BEFORE NORTHLAND REGIONAL COUNCIL

UNDER	the Resource Management Act 1991
AND	
IN THE MATTER	of applications to renew the resource consents associated with the operation of the wastewater treatment plants at Opononi and Kohukohu
BETWEEN	**FAR NORTH DISTRICT COUNCIL** **Applicant** **NORTHLAND REGIONAL COUNCIL** **Consent Authority**

EVIDENCE OF BRETT JAMES BEAMSLEY

(HYDRODYNAMIC MODELLING)

MAY 2023

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INTRODUCTION

Qualifications and experience

1. My full name is Dr Brett James Beamsley. I am the General Manager of MetOcean Solutions (**MOS**) which in 2018 became fully amalgamated within The Meteorological Service of New Zealand (**MetService**). As well as providing operational forecasting, MOS is a science-based consultancy that offers specialist numerical modelling and analytical services in meteorology and oceanography. I have held this position for five years, prior to which I held the position of senior scientist and project director within MOS.

2. I have a PhD in physical oceanography and nearshore sediment dynamics from the University of Waikato. I have more than 25 years' experience in physical oceanography, coastal processes, and ocean engineering application. I have prepared and presented hydrodynamic evidence at six council resource consent hearings, and Environment Court hearings. I am familiar with the application site and the surrounding locality.

3. I confirm that the evidence I present is within my area of expertise and I am not aware of any material facts which might alter or detract from the opinions I express. I have read and agree to comply with the Code of Conduct for expert witnesses as set out in the Environment Court Practice Note 2022. The opinions expressed in this evidence are based on my qualifications and experience and are within my area of expertise. If I rely on the evidence or opinions of another, my evidence will acknowledge that position.

Involvement with this Application

4. I first became involved in the Hokianga Harbour Hydrodynamic Study in 2019.

5. My hydrodynamic modelling team and I prepared the report dated March 2020 titled "Hokianga Harbour Hydrodynamic Study".

Purpose and scope of evidence

6. To the best of my knowledge, none of the submissions raise issues that are relevant to my area of expertise.

7. In my evidence I will:

   a. Summarise the key findings of the earlier work (as referred to above);

   b. Address the issue of the reasonable mixing zone and sufficient dilution raised in the Council's s42A report.

EXECUTIVE SUMMARY

8. Far North District Council (**FNDC**) currently discharges wastewater from four municipal Wastewater Treatment Plants (**WWTP**) into the Hokianga Harbour and its tributaries.

9. FNDC has commissioned MOS to undertake a hydrodynamic modelling study of the wastewater discharges. In order to support the modelling, MOS partnered with Cawthron Institute to undertake a data collection campaign which included the measurement of water level and currents within Hokianga Harbour.

10. 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 the discharges.

11. The approach consisted of running year-long simulations within two contrasting periods (El Niño and La Niña). This allowed robust probabilistic estimates of the plume dispersion and dilution patterns to be determined and thus provided some guidance on expected concentration levels associated with the Hokianga Harbour WWTP discharges. The year-long simulations also included the highest discharge recorded, to assess the impact of an isolated extreme event.

12. The model results were processed in terms of dilution factors. A dilution factor of 1:1000 indicates a contaminant concentration is 1000 time smaller than the concentration discharged.

13. Results showed that each WWTP discharge presented different plume extents due to their location within the harbour and the discharge volumes. Key features for the two WWTP the subject of this hearing are:

   a. The Opononi WWTP discharge presented an elongated plume stretching towards the entrance of Hokianga Harbour. Median dilution factors are as high as 1 in 5,000 within 100 m of the discharge.

b. The Kohukohu WWTP discharge plume is mostly confined to the vicinity of the discharge location with a median dilution factor of 1 in 50,000 at approximately 50 m of the discharge.

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

KEY FINDINGS OF EARLIER WORK

15. FNDC commissioned MOS to undertake a hydrodynamic modelling study of the wastewater discharges from four municipal wastewater treatment plants (WWTP) into the Hokianga Harbour or its tributaries (Figure 1).

