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PEOPLE'S REPUBLIC OF BANGLADESH

Ministry of Irrigation, Water Development and Flood Control  
Bangladesh Water Development Board

**CYCLONE PROTECTION PROJECT II - FAP 7  
FEASIBILITY AND DESIGN STUDIES**

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**FINAL PROJECT PREPARATION REPORT  
APPENDIX A - HYDRAULIC STUDIES**

May 1992

Joint Venture of  
**KAMPSAX INTERNATIONAL A/S,**  
**BCEOM**  
**DANISH HYDRAULIC INSTITUTE**  
in association with  
**DEVELOPMENT DESIGN CONSULTANTS LTD**

Financed by European Community - Project No. ALA/87/05

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## **REPORT VOLUMES**

The present Report Volume is part of the

**CYCLONE PROTECTION PROJECT II - FAP 7  
FEASIBILITY AND DESIGN STUDIES  
BWDB COMPONENT  
FINAL PROJECT PREPARATION REPORT**

Consisting of the following Volumes :

- Volume 1        -    Main Report
- Volume 2        -    Annexes I - XI, XIII
- Volume 3        -    Annex XII - Polder Data
- Appendix A      -    Hydraulic Studies
- Appendix B      -    Field Surveys and Soil Investigations
- Appendix C      -    Embankment Design
- Appendix D      -    Agriculture
- Appendix E      -    Socio-Economics
- Appendix F      -    Operation & Maintenance
- Appendix G      -    Cyclone Early Warning System
- Appendix H      -    Afforestation
- Appendix I      -    Feasibility Study on Patenga Project.
- Appendix J      -    Fisheries.

## ABBREVIATIONS AND GLOSSARY

ALR	Advanced Logic Research
BCEOM	Bureau Central d'Etudes pour les equipments d'Outre-Mer
BIWTA	Bangladesh Inland Water Transport Authority
BMD	Bangladesh Meteorological Department
BWDB	Bangladesh Water Development Board
CGI	Computer Graphics Interface
CPP2	Cyclone Protection Project II
DDC	Development Design Consultants
DHI	Danish Hydraulic Institute
DOS	Disk operation System, i.e. Computer Operating System for PC's.
FAP	Flood Action Plan
HP	Hewlett Packard
HWL <sub>20</sub>	High Water Level with a return period of 20 years
JONSWAP	Joint North Sea Wave Project
LAT	Lowest Astronomical Tide
LRP	Land Reclamation Project
MIKE 11	DHI's one-dimensional Hydrodynamic Modelling System
MIKE 21	DHI's two-dimensional Hydrodynamic Modelling System used e.g. for simulating cyclone generated surges
MSL	Mean Sea Level
NFS	Network File System
OSF	Open Software Foundation
PWD	Public Works Datum
RDBMS	Relational Data Base Management System
RHD	Road and Highways Department
SCO	Santa Cruz Operations
SVS	Silicon Valley Software
TCP/IP	Transmission Control Protocol/Internet Protocol
TOR	Terms of Reference
UNIX	Computer operating system (like DOS for PC's)



## 1.

**INTRODUCTION**

The present report describes the hydraulic studies carried out as a part of the BWDB component of the Cyclone Protection Project II (Feasibility and Design Studies).

The work has been carried out in accordance with the Revised Terms of Reference of November 1990 (Ref. /2/) and with the Consultancy Contract for Project No. ALA/87/05 between the Commission of the European Communities and the Joint Venture of Kampsax International A/S, BCEOM and Danish Hydraulic Institute.

## 2. STUDY OBJECTIVES

The main objectives of the hydraulic studies are:

- A To determine wave heights and water levels to be used for the design of the embankments, which are to be constructed or rehabilitated under the Mid Term Plan.
- B To conduct a preliminary mathematical model study of cyclone generated surges, which are needed for a preliminary assessment of long term structural measures for protection against cyclonic surges.
- C To prepare TOR for a detailed mathematical model study of cyclone generated surges, which are to form the basis for the design of embankments to be constructed under the Long Term Plan.

With this in mind the hydraulic studies have been divided into the following main tasks:

In order to meet objective A the following tasks have been undertaken:

- Collection of all available data relating to extreme water levels followed by a statistical analysis in order to determine the level of the annual maximum water level with return period 1 - 20 years along the coastal belt.
- Determination of the corresponding nearshore wave conditions as determined by wave breaking in front of the sea-facing embankments.

Objective B was met by carrying out the following:

- Collection of all available data relating to the height of the cyclonic surges experienced in Bangladesh.
- Supplementing and verifying these data through mathematical modelling of cyclone surges based on available data on the meteorological conditions during the passage of cyclones.
- Assistance to the local partner in purchasing, installing and operating the powerful computer needed for the mathematical surge modelling. The assistance was needed, as very little experience existed in Bangladesh regarding such computers. Furthermore a basic introduction to the theoretical and practical aspects of the mathematical modelling was provided.



Finally objective C was met through the task described below:

- Preparation of TOR for a detailed mathematical model study of cyclonic surges, their height and frequency of occurrence in different parts of the coastal belt. The modelling of the surges shall take into account the local effects of the bathymetry on the surge and tide, and the interaction between the two. Furthermore the propagation of the surges upstream inland waterways shall be included.

### 3. ASSESSMENT OF EXTREME WATER LEVELS AND WAVE CONDITIONS

#### 3.1 Assessment of Extreme Water Levels

##### 3.1.1 Data Collection

Water level data during monsoon periods for the 24 stations listed in Table No. 3.1 was collected. The data were mostly 3 hourly visual observations (although a few data sets are from auto gauge stations) and thus includes the combined tide, surge and annual mean water level variation.

The data were collected from the following authorities:

- BWDB, Hydrological Department
- BIWTA
- LRP
- Chittagong Port Authority

Station		Length of Data Period (Years)	High Water Level (return period of 20 years) (m)
Number	Name		
1	Kaikhali	21	3.75
2	Kobakak	20	3.14
3	Mongla	20	3.19
4	Chardonia	20	3.11
5	Rayanda	18	3.61
6	Patharghata *	27	3.48
7	Bamna	26	3.34
8	Khepupara *	17	2.98
9	Patuakhali	19	2.70
10	Galachipa	17	3.52
11	Dasmunia	17	3.48
12	Daulatkhan	21	4.59
13	Hatia	19	5.21
14	Bhatirteck	4	-
15	Companyganj	15	7.19
16	Sandwip	12	6.25
17	Sonapur	16	7.42
18	Patenga	15	4.41
19	Chittagong	17	4.71
20	Banigram	18	4.74
21	Lemsi Khali	15	4.78
22	Shaflapur	14	4.62
23	Cox's Bazar *	17	4.09
24	Teknaf	17	2.26

Table No. 3.1 Stations included in the statistical analysis for determination of design water level. Westernmost stations are listed first, Easternmost stations last. (See also Dwg. No. 3.1).

\* Station with autogauge.



### 3.1.2

#### Statistical Analysis

The annual maximum water levels during the monsoon period were extracted for each station and a Gumbel analysis performed. From this analysis the water levels with a return period of 20 years (as listed in Table No. 3.1) were extracted. The results are also shown in Dwg. No. 3.1.

### 3.2

#### Assessment of Extreme Wave Heights

#### 3.2.1

##### Data Collection

In the search for wave measurements to be used for the wave height statistics for locations along the coast of Bangladesh no useful data have been identified. Measuring programmes have been carried out as part of a number of projects (e.g. projects studying the conditions at the entrance to the harbour of Chittagong, and the Land Reclamation Project), but only for limited periods and with limited data coverage.

Only extreme wave conditions are of interest, and as wave breaking will always occur at the nearshore water depths considered in this project (1 to 10 meters), good estimates of the wave height in front of the embankments have been based on the available offshore wave height statistics and an assessment of the effects of wave breaking.

Offshore wave observations for the Bay of Bengal are available as ship observations from British Maritime Technology, which (for the Bay of Bengal) have collected and processed 18,294 observations (see Global Wave Statistics, Ref. /6/).

#### 3.2.2

##### Statistical Analysis of Offshore Wave Heights

Based on the ship observations mentioned above the exceedance diagram for the significant wave heights was made (see Dwg. No. 3.2). As the coast of Bangladesh is exposed to high waves only from South-east, South and South-west, only these three directions were included in the analysis.

The statistics show the significant wave height as function of the probability of occurrence (exceedance frequency). The events shown refer to 12 hours duration. This approach has been used to ensure the occurrence of one high water in this period.

Assuming that the peak period is 6% higher than the significant wave period and that the waves in the Bay of Bengal fit a standard JONSWAP spectrum, the significant wave periods have been determined as shown in Table 3.2.

Return Period (Years)	2.5	5	10	20	50	100
Offshore Significant Wave Height (m)	6.9	7.6	8.2	8.8	9.6	10.2
Offshore Significant Wave Period (s)	11.1	11.7	12.2	12.5	13.1	13.6

Table 3.2: Offshore Significant Wave Heights and Wave Periods

### 3.2.3

#### Determination of Nearshore Wave Heights

When the waves from the Bay of Bengal approach coast of Bangladesh they are subject to the following types of transformation:

- Shoaling
- Wave breaking
- Refraction
- Reflection

In the present project only sea-facing embankments are considered and the bottom contours in front of these embankments can be considered more or less parallel. Therefore only shoaling and wave breaking are considered in the following calculations. Anyway, in the present case refraction and shoaling only have a small effect on the wave heights compared to wave breaking.

The nearshore wave heights has been calculated as a function of the bottom slope and the depth. As an example the results for an offshore significant wave height of 8.8 m and a corresponding significant wave period of 12.5 s are shown in Table 3.3. The procedure used in the calculations is the one described by Goda in Ref./7/.

Depth (m)	Bottom Slope				
	1/1000	1/500	1/200	1/100	1/50
10	6.04	6.06	6.13	6.26	6.52
9	5.52	5.54	5.60	5.72	5.96
8	5.00	5.02	5.07	5.17	5.39
7	4.47	4.49	4.54	4.63	4.83
6	3.95	3.97	4.01	4.09	4.26
5	3.43	3.44	3.48	3.55	3.69
4	2.91	2.92	2.95	3.00	3.13
3	2.39	2.39	2.42	2.46	2.56
2	1.86	1.87	1.89	1.92	2.00

Table 3.3: Example of significant wave height,  $H_s$  (m), occurring 12 hrs/20 years during the period May-September. Offshore wave parameters:  $H_s = 8.2$  m,  $T_s = 12.2$  s.



#### 4. PRELIMINARY MATHEMATICAL MODEL STUDY OF CYCLONIC SURGES

##### 4.1 Methodology

The extreme surge levels experienced along the coastal of Bangladesh are generated by cyclones travelling on north to north-easterly tracks up through the Bay of Bengal. After crossing the Bangladeshi coast they quickly dissolve. As seen from Fig No. 4.1 Bangladesh is severely affected by cyclones and depressions.

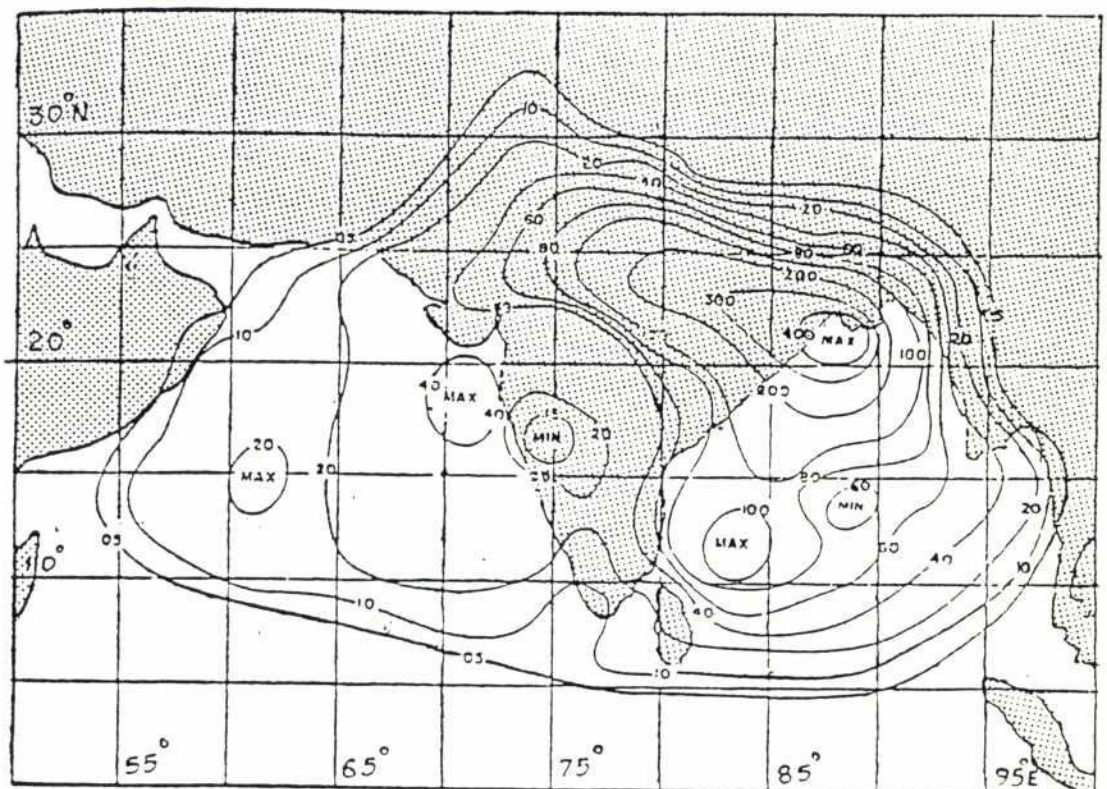


Fig No. 4.1 : Number of cyclones and depressions passing  $2\frac{1}{2}$  degree alt./long squares 1877-1974 (from Ref /3/)

When making an assessment of for example the 20 year event of a physical phenomenon like cyclone generated surges two different approaches can be taken:

- Either a statistical analysis can be made on the basis of measurements. This requires, however, that a reasonable large number of events have occurred during the measuring period. It also requires, that the area to be considered is covered sufficiently by measuring stations.



- Or a numerical model covering the area of interest can be made. A reasonable number of events will then have to be simulated.

For severe cyclones, which on the average only occur approximately every second year, the first approach requires very long series of measurements. Furthermore, measuring devices are often damaged during the passage of a cyclone, which results in the loss of data needed for a study like the present one. Secondly, meteorological data (e.g. data on cyclones) are normally available for a very long period. Thus, on this background it was decided to apply a numerical surge model.

During the present phase of the project, the Mid Term Plan, it is, however, not envisaged that the final design surge levels are to be determined. The purpose of the modelling during this phase is to gain some experience in the modelling of surges along the coast of Bangladesh, experience which can be applied in additional simulations during the Long Term Plan. The number of cyclones simulated is thus much smaller than what would normally be required in order to make a statistical analysis.

The modelling procedure, which was applied, consisted of the following tasks :

- Meteorological key parameters for all cyclones occurring within a certain period were collected.
- A numerical cyclone model, which on the basis of the collected key parameters generates the wind and pressure fields during the passage of a cyclone, was developed.
- A numerical surge model of the Bay of Bengal with a refined resolution along the coast of Bangladesh was setup.
- The surge model complex was calibrated and verified for tide.
- The cyclone model and the surge model were then used for the simulation of the selected cyclone periods.
- Finally the maximum surge levels occurring during the 7 cyclones were extracted.

## 4.2

### Selection of Cyclones and Collection of Cyclone Data

At an early stage in the project, that is, before the design criteria had been fixed as the 20 year event, it was decided to simulate the surges for all cyclones, which occurred during the period 1977-1988. On the one hand it might have been more consistent to select a 20 year period, but as the data for the period had already been collected and in order to keep the number of cyclone periods within reasonable limits, the 12 year period was not

extended. Secondly, the number of cyclones found within a 20 year period would be too small to establish design criteria for the whole coast of Bangladesh (see section 3.4.2).

