EIA STUDY FOR PROJECT WAVE: COMPONENTS 1 & 2

EFFLUENT DISCHARGE MODELING REPORT FOR MIRFA SWTP

SEPTEMBER 2022

Prepared by:
Dome HSE Consulting
A Division of
Dome Oilfield Engineering & Services LLC

Dome HSE Consulting
A Division of
Dome Oilfield Engineering & Services L.L.C
1503, Al Masaood Tower
Hamdan Street, P.O.Box 6924
Abu Dhabi, United Arab Emirates
Tel: +971 2 6348000
Fax: +971 2 6348826
E-Mail: domead@domeint.com
Web site: www.domeint.com

Client: ILF/ADNOC Onshore			**Project No:** ED20.17		
Report Summary: EIA Study for Project Wave: Components 1 & 2 – Effluent Discharge Modeling Report_Mirfa SWTP			**Date:** 26th September 2022 **Document No:** ED21.17_Effluent Discharge Modeling Report_Mirfa SWTP		
3	Re-issued as Final	GH	NR	HA	29-Sep-22
2	Issued as Final	GH	NR	HA	18-Aug-21
1	Issued as Final	GH	NR	HA	11-Aug-21
0	Issued for Client Review	GH	NR	HA	01-Aug-21
Revision	**Description**	**Originator**	**Reviewed**	**Approved**	**Date**
The preparation of this report by Dome has been undertaken within terms of the Brief using all reasonable skills and care. The report has been prepared in accordance with the relevant UAE laws and regulations for review by the appropriate designated authorities. Dome accepts no responsibility for data provided by other bodies and no legal liability arising from the use by other persons of data or opinions contained in this report.			Distribution ☒Official ☐Public ☒Confidential		

TABLE OF CONTENTS

1 INTRODUCTION 1
1.1 Project Overview 1
1.2 Study Scope and Objectives 1
2 SIMULATION METHODOLOGY 3
2.1 Simulation Models and Modeling Process 3
2.2 Regulatory Guidelines and Requirements 5
3 MODELING METHODOLOGY 6
3.1 Overview 6
3.2 HYCOM 6
3.3 GCOM3D 7
3.4 Model Grids and Bathymetry 8
3.5 Verification of GCOM3D Sea levels 10
3.6 Verification of GCOM3D Currents 10
3.7 Plume Discharge Modelling 12
4 RESULTS AND DISCUSSIONS 14
4.1 Currents in the Vicinity of the Outfall 14
4.2 Plume Dispersion Results 14
5 CONCLUSIONS 20
6 REFERENCES 21

APPENDICES

AppendiX A – Meteorology and Oceonography in the Arabian Gulf

Appendix B – Bathymetry and ADCP Reports

LIST OF TABLES

Table 2.1 – Summary of Modeling Parameters and Inputs 3
Table 3.1 – Ocean Modelling Overview 8
Table 3.2 – Plume Discharge Modelling Overview 13

LIST OF FIGURES

Figure 1.1 – Proposed Al Nouf Pipeline Route and Associated Facilities 1
Figure 1.2 – Location of the Proposed SWTP and Intake/Outfall Configuration 2
Figure 2.1 – Preliminary Diffuser Design Configuration 4
Figure 3.1 – Modelling Flow Chart 6
Figure 3.2 – Surface Ocean currents in the Sea of Oman and the Arabian Gulf from HYCOM 7
Figure 3.3 – Region Covered by the Bathymetric Survey 9
Figure 3.4 – Bathymetric contours (MSL) after inclusion of the Bathymetric Survey Data 9
Figure 3.5 – Sea level predictions from GCOM3D (red) compared ADCP Data 10
Figure 3.6 – Near surface current speed predictions from GCOM3D (blue) compared with measurements of near surface currents by the ADCP (red). 11
Figure 3.7 – Near surface current direction predictions from GCOM3D (blue) compared with measurements of near surface current directions by the ADCP (red). 11
Figure 4.1 – Example of near surface currents in the coastal region surrounding Mirfa. 14
Figure 4.2 – Salinity levels (%) Above Ambient from the Brine Discharge in Winter Months (Regulatory Compliance – Outfall Option 1) 15
Figure 4.3 – Salinity levels (%) Above Ambient from the Brine Discharge in Summer Months (Regulatory Compliance – Outfall Option 1) 15
Figure 4.4 – Salinity levels (%) Above Ambient from the Brine Discharge in Winter Months (Recirculation – Outfall Option 1) 17
Figure 4.5 – Salinity levels (%) Above Ambient from the Brine Discharge in Summer Months (Recirculation – Outfall Option 1) 17
Figure 4.6 – Salinity levels (%) above ambient from the brine discharge at the extended pipeline in winter months (Recirculation – Outfall Option 2) 19
Figure 4.7 – Salinity levels (%) above ambient from the brine discharge at the extended pipeline in summer months (Recirculation – Outfall Option 2) 19
Figure A.1 – Sample Wind Field over the Arabian Gulf from ECMWF 23
Figure A.2 – Wind Rose in the Study Region from the ECMWF Atmospheric Model 24
Figure A.3 – Surface currents as the tide starts to flood at the Straits of Hormuz 25
Figure A.4 – Surface currents at peak flood tide through the Straits of Hormuz 26
Figure A.5 – Surface currents as the tide begins to ebb at the Straits of Hormuz 26

ABBREVIATIONS

CFD	Computational Fluid Dynamics
DOME	Dome Oilfield Engineering & Services
EIA	Environmental Impact Assessment
ECMWF	European Centre for Medium Range Weather Forecast
GCOM3D	GEMMS 3D Ocean Model
GEMMS	Global Environmental Modelling & Monitoring Systems
HSE	Health Safety and Environment
HSEIA	Health Safety& Environmental Impact Assessment
HYCOM	US Navy Hybrid Coordinate Global Ocean Model
LAT	Lowest Astronomical Tide
MSL	Mean Sea Level
MIWP	Mirfa Independent Water and Power
PLUME3D	GEMMS 3D Plume Dispersion Model
PPT	Parts Per Thousand
SWTP	SeaWater Treatment Plant
UAE	United Arab Emirates

1 INTRODUCTION

1.1 PROJECT OVERVIEW

ADNOC Onshore is implementing the Project Wave (the Project), which aims to utilize treated seawater as an alternative for the injection requirements on all ADNOC Onshore fields (BAB, Bu Hasa, NEB and South East). This Project Wave represent ADNOC ++ initiatives for ensuring an additional and more sustainable source of water for injection in ADNOC Onshore fields. The Project will include the following components (see Figure 1.1):

- Component-1: construction of a Seawater Treatment Plant (SWTP) at two locations (Mirfa and Nouf). Each consists of Seawater Intake, Outfall, Filtration and Sulphur Reduction Plant (SRP).
- Component-2: build a network of pipelines to transport treated, filtered, low-Sulphate seawater to all Onshore Fields (nine separate battery limits).
- Component-3: build a centralized pumping station and in-field distribution network to distribute treated water up to water injection wells.

The scope of the current Project is limited to Components 1 and 2 (i.e. Component 3 is located within existing oilfields and being implemented separately by ADNOC Onshore). ILF Consulting Engineers Abu Dhabi has been awarded by ADNOC with the Technical Advisor Services for the Project.

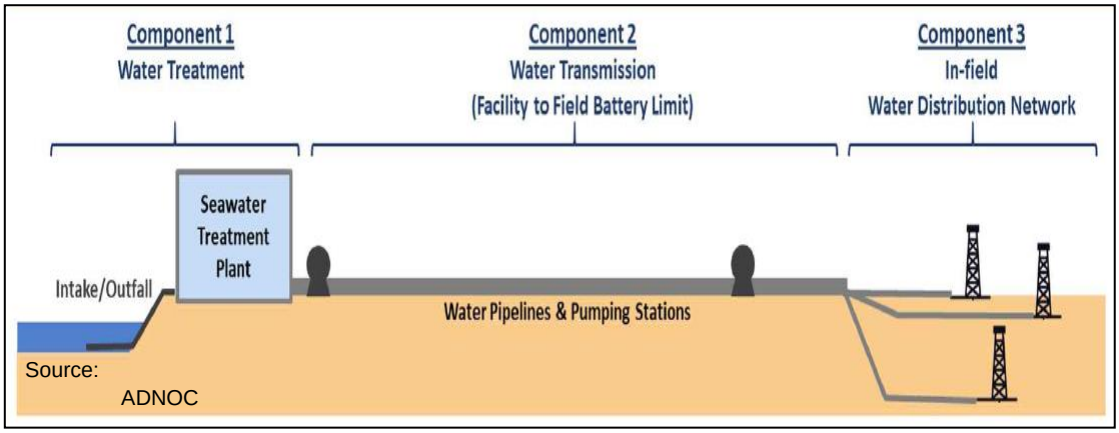


Figure 1.1 – Proposed Al Nouf Pipeline Route and Associated Facilities

Dome Oilfield Engineering & Services LLC (Dome) has been appointed by ILF and ADNOC Onshore to carry out the Environmental Impact Assessment (EIA) study for the proposed SeaWater Treatment Plant (SWTP) at Mirfa, including the proposed water distribution pipeline route. As part of the EIA study scope, an effluent discharge modeling was undertaken by Dome in partnership with Global Environmental Modelling and Monitoring Systems (GEMMS) in order to assess the fate of the effluent water (brine) discharge from the operation of the SWTP.

1.2 STUDY SCOPE AND OBJECTIVES

The two main objectives of the effluent discharge modeling were to assess:

- The regulatory compliance of the brine discharged from the proposed SWTP in Mirfa with the EAD prescribed mixing zone; and
- The potential for recirculation of brine from the outfall to the seawater intake and define optimum location for the outfall.

Figure 1.2 provides the proposed design of intake channel and outfall pipeline of the SWTP. The effluent will be discharged through a pipeline that will run in parallel with the proposed intake channel. The initial location proposed by the ILF/ADNOC for the end of the outfall pipe is approximately 600 m from the entrance to the seawater intake channel (i.e. Outfall Option 1, see Figure 1.2).

In order to study the potential for recirculation of brine to the sea water intake channel, a second simulation was undertaken with the outfall pipe extended by 300 m from the initial location (i.e. Outfall Option 2, see Figure 1.2). In this configuration, the end of the outfall pipe is approximately 900 m from the entrance to the seawater intake channel. The outfall discharge was assumed to have three (3) standard diffuser ports, 10 metres apart, oriented at 15 degrees to the horizontal. Two (2) ports were located on the north eastern side of the outfall pipe (the opposite side to the sea water intake channel) and the other port was located between the first two ports but on the south western side of the outfall pipe.

The existing Mirfa Independent Water and Power (MIWP) brine and cooling water shoreline discharges (see Figure 1.2) were included in the study but they did not have any significant impact on the results due to the location and the dilution of the brine discharge by the much larger volume of the associated cooling water discharge.

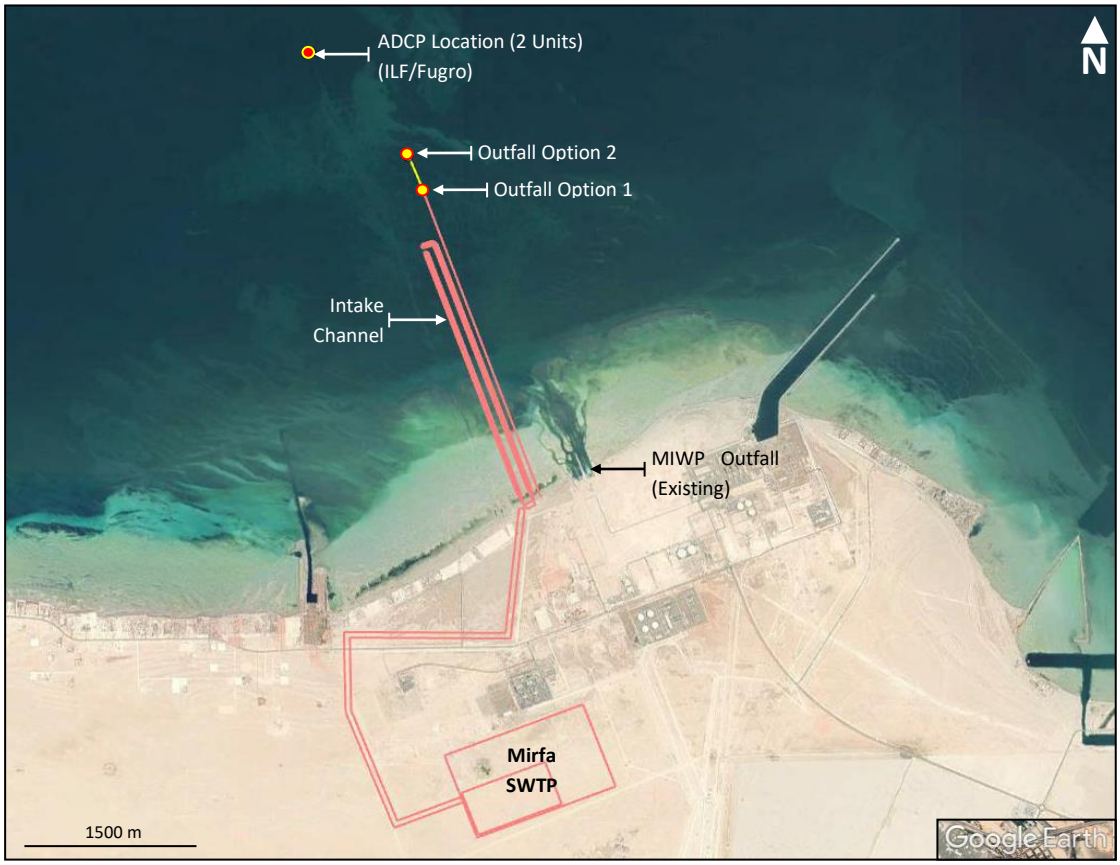


Figure 1.2 – Location of the Proposed SWTP and Intake/Outfall Configuration

2 SIMULATION METHODOLOGY

2.1 SIMULATION MODELS AND MODELING PROCESS

The brine discharge was simulated using five sophisticated atmospheric and marine models:

- The European Centre for Medium Range Weather Forecast (ECMWF) reanalysed forecast data (ERA5) to obtain wind and atmospheric pressure fields over the Arabian Gulf region;
- The United States Navy Global Ocean Model (HYCOM) to obtain boundary conditions and temperature and salinity forcing for GCOM3D;
- The GEMMS 3D Coastal Ocean Model (GCOM3D) which predicts the variation horizontally and vertically of the currents, sea levels, temperature and salinity in the Project area;
- The Cornell Mixing Zone Model (CORMIX), which simulates the near field dispersion of the discharge; and
- The GEMMS 3D Plume Dispersion Model (PLUME3D), which simulates the far-field dispersion of the discharge.

The major stages of the methodology were:

- Setup an accurate bathymetric representation of the study region from data provided by ILF/Fugro, blended into the existing GEMMS bathymetric database for the Arabian Gulf.
- Establish GCOM3D (the 3D hydrodynamic model) for the area of interest;
- Extract hourly wind fields from the ECMWF Global Atmospheric Prediction Model for a winter month and a summer month to simulate seasonal variations;
- Derive boundary conditions and temperature and salinity forcing from HYCOM;
- Predict 3D currents with GCOM3D, driven by winds, atmospheric pressure, tides, large scale Gulf currents, temperature and salinity, for the chosen simulation periods;
- Investigate the dispersion of the brine plume discharged from the outfall using CORMIX and the PLUME3D model driven by the currents predicted by GCOM3D.
- Analyse all results and formulate a scientific report

Table 2.1 provides the summary of the dispersion modelling assumptions and modelling parameters based on data provided by ILF.

Table 2.1 – Summary of Modeling Parameters and Inputs

Bathymetry	Local bathymetry provided by the client was blended with data from the GEMMS Arabian Gulf database which has been built up from a large number of studies in the region
Meteorological data	ECMWF winds and atmospheric pressures
Tidal data	Tidal verification data was derived from the GEMMS Arabian Gulf tidal database built from high resolution tidal modelling of the Arabian Gulf with data assimilation.
Large scale ocean currents	Boundary conditions for the GEMMS 3D Ocean Model (GCOM3D) were obtained from the GEMMS 3D Arabian Gulf Ocean Model which is nested inside the US Navy Global Ocean Model (HYCOM)
Thermodynamic Forcing	HYCOM Arabian Sea and Arabian Gulf output
Sea water intake channel opening	Latitude: 24.13850 N, Longitude: 53.41570 E

Seawater intake flow rate	32,385 m^3/hr
Outfall flow rate	10,319 m^3/hr
Temperature of discharge waters	<42 degrees
Salinity of brine discharge waters	< 75 ppt (parts per thousand)
Location of the end of the outfall pipe	
Outfall Option 1	Latitude: 24.14380 N, Longitude: 53.41550 E
Outfall Option 2	Latitude: 24.14660 N, Longitude: 53.41440 E
Distance from outfall to sea water intake	
Outfall Option 1	600 m
Outfall Option 2	900 m
Outfall pipe diffuser configuration	3 diffusers at right angles to the outfall pipe, 10m apart, at 15 degrees to horizontal on alternate sides of the pipe (2 on opposite side to sea water intake) Note: The aim of including diffusers was purely to illustrate the extra dilution possible from diffusers. The diameter of the diffuser ports was arbitrarily chosen to be 50cm. A larger number of smaller ports would be expected to produce greater initial dilution.
Discharge data of Existing MIWP (provided by MIPCO on May 2021 through ILF/ADNOC)	
Thermo-saline discharge rate from MIWP outfall	Brine - 8,916 m^3/hr Cooling water - 165,800 m^3/hr
Salinity of MIWP discharge	<81 ppt
Ambient Conditions and other parameters	
Ambient seawater temperature	Obtained from GCOM3D
Ambient seawater salinity	Obtained from GCOM3D
Simulation Periods	Summer: July 1–31, Winter: January 1-31
Discharge modelling output	Salinity dilution percentages around outfall

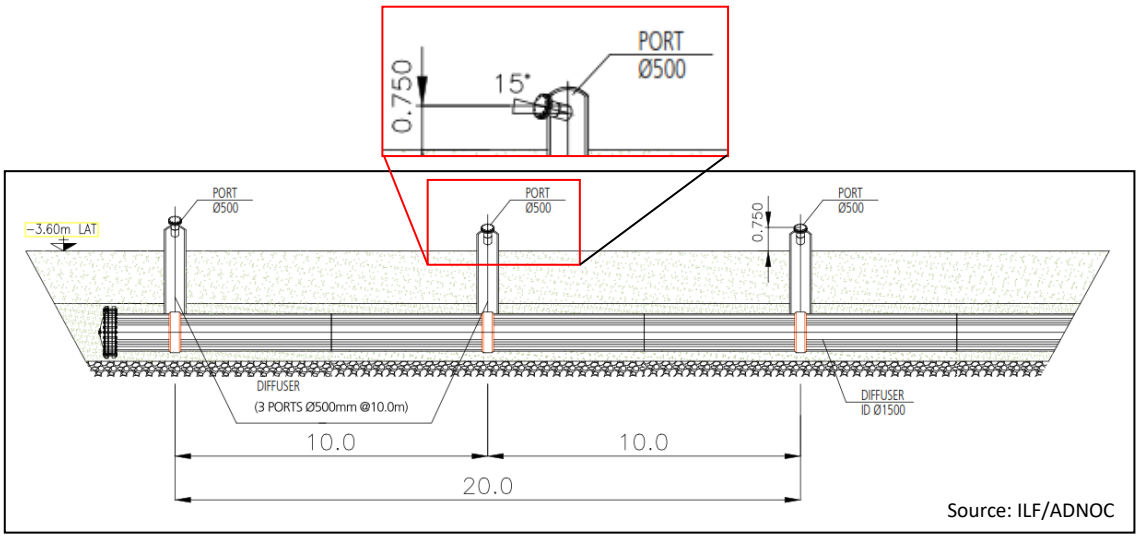


Figure 2.1 – Preliminary Diffuser Design Configuration

2.2 Regulatory Guidelines and Requirements

The results of the plume dispersion modelling need to be assessed against the local regulatory requirements relating to any increased salinity due to discharges into the marine environment. Accordingly, the study was undertaken in line with the relevant requirements of EAD as defined in the Technical Guidance Document for Hydrodynamic Modeling (EAD-EQ-PR-TG-13). In the EAD's Marine Water Quality Regulation in the Emirate of Abu Dhabi (2021, Annex 5), the allowable increment must be <5% in comparison with the initial salinity, which is generally considered at the mixing zone boundary. As per the EAD guidelines, the mixing zone was set at 100 m from the discharge point.

The minimum dilutions required to satisfy the regulatory requirements can be calculated as follows:

If: S1: maximum discharge salinity = 75 ppt

S2: minimum ambient salinity = 42 ppt

(conservative value based on measurements off Ruwais by Atkins, 2009)

n: minimum number of dilutions required

Then: $(S1+n \times S2) / (n+1) = 1.05 \times S2$

Or: $n = (S1 - 1.05 \times S2) / (0.05 \times S2)$

Therefore: **n = 15**

Note that:

- To obtain dilution to within 1 ppt of ambient requires a dilution of 32
- To obtain dilution to within 0.5 ppt of ambient conditions requires a dilution of 65
- If the requirement was to be within 3% of ambient conditions at the mixing zone boundary, a dilution of 25 would be required

Further requirements relating to the modelling process were provided by EAD in their review of the Method Statement (Method Statement for EBS and Hydrodynamic Modeling, Rev. 1, DPA2105172) for this Project, namely:

- The model should help in defining the most efficient location for the outfall in terms of flushing.
- Animation videos for the model must be provided.
- The mesh growth rate should not exceed 10 % to make sure it works efficiently.
- The sensitivity test for the mesh size must be provided.

Note that:

- The comment relating to mesh growth rate is not applicable to this study as the hydrodynamic model runs on a regular grid and the plume dispersion model is a Lagrangian particle model and so does not run on a grid.
- As discussed later, the hydrodynamic modelling was carried out on a series of nested grids, culminating in a 20 metre grid in the Mirfa region
- An animation of the currents will be provided separately as required based on the required format by EAD.

3 MODELING METHODOLOGY

3.1 OVERVIEW

As for all coastal projects in the UAE, the fate of ocean discharges is strongly affected by the complex currents and tides. It is therefore important to establish an ocean model capable of accurately simulating the Gulf oceanography to provide reliable predictions of water movements within the Arabian Gulf as well as simulating the flows in the region of interest.

The hydrodynamics was simulated by GCOM3D driven by large scale Gulf currents, Arabian Gulf tidal predictions, ECMWF meteorological data and the bathymetry of the project area. The effluent discharge was modelled utilising PLUME3D for far-field simulations, and CORMIX for near-field simulations. An overview of the modelling approach is presented in Figure 3.1.

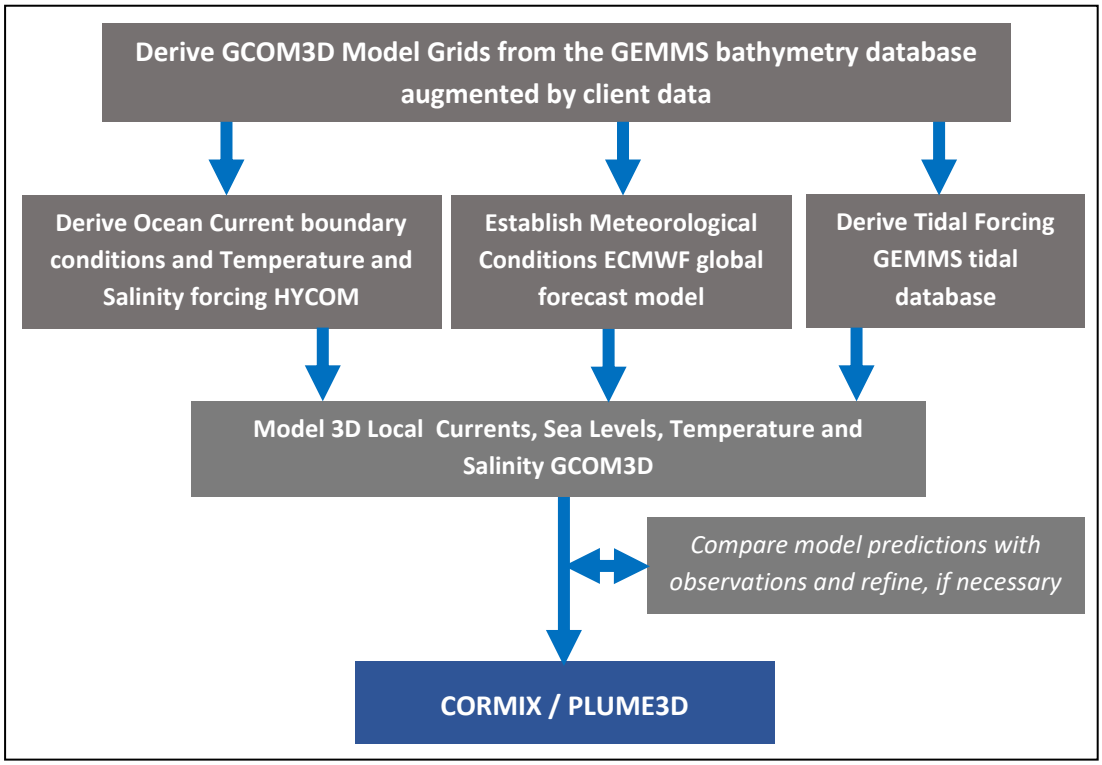


Figure 3.1 – Modelling Flow Chart

3.2 HYCOM

HYCOM is a hydrostatic, primitive equation general circulation model run globally by the United States Navy Research Laboratories. Flexible options for the vertical grid enable HYCOM to conserve water mass properties using isopycnal coordinates when there is strong vertical stratification and still provide adequate vertical resolution in regions with weak stratification, such as the surface mixed layer.

In HYCOM, different mixing schemes are incorporated but the NASA Goddard Institute for Space Studies level 2 turbulence closure [Canuto et al., 2001, 2002] scheme is the most sophisticated, being an extension of the original Yamada-Mellor turbulence closure scheme.

GCOM3D routinely uses HYCOM to provide boundary conditions for ocean currents and domain nudging of salinity and temperature fields.A sample of the ocean currents in the Arabian Gulf from HYCOM used in this study is shown in Figure 3.2.

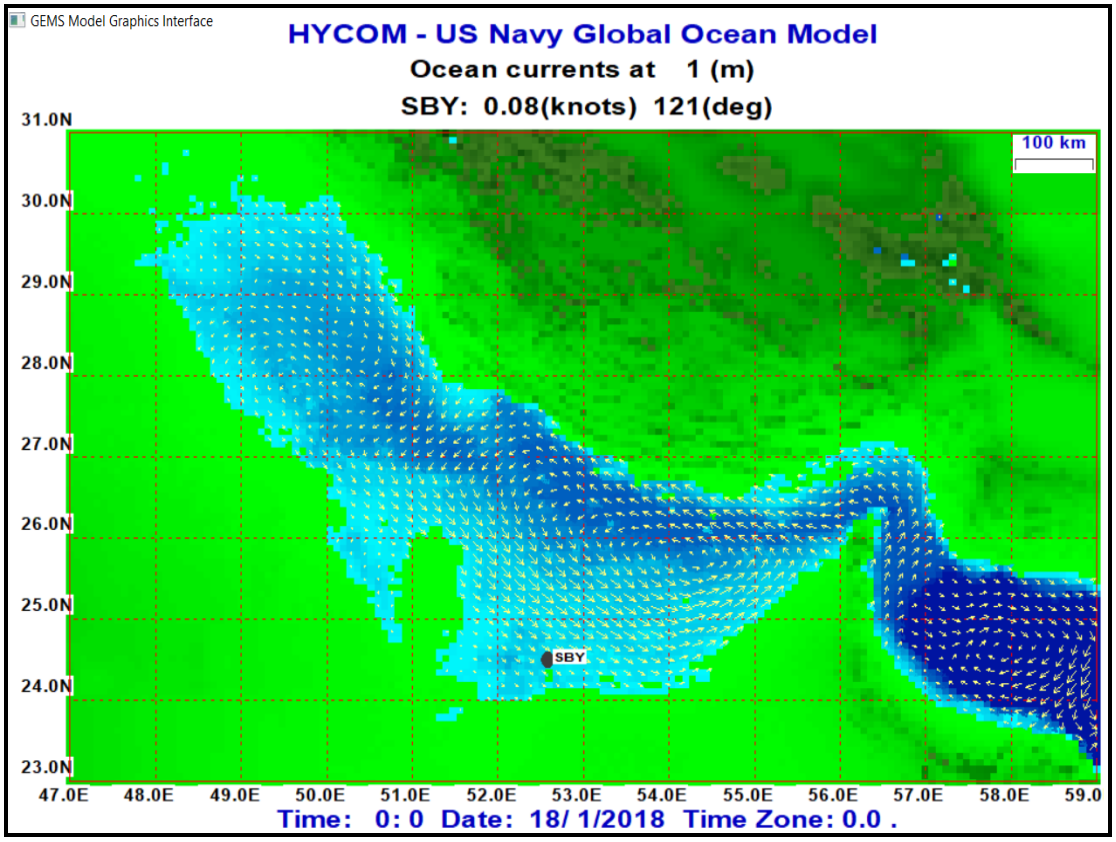


Figure 3.2 – Surface Ocean currents in the Sea of Oman and the Arabian Gulf from HYCOM

3.3 GCOM3D

GCOM3D was first developed in 1984 and has a proven record for modelling ocean currents in the Red Sea and Arabian Gulf, and has been validated extensively in many locations around the world.

GCOM3D is a freely scalable and re-locatable model, which has a proven track record for modeling currents, saline, thermal plume, oil spill and dredging discharges in the Arabian Gulf and has been validated extensively in that region, and in many other locations around the world.

GCOM3D is the Australian Government real-time coastal ocean prediction model, which has a major role in predicting ocean currents for Search and Rescue operations around Australia and the Pacific Islands. GCOM3D has also been used in a wide range of ocean environmental studies including prediction of the fate of oil spills, sediments, drill cuttings, produced formation water and cooling waters as well as in other coastal ocean modeling studies such as storm surges and coastal engineering projects.

GCOM3D (Hubbert 1993, 1999) calculates water currents in both the horizontal and vertical planes. The model operates on a regular horizontal grid and uses a z-coordinate vertical-layering scheme (there is a varying number of layers, depending on the depth of water, and each layer has a constant thickness).

This scheme avoids errors in current predictions at a particular depth caused by averaging of currents over varying depths, as used in sigma co-ordinate and “depth-averaged” model schemes. GCOM3D was the first 3D hydrodynamic model to be used for consulting studies in the Arabian Gulf (DOME, 1999) and since then has been used in over 50 environmental studies in the region, many of which have been for ADNOC.

To model the 3D currents in the vicinity of Mirfa it is necessary to start by modeling the currents throughout the entire Arabian Gulf, driven by winds and tides, with open boundaries east of the Straits of Hormuz. The open boundary conditions for this large domain are easily defined from global tidal data. Higher resolution modeling is then nested inside the Arabian Gulf model. Using this method, GCOM3D has been able to simulate the currents in the Arabian Gulf to a higher degree of accuracy than most other models. An overview of the hydrodynamic modelling undertaken in this study is summarised in Table 3.1.

Table 3.1 – Ocean Modelling Overview

Task	Hydrodynamic Modelling
Model	GCOM3D
Model Features	3-dimensional Horizontal and vertical planes z-coordinate vertical layering scheme
Meteorological Data	European Centre for Medium Range Weather Forecasting (ECMWF) Re-Analysis Interim Data (ERA-Interim) at 80 km spatial and 6-hour temporal resolution.
Period Modelled	Simulations of effluent discharge scenarios for one month in summer and one month in winter
Model Verification	In the absence of current measurements, verification against water heights will be carried out.
Resolution	GCOM3D runs on a regular grid and the resolution was chosen to adequately resolve the coastal features in the vicinity of the discharge locations.

3.4 Model Grids and Bathymetry

Bathymetry for work in the Arabian Gulf is derived from the GEMS 1 minute resolution database of the region - which was originally derived from U.S. Navy data and marine charts and has since been augmented for the many projects undertaken in the UAE.

The circulation in the region surrounding the outfall was simulated on a high resolution grid, nested inside the Arabian Gulf grid. Bathymetry for this grid was established from the existing data in the GEMMS bathymetric database, augmented by data from a bathymetric survey undertaken by the client and aligning the coastline with the help of Google Earth images. The region covered by the bathymetric survey is illustrated in Figure 3.3.

Given that this region of the coastal is very shallow, with significant intertidal zones, it was important to be certain that the survey data blended smoothly with the bathymetry outside the surveyed region. The bathymetric contours shown in Figure 3.4 are relative to Mean Sea Level (MSL) and indicate that this requirement was achieved.

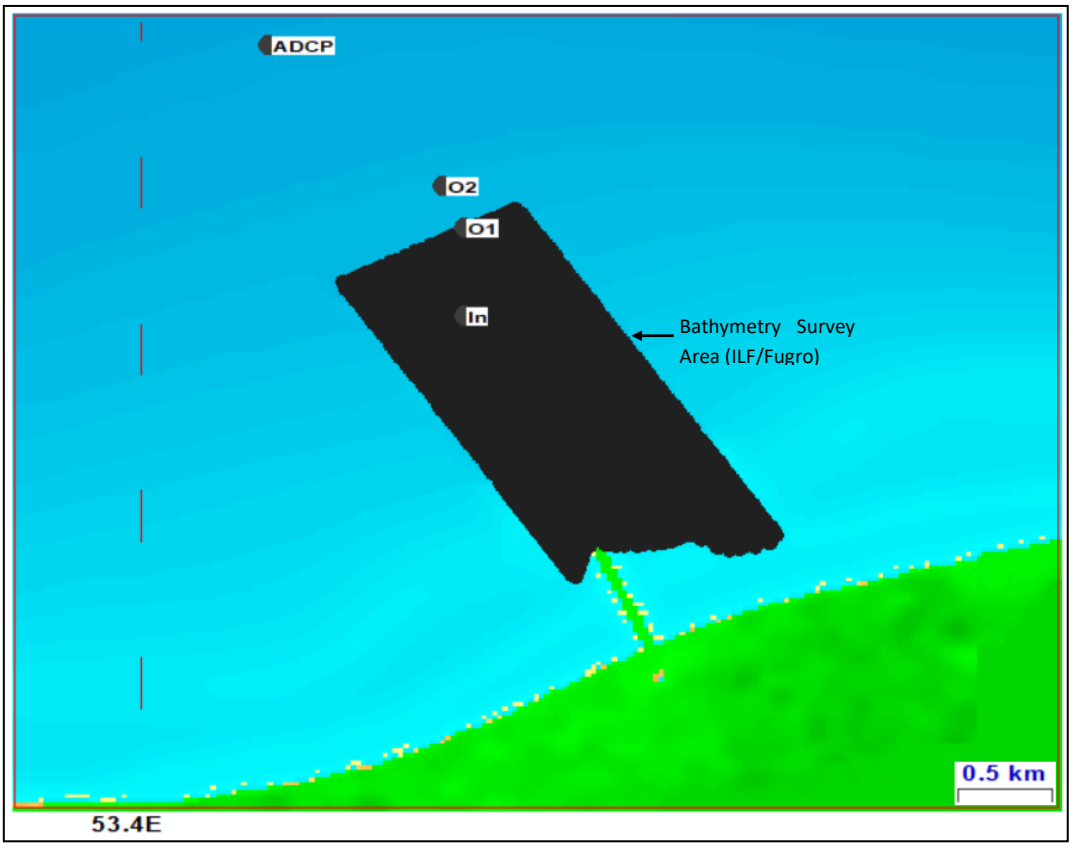


Figure 3.3 – Region Covered by the Bathymetric Survey

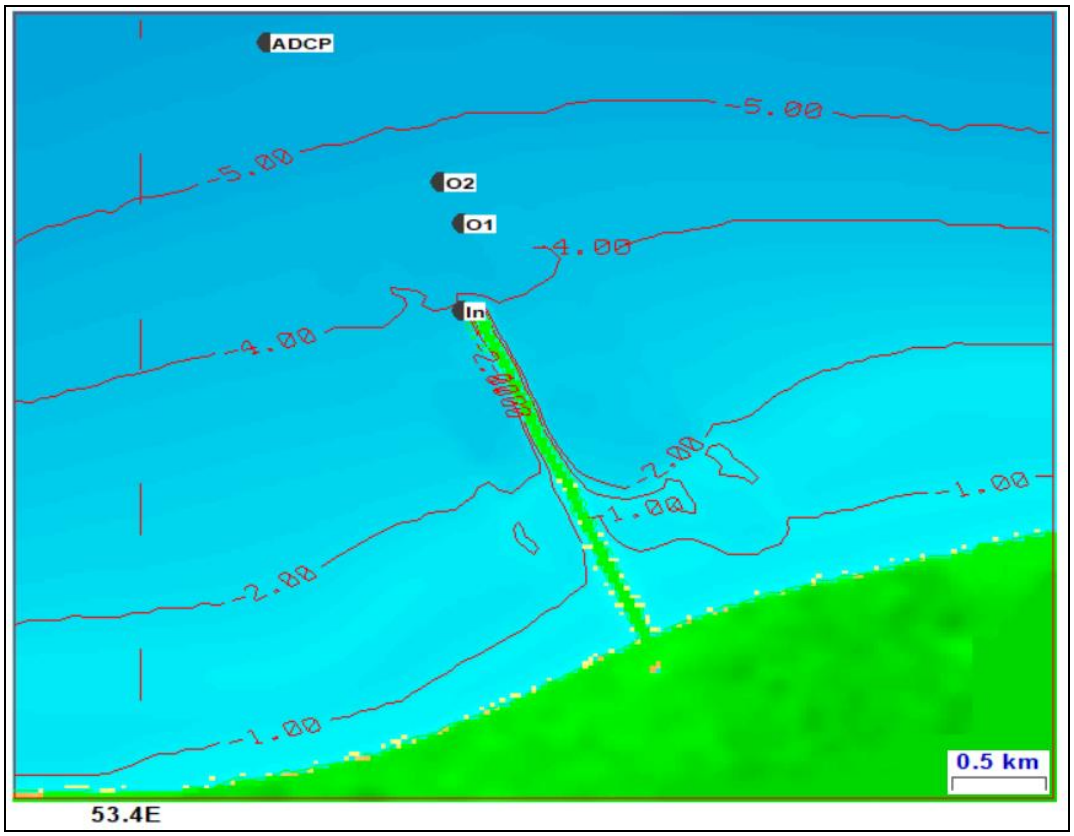


Figure 3.4 – Bathymetric contours (MSL) after inclusion of the Bathymetric Survey Data

3.5 VERIFICATION OF GCOM3D SEA LEVELS

Verification of the accuracy of the sea levels and currents predicted by GCOM3D was possible due to the installation of an Acoustic Doppler Current Profiler (ADCP) for a period of one month (01/05/2021 to 03/06/2021) seaward of the outfall discharge location (Figure 1.2). Sea levels during the measurement period predicted by GCOM3D are compared with sea level data measured by the ADCP in Figure 3.5.

Correlation analysis of the two time series produced a correlation factor of 0.96. This indicates that GCOM3D is representing the tidal regime in the Mirfa region with a high degree of accuracy.

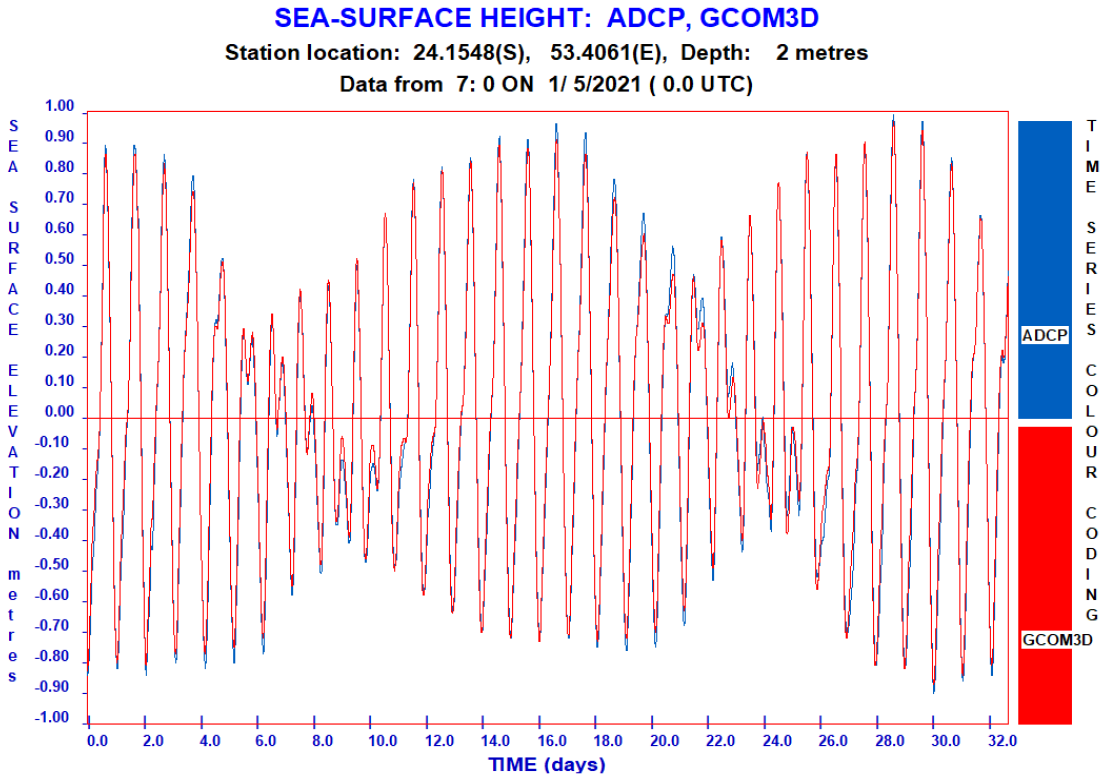


Figure 3.5 – Sea level predictions from GCOM3D (red) compared ADCP Data

3.6 VERIFICATION OF GCOM3D CURRENTS

Near surface current speeds and directions predicted by GCOM3D were verified by comparing the easterly and northerly components of the current with ADCP measurements in Figures 3.6 and 3.7 respectively. Correlation analysis produced a correlation factor of 0.85 for the easterly component and 0.91 for the northerly component. Given the greater volatility in currents than in sea levels these results indicate that GCOM3D is representing the current variations in the Mirfa region with a high degree of accuracy.