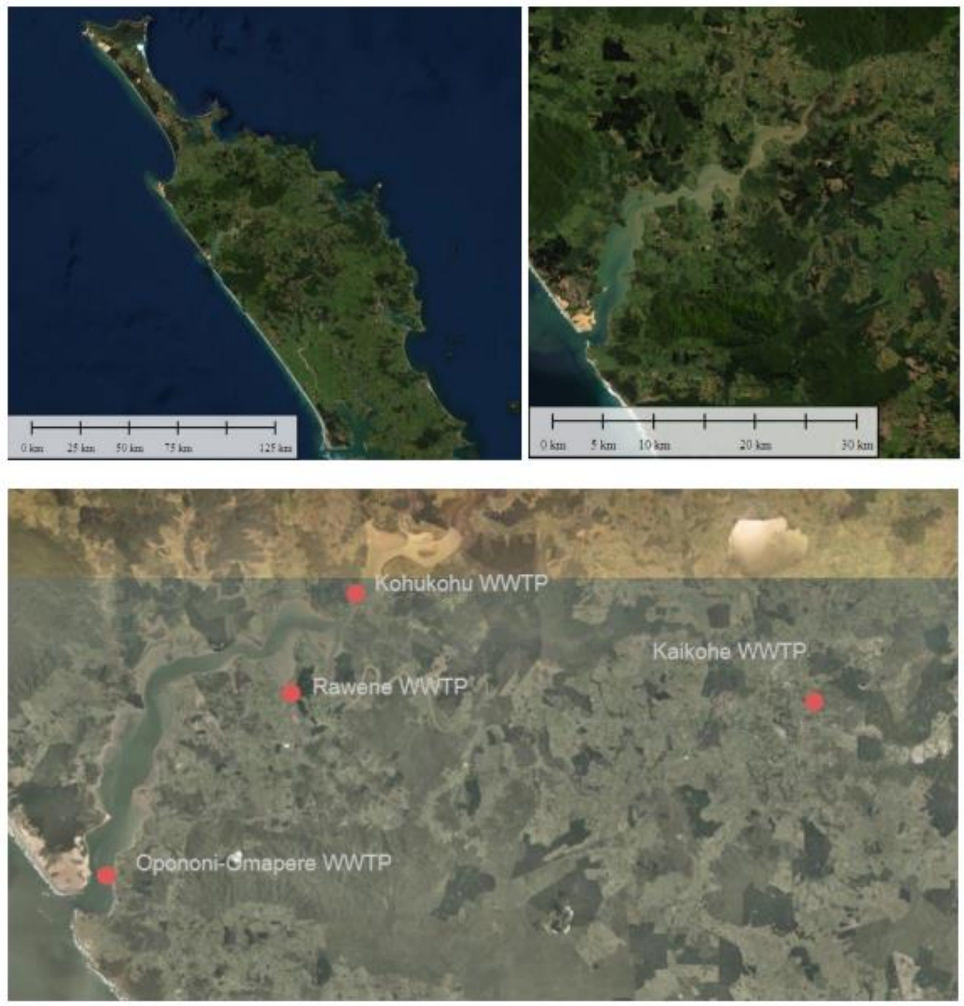

Figure 1 - Hokianga Harbour location (top) and the four Wastewater Treatment Plants in Hokianga Harbour (bottom).

16. In order to support the modelling, MOS partnered with Cawthron Institute to undertake data collection campaign which included measurements of water level and currents within Hokianga Harbour.

17. The field measurement campaign assisted with the characterisation of the hydrodynamic regime within Hokianga Harbour and provided the necessary field data for calibration and validation of the hydrodynamic model.

18. The campaign consisted of the collection of water level and current velocity using four separate moorings at ~5 to 26 m water depths (Chart Datum - CD) for 30 days. Two of the moorings included bottom mounted Acoustic Doppler Current Profilers (ADCPs) with the other two featuring mid-water mounted FSI current meters. All moorings included pressure sensors.

