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ECOLOGICAL ASSESSMENT OF A PROPOSED MUSSEL FARM SITE NORTH-WESTERN FIRTH OF THAMES

For Takutai Ltd.

Application for Resource Consent

Ecological Report

January 2019

REPORT INFORMATION AND QUALITY CONTROL

Prepared for:	Takutai Ltd.

Authors:	Oliver Bone Ecology Consultant	
Reviewer:	Mark Poynter Principal Marine Consultant/Manager	
Approved for Release:	Michael Lindgreen Director	

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EXECUTIVE SUMMARY

Takutai Ltd (Takutai) proposes to develop a mussel farm and spat collecting site in the north western Firth of Thames adjacent to Ponui Island. This report has been prepared by 4Sight Consulting Ltd (4Sight) on behalf of Takutai to assess the ecological suitability of the site and the potential ecological and water quality effects of the proposal. An initial proposed farm site of 87 ha was surveyed in November 2007. Following the initial survey the proposal was expanded to 221 ha with a second survey of the additional ~134 ha completed in October 2018. The information in this report presents the results of both surveys.

A range of parameters have recently been specified by the Waikato Regional Council (WRC) to accompany proposals for marine farms in the Firth of Thames (Keeley et al. 2015). While the proposed farm is within Auckland Council jurisdiction, the WRC information requirements provide a guide which is relevant to this site. Parameters cover water quality, sediment chemistry, benthic fauna and flora, seafloor characteristics, hydrodynamics and farm design.

The field information is supported by a review of the large body of scientific literature that has been generated in relation to the expansion of the mussel farm industry in New Zealand. The field data and literature provide for a comprehensive assessment of the site and the ecological and water quality effects of the proposal.

In terms of water quality, synoptic sampling revealed water temperatures between approximately 16 – 22.5°C and salinity between 34-35 ppt at the proposed farm site. These values are consistent with well mixed open coastal waters. Chlorophyll *a* ranged from 0.0003 - 0.0006 g/m^3. Dissolved reactive phosphorus ranged from 0.0095 – 0.0106 g/m^3 and total nitrogen ranged from 0.08 - 0.3 g/m^3. Water clarity as measured by Secchi disk, ranged from 5.8 – 9.35 m. The water quality data suggests that chlorophyll *a*, temperature and water clarity can vary widely over small spatial and temporal scales at this site. Nutrients were within the ranges reported by other studies in the Firth of Thames.

In terms of sediment chemistry, the total organic matter content in the sediments (as a percentage of dry weight) ranged from 5.5 to 9%. Concentrations of total organic carbon in the sediments ranged from 0.76 – 1.3 g/100g dry wt, total nitrogen ranged from <0.13 – 0.21 g/100g dry wt and total recoverable phosphorus ranged from 610 – 1950 mg/kg dry wt. Total free sulphides were measured in sediment samples taken in the expanded survey area and were determined to be nil (given available analytical methods) or at levels below the laboratory detection limit of 69µM.

Overall, sediments showed levels of total organic matter, total organic carbon and total nitrogen consistent with the ranges in values reported elsewhere in the Firth of Thames. Levels of total phosphorus were somewhat higher than reported elsewhere in the Firth of Thames. Total free sulphides (as an indicator of organic loading) were sampled to provide a TFS baseline and were low.

The benthic fauna and flora were composed of genera that are common and widespread in the NZ coastal environment and community types which have been widely reported in the Firth of Thames.

In terms of seafloor physical characteristics, the topography was confirmed to be relatively homogeneous and the substrates were composed of mud with a minor sand and shell hash component. This too is typical of that reported in other studies of the Firth of Thames.

The site sits in a highly open hydrodynamic setting where tidal and residual currents will ensure a high level of exchange as water passes through the site. Current velocities between 0.16 – 0.33 m.s^{-1} were recorded. This is consistent with the range in velocities reported in other studies of the Firth of Thames and places the site within the 'high-flow' category of Keeley et al. (2013). This suggests that farm derived particulate matter will predominantly be dispersed and accumulation below the farm is likely to be minimal. Furthermore, the farm design, which is highly porous, is expected to encourage mixing and dispersal of particulate matter.

Based on the hydrodynamic setting and the well documented influence of large-scale oceanographic drivers such as El Niño and La Niña cycles in the Firth, it is concluded that phytoplankton depletion is likely to be limited, transient, spatially variable and not to affect ecosystem processes beyond the farm. This is supported by a strong body of local literature and experience.

Overall, comparison of these results with findings from other sites in the Firth of Thames and the New Zealand coast indicate that the site is a typical soft-bottomed area of the outer Firth of Thames. There are no unique physical or ecological characteristics of concern or particular interest in terms of potential effects. From an ecological and water quality perspective, it is concluded that the proposed farm site represents a suitable location for the proposed mussel farming and spat collection activities. Any ecological and water quality impacts from the proposed marine farming activities are not expected to be adverse and of ecological significance (and can be considered to be minor or less than minor).

1 INTRODUCTION

1.1 Background

4Sight Consulting Ltd (4Sight) was engaged by Takutai Ltd (Takutai) to assess the ecological effects associated with their proposal to farm greenshell mussels (*Perna canaliculus*) and collect mussel spat within an 87 ha area in the north western Firth of Thames (Figure 1)

Figure 1: Initial proposed farm site (source GoogleMaps 2018)

Following an initial survey of an 87 ha site, the proposed farm was expanded to the north and west to cover a total area of 221 ha (Figure 2). 4Sight was subsequently engaged to extend the initial survey to account for this expanded marine farm footprint. The expanded survey was conducted within the remaining 135 ha 'L' shaped area. The 'initial' and 'expanded' marine farm surveys are referred to throughout this document to differentiate between the surveys.

Figure 2: 'Expanded' proposed farm site (red boundaries), initial proposed site shaded grey (Source GoogleMaps 2018)

The proposed marine farm is located approximately 4 km to the east of Ponui Island in the north western Firth of Thames. Water depths at the initial site range from ~21 m at the southwest corner to ~24 m in the northeast portion of the site. The initial site was 1200m long (east-west axis) x 700 m wide (north-south axis). The expanded marine farm covers the majority of the initial site and is extended ~ 600 m to the north and ~ 630 m to the west. Water depths at the expanded site range from ~23 m at the southwest corner to ~29 m in the northeast portion of the site. The expanded site is orientated slightly to the east with an east-west axis of 1700 m and a roughly north-west/south-east axis of 1324 m.

For consenting purposes, 'mussel farming' refers to the culture of shellfish greater than 40mm length. A detailed description of the spat catching process is provided in the Planner's Report. This report relates to both activities.

Before the depletion of the natural mussel populations throughout most of the Firth, which was mainly caused by commercial dredging from the 1900's to the 1960's, there were dense beds of wild mussels in the Waimango Point area (Besant and Hooker 1996). It is probable that remnant wild beds remain around the western Firth and beyond, that would provide a source of larval mussels to the proposed Ponui farm. Parts of the Firth have been shown to sustain high spat settlement. Hayden and Kendrick (1992) reported high settlement at 3 sites along the eastern side of the Firth and also reported a long spat season. Spat fall of up to 9000 spat per metre of dropper have been recorded for the Wilson's Bay area (Fisheries Consultancy Services Ltd 2002).

Spat supply is a critical and at times limiting resource to the NZ mussel industry. Spat presently used to stock mussel farms in the Firth of Thames comes predominantly from Ninety Mile Beach in Northland. This spat is expensive to source and carries a high cost in terms of mortality and management and both biological and commercial risk. Any ability to collect spat close to crop farms is advantageous as it allows reduced handling time, potentially reduced mortality of translocated spat, reduced farm and labour costs, reduced biological risks and greater fine tuning between the supply of spat and the crop farm requirements over an extended spat season.

Unlike post juvenile mussels which are farmed all year round, mussel spat catching lines will be deployed over the period August/September through to April/May. Mussel spawning is unpredictable and within this deployment period spat settlement can be highly variable in space and time. A low density of test lines is typically deployed randomly for short periods. These lines are checked regularly and either retrieved after two to three weeks or, during periods of spat settlement, are supported by short periods of higher density spat rope deployment throughout the farm. On retrieval, settled spat lines are transferred to other marine farms or to growing lines within the overall farm area.

1.2 Potential ecological effects

The potential effects of mussel farming occur primarily in the water column and on the seabed (Keeley et al. 2009, Gillespie and Heath 2013, Ministry for Primary Industries 2013) In the water column mussels consume plankton (mainly phytoplankton) and excrete dissolved nutrients and particulate matter (faeces and pseudofaeces). Phytoplankton is the main food source for mussels and other filter-feeding organisms, and the potential depletion of phytoplankton downstream of mussel farms and the cumulative impact of multiple mussel farms within an embayment have often been considered in assessing the potential ecological impact of new mussel farms. Previous predictions of the extent and intensity of food depletion effects for various mussel farm developments in New Zealand generally concluded that mussel farming can lead to measurable water column effects at a local farm scale, but that significant alteration of ecosystem characteristics is unlikely (Keeley et al. 2009).

The main potential effects on the seabed (benthic effects) caused by mussel farming are some organic enrichment of the sediments beneath the farm, and accumulation of biodeposits, biofouling and shell debris dropping from the farm structures. These factors can cause changes to the community of organisms living at the seabed and are most obvious directly beneath the farm. Previous studies and surveys conducted in a range of environments and locations around New Zealand have found that the level of effects of bio deposition from mussel farms is generally low to moderate, and effects are generally not detectable beyond 20 to 50 m from the farm boundary (Keeley et al. 2009).

Other potential effects of mussel farming that may be considered include effects on waves and currents, interference with marine mammal migration or feeding habitat, effects on fish populations, and seabirds.

1.3 Approach taken for the assessment

Auckland Council do not have a mussel farm specific guideline on information requirements to support applications. On this basis the ecological assessment broadly followed the guideline requirements for a baseline survey to support marine farm consent applications as used in the Waikato region. Those guideline requirements are presented in Appendix A of this report. This approach was used because there is a substantial body of research and reports underpinning those requirements (e.g. Forrest and Cornelisen 2015, Forrest et al. 2015, Keeley et al. 2015) and that information is considered to be equally applicable to the Auckland Council area.

The assessment of effects focusses on potential effects to the benthos and water column. The field survey was designed to characterise key ecological features at the site including seabed sediment physical and chemical properties and the faunal community living within the sediment. A synoptic survey of basic water quality chemistry parameters (nutrient and chlorophyll-*a* concentrations) and prevailing current conditions and direction was also undertaken. Both the initial and expanded marine farm survey design were based on the same principles, the only major difference being that the quantity of samples was increased for the expanded survey to account for the larger area being surveyed. Total free sulphides (TFS) in sediments were also analysed in the expanded survey but not in the initial survey.

2 METHODS

Sampling of seabed bathymetry, water quality, sediment physical and chemical characteristics, and seabed biological communities was conducted by qualified 4Sight staff and staff from the University of Waikato Environmental Research Institute. The initial survey was conducted on 6th of December 2017 aboard the University of Waikato vessel Tai Rangahau. The expanded survey was conducted between the 24th – 26th November 2018 aboard the University of Waikato vessel Taitimu. Sample locations are shown for the initial survey (Figure 3) and the expanded survey (Figure 4).

2.1 Bathymetry

In order to depict the bathymetry and seabed topography at the site (both initial and expanded surveys), 40 m wide side-scan sonar swaths along tracks approximately 30 m apart, were made throughout the proposed site using a high-frequency (800 kHz) Lowrance total scan transducer. The position of the side-scan sonar was automatically recorded every 2 seconds along each swath from a GPS and saved in real time to a laptop on board the vessel using Reefmaster software and post-processed with Reefmaster sidescan mosaic to produce geo-referenced images that could be opened in ArcMap v10.5 GIS or Google Earth, where locations of features of interest could be determined.

2.2 Currents

In the initial survey a vessel-mounted RDI Acoustic Doppler Current Profiler (ADCP) was deployed along 2 transects running approximately east-west, and north-south through the site to broadly characterise currents at the site at a particular time and tidal state during the survey. An ADCP uses the Doppler shift to measure currents in the ocean. Data describing full water column currents were collected continuously during each of the transects. In addition to the ADCP transects, the opportunity was taken to deploy a single drogue to characterise the drift trajectory of near-surface currents at a different tidal state during the survey. In the expanded survey six such drogues were deployed, three on the flood tide and another three on the ebb tide. Information generated from the drogue drift trajectories provides 'spot check' information to support the current profiles characterised via ADCP in the initial survey. This aspect of the work was not considered necessary to repeat in the expanded survey.

2.3 Water quality

Water samples for the analysis of total nitrogen, dissolved reactive phosphorous, total phosphorous and chlorophyll *a* were taken at the surface and at mid water. A Van Dorn sampler was used to collect the mid-water samples. Samples were taken at three locations in the initial survey (Figure 3) and at three locations on both a flood and ebb tide in the expanded survey (Figure 4). Samples were stored chilled and delivered to Hill Laboratories for analysis within 48 hrs. Laboratory results and methods used for the analyses are shown in Appendix B.

2.4 Seabed characteristics

Field sampling using a Ponar grab, a modified scallop dredge, and SCUBA was conducted to describe benthic physicochemical and biological characteristics at the proposed site.

2.4.1 Sediment physicochemistry

A 'Petite Ponar' grab (8.2 litres volume) was used to obtain sediment samples to describe sediment physical and chemical properties at six locations in the initial survey and at another six locations from the area of the expanded site in the expanded survey. A sub-sample was taken from the top 2 cm of sediment in each grab sample and transferred to a container (500 ml plastic in the initial survey, 300 ml glass in the expanded survey). The samples were stored chilled and transported to Hill Laboratories within 48 hrs for analysis of organic matter, total recoverable phosphorous, total nitrogen, and total organic carbon. Laboratory results and methods used for the analyses are presented in Appendix B. In the initial survey a second ~500 ml representative sub-sample was also taken and archived for later analysis of sediment grain size distribution if required. In the expanded survey an approximately 50 ml representative sub-sample was taken and analysed for particle size distribution via laser diffraction.

In the expanded farm survey additional triplicate 5ml samples were taken via syringe from the top 2cm of each of the six grabs. These were stored at 1-4°C and transported to Cawthron within 36 hours for analysis of total free sulphides (TFS) using Cawthron protocol 60.102.

SCUBA dive surveys were also conducted to obtain undisturbed sediment samples to aid in characterising sediment texture and to assist in determination of the presence and depth of any redox potential discontinuity layer (redox layer or RPD). A video transect and visual description of the seafloor was also recorded during each dive. In the initial survey a single dive was conducted (Figure 3) and in the expanded survey three dives were conducted (Figure 4).

2.4.2 Infauna

Using the 'Petite Ponar' grab, seabed samples were obtained at 10 locations in the initial survey (Figure 3) and 15 locations in the expanded survey (Figure 4) to characterise the infaunal community (assemblage of animals living in the sediment). The contents of each grab sample were washed through a 0.5 mm sieve in the field, and the retained material was transferred to a plastic jar and preserved in 70% ethanol. Samples were fixed in Rose Bengal stain to assist in detection of small biota. In the laboratory, animals were separated from detritus under a binocular microscope. Processed samples were identified to the lowest practicable taxonomic level and counted by Coastal Ecology Consultants (Mr G. Stephenson).

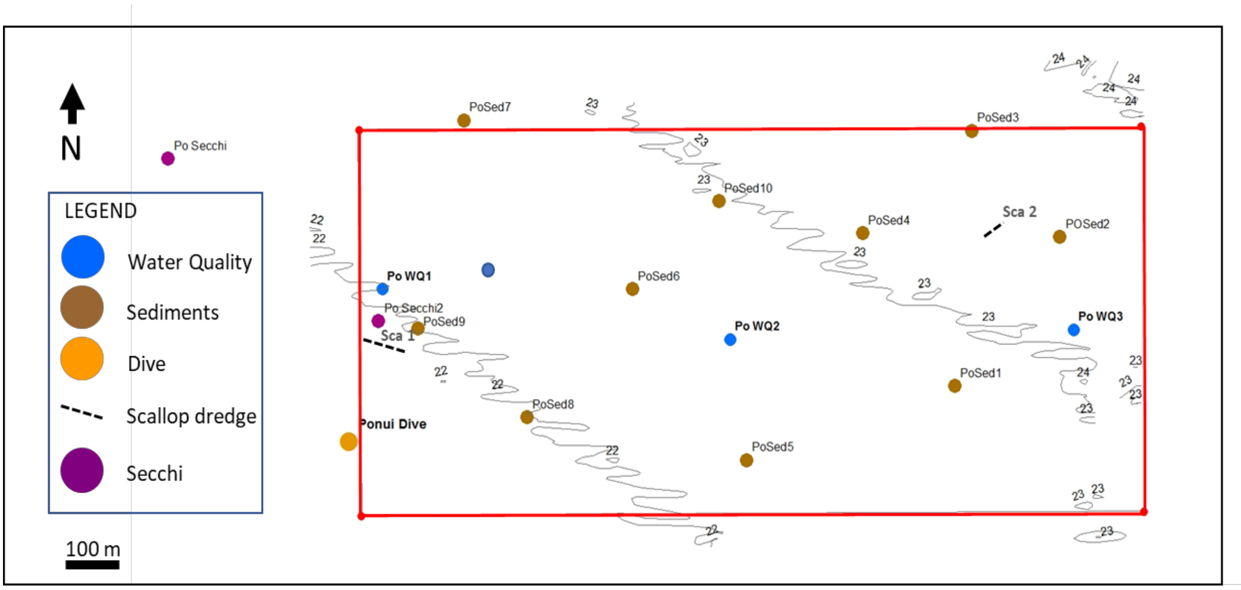

Figure 3: Site map showing sample locations of initial survey. Red line depicts site boundaries.

