

# ENVIRONMENTAL PARAMETERS, THEIR MEASUREMENT ANALYSIS AND APPLICATION TO OCEAN ENGINEERING PROBLEMS

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## 1.0 GENERAL

Waves, currents, tides and wind are the major environmental parameters an ocean engineer is interested in and a proper evaluation of the same is very essential for the design, operation and maintenance of coastal and offshore structures. As the environment is stochastic (random) in nature, regular monitoring of the same over a longer duration say 5 to 10 years is necessary so as to use probabilistic methods to evaluate the design parameters. Earlier to the development of sophisticated instruments monitoring of marine environment especially waves were carried out visually. These visually observed data have many inherent limitations such as human errors involved in the observations, continuity in the observed data, non suitability of the data base itself for computer aided analysis to evaluate design parameters. With the development of sophisticated instruments it has now become possible to monitor the environment accurately. In the following sections measurement, analysis and application of environmental design parameters related to waves, currents, wind and tides have been discussed with some examples.

## 2.0 ENVIRONMENTAL PARAMETERS:

2.1 Waves : Waves discussed here are the wind generated surface gravity waves having periods usually found in the range 4 to 20 seconds. A regular or sinusoidal wave is defined by its height,  $H$  and period,  $T$ . On the contrary ocean waves are random in nature and one has to go for probabilistic methods to describe them.

Many types of instruments are now available in the market to measure the ocean waves. These instruments can be broadly classified in to 3 categories based on the principle they adopt to measure the waves. They are resistance/capacitance type, pressure type and surface floating buoy type. In recent years remote sensing techniques are being adopted for wave measurements.

Most widely used are the surface floating type wave rider buoys manufactured by the Data Well laboratories in Netherlands. A wave rider buoy (Fig. 1) has a spherical steel or cunnifer hull and is available in two sizes viz 70 cm 90 cm in diameter. Housed inside the buoy is an accelerometer which measures the vertical accelerations of the buoy as the buoy follow the water surface fluctuations. These vertical accelerations are integrated twice to obtain vertical displacements and is telemetered to a receiving station with in a range of about 30 Km. At the receiving station the data received are recorded on stripchart paper in analog form and in cassettes in digital form. The analog data recorded on strip chart paper are analysed in the time domain

using Tucker's method. The digital data recorded on cassettes are subjected to frequency domain analysis using Fast Fourier transform (FFT) techniques on a digital computer. Typical output of time domain analysis are significant wave height,  $H_s$  which is defined as the average of highest one third of all waves; zero up crossing period  $T_z$ , maximum wave height  $H_{max}$ , and the period associated with it,  $T_{Hmax}$ . These wave parameters are later used to obtain their daily monthly and seasonal distributions. Longterm distribution and evaluation of design wave with a required return period is made by fitting the wave height data to theoretical probability distributions like Weibull or Gumbel. Fig. 2 shows a typical example. Frequency domain analysis of the wave data gives information on the energy distribution over a range of frequencies known as "wave spectra" in addition to all the other statistical parameters  $H_s, T_z, H_{max}$  etc.

Analysis of waves discussed above do not yield information about their directions of arrival as the instruments used for measurements do not have sensors to measure the directions. This information has been found useful in the design of coastal and offshore structures, harbour entrances etc. and expected to help in reducing the overall costs of constructions. Earlier measurements of directional waves were made using array of pressure gauges. Presently quite a few manufacturing companies have come out with moored buoy systems which can measure, store and telemeter the directional wave data. Principle adopted to obtain directional information are either they measure the pitch and roll motions of the buoy or measure the orbital velocities of water particles of the waves. Some of the commercially available ones are WAVEC buoy and Directional wave rider buoy manufactured by the DataWell laboratories in Netherlands, SEASCAN buoy manufactured by Seatex company of Norway. By fitting a platform transmitter (PTT) and making use of the ARGOS satellite one can receive the data from these buoys with the help of a local user terminal (L.U.T) installed in the laboratory. This would enable to operate the buoys deployed at far off places in the ocean and receive the data at land stations. Typical results of analysed directional wave data are shown in Fig. 2.

