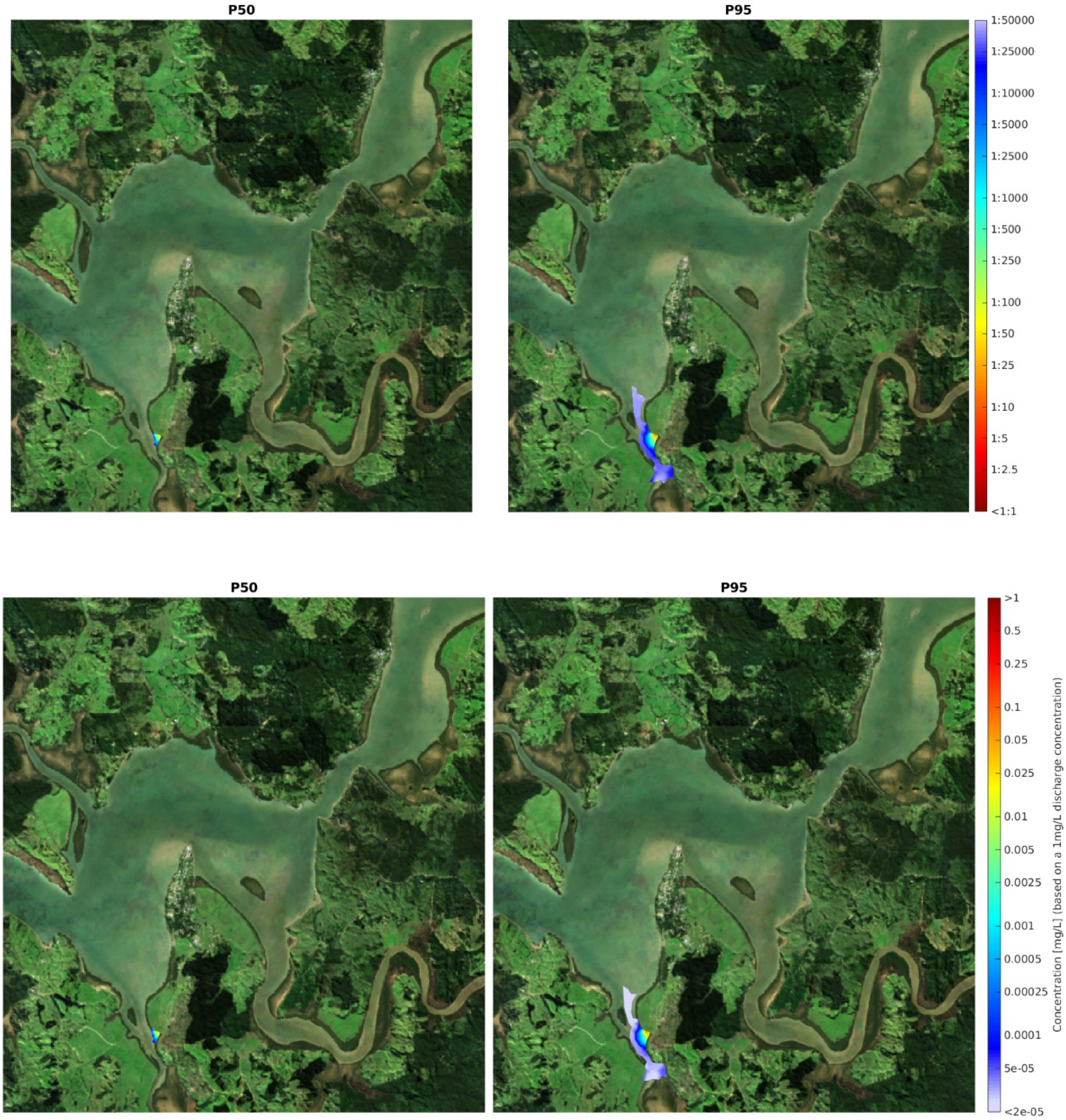

Figure 5.18 50th Percentile and 95th Percentile Dilution factor (top) and tracer concentration in mg/L (bottom) for Rawene WWTP during El Nino year.

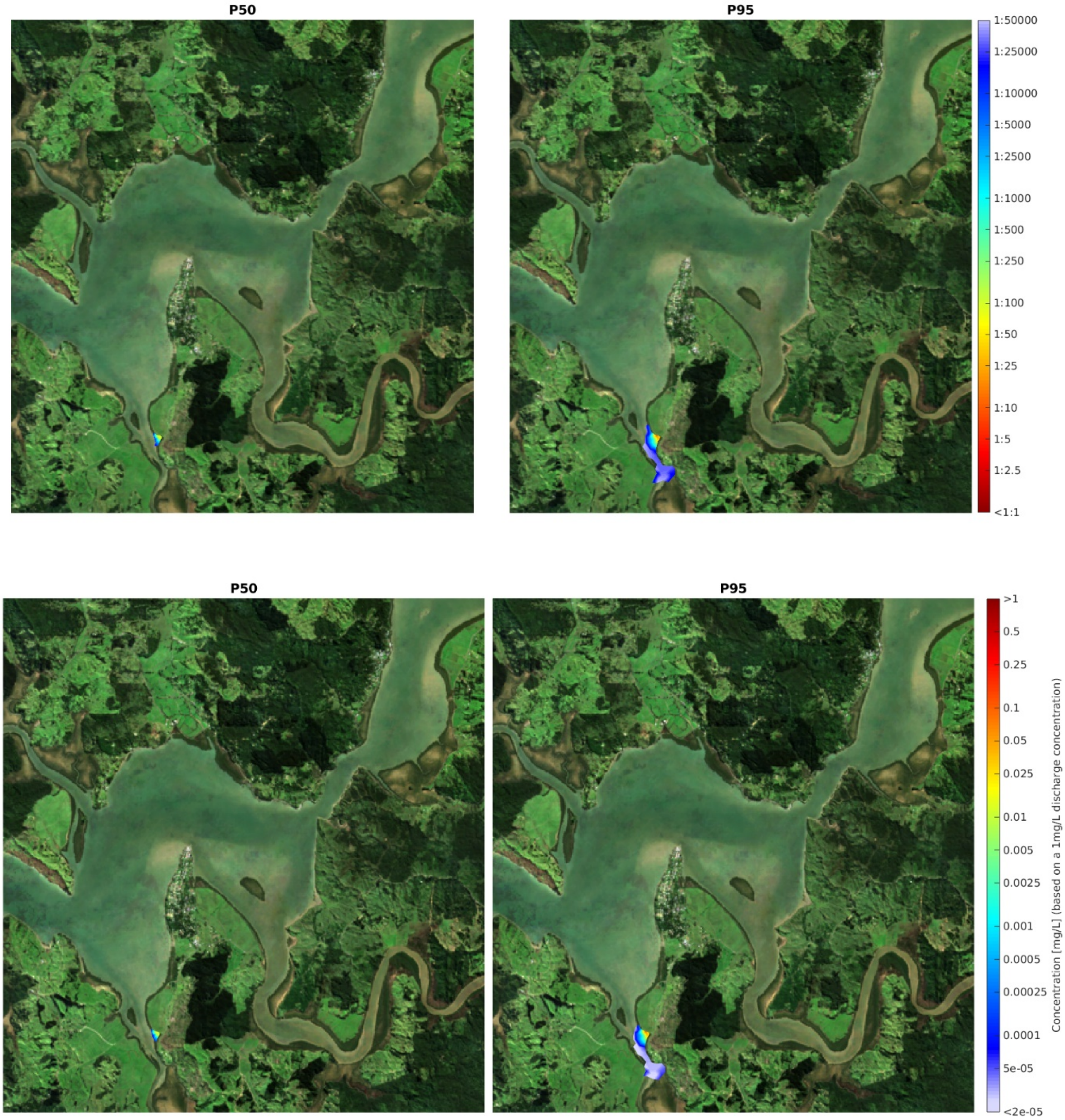

Figure 5.19 50^{th} Percentile and 95^{th} Percentile Dilution factor (top) and tracer concentration in mg/L (bottom) for Rawene WWTP during La Nina year.

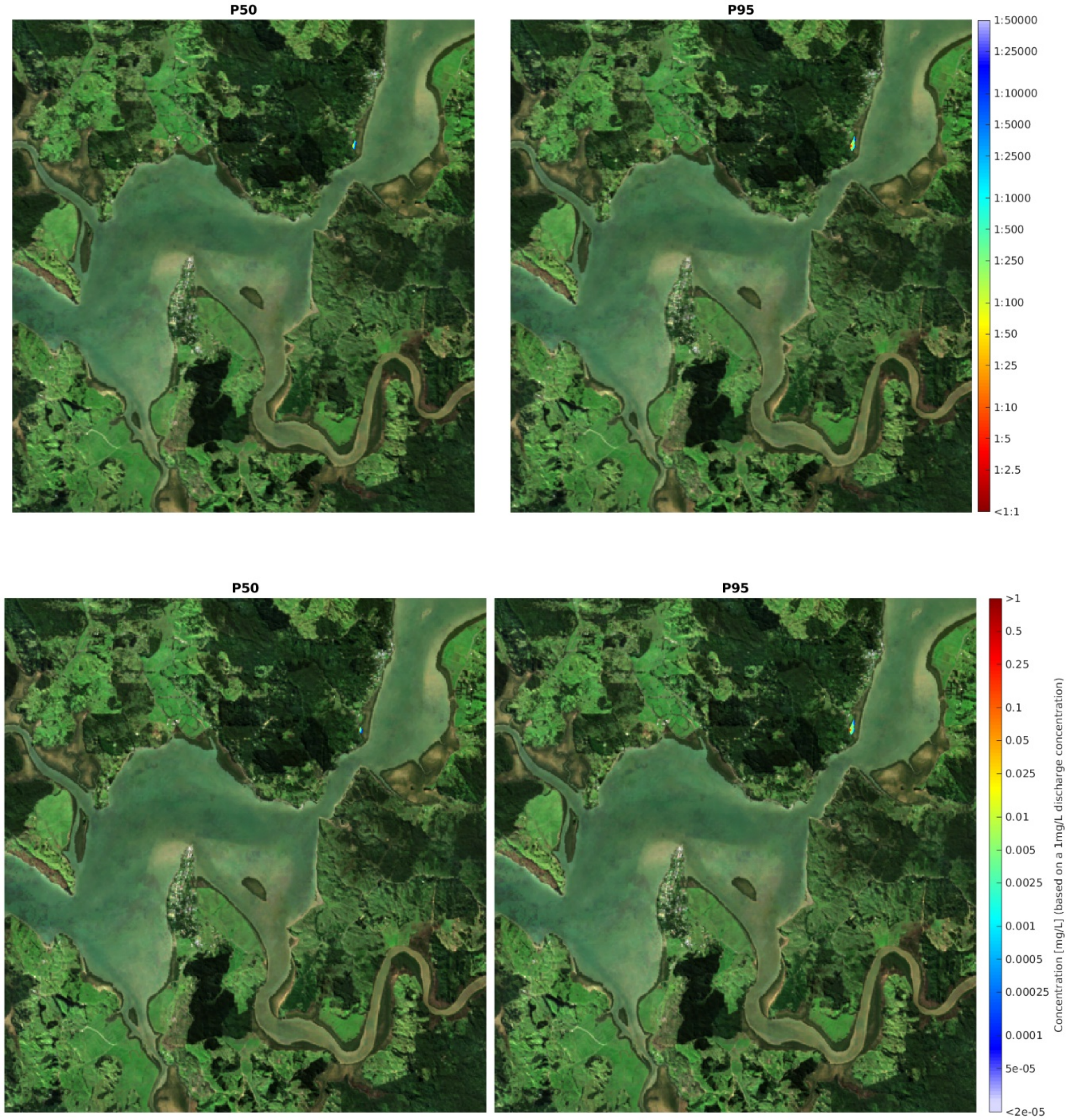

Figure 5.20 50th Percentile and 95th Percentile Dilution factor (top) and tracer concentration in mg/L (bottom) for Kohukohu WWTP during El Nino year.

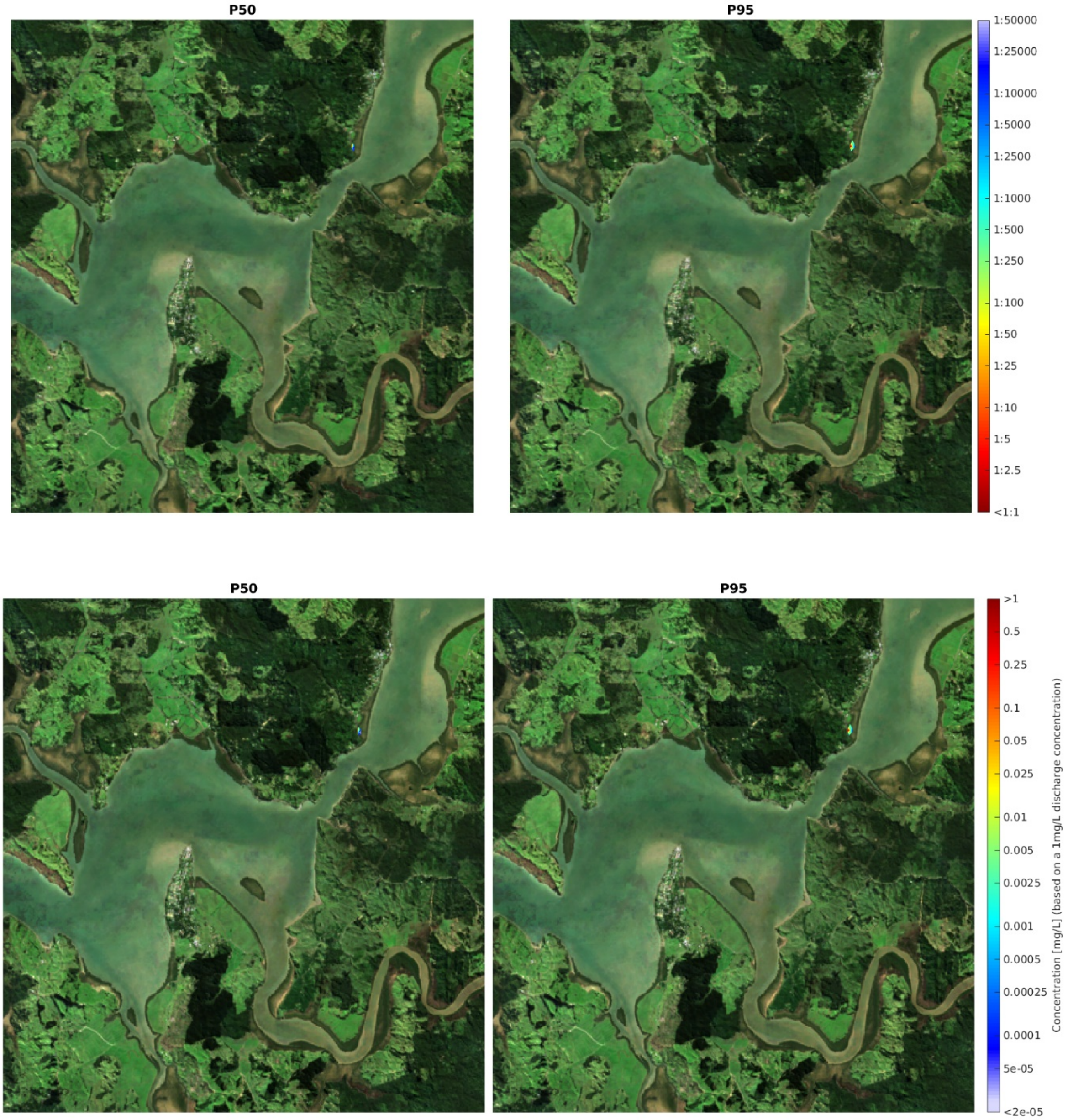

Figure 5.21 50th Percentile and 95th Percentile Dilution factor (top) and tracer concentration in mg/L (bottom) for Kohukohu WWTP during La Nina year.

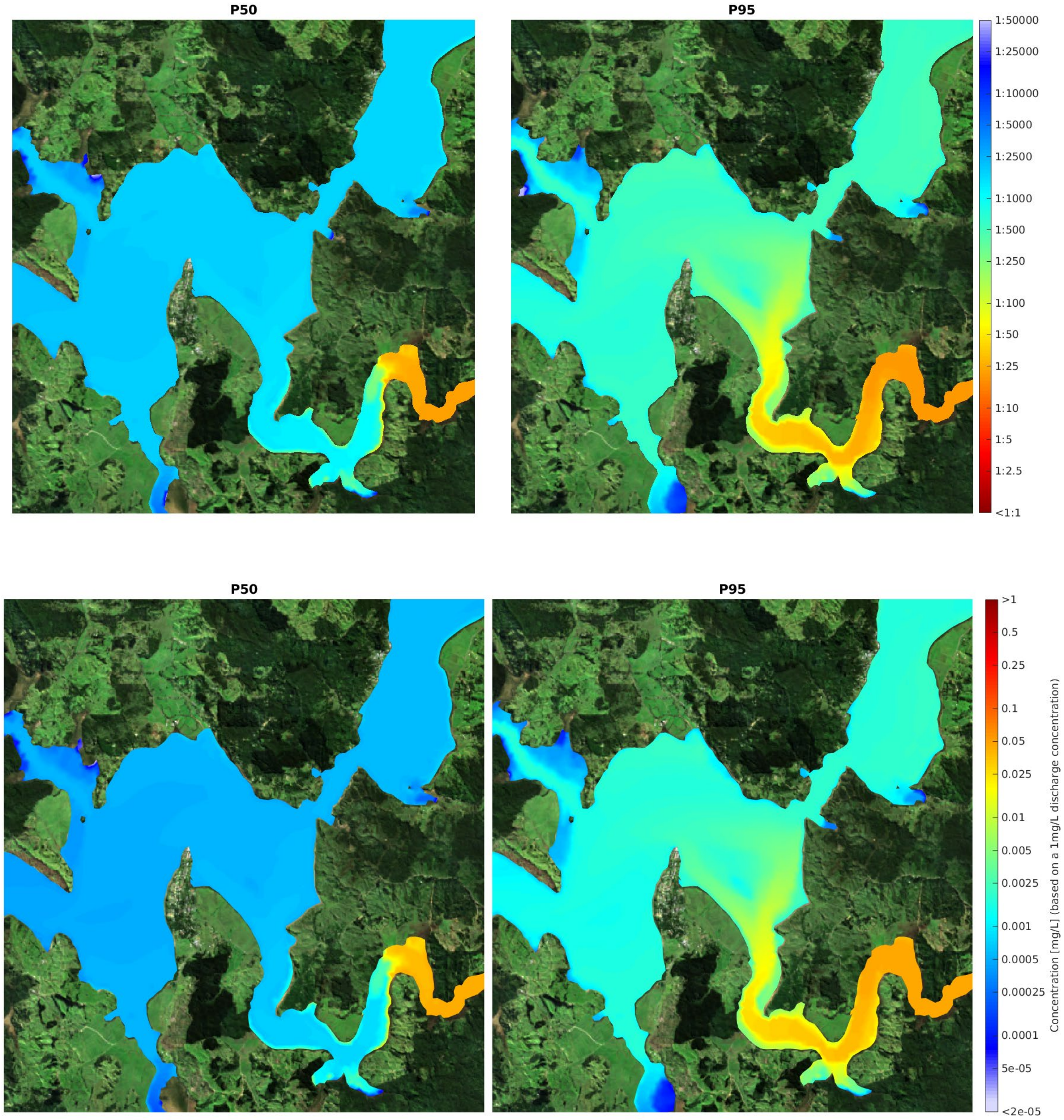

Figure 5.22 50th Percentile and 95th Percentile Dilution factor (top) and tracer concentration in mg/L (bottom) for Kaikohe WWTP during El Nino year.

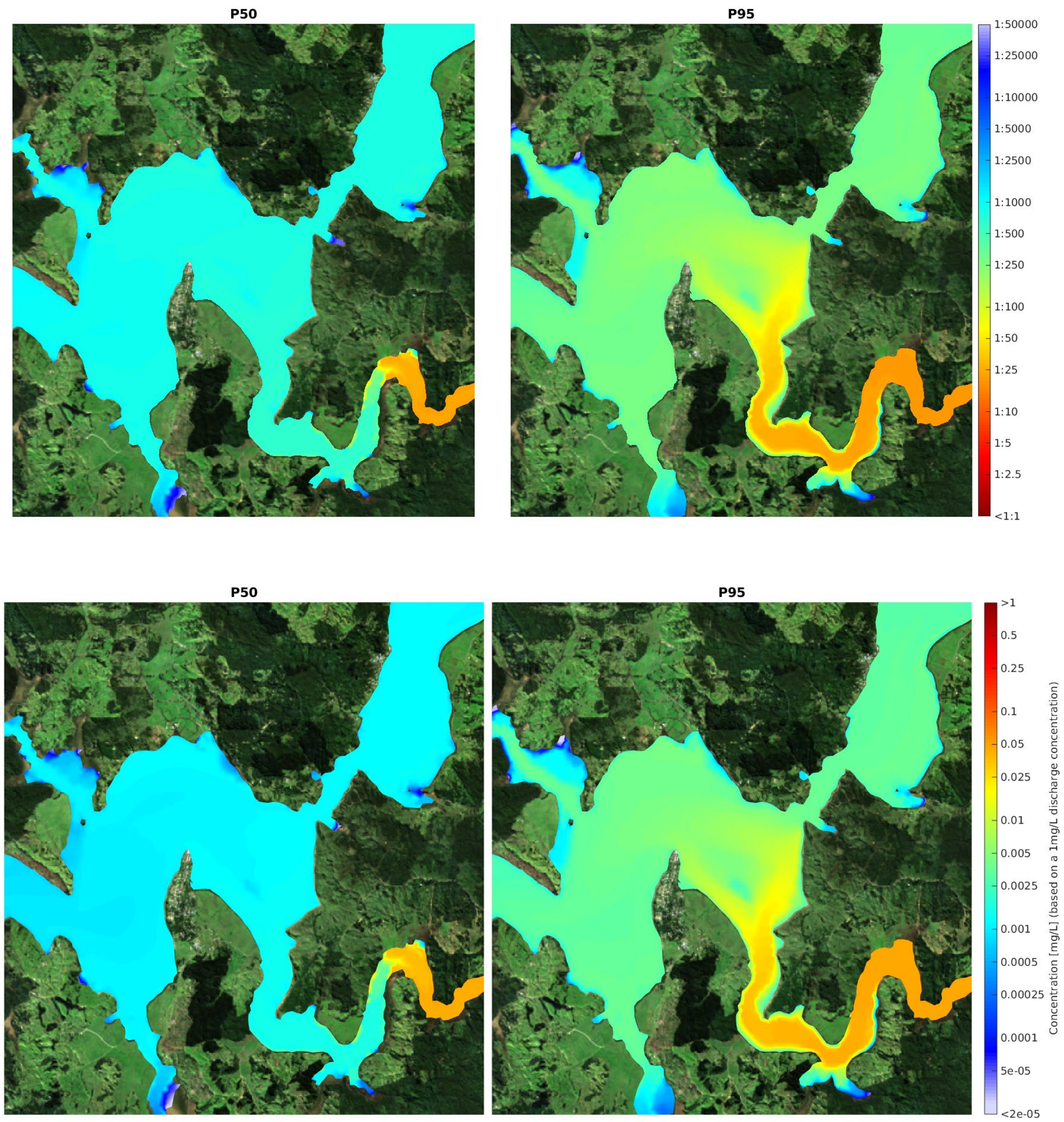

Figure 5.23 50th Percentile and 95th Percentile Dilution factor (top) and tracer concentration in mg/L (bottom) for Kaikohe WWTP during La Nina year.

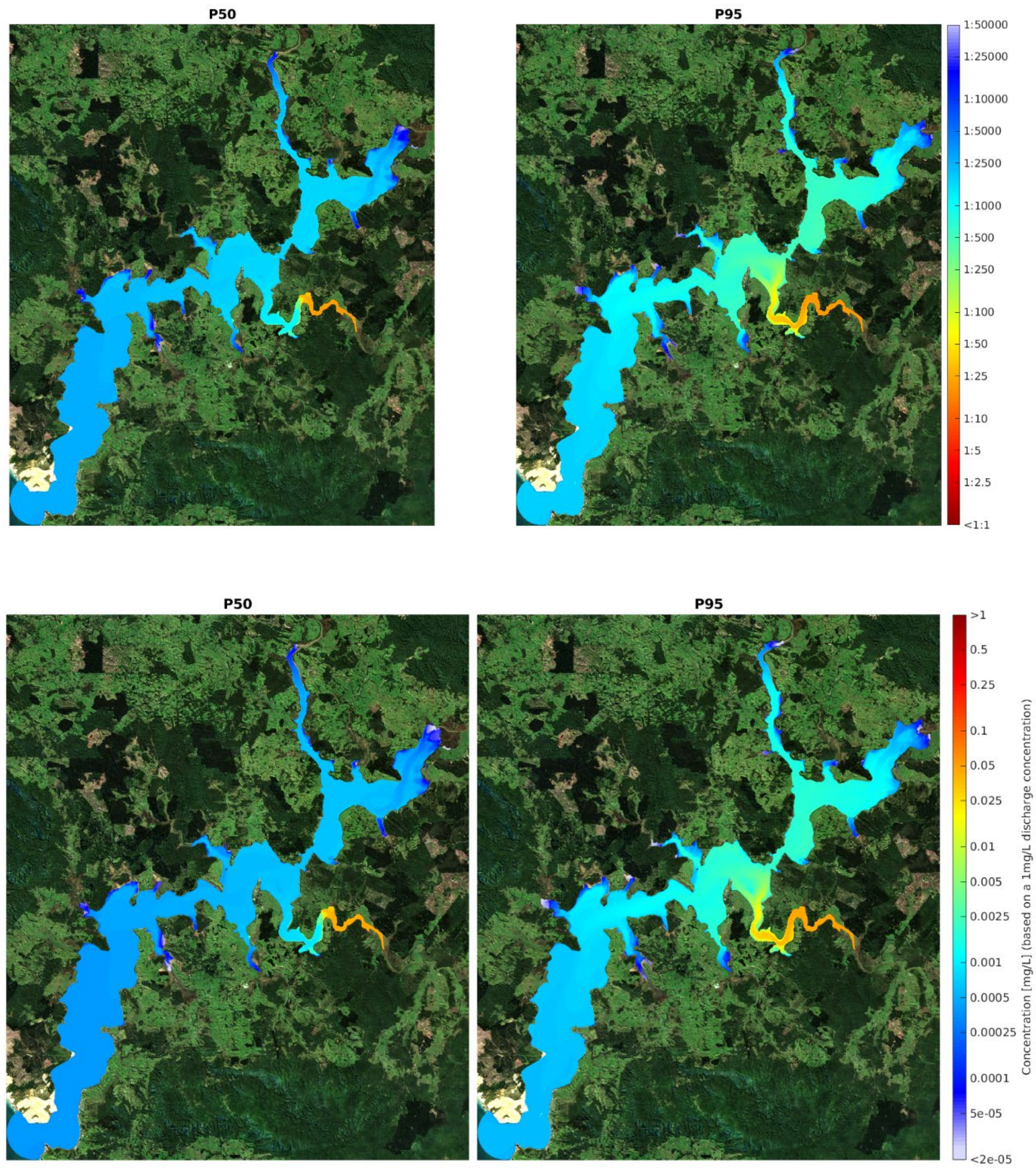

Figure 5.24 50th Percentile and 95th Percentile Dilution factor (top) and tracer concentration in mg/L (bottom) for the four WWTPs combined during El Nino year.

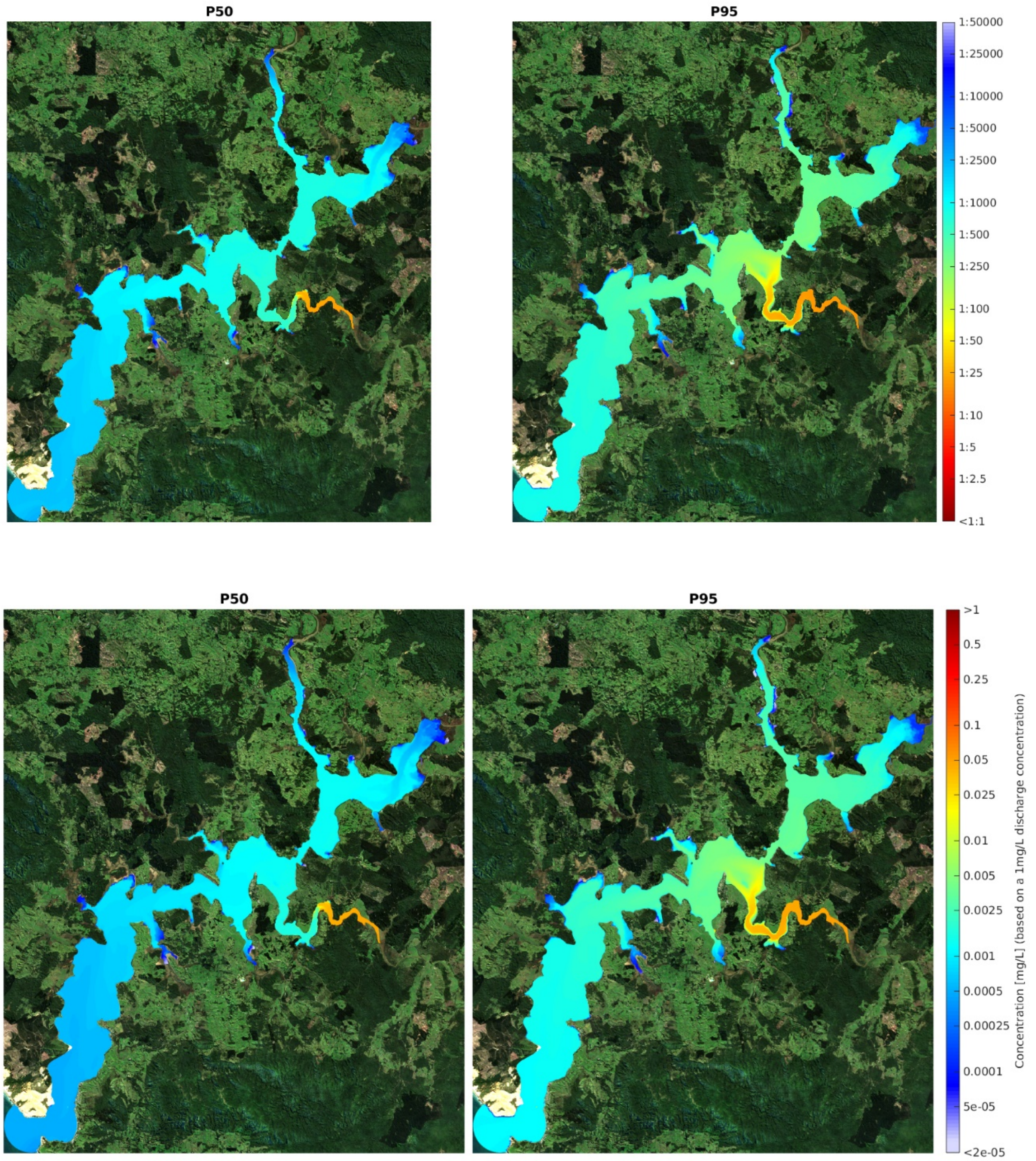

Figure 5.25 50^{th} Percentile and 95^{th} Percentile Dilution factor (top and tracer concentration in mg/L (bottom) for the four WWTPs combined during La Nina year.

5.3.2 Time Series of dilution

Time-series of tracer concentrations were extracted at selected locations (see Figure 5.26) within Hokianga Harbour. Figure 5.27 to Figure 5.31 presents the time-series tracer concentration in mg/L (based on a 1mg/L concentration at the discharge point) at location P1, P2, P3, CR1 and CR4. Locations near Opononi have been selected following communications with Streamlined Ltd (who is currently undertaking the QMRA for Opononi WWTP) and the timeseries data was provided to them for the assessment.

The concentration for each contaminant (e.g. E.coli / Faecal coliforms, Total Suspended Solids, Biological Oxygen Demand, Total Ammoniacal Nitrogen) can be estimated by multiplying the timeseries concentration by the expected concentration to be discharged or the Consent limit. However, it should be noted that the contaminants estimate may be conservative as no decay was considered for the passive tracer used in the simulations.

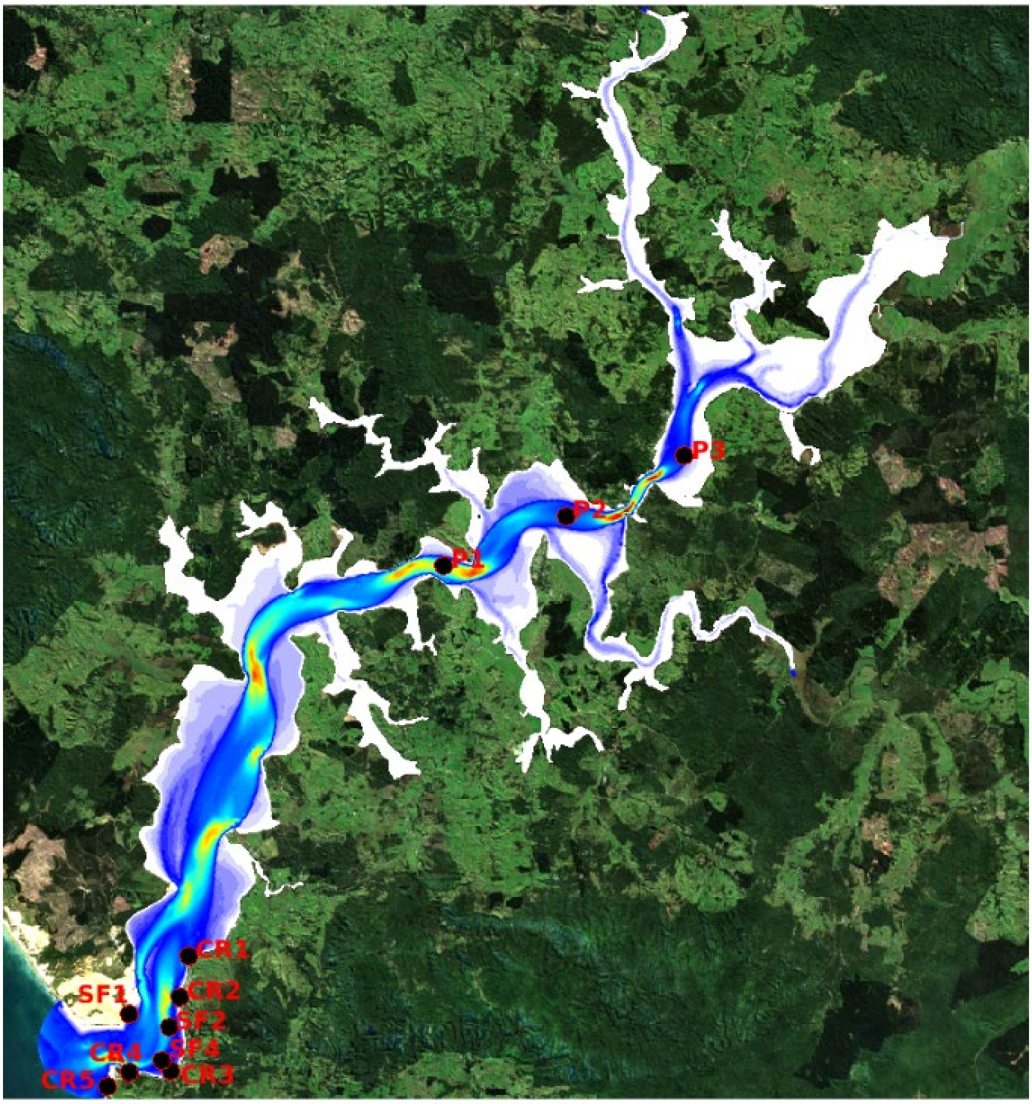

Figure 5.26 Location for tracer concentration timeseries extraction and analysis

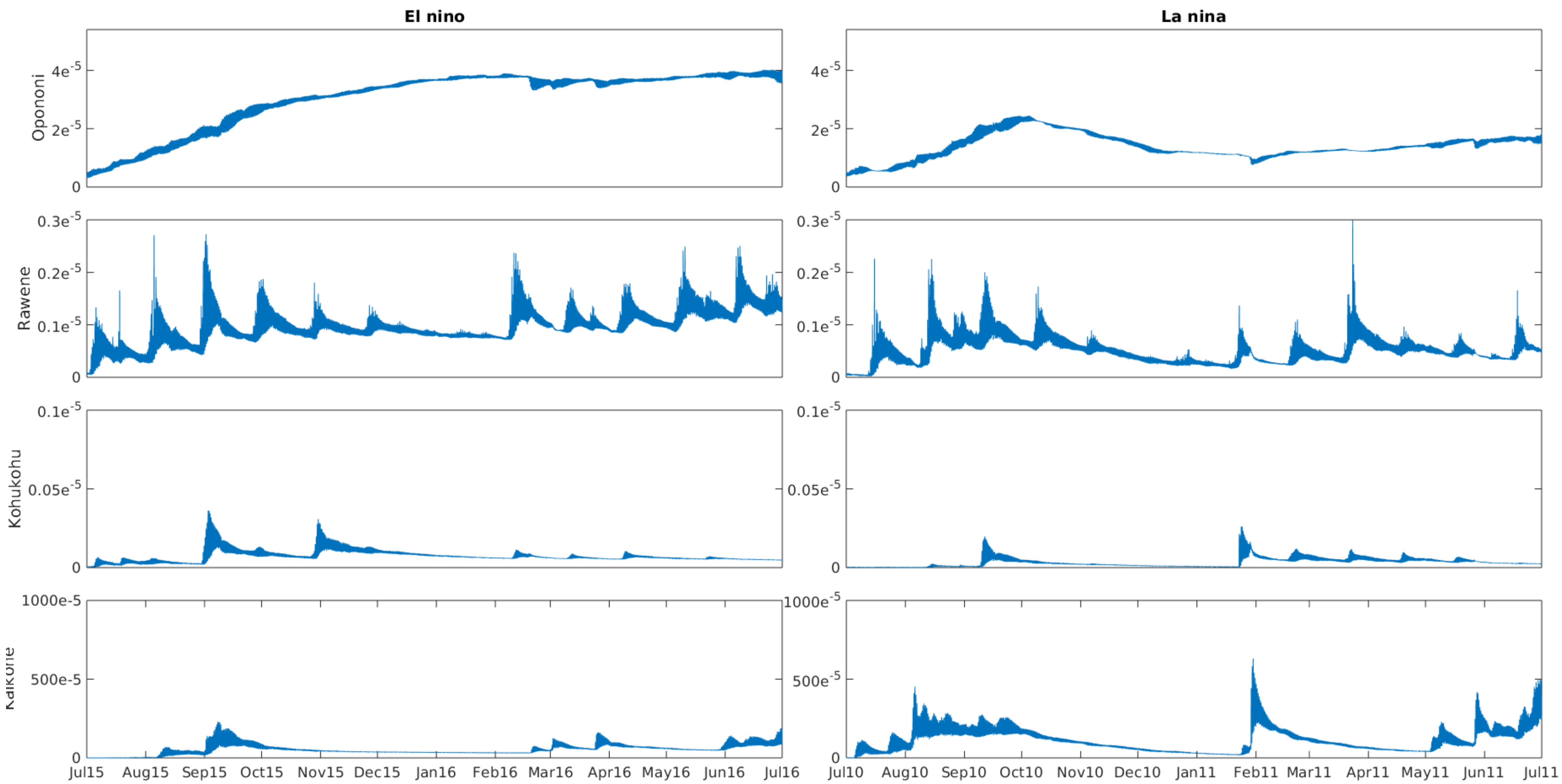

Figure 5.27 Timeseries of tracer concentration in mg/L (based on a 1mg/L concentration at the discharge point) at location P1 for each WWTP discharge for the El Nino and La Nina year simulations.

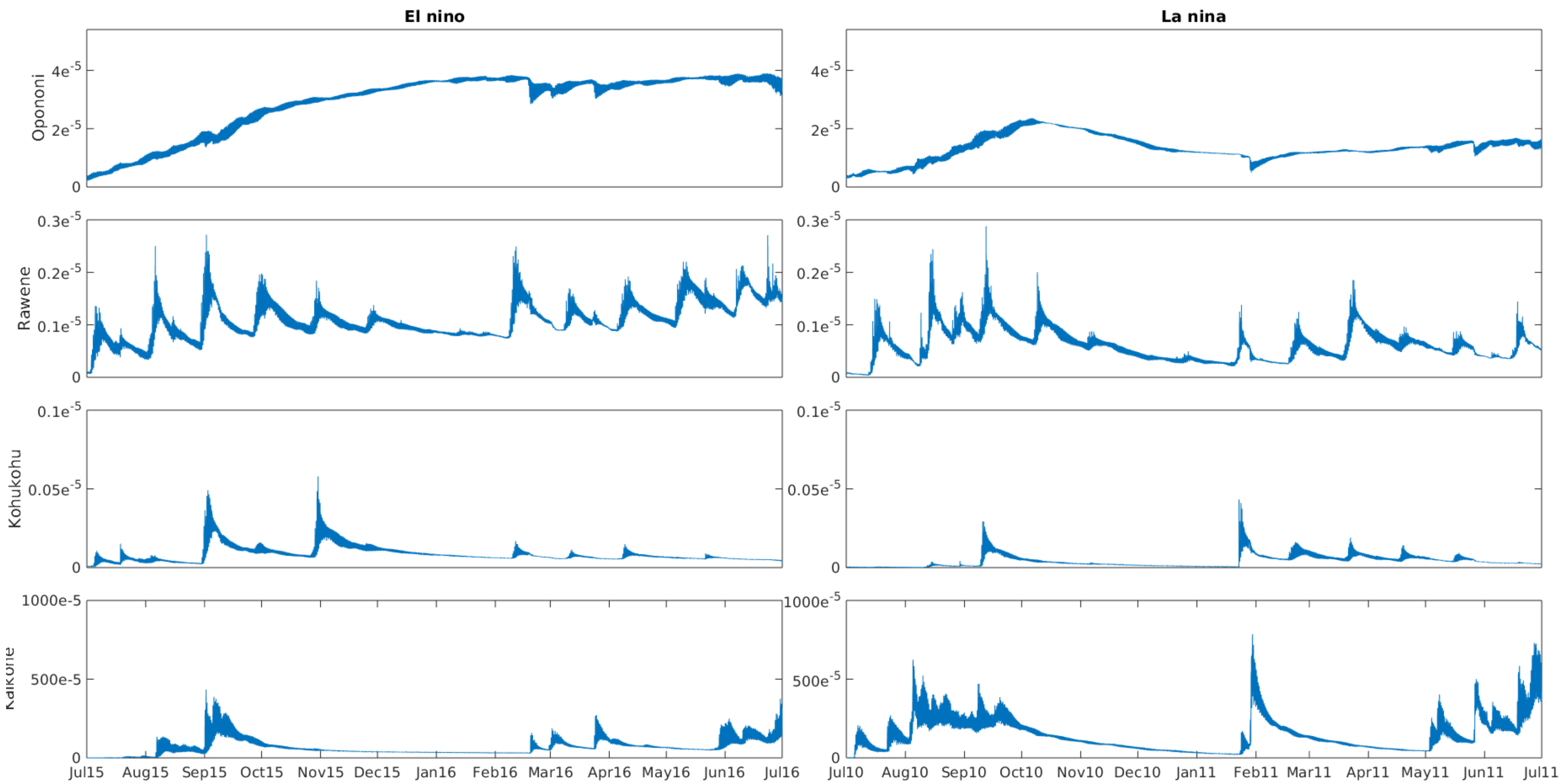

Figure 5.28 Timeseries of tracer concentration in mg/L (based on a 1mg/L concentration at the discharge point) at location P2 for each WWTP discharge for the El Nino and La Nina year simulations.