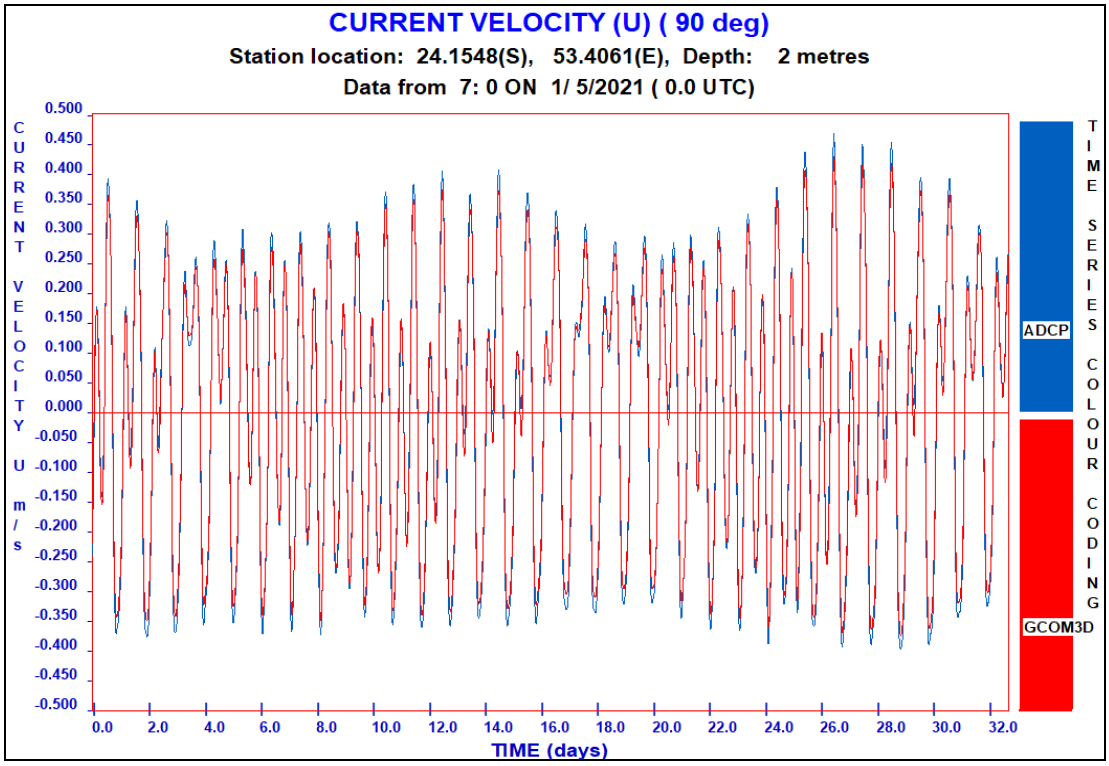


Figure 3.6 – Near surface current speed predictions from GCOM3D (blue) compared with measurements of near surface currents by the ADCP (red).

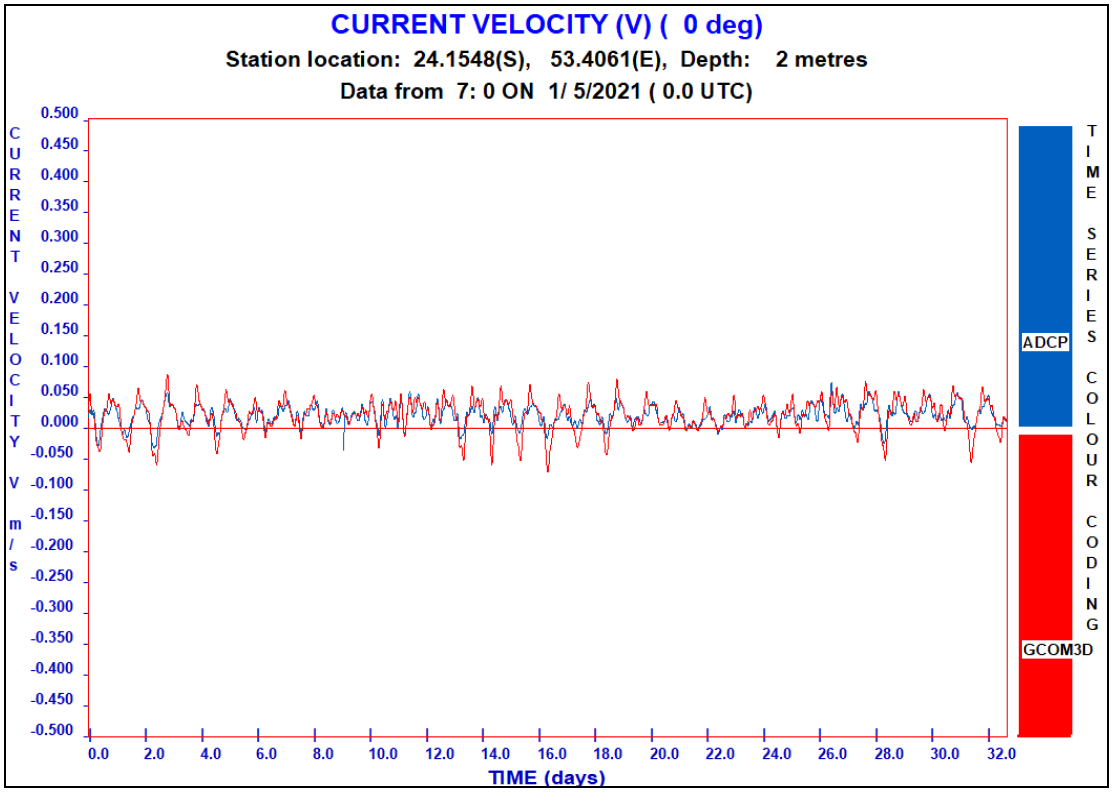


Figure 3.7 – Near surface current direction predictions from GCOM3D (blue) compared with measurements of near surface current directions by the ADCP (red).

3.7 PLUME DISCHARGE MODELLING

The mixing and dilution of reject waters from a marine outfall can be considered in two distinct spatial zones, near-field and far-field dilution. The initial, near-field dilution of the reject waters is a function of several parameters including:

- The physical properties of the discharge;
- The momentum flux of the discharge velocity, which induces entrainment of the surrounding ambient fluid;
- The speed (and direction) of the receiving waters; and
- The design of the diffuser (if any).

Far-field horizontal and vertical mixing and dilution rely on the ambient conditions of the receiving waters (tidal and wind driven currents, wave induced turbulence and density gradients). Some plumes are positively buoyant and will rise to the surface (e.g. oil) whilst negatively buoyant plumes (e.g. brine) will sink to the bottom of the water column. In both cases similar near-field mixing processes of entrainment induced by momentum flux occur, but buoyant plumes experience more mixing in the far-field than dense plumes, as buoyant plumes ultimately reside near the surface where turbulent mixing due to winds and waves is more pronounced.

In the far-field, dense plumes tend to move in the lower part of the water column where mixing occurs predominantly due to bed velocities, baroclinic flows and turbulent mixing down from the surface, which are typically less energetic, depending on the depth of the water, than the processes closer to the surface. Simulation of these processes can be carried out in three ways:

- The use of near field dilution algorithms which define the near-field dilution achieved by different discharge/diffuser configurations;
- The use of specific near-field CFD (computational fluid dynamics) sub-models such as the USEPA CORMIX model to define the behaviour of the reject flow in the first few metres from the outlet; or
- Undertake laboratory studies with scaled down models of diffusers to measure initial dilution under a range of receiving water conditions. A relationship can then be determined which can be used in far-field modelling to define the initial dilution.

GEMMS has written software to derive the key near-field mixing results from CORMIX and inject these data directly into PLUME3D which then simulates the far-field mixing of the plume. This is now the preferred method adopted by GEMMS in all outfall dispersion studies.

3.7.1 NEAR FIELD MODELING WITH CORMIX

The link between the near-field and far-field simulations is not an exact science. However, the estimation of near-field behaviour utilising near-field modelling software such as CORMIX is preferable to utilising simplified algorithms for this behaviour within the far-field modelling.

CORMIX is a straight line, scenario model that cannot take into account differences in ambient conditions over time. However it is useful for estimating the initial dispersion of the effluent discharge caused by turbulence associated with the initial momentum and buoyancy of the discharge due to the exit velocity and the initial differential in density between the discharge and ambient waters.

3.7.2 Far Field Modeling with PLUME3D

PLUME3D is a lagrangian random walk far-field plume dispersion model which obtains oceanic conditions from GCOM3D and includes 3D plume dispersion algorithms for modelling the far-field behaviour of a wide variety of discharge materials including sediments, sewerage, thermal discharges, oils and chemicals, accounting for processes such as dispersion, diffusion and dissolution, under defined release conditions (quantity, rate etc.).

PLUME3D uses predictions from GCOM3D to provide the ocean conditions into which the discharge is released. The lagrangian nature of the model allows the discharge plume to be simulated throughout the water column taking into account the effects of natural processes such as surface waves, horizontal diffusion and dispersion. The model is free from numerical diffusion problems (such as experienced by Eulerian models) because it is not run on a grid.

The plume model can be used stochastically if required, to simulate a large number of random events over time or can be used for specific case studies in a deterministic mode.

PLUME3D can model the behaviour of a variety of constituents within a single release volume given information on the density and other physical and chemical parameters. The model reports mass and concentration levels on the water surface, on shorelines, in the sediments or through the water column. Where multiple constituents are involved, the model can report the distribution of each constituent individually. Horizontal and vertical cross-sections are also available to better illustrate the three dimensional distributions.

Like GCOM3D, PLUME3D has been used in a large number of studies since 1999 in the Arabian Gulf, many of which were for ADNOC. Table 3.2 summarises the plume dispersion modelling approach.

Table 3.2 – Plume Discharge Modelling Overview

Stage	Near-field Plume Modelling	Far-field Plume Modelling
Model	CORMIX	PLUME3D
Task Pre-requisite	GCOM3D Hydrodynamic Modelling	GCOM3D Hydrodynamic Modelling
Model Features	Mixing zone model for near-field applications	Lagrangian random walk far-field plume dispersion model
No. of Sources	Effluent discharge location defined by client	Effluent discharge location defined by client
Parameters Simulated	Temperature, dilution	Temperature, dilution
Grid Resolution	CORMIX does not run on a grid	PLUME3D is a lagrangian particle model and therefore does not run on a grid

4 RESULTS AND DISCUSSIONS

4.1 CURRENTS IN THE VICINITY OF THE OUTFALL

Figure 4.1 illustrates the ocean currents in the coastal regions surrounding Mirfa, modelled by GCOM3D for comparison with the ADCP data.

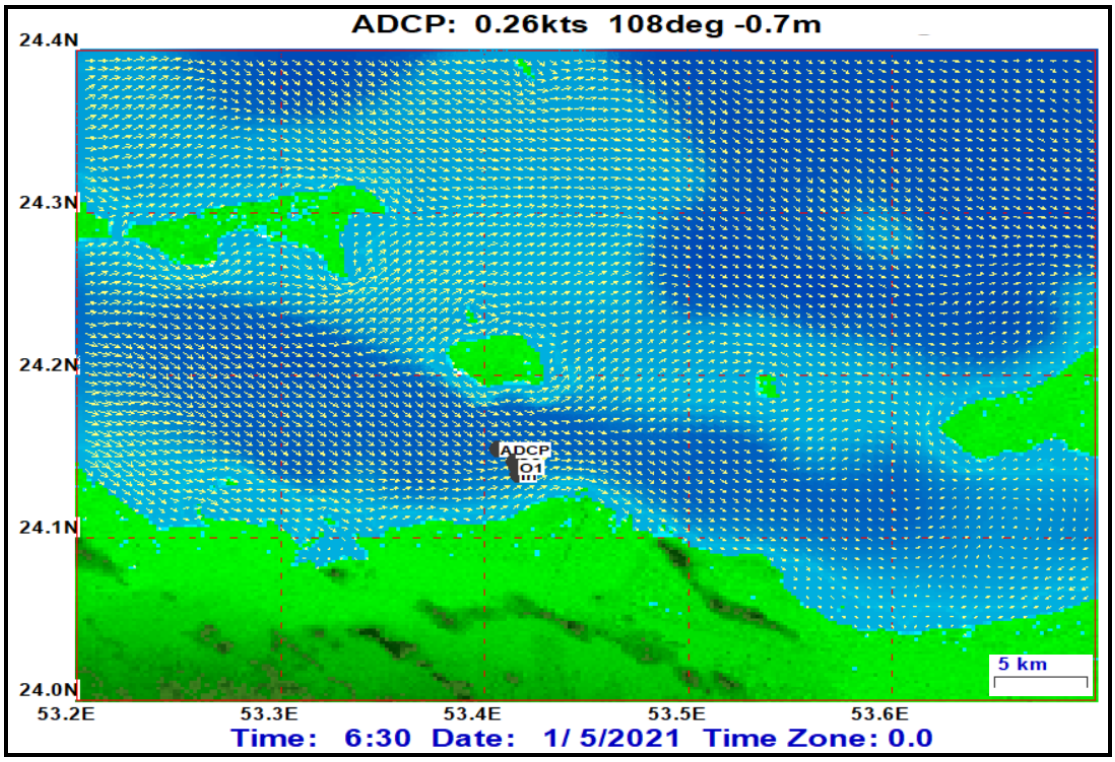


Figure 4.1 – Example of near surface currents in the coastal region surrounding Mirfa.

4.2 PLUME DISPERSION RESULTS

The results of the dispersion modelling during summer and winter conditions were analysed on a high resolution grid and the 95th percentile dilutions were calculated in summer (represented by July, 2018) and winter (represented by January 2018).

4.2.1 SATISFACTION OF REGULATORY REQUIREMENTS FOR THE OUTFALL LOCATION OPTION 1

The regulatory requirement discussed earlier is a reduction of the brine salinity to within 5% of ambient levels within 100 m from the discharge location. This was shown to require a minimum of 15 dilutions of the brine discharge before reaching the mixing zone boundary.

In order to look closely at the behaviour of the brine in the vicinity of the mixing zone the model output was analysed on a 1 m resolution grid surrounding the outfall diffuser ports. The results for the 95th percentile of dilution are shown in Figure 4.2 (winter) and Figure 4.3 (summer). The black circle in Figures 4.2 and 4.3 has a radius of approximately 100 m and hence indicates the extent of the mixing zone.

Figures 4.2 shows that in winter, the brine is diluted in all directions by more than 30 times within 50 metres of the diffuser ports. In fact, the brine is diluted in most directions, other than to the south east, by more than 40 times before it reaches the edge of the mixing zone.

Figure 5.3 shows a similar result in summer whereby at least 30 dilutions is achieved within 50 m of the diffuser ports. A notable difference from the winter results is that, in summer, the far-field dilution of the plume is slower and the plume has a tendency to move in an eastward or shoreward direction.

Noting that the regulatory requirement end of mixing zone salinity limit was to achieve at least 15 dilutions within 100 m of the diffuser ports, it can be concluded that this requirement is easily achieved in both summer and winter conditions in all directions.

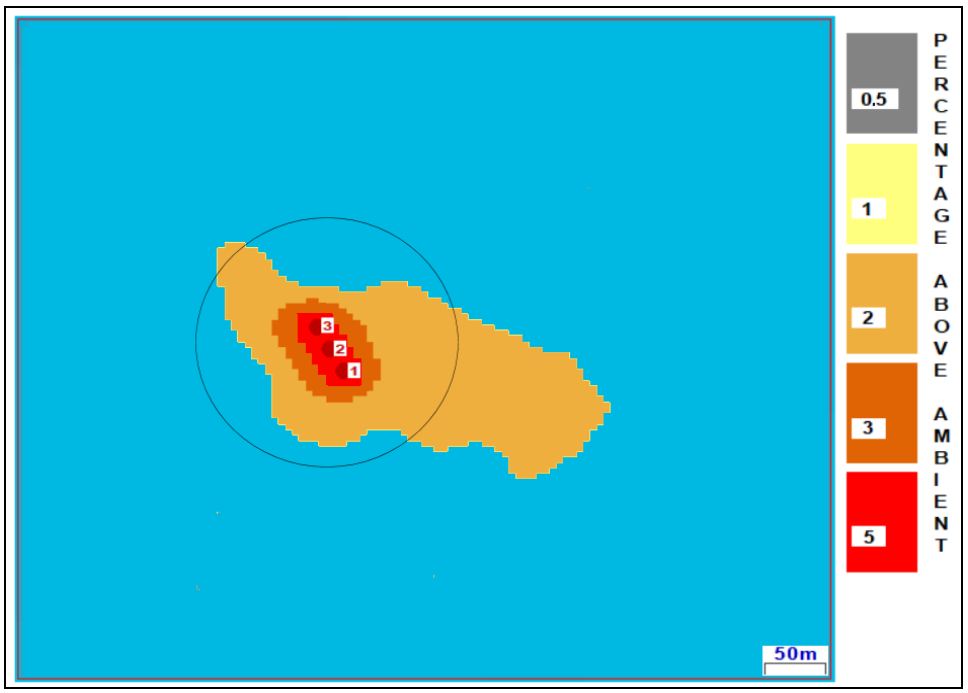


Figure 4.2 – Salinity levels (%) Above Ambient from the Brine Discharge in Winter Months (Regulatory Compliance – Outfall Option 1)

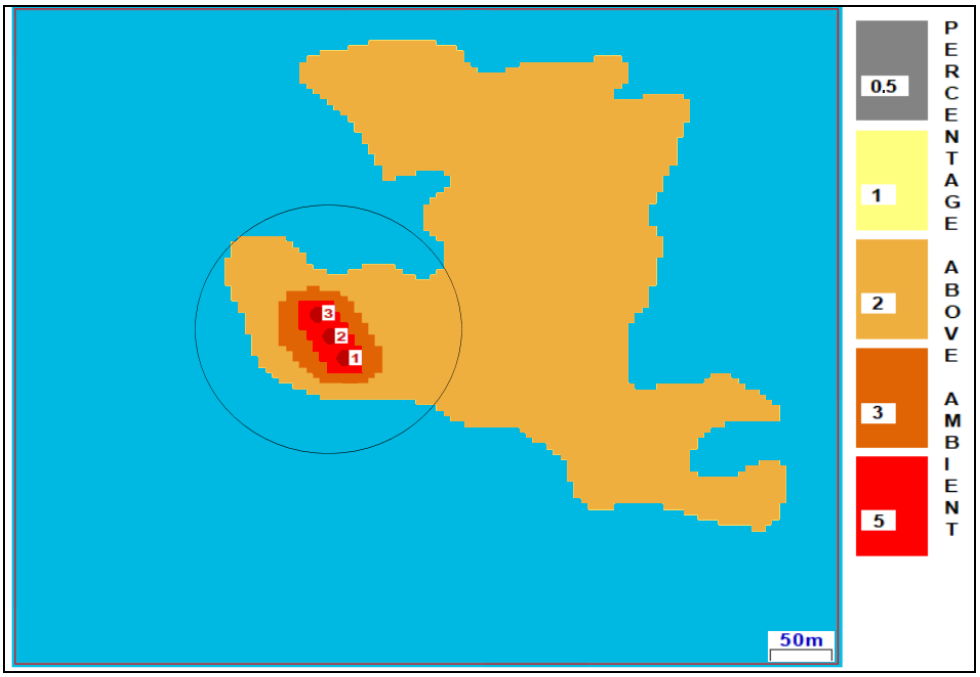


Figure 4.3 – Salinity levels (%) Above Ambient from the Brine Discharge in Summer Months (Regulatory Compliance – Outfall Option 1)

4.2.2 Satisfaction of Regulatory Requirements for the Outfall Location Option 2

Given that the second outfall location is extended further offshore into slightly stronger currents there is no doubt that the EAD regulatory requirement is easily met at this location also. Thus, no further assessment was undertaken.

4.2.3 Potential for Reciculation into the Seawater Intake Outfall Location Option 1

According to the bathymetric data supplied by the ILF, the entrance to the sea water intake is in a depth of approximately 4 m relative to mean sea level. Whereas the depth of the sea water at the outfall diffuser ports is approximately 4.5 m.

The brine plume will tend to move near the sea bed, due to it being denser than the surrounding sea water, under the influence of the prevailing bottom currents. Due to the very shallow nature of the water the wind driven current will still be significant near the bottom and its influence will combine with the coast parallel forcing of the flood and ebb tide. The distance between the first diffuser port and the sea water intake is approximately 600 metres so the gradient of the sea bed between the outfall and the sea water intake is approximately 1/1200, which is a negligible influence on the movement of the brine plume.

To study the potential for highly diluted brine to recirculate into the sea water intake the results were analysed on a larger grid with a resolution of 4 m. The results obtained in winter (Figure 4.4) indicate that at least 100 dilutions of the brine plume are achieved before any brine from the diffuser ports reaches the sea water intake. This equates to an increase in salinity of less than 0.5 ppt

The results obtained in summer (Figure 4.5) indicate that at least 50 dilutions of the brine plume are achieved before any component of the brine plume approaches the sea water intake. This equates to an increase in salinity of less than 1 ppt.

The Influences Contributing to these Results

On exiting the diffuser ports (angled at 15 degrees to the horizontal) the discharge has a small vertical velocity as it meets the currents flowing across the outfall pipe and undergoes “near-field” mixing. This initial mixing generally contributes a large part of the overall mixing.

The diluted plume then travels away from the diffuser ports, undergoing the slower process of “far-field” mixing, and tends to sink closer to the sea bed as a result of the brine being denser than the ambient seawater.

There are three influences which impact significantly on the far-field dispersion of the brine output:

- As can be seen from the results the dominant influences on the dispersion of the brine plume are the flood and ebb tide but, due to the very shallow water, the prevailing north westerly wind is also an important factor.
- The north westerly wind will tend to push the plume towards the sea water intake channel, albeit in a highly diluted state. The stronger winds from the northwest in summer will tend to push more brine in a shoreward direction than in winter.
- The seawater intake channel is bounded by bunds which prevent flow along the coast between the opening of the intake channel and the coast. This forces the flow to go around the end of the sea water intake thus creating a flow towards the coast on the other side. When the tide is flooding this flow is "sucking" the brine plume towards the entrance to the intake channel.



Figure 4.4 – Salinity levels (%) Above Ambient from the Brine Discharge in Winter Months (Recirculation – Outfall Option 1)

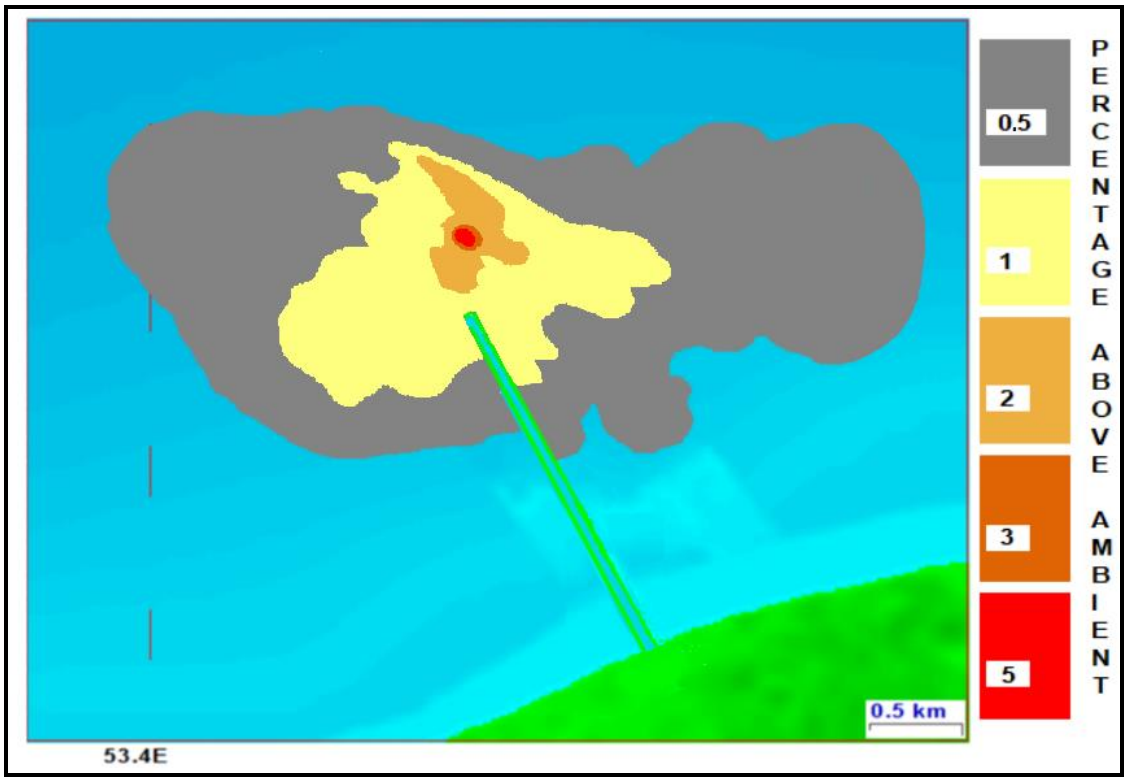


Figure 4.5 – Salinity levels (%) Above Ambient from the Brine Discharge in Summer Months (Recirculation – Outfall Option 1)

4.2.4 Potential for Reciculation into the Seawater Intake Outfall Location Option 2

The depth of the sea water at the extended outfall diffuser ports is approximately 4.8 m and the distance between the first diffuser port and the sea water intake is approximately 900 m. In this case the gradient of the sea bed between the outfall and the sea water intake is approximately 1/1100 and therefore, as for the first outfall location, is a negligible influence on the movement of the brine plume.

The results obtained in winter (Figure 4.6) indicate that at least 100 dilutions of the brine plume are achieved before any brine from the diffuser ports reaches the sea water intake. This equates to an increase in salinity of less than 0.3 ppt.

The results obtained in summer (Figure 4.7) indicate that at least approximately 70 dilutions of the brine plume are achieved before any component of the brine plume approaches the sea water intake. This equates to an increase in salinity of less than 0.5 ppt.

It is important to note that any increases of salinity at the seawater intake are not cumulative. If the salinity level of the seawater intake increases slightly, resulting in a small increase in the salinity of the outfall discharge, the long term outcome will not change. The Arabian Gulf can be considered to be an infinite receptor in this case and the strength of the currents in the channel off Mirfa will continue to mix discharged waters with Gulf waters.

The Influences Contributing to these Results

On exiting the diffuser ports (angled at 15 degrees to the horizontal) the discharge has a small vertical velocity as it meets the currents flowing across the outfall pipe and undergoes “near-field” mixing.

The diluted plume then travels away from the diffuser ports, undergoing the slower process of “far-field” mixing, and tends to sink closer to the sea bed as a result of the brine being denser than the ambient seawater.

There are three influences which impact significantly on the dispersion of the brine output:

- As can be seen from the results the dominant influences on the dispersion of the brine plume are the flood and ebb tide but, due to the very shallow water, the prevailing north westerly wind is also an important factor.
- The north westerly wind will tend to push the plume towards the sea water intake channel, albeit in a highly diluted state. The stronger winds from the northwest in summer will tend to push more brine in a shoreward direction than in winter.
- The seawater intake channel is bounded by bunds which prevent flow along the coast between the opening of the intake channel and the coast. This forces the flow to go around the end of the sea water intake thus creating a flow towards the coast on the other side. When the tide is flooding this flow is "sucking" the brine plume towards the entrance to the intake channel.

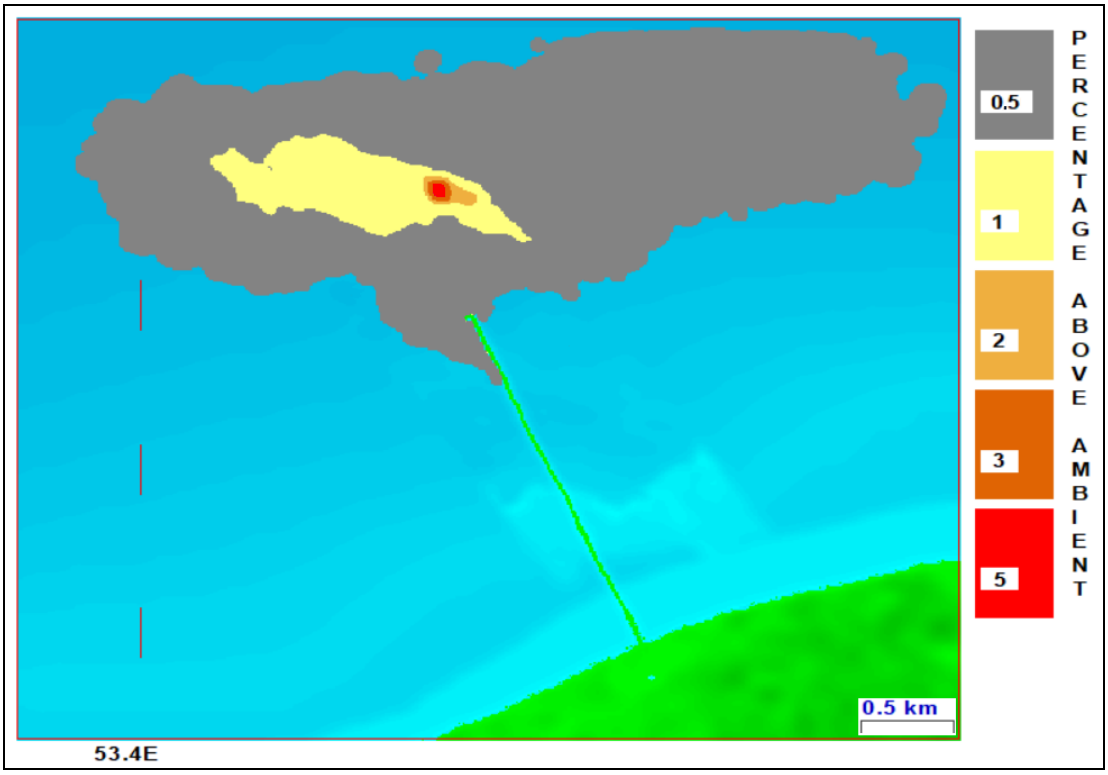


Figure 4.6 – Salinity levels (%) above ambient from the brine discharge at the extended pipeline in winter months (Recirculation – Outfall Option 2)

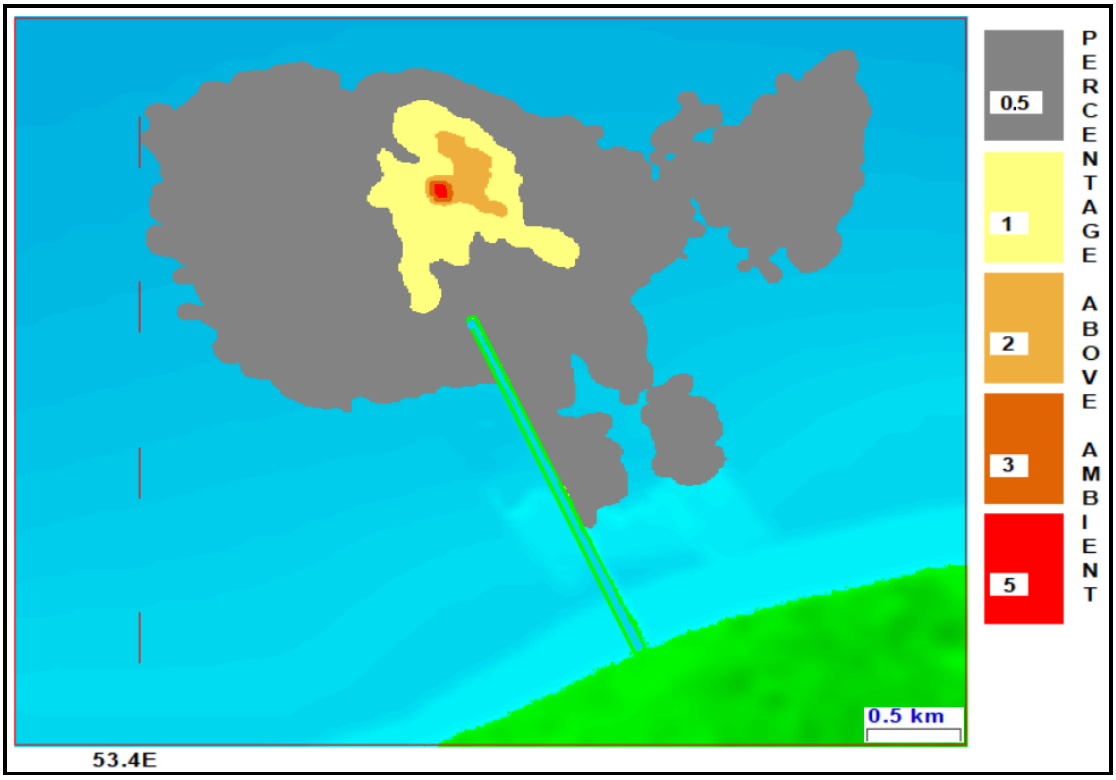


Figure 4.7 – Salinity levels (%) above ambient from the brine discharge at the extended pipeline in summer months (Recirculation – Outfall Option 2)

5 CONCLUSIONS

The main objectives of the study were to assess:

a) The regulatory compliance of the brine discharged from the proposed SWTP in Mirfa with the EAD prescribed mixing zone; and

b) The potential for recirculation of brine from the outfall to the seawater intake

With reference to these two objectives it can be concluded that:

a) The EAD regulatory mixing zone requirements can be easily achieved;

b) For an outfall located 600 m further out to sea from the seawater intake channel, the maximum recirculation of the brine from the outfall to the seawater intake is less than 1 ppt; and

c) For an outfall located 900 m further out to sea from the seawater intake channel the maximum recirculation of the brine from the outfall to the seawater intake is less than 0.5 ppt.

6 REFERENCES

1. Atkins, 2009: Phase 1 Health Safety and Environmental Impact Assessment for the Ruwais Refinery Expansion Project, Volume 3.
2. IFC, 2007a: International Finance Corporation, World Bank Group, Environmental, Health, and Safety (EHS) Guidelines General EHS Guidelines: Environmental Wastewater and Ambient Water Quality, April 2007.
3. IFC, 2007b: International Finance Corporation, World Bank Group, Environmental, Health, and Safety Guidelines for Onshore Oil and Gas Development. April 2007.
4. IFC, 2008: International Finance Corporation, World Bank Group, Environmental, Health, and Safety Guidelines Thermal Power Plants, December 2008.
5. MEDRC, 2010: Environmental planning, prediction and management of brine discharges from desalination plants. MEDRC Project 07-AS-003, Sultanate of Oman.
6. UAE_1: Regulation for the Protection of the Marine Environment, UAE, The Cabinet.
7. Yao, Fengchao and Johns, William E., 2010: A HYCOM Modeling Study of the Arabian Gulf: Journal of Geophysical Research, Vol. 115, C11017

Appendix A

Meteorology and Oceonography in the Arabian Gulf

A.1 METEOROLOGY

The meteorological analysis is critical to the outcomes of the study. The best plume model in the world will produce the wrong results if the ocean currents and winds are not accurate. In earlier studies of the fate of oil spills and other discharge plumes, the consultants used the best available meteorological station winds to drive ocean models. However it has now been shown that when using coastal winds, or even winds measured on site, the errors are quite large due to the fact that:

- These winds are only accurate at the site;
- As a plume drifts on the currents it moves into areas influenced by winds, which are different to those at the release site;
- Even at the release site the currents are not just driven by the local wind but are also a result of currents flowing into the area which are driven by different winds to those experienced at the release site.

In order to overcome this problem, gridded wind fields from the ECMWF global atmospheric forecast model are used, augmented by local station data, to drive GCOM3D and associated marine discharge models. Local wind observations are still important however because they are essential for verifying the model winds and, if necessary, scaling them.

An example wind field over the Arabian Gulf is shown in Figure A.1. The local winds at study region, derived from multiple years of ECMWF model output, are illustrated in the wind rose shown in Figure A.2. The wind rose shows a dominant (but not exclusive) north westerly wind flow over the region.

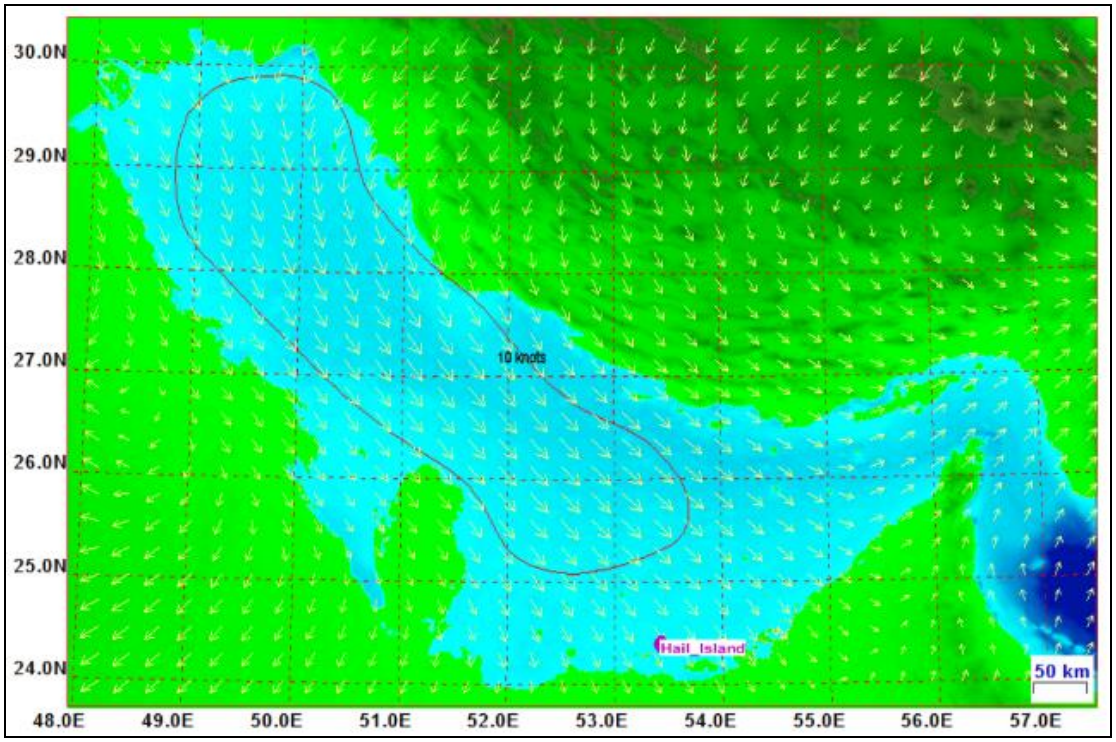


Figure A.1 – Sample Wind Field over the Arabian Gulf from ECMWF

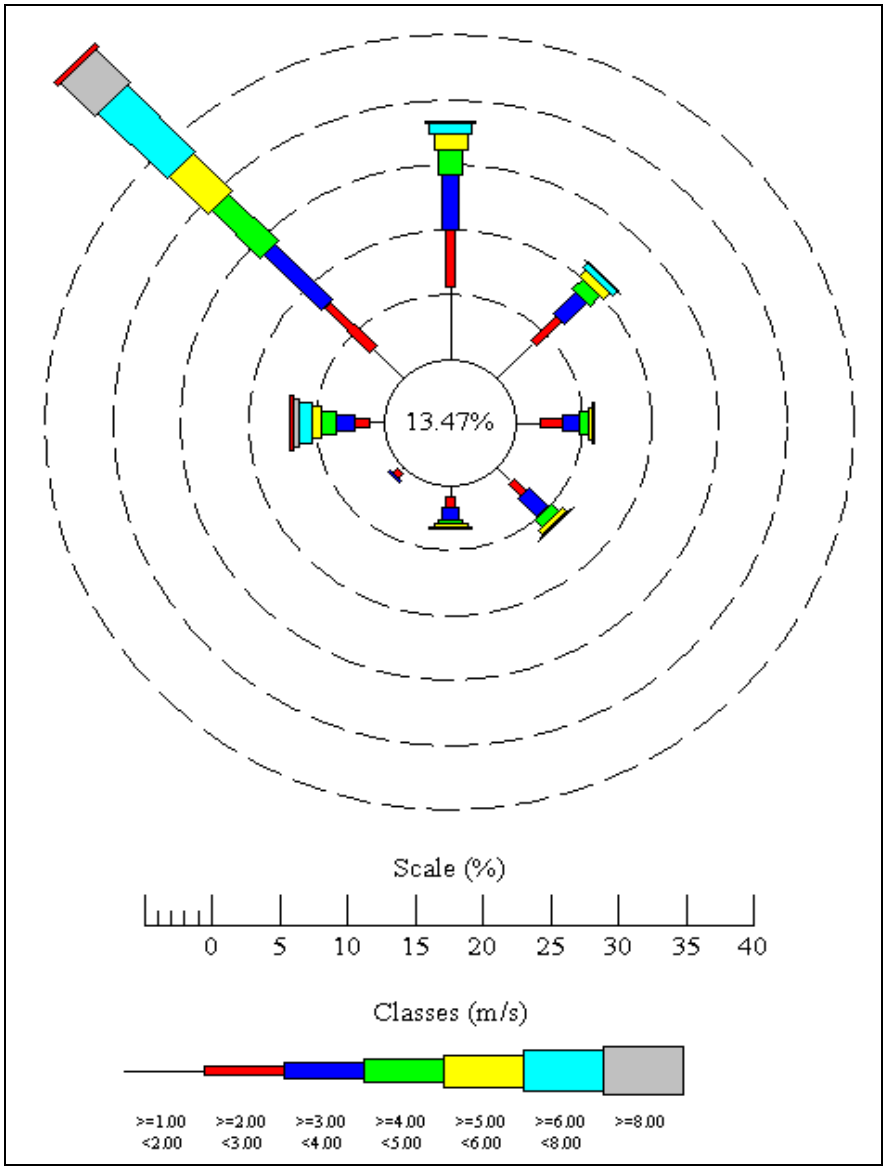


Figure A.2 – Wind Rose in the Study Region from the ECMWF Atmospheric Model

A.2 CURRENTS AND TIDES IN THE ARABIAN GULF

As for all coastal developments in the UAE, there is an important interaction with the currents and tides of the Arabian Gulf. It is therefore important to establish an ocean model capable of simulating the Gulf oceanography as well as the proposed Project.

