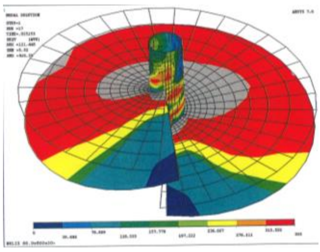
NEW ZEALAND KING SALMON

ENGINEERING FEASIBILITY OF THE PROPOSED SALMON FARM AT NORTH BLOWHOLE POINT SITE (34)



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by

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EXECUTIVE SUMMARY

The purpose of this document is to report on the engineering feasibility study of the proposed North Blowhole Point Site (34) salmon farm at the north end of Waitata Reach at the entrance to Pelorus Sound. The work, commissioned by New Zealand King Salmon Company Limited (King Salmon) and carried out by OCEL Consultants NZ Limited (OCEL), encompassed a preliminary structural design and mooring analysis as part of determining the engineering feasibility of the proposal.

The North Blowhole Point Site (34) is located in 28 - 80 m water depth in a region of moderate to strong tidal currents – maximum tidal current velocity ranging up to 0.8 m/sec recorded throughout most of the water column. The NZKS farms in Waitata Reach are different from the other King Salmon sites in the Sounds in that the farms are exposed both to locally generated short period waves characteristic of the Sounds and to longer period swell waves generated on the open sea fetch to the north east into the South Taranaki Bight. The long period swell waves though infrequent can be a governing load case for the structural design of the farm structure.

The design of the floating farm structure is based on offshore engineering principles adapted to account for the flexible nature of the marine farm structures and suspended nets. As part of the confirmation of the theoretical approach a hydrodynamic force monitoring program will be implemented – the same as has been done for the King Salmon farms on Waitata Reach (Waitata and Kopaua) and in the Tory Channel high current area – to check the actual loads experienced by the structure. Large diameter 76 m (240 m circumference) plastic (HDPE) circle structures will be used for the farm. The diameter of the plastic circles is less than the wave length of the swell waves that can reach Waitata Reach. The flexible nature of the plastic circle farm structures means that the plastic circles can ride the wave profile. The net wave force on the farm will be significant only in swell events.

For steep short period locally generated wind waves on Waitata Reach fetches the wave lengths are much less than the farm diameter and the net wave force on the farm will be low. The wave induced hydrodynamic loads across the farm close to cancel out. Tidal current induced hydrodynamic loading dominates and produces the forces the mooring system must resist. The mooring system is designed to achieve a factor of safety of 5 for the mooring line elements.

The farm will be anchored by screw anchors. These are lightweight and efficient and can be installed with a high degree of accuracy. They can also be installed diverless which is important given the water depth (up to 80 m) at the farm location. Screw anchors cause minimal disturbance to the seabed during installation. The connecting warp is the only evidence of their presence at seabed level. Monitoring the installation torque provides a good indication of the anchor pullout capacity. A pullout test will also be performed on a representative anchor to check screw anchor capacity and to confirm the relationship between installation torque and pullout capacity. The mooring lines will incorporate elastic Marine Flex units both to accommodate the high tidal range (4 m) at the mouth of the Pelorus and to eliminate snatch loading in the mooring system under swell wave loading.

The proposed salmon farm at North Blowhole Point Site (34) is fully feasible from a mooring and structural safety standpoint and will use the same mooring system as employed for the already established farms on Waitata Reach at Waitata and Kopaua. Large diameter plastic circles will be used for the farm pens. Plastic circle support structures are relatively unknown in New Zealand but are well proven internationally and well suited for use in areas subject to wave action and strong tidal currents. The North Blowhole Point Site farm will use existing proven technology, based on experience and will benefit from King Salmon's ongoing development and refinement work to ensure a safe secure structure with known factors of safety.

1.0 INTRODUCTION

King Salmon is proposing to build, a new salmon farm site at the North Blowhole Point Site (34), at the north end of Waitata Reach at the entrance to Pelorus Sound. This report reviews the suitability of the proposed site based on engineering considerations and identifies a design for the location.

The concomitant of the farm's location at the entrance to a major Sound is a strong tidal current environment. The farm design will be quite different from the existing farm structures in that it will utilise plastic (polyethylene HDPE) circle structures, 76 m in diameter, fabricated from HDPE pipe lengths bent to a 38 m radius.

The use of polyethylene material as opposed to steel for the existing farms eliminates corrosion concerns. Plastic circle aquaculture structures are well proven internationally in all but the most extreme environments.