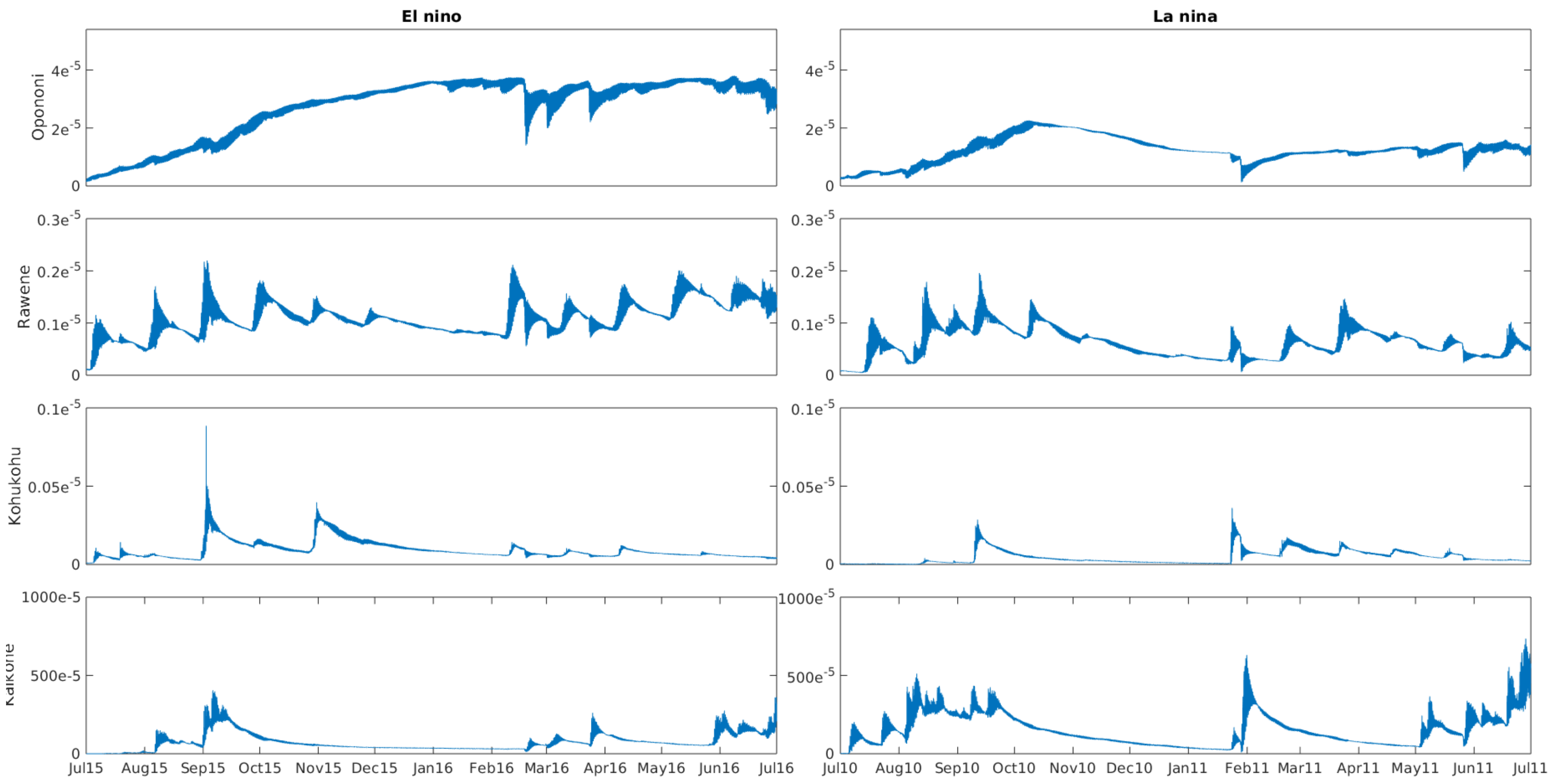

Figure 5.29 Timeseries of tracer concentration in mg/L (based on a 1mg/L concentration at the discharge point) at location P3 for each WWTP discharge for the El Nino and La Nina year simulations.

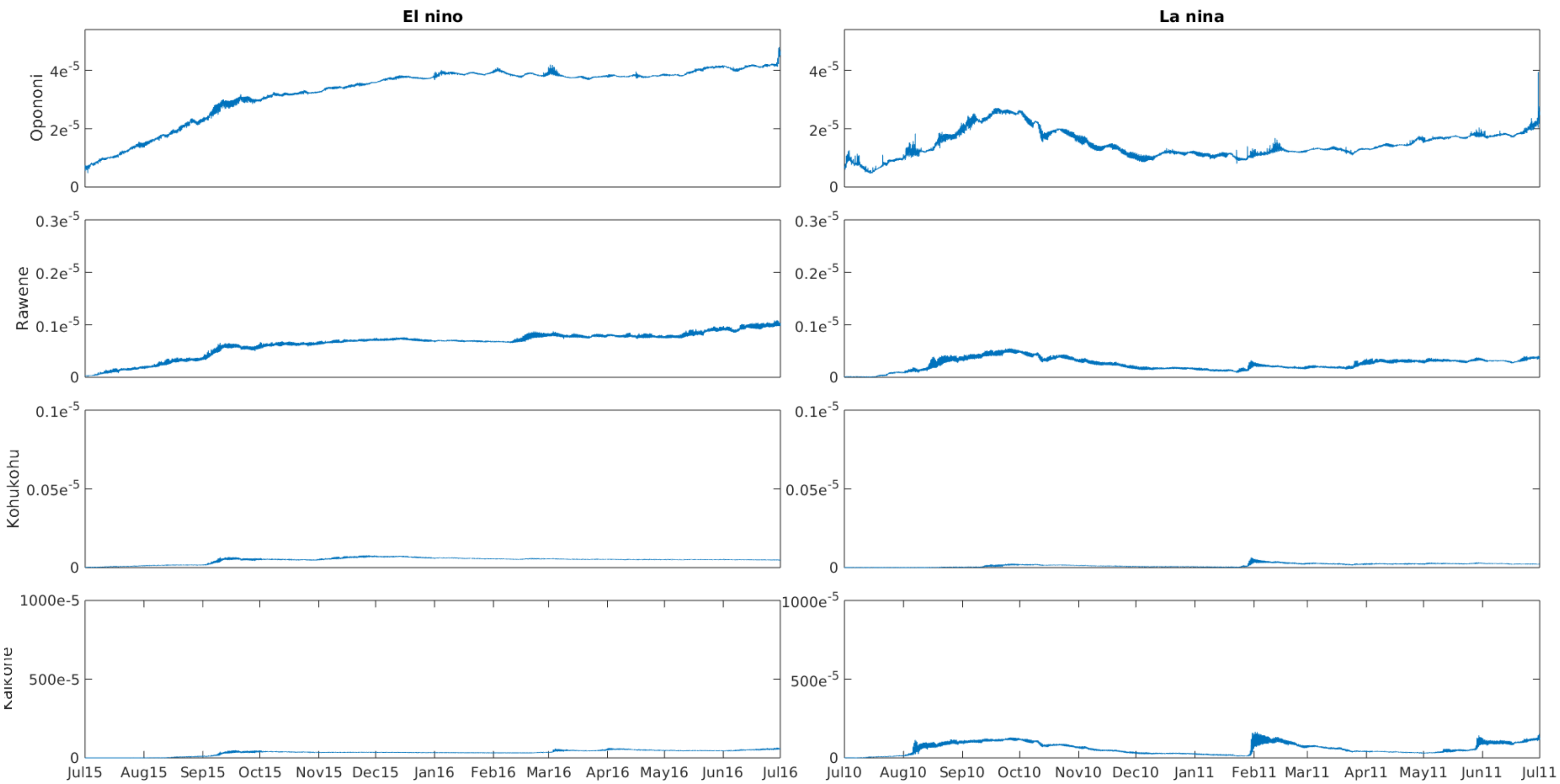

Figure 5.30 Timeseries of tracer concentration in mg/L (based on a 1mg/L concentration at the discharge point) at location CR1 for each WWTP discharge for the El Nino and La Nina year simulations.

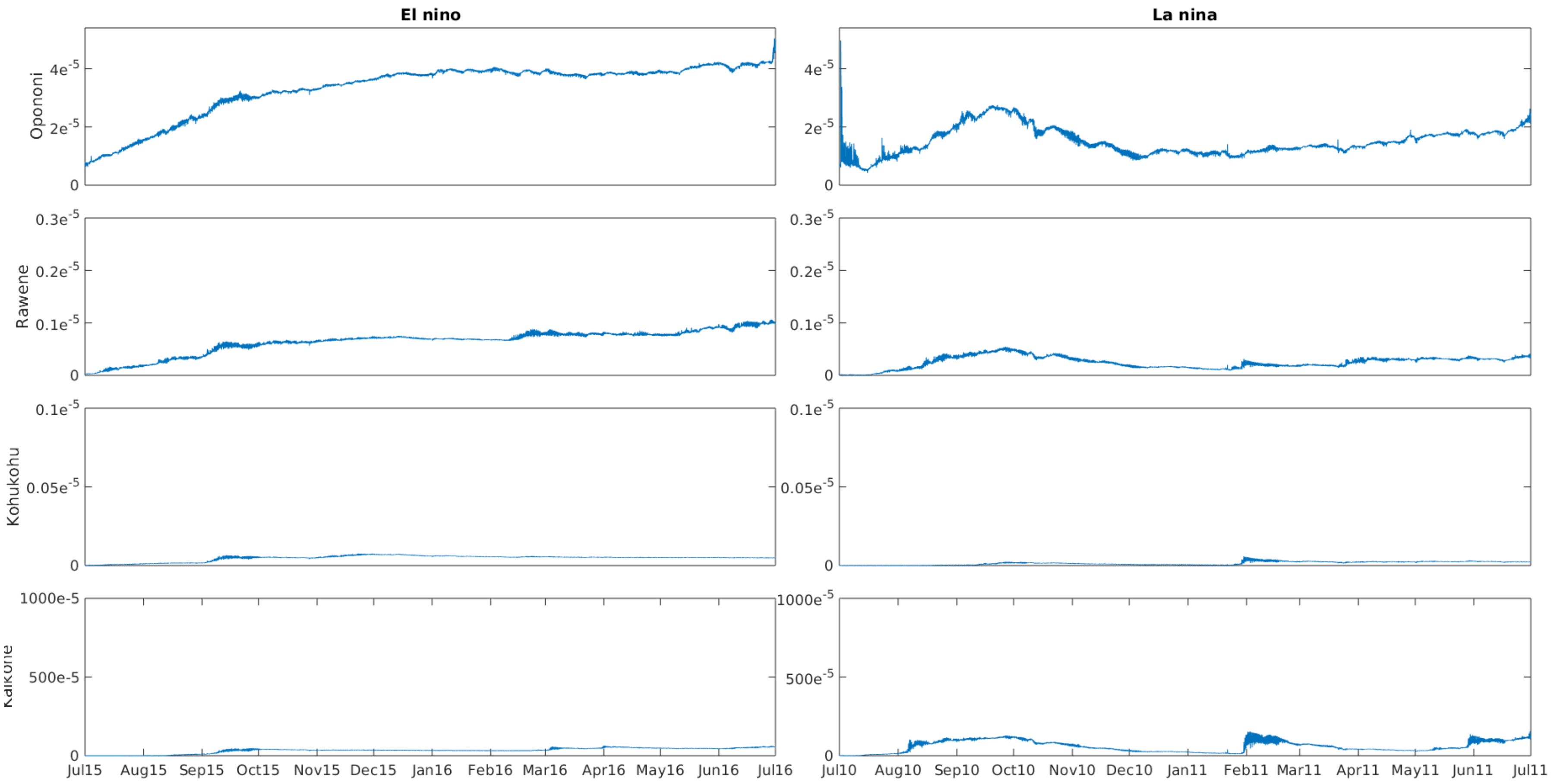

Figure 5.31 Timeseries of tracer concentration in mg/L (based on a 1mg/L concentration at the discharge point) at location CR4 for each WWTP discharge for the El Nino and La Nina year simulations.

5.3.3 Discussion

Opononi WWTP :

The modelled discharge at the Opononi WWTP typically varied from approximately 100 m^3/day to the proposed limit of 450 m^3/day . Results show that the dilution factor is about 1 in 25,000 near the discharge for the 50th percentile and about 1 in 1000 for the 95th percentile for both El Nino and La Nina. The plume is advected by tidal currents toward the entrance of the harbour with a dilution of 1 in 5,000 at about 750m for El Nino and 500m for La Nina. Near the shoreline the dilution is about 1 in 25,000 or more.

Rawene WWTP :

The modelled discharge at the Opononi WWTP typically varied from approximately 50 m^3/day to the proposed limit of 254 m^3/day. Results show that the plume is mostly contained within the Omanaia River and dilution factor at about 100 m from the discharge is about 1 in 5,000 near for the 50th percentile (El Nino and La Nina) and about 1 in 500 for the 95th percentile and 1 in 1000 for the 95th percentile. The plume mostly extended north and south, with a 95th percentile dilution of 1 in 50,000 at about 1000 m (El Nino) and 300 m (La Nina) towards the north and about 700 m towards the south for both El Nino and La Nina.

Kohukohu WWTP :

The modelled discharge at the Kohukohu WWTP typically varied from approximately 2 m^3/day to the proposed limit of 40 m^3/day . Results show that the plume is mostly confined to the vicinity of the discharge location with a dilution factor of 1 in 50,000 at approx. 50 m and 100 m for the 50th percentile and 95th percentile respectively.

Kaikohe WWTP :

The modelled discharge at the Kaikohe WWTP typically varied from approximately 500 m^3/day to the proposed limit of 1710 m^3/day. As discussed previously more than 30 km upstream of the Waima River connection to Hokianga Harbour. The WWTP contaminant concentration gets diluted as it flows from Kaikohe to the harbour due to the little tributaries joining along the stream.

Results show that the 50th percentile dilution factor is about 1 in 25 up to 1000 m upstream of the Motukiore Road within the Waima River. Dilution then increase to about 1 in 2500 as it reaches the harbour near Rawene.

Dilution factor for the 95th percentile is about1 in 25 as far as the 'Y' junction where the Waima River connect to the harbour. Near Rawene the dilution is about 1 in 100.

Results are similar for both El Nino and La Nina with a slight increase in dilution during El Nino.

6. Conclusions

A hydrodynamic modelling study was undertaken to investigate dispersion of four WWTP discharge waters into Hokianga Harbour.

A field measurement campaign was first undertaken by Cawthron Institute and provided the necessary field data for calibration and validation of the hydrodynamic model. Water level and current were measured at four locations within Hokianga Harbour, Omapere, Matawhera, Onoke and The Narrows.

The open-source SCHISM system was setup and used to run high-resolution hydrodynamics and tracer dispersion simulations of the Opononi, Rawene, Kohukohu and Kaikohe WWTP discharge.

Comparisons between the model and measured water elevations show that the model captures the propagation of the tidal wave within the model domain well, including the phasing and amplitudes at various points. Principal model and measured tidal constituents show good agreement.

The shift of the FSI during the deployment period restricted the suitable methods that could be used to separate the total measured velocity into tidal and residual components.

Comparison of the total velocity indicates that the model generally reproduces well the phase and amplitude of tidal flows within the harbour. The stronger ebb tide compared to the flood tide can be seen in the model results.

Comparing the residual component of the velocity shows deviations between the model and in-situ measurements; most of the episodes are correctly reproduced. Interestingly, the model tends to reproduce the direction of change (i.e. velocity increase or decrease) but not always the velocity magnitude.

Overall, the comparisons indicate that the model reproduces the measured velocities, water elevations and salinity to a reasonable degree. In particular, the model appears to robustly reproduce the tidal dynamics in the study region, which makes it fit for the present purpose of producing waste-water studies inside the harbour.

Tracer dispersion simulations were undertaken for a full El Nino and La Nina year. The model simulation results were processed in terms of dilution factors which were determined by dividing the tracer concentration at any grid point to the discharged concentration. Results were presented in terms of the 50th and 95th percentile concentration and dilution factors which consists of a statistical representation of the plume extent.

Timeseries of concentration levels were extracted at selected location within the harbour and provided to consultants undertaking the QMRA.

Results shows that each WWTP discharges present very different plume extents due to their location within the harbour and the actual discharge volumes. Some of the key features for each discharge are:

- The Opononi WWTP discharge presents an elongated plume stretching toward the entrance of Hokianga harbour. Dilution factors for the 50th percentile are as high as 1 in 5000 within 100 m of the discharge.
- The Rawene WWTP discharge plume is mostly contained within the Omanaia River and dilution factors for the 50th percentile are about 1 in 5000 at 100 m from the discharge location
- The Kohukohu WWTP discharge plume is mostly confined to the vicinity of the discharge location with a dilution factor of 1 in 50,000 at approx. 50 m for the 50th percentile.
- The Kaikohe WWTP discharge plume present dilution factors of 1 in 25 within the Waima River as far as downstream as the last bend before Motukiore Road. Dilution is about 1 in 1000 to 1 in 2500 within the harbour.

7.References

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Appendix A: Sub-bottom Profile Survey, Rawene, Hokianga Harbour (Scantec Ltd)

S92 Response - Appendix 2

Quantitative Microbial Risk Assessment

A Quantitative Microbial Risk Assessment of the Opononi WWTP discharge and receiving environment

Action	Name	Date
Draft prepared by	Christopher A. Dada	30th January 2020
Draft internally reviewed by	Mike Stewart	3rd February 2020
Final prepared by	Christopher A. Dada	13th March 2020

Report FNC1901
Prepared for Far North District Council
March 2020

Dada A.C (2020) A Quantitative Microbial Risk Assessment of the Opononi WWTP discharge and receiving environment. FNC1901, Streamlined Environmental, Hamilton, 43 pp.

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Contents

Executive Summary

Wastewater is treated at the Opononi wastewater treatment plant (WWTP) using a combination of mechanically aerated lagoon, with one brush aerator, followed by a detention pond (for retention and sludge settling) prior to transfer of wastewater to the constructed wetland treatment system. Treated effluent discharges to the Hokianga Harbour during an outgoing tide via a submerged. Apart from the Opononi WWTP, three other upstream WWTPs (i.e. Kaikohe, Kohukohu and Rawene WWTPs) discharge into the Hokianga Harbour.

As part of the process of renewing the consent for the Opononi Wastewater Treatment Plant (WWTP) marine shoreline discharge, a Quantitative Microbial Risk Assessment (QMRA) has been prepared to assess the viral enteric illness risks related to contact recreation and consumption of harvested shellfish , as well as the acute febrile illness (respiratory) risks associated with potential inhalation of spray droplets following discharge from the outfall. The QMRA is a fundamental part of the discharge application, not only because it provides an assessment of the health risks associated with the outfall discharge, but also because it provides an indication of the WWTP virus treatment/disinfection required to alleviate those risks.

Presented in this report is information on all water-related enteric and respiratory illnesses whose causative agents have an established dose-response formulation. Consistent with previous QMRAs, for environmental waters impacted by treated wastewater, the ideal pathogens considered for this human risk assessment are the viruses: norovirus, enterovirus and adenovirus. While norovirus and enterovirus are used as QMRA pathogens to assess risks associated with ingestion of water or raw shellfish harvested from the exposure sites, adenovirus is used to assess risks associated with inhalation of water. Typical concentrations of these viruses in untreated wastewater, as have been documented in previous New Zealand QMRAs, were used to assess risks associated with ingestion of potentially polluted water and inhalation of aerosolised pathogens e.g. during water-skiing or for people accessing the shore close to the outfall being subject to wave/wind driven spray. In addition to recreational exposure, this QMRA assessed three established shellfish gathering sites for risks related to consumption of raw shellfish harvested at these sites. Pathogen concentrations arising from the discharge of treated wastewater from an outfall into the ocean near the harbour were predicted at these sites using a hydrodynamic model calibrated by MetOcean (2020).

As with previous NZ QMRAs, we sought out to determine if there will be any risks associated with the discharge, should various levels of log removals be achieved at the Opononi WWTP. Four scenarios of virus removal in the existing treatment systems at the Opononi WWTP were modelled, these being 1-log, 2-log, 3-log and 4-log reductions corresponding to 10-, 100-, 1,000- and 10,000-fold reductions in virus concentrations.

At the end of the QMRA, a comparative analysis was conducted. That is, we determined the virus log reductions assumed to be achieved at the Opononi WWTP (as informed by previously published values for similar treatment systems)[1]. We then assessed whether this level of treatment is associated with any form of health risks based on our QMRA results for that level of treatment.

In order to optimize public health protection, this QMRA applied a precautionary approach all through the entire process, for instance through the inclusion of occasional very high influent virus concentrations that occur during on-going but undetected viral illness outbreak in the community.

Hydrodynamic Modelling

A three-dimensional hydrodynamic model was calibrated by MetOcean. This included a comparison of model performance against measured water levels and currents and the mixing of the treated wastewater plume and oceanic waters near the discharge point (MetOcean 2020). Time series of virus dilutions were extracted from the year-long 2017 simulation (*el nino* and *la nina*) for 8 selected exposure sites and subsequently provided to SEL and applied in the QMRA to assess the risk of recreational illness (i.e. swimmers and people in close proximity to wave/wind driven spray) and individuals who consume raw shellfish.

QMRA Results

Results of the QMRA show that if 1-log virus (i.e. 10-fold) reduction is achieved by the WWTP, then at all the sites illness risks associated with ingestion and inhalation of water potentially containing enterovirus or norovirus from the discharge will be reduced below the “no observable adverse effect level” (NOAEL). However, under this same virus reduction level, the discharge of treated wastewater from the WWTP generally poses “low” risk of illness associated with consumption of raw shellfish (although the IIRs were only fractionally above the 1% threshold for NOAL).

Wastewater treatment that reduces virus concentrations in the WWTP discharge by 2-log (i.e. 100-fold) reduction will reduce health risks associated with the discharge (in relation to inhalation, ingestion during swimming and consumption of shellfish harvested) at all exposure sites, to levels below the NOAEL.

In published literature, a 2log virus removal is the most predominantly reported level of reduction in virus concentrations in constructed wetland treatment systems. In line with the QMRA results, if the wetland treatment system is achieving a 2log virus removal, as commonly indicated by available literature, the level of treatment currently applied at the Opononi WWTP is sufficient to reduce illness risks associated

[1] An equally robust approach to determine the virus log reductions currently being achieved at the Opononi WWTP is to make a statistical comparison of a year long monitoring exercise of virus influent and effluent virus concentrations.

with recreation or consumption of harvested raw shellfish below the “no observable adverse effect level” (NOAEL).

1. Introduction

Wastewater is treated at the Opononi wastewater treatment plant (WWTP) using a combination of mechanically aerated lagoon, with one brush aerator, followed by a detention pond (for retention and sludge settling) prior to transfer of wastewater to the constructed wetland treatment system. Treated effluent discharges to the Hokianga Harbour (approximately 2.6km from the Harbour mouth) during an outgoing tide via a submerged outfall. Apart from the Opononi WWTP, three other upstream WWTPs (i.e. Kaikohe, Kohukohu and Rawene WWTPs) discharge into the Hokianga Harbour.

As part of the process of renewing resource consents for the Opononi WWTP discharge into the Hokianga Harbour, a Quantitative Microbial Risk Assessment (QMRA) is required to address enteric illness risks related to consumption of harvested shellfish and contact recreation, as well as acute febrile illness risks associated with potential inhalation of water following the discharge and dilution in the receiving environment. The QMRA is a fundamental part of the discharge application, not only because it interfaces with the hydrodynamic studies, but because it provides some feedback loop to the WWTP treatment requirement.

To allow the Northland Regional Council (NRC) to properly assess risk to human health from the Opononi WWTP discharge, Question 2 of the S92 request for further information specifically requests that:

> *"the applicant shall identify recreational swimming and food gathering areas that are within the area between where the discharge leaves the channel and the shore. A quantitative microbiological risk assessment of the level of risk to public health shall be undertaken for these identified areas. If there is a quantifiable risk to public health in an area, then the assessment shall recommend mitigation measures to reduce this risk to an acceptable level"*

This QMRA report is designed to fulfil the requirements of the S92 request from NRC and is presented into topical sections. Section 2 presents a general summary of the hydrodynamic modelling (from MetOcean) which provides insights on the fate of the wastewater plume in the receiving environment. Section 3 captures a discussion on the approach used in the QMRA modelling, while Section 4 and 5 report and discuss the results of risks associated with ingestion and inhalation of water and consumption of shellfish at sites potentially impacted by the treated Opononi WWTP discharge water. Section 6 provides recommendations and section 7 conclusion.

2. Dilution modelling

MetOcean (2020) conducted three-dimensional hydrodynamic model simulations carried out for the assessment of the public health risk associated with the Opononi

WWTP. This allows quantitative estimations of distribution of wastewater dilutions at key sites in the receiving environment.

To ensure that a worst-case scenario is captured in the modelling:

(a) All four WWTPs discharging into the harbour were simultaneously “turned on”, such that the effect modelled at exposure sites in this QMRA for Opononi WWTP also captured additional effects from WWTPs upstream of the Opononi WWTP.
(b) A conservative tracer run was adopted in the hydrodynamic modelling. That is, the ‘effective’ dilutions are generally reflective of physical dilution due to currents only (that is, solar inactivation was excluded). The reasons for the exclusion of solar inactivation in the hydrodynamic model are supported by published literatures (e.g. see Silverman 2013, Linden et al 2007; Jin & Flury 2002). To summarise, the effectiveness of sunlight inactivation of waterborne viruses depends on complex and variable environmental factors (e.g. the intensity and spectrum of sunlight), characteristics of the water containing the virus particles (e.g. pH, dissolved oxygen, ionic strength, source and concentration of photosensitizers), and peculiarities of the virus particles (e.g. virus structures, genome type and prevalence of sites susceptible to photo-transformation; protein capsid composition and structure). These uncertainties present a core challenge in accurately modelling virus inactivation rates. Despite the uncertainties associated with estimating the actual rates of UV inactivation that would take place in the receiving environment, it is certain that ultraviolet inactivation will occur. MetOcean’s approach to exclude ultraviolet inactivation from the hydrodynamic module (as was applied in the conservative tracer model run) is thus, from a public health protection perspective, a highly precautionary approach.

Consequently, the reported risks from this QMRA include the worst-case scenario and may be overstated.

Far North District Council (FNDC) identified eight potential sites where recreation and raw shellfish harvesting is most likely to occur in the receiving environment. These sites were applied as key exposure sites in this QMRA (see Figure 1 and Table 1).

Time series of dilutions of virus concentrations were extracted from the year-long 2018 simulation for selected locations shown in Table 1. This time series data was later applied in the QMRA to assess the risk of illness to recreation (i.e. swimmers and inhalation) and individuals who consume raw shellfish (Section 3).

Table 1. Geographical coordinates and description of the exposure sites under consideration in this QMRA.

Site number	Site name	Latitude	Longitude	Description
1	CR1	-35.504251°	173.390411°	Upstream of the Opononi WWTP discharge, Hokianga Harbour Opononi LAWA site
2	CR2	-35.515411°	173.387529°	Upstream of the Opononi WWTP discharge
3	SF1	-35.519921°	173.371407°	Downstream of the Opononi WWTP discharge, situated west of the Opononi WWTP outfall
4	SF2	-35.523065°	173.384118°	Downstream of the Opononi WWTP discharge
5	CR3-SF3	-35.534885°	173.384695°	Downstream of the Opononi WWTP discharge, Omapere at Old Wharf Road LAWA site
6	SF4	-35.532088°	173.381731°	Downstream of the Opononi WWTP discharge
7	CR4-SF5	-35.535154°	173.371413°	Downstream of the Opononi WWTP discharge
8	CR5-SF6	-35.538855°	173.364246°	Downstream of the Opononi WWTP discharge

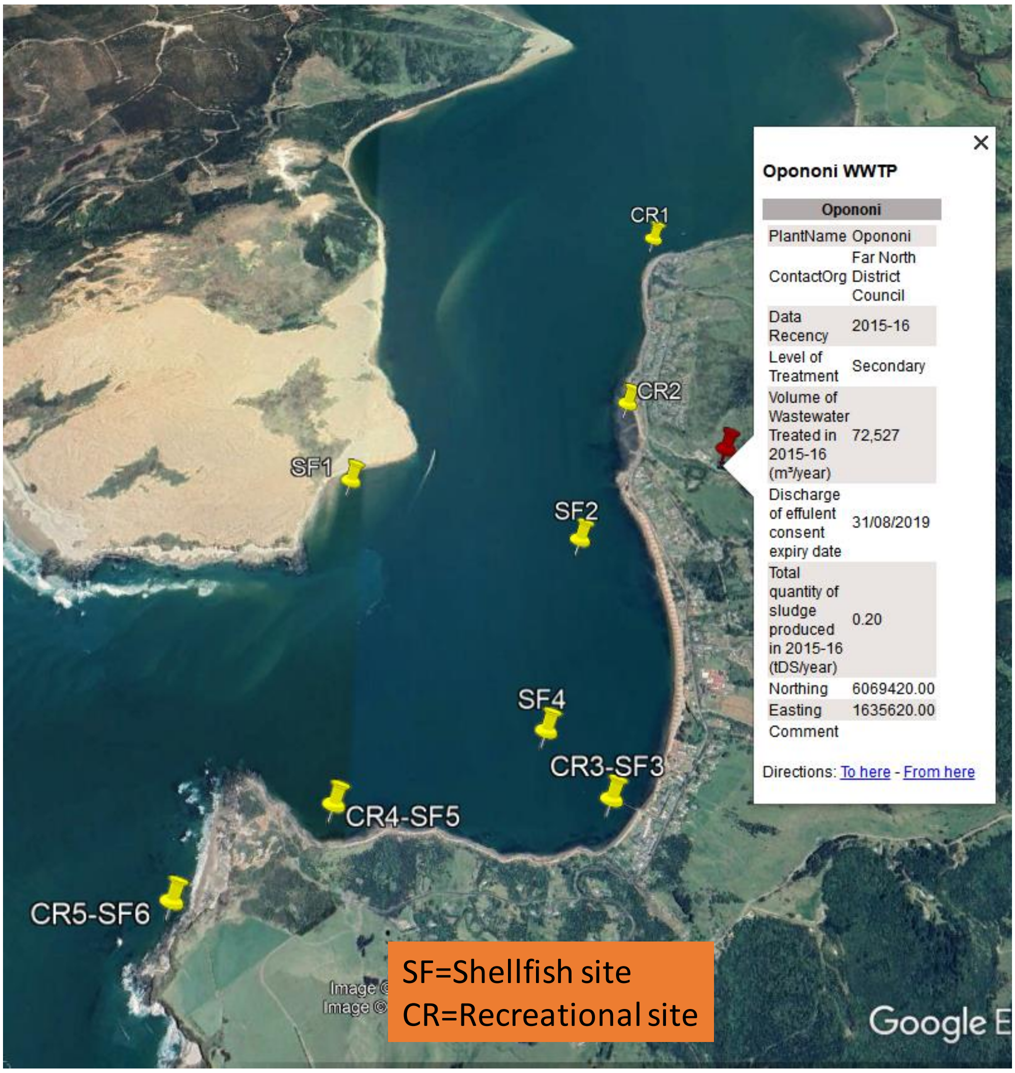

Figure 1. Location of assessment sites under consideration in this QMRA.

The 95th percentile dilutions of the virus dilutions during the conservative tracer model runs are presented in Table 2. High dilutions of up to 10^5 were observed during both *el nina*[2] and *la nina* conditions. For instance, dilutions in the receiving environment ranged from 2.03 x 10^5 at SF1 (the shoreline site situated west of the Opononi WWTP outfall) to 2.31 x 10^5 at Site CR5-SF6 (the outlet of the harbour).

Table 2. 95th percentile dilutions from the annual simulation of a conservative tracer at the QMRA sites. Source concentration is assumed to be 1 Unit.

Scenario	CR1	CR2	CR3-SF3	CR4-SF5	CR5-SF6	SF1	SF2	SF4
El nino	2.30E+05	2.31E+05	2.14E+05	2.11E+05	2.31E+05	2.03E+05	2.07E+05	2.11E+05
La nina	1.34E+05	1.36E+05	1.26E+05	1.28E+05	1.68E+05	1.26E+05	1.32E+05	1.26E+05

3. Quantitative Microbial Risk Assessment

3.1 Overview

Quantitative Microbial Risk Assessment (QMRA) is a framework that applies information and data incorporated into mathematical models to assess the potential public health risks from pathogens after discharge in a receiving environment such as water[3]. While quantitative risk assessment was initially designed to assess risks of exposure to various hazards, particularly chemicals, it has since been modified to incorporate risks related to exposure to microbial pathogens (NRC 1983). Risk is the combination of the likelihood of identified hazards causing harm in exposed populations in a specified time frame and the severity of the consequences (Hrudey, Hrudey, and Pollard 2006).

Typically, four steps are involved in a QMRA (Haas, Rose, and Gerba 1999). These are: hazard identification, exposure assessment, dose-response analysis, and risk characterization.

[2] El Niño and La Niña, the two most common climatic conditions experienced in NZ, are "opposite phases of a naturally occurring global climate cycle known as the El Niño Southern Oscillation, or ENSO for short. ENSO influences rainfall, temperature, and wind patterns" (kindly see https://niwa.co.nz/climate/information-and-resources/elnino) .
[3] It is important to note that the assessment only relates to the risk from a particular discharge, i.e. it doesn't take into account the risks associated with other discharges (for example, stormwater or non-point source discharges) that may be in the area.

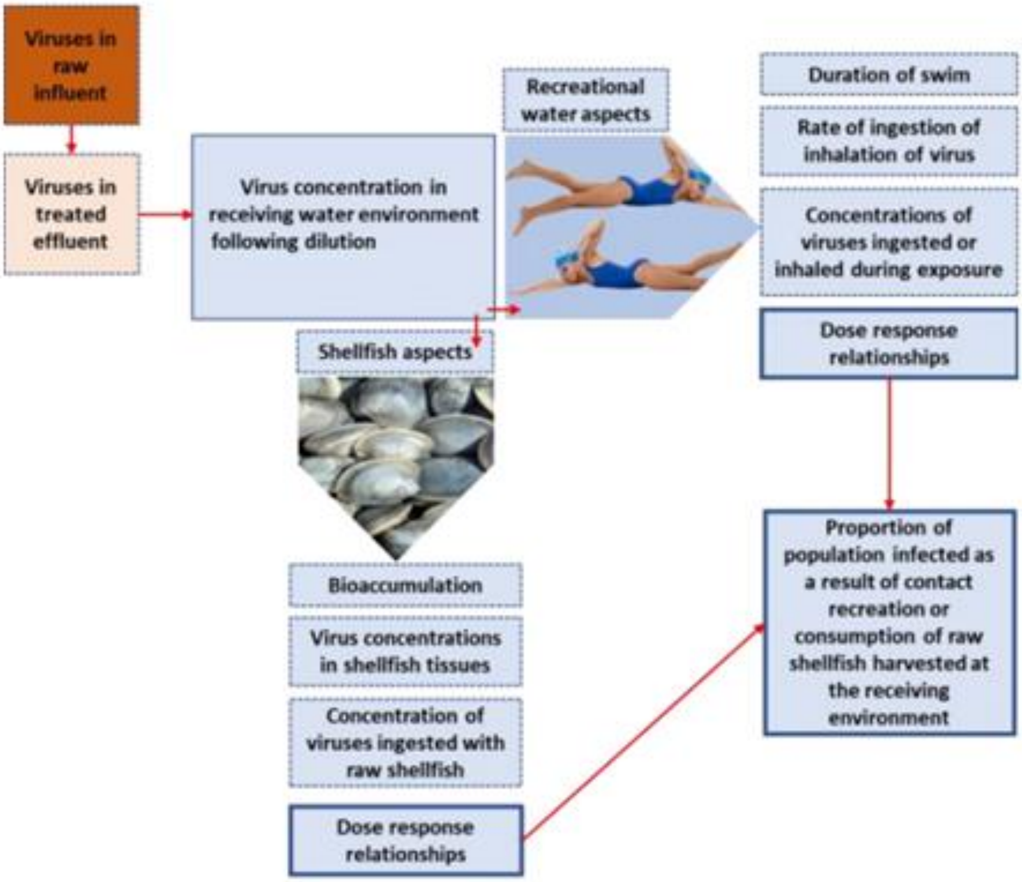

Figure 2. Typical stages in a QMRA.

3.2 Hazard analysis

Wastewater can contain several pathogenic species (Jacangelo et al. 2003; McBride 2007). The majority of pathogens in wastewater are enteric, that is, they affect the digestive system, and may present a serious health risk if ingested (Hai et al. 2014). These include: protozoans, which can cause life-threatening diseases including giardiasis, cryptosporidiosis, helminthiasis, dysentery and amoebic meningoencephalitis (Bitton 2010); viruses, which can cause paralysis, meningitis, respiratory disease, encephalitis, congenital heart anomalies and acute febrile respiratory illnesses (AFRI) and gastrointestinal illnesses (GI) (Melnick, Gerba, and Wallis 1978; Toze 1997; Okoh, Sibanda, and Gusha 2010); and bacteria, consisting of the enteropathogenic and opportunistic bacteria which cause gastrointestinal diseases such as cholera, dysentery, salmonellosis, typhoid and paratyphoid fever (Toze 1997; Cabral 2010).

Because the tests for pathogens are time-consuming and expensive, it is not practical to implement such testing on a routine basis. Instead, regulatory bodies support testing for faecal indicator bacteria (FIB) (e.g. enterococci and faecal coliforms) as a cost-effective means to assessing the presence of faecal contamination and the quality of treated effluent. These generally non-pathogenic bacteria are contained in the gut of warm-blooded animals, including humans, in large concentrations. Research shows that most pathogens die at the same rate as FIB, and hence the numbers of FIB in the treated effluent can be used to indicate the presence of pathogens.

While focus has been placed on enterococci concentrations for regulatory purposes, limitations associated with the use of conventional FIB as an indicator for viruses is well documented (Wade et al. 2008, Wade et al. 2010, USEPA 2015). Furthermore, as most standard wastewater treatment and disinfection processes vary in their efficiency in eliminating viruses, treated effluent may still contain concentrations of enteric viruses that present a significant public health risk (Lodder et al. 2010; Okoh, Sibanda, and Gusha 2010). Several enteric viruses have been described in published literature as associated with outbreaks due to exposure to polluted recreational water (Jiang et al., 2007; Sinclair et al., 2009, USEPA 2015). These include noroviruses, adenoviruses, hepatitis A viruses, echoviruses and Coxsackie viruses (Hauri et al. 2005; Lodder et al. 2010). Literature has also suggested that the greatest public health risk linked with the discharge of treated wastewater relates mainly to viruses (Courault et al. 2017; Prevost et al. 2015). A unique characteristic of viral infections is that a high proportion of the exposed populations could be potentially affected, often leading to very high incidences of gastroenteritis that can then be spread by person-to-person contact to other individuals who were not directly exposed to the polluted waters (Patel et al. 2008; Widdowson, Monroe, and Glass 2005). For instance, a single vomiting incident from an individual infected with norovirus could expel up to 30 million virus particles (Tung-Thompson et al. 2015). In community settings, this could result in contamination of surfaces with large numbers of viruses, effectively promoting the further spread of the pathogens.

For environmental waters impacted by treated wastewater, the ideal reference pathogens considered for human risk assessment are the viruses: norovirus, enterovirus and adenovirus (McBride 2016a,b). These viruses have been used as representative viruses for previous studies in New Zealand (McBride 2011, 2012, 2016a,b). While norovirus and enterovirus are significant contributors to enteric infections, adenovirus (Type 4) can cause respiratory illnesses via inhalation of aerosols from contaminated water during swimming, water-skiing or people accessing the shore close to the outfall being subject to wave/wind driven spray. Hence, in this study, norovirus and enterovirus were used as reference QMRA pathogens for primary contact recreation and shellfish consumption. For secondary contact recreation, which includes activities such as shoreline walking, jogging, paddling, wading, boating and fishing, in which there may be some direct contact but the chance of swallowing water is unlikely, only adenovirus (Type 4) was used as reference pathogen for assessing risks associated with inhalation of potentially polluted water (e.g. from wind or wave-induced spray) containing aerosolised pathogens. Other technical reasons that warranted the choice of these reference pathogens are detailed in Appendix 1. Typical concentrations of these reference viruses in untreated wastewater are presented in Table 3 and are in line with values have been documented in several previous New Zealand QMRAs (e.g. Dada 2018a; 2018b; McBride 2011, 2016a, b).

3.3 Exposure Assessment

Exposure assessment involves identification of populations that could be affected by pathogens. The main individuals at risk of exposure to pathogens in the receiving environment of the Opononi WWTP are those that engage in any sort of contact recreation or those who consume raw shellfish collected from any site potentially impacted by the discharge. In order to assess the potential level of exposure, the following were considered:

- proximity of the QMRA site[4] to the discharge outlet;
- the possible exposure pathways that allow the pathogen to reach people and cause infection (through the air, through ingesting polluted water, consuming shellfish etc.);
- range (minimum, maximum and median) of pathogen concentrations in treated effluent;
- discharge volumes of the treated wastewater;
- the environmental fate of the microbial contaminants in the receiving environment: dilution of viral pathogens in the receiving marine environment;
- how much water a child[5] will ingest or inhale over a period of time during a particular recreational activity;
- how much raw shellfish harvested from the impact sites that an individual will consume at one sitting; and
- estimation of the amount, frequency, length of time of exposure, and doses for an exposure.

3.3.1 Opononi WWTP influent and effluent virus concentrations

There are no available data on the influent and effluent virus concentrations in the Opononi WWTP discharge. Notwithstanding, a range of influent virus concentrations have already been reported in long term studies in New Zealand, and these have been used as representative influent virus concentrations in previous New Zealand QMRAs (e.g. Dada 2018a; 2018b; McBride 2016a,b). Influent virus concentrations (minimum, maximum and median) applied in this QMRA were therefore based on these previous documented ranges (see Table 3).

[4] FNDC was responsible for identifying potential exposure sites for the QMRA.
[5] A child is considered the worst-case risk because studies show that ingestion rates for children are twice as much as for adults (e.g. Dufour et al.2006) as reported in McBride (2017) QMRA for Bell Island WWTP outfall.

A range of possible $\log_{10}$ reductions[6] in virus concentrations are possible following WWTP treatment processes. For instance, this could range from 1-log reduction to as high as 4-log reductions. In this QRMA, we assessed health risks that would be associated with the discharge, assuming any of these levels of influent virus reductions is achieved at the Opononi WWTP before the treated wastewater is discharged into the receiving environment.

At the end of the QMRA, a validation exercise was then conducted. That is, we determined the virus log reductions currently being achieved at the Opononi WWTP (as informed by previously published values for similar treatment systems)[7]. We then assessed whether this level of treatment is associated with any form of health risks based on our QMRA results for that level of treatment.

3.3.2 Predicting exposure doses

The dose of the pathogen that an individual ingests, inhales or comes in contact with is an important component of the dose-response models used to predict the probability of infection or illness. In order to convert pathogen concentrations into doses, reference was made to the influent virus concentrations, the ingestion or inhalation rates for the water users (adults and children, in the case of swimming or other contact recreation), as well as shellfish bioaccumulation factors (in the case of shellfish harvesters). Details of these dose response models are presented in Appendices 1 to 3.

For risks due to swimming, water ingestion rates applied in the QMRA (Table 3) were based on previous studies that have applied biochemical procedures to trace a decomposition product of chlorine-stabilizing chloroisocyanurate which passes through the surveyed swimmers' bodies unmetabolized (Dufouer et al 2006, McBride 2016).

Table 3 Distributions and inputs for the QMRA (Adapted from McBride 2016a,b).

Parameter	QMRA Statistics applied	Comments
Influent concentration, Adenovirus	Minimum = 2,000 Median = 5,000 Maximum = 30,000,000	Hockey stick distribution, as previously described (McBride 2007, 2011; 2012; 2016 a,b). Norovirus harmonization factor of 18.5 was included, in line with McBride 2011 and 2017)
Influent concentration, Norovirus	Minimum = 100 Median = 10,000 Maximum = 10,000,000	
Influent concentration, Enterovirus	Minimum = 500 Median = 4,000 Maximum = 50,000,000	

[6] Also called log removal value (LRV). It is a measure of the ability of a treatment processes to remove the viruses in question. An LRV of 1 (i.e. 1log removal) is equivalent to 90% removal of a target pathogen, an LRV of 2 (i.e. 2log removal) is equivalent to 99% removal, an LRV of 3 is equivalent to 99.9% removal, and 4 log reduction = 99.99% reduction etc.
[7] An equally robust approach to determine the virus log reductions currently being achieved at the Opononi WWTP is to make a statistical comparison of a year-long monitoring exercise of virus influent and effluent virus concentrations.

