Waikato Regional Council

Technical review of the *Raglan Wastewater Treatment Plant Discharge Assessment* report as prepared by DHI for BECA

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SOLUTIONS

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1. Introduction

Waikato Regional council have commissioned MetOcean Solutions (a division of MetService) to undertake a technical scientific review of the Raglan Wastewater Treatment Plant Discharge Assessment document prepared for BECA as part of the reconsenting of the Raglan Wastewater Treatment Plant by DHI (Oldman, 2019) and the relevant sections of BECA, (2019). The technical scientific review focuses only to the MetOcean Solutions area of expertise; specifically, the choice of numerical models used, the configuration and validations of the numerical models and the applicability of the events used to quantify the potential dispersion of contaminants within the receiving environs.

The report is structured as follows: Section 2 provides detailed technical reviews of the relevant modelling undertaken, while Section 3 provides a more concise summary. References cited are provided in Section 4

2. Numerical model assessment

Numerical modelling the dispersion of contaminant discharges into the marine environment from either an open-ended pipe or through a series of diffusers requires consideration of both Near and Far field advection and dispersion.

Near field models are used to quantify the dispersion and dilution characteristics of a discharge where the momentum and/or density characteristics of the discharge dominates the advection processes. Within the Near-field regions, discharge volumes, velocities, port openings or diffuser configurations, ambient receiving water velocity and salinity, wave action and wind speed influence near field plume characteristics.

Far-field models typically consist of advecting either Eulerian or Lagrangian particles passively (usually) within a hydrodynamic flow field either during the running of the hydrodynamic model or in an offline mode.

Near and far-field models can either be combined numerically into a seamless modelling solution, or they can be run independently with the near-field modelling providing the initial location, shape and dilution of the plume (for the given discharge, configuration and ambient conditions) which are ingested into the Far-field modelling and the particles advected within the receiving environment, with current velocities defined using a decoupled hydrodynamic model..

Oldman, 2019 appears to have applied a decoupled approach to the far field modelling, first undertaking hydrodynamic modelling, then undertaking dispersion modelling (near and far-field) within the hydrodynamic framework.

2.1 Hydrodynamic model

Oldman, 2019 does not stipulate the model used to undertake the hydrodynamics, however it can be assumed that the model uses is Mike21 and Mike 3 Flow Model FM ECO Lab. Both models can be considered industry standard tools and are, assuming they are suitably calibrated and validated, appropriate for undertaking hydrodynamic and far-field dispersion modelling.

The report provides information on the bathymetry datasets used to derive the model domain, and these are appropriate.

Model forcing or boundary conditions for the hydrodynamic model are not well described, and while there is information on the atmospheric and fluvial boundaries, no information is presented describing the offshore boundary conditions used within the hydrodynamic modelling, and it is unclear if tidal only boundary conditions are applied, or tidal and residual boundaries (velocities and elevations). The report would benefit from a more complete description of the model, boundary conditions, physics and assumptions being applied, i.e., 2D or 3D, model resolution, inclusion of Coriolis etc. etc.

2.1.1 Model calibration and validation

The calibration and validation of the hydrodynamic model was undertaken using existing available data from within Whāingaroa/Raglan Harbour, and immediately offshore. No instrument deployments were undertaken specifically to support this work.

Two sites were used to validate the model predicted water levels; Manu Bay tide gauge and The Wharf tide gauge.

Comparisons between what appears to be the tidal component only of the total water levels are made at both sites and illustrate relatively good agreement between the model predicted and the observed tidal magnitudes, however it would be useful to also show a comparison between the individual model and observed constituents phases and amplitudes. Residual water levels do not appear to be included in the modelling, or there is no comparison between the predicted and observed residual presented. Oldman, 2019 presents a comparison between the measured residual water levels at Manu Bay and The Wharf, which show good agreement, but it is unclear if these residual levels are included in the modelling or not, nor is it clear if events that have a residual water level up to 1.0 m above tidally predicted levels will have an impact on the harbour hydrodynamics and the dynamics of plumes exiting the harbour. It would be useful for the report to be more explicit around specifically what has and what has not been included in the modelling, and if processes have not been included in the modelling, what is the impact on the outcomes of not including these processes on the outcomes.

NIWA current meter data are used to infer validation of the hydrodynamic model, however Oldman, 2019 notes that there is uncertainty around the location of the instrument deployment and that it is likely that the bathymetry has changes since the original deployment. Given the uncertainty in location, it is not clear how locations of the instrument and the model output points were collocated. Given the uncertainties around location and bathymetry (as noted by Oldman, 2019) these data are not suitable for validation or calibrating the numerical model.

A qualitative comparison along a measure (along an Acoustic Doppler Current Profiler Transects) and modelled transects illustrates that the hydrodynamic model by and large replicates the expected current velocities appropriately, though it is not clear how Oldman (2019) has overcome the difficulty of matching the data from the ADCP (which is moving in tame and recording a value every 0.3 m of water column) with the equivalent model predictions which will be instantaneous in time; and further details on this would be useful.