The tidal heights and phases in the Arabian Gulf vary significantly from east to west. This phenomenon is due to the narrow entrance to the Arabian Gulf, through the Straits of Hormuz, the flood tide is unable to propagate fully to the western end of the Gulf before the tide starts to ebb in the Gulf of Oman. This causes the Arabian Gulf to act more like an embayment than an open sea resulting in varying tidal amplitudes and phases. In addition, there can be significant temperature and density driven circulations within the Arabian Gulf adding to the complexity of the circulation.

Sample output from the Arabian Gulf modelling with GCOM3D illustrating the various stages of the tidal propagation within the Gulf are shown in Figure A.3 to Figure A.5. Currents within the study region may be related to four main sources:

- The bathymetry of the Arabian Gulf;
- Tidal forces;
- Wind forces; and
- Density differences in the Gulf waters.

Each of the major forcing processes has associated with it varying amounts of energy and different time scales. Tides change over a few hours at diurnal (daily) or semi-diurnal (twice daily) periods and typically contain significantly more energy than density driven currents. Wind-driven currents develop and subside over a time scale of days and also generally contain more energy than density currents.

The tidal regime in the study region of the Gulf is mixed, semi-diurnal, which means that there are two high and two low tides daily, with a large diurnal inequality in high and low water levels. At spring tides, the tide is more semi-diurnal character while during neap tides the pattern is more diurnal.

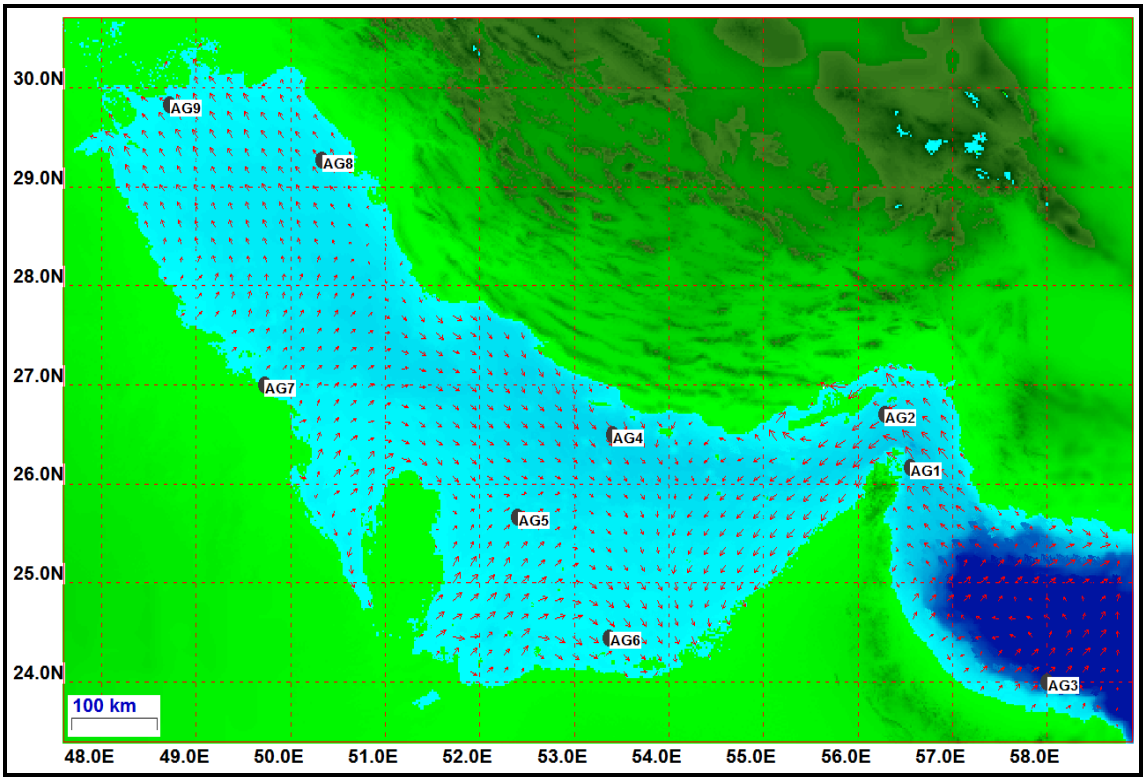


Figure A.3 – Surface currents as the tide starts to flood at the Straits of Hormuz

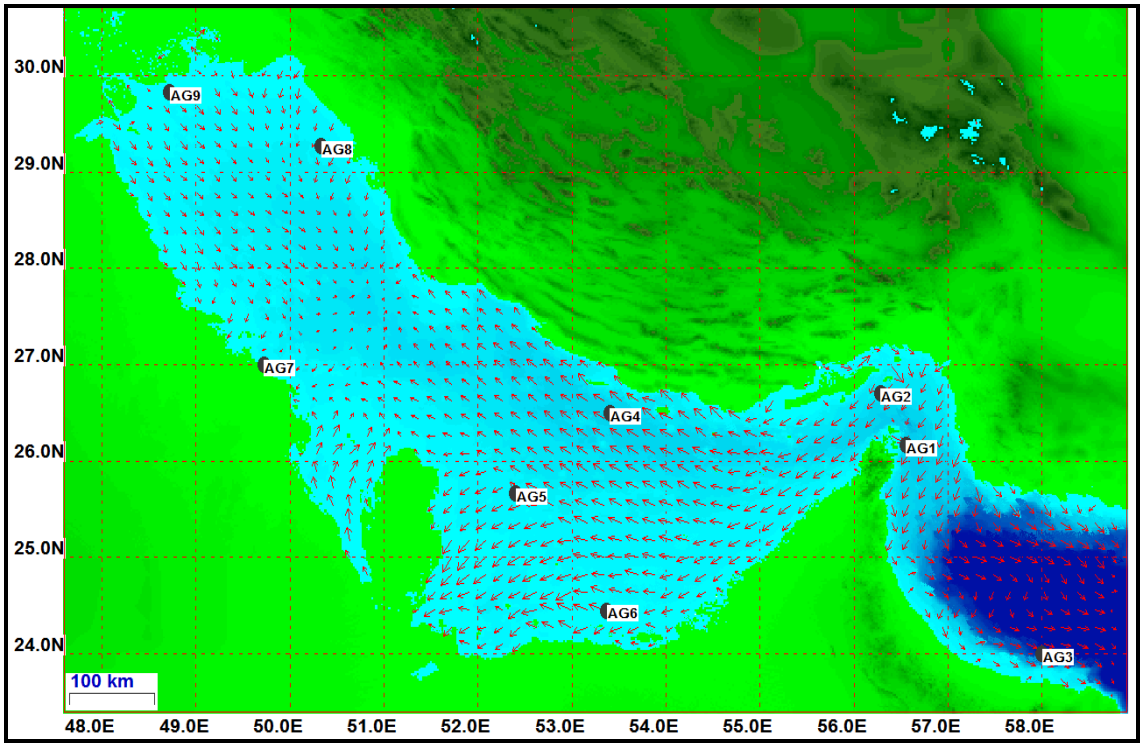


Figure A.4 – Surface currents at peak flood tide through the Straits of Hormuz

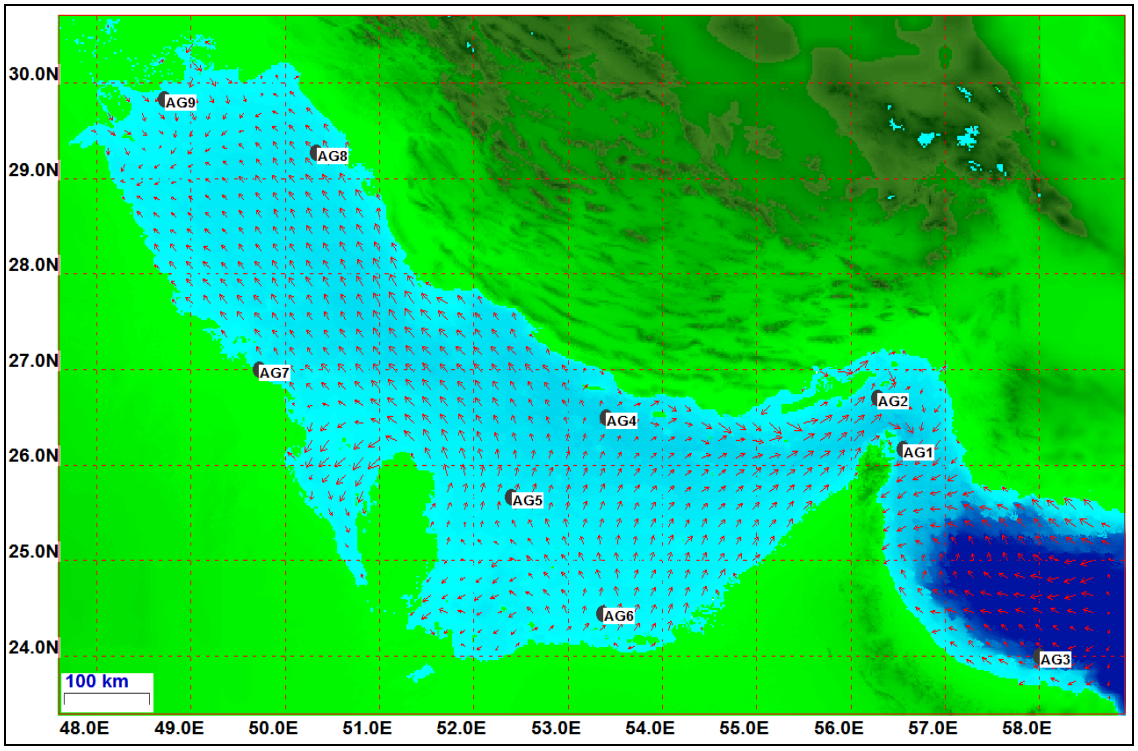


Figure A.5 – Surface currents as the tide begins to ebb at the Straits of Hormuz

Appendix B

Bathymetry and ADCP Reports

BATHYMETRIC AND GEOPHYSICAL SURVEYS AT MIRFA AND NOUF AL DABBYAH AREAS

BATHYMETRIC AND GEOPHYSICAL SURVEY REPORT AT MIRFA PLANT SITE

CONTRACTOR DOC TITLE	BATHYMETRIC AND GEOPHYSICAL SURVEY REPORT AT MIRFA PLANT SITE
CONTRACTOR	FUGRO
FUGRO PROJECT NO.	MRU096

CONTRACTOR DOC NO: MRU096-V02-SR-MIRFA

Rev	Date	Status	Status Description	Prepared	Reviewed	Approved	Company Approval
01	03/06/2021	IFR	Issued for Review	V. Vadakkinayil	D. Duguid / R. Nair	V. Nambiar	

This Document is intended for use by ADNOC and its nominated Consultants, Contractors, Manufacturers and Suppliers.

SUMMARY OF DOCUMENT REVISIONS			
Rev. No.	**Date Revised**	**Section Revised**	**Revision Description**
01	03/06/2021	-	

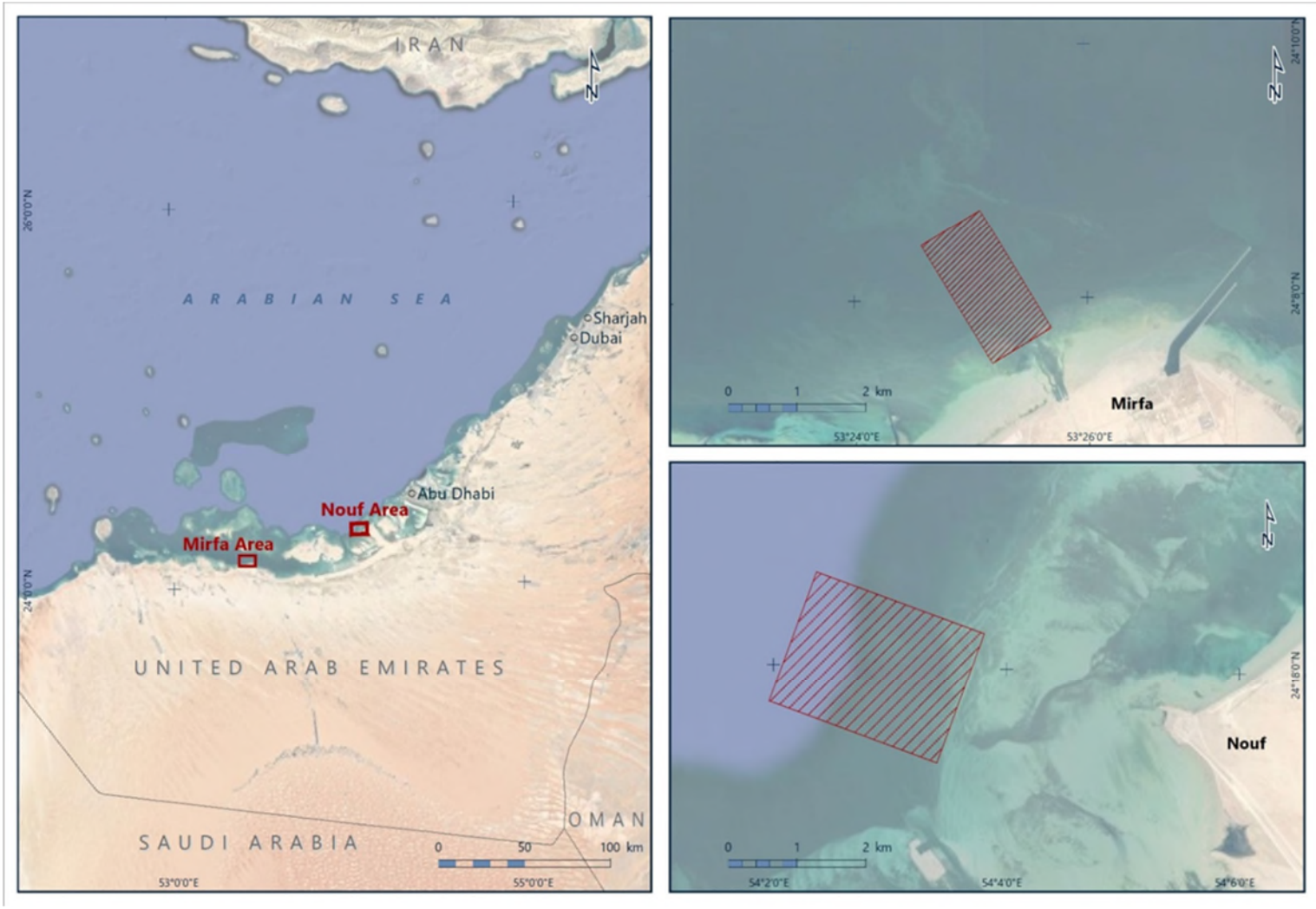
INTERNAL DISTRIBUTION LIST		
Company	**Project Role**	**Name**
FUGRO	Project Director	Michael Meyer
FUGRO	Project Manager – Nearshore Geotechnical Survey	Muhammad Ishaq
FUGRO	Project Manager – Bathymetric Survey	Venugopalan Nambiar
FUGRO	Director Marine Geophysics	Gerard Ferreira
FUGRO	Client Deliverables Manager	Tony Farn
FUGRO	Country QHSSE Manager	May De la Cruz
FUGRO	Operations Manager	Richard Harding
FUGRO	Data Centre Manager	David Duguid
FUGRO	Regional Business Line Director Marine Site Characterisation	Remmelt de Jong

PROJECT DEFINITIONS AND REFERENCES

PROJECT DEFINITIONS

PROJECT	BATHYMETRIC SURVEYS FOR WAVE PROJECT
COMPANY	Abu Dhabi National Oil Company for Onshore Oil Operations (ADNOC Onshore)
CLIENT	ILF Consulting Engineers - Abu Dhabi
CONTRACTOR	FUGRO
ADNOC JOB NO:	TBA
SCOPE OF WORK	Appendix 4.1 - Scope of Work Offshore Bathy.docx
CALL OFF ORDER NO:	TBC
FUGRO REFERENCE	Fugro Technical Proposal_184930

ABBREVIATIONS	
ADNOC	Abu Dhabi National Oil Company
CM	Centre of Meridian
CTDS	Conductivity, Temperature, Depth and Salinity
DGNSS	Differential Global Navigation Satellite System
DGPS	Differential Global Positioning System
EPSG	European Petroleum Survey Group
GPS	Global Positioning System
HSSE	Health, Safety, Security and Environment
ITRF	International Terrestrial reference Frame
LAT	Lowest Astronomical Tide
M	Meters
m/s	Meters per Second
MBES	Multibeam Echo Sounder
MSL	Mean Sea Level
MSS	Mean Sea Surface
QA	Quality Assurance
QHSSE	Quality, Health, Safety, Security and Environment
REP	Representative
SBES	Single Beam Echo Sounder
SBP	Sub-bottom Profiler
SSS	Sidescan Sonar
UTM	Universal Transverse Mercator
WGS84	World Geodetic System (1984)



GENERAL LOCATION MAP

SUMMARY OF RESULTS

The bathymetric and geophysical survey at Mirfa Plant Site was conducted over a 2000 m × 1000 m area. Due to navigational safety constraints, only single beam echo sounder data was acquired in a small area close to the southern survey limits. During high tides, the survey was extended beyond the southern margin towards the coast, where the boat could navigate safely.

WGS84 Ellipsoid, WGS84 Datum (ITRF2014), UTM Projection, Zone 39 North, CM 51° East

Bathymetry:	Vertical Datum	:	LAT
	Minimum water depth within the survey area (including soundings beyond the survey boundary)	:	–0.5 m (drying height) at 746 007 mE, 2 670 508 mN) (towards southern limit of survey area)
	Maximum water depth within the survey area	:	3.6 m at 745 552 mE, 2 672 055 mN (towards northern limit of survey area)
	Maximum gradient within the survey area:	:	Overall gradient < 3° 10° (localised over undulated seabed) at 745 528 mE, 2 671 483 mN (central survey area)

Seabed Sediments:

Type 1 : Medium reflective seabed, interpreted as predominantly SAND, becoming dense to variably cemented in places.

Type 2 : Mottled low and high reflective seabed, interpreted as cemented SAND/CALCARENITE with pockets of SAND.

Seabed Features: Prominent seabed features include pinnacles, areas of pinnacles, a seabed scar, minor sand ripples, rugged/irregular seabed, a seabed ridge, areas of backfill and area of rock outcrops.

Sonar Contacts: Three items of debris and one area of debris were detected.

Magnetic Anomalies: Thirty-seven magnetic anomalies were interpreted within the survey area comprising twenty anomalies of unknown origin. These could not be attributed to any known sources and may represent ferrous debris, which are either smaller than the resolution of the sidescan sonar/multibeam echo sounder systems or buried at shallow depths below seabed.

Existing Utilities: A pipeline was seen to run from the north-north-western survey boundary in a southerly direction towards shore. Caution is advised for operations near this pipeline.

Shallow Geology: The seabed comprising SAND and cemented SAND/CALCARENITE offered high acoustic impedance to the sub-bottom profiler signal. The penetration was probably limited due to hard seabed conditions across the majority of the survey area.

BATHYMETRIC AND GEOPHYSICAL SURVEY DOCUMENT STRUCTURE

Document Description	Fugro Document No.
Technical and Operations Report	MRU096-V01-SR-TO
Survey Report – Mirfa Plant Site	**MRU096-V02-SR-MIRFA (This Report)**
Survey Report – Nouf Al Dabbyah Site	MRU096-V03-SR-NOUF

CONTENTS

1. INTRODUCTION AND SCOPE OF WORK 10
1.1 INTRODUCTION 10
1.2 SCOPE OF WORK – BATHYMETRIC AND GEOPHYSICAL SURVEYS 11
1.3 PROPOSED SURVEY LOCATIONS 12
1.3.1 Survey Design – Bathymetric and Geophysical Survey 12
1.3.2 Survey Sensor Overview 13
2. REFERENCE DOCUMENTATION 15
3. SURVEY CONTROL PARAMETERS 16
3.1 UNITS 16
3.2 GEODETIC PARAMETERS 16
3.3 VERTICAL CONTROL 17
3.4 TIME 17
3.5 KEY SEABED FEATURES AND SONAR CONTACT DEFINITIONS 18
4. SURVEY RESULTS 19
4.1 GENERAL 19
4.2 BATHYMETRY 19
4.3 SEABED SEDIMENTS 19
4.4 SEABED FEATURES 22
4.4.1 Pinnacles/Areas of Pinnacles 22
4.4.2 Sand Ripples 25
4.4.3 Rugged/Irregular Seabed 26
4.4.4 Seabed Scars 26
4.4.5 Seabed Ridge 27
4.4.6 Areas of Backfill 27
4.4.7 Rock Outcrops 28
4.5 SONAR CONTACTS 29
4.6 MAGNETIC ANOMALIES 31
4.7 EXISTING UTILITIES 33
4.8 SHALLOW GEOLOGY 34
4.9 CONCLUSIONS 36

APPENDIX

A. CHARTS

FIGURES IN THE MAIN TEXT

Figure 1.1: Survey Rrunline Diagram at Mirfa Plant Site 14
Figure 4.1: Sidescan Sonar Data Coverage across the 2000 m x 1000 m Survey Area 20
Figure 4.2: Sidescan data showing sediment Type 1 and Type 2 21
Figure 4.3: SSS image showing Pinnacles 24
Figure 4.4: MBES and SSS images showing Area of Pinnacles 25
Figure 4.5: SSS image showing Area of Minor Sand Ripples 26
Figure 4.6: MBES and SSS images showing Rugged/Irregular Seabed 26
Figure 4.7: MBES and SSS images showing Seabed Ridge 27
Figure 4.8: MBES and SSS images showing Area of Backfill 27
Figure 4.9: MBES and SSS images showing Areas of Rock Outcrop 28
Figure 4.10: MBES and SSS images showing Debris MIRFA-DB01 29
Figure 4.11: MBES and SSS images showing Debris MIRFA-DB02 30
Figure 4.12: MBES and SSS images showing Debris MIRFA-DB03 30
Figure 4.13: MBES and SSS images showing Area of Debris 30
Figure 4.14: Magnetic anomaly of Unknown Origin 32
Figure 4.15: Magnetic anomaly associated with MIRFA_AD01 and MIRFA_DB01 32
Figure 4.16: Magnetic anomaly associated with MIRFA_DB02 33
Figure 4.17: MBES and SSS images showing Exposed Pipeline 33
35
Figure 4.18: Pinger SBP data showing NW-SE Shallow Geology 35

TABLES IN THE MAIN TEXT

Table 1.1: Mirfa Plant Site Survey Area Coordinates 12
Table 1.2: Bathymetric and Geophysical Survey Design 12
Table 1.3: Geophysical Survey Equipment 13
Table 2.1: Reference Documentation 15
Table 3.1: Geodetic Parameters at Mirfa Plant Site 16
Table 3.2: Tide Gauge Location 17
Table 4.1: Pinnacles 22
Table 4.2: Areas of Pinnacles 25
Table 4.3: Sonar Contacts 29
Table 4.4: Magnetic Anomalies 31

.

1. INTRODUCTION AND SCOPE OF WORK

1.1 INTRODUCTION

Fugro was contracted by ILF Consulting Engineers - Abu Dhabi (Client) on behalf of Abu Dhabi National Oil Company for Onshore Oil Operations (ADNOC Onshore) (Company) for the Provision of Bathymetric, Metocean and Nearshore Geotechnical Services For Wave Project (Package C), offshore Abu Dhabi, United Arab Emirates.

The objective of the Wave Project represents ADNOC's initiatives in ensuring an additional source of water for injection to the ADNOC onshore and offshore oil and gas fields. The scope of the project looks to use treated seawater as an alternative for all ADNOC onshore fields.

The Geophysical Survey was carried out using the survey launch Fugro Surveyor, fitted with Single Beam and Multibeam Echo Sounders, Motion Sensors, Sidescan Sonar, Sub-bottom Profiler (Pinger) and Magnetometer in conjunction with Differential Global Navigation Satellite System (DGNSS).

The port calibrations and functional tests of equipment were performed between 26 and 30 April 2021 while the vessel was alongside the Fugro Jetty in Mussafah, and at Mirfa Port, Abu Dhabi. The survey was conducted between 3 and 9 May 2021.

This document, MRU096-V02-SR-MIRFA, details the results from the bathymetric and geophysical survey for Mirfa Plant Site: Bathymetry, Seabed Features, Lithology, Magnetic Anomalies and Shallow Geological information.

All coordinates in this report are referenced to WGS84 Ellipsoid, WGS84 Datum (ITRF2014), UTM Projection, Zone 39 North, CM 51° East.

1.2 Scope of Work – Bathymetric and Geophysical Surveys

The scope of work can be summarised as:

- Establish bathymetry;
- Identification of existing pipelines, cables, or other services;
- Identify and locate any seabed obstacles, including rock outcrops, low-lying islands etc;
- Sub-bottom profiling the uppermost maximum penetration to determine the shallow geology of area of survey;
- Record magnetic anomalies to identify any potential ferrous items on or below the seabed (wrecks, ferrous debris, pipelines and cables) using a towed magnetometer
- Prepare a detailed report/charts describing survey results;

To achieve these objectives, the following were undertaken:

- High precision primary (StarPack G2+ DGNSS, SBES, MBES, SSS, SBP and magnetometer were deployed as a minimum;
- Provision of positioning and navigation on a suitably equipped vessel to obtain survey data using DGNSS;
- Acquired bathymetric data using SBES and MBES systems in conjunction with heave/motion sensor units;
- All survey sensors were run on all lines with 20 m line spacing to provide full coverage of MBES and SSS, with 100 % seabed coverage;
- Initially, all soundings were reduced to Lowest Astronomical Tide (LAT) using predicted tides. Observed tides will be applied once that data becomes available;
- Obtained seabed imagery using a towed sidescan sonar system to map soil types, seabed conditions and identified, reported all debris/obstructions within the surveyed areas;
- Assessed the seabed and shallow sub-seabed soils and conditions by using Pinger sub-bottom profiling device;
- Recorded magnetic data to identify any potential ferrous items on or below the seabed (wrecks, ferrous debris, pipelines and cables) using a towed magnetometer.

1.3 Proposed Survey Locations

The proposed survey locations are defined by the coordinates presented in Table 1.1. These coordinates have been extracted from a client-supplied drawing.

Table 1.1: Mirfa Plant Site Survey Area Coordinates

WGS84 Ellipsoid, WGS84 Datum (ITRF 2000), UTM Projection, Zone 39 North, CM 51° East		
Location	**Eastings [m]**	**Northings [m]**
Mirfa P1	745 722.721	2 672 407.062
Mirfa P2	746 758.489	2 670 696.161
Mirfa P3	745 903.039	2 670 178.277
Mirfa P4	744 867.270	2 671 889.178
Source: 12389-ILF-UEO-OD-0015-A1_D.pdf		

1.3.1 Survey Design – Bathymetric and Geophysical Survey

The Bathymetric and Geophysical Surveys cover the area illustrated in Figure 1.1. Table 1.2 summarises the deployed sensors and the methods used to achieve the necessary coverage.

Table 1.2: Bathymetric and Geophysical Survey Design

Survey Sensors :	Single Beam Echo Sounder (SBES); R2Sonic Multibeam System; SonarTech Sidescan Sonar; GeoAcoustics GeoPulse 5210A/Pinger Sub-bottom Profiler; Geometrics G-882 Magnetometer; Positioning Starfix G2+ DGNSS.	
Data Coverage and Line Spacing :	Survey lines were run with 20 m line spacing to provide 100 % MBES and SSS coverage between two adjacent lines in water depths greater than 3 m. Crosslines were run at 500 m intervals. Additional lines were run wherever required. Note: The bathymetric survey (SBES) was extended over the shallow water area towards shore, up to the 1 m water depth mark, during high tides.	
	Mirfa Plant Site:	
	Survey (All sensors)	**Number of Lines**
	Mainline - Line spacing 20 m	51
	Crossline - Line spacing 500 m	4
	SBES Lines – Line spacing 20 m	68
Sounding Reduction :	Water depths were initially reduced to Lowest Astronomical Tide (LAT) using predicted tides. Observed tides will be applied to reduce bathymetry once that data becomes available.	

1.3.2 Survey Sensor Overview

Table 1.3 lists the survey sensors mobilised onboard survey launch Fugro Surveyor and their operating parameters.

Table 1.3: Geophysical Survey Equipment

No.	Equipment Name	Unit	Frequency	Recording Length/Range
1	Single Beam Echo Sounder (SBES)	Odom EchoTrac MKIII	33/200 kHz	NA
2	Multibeam Echo Sounder (MBES)	R2Sonic 2024	300 kHz	Variable
3	Sidescan Sonar (SSS)	SonarTech	400 kHz	35 m
4	Sub-bottom Profiler (SBP) - Pinger	GeoPulse 136A	3.5 kHz	50 ms
5	Magnetometer	Geometrics G-882	1 Hz	NA
6	Sound Velocity Profiler (SVP)	Valeport 6205	NA	NA

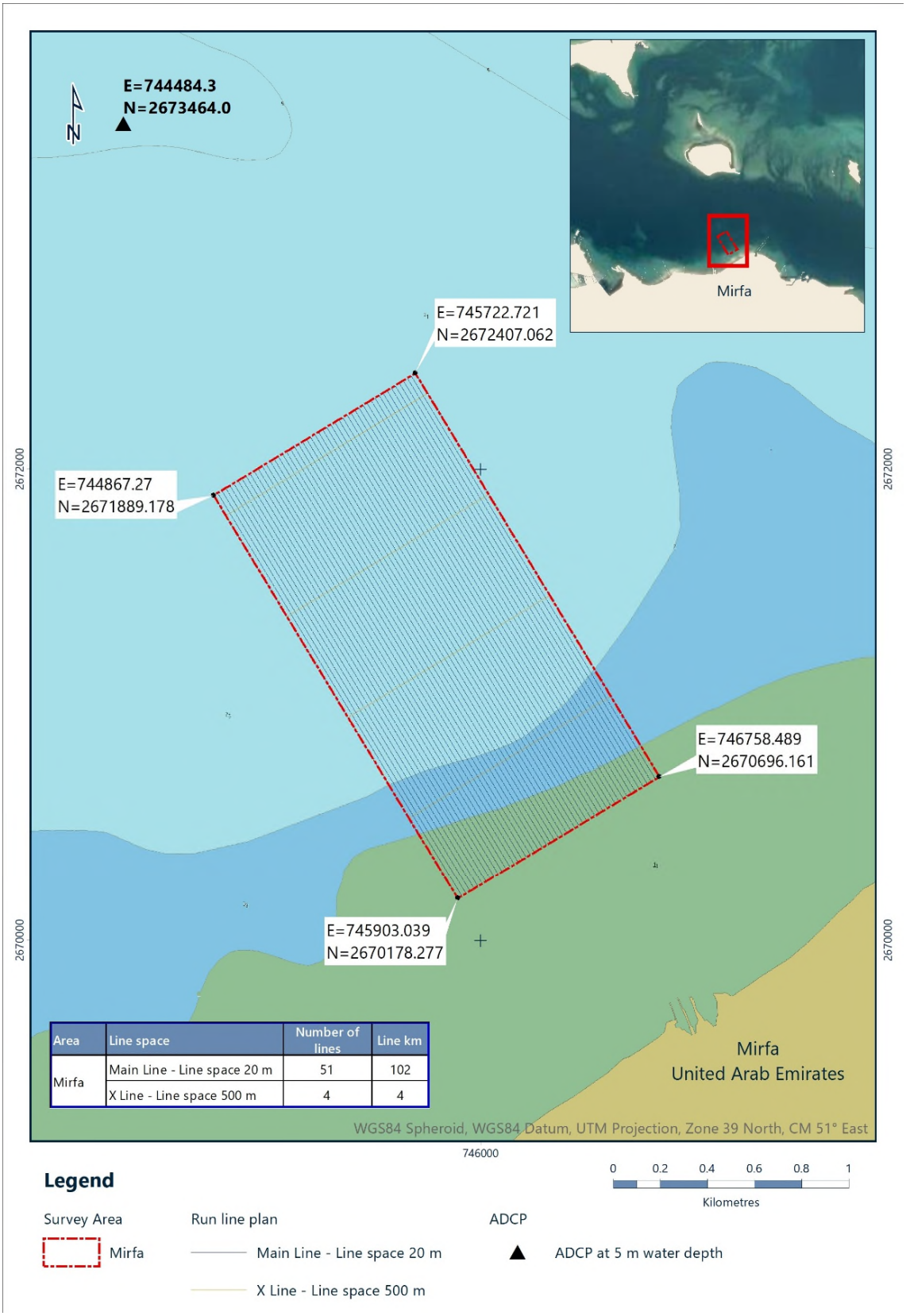


Figure 1.1: Survey Rrunline Diagram at Mirfa Plant Site

2. REFERENCE DOCUMENTATION

Table 2.1 lists the documentation referenced during preliminary survey report.

Table 2.1: Reference Documentation

No.	Document Name	Document Identity
1	Contract Ref No:	12389-ILF-UEO-OD-0006 Package C-Offshore Surveys Subcontract Agreement
2	Letter of Award	12389-ILF-UEO-OC-001
3	Scope of Work	Document No. Appendix 4.1-Scope of Work Offshore Bathy
4	Scope of Work Drawing	12389-ILF-UEO-OD-0015-A1_D
5	Scope of Work Drawing	12389-ILF-UEO-OD-0016-A1_D
6	Scope of Work Drawing	12389-ILF-UEO-OD-0022-A1_B
7	Scope of Work Drawing	12389-ILF-UEO-OD-0023-A1_B
Fugro Project Procedure Documents		
Technical and Commercial Documents		
1	Fugro Proposal	184930-01-ILF-ADNOC Wave
2	Bill of Quantities	Appendix 5.2-12389_Target rates_11032021
HSE Documents		
1	Project Health, Safety, Security and Environmental Plan	MRU096-HSSE
2	Project Emergency Plan	MRU096-ERP
3	Project Quality Plan	MRU096-QP
Project Execution Plan		
1	Project Execution Plan Bathymetric and Geophysical Survey - Offshore	MRU096-PEP
2	Bathymetric and Geophysical Survey - Offshore - Risk Assessment	MRU096-RA

3. SURVEY CONTROL PARAMETERS

3.1 Units

- Coordinates are expressed in international metres [m];
- Linear measurements are expressed in metres [m];
- Angular units are expressed in degrees [°].

3.2 Geodetic Parameters

The survey was conducted using WGS84 geodetic parameters.

Table 3.1: Geodetic Parameters at Mirfa Plant Site

Global Positioning Geodetic Coordinate Reference System Parameters [1)]		
Datum:	WGS84	EPSG Code: 6326
Ellipsoid:	WGS84	Epoch: ITRF2014; May 2021
Semi-major Axis:	a = 6 378 137.000 0 m	
Semi-minor Axis:	b = 6 356 752.314 2 m	
Inverse Flattening:	1/f = 298.257 223 6	
Projection Parameters		
Map Projection:	Universal Transverse Mercator	EPSG Code 16039
Grid System:	UTM Zone 39 N	
Central Meridian:	51° 00′ 00″ East	
Latitude of Origin:	00° 00′ 00″ North	
False Easting:	500 000 m	
False Northing:	0 m	
Scale Factor on Central Meridian:	0.9996	
Units:	Metre	

Notes:
1. Fugro Starfix navigation software always uses WGS84 as the primary datum for any geodetic calculations.
2. Right-handed coordinate frame rotation convention used by Fugro Starfix navigation software.
3. Source: ADNOC document; Engineering Specification for Offshore Geophysical Surveys

3.3 Vertical Control

All water depths have currently been reduced to Lowest Astronomical Tide (LAT) using predicted tides.

Additionally, height variations during the survey were determined using Fugro StarPackG2+ DGNSS data and assessments made by Fugro Starfix.MSS (Mean Sea Surface) software.

Prior to the survey commencement, a tide gauge was deployed to the north of the survey area. Tide data will be collected over a 30-day period. Water depths will be reduced using observed tides once the tide gauge data becomes available.

Table 3.2: Tide Gauge Location

WGS84 Ellipsoid, WGS84 Datum (ITRF 2000), UTM Projection, Zone 39 North, CM 51° East		
Tide Gauge ID	**Eastings [m]**	**Northings [m]**
MIRFA ADCP1	744 484.3	2 673 464.0

3.4 Time

All survey data were logged in UTC. Local UAE time is UTC + 4 hours.

3.5 Key Seabed Features and Sonar Contact Definitions

Seabed Scar: Drag marks on the seabed mainly caused by anchor dragging/cable plough and trawling or fishing activities.

Pinnacle: A column of coral or rocks with a lofty peak and measurable height above seabed.

Ridge: A build-up of sediment forming a linear mound with a continuous crest.

Sand Ripples: Small-scaled ridges of sand produced by flowing water or wave action.

Outcrop A portion of bedrock or other stratum protruding through the seabed sediment level.

Sonar Contact: General term for a discrete object exhibiting high reflectivity on sidescan sonar records.

Debris: Defined as being, most probably, a man-made object generally with a measurable height above seabed.

4. SURVEY RESULTS

4.1 General

The Bathymetric and Geophysical Survey at Mirfa Plant Site was conducted over a 2000 m × 1000 m area as illustrated in Figure 4.1. Due to navigational safety constraints, only single beam echo sounder data was acquired over a small area close to the southern survey limits. During high tide, the survey was extended beyond the southern margin towards the coast, up to where the boat could navigate safely.

4.2 Bathymetry

Water depths were reduced to Lowest Astronomical Tide (LAT) using predicted tides. Final reduction will be done using observed tides once the tide gauge data becomes available.

Minimum water depth within the survey area : -0.5 m (drying height) at
746 007 mE, 2 670 508 mN
(towards southern limit of survey area)

Maximum water depth within the survey area : 3.6 m at 745 552 mE, 2 672 055 mN
(towards northern limit of survey area)

Maximum gradient within the survey area : Overall gradients <3°
10° (localised over undulated seabed),
at 745 528 mE, 2 671 483 mN
(central survey area)

4.3 Seabed Sediments

The interpretation of seabed sediments was based mainly on the variations in acoustic reflectivity observed on the sidescan sonar records. Two sediment types were interpreted within the survey area as described below and illustrated in Figure 4.2;

Type 1 : Medium reflective seabed, interpreted as Predominantly SAND, becoming dense to variably cemented in places;

Type 2 : Mottled low and high reflective seabed, interpreted as cemented SAND/ CALCARENITE with pockets of SAND.

