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Draft

TABEER ENERGY (PRIVATE) LIMITED
HSSE MANAGEMENT SYSTEM

OUTLINE

1. PURPOSE

Tabeer Energy (Private) Limited (the "Company" or "TEPL") has the Vision to become a safe and reliable provider of Regasfied Liquefied Natural Gas - RLNG. The TEPL Commitment and Policy on Health, Safety, Security, the Environment and social Performance ("HSSE") is designed to help protect people and the environment in accordance with:

i. The prevailing laws and regulations, in particular the Government Regulation regarding Management System of Work Safety, Health, Security and
ii. Internal Policies - The HSSE Management System specifically describes how TEPL will achieve the HSSE component of its vision and mission.

The HSSE Management System is developed with the purpose and objectives to protect people and the environment and system at the working place, by involving elements from the management, workers, work environment and condition which are integrated to prevent and decrease work accident and disease, as well as to create a productive, efficient and safe work place.

To achieve the above objective and purposes, the Company shall implement the following:

i. To specifically communicate that the processes, plans, programs and TEPL's management systems will implement to achieve a world-class HSSE performance.
ii. The HSSE Management System defines the steps to be implemented and maintained by TEPL management in support of the high standards identified in its mission statement.
iii. This Management System becomes effective starting after this document approved. HSSE Department is responsible for periodic reviews of this Policy and to recommend corrections, changes, or additions to this Policy to the Board of Directors.
iv. The HSSE Department, in concert with the other Directorates, will provide programs, plans, and procedures to implement an effective HSSE Management System consistent with the HSSE Policy.
v. The TEPL HSSE Management System defines the programs, manuals, guidelines, and practices necessary to assure the HSSE Policy is successfully implemented.

2. SCOPE

2.1. In Scope

This Regulation applies to: The entire working area of Company, Head Office in Karachi and TEPL Site (Jetty, Pipeline and Onshore Receiving Facility -ORF). FSRU & Contractor security post outside the fence are excluded.

2.2. Out of Scope

Outside areas that are not under the control and responsibility of the Company.

3. References

3.1. Internal References

Document Type	Document Number	Document Title
Policy	HSSE-XXX (Draft)	Quality, Health, Safety, Security an Environment (HSSE) Policy

3.2. External Reference

Document Type	Document Number	Document Title
Rule	HSSE - XXXX	Occupational Health and Safe System

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4. DEFINITION

Term	Definition
Company:	Tabeer Energy (Private) Limited RLNG (TEPL). In this document, Company" and "TEPL" may be used interchangeably.
Internal Policies:	Code of Conduct, Company Regulation, Employment Agreement and/or Seconded Employee Agreement (as relevant) and other applicable policies.
RLNG:	Is Liquefied Natural Gas that has been warmed up from about -160 degrees to about +12 degree C
Risk Assessment:	Is a system to identify potential hazards and liabilities, to assess, to evaluate, to mitigate risks to acceptable level of risk.
Safety:	Is the control of recognized hazards to achieve an acceptable level of risk
Incident:	Is an undesired event that results in harm to people, damage to property or loss to process and reputation
Near Miss:	Is an undesired event which under slightly different circumstances could have resulted in harm to people, damage to property or loss to process and reputation
Permit To Work:	Is a system to incorporate checks and authorizations consistent with operational risks.
PPE (Personal Protective Equipment):	Is protective gears designed to protect the wearer's body from injury when doing the specific task.
Management of Change:	Is a system to manage both temporary and permanent changes to operations or business
Incident Investigation:	Is a methodical examination to define facts and to determine causes of incident in order to prevent similar incident in the future
Stakeholders:	Is a party that can affect or be affected by the actions of the business as a whole.
Acceptable Level of Risk (ALARP):	Is an agreed level of risks decided by senior management within an organization/company.

Process Safety Management:	Is an analytical tool focused on preventing releases of any substance defined as a "highly hazardous chemical" by the EPA or OSHA. Process Safety Management (PSM) refers to a set of interrelated approaches to managing hazards associated with the process industries and is intended to reduce the frequency and severity of incidents resulting from releases of chemicals and other energy sources.

5. Regulation Section

5.1. Policy

Commitment:

TEPL RLNG is committed to conducting business in a manner that protects the safety and health of personnel, its contractors, its customers, and the public in its operations. We are an RLNG company that operates with social and environmental consciousness. We act with honesty, respect, responsibility and commitment while performing our duties. Furthermore, we are committed to conducting business in a manner that is compatible with the balanced environmental and economic needs of the communities in which we operate. (needs to match HSSE Policy Statement which is being prepared)

These values require facilities to be designed, constructed and operated to accept standards in compliance with all applicable laws and regulations, in particular for Government Law No. XXXX and other HSSE regulations. This HSSE Management System (HSSE-MS) is the framework we use to provide the necessary systematic approach to meeting our commitments.

HSSE Management System

This Management System consists of 10 (ten) Elements and 53 Expectations. The Elements define the strategic areas addressed by the System. The Elements are:

Element 1. Leadership & Culture
Element 2. Personnel & Training
Element 3. Contractors
Element 4. Risk Management
Element 5. New Projects & Modifications
Element 6. Operations
Element 7. Management of Change

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Element 8. Incident Investigation

Element 9. Crisis & Continuity Management

Element 10. Assessment

Each Element has a number of expectations associated with it. This Management System will be periodically reviewed in consultation with other Directorates and modified as necessary by HSSE department of the Company.

5.1.1. Element 1. Leadership & Culture

Management provides the vision, sets the expectations and provides the resources for implementation of this HSSE-MS. Successful implementation requires understanding, active involvement, and commitment by all personnel.

Expectations:

1.1. Management ensures the implementation of the HSSE-MS and establishes the scope, objectives, priority and pace for implementation.

1.2. Active and visible participation by management ensures the Management System is supported and maintained throughout the organization.

1.3. Management establishes and tracks achievement of key HSSE performance goals and objectives to assure the ongoing integrity of the operations.

1.4. Management fosters a positive HSSE culture which supports and encourages open dialogue about behaviors, incidents, concerns and non-compliances.

1.5. All personnel are actively involved in the development, implementation and functioning of the HSSE -MS.

1.6. All personnel are responsible and accountable for the integrity of the operations as it pertains to themselves and their work environment.

Who's involved:

- TEPL Managing Director and all BoDs
- Project / Plant Manager
- All line managers and supervisors

Key Process:

- Management Walk-thru
- HSSE Meetings
- Incident Reporting System

- Personal Performance Contract
- Safety Consultative Forum
- Toolbox Meeting / Pre-Job Safety Meeting
- HSSE Performance Indicator
- Digital Action Tracking System
- Lessons Learned
- Risk Assessments
- Risk Register and Profile
- HSSE Promotional Campaigns
- HSSE Inspection

Must Have:

- ALL personnel including managers, supervisors and contractors are to be involved in HSSE meetings
- All managers and supervisor should perform HSSE Mgt Walk-thru
- Managing Director/Director to visit sites on regular basis and actively involved the workforce in the visit
- Clearly define goals and individual roles and responsibilities

5.1.2. Element 2: Personnel and Training

TEPL believes that all incidents are preventable. Our personnel hold the key to prevention because most incidents are a result of unsafe action of individuals. Careful selection, placement, training, development and assessment of personnel are necessary for achieving our HSSE expectations.

Expectations:

2.1. A system is in place to observe the behaviors of personnel and implement measures to encourage behaviors that promote achievement of HSSE expectations.

2.2. An employee training system is in place to ensure competence, maintenance of necessary job skills and compliance with regulatory requirements.

2.3. Employee selection and placement processes consider HSSE performance and necessary job skills and knowledge.

2.4. Employees receive feedback on their HSSE performance

Who's involved:

- HR manager and teams

- Plant manager / Project Manager
- All management and employee

Key Process:

- Key performance indicator
- Training provider
- HSSE training programs/matrix
- Selection process
- Competency assessment
- Operator training simulator
- Health surveillance
- Permit To Work training
- Hazard reporting system
- Incident investigation & reporting training
- Process safety management training
- Emergency response training
- Emergency fire training
- Crisis management training
- Occupational health assessment
- Alcohol & drugs policy
- Task risk assessment
- Job descriptions
- Succession planning

Must have:

- Supervisors to be trained in competency assessment
- Training programme development and implementation for TEPL and contractor
- Feedback of performance to all employees

5.1.3. Element 3: Contractors

Contractors and other third parties provide materials and services on behalf of TEPL and have an effect on TEPL operations. It is essential that these services be monitored and held to standards consistent with TEPL policies and objectives.

Expectations:

3.1. A system is in place for evaluation, selection and on-going assessment of critical material vendors and service contractors that includes an assessment of their capabilities to perform services or provide materials in accordance with HSSE requirements.

3.2. A system is in place to periodically assess performance of critical material vendors and service contractors. Performance feedback is provided to these contractors to promote continuous improvement.

3.3. Roles, responsibilities, and performance criteria (including HSSE) are defined, understood and agreed upon by the Company and the contractors and are addressed in the contract.

Who's involved:

- Managing Director and all BoDs
- Tender Board Committee
- Plant Manager / Project Manager
- Supply Chain Manager
- HSSE Manager
- All supervisors

Key Process:

- Contractor Management Process
- Contractor Kick-off Meetings
- Procurement Procedures
- Contractor Competency Assurance
- Contract Interface Documentation
- Contractor HSSE Plans
- Contractor HSSE Performance Review
- Quality Control Procedure
- Equipment Specifications
- Stakeholder Engagement Process

Must have:

- CSMS or equivalent implementation
- Approved Vendor List
- Approved equipment & contractor personnel qualification
- Experience and competent contractors

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5.1.4. Element 4: Risk Management

Comprehensive risk management reduces operating hazards and the potential for quality, health, safety and environmental incidents and liabilities. Hazard identification and risk mitigation is a key component of all activities to make certain that risks to personnel, the public, to quality, or the environment are effectively controlled within TEPL's tolerance for risk.

Expectations:

4.1. A system is in place to identify potential hazards and liabilities, to assess risk, to evaluate prevention and mitigation measures, and to ensure that control techniques are implemented for the ongoing management of risk for TEPL activities.

4.2. A system is in place that provides a comprehensive approach to manage personnel exposures in the workplace and provides for communication of those exposures to affected personnel.

4.3. Risk mitigation techniques are considered according to the following priority:

a. Elimination
b. Substitution
c. Engineering
d. Administrative controls;
e. Personal Protective Equipment (PPE)

Who's involved:

- Managing Director and BoD
- Plant Manager / Project Manager
- Asset Integrity asset Management
- Operation/Maintenance Manager
- Employees
- HSSE Manager

Key Process:

- Risk Assessment Matrix
- Safety Case / Major Accident Risk
- Safety Critical Elements
- Risk Register and Risk Profile
- Permit To Work System
- Risk Assessment Tier 1 & Tier 2
- Quantified Risk Assessment
- Environment Impact Analysis

- Environmental Aspect Impact
- Health Risk Assessments
- HAZOP / HAZID
- Risk Based Inspection (RBI)
- Management of Change (MoC)
- HSSE Regulation, Other Requirements and Evaluation of Compliance
- Environmental & Industrial Hygiene Monitoring

Must have:

- Competent persons to carry out Risk Assessments
- QRA Study
- Environmental Bank Data
- Risk Based Inspection Models
- Commitment to reduce risk to ALARP (As Low As Reasonable Practicable)

5.1.5. <u>Element 5: New Projects & Modifications</u>

Use of accepted standards, procedures and specifications for facility design, construction and startup activities is essential for achieving HSSE Expectations.

Expectations:

5.1. A system is in place for managing design and construction activities in compliance with regulatory, legal, operating company and permit requirements.

5.2. Risk assessments are conducted at specified project stages.

5.3. Where regulations do not exist, the system incorporates use of practices, standards and specifications which embody responsible design, construction and operational practices.

5.4. Deviation from approved design, design criteria, standards or specifications are reviewed and approved by a designated authority.

5.5. Pollution prevention, waste minimization, and energy conservation are addressed in the design.

5.6. The design of each installation considers eventual abandonment.

5.7. Quality control and inspection ensure that facilities are designed and constructed in accordance with agreed design criteria.

5.8. Long-term operability and maintainability are incorporated into the design.

5.9. An appropriate pre-start up review is performed.

Who's involved:

- Process Engineer / Manager

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- Plant Manager / Project Manager
- Asset Integrity Management Specialist
- Operation Manager
- Maintenance Manager

Key process:

- Project Management System
- Environmental Aspect Impact Assessment
- QRA, Risk profile, Risk Register
- Management of Change
- Document Control
- Commissioning Standards
- Procurement Procedures
- HAZOPs
- HSSE Plan
- QA/QC Procedures
- Design criteria
- Engineering Procedures

Must have:

- All changes are screened for risk and reflected in the basis of design for all facilities
- Modification to software and hardware of the existing RLNG Plant must be controlled.
- Process Safety Management Plan

5.1.6. Element 6: Operations

Operation within established parameters is essential to achieving the values of TEPL. This requires operating, inspection, and maintenance procedures, and information on the processes, facilities, and materials handled.

Expectations:

6.1. System is in place that provides procedures necessary for operations, simultaneous operations, maintenance, and equipment integrity; and provides for updating those procedures at specified intervals.

6.2. Permit to work system is in place that incorporates checks and authorizations consistent with operational risks.

6.3. A system is in place to ensure critical shutdown systems, critical relief equipment, and critical process control-systems are tested and undergo necessary preventative maintenance.

6.4. A system is in place that assures environmental requirements are met. Pollution control measures are tested and undergo regular testing and necessary preventative maintenance.

6.5. A system is in place to ensure that documentation and drawings deemed necessary for operation and maintenance of facilities are accessible and current.

6.6. A system is in place for managing operations in compliance with regulatory, legal, lender and permit requirements.

6.7. A plan is in place to provide for proper abandonment or de-commissioning of facilities.

6.8. Pollution prevention, waste minimization, and energy conservation are addressed in the operations. Disposal of waste material takes place only at approved sites.

6.9. Repair and replacement-in-kind will consider the quality and integrity of materials and installation techniques.

6.10. A system is in place to assure the products of the plant meet customer specifications.

Who's involved:

- Plant / Project Manager
- Operation Manager
- Maintenance Manager
- All department managers
- All Maintenance technicians
- Inspection contractors
- Asset Integrity Management
- Field Operators

Key process:

- Pre-startup & Post startup review
- Register of protective devices
- Site Operating & Maintenance Procedures
- Procedures for abnormal condition
- Reliability Based Maintenance Standard
- PTW System
- Over-ride Procedures
- Condition Monitoring

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- Safety critical equipment inspection
- Design criteria
- Commissioning standards/procedures
- Shift handover procedure
- Isolation procedures
- Operating envelops
- SIMOPs procedures
- Process Safety Management Plan

Must have:

- Labor competence and qualifications.
- All critical activities are controlled and planned with risk assessment.
- The period of shutdown performed for maintenance and testing activities.

5.1.7. Element 7: Management of Change

Hazards associated with changes in organization, operations, procedures, design criteria, facilities, regulatory or permit requirements are evaluated and managed.

Expectations:

7.1. A system is in place for the management of both temporary and permanent changes to operations, procedures, practices, design criteria, and facilities. Temporary changes have a specified time limitation.

7.2. Changes to laws, regulations, or permit requirements are identified and incorporated into policies, practices, procedures, documentation, training, design criteria, and operations as appropriate.

7.3. Organizational and personnel changes with significant implications are qualitatively evaluated for operational impacts.

Who's involved:

- Managing Director and BOD
- Plant Manager / Project Manager
- Operations Manager
- Maintenance Manager
- All department Managers
- Asset Integrity Management

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- Supply Chain Manager

Key process:

- MoC procedures
- Document control system
- Risk assessment reviews
- Risk Assessments
- QRA or Major Hazard Assessment
- Environmental Assessments
- Over-ride procedures
- HAZOP / HAZID
- Integrity Management Standard
- Action tracking system
- Project Peer Reviews
- As-built verification process

Must have:

- QRA, HAZOP & Current Risk Assessments
- Basis of design for all facilities
- Core legislations list
- Up-to-date documentation

5.1.8. Element 8: Incident Investigation

Effective reporting, investigation, and follow-up of incidents and near misses are necessary to achieve our mission.

Expectations:

8.1. A system is in place for timely reporting, investigating, analyzing, and follow-up of incidents and near misses.

8.2. Investigations identify root causes and contributing factors.

8.3. Action items arising from incident investigations are closed in a timely manner.

8.4. Analysis is employed to identify incident trends.

8.5. Lessons learned from incidents and near misses are communicated throughout the organization and to other applicable stakeholders.

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Who's involved:

- Plant Manager / Project Manager
- All Department Manager
- HSSE Manager
- All line supervisors
- All employees and contractor workers

Key process:

- Incident Reporting Process
- Lesson Learned
- Hazard & Near-Miss Reporting System
- Asset Integrity Management Standard
- Risk Assessment
- Action tracking system
- HSSE Performance Review
- Incident analysis and trend

Must have:

- A management trained in incident investigation & reporting process.
- All employees to be aware of reporting requirement.
- Employee involvement in reporting and investigation.
- Communication system for Lesson Learned.

5.1.9. Element 9: Crisis and Continuity Management

Planning and preparedness help ensure that in the event of an incident, effective action are taken for the protection of personnel, contractors, the public, the environment and stakeholder assets.

Expectations:

9.1. A system is in place for emergency preparedness. Emergency response plans are documented, accessible and clearly communicated.

9.2. Equipment, facilities, and trained personnel needed for emergency response, including mutual aid providers, are defined and readily available.

9.3. Community expectations, concerns, and potential impacts are identified and addressed.

9.4. Crisis management and media communications training is provided for designated emergency response personnel.

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9.5. Plans incorporate coordinating with government agencies, media, and the community (including neighboring facilities).

9.6. Business resumption plans are in place.

Who's involved:

- Managing Director and all BoDs
- Plant Manager / Project Manager
- HSSE Manager
- Emergency Response Team
- Media relation officer
- Operation Manager
- Community Relation Manager
- Process Engineer
- HR Manager
- Maintenance Manager
- Marine Superintendent

Key process:

- Emergency response training program
- Exercise and drill schedule
- Emergency response plans
- Competence assurance
- Medical contingency plan
- On-scene Commander Assessment
- Oil Spill Response Plan (OSRP)
- Safety critical equipment maintenance
- Action tracking system
- Emergency duty roster
- Security plan
- Business Continuity Plan (BCP)
- Pre Fire Plan

Must have:

- Emergency Response Team to be fully competent
- On-scene commanders to be fully competent in command and control
- Full range of risks identified

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- Employee fully involved in drill & exercises
- Call-out tree system
- Media/press statement
- Spill response equipment
- Emergency Crisis Center

5.1.10. Element 10: Assessment

A process which assesses performance relative to expectations is essential to improving performance.

Expectations:

10.1. A system is in place to periodically conduct assessments which determine the overall degree of conformance with expectations within the HSSE Management System. The Company shall use the result of such assessment as an audit report of MS-HSSE, if in the future the Company is required to submit a HSSE audit report to the authority as required by the prevailing laws in Pakistan.

10.2. The employee is actively involved in periodic self-assessments of the effectiveness of processes and procedures to meet the HSSE Expectations.

10.3. HSSE performance indicators (both leading and lagging) are established, communicated and understood throughout the organization.

10.4. The TEPL leadership team periodically reviews the HSSE management system to ensure it is continually delivering consistent, desired performance. Based on the review, new risk-based targets are considered and established as necessary to drive improvements.

Who's involved:

- Managing Director and BoD
- Plant Manager / Project Manager
- Operation Manager
- Maintenance Manager
- HSSE Manager
- Employees

Key process:

- ISO certification (Hold)
- Management Team meetings

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- Safety Consultative Forum
- Risk Assessment Tier-1 and Tier-2
- HSSE Performance Review
- Environmental Aspect and Impact Register
- Lessons Learned
- Contractor Safety Management System
- Action Tracking System

Must have:

- Periodic Performance Review
- Internal Auditor competency
- ISO team and ISO Champion (HOLD)

6. COMPLIANCE

Any actual or suspected breach of this Regulation and its overall complementary Regulations shall be reported to Compliance Committee, who will report to the Managing Director.

Failure to comply with this Regulation may result in disciplinary actions against the relevant Personnel. Any Personnel found not in compliance with this Regulation and its overall complementary Regulations will be subjected to sanctions as set forth in Code of Conduct (CoC) and Company Regulation.

Any exception to this Regulation shall require approval from Board of Director.

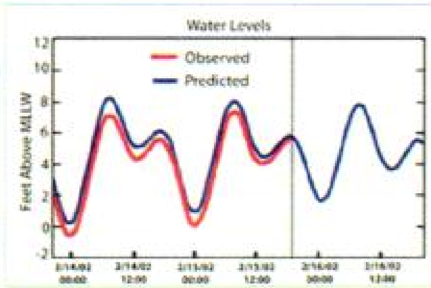
7. APPENDICES

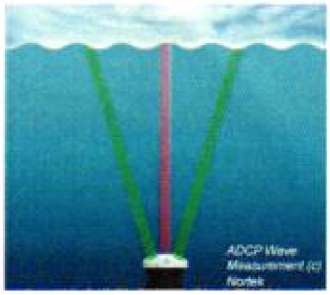
There is no appendix applicable to this Regulation.

TABEERENERGY

JGC Corporation

Pakistan FSRU Project Chann Waddo Creeck Port Qasim





Draft Final Metocean Data Collection Report
August 2018

Techno-Consult International (Pvt.) Ltd.

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CLIENT:	JGC Corporation, Japan
PROJECT:	**Pakistan FSRU Project Chan Waddo Creek Port Qasim**

		Signature	**Dated**
Prepared By TCI: (Project Manager)	W. Ahmed	________	________
Reviewed By TCI: (Project Director)	Saleem Ahmed	________	________
Approved by JGC Client: (FSRU Project Manager)	Keita Uchino	________	________
Approved by JGC PM:		________	________

Issue / Revision Index

Issue Code	Revision					Revision Details
	No.	By	Rev'd	App	Date	
RR	00	WA	SA	SA	03 Jul 2018	Commented by JGC 07 Aug 2018
RR	01	WA	SA	SA	16 Aug 2018	Re-Commented 28 Aug 2018
FV	02	WA	SA	SA	10 Sept 2018	

Issue Codes: RC =Released for Construction, RD = Released for Design, RF = Released for Fabrication, RI = Released for Information, RP = Released for Purchase, RQ = Released for Quotation, RR = Released for Review & Comments, FV= Released as Final Version.

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FSRU BASED LNG IMPORT TERMINAL IN CHANN WADDO CREEK AT PORT QASIM'S FIELD DATA COLLECTION REPORT

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1.0 INTRODUCTION

1.1 Project Description

Pakistan's growing energy needs requires reliable maritime infrastructure facilities for import of fuel in form of Oil and Gas. In this connection Tabeer Energy (Private) Limited as TEPL has taken on a commitment to provide additional maritime infrastructure at Port Qasim to facilitate the import of natural gas in form of LNG.

TEPL, an SPV created by Mitsubishi Corporation for the project, is actively engaged in sponsoring and developing an FSRU based LNG terminal at Port Qasim namely Tabeer LNG Project at Chann Waddo Creek. The Terminal is proposed to be constructed at Chann Waddo creek in close vicinity of the confluence of Chann Waddo, Rakkhal and Jharri Creeks close to the entrance to Port Qasim. Chann Waddo creek is located east of Phitti Creek.

Figure 1 showing Project Location Plan

An application for NOC has been applied and in consonance with PQA requirements certain essential investigations and Metocean studies are required to be undertaken. M/s JGC Corporation of Japan are appointed as engineers for Pre FEED work and M/S. Techno-Consult International (Pvt.) Ltd. (TCI) has been commissioned as consultants to carry out field studies and investigative works for the proposed LNG terminal.

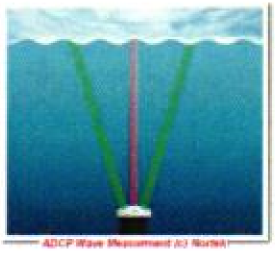
Tentatively, the terminal will be designed to host **one liquid bulk pier** suitable for Qmax type LNG Carriers. The berth will consist of Mooring and Breasting dolphins and a Jetty Head built on a suitable platform with pile foundations. The storage vessel FSRU will be permanently moored to the berth & the supply vessel (LNGC) will be moored alongside FSRU to carry out Ship to Ship transfer (STS). The supply line to the SSGC designated shore point will follow an alignment along the creek banks, delivering gas to on-shore installations for customer distribution.

In connection with hydraulic studies, M/s JGC Corporation of Japan commissioned Techno-Consult International (TCI) to undertake hydraulic and hydrodynamic measurements. Part of this includes the establishment of a local tidal datum based on 30 days of tidal data.

The project is located in the vicinity of Port Qasim at the confluence of Chann Waddo, Rakkhal, and Jharri Creek. It is bound by the Arabian sea at 24°43'09.85"N latitude and 67°12'50.40"E Longitude as shown in the figure.

1.2 Investigative Campaign

In support of Pre-FEED and FEED studies, Metocean survey for one month has been commissioned by JGC. This will also serve as a basic platform for the technical proposal, to be submitted to Port Qasim. This proposal will support the BOT concession application of TEPL.



ADCP Wave Measurement (c) Nortek

1.2.1 Site Description

The site is located in Chan Waddo Creek where the width varies between 400 to 500 m. This creek also presents with naturally deep waters (20-25 m) at select locations which are favorable for deep sea vessels. However, dredging may be required to maintain a smooth turning radius for large vessels.

Of particular importance at this location, is a deep swatch that exists at the confluence point. It appears that this swath impacts local tidal streams and current patterns. Hence, prior to the identification of a suitable berth location, hydrodynamics of the tidal flow at the terminal area must be established. By doing so, the challenges presented by site anomalies such as the swath can be overcome.

1.2.2 Outline Scope

A survey plan and specification were provided by JGC. After careful analysis and planning the field investigation campaign was initiated on 28th March 2018.

1.2.3 Metocean Data

The Metocean measurements specifications provided have been met. Essentially these are:

Table 1 showing: JGC Coded Work Items

1130	Oceanographic Survey		
1131	Tide	Day	30
1132	Current	Day	30
1133	Wave	Day	30
1134	Temperature	Day	30
1135	Wind	Day	30

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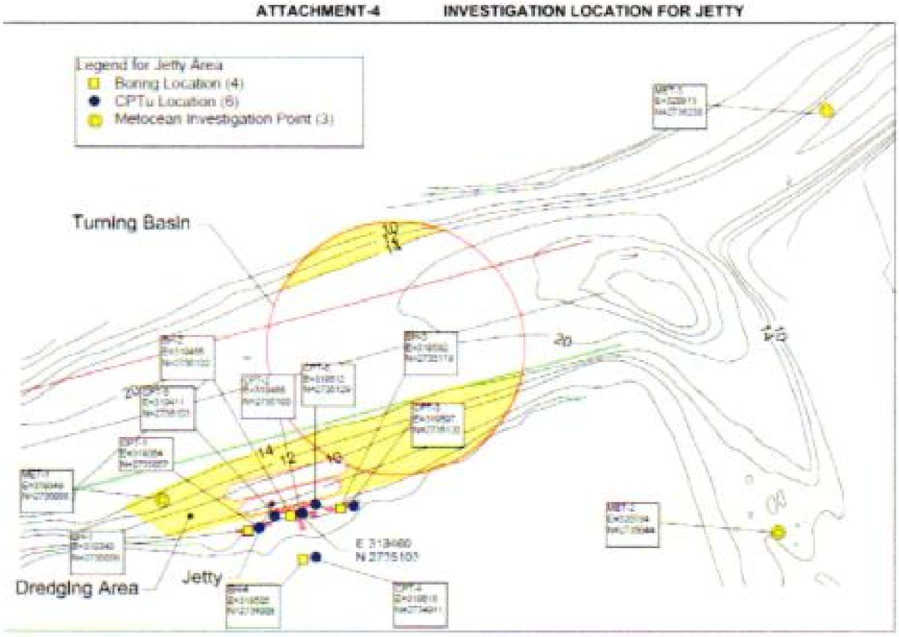

JGC

Figure 2 specified Location Measurements

2.0 SCOPE

The scope work is divided into the following components:

- Tidal Observations at one Location T5 (Lat 24°43' 29.88816", Long 067°12' 36.34831")
- Moored ADCP Current Measurements at 04 Locations MET-1, MET-2, MET-3 and MET-4
- Salinity, Temperature at 3 Locations MET-1, MET-2, and MET-3
- Sea Bed Sampling at 04 Locations from MET-1, MET-2, MET-3 and MET-4
- Sea Water Sampling 09 samples

Other Studies

In addition to the above, a UXO and Factual weather data study has also been scheduled. The report will be submitted upon receipt of data & information from relevant agencies.

Equipment Employed

TCI has employed equipment which fully meets the technical requirements given in the specifications for Metocean data collection

Water sample being preserved for lab testing

All marine survey equipment and survey boats are owned by TCI with the exception of a magnetometer there was no need to outsource the equipment for this campaign..

2.1 Salient Features of Marine Facility

Terminal

Tabeer Energy is SPV for implementation of LNG terminal. JGC Corporation of Japan is in process of Pre-FEED study for development Terminal for imported LNG regasification project. This project consists of an FSRU based terminal at the Chan Waddo Creek site, taking an easterly route to Port Muhammad Bin Qasim (Port Qasim). After having reached Port Qasim, the regasified liquid natural gas (RLNG) will make its way into the existing pipeline grid at the SSGC connection to reach end users.

The proposed location for the LNG Terminal is at the confluence of Chann Waddo, Rakkhal & Jharri Creek. It leads into Port Qasim following a 16 kilometer easterly route on which twin Tenaga class storage vessels will be permanently moored at the jetty. The storage will be supplied by conventional LNG carriers (QFlex and QMax type).

Main Jetty:

- Open Piled structure
- Working platform fitted with loading arms
- Control room
- Security room
- Twin berthing dolphins
- Three mooring dolphins on each side
- Quick release capstans
- Heavy duty fenders
- Firefighting equipment
- Electric generators
- Re gasification facility on platform or floating utilizing Air Vaporizer Banks technology

2.1.1 Pipeline Connection to Shore

A route for pipeline has been identified which is also in the process of being surveyed. This will serve as FSRU HP transfer system to the Tabeer Energy / SSGC connecting point on shore. The route has been adapted after careful consideration of technical feasibility, pipe length, mangrove impact, constructability and cost considerations.

3.0 RESOURCE MANAGEMENT & HSE CONSIDERATIONS

Immediately after the project was awarded, a cell was setup to carry out the metocean data collection tasks and responsibility as mentioned in the scope of work, keeping in view the HSE requirement.

Dual diver operation with supervisor meeting HSE protocols

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The project preparation required scheduling, mobilization and resource allocation. A variety of technical bottlenecks were also taken into consideration. The equipment to be deployed was isolated and put on diagnostic tests as a pre-requisite. New batteries for the Instruments were ordered from the manufacturer as they have a shelf life. Extra care was taken against loss/theft of equipment by installing audible pingers. Stainless steel cages (non magnetic) with anchors were deployed in the form of a star topology to restrict the movement of ADCP's due to excessive currents and debris and unwaranted fisherman with dragnets.

Pinger for location of ADCP

All personnel related to field activities were under strict instructions to comply with life safety regulation. TCI divers and diving equipment are all certified and upto the standards. The diving equipment is also upgarded with audio signling capability for voice communication.

4.0 PROJECT CELL

4.1 Project Manpower and Equipment Resources

The manpower for the project has been allocated accoridng to the individual skills and the tehcnicality involved in the project. The team is fully compliant with HSE requirements along with certification as per job responsibility.

The member of the project cell along with their designation and responsibility are as follows:

Table 2 showing: List of Project Manpower

S.No	Name of Person	Designation	Project Responsibility
1	Waseem Ahmed	Vice President	Monitor Overall Project & Administrative Control
2	Jawaduddin Athar Chughtai	Survey Manager	Survey Planning/Data Analysis and Reporting
3	Cdr (r) Arif Hussain	Hydrographic Surveyor	Field Survey Coordination and Operations
4	Tasleem Ahmed	Chief Surveyor	Responsible for land Operation
5	Khursheed Hussain	Senior Surveyor	Responsible for sea Operation
6	Abdul Waheeed	Instrument Technician	Configure & data retrieval from equipment
7	M. Javed	Diving Chief	Diving team leader for underwater activities
8	A. Razaq	Diver	Main Diver for cage deployment
9	Wali ur Rehman	Diver	Assistant Diver as per HSE requirement
10	Khalid Ahmed	Data Processer	CAD Manager
11	Syed Anil	Data Processer	Desktop publisher
12	M. Irfan	Boat Driver	Boat Driver for Breakwater
13	Sualah Mohammed	Driver	Assistant Boat Driver for Breakwater
14	Abdul Waheed	Driver	
15	Munawar Ahmed	Driver	

Table 3 showing: List of Equipment Resources Deployed for Field data Collection

S.No	Resources	Units
1	RDI Sentinel 600 Workhorse ADCP (First batch - 30 days)	04
2	RDI Sentinnel V50's (second batch – 29 days)	04
3	Audible pingers	04
4	Hydrophone	One
5	Stainless Steel Cages for ADCP Deployment (Non Magnetic)	04
7	Ponar Grab sampler	One
8	Underwater Digital Camera for Photography and Videography	One
9	Survey Boat (M 1025)30ft out going, equipped with Navigational aids	One
10	Waterproof Laptop for field operations	One
10	Guard Boat for Deployed ADCPs	03
11	4x4 Hilux Vehicle	Two
12	Suzuki Van	One
13	Handheld GPS	One

5.0 FIELD ACTIVITIES

5.1 Work Permit

First and foremost, official permission had to be obtained from Port Qasim Authority to commence survey works. Swift mobilization and completion of Metocean data collection activities is very important. TCI is fully aware of work permits and permission requirements for working in Port Qasim waters. We have carried out more than two dozen such assignments in Port Qasim alone. As such based on reference letters from Mitsubishi Co and remaining follow-up in obtaining permission, we obtained formal permission from PQA in time for our field teams. No delay in work schedule was incurred due to this lead item.

5.2 Reconnaissance

Reconnaissance survey was carried out by TCI Senior Surveyor and marine expert prior to mobilizing on the field. Key issues pertaining to data observation, data integrity and safety was considered and accordingly the activity was planned. The coordinates system for carrying out survey activates is as follows: WGS 84 spheroid, UTM grid Zone 42N.

GPS Position being verified for [illegible]

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5.2.1 Bench Marks

The proposed LNG terminal site is located along southern portion of Chann Waddo Creek which is predominantly made up of tidal plains as this creek forms part of the Indus Delta system. The terminal site area is mostly un-developed, bound by tidal mudflats. Subsequent topographic surveys revealed that there is hardly any ground patch which remains dry at all times. The areas abounding the terminal site were found to be inundated particularly during high waters which leaves the ground soft and muddy. Given the greenfield nature of this site, availability of bench marks with a datum value inscribed on it was found to be unlikely. Upon initial reccies, no benchmark of either PQA or any other project sponsor, could be located. As such, one of the main components of establishing a bench mark is to create a Permanent Reference Monument (PRM's). Two number piles were driven in ground to create these bench marks. Later in the survey campaign, accurate GPS readings were taken at these points and coupled with tidal analysis to establish the local chart datum at these PRM's. These two PRM's could be used in future for geometrical layout of the terminal which in this case would be the new Tabeer Energy LNG terminal.

The established Bench marks will play a pivotal role in terminal layout and would serve as a firm and fixed platform representing the local tidal datum.

The tidal datum computed after performing harmonic analysis on 79 days of observed tidal data were then transferred to these two points as depicted in Figure 12.

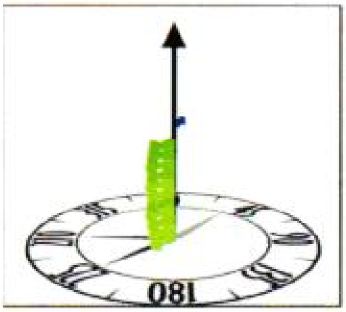
The horizontal value of these benchmarks were also tied to the existing geodetic control of PQA though precision GPS observations.

The locations of Metocean equipment deployed were computed in the same grid system which is in use by Port Qasim Hydrographic Department i.e., WGS-84 and UTM local grids.

5.2.2 Objective of Metocean Investigations

A basic understanding of marine and coastal hydrodynamics is an important component in coastal and offshore planning and design. Hydro-met conditions also becomes an integral part to be examined. Perhaps the most important meteorological consideration relates to the dominant role of winds in wave generation. However, many other meteorological processes (e.g., direct wind forces on structures, precipitation, wind-driven coastal currents and surges) cannot be ignored.

Knowledge of waves and currents and the forces they generate is essential for the design of coastal structures since they are the major factor that govern the design criteria. These environmental forces also affect geometry of beaches, the planning and design of permanent marine works, waterways, shore protection measures, hydraulic structures, and other civil and coastal works. Estimates of wave conditions are needed in almost all coastal engineering studies.