Oldman (2019) has applied a semi-quantitive validation approach by considering measured depth averaged speed data from the ADCP transects and co-locating model data for the same time. Comparisons between the modelled and measured data, given this processing step, suggests that, when taking into consideration all the potential errors, the model does and ok job at predicting the channel hydrodynamics, thought the RMSE is relatively high at 0.18 $m.s^{-1}$. It would have been useful to see a comparison between the model predicted and measured current velocities (as opposed to speed) to ensure that the model was adequately predicting the current velocities within the channel (e.g. Figure 2.1 and Figure 2.2).

Qualitative comparisons of the net flux through the transverse transects appear to show relatively good agreement given the likelihood that the bathymetry has been modified since the data was collected (see Figure 4.10 of Oldman, 2019). Similarly, qualitative comparisons between the depth averaged current speeds are presented and show relatively good agreement given the caveats on the bathymetry noted above.

Oldman (2019) presents a comparison between the minimum salinities observed at monitoring sites maintained by the Waikato Regional Council and those predicted by the numerical model. The data do not overlap temporally, so no direct comparisons can be made nor inference to the validity of the model to predict salinities or mixing with the harbour. A more robust methodology would have been to model one of the periods where there were measured salinity data and compare results directly.

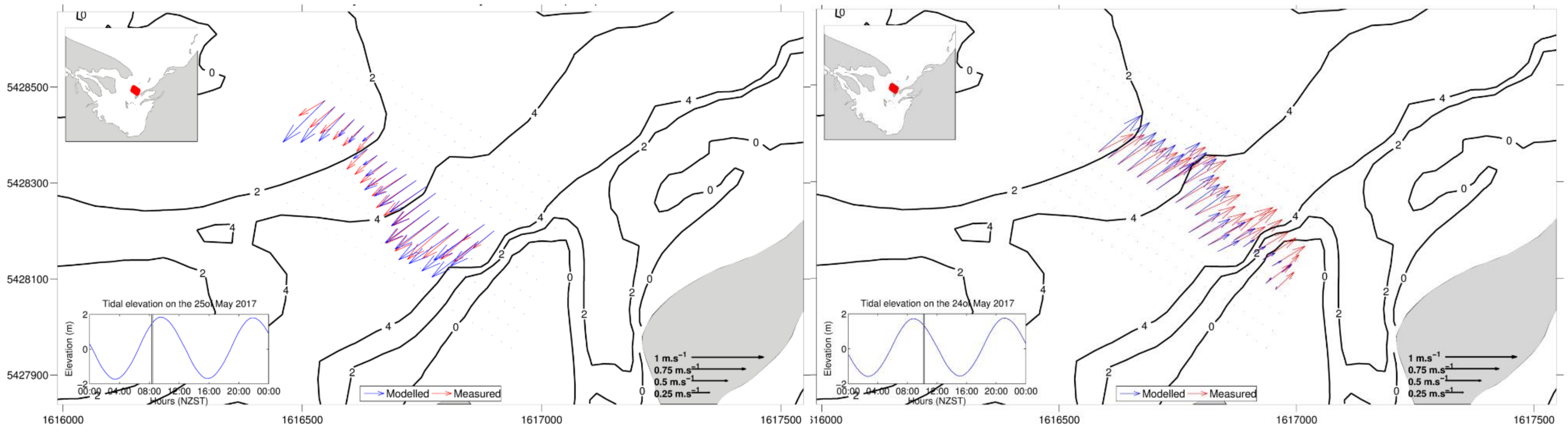

Figure 2.1 Comparison between measured and modelled depth-averaged current velocities at peak flood (left) and peak ebb (right) at the section A.

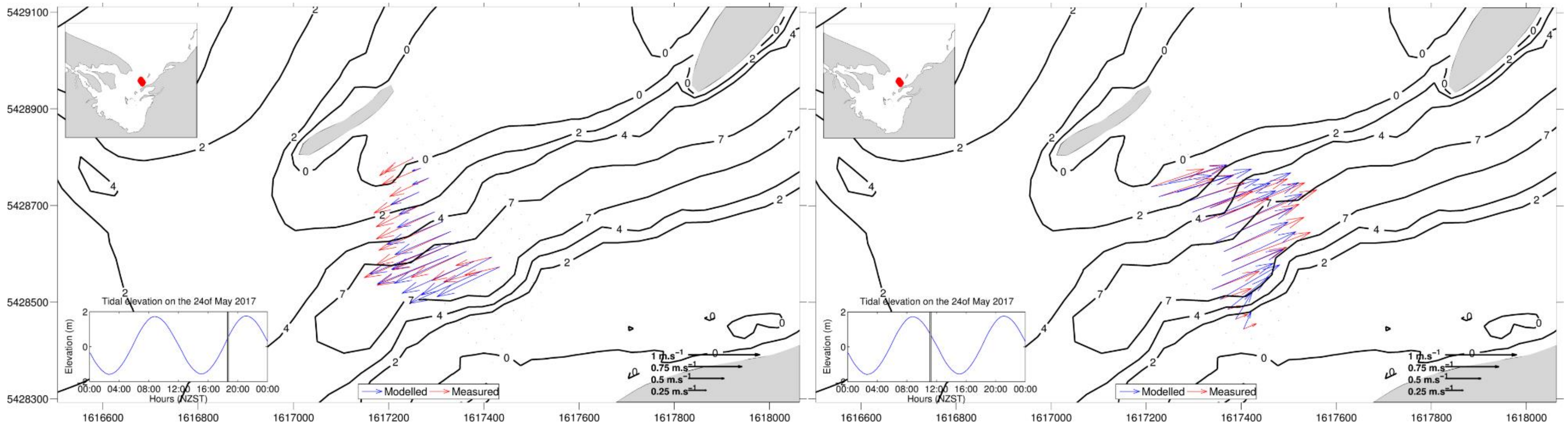

Figure 2.2 Comparison between measured and modelled depth-averaged current velocities at peak flood (left) and peak ebb (right) at the section B.