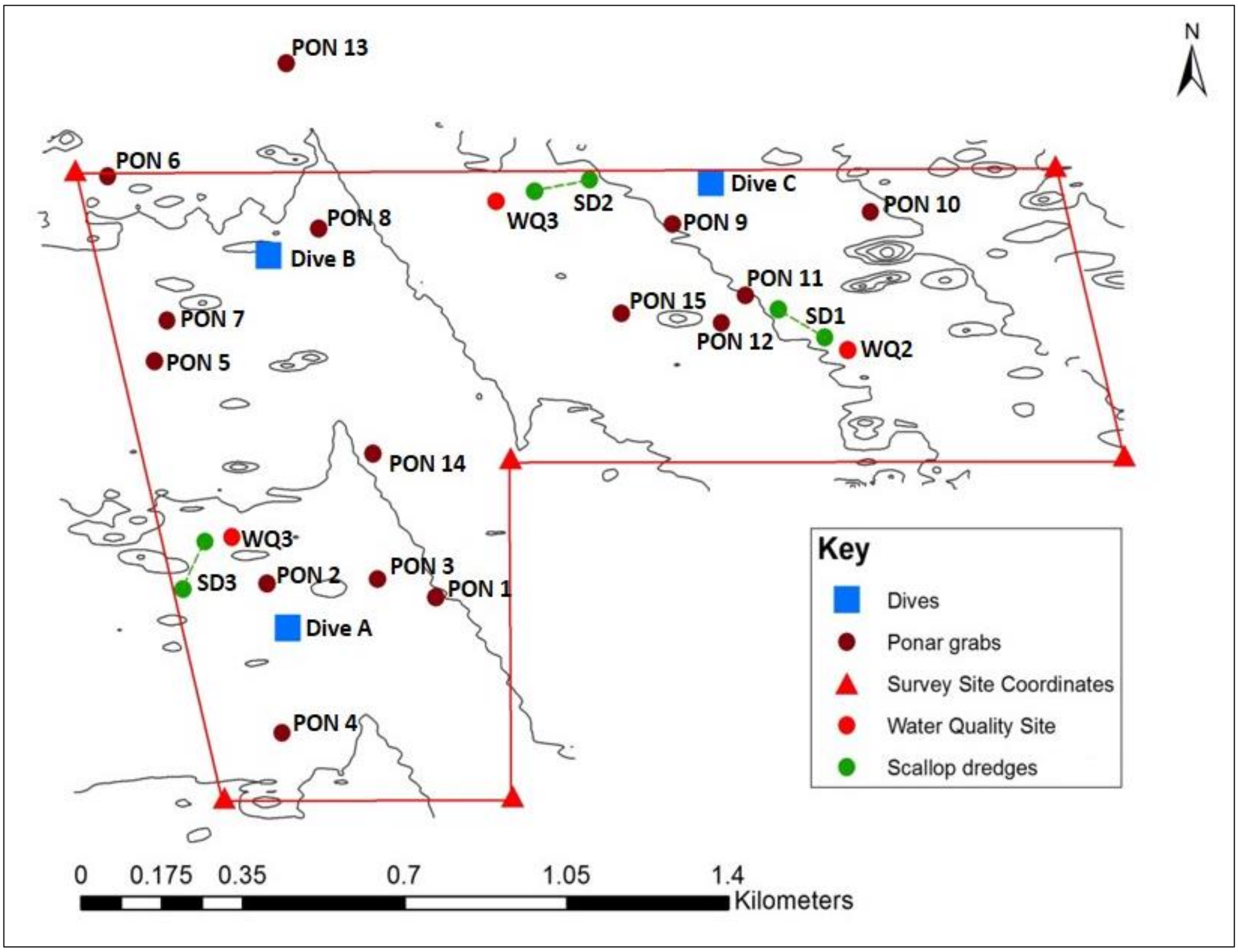

Figure 4: Site map showing sample locations of expanded farm survey. Red line depicts site boundaries.

2.4.3 Epifauna

A modified recreational scallop dredge (mouth dimensions 600 mm x 200 mm, mesh size 3 mm) was deployed along two transects in the initial survey and along three transects in the expanded survey (Figure 3 and Figure 4, respectively). This method was utilised to sample any large animals living on, or close to the sediment surface (i.e. conspicuous epifauna such as starfish and snails.

3 RESULTS

3.1 Bathymetry and substratum type

The seabed at both the initial and expanded proposed site was relatively flat and featureless. The water depth at the initial site ranged from ~21 m to ~24 m and at the expanded site from ~23 m to ~29 m. That is, the site deepens toward the northeast. No three-dimensional features that would indicate the presence of special ecological attributes such as rocky or biogenic reef were detected by the sonar survey in either the initial or expanded surveys (Figure 5 and Figure 6, respectively). The uniformity of colour in these figures indicates a largely homogeneous substrate.

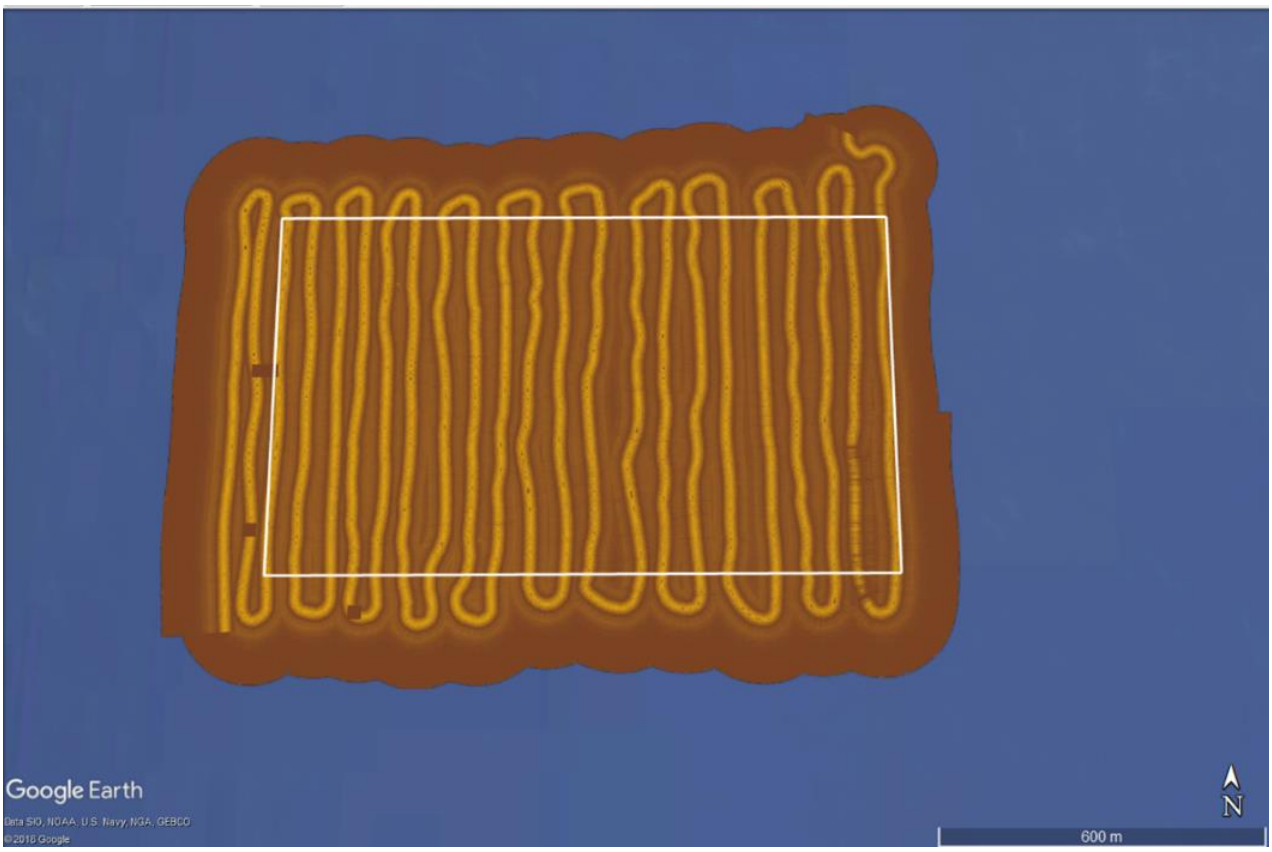

Figure 5: Image output from initial survey sidescan sonar data showing survey track and absence of prominent three dimensional features on the seabed.

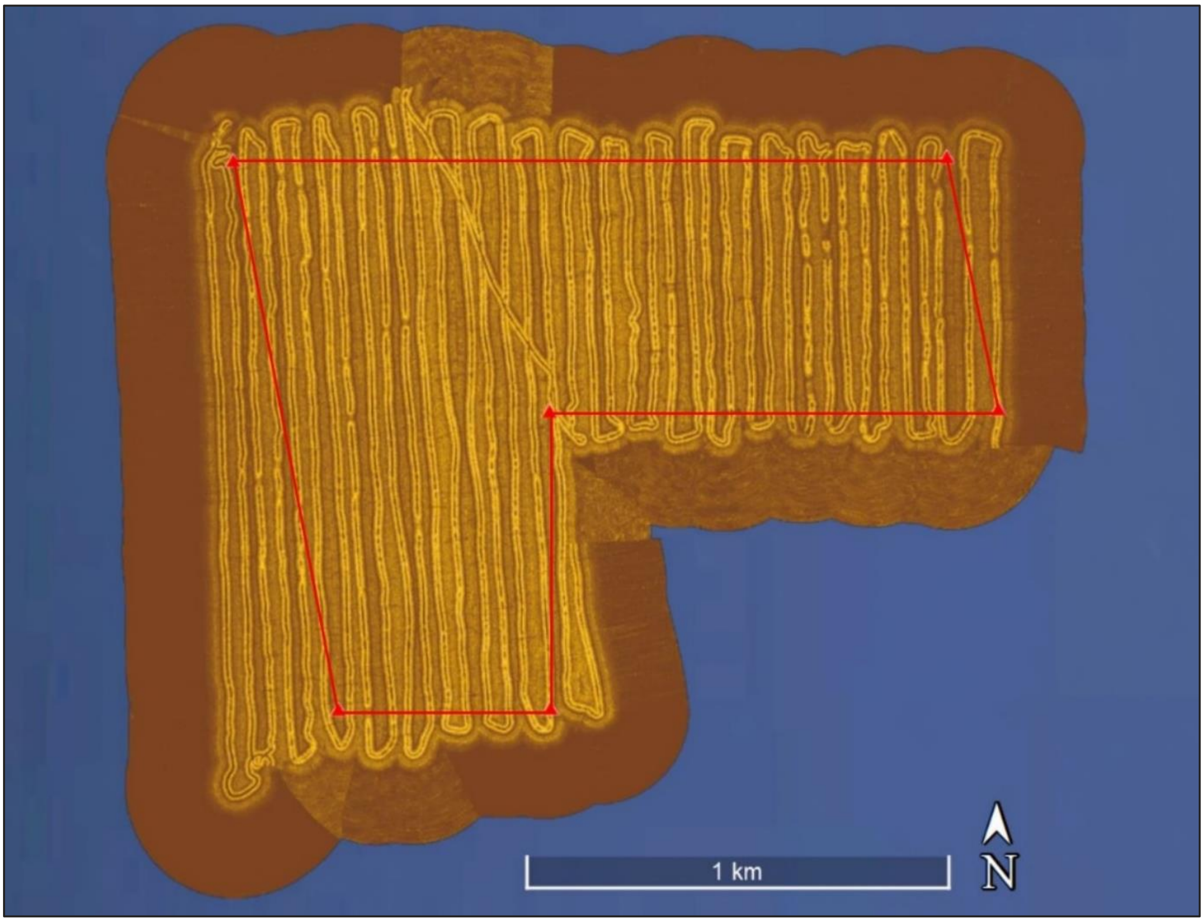

Figure 6: Image output from the expanded survey side-scan sonar data showing survey track and absence of prominent three-dimensional features on the seabed

The seafloor hardness (measured as backscatter or the sonar reflection) is presented below for both the initial and expanded surveys (Figure 7 and Figure 8, respectively). The sonar signals sent to the seafloor are reflected differently depending on the composition and hardness of the seafloor. Broadly speaking, soft sediments such as mud absorb and diffuse the signal while hard surfaces such as shell and rock reflect the signal more strongly. The hardness signature is colour coded and soft sediment, in this case mud, is recorded as green. The shades of light to darker green both represent a muddy surficial substrate. The western third of the initial survey area appeared to show a slightly different signature to the remainder of that site. This represents similar mud habitat and was not differentiated in terms of other seabed features sampled (i.e. sediment texture of recovered samples or biota). 'Harder' surfaces such as rock, would be recorded in a sharply contrasting colour. No rock or reef was recorded in either the initial or expanded surveys.

Figure 7: Seafloor hardness and depth contours from the initial survey. The green and paler green colour in the image represents soft sediment.

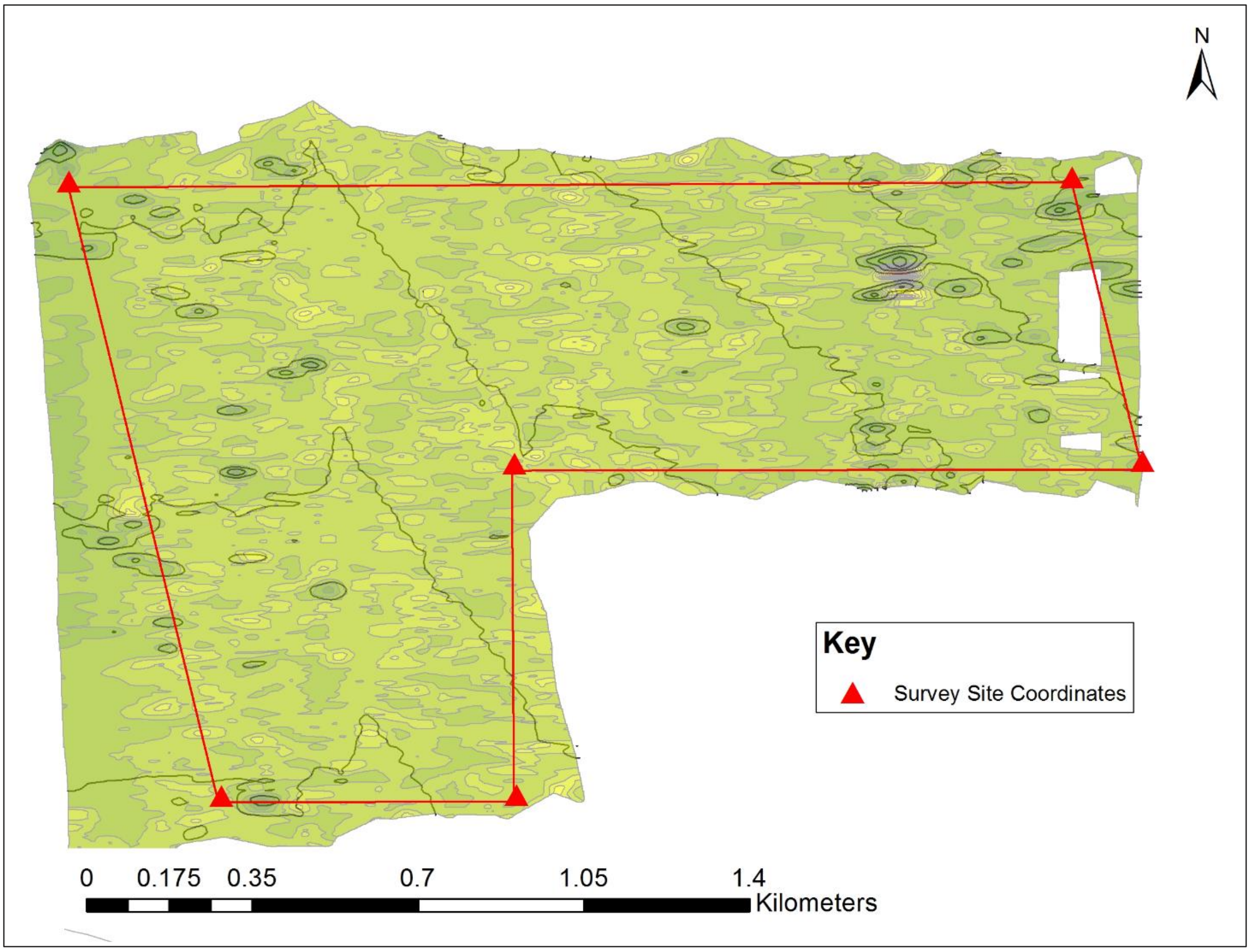

Figure 8: Seafloor hardness and depth contours from the expanded farm survey. The green and paler green colour in the image represents soft sediment

3.2 Currents

3.2.1 ADCP transects

Vessel tracks and stick vector diagrams depicting data collected from ADCP transects taken in the initial survey are shown in Figure 9. At the time of the synoptic survey (between 1020 and 1048 on 6/12/17), during an ebbing tide (recently turned), the ADCP data indicated that currents were flowing very slightly east of north and average current speed during the north-south transect was ~0.19 $m.s^{-1}$, and during the west-east transect was ~0.16 $m.s^{-1}$ (Table 1). These velocities recorded early in the ebb flow phase indicate that the currents at the site are likely to be relatively strong at peak flow, and the site is likely to be well flushed by tidal flows.

