Bay of Plenty
Current and Temperature Measurements: Aquaculture Management Areas

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Bay of Plenty
Current and Temperature Measurements: Aquaculture Management Areas

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Bay of Plenty
Current and Temperature Measurements:
Aquaculture Management Areas

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Report prepared for Bay of Plenty Regional Council

Executive Summary

Temperature and current measurements were made in the eastern Bay of Plenty to record the 3-dimensional structure of the Bay. This sub-programme formed part of the larger ASR Ltd study being undertaken for Environment Bay of Plenty with the goals to:

- Be informed about offshore oceanographic and ecological systems when choosing open coast AMA sites, for a sustainable environment, kaimoana and aquaculture industry in the Bay of Plenty

- Do background monitoring to complement the monitoring required under coastal permits for the proposed farm(s)

- Involve local iwi in determining effects on kaimoana, aquaculture planning and training

- Involve graduate university students who will be better trained for the expected future growth of the industry

To record circulation characteristics, StowAway Tidbit Temperature Loggers (Figure 2.1) were deployed at specific water depths on temperature-strings, and a SonTek ADP (Acoustic Doppler Profiler) current meter was deployed on a bottom-mounted frame (Figure 2.2).

Figure 2.3 illustrates both the long-term deployment locations offshore from Pukehina and Opotiki (at the 65 m isobath) and the short (>30 min) deployments along the Pukehina, Whakatane and Opotiki transects (at the 20, 50 and 100 m isobaths).

The data covers the period September, 2003 to January 2005 and is fully summarised in Figure 2.4.

The region is often stratified. Temperature creates vertical structure that constantly varies at all time scales, but substantially from daily to annual, while the freshwater inflow can form plumes over large sections of the shelf. The stratification feeds back into the circulation,

which is strongly affected by vertical density structure. Nearly always, the near-surface and near-bed segments of the water column have very different speeds and directions.

The circulation is obviously complex and the most sophisticated 3-dimensional baroclinic computer models will be required for this to be simulated. The measurements are informative and highly suitable for the next stage of the study.

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1. Introduction

1.1 Background – The Project

New Zealand has been experiencing a rapid growth in the aquaculture industry in recent years. This growth, coupled with outdated legislation has prompted the government to reform the aquaculture legislation. The changes started with the enactment of the Resource Management (Aquaculture) Amendment Act 2002. The amendment has signalled a number of changes to the legislative framework that will have significant and far reaching effects on Regional Councils. The cabinet papers directing the substantive legislative changes signal the intention that Regional Councils will need to prescriptively zone for aquaculture. In carrying out this zoning Councils will not be able to zone for aquaculture unless they are able to ensure the sustainability of the resource. This creates a need for a scientifically defendable understanding of the physical interactions in the offshore environment.

There is some urgency in gaining this understanding as the faster that the Regional Coastal Plan can be changed to allow for aquaculture, the less uncertainty there will be for the aquaculture industry. The Bay of Plenty will have the largest single farm in the country, based on new technology, in the offshore environment, which has not been used previously for marine farming in this country. A number of similar applications are currently in process in Gisborne, Napier, Canterbury and Bay of Plenty. Implementing monitoring at the earliest stage possible will provide valuable information for all of these ventures.

Alongside the changes in legislation has been a change in types of marine farming proposed. The average marine farm size in 2001 was 4 ha (pers comm. MfE staff). In the last 2 years there have been a number of applications nationwide for single farms of up to 10 000 ha.

Previous experience of marine farming derives from estuaries and bays (e.g. Marlborough Sounds) and large embayments (e.g. Firth of Thames). Applications now being received are for open coast sites (e.g. Bay of Plenty). Each of these environments has different characteristics. In the Bay of Plenty, an offshore green mussel farm is proposed off Opotiki of 4760 Ha in 30-50 m depths, with the closest land approximately 6 km from the shore (Figure 1.1). Another application in the Bay of Plenty (not subject to the moratorium act) brings the total space subject to development to around 9000 Ha (Figure 1.1).

Further applications are expected in the future and Environment Bay of Plenty (EBoP) needs to

1. Ensure the current proposals are monitored and are sustainable; and
2. Make decisions about other sites suitable for aquaculture, which sustain the environment and lead to an effective aquaculture industry. These Aquaculture Management Areas (AMAs) are to be included in the coastal plan.

Although some high quality measurements are available, no detailed research has been done in the Bay of Plenty which adequately considers the coupled dynamics and interactions of physical processes, nutrients and phytoplankton that would provide sufficient insights into the possible impacts of AMAs on the wider ecological environment.

As noted by Park (1998), “One area of weakness that still exists in understanding the oceanographic dynamics of the continental shelf of the Bay of Plenty is the influence in terms of frequency and intensity of currents”.

In addition, mussels are known to extract both phytoplankton and zooplankton from the water column. Moreover, most nutrients arriving at the coast are expected to come from deeper water in the bottom mixed layer (Park, 1998). To reach the coast, this nutrient-rich seawater must pass through the AMAs and so impacts on the inshore wider environment are possible. Other impacts include changes to species composition at the site, changes to the phytoplankton mix as mussel feeding can lead to selective re-growth of the faster growing species, and loss of zooplankton with impacts on fisheries, kaimoana and natural ecology. There are several other issues to address, which are discussed below.

The goals of this project are to provide focussed information over-viewing the Bay of Plenty for planning of AMAs. The aims are achieved by establishing data collection programmes coupled with sophisticated numerical models. The information also can be readily absorbed into monitoring programs, e.g. for particular farms in the future and comparisons with control sites to determine impacts.

The investigations will lead to applications to the New Zealand government's Public Good Science Fund to undertake detailed research.

There will be significant potential benefits to the aquaculture industry. By overcoming the uncertainties about potential impacts and providing the essential information needed for the Regional Council to effectively treat the planning issues, the industry has a clear path forward in the light of the knowledge gains. The development of the industry is presently hindered by lack of information about Bay waters, particularly as individual farm applicants are not required or able to treat the full Bay system, although they will be required to monitor and describe the effects of their proposed farms on the environment.

Local iwi will also gain access to information about potential impacts on kaimoana and possibilities of establishing their own farms and training, through direct involvement in the project.

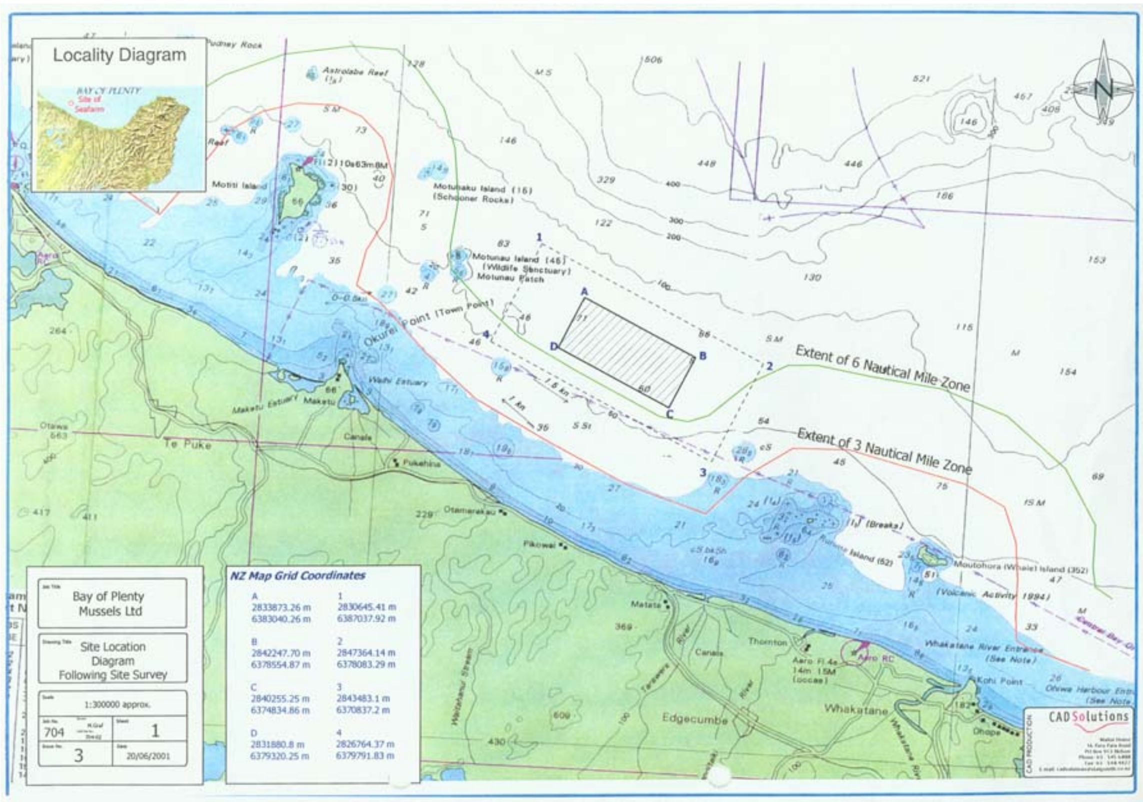

Figure 1.1 Planned offshore aquaculture sites in the Bay of Plenty

1.2 Background – Report Structure

This report summarises the temperature and current data collected by ASR Ltd as part of the Aquaculture Management Area (AMA) project. The report includes short period transect deployment data and long term data collection at both the Pukehina and Opotiki site. The long term deployment data has been processed to extract tidal and residual current data, as well as tidal constituents for both the Pukehina and Opotiki sites. Wind data from the Whakatane wind station is included, however correlating the wind and current data are not carried out and is beyond the scope of this report.

The list of reports that are relevant to the study are listed below:

- Longdill, P.C., Black, K.P., Park, S. and Healy, T.R., 2005. *Bay of Plenty Shelf Physical and Chemical Properties 2003-2004 : Choosing open coast AMAs to sustain the environment, kaimoana and aquaculture industry.* Report for Environment Bay of Plenty, ASR Ltd, P.O. Box 67, Raglan, NZ, and the University of Waikato. 35p

- Longdill, P. C., and Black, K. P., and Healy, T.R. 2005. *Locating aquaculture management areas – an integrated approach.* Report for Environment Bay of Plenty, ASR Ltd, P.O. Box 67, Raglan, NZ, and the University of Waikato. 53p.

- Longdill, P.C., Black, K.P. 2006. *Numerical Hydrodynamic Modelling: Aquaculture Management Areas.* Report for Environment Bay of Plenty, ASR Ltd, PO Box 67, Raglan, New Zealand. 67p.

- Longdill, P.C., Black, K.P., Haggit, T. and Mead, S.T., 2006. *Primary Production Modelling, and Assessment of Large Scale Impacts of Aquaculture Management Areas on the Productivity within the Bay of Plenty.* Report for Environment Bay of Plenty, ASR Ltd, PO Box 67, Raglan, New Zealand. 51p

- Black, K.P., Haggit, T., Mead, S.T., Longdill, P., Prasetya, G. and Bosserelle, C., 2006. *Bay of Plenty Primary Production Modelling: Influence of climatic variation and change*. Report for Environment Bay of Plenty, ASR Ltd, PO Box 67, Raglan, New Zealand. 43p.

- Mead, S.T., Longdill, P.C., Moores, A., Beamsley, B., and Black, K.P., 2005. *Underwater Video, Grab Samples and Dredge Tows of the Bay of Plenty Sub-Tidal Area (10- 100 m depth).* Report for Environment Bay of Plenty, ASR Ltd, PO Box 67, Raglan, New Zealand. 34p

- Park, S.G. and Longdill, P.C. 2006. Synopsis of SST and Chl-a in Bay of Plenty waters by remote sensing. *Environment BOP Environmental Publication 2006/13. Environment Bay of Plenty, PO Box 364, Whakatane*.

The structure of the report is as follows;

Section 1	Introduction and background to the project
Section 2	Instrument deployment specifics; including instrument locations, set-up parameters, deployment durations etc (e.g. time of sampling),
Section 3	Presentation of collected data, and
Section 4	Summary of data and details of what further data processing and interpolation will be conducted as part of future reports

This report is designed to supplement the complete data report to be prepared by Environment Bay of Plenty.

2 Instrument and transect locations

In order to provide information on the circulation characteristics within The Bay of Plenty ASR Ltd, in conjunction with Environment Bay of Plenty, deployed and maintained several instruments arrays offshore from both Pukehina and Opotiki. The data covers the period September, 2003 to January 2005.

Instruments included several StowAway Tidbit Temperature Loggers (Figure 2.1), deployed at specific water depths on temperature-strings, and a SonTek ADP (Acoustic Doppler Profiler) current meter deployed on a bottom mounted frame (Figure 2.2).

2.1 Temperature string deployment specifics

Figure 2.3 illustrates the locations at which the temperature-strings were deployed offshore from both Pukehina and Opotiki, while Figure 2.4 defines the duration over which data was collected at each of the sites. Instruments were deployed along transects orientated shore-normally.

Temperature sensors tended to be concentrated in the upper portion of the water column as this is where the majority of the temperature variation (due to solar radiation) was expected, while sensors at or near the seabed would be expected to pick up intrusions of cooler bottom oceanic waters.

Temperature sensors were programmed to record ambient temperatures at hourly intervals at the start of each hour.

2.1.1 Temperature string mooring systems

Early temperature string mooring systems consisted of an anchoring weight (~40 kg), consisting of large chain links, with a line to a surface float. A lead weight was attached to the surface line immediately below the lowest temperature sensor not on the seafloor. The lead weight acted to keep the line between the surface float and the weight taut and the temperature sensors at a consistent water depth relative to the surface. Figure 2.5A illustrates a schematic of the mooring system used in the earlier deployments.

Loss of two temperature strings offshore from Opotiki resulted in new temperature string mooring systems with retrieval back-up systems being designed. While the reason for the loss of the temperature strings is not known, other instruments along the same transect have shown evidence of the lines linking the surface floats to the anchoring weights being cut, either deliberately or as a result of being fouled in an engine prop. The new mooring system design is shown in Figure 2.5B and consists of two back-up retrieval systems. The two back-up systems are;

1. The ground line linking the anchoring weight to the crown-anchor can be grappled for, and
2. Inclusion of a sub-surface float; if the surface floats are missing the sub-surface floats should be able to be located.

2.1.2 Pukehina transect

Figure 2.4 illustrates the deployment duration for each of the temperature strings deployed along the Pukehina transect. Three separate temperature strings were deployed offshore from Pukehina, one each on the 15, 30 and 65 m isobath. Co-ordinates of the temperature strings are given in Table 2.1, as are the depths at which temperature sensors were placed (relative to the surface).

The temperature string at the 65 m isobath offshore from Pukehina (the ADP site) was on-site from 1 pm on the 22nd of September, 2003 to the 19th March, 2004, while the temperature strings at both the 15 and 30 m isobath covered the period from 10:00 am on the 4th of December, 2003 to the 9:00 am on the 19th March, 2004. Figure 2.4 illustrates the deployment duration for each of the temperature strings deployed along the Pukehina transect

2.1.3 Opotiki transect

Figure 2.4 illustrates the deployment duration for each of the temperature strings deployed along the Opotiki transect. Four temperature strings were placed offshore from Opotiki, approximately offshore from the Waioeka River; one each at the 15, 30, 40 and 65 m isobath (Figure 2.3). Table 2.2 gives the co-ordinates (in both NZMG and Lat-Long WGS84) of each of the temperature strings as well as the depths (relative to the surface) that each of the temperature sensors was deployed at.

Unfortunately, the first deployment of temperature strings at the 30 and 40 m isobath were lost (leading to the re-designing of the mooring systems). However, data from the temperature string at the 15 and 65 m isobath sites over the first deployment period are available. New temperature strings were deployed at the 30 and 40 m isobath on 22nd October.

The temperature string at the 65 m isobath (ADP site) was deployed from 4 pm on the 19th of March, 2003 to 7 am on the 22nd of October, 2004, at which point it was downloaded and redeployed. Some data was lost due to the temperature string being removed and the mooring system being replaced (to include the back-up retrieval systems as defined in Section 2.1.1).

The temperature strings at the 15 and 65 m isobath sites, along with new temperature strings at the 30 and 40 m isobath were deployed from the 22nd of October, 2004 to 3rd of January, 2005. Temperature data at the 65 m ADP site was lost due to the loss of the surface buoys, subsurface floats and all 3 temperatures sensors from the temperature sting. As the 20 m sub-surface temperature sensor was missing from the remaining mooring line attached to the ADP frame, it is probable that the line was cut; either intentionally or by a vessel propeller.

Figure 2.1 A StowAway Tidbit Temperature Logger as used to record sea temperature.

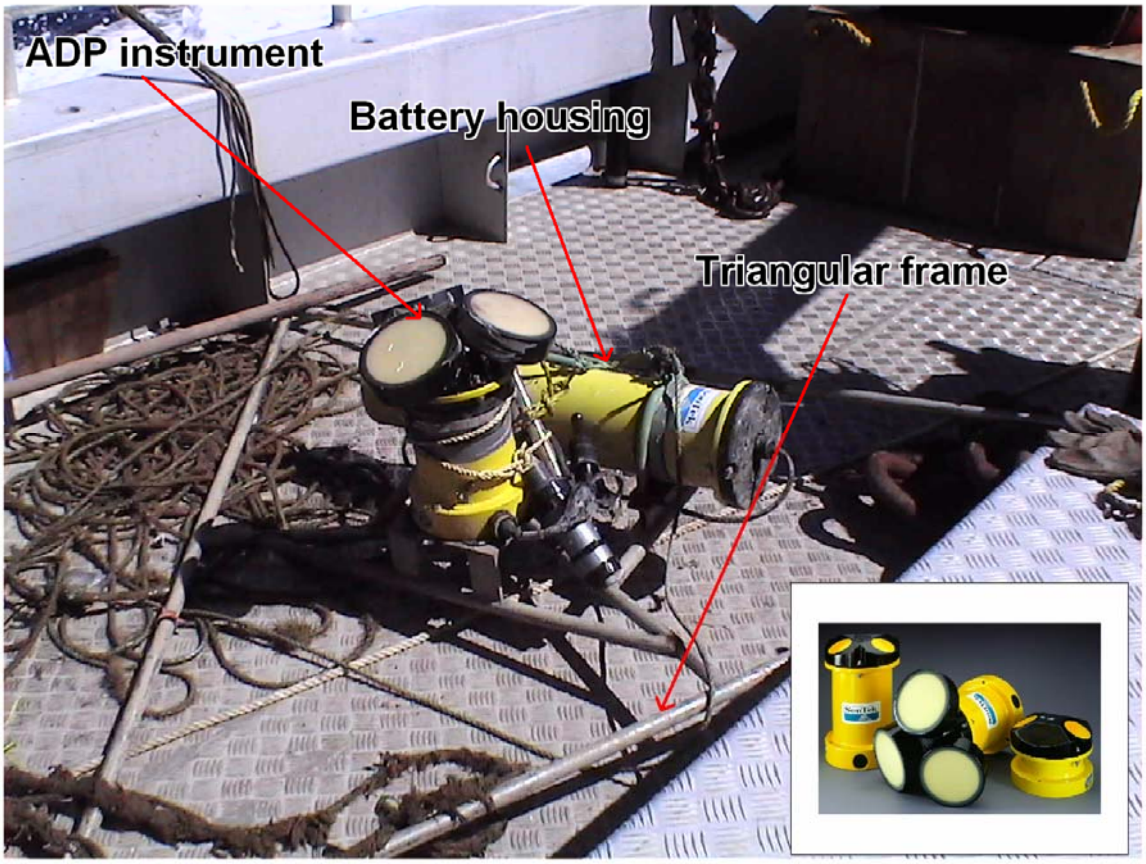

Figure 2.2 The SonTek ADP (Acoustic Doppler Profiles) and bottom mounted mooring frame.

