Appendix 3

Oceanography at Solwara 1

OCEANOGRAPHY AT SOLWARA 1

Solwara 1 Project

Prepared for:

Nautilus Minerals

Prepared by:

Coffey Natural Systems

September 2008

CR_853_16_v1

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OCEANOGRAPHY AT SOLWARA 1

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1. INTRODUCTION

1.1 Background

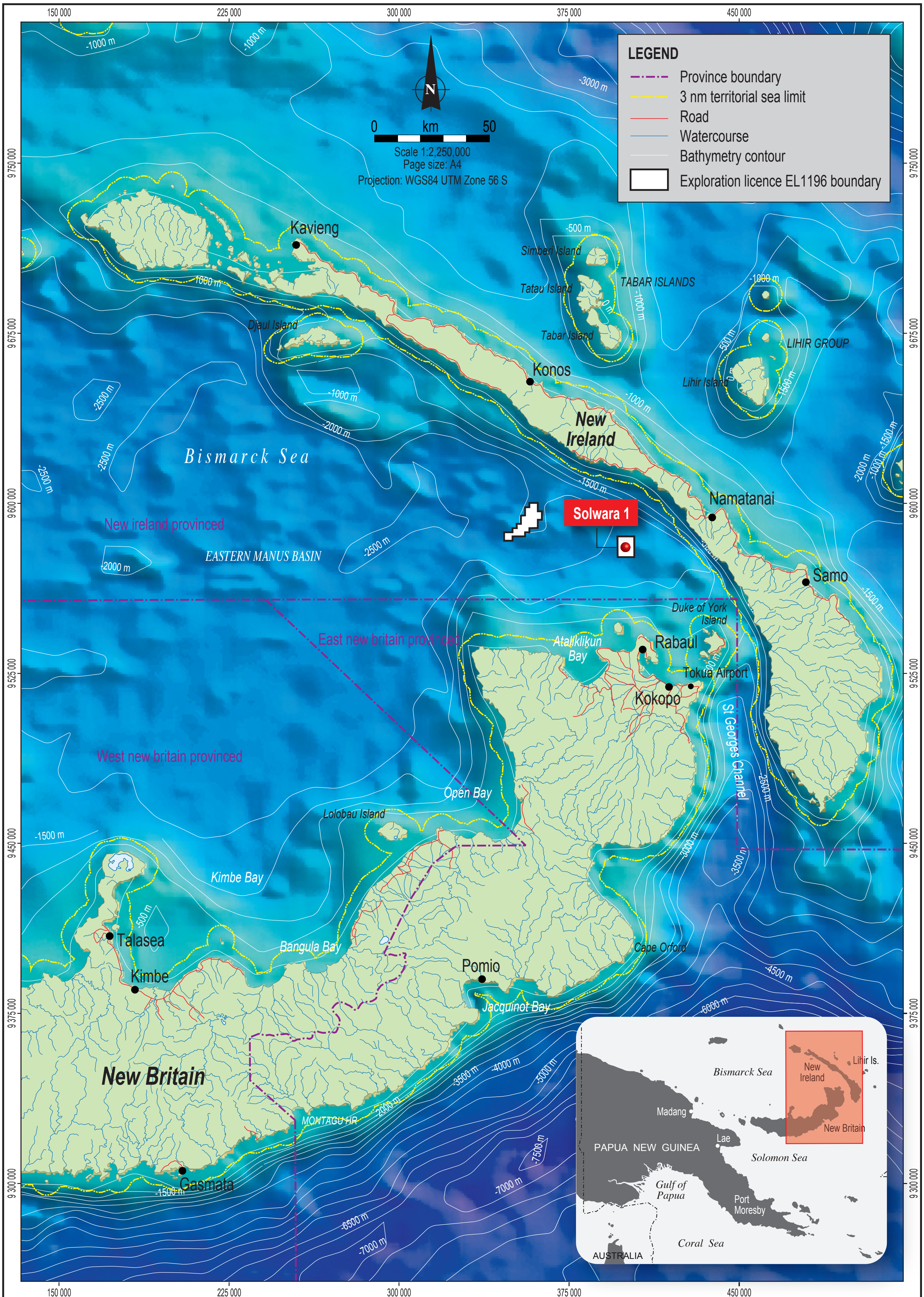
Nautilus Minerals Niugini Limited (Nautilus) is advancing a proposal to develop the Solwara 1 Project (‘the Project’). The development involves the recovery of high-grade polymetallic Seafloor Massive Sulphide (SMS) deposits that are located at approximately 1,600 m water depth on the floor of the Bismarck Sea, New Ireland Province, Papua New Guinea (PNG), about 50 km north of Rabaul (Figure 1.1).

The Project comprises two phases and it is proposed to develop Phase 1 in advance of Phase 2. The two Project phases can be summarised as follows:

- **Phase 1**. The first phase involves mining and whole-of-ore export of copper- and gold-rich SMS ore deposits from the seafloor at approximately 1,600 m water depth.
- **Phase 2**. The second phase involves processing the recovered materials locally in PNG and a feasibility study will commence when Phase 1 has demonstrated the extraction and recovery process and the Project has successfully achieved commercial production.

In August 2006, Coffey Natural Systems (then Enesar Consulting Pty Ltd) initiated an oceanographic data collection program to understand how the oceanographic climate will influence Phase 1 of the Project. The program comprised:

- Oceanographic profiles through the water column (i.e., temperature, salinity, conductivity, transmissivity and photosynthetically active radiation [PAR]).
- In situ measurements of ocean currents over the entire water column (surface to the seafloor), covering a non-contiguous, 12-month period.



coffey natural systems	Date: 22.09.2008 MXD: 7008_Nautilus_Solwara 1 File Name: 853_16_F01.01_GIS_AI	Nautilus Minerals Niugini Solwara 1 Project	NAUTILUS Minerals Niugini	Project location	Figure No: 1.1

1.2 Objectives

The objectives of the oceanographic study and this report are to:

- Examine the range of oceanographic parameters at Solwara 1, including the:
  – Variability of the depth of the surface mixed layer[1].
  – Variability of the depth of the euphotic zone[2].
- Determine oceanographic currents over the water column from near-surface to near-seabed in the vicinity of Solwara 1.

This data is required for engineering and environmental investigations to provide a basis for:

- The engineering design of mining equipment for use at Solwara 1.
- Modelling the behaviour and fate of the material to be returned to the ocean in the dewatering process.
- Modelling behaviour and fate of unconsolidated sediment disposal and competent waste material side cast at Solwara 1 during operations.
- Understanding the seafloor environment in which deep-sea animals live and propagate.

[1] The surface mixed layer is the upper layer in the ocean that is kept well mixed by the turbulent action of wind and waves, and therefore tends to be composed of water of similar temperature, salinity and density. The bottom of the surface mixed layer is always marked by an abrupt density discontinuity. Below this depth the density increases progressively with depth.

[2] The euphotic zone is the zone in the upper ocean where photosynthesis takes place. The base of the euphotic zone is defined as the depth where transmitted light from the surface reaches 1%.

2. SETTING

The Project is located within Nautilus tenement EL1196 in the Manus Basin, in the eastern Bismarck Sea (Figure 1.1). The basin is an active back-arc basin that is cross-cut by a set of major west to north-west trending transform faults, producing three sub-basins referred to as the Eastern, Central and Western Manus basins. The Project is situated within the Eastern Manus Basin.

2.1 Bismarck Sea

The Bismarck Sea is bounded to the southwest by the northeast coast of Papua New Guinea and to the northwest through to the southeast by the Bismarck Archipelago, consisting of the Admiralty Islands (north), New Ireland (east), and New Britain (southeast) (see Figure 1.1).

The Bismarck Archipelago extends around to the east and north, enclosing the Bismarck Sea and separating it from the Pacific Ocean. To the south, it is linked to the Solomon Sea by the Vitiaz Strait. The Bismarck Sea has a total surface area of approximately 40,000 km^2 and maximum depths reaching in the order of 2,500 m.

Weather in the Bismarck Sea is driven by the larger weather patterns over the Pacific Ocean and the Project area experiences two very distinct seasons associated with the Southeast Asian/Australian monsoon system. The southeast monsoon season extends from May to October and the northwest monsoon season occurs from November to April.

Northwest trade winds bring in low-pressure troughs resulting in heavy rainfall during the northwest monsoon (wet) season. Historical data collected over 23 years from 1946 to 1969 shows that northwesterly winds dominate the Project area in January and strengthen during the day. The northwesterlies are not as well developed in the transition period around April and are replaced in July by moderate to fresh south-southeasterly winds that are relatively constant throughout the day. The southeasterly monsoon season gradually weakens and the cycle is completed by the strengthening of the northwesterly component and return to January conditions (McAlpine, 1983).

The Bismarck Sea is free from tropical cyclone activity. Significant wave heights[3] are thought to exceed 2 m about 5% of the year (Triton, 2006).

2.2 Solwara 1

Solwara 1 is located on the northwestern flank of North Su which is an actively erupting subsea volcano. South Su lies about 2 km distant from Solwara 1 on the opposite southeastern flank of North Su (see Figure 2.1). Both Solwara 1 and South Su contain discrete zones of active hydrothermal venting.

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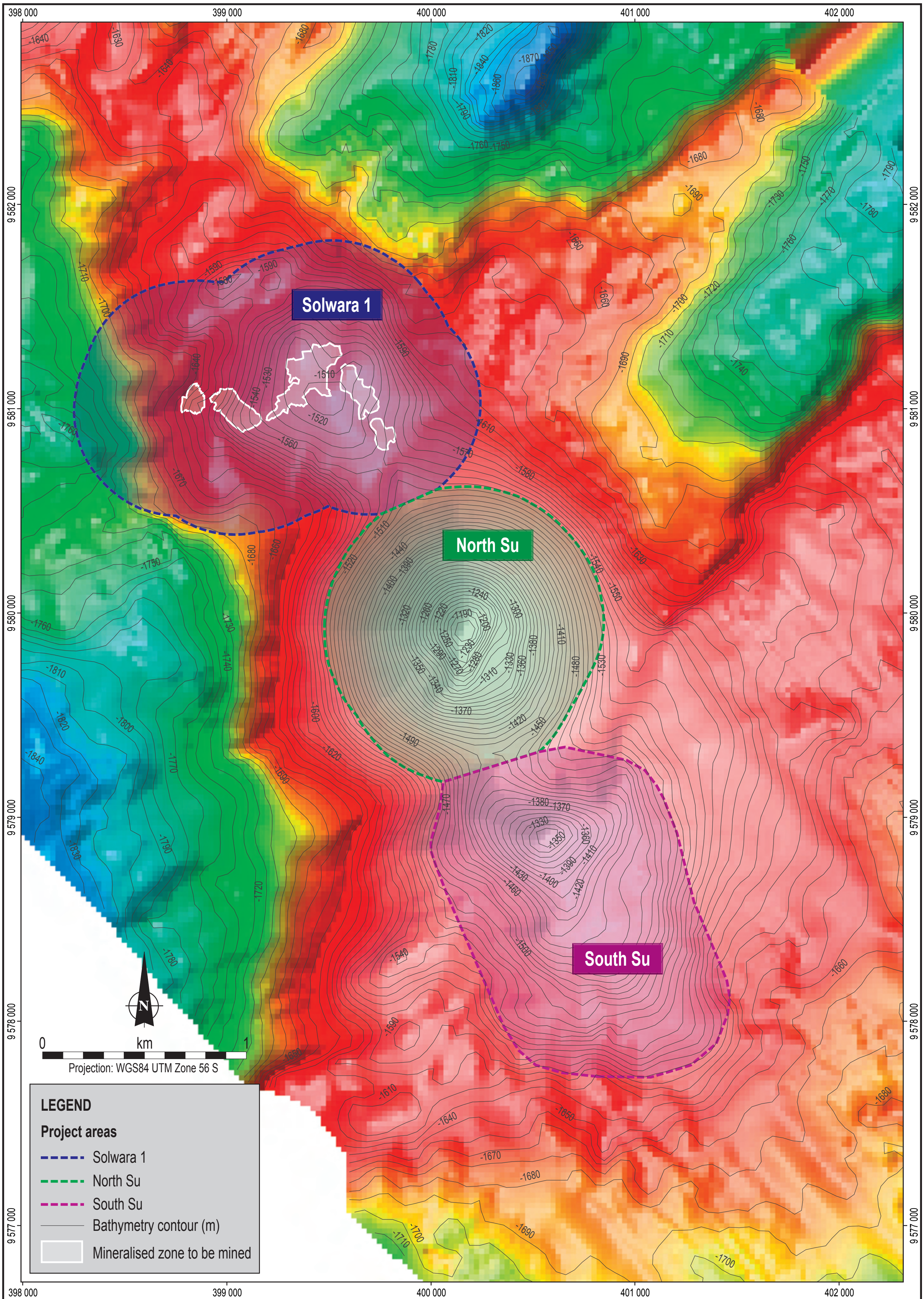
[3] The average height (trough to crest) of the one-third of the largest waves.



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Date: 25.08.2008
MXD: 7008 Solwara 1 Project GIS
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Nautilus Minerals Niugini
Solwara 1 Project

NAUTILUS

Solwara 1 Project area

Figure No: 2.1

Mineral resource investigations have identified five main zones of mineralisation (Figure 2.1), that will form the basis of mining activities. At Solwara 1, it is estimated that there are 40,000 chimneys over 0.25 m high. Between the chimneys, the seafloor consists of exposed hard sulphide deposits (target ore) interspersed with thin veneers of unconsolidated sediment, thought to have a maximum depth of 6 m.

3. PHYSICAL OCEANOGRAPHY

3.1 Bathymetry

From mid 2006 to late 2006, Woods Hole Oceanographic Institution (WHOI) undertook a survey of the Eastern Manus Basin, focussing on hydrothermal vent systems. The survey included high-resolution 3D bathymetric mapping of the seafloor using an autonomous underwater vehicle (AUV).

Regional bathymetry of the eastern Bismarck Sea, based on the 2006 WHOI survey, is shown in Figure 3.1. The morphology of the seafloor is a reflection of the seismically active nature of the Eastern Manus Basin, resulting in features associated with volcanic, tectonic, and hydrothermal processes. These features comprise ridges, vents, seamounts and sub-sea volcanoes (active and dormant). Depths in the Eastern Manus Basin reach in excess of 2,500 m, while the ridges rise some 1,000 m to depths of approximately 1,500 m. Solwara 1 is located within the area shown as SuSu in Figure 3.1, which also contains North Su and South Su[4].