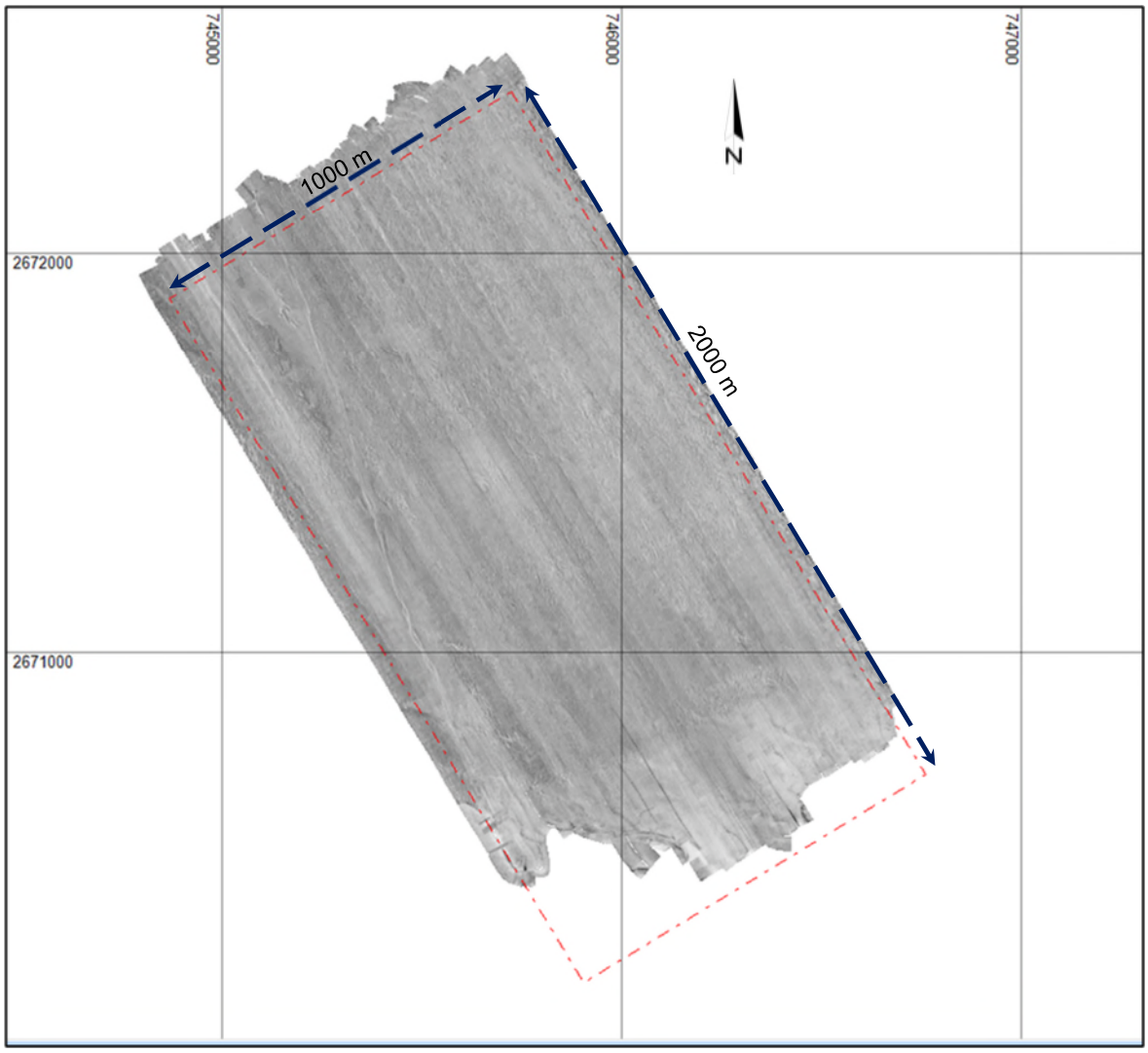


Figure 4.1: Sidescan Sonar Data Coverage across the 2000 m x 1000 m Survey Area

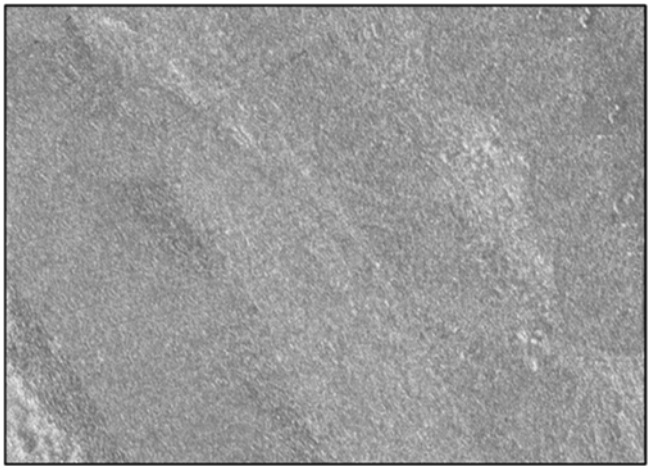
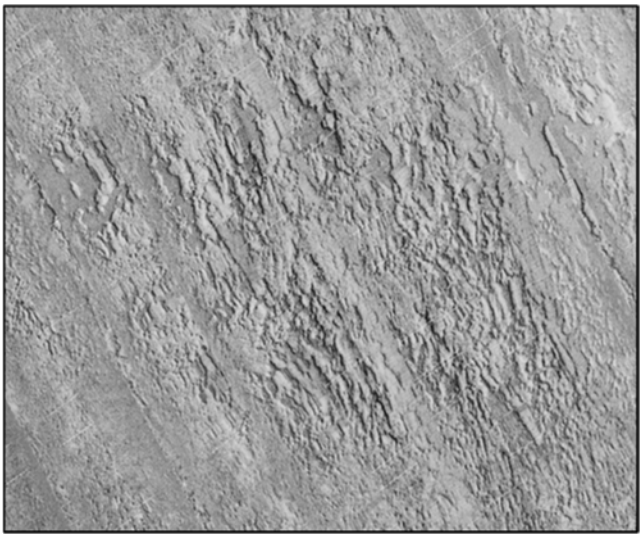
Type 1: Medium reflective seabed, interpreted as predominantly SAND.	
Type 2: Mottled low and high reflective seabed, interpreted as cemented SAND/CALCARENITE.	

Figure 4.2: Sidescan data showing sediment Type 1 and Type 2

4.4 Seabed Features

Morphological seabed features such pinnacles, area of pinnacles, a seabed scar, minor sand ripples, rugged/irregular seabed, a seabed ridge, areas of backfill and rock outcrops were interpreted within the Mirfa survey area.

4.4.1 Pinnacles/Areas of Pinnacles

Seventy-four pinnacles were interpreted within the survey area as detailed in Table 4.1.

Table 4.1: Pinnacles

WGS84 Ellipsoid, WGS84 Datum (ITRF2014), UTM Projection, Zone 39 North, CM 51° East				
Sl. No.	**Seabed Feature**	**Easting [m]**	**Northing [m]**	**Height [m]**
1	Pinnacle	745 820.5	2 672 144.7	0.1
2	Pinnacle	745 856.3	2 672 140.7	0.3
3	Pinnacle	745 871.2	2 672 104.8	0.2
4	Pinnacle	745 877.2	2 672 108.0	0.3
5	Pinnacle	745 879.1	2 672 108.2	0.2
6	Pinnacle	745 878.7	2 672 056.9	0.1
7	Pinnacle	746 092.8	2 671 687.7	0.2
8	Pinnacle	746 522.6	2 670 839.4	0.1
9	Pinnacle	746 528.7	2 670 689.8	0.5
10	Pinnacle	746 296.9	2 670 771.7	0.3
11	Pinnacle	746 142.2	2 670 779.8	0.2
12	Pinnacle	745 849.0	2 670 590.5	0.5
13	Pinnacle	745 848.0	2 670 586.7	0.7
14	Pinnacle	745 682.9	2 670 589.2	0.2
15	Pinnacle	745 675.0	2 670 803.4	0.3
16	Pinnacle	745 640.5	2 670 712.6	0.1
17	Pinnacle	745 638.1	2 670 737.1	0.4
18	Pinnacle	745 590.5	2 670 752.7	0.4
19	Pinnacle	745 573.5	2 670 881.8	0.2
20	Pinnacle	745 531.7	2 670 849.5	0.2
21	Pinnacle	745 547.7	2 670 876.1	0.2
22	Pinnacle	745 542.4	2 670 867.8	0.5
23	Pinnacle	745 334.4	2 671 440.7	0.1
24	Pinnacle	745 219.1	2 671 513.8	0.1

WGS84 Ellipsoid, WGS84 Datum (ITRF2014), UTM Projection, Zone 39 North, CM 51° East				
Sl. No.	Seabed Feature	Easting [m]	Northing [m]	Height [m]
25	Pinnacle	745 336.9	2 671 506.5	0.5
26	Pinnacle	745 176.2	2 671 576.6	0.1
27	Pinnacle	745 172.0	2 671 579.8	0.2
28	Pinnacle	745 188.7	2 671 574.3	0.1
29	Pinnacle	745 296.6	2 671 538.0	0.3
30	Pinnacle	745 287.0	2 671 546.2	0.4
31	Pinnacle	745 292.9	2 671 543.4	0.4
32	Pinnacle	745 305.2	2 671 565.1	0.3
33	Pinnacle	745 302.2	2 671 576.4	0.3
34	Pinnacle	745 302.0	2 671 582.7	0.3
35	Pinnacle	745 201.5	2 671 687.3	0.2
36	Pinnacle	745 204.6	2 671 687.1	0.3
37	Pinnacle	745 204.0	2 671 690.2	0.3
38	Pinnacle	745 243.1	2 671 712.0	0.2
39	Pinnacle	745 194.7	2 671 766.6	0.3
40	Pinnacle	745 028.1	2 671 914.2	0.3
41	Pinnacle	745 207.7	2 671 781.4	0.1
42	Pinnacle	745 244.3	2 671 763.2	0.4
43	Pinnacle	745 240.9	2 671 772.1	0.3
44	Pinnacle	745 019.9	2 671 958.3	0.3
45	Pinnacle	745 104.2	2 671 896.9	0.3
46	Pinnacle	745 135.1	2 671 880.9	0.3
47	Pinnacle	745 144.1	2 671 873.4	0.2
48	Pinnacle	745 065.0	2 671 944.8	0.3
49	Pinnacle	745 461.1	2 671 602.3	0.2
50	Pinnacle	745 459.6	2 671 604.3	0.2
51	Pinnacle	745 119.9	2 671 906.2	0.2
52	Pinnacle	745 463.0	2 671 606.3	0.2
53	Pinnacle	745 212.2	2 671 834.9	0.5
54	Pinnacle	745 212.9	2 671 856.6	0.1
55	Pinnacle	745 205.0	2 671 866.9	0.6
56	Pinnacle	745 194.7	2 671 887.3	0.3
57	Pinnacle	745 376.7	2 671 724.8	0.2

WGS84 Ellipsoid, WGS84 Datum (ITRF2014), UTM Projection, Zone 39 North, CM 51° East				
Sl. No.	Seabed Feature	Easting [m]	Northing [m]	Height [m]
58	Pinnacle	745 378.4	2 671 729.2	0.2
59	Pinnacle	745 378.1	2 671 731.1	0.3
60	Pinnacle	745 441.5	2 671 692.8	0.3
61	Pinnacle	745 416.7	2 671 733.5	0.3
62	Pinnacle	745 409.7	2 671 743.2	0.1
63	Pinnacle	745 150.5	2 672 042.6	0.4
64	Pinnacle	745 518.2	2 671 640.4	0.2
65	Pinnacle	745 519.9	2 671 648.7	0.4
66	Pinnacle	745 495.0	2 671 702.0	0.2
67	Pinnacle	745 685.0	2 672 332.5	0.1
68	Pinnacle	745 726.9	2 672 228.4	0.2
69	Pinnacle	745746.1	2 672 242.3	0.2
70	Pinnacle	745 749.0	2 672 241.1	0.3
71	Pinnacle	745751.0	2 672 242.7	0.2
72	Pinnacle	745 755.1	2 672 242.2	0.2
73	Pinnacle	745 757.6	2 672 180.4	0.3
74	Pinnacle	745 766.9	2 672 228.2	0.1

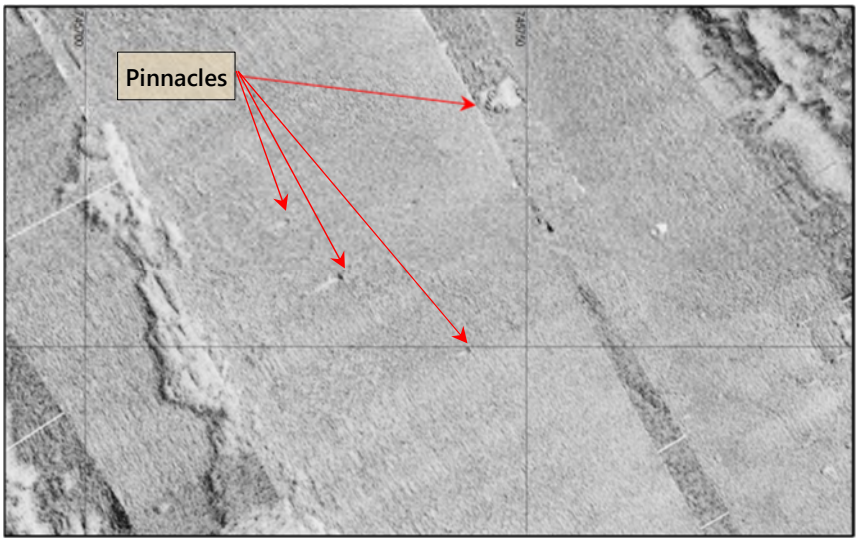


Figure 4.3: SSS image showing Pinnacles

In addition to isolated pinnacles, seven areas of pinnacles were also interpreted within the survey area. The distribution of these areas of pinnacles is detailed in Table 4.2.

Table 4.2: Areas of Pinnacles

WGS84 Ellipsoid, WGS84 Datum (ITRF2014), UTM Projection, Zone 39 North, CM 51° East				
Sl. No.	**Seabed Feature**	**Easting [m]**	**Northing [m]**	**Maximum Height [m]**
1	Area of Pinnacles	746 270.0	2 671 467.5	0.3
2	Area of Pinnacles	745 562.6	2 670 832.6	0.3
3	Area of Pinnacles	745 544.3	2 670 860.9	0.3
4	Area of Pinnacles	745 366.1	2 671 406.0	0.5
5	Area of Pinnacles	745 219.0	2 671 539.0	0.4
6	Area of Pinnacles	745 284.3	2 671 630.8	0.5
7	Area of Pinnacles	745 235.8	2 671 746.9	0.3

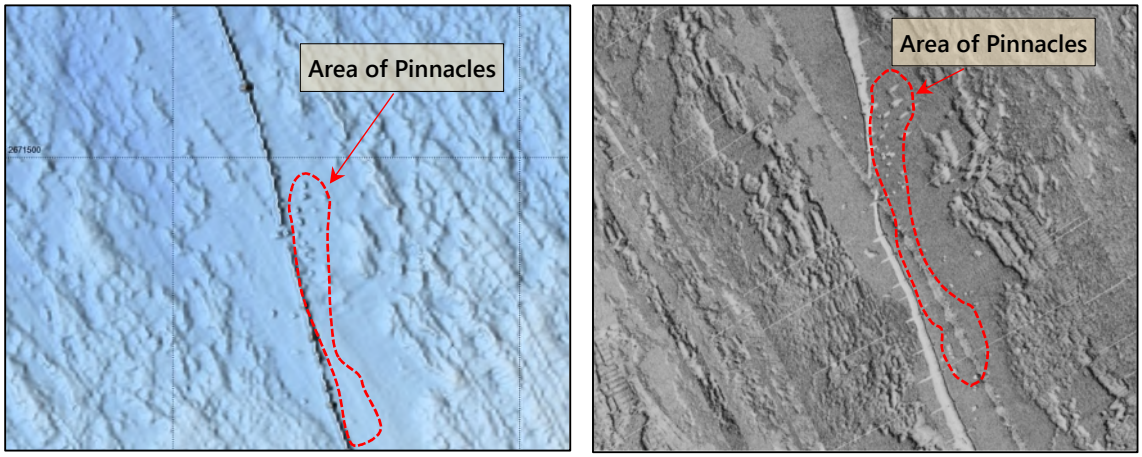


Figure 4.4: MBES and SSS images showing Area of Pinnacles

4.4.2 Sand Ripples

An area of minor sand ripples, with no measurable height, indicative of mobile sediments was interpreted within the survey area.

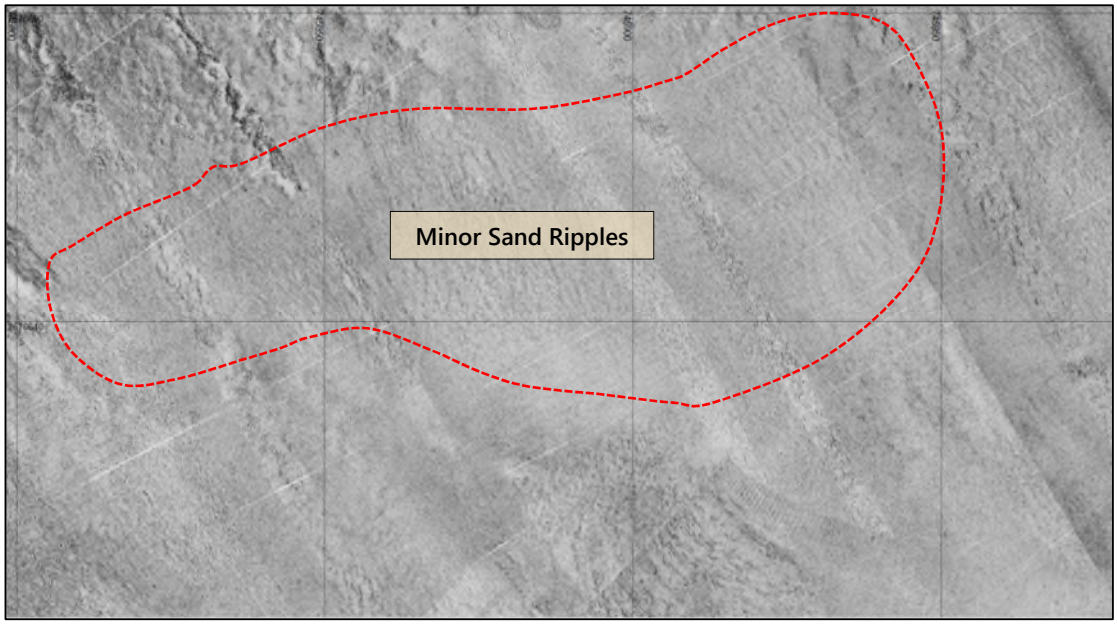


Figure 4.5: SSS image showing Area of Minor Sand Ripples

4.4.3 Rugged/Irregular Seabed

The seabed within the surveyed area showed a rugged/irregular topography.

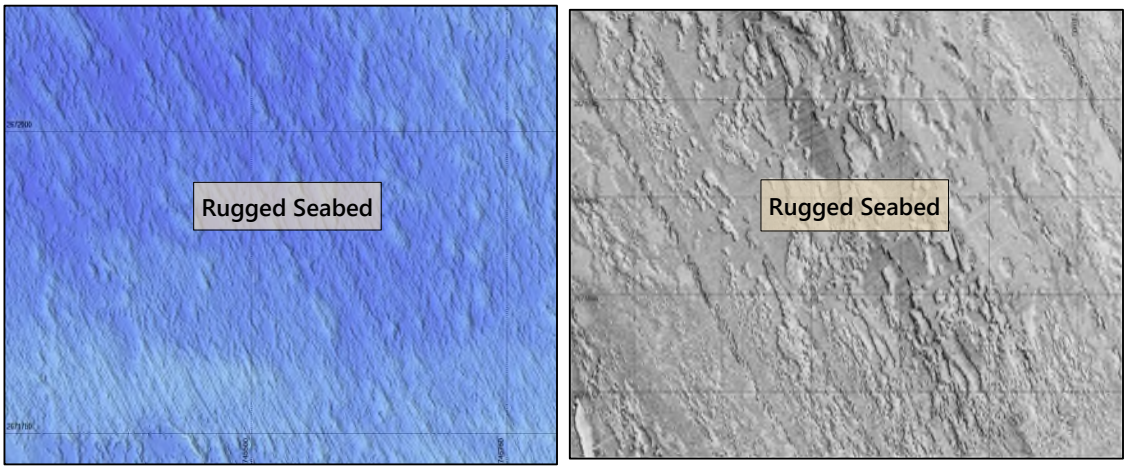


Figure 4.6: MBES and SSS images showing Rugged/Irregular Seabed

4.4.4 Seabed Scars

One seabed scar was interpreted within the survey area.

4.4.5 Seabed Ridge

One seabed ridge with maximum height of 0.5 m was interpreted within the surrey area.

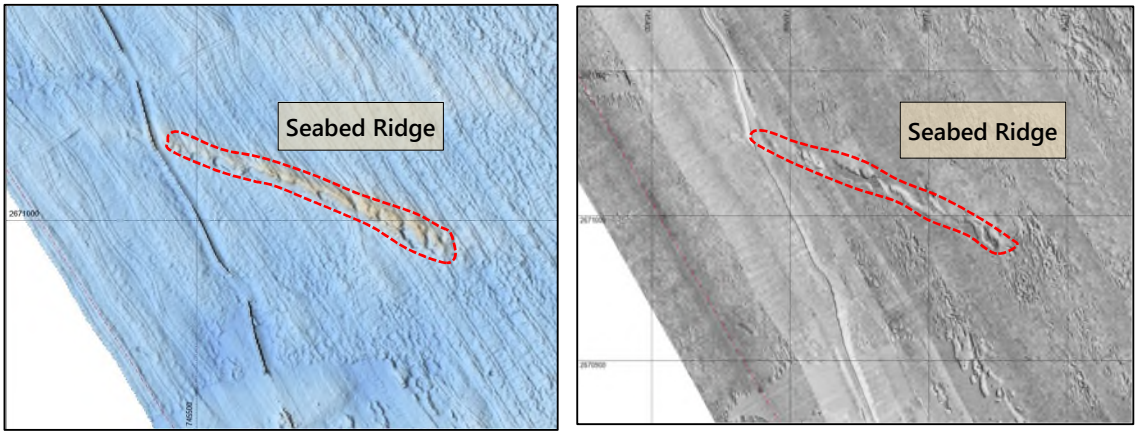


Figure 4.7: MBES and SSS images showing Seabed Ridge

4.4.6 Areas of Backfill

Two areas of backfill were interpreted over a pipeline within the surrey area.

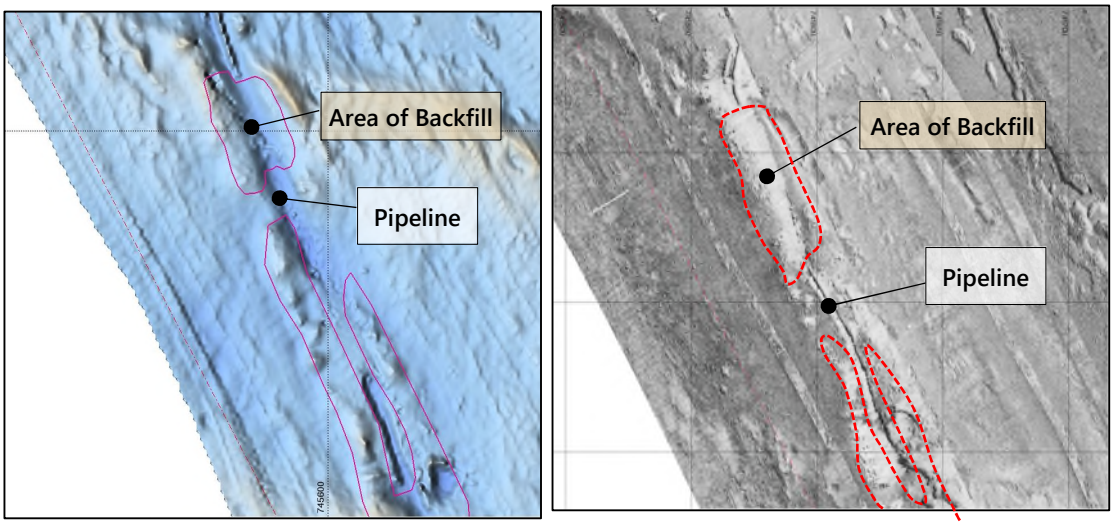


Figure 4.8: MBES and SSS images showing Area of Backfill

4.4.7 Rock Outcrops

Eight areas of rock outcrops with height varying from 0.2 m to 0.3 m were interpreted across the survey area.

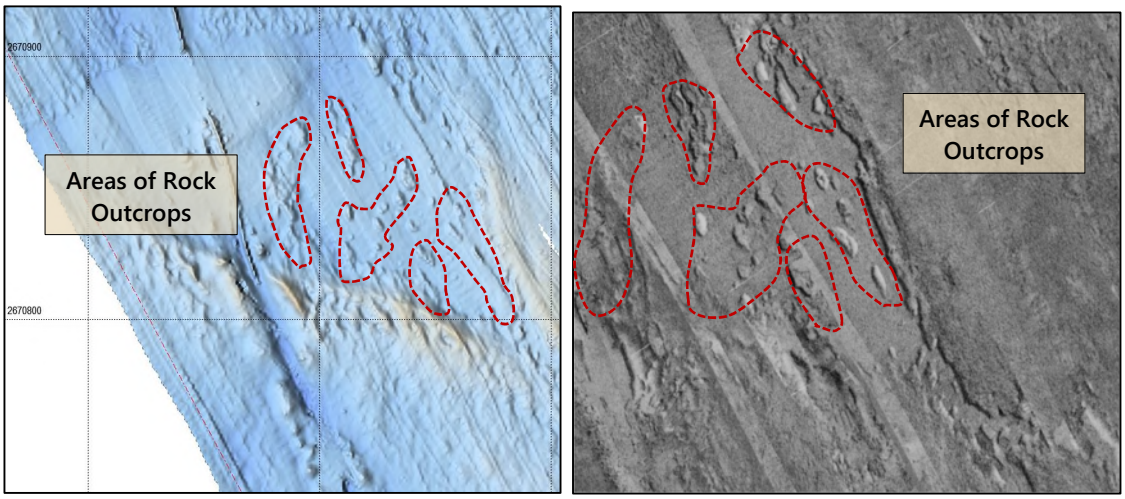


Figure 4.9: MBES and SSS images showing Areas of Rock Outcrop

4.5 Sonar Contacts

Three items of debris and one area of debris were interpreted within the survey area, as detailed in Table 4.3.

Table 4.3: Sonar Contacts

WGS84 Ellipsoid, WGS84 Datum (ITRF2014), UTM Projection, Zone 39 North, CM 51° East					
No.	ID	Easting [m]	Northing [m]	Distance [m]/Bearing [°] from Centre of Mirfa Plant Site	Dimensions [m] (L × W × H)
1	MIRFA - DB01	745 529.6	2 670 863.2	514.5/213°	1.0 × 0.6 × 0.2
2	MIRFA - DB02	745 366.3	2 671 436.5	469.1/288°	0.7 × 0.4 × 0.4
3	MIRFA - DB03	745 760.9	2 672 239.3	948.0/357°	1.5 × 1.5 × 0.2
4	MIRFA - AD01	745 534.7	2 670 845.9	526.3/212°	Maximum 1.6 × 0.6 × 0.2

DB – Debris; AD – Area of Debris

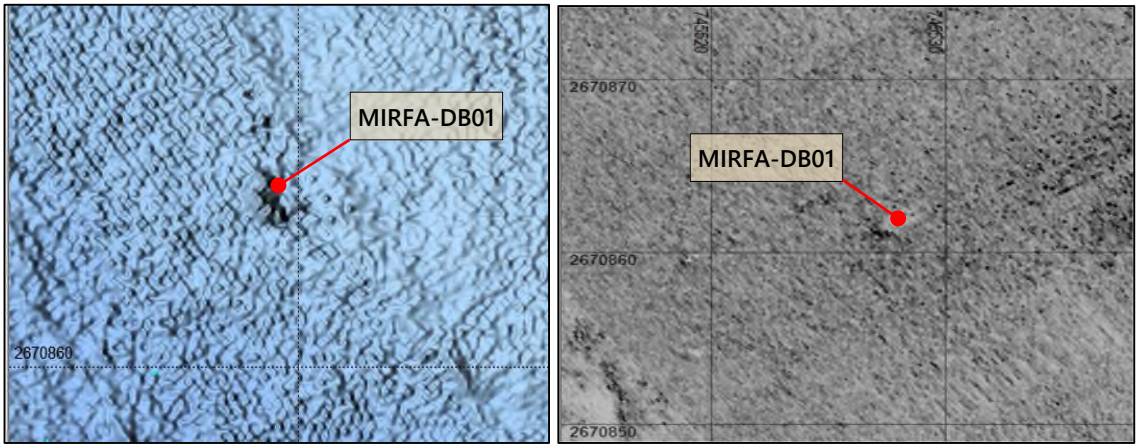


Figure 4.10: MBES and SSS images showing Debris MIRFA-DB01

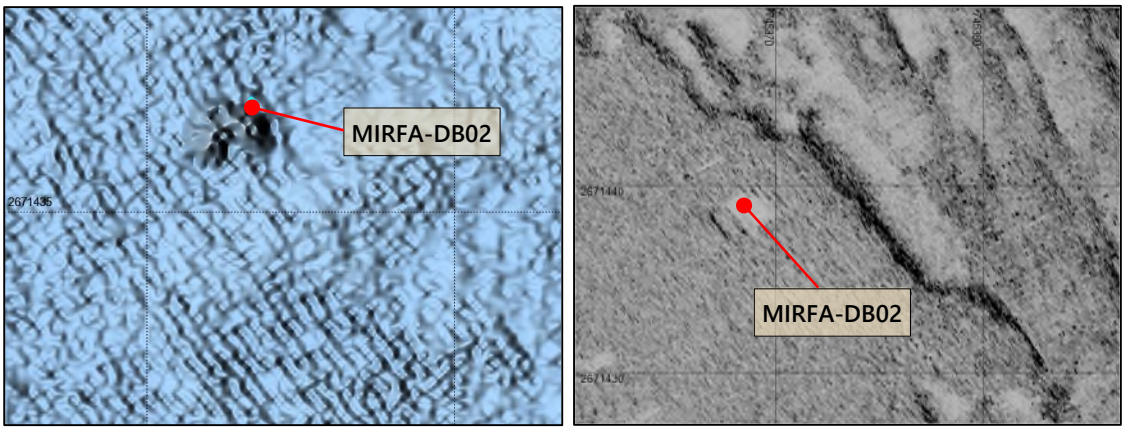


Figure 4.11: MBES and SSS images showing Debris MIRFA-DB02

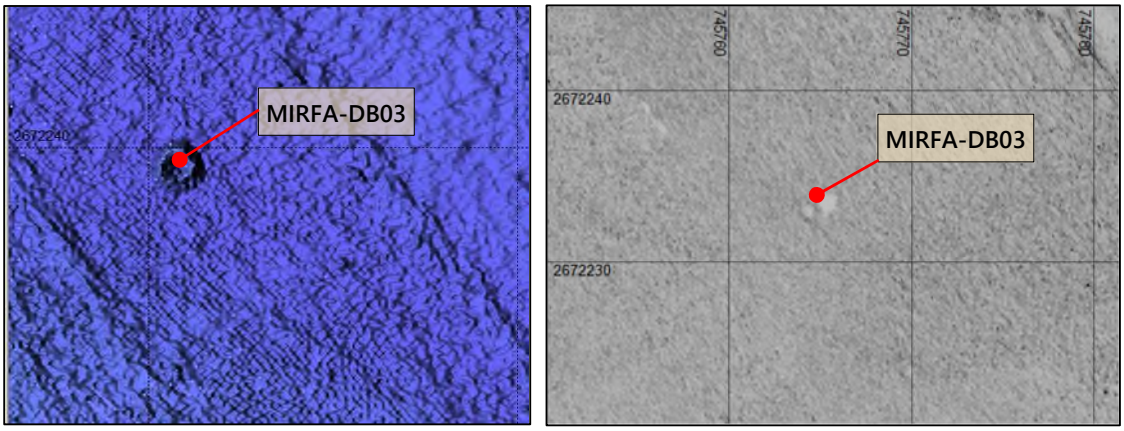


Figure 4.12: MBES and SSS images showing Debris MIRFA-DB03

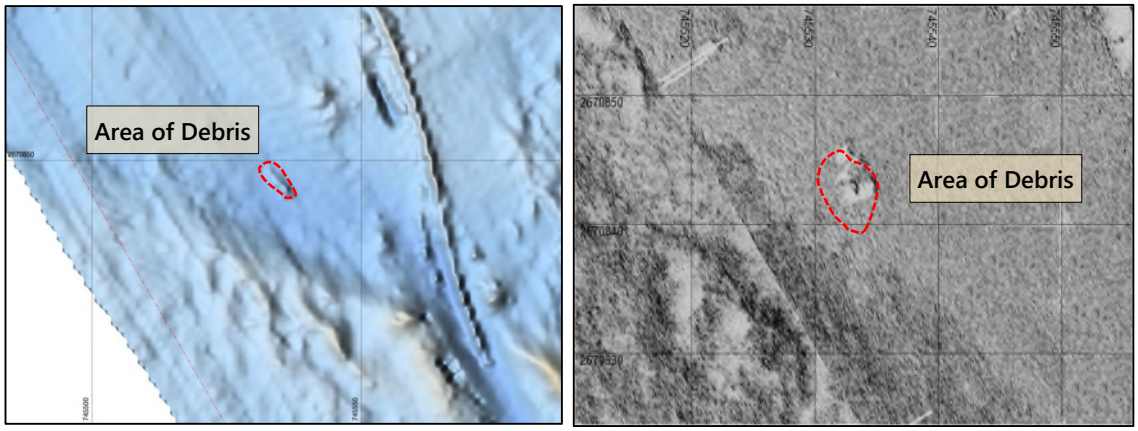


Figure 4.13: MBES and SSS images showing Area of Debris

4.6 Magnetic Anomalies

Thirty-seven magnetic anomalies were interpreted within the survey area. Of these, fourteen were associated with an existing pipeline. Two anomalies, MIRFA-MA12 and MIRFA-MA24, were associated with debris MIRFA-DB01 and MIRFA-DB02, respectively. Anomaly MIRFA-MA11 was associated with area of debris MIRFA-AD01. The twenty remaining anomalies could not be attributed to any known sources and may represent ferrous debris, which are either smaller than the resolution of the sidescan sonar/multibeam echo sounder systems or buried at shallow depths below seabed. Table 4.4 details the magnetic anomalies excluding those associated with the existing pipeline.

Table 4.4: Magnetic Anomalies

WGS84 Ellipsoid, WGS84 Datum (ITRF2014), UTM Projection, Zone 39 North, CM 51° East						
No.	**ID**	**Easting [m]**	**Northing [m]**	**Distance [m]/Bearing [°] from Centre of Mirfa Plant Site**	**Anomaly [nT]**	**Remarks**
1	MIRFA-MA01	746 179.9	2 670 604.6	779.9/152°	36	Unknown origin
2	MIRFA-MA02	745 952.7	2 670 975.7	346.5/156°	20	
3	MIRFA-MA03	745 970.7	2 670 594.2	716.1/167°	18	
4	MIRFA-MA04	745 827.3	2 671 104.9	188.4/176°	78	
5	MIRFA-MA05	745 633.5	2 670 643.4	673.6/195°	11	
6	MIRFA-MA06	745 635.4	2 670 725.6	594.2/197°	3	
7	MIRFA-MA08	745 634.2	2 670 766.2	556.0/199°	2	
8	MIRFA-MA10	745 598.6	2 670 896.4	450.5/208°	2	
9	MIRFA-MA11	745 535.3	2 670 848.0	524.2/212°	14	Associated with area of debris MIRFA-AD01
10	MIRFA-MA12	745 526.5	2 670 863.3	516.1/214°	8	Associated with debris MIRFA-DB01
11	MIRFA-MA14	745 515.2	2 670 932.0	467.7/220°	20	Unknown origin
12	MIRFA-MA15	745 478.3	2 670 984.8	454.7/227°	10	
13	MIRFA-MA18	745 596.8	2 671 290.8	216.1/269°	2	
14	MIRFA-MA20	745 248.2	2 671 320.5	565.4/ 273°	2	
15	MIRFA-MA21	745 362.1	2 671 332.0	452.5/ 275°	12	
16	MIRFA-MA24	745 369.0	2 671 438.7	467.3/ 288°	4	Associated with MIRFA - DB02
17	MIRFA-MA26	745 515.9	2 671 425.9	325.5/ 294°	2	Unknown origin

WGS84 Ellipsoid, WGS84 Datum (ITRF2014), UTM Projection, Zone 39 North, CM 51° East						
No.	ID	Easting [m]	Northing [m]	Distance [m]/Bearing [°] from Centre of Mirfa Plant Site	Anomaly [nT]	Remarks
18	MIRFA-MA27	745 287.1	2 671 569.4	594.2/ 298°	45	
19	MIRFA-MA31	745 185.3	2 671 816.8	817.7/ 310°	6	
20	MIRFA-MA33	745 046.4	2 671 974.5	1025.9/312°	4	
21	MIRFA-MA34	745 116.4	2 672 006.1	997.0/316°	3	
22	MIRFA-MA35	745 126.8	2 671 991.3	979.2/316°	11	
23	MIRFA-MA37	745 158.8	2 672 025.7	982.4/ 318°	9	

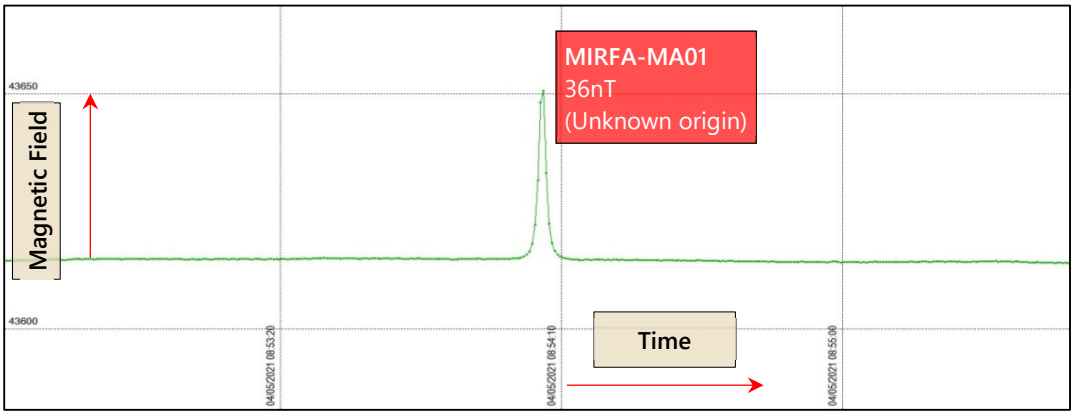


Figure 4.14: Magnetic anomaly of Unknown Origin

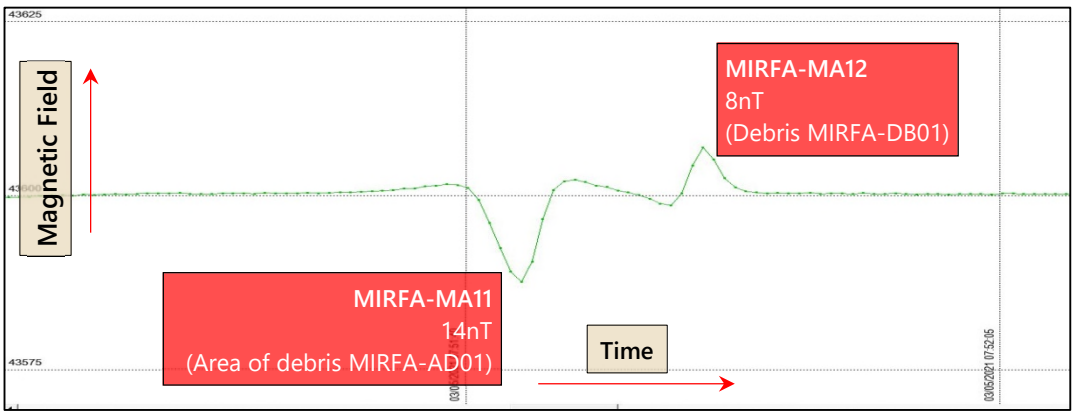


Figure 4.15: Magnetic anomaly associated with MIRFA_AD01 and MIRFA_DB01

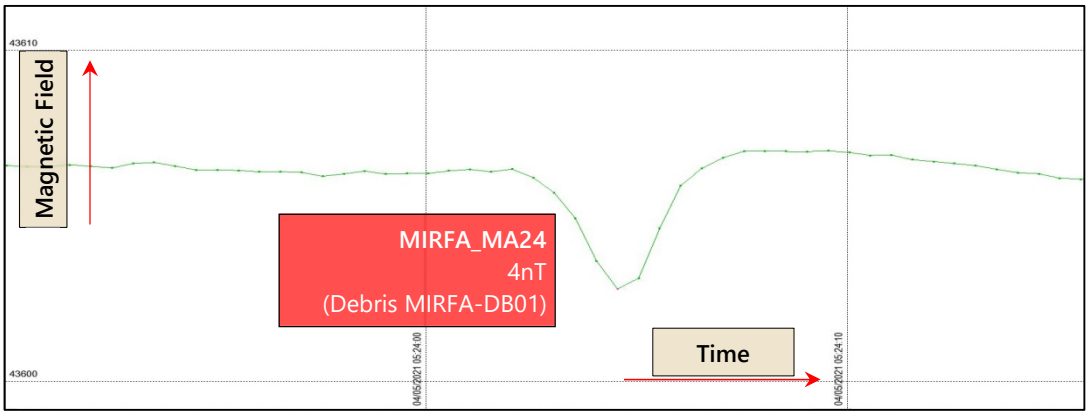


Figure 4.16: Magnetic anomaly associated with MIRFA_DB02

4.7 Existing Utilities

One pipeline was seen to run from the north-north-western survey boundary in a southerly direction towards shore. The identity and status of this pipeline is unknown. The pipeline was seen to be resting on supports within the majority of the survey area. Caution is advised in conducting operations near this pipeline.