19. The data was checked and went through quality control processes with data associated with pre-deployment and retrieval of the instrument being removed. Pressure data was converted to water level. Current magnitude and direction were calculated from U and V velocities. Native files from the ADCPs were processed and various variables (e.g., velocities, depth, pitch, roll, amp, echo) were exported.

20. More details about the instruments and the data recorded can be found in Section 2 of the 2020 report.

21. The discharge of wastewater into Hokianga Harbour was modelled using a high-resolution hydrodynamic model with a Eulerian tracer technique applied in order to quantify the likely dilution of the discharged wastewater.

22. The 3D hydrodynamics of the Hokianga Harbour was modelled using the open-source hydrodynamic Semi-Implicit Crossscale Hydroscience Integrated System Model (**SCHISM**).

23. SCHISM is a prognostic finite-element unstructured-grid model designed to simulate 3D baroclinic, 3D barotropic or 2D barotropic circulation. A detailed description of the SCHISM model formulation, governing equations and numerics, can be found in Zhang and Baptista (2008).

24. SCHISM is computationally efficient in the way it resolves the shape and complex bathymetry associated with estuaries. SCHISM has been used extensively within the scientific community, where it forms the backbone of operational systems used to nowcast and forecast estuarine water levels, storm surges, velocities, water temperature and salinity. In my opinion the SCHISM model is appropriate for this purpose and is well used within the industry and applies industry standard numerics to resolve current velocities and water levels within a numerical domain.

25. 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.

26. The model vertical discretisation of the water column was configured with increased vertical resolution at the surface. This is appropriate for investigating the stratified flow regime that is expected within the harbour due to the mixing of the river freshwater and denser marine water which leads to a concentration of freshwater in the upper layers of the water column.

27. Model bathymetry was compiled using an extensive national and regional bathymetric dataset derived from Electronic Navigation Charts (ENC). GEBCO data was also used to characterise the deepest offshore areas. These datasets were updated with available hydrographic surveys for the region, including: LIDAR data, hydrographic surveys completed by LINZ in 2015, and hydrographic surveys completed by NRC in 2006.

28. The triangular elements of the model mesh are shown in Figure 2 and model bathymetry is presented in Figure 3.

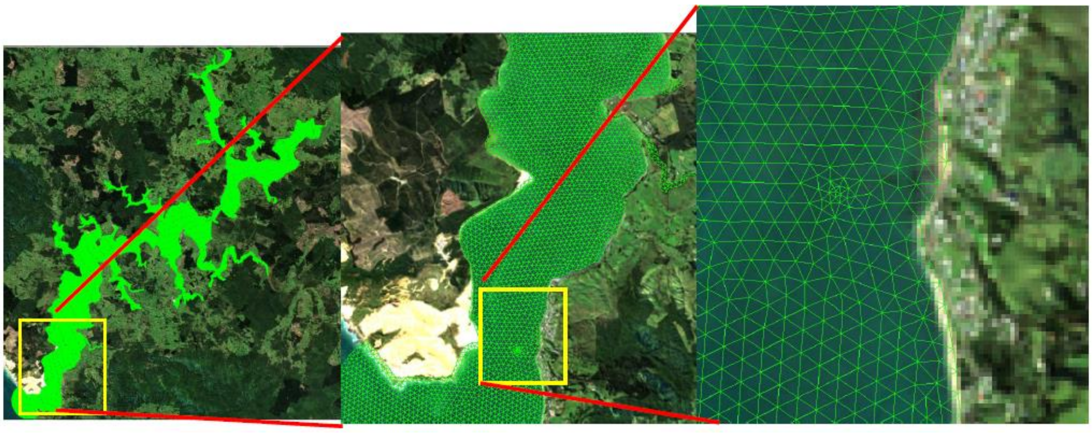

Figure 2 - Triangular model mesh defined for the Hokianga Harbour. Left map shows the entire domain and right map shows the grid refinement around the Opononi discharge location.