2.2 Near Field Model

Within Oldman, 2019, near-field modelling of the initial turbulent mixing was undertaken using CORMIX[1]. CORMIX is a USEPA-supported mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones resulting from continuous point source discharges. The system emphasizes the role of boundary interaction to predict steady-state mixing behaviour and plume geometry.

CORMIX (the near-field model) is an appropriate, industry standard tool for assessing the initial near-field dispersion of the discharged wastewater into the receiving environment.

2.2.1 Near Field Modelling initial conditions and scenarios

Initial ambient conditions were defined from the hydrodynamical modelling, with 8 scenarios modelled; including both Spring and Neap tidal stages. Ambient current velocities and water depths were modified accordingly within CORMIX.

The range in ambient velocities considered is relatively limited for the analysis and unlikely to adequately represent the likely range of current velocities experienced during a discharge window, as shown in Figure 4.3 of Oldman, 2019 and as implied by 32.9% of discharge events occurring before high water (Table 3.1 of Oldman, 2019), and as such spanning slack water where current velocities are likely to be minimal .

The number of ambient current velocities (i.e. resolutions at which the range is represented) simulated is relatively small and are not expected to completely span the likely ambient current velocities during discharges,

The report does not provide information on the relative densities of either the discharged wastewater or the ambient harbour water, so we are unable to comment on the appropriateness of the choices made. Similarly, no reference is made to the wind or wave conditions assumed during discharges - both of which can influence dilutions.

The report presents only average discharge velocities of wastewater associated with a mean daily discharge (of 1175 $m^3.day^{-1}$) and a median discharge duration (2 hr and 15 min), i.e. 0.06 $m^3.s^{-1}$, while a projected peak summer flow is of the order 0.15 $m^3.s^{-1}$ (Oldman 2019, Section 2, after Gibbs and Watson, 1996). The measured inflow and discharge outflow is for a period spanning 2016-2019 is presented in Figure 2.3 and show significant temporal variation in the daily average discharge volumes, with the previous consented discharge level significantly higher than results presented in the report (i.e. 2500 m^3 per day consented vs 1175 m^3 per day presented in the reports).

If not already doing so, the report would benefit from considering other discharge velocities and durations other than those related to the mean volume and median discharge duration, including under more extreme conditions where discharge velocities,

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[1] http://www.cormix.info/

or volumes are likely to be higher and the potential impact of the discharged wastewater likely to be greater.

Near-field modelling of alternative discharge locations within the harbour are presented in Section 5.3 of Oldman, 2019 assuming a 0.3 m diameter discharge pipe with a 6 port, 100 mm diffuser diameter. Only minimum dilutions are presented, and there is not enough information provided within the report to be able to comment on the assumed ambient current velocities nor the wastewater discharge velocities. Irrespective, the comparisons are useful for showing comparative dilutions between individual discharge sites.

An additional offshore discharge location is mentioned in Section 5.5.1 (Far Field Modelling), however the report makes no mention of undertaking near-field modelling at this site (though the report does note that the "*offshore site provides the opportunity for much greater dilution due to increased water depth and the combined effect of currents and waves ensuring full mixing in the water column*", however this is not apparent in the associated figure – Figure 5.8 of Oldman, 2019).

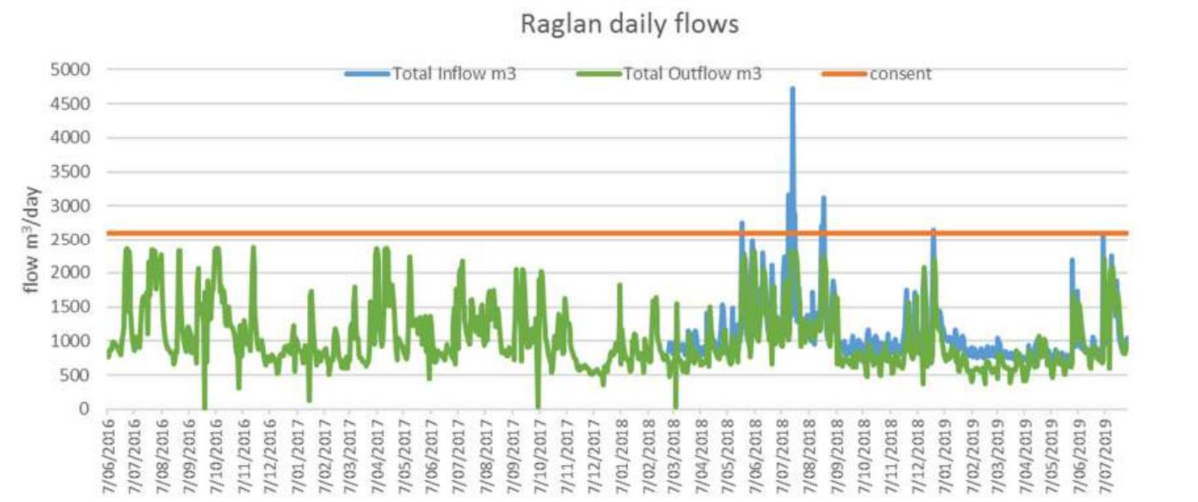


Figure 2.3 Measured inflow and outflow from the Raglan waste water treatment plant (daily values).