Parameter	QMRA Statistics applied	Comments
Duration of swim (hours)	Minimum = 0.1 Median = 0.25 Maximum = 2	For child or adult (McBride 2007, 2011; 2012; 2016 a,b)
Swimmers water ingestion rate, mL per hour	Minimum = 20 Median =50 Maximum = 100	PERT distribution for a child rate. Typically, adult rate is half the child rate (Dufour et al, 2006)
Water inhalation rate, mL per hour	Minimum = 10 Median =25 Maximum = 50	PERT distribution for an adult, assumed as half of child rate (McBride 2007, 2011; 2012; 2016 a,b)
Dose response parameters	Enterovirus (beta-binomial model, α = 1.3, β =75) Prob(illness/infection)=1	Dada 2018a; 2018b; McBride 2007, 2011; 2012; 2016; Stewart et al. 2017, Soller et al. 2010a,b
	Adenovirus Type 4 (simple binomial model, r = 0.4142). Only 3-10% of adenoviruses cause respiratory illnesses. Prob(illness/infection)=0.5	Dada 2018a; 2018b; McBride 2007, 2011; 2012; 2016; Stewart et al. 2017, Soller et al. 2010 a,b, Kundu et al. 2013
	Norovirus (beta-binomial model, α = 0.04, β =0.055) Prob(illness/infection)=0.6	Dada 2018a; 2018b; McBride 2007, 2011; 2012; 2016; Stewart et al.2017, Soller et al. 2010 a,b
Shellfish size	α = 2.2046 β = 75.072 γ = -0.903	Loglogistic distribution between 5g and 800g, based on estimates of daily intake of consumers of raw shellfish (see McBride 2005, McBride 2007, 2011; 2012; 2016, Russel et al.1999)
Pathogen bioaccumulation factor (PBAF)	Mean = 49.9 Standard deviation = 20.93	Normal distributions around mean. Pathogen dose upon consumption of 100 grams of shellfish is a product of the PBAF and the number of pathogens in an equivalent volume of water (see Burkhardt & Calci 2000, McBride 2007, 2011; 2012; 2016)

In order to assess risks due to consumption of raw harvested shellfish, ingestion rates used were in line with estimates of daily intake of 98 consumers of mussels, oysters, scallops, pipi and tuatua in the 1997 National Nutrition Survey, as reported in previous New Zealand QMRAs (e.g. Dada 2018a,b, Stewart et al.2017, McBride 2005, 2016a,b).

It is important to note that previous QMRA reports (e.g. McBride 2016 a, b) have assessed risks due to ingestion of raw shellfish tissue using bivalve molluscs as the vector. This is because bivalve molluscs are very common and accessible in New Zealand waters, are very frequently consumed raw; and because they are known to 'bioaccumulate' pathogens, hence the additional multiplier effect called the pathogen bioaccumulative factor (PBAF, see Table 3) applied in our model (Bellou, Kokkinos, and Vantarakis 2013; Hanley 2015; Hassard et al. 2017).

3.3.3 Dose-response models

Dose-response models estimate the risk of a response (for example, infection or illness) given a known dose of a pathogen. Dose-response models are mathematical functions which describe the dose-response relationship for specific pathogens, transmission routes and hosts. Additional dose-response details are presented in the Appendix 2 and 3.

3.3.4 Risk characterization

Information from the previous steps were incorporated into Monte Carlo simulations to determine the likelihood of illness from exposure to pathogens. The Monte Carlo simulation is a randomization method that applies multiple random sampling from distributions assigned to key input variables in a model, in a way that incorporates the uncertainty profiles of each key input variable into the uncertainty profile of the output.

Typically, in a Monte Carlo model run, 100 individuals who do not have prior knowledge of existing contamination in the water are 'exposed' to potentially infectious water on a given day and this exposure is repeated 1,000 times. Therefore, the total number of exposures is 100,000. The result of the analysis is a full range of possible risks, including average and worst-case scenarios, associated with exposure to pathogens during the identified recreational activities or following consumption of raw shellfish. Monte Carlo simulations were undertaken using @Risk software (Palisade, NY). QMRA results are reported in terms of both infection and illness. It is noted however, that not all individuals that become infected eventually become ill. Although pathogen-dose response models in literature were determined based on infection endpoint, illness endpoint can be estimated simply using a uniform probability for illness as was done in several previous QMRAs (e.g. McBride 2011, 2017). Infection/illness ratios of 0.6 and 0.5 were applied for noroviruses and adenoviruses (McBride 2016), respectively. Due to the relative unavailability of dose-response and morbidity data for enterovirus, a precautionary approach was used in this study, that is, it was assumed that every individual who contracted enterovirus infections also became ill, hence a conservative infection/illness ratio of 1 was applied. This is in line with methods applied in previous New Zealand QMRAs (e.g. McBride 2011, 2016).

The predicted risk is reported as the IIR (individual illness risk), calculated as the total number of infection cases divided by the total number of exposures, expressed as a percentage. The IIR is then compared with thresholds defined in the New Zealand "*Microbiological Water Quality Guidelines for Marine and Freshwater Recreational Areas*" (MfE/MoH 2003). Depending on the risk being examined, the applicable NZ thresholds differ.

In the case of risk due to gastrointestinal illnesses (GI) as a result of ingestion of polluted water while swimming or consumption of raw shellfish harvested from the impacted sites, the following thresholds apply:

- high illness risk (>10% GI illness);
- moderate illness risk (5-10% GI illness);
- low illness risk (1-5% GI illness);
- NOAEL (<1%); the 1% IIR threshold, also referred to as the 'no observable adverse effects level (NOAEL), is the widely-accepted threshold when assessing the effect of wastewater discharge on recreational health risk (Dada 2018a; 2018b; McBride 2016a,b, 2017; Stewart et al.2017).

In the case of acute febrile respiratory illness (AFRI) risks due to inhalation of pathogens in spray water, near or at the impacted sites, comparatively lower thresholds apply:

- high illness risk (>3.9% AFRI illness);
- moderate illness risk (1.9-3.9% AFRI illness);
- low illness risk (0.3-<1.9% AFRI illness);
- NOAEL (<0.3%).

With respect to the MfE/MoH (2003) guidelines for marine waters[8]:

- High risks relate to 95th percentile enterococci concentrations greater than 500 enterococci/100mL.
- Moderate risks relate to 95th percentile enterococci concentrations between 201 and 500 enterococci/100mL.
- Low risks generally relate to 95th percentile enterococci concentrations between 41 and 200 enterococci/100mL.
- NOAEL relate to 95th percentile concentrations ≤40 enterococci/100mL.

4. QMRA Results

The results of the QMRA analysis for individuals exposed to a range of reference pathogens under the various proposed discharge scenarios are presented in Table 4 to Table 8.

[8] in Hudson and McBride (2017)

4.1 Risks associated with ingestion of water

Table 4. Child's Enteric Illness Risk (%) at eight identified sites potentially impacted by enterovirus during different Opononi WWTP discharge scenarios.

Virus Log Reduction	Exposure site	El nino		La nina	
		Summer	Annual	Summer	Annual
1 Log Reduction	CR1	<0.1	<0.1	<0.1	<0.1
	CR2	<0.1	<0.1	<0.1	<0.1
	CR3-SF3	<0.1	<0.1	<0.1	<0.1
	CR4-SF5	<0.1	<0.1	<0.1	<0.1
	CR5-SF6	<0.1	<0.1	<0.1	<0.1
	SF1	<0.1	<0.1	<0.1	<0.1
	SF2	<0.1	<0.1	<0.1	<0.1
	SF4	<0.1	<0.1	<0.1	<0.1
2 Log Reduction	CR1	<0.1	<0.1	<0.1	<0.1
	CR2	<0.1	<0.1	<0.1	<0.1
	CR3-SF3	<0.1	<0.1	<0.1	<0.1
	CR4-SF5	<0.1	<0.1	<0.1	<0.1
	CR5-SF6	<0.1	<0.1	<0.1	<0.1
	SF1	<0.1	<0.1	<0.1	<0.1
	SF2	<0.1	<0.1	<0.1	<0.1
	SF4	<0.1	<0.1	<0.1	<0.1
3 Log Reduction	CR1	<0.1	<0.1	<0.1	<0.1
	CR2	<0.1	<0.1	<0.1	<0.1
	CR3-SF3	<0.1	<0.1	<0.1	<0.1
	CR4-SF5	<0.1	<0.1	<0.1	<0.1
	CR5-SF6	<0.1	<0.1	<0.1	<0.1
	SF1	<0.1	<0.1	<0.1	<0.1
	SF2	<0.1	<0.1	<0.1	<0.1
	SF4	<0.1	<0.1	<0.1	<0.1
4 Log Reduction	CR1	<0.1	<0.1	<0.1	<0.1
	CR2	<0.1	<0.1	<0.1	<0.1
	CR3-SF3	<0.1	<0.1	<0.1	<0.1
	CR4-SF5	<0.1	<0.1	<0.1	<0.1
	CR5-SF6	<0.1	<0.1	<0.1	<0.1
	SF1	<0.1	<0.1	<0.1	<0.1
	SF2	<0.1	<0.1	<0.1	<0.1
	SF4	<0.1	<0.1	<0.1	<0.1

IIR> 10%	High enteric illness risk
IIR (5.0-10%)	Moderate enteric illness risk
IIR (1.0-4.99%)	Low enteric illness risk
IIR <1%	NOAEL

Table 5. Child's Enteric Illness Risk (%) at eight identified sites potentially impacted by norovirus during different Opononi WWTP discharge scenarios.

Virus Log Reduction	Exposure site	El nino		La nina	
		Summer	Annual	Summer	Annual
1 Log Reduction	CR1	<0.1	<0.1	<0.1	<0.1
	CR2	<0.1	<0.1	<0.1	<0.1
	CR3-SF3	<0.1	<0.1	<0.1	<0.1
	CR4-SF5	<0.1	<0.1	<0.1	<0.1
	CR5-SF6	<0.1	<0.1	<0.1	<0.1
	SF1	<0.1	<0.1	<0.1	<0.1
	SF2	<0.1	<0.1	<0.1	<0.1
	SF4	<0.1	<0.1	<0.1	<0.1
2 Log Reduction	CR1	<0.1	<0.1	<0.1	<0.1
	CR2	<0.1	<0.1	<0.1	<0.1
	CR3-SF3	<0.1	<0.1	<0.1	<0.1
	CR4-SF5	<0.1	<0.1	<0.1	<0.1
	CR5-SF6	<0.1	<0.1	<0.1	<0.1
	SF1	<0.1	<0.1	<0.1	<0.1
	SF2	<0.1	<0.1	<0.1	<0.1
	SF4	<0.1	<0.1	<0.1	<0.1
3 Log Reduction	CR1	<0.1	<0.1	<0.1	<0.1
	CR2	<0.1	<0.1	<0.1	<0.1
	CR3-SF3	<0.1	<0.1	<0.1	<0.1
	CR4-SF5	<0.1	<0.1	<0.1	<0.1
	CR5-SF6	<0.1	<0.1	<0.1	<0.1
	SF1	<0.1	<0.1	<0.1	<0.1
	SF2	<0.1	<0.1	<0.1	<0.1
	SF4	<0.1	<0.1	<0.1	<0.1
4 Log Reduction	CR1	<0.1	<0.1	<0.1	<0.1
	CR2	<0.1	<0.1	<0.1	<0.1
	CR3-SF3	<0.1	<0.1	<0.1	<0.1
	CR4-SF5	<0.1	<0.1	<0.1	<0.1
	CR5-SF6	<0.1	<0.1	<0.1	<0.1
	SF1	<0.1	<0.1	<0.1	<0.1
	SF2	<0.1	<0.1	<0.1	<0.1
	SF4	<0.1	<0.1	<0.1	<0.1

IIR> 10%	High enteric illness risk
IIR (5.0-10%)	Moderate enteric illness risk
IIR (1.0-4.99%)	Low enteric illness risk
IIR <1%	NOAEL

4.2 Risks associated with inhalation of water

Table 6. Child's Acute Febrile Illness Risk (%) at eight identified sites potentially impacted by adenoviruses during different Opononi WWTP discharge scenarios.

		El nino		La nina	
Virus Log Reduction	Exposure site	Summer	Annual	Summer	Annual
1 Log Reduction	CR1	<0.1	0.12	<0.1	0.14
	CR2	<0.1	<0.1	<0.1	0.21
	CR3-SF3	<0.1	0.15	<0.1	0.23
	CR4-SF5	<0.1	0.11	<0.1	0.21
	CR5-SF6	<0.1	0.11	<0.1	0.15
	SF1	<0.1	0.17	<0.1	0.21
	SF2	<0.1	<0.1	<0.1	0.25
	SF4	<0.1	0.15	<0.1	0.26
2 Log Reduction	CR1	<0.1	<0.1	<0.1	<0.1
	CR2	<0.1	<0.1	<0.1	<0.1
	CR3-SF3	<0.1	<0.1	<0.1	<0.1
	CR4-SF5	<0.1	<0.1	<0.1	<0.1
	CR5-SF6	<0.1	<0.1	<0.1	<0.1
	SF1	<0.1	<0.1	<0.1	<0.1
	SF2	<0.1	<0.1	<0.1	<0.1
	SF4	<0.1	<0.1	<0.1	<0.1
3 Log Reduction	CR1	<0.1	<0.1	<0.1	<0.1
	CR2	<0.1	<0.1	<0.1	<0.1
	CR3-SF3	<0.1	<0.1	<0.1	<0.1
	CR4-SF5	<0.1	<0.1	<0.1	<0.1
	CR5-SF6	<0.1	<0.1	<0.1	<0.1
	SF1	<0.1	<0.1	<0.1	<0.1
	SF2	<0.1	<0.1	<0.1	<0.1
	SF4	<0.1	<0.1	<0.1	<0.1
4 Log Reduction	CR1	<0.1	<0.1	<0.1	<0.1
	CR2	<0.1	<0.1	<0.1	<0.1
	CR3-SF3	<0.1	<0.1	<0.1	<0.1
	CR4-SF5	<0.1	<0.1	<0.1	<0.1
	CR5-SF6	<0.1	<0.1	<0.1	<0.1
	SF1	<0.1	<0.1	<0.1	<0.1
	SF2	<0.1	<0.1	<0.1	<0.1
	SF4	<0.1	<0.1	<0.1	<0.1

IIR> 3.9%	High AFR illness risk
IIR (1.9 - 3.9%)	Moderate AFR illness risk
IIR (0.3 - <1.9%)	Low AFR illness risk
IIR <0.3%	NOAEL

*AFR =Acute Febrile Respiratory

4.3 Risks associated with shellfish harvesting and consumption

Table 7. Individual's Illness Risk (%) associated with consumption of raw shellfish collected at exposure sites that are potentially impacted with enteroviruses as a result of Opononi WWTP discharge.

Virus Log Reduction	Exposure site	El nino		La nina	
		Summer	Annual	Summer	Annual
1 Log Reduction	CR1	0.67	1.13	0.70	0.89
	CR2	0.60	0.89	0.60	1.13
	CR3-SF3	0.73	0.94	0.64	1.40
	CR4-SF5	0.71	0.96	0.72	1.10
	CR5-SF6	0.67	0.94	0.62	1.32
	SF1	0.70	0.76	0.76	1.28
	SF2	0.73	1.19	0.69	1.03
	SF4	0.65	1.10	0.85	0.98
2 Log Reduction	CR1	<0.1	0.21	0.11	0.17
	CR2	<0.1	0.14	<0.1	0.25
	CR3-SF3	0.12	0.17	<0.1	0.28
	CR4-SF5	<0.1	0.17	0.13	0.20
	CR5-SF6	<0.1	0.17	0.10	0.24
	SF1	0.10	0.12	0.11	0.25
	SF2	<0.1	0.18	0.11	0.22
	SF4	0.13	0.19	0.14	0.21
3 Log Reduction	CR1	<0.1	<0.1	<0.1	<0.1
	CR2	<0.1	<0.1	<0.1	<0.1
	CR3-SF3	<0.1	<0.1	<0.1	<0.1
	CR4-SF5	<0.1	<0.1	<0.1	<0.1
	CR5-SF6	<0.1	<0.1	<0.1	<0.1
	SF1	<0.1	<0.1	<0.1	<0.1
	SF2	<0.1	<0.1	<0.1	<0.1
	SF4	<0.1	<0.1	<0.1	<0.1
4 Log Reduction	CR1	<0.1	<0.1	<0.1	<0.1
	CR2	<0.1	<0.1	<0.1	<0.1
	CR3-SF3	<0.1	<0.1	<0.1	<0.1
	CR4-SF5	<0.1	<0.1	<0.1	<0.1
	CR5-SF6	<0.1	<0.1	<0.1	<0.1
	SF1	<0.1	<0.1	<0.1	<0.1
	SF2	<0.1	<0.1	<0.1	<0.1
	SF4	<0.1	<0.1	<0.1	<0.1

IIR> 10%	High enteric illness risk
IIR (5.0-10%)	Moderate enteric illness risk
IIR (1.0-4.99%)	Low enteric illness risk
IIR <1%	NOAEL

Table 8. Individual's Illness Risk (%) associated with consumption of raw shellfish collected at exposure sites that are potentially contaminated with noroviruses as a result of Opononi WWTP discharge.

		El nino		La nina	
Virus LogReduction	Exposure site	Summer	Annual	Summer	Annual
1 Log Reduction	CR1	0.96	1.15	0.95	1.03
	CR2	0.95	0.99	0.91	0.98
	CR3-SF3	0.92	1.00	0.96	1.03
	CR4-SF5	0.91	1.10	0.95	1.17
	CR5-SF6	0.92	1.07	0.90	1.07
	SF1	0.90	1.04	0.91	1.05
	SF2	0.89	1.03	0.91	1.01
	SF4	0.90	0.99	0.94	1.01
2 Log Reduction	CR1	0.28	0.37	0.26	0.31
	CR2	0.22	0.34	0.25	0.36
	CR3-SF3	0.30	0.37	0.25	0.50
	CR4-SF5	0.27	0.32	0.27	0.39
	CR5-SF6	0.24	0.42	0.25	0.29
	SF1	0.23	0.32	0.24	0.30
	SF2	0.27	0.35	0.24	0.35
	SF4	<0.1	<0.1	<0.1	<0.1
3 Log Reduction	CR1	<0.1	<0.1	<0.1	<0.1
	CR2	<0.1	<0.1	<0.1	<0.1
	CR3-SF3	<0.1	<0.1	<0.1	<0.1
	CR4-SF5	<0.1	<0.1	<0.1	<0.1
	CR5-SF6	<0.1	<0.1	<0.1	<0.1
	SF1	<0.1	<0.1	<0.1	<0.1
	SF2	<0.1	<0.1	<0.1	<0.1
	SF4	<0.1	<0.1	<0.1	<0.1
4 Log Reduction	CR1	<0.1	<0.1	<0.1	<0.1
	CR2	<0.1	<0.1	<0.1	<0.1
	CR3-SF3	<0.1	<0.1	<0.1	<0.1
	CR4-SF5	<0.1	<0.1	<0.1	<0.1
	CR5-SF6	<0.1	<0.1	<0.1	<0.1
	SF1	<0.1	<0.1	<0.1	<0.1
	SF2	<0.1	<0.1	<0.1	<0.1
	SF4	<0.1	<0.1	<0.1	<0.1

IIR> 10%	High enteric illness risk
IIR (5.0-10%)	Moderate enteric illness risk
IIR (1.0-4.99%)	Low enteric illness risk
IIR <1%	NOAEL

5. Discussion

5.1 Overview

In order to optimize public health protection, a precautionary approach to this QMRA has been applied through the entire process. For instance, using a hockey-stick distribution fitting, the QMRA included considerations for very high influent virus concentrations that occasionally occur during illness outbreaks in the community. While these high concentrations are rare, they have a high potential impact on the estimated risks. Another precautionary approach in this QMRA is to report the children's illness risk as opposed to the generally lower adults' risk[9], particularly considering that the . This is consistent with previous QMRAs e.g. the Bell Island QMRA (McBride 2017). This QMRA also included a dilution-only scenario which does not include solar ultraviolet-based inactivation of viruses, to capture risks posed to early-morning recreational water users. Therefore, the reported risks from this QMRA include the worst-case scenario and may be overstated.

5.2 QMRA results for recreation – ingestion of water

The QMRA results for children (Table 4 to Table 5) show that if a 1-log virus reduction for enterovirus or norovirus is achieved by the Opononi WWTP, then at all eight assessment sites, illness risks associated with ingestion of water potentially polluted by enterovirus or norovirus are reduced below the "no observable adverse effect level" (NOAEL).

5.3 QMRA results for recreation – inhalation of water

The QMRA results for children (Table 6) generally indicate that individual illness risks (IIR) were slightly higher during *la nina* than *el nino* conditions. This is understandable as the hydrodynamic modelling showed comparatively lower dilutions during *la nina* conditions. For instance, 95^{th} percentile dilutions at the CR3-SF3 site, downstream of the Opononi WWTP discharge (Omapere at Old Wharf Road LAWA site) under *el nino* conditions was 2.14×10^5, nearly double the 95^{th} percentile dilution achieved during *la nina* conditions at the same site (see Table 2).

The QMRA modelling found that if a 1-log virus reduction for adenovirus is achieved by the Opononi WWTP, then at all eight assessment sites, illness risks associated with inhalation of water potentially polluted by adenovirus are reduced below the "no observable adverse effect level" (NOAEL).

[9] The 1997 National Nutrition Survey, as reported in previous New Zealand QMRAs (e.g. Dada 2018a,b, Stewart et al.2017, McBride 2005, 2016a,b) was based on adults' consumption rate for raw harvested shellfish. This study consistent with previous New Zealand QMRAs (e.g. Dada 2018a,b, Stewart et al.2017, McBride 2005, 2016a,b) used children's consumption rate that is double the published adults' rate. Hence, the risks herein reported are conservative.

5.4 QMRA results for shellfish harvesting and consumption

The QMRA modelling results for shellfish harvesting and consumption (Table 7 and Table 8) show that if a 1-log virus reduction for norovirus and enterovirus is achieved by the Opononi WWTP, then at all sites, low illness risks are associated with consumption of raw shellfish. It is important to note that the generally "low" risk of illness associated with consumption of raw shellfish harvested at these sites may be as a result of the exclusion of inactivation occurring as a result of solar radiation in the receiving environment[10]. We note also that the IIRs associated with consumption of raw shellfish are only fractionally above the 1% threshold for NOAL.

Risks associated with shellfish consumption were generally higher than for ingestion of water while swimming because of the conservative approach used for the modelling of enteric illness risks associated with shellfish risk consumption. We applied the bioaccumulation factor to assess risk associated with ingestion of raw shellfish tissue. Also, we assumed that consumption of shellfish is instantaneous (i.e. without depuration). While depuration of shellfish after harvesting and adequate refrigeration before consumption are key steps that commercial harvesters take to reduce health risks, these steps are not routinely taken by consumers of recreational shellfish. Hence consideration of depuration was not included in this QMRA. As noted in McBride (2017), this explains why risks from raw shellfish consumption are always calculated to be rather higher than risks associated with swimming in or near to the shellfish-harvesting waters.

Additionally, all four WWTPs discharging into the harbour were simultaneously "turned on", i.e. discharging wastewater, such that the effect modelled at exposure sites in this QMRA for Opononi WWTP also captured additional effects from WWTPs upstream of the Opononi WWTP. Given these considerations, we are following conservative principles and hence, reporting a worst-case scenario.

If a 2-log reduction in enterovirus and norovirus concentrations is achieved at the WWTP before discharge, enteric illness risks among individuals who consume raw shellfish collected at the shellfish harvesting sites are reduced to below the NOAEL at all the exposure sites.

5.5 Comparison of QMRA results with existing virus removals at the Opononi WWTP

The QMRA shows that if a 2-log (i.e. 100-fold) reduction in enterovirus, norovirus and adenovirus concentrations is achieved at the Opononi WWTP before discharge, enteric and acute respiratory febrile illness risks among individuals who engage in recreation or consume raw shellfish collected at the shellfish harvesting sites are reduced below the NOAEL at all sites assessed. Furthermore, the results show that if a 1-log (i.e. 10-fold) reduction in enterovirus, norovirus and adenovirus

[10] Since conservative tracer dilutions were used for the QMRA herein reported.

concentrations is achieved at the Opononi WWTP before discharge, enteric illness risks are only fractionally above the no observable effect threshold.

Further to the results obtained in this QMRA, it was necessary to assess if the current treatment system at the Opononi WWTP achieves this level of virus reduction. There are no monitoring data on the range of actual reduction in influent virus concentration at Opononi WWTP. However, literature reveal that the performance of constructed wetland systems used for wastewater treatment will vary depending on the presence and type of plants, filter depth and sand type, operational parameters, temperature effects and retention time (Quiñónez-Dìaz et al 2001). Notwithstanding, a summary of virus removals reported in available literature (Table 9) suggest that 2log virus removals is the most predominantly reported level of reduction in virus concentrations in wetlands. Therefore, and in the absence of any monitoring data, this information suggests that the level of treatment currently applied at the Opononi WWTP (if its virus reduction performance is consistent with the literature, i.e. an average 2log virus removal) is sufficient to reduce illness risks associated with recreation or consumption of harvested raw shellfish below the "no observable adverse effect level" (NOAEL).

Another indication that the required 2-log virus removal is currently being achieved at the Opononi WWTP is reflected in the faecal indicator bacteria concentration of the receiving environment water samples. Available water quality data[11] for the CR3-SF3 site (i.e. Omapere at Old Wharf Road, downstream of the Opononi WWTP discharge) and Hokianga Harbour Opononi LAWA (upstream of the Opononi WWTP discharge) sites indicates that only low health risk exists at these sites if used for recreational bathing. For instance, the 5-year 95th percentile enterococci concentration for Omapere at Old Wharf Road and Hokianga Harbour Opononi are 52 enterococci/100 mL and 70 enterococci/100 mL, respectively[12]. These concentrations are marginally above the threshold for sites classified as A in terms of the Microbiological Assessment Category (MAC) guidelines (MfE/MoH 2003), hence are classified as B. While there is no data on a recent Sanitary Inspection Category (SIC) for these sites, other potential contaminant sources (such as urban runoff, streams draining catchments etc.) may impair water quality during storm events. This was reflected in the enterococci data routinely collected by the NRC at CR3-SF3 site. For instance, enterococci concentrations at CR3-SF3 site generally did not exceed the acceptable[13] single sample threshold of 140 enterococci/100 mL (Green mode, see

[11] The Northland Regional Council has routinely monitored bathing sites, including coastal sites that are upstream and downstream of the Opononi WWTP (i.e. Hokianga Harbour Opononi and Omapere at Old Wharf Road, respectively). While data at the Omapere at Old Wharf Road site has only been collected since 2018 till date, enterococci data has since 2009 been collected at the Hokianga Harbour Opononi site. In terms of the Microbiological Assessment Category (MAC) guidelines (MfE/MoH 2003), enterococci <40 cells/mL =Band A, >40 and <200 cells/mL =Band B, >200 and <500 cells/mL =Band C and >500 cells/mL = Band D.

[12] 2014/15-2019/20 bathing seasons, although Omapere at Old Wharf Road site has only been collected since 2018 till date

[13] The most recent data (5 year long, 2014-2019) are herein analysed in relation to the guidelines stipulated in the Ministry for Environment/Ministry of Health (MfE/MoH) 2003 Microbiological water quality guidelines for marine and freshwater recreational areas. The MoH guidelines propose a three-tier management framework based on enterococci indicator values, i.e. surveillance (green), alert (amber) and action (red) modes. For the Microbiological Assessment Category (MAC) marked as "acceptable/green", no single sample should present with enterococci greater than 140 enterococci/100 mL. The alert mode requires investigation of the causes of the elevated levels and increased sampling to enable the risks to bathers to be more accurately assessed. The action mode requires the local authority and health authorities to warn the public that the beach is considered unsuitable for recreation.

upper image in Figure 3), except in one instance on the 3rd of December 2018 *when a lot of storm water was released onto the beach*[14] (observed concentration on storm event day = 680 enterococci/100 mL).

Table 9 Commonly reported virus removals in wetland treatment systems.

Type of wetland	Virus/Indicators studied	Virus removals (in %)	Virus log removals	Reference
Subsurface-flow wetland	Bacteriophages	98.80%	~2 log	Vidales et al (2003)
Surface flow wetlands	Enteric viruses (norovirus, adenovirus and enterovirus)	90-99.9%	1 to 3 log	Rachmadi, et al (2016)
Surface flow wetlands	MS-2 bacteriophages	99%	2 log	Gersberg RM et al (1989)
Surface flow wetlands	Enteric viruses	95-99%	~2 log	Gerba CP et al (2013)
Free water surface plus horizontal subsurface flow wetland	Adenovirus	99%	2 log	Kaliakatsos et al (2019)
Free water surface plus horizontal subsurface flow wetland	Enterovirus	99.9%	3 log	Kaliakatsos et al (2020)
Laboratory-simulated wetland	MS2, PRD1, and indigenous bacteriophages	99%	2 log	Vinluan (1996)
Aerated constructed wetland	Bacteriophages	99%	2 log	Stefanakis et al (2019)
Aerated constructed wetland	Enteric viruses	98 %	~2 log	Quiñónez-Dìaz et al (2001)
Subsurface flow wetland	Enteric viruses	98 %	~2 log	Karpiscak et al. (1996)

[14] Comments attached to Enterococci data recorded by Northland Regional Council

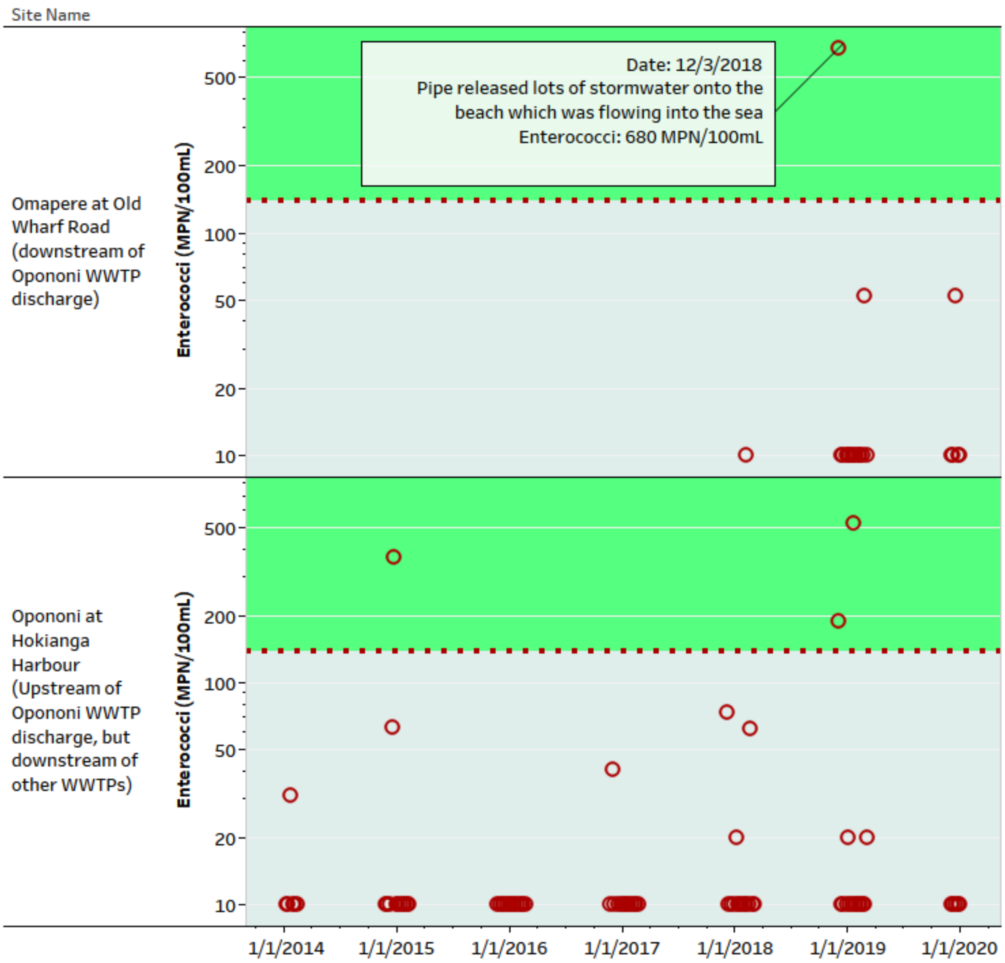

Figure 3. Enterococci concentrations of water samples collected at the Omapere at Old Wharf Road (upper image) and Hokianga Harbour Opononi (lower image) sites. Samples with enterococci concentrations below the acceptable enterococci concentrations of 140 enterococci/100 mL (Green mode) for marine waters are shaded in light blue, otherwise green[15].

The MetOcean hydrodynamic model, which included considerations for tidal movement, has shown that during conditions of backflushing of tidal waves back into the Harbour, the dilution in the receiving environment is very high (for example 95th percentile dilution at Site CR1 is 230,000 and 134,000 during *el nino* and *la nina* conditions) , given the small amount of the discharge and the large amount of water available for mixing in the Hokianga Harbour. It was thus not surprising that this QMRA predicted that health risks associated with swimming at Site CR1 (Upstream of the Opononi WWTP discharge and closest to the Hokianga Harbour Opononi LAWA

[15] While enterococci data at the Omapere at Old Wharf Road site has only been collected since 2018 till date, enterococci data has since 2009 been collected at the Hokianga Harbour Opononi site. Also, there is no data on sanitary inspection categories of the assessment site. Hence, it was impossible to analyse the enterococci data based on MoH/MfE (2003) criteria using Microbiological Assessment and Sanitary Inspection Categories (MAC-SIC). Hence, the MoH/MfE (2003) criteria based on surveillance, alert and action levels for marine waters was adopted.

site where NRC conducts routine microbiological monitoring of recreational water quality) was below the no observable adverse effects level. In agreement with our QMRA results, at Hokianga Harbour Opononi site, only two samples out of the last 67 monthly water samples collected between 2015 and 2019 exceeded acceptable enterococci concentrations of 140 enterococci/100 mL (Green mode, see lower image in Figure 3). This indicates that in terms of recreation, the water at Hokianga Harbour Opononi site was generally of acceptable quality and was not being impacted by the Opononi WWTP.

One important conservative, yet representative approach in this QMRA is the use of dilution factors that would be obtained should Opononi WWTP discharge wastewater into the Hokianga Harbour already receiving treated wastewater input from all three upstream WWTPs (i.e. Kaikohe, Kohukohu and Rawene WWTPs). This explains why all four WWTPs discharging into the harbour were simultaneously turned on, such that the effect modelled at exposure sites in this QMRA for Opononi WWTP also captured additional effects from WWTPs upstream of the Opononi WWTP.

It is important to note that the QMRA results herein presented are for attributable risk, i.e., the increment in risk associated with the Opononi WWTP. Hence, it does not include risks associated with overflows or stormwater runoff from catchment sources.

6. Conclusions

The QMRA shows that if 1-log virus reduction (i.e. 10-fold) is achieved by the Opononi WWTP, then at all sites assessed, illness risks associated with ingestion of water potentially containing enterovirus or norovirus from the discharge will be reduced below the “no observable adverse effect level” (NOAEL). However, under this same virus reduction level, the discharge of treated wastewater from the WWTP generally poses “low” risk of illness associated with consumption of raw shellfish (although the IIRs were only fractionally above the 1% threshold for NOAL).

Wastewater treatment that reduces virus concentrations in the Opononi WWTP discharge by 2-log reduction (i.e. 100-fold) will reduce health risks associated with the discharge (in relation to inhalation, ingestion during swimming and consumption of shellfish harvested) at all exposure sites, to levels below the NOAEL.

In published literature, a 2log virus removal is the most predominantly reported level of reduction in virus concentrations in constructed wetland treatment systems. In line with the QMRA results, if the Opononi wetland treatment system is achieving a 2log virus removal as commonly indicated by available literature, the level of treatment currently applied at the Opononi WWTP is sufficient to reduce illness risks associated with recreation or consumption of harvested raw shellfish below the “no observable adverse effect level” (NOAEL).

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Appendices

Appendix 1 Additional notes on choice of QMRA reference pathogens

We selected noroviruses as the first representative viral pathogen for this QMRA because:

1. Noroviruses are host-specific, present mostly in human waste. This makes them ideal candidates for tracking primary sources of human-related faecal contamination in the environment (Ahmed et al., 2010; Mara and Sleigh, 2010).
2. Human noroviruses are now the most common cause of gastroenteritis outbreaks in children in developed countries worldwide, implicated in >90% of nonbacterial and ≈50% of all-cause epidemic gastroenteritis worldwide (Lopman et al. 2016; Lofranco 2017). They are unquestionably the most common viral cause of gastroenteritis[16] for which dose-response data are available (Mara and Sleigh, 2010; Teunis et al., 2008, CDC 2015, Farkas et al.2017).
3. As with other enteric viruses, they are often symptomatic or pauci-symptomatic[17]; they can even present a high risk of morbidity and mortality in vulnerable (high-risk) populations such as young children, elderly individuals and immunocompromised patients (Prevost et al., 2015).
4. Noroviruses often present higher illness risks than other viruses ((Vergara, Rose, and Gin 2016). Also, noroviruses have a much lower ID_{50} (the minimum dose of norovirus pathogens that can cause infection in 50% of exposed and susceptible subjects) than other viruses. Dose-response relationships suggest that a single norovirus particle can cause infections in more than 40% of susceptible individuals, a rate much higher than other viruses (McBride, 2011).
5. Norovirus outbreaks can occur throughout the year, but have been reported to occur more frequently during the colder winter seasons in temperate climates (Lofranco 2017; CDC 2014; Maunula, Miettinen, and Von Bonsdorff 2005; Ahmed, Lopman, and Levy 2013). A similar observation was made in the scoping and surrogate study on virus concentration at Mangere WWTP influent, New Zealand (Simpson et al.2003).

We selected enterovirus as a second representative viral pathogen for this QMRA because:

1. Enterovirus, one of the largest genera of viruses classified within the Picornaviridae family, represents a significant burden to public health globally (Lofranco 2017).
2. Enteroviruses target either intestinal or upper respiratory tract cells resulting in an upper respiratory tract infection or gastrointestinal illness. Enterovirus

[16] norovirus mainly affects children under the age of three
[17] i.e. presenting few symptoms.

types can cause a wide spectrum of diseases within humans and present a broad range of symptoms.

3. Enteroviruses are also transmissible via sewage contaminated waters (Lofranco 2017; Health Canada 2012).
4. Although human enterovirus outbreaks can occur throughout the year depending on the strain, in temperate climates, enterovirus infections are most prevalent during summer months (Sedmak, Bina, and MacDonald 2003; Costan-Longares et al. 2008; PHAC 2015).

We selected adenovirus as the third representative viral pathogen for this QMRA because:

1. Adenovirus, a double-stranded DNA virus, is often detected in these same environments as noroviruses and enteroviruses (Choi and Jiang 2005; Sassoubre, Nelson, and Boehm 2012). However, compared to other viruses, it has been reported to have prolonged survival time and increased resistance to disinfection e.g. UV treatments (Albinana-Gimenez et al. 2009; Wyer et al. 2012; Kundu, McBride, and Wuertz 2013; Hewitt et al. 2013).
2. This pathogenic virus has a low infectious dose and is thus of great importance in public health (Donzelli et al. 2015). Human adenoviruses (HAdVs) cause numerous symptomatic and asymptomatic infections affecting the respiratory tract, the eyes, and the gastrointestinal tract (Carducci et al. 2016). They can be excreted in the faeces, urine, and respiratory secretions and transmitted via contact with the eyes, the faecal-oral route, or inhalation (Bambic et al. 2015)..
3. HAdVs have a number of features that justify their use as index pathogens for air in occupational settings possibly contaminated by faecally-excreted pathogens (Donzelli et al. 2015).

Appendix 2 Additional notes on dose-response characterization

A rich discussion on dose-response functions already exists in published literature (e.g. See McBride 2011, 2016a, Vergara et al.2016, USEPA 2010, WHO 2016). Dose-infection curves for the viral pathogens used have been established from clinical test results of subsets of volunteers challenged with laboratory-prepared aliquots of viral suspensions at varying serial dilutions of known mean[18] doses of viruses (Haas et al.1999). These were based primarily on two assumptions. This first assumption is the 'single-hit' hypothesis, which is that a single viral pathogen would evade the host defense mechanisms and reach its potential infection site, establish itself and then cause infection. The second assumption is based on a Poisson distribution of the viral pathogens in the laboratory-prepared viral aliquot, which better reflects a random, well-mixed population. These assumptions can be described with probability distributions.

When the probability of ingesting a dose of pathogens is Poisson-distributed and all of the ingested pathogens have an equal probability of initiating infection, the exponential dose-response model is appropriate:

$$P_{\mathrm{inf}(d;r)} = 1 - e^{-rd} \qquad \text{....eqn(1)}$$

where P_{inf} is the probability of infection, d is dose (number of pathogens), e represents the standard exponential constant, 2.7183, and r is a parameter of the distribution equal to the probability that an individual pathogen initiates infection.

When the probability of ingesting pathogens is Poisson-distributed and the probability that individual pathogens initiate infection is beta-distributed, the beta-Poisson model is appropriate:

$$P_{\mathrm{inf}(d;\alpha,\beta)} = 1 - {}_1Fe_1(\alpha, \alpha + \beta, -d) \qquad \text{....eqn(2)}$$

where α and β are parameters of the Beta distribution and $_1F_1$ denotes a confluent hypergeometric function. A commonly used approximation to the beta-Poisson may be used when β >> 1 and β >> α, which is usually so in most cases. This approximation is:

$$P_{\mathrm{inf}(d;\alpha,\beta)} = 1 - \left(1 + \frac{d}{\beta}\right)^{-\alpha} \qquad \text{....eqn(3)}$$

where P_{inf} is the probability of infection, d = mean dose, α and β are 'nonnegative shape' and location parameters, respectively. This approximation however is inadequate for noroviruses because the fitted α and β parameters *(i.e* β = 0.055, *α = 0.04)* do not comply with the condition β >> 1 and β >> α, hence the push for the use

[18] Doses in individuals' challenges are not measured, instead the average dose given to each member of a group is known.

of the much-more-difficult-to-evaluate hypergeometric equation (2) (as argued in McBride 2011).

