IN THE MATTER OF	the Resource Management Act 1991
AND	
IN THE MATTER OF	resource consent applications and Notices of Requirement by the Bay of Plenty Regional Council to undertake the proposed Kaituna River Re-diversion and Ongatoro / Maketū Estuary Enhancement Project

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STATEMENT OF EVIDENCE OF BENJAMIN JOHN TUCKEY

INTRODUCTION

Qualifications and Experience

1. My full name is Benjamin John Tuckey. I am currently employed as a Principal Coastal Scientist with DHI Water and Environment Limited (DHI) in Auckland, where I have worked for over eight years. DHI is a specialist water engineering consultant, with its headquarters in Denmark. DHI develop commercial numerical modelling software, and apply these to investigate the movement of water in rivers, pipes and coastal environments. DHI Software is recognised worldwide and is widely used in New Zealand by local and regional authorities and their consultants.

2. I have a Bachelor of Science (Physics) and a Master of Science (Physics) from the University of Otago. I have over 11 years of experience as a coastal scientist with a focus on numerical modelling. Relevant projects that I have worked on and my role in these projects are as follows:

   - Whakatane River Entrance Improvement Project, Whakatane, Bay of Plenty – Project Manager and Modeller.
   - Opotiki Harbour Access Modelling and Preliminary Design, Opotiki, Bay of Plenty – Project Modeller.
   - Porirua Harbour Sediment Modelling, Transmission Gully Impact Assessment, Porirua, Wellington - Project Manager and Modeller.
   - Bream Bay Wastewater Dilution and Dispersion Study - Project Manager and Modeller.

- Whakatane River Saline Intrusion Study, Whakatane, Bay of Plenty – Project Manager and Modeller.
- Waituna Lagoon Pre-feasibility Engineering Scoping for Lagoon Closings/Openings, Southland - Project Manager and Technical Lead.
- Browse Liquid Natural Gas Precinct Wastewater Dilution Study, James Price Point, Western Australia – Technical Manager.

Scope of Evidence

3. I first became involved in the Project in 2008, when I assisted with investigating options for the re-diversion. In 2013, DHI was commissioned to carry out a numerical modelling assessment to predict the impact of the Project. The assessment focussed on changes in the hydrodynamics, morphology and water quality of the lower Kaituna River and Ongatoro / Maketū Estuary. The details and findings of the assessment are covered in detail in the Numerical Modelling report.[1]

4. My evidence will outline:

   4.1 The numerical models used and data collected for the Project including the model calibration/validation;

   4.2 The key findings from the predictions in relation to hydrodynamics, morphology and water quality of the lower river and estuary;

   4.3 The potential impact of additional sediment supply in future from the river on the river mouth and the estuary; and

   4.4 The additional proposed data collection to confirm and validate a key finding of the modelling assessment in respect of ebb tide volume.

5. The key findings of the model that I outline in this evidence contributed to the assessments of environmental effects of the Project undertaken by the technical expert team and described in their evidence.

6. I will also provide comments on the submissions as they relate to the scope of my evidence. Other witnesses also provide comments on the submissions relevant to their areas of expertise and project involvement.

7. I have read and am familiar with the section 42A report and the proposed set of consent conditions and will refer to these where relevant to my evidence.

[1] Dated 27 June 2014 and contained in Volume 1, Tab B of the AEE.

8. Lastly, I have read the Code of Conduct for Expert Witnesses in the Updated Environment Court Practice Note (2014) and agree to comply with the Code. This evidence is within my area of expertise, except where relying on the evidence of another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

EXECUTIVE SUMMARY

9. To assess the potentially positive and adverse impacts of the Project for typical (likely to occur frequently) and extreme (which will occur infrequently) conditions, a suite of numerical models were developed. Throughout the study, a conservative approach was taken, for both the development of the numerical models and the interpretation of model predictions. This was to ensure the positive impacts of the Project were not overstated or conversely the adverse impacts understated. The main findings from the predictions of the numerical modelling assessment were:

9.1 The Project will significantly increase the volume of water which enters the estuary from the river and will decrease the volume of water that will enter through the estuary mouth. There will be no impact on swimmer safety in the lower estuary for typical conditions. Without mitigation, flow to the Lower Kaituna Wildlife Management Reserve will be reduced for typical conditions and drainage of the surrounding catchments to the estuary will be impacted.

9.2 The estuary mouth will switch from a flood dominated to an ebb dominated system, which will reduce the current expansion of the flood tide delta and potentially even erode areas of the delta. The morphological behaviour of the river mouth or estuary entrance for adverse or typical conditions will not change significantly. There is the potential for long term erosion to occur within parts of the estuary with some areas of deposition also possible.

9.3 Without mitigation, the Project will increase the flood hazard for Maketū township for some flood scenarios. Flood hazard for the lower river will be decreased.

9.4 Overall mean salinities will decrease throughout the estuary. There will be no significant impact on the salt wedge extent for mean river flow, however the maximum upstream location of the salt wedge will increase by 200 – 250 m for low river flow conditions.

9.5 There will be negligible impact on the potential for blue-green algae blooms and the bathing water suitability in the lower estuary. There will be a small impact on mean nutrient levels within the estuary and the current non-compliance for safe shellfish gathering in the lower estuary will be further exacerbated.