Ocean currents can be classified in a number of different ways. Some important types include the following:

Periodic - due to the effect of the tides; such Currents may be rotating rather than having a simple back and forth motion. The currents accompanying tides are known as tidal currents;

Temporary - due to seasonal winds;

Permanent or ocean - constitute a part of the general ocean circulation. The term DRIFT CURRENT is often applied to a slow broad movement of the oceanic water;

Nearshore - caused principally by waves breaking along a shore.

Nearshore current system caused primarily by wave action in and near the breaker zone, and which consists of four parts: the shoreward mass transport of water; longshore currents; seaward return flow, including rip currents; and the longshore movement of the expanding heads of rip currents. Coastal Currents are one of the offshore currents flowing generally parallel to the shoreline in the deeper water beyond and near the surf zone; these are not related genetically to waves and resulting surf, but may be related to tides, winds, or distribution of mass.

Tidal Currents are alternating horizontal movement of water associated with the rise and fall of the tide caused by the astronomical tide-producing forces.

Flood Currents are tidal current toward shore or up a tidal stream. Usually associated with the amplification in the height of the tide

Ebb Currents are tidal currents away from the shore or down a tidal stream. Usually associated with the decrease in the height of the tide.

Studying waves and current information integrally will help understand the wave and current interaction processes going on at the deployed site. In nearshore, depending on the state of tide, the wave induced currents are a common phenomenon which need to be isolated from tidal currents. These analyses have significance in assessing sediment transport mechanisms.

Consequently, transformation studies require careful analysis. They are but one part of selecting project design criteria.

In this report we have the stratified current observations made at the same location as the waves were observed.

6.0 TIDAL OBSERVATION CAMPAIGN

6.1 Tidal Observations at Location Tango-5

6.1.1 General

Sutronics USA GSPRS Modem for Telemetric Data Transfer

Tide observation at station Tango-5 was carried out for 41 days. Digital recording and telemetric data transmission via GSPRS modem was used to obtain near real time data.

Data was quality checked and later used in Harmonic Analysis.

6.1.2 Scope and specification of survey

Measurements at Tango-5 tide gauge

The scope and specification of tidal data was essentially to collect tidal heights at 10-minute intervals at a suitable location away from open sea environment and preferably close to the location of the proposed LNG terminal.

- 41 days tidal observations using digital tidal gauge. Actually enhanced time series of 79 days was finally employed in tidal analysis.
- Tidal Time series data collection, leveling, Installation & setup tide gauge with drilled-in attachments, recording tidal heights at 10 min. intervals and periodic inspection of tide gauge '0' level, vent tubes and downloading of data from the level gauge as allowed by sea.
- Q/C on acquired Tidal data, Tidal Time series data preparation for Harmonic Analysis & determination of tidal constituents, plotting of tidal values and determination of tidal constituents using harmonic analysis.
- Based on 79 days' data, Tidal Prediction for 19 years i.e. one epoch, mean high, low and HAT / LAT and chart datum calculations (requested by Client but not complying per international standards)
- Transfer of datum from tide gauge '0' to nearest Bench Mark for later use by client. This be in form of interim Vertical Datum Bench Mark (not recommended to be used in construction works until full year data analysis is made)
- Deliverables: Tide Time series plotted on graph paper, Input data and results from harmonic analysis software, Tide Prediction for 19 years (entire epoch), Computed datum value duly transferred on Bench Mark.

6.1.3 Tide/Water Level Observation

It is recommended that at least one year long tidal observations be made at or near the proposed LNG terminal site and local tidal datum and associated water levels such as MSL, MHHW, MLLW, HAT, LAT be recomputed by repeating the harmonic analysis. During the Metocean campaign, the electronic tide gauge by Valeport (UK) was deployed at Tango-5 station to collect the water level and for computation of local tidal datum. The tidal heights were averaged across a 10 minutes interval.

The tide is a periodical movement in the level of the surface of the sea or ocean, due to the gravitational attraction between the Earth, Moon and Sun.

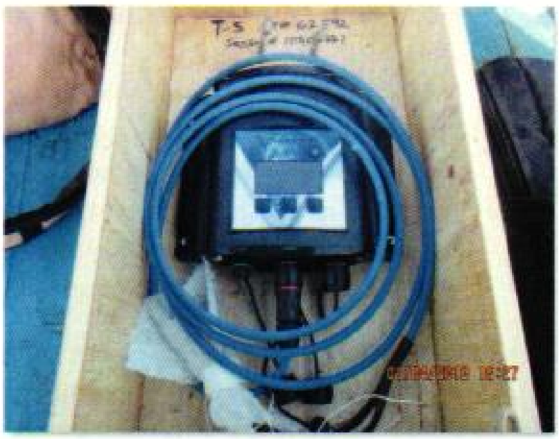
Tidal observation has been carried out during entire investigation period at location as indicated on the figure.

Figure 3 Showing tidal observation locations

6.1.4 Tide/water level observation (short term)

The location has been set in a manner that tide water level is clear and already attenuated with noise observed in tidal data within the near shore zone.

This digital tidal gauge which are either vented and non-ventedtype broadcast tidal times and heights by GSM modem to shore stations for data Q/C check before transmitting to JGC. Tidal harmonic analysis was performed after minimum 41 days of extracting basic tidal constituents. As more data came in, this analysis was repeated as the remaining tidal constituents mature over a given time period. This improves the accuracy of the MSL and tidal local chart datum which is a must requirement for the terminal development and layout. At present there is no tidal datum available at the Chan Waddo location.



The tide at the entrance and 50 km inshore has a time delay of 20+ minutes. This means that when High water occurs at entrance it takes 20 minutes to occur inshore at Phitti Creek. Similarly, the tide occurring near triangular area close to Bundal Island at Port Qasim Phitti creek entrance arrives slightly later at the Chan Waddo site. From the total set of tidal constituents derived from observed data, a certain set of constituents were used in determination of the Chart Datum (CD) value. This CD value was subsequently transferred to the set of Permanent Reference Monuments (PRM) constructed near the proposed terminal site.

Table 4 showing: Location of Tide Gauge T5

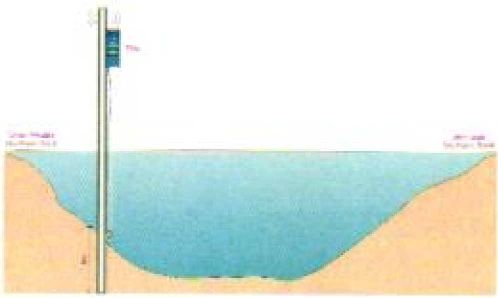
Description	Easting (m)	Northing (m)
T5 Northern Bank of Chann Waddo creek opposite to Terminal site	318962E	2735678N

Tidal Observation Interval

The Tidal observation have been recorded at every 10 minutes interval period

6.1.5 Sketch showing cross section of creek and gauge location

The sketch below shows the configuration of the tide gauge with respect to the creek cross section.



6.1.6 **For more details on this configuration, please refer to figure 12 in Section 7.16. The figure shows the depth at which the tide gauge '0' was positioned such that lowest occurring height of the waters could be captured during the tide observation period. The sketch also shows the relationship of the tide gauge assembly, sensor level, mean water level, and levels of the two monuments constructed at opposite island where the levels were transferred. RTX and static GPS observation made**

It is most essential to observe and check the levels of the tide gauge before and after the observation period in order to capture any settlement. However, efforts were made to prevent any slippage to the tide gauge sensor level as it was bolted to the pipe assembly.

The levels were read by high precision RTK method and are summarized below:

Pre observation
RTX Level of tide gauge sensor on 23rd March 2018 -48.703m

Post Observation
RTX Level of tide gauge sensor on 16th July 2018 -48.720m

Difference observed 17 mm (this is due to RTX inherent accuracies)

6.1.7 Tide gauge model, make and description

The specification of the water level recorder used is as follows:

Valeport Tide Gauge

Tide Master by Valeport, UK Ltd.

S/N 62592 Firmware version 0741705B9

6.1.8 Tide data collection start and end periods

Actual tide observation periods are as follows:

Flagged mount of Tango - 5 Digital Tidal Observation Station

__Tango 5__

Start Time 1650h of 01-04-2018

Equipment tampered on 17-05-2018

Tide Data Time series disconnect instance 0520h of 17-05-2018

Bridging from Met 1 ADCP station water level sensor carried out from 17-05-2018 to 20-06-2018

Hence total observed time series was from 01-04-2018 to 20-06-2018 i.e. 79 days

6.1.9 Downloading of data

Diver assisted field trip allowed successful downloading of data from both the tide gauge and Met 1 ADCP stations. The schedule of data retired from tide gauges is as under:

Recorded data was downloaded on 24-042018 & 01-06-2018 after 60 days

Equipment tampering observed on 17-05-2018

Data from Met-1 ADCP water level sensor downloaded on 22-05-2018

6.1.10 Vandalism and Tampering of Equipment (insert pictures)

Report from site visit of 01-06-2018 revealed tampering of tidal gauge equipment assembly at Tango 5. Several possibilities come to mind. These include intervention of local fishermen who typically salvage any valuables found in the sea, collision of a fishing or passing vessel or an act of vandalism.

It may be noted that Port Qasim respective department of Operations were already informed of the survey campaign activities while seeking initial permission to work at Chan Waddo Site. They were asked to issue cordon off warnings and notices to mariners in the project vicinity area.

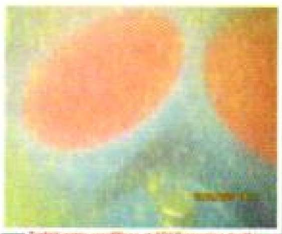
The pictures below show evidence of damage to the vented tide gauge umbilical cable:

[illegible]

[illegible]

[illegible]

6.1.11 Bridging of data for enhancement of time series (more than 60 days through MET 1 ADCP data)



[illegible]

Owing to equipment tampering by probable local fishermen or passing vessel collision resulted in loss of continuity of data collection at Tango-5. This loss occurred with effect from 17-05-2018.

Met-1 ADCP profiler incidentally has a level data sensor and recorded tide values. Hence continuity in time series could be successfully achieved by bridging the Tango 5 tide gauge data with that of the ADCP profiler. The common elevation component of Mean Sea level of both instruments was used to match the data.

This helped reconstruct a consistent and continuous time series of 53 days which was used in harmonic analysis and datum computation.

The time series was further enhanced by adding another 30 days of date from Met 1 observation station leading to a total time series length of 79 days

6.1.12 Actual tidal time series

The actual length of time series passed on to the HAMEL software to analysis tide signal for constituents was

Table 5 Showing HAMELS analysis period for WTWC run

Data Source	Tide data from	To
Tango -5 tidal heights	01-04-2018	17-05-2018
Met 1 tidal heights (parallel deployment)	24-04-2018	22-05-2018
Pak Tide Table	01-04-2018	20-06-2018
Met 1 tidal heights (redeployment on 22-05-2018)	22-05-2018	20-06-2018

6.1.13 Quality (Q/C) checks on tidal data

Quality Control on retrieved data was undertaken. Prior to deployment the YSI Tide gauge was checked for sensor calibration and to ensure correct height of water column is being recorded.

Prior to harmonic analysis the data has been subjected to rigorous quality checks. Checks on data continuity and integrity were applied prior to handover to HAMELS analysis suite. These checks involved detection of time shifts and out of range shifts in consecutive tide recordings. The data was further put through quality control checks, details of which are provided below.

These include computation of following statistics and tests on data:

i. Determining Julian Time Interval <typical 10-minute observation frequency> for addition to time stamps in excel
ii. Manually (forced) generated time stamp from exact start date and time and comparison with tide gauge time stamp for consistency or observation of slippages if any. Start and end date and time must equate upto seconds. The time stamp against each pair of tide data was compared with the virtually generated time. This comparison helped identify any gaps or voids in time series. Start and end times of the YSI tidal station were compared with PC generated 10 minute intervals and both the time stamps compared well.
iii. Ten minute difference check to see if exact ten minute interval was followed by tide gauge
iv. Manual plotting of tide signal graphs to observe any major spikes or anomalies observed in tidal height data
v. Difference between heights for unusually high deviation between consecutive tidal values by obtaining maximum and minimum differences between any two successive heights

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6.1.14 **Data released for Harmonic Analysis**

Finally after data quality checks and comparison of phase with other sources, the continuous data of 79 days was released to following Harmonic analysis software.

6.1.15 **Software employed in Harmonic Analysis**

Tidal data was analyzed using standard Harmonic Analysis procedures. Two separate methods were used to analyze data for extraction of tidal constituents. Both methods essentially follow the HAMELS procedure.

Method used in software to analyze water level time series was the commonly known procedure of Harmonic Analysis, Method of Least Squares (HAMELS). In this method, a progressive reduction in variance (mean square deviation about the mean) is achieved by adding harmonic terms with specific astronomical frequencies to a general least squares model of the type used for multiple regression. The software used was

Method 1: T Tide in Matlab

Method 2: WTWC Software in MATLAB

Method 1: T Tide Harmonic Analysis Toolbox

A Matlab adaptation of industry's widely-used program for performing harmonic analysis of oceanic tides is the FORTRAN Demonstration of tidal analysis package created by Mike Foreman (IOS).

The Matlab routine by R. Pawlowicz, B. Beardsley, and S. Lentz, "Classical tidal harmonic analysis including error estimates in MATLAB using T_TIDE", Computers and Geosciences 28 (2002), 929-937.

On completion of HAMELS procedure, the tidal constants for constituents selected during analysis were saved and employed in predictions of the astronomical tide i.e. water level that varies at known tidal frequencies attributable to gravitational interactions between the earth, moon and sun.

The water level analysis varies at both tidal and non-tidal frequencies, including frequencies so low they appear as a mean level or linear trend in short series. Objective of analysis has been to separate these components so that a tidal height prediction can be made with the component that is predictable – the water level that oscillates at tidal frequencies.

Method 2: Datum transfer Schematic Diagram

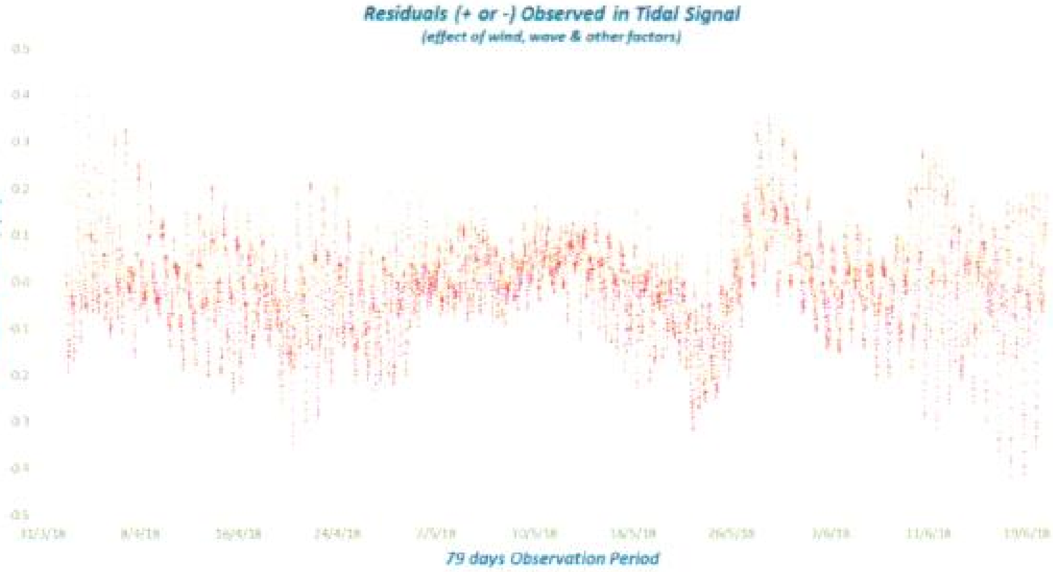
The figure below demonstrates the configuration of tide gauge as well as datum transfer values used to derive Chart Datum values at the 02 Permanent Reference Monuments (PRM) created on shore of proposed jetty site on the island at higher grounds.

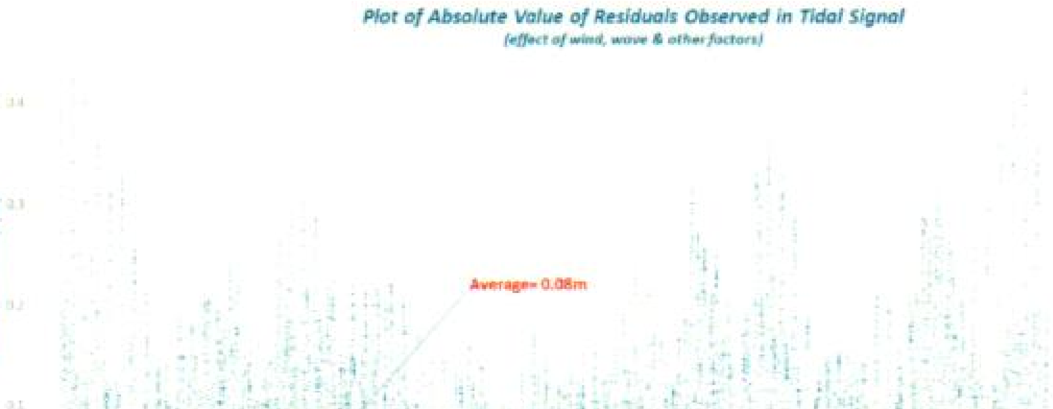
This involves RTK based level observation at the tide gauge '0' mark, level observation at PRM's. The GPS RTX was only method available to transfer levels as a normal level instrument would not provide enough range to transfer submarined tide gauge '0' mark elevation to island bearing PRM's on other side of the creek.

6.1.16 **Residuals extracted from tidal signal**

The residuals obtained from tidal signal analysis revealed that for the initial deployment of 30 days during April to May 2018, the sea state was relatively calm and effect of wind on surface currents and formation of local waves was minimal. However, as the Monsoon wind got engaged the effect on local wind setup and wind shear grew and is visible in the plot of residual for subsequent deployment upto 20 June shown below. The analysis was subsequently repeated and residual values obtained on the 79 days of tidal data. In Figure 5 absolute values of residual were also plotted.

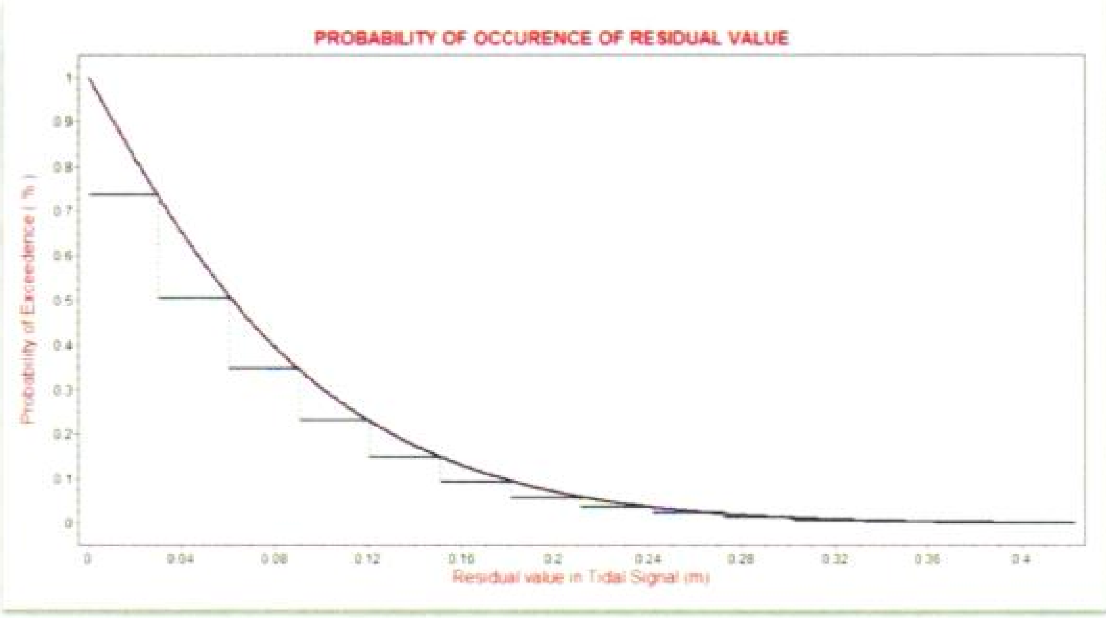
Figures 4 to 5 below represent actual and absolute residual value plots respectively from comprehensive analysis of 79 days tidal data





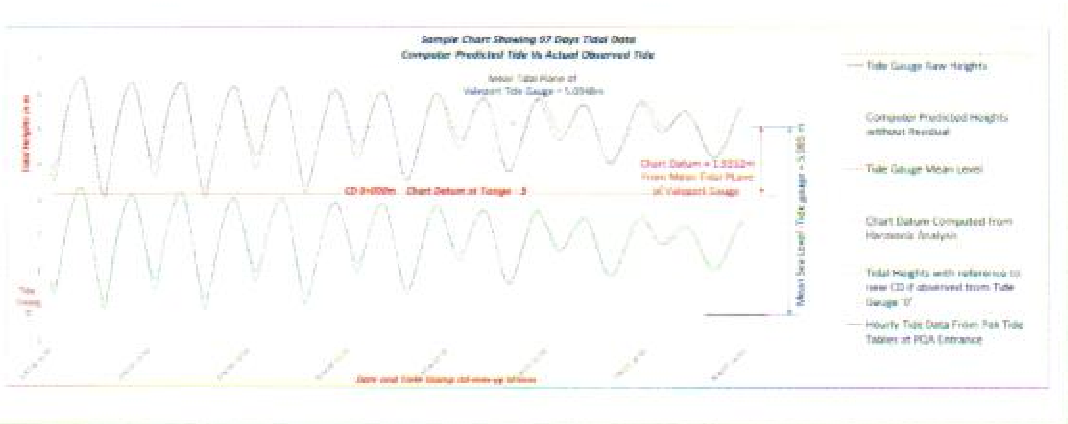
A distribution was fitted to assess sustained residual values in tidal signal during the 79 days observation period. It can be seen from the probability plot that for only 10% of time the residual was of the order of 0.16 m to 0.4 m. The average residual value was 0.08 m whereas for 90% of time the residual was below 0.16 m. This is shown in Figure 6 below:

Figure 6 Probability Chart for Distribution of Residual in Data



A 07 days comparison was made to prove efficacy of tidal analysis and constituents obtained.

Figure 7 shows 07 days comparison of tide predicted vs. observed and from Pakistan Tide Tables

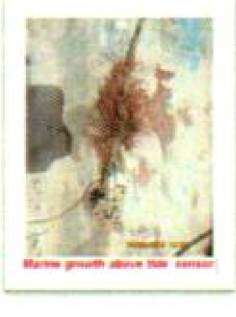


It should be kept in mind that tidal observation period of 30 days is not sufficient to extract more than 20 constituents. However for preliminary planning purposed this appears sufficient.

Nonetheless TCI endeavored to maximize the amount of tidal data which can be put forth for the harmonic analysis. First the 29 day data was increased to 51 days by supplementing the data from ADCP depth sensor. Then later additional one month of data was added from second deployment of ADCP's to obtain a tidal signal of 79 days.

This data allowed a continuous time series of 79 days which was forwarded to the tidal analysis team to perform HAMELS analysis and determine constituents leading to the establishment of tidal datum.

6.1.17 **Equipment tampering & vandalism and impact to times series**



The impact of tampering of tidal data collection equipment was minimized by bridging the time series with data obtained from depth sensor of the closes deployment ADCP i.e. Met 01. This depth sensor information provided tidal heights which were supplemented to tango 5 stations via compaction and cross relating of Mean Tidal Planes of both the equipment.

6.1.18 **Remarks on reliability of datum computed**

Need for further analysis: It is to be noted that, on request of Client, this interim tidal analysis has been prepared on basis of 79 days of tidal data available in hand. Whilst from the 79 days tidal observations, the low and high water values obtained / predicted in this report are appear to be acceptable for preliminary planning purposes. Note that the length of time series of 1896 hours is insufficient to extract all the Semidiurnal and long period tidal constituents from the harmonic analysis. For a relatively short series of observations (79 days in this case), there are limits to the number of constituents that can be used in a harmonic analysis of the tide. Difficulty caused by short series length arises in the resolution of certain constituents that are close to others in frequency. The major solar semidiurnal constituent S2, for example, has a frequency of exactly 2 cycles per mean solar day; the semidiurnal constituents T2 (1.9973 cpd), R2 (2.0027 cpd) and K2 (2.0055 cpd) are all very close to this frequency and can be difficult to resolve from a short series. Design High Water (DHW) and Design Low Water (DLW) levels representing 10 % and 90% accumulative frequencies respectively are best determined on complete tidal time series of atleast one year.

6.1.19 **Conversion of time series observed to local chart datum value computed**

The chart above defines various levels and reference values derived from harmonic analysis software to transfer and establish Chart Datum values at the PRM's.

The local established Chart Datum values transferred to the two monuments are given as under:

PQA / TCI TEGC – 01 is + 3.090 m CD

PQA / TCI TEGC – 02 is + 3.237 m CD

7.0 TIDAL ANALYSIS

7.1 Method 2 WTDC in MATLAB by Prof. Boon

The software used was World Tide and World Currents (WTWC) authored by John D Boon. WTWC has a Graphical User Interface (GUI) permits quick separation of a time series of water level measurements into its tidal and non-tidal components using a selective least squares harmonic reduction employing up to 35 tidal constituents.

On completion of HAMELS procedure, the tidal constants for constituents selected during analysis were saved and employed in predictions of the astronomical tide i.e. water level that varies at known tidal frequencies attributable to gravitational interactions between the earth, moon and sun.

The water level analysis varies at both tidal and non-tidal frequencies, including frequencies so low they appear as a mean level or linear trend in short series. Objective of analysis has been to separate these components so that a tidal height prediction can be made with the component that is predictable – the water level that oscillates at tidal frequencies.

7.2 Pre Analysis Statistics

The pre analysis statistics was determined after execution of WTWC code on the quality checked data. The summary of the initial statistics are as follows:

Table 6 showing Pre Analysis Statistics

RMS= 0.153 meters %R_var= 96.59
x = Frequency (cycles/day) = 3.861
y = First Trial, Peak Energy = 0.001829
Mean water level: 5.0964 meters

Tide Form: The tide form number determined was 0.45 indicating that PQA bears a mixed, mainly semidiurnal tide characteristic.

7.3 Energy Pending

Fourier periodogram for residual signal was used in choosing each constituent which is to be included in the harmonic analysis. Periodogram helped identify important tidal constituents from energy peaks associated with specific frequencies representing oscillations left out of the model – left out but still present in the residual signal.

The significant energy (variance) at sub tidal frequencies puts a cap on what can be achieved with an astronomical tide model no matter how many constituents are used. Hence a multivariate analysis was carried out.

Through the initials runs of the HAMELS and the Fourier Periodogram, attempt were made to characterize energy residing the tidal residuals i.e. the difference of the observed tide and predicted tide.

The energy forming the residuals can be attributed to local meteorological phenomenon such as wind, wave, currents, pressures and those elements which cannot be associated with astronomical forces contributing to generation of tide.

7.4 RMS Error

The RMS error, calculated as the square root of the mean square difference between observed and predicted water levels, is a measure of the expected error associated with an individual tidal prediction. This represent the quality of fitness between the observed and the predicted curves. The lower the RMS the better the fit becomes. The RMS also indicates the impact of successive addition of harmonic constituents and their suitability for adaption.

7.5 Percent Reduction in Variance, (%R_Var)

The Percent Reduction in Variance (%R_Var) is the percentage of the Up variance in water levels explained by the astronomical model. The higher the value the better the representation of the predicted model becomes. Ideally, inclusion in the model of any one constituent suggested by the period gram should result in a noticeable decrease in RMS error combined with an increase in %R_Var. However, if the data are taken from a region with strong metrological forcing in relation to the water levels, a high %R_Var and a low RMS error may be impossible to achieve.

7.6 Stage-Wise Analysis

The tidal levels were analyzed in different stages. In the first stage, the five Principal Major Constituents, O1, K1, N2, M2 and S2 were determined. The amplitude and phase values of the 5 major constituents were as under:

7.7 De-Tiding

Figure 8 showing First Run of De Tiding exercise

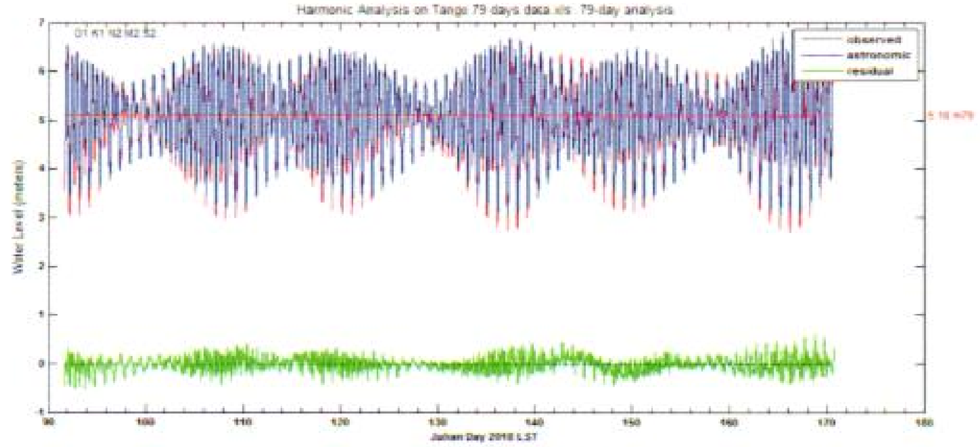
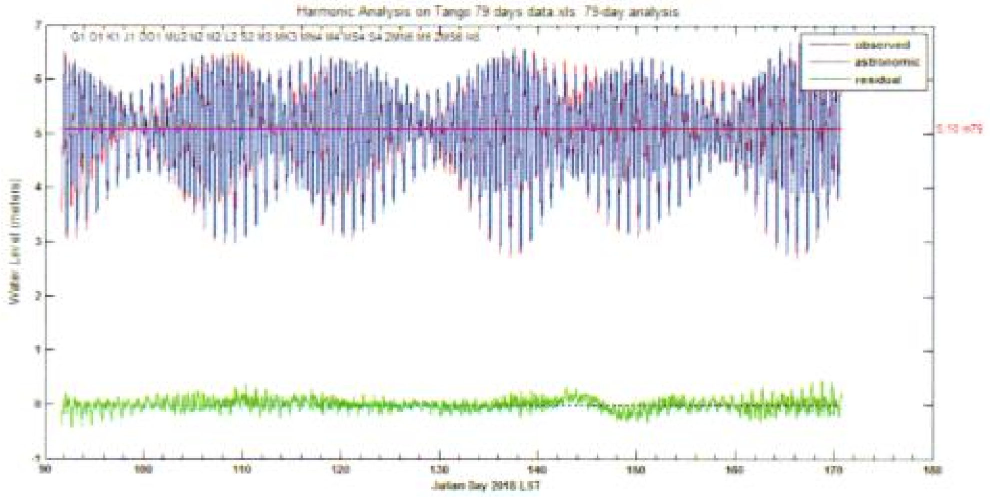


Figure 9 showing Final Run of de-tiding



The program provides both the high band periodogram (1 to 8 cpd) and a low band periodogram (0 to 3 cpd). The high band periodogram is used most often for constituent identification; the low band feature can be used to characterize sub-tidal oscillations that are usually associated with metrological forcing (wind stress, atmospheric pressure change). In the 1st stage analysis, the high band residual periodogram was obtained as under:

Figure 10 showing high band Periodogram of initial and final stages

1st Run – Frequency Vs Energy Residual Periodogram

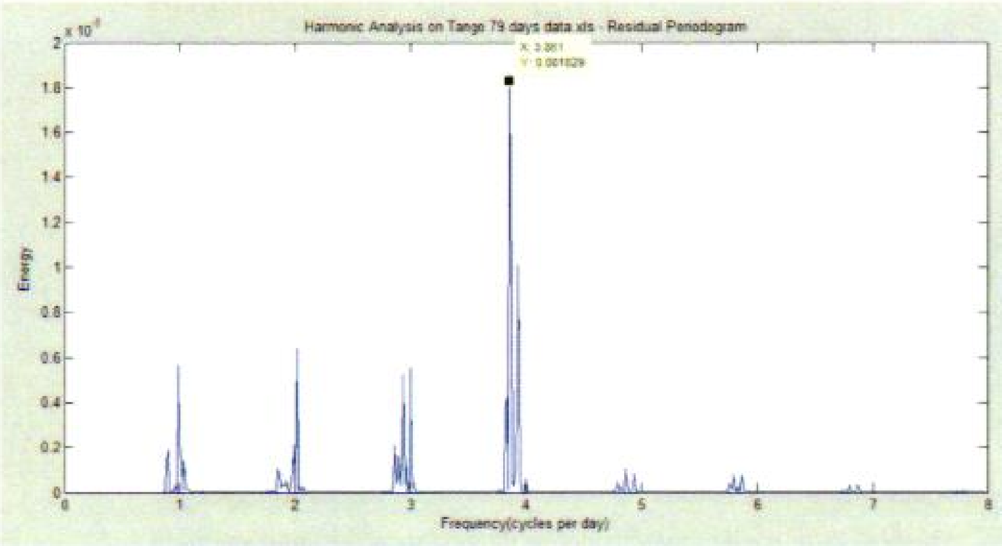
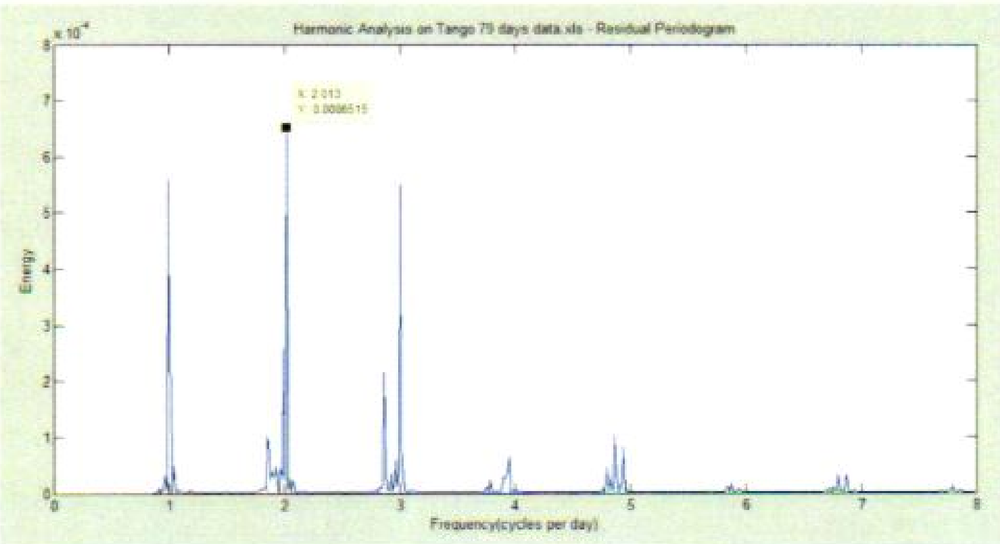


Figure 11 Last Run – Frequency Vs Energy Residual Periodogram



In next stages, the above likely constituents, obtained from residual periodogram were added and analyzed. Besides, RMS error and %R_Var, the other criteria for selection or rejection of a constituent are as follows:

Table 7 showing RMS and %R_ Variance Values

	O1	K1	N2	M2
Amplitude 1st Run	0.208	0.417	0.203	0.95
Phase 1st Run	2.86	35.63	158.27	252.91
Amplitude Last Run	0.207	0.418	0.204	0.95
Phase Last Run	3.58	35.26	158.63	253.02
% Change in Amplitude from Basic Run =	-0.48%	0.24%	0.49%	0.00%
% Change in Phase from Basic Run =	25.17%	-1.04%	0.23%	0.04%
	Pass	Pass	Pass	Pass

y = First Trial, Peak Energy = 0.001829	0.0018290
y = Final Trial, Peak Energy = 0.0006515	0.0006515
Energy decreased by =	0.0011775
% decrease in energy =	64.38%
1st Trial, RMS & %R =	RMS= 0.153 meters %R_var= 96.59
Final Trial, RMS & %R =	RMS= 0.113 meters %R_var= 98.14

The RMS Error and Percent Reduction in Variance were improved from

1st Trial, RMS & %R =	RMS= 0.153 meters %R_var= 96.59

to

Final Trial, RMS & %R =	RMS= 0.113 meters %R_var= 98.14

7.8 Using Constituent Amplitude and Phase Estimates

After conducting an analysis with a new tidal constituent added to the model, first it is checked that the amplitude is present for that constituent in the model. It is also checked that it should exceed at least 1% of the largest major constituent amplitude.

In final stage, the following constituents were finally selected.