2.3 Far Field Model

The report does not detail how the initial near-field dilution modelling is integrated into the far field model. When separate Near and Far field modelling is undertaken, it is typical to apply a look-up table approach, where the location, shape and dilution at the edge of the near field are defined for specific ambient current velocities using a Near Field model and applied to the Far Field model at each time-step. Details within the report are not sufficient to determine if this approach, or another, has been used for the far field modelling. A typical look up table approach involves defining the near-field plume characteristics (plume extent, initial dilution) under a range of representative conditions (water depth, current velocities, discharge characteristics, diffuser configurations) for input into the far-field model, with these parameters varying with time depending on the ambient conditions. The range and resolution of the values within the look up table need to be appropriate to cover the expected range of conditions the discharged plume is likely to experience within the near-field.

The report does not detail if far-field modelling was undertaken using either Lagrangian or Eulerian particle tracking, nor are enough details of the methodologies and assumptions of the approach supplied to comment on the suitability of the parameters used in the modelling. i.e. horizontal and vertical diffusion coefficients, densities and other assumptions related to defining Eulerian tracers.

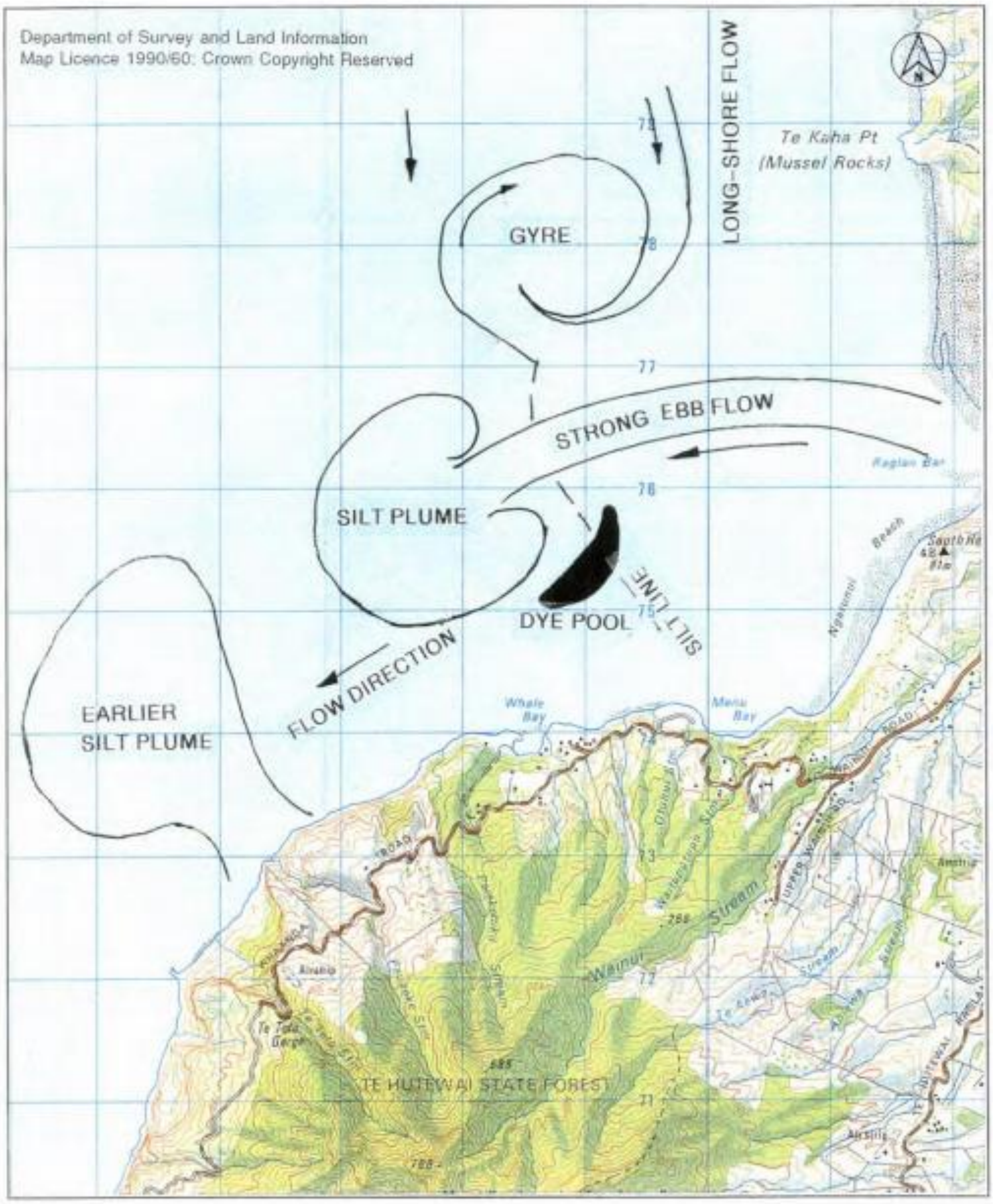
Comparisons between alternative discharge locations (section 5.5.1) are appropriate for examining the comparative effect of moving the discharge location, however Oldman, 2019 makes the statement that the "*offshore site provides the opportunity for much greater dilution due to increased water depth and the combined effect of currents and waves ensuring full mixing in the water column*", however this is not apparent in the associated figure – Figure 5.8. From a technical perspective this is probably correct, but results presented do not illustrate this finding.