One approach to QMRA is to use individual exposure per exposure occasion to represent a group visiting a polluted beach. This approach often produces unrealistic risk profiles. A very robust QMRA approach is to expose multiple people on each exposure occasion. In this case, it is possible to assign individual doses, thus eliminating the need for the Poisson averaging. Hence, for the constant r, the simple one-parameter exponential model is easily replaced by the simple bionomial model:

$$P_{inf} = 1 - (1 - r)^{i} \qquad \text{....eqn(4)}$$

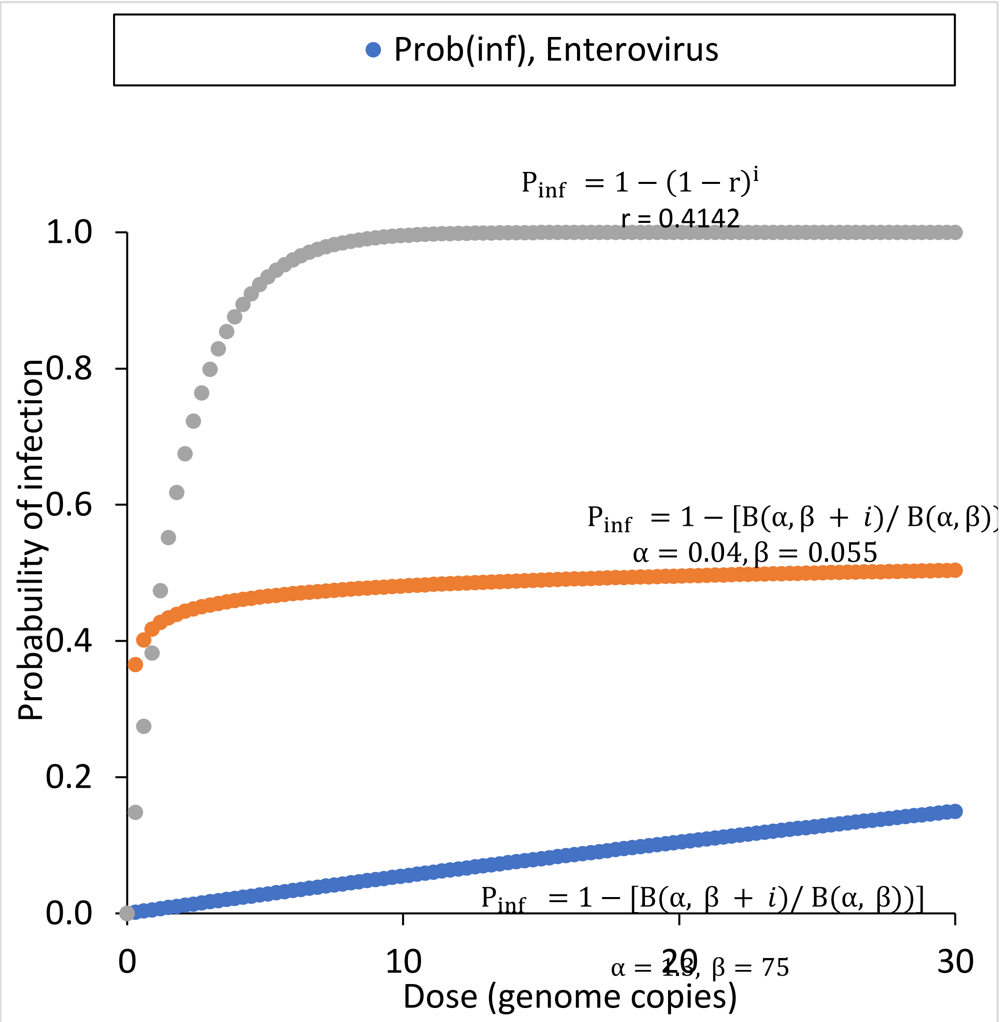
where *i* is the individual dose. Similarly, the two-parameter beta-Poisson model (eqn 2) becomes replaced with the beta-bionomial model, below, which is easily executed using the natural logarithm of the gamma function in Excel[19]:

$$P_{inf} = 1 - [B(\alpha, \beta + i) / B(\alpha, \beta))] \qquad \text{....eqn(5)}$$

where P(i) is probability of infection, β is a standard beta function (Abramowitz and Stegun, 1964; Teunis et al., 2008), α and β are shape and location parameters and *i* represents a dose received by an individual.

[19] Prob of infectin = $1 - \text{EXP}\{\text{GAMMALN}(\beta + i) + \text{GAMMALN}(\alpha + \beta) - [\text{GAMMALN}(\alpha + \beta + i) + \text{GAMMALN}(\beta)]\}$ (as in McBride 2011)

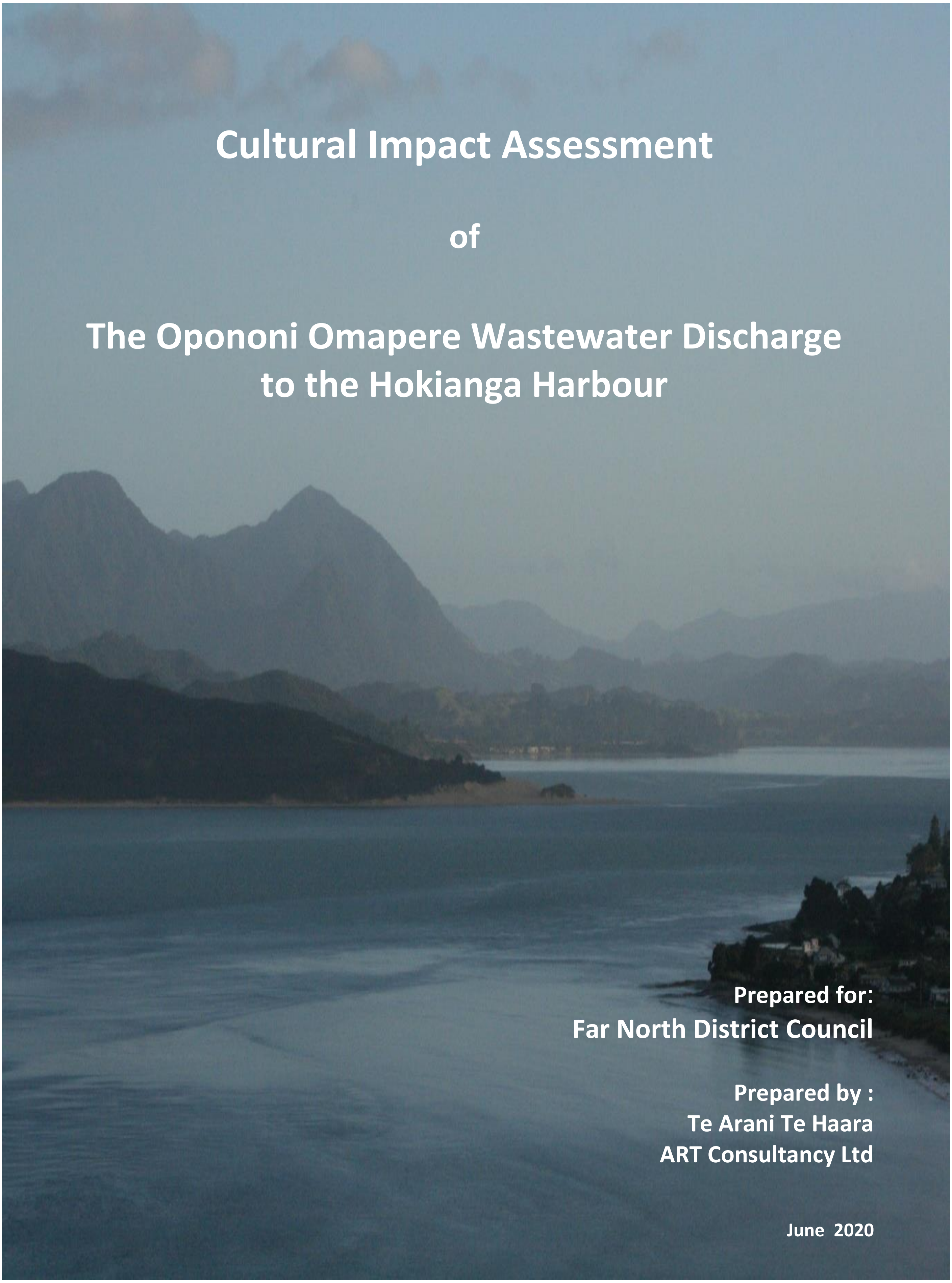
Appendix 3 Dose-response curves applied in this QMRA



Plots of individual dose response curve for adenovirus type 4, enterovirus and norovirus used in this QMRA

S92 Response - Appendix 3

Cultural Impact Assessment



Cultural Impact Assessment

of

The Opononi Omapere Wastewater Discharge to the Hokianga Harbour

Prepared for:
Far North District Council

Prepared by :
Te Arani Te Haara
ART Consultancy Ltd

June 2020

TABLE OF CONTENTS

Cultural Impact Assessment for the Opononi Omapere Wastewater Treatment Plant discharge to the Hokianga Harbour.

This report has been provided for the Far North District Council by ART Consultancy Ltd. No liability is accepted by this entity, any of its employees, or its sub-contractors in respect to its use by any other parties.

Quality Assurance Statement		
Task	**Responsibility**	**Signature**
Prepared by:	Te Arani Te Haara	
Reviewed by:	Andrea Carling	
On behalf of:	ART Consultancy LTD	
Approved for Issue by:		

Revision Status			
Version	**Date**	**Author**	**What Changed and Why**
1	17/05/2020	TNT	Initial draft provided by Te Arani Te Haara
2	20/06/2020	AC	Revised Draft 1 Information analysed, and further contribution made. Initial assessment and further information required to be made.
3	24/06/2020	TNT	Revised Draft 2. Affected Parties provided more information and guidance on report content through email 2020. Draft completed with information available.
4	29/06/2020	TNT	Revised Draft document for sign off by Hapu / Iwi and presented to Council.

1 INTRODUCTION

1.1 Introduction

This Cultural Impact Assessment (CIA) has been commissioned by Far North District as part of its resource consent renewals process for the Opononi Omapere Wastewater Treatment Plant. Cultural Impact Assessments are an important part of assessing the impact that an activity or management approach will have on Manawhenua, Manamoana, Manatangata values associated with a specific area or taonga.

The Māori world view acknowledges a natural order to the universe, a balance or equilibrium, and identifies that when part of this system shifts; the entire system is put out of balance. To better understand the natural order, one must first understand the relationship.[1]

One of the defining principles of Te Ao Maori is whanaungatanga or one's relationship with the World. Whanaungatanga explains how all things are related, assets, birthrights and obligations in relation to each other, the environment and all its resources. In times gone by this matauranga or knowledge was transmitted from generation to generation verbally through pepeha, whakatauki, tauparapara, waiata, place names, as well as whakairo, raranga and ta moko. These ancestral links clearly demonstrate the relationship of the people with their environment and governed how they saw, understood and worked with the different ecosystems and its services.

This assessment provides due recognition to the tribal histories of those Hapu / Iwi who occupied the area in and around the Hokianga Harbour, their genealogical ties to the land, the moana and each other. Equally important is the process that they went through to exercise Rangatiratanga as reflected in the statement derived from the Waitangi Tribunal Report.

> *"When Rangatira gathered, they bought with them an understanding of the world that was based on whakapapa; on the values of Whanaungatanga, Manaakitanga, Kaitiakitanga, and Rangatiratanga; on the imperatives of Mana, Tapu, and Utu. They came from a world in which each Hapu operated autonomously and exercised power over its own territories. Retaining that autonomy, even when acting in alliance with*

[1] Maori Marsden

other Hapu. The Rangatira brought also their own individual experiences and concerns, based on the interests of their Hapu[2]."

Whilst there are varying schools of thought as to who holds Manawhenua, Manamoana and Manatangata, acknowledgement and due recognition has been exercised in an effort of maintaining an unbiased opinion, promote active participation and move towards achieving a more sustainable outcome for future generations.

In taking this position, it is fair to say that there are fundamental beliefs and values among the Hapu / Iwi that are shared and linked with the natural environment. These values form the foundation of this Cultural Assessment.

1. 2 Report Production

The drafting of this report has been undertaken by ART Consultancy Ltd with the assistance and contribution of Kaumatua / Kuia, Treaty Claimants, Nga Hapu / Iwi, Takiwa, Community Groups, local Kura and information sourced from key documents. Te Arani Te Haara was responsible for analysing this information and is the principal author of this assessment.

Te Arani has whakapapa ties to the hapu / Iwi within the Hokianga Harbour Catchment, has extensive experience in Indigenous Environmental Management, played a key role in the development and drafting of the Te Kahukura of Ngati Korokoro, Ngati Wharara, me Te Pouka, Nga hapu o Te Wahapu o Te Hokianga- nui- o- Kupe, Hapu Environmental Management Plan. Assisted with the drafting of the Cultural Impact Assessment on behalf of Ngati Rehia for the Kerikeri Wastewater Treatment Plant upgrade and completed cultural audits on 4 Hapu / Iwi Management Plans including Te Roroa Environmental Management Plan. Te Arani has a Post Grad Diploma of Business in Maori Development.

1:3 Purpose

The intent of this report is to provide both the Consent Holder and Consenting Authority with an appraisal of the impact that the proposed activities will have on Mana Whenua, Mana Moana and Mana Tangata cultural values and to more specifically:

[2] Waitangi Tribunal / He Whakaputanga me Te Tiriti / The Declaration / and the Treaty Waitangi Tribunal Report 2014: National Library of New Zealand Cataloguing in Publication Data.

Task	Reference	Page Number
Assess the effects on and access to mahinga kai	Sec 8.3 Effects on Mahinga Kai	Pgs 34 – 35
Damage, destruction, or loss of access to wahi tapu sites or customary value and other ancestral sites and taonga with which Maori have a special relationship	Sec 8:2 Effect of the mauri (life sustaining capabilities)	Pgs 33 - 34
Effects on Indigenous biodiversity in the beds of the waterbody or the coastal marine area where it impacts on the ability of tangata whenua to carry out cultural and traditional activities	Sec 8:4 Effects on Indigenous Biodiversity	Pgs 35 - 36
Effects on taiapure or mataitai or non-commercial fisheries		
Effects on protected customary rights	N/A	
Effects on sites and areas of significance to tangata whenua	Sec 8.5 Case Study – Effects on site of significance	Pgs 36 - 40

In addition to the above, encourage active participation by tangata whenua in Council's decision making processes ie: develop a relationship based on partnership, participation and protection of a taonga which plays an fundamental part in the lives of the people of Hokianga and of our nation. Essentially to:

a) Identify which tangata whenua are adversely affected by the application in accordance with Policy D.1.3 of the Proposed Regional Plan

b) Build Council's capacity and understanding of the tangata whenua values and the effects that the discharge to the harbour has on these values.

c) Provide guidance and direction of how any adverse effects on cultural values can be avoided, remedied or mitigation.[3]

1.4 Scope

The scope of this report includes:

[3] Savill Stuart, Section 91(1) Request for Further Information.20190722

- An overview of the Hokianga Harbour Catchment and work that has is and will be undertaken in the near future.

- Descriptions of the proposed changes to Opononi, Omapere wastewater discharge system.

- Summary of the planning framework for assessing the cultural effects of the discharge.

- Description of relevant cultural values and tikanga specific to the discharge of treated wastewater into the harbour.

- Identification of geographical areas of cultural significance in and around the discharge.

- Assessment of the cultural impacts that the current wastewater discharge has on the Hokianga Harbour and connected environments.

- Recommendations for any cultural mitigation measures; and

- Recommend any appropriate resource consent conditions including cultural health monitoring

2 HARBOUR CATCHMENT

2:1 Hokianga Harbour Catchment

The Hokianga Harbour is the fourth largest harbour in New Zealand in terms of water volume and geographical spread. Originally a large drowned valley, the harbour is long, narrow, and surrounded by dense mangrove forests which contain some of the largest salt marsh areas left in Northland. [4]

It holds some of the last remnants of low-lying swamp forest/ swamp shrub land habitats, large stands of native forests that provide upper catchment and water quality protection that feeds into the harbour river system. Such river systems and underground aquifers start as far inland as the

[4] Natural Areas of Hokianga Ecological Area (2004), Department of Conservation, Conning Linda, Holland Wendy, Miller Nigel, Pg 3

Puketi and Ratea Forest, Te Kauae o Ruru Wahine Ranges, Whakatere Ranges, Mangakahia, and the awha at Ngawha.

The consent application estimates that the total nutrient loading that enters the Hokianga Harbour via these river systems is in the vicinity of 2.8 tonnes per day. Of the total nutrient loading 0.03% is related to Wastewater Treatment Plant discharges. The remaining 97 percent can be traced back to agriculture, forestry, horticulture and other land use activities[5].

Far North District Council owns and operations four Wastewater Treatment Schemes that discharge into the Harbour Catchment. These include.

- Kohukohu, that exits through an unnamed drain into the harbour
- Kaikohe via the Wairoro Stream, that flows into the Punakitere River and onto the Waima River
- Rawene via the Omanaia River, and
- Opononi Omapere via an outflow pipe that discharges into the harbour.

The Opononi Omapere WW Scheme lies at the south west end of the harbour catchment.

2.2 Community Liaison Groups

One of the conditions of the current resource consent was that Community Liaison Groups were to be established. This was considered to be the most effective means of keeping individual communities informed and involved in Council's decision making. A process that would save time, reduce costs and avoid unnecessary lengthy delays in trying to gain consensus from wider community engagement.

Two groups have been set up one in Rawene, Te Mauri o Te Wai and the other in Opononi Omapere Community Liaison Group. Both groups function independently of each other and have representatives from local Marae, Hapu, Iwi and Community.

2.2 Long term Plan

Over the next 10 years all 4 WWTP resources consents will have expired or are due to expire:

- Kohukohu expired 31st October 2016

[5] River Water Quality and Ecology in Northland 2012 -2016 Northland Regional Council,

- Opononi, Omapere expired on the 31st August 2019 and is going through the renewal process at present
- Kaikohe WWTP is due to expire in 2021
- Rawene WWTP will expire 31st October 2023 and

Council's Long-term Plan 2018-28 identifies a number of Capital Works programs that will have a direct bearing on the Harbour Catchment over the next 8 years are.

- Kaikohe Wastewater upgrade
- Kaikohe Stormwater network upgrade and a
- Minor Upgrade to the Opononi Stormwater network[6]

Whilst these projects have been scheduled, these are subject to change pending notification and consultation through Council's Annual or Long-term Plan process.

3 AREA SERVED BY THE SCHEME

3:1 Area Served

The Opononi Omapere WWTP serves the urban area of Opononi and Omapere. This consists of a mix of residential, commercial, educational, recreational, and accommodation properties. Council's rating system for WW connections is based on Separately Used Inhabited Part (SUIP) and not on each pan per se. A residential property might have more than one pan but only one SUIP. There are currently 354 properties connected to the WWTP, 9 commercial properties which each have an addition SUIP and 119 residential sections available for connection. This brings the total number to 482 connections as of March 2020.

3:2 Growth and Development

There is definitely potential for development within the Opononi Omapere area, however, the probability of this occurring in the short term based on statistical data for this area indicates a decline in the number of permanent residents. This coupled with the state of the global economy; the aftermath of Covid19 and the drastic drop in tourist numbers, any potential growth to the area will be the product of holiday home occupation. Even, though Opononi Omapere is considered to be

[6] Far North District Council's Long Term Plan 2018-28, Pg 61-62 Infrastructure Financials, Summary of significant expenditure o

a popular holiday destination, there are no significant service industries connected to the wastewater scheme[7].

4 TREATMENT PLANT

4:1 Treatment Plant

The Opononi Omapere Wastewater Treatment Plant is located on land at the end of Bakers Road, Opononi. The land, plant and reticulated network are owned by the Far North District Council and managed by its alliance partner. The alliance* partner is responsible for the operational and monitoring programme of the plant.

The WWTP is described as a simple pond system. The existing sewerage reticulation consists of gravity sewers, raising mains and 6 pumping stations. Effluent from the Opononi Omapere township is pumped through a single inflow pipe directly onto a mechanical step screen. Screening of effluent before it enters the aerated pond is the first step in the wastewater treatment process. It is critical to removing contents that have the potential to cause damage to and clogging downstream equipment and piping further on in the treatment process. Wastewater moves from the aerated pond to the detention pond via a fixed weir which operates on the basis of what comes in equals what goes out. The pond operates on a 95% threshold before water is transferred over to the next pond or into the wetland as the case might be. A mechanical brush aerator is used as a means of circulating oxygen through the water column resulting in a more effective treatment of contaminants and an overall decrease in sludge production.

From the aerated lagoon, the effluent then flows into a detention pond.[8] This detention pond is used for retention and sludge settling prior to transferring to the constructed wetland. The holding capacity of the aeration pond and the detention pond are 1475 m^3 and 1850m^3 respectively. From the detention pond wastewater is pumped up into the constructed wetland which consists of five surface flow cells and a holding pond. Discharge from the holding pond is controlled by a tidal clock and a control value system. Treated wastewater is discharged from the holding pond on the outgoing tide via a submerged outfall pipe. The outfall pipe is fixed to the seabed in close proximity to the main channel, about 2.6km from the harbour entrance.

[7] Information sourced from Application for Resource Consent – Jessica Crawford.
[8] This is also referred to as the retention or maturation pond.

4:2 Current Discharges

The average daily discharge flow rate is presently 285m^3 /d and varies according to summer or winter flows. For the last 2-year period the average summer flow has been 168m^3 /d with the average winter flow of 229m^3 /d. The following tables provide details of discharge volumes and quality conditions as set by the current consent conditions and discharge rates. As indicated below these figures vary according to community use.

Discharge Rates	Current Consented Conditions	Current Discharge Rates	Proposed Discharge Rates
Discharge Flow Rate	58.9 cubic metres per hour		75 cubic metres per hour
Maximum or Peak Discharge Rate	685 cubic metres per day	685 cubic metres per day	450 cubic metres per day
Average Daily Flow Discharge	240 cubic metres per day	285 cubic metres	240 cubic metres
Average Summer flow for last 2 years		168 cubic metres per day	
Average Winter flow for the last 2 years		229 cubic metres per day.	

Determinand	Median Concentration	90 percentile Concentration	Monitoring for the 2019
5 day Biochemical Oxygen Demand (grams per cubic metre)	20	35	
Escherichia Coli (per 100 millilitres)	3,000	5,500	
Total ammoniacal nitrogen (grams per cubic metre)	30	38	
Total suspended solids (grams per cubic metre)	35	80	

Although, Council has reported that the treated wastewater concentrations are meeting the expected targets for a system such as the OWWTP design as outlined above, however, quarterly monitoring reports state otherwise.

4.3 Monitoring of WWTP

Over the life span of the current consent utilising the testing points within the WWTP envelope, statistical data indicate that:

1. 149 tests have been carried out by the Consenting Authority[9]

2. Of the 149 site inspections completed 145 have been carried by the same Observing Officer with the exception of the last four inspections.

3. Monitoring statistics indicate that of the 149 inspections:
   - 27 Full compliance
   - 6 Low Risk non-compliance
   - 42 Moderate non-compliance
   - 40 Significant non-compliance
   - 34 Follow-up on non-compliance

A further break down of these figures indication that there were:

- 4 formal enforcement notices for non-compliance issued

- Repeated reports that levels of contaminants were exceeded in various areas of the treatment process.

- Significant resources expended on upgrades to the WWTP

- Funds set aside for further technology upgrades to the WWTP.

- Technology upgrades planned but as yet have not been openly discussed with the Community Liaison Group.

- 2 unauthorised or unplanned discharges

- 3 recorded instances of equipment failure

Furthermore, there were:

- Concerns raised by the Community Liaison Group of the impact that Council Infrastructure using the stream or operating in close proximity of the Waiarohia Stream was having on the life generating capacities of the stream.

- Discussions regarding a request for further funds through Council's Long-Term Plan process to assist with wetland refurbishment and much needed rehabilitation work on the Waiarohia Stream.

4:4 Structural Integrity of Sewer Outfall Pipe

[9] Consenting Authority is Northland Regional Council

Inspections of the outfall pipeline are carried out at least once every two years with the last test being completed in 2018. In 2009 it was reported that the outfall pipe along with the diffusers at the end of the pipe had been damaged, thus reducing the length of the outfall pipe by 50 metres. The damaged portion has been replaced by a 10-meter flexible steel wire reinforced rubber hose fastened to a floatation device. This allows the hose to stay above the moving seabed and flex with the current. Regular surveys and maintenance of the structure ensures that the integrity of the structure is kept in good working condition.

4:5 Future Wastewater System and Discharges

Council has expended considerable resources over the last ten years and continues to seek further assistance through Council's Long-term Plan process. As part of the application for renewal, Council is considering the following wastewater system and discharge improvements.

- Technology to improve quality of wastewater discharge
- Install a pump capable of discharging at 75m3 per hour to enable a maximum discharge rate of 450m^3 within the tidal time available
- Wetland refurbishment
- Rehabilitation work on the Waiarohia Stream pending a successful bid for funding
- Seeking a longer term for the consent - 35 years

5 INFORMATION REQUEST

5:1 Sec 92 (1) - Request for Further Information

A Section 92 (1)[10] request allows a Regulatory Authority to call for further information and /or commission reports to quantify and qualify an application for consent. Such requests are to be made available within a specific time frame and submitted to the Consenting Authority before the hearing of an application or if there is no hearing before the decision to refuse or grant consent.

On 20th July 2019, the Consent Authority issued a request for further information which included the following:

- A copy of the Met-Oceans Hydrodynamic Survey Study
- Evidence to prove that the risks to human health had been accurately assessed

[10] Resource Management Act (1991

- Details of land disposal options considered, the decision reached and the reasons why.
- Determination of which tangata whenua are affected by the application
- Provide an assessment of the cultural values and effects that the activity will have on tangata whenua.
- Demonstrate that due consideration has been given to the existing Iwi / Hapu Environmental Management Plans and Statutory Acknowledgement Areas.

In response to this request the following reports and assessments provided.

- Met-Oceans Hydrodynamic Survey Study
- Quantitative Microbial Risk Assessment
- Investigation into Alternative Land Disposal
- An Assessment of the Effects on Cultural Values

5:2 2020 Met-Oceans Hydrodynamic Survey

A Hydrodynamic Survey is a study of fluids in motion. Generation of this motion can be caused by a combination of forces such as tide, wind, waves, gradient, and masses of fluid entering the marine environment.

> *"The release of contaminants into the ocean environment through an outfall pipe is normally continuous overtime but often subject to significant fluctuations that maybe triggered by wet weather or high flows in released quantities. The fate of these pollutants can be calculated on the basis of hydrodynamic modelling using historical conditions (data) enabling estimations of the predicted general spatial dispersion[11]."*

In 2018 Far North District Council commissioned a hydrodynamic survey to investigate the dispersion of wastewater into the harbour. The Opononi Wastewater Treatment Plant releases contaminants into the ocean environment for a maximum of 3 hours each tidal cycle via an outfall pipe. Due to the close proximity of the outfall pipe to the main channel of the harbour the flushing and dilution capacity of the system is considered to be high resulting in almost an immediate dilution of the discharge.

Findings of the study showed that:

> *"The modelled discharge at the Opononi WWTP typically varied from approximately 100 m3/day to the proposed limit of 450 m3/day. Results showed that the dilution*

[11] MOS Hokianga Harbour Hydrodynamic Study – Executive Summary.

factor is about 1 in 25,000 near the discharge for the 50th percentile and about 1 in 1000 for the 95th percentile for both El Nino and La Nina. The plume followed the tidal currents and mostly extended toward the entrance of the harbour with a dilution of 1 in 5,000 at about 750m for El Nino and 500m for La Nina. Near the shoreline the dilution is about 1 in 25,000 or more."

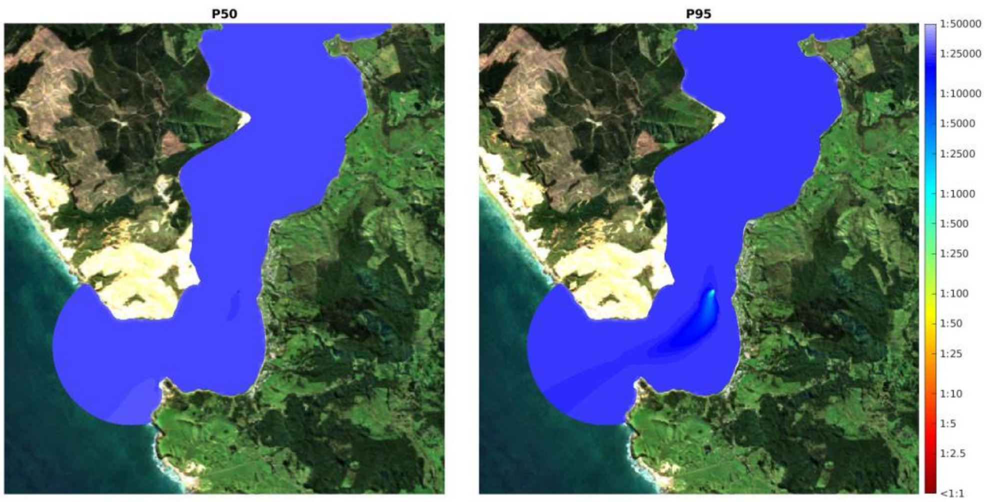


Figure 5:50th Percentile and 95th Percentile Dilution factor for Opononi WWTP during El Nino year.

5:3 2020 Quantitative Microbial Risk Assessment

The QMRA is a fundamental part of the discharge application, not only because it provides an assessment of the health risks associated with the outfall discharge, but also because it provides an indication of the WWTP virus treatment/disinfection required to alleviate those risks.

Wastewater influent from a township like Opononi and Omapere is expected to contain BOD, Ammoniacal-N, Nitrogen, Phosphorus, Faecal Bacteria and Pathogens. To better manage the associated risks to human health, trigger value concentrations have been used as a means of monitoring biological effects as opposed to compliance limits. Streamlined Environmental Ltd has used previously published values from similar treatment systems across New Zealand as means to inform the QMRA report due to the unavailability of influent and effluent virus concentration data for the plant[12].

[12] Page 14, QMRA report Streamlined Environmental

When evaluating viral reduction, the reduction is the difference between the total virus sample in and the total virus sample out. The results of the relative numbers of living microbes eliminated by disinfection are calculated and expressed as log reductions.

The information recorded by QMRA was generated using published values from a similar treatment system to that of the Opononi WWTP. These results indicate:

> *"If 1-log virus reduction (i.e. 10-fold) is achieved by the Opononi WWTP, then at all sites assessed, illness risks associated with ingestion of water potentially containing enterovirus or norovirus from the discharge will be reduced below the "no observable adverse effect level" (NOAEL). However, under this same virus reduction level, the discharge of treated wastewater from the WWTP generally poses "low" risk of illness associated with consumption of raw shellfish (although the IIRs were only fractionally above the 1% threshold for NOAL).*
>
> *Wastewater treatment that reduces virus concentrations in the Opononi WWTP discharge by 2-log reduction (i.e. 100-fold) will reduce health risks associated with the discharge (in relation to inhalation, ingestion during swimming and consumption of shellfish harvested) at all exposure sites, to levels below the NOAEL.*
>
> *In published literature, a 2log virus removal is the most predominantly reported level of reduction in virus concentrations in constructed wetland treatment systems. In line with the QMRA results, if the Opononi wetland treatment system is achieving a 2log virus removal as commonly indicated by available literature, the level of treatment currently applied at the Opononi WWTP is sufficient to reduce illness risks associated with recreation or consumption of harvested raw shellfish below the "no observable adverse effect level" (NOAEL)."*

5:4 Disposal Investigations

5:4:1 Background

One of the requirements of the current consent as set out in Section 105(1)(c) of the RMA requires the consent authority must have regard to any possible alternative methods of discharge, including discharge into any other receiving environment. VK Consulting Environmental Engineers Ltd completed the initial investigation and after due consideration by FNDC and the members of the Community Liaison Group concluded that the investigation did not sufficiently meet the expectations or the requirements of the group. As a consequence, a supplementary investigation was called for that was undertaken by Mott Macdonald.

5:4:2 2011 VK Consulting Environmental Engineering Ltd –Full Land Disposal

VK Environmental Engineering Ltd identified that:

- A very large area of land was required if full land disposal was to be considered
- The area of study had poor soil retention capabilities
- The steepness of the surrounding land increased the risk of run-off
- Pipeline construction costs were significant if the intent was to move the treated wastewater out of the urban area over to Pakanae, Koutu or Waimamaku.

5:4:2 2014 Mott Macdonald – Investigation into Partial Land Disposal.

A further investigation was carried out to look into the practicalities of partial land disposal (a mix between discharge to land during dry periods and discharge to water during wet weather periods.

The report identified that such actions would remove the need for storage and significantly reduced the amount of land required for land-based disposal. In addition to this Mott Macdonald acknowledged that:

a) Both land areas in close proximity to the WWTP were unstable for irrigation due to the steepness of the terrain
b) The soil permeability was considered poor
c) The identified discharge distribution ratio was 5 months to land and 7months to water
d) There are significant physical constraints when moving from land disposal to sea and depends heavily on weather conditions.

Mott Macdonald concluded that:

"After taking every possible scenario into consideration, the most practical option for minimising any resulting adverse effect on the environment was to maintain discharge to water."

5:4:3 Costs of Land Disposal

"Both Consultants reported that the cost of introducing a land disposal scheme was between $2.5 to $5.0 million, with operating expenses around $200,000 to $300,000[13].

5:4:4 Opononi Omapere Community Liaison Group

One of the conditions of the current consent was the establishment of a Community Liaison Group. The Community Liaison Group (CLG) for the Opononi Omapere WWTP was established in 2009. Records identify that the CLG is said to be made up of representatives from Te Whakamaharatanga Marae, Waimamaku, Te Kaiwaha Marae, Waiwhatawhata, Te Whakarongotai Marae, Kokohuia, Maraeroa Marae, Pakanae, Te Runanga o Te Rarawa, a duly appointed representative from each of the Opononi and Omapere Communities and the Consent Holder. The area of interest was specifically limited to the area serviced by the WWTP.

The primary role of the CLG as far as can be ascertained was to act in an advisory capacity. As a result, the members of the CLG or as independent individuals were instrumental in influencing Council's decisions making processes by providing the following guidance and direction as outlined below.

Directive	Action	Outcome	Date
Discharge of wastewater to water body is culturally offensive and degrading.	Appeal against resource consent application	• Submission lodged with Council and Environment Court by the Marae Groups and Iwi Authority.	30 Jan 2009

13

Conditions Imposed by Environment Court	Council to: set up a Community Liaison Group with representatives from the 4 Marae, Te Runanga o Te Rarawa and duly appointed representatives from the communities of Opononi and Omapere • Investigate alternative land areas that can be considered by local iwi to be suitable for treated wastewater discharge from OOWWTP	• Resource Consent signed off by Environment Court	18 Nov 2009
Communication with Appellants	Letters drafted to Marae and Iwi identified as part of the Environment Court process	• Letters sent out to those groups identified in Environment Court ruling. (outlined above)	
First meeting to be held with CLG 1 month of the commencement of the consents	Meeting called with Community Liaison Group to discuss scope, process and timetable of investigation	• Scope of Investigation – "Is land disposal feasible and possible?" Report to include: • Land areas considered by local Iwi to be suitable as discharge to land • Consent Holder to investigate identified land areas for potential discharge • Conclusions as to whether identified land areas can be technically utilised as treated wastewater discharge areas. • Meetings to be held quarterly to discuss progress on the investigation, until such time that the investigation is completed.	18 Dec 2009

Environment Court directive for Council to Investigate alternative land disposal options	Council to engage consultants to carry out investigation	VK Consultant Environmental Engineering Ltd engaged to carry out investigation.	???
Council initiates meeting with Consultant and Local Iwi	• Criteria determined for identifying land blocks • Land available for irrigation of effluent • Well to moderately well drained • Not excessively steep or sloping • A minimum of 10 ha in area	Scope based on technical feasibility of each land block.	30 Sept 2010
Follow-up meeting with CLG, Consultant and Council	• Sites selected for investigation. • Landowners to be notified before the report published	Land blocks identified as potential options	7 Dec 2010

A summary of the findings is presented below:

Parameter	**Site**					
	1	2	3	4	5	6
Discharge Point	Harbour	Land	Land	Land	Land	Land
Is the site well drained? (1)	N/A	NO	NO	NO	NO	YES
Is the site slope suitable?	N/A	YES	YES	NO	YES	YES
Is there sufficient area of land?	N/A	YES	YES	YES	NO	YES
Is the land available? (2)	N/A	UNSURE	YES	UNSURE	UNSURE	UNSURE
Is the option technically feasible?	YES	YES	YES	NO	NO	YES
Capital Cost	NIL	\$3.7M	\$2.6M	N/A	\$3.6M(3)	\$4.3M

Consultant to assess land block suitability	• Land assessment completed	• Summary of findings presented as part of Feasibility Study[14].	2011

[14] Far North District Council Opononi Omapere Wastewater Treatment Plan – Alternative Disposal Options – VK Consulting Environmental Engineering Ltd Feasibility Study

		See Fig 1 Summary of findings[15].	
	• Consultant (VK CEE Ltd) presents findings of investigation	• None of the sites met all of the criteria requirements [16] tions 1, 2,3 & 6 • Options 1,2,3 & 6 were identified as being technically feasible with provisos • Options 2 & 3 only marginally feasible due to poor drainage and there would be times when irrigation would not be possible and storage would be necessary • Option 6 presented the best site in terms of flat land and drainage. • Site limitations include: Site maybe located on a flood plain • Distance • Significant hill along pumping route • Option 4 & 5 not technically feasible	
Review Feasibility Study completed by VKCEE Ltd	Feasibility Study reviewed by CLG and Council	• CLG identified that the study did not sufficiently meet the expectations	

[15] A detailed analysis can be sourced as part of Far North District Council Opononi Omapere Wastewater Treatment Plant – Alternative Disposal Options - VK Consulting Environmental Engineering Ltd Feasibility Study

[16] Criteria requirements outlined in meeting dated 30 Sept 2010

		and requirements. • In particular: Addressing options for improving the wastewater treatment system itself • Provide an assessment of the costs associated with partial land disposal. (e.g. during summer or dry weather conditions only)	
	Mott Macdonald engaged	• Scope of the Assignment • Improve water quality within the treatment plant system • Explore the option of partial land disposal. • Provide an assessment of costs associated with partial land disposal	

6 PLANNING FRAMEWORK

6.1 General

The purpose of the Resource Management Act 1991 (RMA) is to promote the sustainable management of natural and physical resources. A review of all the relevant legislation and planning documents have been completed as outlined in the renewal application. For the purpose of this section of the CIA only those parts of the planning framework that directly influence or impact cultural matters will be discussed. Of particularly relevance are sections 5, 6, 7 and 8.

6.2 Part 2 Provisions

The Resource Management Act (RMA) 1991 recognises the relationship of Maori, their culture and traditions with their ancestral lands, water, sites, wahi tapu and other taonga as a matter of national importance (Part II).

Section 7 of the Act identifies kaitiakitanga as a matter that particular regard must be given in relation to managing the use, development and protection of natural and physical resources, and section 8 establishes that all persons exercising functions and powers under the Act shall take into account the principles of the Treaty of Waitangi.

6:3 Tangata Whenua Affected Party

One of the objectives of this exercise is to identify which tangata whenua groups are affected by the proposed activities. In identifying these groups, a number of key considerations were taken into account.

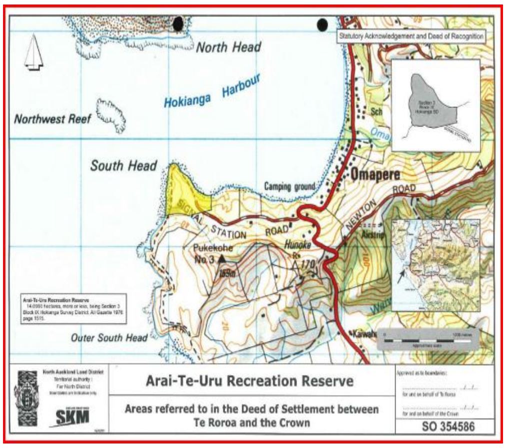
1) The existence of Statutory Acknowledgements areas
2) Tribal overlaps
3) Hapu and or Iwi Management Plans
4) *Treaty Claims*
5) Any other extenuating circumstances

As a result of taking all these key considerations into account the following groups have been identified as having Ahi Kaa status, with overlapping boundaries.

- Nga Hapu o Ngati Korokoro. This Hapu have lodged a claim through the Waitangi Tribunal claiming manawhenua, manamoana and manatangata of the area of study. This is claim is over and above those represented under the Pakanae Resource Management Committee
- Pakanae Resource Management Committee representing Ngati Korokoro, Ngati Wharara and Te Pouka.
- Te Hikutu
- Ngapuhi
- Te Rarawa
- Te Roroa

6:4 Statutory Acknowledgement Areas

Statutory Acknowledgements relate to Crown-owned land and includes land, geographical features, lakes, rivers, wetlands, and coastal marine areas[17]. There are two Statutory Acknowledgment Areas relevant to this report: the Arai-Te-Uru Recreational Reserve and a section of the Hokianga Harbour. Whilst one is land based and the other a section of the seabed; both are intrinsically connected and form part of the cultural landscape as outline in Section 7 Cultural Values and Tikanga.



The Te Roroa Deed of Settlement 2005 records the apology given by the Crown to Te Roroa in 2005 and gives effect to the provisions of the Act in granting a Statutory Acknowledgement area over the Arai-Te-Uru Recreational Reserve. This reserve has been gazetted and is duly noted in the Schedule 4 of the Deed of Settlement Act and also identified as a site of cultural significance within the Far North District Plan, Appendix 1F listing the Pakanae Resource Committee as the requesting party.

Likewise, a Statutory Acknowledgement Area over a part of the Hokianga Harbour has been granted as part of the Te Runanga o Te Rarawa Deed of Settlement 2015. Although provisions have been made through the Settlement process, details will not be finalised until the treaty claims have been addressed and settled under the Marine and Coastal (Takutai Moana) claims.

6:5 Hapu and Iwi Environmental Management Plans

There are two Environmental Management Plans lodged with Council relevant to this study area; Nga Ture mo Te Taiao o Te Roroa and Te Kahukura o Ngati Korokoro, Ngati Wharara me Te Pouka o Te Wahapu o Hokianga-nui a Kupe Hapu Environmental Management Plan. Through whakapapa ties, both the Hapu and Iwi groups recognize this relationship and the overlapping boundaries that exist.

6:5:1 Nga Ture mo Te Taiao o Te Roroa

Of particular importance to this report is Nga Ture mo Te Taiao o Te Roroa 2010. The plan is a statement of the values and policies recorded by Te Roroa in respect to natural resources and the environment. It contains specific policies on sewage disposal, discharge to water and freshwater

[17] www.boprc.govt.nz/your-council/working-with-iwi/statutory-acknowledgements

management. The Iwi Management Plan (IMP) was developed by Te Whatu Ora Trust and adopted by Te Roroa as the Iwi authority, and as such is applicable to RMA planning processes undertaken by district and regional councils. The IMP was lodged with Far North District Council, in February 2010 and is yet to be lodged with Northland Regional Council.

Policies that are most relevant to this CIA are those applicable to discharge of contaminants to water (Section 16)

4. Discharge of human effluent treated or untreated, directly to water is culturally repugnant. All discharges of pollutants or contaminants to natural water bodies, including oceans, should be avoided.
5. NRC will have an integrated catchment management planning and implementation programme that includes all water bodies in our rohe.
6. Activities potentially affecting water bodies will be managed on an integrated catchment basis.

The following Methods of implementation are also relevant particularly to waste discharge

1. Councils and Te Roroa will together jointly develop integrated catchment management strategies including mechanisms for allocating water and monitoring for all water bodies in our rohe.
2. Te Roroa Marae and hapu will be supported to take positive action to enhance water bodies.
3. Te Roroa Whatu Ora and Manawhenua Trusts Board will advocate for the enhancement of all our water bodies and will work with any party promoting or implementing positive actions to improve water quality. We will request statutory authorities to:

   g: ensure that small rural coastal communities have communal land-based treatment facilities and septic tank installations that treat sewerage to a very advanced standard before discharge to soakage fields.

   i: stipulate that consents for works have regular monitoring of cultural health and macro invertebrate. Where data shows that there is an adverse effect on water quality then activities must cease.

6:5:2 Te Kahukura o Ngati Korokoro, Ngati Wharara me Te Pouka o Te Wahapu o Hokianga-nui a Kupe Hapu Environmental Management Plan

Included as part of this planning framework is also the Te Kahukura o Ngati Korokoro, Ngati Wharara me Te Pouka o Te Wahapu o Hokianga-nui a Kupe Hapu Environmental Management Plan was completed in 2008 and was not lodged with Council until 2015.

The policies most applicable to this assessment are those located in the Wastewater section of the plan which identifies:

Policies

- Limiting effluent discharge to sea.
- Increasing effluent discharge quality.
- That land base effluent discharge systems and other effluent treatment options be investigated, ie UV radiation, spray irrigation.

The establishment of a Community Liaison Group has seen considerable steps towards giving effect to these polices, bearing in mind there is still some way to go.

The Moana section is also relevant to this report, particularly the following policies stating:

- Direct discharge of contaminants into water, particularly sewerage and animal effluent is offensive and degrading to the traditional, cultural and spiritual values of the Hapū

- Present infrastructure is not meeting the current demand of increasing development within our rohe and therefore the Hapū will encourage new and existing stakeholders to apply more effective alternative methods for treatment and methods of discharging contaminants.

- To reduce the allowable amount on all land use applications for contaminant discharge.

- The Hapū will support the customary practice of rāhui, where evidence shows that current fish, shellfish, and marine vegetation stocks are unable to sustain present and future generations.

- The Hapū will oppose the construction and development of any future marinas, jetties or wharves that have the potential to cause adverse effects to our harbour.

Finally, policies from the Water Catchment section of the plan identify that:

- Annual audits on the health of all waterways are conducted to determine quality and quantity in line with National Standards.
- No discharges of contaminants to our waterways be allowed.