10. The potential for future increased sediment loads within the Kaituna River was investigated with sensitivity testing and was predicted to have negligible impact on both flood release and navigation through the Kaituna River mouth, which was a concern raised by an external peer review of the study, and related to the concern expressed by 18 submitters that the Project might negatively affect navigation.

11. A consent condition has been proposed (Proposed Condition 27) that requires the Consent Holder to collect additional data, for both the existing situation and with the re-diversion operating, to support the key finding of the model that the ebb tide volume will not be significantly reduced as a result of the Project.

THE MODELS

12. A suite of numerical models were developed, calibrated (or validated) and applied to investigate and compare the performance and impact of a proposed option for diverting additional flow from the Kaituna River to the Ongatoro / Maketū Estuary. The following key models were developed for the Project. An overview of all the numerical models applied in the study is presented in Table 1.

MIKE 21 FM - Two Dimensional Hydrodynamic Model

13. MIKE 21 FM is numerical modelling software developed by DHI that solves the physical equations governing the movement of water within a body of water (for this Project, the main focus was on the lower Kaituna River and the Ongatoro / Maketū Estuary). The software uses physical information referred to as bathymetry, to form a mathematical description of the physical system, i.e. a model. Once developed, different inputs can be fed to the model, including sea levels, river flow and wind, which are then processed by the model on a computer to generate a prediction of water levels and flows (the hydrodynamics) within the modelled area.

14. A two dimensional hydrodynamic model assumes a depth averaged velocity for the movement of water from the water surface to the river or seabed (the water column). A flexible mesh (FM) approach has been used for the Project. The flexible mesh allows the model domain to be described as triangles or rectangles of varying sizes. This enables the model to have a high resolution in areas of importance and a low resolution in other areas. This reduces the time required for model simulations to run. The model creates triangular prisms or cuboids and then solves the physical equations in each triangular prism or cuboid in the model. An example of model bathymetry and mesh for the Project is shown in Figure

1. This illustrates how a combination of triangles and rectangles was used to describe and resolve the model bathymetry.

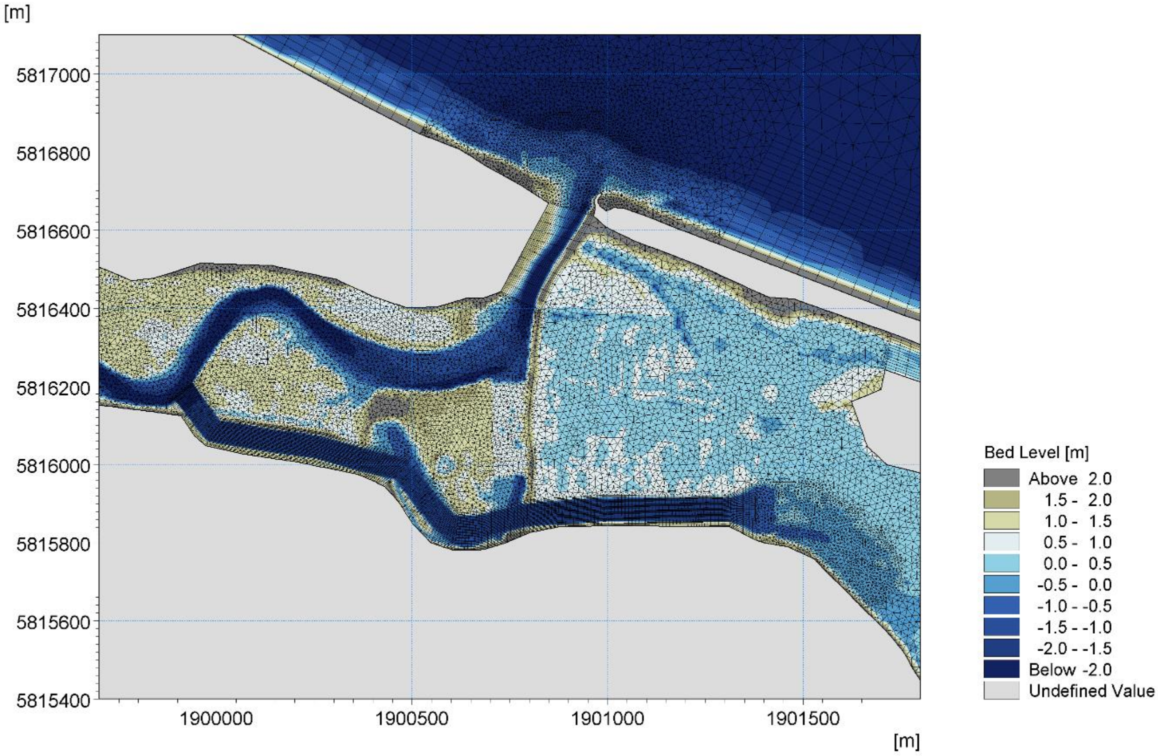

Figure 1 Model bathymetry and mesh for the Proposed Re-diversion Project

MIKE 21 SW – Wave Model

15. MIKE 21 SW is numerical modelling software developed by DHI which solves physical equations governing the growth, decay and movement of waves. A flexible mesh (FM) approach is used similar to MIKE 21 FM model. When coupled with MIKE 21 FM, hydrodynamic behaviour such as wave driven currents (movement of water along shore generated by breaking waves), can also be calculated.