The periods, during which surge levels were computed, are listed in Table No. 4.1.

Dates of Occurrence		Affected Area	Nature of the Phenomena
1977	May 12- May 13	Khulna Noakhali Patuakhali Barisal Chittagong and Offshore Islands	Cyclonic storm 70 m.p.h.
1978	Oct. 2- Oct. 4	Khulna and Sundarban Coastal	Cyclonic storm 46 m. p. h.
1983	Oct. 14- Oct. 16	Chittagong coast near Feni river	Cyclonic storm, with a speed of 122 km/h
1983	Nov. 8- Nov. 10	Chittagong Cox's Bazar coast near Kutubdia and the low lying areas of St. Martin, Teknaf, Ukhya, Moheskhali & Sonadia.	Severe cyclonic storm with a speed of 136 km/h and a storm surge of 5 feet.
1985	May 23- May 25	Chittagong, Noakhali coast	Severe cyclonic storm with a max. speed of 154 km/h and surge of 14 ft.
1986	Nov. 8- Nov. 10	Chittagong, Patuakhali, Barguna and Patharg- hata	Cyclonic storm, wind speed 110 km/h at Chittagong & 90 km/h at Khulna
1988	Nov. 28 Nov. 30	Khulna coast near river Raimangal	Severe cyclonic storm (hurricane) with a core of hurricane wind speed 160 km/h, storm surge of 14.5 ft at Mongle Point.

Table 4.1 Selected cyclones (from Ref. /4/).

Simulation of April 1991 cyclone is included in Annex D to the present report.

For use in the cyclone model described in section 4.3 the following key parameters were collected for the 7 cyclones listed from the Storm Warning Center at Bangladesh Meteorological Department (BMD) :

- Position of the centre of the cyclone in latitude and longitude.

- Central pressure and neutral pressure (the pressure outside the area influenced by the cyclone)

or

- the pressure drop (neutral pressure minus central pressure)
- Radius to maximum wind speed.
- Maximum wind speed, if available. Otherwise the following relationship (provided by BMD) was used :

$$V_{\max} = 14.4 \Delta p^{1/2}$$

Where  $V_{\max}$  is in knots

$\Delta p$  is the pressure drop in millibars

For each cyclone the above mentioned parameters were collected for a period covering the time from the cyclone entered the Bay of Bengal until it dissolved after hitting land.

Synoptic weather charts could not be made available to the project.

#### 4.3

##### Description of Cyclone Model

During the last two decades a considerable amount of research has been carried out within modelling of cyclone wind and pressure fields, and the general conclusion is, that the following parameters describe the wind fields quite well:

- Radius to maximum winds,  $R_m$
- Maximum wind speed,  $V_{\max}$
- Cyclone track, forward speed  $V_f$  and direction

while

- Central pressure,  $P_c$  and
- Neutral pressure,  $P_n$

can be used for a description of the pressure field.

The wind field consists of a rotational and a translational component. At a distance,  $R$ , from the centre of the cyclone the rotational wind speed,  $V_r$  is given as



$$V_r = V_{\max} (R/R_m) \exp (7(1-R/R_m)) \text{ for } R < R_m$$

$$V_r = V_{\max} \exp ((0.0025 R_m + 0.05) (1-R/R_m)) \text{ for } R \geq R_m$$

Where  $R$  and  $R_m$  are in km, While the translational component,  $V_t$ , is given as

$$V_t = -0.5 V_t (-\cos(\phi))$$

where  $\phi$  is the latitude,

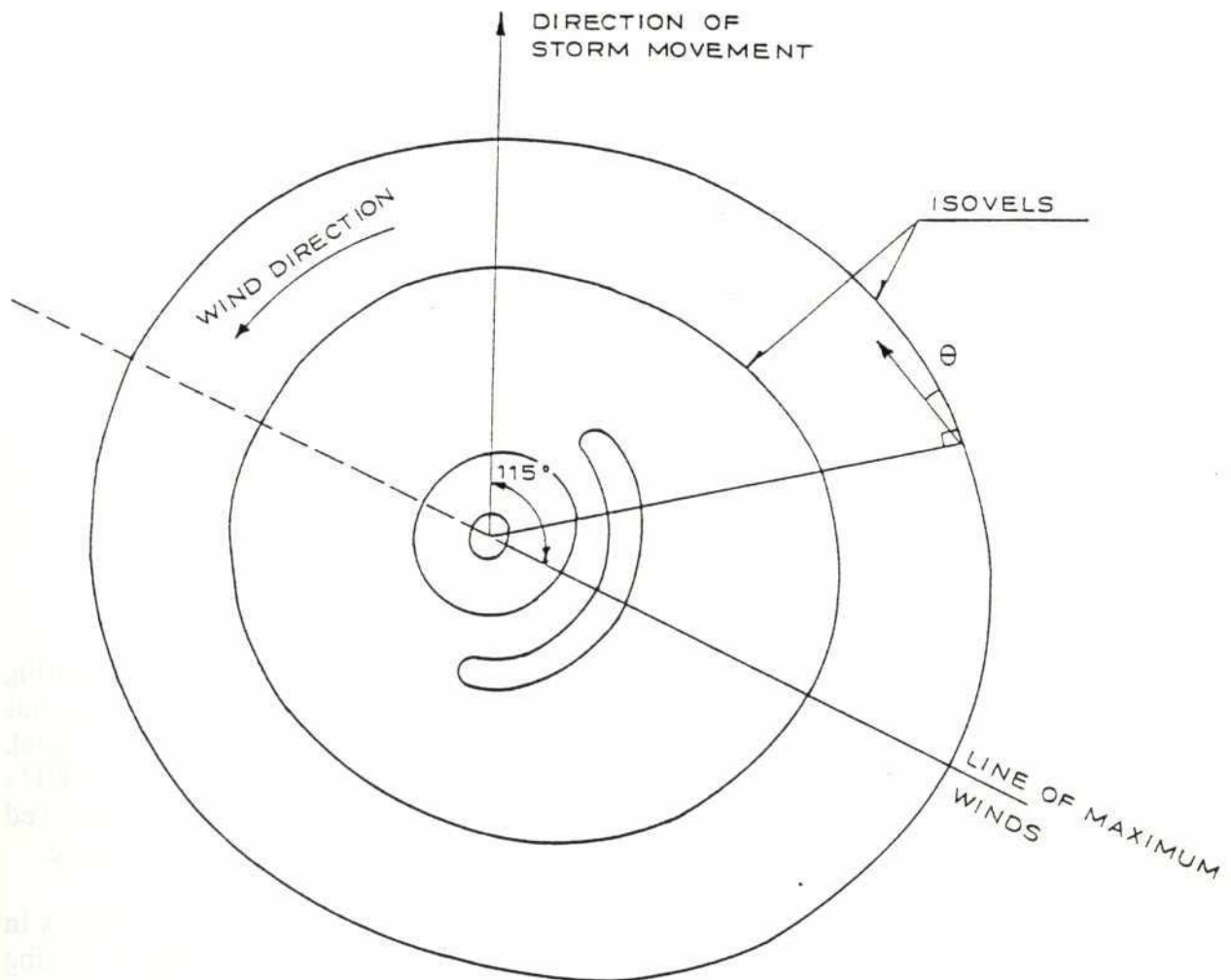


Fig. 4.2 : Cyclone isotach pattern

and the total wind speed,  $V$ , as

$$V = V_r + V_t$$

A general cyclone isotach pattern is shown in Fig. No. 4.2. The line of maximum winds is at an angle of  $115^\circ$  measures clockwise from a line extending from the centre of the cyclone in the direction of the storm movement. On the northern hemisphere cyclones rotates in an anticlockwise direction around the centre, while they rotate clockwise on the southern hemisphere.

The wind direction at a particular location is parallel to the tangent to the tangent except for deflection angle,  $\theta$  turning the direction of the wind towards the centre of the cyclone. This is deflection is caused by the friction between water and air and is given as

$$\begin{aligned} \theta &= 10^\circ & 0 < R \leq R_m \\ \theta &= 10^\circ + (R - R_m)/(0.2 \cdot R_m) \cdot 15^\circ & R_m < R \leq 1.2 R_m \\ \theta &= 25^\circ & 1.2 R_m < R \end{aligned}$$

Finally, the pressure,  $P$ , at a particular location is given as

$$P = P_c + (P_n - P_c) \exp (-R_m/R)$$

#### 4.4 Description of Surge Model

##### 4.4.1 General

For the modelling of the surge level variations in the Bay of Bengal during the passage of cyclones the hydrodynamic modelling system, MIKE 21, has been applied. MIKE 21 is a general modelling system for 2-dimensional, free-surface flows, and is a microcomputer-based development of DHI's System 21, which during the last 20 years has been applied and improved through the experience gained from over 300 applications world-wide.

MIKE 21 simulates the time-varying water level variations and flows in lakes, estuaries, bays and coastal areas in response to a variety of forcing functions. The water levels and flows, which are resolved on a rectangular grid covering the area of interest, can be calculated when MIKE 21 is provided with the bathymetry, bed resistance coefficients, wind and pressure field, hydrographic boundary conditions etc. MIKE 21 solves the equations of continuity and conservation of momentum using implicit finite difference methods. A short description of the modelling system is enclosed as appendix B.

## 4.4.2

## Model Areas

The area covered by the hydrodynamic models are shown in Fig. No. 4.3. In principle only one model is needed, but a grid size of 2 km. was necessary along the Bangladeshi coast in order to get reasonable results in this area, and at the same time the whole northern part of the Bay of Bengal had to be covered in order to include the areas, where the cyclonic surge affecting the Bangladeshi coast are generated. Fulfilling these two requirements in one model would lead to a model with too many grid points. Therefore a Regional Model with a grid spacing of 6 km and an Intermediate Model with a grid spacing of 2 km were applied.

The bathymetries for the two model areas have been digitized and converted to a common datum, MSL, from the following charts :

- BWDB, LRP, Survey & Study Division, Chittagong, Bathymetric Chart for the project area surveyed 1979-1988, scale 1:250,000, datum: PWD.
- British Admiralty Chart No. 859, Raimangal River to Elephant Point, scale 1:300,000, datum: LAT.
- British Admiralty Chart No. 894, The Sandheads, Paradip to Raimangal River, scale 1:300,000, datum: LAT.
- British Admiralty Chart No. 829, Bay of Bengal, Northern Part, scale 1:1,500,000, datum: LAT.

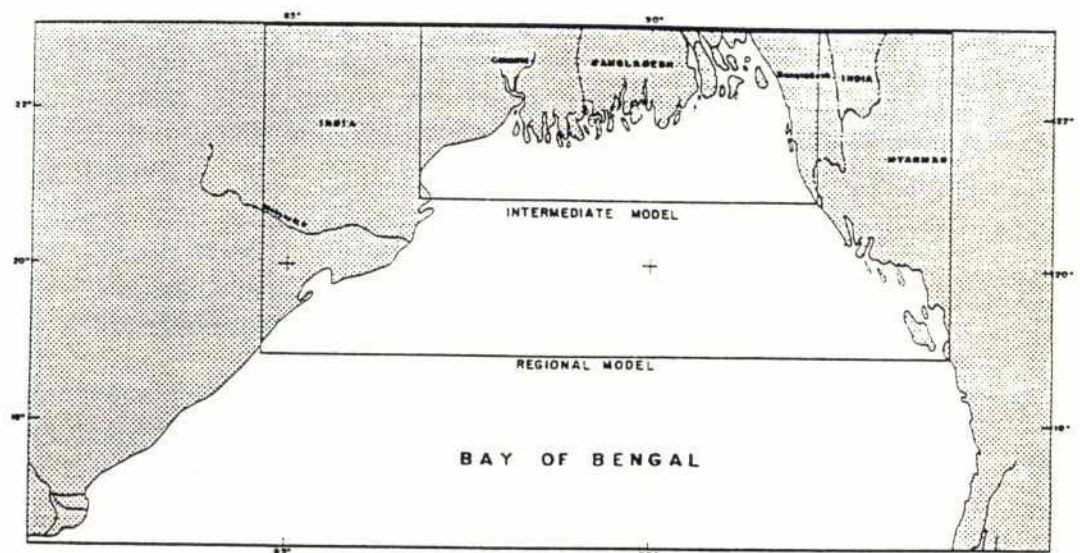


Fig. No. 4.3 : Areas covered by the Hydrodynamic models.



Dwg 4.1 and 4.2 show the digitized bathymetries for the regional and the intermediate models. Furthermore the part of the intermediate model covering Bangladesh is shown in Dwg. No. 4.3.

The hydrodynamic simulations, which cover periods from 36 to 60 hours, were made using time steps of 6 and 3 minutes for the Regional and Intermediate model respectively, while the time step used in the calculation of the cyclonic wind and pressure fields was 1 hour.

#### 4.5 Calibration and Verification of Model Complex

##### 4.5.1 Methodology

Before a mathematical model is used to produce any results applied in e.g. a design phase it should be tuned and tested. This is normally done by first calibrating the model in order to make it reproduce a set of measurements satisfactory, and then secondly validating it by comparing the simulation results from new period with a new set of measurements. If this second comparison fulfills the specifications to the accuracy of the model, the model is ready to be used for "production simulations".

In the present project there are two models: the cyclone wind and pressure model and the hydrodynamic model. This model complex should thus be calibrated and verified by first looking at the wind and pressure model and then at the total model complex. Only very few wind and pressure data were, however, made available for the calibration and verification of the wind and pressure model. Therefore it was impossible to calibrate and verify the model complex as a whole. on the other hand, it was possible to tune the hydrodynamic model to reproduce a phenomenon, which from a hydrodynamic point of view has many similarities with cyclonic surge: tide. This also means, that possible discrepancies between simulated and measured surges are most probably caused by the untuned cyclone wind and pressure model.

As tide is deterministic and as the period covered in the tidal model calibration includes minimum neap tide as well as maximum spring tide, the calibration has also been considered a model verification.

Although the cyclone model can not be tuned tested, the "connection" between the two models can, i.e. the transfer of the energy from the wind to the water surface. A sensitivity test of the wind friction factor was therefore carried out.

Another factor having an influence on the accuracy of the results is the representation of the rivers not covered by the model area. a sensitivity test illustrating this factor was also carried out.

It should be noted, that if e.g. weather charts including synoptic informa-



msk JwTA

- Boundary data. The tidal constituents used for the prediction along the southern boundary have been changes slightly. The final choice is listed in Table No. 4.3.

Total constituent		Grid Points		
		2-65	66-124	125-153
$M_2$	Amp(m)	0.49	Linear	0.89
	Phase (deg)	249.5	Interpolation	265.0
$S_2$	Amp(m)	2.23	Linear	0.44
	Phase (deg)	280.5	Interpolation	302.0
$K_1$	Amp(m)	0.13	Linear	0.18
	Phase (deg)	339.5	Interpolation	332.0
$O_1$	Amp(m)	0.07	Linear	0.08
	Phase (deg)	310.5	Interpolation	307.0

Table No. 4.3      Tidal constants used for prediction of tidal evaluations at southern boundary.

- Water depth. It was necessary to introduce a correction to the water levels of 2.5 - 3.0 m in order to obtain correct tidal phases. This might at first seem a rather large correction, but keeping in mind, that sea charts are made for navigational purposes, where the minimum depth is most important, the correction can be justified.