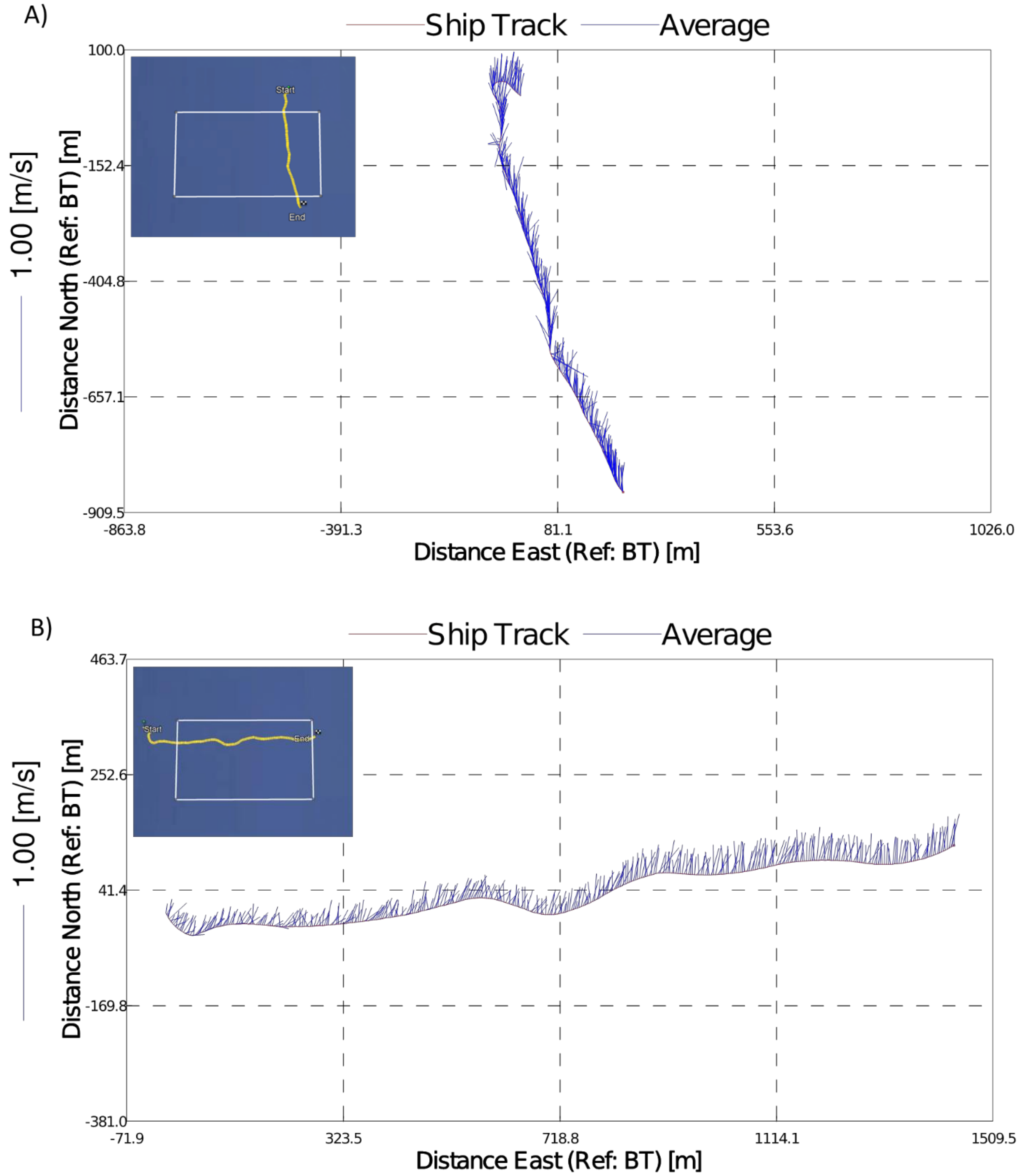

Figure 9: Vessel track and current stick vectors for ADCP transects A) North-South transect and B) West-East transect. Yellow lines within blue insets depict track positions in relation to the white site boundaries.

Table 1: Summary of average current speed and direction during ADCP transects during the initial survey.

Transect	Start time	End time	Mean current speed ($m.s^{-1}$)	Mean current direction (°)
N-S	1039	1048	0.193	0.81
E-W	1023	1035	0.158	14.29

3.2.2 Drogue deployment

In the initial survey a single sail drogue was deployed near the southwestern corner of the site at 1626 hrs and recovered at 1703 hrs (Figure 10). During this period, the tide had recently turned from ebb to flood (i.e. incoming tide) and there was a light northerly breeze of 10-12 knots. The drogue track indicated that the near-surface current velocity was ~0.155 $m.s^{-1}$ in a southerly direction. In the expanded survey on 25/10/2018 three sail drogues were released at approximately mid flood tide between 0650 hrs and 0730 hrs, and another three sail drogues were released at approximately mid ebb tide between 1125 hrs and 1210 hrs (Figure 11). There was a light westerly breeze of approximately 5-10 knots during all drogue deployments. The drogue tracks from these deployments indicated that the near-surface current velocity was ~0.3 $m.s^{-1}$ in a southerly direction on the flood tide and ~0.19 $m.s^{-1}$ in a north easterly direction on the ebb tide (Table 2). These results are consistent with the documented tidally dominated nature of the currents in the Firth of Thames that flow predominantly north to south during the flood tide and south to north during the ebb tide.

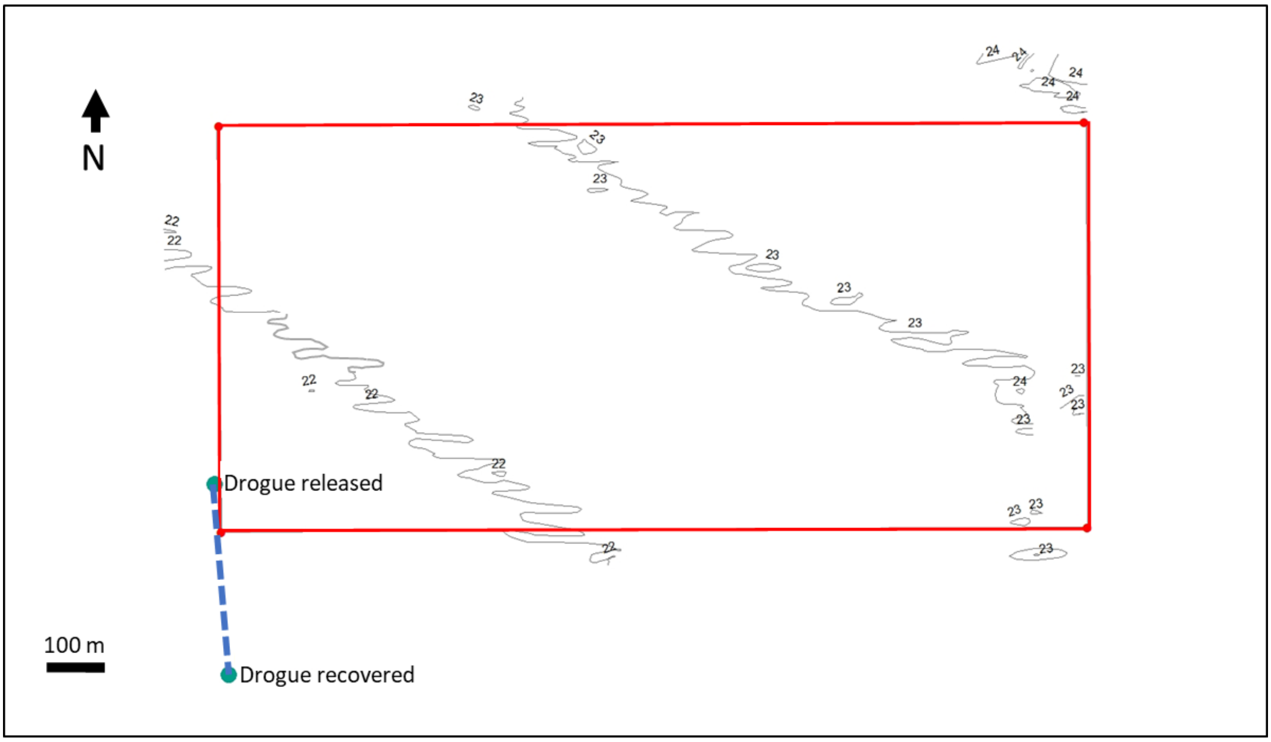

Figure 10: Location of drogue release and pick-up points (blue dots) from the initial survey showing direction and distance of travel.

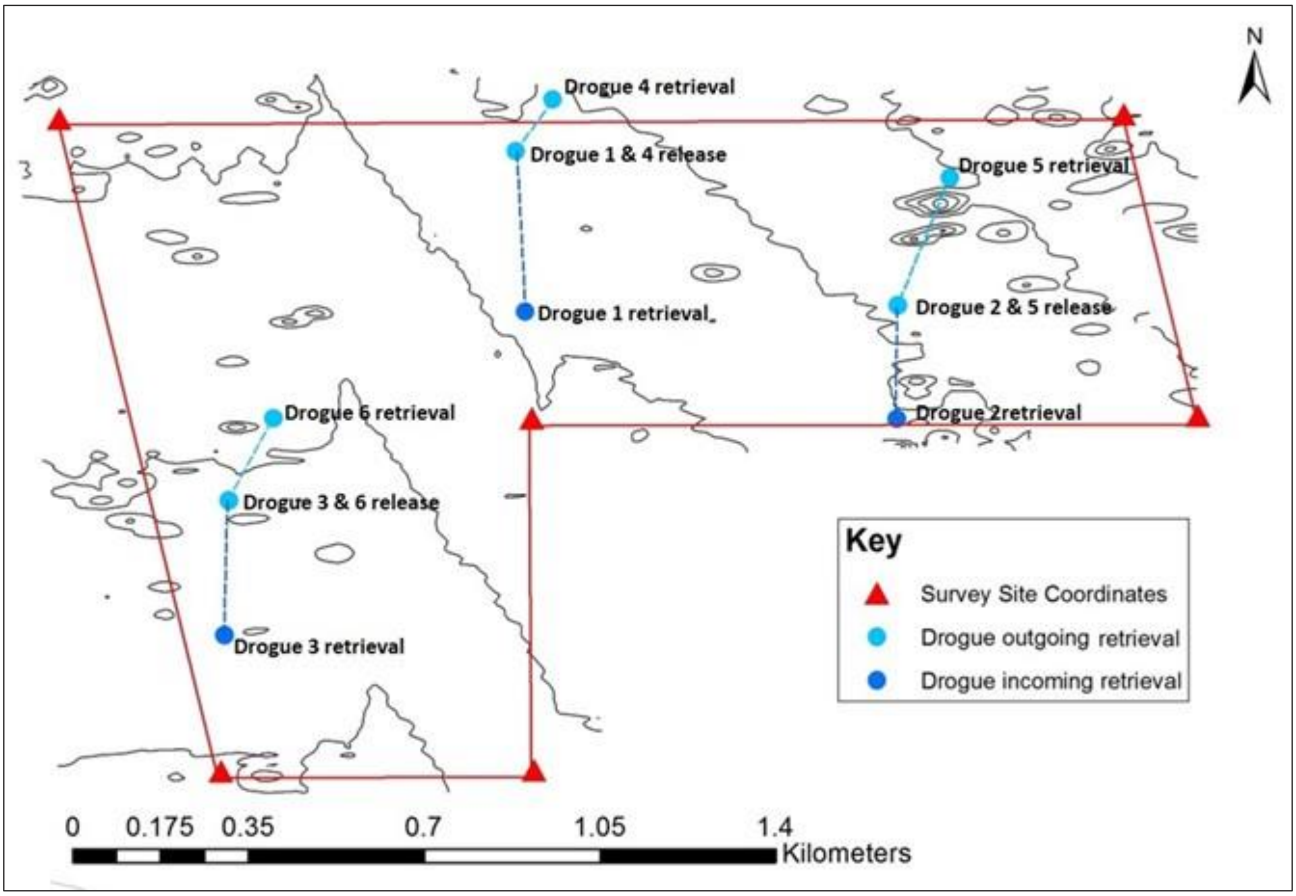

Figure 11: Location of drogue release and pick-up points on the flood tide (dark blue) and ebb tide (light blue) from the expanded farm survey showing direction and distance of travel.

Table 2:Current speed and direction at the proposed site as determined by sail drogues released at mid-ebb and mid-flood tide during the expanded survey

Drogue survey	Deploy time	Retrieve time	Distance travelled (m)	Current speed (m.s^{-1})	Current direction (°)
Flood 1	6:50	7:06	320	0.33	177.31
Flood 2	7:10	7:23	226	0.29	180.54
Flood 3	7:28	7:45	268	0.26	181.51
Flood average				**0.30**	**179.79**
Ebb 1	11:12	11:25	118	0.15	29.94
Ebb 2	11:28	11:47	267	0.23	18.20
Ebb 3	11:50	12:07	178	0.17	23.41
Ebb average				**0.19**	**23.85**

3.3 Water quality

3.3.1 Initial survey

In the initial survey water sampling was undertaken between 1300 and 1600 hrs in approximately the last quarter of the ebb tide (a 3.3 m high tide at 0953 hrs and 0.1m low tide at 1603 hrs at Man O'War Bay, Waiheke Island). The sea was calm with a slight sea (~0.5 m) and a light wind (10-12 knots) from the northerly quarter. Water temperature ranged between 21.7°C and 22.5°C, which is considered to be high for early December.

Salinity was consistent with well mixed open coastal waters (35 ppt). Water clarity was measured using a Secchi disc at two sites. The first secchi measurement ('Po Secchi', Figure 3) was a short distance to the west of the proposed farm site but is still considered characteristic of the clear water conditions prevailing at that time. Vertical clarity at this site was measured at 10 m at 1100 hrs, which was 1 hour after high tide. This is high clarity compared to reported values for the Firth of Thames, which are typically half of this value or less (for example see Broekhuizen et al. 2004). A second secchi measurement ('Po Secchi2', Figure 3) was taken towards the western boundary of the site at approximately 1300 hrs, or about mid ebb tide. This measurement showed a significant reduction in vertical clarity, which was measured at 5.8m.

Results from the initial survey water quality sampling are presented in Table 3.

Table 3: Laboratory results from the initial survey for nutrients and chlorophyll *a* in samples from the surface (s) and midwater (m) at three sites.

Parameter	WQ1s	WQ1m	WQ2s	WQ2m	WQ3s	WQ3m
Salinity	35	35	35	35	35	35
Total Nitrogen (g/m^3)	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	0.3
Nitrate-N + Nitrite-N (g/m^3)	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Kjeldahl Nitrogen (TKN) (g/m^3)	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.3
Dissolved Reactive Phosphorus (g/m^3)	0.0102	0.0102	0.0103	0.0101	0.0095	0.0103
Total Phosphorus (g/m^3)	0.012	0.013	0.017	0.015	0.012	0.016
Chlorophyll *a* (g/m^3)	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003

3.3.2 Expanded survey

In the expanded survey two sets of water samples at three sites were taken from both the surface and at midwater.

The first set of water samples was taken on 24/10/2018 between 1015 hrs and 1115 hrs at mid ebb tide (2.8 m high tide at 0737 hrs and 0.8m low tide at 1345 hrs at Man O'War Bay, Waiheke Island). The sea was calm with a slight sea (~0.3 m) and a light westerly breeze (5-10 knots). Water temperature ranged between approximately 16°C - 18°C. Salinity was consistent with well mixed open coastal waters (~34-35 ppt). Water clarity measured using a Secchi disc was recorded as 8.25 m at WQ1, 10.75 m at WQ2, and 8.4 m at WQ3 (Figure 4).

The second set of water samples was taken on 25/10/2018 between 0700 hrs and 0735 hrs in the last quarter of the flood tide (0.7 m low tide at 0210 hrs and 2.8 m high tide at 0823 hrs at Man O'War Bay, Waiheke Island). The sea was calm with a slight sea (~0.5 m) and a westerly breeze (~12 knots). Water temperature ranged between approximately 16°C - 18°C and salinity was consistent with well mixed open coastal waters (~34-35 ppt). Water clarity measured using a Secchi disc was recorded as 8.25 m at WQ1, 8.85 m at WQ2, and 9.35 m at WQ3 (Figure 4).

As for the initial survey, the water clarity values recorded in this expanded survey are high compared to reported values for the Firth of Thames, which are typically half of the recorded values or less (e.g. Broekhuizen et al. 2004).

Results from the first set of the expanded survey water quality sampling are presented in Table 4 and results from the second set of the expanded survey water quality sampling are presented in Table 5.

Table 4: Laboratory results from the expanded site survey for nutrients and chlorophyll *a* in samples taken at mid ebb tide from the surface (s) and midwater (m) at three sites.

Parameter	Ex-WQ1s (ebb)	Ex-WQ1m (ebb)	Ex-WQ2s (ebb)	Ex-WQ2m (ebb)	Ex-WQ3s (ebb)	Ex-WQ3m (ebb)
Temperature (°C)	17.42	16.42	16.91	16.56	17.26	16.61
Turbidity (NTU)	0.25	0.42	0.27	0.28	0.35	0.28
Salinity (PPT)	34	35	34	34	34	35
Total Suspended Solids (g/m^3)	< 3	5	< 3	< 3	< 3	< 3
Total Nitrogen (g/m^3)	0.12	0.22	< 0.08	0.26	0.14	0.11
Nitrate-N + Nitrite-N (g/m^3)	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Kjeldahl Nitrogen (TKN) (g/m^3)	0.12	0.22	< 0.08	0.26	0.14	0.11
Dissolved Reactive Phosphorus (g/m^3)	0.0105	0.0099	0.0105	0.0102	0.0105	0.0101
Total Phosphorus (g/m^3)	0.016	0.012	0.016	0.016	0.016	0.016
Chlorophyll *a* (g/m^3)	0.0003	0.0005	0.0003	0.0006	0.0003	0.0003

Table 5: Laboratory results from the expanded farm survey for nutrients and chlorophyll *a* in samples taken on the flood tide from the surface (s) and midwater (m) at three sites.

