Pakiri Sand Extraction Consents

Assessment of Effects on Coastal Processes - New Consent Area Appendix

IZ111900-NM-RPT-0004 | B

July 17, 2020

McCallum Bros Ltd

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Pakiri Sand Extraction Consents

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Appendix A. Mangawhai-Pakiri Sand Extraction Volumes 2003-2020

Table 1: Inshore Extraction Area. Volumes in m^3

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
September		6,200	7,810	7,100	5,680	2,080	2,730	920	2,300	1,380	2,300	920	1,600	1,260	800	3,930	5,400	4,280
October		6,700	7,100	5,680	5,680	2,130	2,840	4,140	460	2,300	1,840	1,380	920	1,380	800	6,900	8,120	6,180
November		6,475	7,810	4,970	4,970	6,790	1,420	2,300	1,840	920	1,840	1,380	920	1,380	800	7,800	7,060	6,750
December		7,375	4,260	5,680	5,680	710	4,260	-	1,840	2,300	1,380	2,300	920	1,840	1,720	4,700	5,400	5,000
January	2,050	2,850	3,450		2,780	2,740	460	1,840	460	920	-	-	1,380	920	800	7,240	6,000	4,500
February	3,650	3,675	7,110		4,320	3,540	460	460	3,220	2,300	1,380	920	920	920	1,140	1,260	3,200	7,050
March	8,425	5,925	7,030	1,380	4,730	2,130	-	2,760	2,300	2,760	1,380	920	920	1,380	800	5,920	6,020	4,500
April	5,275	5,775	7,920	4,600	9,090	4,930	-	920	2,760	1,598	2,300	2,180	920	2,060	460	5,500	7,660	-
May	4,675	3,300	8,020	1,380	6,990	5,680	1,610	1,840	1,840	1,840	920	460	1,380	2,090	1,260	8,020	7,440	5,400
June	5,950	7,090	5,960		2,330	3,550	1,320	2,300	2,760	3,220	920	1,226	1,720	1,260	920	6,280	5,120	8,100
July	6,425	3,775	5,680		1,400	4,260	1,840	2,300	1,380	1,840	920	920	1,840	2,060	1,720	7,120	7,520	
August	7,175	3,165	7,100		9,250	4,970	2,300	2,760	2,300	1,380	1,380	800	1,260	1,720	2,670	6,930	5,780	
TOTAL	**53,000**	**62,305**	**79,250**	**65,450**	**62,900**	**43,510**	**19,240**	**22,540**	**23,460**	**22,758**	**16,560**	**13,406**	**14,700**	**18,270**	**13,890**	**71,600**	**74,720**	51,760

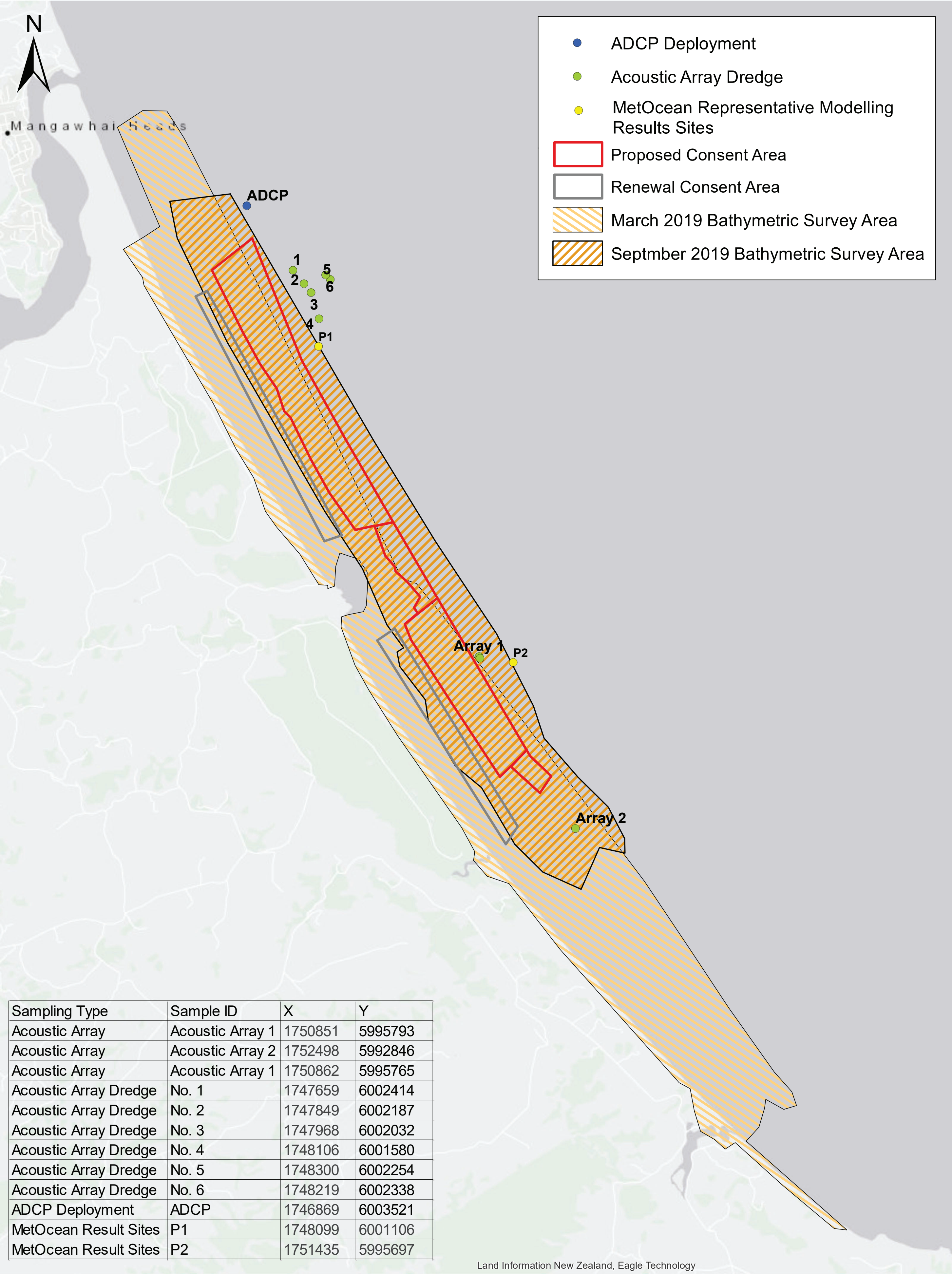
Note: The Year is the Extraction Year from beginning September of the preceding year
to end of August of the named year

Table 2: Offshore Extraction Area. Volumes in m^3

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
September				2,750	7,420	12,800	7,760	5,000	10,520	3,748	7,760	10,660	9,320	13,925	14,580	13,660	8,780
October				3,160	5,980	7,600	7,530	6,900	5,495	8,096	10,680	15,480	10,120	13,540	6,720	12,060	12,780
November				7,360	4,780	4,600	7,360	10,660	7,660	8,990	10,880	12,060	11,020	15,120	9,540	12,750	12,720
December				4,600	5,105	7,300	5,630	5,920	3,620	4,430	6,900	7,460	8,740	11,560	7,820	10,460	7,600
January				2,720	5,980	6,860	5,260	4,100	7,645	4,557	10,120	8,740	7,820	14,560	6,420	12,360	9,900
February				7,820	8,170	5,440	9,740	7,240	7,128	9,660	9,391	9,140	8,960	10,520	8,240	13,140	9,000
March				5,112	8,300	5,980	6,220	6,420	6,268	7,082	8,000	9,530	10,400	15,000	9,820	12,850	9,800
April				3,680	7,550	6,440	5,760	6,380	5,260	6,350	12,660	11,120	13,540	11,240	9,300	11,800	-
May				5,520	9,600	10,768	7,050	7,660	9,722	7,240	8,820	11,880	12,980	13,980	12,760	10,940	9,000
June				1,840	5,520	6,260	7,700	4,790	7,738	5,920	9,186	10,440	10,620	15,370	8,720	11,040	9,000
July				6,820	6,430	6,820	8,180	5,365	5,000	9,220	11,379	10,100	10,900	14,060	14,060	10,530	
August				4,600	9,270	2,300	6,780	4,960	3,160	7,360	10,560	10,580	13,980	13,160	10,340	11,960	
TOTAL	**97,354**	**72,980**	**60,834**	**55,982**	**84,105**	**83,168**	**84,970**	**75,395**	**79,216**	**82,653**	**116,336**	**127,190**	**128,400**	**162,035**	**118,320**	**143,550**	88,580

Note: The Year is the Extraction Year from beginning September of the preceding year to end of August of the named year

Appendix B. MBL 2019 Instrument Deployment and Bathymetric Survey Locations



Sampling Type	Sample ID	X	Y
Acoustic Array	Acoustic Array 1	1750851	5995793
Acoustic Array	Acoustic Array 2	1752498	5992846
Acoustic Array	Acoustic Array 1	1750862	5995765
Acoustic Array Dredge	No. 1	1747659	6002414
Acoustic Array Dredge	No. 2	1747849	6002187
Acoustic Array Dredge	No. 3	1747968	6002032
Acoustic Array Dredge	No. 4	1748106	6001580
Acoustic Array Dredge	No. 5	1748300	6002254
Acoustic Array Dredge	No. 6	1748219	6002338
ADCP Deployment	ADCP	1746869	6003521
MetOcean Result Sites	P1	1748099	6001106
MetOcean Result Sites	P2	1751435	5995697

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CLIENT McCallum Bros	
PROJECT Pakiri Sand Extraction Consent Renewal	
SCALE 1:60,000 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 06/26/2020

ADCP, Acoustic Array Dredge Sampling Locations and Bathymetric Survey Extents

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Appendix C. Bathymetric Survey Methodology

All bathymetric surveys were undertaken under the supervision of Survey Worx Ltd, registered professional surveyors.

The survey were undertaken using a WASSP WMB 3250 Multibeam and SMC IMU108 motion sensor mounted on MBL vessel Acheron III. The WASSP, GPS antenna and motion sensor were positioned on the vessel on mounts manufactured specifically for the installation of the equipment by Electronic Navigation Limited.

The WASSP typically transmits a pure tone pulse of 160 kHz and 150 ms long within a swath of120° (across-track) per 1.5° (along-track), at a ping rate varying with water depth. On receive, the signal is sampled at a rate of 15 kHz, and 224 beams are formed using the Fast Fourier Transform (FFT) algorithm. The receiving beam width in the across-track plane varies with the beam steering angle from 1.5°at normal incidence up to 3.0°at 60°. The data were acquired with Hypack/ Hysweep 2010 survey software and recorded in both the Simrad .all format and the Hypack .hsx format. Tides corrections were provided by tide models supplied by Electronic Navigation Limited.

No squat and settlement trials using total station were carried out for preparation to this survey. An estimation of the dynamic draught of the vessel was measured by computing the mean difference between data acquired (1) at survey speed and (2) while static, over a flat calibration area near compass dolphin (Port of Auckland). The measured difference was 0.06 m. and also from detailed design drawings for the boat.

Vessel attitude and heave during survey were measured by the motion sensor, and input directly into the WASSP Processing Unit for integration by the WASSP firmware.

Vessel position was measured by a Trimble R6 model 3 GPS receiver, computing a Network (RTK GPS) solution from radio corrections. No geodetic controls on land were used.

An estimate of the sounding error budget for the survey is listed below. The estimates provided are for soundings gathered at minimum, intermediate, and maximum depth levels and are developed on system accuracies for 60° angle (outer beams). LINZ accuracy standards are indicated for information, but contract did not specify any standard to meet.

	Source of error	Depth in meters		
		30 m	35 m	40 m
a	Draught Setting	0.05	0.05	0.05
b	Variation of Draught	0.05	0.05	0.05
c	Sound Velocity	0.12	0.13	0.15
d	Spatial Variation in SV	0.1	0.1	0.1
e	Temporal Variation in SV	0.05	0.05	0.05
f	Application of Measured SV	0.05	0.05	0.05
g	Depth Measurement (Instrument)	0.3	0.32	0.35
h	Depth Measurement (Resolution)	0.01	0.01	0.01
I	Heave	0.2	0.2	0.2
j	Settlement and Squat	0.2	0.2	0.2
k	Roll, Pitch and Seabed Slope	NA	NA	NA
l	Tidal Readings	0.5	0.5	0.5
m	Co-Tidal Correction	NA	NA	NA
n	Tide Corrections	0.05	0.05	0.05
o	Trace Reading	NA	NA	NA
	Total Standard Error $\sqrt{a^2 + b^2 + \ldots}$	0.82	0.83	0.84
	LINZ accuracy standards			
	MB Special	0.34	0.36	0.39
	MB-1	0.5	0.54	0.59
	MB-2	0.67	0.72	0.78
	MB-3	0.84	0.9	0.98

Notes:

a: No bar check was carried out. Worst-case value estimated from total station measurements standard error, and static waterline visual estimation.

b: Estimation from change in tank contents.

c: Based on SV-plus accuracy.

d,e: Worst-case estimation considering size of survey area and frequency of SV casts.

f: SV applied in WASSP WMB3250 and in post-processing with Hypack.

g,h: Estimations from WASSP WMB3250 sounding accuracy from WASSP document, using outer beams.

i: Significant errors in heave measurements due to sea conditions at time of acquisition

j: Maximum error in dynamic draught estimation procedure.

k: Not applicable. Single-beam only.

l: Significant potential error as tide models were used instead of measurements. Maximum error estimated from comparison between lines and cross-lines.

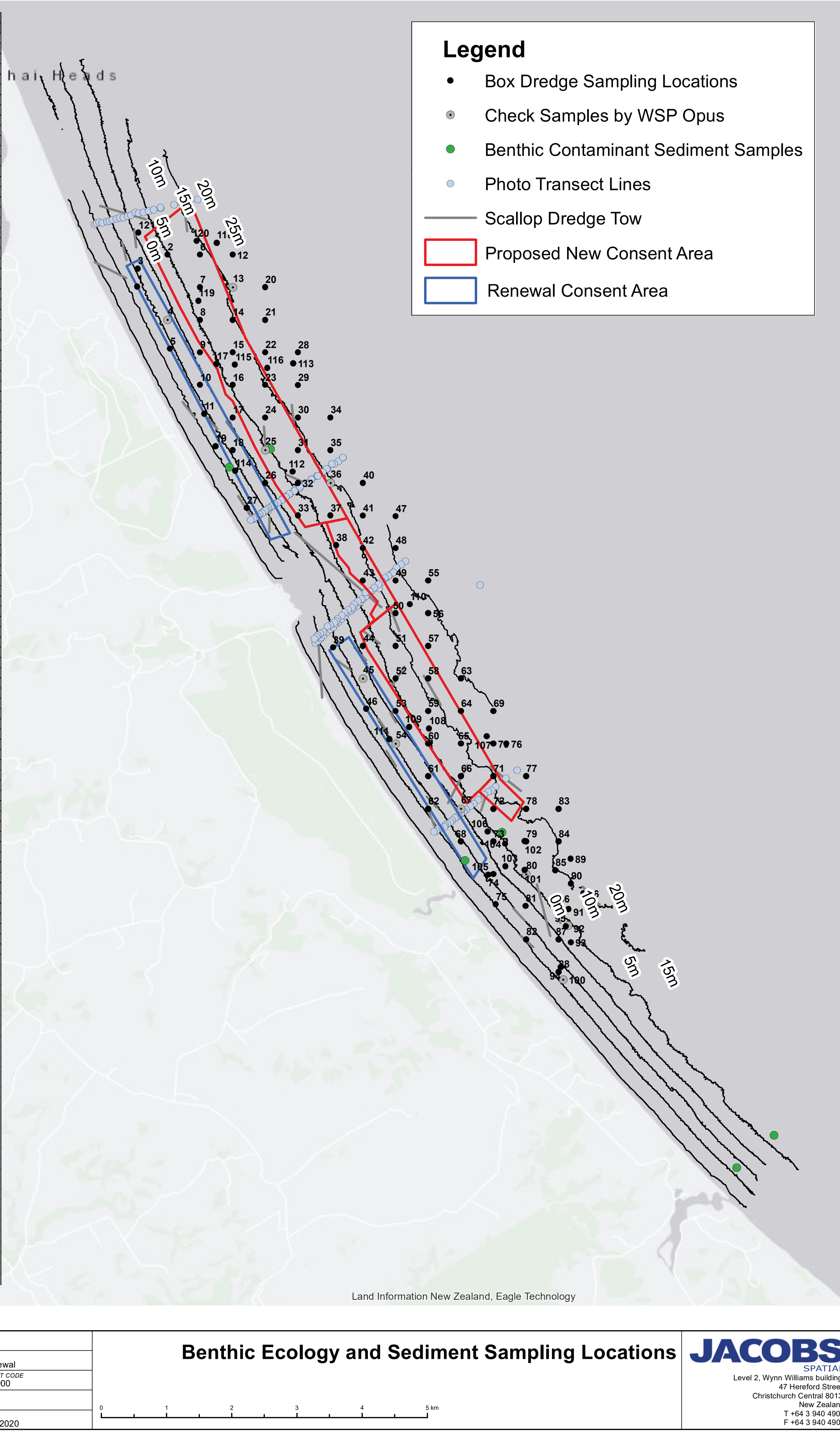
m: Not applicable. Tide models were used.

n: tide data sampled at 6 minutes. Interpolation is done by Hypack software.

o: Not applicable. Soundings were derived digitally.

Appendix D. Seabed Sediment Sampling Locations

	NZTM	
Sample ID	X	Y
1	1746153	6001652
2	1746619	6002139
3	1746164	6001925
4	1746619	6001139
5	1746657	6000694
6	1747119	6002139
7	1747119	6001639
8	1747119	6001139
9	1747119	6000639
10	1747119	6000139
11	1747181	5999700
12	1747619	6002139
13	1747619	6001639
14	1747619	6001139
15	1747619	6000639
16	1747619	6000139
17	1747619	5999639
18	1747619	5999139
19	1747353	5999202
20	1748119	6001639
21	1748119	6001139
22	1748119	6000639
23	1748119	6000139
24	1748119	5999639
25	1748119	5999139
26	1748119	5998639
27	1747835	5998256
28	1748619	6000639
29	1748619	6000139
30	1748619	5999639
31	1748619	5999139
32	1748619	5998639
33	1748619	5998139
34	1749119	5999639
35	1749119	5999139
36	1749119	5998639
37	1749119	5998139
38	1749206	5997683
39	1749160	5996113
40	1749619	5998639
41	1749619	5998133
42	1749619	5997639
43	1749619	5997139
44	1749619	5996139
45	1749619	5995639
46	1749670	5995173
47	1750119	5998124
48	1750119	5997639
49	1750119	5997139
50	1750119	5996639
51	1750119	5996139
52	1750119	5995639
53	1750119	5995139
54	1750119	5994639
55	1750619	5997139
56	1750619	5996639
57	1750619	5996139
58	1750619	5995639
59	1750619	5995139
60	1750619	5994639
61	1750619	5994139
62	1750619	5993639
63	1751119	5995639
64	1751119	5995139
65	1751119	5994639
66	1751119	5994139
67	1751119	5993639
68	1751119	5993139
69	1751619	5995139
70	1751619	5994639
71	1751619	5994139
72	1751619	5993639
73	1751619	5993139
74	1751619	5992639
75	1751656	5992176
76	1751820	5994638
77	1752119	5994139
78	1752119	5993639
79	1752119	5993139
80	1752119	5992639
81	1752114	5992149
82	1752119	5991639
83	1752619	5993639
84	1752619	5993139
85	1752568	5992699
86	1752619	5992139
87	1752619	5991639
88	1752619	5991139
89	1752803	5992873
90	1752810	5992494
91	1752775	5992103
92	1752761	5991851
93	1752809	5991592
94	1752653	5991212
95	1752732	5991837
96	1753002	5992343
100	1752690	5991022
101	1752100	5992701
102	1752097	5993145
103	1751803	5992760
104	1751801	5993106
105	1751538	5992629
106	1751530	5993291
107	1751518	5994753
108	1750629	5994872
109	1750327	5994895
110	1750337	5996778
111	1750022	5994710
112	1748537	5998808
113	1748548	6000474
114	1747656	5998825
115	1747655	6000452
116	1748152	6000403
117	1747367	6000464
118	1747371	6002321
119	1747094	6001433
120	1747064	6002349
121	1746173	6002476
SED 9	1743576	6010593
SED 10	1743851	6010912
SED 11	1744814	6012020
SED 13	1744383	6011506



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Benthic Ecology and Sediment Sampling Locations

CLIENT McCallum Bros	
PROJECT Pakiri Sand Extraction Consent Renewal	
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Appendix E. Pakiri Hindcast Metocean Study: Wind, wave and current ambient and extreme statistics. Report by MetOcean Solutions, August 2019.

Pakiri Hindcast Metocean Study

Wind, wave and current ambient and extreme statistics

Report prepared for JACOBS and McCallum Bros Ltd

August 2019

MetOcean SOLUTIONS

Document History

Versions

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1. Introduction

JACOBS and McCallum Bros Ltd has commissioned MetOcean Solutions (MOS, subsidiary of Meteorological Service of New Zealand Ltd) to provide a summary of metocean conditions offshore Pakiri, New Zealand (Figure 1.1, Table 1.1). An overview of the metocean conditions is required to provide an initial characterisation of the environment from a marine operability perspective, plus identify potential hazards and document the important aspects of the environmental conditions that may require further attention.

Numerical hindcasting techniques are the primary source of oceanographic and meteorological data used in preparing this report, and a brief summary of the data sources is provided in Section 2. Results for the site specific wind conditions are provided in Section 3. The wave climate is detailed in Section 4. The current climate is described in Section 5. Workability statistics are given in Section 6. Extreme statistics are reported in Section 7. Metocean statistics for the period Nov 2018 – Jun 2019 are compared to the long term statistics in Section 8. Analytical methods are described in Section 9 and the references cited are listed in the final Section 10.

Note that the standard oceanographic directional conventions are applied in this report, with waves and winds reported in the 'coming from' directional reference.

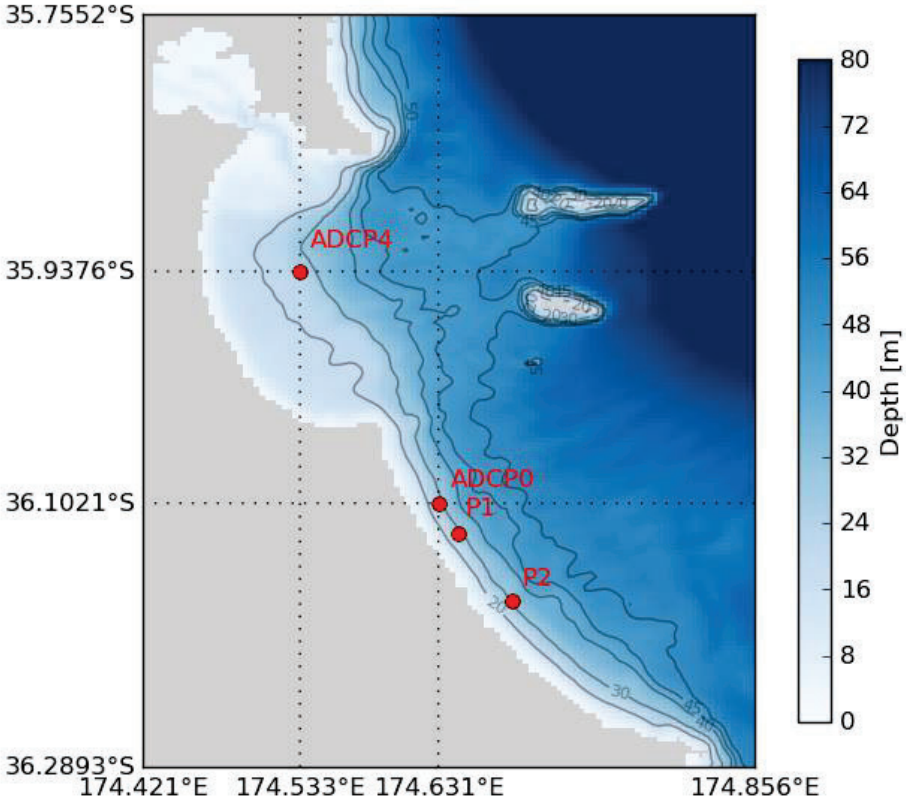

Figure 1.1 *Map showing the area of interest and the representative sites P1 and P2 offshore Pakiri, New Zealand. Also shown are the current validation sites ADCP0 and ADCP4.*

Table 1.1 *Coordinates and approximate water depth at the representative data reporting and validation sites.*

Site	World Geodetic System 1984 (WGS84)		Water depth (m)
	Longitude	Latitude	
P1	174.645715° E	36.123430° S	29
P2	174.683809°E	36.171665° S	32
ADCP0	174.631300° E	36.102070° S	25
ADCP4	174.533060° E	35.937560° S	25

2. Metocean datasources

2.1. Wind data

The near surface wind and visibility fields were prescribed by a 38-year regional atmospheric hindcast carried out by MOS. The WRF (Weather Research and Forecasting) model was established over all New Zealand at hourly intervals and 12 km resolution with a nested domain over central regions at 4 km resolution. The hindcast was specifically tuned to provide highly accurate marine wind fields for metocean studies around New Zealand.

The WRF model boundaries were sourced from the CFSR (Climate Forecast System Reanalysis) dataset distributed by NOAA (Saha et al., 2010).

Validation of the WRF reanalysis has been undertaken at various locations around New Zealand.

2.2. Wave data

Directional wave spectra within the Hauraki Gulf have been defined from a 40-year period (1979–2018) high-resolution SWAN (Simulating WAves Nearshore) wave hindcast. First, a global scale wave hindcast was produced by MetOcean Solutions Ltd using the WW3 (WAVEWATCH III) model with a resolution of 0.5° by 0.5° applying the source terms parameterizations of Ardhuin et al. (2010). The CFSR wind field was used for wind forcing and the Tolman and Chalikov (1996) physics options were applied in the model configuration. No wave height data assimilation was performed on this hindcast. These hindcast data were extracted at 3-hour intervals and were used to prescribe spectral boundaries for a regional New Zealand North Island SWAN wave model domain (at 0.04° by 0.04° resolution, i.e. approximately 4 km). Finally, a high resolution nest of the Hauraki Gulf (at 0.008° by 0.008° resolution, i.e. approximately 800 m) has been implemented and run over 37 years. Both SWAN model domains are illustrated in Figure 2.1.

SWAN is a third generation ocean wave propagation model which solves the spectral action density balance equation (Booij et al., 1999). The model simulates the growth, refraction and decay of each frequency-direction component of the complete sea state, providing a realistic description of the wave field as it changes in time and space. Physical processes that are modelled include the generation of waves by surface wind, dissipation by white-capping, resonant nonlinear interaction between the wave components, bottom friction and depth limited breaking dissipation. A detailed description of the model equations, parameterisations and numerical schemes can be found in Holthuijsen et al. (2007) and in the SWAN documentation[1]. SWAN was configured with 23 frequency bins and 36 directional bins.

SWAN was run with wind fields specified from the WRF model as described in Section 2.1. Model depths were constructed from a combination of several surveys which include multibeam, single beam, LiDAR, Electronic Nautical Charts (ENCs), obtained from different organisations (including councils, NIWA, LINZ and the Department of Conservation).

[1] http://swanmodel.sourceforge.net/online_doc/online_doc.htm

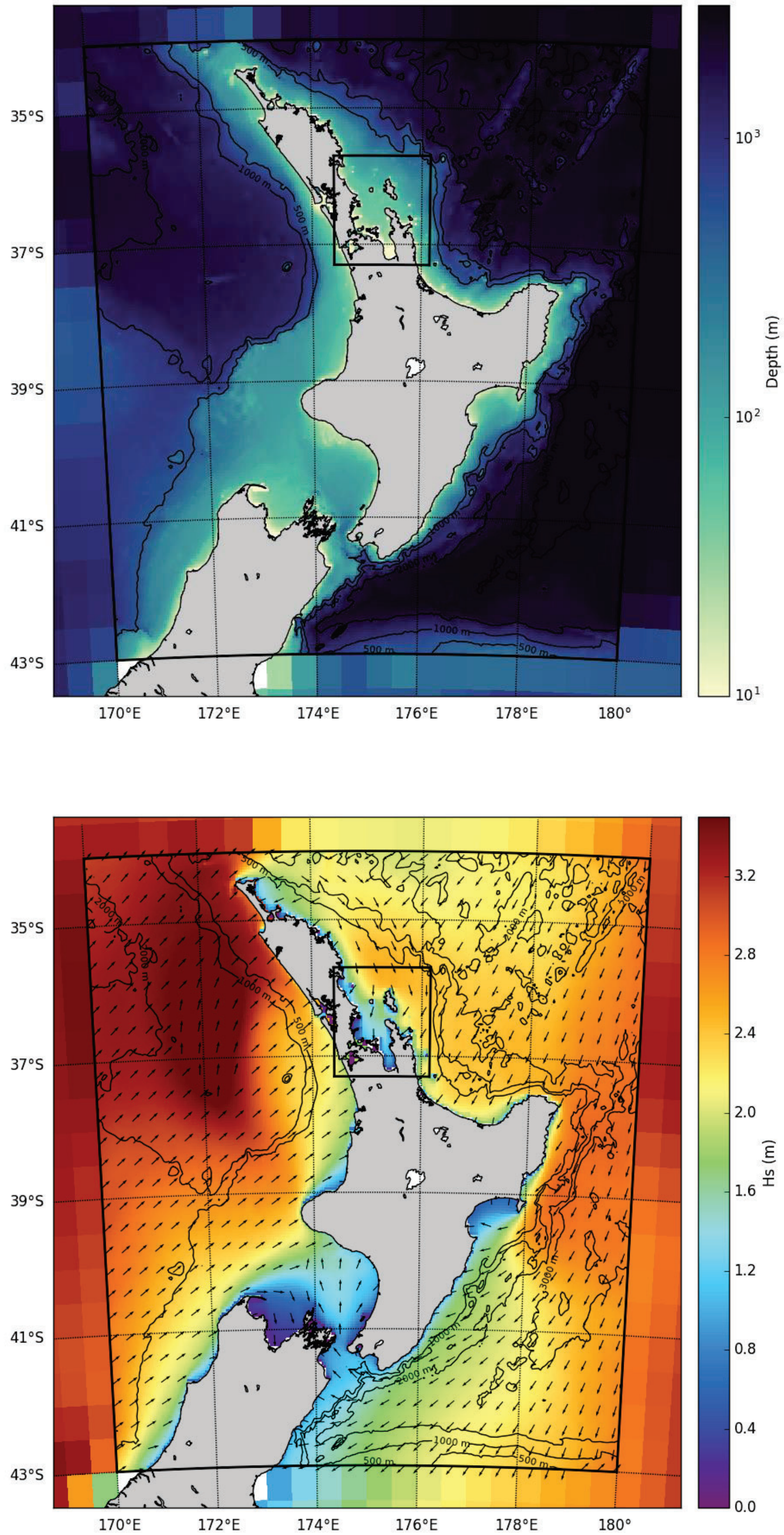

Figure 2.1. *Snapshots of (top) model depths and (bottom) significant wave height from the regional NZ North Island 4-km SWAN domain on 01 January 2012, shown within the area delimited by the outer black rectangle. Model data from the 0.5° global wave model are shown outside of this area. Extension of high resolution Hauraki Gulf 800-m SWAN nest is shown by the inner black rectangle.*

2.3. Current data

A 19-year (Jan 2000 – Jun 2018) hindcast was performed using the ROMS hydrodynamic model version 3.7 (Haidvogel 2008) to characterise the tidal and residual shelf scale circulation regime of the Hauraki Gulf. The application of the ROMS model at regional scale fully captures the interaction of the wind and tidal circulation with the morphology of the Hauraki Gulf. This modelling tool has been used widely in the scientific and commercial consultancy communities for a wide range of ocean basin at regional and coastal scales.

ROMS has a curvilinear horizontal coordinate system and solves the hydrostatic, primitive equations subject to a free-surface condition. It is a state-of-the-art model widely used for regional and coastal dynamics assessment. Its terrain-following vertical coordinate system results in accurate modelling of shelf seas with variable bathymetry, allowing the vertical resolution to be inversely proportional to the local depth. Besides tidal and wind-driven currents, ROMS resolves frontal structures and baroclinic pressure gradients quite well. Vertical mixing may be resolved by different separate turbulent closure schemes, that are flexible to shallow and deep water dynamics. These features make ROMS particularly well-adapted for the modelling of regional hydrodynamic systems and ROMS is one of the hydrodynamic models most used for regional study applications. It is a modern code which captures sub-, meso- and macro-scale hydrodynamic mechanisms while maintaining robustness, accuracy and numerical stability.

The ROMS model data was used to calculate ambient and extreme residual (non-tidal) current and surge statistics reported in this study.

ROMS model domains

The hindcast setup was configured with a three-level nesting approach to best transfer the energy gradually from larger to smaller coastal scales, and to properly resolve the flow associated with local and remote forcing, both essential for the resultant currents in the area of interest. The open boundary conditions that were imposed to the highest level nest (NZ) consisted of tri-dimensional velocity, temperature, salinity and sea surface height fields derived from the 6-hourly Climate Forecast System Reanalysis (CFSR) product (Saha et al., 2010) from the National Centers for Environmental Prediction (NCEP), which consisted of a 0.5 degree global reanalysis with comprehensive data assimilation.

The larger scale ROMS nest encompassed the entire New Zealand area with 7 km horizontal resolution, the goal of which was to absorb the basin scale circulation estimated by the CFSR global reanalysis, thus avoiding a large parent-to-child resolution step. This domain, called NZ hereinafter, was able to more adequately capture the oceanic circulation and its variability. The second domain (HRKI) covered the entire Hauraki Gulf and continental shelf surrounding the area of interest with a horizontal resolution of 1.7 km. With this grid spacing, the local bathymetry was more accurately captured resulting in fine scale representation of the local coastal currents. The third domain (Pakiri) covers the northern Hauraki Gulf including the area of interest with a much higher resolution (350 m), and resolved the detailed, local wind-driven and tidal circulation, producing accurate currents and thermohaline fields to support the subsequent local scale hydrodynamic models.

The 3D flow and thermohaline fields were transferred from the top level domains to the refined ones by the offline one-way nesting technique commonly used with ROMS.CFSR 3D fields were fed to NZ at 6-hourly intervals and NZ-HRKI and HRKI / Pakiri ROMS at 3-hourly intervals.

All ROMS domains were submitted to spin-up phases prior to the 19-year hindcast period to allow the adjustment of the coarser initial conditions to higher resolution and its better represented bathymetry. The spin-up times were hierarchically established according to the main scales that each one was required to resolve. This information, along with all other relevant information for each of the hydrodynamic model domains considered for this study, is summarised in Table 2.1. The bathymetry for the ROMS grids was derived from electronic navigation charts and field data whenever available.

Table 2.1 ROMS model nests configurations.

Model Settings	NZ	HRKI	Pakiri
Horizontal Resolution	8 km (0.08° x 0.06°)	1.7 km (0.02° x 0.02°)	400-300 m (0.004° x 0.003°)
Dimension	3D	3D	3D
Vertical layers	30	19	N.A.
Tidal forcing	No	No	Yes
Meteo forcing	MSL WRF NZRA	MSL WRF NZRA	MSL WRF NZRA

ROMS model validation

The final hydrodynamic hindcast product was validated against co-temporal current time series obtained from measured data at locations ADCP4 and ADCP0 as illustrated in *Figure 2.2*.

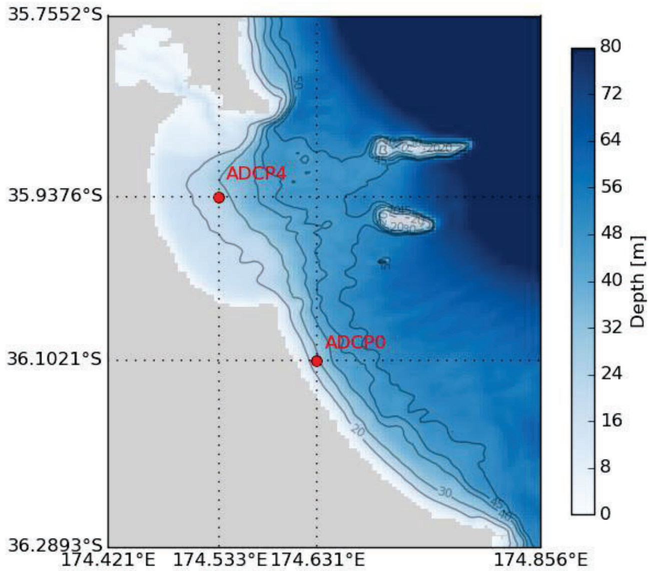

Figure 2.2. Bathymetry map showing the measurement locations.

Modelled and measured current time series were vertically-averaged from 5 to 25 m depth and re-sampled to 1-hour intervals for a consistent time-domain comparison of total, non-tidal and tidal currents. The tidal flow was obtained from a harmonic decomposition. A 30-hour low-pass filter was applied to separate the non-tidal flow from the total signal. This approach was used in order to reduce potential noise contamination from the t due to the short time extent of the measured current data used for the analysis.

Although the period covered by the measurements are not long enough to assess the model performance throughout all possible weather scenarios, results from modelled and measured depth-averaged currents comparison indicate the model resolves faithfully the circulation regime at both locations (*Figure 2.3*-*Figure 2.8*). Flow orientation and direction are reasonably well reproduced by the model, as shown on the Rose plots (*Figure 2.5*-*Figure 2.6*). The model generally underestimates the current magnitudes by approximately 30% (*Figure 2.3*-*Figure 2.4*), which in part is due to non-tidal (residual) flow forced by strong wind events not being well replicated and an overall underestimation of the tidal magnitudes.

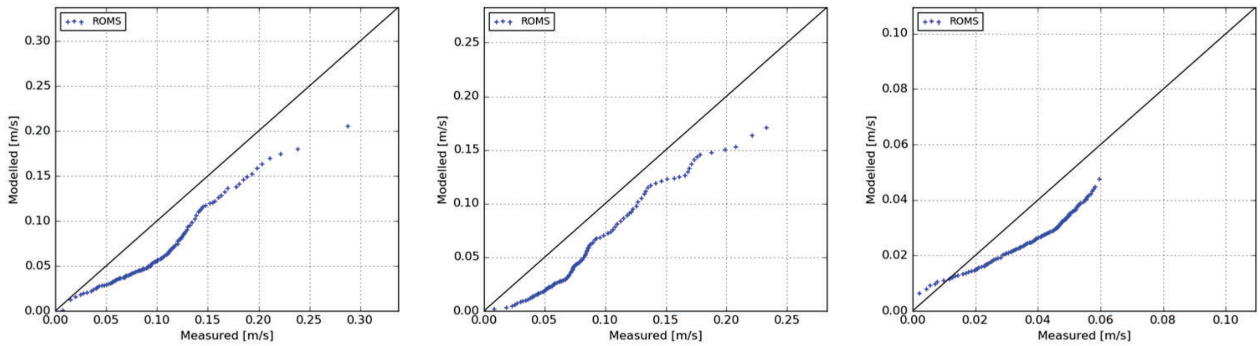

Figure 2.3. *Quantile-Quantile plots of the measured and modelled total (left), non-tidal (center) and tidal (right) depth-averaged current speed at location ADCP4 (12 June – 13 July 2016).*

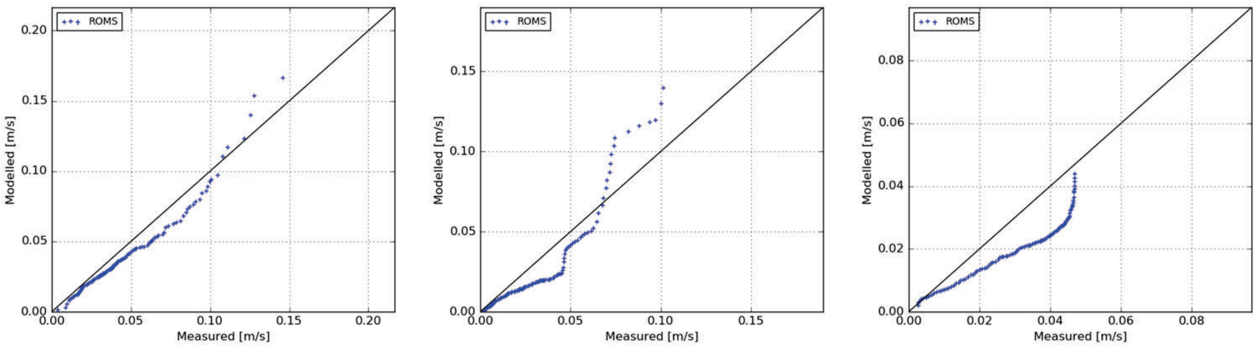

Figure 2.4. *Quantile-Quantile plots of the measured and modelled total (left), non-tidal (center) and tidal (right) depth-averaged current speed at location ADCP0 (20 – 31 May 2019).*

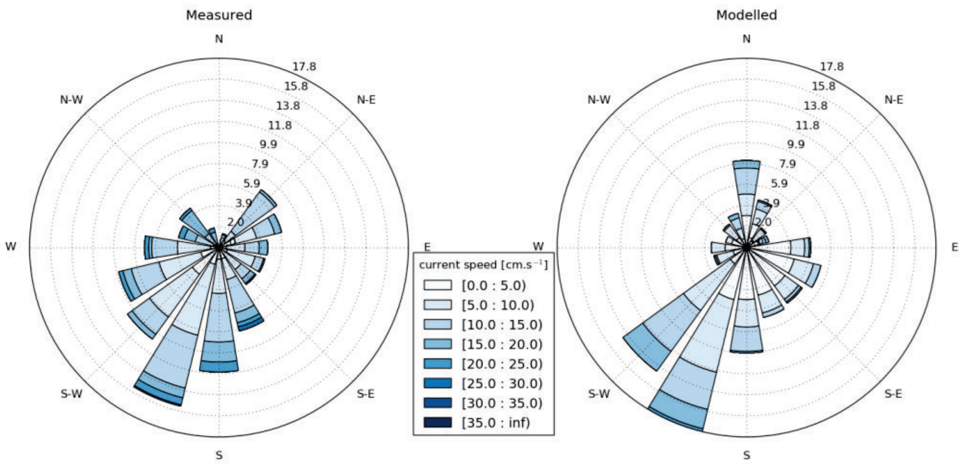

Figure 2.5. *Measured (left) and modelled (right) total depth-averaged current rose at location ADCP4 (12 June – 13 July 2016).*

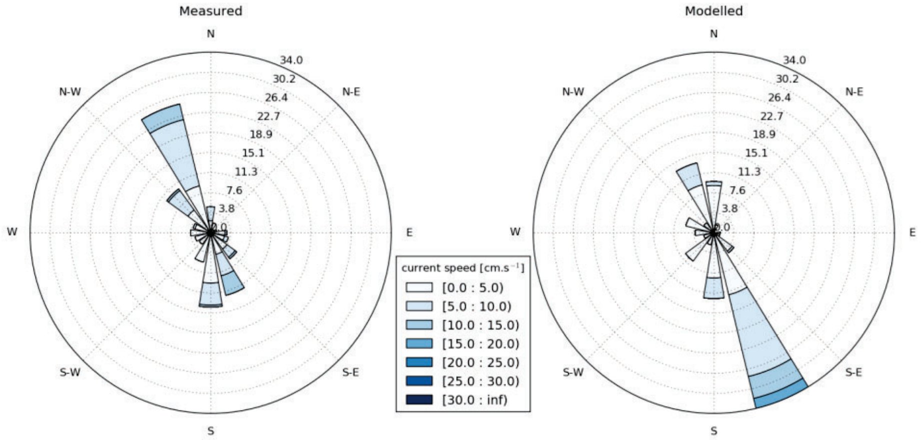

Figure 2.6. *Measured (left) and modelled (right) total depth-averaged current rose at location ADCP0 (20 – 31 May 2019).*

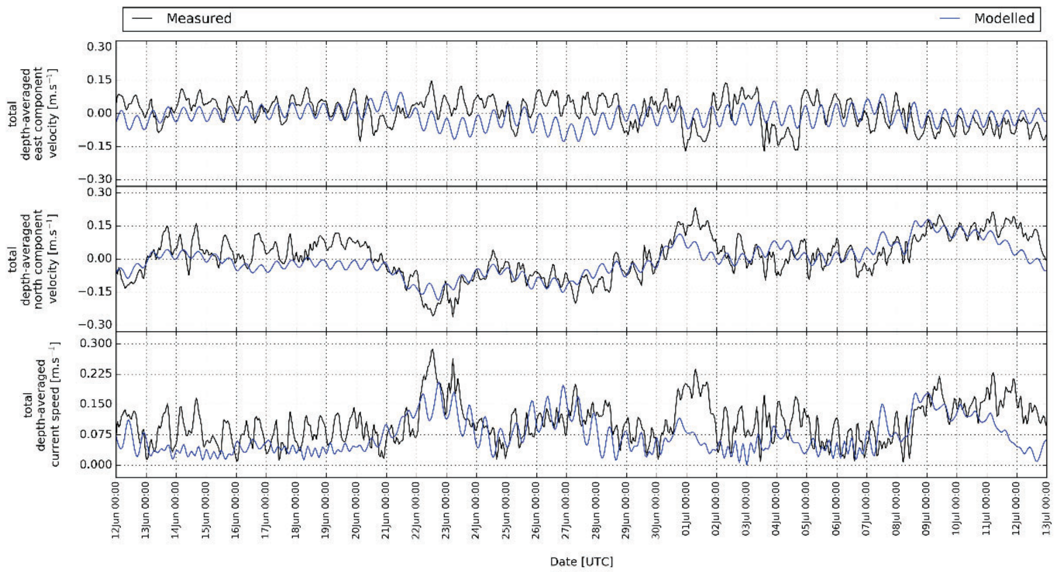

Figure 2.7. *Time series of modelled (blue) and measured (black) total depth-averaged current velocity at location ADCP4 (12 June – 13 July 2016).*

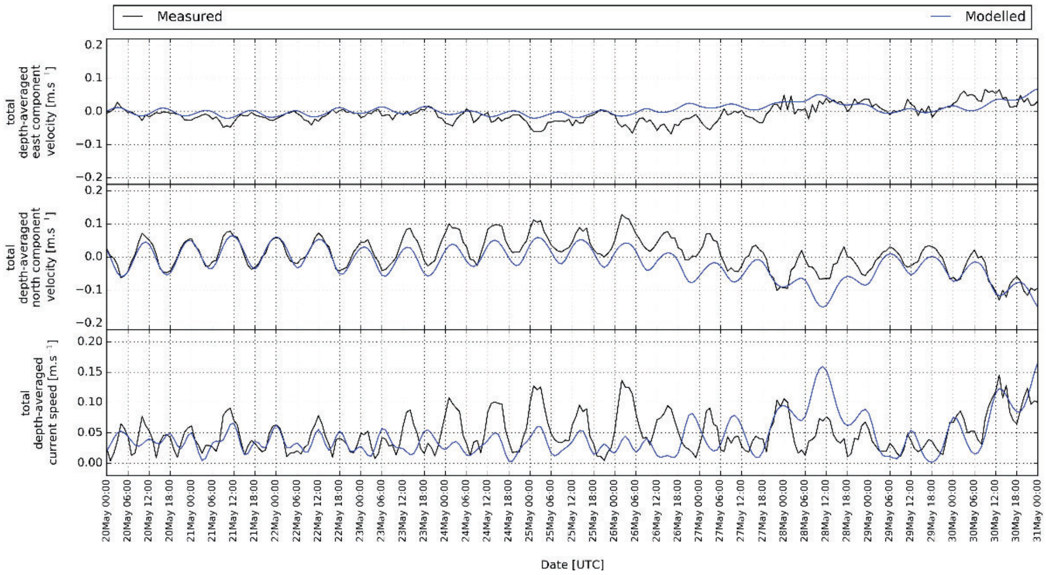

Figure 2.8. Time series of modelled (blue) and measured (black) total depth-averaged current velocity at location ADCP0 (20 – 31 May 2019).

3. Wind climate

3.1. P1

A summary of the wind speed statistics for the 10-minute mean at 10 m elevation at P1 is provided in Table 3.1.

The monthly and annual 10-min wind speed exceedance probabilities are provided in Table 3.2, and indicate the wind speeds exceeding 18 $m.s^{-1}$ can occur throughout the year, with March having the highest occurrence of strong wind events at P1.

The annual joint probability distribution of the wind speed and direction is presented in Table 3.3.

The annual and monthly non-exceedance persistence probabilities for 10-min wind speed at P1 (Table 3.4 to Table 3.15) can be used to estimate the operational uptime for tasks with wind speed limitations of variable duration. For example, at P1 on average in February, wind speeds are less than 4.0 $m.s^{-1}$ for durations of 36 hours and greater for 1.43% of the time (Table 3.5).

The monthly and annual 10-min wind roses are illustrated in Figure 3.1, showing the annual predominance of winds coming mainly from the WSW quadrants.

Table 3.1 Annual and monthly 10-min wind speed statistics at P1.

Period (01 Jan 1979 – 31 Dec 2018)	10-min wind speed statistics [1]												
	10-min wind speed (m/s)			Exceedance percentile for 10-min wind speed (m/s)									Main [4] Direction(s)
	max	**mean**	**std**	**p1**	**p5**	**p10**	**p50**	**p80**	**p90**	**p95**	**p98**	**p99**	
January	20.96	6.03	2.90	0.80	1.78	2.53	5.76	8.31	9.78	11.24	13.03	14.12	NE SW
February	19.19	5.88	2.85	0.70	1.68	2.35	5.64	8.08	9.58	10.86	12.85	14.14	E SW
March	25.43	6.10	2.95	0.78	1.77	2.48	5.86	8.40	9.89	11.28	13.31	14.32	E SW
April	21.49	6.01	2.88	0.87	1.75	2.46	5.73	8.33	9.79	11.21	12.76	13.76	SW
May	21.57	6.44	3.03	0.85	1.83	2.62	6.18	8.93	10.51	11.79	13.28	14.35	SW W
June	24.44	6.84	3.25	0.94	1.96	2.84	6.52	9.42	11.10	12.81	14.57	15.82	SW W
July	24.38	7.01	3.48	0.98	2.06	2.92	6.51	9.67	11.77	13.69	15.59	16.73	SW W
August	20.58	6.77	3.22	1.03	2.03	2.84	6.38	9.29	11.15	12.76	14.47	15.55	SW W
September	22.17	6.79	3.16	0.88	2.01	2.82	6.55	9.29	10.90	12.45	14.27	15.66	SW W
October	20.93	6.74	2.99	0.91	2.06	2.88	6.58	9.20	10.74	11.97	13.43	14.29	SW W
November	19.96	6.52	2.93	0.94	2.09	2.81	6.31	8.86	10.30	11.66	13.23	14.62	SW W
December	20.54	6.04	2.80	0.82	1.88	2.65	5.80	8.25	9.79	11.09	12.60	13.75	N SW W
Winter[3]	24.44	6.87	3.32	0.98	2.02	2.87	6.47	9.46	11.34	13.08	14.91	16.12	SW W
Spring	22.17	6.69	3.03	0.91	2.05	2.84	6.48	9.12	10.66	12.05	13.66	14.86	SW W
Summer[2]	20.96	5.98	2.85	0.78	1.78	2.51	5.73	8.23	9.72	11.07	12.84	13.98	E SW
Autumn	25.43	6.19	2.96	0.83	1.78	2.51	5.92	8.56	10.10	11.48	13.12	14.21	SW
All	25.43	6.43	3.07	0.87	1.90	2.66	6.14	8.84	10.47	11.98	13.77	14.98	SW W

Notes: (1) All statistics derived from hindcast wind data (10-min mean at 10 m AMSL) for the period 01 January 1979 to 31 December 2018.
(2) Summer: April to September.
(3) Winter: October to March.
(4) Main directions are those with greater than 15% occurrence and represent directions from which the winds approach.

Table 3.2 Monthly and annual 10-min wind speed exceedance probabilities (%) at P1.

U_{10min} (m/s)	Exceedance (%)												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**annual**
>0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
>2	93.58	92.87	93.63	93.31	93.98	94.80	95.25	95.20	95.01	95.28	95.45	94.33	94.40
>4	74.15	72.87	74.65	74.75	77.57	80.67	80.97	80.20	80.77	81.61	79.74	75.43	77.80
>6	46.57	44.71	47.94	46.00	52.59	56.53	56.65	55.10	57.21	57.59	54.37	46.77	51.87
>8	22.70	20.71	23.38	22.96	29.16	32.83	33.38	31.33	32.45	31.76	28.92	21.94	27.66
>10	8.97	8.10	9.50	9.00	12.86	15.94	17.88	15.44	14.81	14.14	11.62	8.95	12.29
>12	3.49	2.83	3.75	3.42	4.45	7.03	9.23	7.04	6.26	4.95	4.08	2.78	4.96
>14	1.10	1.07	1.27	0.88	1.26	2.83	4.28	2.66	2.28	1.23	1.36	0.82	1.76
>16	0.37	0.30	0.41	0.27	0.32	0.85	1.64	0.75	0.82	0.23	0.40	0.21	0.55
>18	0.13	0.06	0.15	0.08	0.06	0.26	0.55	0.21	0.21	0.06	0.14	0.06	0.17
>20	0.03	0.00	0.07	0.03	0.01	0.06	0.27	0.05	0.04	0.02	0.00	0.03	0.05
>22	0.00	0.00	0.05	0.00	0.00	0.01	0.08	0.00	0.01	0.00	0.00	0.00	0.01
>24	0.00	0.00	0.02	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.3 Annual joint probability distribution (in %) of the wind speed and wind direction at P1.

U10min (m/s)	Wind direction (degT)									
	337.5-22.5	**22.5-67.5**	**67.5-112.5**	**112.5-157.5**	**157.5-202.5**	**202.5-247.5**	**247.5-292.5**	**292.5-337.5**	**Total**	**Exceed%**
>0<=2	0.72	0.75	0.65	0.45	0.62	0.93	0.82	0.65	5.59	100.00
>2<=4	1.97	2.20	1.93	1.55	1.98	3.11	2.16	1.71	16.61	94.40
>4<=6	2.66	2.33	2.36	2.21	2.70	6.07	4.32	3.28	25.93	77.80
>6<=8	2.50	2.03	2.35	1.70	1.51	6.45	4.73	2.94	24.21	51.87
>8<=10	2.02	1.40	1.68	1.13	0.67	3.51	3.35	1.60	15.36	27.66
>10<=12	1.35	0.84	1.05	0.62	0.25	1.22	1.36	0.64	7.33	12.29
>12<=14	0.69	0.57	0.57	0.38	0.08	0.30	0.43	0.18	3.20	4.96
>14<=16	0.24	0.28	0.29	0.17	0.02	0.08	0.09	0.04	1.21	1.76
>16<=18	0.07	0.09	0.11	0.06	0.01	0.01	0.02	0.01	0.38	0.55
>18<=20	0.02	0.03	0.05	0.01	*	*	*	*	0.11	0.17
>20<=22	0.01	0.01	0.01	0.01	-	-	-	*	0.04	0.05
>22<=24	*	*	*	0.01	-	-	-	-	0.01	0.01
>24<=26	-	*	-	*	-	-	-	-		
Total	12.25	10.53	11.05	8.30	7.84	21.68	17.28	11.05	100.00	

Notes: * represents less than 0.005%.

Table 3.4 Annual and monthly non-exceedance persistence (%) for wind speed below 2.0 m/s at P1.

U10min (m/s)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	1.16	0.05	0.00	0.00	0.00	0.00	0.00
Feb	1.71	0.30	0.00	0.00	0.00	0.00	0.00
Mar	1.56	0.16	0.00	0.00	0.00	0.00	0.00
Apr	2.54	0.93	0.16	0.00	0.00	0.00	0.00
May	2.42	1.21	0.18	0.10	0.00	0.00	0.00
Jun	2.02	0.90	0.07	0.00	0.00	0.00	0.00
Jul	1.39	0.36	0.08	0.00	0.00	0.00	0.00
Aug	1.68	0.66	0.00	0.00	0.00	0.00	0.00
Sep	1.67	0.47	0.07	0.00	0.00	0.00	0.00
Oct	1.20	0.25	0.00	0.00	0.00	0.00	0.00
Nov	0.70	0.05	0.00	0.00	0.00	0.00	0.00
Dec	0.52	0.05	0.00	0.00	0.00	0.00	0.00
annual	1.56	0.45	0.05	0.01	0.00	0.00	0.00

Table 3.5 Annual and monthly non-exceedance persistence (%) for wind speed below 4.0 m/s at P1.

U10min (m/s)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	18.55	10.60	5.23	2.77	1.34	0.34	0.00
Feb	20.09	12.71	6.88	3.62	1.43	0.33	0.33
Mar	18.80	13.11	7.49	3.98	2.34	1.65	0.29
Apr	19.56	14.33	9.33	6.73	3.80	1.90	0.30
May	17.35	13.28	9.22	7.39	3.63	1.37	0.00
Jun	14.49	10.35	7.40	5.47	2.67	1.78	0.60
Jul	14.70	10.48	6.94	4.90	2.49	1.12	0.72
Aug	14.17	9.52	5.73	3.22	1.88	0.74	0.00
Sep	13.82	9.74	5.76	3.67	1.82	0.38	0.00
Oct	13.00	8.06	3.64	1.65	0.62	0.00	0.00
Nov	13.98	7.48	3.17	1.58	0.74	0.60	0.00
Dec	16.92	8.97	4.12	1.98	0.33	0.17	0.00
annual	16.42	10.88	6.35	4.01	2.00	0.92	0.19

Table 3.6 Annual and monthly non-exceedance persistence (%) for wind speed below 6.0 m/s at P1.

U10min (m/s)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	48.94	43.69	35.72	30.92	25.01	17.41	9.56
Feb	50.66	46.30	38.94	33.44	26.73	16.28	9.71
Mar	47.44	42.06	36.18	31.62	25.83	18.25	9.12
Apr	49.85	44.65	39.97	35.59	29.28	21.57	12.54
May	42.88	39.18	35.74	31.91	26.60	21.85	13.34
Jun	39.29	35.58	31.32	28.24	22.56	16.84	7.68
Jul	38.72	33.85	29.74	26.38	19.97	14.50	7.79
Aug	40.31	35.47	29.63	26.15	19.34	13.13	5.14
Sep	37.63	32.34	26.76	22.48	18.69	14.08	7.73
Oct	37.58	31.53	24.42	19.38	14.59	9.85	5.46
Nov	40.30	33.79	25.29	21.69	15.62	9.51	4.49
Dec	47.98	41.74	33.05	27.03	21.57	13.85	6.81
annual	43.62	38.64	32.60	28.28	22.73	16.11	8.94

Table 3.7 Annual and monthly non-exceedance persistence (%) for wind speed below 8.0 m/s at P1.

U10min (m/s)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	74.96	72.31	68.22	64.72	60.63	52.99	43.66
Feb	76.91	74.56	71.93	68.86	64.99	58.80	48.85
Mar	74.32	71.74	68.82	66.89	62.76	59.81	48.95
Apr	74.44	71.40	69.42	67.00	63.39	56.64	47.73
May	67.51	64.98	62.16	59.60	54.26	48.03	39.94
Jun	63.94	61.63	58.58	56.06	49.77	43.39	32.56
Jul	63.83	60.72	57.73	54.83	47.94	43.04	31.84
Aug	65.90	63.18	60.45	57.72	51.81	44.66	31.49
Sep	64.48	61.04	56.57	52.93	47.26	42.08	32.25
Oct	65.00	62.02	56.49	53.18	47.91	39.80	28.58
Nov	68.12	63.82	57.66	53.37	47.73	40.06	30.50
Dec	76.01	73.30	68.66	64.01	60.55	51.46	40.41
annual	69.73	66.98	63.53	60.50	55.88	49.84	40.11

Table 3.8 Annual and monthly non-exceedance persistence (%) for wind speed below 10.0 m/s at P1.

U10min (m/s)	**Duration (hours)**						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	90.18	89.47	88.65	87.60	85.32	82.39	77.31
Feb	91.34	90.43	89.56	88.47	87.52	85.25	80.91
Mar	89.49	88.73	87.51	86.32	84.79	82.15	78.09
Apr	90.01	88.93	88.34	87.65	85.80	82.64	76.39
May	85.57	84.28	82.64	81.36	78.63	74.19	68.22
Jun	82.35	80.31	78.69	77.76	74.27	70.44	60.68
Jul	80.21	78.84	77.04	75.31	71.08	67.44	59.38
Aug	82.97	81.45	79.84	78.31	75.24	70.86	60.98
Sep	83.39	81.68	79.82	77.98	73.05	67.47	59.29
Oct	84.67	82.82	80.57	78.80	74.97	70.58	62.03
Nov	87.53	85.71	83.45	82.23	79.17	74.02	65.88
Dec	90.14	88.98	87.66	86.63	84.35	80.74	76.15
annual	86.52	85.30	84.03	82.94	80.50	77.14	71.42

Table 3.9 Annual and monthly non-exceedance persistence (%) for wind speed below 12.0 m/s at P1.

U10min (m/s)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	96.14	95.93	95.71	95.57	95.25	94.49	92.13
Feb	96.92	96.67	96.55	96.29	95.75	95.41	93.87
Mar	95.90	95.70	95.43	95.04	94.41	93.50	91.45
Apr	96.20	95.64	95.35	94.86	94.30	93.00	90.42
May	94.98	94.46	94.06	93.33	92.24	91.10	87.33
Jun	92.33	91.70	91.25	90.31	88.57	86.63	81.49
Jul	89.78	89.00	88.41	87.54	85.92	83.39	76.59
Aug	92.23	91.74	90.69	89.88	88.11	86.80	81.60
Sep	93.07	92.49	91.63	90.94	89.74	86.61	82.10
Oct	94.53	93.89	93.11	92.25	91.18	88.13	84.44
Nov	95.54	95.24	94.52	94.08	93.43	91.98	89.49
Dec	97.05	96.68	96.11	95.51	94.98	94.27	92.46
annual	94.57	94.19	93.79	93.30	92.66	91.58	89.16

Table 3.10 Annual and monthly non-exceedance persistence (%) for wind speed below 14.0 m/s at P1.

U10min (m/s)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	98.65	98.59	98.41	98.41	98.41	98.26	97.82
Feb	98.83	98.71	98.57	98.48	98.38	98.38	97.96
Mar	98.57	98.46	98.30	98.30	98.19	98.03	97.64
Apr	99.00	98.96	98.79	98.79	98.57	98.41	98.16
May	98.57	98.42	98.31	98.17	98.06	97.77	96.96
Jun	96.91	96.47	96.24	96.07	95.66	94.56	93.07
Jul	95.16	94.97	94.81	94.52	93.89	93.34	90.40
Aug	97.07	96.84	96.78	96.56	95.64	94.88	93.54
Sep	97.44	97.33	96.88	96.72	96.30	94.77	93.54
Oct	98.69	98.63	98.57	98.28	97.83	97.25	95.70
Nov	98.53	98.53	98.42	98.26	98.04	97.76	96.82
Dec	99.08	99.05	99.00	98.92	98.92	98.48	98.10
annual	98.06	97.95	97.85	97.76	97.66	97.51	97.07

Table 3.11 Annual and monthly non-exceedance persistence (%) for wind speed below 16.0 m/s at P1.

U10min (m/s)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	99.58	99.58	99.53	99.53	99.43	99.43	99.43
Feb	99.68	99.63	99.57	99.49	99.26	99.26	98.77
Mar	99.56	99.56	99.56	99.48	99.48	99.48	99.48
Apr	99.71	99.64	99.64	99.64	99.53	99.36	99.36
May	99.65	99.55	99.55	99.47	99.47	99.47	99.47
Jun	99.10	99.02	99.02	98.95	98.75	98.58	98.18
Jul	98.18	98.08	98.02	97.94	97.63	97.21	95.98
Aug	99.14	99.04	98.99	98.99	98.68	98.53	98.17
Sep	99.08	99.08	98.98	98.68	98.68	98.21	97.13
Oct	99.77	99.77	99.77	99.77	99.77	99.77	99.34
Nov	99.60	99.60	99.60	99.60	99.60	99.47	98.76
Dec	99.78	99.78	99.73	99.73	99.73	99.58	99.37
annual	99.41	99.39	99.36	99.32	99.31	99.28	99.21

Table 3.12 Annual and monthly non-exceedance persistence (%) for wind speed below 18.0 m/s at P1.

U10min (m/s)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	99.83	99.83	99.83	99.83	99.83	99.83	99.83
Feb	99.94	99.94	99.89	99.89	99.89	99.89	99.65
Mar	99.83	99.83	99.83	99.83	99.83	99.83	99.83
Apr	99.92	99.92	99.92	99.92	99.92	99.92	99.74
May	99.93	99.93	99.93	99.93	99.93	99.93	99.93
Jun	99.72	99.69	99.64	99.64	99.54	99.38	99.17
Jul	99.39	99.35	99.29	99.29	99.29	99.29	99.09
Aug	99.79	99.79	99.79	99.79	99.79	99.79	99.61
Sep	99.76	99.76	99.76	99.76	99.76	99.60	99.18
Oct	99.94	99.94	99.94	99.94	99.94	99.94	99.76
Nov	99.83	99.83	99.83	99.83	99.83	99.68	99.68
Dec	99.94	99.94	99.94	99.94	99.94	99.94	99.94
annual	99.82	99.82	99.81	99.81	99.81	99.81	99.81

Table 3.13 Annual and monthly non-exceedance persistence (%) for wind speed below 20.0 m/s at P1.

U10min (m/s)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	99.97	99.97	99.97	99.97	99.97	99.97	99.97
Feb	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mar	99.93	99.93	99.93	99.93	99.93	99.93	99.93
Apr	99.97	99.97	99.97	99.97	99.97	99.97	99.97
May	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Jun	99.94	99.94	99.89	99.89	99.79	99.79	99.79
Jul	99.70	99.63	99.63	99.63	99.63	99.63	99.63
Aug	99.95	99.95	99.95	99.95	99.95	99.95	99.95
Sep	99.96	99.96	99.96	99.96	99.96	99.96	99.96
Oct	99.98	99.98	99.98	99.98	99.98	99.98	99.98
Nov	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dec	99.97	99.97	99.97	99.97	99.97	99.97	99.97
annual	99.95	99.94	99.94	99.94	99.94	99.94	99.94

Table 3.14 *Annual and monthly non-exceedance persistence (%) for wind speed below 22.0 m/s at P1.*

U10min (m/s)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Feb	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mar	99.95	99.95	99.95	99.95	99.95	99.95	99.95
Apr	100.00	100.00	100.00	100.00	100.00	100.00	100.00
May	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Jun	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Jul	99.91	99.91	99.91	99.91	99.91	99.91	99.91
Aug	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Sep	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Oct	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nov	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dec	100.00	100.00	100.00	100.00	100.00	100.00	100.00
annual	99.99	99.99	99.99	99.99	99.99	99.99	99.99

Table 3.15 Annual and monthly non-exceedance persistence (%) for wind speed below 24.0 m/s at P1.

U10min (m/s)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Feb	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mar	99.98	99.98	99.98	99.98	99.98	99.98	99.98
Apr	100.00	100.00	100.00	100.00	100.00	100.00	100.00
May	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Jun	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Jul	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Aug	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Sep	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Oct	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nov	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dec	100.00	100.00	100.00	100.00	100.00	100.00	100.00
annual	100.00	100.00	100.00	100.00	100.00	100.00	100.00

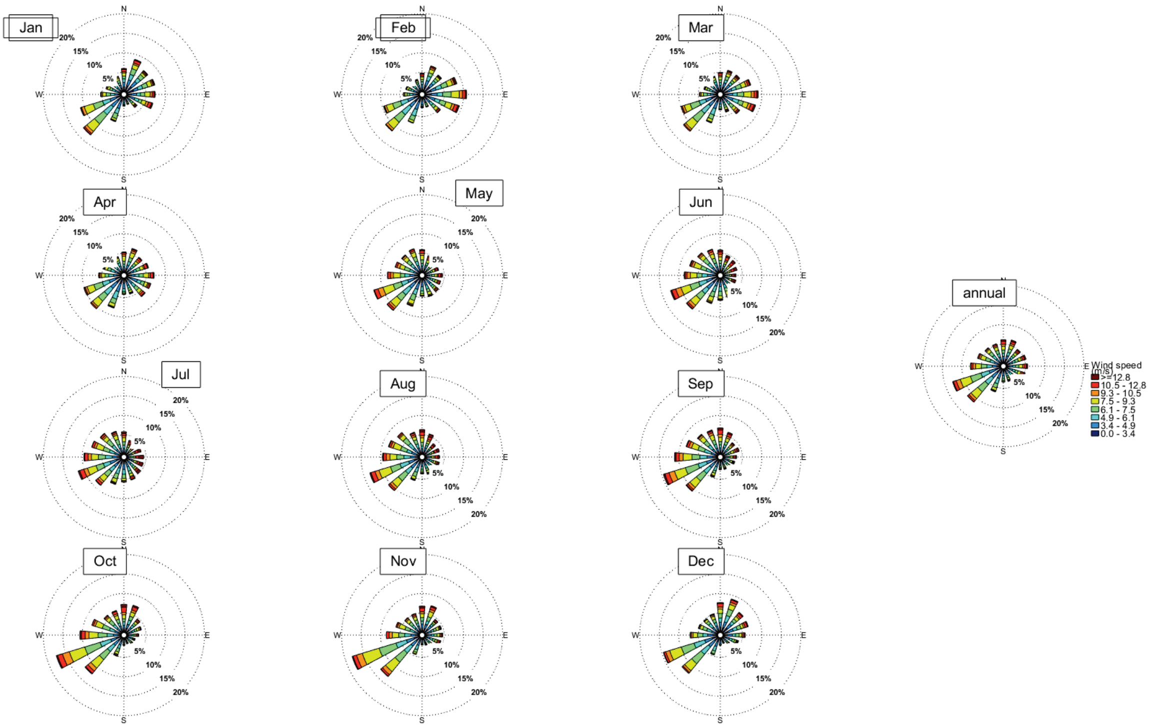

Figure 3.1 Monthly and annual wind rose plot (10-minute mean at 10 m AMSL) at P1. Sectors indicate the direction from which the winds blow.

3.2. P2

A summary of the wind speed statistics for the 10-minute mean at 10 m elevation at P2 is provided in Table 3.16.

The monthly and annual 10-min wind speed exceedance probabilities are provided in Table 3.17, and indicate the wind speeds exceeding 18 $m.s^{-1}$ can occur throughout the year, with March having the highest occurrence of strong wind events at P2.

The annual joint probability distribution of the wind speed and direction is presented in Table 3.18.

The annual and monthly non-exceedance persistence probabilities for 10-min wind speed at P2 (Table 3.19 to Table 3.30) can be used to estimate the operational uptime for tasks with wind speed limitations of variable duration. For example, at P2 on average in February, wind speeds are less than 4.0 $m.s^{-1}$ for durations of 36 hours and greater for 3.18% of the time (Table 3.20).

The monthly and annual 10-min wind roses are illustrated in Figure 3.2, showing the annual predominance of winds coming mainly from the SW quadrants.

Table 3.16 Annual and monthly 10-min wind speed statistics at P2.

Period (01 Jan 1979 – 31 Dec 2018)	10-min wind speed statistics (1)												
	10-min wind speed (m/s)			Exceedance percentile for 10-min wind speed (m/s)									Main (4) Direction(s)
	max	mean	std	p1	p5	p10	p50	p80	p90	p95	p98	p99	
January	20.24	5.83	2.81	0.89	1.79	2.51	5.51	8.06	9.51	10.99	12.74	13.69	NE SW
February	18.46	5.69	2.76	0.82	1.72	2.35	5.39	7.80	9.33	10.61	12.50	13.76	E SW
March	24.84	5.91	2.86	0.77	1.78	2.47	5.65	8.11	9.61	11.05	12.91	13.94	E SW
April	21.42	5.83	2.80	0.81	1.74	2.44	5.50	8.08	9.54	10.94	12.43	13.51	SW
May	21.05	6.28	2.98	0.87	1.83	2.57	5.97	8.74	10.31	11.51	13.10	14.04	SW W
June	23.61	6.67	3.20	0.94	1.96	2.80	6.34	9.24	10.89	12.60	14.26	15.45	SW W
July	23.37	6.84	3.41	0.92	2.06	2.88	6.31	9.44	11.54	13.39	15.24	16.39	SW W
August	20.54	6.59	3.17	0.96	1.95	2.76	6.19	9.13	10.91	12.50	14.21	15.22	SW W
September	21.74	6.63	3.11	0.82	1.88	2.78	6.38	9.09	10.70	12.24	14.05	15.38	SW W
October	20.24	6.56	2.92	1.03	2.09	2.84	6.37	8.98	10.48	11.77	13.15	13.95	SW W
November	19.93	6.33	2.86	1.00	2.09	2.80	6.10	8.63	10.09	11.42	12.95	14.24	SW W
December	19.89	5.86	2.72	0.93	1.91	2.62	5.56	8.01	9.51	10.81	12.34	13.36	N SW W
Winter(3)	23.61	6.70	3.26	0.94	2.00	2.82	6.29	9.27	11.09	12.80	14.62	15.77	SW W
Spring	21.74	6.51	2.97	0.95	2.01	2.81	6.28	8.89	10.41	11.81	13.36	14.55	SW W
Summer(2)	20.24	5.79	2.76	0.86	1.80	2.49	5.49	7.95	9.45	10.82	12.52	13.62	E SW
Autumn	24.84	6.01	2.89	0.81	1.79	2.49	5.71	8.32	9.85	11.23	12.82	13.87	SW
All	24.84	6.26	3.00	0.88	1.89	2.64	5.93	8.62	10.24	11.73	13.47	14.66	SW W

Notes: (1) All statistics derived from hindcast wind data (10-min mean at 10 m AMSL) for the period 01 January 1979 to 31 December 2018.
(2) Summer: April to September.
(3) Winter: October to March.
(4) Main directions are those with greater than 15% occurrence and represent directions from which the winds approach.

Table 3.17 Monthly and annual 10-min wind speed exceedance probabilities (%) at P2.

U_{10min} (m/s)	Exceedance (%)												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**annual**
>0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
>2	93.74	93.02	93.60	93.36	93.89	94.91	95.34	94.75	94.46	95.31	95.44	94.46	94.36
>4	72.27	71.21	73.11	73.19	75.82	79.19	80.01	78.68	79.76	80.24	78.49	73.75	76.33
>6	42.96	41.04	44.87	42.60	49.63	54.26	54.17	52.52	55.10	55.16	51.32	43.26	48.95
>8	20.47	18.21	20.88	20.76	27.42	30.92	31.76	29.24	30.46	29.33	26.29	20.07	25.52
>10	7.87	7.17	8.26	8.11	11.74	14.68	16.86	14.51	13.31	12.48	10.47	7.79	11.13
>12	2.90	2.62	3.37	2.85	3.80	6.31	8.45	6.33	5.55	4.31	3.70	2.51	4.40
>14	0.80	0.84	0.96	0.70	1.02	2.36	3.76	2.25	2.02	0.95	1.09	0.70	1.46
>16	0.33	0.20	0.33	0.25	0.20	0.74	1.23	0.60	0.69	0.20	0.29	0.18	0.44
>18	0.11	0.02	0.09	0.05	0.03	0.21	0.47	0.17	0.17	0.07	0.07	0.06	0.13
>20	0.01	0.00	0.05	0.02	0.01	0.06	0.24	0.02	0.02	0.01	0.00	0.00	0.04
>22	0.00	0.00	0.05	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.00	0.00	0.01
>24	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 3.18 Annual joint probability distribution (in %) of the wind speed and wind direction at P2.

U10min (m/s)	Wind direction (degT)									
	337.5-22.5	22.5-67.5	67.5-112.5	112.5-157.5	157.5-202.5	202.5-247.5	247.5-292.5	292.5-337.5	Total	Exceed%
>0<=2	0.70	0.71	0.60	0.46	0.64	0.96	0.89	0.67	5.63	100.00
>2<=4	2.08	2.23	2.06	1.65	2.45	3.39	2.39	1.79	18.04	94.36
>4<=6	2.83	2.31	2.50	2.40	2.87	6.75	4.67	3.06	27.39	76.33
>6<=8	2.49	1.92	2.41	1.68	1.49	5.82	4.93	2.69	23.43	48.95
>8<=10	1.97	1.34	1.64	1.10	0.60	2.74	3.39	1.60	14.38	25.52
>10<=12	1.25	0.83	0.99	0.60	0.22	0.82	1.38	0.64	6.73	11.13
>12<=14	0.64	0.53	0.54	0.36	0.07	0.21	0.41	0.17	2.93	4.40
>14<=16	0.22	0.24	0.24	0.14	0.02	0.04	0.08	0.04	1.02	1.46
>16<=18	0.06	0.08	0.09	0.05	0.01	0.01	0.01	0.01	0.32	0.44
>18<=20	0.01	0.02	0.03	0.02	*	-	*	*	0.08	0.13
>20<=22	0.01	0.01	0.01	0.01	-	-	-	-	0.04	0.04
>22<=24	-	*	*	0.01	-	-	-	-	0.01	0.01
>24<=26	-	-	-	*	-	-	-	-		
Total	12.26	10.22	11.11	8.48	8.37	20.74	18.15	10.67	100.00	

Notes: * represents less than 0.005%.