MIKE 21 ST – Sediment Transport Model

16. MIKE 21 ST is numerical modelling software developed by DHI that calculates the potential for sediment transport at a location within a model domain, based on the hydrodynamic and wave conditions provided by the MIKE 21 FM and MIKE 21 SW models. The coupled models produce a morphological model which is able to calculate the response of the sea or river bed due to the calculated hydrodynamics and waves at the location. This morphological model was utilised to assess the likely morphological response (i.e. change in bathymetry) with the Project for the Lower Kaituna River and Ongatoto / Maketū Estuary, for both typical and extreme conditions. This model was also utilised to assess the impact

on flood hazard in the lower river and estuary and navigation through both Te Tumu Cut and the estuary entrance.

MIKE 3 FM - Three Dimensional Hydrodynamic Model

17. MIKE 3 FM is numerical modelling software developed by DHI that solves the physical equations governing the movement of water within a body of water. MIKE 3 FM is a three dimensional model. A three dimensional model divides the water column into a specified number of layers thereby creating a number of triangular prisms or cuboids through the water column. The model then solves the physical equations in each triangular prism or cuboid in the model. This allows differences in the movement of water from the water surface to the river or sea bed to be accounted for in the model predictions.

18. A three dimensional model was required to be able reproduce the behaviour of the salt wedge within the lower Kaituna River. On a flood tide (moving from low to high tide), water levels will increase within the open ocean and force seawater to move up the Kaituna River. The saline seawater is more dense than the fresh river water and therefore some freshwater will float over the salt wedge as it propagates upstream. On the ebb tide (moving from low to high tide), the salt wedge is forced back down the river, by river water, as open ocean water levels decrease. The water column must be split into layers (i.e. not depth averaged) to simulate this type of behaviour. The three dimensional hydrodynamic model not only reproduces the varying currents throughout the water column, it also reproduces the behaviour where the fresh river water is less dense then saline ocean water and will float on top of the ocean water and will inhibit mixing between the two water bodies. This behaviour is illustrated in Figure 2.

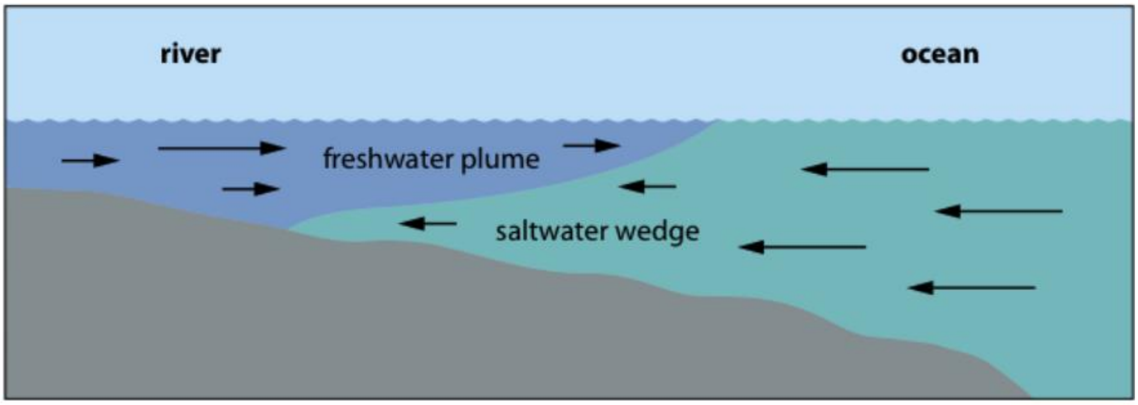

Figure 2 Propagation of saltwater wedge up river (Source: Soren Henrich).

19. The time for three dimensional hydrodynamic computer simulations to complete are significantly greater than two dimensional hydrodynamic computer simulations. Therefore typically the period of time you simulate with a three dimensional hydrodynamic model is

normally significantly less than period of time you can model with a two dimensional hydrodynamic model.

20. The three dimensional hydrodynamic model was used during the modelling for the Project for all aspects of the impact assessment where it was important to reproduce mixing between the river and ocean water. This included assessing the impacts on the salt wedge in the river, assessing changes to salinity within the estuary and assessing changes to water quality (for blue-green algae, shellfish collection, bathing suitability and nutrients), of the water which will enter the estuary from the river via Fords Cut. To significantly reduce simulation run times, a two dimensional model was sometimes used to assess mixing of the water from the re-diversion and the water from open ocean within the estuary and the resulting water quality.

21. Blue-green algae, bacteria (indicators for bathing suitability and shellfish collection) and nutrients were included in both the two and three dimensional hydrodynamic models as tracers. The tracer diffuses throughout the model according to selected diffusion parameters in the model and advects according to the movement of water predicted by the model. Diffusion describes the spread of particles through random motion from regions of higher concentration to regions of lower concentration and is analogous with dispersion, while advection is the transport of particles as a result of the movement of the fluid which contains the particles. A good illustration of the difference between diffusion and advection is adding sugar to a cup of coffee. If you stir the sugar into the coffee (adding advective transport) it will spread throughout the coffee much faster than allowing diffusion to spread the sugar through the coffee on its own.

22. Blue green algae and nutrients were included as conservative tracers, which means they did not decay. This was not deemed suitable for bacteria, which has a relatively high die off rate, especially in sunlight with clear water. Suitable decay rates were selected for the bacteria that were considered conservative, consistent with decay that would occur in turbid water or in non-sunlight hours.