The Waitata Reach location is different to other NZKS sites within the Sounds to the extent that it has exposure to a long wave fetch to the north east. The North Blowhole Point Site also has some exposure to the north. There is the potential for the site to experience relatively long period ocean swell in addition to the short period seastates characteristic of the Sounds, a feature that has to be allowed for in the design of the farm structures and a feature that can govern the design. The plastic circle structures are well suited to cope with combinations of strong tidal flows and swell wave conditions.

The design of the floating farm structure is based on offshore engineering principles, however, the calculation methods need to be adapted to account for the flexible nature of the marine farm structures and suspended nets. As part of the confirmation of the theoretical approach a hydrodynamic force monitoring program has been put in place to check the actual loads experienced by existing farm structures. This is part of the King Salmon policy of ensuring the safety and security of the company's farm structures. For the proposed new location the same policy will be implemented. The self recording (and real time readout) load cell devices used to monitor the relatively steady slow fluctuating tidal current loads on the moorings will be complemented by load cell devices that can monitor higher frequency wave loads. The farm components, structural and mooring, will have a known factor of safety.

2.0 LOCATION

The proposed new King Salmon farm North Blowhole Point Site (34) is located at the north end of Waitata Reach at the entrance to Pelorus Sound between Blowhole Point and Mataka Point. It is in a region of moderate to strong tidal currents - as is to be expected given its location at the entrance of a large sound. In that regard the new farm will be similar to the existing King Salmon farms in strong tidal current locations on Waitata Reach for the Waitata and Kopaua farms and in Tory Channel, at Te Pangu and at Clay Point.

The Waitata Reach sites however are different from Tory Chanel sites, and from other King Salmon farm locations in the Sounds, in that the Reach is exposed both to locally generated short period waves on Waitata Reach and to longer period waves (T > 8 secs) swell generated on the open fetch to the north east. None of the other farms are subjected to relatively long period swell.

The long period swell reaching the farm site from the north and north east fetches, bounded/limited by the North Island will be attenuated by refraction and diffraction effects resulting from the presence of the Chetwode Islands on the wave approach path to the farm site. Although reduced in height from the open sea condition the swell waves will still be an important, even governing, load case for the structural design of the farm structure. The swell wave lengths are greater than the diameter of the plastic circles.

The tidal current speeds at the North Blowhole Point Site (34) are similar to the currents experienced at Waitata and Te Pangu. The longitudinal axis of the farm is aligned with the tidal flows approximately parallel to the coast between Blowhole Point and Mataka Point.

The proposed farm site is located in deep water, in water depths ranging from 28 m to over 80 m. The seabed at the farm location slopes offshore down in to the centre of the north entrance to Pelorus Sound and consists of sandy mud with a varying component of shell gravel.

3.0 DEVELOPMENT

The North Blowhole Point Site (34) farm will be different from the existing NZKS farms on Waitata Reach, – other than the proposed Mid Channel Site (125) - to the extent that it will use plastic circle cage structures. These structures have the capacity to operate in high energy seastate conditions by virtue of the inherent flexibility of the plastic pipe. The structures bend with the waves. The structures are stiffer in the horizontal plane than in the vertical plane through the use of two pipes linked in parallel to form the circle. The pipes are individually bent then linked by connectors to form a torus shape. Linking the two pipes in parallel greatly increases the stiffness in the horizontal plane without impairing flexibility in the vertical plane.

The mooring design will benefit from the ongoing King Salmon research into quantifying hydrodynamic forces on marine farms.

Marine farming has essentially evolved in a trial and error, pioneering fashion, practical operational personnel developing practical solutions to problems as they arise. This has worked well for King Salmon.

As marine farms have moved out of sheltered environments into more challenging and productive areas subject to higher environmental loads, in particular tidal currents and wave action, engineering input is required to ensure that the farm structures remain safely moored. King Salmon have recognised this requirement and have engaged OCEL for mooring design and structural analysis work.

The engineering approach requires quantification of the environmental forces and the establishment of a safety factor – available resistance/force applied – for the farm. In order to establish a factor of safety for the farm as a whole it is necessary to know the tidal current and wave induced hydrodynamic forces acting on the farm.

Offshore engineering principles can be applied but the fish net cages are not readily amenable to the theoretical analysis of the hydrodynamic forces produced by tidal currents. The cages are flexible and can deform and are partly transparent to water movement. Hydrodynamic coefficients are available for common fixed shapes, and have been established for net structures.