The features of the seafloor at Solwara 1 and its immediate surrounds are shown in Figure 2.1. The area is dominated by North Su, rising some 800 m from the seafloor. Solwara 1 and South Su, essentially flanks of North Su, rise approximately 500 m and 670 m from the seafloor respectively. The seafloor surrounding Solwara 1 exceeds depths of 2,000 m within 3 km from the mound.

3.2 Water Column Structure

Oceanographic profiling data was collected by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) between 1985 and 2000. Over this period, some 85 oceanographic profiles were performed in the Eastern Manus Basin, including at Solwara 1, and these measured changes in temperature, salinity, oxygen and turbidity with depth.

In addition, Nautilus conducted over 35 oceanographic profiles at Solwara 1 from 2005 to 2008 and these measured salinity, temperature, transmissivity and photosynthetically active radiation (PAR).

Interpretation of available data indicates that:

- Sea surface temperatures vary from 27°C to 31°C during the southeast monsoon season and range from 29°C to 31°C during the northwest monsoon season (see Figure 3.2).
- The surface mixed layer at Solwara 1 varies in depth from the surface to 185 m below the surface (Figure 3.2), which is deeper than surface mixed layers generally found near the coast. It is typical for surface mixed layers in the open sea (i.e., at Solwara 1) to be deeper than coastal locations.

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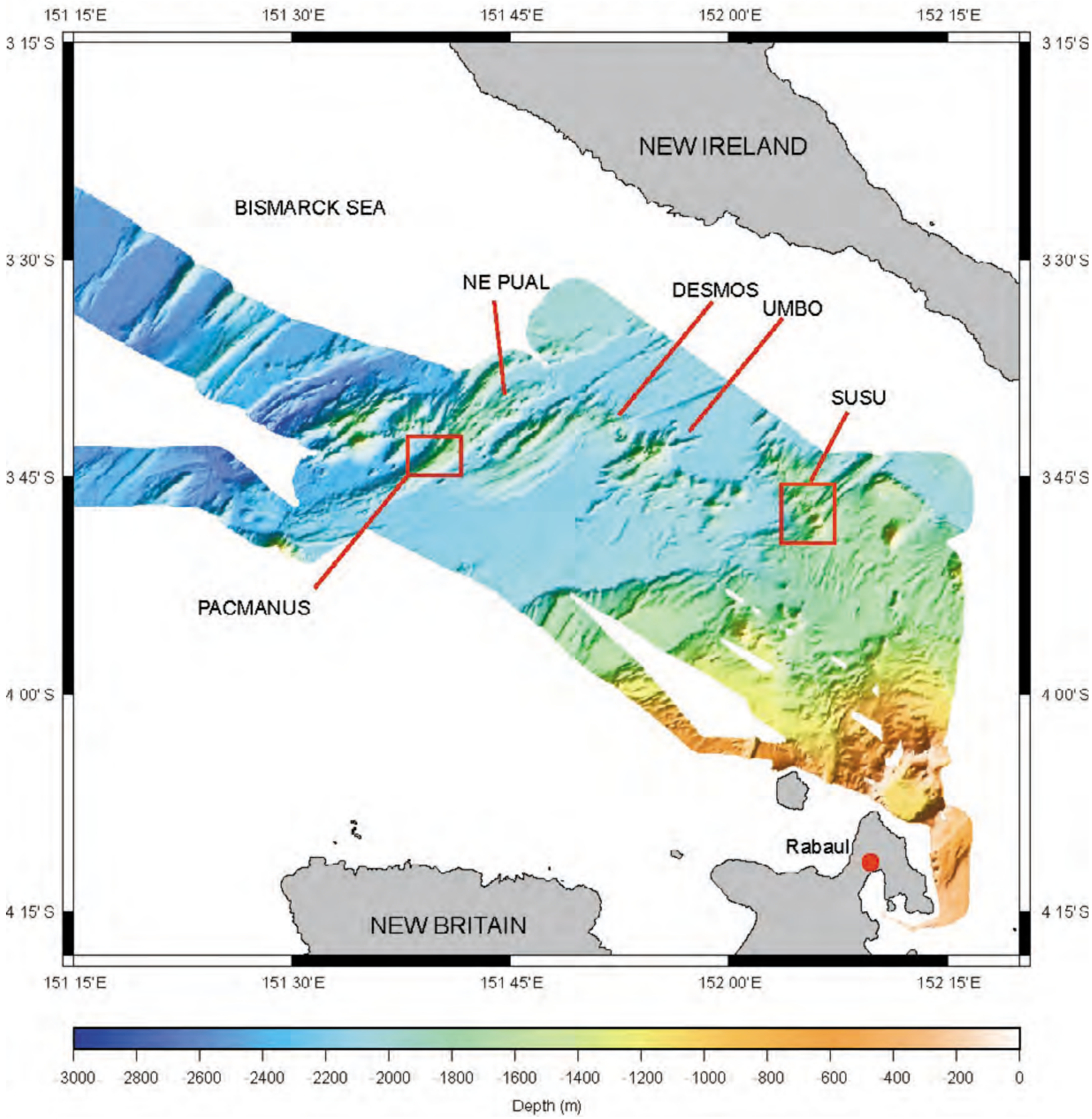
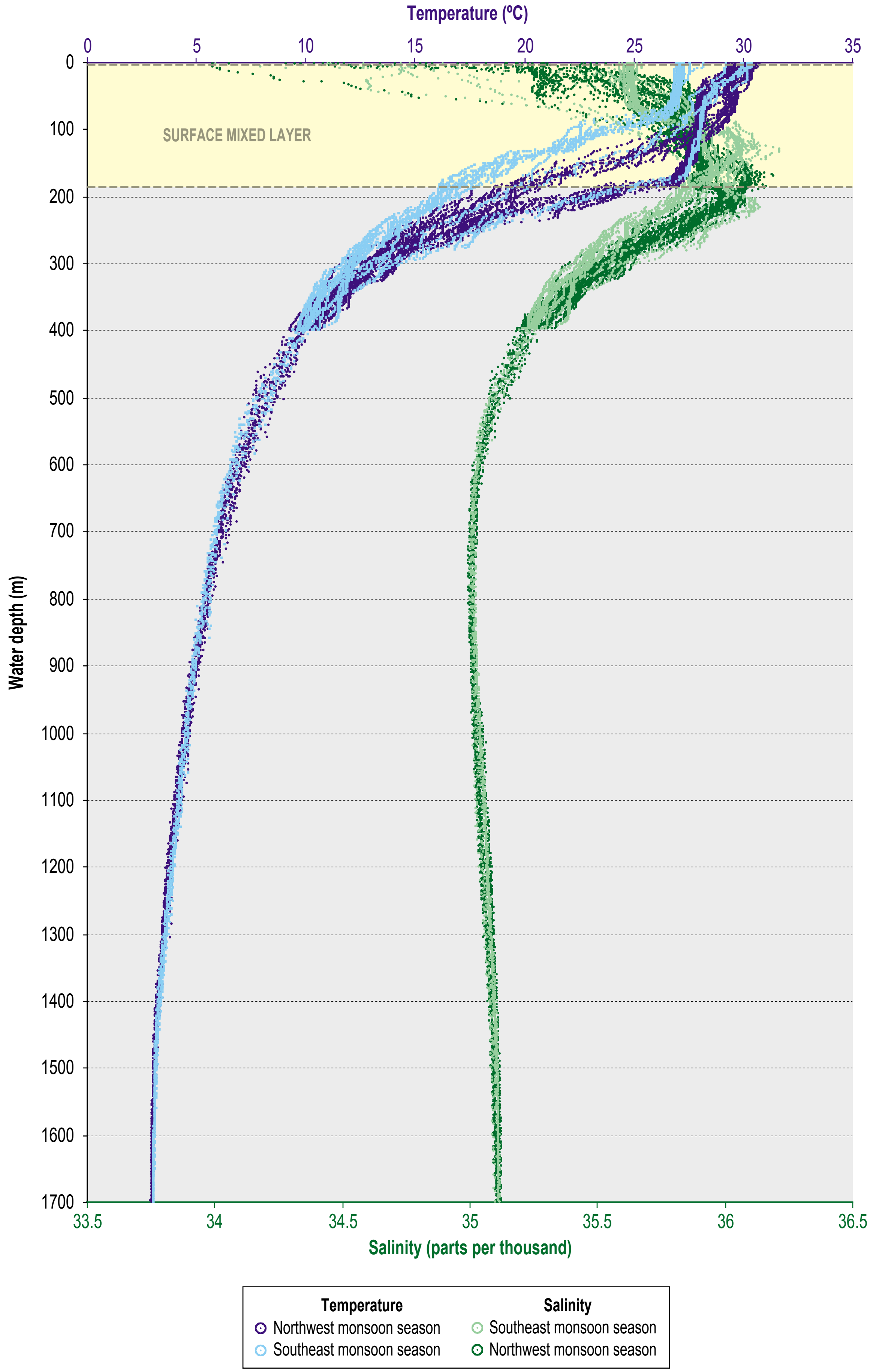
[4] When first discovered, Solwara 1, North Su and South Su were collectively known as SuSu Knolls.



coffey natural systems	Job No: 7008	Nautilus Minerals Niugini	Bathymetry of the eastern Bismarck Sea	Figure No: 3.1
	File Name: 853_16_F03.01_HB	Solwara 1 Project		



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Job No: 7008	Nautilus Minerals Niugini	NAUTILUS Minerals Niugini	Oceanographic profiles 1985 to 2000	Figure No: 3.2
File Name: 853_16_F03.02_HB	Solwara 1 Project			

- Surface mixed layers are deepest during the northwest monsoon season, likely due to relatively stronger winds present during this season (when compared to the southeast monsoon season) which mix surface waters to a deeper depth.
- Water temperature at the base of the surface mixed layer is approximately 27°C (Figure 3.2). Below the surface mixed layer temperature decreases to around 10°C at 400 m depth. Below this, temperatures decrease with depth at the same rate year-round, remaining at approximately 3°C at 1,500 m depth (the depth at the top of the Solwara 1 mound).
- Salinity at the surface varies between 34.0 and 35.7 parts per thousand (ppt) at the surface (Figure 3.2). Salinity is generally lower during the wetter northwest monsoon season, due to some dilution of saline sea water with fresh rainwater.
- Salinity peaks at around 150 to 250 m water depth where it can reach 36.2 ppt (Figure 3.2). Salinity decreases with depth to around 35.1 ppt at 600 m and then remains relatively constant with increasing depth. Salinity at the top of Solwara 1 mound is around 35.1 ppt year round.
- The euphotic zone thickness ranges between 33 to 80 m below the surface.

3.3 Ocean Currents

3.3.1 Regional Current Circulation

Surface Currents

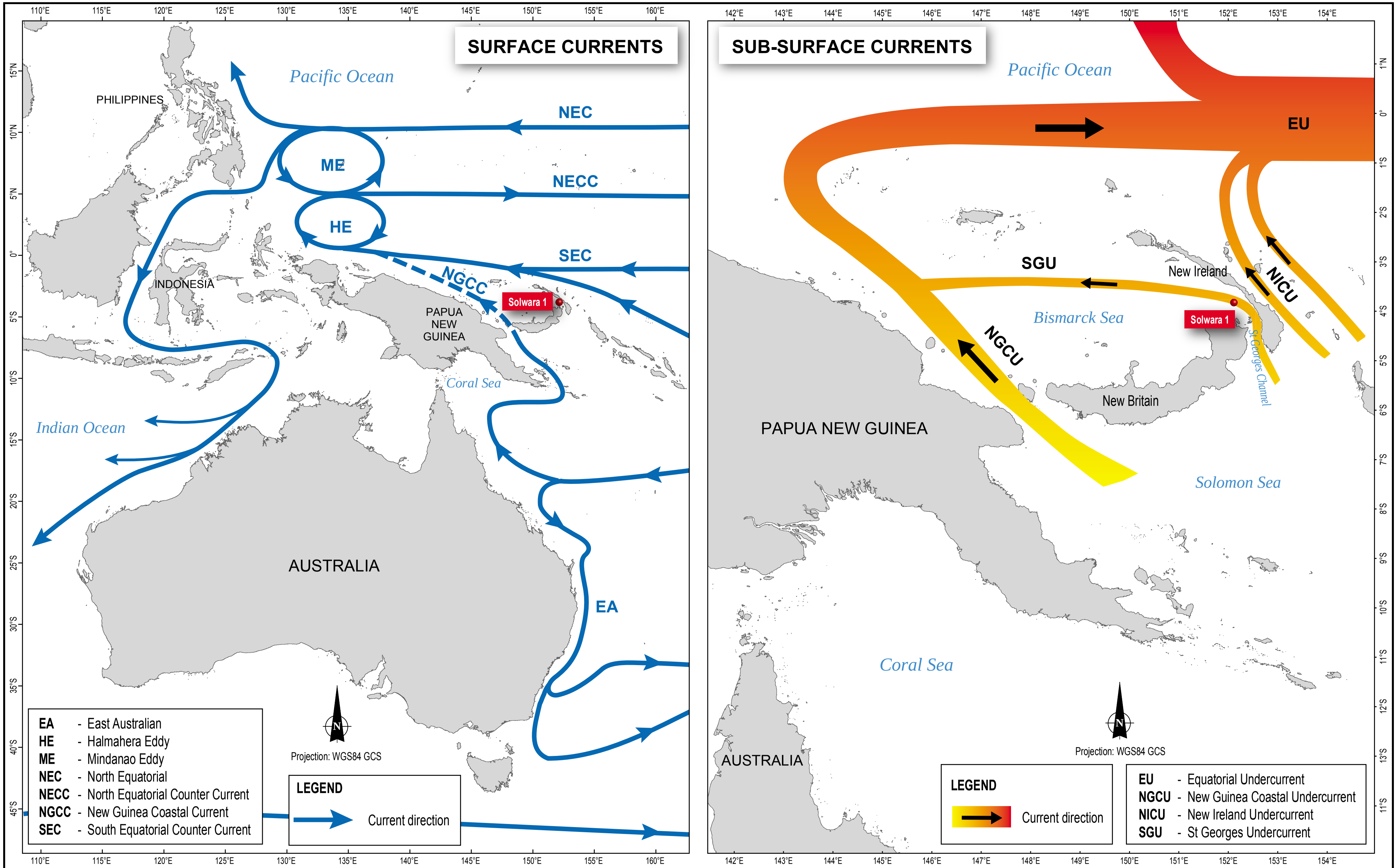
During the southeast monsoon season (May to October) the major surface current system of the Pacific Ocean involves a broad westward flow of water on the northern arm of the South Pacific gyre[5].