LITDRIFT – Littoral Drift Model

23. Littoral drift is the process by which beach sediment is moved along the shoreline predominantly by wave driven currents generated by breaking waves. LITDRIFT is numerical modelling software developed by DHI that calculates the amount of sediment which will be transported by littoral drift through an assumed coastal profile. A coastal profile is the bathymetry along a line normal to coastline from the sand dune typically out beyond the zone of wave breaking. The model is significantly simpler than two or three dimensional hydrodynamic models, which allows simulations to be carried out for much

longer time frames. For the Project the LITDRIFT model was used to assess the movement of sediment along the Maketū coastline over a ten year period.

Table 1 Overview of models applied in study.

Area of Application	Model	Purpose	Provides Data to
Wave climate	DHI Pacific Ocean wave model (MIKE 21 SW).	Generate boundary conditions for regional wave model.	Regional wave model.
	Regional Bay of Plenty wave model (MIKE 21 SW).	Generate 10 year wave data time series at study site.	LITPACK, local wave model component of morphological model.
	Local wave model (MIKE 21 SW)	Wave component of morphological model	Local morphological model.
Littoral sediment processes	LITPACK (LITDRIFT module).	Calculate long term littoral sediment transport rates.	Coastal impact assessment.
Coastal hydrodynamics	Regional hydrodynamic model (MIKE 21 HD FM)	Generate boundary conditions for 2D local hydrodynamic model.	Local 2D hydrodynamic model.
Coastal, river and estuary hydrodynamics	Local 2D hydrodynamic model (MIKE 21 HD FM)	Hydrodynamic component of morphological model and generate boundary conditions for 3D hydrodynamic model.	Local morphological model and local 3D hydrodynamic model.
Salinity distribution	Local 3D hydrodynamic model (MIKE 3 HD FM)	Assess salinity distribution within river and estuary	Salinity distribution assessment
Water quality	Local 3D hydrodynamic model – river only (MIKE 3 HD FM)	Assess blue-green algae, bacteria and nutrient concentrations which enter estuary from river.	Local 2D hydrodynamic model – no river
	Local 2D hydrodynamic model – no river (MIKE 21 HD FM)	Assess blue-green algae, bacteria and nutrient concentrations within estuary	Water quality assessment
River mouth and estuary (including estuary mouth) hydraulics and morphology	Morphological model - sediment transport (MIKE 21 ST) coupled with local hydrodynamic (MIKE 21 HD FM) and wave models (MIKE 21 SW)	Assess effects of coastal sediment processes and river and estuary processes including impact of flood events on water levels	Assessment of behaviour of morphological river and estuary including flood level assessment.

DATA COLLATION AND COLLECTION

24. To develop and calibrate/validate the numerical models outlined above, an extensive field data collection campaign was carried out to complement any existing available data. The collection campaign included bathymetry, sediment grab samples, salinity profiles, wind and hydrographic data from selected locations within river, estuary and near shore environment. A description of the different types of data collated or collected for the study and how this data was utilised for the study is summarised in Table 2.

25. The data campaign for the Project was designed to provide an appropriate data set for the numerical models reliant on the data. Particular focus was placed on obtaining an excellent bathymetry data set, since an accurate and reliable bathymetry is a key component of the types of models developed for the Project. A good bathymetry will significantly improve the

accuracy of such a model. In most cases there was even a substantial overlap between the different bathymetry data sources to ensure the correctness of the bathymetry data.

Table 2 Overview of data utilised for this study.

Data Type	Description	Time Frame	How Data Utilised
Bathymetry	Single and multibeam survey	March / April 2013	Estuary ebb delta, surf zone, lower Kaituna River including ebb delta.
	C-MAP (Nautical Charts)	N/A	Open ocean model bathymetry offshore of LiDAR coverage.
	LiDAR	May 2013	Estuary and open ocean bathymetry.
	Beach profiles	1978 to 2013	Long term littoral processes assessment using LITPACK.
Hydrographic	Ford's Loop - Water levels	March / April 2013	Calibration of 2D and 3D local hydrodynamic models.
	Ford's Cut – Water levels and currents	March / April 2013	Calibration of 2D and 3D local hydrodynamic models.
	Mid estuary – Water levels and currents	March / April 2013	Calibration of 2D and 3D local hydrodynamic models.
	Estuary entrance – Water levels and currents	March / April 2013	Calibration of 2D and 3D local hydrodynamic models.
	Offshore of Okurei Point – Water levels and currents	March / April 2013	Calibration of 2D and 3D local hydrodynamic models.
	Offshore of Okurei Point – Significant wave height, mean wave direction,	March / April 2013	Calibration of local wave model.
	13km off Pukehina Beach Significant wave height, mean wave direction, wave period.	2003 to 2010	Calibration of regional wave model.
Sediment grab profiles	River, estuary and open ocean	April 2013	Sediment characteristics for morphological and LITPACK models.
Flow transects (full tidal cycle)	River mouth, Ford's Cut culverts, estuary entrance	4th April 2013	Calibration of 2D local hydrodynamic model.
	Offshore of Okurei Point	4th April 2013	Validation of 2D local hydrodynamic model.
Freshwater inflows	Inflows for significant freshwater sources	1990 – 2013 or March / April 2013	Analysis of flow occurrence. Inflows for local 2D and 3D hydrodynamic and water quality models.
	1% and 5% AEP design hydrographs for significant sources	N/A	Inflows for morphological model
Drains flows	Base and rain event inflows for significant contributors of pollutant to estuary.	N/A	Inflows for local 2D and 3D hydrodynamic and water quality models.
Salinity profiles	River and estuary	4th April 2013	Calibration of 3D local hydrodynamic model
Salinity	Ford's Cut, mid estuary and estuary entrance	March/ April 2013	Calibration of 3D local hydrodynamic model
Water quality	Blue-green algae, bacteria and nutrient data within estuary and river.	1990 - 2013	Generation of appropriate model boundary conditions. Water quality model validation.
Climate	CCMP wind	2000 – 2010	Forcing for regional and local wave models.
	NOAA wind	March/ April 2013	Forcing for regional wave and hydrodynamic models.
	Wind from estuary	March/ April 2013	Forcing for local wave and hydrodynamic models.
	Tauranga Atmospheric Pressure	March/ April 2013	Assess impact of atmospheric pressure on water levels.