Simulations appear to have been conducted over a full calendar year (2018) though start and finish times are not indicated. It is not apparent if time-varying wastewater discharges (both temporally variable starts and finishes, and discharge velocities) or constant in time (both regarding timing of discharges relative to tidal stage and volume of discharge) have been modelled. Ideally, simulations would have been conducted considering full time-varying approach, based on actual discharge characteristics for the period being considered, but it is not clear if this is the methodology applied.

Oldman (2019) notes that the offshore currents outside the harbour from the modelling shoe a predominance of the northerly directed current direction and states that this is consistent with the observed dye test undertaken by NIWA and as provided in Appendix A of Oldman (2019). This appears to be an incorrect statement as they dye release observations and associated figures presented in Appendix A of Oldman (2019) clearly indicate a southeast directed current direction (see Figure 2.4), and also is apparent in various historical aerial images available on Google Earth (i.e. Figure 2.5). It is not clear if the hydrodynamic modelling undertaken captures these SE current velocities or not, and it would be interesting to determine under which climatic conditions they occur (assuming the modelling captures this process).

Oldman (2019) presents results for a future discharge volume based on an increase from 1175 m^3 per day to 2335 m^3 per day. These discharge volumes are based on mean daily discharges for the existing and a hypothetical future state/population. It is not clear if the modelling considered time-varying discharge volumes, nor is it clear if the modelling considered variable discharge durations and variable start/stop times (relative to tidal stages) for the discharges.

It is beyond the scope of this review to comment on the suitability of the locations chosen for the Quality Management Risk Assessment (QMRA), or the dilutions/concentrations used to define relative risk.



NIWA

Figure 2.4 Schematic image from NIWA showing dispersion characteristics of dye offshore Whāingaroa/Raglan Harbour, and a general SE flow direction (after Oldman, 2019).