Dwg. No. 4.7 through 4.14 show the comparison between the predicted and the computed (or simulated) tidal elevations resulting from the model calibration. From the drawings it is seen, that the model reproduces the tide very accurately all over the model except for the area around the northern part of Hatia and Sandwip Island. In this area the shallow water constituents are extremely important, and as only 4 constituents are given at the open southern boundary, it will be very difficult to reproduce the tide in this area.

The 4 constituent are nevertheless scale to approximate the effect of 19 additional constituents, but as this is done at the southern boundary very far from Sandwip and Hatia, as inaccuracies in the approximation are amplified in shallow water and as there are furthermore large seasonal variations (according to Ref. /8/) around Sandwip and Hatia, a revised description of the boundary data is needed to improve the tidal elevations in this shallow area. The model is, however, not going to be used for tidal predictions in the present phase of the project, and as the reasons for the inaccuracies are known and should not effect the accuracy of the surge calculations, the model is considered to be calibrated for simulations of cyclonic surge.



It should be mentioned, that the model calibration is partly based on earlier work carried out in connection with hydrodynamic modelling of the current patterns around the Pussur-Sibsa and Karnafuli River entrances (see Ref. /11/).

#### 4.5.3 Wind Friction Sensitivity Test

The transfer of the wind energy to the sea surface is proportional to the square of the wind speed. The proportionality factor, the wind friction coefficient, can in open sea areas be considered constant, while e.g. Smith and Banke (Ref. /10/) have suggested, that in shallow areas (like estuaries) it should only be kept constant for wind speeds in excess of 30 m/s, while it below this limit should decrease linearly.

The November 1988 cyclone was therefore simulated using both a constant and a linearly decreasing wind friction coefficient below 30 m/s.

The results of the two simulations were practically identical, which is due to the fact that is the high wind speeds (above 3 m/s), which determines the wind generated setup.

All simulations were therefore made using a constant wind friction coefficient of 0.0026.

#### 4.5.4 Meghna River Sensitivity Test

One of the advantages of MIKE 21 in comparison to some other hydrodynamic models is its capability to simulate the flooding and drying of land areas during high and low tide. This however requires information not only about the water depths but also of the height of the low lying land areas. As this latter information was not directly available the flooding and drying facility was not applied.

During the latter stages of the production simulations it was realized, that by not including this facilities to high surges were probably computed in some areas.

This was a conclusion drawn indirectly for a test showing the influence on the surge results from including smaller or larger parts of the Meghna River lying outside the model area by comparing Dwg No. 4.15 with 4.16 a local effect around the mouth of the Meghna River is seen. Including the river correctly in the model without knowing the side of the areas which are flooding high area/inundated, is however not possible. Therefore no attempt to do this was made.

#### 4.5.5 Combined Tide and Surge Sensitivity Test

It has not been in the tension to include tide in the production simulation.

However, as part of the preparation for the future mathematical model study one of the cyclones, the May 1977 cyclone, was simulated applying tide and cyclonic wind at the same time.

The tide applied was not the actual tide, but a tide with a high water coincided with the maximum surge as this yields the highest combined tide and surge. After having extracted the tide from this combined simulation it can be compared to the surge-only simulation. The difference between the ways of computing the surge is shown in Dwg No. 4.17, while the results from the surge-only is shown in Dwg No. 4.18. From this two drawings it can be concluded, that in the extreme case, when maximum tide and maximum surge coincides, tide has a significant effect on the computed surge heights. It is therefore recommended, that tide is included in future surge simulations.

#### 4.5.6 Conclusion on the Accuracy of the Model Complex

The surges produced by the cyclone and hydrodynamic are considered to give a good assessment of the surges along the Bangladeshi Coast.

A number of factors affecting the accuracy have been identified during the calibration, verification and production simulations. It is recommended that they are studied further in the next phase of the project. They are :

- Flooding and drying of land areas should be included in the simulations.
- The part of the rivers which extend inland should be represented in the model.
- Tide should be included in future surge simulations.
- When tide is to be included in the simulations, the open boundary conditions should be improved in order to reproduce the tidal variations around Hatia and Sandwip more correctly.
- With more information on the cyclonic wind field (e.g. synoptic weather charts) a calibration of the cyclone wind and pressure model can be achieved.

#### 4.6 Simulation of Surges During the 7 Selected Cyclones

##### 4.6.1 Overview

The exact duration of the simulations for the 7 selected cyclones are listed in Table No. 4.4. Also listed are the number of BIWTA stations with measured water levels available for comparison with the simulation results. The location of these stations are also shown in Fig. No. 4.4.



For each cyclone the following drawings are included:

- Maximum surge levels during the simulation.
- 12 hourly isobars for the regional model.
- Maximum occurring wind speed in the regional model during the simulation.
- 12 hourly cyclone wind fields for the Bangladesh part of the intermediate model.
- Measured water levels at the available stations before, during and after the passage of the cyclone.

Period	Number of Stations with Measurements
1977, May 12 0000 hrs - May 13 1200 hrs	10
1978, October 2 0000 hrs - October 4 1200 hrs	11
1983, October 14 0000 hrs - October 16 0000 hrs	12
1983, November 8 0000 hrs - November 10 1200 hrs	13
1985, May 23 0000 hrs - May 25 1200 hrs	11
1986, November 8 0000 hrs - November 10 1200 hrs	12
1988, November 28 0000 hrs - November 30 1200 hrs	13

Table No. 4.4 : Production Simulations.

- Comparison of computed and measured surge at the available stations during the passage of the cyclone.

It should be mentioned that extracting the tide from the measurements in order to get the surge can be done in several ways:

- If the tidal constants are available this will yield the best tidal signal, which is then extracted from the measurements. As the tidal constants were only made available by BIWTA for Hiron Point this approach had to be dropped.
- If long time series of measurements are available these can be analyzed in order to extract the tidal constants. Approximately one

month including the cyclone period) was available for each station, which is sufficient to extract a large number of constituents (30 or more), if the meteorological influence is small. An analysis including the maximum number of constituents was made for Hiron Point and compared to an analysis, in which only 4 constituents were included (see Dwgs. Nos. 4.19-4.22).

From this comparison it was concluded, that only 4 constituents should be used, when generating the tide to be extracted from the measurements, as part of the surge will otherwise be contained in the larger number of tidal constants.

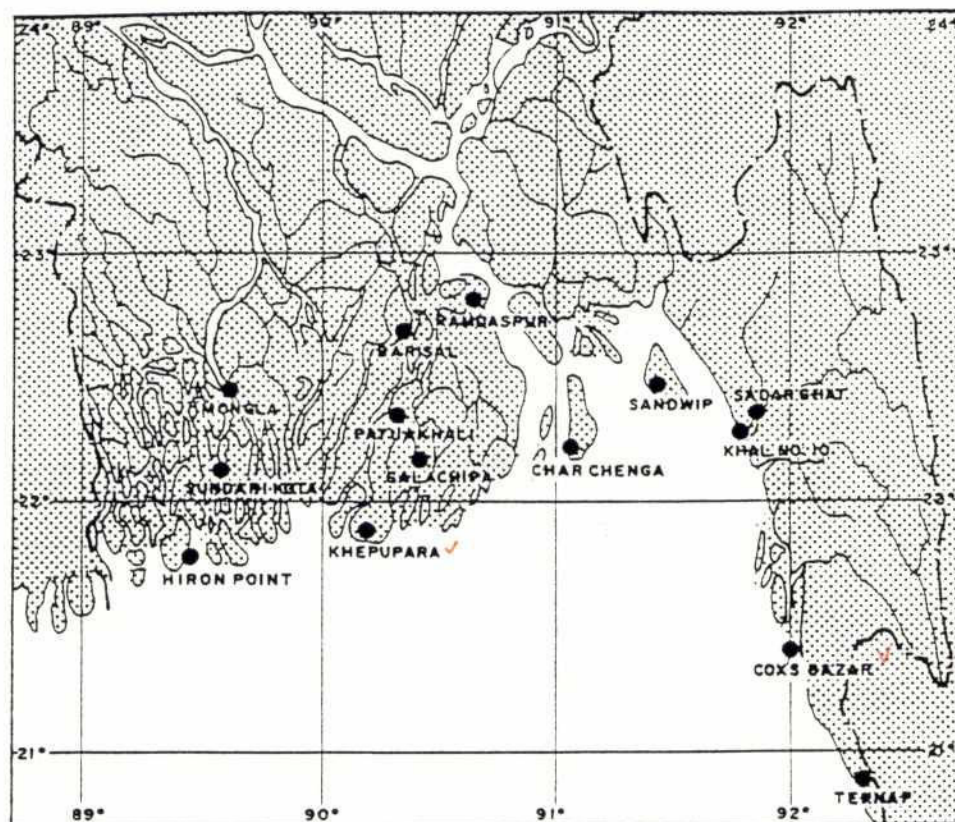


Fig. No. 4.4 : Stations for which computed and simulated surges are compared.

Finally, the maximum surge found during all 7 simulations are shown in Dwg. No. 4.23.



## 4.6.2

## Cyclone of May 12-13, 1977

The results from the simulation and the comparison with the measurements are shown in Dwg. 4.24-4.49.

The cyclone, which is classified as a severe cyclonic storm, travelled up through the bay of Bengal hitting the coast of Bangladesh east of Khepupara. The maximum wind speed was 35 m/s with a radius to maximum wind of 96 Km, while a surge of up to 4.5 m was produced between Sandwip and Hatia (see Dwg. No. 4.24).

Looking at the comparisons between the computed and the measured surges the following is noted:

- The computed surge at Barisal is much higher than the measured one, which is caused by the following:
  - a) Barisal lies not at the coast but on a river. In order to achieve good results here a better description of the river system including flood plains should be included in the model. This might be done using a one-dimensional hydrodynamic model (like MIKE 11) coupled with the two-dimensional one (MIKE 21).
  - b) Flooding of tidal flats are not included, which might reduce the wind setup.
  - c) It has not been possible to calibrate the cyclone model. Secondly, the radius to maximum wind speed and the maximum wind speed might be on the high side.
- At Cox's Bazar the measured surge is higher than the computed one. The reasons for this difference are the same as listed for Barisal except for (a), as Cox's Bazar is situated on the coast.
- No conclusion can be drawn from the comparison at Galachipa, as some measurements are missing.
- At Hiron Point a negative surge is computed, while a minor positive one is measured. This indicates, that the radius to maximum wind is too large.
- No conclusions can be made at Khepupara, as the measurements are incomplete.
- Mongla is situated inland like Barisal. The negative surge computed is caused by the following:



- a) Like cause (a) for Barisal. This means, that with the discretization used the water is blown out of the river in the model, and there is nothing to replace it like in the real river.
- b) The radius to maximum wind is probably too large.
- The measurements at Ramdaspur covers too small a period.
- The computed surge at Sadarghat (near Chittagong) is much higher than the measured one. This is most likely caused by too high maximum wind speeds and a too large radius to maximum wind.
- At Sandwip the computed surges are also much higher than the measured one, which is caused by:
  - a) The missing flooding facility.
  - b) Too high winds and too large a cyclone.
  - c) The absence of the possibility for the water to flow up the Meghna River (and other rivers).
- Sundarikota experienced the same difference between the computed and the measured surge as Mongla.

At first the comparisons might seem quite disappointing, but on the other hand, as long as the differences can be explained and there are ways to improve the computed surges, the simulation fulfills one of the objectives.

#### 4.6.3 Cyclone of October 2-4, 1978

The results from the simulation and the comparison with the measurements are shown in Dwg. 4.50-4.81.

The cyclone, which is classified as a cyclonic storm, travelled up through the Bay Bengal hitting the coast of Bangladesh near Khepupara. The maximum wind speed was 23 m/s with a radius to maximum wind of 64 km, while a surge of up to 2 m was produced between Sandwip and Hatia (see Dwg. no. 4.50)

Looking at the comparisons (Dwgs. Nos. 4.71-4.81) it is seen, that neither the computed surges nor the measured ones are very high. As for the May 1977 cyclone the computed surges are generally higher which have the same causes as given in section 4.6.2.

#### 4.6.4 Cyclone of October 14-16, 1983

The results from the simulation and the comparison with the measure-

ments are as shown in Dwgs. 4.82-4.113.

The cyclone, which is classified as a cyclonic storm, travelled up through the Bay of Bengal hitting the coast of Bangladesh near Feni River. The maximum wind speed was 29 m/s with a radius to maximum wind of 65 km, while a surge of up to 4 m was produced at the mouth of Feni River (see Dwg. 4.82).

Looking at the comparisons (Dwgs. Nos. 4.102-4.113) it is seen, that the computed surge is much too high at Khal No. 10, Sandarghat and Sandwip. This again indicates that the flooding facility is needed, that the storage capacity of the rivers is needed and that a calibration of the cyclone model is required.

#### 4.6.5

##### Cyclone of November 8-10, 1983

The results from the simulation and the comparison with the measurements are shown in Dwgs. 4.114-4.149.

The cyclone, which is classified as a severe cyclonic storm, travelled up through the Bay of Bengal hitting the coast of Bangladesh near Kutubdia Island. The Maximum wind speed was 36 m/s with a radius to maximum wind of 65 km, while a surge of up to 1.5 m was produced south of Kutubdia Island ( see Dwgs. Nos. 4.114).

Looking at the comparisons (Dwgs Nos. 4.237-4.149) it is seen, that the positive surge produced at Teknaf is well reproduced by the model, while the negative surges simulated elsewhere are not found in the measurements. The cause for this difference are the same as given as given for the cyclone of May 1977.

#### 4.6.6

##### Cyclone of May 23-25, 1985

The results from the simulation and the comparison with the measurements are shown in dwgs. 4.150-4.181.

The cyclone which is classified as a severe cyclonic storm with a core of hurricane wind, travelled up through the Bay of Bengal crossing the coast of Bangladesh near Chittagong. The maximum wind speed was 46 m/s with a radius to maximum wind of 60 km, while a surge of up to 3 m was produced near Kutubdia Island (see Dwg. No. 4.150).

Looking at the comparisons (Dwgs. Nos. 4.137-4.181) it is seen, that the positive surges generally are reproduced well except for those at Cox's Bazar and Sadarghat. At these two stations no surge is found in the measurements are therefore mos probably erroneous.



#### 4.6.7 Cyclone of November 8-10, 1986

The results from the simulation and the comparison with the measurements are shown in dwgs 4.182-4.213.

The cyclone, which is classified only as a well marked low, travelled up through the Bay of Bengal along the east coast of India crossing the coast of Bangladesh near Raimangal River. The maximum wind speed was 23 m/s with a radius to maximum wind of 48 km, while a surge of up to 2 m was produced north of Sandwip (see Dwg. No. 4.182).

Looking at the comparisons ( Dwg. Nos. 4.202-4.213) it is seen, that the computed surges generally compare fairly well with the measured ones, although the computed surges are somewhat higher than the measured ones, as has been the case for the previous simulations.

#### 4.6.8 Cyclone of November 28-30, 1988

The results from the simulation and the comparison with the measurements shown in Dwgs. 4.214-4.249.

The cyclone, which is classified only as a severe cyclonic storm with a core of hurricane wind, travelled up through the Bay of Bengal crossing the coast of Bangladesh River. The maximum wind speed was 46 m/s with a radius to maximum wind of 70 km, while a surge of up to 4 m was produced at the Meghna River mouth ( see Dwg. No. 4.214).

Looking at the comparisons (Dwgs. Nos. 4.237-4.249) the same pattern as seen for the other cyclones is repeated:

- The computed surges at the river stations are much too high.
- The computed surges in the areas close to the river mouths are also too high.
- The comparison is reasonable for stations at the coast like Hiron Point, although the computed surges also here are on the high side.