MODEL CALIBRATION / VALIDATION

26. It is standard practice to calibrate or validate a numerical model to improve and illustrate the predictive ability of a model.

27. The predictive ability of a numerical model is determined by comparing the predictions of the model with observed data. For example, for the two dimensional hydrodynamic model of the lower river and estuary, we used derived open ocean water levels and river flow to force the movement of water within the model. Observed water levels, currents and tidal flow data were compared with those predicted by the model at locations from within the model domain. Model inputs or selected parameters within the model were then adjusted to improve the agreement between the observed and predicted data. This is typically called model calibration.

28. If the calibrated model is then shown to be able to satisfactorily predict the hydrodynamics for the existing situation for periods different than the calibration period (typically called model validation), it is reasonable to assume that the model, modified to include a proposed situation, will adequately predict the hydrodynamics for this proposed situation. A similar approach can be assumed suitable for the other numerical models (i.e. morphological and three dimensional hydrodynamic models).

29. The predictive ability of the hydrodynamic component of the morphological model was assessed using water level, current and tidal flow data (i.e. the volume of water flowing into and out of the river or the estuary) collected at different locations within the lower river and estuary.

30. The predictive ability of the morphological model was assessed using bathymetry surveys carried out for the Kaituna River mouth, pre and post a significant flood event within the river. Model validation of the morphological model was achieved by illustrating the model could reasonably reproduce the changes in bathymetry that occurred for the river mouth when the significant flood event was simulated.

31. The three dimensional hydrodynamic model was calibrated so that the model could reasonably reproduce the behaviour of the salt wedge in the lower river over a tidal cycle and the subsequent salinity within the estuary. The model was then validated against the less extensive longer term salinity data set collected within the estuary, which indicated the model was reasonably predicting the ratio of fresh and salt water entering the estuary from the river and the resulting mixing with the ocean water entering the estuary through the estuary mouth.

32. It is my opinion that suitable calibrations and/or validations were achieved for all of the developed numerical models and the predictive ability of the numerical models was within the limits of what would be considered industry standard. The large amount of data that was collected for the Project, during the data collection campaign, increased the confidence in the predictive abilities of the models.

PEER REVIEW

33. My work on the Project was internally peer reviewed at DHI by Dr Claus Pederson, a Coastal Geomorphologist with over 20 years experience, Jørgen Krogsgaard Jensen, an Ecologist with over 35 years experience and John Oldman a Principal Coastal Scientist with over 30 years experience. The client also carried out a number of external peer reviews of both:

    33.1 the model development and calibration; and

    33.2 the interpretations and findings from the numerical modelling assessments.

34. The model peer reviews were completed before the commencement of the actual assessments to ensure all parties deemed the performance of numerical models satisfactory. This is best practice for this type of numerical modelling study.

KEY FINDINGS

35. A numerical modelling study was carried out to assess the impact of the Project, namely of the proposed partial re-diversion of the Kaituna River to the Ongatoro / Maketū Estuary and the creation of new wetland areas. The study focussed on assessing changes in the hydrodynamics, morphology and water quality that may occur in the lower Kaituna River and Ongatoro / Maketū Estuary with emphasis on:

    35.1 The volume of additional water that will enter the estuary from the river through the proposed re-diversion channel;

    35.2 Changes in morphology of the lower river, estuary (particularly Papahikahawai Creek and the flood tide delta), spit and river and estuary entrances for typical and extreme conditions;

    35.3 Flood risk for lower Kaituna River, estuary and in particular Maketū township;

    35.4 Overall salinity within the estuary for typical and extreme conditions;

35.5 Risk of non-compliance with blue-green algae, shellfish collection and bathing suitability New Zealand guidelines within the lower estuary, due to increased loads from the river; and

35.6 Nutrient concentrations for typical and extreme conditions within the estuary due to increased loads from the river.

36. The predictions from the numerical modelling assessment produced the following key findings for the Project:

Hydrodynamics

37. The key findings for the impacts on the hydrodynamics of the lower river and estuary were as follows:

37.1 The Project will significantly increase the volume of water that enters the estuary from the river and will significantly reduce the volume of water which enters the estuary through the estuary mouth. The morphological model predicted that for a mean tide (tide when there is approximately an average difference in water level between low and high tide at the site), the volume of water that enters the estuary from the river increases from 151,000 to 583,500 m^3 (286% percentage increase) with the Project. Correspondingly, for mean tide, the volume of water that enters the estuary through the estuary mouth decreases from 824,000 to 681,000 m^3 (17% percentage decrease).