Table 8 showing final set of constituents

Statistics	Stage-III	O1	K1	N2	M2	S2	M4	MS4	MN4	MK3	Q1	[illegible]	M3		L2	2MS6	M6	S4	2MN6	MK4	OO1	M8
RMS= 0.113 meters	Amplitude	0.207	0.418	0.204	0.95	0.159	0.007	0.06	0.045	0.048	0.037	0.037	0.028		0.012	0.023	0.017	0.004	0.012	0.007	0.004	0.005
x=Frequency (cycles	Phase	3.58	35.26	158.63	253.02	317.71	301.49	16.16	226.45	158.88	294.31	131.77	135.34		214.07	159.27	65.13	121.19	314.6	96.34	273.83	109.14
y=Final Trial, Peak E	% Change in Amp =	0.00%	0.00%	1.20%	0.00%		0.00%	0.00%	0.00%	1.10%	0.00%	0.00%	0.00%		1.00%	0.00%	0.00%	1.10%	0.00%	1.10%	0.00%	
	% Change in Phase =	0.00%	0.00%	1.10%	1.10%		0.00%	0.00%	0.00%	1.10%	0.00%	0.00%	-0.21%		1.00%	0.01%	0.03%	0.01%	0.00%	-0.02%	-0.01%	
Pass		Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass	

7.9 Post Analysis Information and Statistics

<_______A3 Sheets pls_______>

The constituents determined on basis of 79 days data are presented in tables below:
Table below shows the step wise process to extract constituents in WTWC Software

Tidal Station Tango 5 - 79 days Tidal Observation

Harmonic Analysis for Predicting Tidal Constituents

Using WTWC (World Tide World Current Software - Prof. Boon)

Basic Run

Statistics	Satge-I	O1	K1	N2	M2	S2
RMS= 0.153 meters %R_var= 96.59	Amplitude	0.208	0.417	0.203	0.95	0.357
x= Frequency (cycles/day) = 3.861	Phase	2.06	35.63	158.27	252.91	338.03

y= First Trial, Peak Energy = 0.001829
Mean water level: 3.0964 meters

WTWC CD (Basic Run)	
tide	amplitude
*O1	0.2080
*K1	0.4170
*M2	0.9500
*S2	0.3570
CD =	1.932

Add M4

RMS= 0.138 meters %R_var= 97.20
x= Frequency (cycles/day) = 3.937
y= Peak Energy = 0.001011
Mean water level: 3.0964 meters

Stage-II	O1	K1	N2	M2	S2	M4
Amplitude	0.208	0.417	0.203	0.95	0.357	0.088
Phase	2.83	35.63	158.26	252.92	338.05	298.12
% Change in Amp. =	0.00%	0.00%	0.00%	0.00%		
% Change in Phase =	-1.05%	0.00%	-0.01%	0.00%		
Pass	Pass	Pass	Pass	Pass		

Add MS4

RMS= 0.131 meters %R_var= 97.48

Stage-III	O1	K1	N2	M2	S2	M4	MS4
Amplitude	0.208	0.417	0.203	0.95	0.357	0.086	0.06
Phase	2.99	35.63	158.26	252.92	338.06	299.99	18.46
% Change in Amp. =	0.00%	0.00%	0.00%	0.00%		-2.27%	
% Change in Phase =	0.71%	0.00%	0.00%	0.00%		0.63%	
Pass	Pass	Pass	Pass	Pass		Pass	

Add MN4

RMS= 0.127 meters %R_var= 97.64

Stage-IV	O1	K1	N2	M2	S2	M4	MS4	MN4
Amplitude	0.208	0.417	0.203	0.95	0.357	0.087	0.061	0.044
Phase	2.85	35.62	158.28	252.92	338.06	301.27	15.71	216.32
% Change in Amp. =	0.00%	0.00%	0.00%	0.00%		1.16%	1.67%	
% Change in Phase =	0.00%	-0.03%	0.01%	0.00%		0.43%	-4.56%	
Pass	Pass	Pass	Pass	Pass		Pass	Fail	

Add MK3

RMS= 0.123 meters %R_var= 97.73

Stage-V	O1	K1	N2	M2	S2	M4	MS4	MN4	MK3
Amplitude	0.208	0.418	0.203	0.95	0.357	0.087	0.061	0.043	0.047
Phase	2.86	35.61	158.28	252.92	338.07	301.36	18.81	216.2	357.71
% Change in Amp. =	0.00%	0.24%	0.00%	0.00%		0.00%	0.00%	2.27%	
% Change in Phase =	0.35%	-0.03%	0.00%	0.00%		0.03%	0.64%	-0.06%	
Pass	Pass	Pass	Pass	Pass		Pass	Pass	Pass	

Add Q1

RMS= 0.121 meters %R_var= 97.87

Stage-VI	O1	K1	N2	M2	S2	M4	MS4	MN4	MK3	Q1
Amplitude	0.208	0.417	0.203	0.95	0.357	0.087	0.061	0.045	0.047	0.037
Phase	3.32	35.49	158.25	252.92	338.09	301.33	15.53	216.22	357.6	282.87
% Change in Amp. =	0.00%	-0.24%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	
% Change in Phase =	16.08%	-0.45%	-0.02%	0.00%		0.01%	0.13%	0.01%	-0.03%	
Pass	Fail	Pass	Pass	Pass		Pass	Pass	Pass	Pass	

Add J1

RMS= 0.118 meters %R_var= 97.96

Stage-VII	O1	K1	N2	M2	S2	M4	MS4	MN4	MK3	Q1	J1
Amplitude	0.207	0.418	0.209	0.95	0.357	0.087	0.061	0.045	0.047	0.038	0.037
Phase	3.61	35.26	158.27	252.93	338.1	301.4	15.68	216.2	357.58	264.25	130.91
% Change in Amp. =	-0.48%	0.24%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	2.70%	
% Change in Phase =	8.73%	-0.54%	0.01%	0.00%		0.01%	0.82%	-0.01%	-0.01%	0.49%	
Pass	Fail	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	

Add M3

RMS= 0.116 meters %R_var= 98.02

Stage-VIII	O1	K1	N2	M2	S2	M4	MS4	MN4	MK3	Q1	J1	M3
Amplitude	0.207	0.418	0.203	0.95	0.357	0.087	0.061	0.045	0.048	0.038	0.037	0.026
Phase	3.59	35.26	158.25	252.93	338.1	301.47	15.9	216.27	358.74	264.28	130.96	135.15
% Change in Amp. =	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	2.13%	0.00%	0.00%	
% Change in Phase =	-0.56%	0.00%	-0.01%	0.00%		0.02%	0.13%	0.03%	0.32%	0.01%	0.04%	
Pass	Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	

WTWC Tidal Analysis Cont'd

Add L2

Statistic	Stage IX	O1	K1	N2	M2	S2	M4	MS4	MN4	MK3	Q1	J1	M3	L2
RMS= 0.115 meters %R_var= 98.08	Amplitude	0.207	0.418	0.204	0.95	0.359	0.087	0.061	0.048	0.048	0.038	0.037	0.028	0.021
	Phase	3.59	35.25	156.34	253.01	337.72	301.47	15.88	216.26	358.8	284.25	131.03	135.37	213.36
	% Change in Amp. =	0.00%	0.00%	0.49%	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
	% Change in Phase =	0.00%	-0.03%	0.06%	0.03%		0.00%	-0.13%	0.00%	0.02%	-0.01%	0.05%	0.36%	
Pass		Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass	

Add 2MS6

Statistic	Stage X	O1	K1	N2	M2	S2	M4	MS4	MN4	MK3	Q1	J1	M3		L2	2MS6
RMS= 0.114 meters %R_var= 98.09	Amplitude	0.207	0.418	0.204	0.95	0.359	0.087	0.061	0.048	0.048	0.038	0.037	0.028		0.021	0.018
	Phase	3.59	35.25	156.35	253.01	337.72	301.47	15.9	216.25	358.81	284.24	131.05	135.33		213.37	142.72
	% Change in Amp. =	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	
	% Change in Phase =	0.00%	0.00%	0.01%	0.00%		0.00%	0.13%	0.00%	0.00%	0.00%	0.02%	-0.03%		0.00%	
Pass		Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass		Pass	

Add M6

Statistic	Stage X	O1	K1	N2	M2	S2	M4	MS4	MN4	MK3	Q1	J1	M3		L2	2MS6	M6
RMS= 0.114 meters %R_var= 98.11	Amplitude	0.207	0.418	0.204	0.95	0.359	0.087	0.061	0.048	0.048	0.038	0.037	0.020		0.021	0.017	0.017
	Phase	3.6	35.25	156.35	253.01	337.72	301.49	15.89	216.3	358.82	284.24	131.04	135.33		213.40	140.18	63.54
	% Change in Amp. =	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	-5.56%	
	% Change in Phase =	0.28%	0.00%	0.00%	0.00%		0.01%	-0.06%	0.02%	0.00%	0.00%	-0.01%	0.00%		0.03%	-1.68%	
Pass		Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass		Pass		

Add S4

Statistic	Stage XI	O1	K1	N2	M2	S2	M4	MS4	MN4	MK3	Q1	J1	M3		L2	2MS6	M6	S4
RMS= 0.113 meters %R_var= 98.12	Amplitude	0.207	0.418	0.204	0.95	0.359	0.087	0.06	0.048	0.048	0.038	0.037	0.028		0.021	0.017	0.017	0.014
	Phase	3.61	35.25	156.36	253.01	337.72	301.69	16.18	216.41	358.84	284.23	131.03	135.32		213.49	140	63.52	130.61
	% Change in Amp. =	0.00%	0.00%	0.00%	0.00%		0.00%	-1.64%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	
	% Change in Phase =	0.28%	0.00%	0.01%	0.00%		0.06%	1.80%	0.05%	0.01%	0.00%	-0.01%	-0.01%		0.03%	-0.02%	-0.38%	
Pass		Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass		Pass	Pass	Pass	

Add 2MN6

Statistic	Stage XII	O1	K1	N2	M2	S2	M4	MS4	MN4	MK3	Q1	J1	M3		L2	2MS6	M6	S4	2MN6
RMS= 0.113 meters %R_var= 98.13	Amplitude	0.207	0.418	0.204	0.95	0.359	0.087	0.06	0.048	0.048	0.038	0.037	0.028		0.021	0.017	0.017	0.014	0.011
	Phase	3.61	35.25	156.36	253.01	337.72	301.69	16.15	216.44	358.85	284.23	131.02	135.33		213.51	139.25	66.17	133.6	334.42
	% Change in Amp. =	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	
	% Change in Phase =	0.00%	0.00%	0.00%	0.00%		0.00%	-0.19%	-0.01%	0.00%	0.00%	-0.01%	0.01%		0.01%	-0.54%	1.60%	-0.03%	
Pass		Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	

Add MU2

Statistic	Stage XIII	O1	K1	N2	M2	S2	M4	MS4	MN4	MK3	Q1	J1	M3		L2	2MS6	M6	S4	2MN6	MU2
RMS= 0.113 meters %R_var= 98.14	Amplitude	0.207	0.418	0.204	0.95	0.359	0.087	0.06	0.048	0.048	0.038	0.037	0.028		0.021	0.017	0.017	0.014	0.011	0.307
	Phase	3.6	35.25	156.42	253.01	337.71	301.69	16.16	216.44	358.83	284.25	131.01	135.25		214.04	139.25	66.16	133.57	334.46	95.34
	% Change in Amp. =	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	
	% Change in Phase =	-0.28%	0.00%	0.16%	0.00%		0.00%	0.06%	0.00%	0.01%	0.01%	-0.01%	-0.01%		0.25%	0.00%	-0.02%	-0.02%	0.01%	
Pass		Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	

Add OO1

Statistic	Stage XIV	O1	K1	N2	M2	S2	M4	MS4	MN4	MK3	Q1	J1	M3		L2	2MS6	M6	S4	2MN6	MU2	OO1
RMS= 0.113 meters %R_var= 98.14	Amplitude	0.207	0.418	0.204	0.95	0.359	0.087	0.06	0.048	0.048	0.037	0.037	0.028		0.021	0.017	0.017	0.014	0.011	0.307	0.004
	Phase	3.58	35.26	156.43	253.02	337.71	301.69	16.19	216.44	358.69	284.31	131.17	135.35		214.07	139.25	66.17	133.57	334.44	95.35	279.97
	% Change in Amp. =	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	-2.63%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
	% Change in Phase =	-0.56%	0.03%	0.01%	0.00%		0.00%	0.00%	0.00%	0.00%	0.02%	0.12%	0.00%		0.01%	0.00%	0.02%	0.00%	0.00%	0.01%	
Pass		Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	

Add M8

Statistic	Stage XV	O1	K1	N2	M2	S2	M4	MS4	MN4	MK3	Q1	J1	M3		L2	2MS6	M6	S4	2MN6	MU2	OO1	M8
RMS= 0.113 meters %R_var= 98.14	Amplitude	0.207	0.418	0.204	0.95	0.359	0.087	0.06	0.048	0.048	0.037	0.037	0.028		0.021	0.017	0.017	0.014	0.011	0.307	0.004	0.005
ν = Frequency (cycles/day) = 2.010	Phase	3.58	35.26	156.60	253.02	337.71	301.69	16.38	216.45	358.83	284.31	131.17	135.34		214.27	139.27	66.19	133.69	334.43	95.34	279.93	109.14
ν = Final Trial, Peak Energy = 0.0006515	% Change in Amp. =	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
	% Change in Phase =	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%		0.00%	0.01%	0.03%	0.01%	0.00%	-0.01%	-0.01%	
Pass		Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass		Pass	Pass	Pass	Pass	Pass	Pass	Pass	

Final Result

	1	2	3	4	5	6	7	8	9	10	11	12		13	14	15	16	17	18	19	20
20 constituents passed in WTWC :	O1	K1	N2	M2	S2	M4	MS4	MN4	MK3	Q1	J1	M3		L2	2MS6	M6	S4	2MN6	MU2	OO1	M8

ν = First Trial, Peak Energy = 0.001529 — 0.0015290
ν = Final Trial, Peak Energy = 0.0006515 — 0.0006515
Energy decreased by = 0.0012775
% decrease in energy = 64.36%
1st Trial RMS & %R = RMS= 0.150 meters %R_var= 96.58
Final Trial RMS & %R = RMS= 0.113 meters %R_var= 98.14

WTWC CD (Final Run)	
tide	amplitude
*O1	0.2070
*K1	0.4180
*M2	0.9500
*S2	0.3590
CD =	1.934

	O1	K1	N2	M2
Amplitude 1st Run	0.208	0.417	0.203	0.95
Phase 1st Run	2.86	35.63	156.27	252.91
Amplitude Last Run	0.207	0.418	0.204	0.95
Phase Last Run	3.58	35.26	156.63	253.02
% Change in Amplitude from Base Run =	-0.48%	0.24%	0.49%	0.00%
% Change in Phase from Base Run =	25.17%	-1.04%	0.23%	0.04%
	Pass	Pass	Pass	Pass

7.10 Comparison of Results from TTide and WTWC Tidal Analysis Suites

A comparison of results were made using both methods and generally the results were found in good agreement.

Table 9 showing comparison of constituents extracted from two separate software suites

High Band Residual Periodogram							
TTIDE RESULTS					WTWC RESULTS		
Peaks	Constituents in T Tide	Frequency (cpd)	Amplitude	Difference in Amplitude	Amplitude	Constituents in WTWC	Remarks
1	M2	0.0805114	0.94862671	0.001	0.950	M2	Major Constituents
2	K1	0.0417807	0.42067503	-0.003	0.418	K1	
3	S2	0.0833333	0.35816421	0.001	0.359	S2	
4	O1	0.0387307	0.20801399	-0.001	0.207	O1	
5	N2	0.0789992	0.20562125	-0.002	0.204	N2	
6	M4	0.1610228	0.08703598	0.000	0.087	M4	Pass
7	MS4	0.1638447	0.05988777	0.000	0.06	MS4	Pass
8	MN4	0.1595106	0.04635968	-0.001	0.045	MN4	Pass
9	MK3	0.1222921	0.04547125	0.003	0.048	MK3	Pass
10	SK3	0.1251141	0.04346626			Not in WTWC	
11	MM	0.0015122	0.04086009			Not in WTWC	
12	NO1	0.0402686	0.03824406			Not in WTWC	
13	Q1	0.0372185	0.03603631	0.001	0.037	Q1	Pass
14	J1	0.0432929	0.03603422	0.001	0.037	J1	Pass
15	MO3	0.1192421	0.03203949			Not in WTWC	
16	MSF	0.0028219	0.02984892			Not in WTWC	
17	M3	0.1207671	0.02873549	-0.001	0.028	M3	Pass
18	2MK5	0.2028035	0.02288071			Not in WTWC	
19	L2	0.0820236	0.0218163	-0.001	0.021	L2	Pass
20	2MS6	0.2443561	0.01714543	0.000	0.017	2MS6	Pass
21	M6	0.2415342	0.01678985	0.000	0.017	M6	Pass
22	S4	0.1666667	0.01419229	0.000	0.014	S4	Pass
23	3MK7	0.2833149	0.01140238			Not in WTWC	
24	2MN6	0.2400221	0.01137267	0.000	0.011	2MN6	Pass
25	MU2	0.0776895	0.00889131	-0.002	0.007	MU2	Pass
26	OO1	0.0448308	0.00877602	-0.005	0.004	OO1	Pass
27	ETA2	0.0850736	0.00858955			Not in WTWC	
28	SN4	0.1623326	0.00770463			Not in WTWC	
29	UPS1	0.046343	0.00612549			Not in WTWC	
30	2SM6	0.2471781	0.00534584			Not in WTWC	
31	M8	0.3220456	0.00476846	0.000	0.005	M8	Pass
32	ALP1	0.0343966	0.0033041			Not in WTWC	
33	2Q1	0.0357064	0.00246341			Not in WTWC	
34	EPS2	0.0761773	0.00196482			Not in WTWC	
35	2SK5	0.2084474	0.00159295			Not in WTWC	

The list of constituents adapted for tide prediction are as under:

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Table 10 Showing list of Constituents, Phase and Amplitude adapted

Tidal Analysis Results

Station : Tango 5

Location : Chan Waddo Creek

Software: TTIDE

79 Days of Tidal Data

(Source Valeport Tide Gauge, Met-01
ADCP Depth Data)

Constituent Name	Frequency Cycles/	Amplitude (m)	Amplitude Error	Phase	Phase Error
M2	0.080511	0.948627	0.021923	308.272	1.067846
K1	0.041781	0.420675	0.020576	44.1114	2.686116
S2	0.083333	0.358164	0.017512	337.5757	3.015398
O1	0.038731	0.208014	0.023215	49.71303	5.204505
N2	0.078999	0.205621	0.01641	297.376	4.68153
M4	0.161023	0.087036	0.008746	53.071	5.414767
MS4	0.163845	0.059888	0.008692	71.3181	8.323622
MN4	0.159511	0.04636	0.009577	50.64202	10.12025
MK3	0.122292	0.045471	0.011893	65.36735	13.21593
SK3	0.125114	0.043466	0.010336	128.5024	12.07801
MM	0.001512	0.04086	0.031508	3.778115	50.6063
NO1	0.040269	0.038244	0.028317	92.80821	47.55185
Q1	0.037219	0.036036	0.02095	51.92874	34.22354
J1	0.043293	0.036034	0.018315	59.46627	30.14427
MO3	0.119242	0.032039	0.010992	37.67474	20.68966
MSF	0.002822	0.029849	0.034551	181.2367	68.89015
M3	0.120767	0.028735	0.009994	43.07341	18.82083
2MK5	0.202804	0.022881	0.010014	170.008	31.58963
L2	0.082024	0.021816	0.015808	278.397	41.30229
2MS6	0.244356	0.017145	0.004771	250.306	14.91969
M6	0.241534	0.01679	0.004412	230.634	13.33221
S4	0.166667	0.014192	0.009343	130.2175	38.6445
3MK7	0.283315	0.011402	0.004883	3.846861	24.80771
2MN6	0.240022	0.011373	0.005053	223.0964	19.80038
MU2	0.077689	0.008891	0.016513	205.5687	104.7277
OO1	0.044831	0.008776	0.023514	77.22195	173.6707
ETA2	0.085074	0.00859	0.017911	206.6076	130.5426
SN4	0.162333	0.007705	0.007431	3.399213	58.13376
UPS1	0.046343	0.006125	0.02066	91.63827	169.2846
2SM6	0.247178	0.005346	0.004481	309.1581	51.98274
M8	0.322046	0.004768	0.001585	331.6063	18.96506
ALP1	0.034397	0.003304	0.014001	142.6578	202.4479
2Q1	0.035706	0.002463	0.015767	32.67627	206.5705
EPS2	0.076177	0.001965	0.011489	305.8301	229.838
2SK5	0.208447	0.001593	0.006907	272.1058	221.1648

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7.11 Comparison of Chart Datum

Subsequent to Harmonic analysis and determination of amplitudes of some of the major constituents, the Chart Datum was computed on basis of Indian Spring Low Water (I.S.L.W.). This datum was originated by Darwin when investigating tides of Subcontinent, also called the Indian Tidal Plane. It is an elevation depressed below mean sea level by an amount equal to the sum of the amplitudes of the harmonic constituents O1, K1, M2 and S2.

A comparison of Chart Datum computed using both analysis is given below

Table 11 showing comparison of tidal datum IMSLW computed using two software

Ttide CD	
tide	amplitude
*O1	0.2080
*K1	0.4207
*M2	0.9486
*S2	0.3582
CD =	**1.935**

WTWC CD (Final Run)	
tide	amplitude
*O1	0.2070
*K1	0.4180
*M2	0.9500
*S2	0.3590
CD =	**1.934**

7.12 Comparison with other tide station data (PN tide table, Bundal Island station combined plots of typical 07 days data)

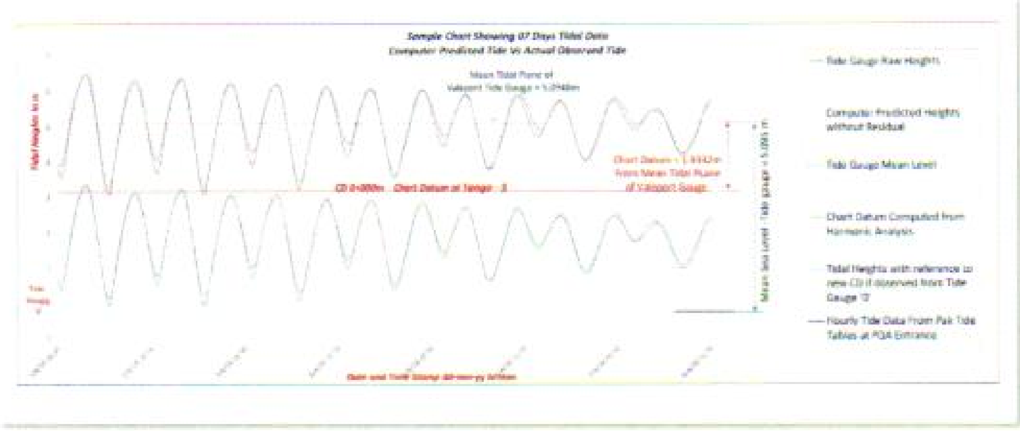
Prior to and after harmonic analysis, a manual comparison of tidal heights was made between nearby stations such as near Bundal Island platform and those published in the Pakistan tide table. Prior to harmonic analysis, the comparison of heights cannot be made as datum is not determined. However the phase and any lags can be observed.

The comparison prior to HAMELS is shown in figure below:

The 79 days tidal data has been reduced to the newly established Chart datum at Chan Waddo Creek and file containing data is enclosed in the relevant Appendix.

A 07-day comparison of predicted tide was made with the actual tide observed at T5 location, Pakistan tide tables, and Bundal Island Tide and those predicted by TTide software utilizing the extracted tidal constituents is given below.

Figure 12 showing comparison of tidal value predicted vs. observed



The comparison of these three sources of tides generally was in consonance considering both phase and amplitude values.

7.13 Note on length of time series obtained

The JGC survey specifications calls for employment of international best practices and defined standards. TCI has already pointed out in agreement, discussions and meeting notes that establishment of precise tidal datum and accurate and reliable design reference values such MHHWS, MLLWS, HAT, LAT, MSL require atleast a one year (365 days' time series). Use of 70 to 79 days of tidal height data would allow extraction of a limited number of constituents. The typical maturity ages of tidal constituents are as follows:

Note on Maturity of Tidal Constituents: The tidal analysis and prediction of 19.8 years metonic cycle (for HAT/LAT) has been carried out on only 79 days of data. However the accuracy of these predictions are limited by the number of constituents that can be extracted from the length of time series employed. As per international best practice, a minimum of 365 days of tidal data is required before the times series is subjected to analysis and long term predictions. Some constituents mature earlier while others take time. It is highly recommended that for ascertaining design parameters with respect to design water levels a complete year of tidal observation should be made, the analysis performed again and the values given in this report revised in light of complete one year of tidal data. For information the typical dates for maturity of various constituents are given in table below.

Table 12 showing constituents maturity ages

Shallow Water Constituent	Record Length (h) Required for Constituent Inclusion	Component Main Constituents and Record Lengths (h) Required for Their Inclusion in the Analysis					
SO_1	4383	S_2	355	O_1	328		
MKS_2	4383	M_2	13	K_2	4383	S_2	356
MSN_2	4383	M_2	13	S_2	355	N_2	662
MO_3	656	M_2	13	O_1	328		
SO_3	4383	S_2	355	O_1	328		
MK_3	656	M_2	13	K_1	24		
SK_3	355	S_2	355	K_1	24		
MN_4	662	M_2	13	N_2	662		
M_4	25	M_2	13				
SN_4	764	S_2	355	N_2	662		
MS_4	355	M_2	13	S_2	355		
MK_4	4383	M_2	13	K_2	4383		
S_4	355	S_2	355				
SK_4	4383	S_2	355	K_2	4383		
$2MK_5$	24	M_2	13	K_1	24		
$2SK_5$	178	S_2	355	K_1	24		
$2MN_6$	662	M_2	13	N_2	662		
M_6	26	M_2	13				
$2MS_6$	355	M_2	13	S_2	355		
$2MK_6$	4383	M_2	13	K_2	4383		
$2SM_6$	355	S_2	355	M_2	13		
MSK_6	4383	M_2	13	S_2	355	K_2	4383
$3MK_7$	24	M_2	13	K_1	24		
M_8	26	M_2	13				

7.14 Tide Predictions

Based on the 67 numbers tidal constituents obtained from the one year data, tide predictions were attempted for 19 years Metonic cycle to obtain provisional HAT, LAT, MSL values.

Based on the constituents determined for the one year of data, a prediction was made for two weeks following the one year data. This prediction was superimposed upon the incoming data for two weeks to see the quality and effectiveness of the predictions. It can be seen from the attached figure that the predicted tidal data compares well with the incoming observed data. The phase of the tide match reasonably well whereas the amplitude also matches overall but with slight variation during neap cycles. This is primarily due to effect of local wind and met conditions which appear in form of residual after de-tiding. As the tide prediction model purely provides tide generation as a consequence of movement of astronomical bodies alone, it does not predict the water level rise due to wind, surges or wave setup effects. Hence it can be inferred that tidal constituents and based on which local datum has been computed can be used as an initial estimate to determine a first estimate of the local tidal datum and MSL.

7.15 19 years Metonic Cycle

The values extracted from predictions were between 2010 and 2028 are maxima and minima values summarized in section 11.2. Long term predictions require much more data time series than 365 days. It is therefore emphasized that the predictions made herein are purely for initial planning purposes and subject to change when harmonic analysis carried out on a longer duration time series. Appendix C contains actual Tango 5 raw tidal data used in forecasting.

7.16 Final Tidal Heights and Determination of PRM CD Values

Based on harmonic analysis of 79 days of tidal heights at 10 min intervals and prediction of tide for 19.8 years metonic cycle upto year 2038, after subjecting the long time series of tidal heights to a statistical analysis the values as required in JGC specifications were determined. These were then transferred to the PRM's created on island onshore of proposed LNG terminal.

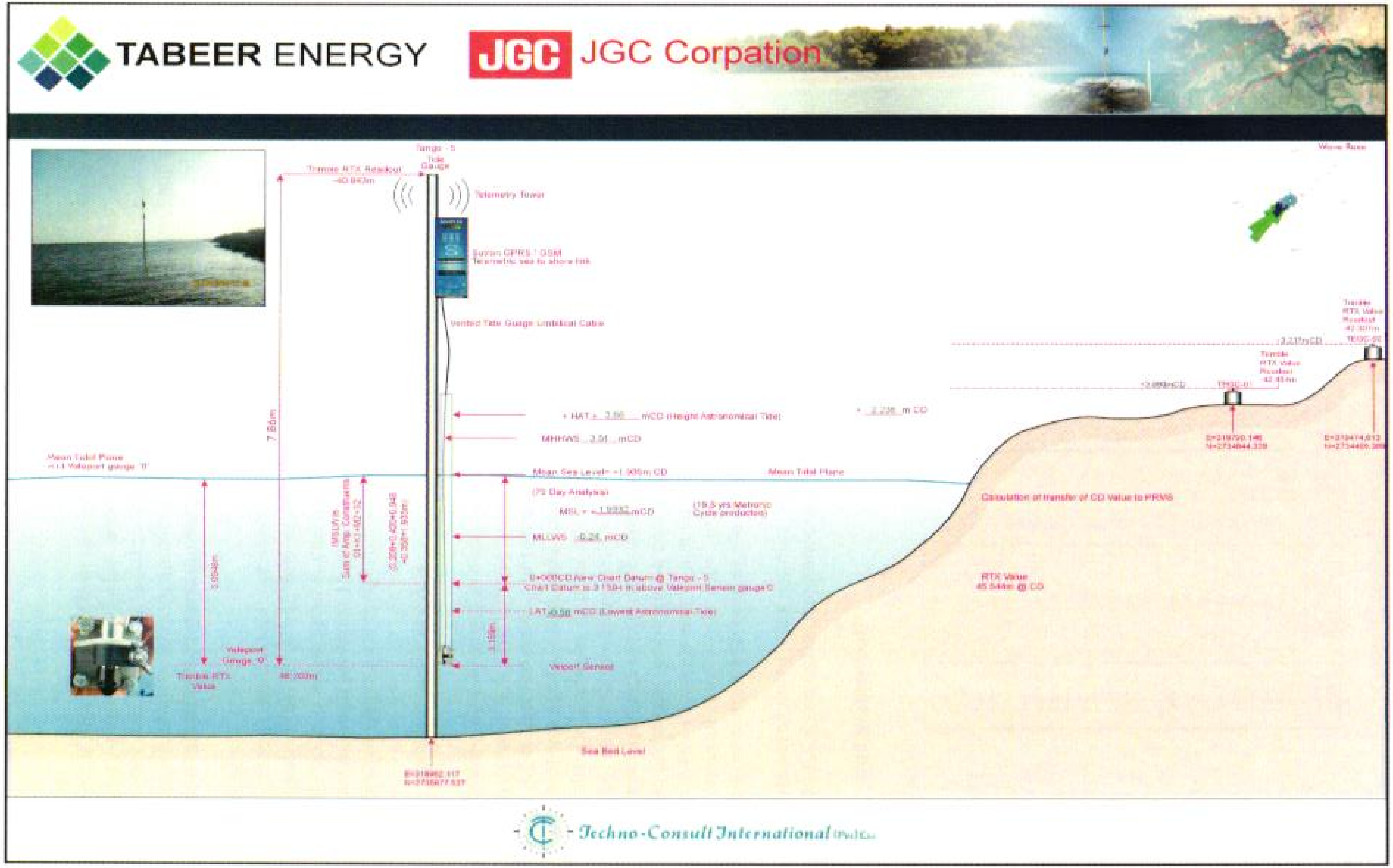


Figure 13 showing graphical representation of the transfers process and levels obtained

Based on the 19.8 year prediction of tidal levels, the data points 346,895 in total were analyzed to determine monthly Spring tide High and Low waters observed in the metonic cycle period.

Table 13 Sea Levels with Reference to Local Chart Datum

19 Year Tide Prediction Period: 2018 to 2037 (m)	
HAT (Highest Astronomical Tide)	3.66
LAT (Lowest Astronomical Tide)	-0.50
MHWS (Mean High Water Springs)	3.51
MLWS (Mean Low Water Springs)	-0.24

The above values are derived from 79 days of tidal data with extraction of harmonic constituents only.

Table 14 showing assigned values to monuments in local CD values

Bench Mark ID	Established Local Chart Datum by measuring very short term tidal observation and harmonic analysis
PQA / TCI TEGC – 01	+ 3.090 m CD
PQA / TCI TEGC – 02	+ 3.237 m CD

7.17 Concluding remarks and recommendations

Albeit on short term observation period, a tidal analysis has been successfully carried out. These have been based on 79 days data analyzed through software model. Comparison with other sources of tide data reveals minor departures in amplitude and phases computed. Based on 79 days data a water level prediction of 19 years have resulted in HAT, LAT, MHHW, MLLW values. These values are for initial assessment purposes and based on more rigorous data (at least 365 days) and tidal analysis revealing full set of constituents, a re-prediction of 19-year Metonic cycle should be made.

While tidal analysis determines water level variations purely as a consequence of movement of astronomical bodies, the design water levels must also account for other resulting from other phenomenon contributing to residual values to include storm surge, local wind and wave setup, sea level rise, plate tectonics and other incursions in tidal heights. It is recommended that these be carried out and accounted for while establishing maritime design parameters for the water front LNG facility.

Furthermore, as per international best practice followed for any new coastal facility development, a permanent tidal station and wave gauge must be established at Chan Waddo LNG terminal site location. It should be equipped with a radar type tidal gauge and manned by qualified personnel. Data to be collected in digital form on a continual basis and analyzed regularly. This recommendation is further elucidated by effects of Global Climate Change which is increasingly being recognized by responsible developers and terminal operators.

8.0 Current Profile Measurement

8.1 Current Measurement 41 days (synodic period)

Currents are of significance in the proposed LNG terminal site of Chan Waddo Creek. From TCI's experience, there is eddy and caustic action at the confluence of Chann Waddo, Rakkhal and Jharri Creeks. Over time this anomaly has resulted in formation of a deep swatch which goes as deep as -35 m CD. This difference in depth cause turbulent conditions which have to be seen in particular while examining the navigability of vessels at the larger width available at the confluence. Of particular significance is the examination of turning circle for swinging of vessels prior to berthing at the terminal. A creation of turning circle at the LNG terminal site would involve excavation of creek banks to accommodate the 2 x LOA of the vessel. Previous terminals have also faced review of this navigational concern.

The stratified current profile can be observed using worked renowned RDI Teledyne equipment viz. RDI Sentinel Workhorses ADCP profiler of 600 HZ cycle rates. This equipment which is wholly owned by TCI is typically moored at sea bed and records current profile data.

The locations were carefully established in consultation with oceanographic team. These locations were later refined after consultation with JGC and the numerical modeling team. Also, confirmed was the bin size which is the interval size along water column along which the current magnitude and direction (the SET) is to be observed. It is typically 1 to 1.5 m which can be easily selected in consultation with JGC.

ADCP Equipment being readied for deployment

Tidal ellipses were prepared. State of the Art software to present stratified current data such as Teledyne Equipment's "Velocity Base" Software was used to develop neat plots of current distribution pattern throughout the tidal cycle.

Current measured through stratified current profiler i.e. Teledyne RDI Sentinel Workhorse was acquired by 24/7 observations set at a suitable time interval.

8.2 Current Observation Campaign (Met 1 to 4)

Current data is required for flow modelling, ship-motion, mooring and structural design of water-front structures. The information also provides a direct input for determining scour potential at pile base and pipe root beddings. This information was collected using Acoustic Doppler Current Profiler (ADCP). Some interested phenomenon can be examined using data acquired by these ADCP profilers.

Deployed configuration of ADCP

8.3 Scope and Specifications

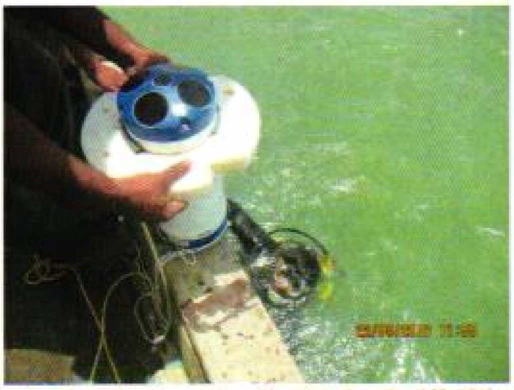
8.4 Locations of Wave and Current Measurements

Table 15 Coordinates of ADCP deployment locations

First Batch 30 Days							
S-NO.	Loction	Equipment	Equipment Serial number	Date Deployed	Date Retrieved	Northing (UTM 42)	Easting (UTM 42)
1	MET-3	ADCP RDI	12434	19-04-18	24-05-18	320693	2736225
2	MET-4	ADCP RDI	10907	19-04-18	22-05-18	314172	2731432
3	MET-1	ADCP RDI	12854	24-04-18	22-05-18	319237	2735189
4	MET-2	ADCP RDI	10903	24-04-18	22-05-18	320726	2734790
Second Batch							
S-NO.	Loction	Equipment	Equipment Serial number	Date Deployed	Date Retrieved	Northing (UTM 42)	Easting (UTM 42)
1	MET-3	ADCP V sentinal	144	24-05-18	20-06-18	320693	2736225
2	MET-4	ADCP V sentinal	118	22-05-18	21-06-18	314172	2731432
3	MET-1	ADCP V sentinal	119	22-05-18	20-06-18	319237	2735189
4	MET-2	ADCP V sentinal	121	22-05-18	20-06-18	320726	2734790

8.5 Currents Measurement

ADCPs were installed on the seafloor at one location in the vicinity of project site, the ensemble interval is to be 20 minutes at a ping rate of 2 Hz and 120 pings per ensemble for currents.