Parameter	Ex-WQ1s (flood)	Ex-WQ1m (flood)	Ex-WQ2s (flood)	Ex-WQ2m (flood)	Ex-WQ3s (flood)	Ex-WQ3m (flood)
Temperature (°C)	16.85	16.64	16.87	16.56	16.83	16.61
Turbidity (NTU)	0.37	0.53	0.3	0.33	0.35	0.44
Salinity (PPT)	34	34	34	34	34	35
Total suspended solids (g/m^3)	< 3	< 3	< 3	< 3	< 3	< 3
Total Nitrogen (g/m^3)	< 0.08	< 0.08	0.13	< 0.08	0.17	< 0.08
Nitrate-N + Nitrite-N (g/m^3)	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Kjeldahl Nitrogen (TKN) (g/m^3)	< 0.08	< 0.08	0.13	< 0.08	0.17	< 0.08
Dissolved Reactive Phosphorus (g/m^3)	0.0104	0.0103	0.0106	0.0104	0.0105	0.01
Total Phosphorus (g/m^3)	0.016	0.016	0.018	0.014	0.016	0.016
Chlorophyll *a* (g/m^3)	< 0.0002	0.0003	< 0.0002	0.0004	0.0003	0.0006

3.3.3 Nutrients

In the initial survey both nitrate and total oxidized nitrogen concentrations were below the detection limit of the laboratory analytical method. In the expanded survey an analytical method with a lower detection limit was used for measuring total oxidised nitrogen. Total oxidised nitrogen was below the detection limit used in the initial survey for all samples taken in the expanded survey. However, the total oxidised nitrogen levels recorded in the expanded survey using the lower detection limit showed that levels ranged between <0.08 g/m^3 to 0.26 g/m^3 and were noticeably lower during the flood tide compared to the ebb tide. Nitrate remained below the analytical detection limit for samples taken on both the flood and ebb tide in the expanded survey. The nitrate levels recorded in both the initial and expanded survey are low compared to previously reported values (Broekhuizen et al. 2002).

In the initial survey Dissolved Reactive Phosphorous (DRP) was present in the seawater samples at levels between 0.0095 and 0.0103 g/m^3. In the expanded survey DRP was present at levels between 0.0099 and 0.0106 g/m^3. This range is at the low end of reported values for the Wilsons Bay area (Broekhuizen et al. 2002). This is also approximately at the ANZECC (2000) default guideline value (South East Australian waters) of 0.01 g/m^3 for marine waters and suggests that at the time of sampling levels of this nutrient were not significantly elevated.

Nutrient concentrations recorded in both the initial and expanded survey were consistent with the expectations for deep subtidal dominated estuaries in New Zealand (e.g. Dudley et al. 2017). The consistency of results between the surface and mid-water samples indicates well-mixed coastal water. All the values were below published stressor and toxicant guidelines for the protection of saltwater aquaculture species (Keeley et al. 2015).

3.3.4 Chlorophyll *a*

In the initial survey chlorophyll *a* levels at all sites were below the detection limit of the laboratory analytical method used (0.003 g/m^3). In the expanded survey an analytical method with a lower detection limit of 0.0002 g/m^3 was used. Chlorophyll *a* levels recorded in the expanded survey using the lower detection limit showed that levels ranged between <0.0002 g/m^3 to 0.0006 g/m^3 and were on average lower during the flood tide compared to the ebb tide and lower at the surface compared to at mid water.

Previously reported concentrations of chlorophyll *a* in the Firth of Thames ranged from 0.003-0.004 g/m^3 in spring and from 0.001-0.002 g/m^3 in summer (Broekhuizen et al. 2002, James and Jamieson 2017). Hence, chlorophyll *a* levels greater than the nominal detection limit of the analytical method used in the initial survey would be considered to be at the higher end of the range of values expected. The chlorophyll *a* levels recorded in the expanded survey indicate that chlorophyll *a* levels at the proposed farm site were approximately an order of magnitude lower than what might be expected based on the levels reported by Broekhuizen et al. (2002) and James and Jamieson (2017). This is consistent with the highly variable nature of chlorophyll *a* levels in the Firth of Thames (Broekhuizen et al. 2004)

3.4 Seabed characteristics

3.4.1 Sediment appearance and texture

Visual assessment of grab samples and cores taken by divers showed that sediments at all stations from both the initial and expanded survey were composed of a layer of soft fine-grained brown/grey sandy mud overlaying a harder packed layer of grey sandy mud with a component of shell hash and gravel (Figure 12 and Figure 13). The redox potential discontinuity layer was indistinct in the ponar grab samples and the cores sampled by divers. The cores displayed a gradual or streaky transition from brown/grey sediment to a darker grey colour in the deeper portions of the sediment (Figure 14 and Figure 15).

Figure 12: Ponar grab contents from the initial survey at stations Sed1, Sed6 and Sed9 showing the characteristic muddy sediments of the grab samples.

Figure 13: Ponar grab contents from the expanded farm survey at stations 7, 9 and 15 showing the characteristic muddy sediments of the grab samples.

Figure 14: Sediment cores from the initial survey sampled via SCUBA at the dive site

Figure 15: Sediment cores from the expanded farm survey sampled via SCUBA from site 'Dive A'

3.4.2 Sediment chemistry

Results of chemical analyses of sediment samples are presented in Table 6 for the initial survey and Table 7 for the expanded survey. The total organic matter (TOM) content of the sediments (determined as a percentage of dry weight) ranged from 6.8% to 9% in the initial survey and from 5.5% to 7.5 % in the expanded survey. These values are consistent with values obtained in a previous study from the Firth of Thames that reported values ranging from 4% to 11%, and mostly between 7-8% (e.g. Morrisey et al. 2016). Concentrations of total organic carbon and total nitrogen in both the initial and expanded surveys also fell within the range of previously reported values in the Firth (e.g. Giles et al. 2006). Total recoverable phosphorus levels in both the initial and expanded surveys appear relatively high in comparison to other values reported for the Firth of Thames (Environment Waikato 2007). The phosphorus value at the 'Seds3' site from the initial survey appears exceptionally high and may be anomalous. Total free sulphide (TFS) concentrations were only sampled in the expanded survey but were either not present or below the laboratory detection limit (<69 µM) at all sites. This is consistent with expectations for marine sediments that are exposed to natural (low) levels of organic matter loading (Wildish et al. 2001, Hargrave et al. 2008, Keeley and Taylor 2015).

Table 6: Laboratory results for sediment chemistry from the initial survey.

	Seds1	Seds2	Seds3	Seds4	Seds5	Seds6
Total Organic Matter (g/100g dry wt)	8.3	9	9	8.2	8.4	6.8
Ash (g/100g dry wt)	92	91	91	92	92	93
Total Recoverable Phosphorus (mg/kg dry wt)	610	660	1,950	850	940	720
Total Nitrogen (g/100g dry wt)	0.15	0.18	0.21	0.17	0.18	0.14
Total Organic Carbon (g/100g dry wt)	1.27	1.17	1.3	1.16	1.15	0.89

Table 7: Laboratory results for sediment chemistry from the expanded farm survey.

	Ex-Seds1	Ex-Seds2	Ex-Seds3	Ex-Seds4	Ex-Seds5	Ex-Seds6
Total Organic Matter (g/100g dry wt)	6.2	7.2	7.5	6	5.5	6.9
Ash (g/100g dry wt)	94	93	92	94	95	93
Total Recoverable Phosphorus (mg/kg dry wt)	740	760	820	650	720	620
Total Nitrogen (g/100g dry wt)	0.14	0.16	0.16	0.13	< 0.13	0.14
Total Organic Carbon (g/100g dry wt)	0.93	1.05	1.05	0.86	0.76	0.97
Total Free Sulphide (µM)	0	0	<69	0	0	0

Particle size analysis of six sediment samples was undertaken in the expanded survey. The results (refer to Appendix B for analysis reports) reinforce the visual observations of the sediments, indicating that they are predominately composed of mud with a small component of fine sand and shell hash. A summary of the results is presented in Table 8.

Table 8: Particle size distribution at 10%, 50% and 90% of the sample volume

Percentage volume under	PON 2	PON 4	PON 6	PON 8	PON 9	PON 12
10%	3.06 µm	3.53 µm	2.89 µm	3.68 µm	3.30 µm	3.38 µm
50%	27.3 µm	39.5 µm	23.2 µm	41.6 µm	31.8 µm	29.3 µm
90%	270 µm	323 µm	235 µm	387 µm	303 µm	280 µm

3.4.3 Infauna

In the initial survey a total of 42 separate faunal taxa were identified from all grab samples (Appendix C). The average taxon richness (number of separate taxa) per grab sample was 19 and ranged between 12 and 24 taxa per sample. The average abundance (number of individual specimens) per grab sample was 102 and ranged from 51 to 142 specimens per sample.

In the expanded survey a total of 51 separate faunal taxa were identified from all grab samples (Appendix C). The average taxon richness (number of separate taxa) per grab sample was 18.73 and ranged between 14 and 24 taxa per sample. The average abundance (number of individual specimens) per grab sample was 196.3 and ranged from 122 to 318 specimens per sample.

In the initial survey the most commonly sampled taxa were representatives from several families of polychaete worms (Nephtyidae, Cirratulidae and Cossuridae), and small crustaceans from the orders (Amphipoda, Cumacea and

Ostracoda). Tanaid crustaceans were the most abundant taxa sampled and the most commonly sampled mollusc was a small deposit-feeding bivalve (*Linucula hartvigiana*).

In the expanded survey the most commonly sampled taxa were representatives from several families of polychaete worms (Cirratulidae and Cossuridae, Sigalionidae and Terebellidae), and small crustaceans from the orders (Amphipoda, Cumacea, Ostracoda and Tanaidacea). As in the initial survey, Tanaid crustaceans were the most abundant taxa sampled overall. The most commonly sampled mollusc in the expanded survey was a small deposit-feeding bivalve (*Arthritica bifurca*).

Taxa encountered were all considered typical and widespread in soft sediment habitat in and around the Firth of Thames (e.g. Brown and Asher 2000).

3.4.4 Epifauna

In the initial survey the conspicuous large bodied macrofauna present comprised heart urchins (*Echinocardium cordatum*), brittle stars (*Amphiura* sp.) and the tube casings of polychaete worms (Figure 16).

In the expanded survey the scallop dredge collected hermit crabs, along with a similar assemblage to the initial survey, of heart urchins (*Echinocardium cordatum*), brittle stars (*Amphiura* sp.) and the tube casings of polychaete worms (Figure 17).

Organisms retrieved were similar in all scallop dredge tows conducted in both the initial and expanded survey and comprised taxa also recorded in the ponar grab samples (though one bryozoan specimen was retrieved in the expanded survey and none were recorded in the initial survey). The taxa retrieved are common and widespread in the Firth of Thames and around New Zealand's coastal continental shelf (e.g. McKnight 1969, Brown and Asher 2000).

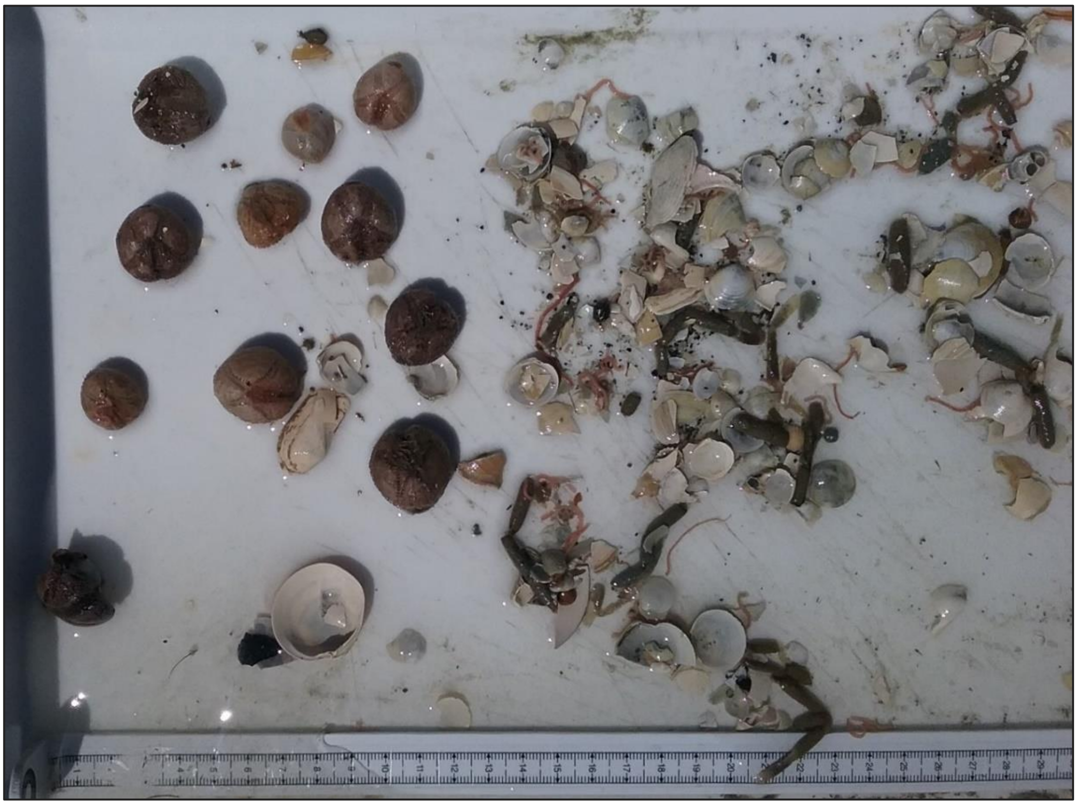

Figure 16: Typical contents of scallop dredge tow from the initial survey.

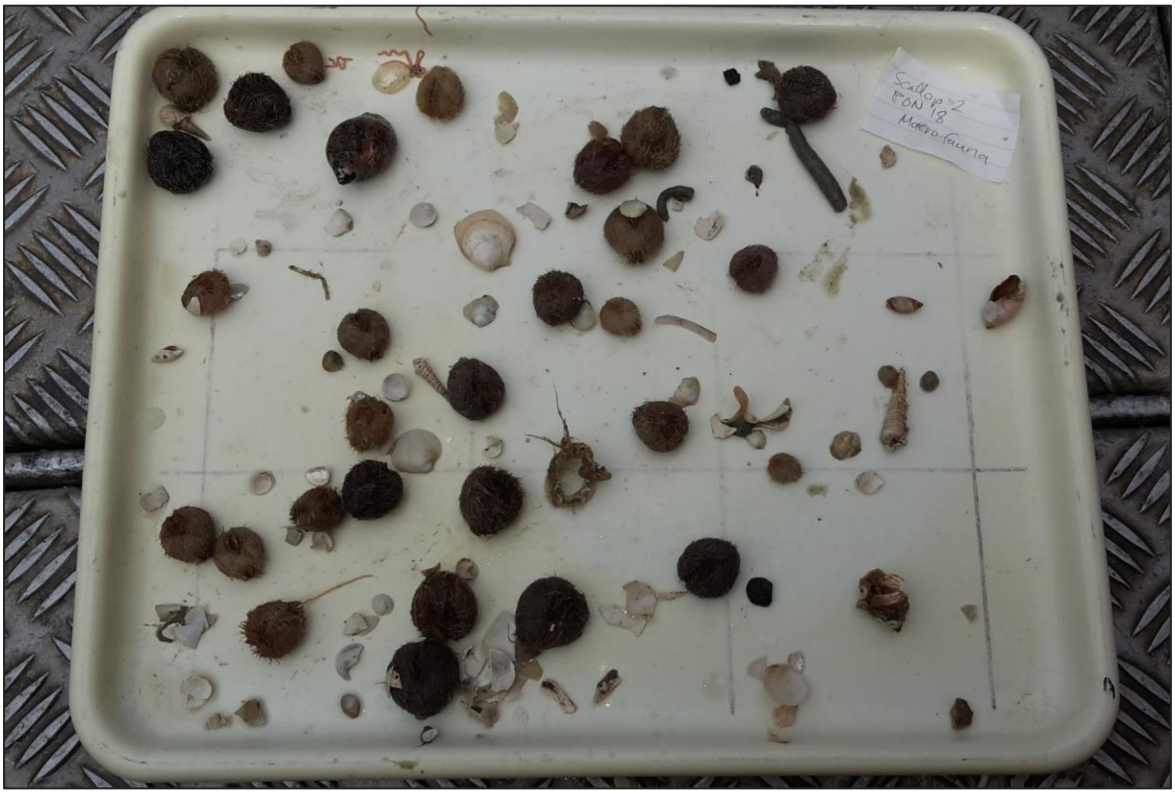

Figure 17: Typical contents of scallop dredge tow from the expanded farm survey.

4 DISCUSSION

4.1 Assessment of effects

4.1.1 Water column

The feeding activity of a farmed population of mussels suspended from the surface removes organic material including phytoplankton from the water column. The collective effect of the filtering by the mussels within a farm, can potentially lead to a halo of water depleted of phytoplankton (and some changes to other water column properties such as nutrient concentrations) extending beyond the farm area.

The scale, duration and the ecological significance of such beyond-farm effects in the Firth of Thames have been the subject of modelling studies and field surveys over the last 17 years. These studies have considered the hydrodynamic environment, phytoplankton and zooplankton and water chemistry of the Firth of Thames. Much of this research has been undertaken in the specific context of assessing the potential for impacts associated with existing large-scale mussel farming activities (e.g. the 2500 ha Wilson Bay Marine Farming Zone (WBMFZ) in the eastern Firth), or proposed mussel farms (such as for the 6000 ha proposed western Firth Aquaculture Management Areas, which is being pursued in part). When the Wilson Bay zone was established it was the largest concentration of mussel farms in one location in New Zealand (Sea Change 2014). It totals about 1200 ha of farmable space in a total marine farm zone of about 2500 ha. Comprehensive and quantitative monitoring requirements were imposed, and multiple physical and biophysical models were developed, to predict various ecological dynamics including the potential for phytoplankton depletion. Citing NIWA research (Stenton-Dozey, J., Zeldis 2012), the Marine Spatial Plan document (Sea Change 2017) reported that from 12 years of monitoring data supported by synoptic surveys, NIWA concluded that no significant depletion of phytoplankton has occurred from mussel farming in the Firth.