Table 3.19 Annual and monthly non-exceedance persistence (%) for wind speed below 2.0 m/s at P2.

U10min (m/s)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	1.00	0.10	0.00	0.00	0.00	0.00	0.00
Feb	1.49	0.34	0.00	0.00	0.00	0.00	0.00
Mar	1.52	0.16	0.00	0.00	0.00	0.00	0.00
Apr	2.56	0.77	0.08	0.00	0.00	0.00	0.00
May	2.57	1.13	0.33	0.11	0.00	0.00	0.00
Jun	2.22	0.88	0.07	0.00	0.00	0.00	0.00
Jul	1.47	0.47	0.09	0.09	0.00	0.00	0.00
Aug	2.08	0.76	0.00	0.00	0.00	0.00	0.00
Sep	2.11	0.69	0.07	0.00	0.00	0.00	0.00
Oct	1.25	0.26	0.00	0.00	0.00	0.00	0.00
Nov	0.92	0.05	0.00	0.00	0.00	0.00	0.00
Dec	0.46	0.00	0.00	0.00	0.00	0.00	0.00
annual	1.65	0.47	0.05	0.02	0.00	0.00	0.00

Table 3.20 Annual and monthly non-exceedance persistence (%) for wind speed below 4.0 m/s at P2.

U10min (m/s)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	20.71	12.82	6.26	3.33	1.54	0.34	0.00
Feb	21.94	15.61	9.67	5.85	3.18	0.83	0.39
Mar	20.70	15.03	8.99	5.59	2.79	1.97	0.00
Apr	20.95	15.76	11.11	7.82	4.71	2.35	0.58
May	18.94	14.43	10.65	8.79	5.08	1.72	0.90
Jun	15.60	11.69	8.51	6.58	3.90	2.64	0.89
Jul	15.36	11.70	7.98	5.34	2.92	1.44	0.45
Aug	16.11	11.04	7.25	4.40	2.80	0.53	0.00
Sep	14.82	10.83	6.76	4.40	2.15	0.39	0.00
Oct	14.32	9.80	5.00	3.06	1.35	0.37	0.00
Nov	15.12	8.57	3.69	2.10	0.82	0.54	0.32
Dec	18.78	10.51	5.11	2.70	0.72	0.00	0.00
annual	17.92	12.48	7.68	5.09	2.73	1.16	0.36

Table 3.21 Annual and monthly non-exceedance persistence (%) for wind speed below 6.0 m/s at P2.

U10min (m/s)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	52.78	48.30	39.95	34.99	29.30	22.05	11.84
Feb	54.79	50.79	44.51	39.31	32.83	23.94	14.83
Mar	51.05	46.45	40.55	36.20	30.50	24.25	13.98
Apr	53.77	49.68	44.76	41.28	34.19	26.22	18.61
May	46.36	42.53	39.54	36.18	30.54	26.53	16.99
Jun	41.89	38.15	34.42	31.02	25.14	19.31	10.97
Jul	41.90	37.30	33.06	29.31	22.28	17.88	10.02
Aug	42.85	38.89	33.51	29.97	22.49	16.31	8.00
Sep	39.99	34.70	29.93	25.54	21.75	16.54	10.02
Oct	40.22	34.80	27.86	23.44	17.63	12.68	6.46
Nov	43.90	38.07	30.11	25.17	19.72	12.74	7.45
Dec	52.07	46.96	38.50	33.17	27.53	20.00	10.97
annual	46.92	42.49	36.77	32.58	26.85	20.53	12.63

Table 3.22 Annual and monthly non-exceedance persistence (%) for wind speed below 8.0 m/s at P2.

U10min (m/s)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	77.26	75.02	71.75	68.89	65.24	59.32	49.15
Feb	80.10	78.32	76.05	73.66	70.27	64.87	57.23
Mar	77.00	75.01	72.71	70.95	67.29	64.20	55.26
Apr	76.92	74.27	72.41	70.24	66.59	61.57	51.68
May	69.36	66.82	64.26	62.18	56.68	51.54	42.17
Jun	65.85	63.44	61.05	58.91	53.37	47.02	35.60
Jul	65.41	62.51	60.31	57.63	51.07	45.69	34.09
Aug	67.89	65.27	62.67	59.86	54.70	47.85	34.44
Sep	66.92	63.67	59.40	55.92	50.36	45.09	34.59
Oct	67.73	64.89	59.40	56.86	51.73	44.44	33.42
Nov	71.31	67.61	61.52	58.24	52.02	44.24	34.22
Dec	77.99	75.40	71.45	68.21	65.28	56.96	46.49
annual	72.07	69.55	66.57	64.07	59.68	54.02	44.53

Table 3.23 Annual and monthly non-exceedance persistence (%) for wind speed below 10.0 m/s at P2.

U10min (m/s)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	91.36	90.83	89.92	89.15	87.68	85.32	80.07
Feb	92.42	91.73	90.84	90.12	88.84	87.03	82.93
Mar	91.01	90.33	89.52	88.63	87.23	84.59	81.11
Apr	91.01	90.23	89.47	88.68	86.84	84.14	78.68
May	86.94	85.84	84.32	82.84	80.41	76.70	71.20
Jun	83.50	81.44	79.98	79.15	76.54	72.44	63.98
Jul	81.53	80.25	78.38	76.36	73.31	69.01	60.36
Aug	83.97	82.75	81.01	79.63	76.51	72.55	62.88
Sep	85.15	83.79	82.02	80.11	75.77	70.93	63.24
Oct	86.21	84.79	82.61	80.61	77.07	73.70	66.64
Nov	88.67	87.20	85.21	84.51	81.74	77.13	70.35
Dec	91.52	90.58	89.25	88.37	86.97	82.86	78.29
annual	87.80	86.80	85.57	84.58	82.55	79.55	74.29

Table 3.24 Annual and monthly non-exceedance persistence (%) for wind speed below 12.0 m/s at P2.

U10min (m/s)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	96.78	96.58	96.30	96.30	96.10	95.79	92.84
Feb	97.18	97.02	96.90	96.57	95.99	95.65	94.29
Mar	96.37	96.06	95.90	95.67	94.85	94.41	92.86
Apr	96.75	96.16	95.99	95.57	95.26	94.06	92.39
May	95.74	95.28	94.90	94.32	93.44	92.57	89.11
Jun	93.16	92.43	92.16	91.22	90.00	87.94	84.03
Jul	90.57	89.92	89.61	88.89	86.79	83.93	77.92
Aug	92.97	92.46	92.01	91.15	89.39	88.08	83.20
Sep	93.83	93.34	92.60	91.52	90.51	87.82	84.20
Oct	95.15	94.79	94.05	93.32	92.15	89.50	85.79
Nov	95.99	95.62	94.85	94.49	93.97	92.81	90.02
Dec	97.30	97.14	96.69	96.17	95.64	94.94	93.76
annual	95.17	94.82	94.54	94.10	93.54	92.61	90.48

Table 3.25 Annual and monthly non-exceedance persistence (%) for wind speed below 14.0 m/s at P2.

U10min (m/s)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	99.10	99.07	99.07	99.00	98.90	98.90	98.70
Feb	99.00	98.88	98.82	98.73	98.63	98.63	98.19
Mar	98.95	98.81	98.64	98.64	98.53	98.53	98.34
Apr	99.21	99.10	98.99	98.99	98.77	98.60	98.38
May	98.86	98.79	98.79	98.64	98.52	98.37	97.96
Jun	97.48	97.06	97.01	97.01	96.58	95.64	94.58
Jul	95.80	95.63	95.45	95.16	94.73	93.90	91.57
Aug	97.48	97.29	97.29	97.07	96.34	95.60	94.28
Sep	97.75	97.71	97.26	97.19	96.67	95.45	94.64
Oct	98.99	98.89	98.89	98.74	98.62	98.20	96.72
Nov	98.81	98.81	98.76	98.68	98.36	98.23	97.54
Dec	99.24	99.20	99.20	99.12	99.12	98.98	98.63
annual	98.40	98.31	98.25	98.21	98.10	97.98	97.72

Table 3.26 Annual and monthly non-exceedance persistence (%) for wind speed below 16.0 m/s at P2.

U10min (m/s)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	99.63	99.63	99.58	99.58	99.58	99.58	99.58
Feb	99.76	99.76	99.63	99.63	99.40	99.40	98.92
Mar	99.64	99.64	99.64	99.56	99.56	99.56	99.56
Apr	99.73	99.65	99.65	99.65	99.55	99.39	99.39
May	99.80	99.73	99.73	99.65	99.65	99.65	99.65
Jun	99.22	99.22	99.17	99.09	98.90	98.74	98.33
Jul	98.65	98.56	98.56	98.48	98.05	97.89	97.26
Aug	99.31	99.21	99.16	99.16	99.06	99.06	98.51
Sep	99.23	99.23	99.23	98.93	98.93	98.63	97.51
Oct	99.80	99.80	99.80	99.80	99.80	99.80	99.13
Nov	99.70	99.70	99.70	99.70	99.70	99.56	99.33
Dec	99.81	99.81	99.76	99.76	99.76	99.63	99.63
annual	99.53	99.51	99.50	99.47	99.45	99.44	99.39

Table 3.27 Annual and monthly non-exceedance persistence (%) for wind speed below 18.0 m/s at P2.

U10min (m/s)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	99.85	99.85	99.85	99.85	99.85	99.85	99.85
Feb	99.98	99.98	99.98	99.98	99.98	99.98	99.98
Mar	99.91	99.91	99.91	99.91	99.91	99.91	99.91
Apr	99.95	99.95	99.95	99.95	99.95	99.95	99.95
May	99.97	99.97	99.97	99.97	99.97	99.97	99.97
Jun	99.79	99.75	99.70	99.70	99.60	99.45	99.24
Jul	99.49	99.46	99.46	99.46	99.46	99.46	99.25
Aug	99.83	99.83	99.83	99.83	99.83	99.83	99.83
Sep	99.82	99.82	99.82	99.82	99.82	99.67	99.24
Oct	99.93	99.93	99.93	99.93	99.93	99.93	99.75
Nov	99.93	99.85	99.85	99.85	99.85	99.70	99.70
Dec	99.94	99.94	99.94	99.94	99.94	99.94	99.94
annual	99.87	99.85	99.85	99.85	99.85	99.85	99.85

Table 3.28 Annual and monthly non-exceedance persistence (%) for wind speed below 20.0 m/s at P2.

U10min (m/s)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Feb	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mar	99.95	99.95	99.95	99.95	99.95	99.95	99.95
Apr	99.98	99.98	99.98	99.98	99.98	99.98	99.98
May	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Jun	99.94	99.94	99.94	99.94	99.84	99.84	99.84
Jul	99.71	99.64	99.64	99.64	99.64	99.64	99.64
Aug	99.98	99.98	99.98	99.98	99.98	99.98	99.98
Sep	99.98	99.98	99.98	99.98	99.98	99.98	99.98
Oct	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Nov	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dec	100.00	100.00	100.00	100.00	100.00	100.00	100.00
annual	99.96	99.96	99.96	99.96	99.96	99.96	99.96

Table 3.29 Annual and monthly non-exceedance persistence (%) for wind speed below 22.0 m/s at P2.

U10min (m/s)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Feb	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mar	99.95	99.95	99.95	99.95	99.95	99.95	99.95
Apr	100.00	100.00	100.00	100.00	100.00	100.00	100.00
May	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Jun	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Jul	99.96	99.96	99.96	99.96	99.96	99.96	99.96
Aug	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Sep	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Oct	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nov	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dec	100.00	100.00	100.00	100.00	100.00	100.00	100.00
annual	99.99	99.99	99.99	99.99	99.99	99.99	99.99

Table 3.30 Annual and monthly non-exceedance persistence (%) for wind speed below 24.0 m/s at P2.

U10min (m/s)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Feb	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mar	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Apr	100.00	100.00	100.00	100.00	100.00	100.00	100.00
May	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Jun	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Jul	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Aug	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Sep	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Oct	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nov	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dec	100.00	100.00	100.00	100.00	100.00	100.00	100.00
annual	100.00	100.00	100.00	100.00	100.00	100.00	100.00

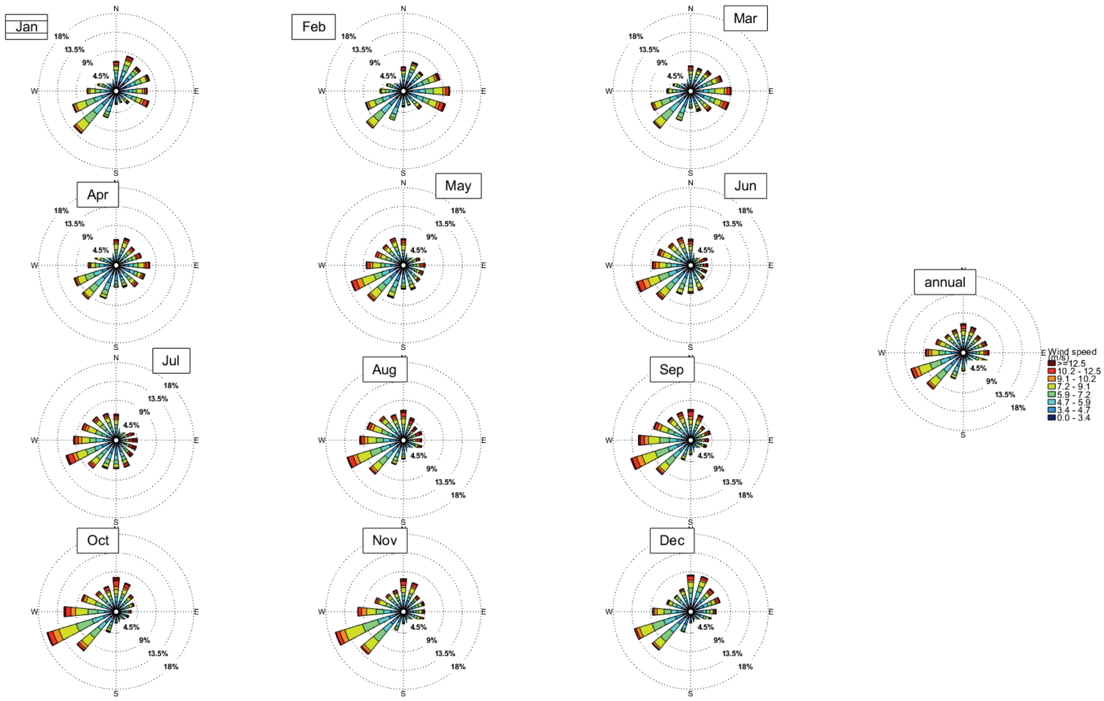

Figure 3.2 Monthly and annual wind rose plot (10-minute mean at 10 m AMSL) at P2. Sectors indicate the direction from which the winds blow.

4. Wave climate

4.1. P1

A summary of the total significant wave height statistics (H_s) at P1 is provided in Table 4.1. Summary of significant wave height statistics for swell and windseas components are provided in Table 4.2 and Table 4.3 respectively. Details on the partitioning method for sea and swell components are presented in Section 8.2.

The annual joint probability distribution of the total significant wave height and mean wave direction at peak energy is presented in Table 4.4.
The annual joint probability distribution of the total significant wave height and peak period is presented in Table 4.5.

The annual and monthly non-exceedance persistence probabilities for total significant wave height at P1 (Table 4.6 to Table 4.18) can be used to estimate the operational uptime for tasks with wind speed limitations of variable duration. For example, at P1 on average in February, total significant wave heights are less than 0.5 m for durations of 36 hours and greater for 5.51% of the time (Table 4.7).

Wave roses for the monthly and annual total significant wave height are presented in Figure 4.1, showing the predominance of waves incoming from the ENE sector.

Table 4.1 Annual and monthly total significant wave height statistics at P1.

Period (01 Jan 1979 – 31 Dec 2018)	Total significant wave height statistics [1]													
	Total significant wave height (m)				Exceedance percentile for total significant wave height (m)									Main [4] Direction(s)
	min	max	mean	std	p1	p5	p10	p50	p80	p90	p95	p98	p99	
January	0.25	5.10	0.97	0.52	0.33	0.41	0.48	0.85	1.28	1.62	1.96	2.51	2.84	NE
February	0.25	4.38	1.01	0.51	0.34	0.44	0.52	0.89	1.33	1.64	1.98	2.48	2.91	NE E
March	0.19	5.23	1.01	0.56	0.31	0.42	0.49	0.86	1.36	1.69	2.04	2.66	3.06	NE E
April	0.14	5.20	0.94	0.56	0.25	0.34	0.39	0.81	1.29	1.65	2.07	2.55	2.85	NE E
May	0.10	5.14	0.89	0.59	0.19	0.27	0.33	0.73	1.24	1.66	2.07	2.59	2.98	NE E
June	0.10	5.97	0.96	0.70	0.19	0.26	0.32	0.75	1.40	1.92	2.35	2.97	3.42	NE E
July	0.08	6.37	1.02	0.79	0.19	0.28	0.34	0.77	1.46	2.05	2.75	3.44	3.83	NE E
August	0.13	5.49	0.94	0.67	0.21	0.29	0.34	0.75	1.30	1.80	2.34	3.00	3.41	NE E
September	0.09	5.20	0.90	0.61	0.22	0.30	0.35	0.73	1.26	1.68	2.09	2.68	3.24	NE E
October	0.15	4.70	0.81	0.51	0.23	0.29	0.34	0.66	1.12	1.51	1.88	2.29	2.58	N NE E
November	0.14	5.56	0.83	0.53	0.25	0.33	0.37	0.68	1.13	1.48	1.82	2.35	2.77	NE E
December	0.23	4.97	0.92	0.50	0.30	0.39	0.44	0.79	1.22	1.53	1.86	2.43	2.71	NE
Winter[3]	0.08	6.37	0.97	0.72	0.19	0.27	0.33	0.76	1.38	1.91	2.47	3.18	3.62	NE E
Spring	0.09	5.56	0.85	0.55	0.23	0.30	0.35	0.69	1.17	1.55	1.93	2.43	2.84	N NE E
Summer[2]	0.23	5.10	0.97	0.51	0.32	0.41	0.47	0.84	1.28	1.60	1.93	2.48	2.84	NE
Autumn	0.10	5.23	0.95	0.57	0.23	0.33	0.39	0.81	1.29	1.67	2.07	2.59	2.97	NE E
All	0.08	6.37	0.93	0.60	0.23	0.32	0.38	0.78	1.28	1.68	2.09	2.70	3.14	NE E

Notes: (1) All statistics derived from hindcast wave data for the period 01 January 1979 to 31 December 2018.
(2) Summer: April to September.
(3) Winter: October to March.
(4) Main directions are those with greater than 15% occurrence and represent directions from which the waves approach.

Table 4.2 Annual and monthly significant swell wave height statistics at P1.

Period (01 Jan 1979 – 31 Dec 2018)	Significant swell wave height statistics (1)													
	Significant swell wave height (m)				Exceedance percentile for significant swell wave height (m)									Main (4) Direction(s)
	min	max	mean	std	p1	p5	p10	p50	p80	p90	p95	p98	p99	
January	0.14	3.94	0.59	0.35	0.20	0.25	0.28	0.49	0.77	1.03	1.35	1.68	1.85	NE
February	0.14	3.13	0.63	0.35	0.19	0.25	0.29	0.54	0.83	1.09	1.29	1.60	1.87	NE E
March	0.10	4.01	0.61	0.39	0.17	0.24	0.28	0.50	0.84	1.07	1.34	1.70	2.03	NE E
April	0.07	3.98	0.55	0.39	0.14	0.19	0.22	0.43	0.79	1.05	1.32	1.67	1.96	NE E
May	0.04	4.12	0.49	0.40	0.07	0.11	0.14	0.36	0.70	0.99	1.29	1.67	1.99	NE E
June	0.02	4.97	0.53	0.49	0.06	0.10	0.13	0.36	0.78	1.17	1.54	1.94	2.32	NE E
July	0.03	5.34	0.58	0.58	0.06	0.09	0.12	0.37	0.87	1.33	1.76	2.33	2.69	NE E
August	0.06	4.44	0.52	0.45	0.09	0.13	0.15	0.37	0.75	1.05	1.37	1.91	2.37	NE E
September	0.03	4.15	0.47	0.42	0.07	0.11	0.13	0.34	0.67	0.94	1.29	1.66	2.15	NE E
October	0.06	3.42	0.39	0.31	0.08	0.11	0.13	0.28	0.55	0.79	1.03	1.39	1.57	NE E
November	0.07	4.51	0.43	0.34	0.10	0.14	0.17	0.32	0.59	0.81	1.03	1.39	1.65	NE E
December	0.08	3.79	0.54	0.33	0.16	0.21	0.25	0.44	0.71	0.95	1.17	1.50	1.71	NE
Winter(3)	0.02	5.34	0.54	0.51	0.07	0.11	0.14	0.37	0.79	1.18	1.58	2.07	2.50	NE E
Spring	0.03	4.51	0.43	0.36	0.08	0.12	0.14	0.31	0.60	0.85	1.12	1.47	1.74	NE E
Summer(2)	0.08	3.94	0.58	0.35	0.18	0.24	0.27	0.49	0.78	1.03	1.27	1.60	1.80	NE
Autumn	0.04	4.12	0.55	0.40	0.09	0.15	0.20	0.44	0.78	1.04	1.32	1.68	1.99	NE E
All	0.02	5.34	0.53	0.41	0.08	0.13	0.17	0.41	0.74	1.02	1.33	1.72	2.06	NE E

Notes: (1) All statistics derived from hindcast wave data for the period 01 January 1979 to 31 December 2018.
(2) Summer: April to September.
(3) Winter: October to March.
(4) Main directions are those with greater than 15% occurrence and represent directions from which the waves approach.

Table 4.3 Annual and monthly significant sea wave height statistics at P1.

Period (01 Jan 1979 – 31 Dec 2018)	Significant sea wave height statistics (1)													
	Significant sea wave height (m)				Exceedance percentile for significant sea wave height (m)									Main (4) Direction(s)
	min	max	mean	std	p1	p5	p10	p50	p80	p90	p95	p98	p99	
January	0.13	3.29	0.73	0.44	0.20	0.28	0.32	0.62	0.99	1.28	1.63	2.10	2.34	N NE E
February	0.13	3.18	0.76	0.43	0.23	0.31	0.36	0.65	1.03	1.30	1.66	2.10	2.43	NE E
March	0.08	3.39	0.77	0.47	0.19	0.28	0.33	0.63	1.05	1.38	1.72	2.15	2.42	NE E
April	0.08	3.35	0.73	0.46	0.14	0.22	0.28	0.62	1.00	1.33	1.71	2.12	2.36	NE E
May	0.05	3.33	0.71	0.49	0.12	0.20	0.25	0.57	0.99	1.35	1.75	2.20	2.47	N NE E
June	0.06	3.61	0.76	0.56	0.12	0.19	0.24	0.59	1.09	1.54	2.01	2.49	2.71	N NE
July	0.03	3.48	0.80	0.61	0.12	0.21	0.26	0.60	1.10	1.67	2.27	2.68	2.87	N NE E
August	0.06	3.29	0.75	0.55	0.14	0.21	0.26	0.58	1.05	1.51	2.01	2.46	2.66	N NE
September	0.06	3.27	0.74	0.51	0.15	0.24	0.28	0.59	1.02	1.40	1.83	2.29	2.61	N NE
October	0.05	3.23	0.68	0.45	0.16	0.23	0.27	0.55	0.94	1.28	1.65	2.07	2.30	N NE
November	0.09	3.26	0.68	0.45	0.17	0.25	0.29	0.55	0.94	1.26	1.59	2.09	2.39	N NE
December	0.10	3.29	0.71	0.44	0.18	0.26	0.31	0.59	0.96	1.26	1.62	2.00	2.35	N NE
Winter(3)	0.03	3.61	0.77	0.58	0.13	0.20	0.25	0.59	1.08	1.56	2.10	2.55	2.76	N NE
Spring	0.05	3.27	0.70	0.47	0.16	0.24	0.28	0.56	0.97	1.32	1.69	2.16	2.42	N NE
Summer(2)	0.10	3.29	0.74	0.44	0.20	0.28	0.33	0.62	0.99	1.28	1.64	2.07	2.37	N NE E
Autumn	0.05	3.39	0.73	0.47	0.14	0.23	0.29	0.61	1.01	1.35	1.72	2.16	2.42	N NE E
All	0.03	3.61	0.73	0.49	0.15	0.23	0.29	0.60	1.01	1.37	1.78	2.28	2.55	N NE E

Notes: (1) All statistics derived from hindcast wave data for the period 01 January 1979 to 31 December 2018.
(2) Summer: April to September.
(3) Winter: October to March.
(4) Main directions are those with greater than 15% occurrence and represent directions from which the waves approach.

Table 4.4 Annual joint probability distribution (in %) of the total significant wave height and mean wave direction at peak energy at P1.

Hs (m)	Mean wave direction at peak energy (degT)									
	337.5-22.5	**22.5-67.5**	**67.5-112.5**	**112.5-157.5**	**157.5-202.5**	**202.5-247.5**	**247.5-292.5**	**292.5-337.5**	**Total**	**Exceed%**
>0<=0.5	1.04	14.45	4.89	0.35	0.13	0.72	0.56	0.21	22.35	100.00
>0.5<=1	4.78	27.98	9.86	0.75	0.03	0.09	0.29	0.47	44.25	77.66
>1<=1.5	2.25	13.36	3.95	0.25	-	-	*	0.05	19.86	33.42
>1.5<=2	0.85	5.40	1.38	0.09	-	-	-	*	7.72	13.56
>2<=2.5	0.26	2.24	0.61	0.01	-	-	-	-	3.12	5.84
>2.5<=3	0.07	1.10	0.29	*	-	-	-	-	1.46	2.72
>3<=3.5	0.01	0.54	0.14	*	-	-	-	-	0.69	1.25
>3.5<=4	*	0.28	0.04	-	-	-	-	-	0.32	0.56
>4<=4.5	-	0.11	0.01	-	-	-	-	-	0.12	0.24
>4.5<=5	-	0.05	0.01	-	-	-	-	-	0.06	0.12
>5<=5.5	-	0.02	0.01	-	-	-	-	-	0.03	0.05
>5.5<=6	-	0.01	*	-	-	-	-	-	0.01	0.01
>6<=6.5	-	*	*	-	-	-	-	-		
Total	9.26	65.54	21.19	1.45	0.16	0.81	0.85	0.73	100.00	

Notes: * represents less than 0.005%.

Table 4.5 Annual joint probability distribution (in %) of the total significant wave height and peak period at P1.

Hs (m)	Peak period (s)											
	2-4	**4-6**	**6-8**	**8-10**	**10-12**	**12-14**	**14-16**	**16-18**	**18-20**	**20-22**	**Total**	**Exceed%**
>0<=0.5	2.14	0.70	1.77	9.24	5.39	1.73	0.81	0.33	0.10	0.03	22.24	100.00
>0.5<=1	2.31	4.66	7.98	17.84	7.85	2.46	0.79	0.26	0.08	0.01	44.24	77.66
>1<=1.5	*	4.57	3.35	7.24	3.43	0.99	0.25	0.03	0.01	-	19.87	33.42
>1.5<=2	-	1.49	1.84	2.22	1.55	0.52	0.08	0.01	*	-	7.71	13.56
>2<=2.5	-	0.04	1.56	0.71	0.55	0.21	0.03	*	-	-	3.10	5.84
>2.5<=3	-	-	0.77	0.35	0.26	0.08	0.01	*	-	-	1.47	2.72
>3<=3.5	-	-	0.19	0.31	0.13	0.05	*	*	*	-	0.68	1.25
>3.5<=4	-	-	0.02	0.21	0.06	0.02	*	*	-	-	0.31	0.56
>4<=4.5	-	-	*	0.08	0.03	0.01	-	-	-	-	0.12	0.24
>4.5<=5	-	-	-	0.03	0.03	0.01	-	-	-	-	0.07	0.12
>5<=5.5	-	-	-	0.01	0.02	*	-	-	-	-	0.03	0.05
>5.5<=6	-	-	-	*	0.01	*	-	-	-	-	0.01	0.01
>6<=6.5	-	-	-	-	*	-	-	-	-	-		
Total	4.45	11.46	17.48	38.24	19.31	6.08	1.97	0.63	0.19	0.04	100.00	
>Exceed%	99.90	95.45	83.99	66.50	28.25	8.92	2.85	0.88	0.24	0.04		

Notes: * represents less than 0.005%.

Table 4.6 Annual and monthly non-exceedance persistence (%) for significant wave height below 0.0 m at P1.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00
annual	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 4.7 Annual and monthly non-exceedance persistence (%) for significant wave height below 0.5 m at P1.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	11.76	11.03	10.02	9.23	7.21	5.36	2.99
Feb	8.28	7.59	6.91	6.20	5.51	4.14	2.32
Mar	10.44	9.48	8.81	8.16	7.26	5.59	3.08
Apr	20.52	19.55	18.78	17.94	15.70	13.76	8.83
May	27.01	26.14	24.77	23.37	20.27	18.77	14.00
Jun	29.01	27.92	26.86	25.76	23.33	20.50	14.58
Jul	24.54	23.64	22.44	20.56	17.83	14.24	9.93
Aug	26.64	25.64	24.52	22.71	18.89	15.07	9.62
Sep	26.50	25.42	24.11	23.23	20.15	17.70	11.15
Oct	31.28	29.68	27.01	25.11	21.32	17.95	11.26
Nov	28.10	26.34	24.42	22.51	18.31	13.43	7.89
Dec	16.18	14.90	13.76	13.13	10.05	7.31	3.55
annual	21.79	20.77	19.60	18.43	15.83	13.34	8.81

Table 4.8 Annual and monthly non-exceedance persistence (%) for significant wave height below 1.0 m at P1.

Hs (m)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	63.47	62.42	61.08	60.60	58.31	55.48	50.51
Feb	58.75	58.01	56.79	56.19	53.64	51.16	43.89
Mar	60.88	60.14	59.38	58.18	56.27	54.59	50.02
Apr	64.32	63.66	63.00	62.08	60.00	57.34	52.31
May	68.64	68.26	67.39	66.81	65.23	63.04	57.79
Jun	65.54	64.81	63.52	62.71	59.73	57.64	52.42
Jul	63.31	62.73	61.83	61.03	57.69	54.64	48.97
Aug	66.51	66.04	65.20	64.24	62.26	59.50	52.01
Sep	67.50	66.68	65.76	64.75	62.05	59.01	52.09
Oct	74.14	73.56	73.09	71.95	70.06	67.65	61.34
Nov	73.61	72.72	71.85	70.90	68.75	65.73	59.67
Dec	67.16	66.32	64.70	64.21	62.57	60.42	54.76
annual	66.26	65.69	64.85	64.18	62.28	60.17	55.33

Table 4.9 Annual and monthly non-exceedance persistence (%) for significant wave height below 1.5 m at P1.

Hs (m)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	87.12	86.80	86.67	86.34	85.29	84.01	81.21
Feb	86.31	85.96	85.30	84.86	83.93	83.44	80.67
Mar	84.58	84.13	83.80	82.89	81.22	80.41	77.85
Apr	86.52	86.18	86.00	85.75	84.30	83.16	80.59
May	87.19	86.94	86.69	86.22	84.77	84.30	82.17
Jun	82.34	82.03	81.71	81.21	80.54	78.36	74.55
Jul	80.57	80.24	79.71	79.39	78.14	75.83	70.77
Aug	84.58	84.28	83.98	83.39	82.01	81.10	77.64
Sep	86.44	86.25	85.77	84.85	83.60	81.63	76.70
Oct	89.59	89.20	88.90	88.26	87.43	86.10	82.86
Nov	90.45	90.08	89.28	89.02	88.61	87.98	85.42
Dec	88.91	88.64	88.04	87.88	87.44	85.76	83.82
annual	86.26	86.03	85.73	85.40	84.63	83.69	81.52

Table 4.10 Annual and monthly non-exceedance persistence (%) for significant wave height below 2.0 m at P1.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	95.30	95.19	95.14	95.14	94.68	94.40	92.68
Feb	95.08	94.97	94.90	94.74	94.47	94.31	93.46
Mar	94.48	94.45	94.40	94.32	93.69	93.24	91.04
Apr	94.21	94.04	93.93	93.93	93.21	92.92	91.66
May	94.23	94.14	93.97	93.59	93.17	93.03	91.34
Jun	91.11	90.82	90.66	90.34	89.45	88.79	86.56
Jul	89.36	89.20	89.03	88.87	88.17	87.27	83.68
Aug	92.56	92.41	92.24	92.16	91.29	89.93	88.36
Sep	94.23	94.17	93.87	93.71	92.88	92.12	89.31
Oct	96.03	95.97	95.72	95.65	94.99	94.52	92.36
Nov	96.25	96.10	95.98	95.81	95.49	95.16	94.28
Dec	96.04	95.93	95.56	95.49	95.15	95.15	94.73
annual	94.08	94.01	93.92	93.85	93.61	93.31	92.15

Table 4.11 Annual and monthly non-exceedance persistence (%) for significant wave height below 2.5 m at P1.

Hs (m)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	97.85	97.81	97.75	97.75	97.54	97.40	96.71
Feb	98.04	97.95	97.89	97.73	97.46	97.29	97.07
Mar	97.49	97.49	97.42	97.42	97.30	97.01	96.82
Apr	97.53	97.29	97.18	97.11	96.77	96.27	95.82
May	97.64	97.60	97.60	97.43	97.43	96.67	96.49
Jun	95.89	95.84	95.67	95.50	95.38	94.57	92.96
Jul	93.62	93.59	93.47	93.47	93.04	92.76	90.55
Aug	95.88	95.85	95.79	95.79	95.26	94.95	94.09
Sep	97.34	97.26	97.07	97.07	96.84	96.20	94.64
Oct	98.71	98.67	98.62	98.62	98.39	98.06	97.12
Nov	98.48	98.43	98.38	98.22	97.99	97.99	97.57
Dec	98.22	98.17	98.02	97.87	97.87	97.71	97.52
annual	97.23	97.19	97.13	97.11	97.06	96.98	96.69

Table 4.12 Annual and monthly non-exceedance persistence (%) for significant wave height below 3.0 m at P1.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	99.30	99.30	99.30	99.23	99.12	99.12	98.90
Feb	99.12	99.12	99.00	98.81	98.81	98.81	98.13
Mar	98.82	98.82	98.77	98.77	98.77	98.77	98.53
Apr	99.25	99.22	99.17	99.09	98.86	98.68	98.68
May	99.00	99.00	98.95	98.95	98.75	98.75	98.39
Jun	98.02	97.98	97.82	97.73	97.63	97.29	96.66
Jul	96.28	96.17	96.05	96.05	95.81	95.67	94.32
Aug	97.90	97.81	97.81	97.64	97.55	97.41	97.23
Sep	98.65	98.65	98.60	98.52	98.52	98.36	97.68
Oct	99.70	99.70	99.70	99.62	99.62	99.62	98.99
Nov	99.32	99.32	99.32	99.32	99.19	99.19	98.72
Dec	99.35	99.31	99.31	99.31	99.12	98.95	98.95
annual	98.73	98.71	98.68	98.68	98.66	98.65	98.61

Table 4.13 Annual and monthly non-exceedance persistence (%) for significant wave height below 3.5 m at P1.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	99.78	99.78	99.78	99.78	99.78	99.78	99.78
Feb	99.66	99.66	99.53	99.53	99.31	99.31	98.80
Mar	99.48	99.48	99.43	99.43	99.43	99.43	99.43
Apr	99.70	99.70	99.70	99.70	99.59	99.42	99.42
May	99.58	99.54	99.54	99.54	99.54	99.54	99.54
Jun	99.08	99.05	98.93	98.84	98.73	98.73	98.31
Jul	98.09	98.02	98.02	98.02	97.92	97.77	96.42
Aug	99.17	99.06	98.95	98.95	98.95	98.80	98.80
Sep	99.29	99.29	99.29	99.21	99.21	99.05	98.86
Oct	99.93	99.93	99.93	99.93	99.93	99.93	99.73
Nov	99.69	99.69	99.69	99.69	99.69	99.55	99.31
Dec	99.70	99.70	99.70	99.70	99.59	99.59	99.59
annual	99.43	99.41	99.40	99.40	99.40	99.40	99.36

Table 4.14 Annual and monthly non-exceedance persistence (%) for significant wave height below 4.0 m at P1.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	99.90	99.90	99.90	99.90	99.90	99.90	99.90
Feb	99.98	99.98	99.98	99.98	99.98	99.98	99.72
Mar	99.73	99.73	99.73	99.73	99.73	99.73	99.73
Apr	99.87	99.87	99.87	99.87	99.87	99.87	99.68
May	99.82	99.78	99.78	99.78	99.78	99.78	99.78
Jun	99.54	99.54	99.54	99.46	99.36	99.36	98.94
Jul	99.19	99.19	99.19	99.19	99.09	99.09	98.88
Aug	99.72	99.72	99.72	99.72	99.72	99.72	99.52
Sep	99.63	99.59	99.59	99.51	99.51	99.51	99.30
Oct	99.97	99.97	99.97	99.97	99.97	99.97	99.97
Nov	99.81	99.81	99.81	99.81	99.81	99.67	99.67
Dec	99.88	99.88	99.88	99.88	99.88	99.88	99.88
annual	99.76	99.75	99.75	99.75	99.75	99.75	99.75

Table 4.15 Annual and monthly non-exceedance persistence (%) for significant wave height below 4.5 m at P1.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	99.94	99.94	99.94	99.94	99.94	99.94	99.94
Feb	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mar	99.83	99.83	99.83	99.83	99.83	99.83	99.83
Apr	99.96	99.96	99.96	99.96	99.96	99.96	99.96
May	99.94	99.94	99.94	99.94	99.94	99.94	99.94
Jun	99.79	99.79	99.79	99.79	99.69	99.69	99.50
Jul	99.58	99.53	99.53	99.53	99.53	99.53	99.53
Aug	99.93	99.93	99.93	99.93	99.93	99.93	99.93
Sep	99.85	99.85	99.85	99.85	99.85	99.85	99.63
Oct	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Nov	99.86	99.86	99.86	99.86	99.86	99.70	99.70
Dec	99.96	99.96	99.96	99.96	99.96	99.96	99.96
annual	99.88	99.88	99.88	99.88	99.88	99.88	99.88

Table 4.16 Annual and monthly non-exceedance persistence (%) for significant wave height below 5.0 m at P1.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Feb	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mar	99.94	99.94	99.94	99.94	99.94	99.94	99.94
Apr	99.98	99.98	99.98	99.98	99.98	99.98	99.98
May	99.98	99.98	99.98	99.98	99.98	99.98	99.98
Jun	99.93	99.93	99.93	99.93	99.93	99.93	99.93
Jul	99.75	99.75	99.75	99.75	99.75	99.75	99.75
Aug	99.97	99.97	99.97	99.97	99.97	99.97	99.97
Sep	99.97	99.97	99.97	99.97	99.97	99.97	99.97
Oct	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nov	99.91	99.91	99.91	99.91	99.91	99.91	99.73
Dec	100.00	100.00	100.00	100.00	100.00	100.00	100.00
annual	99.95	99.95	99.95	99.95	99.95	99.95	99.95

Table 4.17 Annual and monthly non-exceedance persistence (%) for significant wave height below 5.5 m at P1.

Hs (m)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Feb	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mar	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Apr	100.00	100.00	100.00	100.00	100.00	100.00	100.00
May	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Jun	99.97	99.97	99.97	99.97	99.97	99.97	99.97
Jul	99.90	99.90	99.90	99.90	99.90	99.90	99.90
Aug	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Sep	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Oct	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nov	99.93	99.93	99.93	99.93	99.93	99.93	99.74
Dec	100.00	100.00	100.00	100.00	100.00	100.00	100.00
annual	99.98	99.98	99.98	99.98	99.98	99.98	99.98

Table 4.18 Annual and monthly non-exceedance persistence (%) for significant wave height below 6.0 m at P1.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Feb	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mar	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Apr	100.00	100.00	100.00	100.00	100.00	100.00	100.00
May	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Jun	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Jul	99.98	99.98	99.98	99.98	99.98	99.98	99.98
Aug	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Sep	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Oct	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nov	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dec	100.00	100.00	100.00	100.00	100.00	100.00	100.00
annual	100.00	100.00	100.00	100.00	100.00	100.00	100.00

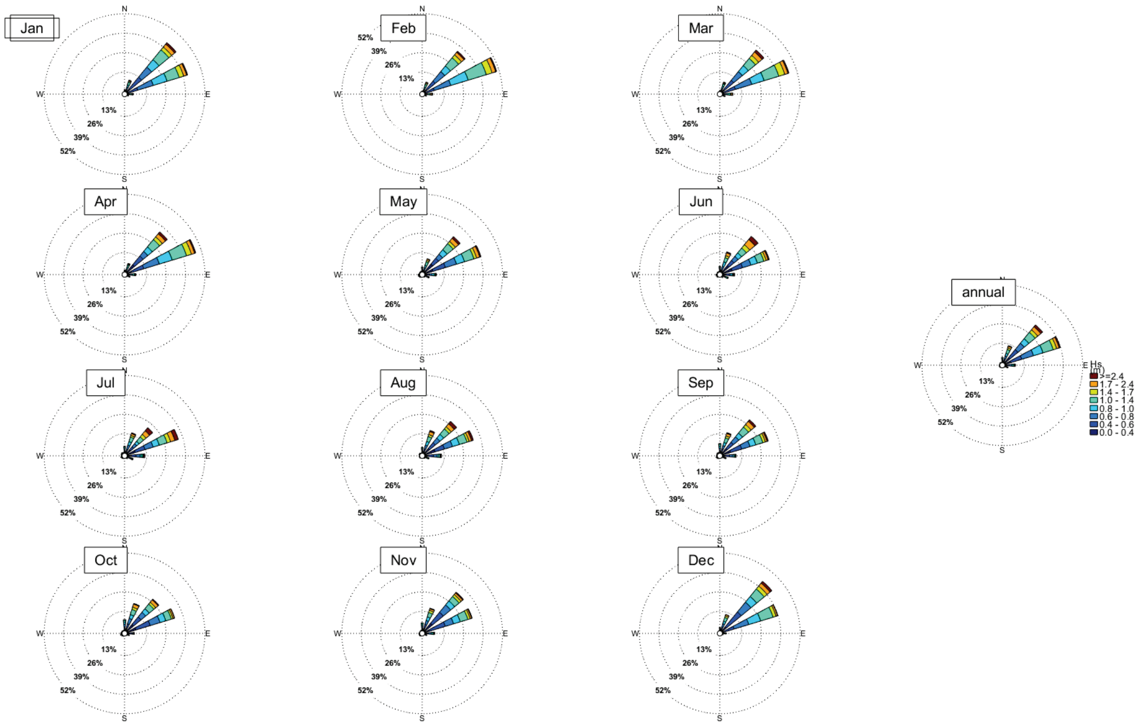

Figure 4.1 Monthly and annual wave rose plot for the total significant wave height at P1. Sectors indicate the direction from which waves approach.

4.2. P2

A summary of the total significant wave height statistics (H_s) at P2 is provided in Table 4.19. Summary of significant wave height statistics for swell and windseas components are provided in Table 4.20 and Table 4.21 respectively. Details on the partitioning method for sea and swell components are presented in Section 8.2.

The annual joint probability distribution of the total significant wave height and mean wave direction at peak energy is presented in Table 4.22.
The annual joint probability distribution of the total significant wave height and peak period is presented in Table 4.23.

The annual and monthly non-exceedance persistence probabilities for total significant wave height at P2 (Table 4.24 to Table 4.36) can be used to estimate the operational uptime for tasks with wind speed limitations of variable duration. For example, at P2 on average in February, total significant wave heights are less than 0.5 m for durations of 36 hours and greater for 5.56% of the time (Table 4.25).

Wave roses for the monthly and annual total significant wave height are presented in Figure 4.2, showing the predominance of waves incoming from the NE sector.

Table 4.19 Annual and monthly total significant wave height statistics at P2.

Period (01 Jan 1979 – 31 Dec 2018)	Total significant wave height statistics (1)													
	Total significant wave height (m)				Exceedance percentile for total significant wave height (m)									Main (4) Direction(s)
	min	max	mean	std	p1	p5	p10	p50	p80	p90	p95	p98	p99	
January	0.25	5.24	0.98	0.52	0.33	0.42	0.48	0.85	1.29	1.62	1.97	2.51	2.86	NE
February	0.24	4.47	1.02	0.51	0.35	0.44	0.52	0.90	1.33	1.65	1.97	2.49	2.95	NE E
March	0.19	5.18	1.01	0.57	0.32	0.42	0.49	0.87	1.36	1.70	2.06	2.65	3.05	NE E
April	0.14	5.30	0.95	0.56	0.26	0.34	0.39	0.82	1.30	1.65	2.10	2.58	2.89	NE E
May	0.10	5.18	0.90	0.60	0.19	0.28	0.34	0.75	1.25	1.68	2.09	2.59	3.05	NE E
June	0.09	6.02	0.97	0.72	0.18	0.26	0.32	0.77	1.42	1.96	2.39	3.04	3.48	NE E
July	0.08	6.31	1.04	0.80	0.19	0.28	0.34	0.79	1.48	2.07	2.75	3.46	3.87	NE E
August	0.14	5.55	0.95	0.67	0.21	0.29	0.35	0.76	1.33	1.83	2.36	3.02	3.45	NE E
September	0.09	5.22	0.92	0.62	0.22	0.30	0.36	0.75	1.28	1.70	2.12	2.71	3.29	N NE E
October	0.14	4.71	0.82	0.52	0.23	0.30	0.34	0.67	1.14	1.53	1.92	2.34	2.62	N NE E
November	0.16	5.49	0.84	0.53	0.25	0.33	0.39	0.69	1.14	1.50	1.84	2.35	2.82	NE E
December	0.21	5.08	0.93	0.51	0.31	0.39	0.45	0.80	1.23	1.55	1.87	2.46	2.74	NE
Winter(3)	0.08	6.31	0.99	0.73	0.19	0.28	0.33	0.77	1.41	1.94	2.50	3.21	3.65	NE E
Spring	0.09	5.49	0.86	0.56	0.23	0.31	0.36	0.70	1.19	1.57	1.97	2.47	2.89	N NE E
Summer(2)	0.21	5.24	0.97	0.51	0.32	0.42	0.48	0.85	1.29	1.61	1.95	2.49	2.86	NE
Autumn	0.10	5.30	0.96	0.58	0.24	0.33	0.40	0.82	1.31	1.68	2.08	2.60	3.01	NE E
All	0.08	6.31	0.94	0.60	0.23	0.32	0.38	0.79	1.29	1.69	2.12	2.72	3.18	NE E

Notes: (1) All statistics derived from hindcast wave data for the period 01 January 1979 to 31 December 2018.
(2) Summer: April to September.
(3) Winter: October to March.
(4) Main directions are those with greater than 15% occurrence and represent directions from which the waves approach.

Table 4.20 Annual and monthly significant swell wave height statistics at P2.

Period (01 Jan 1979 – 31 Dec 2018)	Significant swell wave height statistics (1)													
	Significant swell wave height (m)				Exceedance percentile for significant swell wave height (m)									Main (4) Direction(s)
	min	max	mean	std	p1	p5	p10	p50	p80	p90	p95	p98	p99	
January	0.14	4.23	0.60	0.36	0.21	0.25	0.29	0.50	0.77	1.04	1.36	1.71	1.91	NE
February	0.14	3.25	0.63	0.35	0.20	0.26	0.30	0.54	0.84	1.09	1.31	1.62	1.91	NE E
March	0.10	4.11	0.62	0.40	0.17	0.25	0.29	0.51	0.84	1.08	1.36	1.77	2.11	NE E
April	0.08	4.14	0.56	0.40	0.15	0.20	0.23	0.44	0.78	1.05	1.33	1.70	2.06	NE E
May	0.04	4.19	0.50	0.41	0.07	0.11	0.14	0.37	0.71	0.99	1.30	1.70	2.05	NE E
June	0.02	5.06	0.54	0.51	0.07	0.11	0.14	0.36	0.79	1.20	1.60	2.05	2.42	NE E
July	0.03	5.27	0.58	0.58	0.06	0.10	0.12	0.38	0.88	1.36	1.77	2.38	2.77	NE E
August	0.06	4.54	0.53	0.46	0.09	0.13	0.15	0.38	0.76	1.07	1.40	1.99	2.42	NE E
September	0.03	4.31	0.48	0.43	0.06	0.11	0.14	0.35	0.67	0.95	1.29	1.75	2.22	NE E
October	0.05	3.46	0.39	0.32	0.08	0.11	0.14	0.29	0.55	0.79	1.06	1.42	1.60	NE E
November	0.07	4.45	0.43	0.34	0.10	0.15	0.17	0.33	0.59	0.82	1.05	1.42	1.64	NE E
December	0.09	3.95	0.54	0.34	0.17	0.22	0.26	0.45	0.71	0.95	1.21	1.53	1.81	NE
Winter(3)	0.02	5.27	0.55	0.52	0.07	0.11	0.14	0.38	0.80	1.20	1.62	2.13	2.56	NE E
Spring	0.03	4.45	0.43	0.37	0.08	0.12	0.15	0.32	0.60	0.85	1.13	1.52	1.80	NE E
Summer(2)	0.09	4.23	0.59	0.35	0.19	0.24	0.28	0.49	0.77	1.03	1.29	1.64	1.87	NE
Autumn	0.04	4.19	0.56	0.41	0.10	0.16	0.20	0.44	0.78	1.05	1.33	1.73	2.07	NE E
All	0.02	5.27	0.53	0.42	0.09	0.14	0.17	0.41	0.74	1.03	1.35	1.78	2.12	NE E

Notes: (1) All statistics derived from hindcast wave data for the period 01 January 1979 to 31 December 2018.
(2) Summer: April to September.
(3) Winter: October to March.
(4) Main directions are those with greater than 15% occurrence and represent directions from which the waves approach.

Table 4.21 Annual and monthly significant sea wave height statistics at P2.

Period (01 Jan 1979 – 31 Dec 2018)	Significant sea wave height statistics (1)													
	Significant sea wave height (m)				Exceedance percentile for significant sea wave height (m)									Main (4) Direction(s)
	min	max	mean	std	p1	p5	p10	p50	p80	p90	p95	p98	p99	
January	0.13	3.28	0.74	0.44	0.20	0.28	0.32	0.63	0.99	1.29	1.64	2.08	2.30	N NE E
February	0.12	3.15	0.77	0.43	0.23	0.32	0.36	0.65	1.03	1.30	1.65	2.08	2.43	NE E
March	0.08	3.35	0.77	0.46	0.20	0.28	0.33	0.64	1.05	1.37	1.71	2.13	2.44	NE E
April	0.08	3.34	0.73	0.46	0.15	0.22	0.28	0.63	1.01	1.34	1.70	2.10	2.34	N NE E
May	0.05	3.33	0.72	0.49	0.13	0.20	0.25	0.58	1.01	1.37	1.76	2.21	2.46	N NE E
June	0.06	3.59	0.77	0.57	0.12	0.18	0.24	0.60	1.11	1.56	2.02	2.49	2.72	N NE E
July	0.03	3.47	0.81	0.61	0.12	0.21	0.26	0.62	1.12	1.67	2.25	2.65	2.84	N NE E
August	0.06	3.27	0.76	0.55	0.14	0.21	0.26	0.59	1.07	1.52	2.02	2.46	2.66	N NE E
September	0.06	3.27	0.75	0.51	0.14	0.24	0.28	0.61	1.05	1.42	1.85	2.30	2.62	N NE
October	0.07	3.19	0.69	0.46	0.17	0.24	0.28	0.56	0.96	1.30	1.67	2.10	2.31	N NE
November	0.09	3.22	0.69	0.45	0.17	0.25	0.29	0.57	0.95	1.28	1.63	2.07	2.42	N NE
December	0.10	3.27	0.72	0.44	0.18	0.26	0.31	0.60	0.97	1.28	1.64	2.03	2.37	N NE
Winter(3)	0.03	3.59	0.78	0.58	0.13	0.20	0.26	0.61	1.10	1.58	2.10	2.55	2.75	N NE E
Spring	0.06	3.27	0.71	0.47	0.17	0.24	0.28	0.58	0.99	1.34	1.71	2.17	2.45	N NE
Summer(2)	0.10	3.28	0.74	0.44	0.20	0.28	0.33	0.63	1.00	1.29	1.64	2.06	2.36	N NE E
Autumn	0.05	3.35	0.74	0.47	0.15	0.23	0.29	0.62	1.02	1.36	1.72	2.14	2.41	N NE E
All	0.03	3.59	0.74	0.49	0.15	0.24	0.29	0.61	1.03	1.38	1.79	2.27	2.55	N NE E

Notes: (1) All statistics derived from hindcast wave data for the period 01 January 1979 to 31 December 2018.
(2) Summer: April to September.
(3) Winter: October to March.
(4) Main directions are those with greater than 15% occurrence and represent directions from which the waves approach.

Table 4.22 Annual joint probability distribution (in %) of the total significant wave height and mean wave direction at peak energy at P2.

Hs (m)	Mean wave direction at peak energy (degT)									
	337.5-22.5	**22.5-67.5**	**67.5-112.5**	**112.5-157.5**	**157.5-202.5**	**202.5-247.5**	**247.5-292.5**	**292.5-337.5**	**Total**	**Exceed%**
>0<=0.5	0.98	14.18	4.43	0.26	0.28	0.51	0.63	0.14	21.41	100.00
>0.5<=1	5.04	28.90	9.22	0.44	0.05	0.24	0.28	0.31	44.48	78.59
>1<=1.5	2.47	14.24	3.37	0.12	-	0.04	*	*	20.24	34.12
>1.5<=2	0.93	5.75	1.11	0.03	-	*	-	-	7.82	13.88
>2<=2.5	0.32	2.42	0.50	*	-	-	-	-	3.24	6.06
>2.5<=3	0.09	1.18	0.25	-	-	-	-	-	1.52	2.81
>3<=3.5	0.02	0.56	0.12	-	-	-	-	-	0.70	1.29
>3.5<=4	*	0.28	0.03	-	-	-	-	-	0.31	0.59
>4<=4.5	*	0.13	0.01	-	-	-	-	-	0.14	0.27
>4.5<=5	-	0.06	0.01	-	-	-	-	-	0.07	0.13
>5<=5.5	-	0.03	0.01	-	-	-	-	-	0.04	0.05
>5.5<=6	-	0.01	*	-	-	-	-	-	0.01	0.01
>6<=6.5	-	*	*	-	-	-	-	-		
Total	9.85	67.74	19.06	0.85	0.33	0.79	0.91	0.45	100.00	

Notes: * represents less than 0.005%.

Table 4.23 Annual joint probability distribution (in %) of the total significant wave height and peak period at P2.

Hs (m)	Peak period (s)										
	2-4	**4-6**	**6-8**	**8-10**	**10-12**	**12-14**	**14-16**	**16-18**	**18-20**	**20-22**	**Total**	**Exceed%**
>0<=0.5	1.79	0.81	1.86	8.70	5.25	1.58	0.77	0.37	0.14	0.04	21.31	100.00
>0.5<=1	2.26	4.64	8.32	17.49	8.17	2.32	0.76	0.35	0.13	0.03	44.47	78.59
>1<=1.5	*	4.66	3.82	7.18	3.31	0.97	0.26	0.03	0.01	*	20.24	34.12
>1.5<=2	-	1.40	2.04	2.31	1.43	0.54	0.09	0.01	*	-	7.82	13.88
>2<=2.5	-	0.03	1.60	0.75	0.59	0.21	0.04	0.01	-	-	3.23	6.06
>2.5<=3	-	-	0.75	0.38	0.28	0.09	0.01	*	-	-	1.51	2.81
>3<=3.5	-	-	0.20	0.32	0.13	0.05	*	*	*	*	0.70	1.29
>3.5<=4	-	-	0.02	0.21	0.06	0.03	*	*	*	-	0.32	0.59
>4<=4.5	-	-	*	0.10	0.04	0.01	*	*	-	-	0.15	0.27
>4.5<=5	-	-	-	0.03	0.03	0.01	-	-	-	-	0.07	0.13
>5<=5.5	-	-	-	0.01	0.02	0.01	-	-	-	-	0.04	0.05
>5.5<=6	-	-	-	*	0.01	*	-	-	-	-	0.01	0.01
>6<=6.5	-	-	-	-	*	*	-	-	-	-		
Total	4.05	11.54	18.61	37.48	19.32	5.82	1.93	0.77	0.28	0.07	100.00	
>Exceed%	99.90	95.85	84.32	65.71	28.22	8.90	3.08	1.13	0.36	0.07		

Notes: * represents less than 0.005%.

Table 4.24 Annual and monthly non-exceedance persistence (%) for significant wave height below 0.0 m at P2.

Hs (m)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00
May	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jun	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jul	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sep	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Oct	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00
annual	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 4.25 Annual and monthly non-exceedance persistence (%) for significant wave height below 0.5 m at P2.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	10.98	10.18	8.91	8.12	6.84	5.00	1.55
Feb	8.00	7.46	6.91	6.16	5.56	4.40	2.58
Mar	10.10	9.54	8.65	7.94	7.12	5.46	3.15
Apr	19.71	18.80	18.09	17.29	15.14	13.40	8.94
May	26.44	25.46	24.15	23.15	20.43	18.64	14.62
Jun	28.00	27.04	25.89	24.99	22.80	20.27	12.41
Jul	24.01	22.94	21.39	19.82	17.29	13.87	9.83
Aug	25.87	25.04	23.49	21.94	18.59	15.69	9.83
Sep	24.91	23.90	22.41	21.57	18.48	16.58	9.74
Oct	29.85	27.94	26.05	24.10	21.01	17.65	10.12
Nov	26.30	24.32	22.79	20.48	16.24	12.59	7.21
Dec	14.82	13.66	12.40	11.92	8.88	6.67	3.28
annual	20.85	19.84	18.65	17.59	15.22	13.02	8.34

Table 4.26 Annual and monthly non-exceedance persistence (%) for significant wave height below 1.0 m at P2.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	63.33	62.58	61.03	60.40	57.74	54.53	50.85
Feb	58.26	57.39	56.47	55.57	53.29	50.15	44.26
Mar	60.12	59.71	58.89	58.10	55.84	54.62	49.30
Apr	64.23	63.38	62.62	61.81	59.85	56.89	51.50
May	67.63	67.20	66.74	65.86	64.05	61.26	55.75
Jun	64.71	64.01	63.05	61.77	59.34	57.50	52.71
Jul	62.48	61.92	61.08	60.19	56.25	52.75	47.93
Aug	65.30	64.76	64.00	63.10	61.16	58.57	49.94
Sep	66.40	65.59	64.61	63.78	61.11	57.92	50.89
Oct	73.42	72.74	72.15	71.12	69.02	65.84	59.62
Nov	72.79	72.09	70.91	70.26	68.55	65.31	58.61
Dec	66.63	65.84	64.28	63.97	62.20	60.24	54.24
annual	65.55	64.99	64.18	63.53	61.65	59.24	54.31

Table 4.27 Annual and monthly non-exceedance persistence (%) for significant wave height below 1.5 m at P2.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	87.02	86.83	86.71	86.30	85.25	84.02	81.09
Feb	86.02	85.61	84.95	84.76	83.82	83.47	81.17
Mar	84.62	84.32	83.76	83.12	81.54	80.42	77.77
Apr	86.56	86.39	85.95	85.52	84.29	83.17	79.66
May	86.73	86.42	86.24	85.61	85.06	83.24	81.08
Jun	81.81	81.48	81.37	80.78	79.75	77.54	73.93
Jul	80.26	79.92	79.46	79.13	77.77	76.09	70.51
Aug	84.27	83.98	83.69	83.14	81.66	80.43	77.33
Sep	85.96	85.77	85.30	84.46	83.08	81.12	76.57
Oct	89.29	89.05	88.53	88.14	87.22	85.90	82.42
Nov	89.89	89.57	88.78	88.46	87.70	86.88	83.79
Dec	88.29	88.01	87.52	87.45	86.46	84.92	82.60
annual	85.94	85.74	85.42	85.12	84.33	83.36	81.14

Table 4.28 Annual and monthly non-exceedance persistence (%) for significant wave height below 2.0 m at P2.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	95.17	95.13	95.13	95.06	94.73	94.13	92.54
Feb	95.02	94.95	94.89	94.73	94.46	94.09	93.44
Mar	94.39	94.35	94.35	94.28	93.53	93.09	91.15
Apr	94.19	94.08	93.97	93.88	93.14	92.84	91.34
May	93.96	93.86	93.64	93.26	92.86	92.71	90.53
Jun	90.45	90.24	89.92	89.85	88.61	88.10	85.61
Jul	89.10	88.90	88.72	88.48	87.86	87.11	83.05
Aug	92.24	92.05	91.78	91.63	90.61	89.54	88.19
Sep	93.84	93.70	93.39	93.06	92.47	91.57	88.53
Oct	95.67	95.61	95.27	95.19	94.64	93.88	91.21
Nov	96.27	96.09	95.96	95.89	95.57	95.25	94.35
Dec	95.89	95.78	95.42	95.33	94.99	94.99	94.12
annual	93.86	93.79	93.68	93.60	93.37	93.04	91.82

Table 4.29 Annual and monthly non-exceedance persistence (%) for significant wave height below 2.5 m at P2.

Hs (m)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	97.91	97.87	97.74	97.74	97.64	97.50	96.81
Feb	98.02	97.89	97.82	97.74	97.47	97.30	97.07
Mar	97.41	97.41	97.28	97.28	97.17	96.88	96.69
Apr	97.51	97.31	97.20	97.12	96.78	96.47	96.28
May	97.57	97.54	97.49	97.40	97.27	96.50	96.50
Jun	95.63	95.50	95.39	95.23	95.11	94.12	92.73
Jul	93.59	93.56	93.44	93.44	93.02	92.88	90.68
Aug	95.68	95.68	95.62	95.62	94.86	94.22	93.57
Sep	97.18	97.15	96.91	96.91	96.68	96.03	94.24
Oct	98.58	98.51	98.46	98.46	98.23	97.73	97.01
Nov	98.42	98.38	98.31	98.16	97.93	97.93	97.50
Dec	98.08	98.01	97.90	97.67	97.67	97.51	97.09
annual	97.14	97.10	97.02	97.00	96.95	96.85	96.62

Table 4.30 Annual and monthly non-exceedance persistence (%) for significant wave height below 3.0 m at P2.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	99.28	99.25	99.25	99.17	99.07	99.07	98.84
Feb	99.09	99.09	98.98	98.80	98.70	98.70	98.21
Mar	98.84	98.84	98.79	98.79	98.79	98.79	98.36
Apr	99.21	99.18	99.12	99.05	98.82	98.64	98.64
May	98.90	98.90	98.84	98.84	98.64	98.64	98.28
Jun	97.91	97.83	97.72	97.54	97.54	97.20	96.57
Jul	96.23	96.13	96.13	96.13	95.88	95.60	94.03
Aug	97.84	97.75	97.75	97.67	97.43	97.43	97.06
Sep	98.55	98.55	98.50	98.42	98.18	98.02	97.11
Oct	99.70	99.70	99.70	99.62	99.62	99.62	98.99
Nov	99.29	99.29	99.22	99.22	99.09	99.09	98.62
Dec	99.31	99.27	99.27	99.27	99.08	98.91	98.91
annual	98.69	98.67	98.64	98.64	98.60	98.59	98.50

Table 4.31 Annual and monthly non-exceedance persistence (%) for significant wave height below 3.5 m at P2.

Hs (m)	**Duration (hours)**						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	99.73	99.73	99.73	99.73	99.73	99.73	99.73
Feb	99.67	99.67	99.55	99.45	99.34	99.34	98.80
Mar	99.44	99.41	99.41	99.41	99.31	99.31	99.31
Apr	99.69	99.69	99.69	99.69	99.58	99.58	99.40
May	99.50	99.46	99.46	99.46	99.46	99.46	99.46
Jun	99.05	99.05	98.93	98.84	98.73	98.73	98.31
Jul	98.08	97.99	97.99	97.99	97.90	97.58	96.22
Aug	99.07	98.99	98.89	98.89	98.89	98.74	98.74
Sep	99.23	99.23	99.23	99.16	99.16	98.99	98.80
Oct	99.92	99.92	99.92	99.92	99.92	99.92	99.72
Nov	99.67	99.67	99.67	99.67	99.54	99.54	99.31
Dec	99.70	99.70	99.70	99.70	99.60	99.60	99.60
annual	99.40	99.38	99.37	99.37	99.37	99.37	99.33

Table 4.32 Annual and monthly non-exceedance persistence (%) for significant wave height below 4.0 m at P2.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	99.89	99.89	99.89	99.89	99.89	99.89	99.89
Feb	99.95	99.95	99.95	99.95	99.85	99.85	99.59
Mar	99.70	99.70	99.70	99.70	99.61	99.61	99.61
Apr	99.87	99.87	99.87	99.87	99.87	99.87	99.68
May	99.78	99.70	99.70	99.70	99.70	99.70	99.70
Jun	99.47	99.47	99.41	99.41	99.31	99.31	98.88
Jul	99.14	99.14	99.14	99.14	99.03	99.03	98.57
Aug	99.68	99.68	99.62	99.62	99.62	99.62	99.42
Sep	99.53	99.53	99.53	99.45	99.45	99.45	99.25
Oct	99.97	99.97	99.97	99.97	99.97	99.97	99.97
Nov	99.80	99.80	99.80	99.80	99.80	99.66	99.66
Dec	99.86	99.86	99.86	99.86	99.86	99.86	99.86
annual	99.72	99.72	99.72	99.72	99.70	99.70	99.70

Table 4.33 Annual and monthly non-exceedance persistence (%) for significant wave height below 4.5 m at P2.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	99.93	99.93	99.93	99.93	99.93	99.93	99.93
Feb	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mar	99.83	99.83	99.83	99.83	99.83	99.83	99.83
Apr	99.92	99.92	99.92	99.92	99.92	99.92	99.74
May	99.94	99.94	99.94	99.94	99.94	99.94	99.94
Jun	99.78	99.78	99.78	99.78	99.68	99.68	99.48
Jul	99.55	99.51	99.51	99.51	99.51	99.51	99.51
Aug	99.90	99.90	99.90	99.90	99.90	99.90	99.90
Sep	99.84	99.84	99.84	99.84	99.84	99.84	99.63
Oct	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Nov	99.86	99.86	99.86	99.86	99.86	99.70	99.70
Dec	99.92	99.92	99.92	99.92	99.92	99.92	99.92
annual	99.87	99.87	99.87	99.87	99.87	99.87	99.87

Table 4.34 Annual and monthly non-exceedance persistence (%) for significant wave height below 5.0 m at P2.

Hs (m)	Duration (hours)						
	6	12	18	24	36	48	72
Jan	99.98	99.98	99.98	99.98	99.98	99.98	99.98
Feb	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mar	99.92	99.92	99.92	99.92	99.92	99.92	99.92
Apr	99.98	99.98	99.98	99.98	99.98	99.98	99.98
May	99.96	99.96	99.96	99.96	99.96	99.96	99.96
Jun	99.91	99.91	99.91	99.91	99.91	99.91	99.91
Jul	99.77	99.77	99.77	99.77	99.77	99.77	99.77
Aug	99.96	99.96	99.96	99.96	99.96	99.96	99.96
Sep	99.96	99.91	99.91	99.91	99.91	99.91	99.91
Oct	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nov	99.91	99.91	99.91	99.91	99.91	99.91	99.73
Dec	99.98	99.98	99.98	99.98	99.98	99.98	99.98
annual	99.94	99.94	99.94	99.94	99.94	99.94	99.94

Table 4.35 Annual and monthly non-exceedance persistence (%) for significant wave height below 5.5 m at P2.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Feb	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mar	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Apr	100.00	100.00	100.00	100.00	100.00	100.00	100.00
May	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Jun	99.97	99.97	99.97	99.97	99.97	99.97	99.97
Jul	99.88	99.88	99.88	99.88	99.88	99.88	99.88
Aug	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Sep	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Oct	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nov	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dec	100.00	100.00	100.00	100.00	100.00	100.00	100.00
annual	99.99	99.99	99.99	99.99	99.99	99.99	99.99

Table 4.36 Annual and monthly non-exceedance persistence (%) for significant wave height below 6.0 m at P2.

Hs (m)	Duration (hours)						
	6	**12**	**18**	**24**	**36**	**48**	**72**
Jan	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Feb	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mar	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Apr	100.00	100.00	100.00	100.00	100.00	100.00	100.00
May	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Jun	99.99	99.99	99.99	99.99	99.99	99.99	99.99
Jul	99.96	99.96	99.96	99.96	99.96	99.96	99.96
Aug	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Sep	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Oct	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nov	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Dec	100.00	100.00	100.00	100.00	100.00	100.00	100.00
annual	100.00	100.00	100.00	100.00	100.00	100.00	100.00

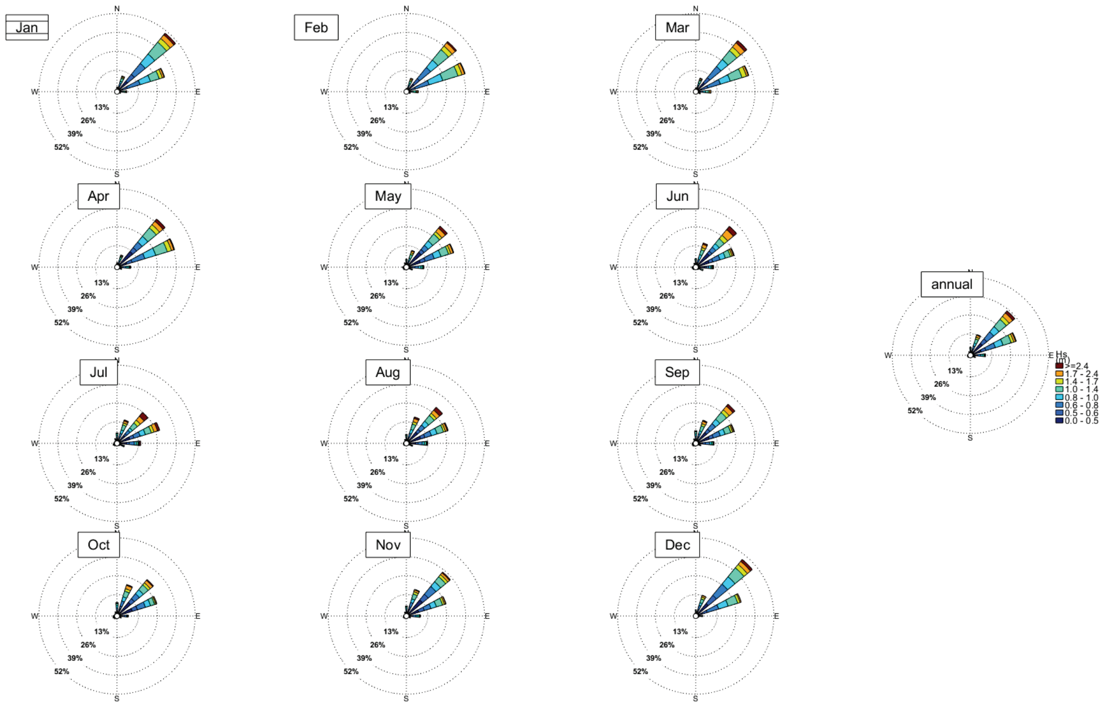

Figure 4.2 Monthly and annual wave rose plot for the total significant wave height at P2. Sectors indicate the direction from which waves approach.

5. Current climate

5.1. P1

A summary of the surface, mid-depth and near-bottom non-tidal current speed statistics at P1 are provided in Table 5.1, Table 5.2 and Table 5.3 respectively.

The annual joint probability distribution of the non-tidal surface, mid-depth and near-bottom current speed and direction is presented from Table 5.4 to Table 5.6.

The annual joint probability distribution of tidal depth-averaged current speed and direction is presented in Table 5.7, with the corresponding rose provided in Figure 5.1.

Table 5.1 Annual and monthly surface non-tidal current speed statistics at P1.

Period (01 Jan 2000 – 31 Dec 2018)	Surface current speed statistics (1)													
	Surface current speed (m/s)				Exceedance percentile for surface current speed (m/s)									Main (4) Direction(s)
	min	max	mean	std	p1	p5	p10	p50	p80	p90	p95	p98	p99	
January	0.00	0.50	0.13	0.07	0.01	0.03	0.04	0.12	0.19	0.23	0.27	0.32	0.36	SE NW
February	0.00	0.59	0.12	0.07	0.01	0.02	0.04	0.10	0.17	0.21	0.25	0.31	0.36	SE NW
March	0.00	0.52	0.10	0.07	0.01	0.02	0.03	0.09	0.15	0.20	0.24	0.30	0.33	SE NW
April	0.00	0.52	0.09	0.07	0.01	0.01	0.02	0.08	0.14	0.18	0.22	0.27	0.32	SE S NW
May	0.00	0.45	0.10	0.07	0.01	0.02	0.02	0.08	0.15	0.19	0.24	0.28	0.30	SE S NW
June	0.00	0.57	0.10	0.07	0.01	0.02	0.03	0.09	0.16	0.20	0.25	0.29	0.32	SE S
July	0.00	0.82	0.12	0.10	0.01	0.02	0.03	0.10	0.18	0.24	0.30	0.38	0.47	SE S
August	0.00	0.60	0.11	0.07	0.01	0.02	0.03	0.10	0.17	0.21	0.26	0.30	0.34	SE S
September	0.00	0.57	0.12	0.08	0.01	0.03	0.04	0.11	0.18	0.22	0.27	0.32	0.37	SE
October	0.00	0.49	0.13	0.07	0.01	0.03	0.04	0.12	0.18	0.23	0.26	0.31	0.35	E SE
November	0.00	0.51	0.13	0.07	0.01	0.03	0.04	0.12	0.18	0.23	0.27	0.32	0.35	E SE
December	0.00	0.57	0.13	0.08	0.01	0.03	0.05	0.12	0.19	0.23	0.27	0.33	0.36	E SE
Winter(3)	0.00	0.82	0.11	0.08	0.01	0.02	0.03	0.09	0.17	0.22	0.27	0.33	0.38	SE S
Spring	0.00	0.57	0.13	0.07	0.01	0.03	0.04	0.11	0.18	0.23	0.27	0.32	0.35	E SE
Summer(2)	0.00	0.59	0.13	0.08	0.01	0.03	0.04	0.12	0.18	0.22	0.27	0.32	0.36	SE NW
Autumn	0.00	0.52	0.10	0.07	0.01	0.02	0.02	0.08	0.15	0.19	0.23	0.28	0.32	SE S NW
All	0.00	0.82	0.12	0.08	0.01	0.02	0.03	0.10	0.17	0.22	0.26	0.31	0.35	SE NW

Notes: (1) All statistics derived from hindcast current data for the period 01 January 2000 to 31 December 2018.
(2) Summer: April to September.
(3) Winter: October to March.
(4) Main directions are those with greater than 15% occurrence and represent directions from which the currents is going to.

Table 5.2 Annual and monthly mid-depth non-tidal current speed statistics at P1.

Period (01 Jan 2000 – 31 Dec 2018)	Mid-depth current speed statistics (1)													
	Mid-depth current speed (m/s)				Exceedance percentile for mid-depth current speed (m/s)									Main (4) Direction(s)
	min	**max**	**mean**	**std**	**p1**	**p5**	**p10**	**p50**	**p80**	**p90**	**p95**	**p98**	**p99**	
January	0.00	0.31	0.06	0.04	0.01	0.01	0.02	0.05	0.10	0.12	0.15	0.18	0.20	N SE S NW
February	0.00	0.37	0.06	0.04	0.00	0.01	0.01	0.05	0.09	0.12	0.14	0.18	0.20	N SE S NW
March	0.00	0.32	0.06	0.05	0.00	0.01	0.01	0.04	0.09	0.12	0.15	0.19	0.22	N SE S NW
April	0.00	0.30	0.05	0.04	0.00	0.01	0.01	0.04	0.08	0.11	0.13	0.17	0.19	N SE S NW
May	0.00	0.28	0.06	0.04	0.00	0.01	0.01	0.05	0.09	0.12	0.14	0.17	0.19	SE S NW
June	0.00	0.32	0.06	0.04	0.00	0.01	0.01	0.05	0.10	0.12	0.15	0.17	0.19	SE S NW
July	0.00	0.59	0.07	0.06	0.00	0.01	0.01	0.06	0.11	0.14	0.18	0.24	0.31	SE S NW
August	0.00	0.39	0.07	0.05	0.00	0.01	0.02	0.06	0.10	0.13	0.15	0.18	0.21	SE S
September	0.00	0.39	0.07	0.05	0.00	0.01	0.02	0.06	0.10	0.13	0.15	0.19	0.22	SE S
October	0.00	0.31	0.07	0.04	0.01	0.01	0.02	0.06	0.11	0.13	0.15	0.18	0.19	SE S
November	0.00	0.34	0.07	0.05	0.01	0.01	0.02	0.06	0.10	0.13	0.16	0.18	0.20	SE S NW
December	0.00	0.42	0.06	0.04	0.01	0.01	0.02	0.05	0.09	0.12	0.15	0.19	0.21	N SE S NW
Winter(3)	0.00	0.59	0.07	0.05	0.00	0.01	0.01	0.05	0.10	0.13	0.16	0.20	0.23	SE S
Spring	0.00	0.39	0.07	0.05	0.01	0.01	0.02	0.06	0.10	0.13	0.15	0.18	0.21	SE S NW
Summer(2)	0.00	0.42	0.06	0.04	0.00	0.01	0.02	0.05	0.09	0.12	0.15	0.18	0.21	N SE S NW
Autumn	0.00	0.32	0.06	0.04	0.00	0.01	0.01	0.04	0.09	0.12	0.14	0.17	0.20	N SE S NW
All	0.00	0.59	0.06	0.05	0.00	0.01	0.01	0.05	0.10	0.12	0.15	0.18	0.21	SE S NW

Notes: (1) All statistics derived from hindcast current data for the period 01 January 2000 to 31 December 2018.
(2) Summer: April to September.
(3) Winter: October to March.
(4) Main directions are those with greater than 15% occurrence and represent directions from which the currents is going to.