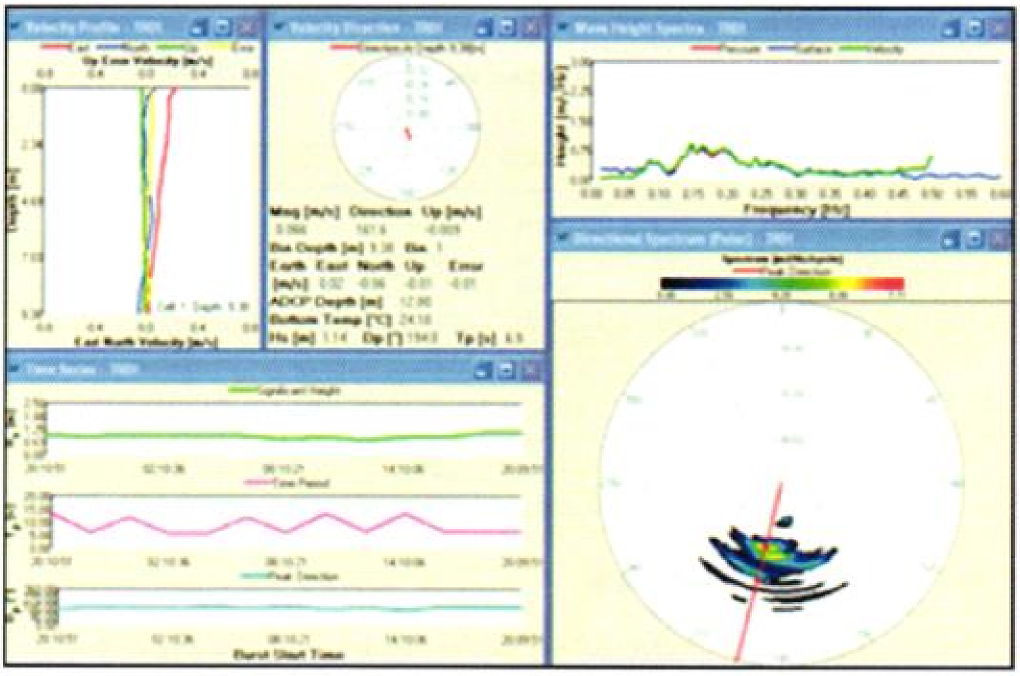


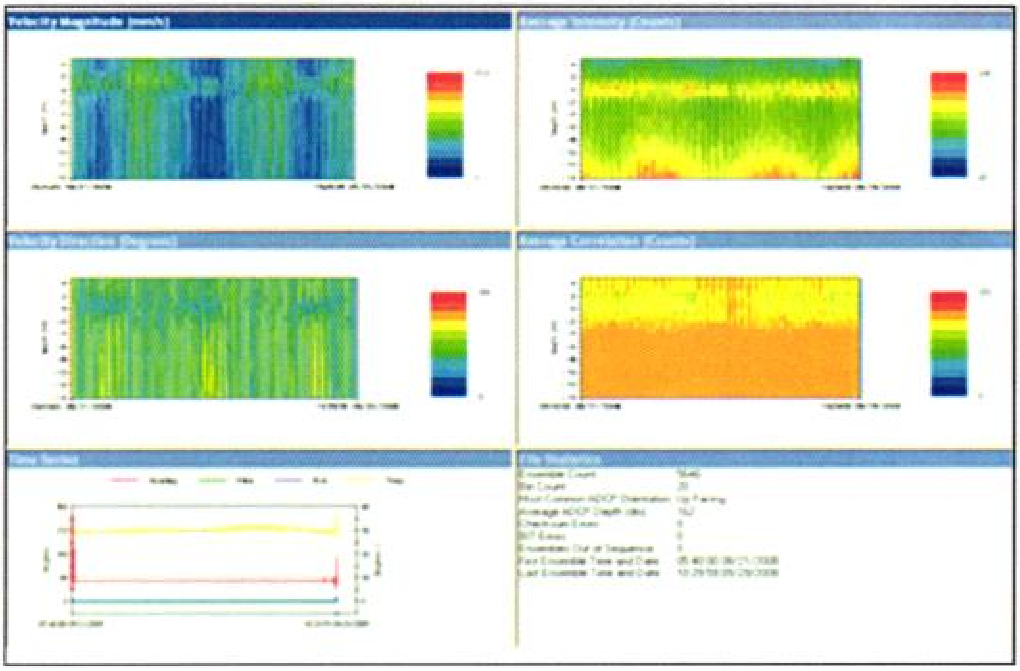
Sentinnel V being retrieved for data download Met 01

9/10

Table 16 showing Parameters for ADCP Current Observation

Bottom Mounted ADCP	Stations	
Start	1	30 Days
End		-do-
Accuracy		1-2 cm/s
Ensemble interval		20 minutes
Ping rate		2 Hz
Pings per ensemble		2 minutes





Accurate assessment of current data is essential for feasibility and design of marine terminals. It is one of the basic data sets required for planning of the terminal, including layout development and assessment of the need for marine protection. It provides essential information for detailed studies of currents, ship movement, navigation, sedimentation, mooring analysis, and assessment of the impact of the terminal on the coastline.

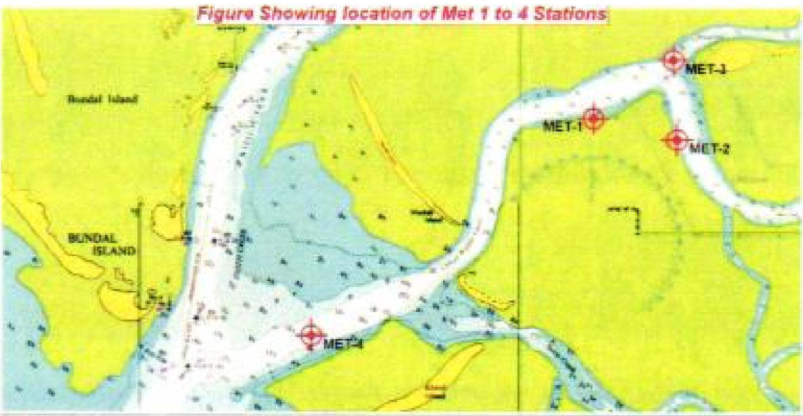
For current data collection with equipment positioned on the seafloor, an RDI Sentinel 600 Workhorse ADCP has been programmed to record time-series of vertical profiles in layered currents and water depths, an extensive temporal dataset for current has been acquired through the deployment of moored ADCPs at three locations simultaneous for current measurement of 3 layers (surface, 0.6H, bottom) at 3 points (HD-1, HD-2, and HD-3) for one month during dry and as well as wet seasons.

Attachment of pinger to mounting cage

To collect current velocities that is, speed and direction simultaneous measurement of 3 layers (surface, 0.6H, bottom) at 3 points (HD-1, HD-2, and HD-3). The end result is used for calibrating and adjusting the mathematical model that is used for detail design.

Simultaneous continuous (one month) current measurement of 3 layers (surface, 0.6H, bottom) ADCP Deployment at following three fixed locations would cover both Spring and Neap tides, location as indicated in figure.

Figure 14 Showing ADCP current measurement locations



8.6 ADCP Current Measurement Deployment Summaries

Table 17 showing deployment summaries for batch 2

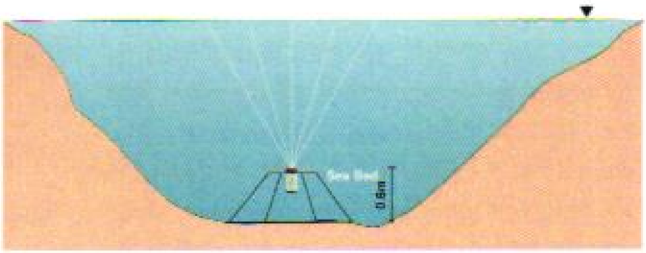
Deployment Credentials Batch 2	
Met 1	Met 2
-----Deployment Summary-----	-----Deployment Summary-----
492 kHz Upward SentinelV ADCP, Firmware Vers. 47.19 in 13.0 Meters Depth	492 kHz Upward SentinelV ADCP, Firmware Vers. 47.19 in 13.5 Meters Depth
Start Time 05/22/18 -- 10:00:00	Start Time 05/22/18 -- 11:00:00
Stop Time 06/20/18 -- 18:17:17	Stop Time 06/20/18 -- 18:12:33
746 Total Bursts Collected 1 Every 60.00 Minutes	747 Total Bursts Collected 1 Every 60.00 Minutes
Each Burst Contains 2100 Samples Collected at 2.0Hz	Each Burst Contains 2100 Samples Collected at 2.0Hz
17 Depth Cells of 1.00 Meters Width, Starting 2.26 Meters beyond the Transducer	17 Depth Cells of 1.00 Meters Width, Starting 2.26 Meters beyond the Transducer
-----Wave Processing Summary-----	-----Wave Processing Summary-----
Bins Available For Directional Spectrum 1-17	Bins Available For Directional Spectrum 1-17
Bins Available For Height Spectrum 1-17	Bins Available For Height Spectrum 1-17
Maximum cutoff Frq. 0.95 Hz, Minimum Included Wave Period 1.05 s.	Maximum cutoff Frq. 0.95 Hz, Minimum Included Wave Period 1.05 s.
Height and Directional Spectrum have 64 Freq Bands from 0 to 1.0 Hz	Height and Directional Spectrum have 64 Freq Bands from 0 to 1.0 Hz
---------Currents---------	---------Currents---------
Raw Ensembles Were Burst Sampled	Raw Ensembles Were Burst Sampled
Met 3	Met 4
-----Deployment Summary-----	-----Deployment Summary-----
492 kHz Upward SentinelV ADCP, Firmware Vers. 47.19 in 10.3 Meters Depth	492 kHz Upward SentinelV ADCP, Firmware Vers. 47.19 in 14.1 Meters Depth
Start Time 05/24/18 -- 09:00:00	Start Time 05/21/18 -- 08:00:00
Stop Time 06/20/18 -- 18:10:40	Stop Time 06/21/18 -- 19:13:40
696 Total Bursts Collected 1 Every 60.00 Minutes	779 Total Bursts Collected 1 Every 60.00 Minutes
Each Burst Contains 2100 Samples Collected at 2.0Hz	Each Burst Contains 2100 Samples Collected at 2.0Hz
16 Depth Cells of 1.00 Meters Width, Starting 2.24 Meters beyond the Transducer	17 Depth Cells of 1.00 Meters Width, Starting 2.25 Meters beyond the Transducer.
-----Wave Processing Summary-----	-----Wave Processing Summary-----
Bins Available For Directional Spectrum 1-16	Bins Available For Directional Spectrum 1-17
Bins Available For Height Spectrum 1-16	Bins Available For Height Spectrum 1-17
Maximum cutoff Frq. 0.95 Hz, Minimum Included Wave Period 1.05 s.	Maximum cutoff Frq. 0.95 Hz, Minimum Included Wave Period 1.05 s.
Height and Directional Spectrum have 64 Freq Bands from 0 to 1.0 Hz	Height and Directional Spectrum have 64 Freq Bands from 0 to 1.0 Hz
---------Currents---------	---------Currents---------
Raw Ensembles Were Burst Sampled	Raw Ensembles Were Burst Sampled

8.7 Current Observation Period

Table 18 Observation cycles of both batch 1 and batch 2 deployments

First Batch 30 Days							
S-NO.	Loction	Equipment	Equipment Serial number	Date Deployed	Date Retrieved	Northing (UTM 42)	Easting (UTM 42)
1	MET-3	ADCP RDI	12434	19-04-18	24-05-18	320693	2736225
2	MET-4	ADCP RDI	10907	19-04-18	22-05-18	314172	2731432
3	MET-1	ADCP RDI	12854	24-04-18	22-05-18	319237	2735189
4	MET-2	ADCP RDI	10903	24-04-18	22-05-18	320726	2734790
Second Batch							
S-NO.	Loction	Equipment	Equipment Serial number	Date Deployed	Date Retrieved	Northing (UTM 42)	Easting (UTM 42)
1	MET-3	ADCP V sentinal	144	24-05-18	20-06-18	320693	2736225
2	MET-4	ADCP V sentinal	118	22-05-18	21-06-18	314172	2731432
3	MET-1	ADCP V sentinal	119	22-05-18	20-06-18	319237	2735189
4	MET-2	ADCP V sentinal	121	22-05-18	20-06-18	320726	2734790

Sketch showing typical deployment geometry



8.8 ADCP programming parameters (ensemble, Ping rate, interval, freq)

Wave and Current Measurement Parameters

The current observation have been recorded at every 10 minutes interval with 6 readings per hour.

Wave measurements were hourly interval and burst of 20 min

Table 19 showing Wave and Current measurement parameters

Bottom Mounted ADCP		Location	Parameters
Current Observation		Met 1 to Met 4	
Ensemble interval			10 min
Ping rate			2 Hz
Pings per ensemble			60
Burst for directional spectra	Interval	Met 1 to Met 4	1 hour
	Duration		20 min
	Ping rate		2 Hz

Pre-deployment Bench Test	
TS Test:	This shows the current setting of the real time clock. Verify the clock setting.
PS0 Test:	For displays system parameters. Verify the information is consistent with what you know about the setup of your system.
PA Test:	For extensive pre-deployment test that tests the signal path and all major signal processing subsystems.
PC2 Test:	For continuously updates sensor display.
RS Test:	To show the amount of used and free recorder space in megabytes.
PC1 Test:	For Beam continuity test.
Compass calibration	
Pressure sensor	
RDI specifies battery packs to have 400 watt-hours (Wh) of usable energy at 0°C	

9.0 ADCP MODELS AND MAKE (WORKHORSE AND SENTINEL V'S) EMPLOYED IN DATA COLLECTION

9.1 Equipment used for wave and current measurement

Pinger being readied for installation in ADCP moorings

Two numbers of Workhorse Sentinel ADCP 600 kHz ADCPs manufactured by Teledyne RDI Inc., the best in the industry, were deployed for equipment manufacture specifications. The instruments were fitted on these cages independently. The cages were equipped with Audible pingers for relocating in case if the equipment gets dislodge. The equipment at 20 meter depth is also fitted with optional telemetry option, so that the data can be delivered to shore. For safeguarding of the equipment that is more prone to vandalism we have manage to install a floating buoy which serves as a deterrent to fishing trawler to change their course and as well as a platform for telemetric equipment.

9.2 Method Statement

ADCP Mooring deployment at Met 01

62 feet fishing trawler was hired with on-board lifting winch for the deployment of the ADCPs equipment. A team of field engineer along with 4 divers were engaged to make sure that the equipment was placed upright on sea bed. Also six numbers of large Anchor (80 kg each) were placed in star formations, to tie the equipment cage to the ground and reduce the possibility of being dragged on the floor to stop the equipment from dragging on the floor.

The equipment before deployment was programmed and turned on with the on-board laptop and then lowered to floor. All possible measures were taken to make sure that the instrument is pinging and the data is being recorded. After the deployment the pingers audible signal is cross-checked by the Hydrophone and concurred for instrument presence and the placement tilt angle. To further safeguard the equipment sinker blocks of 500 kg with chain and floating buoy were placed in diamond formation for the unit protection.

Prior to the deployment of the ADCPs for wave and current observation, the RDI unit was programmed with the proprietary WinSC software.

Pingers fro mounting with ADCP's at Met 1 to 4

Use of Hydrophone on board to locate pinger and ADCP equipment

Batch 1 Sentinnel Workhorse ADCP equipment ready for lowering

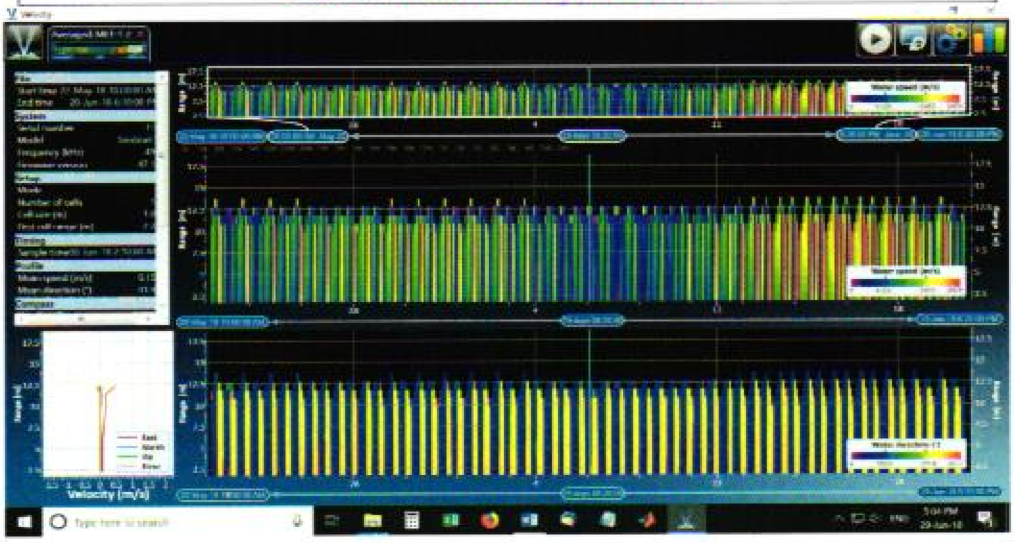
ADCP Non Magnetic Mooring cage being readied for deployment

9.3 Current time series obtained (current JPG plots from Velocity software)

Figures showing graphical time series for currents observed at stations Met 1 to 4

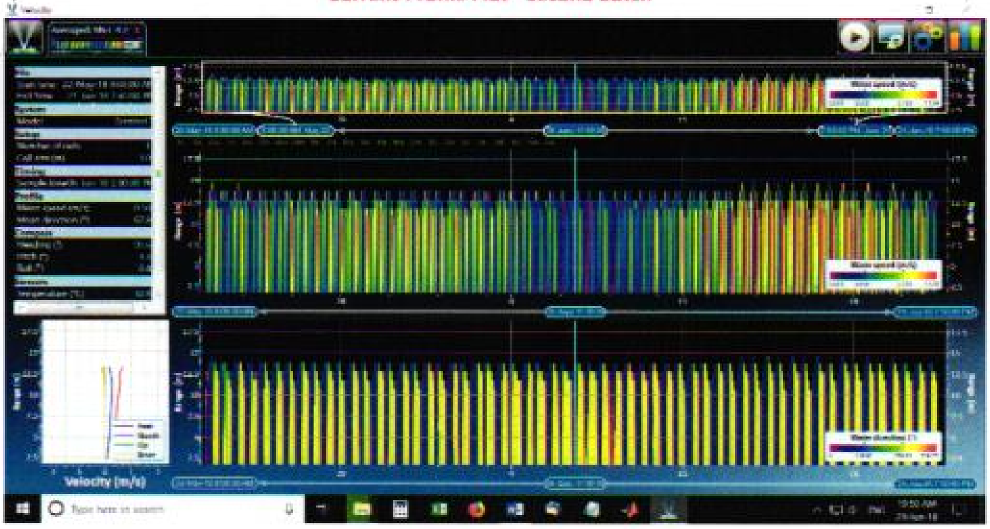
Station : Met 1

Current Profile Plot - Second batch



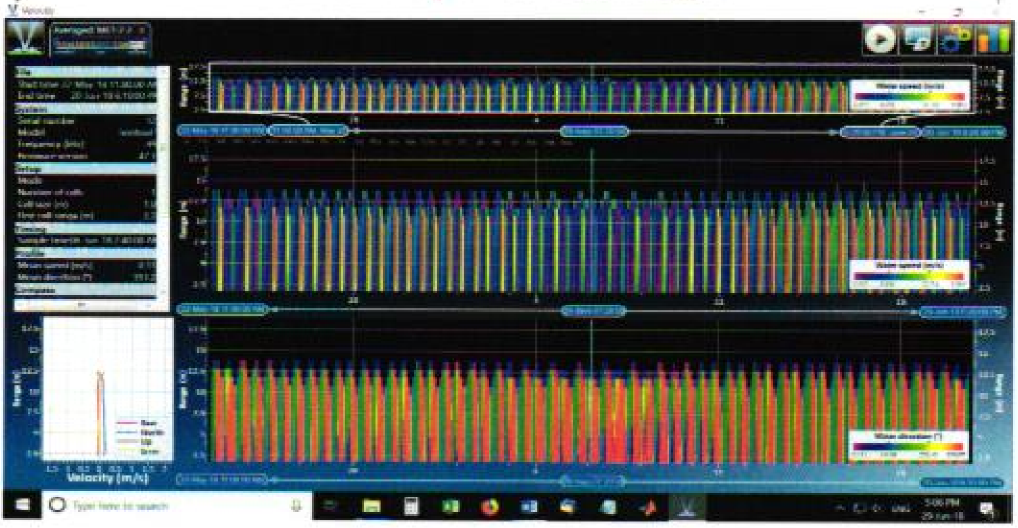
Station : Met 04

Current Profile Plot - Second batch



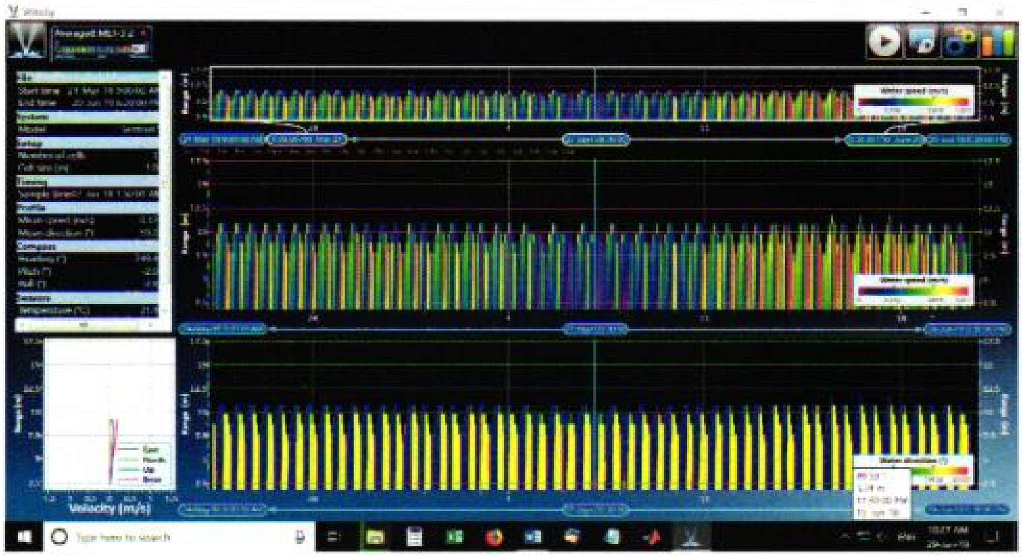
Station : Met 02

Current Profile Plot - Second batch



Station : Met 03

Current Profile Plot - Second batch



9.4 Software employed to process & analyze current data (RDI Velocity)

Software deployed to download and process current and wave data was the Velocity software from RDI Teledyne USA.

The Velocity Post-Processing Software is an intricate 2D and 3D graphs which delivers time series graphs, contour graphs, and profile graphs. The basic/conventional processing features including averaging, coordinate transforms, and velocity reference. It keeps a comprehensive log of all loaded and recent data files and allows export to multiple outputs formats.

Use of winch to lower ADCP cage mounting

ADCP units were programmed by the ReadyV / Pre-Deployment Software which resides onboard the ADCP Sentinnel V's. The software allows to configure, deploy, and recover data.

9.5 Vandalism and Equipment tampering observed

No significant vandalism was observed on the ADCP deployment for Met 1 to 4 stations. However, Met 01 slipped slightly towards the channel which could probably due to surge of a passing vessel or natural slippage or sloughing of the sea bed slope.

Met 02 Equipment being lowered

9.6 Tidal Ellipses Met 1 to 4 (Polar plots of mag and dir)

Based on the Northing and Easting components of the current vector extracted from the Velocity software, tidal ellipses have been plotted. These are presented below for Met 1 to 4 observations:

Figure 15 showing Top Middle and Bottom layers of tidal flow at Met 1 to 4

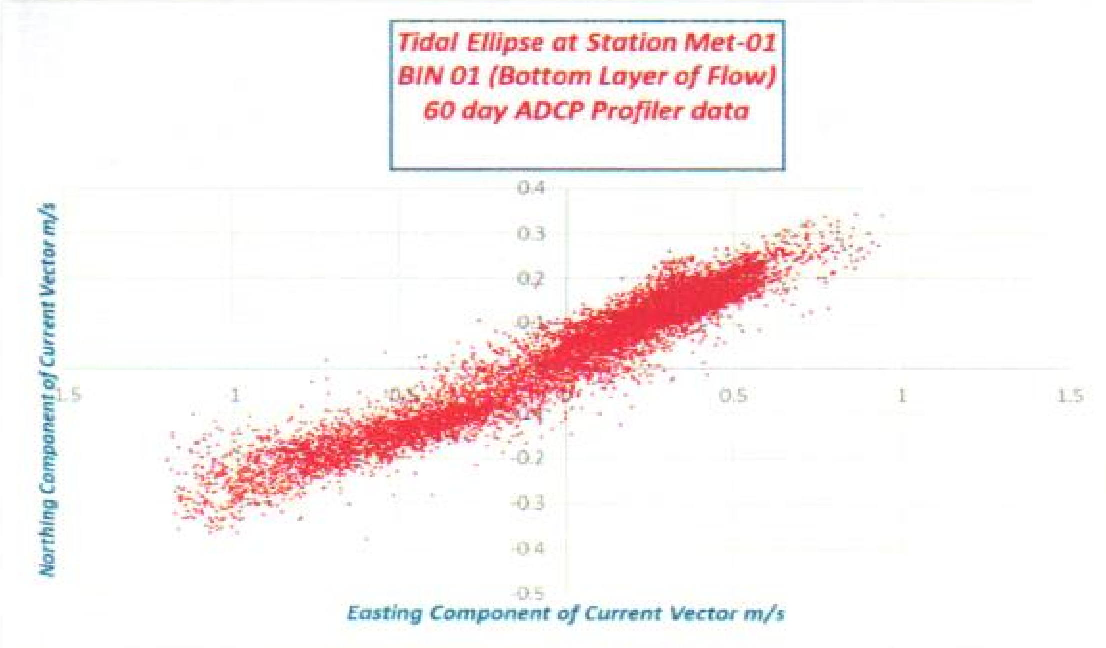


Figure 16 showing Top Middle and Bottom layers of tidal flow at Met 1 to 4

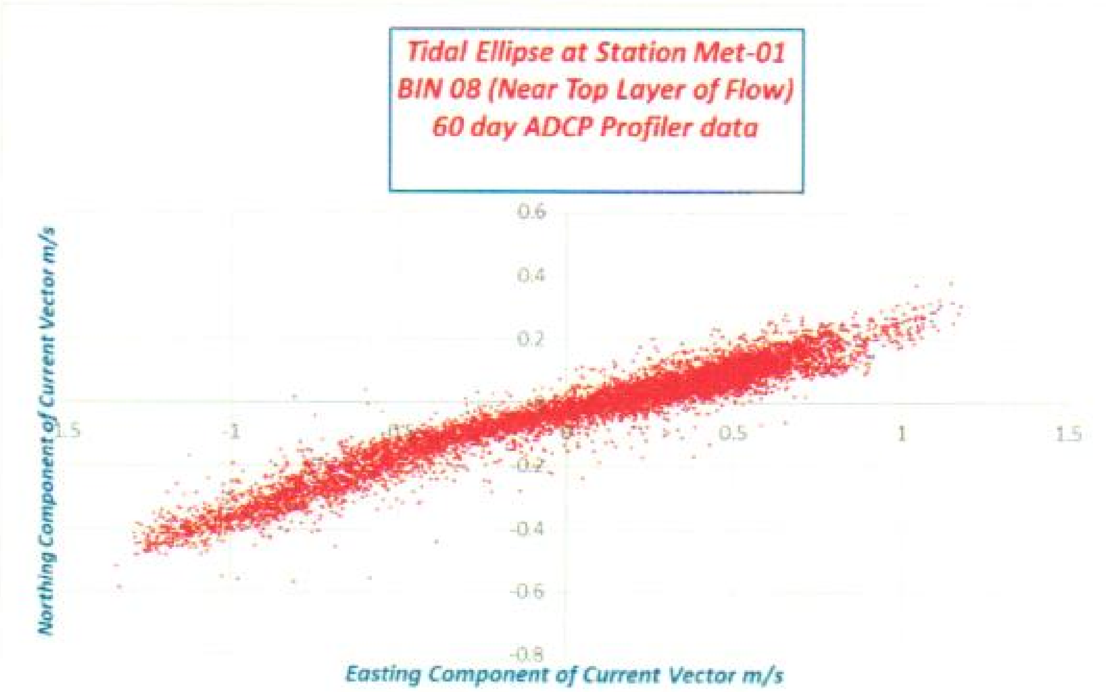


Figure 17 showing Top Middle and Bottom layers of tidal flow at Met 1 to 4

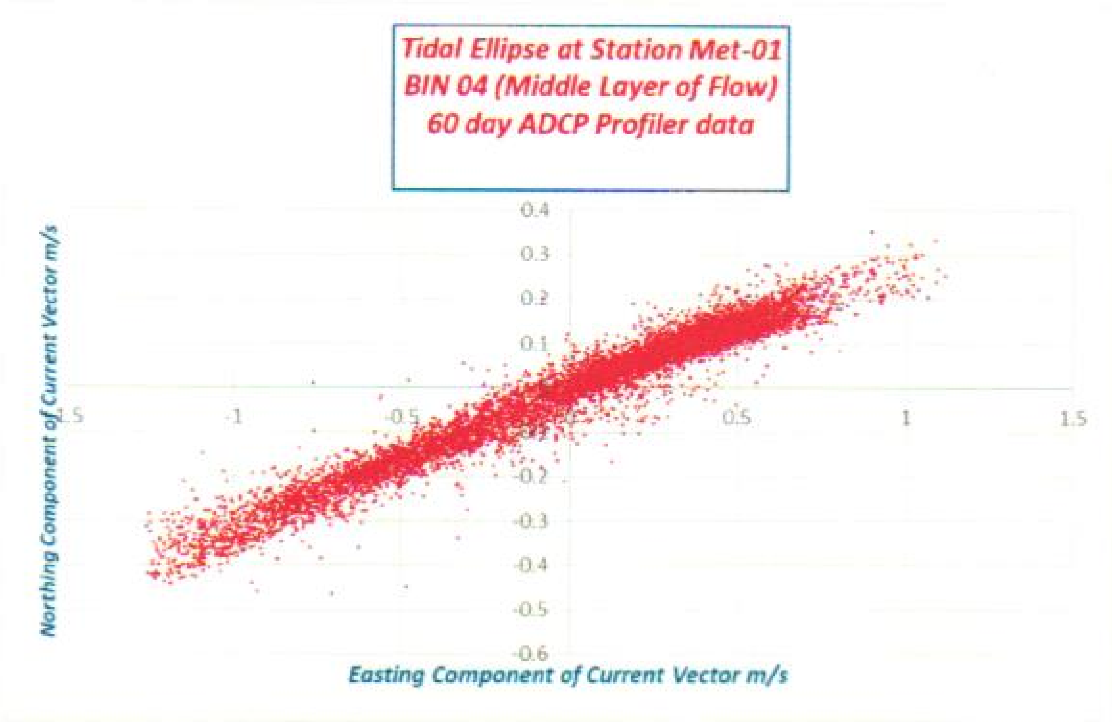


Figure 18 showing Top Middle and Bottom layers of tidal flow at Met 1 to 4

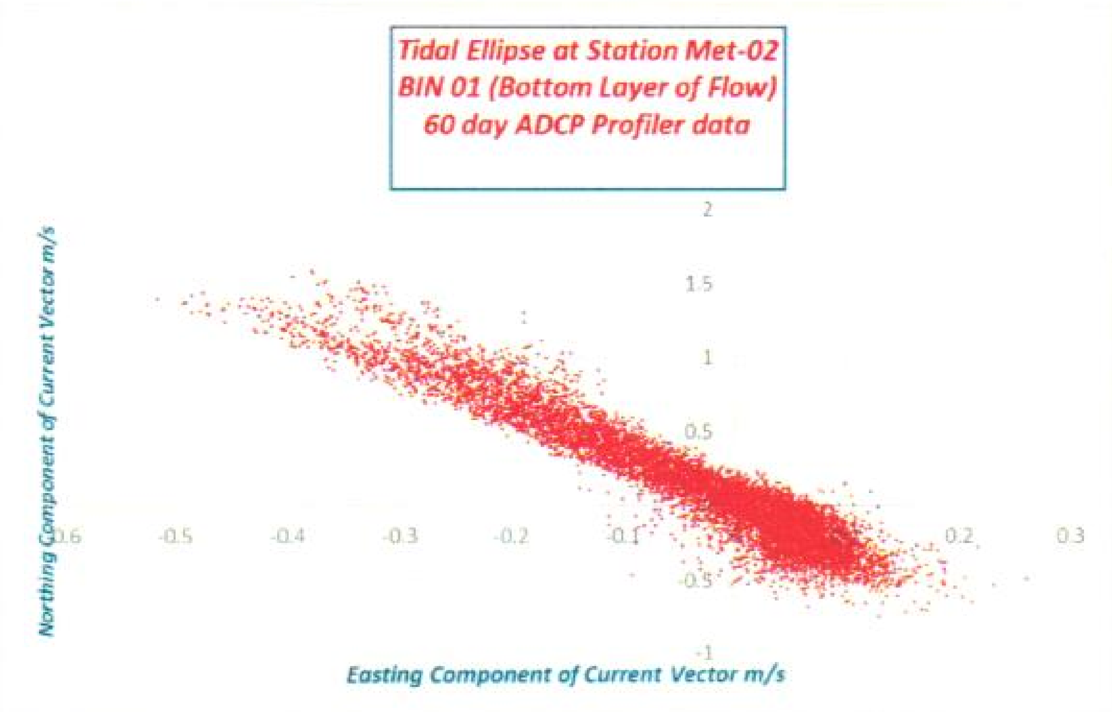


Figure 19 showing Top Middle and Bottom layers of tidal flow at Met 1 to 4

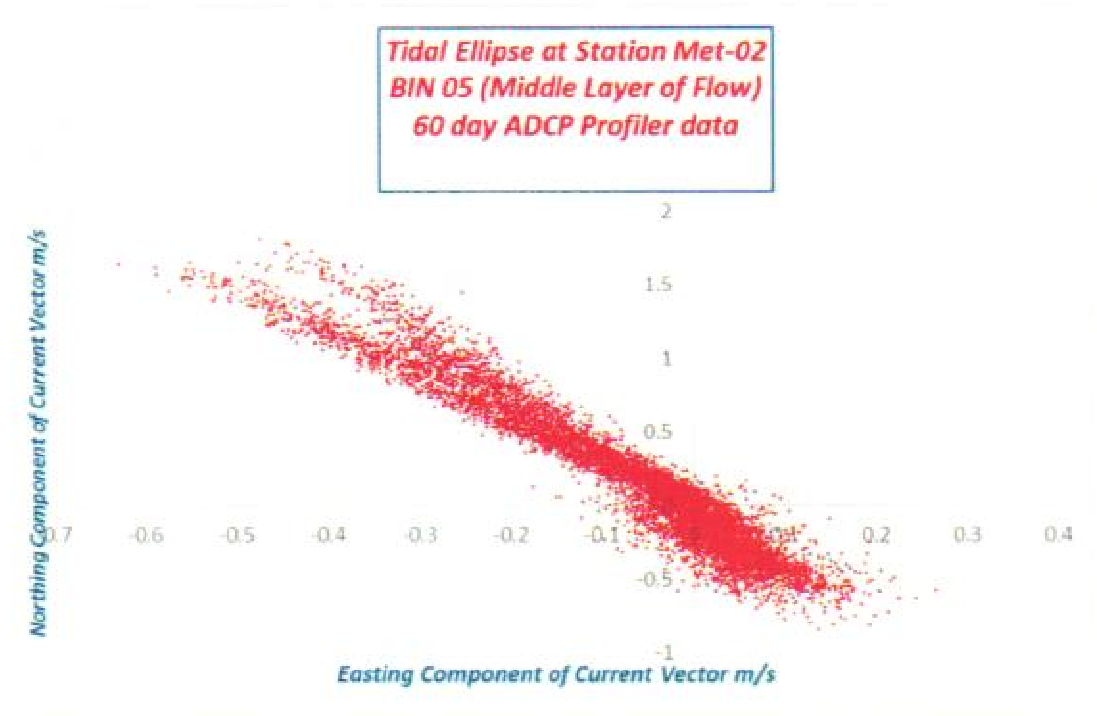


Figure 20 showing Top Middle and Bottom layers of tidal flow at Met 1 to 4

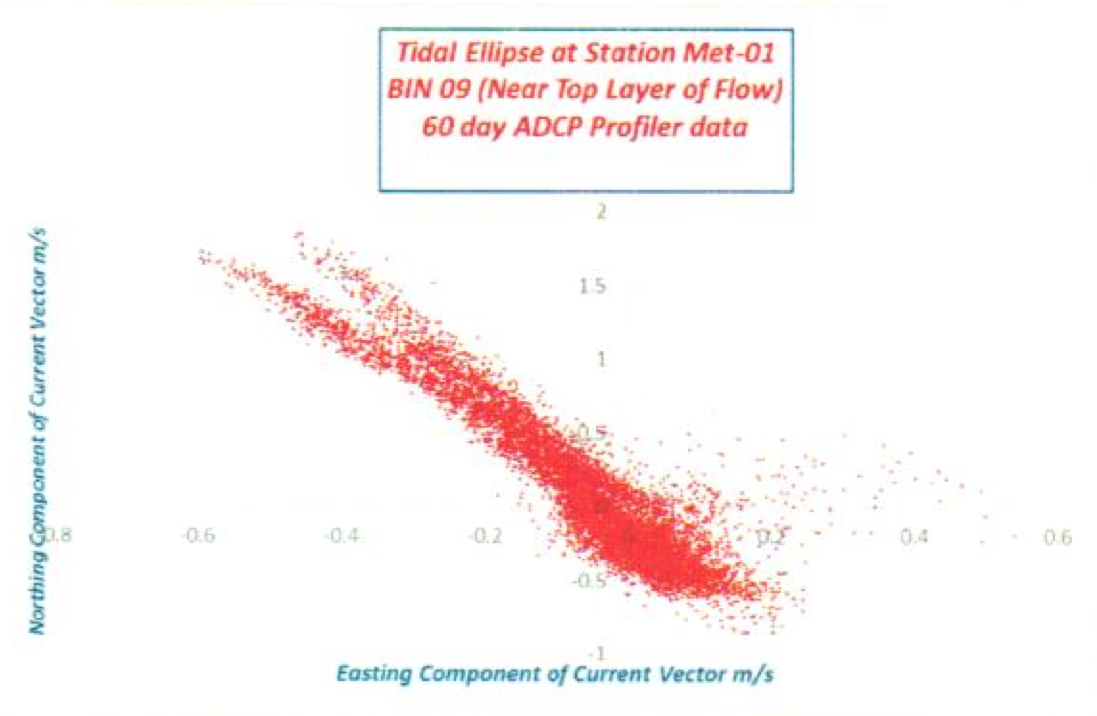


Figure 21 showing Top Middle and Bottom layers of tidal flow at Met 1 to 4

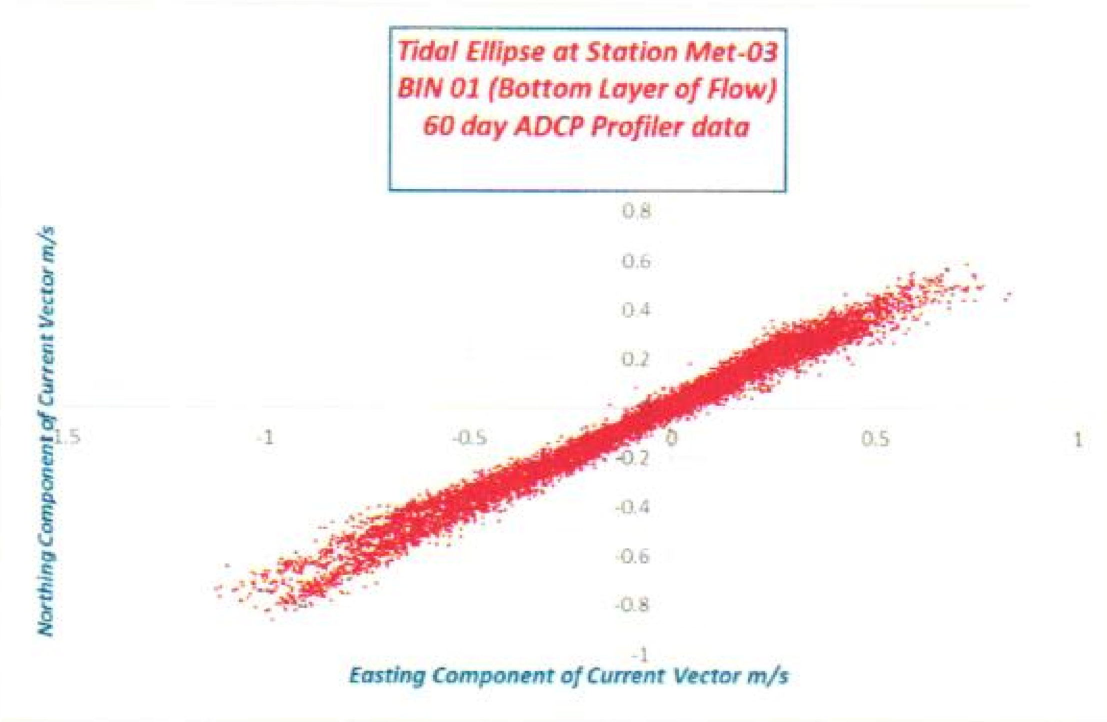


Figure 22 showing Top Middle and Bottom layers of tidal flow at Met 1 to 4

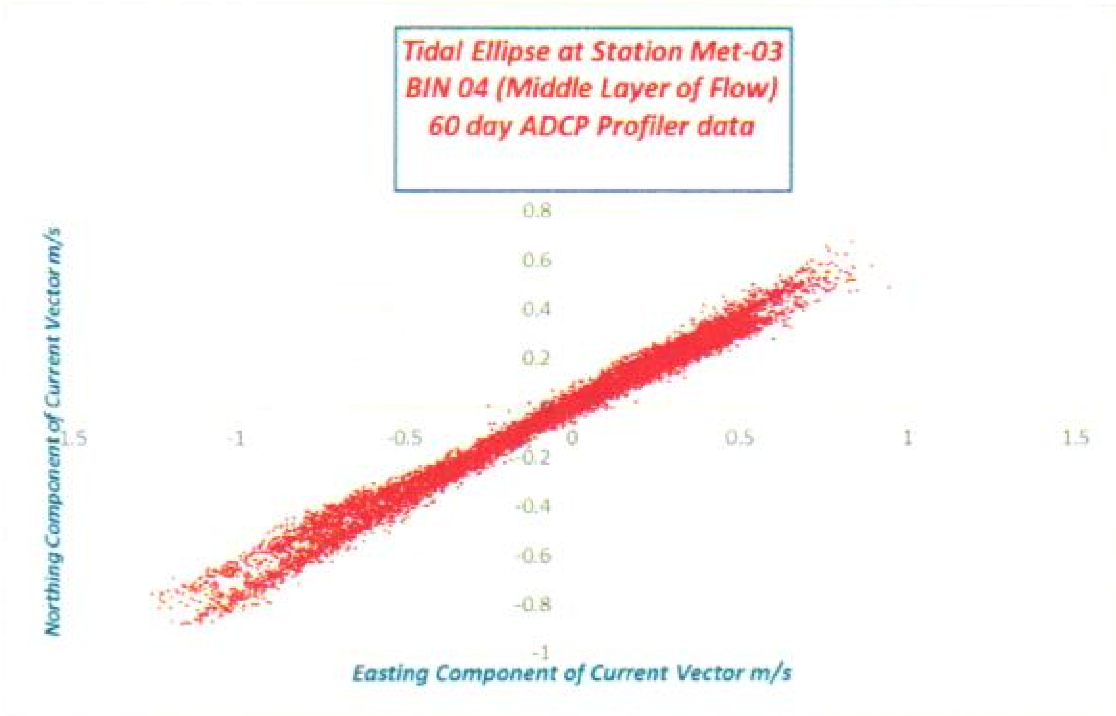


Figure 23 showing Top Middle and Bottom layers of tidal flow at Met 1 to 4

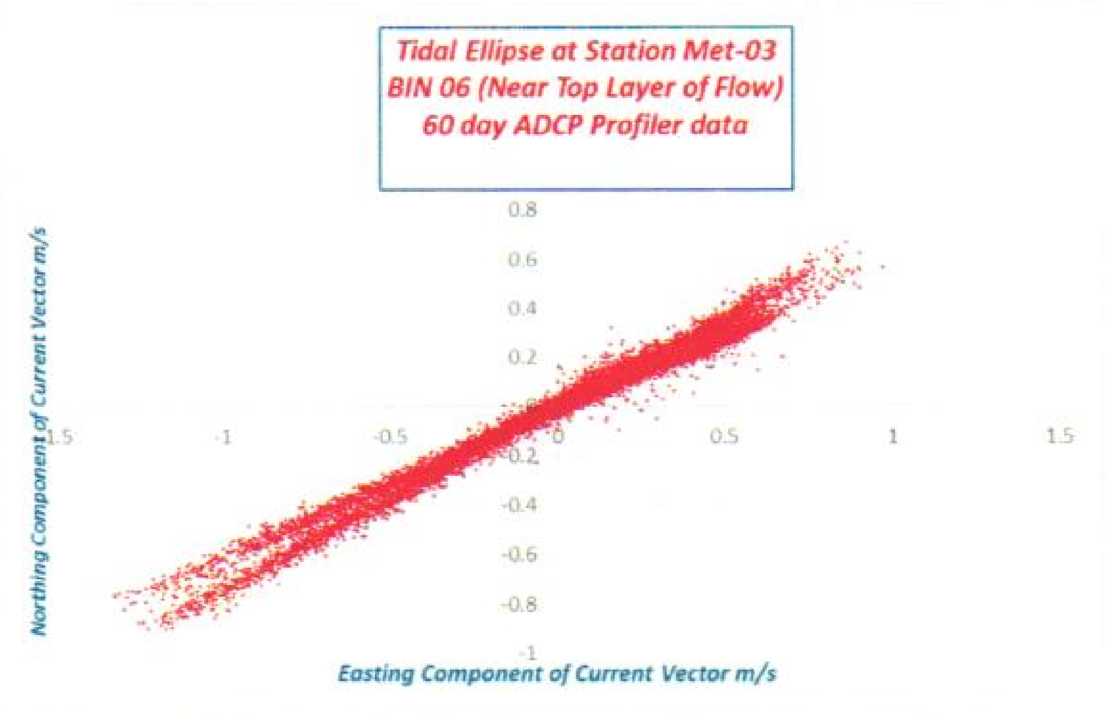


Figure 24 showing Top Middle and Bottom layers of tidal flow at Met 1 to 4

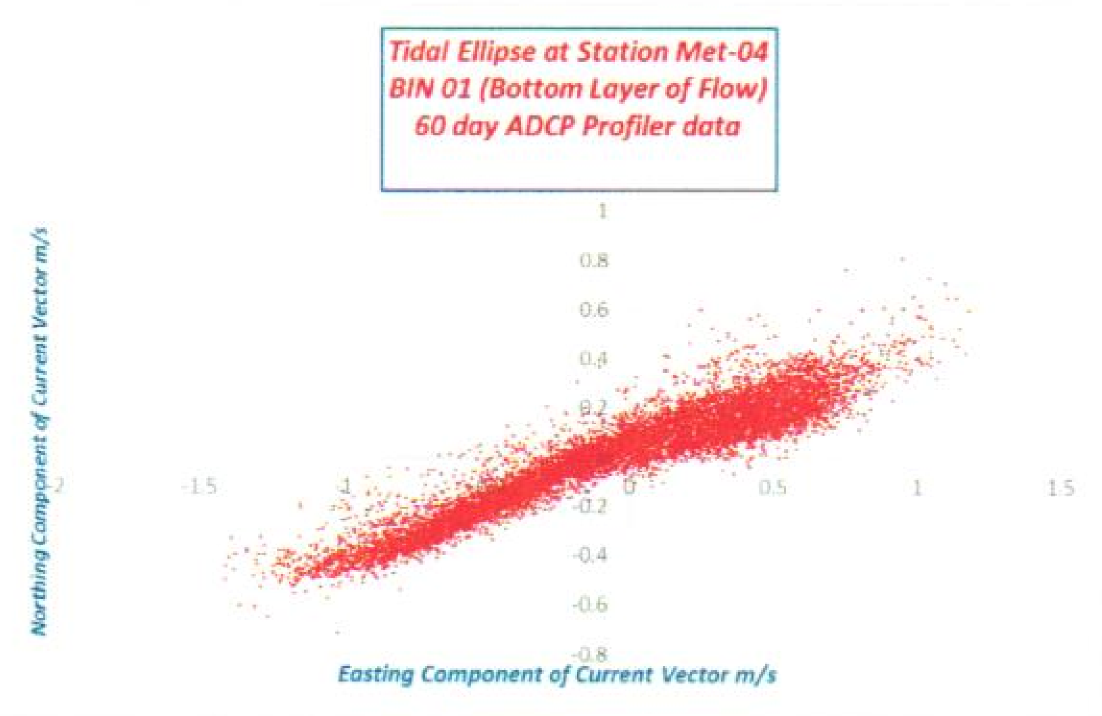


Figure 25 showing Top Middle and Bottom layers of tidal flow at Met 1 to 4

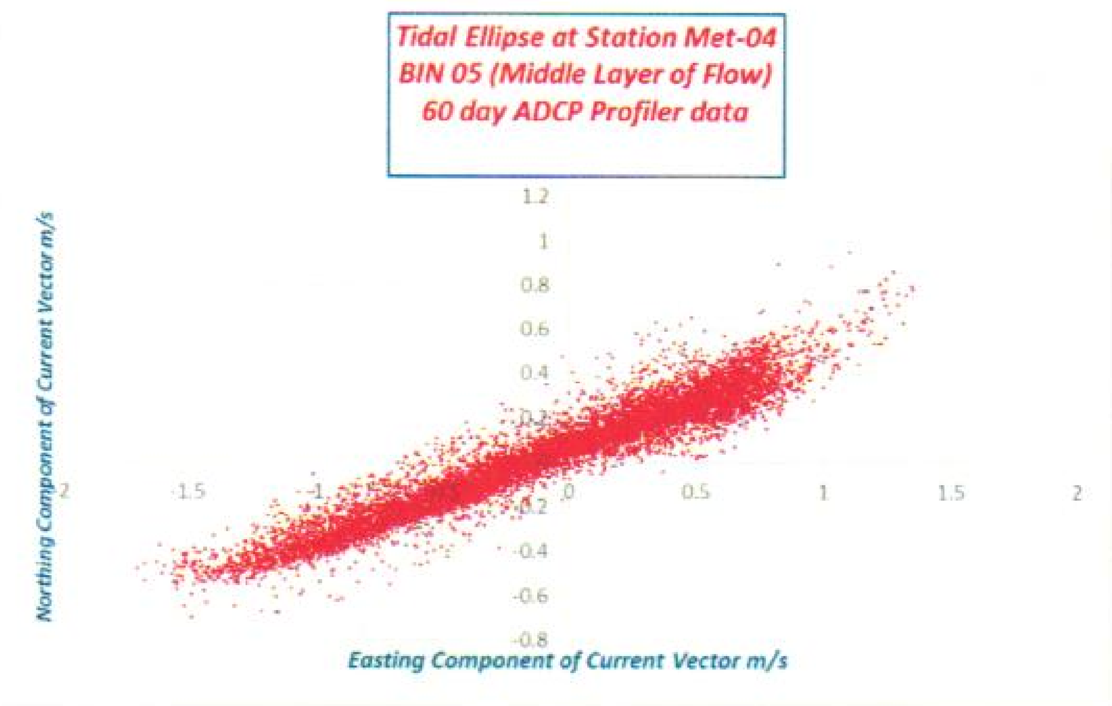
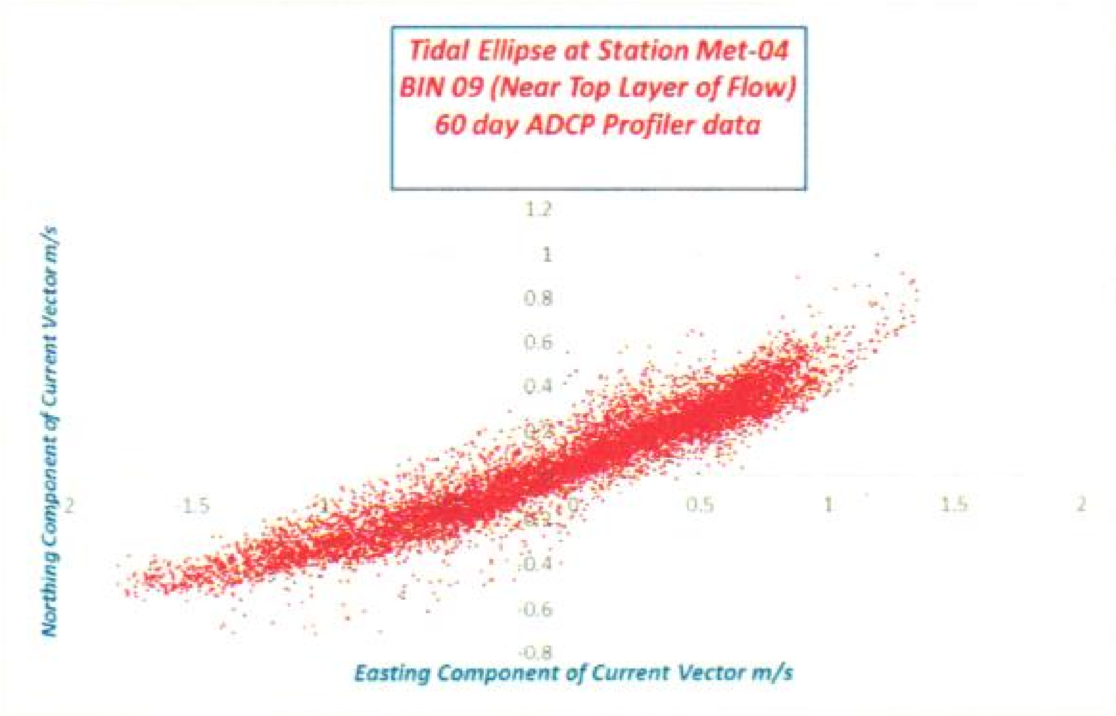


Figure 26 showing Top Middle and Bottom layers of tidal flow at Met 1 to 4



Statistical Analysis of Current Data

Current roses for Met 1 to 4 supported by frequency and magnitude distribution tables are given below:

Figure 27 showing current roses calculated for Met 1 to 4

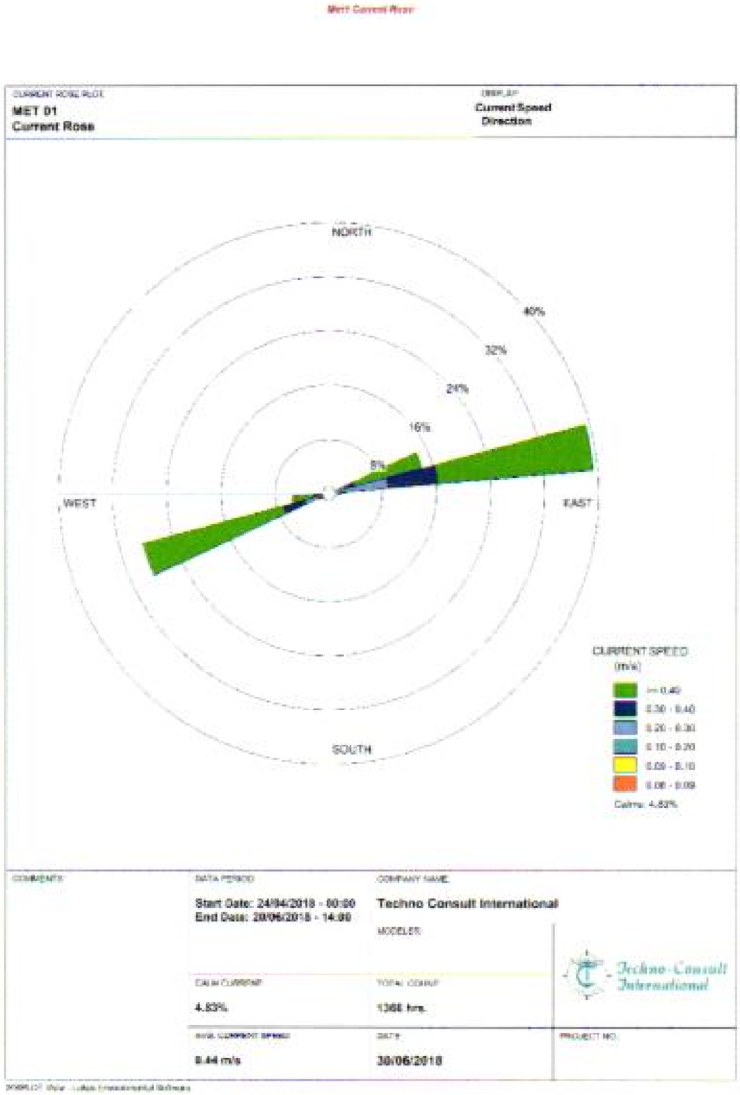


Figure 28 showing current roses calculated for Met 1 to 4

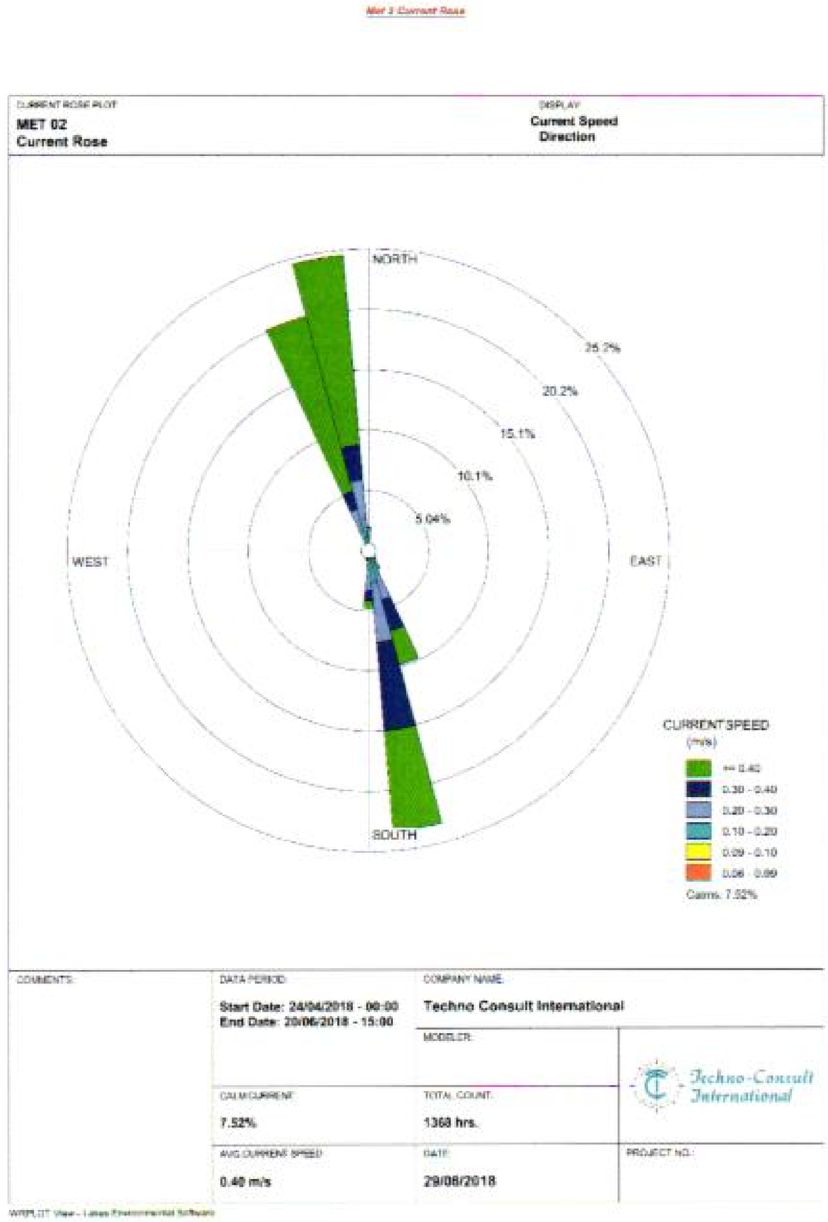
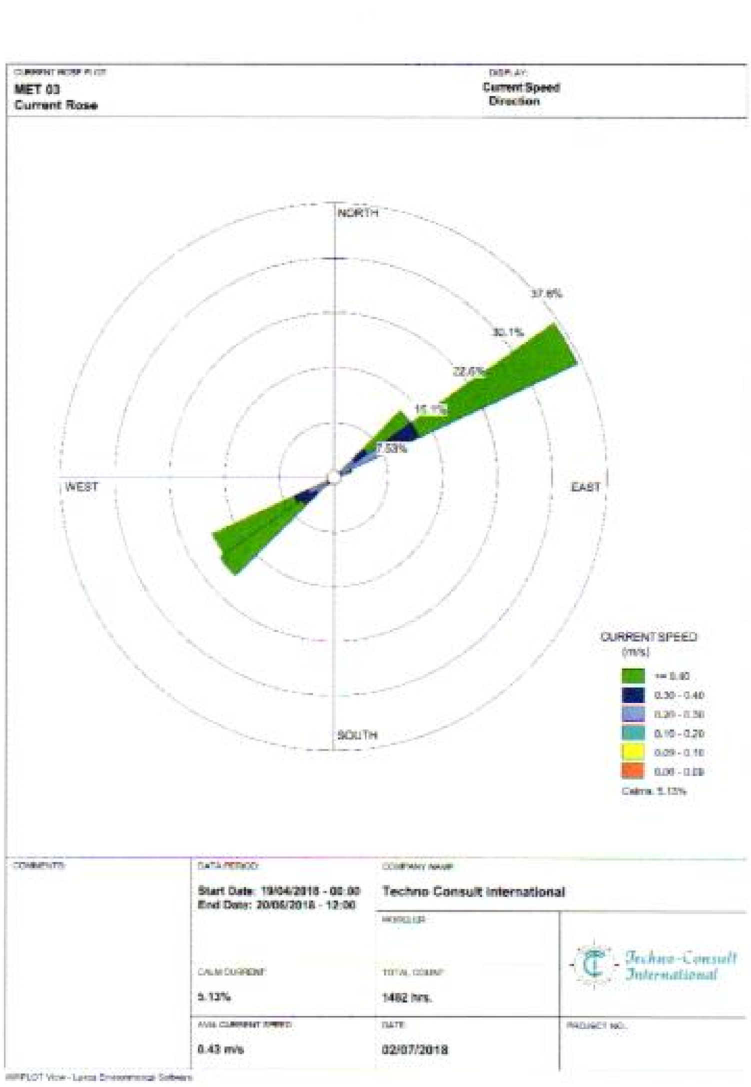


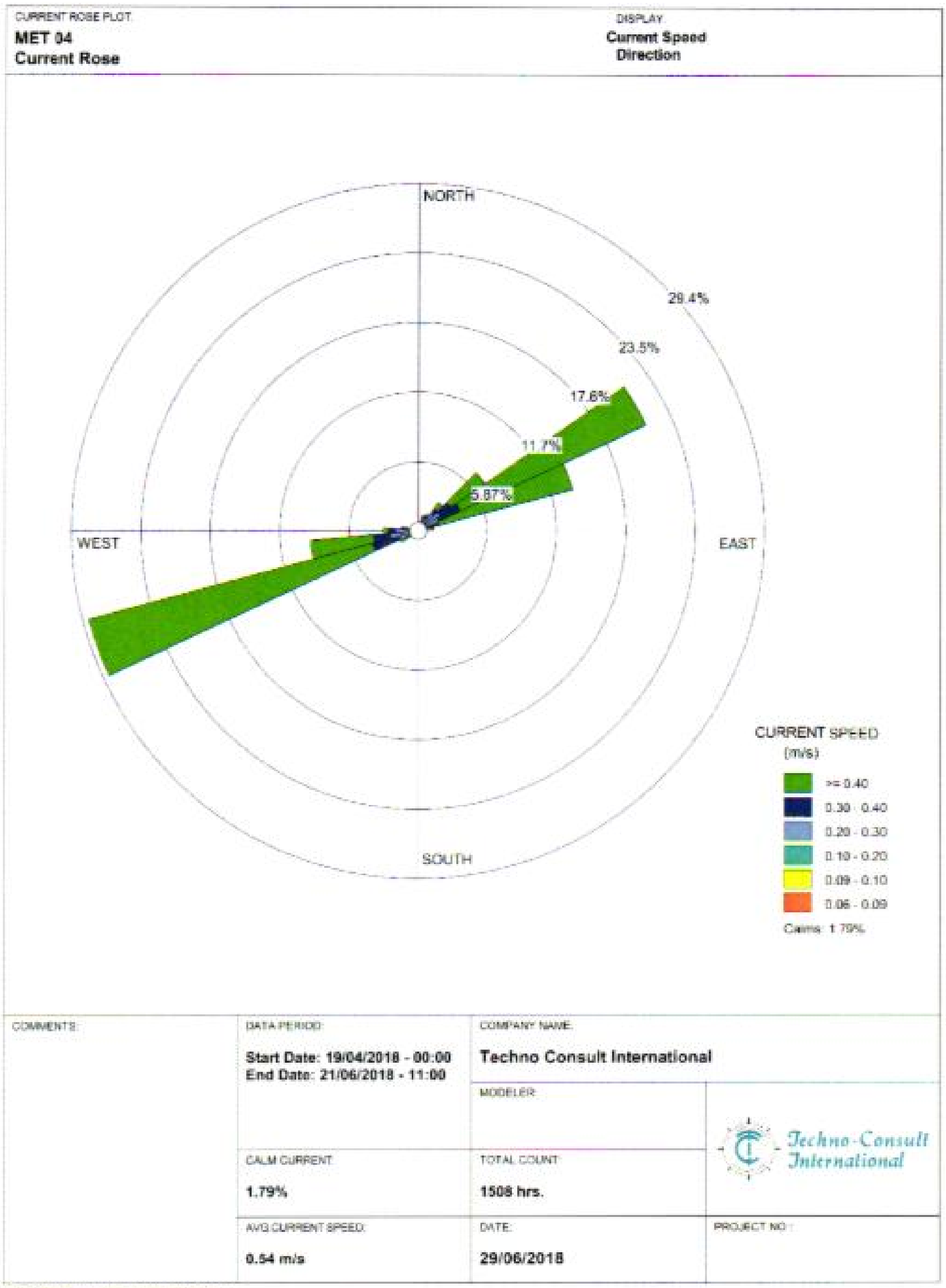
Figure 29 showing current roses calculated for Met 1 to 4



427

Figure 30 showing current roses calculated for Met 1 to 4

Met4 Current Rose



WRPLOT View - Lakes Environmental Software

Table 20 showing Current Frequency Distribution and Count values for Met 1 to 4

Met 01 Current Frequency Distribution Count Plot

Station ID: 1
Run ID: met1
Start Date: 24/04/2018 - 00:00
End Date: 20/06/2018 - 14:00

Frequency Distribution
(Normalised)

Speed m/s

Current Direction	0.00 - 0.05	0.05 - 0.10	0.10 - 0.20	0.20 - 0.30	0.30 - 0.40	>= 0.40	Total
355.00 - 5.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5.00 - 15.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
15.00 - 25.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
25.00 - 35.00	0.000000	0.000000	0.000732	0.000000	0.000000	0.000000	0.000732
35.00 - 45.00	0.000000	0.000000	0.000732	0.000732	0.000000	0.000000	0.001463
45.00 - 55.00	0.000000	0.000000	0.001463	0.000000	0.000732	0.000000	0.002195
55.00 - 65.00	0.000000	0.000000	0.003658	0.001463	0.003658	0.000732	0.009510
65.00 - 75.00	0.000000	0.000000	0.013168	0.009510	0.015362	0.104609	0.142648
75.00 - 85.00	0.000000	0.000000	0.032919	0.055596	0.073884	0.229700	0.392099
85.00 - 95.00	0.000000	0.000000	0.011704	0.002926	0.002195	0.000732	0.017557
95.00 - 105.00	0.000000	0.000000	0.003658	0.000000	0.001463	0.000732	0.005852
105.00 - 115.00	0.000000	0.000000	0.000732	0.000000	0.000000	0.000000	0.000732
115.00 - 125.00	0.000000	0.000000	0.000000	0.000732	0.000000	0.000000	0.000732
125.00 - 135.00	0.000000	0.000000	0.000732	0.000000	0.000000	0.000000	0.000732
135.00 - 145.00	0.000000	0.000000	0.000732	0.000000	0.000000	0.000000	0.000732
145.00 - 155.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
155.00 - 165.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
165.00 - 175.00	0.000000	0.000000	0.000732	0.000000	0.000000	0.000000	0.000732
175.00 - 185.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
185.00 - 195.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
195.00 - 205.00	0.000000	0.000000	0.001463	0.000732	0.000000	0.000000	0.002195
205.00 - 215.00	0.000000	0.000000	0.000732	0.000000	0.000000	0.000000	0.000732
215.00 - 225.00	0.000000	0.000000	0.002926	0.000732	0.000000	0.000000	0.003658
225.00 - 235.00	0.000000	0.000000	0.008047	0.002195	0.000000	0.000000	0.010241
235.00 - 245.00	0.000000	0.000000	0.008778	0.003658	0.000000	0.003658	0.016094
245.00 - 255.00	0.000000	0.000000	0.014631	0.021946	0.070227	0.207022	0.284565
255.00 - 265.00	0.000000	0.000000	0.006584	0.003658	0.010241	0.032919	0.053401
265.00 - 275.00	0.000000	0.000000	0.001463	0.000000	0.000000	0.000732	0.002195
275.00 - 285.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
285.00 - 295.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
295.00 - 305.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
305.00 - 315.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
315.00 - 325.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
325.00 - 335.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
335.00 - 345.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
345.00 - 355.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sub-Total:	0.000000	0.000000	0.115582	0.106072	0.141185	0.588149	0.950988
Calms:							0.048281
Missing/Incomplete:							0.000732
Total:							1.000000

Met 01 Current Count Distribution Plot -Normalized

Station ID: 1
Run ID: met1
Start Date: 24/04/2018 - 00:00
End Date: 20/06/2018 - 14:00

Frequency Distribution
(Count)

Speed m/s

Current Direction	0.00 - 0.05	0.05 - 0.10	0.10 - 0.20	0.20 - 0.30	0.30 - 0.40	>= 0.40	Total
355.00 - 5.00	0	0	0	0	0	0	0
5.00 - 15.00	0	0	0	0	0	0	0
15.00 - 25.00	0	0	0	0	0	0	0
25.00 - 35.00	0	0	1	0	0	0	1
35.00 - 45.00	0	0	1	1	0	0	2
45.00 - 55.00	0	0	2	0	1	0	3
55.00 - 65.00	0	0	5	2	5	1	13
65.00 - 75.00	0	0	18	13	21	143	195
75.00 - 85.00	0	0	45	76	101	314	536
85.00 - 95.00	0	0	16	4	3	1	24
95.00 - 105.00	0	0	5	0	2	1	8
105.00 - 115.00	0	0	1	0	0	0	1
115.00 - 125.00	0	0	0	1	0	0	1
125.00 - 135.00	0	0	1	0	0	0	1
135.00 - 145.00	0	0	1	0	0	0	1
145.00 - 155.00	0	0	0	0	0	0	0
155.00 - 165.00	0	0	0	0	0	0	0
165.00 - 175.00	0	0	1	0	0	0	1
175.00 - 185.00	0	0	0	0	0	0	0
185.00 - 195.00	0	0	0	0	0	0	0
195.00 - 205.00	0	0	2	1	0	0	3
205.00 - 215.00	0	0	1	0	0	0	1
215.00 - 225.00	0	0	4	1	0	0	5
225.00 - 235.00	0	0	11	3	0	0	14
235.00 - 245.00	0	0	12	5	0	5	22
245.00 - 255.00	0	0	20	30	96	283	389
255.00 - 265.00	0	0	9	5	14	45	73
265.00 - 275.00	0	0	2	0	0	1	3
275.00 - 285.00	0	0	0	0	0	0	0
285.00 - 295.00	0	0	0	0	0	0	0
295.00 - 305.00	0	0	0	0	0	0	0
305.00 - 315.00	0	0	0	0	0	0	0
315.00 - 325.00	0	0	0	0	0	0	0
325.00 - 335.00	0	0	0	0	0	0	0
335.00 - 345.00	0	0	0	0	0	0	0
345.00 - 355.00	0	0	0	0	0	0	0
Sub-Total:	0	0	158	145	193	804	1300
Calms:							66
Missing/Incomplete:							1
Total:							1367