7 CULTURAL VALUES AND TIKANGA

7:1 Cultural Values

Cultural values are the core principles and ideals upon which a community exists. These values are a combination of beliefs, customs, rituals traditions that are founded on principles of cultural law and practices.

The underlying concepts are to promote, protect, maintain and / or enhance the mauri of the resource. In reviewing the Hapu / Iwi Environmental Management Plans, a number of common threads emerge that are considered to be at the forefront of the Hapu / Iwi relationship within this environment. This understanding is based on the ideology that:

1. Water is a living entity – it has mauri, a life source or life generating capabilities.
2. There are certain rules or laws (tikanga) that govern the maintenance of these life generating capabilities (mauri). These rules or laws are best described as being constant, unchanging and cemented in place.
3. Kawa is the implementation tikanga. These are the practices, processes and procedures that are used in carrying out the implementation of the law. Kawa is considered to be compliant and adaptable to meet specific situations in order to manage the risk. The decision to move forward is based on quality information, robust discussion, and consensus to move forward.

4. The keystone of tikanga and kawa is Karakia. Karakia is an acknowledgment of the Supreme Creator of all things and holds a pivotal role in all operational activities. Nothing is carried out without this acknowledgement before commencement and in closing activities.

5. Wāhi Tapu is the only category of sites of cultural significant that MUST be actively avoided by any development so as to not disturb the mauri and wairua of the area.

7:2 Mauri and wairua

"*We recognize the spiritual existence of all things alongside the physical."* All things we see and touch are made up of a physical and a spiritual element. These elements are best described in the following whakatauki or proverb that states

"Ko au te wai, Ko te wai au."

I am the water and the water is me.

Both entities possess a life force or wairua, both have life supporting capacities or mauri, and both have a genealogical relationship or whakapapa to each other. Te Roroa describes the mauri and wairua of water perfectly with the following statements.

1. *"Water is a sacred resource and a taonga tuku iho a gift from our Tupuna (Ancestors).*
2. *Water in Te Ao Maori is considered to be the life blood of our ancestors.*
3. *It is central to our existence.*
4. *Our mana is intertwined with water.*
5. *It is used to feed, transport, cleanse, purify and is the home to important mahinga kai and cultural materials.*
6. *All water bodies*[18] *are named, some tapu, and some associated with pa and gardens.*
7. *Traditionally, our tupuna distinguished between types of water, wai tapu, wai noa, wai mate, wai ora etc.*
8. *Water bodies formed traditional boundaries".*

Wairua and mauri are important indicators in assessing the environmental health at both the physical and spiritual levels based on matauranga Maori principles.

7:3 Tikanga

Wastewater is a modern creation. The discharge of contaminants to water, or the mixing of waters from different environments is considered offensive. Ideally, wastewater discharge locations should be land based with wahi tapu avoided at all costs.

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[18] Nga Ture o Te Taiao O TE Roroa 2008 Water body: includes creeks, streams, wetlands, swamps, springs, lakes, aquifers, estuarine and coastal waters, all within the domain of Tangaroa.

7.4 Associations with the Harbour

Cultural, spiritual, and historical association reinforces tribal identity and reaffirms the importance of the harbour. In essence, it symbolises the shared responsibility to protect the mauri of the Harbour not only by those who whakapapa to Hokianga but more importantly to future generations.

This report does not individualise references to specific Hapu / Iwi sites, objects or features that have been identified as part of the cultural landscape; it is however suffice to say, that through whakapapa ties, the land, the water and the people are interconnected.

What has been captured in this section is only a snapshot of the cultural landscape within the Wahapu. There are many more sites that have not been recorded perhaps for fear of desecration or because of the sacredness of these areas; and as a result, owners of this information prefer that they remain as silent files. For those sites that are more prominent and well known, information can be source in the public arena.

Those that have surfaced in the public arena, the repository of this information remains the intellectual property of individuals, whanau, Hapu and Iwi as Kaitiaki. Accordingly, this segment has been guided by information sourced from Appendix 1F in the Far North District Plan, Treaty Deeds of Settlement, and key individuals. Acknowledgements will be made accordingly at the end of the report.

7:4:1 Geographical Features

Rising above the coastal marine area are the majestic mountains that stand as sentinels overlooking the vast coastline of the Hokianga Harbour and the wider ocean expanse or Te Moana-nui-o-Kiwa. These sentinels were used as reference points along the navigational pathway. Pa sites were strategically located along the harbour which often included autonomous communal settlements or papakainga. These significant geographical features include Arai-Te-Uru, Pukekohe, Te Hunoke, Maungaroa, Wheoro-oro, Tumarere, Aotea, Whiria, Te Ramaroa, Niwa, Maukoro Pa, Puke Rangatira.

Last remaining relics of Signal Station on the outcrop of Arai-Te-Uru with Niwa in the foreground.

7:4:2 Tauranga Waka or Landing Sites

The harbour has always been a means of transport for hapu living around the shores of the harbour. Te Rarawa refers to these as *"unga ki uta"* or routes that were used to move freely up and down the harbour[19]. Places associated with tauranga waka include, Arai-Te-Uru, Pouahi, Waihuka, Whanui, Matahourua, Te Paraoa, and Kakakaharoa. Safe anchorages to disembark and gather food, visit whanau or set up lodgings.

7:4:3 Settlement Sites

Early settlements were set up throughout the Wahapu close to food rich rivers, beaches and forests. These settlements were often permanent, however, there were many that were occupied on a temporary basis as whanau moved from one seasonal resource to the next, returning when food sources were at their peak. Such sites included, Arai-Te-Uru, Ruaputa, Tangikura, Waihuka, Pakanae, Maukoro, Pouahi, Te Whatupungapuna, and Kakakaharoa.

7:4:4 Mahinga Kai or Kapata Kai

For Hapu and Iwi groups the harbour was their mahinga kai or pantry. Such supplies as koura, kutai, paua, kina, tamure, kahawai, kanae, pipi, tuatua, toheroa, pupu and rimurimu to name a few were in plentiful supply. Food stocks were regulated by seasonal use and gathering would only take place when the resource was at its peak. If a resource were under threat a rahui or a prohibition would be imposed to allow stocks to regenerate.

These food gathering places were often marked by toka or rocks known as "*toka ahika and toka mapuna,*" rocks that lie below the water. Many of these rocks acted as beacons for food gathering, navigation channels, and reminders of events that have been etched in the tapestry of time of the Hapu / Iwi and weaved into the landscape. These places included such locations Arai-Te-Uru, Morunga, Waiarohia, Waimahutahuta, Pouahi, Waitapu, Whanui, and Nuhaka

7:4:5 Wāhi Tapu

While all sites hold significant value to local tangata whenua, none more than wāhi tapu are the only sites to be actively avoided by any development. This position is owed to the spiritual ramification of disturbing concentrated mauri and wairua resident in these areas. Of these particular sacred sites or wahi tapu are Arai-Te-Uru, Morunga, Waihuka, Ahika, Tokotaa, Kahakaharoa also known to Te

[19] Pg 60 Te Rarawa Deed of Settlement Documents Schedule

Rarawa as Waimako, Puke Rangatira, Kakakaharoa, Kawahitiki, Motukauri, Wai-o-te-kauri, Waitapu, and Te Ramaroa. Sites that are constant reminders of our ancestral connections.

7:4:6 Kaitiakitanga

The relationship of the tangata whenua with the landscape - the land, water, and cultural heritage sites – is often expressed through the principle of kaitiakitanga, or the rights and responsibilities associated with holding manawhenua or customary authority over a particular area.

Part 2 of the Resource Management Act 1991 defines kaitiakitanga as: *…the exercise of guardianship by the Tangata Whenua of an area in accordance with tikanga Maori in relation to natural and physical resources; and includes the ethic of stewardship.*

This responsibility is reflective as being part and parcel of being identified as an *"Affected Party."*

8 CULTURAL IMPACT ASSESSMENT OF DISCHARGES

8:1 General

One of the main objectives of this report is to identify the potential effect that the discharge activities have on the cultural values of the Hapu and the Iwi. In assessing the actual and potential effects of renewing the existing consent, during the course of engagement with Hapu and Iwi groups a number of concerns have been raised. These concerns include:

- Effects on the mauri of the Harbour
- Effects on Mahinga Kai
- Effects on Indigenous Biodiversity
- Effects on Areas of Significance
- Case Study - Effects of the mauri of the Waiarohia Stream
- Cumulative effects
- Climate Change
- Consideration of future growth of the Opononi Omapere area

Each point is discussed below.

8:2 Effects on the mauri of the Harbour

One of the main concerns raised by both Hapu and Iwi groups was that the mauri of the water bodies and the degradation or destruction of the associated ecosystems by exploitation, contamination and or abuse.

For tangata whenua the ethos is that the harbour must be managed in such a way that the life bearing capacities or mauri of the water body is not compromised. *"Traditionally, our tupuna distinguished between types of water, wai tapu, wai noa, wai mate, wai ora etc."* Mixing of waters from different environments via discharge activities according to principles of tikanga is considered to have an adverse effect on the mauri of the harbour.

Assessing the actual or potential effects of a discharge activity on the mauri of a waterway involves consideration of two factors:

a) The quality of the discharge entering the waterway, and
b) The ability of the waterway as a receiving environment to absorb or cope with the discharge.

Indicators used to assess the condition, or the mauri of the water body included:

CULTURAL INDICATORS	
Visual water clarity	Abundance and diversity of species
Kai safe to harvest	Debris being washed ashore
Suitability for cultural use	Suitable for human contact
Catchment Land use	

8:3 Effects on Mahinga Kai

Visual observations of the area along the foreshore at low tide back from the outfall pipe have highlighted a number of key concerns that have led the Hapu / Iwi to conclude that the quality of the treated wastewater is having an adverse effect on the receiving environment. More specifically a comparison over the last 10 years has identified the following:

Past	Now
• Sea snails (Littorina littorea) were plentiful in and round the rocks at low tide	• Population counts have dropped drastically over the last 10 years
• Common Limpet (Petella vulgate) numbers in this area were found on almost every other rock.	• Numbers have declined considerably. Inspection of the area at low tide identified as few as one per cubic meter radius.
• Presence of a Crab at the tidal interface and the Waiarohia stream	• The crab at the tidal interface has disappeared.
• Paua gathered have a green residue on the surface.	• Collecting of paua and kina around the toka ahika has now ceased.
• Harbour was once teeming with life	• Loss of intertidal habitats has resulted in loss of fishery nurseries

8:4 Effects on the Indigenous Biodiversity

The lower Hokianga Harbour has been identified as having ecological significances with special and unique habitats[20]. A study completed by Davidson and Kerr in 2005 identified that the lower harbour:

> "*is characterised by relatively high salinity oceanic water, presence of particular truly marine invertebrate and algae species, soft substratum dominated by sands, numerous areas of boulder and rock, strong tidal currents, low water turbidity and relatively short water residence times*".

High volumes of kelp continue to be washed ashore indicating to tangata whenua that the health of the ecosystem is out of balance. This is supported by studies by the University of California, Cheadle Centre for Biodiversity and Ecological Restoration who identified that:

[20] ww.nrc.govt.nz/media/9400/hokiangaharbourentranceandlowerharboursignificantecologicalmarineareaassessmentsheet.pdf

"A *healthy ecosystem is a system that is finely balanced and if certain species disappears, then the whole ecosystem can drastically change[21]".*

In 2006 local divers reported a kina population explosion. Sea urchins have been known to clean the sea floor of kelp fragments that litter the seabed and more ominously graze on the stalks of the kelp to the point where they break off.

There are a number of different opinions as to why the kina explosion occurred, that include.

- the loss of predator species, such as snapper and crayfish in this area as a result of overfishing
- a consequence of the wastewater discharge.

Whilst the loss of predator species has not been validated, surveys and reports indicate that

- the wastewater discharge pipe is located adjacent to the main channel
- Wastewater discharge occurs on the outgoing tide
- the residency time of the discharge remaining in the immediate area is relatively short.
- this position is further supported by the Hydrological study.

From a western paradigm , it is highly probable that the effect of the discharge of treated wastewater in the lower section of the harbour has little or no effect on the marine ecology, however, from a cultural paradigm such phenomenon is a clear indication of more serious underlying problems.

8:5 Effects on Areas of Significance

While the discharge of treated wastewater is only one contributor to the present state of the environment, the impacts that human activities on the ecological values throughout the entirety of the catchment has had a significant bearing customary rights. Observations carried by RJ Davidson and V. Kerr in 2005 on the Habitats and Ecological Values of the Hokianga, identified a number of contamination sources and potential sources of entering the harbour which included.

- *"run off from adjacent farms, particularly dairy/cattle lots.*

[21] www.ccber.ucsb.edu/collections-botanical-collections-algae/ecology-seaweed-and-its-environmental-significance

- *enrichment Harbour from a variety of human activities occurring in the catchments.*
- *discharge of the adjacent sewage treatment ponds; and*
- *stormwater from adjacent townships.*
- *leachate from any rubbish dumps (active or closed).*
- *stormwater run-off from townships;"*

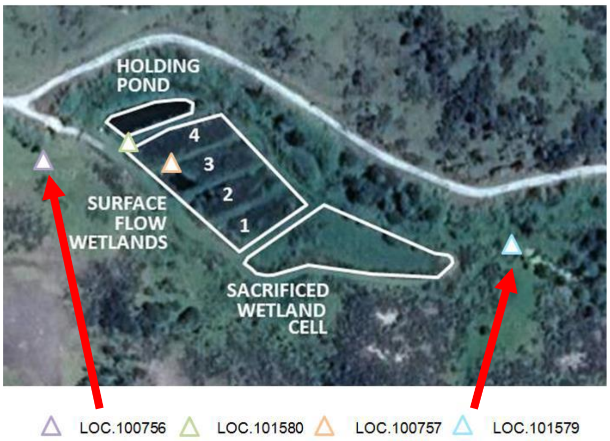
Unfortunately, Davidson and Kerr's study did not capture any data on the level of contamination"[22] They did however identify that substantial areas of the harbour had been impacted by human intervention resulting in permanent loss or modification. Furthermore, they noted that particular areas of harbour margins remained accessible to stock especially along river arms and pest weeds along the fringes have all contributed toward the degradation of the ecological values of the harbour.

For tangata whenua the harbour and its tributaries have been an integral part of its cultural fabric. The harbour was once teeming with life is now seriously under threat by

> *"Human and animal effluent, chemicals, fertilisers, pesticides, sediment, stormwater, run-off and litter. Land uses, particularly clearance, the degradation of riparian margins and drainage of wetlands have caused enormous damage."* [23]

An example of this is the effects that Council Infrastructure has had on the Waiarohia Stream.

8:5:1 Case Study - Effects or Potential Effects on the Waiarohia Stream



Discussions with the WWTP Operators identified a number of potential risks that could have a bearing on the receiving environment. These included:

- Contamination by stock, water fowl and runoff as a result of extreme weather conditions
- Lack of a riparian buffer zone along the

[22] Pg 17 – 20 , RJ Davidson, V Kerr, 2005 Habitats and Ecological Values of the Hokianga,

[23] Sec 16, Nga Ture of Te Taiao o Te Rorora

eastern boundary

- Prioritization and affordability of remedial work and improvements to infrastructure

A stream flows around the eastern parameters of the established wetland carrying water that comes off the surrounding hills. Two water quality testing points are marked within the WWTP envelope. One at the top of the sacrificed wetland cell (LOC 101579) and the other just before the stream enters the main channel of the Waiarohia Stream (LOC 100756).

1. During periods of heavy rain, the volume of water from the surrounding catchment increases considerably. Two adverse weather events during the term of the current consent have seen the tributary burst its banks and flow into the established wetlands causing contamination of the treated wastewater. This in turn has caused a flow on effect into the Waiarohia Stream resulting in wastewater having to be discharged via the outfall pipe, outside of the designated timeframe.

2. Over the last 18 months the majority of the WWTP envelope has been re-fenced with only the rear still outstanding. Unfortunately, wandering cattle have broken through at the rear of the property and entered into the restricted area in search of water, further compromising water quality.

3. A riparian buffer zone is considered to be an important conservation tool in reducing the amount of pollutants going into water ways. The lack of a riparian buffer zone along the length of the eastern stream allows pollutants from surrounding land use activities to enter the waterway unrestricted.

4. Prioritization and the allocation of scarce resources towards remedial work or improvements to infrastructure is a major concern especially in the South Hokianga. For example:
    - The area is considered to be a low growth area
    - All budgets are contestable and often driven by public outcry
    - Prioritization and allocation of resources are required to go through a public consultation process prior to adoption
    - There is always a possibility of works being postponed or deferred due to funding constraints or a state of emergency.

8:5:2 Effects on the Mauri on the Waiarohia Stream

A number of concerns have been raised by tangata whenua with respect of the resource consent application and the adverse effect the discharge has on the life bearing capacities or mauri of the Waiarohia Stream.

Indicators used by the tangata whenua to assess the condition, or the mauri, of a waterway include:

• Flow characteristics / movement of water	• Is it safe to gather plants for kai?
• Nature and extent of riparian vegetation	• Abundance and diversity of species
• Clarity of the water	• Suitability for cultural use
• Catchment land use	• Water temperature • Suitability of waterway for cultural use
• Smell of the water and surrounding environment	• Ratio of native plants to exotic and/or noxious weeds

A number of key visual factors lead tangata whenua to conclude that the mauri of the Waiarohia Stream Catchment continues to be compromised.

- Absence of suitable riparian planting around the eastern drain of the WWTP envelope to assist with filtration of contaminants from surrounding land use activities.
- The Waiarohia Stream around the Transfer Station is dominated by exotic species and noxious vegetation which do little in terms of mitigating effects on waterway health from runoff or ground water seepage.
- Dilution is not a mitigating factor in this stream due to low surface flows.
- The Transfer Station setback from the water body of approximately 2 metres due to natural accretion is no longer considered an acceptable distance.
- Non existing water quality testing carried out downstream of the Transfer Station.
- A build up of sand at the mouth of the Waiarohia Stream.

The assumption that the adverse effects of the proposed discharge on the environment will only be minor is culturally unacceptable and does not recognize or provide for the inherent value of the waterway and the loss of life supporting capabilities. Whanau tell of a particular crab species whose habitat was located around the tidal interface that has now disappeared. Not only is there a discharge into the main channel of the harbour, there is also the issue of the water quality that flows on pass the transfer station and out into the harbour. Monitoring of water quality before it flows into the harbour continues to be left unchecked.

8:5:3 Cumulating Effects

The Waiarohia Stream has seven small tributaries that feed into the Waiarohia stream from the surrounding catchment. Far North District Council has three Infrastructure Assets sited along the length of the Waiarohia Stream.

Waiarohia Stream adjacent to the SH 12

Located at the top of the catchment is the Waiarohia Dam. This is used as one of the supplementary water sources that feed the Opononi Omapere town water supply. A weir assists with maintaining an acceptable amount of water in the dam whilst controlling water flow rate down into the lower reaches of the catchment.

The weir at the top of the catchment not only restricts the natural flow of the water from the mountains to the sea but also impedes the longitudinal movement of tuna, small vertebrate, and crustaceans up and down the river.

The Refuse and Recycling Station is the last of the three Council infrastructure assets located in close proximity to the Waiarohia Stream. The Refuse and Recycling Transfer Station is positioned on a berm or an artificial embankment approximately 3.5-meter-high and within 2 metres of the Waiarohia Stream.

The bins, baskets and cages are placed directly on or are slightly raised above a compacted metal, limestone or concrete construct. The area within the service area is constructed of bitumen concrete. The service delivery includes household refuse, recycling of cardboard, newspaper, certain plastics, glass, aluminium cans, plastic bottles, and green waste. Holes in the base of the bins allow water to escape and empty onto the surrounding compacted foundation construct.

The impermeable surface and compacted foundation construct increase the probability of surface runoff or by leaching into ground water in close proximity to the Waiarohia Stream. Embankment along the Stream predominantly consists of flame trees and vegetation plants considered to be noxious plants ie: phoenix palms, oleander trees, bamboo, kikuyu and wandering dew.

8:6 Climate Change

The Opononi Omapere WWTP is one of 15 Council owned and operated schemes throughout the district and 1 of 4 schemes that discharges into the Hokianga Harbour. The reticulated network is approximately 13.5km in length and located in a Coastal Erosion and Coastal Flooding Hazard Zone.

According to the information provided as part of the application, over the next 45 years, 930 metres of the reticulated network will be affected by coastal erosion and flooding. Council has indicated that the relocation of sections of the network will be managed by the 30 year Infrastructure Strategy.

This situation is further exacerbated by extreme rainfall which is predicted to increase in frequency and severity due to global warming. The likely impact on current infrastructure will be:

- An increase in storm water inflows into the wastewater network and
- An increase in ground water infiltration

This increase will result in:

- Network being overloaded
- Reduction in Wastewater treatment capacity
- Reduction in residency time in the treatment system and
- Increase in the frequency of network overflows.

In managing this process moving forward, Council has identified climate change as a strategic priority that will be incorporated as part of its 30-year Infrastructure Strategy. A process that requires active management alongside affected communities. Council is anticipating that the likely responses will be varied from:

- Asset relocation
- Managed retreat
- Reduction of Services.

The expectation of Hapu / Iwi groups is that those key organisations responsible for managing climate change will work in partnership with affected parties to find practical solutions to complex problems, in particular, the development of key management plans and assessments.

8:7 Future Growth

The WWTP serves the residential and commercial population of the communities of Opononi Omapere. The WWTP scheme currently has the service capability of 482 properties, of which 119 properties are yet to be connected. According to Forecast IDNZ, Opononi Omapere is not expected to experience any growth over the next 23 years which suggests that the current system meets current and future demands.

Hapu and Iwi groups are concerned that:

- The current consent does not adequately recognize or provide for future growth in over and above the 119 properties that are yet to be connected.
- In accounting terms, the useful life of the asset is currently estimated to be 35 years which matches the proposed consenting timeframe. Should the timeframe be reduced then the associated costs to maintain the asset will reflect an increase in annual rates payable. With anticipated increasing costs in servicing the plant and no predicted growth over the next 23 years, the cost of maintaining the WWTP will likely exceed the revenue collected, which may result in a reduction in services provided or a possible managed retreat, whatever that looks like.

- Climate change will further impact on ongoing compliance issues.

- Council will take the easy option and actively engage with only one group in the community i.e. Community Liaison Group, when developing the 30 year Infrastructure Strategy which includes the relocation of 930 metres of reticulation network or other key documents that have an direct impact on cultural values.

- Council's Iwi / Hapu contacts database is known to be outdated which theoretically means that if the information recorded in that database is incorrect certain groups could be unintentionally miss out or worst still left out of discussions that have long term implications to overall community wellbeing.

9 ADDRESSING ADVERSE EFFECTS ON CULTURAL VALUES

9:1 Baseline

The benchmark policy set by Hapu and Iwi is that discharge to a water body is unacceptable. This policy is particularly relevant to the discharge of sewage to any water body treated or otherwise. Since 1982 when the WWTP was built the impacts on the health of the harbour and connecting waterways, water quality and mahinga kai areas have been significant. From this baseline, Hapu and Iwi are able to participate via a Cultural Impact Assessment that carries with it no guarantees of avoidance, mitigation, or remedial prioritization timeframes. Such an assessment focuses primarily on the volume and quality of the discharge, the nature of the receiving environment and the available alternatives.

The assessment of the impacts on cultural values associated with the activities has been completed. The results concluded that:

- It is beyond question that the impact on cultural values is significant given the nature of the discharge, the quality of the treated wastewater and the degraded health of the receiving environment.

- Wastewater discharge represents only 0.03% of the total nutrient loading of 2.8 tonnes per day that goes into the Hokianga Harbour. Those Hapu and Iwi that collectively share Kaitiakitanga responsibilities of the harbour are adamant that both local and regional Council's have a statutory responsibility to ensure that responsible land use practices are implement throughout the whole catchment. With the recent announcement by Central Government of financial assistance to clean up waterways across the country, it is timely that both Regional and District Council seriously consider an Integrated Catchment management approach for improving water quality of the Hokianga Harbour as opposed to trying to improve water quality on an individual point or non-point source basis. As a result one of the conditions of consent must include a commitment to undertaking an Integrated Catchment

Management approach to improving water quality coupled with a measure of good will by commencing with the rehabilitation of the Waiarohia Stream and the riparian planting of the eastern stream within the WWTP envelope.

- While public consultation is in accordance with the spirit of democracy, Council has seen fit to adopt a hybrid communication strategy that includes a combination of consultation and engagement. This strategy enabled the establishment of a core advisory group whose main objectives were to inform Council's decision-making processes relevant to the Opononi Omapere WWTP and to keep those organisations they are responsible up to speed with any issues or outcomes. Unfortunately, concerns have been raised by particular groups that those current sitting on the advisory group may not necessarily have the authority or support of all those organisations that were originally enlisted. The general perception is that the advisory group is more exclusive rather than inclusive of other groups that maybe considered an affected party.

- Council has indicated that there is a financial commitment to installing new technologies to improve water quality prior to discharging to the harbour via the outfall pipe. Although this has been highlighted there is no indication what these new technologies are or the time frame as to when this work might be completed. Irrespective of this, what is known is the fact that the current treated wastewater does not meet the current discharge standards as identified by the monitoring statistics recorded by Northland Regional Council.

9:2 Recommendations

A significant part of the CIA process is determining whether adverse effects on cultural values can be avoided, remedied, or mitigated. While the activities associated with the Opononi Omapere Wastewater Treatment Plant are considered as having significant adverse effects on cultural values, consultation with Hapu and Iwi representatives for the purposes of this report indicate that there are options to avoid, remedy or mitigate such effects, through addressing issues such as quality of the effluent and the ability of the receiving environment to absorb or cope with waste. The following recommendations are provided to assist the both Far North District Council (the Applicant) and Northland Regional Council (Consenting Authority) to take note and address cultural concerns, and to provide a basis for active participation in an effort to protect, preserve and conserve the cultural integrity of the harbour.

9:2:1 Recommendation 1: Affected Party Status

It must be acknowledged from a Hapu and Iwi prospective that the representatives on the Community Liaison Committee have been instrumental in promoting and ensuring cultural values are important considerations in the decision making process in respect of the discharge into to the Hokianga Harbour. Whilst there are opposing views regarding representation on the Community Liaison Group one thing has come across loud and clear is the fact that Nga Hapu o Ngati Korokoro will speak for Ngati Korokoro. Nga Hapu o Ngati Korokoro is not to be confused with Ngati Korokoro represented by the Pakanae Marae Resource Committee.

By virtue of whakapapa ties Nga Hapu o Ngati Korokoro and Te Roroa claim affected party status over and above that of the general public. In the case of Nga Hapu o Ngati Korokoro, Nga Hapu o Ngati Korokoro consider themselves to be independent of the owners of the Te Kahukura o Ngati Korokoro, Ngati Wharara me Te Pouka o Te Wahapu o Hokianga-nui a Kupe Hapu Environmental Management Plan and have lodged a claim with the Office of Treaty Settlements in respect of having Manawhenua, Manamoana and Manatangata over the area relevant to this assessment. Irrespective of the fact that this treaty claim has not been settled it is ***recommended*** that should the Community Liaison Group remain as part of the Council / Community interface that representation on the Community Liaison Group be increased by two seats to include Nga Hapu o Ngati Korokoro and Te Roroa in the interim until such time that a determination is made via the Treaty Settlement process. It is anticipated that this would also entail a review of the Terms of Reference for the Group.

9:2:2 Recommendation 2: Updating Council Hapu and Iwi Contact Database

In light of the affected party status, Nga Hapu o Ngati Korokoro ***recommends*** that Council updates its Contact Database to include Nga Hapu O Ngati Korokoro as an affected party to all matters pertaining to community consultation and engagement in relation to Infrastructure Plans, Council's Infrastructure Assessment, Strategies, and resource consent applications.

9:2:3 Recommendation 3: Improvements to the Quality of the Discharge.

The quality of the discharge must be improved. Information provided by Northland Regional Council of recordings taken from LOC 101579 (above the marsh) and LOC 100756 (below the marsh) within the WWTP envelope indicate that were not meeting Compliance Standards. The QMRA report identified that at the time that the QMRA report was generated there was no data available on the influent and effluent virus concentrations for the WWTP. As result the data utilised in this report was a representation of similar New Zealand systems. In as much as this may seem minute and insignificant, unfortunately from a tikanga prospective this is not considered to be a true assessment of the wastewater discharge going into the harbour. Until such time that this can be proven otherwise, Hapu and Iwi remain resolute that the quality of the discharge is without a doubt is having significant adverse effects on the mauri of the Harbour and placing at risk the relationship that Hapu and Iwi have with the Harbour.

Hapu and Iwi are of the opinion that the discharge to the harbour must meet Compliance water quality standards. Council has indicated that the Community Liaison Group are currently discussing options treatment options and that funds are available for the upgrade. Details of both the technology upgrade the funds available are ambiguous. Irrespective of this fact, Hapu and Iwi ***recommend*** Council take immediate steps to address and rectify the issues non-compliance. It is considered that to delay installation of the technology is unwarranted and deemed to be an abuse of power.

9:2:4 Recommendation 4 Term of the Consent

Hapu and Iwi are seriously concerned in respect to the proposed 35 year term. The general consensus is that this timeframe is extremely long given Council's past performance in managing water quality In reviewing the documentation provided by Council the participating Hapu and Iwi Groups in particular those identified as Affected Parties in this report have identified the following steps they would like to be implemented to manage the risk and protect the health of the environment and its people.

Wastewater Infrastructure Improvements	Catchment Advocacy	Community Advocacy
• **Reticulation upgrade and technology upgrades** • Pump upgrade • Technology upgrade to improve disinfection to reduce bugs and add value to current anaerobic treatment process • **Discharge Management** • Making crucial upgrades ie: pump and new disinfectant technology • Development and	• Contribute to driving catchment improvements • FNDC to be part of Catchment decision making • Work with FNDC and NRC to make change • Work with FNDC and NRC to create opportunities • Providing funding for Catchment	• Council and tangata whenua • Review of current CLG representation

Implementation of a more effective Monitoring Program using both Western methodologies and Cultural Health Index • **Relocation Reticulation Pipes** • Input and participation in 30 year Infrastructure Management Strategy	administration • Take active measures towards setting up Catchment Management Board using an integrated approach		

The catchment aspects were proposed in response to community recognition that the harbour is in a serious state of decline even before it reaches Opononi Omapere. Council's application has identified that in comparison to the wider catchment, Council is a comparatively small contributor to the harbour's degradation in respect to other contributors. In terms of tikanga, adopting the attitude of out of sight out of mind is no longer acceptable. Council has demonstrated its commitment to working with community groups such as Te Mauri o Te Wai and tangata whenua groups in an effort to find discharge to land options, however, in as far as an integrated catchment approach to arrest or at very least proactively manage contaminants entering the harbour system Community Groups are of the opinion that both territorial authorities have failed to respond positively.

If consideration were to be given for the term of 35 years the expectation by Hapu and Iwi would be that the prerequisite would and recommendation would be that that each of the items identified in the following tables implement and recorded as one of the conditions in granting consent.

Immediately	**Within 5 years**	**Within 10 years**	**Within 15 years**	**Within 20 years**
• Update Iwi / Hapu Contacts Database • Additional 2 seats on the Community Liaison Group • Review of current Monitoring Program an co-design a program that meets the requirements of both territorial authorities and tangata whenua	• Riparian strip planted along Eastern boundary of WWTP envelop • Monitoring reports provided to tangata whenua along with action taken to mitigate breaches • Initiate Bi-annual Council workshop with tangata whenua reporting	• Continue reticulation improvements • Ongoing Monitoring reports provided to tangata whenua inclusive of any breaches and migration action • Continue Bi-annual Council and tangata whenua	• Ongoing Monitoring reports provided to tangata whenua inclusive of any breaches and migration action taken • Catchment have covered a significant portion (to be determined) of the catchment area	• Ongoing Monitoring reports provided to tangata whenua inclusive of any breaches and migration action taken • Continue Bi-annual Council and tangata whenua workshop on reporting on Capital works

• Installation of new technologies to improve water quality and manage risks. • FNDC to engage with tangata whenua re: 30 year Infrastructure Management Strategy • FNDC to advocate a comprehensive study of the Hokianga Harbour Catchment be carried • Hokianga Harbour Catchment Management Plan initiated	on Capital Works Program for South Hokianga (30-year Infrastructure Strategy milestones and New Accounting Policy, Long Term Plan and Annual Plan. • Rehabilitation of Waiarohia Stream • Hokianga Harbour Catchment Board established • Hokianga Harbour Catchment Management Plan Completed • Transfer Station setback increased at least 30mtres from water body • 1 of the 4 WWTP transferred to land-based disposal • Progress solutions for transfer to land-based disposal for Opononi WWTP	workshop on reporting on Capital works Program for South Hokianga (update on 30 year Infrastructure Strategy milestones) • Hokianga Harbour Catchment Project underway • 2 of the 4 WWTP transferred to land-based disposal • Options for Opononi WWTP identified.	• Continue Bi-annual Council and tangata whenua workshop on reporting on Capital works Program for South Hokianga (30 year Infrastructure Strategy milestones) • 3 of the 4 WWTP transferred to land based disposal • Best Option identified and project plan development started.	Program for South Hokianga (30 year Infrastructure Strategy milestones) • Catchment has had project works established over much of its area and maintenance of these areas will be ongoing. • RC required for Opononi Omapere WWTP (New Consent or Renewal)

9:2:5 Recommendation 5: Integrated Catchment Management Approach

Hapu and Iwi who collectively share kaitiakitanga responsibilities over the expanse of the harbour catchment are adamant that both local and regional Council's have a statutory responsibility to ensure responsible land use practices are implemented according to permitted standards. In addition to this there is an expectation by tangata whenua that those responsible for meeting and monitoring compliance standards should be setting the example.

Tangata Whenua recognise that damage that is being created by the total nutrient loading that is entering the harbour catchment on a daily basis and strongly believe that immediate action is required if the state of the harbour is to be remedied, mitigations measures applied or avoided all together.

Management of coastal waterways and estuaries are spread across a number of agencies with numerous stakeholders' e.g. environmental groups, recreational and commercial fishermen and Hapu and Iwi groups that have claims to manawhenua, manamoana and manatangata who have expressed concerns regarding the current state of the harbour environment. .

The recent announcement by Central Government of financial assistance to clean up waterways across the country is considered a prime time for both Regional and District Council to seriously consider a Integrated management approach towards improving water quality of the entire Hokianga Harbour as opposed to only addressing water quality issues in relation to on individual point or non-point source.

As a result, Hapu and Iwi ***recommend*** that a coordinated and concerted approach to be taken to manage the revitalisation of Hokianga Harbour.

They further ***recommend*** that a comprehensive study of the harbour catchment including cultural impacts be completed and positive steps be taken to secure appropriate resources to support this process and that a Catchment Management Board be established over the harbour.

10 Conclusion

The Hokianga Harbour is a taonga tuku iho, a treasure handed down, that holds significant historic and cultural significance to Hapu Iwi and Ngapuhi-nui-tonu.

The Cultural Impact Assessment has found that the current discharge from the Opononi Omapere Wastewater Treatment Plant in its present state is culturally unacceptable. The CIA supports the work completed by the Community Liaison Group thus far who have been instrumental in their efforts to add value towards finding an amicable solution to the discharging of treated wastewater.

An important component of the CIA is the relationship between tangata whenua and the harbour, and how this relationship influences the response by Hapu and Iwi to these activities such as the discharge of contaminants to water. Unfortunately, many members of our community have adopted an out of sight, out of mind mindset, not only in Opononi Omapere but throughout Aotearoa. As a result, in managing current loading, Hapu and Iwi recognize that there is no short term fix to re-diverting discharge to land and acknowledge that there are some hard decisions that need to be made in regards to the future upgrades, relocation of reticulation infrastructure, affordability and maintenance of the wastewater reticulation scheme.

It is the hope of participating Hapu and Iwi groups that the issues and recommendations highlighted in this report will provide a basis for improvements to occur and a platform for more robust relationships between all parties that have a vested interest in the future of Hokianga Harbour.

In as much as issues relating to the harbour are constantly raised at district and regional level the information held on file is considered to be passed the used by date. Tangata whenua unitedly agree that if significant improvements are to be made quality information is a pre-requisite. As a result, a comprehensive study of the harbour catchment including cultural impacts is considered a priority. However, for this to occur significant resourcing will be necessary.

Central Government's recent announcement to invest $700m into cleaning up waterways is considered to be a prime opportunity for both tangata whenua, key stakeholders, and crown agencies to work together to preserve this iconic heritage treasure. This in itself supports the principles of Te Tiriti and the key baseline values of Hapu and Iwi.

Hapu and Iwi groups acknowledge the fact that Council is well aware of the fact that the current discharge does not consistently meet compliance standards and that immediate improvements are required to bring this up to compliance standards, but are less informed as to how this will be carried out, what technology will be used, and when this will be carried out, given that there's been a recalibration of Capital Work Programmes, and a call from Council to carry out an assessment of the condition the of Council owned infrastructure assets.

Finally, it is important to acknowledge that a late submission was received from Ms Cheryl Turner et al dated 28th July, as this was received after the close of business that day, this submission was not included within the Cultural Assessment process.

As a matter of courtesy and to maintain amicable working relationships, a meeting was held with this group to ascertain their concerns. The three main points of contention identified were:

1) Reference to Nga Hapu o Ngati Korokoro

2) Change from overlapping boundaries to areas overlapping interests
3) Insertion of a new section on Te Takutai Moana.

As the above points are outside of the current contract further consultation would be required, this has not occurred and therefore the Cultural Impact Assessment does not include the late submission concerns.

11 ACKNOWLEDGEMENTS AND REFERENCES

11:1 Acknowledgements

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Northland Regional Council 2018 Crown Deed of Settlement 2015 *Statutory Acknowledgement Area Te Rarawa Hokianga Harbour*

Waitangi Tribunal Reports

National Library of New Zealand Cataloguing in Publication Data. 2014 *Waitangi Tribunal / He Whakaputanga me Te Tiriti / The Declaration / and the Treaty Waitangi Tribunal Report*

Resource Information

Department of Conservation: 2004 9Linda Conning, Wendy Holland, Nigel Miller0. *Natural Areas of Hokianga Ecological Area.*

Northland Regional Council River 2012 -2016 *Water Quality and Ecology in Northland*

Habitats and Ecological Values of the Hokianga RJ Davidson, V Kerr, 2005

Resource Maps

Northland Land District Territorial Authority Far North District

S92 Response - Appendix 4

Opononi WWTP Issues and Options - Jacobs

Opononi / Omapere WWTP Upgrade

Opononi WWTP Issues and Options

IZ134400-GN-RPT-001 | F

October 15, 2020

Far North District Council

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Opononi / Omapere WWTP Upgrade

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Contents

Executive Summary

Issues Assessment

The Opononi wastewater treatment plant (WWTP) discharges treated wastewater into the Hokianga Harbour. The resource consent for the harbour discharge expired in August 2019 and Far North District Council (FNDC) are investigating options to improve the performance of the WWTP, as well as considering removing the discharge from the harbour altogether by moving to a land disposal system.

The Opononi WWTP is in not complying with the current consent E.coli, ammonia, biological oxygen demand (BOD) and total suspended solids (TSS) standards. The rolling 12-month median effluent E.coli concentration regularly exceeds the consent limit of 3,000 cfu/100 mL and has a 32% compliance rate based on samples taken since January 2016. Effluent ammonia nitrogen concentrations have increased since January 2017 and now exceed the rolling 12-month median limit of 30 mg/L. Total suspended solids concentrations show seasonal spikes each summer which are likely caused by increased algae growth. The spikes result in breaches of the rolling 12-month median limit of 35 mg/L.

Hydrodynamic modelling results showed a high level of dilution in the harbour with a median dilution factor of approximately 25,000 near the discharge point. The 95th percentile (exceeded 95 percent of the time) dilution was 1,000 near the discharge, 5,000 at about 500m down current and 25,000 at the shoreline.

Improvements to the WWTP are required to support compliance with the current resource consent conditions, and the likely future discharge consent conditions. If the harbour discharge is retained, it is unlikely that a resource consent with more relaxed standards would be granted by NRC. Land disposal has also been investigated as an option for the Opononi WWTP discharge. However, this presents technical and cost challenges due to the steep terrain and poorly draining soils.

Options Assessment

A number of treatment and disposal options have been considered for the Opononi WWTP. Combining the treatment options with suitable disposal options, a number of viable schemes have been identified. From these schemes, four upgrade options have been identified which can address the BOD, TSS, E.coli and ammonia issues:

- Option 4a – Optimised process, chemically assisted solids removal, UV, with an in-pond or in-wetland ammonia removal process (e.g. Bioshells, zeolite fill-and-draw wetland etc) and harbour discharge.
- Option 4b – Optimised process, chemically assisted solids removal, UV, with an external ammonia removal package plant (e.g. SAF) and harbour discharge.
- Option 5 - Optimisation of the current process and discharge of the treated wastewater to land.
- Option 6 – New activated sludge plant plus UV disinfection and harbour discharge.

Cost Estimates

The proposed options were endorsed by FNDC and conceptual level costs for these options have been estimated to ±50% accuracy. These costs are summarised as:

Option	Option 4a	Option 4b	Option 4c	Option 4d
Capital Cost	$2.929M	$4.930M	$18.021M	$4.374M

An MCA has been completed, which demonstrates that Option 4b is preferred under most scenarios, with Option 4a ranked very closely. The options are very similar with the key difference being whether the N removal is in pond or via external process. Option 4a has a lower cost, but is relied on less proven technologies, resulting in 4b being considered safer from an environmental risk perspective. It is recommended that Option 4b or 4a be implemented for the Opononi WWTP. It is worth noting that only Option 5 scored well in terms of cultural context, but that the very high cost of this option meant that it did not score well overall.

1. Introduction

1.1 Project Background

The Opononi wastewater treatment plant (WWTP) services the communities of Opononi and Omapere. The WWTP was constructed in 1985 and consists of an inlet screen, a partially mixed aerated lagoon, a maturation pond, a surface flow wetland, and an effluent storage pond. Treated wastewater is pumped from the storage pond into the Hokianga Harbour on the outgoing tide, via an outfall pipe.

The existing resource consent for the outfall discharge was granted in November 2009, with an expiry date of 31 August 2019. The consent conditions included a requirement to investigate land disposal options and to form a community liaison group (Opononi Omapere Community Liaison Group, OOCLG) to meet at least once per year to discuss matters related to the consent. A copy of the existing resource consent is provided in Appendix A. During the consent period, Far North District Council (FNDC) has commissioned two reports on land disposal of the treated wastewater and has met regularly with the OOCLG to discuss land disposal as well as options for improving the WWTP treatment performance.

In May 2019 FNDC applied to Northland Regional Council (NRC) to renew the existing discharge consent and in July 2019 NRC replied with a request for additional information. FNDC are currently gathering the additional information requested and are continuing to consult with the OOCLG with a view to confirming an upgrade strategy for the WWTP.

FNDC have engaged Jacobs to assist with the latter piece of work by developing a short list of WWTP upgrade options, including land disposal as a disposal option, to present to the OOCLG for discussion and consideration. An agreed strategy will likely be taken forward to include in the consent application and FNDC's long term plan (LTP).

1.2 Purpose of this Report

The purpose of this report is to present the main issues facing the Opononi WWTP and a identify viable improvement options to address the issues. The options will include land disposal as an option which removes the need for harbour discharge.

The report will be used by FNDC to inform assessment of the options to identify a preferred upgrade strategy, as well as informing the OOCLG regarding the options. To aid the assessment of the options, a set of assessment criteria are also presented to enable a multi-criteria analysis (MCA) of the options to be carried out using a consistent approach. This should be completed at a collaborative workshop with the OOCLG where the options will be discussed, with the aim being FNDC and OOCLG agreeing on a preferred upgrade strategy.

2. Design Basis

2.1 Design Horizon

The design horizon for this report is 2055, to align with the 35-year consent duration applied for by FNDC.

2.2 Design Population

2.2.1 Permanent Residents

The permanent resident population of Opononi and Omapere was 546 at the 2018 Census. Long-term population forecasting indicates a decrease in the permanent population of the wider South Hokianga area (FNDC, 2018). For the purposes of this report the permanent resident population of Opononi is assumed to remain static over the design period.