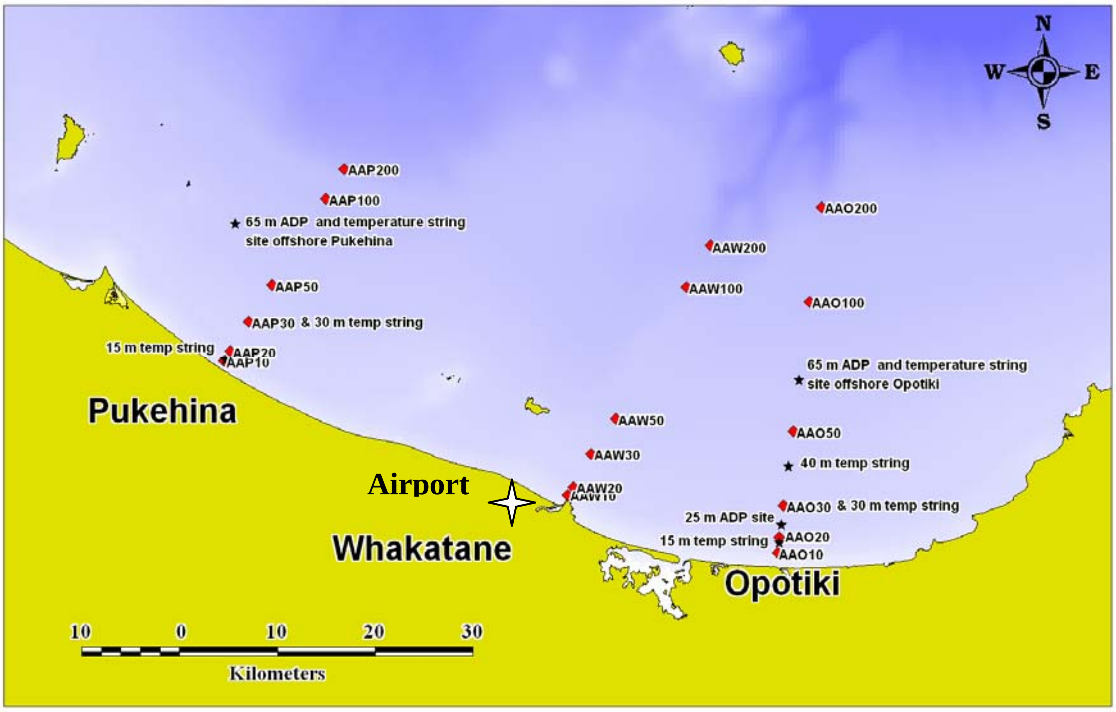

Figure 2.3 Temperature string, ADP deployment and transect sites within the Bay of Plenty. Also shown is the location of the Whakatane Airport.

Figure 2.4 Project time-line illustrating the data coverage duration for each of the instruments deployed during the study

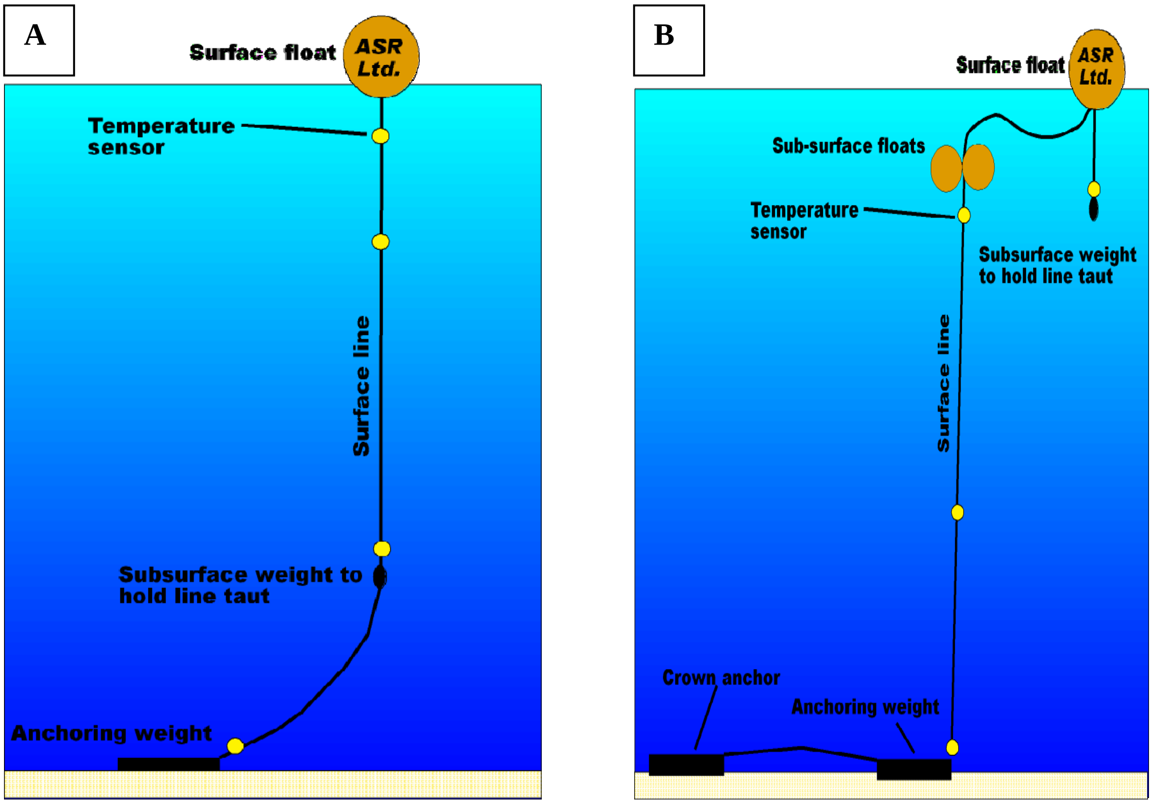

Figure 2.5 Temperature string mooring systems used during the field deployment program. The initial mooring system (A) was supplemented with the new mooring system (B) which included alternative retrieval features (i.e. ground line linking the crown anchor and the anchoring weight that can be grappled for, and the sub-surface floats).

2.2 Acoustic Doppler Profiler (ADP) Deployment Specifics

Figure 2.3 illustrates the both the long term deployment locations offshore from Pukehina and Opotiki (at the 65 m isobath) and the short (>30 min) deployments along the Pukehina, Whakatane and Opotiki transects (at the 20, 50 and 100 m isobaths).

The programming of the ADP varied depending on the type of deployment (i.e. long or short term deployments). The instrument settings were,

1. **Long term.**

   10 min averaging interval every hour

   2 m bins

   1.0 m blanking distance from the bottom

2. **Short term > 30 min(transects)**

   5 min averaging interval every 5 minutes (resulting in 6 or more profiles per deployment)

   2 m bins

   1.0 m blanking distance from the bottom

For the short term deployment the ADP was set up to record data in 2.0 m bins ranging from centres 2.0 m above the bed (after blanking distance of 1.0 m) to 60 m above the bed. On some of the deeper deployments the number of bins was increased to 40 so the ADP could measure velocities to 80 m above the bed, however these ranges (>70 m) are working at the limits of the 500 kHz ADP used. During the long-term deployments the ADP was set to record 30 bins at 2 m spacing (i.e. 60 m)

The ADP measured current velocities relative to an ENU (east-north-up, magnetic) co-ordinate system, allowing the cross- and along-shore current velocities to be determined.

2.2.1 ADP mooring system

The mooring system used to deploy the ADP current meter(s) varied depending on the type of deployment. Long term deployments offshore from both Pukehina and Opotiki consisted of a large steel (radar reflecting) marker buoy with a flashing light as a warning to vessels (Figure 2.6) anchored by approximately 200 kg of chain. A 70 m ground line linked the 200 kg of chain to ADP frame, while a light surface line linked the ADP frame to two small surface floats on which temperature sensors were located. The light surface line was used to retrieve the ADP for servicing and when the ADP was to be used to measure current velocities at the transect sites. The long term mooring system is shown in Figure 5.7A.

For the transect surveys, because a vessel was on site during the entire deployment the mooring system was simplified and consisted of a single light line linking the bottom mounted ADP frame to a surface float, as illustrated in Figure 5.7B.

Figure 2.6 Large steel radar-reflecting buoy used to mark the long term ADP deployment sites offshore from Pukehina and Opotiki

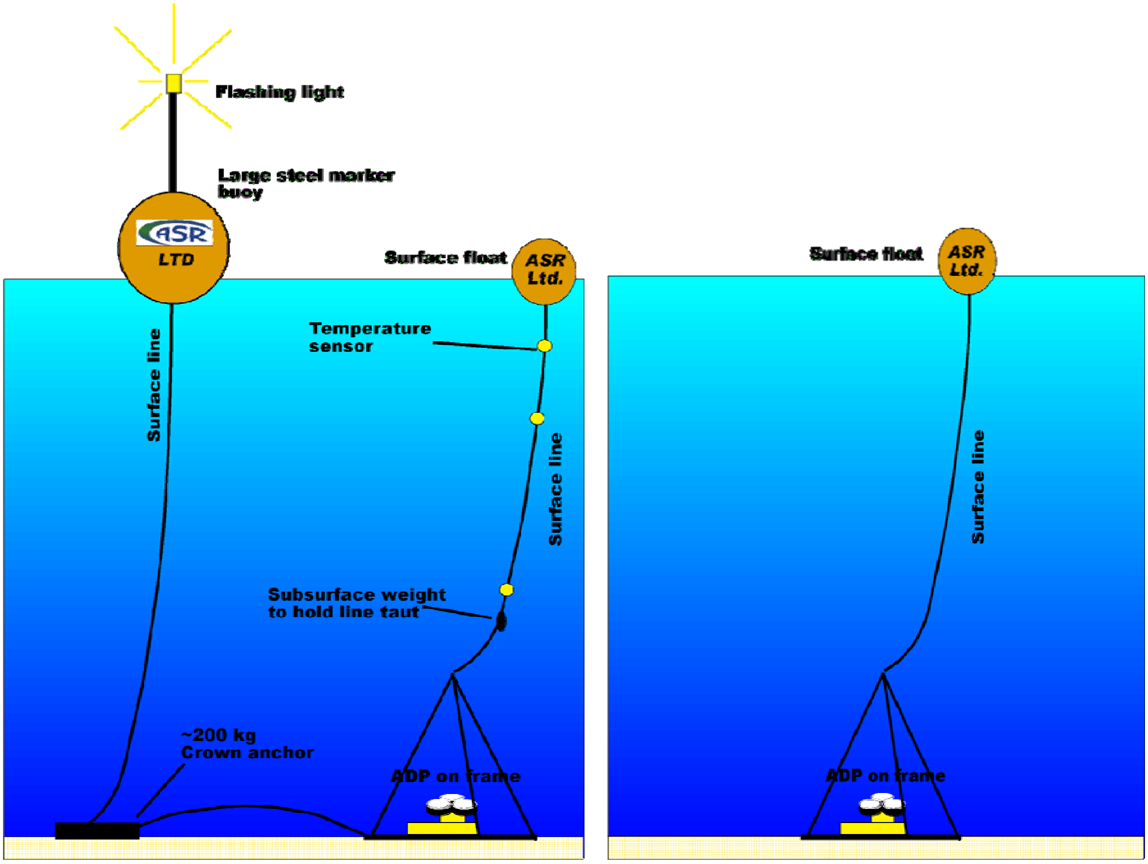

Figure 2.7 Schematic of the ADP mooring systems used for both the long (A) and short term (B) deployments.

2.2.2 Long term deployments

2.2.2.1 Pukehina site

The long term ADP deployment site offshore from Pukehina is shown in Figure 2.3. The actual location is offset to the east from the Pukehina transect monitored as part of the fieldwork programme. The location was adjacent to the Environment Bay of Plenty (EBOP) WaveRider buoy, and located on a section of known foul-ground that is avoided by commercial trawlers. The Pukehina site was in ~ 65 m water depth (Chart Datum).

The ADP was deployed at the site on the 22nd September 2003 and retrieved on the 19th March 2004. Some data was lost due to interference with the mooring system and deployment error.

2.2.2.2 Opotiki site

Figure 2.3 shows the location of the long-term ADP deployment site offshore from Opotiki. To insure that the data from the Opotiki site was directly comparable to the data collected at the Pukehina site the instrument was deployed at the 65 m isobath offshore from Opotiki, on the Opotiki transect.

The instrument was deployed on the 19^{h} March 2004 and retrieved on the 3rd January 2005.

In addition to the ADP at the 65 m site, a second ADP (100 kHz, range ~30 m) was deployed for a short duration along the Opotiki transect at the 25 m isobath. The 25 m ADP was deployed on the 19^{h} March 2004 and retrieved on the 8th April 2004. Some data was lost due to interference with the mooring system and deployment error.

2.2.3 Transect deployment

ADP instrument settings for the short-term transect deployments are given in Section 2.2. Figure 2.3 illustrates the locations at which the short-term profile measurements were made on the Pukehina, Whakatane and Opotiki transects, while the co-ordinates of each of the sites are given in Table 2.3.

Tables 2.4 to 2.6 give the dates and locations that data is available for the Pukehina, Whakatane and Opotiki transect respectively. Some data was lost due to errors in deploying the ADP frame. At each site greater than 6 consecutive 5-minute averaged current velocity profiles were measured, requiring the ADP to be deployed for at least 30 minutes at each site.

For comparison, the transect data has been grouped based on the date that each of the transects was collected, resulting in a total of 6 distinct transect datasets,

Period 1 16th to 17th September, 2003,

Period 2 4th to 5th December, 2003,

Period 3 1st April, 2004,

Period 4 8th April, 2004,

Period 5 1st to 2nd August, 2004, and

Period 6 22nd September, 2003.

Table 2.1 Temperature String locations offshore from Pukehina. Also given are the depths below the surface at which sensors were placed.

	Easting m (NZMG)	Northing m (NZMG)	Longitude WGS84	Latitude WGS84	Sensor depth from surface (m)
Temp string @ ADP site @ 65 m isobath	2829040	6383170	176.6162	-37.6962	2, 8, 20
Temp string @ 15 m isobath	2828003	6369198	176.6136	-37.8181	1, 5, 15
Temp string @ 30 m isobath	2830408	6343078	176.3811	-37.4711	1, 5, 10, 30

Table 2.2 Temperature String locations offshore from Opotiki. Also given are the depths below the surface at which sensors were placed. Unfortunately the first deployment of temperature strings at the 30 and 40 m isobath were lost so no data is available. New strings were re-deployed on the same sites on the 22nd of October using mooring systems designed with back-up retrieval systems, the data from which will be available early December at the completion of the field data collection program

	Easting (NZMG)	m Northing (NZMG)	m Longitude WGS84	Latitude WGS84	Sensor depth from surface (m)
Temp string @ ADP site @ 65 m isobath	2,886,665	6,367,135	177.27753	-37.817718	2, 8, 20
Temp string @ 15 m isobath	2,884,588	6,350,510	177.2629	-37.968225	1, 5, 15
Temp string @ 30 m isobath	2,885,047	6,354,233	177.26611	-37.934523	1, 5, 10, 30
Temp string @ 40 m isobath	2,885,566	6,358,296	177.26982	-37.897736	1, 5, 10, 40

Table 2.3 ADP short-term transect deployment co-ordinates offshore from Pukehina, Whakatane and Opotiki. Locations are also shown in Figure 2.3.

Transect	Site name	Water depth	Easting (NZMG)	Northing (NZMG)	Latitude WGS84	Longitude WGS84
Pukehina	AAP20	20 m	2828533	6370066	-37.485156	176.365923
Pukehina	AAP50	50 m	2832774	6376884	-37.450500	176.394112
Pukehina	AAP100	100 m	2838278	6385687	-37.401235	176.431088
Whakatane	AAW20	20 m	2863604	6356112	-37.553541	177.011728
Whakatane	AAW50	50 m	2867899	6363124	-37.514193	177.040000
Whakatane	AAW100	100 m	2875140	6376649	-37.441298	177.083048
Opotiki	AAO20	20 m	2884636	6350990	-37.574997	177.154748
Opotiki	AAO50	50 m	2886021	6361859	-37.515570	177.162304
Opotiki	AAO100	100 m	2887710	6375147	-37.444258	177.170621

Table 2.4 Dates and transect sites offshore from Pukehina for which ADP data is available. Site locations are shown in Figure 2.3, and listed in Table 2.3

Date	20 m isobath site	50 m isobath site	100 m isobath site
16/10/03	No	Yes	Yes
05/12/03	Yes	Yes	Yes
01/04/04	Yes	Yes	Yes
08/04/04	No	Yes	No
02/08/04	Yes	Yes	Yes

Table 2.5 Dates and transect sites offshore from Whakatane for which ADP data is available. Site locations are shown in Figure 2.3, and listed in Table 2.3

Date	20 m isobath site	50 m isobath site	100 m isobath site
17/10/03	Yes	Yes	Yes
04/12/03	Yes	Yes	Yes
08/04/04	Yes	Yes	Yes
01/8/04	Yes	Yes	Yes
22/10/04	Yes	Yes	Yes

Table 2.6 Dates and transect sites offshore from Opotiki for which ADP data is available. Site locations are shown in Figure 2.3, and listed in Table 2.3

Date	20 m isobath site	50 m isobath site	100 m isobath site
17/10/03	No	No	Yes
03/12/03	Yes	Yes	Yes
08/04/04	No	Yes	Yes
01/8/04	Yes	Yes	Yes
22/10/04	Yes	Yes	Yes

3 Data summary

This section summarises the temperature and current data collected as part of the AMA programme for the Bay of Plenty. Only limited processing of the data has been undertaken for this report, and more extensive processing will be conducted as part of future reports.

All the data has been rotated so that the velocities (both current and wind data) are given relative to the orientation of the local bathymetry contour, i.e. approximately shore parallel and shore normal and in addition, for the long period deployment, relative to True North/East. Positive directions are heading offshore or towards True North (i.e. -ve directions = onshore or True South) and towards the True East/right

3.1 Temperature string data

3.1.1 Pukehina transect

The deployment locations for the temperature strings at the sites offshore from Pukehina are shown in Figure 2.3. Temperature time-series for the 65, 30 and 15 m sites offshore from Pukehina (at each of the depths where temperature sensors were located, Table 2.2) are shown in Figures 3.1 to 3.3 respectively.

The temperature stratification at all sites along the Pukehina transect show the surface waters to be warmest. Additionally the surface water shows a distinct diurnal pattern, with warmest waters occurring during the day (due to solar heating of the surface layer), while the deeper water is comparatively more stable. A strong decrease in temperatures at all sites is shown to occur over an approximate 10 day period from the 9th to the 19th of February, 2003 (Figures 3.1 to 3.3).

3.1.2 Opotiki transect

Figure 2.3 illustrates the locations at which temperature strings were deployed along the Opotiki transect. Temperature time-series for the 65, 40, 30 and 15 m sites (at the depths where temperature sensors were located, Table 2.2) are shown in Figures 3.4-3.7 respectively.