Table 21 showing Current Frequency Distribution and Count values for Met 1 to 4

Met 02 Current Frequency Distribution Count Plot

Station ID: 2
Run ID: met2

Frequency Distribution
(Count)

Speed m/s

Current Direction	0.06 - 0.09	0.09 - 0.10	0.10 - 0.20	0.20 - 0.30	0.30 - 0.40	>= 0.40	Total
355.00 - 5.00	0	0	19	7	1	0	27
5.00 - 15.00	0	0	7	0	0	0	7
15.00 - 25.00	0	0	3	0	0	0	3
25.00 - 35.00	0	0	1	0	0	0	1
35.00 - 45.00	0	0	1	0	0	0	1
45.00 - 55.00	0	0	3	0	0	0	3
55.00 - 65.00	0	0	1	0	0	0	1
65.00 - 75.00	0	0	2	0	0	0	2
75.00 - 85.00	0	0	0	0	0	0	0
85.00 - 95.00	0	0	0	0	0	0	0
95.00 - 105.00	0	0	0	0	0	0	0
105.00 - 115.00	0	0	1	0	0	0	1
115.00 - 125.00	0	0	1	0	0	0	1
125.00 - 135.00	0	0	5	0	0	0	5
135.00 - 145.00	0	0	11	1	0	0	12
145.00 - 155.00	0	0	15	8	0	0	23
155.00 - 165.00	0	0	78	30	17	40	165
165.00 - 175.00	0	0	78	63	102	115	322
175.00 - 185.00	0	0	27	24	12	3	66
185.00 - 195.00	0	0	5	5	2	0	12
195.00 - 205.00	0	0	10	0	0	0	10
205.00 - 215.00	0	0	1	0	0	0	1
215.00 - 225.00	0	0	1	0	0	0	1
225.00 - 235.00	0	0	0	0	0	0	0
235.00 - 245.00	0	0	0	0	0	0	0
245.00 - 255.00	0	0	0	0	0	0	0
255.00 - 265.00	0	0	0	0	0	0	0
265.00 - 275.00	0	0	0	0	0	0	0
275.00 - 285.00	0	0	0	0	0	0	0
285.00 - 295.00	0	0	1	0	0	0	1
295.00 - 305.00	0	0	0	0	0	0	0
305.00 - 315.00	0	0	0	0	0	0	0
315.00 - 325.00	0	0	5	0	0	0	5
325.00 - 335.00	0	0	8	0	0	0	9
335.00 - 345.00	0	0	27	28	21	201	277
345.00 - 355.00	0	0	35	48	40	217	338
Sub-Total:	0	0	249	214	217	558	1565
Calms:							103
Missing/Incomplete:							1
Total:							1669

Average Current Speed: 0.32 m/s

Met 02 Current Frequency Distribution Plot -Normalized

Station ID: 2
Run ID: met2

Frequency Distribution
(Normalized)

Speed m/s

Current Direction	0.06 - 0.09	0.09 - 0.10	0.10 - 0.20	0.20 - 0.30	0.30 - 0.40	>= 0.40	Total
355.00 - 5.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
5.00 - 15.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
15.00 - 25.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25.00 - 35.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
35.00 - 45.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
45.00 - 55.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
55.00 - 65.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
65.00 - 75.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
75.00 - 85.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
85.00 - 95.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
95.00 - 105.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
105.00 - 115.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
115.00 - 125.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
125.00 - 135.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
135.00 - 145.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
145.00 - 155.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
155.00 - 165.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
165.00 - 175.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
175.00 - 185.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
185.00 - 195.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
195.00 - 205.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
205.00 - 215.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
215.00 - 225.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
225.00 - 235.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
235.00 - 245.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
245.00 - 255.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
255.00 - 265.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
265.00 - 275.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
275.00 - 285.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
285.00 - 295.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
295.00 - 305.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
305.00 - 315.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
315.00 - 325.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
325.00 - 335.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
335.00 - 345.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
345.00 - 355.00	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sub-Total:	0.000000	0.000000	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Calms:							[illegible]
Missing/Incomplete:							[illegible]
Total:							1.000000

Average Current Speed: [illegible] m/s

930

Table 22 showing Current Frequency Distribution and Count values for Met 1 to 4

Met 03 Frequency Distribution Count Plot

Station ID: 3
Run: [illegible]
Start Date: 19/04/2018 - 00:00
End Date: 20/04/2018 - [illegible]

Frequency Distribution
(Count)

Speed m/s

Current Direction	0.06 - 0.09	0.09 - 0.10	0.10 - 0.20	0.20 - 0.30	0.30 - 0.40	> 0.40	Total
355.00 - 5.00	0	0	0	0	0	0	0
5.00 - 15.00	0	0	0	0	0	0	0
15.00 - 25.00	0	0	1	0	0	0	1
25.00 - 35.00	0	0	1	0	0	0	1
35.00 - 45.00	0	0	4	1	1	0	6
45.00 - 55.00	0	0	17	35	31	109	192
55.00 - 65.00	0	0	37	73	83	354	547
65.00 - 75.00	0	0	19	15	2	1	37
75.00 - 85.00	0	0	12	0	0	0	12
85.00 - 95.00	0	0	0	0	0	0	0
95.00 - 105.00	0	0	0	0	0	0	0
105.00 - 115.00	0	0	1	0	0	0	1
115.00 - 125.00	0	0	0	0	0	0	0
125.00 - 135.00	0	0	0	0	0	0	0
135.00 - 145.00	0	0	0	0	0	0	0
145.00 - 155.00	0	0	0	0	0	0	0
155.00 - 165.00	0	0	0	0	0	0	0
165.00 - 175.00	0	0	0	0	0	0	0
175.00 - 185.00	0	0	0	0	0	0	0
185.00 - 195.00	0	0	2	0	0	0	2
195.00 - 205.00	0	0	0	0	0	0	0
205.00 - 215.00	0	0	9	2	0	0	11
215.00 - 225.00	0	0	11	4	3	2	20
225.00 - 235.00	0	0	17	28	36	203	284
235.00 - 245.00	0	0	30	28	32	183	273
245.00 - 255.00	0	0	12	1	0	0	13
255.00 - 265.00	0	0	3	0	0	0	3
265.00 - 275.00	0	0	1	0	0	0	1
275.00 - 285.00	0	0	0	0	0	0	0
285.00 - 295.00	0	0	2	0	0	0	2
295.00 - 305.00	0	0	0	0	0	0	0
305.00 - 315.00	0	0	0	0	0	0	0
315.00 - 325.00	0	0	0	0	0	0	0
325.00 - 335.00	0	0	0	0	0	0	0
335.00 - 345.00	0	0	0	0	0	0	0
345.00 - 355.00	0	0	0	0	0	0	0
Sub-Total:	0	0	179	187	188	852	1406
Calms:							76
Missing/Incomplete:							0
Total:							1482

Met 03 Frequency Distribution Plot- Normalized

Station ID: 3
Run: [illegible]
Start Date: 19/04/2018 - 00:00
End Date: 20/05/2018 - 17:00

Frequency Distribution
(Normalized)

Speed m/s

Current Direction	0.06 - 0.09	0.09 - 0.10	0.10 - 0.20	0.20 - 0.30	0.30 - 0.40	> 0.40	Total
355.00 - 5.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5.00 - 15.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
15.00 - 25.00	0.000000	0.000000	0.000675	0.000000	0.000000	0.000000	0.000675
25.00 - 35.00	0.000000	0.000000	0.000675	0.000000	0.000000	0.000000	0.000675
35.00 - 45.00	0.000000	0.000000	0.002699	0.000675	0.000675	0.000000	0.004049
45.00 - 55.00	0.000000	0.000000	0.011471	0.023617	0.020918	0.073549	0.129555
55.00 - 65.00	0.000000	0.000000	0.024966	0.049258	0.056005	0.238866	0.369096
65.00 - 75.00	0.000000	0.000000	0.012821	0.010121	0.001350	0.000675	0.024966
75.00 - 85.00	0.000000	0.000000	0.008097	0.000000	0.000000	0.000000	0.008097
85.00 - 95.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
95.00 - 105.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
105.00 - 115.00	0.000000	0.000000	0.000675	0.000000	0.000000	0.000000	0.000675
115.00 - 125.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
125.00 - 135.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
135.00 - 145.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
145.00 - 155.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
155.00 - 165.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
165.00 - 175.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
175.00 - 185.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
185.00 - 195.00	0.000000	0.000000	0.001350	0.000000	0.000000	0.000000	0.001350
195.00 - 205.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
205.00 - 215.00	0.000000	0.000000	0.006073	0.001350	0.000000	0.000000	0.007422
215.00 - 225.00	0.000000	0.000000	0.007422	0.002699	0.002024	0.001350	0.013495
225.00 - 235.00	0.000000	0.000000	0.011471	0.018893	0.024291	0.136977	0.191633
235.00 - 245.00	0.000000	0.000000	0.020243	0.018893	0.021592	0.123482	0.184211
245.00 - 255.00	0.000000	0.000000	0.008097	0.000675	0.000000	0.000000	0.008772
255.00 - 265.00	0.000000	0.000000	0.002024	0.000000	0.000000	0.000000	0.002024
265.00 - 275.00	0.000000	0.000000	0.000675	0.000000	0.000000	0.000000	0.000675
275.00 - 285.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
285.00 - 295.00	0.000000	0.000000	0.001350	0.000000	0.000000	0.000000	0.001350
295.00 - 305.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
305.00 - 315.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
315.00 - 325.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
325.00 - 335.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
335.00 - 345.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
345.00 - 355.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sub-Total:	0.000000	0.000000	0.120783	0.126181	0.126856	0.574899	0.948718
Calms:							0.051282
Missing/Incomplete:							0.000000
Total:							1.000000

Table 23 showing Current Frequency Distribution and Count values for Met 1 to 4

Met04 Current Frequency Distribution Count Plot
Run ID: Met4

Station ID: 4
Start Date: 19/04/2018 - 00:00
End Date: 21/04/2018 - 11:00

Frequency Distribution
(Count)

Speed m/s

Current Direction	0.06 - 0.09	0.09 - 0.10	0.10 - 0.20	0.20 - 0.30	0.30 - 0.40	>= 0.40	Total
355.00 - 5.00	0	0	6	1	0	0	7
5.00 - 15.00	0	0	5	5	0	0	10
15.00 - 25.00	0	0	12	3	3	2	20
25.00 - 35.00	0	0	13	5	3	3	24
35.00 - 45.00	0	0	13	14	8	9	44
45.00 - 55.00	0	0	5	29	17	54	105
55.00 - 65.00	0	0	6	23	31	260	320
65.00 - 75.00	0	0	6	[illegible]	14	171	204
75.00 - 85.00	0	0	1	2	5	12	20
85.00 - 95.00	0	0	1	1	0	1	3
95.00 - 105.00	0	0	0	0	0	0	0
105.00 - 115.00	0	0	0	0	0	0	0
115.00 - 125.00	0	0	1	0	0	0	1
125.00 - 135.00	0	0	0	0	0	0	0
135.00 - 145.00	0	0	0	0	0	0	0
145.00 - 155.00	0	0	0	0	0	0	0
155.00 - 165.00	0	0	0	0	0	0	0
165.00 - 175.00	0	0	1	0	0	0	1
175.00 - 185.00	0	0	0	0	0	0	0
185.00 - 195.00	0	0	0	0	0	0	0
195.00 - 205.00	0	0	0	0	0	0	0
205.00 - 215.00	0	0	2	0	0	0	2
215.00 - 225.00	0	0	1	1	0	1	3
225.00 - 235.00	0	0	0	3	3	3	9
235.00 - 245.00	0	0	2	2	3	18	25
245.00 - 255.00	0	0	3	17	34	374	434
255.00 - 265.00	0	0	12	24	21	81	138
265.00 - 275.00	0	0	15	14	9	1	44
275.00 - 285.00	0	0	3	7	2	4	23
285.00 - 295.00	0	0	6	1	1	0	8
295.00 - 305.00	0	0	7	0	0	0	7
305.00 - 315.00	0	0	4	1	2	0	7
315.00 - 325.00	0	0	6	1	0	0	7
325.00 - 335.00	0	0	5	0	0	0	5
335.00 - 345.00	0	0	5	0	0	0	5
345.00 - 355.00	0	0	6	1	0	0	7
Sub-Total:	0	0	158	167	155	1006	1487
Calms:							27
Missing/Incomplete:							1
Total:							1505

Average Current Speed: 0.34 m/s

Met4 Current Frequency Distribution Plot -Normalized
Run ID: Met4

Station ID: 4
Start Date: 19/04/2018 - 00:00
End Date: 21/04/2018 - 11:00

Frequency Distribution
(Normalized)

Speed m/s

Current Direction	0.06 - 0.09	0.09 - 0.10	0.10 - 0.20	0.20 - 0.30	0.30 - 0.40	>= 0.40	Total
355.00 - 5.00	0.000000	0.000000	0.003976	0.000663	0.000000	0.000000	0.004639
5.00 - 15.00	0.000000	0.000000	0.003313	0.003313	0.000000	0.000000	0.006627
15.00 - 25.00	0.000000	0.000000	0.007952	0.001988	0.001988	0.001325	0.013254
25.00 - 35.00	0.000000	0.000000	0.008615	0.003313	0.001988	0.001988	0.015905
35.00 - 45.00	0.000000	0.000000	0.008615	0.009278	0.005302	0.005964	0.029158
45.00 - 55.00	0.000000	0.000000	0.003313	0.019218	0.011266	0.035785	0.069583
55.00 - 65.00	0.000000	0.000000	0.003976	0.015242	0.020543	0.172300	0.212061
65.00 - 75.00	0.000000	0.000000	0.003976	0.008615	0.009278	0.113320	0.135189
75.00 - 85.00	0.000000	0.000000	0.000663	0.001325	0.003313	0.007952	0.013254
85.00 - 95.00	0.000000	0.000000	0.000663	0.000663	0.000000	0.000663	0.001988
95.00 - 105.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
105.00 - 115.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
115.00 - 125.00	0.000000	0.000000	0.000663	0.000000	0.000000	0.000000	0.000663
125.00 - 135.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
135.00 - 145.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
145.00 - 155.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
155.00 - 165.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
165.00 - 175.00	0.000000	0.000000	0.000663	0.000000	0.000000	0.000000	0.000663
175.00 - 185.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
185.00 - 195.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
195.00 - 205.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
205.00 - 215.00	0.000000	0.000000	0.001325	0.000000	0.000000	0.000000	0.001325
215.00 - 225.00	0.000000	0.000000	0.000663	0.000663	0.000000	0.000663	0.001988
225.00 - 235.00	0.000000	0.000000	0.000000	0.001988	0.001988	0.001988	0.005964
235.00 - 245.00	0.000000	0.000000	0.001325	0.001325	0.001988	0.011928	0.016567
245.00 - 255.00	0.000000	0.000000	0.001988	0.011266	0.022531	0.247846	0.287608
255.00 - 265.00	0.000000	0.000000	0.007952	0.015905	0.013917	0.053678	0.091451
265.00 - 275.00	0.000000	0.000000	0.009940	0.009278	0.005302	0.004613	0.029128
275.00 - 285.00	0.000000	0.000000	0.001988	0.004639	0.001325	0.002651	0.015242
285.00 - 295.00	0.000000	0.000000	0.003976	0.000663	0.000663	0.000000	0.005302
295.00 - 305.00	0.000000	0.000000	0.004639	0.000000	0.000000	0.000000	0.004639
305.00 - 315.00	0.000000	0.000000	0.002651	0.000663	0.001325	0.000000	0.004639
315.00 - 325.00	0.000000	0.000000	0.003976	0.000663	0.000000	0.000000	0.004639
325.00 - 335.00	0.000000	0.000000	0.003313	0.000000	0.000000	0.000000	0.003313
335.00 - 345.00	0.000000	0.000000	0.003313	0.000000	0.000000	0.000000	0.003313
345.00 - 355.00	0.000000	0.000000	0.003976	0.000663	0.000000	0.000000	0.004639
Sub-Total:	0.000000	0.000000	0.104705	0.110656	0.102717	0.666667	0.982445
Calms:							0.017893
Missing/Incomplete:							0.000663
Total:							1.000000

Average Current Speed: 0.34 m/s

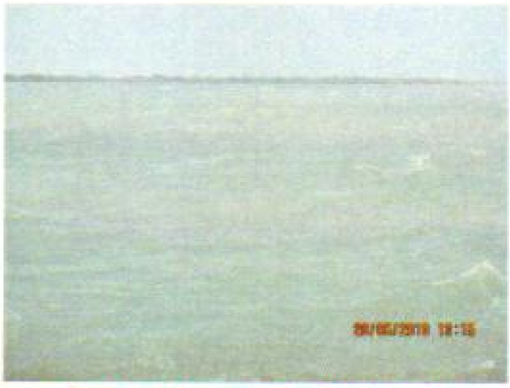
9.7 Concluding remarks / Summary

The site for LNG terminal in Chan Waddo Creek is at the confluence of two creeks.

Port Qasim tide is considered as ebb dominated tide with diurnal in-equality. This means there are two high and low waters in a tidal cycle.

The ebbing from Chan Waddo Creek and Jharri Creek results in mixing of return tidal flows from two creeks and as such presents with turbulent water conditions at the confluence.

Evidence of this can be seen by observing the presence of a deep swatch in the bathymetry of the near site area. The depth at swatch goes upto to 40 m.



Small crested waves in Chan Waddo creeks

There is also potential of wind shear on the surface currents. The Chan Waddo Creek especially at the entrance is oriented the predominant SW direction which is same direction for prevailing winds during monsoon period. This means that wind is in same direction as the creek flows. This has some effect on local waves as during ebbing conditions the wind blowing from opposite side can interact with the current leading to choppy conditions.

Table 24 showing current minima and maxima values

FIRST BATCH DEPLOYMENT FROM 24/04/2018 TO 22/05/2018								
PARAMETER	MET 01		MET 02		MET 03		MET 04	
	Min	Max	Min	Max	Min	Max	Min	Max
Mean Speed (m/s)	0.002	1.292	0.002	1.699	0.001	1.444	0.006	1.637

SECOND BATCH DEPLOYMENT FROM 22/05/2018 TO 20/06/2018								
PARAMETER	MET 01		MET 02		MET 03		MET 04	
	Min	Max	Min	Max	Min	Max	Min	Max
Mean Speed (m/s)	0.001	1.297	0.001	1.720	0.002	1.411	0.006	1.657

Refer to A3 sheets of current data in Appendix A (actual printout of data)
ADCP Current Measurements

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10.0 WAVE OBSERVATION CAMPAIGN (Met 1 to 4)

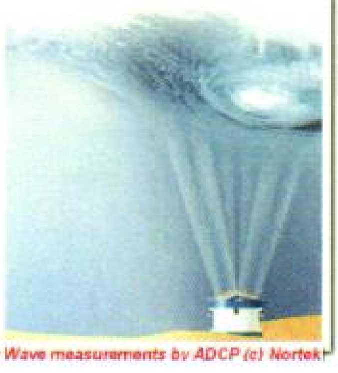
10.1 General

It has been well established that waves transmit energy not water mass across ocean surface. Water does not move but energy does. The speed of wave transmission is dependent on its wave length. Longer wave length move/transmit energy faster as compared to shorter wavelengths. Also longer period waves carry higher energy levels than short crested ones.

Wave generation and propagation are complex processes and statistics play an important role in the description of the wave climate in a given coastal location. A simple way to define a sea state is to mention its 'significant wave height Hs' which is defined as the average of the one third highest waves of that sea state.

As per international practice, design of coastal structures is based on the principle of 'accepting a certain level of damage to the structure, for a certain probability of occurrence of the waves'. One could indeed accept a lot of damage for a very rare event, or very little damage for a more frequent event. For modern coastal structures, it is usually accepted to have very little damage for a one in hundred year's storm event. Thus, significant wave height "Hs" for one in hundred years is sought for the design of marine structures.

Wave height is often the most significant factor influencing a project. Designing with a wave height that is overly conservative can greatly increase the cost of a project and may make it uneconomical.

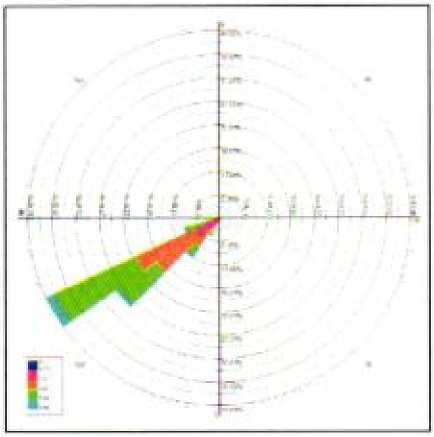

Wave measurements by ADCP (c) Nortek

In this report we have presented the significant wave heights and periods as recorded by the instruments.

The equipment was programmed for sampling and recording of wave series at waves bursts of given specifications. In this case, a regular interval of one second over 20 minutes continuously, every 60 minutes. See section on methodology later in this proposal for more details and specimen data plots.

Location for wave measurement equipment was determined so as to assess impact of small crested waves generated as a result of fetch available (approx. 10 kms) particularly in the stretches SW of the terminal as the Chan Waddo creek is more or less parallel to the predominant wind direction which is Southwesterly.

The wave observation reveals a wave spectrum for the deployed location. Although impact of waves at site were more prominent in the predominant season of the year i.e. SW Monsoon, during other months it will give an idea of small crested waves that are generated by the fetch available in Chan Waddo creek i.e. from entrance to Chan Waddo Creek to the site.



In addition to all original measured wave data from wave observation equipment, data presented included significant waves heights, significant wave periods, directions, H1/10.

The collected raw data series downloaded from wave recorder was examined for quality control and error checking. Necessary flags in the wave data recording system were enabled such that Wave height, frequency and direction are read and recorded as per the specs of JGC.

10.2 Scope and Specifications

Post processing of wave data was made to extract technical wave parameters to include:

- Maximum wave & Period (Hmax, Tmax)
- Wave direction (degrees North)
- Significant Wave height & Periods (H1/3, T1/3)
- Mean wave heights and Periods (Hmean, Tmean).

Diver Ops for Deployment & Retrieval

10.3 Location plan with WGS 84 and UTM Co-ord.

As per JGC requirement, the location plan of deployment for wave equipment was same as ADCP current measurement stations as the same ADCP recorder also acquired wave data.

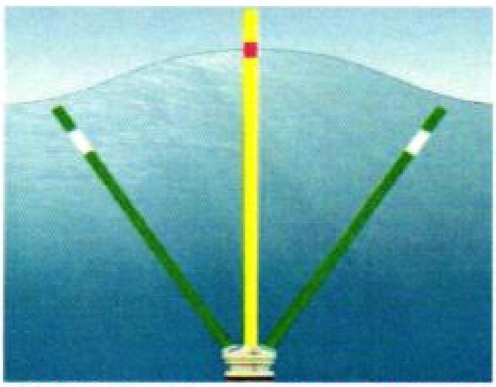
Diver being readied for deployment dive

10.4 ADCP programming parameters (wave burst, significant ht, H 1/10, period etc, ensemble, Ping rate, interval, 2 hz freq)

Table 25 showing Parameters for ADCP Wave Observation

Bottom Mounted ADCP		**Station**	
Start		1	30 Days
End			-do-
Accuracy			1-2 cm/s
Ensemble interval			60 min
Ping rate			2 Hz
Pings per ensemble			60
Burst for directional spectra	Interval		1 hour
	Duration		20 minutes
	Ping rate		2 Hz

Batch 1 ADCP for Wave and Current Observations



ADCP Surface Tracking beams (c) Nortek

10.5 Deployment summary (start & end periods of the two time deployments)

Table 26 of deployment summaries for wave observation equipment

First Batch 30 Days							
S-NO.	Loction	Equipment	Equipment Serial number	Date Deployed	Date Retrieved	Northing (UTM 42)	Easting (UTM 42)
1	MET-3	ADCP RDI	12434	19-04-18	24-05-18	320693	2736225
2	MET-4	ADCP RDI	10907	19-04-18	22-05-18	314172	2731432
3	MET-1	ADCP RDI	12854	24-04-18	22-05-18	319237	2735189
4	MET-2	ADCP RDI	10903	24-04-18	22-05-18	320726	2734790
Second Batch							
S-NO.	Loction	Equipment	Equipment Serial number	Date Deployed	Date Retrieved	Northing (UTM 42)	Easting (UTM 42)
1	MET-3	ADCP V sentinal	144	24-05-18	20-06-18	320693	2736225
2	MET-4	ADCP V sentinal	118	22-05-18	21-06-18	314172	2731432
3	MET-1	ADCP V sentinal	119	22-05-18	20-06-18	319237	2735189
4	MET-2	ADCP V sentinal	121	22-05-18	20-06-18	320726	2734790

10.6 ADCP models and make (Workhorse and Sentinel V's) employed in data collection

The make and model of the wave recording gauges are same as ADCP based current observation equipment. As explained earlier in report, the ADCP profiler records both currents and waves within the same equipment assembly.

10.7 Plot of significant wave height time series, Wave Roses and Frequency Distribution tables

Lowering of ADCP at Met 04

Figure 31 Wave roses calculated and plotted for Met 1 to 4 stations

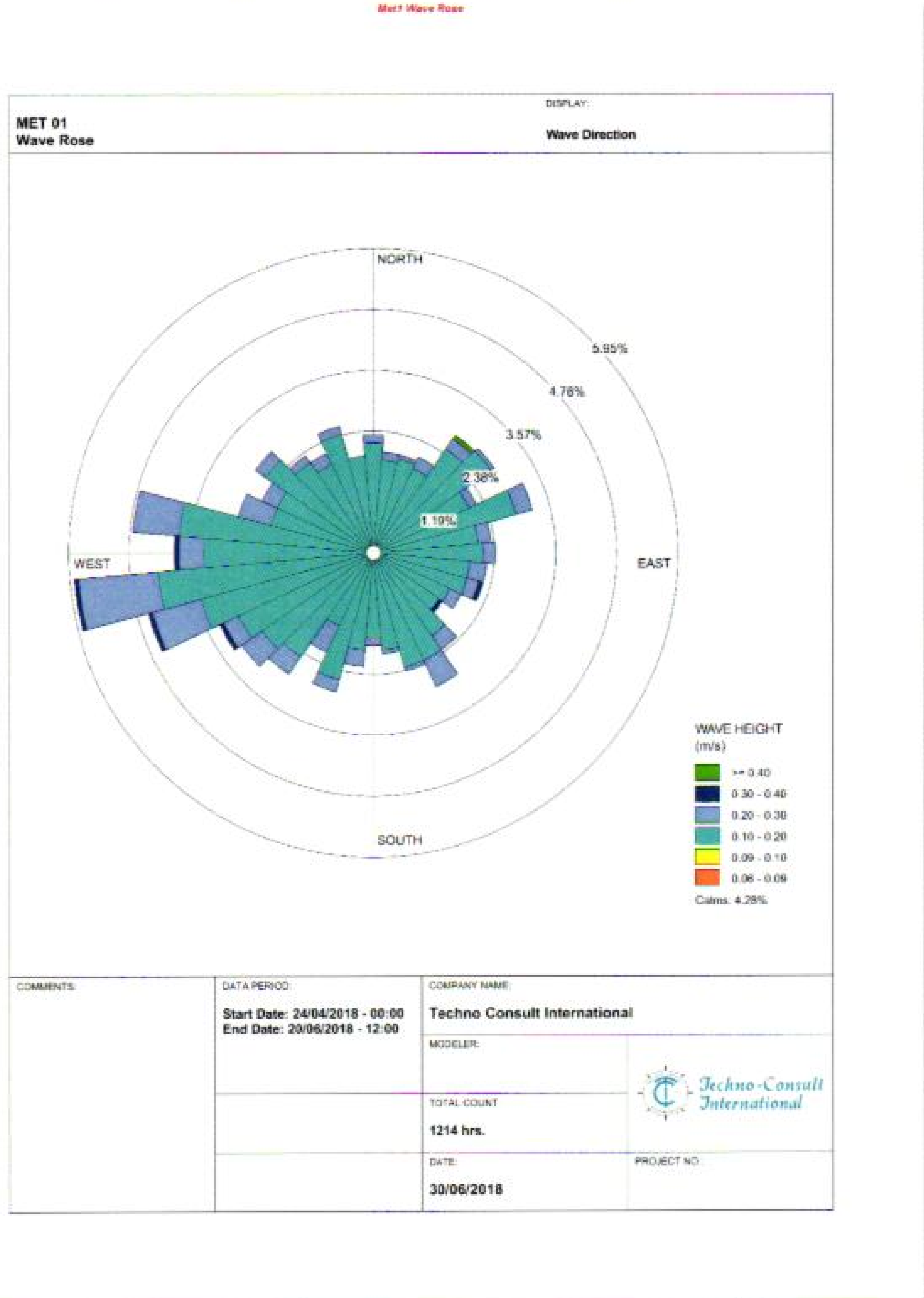


Figure 32 Wave roses calculated and plotted for Met 1 to 4 stations

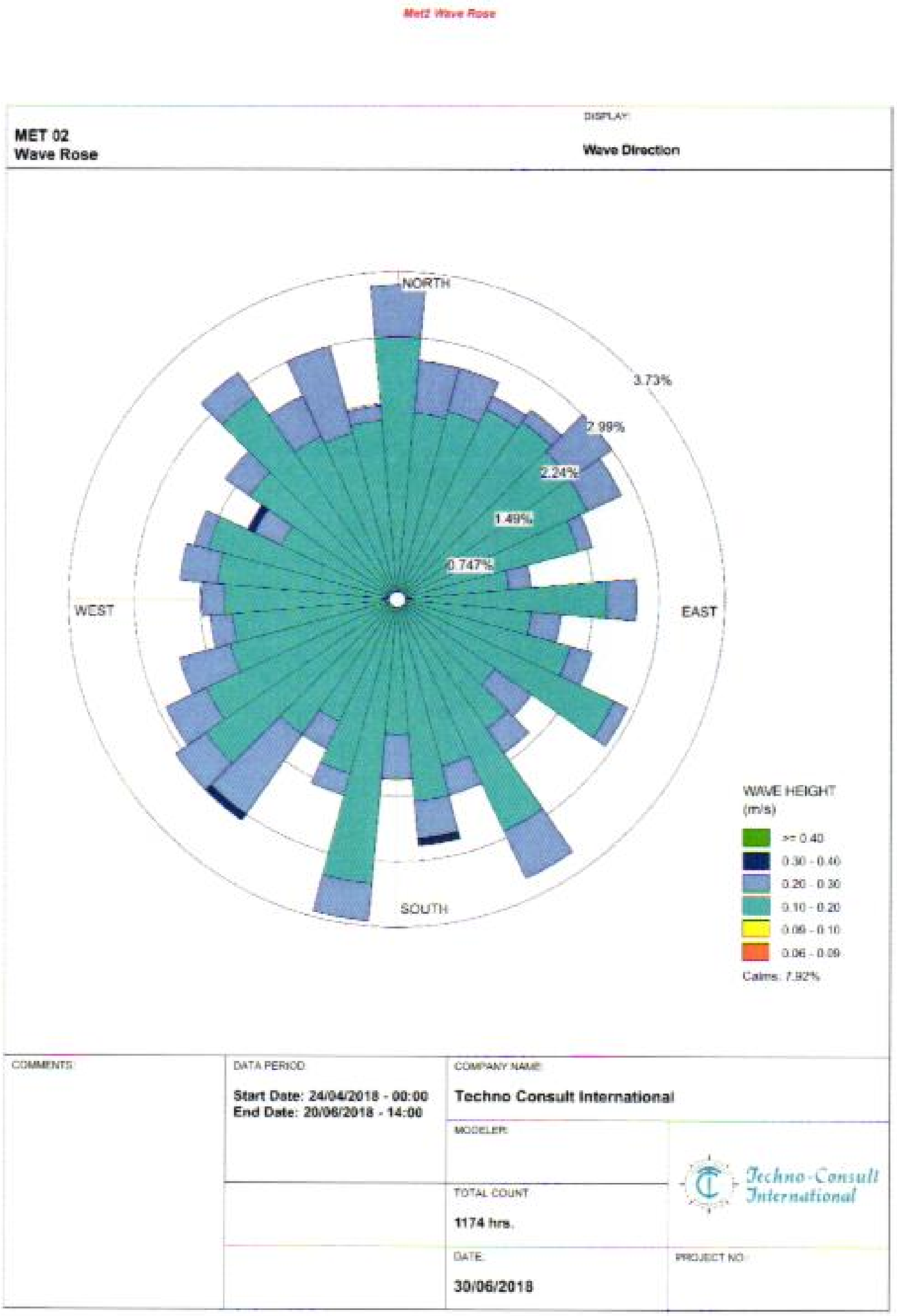
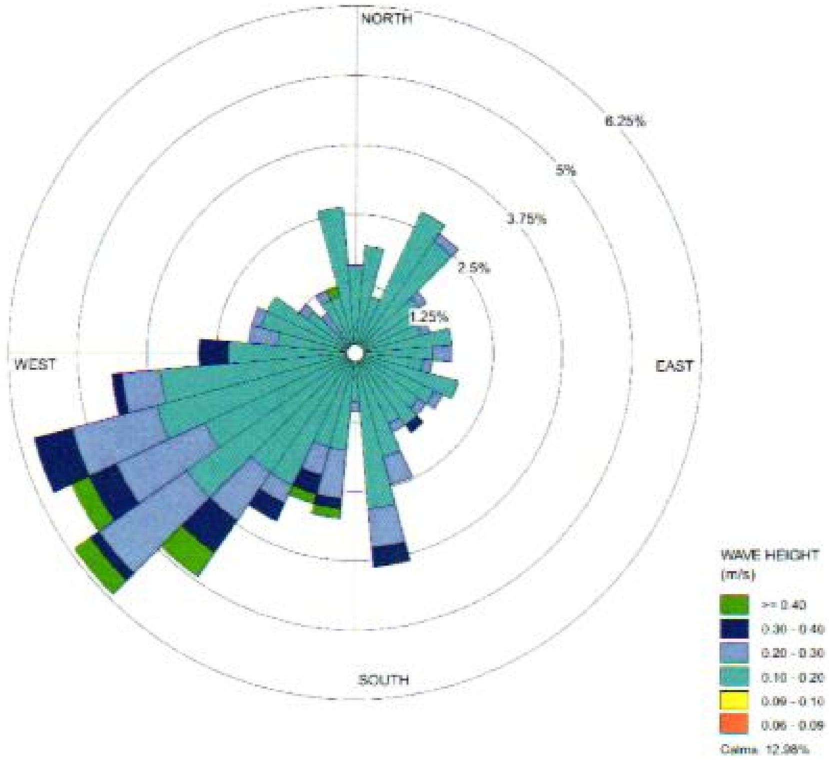