2.2 Currents: Currents are undoubtedly one of the most complex parameters in the ocean to establish as they are generated by so many factors. Principle components of current system are the tidal currents, wind driven currents, density currents and slope currents. The tidal currents are the most regular and can be determined and discriminated from the total current. Wind driven currents can be classified into long periodic which vary with the seasonal changes in the wind field and short periodic which are strongly dependent on the daily variations in the wind field. Density currents are due to horizontal gradients in the density distribution. Slope currents are the results of piling of water along the coast in certain areas due to converging winds. It is the slope of the surface that give rise to currents at all levels between the surface and the bottom. In ocean engineering activities tidal currents and wind driven short period currents (residual currents) play a very important role. While there are many instruments available to measure the tidal currents it is rather difficult to measure the wind driven currents. But on the other hand they could be estimated from the measured currents using self recording current meters by subtracting the tidal currents. For use in engineering applications wind driven currents at the surface has been usually assumed to be 2% - 4% of the wind velocity at 10 m above the sea surface based

on field investigations using drifting cards, drifting paraffin flakes, floating oil etc.

Basically there are two principles to measure currents. They are either to measure the passing water at a fixed point (Eulerian) or to follow the path of water particle (Lagrangian). Most commonly adopted in practice are the measurements at a fixed point. These are carried out either by lowering a current meter at station to a desired depth and record directly the value of current speed and direction or by deploying a self recording type current meter in a mooring and record the raw data on magnetic tapes at pre set intervals say 10 min, 15 min, 1 hour etc (Fig 1). These tapes are later analysed in the laboratory using a computer to obtain various statistical parameters. Typical results of such analysis are shown in Fig. 3.

2.3 Tides: Tides are regular rise and fall of ocean surface. Tides are produced by the gravitational and centrifugal effects from the revolution of the Moon around the Earth and the Earth around the Sun. Since the exciting forces are periodic in nature with two dominating components of slightly more than 12 hour (semidiurnal) and about 24 hour period (diurnal) respectively, the tides will exhibit one or both of these periods. Tides in deep seas are only a few centimeters in height. Large tidal ranges (difference between high water and low water) observed at many coastal locations are due to amplification by the local topography in combination with Coriolis acceleration.

Many methods are being adopted to measure ocean tides. Starting from simple tide poles, tide gauges to self recording type water level recorders which record the data on magnetic tapes at pre set intervals say 10 min, 15min or 1 hour etc (Fig. 1). These tapes are later analysed in the laboratory to evaluate various statistical parameters (Fig. 4).

2.4 Wind : Wind is basically transportation of air masses due to temperature variations in the atmosphere. Wind is generally described as a combination of a steady component (mean wind speed with direction) and a fluctuating component (wind turbulence). Wind vane anemometers are widely used for measuring wind velocity and direction. For more systematic measurements an automatic weather stations is used. These weather stations have sensors to measure humidity, air temperature, radiation, rainfall in addition to wind velocity and direction and record the data on magnetic tapes. These tapes are later analysed in the laboratory to evaluate various statistical parameters.

### 3.0 ENVIRONMENTAL LOADS ON STRUCTURES

Environmental loads on structures can be classified in to 3 types viz, steady, time dependent and cyclic in addition to those resulting from freak events like earth quake, storm surge etc. Currents and wind exerts steady loads and where as in waves the loads are time dependent due to changes in the flow velocity and acceleration. Cyclic loads are caused by vortex shedding on the structure due to flow separation and can occur both in steady currents, wind and waves. The resulting three types of forces on the structure due to above environmental loads are drag force, inertia force and transverse or lift force.

Drag and lift forces are due to flow velocities and occur in steady currents, wind and waves. Inertia force is purely dependent of flow acceleration and occurs in waves.

Steady current & wind

Forces in currents and wind are proportional to square of the velocity of the flow.

$$\text{Drag force, } F_D = 0.5 * C_D * L * U^2$$

$$\text{Lift force, } F_L = 0.5 * C_L * L * U^2$$

Where  $C_D$  and  $C_L$  are drag and lift coefficients;

$L$  &  $D$ , the characteristic length & diameter of the structure and  $U$  the mean velocity of flow.