Three StowAway temperature sensors were deployed on the temperature string at the 65 m isobath; one each at 2 m, 8 m, and 20 m water depths (as measured from the sea surface). The deployment period extended from 4 pm on the 19th of March, 2003 to 22nd of the October, 2004. The temperature stratification offshore from Opotiki at the 65 m site is not as well defined as the data from the 65 m site offshore from Pukehina, with only limited variation between the data presumably due to the time of the year (i.e. over the winter months).

3.2 ADP current meter data

3.2.1 Long term deployments

This report presents the depth-averaged current velocities at both the long term deployment sites (i.e. Pukehina and Opotiki). The data has been processed to separate the tidal component and both the tidal and residual current velocities (using ASRToolBox; data processing software) are presented. The current velocities have been rotated relative to the local bathymetric contour at each of the sites (i.e. orientated offshore and alongshore) as well as relative to True North (i.e. taking into consideration the magnetic deviation).

3.2.1.1 Pukehina deployment

Tidal Current Velocity Component

Data from the long term deployment at the Pukehina site (Figure 2.3) spans two periods;

1. 22/09/03 3pm to 16/10/03 9am

2. 18/10/03 12am to 02/12/03 9am

The two periods provide almost 69 days of current velocity data at the site; recorded hourly throughout the water column. The depth averaged current velocities are used to determine tidal and residual current velocities.

Tidal velocities for the longer of the two deployment periods is given in Figures 3.8A and B ('A' relative to True North and East, while 'B' is relative to the offshore and longshore directions). This data will be used for numerical model validation.

The tidal velocities (both directions) tend to have a maximum of about 0.05 $m.s^{-1}$ (Figure 3.8a and b). The tidal constituents for the site derived from the data are given in the Appendix.

Residual Current Velocity Component

Residual current velocities are determined by removing the tidal signal from the depth averaged velocity. Figures 3.9A and B define the residual current velocities for the True North/East and the onshore/longshore velocity field respectively for the longest period over which data was collected. The X and Y scales of Figures 3.9A and B are identical to the tidal velocity figures so that a direct comparison can be made. The velocities of the residual currents are almost an order of magnitude larger than the tidal velocities and have a maximum of approximately 0.25 $m.s^{-1}$. Notably, the True East/longshore component of the velocity field is significantly larger that the True North/offshore component.

Residual current velocity forcing mechanisms include large scale geostrophic currents, and more localised forcing mechanisms such as wind velocities. True North/East and offshore/longshore components of the wind velocities for the same period as the residual velocities are shown in Figures 3.10A and B respectively. The wind velocities were measured hourly at the Whakatane Airport (Figure 2.3). Comparing the relative components of the wind and residual current (i.e. True North Wind and Residual current) shows that a degree of correlation exists between the residual current velocity and wind velocity.

3.2.1.2 Opotiki deployment

Tidal Current Velocity Component

Data from the long term deployment at the Opotiki site (Figure 2.3) spans 5 periods;

1. 19/03/04 3pm to 26/03/04 9am

2. 03/06/04 4pm to 12/06/04 10am

3. 12/06/04 12am to 04/08/04 9am

4. 03/08/04 11am to 22/10/04 6am

5. 22/10/04 5pm to 03/01/05 10am

Tidal velocities determined from the three longest consecutive deployment periods (a total of approximately 132 days of data) are illustrated in Figure 3.11 A and B (‘A‘ relative to True North and East, while ‘B’ is relative to the offshore and longshore directions).

The tidal velocities at the Opotiki Site (both directions) tend to have a maximum velocity slightly larger than the Pukehina site, at about 0.10 $m.s^{-1}$ (Figure 3.11A and B), regardless of the direction. . The tidal constituents for the site derived from the data are given in the Appendix.

Residual Current Velocity Component

Residual currents for the time period covering the three longest consecutive deployment periods are shown in Figure 3.12 A and B (‘A‘ relative to True North and East, while ‘B’ is relative to the offshore and longshore directions). The residual velocities at the Opotiki site tend to be more symmetrically distributed about unity than the residual velocities measured at the Pukehina site,

True North/East and offshore/longshore components of the wind velocities for the same period as the residual velocities are shown in Figures 3.13A and B respectively. The wind velocities were measured hourly at the Whakatane Airport (Figure 2.3). Comparing the relative components of the wind and residual current (i.e. True North Wind and Residual current) shows that a degree of correlation exists between the residual current velocity and wind velocity.

3.2.2 Transect deployment

The profiles were averaged to determine the typical current profile shape (i.e. direction and variation with elevation within the water column). Taking into consideration the orientation of the local depth contours (Figure 2.8), offshore and alongshore averaged current velocity profile from each deployment were determined for each profile. Tables 2.4 to 2.6 give the dates and locations that data is available for the Pukehina, Whakatane and Opotiki transect respectively.

The data was rotated to give both the longshore and offshore orientated velocity components at each of the sites. Figures 3.14 to 3.19 give the offshore/longshore velocity component (as defined in section 2.2.3) that the transect data covers. The velocity components are shown to vary throughout the profile.

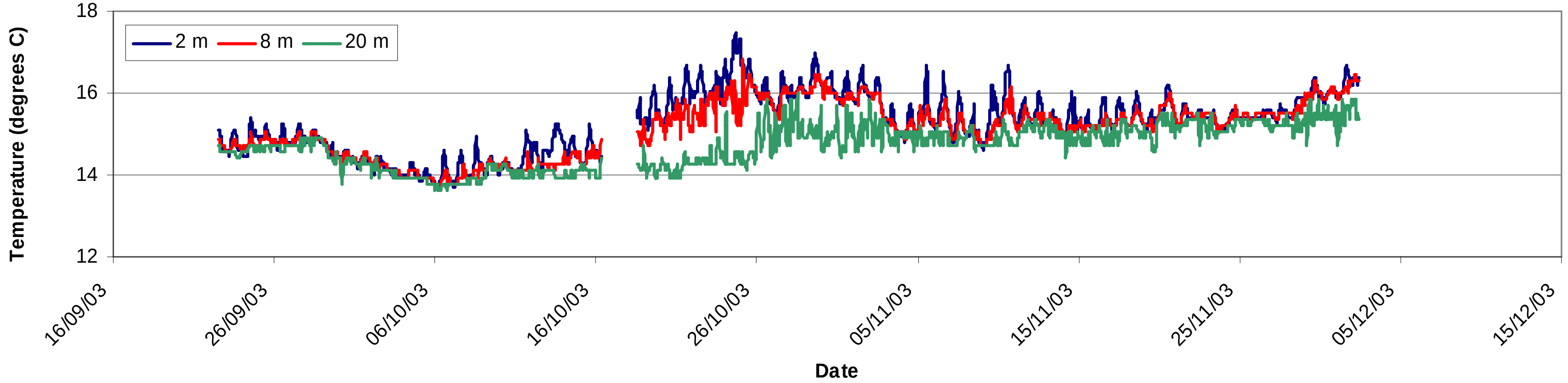

Figure 3.1 Temperature data at the 65 m site offshore from Pukehina. Temperature sensors were deployed at 2 m, 8 m and 20 m below the surface, taking temperature measurements every hour.

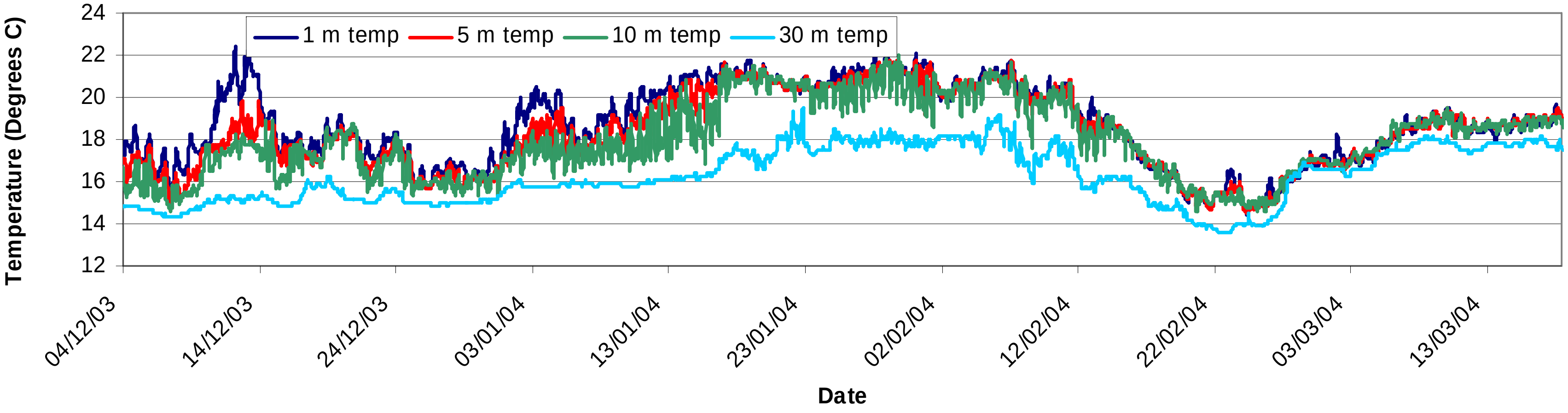

Figure 3.2 Temperature data at the 30 m site offshore from Pukehina. Temperature sensors were deployed at 1 m, 5 m, 10 m and at the seabed (~30 m) below the surface, taking temperature measurements every hour.

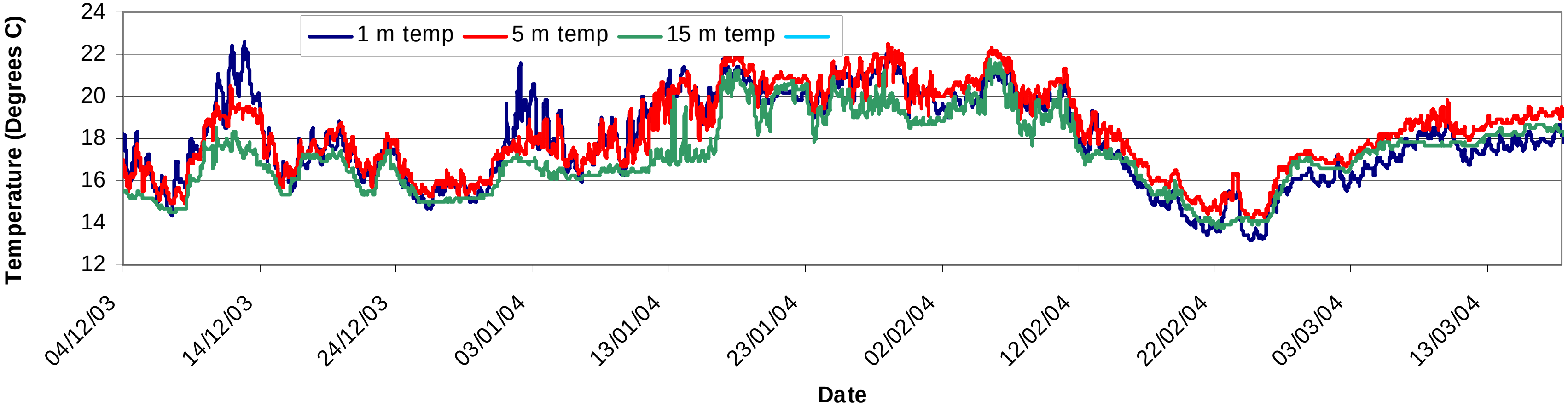

Figure 3.3 Temperature data at the 15 m site offshore from Pukehina. Temperature sensors were deployed at 1 m, 5 m and at the seabed (~15 m) below the surface, taking temperature measurements every hour.

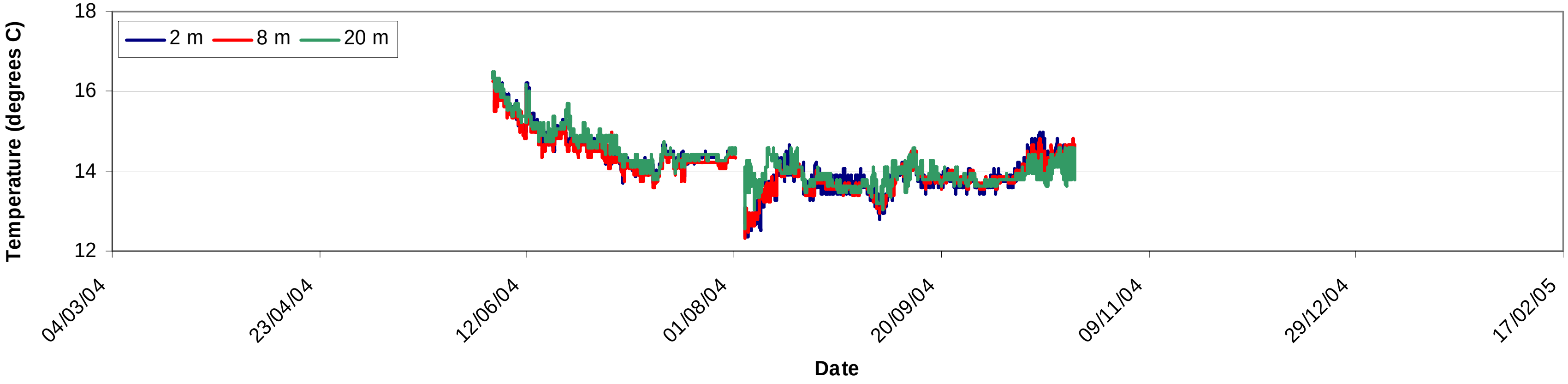

Figure 3.4 Temperature data at the 65 m site offshore from Opotiki. Temperature sensors were deployed at 2 m, 8 m and 20 m below the surface, taking temperature measurements every hour. Some data loss occurred during the deployment due to the loss of the surface buoys.

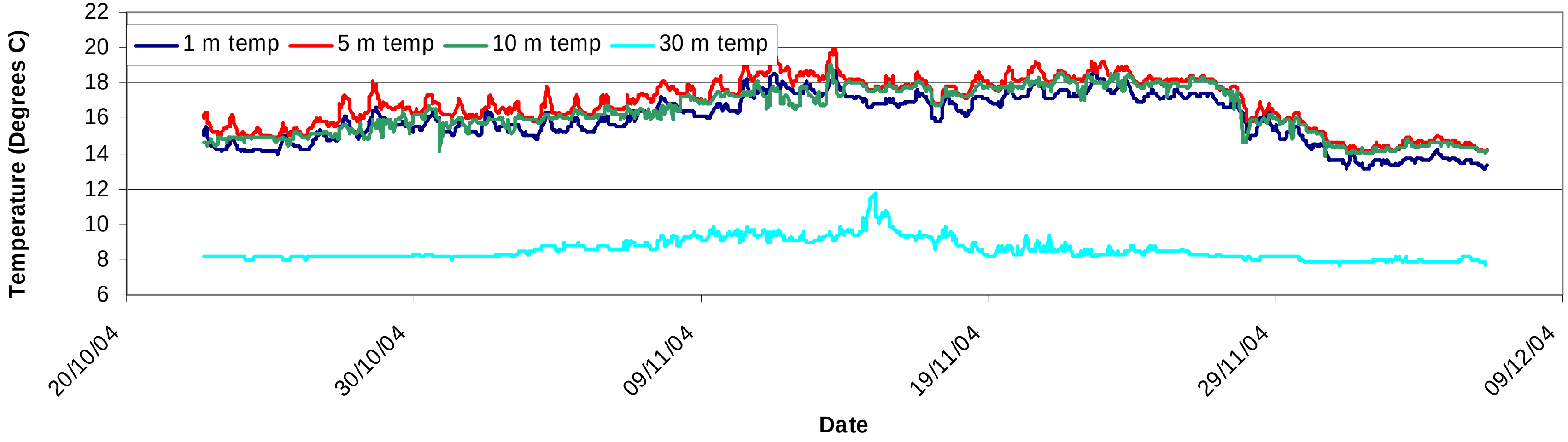

Figure 3.5 Temperature data at the 40 m site offshore from Opotiki. Temperature sensors were deployed at 1 m, 5 m and at 30 m below the surface, taking temperature measurements every hour. Solar heating of the surface water is evident in the upper most temperature data.

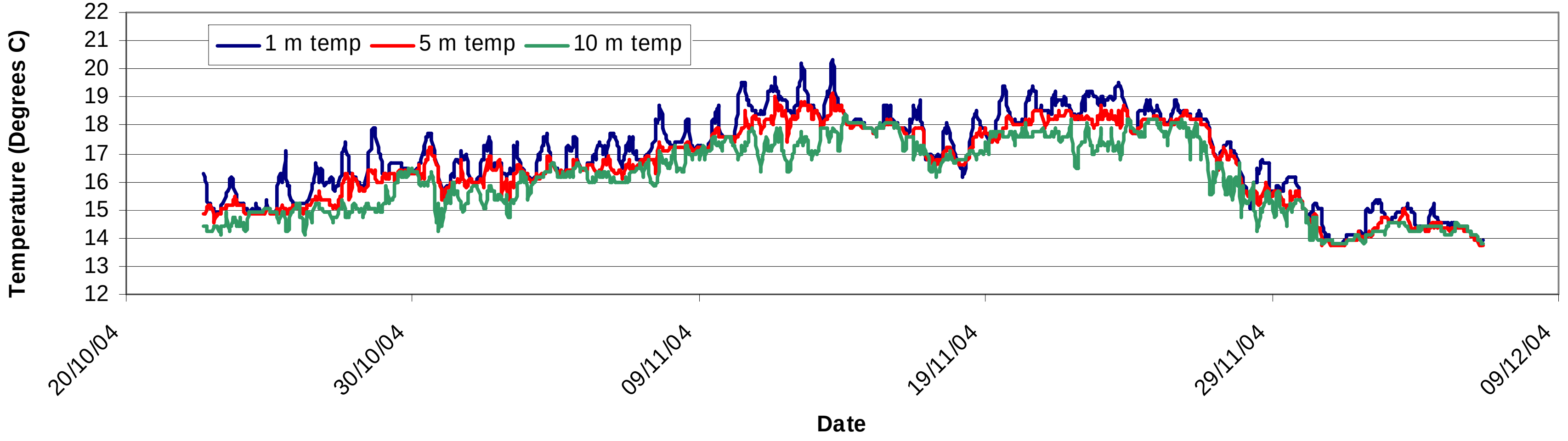

Figure 3.6 Temperature data at the 30 m site offshore from Opotiki. Temperature sensors were deployed at 1 m, 5 m and at 10 m below the surface, taking temperature measurements every hour. Solar heating of the surface water is evident in the 1 m temperature data.