An earlier review by the Ministry of Fisheries that specifically considered the WBMFZ in terms of impacts on fisheries and which considered much of the same earlier research, concluded that '…any change in phytoplankton or zooplankton community composition would not be so excessive or disproportionate as to have undue effects on the sustainability of fisheries resources…' (Ministry of Fisheries 2009). The terminology 'undue effect' was clarified in that report specifically in relation to fisheries resources, as being significantly more than an adverse effect that is just contrary or injurious. In short, that analysis was focused on a scale of effect that might threaten the sustainability and productivity of fisheries resources long term. On that basis, the Ministry of Fisheries conclusions while discounting wider scale effects, did not necessarily exclude impacts at a more local spatial or temporal scale.

The Firth is likely to be resistant to phytoplankton depletion caused by variations in nutrient availability caused by filtering by mussels. A recent study reports that nutrient from the Firth catchment dominates dissolved inorganic nitrogen (DIN) stocks in the Firth (Green and Zeldis 2015). It is that source and periodic oceanic upwelling events that are likely to govern nutrient availability for ecosystem processes.

The potential for sustained local scale impacts has also repeatedly been determined as unlikely to be significant. Broekhuizen et al. (2002) highlighted the important and dominating role of local and wider scale oceanographic influences (e.g. El Niño) on winds, currents, mixing and nutrient supply in the Firth. These and other macro influences may override or mask local spatial and temporal effects. Various studies have observed and confirmed through measurements that the natural environment in the Firth is highly variable at a local scale and the extent and specific location of any phytoplankton depletion would likely vary day to day because of changing wind-driven circulation patterns (Stenton-Dozey et al. 2008). In relation to the Hauraki Gulf and the Firth and other regions such as the Marlborough Sounds, Broekhuizen et al. (2004) comment that historic data indicates there is enormous variability in plankton systems at scales of days, weeks or years and concluded that in comparison with the natural range in variability, modelled predicted impacts of mussel farming are small, particularly in the far field (i.e. at scales beyond the farmed area). This variability was reflected at the proposed site, at which a 50% reduction in measured water clarity was observed over the period of 3 hours during the initial survey. This was attributed to natural change during an ebb tidal phase.

4.1.1.1 Ponui farm site phytoplankton effects

Taking consideration of this wider perspective, the effect of the proposed Ponui application on water column and phytoplankton dynamics can be assessed.

The farm is to be set up in a conventional way, and in terms of mussel line and probable crop density, is like farms elsewhere in the Firth. An overall indicative layout is presented in the Planners Report. In summary, the proposed farm has North and South borders of 1700 m and (slightly east tilted) East and West borders of 1324 m. It will be comprised of multiple farm blocks and has a porous 'structure'. There will be 100 m gaps between the blocks and 20-25 m between the mussel lines, which will be orientated parallel to the current direction. The relatively deep water at this location (being ~23-29 m) also means that there will be a significant water column beneath the farm structures and seabed. This water will be unaffected by the filtering effects of mussels on the farm ropes. Water passing through this deeper part of the water column may also do so at a faster rate than through the farm itself, due to the drag effect of farm structures above on water velocity. This will further encourage mixing and should reduce the extent of any phytoplankton depletion beyond the farm footprint.

Water circulation in the Firth is tidally driven with peak currents of more than 0.4 $m.s^{-1}$ being recorded (Stenton-Dozey et al. 2008). Flood tides have been reported to be stronger on the eastern side of Firth and ebb tides stronger on the western side (Stephens 2003, Broekhuizen et al. 2004). On average, 78% of the total current signal reported by Stephens (2003) was due to tidally driven currents with the remaining 22% being due to wind driven currents.

The average current velocities throughout the water column measured at the proposed farm at the time of the initial survey were ~0.2 $m.s^{-1}$ (~0.19 $m.s^{-1}$ and ~0.16 $m.s^{-1}$ during the N-S and E-W transects respectively). During the expanded survey approximate current velocities of 0.3 $m.s^{-1}$ in a southerly direction and 0.19 $m.s^{-1}$ in an approximately northerly direction were recorded during the flood and ebb tides, respectively. This data indicates that the site is well flushed and can be regarded as a 'high-flow' site according to the classification of Keeley et al. (2013). The tidal state at the time of the ADCP survey had only recently turned from high tide to an ebbing tide, so the tidal stream is unlikely to have been running at maximum strength, and there would be periods of greater current speeds at the site at other times. The location also has a high exposure to near surface wind driven currents from all quarters and is relatively exposed to locally generated wave conditions. On that basis, residual (non-tidal) currents are likely to be highly variable. This is important as the actual location of any plume of plankton change will be strongly influenced by residual currents (Oldman et al. 2007, Addendum 1 to Appendix 2). Any phytoplankton depletion halo is likely to be highly variable and will not only change with each tidal state (ebb/flood) but also with prevailing conditions on any day. The tidal and residual currents at the site should enable good delivery of phytoplankton to mussels within the farm, and adequate mixing with the surrounding water mass thereby facilitating a rapid return to background phytoplankton concentration downstream of the farm. Mixing of waters within and downstream of the mussel farm will also promote nutrient cycling and should limit the potential for sustained or significant impacts on phytoplankton production. There are no other marine farms (either existing or under application) in the Firth of Thames close enough to the proposed site that there is a risk of effects of phytoplankton consumption within the proposed farm affecting any other farms (Figure **18**). Therefore, the risk of cumulative adverse effects from this farm on phytoplankton concentrations in the water column is considered to be negligible.

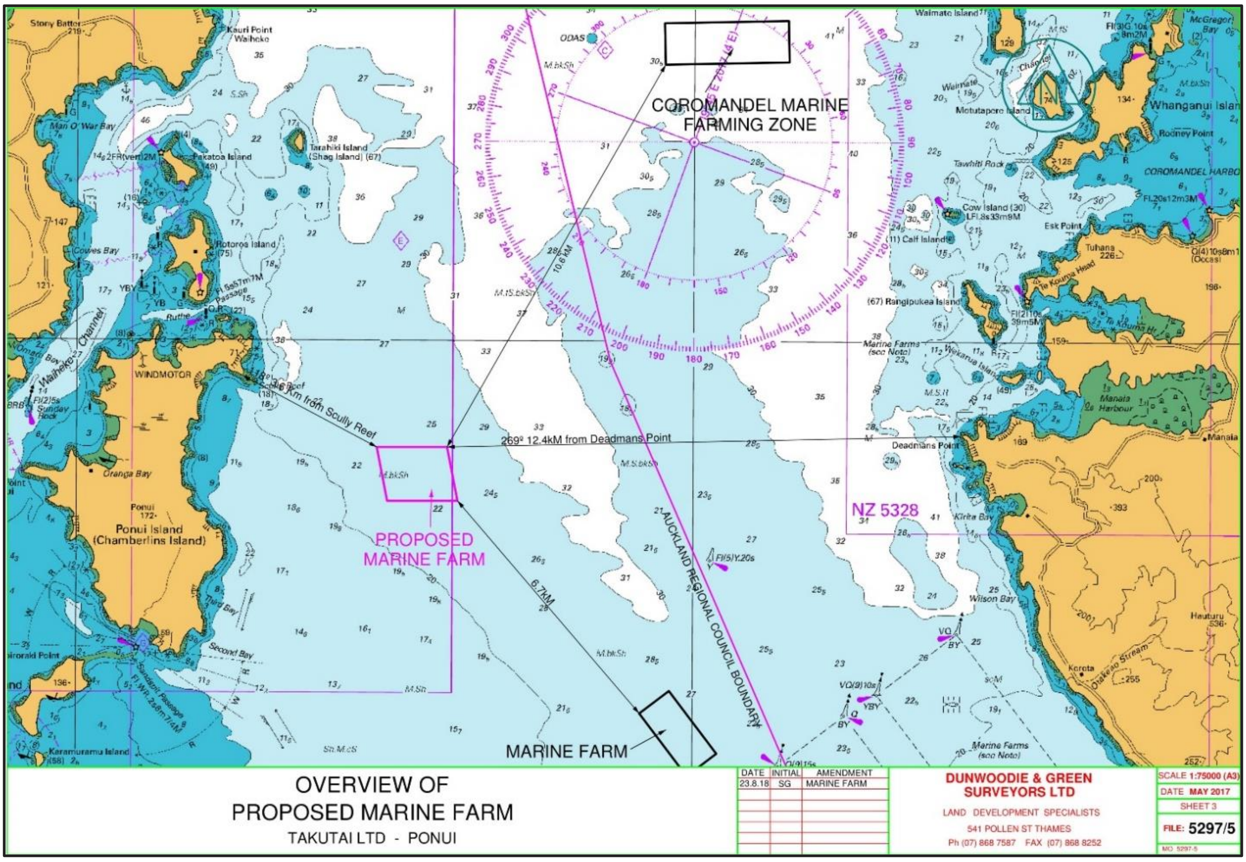

Figure 18: Proposed marine farm in relation to the closest consented marine farms in the Firth of Thames

Detailed modelling and synoptic surveys of the Wilson Bay Marine Farm Zone effects have not shown significant adverse ecological effects in relation to phytoplankton depletion or other adverse water column effects. On that basis, and in combination with knowledge of other factors which are important in governing nutrient availability in the Firth, such as the complex and open hydrodynamic setting and the dominance of catchment derived nutrient, the potential for off-site water column effects, including phytoplankton depletion, that might adversely affect other mussel farms, or the ecology of shorelines, or the wider marine ecosystem is highly unlikely.

4.1.2 Benthic effects

The seabed at the proposed farm site is flat, relatively featureless mud habitat that is common throughout much of the Firth of Thames. The macrofaunal assemblage inhabiting the seabed comprised common and widespread taxa dominated by deposit feeding organisms that are generally well adapted to muddy, depositional environments. The effects of mussel farming over that type of mud habitat and associated faunal communities are well documented from numerous surveys and studies conducted in the Firth of Thames and other areas around New Zealand (see Ministry for Primary Industries 2013). The accumulation of biodeposits, fouling organisms (organisms other than mussels growing on farm structures such as other shellfish, bryozoans, sponges and algae) and shell debris dropping from the farm structures is likely to result in some changes to the benthos that may be viewed as both positive and negative. For instance, there may be an increase in the biomass of small opportunistic sediment-dwelling species, and the build-up of shell litter beneath farm lines will increase biodiversity by providing habitat for encrusting organisms (e.g. bryozoans, anemones), and other species that require a hard substratum or 3-dimensional habitat as a refuge from predators (e.g. D'Amours et al. 2008).

Experimental work and modelling examining the benthic effects of finfish aquaculture has indicated that sites with mean current speeds >0.15 $m.s^{-1}$ (Keeley et al. 2013) can be broadly described as 'dispersive' or 'high flow' sites (where the magnitude of deposition directly below a marine farm will be lower but the spatial extent of the footprint will be greater), and those with lesser current speeds can be considered 'low-flow' sites (greater intensity of deposition beneath the farm, but spatial extent of footprint less) (Cromey et al. 2002, Keeley et al. 2013). The severity of depositional effects from mussel farming in New Zealand is generally considered to be low, and the dispersive nature of the site conferred by the relatively strong currents and ample water depth further reduces the risk of deposition from the farm causing any significantly detrimental effects on the seabed. It is known that the wider Firth of Thames once harboured extensive biogenic reefs of wild green lipped mussels (Reid 1969) that are likely to have conferred benefits to the water quality and ecology of the region through feeding activity, increased biodiversity, filtering of particulate matter from the water column and contributing to the cycling of nutrients at the seabed (e.g. McLeod et al. 2012). Therefore, the deposition and persistence of live mussels on the seabed resulting from drop-off from farm structures may be considered as a positive effect.

In summary, the common and widespread occurrence of the type of mud habitat and associated faunal community found at the proposed site, the dispersive nature of the site conferred by the hydrodynamic characteristics of the area, the relatively benign changes to the seabed ecology expected beneath the farm, and the potential for some positive ecological effects of the farming activity indicate that the benthic effects resulting from the proposed mussel farm are expected to be only minor.

4.1.3 Other potential effects

Mussel farms are known to attract fish, starfish, crabs, other marine life and seabirds (Keeley et al. 2009). In addition to growing the culture species, farms function as mid-water artificial reefs and create habitats. Artificial structures provide new foraging habitat, food sources, breeding habitat, and refuge from predators for some species. These are for the most part positive effects and they are likely to occur in the proposed farm area.

Potential effects on marine mammals (seals, dolphins and whales) relate mainly to habitat modification, entanglement in structures and habitat exclusion.

Keeley et al. (2009) notes that there are legitimate concerns regarding the proposed establishment of large offshore marine farms, particularly where these interact with seasonal migration patterns of whales. Seasonal whale migration issues are not likely to be a concern in this part of the Firth. Whale migration pathways are not recorded to overlap or be close to the proposed marine farm site (Lloyd 2003).

One 'resident' species which can be encountered throughout the year in the general area of the Hauraki Gulf to the north of the Firth, is Brydes whale. This is listed as having a 'nationally critical' threat status (Hitchmough et al. 2007). The Hauraki Gulf SOE report (Hauraki Gulf Forum 2014) cites records and research on Brydes whale sightings and mortality. Figure 6B of that report presents a map of sightings covering the period 2000-08. There are no records for the Firth of Thames proper, or other information which would suggest these whales are common in this area or even occur.

This is supported by the longer-term records available through the Ministry of Fisheries data base dating back to 1992 (National Aquatic Biodiversity Information System (NABIS), undated.). That information records that although Brydes whale is a surface feeder, it occurs mostly in waters of 40m depth or more. Most records are north of Waiheke although there are scattered records for what might be regarded as the outer Firth. Lloyd (2003) does note two whale deaths attributed to entanglement in mussel spat lines near Great Barrier Island in the mid 1990's.

We conclude that the risk of Brydes whale or other whale species and dolphins becoming entangled in the proposed farm structures is small and probably negligible.

One major ecosystem feature which also requires mention is the Ramsar wetland site in the southern and southwestern Firth. This internationally recognised site contains about 9000 ha of intertidal and coastal margins from approximately Miranda around the southern Firth coastline to Thames. At its closest point the Ramsar site is more than 25km from the proposed mussel farm and spat catching area. It has been recognised that given the localised footprint of marine farming effects as studied elsewhere in the Firth (Brownill 2008), effects on the Ramsar site are unlikely. We conclude that effects from the mussel farm on the Ramsar site are negligible.

4.2 Monitoring Recommendations

A monitoring regime is presented in Appendix D. This regime is based on that recently approved by Commissioners in relation to applications by Westpac Mussels Ltd to farm mussels at two sites in the Firth of Thames (Auckland Council, April 2018; hereafter 'Westpac Decision').

In the Westpac Decision there is detailed consideration of the need or otherwise, for ecological and water quality effects monitoring in relation to mussel farming in the Firth of Thames setting. That discussion has general application and is also relevant to the proposed Takutai farm proposal.

The Westpac Decision (Clause 51, page 13) noted '… *The conclusion of both experts* [in this case Mark Poynter for Westpac and Dr Sivaguru for Auckland Council] *was that the ecological effects of the proposal on the water column and seabed would be less than minor at both the applicant's sites, and the application could be granted. We accept that conclusion*…'

Broadly, and to paraphrase, the Westpac Decision did not find that there was a case to be made for phytoplankton (via Chlorophyll-*a*) or other water quality monitoring based on a concern regarding possible phytoplankton depletion or other associated water column effects. Such effects were accepted as not being significant, or likely to be so in the future.

Although the Westpac Decision accepted that seabed effects would also be minor (as quoted above), the Commissioners were clearly of a view that some benthic monitoring was still warranted.

Consequently, the Westpac Decision requires an environmental monitoring plan to be submitted prior to the installation of any structures on the site. The consent conditions are specific as to the parameters to be assessed as part of benthic sediment monitoring and when monitoring is to occur but beyond that it simply identifies what topics need to be covered in the plan. These include procedures and process for the monitoring, reporting and review, and sample site selection and replication.

The recent 'direction' from the Commissioners in the Westpac Decision, which was accepted by Auckland Council, is taken as the likely basis for an acceptable threshold of monitoring for the Takutai proposal.

5 CONCLUSION

The following factors limit the risk of detrimental effects to the water column and benthic habitat from the proposed mussel farming and spat collecting activities:

- The site is in relatively deep water and is subject to moderately strong tidally driven currents as well as exposure to residual wind driven currents from a wide aspect. These physical characteristics will encourage the dispersal and dilution of any farm derived 'particulates' and should avoid, or adequately mitigate, the risk of adverse depositional effects;
- The site is located a significant distance from shore areas, and will not adversely affect shoreline habitats;
- The site is positioned over muddy and modified substrates that contain a common and widespread invertebrate assemblage that are not considered to be sensitive to, or likely to be adversely affected by, the nature and scale of the proposed farming activities.
- This conclusion is supported by the New Zealand literature, which indicates that mussel farming has minor effects in relatively open and well flushed environments.

Further, it is concluded that:

- Effects on fish and fishing and seabirds are likely to be positive, neutral or at least not adverse;
- The risk of entanglement of whales or dolphins is remote and effects on cetaceans are less than minor;
- Biosecurity at the farm can be managed through an appropriate Biosecurity Management Plan;
- It is highly unlikely that adverse cumulative ecological or water quality effects will occur, taking into account the existing approved mussel farms in the Firth;
- There are likely to be positive ecological effects associated with the mussel farm and spat collection structures (anchoring systems, backbone warps and buoys);
- Ecological effects on the benthos and in the water column beyond the farm are not expected to be adverse or significant and are expected to be minor; and
- Ecological monitoring is proposed which is in line with recent Auckland Council decisions on mussel farms in the Firth of Thames.

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7 REFERENCES

Auckland Council. April 2018. Decision following the hearing of an application for resource consent under the Resource Management Act 1991: Rangipakihi and Waitoetoe Mussel Farms.

Australian and New Zealand Environment and Conservation Council. 2000. Australian and New Zealand guidelines for fresh and marine water quality. ANZECC, Canberra.

Besant, P., and S. Hooker. 1996. The history of the wild mussel (Perna canaliculus) fishery in the Firth of Thames and its relevance to present aquaculture of this species in the area.