In the absence of readily applicable theory field measurement of the actual forces can supply the answers. King Salmon have instituted programs at the Waitata, Kopaua, Te Pangu and Clay Point farms to measure mooring line tensions using load cell devices connected in line in the mooring arrangement. The target maximum tension in any of the mooring lines is less than 5 tonne.f. Where monitoring shows that this load is being exceeded then the reasons for that are investigated, the cause identified and the situation rectified to bring the tension down to the desired maximum, consistent with keeping the factor of safety for the system at 5. The same policy will be followed for the proposed new farm location. The moorings will also be kept pretensioned, in conformance with King Salmon mooring practice, to spread the load evenly between the moorings. The use of MarineFlex elastic elements in the mooring line assemblies assists to evenly spread the load and avoid shock loading.

Knowing the maximum force and the minimum breaking load (MBL) of each element in the mooring line assembly allows a factor of safety (FofS) to be established for the mooring line and ultimately for the whole farm. The target FofS is 5.

The wave loading on the individual plastic circles constituting the farm structure is significant in a swell event because the diameter of each cage is less than the swell wave length – deepwater wavelength $L_o = 1.56.T^2 = 98$ m for an 8 second period wave. The MarineFlex units incorporated in the mooring arrangement allow the plate circles to move with the swell waves and minimise wave loading.

For short period waves because the diameter is several multiples of the short period wave length the resulting net wave force is close to zero. The wave induced hydrodynamic force on the cage is forward, in the direction of wave advance, under the wave crest and backward under the trough. The forces cancel out over a complete wave length.

The structure must be flexible enough to ride the wave profile so that the structural elements do not have to span between wave crests. The plastic cage structures follow the wave profile, the bigger the diameter of the cage the more flexible it is in the vertical plane.

An indicative farm structure layout, shown in drawing DR-150902-007 Rev 8 shows three 76 m diameter (240 m circumference) plastic circle cages in a single row configuration.

4.0 ENVIRONMENTAL CONDITIONS

4.1 Wind Conditions

The location is subject to high wind speeds however the wind loading on the farm structure is small in relation to the tidal current and wave loading, essentially only walkway handrailing and nets project any distance above water level. The wind loading is important for the independent barge moorings.

4.2 Wave climate

The location is subject to locally generated wind waves on Watata Reach and to swell waves generated on the open sea fetch to the north at the western entrance to Cook Strait and further north into the Taranaki Bight.

The wave climate in the Waitata Reach at the entrance to Pelorus Sound was assessed by NIWA for OCEL in 2008 to generate design wave information for the design of the proposed salmon farm structure at White Horse Rock on the western side of the Reach. The principal interest is in the longer period waves, considered as swell for the study, generated by north easterly winds on the 100 to 150 km fetch extending into the South Taranaki Bight and the Greater Cook Strait area up to Wanganui, north east of Waitata Reach. True ocean swell entering the Greater Cook Strait from the Tasman Sea does not reach the farm site because of topographic sheltering effects. The site is only open to longer period waves through narrow north and north easterly windows that act as wave direction filters.

The wave climate was assessed based on available wind records using empirical relationships for fetch-limited wave growth. As no suitable wind or wave data were available in the vicinity of the site a linear transformation was applied to the wind data that was available – for Stephens

Island and the Brothers – with the parameters of the transformation tuned by comparing the resulting wave statistics against available spectral wave generation modelling results.

NIWA predicted the maximum significant wave height H_s generated on the north east fetch to be 1.1 m although noted there was some uncertainty in the high energy tail of the predicted wave height distribution which is very sensitive to the possibility of a small number of events in which the local wind speed is not markedly scaled down from the highest speeds observed at Stephens Island. A few such events could considerably increase the maximum predicted significant wave heights to values over 1.5 m. A value of H_s = 1.5 m has been taken for the design. The associated peak energy wave period was taken as T_p = 4.6 seconds. The significant wave height H_s is used to characterise the sea state spectra. The maximum wave height, used for the design occurring in a 4 hour period is taken as H_m = 1.8 Hs. For design purposes the maximum wave height was taken as H_m = 3 m. The wave length is taken as $L = g/2\pi.T_p^2 = 1.56T_p^2 = 33$ m. That is less than half the diameter of the plastic circles.

As noted in the foregoing the NIWA wave climate study was for the entrance from the open sea to Waitata Reach, this is applicable for the North Blowhole Point Site (34).

The longer period swell waves can approach the proposed farm structure (heading north north east) either approximately aligned to the farm alignment or as a quartering sea. The structure will ride the swell principally in the heaving and pitching modes. The wave lengths are less than the individual plastic circle cage diameter for the Tp = 4.6 second period wave, so the net wave force on the structure is close to zero. However the wave load case will be considered for swell waves 8 – 10 second period as well because the wave load will be significant. The cages will ride the wave profile. The swell wave loading will be minimised because MarineFlex units will be incorporated in the mooring lines. For the plastic circle cages the direction of wave approach makes no difference.