This wind-driven, surface-current system, known as the Southern Equatorial Current (SEC) produces current flows through the Coral Sea that branch north when they meet northeastern Australia. These currents meet to form the New Guinea Coastal Current (NGCC) (Figure 3.3).

The NGCC flows through the Louisiade Archipelago and Vitiaz Strait into the Bismarck Sea. The more northern component of the SEC tends to flow past the Solomon Islands and can either enter the Bismarck Sea through St Georges Channel or Ysabel Channel from the north.

During the northwest monsoon season (November to April), the NGCC and the northern arm of the East Australian Current can reverse direction and flow southeast through the Vitiaz Strait along the northern coast of Papua New Guinea (Steinberg, 2006).

[5] A gyre is any manner of swirling vortex. It is often used to describe large-scale wind or ocean currents. Gyres are caused by the Coriolis effect, the planetary vorticity along with horizontal and vertical friction that determine the circulation patterns from the wind curl (torque).



Source:
Adapted from Steinberg, 2006.

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Job No: 7008

File Name: 7008_16_F03.03_HB

Nautilus Minerals Niugini

Solwara 1 Project

NAUTILUS Minerals Niugini

Regional currents

Figure No: **3.3**

The Bismarck Archipelago acts as a barrier to the main SEC flow and any circulation outside the major current pathways is likely to be characterised by complex flows and recirculations in the sheltered side of the island arcs, especially during the prevailing southeast monsoon season (Steinberg, 2006).

The abnormal hydrodynamic conditions associated with El Niño-Southern Oscillation (ENSO), result in a change in the structure and also the surface circulation of the southwestern Pacific. The South Equatorial Current becomes the main current flowing westwards.

Computer modelling indicates that surface currents enter and leave the eastern Bismarck Sea in the vicinity of Solwara 1 through St Georges Channel (King, pers. com., 2007).

Sub-surface Currents

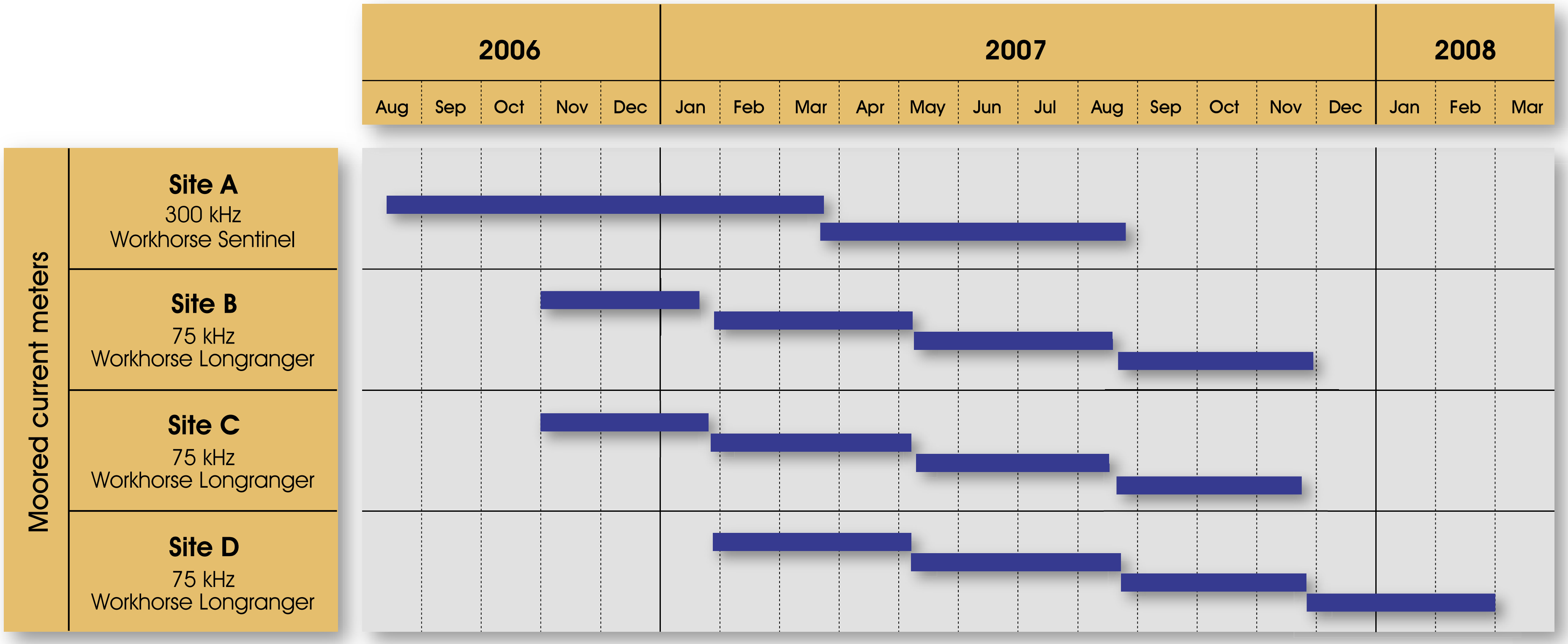
Below the surface, large-scale sub-surface currents flow through the waters of PNG (Wells et. al., 1999). The New Guinea Coastal Undercurrent transports water at 220 m depth from the Solomon Sea, through the Vitiaz Strait and into the Bismarck Sea (Figure 3.3). Further to the east, the St Georges Undercurrent enters the Bismarck Sea from the Solomon Sea, eventually flowing in a westerly direction at 220 m water depth. The two sub-surface currents flow in the same direction year-round. They meet in the eastern Bismarck Sea and flow to the northwest until reaching the equator, where they turn to the east and form the Equatorial Undercurrent.

3.3.2 Measured Currents at Solwara 1

Instrumentation

Acoustic Doppler Current Profilers (ADCP) were used to measure both horizontal and vertical currents through the water column at Solwara 1. An ADCP can measure three-dimensional current velocities in multiple layers through the water column.

An ADCP is an acoustic instrument that transmits bursts of sound (pings) through the water column from a transducer assembly along four separate beams. The transducers receive the backscattered sound echoes from particulate matter (suspended sediment, gas bubbles, plankton, etc.,) suspended in the water column. The motion of these particles relative to the ADCP causes the echoes to change in frequency (the Doppler shift), which the ADCP measures as a function of depth to resolve water velocities.



coffey natural systems	Job No: 853 File Name: 853_16_F03.04_HB	Nautilus Minerals Niugini Solwara 1 Project	Timeline of current metering data avaibility	Figure No: 3.4

Long-term Characterisation of Currents at Solwara 1

Three-dimensional currents from the surface to the seafloor were measured at Solwara 1 using four ADCPs (see Figure 3.5).

Site A

An upward-facing 300 kHz ADCP located at Site A on the top of Solwara 1 mound measured currents from as close to the seafloor as possible to approximately 80 m above the seafloor (Figure 3.5) over a 12 month period covering August 2006 to August 2007 (Figure 3.4).

The 300 kHz ADCP was deployed and recovered twice (i.e., every six months) by a remotely operated vehicle (ROV) from a surface support ship. This method of deployment and recovery ensured that no mooring consumables with the potential to foul mining equipment were left at Solwara 1 after final recovery of the instrument. Deployment details are provided in Table 3.1.

The 300 kHz ADCP was programmed to measure current velocities every 20 minutes. Current velocities were measured at 4 m intervals, from the location of the instrument to 80 m above the instrument.

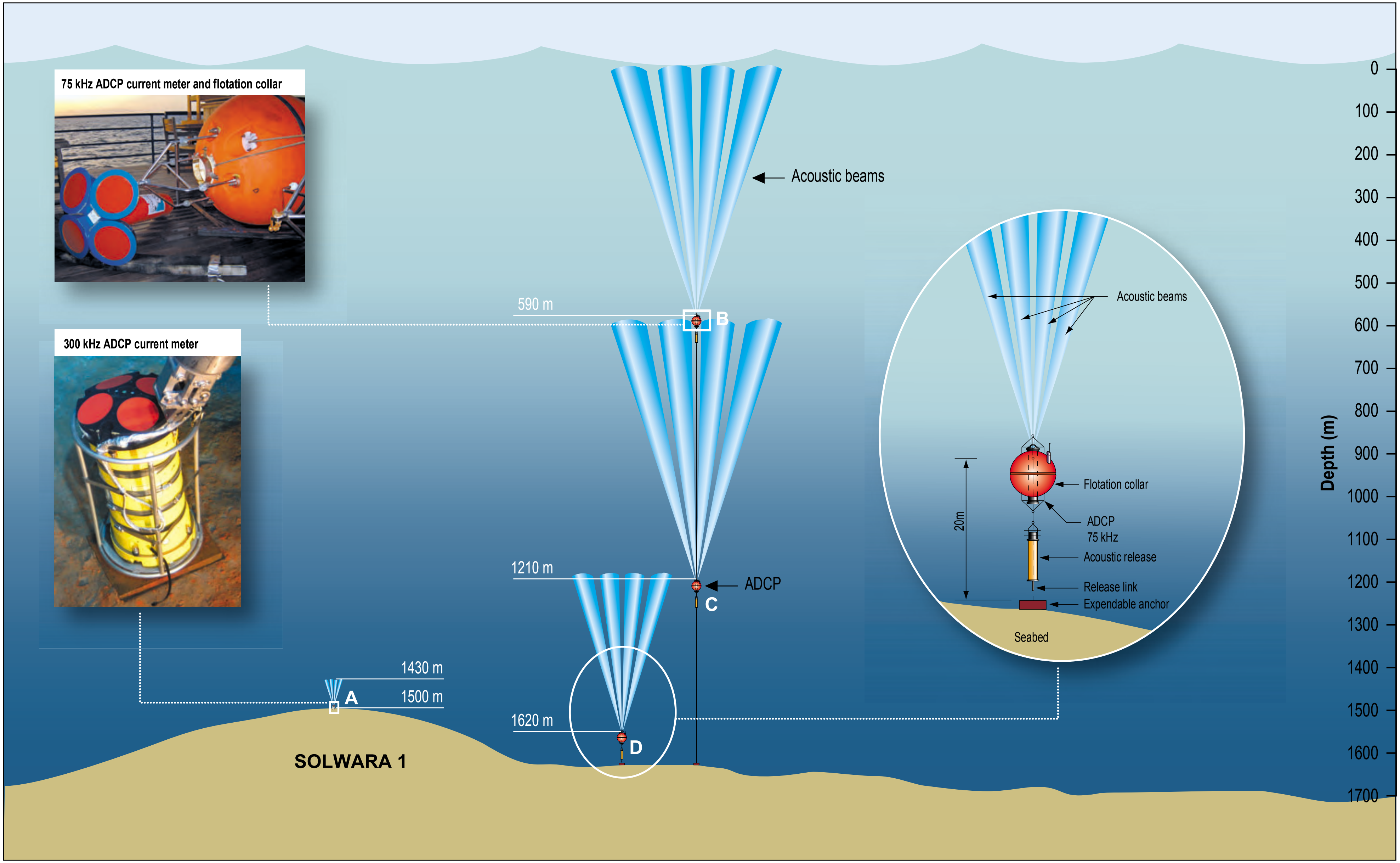
Sites B, C and D

Two additional moorings comprising three 75 kHz ADCPs were deployed at eastern extent of Solwara 1 (Figure 3.5) at sites B, C and D. Details of deployment depths and durations are shown in Table 3.1. The frequency of the 75 kHz instruments enabled measurement of current velocity profiles over approximately 600 m, thereby allowing currents to be measured over the entire water column.

The 75 kHz ADCPs were deployed in an upward-looking orientation (Figure 3.5). Each ADCP was housed within a flotation collar on a taught-wire mooring cable, moored to the seafloor with 600 kg concrete sacrificial anchors. There were two moorings:

- One mooring contained two 75 kHz ADCPs at approximately 600 and 1,200 m water depth, sites B and C, respectively. The instruments were deployed on three occasions and currents were measured over the period November 2006 to November 2007.
- The second mooring contained a single 75 kHz ADCP positioned 25 m above the seabed (Site D). The 75 kHz ADCP was deployed four times, enabling currents to be measured from late January 2007 to the end of February 2008.

The 75 kHz ADCPs were recovered, serviced and re-deployed every 90 days. The instruments were recovered by activating an acoustic release located in the mooring just below the 75 kHz ADCP. A UHF radio transmitter and pressure-activated strobe light was also embedded in each mooring flotation collar to enable location and recovery of the instruments.



coffey natural systems	Job No: 853	Nautilus Minerals Niugini	Current meter deployments at Solwara 1	Figure No: 3.5
	File Name: 853_16_F03.05_HB	Solwara 1 Project		

The 75 kHz ADCP moorings were located immediately east of the proposed Solwara 1 mine area.

The 75 kHz ADCPs were programmed to measure current velocities every hour. For each of the deployments, current velocities were measured every 16 m, throughout the water column.