Broekhuizen, N., J. Ren, J. Zeldis, and S. Stevens. 2004. Ecological sustainability assessment for Firth of Thames shellfish aquaculture: Tasks 2-4–Biological modelling. Prepared for Auckland Regional Council, Environment Waikato and Western Firth of Thames Mussel Industry Consortium.

Broekhuizen, N., J. Zeldis, S. A. Stephens, J. W. Oldman, A. H. Ross, J. Ren, and M. R. James. 2002. Factors related to the sustainability of shellfish aqaculture operations in the Firth of Thames: A Preliminary Analysis. Prepared for Environment Waikato and Auckland Regional Council.

Brown, S., and R. A. Asher. 2000. Benthic survey and assessment of effects for a proposed mussel spat catching site: Waimangu Point, Firth of Thames. Prepared for Thames Mussels Ltd. Cawthron report No 596.

Brownill, B. 2008. Muddy Feet Phase II. Firth of Thames Ramsar Site Gap Analysis: Report prepared for the Muddy Feet Steering Group by Tikapa Kahawai Coastal/Marine Advisory Service Kaiaua, New Zealand.

Cromey, C. J., T. D. Nickell, and K. D. Black. 2002. DEPOMOD-modelling the deposition and biological effects of waste solids from marine cage farms. Aquaculture 214:211–239.

D'Amours, O., P. Archambault, C. W. McKindsey, and L. E. Johnson. 2008. Local enhancement of epibenthic macrofauna by aquaculture activities. Marine Ecology Progress Series 371:73–84.

Dudley, B., J. Zeldis, Olivia Burge, and O. Burge. 2017. New Zealand Coastal Water Quality Assessment. National Institute of Water & Atmospheric Research Ltd, Christchurch.

Environment Waikato. 2007. Trace Elements in Sediments of the Lower Eastern Coast of the Firth of Thames. Environment Waikato Technical Report 2007/08.

Fisheries Consultancy Services Ltd. 2002. Application for Resource Consent - Provision of Further Information to Waikato Regional Council.

Forrest, B., and C. Cornelisen. 2015. Monitoring framework for the Waikato coastal marine area: Report 1 - Rationale and key elements.

Forrest, B., C. Cornelisen, D. Clement, N. Keeley, and D. Taylor. 2015. Monitoring framework for the Waikato coastal marine area: Report 2–Regional aquaculture monitoring priorities and guidance.

Giles, H., C. A. Pilditch, and D. G. Bell. 2006. Sedimentation from mussel (Perna canaliculus) culture in the Firth of Thames, New Zealand: Impacts on sediment oxygen and nutrient fluxes. Aquaculture 261:125–140.

Gillespie, R. P., and P. Heath. 2013. Literature review of ecological effects of aquaculture.

Green, M., and J. Zeldis. 2015. Firth of Thames water quality and ecosystem health 4355:177.

Hargrave, B. T., M. Holmer, and C. P. Newcombe. 2008. Towards a classification of organic enrichment in marine sediments based on biogeochemical indicators. Marine Pollution Bulletin 56:810–824.

Hauraki Gulf Forum. 2014. State of our Gulf 2014. Tikapa Moana-Hauraki Gulf. State of the Environment Report. Prepared on behalf of Auckland Council.

Hayden, B., and T. Kendrick. 1992. Predicting the settlement of greenshell mussels, Perna canaliculus, from the abundance of larvae. Pages 7–10 Proceedings of the Second International Temperate Reef Symposium. NIWA, Wellington.

Hitchmough, R. ., L. . Bull, and P. (Comps. . Cromarty. 2007. New Zealand Threat Classification System lists—2005. Wellington, N.Z.

James, Mark; Jamieson, S. 2017. Assessment of ecological effects of a proposed marine farm in the Western Firth of Thames. Prepared for Western Firth Marine Farming Consortium.

Keeley, N. B., B. M. Forrest, G. Hopkins, P. Gillespie, B. Knight, S. Webb, D. Clement, and J. Gardner. 2009. Sustainable Aquaculture in New Zealand: Review of the Ecological Effects of Farming Shellfish and Other Non-finfish Species. Cawthron Institute, Nelson.

Keeley, N. B., B. M. Forrest, and C. K. Macleod. 2013. Novel observations of benthic enrichment in contrasting flow regimes with implications for marine farm monitoring and management. Marine Pollution Bulletin 66:105–116.

Keeley, N. B., and D. T. Taylor. 2015. A Review of Total Free Sulfide Concentrations in Relation to Salmon Farm Monitoring in the Marlborough Sounds. Cawthron Report No. 2742.

Keeley, N., C. Cornelisen, B. Knight, B. Forrest, and D. Taylor. 2015. Monitoring framework for the Waikato Coastal Marine Area: Report 3–seabed and water column monitoring and standards. Prepared for Waikato Regional Council. Hamilton.

Lloyd, B. D. 2003. Potential effects of mussel farming on New Zealand's marine mammals and seabirds: A discussion paper. Department of Conservation, Wellington, New Zealand. DOC Science Publishing. vii + 34p. 2003.:43.

McKnight, D. G. 1969. Infaunal benthic communities of the New Zealand Continental Shelf. New Zealand Journal of Marine and Freshwater Research 3:409–444.

McLeod, I. M., D. M. Parsons, M. A. Morrison, A. Le Port, and R. B. Taylor. 2012. Factors affecting the recovery of soft-sediment mussel reefs in the Firth of Thames, New Zealand. Marine and Freshwater Research 63:78–83.

Ministry for Primary Industries. 2013. Overview of ecological effects of aquaculture. Ministry for Primary Industries, Wellington.

Ministry of Fisheries. 2009. Wilson Bay Interim Aquaculture Management Areas (AMAs) Final Evaluation Report.

Ministry of Primary Industries. 2018. National Aquatic Biodiversity Information System. http://www.nabis.govt.nz/map.aspx?topic=Aquaculture.

Morrisey, D. ., N. . Keeley, D. . Elvines, and D. Taylor. 2016. Firth of Thames and Hauraki Gulf enrichment stage mapping.

Oldman, J., J. Hong, S. Stephens, and N. Broekhuizen. 2007. Verification of Firth of Thames Hydrodynamic Model Prepared for Auckland Regional Council. Auckland.

Reid, B. 1969. Mussel survey Hauraki Gulf and Firth of Thames.1958. Fisheries Tech Report No 34.

Sea Change. 2014. Sea Change Hauraki Gulf Marine Spatial Plan. Aquaculture Round Table. Technical Report 2: synthesis of issues and options.

Sea Change. 2017. Sea Change - Tai Timu Tai Pari.

Stenton-Dozey, J., Zeldis, J. 2012. Wilson Bay Marine Farming Zone Area A water quality monitoring biennial report for May 2010 to March 2012, NIWA client report CHC2012-062 prepared for Wilson Bay Group A Consortium.

Stenton-Dozey, J., D. Morrisey, N. Broekhuizen, and J. Oldman. 2008. Fisheries Resource Impact Assessment (Wilsons Bay Area B Interim AMA). Prepared for Ministry of Fisheries. NIWA Client Report: CHC2008-145.

Stephens, S. 2003. Ecological sustainability assessment for Firth of Thames shellfish aquaculture: Task 1-hydrodynamic modelling. NIWA Report HAM2003-113. 32p.

Wildish, D. J., B. T. Hargrave, and G. Pohle. 2001. Cost-effective monitoring of organic enrichment resulting from salmon mariculture. ICES Journal of Marine Science 58:469–476.

4SIGHT CONSULTING

Appendix A:

Waikato Regional Council recommended parameters to be included in the baseline survey for a new marine farm.

Recommended parameters	**Parameter measured in this survey**
Water quality	
Temperature	✓
Salinity	✓
Water clarity	✓
Ammonium (NH_4-N	*NA
Ammonia (NH_3-N	*NA
Oxides of Nitrogen (NO_X-N)	✓
Total N (TN)	✓
Dissolved reactive phosphorus (DRP)	✓
Total Phosphorus (TP)	✓
Chlorophyll *a*	✓
Sediment chemistry	
Organic carbon	✓
Nitrogen	✓
Phosphorus	✓
Benthic fauna and flora	
Macroinfauna species	✓
Macroinfauna community parameters (abundance, richness, diversity)	✓
Epifauna species	✓
Epiflora	✓
Seafloor	
Sediment grain size	✓ *Samples from initial survey archived
Substrate type (e.g. mud, sand, rock)	✓
Hydrodynamics	
Current speed	✓
Current direction	✓
Farm characteristics	
Farm layout	✓

Appendix B:

Laboratory reports for water quality and sediment quality analyses

R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

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ANALYSIS REPORT

SPv1

Client:	4SIGHT Consulting Limited	**Lab No:**	1892051
Contact:	Mark Poynter	**Date Received:**	08-Dec-2017
	C/- 4SIGHT Consulting Limited	**Date Reported:**	20-Dec-2017
	PO Box 402053	**Quote No:**	89164
	Tutukaka 0153	**Order No:**	AA2655
		Client Reference:	Ponui
		Submitted By:	Mark Poynter

Sample Type: Saline

Sample Name:		Ponui WQ1s 06-Dec-2017	Ponui WQ1m 06-Dec-2017	Ponui WQ2s 06-Dec-2017	Ponui WQ2m 06-Dec-2017	Ponui WQ3s 06-Dec-2017
Lab Number:		1892051.1	1892051.2	1892051.3	1892051.4	1892051.5
Salinity*		35	35	35	35	35
Total Nitrogen*	g/m³	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3
Nitrate-N + Nitrite-N	g/m³	< 0.0010	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Kjeldahl Nitrogen (TKN)*	g/m³	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Dissolved Reactive Phosphorus	g/m³	0.0102	0.0102	0.0103	0.0101	0.0095
Total Phosphorus*	g/m³	0.012	0.013	0.017	0.015	0.012
Chlorophyll a*	g/m³	< 0.003	< 0.003	< 0.003	< 0.003	< 0.003

Sample Name:		Ponui WQ3m 06-Dec-2017				
Lab Number:		1892051.6				
Salinity*		35	-	-	-	-
Total Nitrogen*	g/m³	0.3	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	< 0.0010	-	-	-	-
Total Kjeldahl Nitrogen (TKN)*	g/m³	0.3	-	-	-	-
Dissolved Reactive Phosphorus	g/m³	0.0103	-	-	-	-
Total Phosphorus*	g/m³	0.016	-	-	-	-
Chlorophyll a*	g/m³	< 0.003	-	-	-	-

Sample Type: Sediment

Sample Name:		Ponui 1 06-Dec-2017	Ponui 2 06-Dec-2017	Ponui 3 06-Dec-2017	Ponui 4 06-Dec-2017	Ponui 5 06-Dec-2017
Lab Number:		1892051.7	1892051.8	1892051.9	1892051.10	1892051.11
Organic Matter*	g/100g dry wt	8.3	9.0	9.0	8.2	8.4
Ash*	g/100g dry wt	92	91	91	92	92
Total Recoverable Phosphorus	mg/kg dry wt	610	660	1,950	850	940
Total Nitrogen*	g/100g dry wt	0.15	0.18	0.21	0.17	0.18
Total Organic Carbon*	g/100g dry wt	1.27	1.17	1.30	1.16	1.15

Sample Name:		Ponui 6 06-Dec-2017				
Lab Number:		1892051.12				
Organic Matter*	g/100g dry wt	6.8	-	-	-	-
Ash*	g/100g dry wt	93	-	-	-	-
Total Recoverable Phosphorus	mg/kg dry wt	720	-	-	-	-
Total Nitrogen*	g/100g dry wt	0.14	-	-	-	-
Total Organic Carbon*	g/100g dry wt	0.89	-	-	-	-

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SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	1-6
Total Kjeldahl Digestion*	Sulphuric acid digestion with copper sulphate catalyst.	-	1-6
Total Phosphorus Digestion*	Acid persulphate digestion.	-	1-6
Salinity*	Conductivity Meter (WTW Cond 340i with nonlinear temperature compensation according to EN 27 888). APHA 2520 B 22nd ed. 2012.	0.2	1-6
Total Nitrogen*	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3.	0.05 g/m^3	1-6
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO3- I 22nd ed. 2012 (modified).	0.0010 g/m^3	1-6
Total Kjeldahl Nitrogen (TKN)*	Total Kjeldahl digestion, phenol/hypochlorite colorimetry. Discrete Analyser. APHA 4500-N_{org} D. (modified) 4500 NH_3 F (modified) 22nd ed. 2012.	0.10 g/m^3	1-6
Dissolved Reactive Phosphorus	Saline sample. Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G 22nd ed. 2012.	0.0010 g/m^3	1-6
Total Phosphorus*	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis) 22nd ed. 2012. Also modified to include the use of a reductant to eliminate interference from arsenic present in the sample. NAWASCO, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	1-6
Chlorophyll a*	Acetone extraction. Spectroscopy. APHA 10200 H (modified) 22nd ed. 2012.	0.003 g/m^3	1-6

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	7-12
Organic Matter*	Calculation: 100 - Ash (dry wt).	0.04 g/100g dry wt	7-12
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	7-12
Ash*	Ignition in muffle furnace 550°C, 6hr, gravimetric. APHA 2540 G 22nd ed. 2012.	0.04 g/100g dry wt	7-12
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	7-12
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	7-12
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	7-12

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

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R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

SUPv1

Client:	4SIGHT Consulting Limited	**Lab No:**	2070442
Contact:	Oliver Bone	**Date Received:**	26-Oct-2018
	C/- 4SIGHT Consulting Limited	**Date Reported:**	02-Nov-2018
	PO Box 402053	**Quote No:**	95280
	Tutukaka 0153	**Order No:**	AA2655
		Client Reference:	
		Submitted By:	Oliver Bone

Sample Type: Saline

Sample Name:		PO18-1 Surf 24-Oct-2018 10:00 am	PO18-1 Mid 24-Oct-2018 10:00 am	PO18-2 Surf 24-Oct-2018 10:00 am	PO18-2 Mid 24-Oct-2018 10:00 am
Lab Number:		2070442.1	2070442.2	2070442.3	2070442.4
Turbidity*	NTU	0.253 ± 0.042	0.417 ± 0.044	0.274 ± 0.042	0.275 ± 0.042
Salinity*		34.20 ± 0.44	34.60 ± 0.44	34.30 ± 0.44	34.50 ± 0.44
Total Suspended Solids*	g/m^3	< 3 ± 2.1	4.9 ± 2.1	< 3 ± 2.1	< 3 ± 2.1
Total Nitrogen*	g/m^3	0.115 ± 0.036	0.224 ± 0.043	< 0.08 ± 0.034	0.264 ± 0.046
Nitrite-N	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Nitrate-N	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Nitrate-N + Nitrite-N	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Kjeldahl Nitrogen (TKN)*	g/m^3	0.115 ± 0.036	0.224 ± 0.043	< 0.08 ± 0.034	0.264 ± 0.046
Dissolved Reactive Phosphorus	g/m^3	0.0105	0.0099	0.0105	0.0102
Total Phosphorus*	g/m^3	0.0155 ± 0.0034	0.0125 ± 0.0032	0.0155 ± 0.0034	0.0155 ± 0.0034
Chlorophyll a*	g/m^3	0.000342 ± 0.000061	0.000540 ± 0.000095	0.000310 ± 0.000056	0.000557 ± 0.000098

Sample Name:		PO18-3 Surf 24-Oct-2018 10:00 am	PO18-3 Mid 24-Oct-2018 10:00 am	PO18-4 Surf 25-Oct-2018 10:00 am	PO18-4 Mid 25-Oct-2018 10:00 am
Lab Number:		2070442.5	2070442.6	2070442.7	2070442.8
Turbidity*	NTU	0.354 ± 0.043	0.280 ± 0.042	0.374 ± 0.043	0.531 ± 0.046
Salinity*		34.40 ± 0.44	34.60 ± 0.44	34.30 ± 0.44	34.30 ± 0.44
Total Suspended Solids*	g/m^3	< 3 ± 2.1	< 3 ± 2.1	< 3 ± 2.1	< 3 ± 2.1
Total Nitrogen*	g/m^3	0.135 ± 0.037	0.106 ± 0.036	< 0.08 ± 0.034	< 0.08 ± 0.034
Nitrite-N	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Nitrate-N	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Nitrate-N + Nitrite-N	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Kjeldahl Nitrogen (TKN)*	g/m^3	0.135 ± 0.037	0.106 ± 0.036	< 0.08 ± 0.034	< 0.08 ± 0.034
Dissolved Reactive Phosphorus	g/m^3	0.0105	0.0101	0.0104	0.0103
Total Phosphorus*	g/m^3	0.0155 ± 0.0034	0.0155 ± 0.0034	0.0155 ± 0.0034	0.0155 ± 0.0034
Chlorophyll a*	g/m^3	0.000290 ± 0.000053	0.000348 ± 0.000062	< 0.0002 ± 0.000038	0.000328 ± 0.000059

Sample Name:		PO18-5 Surf 25-Oct-2018 10:00 am	PO18-5 Mid 25-Oct-2018 10:00 am	PO18-6 Surf 25-Oct-2018 10:00 am	PO18-6 Mid 25-Oct-2018 10:00 am
Lab Number:		2070442.9	2070442.10	2070442.11	2070442.12
Turbidity*	NTU	0.296 ± 0.042	0.326 ± 0.043	0.347 ± 0.043	0.441 ± 0.044
Salinity*		34.30 ± 0.44	34.50 ± 0.44	34.50 ± 0.44	34.70 ± 0.44
Total Suspended Solids*	g/m^3	< 3 ± 2.1	< 3 ± 2.1	< 3 ± 2.1	< 3 ± 2.1
Total Nitrogen*	g/m^3	0.134 ± 0.037	< 0.08 ± 0.034	0.168 ± 0.039	< 0.08 ± 0.034
Nitrite-N	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Nitrate-N	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Nitrate-N + Nitrite-N	g/m^3	< 0.0010	< 0.0010	< 0.0010	< 0.0010
Total Kjeldahl Nitrogen (TKN)*	g/m^3	0.134 ± 0.037	< 0.08 ± 0.034	0.168 ± 0.039	< 0.08 ± 0.034
Dissolved Reactive Phosphorus	g/m^3	0.0106	0.0104	0.0105	0.0100
Total Phosphorus*	g/m^3	0.0185 ± 0.0037	0.0145 ± 0.0034	0.0165 ± 0.0035	0.0165 ± 0.0035
Chlorophyll a*	g/m^3	< 0.0002 ± 0.000038	0.000448 ± 0.000079	0.000267 ± 0.000049	0.00064 ± 0.00012

The reported uncertainty is an expanded uncertainty with a level of confidence of approximately 95 percent (i.e. two standard deviations, calculated using a coverage factor of 2). Reported uncertainties are calculated from the performance of typical matrices, and do not include variation due to sampling.