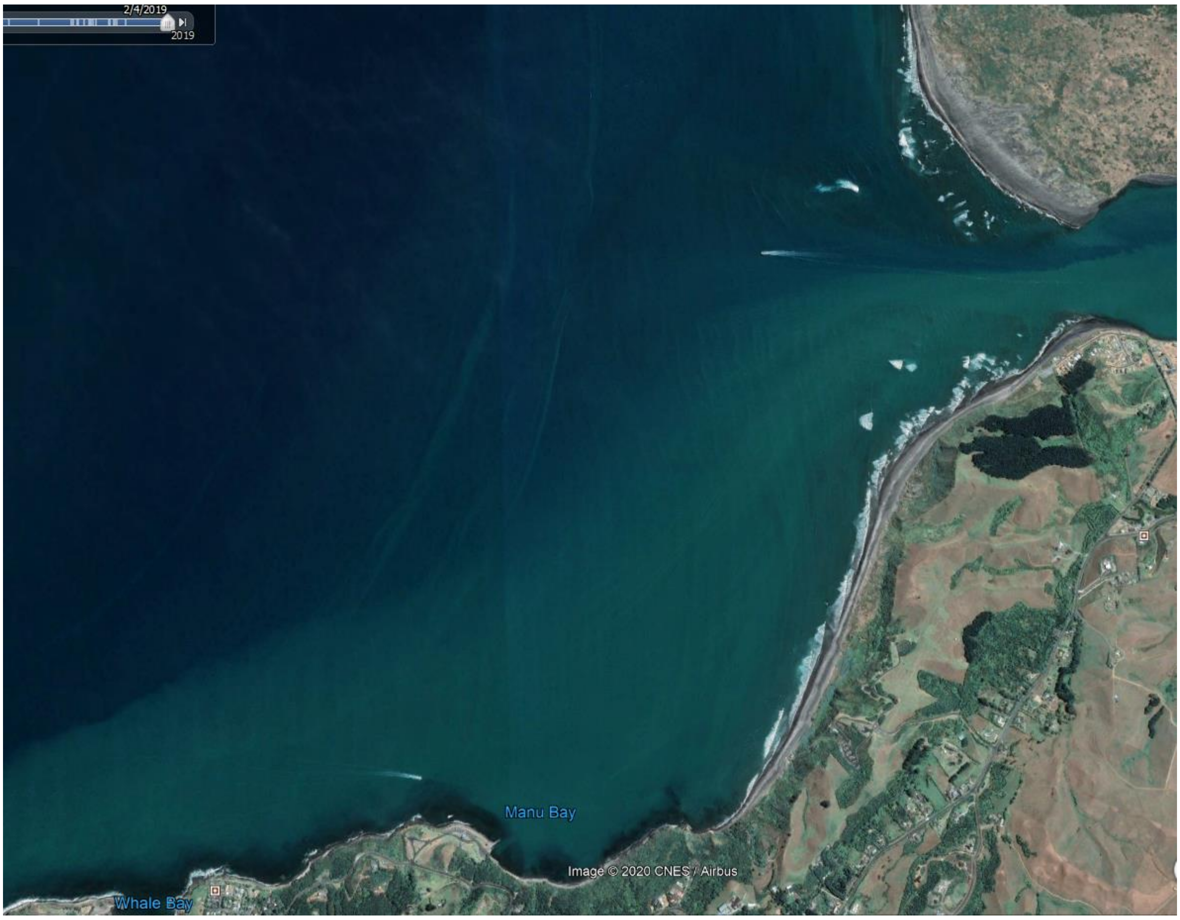


Figure 2.5 Aerial image of Whāingaroa/Raglan Harbour entrance illustrating the presence of a turbid plume extending SE from the harbour entrance.

2.4 Wave model

Wave modelling was undertaken using the MIKE21 SW model, however no information is provided on the configuration or physical parameter assumptions made within the model. While time-varying water levels were included in the wave modelling, it is not clear if a coupled wave/current approach to modelling the incident waves has been applied.

Calibration and validations of the wave modelling is relatively poor, and the justification for not presenting statistics relating to the degree of agreement between the model and measured data is not valid.

It is likely that the validation/calibration of the wave model would benefit from applying higher resolution wind forcing, rather than relying on global wind products or by applying a coupled wave/current modelling approach (given the locations of the measured wave buoy data).

It is not clear how the wave modelling was used within the context of the wastewater plume near-field dispersion modelling, as no information is provided. Wave radiation stresses were applied to the hydrodynamic model as boundary conditions, which is appropriate assuming the wave climate is able to be accurately quantified. It would be interesting to examine the impact of the wave modelling on the dispersion of the wastewater in the far-field by undertaking sensitivity analysis around the impact of including or not wave radiation stress.

3.BECA summary document review

This section reviews the relevant aspects of the BECA, (2019) summary document as they relate to the MetOcean Solutions areas of expertise; specifically Section 3.1.4, and excludes comments as they relate to Oldman, (2019); which are addressed in Section 2.

BECA, (2019) note that Greer, (2015) found that fluvial discharges into the Whāingaroa/Raglan Harbour had a greater influence ion the entire harbour water quality relative to the discharge of wastewater with regards to Faecal Coliforms. BECA, (2019) do not however that there was uncertainty around the predicted source Faecal Coliforms concentrations and as such is difficult to draw any conclusion from the work of Greer, (2015).

BECA, (2019) also reference the report of Greer et al., (2016). It is important to note, while BECA, (2019) use the report to infer scale of effects with regards to the discharging of wastewater into the harbour and fluvial derived contaminant within the *entire* harbour caveats around the Greer et al., (2016) note that;

> The accuracy of information and model simulations presented in this document is entirely reliant on the accuracy and completeness of available information. Furthermore, the models described in this document may not be suitable for any purpose(s) other than those specified.
>
> Council requests that if excerpts or inferences are drawn from this document for further use by individuals or organisations, due care should be taken to ensure that the appropriate context has been preserved and is accurately reflected and referenced in any subsequent spoken or written communication.

As such, care should be taken when referencing and applying information within these reports beyond that which they were intended.

BECA, (2019) present a figure where a 20% threshold has been applied to infer the flushing of the cell (see BECA, (2019)), suggesting a dilution of 0.2 at which point the cell can be considered flushed. The 20% threshold as applied by Greer et al., (2016) was one of a range of thresholds used to illustrate the effect of choosing different thresholds, while the majority of the study presented results (including for Whāingaroa/Raglan Harbour) applied a threshold of 5%. To illustrate the potential differences in harbour wide residence times reproduced by BECA, (2019) and those reported in Greer et al., (2016) (at 5% threshold), the relevant model outcomes are presented in Figure 3.1 and illustrate that by choosing a higher threshold, residency times can appear significantly reduced. This highlights the importance of understanding the caveats as described above when applying the findings of Greer et al., (2016) beyond their intended use.