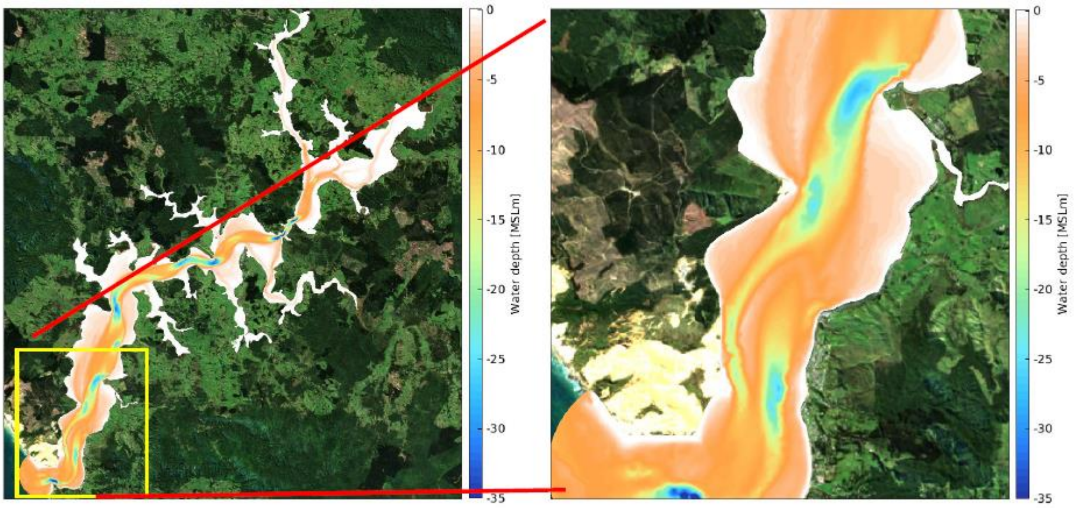

Figure 3 – Model bathymetry showing the water depth in metres below mean sea level. Left map show the entire domain and right map is a zoom over the Opononi discharge location.

29. Model boundary conditions and forcing are set out below.

a. Atmospheric forcing: Spatially variable Weather and Research Forecasting (**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.

b. Open boundary and tidal forcing: Tidal constituents were calculated from a larger New Zealand SCHISM domain (Figure 4.7 in section 4.3.2 of the 2020 report). Depth averaged velocity, elevations, tidal phases and amplitudes for the main primary and secondary tidal constituents were derived near the Hokianga Harbour entrance using harmonic analysis. Residual surface elevation at the offshore boundary was combined from multiple factors (atmospheric pressure, tide and wave). The impact of the wave on the offshore boundary was calculated using a basic wave set-up equation.

c. River discharge: Four major rivers were included in the model (Waima River, Waihou River, Orira River and Mangamuka River). In order to account for the discharges from the surrounding streams, the river discharges were increased by a percentage calculated during the calibration of the model.

d. Temperature and salinity: Uniform salinity and temperature fields from the HYCOM model were applied to the open ocean model boundary.

River salinity was defined as freshwater, and river temperature was only measured at the Waiapa river (upstream from Waihou river). The same temperature was used in all rivers.

30. WWTP discharge characteristics were retrieved from previous resource consent and information provided by FNDC:

a. Opononi WWTP discharges directly into the harbour via an outfall pipe for a maximum of 4 hours on an outgoing tide with a limit of 685 m^3/day. Going forward, 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 with a discharge limit of 450 m^3/day.

b. Kohukohu WWTP discharges into an unnamed tributary of the Hokianga Harbour as continuous gravity discharge. Known to have zero discharge in dry periods. Discharge limit is 40 m^3/day (measured as a rolling 30 day average).

31. A review of the discharge rate timeseries data was undertaken (Figure 4) and an annual representation of the variability in the discharge rate, as well as a maximum, similar to the proposed resource consent was chosen for each of the discharge locations. If needed, the discharge was increased to reach the resource consent limit.