For further information on uncertainty of measurement at Hill Laboratories, refer to the technical note on our website: www.hill-laboratories.com/files/Intro_To_UOM.pdf, or contact the laboratory.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	1-12
Total Kjeldahl Digestion - Trace level*	Sulphuric acid digestion with copper sulphate catalyst.	-	1-12
Turbidity*	Saline sample. Analysis using a Hach 2100N, Turbidity meter. APHA 2130 B 22nd ed. 2012.	0.05 NTU	1-12
Salinity*	Conductivity Meter (WTW Cond 340i with nonlinear temperature compensation according to EN 27 888). APHA 2520 B 22nd ed. 2012.	0.2	1-12
Total Suspended Solids*	Saline sample. Filtration using Whatman 934 AH, Advantec GC-50 or equivalent filters (nominal pore size 1.2 - 1.5µm), gravimetric determination. APHA 2540 D (modified) 22nd ed. 2012.	3 g/m^3	1-12
Total Nitrogen*	Calculation: TKN + Nitrate-N + Nitrite-N. Please note: The Default Detection Limit of 0.05 g/m^3 is only attainable when the TKN has been determined using a trace method utilising duplicate analyses. In cases where the Detection Limit for TKN is 0.10 g/m^3, the Default Detection Limit for Total Nitrogen will be 0.11 g/m^3.	0.05 g/m^3	1-12
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO3- I 22nd ed. 2012 (modified).	0.0010 g/m^3	1-12
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1-12
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO3- I 22nd ed. 2012 (modified).	0.0010 g/m^3	1-12
Total Kjeldahl Nitrogen (TKN)*	Total Kjeldahl digestion, phenol/hypochlorite colorimetry (Discrete Analysis). Trace level. APHA 4500-Norg D. (modified) 4500 NH3 F (modified) 22nd ed. 2012.	0.05 g/m^3	1-12
Dissolved Reactive Phosphorus	Saline sample. Molybdenum blue colorimetry. Flow injection analyser. APHA 4500-P G 22nd ed. 2012.	0.0010 g/m^3	1-12
Total Phosphorus*	Total phosphorus digestion, ascorbic acid colorimetry. Discrete Analyser. APHA 4500-P B & E (modified from manual analysis) 22nd ed. 2012. Also modified to include the use of a reductant to eliminate interference from arsenic present in the sample. NAWASCO, Water & soil Miscellaneous Publication No. 38, 1982.	0.004 g/m^3	1-12
Chlorophyll a*	Acetone extraction. Fluorometer. APHA 10200 H (modified) 22nd ed. 2012.	0.0002 g/m^3	1-12

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

This certificate of analysis must not be reproduced, except in full, without the written consent of the signatory.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

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Hill Laboratories
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R J Hill Laboratories Limited
28 Duke Street Frankton 3204
Private Bag 3205
Hamilton 3240 New Zealand

T 0508 HILL LAB (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Client:	4SIGHT Consulting Limited	**Lab No:**	2070446	SUPv1
Contact:	Oliver Bone	**Date Received:**	26-Oct-2018	
	C/- 4SIGHT Consulting Limited	**Date Reported:**	02-Nov-2018	
	PO Box 402053	**Quote No:**	95279	
	Tutukaka 0153	**Order No:**	AA2655	
		Client Reference:		
		Submitted By:	Oliver Bone	

Sample Type: Sediment

Sample Name:		PO18 - 1 25-Oct-2018 9:15 am	PO18 - 2 25-Oct-2018 9:34 am	PO18 - 3 25-Oct-2018 10:20 am	PO18 - 4 25-Oct-2018 11:13 am
Lab Number:		2070446.1	2070446.2	2070446.3	2070446.4
Organic Matter*	g/100g dry wt	6.2	7.2	7.5	6.0
Dry Matter	g/100g as rcvd	47.8 ± 5.0	41.6 ± 5.0	41.8 ± 5.0	48.7 ± 5.0
Ash*	g/100g dry wt	93.8 ± 1.4	92.8 ± 1.4	92.5 ± 1.4	94.0 ± 1.4
Total Recoverable Phosphorus	mg/kg dry wt	737 ± 79	764 ± 81	817 ± 86	648 ± 70
Total Nitrogen*	g/100g dry wt	0.135 ± 0.041	0.160 ± 0.042	0.158 ± 0.042	0.127 ± 0.041
Total Organic Carbon*	g/100g dry wt	0.930 ± 0.085	1.049 ± 0.093	1.048 ± 0.093	0.862 ± 0.080

Sample Name:		PO18 - 5 25-Oct-2018 11:53 am	PO18 - 6 25-Oct-2018 12:34 pm		
Lab Number:		2070446.5	2070446.6		
Organic Matter*	g/100g dry wt	5.5	6.9	-	-
Dry Matter	g/100g as rcvd	53.0 ± 5.0	45.5 ± 5.0	-	-
Ash*	g/100g dry wt	94.5 ± 1.4	93.1 ± 1.4	-	-
Total Recoverable Phosphorus	mg/kg dry wt	718 ± 77	615 ± 67	-	-
Total Nitrogen*	g/100g dry wt	< 0.13 ± 0.041	0.144 ± 0.041	-	-
Total Organic Carbon*	g/100g dry wt	0.756 ± 0.073	0.973 ± 0.088	-	-

The reported uncertainty is an expanded uncertainty with a level of confidence of approximately 95 percent (i.e. two standard deviations, calculated using a coverage factor of 2). Reported uncertainties are calculated from the performance of typical matrices, and do not include variation due to sampling.

For further information on uncertainty of measurement at Hill Laboratories, refer to the technical note on our website: www.hill-laboratories.com/files/Intro_To_UOM.pdf, or contact the laboratory.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.
Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sediment

Test	Method Description	Default Detection Limit	Sample No
Environmental Solids Sample Drying*	Air dried at 35°C Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-6
Environmental Solids Sample Preparation	Air dried at 35°C and sieved, <2mm fraction. Used for sample preparation. May contain a residual moisture content of 2-5%.	-	1-6
Organic Matter*	Calculation: 100 - Ash (dry wt).	0.04 g/100g dry wt	1-6
Dry Matter (Env)	Dried at 103°C for 4-22hr (removes 3-5% more water than air dry) , gravimetry. (Free water removed before analysis, non-soil objects such as sticks, leaves, grass and stones also removed). US EPA 3550.	0.10 g/100g as rcvd	1-6
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-6

Sample Type: Sediment			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ash*	Ignition in muffle furnace 550°C, 6hr, gravimetric. APHA 2540 G 22nd ed. 2012.	0.04 g/100g dry wt	1-6
Total Recoverable Phosphorus	Dried sample, sieved as specified (if required). Nitric/Hydrochloric acid digestion, ICP-MS, screen level. US EPA 200.2.	40 mg/kg dry wt	1-6
Total Nitrogen*	Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-6
Total Organic Carbon*	Acid pretreatment to remove carbonates present followed by Catalytic Combustion (900°C, O2), separation, Thermal Conductivity Detector [Elementar Analyser].	0.05 g/100g dry wt	1-6

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

Analysis - Under

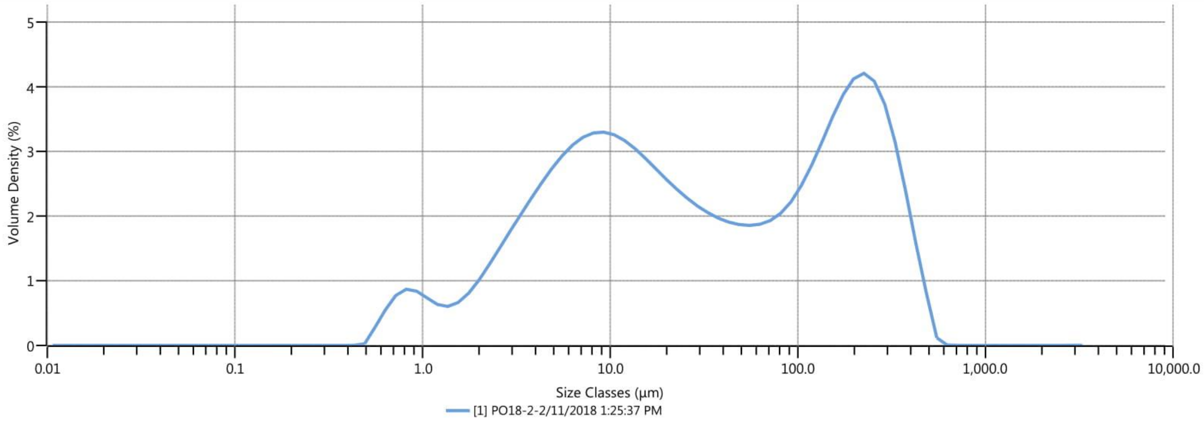
Measurement Details	
Sample Name	PO18-2
SOP File Name	Marine Sediment.msop
Lab Number	2018241/1
Operator Name	rodgers

Measurement Details	
Analysis Date Time	2/11/2018 1:25:37 PM
Measurement Date Time	2/11/2018 1:25:37 PM
Result Source	Measurement

Analysis	
Particle Name	Marine Sediment
Particle Refractive Index	1.500
Particle Absorption Index	0.200
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.71 %
Laser Obscuration	16.40 %

Result	
Concentration	0.0182 %
Span	9.803
Uniformity	2.978
Specific Surface Area	795.1 m^2/kg
D [3,2]	7.55 µm
D [4,3]	90.3 µm
Dv (10)	3.06 µm
Dv (50)	27.3 µm
Dv (90)	270 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0500	0.00	7.80	26.38	88.0	65.03	350	95.86	1410	100.00
0.0600	0.00	15.6	40.75	105	67.70	420	98.48	1680	100.00
0.120	0.00	31.0	51.81	125	70.75	500	99.79	2000	100.00
0.240	0.00	37.0	54.15	149	74.43	590	100.00	2380	100.00
0.490	0.00	44.0	56.34	177	78.59	710	100.00	2830	100.00
0.980	2.73	53.0	58.62	210	83.12	840	100.00	3360	100.00
2.00	6.05	63.0	60.72	250	87.90	1000	100.00		
3.90	13.33	74.0	62.72	300	92.56	1190	100.00		

Analysis - Under

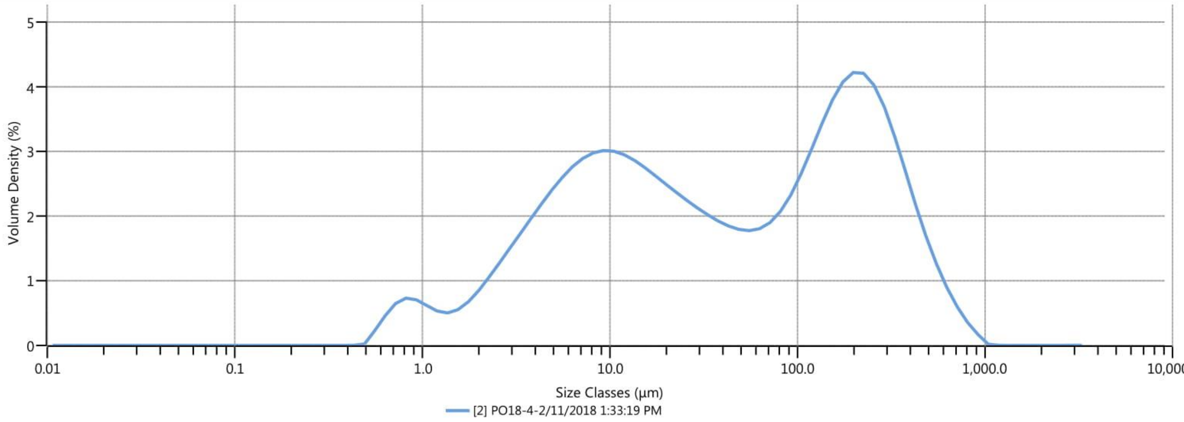
Measurement Details	
Sample Name	PO18-4
SOP File Name	Marine Sediment.msop
Lab Number	2018241/2
Operator Name	rodgers

Measurement Details	
Analysis Date Time	2/11/2018 1:33:19 PM
Measurement Date Time	2/11/2018 1:33:19 PM
Result Source	Measurement

Analysis	
Particle Name	Marine Sediment
Particle Refractive Index	1.500
Particle Absorption Index	0.200
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.48 %
Laser Obscuration	18.46 %

Result	
Concentration	0.0239 %
Span	8.083
Uniformity	2.621
Specific Surface Area	690.4 m^2/kg
D [3,2]	8.69 µm
D [4,3]	115 µm
Dv (10)	3.53 µm
Dv (50)	39.5 µm
Dv (90)	323 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0500	0.00	7.80	22.81	88.0	59.79	350	91.70	1410	100.00
0.0600	0.00	15.6	36.11	105	62.61	420	94.77	1680	100.00
0.120	0.00	31.0	46.87	125	65.92	500	96.94	2000	100.00
0.240	0.00	37.0	49.18	149	69.90	590	98.36	2380	100.00
0.490	0.00	44.0	51.31	177	74.32	710	99.32	2830	100.00
0.980	2.29	53.0	53.49	210	79.00	840	99.81	3360	100.00
2.00	5.07	63.0	55.50	250	83.76	1000	100.00		
3.90	11.27	74.0	57.45	300	88.35	1190	100.00		

Analysis - Under

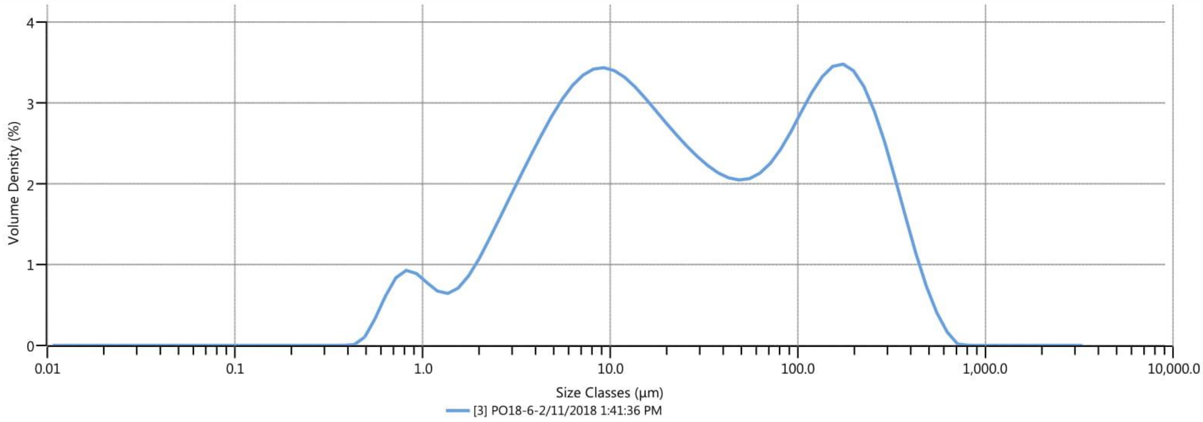
Measurement Details	
Sample Name	PO18-6
SOP File Name	Marine Sediment.msop
Lab Number	2018241/3
Operator Name	rodgers

Measurement Details	
Analysis Date Time	2/11/2018 1:41:36 PM
Measurement Date Time	2/11/2018 1:41:36 PM
Result Source	Measurement

Analysis	
Particle Name	Marine Sediment
Particle Refractive Index	1.500
Particle Absorption Index	0.200
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.55 %
Laser Obscuration	23.50 %

Result	
Concentration	0.0257 %
Span	10.017
Uniformity	3.024
Specific Surface Area	851.6 m^2/kg
D [3,2]	7.05 μm
D [4,3]	78.4 μm
Dv (10)	2.89 μm
Dv (50)	23.2 μm
Dv (90)	235 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0500	0.00	7.80	27.71	88.0	69.42	350	96.59	1410	100.00
0.0600	0.00	15.6	42.74	105	72.58	420	98.35	1680	100.00
0.120	0.00	31.0	54.60	125	76.05	500	99.39	2000	100.00
0.240	0.00	37.0	57.15	149	79.89	590	99.87	2380	100.00
0.490	0.04	44.0	59.52	177	83.80	710	100.00	2830	100.00
0.980	3.03	53.0	62.01	210	87.63	840	100.00	3360	100.00
2.00	6.57	63.0	64.37	250	91.21	1000	100.00		
3.90	14.15	74.0	66.68	300	94.42	1190	100.00		