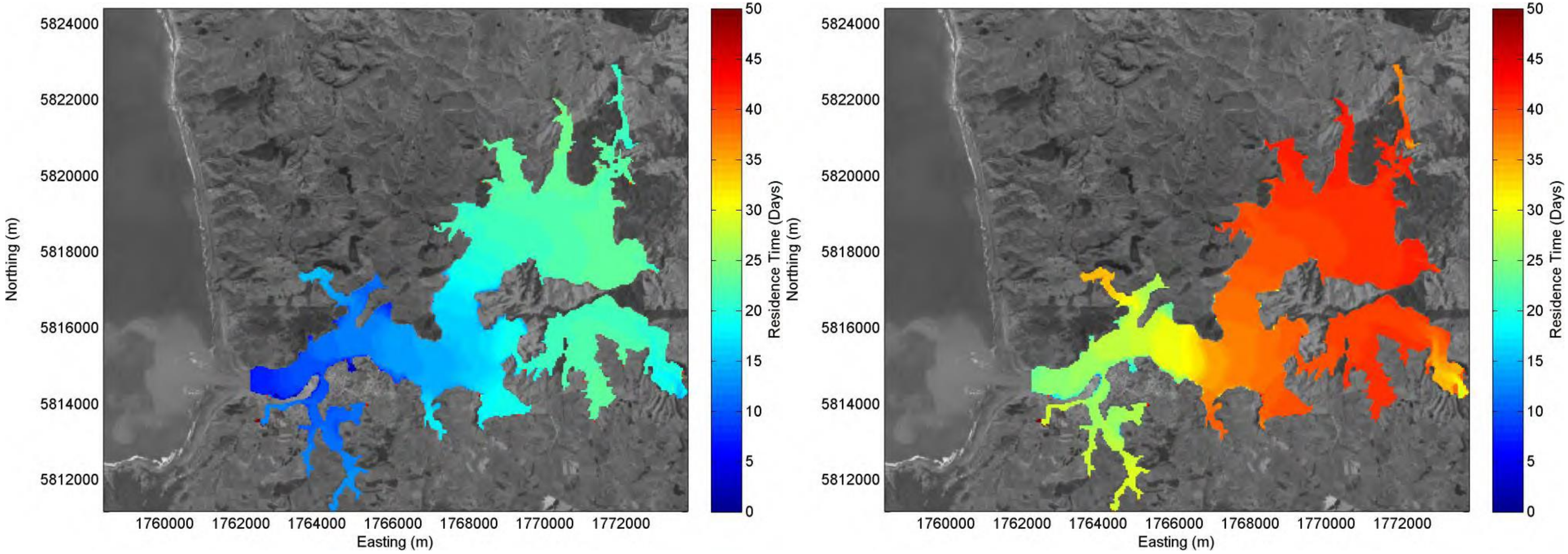


Figure 3.1 Residency times for Whāingaroa/Raglan Harbour assuming a mid-range tide and tracer released at high tide. On the Left are residency times assuming a 20% threshold (i.e. once dilutions reaches a level of 0.2 the cell is assumed to be flushed), while on the Right are residency times associated with a 5% threshold ((i.e. once dilutions reaches a level of 0.05 the cell is assumed to be flushed) After Greer et al., (2016)

4. Summary

MetOcean Solutions (a division of MetService) has undertaken a technical scientific review of the Raglan Wastewater Treatment Plant Discharge Assessment document prepared for BECA as part of the reconsenting of the Raglan Wastewater Treatment Plant by DHI (Oldman, 2019) and the BECA, (2019) summary document.

The review of Oldman, (2019) considers the numerical models applied to both the near and far field modelling, model parameters and configurations (including boundary conditions) where provided, validation and calibrations of the models as presented, and simulations undertaken.

The review of the BECA, (2019) summary report considers the appropriateness of the summarised findings and conclusions.

The following are bulleted summaries of that review, while details are presented in the relevant sections above.

4.1 Report structure

- The Oldman, (2019) report structure is relatively poor, with no clear definition of the methodology being applied in any of the aspects being considered, i.e. establishment of the numerical modelling, justification of the choices of being simulated. This results in it being difficult to follow what has and has not been undertaken in the study and how various models have been applied.

4.2 Hydrodynamic model and validation (Oldman, 2019)

- The numerical model used, while not explicitly stated, is believed to be Mike21 and Mike 3 Flow Model FM ECO Lab. Both models can be considered industry standard tools and are, assuming they are suitably calibrated and validated, appropriate for undertaking hydrodynamic and far-field dispersion modelling.
- Model forcing or boundary conditions for the hydrodynamic model are not well described, and while there is information on the atmospheric and fluvial boundaries, no information is presented describing the offshore boundary conditions used within the hydrodynamic modelling nor if Coriolis is considered.
- It is not clear if tidal forcing only or tidal and residual water levels are used to force the model.
- The report would benefit from a more complete description of the hydrodynamic model, boundary conditions and assumptions being applied (including applied physical parameters), 2D or 3D, model resolution etc. etc.
- Hydrodynamic model calibration and validations was undertaken using historical data.
- Model and measured tidal water level comparisons show relatively good agreement, though it would be useful to present comparisons between constituent phases and amplitudes.
- It is not clear if residual water levels have been included in the modelling.

- It would be useful for the report to be more explicit around specifically what has and what has not been included in the modelling, and if processes have not been included in the modelling, what is the impact on the outcomes of not including these processes.
- Current velocity comparisons have been presented between the model outcomes and historical data collected by NIWA, however acknowledged limitations of the measured data suggest these data are not suitable for validations or calibration of the numerical model.
- A qualitative comparison of current velocities (Figure 4.7 of Oldman, 2019) suggests the hydrodynamic model by and large replicates the expected current velocities, however details on how the co-located data (temporal and spatial) were derived is not well described in the report.
- A semi-quantitive validation is presented, suggests that, given all the likely uncertainties, the model does an ok job at predicting the channel hydrodynamics all be it with a relatively high RMSE of 0.18 m.s^{-1}.
- Additional qualitative comparisons between current velocities along the measured transects would have been useful.
- Qualitative comparisons of the net flux through transverse transects appear to show relatively good agreement given the likelihood that the bathymetry has been modified since the data was collected.
- While the best endeavours have been made to validate the calibrate the model against historical data, it is difficult to explicitly state that the model accurately captures the hydrodynamic forcings within the environs and the modelling work would have significantly benefited from additional observations/data collections to reduce the level of uncertainty in the hydrodynamic outcomes.