4.3 Tidal Currents

The dominant environmental force on the farm is the hydrodynamic drag exerted by the tidal currents in the Sound.

The tidal currents were measured at the North Blowhole Point Site (34) farm site by NIWA in 2015 using a 3D Acoustic Doppler Current Profiler (ADCP) self recording directional current meter. An ADCP uses the Doppler shift to measure ocean currents. Data measuring full water column currents were collected every 10 minutes with varying bin sizes dependent on site characteristics. Each depth measured is referred to as a bin and the full column of bins is referred to as a profile. A well known limitation of ADCP's is the loss of data near the surface due to the spreading of the acoustic beams on the instrument (~10% of water depth). Therefore each profile from an ADCP provides current measurements from close to the seabed to within the top 10% of water depth where the instrument was deployed.

Flow charts in the form of a current rose plot of current speed and directions for all bins and a plot of average direction and magnitude in each bin taken from the NIWA Benthic Ecological Assessment report are shown in Figure Nos 1 and 2. Note that the current rose plots indicate the direction the water is moving to not where the water has travelled from.

Te dominant direction of flow was to the south west (Figure No 1) corresponding to the flood tide. Approximately 17% of profiles exceeded 0.2 m/sec and 5% of profiles exceed 0.34 m/sec over the 36 day ADCP deployment. Examining all of the observations by magnitude and direction, higher current speeds up to 0.65 m/sec were associated with the flows towards the south west (Figure No 2). Mean current speed from 20 m depth to the seabed was 0.13 m/sec. The maximum current speed was 0.8 m/sec.

The tidal currents are unbalanced, the flood tide is dominant indicating that the bulk of the ebb tide is directed out the north east entrance to the Sound, which is to be expected given the alignment of Waitata Reach relative to the north entrance to the Sound where the farm is located.

By way of comparison the maximum current speed at the Clay Point site was .93 cm/sec (close to 2 knots).

5.0 MARINE FARM STRUCTURE AND LAYOUT

5.1 Farm Structure

The farm structure will be consist of three independent 76 m diameter (240 m circumference) plastic circle cages in line as shown in Drawing No DR-150902-007 Rev 8. The nets are suspended from the plastic circle floating pipe elements, typically two 500 mm diameter HDPE pipes bent to 38 m radius and held together in parallel to form a torus shape in the horizontal plane. The pipes are held apart in parallel by PE brackets at intervals around the circumference of the circle. The brackets in corporate an upstand for a handrail. The mooring lines attach to designated brackets equi spaced around the circumference.

5.2 Mooring Arrangement

The indicative mooring arrangement is shown in drawings DR-150902-007 Rev 8 and DR-150902-011 Rev 2. The mooring lines are connected to spar buoys on the surface – four per cage – so that the mooring lines are horizontal and do not exert down drag on the farm structure. Each spar buoy is held in place by mooring lines connected from the bottom of the spar to screw anchors, 3 anchor pairs per spar buoy. There will be four spar buoys per plastic circle, arranged on a square grid. The in line configuration of the plastic circles affords some shelter to the down current cages. The mooring lines from the spar buoys to the screw anchors will incorporate MarineFlex units to provide flexibility both to accommodate the 4 m tidal range at the location and ensure even distribution of mooring loads. The mooring lines from the spar buoys to the cages are pre-tensioned to 10 kN to ensure an even distribution of the total load on the farm to the mooring lines.

The mooring lines are pretensioned using a hydraulic ram to take up on the mooring line. Once the desired pretension is reached the line is shackled off. Each mooring line will consist of a 40 mm diameter polypropylene rope strop connected directly to the spar buoy at one end and to a chain tail at the cage end. The purpose of the chain tail is to allow fine adjustment of the line length and thus mooring line tension. The chain is connected via a shackle to the anchor pad eyes on the plastic circle structure. The ends of the polypropylene strops terminate in spliced eyes with hard thimbles and the connection to the anchor and the chain is via shackles. This eliminates the need for knots which can significantly reduce the strength of the polypropylene line below the minimum breaking load (MBL). The use of spliced eyes and thimbles with connecting shackles keeps the strength of the mooring line close to the MBL of the polypropylene rope. Drift algae may attach to the moorings but the additional drag is not significant and will not compromise the moorings or have an impact on the factor of safety.