#### 4.7 Preliminary Estimates of Surges Levels along the Coast of Bangladesh

The 7 cyclones were selected from a period of 12 years, which means, that the combined maximum surge should correspond to a 12 year event assuming that the cyclones represent all possible cyclone tracks and intensities. However, this last assumption is not fulfilled and furthermore the simulated surges are on the high side, so no return period is associated with the computed surges. On the other hand, they give an overall picture of which areas are exposed to high surges and which are not, and a good basis for further work.



## 5. INSTALLATION OF COMPUTER HARDWARE AND SOFTWARE AT DDC AND TRAINING IN ITS USE

### 5.1 Computer Hardware

Simulation of cyclone generated surges in the Bay of Bengal using an advanced numerical model like MIKE 21 requires a powerful computer both regarding the computational speed the memory capacity. A PC (for example based on a 286 or 386 processor) running the DOS operating system does not meet the requirements, and therefore a computer based on the 486 processor (supplemented by an Weitec accelerator card) running the UNIX operating system was purchase for the project.

Following is a list of the hardware acquired during the initial stages of the project. Due to delivery delays the last pieces were received in September 1990, 4 months behind schedule.

- ALR Powercache 4e Model 650H
- CPU: Intel 80486 (25 MHz)
- RAM: 16 Mbytes
- 1.2 Mbytes 5.25" diskette drive
- 1.44 Mbytes 3.5" diskette drive
- 650 Mbytes harddisk
- 150 Mbytes tape streamer
- 21" monitor with a resolution of 1024x768 pixels
- Optical mouse
- Ethernet controller
- Weitec Abacus 4167 coprocessor
- UPS power backup system (backup time: 20 min).

Furthermore an HP LaserJet II for all b/w graphical presentations and an HP PaintJet for colour presentations were made available to the project by DDC.

### 5.2 Computer Software

The following software was purchased for use by the project:

- SCO Open Desktop (including SCO UNIX System V, INGRES RDBMS, SCO NFS, TCP/IP, DOS/Merge, X-Windows and OSF/Motif)
- SVS Fortran 77 Compiler

- Open Desktop Development System (including the CGI graphical subroutine package)
- Open Desktop Server Upgrade (enabling the system to work as a server in a network).

Furthermore, the Hydrodynamic Module of the Modelling System for Estuaries, Coastal Waters and Seas, MIKE 21, from DHI was applied. As the graphical subroutine package normally used by MIKE 21 (called UNIRAS) is not yet available for a 80486 machine running SCO UNIX, the graphical presentation tools of MIKE 21 were adopted to use the CGI subroutine package. Finally a cyclone wind and pressure model as well as a tidal analysis/prediction program was adopted for the computer.

### 5.3

#### Training

The number of computers running the UNIX operating system is presently increasing very rapidly. The main reason for this is that, unlike other operating systems (except DOS), UNIX is not controlled by and thus limited to be used on computers from one manufacturer, but can be used on computers (small as well as large) manufactured by a very large number of companies. However, as UNIX is not yet widely used in Bangladesh a course (including exercises) was included in the project. During the 6 days (mornings only) allocated for the course lectures and exercises on the following topics were conducted:

- Basic command and utilities as well as more advanced utilities.
- File structure and shells.
- The vi editor.

A 6 day course (mornings only) in the use of the hydrodynamic modelling system, MIKE 21, was also held. The purpose of the course was not to enable the participants to carry out a whole model study, as this requires a much longer training period, but to enable them to get an overview of the type of problems, which can be solved using the modelling system. The main points covered during the course were:

- How is a differential equation converted into a computer program (the finite difference method).
- Modelling Procedure, Step-by-Step.
- Wind setup in a lake (a small example).
- Tidal flow an estuary (Donegal Bay, Ireland).
- Flow pattern around a harbour 9 Helsingor Harbour, Denmark).
- Overview of Application Areas.



## 6. SUMMARY AND CONCLUSIONS

### 6.1 Preliminary Mathematical Model Study of Cyclonic Surges

#### 6.1.1 Description of Model Complex

In order to assess the extreme surges along the Bangladeshi coast generated by cyclones it was decided to make a mathematical study as the water level data obtained from the area do not contain all cyclonic surges. It was also realized that meteorological and hydrodynamical processes in the Bay of Bengal and especially in the shallow areas of the coast of Bangladesh are extremely complicated.

On this background a complex of mathematical models were setup:

- A cyclone wind and pressure model describing the time varying wind and pressure field over the Bay of Bengal during the passage of a cyclone was created. It is a schematic model, which will gain considerably in accuracy if more meteorological information can be made available for its tuning.
- Using DHI's Hydrodynamic Modelling System, MIKE 21, models of the time varying water level and current variations in the northern part of the Bay of Bengal were setup. The model areas are shown in Figure No. 4.3.
- As there was no meteorological data to calibrate the cyclone model against, a calibration of the combined cyclone and hydrodynamic models was not attempted. However, a tidal calibration and verification was carried out for the hydrodynamic model.
- Sensitivity tests with the purpose of estimating the effects of the following factors on the results from the hydrodynamical model were conducted:
  - a The effects of varying the wind friction factor.
  - b The effect of not including the storage capacity of the rivers not included in the model, and of not including the flooding and drying facility.
  - c The effect of not including the tide in the simulations of the cyclonic surge.

#### 6.1.2 Simulation of Cyclone Surges

The 7 most severe cyclones from the period 1977-1988 were selected for modelling, and the results from each simulation were compared to



measurements. Generally the computed surges were higher than the measured ones, which has to be taken into account, when the final modelling is to be carried out. In general, a lot of experience concerning hydrodynamic modelling in the coastal belt of Bangladesh has been gained.

The maximum surges reached during all 7 cyclones are shown in Dwg. No. 4.23.

## 6.2 **Installation of Computer Hardware and Software at DDC and Training in Its Use**

In order to meet the hardware requirements of the hydrodynamical model, MIKE 21, furthermore do not run under the DOS operating system, UNIX was installed on the computer.

Both UNIX and MIKE 21 are products unfamiliar to DDC. Therefore a two week course was conducted focussing on their use.

## 7.

## REFERENCES

- /1/ Cyclone Protection Project II, Feasibility and Design Studies, Inception Report, BWDB Component, prepared for BWDB and RHD by Kampsax International, BCEOM and DHI in association with DDC, November 1990.
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- /4/ Bangladesh Bureau of Statistics, Statistical Year-book of Bangladesh, 1989.
- /5/ Leedshill Deleuwe, Engineering and Economic Evaluation Report for the Coastal Embankment Project, December 1968.
- /6/ Global Wave Statistics, Compiled and edited by British Maritime Technology, 1986.
- /7/ Goda, Y., Random Seas and Design of maritime Structures, University of Tokyo Press, 1985.
- /8/ Admiralty Tide Tables, Vol.2, 1990, The Hydrographic Office, London, 1989.
- /9/ Simplified Harmonic Method of Tidal Prediction N.P. 159, The Hydrographer of the Navy, UK, 1947.
- /10/ Smith, S.D. and Banke, E.G., Variation of the Sea Drag Coefficients with Wind Speed, Quart. J.R. Met. Soc., Vol. 101, pp 665-673, 1975.
- /11/ Mathematical Model Study of the Pussur-Sibsa and Karnafuli River Entrance, Inception Report, prepared by Danish Hydraulic Institute, Bangladesh University of Engineering & Technology and Bangladesh Engineering & Technology Services Ltd., December 1990.

# ANNEX A TO REPORT ON HYDRAULIC STUDIES

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## ANNEX A

Simulation of April 1991 Cyclone



# ANNEX A TO REPORT ON HYDRAULIC STUDIES

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## DRAWINGS

## 1. INTRODUCTION

The present note which is an addendum to the report titled "Cyclone Protection Project II (FAP 7), Feasibility and Design Studies, BWDB Component, Hydraulic Studies" describes the results of one additional numerical simulation of cyclone generated surge. The cyclone in question is the one which hit the coast of Bangladesh on the morning of April 30, 1991, and which was one of the most serious cyclones to affect Bangladesh during the last couple of decades. More than 100,000 people lost their lives.

The April 1991 cyclone was not included as one of the seven cyclones simulated during the "Hydraulic Studies" as these were carried out during the second half of 1990. However, because of the severity of the cyclone and because measurements of maximum surge along the East coast of Bangladesh were available it was decided to simulate this cyclone also.

## 2. CYCLONE MODELLING

The description of the general cyclone model used to produce the time varying cyclonic wind and pressure fields during the passage of the cyclone of 29-30 April, 1991, can be found in Ref. /1/ (Chapter 4.3).

The parameters available for describing the cyclone (officially called "Tropical cyclone 02B") were as follows:

- maximum wind speed of 225-230 km/h
- radius to maximum wind speed of 75 km
- maximum pressure drop of 70-75 millibars (i.e. a drop from 1010 mb to 940-935 mb) as shown in Fig. No. 2.1, which are readings made in Chittagong

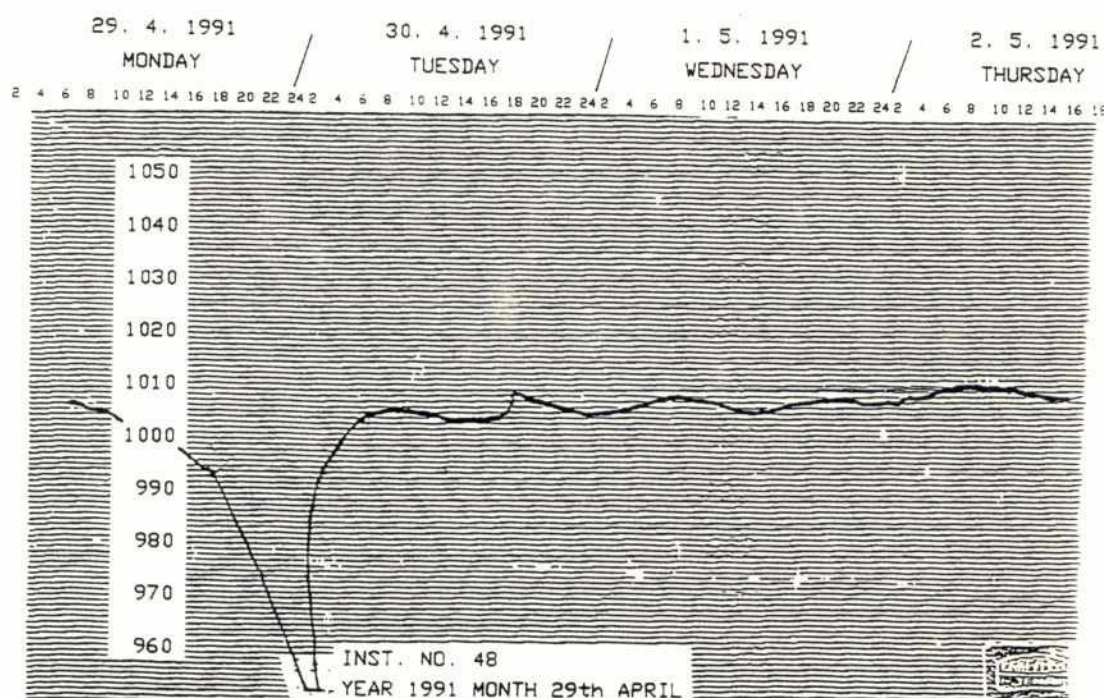


Fig. No. 2.1

Atmospheric pressure reading at Chittagong during passage of cyclone 02B.



• cyclone track as shown in Fig. 2.2.

The parameters were obtained from Bangladesh Meteorological Department.

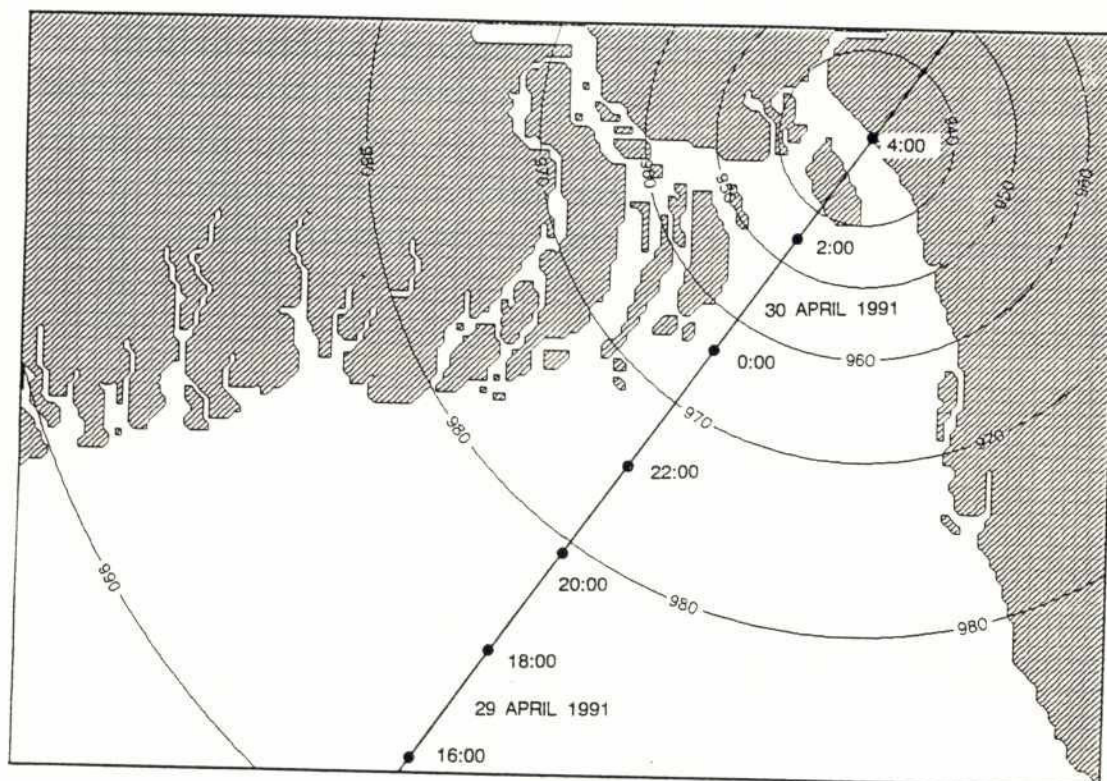


Fig. No. 2.2

Track of cyclone 29-30 April, 1991.

A comparison of the recorded and the computed pressure variation at Chittagong is shown in Fig. No. 2.3. From this figure a difference between the recorded and the computed pressure is seen. This difference is either caused by using too large a radius to maximum wind speed in the cyclone model or because the exponential description of the spacial pressure variation used in the cyclone model does not fit the present cyclone well.