2.2.2 Holiday Makers

The Opononi and Omapere population increases significantly over the Christmas holiday period due to the influx of holiday makers. At the 2018 Census, approximately 40% of the houses in Opononi and Omapere were unoccupied; the majority of these are assumed to be holiday homes. Based on the 2018 Census data, the total number of holiday homes connected to the Opononi/Omapere sewer scheme is estimated to be 160.

Whilst there is no data on holiday home occupancy during the Christmas holiday period, the increase in wastewater flows during this period is known (see Section 2.3). An increase in the number of holiday homes and/or occupancy has been allowed for in the WWTP design. For the purposes of this report, an increase of 2% per year in holiday maker population has been assumed over the 35-year design period, resulting in a total increase of 96% by 2055.

2.3 Wastewater Flows and Loads

2.3.1 Dry Weather Flows

The dry weather flows to the WWTP reflects the influx of holiday makers. Influent flows increase every summer, peaking in January and reducing to base (permanent resident) flows from May to September.

Dry weather influent flows from 2010 to 2019 are shown in Figure 2-1. A dry weather day is defined as any day where the total rainfall for that day and the preceding two days is less than 0.5mm, which on average accounted for 31% of the days in the year. The average dry weather flow (ADWF) statistics are presented in Table 2-1.

Table 2-1: Opononi WWTP Dry Weather Flow Statistics 2010 – 2019

Parameter	Units	Value
Peak 30-day ADWF	m^3/day	309
Annual AWDF	m^3/day	178

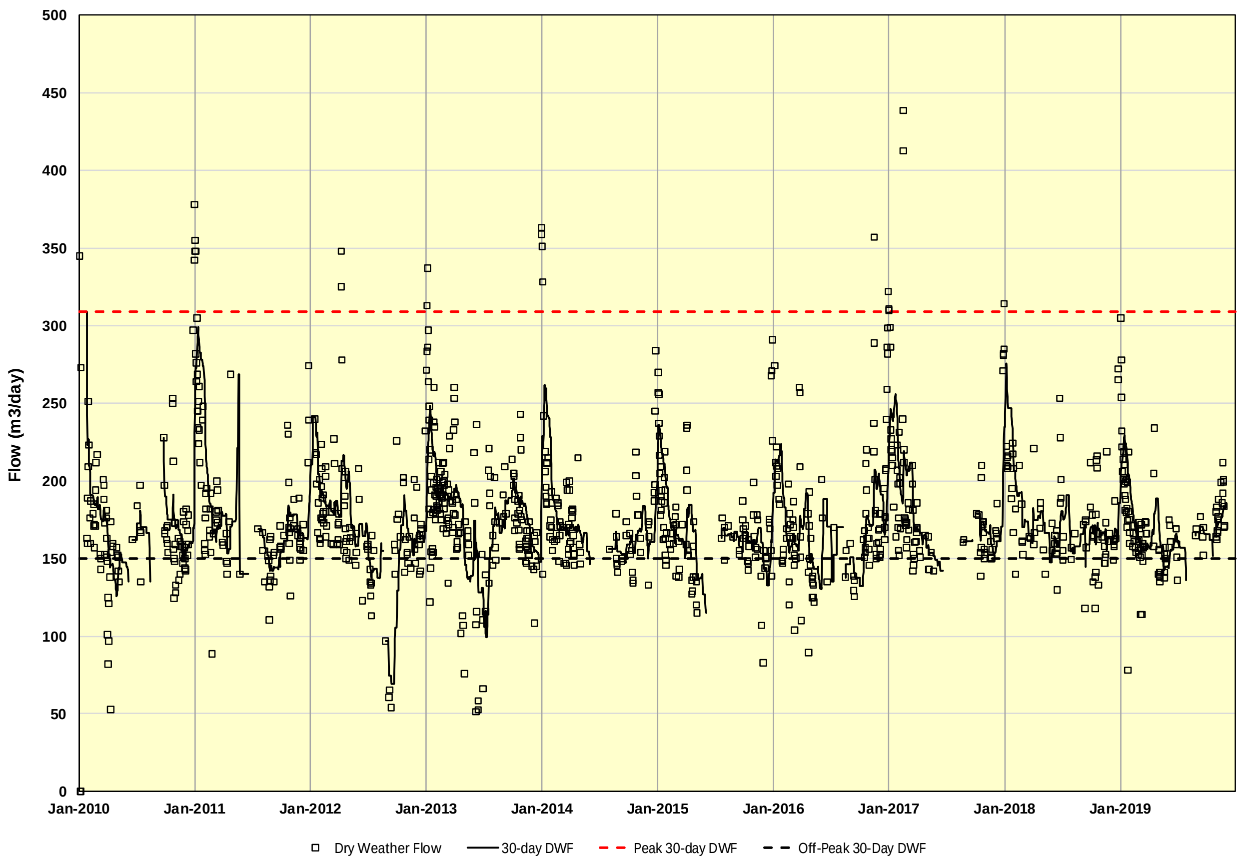

Figure 2-1: Opononi WWTP Dry Weather Flows 2010 – 2019

2.3.2 Wet Weather Flows

A wet weather flow day is defined as any day with more than 5mm rainfall. For the Opononi WWTP this accounted for 16% of the days since January 2010. The average wet weather flow during this period was 287 m^3/day.

The peak recorded wet weather influent flow (PWWF) since January 2010 was 1,290 m^3/day, recorded in January 2011 and was related to a 140 mm rainfall event (FNDC, 2018). This PWWF equates to approximately five times the ADWF for January. A wet weather peaking factor of 5 x ADWF is not unreasonable for sewer systems the age of Opononi/Omapere.

The Opononi WWTP provides wet weather storage capacity within the aerated facultative pond, maturation pond, and effluent storage pond, which allows the influent wet weather flows to be buffered. The peak pond outlet flow is 734 m^3/day and the 99-percentile outlet flow is 490 m^3/day. However, FNDC have applied for a maximum effluent discharge volume of only 450 m^3/day in their 2018 consent application, which is considerably lower than the actual maximum and should be revised.

2.3.3 Pollutant Loads

The sewer catchment of Opononi and Omapere is predominantly domestic, with no significant trade waste inputs. Pollutants of concern in domestic wastewater are BOD, total suspended solids, E.coli, total nitrogen sometimes total ammoniacal nitrogen – TAN) and total phosphorus. There is no routine sampling of the Opononi WWTP influent, however influent samples taken in 2016 and 2018 (and tested for BOD and TSS) were within the ranges expected for domestic wastewater, albeit at the higher end of the typical range. This is similar to other locations around the Far North District, such as the Taipa WWTP which shows higher strength influent. Table 2-2 contains data on the average BOD, TSS, COD and E.coli concentrations of the influent.

Table 2-2 Opononi WWTP Influent Concentrations

Parameter	Units	No. of Samples	Average Concentration
BOD	g/m^3	6	255
TSS	g/m^3	11	229
COD	g/m^3	4	543
E.coli	mpn/100mL	10	2.39×10^7

2.4 Summary

The design basis for the Opononi WWTP is provided in Table 2-3.

Table 2-3: Opononi WWTP Issues and Options Report Design Basis

Parameter	Units	Current	2055	Comment
Permanent resident population		546	546	2018 census; no increase over design period
Number of holiday homes		160	272	Linear growth (2% of current homes)
Holidaymaker population (peak month)		580	980	Estimate based on observed flow increase
Holiday home occupancy (peak month)		3.6	3.6	
Total population (peak month)		1,125	1,530	
Peak 30-day ADWF	m^3/day	309	420	Pro rata off existing flow data
Annual average ADWF	m^3/day	178	200	Pro rata off existing flow data
PWWF	m^3/day	1,290	1,400	Pro rata off existing flow data
Per capita influent BOD load	g/p/d	70		Typical value for domestic wastewater.

2.5 Land Disposal Design Basis

2.5.1 Hydraulic Loading Rate

The methodology for determining the hydraulic loading rate is based on the procedure for “Type 1” slow rate systems provided in the USEPA Process Design Manual for Land Treatment of Municipal Wastewater Effluents (USEPA, 2006). The method set out in the USEPA manual is a standard water balance methodology based on percolation rate to groundwater. Type 1 systems are designed for year-round deep percolation to groundwater as opposed to deficit irrigation systems, which avoid percolation by irrigating only the amount of water either evaporated or used by the plants (evapotranspiration). Often deficit irrigation is used in locations with long dry summer conditions. In wetter climates, deficit irrigation is unlikely to be applicable.

Using the USEPA design methodology, a hydraulic loading rate of 2.0 mm/day is derived as shown in Table 2-4. However, this would need to be confirmed with site specific testing of the ground conditions.

Table 2-4: Opononi WWTP Land Disposal Hydraulic Loading Rate

Parameter	Units	Value	References
Soil type		Clay loam	VK Consulting (2011); Mott MacDonald (2014)
Soil permeability (preliminary design)	mm/day	60	Category 4, Table 5.2 NZS1547 (2012)
Design safety factor		5%	USEPA (2006) type 1 slow rate design methodology
Design annual percolation rate	mm/day	3.0	Soil permeability x safety factor
Annual rainfall	mm /year	1,234	NIWA (2013)
Annual evapotranspiration	mm /year	877	NIWA (2013)
Land disposal hydraulic loading rate	mm/day	2.0	Percolation – rainfall + evapotranspiration

2.5.2 Effluent Quality Requirements

The current effluent quality produced by the WWTP should be sufficient for land disposal. Buffer zones and irrigation stand down periods will provide public and stock health protection from pathogens. Due to the steep terrain, drip line application would likely be required and therefore spray drift is not an issue and UV disinfection should not be needed. It is expected that a disc filter will be required downstream of the irrigation pumps in order to protect the drippers from blockage.

2.5.3 Irrigation Storage Requirement

For preliminary design purposes, 30-days storage (at ADWF) is assumed for the irrigation storage pond. This is a conservative value and provides storage for a period of prolonged wet weather when the land has continuous surface ponding and is unsuitable for irrigation. The storage requirement may be reduced following more detailed site investigations and rainfall analysis. However, given the poorly draining soils in the area, at this stage a conservative value is considered appropriate.

2.5.4 Land Disposal Design Basis Summary

The design basis for land disposal is presented in Table 2-5.

Table 2-5: Opononi WWTP Land Disposal Design Basis

Parameter	Units	Value
ADWF	m^3/day	178
Hydraulic loading rate	mm/day	2.0
Irrigated area	Ha	10
Allowance for buffer zones and storage pond	%	20
Total land area required	Ha	12
Irrigation application method		Dripline
Number of days storage required at ADWF	days	30
Irrigation storage pond volume	m^3	5,300

It should be noted that the land disposal option is currently at the preliminary concept stage and its purpose is to enable stakeholders to compare land disposal with the harbour discharge options. There is a high degree of uncertainty regarding land availability, as well as the technical feasibility and consenting of land disposal, given that site investigations and discussions with land owners have not yet taken place.

3. Existing WWTP

3.1 Existing WWTP Overview

The Opononi WWTP consists of an inlet screen, an aerated facultative pond (termed the “aeration pond”) containing a single brush aerator, and a maturation pond (termed the “detention pond”). Effluent is pumped from the maturation pond to a series of four constructed surface flow wetland cells located above the ponds. The first and largest wetland cell has been sacrificed to enable placement of sludge to avoid the costs of taking the sludge off-site. Treated effluent from the wetland is stored in storage pond and is pumped into the Hokianga Harbour twice per day on the outgoing tide via an outfall pipe.

An aerial photo showing the elements of the Opononi WWTP is provided in Figure 3-1.

Figure 3-1: Aerial Photograph of Opononi WWTP

3.2 Aerated Facultative Pond

The aerated facultative pond is 3 meters deep with a volume of approximately 1,200 m^3. The pond has a concrete wave band and it is assumed to have a clay liner given the clay soils in the area. The pond was de-sludged in the summer of 2018/2019, along with the maturation pond. The pond is smaller than a conventional oxidation pond and relies on a 5.5 kW brush aerator to increase the BOD treatment capacity of the pond. The brush aerator replaced two aspirating-type aerators.

With unaerated facultative ponds (often termed oxidation ponds) the aeration needed for the aerobic breakdown of organic matter (BOD) is provided by algae and wind. The “natural” capacity of oxidation ponds is proportional to pond surface area and can be estimated using empirical equations (Mara, 2010).

Calculations indicate that the existing brush aerator should be sufficient to cater for both current and future peak loads. The pond BOD capacity and design loads are provided in Table 3-1.

Table 3-1: Opononi WWTP: Facultative Pond BOD loading capacity versus

Parameter	Units	Value	Comment
Water surface area	m^2	900	
Average temperature (January)	C	19	
“Natural” BOD surface loading capacity in summer	kg/ha/d	235	Mara (2010) formula
“Natural” BOD capacity in summer	kg/day	21	
Aerator BOD capacity	kg/day	105	5.5 kW x 0.8 kgO_2/kWh x 24 h
Aerated pond BOD capacity	kg/day	126	Natural capacity plus aerator capacity
Estimated peak month BOD load to pond (current)	kg/day	79	Population x 70 g/p/d
Estimated peak month BOD load to pond (2055)	kg/day	107	Population x 70 g/p/d

3.3 Disinfection in Facultative and Maturation Ponds

The main purpose of the maturation pond is disinfection through natural die-off of pathogens, as well as some residual BOD removal. The amount of disinfection provided by ponds is a function of hydraulic retention time (HRT) and temperature and can be estimated using a first-order decay model (Mara, 2010). The predicted log removal of *E. coli* during the January peak season, using the standard first-order decay model, is shown in Table 3-2.

Table 3-2: Opononi WWTP: Expected Disinfection Performance of Facultative and Maturation Ponds

Parameter	Units	Facultative	Maturation	Total
Pond volume	m^3	1,200	1,470	
Hydraulic retention time (peak month dry weather flow) - current	days	3.9	4.8	8.7
Hydraulic retention time (peak month dry weather flow) - 2055	days	2.9	3.5	6.4
First order decay coefficient (20 degrees)	day-1	2.60 (Mara, 2010)		
First order decay coefficient (19 degrees)	day-1	2.185 (average January temperature)		
E coli log removal (peak month dry weather flow) - current		0.9	1.1	2.0
E coli log removal (peak month dry weather flow) - 2055		0.9	0.9	1.8

The retention times are short compared to conventional oxidation pond systems which typically have HRTs in the 25–30-day range. Therefore, the log removal of indicator bacteria will be lower than for conventional pond systems. These low retention times suggest that the ponds are undersized for effective removal of BOD, nitrogen and E.coli.

As shown in Table 3-2 an overall 10% reduction in disinfection performance (as measured by *E. Coli* log removal) is predicted over the design period due to increased population. The reduction in performance could be compensated for by installing baffles in both ponds. The installation of baffles in ponds has shown to improve disinfection performance by reducing short-circuiting and “dead zones”, thereby improving the HRT distribution of the pond (IWA, 2012).

3.4 Ammonia Removal in Facultative and Maturation Ponds

The ammonia removal efficiency of facultative ponds can be estimated using an empirical first order formula based on surface loading rate and pH (Pano and Middlebrooks, 1982). Using the Pano and Middlebrooks equation, the expected ammonia removal efficiencies are shown in Table 3-3. The short retention time is a key factor in the low ammonia treatment through the ponds.

Table 3-3: Theoretical Ammonia Removal in Facultative and Maturation Ponds (Pano & Middlebrooks, 1982)

Parameter	Units	Facultative	Maturation	Total
Pond volume	m^3	1,200	1,470	
Hydraulic retention time (peak month dry weather flow) - current	days	3.9	4.8	8.7
Hydraulic retention time (peak month dry weather flow) - 2055	days	2.9	3.5	6.4
First order ammonia removal coefficient	day-1	0.00541	0.00950	
Ammonia removal (peak month dry weather flow) - current		2.1%	4.3%	6.4%
Ammonia removal (peak month dry weather flow) - 2055		1.5%	3.2%	4.7%

3.5 Surface Flow Wetlands

The surface flow wetlands consist of five wetland cells in series. The wetland was de-sludged and replanted in 2015. Cell 1, the largest cell, is currently not in use as it is being used to store the sludge from the other wetlands. The wetland cells are overgrown and in need of maintenance (Figure 3-2).

The main function of the wetlands is to provide additional treatment through natural pathogen die-off, algae removal through shading of the water, as well as ammonia removal through nitrification in the wetland root system.

3.5.1 Hydraulic Loading Rate

The wetland is undersized for the peak summer population loading, when compared with typical loading rates. The current total operational wetland surface area (cells 2 – 5) is 1,625 m^2 which equates to a surface loading rate of around 106 mm/day at the peak month dry weather flow. This is in the middle of the typical range for surface flow wetlands in New Zealand; a 2000 survey of constructed wetlands in New Zealand reported hydraulic loading rates of 25 – 178 mm/day, with an average surface loading rate of 78 mm/day (Tanner *et al*, 2000). The USEPA constructed wetland design manual suggests lower surface loading rates of 15-50 mm/day (EPA, 1988).

3.5.2 BOD Surface Loading Rate

Based on inter-stage sampling carried out in 2016 and 2018, the average BOD concentration of the maturation pond effluent (wetland influent) was 40 mg/L. Using this value, the BOD surface loading rate at the current peak month dry weather flow is around 6 $g/m^2/day$. This loading rate is in the middle of the range of BOD loading rates found in the survey of New Zealand surface flow wetlands (Tanner *et al*, 2000).

3.5.3 Ammonia Removal

Ammonia removal in surface flow wetlands can be estimated using the areal-based P-k-C* model (Kadlec & Wallace, 2009). From observed ammonia removal efficiencies in surface flow wetlands, the following average values (derived from hundreds of existing systems) were used in the calculation:

$C^* = 0$ mg/L

$K_{20} = 14.7$ m/yr (40.3 mm/day)

$\Theta = 1.049$

For the Opononi wetland P = 4 or 5 (number of wetland cells in series)

Using the standard model, a theoretical ammonia removal efficiency of 22% is calculated at the current peak 30 day rolling ADWF. This increases to 29% if wetland cell 1 is included in the treatment process.

Figure 3-2: View of Constructed Wetland looking East

3.5.4 Disinfection

Pathogen reduction in the surface flow wetland can be estimated using the first-order model used for the facultative and maturation ponds. Using this model, a log reduction of around 0.9 is estimated at the current peak 30 day rolling ADWF. This increases to 1.2 if wetland cell 1 is included in the treatment process.

3.5.5 Wetland Treatment Summary

A summary of the theoretical treatment performance of the wetlands is provided in Table 3-4.

3.6 Effluent Storage Pond

The effluent storage pond is used to store effluent between outgoing tides. The effluent storage pond has a total volume of approximately 350 m^3 at top water level based on the WWTP drawings. The pond operates on start and stop level control and discharges twice per day on the outgoing tide. Pond start and stop levels are not known however the retention time in the effluent storage pond is in the order to 1-2 days during dry weather.

The effluent storage pond is not shaded and there is potential for algal growth in the pond which could negate any suspended solids removal occurring in the more shaded wetland cells. During a recent site visit the pond appeared to have a high algae content (Figure 3-3) although it was not clear whether the algae had grown in the storage pond or had passed through from the wetland cells.

Table 3-4: Opononi WWTP Surface Flow Wetlands Theoretical Treatment Performance

		Cells 2 - 5	Cells 1 - 5
Total surface area	m^2	1,625	2,286
Total volume	m^3	300	425
Peak month ADWF - current	m^3/day	178	178
Peak month ADWF - 2055	m^3/day	200	200
Surface loading rate at Peak month ADWF - current	mm/day	190	135
Surface loading rate at Peak month ADWF - 2055	mm/day	259	184
Hydraulic retention time at Peak month ADWF - current	days	0.97	1.4
Hydraulic retention time at Peak month ADWF - 2055	days	0.72	1.0
BOD surface loading rate at Peak month ADWF - current	$gm^{-2}day^{-1}$	7.6	5.4
BOD surface loading rate at Peak month ADWF - 2055	$gm^{-2}day^{-1}$	10.3	7.4
Theoretical ammonia removal (peak month dry weather flow) – current		23%	29%
Theoretical ammonia removal (peak month dry weather flow) – 2055		18%	22%
Theoretical E. Coli log removal (peak month dry weather flow) – current		0.74	1.0
Theoretical E. Coli log removal (peak month dry weather flow) – 2055		0.57	0.79

Figure 3-3: Effluent Storage Pond

4. Effluent Quality

Under the current consent conditions, effluent samples are taken monthly from the effluent storage pond, located downstream of the final wetland cell. Compliance against the resource consent standards is measured using rolling 12-monthly median and 90th percentile values (i.e. rolling medians and 90th percentiles calculated from the most recent 12 samples). This can result in a single event causing multiple breaches of the consent over several months. Alternative approaches exist for consent conditions and these should be considered for future resource consent application, such as calendar year median and 90th percentiles.

4.1 E.coli

Figure 4-1 shows the effluent sampling results for *E. coli* concentrations from 2010 – 2019, along with the resource consent median and 90th percentile limits (shown as dashed lines).

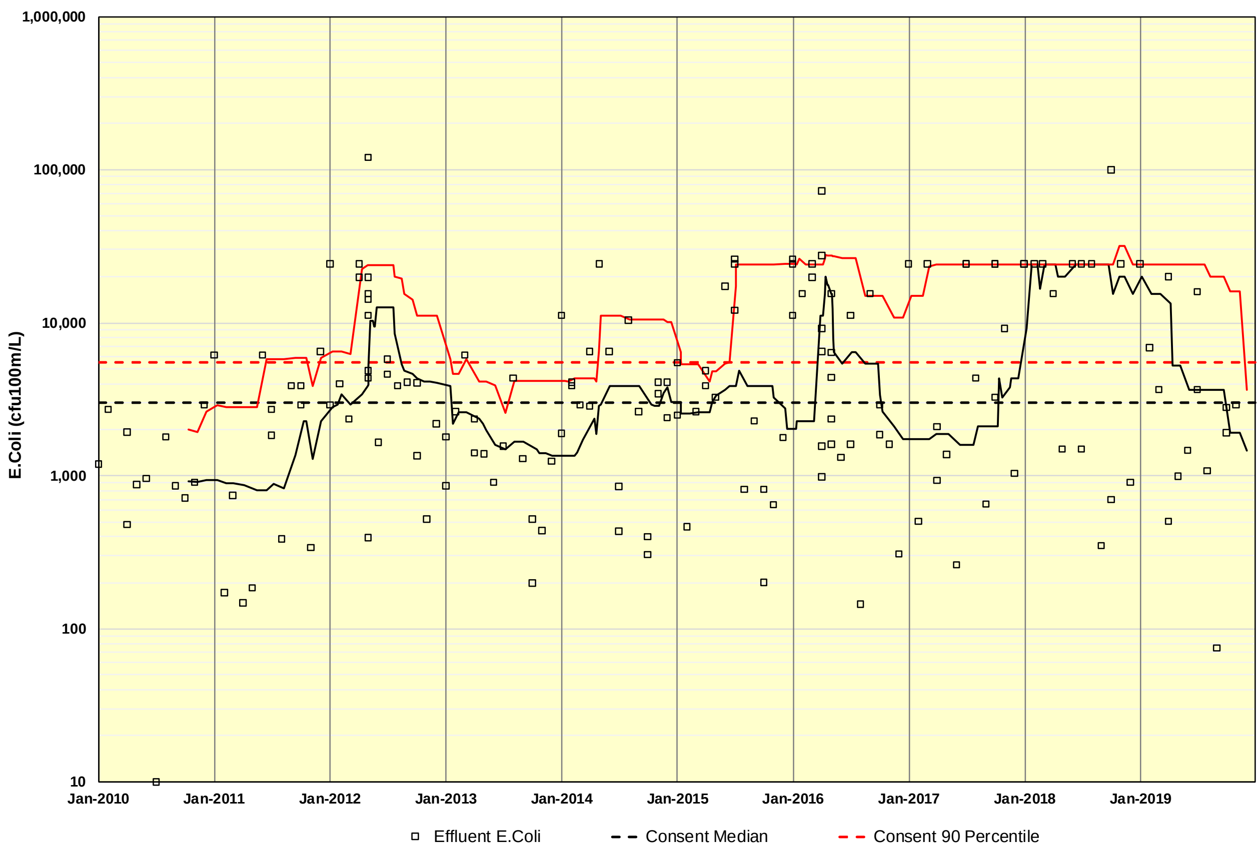

Figure 4-1: Opononi WWTP effluent E. coli concentrations 2010 – 2019

The Opononi WWTP does not comply with the current *E.coli* consent conditions, which is not surprising given the relatively short HRT in the ponds and wetlands. The median raw wastewater E. coli concentration during testing in 2016 and 2018 was in the order of 10^7 cfu/100mL. Therefore, the WWTP is achieving on average around 3.0 - 3.5 log removal of *E. Coli*. This agrees with the first-order decay model results presented in Section 3.

A median 4-log *E. Coli* removal is needed across the entire pond / wetland system in order to assure compliance with the current median consent standard, i.e. an additional 1 log removal is required from the system in order to comply with the current consent standards.

Optimising the existing system for disinfection (reinstating wetland cell 1 and installing baffles in the maturation pond, see Section 6) would improve performance but would probably still not achieve the required 4-log removal over the peak summer season. Additional measures (e.g. UV disinfection) will be required to comply with the current consent conditions. Options for improving *E. Coli* performance are presented in Section 6.1.

Bacterial concentrations in wastewater tend to follow exponential growth and decay curves and hence are normally plotted on a log scale (Figure 4-1). The 90th percentile consent standard of 5,500 cfu/100mL is in the same order of magnitude as the median standard (3,000 cfu/100 mL), less than a half-log difference.

4.2 Ammoniacal Nitrogen

Figure 4-2 shows the effluent sampling results for ammoniacal nitrogen from 2010 – 2019 along with the resource consent median and 90th percentile limits (shown as dashed lines).

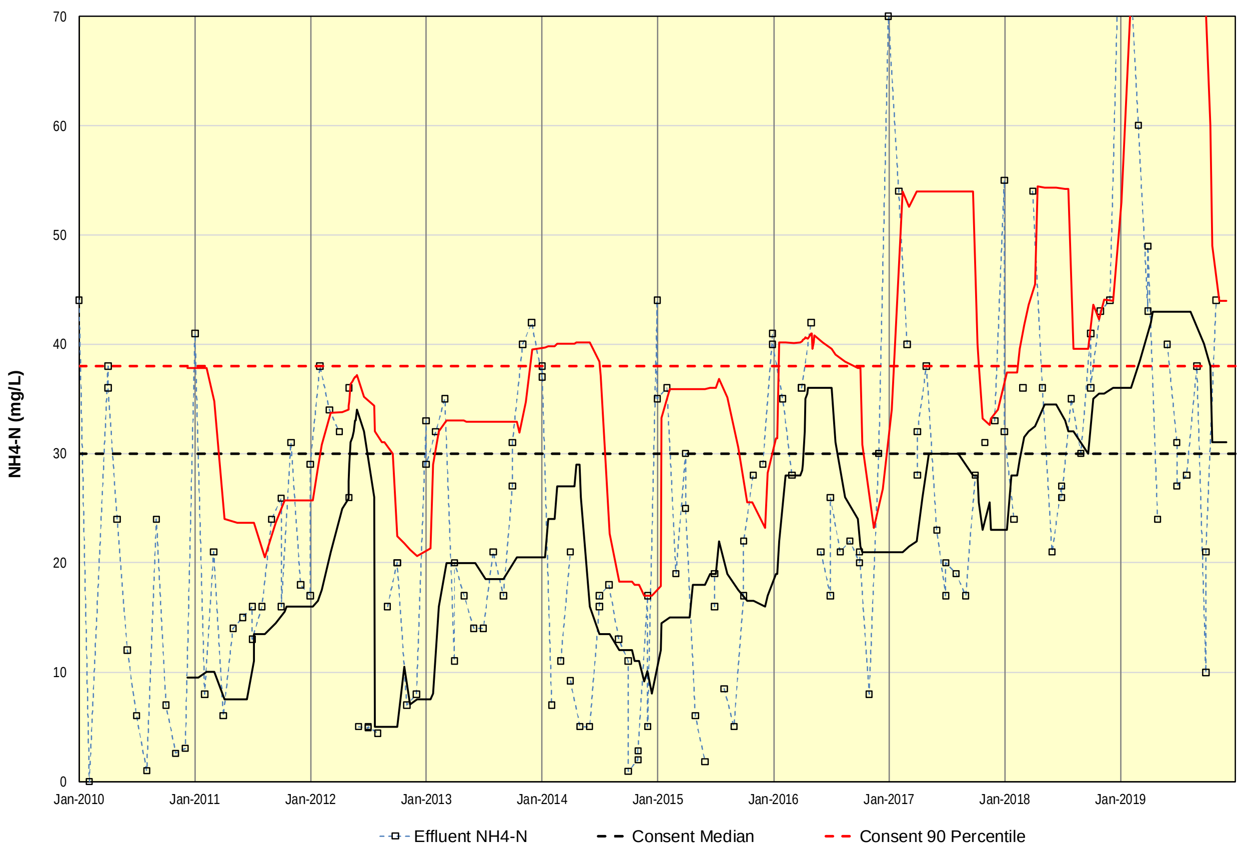

Figure 4-2: Opononi WWTP effluent NH_4-N concentrations 2010 – 2019

The current system does not comply with the consent conditions for ammonia. There is a regular spike in effluent ammonia concentrations every summer (Figure 4-2). This could be due to the seasonal population increase or the warmer temperatures causing an increase in anaerobic activity in the pond. It could also be attributed to the warming of the wetland sludge layers potentially releasing ammonia into the liquid stream (or a combination of these theories). Further investigation is needed to confirm the cause of the seasonal ammonia spikes.

Using the hydraulic retention times in the facultative and maturation ponds, the surface hydraulic loading rate on the wetlands, and standard empirical equations, a theoretical overall ammonia removal efficiency of 28% is calculated across the ponds and wetlands during peak month dry weather flows (Section 3). There is no data on the influent ammonia concentrations.

As mentioned previously, the effluent ammonia concentration have been increasing steadily since January 2015 (Figure 4-2). Dry weather flows have not increased over this period (Figure 2-1). The increase could be related to sludge build-up in the ponds releasing ammonia in the warmer temperatures. As both ponds were de-sludged in early 2019, ammonia concentrations may return to the pre-2015 levels. Elsewhere in the Far North District high concentration influent characteristics have been observed which would impact on the ammonia concentration of the treated wastewater. Further monitoring in 2020 will confirm this.

Regardless of the cause for elevated ammonia, based on current and historic performance, additional ammonia removal measures are likely required to comply with the current consent standards. Options for improving ammonia performance are presented in Section 6.2.

4.3 BOD and Total Suspended Solids

Figure 4-3 and Figure 4-4 show the effluent sampling results for BOD and total suspended solids from 2010 – 2019 along with the resource consent median and 90th percentile limits (shown as dashed lines).

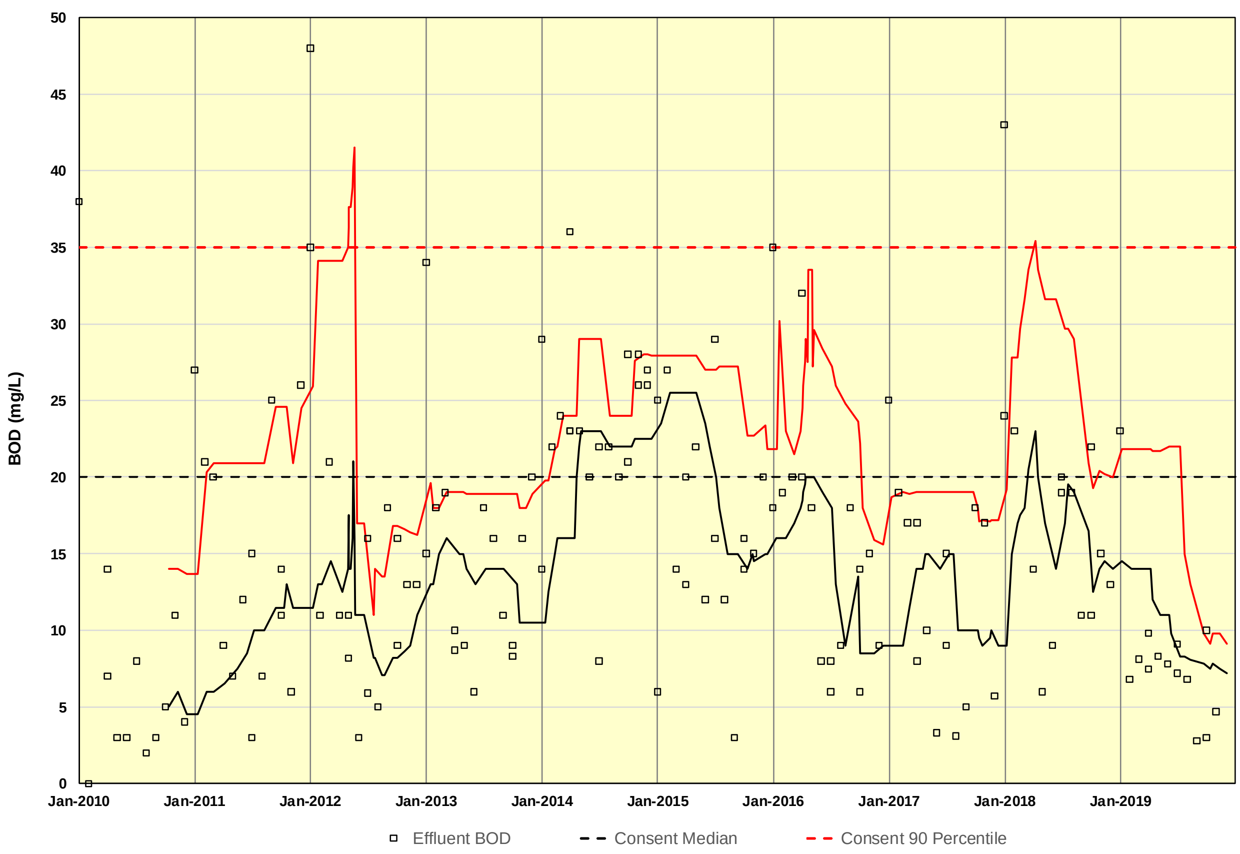

Figure 4-3: Opononi WWTP effluent BOD concentrations 2010 – 2019

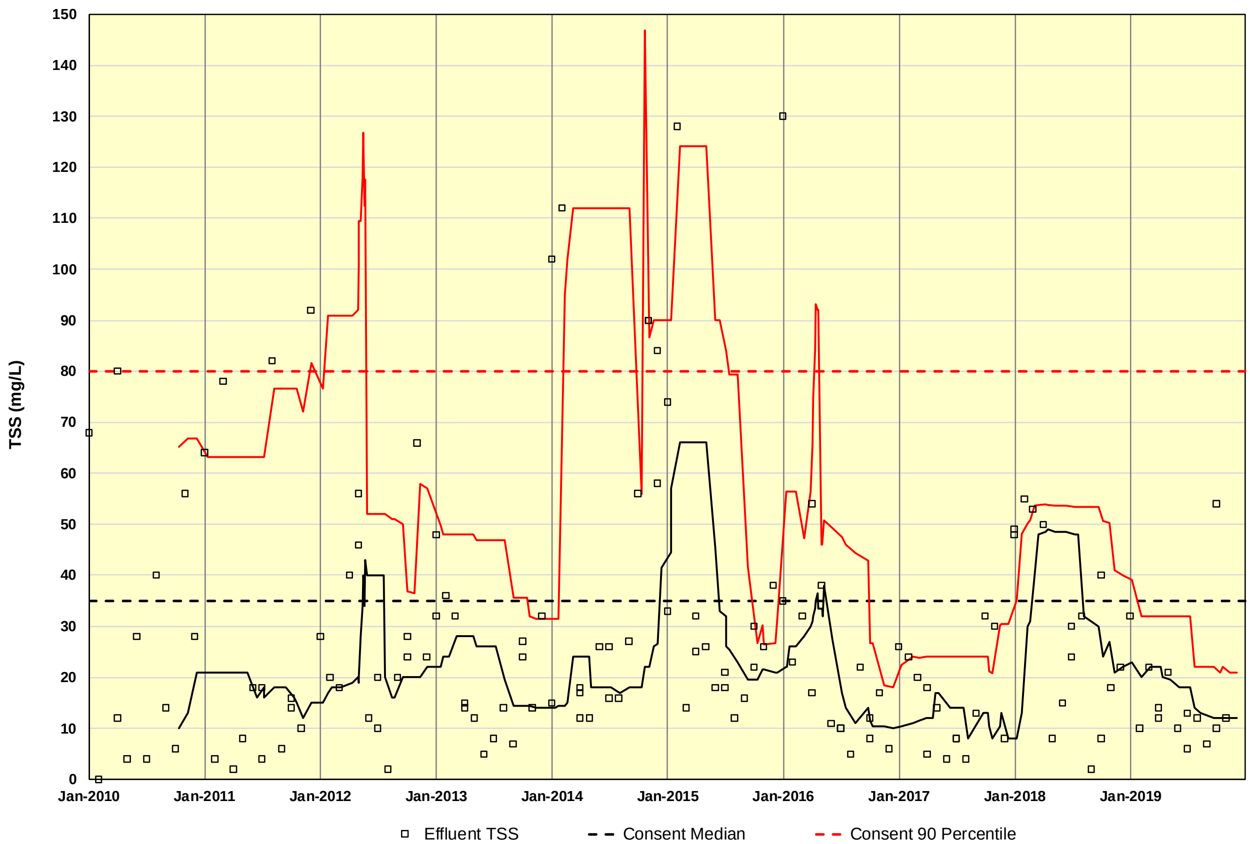

Figure 4-4: Opononi WWTP effluent TSS concentrations 2010 - 2019

The current system does not comply with the consent total suspended solids (TSS) conditions. This is likely due to the low HRT not providing sufficient time for the solids to settle. Suspended solids concentrations have a seasonal pattern typical for pond treatment systems, reflecting the natural increase in algae growth over summer (Figure 4-4). Options for improving TSS performance are presented in Section 6.3.

BOD largely follows the TSS trend. A reduction in BOD concentration is apparent over the last year, reflecting the reduction in TSS, possibly due to the pond de-sludging which would reduce the potential for solids carryover as well as increasing the HRT in the ponds and allowing more settling time.

4.4 Overall Effluent Compliance Statistics

The overall effluent quality statistics from 2016 to 2019 are presented in Table 4-1. This data reflects the performance with the current wetland configuration (i.e. since replanting and taking Cell 1 off line). Compliance rate is calculated as the number of rolling 12 monthly-sample median or 90th percentile values that comply with the consent standard divided by the total number of samples.

Table 4-1: Opononi WWTP Effluent Quality Summary 2016 - 2019

Parameter	Units	No. of Samples	Median			90th percentile		
			Consent	Overall	Compliance Rate	Consent	Overall	Compliance Rate
E. coli	cfu/100mL	72	3.0x103	4.4x103	32%	5.5x103	2.4x104	1%
NH_4-N	mg/L	60	30	30	53%	38	43	44%
BOD	mg/L	60	20	11	86%	35	23	99%
TSS	mg/L	60	35	16	85%	80	49	95%

From this data it is clear that the WWTP is not able to meet the current consent conditions across all four parameters.

4.5 Statistical Issues with Current Consent Compliance Criteria

Some statistical inconsistencies within the current consent compliance criteria should be addressed in the new resource consent, in order to comply with best practice as set out in the New Zealand Municipal Wastewater Monitoring Guidelines (2002). This will also aid in avoiding unnecessary technical non-compliances.

4.5.1 Percentiles versus Look-up Tables

The current compliance criteria are listed as median and 90^{th} percentile values calculated from the most recent 12 samples (taken monthly). The 90^{th} percentile values are calculated by excel which is not a transparent method and places an undue risk of false non-compliance on the discharger. The method recommended by the New Zealand Municipal Wastewater Monitoring Guidelines is to use a maximum number of exceedances rather than percentiles. Look-up tables can be used to determine the number of allowable exceedances based on the number of samples and discharger's risk. For example, for 12 samples, the number of allowable exceedances for median and 90^{th} percentile standards are 8 and 3 respectively (to keep the discharger's risk less than 10%) (NZWERF 2002).

4.5.2 Rolling versus Calendar Compliance Period

The current consent uses a rolling period (i.e. the most recent 12 samples) rather than a 12-month calendar period. Calendar compliance periods are recommended in the New Zealand Municipal Wastewater Monitoring Guidelines as they avoid multiple non-compliances due to the same sample (NZWERF 2002).

5. Receiving Environment

5.1 Harbour Values and Water Quality Standards

Important values of the Hokianga Harbour that can be impacted by wastewater discharges include:

§ Recreation and aesthetics: Water quality should be suitable for swimming at all times and the visual and aesthetic values of the environment should be maintained.

§ Shellfish consumption: The harbour should continue to support the healthy growth and survival of shellfish, and it should be safe to gather shellfish for human consumption at all times.

§ Aquatic ecosystem health: The harbour should continue to maintain the healthy functioning of aquatic ecosystems.

The Proposed Regional Plan for Northland (NRC 2019) Policy H.3.3 (Coastal water quality standards) contains coastal water quality standards that are designed to protect the recreational, aesthetic, shellfish gathering and ecosystem values of coastal waters in the region. The standards are therefore useful to assess whether the discharge could be affecting any of the important harbour values listed above. Standards in Policy H.3.3 of relevance to wastewater discharges are shown in Table 5-1.

Table 5-1: PRP for Northland (July 2019) Policy H.3.3 - Coastal Water Quality Standards for Estuaries*

Parameter	Units	Median	90th percentile	95th percentile
Faecal coliforms (shellfish gathering)	cfu/100mL	14	43	
Enterococci (contact recreation)	cfu/100mL			200
Ammoniacal nitrogen	mg/L	0.023		

* This policy is currently under appeal and is not operative

The following points are noted in relation to the Opononi discharge:

§ Phosphorus is not normally a concern in coastal waters as nitrogen is almost always the limiting nutrient (NIWA, 2018). None of the current consents for WWTP's discharging directly into the Hokianga Harbour (Opononi, Rawene, Kohukohu) contain phosphorus limits.

§ Based on the Estuary Trophic Index toolbox (NIWA 2018) the Hokianga Harbour has a low physical susceptibly to nitrogen impacts and experiences minor stress from catchment nitrogen loads (FNDC 2018). None of the WWTP's discharging directly into the Hokianga Harbour contain total nitrogen limits and total nitrogen is not considered to be an issue for the Opononi WWTP discharge.

§ Ammoniacal nitrogen limits are included in the current Opononi WWTP resource consent conditions. Chronic exposure to concentrations above those set out in Table 5-1 can be harmful to marine fauna.

§ The indicator bacteria used for marine water quality monitoring are faecal coliforms (shellfish consumption) and enterococci (contact recreation). *E. coli* is regarded as a more accurate pathogen indicator compared to faecal coliforms. The impacts on shellfish gathering have been assessed by way of a quantitative microbial risk analysis (QMRA).

5.2 Dilution in Harbour

5.2.1 Hydrodynamic Modelling Study

Treated wastewater from the Opononi WWTP is discharged on the outgoing tide into the Hokianga Harbour. The outfall discharge point is around 12 meters below mean sea level, approximately 400 meters from the Opononi shoreline, opposite the mouth of the Waiahoria Stream. An aerial photo showing the outfall discharge point location is provided in Figure 5-1.