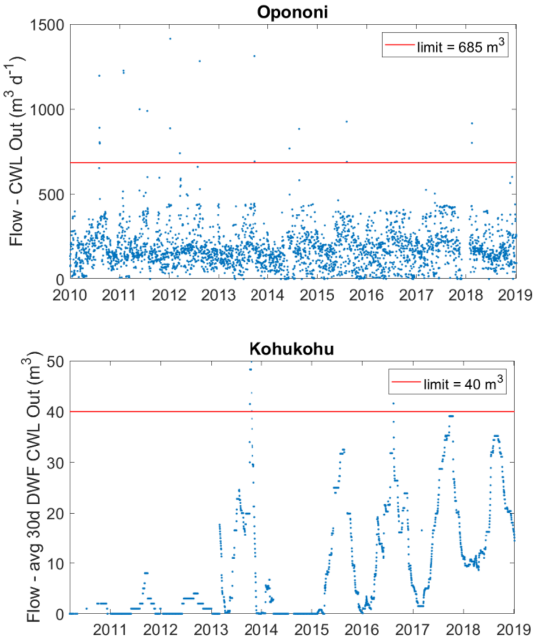

Figure 4 – Discharge timeseries (blue) and resource consent limits (red).

32. The model runs consisted of year-long simulations based on two contrasting periods (La Niña and El Niño, June 2010 – June 2011, and June 2015 – June 2016, respectively).

33. The model simulations covered a full year period with associated discharge rate as well as an extra two days where the discharge rate was set to the highest discharge on record in order to assess the impact of an isolated extreme event.

34. The SCHISM model represented the release of the contaminant as a discharge flow (with a tracer concentration) 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 .

35. Different passive Eulerian tracers (neutrally buoyant, no decay) were used for each WWTP discharge. A nominated concentration value of 1 mg.L^{-1} 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.

36. Detailed description and plots of model verification can be found in section 5.1 of the original 2020 report. 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 also in terms of currents (Figure 5), temperature and salinity patterns .