Table 5.3 Annual and monthly near-bottom non-tidal current speed statistics at P1.

Period (01 Jan 2000 – 31 Dec 2018)	Near-bottom current speed statistics [1]													
	Near-bottom current speed (m/s)				Exceedance percentile for near-bottom current speed (m/s)									Main [4] Direction(s)
	min	max	mean	std	p1	p5	p10	p50	p80	p90	p95	p98	p99	
January	0.00	0.27	0.04	0.03	0.00	0.01	0.01	0.04	0.06	0.09	0.10	0.14	0.16	N S NW
February	0.00	0.32	0.04	0.03	0.00	0.01	0.01	0.03	0.06	0.08	0.11	0.14	0.17	N S
March	0.00	0.27	0.05	0.04	0.00	0.01	0.01	0.04	0.07	0.10	0.12	0.15	0.17	N SE S
April	0.00	0.26	0.05	0.03	0.00	0.01	0.01	0.04	0.07	0.10	0.11	0.14	0.17	N SE S
May	0.00	0.25	0.06	0.04	0.00	0.01	0.01	0.05	0.09	0.11	0.13	0.15	0.17	N SE S
June	0.00	0.30	0.06	0.04	0.00	0.01	0.01	0.05	0.09	0.11	0.13	0.15	0.17	N SE S
July	0.00	0.51	0.07	0.05	0.01	0.01	0.02	0.05	0.10	0.13	0.16	0.21	0.26	N SE S
August	0.00	0.33	0.06	0.04	0.00	0.01	0.02	0.05	0.09	0.11	0.13	0.16	0.18	SE S
September	0.00	0.34	0.06	0.04	0.01	0.01	0.02	0.06	0.09	0.12	0.14	0.16	0.18	SE S
October	0.00	0.26	0.06	0.04	0.00	0.01	0.02	0.05	0.09	0.11	0.13	0.16	0.17	S
November	0.00	0.30	0.05	0.04	0.00	0.01	0.01	0.04	0.08	0.10	0.12	0.15	0.18	N S
December	0.00	0.36	0.04	0.03	0.00	0.01	0.01	0.04	0.06	0.08	0.10	0.13	0.17	N S
Winter[3]	0.00	0.51	0.06	0.04	0.00	0.01	0.02	0.05	0.09	0.12	0.14	0.17	0.20	N SE S
Spring	0.00	0.34	0.06	0.04	0.00	0.01	0.02	0.05	0.09	0.11	0.13	0.16	0.18	S
Summer[2]	0.00	0.36	0.04	0.03	0.00	0.01	0.01	0.04	0.06	0.08	0.10	0.14	0.17	N S
Autumn	0.00	0.27	0.05	0.04	0.00	0.01	0.01	0.04	0.08	0.10	0.12	0.15	0.17	N SE S
All	0.00	0.51	0.05	0.04	0.00	0.01	0.01	0.04	0.08	0.11	0.13	0.16	0.18	N SE S

Notes: (1) All statistics derived from hindcast current data for the period 01 January 2000 to 31 December 2018.
(2) Summer: April to September.
(3) Winter: October to March.
(4) Main directions are those with greater than 15% occurrence and represent directions from which the currents is going to.

Table 5.4 Annual joint probability distribution (in %) of the surface non-tidal current speed and direction at P1.

Ures (m/s)	Direction (degT)									
	337.5-22.5	**22.5-67.5**	**67.5-112.5**	**112.5-157.5**	**157.5-202.5**	**202.5-247.5**	**247.5-292.5**	**292.5-337.5**	**Total**	**Exceed%**
>0<=0.05	2.61	2.02	2.48	3.80	2.79	1.60	1.58	2.77	19.65	100.00
>0.05<=0.1	3.02	2.52	4.07	7.21	3.73	2.08	2.47	4.15	29.25	80.41
>0.1<=0.15	1.98	1.52	3.21	7.22	2.97	1.74	2.06	3.15	23.85	51.17
>0.15<=0.2	0.97	0.48	1.46	5.44	2.05	0.59	1.05	2.30	14.34	27.25
>0.2<=0.25	0.34	0.07	0.45	3.35	1.19	0.13	0.30	1.39	7.22	12.94
>0.25<=0.3	0.12	0.01	0.10	1.59	0.55	0.01	0.09	0.72	3.19	5.71
>0.3<=0.35	0.03	-	0.02	0.68	0.25	-	0.02	0.45	1.45	2.52
>0.35<=0.4	0.01	-	*	0.20	0.08	-	*	0.27	0.56	1.06
>0.4<=0.45	*	-	-	0.07	0.03	-	-	0.16	0.26	0.51
>0.45<=0.5	*	-	-	0.02	0.01	-	-	0.08	0.11	0.24
>0.5<=0.55	-	-	-	0.01	0.01	-	-	0.05	0.07	0.13
>0.55<=0.6	-	-	-	-	*	-	-	0.02	0.02	0.06
>0.6<=0.65	-	-	-	-	-	-	-	0.01	0.01	0.04
>0.65<=0.7	-	-	-	-	-	-	-	0.01	0.01	0.02
>0.7<=0.75	-	-	-	-	-	-	-	*		0.01
>0.75<=0.8	-	-	-	-	-	-	-	0.01	0.01	0.01
>0.8<=0.85	-	-	-	-	-	-	-	0.01	0.01	0.01
Total	9.08	6.62	11.79	29.59	13.66	6.15	7.57	15.55	100.00	

Notes: * represents less than 0.005%.

Table 5.5 Annual joint probability distribution (in %) of the mid-depth non-tidal current speed and direction at P1.

Ures (m/s)	**Direction (degT)**									
	337.5-22.5	**22.5-67.5**	**67.5-112.5**	**112.5-157.5**	**157.5-202.5**	**202.5-247.5**	**247.5-292.5**	**292.5-337.5**	**Total**	**Exceed%**
>0<=0.05	7.04	2.75	2.94	10.70	11.10	3.17	3.03	7.82	48.55	100.00
>0.05<=0.1	4.42	0.12	0.13	10.00	11.80	0.23	0.21	6.32	33.23	51.54
>0.1<=0.15	1.18	*	-	4.13	5.22	0.01	0.01	2.67	13.22	18.29
>0.15<=0.2	0.27	-	-	1.15	1.21	*	-	1.08	3.71	5.02
>0.2<=0.25	0.04	-	-	0.16	0.17	-	-	0.54	0.91	1.32
>0.25<=0.3	0.01	-	-	0.02	0.01	-	-	0.20	0.24	0.41
>0.3<=0.35	*	-	-	*	*	-	-	0.10	0.10	0.17
>0.35<=0.4	-	-	-	-	-	-	-	0.03	0.03	0.07
>0.4<=0.45	-	-	-	-	-	-	-	0.02	0.02	0.04
>0.45<=0.5	-	-	-	-	-	-	-	0.01	0.01	0.02
>0.5<=0.55	-	-	-	-	-	-	-	0.01	0.01	0.01
>0.55<=0.6	-	-	-	-	-	-	-	*		
Total	12.96	2.87	3.07	26.16	29.51	3.41	3.25	18.80	100.00	

Notes: * represents less than 0.005%.

Table 5.6 Annual joint probability distribution (in %) of the near-bottom non-tidal current speed and direction at P1.

Ures (m/s)	**Direction (degT)**									
	337.5-22.5	**22.5-67.5**	**67.5-112.5**	**112.5-157.5**	**157.5-202.5**	**202.5-247.5**	**247.5-292.5**	**292.5-337.5**	**Total**	**Exceed%**
>0<=0.05	9.31	4.13	3.55	10.71	14.38	3.79	2.87	6.71	55.45	100.00
>0.05<=0.1	6.43	0.72	0.30	5.13	16.41	0.51	0.14	3.06	32.70	44.64
>0.1<=0.15	2.06	0.06	*	0.81	5.50	0.04	0.01	0.97	9.45	11.88
>0.15<=0.2	0.62	*	-	0.10	0.72	-	*	0.40	1.84	2.40
>0.2<=0.25	0.16	-	-	0.01	0.03	-	-	0.17	0.37	0.57
>0.25<=0.3	0.04	-	-	-	*	-	-	0.09	0.13	0.20
>0.3<=0.35	0.01	-	-	-	-	-	-	0.03	0.04	0.07
>0.35<=0.4	0.01	-	-	-	-	-	-	0.01	0.02	0.04
>0.4<=0.45	*	-	-	-	-	-	-	0.01	0.01	0.02
>0.45<=0.5	-	-	-	-	-	-	-	*		
>0.5<=0.55	-	-	-	-	-	-	-	*		
Total	18.64	4.91	3.85	16.76	37.04	4.34	3.02	11.45	100.00	

Notes: * represents less than 0.005%.

Table 5.7 Annual joint probability distribution (in %) of the depth-averaged tidal current speed and direction at P1.

Ures (m/s)	**Direction (degT)**									
	337.5-22.5	**22.5-67.5**	**67.5-112.5**	**112.5-157.5**	**157.5-202.5**	**202.5-247.5**	**247.5-292.5**	**292.5-337.5**	**Total**	**Exceed%**
0-0.02	8.40	1.24	1.59	13.27	7.22	1.20	1.58	14.88	49.38	100.00
0.02-0.04	0.16	-	-	24.87	0.14	-	-	24.94	50.11	50.62
0.04-0.06	-	-	-	0.43	-	-	-	0.08	0.51	0.51
Total	8.56	1.24	1.59	38.57	7.36	1.20	1.58	39.90	100.00	

Notes: * represents less than 0.005%.

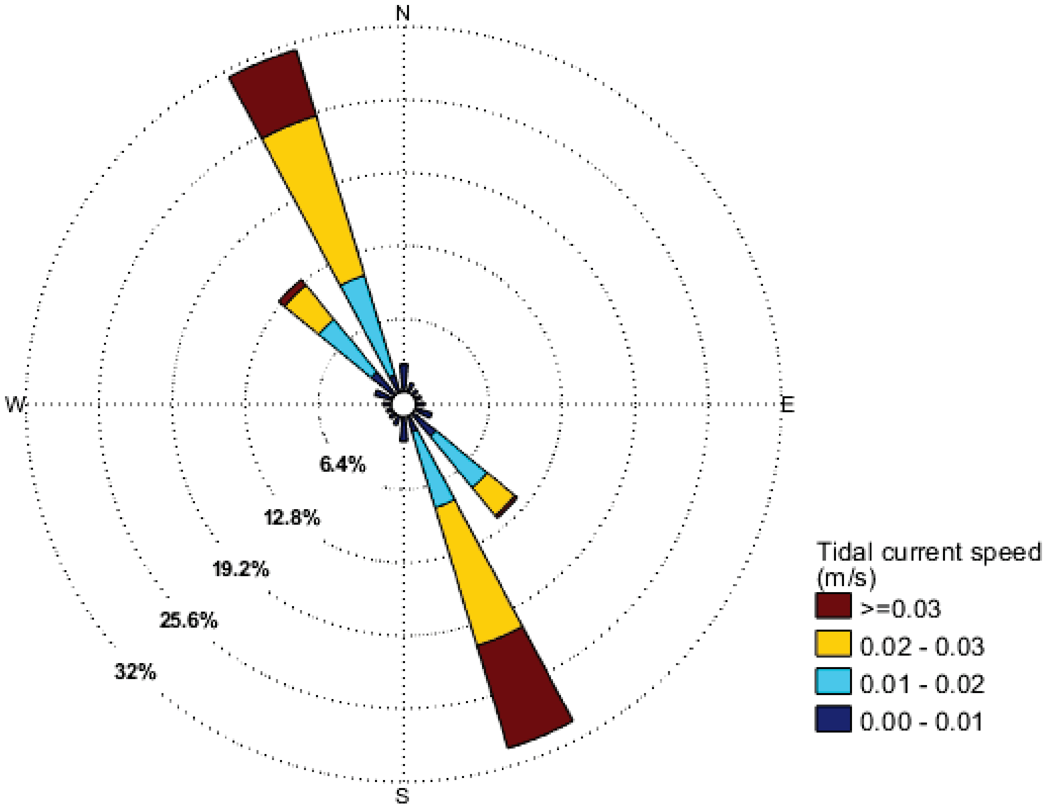

Figure 5.1 Tidal current rose at P1. Sectors indicate the direction to which the current is flowing.

5.2. P2

A summary of the surface, mid-depth and near-bottom non-tidal current speed statistics at P2 are provided in Table 5.8, Table 5.9 and Table 5.10 respectively.

The annual joint probability distribution of the non-tidal surface, mid-depth and near-bottom current speed and direction is presented from Table 5.11 to Table 5.13.

The annual joint probability distribution of tidal depth-averaged current speed and direction is presented in Table 5.14, with the corresponding rose provided in Figure 5.2.

Table 5.8 Annual and monthly surface non-tidal current speed statistics at P2.

Period (01 Jan 2000 – 31 Dec 2018)	Surface current speed statistics (1)													
	Surface current speed (m/s)				Exceedance percentile for surface current speed (m/s)									Main (4) Direction(s)
	min	**max**	**mean**	**std**	**p1**	**p5**	**p10**	**p50**	**p80**	**p90**	**p95**	**p98**	**p99**	
January	0.00	0.51	0.13	0.07	0.01	0.03	0.04	0.12	0.19	0.23	0.27	0.32	0.36	SE NW
February	0.00	0.53	0.12	0.07	0.01	0.02	0.03	0.11	0.17	0.21	0.26	0.32	0.36	SE NW
March	0.00	0.55	0.10	0.07	0.01	0.02	0.03	0.09	0.15	0.20	0.23	0.29	0.32	SE NW
April	0.00	0.50	0.09	0.07	0.01	0.01	0.02	0.08	0.14	0.18	0.22	0.27	0.30	SE NW
May	0.00	0.44	0.11	0.07	0.01	0.02	0.02	0.09	0.17	0.21	0.25	0.29	0.32	SE
June	0.00	0.57	0.11	0.08	0.01	0.02	0.03	0.10	0.17	0.22	0.26	0.30	0.34	SE
July	0.00	0.79	0.13	0.09	0.01	0.02	0.03	0.11	0.19	0.25	0.30	0.36	0.44	SE
August	0.00	0.58	0.12	0.08	0.01	0.02	0.03	0.11	0.18	0.23	0.26	0.30	0.33	SE
September	0.00	0.56	0.13	0.08	0.01	0.03	0.04	0.12	0.19	0.24	0.28	0.33	0.38	E SE
October	0.00	0.48	0.13	0.08	0.01	0.03	0.04	0.12	0.19	0.24	0.28	0.32	0.35	E SE
November	0.00	0.46	0.13	0.07	0.01	0.03	0.04	0.12	0.19	0.23	0.27	0.32	0.35	E SE
December	0.00	0.55	0.13	0.08	0.01	0.03	0.05	0.12	0.19	0.23	0.27	0.33	0.36	E SE
Winter(3)	0.00	0.79	0.12	0.08	0.01	0.02	0.03	0.11	0.18	0.23	0.27	0.33	0.36	SE
Spring	0.00	0.56	0.13	0.08	0.01	0.03	0.04	0.12	0.19	0.24	0.28	0.32	0.36	E SE
Summer(2)	0.00	0.55	0.13	0.07	0.01	0.03	0.04	0.12	0.18	0.23	0.27	0.32	0.36	SE NW
Autumn	0.00	0.55	0.10	0.07	0.01	0.02	0.02	0.09	0.15	0.20	0.24	0.28	0.32	SE NW
All	0.00	0.79	0.12	0.08	0.01	0.02	0.03	0.11	0.18	0.22	0.27	0.32	0.35	SE NW

Notes: (1) All statistics derived from hindcast current data for the period 01 January 2000 to 31 December 2018.
(2) Summer: April to September.
(3) Winter: October to March.
(4) Main directions are those with greater than 15% occurrence and represent directions from which the currents is going to.

Table 5.9 Annual and monthly mid-depth non-tidal current speed statistics at P2.

Period (01 Jan 2000 – 31 Dec 2018)	Mid-depth current speed statistics [(1)]													
	Mid-depth current speed (m/s)				Exceedance percentile for mid-depth current speed (m/s)									Main [(4)] Direction(s)
	min	max	mean	std	p1	p5	p10	p50	p80	p90	p95	p98	p99	
January	0.00	0.29	0.06	0.04	0.01	0.01	0.02	0.05	0.09	0.12	0.14	0.18	0.20	SE S NW
February	0.00	0.33	0.06	0.04	0.00	0.01	0.01	0.05	0.09	0.12	0.15	0.18	0.21	SE S NW
March	0.00	0.35	0.06	0.04	0.00	0.01	0.01	0.04	0.08	0.11	0.14	0.18	0.21	SE NW
April	0.00	0.27	0.05	0.04	0.00	0.01	0.01	0.04	0.08	0.11	0.14	0.17	0.18	SE NW
May	0.00	0.27	0.06	0.05	0.00	0.01	0.01	0.05	0.10	0.14	0.16	0.19	0.20	SE NW
June	0.00	0.31	0.07	0.05	0.00	0.01	0.02	0.06	0.11	0.14	0.16	0.19	0.21	SE NW
July	0.00	0.53	0.08	0.06	0.00	0.01	0.02	0.07	0.12	0.16	0.19	0.23	0.28	SE NW
August	0.00	0.37	0.08	0.05	0.01	0.01	0.02	0.07	0.12	0.14	0.16	0.18	0.20	SE
September	0.00	0.36	0.07	0.05	0.00	0.01	0.02	0.06	0.12	0.14	0.17	0.20	0.23	SE
October	0.00	0.29	0.07	0.05	0.01	0.01	0.02	0.06	0.11	0.14	0.16	0.19	0.21	SE S NW
November	0.00	0.31	0.07	0.05	0.01	0.01	0.02	0.05	0.10	0.13	0.16	0.18	0.20	SE S NW
December	0.00	0.40	0.06	0.04	0.01	0.01	0.02	0.05	0.09	0.12	0.15	0.18	0.21	SE S NW
Winter[(3)]	0.00	0.53	0.08	0.05	0.00	0.01	0.02	0.07	0.12	0.14	0.17	0.20	0.23	SE NW
Spring	0.00	0.36	0.07	0.05	0.01	0.01	0.02	0.06	0.11	0.14	0.16	0.19	0.21	SE S NW
Summer[(2)]	0.00	0.40	0.06	0.04	0.00	0.01	0.02	0.05	0.09	0.12	0.15	0.18	0.20	SE S NW
Autumn	0.00	0.35	0.06	0.05	0.00	0.01	0.01	0.04	0.09	0.12	0.15	0.18	0.20	SE NW
All	0.00	0.53	0.07	0.05	0.00	0.01	0.02	0.05	0.10	0.13	0.16	0.19	0.21	SE NW

Notes: (1) All statistics derived from hindcast current data for the period 01 January 2000 to 31 December 2018.
(2) Summer: April to September.
(3) Winter: October to March.
(4) Main directions are those with greater than 15% occurrence and represent directions from which the currents is going to.

Table 5.10 Annual and monthly near-bottom non-tidal current speed statistics at P2.

Period (01 Jan 2000 – 31 Dec 2018)	Near-bottom current speed statistics [1]													
	Near-bottom current speed (m/s)				Exceedance percentile for near-bottom current speed (m/s)									Main [4] Direction(s)
	min	max	mean	std	p1	p5	p10	p50	p80	p90	p95	p98	p99	
January	0.00	0.26	0.05	0.03	0.00	0.01	0.01	0.04	0.07	0.09	0.11	0.14	0.17	N SE S NW
February	0.00	0.29	0.04	0.03	0.00	0.01	0.01	0.03	0.07	0.09	0.11	0.14	0.17	N SE S NW
March	0.00	0.26	0.05	0.04	0.00	0.01	0.01	0.04	0.08	0.10	0.12	0.15	0.17	N SE S NW
April	0.00	0.30	0.05	0.04	0.00	0.01	0.01	0.04	0.08	0.10	0.12	0.15	0.17	N SE S
May	0.00	0.24	0.06	0.04	0.00	0.01	0.01	0.05	0.10	0.13	0.15	0.17	0.19	N SE S
June	0.00	0.29	0.07	0.04	0.01	0.01	0.02	0.06	0.10	0.13	0.14	0.17	0.19	SE S
July	0.00	0.47	0.07	0.05	0.01	0.01	0.02	0.07	0.11	0.14	0.17	0.20	0.25	SE S
August	0.00	0.32	0.07	0.04	0.01	0.01	0.02	0.07	0.11	0.13	0.14	0.17	0.18	SE S
September	0.00	0.33	0.07	0.04	0.00	0.01	0.02	0.06	0.11	0.13	0.15	0.18	0.20	SE S
October	0.00	0.24	0.07	0.04	0.00	0.01	0.02	0.06	0.11	0.13	0.15	0.17	0.18	SE S
November	0.00	0.28	0.06	0.04	0.00	0.01	0.02	0.05	0.09	0.12	0.14	0.17	0.18	SE S NW
December	0.00	0.35	0.05	0.04	0.00	0.01	0.01	0.04	0.07	0.09	0.11	0.15	0.17	N SE S NW
Winter[3]	0.00	0.47	0.07	0.05	0.01	0.01	0.02	0.06	0.11	0.13	0.15	0.18	0.20	SE S
Spring	0.00	0.33	0.07	0.04	0.00	0.01	0.02	0.06	0.10	0.13	0.15	0.17	0.19	SE S
Summer[2]	0.00	0.35	0.05	0.03	0.00	0.01	0.01	0.04	0.07	0.09	0.11	0.14	0.17	N SE S NW
Autumn	0.00	0.30	0.05	0.04	0.00	0.01	0.01	0.04	0.08	0.11	0.13	0.16	0.18	N SE S NW
All	0.00	0.47	0.06	0.04	0.00	0.01	0.01	0.05	0.09	0.12	0.14	0.17	0.19	SE S NW

Notes: (1) All statistics derived from hindcast current data for the period 01 January 2000 to 31 December 2018.
(2) Summer: April to September.
(3) Winter: October to March.
(4) Main directions are those with greater than 15% occurrence and represent directions from which the currents is going to.

Table 5.11 Annual joint probability distribution (in %) of the surface non-tidal current speed and direction at P2.

Ures (m/s)	Direction (degT)									
	337.5-22.5	**22.5-67.5**	**67.5-112.5**	**112.5-157.5**	**157.5-202.5**	**202.5-247.5**	**247.5-292.5**	**292.5-337.5**	**Total**	**Exceed%**
>0<=0.05	2.15	1.73	2.44	4.01	2.26	1.39	1.69	2.93	18.60	100.00
>0.05<=0.1	2.41	2.29	3.73	7.75	2.72	2.09	2.52	3.99	27.50	81.46
>0.1<=0.15	1.57	1.50	3.47	7.69	2.56	1.70	2.25	3.09	23.83	53.96
>0.15<=0.2	0.77	0.50	2.00	6.58	1.70	0.58	1.25	2.18	15.56	30.08
>0.2<=0.25	0.21	0.07	0.75	4.30	0.90	0.11	0.46	1.30	8.10	14.54
>0.25<=0.3	0.06	*	0.21	2.21	0.42	0.02	0.15	0.69	3.76	6.44
>0.3<=0.35	0.01	*	0.04	1.00	0.12	-	0.03	0.42	1.62	2.66
>0.35<=0.4	*	-	0.01	0.31	0.05	-	0.01	0.23	0.61	1.04
>0.4<=0.45	*	-	*	0.09	0.01	-	*	0.13	0.23	0.43
>0.45<=0.5	-	-	-	0.03	*	-	-	0.06	0.09	0.19
>0.5<=0.55	-	-	-	0.01	*	-	-	0.03	0.04	0.09
>0.55<=0.6	-	-	-	*	-	-	-	0.02	0.02	0.05
>0.6<=0.65	-	-	-	-	-	-	-	0.01	0.01	0.03
>0.65<=0.7	-	-	-	-	-	-	-	*		0.01
>0.7<=0.75	-	-	-	-	-	-	-	0.01	0.01	0.01
>0.75<=0.8	-	-	-	-	-	-	-	*		
Total	7.18	6.09	12.65	33.98	10.74	5.89	8.36	15.09	100.00	

Notes: * represents less than 0.005%.

Table 5.12 Annual joint probability distribution (in %) of the mid-depth non-tidal current speed and direction at P2.

Ures (m/s)	Direction (degT)									
	337.5-22.5	22.5-67.5	67.5-112.5	112.5-157.5	157.5-202.5	202.5-247.5	247.5-292.5	292.5-337.5	Total	Exceed%
>0<=0.05	5.38	2.40	3.19	12.90	7.79	2.64	3.29	8.81	46.40	100.00
>0.05<=0.1	2.23	0.08	0.25	17.11	4.22	0.17	0.35	7.81	32.22	53.68
>0.1<=0.15	0.31	*	*	10.60	1.05	*	*	3.09	15.05	21.42
>0.15<=0.2	0.03	-	-	3.53	0.18	-	-	1.19	4.93	6.33
>0.2<=0.25	-	-	-	0.61	0.02	-	-	0.43	1.06	1.41
>0.25<=0.3	-	-	-	0.07	-	-	-	0.16	0.23	0.34
>0.3<=0.35	-	-	-	0.01	-	-	-	0.05	0.06	0.11
>0.35<=0.4	-	-	-	*	-	-	-	0.03	0.03	0.05
>0.4<=0.45	-	-	-	-	-	-	-	0.01	0.01	0.02
>0.45<=0.5	-	-	-	-	-	-	-	0.01	0.01	0.01
>0.5<=0.55	-	-	-	-	-	-	-	*		
Total	7.95	2.48	3.44	44.83	13.26	2.81	3.64	21.59	100.00	

Notes: * represents less than 0.005%.

Table 5.13 Annual joint probability distribution (in %) of the near-bottom non-tidal current speed and direction at P2.

Ures (m/s)	**Direction (degT)**									
	337.5-22.5	**22.5-67.5**	**67.5-112.5**	**112.5-157.5**	**157.5-202.5**	**202.5-247.5**	**247.5-292.5**	**292.5-337.5**	**Total**	**Exceed%**
>0<=0.05	7.51	3.53	4.12	12.81	9.15	3.13	3.07	7.77	51.09	100.00
>0.05<=0.1	4.79	0.54	0.54	13.03	8.06	0.41	0.25	4.80	32.42	49.02
>0.1<=0.15	1.54	0.03	0.01	4.85	4.74	0.04	0.01	1.62	12.84	16.54
>0.15<=0.2	0.35	*	-	0.88	1.20	-	-	0.62	3.05	3.66
>0.2<=0.25	0.07	-	-	0.08	0.10	-	-	0.23	0.48	0.62
>0.25<=0.3	0.01	-	-	0.01	*	-	-	0.06	0.08	0.14
>0.3<=0.35	*	-	-	-	-	-	-	0.03	0.03	0.06
>0.35<=0.4	-	-	-	-	-	-	-	0.01	0.01	0.02
>0.4<=0.45	-	-	-	-	-	-	-	0.01	0.01	0.01
>0.45<=0.5	-	-	-	-	-	-	-	*		
Total	14.27	4.10	4.67	31.66	23.25	3.58	3.33	15.15	100.00	

Notes: * represents less than 0.005%.

Table 5.14 Annual joint probability distribution (in %) of the depth-averaged tidal current speed and direction at P2.

Utide (m/s)	**Direction (degT)**									
	337.5-22.5	**22.5-67.5**	**67.5-112.5**	**112.5-157.5**	**157.5-202.5**	**202.5-247.5**	**247.5-292.5**	**292.5-337.5**	**Total**	**Exceed%**
0-0.02	6.16	0.95	1.24	7.29	5.58	0.94	1.25	7.62	31.03	100.00
0.02-0.04	0.76	-	-	20.12	0.63	-	-	24.32	45.83	68.96
0.04-0.06	-	-	-	12.70	-	-	-	10.27	22.97	23.13
0.06-0.08	-	-	-	0.16	-	-	-	-	0.16	0.16
Total	6.92	0.95	1.24	40.27	6.21	0.94	1.25	42.21	100.00	

Notes: * represents less than 0.005%.

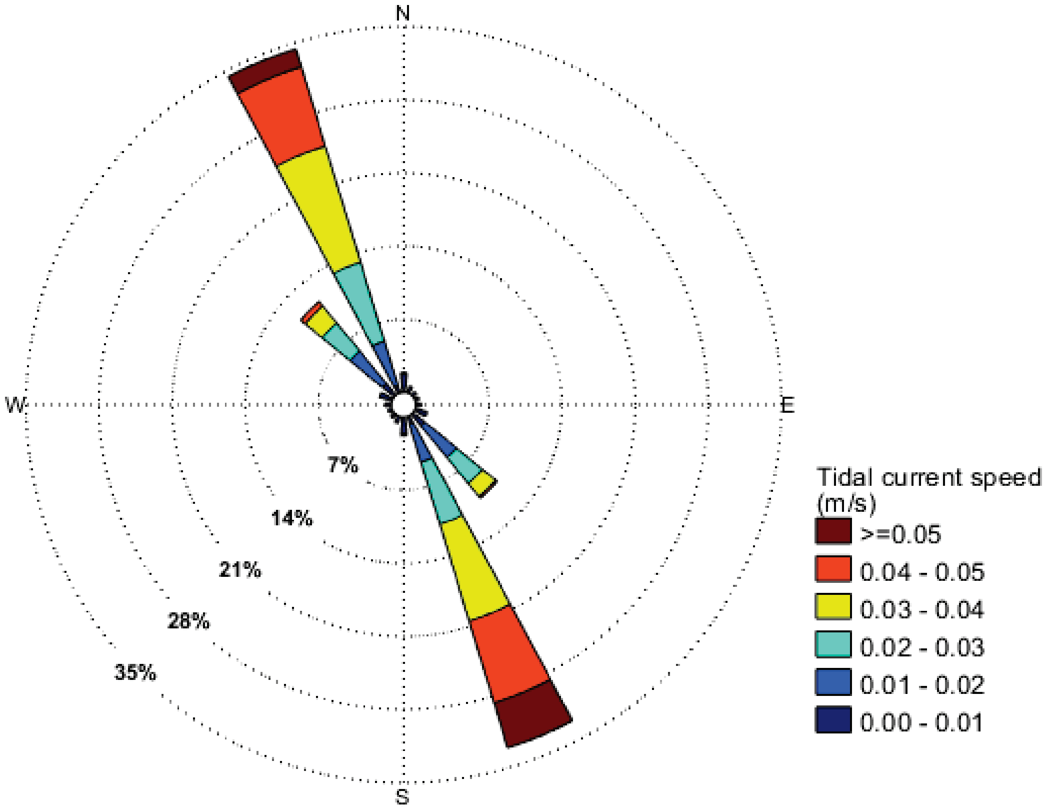

Figure 5.2 Tidal current rose at P2. Sectors indicate the direction to which the current is flowing.

6. Workability statistics

Annual and monthly workability statistics for the operational area are presented in Table 6.1 to Table 6.4 to as persistence probabilities for the following co-temporal criteria:

- Hs swell < 1.5 m and Wind speed < 25 knots (from NW to SE, clockwise) or Wind speed < 40 knots (from SE to NW, clockwise).
- Hs swell < 2.5 m and Wind speed < 25 knots (from NW to SE, clockwise) or Wind speed < 40 knots (from SE to NW, clockwise).

An example interpretation is as follows. Based on the limiting criteria indicated above, the month of February has the highest workability (Table 6.1); for durations of at least 12 consecutive hours the average workability is 97.91%.

Table 6.1 Annual and monthly workability probabilities (% of workable time) for marine operations at P1 for several durations. Workability is based on Hs swell < 1.5 m and Wspd < 25 knots (from NW to SE, clockwise) or Wspd < 40 knots (from SE to NW, clockwise).

%	Duration (hours)											
	> 6	> 12	> 18	> 24	> 30	> 36	> 42	> 48	> 54	> 60	> 66	> 72
Jan	97.17	97.02	96.91	96.76	96.76	96.64	96.64	96.48	96.30	95.88	95.40	95.40
Feb	98.07	97.91	97.84	97.58	97.46	97.18	97.01	96.46	96.03	95.79	95.79	95.79
Mar	97.48	97.39	97.27	97.11	97.01	96.50	96.36	96.20	96.02	95.81	95.11	95.11
Apr	97.45	97.13	97.07	96.99	96.89	96.76	96.62	96.29	96.08	95.86	94.91	94.91
May	97.50	97.25	97.18	96.68	96.48	96.36	96.22	96.06	95.66	95.66	95.44	95.44
Jun	95.93	95.39	95.26	95.01	94.90	94.63	94.18	93.47	93.08	92.19	91.95	91.95
Jul	95.09	94.88	94.52	94.18	94.07	93.16	92.84	91.63	91.23	90.35	90.10	88.51
Aug	97.17	96.95	96.82	96.59	96.07	95.81	95.38	94.86	94.67	94.46	93.99	92.95
Sep	97.98	97.81	97.48	97.17	96.73	96.33	96.04	95.36	94.77	93.22	92.26	91.74
Oct	98.91	98.73	98.37	98.29	97.98	97.85	97.55	96.88	96.51	96.10	95.15	94.64
Nov	98.95	98.88	98.69	98.19	97.66	97.66	97.23	97.23	97.23	97.23	96.26	95.99
Dec	98.42	98.30	97.99	97.76	97.76	97.63	97.48	97.48	97.10	96.90	96.90	96.65
Annual	97.53	97.36	97.26	97.08	97.01	96.95	96.79	96.59	96.41	96.16	96.00	95.78

Table 6.2 Annual and monthly workability probabilities (% of workable time) for marine operations at P2 for several durations. Workability is based on Hs swell < 1.5 m and Wspd < 25 knots (from NW to SE, clockwise) or Wspd < 40 knots (from SE to NW, clockwise).

%	Duration (hours)											
	> 6	**> 12**	**> 18**	**> 24**	**> 30**	**> 36**	**> 42**	**> 48**	**> 54**	**> 60**	**> 66**	**> 72**
Jan	97.01	96.73	96.51	96.51	96.51	96.38	96.38	96.38	96.38	96.18	95.70	95.44
Feb	97.95	97.80	97.60	97.52	97.52	97.12	96.95	96.76	96.56	96.10	96.10	96.10
Mar	97.25	97.14	97.03	96.87	96.87	96.25	95.80	95.80	95.62	95.20	94.73	94.22
Apr	97.14	96.75	96.75	96.67	96.46	96.21	96.21	95.86	95.28	95.06	94.83	94.83
May	97.42	97.25	97.25	96.79	96.39	96.26	96.11	95.95	95.57	95.57	95.10	95.10
Jun	95.38	95.10	94.93	94.53	94.42	94.16	93.69	92.99	92.20	91.75	91.51	91.51
Jul	95.00	94.78	94.50	94.16	93.83	93.05	92.59	92.42	91.65	90.57	90.07	89.01
Aug	97.07	96.97	96.91	96.60	96.19	96.07	95.36	94.83	94.64	94.64	93.94	92.93
Sep	97.67	97.54	97.22	96.97	96.76	96.64	96.33	95.65	95.25	94.59	93.63	93.12
Oct	98.61	98.37	98.00	97.85	97.54	97.41	97.12	96.61	96.22	96.22	95.28	94.52
Nov	99.06	99.00	98.87	98.45	98.04	97.92	97.46	97.46	97.46	97.23	96.51	96.51
Dec	98.25	98.01	97.75	97.60	97.49	97.49	97.49	97.32	96.75	96.75	96.53	96.53
Annual	97.34	97.18	97.09	96.94	96.85	96.78	96.62	96.53	96.29	96.17	96.03	95.85

Table 6.3 Annual and monthly workability probabilities (% of workable time) for marine operations at P1 for several durations. Workability is based on Hs swell < 2.5 m and Wspd < 25 knots (from NW to SE, clockwise) or Wspd < 40 knots (from SE to NW, clockwise).

%	Duration (hours)											
	> 6	**> 12**	**> 18**	**> 24**	**> 30**	**> 36**	**> 42**	**> 48**	**> 54**	**> 60**	**> 66**	**> 72**
Jan	99.72	99.64	99.48	99.48	99.48	99.48	99.48	99.32	99.14	98.92	98.68	98.43
Feb	99.79	99.54	99.47	99.19	99.09	98.66	98.66	98.47	98.04	98.04	98.04	97.76
Mar	99.53	99.46	99.34	99.25	99.05	98.67	98.67	98.51	98.13	97.92	97.92	97.92
Apr	99.68	99.20	99.14	99.14	99.04	98.92	98.78	98.44	98.24	98.02	97.79	97.79
May	99.73	99.54	99.48	99.15	99.05	98.93	98.63	98.31	97.72	97.72	97.72	97.72
Jun	99.50	99.15	99.09	99.00	98.89	98.48	97.87	96.98	96.59	96.14	95.90	95.64
Jul	99.15	98.88	98.53	98.19	98.08	97.55	97.39	96.71	96.51	95.85	95.12	93.52
Aug	99.33	99.05	98.92	98.77	98.46	98.08	97.65	97.30	96.92	96.71	96.23	95.20
Sep	99.66	99.48	99.15	98.83	98.49	98.09	97.80	97.29	96.69	95.59	94.63	93.84
Oct	99.88	99.77	99.35	99.27	99.07	98.82	98.53	97.86	97.67	97.67	96.50	95.99
Nov	99.82	99.75	99.62	99.30	98.98	98.98	98.25	98.25	98.25	98.25	97.77	97.50
Dec	99.77	99.69	99.33	99.01	98.90	98.90	98.75	98.75	98.37	98.17	98.17	98.17
Annual	99.65	99.48	99.37	99.26	99.20	99.13	98.95	98.83	98.65	98.59	98.40	98.18

Table 6.4 Annual and monthly workability probabilities (% of workable time) for marine operations at P2 for several durations. Workability is based on Hs swell < 2.5 m and Wspd < 25 knots (from NW to SE, clockwise) or Wspd < 40 knots (from SE to NW, clockwise).

%	Duration (hours)											
	> 6	**> 12**	**> 18**	**> 24**	**> 30**	**> 36**	**> 42**	**> 48**	**> 54**	**> 60**	**> 66**	**> 72**
Jan	99.77	99.66	99.55	99.55	99.55	99.55	99.55	99.55	99.55	99.33	99.10	98.85
Feb	99.80	99.60	99.48	99.21	99.21	99.07	99.07	98.88	98.68	98.45	98.45	98.45
Mar	99.59	99.46	99.34	99.26	99.26	99.01	98.72	98.55	98.37	98.17	98.17	97.92
Apr	99.58	99.20	99.08	99.00	98.90	98.90	98.90	98.56	98.56	98.34	98.34	98.34
May	99.74	99.55	99.55	99.23	99.12	99.01	98.70	98.38	98.00	98.00	98.00	98.00
Jun	99.36	99.17	99.06	98.97	98.87	98.59	97.98	97.09	96.71	96.04	95.80	95.27
Jul	99.09	98.76	98.48	98.14	97.92	97.38	97.23	97.06	96.28	95.63	95.14	93.81
Aug	99.43	99.25	99.07	98.91	98.71	98.33	97.76	97.41	97.03	97.03	96.55	95.53
Sep	99.65	99.47	99.28	99.03	98.92	98.66	98.36	97.84	97.45	97.01	96.29	95.50
Oct	99.95	99.81	99.43	99.12	98.91	98.66	98.52	98.02	98.02	98.02	97.09	96.33
Nov	99.89	99.82	99.77	99.43	99.22	99.22	98.63	98.63	98.63	98.63	97.92	97.92
Dec	99.81	99.59	99.33	99.10	98.90	98.90	98.90	98.73	98.16	98.16	98.16	98.16
Annual	99.66	99.50	99.42	99.29	99.26	99.19	99.06	98.96	98.85	98.81	98.69	98.52

7. Extreme metocean statistics

Note an arbitrary minimum number of 10 storm peaks has been was chosen for reliable distribution fitting. This results in specific directional return period values being omitted (see Section 9.3).

7.1. P1

The directional return period values for wind, wave and current extremes are given in Table 7.1 to Table 7.9 for 1, 10, 50 and 100-year return periods.

Contour plot of omni-directional bi-variate return period values for significant wave height and peak wave period are presented in Figure 7.1.

Table 7.1 Annual independent omni-directional extreme criteria for wind, wave and current at P1.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	18.31	22.13	24.69	25.78
10min wind speed	U_{10min}	$m.s^{-1}$	19.74	23.95	26.79	27.98
1 min wind speed	U_{1min}	$m.s^{-1}$	21.57	26.29	29.47	30.82
3s wind gust	U_{3s}	$m.s^{-1}$	23.95	29.34	32.97	34.51
Significant wave height	H_s	m	4.46	5.67	6.29	6.52
Peak wave period	T_p	s	9.61	10.73	11.25	11.43
Maximum individual wave height	H_{max}	m	8.57	10.59	11.54	11.91
Maximum individual wave crest	C_{max}	m	5.53	6.78	7.38	7.59
Surface current speed	U_{surf}	$m.s^{-1}$	0.51	0.67	0.78	0.82
Mid-depth current speed	U_{mid}	$m.s^{-1}$	0.30	0.41	0.48	0.51
Near-bottom current speed	U_{bot}	$m.s^{-1}$	0.26	0.36	0.43	0.46

Table 7.2 Annual independent North extreme criteria for wind, wave and current at P1.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	14.03	16.99	19.01	19.87
10min wind speed	U_{10min}	$m.s^{-1}$	15.03	18.28	20.51	21.46
1 min wind speed	U_{1min}	$m.s^{-1}$	16.31	19.93	22.43	23.50
3s wind gust	U_{3s}	$m.s^{-1}$	17.97	22.09	24.93	26.15
Significant wave height	H_s	m	2.41	3.10	3.43	3.54
Peak wave period	T_p	s	6.80	7.44	7.70	7.79
Maximum individual wave height	H_{max}	m	4.67	5.88	6.50	6.71
Maximum individual wave crest	C_{max}	m	2.96	3.75	4.14	4.29
Surface current speed	U_{surf}	$m.s^{-1}$	0.24	0.34	0.41	0.44
Mid-depth current speed	U_{mid}	$m.s^{-1}$	0.14	0.19	0.23	0.24
Near-bottom current speed	U_{bot}	$m.s^{-1}$	0.21	0.33	0.43	0.47

Table 7.3 Annual independent North-East extreme criteria for wind, wave and current at P1.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	14.28	17.96	20.42	21.46
10min wind speed	U_{10min}	$m.s^{-1}$	15.30	19.36	22.07	23.22
1 min wind speed	U_{1min}	$m.s^{-1}$	16.60	21.15	24.19	25.49
3s wind gust	U_{3s}	$m.s^{-1}$	18.30	23.48	26.96	28.43
Significant wave height	H_s	m	4.34	5.44	5.91	6.06
Peak wave period	T_p	s	9.70	10.72	11.11	11.24
Maximum individual wave height	H_{max}	m	8.34	10.30	11.23	11.57
Maximum individual wave crest	C_{max}	m	5.33	6.58	7.17	7.38
Surface current speed	U_{surf}	$m.s^{-1}$	0.17	0.21	0.25	0.27
Mid-depth current speed	U_{mid}	$m.s^{-1}$	-	-	-	-
Near-bottom current speed	U_{bot}	$m.s^{-1}$	0.08	0.13	0.18	0.20

Table 7.4 Annual independent East extreme criteria for wind, wave and current at P1.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	14.72	19.33	22.51	23.88
10min wind speed	U_{10min}	$m.s^{-1}$	15.78	20.87	24.40	25.91
1 min wind speed	U_{1min}	$m.s^{-1}$	17.15	22.86	26.82	28.53
3s wind gust	U_{3s}	$m.s^{-1}$	18.92	25.44	29.98	31.93
Significant wave height	H_s	m	2.99	4.66	5.75	6.20
Peak wave period	T_p	s	16.71	19.21	20.27	20.63
Maximum individual wave height	H_{max}	m	6.13	8.98	10.52	11.02
Maximum individual wave crest	C_{max}	m	3.91	5.75	6.75	7.06
Surface current speed	U_{surf}	$m.s^{-1}$	0.20	0.29	0.36	0.40
Mid-depth current speed	U_{mid}	$m.s^{-1}$	-	-	-	-
Near-bottom current speed	U_{bot}	$m.s^{-1}$	-	-	-	-

Table 7.5 Annual independent South-East extreme criteria for wind, wave and current at P1.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	14.05	18.54	21.63	22.95
10min wind speed	U_{10min}	$m.s^{-1}$	15.04	20.01	23.43	24.89
1 min wind speed	U_{1min}	$m.s^{-1}$	16.32	21.89	25.74	27.39
3s wind gust	U_{3s}	$m.s^{-1}$	17.99	24.35	28.76	30.65
Significant wave height	H_s	m	-	-	-	-
Peak wave period	T_p	s	-	-	-	-
Maximum individual wave height	H_{max}	m	-	-	-	-
Maximum individual wave crest	C_{max}	m	-	-	-	-
Surface current speed	U_{surf}	$m.s^{-1}$	0.40	0.50	0.56	0.59
Mid-depth current speed	U_{mid}	$m.s^{-1}$	0.22	0.29	0.34	0.36
Near-bottom current speed	U_{bot}	$m.s^{-1}$	0.14	0.19	0.23	0.24

Table 7.6 Annual independent South extreme criteria for wind, wave and current at P1.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	10.57	14.03	16.25	17.19
10min wind speed	U_{10min}	$m.s^{-1}$	11.25	15.01	17.45	18.47
1 min wind speed	U_{1min}	$m.s^{-1}$	12.12	16.29	18.98	20.11
3s wind gust	U_{3s}	$m.s^{-1}$	13.25	17.94	20.98	22.26
Significant wave height	H_s	m	-	-	-	-
Peak wave period	T_p	s	-	-	-	-
Maximum individual wave height	H_{max}	m	-	-	-	-
Maximum individual wave crest	C_{max}	m	-	-	-	-
Surface current speed	U_{surf}	$m.s^{-1}$	0.31	0.38	0.42	0.44
Mid-depth current speed	U_{mid}	$m.s^{-1}$	0.20	0.27	0.31	0.33
Near-bottom current speed	U_{bot}	$m.s^{-1}$	0.19	0.23	0.26	0.28

Table 7.7 Annual independent South-West extreme criteria for wind, wave and current at P1.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	12.86	16.39	18.90	19.99
10min wind speed	U_{10min}	$m.s^{-1}$	13.74	17.60	20.34	21.54
1 min wind speed	U_{1min}	$m.s^{-1}$	14.87	19.15	22.20	23.52
3s wind gust	U_{3s}	$m.s^{-1}$	16.35	21.17	24.61	26.11
Significant wave height	H_s	m	-	-	-	-
Peak wave period	T_p	s	-	-	-	-
Maximum individual wave height	H_{max}	m	-	-	-	-
Maximum individual wave crest	C_{max}	m	-	-	-	-
Surface current speed	U_{surf}	$m.s^{-1}$	0.18	0.23	0.29	0.31
Mid-depth current speed	U_{mid}	$m.s^{-1}$	-	-	-	-
Near-bottom current speed	U_{bot}	$m.s^{-1}$	-	-	-	-

Table 7.8 Annual independent West extreme criteria for wind, wave and current at P1.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	13.10	15.84	17.66	18.43
10min wind speed	U_{10min}	$m.s^{-1}$	14.00	17.00	18.99	19.83
1 min wind speed	U_{1min}	$m.s^{-1}$	15.16	18.49	20.71	21.64
3s wind gust	U_{3s}	$m.s^{-1}$	16.67	20.44	22.94	24.00
Significant wave height	H_s	m	-	-	-	-
Peak wave period	T_p	s	-	-	-	-
Maximum individual wave height	H_{max}	m	-	-	-	-
Maximum individual wave crest	C_{max}	m	-	-	-	-
Surface current speed	U_{surf}	$m.s^{-1}$	0.21	0.31	0.41	0.46
Mid-depth current speed	U_{mid}	$m.s^{-1}$	-	-	-	-
Near-bottom current speed	U_{bot}	$m.s^{-1}$	-	-	-	-

Table 7.9 Annual independent North-West extreme criteria for wind, wave and current at P1.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	11.58	14.91	17.16	18.12
10min wind speed	U_{10min}	$m.s^{-1}$	12.35	15.98	18.45	19.49
1 min wind speed	U_{1min}	$m.s^{-1}$	13.33	17.36	20.09	21.25
3s wind gust	U_{3s}	$m.s^{-1}$	14.61	19.15	22.23	23.55
Significant wave height	H_s	m	-	-	-	-
Peak wave period	T_p	s	-	-	-	-
Maximum individual wave height	H_{max}	m	-	-	-	-
Maximum individual wave crest	C_{max}	m	-	-	-	-
Surface current speed	U_{surf}	$m.s^{-1}$	0.47	0.71	0.87	0.95
Mid-depth current speed	U_{mid}	$m.s^{-1}$	0.30	0.48	0.60	0.66
Near-bottom current speed	U_{bot}	$m.s^{-1}$	0.23	0.43	0.57	0.63

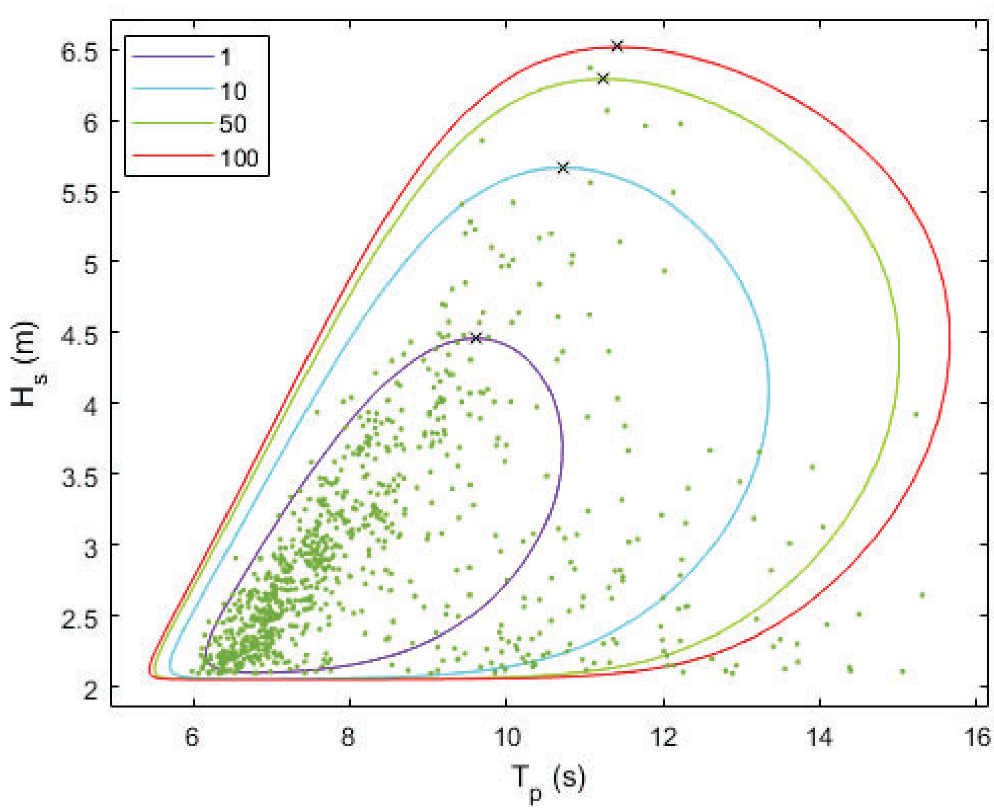

Figure 7.1 Contour plot of omni-directional bi-variate (Hs-Tp) return period values for 1, 10, 50 and 100-year ARIs. The dark crosses correspond to the estimated deterministic Hs and associated Tp return period values for each ARI indicated in the legend at P1.

7.2. P2

The directional return period values for wind, wave and current extremes are given in Table 7.10 to Table 7.18 for 1, 10, 50 and 100-year return periods.

Contour plot of omni-directional bi-variate return period values for significant wave height and peak wave period are presented in Figure 7.2.

Table 7.10 Annual independent omni-directional extreme criteria for wind, wave and current at P2.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	17.89	21.51	23.93	24.95
10min wind speed	U_{10min}	$m.s^{-1}$	19.27	23.26	25.93	27.06
1 min wind speed	U_{1min}	$m.s^{-1}$	21.04	25.51	28.50	29.77
3s wind gust	U_{3s}	$m.s^{-1}$	23.35	28.44	31.85	33.29
Significant wave height	H_s	m	4.51	5.74	6.39	6.62
Peak wave period	T_p	s	9.72	10.91	11.48	11.67
Maximum individual wave height	H_{max}	m	8.64	10.66	11.61	11.96
Maximum individual wave crest	C_{max}	m	5.59	6.83	7.42	7.63
Surface current speed	U_{surf}	$m.s^{-1}$	0.49	0.63	0.72	0.76
Mid-depth current speed	U_{mid}	$m.s^{-1}$	0.30	0.39	0.46	0.48
Near-bottom current speed	U_{bot}	$m.s^{-1}$	0.27	0.36	0.42	0.45

Table 7.11 Annual independent North extreme criteria for wind, wave and current at P2.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	13.87	16.85	18.87	19.73
10min wind speed	U_{10min}	$m.s^{-1}$	14.84	18.12	20.35	21.29
1 min wind speed	U_{1min}	$m.s^{-1}$	16.10	19.76	22.25	23.31
3s wind gust	U_{3s}	$m.s^{-1}$	17.74	21.89	24.72	25.93
Significant wave height	H_s	m	2.54	3.42	3.90	4.08
Peak wave period	T_p	s	6.95	7.79	8.18	8.32
Maximum individual wave height	H_{max}	m	4.89	6.41	7.21	7.47
Maximum individual wave crest	C_{max}	m	3.12	4.08	4.62	4.79
Surface current speed	U_{surf}	$m.s^{-1}$	0.21	0.33	0.41	0.45
Mid-depth current speed	U_{mid}	$m.s^{-1}$	0.10	0.14	0.18	0.20
Near-bottom current speed	U_{bot}	$m.s^{-1}$	0.17	0.25	0.31	0.33

Table 7.12 Annual independent North-East extreme criteria for wind, wave and current at P2.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	13.89	17.47	19.83	20.82
10min wind speed	U_{10min}	$m.s^{-1}$	14.87	18.81	21.42	22.52
1 min wind speed	U_{1min}	$m.s^{-1}$	16.13	20.54	23.46	24.69
3s wind gust	U_{3s}	$m.s^{-1}$	17.77	22.79	26.11	27.52
Significant wave height	H_s	m	4.42	5.55	6.04	6.20
Peak wave period	T_p	s	9.75	10.65	11.00	11.11
Maximum individual wave height	H_{max}	m	8.48	10.50	11.43	11.77
Maximum individual wave crest	C_{max}	m	5.38	6.66	7.24	7.45
Surface current speed	U_{surf}	$m.s^{-1}$	0.17	0.20	0.24	0.26
Mid-depth current speed	U_{mid}	$m.s^{-1}$	-	-	-	-
Near-bottom current speed	U_{bot}	$m.s^{-1}$	-	-	-	-

Table 7.13 Annual independent East extreme criteria for wind, wave and current at P2.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	14.39	18.98	22.09	23.42
10min wind speed	U_{10min}	$m.s^{-1}$	15.42	20.48	23.93	25.40
1 min wind speed	U_{1min}	$m.s^{-1}$	16.74	22.42	26.29	27.94
3s wind gust	U_{3s}	$m.s^{-1}$	18.46	24.93	29.36	31.25
Significant wave height	H_s	m	2.85	4.45	5.47	5.90
Peak wave period	T_p	s	16.96	19.22	20.14	20.45
Maximum individual wave height	H_{max}	m	5.75	8.48	10.16	10.71
Maximum individual wave crest	C_{max}	m	3.67	5.46	6.50	6.84
Surface current speed	U_{surf}	$m.s^{-1}$	0.23	0.30	0.37	0.40
Mid-depth current speed	U_{mid}	$m.s^{-1}$	-	-	-	-
Near-bottom current speed	U_{bot}	$m.s^{-1}$	-	-	-	-

Table 7.14 Annual independent South-East extreme criteria for wind, wave and current at P2.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	13.56	18.02	21.05	22.35
10min wind speed	U_{10min}	$m.s^{-1}$	14.51	19.43	22.78	24.22
1 min wind speed	U_{1min}	$m.s^{-1}$	15.72	21.24	25.01	26.62
3s wind gust	U_{3s}	$m.s^{-1}$	17.31	23.59	27.91	29.75
Significant wave height	H_s	m	-	-	-	-
Peak wave period	T_p	s	-	-	-	-
Maximum individual wave height	H_{max}	m	-	-	-	-
Maximum individual wave crest	C_{max}	m	-	-	-	-
Surface current speed	U_{surf}	$m.s^{-1}$	0.41	0.51	0.58	0.60
Mid-depth current speed	U_{mid}	$m.s^{-1}$	0.25	0.30	0.34	0.36
Near-bottom current speed	U_{bot}	$m.s^{-1}$	0.19	0.25	0.29	0.31

Table 7.15 Annual independent South extreme criteria for wind, wave and current at P2.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	10.30	13.88	16.29	17.31
10min wind speed	U_{10min}	$m.s^{-1}$	10.96	14.85	17.48	18.60
1 min wind speed	U_{1min}	$m.s^{-1}$	11.80	16.10	19.01	20.26
3s wind gust	U_{3s}	$m.s^{-1}$	12.90	17.73	21.01	22.41
Significant wave height	H_s	m	-	-	-	-
Peak wave period	T_p	s	-	-	-	-
Maximum individual wave height	H_{max}	m	-	-	-	-
Maximum individual wave crest	C_{max}	m	-	-	-	-
Surface current speed	U_{surf}	$m.s^{-1}$	0.27	0.34	0.38	0.39
Mid-depth current speed	U_{mid}	$m.s^{-1}$	0.12	0.18	0.24	0.28
Near-bottom current speed	U_{bot}	$m.s^{-1}$	0.20	0.24	0.28	0.29

Table 7.16 Annual independent South-West extreme criteria for wind, wave and current at P2.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	12.16	15.50	17.87	18.90
10min wind speed	U_{10min}	$m.s^{-1}$	12.98	16.62	19.21	20.33
1 min wind speed	U_{1min}	$m.s^{-1}$	14.03	18.06	20.92	22.16
3s wind gust	U_{3s}	$m.s^{-1}$	15.40	19.93	23.16	24.56
Significant wave height	H_s	m	-	-	-	-
Peak wave period	T_p	s	-	-	-	-
Maximum individual wave height	H_{max}	m	-	-	-	-
Maximum individual wave crest	C_{max}	m	-	-	-	-
Surface current speed	U_{surf}	$m.s^{-1}$	0.18	0.24	0.31	0.34
Mid-depth current speed	U_{mid}	$m.s^{-1}$	-	-	-	-
Near-bottom current speed	U_{bot}	$m.s^{-1}$	-	-	-	-

Table 7.17 Annual independent West extreme criteria for wind, wave and current at P2.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	13.07	15.71	17.45	18.19
10min wind speed	U_{10min}	$m.s^{-1}$	13.97	16.85	18.76	19.57
1 min wind speed	U_{1min}	$m.s^{-1}$	15.12	18.33	20.45	21.35
3s wind gust	U_{3s}	$m.s^{-1}$	16.63	20.25	22.65	23.66
Significant wave height	H_s	m	-	-	-	-
Peak wave period	T_p	s	-	-	-	-
Maximum individual wave height	H_{max}	m	-	-	-	-
Maximum individual wave crest	C_{max}	m	-	-	-	-
Surface current speed	U_{surf}	$m.s^{-1}$	0.24	0.34	0.40	0.42
Mid-depth current speed	U_{mid}	$m.s^{-1}$	-	-	-	-
Near-bottom current speed	U_{bot}	$m.s^{-1}$	-	-	-	-

Table 7.18 Annual independent North-West extreme criteria for wind, wave and current at P2.

Parameter	Symbol	Units	Return period (year)			
			1	10	50	100
Hourly wind speed	U_{1h}	$m.s^{-1}$	11.61	14.97	17.26	18.24
10min wind speed	U_{10min}	$m.s^{-1}$	12.38	16.04	18.55	19.62
1 min wind speed	U_{1min}	$m.s^{-1}$	13.37	17.43	20.21	21.40
3s wind gust	U_{3s}	$m.s^{-1}$	14.65	19.23	22.37	23.72
Significant wave height	H_s	m	-	-	-	-
Peak wave period	T_p	s	-	-	-	-
Maximum individual wave height	H_{max}	m	-	-	-	-
Maximum individual wave crest	C_{max}	m	-	-	-	-
Surface current speed	U_{surf}	$m.s^{-1}$	0.45	0.69	0.87	0.95
Mid-depth current speed	U_{mid}	$m.s^{-1}$	0.28	0.43	0.55	0.60
Near-bottom current speed	U_{bot}	$m.s^{-1}$	0.23	0.40	0.53	0.58

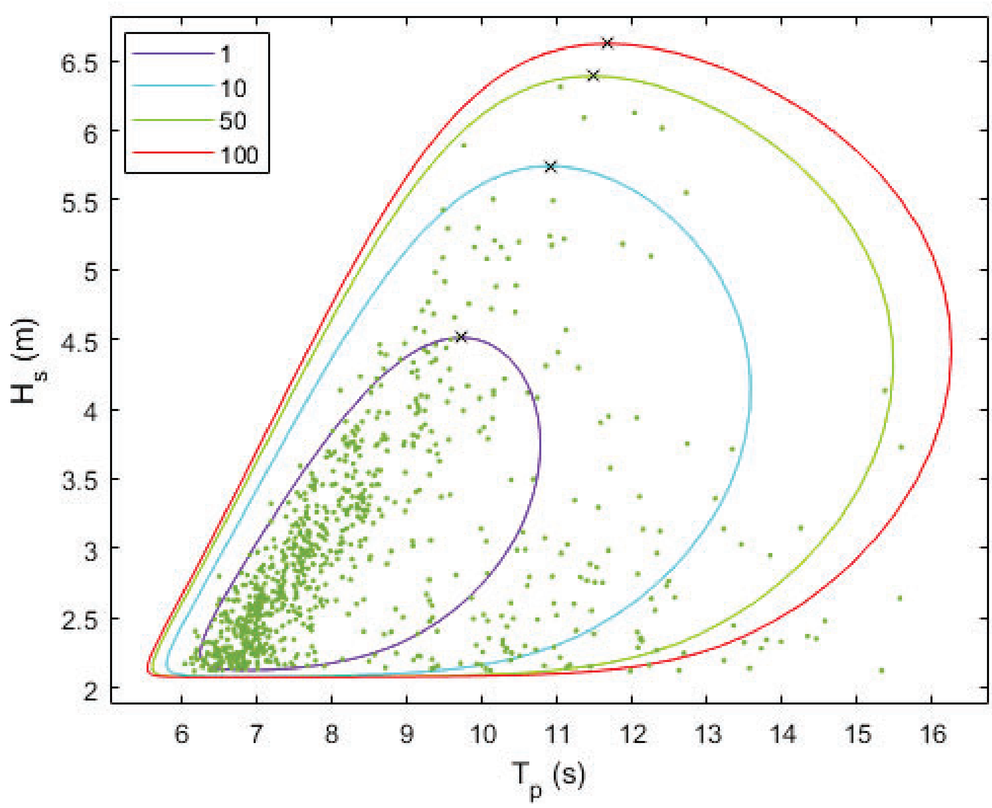

Figure 7.2 Contour plot of omni-directional bi-variate (Hs-Tp) return period values for 1, 10, 50 and 100-year ARIs. The dark crosses correspond to the estimated deterministic Hs and associated Tp return period values for each ARI indicated in the legend at P2.

8. Nov 2018 – Jun 2019

In this section, metocean statistics for the period Nov 2018 – Jun 2019 for one representative site P1 are compared to the long term statistics in Table 8.1 - Table 8.5, Figure 8.1 - Figure 8.5.

From Nov 2018 – Jun 2019, wind conditions were slightly below the averaged long term conditions from 1979-2019, while wave height conditions were significantly lower than the averaged values (Table 8.1 and Table 8.2). The maximum values for wind speed and significant wave height within the period Nov 2018 - Jun 2019 (15.50 $m.s^{-1}$ and 2.83 m, respectively) were also significantly lower than the 1-year omnidirectional ARI values (i.e. 19.74 $m.s^{-1}$ and 4.46 m, respectively, see Table 7.1).

From Nov 2018 – Jun 2019, current conditions were slightly below the averaged long term conditions from 2000-2019 at all levels through the water column (Table 8.3-Table 8.5). The maximum values for current speeds for the period Nov 2018 - Jun 2019 (0.38, 0.20 and 0.17 $m.s^{-1}$ for surface, mid-depth and near-bottom, respectively) were also significantly lower than the 1-year omnidirectional ARI values (i.e. 0.51, 0.30 and 0.26 $m.s^{-1}$, respectively, see Table 7.1).

At the studied location on the east side of NZ, storm conditions are dominated by the passage of post-tropical cyclones, typically from November to April. The weather effects from the last cyclone season (2018-2019) were less severe than the typical storm conditions at the studied location.

Table 8.1 Comparison between the long term wind speed statistics and the recent Nov 2018 – Jun 2019 period at P1. Only the Nov-Jun period is considered for each year.

Parameter	Units	Period	Mean	P25	P75	P99	Max
Wind speed, U_{10min}	**$m.s^{-1}$**	**1979-2019 average**	6.22	4.10	8.02	14.39	18.92
		Nov 2018-Jun 2019	5.45	3.43	7.20	12.45	15.50

Table 8.2 Comparison between the long term significant wave height statistics and the recent Nov 2018 – Jun 2019 period at P1. Only the Nov-Jun period is considered for each year.

Parameter	Units	Period	Mean	P25	P75	P99	Max
Significant wave Height, Hs	**m**	**1979-2019 average**	0.94	0.56	1.15	2.94	4.30
		Nov 2018-Jun 2019	0.74	0.51	0.90	2.04	2.83

Table 8.3 Comparison between the long term residual surface current speed statistics and the recent Nov 2018 – Jun 2019 period at P1. Only the Nov-Jun period is considered for each year.

Parameter	Units	Period	Mean	P25	P75	P99	Max
Surface current speed, U_{surf}	**$m.s^{-1}$**	**2000-2019 average**	0.11	0.06	0.15	0.34	0.48
		Nov 2018-Jun 2019	0.10	0.04	0.14	0.29	0.38

Table 8.4 Comparison between the long term residual mid-depth current speed statistics and the recent Nov 2018 – Jun 2019 period at P1. Only the Nov-Jun period is considered for each year.

Parameter	Units	Period	Mean	P25	P75	P99	Max
Mid-depth current speed, U_{mid}	**$m.s^{-1}$**	**2000-2019 average**	0.06	0.03	0.08	0.20	0.29
		Nov 2018-Jun 2019	0.05	0.02	0.08	0.16	0.20

Table 8.5 Comparison between the long term residual near-bottom current speed statistics and the recent Nov 2018 – Jun 2019 period at P1. Only the Nov-Jun period is considered for each year.

Parameter	Units	Period	Mean	P25	P75	P99	Max
Near-bottom current speed, U_{bot}	**$m.s^{-1}$**	**2000-2019 average**	0.05	0.02	0.07	0.17	0.25
		Nov 2018-Jun 2019	0.04	0.02	0.05	0.13	0.17

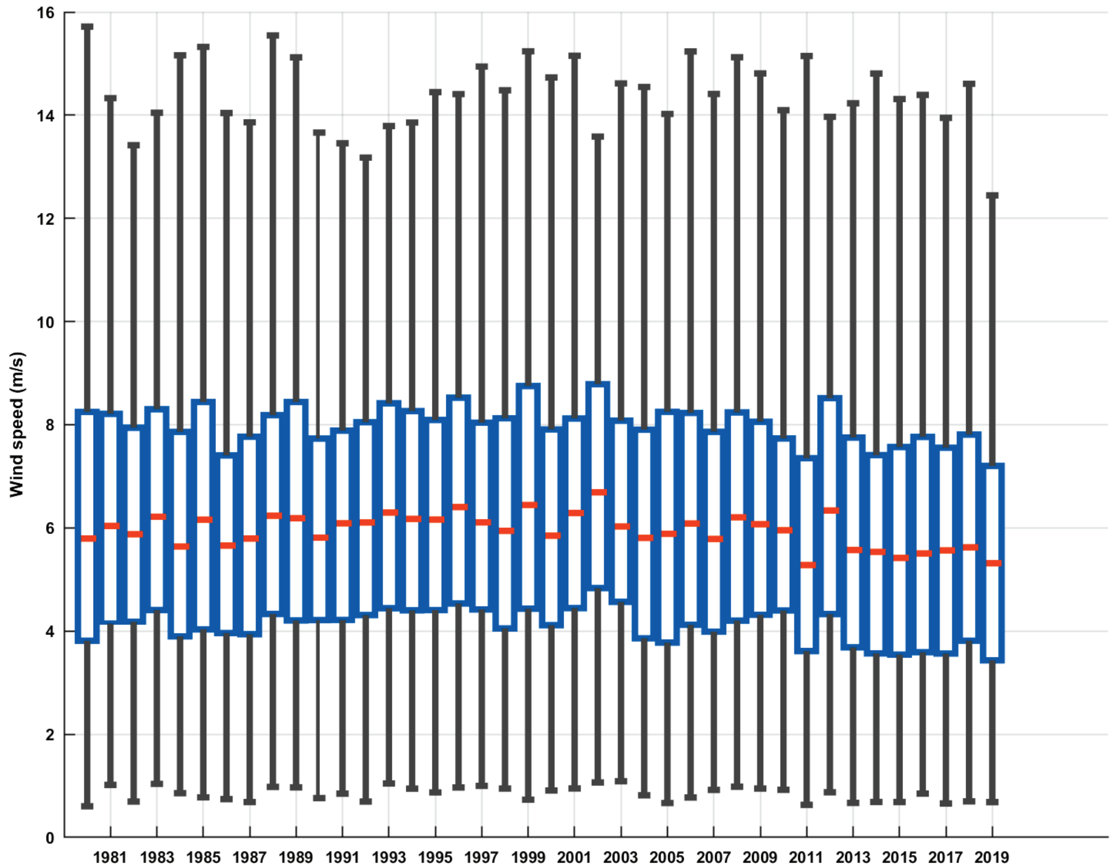

Figure 8.1 *Box plot of wind speed considering only the period Nov-Jun for each year since 1979 at P1. Each period is labelled by the year corresponding the end of the period (e.g. Nov 2018 - Jun 2019 is labelled "2019" on the x-axis). The blue boxes are delimited by the 25th and 75th percentiles of each period bin, while the red line indicates the median and the limits of the dark lines are the 1st and 99th percentiles.*

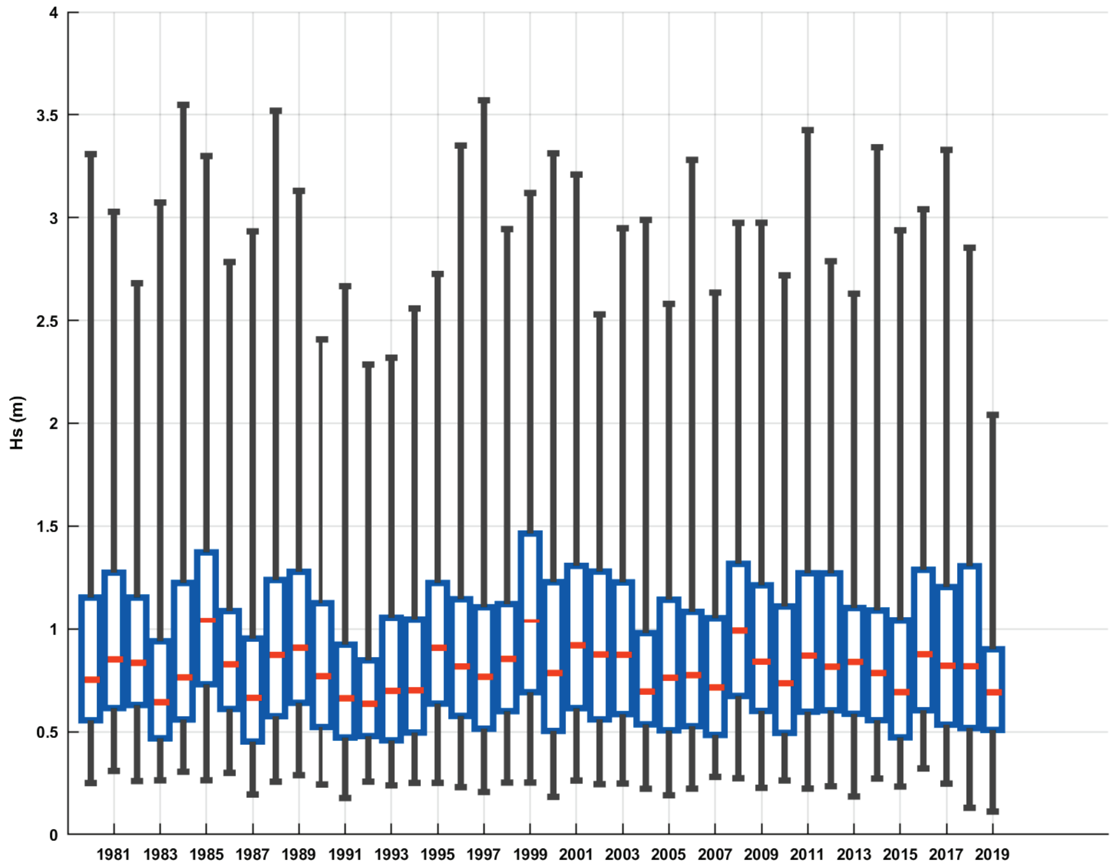

Figure 8.2 As Figure 8.1 but for significant wave height.

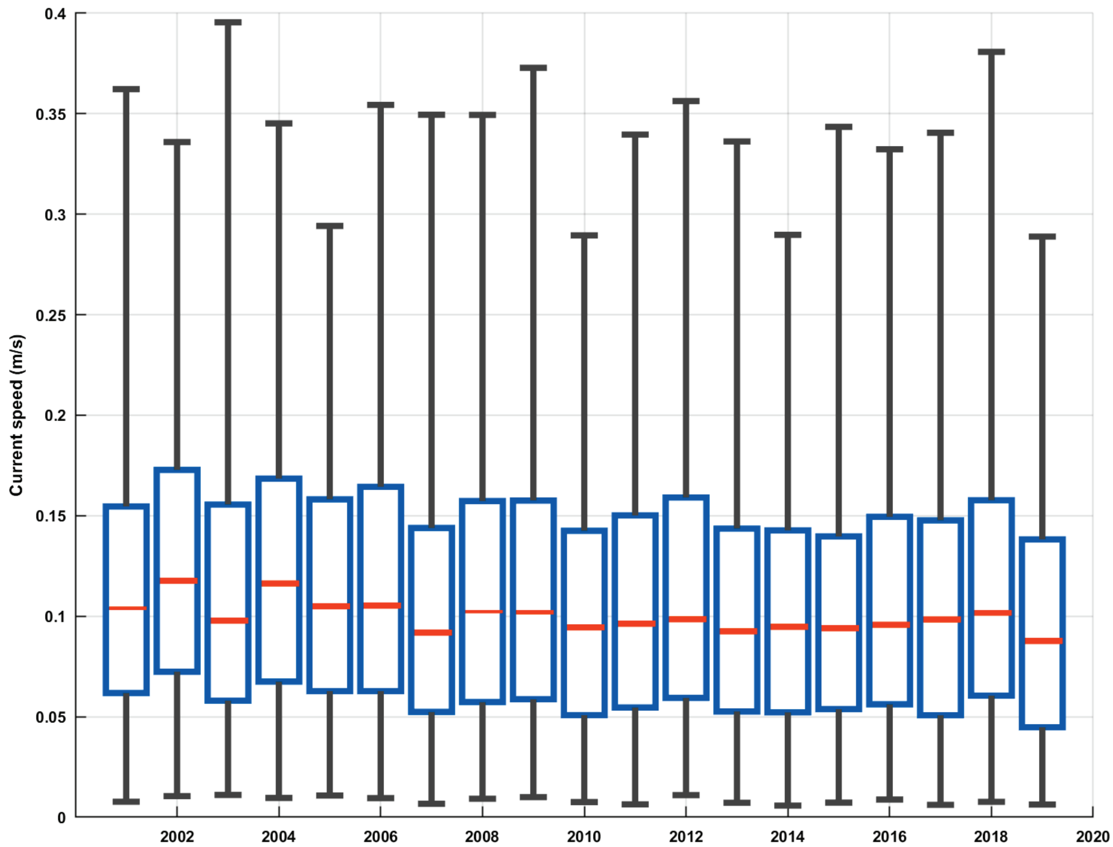

Figure 8.3 As Figure 8.1 but for residual surface current speed.