The mooring lines from the spar buoy to the seabed are relatively steep to keep the farm within the consented seabed footprint and the polypropylene rope is relatively inflexible. The MarineFlex units provide the elastic extension to accommodate the change in mooring line length required and the elastic element prevents snap loading of the mooring lines in wave load conditions. The elastic extensions allow the farm to move in response to swell wave action thereby reducing the net wave loading on the structure. The screw anchors accommodate uplift loads from the mooring lines.

5.3 Anchors

The farm will be anchored by screw anchors. The seabed sediment at the proposed farm location is suited for the use of screw anchors based on experience elsewhere in the Sounds. The diameter of the screw anchor plate used is tailored to the strength of the seabed sediment at the location to achieve the desired pullout resistance. Screw anchors are a particularly efficient way to anchor marine farms. They are lightweight in relation to the holding power or pull out resistance developed and do not require heavy marine plant for their installation and can be installed diverless. They can also be installed with a high degree of accuracy using a Differential Global Positioning System (DGPS) receiver positioned vertically above, and on, the installation axis. The diverless feature is vital for the North Blowhole Point Site (34) farm site given the maximum water depth at the site, 80 m, which is far beyond the limit for air diving. The particular type of screw anchor used for the North Blowhole Point Site (34) farm will be shaftless screw anchors.

Another advantage of screw anchors is that the installation process causes very little disturbance to the seabed. The anchors screw in like a wood screw only the soil in the helix described by the anchor as it screws into the soil is disturbed. This is why close to full pullout strength is obtained immediately after installation. The soil shear strength on the circumference of the cylinder of soil directly above the screw anchor auger plate in its as installed position is virtually undisturbed. Once the screw anchor is in only the shaft or rope projecting above the seabed is evidence of its presence.

The standard screw anchor, as used on mussel farms in the Marlborough Sounds, features the use of an 800 mm diameter steel auger/anchor plate at the end of a 6 m long shaft. Such an anchor is excellent for resisting vertical pullout loads but the principal hydrodynamic forces exerted on farm structures by waves and tidal currents are lateral or horizontal loads. In a Sounds type application the screw anchors resist lateral forces by bending above the anchor plate into approximate line with the applied load. The bending is a permanent or plastic deformation – indicated by slotting in the seabed – which is acceptable if the anchor is not subject to load reversals and the level of strain is limited. Load reversals are a constant of a strong tidal environment, the anchors must be provided with a means of resisting the lateral load. Shaftless screw anchors avoid the need to provide for separate lateral earth pressure resistance. They are installed using a temporary shaft threaded over the top of the polypropylene rope connected to the anchor. Once the anchor has been screwed down to depth the shaft is withdrawn. Inclined loads cause the anchor to rotate into line with the applied load, there is no yielding or bending of a shaft.

Screw anchors fail by pulling out, either the soil fails or the anchor itself fails. The anchors are designed so that failure occurs in the soil not the anchor itself. They do not drag like gravity block anchors.

Screw anchors will be used for all the North Blowhole Point Site (34) farm moorings. A combination of screw anchors and gravity blocks is problematic because when the gravity anchors fail by dragging the load previously taken by the anchor block is transferred to the adjacent screw anchors resulting in the failure of the mooring lines and a cascade failure effect as successive mooring lines fail following load transfer caused by anchor dragging. The target pullout capacity for the anchor is the same or higher than the MBL of the polypropylene anchor rope and shackle connectors to achieve a factor of safety equal to 5.

The amount of torque used to install the anchor gives a good indication of the pullout capacity through a simple linear relationship of the form P (pullout capacity) = k (constant) x T (torque). Standard soil mechanics solutions exist to determine the pullout capacity of screw anchors if the seabed soil strength parameters are known. For the case of the North Blowhole Point Site

(34) location the seabed soil strength parameters are not known. A pullout test will be carried out to determine the screw anchor capacity and from the results of this test the relationship between installation torque and pullout capacity will be known. The pullout capacity of all the anchors installed on the site can then be accurately predicted.

6.0 CONCLUSION

The proposed salmon farm at North Blowhole Point Site (34) is fully feasible from a mooring and structural safety standpoint. It will use existing internationally proven plastic circle technology, and will benefit from King Salmon's ongoing development and refinement work to ensure a safe secure structure with known factors of safety. Screw anchors will be used to moor the farm structure and a level of redundancy provided. Test pullout loading of a representative anchor will be carried out to confirm the anchor pullout capacity.

The long axis of the structure will be aligned with the tidal vector to minimise the mooring forces. The individual cage diameters are less than the wave length of the incident, infrequent, swell waves from the north and north east so the global wave force on the cages will be significant. The inherent flexibility of the cage structure in the vertical plane allows the plastic circle cages to ride the wave profile. The use of MarineFlex elastic elements in the mooring line assemblies ensures even tensioning and reduces wave loading because the farm can move with swell waves.