Waves:

Forces in waves are evaluated as,

$$F = 0.5 * D * C_a * |u| * u + 0.25 * D * C_M * u$$

The total force includes a velocity square dependent term and a sum of two acceleration dependent terms. The first acceleration dependent term is the force on the body due to the pressure gradient in the fluid, known as the Froude-Krylov force and the second is the added mass force due to the presence of the body affecting the flow field. For a circular cylinder the total acceleration force (inertia force) per unit length is given as,

$$\begin{aligned} \text{Inertia force / unit length} &= 0.25 * D * u'' + 0.25 * D * u' * u' \\ &= 0.25 * D * (1 + C_M) * u'' \\ &= 0.25 * D * C_M * u'' \end{aligned}$$

Where  $u'$  and  $u''$  are velocity and acceleration of water particles in wave motion and  $C_M$  and  $C_a$  are added mass and inertia coefficients.

CONCLUSIONS

It is imperative from the above discussions that a realistic assesment of the environment along the coastline including the exclusive economic zone (EEZ) is vital to secure the reliability and safety of coastal and offshore installations; for exploration/ exploitation of natural resources and in general the integrity of the coastline itself.

Caribbean nations are a group of small and large islands having good natural resources. These include artisanal fishing (conch, lobster), pelagic, demersal finfish, mangrove nurseries, turtle nesting sites, oil and gas reserves, bauxite mines and excellent opportunities for offshore fish farming. Natural sandy beaches and coastal reefs have made tourism the second major source of foreign exchange. At the same time some of the important problems which exists seem to be; coastal erosion; pollution from sewage, wastes, fertilizers, oil and ship waste; hurricane devastation etc. Most of the coastal erosion problems are seem to be of man made type and due to removal of coastal trees, dredging, mining and constructional activities without proper assessment of the existing environmental conditions. Some of the examples are Barbados, Grenada, St kitts, St Lucia & Jamica where coastal erosion problem exist due to dredging, construction, forest clearing and sand mining.

Hence to cater to the opportunities for developing the nearshore resource activities and to combat the coastal erosion problem including the natural catastrophies like hurricane and strom surge etc. there is a urgent need for a better understanding of the existing environmental conditions. This could be achieved by undertaking a comprehensive coastal and offshore environmental data collection net work programme with the following major objectives.

- (i) Long term data collection on waves, currents, wind and tide to evaluate engineering design parameters for the design of coastal and offshore structures.
- (ii) Coasal engineering studies/surveys to evaluate the stability of beaches and design of protective measures and to identify areas for developmental activities.
- (iii) Numerical modelling for hind casting waves to evaluate extreme design parameters and modelling of storm surges to develop strategies to combat devastational effects like flooding of low lying areas due to hurricanes etc.

#### REFERENCES

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3. Environmental conditions of the Norweigan continental shelf (1976), Report of Norwegian petroleum directorate.