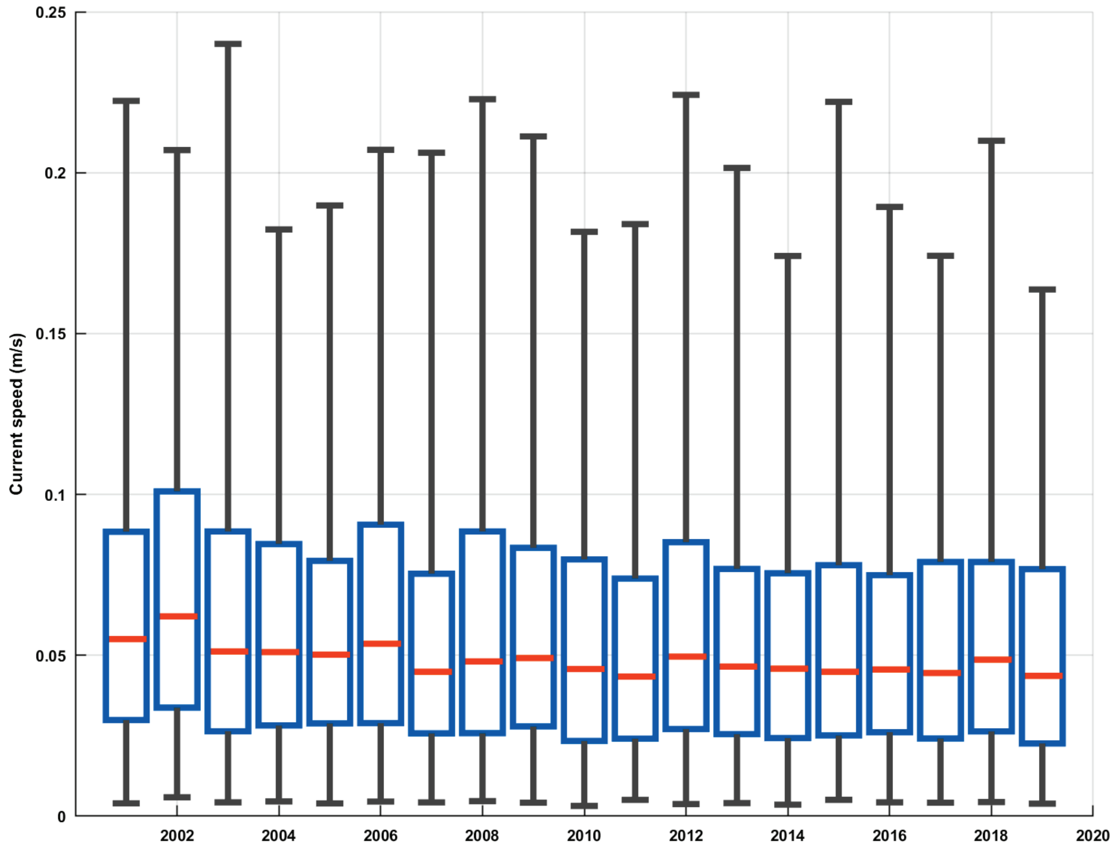

Figure 8.4 As Figure 8.1 but for residual mid-depth current speed.

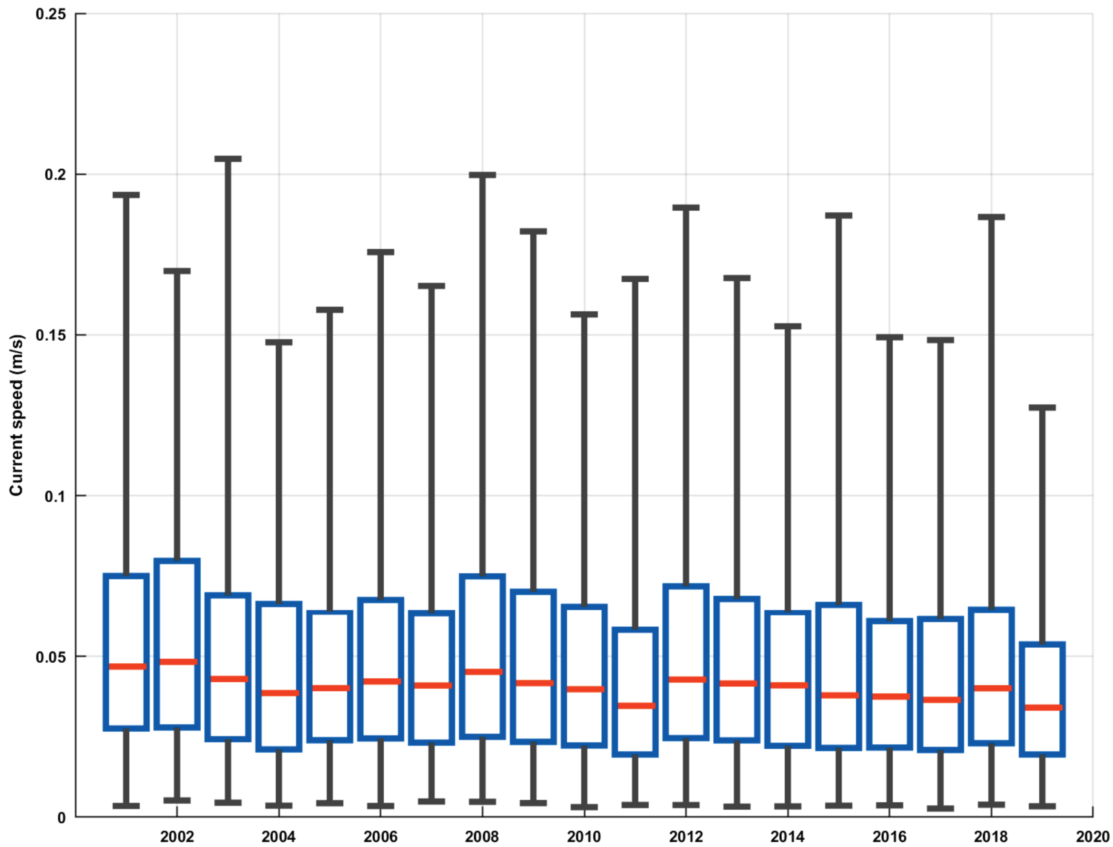

Figure 8.5 As Figure 8.1 but for residual near-bottom current speed.

9. Analytical methods

9.1. Wind

In order to define the design wind speeds, the 10-minute velocity means were extrapolated to shorter (i.e. 3 and 60 seconds) and longer periods (i.e. 1 hour) using the guidelines provided by ISO (2015).

9.2. Wave

The wave spectra were post-processed to calculate wave statistics for the total wave field, as well as for sea and swell components. The spectral partitioning method consists of a split at the frequency corresponding to 8 s period, with sea and swell assigned to the high- and low-frequency parts, respectively. For the total spectra and each partition, one-dimensional frequency spectra were defined by integrating over all directions:

$$E(f) = \int_{-\pi}^{\pi} E(f,\theta)d\theta. \qquad (9.1)$$

Spectral moments were calculated as

$$m_x = \iint f^x E(f,\theta)df\,d\theta, \qquad (9.2)$$

The significant wave height, Hs, mean direction at peak energy, θp, and peak wave period, Tp , are defined as:

$$H_s = 4\sqrt{m_0}, \qquad (9.3)$$

$$Dpm = \tan^{-1}\frac{\int_{-\pi}^{\pi} E(f_p,\theta)\sin\theta\,d\theta}{\int_{-\pi}^{\pi} E(f_p,\theta)\cos\theta\,d\theta}, \qquad (8.4)$$

$$T_p = 1/f_p, \qquad (9.5)$$

where fp is the peak wave frequency of the one-dimensional spectra and En(fp,θ) is the energy contained in the peak wave frequency band. Note that Tp and θp require spectral peaks within a given partition and are not defined when peaks are not identified for that partition.

9.3. Extreme

Directional return period values have been calculated from the hindcast time series of wind, wave and current.

A *Peaks over Threshold* (POT) sampling method is used for event selection, applying the 95th percentile exceedance level as the threshold with a 24 hour window. For wind extreme value analysis (EVA), the 3-parameter Weibull distribution were applied, with Maximum Likelihood Method (MLM) used to find the best-fit of the sampled events to the model distribution. For wave EVA, the selected events were fitted to a Pareto distribution, with the location parameter fixed by the threshold and the MLM used to obtain the scale and shape parameters.

Bivariate return period values were calculated for significant wave height and peak period. The method of Repko et al. (2005) was employed, which considers the distribution of H_s and wave steepness, s. A joint probability distribution function (PDF) is calculated by multiplying marginal distributions of H_s and s (thus assuming they are independent), after which the PDF is transformed back into H_s/T_p space. In addition, a minimum wave steepness threshold of 0.005 is applied to exclude events with very long wave periods, which are not believed to be representative of extreme conditions.

The marginal distributions for H_s and s are estimated by fitting the POT values to a Weibull distribution using the maximum likelihood method (as implemented in the WAFO toolbox). Contours of the return period values were constructed from the joint PDF using the Inverse FORM method (Winterstein et al., 1993) at the return year levels.

The methods used to estimate extreme maximum individual wave height (H_{max}) and maximum wave crest (C_{max}) account for the long-term uncertainty in the severity of the environment and the short-term uncertainty in the severity of the maximum wave of a given sea state, as suggested by Tromans and Vanderschuren (1995) and recommended by ISO (2015). The most probable value of the extreme individual wave height (H_{mp}) of each storm is obtained from the product of the Foristall distributions of individual wave height in each hindcast interval within the storm duration (Forristall, 1978; ISO, 2015). The same technique is used for the most probable value of the extreme individual wave crest (C_{mp}) but using the Weibull distribution with scale and shape parameters dependent on the wave steepness and the Ursell number (ISO, 2015; Forristall, 2000). Note that the resulting short-term distributions for each storm are dependent on the number of intervals with H_s values near the region of maximum peak H_s. The uncertainty in the height and crest of the maximum wave of any storm is represented as a short-term probability distribution conditional on H_{mp} and C_{mp}, respectively (Tromans and Vanderschuren, 1995). The long-term distributions of H_{mp} and C_{mp} are then fitted to Pareto distributions. Finally, the convolutions of the short- and long-term distributions give the complete long-term distributions of H_{max} and C_{max} (Tromans and Vanderschuren, 1995; ISO 2015).

Note an arbitrary minimum number of 10 storm peaks has been was chosen for reliable distribution fitting. This results in specific directional return period values being omitted.

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Appendix F. Assessment of Biogenic Sand Production. Report by Bioresearchers, October 2019

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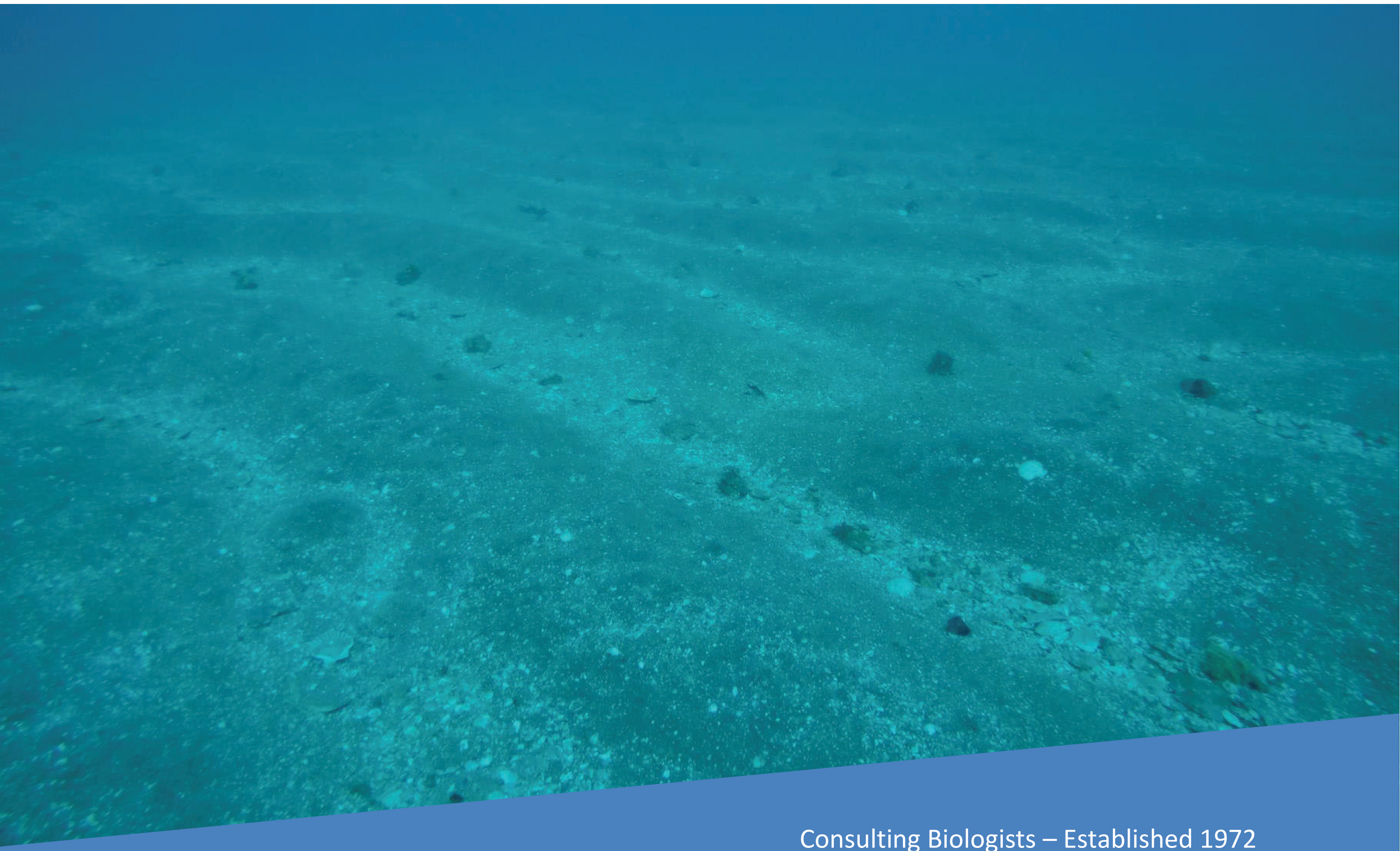
Assessment of Biogenic Sand Production, Pakiri Embayment

October 2019



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Assessment of Biogenic Sand Production, Pakiri Embayment October 2019

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Approved for Release:	Chris Wedding, M.Sc. (Hons) Manager – Ecological Services/Business Unit

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Reference: Bioresearches (2019). Assessment of Biogenic Sand Production, Pakiri Embayment. Report for McCallum Brothers Limited. pp 36

Cover Illustration: Seabed sandscape showing Biogenic shell lag (May 2014)

CONTENTS

1. INTRODUCTION

1.1 Biogenic Sand

Sands in the Pakiri – Mangawhai embayment are primarily quartzo-feldspathic (Schofield, 1970). The sands also contain varying amounts of carbonate, which is generally of biological origin. Biogenic sand is defined as the fraction of sand formed by dead marine biota, and is mostly composed of molluscs, echinoids, foraminifera and bryozoans (De Falco *et al*., 2017).

In order to provide input into a sand budget model, an assessment of the annual biogenic sand production in the Pakiri – Mangawhai embayment, has been calculated from population estimates of living shellfish in the benthic biota of the bay. The Pakiri – Mangawhai embayment has been defined for the purpose of this study, as from Bream Tail to Goat Island, based on these locations providing barriers, limiting but not excluding sand transport alongshore (Hume, 2005). The barriers are rocky reefs that extend from low tide, to at least 27m below mean sea level. The 25m below chart datum contour, which equates to 27m below mean sea level, was defined as the depth of closure during the previous consenting process in 2005 (Hilton, 1990; Healy, 1996; Hilton and Hesp, 1996) (Figure 1). All depths used henceforth in this report will be in reference to mean sea level.

The depth of closure (DOC) is an important concept used in coastal engineering as it defines the offshore extent of cross-shore sediment transport. The DOC is a theoretical depth along a beach profile where sediment transport is very small or non-existent. Its location is dependent on wave height and period, and occasionally, sediment grain size. More specifically, Kraus (1998) states that the "depth of closure for a given or characteristic time interval is the most landward depth seaward of which there is no significant change in bottom elevation and no significant net sediment transport between the nearshore and the offshore." Since the wave height and period change seasonally and over shorter time periods such as storm events, the DOC will theoretically change, this is supported by Nicholls *et al*. (1998), Dolbeth *et al.* (2007) and Carvalho *et al*. (2012). Therefore, rather than a specific or average depth, the DOC should be expressed as a depth range or transitional zone. The transport of material across this average DOC "boundary" is not precluded as the actual DOC would vary depending on wave conditions. Therefore, the additional area offshore of the 27m average DOC, covering 27 – 32m has been included as a separate area in the calculations of biogenic sand production.

1.2 Previous Studies

Hilton (1990) quantified the carbonate content of surficial sediments south of Te Arai Point. In the fine, very well sorted sands of the upper shoreface, Hilton reported the carbonate was only 2-5% of the total sample in depths less than 27m, however this increased to 20-30% in the area between the 27 – 32m depth contours. Hilton determined that the carbonates consisted mostly of fragments of benthic macrofauna of molluscan origin. Based on the benthic biota data collected in the embayment since 1990 (ASR, 2003, 2006, Bioresearches, 1993, 2011, 2016, 2017, 2019a,b, Grace 1991, 2005) this has not changed with molluscs still dominating the biota.

Hilton (1990), by integrating data from trawls, was able to estimate the total mass of live shell material in the surficial seabed sediments (the top 10-15 cm in this case). He reported an average concentration of shell of 97g/m^2.

Hilton (1990) assumed that for a shellfish species of a 10-year life expectancy, 10% of the population would die every year and the shell becomes part of the biogenic sand. This assumes a constant population size, and that recruitment and mortality were constant, which they are generally not. It also appears that he assumed all shellfish had a similar life span, which is also not a valid assumption. His assumptions were based on the information available in 1990, greater information on life span is now available but the population size, mortality and recruitment are still not well understood. Based on these assumptions, he calculated that the existing weight of shell material, 5,300 tonnes, would increase to 73,000,000 tonnes after 100 years. This calculation was incorrect. Hilton mistakenly added the dead shell material back to the live shell material each year for a compounding recalculation of dead shell production over the 100-year time frame. This process grossly overestimated the production of dead shell material over time. Based on his assumptions the live shellfish population was not expected to change year to year therefore the production should be the same each year. Even if the shellfish population varied in size between years the expected dead shell production would not approach the tonnage Hilton calculated. Correcting Hiltons dead shell production calculation overtime, results in an annual shell material production of 530 tonnes, translating to 482m^3/year assuming shell material has a density of 1.1Mg/m^3. Hume *et al.* (1999) suggests these values cover half the bay and should be doubled to a corrected value of 964m^3/year, which is considerably less than that Hilton reported in 1990 of 900,000m^3/year.

The NIWA sand study (Hume *et al.*, 1999) considered Hilton's original shell production value of 900,000m^3/year erroneous and suggested biogenic sand production was less than 12,000m^3/year based on a sediment budget. Barnett in his 2005 environment court evidence suggested it should be near 90,000m^3/year. Neither of the latter estimates of Barnett or NIWA were based on biological science. Hilton's (1990) corrected estimate of 964m^3/year is based on actual biological production but was subject to invalid assumptions which could have resulted in greater production. None of the studies have measured annual variation in production or the effects of long-term ecological changes such as species loss on production.

1.3 Current Study

This assessment is based on the fauna abundance data collected as part of the assessment of effects of sand extraction from the McCallum Bros Ltd (MBL) consented areas in, and from areas further offshore in 2019 (Bioresearches, 2019a,b); from the assessment of effects of the Auckland Offshore sand extraction by Kaipara Limited in 2017 (Bioresearches, 2017); and from an intertidal seafood resources survey for Auckland Regional Council in 1993 (Bioresearches, 1994). In addition, growth rate equations were obtained from New Zealand and international literature. This estimation can be added to that of the non-biogenic sand (i.e. from river, shore and cliff) to make the total sediment input to the budget of the bay.

The study is initially based on the previously accepted enclosed embayment model with a DOC at 27m below mean sea level. It excludes the Mangawhai estuary as a biogenic sand source as estuaries are considered to be sediment "sinks" rather than sources. In addition to the predefined DOC embayment area, an area offshore has been added to the assessment for biogenic sand production, as have rocky shore habitats not previous assessed, and the results provided for each individual area.

MBL has a current consent to extract a maximum allowance of 76,000m^3/year of sand in consent defined extraction areas as shown in pink in Figure 1 and Figure 2 within a nominal water depth range of 7 to 12m. If the consent is to be renewed, the assessment of biogenic sand production will likely form part of the assessment determining a suitable volume of sand for extraction.

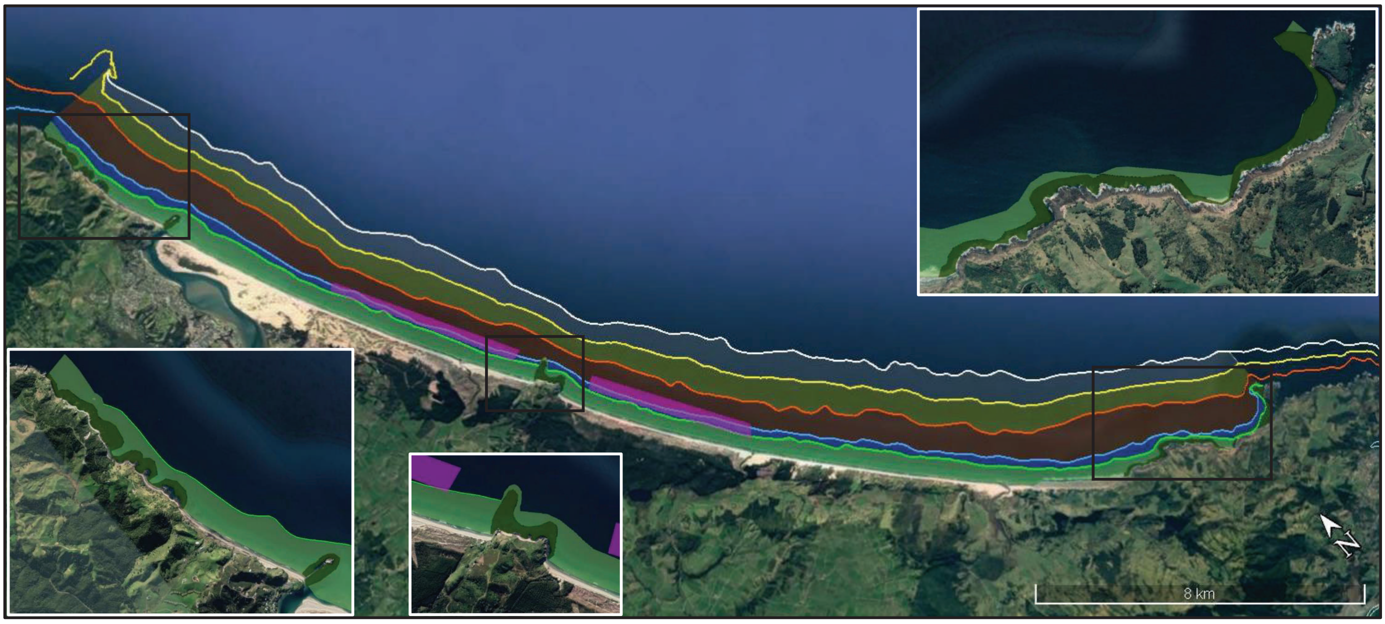

Figure 1 ***Pakiri – Mangawhai embayment with bathymetry mean sea level contours (light green: 7m; blue: 12m; orange: 22m; yellow: 27m; white 32m), the extent of the areas within these contours, and the extraction areas (in pink). The surface considered for the rocky shore is presented in dark green in the three inserts. Map produced with Google Earth 2019 ©.***

2. METHODS

The annual biogenic sand production has been estimated following four major steps:

a) The estimation of densities of benthic biota taxa in number per 100m²
b) The estimation of the shell weight in g/100m²
c) The estimation of the annual shell production (growth) in g/100m² /year
d) The extrapolation of the 3 parameters above for each area and for the whole bay

2.1 Density of benthic biota taxa

The most recent assessment of benthic biota in the Pakiri – Mangawhai embayment, was conducted in early 2019 and used two sampling methods to determine its relative abundance and diversity:

1. **Benthic Infauna:** this involved the collection of 117 samples of benthic biota with a box dredge (18cm wide to a depth of approximately 5-10cm, for a length of approximately 90cm) in a pattern uniformly distributed from the shore to the 27m bathymetric contour on each side of Te Arai point, following a sampling design by Dr Grace. Sample locations are shown in Figure 2 as white squares. Subsamples were screened through a 1mm mesh sieve, and the total sample through a 3.15mm mesh sieve. The 1mm screened samples consisted mostly of polychaetes, amphipods and isopods (Bioresearches 2019a), which are considered a minor source for sand formation. Polychaetes have no calcareous part and small arthropods have a fragile chitin exoskeleton, which would degrade quickly, thus not contributing significantly to biogenic sand production. Therefore, only the 3.15mm screened samples, which contained molluscs and echinoderms, were considered for the biogenic sand production calculation.
2. **Benthic Epifauna:** this involved 33 (65cm wide) variable length dredge tows targeting different depths (white thick lines in Figure 2). The dredge was fitted with a 15mm square mesh bag, thus retained larger biota, the majority of which were molluscs and benthic arthropods, for which the individual lengths were measured.

Analyses of benthic biota showed little difference in community composition and densities between the area north of Te Arai point and the area south of Te Arai point (Bioresearches 2019a, b), but revealed significant differences between inshore (< 12m depth) areas and deeper ones, highlighting the importance of depth in shaping the benthic community composition. Based on these results, biota samples were separated into three depth defined areas, 7 to 12m, 12 to 22m and 22 to 27m, then used to estimate the production of biogenic sand in each area, and the calculations subsequently combined to assess sand production at the level of the whole Pakiri – Mangawhai embayment.

The current 2019 study did not sample from much less than 7m depth. It is known from historical studies (Bioresearches, 1994, 2016) that this 0 – 7m zone has potentially high numbers of some taxa which are not present in deeper waters, such as the tuatua *Paphies subtriangulata*. In addition, rocky shores are present north and south of the embayment, and at Te Arai Point, with gastropod communities different from the rest of the Bay which is dominated by soft sediment. Therefore, the 0 – 7m depth zone has been included and the historical data used to define densities of taxa present. The first historical study relevant to the surf zone of Pakiri Beach and the rocky shore is the assessment of intertidal seafood resources in 1993 where quantitative sampling of edible seafood was carried out at every kilometre along the beach (Bioresearches, 1994). Sample sites are marked as yellow diamonds in Figure 2. The second historical study is the assessment of the benthic ecology along the Hawaiki submarine cable route project landing on the northern part of the Pakiri – Mangawhai embayment (Bioresearches, 2016). Subtidal benthic biota was assessed by grab sampling and tow sampling at regular depths along the cable route. The grab samples only provided qualitative information on biota (presence, not densities) at regular depths, as there were only up to three samples per bathymetry area, and this was considered insufficient to represent the quantity of clumped-distributed species such as molluscs.

While the DOC of the Pakiri – Mangawhai embayment was defined as the 27m depth contour in the 2005 environment court hearing, this does not totally, preclude transport of material across this depth contour as this theoretical boundary is likely the midpoint of a transitional depth range across which limited on-offshore transport intermittently occurs. Therefore, the biogenic sand production from the 27m – 32m depth contours has also been calculated. The samples collected in this area were from three different methods (Table 1): 20 box dredge samples were collected during the 2019 inshore-midshore survey detailed previously (Bioresearches, 2019b). In addition, 31 grab samples were collected with a Ponar grab sampler (229 x 229 mm), and 8 dredge tow samples were also available from a previous study in 2017 (Bioresearches, 2017) orange squares and lines in Figure 2). Data sets from the three samples methods were combined, and the highest average density from either method was retained for each taxon in each depth-defined area.

The four studies use differing sampling methods and also sampled different faunal populations as represented by the differing composition of biota. Therefore the biogenic sand production calculation was based on a combination of the methods, providing representation of all major contributors of sand production. When the data sets were combined, the highest average density from either method was retained for each taxon in each depth-defined area.

The surface area for each of the five areas (0 to 7m, 7 to 12m, 12 to 22m, 22 to 27m, and 27 to 32m) was calculated by defining a polygon constrained by the bathymetry contours relative to mean sea level defined from the Land information New Zealand chart NZ3000522 in Google Earth. The extent of the bay was constrained in the north, to a line between Bream Tail and McGregor Rock, and in the south to a line north from the northern point of Goat Island. A 27m bathymetry contour was interpolated from the 22 and 32m contours using QGIS software. Table 1 presents the surface of each area and identifies the samples collected in each area. The embayment as described has a total surface area of 55,246,242m² to the 27m contour, or 71,064,438m² to the 32m contour.

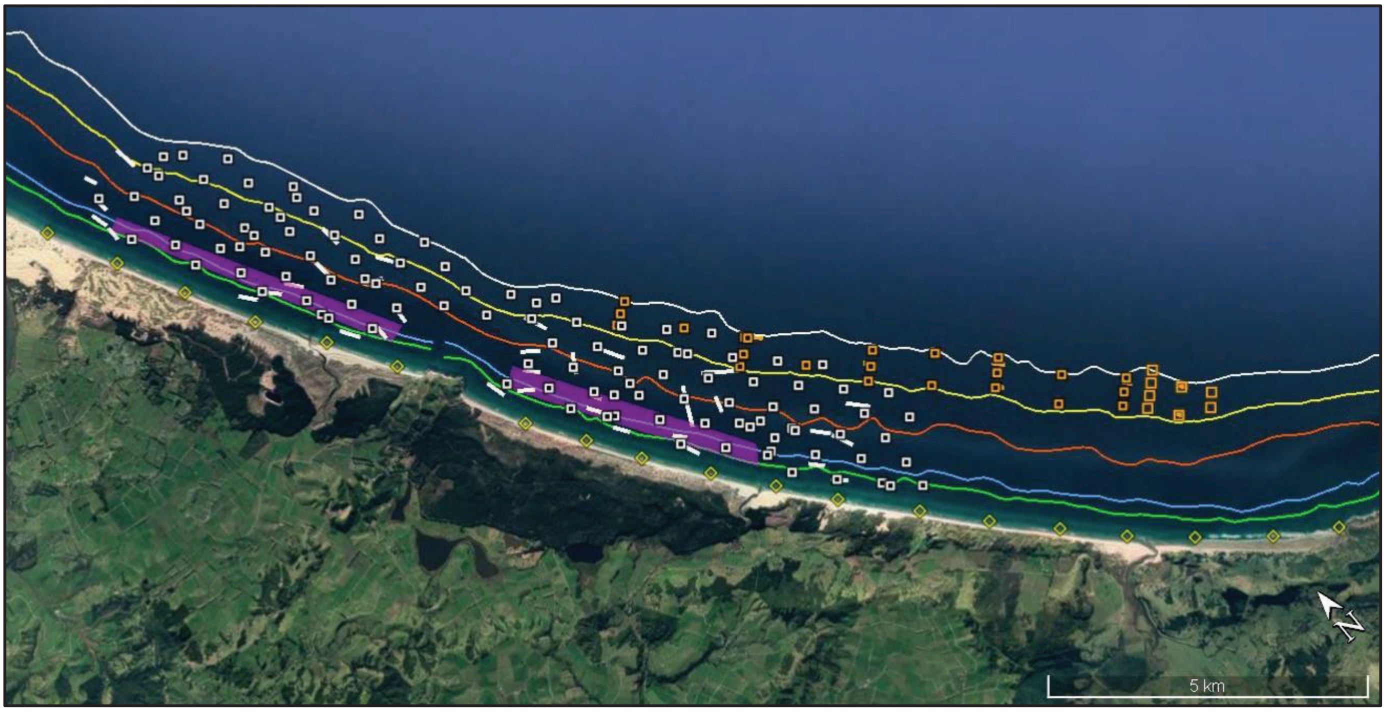

Figure 2 Pakiri – Mangawhai embayment with bathymetry contours, benthic infauna samples and epifauna tows. Map produced with Google Earth 2019 ©.

Key

bathymetry contours (green: 5m; blue: 10m; orange: 20m; yellow: 25m; white: 30m)

benthic infauna samples (white squares: 2019 box dredge samples; Orange squares: 2017 grab samples; yellow diamonds: 1993 quadrats)

epifauna dredge tows (white lines: 2019 samples; orange lines: 2017 samples)

The sand extraction areas are shaded in pink.

Table 1 Benthic samples used to determine the number, weight and growth of biota for biogenic sand calculation.

Area		Rocky shore	0 – 7m depth	7m - 12m depth	12m - 22m depth	22m - 27m depth	27m – 32m depth
Surface (m²)		1,011,139 m²	11,549,658 m²	5,754,054 m²	20,968,451 m²	16,558,156 m²	15,818,196 m²
Infauna (Box dredge)	**Sample codes (PIB)**	-	-	1, 4, 5, 11, 18, 19, 27, 39, 44, 45, 46, 62, 68, 75, 82, 88, 94, 100, 114	2, 3, 8, 9, 10, 16, 17, 25, 26, 32, 33, 52, 53, 54, 60, 61, 66, 67, 73, 74, 80, 81, 86, 87, 92, 93, 101, 103, 104, 105, 106, 108, 111, 117, 121	6, 7, 13 to 15, 22 to 24, 30, 31, 36 to 38, 42, 43, 50, 51, 57 to 59, 64, 65, 70 to 72, 78, 79, 84, 85, 90, 91, 95, 96, 102, 107, 112, 115, 116, 119, 120	12, 20, 21, 28, 29, 34, 35, 40, 41, 49, 56, 63, 69, 76, 77, 83, 89, 110, 113, 118
	Total (year sampled)	**-**	**-**	**19** (2019)	**35** (2019)	**40** (2019)	**20** (2019)
Infauna (grab sample)	**Sample codes**	-	Extrapolated from historical studies (see text)	-	-	-	TN(W), T0(W, 0, 1), T1(W), T2(W, 0, 1), T3(W), T4(0, 1, 2), T5(W,M), T6(1, 2, 3), T7(W, M), T8(1, 2, 3), T9(1, 2, 3, 4), TC(M, W), T10(1, 2)
	Total (year sampled)	-		**-**	**-**	**-**	**31** (2017)
Epifauna (Tow dredge)	**Tow codes**	-	-	22 to 35	8, 9, 11 to 21	1 to 7, 10	T2A, T4A, T6A, T6B, T8A, T8B, TCA, TCB
	Total (year sampled)	**-**	**-**	**14** (2019)	**13** (2019)	**8** (2019)	**8** (2017)
Intertidal seafood	**Sample codes**	7, 21 to 24	1 to 6, 8 to 20				
	Total (year sampled)	**5** (1993)	**19** (1993)				

The surface area sampled by the infauna box dredge was assumed to be relatively constant between samples and estimated to be 0.162m² based on a width of 0.18m and a tow length of approximately 0.9m. The length of each epifauna dredge tow was more variable and calculated surfaces are displayed in Table A 1. The surface area sampled by the infauna grab sampler was calculated as 0.05m² based on a length of 0.229m either side. The biota data from all sampling methods were tabulated, and abundance standardised to numbers per 100m².

Previous analyses of the 94 infauna box dredge samples (3.15mm size mesh) within the 27m depth contour found a total of 104 taxa (Table A 2). To simplify the calculation of shell growth, the original number of taxa was reduced following two steps:

- The taxa with little or no "shell" component (grey text in Table A 2) were discarded for the shell weight and gross calculation.
- The species with a significant "shell" part but with no information on weight and growth, were combined to a higher taxonomic level for which equations from the international literature existed.

Previous analyses of the 35 epifauna dredge tow samples within the 27m depth contour found a total of 29 taxa (Table A 3). Like the infauna samples, the number of taxa were reduced by eliminating those with little or no "shell" component, and in addition, those taxa for which only one individual over the 35 tows were recorded.

Historical intertidal data at Pakiri found tuatua *P. subtriangulata* to be common all along the beach (Table A 4) (Bioresearches 1994). The average density and size of *P. subtriangulata* were used for the estimation of biogenic sand production in the 0 to 7m area. During the study along the Hawaiki cable route (Bioresearches, 2016), two samples of benthic biota were collected within the 7m depth zone: a benthic grab sample at 4m depth, and a 100m long dredge tow centred on the grab sampling location. The sand dollar *Fellaster zelandiae* was found in both samples, while the paddle crab *Ovalipes catharus* was only present in the tow sample. Densities of these two species for the 0 to 7m zone were extrapolated from the densities calculated from the 7 to 12m area. The wheel shell *Zethalia zelandica* was added to the densities of tuatua, paddle crabs and sand dollars, as its distribution is common in shallow depths of soft-bottomed systems and can have dense beds (Hayward & Morley, 2004). Its distribution is clumped thus the high probability of being missed by the 4m grab sample along the cable route.

For the area 27m to 32m with three different types of samples, reduction of taxa followed the same steps as above (removal of taxa with little or "no shell" component and grouping of taxa with one individual only for the whole dataset). The original taxa are presented in Table A 5 (grab samples), Table A 6 (tow samples) and Table A 7 (box samples).

2.2 Shell weight

Of those taxa identified as present in sufficient density, estimates of shell weight /100m² were calculated from individual green weights[1] for each retained taxon. Individual green weights were estimated from the average length measured from tow samples using length-weight equations from the literature (Table A 8). The paddle crab *O. catharus*, the bivalves *Dosinia subrosea*, *Perna canaliculus* and *P. subtriangulata*, and the urchin *Evechinus chloroticus* were the only species with specific information from New Zealand. The green weights of other species found in the Pakiri – Mangawhai embayment samples were estimated from

[1] The weight of fish, aquatic life, or seaweed before any processing commences and before any part is removed.

equations of related species from same genera or families (Table A 8). When taxa had no measured length associated (*i.e.* only collected in box dredge samples), the maximum length found in the literature was used.

2.3 Annual Growth rate shell production

The production of green weight per year was estimated by using taxa specific growth curves from the literature. In most cases, the growth curves correlate age (year) with length (mm), not weight. Therefore, individual lengths at different ages were first calculated with growth equations, then converted to green weight using length-weight equations. Individual growth rates (weight gained per year) were calculated by subtracting the green weights between two consecutive ages. They were averaged to make an average individual green weight growth.

The estimated individual green weight growth was then converted to an individual shell weight growth by applying an estimated percentage of shell weight to green weight (see note 3 in Table A 8). The term "shell" here is not limited to the shell calcium carbonate of molluscs but is also used as a general term for the chitin of arthropods, the test of echinoderms, and the notochord of cephalochordates.

Finally, the individual shell weight growth was multiplied by the number of individuals per $100m^2$ to calculate annual shell weight growth in g /$100m^2$ per year for each taxon.

The methodology presented above uses the average length of each taxon to calculate weight, and the average growth rate over the life span of the animal. However, growth rate can change significantly through life with a rapid growth in the first years and a slow growth when animals reach maturity. Here, the average length of each taxon was used as one age cohort only. Ideally, age-specific growth rates would be used on an age distribution, but for most taxa, growth-specific information was not available. Therefore, the estimation of biogenic production from non-specific averaged growth rates has uncertainties which could not be quantified. In order to check the magnitude of the calculated biogenic production, another method was used by using maximum biomass and maximum age for each taxon and is described below.

2.4 Population mortality shell production

An alternative methodology employed in part by Hilton in 1990, relies on a percentage of the population, based on the maximum age of each taxon, dying each year. This method assumes that recruitment will be the same each year, and that mortality will only occur at maximum age. Both of these assumptions are not likely to be met as such population data is not generally available for the taxon included in this study. However, if these assumptions were true then the production can be given by the equation below, where p= annual shell production; w_i = the weight of the maximum length for the i^{th} taxon (calculated using the length-weight equations from the literature); d_i = the population density (No./$100m^2$) for the i^{th} taxon; a_i = the maximum age for the i^{th} taxon; and N = the total number of taxa in the sample.

$$p = \sum_{i=1}^{i=N} \frac{(w_i \times d_i)}{a_i}$$

If the assumption of zero juvenile mortality is not met, then this method would overestimate the shell production as fewer individuals will reach maximum size. If the assumption of equal recruitment is not met, then the production will vary between years leading to both over and underestimations. If more detailed information were available on size specific mortality, then the calculation could be modified to reflect this. Similarly, if the variation in recruitment were known then production could be expressed as a range. The method also assumes no variation in growth rates between individuals. Growth rates do vary between individuals as commonly shown by population size frequency plots, in which older age cohorts tend to have a wider size range spread, than younger age cohorts.

The maximum age of a taxon is required for this calculation method, and this basic information is not currently known for many species. Hilton assumed that all biota lived to 10 years of age, which is now known not to be valid. Thus, if taxon were shorter lived than 10 years his method underestimated mortality biomass production. Hilton also used the average population size rather than maximum size in his calculation of the mortality biomass. Again, this will have underestimated the mortality biomass production. This study has used more taxa specific maximum age and size estimates than employed in Hilton (1990) and is therefore a better reflection of actual production.

2.5 Shell production for the Pakiri – Mangawhai embayment

To determine the annual shell production for depth defined areas the equation below was used. Here, P = total production of shell per year (Mg) for the embayment as defined to the 27m depth contour; G_i = the annual shell weight growth (g/100m²/yr) for the i^{th} taxon; SA = the surface area of the depth-defined area; and N = the total number of taxa in the area. The production from the adjacent deeper 27 - 32m area has also been calculated separately to allow its inclusion if it is determined as relevant based on the wave climate.

$$P = \sum_{i=1}^{i=N} \frac{(G_i \times SA)}{100}$$

To convert shell production from weight to volume (m³) the density of the shell material is required. The literature suggests compacted shell density ranges between about 1.1Mg/m³ and 1.4Mg/m³ depending on the species (Eziefula *et al*., 2018, Mo *et al.*, 2018). A previous study by NIWA on sand budget in the bay assumed a shell density of 1.6Mg/m³ (Hume *et al*., 1999), however this was not substantiated. A range of values between 1.1 to 1.4Mg/m³ has been used to provide estimates of the likely range in the volume of biogenic sand produced.

3. RESULTS

3.1 Density of benthic biota taxa

Table A 2 to Table A 7 in the appendices, summarise the original number of taxa and individuals found in the soft sediment, and on the rocky shore. After the reduction of taxa to those likely to produce carbonate shell content, numbers were converted to densities per 100m². The data from the infauna and epifauna surveys were then pooled and separated into habitat type and depth-defined areas. Table 2 to Table 7 provide summaries of data divided by habitat and depth range.

For taxa appearing in both the infauna and epifauna surveys, the data from the survey with the highest density was retained. This was always the box dredge infauna method. However, the epifauna method recorded some taxa not found in the infauna survey, and similarly the reverse also occurred.

Each of these tables consists of two parts: the first, defined by white heading text, is based on the annual growth rate calculations. The second, defined by yellow heading text, is based on the population mortality calculation method.

3.2 Weight and shell production

For the annual growth rate part (blue heading white text) of Table 2 to Table 7, each table is divided by thicker lines into three sections across the table;

a) Left: This covers population density and average length.
b) Middle: This uses formula to estimate green weight based on length, then applies an estimate of percentage shell and density to calculate shell weight per area.
c) Right: This summarises the results of calculations for annual shell growth

The length-weight equations and growth rate equations used for each taxon are listed in Table A 8.

For the mortality part (blue heading yellow text) of Table 2 to Table 7, each table is divided by thicker lines into three sections across the table;

a) Left: This covers population density and maximum size.
b) Middle: This uses formula to estimate green weight based on maximum length, then applies an estimate of percentage shell and density to calculate shell weight of maximum-sized individual per area.
c) Right: This presents a maximum age per taxa and calculates annual weight of shell released by mortality.

Table 8 presents the area of each habitat and depth area and summarises the shell production data from both methods. A total weight of shell production from each method for the entire Pakiri – Mangawhai embayment to the predefined 27m below mean sea level DOC, is presented as bold red numbers. The bold italic red numbers show the range of total volume produced per year by each method. The row of blue numbers at the bottom represent the area 27m – 32m depth, located just offshore of the DOC to the embayment.

Table 2 Weight and growth estimated for the rocky shore area 0m – 7m deep following two methodologies

Taxonomic group	Taxa	Density	Survey method	Average length	Actual Weight				Annual growth		
					Individual Green weight	Percentage Shell	Individual shell weight	Shell weight	Individual growth	Individual shell growth	Shell growth
		No. /100m²		(mm)	(g)	%	(g)	(g/100m²)	(g/y)	(g/y)	(g/100m²/y)
Gastropods	*Nerita melanotragus*	10680	quadrat	16	0.4	85	0.34	3631	0.94	0.80	8533
	Cellana ornate	5567	quadrat	18	0.4	70	0.28	1559	0.94	0.66	3663
	Cellana radians	3240	quadrat	26	0.7	70	0.49	1588	0.94	0.66	2132
	Lepsiella scobina	42625	quadrat	15	0.4	85	0.34	14493	3.69	3.14	133693
	Melagraphia aethiops	4767	quadrat	15	3.0	85	2.55	12155	0.94	0.80	3809
	Turbo smaragdus	4400	quadrat	26	4.0	85	3.40	14960	0.94	0.80	3516
	Cookia sulcata	1450	quadrat	58	14.0	85	11.90	17255	0.94	0.80	1159
	Haustrum haustorium	550	quadrat	41	5.3	85	4.51	2478	10.00	8.50	4675
	Thais orbita	3750	quadrat	41	5.3	85	4.51	16894	20.00	17.00	63750
Bivalves	*Perna canaliculus*	3100	quadrat	69	32.0	65	20.80	64480	10.00	6.50	20150
Echinoderms	*Evechinus chloroticus*	3125	quadrat	60	65.0	20	13.00	40625	9.00	1.80	5625
Arthropods	*Leptograpsus variegatus*	1800	quadrat	-	5.0	20	1.00	1800	0.50	0.10	180
Total		**85054**						**191919**			**250885**

Taxonomic group	Taxa	Density	Survey method	Maximum length	Maximum Weight				Annual mortality	
					Individual Green weight	Percentage Shell	Individual shell weight	Shell weight	Maximum age	Shell mortality
		No. /100m²		(mm)	(g)	%	(g)	(g/100m²)	(y)	(g/100m²/y)
Gastropods	*Nerita melanotragus*	10680	quadrat	30	1.1	85	0.94	9986	6	1664
	Cellana ornate	5567	quadrat	50	2.0	70	1.40	7793	6	1299
	Cellana radians	3240	quadrat	50	2.0	70	1.40	4536	6	756
	Lepsiella scobina	42625	quadrat	34	7.8	85	6.63	282604	9	31400
	Melagraphia aethiops	4767	quadrat	30	7.1	85	6.04	28767	6	4794
	Turbo smaragdus	4400	quadrat	91	100.0	85	85.00	374000	8	46750
	Cookia sulcata	1450	quadrat	119	117.0	85	99.45	144203	8	18025
	Haustrum haustorium	550	quadrat	65	30.4	85	25.84	14212	8	1777
	Thais orbita	3750	quadrat	110	200.0	85	170.00	637500	8	79688
Bivalves	*Perna canaliculus*	3100	quadrat	160	110.0	65	71.50	221650	4	55413
Echinoderms	*Evechinus chloroticus*	3125	quadrat	160	230.0	20	46.00	143750	15	9583
Arthropods	*Leptograpsus variegatus*	1800	quadrat	50	10.0	20	2.00	3600	4	900
Total		**85054**						**1872604**	**7 (mean max. age)**	**252050**

Table 3 Weight and growth estimated for the Sandy area 0m – 7m deep following two methodologies

Taxonomic group	Taxa	Density	Survey method	Average length	Actual Weight				Annual growth		
					Individual Green weight	Percentage Shell	Individual shell weight	Shell weight	Individual growth	Individual shell growth	Shell growth
		No. /100m²		(mm)	(g)	%	(g)	(g/100m²)	(g/y)	(g/y)	(g/100m²/y)
Arthropods	*Ovalipes catharus*	130	Box	37	11.4	20	2.28	296	69.00	13.80	1794
Gastropods	*Zethalia zelandica*	9617	Box	10	2.0	80	1.60	15387	0.94	0.75	7232
Bivalves	*Paphies subtriangulata*	1244	quadrat	28	15.0	65	9.75	12129	0.20	0.13	162
Echinoderms	*Fellaster zelandiae*	422	Box	47	10.0	90	9.00	3798	3.10	2.79	1177
Total		**11413**						**31610**			**10365**

Taxonomic group	Taxa	Density	Survey method	Maximum length	Maximum Weight				Annual mortality	
					Individual Green weight	Percentage Shell	Individual shell weight	Shell weight	Maximum age	Shell mortality
		No. /100m²		(mm)	(g)	%	(g)	(g/100m²)	(y)	(g/100m²/y)
Arthropods	*Ovalipes catharus*	130	Box	130	378.0	20	75.60	9825	4	2456
Gastropods	*Zethalia zelandica*	9617	Box	26	6.0	80	4.80	46162	6	7694
Bivalves	*Paphies subtriangulata*	1244	quadrat	80	74.0	65	48.10	59836	5	11967
Echinoderms	*Fellaster zelandiae*	422	Box	100	18.0	90	16.20	6836	10	684
Total		**11413**						**122659**	**6 (mean max. age)**	**22801**

Table 4 Weight and growth estimated for the Sandy area 7m – 12m deep following two methodologies

Taxonomic group	Taxa	Density	Survey method	Average length	Actual Weight				Annual growth		
					Individual Green weight	Percentage Shell	Individual shell weight	Shell weight	Individual growth	Individual shell growth	Shell growth
		No. /100m²		(mm)	(g)	%	(g)	(g/100m²)	(g/y)	(g/y)	(g/100m²/y)
Arthropods	*Pagurus setosus*	65	box	9	0.2	20	0.04	3	0.30	0.06	4
	Ovalipes catharus	130	box	24	3.4	20	0.68	88	69.0	13.80	1793
	other arthropods	487	box	10	0.3	20	0.06	29	0.30	0.06	29
Gastropods	*Cominella adspersa*	3	tow	35	5.3	80	4.24	11	3.69	2.95	8
	Zethalia zelandica	9617	box	10	2.0	80	1.60	15387	0.94	0.75	7232
	Amalda australis	227	box	30	3.3	80	2.64	600	3.69	2.95	671
	other gastropod	97	box	25	2.0	80	1.60	156	2.77	2.22	216
Bivalves	*Myadora* spp.	162	box	28	9.0	50	4.50	731	3.50	1.75	284
	Dosinia subrosea	227	box	40	30.0	65	19.50	4435	7.00	4.55	1035
Echinoderms	*Fellaster zelandiae*	422	box	47	8.0	90	7.20	3041	3.10	2.79	1178
	Amphiura sp.	2	tow	80	5.0	90	4.50	7	1.50	1.35	2
	Astropecten polyacanthus	6	tow	130	16.0	90	14.40	82	3.10	2.79	16
Chordates	*Epigonichthys hectori*	422	box	40	0.3	20	0.06	25	0.20	0.04	17
Total		**11867**						**24595**			**12485**

Taxonomic group	Taxa	Density	Survey method	Maximum length	Maximum Weight				Annual mortality	
					Individual Green weight	Percentage Shell	Individual shell weight	Shell weight	Maximum age	Shell mortality
		No. /100m²		(mm)	(g)	%	(g)	(g/100m²)	(y)	(g/100m²/y)
Arthropods	*Pagurus setosus*	65	box	15	10.0	20	2.00	130	4	32
	Ovalipes catharus	130	box	130	378.0	20	75.60	9825	4	2456
	other arthropods	487	box	15	10.0	20	2.00	975	4	244
Gastropods	*Cominella adspersa*	3	tow	65	32.0	80	25.60	67	9	8
	Zethalia zelandica	9617	box	26	6.0	80	4.80	46160	6	7693
	Amalda australis	227	box	40	7.8	80	6.24	1419	9	142
	other gastropod	97	box	44	15.0	80	12.21	1190	8	149
Bivalves	*Myadora* spp.	162	box	42	30.0	50	15.00	2437	11	244
	Dosinia subrosea	227	box	57	68.0	65	44.20	10052	11	1005
Echinoderms	*Fellaster zelandiae*	422	box	100	18.0	90	16.20	6842	10	684
	Amphiura sp.	2	tow	80	5.0	90	4.50	7	15	0
	Astropecten polyacanthus	6	tow	200	20.0	90	18.00	103	15	7
Chordates	*Epigonichthys hectori*	422	box	80	1.0	20	0.20	84	8	11
Total		**11867**						**79291**	**9 (mean max. age)**	**12578**

Table 5 Weight and growth estimated for the Sandy area 12m – 22m deep following two methodologies

Taxonomic group	Taxa	Density	Survey method	Average length	Actual Weight				Annual growth		
					Individual Green weight	Percentage Shell	Individual shell weight	Shell weight	Individual growth	Individual shell growth	Shell growth
		No. /100m²		(mm)	(g)	%	(g)	(g/100m²)	(g/y)	(g/y)	(g/100m²/y)
Arthropods	*Pagurus setosus*	194	box	16	0.8	20	0.15	29	0.30	0.06	12
	Crabs other than *Ovalipes*	282	box	15	0.9	20	0.18	51	1.00	0.20	56
	other arthropods	317	box	10	0.3	20	0.06	19	0.30	0.06	19
Gastropods	*Zethalia zelandica*	53	box	10	2.0	80	1.60	85	0.94	0.75	40
	Sigapatella tenuis	247	box	5	0.01	50	0.005	1	0.10	0.05	12
	Austrofusus glans	1	tow	33	4.4	80	3.54	4	3.69	2.95	3
	Cominella adspersa	176	box	29	3.0	80	2.42	426	3.69	2.95	521
	Amalda spp.	141	box	25	2.0	80	1.56	220	3.69	2.95	417
	Struthiolaria papulosa	2	tow	60	25.9	80	20.70	34	3.69	2.95	5
	other gastropods	229	box	37	6.2	80	4.96	1137	3.69	2.95	677
Bivalves	*Myadora* spp.	1728	box	23	5.0	50	2.50	4321	3.50	1.75	3025
	Dosinia subrosea	88	box	25	10.0	65	6.50	573	7.00	4.55	401
	Nucula nitidula	494	box	13	0.2	50	0.10	49	0.10	0.05	25
	Glycymeris modesta	35	box	26	6.3	65	4.11	145	1.44	0.94	33
	Atrina zelandica	1	tow	45	8.7	65	5.68	4	12.60	8.19	6
	Gari convexa	459	box	25	0.5	65	0.33	152	1.43	0.93	426
Echinoderms	*Fellaster zelandiae*	212	box	47	8.0	90	7.20	1524	3.10	2.79	590
	Astropecten polyacanthus	9	tow	125	16.0	90	14.40	136	3.10	2.79	26
Total		**4668**						**8910**			**6294**

Taxonomic group	Taxa	Density	Survey method	Maximum length	Maximum Weight				Annual mortality	
					Individual Green weight	Percentage Shell	Individual shell weight	Shell weight	Maximum age	Shell mortality
		No. /100m²		(mm)	(g)	%	(g)	(g/100m²)	(y)	(g/100m²/y)
Arthropods	*Pagurus setosus*	194	box	15	10.0	20	2.00	388	4	97
	Crabs other than *Ovalipes*	282	box	100	200.0	20	40.00	11287	4	2822
	other arthropods	317	box	15	10.0	20	2.00	635	4	159
Gastropods	*Zethalia zelandica*	53	box	26	6.0	80	4.80	254	6	42
	Sigapatella tenuis	247	box	5	0.0	50	0.01	1	6	0
	Austrofusus glans	1	tow	65	32.0	80	25.60	26	9	3
	Cominella adspersa	176	box	65	32.0	80	25.60	4515	9	502
	Amalda spp.	141	box	40	7.8	80	6.24	880	9	98
	Struthiolaria papulosa	2	tow	65	32.0	80	25.60	42	9	5
	other gastropods	229	box	52	22.0	80	17.57	4028	9	448
Bivalves	*Myadora* spp.	1728	box	42	30.0	50	15.00	25926	11	2357
	Dosinia subrosea	88	box	57	68.0	65	44.20	3898	11	354
	Nucula nitidula	494	box	13	0.2	50	0.10	49	8	6
	Glycymeris modesta	35	box	26	5.0	65	3.25	115	10	11
	Atrina zelandica	1	tow	300	88.0	65	57.20	40	15	3
	Gari convexa	459	box	58	4.0	65	2.60	1192	8	149
Echinoderms	*Fellaster zelandiae*	212	box	100	18.0	90	16.20	3429	10	343
	Astropecten polyacanthus	9	tow	200	20.0	90	18.00	170	15	11
Total		**4668**						**56875**	**9 (mean max. age)**	**7411**

Table 6 ***Weight and growth estimated for the area Sandy 22m – 27m deep following two methodologies***

Taxonomic group	Taxa	Density	Survey method	Average length	Actual Weight				Annual growth		
					Individual Green weight	Percentage Shell	Individual shell weight	Shell weight	Individual growth	Individual shell growth	Shell growth
		No. /100m²		(mm)	(g)	%	(g)	(g/100m²)	(g/y)	(g/y)	(g/100m²/y)
Arthropods	*Pagurus setosus*	633	box	13	0.6	20	0.12	76	0.30	0.06	38
	Crabs other than *Ovalipes*	201	box	15	0.9	20	0.18	37	1.00	0.20	40
	other arthropods	340	box	10	0.3	20	0.06	20	0.30	0.06	20
Polyplacophora	*Leptochiton* sp.	93	box	10	0.1	50	0.05	5	0.30	0.15	14
Gastropods	*Stiracolpus pagoda*	170	box	24	0.5	80	0.40	68	1.00	0.80	136
	Sigapatella tenuis	293	box	5	0.01	50	0.003	1	0.10	0.05	15
	Cominella quoyana	355	box	21	1.16	80	0.93	329	3.69	2.95	1048
	Amalda spp.	154	box	25	2.0	80	1.56	241	3.69	2.95	456
	other gastropods	556	box	28	2.7	80	2.18	1209	0.20	0.16	89
Bivalves	*Myadora* spp.	401	box	23	5.0	50	2.50	1003	3.50	1.75	702
	Dosinia subrosea	247	box	25	10.0	65	6.50	1605	7.00	4.55	1123
	Nucula nitidula	509	box	13	0.2	50	0.10	204	0.10	0.05	25
	Glycymeris modesta	31	box	26	6.3	65	4.11	127	1.44	0.94	29
	Gari convexa	340	box	25	0.5	65	0.33	113	1.43	0.93	316
Echinoderms	*Amphiura* sp.	123	box	80	5.0	90	4.50	556	1.50	1.35	167
Chordates	*Epigonichthys hectori*	201	box	40	0.3	20	0.06	12	0.20	0.04	8
Total		**4647**						**6322**			**4226**

Taxonomic group	Taxa	Density	Survey method	Maximum length	Maximum Weight				Annual mortality	
					Individual Green weight	Percentage Shell	Individual shell weight	Shell weight	Maximum age	Shell mortality
		No. /100m²		(mm)	(g)	%	(g)	(g/100m²)	(y)	(g/100m²/y)
Arthropods	*Pagurus setosus*	633	box	15	10.0	20	2.00	1265	4	316
	Crabs other than *Ovalipes*	201	box	100	200.0	20	40.00	8025	4	2006
	other arthropods	340	box	15	10.0	20	2.00	679	4	170
Polyplacophora	*Leptochiton* sp.	93	box	30	4.0	50	2.00	185	15	12
Gastropods	*Stiracolpus pagoda*	170	box	24	0.5	80	0.40	68	3	23
	Sigapatella tenuis	293	box	5	0.01	50	0.01	1	6	0
	Cominella quoyana	355	box	21	1.2	80	0.96	341	9	38
	Amalda spp.	154	box	40	7.8	80	6.24	963	9	107
	other gastropods	556	box	43	13.4	80	10.75	5970	7	853
Bivalves	*Myadora* spp.	401	box	42	30.0	50	15.00	6019	11	547
	Dosinia maoriana	247	box	57	68.0	65	44.20	10914	11	992
	Nucula nitidula	509	box	13	0.2	50	0.10	51	8	6
	Glycymeris modesta	31	box	26	5.0	65	3.25	100	10	10
	Gari convexa	340	box	58	4.0	65	2.60	883	8	110
Echinoderms	*Amphiura* sp.	123	box	80	5.0	90	4.50	556	15	37
Chordates	*Epigonichthys hectori*	201	box	80	1.0	20	0.20	40	8	5
Total		**4647**						**31497**	**8 (mean max. age)**	**4580**

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Table 7 Weight and growth estimated for the Sandy area 27m – 32m deep following two methodologies

Taxonomic group	Taxa	Density	Survey method	Average length	Actual Weight				Annual growth		
					Individual Green weight	Percentage Shell	Individual shell weight	Shell weight	Individual growth	Individual shell growth	Shell growth
		No. /100m²		(mm)	(g)	%	(g)	(g/100m²)	(g/y)	(g/y)	(g/100m²/y)
Arthropods	*Pagurus setosus*	22467	grab	13	0.6	20	0.12	2696	0.30	0.06	1348
	Crabs other than *Ovalipes*	1400	grab	15	0.9	20	0.18	252	1.00	0.20	280
Polyplacophora	*Leptochiton* sp.	1200	grab	10	0.1	50	0.05	60	0.30	0.15	180
Gastropods	*Epitonium* sp.	200	grab	14	0.2	80	0.16	32	1.00	0.80	160
	Turritellidae	2067	grab	24	0.5	80	0.40	827	1.00	0.80	1653
	Rissoina fictor	154	box	5	0.1	80	0.04	6	1.00	0.80	123
	Sigapatella sp.	2667	grab	5	0.0	50	0.01	13	0.10	0.05	133
	Amalda sp.	1067	grab	25	2.0	80	1.60	1707	3.69	2.95	3149
	Austrofusus glans	133	grab	33	4.4	80	3.54	471	3.69	2.95	394
	Cominella quoyana	988	box	20	1.0	80	0.80	790	3.69	2.95	2916
	Antimelatoma buchanani	62	box	20	1.0	80	0.80	49	3.69	2.95	182
	Zeatrophon ambiguus	200	grab	30	3.3	80	2.67	534	3.69	2.95	590
	Xymenella pusilla	62	box	25	2.0	80	1.56	96	3.69	2.95	182
	Cantharidus sp.	133	grab	10	2.0	80	1.60	213	0.94	0.75	100
	Antisolarium egenum	401	box	5	0.7	80	0.59	238	0.94	0.75	302
	Roseaplagis rufozona	93	box	10	2.0	80	1.60	148	0.94	0.75	70
	Solariella tryphenensis	93	box	5	0.7	80	0.59	55	0.94	0.75	70
	Other gastropods	1600	grab	10	2.0	80	1.60	2560	2.22	1.78	2846
Bivalves	*Hunkydora & Myadora*	400	grab	23	5.0	50	2.50	1000	3.50	1.75	700
	Corbula zelandica	401	box	12	5.0	50	2.50	1003	3.50	1.75	702
	Glycymeris modesta	216	box	26	6.3	65	4.10	885	1.44	0.94	202
	Pratulum pulchellum	400	grab	25	5.6	65	3.61	1446	1.44	0.94	374
	Gari & Hiatula	2933	grab	25	0.5	65	0.33	953	1.43	0.93	2727
	Pleuromeris sp.	467	grab	8	5.6	65	3.61	1687	1.44	0.94	437
	Purpurocardia purpurata	123	box	26	6.3	65	4.10	506	1.44	0.94	116
	Limatula maoria	333	grab	8	0.0	50	0.01	2	0.10	0.05	17
	Nucula nitidula	3533	grab	8	0.0	50	0.01	18	0.10	0.05	177
	Atrina zelandica	333	grab	45	8.7	65	5.68	1894	12.60	8.19	2730
	Dosinia sp.	267	grab	25	10.0	65	6.50	1733	7.00	4.55	1213
	Tawera sp.	1267	grab	24	10.0	65	6.50	8233	7.00	4.55	5763
	Zemysina globus	62	box	25	10.0	65	6.50	401	7.00	4.55	281
	Lasaeidae	1333	grab	1	0.0	50	0.01	7	0.10	0.05	67
	Pecten novaezelandiae	15	tow	84	55.7	65	36.19	550	50.00	32.50	494
	Other bivalves	667	grab	23	10.0	65	6.50	4333	5.00	3.25	2167
Echinoderms	*Echinocardium* sp.	1733	grab	30	10.0	20	2.00	3467	10.00	2.00	3467
	Astropecten polycanthus	4	tow	114	14.0	90	12.60	53	3.10	2.79	12
	Amphiura sp.	533	grab	80	5.0	90	4.50	2400	1.50	1.35	720
Chordates	*Epigonichthys hectori*	5467	grab	40	0.3	20	0.06	328	0.20	0.04	219
Total		**55474**						**41646**			**37263**

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Taxonomic group	Taxa	Density	Survey method	Maximum length	Maximum Weight				Annual Mortality	
					Individual Green weight	Percentage Shell	Individual shell weight	Shell weight	Maximum age	Shell mortality
		No. /100m²		(mm)	(g)	%	(g)	(g/100m²)	(y)	(g/100m²/y)
Arthropods	*Pagurus setosus*	22467	grab	15	10.0	20	2.00	44933	4	11233
	Crabs other than *Ovalipes*	1400	grab	100	200.0	20	40.00	56000	4	14000
Polyplacophora	*Leptochiton* sp.	1200	grab	30	4.0	50	2.00	2400	15	160
Gastropods	*Epitonium* sp.	200	grab	14	0.2	80	0.16	32	3	11
	Turritellidae	2067	grab	24	0.5	80	0.40	827	3	276
	Rissoina fictor	154	box	5	0.1	80	0.04	6	3	2
	Sigapatella sp.	2667	grab	8	0.2	50	0.10	267	2	134
	Amalda sp.	1067	grab	40	7.8	80	6.24	6656	10	666
	Austrofusus glans	133	grab	65	32.0	80	25.60	3413	8	427
	Cominella quoyana	988	box	20	1.0	80	0.80	790	8	99
	Antimelatoma buchanani	62	box	20	1.0	80	0.80	49	8	6
	Zeatrophon ambiguus	200	grab	30	3.3	80	2.67	534	8	67
	Xymenella pusilla	62	box	25	2.0	80	1.56	96	8	12
	Cantharidus sp.	133	grab	26	6.0	80	4.80	640	6	107
	Antisolarium egenum	401	box	7	0.8	80	0.64	257	6	43
	Roseaplagis rufozona	93	box	26	6.0	80	4.80	444	6	74
	Solariella tryphenensis	93	box	5	0.7	80	0.59	55	6	9
	Other gastropods	1600	grab	10	2.0	80	1.60	2560	6	401
Bivalves	*Hunkydora* & *Myadora*	400	grab	42	10.0	50	5.00	2000	10	200
	Corbula zelandica	401	box	12	5.0	50	2.50	1003	10	100
	Glycymeris modesta	216	box	26	5.0	65	3.25	702	5	140
	Pratulum pulchellum	400	grab	26	5.0	65	3.25	1300	5	260
	Gari & *Hiatula*	2933	grab	58	11.0	65	7.15	20973	10	2097
	Pleuromeris sp.	467	grab	8	5.6	65	3.64	1699	5	340
	Purpurocardia purpurata	123	box	35	5.0	65	3.25	401	5	80
	Limatula maoria	333	grab	8	0.2	50	0.10	33	2	17
	Nucula nitidula	3533	grab	8	0.2	50	0.10	353	2	177
	Atrina zelandica	333	grab	300	88.0	65	57.20	19067	15	1271
	Dosinia sp.	267	grab	52	40.0	65	26.00	6933	10	693
	Tawera sp.	1267	grab	24	10.0	65	6.50	8233	10	823
	Zemysina globus	62	box	24	10.0	65	6.50	401	10	40
	Lasaeidae	1333	grab	2	0.2	50	0.10	133	2	67
	Pecten novaezelandiae	15	tow	116	128.0	65	83.20	1265	10	127
	Other bivalves	667	grab	30	10.0	65	6.50	4333	9	495
Echinoderms	*Echinocardium* sp.	1733	grab	30	10.0	20	2.00	3467	10	347
	Astropecten polycanthus	4	tow	200	20.0	90	18.00	76	15	5
	Amphiura sp.	533	grab	80	5.0	90	4.50	2400	15	160
Chordates	*Epigonichthys hectori*	5467	grab	80	1.0	20	0.20	1093	8	137
Total		**55474**						**195824**	**7 (mean max. age)**	**35303**

Table 8 Summary of shell production by area in the Pakiri – Mangawhai embayment.

Area	Surface Area	Dominant sampling method	Average density	Actual Shell weight		Annual Shell Growth				Annual Shell Morality			
						Weight		Volume		Weight		Volume	
				Average	Total	Average	Total	Lower	Upper	Average	Total	Lower	Upper
	(m^2)		No./100m^2	g/100m^2	Mg	g/100m^2/y	Mg/y	m^3/y	m^3/y	g/100m^2/y	Mg/y	m^3/y	m^3/y
Rocky shore 0m – 7m	1,011,139	quadrat	85,054	191,919	1,941	250,885	2,537	1,812	2,306	252,050	2,549	1,821	2,317
Shoreline 0m – 7m	11,119,839	box	11,413	31,610	3,515	10,365	1,153	823	1,048	22,802	2,536	1,811	2,305
Shallow 7m - 12m	5,701,399	box	11,867	24,595	1,402	12,485	712	508	647	12,578	717	512	652
Mid 12m - 22m	20,855,709	box	4,668	8,910	1,858	6,294	1,313	938	1,193	7,411	1,600	1,143	1,455
Deep 22m - 27m	16,558,156	box	4,647	5,606	928	4,226	700	500	636	4,580	1,059	757	963
Pakiri – Mangawhai embayment within depth of Closure	55,246,242	box	8,234*	17,457*	9,645	11,609*	**6,414**	***4,581***	***5,831***	14,671*	**8,106**	***5,790***	***7,369***
Offshore 27m – 32m	15,818,196	grab	41,646	56,231	8,895	37,263	**5,894**	***4,210***	***5,358***	35,303	**5,584**	***3,989***	***5,076***

Note:

A range of densities was used for the shell volume with upper defined as 1.1 Mg/m^3 and lower as 1.4 Mg/m^3 (see text).

It was not possible to estimate errors with the methodologies used.

* area weighted average

4. DISCUSSION

4.1 Shell weight annual production

The majority of the calculations of growth rates of taxa present were not based on taxa specific equations as no such equations have been developed for most New Zealand species. Therefore, similar local or international taxa growth rate equations were substituted. The use of non-specific equations and extrapolations provides an estimate of the production albeit with an increased measure of uncertainty. The present estimation assumed a single cohort per taxa (no size distribution of biota available for box dredge) with no migration in or out the system. Until more data on the biology of the biota become available (population dynamics), building more complex growth models of current biota is pointless.

The annual shell production in the Pakiri – Mangawhai embayment (0m – 27m) was estimated to be around 7,200 tonnes depending on the methodology used (by growth rate 6,414 tonnes or by mortality 8,106 tonnes). This was equivalent to a range in volume of 4,600 – 5,800m³ by growth rate or between 5,800 – 7,400m³ by mortality, depending on different crushed shell densities of 1.1 - 1.4 Mg/m³ used (Eziefula *et al.*, 2018). Given the number of estimations, assumptions and substitutions it was not possible to provide an estimation of the error associated with the results produced by either method.

In general, subtidal marine invertebrate communities can support a high diversity of species with different ecological and life history traits. Species with different adaptations, occupy different niches along a depth gradient, which among other factors, varies with sediment texture and with their ability to cope with the physical environment (Dolbeth *et al.,* 2007). The environmental severity conditioning the fauna is determined by the bottom disturbance, which in turn potentially affects sediment texture, food availability and biotic interactions. Both wave climate and morphological parameters showed that the higher the energy to which the community is subjected, the lower the species number and density in the inhabited area (Dolbeth *et al.,* 2007). The DOC reflects differences in hydrodynamics, with lower energy conditions on the seabed, seawards of this boundary. Therefore, both increased food availability and reduced disturbance may allow for the existence of richer and denser assemblages beyond the DOC (Carvalho *et al*., 2012).

The benthic biota data collected in the Pakiri embayment for both the McCallum Brothers Limited and Kaipara Limited consents and in the past (Hilton, 1990, Bioresearches, 2016) show variations in the species composition and abundance with increased depth. The current data shows the inshore areas (0-12m) are dominated by biota adapted to high wave energy such as wheel shells and sand dollar, both of which can occur in high densities. Further offshore between 12 and 27m depth the biota was diverse, but low in abundance. Here, communities were dominated by a few species of polychaete worms and contained moderate numbers of amphipods, hermit crabs, the bivalves *Nucula* and *Myadora* and the Lancelet, *Epigonichthys hectori*. Beyond the predefined 27m DOC, the biota was still diverse with similar species to those present in the mid shore (12 – 27m) but numbers of individuals, particularly bivalves, were greater beyond the 27m depth.

Table 8 shows the average biomass of biota per 100m² decreased with increasing depth to the 27m depth contour. The highest numbers were recorded in the rocky shore areas. The higher numbers recorded in the shallow sandy environments were mostly due to the high abundances of the wheel shells and sand dollars. The decreasing numbers were the result of fewer biota present and their smaller sizes. Beyond the 27m depth contour, the biomass increased again due to increased numbers of bivalves and echinoderms (Table 7).

As there are uncertainties on the amount of sediment and shell material moving to and from the Pakiri – Mangawhai embayment (0m – 27m) across the predefined 27m DOC, the calculation of annual shell production in the 27m – 32m area is also presented. The production in the 27m – 32m area alone (4,000 - 5,400m³ depending on the methodology) is marginally lower but comparable to that of the whole Pakiri – Mangawhai embayment (0m – 27m) (4,600 – 7,400m³ depending on the methodology). Thus, the inclusion of the 27m – 32m area in the biogenic sand budget of the Pakiri – Mangawhai embayment (0m – 32m) gives figures of approximately 8,800 to 12,400m³ of annual biogenic sand production.

Based on the data included in this study the different sampling methods; grab sampler, box dredge, quadrat and dredge tow, appear to produce different densities of biota. The grab sampler samples the smallest area, but the area sampled is standardised. The box dredge samples a similar volume, but a larger area and the area sample varies depending on how well the dredge operates in the sediment. The quadrat again samples a standardised area. The dredge tow samples are very different to the other two samplers in that the area sampled is much greater and is selective for the larger biota only.

Of the six defined areas sampled, only the 27m -32m area was sampled with the grab sampling method and this method systematically produced greater densities in comparison with box dredge or tow dredge samples in the same area. Nonetheless, the higher densities recorded beyond the 27m depth contour are not solely a bias of sampling methodology. Seabed images recorded in four transects in 2019 reported in Bioresearches (2019b) showed increased proportions of shell fragments on the seabed in areas beyond 25m depth (as recorded at the time of sampling), and corroborates the increased biota recorded in the samples. In the absence of data to directly compare the different sampling methods it has been assumed neither sampling method has any greater bias.

4.2 Comparison with previous estimated numbers

Sands in the Pakiri-Mangawhai embayment are primarily quartzo-feldspathic (Schofield, 1970). They also contain varying amounts of carbonate, as sand material.

Based on the 2019 soft shore calciferous biota densities the estimated average concentration of shell is 142g/m², ranging between 56 and 316g/m², which is comparable with Hilton's estimate or 97g/m², albeit for slightly different areas. Hilton's transect areas extended beyond the 27m depth contour and did not include the rocky shore biota, making direct comparison with the current study problematic. When rocky shore biota was included the average concentration of shell increased to 175g/m², due the estimated rocky shore shell biomass of 1920g/m².