Monitoring of the actual hydrodynamic forces exerted on the farm by tidal currents and waves will be undertaken, the same as is done for the Tory Channel farm structures, to confirm that the loadings are within the design loads used. The cause of any load exceedance will be investigated and rectified

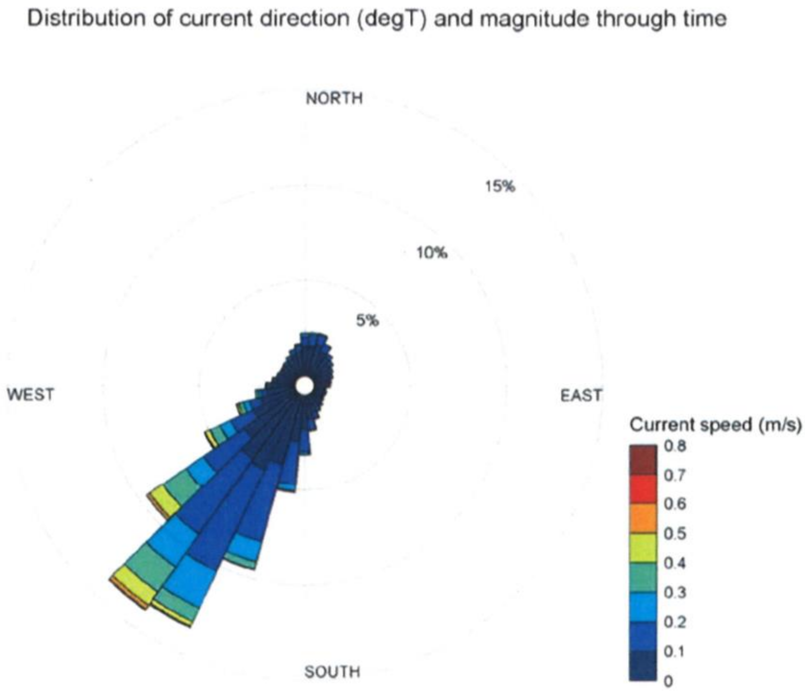


Figure No 1
Current rose showing current directions and magnitudes for all bins at Blowhole Point North