Table 3.1 ADCP Deployments at Solwara 1

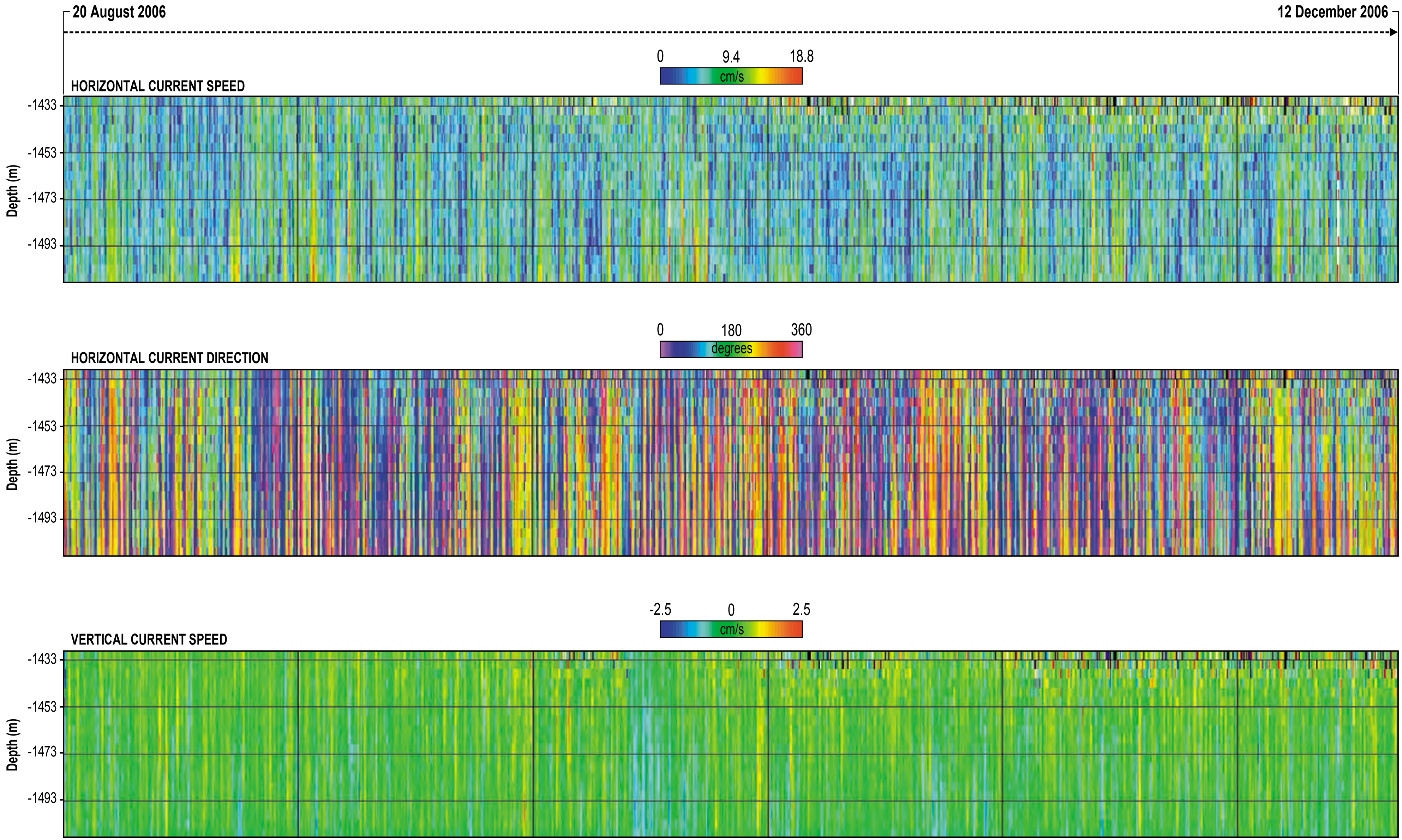
ADCP	Recording range (m)	Depth (m)	Deployment	Recovery
A 300 kHz Workhorse sentinel	80	1,500	20 Aug 06	22 Mar 2007
		1,500	23 Mar 07	26 Aug 2007
B 75 kHz, Workhorse long ranger	600	597	01 Nov 06	25 Jan 2007
		589	30 Jan 07	5 May 2007
		577	08 May 07	24 Aug 2007
		594	26 Aug 07	25 Nov 2007
C 75 kHz, Workhorse long ranger	600	1,200	01 Nov 06	25 Jan 2007
		1,180	26 Jan 07	5 May 2007
		1,205	08 May 07	24 Aug 2007
		1,210	26 Aug 07	25 Nov 2007
D 75 kHz, Workhorse long ranger	600	1,619	30 Jan 07	5 May 2007
		1,625	08 May 07	24 Aug 2007
		1,620	25 Aug 07	25 Nov 2007
		1,621	26 Nov 07	29 Feb 2008

Results

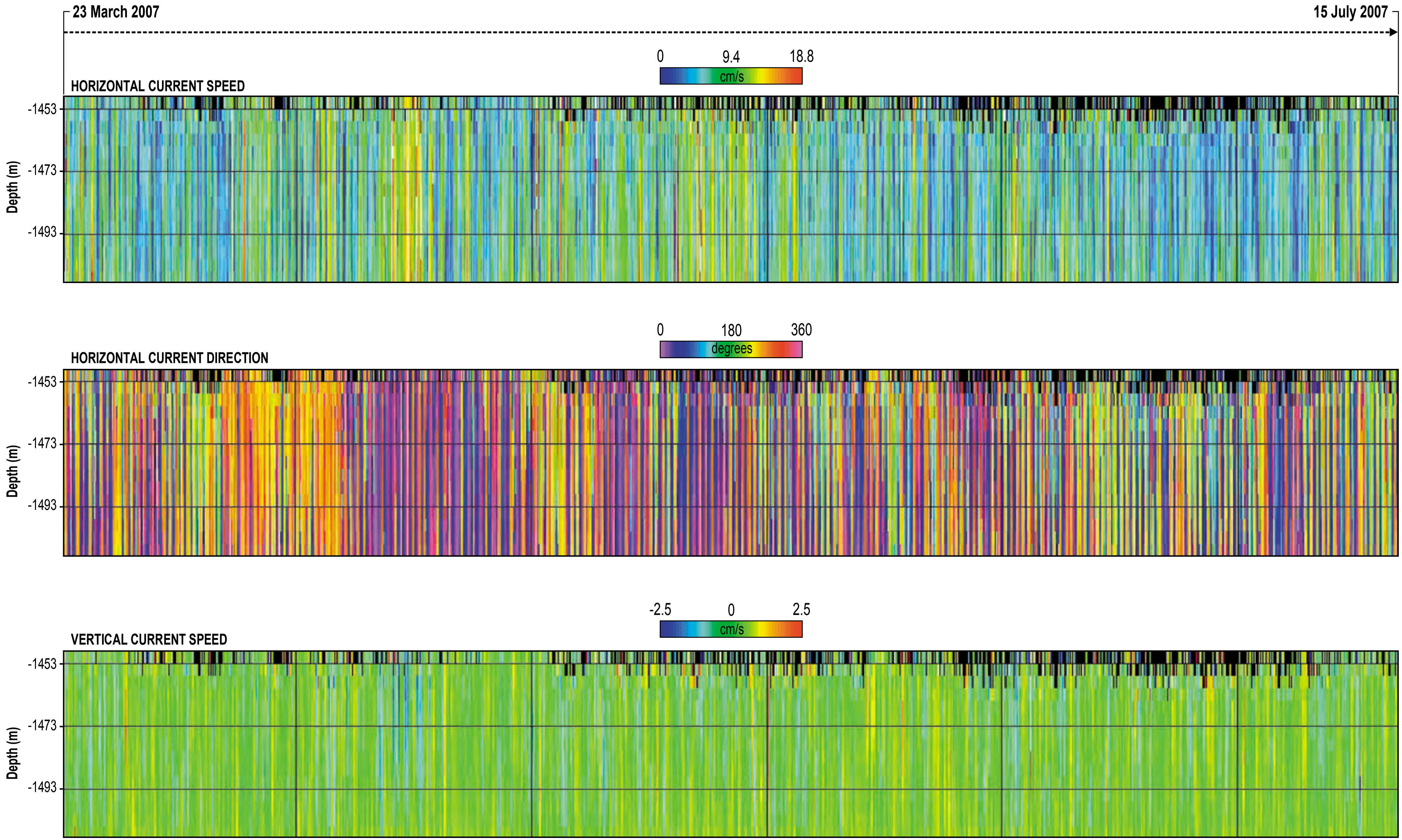
Currents at Solwara 1 Mound – Site A

As shown in Table 3.1, the 300 kHz ADCP at Site A was deployed twice over a 12 month period between 20 August 2006 and 26 August 2007. Currents were recorded from the top of Solwara 1 mound to 80 m above the mound.

Representative sub-sections of currents recorded during these two deployments are presented as time series of three-dimensional current speed and direction in Figures 3.6 and 3.7.



coffey natural systems	Job No: 853	Nautilus Minerals Niugini	NAUTILUS Minerals Niugini	Current velocity time series 20 August 2006 to 12 December 2006
	File Name: 853_16_F03.06_HB	Solwara 1 Project		Figure No: 3.6



coffey natural systems	Job No: 853	Nautilus Minerals Niugini	
	File Name: 853_16_F03.07_HB	Solwara 1 Project	

Current velocity time series
23 March 2007 to 15 July 2007

Figure No: 3.7

Horizontal Currents

Current roses showing horizontal currents recorded over four different depths from the seafloor to 80 m above the seafloor are presented in Figures 3.8 to 3.11 as follows:

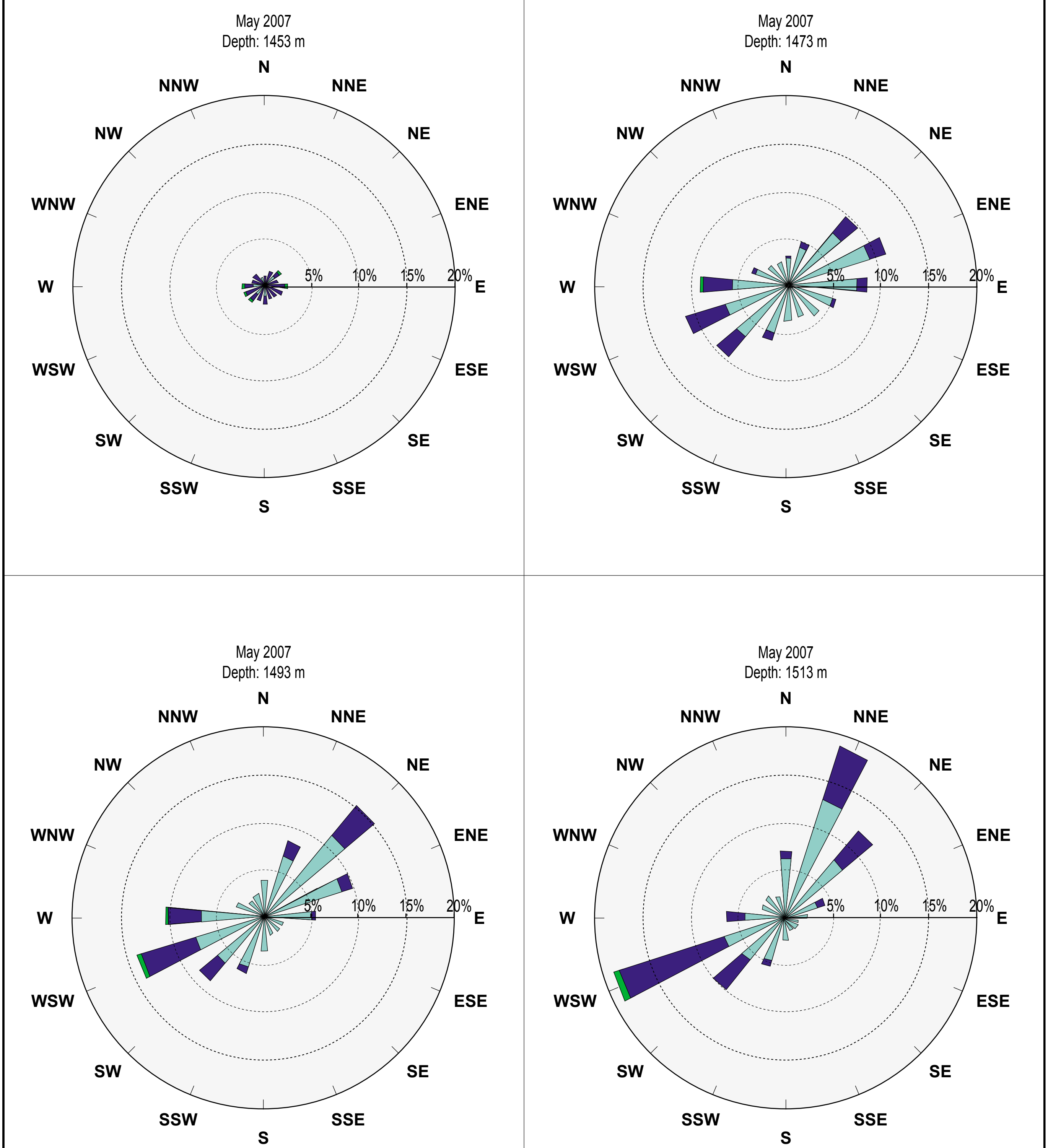
- Figure 3.8 shows horizontal currents in May 2007 i.e., during the transitional period between the northwest and southeast monsoon seasons.
- Figure 3.9 presents horizontal currents during the southeast monsoon season i.e., September 2006.
- Horizontal currents recorded during November 2006 (the transitional period between the southeast and northwest monsoon seasons) are provided in Figure 3.10.
- Horizontal currents present at Solwara 1 mound during February 2007 – the northwest monsoon season – are shown in Figure 3.11.

Results indicate that currents at and immediately above the seafloor at Solwara 1 are relatively weak, averaging 6 cm/s and exceeding 15 cm/s only 5% of the time. At short time scales (i.e., days), flow directions appear to be dominated by tidal influences. Figure 3.8 shows that during any given month in the year currents immediately above the seafloor at Solwara 1 typically flow to the north-northeast and west-southwest, corresponding to the tidal axis at this depth.

The overall net drift over longer time scales (i.e., weeks to months) is shown in Figure 3.12 as a progressive vector diagram and indicates that it is from the southeast to the northwest.

Vertical Currents

Vertical current velocities are generally downward above Solwara 1 mound (shown in Figures 3.6 and 3.7 as negative speeds) with some periodic upward trends (shown as positive speeds).