Hilton (1990) assumed that for a shellfish species of a 10-year life expectancy, 10% of the population would die every year and the shell becomes part of the biogenic sand. This assumes a constant population size, and that recruitment and mortality were constant, which they are generally not. It also appears that he assumed all shellfish had a similar life span, which is also not a valid assumption. We now know biota range in lifespan from 3 to 15 years. Longer lived species would contribute a lesser percentage of the population per year than a short-lived species. His assumptions were based on the information available in 1990, greater information on life span is now available but the population size, mortality and recruitment are still not well understood. We do know from monitoring data (Grace, 1991, 2005, Bioresearches 2019) that the populations of wheel shell and several other species have varied between years which suggested either mortality or more likely recruitment are not constant.

Based on Hilton's assumptions, he calculated that the existing weight of shell material 5,300 tonnes would increase to 73,000,000 tonnes after 100 years. This calculation was incorrect. Hilton mistakenly added the dead shell material back to the live shell material each year for a compounding recalculation of dead shell production over the 100-year time frame. This process grossly overestimated the production of dead shell material over time. One of the major assumptions is that the live shellfish population does not change year to year therefore the production should be the same each year. To quantify any changes year to year or between seasons would require repeated surveys of taxa abundance and sizes, which is beyond the scope needed for this project. Given that mortality and recruitment vary between years and between species the live shellfish population will vary over time. However even if the shellfish population varied in size between years the expected dead shell production would not approach the tonnage Hilton calculated. Correcting Hiltons dead shell production calculation overtime, results in an annual shell material production of 530 tonnes, translating to 482m³/year assuming shell material has a density of 1.1Mg/m³. Hume *et al.* (1999) suggests these values cover half the bay and should be doubled to a corrected value of 964m³/year, which is considerably less than that Hilton reported in 1990 of 900,000m³/year.

The NIWA sand study (Hume *et al*., 1999) considered Hilton's original shell production value of 900,000 m³/year erroneous and suggested the biogenic sand product was less than 12,000 m³/year based on a sediment budget. Barnett in his 2005 environment court evidence suggested it should be near 90,000 m³/year, neither of the latter estimates were based on biological science.

Of these estimates only the Hilton (1990) corrected estimate of 964m³/year is based on actual biological production, but it was based on invalid assumptions and missing significant sources.

In an ideal world with data on distribution and abundance, growth curves, population structure, recruitment and mortality variability available on each of the specific taxa the total shell production could be refined as the sum of each component taxa per area. The estimate produced in this report has attempted to further refine Hilton's assessment by segregating the seabed into five zones based on species composition and abundance and defined by depth. In addition, rather than assuming that all shellfish grow in the same way, taxa specific growth has been applied to each taxon within each zone. Species-specific growth data, age, population structure, recruitment etc, do not generally exist for the species recorded. Therefore, data from similar taxa have been used as estimates for growth and age. Detailed population structure data was generally not available for any of the taxa recorded, therefore the annual growth of the average known size for each taxon was used to provide one estimate of growth. A second estimate of growth was based on the similar method to Hilton of the annual population mortality as estimated by the reciprocal of maximum age. Variability in recruitment and mortality were not available for in the production estimate. Nonetheless, the similarity of the two estimates produced for the rocky and soft shore environments of the Pakiri-Mangawhai embayment to the 27m depth contour (annual growth 4,581 – 5,831 m³/year, and population mortality 5,790 – 7,369 m³/year), provides some confidence in the calculations, and fits within the 12,000m³ net shoreward transport of material proposed by Hume *et al* (1999).

Addition of the results of biogenic sand production from the 27-32 m contour (Table 8), would increase the production by a further 4,200 – 5,400 m³/year under the annual growth methodology, and 4,000 – 5,000 m³/year under the population mortality methodology.

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6. APPENDICES

Table A 1 Surface area calculated for each tow. The width of the dredge was 650mm for the tows up to a depth of 25m, and 600mm for the tows in the 25 – 30m depth area.

Tow Code	Depth area	Distance (m)	Surface (m^2)
1	20 – 25m	383	248.95
2	20 – 25m	595	386.75
3	20 – 25m	514	334.1
4	20 – 25m	387	251.55
5	20 – 25m	284	184.6
6	20 – 25m	334	217.1
7	20 – 25m	392	254.8
8	10 – 20m	205	133.25
9	10 – 20m	289	187.85
10	20 – 25m	322	209.3
11	10 – 20m	301	195.65
12	10 – 20m	347	225.55
13	10 – 20m	255	165.75
14	10 – 20m	357	232.05
15	10 – 20m	317	206.05
16	10 – 20m	655	425.75
17	10 – 20m	275	178.75
18	10 – 20m	157	102.05
19	10 – 20m	233	151.45
20	10 – 20m	315	204.75
21	10 – 20m	258	167.7
22	5 – 10m	281	182.65

Tow Code	Depth area	Distance (m)	Surface (m^2)
23	5 – 10m	277	180.05
24	5 – 10m	233	151.45
25	5 – 10m	272	176.8
26	5 – 10m	279	181.35
27	5 – 10m	228	148.2
28	5 – 10m	254	165.1
29	5 – 10m	274	178.1
30	5 – 10m	296	192.4
31	5 – 10m	270	175.5
32	5 – 10m	319	207.35
33	5 – 10m	336	218.4
34	5 – 10m	315	204.75
35	5 – 10m	234	152.1
T2 A	25 – 30m	100	60
T4 A	25 – 30m	125	75
T6 A	25 – 30m	100	60
T6 B	25 – 30m	100	60
T8 A	25 – 30m	100	60
T8 B	25 – 30m	99	59.4
TC A	25 – 30m	100	60
TC B	25 – 30m	100	60

Table A 2 Infauna taxa found in the 94 box dredge samples (3.15mm mesh size) collected within 0 to 27m depth (Bioresearches, 2019a,b).

Taxa	Total No.
Polychaeta: *Hydroides* sp.	7
Polychaeta: Spionidae	2
Polychaeta: *Paraprionospio pinnata*	7
Polychaeta: Terebellida	11
Polychaeta: Ampharetidae	19
Polychaeta: ?*Lanice* sp.	2
Polychaeta: Cirratulidae	14
Polychaeta: Eunicidae	3
Polychaeta: Lumbrineries sp.	8
Polychaeta: Onuphidae	4
Polychaeta: Goniadidae	1
Polychaeta: Nephtyidae	6
Polychaeta: ?*Aglaophamus/Nephtys*	6
Polychaeta: Nereididae	1
Polychaeta: Phyllodocidae	10
Polychaeta: Polynoidae	4
Polychaeta: Sigalionidae	21
Polychaeta: *Magelona* cf. *dakini*	3
Polychaeta: Capitellidae	26
Polychaeta: *Armandia maculata*	2
Polychaeta: Maldanidae	525
Polychaeta: *Travisia olens*	1
other polychaeta	59
Nemertea	9
Calanoida	2
Cyclopoida	3
Amphipoda: Gammaridea undet.	9
Amphipoda: Gammaridea sp. 2	3
Amphipoda: Gammaridea sp. 3	22
Amphipoda: Gammaridea sp. 5	1
Amphipoda: Lysianassidae	2
Amphipoda: Phoxocephalidae sp. 1	23
Amphipoda: Phoxocephalidae sp. 2	2
Amphipoda: Phoxocephalidae sp. 3	2
Amphipoda: Haustoriidae	1

Taxa	Total No.
Amphipoda: Liljeborgiidae	2
Amphipoda: *Ampelisca chiltoni*	3
Cumacea: *Cyclaspis*	7
Cumacea: *Diastylopsis thileniusi*	2
Decapoda: *Periclimenes yaldwyni*	2
Decapoda: *Ogyrides delli*	2
Decapoda: *Liocarcinus corrugatus*	4
Decapoda: *Ovalipes catharus*	**2**
Decapoda: *Ebalia laevis*	5
Decapoda: Anomura	11
Decapoda: *Pagurus setosus*	**58**
other decapods	3
Arthropoda: Isopods	20
Arthropoda: Mysidae	10
Arthropoda: Pariliacantha	7
Arthropoda: Tanaidacea	1
Arthropoda: Pycnogonida	1
Arthropoda: Coleoptera undet.	2
Polyplacophora: *Leptochiton inquinatus*	**7**
Gastropoda: *Zethalia zelandica*	**300**
Gastropoda: *Antisolarium egenum*	10
Gastropoda: *Maoricolpus roseus*	2
Gastropoda: *Stiracolpus pagoda*	**11**
Gastropoda: *Sigapatella tenuis*	**33**
Gastropoda: *Trichosirius inornatus*	2
Gastropoda: *Cominella adspersa*	**6**
Gastropoda: *Cominella quoyana*	**28**
Gastropoda: Austrofusus glans	1
Gastropoda: *Amalda australis*	**10**
Gastropoda: *Amalda depressa*	**2**
Gastropoda: *Amalda novaezelandiae*	**13**
Gastropoda: Borsoniidae	3
Gastropoda: *Euterebra tristis*	5
Gastropoda: *Pupa affinis*	20
Gastropoda: *Cylichna thetidis*	3

Taxa	Total No.
other gastropods	4
Bivalvia: *Nucula nitidula*	**61**
Bivalvia: *Glycymeris modesta*	**3**
Bivalvia: *Purpurocardia purpurata*	1
Bivalvia: Galeommatidae	3
Bivalvia: *Scalpomactra scalpellum*	2
Bivalvia: *Gari convexa*	**5**
Bivalvia: *Gari lineolata*	**3**
Bivalvia: *Gari stangeri*	**4**
Bivalvia: *Hiatula nitida*	4
Bivalvia: *Zemysina globus*	6
Bivalvia: *Tawera spissa*	8
Bivalvia: *Dosinia lambata*	**2**
Bivalvia: *Dosinia maoriana*	**5**
Bivalvia: *Dosinia subrosea*	**18**
Bivalvia: *Corbula zelandica*	10
Bivalvia: *Myadora boltoni*	**71**
Bivalvia: *Myadora striata*	**45**
Bivalvia: Myadora subrostrata	**13**
Bivalvia: *Hunkydora novozelandica*	2
other Bivalvia	4
Echinodermata: *Amphiura aster*	**15**
Echinodermata: *Fellaster zelandiae*	**16**
other echinoderms	2
Nematoda	8
Foraminifera	7
Bryozoa: *Selenaria concinna*	68
Porifera	11
Leptothecata	2
Actiniaria	1
Epigonichthys hectori	**67**
Limnichthys polyactis	6
TOTAL	**1896**

Note: The grey text taxa were considered to have no or little "shell" component and were not included into the calculation of shell weight and growth. The highlighted taxa in bold are the species for which information on individual weight and growth at a family level was available in the literature. The other highlighted taxa were combined into a higher taxonomic level.

Table A 3 Epifauna taxa found in the 35 dredge tow samples collected within 0 to 27m depth (Bioresearches, 2019a,b).

Taxa	Total No.
Polychaete	21
Amphipods	7
Nemertea	3
Isopod	2
Bryozoa	4
Porifera	6
Decapoda: Paguridae	122
Decapoda: *Ovalipes catharus*	**7**
Decapoda: *other than Ovalipes*	9
Gastropoda: Zethalia zelandica	**7**

Taxa	Total No.
Gastropoda: Dicathais orbita	1
Gastropoda: Cominella adspersa	**32**
Gastropoda: Sigapatella tenuis	1
Gastropoda: Ranella australasia	1
Gastropoda: Austrofusus glans	2
Gastropoda: Amalda australis	**5**
Gastropoda: *Zeatrophon mortenseni*	1
Gastropoda: *Struthiolaria papulosa*	4
Bivalvia: *Atrina zelandica*	**3**
Bivalvia: *Pecten novaezealandiae*	**12**

Taxa	Total No.
Bivalvia: *Tawera spissa*	1
Bivalvia: *Dosinia subrosea*	**9**
Bivalvia: *Myadora striata*	**5**
Bivalvia: *Purpurocardia purpurata*	1
Bivalvia: *Ostrea chilensis*	1
Bivalvia: *Gari convexa*	1
Echinodermata: *Fellaster zelandiae*	**38**
Echinodermata: *Amphiura sp.*	**3**
Echinodermata: *Astropecten polyacanthus*	30
Total	**339**

Note: The grey text taxa were considered to have no or little "shell" component and were not included into the calculation of shell weight and growth. The taxa with only 1 individual were also excluded before combination of the results with infauna as they would have minimal contribution to sand formation. The highlighted taxa in bold are the species for which information on individual weight and growth at a family level was available in the literature.

Table A 4 Shellfish collected in the intertidal zone along the Pakiri Beach in 1993 (Bioresearches, 1994)

Transect	Station	Species	Number/m²	Average length (mm)
1	70	*Paphies subtriangulata*	4	41.3
2	80	*Paphies subtriangulata*	22	48.1
3	90	*Paphies subtriangulata*	25	51.3
4	100	*Paphies subtriangulata*	25	49.0
5	160	*Paphies subtriangulata*	11	49.8
6	120	*Paphies subtriangulata*	5.3	41.3
7	10	*Nerita melanotragus*	21	22.9
7	20	*Cellana ornata*	43	19.9
7	20	*Leptograpsus variegatus*	18	
7	30	*Cellana radians*	35	32.6
7	30	*Lepsiella scobina*	587	15.3
7	30	*Melagraphia aethiops*	45	16.2
7	30	*Turbo smaragdus*	17	39.4
7	50	*Haustrum haustorium*	4	44.3
7	50	*Thais orbita*	16	43.0
8	120	*Paphies subtriangulata*	11	43.8
9	100	*Paphies subtriangulata*	10	42.4
10	100	*Paphies subtriangulata*	6	46.4
11	100	*Paphies subtriangulata*	16	44.9
13	60	*Paphies subtriangulata*	15	50.5
14	65	*Paphies subtriangulata*	19	44.2
15	50	*Paphies subtriangulata*	13	44.5
16	60	*Paphies subtriangulata*	13	46.7
17	60	*Paphies subtriangulata*	12	45.5
18	150	*Paphies subtriangulata*	5	48.5
19	60	*Paphies subtriangulata*	6	46.1
19	70	*Paphies subtriangulata*	13	51.8
20	90	*Paphies subtriangulata*	5	51.7
		Average *Paphies*	**12**	**46.7**

Note: Transect 7 (grey shaded) was at a rock area at Te Arai Point and was not considered for the 0-5m biota of the biogenic study as the species sampled in 7 are representative of a rock substrate, not of a sand system.

Table A 5 Infauna taxa found in the 31 grab samples collected within 27 to 32m depth (Bioresearches, 2017).

Taxa	Total No.	Taxa	Total No.	Taxa	Total No.
Polychaeta: *Euchone pallida*	46	Polychaeta: Paraonidae	9	**Gastropoda: *Cominella quoyana***	**2**
Polychaeta: Sabellidae	12	Polychaeta: *Travisia sp.*	21	**Gastropoda: *Cominella virgata***	**9**
Polychaeta: *Hydroides sp.*	1	Hemichordata	7	Gastropoda: Marginellidae	1
Polychaeta: *Serpula sp.*	5	Phoronida (*Phoronis* sp.)	23	Gastropoda: *Zeatrophon ambiguus*	3
Polychaeta: *Phyllochaetopterus*	5	Nemertea	20	Gastropoda: *Cantharidus sp.*	2
Polychaeta: *Boccardia sp.*	1	Copepoda	12	Gastropoda: *Adelphotectonica reevei*	3
Polychaeta: *Paraprionospio*	14	Amphipoda: Caprellidae	20	Gastropoda Unid. Juv.	9
Polychaeta: *Prionospio sp.*	661	Amphipoda: Haustoriidae	96	Bivalvia: *Hunkydora novozelandica*	1
Polychaeta: *Spio sp.*	13	Amphipoda: Lysianassidae	248	**Bivalvia: *Myadora antipodum***	**3**
Polychaeta: *Spiophanes kroyeri*	34	Amphipoda: Oedicerotidae	2	**Bivalvia: *Myadora striata***	**2**
Polychaeta: *Spiophanes modestus*	1634	Amphipoda: Phoxocephalidae	506	**Bivalvia: *Glycymeris modesta***	**1**
Polychaeta: Ampharetidae	109	Amphipoda: Talitridae	2	**Bivalvia: *Glycymeris sp.***	**2**
Polychaeta: Cirratulidae	49	other amphipods	4526	Bivalvia: *Pratulum pulchellum*	6
Polychaeta: *Lagis australis*	3	Cumacea	502	**Bivalvia: *Gari lineolata***	**4**
Polychaeta: Terebellidae	91	Decapoda: *Pagurus sp.*	337	Bivalvia: *Hiatula sp.*	40
Polychaeta: Dorvilleidae	6	Decapoda: shrimps	4	Bivalvia: *Pleuromeris zelandica*	5
Polychaeta: Lumbrineridae	15	Decapoda: crabs other than Ovalipes	21	Bivalvia: *Pleuromeris sp.*	2
Polychaeta: *Nothria sp.*	122	Isopoda	98	Bivalvia: *Limatula maoria*	5
Polychaeta: *Onuphis*	4	Mysida	19	Bivalvia: *Corbula zelandica*	3
Polychaeta: Onuphidae	3	Podocopida	465	**Bivalvia: *Nucula nitidula***	**53**
Polychaeta: Glyceridae	9	Tanaidacea	43	**Bivalvia: *Atrina zelandica***	**5**
Polychaeta: Goniadidae	61	Ostracoda	660	**Bivalvia: *Dosinia subrosea***	**2**
Polychaeta: Hesionidae	17	Polyplacophora: *Ischnochiton maorianus*	18	**Bivalvia: *Dosinia sp.***	**2**
Polychaeta: Aglaophamus sp.	11	Gastropoda: *Epitonium sp.*	3	Bivalvia: *Notocallista multistriata*	1
Polychaeta: Phyllodocidae	87	Gastropoda: *Maoricolpus roseus*	30	Bivalvia: *Tawera spissa*	1
Polychaeta: Polynoidae	1	Gastropoda: *Zeacolpus sp.*	1	Bivalvia: *Tawera sp.*	17
Polychaeta: Sigalionidae	64	Gastropoda: *Philine sp.*	1	Bivalvia: *Myllita vivens*	1
Polychaeta: *Sphaerosyllis sp.*	39	Gastropoda: *Relichna aupouria*	2	Bivalvia: *Mysella sp.*	19
Polychaeta: Syllidae	63	Gastropoda: *Caecum digitulum*	1	Bivalvia: *Scalpomactra scalpellum*	2
Polychaeta: *Magelona dakini*	11	**Gastropoda: *Sigapatella tenuis***	**38**	Bivalvia: *Diplodonta zelandica*	2
Polychaeta: *Barantolla lepte*	9	**Gastropoda: *Sigapatella sp.***	**2**	Bivalvia Unid. (juv)	3
Polychaeta: *Capitella capitata*	1	Gastropoda: *Tanea sp.*	1	Echinodermata: *Echinocardium sp.*	26
Polychaeta: *Notomastus*	8	Gastropoda: Rissoidae	4	Echinodermata: *Amphiura sp.*	8
Polychaeta: *Armandia maculata*	116	Gastropoda: *Struthiolaria pap.*	1	*Epigonichthys hectori*	82
Polychaeta: *Leodamas cylindrifer*	2	Gastropoda: *Tonna sp.*	1	**TOTAL**	**11634**
Polychaeta: *Orbinia papillosa*	6	**Gastropoda: *Amalda northlandica***	**13**		
Polychaeta: Maldanidae	194	**Gastropoda: *Amalda sp.***	**3**		
Polychaeta: *Aricidea sp.*	8	Gastropoda: *Austrofusus glans*	2		

Note: The grey text taxa were considered to have no or little "shell" component and were not included into the calculation of shell weight and growth. The highlighted taxa in bold are the species for which information on individual weight and growth at a family level was available in the literature.

Table A 6 Epifauna taxa found in the 8 dredge tow samples collected within 27 to 32m depth (Bioresearches, 2017).

Taxa	Total No.	Taxa	Total No.	Taxa	Total No.
Ascidian	38	*Gastropoda: Struthiolaria sp.*	2	*Bivalvia: Zemysina striatula*	2
Octopus	1	*Gastropoda: Monoplex parthenopeus*	1	*Bivalvia: Mesopeplum convexum*	1
Decapoda: Paguridae	8	*Gastropoda: Maoricolpus roseus*	1	*Echinodermata: Astropecten polycanthus*	20
Decapoda: *Ovalipes catharus*	**1**	*Gastropoda: Murexsul espinosus*	2	**TOTAL**	**154**
Polyplacophora	2	***Bivalvia: Pecten novaezelandiae***	**73**		
Gastropod: Cominella adspersa	**1**	*Bivalvia: Irus reflexus*	1		

Note: The grey text taxa were considered to have no or little "shell" component and were not included into the calculation of shell weight and growth. The highlighted taxa in bold are the species for which information on individual weight and growth at a family level was available in the literature.

Table A 7 Infauna taxa found in the 20 box dredge samples (3.15mm mesh size) collected within 27 to 32m depth (Bioresearches, 2019).

Taxa	Total No.	Taxa	Total No.	Taxa	Total No.
Polychaeta: *Euchone* sp.	3	Amphipoda: Haustoriidae	2	Gastropod: *Cylichna thetidis*	3
Polychaeta: *Hydroides* sp.	17	Amphipoda: Liljeborgiidae	9	other gastropods	3
Polychaeta: *Paraprionospio pin.*	2	Cumacea: *Cyclaspis*	2	**Bivalvia: *Nucula nitidula***	**55**
Polychaeta: *Malacoceros*	3	Decapoda: *Liocarcinus corrugatus*	9	**Bivalvia: *Glycymeris modesta***	**7**
Polychaeta: Terebellida	19	Decapoda: *Ebalia laevis*	7	Bivalvia: *Pleuromeris* sp.	11
Polychaeta: Ampharetidae	24	Decapoda: *Notomithrax minor*	2	Bivalvia: *Purpurocardia purpurata*	8
Polychaeta: Cirratulidae	8	Decapoda: Anomura	4	Bivalvia: Galeommatidae	1
Polychaeta: *Lagis australis*	2	Decapoda: Paguridae	55	Bivalvia: *Scalpomactra scalpellum*	1
Polychaeta: Eunicidae	3	Isopods	17	**Bivalvia: *Gari stangeri***	**14**
Polychaeta: Onuphidae	1	Mysidae	1	Bivalvia: *Hiatula nitida*	3
Polychaeta: Goniadidae	1	Tanaidacea	1	Bivalvia: *Zemysina globus*	2
Polychaeta: Nephtyidae	1	Myodocopida	12	Bivalvia: *Tawera spissa*	2
Polychaeta: *Aglaophamus*	1	Pycnogonida	1	**Bivalvia: *Dosinia maoriana***	**5**
Polychaeta: Nereididae	1	Echinodermata: *Leptochiton inquinatus*	35	**Bivalvia: *Dosinia subrosea***	**1**
Polychaeta: Phyllodocidae	3	Gastropod: *Antisolarium egenum*	13	Bivalvia: *Corbula zelandica*	17
Polychaeta: Polynoidae	3	Gastropod: *Roseaplagis rufozona*	3	**Bivalvia: *Myadora subrostrata***	**6**
Polychaeta: Sigalionidae	14	Gastropod: *Solariella tryphenensis*	3	Bivalvia: *Hunkydora novozelandica*	1
Polychaeta: Syllidae	5	Gastropod: *Maoricolpus roseus*	3	other bivalvia	6
Polychaeta: *Magelona dakini*	5	**Gastropod: *Striacolpus pagoda***	**28**	Echinodermata: *Amphiura aster*	6
Polychaeta: Capitellidae	18	Gastropod: *Rissoina fictor*	8	Echinodermata: Ophiuroidea	2
Polychaeta: Cossuridae	4	Gastropod: *Pisinna semisulcata*	3	other echinoderms	2
Polychaeta: Maldanidae	93	Gastropod: *Sigapatella tenuis*	24	Nematoda	18
Polychaeta: *Travisia olens*	4	Gastropod: *Seila cincta*	2	Foraminifera	41
other polychaeta	52	**Gastropod: *Cominella quoyana***	**37**	Bryozoa	45
Nemertea	7	Gastropod: *Austrofusus glans*	1	Porifera	35
Cyclopoida	1	Gastropod: *Xymenella pusilla*	2	Ascidiacea	4
Amphipoda: Gammaridea	64	**Gastropod: *Amalda novaezelandiae***	**3**	*Epigonichthys hectori*	41
Amphipoda: Phoxocephalidae	13	Gastropod: *Antimelatoma buchanani*	3	**TOTAL**	**1005**

Note: The grey text taxa were considered to have no or little "shell" component and were not included into the calculation of shell weight and growth. The highlighted taxa in bold are the species for which information on individual weight and growth at a family level was available in the literature.

Table A 8 List of equations used for weight and growth.

Taxa			Allometric equations			Growth equations		
Taxonomic group	**Family**	**Species**	**Species used for weight estimation**	**Equation length –weight (mm - g)**	**Source**	**Species used for growth estimation**	**Equation age –length (y - mm)**	**Source**
Arthropods	Paguridae	*Pagurus setosus*	*Ovalipes catharus*	$\log(W)=3.32+2.79\log(L)$	Fisheries NZ 2018, vol 2, p467	*Pagurus* sp.	curve in Fig. 5	Mc Lay, 1985
Arthropods	Portunidae	*Ovalipes catharus*	*Ovalipes catharus*	$\log(W)=3.32+2.79\log(L)$	Fisheries NZ 2018, vol 2, p467	*Ovalipes catharus*	from info in text	Fisheries NZ 2018, vol 2, p467
Arthropods	Grapsidae	*Leptograpsus variegatus*	*Ovalipes catharus*	$\log(W)=3.32+2.79\log(L)$	Fisheries NZ 2018, vol 2, p467	*Ovalipes catharus*	from info in text	Fisheries NZ 2018, vol 2, p467
Arthropods		Crabs other than *Ovalipes*	*Ovalipes catharus*	$\log(W)=3.32+2.79\log(L)$	Fisheries NZ 2018, vol 2, p467	*Ovalipes catharus*	from info in text	Fisheries NZ 2018, vol 2, p467
Polyplacophora	Leptochitonidae	*Leptochiton* spp.	*Chiton albolineatus*	$W = 0.0002L^{2.7097}$	Flores-Campana *et al.*, 2012	Estimated from other molluscs		
Gastropods	Trochidae	*Zethalia, Antisolarium, Roseaplagis, Melagraphia*	*Monodonta turbinata*	$W = 0.5099(L/2)-0.5392$	Boucetta *et al.,* 2010	*Phorcus sauciatus*	$L = 31.9\ (1-e^{-0.31(age)})$	Sousa *et al.* 2019
Gastropods	Solariellidae	*Solariella tryphenensis*	*Monodonta turbinata*	$W = 0.5099(L/2)-0.5392$	Boucetta *et al.,* 2010	*Phorcus sauciatus*	$L = 31.9\ (1-e^{-0.31(age)})$	Sousa *et al.* 2019
Gastropods	Neritidae	*Nerita melanotragus*	*Nerita crepidularia*	curve	Jaiswar & Kulkarni 2002	*Phorcus sauciatus*	$L = 31.9\ (1-e^{-0.31(age)})$	Sousa *et al.* 2019
Gastropods	Nacellidae	*Cellana* spp.	*Patella nigra*	from info in text	Echem 2017	*Phorcus sauciatus*	$L = 31.9\ (1-e^{-0.31(age)})$	Sousa *et al.* 2019
Gastropods	Turbinidae	*Turbo, Cookia*	*Turbo bruneus*	$W = 0.00017L^{3.091}$	Saleky *et al.*, 2016	*Phorcus sauciatus*	$L = 31.9\ (1-e^{-0.31(age)})$	Sousa *et al.* 2019
Gastropods	Buccinidae	*Cominella, Austrofusus*	*Buccinum undatum*	$W = 0.000144L^{2.955}$	Heude-Berthelin *et al.*, 2011	*Buccinum undatum*	$L = 73\ (1-e^{-0.221(age)})$	Heude-Berthelin *et al.*, 2011
Gastropods	Muricidae (large)	*Haustrum, Thais*	*Hexaplex nigritus*	$W = 0.000004L^{3.7956}$	Escamilla-Montes *et al.*, 2018	*Concholepas concholepas*	$W = 461.37\ (1-e^{-0.55(age)})^3$	Rabi & Maravi, 1997
Gastropods	Muricidae (small)	*Lepsiella, Xymenella, Zeatrophon*	*Buccinum undatum*	$W = 0.000144L^{2.955}$	Heude-Berthelin *et al.*, 2011	*Buccinum undatum*	$L = 73\ (1-e^{-0.221(age)})$	Heude-Berthelin *et al.*, 2011
Gastropods	Pseudomelatonidae	*Antimelatoma*	*Buccinum undatum*	$W = 0.000144L^{2.955}$	Heude-Berthelin *et al.*, 2011	*Buccinum undatum*	$L = 73\ (1-e^{-0.221(age)})$	Heude-Berthelin *et al.*, 2011
Gastropods	Olividae	*Amalda* spp.	*Buccinum undatum*	$W = 0.000144L^{2.955}$	Heude-Berthelin *et al.*, 2011	*Buccinum undatum*	$L = 73\ (1-e^{-0.221(age)})$	Heude-Berthelin *et al.*, 2011
Gastropods	Struthiolaridae	*Struthiolaria papulosa*	*Buccinum undatum*	$W = 0.000144L^{2.955}$	Heude-Berthelin *et al.*, 2011	*Buccinum undatum*	$L = 73\ (1-e^{-0.221(age)})$	Heude-Berthelin *et al.*, 2011
Gastropods	Turritellidae	*Stiracolpus pagoda*	*Turritella communis*	Curve p179	Allmon, 2011	assumption of 1g/y from gastropod data of same size		
Gastropods	Epitoniidae	*Epitonium* spp.	*Turritella communis*	Curve p179	Allmon, 2011	assumption of 1g/y from gastropod data of same size		
Gastropods	Rissoniidae	*Rissoina fictor*	*Turritella communis*	Curve p179	Allmon, 2011	assumption of 1g/y from gastropod data of same size		
Gastropods	Calyptraeidae	*Sigapatella tenuis*	assumption of 0.005g			assumption of 0.10g / y		
Bivalves	Myochamidae	*Myadora* spp.	1/2 of *Dosinia subrosea*	curve p80 /2	Aljadani, 2013	*Dosinia* spp.	$L = 58.7\ (1-e^{-0.13(age)})$	Fisheries NZ 2018, vol 3, p342
Bivalves	Veneridae	*Dosinia, Tawera*	*Dosinia subrosea*	curve p80	Aljadani, 2013	*Dosinia* spp.	$L = 58.7\ (1-e^{-0.13(age)})$	Fisheries NZ 2018, vol 3, p342
Bivalves	Ungulinidae	*Zemysina globus*	*Dosinia subrosea*	curve p80	Aljadani, 2013	*Dosinia* spp.	$L = 58.7\ (1-e^{-0.13(age)})$	Fisheries NZ 2018, vol 3, p342
Bivalves	Corbulidae	*Corbula zelandica*	½ of *Dosinia subrosea*	curve p80 /2	Aljadani, 2013	*Dosinia* spp.	$L = 58.7\ (1-e^{-0.13(age)})$	Fisheries NZ 2018, vol 3, p342
Bivalves	Nuculidae	*Nucula nitidula*	*Nucula* spp.	from info in text	Allen 1954	*Nucula* spp.	from info in text	Allen 1954

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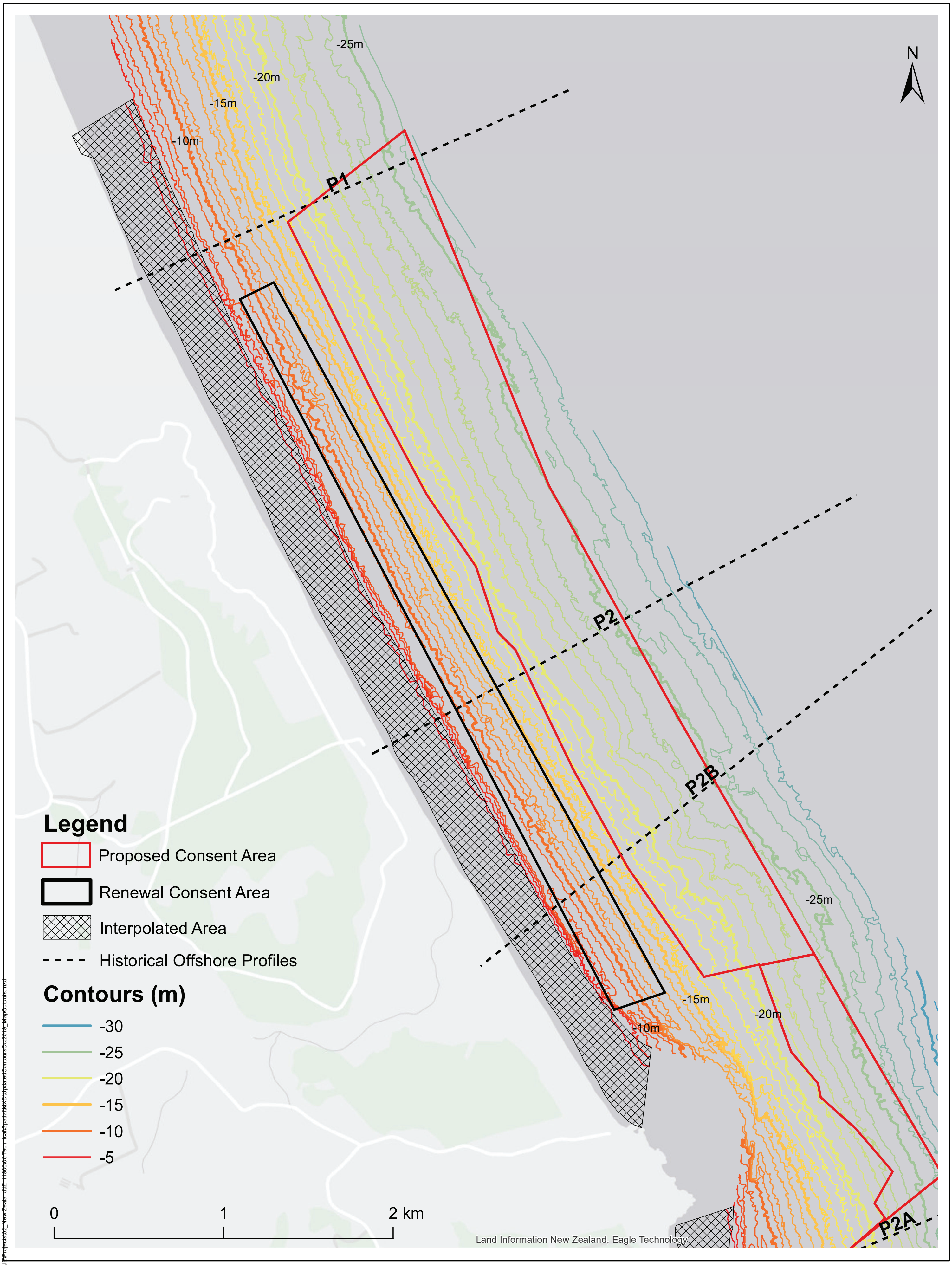
Taxa			Allometric equations			Growth equations		
Taxonomic group	**Family**	**Species**	**Species used for weight estimation**	**Equation length –weight (mm - g)**	**Source**	**Species used for growth estimation**	**Equation age –length (y - mm)**	**Source**
Bivalves	Limidae	*Limatula maoria*	*Nucula* spp.	from info in text	Allen 1954	*Nucula* spp.	from info in text	Allen 1954
Bivalves	Lasaeidae	Lasaeidae	*Nucula* spp.	from info in text	Allen 1954	*Nucula* spp.	from info in text	Allen 1954
Bivalves	Glycymeridae	*Glycymeris modesta*	*Austrovenus stutchburyi*	$W = 0.00014L^{3.29}$	Fisheries NZ 2018, vol 1, p235	*Austrovenus stutchburyi*	$L = 35\ (1-e^{-0.26(age)})$	Fisheries NZ 2018, vol 1, p235
Bivalves	Carditidae	*Purpurocardia, Pleuromeris*	*Austrovenus stutchburyi*	$W = 0.00014L^{3.29}$	Fisheries NZ 2018, vol 1, p235	*Austrovenus stutchburyi*	$L = 35\ (1-e^{-0.26(age)})$	Fisheries NZ 2018, vol 1, p235
Bivalves	Cardiidae	*Pratulum pulchellum*	*Austrovenus stutchburyi*	$W = 0.00014L^{3.29}$	Fisheries NZ 2018, vol 1, p235	*Austrovenus stutchburyi*	$L = 35\ (1-e^{-0.26(age)})$	Fisheries NZ 2018, vol 1, p235
Bivalves	Pinnidae	*Atrina zelandica*	*Pinna bicolor*	W = 3.111Lcm-5.397	Idris *et al.*, 2012	*Pinna bicolor*	$Lcm = 34.66\ (1-e^{-0.8(age)})$	Idris *et al.*, 2012
Bivalves	Psammobiidae	*Gari convexa*	*Gari solida* (Jan 1992)	logW=-4.32+2.792log(L)	Urban & Campos, 1994	*Gari solida* (Jan 1992)	$L = 89.6\ (1-e^{-0.307(age-0.354)})$	Urban & Campos, 1994
Bivalves	Pectenidae	*Pecten novaezelandiae*	*Pecten novaezelandiae*	$W = 0.00042L^{2.662}$	Fisheries NZ 2014	*Pecten novaezelandiae*	$L = 115.9\ (1-e^{-1.2(age)})$	Fisheries NZ 2014
Bivalves	Mytilidae	*Perna canaliculus*	*Perna canaliculus*	From info in text	Fisheries NZ 2018, vol 1, p479	*Perna canaliculus*	From info in text	Fisheries NZ 2018, vol 1, p479
Bivalves	Psammobiidae	*Paphies subtriangulata*	*Paphies subtriangulata*	$W = 0.0002L^{2.927}$	Fisheries NZ 2018, vol 3, p581	*Paphies subtriangulata*	from info in text	Fisheries NZ 2018, vol 3, p581
Echinoderms	Arachnoididae	*Fellaster zelandiae*	*Echinarachnius*	from info in text p56	Lohavanijaya, 1964	*Echinarachnius*	from info in text p56	Lohavanijaya, 1964
Echinoderms	Loveniidae	*Echinocardium* sp.	*Echinocardium cordatum*	log(W)= -3.449 +3.011log(L)	Robinson *et al.*, 2010	*Evechinus chloroticus*	from info in text p657	Fisheries NZ 2018, vol 2, p651
Echinoderms	Echinometridae	*Evechinus chloroticus*	*Evechinus chloroticus*	$W = 0.000627L^{2.88}$	Fisheries NZ 2018, vol 2, p651	*Evechinus chloroticus*	from info in text p657	Fisheries NZ 2018, vol 2, p651
Echinoderms	Amphiuridae	Amphiura sp.	Assumption of ½ Astropecten			Assumption of ½ Astropecten		
Echinoderms	Astropectinidae	*Astropecten polyacanthus*	Echinodermata species	from info in text	Ventura *et al.*, 1995	*Astropecten aranciacus*	$L = 136.75\ (1-e^{-0.44(age-0.017)})$	Baeta *et al.*, 2016
Cephalochordates	Brachiostomidae	*Epigonichthys hectori*	*Branchiostoma belcheri*	range 0.2 to 0.3g at 30 to 40mm	Henmi & Yamaguchi, 2003	Assumption of 0.2g / y		

Note1: Many species have no specific information, and equations from species of the same taxonomic group were used. Calculated growth and weight have numerous biases from these approximations. All results were checked for unreasonable weight ranges and readjusted with other equations if not appropriate.

Note 2: *Amalda* spp includes three species (A. *australis*, A. *depressa* and A. *novaezelandiae*). *Cominella* spp includes two species (C. *adspersa* and C. *quoyana*). *Myadora* spp includes two species (M. *boltoni* and M. *striata*). *Dosinia* spp includes 2 species (D. *subrosea* and D. *maoriana*).

Note 3: The percentage shell weight to green weight was estimated for the thick bivalves (*Glycymeris*, *Gari*, and *Dosinia*) from *Dosinia* values (65%) in Aljadani (2013). The percentage shell weight for other taxonomic groups are estimates based on the "shell" volume, thickness and form. 20% was used for the arthropods and Cephalochordates, considering their thin chitin and volume of notochord. 80% was used for the gastropods considering their general thick shell, except for *Sigapatella*. 50% was used for the thin bivalves such as *Myadora*, *Nucula*, and for *Sigapatella*. 90% was used for echinoderms considering the volume of their test relative to their whole body.

Appendix G. 2019 Bathymetry and Offshore Profiles



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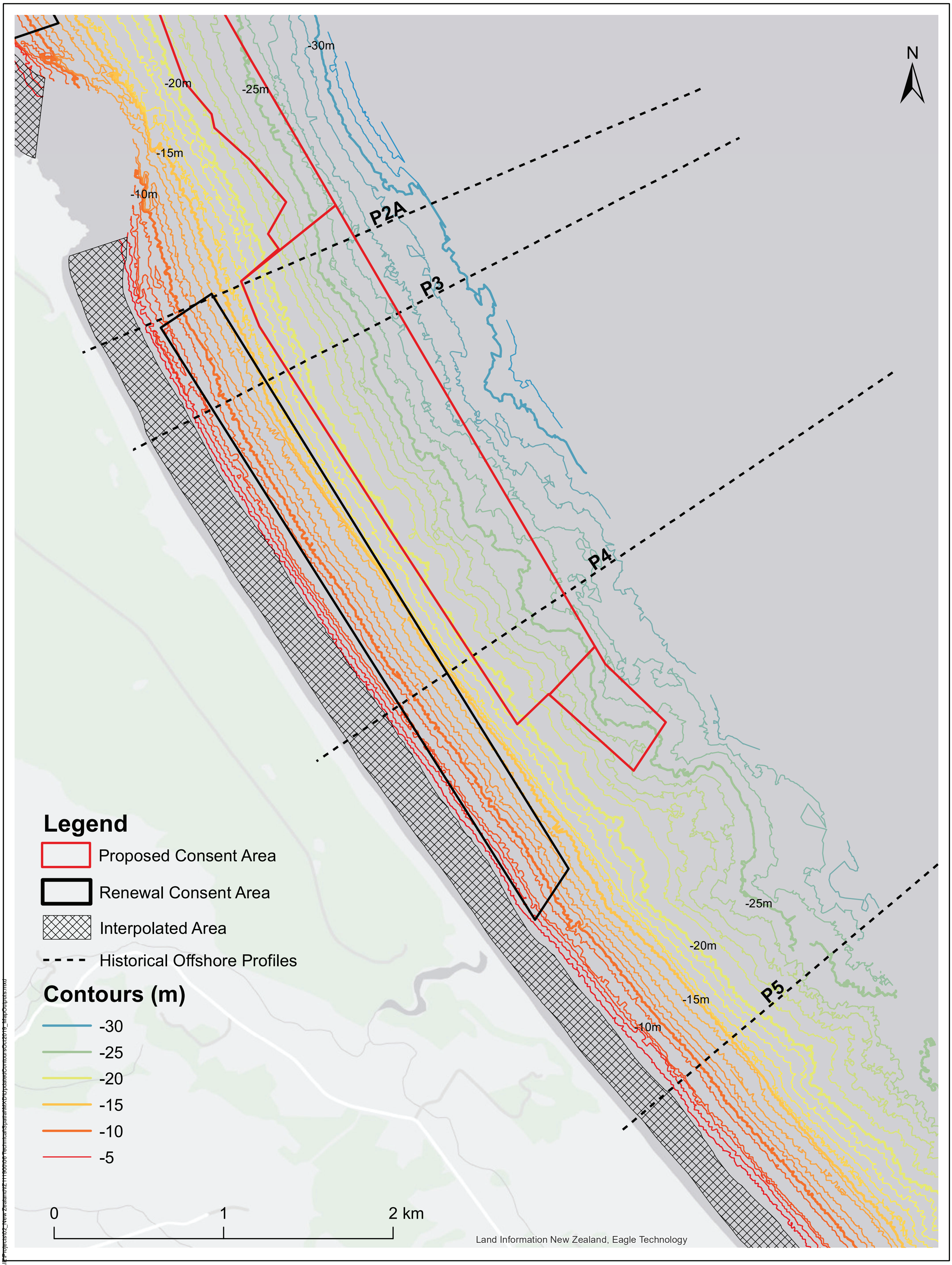
PROJECT Pakiri Sand Extraction Consent			
SCALE 1:20,000 @ A3	PROJECT CODE IZ111900		
PROJECT MANAGER IW	DRAWN KM		
PROJECT DIRECTOR DT	DATE 06/26/2020		

2019 Bathymetry and Offshore Profiles Northern Extraction Area

JACOBS SPATIAL

Level 2, Wynn Williams building,
47 Hereford Street,
Christchurch Central 8013,
New Zealand
T +64 3 940 4900
F +64 3 940 4901



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PROJECT Pakiri Sand Extraction Consent	
SCALE 1:20,000 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 06/26/2020

2019 Bathymetry and Offshore Profiles
Southern Extraction Area

JACOBS SPATIAL
Level 2, Wynn Williams building,
47 Hereford Street,
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T +64 3 940 4900
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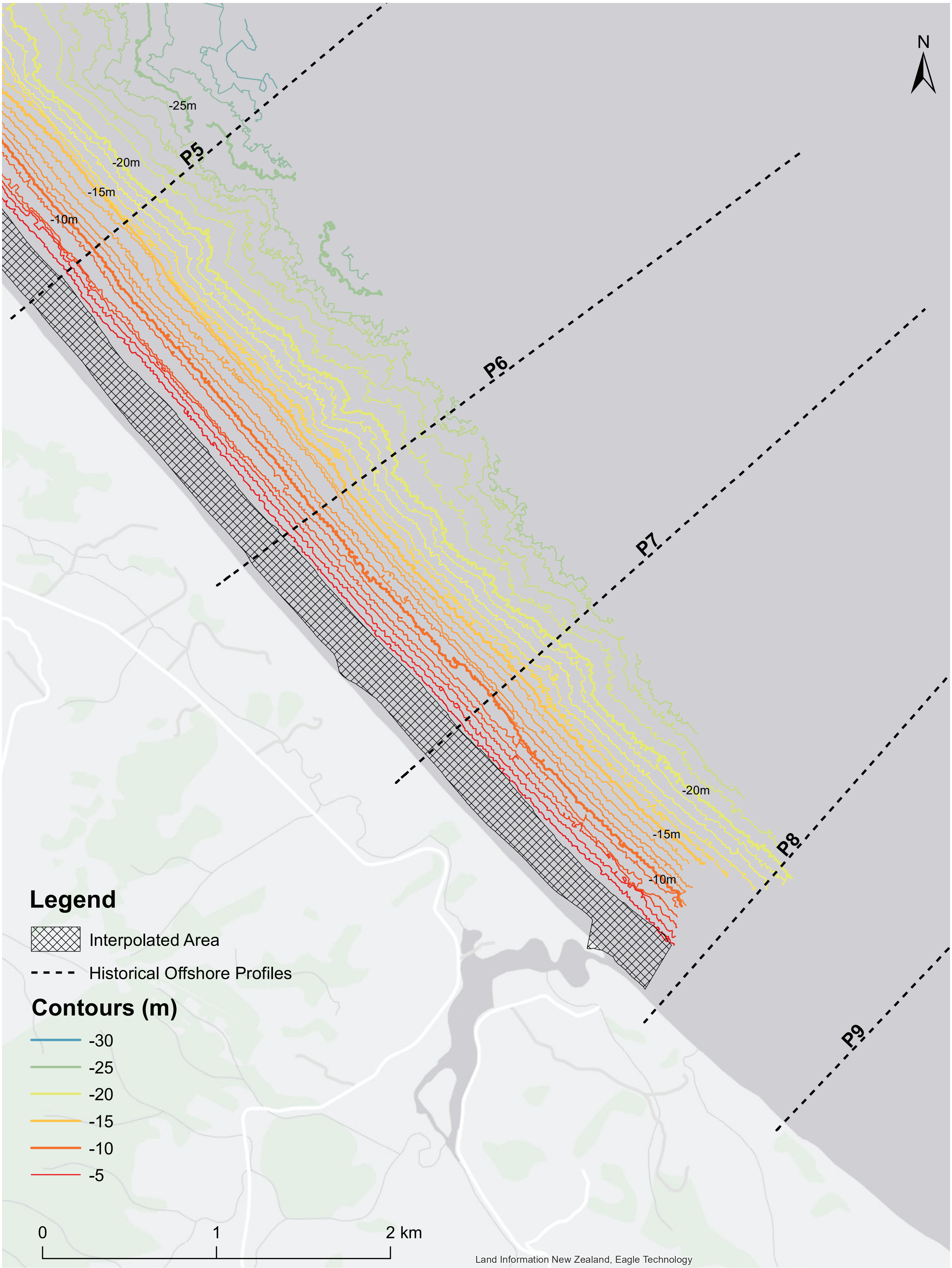

CLIENT McCallum Brothers Limited	
PROJECT Pakiri Sand Extraction Consent	
SCALE 1:20,000 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 06/26/2020

2019 Bathymetry and Offshore Profiles Control Area

JACOBS SPATIAL
Level 2, Wynn Williams building,
47 Hereford Street,
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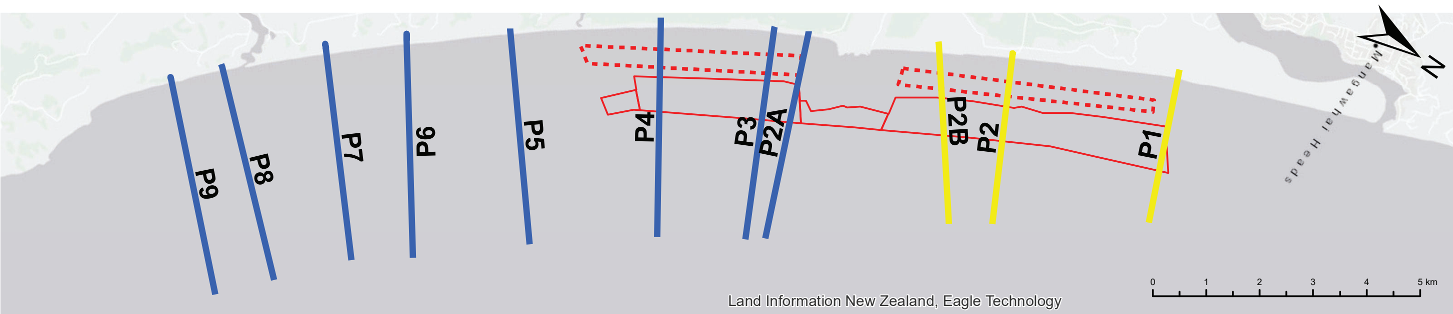

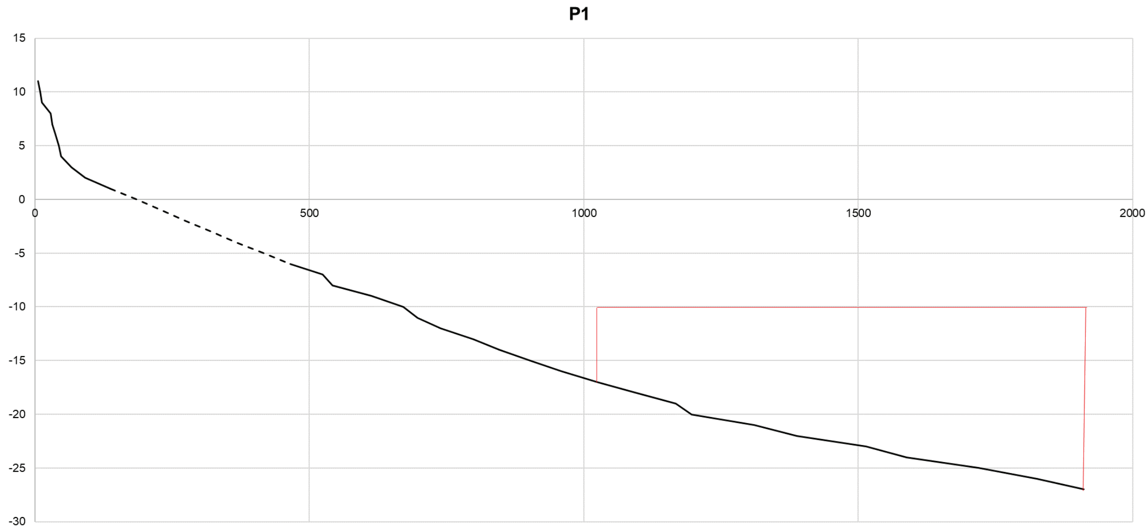

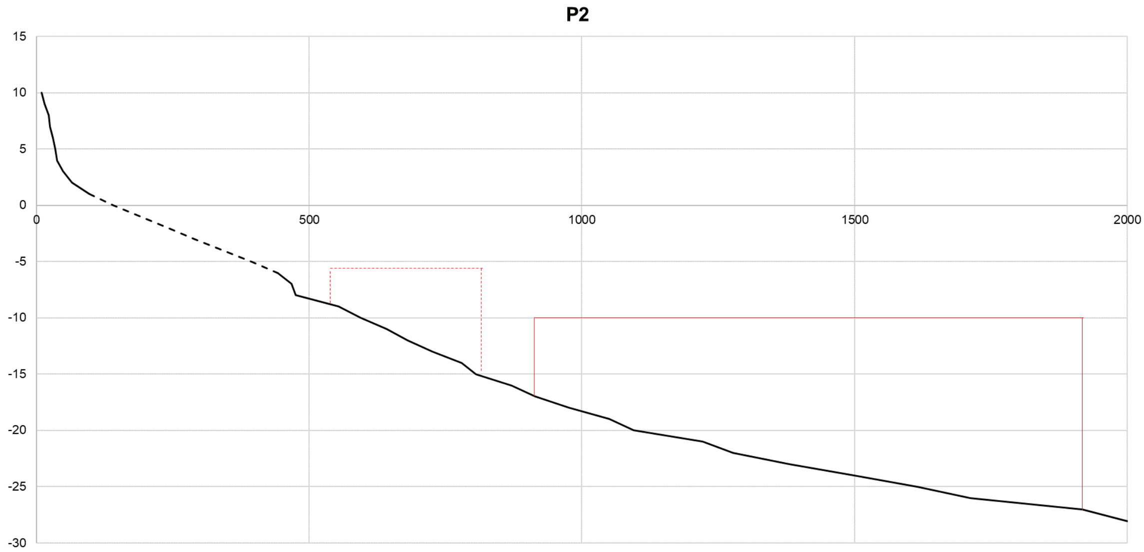

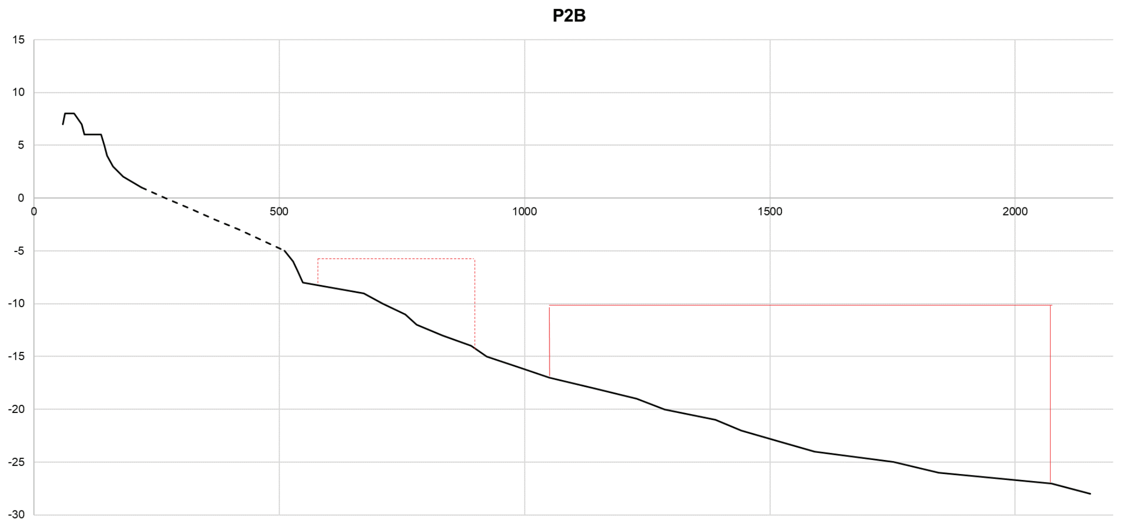

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CLIENT Client	
PROJECT McCallum Brothers Ltd Pakiri Sand Extraction Consent	
SCALE 1:100,000 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 06/26/2020

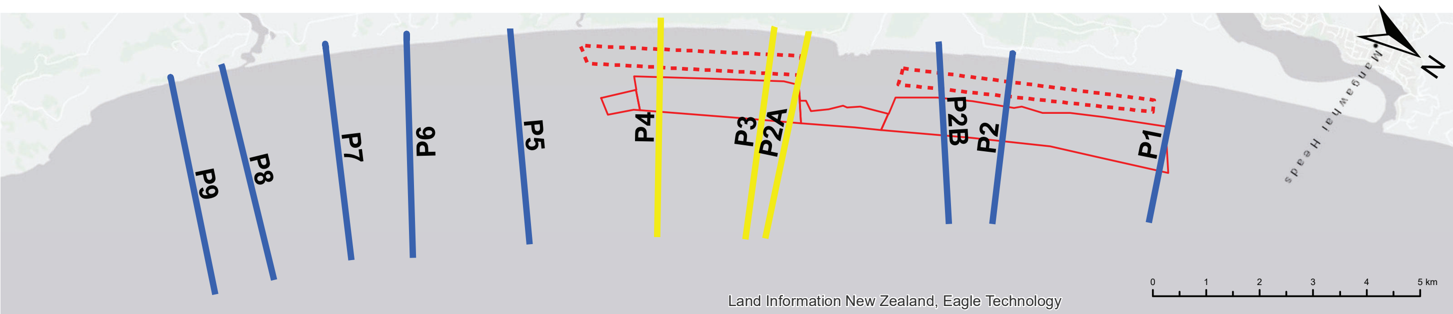
Legend

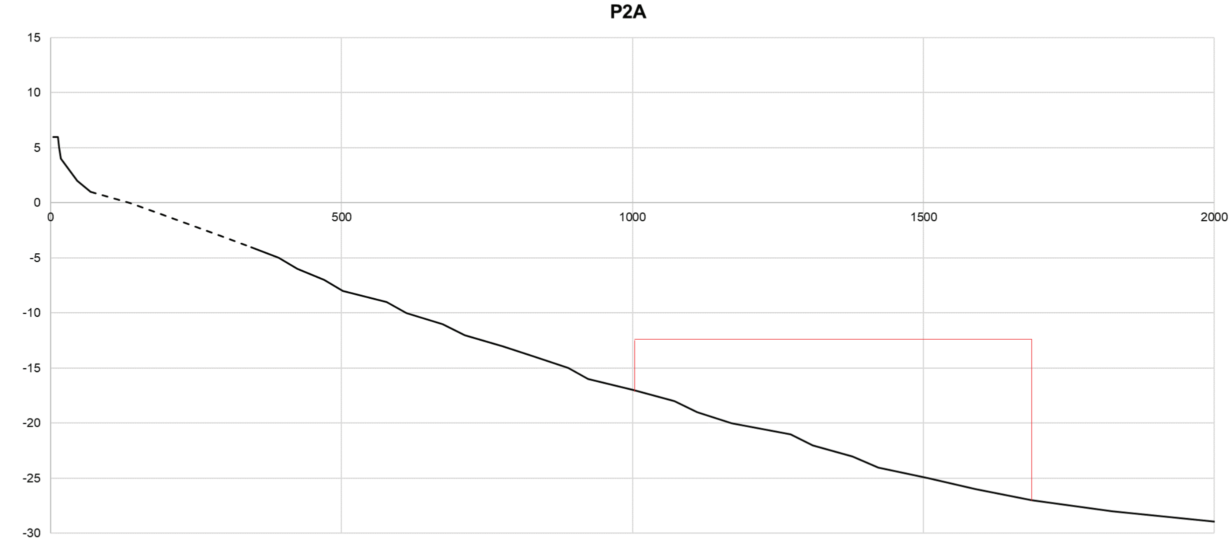
- Proposed Consent Area
- Renewal Consent Area
- Historical Profiles Analysed
- Other Historical Profiles
- Interpolated Survey Data

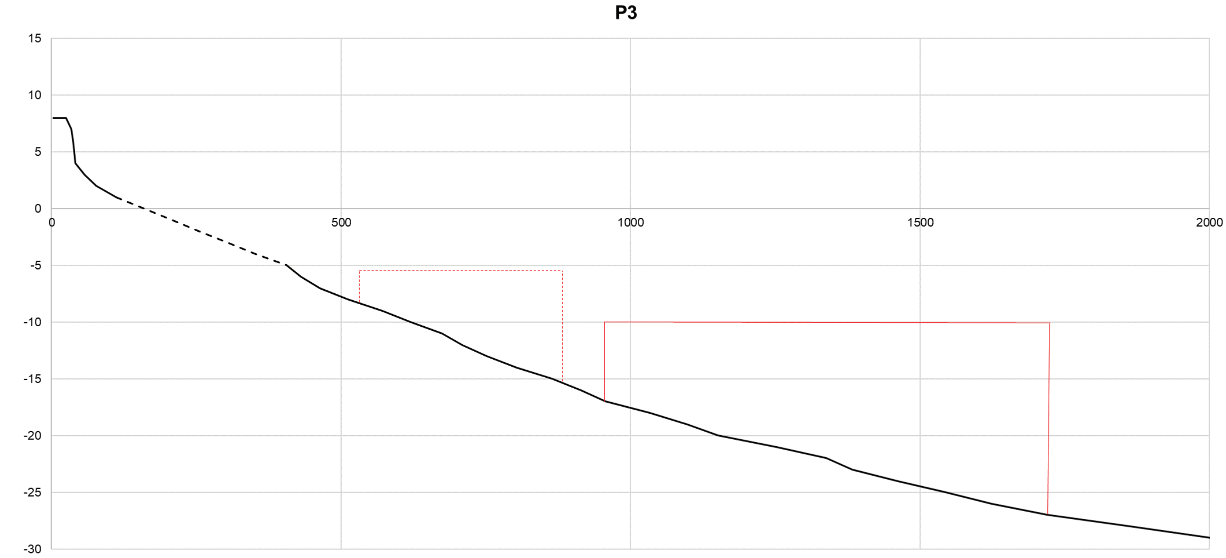
2019 Bathymetry and Offshore Profiles

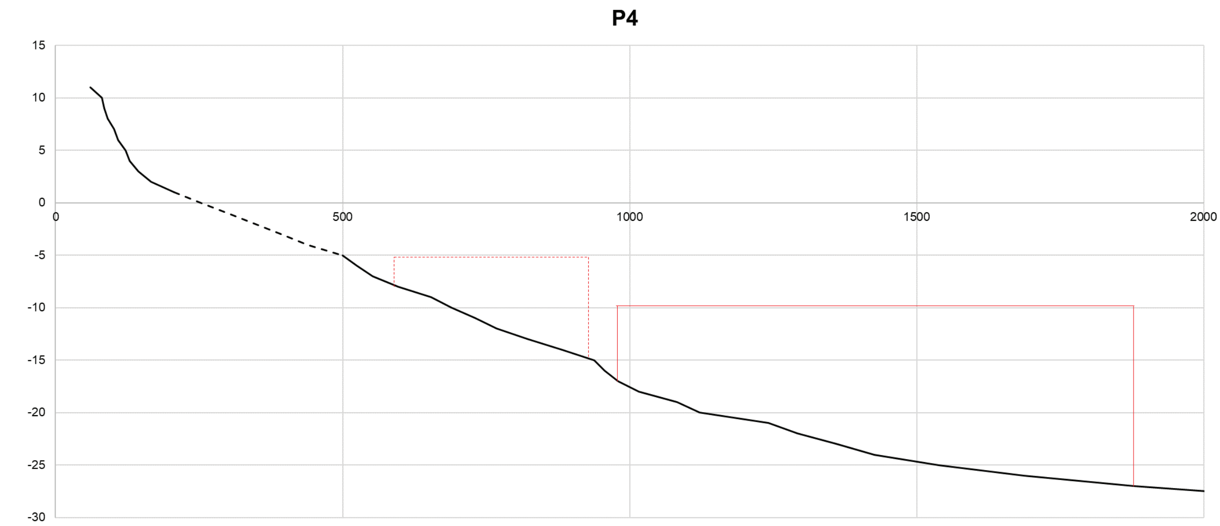
Profiles 1-2b

JACOBS SPATIAL
Level 2, Wynn Williams building,
47 Hereford Street,
Christchurch Central 8013,
New Zealand
T +64 3 940 4900
F +64 3 940 4901









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CLIENT Client	
PROJECT McCallum Brothers Ltd Pakiri Sand Extraction Consent	
SCALE 1:100,000 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 06/26/2020

Legend

- Proposed Consent Area
- Renewal Consent Area
- Historical Profiles Analysed
- Other Historical Profiles
- Interpolated Survey Data

2019 Bathymetry and Offshore Profiles

Profiles 2a-4

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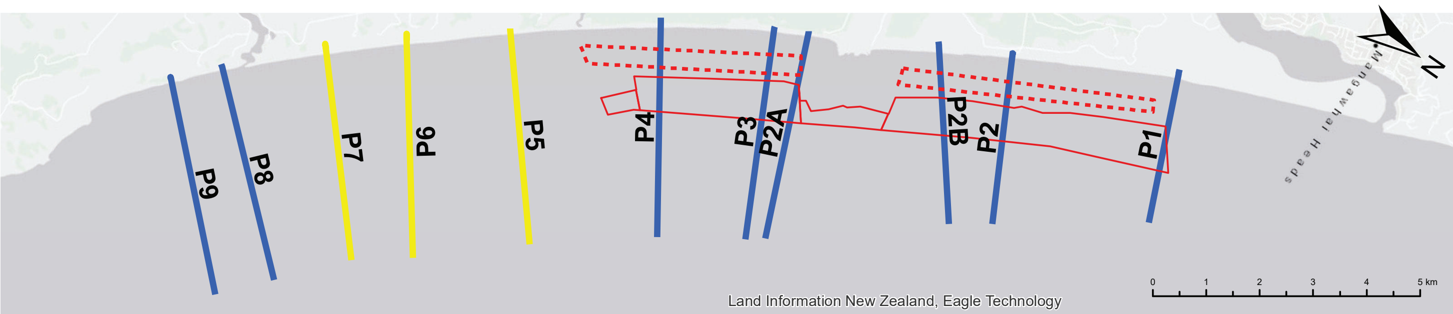

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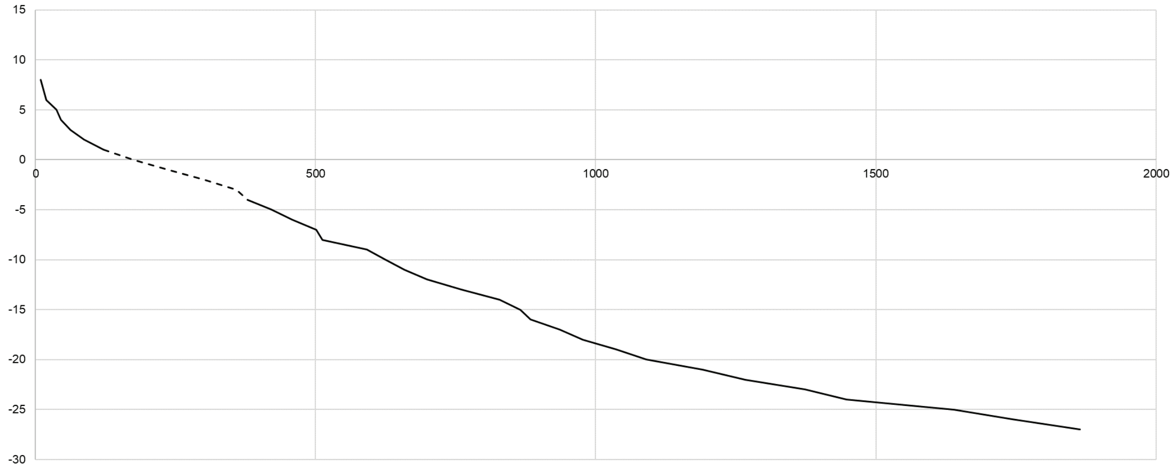
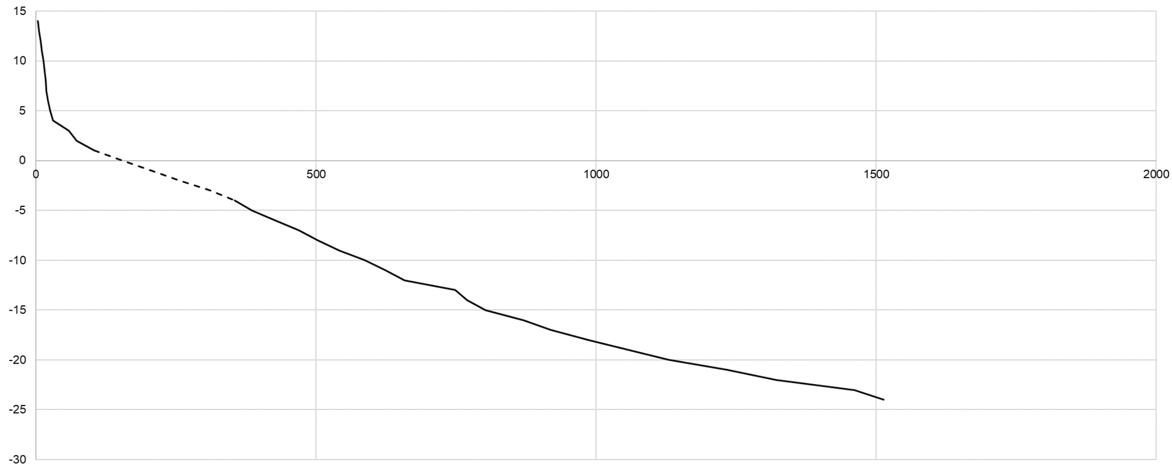
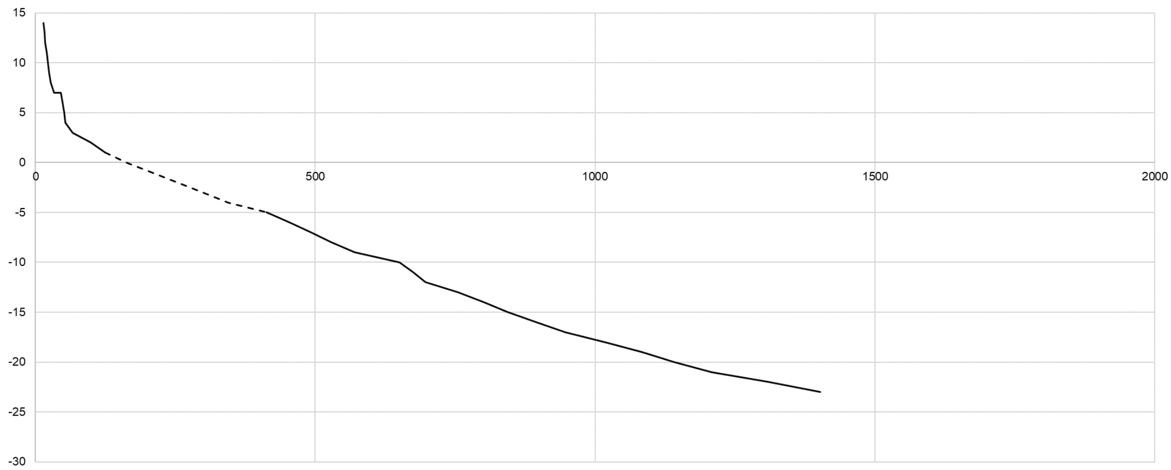


P6



P7



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CLIENT Client	
PROJECT McCallum Brothers Ltd Pakiri Sand Extraction Consent	
SCALE 1:100,000 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 06/26/2020

Legend

- Proposed Consent Area
- Renewal Consent Area
- Historical Profiles Analysed
- Other Historical Profiles
- Interpolated Survey Data

2019 Bathymetry and Offshore Profiles

Profiles 5-7

JACOBS SPATIAL
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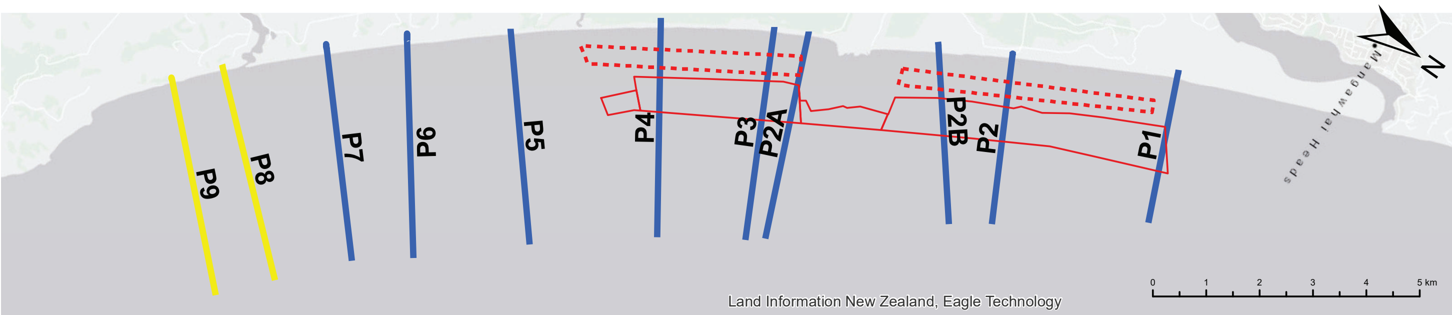

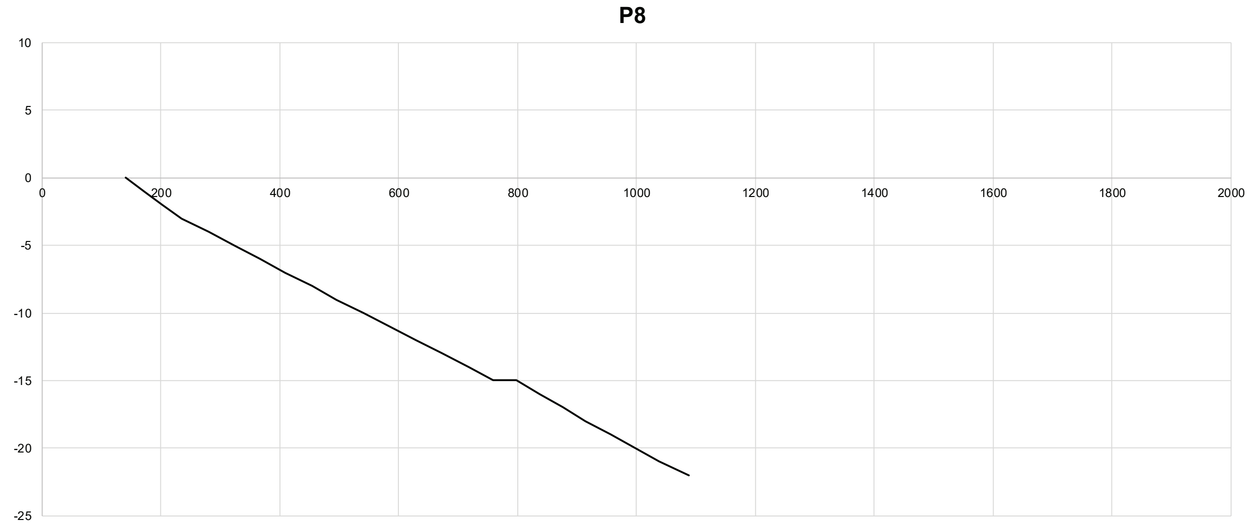

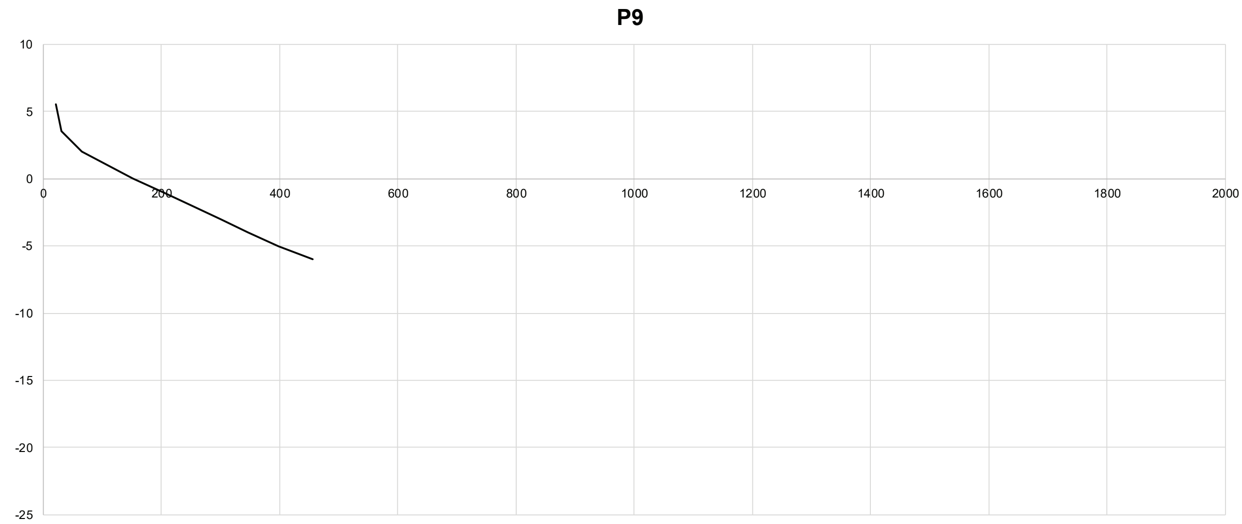

CLIENT Client	
PROJECT McCallum Brothers Ltd Pakiri Sand Extraction Consent	
SCALE 1:100,000 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 06/26/2020

