In the matter of the Resource Management Act 1991

And

In the matter of an application for Resource Consents by Oceania Dairy Limited to construct and operate a pipeline to discharge treated wastewater into the ocean.

STATEMENT OF EVIDENCE OF LUIZ LOBO COUTINHO FOR OCEANIA DAIRY LIMITED

28 May 2020

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INTRODUCTION

1 My full name is Luiz Lobo Coutinho.

2 I hold a BE (Environmental) by the Pontificia Universidade Catolica do Rio de Janeiro (PUC-Rio, Brazil) and a MSc in Hydrogeology, Engineering Geology and Environmental Management by the Technische Universität Darmstadt (TU-Darmstard, Germany). These qualifications have been reviewed by Engineering New Zealand and the New Zealand Qualifications Authority (NZQA) and accepted as a Washington Accord equivalent.

3 I am an environmental engineer working at Babbage Consultants Limited (Babbage) since February 2015. Since then, I have been involved with different projects for Oceania Dairy Limited (**ODL**), including assessments of groundwater take and discharge.

4 I have more than ten years' experience as an environmental engineer, including the last five years at Babbage. I have worked as a consultant for both the private and public sectors (in Rio de Janeiro from 2008 to 2009 and from 2014 to 2015, in Saudi Arabia from 2013 to 2014), as a researcher (at PUC-Rio in 2007 and in TU-Darmstadt from 2009 to 2011), and as a volunteer in environmental education and development (at the Amazonia State in Brazil from 2006 to 2007).

5 During my time at Babbage, I've worked on groundwater projects for residential sites, and the dairy, mining, and forestry industries. This has included assessing the effects of groundwater takes and discharges and investigation into groundwater quality and contamination. I've also carried out assessments of environmental effects on:

5.1 proposed dredging activities in the Coromandel Peninsula;

5.2 the related discharge of dredged material offshore;

5.3 coastal processes and coastal hazard and the effects of a proposed seawall construction on the Kapiti Coast.

6 I have also worked for El Paso Oil and Gas, in 2007, where I was involved in their Environmental Emergency Plan for the offshore oil and gas exploration campaign at the coast of Bahia, Brazil. Part of that work involved assessing coastal processes in the exploration area, assessment of different oil-spill scenarios and plumes and identifying and quantifying risk for environmentally sensitive areas.

7 I have also carried out research into coastal process including wave and current driven coastal erosion. The research, carried out partially in New Zealand, included modelling of sea conditions and sediment transport. The literature review on the subject and results of the research were part of my MSc Thesis for TU-Darmstadt.

8 In preparing this evidence I have reviewed:

8.1 The reports and statements of evidence of other experts giving evidence relevant to my areas of expertise, including:

8.2 Infrastructure construction, Babbage Consultants Limited (evidence presented by Mr Suman Khareedi)

8.3 Oceania Dairy Outfall Dispersion Modelling, report by eCoast Limited;

8.4 Coastal Hazards Assessment, report by Babbage Consultants Limited;

8.5 Wastewater treatment and alternatives, Babbage Consultants Limited (evidence presented by Mr Paul Duder);

8.6 The parts of the section 42A report relevant to my area of expertise.

8.7 Submissions relevant to my area of expertise.

CODE OF CONDUCT

9 While this is a Council Hearing, I acknowledge that I have read and am familiar with the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note 2014, and agree to comply with it. I confirm that this evidence is within my area of expertise, except where I state that this evidence is given in reliance on another person's evidence. I have considered all material facts that are known to me that might alter or detract from the opinions I express in this evidence.

SCOPE OF EVIDENCE

10 My evidence is confined to the matters associated with groundwater at the proposed pipeline path, coastal processes and coastal hazards at the proposed discharge location and along the coastline and the interactions of these with the proposed activity. My evidence includes:

10.1 A description of groundwater along the proposed pipeline path.

10.2 An assessment of effects from the construction of the proposed pipeline on groundwater.

10.3 A description of the coastal processes and coastal hazards at the proposed discharge location and along the greater beach system from Oamaru to Timaru.

10.4 An assessment of effects of the construction and operation of the proposed outfall in the coastal processes and coastal hazards at the proposed discharge location and along the greater beach system from Oamaru to Timaru.

10.5 A description of the dispersion modelling used, including scenarios modelled, input data, model assumptions, calibration, conservatism, and results.

10.6 A discussion as to how further on-site treatment, prior to discharge, will meet parameters for discharge.

10.7 A discussion on cumulative effects of the proposed discharge

EXECUTIVE SUMMARY

11 My key observations and conclusions are:

11.1 Groundwater along the proposed pipeline path is heavily influenced by the surrounding land use. Both groundwater quality and quantity are affected by the irrigation practices and infrastructure in the region, with groundwater levels varying for more than five metres between the irrigation season and off-season.

11.2 The construction of the proposed pipeline is confined to a narrow area along the road reserve. Any excavation will be relatively shallow (no deeper than 3 metres), and the proposed earthworks will be temporary. Impacts to groundwater are only expected to occur if the earthworks extend into the irrigation season. Any impacts on groundwater will be confined to a small area and expected to be less than minor.