Note:

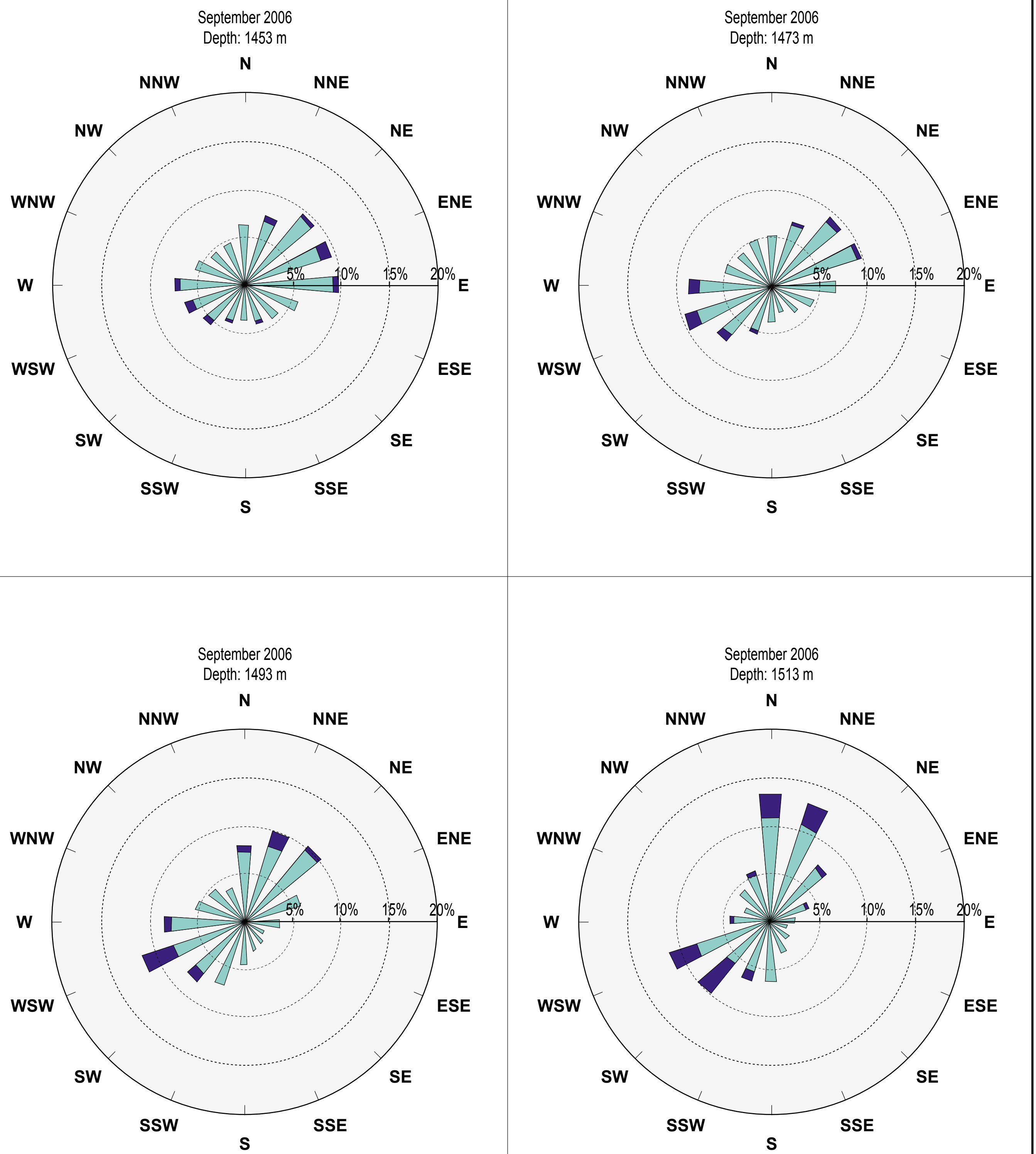
1. Percentages show the proportion of time that currents move in a given direction.
2. Roses show the direction that the currents are moving.

LEGEND

Current speed (m/s)

- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3

coffey natural systems	Job No: 7008	Nautilus Minerals Niugini	NAUTILUS Minerals Niugini	Current roses at 20-m-intervals at Solwara 1 mound during the northwest – southeast monsoon transitional season	Figure No: 3.8
	File Name: 853_16_F03.08_KB	Solwara 1 Project			



Note:

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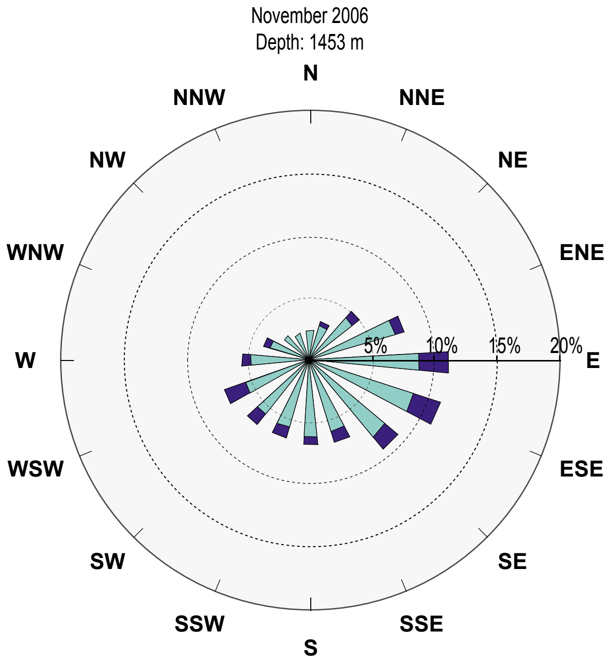
2. Roses show the direction that the currents are moving.

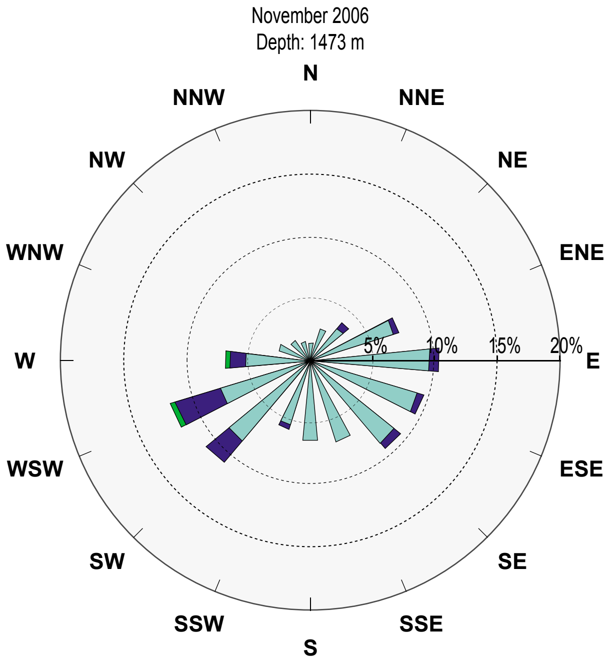
LEGEND

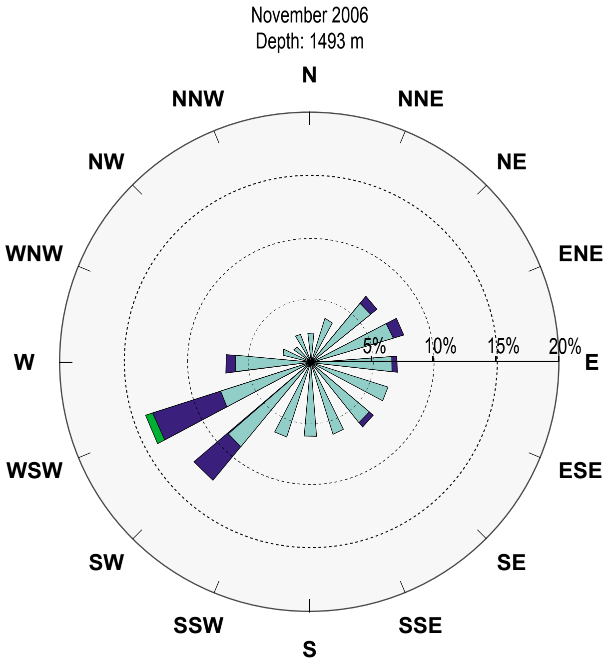
Current speed (m/s)

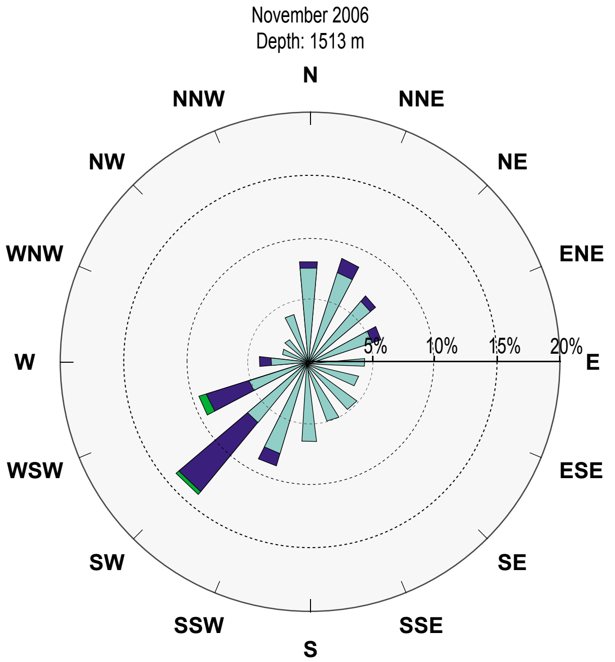
- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3

coffey natural systems	Job No: 7008	Nautilus Minerals Niugini	NAUTILUS Minerals Niugini	Current roses at 20-m-intervals at Solwara 1 mound during the southeast monsoon season	Figure No: 3.9
	File Name: 853_16_F03.09_KB	Solwara 1 Project			









Note:

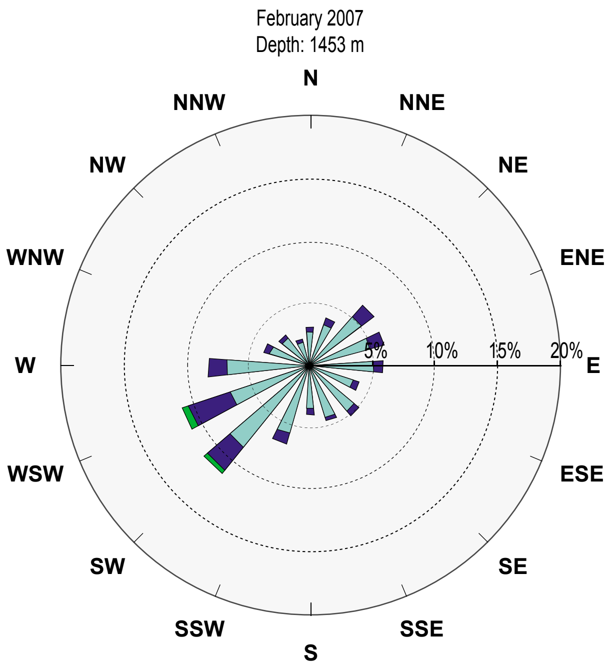
1. Percentages show the proportion of time that currents move in a given direction.
2. Roses show the direction that the currents are moving.

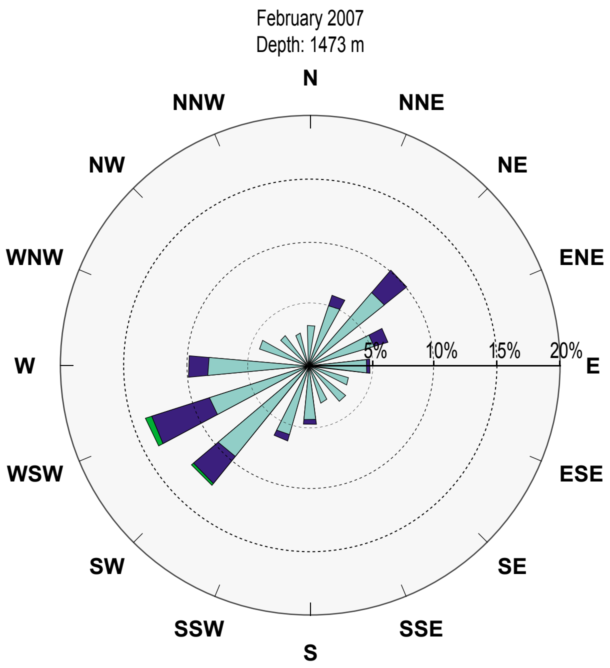
LEGEND

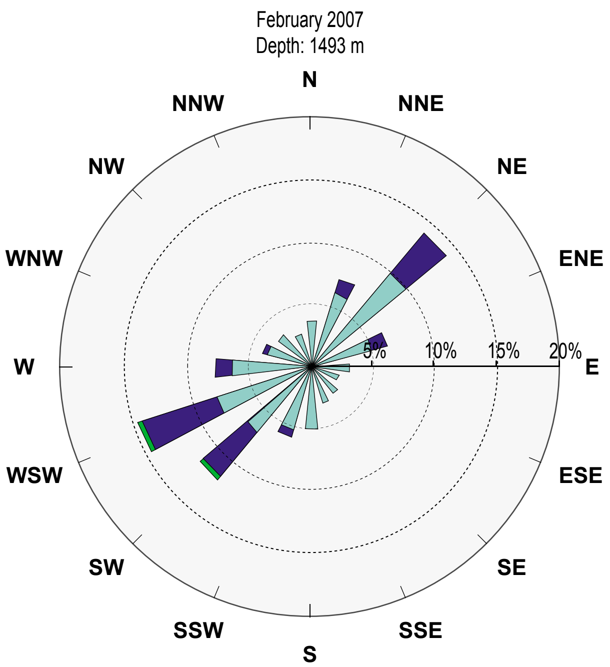
Current speed (m/s)

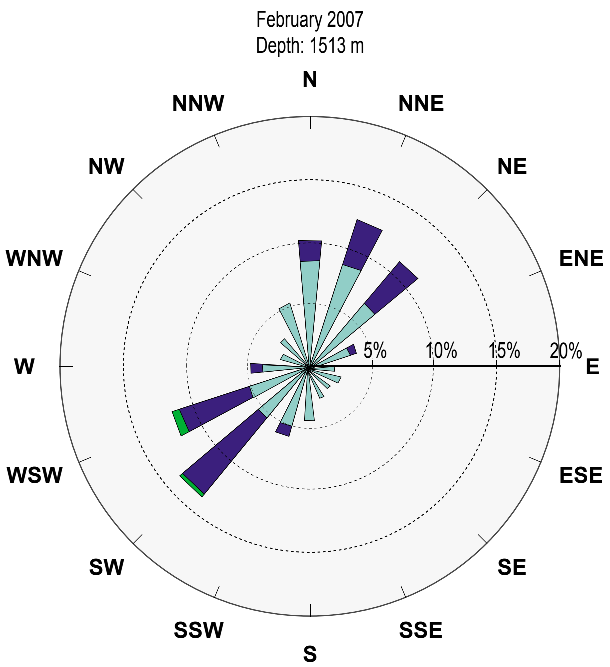
- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3

coffey natural systems	Job No: 7008	Nautilus Minerals Niugini	NAUTILUS Minerals Niugini	Current roses at 20-m-intervals at Solwara 1 mound during the southeast – northwest monsoon transitional season	Figure No: 3.10
	File Name: 853_16_F03.10_KB	Solwara 1 Project			