Legend

- Proposed Consent Area
- Renewal Consent Area
- Historical Profiles Analysed
- Other Historical Profiles

Bathymetric Surveys (2004-2019) at Historical Survey Sites

Profiles 8-9

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47 Hereford Street,
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New Zealand
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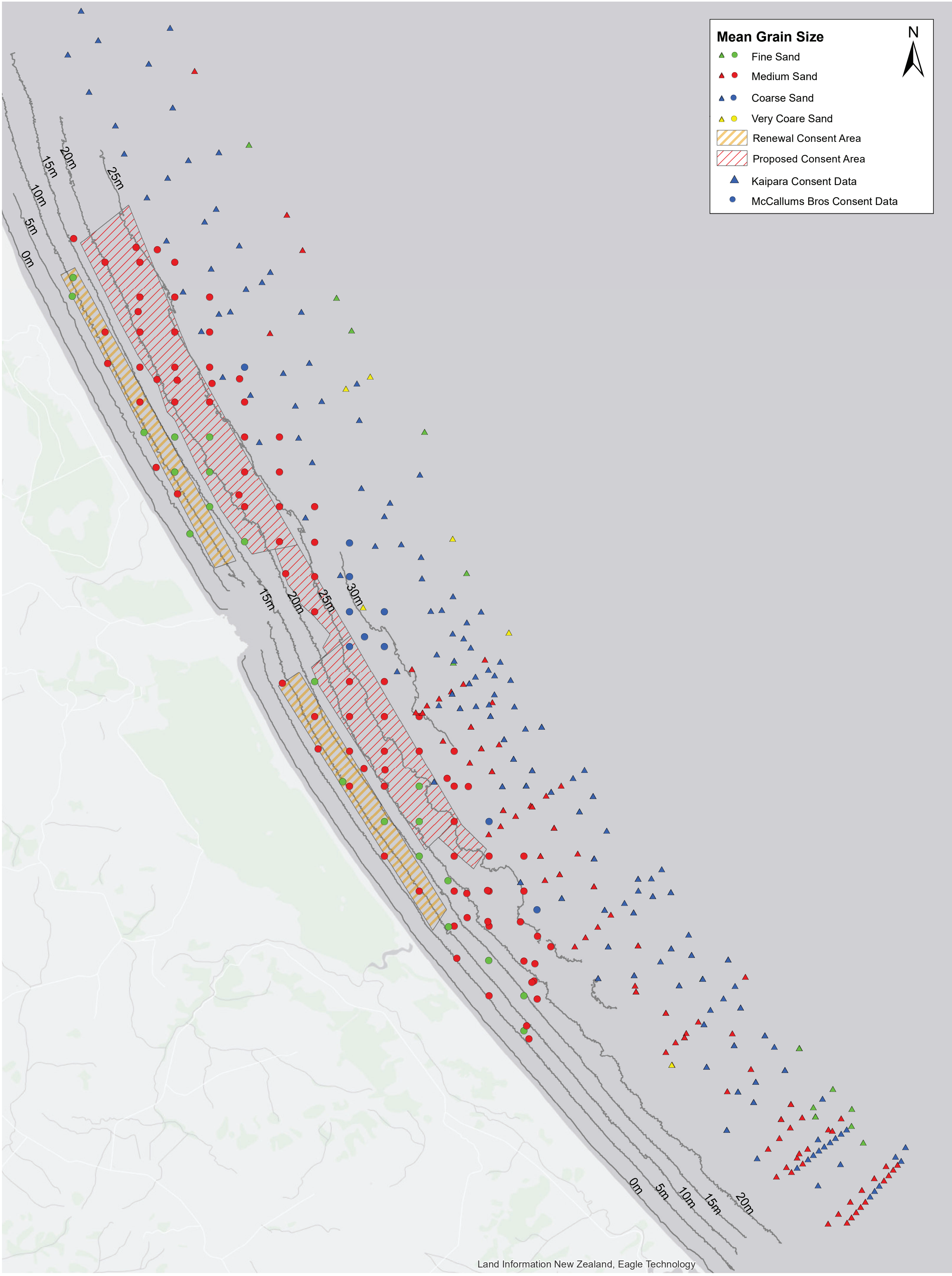
Appendix H. Sediment Sampling Size Distribution Results



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CLIENT McCallum Bros		
PROJECT Pakiri Sand Extraction Consent Renewal		
SCALE 1:50,000 @ A3	PROJECT CODE IZ111900	
PROJECT MANAGER IW	DRAWN KM	
PROJECT DIRECTOR DT	DATE 06/26/2020	

Mean Grain Size
McCallum Bros and Kaipara Ltd Consent Data

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New Zealand
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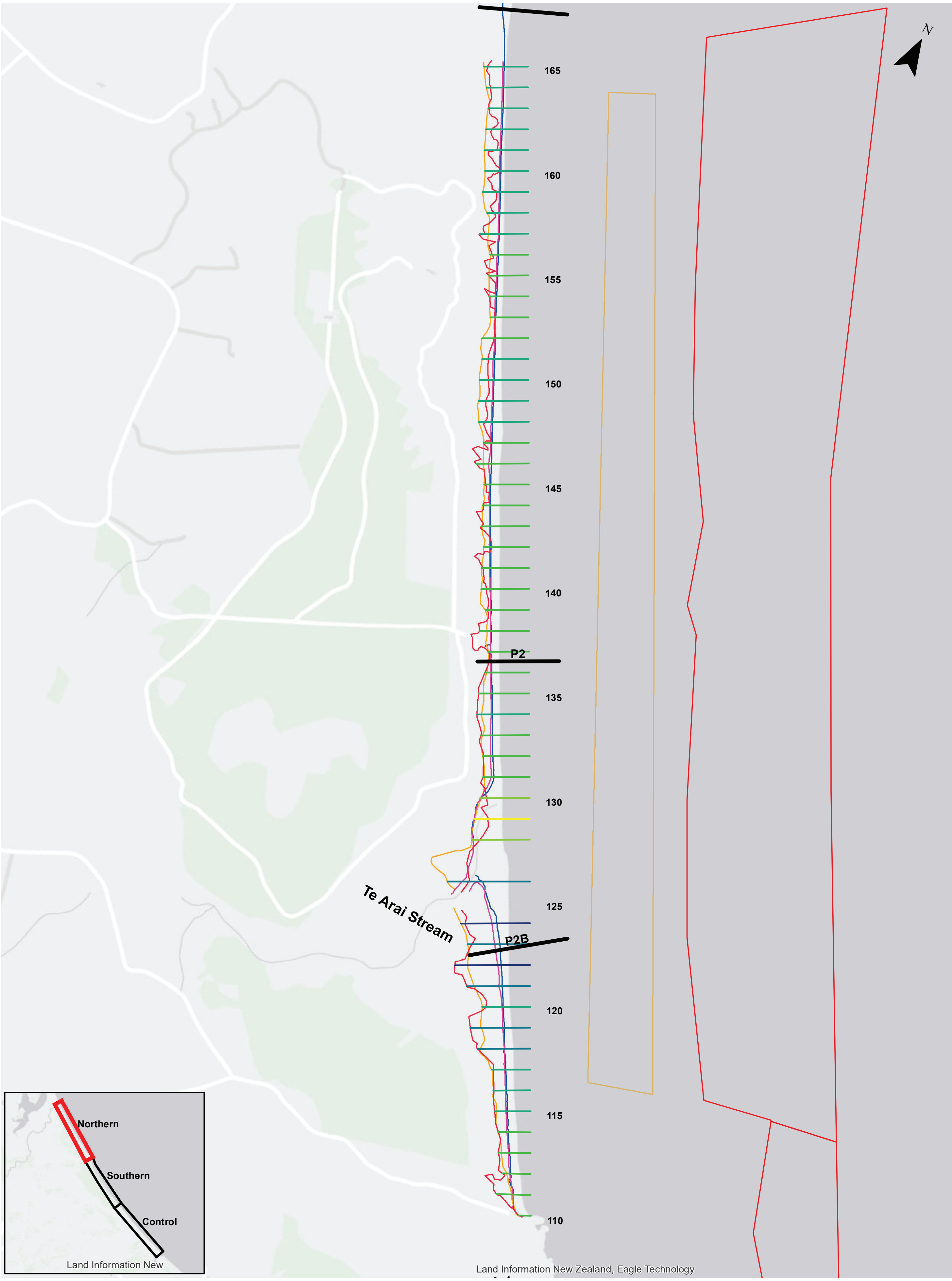
Appendix I. Storm Events from Northport Wave Bouys at Marsden Point Jan 2007 to March 2020

Date	Hours	Hs (m)	Ts (sec)	Dir Magnetic	Dir True (deg)	Dir
2/6/2007-2/9/2007	20	2.93	7.4	81.5	100.5	E
07/10/2007	15	5.59	11	65.6	84.6	E
07/16/2007	8	2.92	7.8	72.1	91.1	E
8/16/2007 - 8/17/2007	31	4.26	9.6	61.2	80.2	E
09/09/2007	10	3.52	7.9	72.1	91.1	E
09/20/2007	16	3.21	7.5	69.4	88.4	E
12/07/2007	14	3.59	7.5	71.5	90.5	E
1/19/2008-1/20/2008	30	3.21	8.1	71.9	90.9	E
01/26/2008	4	2.6	11	61.4	80.4	E
2/22/2008-2/24/2008	22	3.71	9.5	63.5	82.5	E
03/04/2008	8	3.01	7.1	80.9	99.9	E
06/18/2008	7	3.1	8.3	72.8	91.8	E
07/26/2008	9	5.41	9.5	69.7	88.7	E
09/08/2008	**3**	**2.56**	**8.3**	**61.7**	**80.7**	**E**
12/23/2008	5	2.75	7	81.1	100.1	E
02/28/2009	6	3.24	8	64.5	83.5	E
3/5/2009-3/6/2009	21	3.41	8.6	56.7	75.7	E
05/26/2009	6	2.84	7	86.3	105.3	ESE
7/11/2009-7/12/2009	35	6.17	10.3	68.8	87.8	E
08/14/2009	4	2.8	9.8	58.4	77.4	E
5/11/2010-5/12/2010	13	3.42	8.8	58.5	77.5	E
05/21/2010	6	3.08	7.4	77.5	96.5	E
10/12/2010-10/13/2010	4	2.82	7.8	97.5	116.5	SE
29/4/2011-2/5/2011	54	3.93	9	66.6	85.6	E
6/3/2011-6/4/2011	19	3.08	8.1	61.2	80.2	ENE
6/17/2011-6/18/2011	6	2.88	8.1	58.2	77.2	E
7/4/2011-7/5/2011	23	4.48	12.1	66.5	85.5	E
08/04/2011	10	3.23	11	75.3	94.3	E
01/07/2012	4	2.89	7.6	95.6	114.6	SE
03/19/2012	19	3.89	7.9	89.5	108.5	E
4/2/2012-4/5/2012	49	5.65	11.6	72.5	91.5	E
07/03/2012	6	3.04	8	66.5	85.5	E
07/16/2012	3	2.63	14.1	71.5	90.5	E
7/29/2012-7/30/2012	14	3.31	8.6	51.5	70.5	E
8/30/2012-8/31/2012	22	3.46	8.6	83.1	102.1	E
09/28/2012	14	3.62	8.8	78.3	97.3	E

12/23/2012	15	2.96	10.3	69.5	88.5	E
01/06/2013	9	4.15	12.4	75.6	94.6	E
05/04/2013	11	3.47	12.3	65.8	84.8	E
6/27/2013-6/28/2013	13	3.16	9.5	78.9	97.9	E
8/1/2013-8/3/2013	41	3.41	9.1	60.9	79.9	E
9/24/2013-9/25/2013	12	3.73	10.3	87.5	106.5	E
2/6/2014-2/7/2014	15	3.09	7.6	71.1	90.1	E
3/14/2014-3/16/2014	30	5.45	11.1	63.5	82.5	E
04/17/2014	6	3.14	8.9	59	78	E
6/10/2014-6/11/2014	20	3.79	9.5	77.6	96.6	E
7/8/2014-7/12/2014	98	6.37	10.8	57.4	76.4	E
8/30/2014-9/1/2014	40	3.54	8.8	68	87	E
09/29/2014	8	2.99	6.9	86	105	E
12/14/2014-12/17/2014	58	3.32	7.1	101.3	120.3	SE
3/15/2015-3/16/2015	27	4.9	13.1	72.6	91.6	E
01/01/2016	10	3.04	7.9	69.8	88.8	E
3/23/2016-3/24/2016	26	3.14	8.6	62.7	81.7	E
7/9/2016-7/11/2016	20	3.16	7.5	85	104	E
3/8/2017-3/9/2017	12	3.51	7.9	91.1	110.1	E
4/13/2017-4/14/2017	7	2.77	12.2	66.5	85.5	E
04/24/2017	8	2.69	10.4	64.9	83.9	E
6/21/2017-6/22/2017	18	3	7.9	59.9	78.9	E
08/03/2017	8	2.76	7	71.3	90.3	E
11/18/2017-11/19/2017	25	4.01	7.9	78.6	97.6	E
2/8/2018-2/9/2018	32	3.29	6.7	74.4	93.4	E
03/12/2018	14	3.16	6.5	79.1	98.1	E
03/17/2018	5	2.9	5.7	78.7	97.7	E
04/28/2018	3	2.83	7.2	64.1	83.1	E
6/2/2018-6/3/2018	15	3.08	6.6	64.2	83.2	E
6/20/2018-6/21/2018	33	4.1	7.1	81.5	100.5	E
09/19/2018	4	2.705	6.2	73.4	92.4	E
10/2/2019-11/2/2019	23	3.12	8.4	68	87	E
19/09/2018	7	2.82	6.4	74.1	93.1	E
14/10/2019-15/10/2019	27	4.84	8	68	87	E
Total Events	**70**					
Max	**98**	**6.37**	**10.8**	**57.4**	**76.4**	**E**
						E = 65; ENE = 1; SE = 3; ESE = 1

Appendix J. Shoreline Change from DSAS 1961-2018



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CLIENT McCallum Brothers Ltd	
PROJECT Pakiri Sand Extraction Consent Renewal	
SCALE 1:16,720 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 06/26/2020

Linear Regression Rate (m/yr)

- -1.04 - -1
- -1 - -0.75
- -0.75 - -0.5
- -0.5 - -0.25
- -0.25 - 0
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4

Shoreline

- 1961
- 1963
- 1982
- 2007
- 2008
- 2018
- Historical Profile
- Proposed Consent Area
- Renewal Consent Area

Shoreline change from DSAS
Northern Extraction Consent Area

0 500 1,000 Meters

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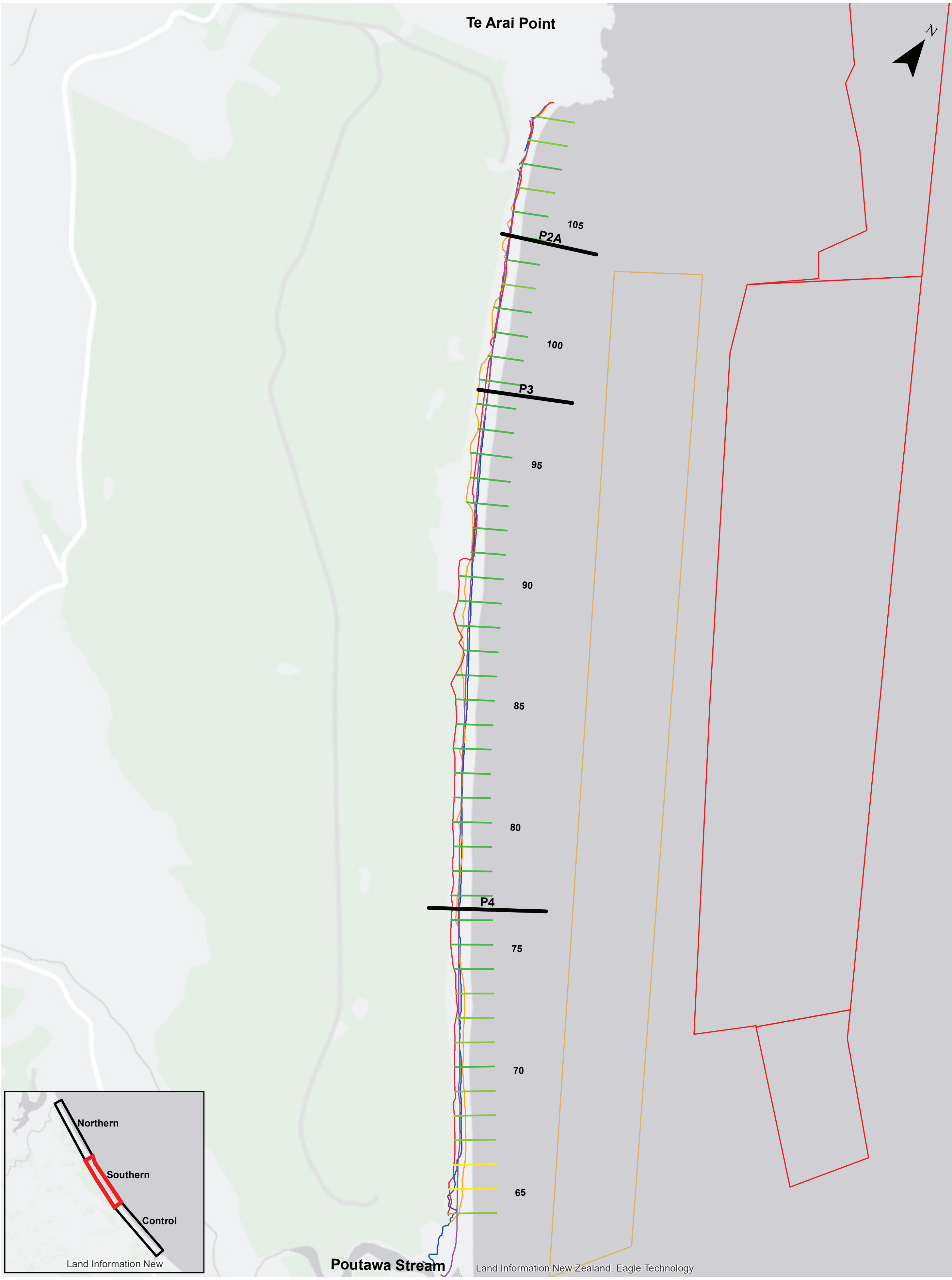

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CLIENT McCallum Brothers Ltd	
PROJECT Pakiri Sand Extraction Consent Renewal	
SCALE 1:14,310 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 06/26/2020

Linear Regression Rate (m/yr)

- -1.04 - -1
- -1 - -0.75
- -0.75 - -0.5
- -0.5 - -0.25
- -0.25 - 0
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4

Shoreline

- 1961
- 1963
- 1982
- 2007
- 2008
- 2018
- Historical Profile
- Proposed Consent Area
- Renewal Consent Area

Shoreline change from DSAS Southern Extraction Consent Area

0 500 1,000 Meters

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New Zealand
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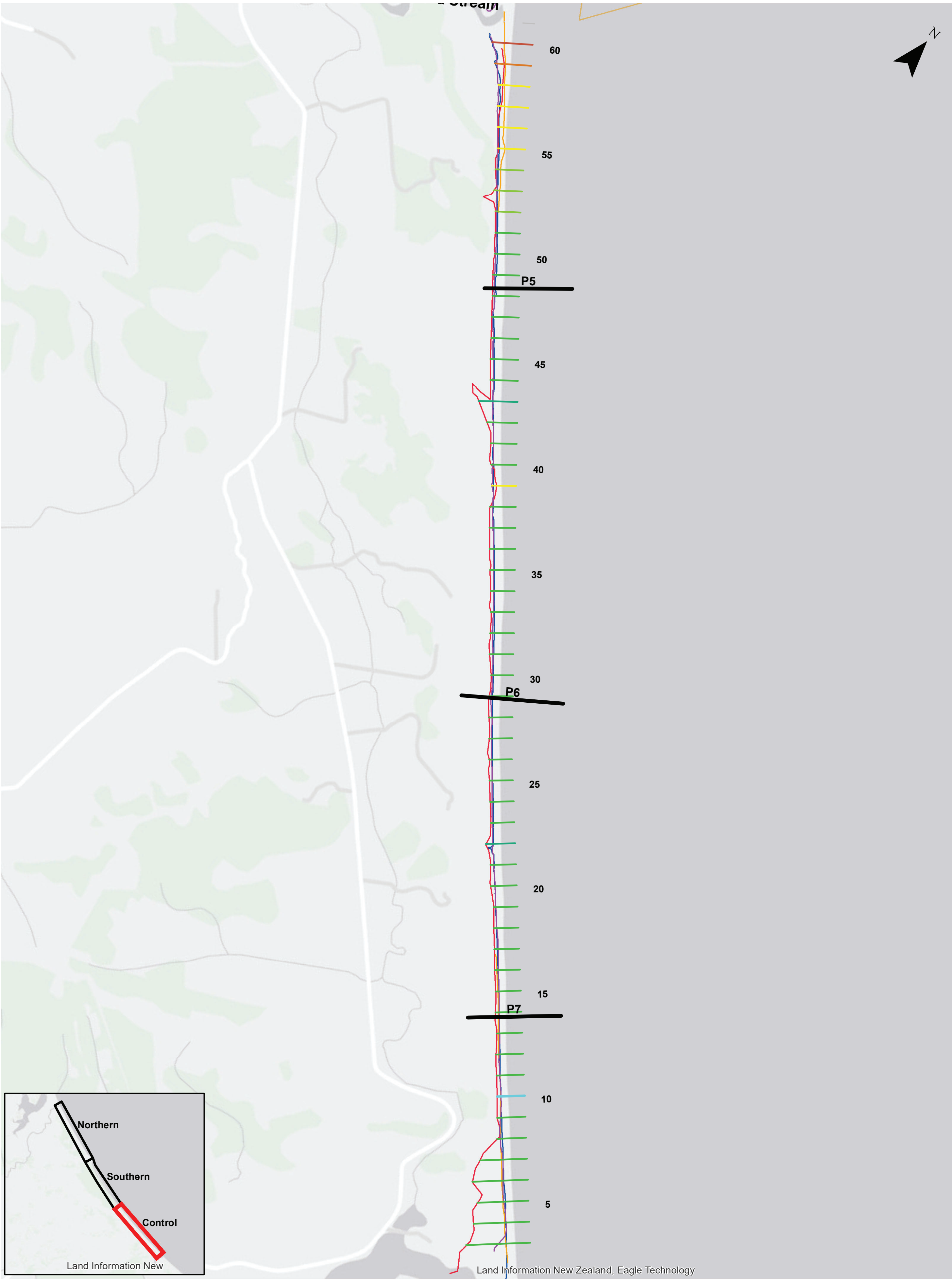
F +64 3 940 4901



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CLIENT McCallum Brothers Ltd			
PROJECT Pakiri Sand Extraction Consent Renewal			
SCALE 1:16,620 @ A3	PROJECT CODE IZ111900		
PROJECT MANAGER IW	DRAWN KM		
PROJECT DIRECTOR DT	DATE 06/26/2020		

Linear Regression Rate (m/yr)

- -1.04 - -1
- -1 - -0.75
- -0.75 - -0.5
- -0.5 - -0.25
- -0.25 - 0
- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4

Shoreline

- 1961
- 1963
- 1982
- 2007
- 2008
- 2018
- Historical Profile

Shoreline change from DSAS Control Area

0 500 1,000 Meters

JACOBS SPATIAL

Level 2, Wynn Williams building,
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New Zealand
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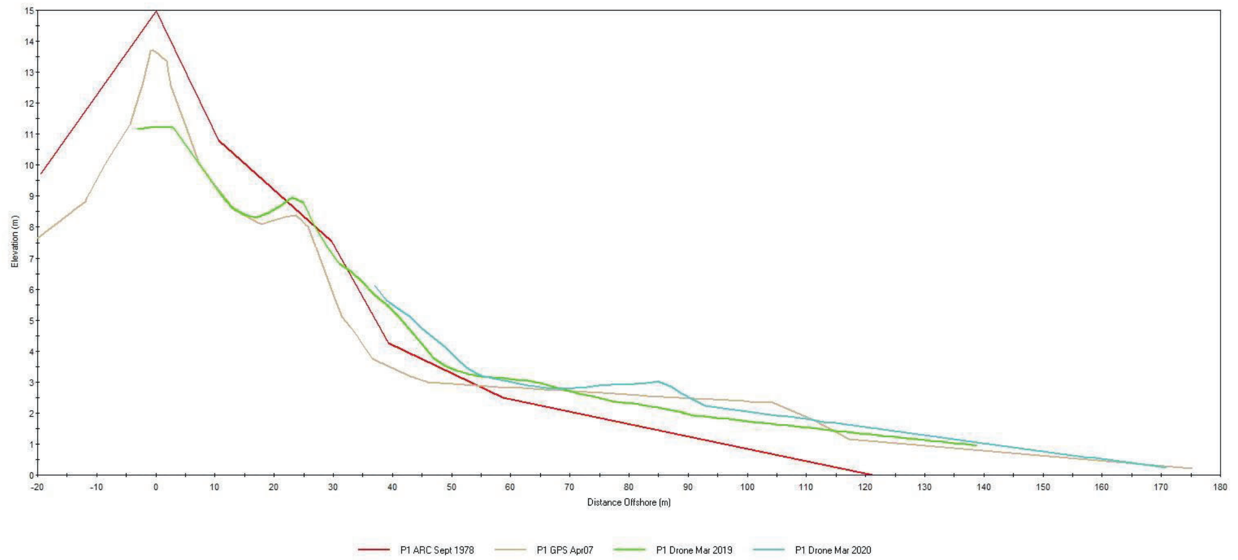
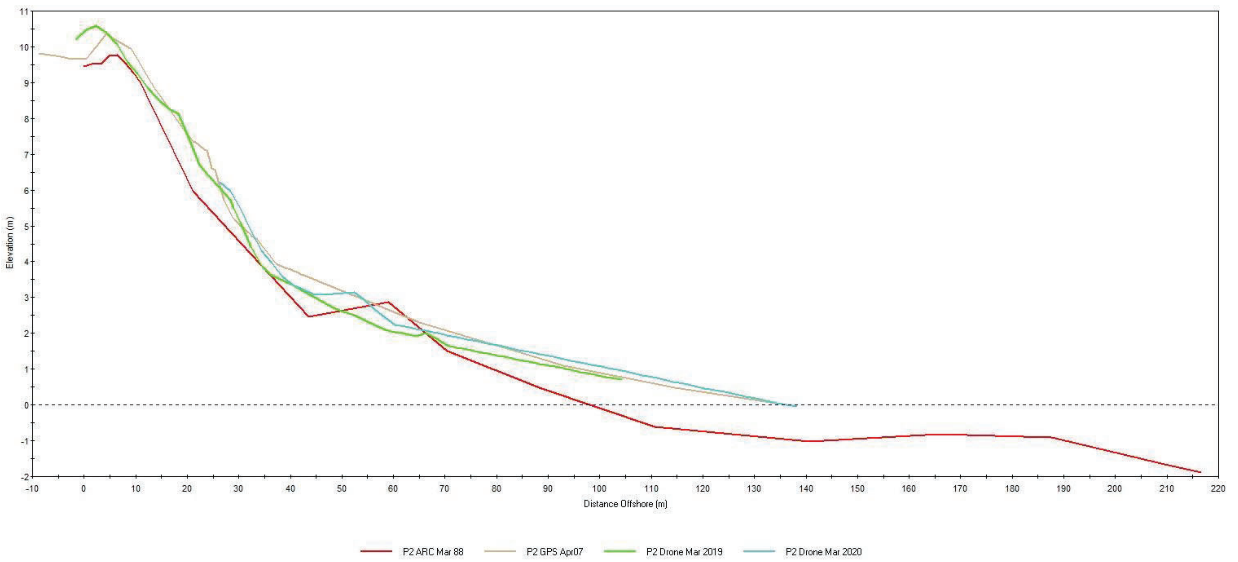
Appendix K. Historical Profile Cross-sections 1978-2000, 2007, 2017-2020

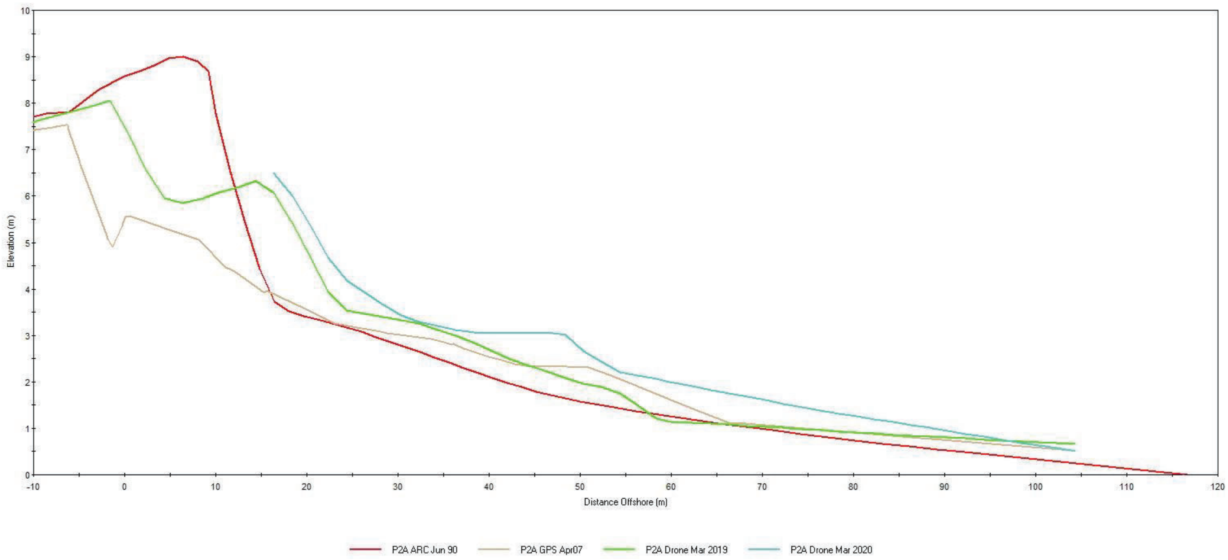
P1 1978-2020



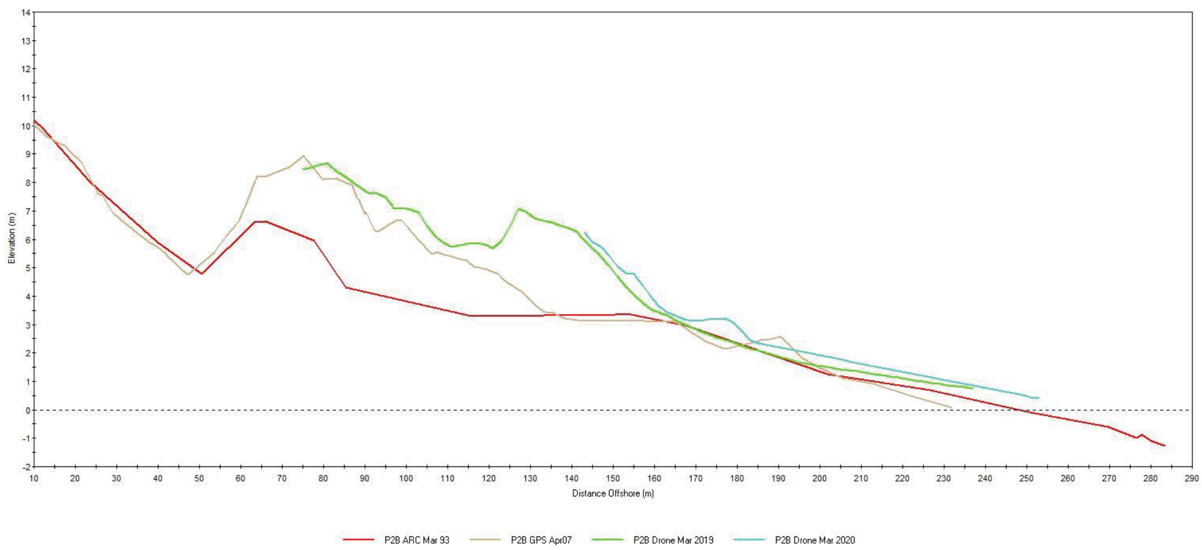
P2 1988-2020

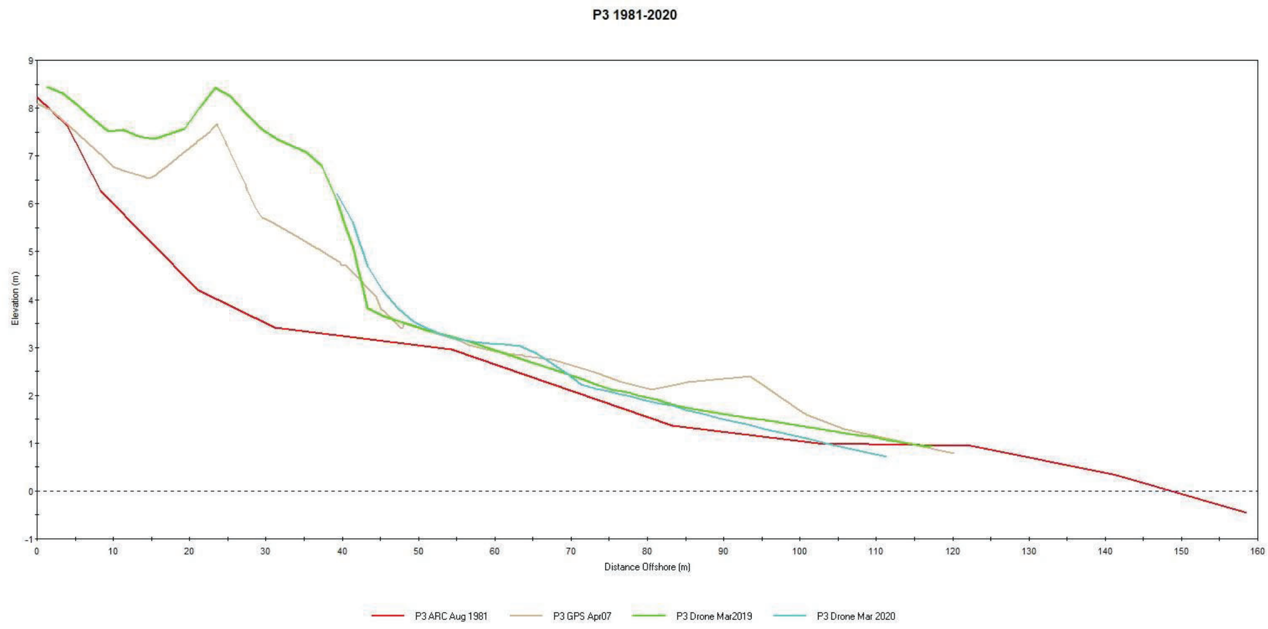


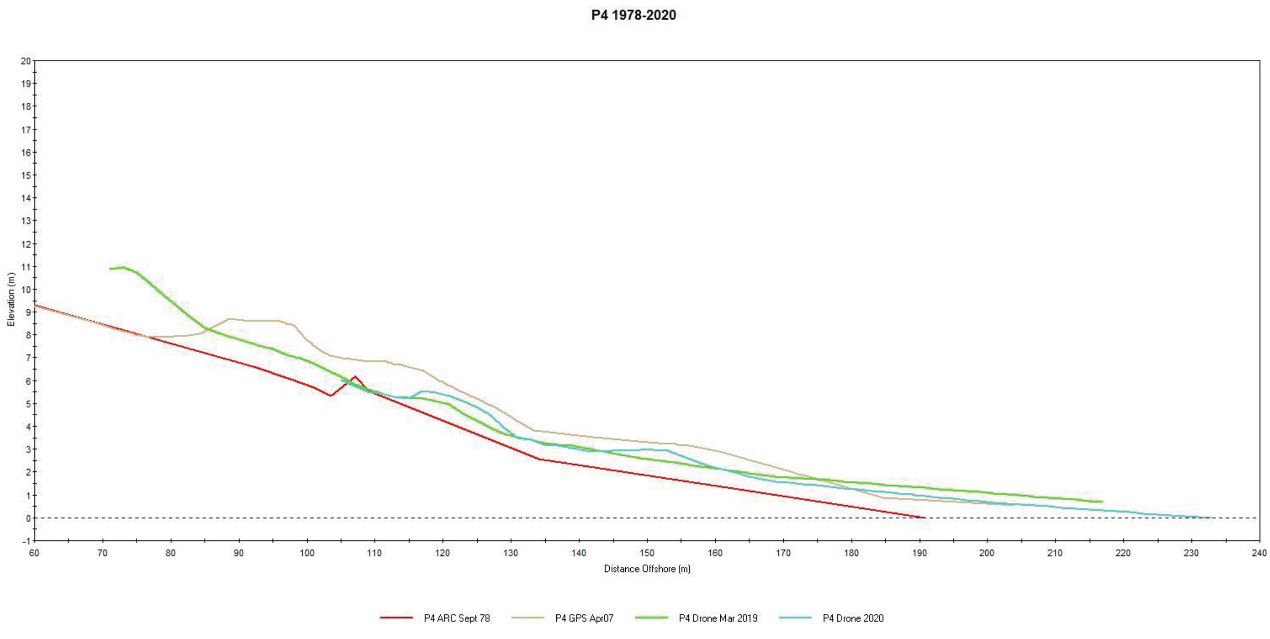
P2A 1990-2020



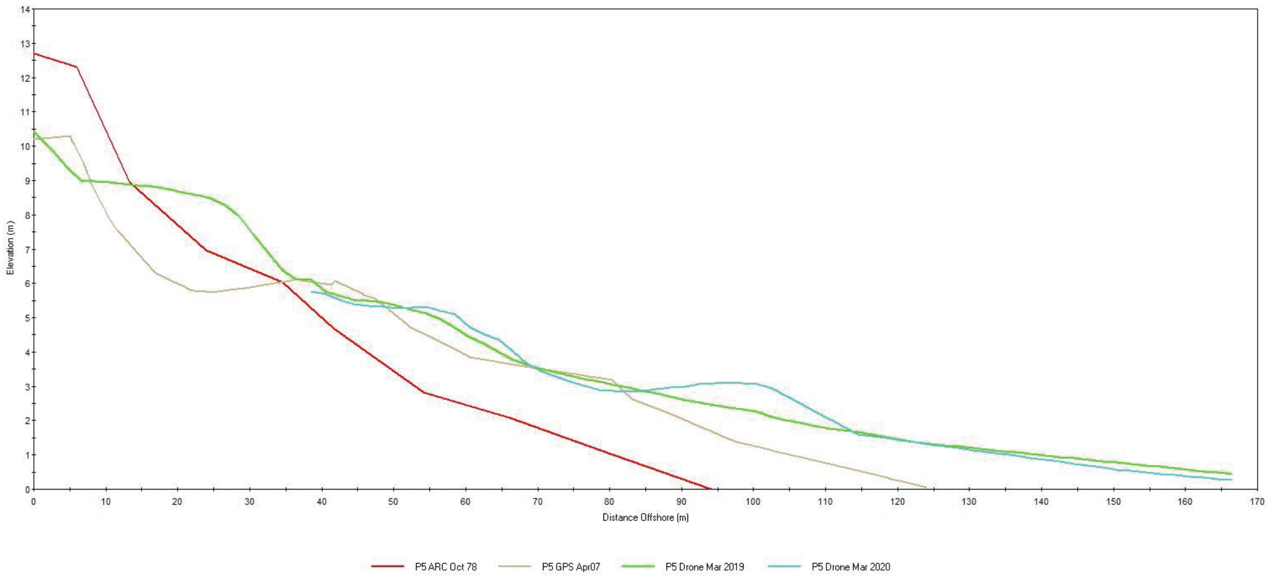
P2B 1993-2020



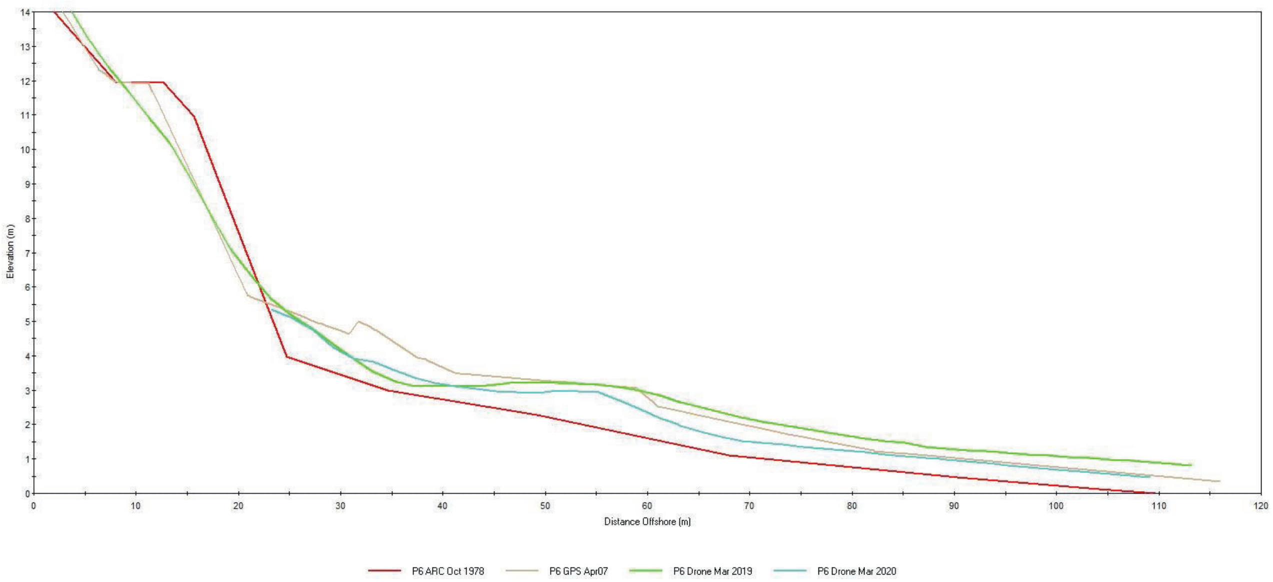

P3 1981-2020
Elevation (m)
Distance Offshore (m)
P3 ARC Aug 1981
P3 GPS Apr07
P3 Drone Mar2019
P3 Drone Mar 2020

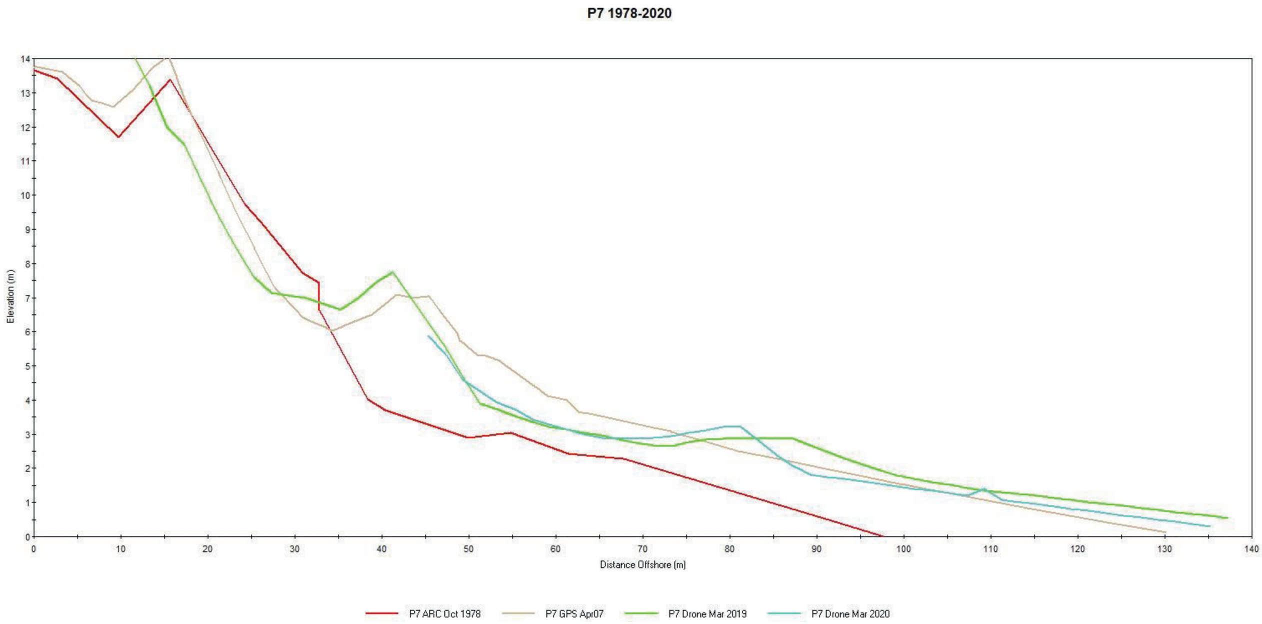

P4 1978-2020
Elevation (m)
Distance Offshore (m)
P4 ARC Sept 78
P4 GPS Apr07
P4 Drone Mar 2019
P4 Drone 2020

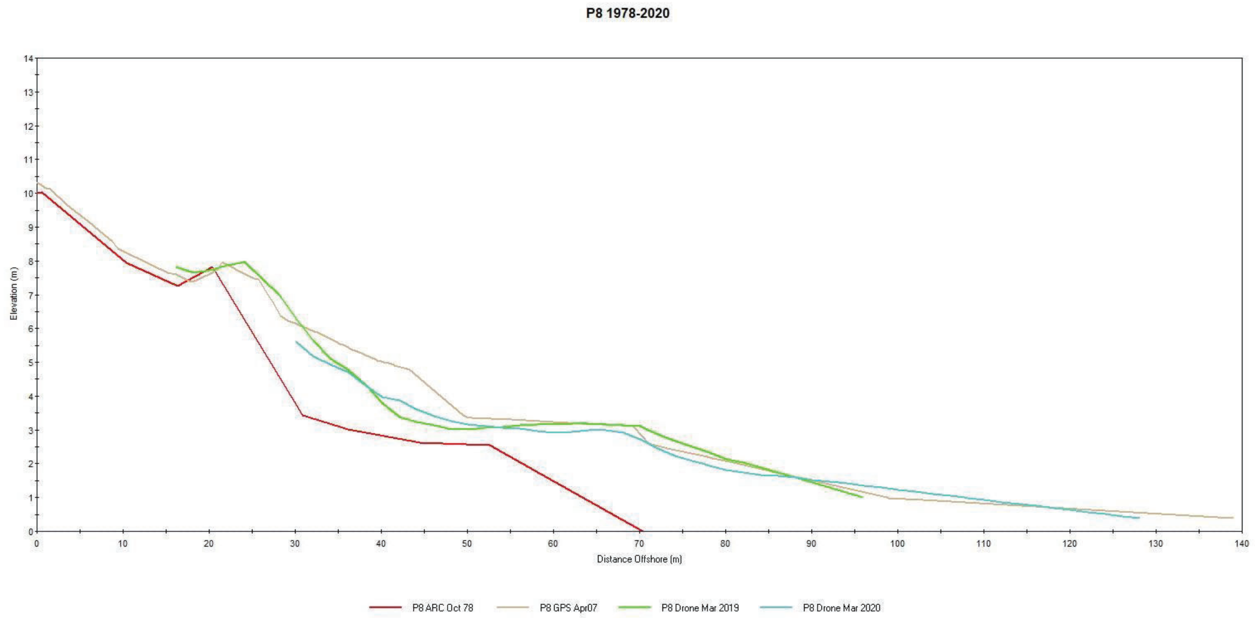
P5 1978-2020



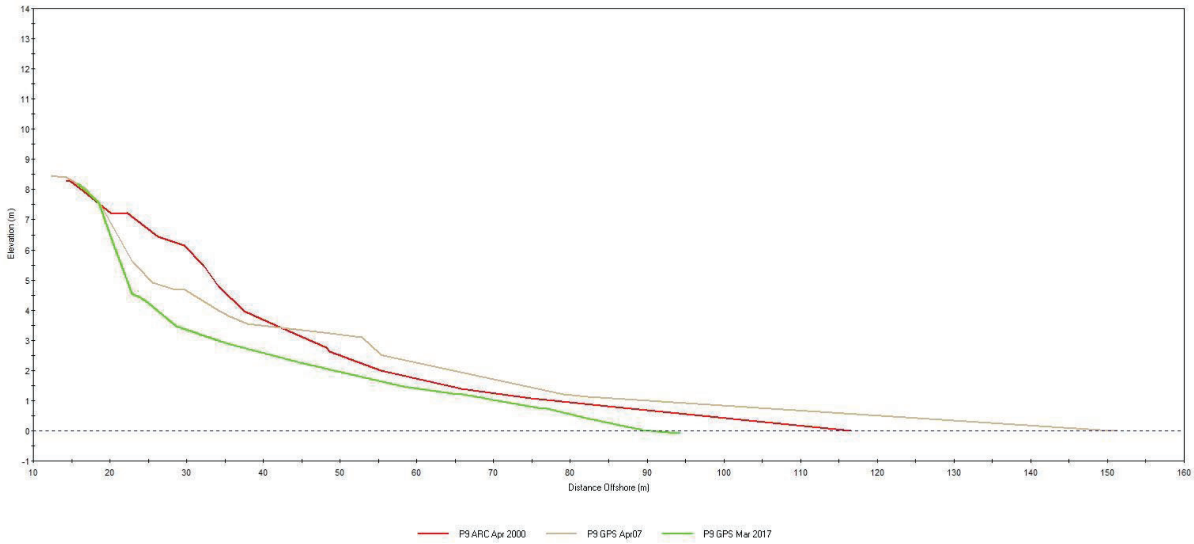
P6 1978-2020




P7 1978-2020
Elevation (m)
Distance Offshore (m)
P7 ARC Oct 1978
P7 GPS Apr07
P7 Drone Mar 2019
P7 Drone Mar 2020


P8 1978-2020
Elevation (m)
Distance Offshore (m)
P8 ARC Oct 78
P8 GPS Apr07
P8 Drone Mar 2019
P8 Drone Mar 2020

P9 2000-2017



14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
Elevation (m)
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
Distance Offshore (m)
P9 ARC Apr 2000
P9 GPS Apr07
P9 GPS Mar 2017

Appendix L. Historical Profile Surveys 2017-2020 from Surveyworx Drone Surveys

PLOT DATE: 3/31/2020 2:18 PM

SURVEYED	SWX	11.03.20
DESIGNED		
DRAWN	RRR	31.03.20
CHECKED		
APPROVED		

APPROVED DATE

REVISION	CHANGES	CHECKED	DATE
0	ORIGINAL ISSUE	CH	05.06.19
2	RE ISSUE	CH	01.08.19
3	NOV 2019 ADDED	RRR	18.12.19
4	MARCH 2020 ADDED	RRR	31.03.20

NOTES:

BEARING AND COORDINATE DATUM IS GEODETIC 2000
ORIGIN IS 16 MT. EDEN 800 000 mN, 400 000 mE
PROJECTION IS TRANSVERSE MERCATOR TO OBTAIN
PROJECTION DISTANCES MULTIPLY BY 0.9999

LEVELS ARE IN TERMS OF MEAN SEA LEVEL
ORIGIN DATUM BEING A9J7 (RL84.55m)

P:\0-TEMPLATES-PLOT FILES\trimble.png

SURVEY EQUIPMENT USED:
INSTRUMENT: TRIMBLE ROBOTIC S8 1"
GPS: TRIMBLE R6/R8 SYSTEMS
PRECISE LEVELLING: TRIMBLE DiNi Series 0.3mm DIGITAL
VERTICAL PLUMMING: FOIF DZJ2 LASER PLUMMIT

SURVEY WORX
CONSTRUCTION & LAND SURVEYORS
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517 Mt Wellington Hway, Auckland, NZ

NZIS REGISTERED PROFESSIONAL SURVEYOR
MEMBERS OF: NZIS

CLIENT
McCULLUM BROS

PROJECT
PAKIRI BEACH

TITLE
AERIAL SURVEY OCTOBER 2017- MARCH 2020 PROFILE LOCATIONS

SCALE	NTS (A1)	NTS (A3)

DRAWING No	SHEET	REVISION
2249-705-12	0 of 10	4

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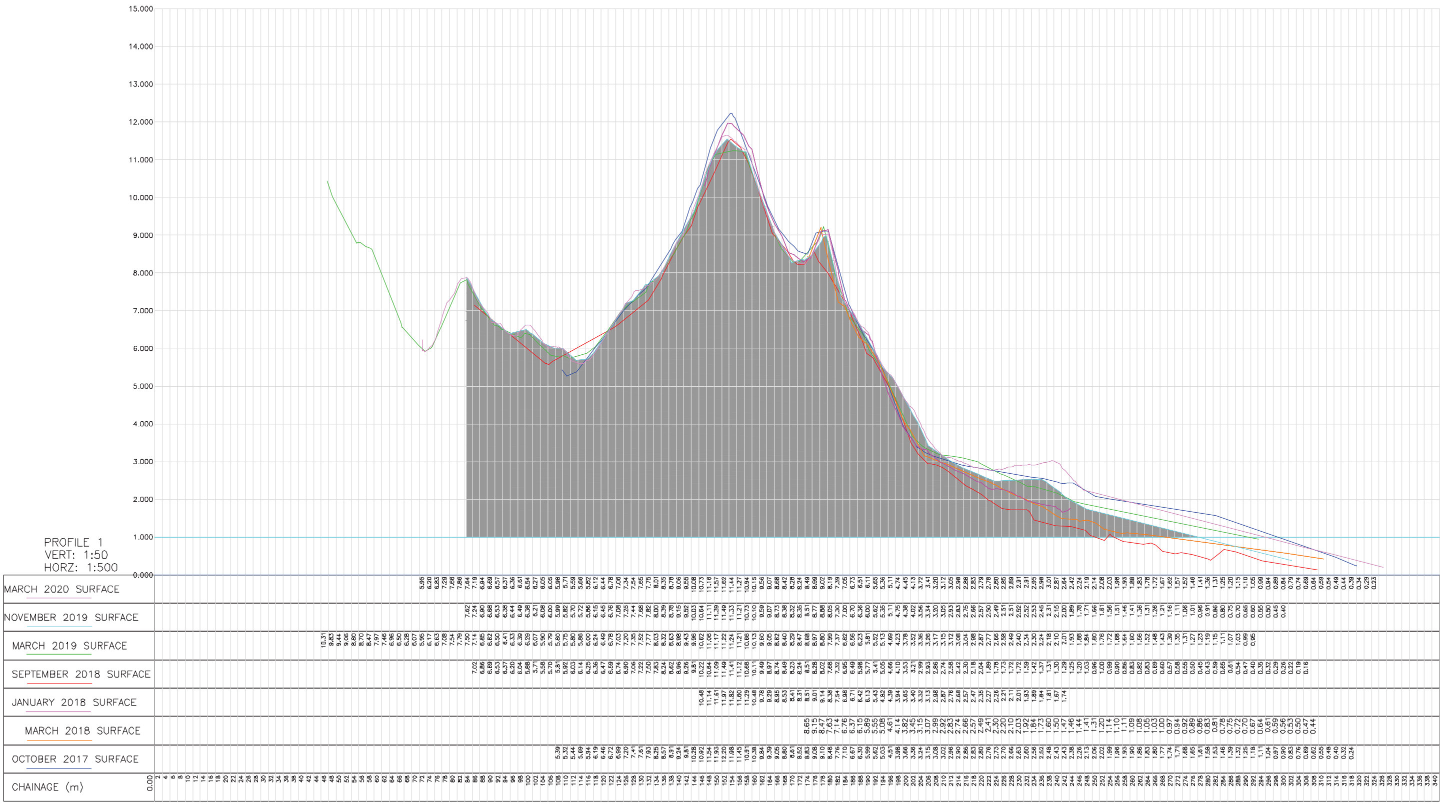

PROFILE 1

SURVEYED	SWX	11.03.20	APPROVED	DATE
DESIGNED				
DRAWN	RRR	31.03.2020		
TRACED				
REVISION		CHANGES	CHECKED	DATE
5	ALL PROFILES EDITED		RRR	31.03.20
4	MARCH 2020 ADDED		RRR	31.03.20
3	NOV 2019 ADDED		RRR	18.12.19
2	RE ISSUE		MC	01.08.19
0	ORIGINAL ISSUE		MC	18.07.19

PLOT DATE: 3/31/2020 2:18 PM

NOTES:

BEARING AND COORDINATE DATUM IS GEODETIC 2000
ORIGIN IS 16 MT. EDEN 800 000 mN, 400 000 mE
PROJECTION IS TRANSVERSE MERCATOR TO OBTAIN
PROJECTION DISTANCES MULTIPLY BY 0.9999

LEVELS ARE IN TERMS OF MEAN SEA LEVEL
ORIGIN DATUM BEING A9J7 (RL84.55m)

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NZIS REGISTERED PROFESSIONAL SURVEYOR

CLIENT: McCULLUM BROS

PROJECT: PAKIRI BEACH

TITLE: AERIAL SURVEY OCTOBER 2017- MARCH 2020 PROFILE

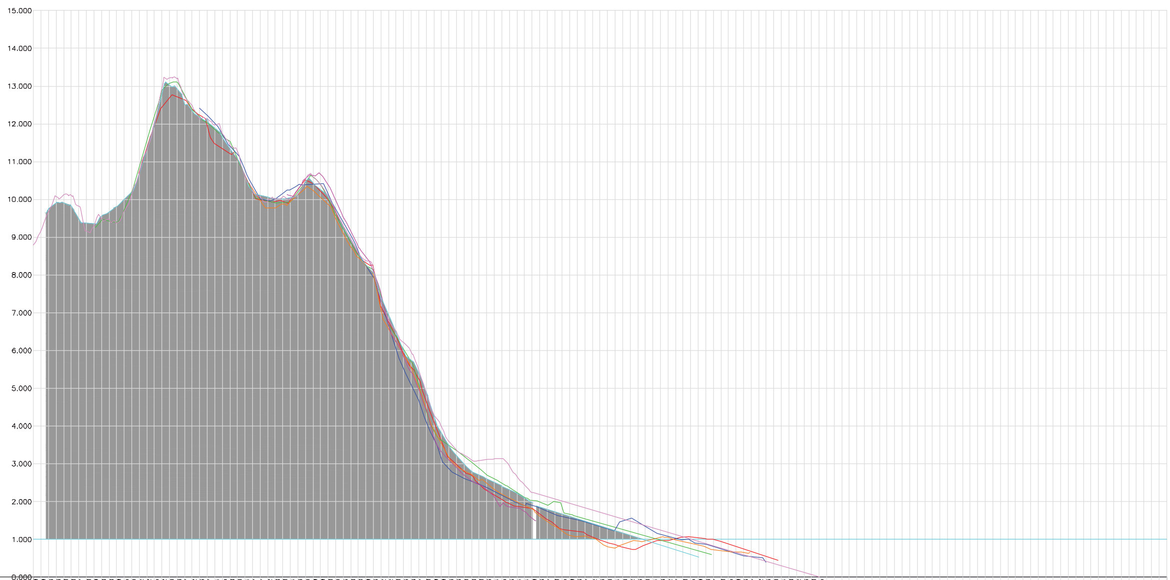
SCALE: 1:500 (A1) 1:1000 (A3)

SHEET: 1 of 10

REVISION: 5

DRAWING No: 2249-705-12

FILE PATH: C:\USERS\REGIS-R7CAD\DESKTOP\11-03-2020\SS\2249-705-12 PROFILE R5.DWG



PROFILE 2
VERT: 1:50
HORZ: 1:500

CHAINAGE (m)	MARCH 2020 SURFACE	NOVEMBER 2019 SURFACE	MARCH 2019 SURFACE	SEPTEMBER 2018 SURFACE	JANUARY 2018 SURFACE	MARCH 2018 SURFACE	OCTOBER 2017 SURFACE
0.00							
2	9.19						
4	9.69	9.75					
6	10.08	9.91					
8	10.13	9.91					
10	10.11	9.83					
12	9.81	9.48					
14	9.17	9.37					
16	9.31	9.36					
18	9.49	9.56	9.45				
20	9.48	9.66	9.43				
22	9.38	9.81	9.41				
24	9.69	10.00	9.73				
26	10.15	10.19	10.19				
28	10.70	10.70	10.85	10.74			
30	11.32	11.33	11.56	11.35			
32	12.02	11.96	12.21	11.94			
34	12.95	12.81	12.88	12.44			
36	13.22	13.02	13.07	12.68			
38	13.20	12.92	13.11	12.71			
40	12.73	12.53	12.77	12.63			
42	12.47	12.34	12.40	12.39			
44	12.12	12.17	12.19	12.24			12.41
46	12.13	12.13	12.01	11.95			12.23
48	11.97	11.90	11.85	11.47			12.02
50	11.74	11.64	11.71	11.35			11.74
52	11.45	11.35	11.54	11.22			11.42
54	11.28	11.07	11.07	11.06			11.21
56	10.60	10.61	10.62	10.64			10.79
58	10.24	10.21	10.21	10.19		10.28	10.37
60	10.07	10.12	10.00	9.99		9.97	10.02
62	9.97	10.07	9.96	9.96		9.78	9.98
64	10.02	10.02	9.91	9.94		9.77	10.01
66	10.08	10.01	9.92	9.95		9.87	10.15
68	10.01	10.05	9.94	9.97	10.10	9.95	10.27
70	10.14	10.13	10.20	10.26	10.26	10.12	10.37
72	10.53	10.44	10.47	10.52	10.56	10.31	10.39
74	10.60	10.44	10.60	10.43	10.64	10.25	10.40
76	10.39	10.26	10.38	10.22	10.66	10.06	10.41
78	10.09	10.06	10.06	9.99	10.40	9.87	10.14
80	9.71	9.69	9.59	9.86	9.98	9.51	9.73
82	9.30	9.26	9.24	9.29	9.54	9.11	9.39
84	8.96	8.91	8.87	8.91	9.17	8.75	9.04
86	8.58	8.57	8.53	8.54	8.76	8.45	8.63
88	8.38	8.28	8.26	8.32	8.48	8.26	8.26
90	8.19	8.05	8.14	8.17	8.08	8.02	7.95
92	7.33	7.41	7.45	7.17	7.51	7.09	7.33
94	6.82	6.96	6.69	6.75	6.69	6.58	6.68
96	6.52	6.48	6.37	6.37	6.24	6.24	6.04
98	6.21	6.00	6.05	5.92	5.85	5.88	5.50
100	5.96	5.75	5.71	5.56	5.43	5.53	5.07
102	5.48	5.41	5.10	5.25	4.96	5.03	4.66
104	4.87	4.90	4.42	4.64	4.42	4.45	4.10
106	4.31	4.28	3.89	4.11	3.75	3.90	3.65
108	3.99	3.82	3.63	3.60	3.33	3.53	3.15
110	3.59	3.48	3.48	3.16	3.10	3.15	2.88
112	3.36	3.23	3.34	2.99	2.89	2.94	2.73
114	3.23	2.99	3.20	2.81	2.71	2.82	2.62
116	3.11	2.79	3.04	2.69	2.55	2.72	2.54
118	3.08	2.70	2.88	2.46	2.45	2.56	2.46
120	3.11	2.61	2.72	2.30	2.31	2.49	2.37
122	3.13	2.51	2.61	2.18	2.13	2.33	2.27
124	3.14	2.41	2.50	2.06	1.93	2.20	2.16
126	2.95	2.32	2.37	1.94	1.87	2.09	2.06
128	2.66	2.22	2.24	1.88	1.83	2.00	1.96
130	2.44	2.10	2.10	1.85	1.74	1.90	1.89
132	2.24	1.97	2.04	1.83	1.56	1.81	1.90
134	2.19	1.86	1.99	1.68		1.62	1.83
136	2.13	1.80	1.91	1.53		1.48	1.74
138	2.07	1.74	2.00	1.40		1.36	1.66
140	2.01	1.68	1.84	1.26		1.23	1.60
142	1.95	1.61	1.67	1.23		1.10	1.56
144	1.89	1.55	1.60	1.20		1.07	1.52
146	1.83	1.49	1.55	1.16		1.09	1.46
148	1.77	1.42	1.49	1.07		1.03	1.40
150	1.72	1.36	1.43	0.99		0.93	1.34
152	1.66	1.30	1.38	0.92		0.81	1.27
154	1.60	1.23	1.32	0.87		0.77	1.25
156	1.54	1.17	1.26	0.79		0.87	1.48
158	1.48	1.11	1.21	0.75		0.95	1.55
160	1.42	1.05	1.15	0.76		0.96	1.47
162	1.36	0.98	1.09	0.85		0.97	1.35
164	1.30	0.92	1.04	0.92		1.01	1.22
166	1.24	0.86	0.98	0.97		1.06	1.13
168	1.18	0.79	0.92	0.98		1.06	1.08
170	1.12	0.73	0.87	1.02		0.99	1.03
172	1.07	0.67	0.81	1.06		0.94	0.99
174	1.01	0.61	0.75	1.07		0.90	0.96
176	0.95	0.54	0.70	1.04		0.85	0.90
178	0.89		0.64	1.01		0.80	0.88
180	0.83			1.00		0.73	0.82
182	0.77			0.94		0.71	0.75
184	0.71			0.87		0.68	0.69
186	0.65			0.81		0.67	0.63
188	0.59			0.75		0.66	0.56
190	0.53			0.68			0.54
192	0.47			0.62			0.53
194	0.42			0.55			
196	0.36			0.49			
198	0.30						
200	0.24						
202	0.18						
204	0.12						
206	0.06						
208	0.01						
210	-0.05						
212							
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PROFILE 2

SURVEYED	SWX	11.03.20	APPROVED	DATE
DESIGNED				
DRAWN	RRR	31.03.2020		
TRACED				
REVISION		CHANGES	CHECKED	DATE
5	ALL PROFILES EDITED		RRR	31.03.20
4	MARCH 2020 ADDED		RRR	31.03.20
3	NOV 2019 ADDED		RRR	18.12.19
2	RE ISSUE		MC	01.08.19
0	ORIGINAL ISSUE		MC	18.07.19

PLOT DATE: 3/31/2020 2:19 PM

NOTES:

BEARING AND COORDINATE DATUM IS GEODETIC 2000
ORIGIN IS 16 MT. EDEN 800 000 mN, 400 000 mE
PROJECTION IS TRANSVERSE MERCATOR TO OBTAIN
PROJECTION DISTANCES MULTIPLY BY 0.9999

LEVELS ARE IN TERMS OF MEAN SEA LEVEL
ORIGIN DATUM BEING A9J7 (RL84.55m)

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NZIS REGISTERED PROFESSIONAL SURVEYOR

CLIENT: McCULLUM BROS

PROJECT: PAKIRI BEACH

TITLE: AERIAL SURVEY OCTOBER 2017- MARCH 2020 PROFILE

SCALE: 1:500 (A1) 1:1000 (A3)

SHEET: 2 of 10

REVISION: 5

DRAWING No: 2249-705-12

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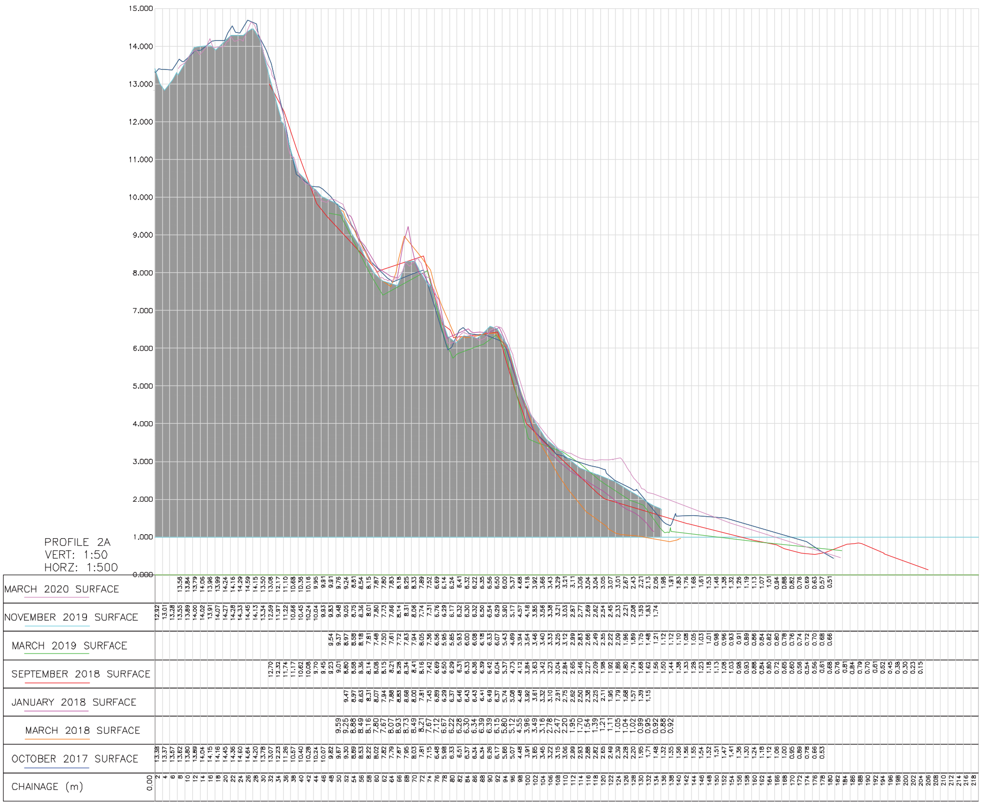

PROFILE 2A

SURVEYED	SWX	11.03.20	APPROVED	DATE
DESIGNED				
DRAWN	RRR	31.03.2020		
TRACED				

REVISION	CHANGES	CHECKED	DATE
5	ALL PROFILES EDITED	RRR	31.03.20
4	MARCH 2020 ADDED	RRR	31.03.20
3	NOV 2019 ADDED	RRR	18.12.19
2	RE ISSUE	MC	01.08.19
0	ORIGINAL ISSUE	MC	18.07.19

PLOT DATE: 3/31/2020 2:19 PM

NOTES:

BEARING AND COORDINATE DATUM IS GEODETIC 2000
ORIGIN IS 16 MT. EDEN 800 000 mN; 400 000 mE
PROJECTION IS TRANSVERSE MERCATOR TO OBTAIN
PROJECTION DISTANCES MULTIPLY BY 0.9999

LEVELS ARE IN TERMS OF MEAN SEA LEVEL
ORIGIN DATUM BEING A9J7 (RL84.55m)

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NZIS REGISTERED PROFESSIONAL SURVEYOR

CLIENT: McCULLUM BROS

PROJECT: PAKIRI BEACH

TITLE: AERIAL SURVEY OCTOBER 2017- MARCH 2020 PROFILE

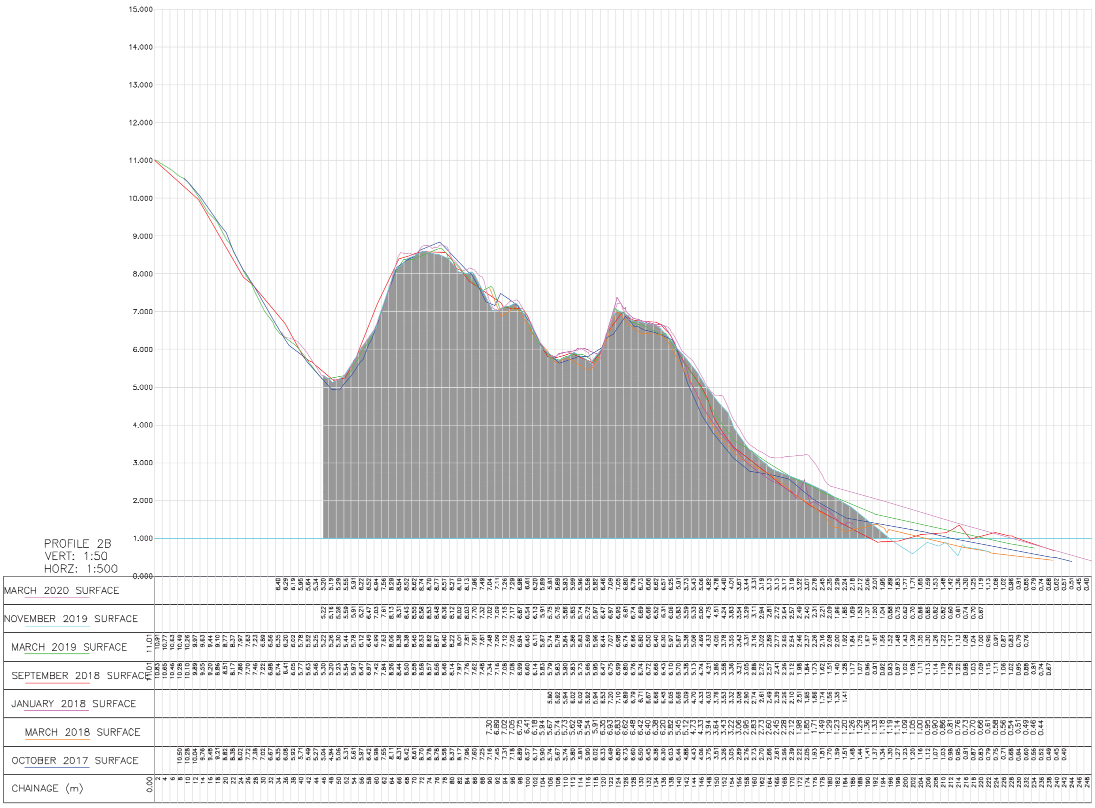
SCALE: 1:500 (A1) 1:1000 (A3)

SHEET: 3 of 10

REVISION: 5

DRAWING No: 2249-705-12

FILE PATH: C:\USERS\REGIS-R7CAD\DESKTOP\11-03-2020\SS\2249-705-12 PROFILE R5.DWG



PROFILE 2B

SURVEYED	SWX	11.03.20	APPROVED / DATE
DESIGNED			
DRAWN	RRR	31.03.2020	
TRACED			

REVISION	CHANGES	CHECKED	DATE
5	ALL PROFILES EDITED	RRR	31.03.20
4	MARCH 2020 ADDED	RRR	31.03.20
3	NOV 2019 ADDED	RRR	18.12.19
2	RE ISSUE	MC	01.08.19
0	ORIGINAL ISSUE	MC	18.07.19

PLOT DATE: 3/31/2020 2:20 PM

NOTES:
BEARING AND COORDINATE DATUM IS GEODETIC 2000
ORIGIN IS 16 MT. EDEN 800 000 mN, 400 000 mE
PROJECTION IS TRANSVERSE MERCATOR TO OBTAIN
PROJECTION DISTANCES MULTIPLY BY 0.9999

LEVELS ARE IN TERMS OF MEAN SEA LEVEL
ORIGIN DATUM BEING A9J7 (RL84.55m)

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NZIS REGISTERED PROFESSIONAL SURVEYOR