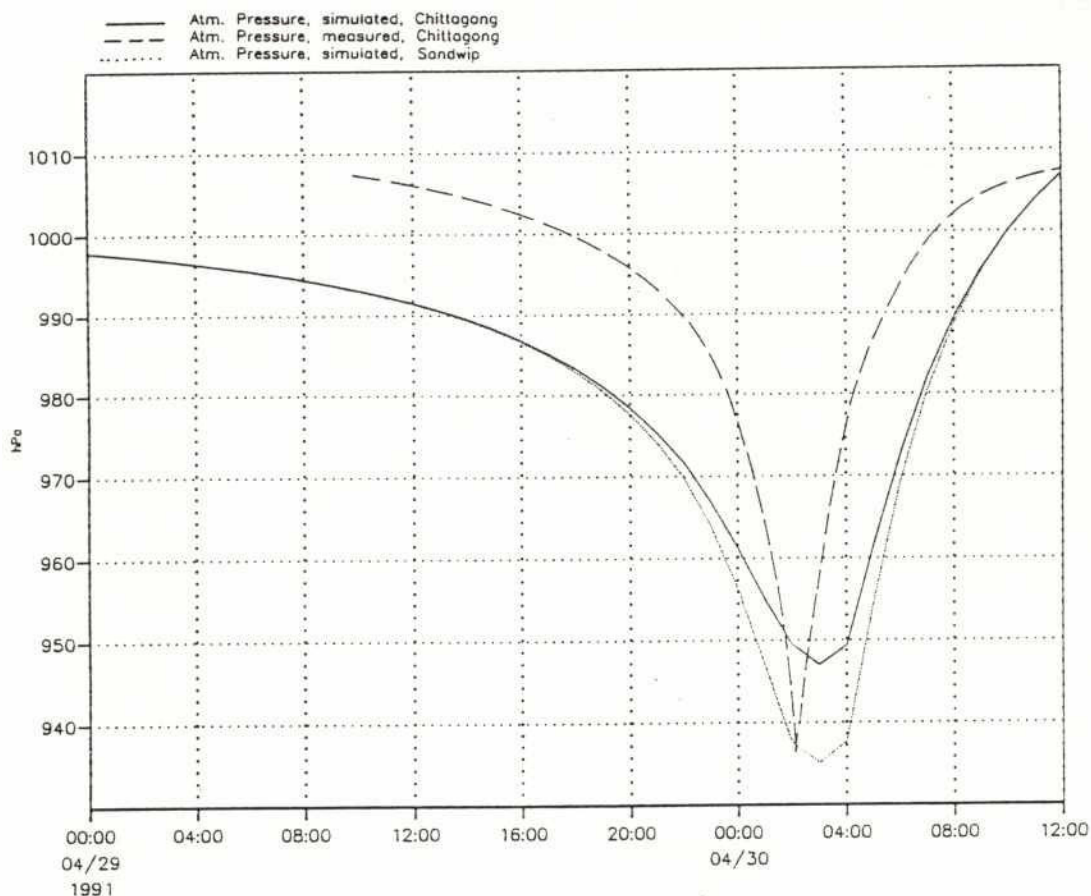


Fig. No. 2.3      Computed and measured atmospheric pressure variation during passage of cyclone.

If more data were available on the size of the cyclone the difference could be investigated further. However, as a pressure drop of 1 mb corresponds to a rise of 1 cm of the water level and as the maximum deviation at any time is 40 mb corresponding to 40 cm (compared to surges of 6-7 m) the differences only influence the computed surges marginally.

A-5.

The cyclone track is shown in Fig. No. 2.2, while the wind and pressure fields from 1600 hrs, 29 April 1991 to 0400 hrs, 30 April 1991 are shown with an interval of 2 hours on Dwgs. Nos. 2.1 to 2.7.

Furthermore, the wind speed and the wind direction at Chittagong and at Sandwip are shown in Fig. No. 2.4. As the eye of the cyclone passes directly across Sandwip the wind speed suddenly drops and the direction changes 180 degrees. At Chittagong, which lies some 40 km from the cyclone track, the influence of the cyclone eye is less pronounced.



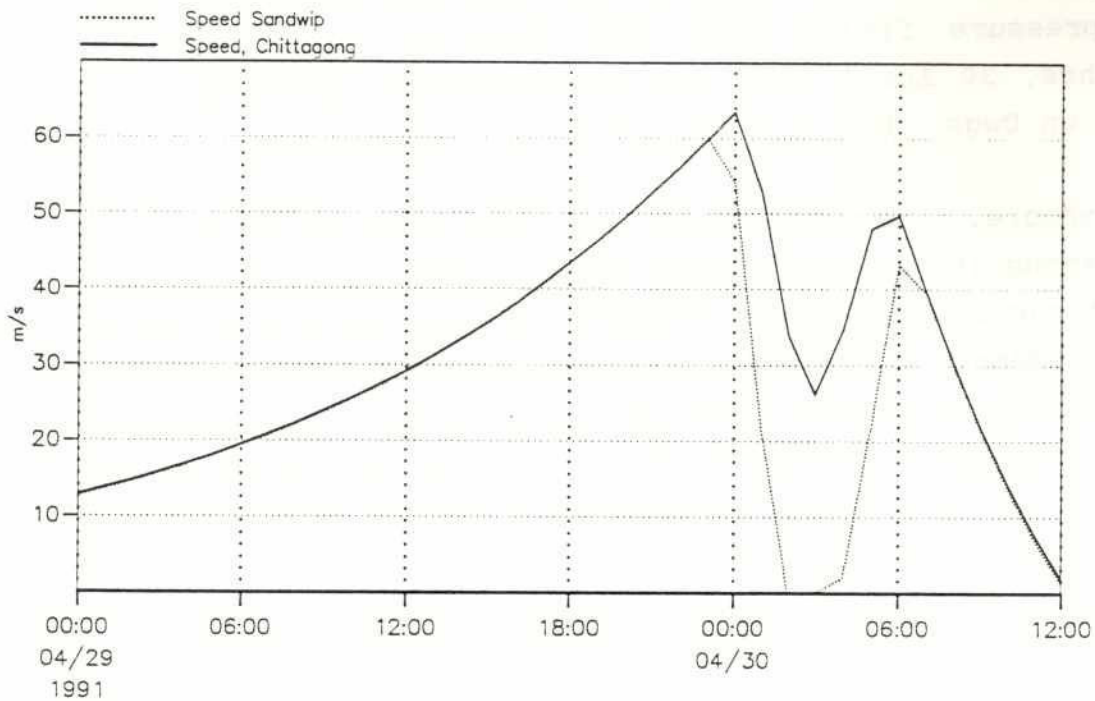


Fig. No. 2.4 (a) Computed wind speed during passage of cyclone.

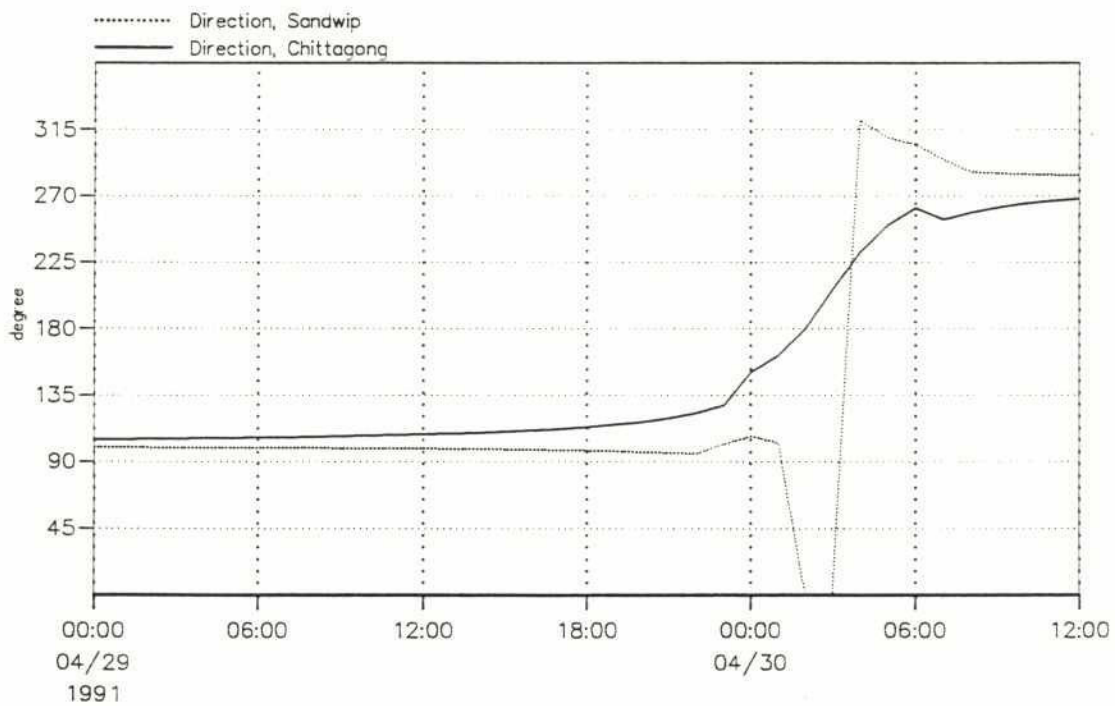


Fig. No. 2.4 (b) Computed wind direction during passage of cyclone.

### 3. SURGE AND TIDE MODELLING

The description of the general surge model used to compute the time varying water levels (and currents) during the passage of the cyclone of 29-30 April, 1991, can be found in Ref. /1/ (Chapter 4.4).

The only difference between the present model setup and the one used for simulating the previous 7 cyclones is that the tidal water level variation is included in the present simulation together with wind forcing, while the previous simulations did not include tide. This means that all non-linear interactions between the tide and the surge generated by the passage of the cyclone automatically are included in this additional simulation, interactions which are especially important during the cyclone of April 1991, as the maximum surge and high tide (which was close to spring tide) occurred nearly simultaneously.

The results of the simulation is presented in the following figures:

- the total surface elevation in the northeast part of the Bay of Bengal at 2 hourly intervals (from 1600 hrs, 29 April 1991 to 0400 hrs, 30 April 1991) are shown in Dwgs. Nos. 3.1 to 3.7.
- the total surface elevation and the predicted tide at Chittagong and Sandwip are shown in Figs. Nos. 3.1 and 3.2. By subtracting the two curves in each figure, a cyclone generated surge of 6.3 m and 6.5 m is found.
- the maximum surface elevation found during the passage of the cyclone in the whole Bay of Bengal is shown in Dwg. No. 3.8.
- measured and computed surge levels along the coast of Bangladesh is shown in Fig. No. 3.3.

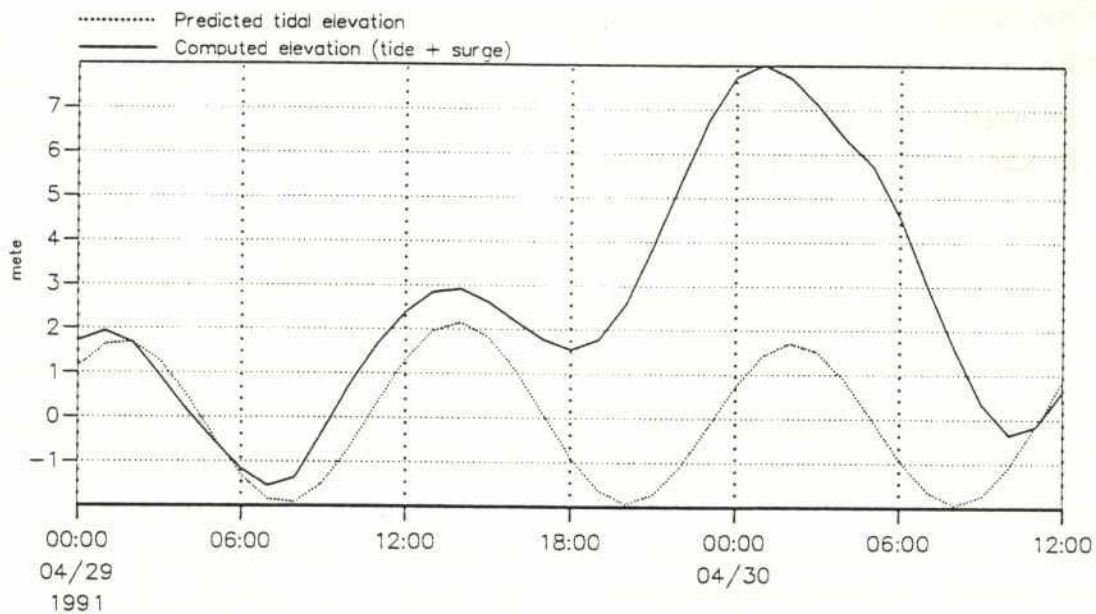


Fig. No. 3.1

Computed surface elevations at Chittagong during passage of cyclone.

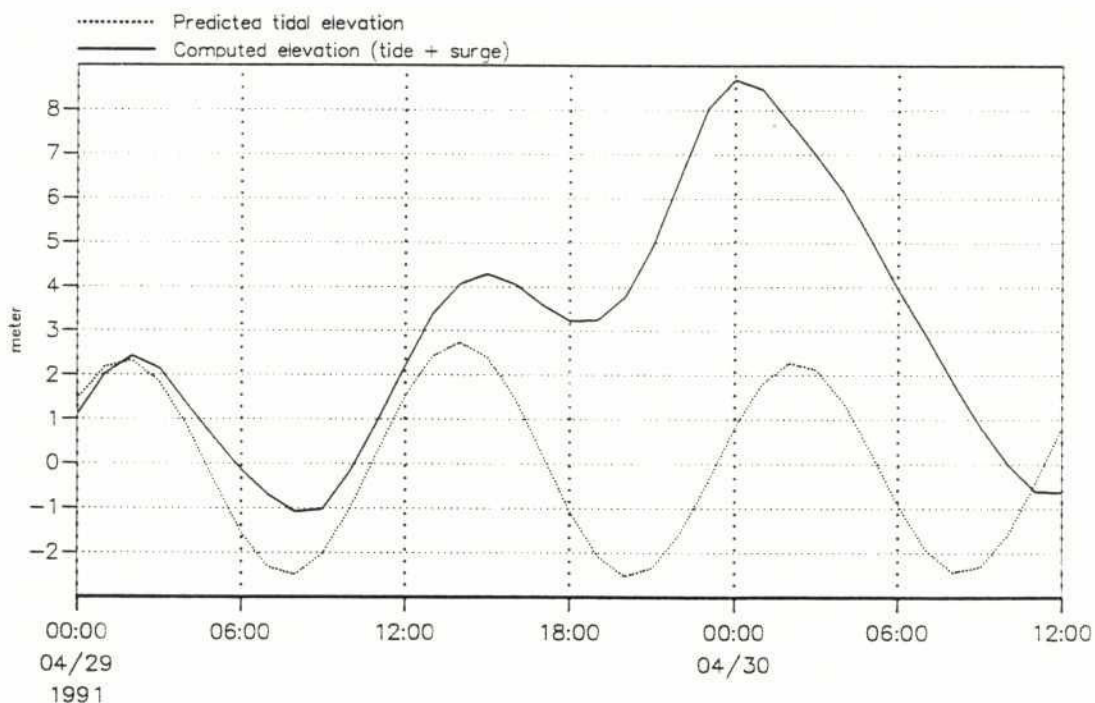


Fig. No. 3.2

Computed surface elevations at Sandwip during passage of cyclone.