37.2 There will not be a significant impact on swimming safety within the lower estuary. This was assessed with the morphological model by comparing how current speeds will change in the lower estuary (area most commonly used for swimming) for the existing and proposed situations for typical river flow and tidal conditions. This showed that currents speeds will not increase a great deal for the swimming area for typical conditions (peak spring tide currents will only increase from 1.27 m/s to 1.40 m/s (a 10% increase) at the diving platform).

37.3 There will be an impact on the flow to the Lower Kaituna Wildlife Management Reserve for typical river flow and tidal conditions. A specifically built two dimensional hydrodynamic model was developed to assess this issue. A way of compensating for this reduction in flow has been identified and this is discussed in more detail in the evidence of Steve Everitt.

37.4 There will be an increase in overall water levels within the estuary which may impact drainage from surrounding farmland unless mitigation is provided. This is discussed in more detail in the evidence of Steve Everitt.

Morphology

38. The morphological impacts of the proposed option in the lower river and estuary were assessed by simulating typical and adverse conditions, for the existing and proposed situations, using the morphological model. The key findings for the morphological impacts of the Project within the lower river and estuary were as follows:

38.1 Within the lower river, it is unlikely there will be new areas of deposition of sediment.

38.2 At present there is a risk of erosion of the inside of the spit north of the existing flood tide delta for typical conditions unless the delta reduces in size. This risk is increased for an extreme flood event with the Project in the short term, but will decrease in the long term subject to erosion of the flood tide delta.

38.3 There is an increase in currents speed in the vicinity of the Maketū Estuary entrance rock wall for significant flood events. This is investigated further in the evidence of Jim Dahm and Steve Everitt.

38.4 The current rate of infilling for the estuary will be halted or substantially reduced. There is also the potential for long term erosion to occur within parts of the estuary, however depending on sediment supply from the river there is also the potential for deposition to occur in some areas, especially in the upper estuary. This is discussed in more detail in the evidence of Jim Dahm.

38.5 Although there will be additional flow through Papahikahawai Creek, there is no evidence that this will increase the risk of scour of the spit to the north of Papahikahawai Creek.

38.6 The estuary mouth will switch from a flood dominated to an ebb dominated system. The ratio of the volume of water exiting compared with entering the estuary mouth will increase from approximately 1.2 to 1.9 with the Project. The current expansion of the flood tide delta will stop or substantially reduce and areas of the delta may even erode. This is discussed in more detail in the evidence of Jim Dahm.

38.7 The Project will not have a significant impact on the morphological behaviour of the river mouth or estuary entrance for adverse or typical conditions. For the river mouth, the models predict that there will be only a very small decrease in the ebb tide flow volume (approximately 4% for a mean tide) through Te Tumu Cut for the proposed option compared with the existing situation. Any water that flows from the river to the estuary is replaced by incoming ocean water on the flood tide. Although there is a significant increase for the flood tide flow volume (approximately 273% for a mean tide) through Te Tumu Cut for the Project compared with the existing situation, the majority of sediment at Te Tumu Cut and across the entrance bars will be transported on the ebb tide. Hence only a significant decrease in the ebb tide volume would have an impact on navigability through the entrance. This is discussed in more detail in the evidence of Dr Martin Single.

Flood Hazard

39. The change to flood hazard with the Project was assessed by simulating a number of flood scenarios (combining different combinations of extreme river flow and sea level), for the existing and proposed situations, using the morphological model. There will be an increase in the flood risk for low-lying parts of Maketū, however these areas of Maketū are already at risk from flooding (especially from elevated sea levels) for the existing situation and the culverts can be operated to manage this risk. The flood risk decreases within the lower Kaituna River. This is discussed in more detail in the evidence of Steve Everitt.

Salinity

40. Impacts of the Project on salinity in the lower river and estuary were assessed by simulating both low and mean river flows with typical tidal conditions, for the existing and proposed situations, using the three dimensional hydrodynamic model. The key findings for the impacts on salinity of the Project within the lower river and estuary were as follows:

40.1 Overall mean salinities will decrease throughout the estuary. The extent of this decrease in salinity is dependent on both the river flow and the location within the estuary.

40.2 For mean flow conditions there will be no significant impact on the maximum upstream extent of the salt wedge in the Kaituna River, while for low river flow the maximum upstream extent of the salt wedge in the Kaituna River will shift 200 – 250 m upstream. This is discussed in more detail in the evidence of Keith Hamill.

40.3 There will be an increase in the salinities at the Titchmarsh intake within the lower Kaituna River, however the Applicant proposes to install a salinity monitor in the river at the intake to ensure that water is not extracted during periods with high salinities. This is discussed in more detail in the evidence of Steve Everitt.

Water Quality

41. The impact of the additional river water to the estuary from the Project on the risk of a blue-green algae bloom, shellfish collection and bathing suitability within the estuary was carried out combining a statistical and modelling (using hydrodynamic models) approach. I note for completeness that the models included loads of bacteria from the river, major drains and the open ocean and did not account for other internal loads (i.e. potential as sediment to function as a bacteria reservoir), meaning it presents a conservative view of the situation.