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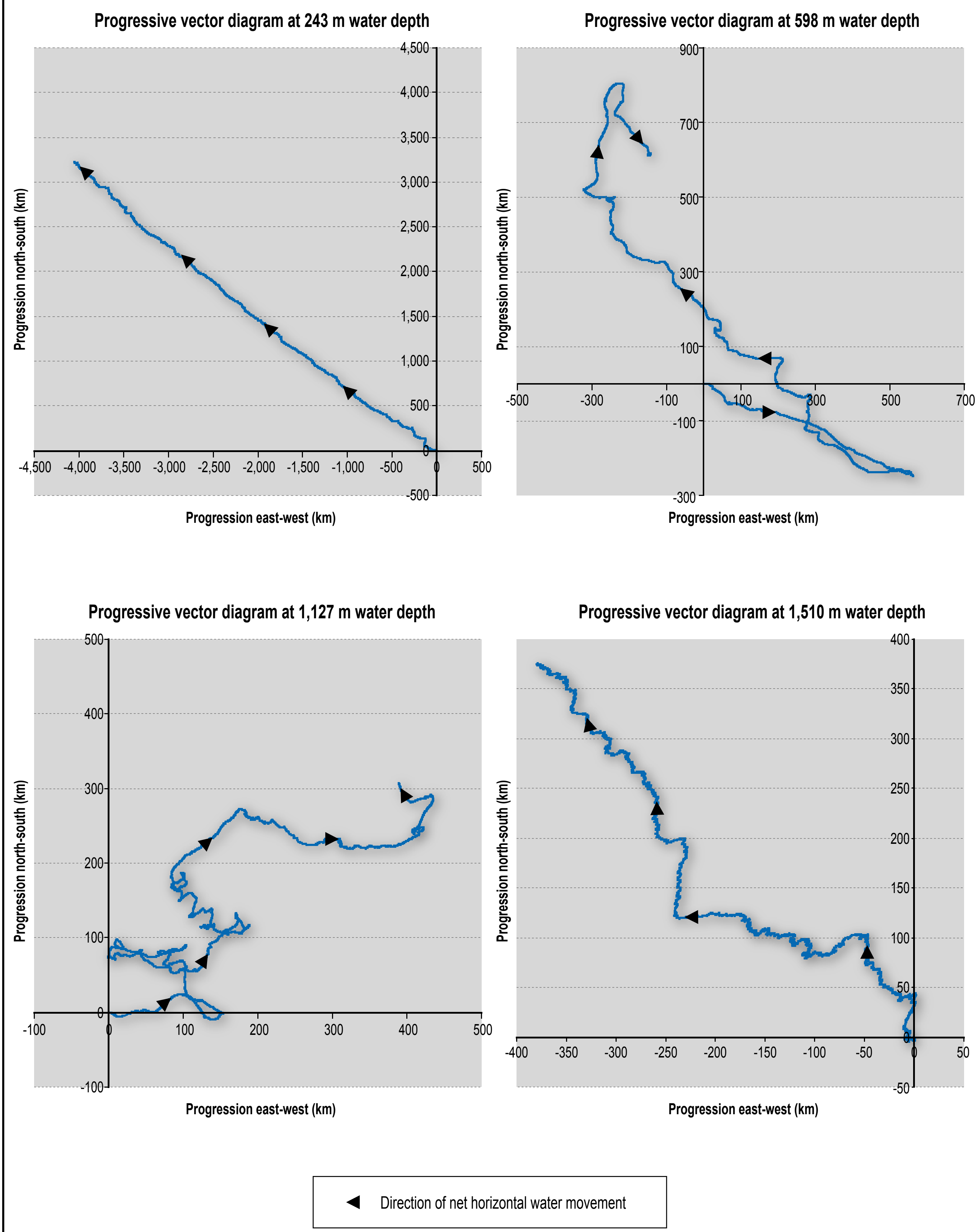
LEGEND

Current speed (m/s)

- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3

coffey natural systems	Job No: 7008	Nautilus Minerals Niugini	NAUTILUS Minerals Niugini	Current roses at 20-m-intervals at Solwara 1 mound during the northwest monsoon season
	File Name: 853_16_F03.11_KB	Solwara 1 Project		Figure No: 3.11



coffey natural systems	Job No: 853	Nautilus Minerals Niugini	NAUTILUS Minerals Niugini	Progressive vector diagram of net horizontal water movement over 12 months at Solwara 1	Figure No: 3.12
	File Name: 853_16_F03.12_HB	Solwara 1 Project			

Full Water Column Currents – Sites B, C and D

Three-dimensional current velocities were recorded over the entire water column at the eastern extent of Solwara 1 at sites B, C and D (Figure 3.4) for at least 12 months at each location (Table 3.1).

Horizontal Currents

Horizontal currents were analysed at six different depths to provide a representative cross section of current speed and direction over the entire water column[6]. Figures 3.13 to 3.16 provide data from the period of record, presented as current roses showing seasonal current speed and direction at various depth intervals as follows:

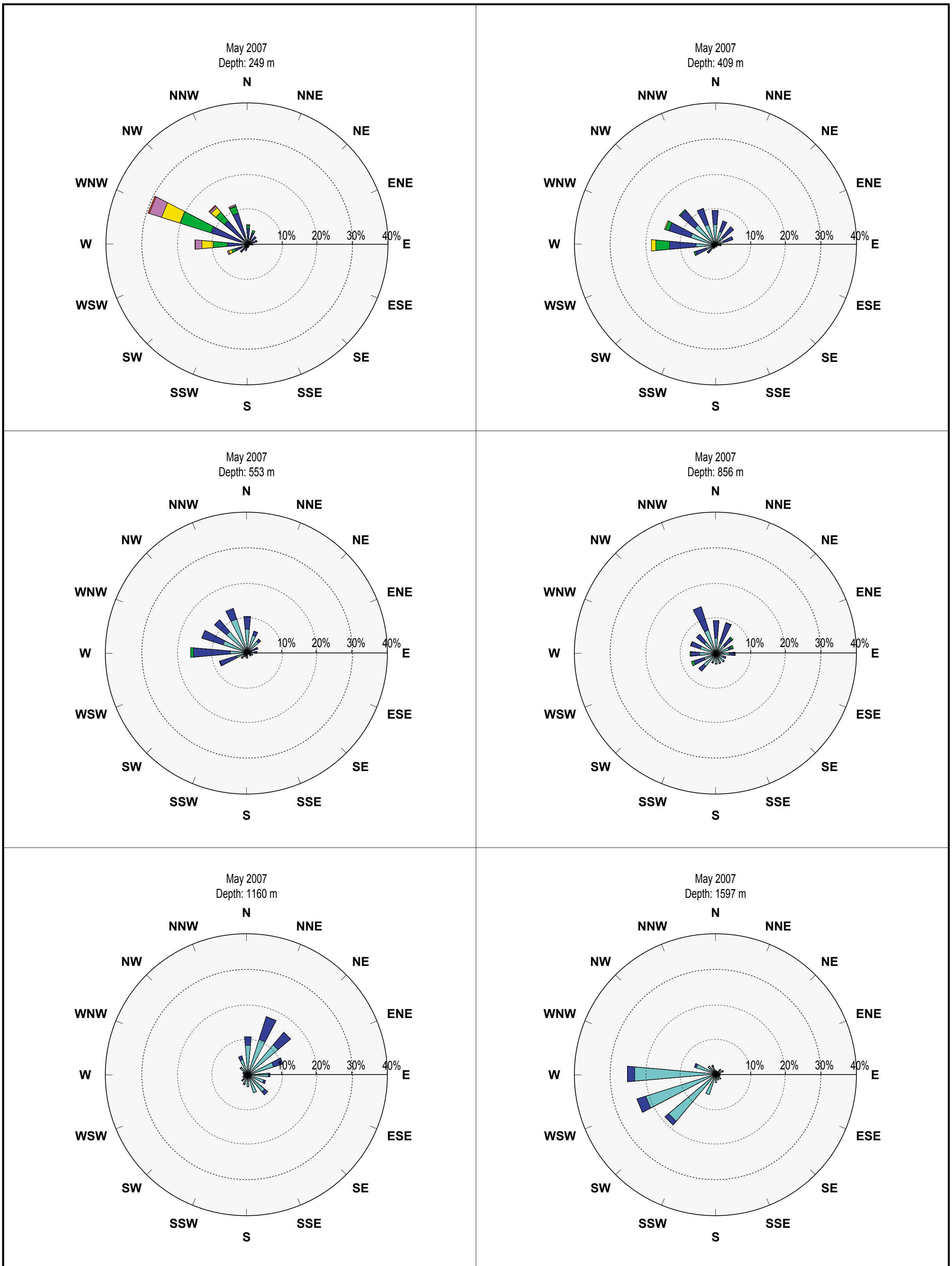
- Horizontal currents recorded during the transitional period between the northwest and southeast monsoon seasons (i.e., May 2007) are shown in Figure 3.13.
- Figure 3.14 shows horizontal currents recorded during the southeast monsoon season i.e., September 2006.
- Horizontal currents recorded during recorded during November 2006 – representative of the transitional period between the southeast and northwest monsoon seasons – is provided in Figure 3.15.
- Finally, horizontal currents recorded in February 2007 during the northwest monsoon season are shown in Figure 3.16.

Current velocities in the upper 400 m of the water column are generally in the order of 10 to 20 cm/s. Strongest current speeds occur during the northwest to southeast monsoon transition season in May in the upper water column at approximately 250 m depth (Figure 3.13). Speeds in excess of 40 cm/s were recorded at this depth during this period for approximately 5% of the time, or, 1 to 2 days during the month. Year-round net water drift at 250 m is to the northwest (Figure 3.12); this direction is likely governed by the St Georges Undercurrent (Section 3.3.1 and Figure 3.3).

Water velocity in the mid-water column (from 400 to 800 m) is also generally between 10 to 20 cm/s. Net drift in the mid water during the northwest monsoon season is to the southeast but changes direction and flows to the west-northwest during the southeast monsoon season (Figure 3.12). During the transitional seasons, water at various depth intervals below 400 m does not appear to follow any distinct pattern, and may be confined by geomorphology as currents tend to flow in an arc between southeast and southwest.

Net water movement between 800 and 1,200 m water depth is generally to the east-northeast but can move to the west on occasions (Figure 3.12). Horizontal current speeds are generally between 10 and 20 cm/s.

[6] As each ADCP was deployed in a slightly different location after their respective recoveries, the depths of the instruments varied to a small extent (tens of metres). As a result, the depth intervals vary marginally for each period represented.



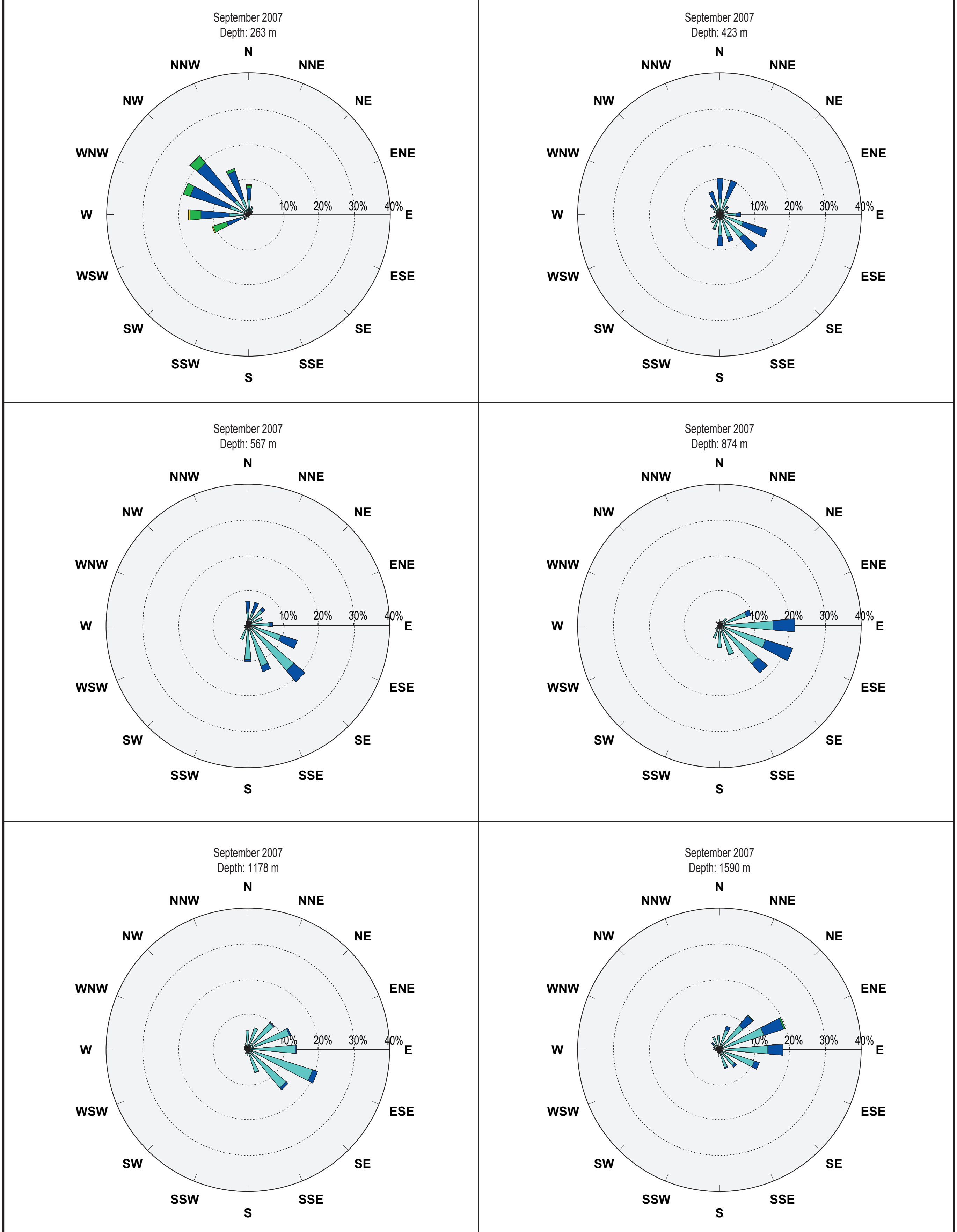
Note:

1. Percentages show the proportion of time that currents move in a given direction.
2. Roses show the direction that the currents are moving.