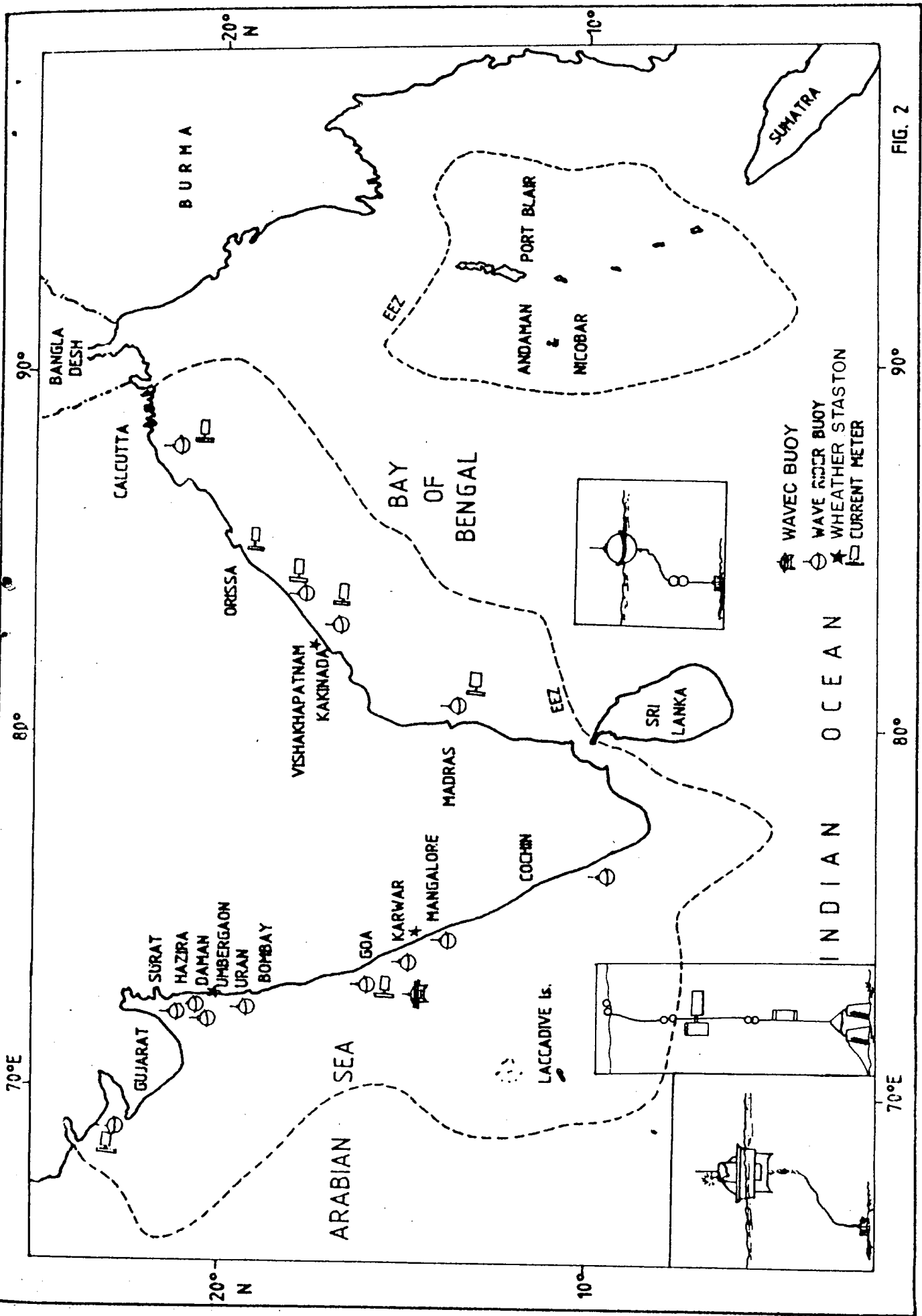
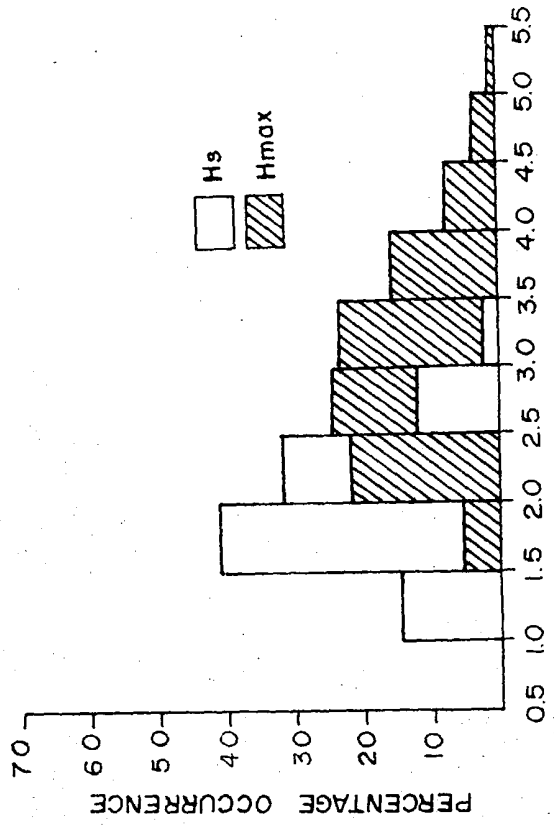
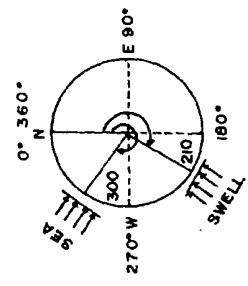
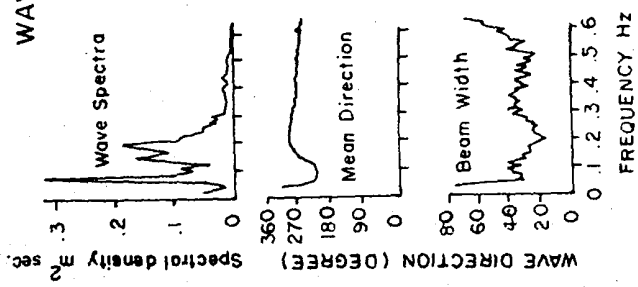