Figure 33 Wave roses calculated and plotted for Met 1 to 4 stations

Met3 Wave Rose

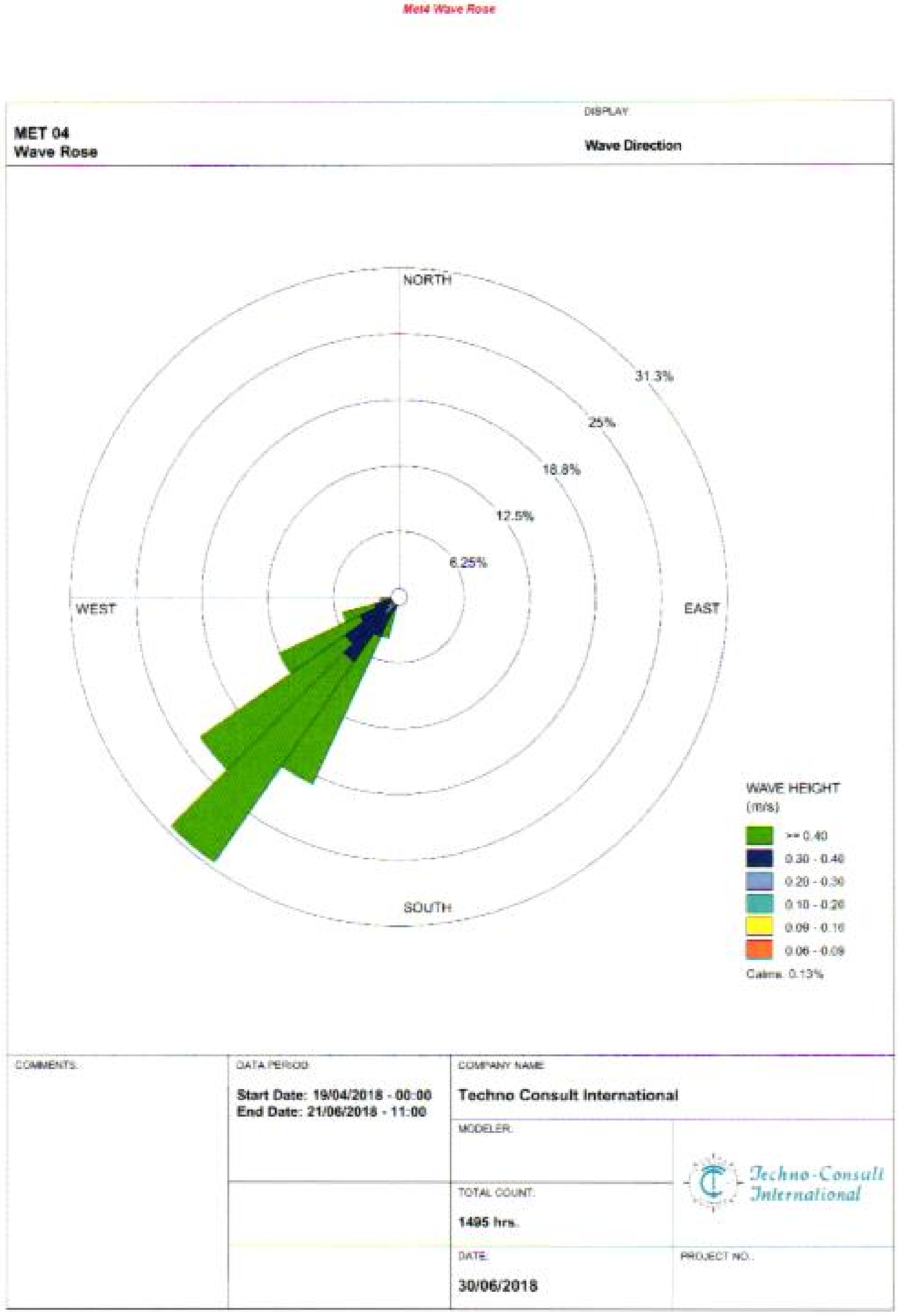
MET 03
Wave Rose

DISPLAY:
Wave Direction



COMMENTS:	DATA PERIOD: **Start Date: 24/05/2018 - 00:00** **End Date: 20/06/2018 - 12:00**	COMPANY NAME: **Techno Consult International**	
		MODELER:	
		TOTAL COUNT: **570 hrs.**	
		DATE: **30/06/2018**	PROJECT NO.:

Figure 34 Wave roses calculated and plotted for Met 1 to 4 stations



For wave data, the supporting frequency and magnitude distribution tables and counts are presented in tables below:

441

Table 27 Wave Magnitude and Direction Frequency Distribution & Count calculations

Met 01 Wave Frequency Distribution Count Plot

Station ID: 1 Run ID: met1
Start Date: 24/04/2018 - 00:00
End Date: 20/06/2018 - 12:00

Frequency Distribution
(Count)

Hs. Height (m)

Wave Direction	0.06 - 0.09	0.09 - 0.10	0.10 - 0.20	0.20 - 0.30	0.30 - 0.40	>= 0.40	Total
355.00 - 5.00	0	0	26	2	0	0	28
5.00 - 15.00	0	0	22	2	0	0	24
15.00 - 25.00	0	0	23	1	0	0	24
25.00 - 35.00	0	0	22	3	0	0	25
35.00 - 45.00	0	0	30	3	0	1	34
45.00 - 55.00	0	0	34	1	0	0	35
55.00 - 65.00	0	0	25	2	0	0	27
65.00 - 75.00	0	0	35	4	0	0	39
75.00 - 85.00	0	0	25	3	0	0	28
85.00 - 95.00	0	0	26	3	0	0	29
95.00 - 105.00	0	0	23	4	0	0	27
105.00 - 115.00	0	0	23	3	1	0	27
115.00 - 125.00	0	0	20	3	0	0	23
125.00 - 135.00	0	0	19	0	1	0	20
135.00 - 145.00	0	0	24	4	0	0	28
145.00 - 155.00	0	0	28	7	0	0	35
155.00 - 165.00	0	0	28	1	0	0	29
165.00 - 175.00	0	0	23	1	0	0	24
175.00 - 185.00	0	0	20	2	0	0	22
185.00 - 195.00	0	0	23	4	0	0	27
195.00 - 205.00	0	0	31	3	0	0	34
205.00 - 215.00	0	0	19	7	0	0	26
215.00 - 225.00	0	0	30	5	0	0	35
225.00 - 235.00	0	0	32	6	0	0	38
235.00 - 245.00	0	0	35	4	1	0	40
245.00 - 255.00	0	0	42	12	1	0	55
255.00 - 265.00	0	0	51	19	1	0	71
265.00 - 275.00	0	0	40	6	1	0	47
275.00 - 285.00	0	0	46	11	0	0	57
285.00 - 295.00	0	0	25	8	0	0	33
295.00 - 305.00	0	0	25	4	0	0	29
305.00 - 315.00	0	0	31	3	0	0	34
315.00 - 325.00	0	0	26	2	0	0	28
325.00 - 335.00	0	0	23	3	0	0	26
335.00 - 345.00	0	0	29	2	0	0	31
345.00 - 355.00	0	0	23	0	0	0	23
Sub-Total:	0	0	1007	148	6	1	1162
Calms:							52
Missing/Incomplete:							0
Total:							1214

Met 01 Wave frequency Distribution Plot -Normalized

Station ID: 1 Run ID: met1
Start Date: 24/04/2018 - 00:00
End Date: 20/06/2018 - 12:00

Frequency Distribution
(Normalized)

Height Hs (m)

Wave Direction	0.06 - 0.09	0.09 - 0.10	0.10 - 0.20	0.20 - 0.30	0.30 - 0.40	>= 0.40	Total
355.00 - 5.00	0.000000	0.000000	0.021417	0.001647	0.000000	0.000000	0.023064
5.00 - 15.00	0.000000	0.000000	0.018122	0.001647	0.000000	0.000000	0.019769
15.00 - 25.00	0.000000	0.000000	0.018946	0.000824	0.000000	0.000000	0.019769
25.00 - 35.00	0.000000	0.000000	0.018122	0.002471	0.000000	0.000000	0.020593
35.00 - 45.00	0.000000	0.000000	0.024712	0.002471	0.000000	0.000824	0.028007
45.00 - 55.00	0.000000	0.000000	0.028007	0.000824	0.000000	0.000000	0.028830
55.00 - 65.00	0.000000	0.000000	0.020593	0.001647	0.000000	0.000000	0.022241
65.00 - 75.00	0.000000	0.000000	0.028830	0.003295	0.000000	0.000000	0.032125
75.00 - 85.00	0.000000	0.000000	0.020593	0.002471	0.000000	0.000000	0.023064
85.00 - 95.00	0.000000	0.000000	0.021417	0.002471	0.000000	0.000000	0.023888
95.00 - 105.00	0.000000	0.000000	0.018946	0.003295	0.000000	0.000000	0.022241
105.00 - 115.00	0.000000	0.000000	0.018946	0.002471	0.000824	0.000000	0.022241
115.00 - 125.00	0.000000	0.000000	0.016474	0.002471	0.000000	0.000000	0.018946
125.00 - 135.00	0.000000	0.000000	0.015651	0.000000	0.000824	0.000000	0.016474
135.00 - 145.00	0.000000	0.000000	0.019769	0.003295	0.000000	0.000000	0.023064
145.00 - 155.00	0.000000	0.000000	0.023064	0.005766	0.000000	0.000000	0.028830
155.00 - 165.00	0.000000	0.000000	0.023064	0.000824	0.000000	0.000000	0.023888
165.00 - 175.00	0.000000	0.000000	0.018946	0.000824	0.000000	0.000000	0.019769
175.00 - 185.00	0.000000	0.000000	0.016474	0.001647	0.000000	0.000000	0.018122
185.00 - 195.00	0.000000	0.000000	0.018946	0.003295	0.000000	0.000000	0.022241
195.00 - 205.00	0.000000	0.000000	0.025535	0.002471	0.000000	0.000000	0.028007
205.00 - 215.00	0.000000	0.000000	0.015651	0.005766	0.000000	0.000000	0.021417
215.00 - 225.00	0.000000	0.000000	0.024712	0.004119	0.000000	0.000000	0.028830
225.00 - 235.00	0.000000	0.000000	0.026359	0.004942	0.000000	0.000000	0.031301
235.00 - 245.00	0.000000	0.000000	0.028830	0.003295	0.000824	0.000000	0.032949
245.00 - 255.00	0.000000	0.000000	0.034596	0.009885	0.000824	0.000000	0.045305
255.00 - 265.00	0.000000	0.000000	0.042010	0.015651	0.000824	0.000000	0.058484
265.00 - 275.00	0.000000	0.000000	0.032949	0.004942	0.000824	0.000000	0.038715
275.00 - 285.00	0.000000	0.000000	0.037891	0.009061	0.000000	0.000000	0.046952
285.00 - 295.00	0.000000	0.000000	0.020593	0.006590	0.000000	0.000000	0.027183
295.00 - 305.00	0.000000	0.000000	0.020593	0.003295	0.000000	0.000000	0.023888
305.00 - 315.00	0.000000	0.000000	0.025535	0.002471	0.000000	0.000000	0.028007
315.00 - 325.00	0.000000	0.000000	0.021417	0.001647	0.000000	0.000000	0.023064
325.00 - 335.00	0.000000	0.000000	0.018946	0.002471	0.000000	0.000000	0.021417
335.00 - 345.00	0.000000	0.000000	0.023888	0.001647	0.000000	0.000000	0.025535
345.00 - 355.00	0.000000	0.000000	0.018946	0.000000	0.000000	0.000000	0.018946
Sub-Total:	0.000000	0.000000	0.829489	0.121911	0.004942	0.000824	0.957166
Calms:							0.042834
Missing/Incomplete:							0.000000
Total:							1.000000

Table 28 Wave Magnitude and Direction Frequency Distribution & Count calculations

Met 02 Wave Frequency Distribution Count Plot

Station ID: 2
Met ID: met2
Start Date: 24/04/2018 - 00:00
End Date: 20/06/2018 14:00

Frequency Distribution
(Count)

Height Hs m

Wave Direction	0.04 0.08	0.09 0.10	0.13 0.20	0.23 0.30	0.30 0.40	>= 0.40	Total
355.00 - 5.00	0	0	61	9	0	0	70
5.00 - 15.00	0	0	47	9	0	0	56
15.00 - 25.00	0	0	49	7	0	0	56
25.00 - 35.00	0	0	50	5	0	0	55
35.00 - 45.00	0	0	59	5	0	1	65
45.00 - 55.00	0	0	62	8	0	0	70
55.00 - 65.00	0	0	53	7	0	0	60
65.00 - 75.00	0	0	60	4	0	0	66
75.00 - 85.00	0	0	48	6	0	0	56
85.00 - 95.00	0	0	54	7	0	0	61
95.00 - 105.00	0	0	41	8	0	0	49
105.00 - 115.00	0	0	47	6	1	0	54
115.00 - 125.00	0	0	52	5	0	0	57
125.00 - 135.00	0	0	35	6	1	0	42
135.00 - 145.00	0	0	45	8	0	0	53
145.00 - 155.00	0	0	62	14	0	0	76
155.00 - 165.00	0	0	51	5	0	0	56
165.00 - 175.00	0	0	50	6	1	0	57
175.00 - 185.00	0	0	38	8	0	0	46
185.00 - 195.00	0	0	61	9	0	0	70
195.00 - 205.00	0	0	55	6	0	0	61
205.00 - 215.00	0	0	37	11	0	0	48
215.00 - 225.00	0	0	52	18	1	0	71
225.00 - 235.00	0	0	63	11	0	0	74
235.00 - 245.00	0	0	63	10	1	0	74
245.00 - 255.00	0	0	65	19	1	0	85
255.00 - 265.00	0	0	73	22	1	0	96
265.00 - 275.00	0	0	63	9	1	0	73
275.00 - 285.00	0	0	70	16	0	0	86
285.00 - 295.00	0	0	51	10	0	0	61
295.00 - 305.00	0	0	42	8	1	0	51
305.00 - 315.00	0	0	55	7	0	0	62
315.00 - 325.00	0	0	59	6	0	0	65
325.00 - 335.00	0	0	47	9	0	0	56
335.00 - 345.00	0	0	52	14	0	0	66
345.00 - 355.00	0	0	47	2	0	0	49
Sub Total:	0	0	1903	322	9	1	2243
Calms:							145
Missing/Incomplete:							0
Total:							2388

Met 02 Wave frequency Distribution Plot -Normalized

Station ID: 2
Met ID: met2
Start Date: 24/04/2018 - 00:00
End Date: 20/06/2018 14:00

Frequency Distribution
(Normalized)

Height Hs m

Wave Direction	0.04 0.08	0.09 0.10	0.13 0.20	0.23 0.30	0.30 0.40	>= 0.40	Total
355.00 - 5.00	0.000000	0.000000	[illegible]	0.003769	0.000000	0.000000	[illegible]
5.00 - 15.00	0.000000	0.000000	0.019682	0.003769	0.000000	0.000000	0.023451
15.00 - 25.00	0.000000	0.000000	0.020519	0.002931	0.000000	0.000000	0.023451
25.00 - 35.00	0.000000	0.000000	0.020938	0.002094	0.000000	0.000000	0.023032
35.00 - 45.00	0.000000	0.000000	0.024707	0.002094	0.000000	0.000419	0.027219
45.00 - 55.00	0.000000	0.000000	0.025963	0.003350	0.000000	0.000000	0.029313
55.00 - 65.00	0.000000	0.000000	0.022194	0.002931	0.000000	0.000000	0.025126
65.00 - 75.00	0.000000	0.000000	0.025126	0.002513	0.000000	0.000000	0.027638
75.00 - 85.00	0.000000	0.000000	0.016750	0.002513	0.000000	0.000000	0.019263
85.00 - 95.00	0.000000	0.000000	0.022613	0.002931	0.000000	0.000000	0.025544
95.00 - 105.00	0.000000	0.000000	0.017169	0.003350	0.000000	0.000000	0.020519
105.00 - 115.00	0.000000	0.000000	0.019682	0.002513	0.000419	0.000000	0.022613
115.00 - 125.00	0.000000	0.000000	0.021776	0.002094	0.000000	0.000000	0.023869
125.00 - 135.00	0.000000	0.000000	0.014657	0.002513	0.000419	0.000000	0.017588
135.00 - 145.00	0.000000	0.000000	0.018844	0.003350	0.000000	0.000000	0.022194
145.00 - 155.00	0.000000	0.000000	0.025963	0.005863	0.000000	0.000000	0.031826
155.00 - 165.00	0.000000	0.000000	0.021357	0.002094	0.000000	0.000000	0.023451
165.00 - 175.00	0.000000	0.000000	0.020938	0.002513	0.000419	0.000000	0.023869
175.00 - 185.00	0.000000	0.000000	0.015913	0.003350	0.000000	0.000000	0.019263
185.00 - 195.00	0.000000	0.000000	0.025544	0.003769	0.000000	0.000000	0.029313
195.00 - 205.00	0.000000	0.000000	0.023032	0.002513	0.000000	0.000000	0.025544
205.00 - 215.00	0.000000	0.000000	0.015494	0.004606	0.000000	0.000000	0.020101
215.00 - 225.00	0.000000	0.000000	0.021776	0.007538	0.000419	0.000000	0.029732
225.00 - 235.00	0.000000	0.000000	0.026382	0.004606	0.000000	0.000000	0.030988
235.00 - 245.00	0.000000	0.000000	0.026382	0.004188	0.000419	0.000000	0.030988
245.00 - 255.00	0.000000	0.000000	0.027219	0.007956	0.000419	0.000000	0.035595
255.00 - 265.00	0.000000	0.000000	0.030570	0.009213	0.000419	0.000000	0.040201
265.00 - 275.00	0.000000	0.000000	0.026382	0.003769	0.000419	0.000000	0.030570
275.00 - 285.00	0.000000	0.000000	0.029313	0.006700	0.000000	0.000000	0.036013
285.00 - 295.00	0.000000	0.000000	0.021357	0.004188	0.000000	0.000000	0.025544
295.00 - 305.00	0.000000	0.000000	0.017588	0.003350	0.000419	0.000000	0.021357
305.00 - 315.00	0.000000	0.000000	0.023032	0.002931	0.000000	0.000000	0.025963
315.00 - 325.00	0.000000	0.000000	0.024707	0.002513	0.000000	0.000000	0.027219
325.00 - 335.00	0.000000	0.000000	0.019682	0.003769	0.000000	0.000000	0.023451
335.00 - 345.00	0.000000	0.000000	0.021776	0.005863	0.000000	0.000000	0.027638
345.00 - 355.00	0.000000	0.000000	0.019682	0.000838	0.000000	0.000000	0.020519
Sub-Total:	0.000000	0.000000	0.800251	0.134841	0.003769	0.000419	0.939280
Calms:							0.060720
Missing/Incomplete:							0.000000
Total:							1.000000

Table 29 Wave Magnitude and Direction Frequency Distribution & Count calculations

Met 03 Wave Frequency Distribution Count Plot

Station ID: 3
Run ID: met3
Start Date: 24/05/2018 - 00:00
End Date: 20/06/2018 - 12:00

Frequency Distribution
(Count)

Height Hs m

Wave Direction	0.06 - 0.09	0.09 - 0.10	0.10 - 0.20	0.20 - 0.30	0.30 - 0.40	>= 0.40	Total
355.00 - 5.00	0	0	9	0	0	0	9
5.00 - 15.00	0	0	11	0	0	0	11
15.00 - 25.00	0	0	6	0	0	0	6
25.00 - 35.00	0	0	16	0	0	0	16
35.00 - 45.00	0	0	14	1	0	0	15
45.00 - 55.00	0	0	8	1	0	0	9
55.00 - 65.00	0	0	8	0	0	0	8
65.00 - 75.00	0	0	7	1	0	0	8
75.00 - 85.00	0	0	10	0	0	0	10
85.00 - 95.00	0	0	8	2	0	0	10
95.00 - 105.00	0	0	7	1	0	0	8
105.00 - 115.00	0	0	11	0	0	0	11
115.00 - 125.00	0	0	9	1	0	0	10
125.00 - 135.00	0	0	8	1	0	0	9
135.00 - 145.00	0	0	9	0	1	0	10
145.00 - 155.00	0	0	8	1	0	0	9
155.00 - 165.00	0	0	11	3	0	0	14
165.00 - 175.00	0	0	16	4	2	0	22
175.00 - 185.00	0	0	5	1	0	0	6
185.00 - 195.00	0	0	10	5	1	1	17
195.00 - 205.00	0	0	10	3	2	1	16
205.00 - 215.00	0	0	15	2	2	0	19
215.00 - 225.00	0	0	15	6	4	3	28
225.00 - 235.00	0	0	21	11	1	2	35
235.00 - 245.00	0	0	17	10	3	2	32
245.00 - 255.00	0	0	21	9	4	0	34
255.00 - 265.00	0	0	20	4	1	0	25
265.00 - 275.00	0	0	13	0	3	0	16
275.00 - 285.00	0	0	8	3	0	0	11
285.00 - 295.00	0	0	10	1	0	0	11
295.00 - 305.00	0	0	10	0	0	0	10
305.00 - 315.00	0	0	6	1	0	0	7
315.00 - 325.00	0	0	2	3	0	0	5
325.00 - 335.00	0	0	6	1	0	0	7
335.00 - 345.00	0	0	6	0	0	1	7
345.00 - 355.00	0	0	15	0	0	0	15
Sub-Total:	0	0	386	76	24	10	496
Calms:							74
Missing/Incomplete:							0
Total:							570

Met 03 Wave frequency Distribution Plot -Normalized

Station ID: 3
Run ID: met3
Start Date: 24/05/2018 - 00:00
End Date: 20/06/2018 - 12:00

Frequency Distribution
(Normalized)

Height Hs m

Wave Direction	0.06 - 0.09	0.09 - 0.10	0.10 - 0.20	0.20 - 0.30	0.30 - 0.40	>= 0.40	Total
355.00 - 5.00	0.000000	0.000000	0.015789	0.000000	0.000000	0.000000	0.015789
5.00 - 15.00	0.000000	0.000000	0.019298	0.000000	0.000000	0.000000	0.019298
15.00 - 25.00	0.000000	0.000000	0.010526	0.000000	0.000000	0.000000	0.010526
25.00 - 35.00	0.000000	0.000000	0.028070	0.000000	0.000000	0.000000	0.028070
35.00 - 45.00	0.000000	0.000000	0.024561	0.001754	0.000000	0.000000	0.026316
45.00 - 55.00	0.000000	0.000000	0.014035	0.001754	0.000000	0.000000	0.015789
55.00 - 65.00	0.000000	0.000000	0.014035	0.000000	0.000000	0.000000	0.014035
65.00 - 75.00	0.000000	0.000000	0.012281	0.001754	0.000000	0.000000	0.014035
75.00 - 85.00	0.000000	0.000000	0.017544	0.000000	0.000000	0.000000	0.017544
85.00 - 95.00	0.000000	0.000000	0.014035	0.003509	0.000000	0.000000	0.017544
95.00 - 105.00	0.000000	0.000000	0.012281	0.001754	0.000000	0.000000	0.014035
105.00 - 115.00	0.000000	0.000000	0.019298	0.000000	0.000000	0.000000	0.019298
115.00 - 125.00	0.000000	0.000000	0.015789	0.001754	0.000000	0.000000	0.017544
125.00 - 135.00	0.000000	0.000000	0.014035	0.001754	0.000000	0.000000	0.015789
135.00 - 145.00	0.000000	0.000000	0.015789	0.000000	0.001754	0.000000	0.017544
145.00 - 155.00	0.000000	0.000000	0.014035	0.001754	0.000000	0.000000	0.015789
155.00 - 165.00	0.000000	0.000000	0.019298	0.005263	0.000000	0.000000	0.024561
165.00 - 175.00	0.000000	0.000000	0.028070	0.007018	0.003509	0.000000	0.038596
175.00 - 185.00	0.000000	0.000000	0.008772	0.001754	0.000000	0.000000	0.010526
185.00 - 195.00	0.000000	0.000000	0.017544	0.008772	0.001754	0.001754	0.029825
195.00 - 205.00	0.000000	0.000000	0.017544	0.005263	0.003509	0.001754	0.028070
205.00 - 215.00	0.000000	0.000000	0.026316	0.003509	0.003509	0.000000	0.033333
215.00 - 225.00	0.000000	0.000000	0.026316	0.010526	0.007018	0.005263	0.049123
225.00 - 235.00	0.000000	0.000000	0.036842	0.019298	0.001754	0.003509	0.061404
235.00 - 245.00	0.000000	0.000000	0.029825	0.017544	0.005263	0.003509	0.056140
245.00 - 255.00	0.000000	0.000000	0.036842	0.015789	0.007018	0.000000	0.059649
255.00 - 265.00	0.000000	0.000000	0.035088	0.007018	0.001754	0.000000	0.043860
265.00 - 275.00	0.000000	0.000000	0.022807	0.000000	0.005263	0.000000	0.028070
275.00 - 285.00	0.000000	0.000000	0.014035	0.005263	0.000000	0.000000	0.019298
285.00 - 295.00	0.000000	0.000000	0.017544	0.001754	0.000000	0.000000	0.019298
295.00 - 305.00	0.000000	0.000000	0.017544	0.000000	0.000000	0.000000	0.017544
305.00 - 315.00	0.000000	0.000000	0.010526	0.001754	0.000000	0.000000	0.012281
315.00 - 325.00	0.000000	0.000000	0.003509	0.005263	0.000000	0.000000	0.008772
325.00 - 335.00	0.000000	0.000000	0.010526	0.001754	0.000000	0.000000	0.012281
335.00 - 345.00	0.000000	0.000000	0.010526	0.000000	0.000000	0.001754	0.012281
345.00 - 355.00	0.000000	0.000000	0.026316	0.000000	0.000000	0.000000	0.026316
Sub-Total:	0.000000	0.000000	0.677193	0.133333	0.042105	0.017544	0.870175
Calms:							0.129825
Missing/Incomplete:							0.000000
Total:							1.000000

Table 30 Wave Magnitude and Direction Frequency Distribution & Count calculations

Met 04 Wave Frequency Distribution Count Plot

Station ID: 4
Run ID: met4
Start Date: 15/04/2018 - 00:00
End Date: 21/06/2018 - 11:00

Frequency Distribution (Count)

Height Hs m

Wave Direction	0.06 - 0.09	0.09 - 0.10	0.10 - 0.20	0.20 - 0.30	0.30 - 0.40	>= 0.40	Total
355.00 - 5.00	0	0	0	0	1	0	1
5.00 - 15.00	0	0	0	0	0	0	0
15.00 - 25.00	0	0	0	0	0	0	0
25.00 - 35.00	0	0	0	0	0	0	0
35.00 - 45.00	0	0	0	0	0	0	0
45.00 - 55.00	0	0	0	0	0	0	0
55.00 - 65.00	0	0	0	0	0	0	0
65.00 - 75.00	0	0	0	0	0	0	0
75.00 - 85.00	0	0	0	0	0	0	0
85.00 - 95.00	0	0	0	0	0	0	0
95.00 - 105.00	0	0	0	0	0	0	0
105.00 - 115.00	0	0	0	0	0	0	0
115.00 - 125.00	0	0	0	0	0	1	1
125.00 - 135.00	0	0	0	0	0	0	0
135.00 - 145.00	0	0	0	0	0	0	0
145.00 - 155.00	0	0	0	0	0	0	0
155.00 - 165.00	0	0	0	0	1	0	1
165.00 - 175.00	0	0	0	1	1	0	2
175.00 - 185.00	0	0	0	2	0	1	3
185.00 - 195.00	0	0	0	2	1	9	12
195.00 - 205.00	0	0	1	6	13	40	60
205.00 - 215.00	0	0	2	14	46	230	292
215.00 - 225.00	0	0	2	27	82	347	458
225.00 - 235.00	0	0	2	19	72	252	345
235.00 - 245.00	0	0	1	18	50	127	196
245.00 - 255.00	0	0	0	7	29	47	83
255.00 - 265.00	0	0	1	1	8	18	28
265.00 - 275.00	0	0	0	1	3	5	9
275.00 - 285.00	0	0	0	2	4	0	6
285.00 - 295.00	0	0	0	1	1	0	2
295.00 - 305.00	0	0	0	0	0	0	0
305.00 - 315.00	0	0	0	0	1	0	1
315.00 - 325.00	0	0	1	0	0	0	1
325.00 - 335.00	0	0	0	0	0	0	0
335.00 - 345.00	0	0	0	0	0	0	0
345.00 - 355.00	0	0	0	0	0	0	0
Sub-Total:	0	0	12	93	313	1077	1493
Calms:							2
Missing/Incomplete:							1
Total:							1496

Met 04 Wave frequency Distribution Plot -Normalized

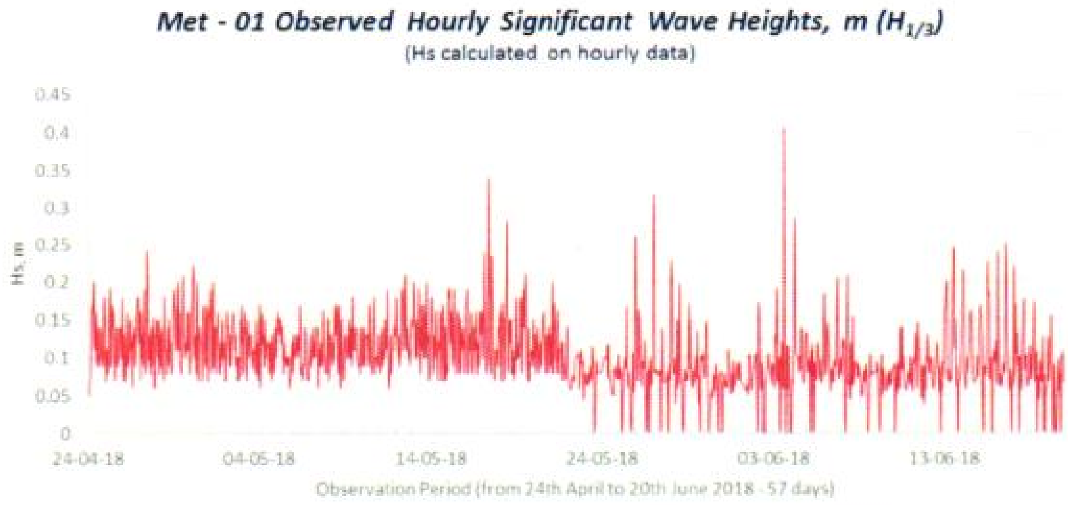
Station ID: 4
Run ID: met4
Start Date: 15/04/2018 - 00:00
End Date: 21/06/2018 - 11:00

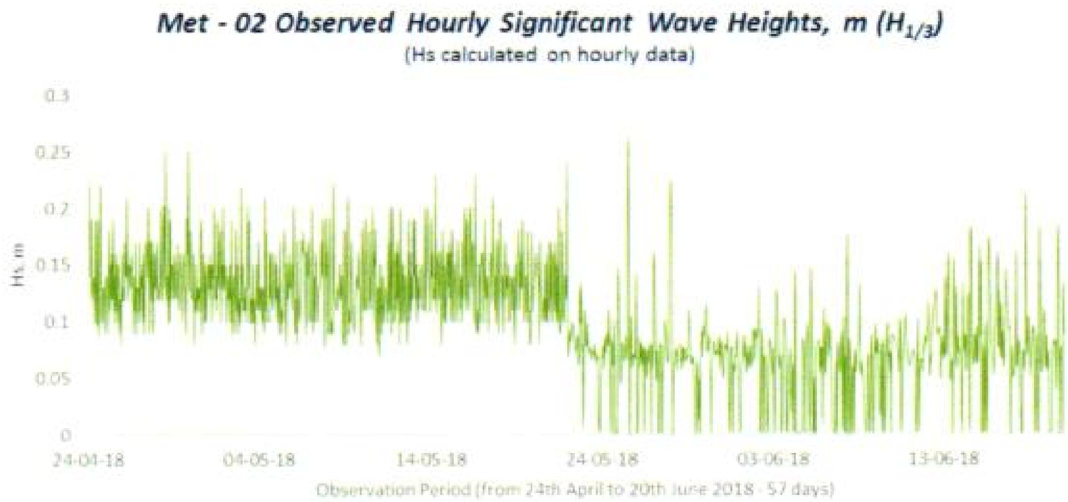
Frequency Distribution (Normalized)

Height Hs m

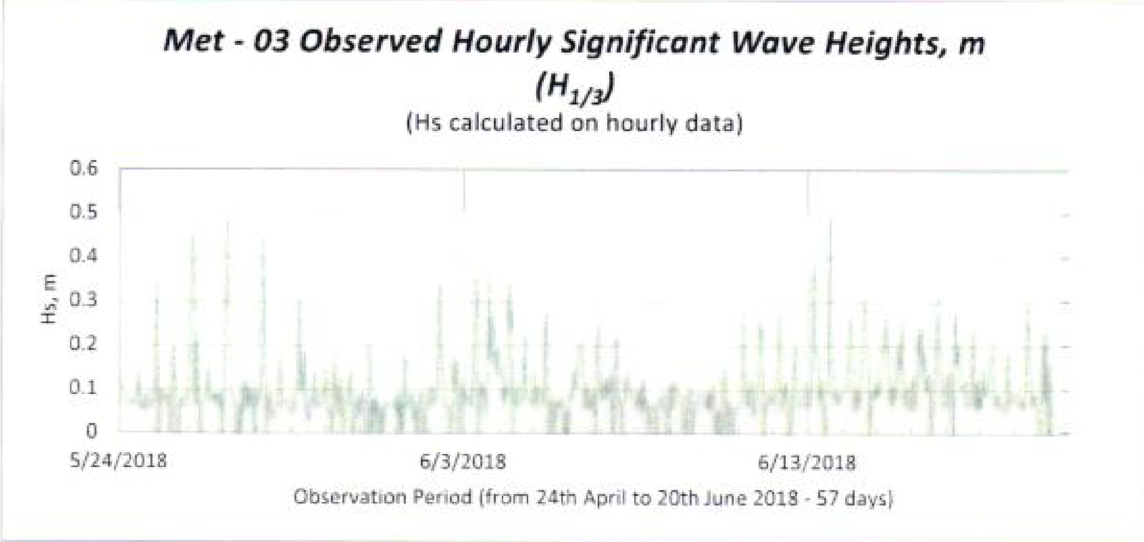
Wave Direction	0.06 - 0.09	0.09 - 0.10	0.10 - 0.20	0.20 - 0.30	0.30 - 0.40	>= 0.40	Total
355.00 - 5.00	0.000000	0.000000	0.000000	0.000000	0.000668	0.000000	0.000668
5.00 - 15.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
15.00 - 25.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
25.00 - 35.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
35.00 - 45.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
45.00 - 55.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
55.00 - 65.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
65.00 - 75.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
75.00 - 85.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
85.00 - 95.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
95.00 - 105.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
105.00 - 115.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
115.00 - 125.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000668	0.000668
125.00 - 135.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
135.00 - 145.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
145.00 - 155.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
155.00 - 165.00	0.000000	0.000000	0.000000	0.000000	0.000668	0.000000	0.000668
165.00 - 175.00	0.000000	0.000000	0.000000	0.000668	0.000668	0.000000	0.001337
175.00 - 185.00	0.000000	0.000000	0.000000	0.001337	0.000000	0.000668	0.002005
185.00 - 195.00	0.000000	0.000000	0.000000	0.001337	0.000668	0.006016	0.008021
195.00 - 205.00	0.000000	0.000000	0.000668	0.004011	0.008690	0.026738	0.040107
205.00 - 215.00	0.000000	0.000000	0.001337	0.009358	0.030749	0.153743	0.195187
215.00 - 225.00	0.000000	0.000000	0.001337	0.018048	0.054813	0.231952	0.306150
225.00 - 235.00	0.000000	0.000000	0.001337	0.012701	0.048128	0.168449	0.230615
235.00 - 245.00	0.000000	0.000000	0.000668	[illegible]	0.033422	0.084893	0.131016
245.00 - 255.00	0.000000	0.000000	0.000000	0.004679	0.019385	0.031417	0.055481
255.00 - 265.00	0.000000	0.000000	0.000668	0.000668	0.005348	0.012032	0.018717
265.00 - 275.00	0.000000	0.000000	0.000000	0.000668	0.002005	0.003342	0.006016
275.00 - 285.00	0.000000	0.000000	0.000000	0.001337	0.002674	0.000000	0.004011
285.00 - 295.00	0.000000	0.000000	0.000000	0.000668	0.000668	0.000000	0.001337
295.00 - 305.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
305.00 - 315.00	0.000000	0.000000	0.000000	0.000000	0.000668	0.000000	0.000668
315.00 - 325.00	0.000000	0.000000	0.000668	0.000000	0.000000	0.000000	0.000668
325.00 - 335.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
335.00 - 345.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
345.00 - 355.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sub-Total:	0.000000	0.000000	0.008684	0.062166	0.209225	0.719920	0.997995
Calms:							0.001337
Missing/Incomplete:							0.000668
Total:							1.000000

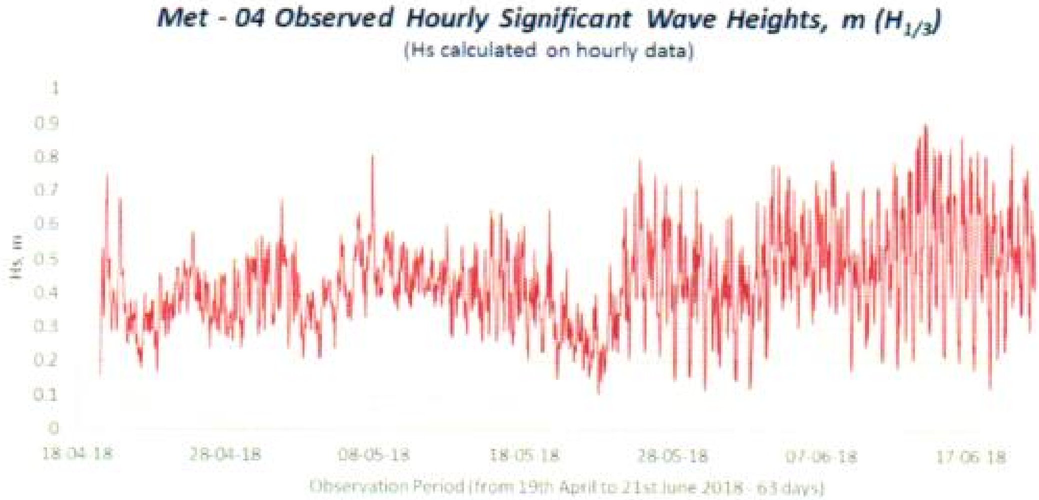
Figure 35 Plots of Hourly Significant Wave height values for Met 1 to 4





94b





10.8 Software employed to process & analyze wave data

The software used to process Currents and Waves were RDI Teledyne Corp's Velocity and WavesMon respectively

Sentinel V50 Wave recorder being deployed

10.9 Limitations and threshold restrictions

During April / May period the ADCP's wave recorder deployment were located well in shore and away from main sea, the sea there was mainly calm the roughness of sea surface was not enough for equipment to detect wave heights. However, in the second batch of deployment, the wind picked up and creeks offered relatively larger wave heights as is evident from tables of data in the Appendix B.