CLIENT: McCULLUM BROS

PROJECT: PAKIRI BEACH

TITLE: AERIAL SURVEY OCTOBER 2017- MARCH 2020 PROFILE

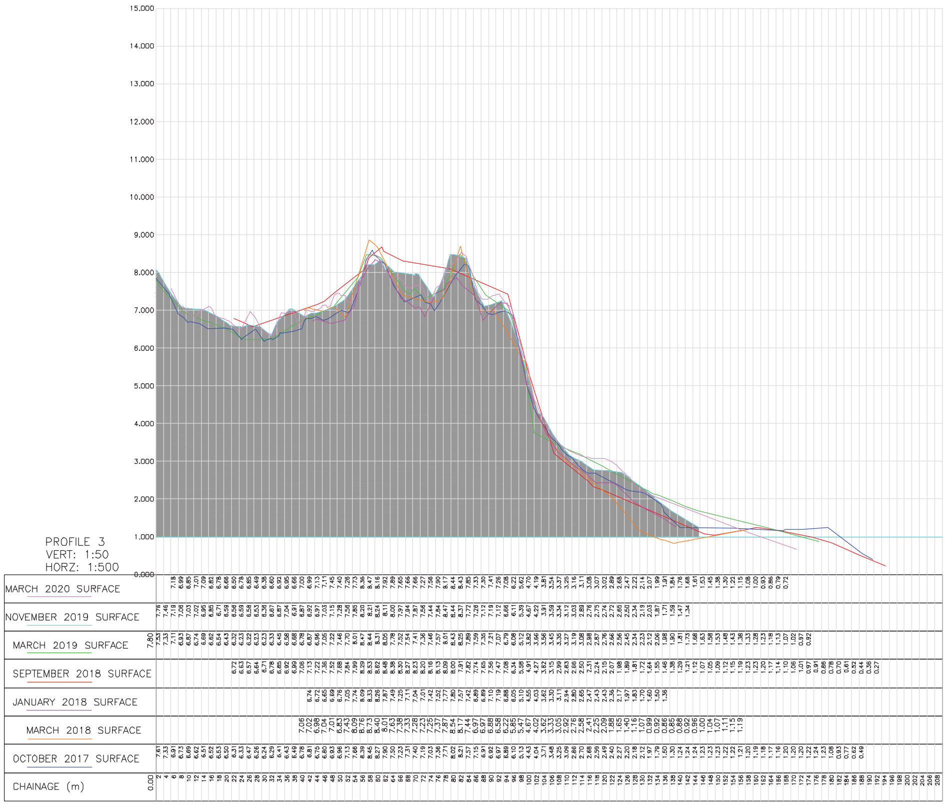
SCALE: 1:500 (A1) 1:1000 (A3)

SHEET: 4 of 10

REVISION: 5

DRAWING No: 2249-705-12

FILE PATH: C:\USERS\REGIS-R7CAD\DESKTOP\11-03-2020\SS\2249-705-12 PROFILE R5.DWG



PROFILE 3

SURVEYED	SWX	11.03.20	APPROVED	DATE
DESIGNED				
DRAWN	RRR	31.03.2020		
TRACED				
REVISION		CHANGES	CHECKED	DATE
5	ALL PROFILES EDITED		RRR	31.03.20
4	MARCH 2020 ADDED		RRR	31.03.20
3	NOV 2019 ADDED		RRR	18.12.19
2	RE ISSUE		MC	01.08.19
0	ORIGINAL ISSUE		MC	18.07.19

PLOT DATE: 3/31/2020 2:20 PM

NOTES:

BEARING AND COORDINATE DATUM IS GEODETIC 2000
ORIGIN IS 16 MT. EDEN 800 000 mN, 400 000 mE
PROJECTION IS TRANSVERSE MERCATOR TO OBTAIN
PROJECTION DISTANCES MULTIPLY BY 0.9999

LEVELS ARE IN TERMS OF MEAN SEA LEVEL
ORIGIN DATUM BEING A9J7 (RL84.55m)

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NZIS REGISTERED PROFESSIONAL SURVEYOR

CLIENT: McCULLUM BROS

PROJECT: PAKIRI BEACH

TITLE: AERIAL SURVEY OCTOBER 2017-MARCH 2020 PROFILE

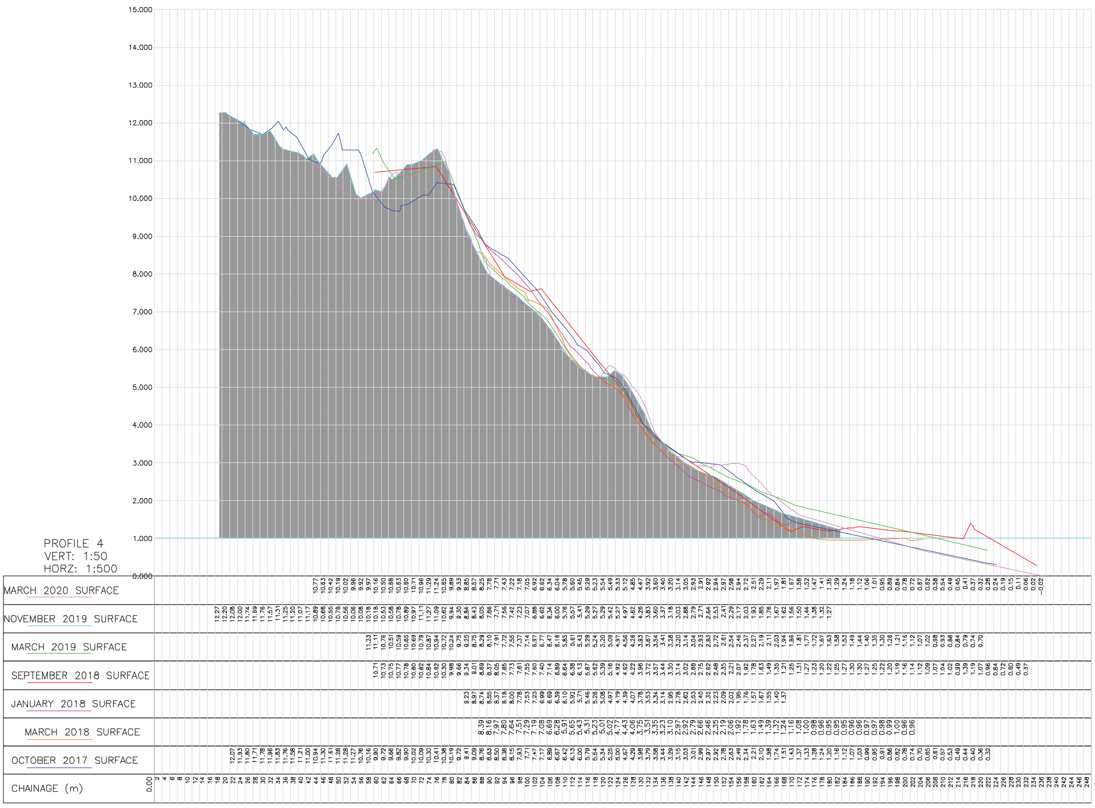
SCALE: 1:500 (A1) 1:1000 (A3)

SHEET: 5 of 10

REVISION: 5

DRAWING No: 2249-705-12

FILE PATH: C:\USERS\REGIS-R7CAD\DESKTOP\11-03-2020\SS\2249-705-12 PROFILE R5.DWG



PROFILE 4

SURVEYED	SWX	11.03.20
DESIGNED		
DRAWN	RRR	31.03.2020
TRACED		

APPROVED DATE

REVISION	CHANGES	CHECKED	DATE
5	ALL PROFILES EDITED	RRR	31.03.20
4	MARCH 2020 ADDED	RRR	31.03.20
3	NOV 2019 ADDED	RRR	18.12.19
2	RE ISSUE	MC	01.08.19
0	ORIGINAL ISSUE	MC	18.07.19

PLOT DATE: 3/31/2020 2:21 PM

NOTES:

BEARING AND COORDINATE DATUM IS GEODETIC 2000
ORIGIN IS 16 MT. EDEN 800 000 mN, 400 000 mE
PROJECTION IS TRANSVERSE MERCATOR TO OBTAIN
PROJECTION DISTANCES MULTIPLY BY 0.9999

LEVELS ARE IN TERMS OF MEAN SEA LEVEL
ORIGIN DATUM BEING A9J7 (RL84.55m)

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CLIENT: McCULLUM BROS

PROJECT: PAKIRI BEACH

TITLE: AERIAL SURVEY OCTOBER 2017- MARCH 2020 PROFILE

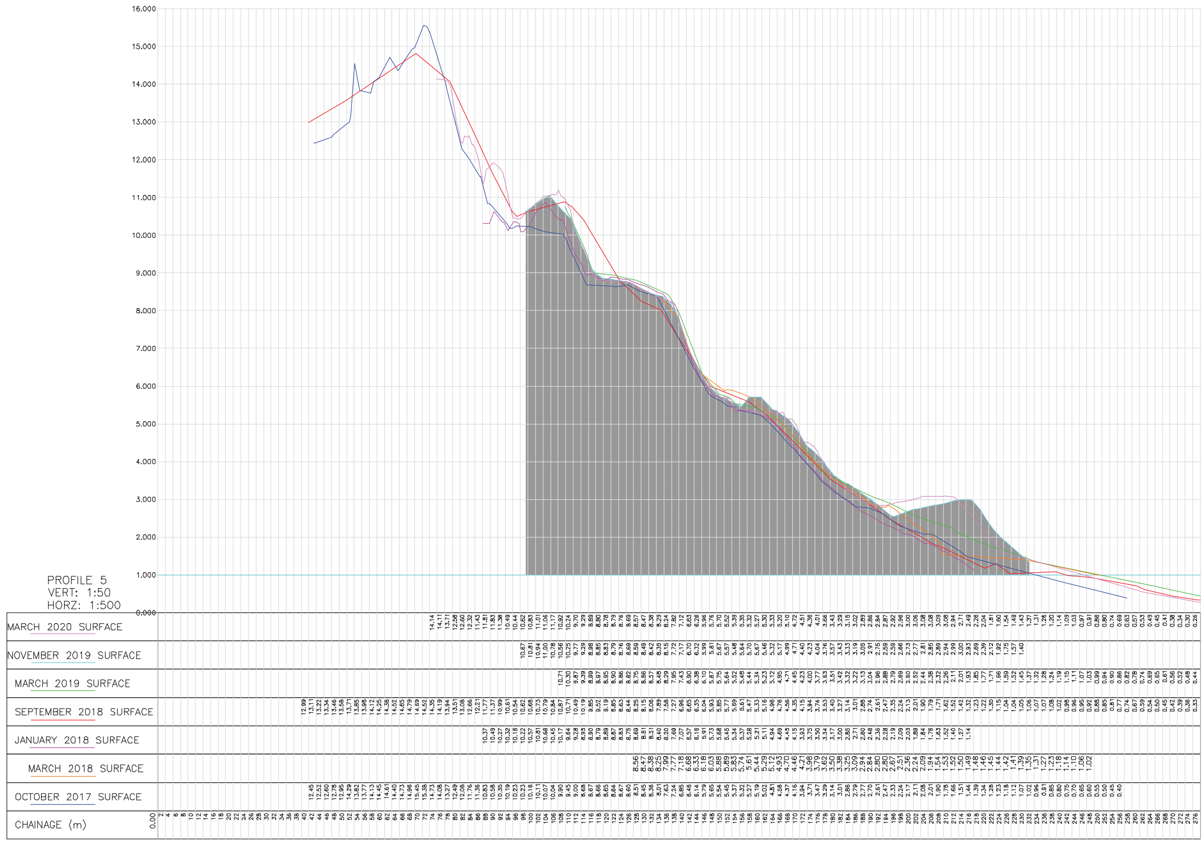
SCALE: 1:500 (A1) 1:1000 (A3)

SHEET: 6 of 10

REVISION: 5

DRAWING No: 2249-705-12

FILE PATH: C:\USERS\REGIS-R7CAD\DESKTOP\11-03-2020\SS\2249-705-12 PROFILE R5.DWG



PROFILE 5

SURVEYED	SWX	11.03.20	APPROVED	DATE
DESIGNED				
DRAWN	RRR	31.03.2020		
TRACED				
REVISION		CHANGES	CHECKED	DATE
5	ALL PROFILES EDITED		RRR	31.03.20
4	MARCH 2020 ADDED		RRR	31.03.20
3	NOV 2019 ADDED		RRR	18.12.19
2	RE ISSUE		MC	01.08.19
0	ORIGINAL ISSUE		MC	18.07.19

PLOT DATE: 3/31/2020 2:21 PM

NOTES:

BEARING AND COORDINATE DATUM IS GEODETIC 2000
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CLIENT: McCULLUM BROS

PROJECT: PAKIRI BEACH

TITLE: AERIAL SURVEY OCTOBER 2017- MARCH 2020 PROFILE

SCALE: 1:500 (A1) 1:1000 (A3)

SHEET: 7 of 10

REVISION: 5

DRAWING No: 2249-705-12

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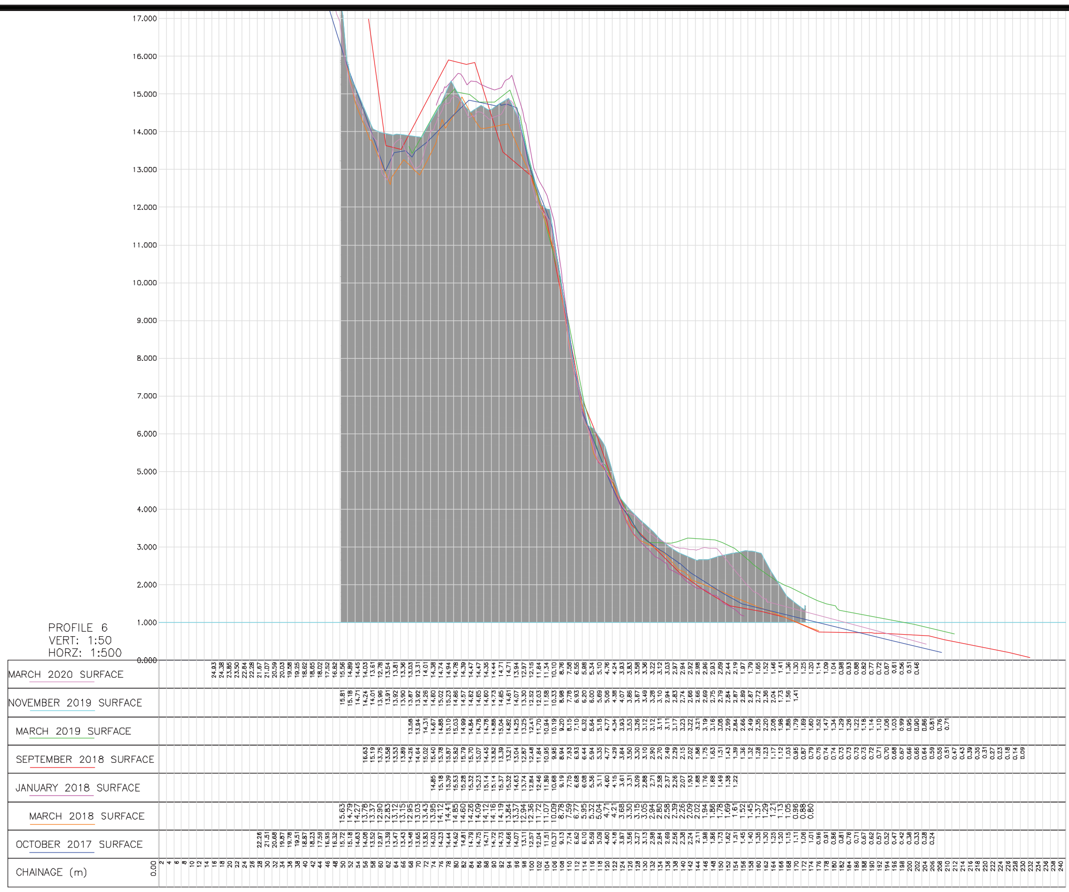

PROFILE 6

SURVEYED	SWX	11.03.20	
DESIGNED			
DRAWN	RRR	31.03.2020	
TRACED			
REVISION	CHANGES	CHECKED	DATE
5	ALL PROFILES EDITED	RRR	31.03.20
4	MARCH 2020 ADDED	RRR	31.03.20
3	NOV 2019 ADDED	RRR	18.12.19
2	RE ISSUE	MC	01.08.19
0	ORIGINAL ISSUE	MC	18.07.19

APPROVED DATE

PLOT DATE: 3/31/2020 2:22 PM

NOTES:

BEARING AND COORDINATE DATUM IS GEODETIC 2000
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LEVELS ARE IN TERMS OF MEAN SEA LEVEL
ORIGIN DATUM BEING A9J7 (RL84.55m)

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NZIS REGISTERED PROFESSIONAL SURVEYOR

CLIENT: McCULLUM BROS

PROJECT: PAKIRI BEACH

TITLE: AERIAL SURVEY OCTOBER 2017- MARCH 2020 PROFILE

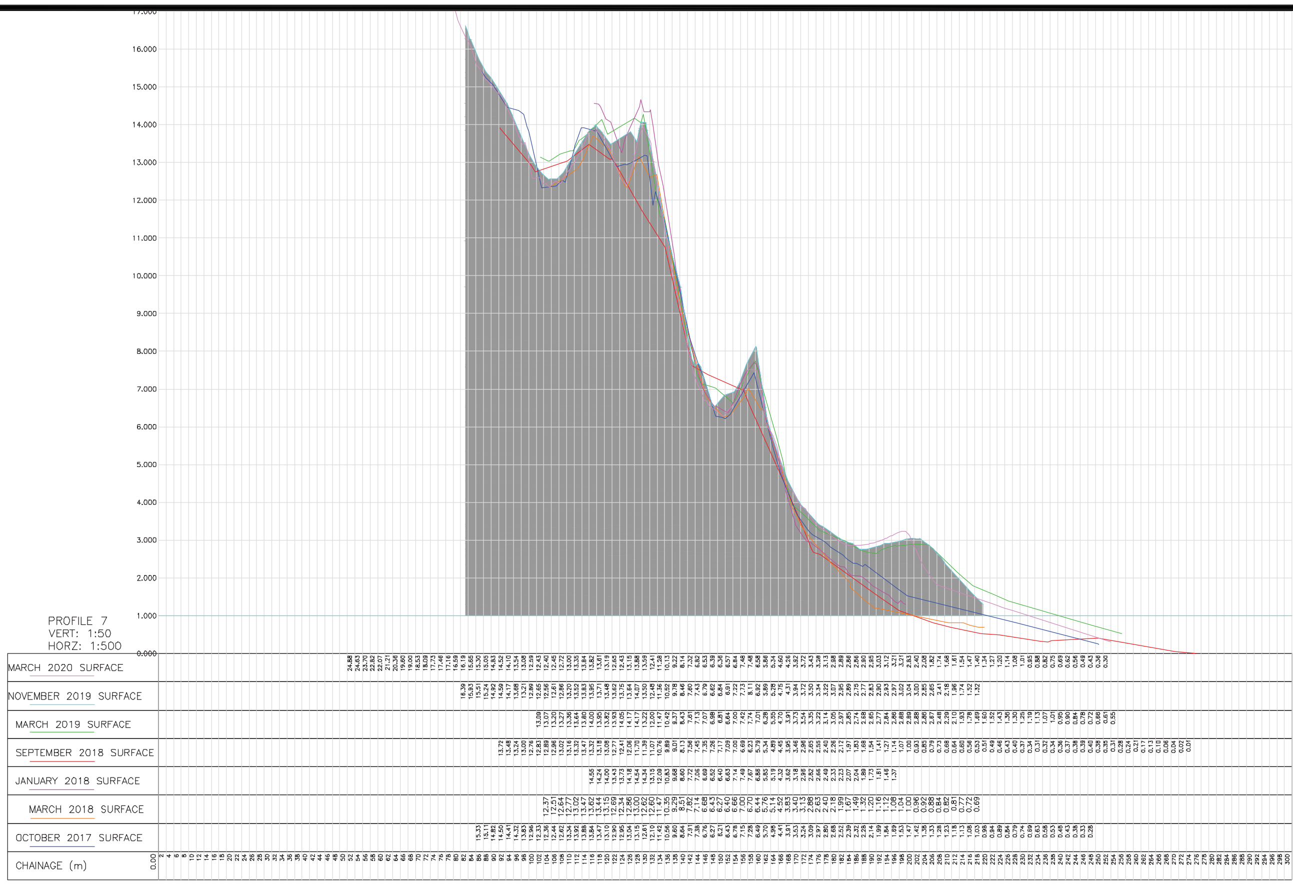
SCALE: 1:500 (A1) 1:1000 (A3)

SHEET: 8 of 10

REVISION: 5

DRAWING No: 2249-705-12

FILE PATH: C:\USERS\REGIS-R7CAD\DESKTOP\11-03-2020\SS\2249-705-12 PROFILE R5.DWG



PROFILE 7

SURVEYED	SWX	11.03.20	APPROVED	DATE
DESIGNED				
DRAWN	RRR	31.03.2020		
TRACED				
REVISION	CHANGES		CHECKED	DATE
5	ALL PROFILES EDITED		RRR	31.03.20
4	MARCH 2020 ADDED		RRR	31.03.20
3	NOV 2019 ADDED		RRR	18.12.19
2	RE ISSUE		MC	01.08.19
0	ORIGINAL ISSUE		MC	18.07.19

PLOT DATE: 3/31/2020 2:22 PM

NOTES:

BEARING AND COORDINATE DATUM IS GEODETIC 2000
ORIGIN IS 16 MT. EDEN 800 000 mN, 400 000 mE
PROJECTION IS TRANSVERSE MERCATOR TO OBTAIN
PROJECTION DISTANCES MULTIPLY BY 0.9999

LEVELS ARE IN TERMS OF MEAN SEA LEVEL
ORIGIN DATUM BEING A9J7 (RL84.55m)

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office +64 09 948 6491
www.surveyworx.co.nz
1016A Great South Road, Penrose Auckland, NZ

NZIS REGISTERED PROFESSIONAL SURVEYOR

CLIENT: McCULLUM BROS

PROJECT: PAKIRI BEACH

TITLE: AERIAL SURVEY OCTOBER 2017-MARCH 2020 PROFILE

SCALE: 1:500 (A1) 1:1000 (A3)

SHEET: 9 of 10

REVISION: 5

DRAWING No: 2249-705-12

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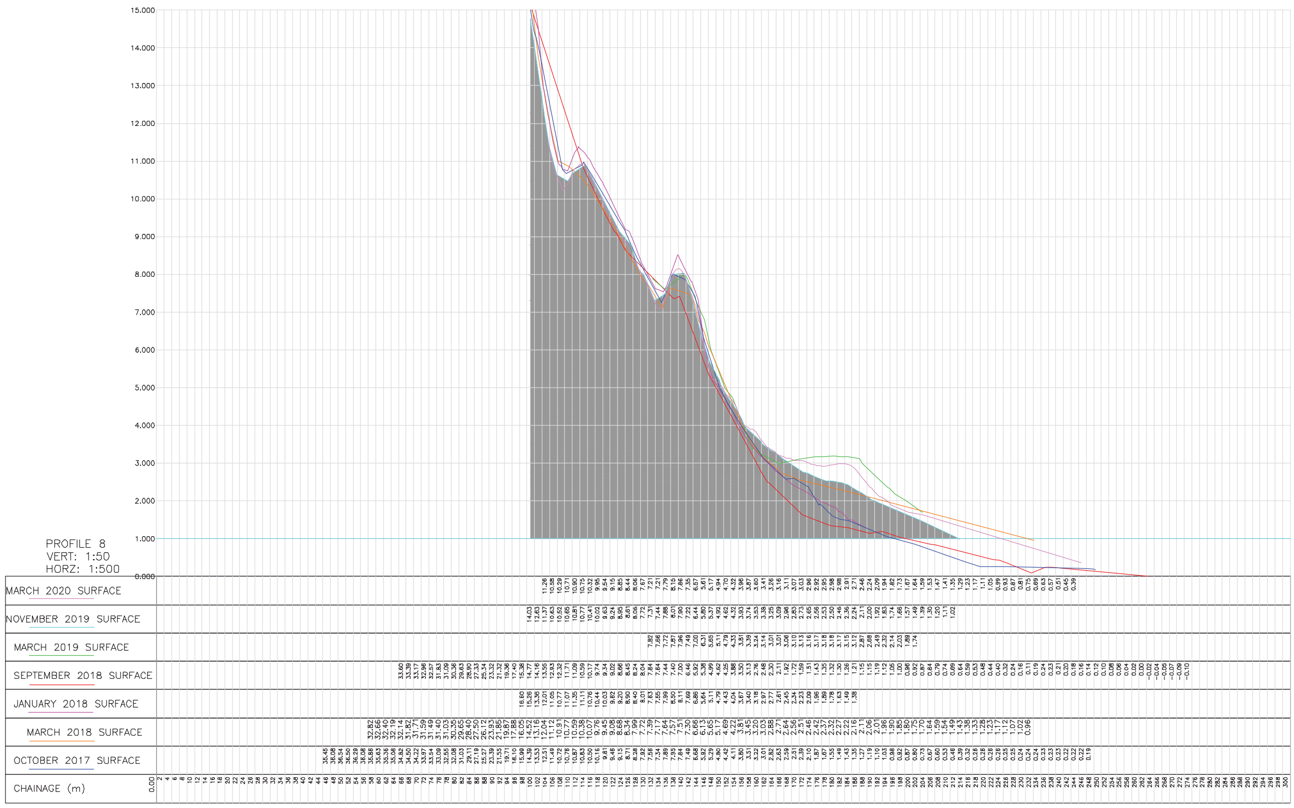

PROFILE 8

SURVEYED	SWX	11.03.20	APPROVED	DATE
DESIGNED				
DRAWN	RRR	31.03.2020		
TRACED				
REVISION	CHANGES		CHECKED	DATE
5	ALL PROFILES EDITED		RRR	31.03.20
4	MARCH 2020 ADDED		RRR	31.03.20
3	NOV 2019 ADDED		RRR	18.12.19
2	RE ISSUE		MC	01.08.19
0	ORIGINAL ISSUE		MC	18.07.19

PLOT DATE: 3/31/2020 2:23 PM

NOTES:

BEARING AND COORDINATE DATUM IS GEODETIC 2000
ORIGIN IS 16 MT. EDEN 800 000 mN, 400 000 mE
PROJECTION IS TRANSVERSE MERCATOR TO OBTAIN
PROJECTION DISTANCES MULTIPLY BY 0.9999

LEVELS ARE IN TERMS OF MEAN SEA LEVEL
ORIGIN DATUM BEING A9J7 (RL84.55m)

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NZIS REGISTERED PROFESSIONAL SURVEYOR

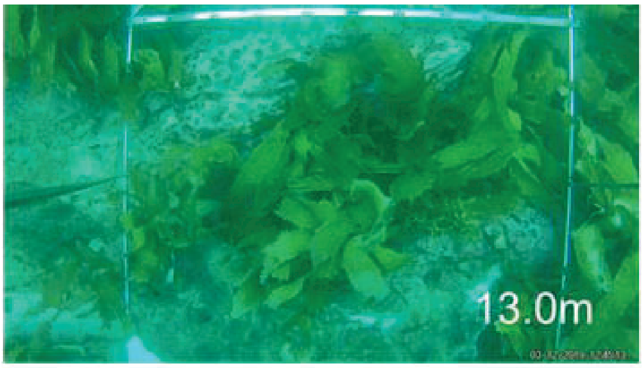
CLIENT	PROJECT	TITLE	SCALE	
McCULLUM BROS	PAKIRI BEACH	AERIAL SURVEY OCTOBER 2017-MARCH 2020 PROFILE	1:500 (A1) 1:1000 (A3)	
			SHEET 10 of 10	REVISION 5
			DRAWING No 2249-705-12	

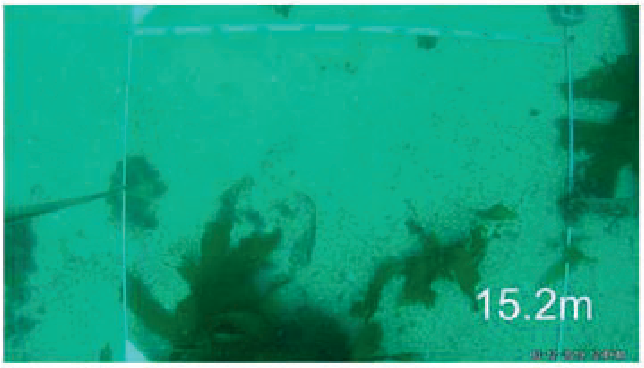
FILE PATH: C:\USERS\REGIS-R7CAD\DESKTOP\11-03-2020\SS\2249-705-12 PROFILE R5.DWG

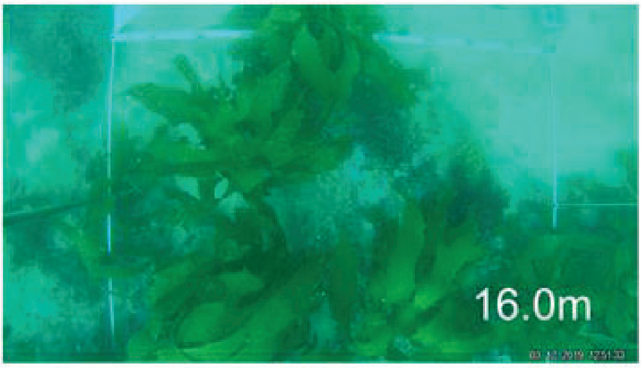
Appendix M. Bream Tail Sediment Photos

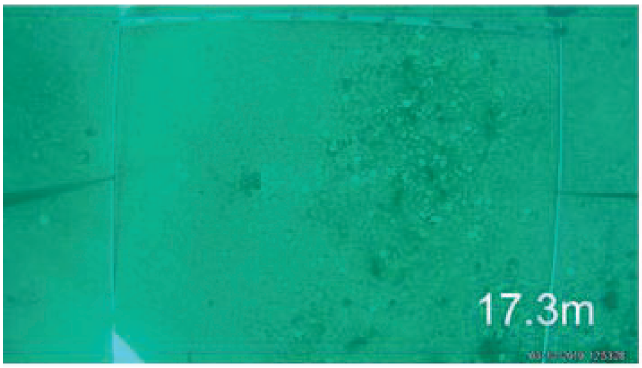
Appendix M. Bream Tail Sediment Photos

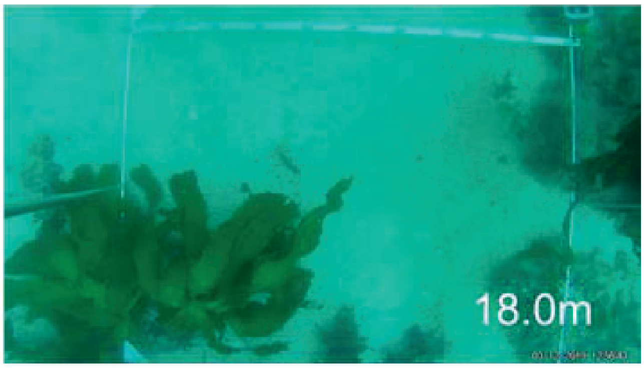
Seabed micro-topography drop camera transect

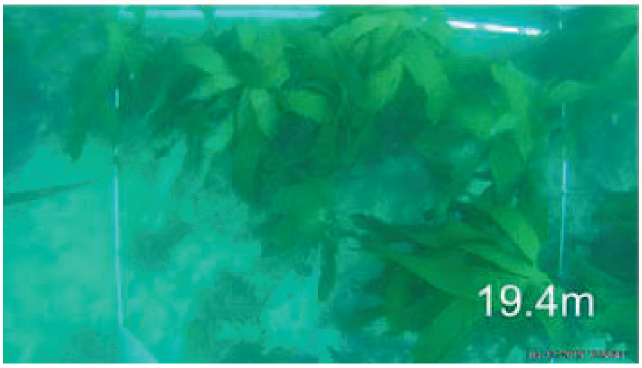


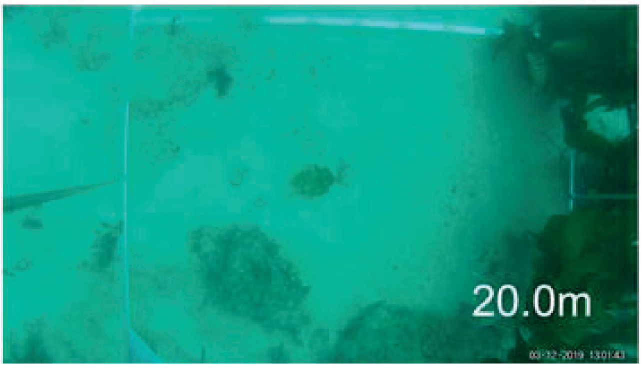


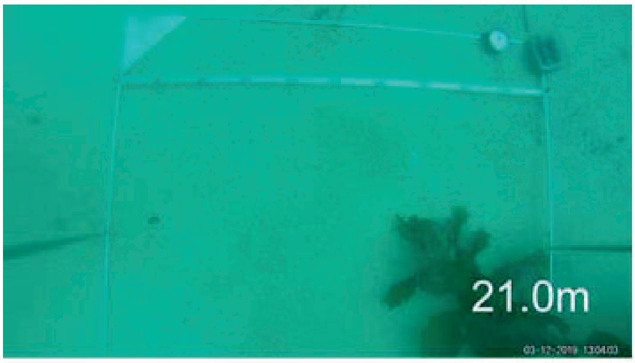








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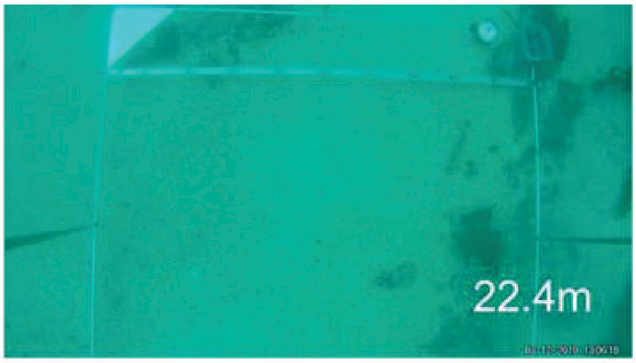
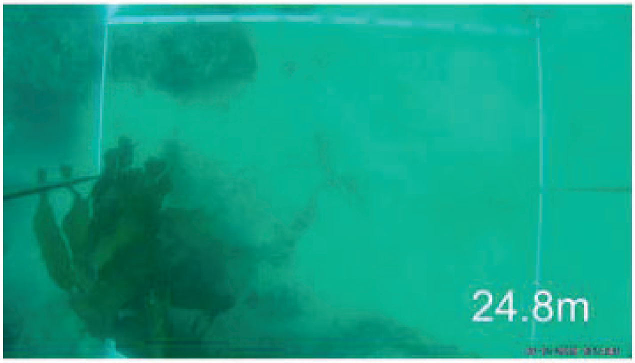

22.4m


23.2m


23.6m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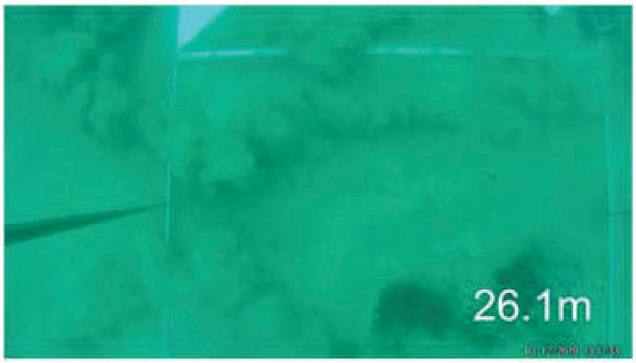
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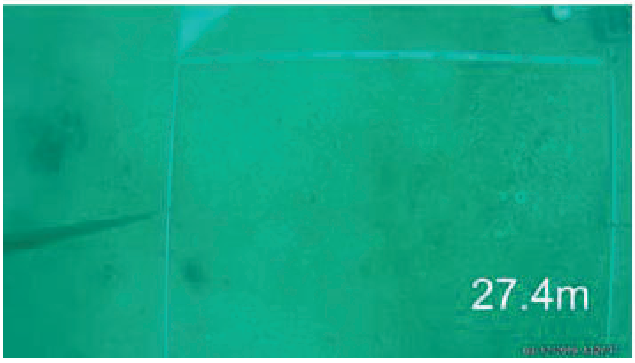
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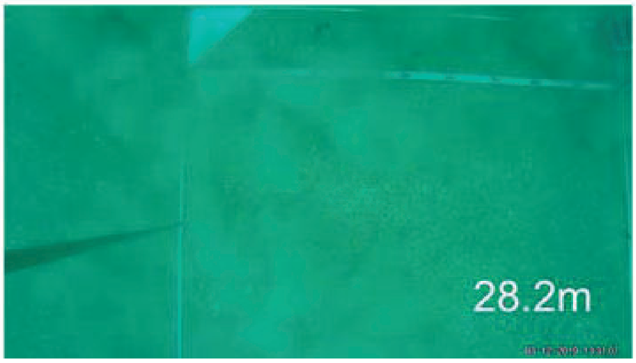
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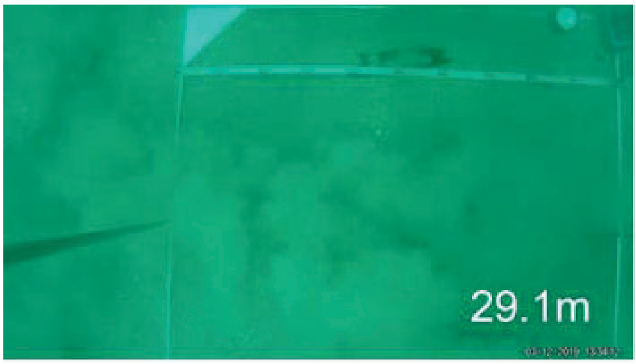
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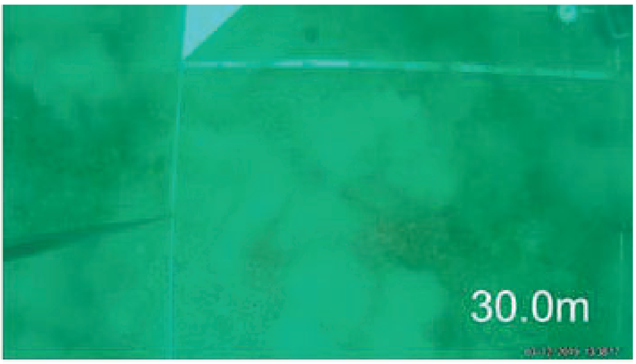
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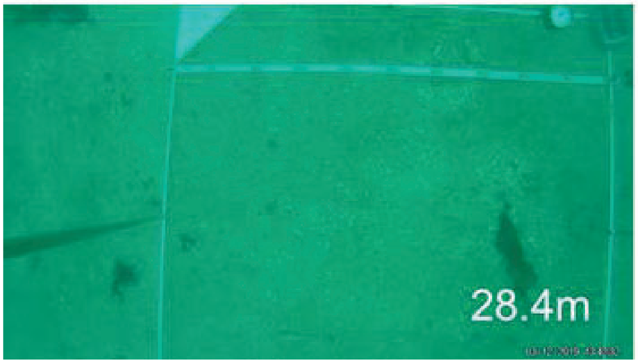
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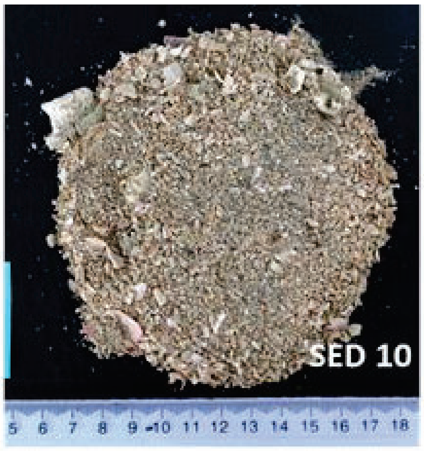
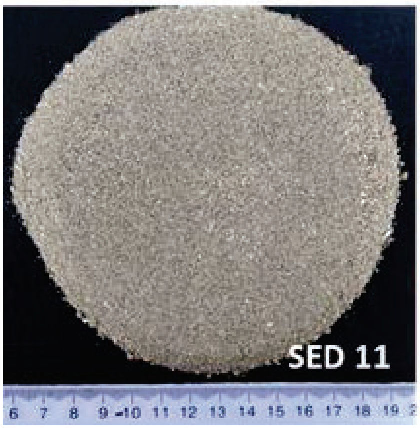
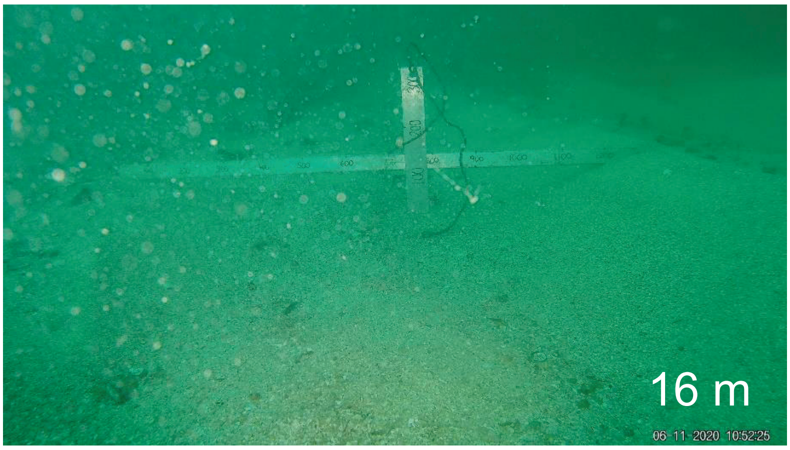
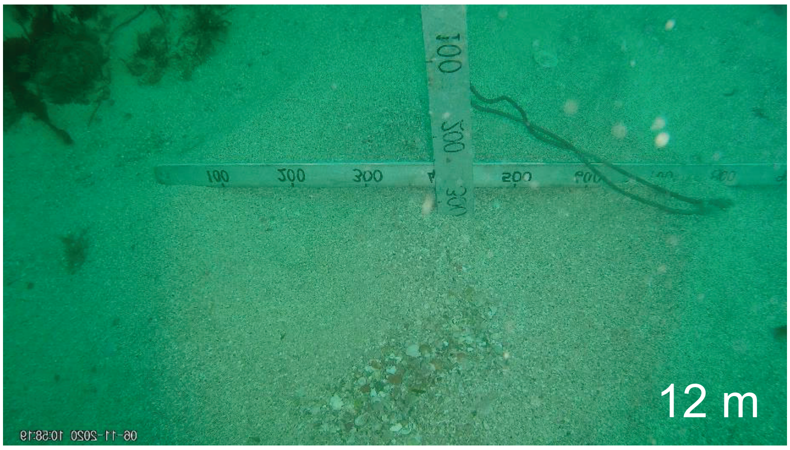
Photographs of sediment samples





Diver Photos May 2020

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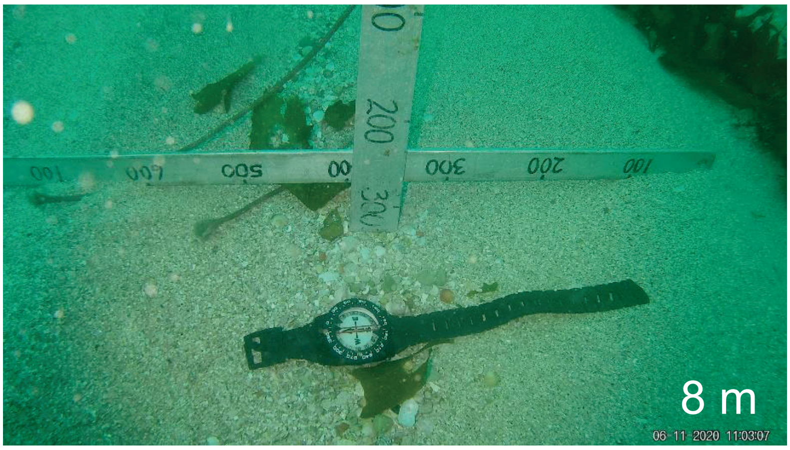
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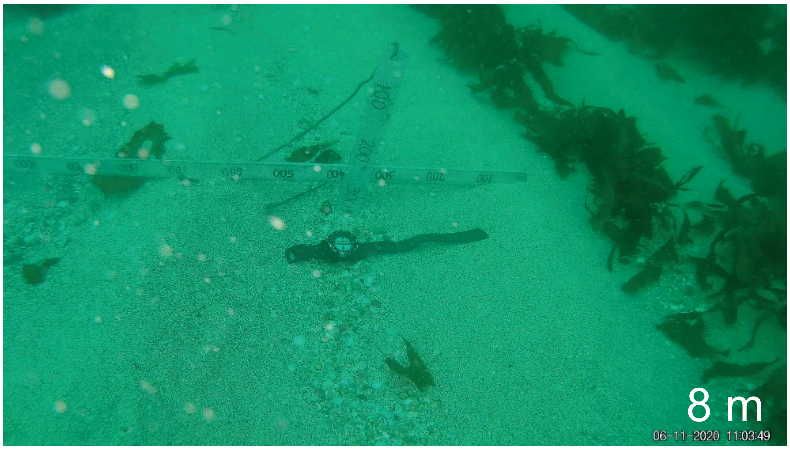
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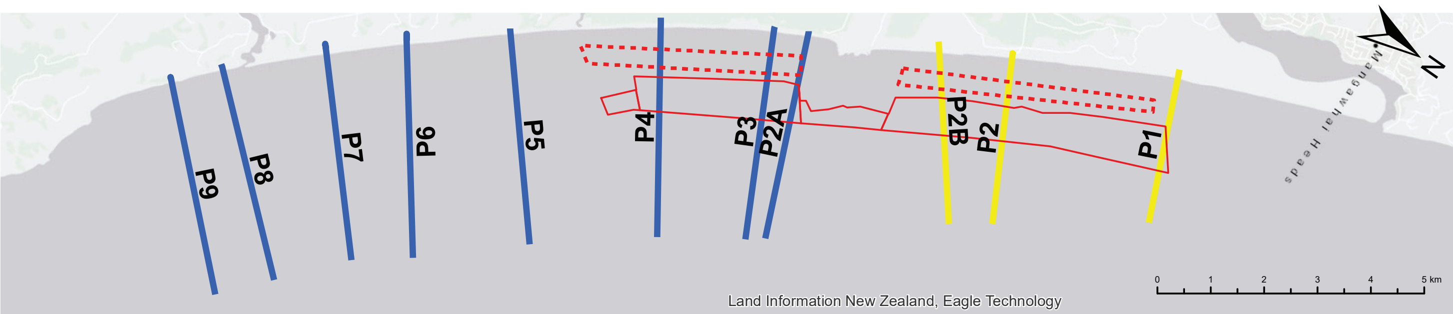
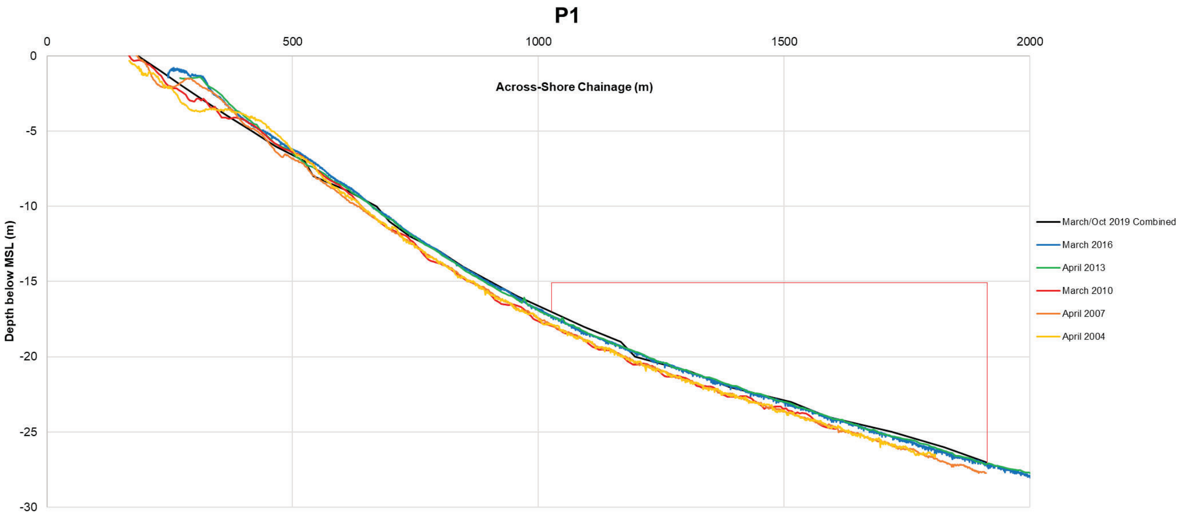
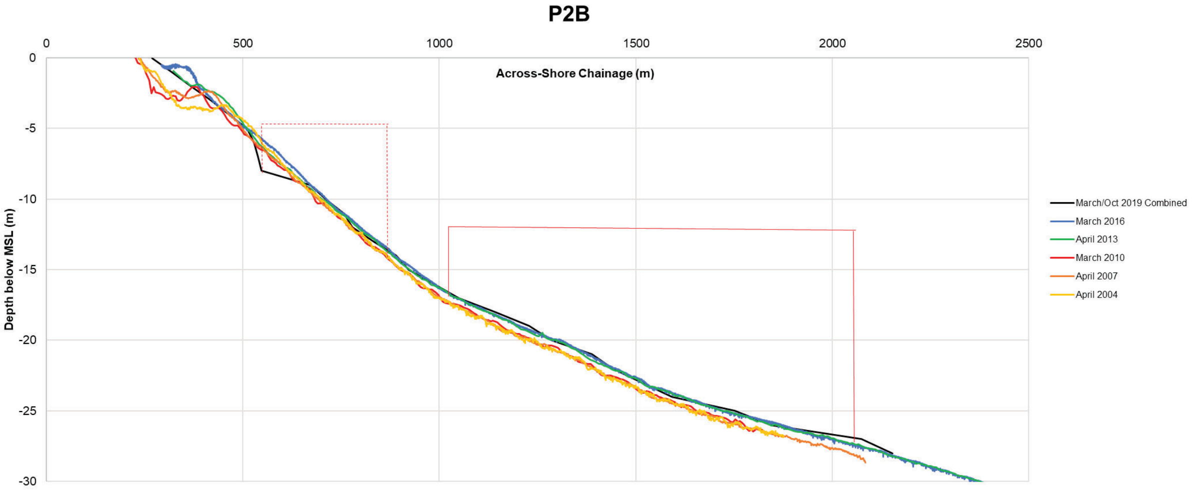
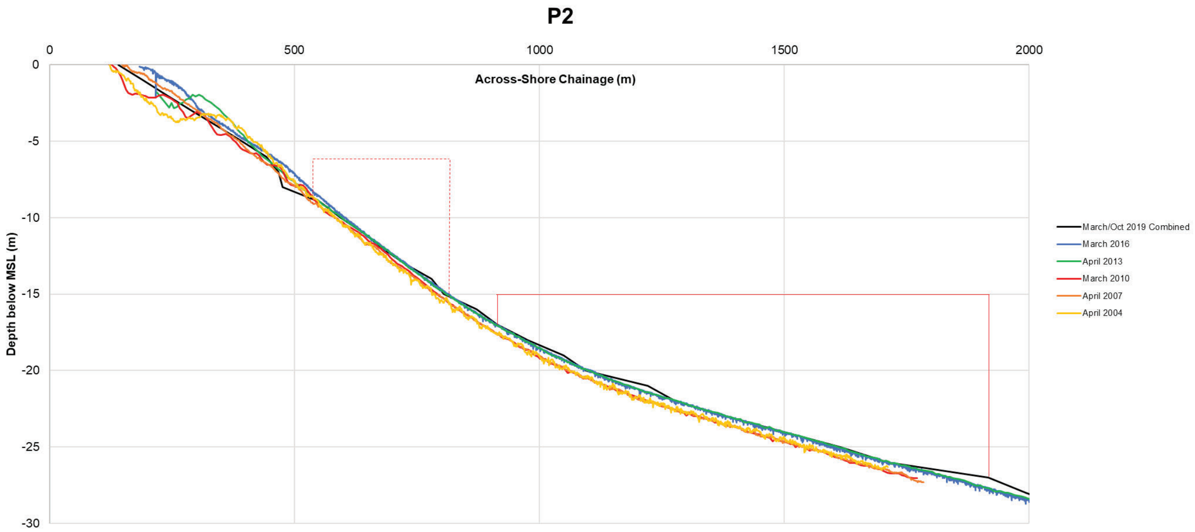
Appendix N. Three Yearly Nearshore Profile Comparisons 2004-2019









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CLIENT Client	
PROJECT McCallum Brothers Ltd Pakiri Sand Extraction Consent	
SCALE 1:100,000 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 06/29/2020

Legend

- Proposed Consent Area
- Renewal Consent Area
- Historical Profiles Analysed
- Other Historical Profiles

Bathymetric Surveys (2004-2019) at Historical Survey Sites

Profiles 1-2b

Note: March/Oct 2019 survey is a combination of a March 2019 (0 to approx -20m contour) survey inshore and the October 2019 survey (seaward of approx -20m contour).

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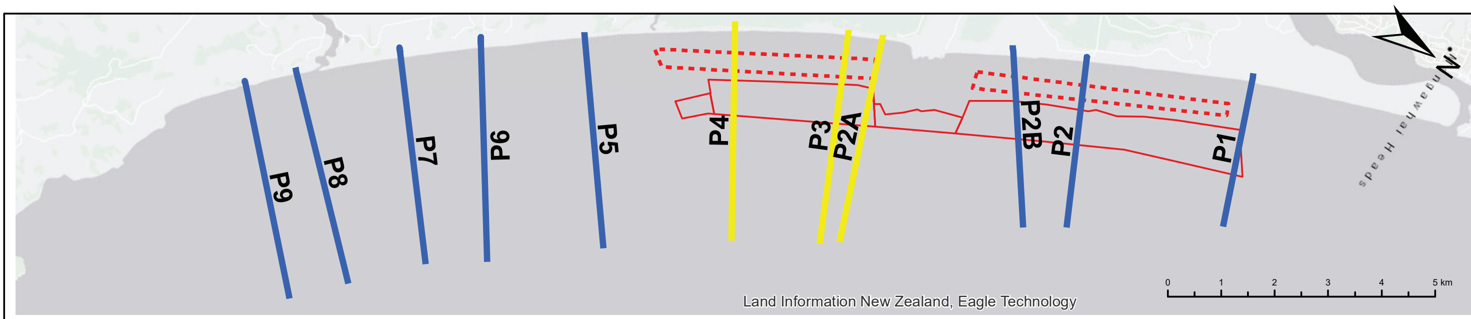

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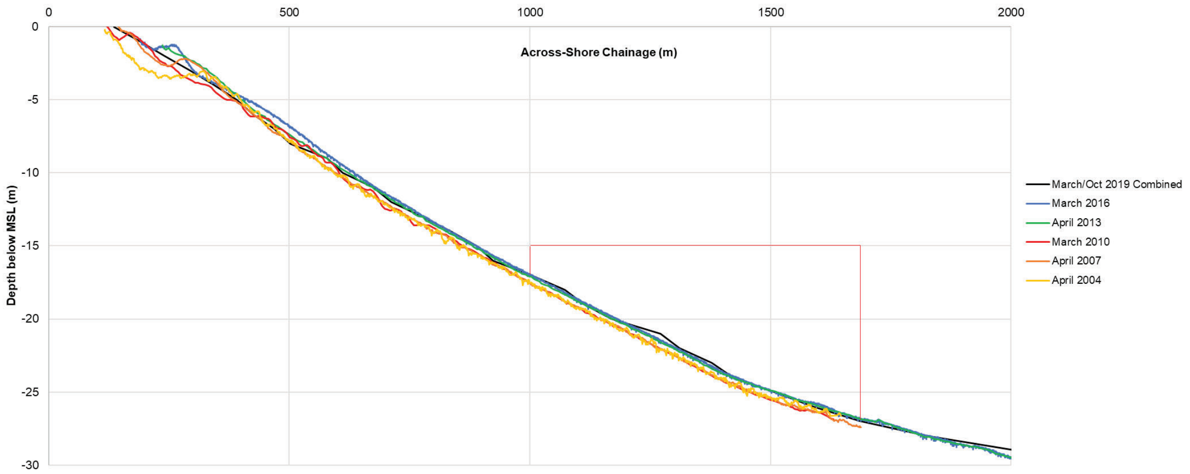

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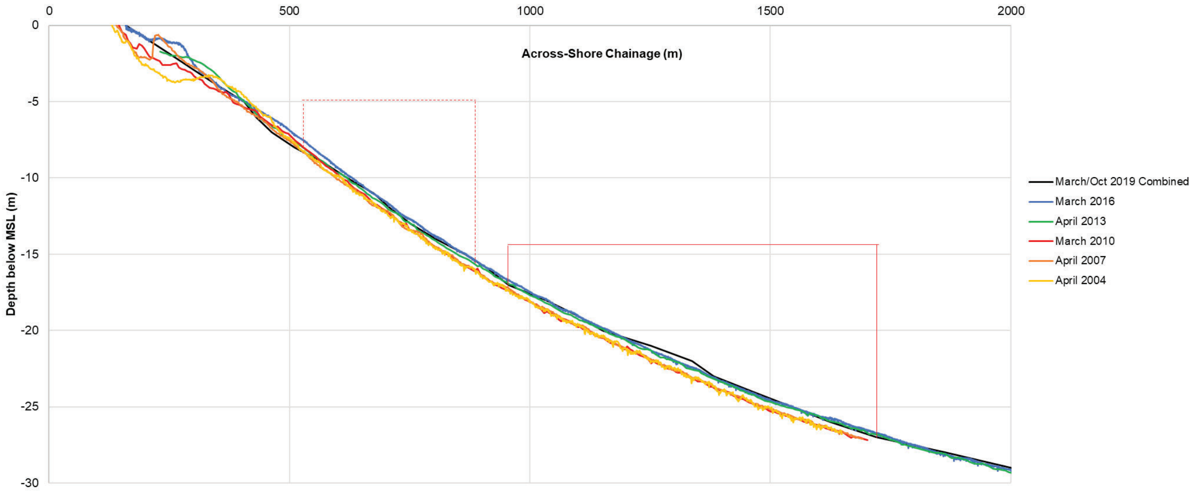

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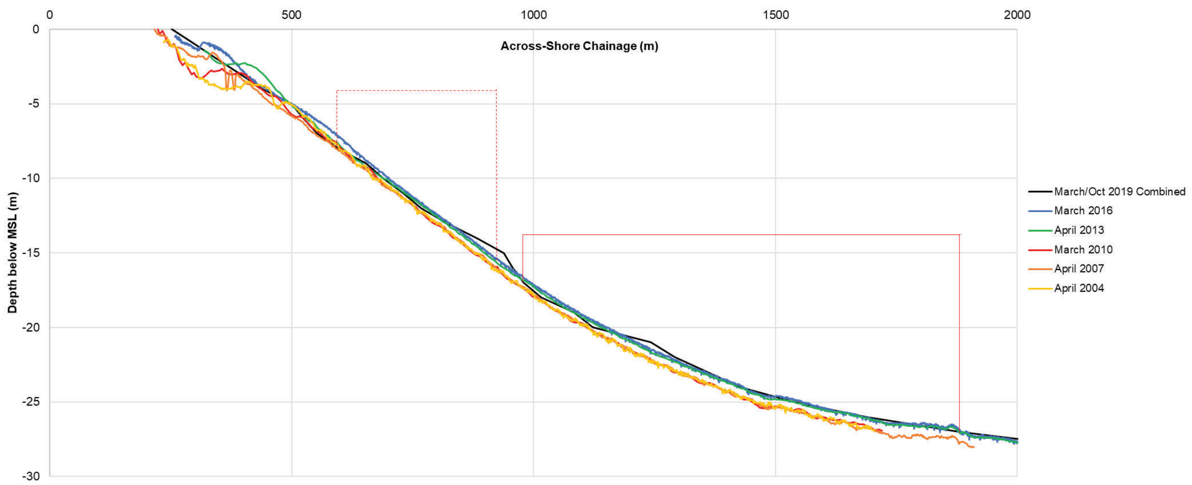

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CLIENT Client	
PROJECT McCallum Brothers Ltd Pakiri Sand Extraction Consent	
SCALE 1:100,000 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 06/29/2020

Legend

- Renewal Consent Area
- Proposed Consent Area
- Historical Profiles Analysed
- Other Historical Profiles

Bathymetric Surveys (2004-2019) at Historical Survey Sites

Profiles 2a-4

Note: March/Oct 2019 survey is a combination of a March 2019 (0 to approx -20m contour) survey inshore and the October 2019 survey (seaward of approx -20m contour).

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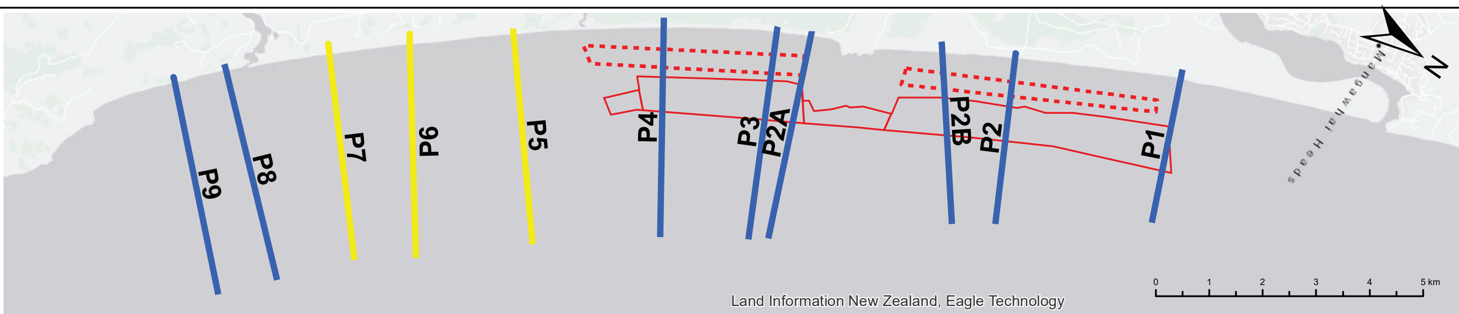

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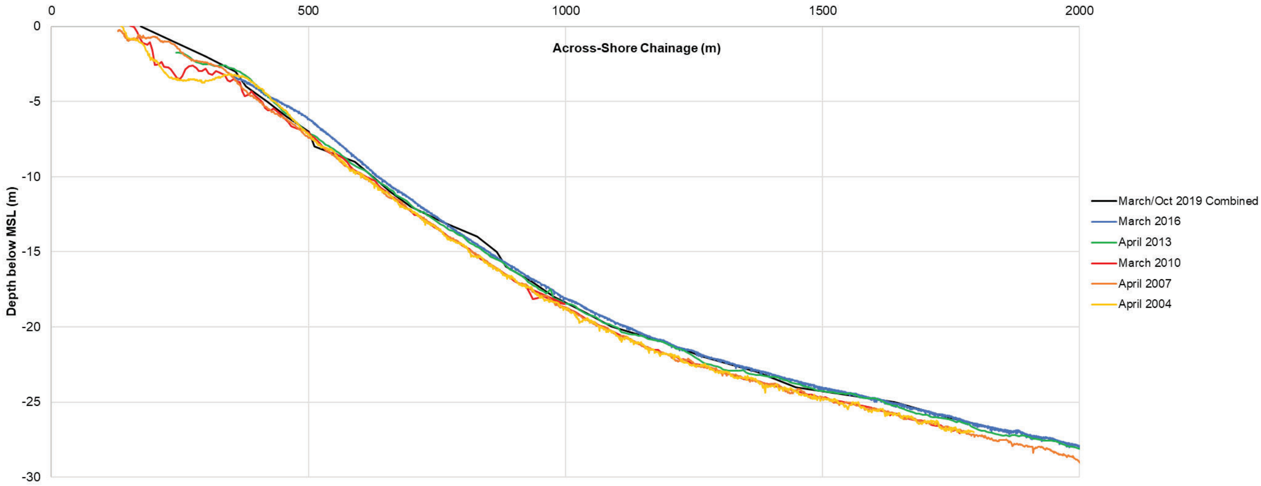

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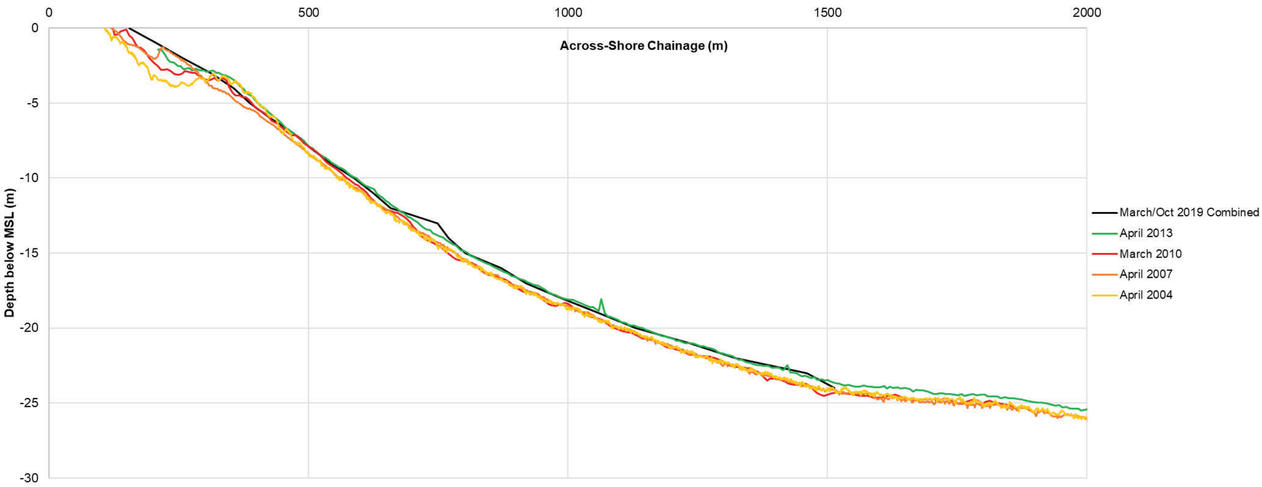

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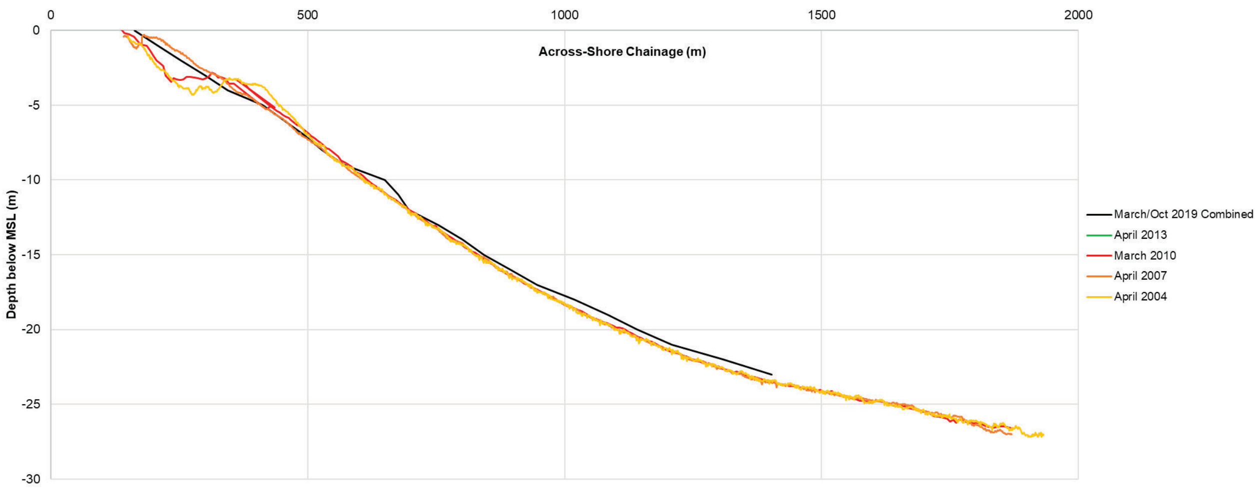

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CLIENT Client	
PROJECT McCallum Brothers Ltd Pakiri Sand Extraction Consent	
SCALE 1:100,000 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 06/29/2020

Legend

- Renewal Consent Area
- Proposed Consent Area
- Historical Profiles Analysed
- Other Historical Profiles

Bathymetric Surveys (2004-2019) at Historical Survey Sites

Profiles 5-7

Note: March/Oct 2019 survey is a combination of a March 2019 (0 to approx -20m contour) survey inshore and the October 2019 survey (seaward of approx -20m contour).