11.3 The coastline at the proposed activity location is an open high energy coast, constantly exposed to strong currents, swells, and winds. The predominant coastal processes are the coastal erosion of the beaches and coastal cliffs and the longshore drift of the eroded material and sediment from the Waitaki River northwards.

11.4 The nearshore sediment transport from the Waitaki River and the coastal erosion of the beach and cliffs along this coast are major sources of sediment to beaches further north, including the coastal barriers along the mouth of Waihao River and the Wainono Lagoon.

11.5 The proposed outfall construction and operation are not expected to change the coastline morphology or affect the natural physical processes acting upon it. Therefore, it is unlikely that the proposed activity will affect the natural erosion and flow of sediment along the beach system.

11.6 The main coastal hazards in the region are coastal erosion and coastal floods. Although at the proposed activity location, a high coastal cliff protects the area from coastal floods, coastal erosion is strongly present.

11.7 The proposed pipeline alignment allows for over 100 years of expected coastline retreat, even considering climate change and sea level rise scenarios of increased erosion rates due to climate change.

11.8 A hydrodynamic numerical model was used to forecast dilution of the proposed discharge and identify the worst-case scenarios for the discharge. An “average year” of hourly dilutions was also modelled to inform the human health risk studies by NIWA. The model is considered conservative, i.e. greater/faster dilution will likely occur.

11.9 Calm conditions were identified as the worst-case scenario for dilution, during which at least 300-fold dilution is expected to occur at a 50 metres radius from the diffusers. Such scenario is expected to happen about two percent of the time and have short durations (i.e. mostly less than 3 hours).

11.10 Expected dilution levels of more than 500-fold at the 50 metres radius form the diffusers are expected to happen over 80% of the time. Further away from the outfall dilution levels are exponentially larger, achieving over 10,000-fold dilution by Morven Beach and the Waitaki River.

11.11 Due to the high energy of the coast and distance to other major sources of contaminants (such as rivers and other existing or proposed outfalls) cumulative effects are unlikely to be detectable. The dilution levels at such distances and the proposed discharge quality implies that any changes in water quality will be orders of magnitude below natural background variations.

EVIDENCE

Hydrogeological Setting

12 The proposed pipeline path is in the Whitneys Creek Groundwater Zone and underlain by the Waitaki Gravel Aquifer ("**the Aquifer**"). As other shallow aquifers of the Canterbury Region, the aquifer is formed by glacial and interglacial deposit sequences in river valleys, resulting in a layered aquifer of gravel deposits with varying horizons of clay-bound, silty-bound and sandy gravels. These layers show a varying thickness across the region, with depths varying from 30 to 60 metres below ground level.

13 The Aquifer is shallow (directly below ground level) and unconfined. Recharge occurs from rainfall and irrigation. Irrigation infrastructure (i.e. channels, and races) have a major influence on the aquifer.

14 According to Rosen & White (2001), since 1971, when the local irrigation schemes began operation, the region experiences high groundwater levels in summer, during the irrigation season, and low groundwater levels in winter. Monitoring data from Oceania confirms this pattern, with recorded groundwater levels rising more than five metres when irrigation starts across the region.

15 Groundwater levels recorded in monitoring bores at and around Oceania are presented in Appendix A and bore locations in Appendix B. The highest groundwater levels occur near the irrigation channels at the northern boundary of the property, where the depth to groundwater can be around two metres below ground level between February and March. Further data obtained from Environment Canterbury, and presented in the map in Appendix B, shows that groundwater levels drop (i.e. the groundwater table is deeper below ground) towards the coast.

Effects of the proposal to groundwater

16 As **Mr. Khareedi** discusses in his evidence, the proposed earthworks for the construction of the pipeline are relatively shallow (three metres deep) and confined to a narrow trench along the road reserve between the factory and the coastline.

17 The proposed earthworks are only likely to intersect groundwater if or when carried out during the irrigation season, and only closer to the factory and irrigation channels where high groundwater levels are observed. There are numerous monitoring bores close to the factory, but less information is available further towards the coast. However, we know that groundwater levels drop significantly between the factory and the coast, and so along the pipeline there will reach a point where groundwater will not be intersected, even if works occur during summer.

18 As detailed in **Mr. Khareedi** evidence, in case of intersecting groundwater, the earthworks will dewater the trenches and discharge the groundwater to land at the nearby fields after going through settling tanks to remove suspended solids.

19 The proposed methodology of dewatering is standard practice in earthworks. The groundwater removed is discharged to the ground within a 50 metres radius of the extraction point, likely on the nearby paddocks or stormwater drains along the roads, where it infiltrates back into the aquifer.

20 There are no expected adverse effects to groundwater quantity from the proposed activity. As the aquifer is shallow, unconfined and of high permeability, any groundwater removed during the earthworks is expected to be returned to the aquifer in short order. Furthermore, any effects are likely to be confined to a small area around earthworks, since recharge from irrigation occurs in all paddocks neighbouring the proposed pipeline path.