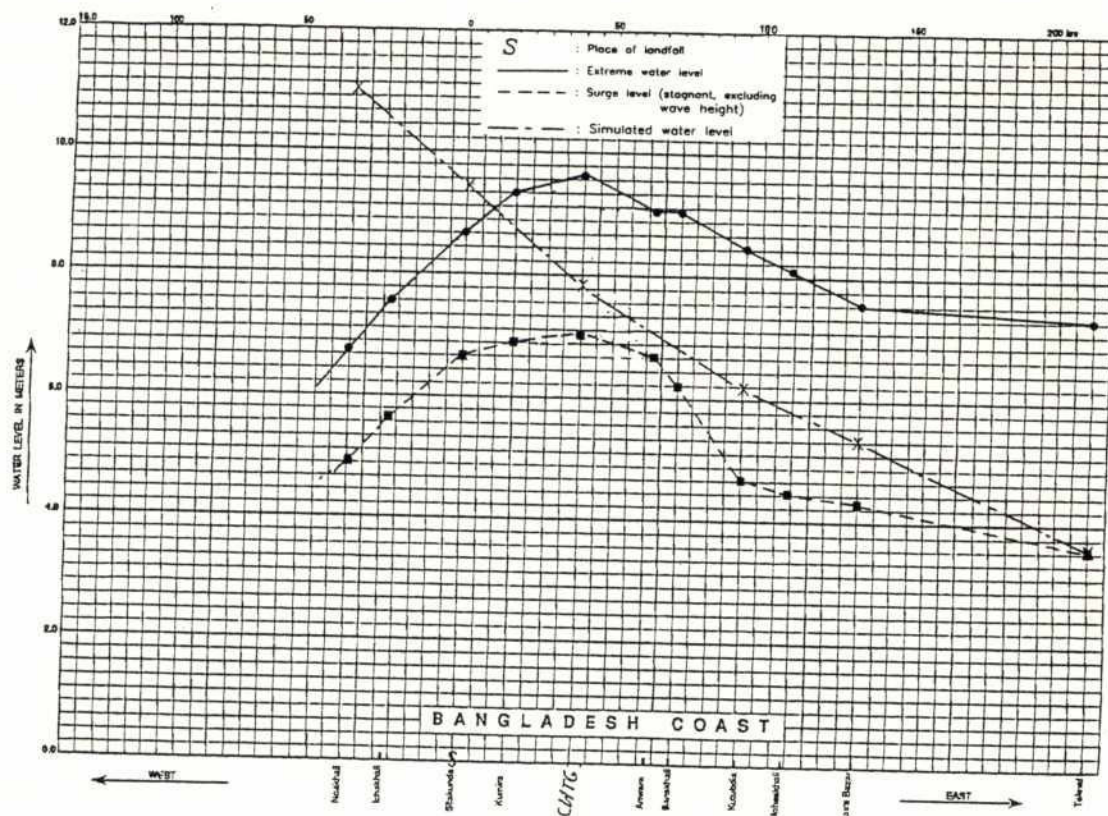


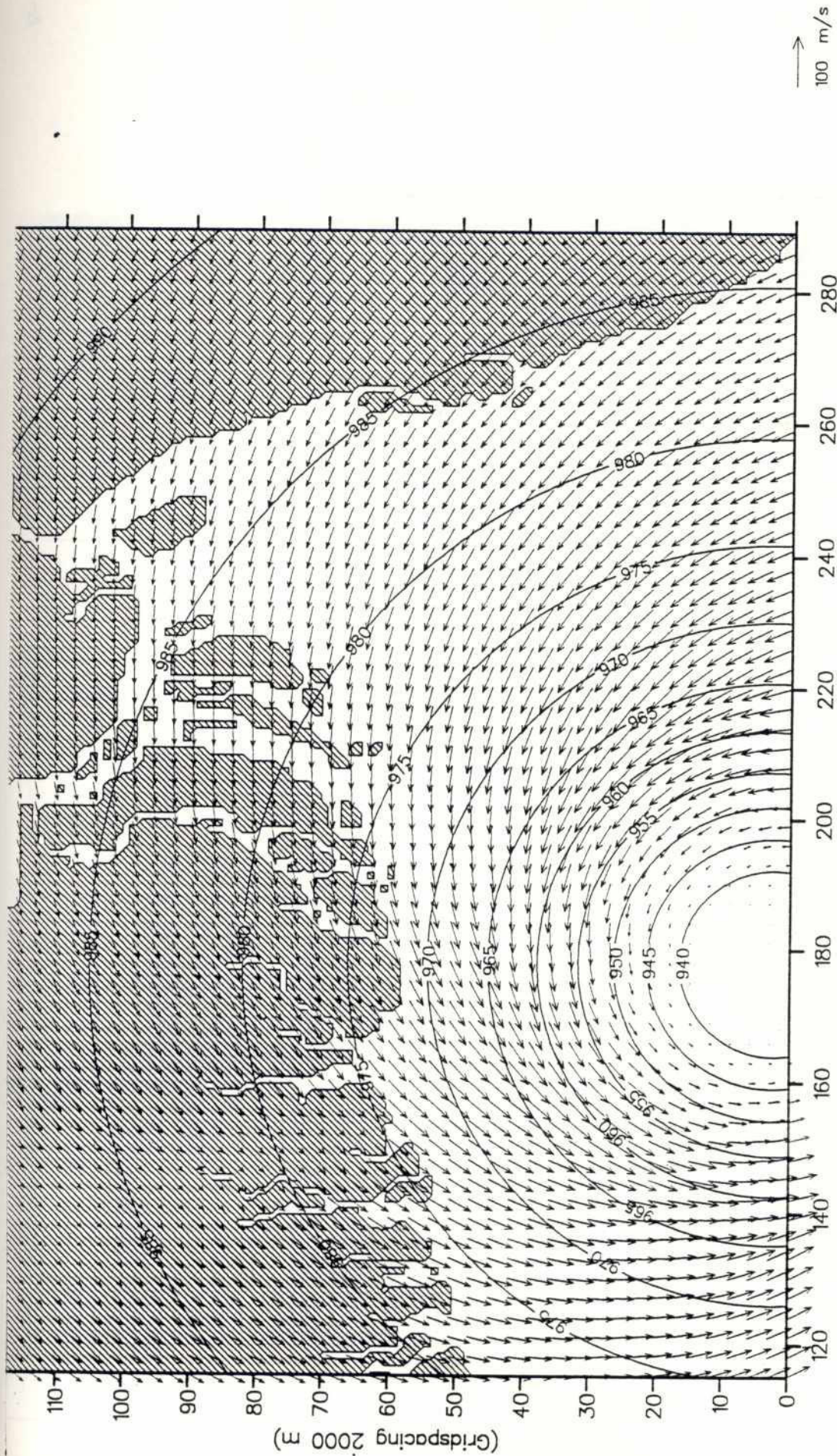
Fig. No. 3.3 Measured and computed water level along the Bangladesh Coast during passage of cyclone.


As seen from Fig. No. 3.3, the model reproduces the surge level reasonably well along the east coast of Bangladesh, while the model overestimates the surges in the large delta to the northwest, north and northeast of Sandwip. Reference is made to Ref. /1/ (Chapter 4.5) for an explanation to this overestimation.

4. REFERENCES

- /1/ Cyclone Protection Project II (FAP 7), Feasibility and Design Studies, BWDB Component, Hydraulic Studies, February 1991.





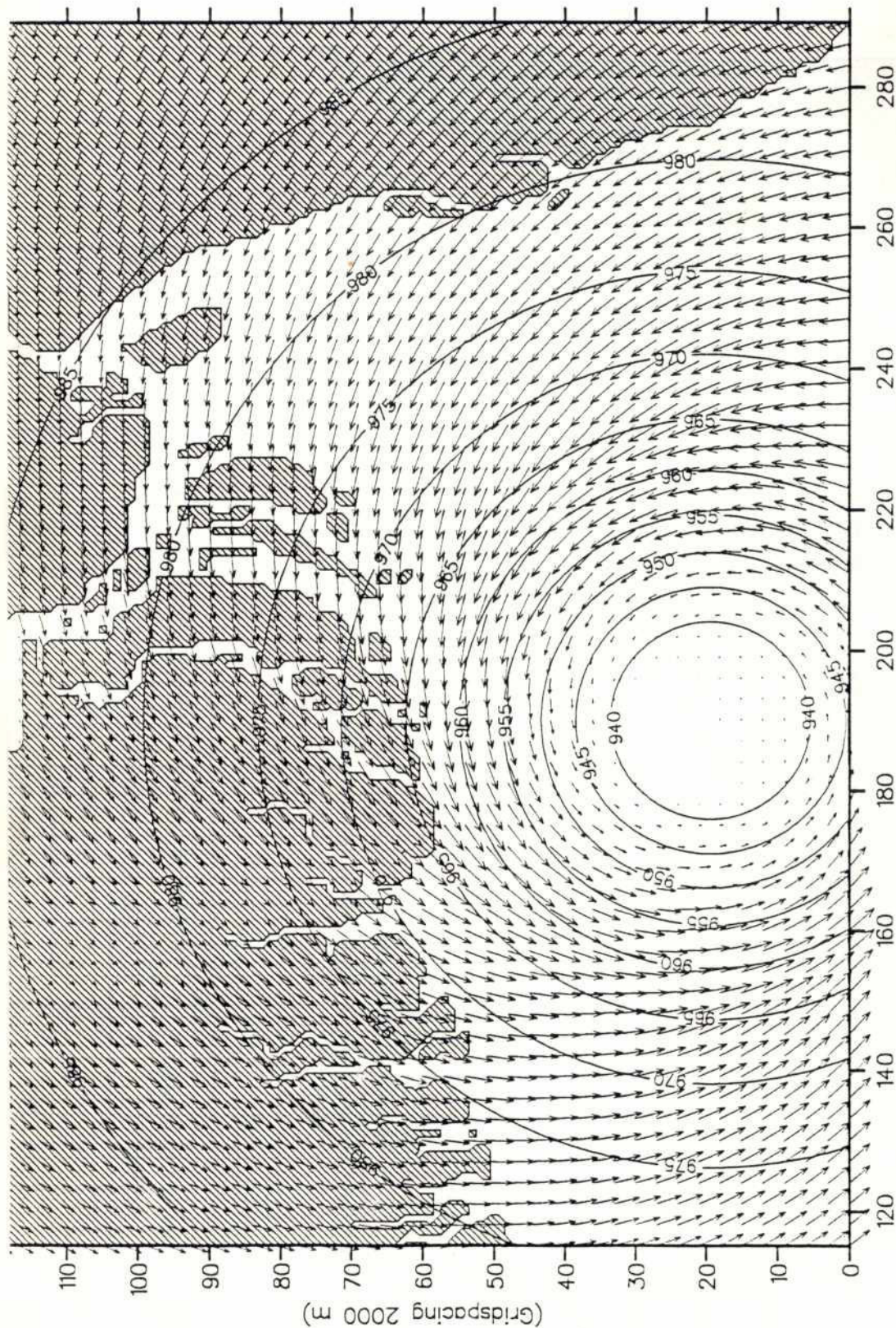
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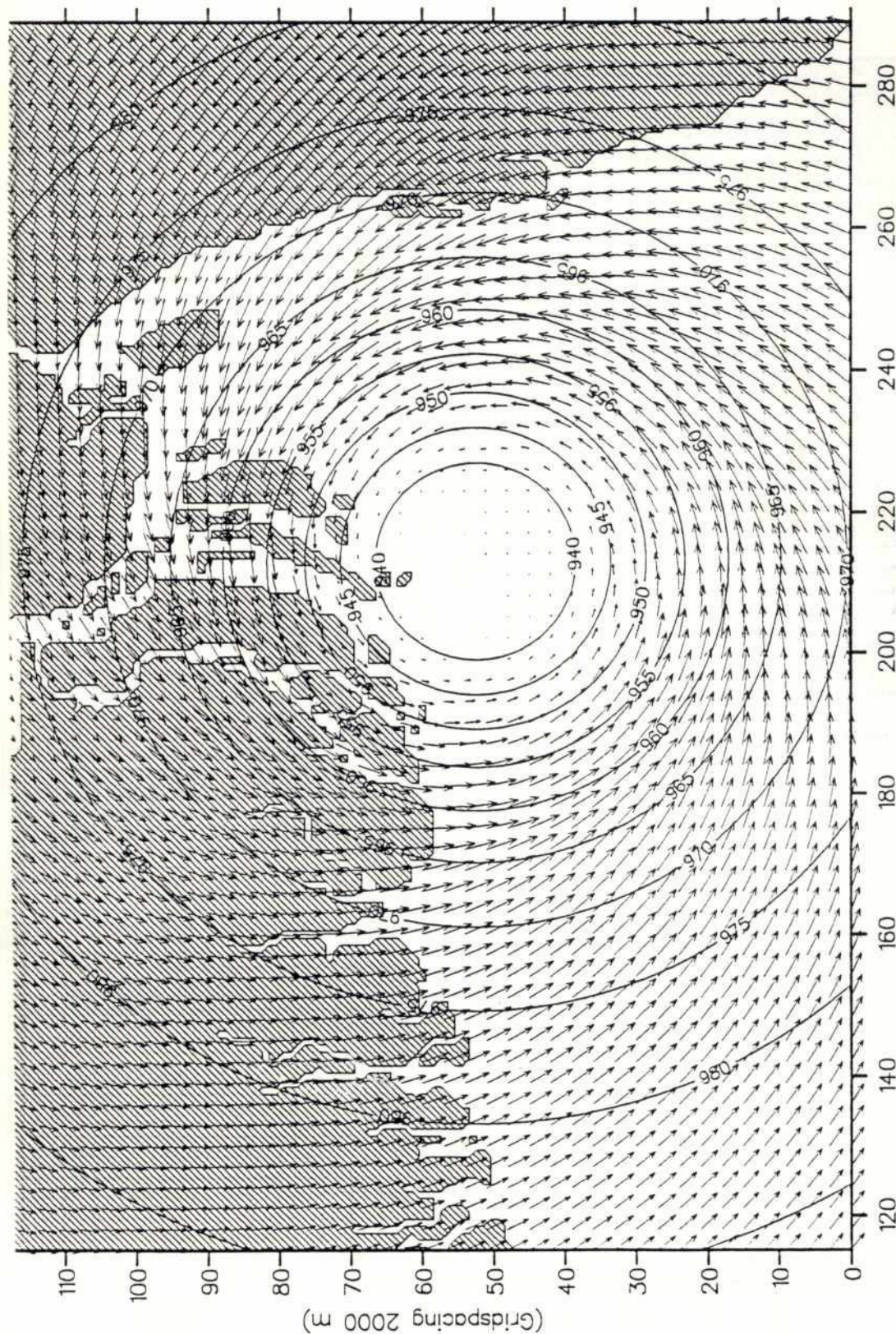
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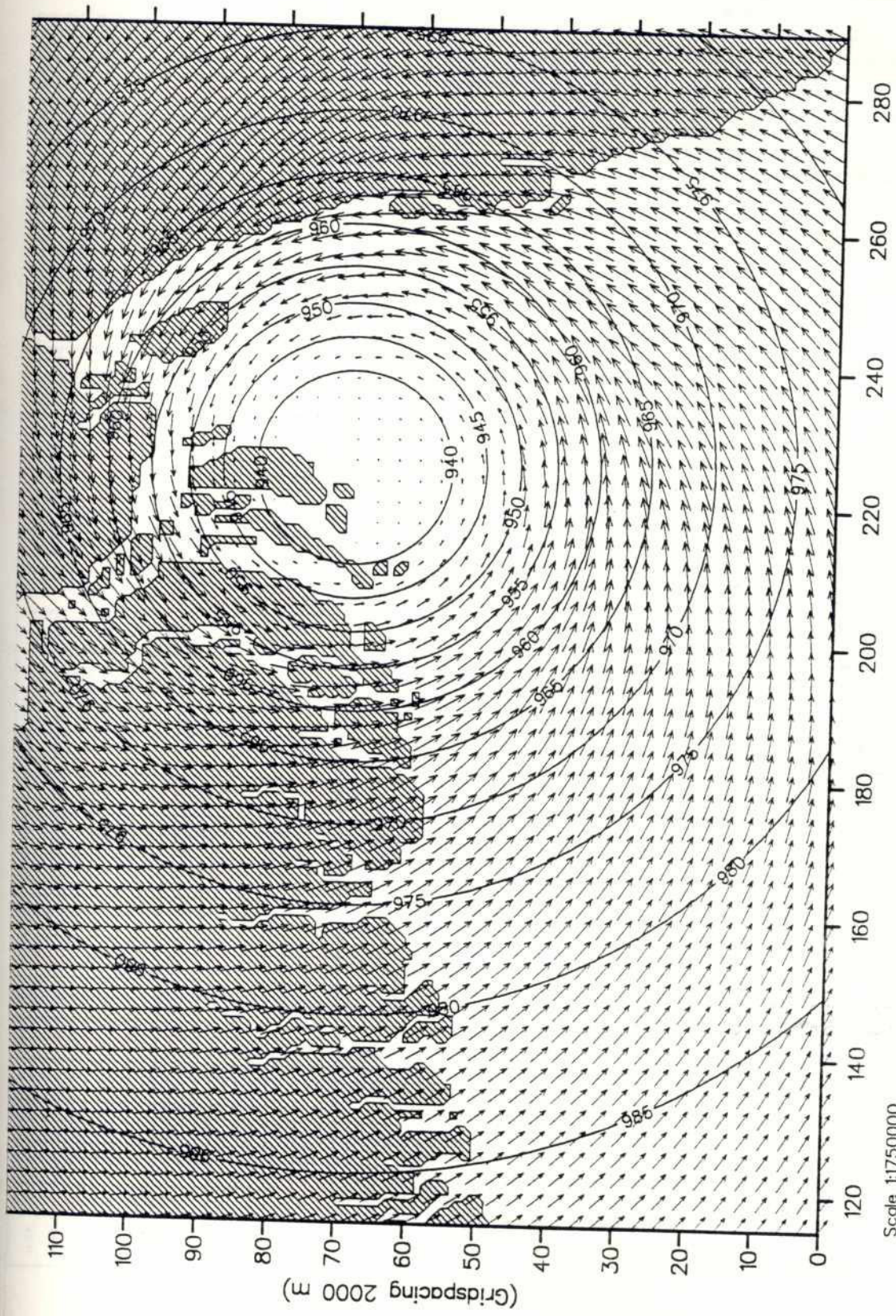