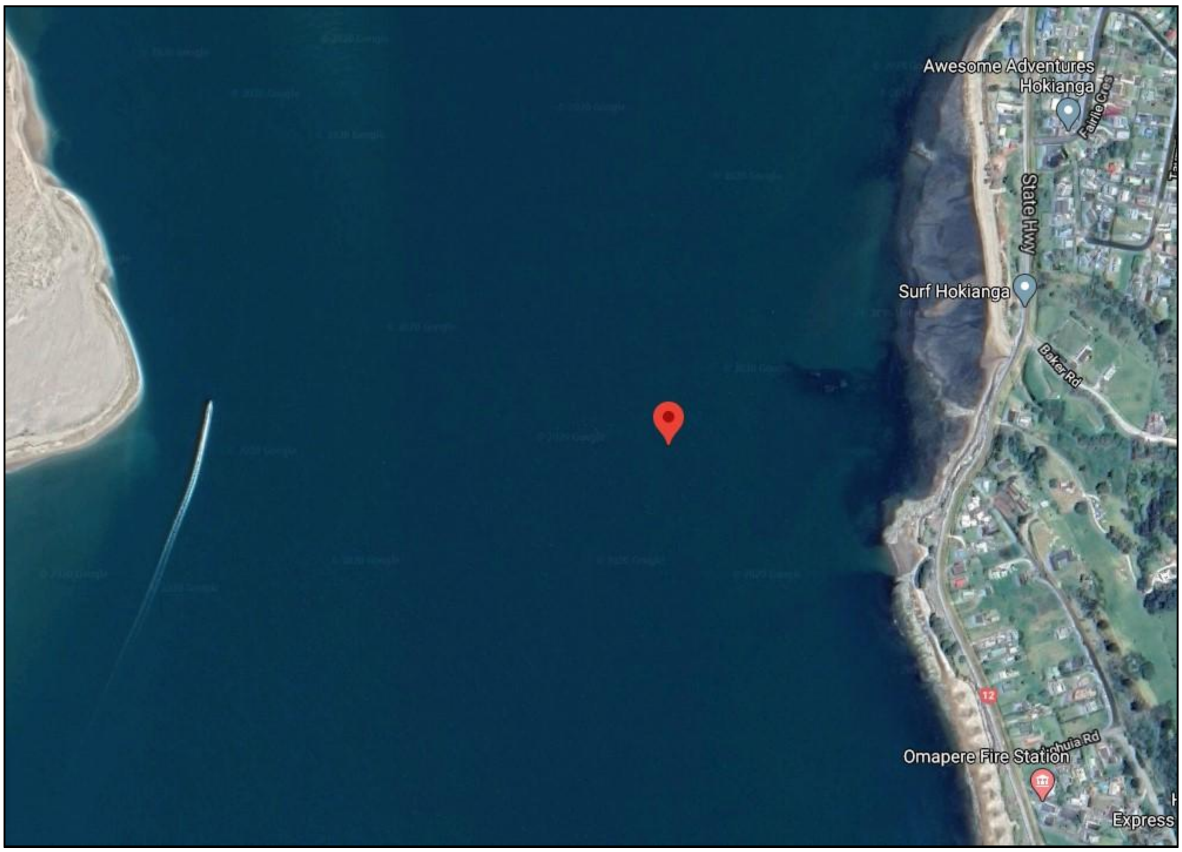

Figure 5-1: Opononi WWTP Outfall Discharge Point Location

In 2019 FNDC commissioned MetOcean Solutions to undertake a hydrodynamic study of the Hokianga Harbour and the dilution and dispersion of the four treated wastewater discharges into the Harbour (Kaikohe, Kohukohu, Rawene and Opononi).

For the Opononi outfall, the modelling results showed a high level of dilution with a median dilution factor of approximately 25,000 near the discharge point. The 95th percentile (exceeded 95 percent of the time) dilution was 1,000 near the discharge, 5,000 at about 500m down current and 25,000 at the shoreline (MetOcean, 2020).

5.2.2 Contaminant Concentrations in Harbour

Using the known effluent pollutant concentrations, and the dilution factors from the hydrodynamic model, the harbour faecal coliform and ammoniacal nitrogen concentrations near the outfall discharge location can be calculated. These are presented in Table 5-2.

Table 5-2: Contaminant Concentrations in Harbour based on 2016 -2019 Effluent Results & Hydrodynamic Model

Parameter	Units	Effluent Results 2016 – 2019	Dilution Factor	Harbour Near Discharge Point	Harbour Near Shoreline	Harbour Water Quality Standards
Median dilution factor				25,000 x	Not provided	
95^{th} percentile dilution factor				1,000 x	25,000 x	
Median Effluent Quality						
E. Coli concentration	cfu/100mL	$4.4x10^3$	Median	0.018	-	14*
			95%ile	4.4	0.018	43*
NH_4-N concentration	mg/L	32	Median	0.001	-	0.023
			95%ile	.032	0.001	
TSS concentration	mg/L	16	Median	<0.001	-	n/a
			95%ile	.016	<0.001	
95^{th} %ile Effluent Quality						
E. Coli concentration	cfu/100mL	$2.4x10^4$	Median	0.96	-	43*
			95%ile	24	0.96	
NH_4-N concentration	mg/L	60	Median	0.002	-	n/a
			95%ile	.06	0.002	
TSS concentration	mg/L	54	Median	0.002	-	n/a
			95%ile	.05	0.002	

* Harbour shellfish consumption standards are in faecal coliforms.

As shown in Table 5-2, dilution reduces contaminant concentrations to below the receiving water standards near the discharge point. Based on this assessment the current effluent discharge is not breaching the receiving water quality standards at the shoreline or even near the outfall discharge.

Upgrading the WWTP to meet the current and future consent standards would provide an additional safeguard against any adverse effects on the environment.

5.2.3 QMRA Outcomes

A QMRA was completed by Streamlined Environmental with the results reported in a report (A Quantitative Microbial Risk Assessment of the Opononi WWTP discharge and receiving environment) in March 2020. The report found that Wastewater treatment that reduces virus concentrations in the WWTP discharge by 2-log (i.e. 100-fold) reduction will reduce health risks associated with the discharge (in relation to inhalation, ingestion during swimming and consumption of shellfish harvested) at all exposure sites, to levels below the NOAEL.

In published literature, a 2log virus removal is the most predominantly reported level of reduction in virus concentrations in constructed wetland treatment systems. In line with the QMRA results, if the wetland treatment system is achieving a 2log virus removal, as commonly indicated by available literature, the level of treatment currently applied at the Opononi WWTP is sufficient to reduce illness risks associated with recreation or consumption of harvested raw shellfish below the “no observable adverse effect level” (NOAEL).

If the wetland performance is in question, UV disinfection can be specified to meet the log reduction requirements indicated by the QMRA. It should be noted that Option 5 does not need this due to the effluent being disposed to land.

6. WWTP Improvement Options

Currently the Opononi WWTP is not meeting the existing consent conditions. Based on the assessment of WWTP performance, the sensitivity of the receiving environment, the consent limits, and the hydrodynamic study outputs, the issues requiring improvement are:

- Reducing effluent indicator bacteria concentrations (i.e. increasing the disinfection performance of the WWTP
- Reducing total suspended solids concentrations
- Reducing ammonia concentrations.

Options for addressing these issues are discussed in the following sections.

6.1 Disinfection Improvements

6.1.1 Wetland Cell 1 Reinstatement

Reinstating wetland cell 1 will increase the residence time in the wetland system by approximately 40%, thereby increasing natural die-off of pathogens and reducing the effluent *E.coli* concentration. The additional retention time may also improve TSS, BOD and ammonia removal.

Reinstating wetland cell 1 would involve clearing out the wetland contents and transporting the contents to a landfill or to the sludge drying beds in Kaitaia. The wetland will then require replanting and plant establishment prior to commissioning.

6.1.2 Baffles in Maturation Pond

The amount of disinfection provided by ponds is a function of HRT, sunlight and temperature, and can be estimated using a first-order decay model (Mara, 2010). Hence, measures that improve the average residence time in a pond will improve disinfection performance.

Plastic curtain baffles installed in the maturation pond would reduce short-circuiting and improve the disinfection performance of the pond (IWA, 2012). Baffle curtains are commonly used in New Zealand ponds as a means of improving disinfection performance (Ratsey, 2016). Plastic curtain stub baffles can be easily retro-fitted next to the pond inlet and outlet to improve performance.

6.1.3 UV Disinfection

A UV disinfection system could be installed on the final effluent prior to discharge to the harbour. UV disinfection of pond or wetland effluent is reasonably common in New Zealand due to increasing effluent bacterial standards; examples include Thames WWTP, and Woodend and Kaiapoi WWTP's (Waimakariri District).

The variable algae content of wetland effluent will result in correspondingly variable UV disinfection performance. Algae reduces UV transmission, shields microorganisms from UV radiation and can also foul the lamp sleeves. To mitigate this, UV systems come with automatic lamp sleeve wipers and some units have a double skinned wiper with acid in the gap to provide a chemical clean of the surface as it wipes.

A 1–2 log removal of faecal coliforms could be achieved with a UV system treating the wetland effluent. The unit could be either installed in a channel or inline in the outfall pipe. During periods of no effluent flow, the unit would be switched off. A small shed containing the control cabinet would be required.

Performance would be significantly improved if a suspended solids removal plant was provided prior to the UV system. Examples of such systems include Waipawa and Waipukurau WWTP's (Central Hawkes Bay District).

6.1.4 Membrane Filtration

Membrane filtration involves filtering the effluent through ultrafiltration membranes with a pore size of around 0.04 microns, which is sufficient to remove most bacteria and viruses as well as all suspended solids.

Membrane filtration provides the highest level of disinfection and suspended solids removal and are typically used for highly sensitive receiving environments. Examples of membrane filtration on pond effluent in New Zealand include Hikurangi WWTP (Whangarei District), Wellsford WWTP (Auckland District) and Motueka WWTP (Tasman District). However, performance at these sites has been variable. Membranes are complex to operate and would involve a step change in operator training, skill level and monitoring. Membranes require the use of potentially hazardous chemicals which must be stored and handled correctly.

6.2 Suspended Solids Improvements

6.2.1 Effluent Storage Pond Cover

Installing a floating plastic cover on the surface of the effluent storage pond would prevent the growth of algae occurring, however any algae passing into the pond from the wetland would remain in suspension. Therefore, the reduction, if any, in TSS concentration is difficult to predict. In addition, the cover would reduce disinfection performance by blocking out UV radiation.

6.2.2 Chemically Assisted Solids Removal (either filtration, settling, or flotation)

Algae is very fine and requires a chemical conditioning process (coagulation and / or flocculation) to remove effectively. Coagulants include aluminium sulphate (alum) and ferric chloride. Polymer flocculants may also be used, either by themselves or in conjunction with a coagulant. The selection of chemical will come down to cost and effectiveness (which can be determined using jar tests).

Following chemical conditioning, the coagulated and flocculated solids are removed in either a clarifier, dissolved air flotation (DAF) unit, or a sand filter. The footprint of lamella settlers or DAF units is generally smaller. It is understood that at least one WWTP in the Far North District, as well as several drinking water treatment plants, use sand filtration (or vermifiltration) and therefore this process is familiar to the Far North Waters Alliance operators. Examples of chemically assisted solids removal on pond effluent include:

§ Coromandel WWTP (sand filtration)

§ Waipawa & Waipukurau WWTP's (lamella clarifier / sand filtration)

§ Waihi WWTP (induced air flotation).

6.2.3 Electrocoagulation

Electrocoagulation is a variant of chemically assisted solids removal. Instead of dosing a metal solution into the wastewater, metals are released from a submerged anode (either iron or aluminium) by passing an electrical current through the water. The coagulated solids are then removed via filtration or clarification in the same manner as chemically assisted solids removal.

A NIWA benchtop study found that the operating cost for electrocoagulation was higher than for conventional chemically assisted solids removal, due to the high electricity consumption and anode replacement. However, electrocoagulation provided disinfection in addition to solids removal (Park and Craggs, 2019). It should be noted that this was a single study based on the batch processing of a sample of wastewater using operating conditions that are vastly different to normal WWTP operation. Hence the result cannot be translated. There are no full-scale applications of electrocoagulation on municipal wastewater in New Zealand. The electrocoagulation process has a large footprint and the anode must be replaced regularly.

6.3 Ammonia Improvements

6.3.1 In-Pond Nitrification Systems

In-pond nitrification systems promote nitrification within ponds by placing a high surface area media in the pond for nitrifying bacteria to grow on. Some systems also include aeration of the media. A variety of systems have been retrofitted on New Zealand ponds, including:

§ Rock filter / sprinkler systems (Rangiora, Motueka)

§ Hanging curtains (Waipawa, Waipukurau)

§ AquaMats (Raglan, Te Kauwhata, Matamata)

§ Bioshells (Kaitangata, Heriot, Paihia).

In-pond nitrification systems have had varying degrees of success to date in New Zealand. The systems use different mechanisms to enhance the same nitrogen removal process and the performance results are highly variable. A challenge with these systems has been to achieve reliable winter performance (when nitrifier growth rates reduce). Most in-pond systems require additional modifications such as aerators and baffles. Lack of robust and consistent monitoring data before and after upgrading (post the handover period) makes the performance improvements difficult to reliably quantify.

Due to the site-specific pond dimensions and loading rates, pilot trials are recommended to confirm which, if any, system would be suitable for Opononi.

6.3.2 External Nitrification Systems

External nitrification systems typically comprise aerated tanks containing a high surface area media. A clarifier downstream of the aeration tank provides separation of the solids generated. In some cases, sludge is returned to the aeration tank creating an activated sludge element to the treatment process. These external systems provide a more controlled environment than the in-pond systems and can be sized to achieve reliable year-round performance. However, they are more complex to operate.

A commonly used nitrification technology is the submerged aerated filter (SAF), which consists of an aeration tank filled with fixed plastic media, followed by a clarifier and return sludge system. SAF's are commonly used in the UK for tertiary ammonia removal on municipal wastewater treatment plants and are reported to achieve less than 1 mg/L ammonia nitrogen year-round (Heath *et al* 2001). In New Zealand, SAF's have been used in on-site wastewater treatment package plants however, we are unaware of any SAFs retrofitted to an oxidation pond.

6.3.3 Fill and Drain Zeolite Wetland

The “fill and drain” wetland process (also known as the Advanced Wetland System or AWS) consists of zeolite beds which adsorb ammonium ions (NH_4^+) and promote the growth of nitrifying bacteria. The wetlands are fed intermittently and ammonium is adsorbed into the zeolite beds during the flooding stage. The adsorbed ammonium is then nitrified in the drain stage as air is drawn into the beds.

A pilot scale fill and drain zeolite wetland has recently been trialled at the Wellsford WWTP and achieved an ammonia removal efficiency of around 50% (Jacobs, 2019). Based on the pilot trial loading rates, the Opononi wetland is large enough to accommodate a fill and draw zeolite wetland in one cell. The fill empty cycle could be timed with the tidal discharge.

Currently this system has only been implemented in New Zealand at pilot scale at one WWTP and the applicability of this system for the Opononi WWTP should also be pilot tested before FNDC commit to this process.

6.3.4 Pond Aeration

Adding additional aerators to the facultative pond could promote nitrification through increased mixing and converting the facultative pond towards a complete mix aerated lagoon process. The increased mixing would create a suspended bacterial floc on which nitrifying bacteria could grow. The sludge layer in the facultative pond would be disturbed by the additional mixing energy and the maturation pond would become a settling pond to store the solids carried over from the facultative pond. Aerating the pond would normally be used to improve BOD treatment.

The energy required to mix ponds using mechanical aerators is in the range 20 – 40 W/m^3 (Metcalf and Eddy, 2014). Based on the facultative pond volume of 1,200 m^3, between 24-48 kW of aeration power would be required to mix the pond. This would incur a high annual power cost and would probably require an upgrade to the site power supply. In addition, the pond would require a plastic liner to protect against scouring from the increased mixing. Alternatively, a concrete pad could be placed beneath the aerators to protect the clay liner.

The pond aeration option also comes with risks due to the relatively short retention time in the pond (3 – 5 days at peak month dry weather flows) which is at the lower end for nitrification. In addition, the nitrifying bacteria could be washed out during high wet weather flows which would disrupt ammonia removal for a period of time while a sufficient nitrifying bacteria population is re-established.

6.4 Activated Sludge Plant

The ponds and wetlands could be replaced by a mechanical activated sludge plant which would produce a high-quality effluent with low BOD, TSS and ammonia concentrations. The activated sludge process provides operational process control and therefore more consistent effluent quality (less variability) than the current pond / wetland process which is essentially uncontrolled and reliant on climatic conditions.

The activated sludge process can take various configurations, including extended aeration or sequencing batch reactor (SBR). The activated sludge process is a high rate process with a hydraulic retention time of less than 24 hours. A UV disinfection unit would also be required to meet the effluent bacterial standards.

7. Land Disposal

7.1 Previous Investigations

Two studies into land disposal for the Opononi WWTP have been completed. These studies and the key findings are summarised in the following sections.

7.1.1 Alternative Disposal Options Study (VK Consulting Ltd, March 2011)

This report investigated the feasibility of five potential land disposal sites suggested by the OOCLG. A map showing the five sites investigated is provided in Figure 7-1.

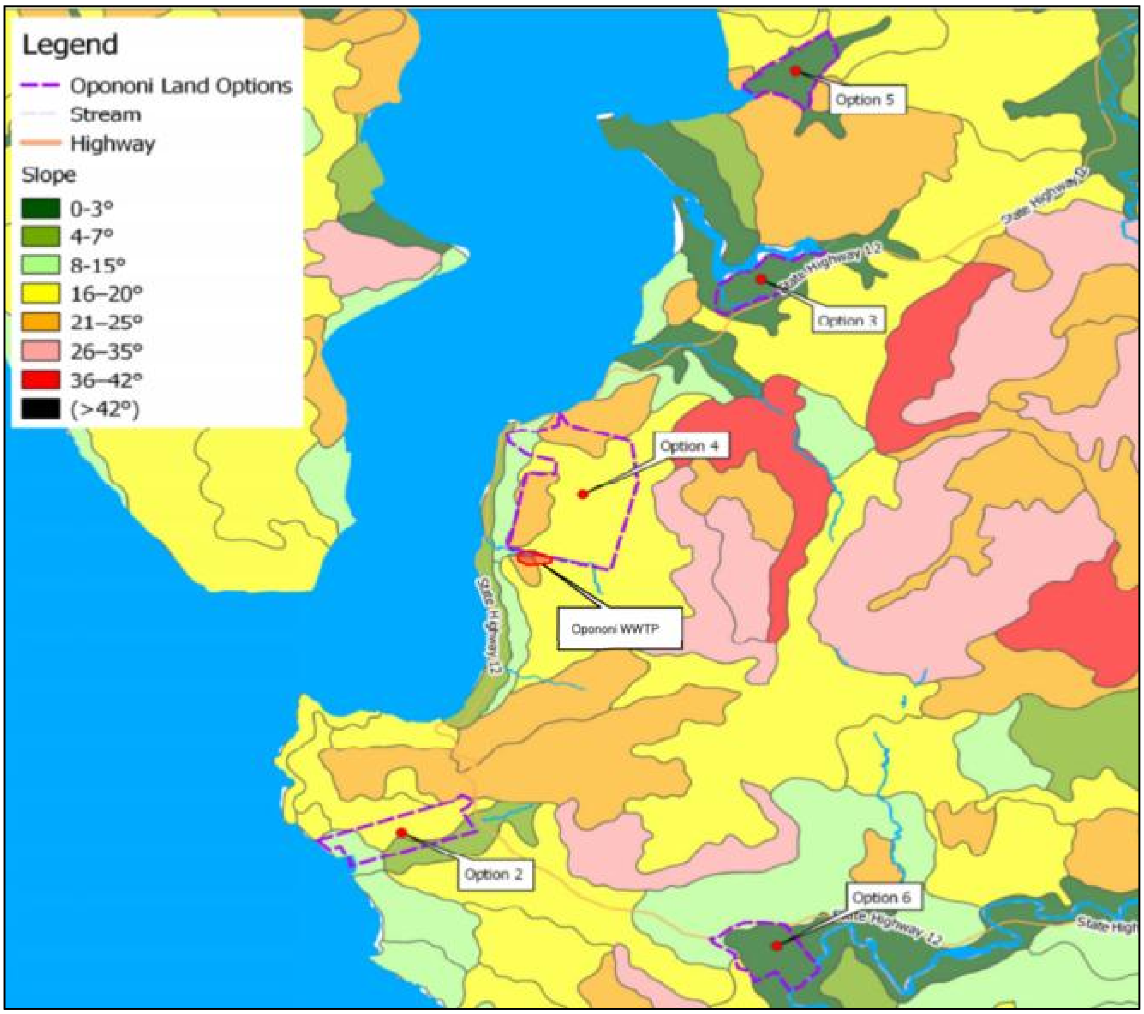

Figure 7-1: Land Disposal Site Locations (Mott MacDonald, 2014)

Of the five sites considered, three were considered feasible (Options 2, 3 and 6 above). Options 2 and 3 had imperfectly to poorly drained clay loam soils and a hydraulic loading rate of 1.7 mm/day was used for these sites. Option 6 (Waimamaku Beach Rd) had moderately well-draining soil and a hydraulic loading rate of 3mm/day was used. Option 6 was furthest from the WWTP (8.3 km) and located on the other side of the Omapere Hill. Capital cost estimates for the land disposal systems ranged from $3.7M to $4.3M (2011 dollars).

7.1.2 Treatment Upgrade and Land Disposal Options (Mott MacDonald, 2014)

This report investigated the feasibility of partial land disposal (summer only) as the land was found to be unsuitable for irrigation for seven months of the year. During the seven months that land disposal was not possible, the treated wastewater would be discharged into the harbour. Two of the sites previously considered in the 2011 VK Consulting report were selected for costing purposes (Options 2 and 4 in Figure 7-1). A design hydraulic loading rate of 1.7 mm/day was used and dripline irrigation was assumed due to the highly sloping land. Capital cost estimates for the land disposal systems were $3.4M and $5.3M (2014 dollars).

7.2 Winter Irrigation and Storage Requirement

A key parameter for land disposal, especially with low permeability soils such as those in the Opononi area, is the allowable irrigation rate over winter or prolonged wet periods and hence the required irrigation storage volume. The 2014 Mott MacDonald investigation found that irrigation was not possible over winter (seven months of the year), which resulted in a winter storage volume of 39,000 m^3. Due to the cost of providing this large storage volume, discharge to harbour over winter was proposed instead.

In contrast, the 2011 VK Consulting report proposed irrigation storage volumes of between 2,000 and 13,000 m^3 depending on the site and irrigation rainfall scenario. A range of potential irrigation rainfall limit scenarios was presented for each site (< 4mm, <10mm, unlimited). The higher the allowable rainfall during irrigation, the lower the storage required.

If land disposal was selected as the preferred discharge option, then winter storage will need to be provided, or harbour disposal during wet weather events would be required which would impact the level of treatment required. Further site-specific investigations and a detailed water balance are required to assess the irrigation storage requirements.

8. Combined Solution Options

An implementable wastewater treatment scheme comprises the collection and transfer system, the treatment process, and the disposal of the treated effluent. For consent renewals, upgrade is not always required if the WWTP is meeting the consent conditions. However, for the Opononi WWTP the system is experiencing compliance issues and therefore treatment process upgrade is required to meet the current consent conditions. Consideration of land-based disposal is also required as part of the previous consent conditions. It should be noted that the effluent quality required for land-based disposal is typically less stringent than for harbour disposal.

Based on our assessment of the current Opononi WWTP performance issues we have identified six options for the Opononi WWTP. Five of the options maintain the current harbour discharge, each option with increasing levels of treatment to address the current non-compliances. Option 5 proposes discharge to land. The options presented are in order of increasing effluent quality and likely cost. The exception is the discharge to land option which will likely be the highest cost option, but has different treatment requirements than for the harbour disposal options.

8.1 Option 1: Optimise Existing WWTP and Maintain Harbour Discharge

Scope of Upgrade Works

This option involves the following upgrade works:

§ Install stub curtain baffles on maturation pond to reduce pond short-circuiting

§ Reinstate Wetland Cell

§ Clear wetlands cells of vegetation overgrowth.

Benefits

The main benefit of Option 1 is that it is a low-cost option that maximises the performance of the existing WWTP infrastructure. This option is considered reasonable as the hydrodynamic modelling report showed that effects from the existing discharge on harbour water quality are within the acceptable limits.

Consequences / Issues

Revised effluent quality standards would be needed to align the consent standards with the optimised plant performance. It is considered unlikely that a resource consent with more relaxed standards would to be granted by NRC.

8.2 Option 2: UV Disinfection and Maintain Harbour Discharge

Scope of Works

This option includes all the items listed in Option 1, plus the installation of a new UV disinfection system on the wetland effluent prior to discharge into the harbour.

Benefits

The UV plant would be sized to provide sufficient disinfection to achieve compliance with the consent *E. coli* standards and as a result public health risks in the harbour would be reduced.

Consequences / Issues

There would only be an improvement in disinfection treatment but the effluent quality would not change in terms of ammonia, BOD and TSS. Revised effluent BOD, TSS and ammonia standards would be needed to align the new consent with the optimised plant performance.

8.3 Option 3: UV Disinfection plus Ammonia Removal and Maintain Harbour Discharge

Scope of Works

This option includes all the items in Option 2, plus the installation of an ammonia removal process. Site specific testing and pilot trials would be recommended prior to selecting the preferred ammonia removal technology.

Benefits

This option would likely be able to achieve sufficient *E. coli* and ammonia treatment.

Consequences / Issues

Depending on the technology selected, increased operational complexity is possible. This option would not improve BOD and TSS treatment. Therefore, this option is unlikely to address the current non-compliance issues, or future proposed conditions.

8.4 Option 4: UV Disinfection, Ammonia Removal, Chemically Assisted Solids Removal and Maintain Harbour Discharge

Scope of Works

This option includes all the items in Option 3, plus a chemical solids removal plant to remove residual algae from the wetland effluent. A chemical storage / dosing shed would be required. Algae removed from the effluent would be returned to the inlet of the WWTP.

Benefits

This option would likely provide sufficient treatment. Furthermore, removing the TSS effluent would likely improve UV disinfection performance. The removal of algae would reduce the green colour of the treated wastewater making a visible improvement in effluent quality (visually clear).

Consequences / Issues

Maintaining good chemical coagulation / flocculation performance can be difficult, and can require ongoing adjustments and optimisation of dose rate and/or chemical. The process will require an increase in operation and maintenance complexity compared with the current system.

8.5 Option 5: Optimise Existing WWTP and a New Discharge to Land

Scope of Works

This option includes the treatment performance items as per Option 1, with disposal via a new land disposal system comprising the following elements:

- Transfer pump station and rising main
- Irrigation storage pond
- Irrigation pump station and disk filter
- Dripline irrigation network.

Benefits

This option removes the discharge from the harbour thereby removing the public health risk associated with a harbour discharge. Because of the steep terrain around Opononi, it is likely that a dripline irrigation system will be required and therefore it is unlikely that UV disinfection will be needed for this option as aerosols are not produced. Ammonia removal is not a priority for land disposal as ammonia is retained in the soil, taken up by grass and, if managed correctly, will not pose a risk to aquatic animals. Therefore, it is expected that only improvements to optimise the performance of the existing infrastructure (Option 1) would be needed.

Consequences / Issues

Currently there is a high degree of uncertainty regarding this option. No site investigations have taken place and no land owners have been approached to ascertain the possibility of land purchase or lease. Resource consents, easements and designations would be needed for the transfer pipeline and disposal area. Assuming a suitable parcel of land can be identified, a five-year timeline is estimated from commencement of site-specific investigations to commissioning of the land disposal system.

The disc filter and dripline irrigation network would require ongoing maintenance and the pasture cut and carry operation (e.g. baleage) will need ongoing management. In addition, the land disposal system is likely to be non-viable during heavy rainfall and vulnerable to extreme weather events, unlike the harbour outfall.

This option is expected to have a high capital and operating cost.

8.6 Option 6: Activated Sludge Plant plus UV Disinfection and Harbour Discharge

Scope of Works

This option includes replacing the existing pond and wetland system with a new activated sludge plant comprising the following elements:

- Inlet screen
- Activated sludge plant (either an SBR or extended aeration plant)
- UV disinfection system

- Sludge thickening, storage and loadout facilities.

Benefits

This option provides the highest effluent quality and the most consistent effluent quality as the process is controlled and does not rely on natural processes, as the current system does.

Consequences / Issues

The activated sludge process is highly mechanised and would require a step change in operation and maintenance effort, staff training and operating costs compared with the current low maintenance, “low tech” system. The process would consume more energy as all of the aeration is provided mechanically. Sludge would need to be processed on a daily basis and a disposal route would need to be found for the waste sludge.

This option makes no use of the existing assets which would be decommissioned. This option is would have a high capital and operating cost.

8.7 Summary

As the Opononi WWTP is not able to meet the current consent limits, only options which address all non-compliant parameters are worth further consideration and investment. Options than cannot address these parameters are considered fatally flawed in terms of the ability to meet the current resource consent conditions.

Of the long-list of options identified above, only options 4, 5 and 6 are expected to meet the required effluent quality standards. Four options will be taken forward for further consideration, and Option 4 has been expanded to options 4a, and 4b – considering different ammonia and solids removal options. As all options will be designed to meet the consent requirements, coupled with the hydrodynamic study findings, the key aspects to consider become reliability of treatment performance and ease of operation, as well as the affordability of the option. Options which are robust, technically proven, and familiar to operators in the district have been shortlisted ahead of options which are currently in trial phase or are complex to operate.

The list of four shortlisted options is outlined below. Note that all options include optimisation of the existing system by installing curtain baffles on the maturation pond, reinstating wetland cell 1, and de-vegetating the overgrowth in the existing wetland cells, as well as installation of UV disinfection:

- Option 4a – Optimised process, chemically assisted solids removal, UV, with an in-pond or in-wetland ammonia removal process (e.g. bioshells, zeolite fill-and-draw wetland) and harbour discharge.
- Option 4b – Optimised process, chemically assisted solids removal, UV, with an external ammonia removal package plant (e.g. SAF) and harbour discharge.
- Option 5 - Optimisation of the current process and discharge of the treated wastewater to land.
- Option 6 – New activated sludge plant plus UV disinfection and harbour discharge.

9. Cost Estimates of Recommended Options

Four options for the Opononi WWTP upgrades have been shortlisted and endorsed by FNDC to be taken forward to complete cost estimates and undergo the MCA process. These include;

1. Option 4a – Optimised process, chemically assisted solids removal, UV, with an in-pond or in-wetland ammonia removal process (e.g. bioshell, zeolite fill and draw wetland) and harbour discharge.

2. Option 4b – Optimised process, chemically assisted solids removal, UV, with an external ammonia removal package plant (e.g. SAF) and harbour discharge.

3. Option 5 – Optimisation of the current process and discharge of the treated wastewater to land.

4. Option 6 - New activated sludge plant plus UV disinfection and harbour discharge

Indicative cost estimates have been completed for each of the options listed in sections 9.1 to 0. These have been compiled from quotes received from contractors and suppliers, previous work on the Opononi WWTP and similar FNDC projects such as the Taipa WWTP upgrades.

The total costs also include contingency amounts and risk allowances as recommended in Table 4.4 of the IChemE Guide to Capital Cost Estimation for a Fluid Processing Plant (IChemE, 2000). It should be noted that the following cost estimates are high-level and have an accuracy of ±50%, more detailed analysis would need to be carried to obtain a more accurate cost estimation. Additionally, differing levels of risk contingency have been applied to the items listed in the cost estimates in the following sections. Items of greater cost and scope certainty have had a lower risk contingencies applied to them and vice versa. The overall risk contingency for each option may be solely contain a low/high or a combination of both lower and higher contingency factors, in this case standard and reduced labels have been used for indication.

9.1 Option 4a Indicative Cost Estimate

Option 4a comprises optimising the current process, providing chemically assisted solids removal and UV disinfection, with an in-pond or in-wetland ammonia removal process (e.g. bioshells or a zeolite fill-and-draw wetland). Discharge remains to harbour. Indicative pricing for Option 4a can be found in Table 9-1, refer to Appendix C for detailed cost estimates and supplier product catalogues.

Table 9-1 Indicative Cost Estimate for Option 4a

Item	Unit	Quantity	Rate	Total	Comment
Opononi WWTP Process Optimisation					
Supply and install baffle curtains	Item	1	$28,000	$28,000	SiteCare quotation. This price includes team mobilisation, price of the Permathene baffle curtains, the tasks and the transport of the collected waste to the Kaikoura landfill.
Wetland vegetation clearance and disposal	Item	1	$66,000	$66,000	SiteCare quote for wetland maintenance 8/07/20. This price includes team mobilisation, price of the Permathene baffle curtains, the tasks and the transport of the collected waste to the Kaitaia landfill. FNDC could execute this work as part of the Far North Waters Alliance rather than an external contractor.

Wetland reinstatement	Item	1	$98,000	$98,000	SiteCare to: - To attend restore " Sacrificed Wetland Cell" as per scope. - Redirect inlet pipeline from WWTP to "Sacrificed Wetland Cell", and install outflow to Wetland Cell
Treatment Upgrades					
Wedeco UV LBX120E UV Disinfection Unit	Item	1	$114,000	$114,000	Based on Xylem price quote includes contingencies for the install, Instrumentation, piping and electrical costs
Instrumentation costs: 1. Flowmeter 2. Turbidity meter 3. UV Transmissivity	Items	1	$53,000	$53,000	Based on quotes received in 2019 from instrumentation suppliers. The total prices includes installation, instrumentation and controls, piping and electrical costs based on factors recommended in Table 4.4 of the IChemE Guide to capital cost estimation.
Solids Removal : DAF Plant	Item	1	$790,000	$790,000	Based on Filtec indicative costs received July 2020. The total price also includes electrical costs as per the factors recommended in Table 4.4 of the IChemE Guide to capital cost estimation for a Fluid Processing Plant.
In-pond Ammonia Removal - Bioshells	Item	1	$780,000	$780,000	Based on Marshall projects indicative costs from July 2020 for supply and install of ~60 bioshells and hexacovers. Note this technology has been costed to provide indicative costs, but other in pond options can be considered. An additional 20% has been added to the final cost on recommendation from the supplier.
Risk Allowance (reduced)	%	54	$1,000,000	$1,000,000	The Risk allowance is based on factor recommend in Table 4.4 of the IChemE Guide to capital cost estimation for engineering and supervision fees for a Fluid Processing Plant for a Fluid Processing Plant. The overall option risk allowance is a combination of a lower contingency factor (34%) applied to the Baffle curtain installation task and the higher contingency factor (54%) applied to the remaining tasks (excluding wetland vegetation clearance).
Total Capital Costs				$2,929,000	

9.2 Option 4b Indicative Cost Estimate

Option 4b is the same as 4a, but instead of an in-pond or wetland ammonia removal system, an external ammonia removal package plant (e.g. SAF) is included. Indicative pricing for Option 4b can be found in Table 9-2, refer to Appendix C for detailed cost estimates and supplier product catalogues.

Table 9-2 Indicative Cost Estimate for Option 4b

Item	Unit	Quantity	Rate	Total	Comment
Opononi WWTP Process Optimisation					
Supply and install baffle curtains	Item	1	$28,000	$28,000	SiteCare quotation. This price includes team mobilisation, price of the Permathene baffle curtains, the tasks and the transport of the collected waste to the Kaitaia landfill.
Wetland vegetation clearance and disposal	Item	1	$66,000	$ 66,000	SiteCare quote for wetland maintenance 8/07/20. This price includes team mobilisation, price of the Permathene baffle curtains, the tasks and the transport of th collected waste to the Kaitaia landfill. FNDC could execute this work as part of the Far North Waters Alliance rather than an external contractor.
Wetland reinstatement	Item	1	$98,000	$98,000	SiteCare to: - To attend restore " Sacrificed Wetland Cell" as per scope. - Redirect inlet pipeline from WWTP to "Sacrificed Wetland Cell", and install outflow to Wetland Cell 1.
Treatment Upgrades					
Wedeco UV LBX120E UV Disinfection Unit	Item	1	$114,000	$114,000	Based on Xylem price quote includes contingencies for the install, Instrumentation, piping and electrical costs.
Instrumentation costs: 1. Flowmeter 2. Turbidity meter 3. UV Transmissivity	Items	1	$53,000	$53,000	Based on quotes received in 2019 from instrumentation suppliers. The total price includes installation, instrumentation and controls, piping and electrical costs based on factors recommended in Table 4.4 of the IChemE Guide to capital cost estimation for a Fluid Processing Plant.

Solids Removal - DAF Plant	Item	1	$555,000	$555,000	Based on Filtec indicative costs received July 2020. The total price also includes electrical costs as per the factors recommended in Table 4.4 of the IChemE Guide to capital cost estimation for a Fluid Processing Plant.
Out of pond Ammonia Removal - SAF Plant	$/m^3/day	178	$13,000	$2,314,000	Consultation with Hynds NZ for a SAFF plant. High level, indicative pricing is $13k/m3/day. The total cost is for delivery of the current ADWF of 178 m3/day, this price includes installation and contractor costs.
Risk Allowance (reduced)	%	54	$ 1,702,000	$ 1,702,000	The Risk allowance is based on factor recommend in Table 4.4 of the IChemE Guide to capital cost estimation for engineering and supervision fees for a Fluid Processing Plant. The overall option risk allowance is a combination of a lower contingency factor (34%) applied to the Baffle curtain installation task and the higher contingency factor (54%) applied to the remaining tasks (excluding wetland vegetation clearance).
Total Capital Costs				$ 4,930,000	

9.3 Option 5 Indicative Cost Estimate

Option 5 comprises optimising the current process and discharging of the treated wastewater to land. Indicative pricing for Option 5 can be found in Table 9-3, refer to Appendix C for detailed cost estimates and supplier product catalogues.

Table 9-3 Indicative Cost Estimate for Option 5

Item	Unit	Quantity	Rate	Total	Comment
Opononi WWTP Process Optimisation					
Supply and install baffle curtains	Item	1	$28,000	$28,000	SiteCare quotation. This price includes team mobilisation, price of the Permathene baffle curtains, the tasks and the transport of the collected waste to the Kaitaia landfill. T
Wetland vegetation clearance and disposal	Item	1	$66,000	$66,000	SiteCare quote for wetland maintenance 8/07/20. This price includes team mobilisation, price of the Permathene baffle curtains, the tasks and the transport of the collected waste to the Kaitaia landfill. FNDC could execute this work as part of the Far North Waters Alliance rather than an external contractor.
Wetland reinstatement	Item	1	$98,000	$98,000	SiteCare to: - To attend restore " Sacrificed Wetland Cell" as per scope. - Redirect inlet pipeline from WWTP to "Sacrificed Wetland Cell", and install outflow to Wetland Cell 1
Treatment Upgrades					
Wedeco UV LBX120E UV Disinfection Unit	Item	1	$114,000	$114,000	Based on Xylem price quote includes contingencies for the install, Instrumentation, piping and electrical costs
Instrumentation costs: 1. Flowmeter 2. Turbidity meter 3. UV Transmissivity	Items	1	$53,000	$53,000	Based on quotes received in 2019 from instrumentation suppliers. The total price includes installation, instrumentation and controls, piping and electrical costs based on factors recommended in Table 4.4 of the IChemE Guide to capital cost estimation.

Solids Removal : DAF Plant	Item	1	$790,000	$790,000	Based on Filtec indicative costs received July 2020. The total price also includes installation and electrical costs as per the factors recommended in Table 4.4 of the IChemE Guide to capital cost estimation.
In-pond Ammonia Removal - Bioshells	Item	1	$780,000	$780,000	Marshall projects indicative costs from July 2020 for supply and install of ~60 bioshells and hexacovers. Note this technology has been costed to provide indicative costs, but other in pond options can be considered. A margin of 20% has been added as recommended by Marshall Projects
Land-based Discharge					
Option 4 - Baker Farm	Item	1	$3,670,000	$3,670,000	The total cost for this option is an inflation adjusted price for Option 4 recommended in Section 3.3 of the 2014 study completed by Mott MacDonald. The study was a high-level cost analysis for Option 4.
Infrastructure Costs	%	76	$2,790,000	$2,790,000	An additional allowance estimate has been added based on factors for purchased equipment installation, instrumentation, and electrical works for a land-based disposal option. These factors have been based on recommendations from Table 4.4 of the IChemE Guide for Capital Cost Estimation
Risk Allowance for Land-based Discharge	%	137	$8,851,000	$8,851,000	A risk allowance for land-based discharge includes factors for the engineering and supervision, construction expenses, contractors fee and contingencies as recommended by Table 4.4 of the IChemE Guide for Capital Cost Estimation
Risk Allowance (reduced)	%	42	$781,000	$781,000	The Risk allowance is based on the contingency factor recommend in Table 4.4 of the IChemE Guide to capital cost estimation for contingencies for a Fluid Processing Plant. The overall option risk allowance is a combination of a lower contingency factor (34%) applied

					to the baffle curtain installation task and the higher contingency factor (54%) applied to the remaining tasks (excluding wetland vegetation clearance).
Total Costs				$18,021,000	

9.4 Option 6 Indicative Cost Estimate

Option 6 is to replace the current WWTP process with a new activated sludge plant process, with UV disinfection and harbour discharge. Indicative pricing for Option 6 can be found in Table 9-4, refer to Appendix C for detailed cost estimates and supplier product catalogues.

Table 9-4 Indicative Cost Estimate for Option 6

Item	Unit	Quantity	Rate	Total	Comment
Decommissioning of current system					
Allowance	Item	1	$300,000	$300,000	This is an estimated allowance for decommissioning the current system and repurposing it
Treatment Upgrades					
Wedeco UV LBX120E UV Disinfection Unit	Item	1	$114,000	$114,000	Based on Xylem price quote includes contingencies for the install, Instrumentation, piping and electrical costs
Instrumentation costs: 1. Flowmeter 2. Turbidity meter 3. UV Transmissivity	Items	1	$114,000	$53,000	Based on quotes received in 2019 from instrumentation suppliers. The total price includes installation, instrumentation and controls, piping and electrical costs based on factors recommended in Table 4.4 of the IChemE Guide to capital cost estimation.
Activated Sludge Treatment Plant					
Indicative Cost of plant	Item	1	$2,478,000	$2,478,000	This price includes: Inlet works, construction costs associated with the SBR system, contractor design, commissioning, power supply and contingencies. It is an adjusted estimate from the Taipa Upgrade Issues and Options Report (May, 2018)
Risk Allowance (standard)	%	54	$1,429,000	$1,429,000	The Risk allowance is based on the contingency factors for engineering and supervision recommend in Table 4.4 of the IChemE Guide to capital cost estimation for contingencies for a Fluid Processing Plant.
Total Capital Costs				$4,374,000	

9.5 Summary of Costs, Benefits and Risks

9.5.1 QMRA Outcomes

As discussed in Section 5.2.3 a QMRA was completed by Streamlined Environmental which found that, if the wetland treatment system is achieving a 2log virus removal as commonly indicated by available literature, the level of treatment currently applied at the Opononi WWTP is sufficient to reduce illness risks associated with recreation or consumption of harvested raw shellfish below the "no observable adverse effect level" (NOAEL).

If the wetland performance is in question, UV disinfection can be specified to meet the log reduction requirements indicated by the QMRA. It should be noted that Option 5 does not need this due to the effluent being disposed to land.

Table 9-5 summarises the benefits, risks and costs for each of the four options.

Table 9-5 Summary of Options Benefits, Risks and Costs

Option	Option 4a	Option 4b	Option 5	Option 6
Benefits and Risks	Relatively low Opex In-pond ammonia removal systems have inconsistent results Will meet consent conditions Ease of operation Fill and Drain wetlands are proven at pilot scale only Highly compatible with existing infrastructure Maintain harbour discharge	Relatively low Opex High quality effluent produced Will meet consent conditions More technical to operate Reliable technology Additional monitoring and maintenance required Limited SAF suppliers in New Zealand Compatible with existing infrastructure Maintain harbour discharge	Expensive option – both Capex and Opex Large footprint required High quality effluent produced Will meet consent conditions More technical to operate Land purchase required Extensive consultation process More acceptable to Maori Compatible with existing infrastructure Establish land-based discharge	Higher Opex High quality effluent produced Will meet consent conditions Small footprint More technical to operate Highly future proofed solution Reliable technology Not compatible with existing infrastructure Maintain harbour discharge

Option	Option 4a	Option 4b	Option 5	Option 6
Capital Cost	$2.929M	$4.930M	$18.021M	$4.374M

10. Multi-Criteria Assessment

10.1 Criteria

The proposed criteria for the Multi Criteria Analysis (MCA) have been provided by FNDC and are outlined in Table 10-1.