LEGEND
Current speed (m/s)

0 - 0.1	0.3 - 0.4
0.1 - 0.2	0.4 - 0.5
0.2 - 0.3	0.5

coffey natural systems	Job No: 7008	Nautilus Minerals Niugini	NAUTILUS Minerals Niugini	Current roses at various intervals over the entire water column during the northwest – southeast monsoon transitional season	Figure No: 3.13
	File Name: 853_16_F03.13_KB	Solwara 1 Project			



Note:

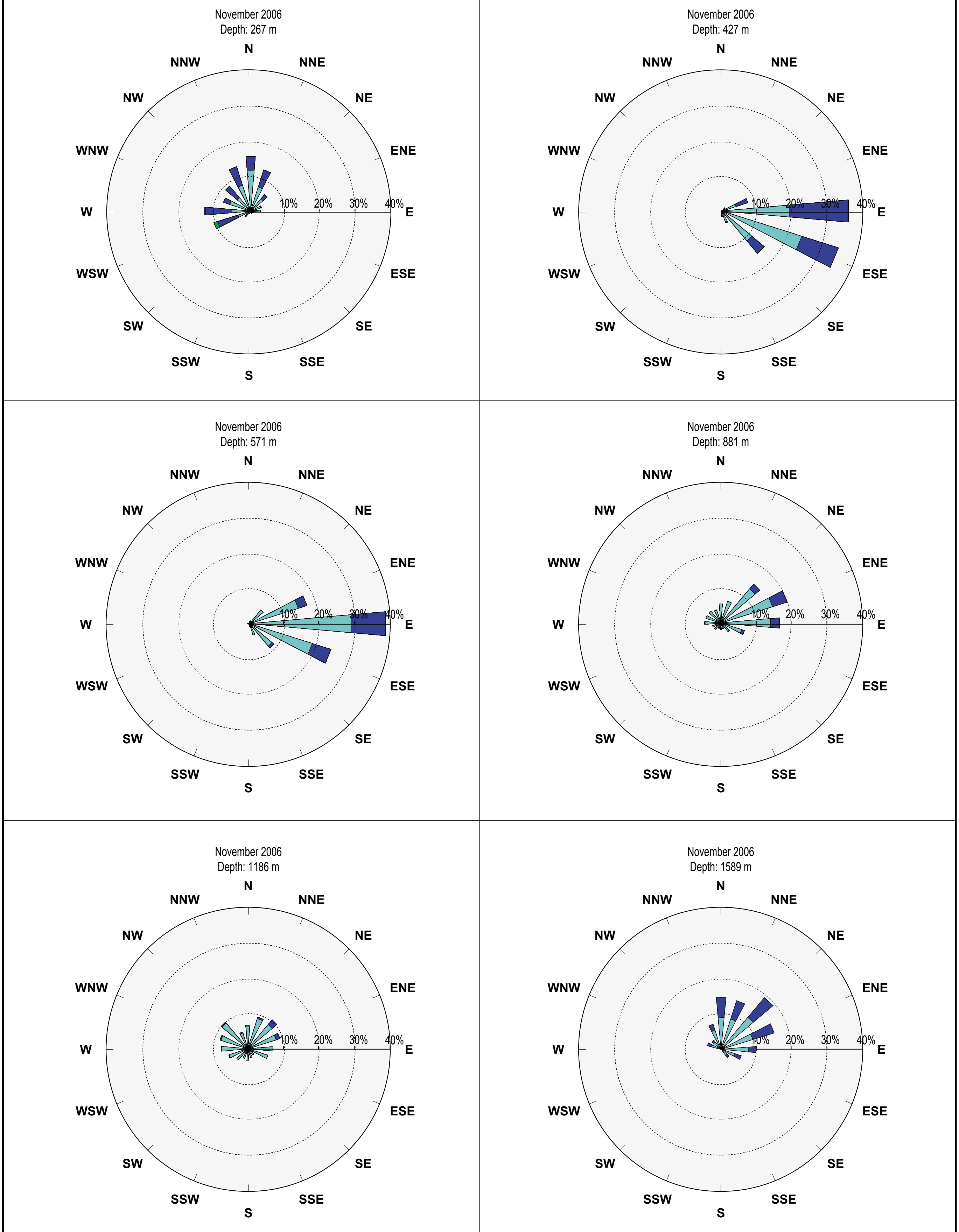
1. Percentages show the proportion of time that currents move in a given direction.
2. Roses show the direction that the currents are moving.

LEGEND
Current speed (m/s)

0 - 0.1	0.3 - 0.4
0.1 - 0.2	0.4 - 0.5
0.2 - 0.3	0.5

coffey natural systems	Job No: 7008	Nautilus Minerals Niugini	NAUTILUS Minerals Niugini	Figure No:
	File Name: 853_16_F03.14_KB	Solwara 1 Project		3.14

Current roses at various intervals over the entire water column during the southeast monsoon season



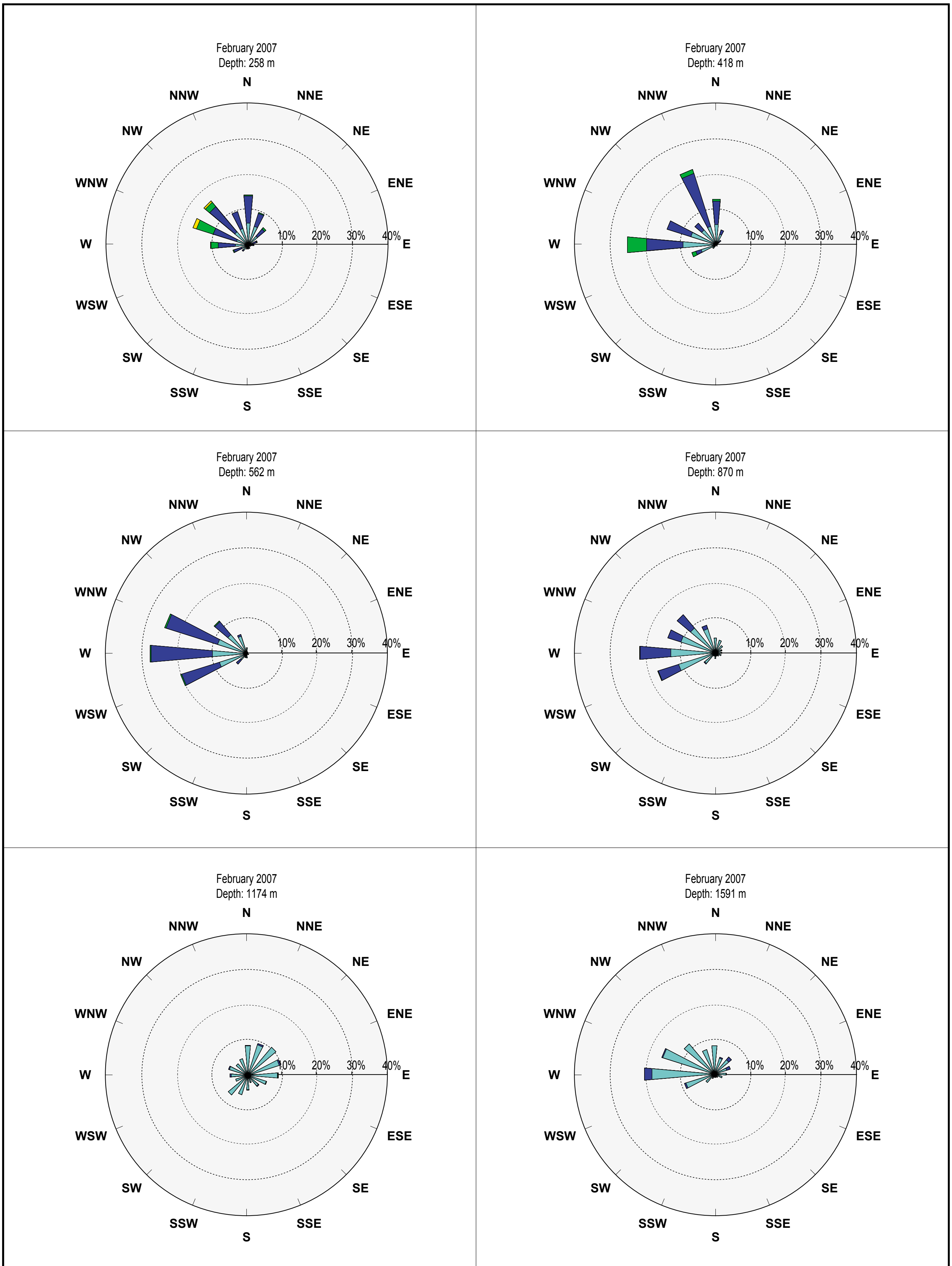
Note:

1. Percentages show the proportion of time that currents move in a given direction.
2. Roses show the direction that the currents are moving.

LEGEND
Current speed (m/s)

- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5

coffey natural systems	Job No: 7008	Nautilus Minerals Niugini	NAUTILUS Minerals Niugini	Current roses at various intervals over the entire water column during the southeast – northwest monsoon transitional season
	File Name: 853_16_F03.15_KB	Solwara 1 Project		Figure No: 3.15



Note:

1. Percentages show the proportion of time that currents move in a given direction.
2. Roses show the direction that the currents are moving.

LEGEND
Current speed (m/s)

- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5

coffey natural systems	Job No: 7008 File Name: 853_16_F03.16_KB	Nautilus Minerals Niugini Solwara 1 Project	NAUTILUS Minerals Niugini	Current roses at various intervals over the entire water column during the northwest monsoon season	Figure No: 3.16

Vertical Currents

Vertical currents have been analysed over the same selected depths and months as the horizontal currents described above. Time series of vertical current velocities are presented in Figures 3.17 to 3.20 as follows[7]:

- Vertical currents presented in Figure 3.17 show horizontal currents in May 2007 i.e., during the transitional period between the northwest and southeast monsoon seasons.
- Figure 3.18 presents horizontal currents during the southeast monsoon season i.e., September 2006.
- Horizontal currents recorded during November 2006 (the transitional period between the southeast and northwest monsoon seasons) are presented in Figure 3.19.
- Horizontal currents present at Solwara 1 mound during February 2007 – the northwest monsoon season – are shown in Figure 3.20.

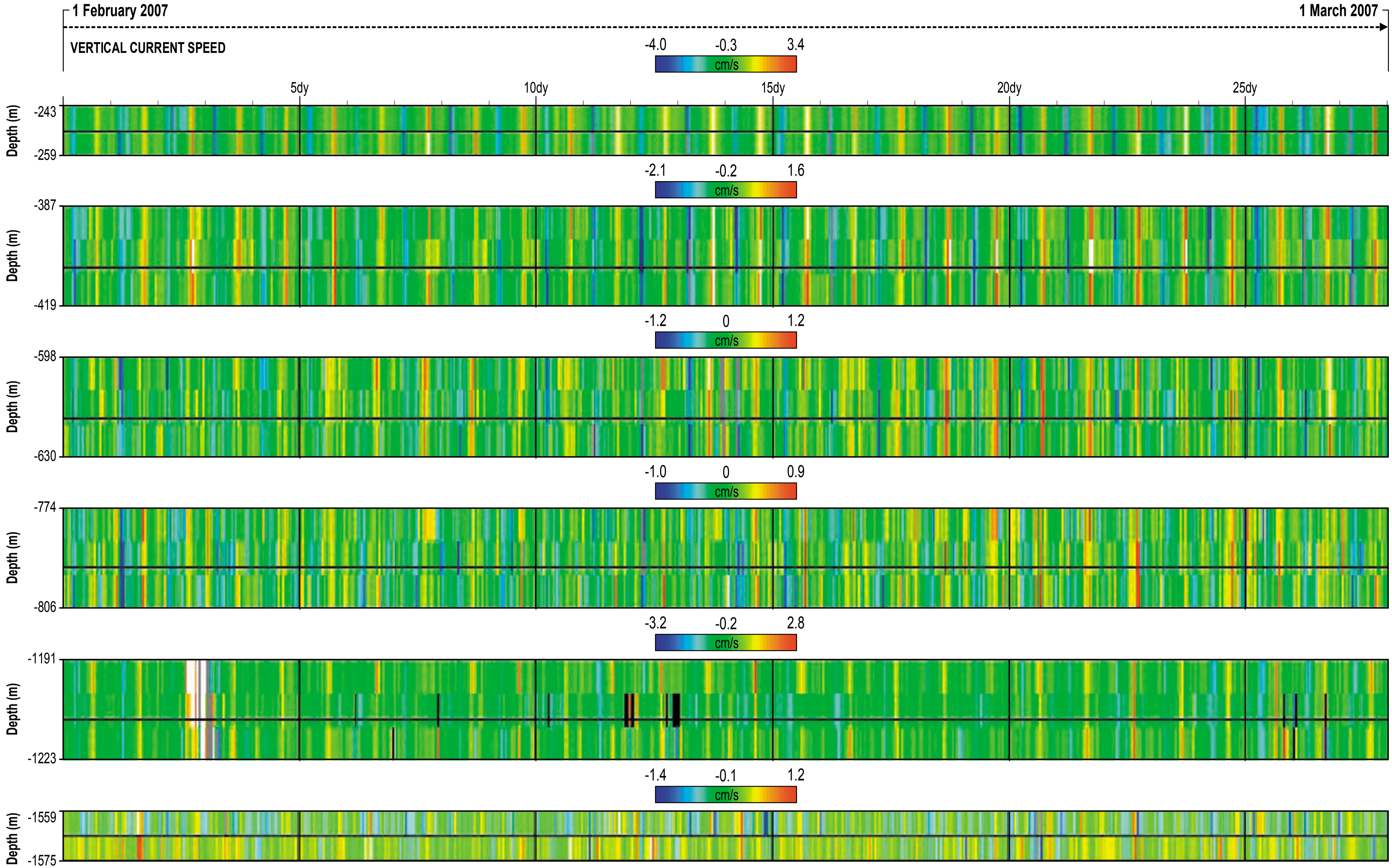
The entire record of currents collected over the data collection program shows periodic upward and downward vertical motions, generally in the upper 400 m of the water column. These vertical motions are particularly prevalent during the northwest monsoon season and transition to the southeast monsoon season.

During the southeast monsoon season, there is much greater variability in vertical movement of water in the upper water column that may indicate a much stronger tidal influence on vertical currents.