FIG. 2

FIG. 1 LOCATION MAP



WAVE HEIGHT IN METRES



DIRECTIONAL WAVE SPECTRA

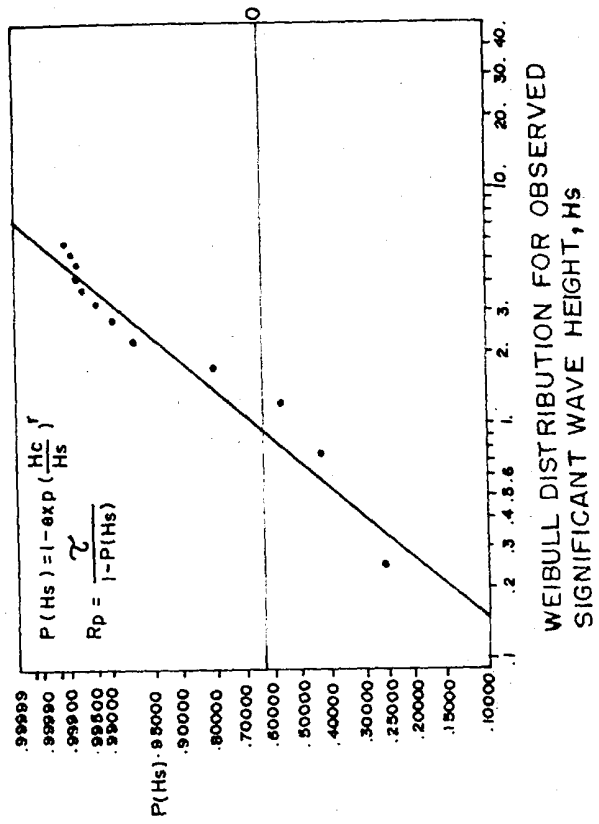
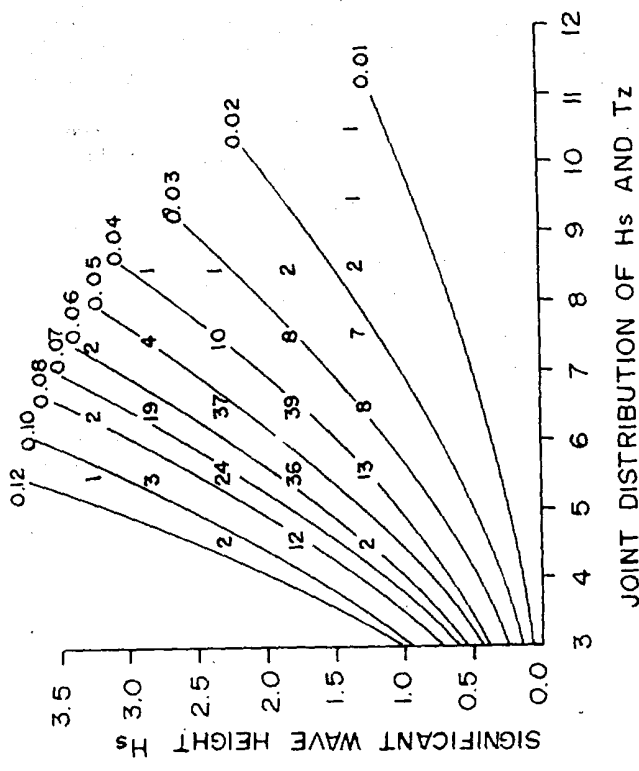