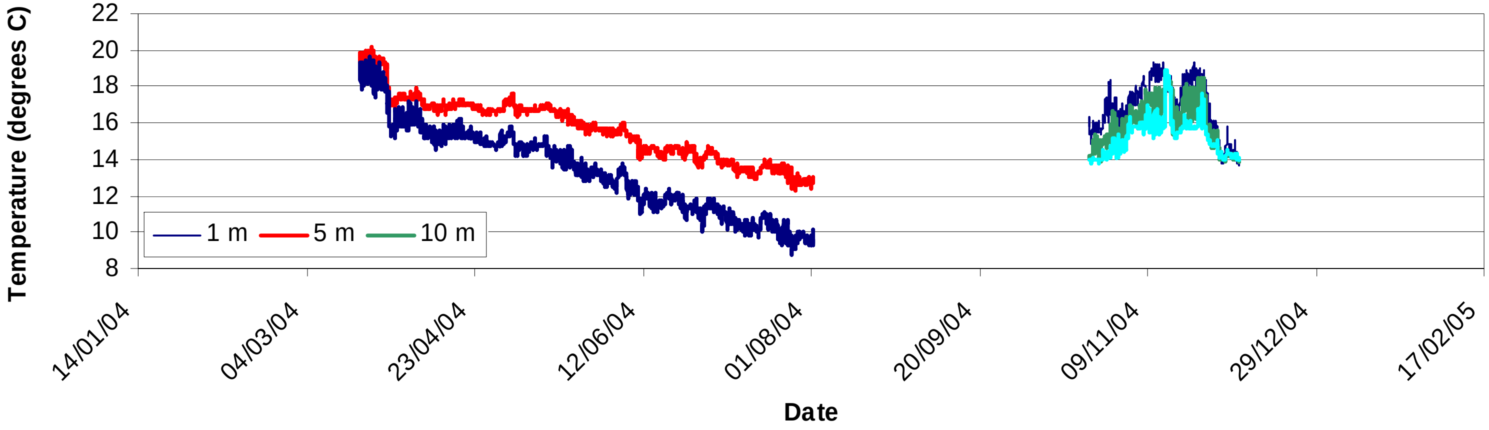

Figure 3.7 Temperature data at the 15 m site offshore from Opotiki. Temperature sensors were deployed at 1 m, 5 m, 10 m and at the seabed (~15 m) below the surface, taking temperature measurements every hour.

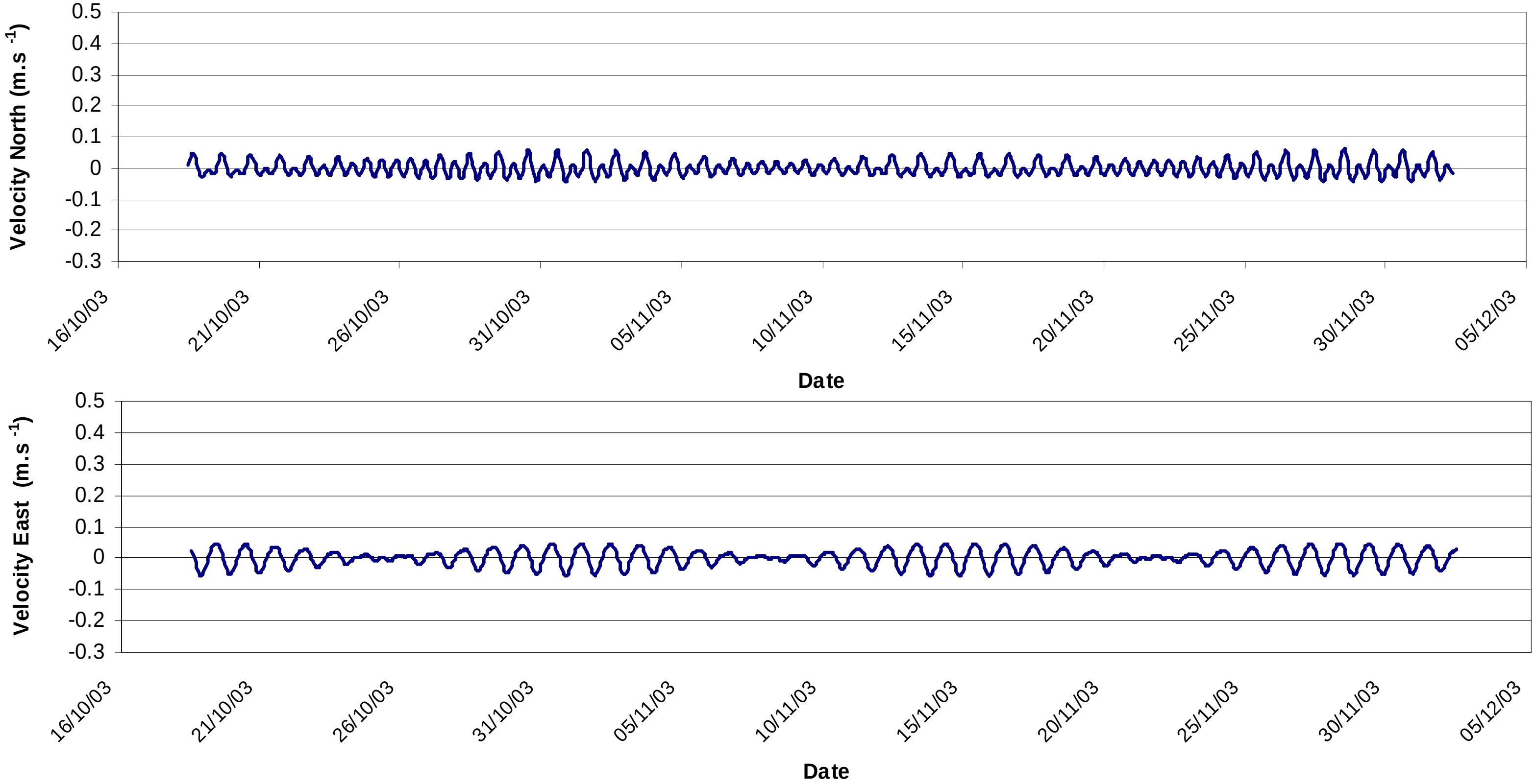

Figure 3.8A Tidal velocities at the Pukehina site, relative to True North and True East (top and bottom figure respectively).

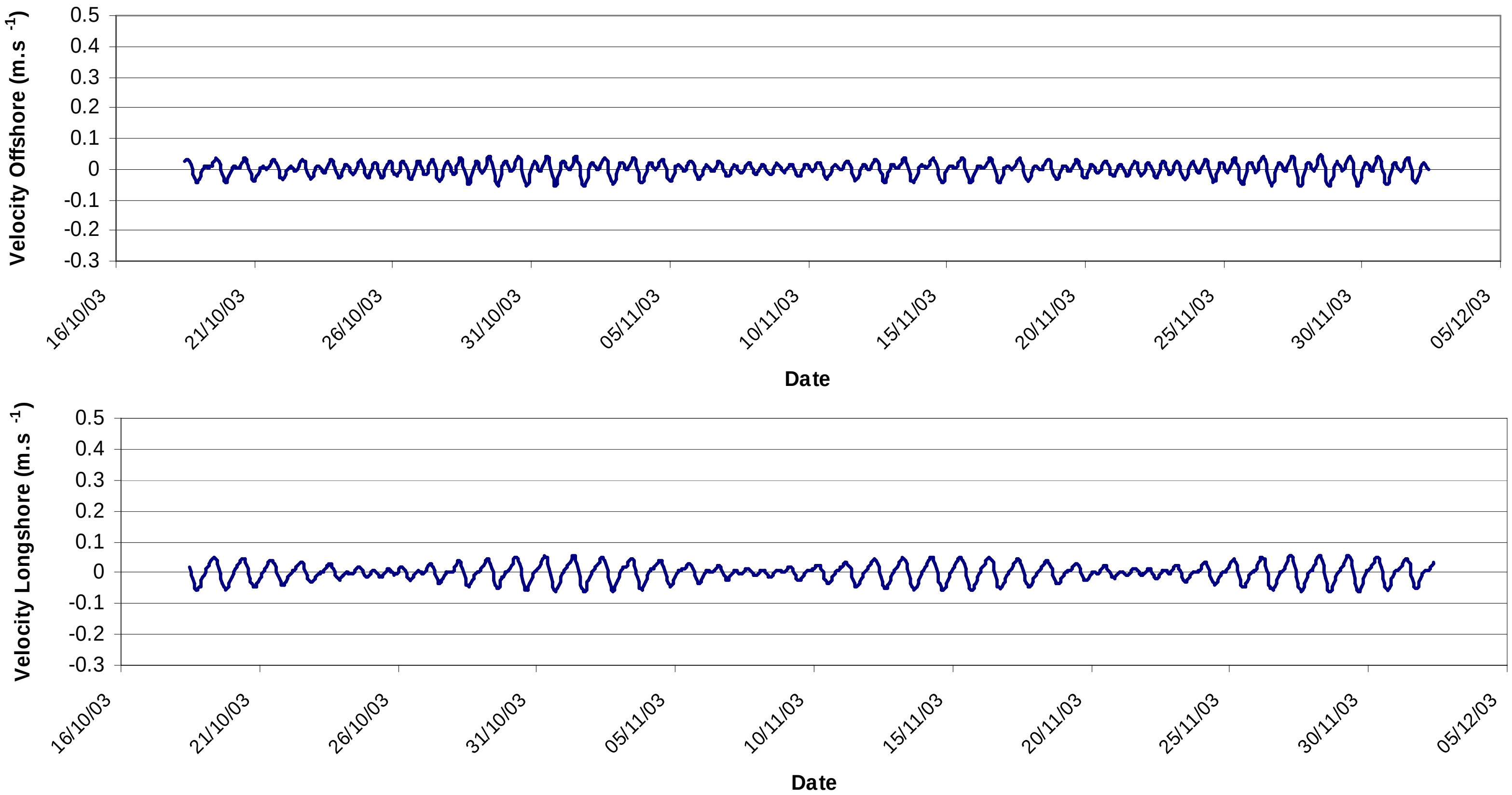

Figure 3.8B Tidal velocities at the Pukehina site, relative to offshore and longshore as defined by the local bathymetric contours (top and bottom figure respectively). +ve directed offshore in the top figure, +ve directed towards the right when looking offshore in the bottom figure.

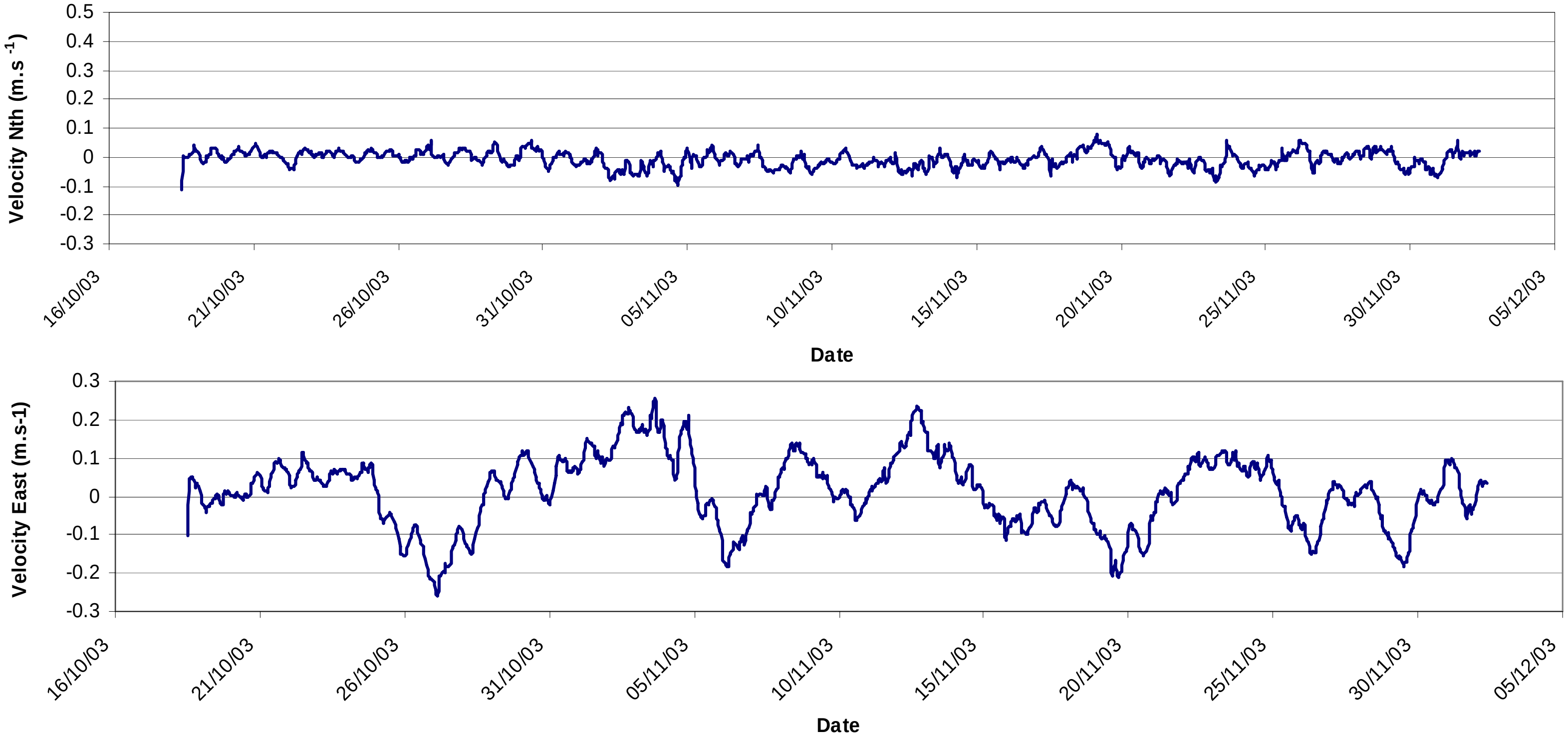

Figure 3.9A Residual current velocities at the Pukehina site, relative to True North and True East (top and bottom figure respectively)

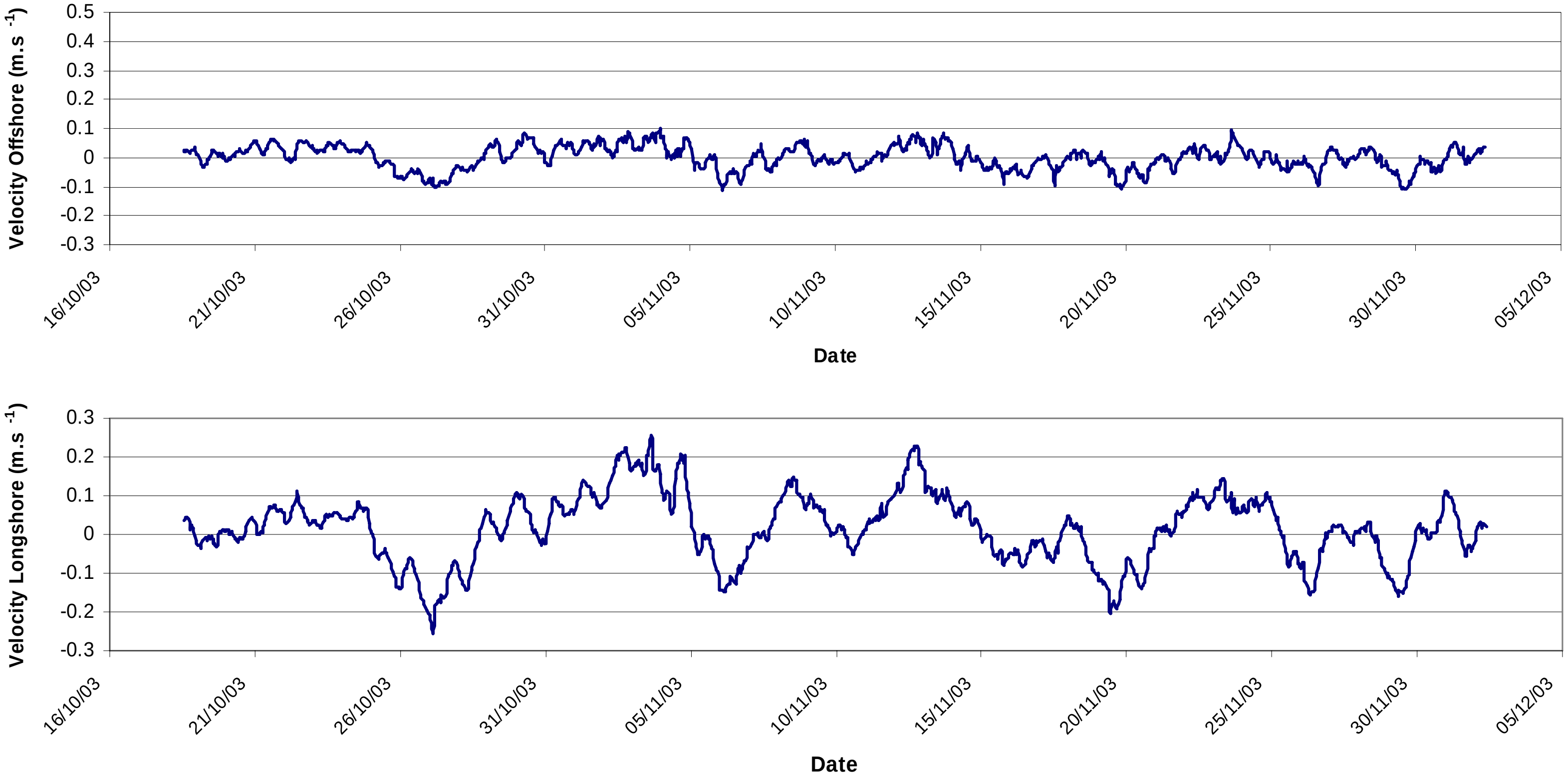

Figure 3.9B Residual current velocities at the Pukehina site, relative to Offshore and Longshore (top and bottom figure respectively). +ve directed offshore in the top figure, +ve directed towards the right when looking offshore in the bottom figure.

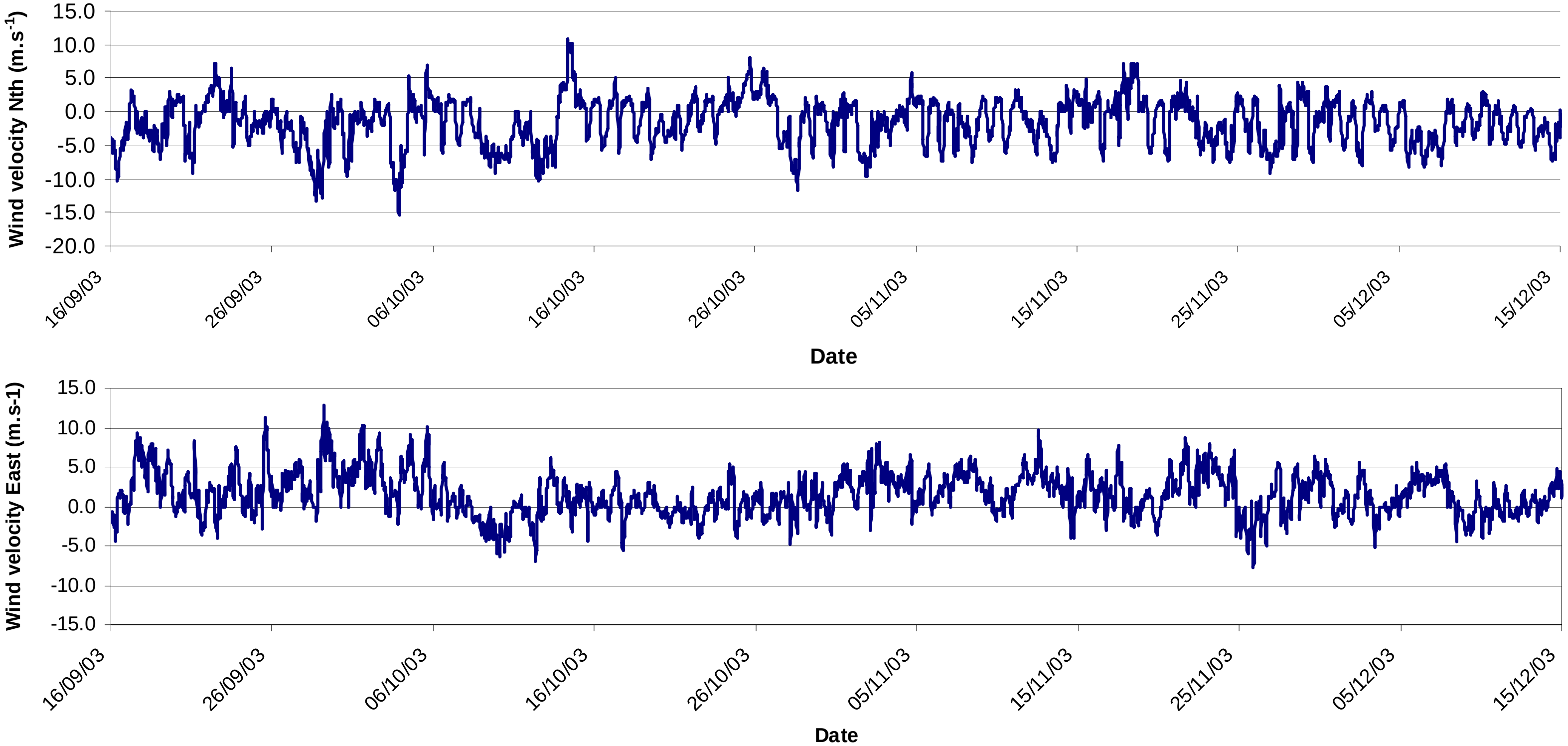

Figure 3.10A Wind velocities as measured at the Whakatane Airport relative to True North and True East (top and bottom figure respectively) recorded concurrently with the deployment of the ADP offshore Pukehina. Some degree of correlation exists between the wind and residual current velocity.