Rough Sea Conditions observed

10.10 Summary of Wave data (Parameters extracted - H max, highest significant ht, max period, peak period etc)

Sentinel V being deplpoyed Met 02

Recovered Sentinnel V50 for data download Met 01

Parameters to be observed from ADCP Wave recording instruments were as follows:

H_{max}
T_{max}
Significant wave $H_{1/3}$
Significant Wave period $T_{1/3}$
Mean wave H_{mean}
T_{mean}

The observed waves properties were originally scheduled for 30 days. However, TCI has provided additional data of 29 days making a total of 60 days of observed wave data.

Table 31 Wave parameters are given below for each Met 01 to 04

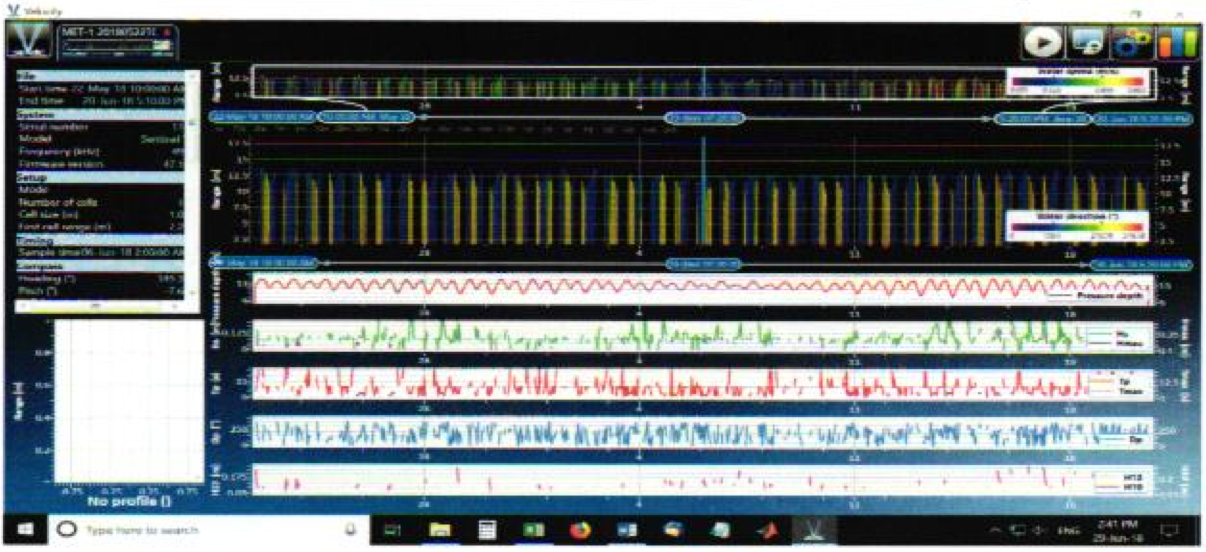
FIRST BATCH DEPLOYMENT FROM 24/04/2018 TO 22/05/2018								
PARAMETER	MET 01		MET 02		MET 03		MET 04	
	Min	Max	Min	Max	Min	Max	Min	Max
Significant Wave Ht (Hs)	0.060	0.340	0.070	0.250	-	-	0.150	0.810
Peak Wave Period (Tp)	2.000	13.400	2.000	50.000	-	-	2.000	23.000
Peak Wave Direction (Dp)	0.000	359.000	1.000	357.000	-	-	1.000	272.000
Maximum Wave Ht- Hmax = 1.6 Hs (Calculated)	0.096	0.540	0.112	0.400	-	-	0.240	1.296
Mean Wave Ht - Hz = Hs / 1.597 (Calculated)	0.037	0.210	0.044	0.157	-	-	0.093	0.507
Mean Period (T mean)	2.100	3.500	2.200	4.200	-	-	2.400	6.900

Table 32 Wave parameters are given below for each Met 01 to 04

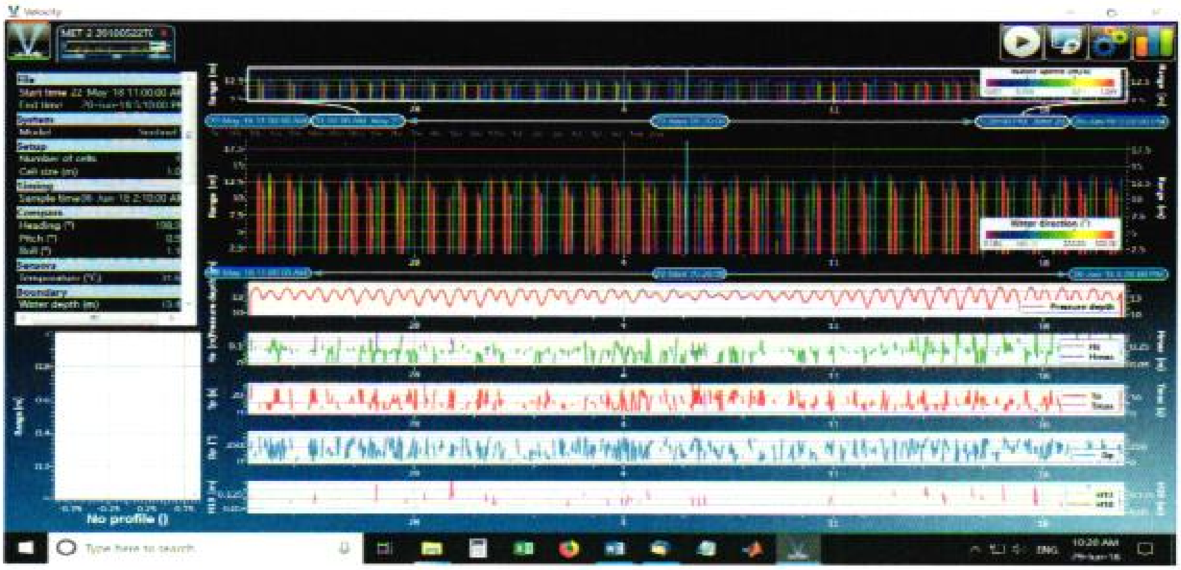
SECOND BATCH DEPLOYMENT FROM 22/05/2018 TO 20/06/2018								
PARAMETER	MET 01		MET 02		MET 03		MET 04	
	Min	Max	Min	Max	Min	Max	Min	Max
Significant Wave Ht (Hs)	0.001	0.407	0.001	0.262	0.001	0.493	0.109	0.909
Peak Wave Period (Tp)	1.100	25.600	1.700	25.600	1.100	25.600	1.900	25.600
Peak Wave Direction (Dp)	3.000	359.000	4.000	360.000	0.000	359.000	14.000	353.000
Maximum Wave Ht- Hmax = 1.6 Hs (Calculated)	0.002	0.651	0.002	0.419	0.002	0.789	0.174	1.454
Mean Wave Ht - Hz = Hs / 1.597 (Calculated)	0.001	0.255	0.001	0.164	0.001	0.309	0.068	0.569
Mean Period (T mean)	1.700	32.000	1.900	32.000	1.700	32.000	2.100	5.500

Figures 36 Time series plots of wave parameters for Met 1 to 4

Station : Met 1
Multiparameter plot of Wave Parameters - Second batch



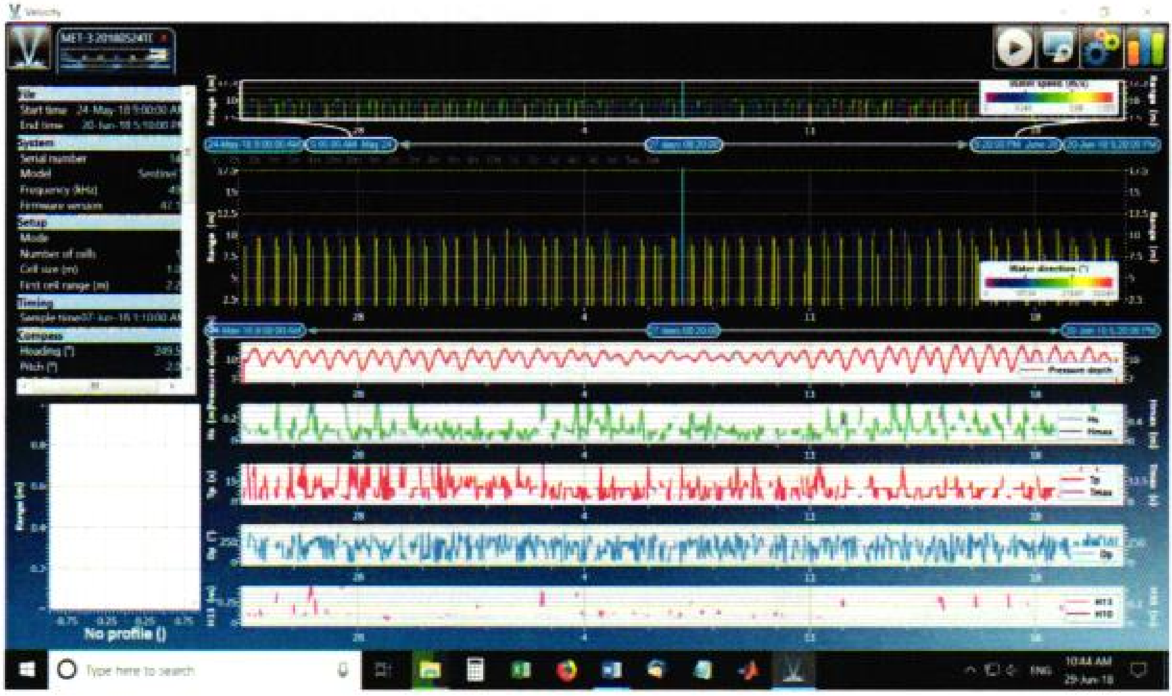
Station : Met 02
Multiparameter plot of Wave Parameters - Second batch



445

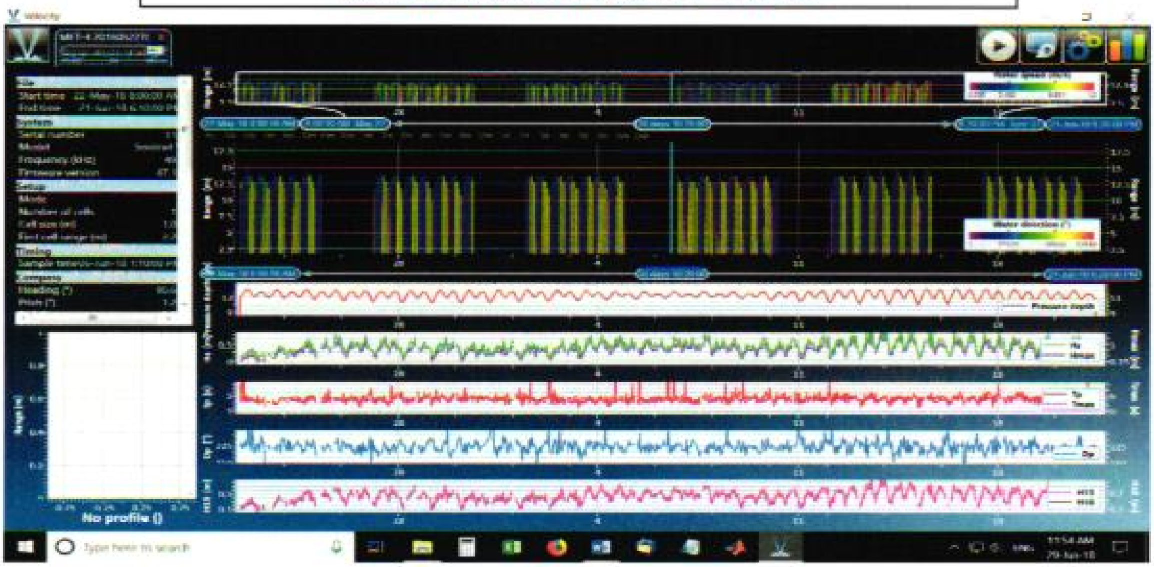
Station : Met 03

Multiparameter plot of Wave Parameters - Second batch



Station : Met 04

Multiparameter plot of Wave Parameters - Second batch



For each of the four MET stations, the recorded data at the desired interval is printed in Appendix B.

10.11 Concluding remarks / Summary

Refer to A3 sheets of wave data in Appendix B (plots and actual printout of data)

Growth observed on ADCP beam sensors

11.0 SALINITY & SEA WATER TEMPERATURE MEASUREMENTS

11.1 Seawater salinity

Sea water sampling were carried out at the following locations:

Met 01

Met 02

Met 03

Niskin bottle for water quality sampling

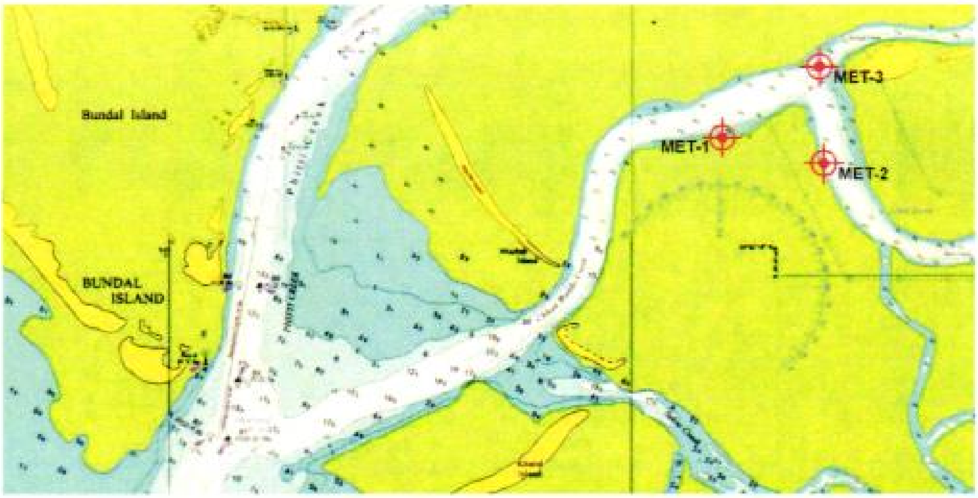
The samples were taken at near surface, middle depth and near bottom.

In accordance with scope, salinity observations were to be undertaken at Met 01, Met-02 and Met03 locations. Water samples were collected using Niskin bottles for measurement of Seawater Salinity at near surface, mid-depth and near bottom at Met 01 to 03 positions. Samples were analyzed in laboratory and results of analysis are provided in Appendix – F.

11.2 Equipment used

Clean Niskin Bottles were used to acquire water samples which were drained into clean containers. These containers were then sent to laboratory for salinity tests.

Figure 37 Showing Salinity Measurement Locations



11.3 Seawater Temperature Measurements

Sea water temperatures were observed using ADCP temperature sensor at locations Met-01, Met02, Met-03 and Met-04. The depth at which temperature readings were about 1 m above seabed at the respective ADCP locations. Recording interval was 10 minutes and for 30 days deployment duration of the ADCP's. The results are presented in Appendix E.

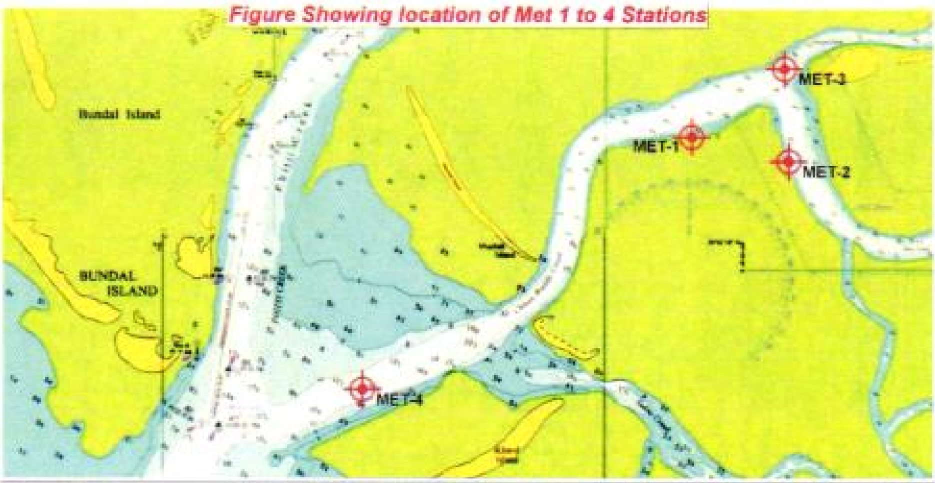
12.0 SEA BED SAMPLING AT 04 LOCATIONS FROM MET-1 TO MET-4

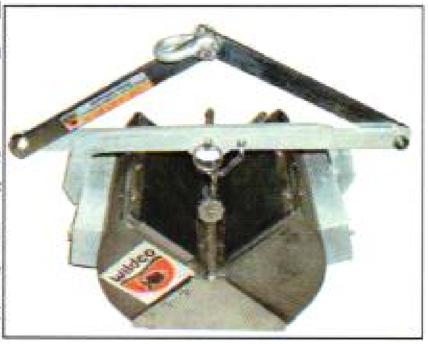
Grab sample being preserved for lab testing

Grab Samples for testing

Sea Bed Grab Samples have been collected using Ponar Grab sampler at 04 locations and sent to lab for grain size analysis. The locations of sea bed sampling are shown in following figure.

Figure 38 Showing Sea Bed Sampling Locations





The Ponar Samplers, or 'Grab Samplers', are widely used in fresh and salt water for taking sea bed samples from hard bottoms such as sand, gravel, consolidated clay.

These samplers are designed to collect an accurate representative sample of the sea bottom. The bite of the sampler is deep enough so all depths are sampled equally. The closing mechanism is design to completely close and hold the sample as well as prevent wash-out during retrieval. Likewise, during descent the sampler is designed to minimize disturbance of the topmost sediment by means of the pressure valve as it is lowered to the bottom.

The physical characteristics of sea bed differ from place to place. Sea bed sampling was carried out where construction of marine structure was proposed or dredging was required.

Ponar Grab sampler being deployed

12.1 Seabed Sampling Locations

The location of sea bed sampling were the same as locations for Met 01 to 04 i.e. the location where ADCP equipment were deployed. On further request of JGC, two additional samples were acquired from south of Bundal Island and SE of MET-4.

The locations are:

1. South of Bundal Island at following coordinates

24° 41´ 11.69" N, 067°07'34.38" E

and

2. South East of Station Met-04 at following coordinates

24° 40´ 31.82 N, 067°10'33.50" N

12.2 Instrument Used

Description	Equipment Specification
Grab Samplers	Ponar Grab Sampler

12.3 Results of Seabed Samples

The collected sea bed samples 06 nos. in all were sent to M/s STS Services for Grain Size analysis results. The Grain Size analysis are included in the Geophysical survey report being submitted separately.

13.0 WEATHER STATION

13.1 General

A weather station at Bundal Island tidal observatory was installed which measured temperature, wind speed/direction, pressure, precipitation, humidity. Under a separate report entitled Factual Weather Data Collection Study, the data acquired from M/S FOTCO Terminals, and long term data purchased from Karachi Airport Met Office was correlated to data observed at the Bundal Island observatory.

Platform housing Weather Station

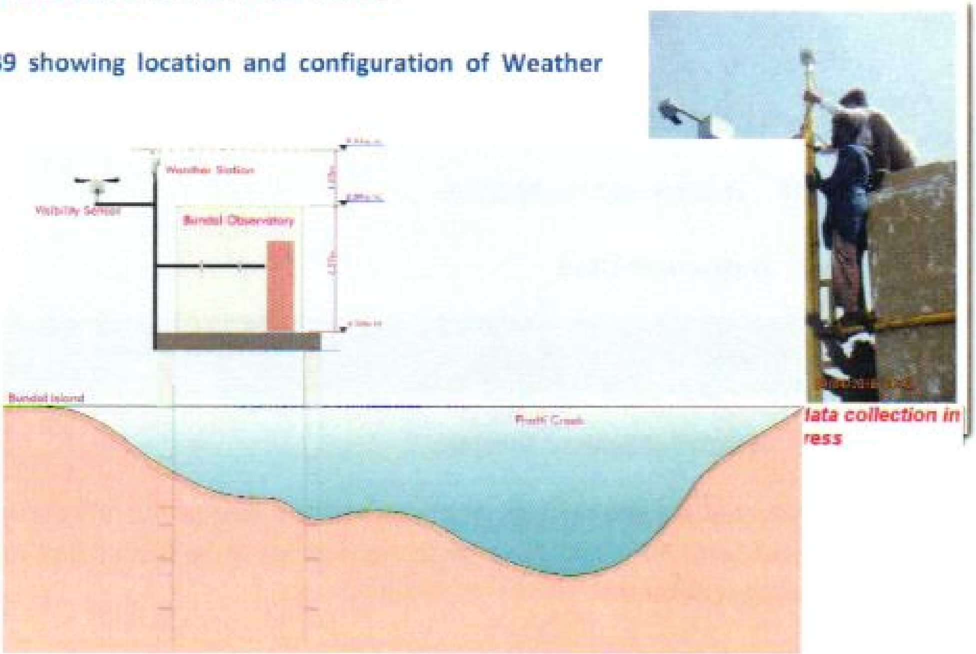
The weather station of TCI recorded maximum wind speed and corresponding direction and mean wind speed and directions are duly represented in an excel table.

The Troposphere layer height of 10 m above the sea surface captures the atmospheric surface layer which is the lowest part of the atmospheric boundary layer. This is normally used in oceanographic observations.

Weather Station near Bundal Island in operation

14.0 SCOPE AND SPECIFICATION OF SURVEY

Figure 39 showing location and configuration of Weather Station



15.0 RTK AND STATIC GPS OBSERVATION MADE AT STATION

RTK based observations were made to mark exact position of the weather station.

The location coordinates (UTM-42 grid) are as under

Easting	312,068 m
Northing	2,733,065 m

15.1 Weather model, make and description

Equipment Manufacturer:	R.M. Young USA
Model:	Response 1 plus Visibility

Integrated weather station has self-recording capability, ultrasonic vanes for wind speed and direction. The equipment is telemetrically linked to shore receiving FTP server through Sutron USA digital modem with GPRS sim (mobiles GSM connection).

15.2 Weather data collection starts and end periods

The Weather station was installed on 4th April 2018 and weather data was captured in two batches.

Batch 1 from 4 April 2018 to 20 April 2018.

Batch 2 from 20 April 2018 to 07 June, 2018.

15.3 List of measurable parameters

The weather station recorded following parameters:

- Date
- Time
- Temp C
- Humidity
- Pressure hpa
- Average Wind Speed m/s : Average Wind Direction (degrees North) the weather station records direction the wind is blowing "From".

Measuring interval is 30 minutes

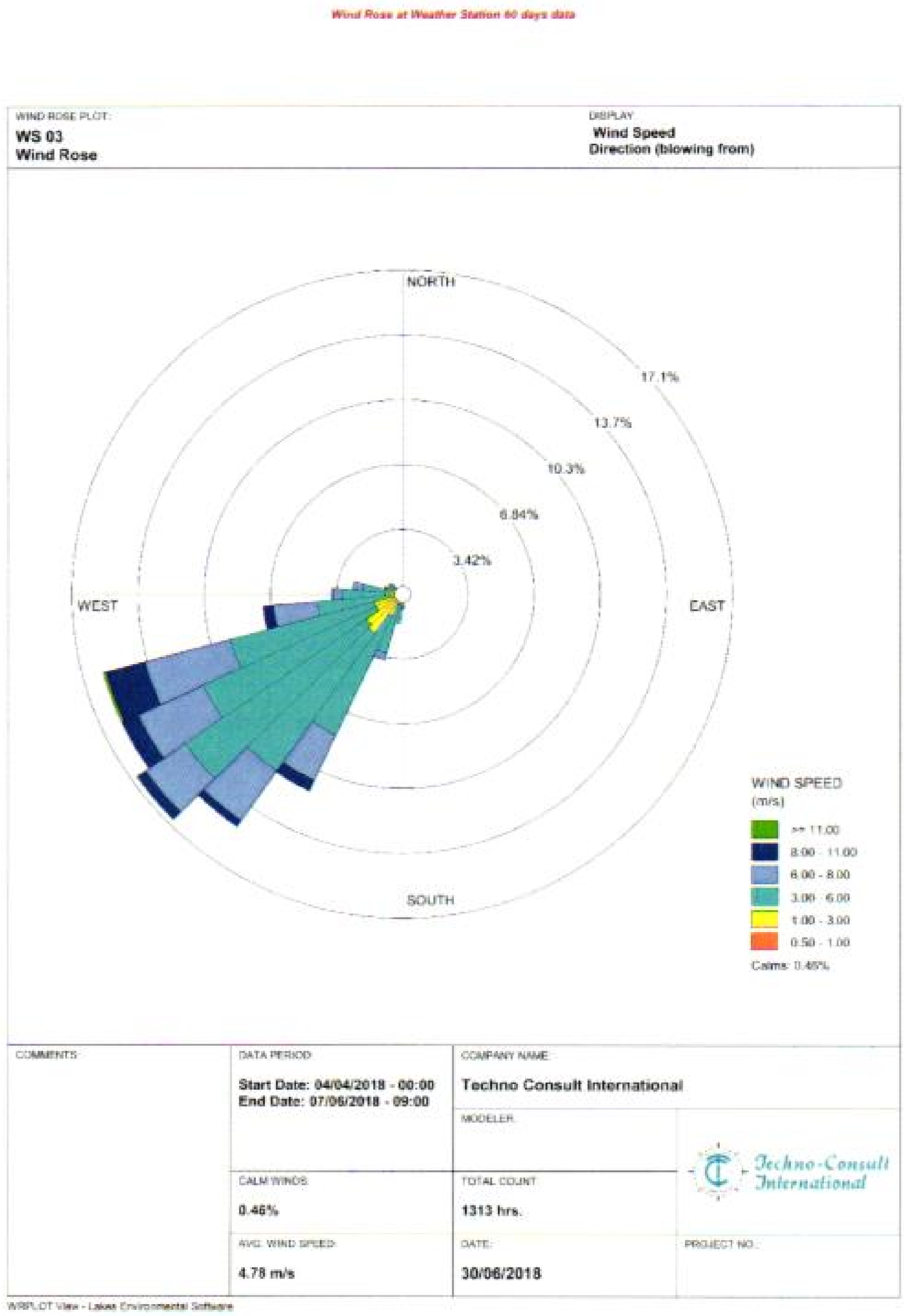
15.4 Downloading of data

The downloading of weather station data was difficult. As such both manual downloading and telemetric methods were applied. Sutron (USA) data send out digital modem was used together with mobile GSPRS service which loaded the weather data automatically to TCI FTP server.

15.5 Plot of computed Wind Rose

The wind data was analyzed using the WRPLOT software which performed a dual parameter frequency and distribution analysis and provided with Joint Probability plots.

Figure 40 Plot of computed wind rose



Tables 33 Calculation of Frequency and count distributions

Weather Station Wind Frequency Count Distribution

Station ID: 3
Run ID: met3
Start Date: 04/04/2018 - 00:00
End Date: 07/06/2018 - 09:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.50 - 2.10	2.10 - 3.60	3.60 - 5.70	5.70 - 8.80	8.80 - 11.10	>= 11.10	Total
355.00 - 5.00	0	1	0	0	0	0	1
5.00 - 15.00	0	0	2	1	0	0	3
15.00 - 25.00	1	0	1	0	0	0	2
25.00 - 35.00	0	0	2	1	0	0	3
35.00 - 45.00	3	1	0	0	0	0	4
45.00 - 55.00	0	3	0	0	0	0	3
55.00 - 65.00	0	0	0	0	0	0	0
65.00 - 75.00	0	1	0	0	0	0	1
75.00 - 85.00	0	0	0	0	0	0	0
85.00 - 95.00	0	0	0	0	0	0	0
95.00 - 105.00	0	0	0	0	0	0	0
105.00 - 115.00	0	0	0	0	0	0	0
115.00 - 125.00	0	0	0	0	0	0	0
125.00 - 135.00	1	0	0	0	0	0	1
135.00 - 145.00	2	1	0	0	0	0	3
145.00 - 155.00	0	0	0	0	0	0	0
155.00 - 165.00	0	1	0	0	0	0	1
165.00 - 175.00	0	3	1	0	0	0	4
175.00 - 185.00	1	3	6	0	0	0	10
185.00 - 195.00	2	9	9	0	0	0	20
195.00 - 205.00	2	11	29	5	0	0	47
205.00 - 215.00	3	29	66	50	2	0	150
215.00 - 225.00	9	45	91	50	1	0	196
225.00 - 235.00	12	41	118	46	3	0	220
235.00 - 245.00	3	37	102	63	5	0	210
245.00 - 255.00	3	32	79	83	12	1	210
255.00 - 265.00	0	14	37	43	1	0	95
265.00 - 275.00	5	13	22	7	1	0	48
275.00 - 285.00	0	15	12	7	0	0	34
285.00 - 295.00	0	7	4	2	0	0	13
295.00 - 305.00	4	6	1	0	0	0	11
305.00 - 315.00	4	4	0	3	0	0	11
315.00 - 325.00	0	0	1	0	0	0	1
325.00 - 335.00	2	0	1	0	0	0	3
335.00 - 345.00	0	1	1	0	0	0	2
345.00 - 355.00	0	0	0	0	0	0	0
Sub-Total:	57	278	585	361	25	1	1307
Calms:							6
Missing/Incomplete:							1
Total:							1314

Frequency of Calm Winds: 0.46%
Average Wind Speed: 4.78 m/s

Weather Station Wind Frequency Distribution -Normalized

Station ID: 3
Run ID: met3
Start Date: 04/04/2018 - 00:00
End Date: 07/06/2018 - 09:00

Frequency Distribution
(Count)

Speed m/s

Wind Direction	0.50 - 2.10	2.10 - 3.60	3.60 - 5.70	5.70 - 8.80	8.80 - 11.10	>= 11.10	Total
355.00 - 5.00	0	1	0	0	0	0	1
5.00 - 15.00	0	0	2	1	0	0	3
15.00 - 25.00	1	0	1	0	0	0	2
25.00 - 35.00	0	0	2	1	0	0	3
35.00 - 45.00	3	1	0	0	0	0	4
45.00 - 55.00	0	3	0	0	0	0	3
55.00 - 65.00	0	0	0	0	0	0	0
65.00 - 75.00	0	1	0	0	0	0	1
75.00 - 85.00	0	0	0	0	0	0	0
85.00 - 95.00	0	0	0	0	0	0	0
95.00 - 105.00	0	0	0	0	0	0	0
105.00 - 115.00	0	0	0	0	0	0	0
115.00 - 125.00	0	0	0	0	0	0	0
125.00 - 135.00	1	0	0	0	0	0	1
135.00 - 145.00	2	1	0	0	0	0	3
145.00 - 155.00	0	0	0	0	0	0	0
155.00 - 165.00	0	1	0	0	0	0	1
165.00 - 175.00	0	3	1	0	0	0	4
175.00 - 185.00	1	3	6	0	0	0	10
185.00 - 195.00	2	9	9	0	0	0	20
195.00 - 205.00	2	11	29	5	0	0	47
205.00 - 215.00	3	29	66	50	2	0	150
215.00 - 225.00	9	45	91	50	1	0	196
225.00 - 235.00	12	41	118	46	3	0	220
235.00 - 245.00	3	37	102	63	5	0	210
245.00 - 255.00	3	32	79	83	12	1	210
255.00 - 265.00	0	14	37	43	1	0	95
265.00 - 275.00	5	13	22	7	1	0	48
275.00 - 285.00	0	15	12	7	0	0	34
285.00 - 295.00	0	7	4	2	0	0	13
295.00 - 305.00	4	6	1	0	0	0	11
305.00 - 315.00	4	4	0	3	0	0	11
315.00 - 325.00	0	0	1	0	0	0	1
325.00 - 335.00	2	0	1	0	0	0	3
335.00 - 345.00	0	1	1	0	0	0	2
345.00 - 355.00	0	0	0	0	0	0	0
Sub Total:	57	278	585	361	25	1	1307
Calms:							6
Missing/Incomplete:							1
Total:							1314

Frequency of Calm Winds: 0.46%
Average Wind Speed: 4.78 m/s

15.6 Concluding Remarks

The weather station data plots through wind rose show predominant wind direction of South to South West which is representative of Port Qasim environmental regime.

Configuration of Weather Station

No significant variation was found in the observed wind pattern.

Appendices containing actual weather raw data in A3 format and converted to local CD (print out and plots)

16.0 APPENDICES

16.1 Appendix – A Current Data

Appendix – A11 Current Data at MET-1 location in first batch recorded at 10-minute interval is comprising of five sheets which are Mean speed & Direction, Easting component of the Current Vector in each bin, Northing component of the current vector in each bin, Magnitude of current in each bin & Direction of current in each bin

Appendix – A12 Current Data at MET-1 location in 2nd batch recorded at 10-minute interval is comprising of five sheets which are Mean speed & Direction, Easting component of the Current Vector in each bin, Northing component of the current vector in each bin, Magnitude of current in each bin & Direction of current in each bin

Appendix – A21 Current Data at MET-2 location in 1st batch recorded at 10-minute interval is comprising of five sheets which are Mean speed & Direction, Easting component of the Current Vector in each bin, Northing component of the current vector in each bin, Magnitude of current in each bin & Direction of current in each bin

Appendix – A22 Current Data at MET-2 location in 2nd batch recorded at 10-minute interval is comprising of five sheets which are Mean speed & Direction, Easting component of the Current Vector in each bin, Northing component of the current vector in each bin, Magnitude of current in each bin & Direction of current in each bin

Appendix – A31 Current Data at MET-3 location in 1st batch recorded at 10-minute interval is comprising of five sheets which are Mean speed & Direction, Easting component of the Current Vector in each bin, Northing component of the current

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vector in each bin, Magnitude of current in each bin & Direction of current in each bin

Appendix – A32 Current Data at MET-3 location in 2nd batch recorded at 10-minute interval is comprising of five sheets which are Mean speed & Direction, Easting component of the Current Vector in each bin, Northing component of the current vector in each bin, Magnitude of current in each bin & Direction of current in each bin

Appendix – A41 Current Data at MET-4 location in 1st batch recorded at 10-minute interval is comprising of five sheets which are Mean speed & Direction, Easting component of the Current Vector in each bin, Northing component of the current vector in each bin, Magnitude of current in each bin & Direction of current in each bin

Appendix – A42 Current Data at MET-4 location in 2nd batch recorded at 10-minute interval is comprising of five sheets which are Mean speed & Direction, Easting component of the Current Vector in each bin, Northing component of the current vector in each bin, Magnitude of current in each bin & Direction of current in each bin

16.2 Appendix – B Waves Data

Appendix – B11 Magnitude and direction of Waves data for different depths/bin hourly recorded at MET-1 location in first batch along with the significant wave height and time period etc.

Appendix – B12 Magnitude and direction of Waves data for different depths/bin hourly recorded at MET-1 location in 2nd batch along with the significant wave height and time period etc.

Appendix – B21 Magnitude and direction of Waves data for different depths/bin hourly recorded at MET-2 location in first batch along with the significant wave height and time period etc.

Appendix – B22 Magnitude and direction of Waves data for different depths/bin hourly recorded at MET-2 location in 2nd batch along with the significant wave height and time period etc.

Appendix – B3 Magnitude and direction of Waves data for different depths/bin hourly recorded at MET-3 location along with the significant wave height and time period etc.

Appendix – B41 Magnitude and direction of Waves data for different depths/bin hourly recorded at MET-4 location in 1st batch along with the significant wave height and time period etc.

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Appendix – B42 Magnitude and direction of Waves data for different depths/bin hourly recorded at MET-4 location in 2nd batch along with the significant wave height and time period etc.

16.3 Appendix – C Tidal Data

Tidal data recorded at T5 location for 10 minutes interval from 1st April to 20th June 2018

16.4 Appendix – D Weather Data

Wind speed and direction recorded at hourly basis at Bunal from 4th April to 7th June 2018.

16.5 Appendix – E Sea Water Temperature

16.5.1 Appendix – E1
Sea water temperature recorded for 10 minutes interval at MET-1 for different bins

16.5.2 Appendix – E2
Sea water temperature recorded for 10 minutes interval at MET-2 for different bins

16.5.3 Appendix – E3
Sea water temperature recorded for 10 minutes interval at MET-3 for different bins

16.5.4 Appendix – E2
Sea water temperature recorded for 10 minutes interval at MET-4 for different bins

16.6 Appendix – F Salinity Data

Salinity data for surface, mid and bed at MET-1, MET-2 & MET-3