21 There are also no expected adverse effects to groundwater quality from the proposed activity. The main recharge of the aquifer occurs through the surface (from rain and irrigation), therefore the discharge of the removed groundwater to surface is not expected to cause any discernible changes to groundwater quality. Any suspended solids carried from the earthworks will be removed through settling tanks and further through soil filtration.

22 An Earthworks Management Plan will be incorporated in the Construction Management Plan. This will include controls such as refuelling vehicles away from the trenches, to protect spills from entering groundwater.

23 The area affected, if any, is relatively small due to the aquifer characteristics and the extents of proposed earthworks. Any impacts to the aquifer are considered temporary and less than minor.

Coastal Environment

24 The proposed ocean discharge location is in a section of the South Canterbury coastline between the Waitaki River and the Waihao River, called the Northern Waitaki Fan (or Northern Fan). This area is part of a larger beach system called the Waitaki System, extending from Oamaru to Timaru, with influences up to Banks Peninsula.

25 The Waitaki System is characterized by an exposed, high energy, coast with a predominantly northwards longshore drift. The beaches in the system are a mixture of greywacke gravel and sand supplied from eroding sea cliffs and rivers (McLean & Kirk, 1969). Hicks et al. (2015) characterised the coastline as a very dynamic, wave-exposed environment comprising steep greywacke sand and coarse gravel beaches.

26 The coastline at the location of the proposed activity (shown in Appendix C) is typical of the Waitaki system, with a narrow strip of (30 m in average) beach in front of large (up to 10 metres high) alluvial cliffs. A large gully intersects the location of the discharge pipe to provide an opening 30 m wide at the cliff face, and extending 90 m further inland from the cliff toe. The gully is not recorded as a natural feature (in local or regional maps and plans) and seems to have been caused (or at least exacerbated) by the discharge from an irrigation exhaust channel. It is also likely that the gully was used to access the beach from the paddocks above the cliff, as it seems to have a man-made, now overgrown, wide path on the southern side connecting the top of the cliff to the beach. The land atop the cliffs and landward from the beach is predominantly used for dairying.

27 Coastal erosion is the predominant costal hazard at the location. Gabites (2012) presented results from ECan's coastal profile monitoring programme for the coastline south of Timaru for the period of 1977 to 2011. The location of the proposed outfall is included in the report and shows erosion rates of approximately half a metre per year.

28 The South Canterbury Coast wave environment is classified as an "east coast swell" type, where the bulk of wave energy acting on the coast is generated by storms in the Southern Ocean. The approach angle of typical storm waves means that refraction is often not complete by the time the waves reach the shore. This results in an oblique wave break at the shore which drives longshore transport of beach sediment northward (Hicks, Hoyle, & Bind, 2015).

29 Hicks and Todd (2003) developed a sediment budget for the Waitaki System, that was later updated by Hicks (2006). The updated sediment budget shows that material from eroding cliffs along the Waitaki Fan (both north and south of the Waitaki River)

are a major source of sediment for the whole beach system, with the erosion of the alluvial cliffs along the Northern Waitaki Fan contributing up to 15 % of the system total sediment input. The Waitaki River is another major source of sediment in the area. This is especially noted on the Waihao-Wainono coast, where this erosion can contribute to up to 30% of the incoming beach material.

30 Climate change is not a coastal hazard by itself, but it changes the incidence and effects of coastal hazards. According to The Ministry for the Environment (2017), gravel beaches (including mixed sand and gravel) with net deficit in sediment supply, will experience an increased rate of retreat. The Regional Coastal Environmental Plan (**RCEP**) for the Canterbury Region delineates two Hazard Zones based on coastal erosion rates and predictions for the next 50 and 100 years (from the RCEP's publication). These two hazard zones are set, at the location of the proposed outfall pipeline, about 75 and 128 m from the current coastline.

31 There is little to no risk of coastal inundations from tsunamis or storm surges in the area due to the location, orientation, and presence of the high cliffs along the coast of the proposed activity. Hazards from tsunami and storm surges are mostly restricted to strong currents, surges in the beaches and cliff face collapses. The Canterbury Tsunami Evacuation Zone Map classifies the coast directly behind the proposed outfall as a *"Red Zone: The tsunami is unlikely to flood land but may cause strong currents and surges in the water and on beaches – stay out of the water and off beaches."* . The area atop the cliffs directly behind the proposed outfall location is not considered an evacuation zone.

Effects of the proposal on coastal processes and hazards

32 As **Mr. Khareedi** discusses in his evidence the proposed outfall will be built without the use of structures along the coastline, permanent or temporary, such as piers or cofferdams. Once completed the pipeline will be below the seabed except for the offshore diffusers.