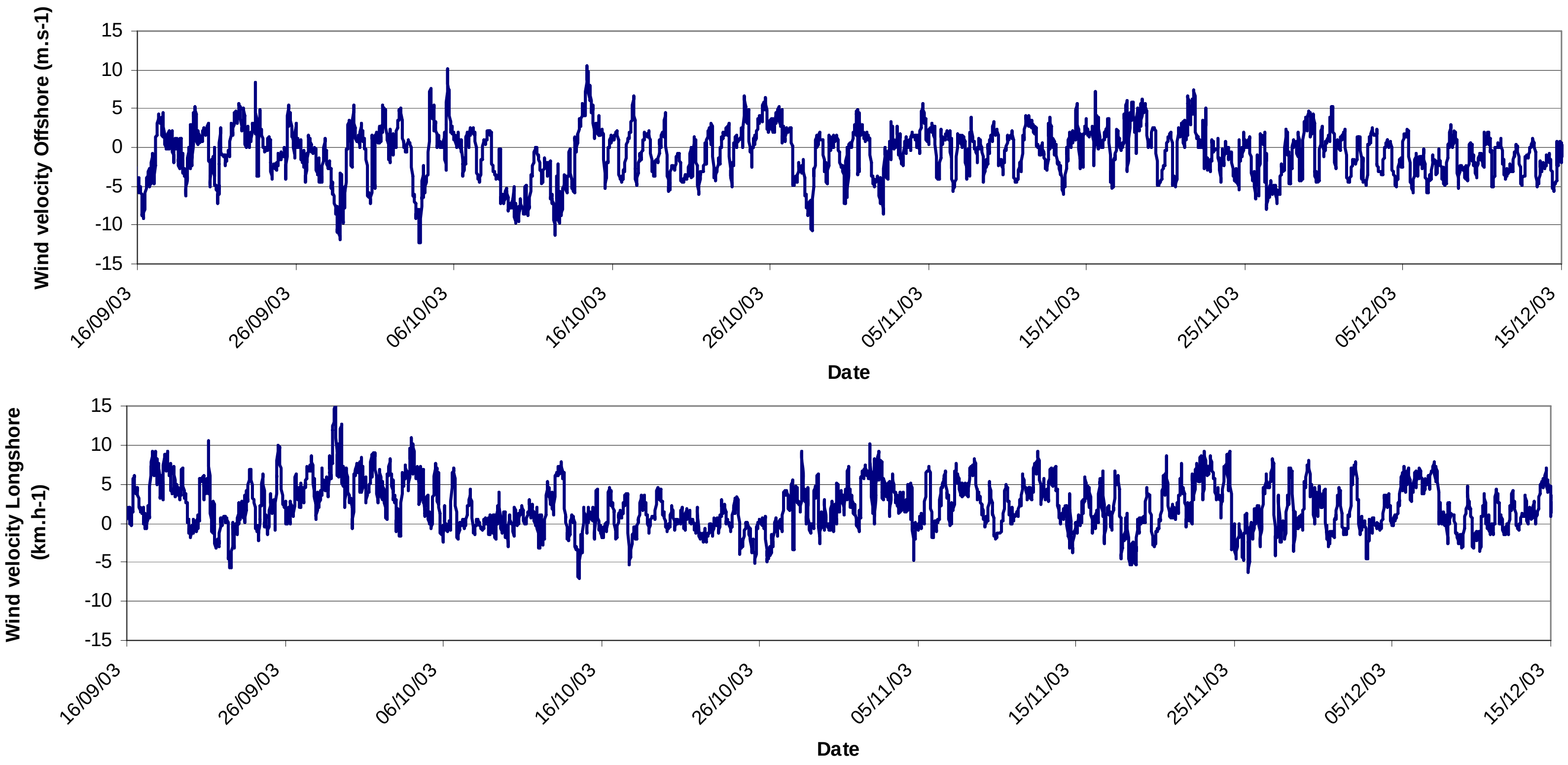

Figure 3.10B Wind velocities as measured at the Whakatane Airport relative to offshore and longshore directions (top and bottom figure respectively) recorded concurrently with the deployment of the ADP offshore Pukehina. Some degree of correlation exists between the wind and residual current velocity.

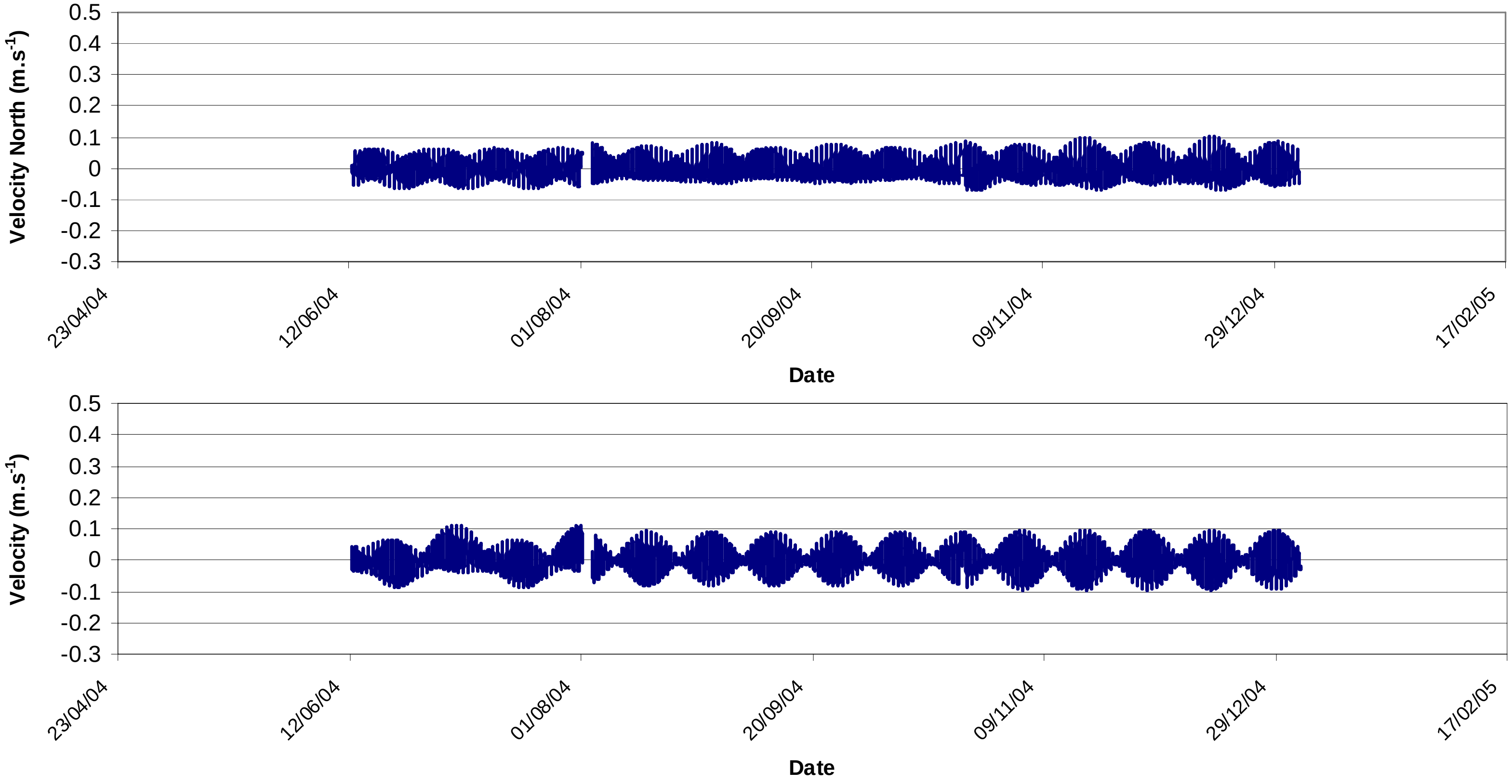

Figure 3.11A Tidal velocities at the Opotiki site, relative to True North and True East (top and bottom figure respectively).

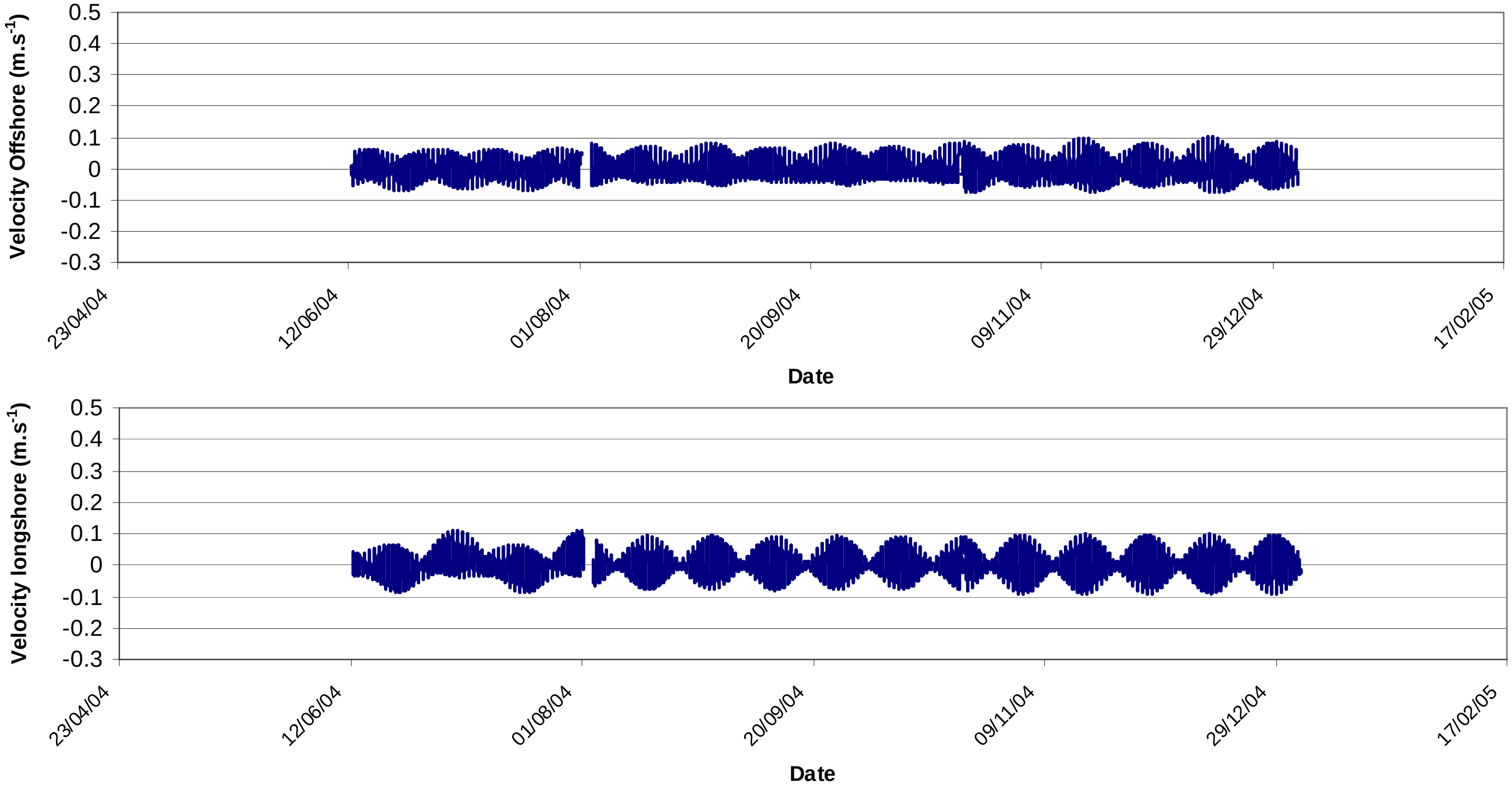

Figure 3.11B Tidal velocities at the Opotiki site, relative to offshore and longshore as defined by the local bathymetric contours (top and bottom figure respectively). +ve directed offshore in the top figure, +ve directed towards the right when looking offshore in the bottom figure.

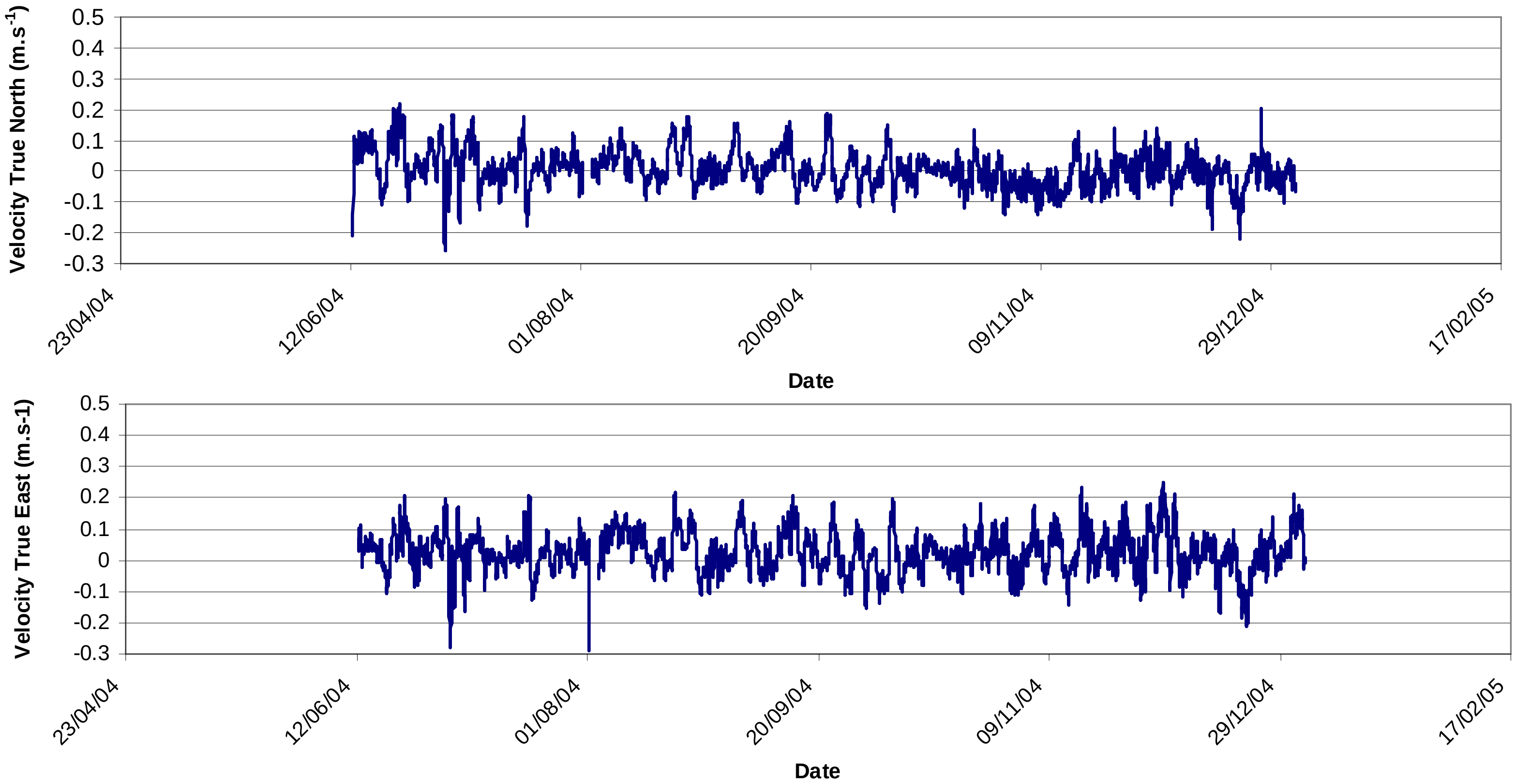

Figure 3.12A Residual current velocities at the Opotiki site, relative to True North and True East (top and bottom figure respectively)

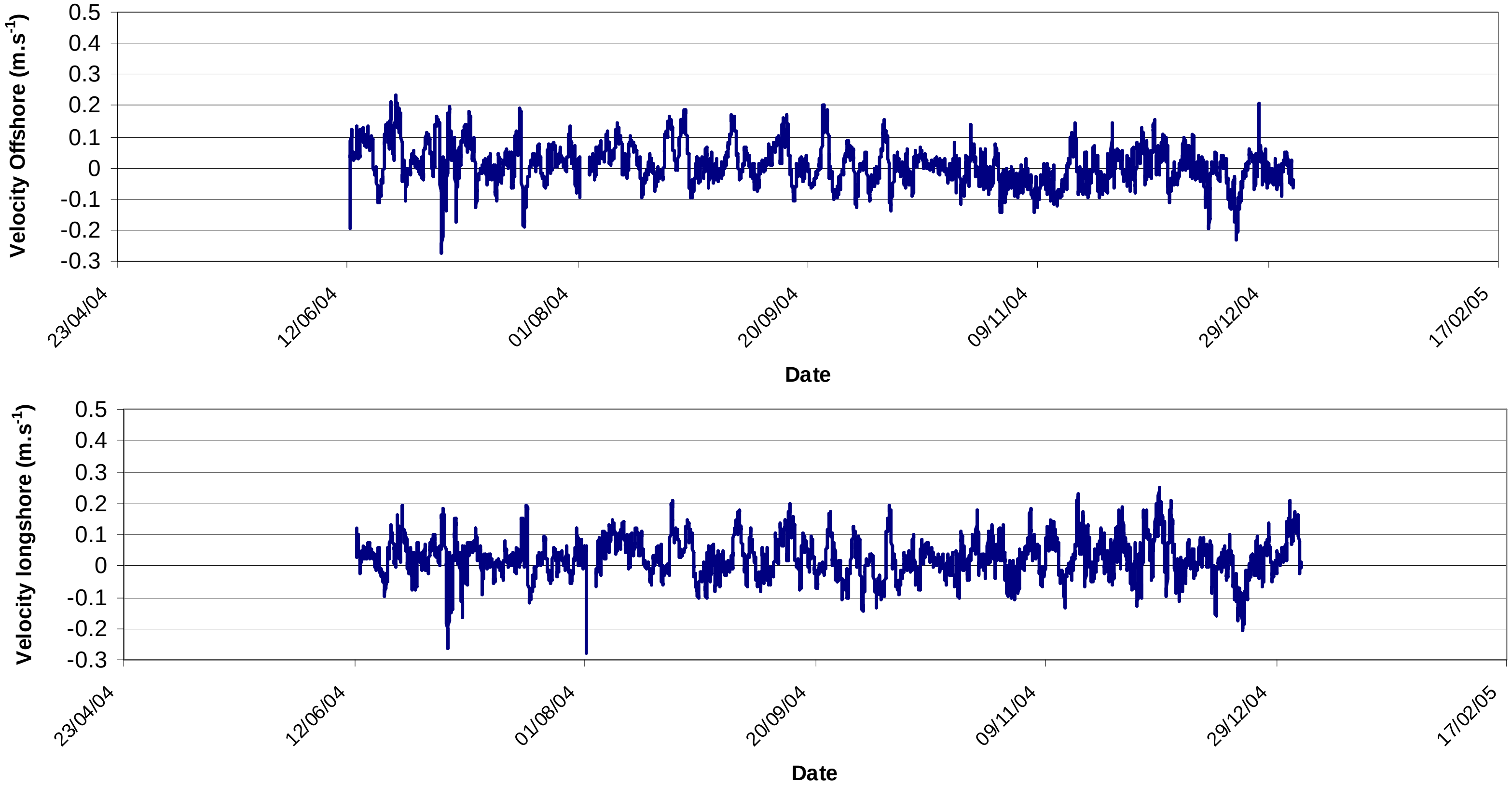

Figure 3.12B Residual current velocities at the Opotiki site, relative to Offshore and Longshore (top and bottom figure respectively). +ve directed offshore in the top figure, +ve directed towards the right when looking offshore in the bottom figure.