The risks and benefits of each option have been identified and were considered using an MCA process in a collaborative workshop held with FNDC on the 26th August 2020. The MCA criteria used can be summarised at a high level as follows:

1. Cultural acceptability: iwi/stakeholder concerns from consultation including effects on the mauri of the water, amenity and perception of a discharge to water.
2. Environmental criteria: ensuring the harbour is safe for recreational activities including the gathering of kai moana, particularly close to the disposal site, and a reduction of nutrient load (N and P) going into the harbour from the WWTP, and that amenity impacts such as noise, visual aesthetics and odours are not significantly impacted
3. Practicability criteria: that the option can be consented in a timely manner, and considers the complexity of the construction process, distance from networks and services and the overall time taken to construct and commission the option
4. Operational Criteria: technical factors including reliability, technical feasibility, robust & proven technology, operational resilience, staging/flexibility for future upgrading, Health and Safety in design and operational complexity.
5. Economic Criteria: Order of magnitude capital and operating cost estimates will inform the affordability of each option as well as the likely impact on rates.

Table 10-1: Opononi WWTP Assessment Criteria

Number	Category	Criteria	Description	Success Factors
1	Māori cultural values	Impacts on Māori cultural values and practices.	Gives effect to Te Mana o te Wai. Acceptability of process to local iwi	The option safeguards Māori cultural values and practices
2	Environmental values	Land Use Effects	Visual, Noise, Traffic impacts	The option can meet required discharge standards for wastewater (and carbon where applicable) The option can meet amenity standards, including odour
		Odour	The degree to which odour can be expected to be discharged beyond the property boundary.	
		Ecological Effects	The degree to which the effluent quality exceeds the minimum environmental and consent requirements.	
		Carbon Footprint	Level of energy consumption, secondary discharges and chemicals required.	

		Public Health	Impacts on mahinga kai Recreational use of the receiving environment Impact of spills and failure	
3	Practicability	Constructability	Complexity of construction process Distance from networks and services Time taken to commission option	The option can be successfully delivered
		Regulations and Planning	Complexity to obtain a consent or other authorisations	
4	Operability	The ease of operation and maintenance	Complexity of operation Required expertise Ease of access H&S risks of plant process. Sludge management Reliance on and complexity of plant consumables and replacement componentry	The option can be successfully used into the future
		Process reliability and resilience	Known performance of others with similar technologies Consistency of quality in the discharge Ability to maintain compliance with resource consents	
		Expandability/ future proofing	The potential for the site to allow for extensions to the treatment process Proofing against changes in compliance requirements	
		Hazards	Proximity to known and potential hazards, e.g., flood plains, climate change hazards	
5	Financial considerations	Capital Cost	Cost of implementation Site investigations and procurement of land Ability to reuse existing FNDC assets	The costs of the option are understood and able to be paid
		Operating and Maintenance Costs	Operations and maintenance requirements (e.g., chemical costs, sludge removal) Power cost	
		Rating impact	Impact on targeted rate relative to other options	

The weightings for the primary and sub-criteria are shown in Table 10-2. The results of the assessment are presented in Table 10-3 and Figure 10-1.

Table 10-2: MCA Primary and sub-criteria weightings

Primary Criteria	Weighting	Secondary Criteria	Weighting
Economic Criteria	40.0%	Capital Cost	33%
		Operating and Maintenance Costs	33%
		Rating Impacts	33%
Environmental Criteria	20.0%	Land Use Effects (visual, noise and traffic impacts)	15%
		Odour (degree to which odour will be eperienced beyond WWTP boundary)	15%
		Ecological Effects (does effluent quality exceed consent limits)	30%
		Carbon Footprint (level of energy and consumables required)	10%
		Public Health (protection of mahinga kai, impact on recreation, impact of spills or failure)	30%
Maori Cultural Values	20.0%	safeguards Māori cultural values and practices	100%
Practicability Criteria	10.0%	Constructability (complexity, distance from services, time to commission)	20%
		Land Purchase (if required)	50%
		Regulations and Planning (complexity in obtaining consent)	30%
Operational Criteria	10.0%	Complexity of operation / required experience	25%
		Sludge management	25%
		Reliance on and complexity of plant consumables and replacement componentry	25%
		Health and Safety risks or plant process / access to site	25%

Table 10-3: MCA Assessment Results

	Option 4a	Option 4b	Option 5	Option 6
Key-Criteria Summary	Optimised process, solids removal, UV, in-pond/wetland N removal, harbour discharge	Optimised process, solids removal, UV, external N removal, harbour discharge	Optimise current process - discharge to land	New activated sludge plant plus UV disinfection and harbour discharge
Economic Criteria	0.35	0.32	0.00	0.19
Environmental Criteria	0.07	0.14	0.13	0.12
Maori Cultural Values	0.00	0.00	0.20	0.00
Practicability Criteria	0.06	0.03	0.03	0.04
Operational Criteria	0.07	0.08	0.05	0.06
Results	0.54	0.58	0.41	0.41
Rank	2	1	3	4

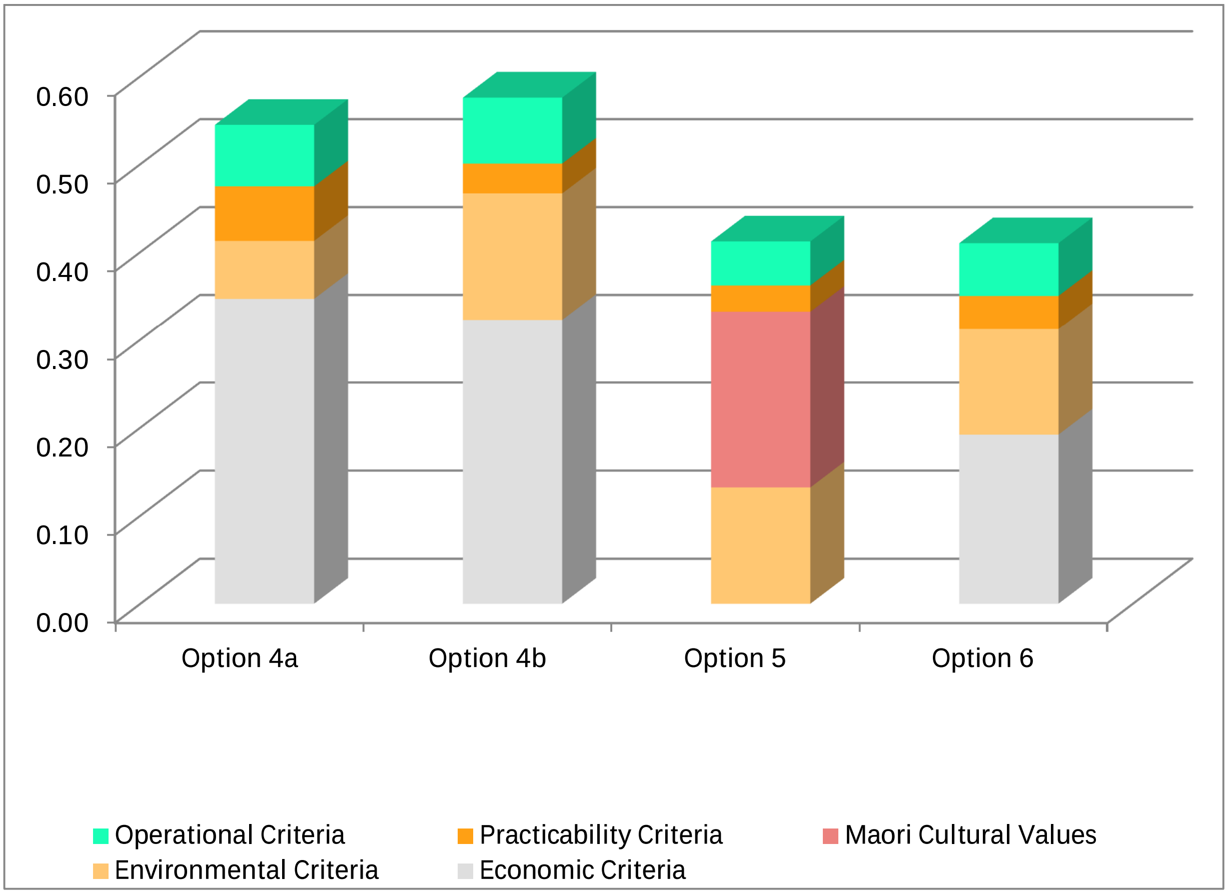

Figure 10-1: MCA Assessment Results – Graphical Representation.

The MCA results show that Options 4a and 4b score very similarly, with Option 4b scoring highest overall – the key benefits being a relatively low cost, a more proven and robust treatment option, and a better environmental outcome. Option 4a and 4b are very similar with the key difference being the N removal process, with 4a being an in-pond system which has a lower cost overall. Option 5 is the only option which scores for cultural at all, but the high cost of this option brings its overall score down.

There was concern that if the weightings were changed, the preferred options may also change, so a number of scenarios were run on the MCA outcomes through changing the weightings (sensitivity analysis) to determine if the preferred options changed. The outcomes of the sensitivity analysis and the changes to the weighting which were adopted are summarised in Table 10-4 and Figure 10-2.

Table 10-4: Sensitivity analysis and impact of weighting changes

Primary Criteria	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Base Case
Economic Criteria	40%	80%	20%	20%	40%
Environmental Criteria	10%	5%	30%	20%	20%
Maori Cultural Values	10%	5%	30%	20%	20%
Practicability Criteria	20%	5%	10%	20%	10%
Operational Criteria	20%	5%	10%	20%	10%
	100%	100%	100%	100%	100%

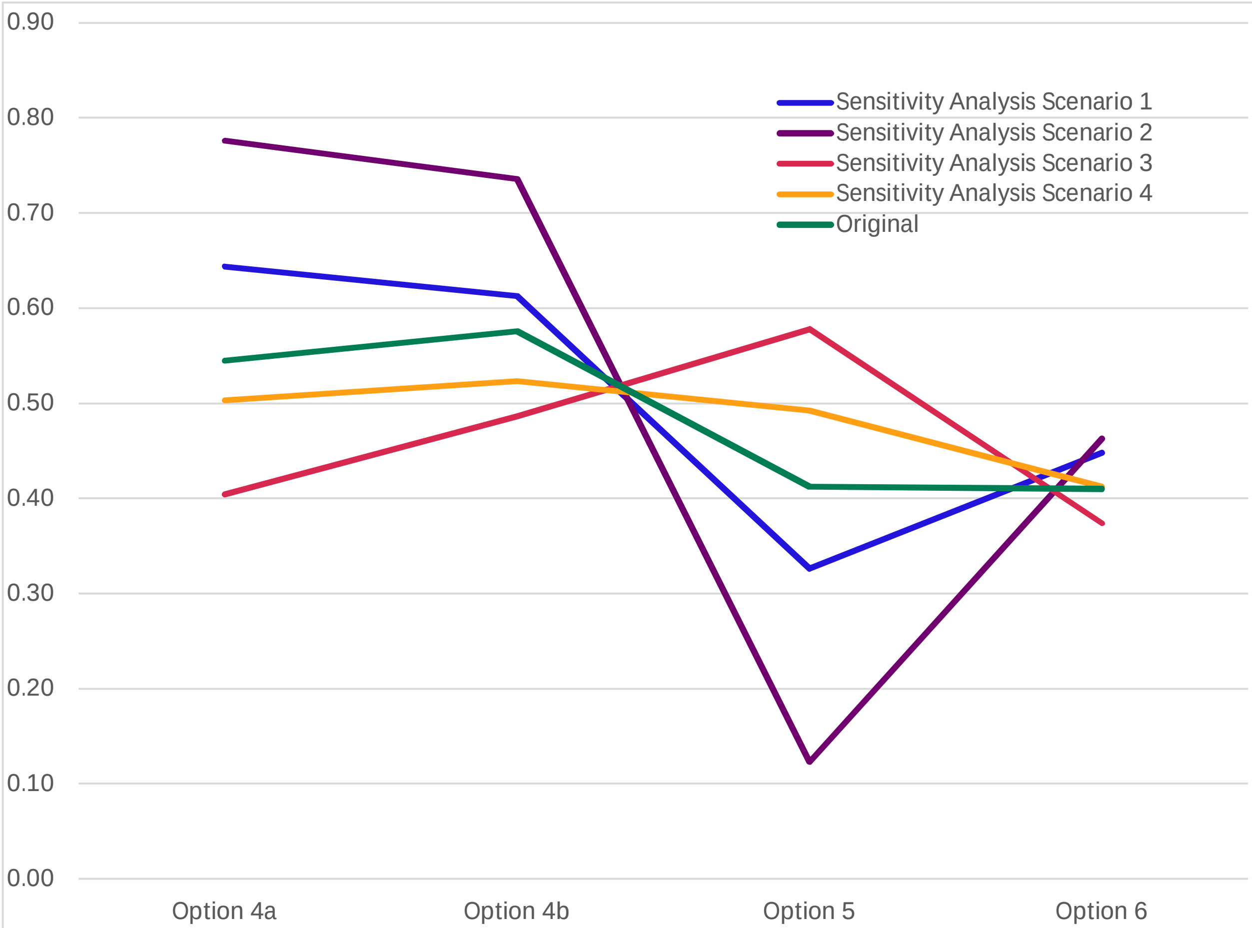

Figure 10-2: Comparison of MCA criteria scores for each scenario

The sensitivity analysis shows that the preferred options do not change under most of the scenarios with 4a and 4b scoring highest overall in nearly all scenarios, but that under Scenario 3, Option 5 becomes preferred. In this scenario more emphases is put on environmental and cultural values.

11. Conclusions and Next Steps

11.1 Summary

The Opononi WWTP is in not complying with the current consent E.coli, ammonia, BOD and total suspended solids standards. The rolling 12-month median effluent E.coli concentration regularly exceeds the consent limit of 3,000 cfu/100 mL and has a 32% compliance rate based on samples taken since January 2016. Effluent ammonia nitrogen concentrations have increased since January 2017 and now exceed the rolling 12-month median limit of 30 mg/L. Total suspended solids concentrations show seasonal spikes each summer which are likely caused by increased algae growth. The spikes result in breaches of the rolling 12-month median limit of 35 mg/L.

Hydrodynamic modelling results showed a high level of dilution in the harbour with a median dilution factor of approximately 25,000 near the discharge point. The 95th percentile (exceeded 95 percent of the time) dilution was 1,000 near the discharge, 5,000 at about 500m down current and 25,000 at the shoreline.

11.2 Conclusion

Improvements to the WWTP are required to comply with the current resource consent conditions. If the harbour discharge is retained it is considered unlikely that a resource consent with more relaxed standards for BOD and TSS would to be granted by NRC. Land disposal of the Opononi WWTP will be difficult and costly due to the steep terrain and poorly draining soils, however previously identified sites are included for comparison with the harbour discharge options.

Four upgrade options have been recommended for the WWTP which can address the BOD, TSS, E.coli and ammonia issues:

- Option 4a – Optimised process, chemically assisted solids removal, UV, with an in-pond or in-wetland ammonia removal process (e.g. Bioshell, zeolite fill and draw wetland etc) and harbour discharge.
- Option 4b – Optimised process, chemically assisted solids removal, UV, with an external ammonia removal package plant (e.g. SAF) and harbour discharge.
- Option 5 - Optimisation of the current process and discharge of the treated wastewater to land.
- Option 6 – New activated sludge plant plus UV disinfection and harbour discharge.

Indicative capital cost summaries have been prepared and are summarised as follows:

Option 4a	Option 4b	Option 5	Option 6
$2.929M	$4.930M	$18.021M	$4.374M

An MCA has been completed, which demonstrates that Option 4b is preferred under most scenarios, with Option 4a ranked very closely. The options are very similar with the key difference being whether the N removal is in pond or via external process. Option 4a has a lower cost, but is relied on less proven technologies, resulting in 4b being considered safer from an environmental risk perspective. It is recommended that Option 4b or 4a be implemented for the Opononi WWTP. It is worth noting that only Option 5 scored well in terms of cultural context, but that the very high cost of this option meant that it did not score well overall.

12. References

AS/NZS 1547:2012 On-site domestic wastewater management

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Appendix A. Existing Resource Consent

COPY OF CONDITIONS IMPOSED BY THE ENVIRONMENT COURT IN ITS DECISION (A121/2009) DATED 18 NOVEMBER 2009

NOTE: *Pursuant to Section 116 of the Resource Management Act 1991, the date of commencement of this consent is 18 November 2009.*

CON20070266701 **Notified New and Replacement**

FAR NORTH DISTRICT COUNCIL, PRIVATE BAG 752, KAIKOHE 0440

To undertake the following activities associated with the operation of a wastewater treatment system on Lot 1 DP 110735 and Lot 1 DP 167208 Blk VII Hokianga servicing the townships of Omapere and Opononi, as defined by the operative Far North District Council Plan, and all existing connections to this system that are outside these townships, as at the date of commencement of these consents:

(01) To discharge treated wastewater into the Hokianga Harbour at or about location co-ordinates 1634768E 6069462N.

(02) To discharge treated wastewater to land from the base of a wastewater treatment system at or about location co-ordinates 1635620E 6069420N and 1635800E 6069350N.

(03) To discharge contaminants, primarily odour, to air from a wastewater treatment system at or about location co-ordinates 1635620E 6069420N and 1635800E 6069350N.

(04) To occupy and use the bed of the Hokianga Harbour for an existing wastewater discharge pipeline structure.

Note: All location co-ordinates in this document refer to Geodetic Datum 2000, New Zealand Transverse Mercator Projection.

Subject to the following conditions:

(01) & (02) Coastal and Land Discharge

1 The quantity of treated wastewater discharged to the Hokianga Harbour shall not exceed 685 cubic metres per day.

2 Notwithstanding Condition 1, the Consent Holder shall minimise, as far as practicable, any increase in the quantity of wastewater discharged to the Hokianga Harbour as a result of stormwater inflow and infiltration into the

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sewage reticulation network and treatment system. This shall include the prevention, as far as is practicable, of stormwater run-off from the surrounding land entering the treatment system. For compliance purposes, the Consent Holder shall record the daily wastewater inflow volume to the treatment system.

3 The Consent Holder shall notify the Northland Regional Council's Monitoring Senior Programme Manager in writing of any proposed changes to the wastewater treatment and coastal discharge system, as installed at the date of commencement of these consents, at least one month prior to the proposed change(s) being undertaken.

4 The Consent Holder shall maintain a meter on both the inlet to, and the outlet from, the treatment system that has a measurement error of ±5% or less. These meters shall then be used to determine compliance with Conditions 1 and 2.

5 The Consent Holder shall re-calibrate the meters required by Condition 4 at least annually to ensure that the specified accuracy is maintained. Written verification from a suitably qualified person that the meter has been calibrated during the previous 12 month period shall be forwarded to the Northland Regional Council's Monitoring Senior Programme Manager by 1 May each year.

6 Treated wastewater shall only be discharged to the Hokianga Harbour for a maximum of three hours each tidal cycle between one hour and four hours after high tide via the discharge pipeline from the treatment system, as installed at the date of commencement of these consents.

7 The Consent Holder shall calibrate the tidal clock used to control the time of discharge to the Hokianga Harbour at least annually to ensure that the programmed high tide discharge time is, as far as is practicable, the same as when high tide actually occurs at the site. Written verification from a suitably qualified person that this calibration has been undertaken during the previous 12 month period shall be forwarded to the Northland Regional Council's Monitoring Senior Programme Manager by 1 May each year.

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8 The Consent Holder shall ensure safe and easy access to Northland Regional Council sampling site 101580, Marsh Discharge, so that treated wastewater samples can be safely collected.

9 There shall be no discharge of contaminants onto or into land, or into water, from any part of the treatment system except via seepage from the base of the treatment system and the designated outlet pipe from the treatment system into the Hokianga Harbour.

10 The discharge of contaminants to land via seepage from the base of the treatment system shall not result in any adverse effects on the water quality of the Waiarohia Stream, as measured immediately downstream of either the treatment ponds or the constructed wetland system. For compliance purposes the downstream water quality shall be compared with the water quality immediately upstream of the constructed wetland system. The error of the analytical method and measuring instrument at the 95%ile confidence level shall be included in determining all parameters.

11 Notwithstanding any other conditions, the discharge of any contaminant (either by itself or in combination with the same, similar or other contaminants or water) shall not result in any of the following effects in the water quality of the Hokianga Harbour, as measured at any point at, or down-current of, where the treated wastewater first contacts the surface of the Hokianga Harbour:

(a) The production of conspicuous oil or grease films, scums or foams, floatable or suspended materials;

(b) Any conspicuous change in the colour or visual clarity;

(c) Any emissions of objectionable odour;

(d) Any significant adverse effects on aquatic life; and

(e) No more than minor adverse change in either the Escherichia coliform or Enterococci concentration.

For compliance purposes, the down-current water quality shall be compared to the background water quality of the Hokianga Harbour at an up-current site that is not affected by this discharge for each of the above parameters. The error of the analytical method and measuring instrument at the 95%ile confidence level shall be included in determining all parameters.

(03) Discharge to Air

12 The Consent Holder's operations shall not give rise to any discharge of contaminants at or beyond the legal boundary of Lot 1 DP 110735 and Lot 1 DP 167208 Blk VII Hokianga which is deemed by a suitably trained and experienced Enforcement Officer of the Regional Council to be noxious, dangerous, offensive or objectionable.

(04) Discharge Pipeline Structure

13 This consent only authorises the existing structure as installed at the date of commencement of this consent.

14 The Consent Holder shall, within three months of the date of commencement of this consent, forward to the Regional Council's Monitoring Senior Programme Manager and the representatives of the community liaison group required by Condition 21, a plan drawn by a registered surveyor that shows the location of the existing pipeline structure from State Highway 12 to the outlet of the pipeline.

15 The pipeline shall be buried at all times and the structural integrity of the pipeline shall be maintained at all times. The Consent Holder shall undertake inspections of the bed of the Hokianga Harbour where the pipeline is installed and also the outlet of the pipeline at least once every two years, with the first inspection occurring within three months of the date of commencement of this consent. The Consent Holder shall give the representatives of the community liaison group required by Condition 21 at least seven days notice of the proposed inspection of the pipeline. A written report on the results of this inspection shall be forwarded to the Northland Regional Council's Monitoring Senior Programme Manager and the representatives of the Community Liaison Group by 1 May every two years from the date of commencement of this consent. The written report for the first inspection shall be forwarded with the plan required by Condition 14 to the Northland Regional Council's Monitoring Senior Programme Manager

and the representatives of the community liaison group required by Condition 21.

Advice Note: Any maintenance or repair work on the discharge pipeline will need to meet the permitted activity criteria of Rule 31.4.4(f) of the Regional Coastal Plan for Northland or otherwise be the subject of an application for resource consent.

General Conditions (01) – (04)

16 The Consent Holder shall maintain the treatment system so that it operates effectively at all times, and a written record of all maintenance undertaken shall be kept. In addition, the Consent Holder shall forward to the Northland Regional Council's Monitoring Senior Programme Manager within six months of the date of commencement of these consents, a maintenance programme for the constructed wetland that includes, but is not limited to, details of how the extent of the areas within the wetland that require plant coverage will be maximised and how the plants within the wetland will be maintained.

17 To prevent damage to the wastewater treatment system, stock shall not be allowed to enter any area that is utilised for the treatment of wastewater.

18 The Consent Holder shall, within six months of the date of commencement of these consents, forward to the Northland Regional Council's Monitoring Senior Programme Manager a list of all existing connections to the Omapere and Opononi Wastewater Treatment System that are outside the townships of Omapere and Opononi, as defined by the operative Far North District Council Plan.

19 The Consent Holder shall monitor these consents in accordance with Schedule 1 (attached). If the monitoring results show that any of the following determinants in the treated wastewater are exceeded, as measured at NRC sampling site 101580:

Determinand	Median Concentration	90 percentile Concentration

Determinand	Median Concentration	90 percentile Concentration
5 day Biochemical Oxygen Demand (grams per cubic metre)	20	35
Escherichia Coli (per 100 millilitres)	3,000	5,500
Total ammoniacal nitrogen (grams per cubic metre)	30	38
Total suspended solids (grams per cubic metre)	35	80

The Consent Holder shall, within one month of becoming aware of any exceedance, forward to the Northland Regional Council's Monitoring Senior Programme Manager a written report that provides the following:

(a) Reasons for the exceedance;

(b) What actions are required to correct the exceedance and prevent it from re-occurring again; and

(c) What actions are intended to be actually undertaken by the Consent Holder to correct the exceedance.

Advice Note: The Northland Regional Council may undertake receiving water sampling of the Hokianga Harbour in the event that there is a non-compliance with any of the trigger level concentrations.

20 The Consent Holder shall undertake an investigation into alternative land areas that are considered by local Iwi to be suitable for the discharge of treated wastewater to land from Opononi and Omapere townships. The Consent Holder shall, within one month of the date of commencement of these consents, meet with the community liaison group required by Condition 21 to discuss the scope, process and timetable of the investigation and final written report. This investigation shall then be completed within 18 months of the date of commencement of these consents and the results forwarded to the representatives of the Community Liaison Group. A written

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report shall be forwarded to the Northland Regional Council's Monitoring Senior Programme Manager and the representatives of the Community Liaison Group within two years of the date of commencement of these consents which includes, but is not limited to, the following:

(a) A detailed map showing the land areas that are considered by local Iwi as being suitable for a discharge to land of treated wastewater.

(b) Details of the Consent Holder's investigation into these identified land areas being utilised as wastewater disposal areas.

(c) Conclusions on whether the identified land areas can technically be utilised as treated wastewater disposal areas.

21 The Consent Holder shall, for the purpose of discussing matters relating to this consent, form a community liaison group consisting of representatives from the Pakanae, Kokohuia, Waiwhatawhata and Waimamaku Marae (Nga Marae O Te Wahapu), Te Runanga O Te Rarawa and also a duly appointed representative from each of the Omapere and Opononi communities. The Consent Holder shall hold a meeting with the liaison group not less than once every year to discuss matters related to these consents. The meeting shall only be held if a representative(s) of the community liaison group request a meeting with the Consent Holder. If such a request is made, then the Consent Holder shall organise a meeting at a local venue for members of the community liaison group to attend, and invite all other representatives of the community liaison group. The meeting shall be held at a time convenient for the majority of the community liaison group. Until such time as the investigation into alternative land disposal areas has been completed, the Consent Holder shall meet with the community liaison group quarterly to discuss progress with the investigation. The Consent Holder shall organise these meetings at a local venue and invite all members of the community liaison group to each meeting. The meeting shall be held at a time that is convenient for the majority of the community liaison group members.

22 The Consent Holder shall, for the purposes of adequately monitoring the consent as required under Section 35 of the Resource Management Act 1991, on becoming aware of any contaminant associated with the Consent Holder's operations escaping otherwise than in conformity with this consent:

(a) Immediately take such action, or execute such work as may be necessary, to stop and/or contain such escape;

(b) Immediately notify the Northland Regional Council's Monitoring Senior Programme Manager, Northland District Health Board's On-call Health Protection Officer and the community liaison group for this consent, by telephone of an escape of contaminant;

(c) Take all reasonable steps to remedy or mitigate any adverse effects on the environment resulting from the escape; and

(d) Report to the Northland Regional Council's Monitoring Senior Programme Manager and the community liaison group for this consent in writing within one week on the cause of the escape of the contaminant and the steps taken or being taken to effectively control or prevent such escape

23 The Northland Regional Council may, in accordance with Section 128 of the Resource Management Act 1991, serve notice on the Consent Holder within two months of the date that it formally receives a report required in accordance with Conditions 19, 20, 22, and Schedule 1, of its intention to review the conditions of these consents.

24 The Regional Council may, in accordance with Section 128 of the Act, serve notice on the Consent Holder of its intention to review the conditions of these consents annually during the month of June. The review may be initiated for any one or more of the following purposes:

(a) To deal with any adverse effects on the environment that may arise from the exercise of the consent and which it is appropriate to deal with at a later stage, or to deal with any such effects following assessment of the results of the monitoring of the consent and/or as a result of the Northland Regional Council's monitoring of the state of the environment in the area;

(b) To require the adoption of the best practicable option to remove or reduce any adverse effect on the environment;

(c) To provide for compliance with rules in any regional plan that has been made operative since the commencement of the consent;

(d) To deal with any inadequacies or inconsistencies the Northland Regional Council considers there to be in the conditions of the consent, following the establishment of the activity the subject of the consent;

(e) To change existing, or impose new limits on, conditions relating to the quality of the discharge and the receiving waters;

(f) To change the monitoring programme contained in Schedule 1; and

(g) To deal with any material inaccuracies that may in future be found in the information made available with the application (notice may be served at any time for this reason).

The Consent Holder shall meet all reasonable costs of any such review.

EXPIRY DATE: 31 AUGUST 2019

SCHEDULE 1

MONITORING PROGRAMME

The Consent Holder shall undertake the following monitoring:

1 Wastewater volumes

The Consent Holder shall keep a written record of both the daily, midday to midday, inflow volumes to the treatment system and the wastewater discharge volume using the meters required by Condition 4 of this Consent.

2 Treated wastewater

The following sampling and analyses shall be undertaken on at least one occasion each calendar month. During the winter months, the sampling shall be undertaken during, or immediately after, a rain event on at least three occasions.

A composite* wastewater sample shall be collected from the outlet of the treatment system at NRC Sampling Site 101580: Marsh discharge.

The composite wastewater sample shall be analysed for the following:

Escherichia coli
5 day Biochemical Oxygen Demand
Total Suspended Solids
Total Ammoniacal Nitrogen

**A sample made up of equal volumes from three samples taken at least one minute apart during the same sampling event.*

Temperature, pH and dissolved oxygen concentration shall be recorded in the wastewater sample using an appropriate meter, and in accordance with standard procedures.

3 Waiarohia Stream

On a quarterly basis, a sample of water shall be collected from the Waiarohia Stream at NRC Sampling Sites:

- 101579: Waiarohia Stream @ Above marsh, approximate location coordinates 1635907E 6069331N; and
- 100756: Waiarohia Stream @ Below marsh, approximate location coordinates 1635728E 6069372N.

These water samples shall then be analysed for Escherichia coli concentration.

The upstream and downstream Escherichia coli concentration shall be compared after each sampling occasion to determine whether there is any adverse effect on the water quality of the Waiarohia Stream as a result of the discharge of contaminants to land via seepage from the base of the constructed wetland system (as regards Condition 10).

This monitoring shall cease after a two year period if the results show that the discharge of contaminants to land via seepage from the base of the constructed

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wetland system is not having an adverse effect on the water quality of the Waiarohia Stream.

4 Compliance with Condition 19

Median Value

The median value for the determinands listed shall be a "rolling" median calculated on the 12 most recent treated wastewater samples collected. Until such time as 12 individual monthly samples have been collected, the results of sampling to date shall be utilised for compliance purposes.

3.2 90th Percentile Value

The 90th percentile value shall be calculated annually for the period 1 May to 30 April using, as a minimum, the results from the monthly sampling required by Section 2. Until such time as 12 individual monthly samples have been collected, the results of sampling to date shall be utilised for compliance purposes.

5 Collection of Samples

All samples shall be collected using standard procedures and in appropriate laboratory supplied containers.

All samples collected as part of this monitoring programme shall be transported in accordance with standard procedures and under chain of custody to the laboratory.

All samples taken shall be analysed at a laboratory with registered quality assurance procedures#, and all analyses are to be undertaken using standard methods, where applicable.

 # Registered Quality Assurance Procedures are procedures which ensure that the laboratory meets recognised management practices as would include registrations such as ISO 9000, ISO Guide 25, Ministry of Health Accreditation.

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6 Non-compliance with Consent Conditions

The Consent Holder shall notify the Regional Council of any non-compliance of the "rolling median" trigger level concentrations stated in Condition 19 or any adverse effects on the water quality of the Waiarohia Stream, immediately after the results of the monitoring required by Sections 2 and 3 are known.

If the Consent Holder detects any noxious, dangerous, offensive or objectionable odours at the legal boundary of the treatment system, then the Regional Council should be notified immediately.

7 Reporting

The Consent Holder shall forward an annual report to the Regional Council's Monitoring Senior Programme Manager and the community liaison group for this consent by 1 May each year, for the preceding year 1 April and 31 March, detailing the following:

- The daily wastewater inflow and discharge volumes, and
- An assessment of any increase in the inflow volumes as a result stormwater infiltration and inflow, and what is proposed to be undertaken to rectify any identified problems. The daily rainfall record for this area shall be included in this assessment to identify rainfall events; and
- The monitoring results for Section 2 and 3; and
- All the calculated "rolling" medians for the period and the 90 percentile value for the determinands listed in Condition 19.

All required numerical monitoring results shall be provided in a Microsoft Excel spreadsheet, or otherwise an alternative format agreed to beforehand with the Regional Council.

Advice Note: The daily rainfall can be taken from the Regional Council rainfall recorder site 534403: Hokianga Harbour - Omapere. This data will be supplied by the Regional Council on written request by the Consent Holder.

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Appendix B. Cost Estimates & Supplier Quotations

Jacobs	CALCULATION SHEET		Ref no.	IZ134400-GN-SCH-001
	Project	Opononi WWTP Options Assessment	Date	15-10-20
	Client	Far North District Council	Project no.	IZ134400
	Page	1 of 1	Designer	JD
	Subject	Opononi WWTP Upgrade Options Assessment	Checked	BM

Item	Unit	Quantity	Rate	Total	Comment
Option 4A – Optimised process, chemically assisted solids removal, UV, with an in-pond or in-wetland ammonia removal process (e.g. bioshell, zeolite fill and draw wetland) and harbour discharge					
Opononi Process Optimisation					
Supply and install baffle curtains	Item	1	$ 27,234	$ 28,000	SiteCare quotation.This price includes team mobilisation, price of the Permathene baffle curtains, the tasks and the transport of the collected waste to the Kaitaia landfill. There is a greater certainty on the scope of this work therefore a lower risk factor has been applied to this task.
Wetland vegetation clearance and disposal	Item	1	$ 65,675	$ 66,000	SiteCare quote for wetland maintenance 8/07/20. This price includes team mobilisation, price of the Permathene baffle curtains, the tasks and the transport of th collected waste to the Kaitaia landfill. No contingency is to be applied to this task as it is not required. Additionally FNDC could execute this work in house without needing an external contractor.
Wetland reinstatement	Item	1	$ 97,765	$ 98,000	SiteCare to: - To attend restore " Sacrificed Wetland Cell" as per scope. - Redirect inlet pipeline from WWTP to "Sacrificed Wetland Cell", and install outflow to Wetland Cell.
Treatment Upgrades					
Wedeco UV LBX120E UV Disinfection Unit	Item	1	$ 46,870	$ 114,000	Xylem price quote includes contingencies for the install, Instrumentation, piping and electrical costs
Instrumentation costs: 1. Flowmeter 2. Turbidity meter 3. UV Transmissivity	Items	1	$ 21,590	$ 53,000	Based on quotes received in 2019 from instrumentation suppliers. The total prices includes installation, instrumentation and controls, piping and electrical costs based on factors recommended in Table 4.4 of the IChemE Guide to capital cost estimation.
Solids Removal : DAF Plant	Item	1	$ 500,000	$ 790,000	Filtec indicative costs received July 2020. The total price also includes electrical costs as per the factors recommended in Table 4.4 of the IChemE Guide to capital cost estimation for a Fluid Processing Plant.
In-pond Ammonia Removal - Bioshells	Item	1	$ 650,000	$ 780,000	Marshall projects indicative costs from July 2020 for supply and install of ~60 bioshells and hexacovers. An addition 20% has been added to the toal cost on recommendation from the supplier.

Jacobs

CALCULATION SHEET		Ref no.	IZ134400-GN-SCH-001
Project	Opononi WWTP Options Assessment	Date	15-10-20
Client	Far North District Council	Project no.	IZ134400
Page	1 of 1	Designer	JD
Subject	Opononi WWTP Upgrade Options Assessment	Checked	BM

Item	Unit	Quantity	Rate	Total	Comment
Risk Allowance (reduced)	%	54	$ 1,000,420.00	$ 1,001,000	The Risk allowance is based on factor recommend in Table 4.4 of the IChemE Guide to capital cost estimation for engineering and supervision fees for a Fluid Processing Plant for a Fluid Processing Plant.
Total Costs				$ 2,930,000	
Option 4b – Optimised process, chemically assisted solids removal, UV, with an external ammonia removal package plant (e.g. SAF) and harbour discharge.					
Opononi Process Optimisation					
Supply and install baffle curtains	Item	1	$ 27,234	$ 28,000	SiteCare quotation.This price includes team mobilisation, price of the Permathene baffle curtains, the tasks and the transport of the collected waste to the Kaitaia landfill. There is a greater certainty on the scope of this work therefore a lower risk factor has been applied to this task.
Wetland vegeation clearance and disposal	Item	1	$ 65,675	$ 66,000	SiteCare quote for wetland maintenance 8/07/20. This price includes team mobilisation, price of the Permathene baffle curtains, the tasks and the transport of th collected waste to the Kaitaia landfill. No contingency is to be applied to this task as it is not required. Additionally FNDC could execute this work in house without needing an external contractor.
Wetland reinstatement	Item	1	$ 97,765	$ 98,000	SiteCare to: - To attend restore " Sacrificed Wetland Cell" as per scope. - Redirect inlet pipeline from WWTP to "Sacrificed Wetland Cell", and install outflow to Wetland Cell 1.
Treatment Upgrades					
Wedeco UV LBX120E UV Disinfection Unit	Item	1	$ 46,870	$ 114,000	Xylem price quote includes contingencies for the install, Instruemntation, piping and electrical costs.
Instrumentation costs: 1. Flowmeter 2. Turbidity meter 3. UV Transmissivity	Items	1	$ 21,590	$ 53,000	Based on quotes received in 2019 from instrumentation suppliers. The total prices includes installation, instrumentation and controls, piping and electrical costs based on factors recommended in Table 4.4 of the IChemE Guide to capital cost estimation for a Fluid Processing Plant.
Solids Removal - DAF Plant	Item	1	$ 500,000	$ 555,000	Filtec indicative costs received July 2020. The total price also includes electrical costs as per the factors recommended in Table 4.4 of the IChemE Guide to capital cost estimation for a Fluid Processing Plant.

Jacobs	CALCULATION SHEET		Ref no.	IZ134400-GN-SCH-001
	Project	Opononi WWTP Options Assessment	Date	15-10-20
	Client	Far North District Council	Project no.	IZ134400
	Page	1 of 1	Designer	JD
	Subject	Opononi WWTP Upgrade Options Assessment	Checked	BM

Item	Unit	Quantity	Rate	Total	Comment
Out of pond Ammonia Removal - SAF Plant	$/m3/day	178	$ 13,000	$ 2,314,000	Consultation with Hydns NZ for a SAFF plant. High level, indicative pricing is $13k/m3/day. The total cost is for delivery of the current ADWF of 178 m3/day, this price includes installation and contractor costs.

	CALCULATION SHEET		Ref no.	IZ134400-GN-SCH-001
Jacobs	Project	Opononi WWTP Options Assessment	Date	15-10-20
	Client	Far North District Council	Project no.	IZ134400
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	Subject	Opononi WWTP Upgrade Options Assessment	Checked	BM

Item	Unit	Quantity	Rate	Total	Comment
Risk Allowance (reduced)	%	54	$ 1,701,880.00	$ 1,702,000	The Risk allowance is based on factor recommend in Table 4.4 of the IChemE Guide to capital cost estimation for engineering and supervision fees for a Fluid Processing Plant.
Total Costs				$ 4,930,000	
Option 5 - Optimisation of the current process and discharge of the treated wastewater to land.					
Opononi Process Optimisation					
Supply and install baffle curtains	Item	1	$ 27,234.00	$ 28,000	SiteCare quotation.This price includes team mobilisation, price of the Permathene baffle curtains, the tasks and the transport of the collected waste to the Kaitaia landfill. There is a greater certainty on the scope of this work therefore a lower risk factor has been applied to this task.
Wetland vegetation clearance and disposal	Item	1	$ 65,675	$ 66,000	SiteCare quote for wetland maintenance 8/07/20. This price includes team mobilisation, price of the Permathene baffle curtains, the tasks and the transport of th collected waste to the Kaitaia landfill. No contingency is to be applied to this task as it is not required. Additionally FNDC could execute this work in house without needing an external contractor.
Wetland reinstatement	Item	1	$ 97,765	$ 98,000	SiteCare to: - To attend restore " Sacrificed Wetland Cell" as per scope. - Redirect inlet pipeline from WWTP to "Sacrificed Wetland Cell", and install outflow to Wetland Cell 1
Treatment Upgrades					
Wedeco UV LBX120E UV Disinfection Unit	Item	1	$ 46,870	$ 114,000	Xylem price quote includes contingencies for the install, Instruemntation, piping and electrical costs
Instrumentation costs: 1. Flowmeter 2. Turbidity meter 3. UV Transmissivity	Items	1	$ 21,590	$ 53,000	Based on quotes received in 2019 from instrumentation suppliers. The total prices includes installation, instrumentation and controls, piping and electrical costs based on factors recommended in Table 4.4 of the IChemE Guide to capital cost estimation.
Solids Removal : DAF Plant	Item	1	$ 500,000	$ 790,000	Filtec indicative costs received July 2020. The total price also includes installation and electrical costs as per the factors recommended in Table 4.4 of the IChemE Guide to capital cost estimation.
In-pond Ammonia Removal - Bioshells	Item	1	$ 650,000	$ 780,000	Marshall projects indicative costs from July 2020 for supply and install of ~60 bioshells and hexacovers. A margin of 20% has been added as recommended by Marshall Projects

	CALCULATION SHEET		Ref no.	IZ134400-GN-SCH-001
Jacobs	Project	Opononi WWTP Options Assessment	Date	15-10-20
	Client	Far North District Council	Project no.	IZ134400
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Item	Unit	Quantity	Rate	Total	Comment
Land-based Discharge					
Option 4 - Baker Farm	Item	1	$ 3,400,000	$ 3,670,000	The total cost for this option is a inlfation adjusted price for Option 4 recommended in the 2014 high level cost analysis completed by Mott MacDonald.

Jacobs	CALCULATION SHEET		Ref no.	IZ134400-GN-SCH-001
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	Client	Far North District Council	Project no.	IZ134400
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	Subject	Opononi WWTP Upgrade Options Assessment	Checked	BM

Item	Unit	Quantity	Rate	Total	Comment
Equipment Allowance	%	76	$ 2,789,200.00	$ 2,790,000	An aditional allowance estimate has been added based on factors for purchased equipment installation, instrumentation, and electrical works for a land based disposal option. These factors have been based on recommendations from Table 4.4 of the IChemE Guide for Capital Cost Estimation
Risk Allowance for Land-based Discharge	%	137	$ 8,850,200.00	$ 8,851,000	A risk allowance for land based discharge includes factors for the engineering and supervision, construction expenses, ontractors fee and contigencies as recommended by Table 4.4 of the IChemE Guide for Capital Cost Estimation
Risk Allowance (reduced)	%	42	780,220	781,000	The Risk allowance is based on the contingency factor recommend in Table 4.4 of the IChemE Guide to capital cost estimation for contingencies for a Fluid Processing Plant.
Total Costs				$ 18,021,000	
Option 6 – New activated sludge plant plus UV disinfection and harbour discharge.					
Decommissioning of current system					
Allowance	Item	1	$ 300,000	$ 300,000	This is an estimated allowance for decomssioning the current system and repurposing it
Treatment Upgrades					
Wedeco UV LBX120E UV Disinfection Unit	Item	1	$ 46,870	$ 114,000	Xylem price quote includes contingencies for the install, Instruemntation, piping and electrical costs
Instrumentation costs: 1. Flowmeter 2. Turbidity meter 3. UV Transmissivity	Items	1	$ 21,590	$ 53,000	Based on quotes received in 2019 from instrumentation suppliers. The total prices includes installation, instrumentation and controls, piping and electrical costs based on factors recommended in Table 4.4 of the IChemE Guide to capital cost estimation.
Activated Sludge Treatment Plant					
Indicative Cost of plant	Item	1	$ 2,477,740	$ 2,478,000	This price includes: Inlet works, construction costs associated with the SBR system, contractor design, comissioning, power supply and contigencies. It is an adjusted estimate from the Taipa Upgrade Issues and Options Report (May, 2018)

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Item	Unit	Quantity	Rate	Total	Comment
Risk Allowance (standard)	%	54	$ 1,428,300.00	$ 1,429,000	The Risk allowance is based on the contingency factor recommend in Table 4.4 of the IChemE Guide to capital cost estimation for contingencies for a Fluid Processing Plant.
Total Costs				$ 4,374,000	