42. The key findings for the impacts on water quality of the Project within the estuary were as follows:

 42.1 There will not be a significant impact on the percentage of time that the New Zealand guidelines for blue-green algae will be exceeded within the lower estuary. The percentage of time that blue green algae will exceed 15,000 algae cells / ml (considered a critical trigger level for contact recreation) at a selected location in the lower estuary will increase from 3.5% to 3.6% with the Project.

 42.2 There will be a small impact on the percentage of time that the New Zealand guidelines for bathing suitability will be exceeded within the lower estuary. At the Maketū boat ramp, the percentage of time that Enterococci bacteria exceed 280 counts / 100 ml (considered a critical trigger level for bathing suitability) increases from 2.0% to 3.3% with the Project. It should be noted that removal of dairy cows from the margins of the upper estuary will reduce the internal loading of bacteria, but this was not included in the model as the reduction could not be accurately estimated.

 42.3 For the existing situation the New Zealand guidelines for shellfish gathering (specifically that concentrations of 43 faecal coliforms should only be exceeded 10% of the time) is not met. The Project further exacerbates this non-compliance. This is discussed in more detail in the evidence of Keith Hamill.

43. For a nutrient impact assessment, simulations were performed for both a dry weather event and a rain event using the hydrodynamic models. It is predicted that the Project will only have a small increase on mean nutrient levels within the estuary. I note for completeness that the dilution model included loads from the river, major drains and the open ocean and did not account for other internal loads, meaning it presents a conservative view of the situation. This is discussed in more detail in the evidence of Keith Hamill.

SEDIMENT LOADS

44. A potential source of sediment to the study site (specifically the Kaituna River mouth and estuary) is sediment supplied from the Kaituna River. What is of importance for the morphological behaviour of the river mouth and estuary is bed material load. Bed material load contains coarser sediment such as sand and gravel which maybe either transported along the river bed or in suspension, and interacts with the bed, thus contributing to erosion and deposition of the bed.

45. However it was concluded through sediment budget calculations that the sediment supply to the Kaituna River mouth from littoral transport (i.e. along the coast) is significantly greater than what is currently supplied by the river (45,000 to 52,000 m^3 per year of sediment via littoral drift compared with 7,000 to 8,500 m^3 per year of sediment transported down the river). It should also be noted that the 45,000 to 52,000 m^3 per year of sediment via littoral drift is a net rate. The net rate is an average over a year of the amount of sediment moving through a line (in both easterly and westerly directions) normal to coastline from the sand dune typically out beyond the zone of wave breaking. The gross amount of sediment movement was calculated to be 400,000 m^3 per year, which is far greater than any river supplied sediment. For this reason, to simplify the modelling approach, bed material supplied from the Kaituna River was not considered for the morphological assessments.

46. Pattle Delamore Partners Ltd (PDP) was engaged by the consent authority to review a number of technical reports supporting the resource consent application. During this review they raised concerns that the bed material supplied from the Kaituna River was not considered for the morphological assessments. PDP highlighted that previous investigations by NIWA indicated that there is the potential the lower river is actually almost at a tipping point (due to current sinks for sediment being filled in) and bed loads may increase significantly in the future (by approximately three times the amount). No work has been completed to date to provide a timeframe (i.e. will it occur in years or decades) for when this significant increase in river supplied sediment may occur.

47. It remains my view that, since the important hydrodynamic behaviour will not be significantly changed with the Project (i.e. ebb tide volume and volume of water through entrance for majority of floods) the morphological behaviour of the entrance will likewise not be significantly impacted. It is my opinion that this would be the same situation if river supplied sediment were to become more significant. However, to support this opinion we carried out a number of sensitivity tests, where a more significant sediment river supply was included in the model.

48. An extreme flood event was simulated, with a total volume of 60,000 m^3 of river supplied sediment to the Kaituna River mouth (over six times what is currently supplied on average per year). A typical year was also simulated, with a total volume of 15,000 m^3 of river supplied sediment to the Kaituna River mouth (note the current river bathymetry cannot realistically transport 15,000 m^3 of sediment during a typical year). For the extreme flood event, there was a localised increase in flood levels at Kaituna River mouth, which did not impact the original findings of the flood hazard assessment. For the typical year simulation, the comparison of the behaviour of the river mouth when comparing the existing situation with the Project, was similar to the original assessment, hence the original findings did not change. The finding that the Project will not have an impact on navigation through Te Tumu Cut, even when considering a possible increase in river supplied sediment, is discussed in more detail in the evidence of Dr Martin Single.

49. There have also been queries over the potential adverse impacts of additional sediment loads to the estuary with the Project. This is addressed in paragraph 58 below, in response to Mr Harwood's submission.

VALIDATION OF KEY FINDING

50. A key finding of the numerical modelling assessment is that the Project will not have a significant impact on the volume of water that exits through Te Tumu Cut on the ebb tide. This is the reason why it has been concluded the Project will not have an impact on morphological response of the Kaituna River mouth and therefore no significant impact on either navigation or flood release at Te Tumu Cut.

51. To provide further evidence that this finding is accurate and that no mitigation is required, further validation has been proposed, to take place once the re-diversion is operating. The proposed conditions (Proposed Condition 27) require that the volume of water which flows through Te Tumu Cut, for the existing and proposed situations be measured. This will be collected for specified river flows and tidal conditions.