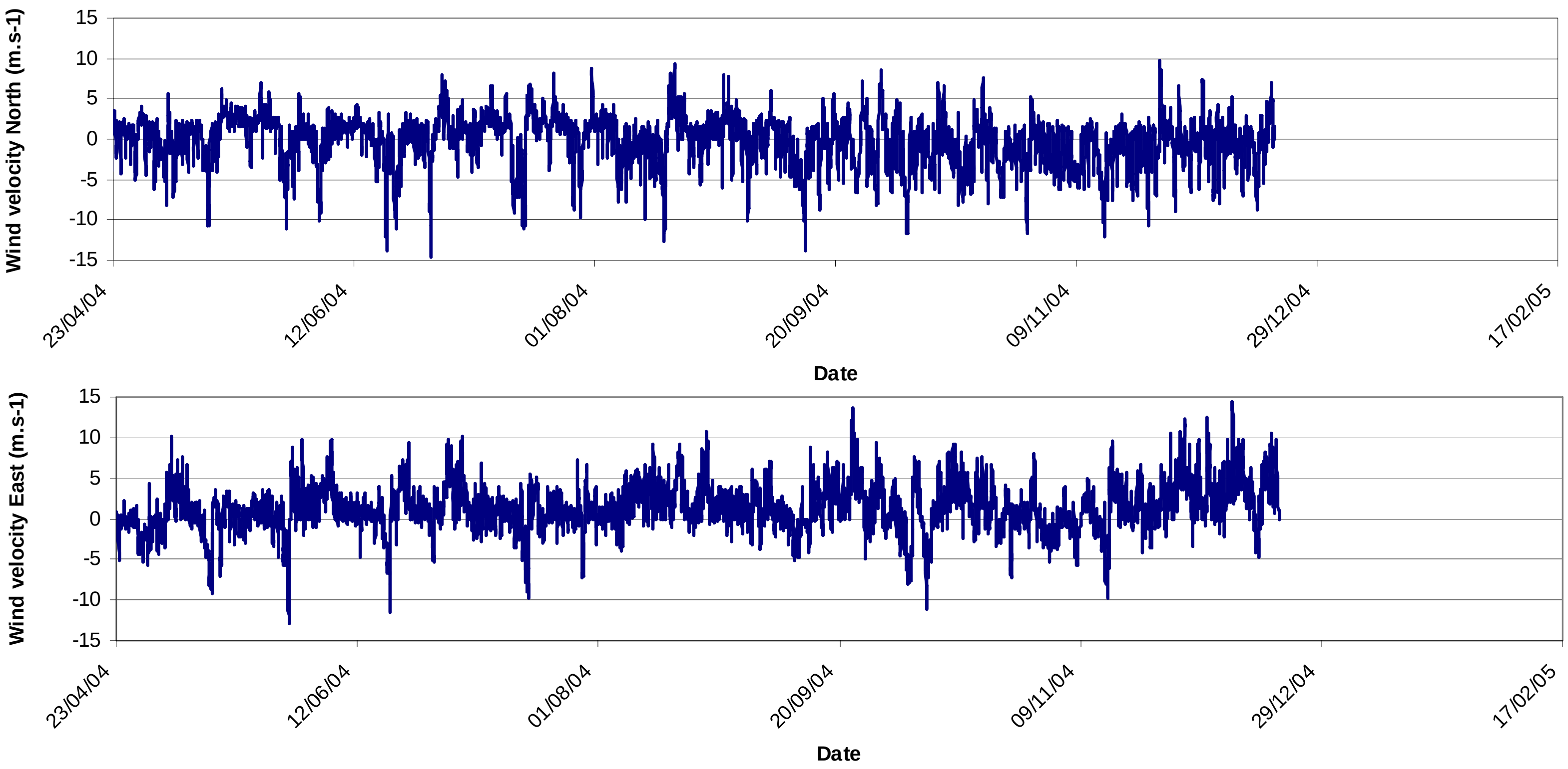

Figure 3.13A Wind velocities as measured at the Whakatane Airport relative to True North and True East (top and bottom figure respectively) recorded concurrently with the deployment of the ADP offshore Opotiki. Some degree of correlation exists between the wind and residual current velocity.

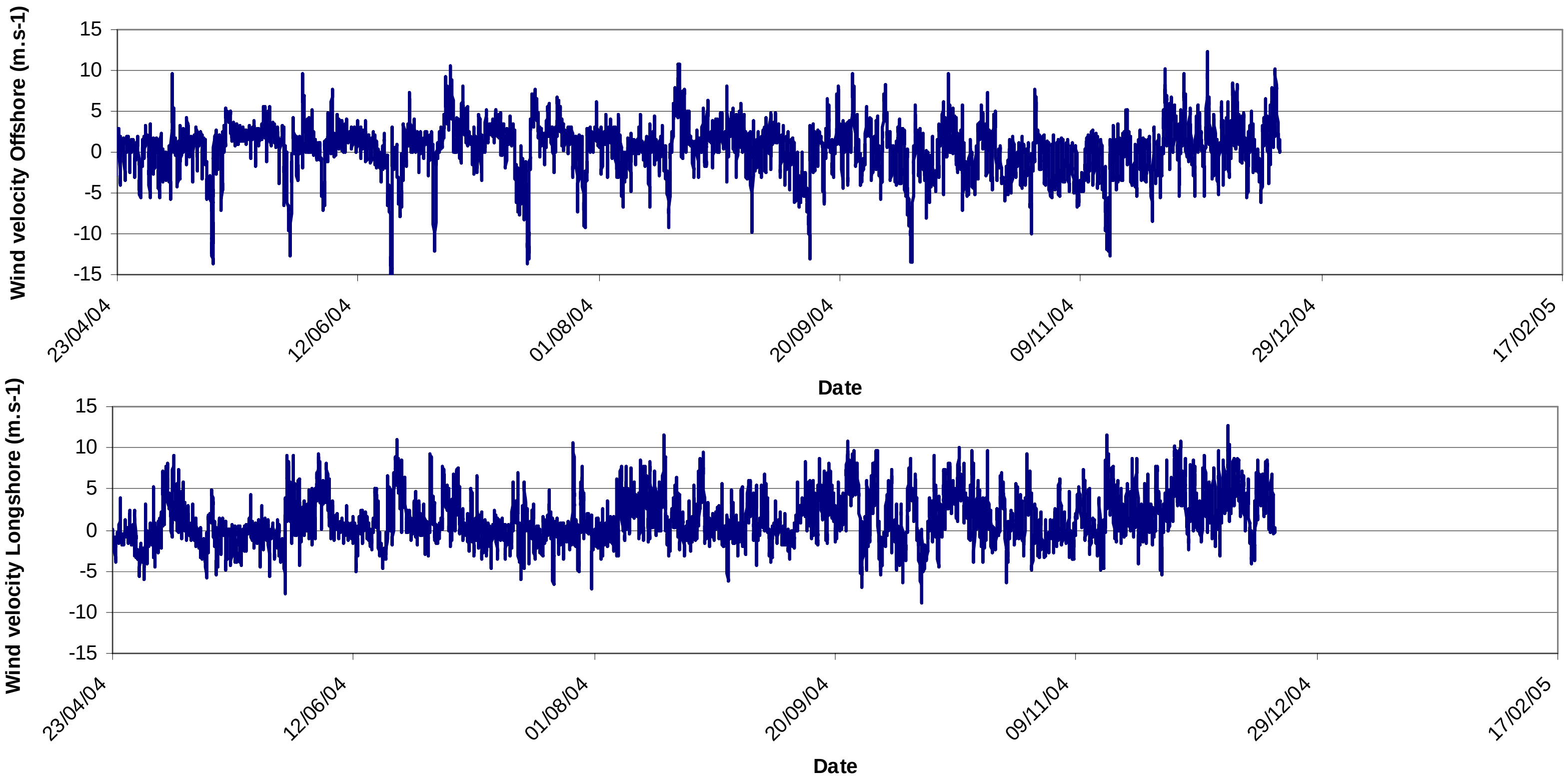

Figure 3.13B Wind velocities as measured at the Whakatane Airport relative to offshore and longshore directions (top and bottom figure respectively) recorded concurrently with the deployment of the ADP offshore Opotiki. Some degree of correlation exists between the wind and residual current velocity.

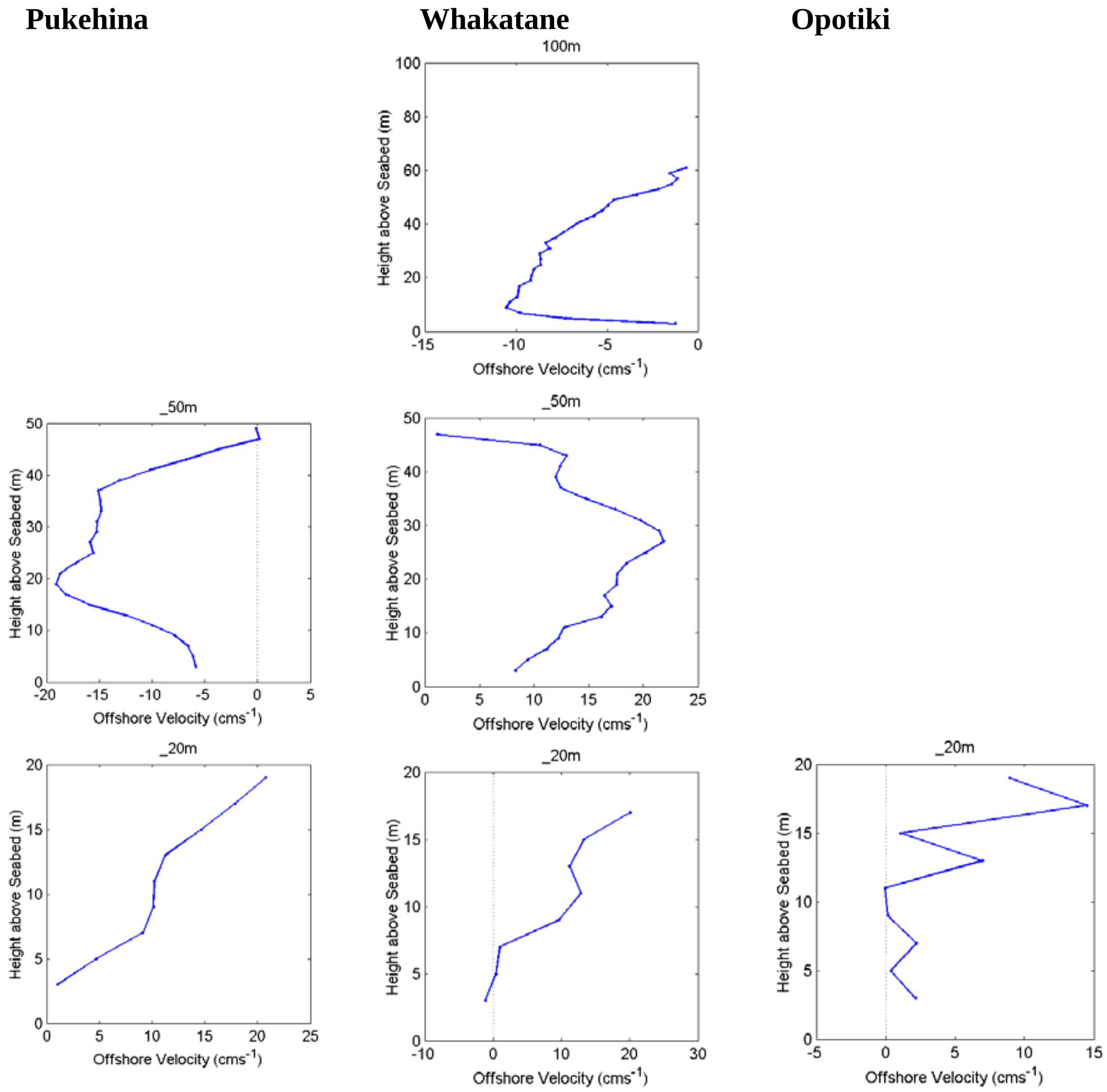

Figure 3.14A Offshore directed velocity component at the 20, 50 and 100 m isobath along the Pukehina, Whakatane and Opotiki transects between the 16th and 17th September, 2003. Positive magnitudes indicate current velocities orientated offshore

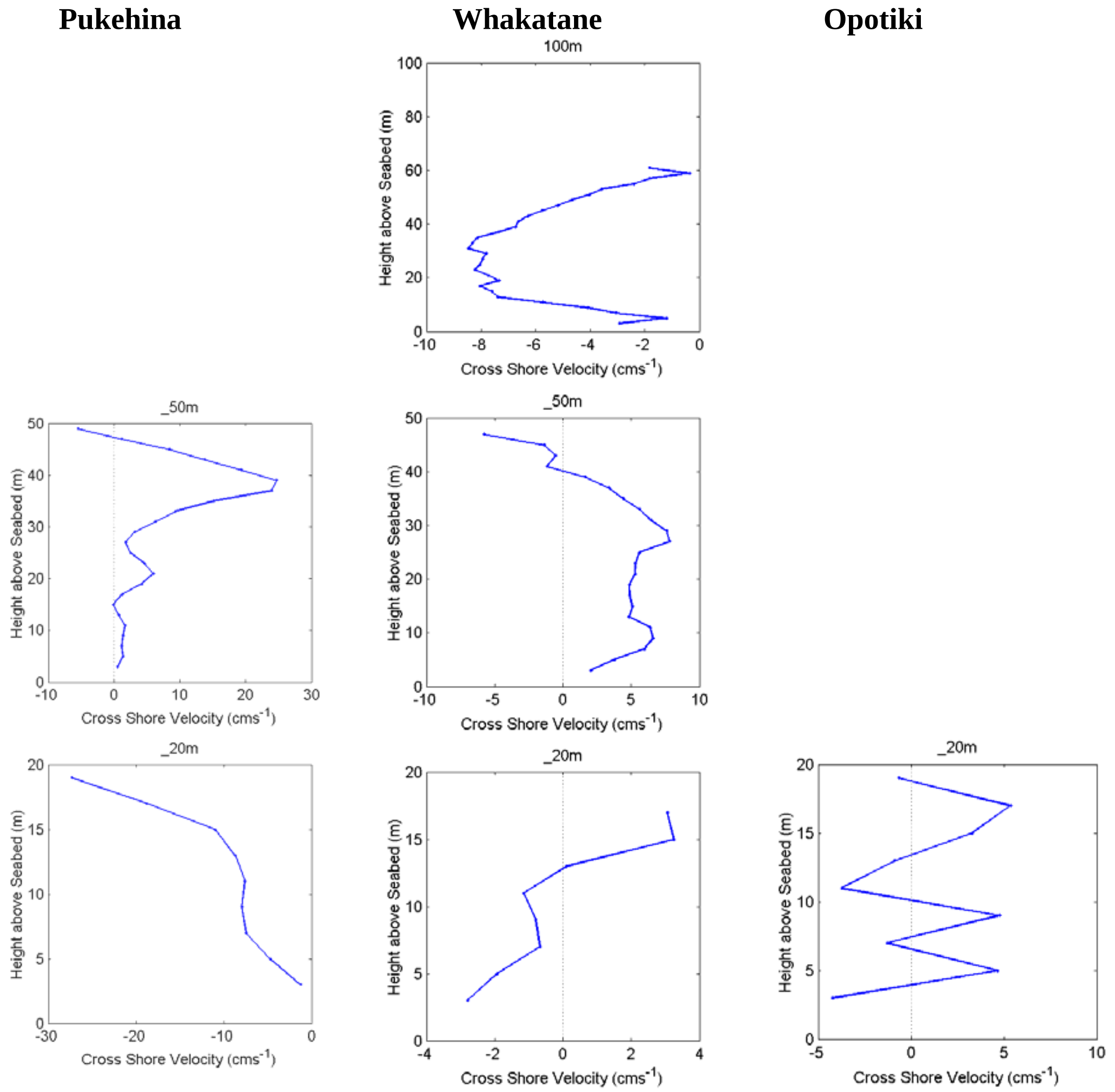

Figure 3.14B Longshore directed velocity component at the 20, 50 and 100 m isobath along the Pukehina, Whakatane and Opotiki transects between the 16th and 17th September, 2003. Positive magnitudes indicate current velocities orientated towards the east