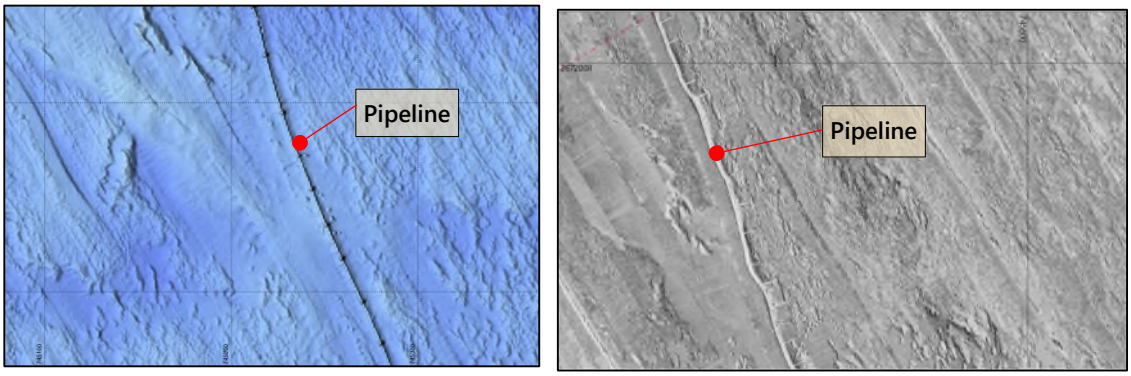


Figure 4.17: MBES and SSS images showing Exposed Pipeline

4.8 Shallow Geology

The interpretation of the shallow geology was based on Pinger sub-bottom profiler (SBP) data. A sub-bottom velocity of 1650 m/s was assumed for travel time to-depth conversion considering the nature of the shallow sediments within survey area.

The seabed sediments were interpreted to predominantly comprise SAND and cemented SAND/CALCARENITE, which offered high acoustic impedance to the SBP signal. The penetration was probably limited due to hard seabed condition in the majority of the survey area. A few weak reflectors were interpreted within 1.0 m below seabed, which could represent minor variations in sediment consolidation..

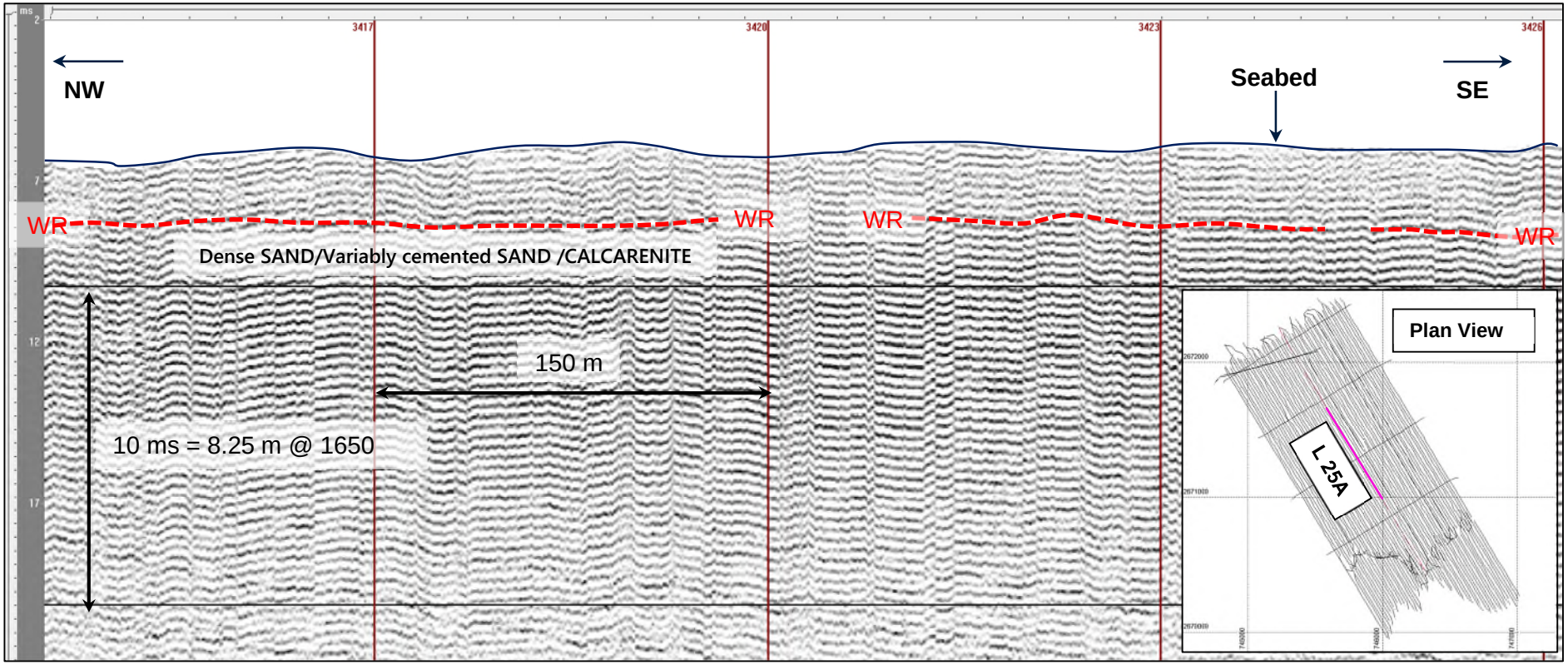


Figure 4.18: Pinger SBP data showing NW-SE Shallow Geology

4.9 Conclusions

- The water depths within the survey area varied between –0.5 m (drying height) and 3.6 m. The seabed within the survey area uneven topography with very gentle to gentle slope gradients. Localised moderate gradients can be expected over an undulated seabed;
- Two sediment types were interpreted within the survey area;
  - Predominantly SAND, becoming dense to variably cemented in places;
  - Cemented SAND/CALCARENITE with pockets of SAND;
- Prominent seabed features include; pinnacles, areas of pinnacles, a seabed scar, minor sand ripples, rugged/irregular seabed, a seabed ridge, areas of backfill and area of rock outcrops;
- Three debris items and one area of debris were detected within the survey area;
- Twenty magnetic anomalies of unknown origin were interpreted within the survey area. These could not be attributed to any known sources and may represent ferrous debris, which are either smaller than the resolution of the sidescan sonar/multibeam echo sounder systems or buried at shallow depths below seabed;
- One pipeline was seen to run from the north-north-western survey boundary in a southerly direction towards shore. Caution is advised when conducting operations near this pipeline;
- The seabed sediments were predominantly comprised SAND and cemented SAND/ CALCARENITE, which showed high acoustic impedance to the sub-bottom profiler signal. The penetration was probably limited due to hard seabed condition in the majority of the survey area.

APPENDIX

A. CHARTS

Drawing Number	Chart Title	Sheet	Scale	Paper Size	Enclosure
MRU096-MR-SS001BA	BATHYMETRY	01 of 02	1:2500	A0	1
MRU096-MR-SS002BA	BATHYMETRY	02 of 02	1:2500	A0	2
MRU096-MR-SS001SA	SEABED FEATURES	01 of 02	1:2500	A0	3
MRU096-MR-SS002SA	SEABED FEATURES	02 of 02	1:2500	A0	4
MRU096-MR-SS003ZA	BATHYMETRY AND LONGITUDINAL PROFILE	01 of 01	1:5000	A0	5

METOCEAN MEASUREMENTS AT MIRFA AND NOUF AL DABBYAH AREAS

METOCEAN MEASUREMENT REPORT AT MIRFA PLANT SITE

DRAFT

CONTRACTOR DOC TITLE	METOCEAN MEASUREMENT REPORT AT MIRFA PLANT SITE
CONTRACTOR	FUGRO
FUGRO PROJECT NO.	OMU041

CONTRACTOR DOC NO: OMU041-R-001

Rev	Date	Status	Status Description	Prepared	Reviewed	Approved	Company Approval
01	20/06/2021	IFR	Issued for Review	Katy Pozerskis/ Samantha Walby	Hithin Kandy/ Robin Newman	Youssef Atmani	

This Document is intended for use by ADNOC and its nominated Consultants, Contractors, Manufacturers and Suppliers.

SUMMARY OF DOCUMENT REVISIONS			
Rev. No.	**Date Revised**	**Section Revised**	**Revision Description**
01	20/06/2021	-	Issued for Review

INTERNAL DISTRIBUTION LIST		
Company	**Project Role**	**Name**
FUGRO	Project Director	Michael Meyer
FUGRO	Project Manager – Nearshore Geotechnical Survey	Muhammad Ishaq
FUGRO	Bathymetric Survey Lead	Venugopalan Nambiar
FUGRO	Metocean Lead	Balu Chandran
FUGRO	Regional Service Line Manager – Metocean	Youssef Atmani
FUGRO	Director Marine Geophysics	Gerard Ferreira
FUGRO	Client Deliverables Manager	Tony Farn
FUGRO	Country QHSSE Manager	May De la Cruz
FUGRO	Operations Manager	Richard Harding
FUGRO	Data Centre Manager	David Duguid
FUGRO	Regional Business Line Director Marine Site Characterisation	Remmelt de Jong

DRAFT

PROJECT DEFINITIONS AND REFERENCES	
PROJECT DEFINITIONS	
PROJECT	METOCEAN MEASUREMENTS FOR WAVE PROJECT
COMPANY	Abu Dhabi National Oil Company for Onshore Oil Operations (ADNOC Onshore)
CLIENT	ILF Consulting Engineers - Abu Dhabi
CONTRACTOR	FUGRO
SCOPE OF WORK	Appendix 4.1 - Scope of Work Offshore Bathy.docx
CALL OFF ORDER NO:	SHORT FORM SERVICES AGREEMENT (Ref. No: 12389-ILF-UEO-OD-0006. Dated: 17-March-2021)
FUGRO REFERENCE	Fugro Technical Proposal_184930

DRAFT

EXECUTIVE SUMMARY

Fugro has been contracted by ILF Consulting Engineers - Abu Dhabi (Client) on behalf of Abu Dhabi National Oil Company for Onshore Oil Operations (ADNOC Onshore) (Company)to provide bathymetric, metocean and nearshore geotechnical services for THE wWave project (package C), offshore United Arab Emirates.

This report pertains to the metocean data collected between 30 April and 4 June 2021. The metocean survey scope included the monitoring of water level, currents, waves, water temperature, wind velocity, air temperature, atmospheric pressure and humidity.

A seabed frame was deployed offshore to collect wave, current, water temperature and water level data at Mirfa. The primary system consisted of a Nortek 1MHz Acoustic Wave and Current profiler (AWAC) and a Valeport MIDAS Water Level Recorder (WLR). A redundancy system was also deployed in order to ensure maximum data return as well as to assist in quality control of the primary datasets. Additionally a meteorological station was installed at the Mirfa Hotel to collect wind velocity, atmospheric pressure, air temperature and humidity data. High data return was achieved for all parameters.

Low wave heights were observed for the majority of the deployment period. Periods of elevated wave height occured when winds were aligned with the area of greatest exposure to the west. The maximum wave height observed was 1.6 m Hmax.

Tidally dominated and rectilinear currents were observed, flooding to the east and ebbing to the west. Depth averaged speeds of up to 0.56 m/s were recorded.

The tidal signature of the site is mixed mainly diurnal and the Highest Astronomical Tide was calculated to be 2.33 m.

Meteorological data display diurnal patterns typically expected of the wider area with daily increases in wind speed linked to thermal increases. Onshore winds were dominant during the deployment and air temperatures reached 45.5°C.

Three sources of seawater temperature data showed excellent agreement and a lack of any vertical temperature structure within the water column. A diurnal pattern was exhibited with peaks reached during the middle of the day. A maximum seawater temperature of 34.2°C was observed.

DRAFT

ABBREVIATIONS AND DEFINITIONS	
ADCP	Acoustic Doppler Current Profiler
AWAC	Acoustic Wave and Current Profiler
Equilibrium tide	The hypothetical tide that would be produced by the lunar and solar tidal forces in the absence of ocean constraints and dynamics.
GMT	Greenwich Mean Time
Greenwich Meridian	A geographical reference line that passes through the Royal Observatory, Greenwich, London, England.
GST	Gulf Standard Time
Hmax	Maximum wave height
HAT	Highest Astronomical Tide *The highest tidal water level expected during a Metonic cycle.*
LAT	Lowest Astronomical Tide *The lowest tidal water level expected during a Metonic cycle.*
Metonic cycle	A 19-year celestial cycle in which there are 235 lunations, or synodic months
Metonic Maximum	Maximum value predicted to occur in a Metonic cycle.
MHHW	Mean Higher High Water *The mean of the higher high water of each day over a Metonic cycle.*
MHW	Mean High Water *MSL plus the lunar semidiurnal tide: Z0 + M2.*
MSL	Mean Sea Level *The average (mean) sea level calculated based on Metonic cycle predictions, to the datum of the analysed data.*
MLW	Mean Low Water *MSL minus the lunar semidiurnal tide: Z0 - M2.*
MLLW	Mean Lower Low Water *The mean of the lower low water of each day over a Metonic cycle.*
MHLR	Mean Higher Lower Range *The mean range of the higher high water to the lower low water.*
MR	Mean Range *The average tidal range throughout a predicted Metonic cycle (derived from the harmonics: M2 x 2).*
MHWI	Mean High Water Interval *The interval in hours between HW at site and HW at Greenwich, UK.*
MLWI	Mean Low Water Interval *The interval in hours between LW at site and LW at Greenwich, UK.*
WLR	Water Level Recorder

DRAFT

CONTENTS

1. INTRODUCTION 8
1.1 EQUIPMENT LOCATIONS 8
2. EQUIPMENT SUMMARY 10
2.1 OFFSHORE INSTRUMENTATION 11
2.1.1 Water Levels 11
2.1.2 Currents, Waves and Water Temperatures 11
2.2 WEATHER STATION 12
3. DATA PROCESSING AND QUALITY CONTROL 13
3.1 DATA RETURN 13
3.2 WATER LEVEL DATA 14
3.3 CURRENT DATA 15
3.4 WAVE DATA 17
3.5 METEOROLOGICAL DATA 18
3.6 QUALITY CONTROL 18
3.7 DATA FILES 18
4. RESULTS 20
4.1 WATER LEVEL DATA 20
4.2 CURRENT DATA 21
4.3 WAVE DATA 21
4.4 WATER TEMPERATURE DATA 22
4.5 METEOROLOGICAL DATA 22
5. DISCUSSION 23

APPENDICES

A. DATA PRESENTATION
A.1 GUIDELINES ON USE OF REPORT
A.2 DATA PRESENTATION
B. EQUIPMENT LOGS

DRAFT

FIGURE IN THE MAIN TEXT

Figure 1.1: Locations of deployed equipment 9

TABLES IN THE MAIN TEXT

Table 1.1: Equipment Summary 8
Table 2.1: Equipment Details 10
Table 2.2: Summary of Valeport MIDAS WLR Sampling Regime at Mirfa-ADCP-P 11
Table 2.3: Summary of Current, Wave and Temperature Sampling Regime at Mirfa-ADCP-P11
Table 3.1: Data Return Statistics 13
Table 3.2: Water level data file 18
Table 3.3: Current data files 19
Table 3.4: Wave data files 19
Table 3.5: Water temperature data files 19
Table 3.6: Meteorological data file 19
Table 4.1: Water level data harmonic analysis statistics 20
Table 4.2: Observed, predicted and residual water level statistics. 20
Table 4.3: Current data harmonic analysis statistics 21
Table 4.4: Depth average observed and residual current velocity statistics 21
Table 4.5: Wave Statistics 21
Table 4.6: Water Temperature statistics 22
Table 4.7: Meteorological Statistics 22

.

DRAFT

1. INTRODUCTION

Fugro was contracted by ILF Consulting Engineers - Abu Dhabi (Client) on behalf of Abu Dhabi National Oil Company for Onshore Oil Operations (ADNOC Onshore) (Company) for the Provision of Bathymetric, Metocean and Nearshore Geotechnical Services For Wave Project (Package C), offshore Abu Dhabi, United Arab Emirates.

The metocean survey scope included the monitoring of water level, currents, waves, water temperature, wind velocity, air temperature, atmospheric pressure and humidity.

This report summarises the equipment configuration, data processing and results, following the completion of the data collection campaign, which took place between 30 April 2021 and 4 June 2021.

1.1 Equipment Locations

Table 1.1: Equipment Summary

Location	Parameter	WGS84 Easting [mE]	WGS84 Northing [mN]	Deployed	Recovered
Mirfa-ADCP-P	Primary Seabed Frame	744484.10	2673463.95	01/05/2021 06:30	03/06/2021 07:30
Mirfa-RCM-P	Primary Mooring	744370.77	2673418.90	03/05/2021 04:25	03/06/2021 06:25
Mirfa-ADCP-R	Redundancy Seabed Frame	744472.26	2673430.19	01/05/2021 05:57	02/06/2021 08:20
Mirfa-RCM-R	Redundancy Mooring	744425.19	2673375.21	03/05/2021 05:20	03/06/2021 06:25
Mirfa-WS	Weather Station	751993.51	2667792.70	30/04/2021 16:08	04/06/2021 04:30

DRAFT



Figure 1.1: Locations of deployed equipment

2. EQUIPMENT SUMMARY

Two seabed frames were deployed offshore to collect current, water temperature and water level data at Mirfa. The primary system was stationed at Mirfa-ADCP-P and consisted of a Nortek acoustic wave and current profiler (AWAC) and a Valeport MIDAS Water Level Recorder (WLR). The redundancy system deployed at Mirfa-ADCP-R consisted of an RDI Acoustic Doppler Current Profiler (ADCP) and a WLR.

Two moorings, both consisting of two Aanderaa Seaguard Recording Current Meters (RCMs), were also deployed at Mirfa to collect water temperature measurements. The primary mooring was stationed at Mirfa-RCM-P and a second redundancy system at Mirfa-RCM-R.

Oceanographic data presented in this report are from the primary systems.

A weather station was installed at the Mirfa Hotel to collect wind velocity, atmospheric pressure, air temperature and percentage humidity data.

Table 2.1: Equipment Details

	Location ID	Equipment	Serial Number	Height Above Seabed [m]
Primary	Mirfa-ADCP-P	AWAC	WAV7629	0.5
		WLR	46016	0.2
	Mirfa-RCM-P	RCM	857	2.5
		RCM	622	1
Redundancy	Mirfa-ADCP-R	ADCP	15464	0.5
		WLR	65476	0.2
	Mirfa-RCM-R	RCM	724	2.5
		RCM	1011	1

DRAFT

2.1 Offshore Instrumentation

All instrumentation was configured to record in GMT (GST − 4 hours) and all coordinates were recorded in WGS84. Processed data will be supplied to the Client in comma delineated ASCII files.

2.1.1 Water Levels

The Valeport MIDAS WLR was deployed to measure the water level at Mirfa. The instrumentation was configured to record every ten minutes.

Table 2.2: Summary of Valeport MIDAS WLR Sampling Regime at Mirfa-ADCP-P

MIDAS WLR Deployment Set Up	
Burst Period	60 seconds
Samples per burst	60
Averaging interval	600 seconds

Further equipment and deployment information can be found in the deployment logs in Appendix B.

2.1.2 Currents, Waves and Water Temperatures

In order to establish the hydrodynamic climate of the survey area, a Nortek AWAC was selected to measure waves and currents. The AWAC was configured to acquire a current measurement every ten minutes and a wave burst every 30 minutes. The AWAC configuration is summarised in Table 2.3. Water temperature data were collected at three water column heights using the Nortek AWAC and two RCMs.

Table 2.3: Summary of Current, Wave and Temperature Sampling Regime at Mirfa-ADCP-P

Instrument	Parameter	Configuration
Nortek AWAC 1MHz	Water Level	Every 10 minutes, averaged over a 300 second burst.
	Current Profile	■ Sampling interval 600 seconds; ■ 300 second burst; ■ Blanking distance 0.4 m; ■ Cell measurement size 0.5 m
	Wave	Every 30 minutes over a 512 second burst at 1 Hz (2 Hz for AST measurements).
	Seabed Water Temperature	Every 10 minutes, averaged over a 300 second burst.
Aanderaa Seaguard RCM	Water Temperature	Every 10 minutes

DRAFT

Further equipment and deployment information can be found in the deployment logs in Appendix B.

2.2 Weather Station

The weather station was installed at the Mirfa Hotel and configured to collect wind velocity, air temperature, atmospheric pressure and humidity measurements every 10 minutes. The weather station was demobilised on 4 June 2021.

DRAFT

3. DATA PROCESSING AND QUALITY CONTROL

3.1 Data Return

Table 3.1 shows the data return statistics for the deployed instrumentation.

Expected records are the number of records anticipated from the deployment period after removal of bad data affected by deployment or recovery operations. Counted records are the total number of records observed in the data file. Good records are valid data excluding any nulled records in the data file averaged across all parameters. Good records as a percentage of expected records are also presented.

Table 3.1: Data Return Statistics

Location	Parameter	Expected Records	Counted Records	Good Records	Good Records as a Percentage of Expected Records
Mirfa-ADCP-P	Water Level	4748	4748	4748	100.00
	Current*	4748	4748	4748	100.00
	Waves	1582	1582	1579	99.81
	Water Temperature	4748	4748	4748	100.00
Mirfa-RCM-P bottom	Water Temperature	4476	4476	4476	100.00
Mirfa-RCM-P top	Water Temperature	4475	4475	4475	100.00
Mirfa-WS	Wind velocity	4971	4970	4968	99.96
	Air Temperature	4971	4970	4968	99.96
	Pressure	4971	4970	4968	99.96
	Humidity	4971	4970	4968	99.96

Notes
* = Values are presented for depth-averaged currents

DRAFT

3.2 Water Level Data

Raw pressure values from the Valeport WLR are imported into Fugro's software. Conversion from raw pressure values to depth is achieved using the algorithms as set out in the UNESCO technical papers in marine science 44 (Fofonoff, 1983) and the Manual of quality control procedures for the validation of oceanographic data (Crease, 1993). User selected values for salinity (44.4 ppt – the average salinity from bottom RCM serial number 622), measured temperatures from the AWAC and a local acceleration due to gravity (9.78898 m/s2) were used to achieve a depth conversion.

Depth data are reduced to the mean of the data set for harmonic analysis. The extracted harmonics are then used to extrapolate the Lowest Astronomical Tide (LAT) and Highest Astronomical Tide (HAT) values relative to the dataset mean. The LAT offset is applied to the data to reduce the tidal records to LAT. The data are then re-analysed and the new LAT value extrapolated; if the LAT value is zero then the analysis is held to be good.

Total observed tidal heights are considered to be a combination of two components in order that they may be described and re-predicted.

- The pure tidal component; the predictable oscillation driven by astronomical forces.
- An inconsistent residual height variation; the variability of the non-tidal surge passing over the site.

This variability may include "instrument noise" but it is usually a measure of the meteorologically-induced residual variability. Local and brief atmospheric disturbances will generate fluctuations in the tidal heights which will be detected in this component after the tidal components have been extracted from the observations.

To separate these components, the dataset is subjected to harmonic analysis extracting a series of periodic curves with the frequency of the major tidal constituents. The number of constituent cosine curves that can be derived depends on the length of the observed data set. From between one and six months of observations, it is reasonable to extract 26 tidal constituents as well as the mean sea level for the month. However, the tidal energy spectrum includes several peaks which are, in fact, unresolved complexes of tidal constituents with very close frequencies. They cannot be separated reliably from a single lunar period but their amplitude relationships are often known at a nearby Standard Port or at a previously monitored tidal site in the region. By transferring these relationships, it is possible to resolve eight additional "related" constituents within the analysis to produce a final table of 34 constituent constants. The equilibrium tidal constant relationships were transferred to the data to resolve the related constituents.

DRAFT

Fugro uses a PC-compatible harmonic analysis program based on the mathematical algorithms developed by Hunter for the Australian Oceanographic Research Organisation: CSIRO. It is a revision of the least-squares, best-fit method used in ELSIE and TIRA, both analysis and predictive programs originally developed by the UK Government research laboratories of the Institute of Oceanographic Sciences. The Hunter program has been fully verified and is in use by government institutes and commercial companies world-wide.

The cosine curve for each derived constituent is defined by amplitude and phase lag (relative to phase at the Greenwich Meridian). The frequency of the constituent is an astronomically-derived global constant. After the constants for the tidal constituents have been derived, they are used to reconstruct a “pure” tidal curve for the observation period. Subtraction of this curve and the mean height from the observed data leaves the non-tidal residual heights. This is again examined as a time series plot and if any sinusoidal pulse remains in the residuals, a poor analysis is indicated. At most locations, the tidal component is dominant and residuals are expected to be small by comparison. Periods of prolonged high residuals generally relate to storm surges and are a genuine non-tidal component of water level. If the residuals are relatively small and either random or slowly changing, predictions for any period may be made with reasonable confidence in their accuracy.

DRAFT

3.3 Current Data

The Nortek AWAC uses acoustic signals produced by transceivers mounted on the head of the instrument. The transceivers are offset at an angle to the vertical producing divergent acoustic signals that are propagated through the water column. The signals are reflected back to the instrument by particulate material in the water column. The returned signal is binned (divided into separate depths) with respect to the return interval. This interval is calculated from the pre-set range and the speed of sound as calculated by the instrument, using the user specified salinity value and the measured temperature. The binned data are processed using Doppler technology and the relative movement of the particulate material in the water column can be ascertained with reference to each beam. The movement of this particulate material is assumed to be caused by the water flow through the field. This movement is converted first to a general flow through the four-beam field referenced to an arbitrary zero direction on the instrument. This is converted to a true speed and direction (relative to magnetic north) by reference to an integral flux gate compass.

Post-processing of AWAC data can be summarised as:

- Converting the data from manufacturer’s binary format into ASCII engineering values;
- Converting the ASCII engineering unit data to Fugro’s software format;
- Calculating speed and direction for each measurement bin from the easting and northing vectors;

- Applying a magnetic to true north direction correction. The magnetic variation (or magnetic declination) value was obtained from the World Magnetic Model (WMM) (https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml), by entering the deployment position and deployment date. The magnetic variation value is added to or taken from all directional values, depending on whether the magnetic variation value is positive (East) or negative (West).
- Removing pre- and post-deployment data;
- Visualising data to identify any degradation of quality at the surface, erroneous values or spikes. The upper 1.5 m of the current profile showed evidence of side-lobe interference and was removed prior to depth averaging.

Total observed currents are considered to be a combination of three components in order that they may be described and re-predicted:

1. The tidal stream component; the predictable oscillation driven by astronomical forces. This may include shallow water or coastal components, sometimes referred to as “tidal residuals”. Circulation in bays and around headlands or sandbanks often results in severe distortions of the typical open-water tidal ellipse. Often a local eddy system will only develop on one stage of the tide and the movement of the water over a point within this eddy may be in the same general direction on both the flood and ebb tide;

2. A mean drift component; the consistent trend in the data reflecting a steady offset distorting the tidal ellipse. The mean net drift over the site does not always indicate an oceanic current is affecting the water column for the reasons mentioned in (i) above. However, by considering the local topography, it is usually possible to assess whether an eddy circulation is responsible for the net movement over the site;

3. An inconsistent residual drift; the variability of the non-tidal current passing over the site. This variability may include “instrument noise” but it is usually a measure of the meteorologically-induced residual variability. Seasonal winds tend to generate oceanic currents which will be detected mainly as the mean drift current (ii). More local and brief atmospheric disturbances will generate fluctuations in the currents which will be detected in this component after the tidal components and mean drift have been extracted from the observations.

To separate these three components, the current dataset is subjected to harmonic analysis extracting a series of periodic curves with the frequency of the major tidal constituents. While tidal heights are analysed as a single amplitude variable, currents have to be analysed as two amplitude variables (easting and northing vectors) due to changing speed and direction with time. After analysis, easting and northing components can be recombined to give predictions as speed and direction.

DRAFT

After the constants for the tidal constituents have been derived, they are used to reconstruct a “pure” tidal stream curve for the observation period. Subtraction of this curve and the mean drift current from the observed data leaves the non-tidal residual flows. This is again examined as a time series plot and if any sinusoidal pulse remains in the residuals, a poor analysis is indicated. At most locations, the tidal component dominates and residuals are expected to be small by comparison. Periods of prolonged high residual values generally relate to storm surges and are a genuine non-tidal component of velocity. If the residuals are relatively small and either random or slowly changing, predictions for any period may be made with reasonable confidence in their accuracy.

3.4 Wave Data

Nortek Storm software was used to process the raw wave data, with individual files created for each wave burst dataset. These consisted of a 512 record time series of all sensors taken at 1 Hz for the pressure signal and the orbital currents, plus a 1024 record time series at 2 Hz for the Acoustic Surface Tracking (AST). A new file was collected every 30 minutes. An additional sensor provided temperature readings so that fluctuations in water density and sound velocity could be computed. The wave heights and frequency were deduced by rapid measurement of instantaneous head of water measured either as pressure, using the precision strain gauge sensor, or range, using a vertical acoustic beam.

The 1024 records of acoustic range were converted to heights by the wave processing software; these values from the wave burst were de-trended to produce a surface wave trace. The surface elevations were combined with the 512 records of easting and northing current vectors to generate three-dimensional data. The three-dimensional wave measurements were then passed through an additional series of routines that produces spectral density matrices allowing the wave energy to be broken down by direction as well as by frequency. The directional wave statistics were then derived from the resultant spectra.

Processed wave statistics based on AWAC AST, AWAC pressure and results from the secondary ADCP were compared. A tilt of the AWAC of approximately 11 ° from vertical, when combined with low wave energy observed on site has rendered the AST-based measurements unreliable. Pressure-based values from the AWAC were supported by those of the secondary ADCP and present the most robust dataset for the site. Zero-up crossing period is not available through this processing method and so has been substituted for mean period (Tm02). At the Mirfa site, waves are often at the limits of detection for the instrument. Wave direction is accurately resolved when wave heights exceed approximately 10 cm.

DRAFT

3.5 Meteorological Data

Wind velocity, atmospheric pressure, air temperature and percentage humidity data were collected by a meteorological station installed at the Mirfa Hotel.

3.6 Quality Control

Data quality control (QC) and processing has been undertaken according to Fugro procedures (EUAF-FGBM-CO-GU01_001), using Fugro's bespoke Meteorological and Oceanographic data processing software..

Data rejected during quality control procedures can be summarised as:

- Temperature data from the Valeport WLR were found to disagree with the three other instruments recording temperature. Therefore, these data were rejected and where temperature was required for pressure-depth conversion, readings from the AWAC were used;
- During visualisation of the meteorological data, two records which exceeded a reasonable rate of change (data spikes) were removed from the time series. Details of these records are available on request;
- The upper 1.5 m of the current profile was removed as readings were indicative of side-lobe interference;
- AST-based wave statistics from the AWAC were rejected during comparison with other processing techniques and the secondary instrument.

3.7 Data Files

Table 3.2 and Table 3.3 describe all data files delivered with this report. All files have been provided in ".csv" comma separated valued file type.

Table 3.2: Water level data file

Data File Name	Columns
MOMU041_MIRFA-P_VMWLR_LAT_RP.csv	Year, Month, Day, Hour, Minute, Second, Julian Day, Depth [m], Depth to mean [m], Residual Height [m], Height to LAT [m], Predicted Height [m].

DRAFT

Table 3.3: Current data files

Data File Name	Columns
MOMU041_MIRFA-P_AWAC_C.csv	Year, Month, Day, Hour, Minute, Second, Julian Day, Velocity n [m/s], Direction n [°T], Easting Vector n [m/s], Northing Vector n [m/s], Vertical Vector n [m/s]
MOMU041_MIRFA-P_AWAC_C_DA_RP.csv	Year, Month, Day, Hour, Minute, Second, Julian Day, Depth Average Velocity [m/s], Depth Average Direction [°T], Depth Average Easting Vector [m/s], Depth Average Northing Vector [m/s], Depth Average Vertical Vector [m/s], Number of good bins [count], Residual Velocity [m/s], Residual Direction [°T], Residual Easting [m/s], Residual Northing [m/s], Predicted Velocity [m/s], Predicted Direction [°T], Predicted Easting [m/s], Predicted Northing [m/s]

Table 3.4: Wave data files

Data File Name	Columns
MOMU041_MIRFA-P_AWAC_Waves.csv	Significant Wave Height Spectral [m], Maximum Wave Height [m], Peak Wave Period Tp [s], Mean Period Tm02 [s], Peak Coming Direction [°T], Mean Coming Direction [°T]
MOMU041_MIRFA-P_AWAC_Waves_2D_Spectral_Time_Series.csv	Year, Month, Day, Hour, Minute, Second, Julian Day, Period n [s], Energy n [m²s], Coming Direction n [°T], Spreading Angle n [°]
Notes n denotes the spectral band.	

Table 3.5: Water temperature data files

Data File Name	Columns
MOMU041_MIRFA-P_AWAC_Temperature.csv	Year, Month, Day, Hour, Minute, Second, Julian Day, Temperature [°C]
MOMU041_MIRFA-P_ASG_Bottom_CTD.csv	Year, Month, Day, Hour, Minute, Second, Julian Day, Temperature [°C]
MOMU041_MIRFA-P_ASG_Top_CTD.csv	Year, Month, Day, Hour, Minute, Second, Julian Day, Temperature [°C]

Table 3.6: Meteorological data file

Data File Name	Columns
MOMU041_MIRFA_MET.csv	Year, Month, Day, Hour, Minute, Second, Julian Day, Wind Speed [m/s],Gust Speed [m/s], Wind Direction [°T],Air Temperature [°C],Air Pressure [mbar],Humidity [%].

DRAFT

4. RESULTS

4.1 Water Level Data

Table 4.1 and Table 4.2 present harmonic analysis and observed, predicted and residual water level statistics.

Table 4.1: Water level data harmonic analysis statistics

Water Level Component	Value (Relative to LAT)
Highest astronomical tide (HAT) [m]	2.33
Mean higher high water (MHHW) [m]	1.73
Mean high water (MHW) [m]	1.63
Mean sea level (MSL) [m]	1.05
Mean low water (MLW) [m]	0.51
Mean lower low water (MLLW) [m]	0.42
Lowest astronomical tide (LAT) [m]	0.00
Mean higher lower range (MHLR) [m]	1.30
Mean range (MR) [m]	1.12
Mean high water interval (MHWI) [hours]	8.75
Mean low water interval (MLWI) [hours]	15.46

Table 4.2: Observed, predicted and residual water level statistics.

Data Type	Minimum	Maximum	Mean	Standard Deviation
Observed water level [m] (Relative to LAT)	0.15	2.11	1.04	0.47
Predicted water level [m] (Relative to LAT)	0.12	2.07	1.04	0.46
Residual water level [m]	-0.18	0.21	0.00	0.06
Notes LAT = Lowest Astronomical Tide				

DRAFT

4.2 Current Data

Table 4.3 and Table 4.4 present harmonic analysis and observed, predicted and residual current velocity and directional statistics respectively. The data are presented as time series in Appendix A.

Table 4.3: Current data harmonic analysis statistics

Data Type	Metonic Maximum Speed [m/s]	Mean Spring Rate [m/s]	Mean Neap Rate [m/s]	Bearing [°T]	Mean Drift [m/s]	Bearing of Mean Drift [°T]
Depth Average	0.57	0.29	0.14	85.9	0.02	340.7

Table 4.4: Depth average observed and residual current velocity statistics

Data Type	Minimum	Maximum	Mean	Standard Deviation
Depth average observed velocity [m/s]	0.00	0.56	0.21	0.11
Depth average observed easting vector [m/s]	-0.43	0.55	0.00	0.23
Depth average observed northing vector [m/s]	-0.09	0.12	0.02	0.02
Depth average observed vertical vector [m/s]	-0.06	0.02	-0.02	0.02
Depth average residual velocity [m/s]	0.00	0.21	0.03	0.02
Depth average residual easting vector [m/s]	-0.21	0.16	0.00	0.04
Depth average residual northing vector [m/s]	-0.12	0.11	0.00	0.01

DRAFT

4.3 Wave Data

Table 4.5 presents a statistical summary of the wave data collected at Mirfa during the measurement period.

Table 4.5: Wave Statistics

Data Type	Minimum	Maximum	Mean	Standard Deviation
Significant Wave Height [m]	0.01	0.96	0.09	0.13
Maximum Wave Height [m]	0.02	1.61	0.14	0.21
Peak Period [s]	2.83	3.88	3.07	0.14
Mean Period [s]	2.55	3.62	2.81	0.12
Dominant Wave Direction [°T]	North Westerly			

4.4 Water Temperature Data

Table 4.6 presents a statistical summary of the water temperature data collected during the observations.

Table 4.6: Water Temperature statistics

Data Type	Minimum	Maximum	Mean	Standard Deviation
RCM Top Water Temperature [°C]	29.5	34.1	32.0	1.3
RCM Bottom Water Temperature [°C]	29.5	34.1	32.0	1.3
AWAC Seabed Water Temperature [°C]	29.6	34.2	32.0	1.3

4.5 Meteorological Data

Table 4.7: presents a statistical summary of the meteorological data collected during 36 days of observations.

Table 4.7: Meteorological Statistics

Data Type	Minimum	Maximum	Mean	Standard Deviation
Wind speed [m/s]	0.4	12.1	3.1	1.6
Gust speed [m/s]	0.6	18.8	5.4	2.5
Air Temperature [°C]	21.5	45.5	31.0	3.8
Air pressure [mbar]	996.4	1007.6	1001.3	2.3
Humidity [%]	9.6	99.9	62.0	16.3

DRAFT

5. DISCUSSION

Wave heights at the Mirfa site were low for the majority of the deployment period; Hs remained under 0.2 m for 88 % of the time. However, some periods of elevated wave activity were observed, with a maximum Hmax of 1.6 m observed on 26 May 2021. Wave height does not appear to be strongly correlated with wind speed but instead is governed by wind direction. Most periods of elevated wave conditions are concurrent with westerly winds, in line with the area of greatest exposure or fetch distance.

Tidally-dominated rectilinear currents were observed on site with an easterly flood and westerly ebb. Depth averaged current speeds reached 0.56 m/s.

Water levels exhibit a mixed, mainly diurnal tidal signature. The maximum tidal height expected on site is 2.33 m. The maximum non-tidal or residual component of water level observed was 0.21 m. This increase in water level occurred on 26 May 2021 when the wind direction reversed rapidly from offshore to onshore.

Meteorological data display a pattern typically expected of the wider area with daily increases in wind speed linked to thermal increase. Onshore winds were dominant during the deployment period.

Seawater temperature also displayed a diurnal pattern with peaks reached during the middle of the day. These daily fluctuations are in the region of 1.5°C. An underlying warming was also observed over the length of the deployment.

..

DRAFT

APPENDICES

A. DATA PRESENTATION

A.1 GUIDELINES ON USE OF REPORT

A.2 DATA PRESENTATION

B. EQUIPMENT LOGS

DRAFT

A. DATA PRESENTATION

A.1 GUIDELINES ON USE OF REPORT

This report (the "Report") was prepared as part of the services (the "Services") provided by Fugro for its client (the "Client") under terms of the relevant contract between the two parties (the "Contract"). The Services were performed by Fugro based on requirements of the Client set out in the Contract or otherwise made known by the Client to Fugro at the time.