52. If the average ebb tide volume is shown to have decreased by greater than 20% for equivalent low flow conditions with the proposed re-diversion operating, the Consent Holder will be required to alter the Project settings to ensure that this is figure is not exceeded (Proposed Condition 27.4). It was calculated that for low flow conditions decreasing the average ebb tide volume by less than 20% would not have a noticeable impact on either navigation or flood release at Te Tumu Cut. This is discussed further in the evidence of Dr Martin Single.

RESPONSE TO SUBMISSIONS

53. I have considered the submissions that have raised issues relating to the scope of my role in the Project.

Eion Harwood

54. Mr Harwood expresses concern that there will be a lack of water current to flush out the anoxic mud and that this may settle out in mid estuary. He reasons that although additional water will enter from the river to the estuary, the energy of this additional water will dissipate quickly once it enters the estuary and there will not be an increase in current speeds for the upper estuary as the numerical model predicts.

55. For the Project, the additional water from Fords Cut will flow through the upper estuary where it will typically meet the water body through the estuary entrance in the mid estuary. Under the existing situation these water bodies meet more in the upper estuary. The fact we have significantly more incoming water from the re-diversion channel filling up the mid to upper estuary (by flowing through the upper estuary) is why you see a significant increase in current speeds and flushing for the upper estuary.

56. I agree that there is a dissipation in energy of the incoming river water as it flows into the estuary. We predict a decrease in the current speeds from the upper to mid estuary for the Project as the estuary widens. However, even though this occurs, the current speeds are still enough to encourage significantly more flushing of the upper estuary than occurs under the existing situation.

57. I do not consider Mr Harwood's concern that the anoxic mud will settle in the mid estuary to be likely to eventuate. There are currently no significant areas of fine sediment (mud) within the mid estuary, indicating that current speeds for even the existing situation are of a magnitude to not allow the long term deposition of fine sediment (mud). Since current speeds will remain above the minimum required to suspend and transport mud and silt particles for this area of the estuary for the Project, it can be assumed that any anoxic mud transported into the mid estuary will not be allowed to settle and will most likely be transported out of the estuary. Keith Hamill discusses the potential impacts of any increase in the level of anoxic mud in the estuary, should it occur.

58. Mr Harwood also raises concerns that there will be additional sediment loaded water introduced to the estuary (especially during flood events). For typical conditions it is unlikely that there will be a significant supply of sediment from the river to the estuary and any

suspended sediment transported to the estuary is likely to be fine and remain in suspension. As a result, the majority will be transported out of the estuary. I agree that during a large flood event there is the potential for a supply of sediment from the river to the estuary, which may result in deposition of sediment occurring in the upper parts of the estuary, for areas where current speeds are not large enough to keep the river supplied sediment in suspension. It is my understanding that the detailed design of the Project will minimise the amount of sediment that would be transported to the estuary from the river during large flood events through the detailed design of the re-diversion connection with the river (i.e. shape and exact location on river).

59. Lastly, Mr Harwood also comments on the fact we provide data for an adverse weather event that occurred on 16 April 2013 but says this is minor in comparison to what can happen. Although this comment is true, the flood hazard assessment (in Section 8 of the DHI report) was actually carried out for significantly greater events than what occurred 16 April 2013, meaning more adverse conditions were taken into account. The findings of the flood hazard assessment illustrate that the Project has the potential to increase the flood risk at Maketū Township, however measures have been developed which will mitigate this risk. This is discussed in more detail in the evidence of Steve Everitt.

60. There have been a number of submissions relating to concerns that the Project will have an impact on navigation through the river mouth. Some of these concerns are based on a misunderstanding that the significant increase in water flowing from the river to estuary will result in less water flowing through Te Tumu Cut. However, this is not the case as detailed in paragraph 38.7. This is discussed in more detail in the evidence of Dr Martin Single.

SECTION 42A REPORT

61. PDP raised a concern similar to Mr Harwood around the deposition of re-suspended anoxic mud in the upper to mid estuary (see paragraph 57 above). Although there may be some minor areas of deposition within the upper estuary where current speeds are not large enough to keep the mud in suspension, it is concluded that the majority of the mud will be flushed out of the estuary. This was discussed at caucusing with PDP on 25 March 2015 and agreement was reached that it is not a major concern. This is discussed further in the evidence of Keith Hamill.

62. PDP raised a concern with the fact that flood flows will be diverted from the river to the estuary for some situations and less scour will occur at the entrance and across the entrance bars. The assessment indicates this will only have a short term impact on the entrance bathymetry and will not have a noticeable impact on navigation safety through the

entrance. This issue was discussed in some detail as part of the caucusing with PDP on 25 March 2015, and the implications are addressed in the evidence of Dr Martin Single.

CONCLUSION

63. The numerical modelling assessment undertaken by DHI to assess the impacts of the proposed partial re-diversion of the Kaituna River to the Ongatoro / Maketū Estuary was comprehensive with a sufficient level of model calibration/validation to provide confidence in the findings of the assessment. It is proposed that a key finding of the assessment, being that the Project will not have a significant impact on the volume of water that exits through Te Tumu Cut on the ebb tide, will be validated through the collection of additional data before and after the partial re-diversion is implemented.

Ben Tuckey

17 April 2015