33 As the construction and operation of the proposed outfall does not include structures in the foreshore or nearshore, there are no expected short-term or long-term changes to longshore drift or to natural coastal process. Therefore, there are no expected effects of the proposed activity on coastal erosion at the location or to the wider beach system. Erosion of the beach and coastal cliff at the proposed outfall location are expected to continue at natural rates and sediment transport northward is not expected to be interrupted, and so there will be no increased erosion to locations further north, such as the Waihao or the Wainono Lagoon.

34 The proposed pipeline alignment allows for over 320 metres of cliff top retreat and 250 metres of beach retreat from long term coastal erosion. Therefore, it is very unlikely that the pipeline will be at risk of being exposed by coastal erosion in the next 100 years.

35 The gully at the proposed outfall location is likely to be used to access the beach during construction and operation. Any changes to the gully are expected to be limited to repairing the existing ramp on the southern side (by removing overgrown vegetation and infilling some areas). Such changes are unlikely to affect coastal hazard risks (such as tsunami run-up or erosion).

Dispersion of effluent

36 eCoast developed and calibrated a hydrodynamic model for the investigation of dilution scenarios for the proposed outfall. The model used Delft Flow and Delft Wave modules from the Delft3D model Suite, which are an industry-standard for hydrodynamic numerical modelling.

37 The model uses offshore data from a series of global databases and calculates the transformations of waves, wind, and currents across a local grid. The resulting waves, wind, and current at each grid cell is then used to determine the behaviour of the effluent plume, such as movement and dilution.

38 The modelling setup used a system of nested model grids with increased resolution closer to the outfall. The cell sizes for the local model grid are eight-by-eight metres. The model grid is created using bathymetry survey data and offshore bathymetry data from LINZ (Land Information New Zealand) and GEBCO (General Bathymetric Chart of the Oceans).

39 The bathymetry survey, carried out by eCoast in late December 2018 to early January 2019, mapped the seafloor at the area around the proposed discharge (approximately 600 by 600 metres), including side-scan sonar surveys to determine the extent of sand-cover versus gravel cover in the nearshore. The results confirm the descriptions in literature (such as Sneddon et al, 2015), of a relatively flat nearshore profile with an absence of permanent hard substrate features, such as bedrock reefs.

40 The model boundary, offshore wave, wind, and currents, are extracted from global models and databases such as:

40.1 TPXO atlas, developed by Oregon State University using TOPEX/Poseidon and Jason satellites, for determining tides;

40.2 European Centre for Medium-range Weather Forecasts (ECMWF) ERA-Interim global atmospheric reanalysis and National Oceanic and Atmospheric Administration (NOAA) Wavewatch III Reanalysis data for waves, including wave height, peak period, wave direction and directional spreading; and

40.3 NCEP Climate Forecast System and Oamaru Airport Aws for wind data. With the Oamaru data being used for the nearshore and the NCEP data for offshore.

41 To calibrate the model (i.e. fine tune the model calculations and verify its accuracy and conservationism), eCoast collected field data for wave, current, and water level with a single point Nortek Aquadopp instrument deployed from 17 December 2018 to 30 January 2019. Wind and wave data recorded were predominantly from the south-east, with strong sustained along-shore currents. The recorded data confirms what is described by the available literature, strong sustained along-shore currents and south-east swells. The data also provided a good variety of sea conditions with up to 1.8 metre swells to calibrate the model.

42 The model calibration simulation was run for the duration of the instrument deployment with a 3-day lead in time from 14 December 2018 until 24 January 2018. eCoast compared the model results for the same period (based on the offshore data and bathymetry survey) with what the instrument actually experienced.

43 The model accurately reproduced the Aquadopp water level record, wave periods and direction, while current speeds and wave hights were generally slightly underestimated. Such underestimation is considered a good layer of conservationism for the model purpose, since it results in greater dispersion in practice than the model anticipates. The model calibration is considered to be reasonably good and provides confidence in dispersion modelling results.

44 Historical wind and wave data for the period 1980-2013 were used to find worst-case and average meteorological conditions. Four scenarios were identified as causing low mixing conditions. Such scenarios occur a total of 20% of the time in total and are therefore considered the 80%ile low dilution scenario. From these, a realistic worst-case scenario for dilution ("calm conditions") happens for only two percent of the time.

45 An iterative process was used to identify an outfall design that increases the dilution rates in all scenarios. Particular attention was given to dilution levels modelled at the edges of the mixing zone (i.e. 50 metres away from discharge) and the dilution levels

at the coastline. Outfall designs modelled started with single point discharges at increasing distances from the coast (300, 400, 500 metres), three (3) discharge points shore-parallel, three (3) discharge points shore-perpendicular, and the spread design (as proposed). The spread design resulted in the highest dilution for the worst-case scenarios modelled. That occurs as the proposed design spreads the discharge points which allows for a higher level of mixing with the sea-water for all wind, current, and wave direction combinations. The other designs tend to result in lower dilution during calm conditions (for single point discharges) or when wind and wave directions are parallel to the diffusers alignment (for shore-parallel or shore-perpendicular designs).

46 The model did not consider any diffuser details, such as valves, standing pipes, or directional flows, only the spatial distribution of the discharge (spread outfall design). This is considered conservative, as any valves or diffuser details that increase the discharge velocity will increase the initial dilution of the ascendant plume.