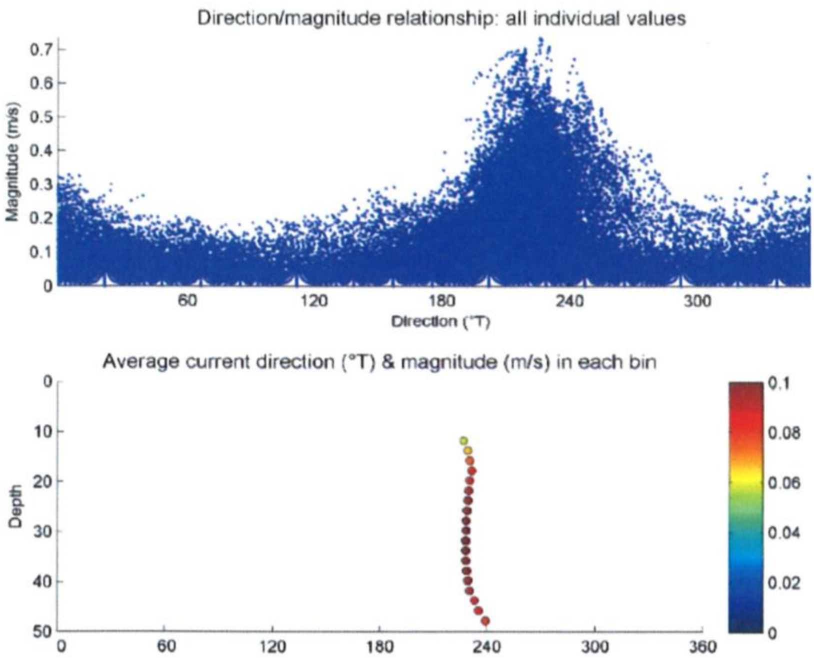
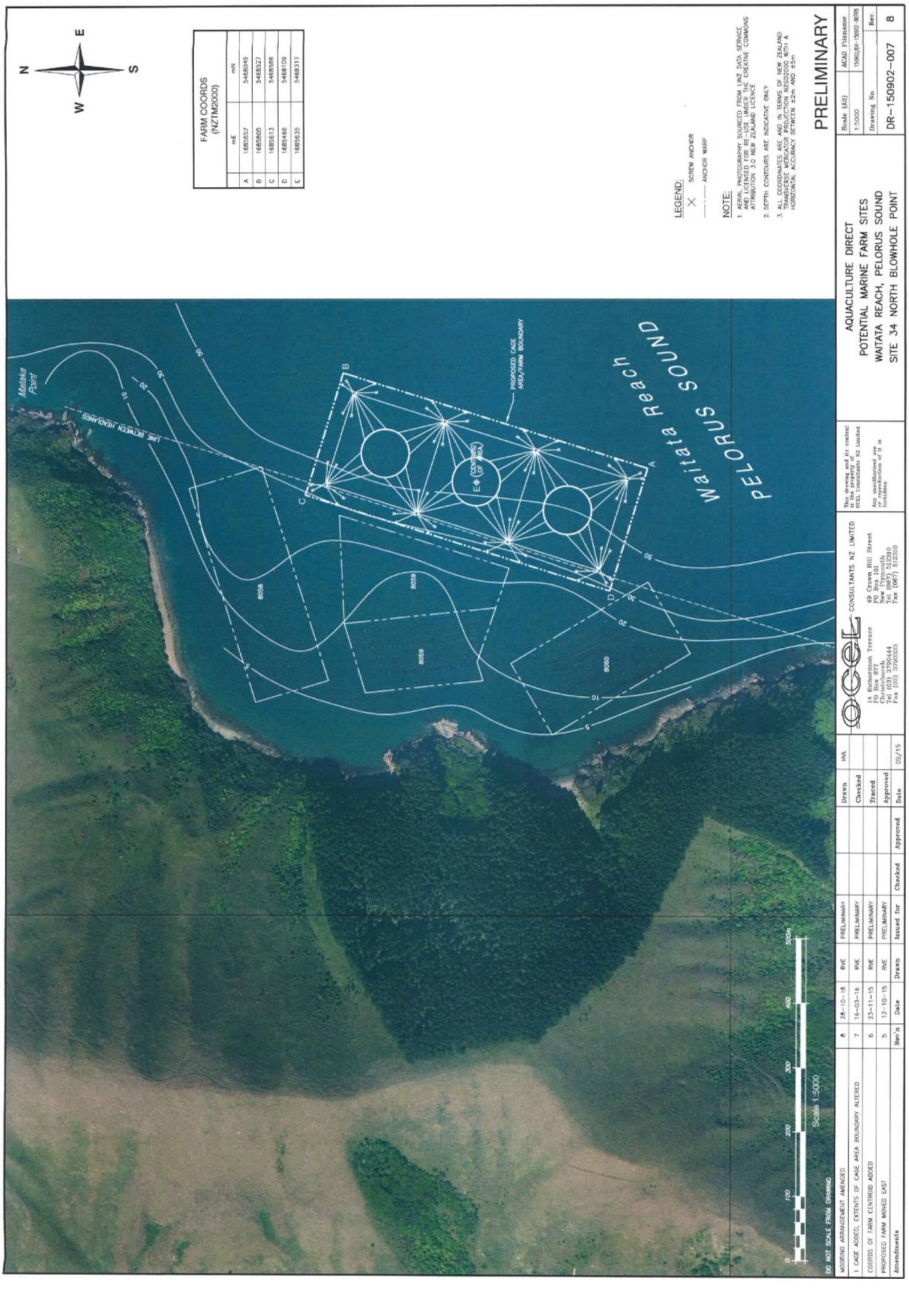