FIG. 2 RESULTS OF WAVE MEASUREMENTS

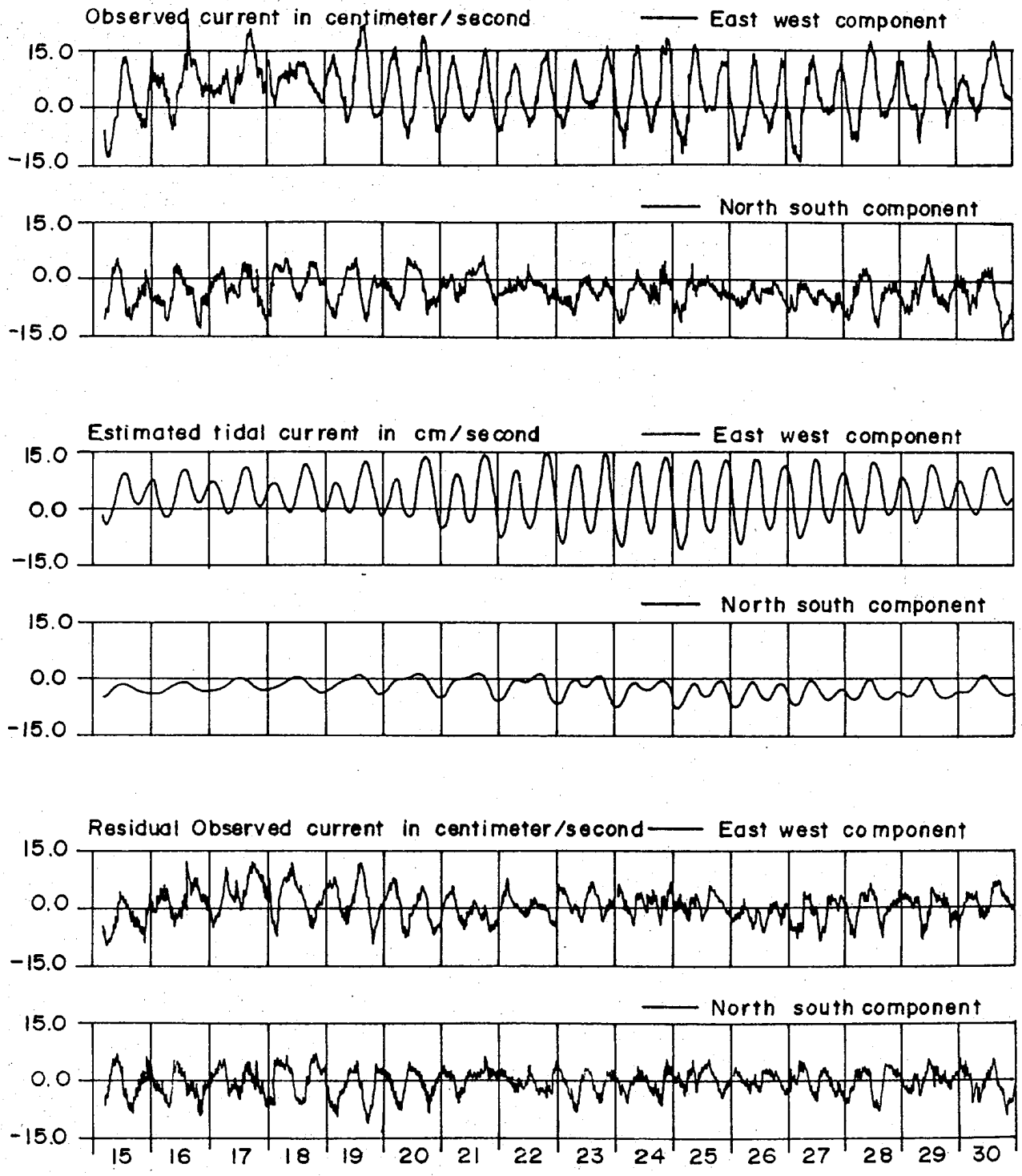
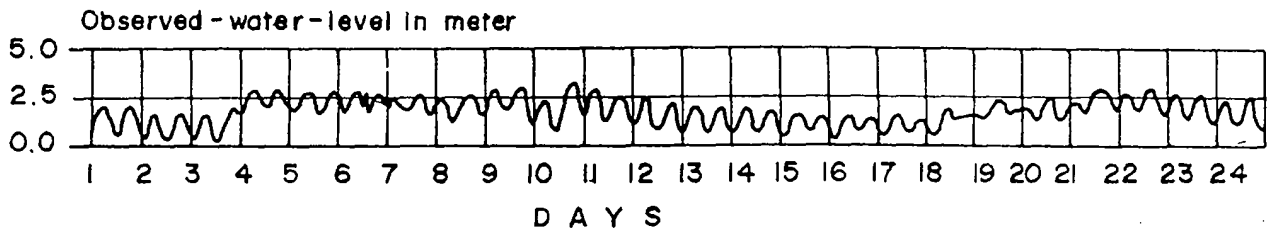
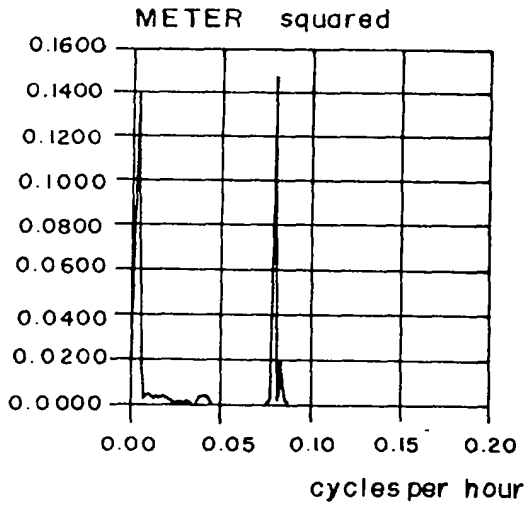