47 The spread outfall design and the worst-case calm seas scenario were used for assessment of effects to water quality and ecology described further in **Dr Wilson** and **Ms. Coates** evidences respectively.

48 The historical data (wind and wave data for the period 1980-2013) was also used to simulate a representative year-long discharge and hourly dilution time-series. Data extracted from this year-long model was used to guide human health risk assessments (further discussed in **Dr Scott**'s evidence). The modelled dilutions along the coast for the average year are shown in Appendix D.

49 For the discharge modelling, the outfall water was released into the top layer of the model, providing a conservative approach to initial mixing. In practice, the discharge will occur at the seafloor (approximately 8 metres deep), and the buoyant plume will rise to the top, as freshwater is lighter than seawater. Dispersion will occur as the plume rises, as well as once it reached the top layer of water. Further near-field modelling using VISJET and Delft3D were used to model the ascendant plume and the initial dilution at the top layer of water. The near-field modelling results confirm the conservationism of the initial model. Results of the near-field model were presented to ECan in correspondence from eCoast, dated 17 November 2019, as part of a S92 request for further information.

50 The offshore data and hydrodynamic modelling of the discharge confirm the characteristic of the coastline as a dynamic and high energy environment. The model shows that at least 300-fold dilution will be achieved at 50 metres from the discharge

points during calm conditions. Such calm scenarios are not long-lasting, with very low occurrence of events persisting for more than 3 hours. A graph of persistence of events per year, based on historical data, is shown in Appendix D.

51 In most sea conditions (80% occurrence) the dilution is expected to be higher than 500-fold at 50 metres from the discharge points, as more energetic wind and wave conditions occur.

Cumulative effects

52 Other point sources along the coast for cumulative effects are the rivers that discharge nutrient rich water from the farmed catchments and other ocean outfalls. The nearest sources are the Waitaki River 7.5kms to the south, and the Waihao River (11kms) and consented Fonterra Studholme outfall (15km) to the north.

53 Data extracted from the hydrodynamic model (for a set of eight locations along the coast, shown in Appendix D) show that dilution increases exponentially with distance away from the discharge point further along the coast. Dilutions modelled for coastal locations in front of Morven Beach Rd 5 kms to the north and Fisheries Rd 7 kms to the south are mostly well over 10,000-fold.

54 Non-point sources have also been considered, as they form part of the background levels. Therefore, as long as non-point sources remain discharging at similar levels to existing, the cumulative effects of this discharge on modelling have been considered.

55 The water quality at the coast and effects on it from the proposed activity are further discussed by Dr Wilson in his evidence.

56 Based on Dr Wilson's assessment of the current and historical water quality at the coast and expected dilution at distances of the other point sources along the coast, no detectable cumulative effects are expected. Any changes in water quality at such distances and dilution levels are expected to be orders of magnitude below natural background variations.

Issues raised by Submitters

57 Several submitters expressed concerns regarding cumulative effects with other outfalls in the region. As detailed previously, and further discussed by Dr. Wilson in his evidence, the modelling shows that the quality of the effluent and dilution at the nearest point discharge will be so high that no cumulative effects are expected to occur.

Section 42A report

58 The technical report in the S42A report that relates to my evidence are that by Mr. Andrews, regarding the dilution modelling, and by Mr. Gabites regarding the coastal hazards.

59 In general, Mr Gabites and I are in agreement, in that effects on coastal processes from the proposed activities will be minor.

60 Mr. Andrews was provided with further details of the modelling as per a S92 further information request. Mr. Andrews and I are in agreement, that the dilution modelling done is adequate for the prediction of effects of the discharge and that the predictions of dilution plumes by the model are conservative.

61 We have provided justification for the outfall design, in that it was the design that provided the most satisfactory dilution in all sea conditions, including the worst case conditions for dilution. Furthermore, as detailed by **Mr. Kareedi** in his evidence, the outfall is proposed to be under the sea bed and will be no harder to maintain than a T shaped design.

Conditions

62 I have reviewed the conditions that are included with the planning evidence of **Ms Singh**. I consider that these conditions are appropriate, for the reasons outlined above in my evidence.

SUMMARY AND CONCLUSION

63 The aquifer underlying the proposed pipeline path is shallow and unconfined with recharge mainly by surface from rain and irrigation. Due to the surface recharge from irrigation, groundwater levels vary seasonally with high groundwater during irrigation season.

64 The proposed earthworks are only likely to affect groundwater if carried during the irrigation season. Nonetheless any impacts are restricted to a small area where trenches would be dewatered and very minor since the groundwater removed would be discharged nearby and infiltrate back into the same aquifer.

65 The proposed outfall will be located in a section of the coast with 10 m high coastal alluvial cliffs and mixed sand and gravel beaches. This coastline is eroding at a rate of 0.3 to 0.5 m/y. The ongoing erosion of the cliffs along this coastline is an important

source of sediment for the beach system extending all the way to Banks Peninsula, including the barriers of the Waihao River and the Wainono Lagoon.