Analysis - Under

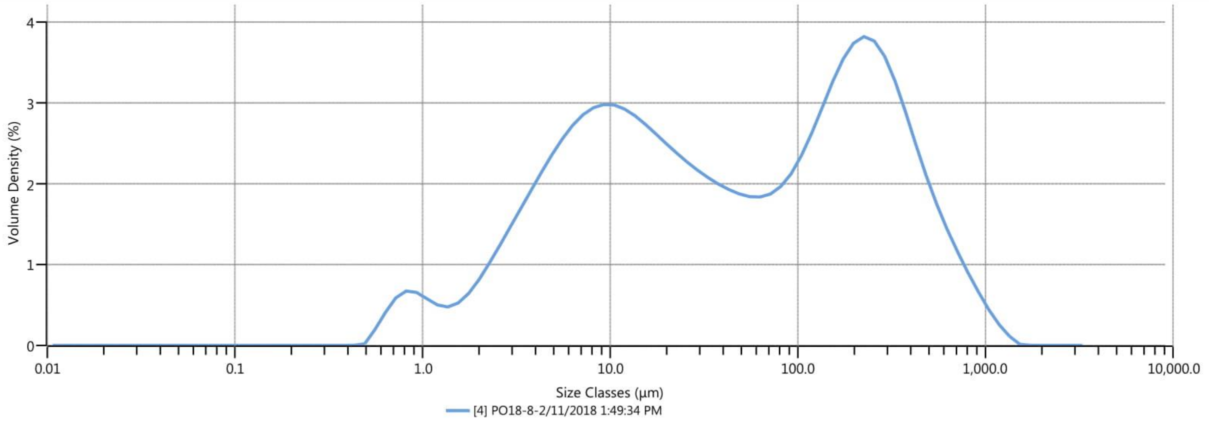
Measurement Details	
Sample Name	PO18-8
SOP File Name	Marine Sediment.msop
Lab Number	2018241/4
Operator Name	rodgers

Measurement Details	
Analysis Date Time	2/11/2018 1:49:34 PM
Measurement Date Time	2/11/2018 1:49:34 PM
Result Source	Measurement

Analysis	
Particle Name	Marine Sediment
Particle Refractive Index	1.500
Particle Absorption Index	0.200
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.47 %
Laser Obscuration	17.99 %

Result	
Concentration	0.0242 %
Span	9.205
Uniformity	2.992
Specific Surface Area	659.1 m^2/kg
D [3,2]	9.10 μm
D [4,3]	137 μm
Dv (10)	3.68 μm
Dv (50)	41.6 μm
Dv (90)	387 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0500	0.00	7.80	22.10	88.0	59.22	350	88.09	1410	99.99
0.0600	0.00	15.6	35.28	105	61.76	420	91.41	1680	100.00
0.120	0.00	31.0	46.10	125	64.64	500	93.99	2000	100.00
0.240	0.00	37.0	48.48	149	68.07	590	95.93	2380	100.00
0.490	0.00	44.0	50.69	177	71.89	710	97.55	2830	100.00
0.980	2.07	53.0	52.98	210	76.01	840	98.64	3360	100.00
2.00	4.71	63.0	55.05	250	80.36	1000	99.40		
3.90	10.73	74.0	57.00	300	84.74	1190	99.81		

Analysis - Under

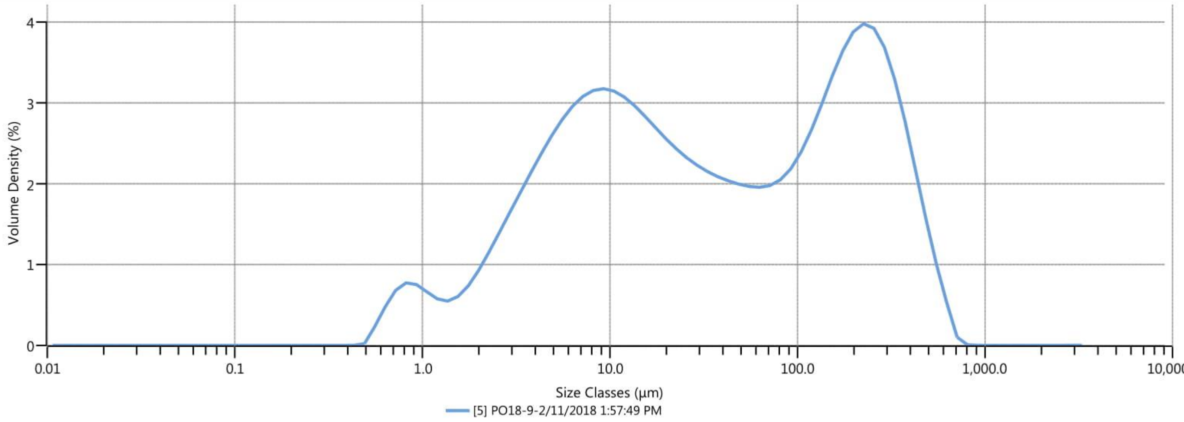
Measurement Details	
Sample Name	PO18-9
SOP File Name	Marine Sediment.msop
Lab Number	2018241/5
Operator Name	rodgers

Measurement Details	
Analysis Date Time	2/11/2018 1:57:49 PM
Measurement Date Time	2/11/2018 1:57:49 PM
Result Source	Measurement

Analysis	
Particle Name	Marine Sediment
Particle Refractive Index	1.500
Particle Absorption Index	0.200
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.52 %
Laser Obscuration	17.86 %

Result	
Concentration	0.0215 %
Span	9.442
Uniformity	2.901
Specific Surface Area	736.5 m^2/kg
D [3,2]	8.15 μm
D [4,3]	102 μm
Dv (10)	3.30 μm
Dv (50)	31.8 μm
Dv (90)	303 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0500	0.00	7.80	24.64	88.0	63.47	350	93.15	1410	100.00
0.0600	0.00	15.6	38.55	105	66.08	420	96.27	1680	100.00
0.120	0.00	31.0	49.66	125	69.01	500	98.35	2000	100.00
0.240	0.00	37.0	52.12	149	72.49	590	99.53	2380	100.00
0.490	0.00	44.0	54.45	177	76.41	710	99.97	2830	100.00
0.980	2.41	53.0	56.88	210	80.67	840	100.00	3360	100.00
2.00	5.44	63.0	59.09	250	85.20	1000	100.00		
3.90	12.22	74.0	61.16	300	89.74	1190	100.00		

Analysis - Under

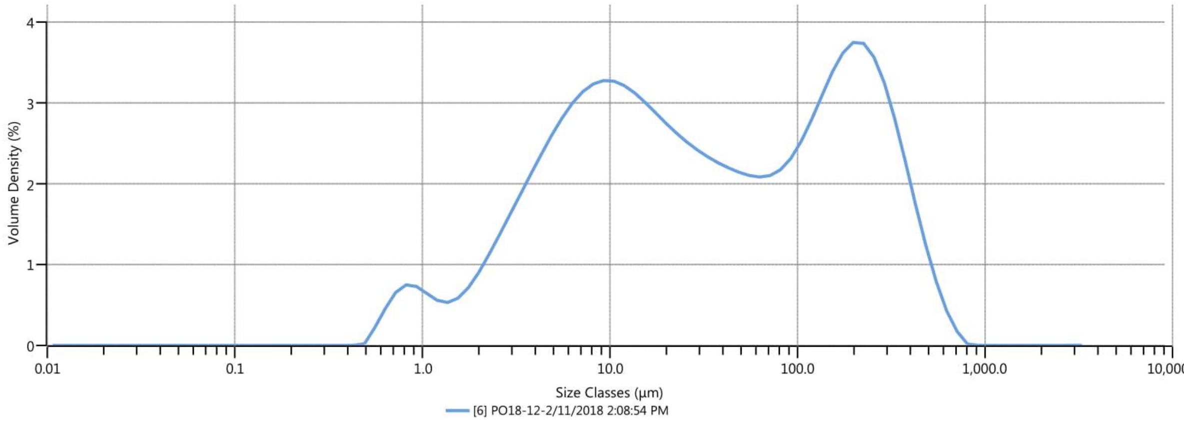
Measurement Details	
Sample Name	PO18-12
SOP File Name	Marine Sediment.msop
Lab Number	2018241/6
Operator Name	rodgers

Measurement Details	
Analysis Date Time	2/11/2018 2:08:54 PM
Measurement Date Time	2/11/2018 2:08:54 PM
Result Source	Measurement

Analysis	
Particle Name	Marine Sediment
Particle Refractive Index	1.500
Particle Absorption Index	0.200
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.51 %
Laser Obscuration	19.07 %

Result	
Concentration	0.0234 %
Span	9.428
Uniformity	2.876
Specific Surface Area	729.0 m^2/kg
D [3,2]	8.23 μm
D [4,3]	94.3 μm
Dv (10)	3.38 μm
Dv (50)	29.3 μm
Dv (90)	280 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0500	0.00	7.80	24.43	88.0	65.69	350	94.40	1410	100.00
0.0600	0.00	15.6	38.92	105	68.45	420	96.96	1680	100.00
0.120	0.00	31.0	50.88	125	71.52	500	98.62	2000	100.00
0.240	0.00	37.0	53.55	149	75.11	590	99.53	2380	100.00
0.490	0.00	44.0	56.07	177	79.04	710	99.93	2830	100.00
0.980	2.31	53.0	58.68	210	83.19	840	100.00	3360	100.00
2.00	5.25	63.0	61.04	250	87.42	1000	100.00		
3.90	11.91	74.0	63.24	300	91.48	1190	100.00		

06.11.2018

Oliver Bone
Ecology Consultant
4Sight Consulting
Oceans Resort Hotel, Marina Road
Tutukaka 0153

Dear Oliver

SEDIMENT SULPHIDE RESULTS

Samples were received 26.10.2018 packed in ice in a cool box.

18 sediment samples were tested for sulphide concentration with a sulphide specific electrode on the same day, 26.10.2018, using Cawthron protocol 60.102.The samples were prepared for measurement by solubilizing the sediments in a high pH solution containing a chelating agent and an anti-oxidant. The electrode output was measured by a millivolt (mV) meter and calibrated using sulphide standards. The sulphide standard was checked for purity using a United States Pharmacopoeia method. Results are found in the table below.

Table 1. Sulphide concentrations in sediments.

Sample ID	Site ID	Sample Concentration in µM
P1	A	0
P1	B	0
P1	C	0
P2	A	0
P2	B	0
P2	C	0
P3	A	<69
P3	B	<69
P3	C	<69
P4	A	0
P4	B	0
P4	C	0
P5	A	0
P5	B	0
P5	C	0
P6	A	0
P6	B	0
P6	C	0

98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042, New Zealand | T (+64) 03 548 2319 | F (+64) 03 546 9464 | www.cawthron.org.nz

Yours sincerely

Fiona Gower
Technical Consultant

Juliette Butler
Laboratory Technician

98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042, New Zealand | T (+64) 03 548 2319 | F (+64) 03 546 9464 | www.cawthron.org.nz

Appendix C:

Fauna identified in grab samples

Species list from the initial survey:

Taxa	**PoSed 1**	**PoSed 2**	**PoSed 3**	**PoSed 4**	**PoSed 5**	**PoSed 6**	**PoSed 7**	**PoSed 8**	**PoSed 9**	**PoSed 10**
ANTHOZOA									1	
NEMERTEA	1		2						1	1
POLYCHAETA										
Ampharetidae			2							
Capitellidae							1		1	
Cirratulidae	5	3		1	4	7	3	5	9	7
Cossuridae	5	7	13	7	3		2	5	9	5
Flabelligeridae			1					1		
Hesionidae		1						1		
Lumbrineridae			1		1					
Maldanidae					1					
Nephtyidae	4	4	4	4	5	1	4	6	2	4
Onuphidae				1		1		1		
Paraonidae			1							1
Polynoidae				1		3	2	2		
Sabellidae	1		3	2			1		1	2
Sigalionidae		3			2		1	3	4	3
Spionidae									1	
Terebellidae			1	1						
GASTROPODA										
Amalda northlandica			1		1			1	1	
Philine sp.			1		1			1		
BIVALVIA										
Arthritica bifurca	1			4	3			6	2	2
Dosinia lambata				1			1	1		
Linucula hartvigiana			1	4	3		4	3	1	3
Purpurocardia purpurata	1				1					1
Theora lubrica	1	4	6		1	1				
Zenatia acinaces		1								
Unidentified bivalve				1						
CRUSTACEA										
Amphipoda except Phoxocephalidae	9	3	7	5	14	4	8	5	4	14
Amphipoda Phoxocephalidae		2	2	2	3		3	4	2	3
Cumacea Bodotriidae	6	5	11	14	2	2	5	2	9	3
Cumacea Diastylidae	8	4	6	10	4	4	4	2	11	2
Decapoda Diogenidae			1				1			
Decapoda Laomediidae							1			
Decapoda Ocypodidae					1					1
Isopoda Asellota	1	5	5	1			1	3		
Mysidacea	2	3	1				1	1	2	1
Ostracoda	8	4	3	14	7	4	4	4	7	6
Tanaidacea	4		1	58	78	40	65	79	20	55
SIPUNCULIDA										1
OPHIUROIDEA										
Amphiuridae	8	2	4	6	2	6	7	6	7	3
ECHINOIDEA										
Echinocardium cordatum	1					1	1			
HOLOTHUROIDEA										
Heterothyone alba			1							
No. Species (richness)	17	15	24	19	20	12	21	22	20	20
No. individuals (abundance)	66	51	79	137	137	74	120	142	95	118

Species list from the expanded survey:

Species	PON 1	PON 2	PON 3	PON 4	PON 5	PON 6	PON 7	PON 8	PON 9	PON 10	PON 11	PON 12	PON 13	PON 14	PON 15
NEMERTEA		2										1	1		
POLYCHAETA															
Capitellidae	1		1		1	1	1	3	2	1	4		3	1	
Cirratulidae	3	9	8	3	3	15	2	2	15	3	6	10	13	7	9
Cossuridae	15	5	2	7	3	8	11	2	14	17	19	14	10	16	11
Dorvilleidae										1					
Echiuridae											1				
Flabelligeridae		5	1				1	1							
Glyceridae				2									1		2
Hesionidae			1	1											1
Lumbrineridae	1	2				1		1		1			1		1
Maldanidae								1						1	
Nephtyidae	2	1	4	3	6		2	2	1	2	4	1	1		1
Nereididae							1							1	
Onuphidae					1					1	1				
Orbiniidae					1								1		
Paraonidae	1		2			1	1			1	1		1		
Phyllodocidae						1	1					1	1		
Pilargiidae													2		
Polynoidae	1									1		1		1	
Sabellidae	1		1					1					1		1
Scalibregmidae				1						1	1				
Sigalionidae	4	5	2	4	6	2	4	2	1	1	3	4	2	3	3
Spionidae						1			1		2		1	3	
Terebellidae	1	4	4	6	3	1	3	2		1	1	2	5	3	3
Trichobranchidae							1		1		2				
GASTROPODA															
Amalda northlandica		1								1					1
Zeacolpus vittata											1				
Sigapatella novaezelandiae	1														
BIVALVIA															
Arthritica bifurca		2	1						6	1	1	1	1		
Dosinia lambata	1		1										1		
Nuculidae					1	1			2	2				1	

Purpurocardia purpurata						1			1						
Thracia vitrea										1					
Unidentified bivalve juveniles						4	2	18		3				1	2
CRUSTACEA															
Amphipoda except Phoxocephalidae	7	4	6	2	6	3	6	2	6	3	6	5	5	3	12
Amphipoda Phoxocephalidae	2	2	2	1	2		4	1	4		1	5	3	1	1
Cumacea Bodotriidae		1		1			2	1	1	1	1	1	1		2
Cumacea Diastylidae	1	4	1	1	3		1		2		4				3
Decapoda Alpheidae?								1			1				
Decapoda Diogenidae			1			1									1
Decapoda Hymenosomatidae															1
Decapoda Laomediidae?				2		1		1	3	1	1	2			2
Decapoda Ocypodidae							1				1				
Decapoda (Family?)	1														
Isopoda Asellota															1
Mysidacea								1							
Ostracoda		2		2		2	5	2	2		1		3		3
Tanaidacea	129	164	239	127	140	130	68	99	170	193	252	108	76	125	151
Unidentified decapod megalopa										2				1	
OPHIUROIDEA															
Amphiuridae	3	5	6	6	1		5	3	2	8	3	1	1	4	5
No. individuals (abundance)	175	218	283	169	177	174	122	146	234	247	318	157	135	172	217
No. species (richness)	18	17	18	16	14	17	20	20	18	23	24	15	23	16	22

Appendix D:

Proposed farm ecological benthic monitoring regime

Proposed Conditions of Consent (based on Westpac Decision)

Environmental Monitoring Plan

1) The consent holder shall submit to the Team Leader - Compliance Monitoring (South) an Environmental Monitoring Plan (EMP) for approval at least one month prior to installing any structures on the site. The purpose of the EMP is to provide procedures and process for the monitoring, reporting and review of the environmental monitoring programme to be undertaken under this consent.
2) The EMP shall provide for monitoring of the following indicators of benthic enrichment: Total free sulphides (TFS); sediment organic matter (SOM); and redox potential (RP).

The EMP may provide for a tiered monitoring programme, whereby monitoring is undertaken consistent with the methods (e.g. number and location of sampling sites) and frequency prescribed below, but in consultation with the Team Leader - Compliance Monitoring (South), and subject to reporting of ongoing results, the methods and frequency may be increased or decreased. The methods and frequency shall only be increased should the monitoring detect an unacceptable adverse effect inconsistent with the application documents

Benthic enrichment

The benthic enrichment monitoring for TFS, OM and RP shall have regard to the benthic enrichment monitoring process outlined in the Waikato Regional Council Technical Report 2015/401. The benthic enrichment monitoring will require monitoring of both reference/control stations and in-farm stations. The number of reference and in-farm stations shall be set in the EMP. It is anticipated that the in-farm monitoring sites are located in areas of greatest-effect.

The EMP shall require baseline monitoring before farm development; monitoring within 6 months of the farm reaching 80% intensity of development or at ten years after commencement of this consent (whichever occurs first); and at 5 years after this stage of development. The need for any further monitoring will be considered in consultation with the Team Leader – Compliance Monitoring (South) in accordance with the above.

Reporting

The EMP shall include procedures to report to Auckland Council on the monitoring information.

The EMP shall include a process to initiate management changes to occur if the monitoring shows unacceptable effects of the marine farm.

Review

The EMP may include review procedures for the monitoring programme. A review may be initiated to update the EMP with new scientific knowledge or to align the monitoring programme with a wider Firth of Thames aquaculture monitoring programme, should one be established.

Any changes to the EMP shall be approved by the Team Leader – Compliance Monitoring (South) prior to implementation'.

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