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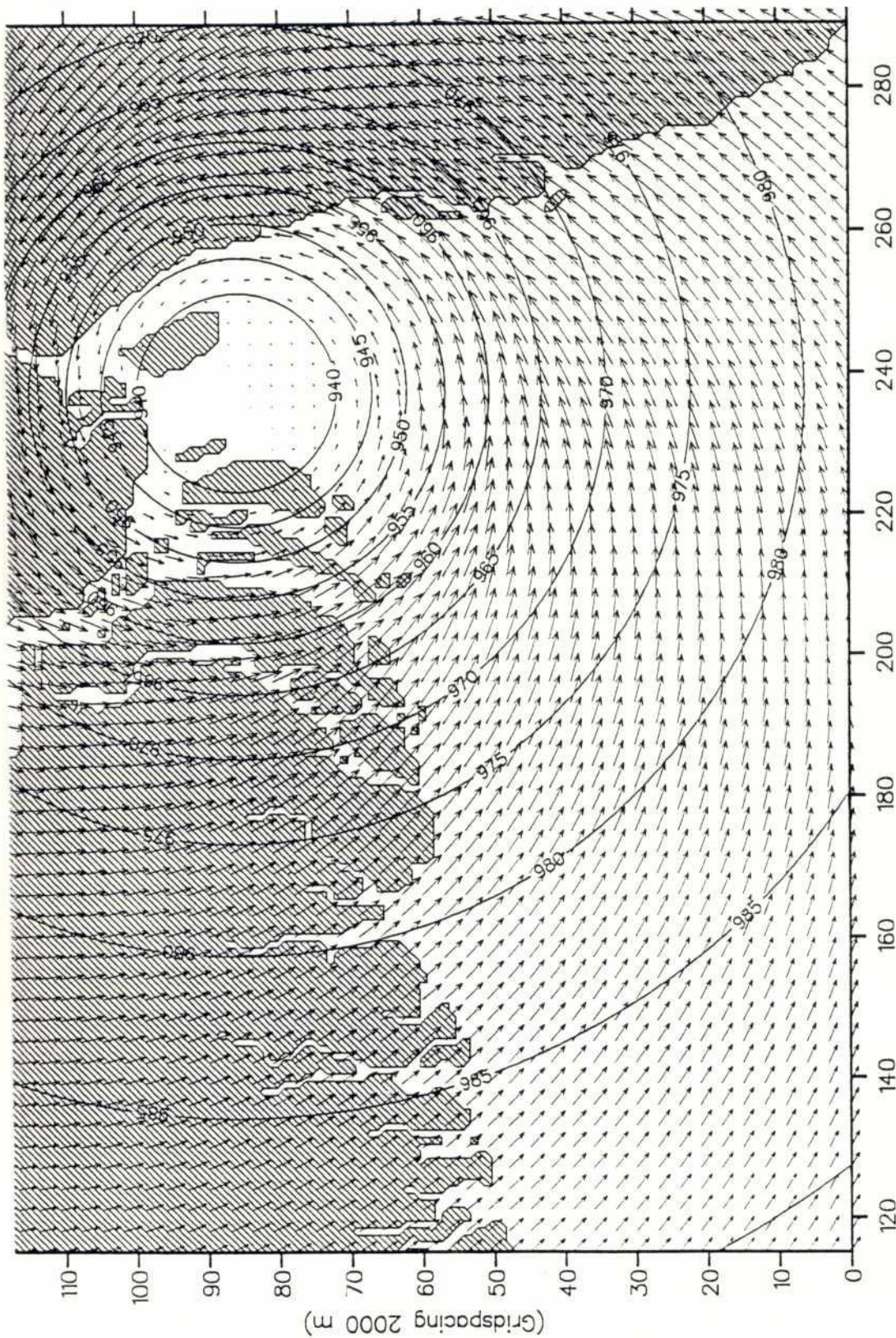





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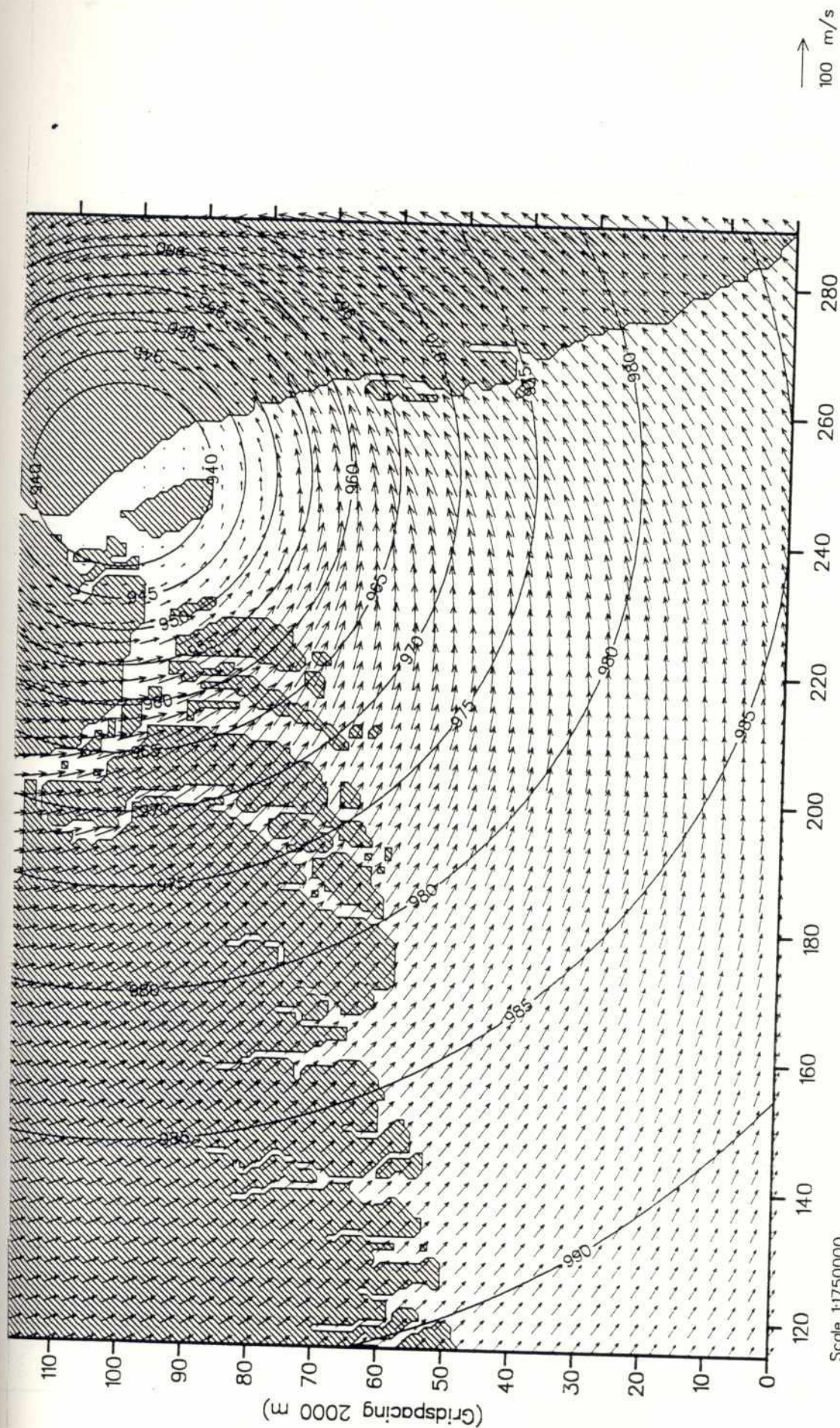




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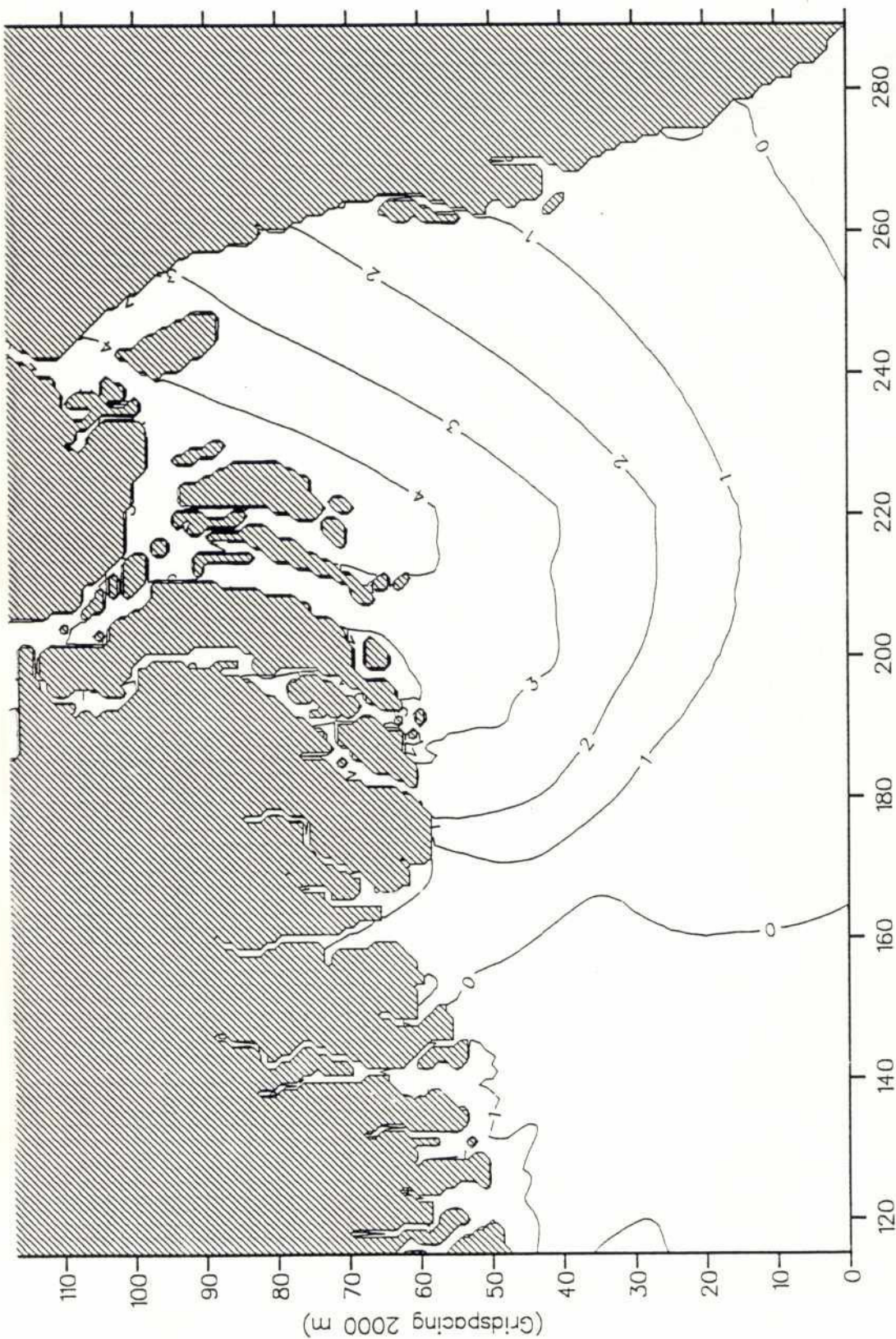


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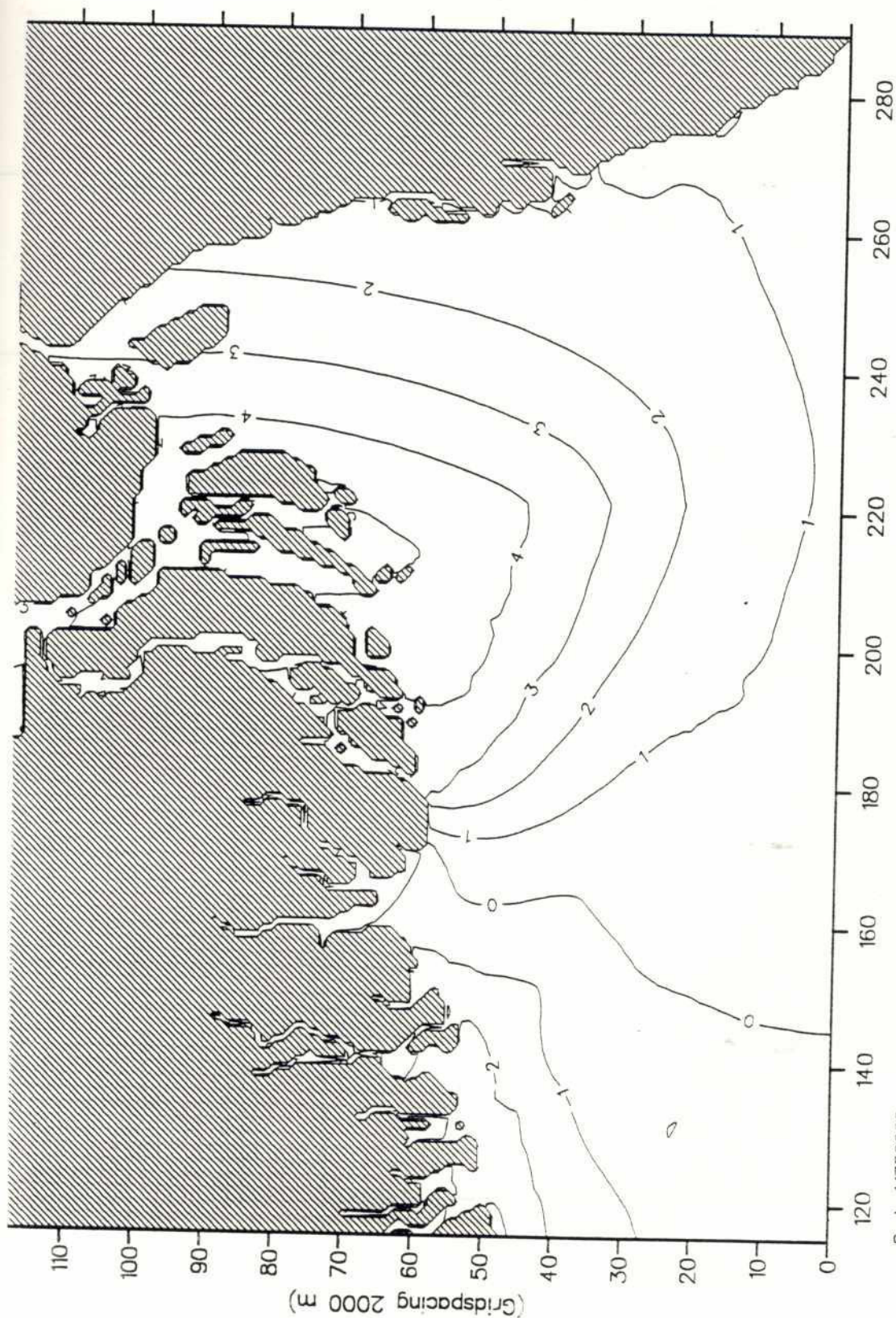