FIG.3 RESULTS OF CURRENT MEASUREMENTS

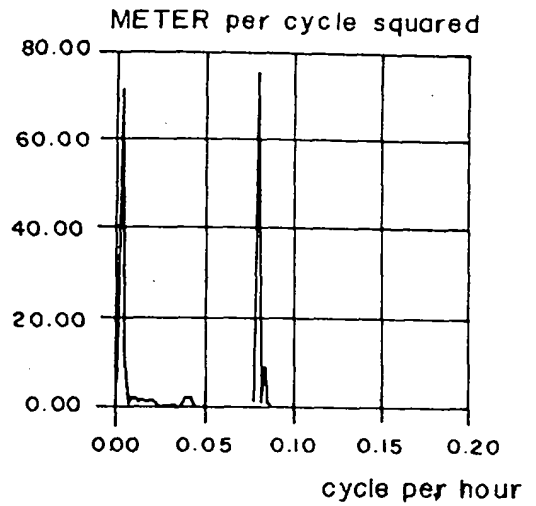




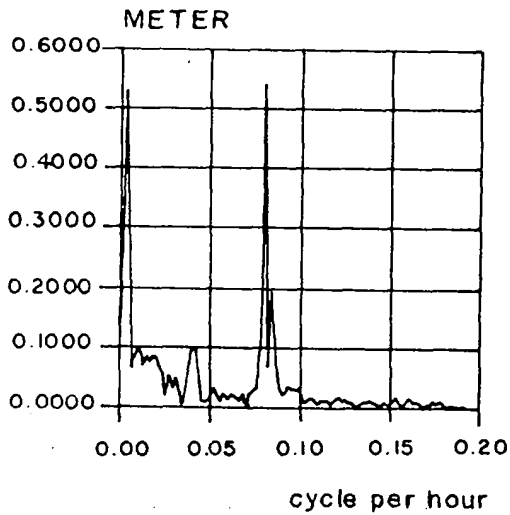
VARIANCE SPECTRUM



VARIANCE DENSITY SPECTRUM



AMPLITUDE SPECTRUM



PHASE SPECTRUM

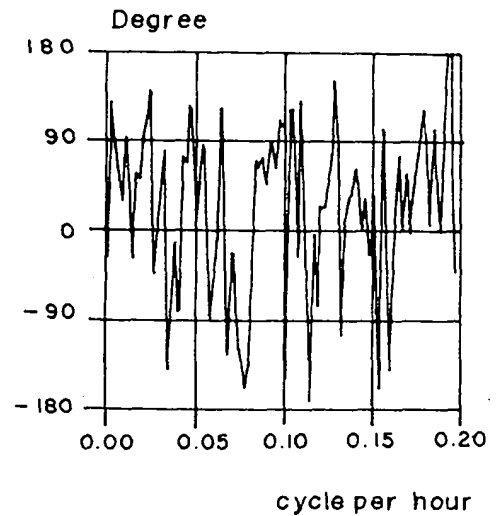


FIG.4 RESULTS OF WATER LEVEL MEASUREMENTS