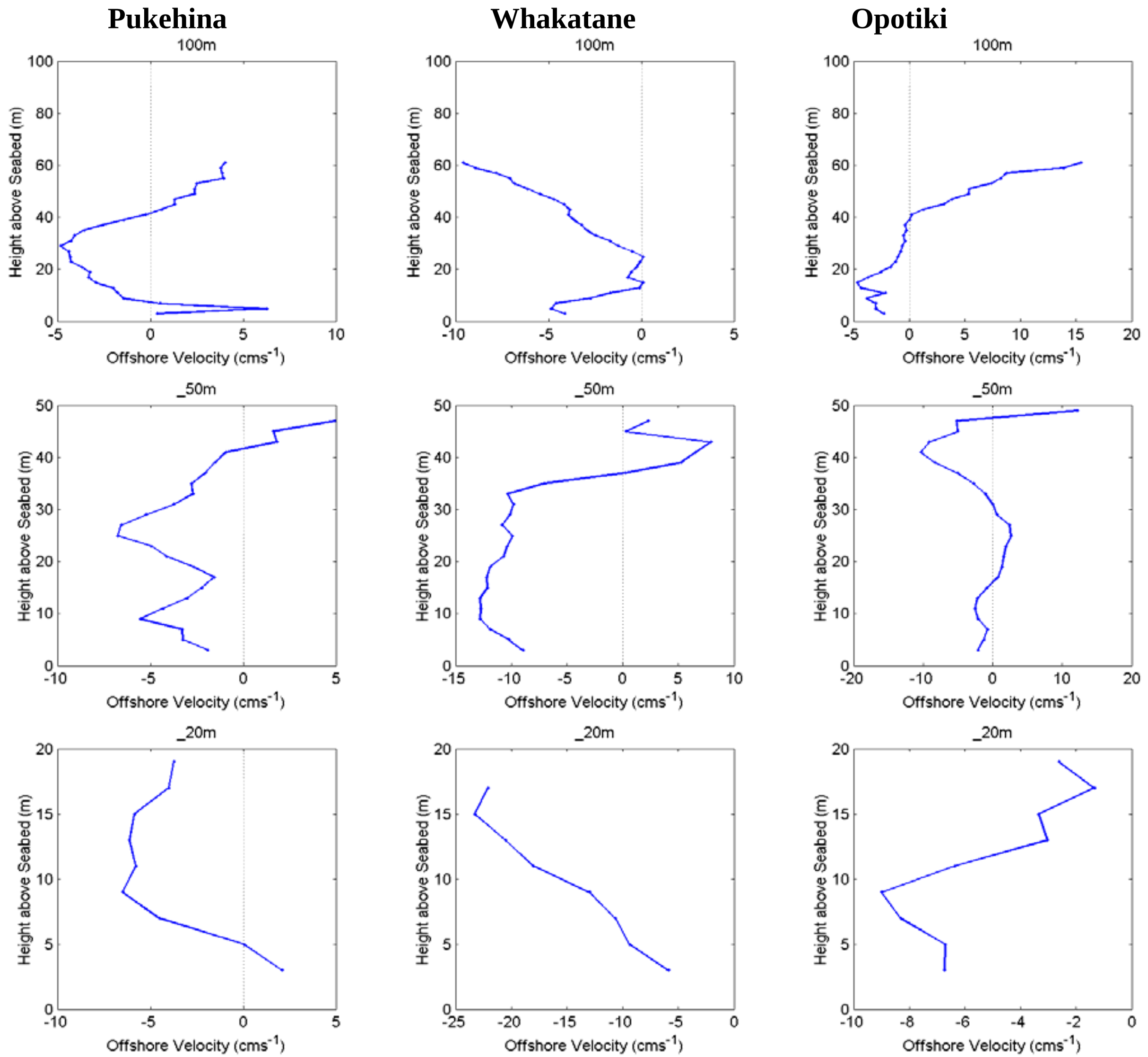

Figure 3.15A Offshore directed velocity component at the 20, 50 and 100 m isobath along the Pukehina, Whakatane and Opotiki transects between the 3rd and 5th December, 2003. Positive magnitudes indicate current velocities orientated offshore

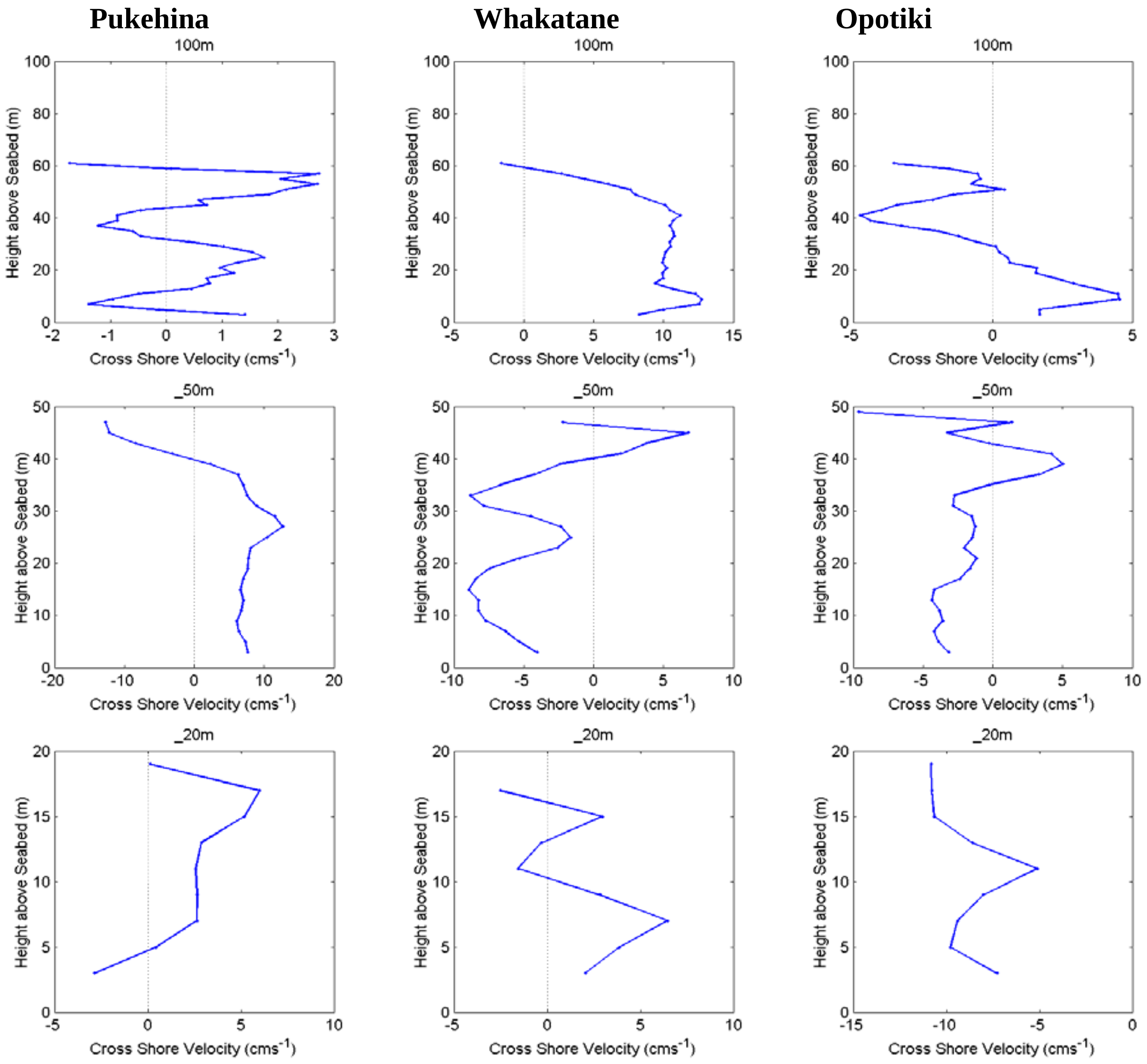

Figure 3.15B Longshore directed velocity component at the 20, 50 and 100 m isobath along the Pukehina, Whakatane and Opotiki transects between the 3rd and 5th December, 2003. Positive magnitudes indicate current velocities orientated towards the east

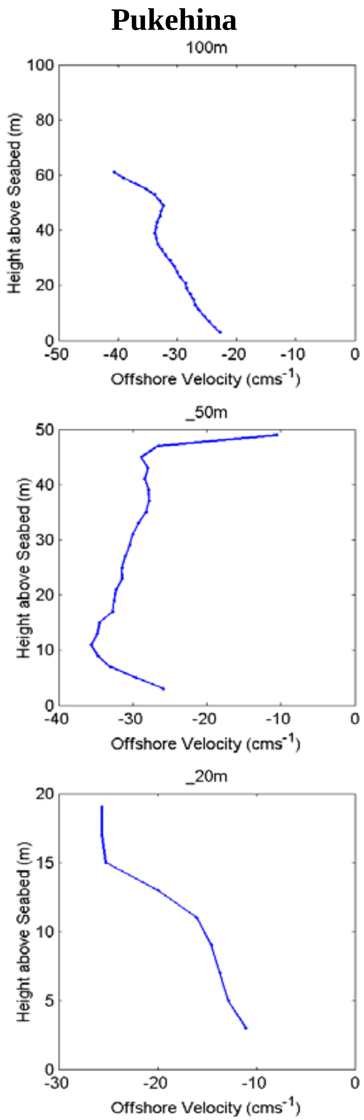

Figure 3.16A Offshore directed velocity component at the 20, 50 and 100 m isobath along the Pukehina transect on the 1st April, 2003. Positive magnitudes indicate current velocities orientated offshore

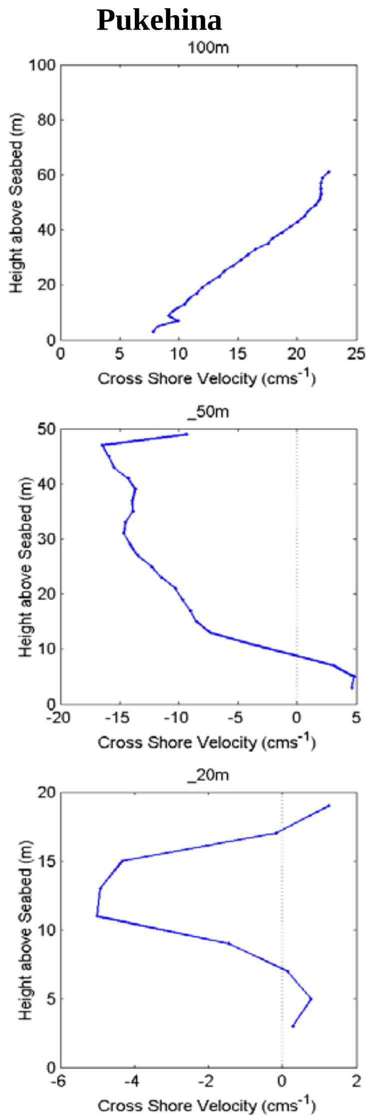

Figure 3.16B Longshore directed velocity component at the 20, 50 and 100 m isobath along the Pukehina transect on the 1st April, 2003. Positive magnitudes indicate current velocities orientated towards the east

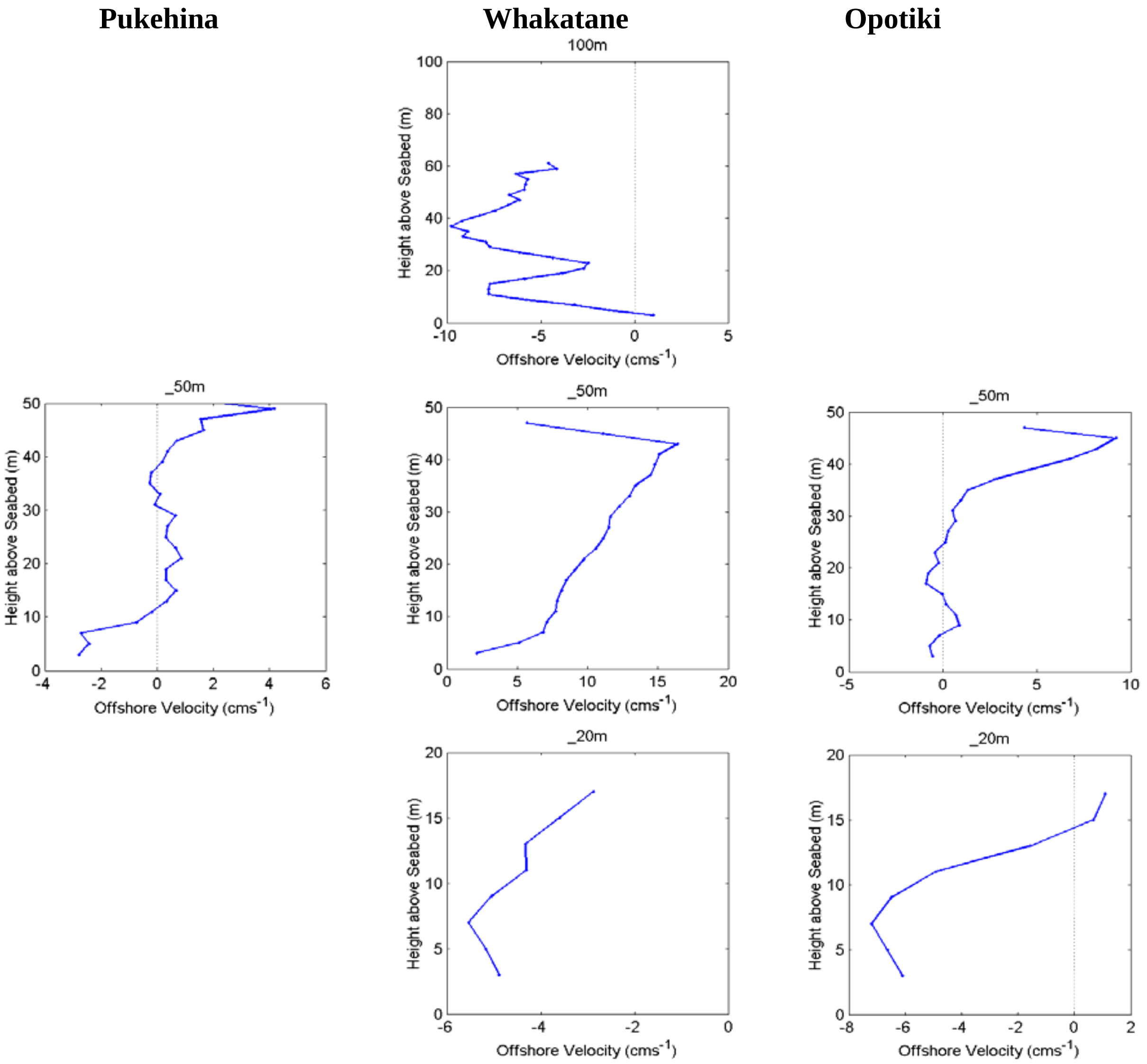

Figure 3.17A Offshore directed velocity component at the 20, 50 and 100 m isobath along the Pukehina, Whakatane and Opotiki transects on the 8th April, , 2003. Positive magnitudes indicate current velocities orientated offshore

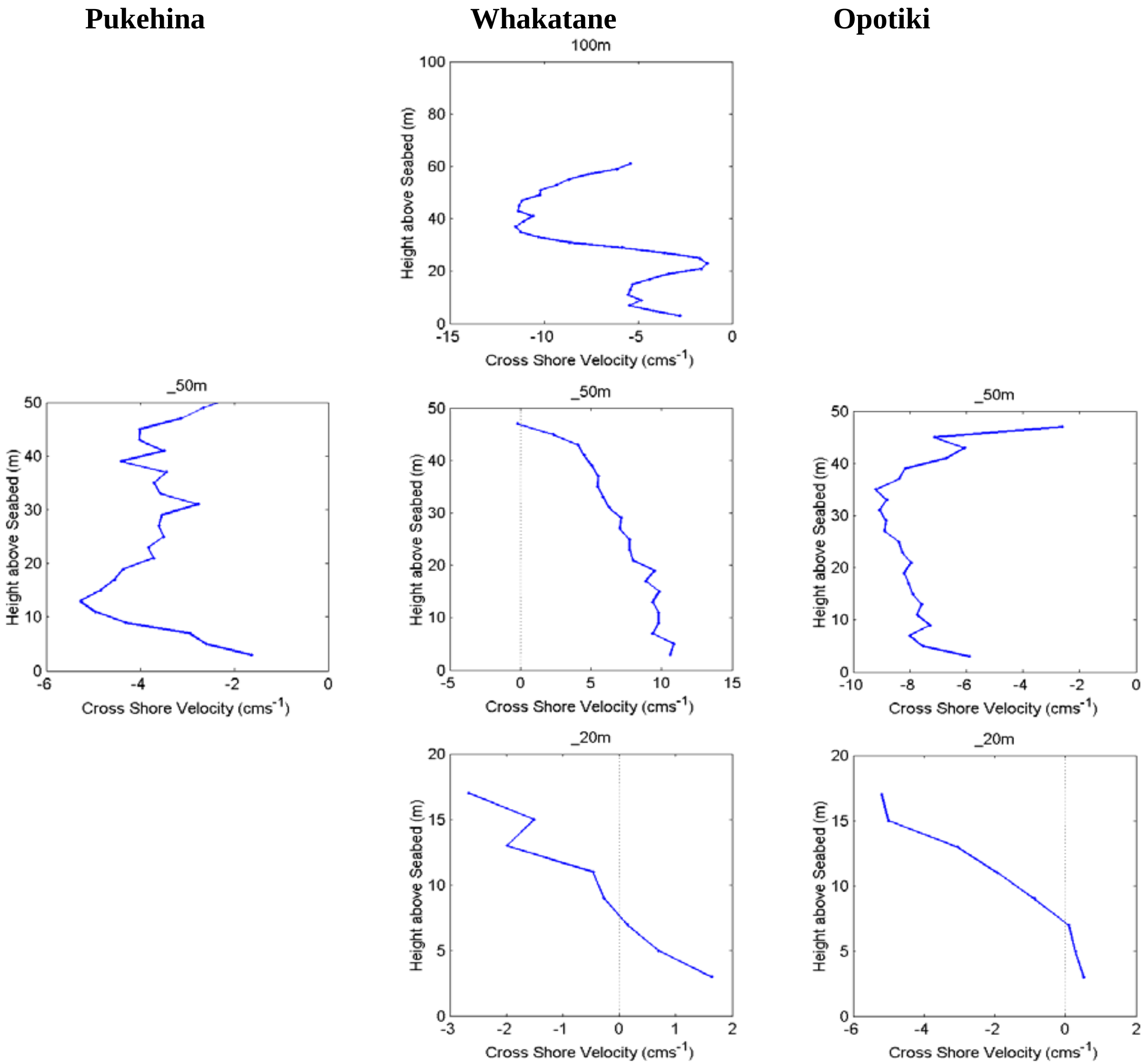

Figure 3.17B Longshore directed velocity component at the 20, 50 and 100 m isobath along the Pukehina, Whakatane and Opotiki transects on the 8th April, , 2003. Positive magnitudes indicate current velocities orientated towards the east