66 The proposed pipeline construction methodology and alignment are not expected to cause changes on the natural physical process occurring in the coastline. Therefore, it is unlikely that the proposed outfall will affect coastal hazard risks on the coast.

67 The proposed pipeline alignment allows for 320 m of cliff retreat and 250 m of beach retreat, while the predicted coastal retreat for the site over the next 100 years, which includes sea level rise and climate change, is 130 m. Therefore, it is very unlikely that the outfall pipeline will be exposed due to natural coastal erosion in the next 100 years, even considering increased erosion rates due to climate change and sea level rise.

68 A conservative hydrodynamic model was created with international wind and wave datasets and calibrated with field data measurements. The model shows that the worst-case scenario for dilution of the wastewater plume is during calm conditions when dilutions at the edge of the mixing zone (50 metres from the diffusers) is at least 300-fold. Under more common conditions (80% of the time) more energetic wind and wave conditions increase dilutions at the edge of the mixing zone to at least 500-fold.

Luiz Lobo Coutinho
28 May 2020

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Appendix A

Figure A-1: Groundwater Levels at the Site

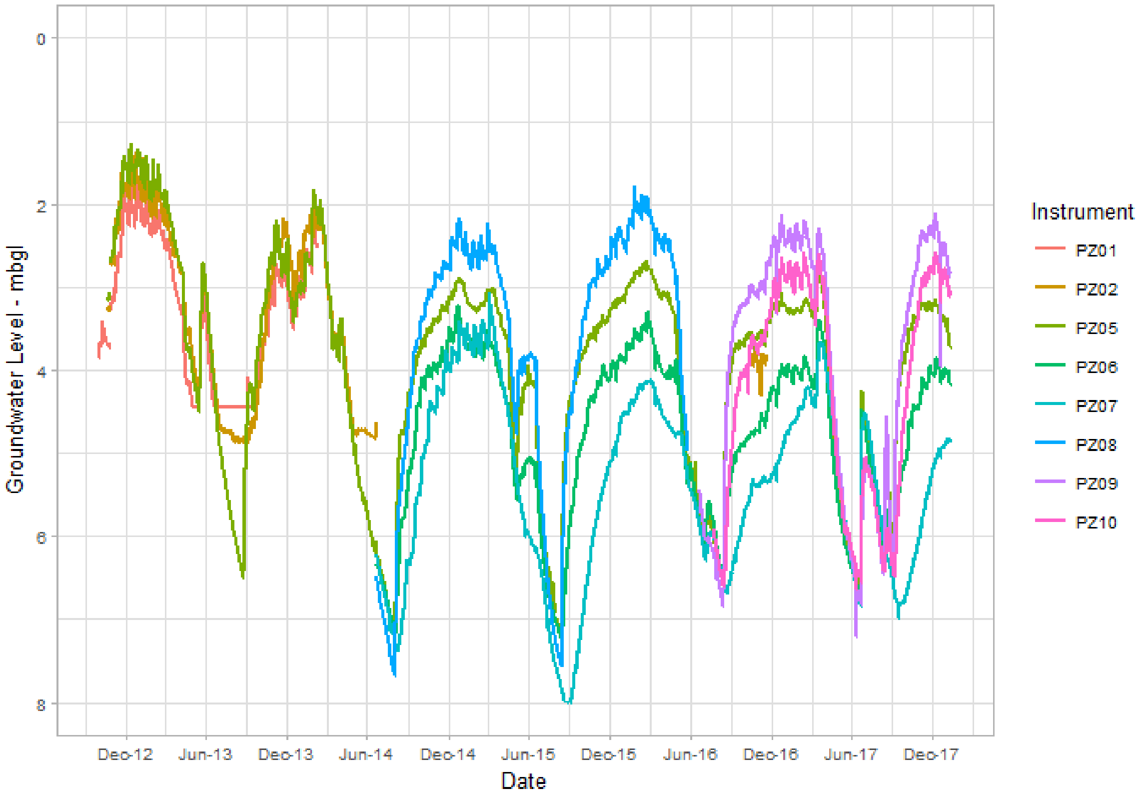
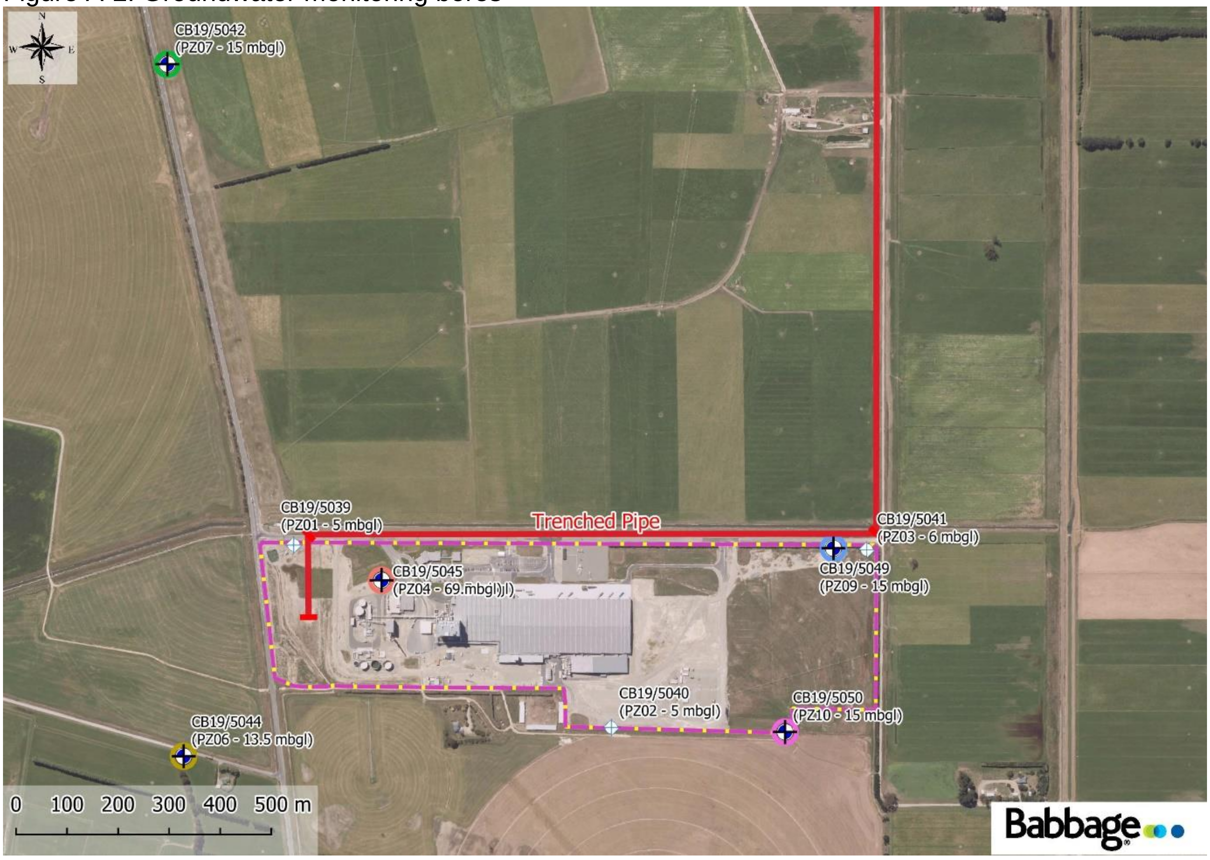