Figure No 2
All observations of current magnitude and direction (top panel) and time-averaged profile magnitude and direction (bottom panel) at Blowhole Point North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A 1685657 5468049
B 1685805 5468527
C 1685613 5468586
D 1685486 5468109
E 1685635 5468312
LEGEND:
SCREW ANCHOR
ANCHOR WARP
PROPOSED CAGE AREA/FARM BOUNDARY
Waitata Reach
PELORUS SOUND
Mataka Point
PRELIMINARY
AQUACULTURE DIRECT
POTENTIAL MARINE FARM SITES
WAITATA REACH, PELORUS SOUND
SITE 34 NORTH BLOWHOLE POINT
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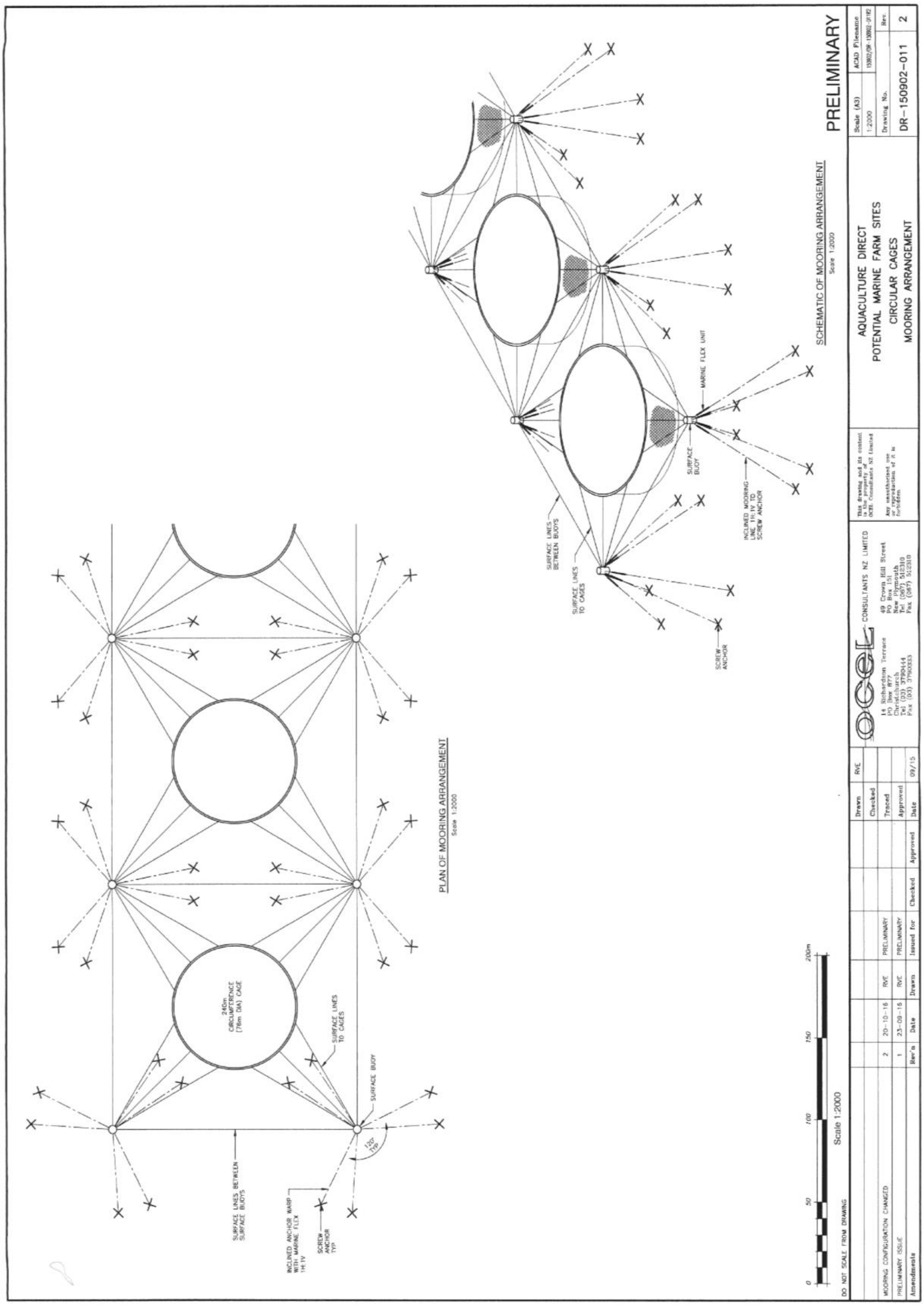
PRELIMINARY
SCHEMATIC OF MOORING ARRANGEMENT
Scale 1:2000
PLAN OF MOORING ARRANGEMENT
Scale 1:2000
240m CIRCUMFERENCE (76m DIA) CAGE
SURFACE LINES TO CAGES
SURFACE BUOY
SURFACE LINES BETWEEN SURFACE BUOYS
INCLINED ANCHOR WARP WITH MARINE FLEX 1H:1V
SCREW ANCHOR TYP
SURFACE LINES BETWEEN BUOYS
SURFACE LINES TO CAGES
MARINE FLEX UNIT
INCLINED MOORING LINE 1H:1V TO SCREW ANCHOR
SCREW ANCHOR
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DO NOT SCALE FROM DRAWING
AQUACULTURE DIRECT
POTENTIAL MARINE FARM SITES
CIRCULAR CAGES
MOORING ARRANGEMENT
Scale (A3) 1:2000
Drawing No. DR-150902-011
Rev 2
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MOORING CONFIGURATION CHANGED
PRELIMINARY ISSUE
Drawn RVE
Date 09/15