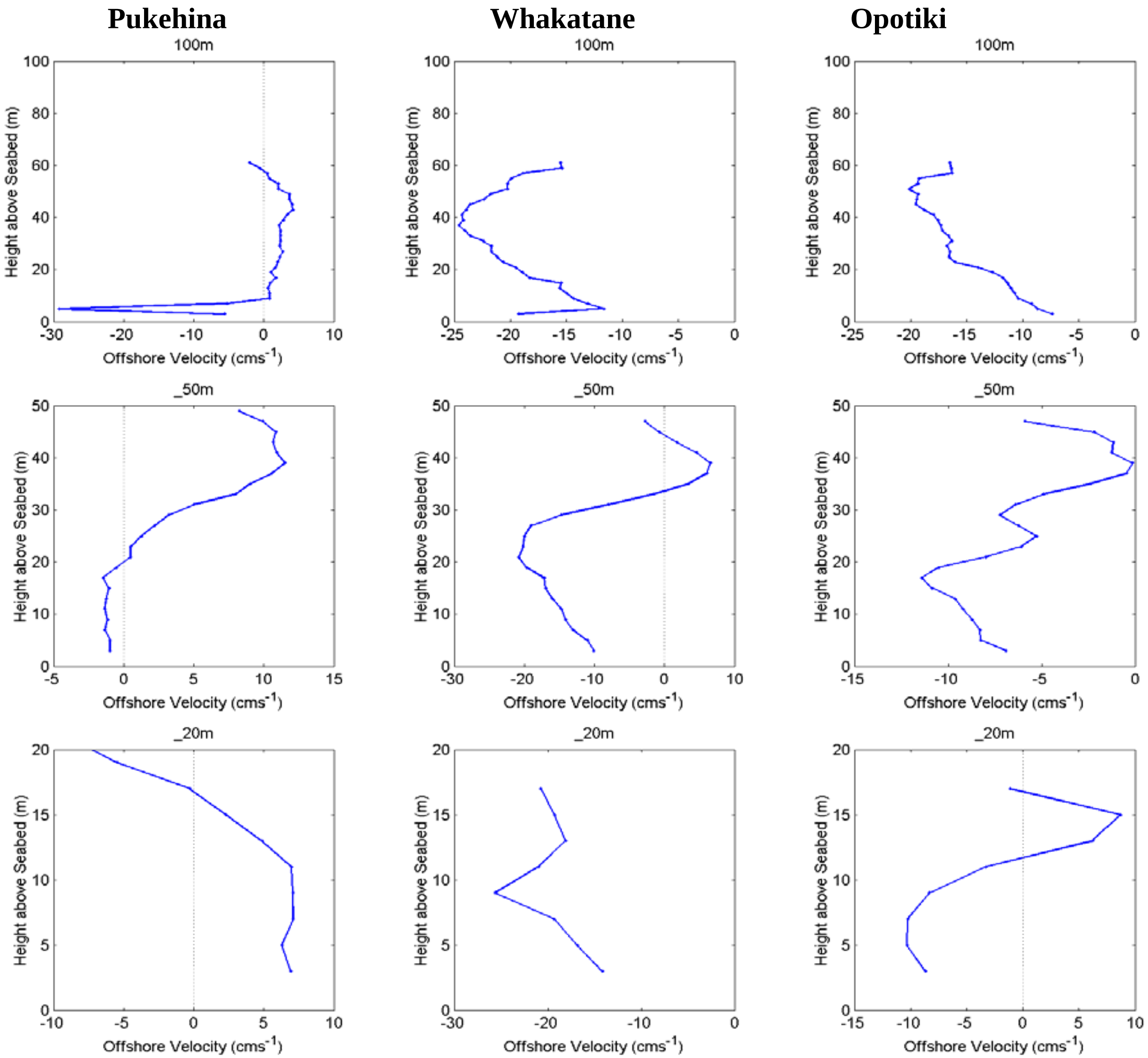

Figure 3.18A Offshore directed velocity component at the 20, 50 and 100 m isobath along the Whakatane and Opotiki transects on the 1st August, , 2003. Positive magnitudes indicate current velocities orientated offshore

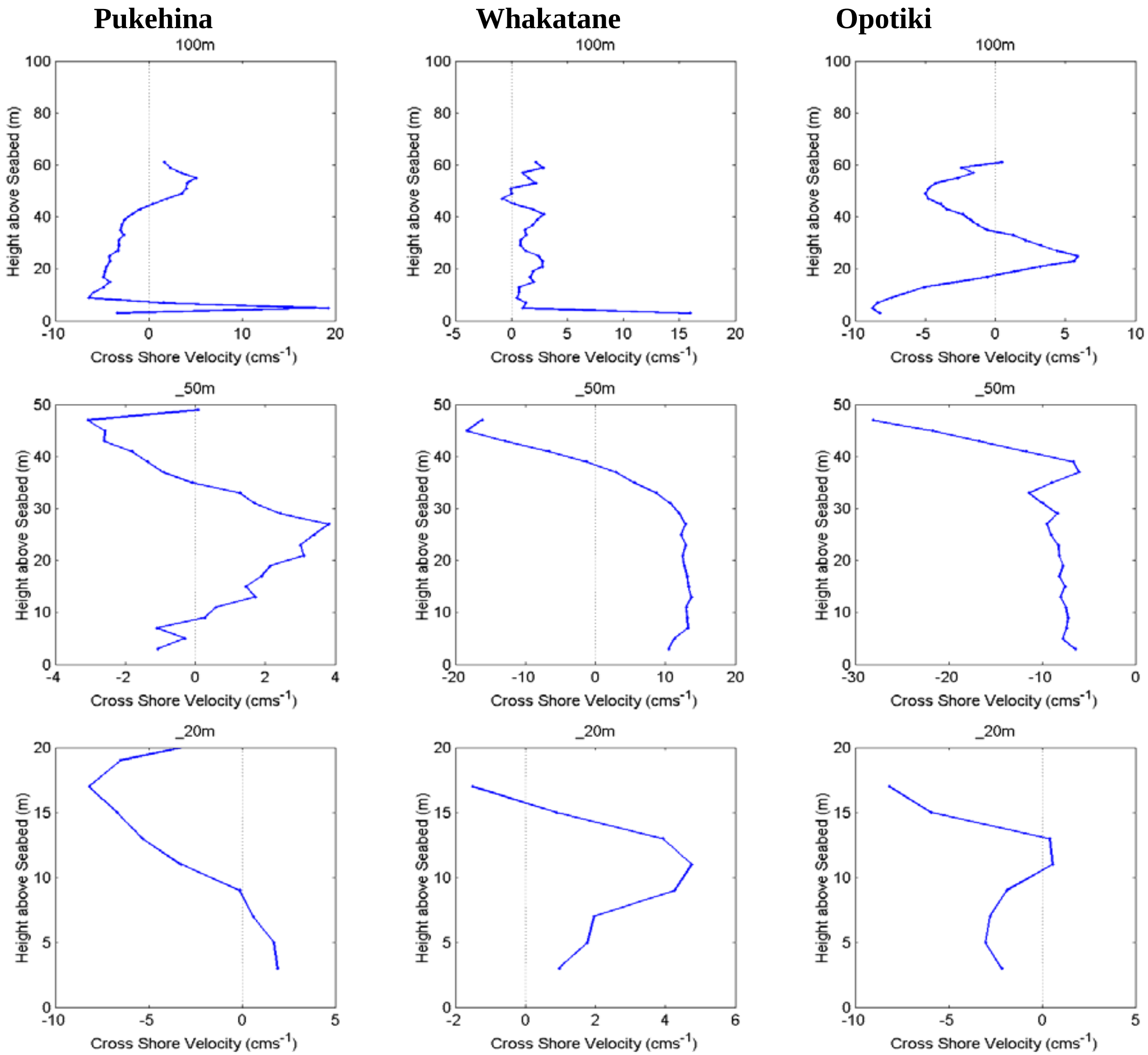

Figure 3.18B Longshore directed velocity component at the 20, 50 and 100 m isobath along the Whakatane and Opotiki transects on the 1st August, , 2003. Positive magnitudes indicate current velocities orientated towards the east

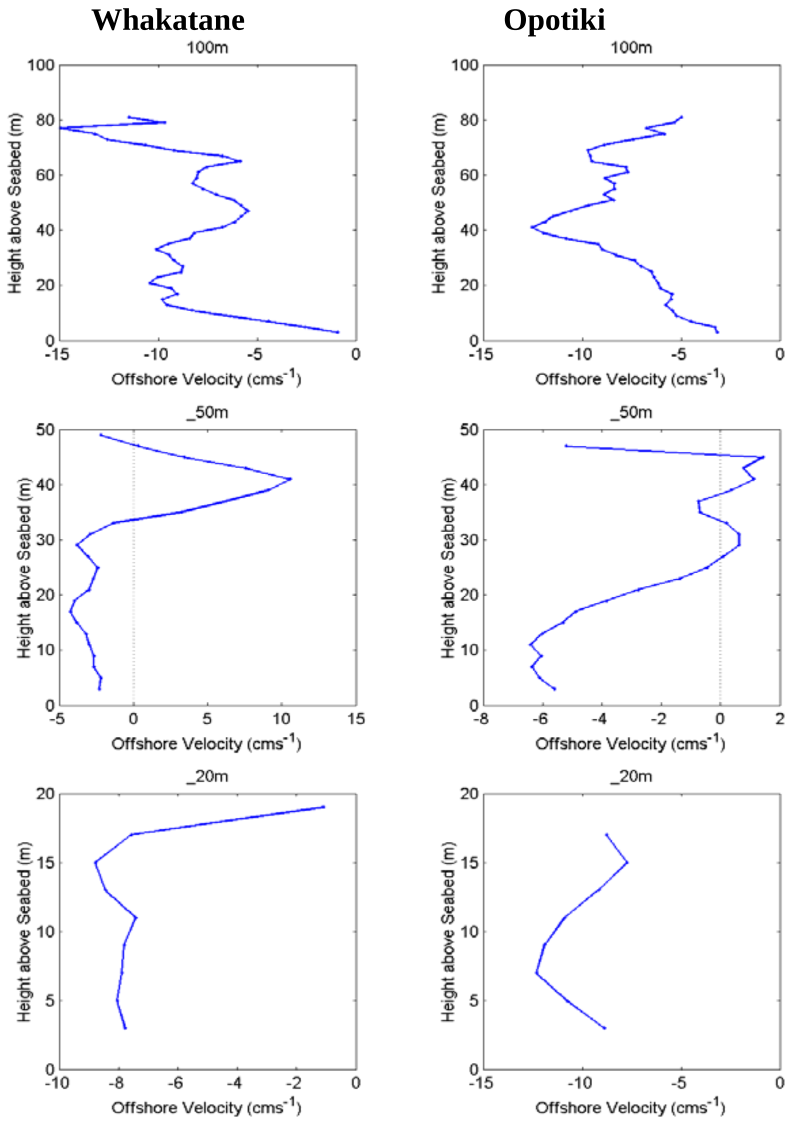

Figure 3.19A Offshore directed velocity component at the 20, 50 and 100 m isobath along the Whakatane and Opotiki transects on the 22nd September, 2003. Positive magnitudes indicate current velocities orientated offshore

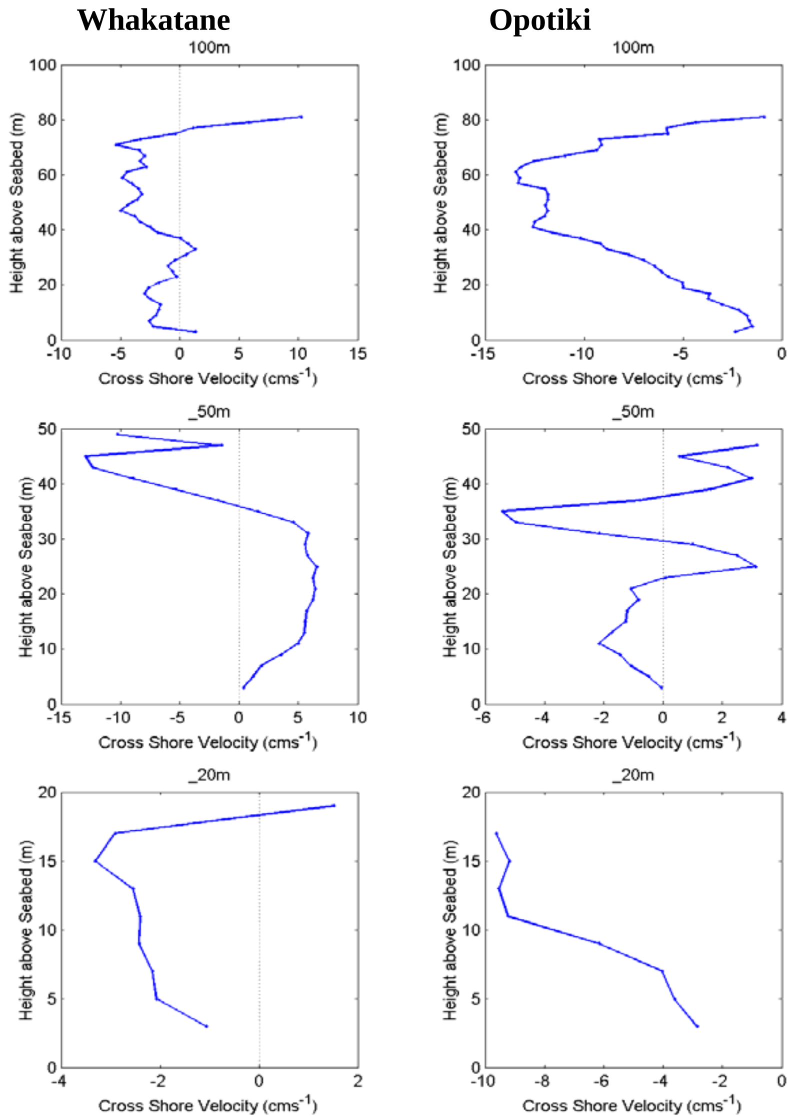

Figure 3.19B Longshore directed velocity component at the 20, 50 and 100 m isobath along the Whakatane and Opotiki transects on the 22nd September, 2003. Positive magnitudes indicate current velocities orientated towards the east

4 References

Park, S., 1998. Bay of Plenty Coastal Water Quality: 1996-1997. A report prepared of Environment Bay of Plenty, no. 98/5

Appendix 1

TIDAL CONSTITUENTS -Pukehina-

NORTH

```
nobs = 1078,  ngood = 1077,  record length (days) = 44.92
start time: 18-Oct-2003 12:00:00
rayleigh criterion = 1.0
Greenwich phase computed with nodal corrections applied to amplitude \n
and phase relative to center time
x0= -0.948, x trend= 0
var(x)= 13.0612   var(xp)= 5.4714   var(xres)= 7.62
percent var predicted/var original= 41.9 %
     tidal amplitude and phase with 95% CI estimates
```

tide	freq	amp	amp_err	pha	pha_err	snr
MM	0.0015122	1.1613	1.356	329.04	79.33	0.73
MSF	0.0028219	0.2744	1.019	175.25	190.39	0.072
ALP1	0.0343966	0.2353	0.428	258.54	125.16	0.3
2Q1	0.0357064	0.4036	0.486	24.65	79.96	0.69
Q1	0.0372185	0.3864	0.528	40.30	74.95	0.54
*O1	0.0387307	1.1822	0.545	100.05	26.82	4.7
NO1	0.0402686	0.1579	0.397	330.81	142.48	0.16
*K1	0.0417807	1.1995	0.525	159.17	25.21	5.2
J1	0.0432929	0.1557	0.391	96.48	164.07	0.16
OO1	0.0448308	0.0975	0.310	75.47	173.65	0.099
UPS1	0.0463430	0.1657	0.282	311.18	134.71	0.34
EPS2	0.0761773	0.0792	0.201	24.84	181.09	0.16
*MU2	0.0776895	0.4389	0.250	158.31	32.53	3.1
*N2	0.0789992	0.6915	0.253	242.06	20.07	7.4
*M2	0.0805114	2.5284	0.260	278.41	6.42	95
L2	0.0820236	0.2912	0.216	300.20	47.43	1.8
S2	0.0833333	0.3198	0.252	326.12	46.27	1.6
ETA2	0.0850736	0.1466	0.194	83.54	79.76	0.57
MO3	0.1192421	0.0547	0.079	82.75	110.75	0.48
M3	0.1207671	0.0762	0.110	180.51	93.05	0.48
MK3	0.1222921	0.0683	0.110	13.67	86.56	0.39
SK3	0.1251141	0.0354	0.076	230.29	138.87	0.22
MN4	0.1595106	0.0484	0.102	171.23	161.10	0.22
M4	0.1610228	0.1275	0.136	226.80	72.73	0.88
SN4	0.1623326	0.0502	0.103	237.61	143.51	0.24
MS4	0.1638447	0.0310	0.114	255.51	184.88	0.075
S4	0.1666667	0.0572	0.121	257.88	118.39	0.22
2MK5	0.2028035	0.0073	0.046	85.23	226.88	0.025
2SK5	0.2084474	0.0524	0.066	355.14	71.14	0.64
2MN6	0.2400221	0.0542	0.114	85.34	151.37	0.22
M6	0.2415342	0.0301	0.122	163.47	196.21	0.061
2MS6	0.2443561	0.0227	0.104	274.99	195.53	0.048
2SM6	0.2471781	0.0283	0.108	346.54	187.61	0.069
3MK7	0.2833149	0.0251	0.075	353.82	199.92	0.11
M8	0.3220456	0.0435	0.077	147.76	124.28	0.32

TIDAL CONSTITUENTS -Pukehina-

EAST

```
nobs = 1078,  ngood = 1077,  record length (days) = 44.92
start time: 18-Oct-2003 12:00:00
rayleigh criterion = 1.0
Greenwich phase computed with nodal corrections applied to amplitude \n
and phase relative to center time

x0= 1.81, x trend= 0

var(x)= 94.5157   var(xp)= 6.9965   var(xres)= 86.9693
percent var predicted/var original= 7.4 %

     tidal amplitude and phase with 95% CI estimates
```

tide	freq	amp	amp_err	pha	pha_err	snr
MM	0.0015122	3.5385	7.575	147.44	151.51	0.22
MSF	0.0028219	1.0371	7.444	236.30	229.00	0.019
ALP1	0.0343966	0.2678	0.762	218.58	163.21	0.12
2Q1	0.0357064	0.5510	0.761	238.36	104.74	0.52
Q1	0.0372185	1.0722	0.989	306.78	57.15	1.2
*O1	0.0387307	2.4040	1.098	355.98	24.43	4.8
NO1	0.0402686	0.4422	0.768	341.45	131.22	0.33
*K1	0.0417807	2.2102	1.168	44.66	28.40	3.6
J1	0.0432929	0.0606	0.709	17.96	226.99	0.0073
OO1	0.0448308	0.3488	0.624	116.97	114.90	0.31
UPS1	0.0463430	0.3410	0.620	295.42	142.25	0.3
EPS2	0.0761773	0.3684	0.274	232.67	43.06	1.8
MU2	0.0776895	0.1402	0.230	77.40	118.03	0.37
N2	0.0789992	0.1415	0.209	169.81	120.06	0.46
*M2	0.0805114	0.5286	0.280	194.31	30.39	3.6
L2	0.0820236	0.0671	0.159	26.45	173.28	0.18
S2	0.0833333	0.1280	0.238	282.17	123.82	0.29
ETA2	0.0850736	0.1925	0.204	309.48	67.43	0.89
MO3	0.1192421	0.0577	0.136	108.73	138.02	0.18
M3	0.1207671	0.1676	0.227	57.67	82.21	0.55
MK3	0.1222921	0.1353	0.196	1.07	85.50	0.48
SK3	0.1251141	0.1113	0.157	199.47	105.39	0.5
MN4	0.1595106	0.0948	0.128	266.28	90.85	0.54
M4	0.1610228	0.0712	0.137	40.45	127.58	0.27
SN4	0.1623326	0.0886	0.129	205.88	97.66	0.47
MS4	0.1638447	0.0446	0.123	75.96	168.53	0.13
S4	0.1666667	0.0618	0.128	186.19	138.37	0.23
2MK5	0.2028035	0.0575	0.129	203.30	136.80	0.2
2SK5	0.2084474	0.0841	0.118	335.53	89.90	0.51
2MN6	0.2400221	0.0377	0.072	51.54	132.59	0.28
M6	0.2415342	0.0239	0.075	90.23	175.99	0.1
2MS6	0.2443561	0.0244	0.072	185.93	176.64	0.11
2SM6	0.2471781	0.0434	0.075	23.01	116.34	0.34
3MK7	0.2833149	0.0593	0.062	72.02	73.57	0.91
M8	0.3220456	0.0129	0.058	95.58	244.31	0.049