Figure A-2: Groundwater monitoring bores



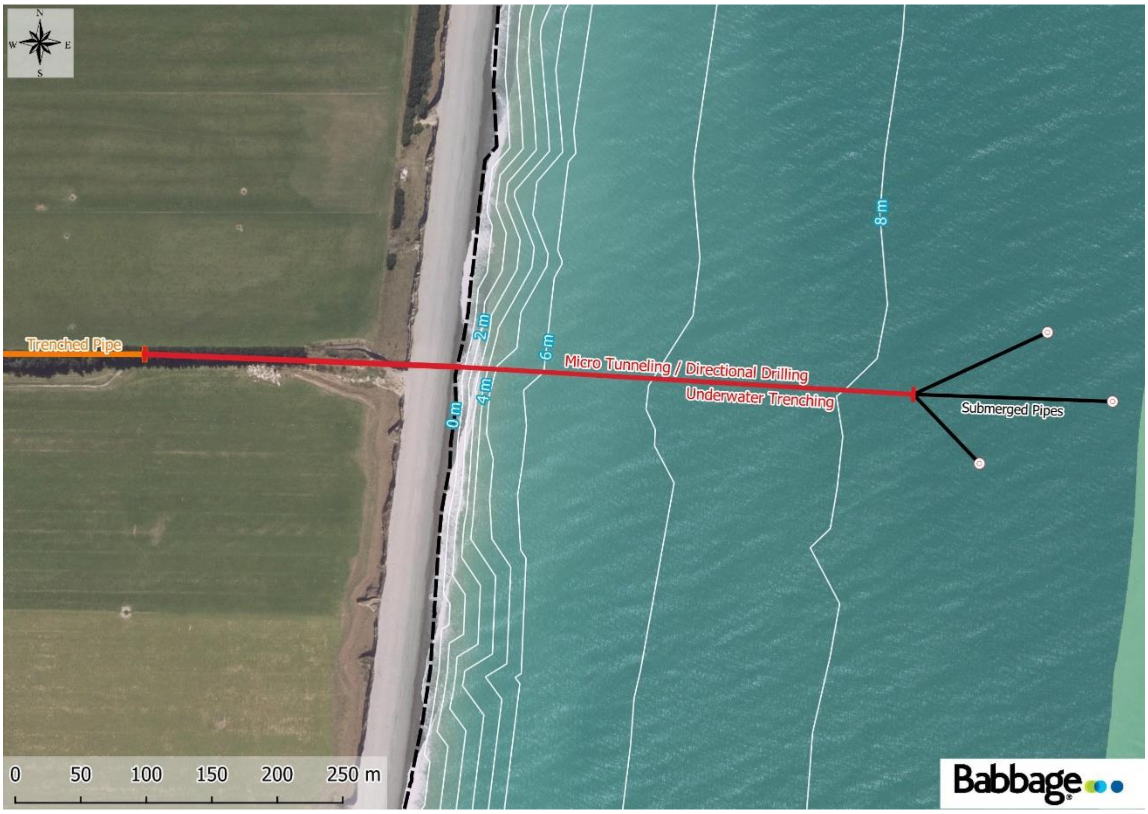
Appendix B

Groundwater Levels by ECAN – pdf to be inserted

Appendix C

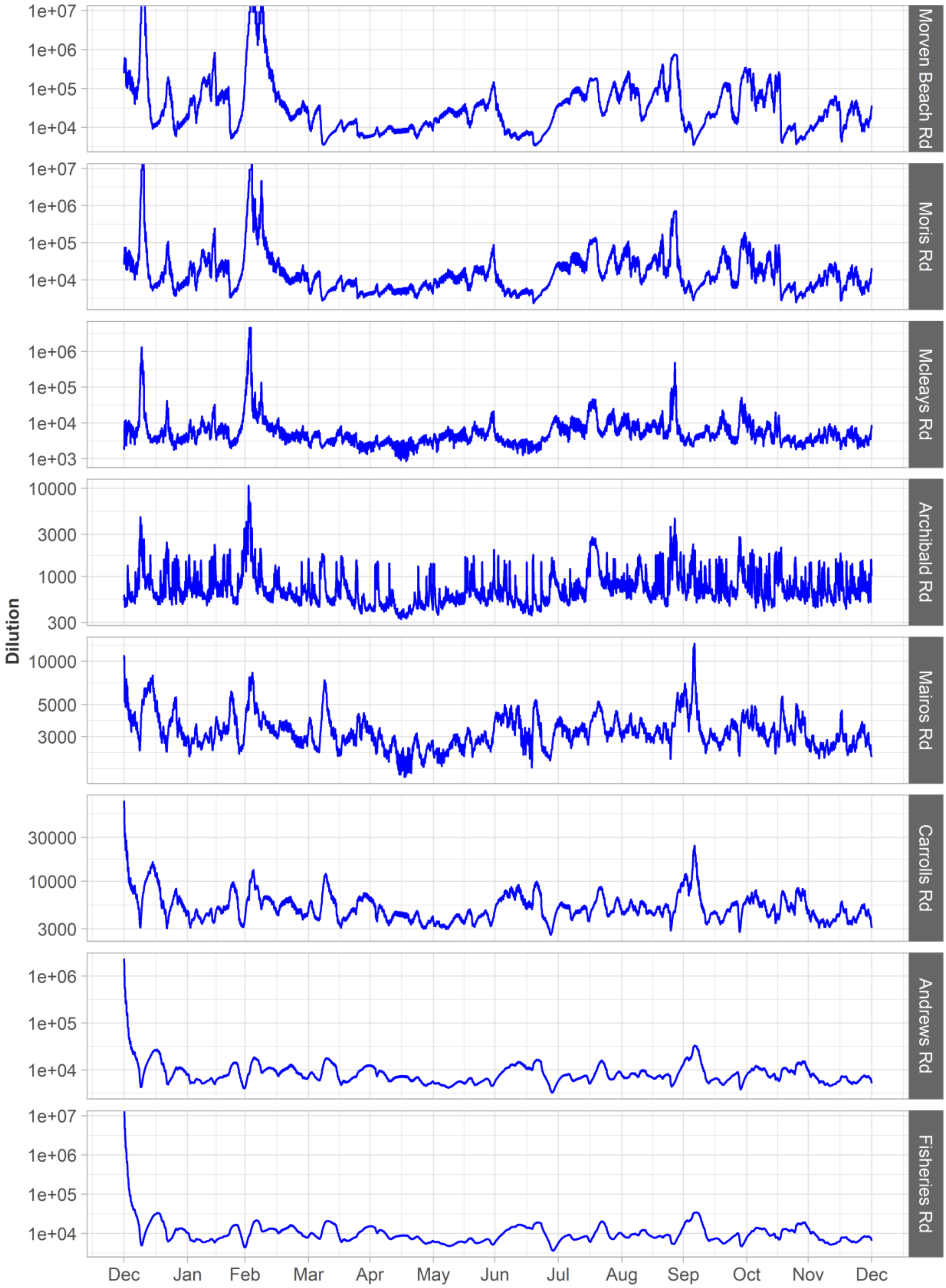
Figure C-1: Proposed pipeline and outfall location on the Northern Waitaki Fan

Figure C-2: Coastline at the proposed outfall location.



Appendix D

Figure D-1: Modelled dilutions for key coastline locations



Appendix D