Fugro's obligations and liabilities to the Client or any other party in respect of the Services and this Report are limited in time and value as defined in Contract (or in the absence of any express provision in the Contract as implied by the law of the Contract) and Fugro provides no other representation or warranty whether express or implied, in relation to the Services or for the use of this Report for any other purpose. Furthermore, Fugro has no obligation to update or revise this Report based on changes in conditions or information which emerge following issue of this Report unless expressly required by the Contract.

The Services were performed by Fugro exclusively for the Client and any other party identified in the Contract for the purpose set out therein. Any use and/or reliance on the Report or the Services for purposes not expressly stated in the Contract, by the Client or any other party is that party's risk and Fugro accepts no liability whatsoever for any such use and/or reliance

DRAFT

A.2 DATA PRESENTATION

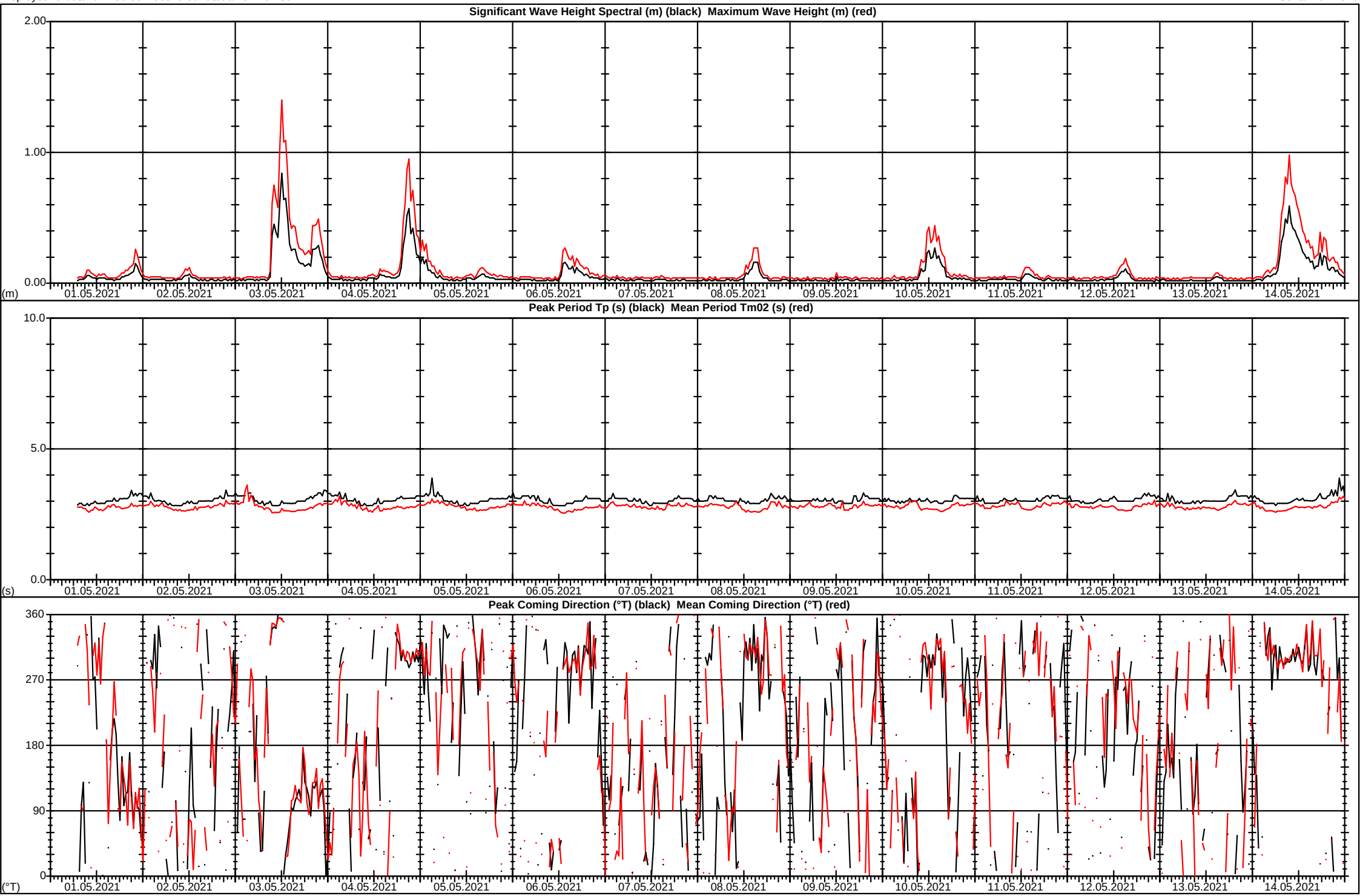
Figure / Table Number	Presentation
Figure A001 – A003	Wave Data Time Series
Figure A004	Wave Rose Diagram
Figure A005 – A007	Spectral Time Series (Energy by Period and Energy by Direction)
Figure B001 – B003	Current Speed and Direction Profile
Figure B004 – B006	Current Data Time Series – Depth Average
Figure B007	Current Data Scatter Plot – Depth Average
Table B001	Current Harmonic Analysis Report – Depth Average
Figure C001	Water Level Time Series
Table C001	Tidal Height Harmonic Analysis Report
Figure D001 – D003	Meteorological Data Time Series
Figure D004	Wind Rose Diagram
Figure E001	Seawater Temperature Time Series

DRAFT

Wave Data Time Series

Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

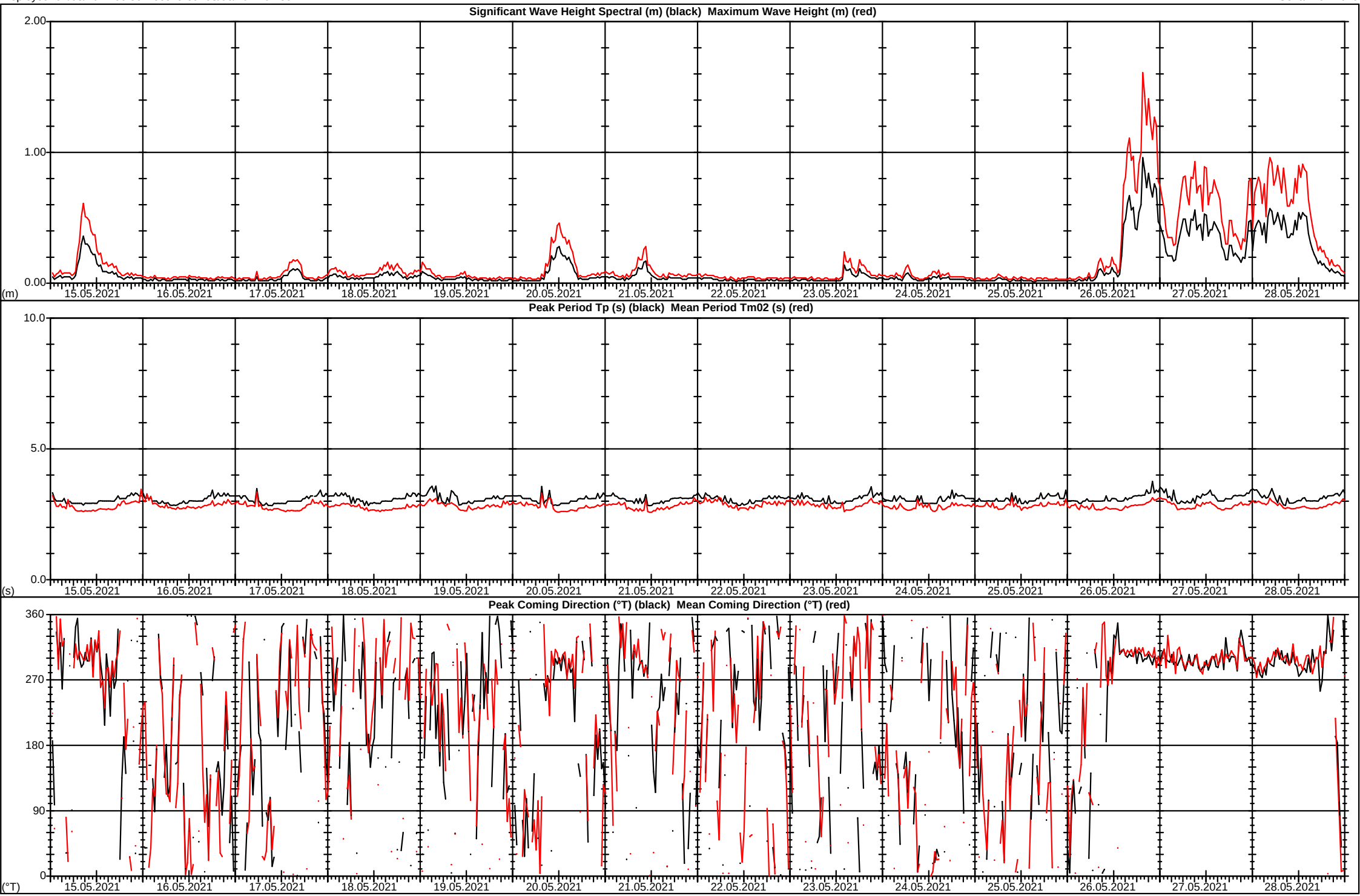
Easting: 744484.10 m E Northing: 2673463.95 m N Site depth below LAT: 5.8m Instrument height above seabed: 0.5m
Wave Monitor / AWAC Storm Data
Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30
Serial No.: 7629



Wave Data Time Series

Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

Easting: 744484.10 m E Northing: 2673463.95 m N Site depth below LAT: 5.8m Instrument height above seabed: 0.5m
Wave Monitor / AWAC Storm Data
Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30
Serial No.: 7629



Wave Data Time Series

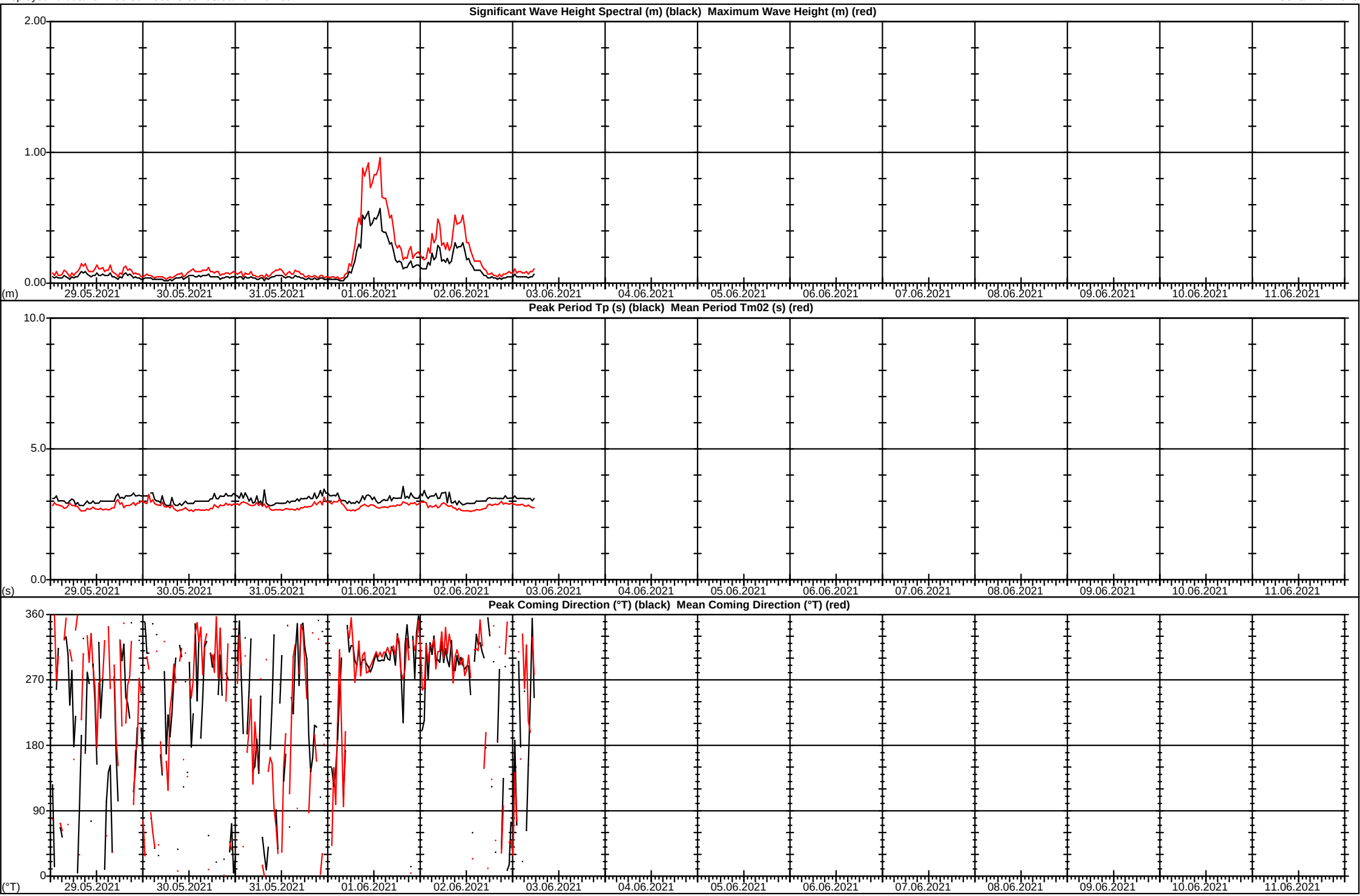
Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

Easting: 744484.10 m E Northing: 2673463.95 m N Site depth below LAT: 5.8m Instrument height above seabed: 0.5m

Wave Monitor / AWAC Storm Data

Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30

Serial No.: 7629



Wave Data Hodogram (Rose Diagram)

Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

Easting: 744484.10 m E Northing: 2673463.95 m N Site depth below LAT: 5.8m Instrument height above seabed: 0.5m

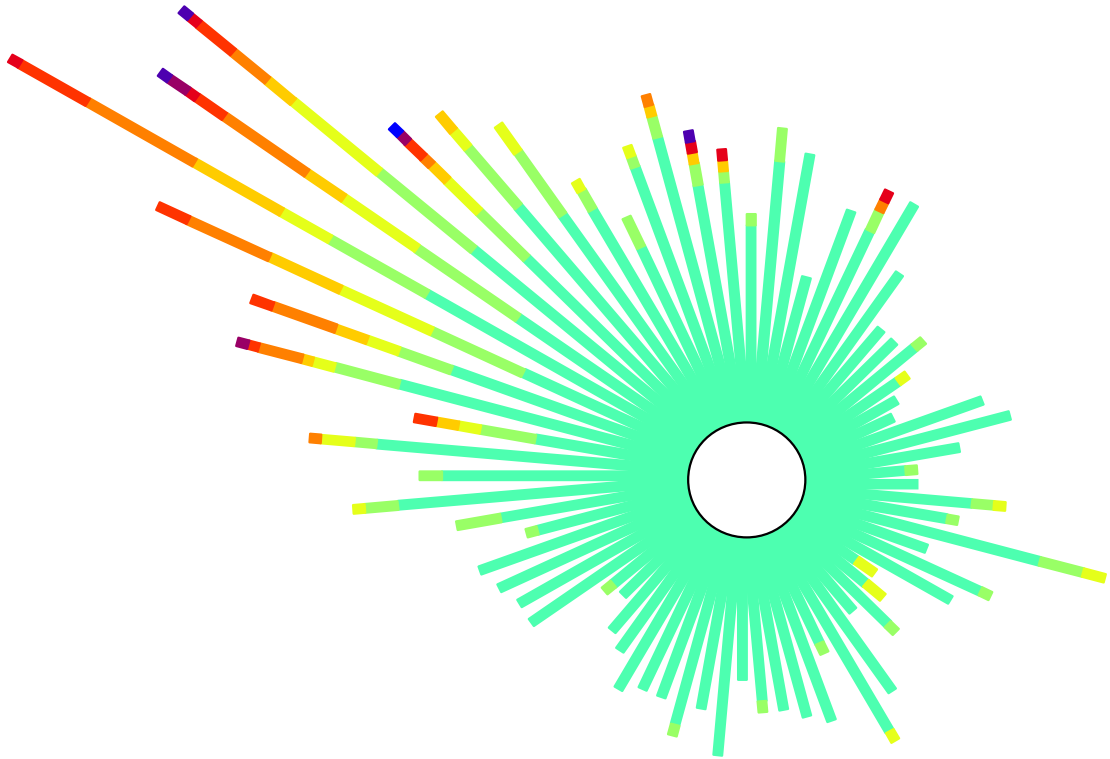
Wave Monitor / AWAC Storm Data

Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30

Serial No.: 7629

Mean Coming Direction (°T)

True North



West

East

Significant Wave Height Spectral (m)

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 (m)

South

Percentage Occurrence

0 2% 4% 6% 8% 10%

Wave Data Energy Spectral Time Series

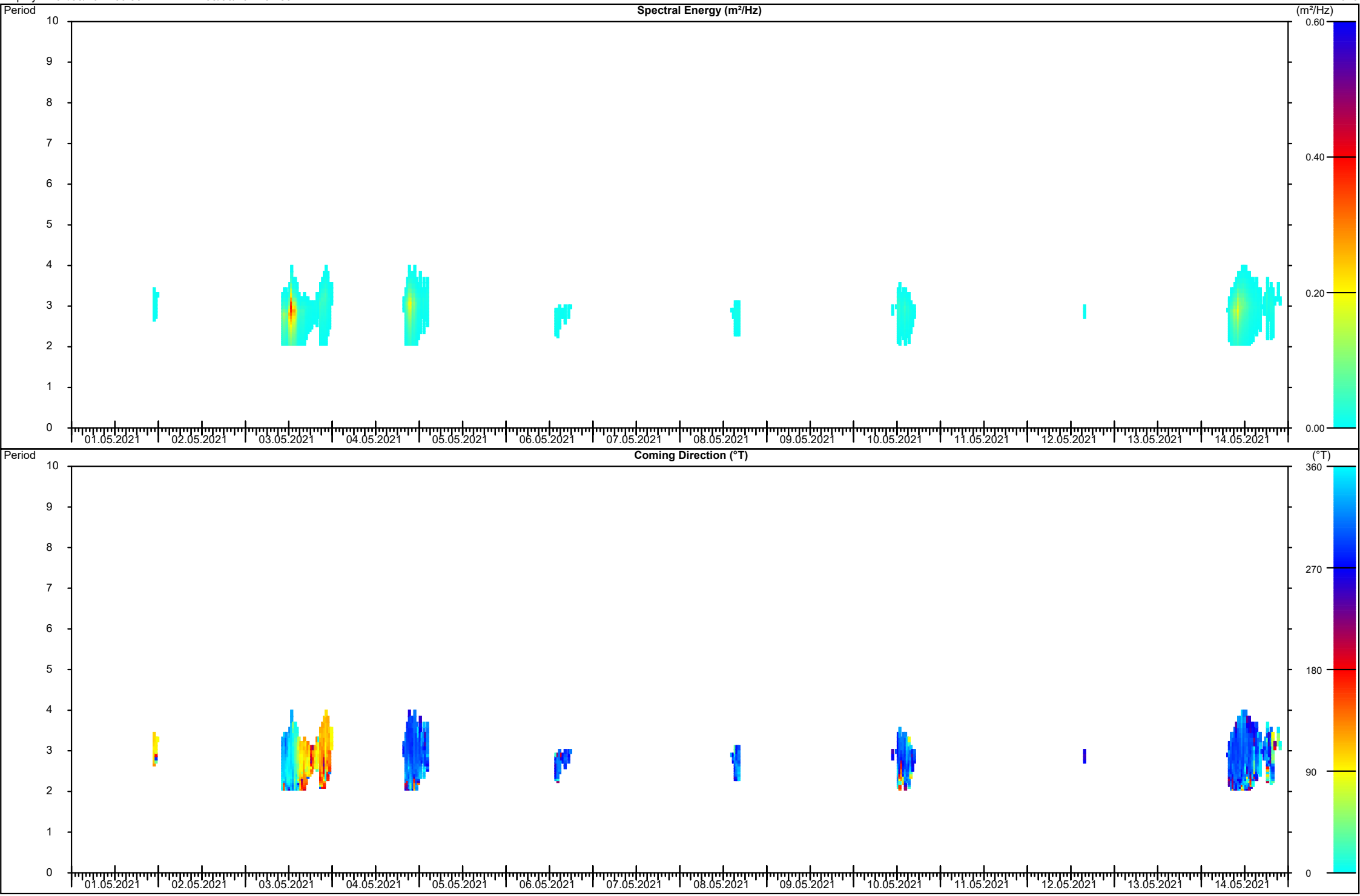
Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

Easting: 744484.10 m E Northing: 2673463.95 m N Site depth below LAT: 5.8m Instrument height above seabed: 0.5m

Nortek Spectra

Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30

Serial No.: 7629



Wave Data Energy Spectral Time Series

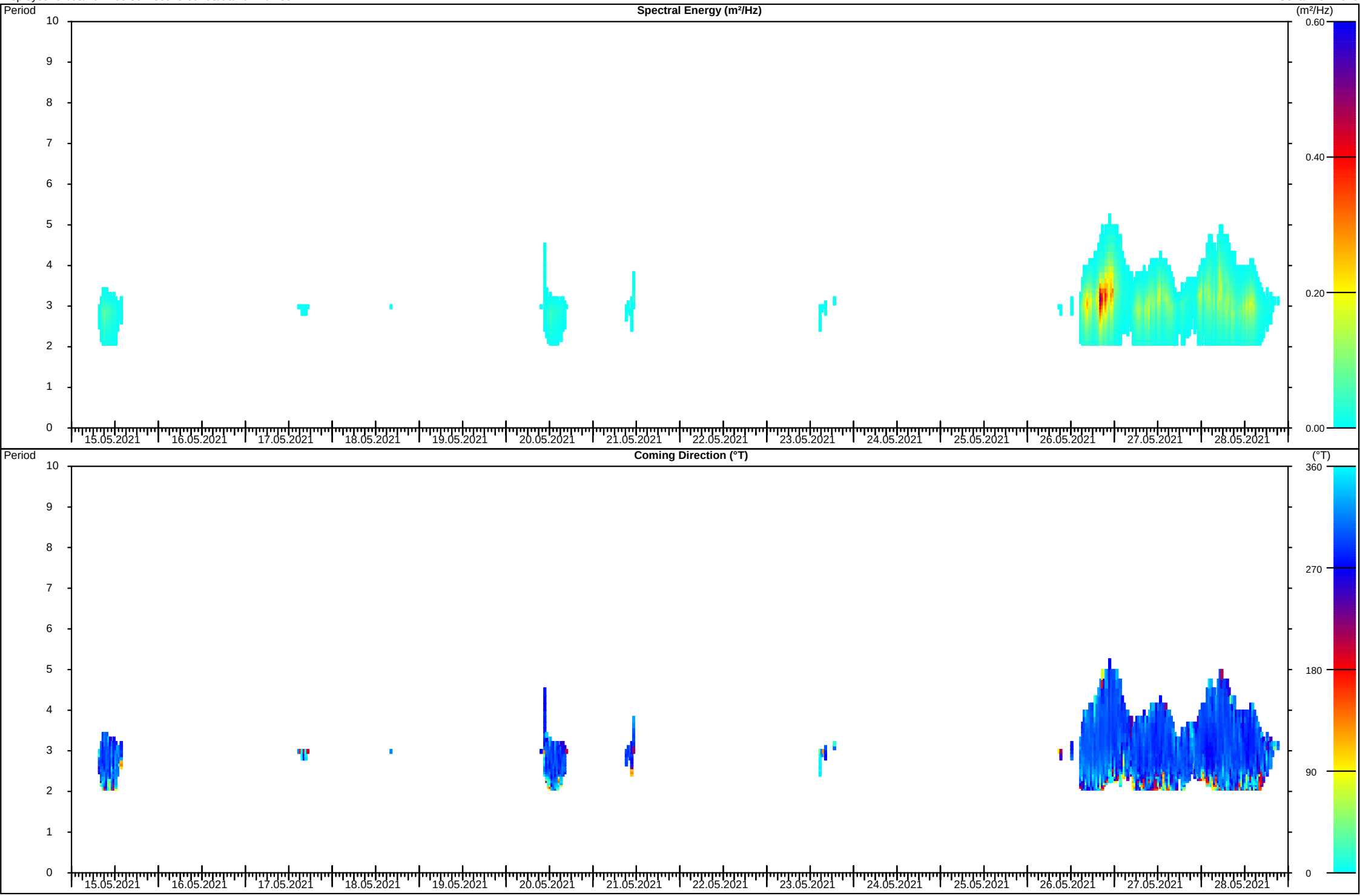
Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

Easting: 744484.10 m E Northing: 2673463.95 m N Site depth below LAT: 5.8m Instrument height above seabed: 0.5m

Nortek Spectra

Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30

Serial No.: 7629



Wave Data Energy Spectral Time Series

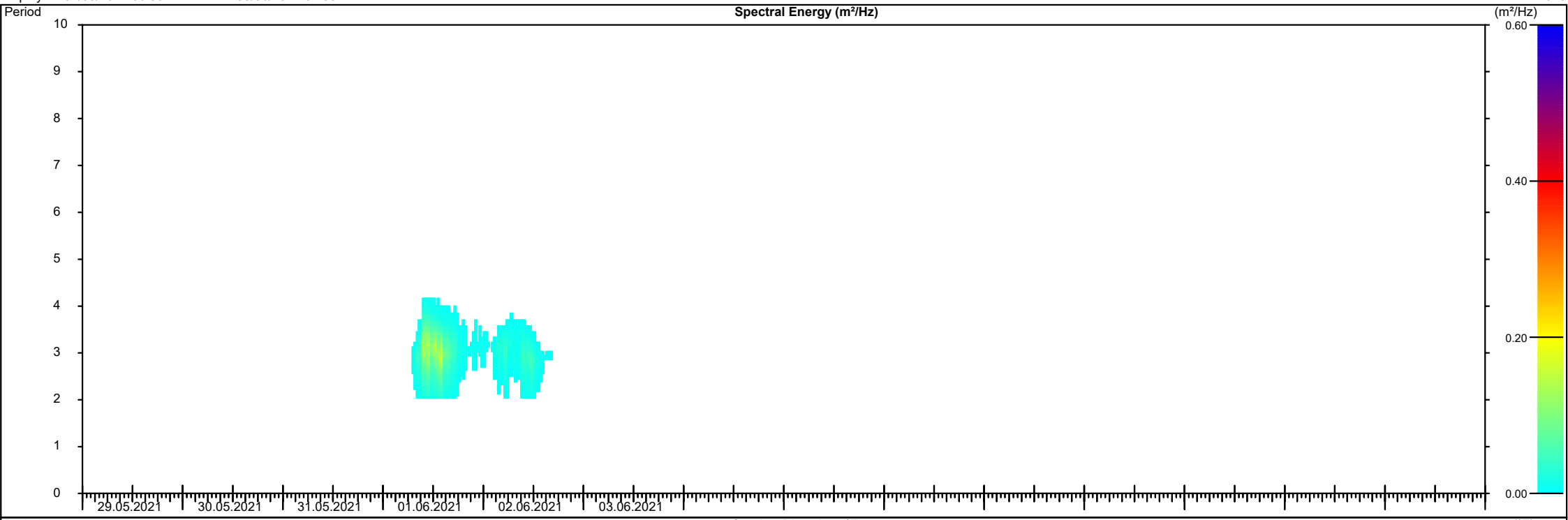
Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

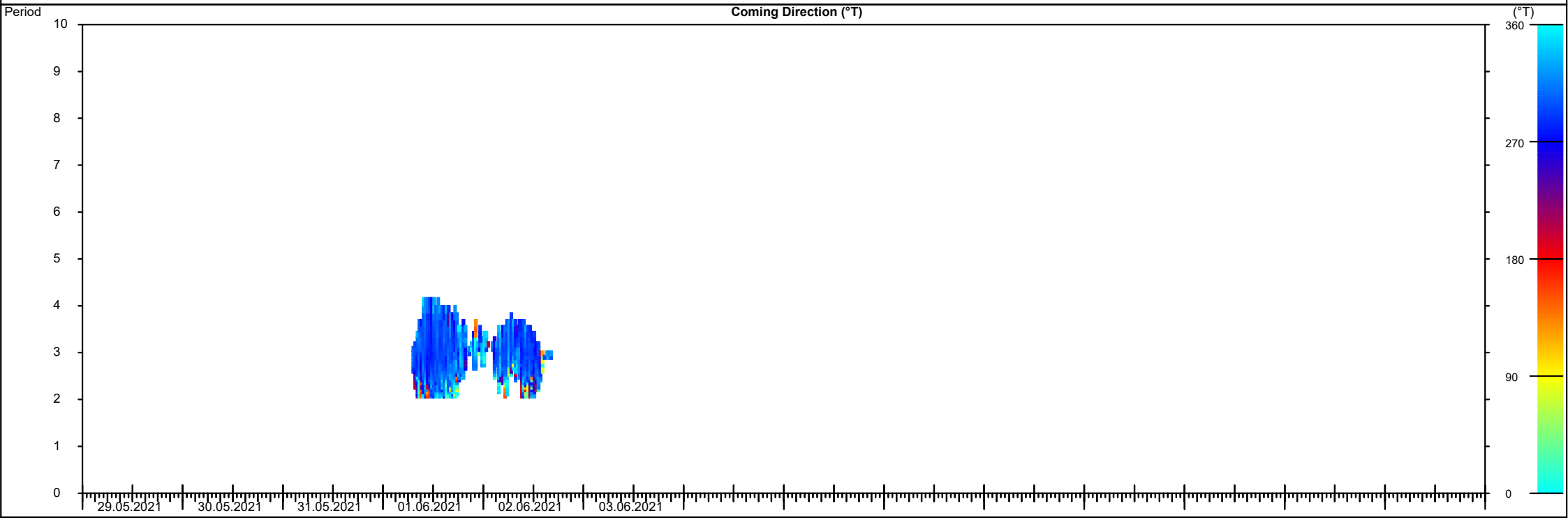
Easting: 744484.10 m E Northing: 2673463.95 m N Site depth below LAT: 5.8m Instrument height above seabed: 0.5m

Nortek Spectra

Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30

Serial No.: 7629





Colour Contour Time Series

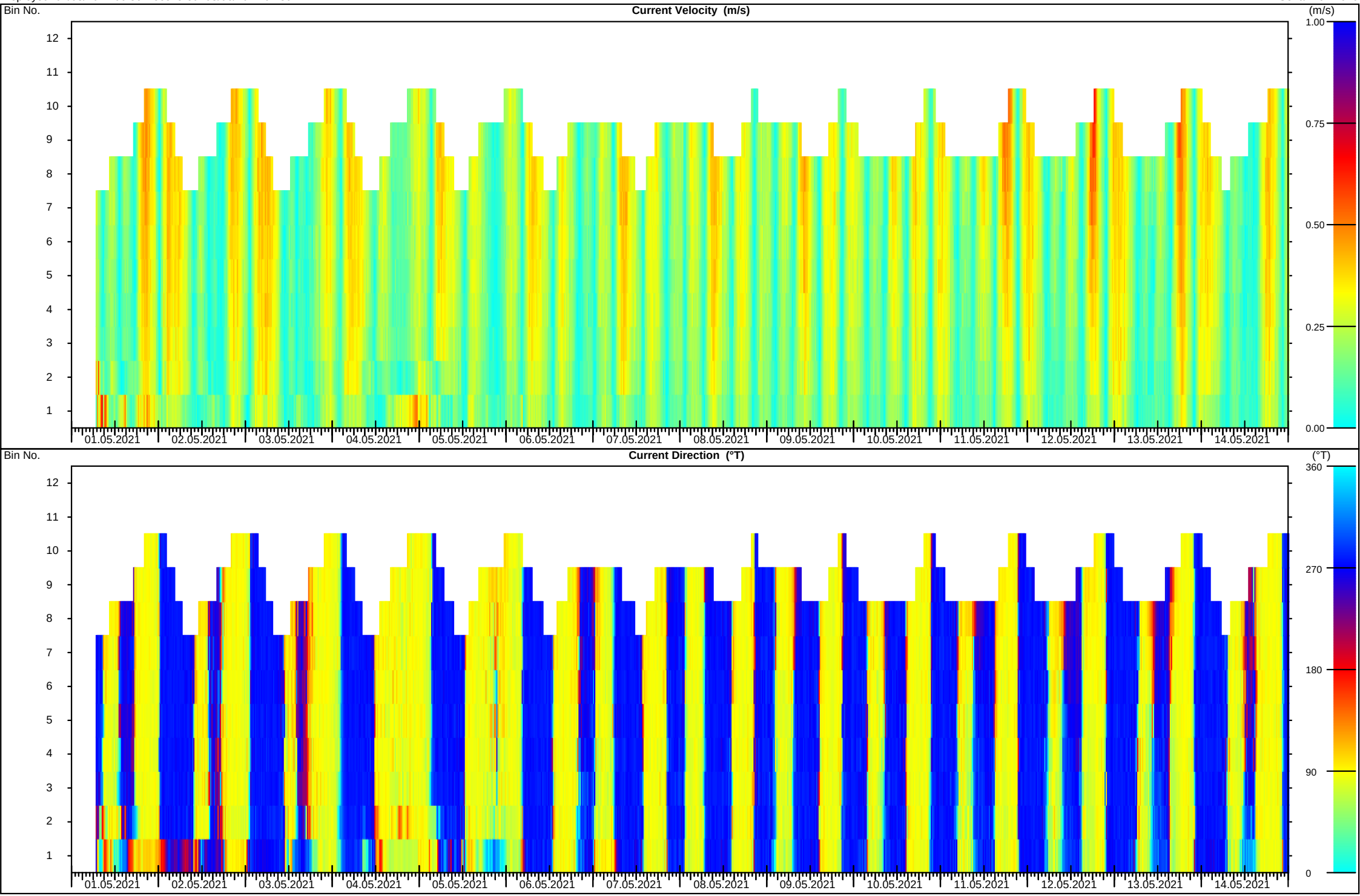
Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

Easting: 744484.10 m E Northing: 2673463.95 m N Site depth below LAT: 5.8m Instrument height above seabed: 0.5m

Current Meter / AWAC

Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30

Serial No.: 7629



Colour Contour Time Series

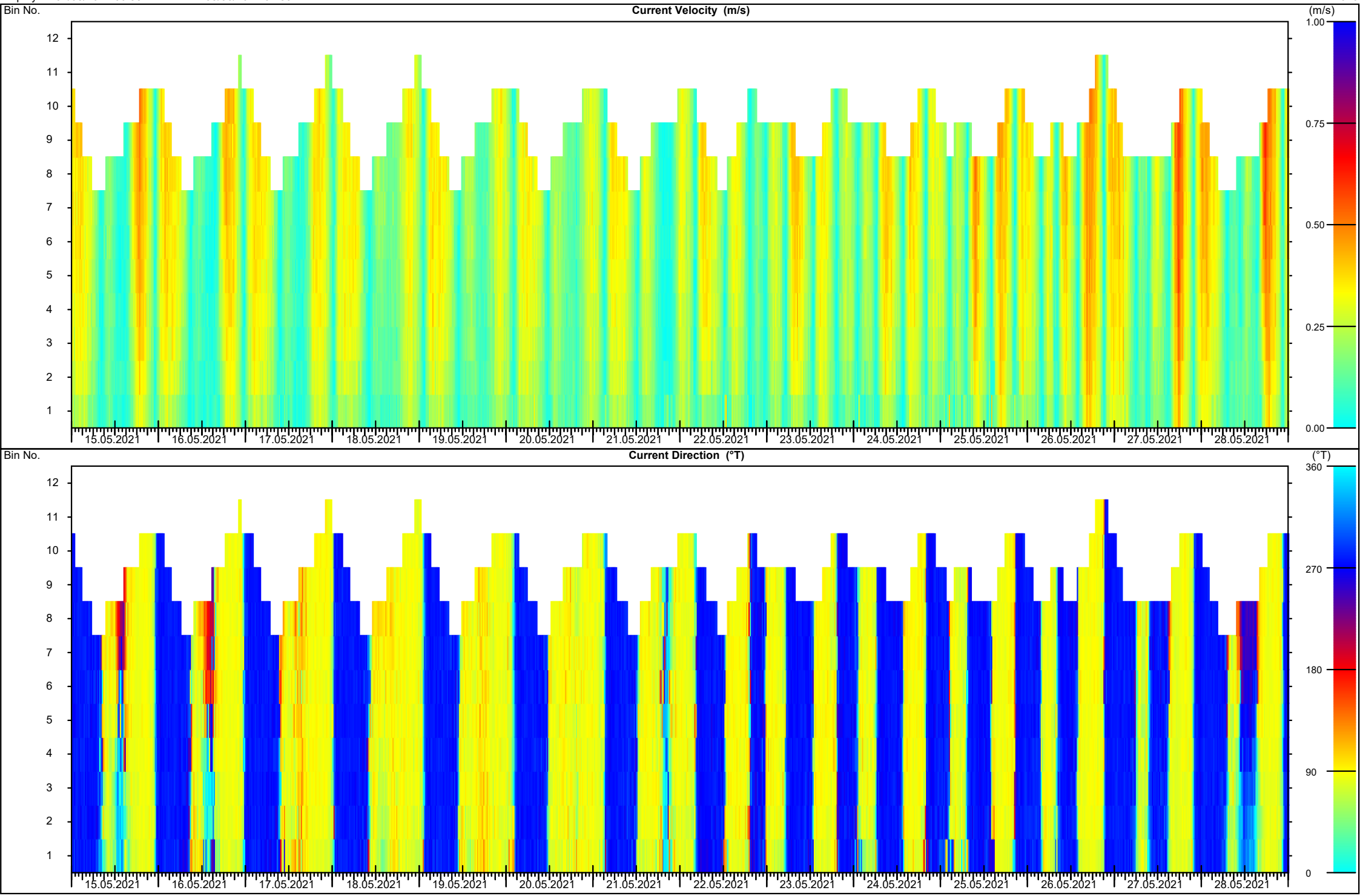
Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

Easting: 744484.10 m E Northing: 2673463.95 m N Site depth below LAT: 5.8m Instrument height above seabed: 0.5m