4.3 Near-field modelling (Oldman, 2019)

- The Near-field model used to describe the initial turbulent mixing (CORMIX) is an appropriate industry standard tool.
- The range and resolution (number) of ambient current velocities presented (and assumed to be considered in the subsequent far field modelling) is limited and are not expected to completely span the likely ambient current velocities during discharges
- The report does not provide enough detail to determine if CORMIX has been applied appropriately, including relative densities of the wastewater and receiving waters, wind/wave conditions etc.
- Dilutions characteristics associated with only the mean daily discharge and a median discharge duration are presented. This is a significantly lower discharge volume that the previously consented values, and significantly less than predicted peak summer flows.
- If not already doing so, the report would benefit from considering other discharge velocities and durations other than those related to the mean volume and median discharge duration, including under more extreme conditions where discharge velocities, or volumes are likely to be higher and the potential impact of the discharged wastewater likely to be greater.

- Near-field modelling of alternative discharge locations are presented and are useful for showing comparative dilutions between individual discharge sites, however an additional offshore discharge location is mentioned within the far field modelling section, with the report suggesting the offshore site provides an opportunity to realise greater dilution. From a technical perspective this is probably correct, but results presented do not illustrate this finding (Figure 5.8 of Oldman, 2019)

4.4 Far-field modelling (Oldman, 2019)

- The report would benefit from additional details on how the near-field modelling was included into the far-field modelling, with insufficient details on how the two modelling aspects were combined.
- The report does not detail if far-field modelling was undertaken using either Lagrangian or Eulerian particle tracking, nor are enough details of the methodologies and assumptions of the approach supplied to comment on the suitability of the parameters used in the modelling.
- Comparisons between alternative discharge locations (section 5.5.1) are appropriate for examining the comparative effect of moving the discharge location.
- Simulations appear to have been conducted over a full calendar year (2018), It would be useful to comment on how typical the discharge and hydrographic conditions in2018 were likely to be.
- It is not apparent if time-varying wastewater discharges (both temporally variable starts and finishes, and discharge velocities) or constant in time (both regarding timing of discharges relative to tidal stage and volume of discharge) have been modelled.
- Oldman (2019) notes that the offshore currents outside the harbour from the modelling shoe a predominance of the northerly directed current direction and states that this is consistent with the observed dye test undertaken by NIWA and as provided in Appendix A of Oldman (2019). This appears to be an incorrect statement (see Figure 2.4),
- It is not clear if the hydrodynamic modelling undertaken captures these SE current velocities.
- Oldman (2019) presents results for a future discharge volume based on an increase from 1175 m^3 per day to 2335 m^3 per day. These discharge volumes are based on mean daily discharges for the existing and a hypothetical future state/population.
- It is not clear if the future discharge modelling considered time-varying discharge volumes, nor is it clear if the modelling considered variable discharge durations and variable start/stop times (relative to tidal stages) for the discharges.

4.5 Wave modelling (Oldman, 2019)

- Wave modelling was undertaken using the MIKE21 SW model, however no information is provided on the configuration or physical parameter assumptions made within the model.
- Calibration and validations of the wave modelling is relatively poor, and the justification for not presenting statistics relating to the degree of agreement between the model and measured data is not valid.
- It is not clear how the wave modelling was used within the context of the wastewater plume near-field dispersion modelling, as no information is provided, however comment is made that wave action will likely increase the mixing and hence dilution for and offshore discharge location.
- Wave radiation stresses were applied to the hydrodynamic model as boundary conditions, which is appropriate assuming the wave climate is able to be accurately quantified.
- It would be interesting to examine the impact of the wave modelling on the dispersion of the wastewater in the far-field by undertaking sensitivity analysis around the impact of including or not wave radiation stress

4.6 BECA summary document review

- BECA, (2019) note that Greer, (2015) found that fluvial discharges into the Whāingaroa/Raglan Harbour had a greater influence ion the entire harbour water quality relative to the discharge of wastewater with regards to Faecal Coliforms. BECA, (2019) do not however that there was uncertainty around the predicted source Faecal Coliforms concentrations and as such is difficult to draw any conclusion from the work of Greer, (2015).
- BECA, (2019) also reference the report of Greer et al., (2016) and present a figure depicting residency times within the harbour. The figure presented is a figure used to examine the % threshold of defining a cell a being flushed or not, with a threshold of 20%, while throughout the report Greer et al., (2016) use a threshold of 5% predominantly.
- The significant differences between the 20% and 5% threshold result highlights the importance of understanding the caveats as defined within Greer et al., (2016) when applying the findings of Greer et al., (2016) beyond their intended use.

5. References

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