The frequency of upwards and downwards motions through the water column evident during the northwest monsoon season does not occur at the semi-diurnal tidal frequency of 12.5 hours, but rather the downwards motions peak at sunrise every day and the upwards motions begin at sunset and last for four to five hours. Due to the regular upward and downward water movements, the vertical motions are not consistent with upwelling and are instead interpreted to represent the vertical migrations of zooplankton i.e., to the surface at sunset and to deeper water at sunrise.

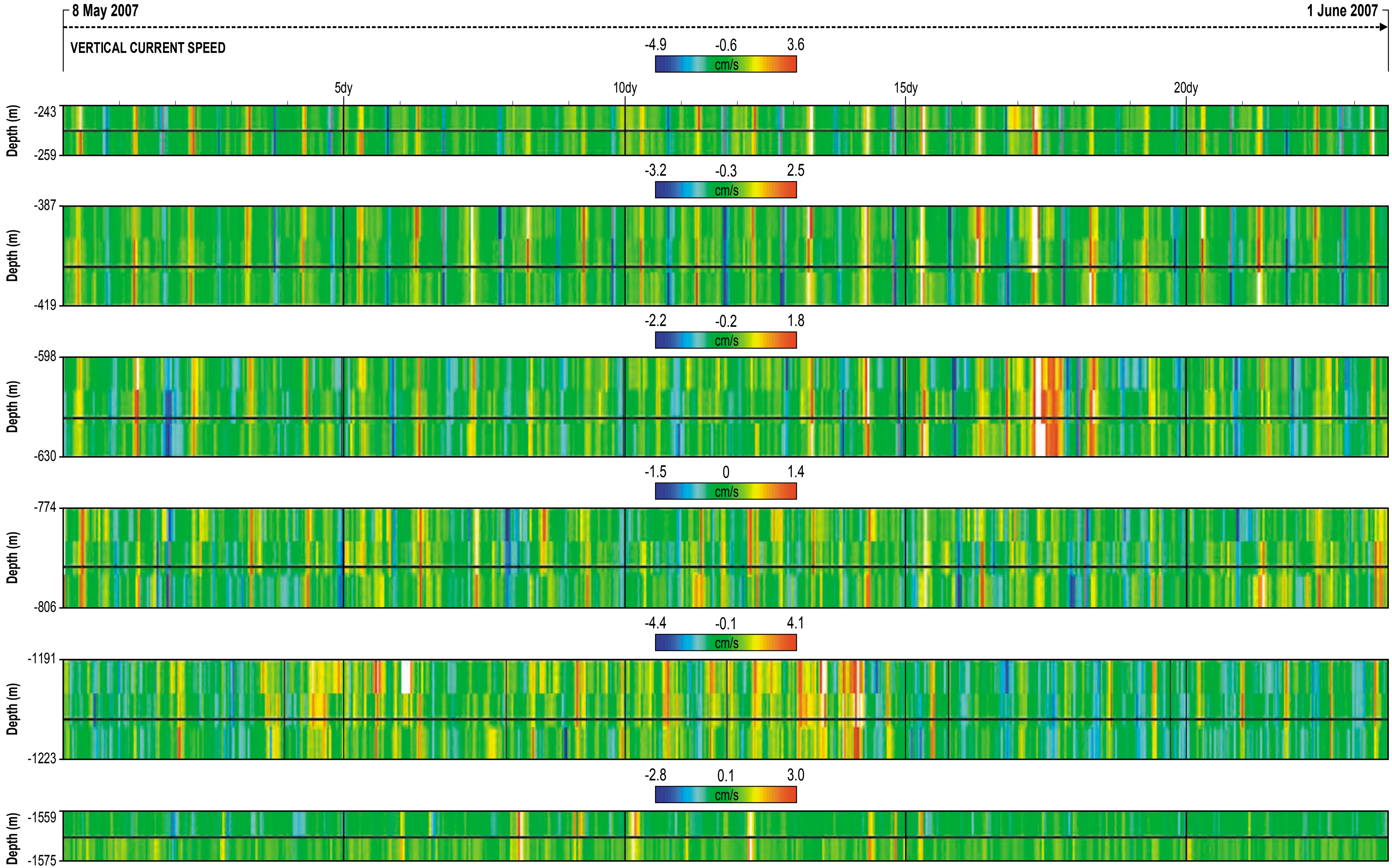
In deeper water, vertical currents are relatively weak (compared to shallower depths) with no apparent net movement either up or down through the water column.

[7] Upward water movements are shown as positive values and downward movements as negative values in Figures 3.17 to 3.20.

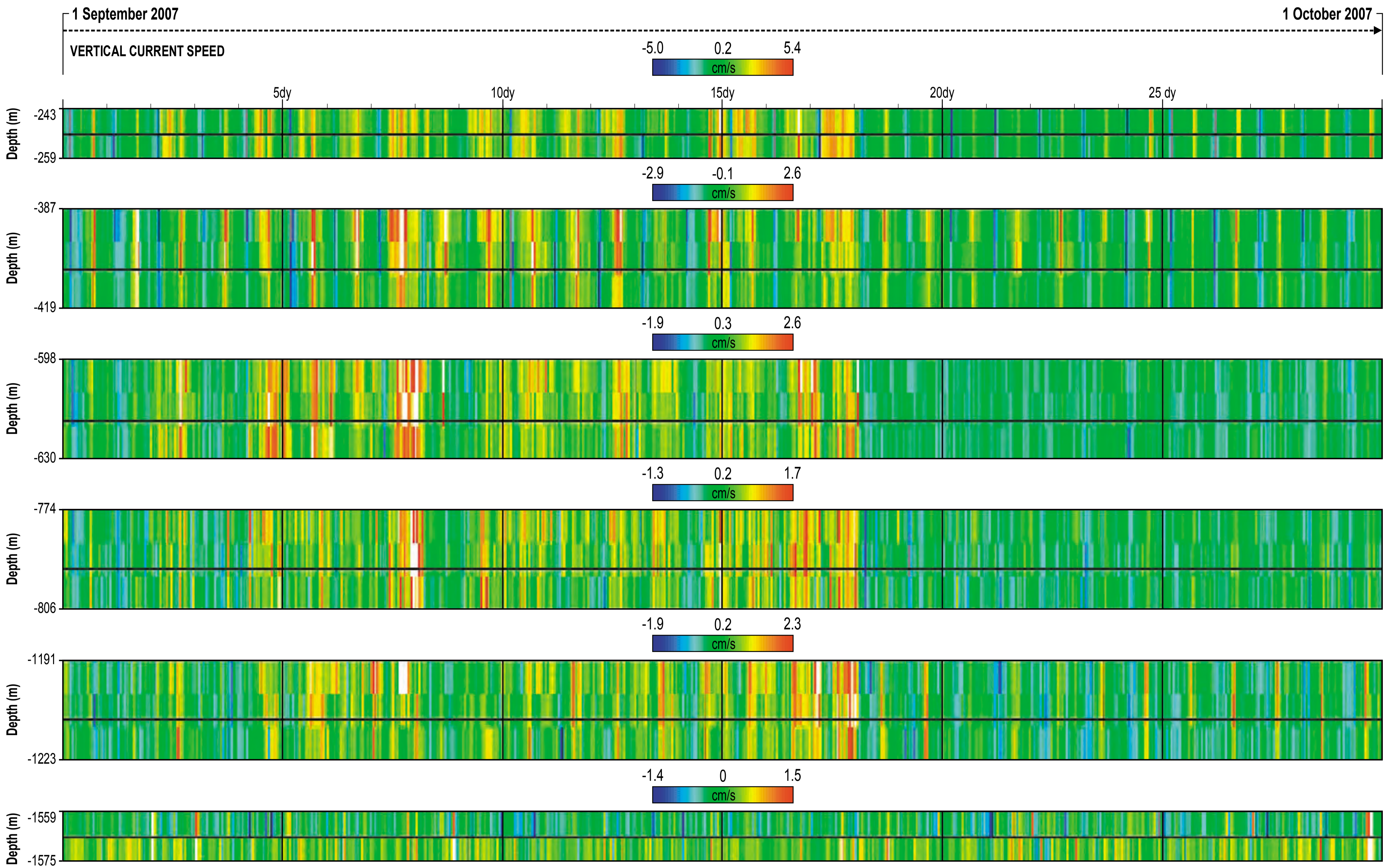


coffey natural systems	Job No: 853	Nautilus Minerals Niugini	Figure No: 3.17
	File Name: 853_16_F03.17_HB	Solwara 1 Project	

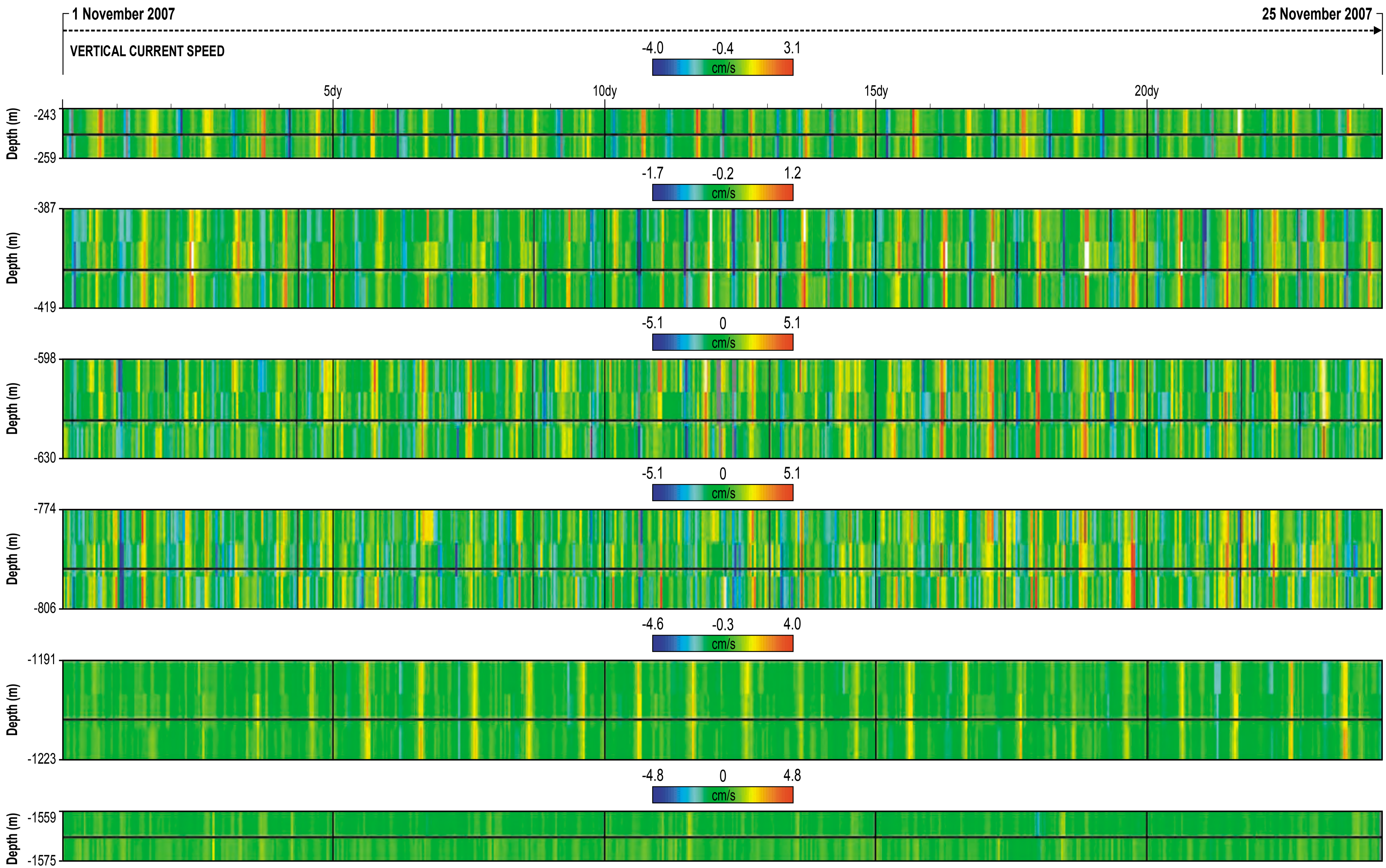
Vertical current velocities at intervals over the water column during the northwest monsoon season



coffey natural systems	Job No: 853	Nautilus Minerals Niugini		Vertical current velocities at intervals over the water column during the northwest-southeast monsoon transitional season
	File Name: 853_16_F03.18_HB	Solwara 1 Project		Figure No: 3.18



coffey natural systems	Job No: 853	Nautilus Minerals Niugini	NAUTILUS Minerals Niugini	Vertical current velocities at intervals over the water column during the southeast monsoon season	Figure No: 3.19
	File Name: 853_16_F03.19_HB	Solwara 1 Project			



coffey natural systems	Job No: 853 File Name: 853_16_F03.20_HB	Nautilus Minerals Niugini Solwara 1 Project	NAUTILUS Minerals Niugini
Vertical current velocities at intervals over the water column during the southeast-northwest transitional monsoon season	Figure No: 3.20		

Tidal Influence

In the upper water column (from 150 m to 250 m below the surface), northwesterly wind-driven currents are relatively strong. The velocity of both the upper and deep-water currents increases as the southeast monsoon season commences.

Analysis of currents suggests that from the surface to 1,200 m depth currents appear to be driven by wind and large-scale water surface and sub-surface currents. In the deeper waters (from 1,470 m to the seafloor), the currents appear to be primarily driven by tides.

4. REFERENCES

King, B. Chief Scientist and Managing Director of Asia-Pacific Applied Science Association. Queensland. E-mail. 13 September 2007.

McAlpine, J. Keig, G. and Falls, R. 1983. Climate of Papua New Guinea. CSIRO. Australia.

Steinberg, C.R., Choukroun, S.M., Slivkoff, M.M., Mahoney, M.V., and Brinkman, R.M. 2006. Currents in the Bismarck Sea and Kimbe Bay, Papua New Guinea. Report prepared by the Australian Institute of Marine Science for The Nature Conservancy. TNC Pacific Island Countries Report No. 6/06.

Triton Consultants Ltd. 2006. SaltyDaug Project Feasibility Study- Mining of Subsea Massive Sulphide Deposits, Metocean Data Summary. Draft report prepared for Placer Dome Group, Vancouver, BC.

Wells, M., Vallis, G., and Silver, S. 1999. Tectonic Processes in Papua New Guinea and Past Productivity in the Eastern Equatorial Pacific Ocean. Nature, Volume 398, April.

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