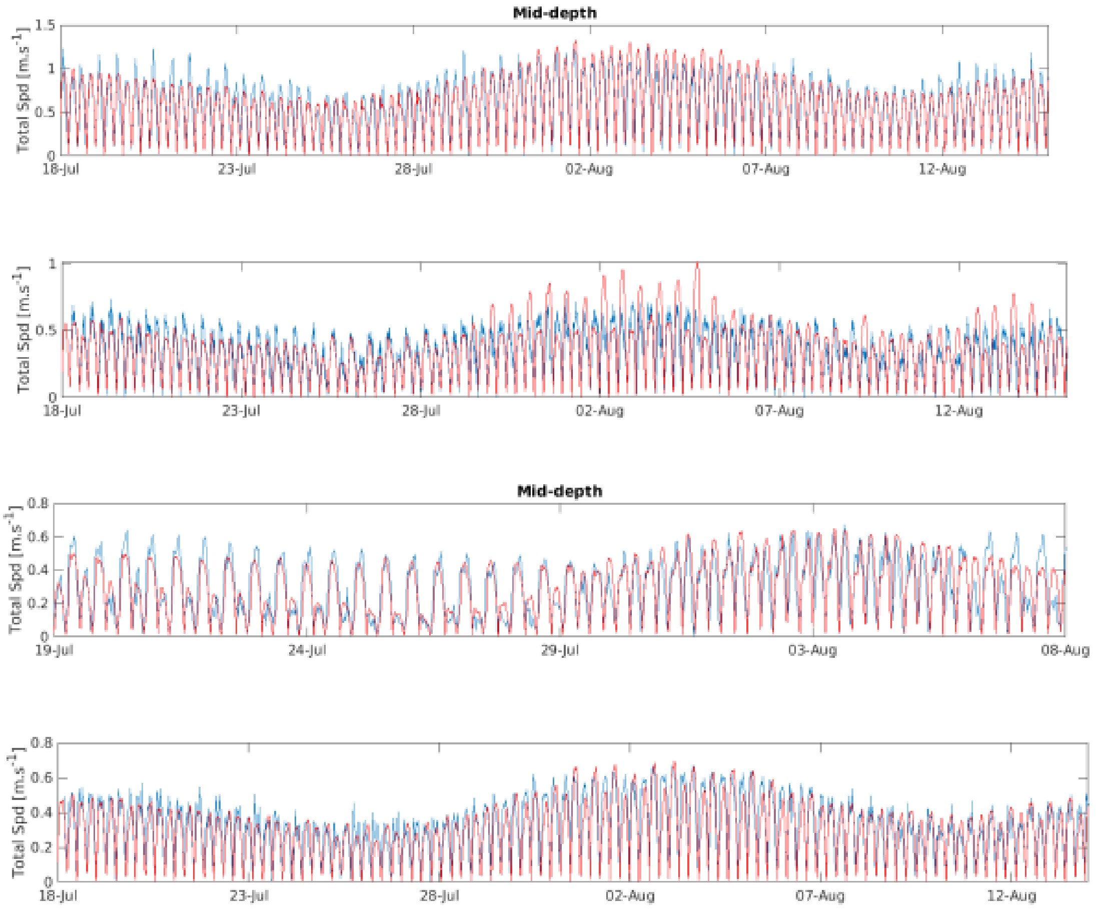

Figure 6 - Measured (blue) and modelled (red) current speeds at field campaign sites (Omapere, Onoke, Matawhera and The Narrows).

37. The WWTP discharge model 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, therefore, indicates the contaminant concentration at that location is 1000 times smaller than that discharged at the WWTP. Specific contaminant concentration levels at environmental receptors were determined by experts through QMRA, using concentration ratios and the expected or measured discharged value.

38. Results were presented in terms of 50th and 95th percentile maps of dilution and tracer concentration. The percentiles were calculated using the hourly output from the model over the full year. The 50th percentile maps represent the dilutions factors and concentration expected to be exceed 50% of the time. The 95th percentile maps represent the dilution factors and concentration expected to be exceeded 5% of the time (or not exceeded for 95% of the time).

39. It should be noted that the contaminant estimates may be conservative as no decay was considered for the passive tracer used in the simulations.

40. 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 1,000 for the 95th percentile for both El Niño and La Niña. The plume is advected by tidal currents toward the entrance of the harbour with a dilution of 1 in 5,000 at about 750 m from the discharge for El Niño and 500 m from the discharge for La Niña. Near the shoreline the dilution is approximately 1 in 25,000 or above (Figure 6 and Figure 7).