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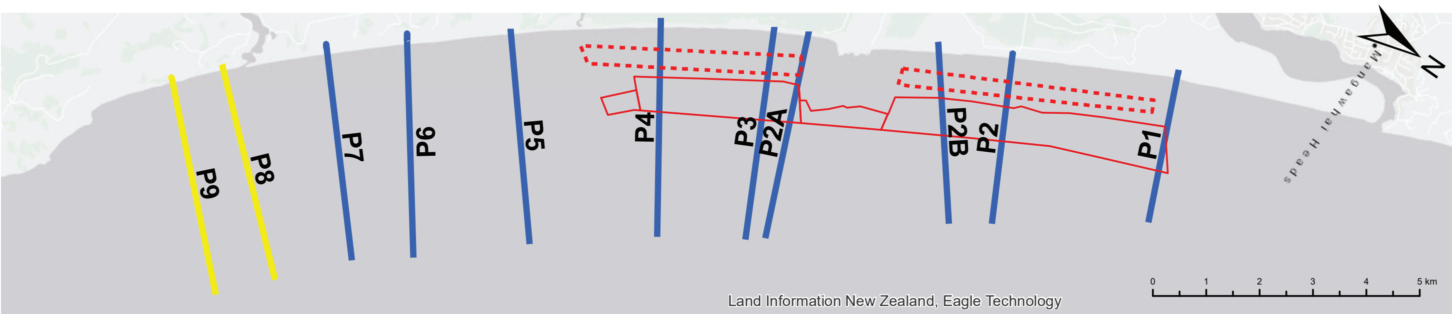

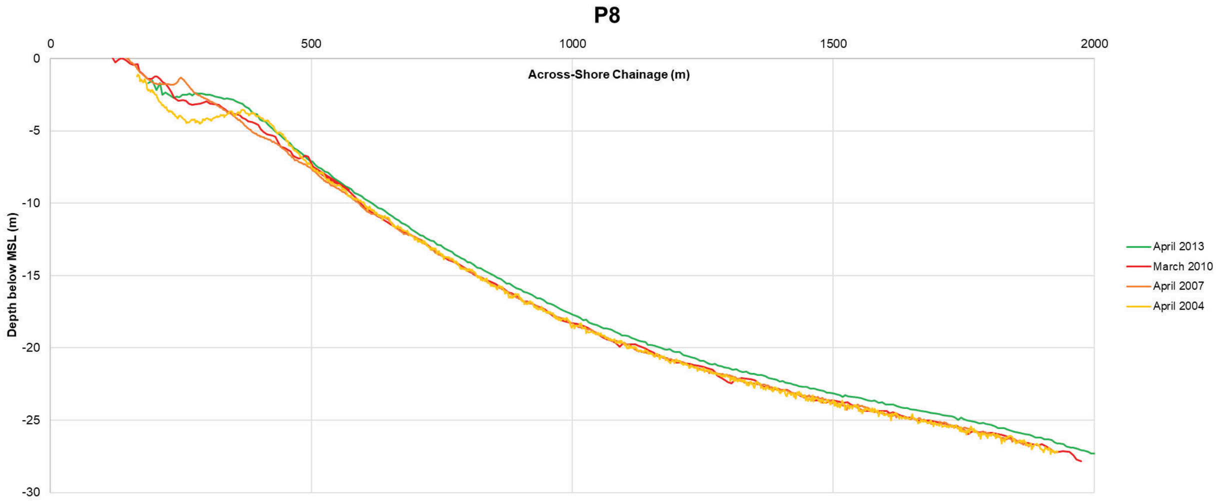

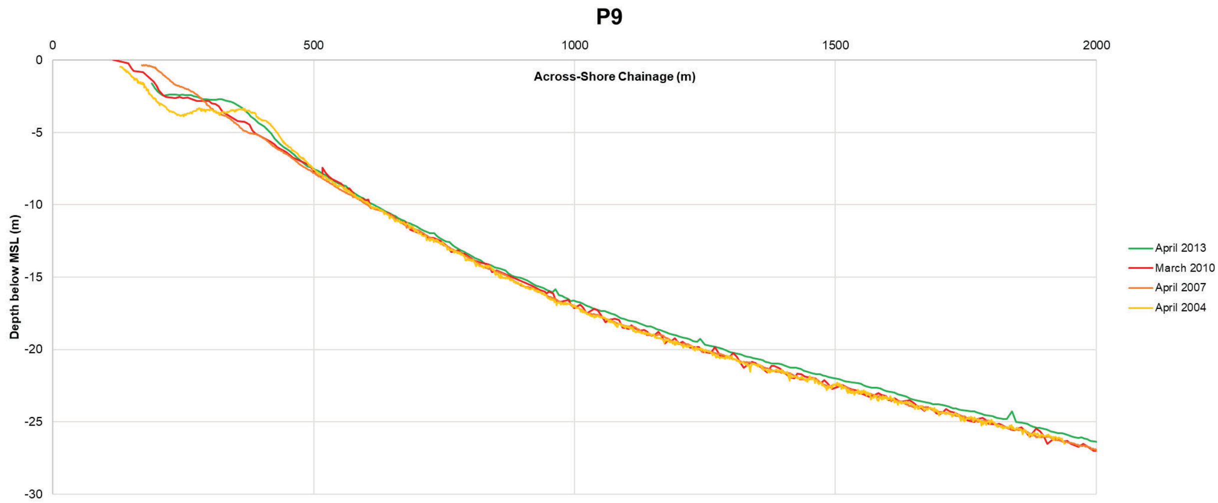

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CLIENT Client	
PROJECT McCallum Brothers Ltd Pakiri Sand Extraction Consent	
SCALE 1:100,000 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 06/29/2020

Legend

- Renewal Consent Area
- Proposed Consent Area
- Historical Profiles Analysed
- Other Historical Profiles

Bathymetric Surveys (2004-2019) at Historical Survey Sites

Profiles 8-9

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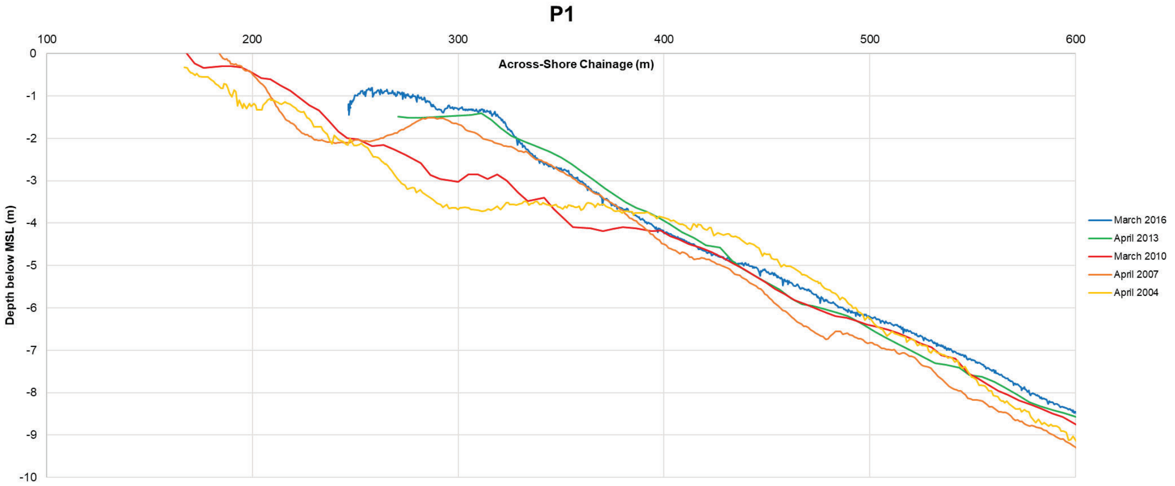
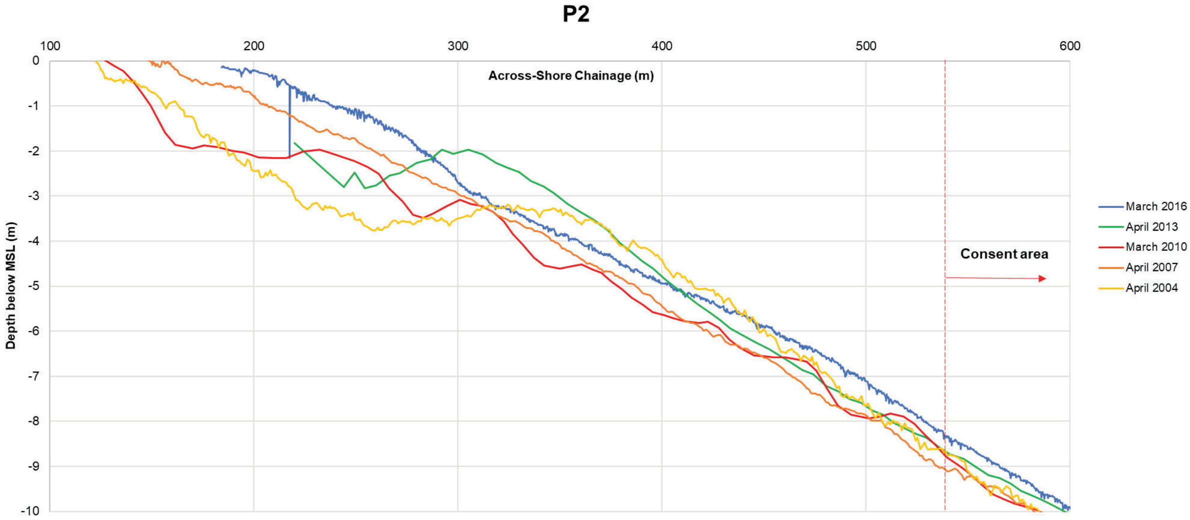
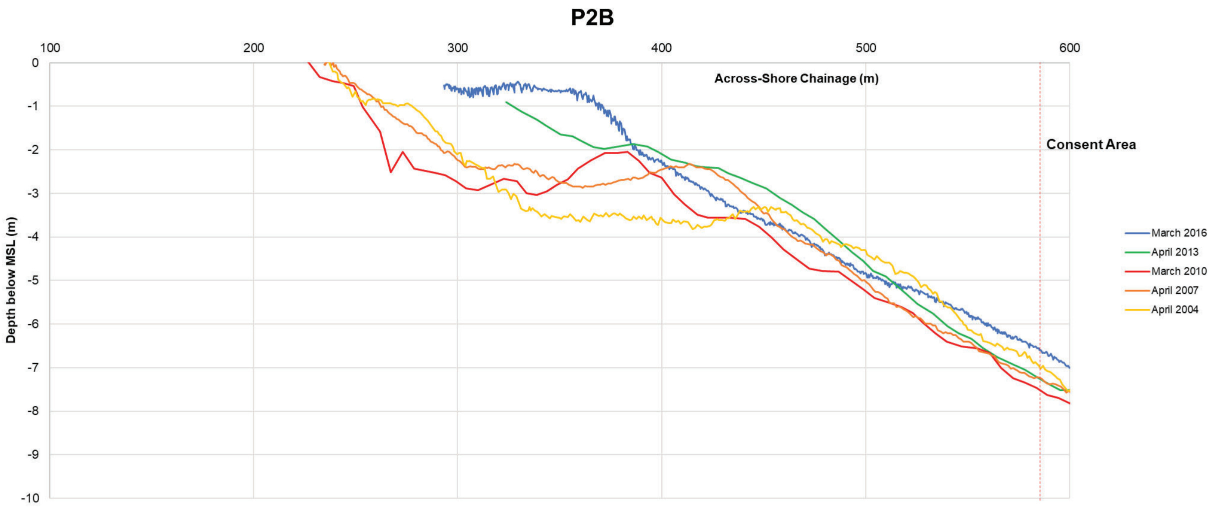
Appendix O. Nearshore Bar Changes 2004-2016







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CLIENT Client	
PROJECT McCallum Brothers Ltd Pakiri Sand Extraction Consent	
SCALE 1:100,000 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 07/20/2020

Legend

- Renewal Consent Area
- Proposed Consent Area
- Historical Profiles Analysed
- Other Historical Profiles

Bathymetric Surveys (2004-2019) at Historical Survey Sites

Profiles 1-2b

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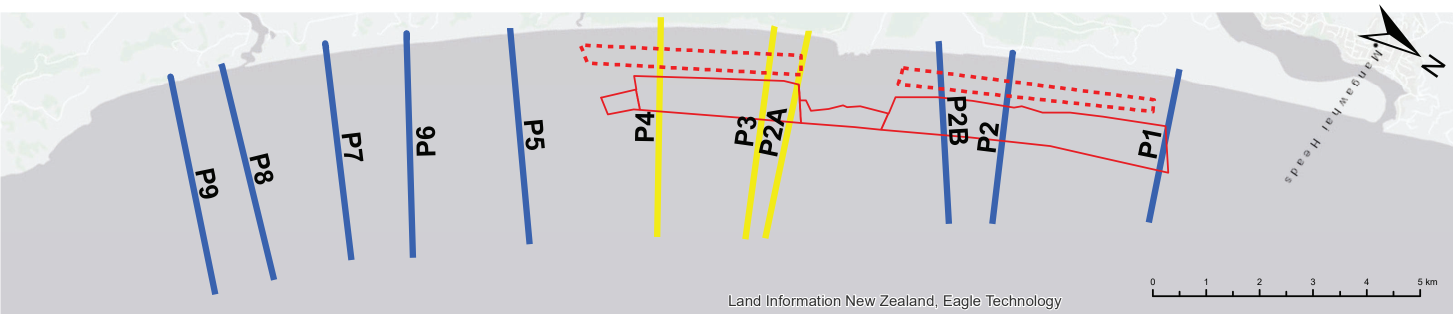

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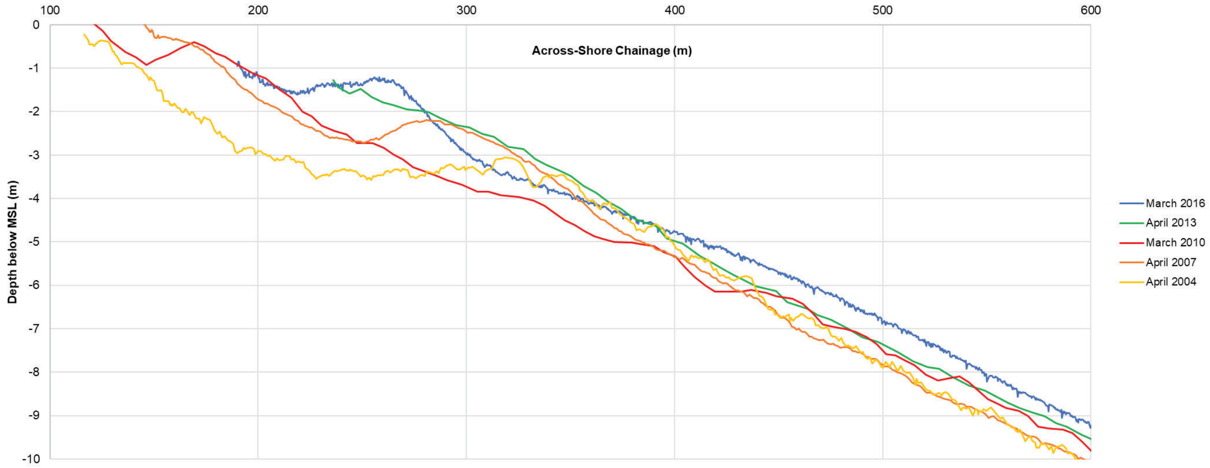

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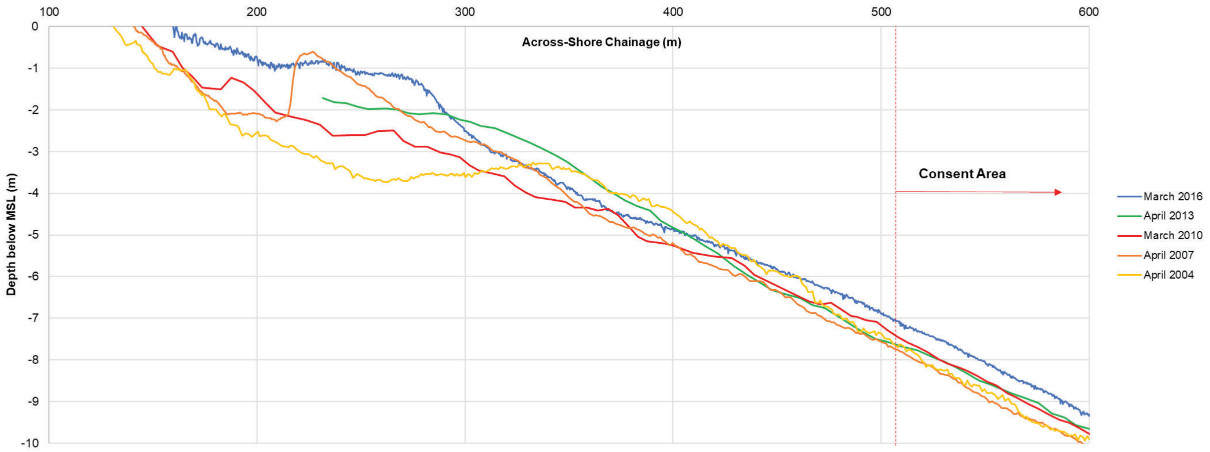

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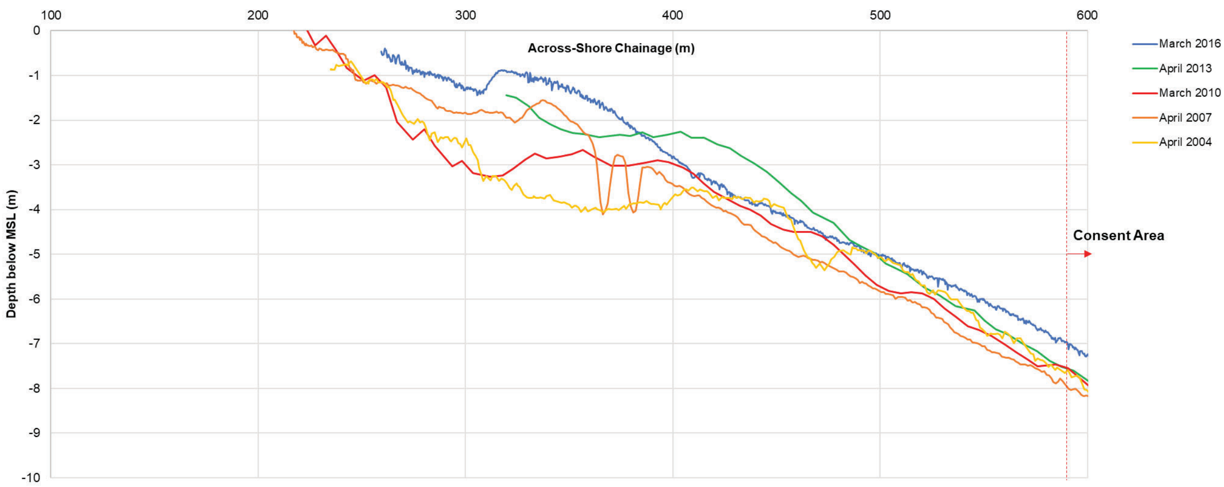

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CLIENT Client	
PROJECT McCallum Brothers Ltd Pakiri Sand Extraction Consent	
SCALE 1:100,000 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 07/20/2020

Legend

- Renewal Consent Area
- Proposed Consent Area
- Historical Profiles Analysed
- Other Historical Profiles

Bathymetric Surveys (2004-2019) at Historical Survey Sites

Profiles 2a-4

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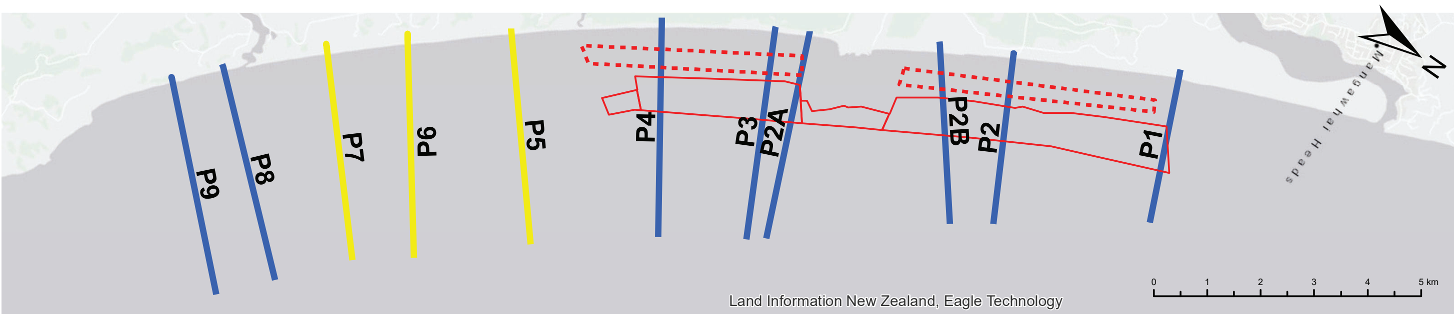

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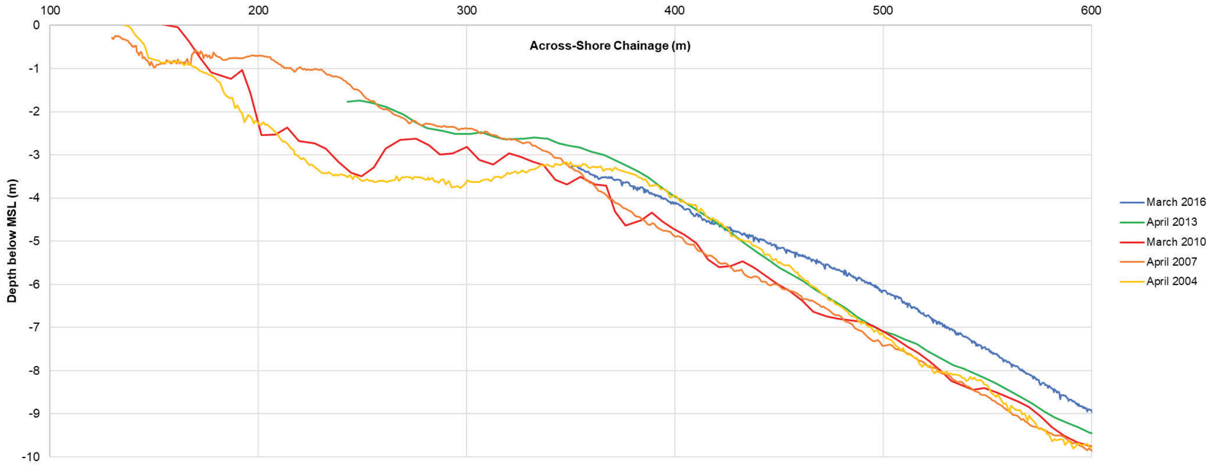

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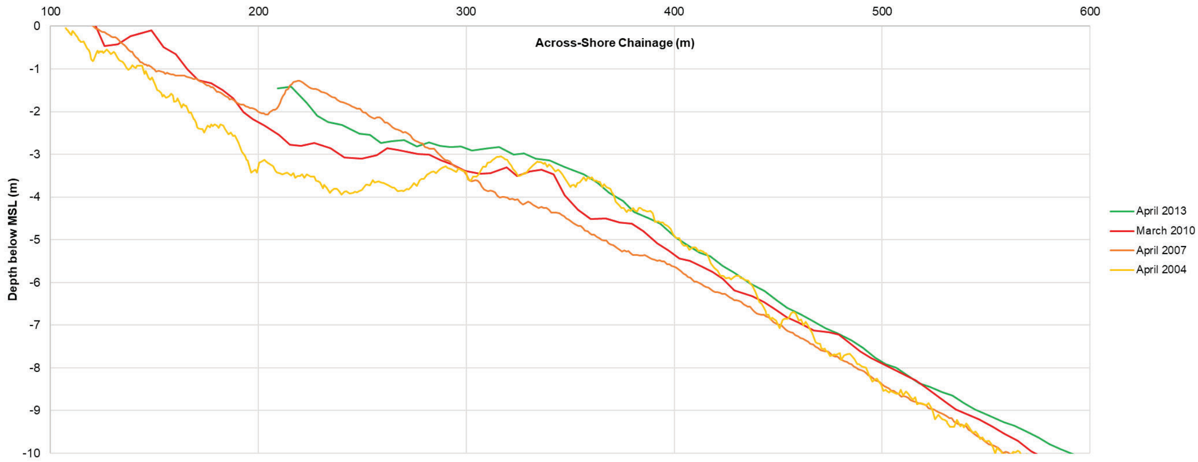

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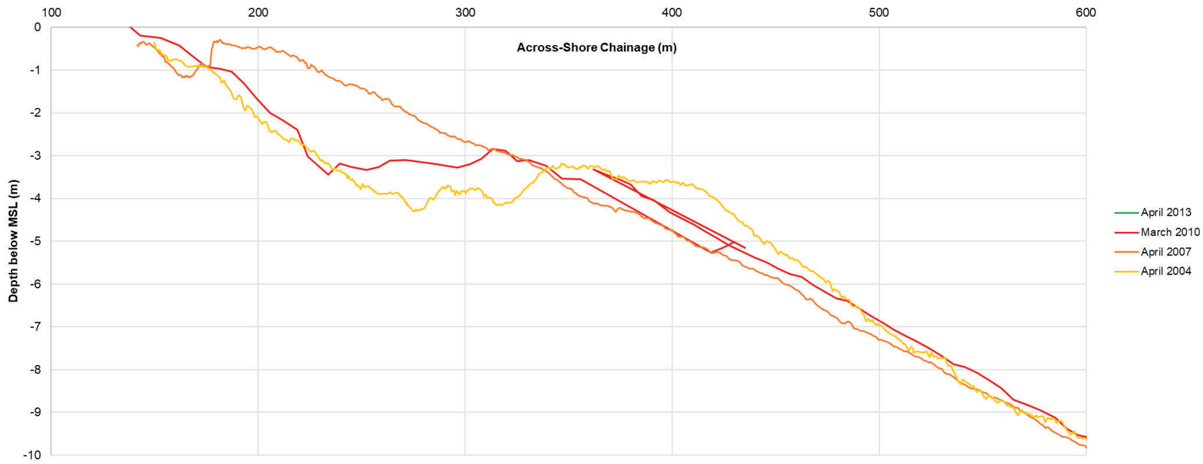

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CLIENT Client	
PROJECT McCallum Brothers Ltd Pakiri Sand Extraction Consent	
SCALE 1:100,000 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 07/20/2020

Legend

- Renewal Consent Area
- Proposed Consent Area
- Historical Profiles Analysed
- Other Historical Profiles

Bathymetric Surveys (2004-2019) at Historical Survey Sites

Profiles 5-7

JACOBS SPATIAL
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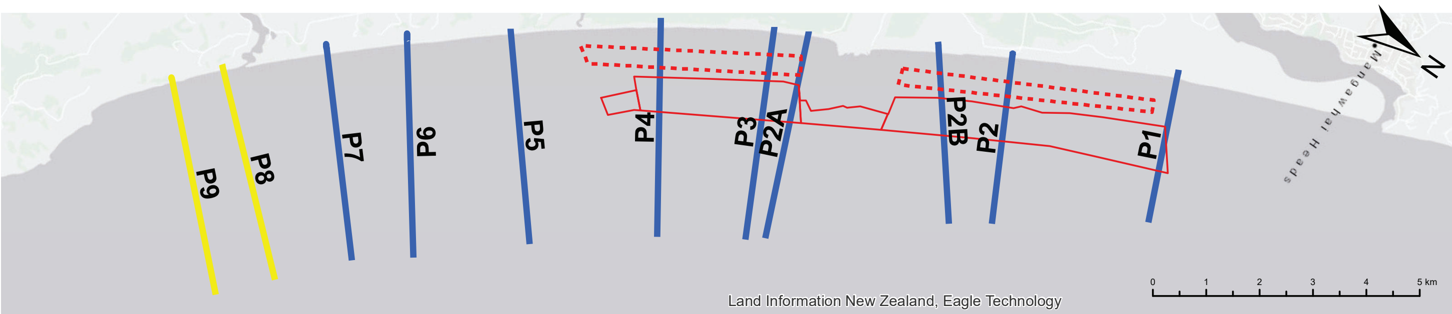

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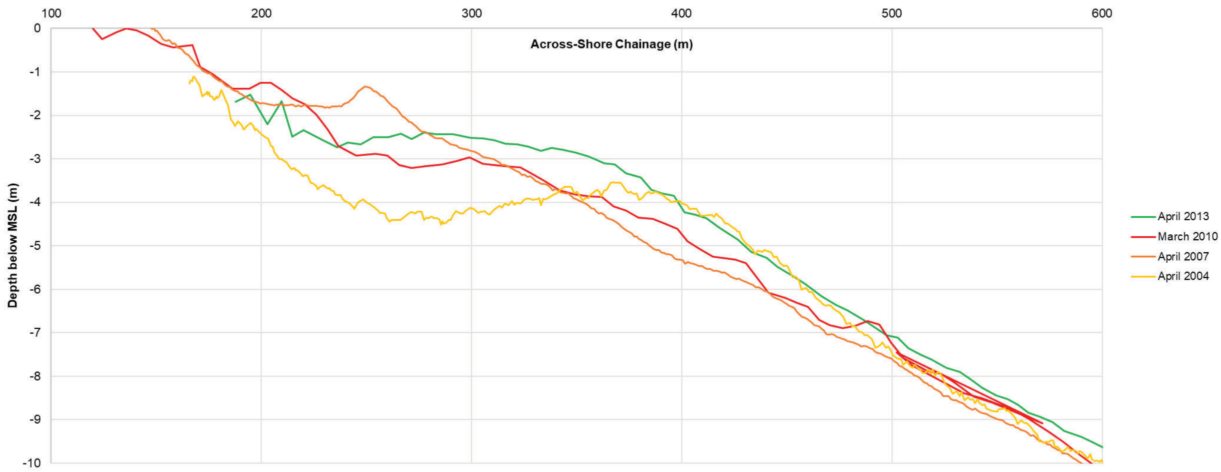
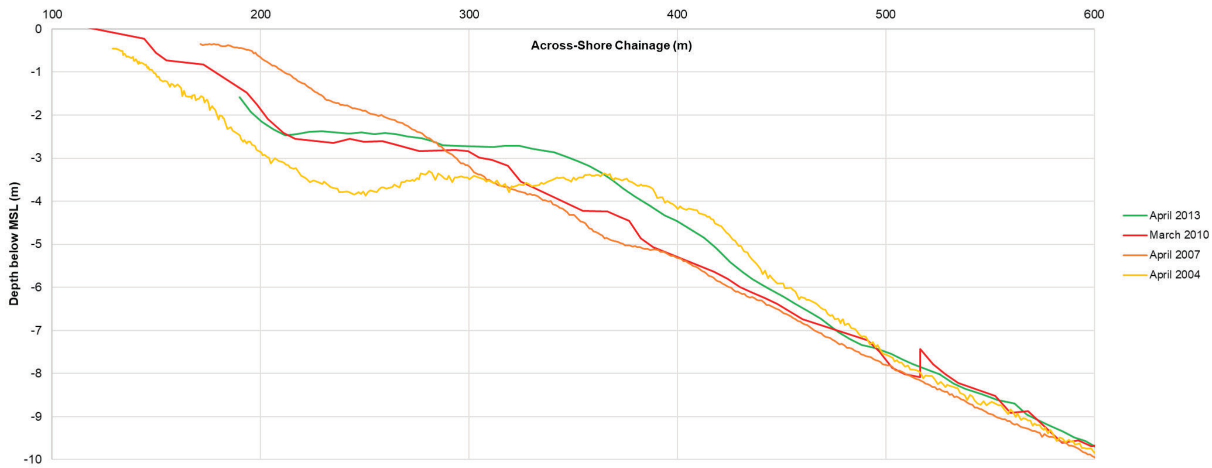


P9



J:\IE\Projects\02_New Zealand\IZ111900\06 Technical\Spatial\MXD\BathyGraphsP8P9_bar.mxd

CLIENT Client	
PROJECT McCallum Brothers Ltd Pakiri Sand Extraction Consent	
SCALE 1:100,000 @ A3	PROJECT CODE IZ111900
PROJECT MANAGER IW	DRAWN KM
PROJECT DIRECTOR DT	DATE 07/20/2020

Legend

- Renewal Consent Area
- Proposed Consent Area
- Historical Profiles Analysed
- Other Historical Profiles

Bathymetric Surveys (2004-2019) at Historical Survey Sites

Profiles 8-9

JACOBS SPATIAL
Level 2, Wynn Williams building,
47 Hereford Street,
Christchurch Central 8013,
New Zealand
T +64 3 940 4900
F +64 3 940 4901

Appendix P. Excursion Distance Analysis – Historical Profile Sites 2007-2020

Net Change Since 2007 at the 1m Contour											
1m contour	P1	P2	P2B	P2A	P3	P4	P5	P6	P7	P8	P9
Apr-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sep-07	-10.9	-32.8	-29.9	-10.0	-26.0	-45.1	-30.4	-23.5	-30.2	-26.0	-22.2
Apr-08	-23.8	-16.1	-27.3	-6.7	-36.6	-27.3	-20.4	-17.2	-22.2	-29.9	-28.2
Sep-08	-27.8	-23.3	-39.6	-19.7	-33.2	-36.1	-35.9	-15.3	-16.5	-40.7	-32.6
Apr-09	-15.5	-29.0	-18.9	-12.5	-42.9	-24.1	-10.2	-11.2	-25.8	-27.5	-22.6
Sep-09	-26.7	-30.0	-44.0	-18.7	-44.6	-67.5	-23.1	-27.5	-29.9	-31.9	-26.1
Mar-10	-21.5	-19.8	-9.5	-10.4	-37.9	-28.4	-19.7	-24.6	-23.2	-25.8	-17.6
Sep-10	-16.0	-26.0	-29.0	-15.1	-45.4	-34.5	-17.5	-30.0	-22.7	-42.6	-23.5
Apr-11	-4.3	-16.5	-15.5	-3.4	-22.3	2.3	-2.6	-11.5	-22.0	-28.4	-9.7
Oct-11	-17.8	-31.9	-33.8	-22.0	-42.7	-28.3	-20.1	-19.7	-20.2	-35.5	-21.1
Apr-12	-9.6	-28.0	-12.2	-7.4	-17.1	-13.7	-8.3	-17.2	-20.3	-24.1	-17.1
Sep-12	-17.8	-29.0	-26.8	-19.4	-25.3	-25.0	-13.9	-17.8	-31.6	-26.9	-21.0
Mar-13	-14.7	-19.7	-22.8	-15.3	-24.0	-7.4	-8.3	-12.4	-11.1	-13.3	-7.2
Sep-13	-11.5	-24.6	-19.4	-3.1	-31.8	-25.4	-9.6	-19.0	-15.3	-16.5	-4.3
Apr-14	-14.0	-21.9	-18.6	-7.7	-32.7	-24.0	-14.7	-20.2	-19.2	-24.8	-19.2
Sep-14	-24.8	-30.3	-40.6	-16.8	-35.9	-29.8	-17.6	-28.7	-18.1	-39.6	-26.6
Mar-15	-21.5	-28.6	-33.7	-9.2	-34.8	-18.9	-14.7	-21.2	-23.2	-27.1	-20.9
Sep-15	7.4	-10.7	-15.3	-0.3	-22.0	-4.2	-4.7	-12.6	-14.4	-29.4	-10.7
Mar-16	-23.9	-4.8	-12.8	1.4	-3.8	-17.8	-24.7	-25.5	-25.4	-28.5	-14.5
Sep-16	-12.7	-22.2	-23.3	-3.7	-37.5	-15.4	-8.3	-14.8	-9.7	-28.1	-14.3
Mar-17	-8.0	-15.3	-0.4	6.3	-21.4	-3.8	10.3	4.3	0.6	-3.9	0.1
Oct-17	23.7	7.4	0.4	13.2	9.0	-1.9	0.4	-7.1	-6.1	-21.2	No data
Mar-18	-5.4	-15.5	-6.8	-25.5	-40.4	-17.4	-31.9	-12.4	-25.3	14.3	No data
Sep-18	-21.4	-14.3	-21.5	0.4	2.4	6.4	-23.6	1.9	-44.5	17.1	No data
Mar-19	16.1	1.2	9.2	-6.1	-1.3	23.9	-6.8	25.0	-25.4	-4.4	No data
Nov-19	3.0	-2.7	-16.3	-4.4	10.3	-0.6	2.4	-6.1	-4.1	-4.0	No data
Mar-20	20.3	10.2	15.8	9.5	11.8	0.9	12.7	-0.2	5.0	7.3	No data

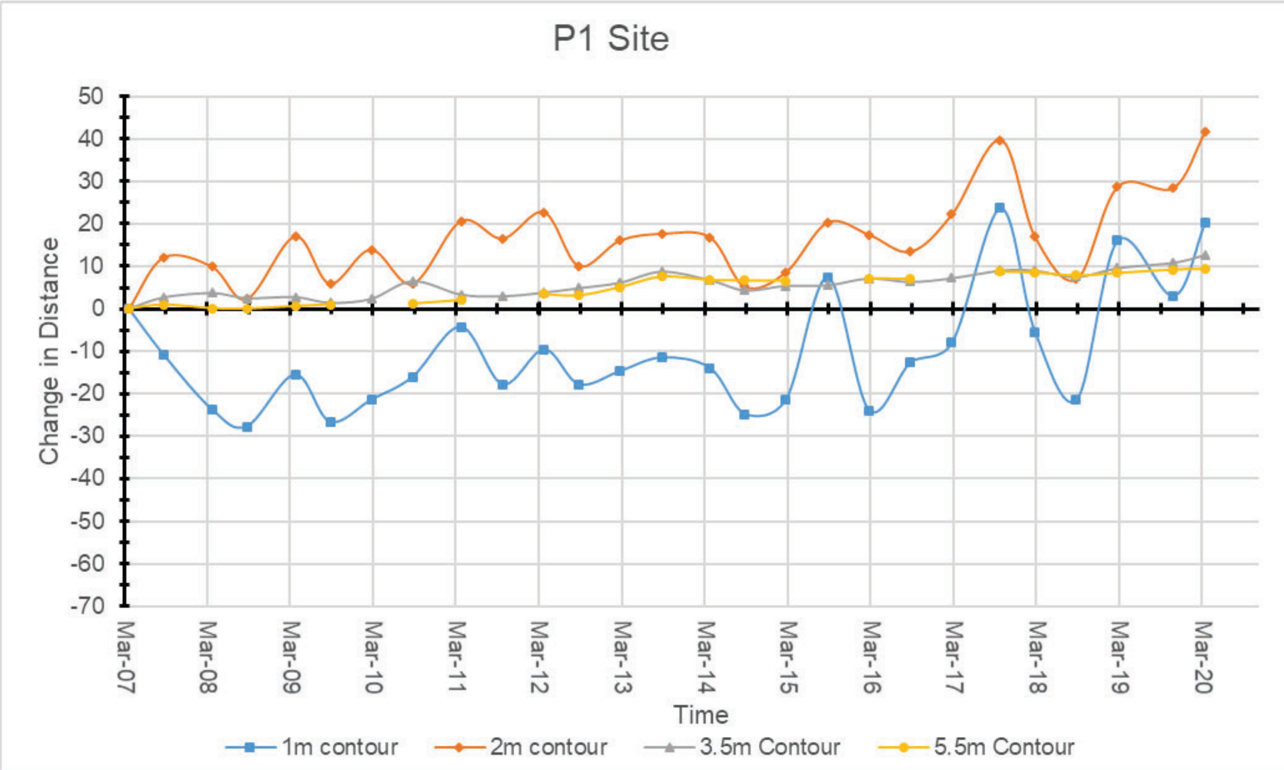
Net Change Since 2007 at the 2m Contour											
2m contour	P1	P2	P2B	P2A	P3	P4	P5	P6	P7	P8	P9
Apr-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sep-07	12.0	-22.6	-37.5	-20.2	-14.1	-36.1	-27.3	-25.5	-21.9	-25.3	-18.0
Apr-08	9.9	-16.2	-36.9	-12.9	-16.8	-29.4	-13.6	-8.2	-11.1	-26.7	-19.5
Sep-08	2.3	-22.7	-45.4	-22.0	-23.1	-34.3	-28.5	-24.7	-20.0	-37.1	-24.9
Apr-09	17.0	-18.4	-20.8	-15.5	-19.9	-20.3	-12.3	-15.6	-17.8	-26.9	-15.9
Sep-09	5.9	-21.1	-44.7	-19.6	-26.8	-55.5	-25.2	-27.0	-22.7	-31.5	-22.0
Mar-10	13.9	-4.2	-23.5	-5.3	-14.9	-27.2	-11.6	-16.9	-19.1	-25.6	-13.5
Sep-10	5.9	-18.5	-36.0	-16.2	-22.6	-28.5	-17.0	-21.6	-14.4	-34.7	-21.4
Apr-11	20.6	-16.0	-29.7	-12.5	-18.5	-12.0	-16.3	-21.0	-14.2	-32.0	-17.2
Oct-11	16.5	-18.1	-34.7	-21.0	-18.7	-18.8	-21.6	-25.8	-22.6	-32.5	-18.9
Apr-12	22.7	-18.3	-24.7	-17.1	-13.1	-20.3	-20.2	-21.5	-23.1	-29.7	-19.8
Sep-12	10.0	-29.0	-36.9	-25.5	-21.3	-29.2	-26.0	-26.6	-29.8	-34.0	-25.6
Mar-13	16.0	-20.6	-25.0	-15.1	-15.8	-13.6	-16.4	-16.8	-16.7	-22.4	-14.0
Sep-13	17.6	-20.6	-30.1	-13.9	-23.5	-27.2	-21.5	-23.6	-20.2	-28.6	-14.7
Apr-14	16.8	-15.6	-26.6	-10.6	-17.5	-20.8	-17.4	-19.7	-16.2	-26.2	-15.7
Sep-14	5.2	-29.3	-42.5	-24.0	-28.4	-29.4	-26.4	-32.2	-19.5	-41.8	-28.7
Mar-15	8.5	-19.0	-33.9	-17.1	-25.3	-21.0	-17.2	-19.9	-17.5	-26.4	-22.9
Sep-15	20.3	-6.2	-30.1	-10.1	-12.1	-9.9	-8.2	-7.5	-9.2	-25.4	-1.5
Mar-16	17.4	-12.1	-32.2	2.5	-12.6	-11.8	-18.7	-19.5	-14.7	-24.1	-12.7
Sep-16	13.4	-15.0	-24.5	-13.5	-21.0	-12.5	-24.1	-14.7	-14.2	-30.8	-15.0
Mar-17	22.2	-15.0	-11.2	-6.0	-18.1	-12.6	-4.5	-9.1	-9.0	-17.1	-13.4
Oct-17	39.7	-14.1	-20.8	-5.3	-9.0	-7.1	-11.8	-19.0	-13.4	-24.5	No data
Mar-18	16.9	-13.3	-23.9	-23.3	-19.7	-15.9	-36.0	-20.2	-23.4	-7.1	No data
Sep-18	6.9	-16.3	-23.9	-15.3	-17.0	-24.7	-40.0	-23.6	-31.7	-14.8	No data
Mar-19	28.7	-7.7	-13.6	-9.5	-5.1	-21.7	-31.9	-3.7	-10.4	8.7	No data
Nov-19	28.4	-9.8	-14.2	-5.7	-8.2	-12.2	5.2	-0.4	6.3	-9.4	No data
Mar-20	41.6	-1.0	-3.3	0.6	-6.9	-5.2	2.3	-9.0	-0.8	-6.2	No data

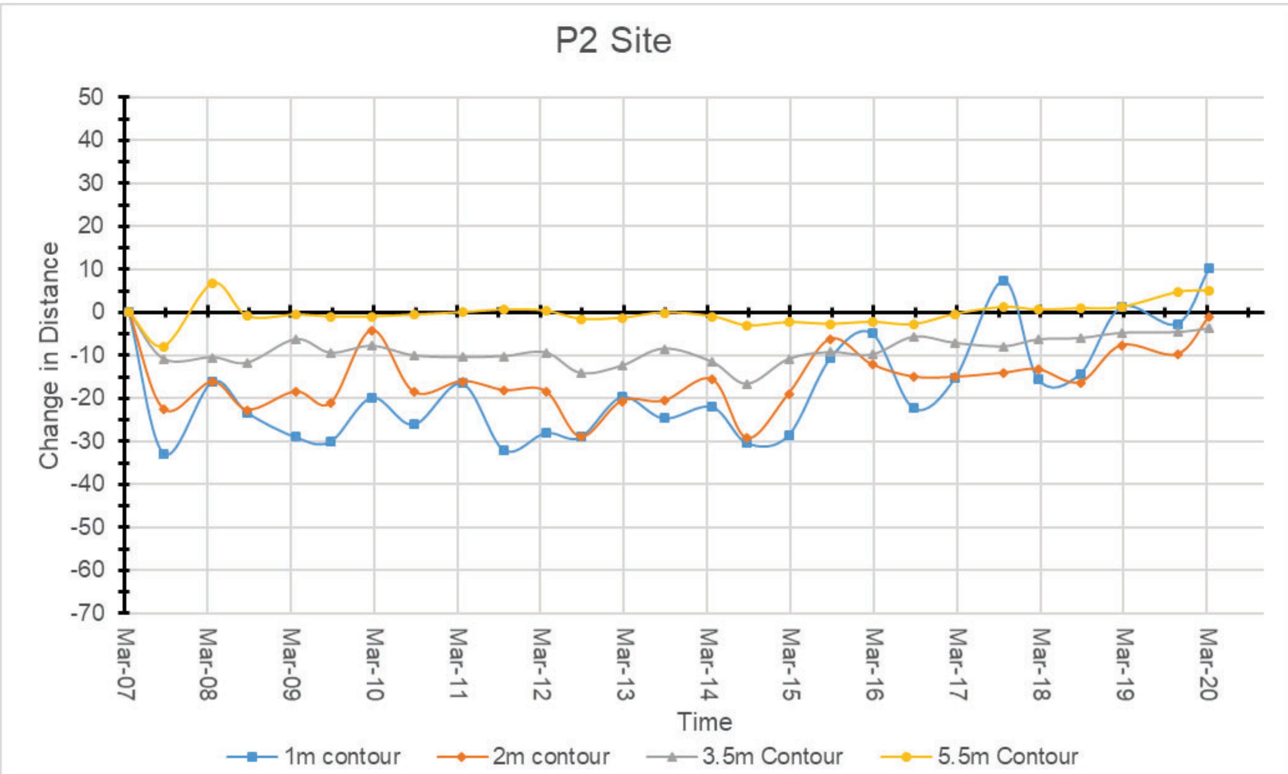
Net Change Since 2007 at the 3.5m Contour

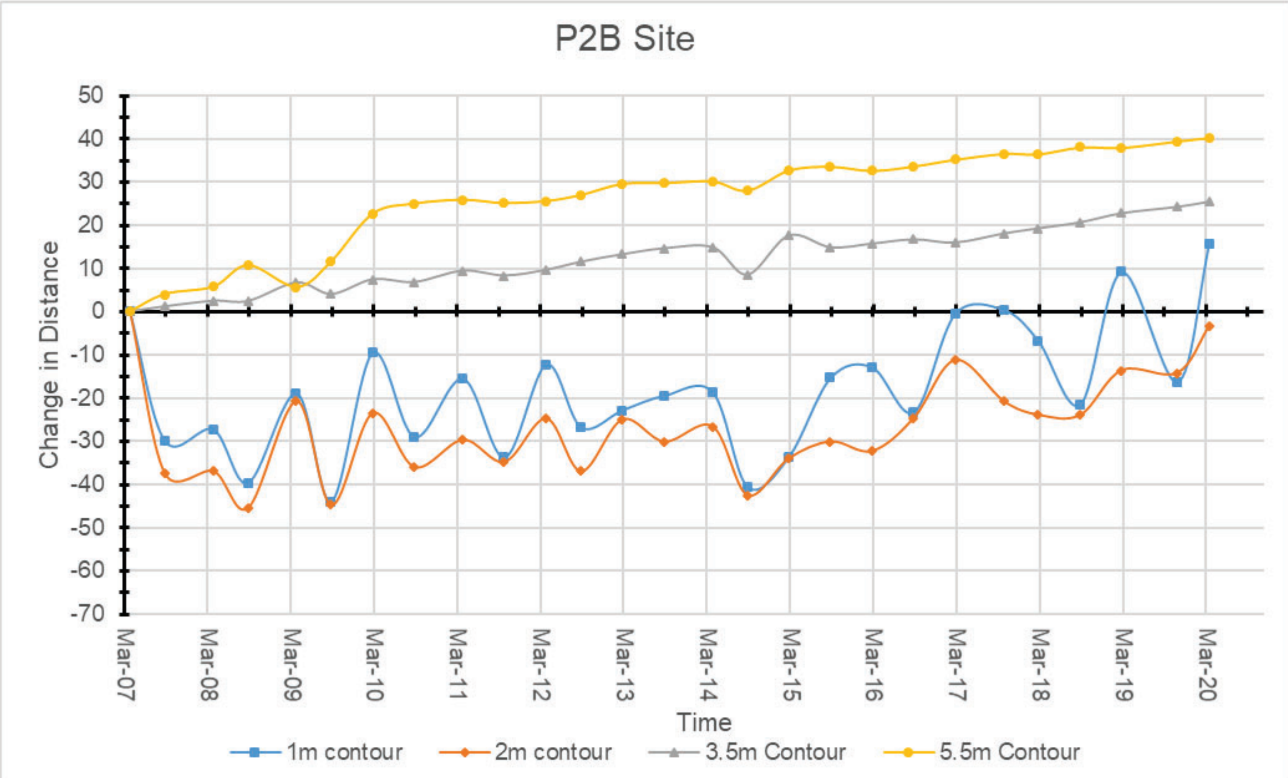
3.5m Contour	P1	P2	P2B	P2A	P3	P4	P5	P6	P7	P8	P9
Apr-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sep-07	2.7	-10.9	1.2	-4.6	-7.2	-10.1	-17.8	-11.2	-12.2	-5.7	-5.1
Apr-08	3.7	-10.5	2.5	-2.1	-7.6	-12.1	-17.1	-14.0	-12.0	-6.6	-7.8
Sep-08	2.5	-11.7	2.4	-20.6	-8.1	-13.5	-22.0	-14.8	-15.4	-13.2	-11.5
Apr-09	2.8	-6.3	6.7	-2.2	-5.6	-7.1	-16.5	-10.4	-12.0	-11.0	-6.7
Sep-09	1.4	-9.4	4.1	-5.0	-7.9	-24.0	-21.4	-13.5	-13.3	-11.6	-10.5
Mar-10	2.3	-7.8	7.5	-2.3	-6.9	-10.3	-18.1	-10.6	-11.8	-12.1	-10.2
Sep-10	6.6	-10.1	6.8	-1.9	-7.2	-9.9	-19.8	-11.7	-11.8	-11.7	-11.0
Apr-11	3.4	-10.4	9.5	0.8	-7.2	9.8	-17.7	-11.9	-12.2	-10.6	-9.8
Oct-11	2.9	-10.2	8.3	-1.4	-9.1	-6.9	-22.0	-12.5	-16.4	-14.0	-12.4
Apr-12	3.9	-9.4	9.7	-1.6	-7.1	-6.2	-21.1	-11.3	-14.0	-12.4	-10.8
Sep-12	4.9	-14.1	11.6	-1.5	-6.5	-9.7	-21.2	-12.3	-18.4	-13.6	-13.3
Mar-13	6.2	-12.4	13.3	-0.1	-3.1	-7.2	-19.7	-8.1	-13.9	-9.3	-9.1
Sep-13	8.8	-8.5	14.7	0.9	-5.7	-7.3	-20.4	-9.3	-13.8	-10.9	-11.8
Apr-14	6.8	-11.6	14.9	0.8	-5.5	-7.3	-18.4	-7.8	-11.1	-8.6	-9.5
Sep-14	4.4	-16.7	8.5	-3.6	-8.7	-10.2	-21.4	-16.9	-14.9	-15.9	-12.6
Mar-15	5.4	-10.9	17.6	-13.0	-7.3	-5.1	-20.0	-7.6	-9.7	-7.6	-10.5
Sep-15	5.6	-9.3	14.9	3.0	-6.5	-4.4	-15.2	-8.6	-8.1	-11.3	-10.7
Mar-16	7.2	-9.8	15.7	4.5	-4.3	-3.6	-18.3	-8.8	-10.4	-8.7	-7.1
Sep-16	6.3	-5.7	16.7	0.1	-5.2	-4.0	-20.1	-12.8	-16.6	-11.8	-10.6
Mar-17	7.3	-7.2	16.0	1.5	-2.9	-3.8	-21.3	-10.5	-12.8	-10.6	-8.9
Oct-17	9.0	-7.9	18.1	2.8	-3.5	-1.2	-21.8	-8.8	-12.5	-7.9	No data
Mar-18	9.0	-6.3	19.3	1.3	-4.5	-4.2	-30.0	-10.3	-13.3	-8.3	No data
Sep-18	7.5	-6.0	20.7	2.5	-4.8	-4.2	-27.3	-10.7	-13.7	-10.4	No data
Mar-19	9.6	-4.8	22.8	0.3	-4.2	-4.7	-22.9	-10.9	-11.6	-11.0	No data
Nov-19	10.9	-4.6	24.3	4.0	-2.6	-1.4	-16.6	-5.3	-8.8	9.3	No data
Mar-20	12.7	-3.7	25.5	4.7	-2.8	-2.3	-18.2	-6.5	-9.3	20.6	No data

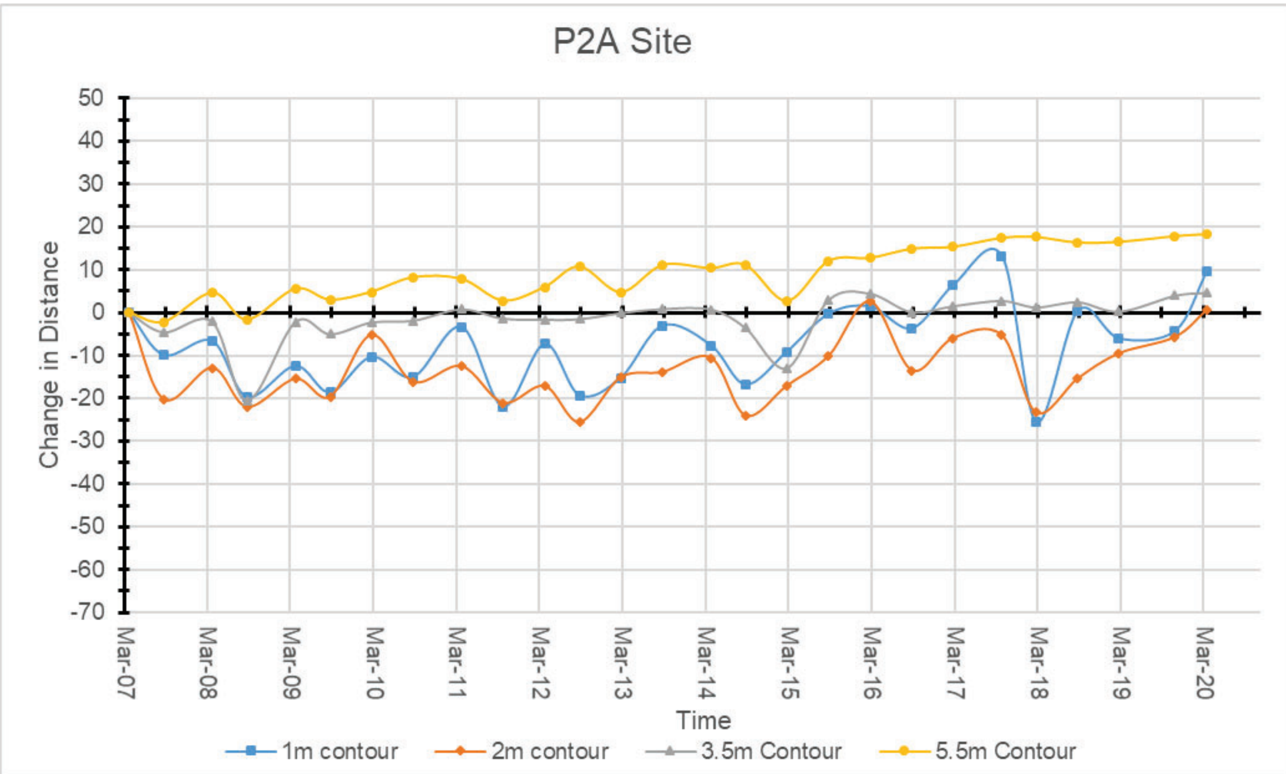
Net Change Since 2007 at the 5.5m Contour

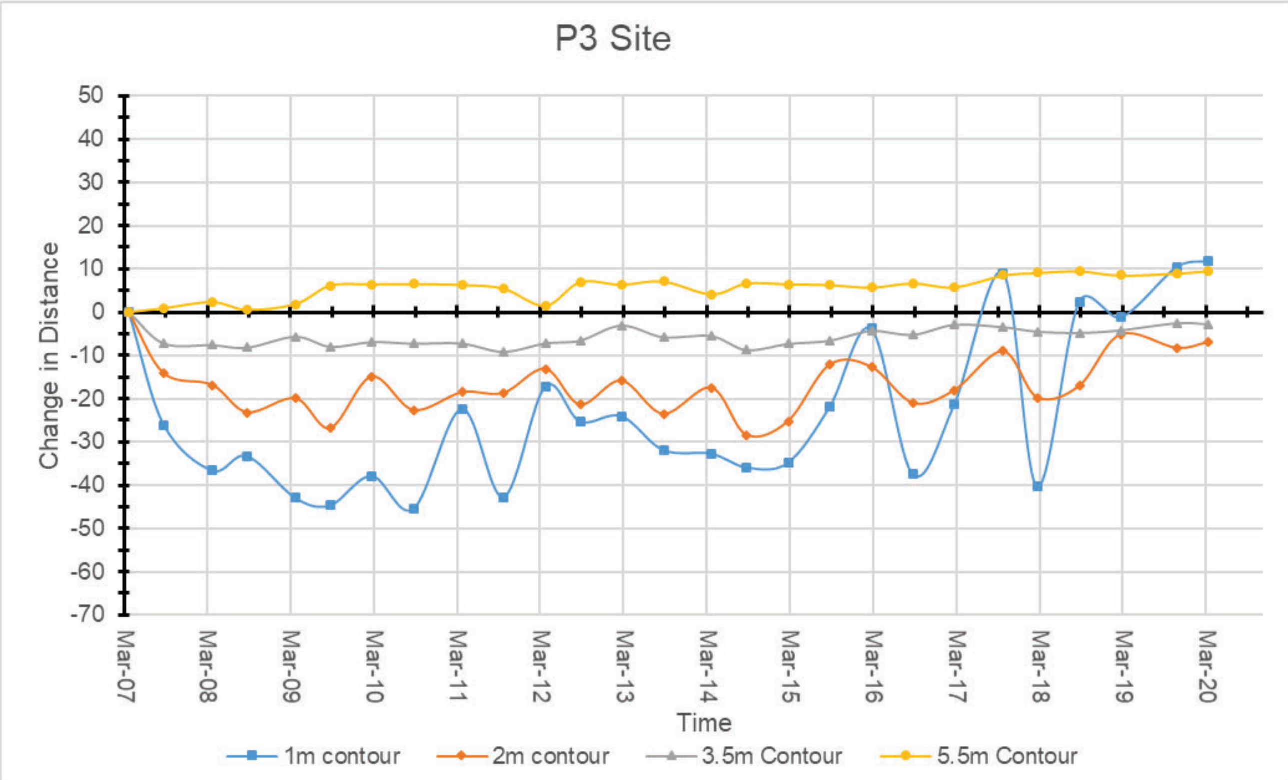
5.5m Contour	P1	P2	P2B	P2A	P3	P4	P5	P6	P7	P8	P9
Apr-07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sep-07	0.9	-7.9	4.0	-2.2	0.9	-1.9	-26.0	0.3	-1.6	-0.9	1.2
Apr-08	0.1	6.8	5.8	4.6	2.4	-4.1	-8.1	-1.1	-1.2	-2.3	-1.4
Sep-08	0.0	-0.9	10.8	-1.7	0.5	-5.5	-12.5	-2.4	-3.4	-2.4	-0.8
Apr-09	0.6	-0.5	5.7	5.6	1.9	-5.0	-8.2	-2.6	-3.3	-3.0	-0.6
Sep-09	1.0	-1.0	11.7	3.0	6.2	-9.0	-9.9	-2.2	-2.4	-2.8	-0.4
Mar-10		-0.9	22.7	4.8	6.5	-7.1	-14.6	-2.2	-1.7	-3.7	-0.7
Sep-10	1.2	-0.5	25.1	8.2	6.5	-6.8	-18.6	-1.7	-1.8	-2.7	-0.6
Apr-11	2.0	0.0	25.9	7.9	6.3	-3.3	-14.6	-0.3	-2.7	-3.0	-1.1
Oct-11		0.7	25.2	2.8	5.5	-4.9	-22.0	-1.7	-5.3	-3.6	-2.0
Apr-12	3.4	0.4	25.6	6.0	1.5	-5.5	-13.4	-1.1	-2.2	-3.3	-1.4
Sep-12	3.1	-1.5	27.1	10.8	7.0	-6.3	-18.5	-1.1	-19.0	-3.7	-2.4
Mar-13	5.1	-1.3	29.6	4.8	6.4	-6.4	-18.5	-0.3	-8.6	-4.1	-2.2
Sep-13	7.6	0.0	29.8	11.1	7.2	-14.1	-17.4	0.7	-2.8	-4.1	-2.5
Apr-14	6.8	-0.9	30.2	10.4	4.2	-7.5	-15.5	-1.6	-9.0	-3.0	-1.6
Sep-14	6.6	-3.0	28.0	11.1	6.7	-6.5	-17.1	-2.4	-3.2	-4.6	-1.8
Mar-15	6.6	-2.3	32.7	2.7	6.5	-7.3	-21.8	-2.0	-3.2	-4.4	-2.4
Sep-15		-2.7	33.6	12.1	6.3	-7.3	-18.2	-1.4	-3.3	-4.4	-2.3
Mar-16	7.2	-2.2	32.6	12.8	5.7	-7.2	-22.1	-1.3	-3.2	-4.4	-1.9
Sep-16	7.0	-2.8	33.7	14.9	6.7	-6.1	-17.4	-0.2	-4.5	-4.1	-2.3
Mar-17		-0.4	35.2	15.4	5.8	-6.9	-20.6	-0.5	-10.2	-2.9	-1.1
Oct-17	8.7	1.2	36.6	17.5	8.5	-3.1	-23.4	0.4	-3.2	-3.0	No data
Mar-18	8.5	0.6	36.5	17.7	9.1	-8.1	-15.0	-0.6	-3.0	-1.7	No data
Sep-18	7.8	0.9	38.1	16.4	9.5	-7.5	-8.3	0.5	-4.3	-3.4	No data
Mar-19	8.4	1.2	38.0	16.6	8.5	-12.7	-4.2	0.7	-2.8	-2.1	No data
Nov-19	9.2	4.7	39.5	17.9	9.0	-8.6	-12.6	2.9	-2.5	-2.9	No data
Mar-20	9.4	5.2	40.3	18.4	9.6	-9.5	-22.0	-0.5	-2.4	-3.8	No data

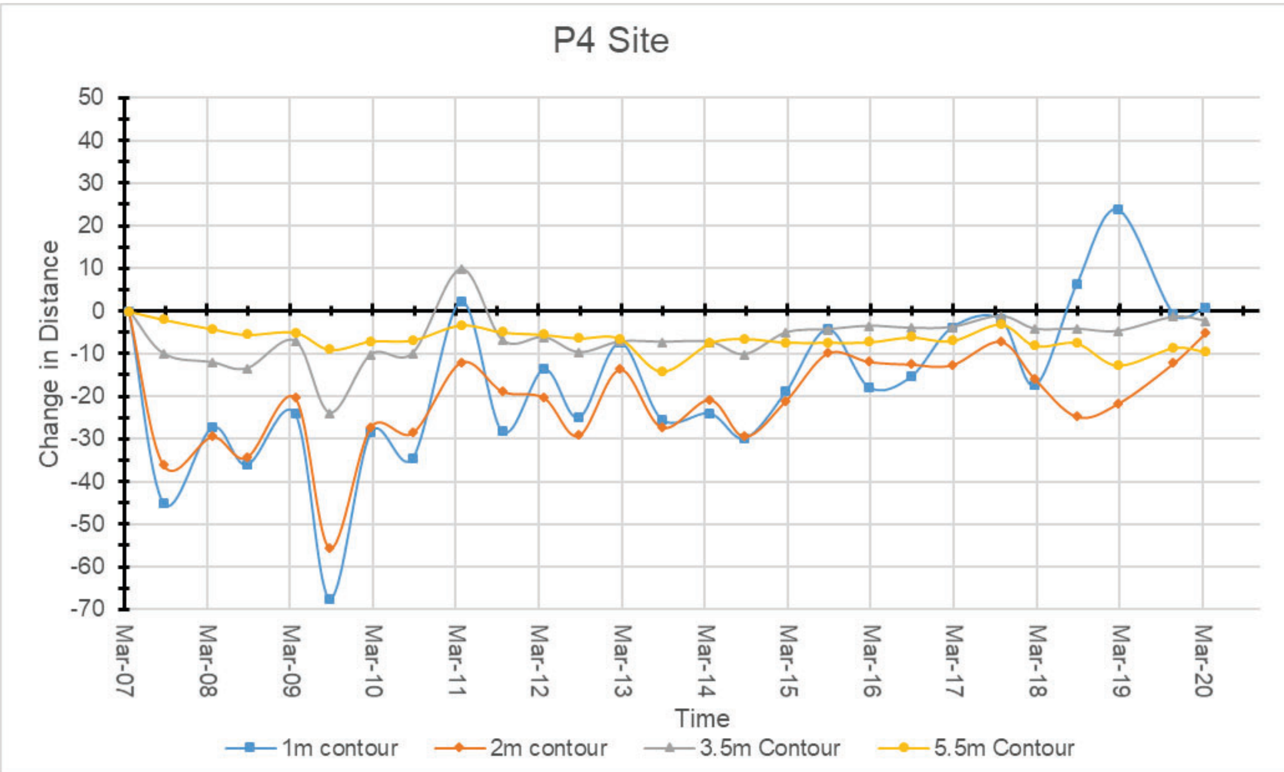

P1 Site
Change in Distance
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
Mar-07
Mar-08
Mar-09
Mar-10
Mar-11
Mar-12
Mar-13
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
Time
1m contour
2m contour
3.5m Contour
5.5m Contour

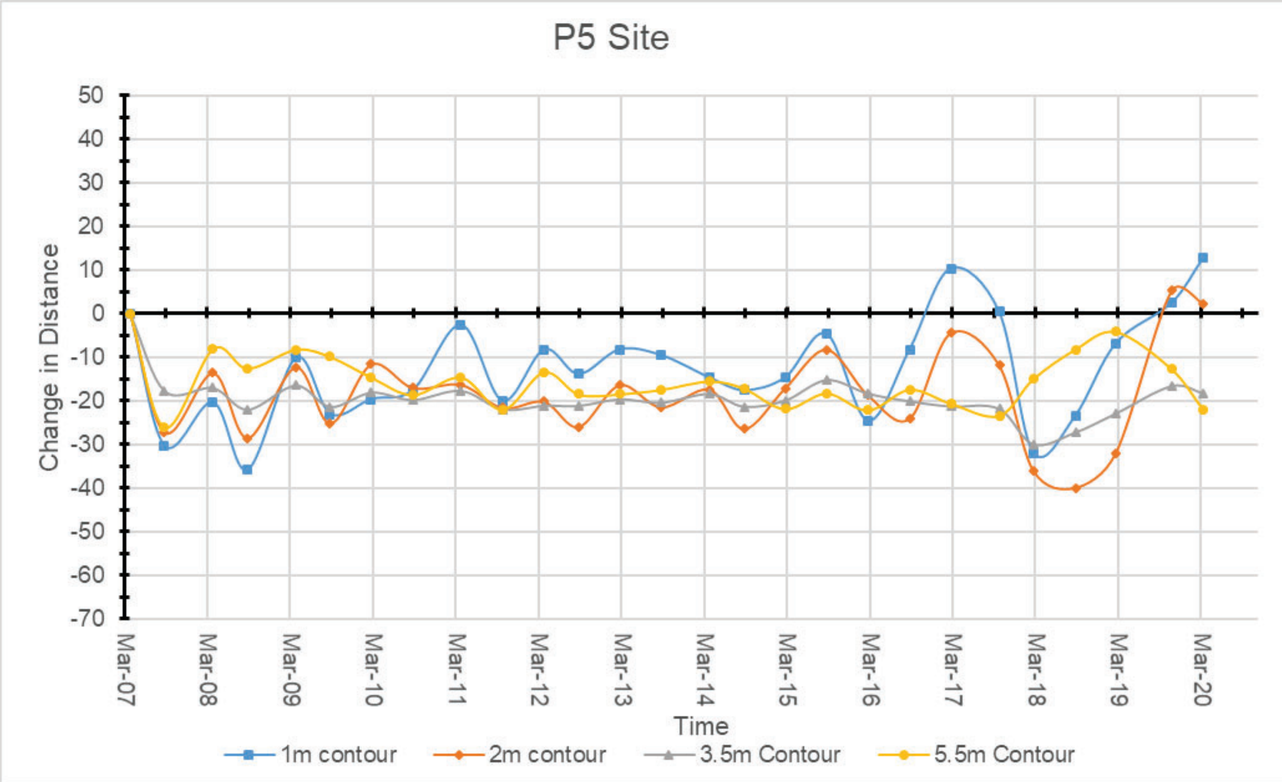

P2 Site
Change in Distance
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
Mar-07
Mar-08
Mar-09
Mar-10
Mar-11
Mar-12
Mar-13
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
Time
1m contour
2m contour
3.5m Contour
5.5m Contour

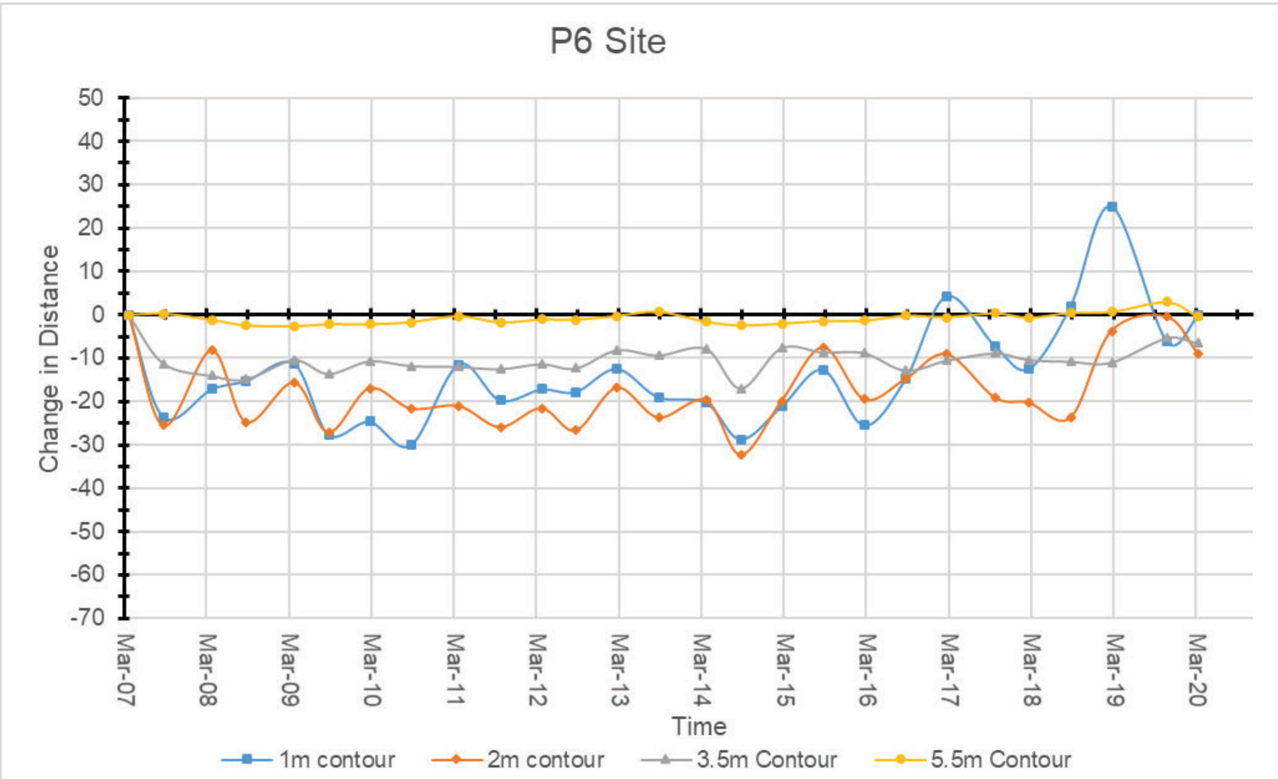

P2B Site
Change in Distance
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
Mar-07
Mar-08
Mar-09
Mar-10
Mar-11
Mar-12
Mar-13
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
Time
1m contour
2m contour
3.5m Contour
5.5m Contour

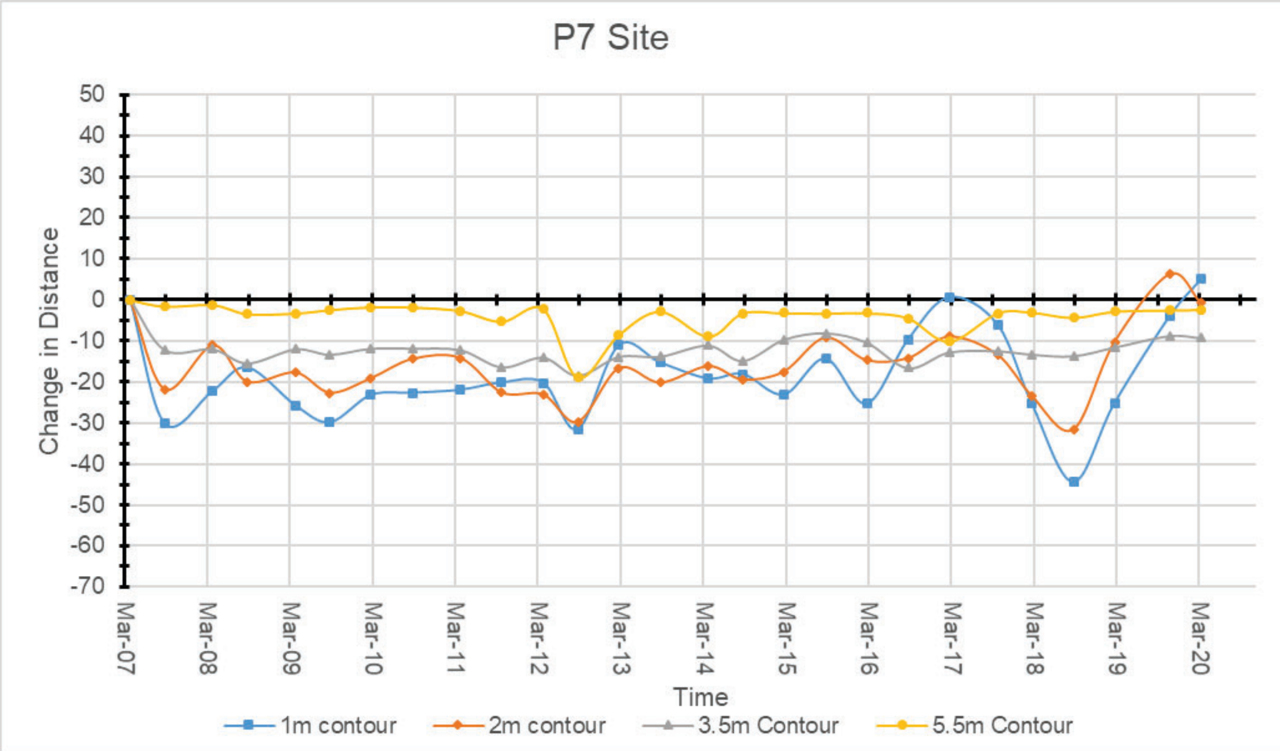

P2A Site
Change in Distance
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
Mar-07
Mar-08
Mar-09
Mar-10
Mar-11
Mar-12
Mar-13
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
Time
1m contour
2m contour
3.5m Contour
5.5m Contour


P3 Site
Change in Distance
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
Mar-07
Mar-08
Mar-09
Mar-10
Mar-11
Mar-12
Mar-13
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
Time
1m contour
2m contour
3.5m Contour
5.5m Contour

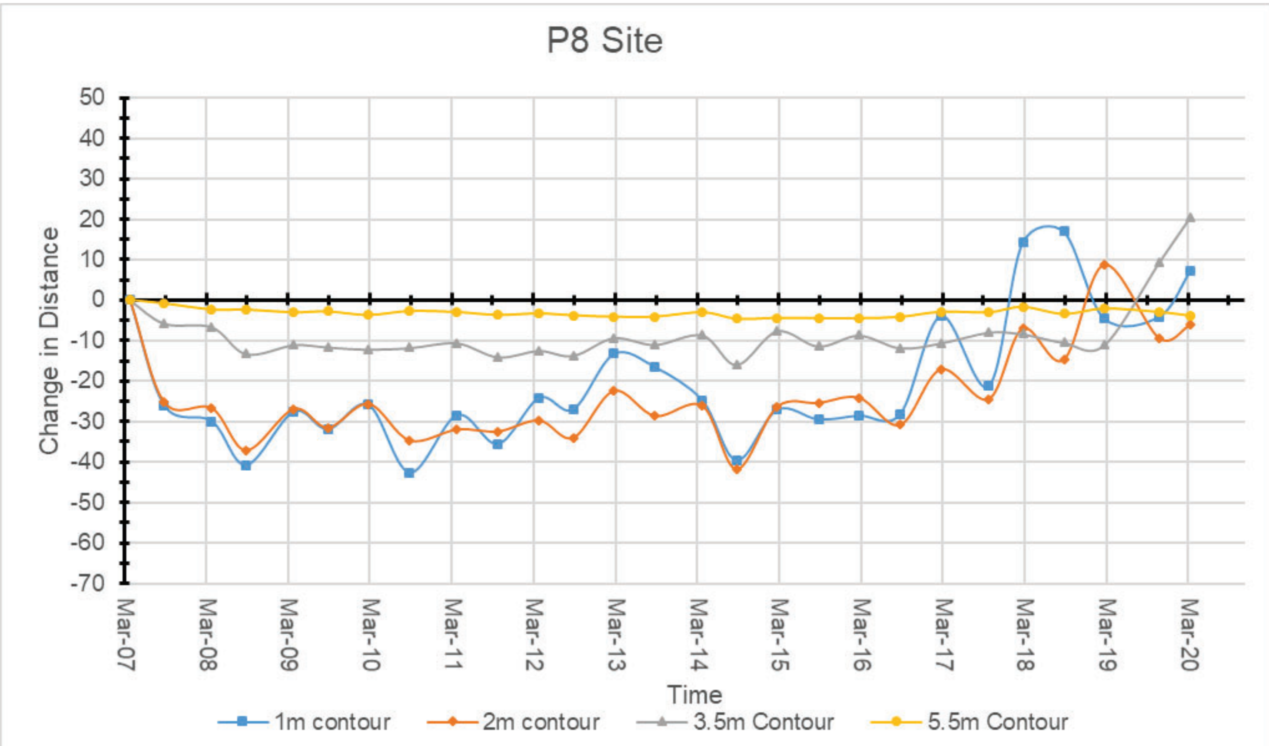

P4 Site
Change in Distance
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
Mar-07
Mar-08
Mar-09
Mar-10
Mar-11
Mar-12
Mar-13
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
Time
1m contour
2m contour
3.5m Contour
5.5m Contour


P5 Site
Change in Distance
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
Mar-07
Mar-08
Mar-09
Mar-10
Mar-11
Mar-12
Mar-13
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
Time
1m contour
2m contour
3.5m Contour
5.5m Contour

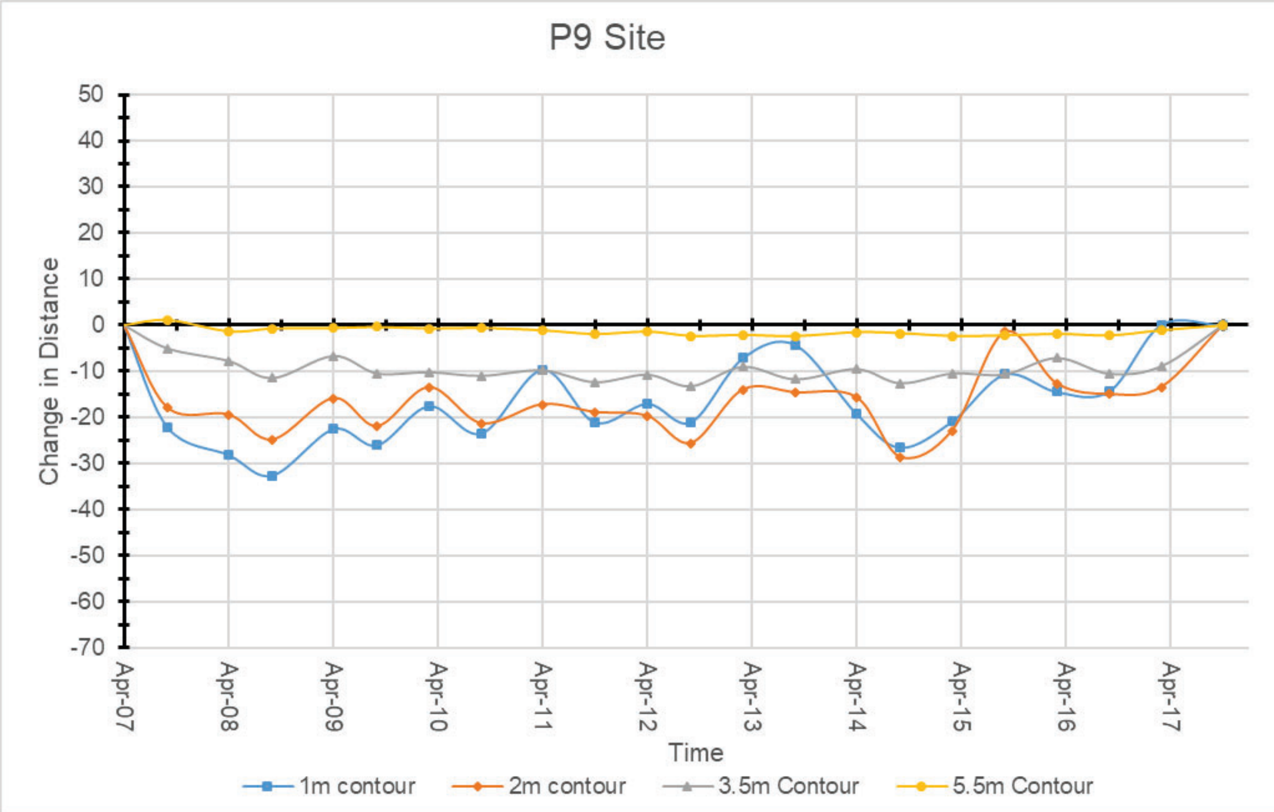

P6 Site
Change in Distance
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
Mar-07
Mar-08
Mar-09
Mar-10
Mar-11
Mar-12
Mar-13
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
Time
1m contour
2m contour
3.5m Contour
5.5m Contour



P7 Site
Change in Distance
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
Mar-07
Mar-08
Mar-09
Mar-10
Mar-11
Mar-12
Mar-13
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
Time
1m contour
2m contour
3.5m Contour
5.5m Contour



P8 Site
Change in Distance
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
Mar-07
Mar-08
Mar-09
Mar-10
Mar-11
Mar-12
Mar-13
Mar-14
Mar-15
Mar-16
Mar-17
Mar-18
Mar-19
Mar-20
Time
1m contour
2m contour
3.5m Contour
5.5m Contour



P9 Site
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
Change in Distance
Apr-07
Apr-08
Apr-09
Apr-10
Apr-11
Apr-12
Apr-13
Apr-14
Apr-15
Apr-16
Apr-17
Time
1m contour
2m contour
3.5m Contour
5.5m Contour

Appendix Q. Cut and Fill Volume Maps for 2007-2017

Legend

- Historical Profiles
- Beach Volume Boxes
- Net Gain
- Unchanged
- Net Loss

N

0 100200 400 600 800 Meters

Pakiri Beach - Elevation Analysis
April 2007 to March 2017

Section 1

CLIENT McCallum Bros	
PROJECT Pakiri Sand Mining	
SCALE 1:25,000 @ A3	PROJECT CODE IZ098900
PROJECT MANAGER EM	DRAWN TN
PROJECT DIRECTOR DT	DATE 29/03/2018
FIGURE NO X	REVISION DRAFT

JACOBS®
Level 3
86 Customhouse Quay
Wellington
Tel +64 4 914 8412

Legend

- Historical Profiles
- Beach Volume Boxes
- Net Gain
- Unchanged
- Net Loss

N

0 100 200 400 600 800 Meters

Pakiri Beach - Elevation Analysis
April 2007 to March 2017

Section 2

CLIENT McCallum Bros	
PROJECT Pakiri Sand Mining	
SCALE 1:25,000 @ A3	*PROJECT CODE* IZ098900
PROJECT MANAGER EM	*DRAWN* TN
PROJECT DIRECTOR DT	*DATE* 29/03/2018
FIGURE NO X	*REVISION* DRAFT

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Legend

- Historical Profiles
- Beach Volume Boxes
- Net Gain
- Unchanged
- Net Loss

N

0 100 200 400 600 800 Meters

Pakiri Beach - Elevation Analysis April 2007 to March 2017

Section 3

CLIENT McCallum Bros	
PROJECT Pakiri Sand Mining	
SCALE 1:25,000 @ A3	PROJECT CODE IZ098900
PROJECT MANAGER EM	DRAWN TN
PROJECT DIRECTOR DT	DATE 29/03/2018
FIGURE NO X	REVISION DRAFT

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