Current Meter / AWAC

Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30

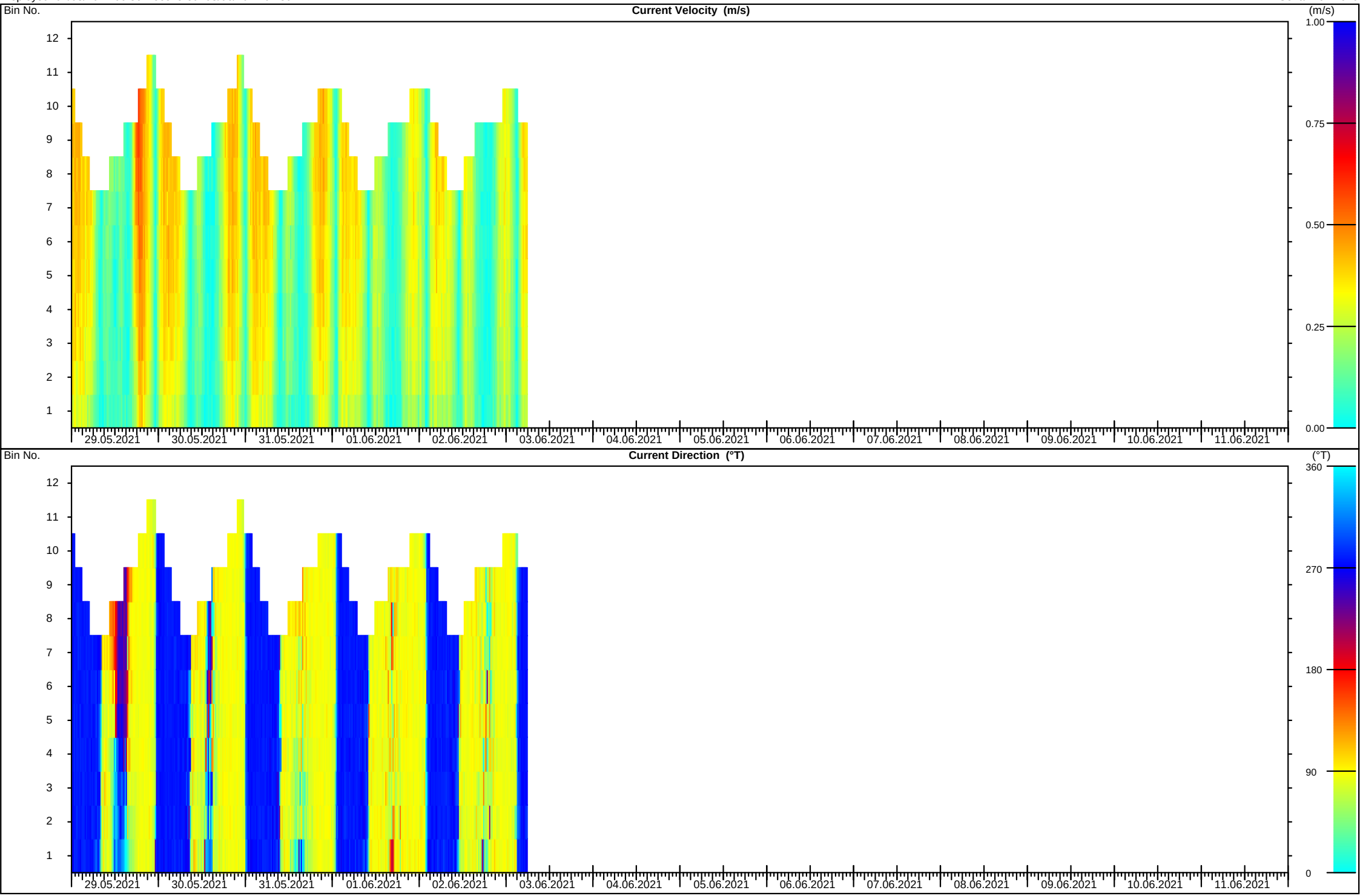
Serial No.: 7629



Colour Contour Time Series

Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

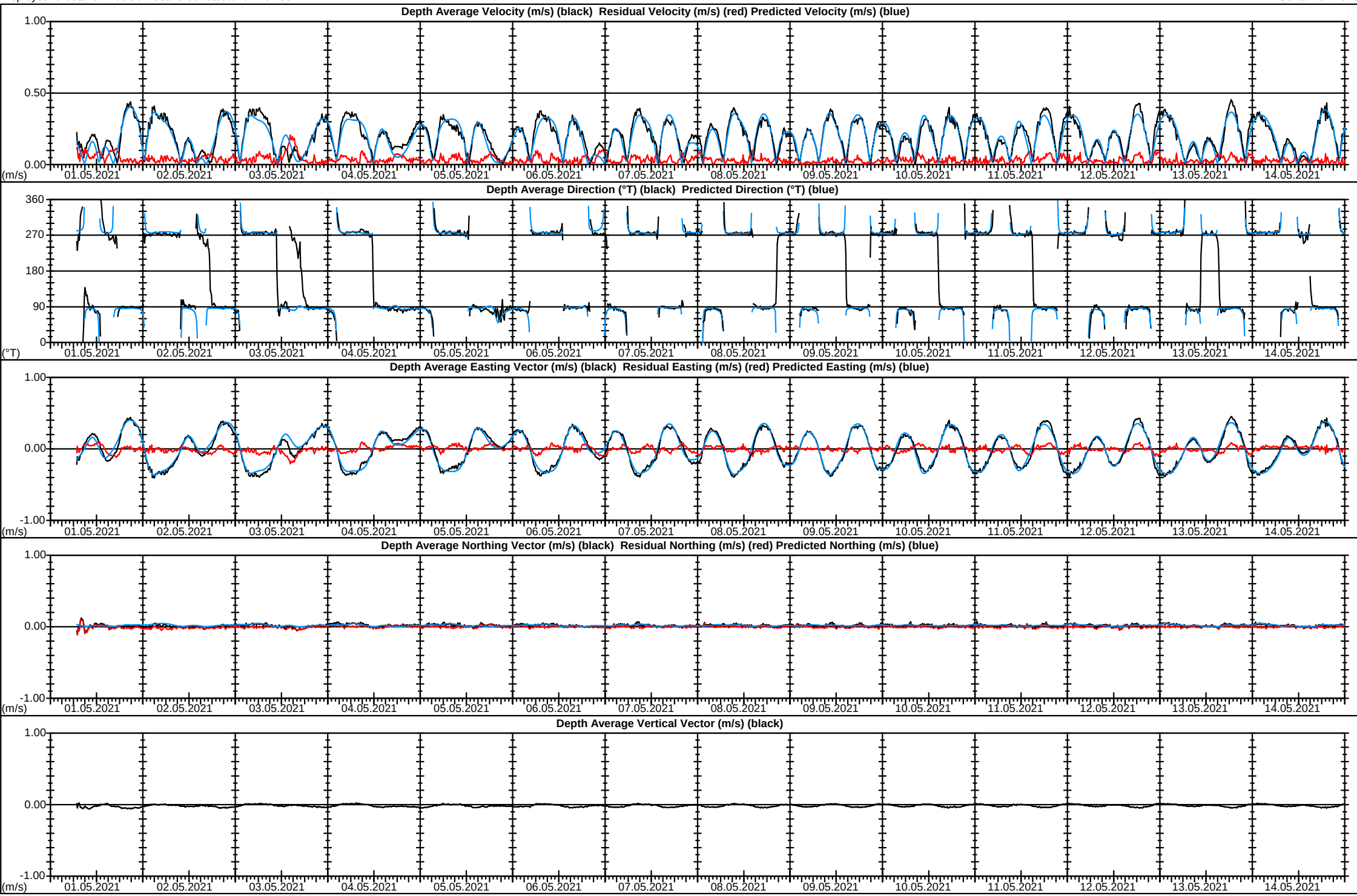
Easting: 744484.10 m E Northing: 2673463.95 m N Site depth below LAT: 5.8m Instrument height above seabed: 0.5m
Current Meter / AWAC
Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30
Serial No.: 7629



Current Data Time Series

Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

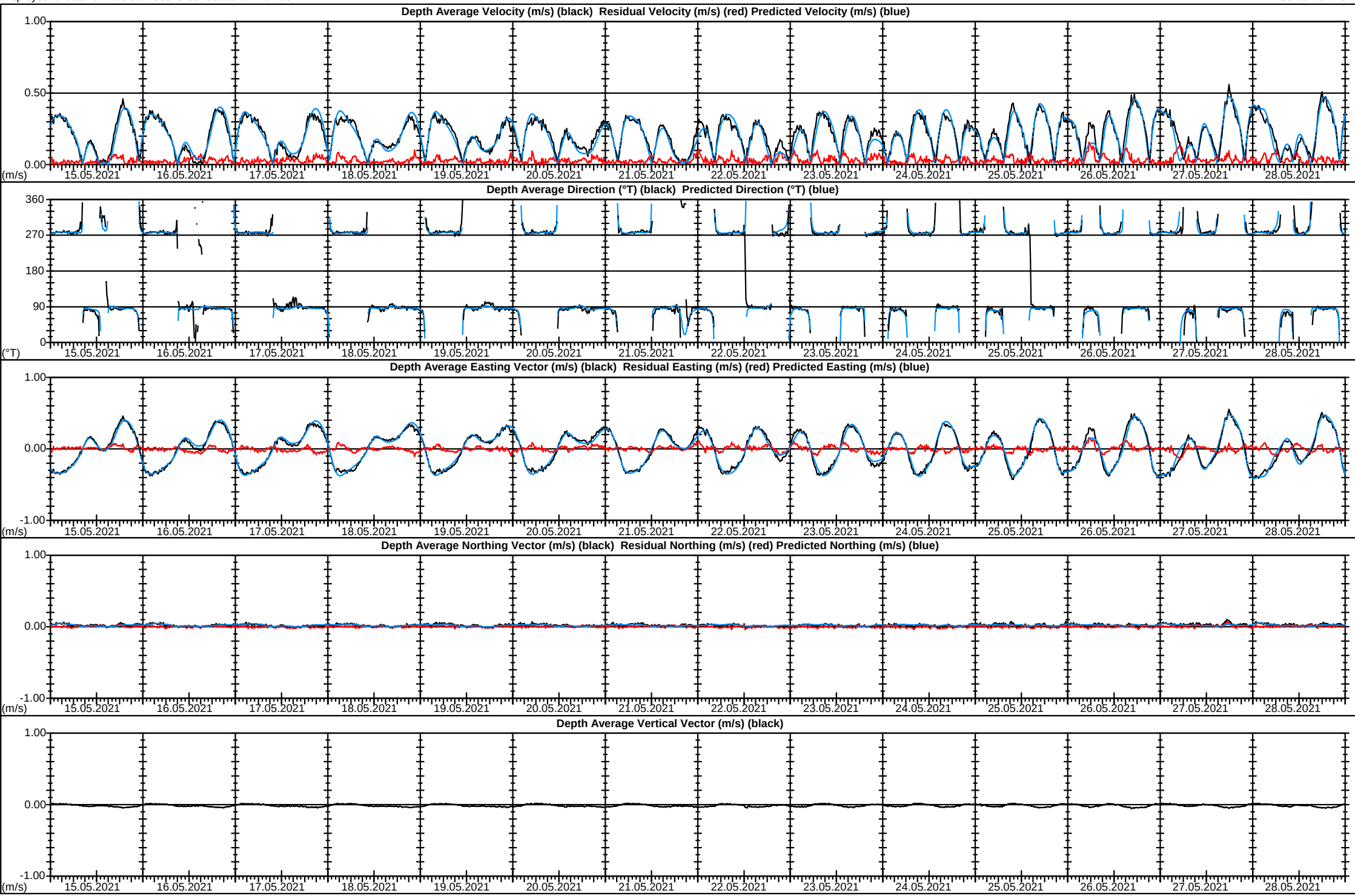
Easting: 744484.10 m E Northing: 2673463.95 m N Site depth below LAT: 5.8m Instrument height above seabed: 0.5m
Current Meter / AWAC
Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30
Serial No.: 7629



Current Data Time Series

Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

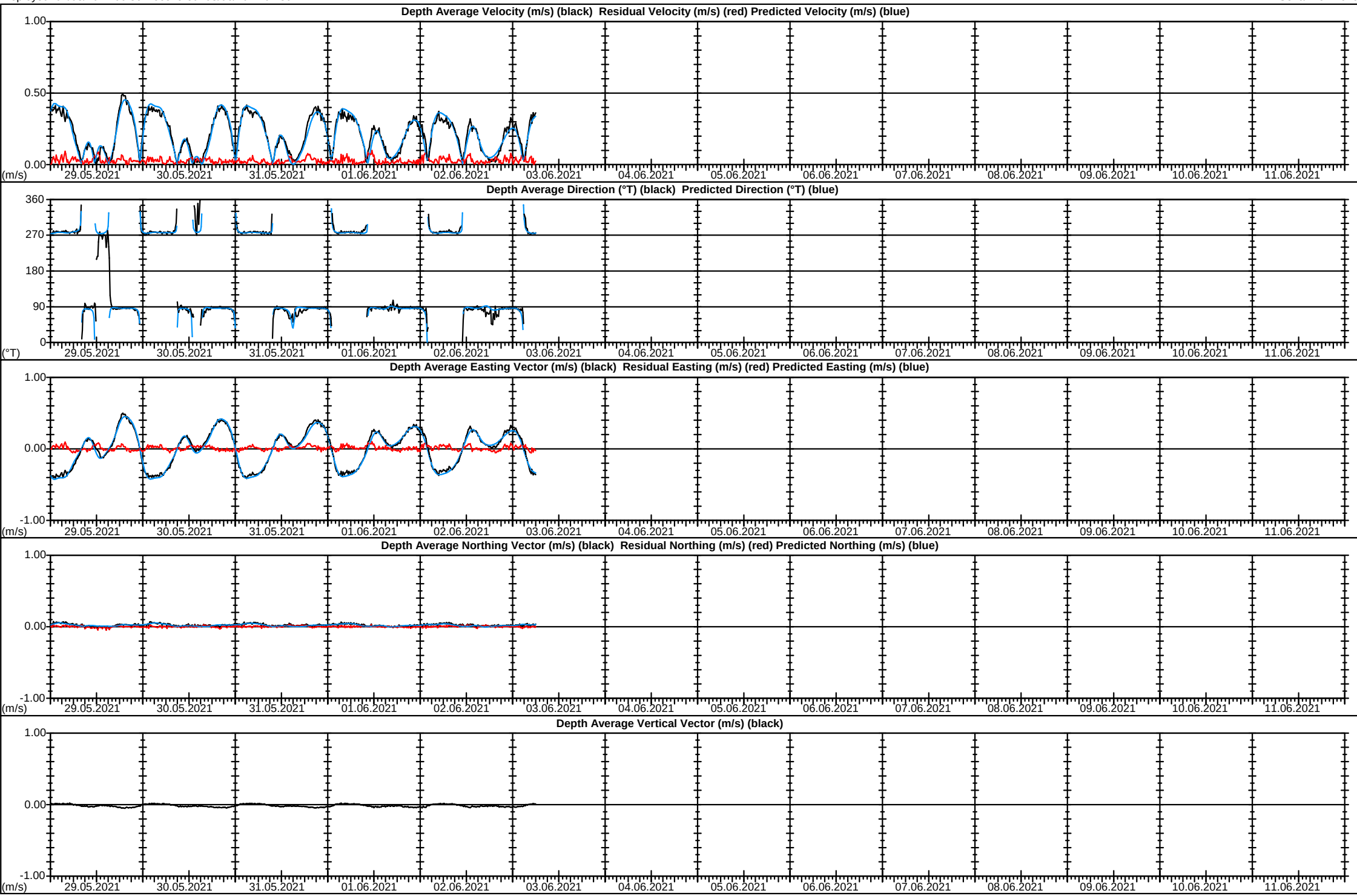
Easting: 744484.10 m E Northing: 2673463.95 m N Site depth below LAT: 5.8m Instrument height above seabed: 0.5m
Current Meter / AWAC
Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30
Serial No.: 7629



Current Data Time Series

Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

Easting: 744484.10 m E Northing: 2673463.95 m N Site depth below LAT: 5.8m Instrument height above seabed: 0.5m
Current Meter / AWAC
Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30
Serial No.: 7629



Current Speed and Direction Scatter Plot

Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

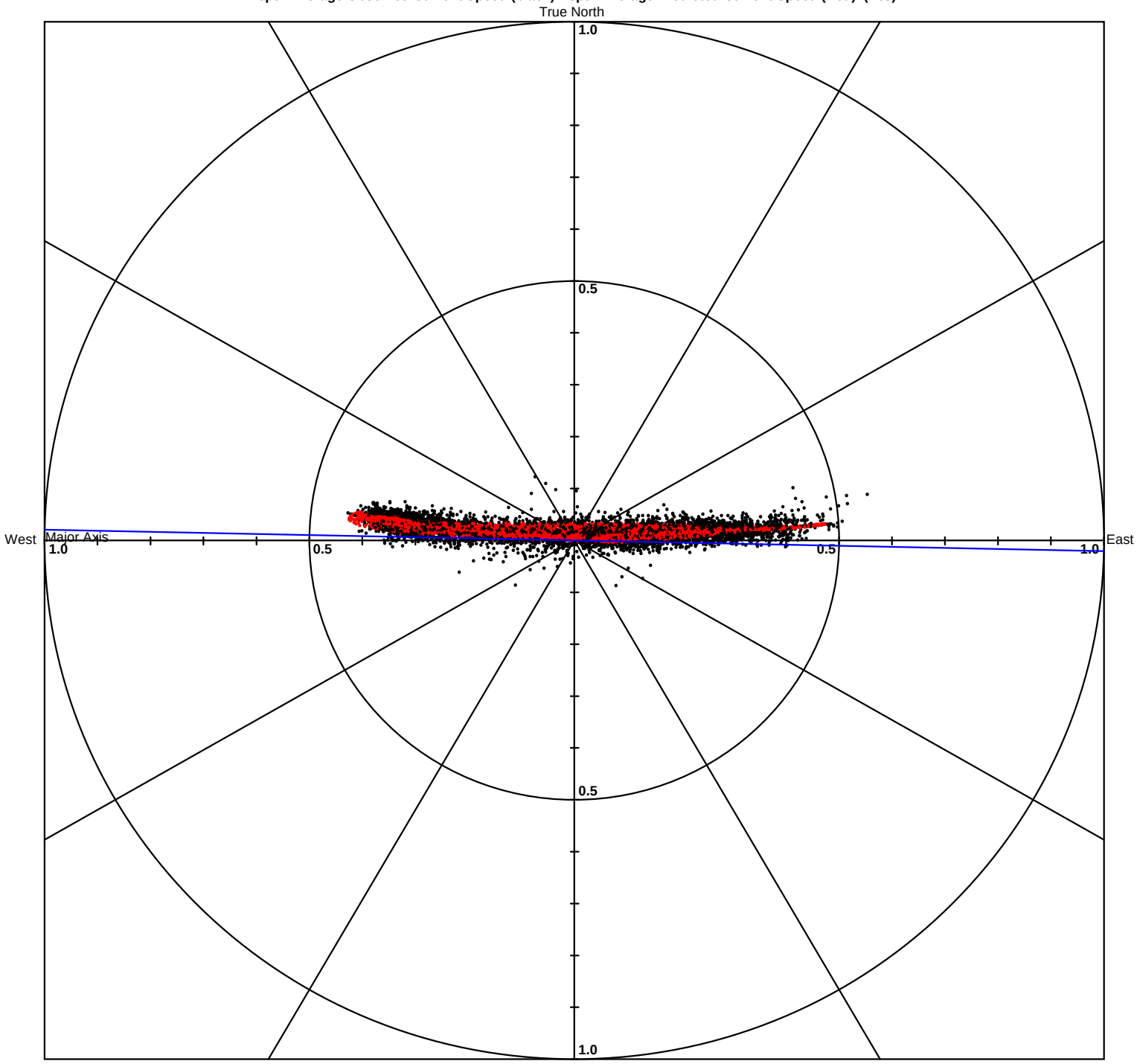
Easting: 744484.10 m E Northing: 2673463.95 m N Site depth below LAT: 5.8m Instrument height above seabed: 0.5m

Current Meter / AWAC

Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30

Serial No.: 7629

Depth Average Observed Current Speed (black) Depth Average Predicted Current Speed (Red) (m/s)



Tick interval: 0.1 Circle Interval: 0.5 Number of records: 4749 Major Axis: 91.2°T-271.2°T

Table B001

CURRENT SPEED HARMONIC ANALYSIS REPORT

Job number: OMU041 Bathymetric, Geophysical surveys and Metocean measurements at *Mirfa and Nouf Al Dabbyah areas, Mirfa-P*
Analysis of Current Meter / AWAC Serial No. 7629
Geographical position: Easting: 744484.10 m E Northing: 2673463.95 m N
Analysis of observations for period: Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 11:30
Seed file for separation of related constituents: EQUILIBR (34)
Speed is in degrees per hour: a constant for each constituent.
Amplitude (H) is in cm/s.
Phase lag (g) is in degrees and synchronises the harmonic to GMT (UT).

RELATED CONSTITUENTS				Easting		Northing	
Number	Constant	Reference	Speed(°/h)	H	g	H	g
1	PI1	K1	14.9178647	0.30	63.5	0.00	206.7
2	P1	K1	14.9589314	5.30	63.5	0.30	206.7
3	PSI1	K1	15.0821353	0.10	63.5	0.00	206.7
4	PHI1	K1	15.1232059	0.20	63.5	0.00	206.7
5	2N2	N2	27.8953548	0.70	138.4	0.00	269.2
6	NU2	N2	28.5125831	1.00	138.4	0.00	269.2
7	T2	S2	29.9589333	0.40	197.1	0.00	169.3
8	K2	S2	30.0821373	2.00	197.1	0.00	169.3

MAJOR CONSTITUENTS			Easting		Northing	
Number	Constant	Speed(°/h)	H	g	H	g
1	Mean		-0.70		2.00	
2	MM	0.5443747	0.40	257.2	0.20	8.4
3	MSF	1.0158958	2.30	189.2	0.20	55.8
4	Q1	13.3986609	1.30	347.3	0.10	70.6
5	O1	13.9430356	8.30	355.4	0.60	125.5
6	M1	14.4920521	1.30	97.8	0.10	245.1
7	K1	15.0410686	16.00	63.5	0.90	206.7
8	J1	15.5854433	0.90	161.6	0.10	311.9
9	OO1	16.1391017	0.40	202.6	0.10	307.1
10	MU2	27.9682084	1.50	275.0	0.00	15.4
11	N2	28.4397295	5.40	138.4	0.00	269.2
12	M2	28.9841042	22.20	178.4	0.20	22.4
13	L2	29.5284789	2.80	210.5	0.10	260.6
14	S2	30.0000000	7.40	197.1	0.10	169.3
15	2SM2	31.0158958	0.70	120.9	0.10	188.6
16	MO3	42.9271398	3.40	178.0	0.30	203.4
17	M3	43.4761563	1.20	152.0	0.10	120.4
18	MK3	44.0251729	2.20	205.5	0.50	211.3
19	MN4	57.4238337	1.40	10.6	0.10	4.7
20	M4	57.9682084	2.50	53.7	0.30	70.1
21	SN4	58.4397295	0.50	232.9	0.20	295.5
22	MS4	58.9841042	0.60	176.1	0.30	331.6
23	2MN6	86.4079380	0.90	332.1	0.00	325.4
24	M6	86.9523127	0.60	342.6	0.20	2.3
25	MSN6	87.4238337	0.50	8.1	0.10	128.6
26	2MS6	87.9682084	1.00	46.0	0.10	42.0
27	2SM6	88.9841042	0.50	41.3	0.20	92.4

VARIANCE ORIGINAL (VO)	0.054	0.000	Metonic Max:	0.568m/s
VARIANCE RESIDUAL (VR)	0.00140	0.00020	MSRate:	0.290m/s
RATIO VR/VO	0.0257	0.6126	MNRate:	0.143m/s
SQRT(VO)	0.233	0.018	Bearing:	85.9°T
SQRT(VR)	0.03740	0.01401	Mean Drift:	0.021m/s
RATIO SQRT(VR)/SQRT(VO)	0.1604	0.7827	Bearing:	340.7°T

DRAFT

Sea Level Data Time Series

Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

Easting: 744484.10 mE Northing: 2673463.95 mN Site depth below LAT: 5.8m Instrument height above seabed: 0.2m

Tide Gauge / Valeport MidaS WLR

Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30

Serial No.: 46016

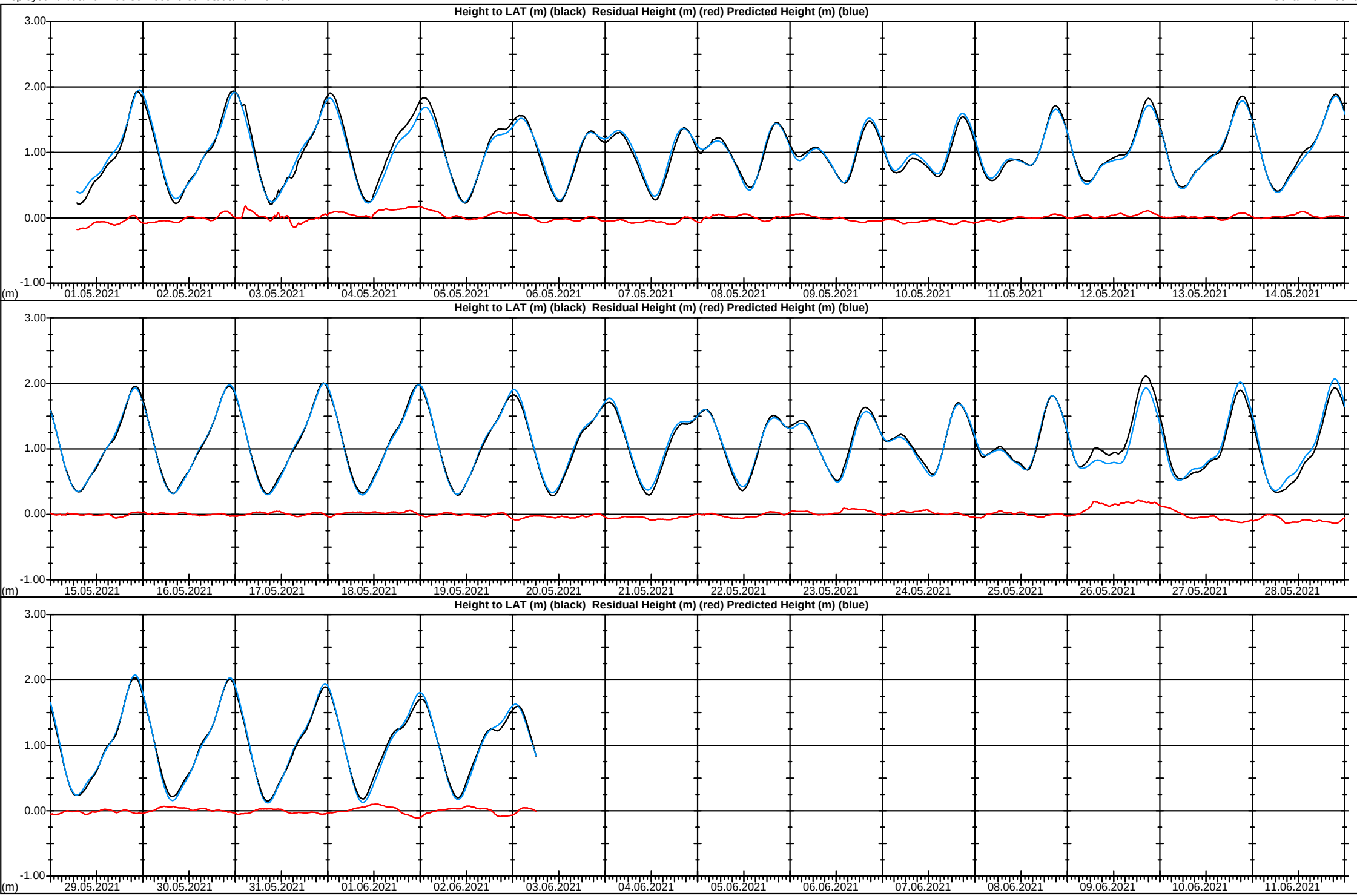


Table C001

TIDAL HEIGHT HARMONIC ANALYSIS REPORT

Job number: OMU041 Bathymetric, Geophysical surveys and Metocean measurements at *Mirfa and Nouf Al Dabbyah areas, Mirfa-P*
Analysis of Tide Gauge / Valeport MidaS WLR Serial No. 46016
Geographical position: Easting: 744484.10 mE Northing: 2673463.95 mN
Analysis of observations for period: Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 11:30
Seed file for separation of related constituents: EQUILIBR (34)
Speed is in degrees per hour: a constant for each constituent.
Amplitude (H) is in cm.
Phase lag (g) is in degrees and synchronises the harmonic to GMT (UT).
Tidal form factor: 2.60 indicative of a mixed mainly diurnal tide

RELATED CONSITUENTS

Number	Constant	Reference	Speed(°/h)	Amplitude	Phase lag
1	PI1	K1	14.9178647	0.9	123.2
2	P1	K1	14.9589314	15.4	123.2
3	PSI1	K1	15.0821353	0.3	123.2
4	PHI1	K1	15.1232059	0.7	123.2
5	2N2	N2	27.8953548	0.6	215.2
6	NU2	N2	28.5125831	0.9	215.2
7	T2	S2	29.9589333	0.4	293.3
8	K2	S2	30.0821373	1.8	293.3

MAJOR CONSTITUENTS

Number	Constant	Speed(°/h)	Amplitude	Phase lag
1	Mean		104.8	
2	MM	0.5443747	6.6	307.9
3	MSF	1.0158958	0.7	119.4
4	Q1	13.3986609	3.2	39.2
5	O1	13.9430356	21.8	59.6
6	M1	14.4920521	3.1	145.9
7	K1	15.0410686	46.4	123.2
8	J1	15.5854433	2.1	169.1
9	OO1	16.1391017	0.6	179.0
10	MU2	27.9682084	2.4	10.5
11	N2	28.4397295	4.7	215.2
12	M2	28.9841042	19.5	261.8
13	L2	29.5284789	2.8	293.3
14	S2	30.0000000	6.7	293.3
15	2SM2	31.0158958	1.1	215.9
16	MO3	42.9271398	0.9	209.5
17	M3	43.4761563	0.8	189.9
18	MK3	44.0251729	2.4	331.1
19	MN4	57.4238337	1.1	347.9
20	M4	57.9682084	1.8	26.1
21	SN4	58.4397295	0.1	48.7
22	MS4	58.9841042	0.7	112.4
23	2MN6	86.4079380	0.1	318.0
24	M6	86.9523127	0.1	324.1
25	MSN6	87.4238337	0.3	10.9
26	2MS6	87.9682084	0.5	14.8
27	2SM6	88.9841042	0.3	57.9

VARIANCE ORIGINAL (VO)	0.217	HAT:	2.332m	MHLR:	1.304m
VARIANCE RESIDUAL (VR)	0.00332	MHHW:	1.728m	MR:	1.117m
RATIO VR/VO	0.0153	MHW:	1.628m	MHWI:	8.753 Hours
SQRT(VO)	0.466	MSL:	1.048m	MLWI:	15.462 Hours
SQRT(VR)	0.05765	MLW:	0.511m		
RATIO SQRT(VR)/SQRT(VO)	0.1238	MLLW:	0.423m		
		LAT:	0.000m		

DRAFT

Meteorological Data Time Series

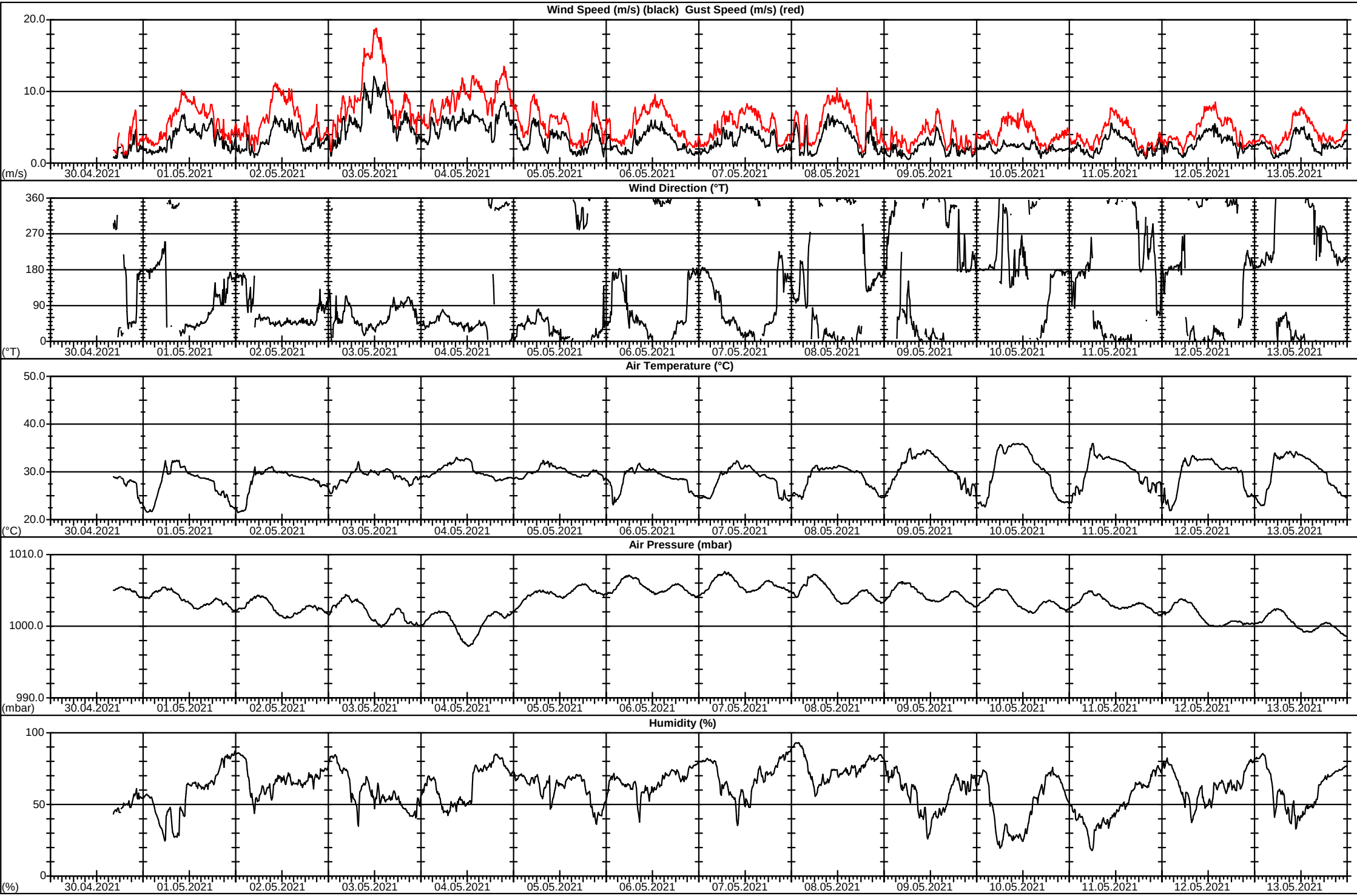
Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

Easting: 751993.51 m E Northing: 2667792.70 m N Instrument height: 12m

Meteorological Station / FSMEMetStation

Start of data: 30/04/2021 16:10 End of data: 04/06/2021 04:30

Serial No.: 724



Meteorological Data Time Series

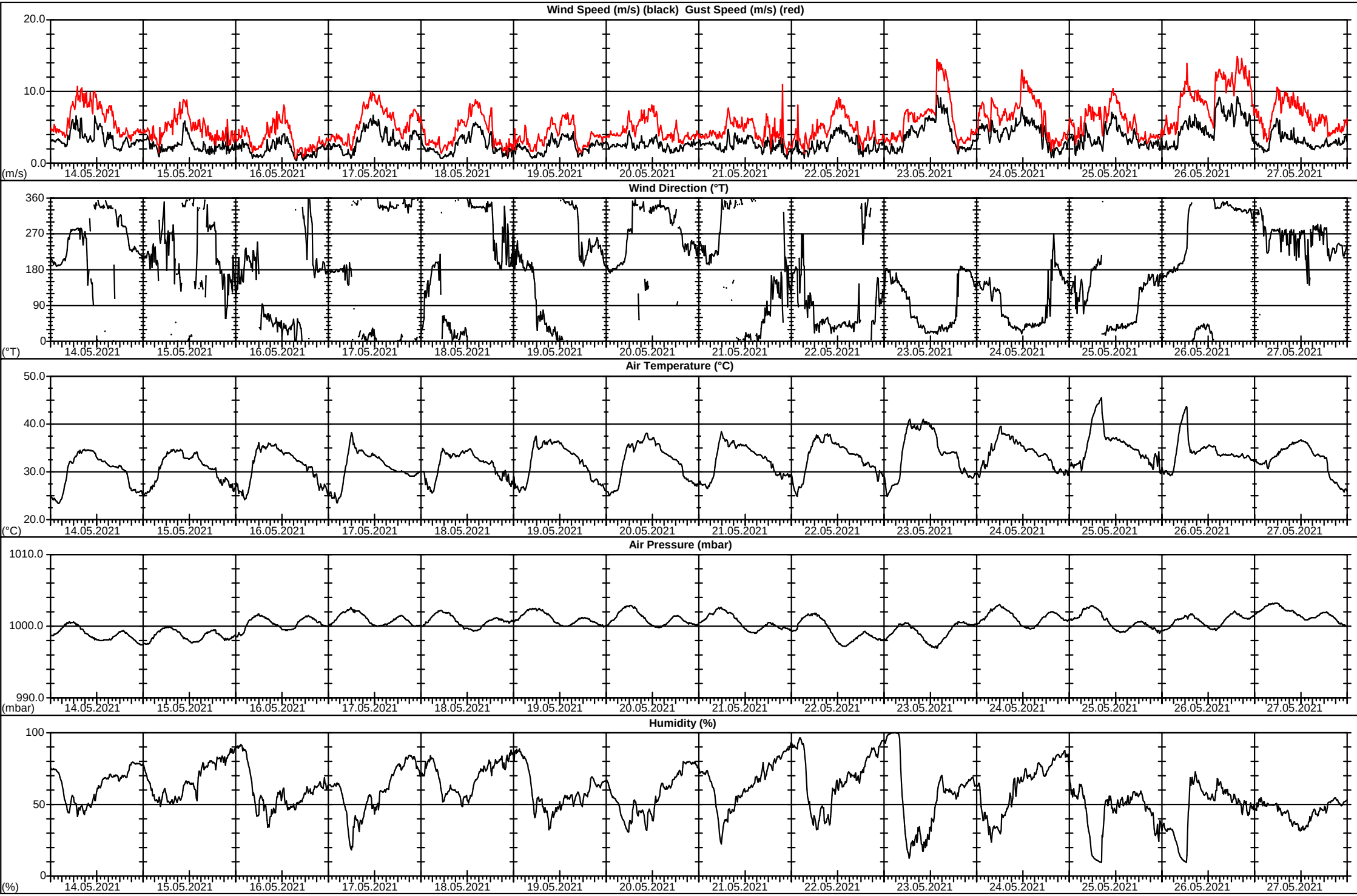
Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

Easting: 751993.51 m E Northing: 2667792.70 m N Instrument height: 12m

Meteorological Station / FSMEMetStation

Start of data: 30/04/2021 16:10 End of data: 04/06/2021 04:30

Serial No.: 724



Meteorological Data Time Series

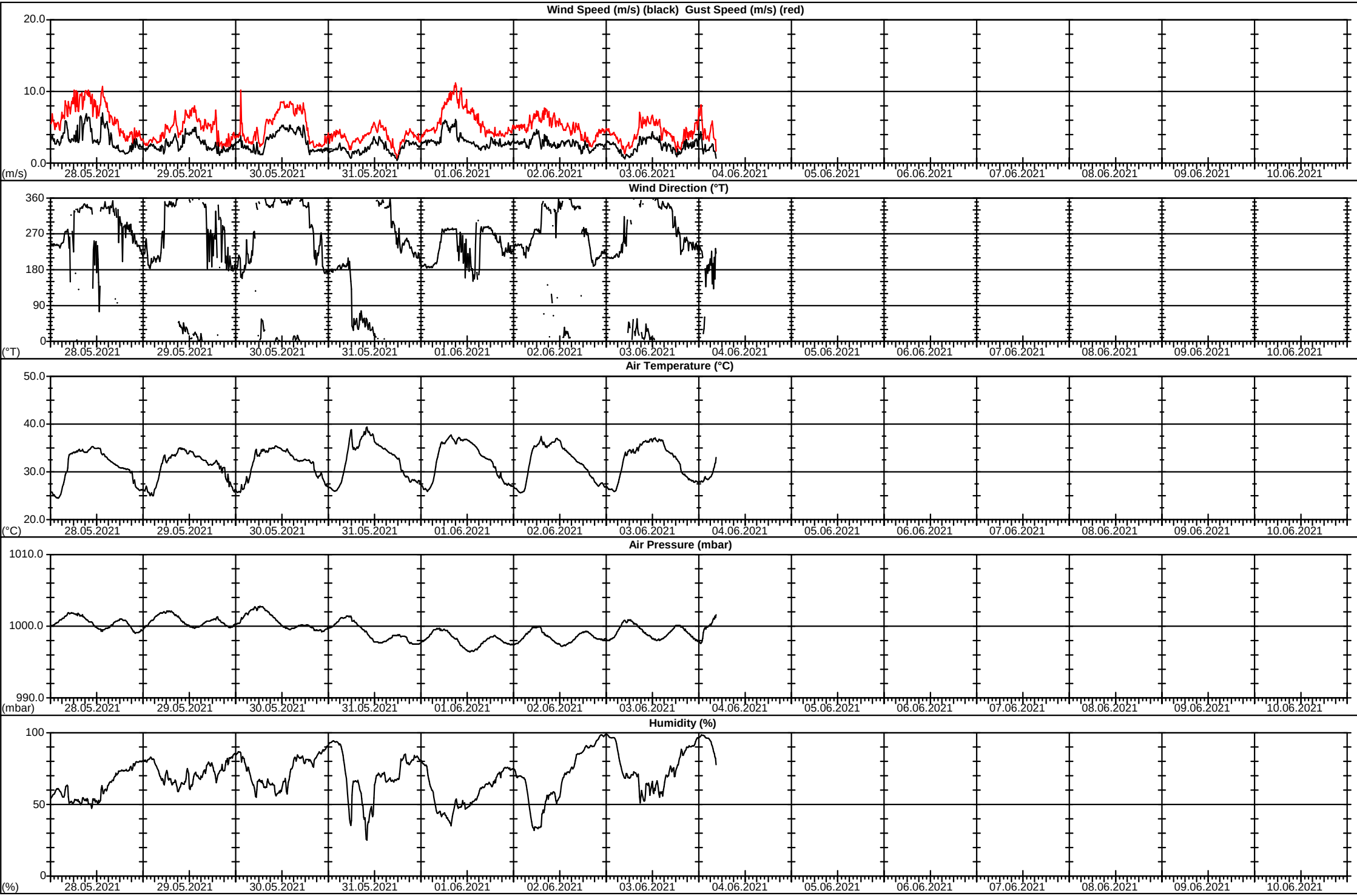
Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

Easting: 751993.51 m E Northing: 2667792.70 m N Instrument height: 12m

Meteorological Station / FSMEMetStation

Start of data: 30/04/2021 16:10 End of data: 04/06/2021 04:30

Serial No.: 724



Meteorological Data Hodogram (Rose Diagram)

Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

Easting: 751993.51 m E Northing: 2667792.70 m N Instrument height: 12m

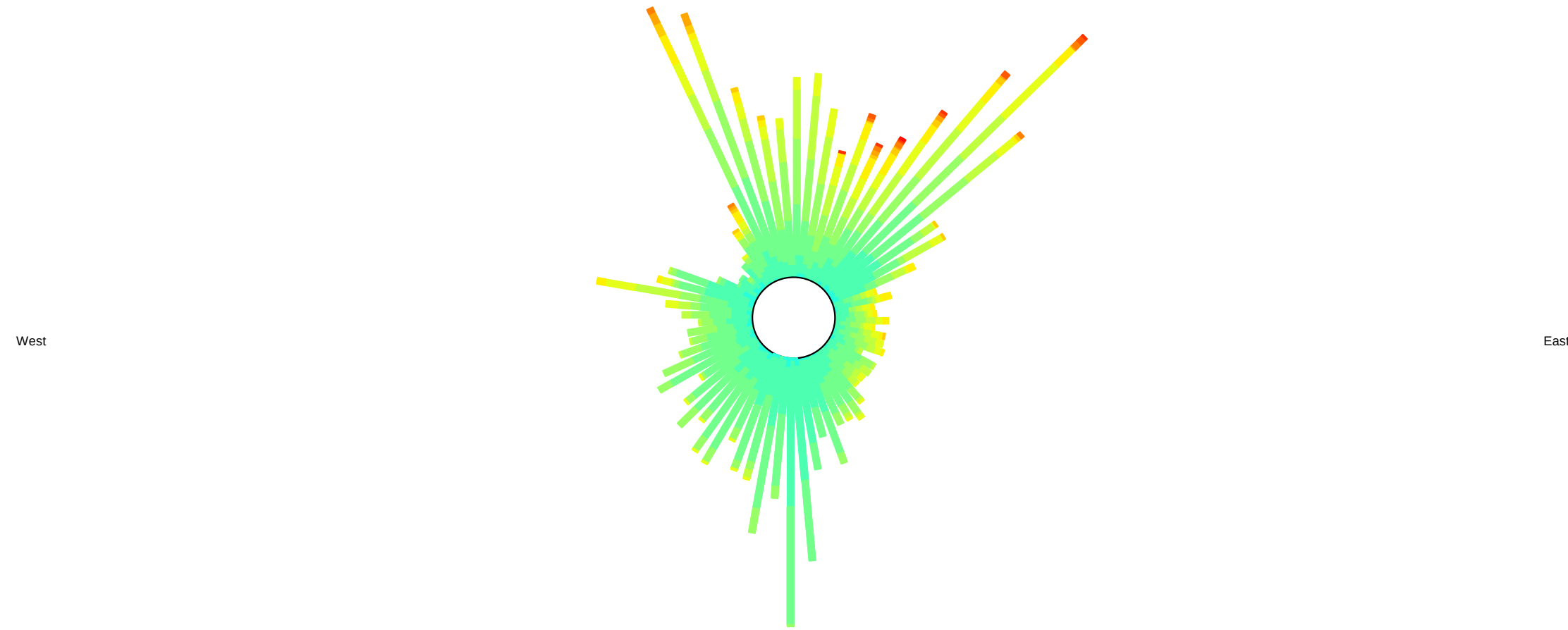
Start of data: 30/04/2021 16:10 End of data: 04/06/2021 04:30

Meteorological Station / FSMEMetStation

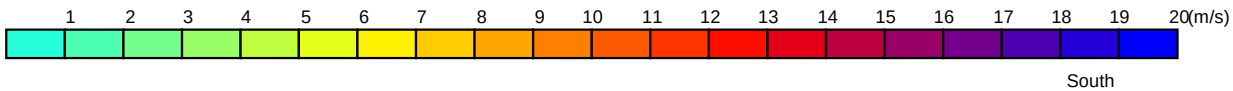
Serial No.: 724

Wind Direction (°T)

True North

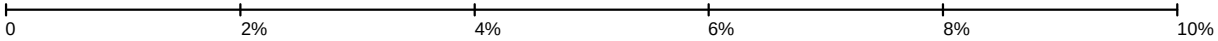


Wind Speed (m/s)



South

Percentage Occurrence



Seawater Temperature Data Time Series

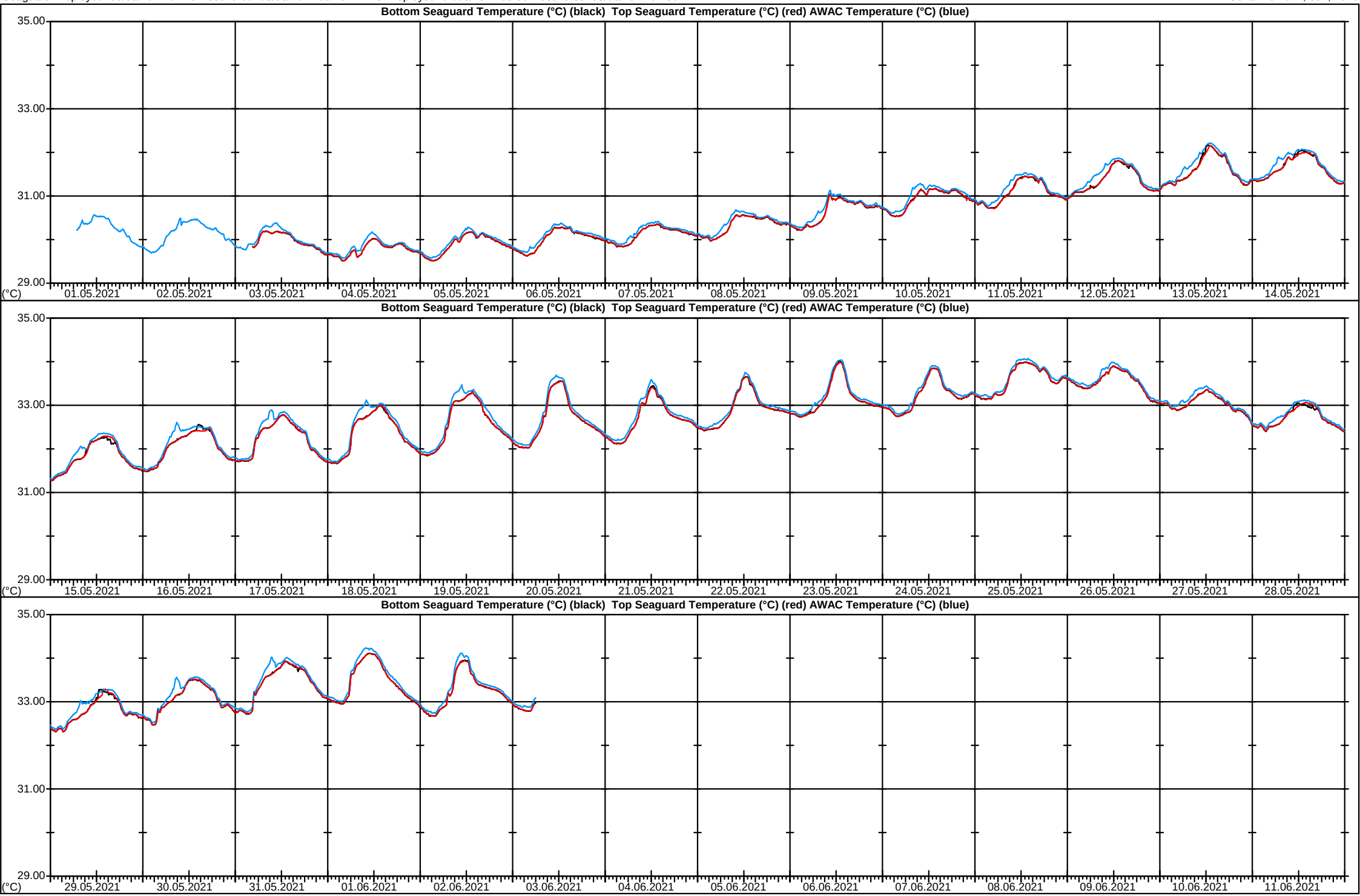
Bathymetric, Geophysical surveys and Metocean measurements at Mirfa and Nouf Al Dabbyah areas, Mirfa

Seaguard: Easting: 744370.77 m E Northing: 2673418.90 m N AWAC: Easting: 744484.10 m E Northing: 2673463.95 m N Instrument height above seabed: 0.5m, 1.5m, 2.5m

Environmental Sensors / AanderaaSeaguard / Current Meter / AWAC

Seaguard: Deployed: 03/05/2021 04:25 Recovered: 03/06/2021 06:25 AWAC: Deployed: 01/05/2021 06:30 Recovered: 03/06/2021 07:30

Serial No.: 622, 857, 7629



B. EQUIPMENT LOGS

DRAFT

Weather Station

1. IDENTIFICATION (Essential reference to mooring log sheet with deployment details)							
Job No.:	*OMU041*	**Job Name:**	*Metocean*	**Mooring Stn. Name:**	*Mirfa-WS*	**Phase**	*1*
2. INSTRUMENT SPECIFICATION							
Instrument S/N:	*724*	**Sensors:**	☒ Wind ☒ Temperature ☒ Humidity ☒ Pressure ☐ Rain ☒ Other (solar radiation)				
3. SET UP							
Sample interval (minutes):	*10*	**Time set:**	☒ GMT ☐ Local	**SD card Size:**	*2 GB*		
4. Installation							
Sensor Height from MSL	*~12 m*	Deployment Note:					
Start Date & Time in GMT:	*30/04/2021 16:08*						
Lat: *24°06'08.70"N*	**Lon:** *53°28'44.36"E*	**Initials:**	*SC*	**Date:**	*30/04/2021*		
5. RECOVERY							
Date and time of stop recording in GMT:	*04/06/2021 04:30*	**Data Recovered:**	*Yes*	**Initials:** *SC*			
Instrument Switched off:	*Yes*	**Data Backup**	*Yes*	**Date:** *04/06/2021*			

DRAFT

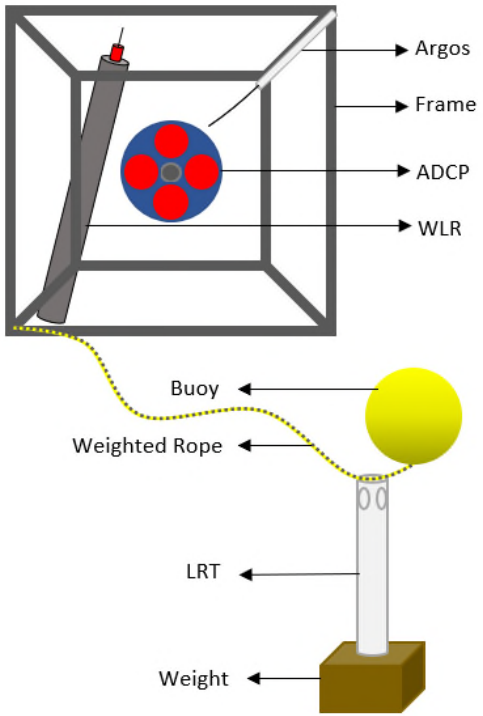
This document is uncontrolled once printed or downloaded and may not reflect the latest version.

Frame/Mooring Log Sheet

1. IDENTIFICATION (Essential reference to mooring log sheet with deployment details)							
Job No.:	*OMU-041*	**Job Name:**	*Metocean*	**Mooring Stn. Name:**	*Mirfa-P*	**Phase:**	*1*

2. INSTRUMENT SPECIFICATION					
Frame LRT Serial No.:	*284388-002*	**Frame LRT Address:**	*069.1*	**Target Latitude / Northing (m):**	*2 673 463.9*
Weight LRT Serial No.:	*254611-003*	**Weight LRT Address:**	*044.1*	**Target Longitude/ Easting (m):**	*744 498.4*

3. MOORING



Instrument	Serial No.	Height Above Seabed	Buoyancy (kg)	Deployed Latitude/ Northing	Deployed Longitude/ Easting	Deployed Date & Time (GMT)	Depth (m)
Frame	-	*0*	*-60*	*24°09'17.19"N*	*053°24'22.05"E*	*01/05/2021 06:30*	*5*
AWAC	*WAV7629*	*0.5*	-				
WLR	*46016*	*0.2*	-				
Argos	*754*	*0.4*	-				
Weighted Rope	-	*0*	-	-	-	-	--
Buoy	-	*3*	*+20*	*24°09'17.17"N*	*053°24'20.93"E*	*01/05/2021 06:30*	*5*
LRT	*254611-003*	*1*	-				
Weight	-	*0*	*-30*				

Date:	*01/05/2021*	**Initials**	*SC*

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

4. RECOVERY				
Release Batteries OK Pre-recovery:	*OK*	**Date and time release (GMT):**	*03/06/2021 11:25*	**Initials:** *SC*
Release NOT tilted Pre-recovery:	*OK*	**Date and time recovery (GMT):**	*03/06/2021 11:30*	

5. STORAGE		
Cleaned Frame	☒	
Cleaned Buoys	☒	
Removed marine Growth from LRTs/DORT	☒	
Battery Level of LRT/DORT	☒	
Changed Batteries of LRTs/DORTs	☒	

6. Signature	*SC*

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

Nortek ADP

1. IDENTIFICATION (Essential reference to mooring log sheet with deployment details)							
Job No.:	*OMU041*	Job Name:	*Metocean*	Mooring Stn. Name:	*Mirfa*	Phase:	*1*

2. INSTRUMENT SPECIFICATION									
Nortek Type:	*AWAC 1MHz*	Serial Number:	*WAV7629*	Asset Number:	*-*	Memory Size:	*153 MB*	Depth Rating (m):	*100*

3. TEST REPORT					
Sensor Visual:	*OK*	Connector Visual:	*OK*	Housing Visual:	*OK*
Canister Visual:	*OK*	Battery secured:	*Yes*	O Rings cleaned and inspected:	*OK*
Communication Type:	*Serial*	Baud rate :	*9600*	I/F Cable Status:	*OK*
Pre-deployment test file name:	*AWAC.wpr*	Data logged and checked:	*Yes*	Test Result:	*OK*
Initial:	*SC*		Date:	*01/05/2021*	

4. DEPLOYMENT PLANING					
No. of cells:	*24*	Power Level:	*High*	Wave commands:	*Yes*
Cell size (m):	*0.5*	Blanking distance (m):	*0.41*	Number of samples:	*512*
Average interval:	*300*	Measurement Load (%):	*18*	Sampling rate (Hz):	*1*
Profile Interval:	*600*	Energy required:	*-*	Interval (s):	*1800*
Assumed duration (days):	*45*	Memory required (MB):	*22 MB*	SUV Mode:	*No*
Estimated depth (m):	*5*	Vertical vel. prec (cm/s)	*0.7*	Ice Mode:	*No*
Fixed Speed of sound (m/s):	*Measured*	Horizon. vel. prec (cm/s)	*2*	SUV Mode:	*No*
Water Salinity (ppt):	*35*	Note:			

5. BATTERIES AND ASSEMBLY							
Battery type:	*Alkaline*	No. of Battery Packs:	*2*	New battery capacity:	*-*	New batteries fitted:	*Yes*
Battery Supplier:	*UK*	Measured Voltage:	*13.6*	Silica desiccant installed:	*Yes*	Instrument sealed:	*Yes*

6. Deployment Set Up

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

Set Clock to PC time:	*Yes*	**Memory cleared:**	*Yes*
Time set to GMT:	*Yes*	**Start at Date and Time (GMT):**	*01/05/2021 04:00:00*
Save deployment configuration file:	*Yes*	**Output to Tell Tale**	*No*
File Name:	*AWAC_CFG*	**Output to Acoustic modem**	*No*
Directory/Filename:	*T:*	**Enable serial output**	*No*
Radio Test performed:	*Yes*	**Height of instrument head above seabed (m):**	*0.5*
Note:			
Initial:	*SC*	**Date:**	*01/05/2021*

7. RECOVERY AND STORAGE

Recovery date and time (GMT):	*03/06/2021 06:05*	**Still pinging:**	*Yes*	**Switch off date and time (GMT):**	*03/06/2021 08:40*
Data recovered:	*Yes*	**Data inspected:**	*Yes*	**Clock error:**	*No*
Data file name:	*AWAC-R.wpr*	**Data File size:**	*27,553 KB*	**Data backed up:**	*Yes*
Check overall condition:	*Yes*	**Inspect transducer heads:**	*OK*	**Disconnect all circuits and lines:**	*Yes*
Clean to remove any biofouling:	*Yes*	**Inspect the connector pins:**	*OK*	**Battery Disconnected:**	*Yes*
Note:					
Initial:	*SC*		**Date:**	*03/06/2021*	

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

Valeport Midas WLR

1. IDENTIFICATION (Essential reference to mooring log sheet with deployment details)							
Job No.:	*OMU041*	Job Name:	*Metocean*	Mooring Stn. Name:	*Mirfa*	Phase:	*1*

2. INSTRUMENT SPECIFICATION									
WLR Type:	*Midas*	Serial Number:	*46016*	Asset Number:	*-*	Memory Size:	*1GB*	Depth Rating (m):	*100*

3. TEST REPORT					
Pressure Sensor Visual:	*OK*	Connector Visual:	*OK*	Housing Visual:	*OK*
Temperature Sensor Visual:	*OK*	Battery secured:	*Yes*	O Rings cleaned and inspected:	*OK*
Communication Type:	*RS232*	Baud rate (Default 9600):	*9600*	I/F Cable Status:	*OK*
Wet test Conducted:	*Yes*	Data logged and checked:	*Yes*	Test Result:	*OK*
Calibration Due date:	*-*	Calibration Certificate Number:	*-*		
Note:-					
Initial:	*SC*			Date:	*01/05/2021*

4. SET UP					
Battery Make:	*Duracell*	Battery Type:	*Alkaline*	New Battery:	*Yes*
Battery Voltage:	*12*	CMOS Voltage:	*3.5*	Calculated battery life (days):	*90*
Sampling Mode:	*Burst*	Sampling Rate (Hz):	*1*	Data Averaging:	*NA*
Sampling Interval (Minutes):	*10*	Samples per Burst:	*60*	Data Average Mode:	*NA*
Time Synchronised to PC:	*Yes*	Time Zone:	*GMT*	Unit Setup:	*dbar*
Site Information:	*Mirfa*	Local Latitude:	*24*	Pressure Tare:	*Off*
Memory cleared:	*Yes*	Instrument Run:	*Yes*	Self-Recording Selected:	*Yes*

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

Housing sealed and clamped:	*Yes*	**WLR Secured to Frame:**	*Yes*	**Sensor Height Above Base (m):**	*0.15*
Anchor Weight (Kg):	*30*	**Length Of Weighted Rope (m):**	*30*	**Rope Canister on Frame:**	*No*
Note:-					
Initial:	*SC*		**Date:**	*01/05/2021*	

5. DEPLOYMENT

Date and Time Plugged (GMT):	*01/05/2021 04:33*	**LED Flash Checked:**	*Yes*	**2nd Cycle of Flashes Observed:**	*Yes*
Time Frame on Seabed (GMT):	*01/05/2021 06:30*	**Frame LRT Status:**	*Recovered*	**Water Depth (m):**	*10*
Time Weight on Seabed (GMT):	*01/05/2021 06:30*	**Weight LRT Status:**	*OK*		
Note:-					
Initial:	*SC*		**Date:**	*01/05/2021*	

6. RECOVERY

Date and Time Recovery Commenced (GMT):	*03/06/2021 11:25*	**Date and Time Recovery Complete (GMT):**	*03/06/2021 11:30*
Date and time Plug disconnected (GMT):	*03/06/2021 07:30*	**Clock error:**	*No*
Data recovered:	*Yes*	**Data File Name:**	*WLR-P.000*
Data Translated in Dbar:	*Yes*	**Data File size:**	*353 KB*
Data backed up:	*Yes*	**Data Inspected and Satisfactory:**	*Yes*
Check overall physical condition:		**Clean to remove any biofouling:**	*Yes*
Note:-			
Initial:	*SC*	**Date:**	*03/06/2021*

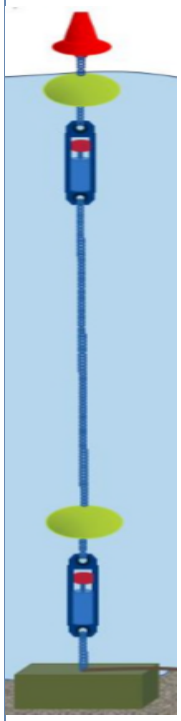
DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

U-Mooring Log Sheet

1. IDENTIFICATION (Essential reference to mooring log sheet with deployment details)							
Job No.:	*OMU041*	**Job Name:**	*Metocean*	**Mooring Stn. Name:**	*RCM-P*	**Phase:**	*1*

2. MOORING			
Target Latitude / Northing (m):	*2 673 463.9*	**Target Longitude/ Easting (m):**	*744 498.4*



Instrument	Serial No.	Height Above Seabed	Buoyancy (kg)	Deployed Latitude/ Northing	Deployed Longitude/ Easting	Deployed Date & Time (GMT)	Depth (m)
Buoy	-	-	*+30*	-	-	-	-
Sub Buoy	-	*3*	*+20*	-	-	-	-
RCM-top	*857*	*2.5*	*-10*	-	-	-	-
Sub Buoy	-	*1.5*	*+20*	-	-	-	-
RCM-bottom	*622*	*1*	*-10*	-	-	-	-
Weight	-	*0*	*-60*	*24°09'15.79" N*	*053°24'18.01" E*	*03/05/2021 04:25*	*5*

Date:	*03/05/2021*	**Initials**	*SC*

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

3. RECOVERY			
Date and time recovery (GMT):	*03/06/2021 06:25*	**Initials:**	*SC*

4. STORAGE		
Cleaned Frame	☒	
Cleaned Buoys	☒	
Removed marine Growth	☒	

5. Signature	*SC*

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

Aanderaa Seaguard

1. IDENTIFICATION (Essential reference to mooring log sheet with deployment details)							
Job No.:	*OMU041*	**Job Name:**	*Metocean*	**Mooring Stn. Name:**	*RCM-P Bottom*	**Phase**	*1*

2. INSTRUMENT SPECIFICATION			
Instrument S/N:	*622*	**Sensors:**	☒ Current ☒ Temperature ☒ Conductivity ☒ Pressure ☐ Turbidity ☐ DO ☐ Other

3. SET UP					
Sample mode set to:	☐Burst ☒Fixed	**DCS ping No:**	*300*	**New Batteries fitted:**	☒ Yes ☐ No
Sample interval (minutes):	*10*	**Sound speed:**	*1525*	**Battery Type:**	☒ Alkaline ☐ Lithium
Time set:	☒ GMT ☐ Local	**SD card Size:**	*2 GB*	**Battery Voltage:**	*9v*
Depth Rating (m):	*1000*	**Memory cleared:**	☒ Yes ☐ No	**Predicted Battery days:**	*160 days*

4. DEPLOYMENT					
All Required Channel selected	*Yes*	Deployment Note:			
O Ring checked and greased:	*Yes*				
Start Date & Time in GMT:	*30/04/2021 07:30*				
Instrument sealed and Clamped:	*Yes*				
In water Date & Time in GMT:	*03/05/2021 04:25*				
Depth at location (m):	*5*	**Initials:**	*SC*	**Date:**	*03/05/2021*

5. RECOVERY					
Date and time of recovery in GMT:	*03/06/2021 06:25*	**Data Recovered:**	*Yes*	**Initials:**	*SC*
Date and time of stop recording in GMT:	*03/06/2021 07:40*	**Data Checked:**	*Yes*		
Instrument Switched off:	*03/06/2021 07:40*	**Data Backup**	*Yes*	**Date:**	*03/06/2021*

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

Aanderaa Seaguard

1. IDENTIFICATION (Essential reference to mooring log sheet with deployment details)							
Job No.:	*OMU041*	**Job Name:**	*Metocean*	**Mooring Stn. Name:**	*RCM-P Top*	**Phase**	*1*

2. INSTRUMENT SPECIFICATION			
Instrument S/N:	*857*	**Sensors:**	☒ Current ☒ Temperature ☒ Conductivity ☒ Pressure ☐ Turbidity ☐ DO ☐ Other

3. SET UP					
Sample mode set to:	☐Burst ☒Fixed	**DCS ping No:**	*300*	**New Batteries fitted:**	☒ Yes ☐ No
Sample interval (minutes):	*10*	**Sound speed:**	*1525*	**Battery Type:**	☒ Alkaline ☐ Lithium
Time set:	☒ GMT ☐ Local	**SD card Size:**	*2 GB*	**Battery Voltage:**	*9v*
Depth Rating (m):	*1000*	**Memory cleared:**	☒ Yes ☐ No	**Predicted Battery days:**	*160 days*

4. DEPLOYMENT					
All Required Channel selected	*Yes*	Deployment Note:			
O Ring checked and greased:	*Yes*				
Start Date & Time in GMT:	*30/04/2021 07:30*				
Instrument sealed and Clamped:	*Yes*				
In water Date & Time in GMT:	*03/05/2021 04:25*				
Depth at location (m):	*5*	**Initials:**	*SC*	**Date:**	*03/05/2021*

5. RECOVERY					
Date and time of recovery in GMT:	*03/06/2021 06:25*	**Data Recovered:**	*Yes*	**Initials:**	*SC*
Date and time of stop recording in GMT:	*03/06/2021 07:40*	**Data Checked:**	*Yes*		
Instrument Switched off:	*03/06/2021 07:40*	**Data Backup**	*Yes*	**Date:**	*03/06/2021*

DRAFT

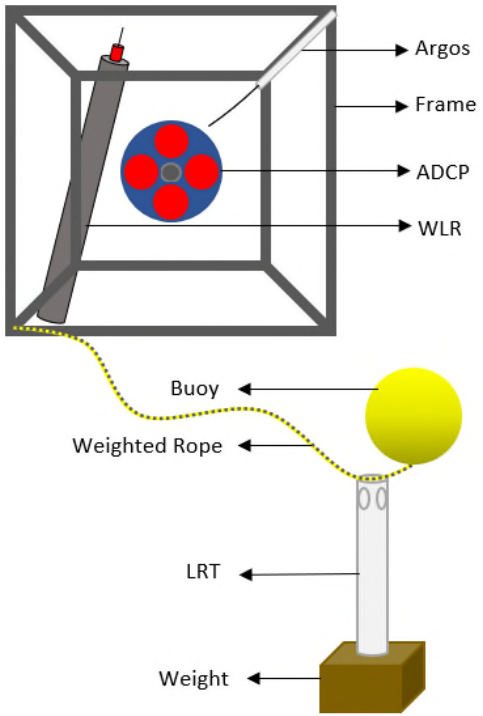
This document is uncontrolled once printed or downloaded and may not reflect the latest version.

Frame/Mooring Log Sheet

1. IDENTIFICATION (Essential reference to mooring log sheet with deployment details)							
Job No.:	*OMU041*	**Job Name:**	*Metocean*	**Mooring Stn. Name:**	*Mirfa-R*	**Phase:**	*1*

2. INSTRUMENT SPECIFICATION					
Frame LRT Serial No.:	*283484-001*	**Frame LRT Address:**	*071.1*	**Target Latitude / Northing (m):**	*2 673 463.9*
Weight LRT Serial No.:	*257371-003*	**Weight LRT Address:**	*057.1*	**Target Longitude/ Easting (m):**	*744 498.4*

3. MOORING



Instrument	Serial No.	Height Above Seabed	Buoyancy (kg)	Deployed Latitude/ Northing	Deployed Longitude/ Easting	Deployed Date & Time (GMT)	Depth (m)
Frame	-	*0*	*-60*	*24°09'16.10"N*	*053°24'21.61"E*	*1/05/2021 07:25*	*5*
ADCP	*15464*	*0.5*	-				
Midas WLR	*65476*	*0.2*	-				
Argos		*0.4*	-				
Weighted Rope	-	*0*	-				
Buoy	-	*3*	*+20*	*24°09'15.31"N*	*053°24'20.86"E*	*1/05/2021 07:26*	*5*
LRT	*257371-003*	*1*	-				
Weight	-	*0*	*-30*				
Date:		*01/05/2021*		**Initials**		*SC*	

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

4. RECOVERY				
Release Batteries OK Pre-recovery:	*NA*	Date and time release (GMT):	*NA*	Initials: *SC*
Release NOT tilted Pre-recovery:	*OK*	Date and time recovery (GMT):	*02/06/2021 05:52*	

5. STORAGE		
Cleaned Frame	☒	
Cleaned Buoys	☒	
Removed marine Growth from LRTs/DORT	☒	
Battery Level of LRT/DORT	☒	
Changed Batteries of LRTs/DORTs	☒	

6. Signature	*SC*

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

RDI Workhorse ADCP (Self Contained)

1. IDENTIFICATION (Essential reference to mooring log sheet with deployment details)							
Job No.:	*OMU-041*	Job Name:	*Metocean*	Mooring Name:	*Mirfa-R*	Phase:	*1*

INSTRUMENT SPECIFICATION					
Serial No.	*15464*	Bottom Track fitted	*No*	Memory fitted (MB)	*1024*
Frequency (kHz)	*1200*	Waves Capability	*Yes*	Planned orientation	*Upward*
CPU Firmware version	*50.40*	Housing depth rating (m)	*50*		

2. PLAN					
				Deployment / CMD name:	*Plan-Mirfa-R*
Choices		Consequences		Wave commands	*Yes*
No. of bins	*24*	First depth cell (m)	*1.05*	Burst Duration (min)	*5*
Bin size (m)	*0.5*	Last depth cell (m)	*12.55*	Burst Interval (min)	*30*
Pings per ensemble	*300*	Predicted max range (m)	*13.61*	Samples per Burst	*600*
Ensemble Interval	*10 Minutes*	Energy required @_*10*_C	*0.9%*	Collect Motion Data	*No*
Deployment duration (days)	*31*	Days spare (see Table1)	*5*		
Depth of transducer (m)	*05*	Velocity Std. dev (cm/s)	*0.4*	Other Commands:	
Water Salinity (ppt)	*35*	Memory required (MB)	*78.16*		
Magnetic Variation set to 0	*Yes*	*Note:*			
Date & time first ping in GMT	*01/05/2021 04:30*				
Record data internally	*Yes*				
Send data out serial port	*No*				

3. BATTERIES AND ASSEMBLY									
Battery type	*Alkaline*	No. of Battery Packs	*1*	New battery capacity (Wh)	*450*	Comms Switch	*RS232*	Battery connected	*Yes*
Battery Supplier	*FGB*	Measured Voltage	*45*	New batteries fitted	*Yes*	Silica desiccant installed	*Yes*	Instrument sealed	*Yes*

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

4. DEPLOY					
In Water test	*No*	DEPLOY to send CMD FILE to ADCP	*Yes*	Dummy plug greased & replaced	*Yes*
Computer clock set to GMT/LT	*GMT*	On Bottom date and time GMT	*01/05/2021 07:25*	Dummy plug tied in	*Yes*
TEST ADCP filename	*Dep Test*	Deployment log filename	*Dep Test*	ADCP Pinging audible	*Yes*
Memory erased	*Yes*	.CMD and log files backed up	*Yes*	Chilli applied to Tx	*No*
Pressure sensor zeroed (AZ)	*Yes*	Initials:	*SC*	Date:	*01/05/2021*

5. RECOVERY							
Still pinging:	*Yes*	Data recovered:	*Yes*	Clock error:	*No*	Data backed up	*Yes*
Switch off date and time (GMT):	*02/06/2021 08:20*	Physical condition:	*OK*	Data inspected:	*Yes*		
Data file name:	*ADCP-R.000*			Initials	*SC*	Date:	*02/06/2021*

6. DEMOBILISATION AND STORAGE			
Check overall condition:			*OK*
Clean externally to remove any biofouling:			*OK*
Inspect transducer heads:			*OK*
Inspect the connector pins for any damage and remove any corrosion:			*OK*
Disconnect all circuits and lines:			*OK*
Clean all joints and remove and store all O-rings:			*OK*
Attach label stating “PREPARATION REQUIRED PRIOR TO DEPLOYMENT”			*No*
Replacement of Parts used:			*No*
Initials:	*SC*	Date:	*02/06/2021*

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

Valeport Midas WLR

1. IDENTIFICATION (Essential reference to mooring log sheet with deployment details)							
Job No.:	*OMU041*	Job Name:	*Metocean*	Mooring Stn. Name:	*Mirfa-R*	Phase:	*1*

2. INSTRUMENT SPECIFICATION									
WLR Type:	*Midas*	Serial Number:	*65476*	Asset Number:	*-*	Memory Size:	*1GB*	Depth Rating (m):	*100*

3. TEST REPORT					
Pressure Sensor Visual:	*OK*	Connector Visual:	*OK*	Housing Visual:	*OK*
Temperature Sensor Visual:	*NA*	Battery secured:	*Yes*	O Rings cleaned and inspected:	*OK*
Communication Type:	*RS232*	Baud rate (Default 9600):	*9600*	I/F Cable Status:	*OK*
Wet test Conducted:	*Yes*	Data logged and checked:	*Yes*	Test Result:	*OK*
Calibration Due date:	*-*	Calibration Certificate Number:	*-*		
Note:-					

Initial:	*SC*	Date:	*01/05/2021*

4. SET UP					
Battery Make:	*Duracell*	Battery Type:	*Alkaline*	New Battery:	*Yes*
Battery Voltage:	*1.6*	CMOS Voltage:	*NA*	Calculated battery life (days):	*30*
Sampling Mode:	*Burst*	Sampling Rate (Hz):	*1*	Data Averaging:	*NA*
Sampling Interval (Minutes):	*10*	Samples per Burst:	*60*	Data Average Mode:	*NA*
Time Synchronised to PC:	*Yes*	Time Zone:	*UTC*	Unit Setup:	*dbar*
Site Information:	*Mirfa*	Local Latitude:	*28*	Pressure Tare:	*Off*
Memory cleared:	*Yes*	Instrument Run:	*Yes*	Self-Recording Selected:	*Yes*

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

Housing sealed and clamped:	*Yes*	**WLR Secured to Frame:**	*Yes*	**Sensor Height Above Base (m):**	*0.2*
Anchor Weight (Kg):	*60*	**Length Of Weighted Rope (m):**	*40*	**Rope Canister on Frame:**	*No*
Note:-					
Initial:	*SC*		**Date:**	*01/05/2021*	

5. DEPLOYMENT

Date and Time Plugged (GMT):	*01/05/2021 05:57*	**LED Flash Checked:**	*NA*	**2nd Cycle of Flashes Observed:**	*NA*
Time Frame on Seabed (GMT):	*1/05/2021 07:25*	**Frame LRT Status:**	*Ok*	**Water Depth (m):**	*19*
Time Weight on Seabed (GMT):	*1/05/2021 07:26*	**Weight LRT Status:**	*OK*		
Note:-					
Initial:	*SC*		**Date:**	*1/05/2021*	

6. RECOVERY

Date and Time Recovery Commenced (GMT):	*02/06/2021 05:40*	**Date and Time Recovery Complete (GMT):**	*02/06/2021 05:52*
Date and time Plug disconnected (GMT):	*02/06/2021 08:40*	**Clock error:**	*No*
Data recovered:	*Yes*	**Data File Name:**	*WLR-R.000*
Data Translated in Dbar:	*Yes*	**Data File size:**	*236 KB*
Data backed up:	*Yes*	**Data Inspected and Satisfactory:**	*Yes*
Check overall physical condition:	*Good*	**Clean to remove any biofouling:**	*Yes*
Note:-			
Initial:	*SC*	**Date:**	*02/06/2021*

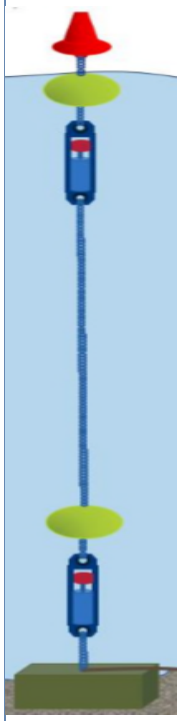
DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

U-Mooring Log Sheet

1. IDENTIFICATION (Essential reference to mooring log sheet with deployment details)							
Job No.:	*OMU041*	**Job Name:**	*Metocean*	**Mooring Stn. Name:**	*RCM-R*	**Phase:**	*1*

2. MOORING			
Target Latitude / Northing (m):	*2 673 463.9*	**Target Longitude/ Easting (m):**	*744 498.4*



Instrument	Serial No.	Height Above Seabed	Buoyancy (kg)	Deployed Latitude/ Northing	Deployed Longitude/ Easting	Deployed Date & Time (GMT)	Depth (m)
Buoy	-	-	*+30*	-	-	-	-
Sub Buoy	-	*3*	*+20*	-	-	-	-
RCM-top	*724*	*2.5*	*-10*	-	-	-	-
Sub Buoy	-	*1.5*	*+20*	-	-	-	-
RCM-bottom	*1011*	*1*	*-10*	-	-	-	-
Weight	-	*0*	*-60*	*24°09'14.34 "N*	*053°24'19.91" E*	*03/05/2021 05:20*	*5*

Date:	*03/05/2021*	**Initials**	*SC*

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

3. RECOVERY			
Date and time recovery (GMT):	*03/06/2021 06:25*	**Initials:**	*SC*
4. STORAGE			
Cleaned Frame	☒		
Cleaned Buoys	☒		
Removed marine Growth	☒		
5. Signature	*SC*		

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

Aanderaa Seaguard

1. IDENTIFICATION (Essential reference to mooring log sheet with deployment details)							
Job No.:	*OMU041*	**Job Name:**	*Metocean*	**Mooring Stn. Name:**	*RCM-P Bottom*	**Phase**	*1*

2. INSTRUMENT SPECIFICATION			
Instrument S/N:	*1011*	**Sensors:**	☒ Current ☒ Temperature ☒ Conductivity ☒ Pressure ☐ Turbidity ☐ DO ☐ Other

3. SET UP					
Sample mode set to:	☐Burst ☒Fixed	**DCS ping No:**	*300*	**New Batteries fitted:**	☒ Yes ☐ No
Sample interval (minutes):	*10*	**Sound speed:**	*1525*	**Battery Type:**	☒ Alkaline ☐ Lithium
Time set:	☒ GMT ☐ Local	**SD card Size:**	*2 GB*	**Battery Voltage:**	*9v*
Depth Rating (m):	*1000*	**Memory cleared:**	☒ Yes ☐ No	**Predicted Battery days:**	*160 days*

4. DEPLOYMENT					
All Required Channel selected	*Yes*	Deployment Note:			
O Ring checked and greased:	*Yes*				
Start Date & Time in GMT:	*30/04/2021 07:20*				
Instrument sealed and Clamped:	*Yes*				
In water Date & Time in GMT:	*03/05/2021 05:20*				
Depth at location (m):	*5*	**Initials:**	*SC*	**Date:**	*03/05/2021*

5. RECOVERY					
Date and time of recovery in GMT:	*03/06/2021 06:25*	**Data Recovered:**	*Yes*	**Initials:**	*SC*
Date and time of stop recording in GMT:	*03/06/2021 09:40*	**Data Checked:**	*Yes*		
Instrument Switched off:	*03/06/2021 09:40*	**Data Backup**	*Yes*	**Date:**	*03/06/2021*

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

Aanderaa Seaguard

1. IDENTIFICATION (Essential reference to mooring log sheet with deployment details)							
Job No.:	*OMU041*	**Job Name:**	*Metocean*	**Mooring Stn. Name:**	*RCM-R top*	**Phase**	*1*

2. INSTRUMENT SPECIFICATION			
Instrument S/N:	*724*	**Sensors:**	☒ Current ☒ Temperature ☒ Conductivity ☒ Pressure ☐ Turbidity ☐ DO ☐ Other

3. SET UP					
Sample mode set to:	☐Burst ☒Fixed	**DCS ping No:**	*300*	**New Batteries fitted:**	☒ Yes ☐ No
Sample interval (minutes):	*10*	**Sound speed:**	*1525*	**Battery Type:**	☒ Alkaline ☐ Lithium
Time set:	☒ GMT ☐ Local	**SD card Size:**	*2 GB*	**Battery Voltage:**	*9v*
Depth Rating (m):	*1000*	**Memory cleared:**	☒ Yes ☐ No	**Predicted Battery days:**	*160 days*

4. DEPLOYMENT					
All Required Channel selected	*Yes*	Deployment Note:			
O Ring checked and greased:	*Yes*				
Start Date & Time in GMT:	*30/04/2021 07:30*				
Instrument sealed and Clamped:	*Yes*				
In water Date & Time in GMT:	*03/05/2021 05:20*				
Depth at location (m):	*5*	**Initials:**	*SC*	**Date:**	*03/05/2021*

5. RECOVERY					
Date and time of recovery in GMT:	*03/06/2021 06:25*	**Data Recovered:**	*Yes*	**Initials:**	*SC*
Date and time of stop recording in GMT:	*03/06/2021 07:40*	**Data Checked:**	*Yes*		
Instrument Switched off:	*03/06/2021 07:40*	**Data Backup**	*Yes*	**Date:**	*03/06/2021*

DRAFT

This document is uncontrolled once printed or downloaded and may not reflect the latest version.

FUGRO