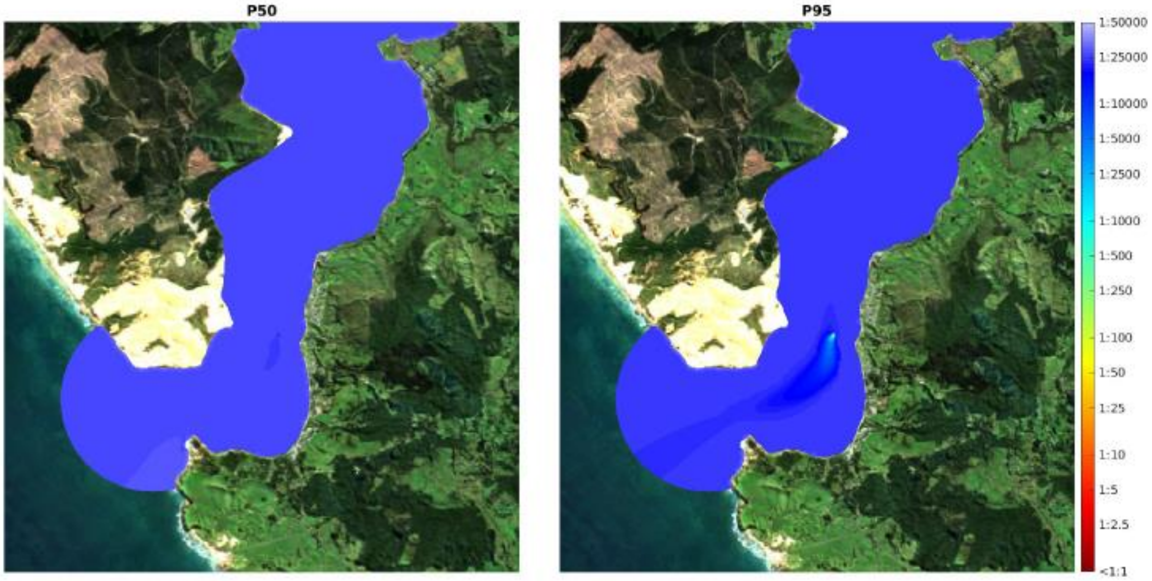

Figure 6 - 50th percentile (left) and 95th percentile (right) of dilution factor for Opononi WWTP during El Niño year.

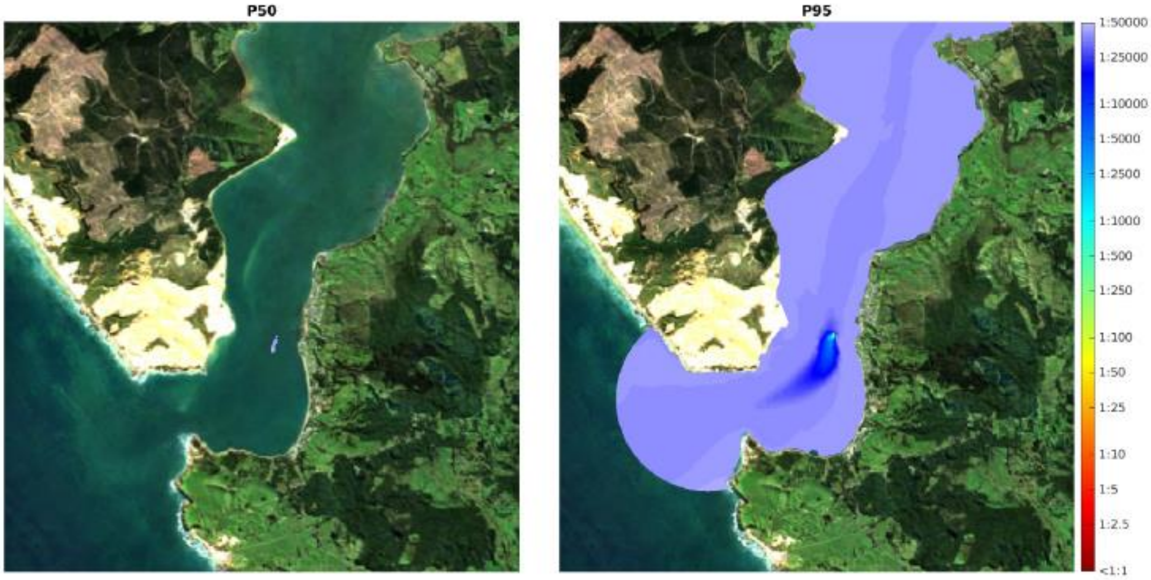

Figure 7 - 50th percentile (left) and 95th percentile (right) of dilution factor for Opononi WWTP during La Niña year.

41. 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 approximately 50 m from the discharge for the 50th percentile and 100 m from the discharge for the 95th percentile (Figure 8 and Figure 9).

Figure 8 - 50th percentile (left) and 95th percentile (right) of dilution factor for Kohukohu WWTP during El Niño year.

Figure 9 - 50th percentile (left) and 95th percentile (right) of dilution factor for Kohukohu WWTP during La Niña year.

42. In conclusion, SCHISM model calibration 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 simulating the hydrodynamics and wastewater discharges inside the harbour. Results shows that each WWTP presented different plume extents due to their location within the harbour and their associated discharges:

   a. The Opononi WWTP discharge presented an elongated plume stretching towards the entrance of Hokianga harbour. Dilution factors for the 50th percentile are as high as 1 in 5,000 within 100 m from the discharge location.

   b. The Kohukohu WWTP discharge plume is mostly confined to the vicinity of the discharge location with a dilution factor for the 50th percentile of 1 in 50,000 at approximately 50 m from the discharge location.

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

COUNCIL'S PRE-HEARING REPORT

44. There are three matters I wish to address.

Dilution

45. The section 42A report indicates in paragraph 64 (page 15) that the Hydrodynamic Study concluded that sufficient dilution is provided at the immediate Opononi WWTP discharge point that will not further exceed water quality. I wish to clarify that this was not a conclusion from our report. Our work was to model the hydrodynamics and dilution, and to report on the results, but not to assess the dilution levels against water quality standards or its potential impact on receptors. That work has been done by others.

Climate Change Effects

46. The section 42A reports noted that submitters commented that the application did not consider the impact of climate change and in particular with regards to catchment flooding and rising sea level rise.

47. When investigating the effect of sea level rise within an estuary a range of processes or parameters are commonly selected to characterise estuarine responses including tidal parameters (tidal range, prism, current velocity, energy, asymmetry), mixing and circulation, saltwater intrusion, stratification, sediment dynamics, and turbidity. However, it is important to account for interactions and complex feedback loops between estuarine hydrodynamics, geomorphic conditions, water quality and vegetation communities in addition to human activities and any proposed man-made coastal management/engineering activities (e.g. coastal structure to limit inundation).

48. Overall, the potential effect of a change in rainfall patterns and an increase in sea level rise on the discharges into Hokianga Harbour may be as follow:

    a. Effect of sea level rise: An increase in saltwater intrusion and an increase in tidal range may occur near Opononi and Kohukohu. An increased inundation of the intertidal area directly near Kohukohu may also occur. These changes would typically lead to an increase in mixing near the discharge points and potentially an increase in dilution of the discharge within the estuary.

    b. Effect of change in rainfall: An increase in rainfall would increase flushing of the estuary with the discharged contaminants being further exported seaward and out of the harbour. Conversely a decrease in rainfall and periods of drought would reduce flushing of the harbour.

49. Whilst these effects of climate change may facilitate or reduce mixing and in turn affect dilution, their impacts are expected to be minor or less than minor in terms of the outcome of the current hydrodynamic modelling results.

Extent of reasonable mixing zone

50. Opononi: The section 42A report indicates (i.e paragraph 134) that the mixing zone could be considered directly at the discharge point, noting that this cannot be measured until the plume reaches the surface. I would like to highlight that during energetic tidal flows the plume may not necessarily reach the surface directly above the discharge point. The surface expression of the plume is likely to be at times upstream or downstream of the discharge point. In these conditions the dilution will likely be relatively high compared to times when the plume is directly above the discharge point (e.g. slack waters). However it might be reasonable to consider a mixing zone extending upstream and

downstream of the discharge rather than a single point location.

51. Kohukohu: The section 42A report indicates that the mixing zone which is currently identified at the Channel Beacon in the Hokianga Harbour downstream of where the discharge leaves the unnamed tributary (NRC Sampling Site 231) should still apply (Paragraph 21 and 115) . I agree this location is a reasonable point to monitor as it provides a fixed location close to where the discharge plume leaves the intertidal flats and reaches the harbour.

Brett James Beamsley

3 May 2023

REFERENCES

MetOcean Solutions (2020). Hokianga Harbour Hydrodynamic Study. Hydrodynamic Study of Wastewater Discharges. Report prepared for Far North District Council.

Zhang, YL and AM Baptista. (2008). A Semi-Implicit Eulerian-Lagrangian Finite Element Model for Cross-Scale Ocean Circulation. *Ocean Modelling* 21: 71–96.