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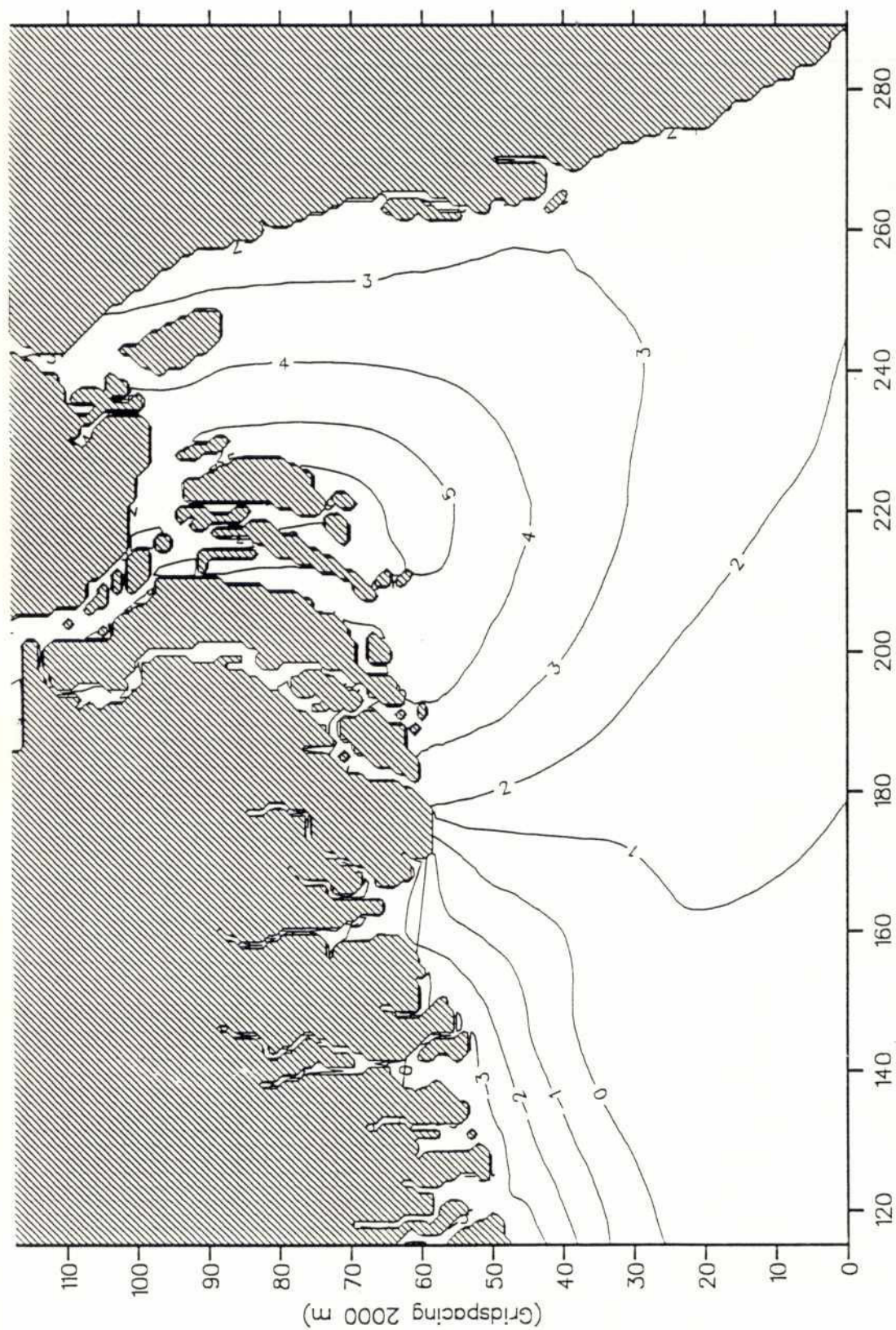
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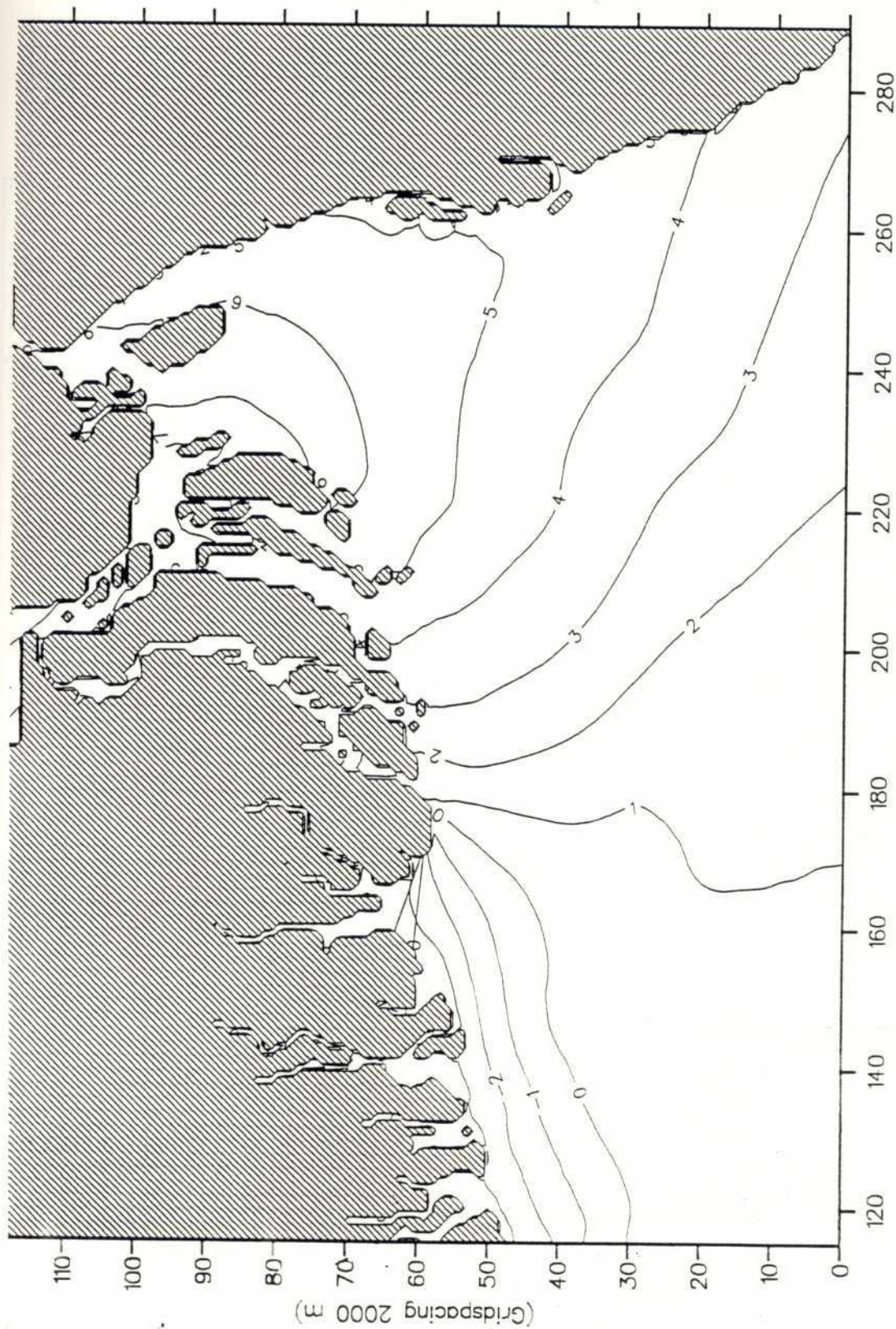




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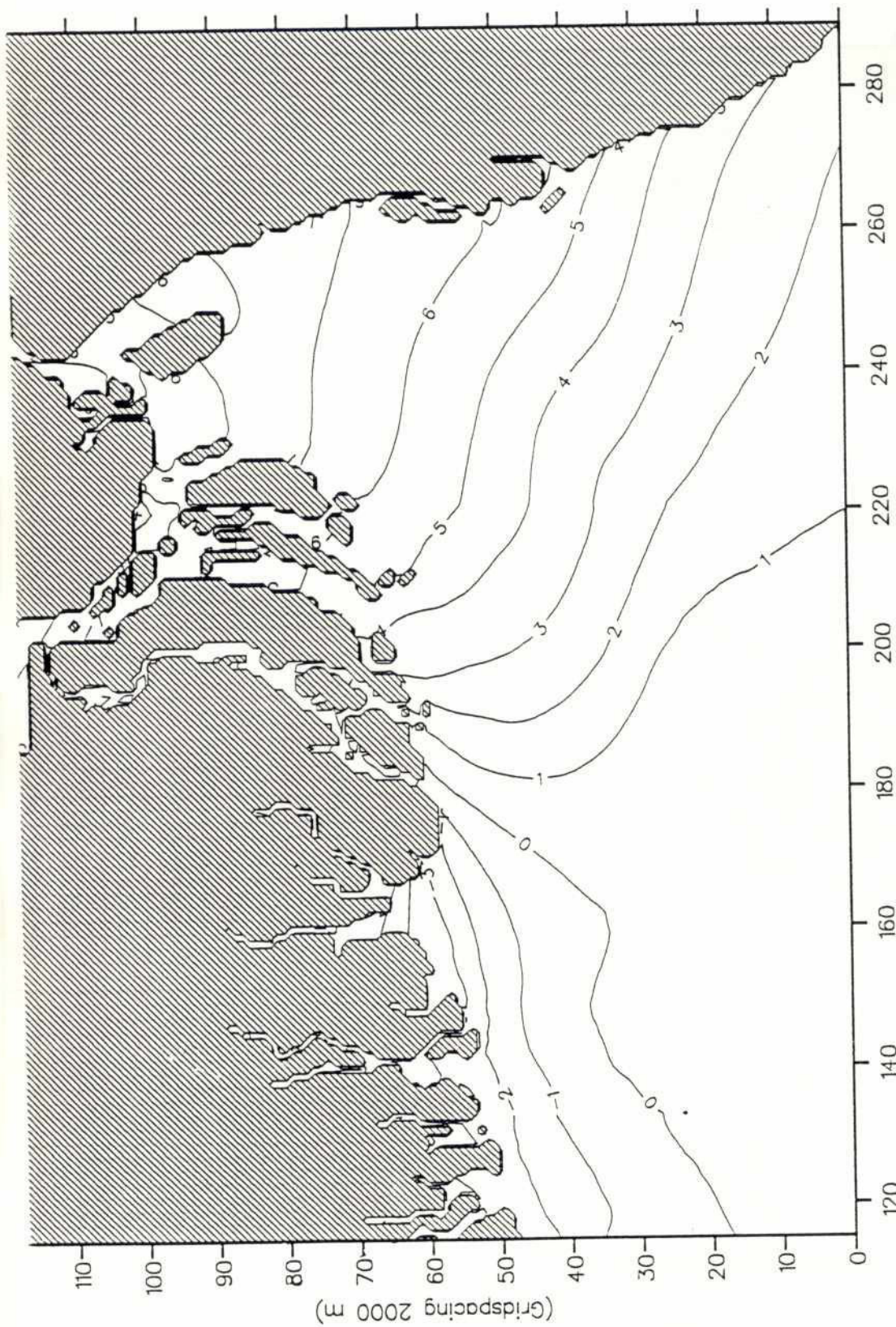


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		Mike 21	

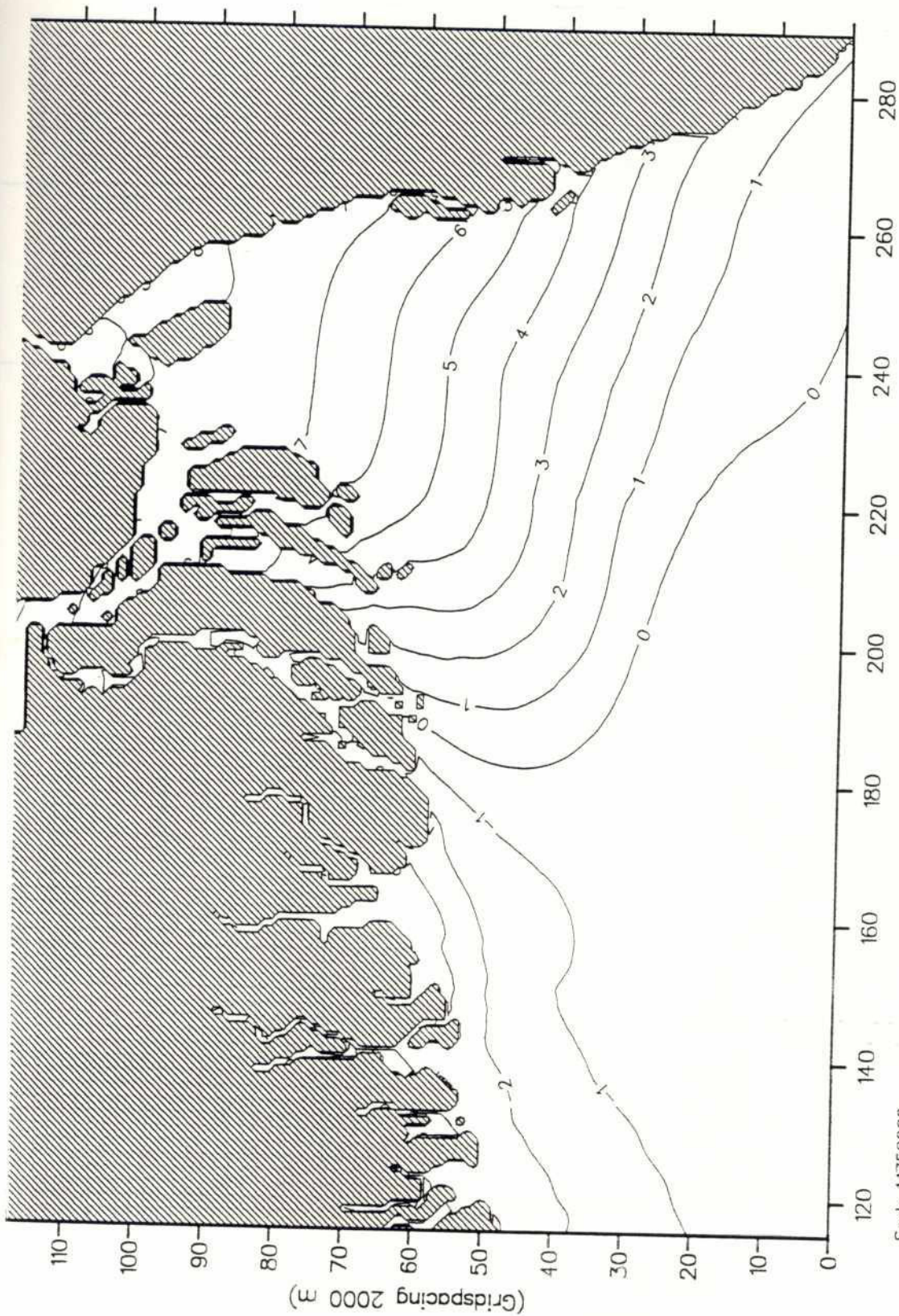




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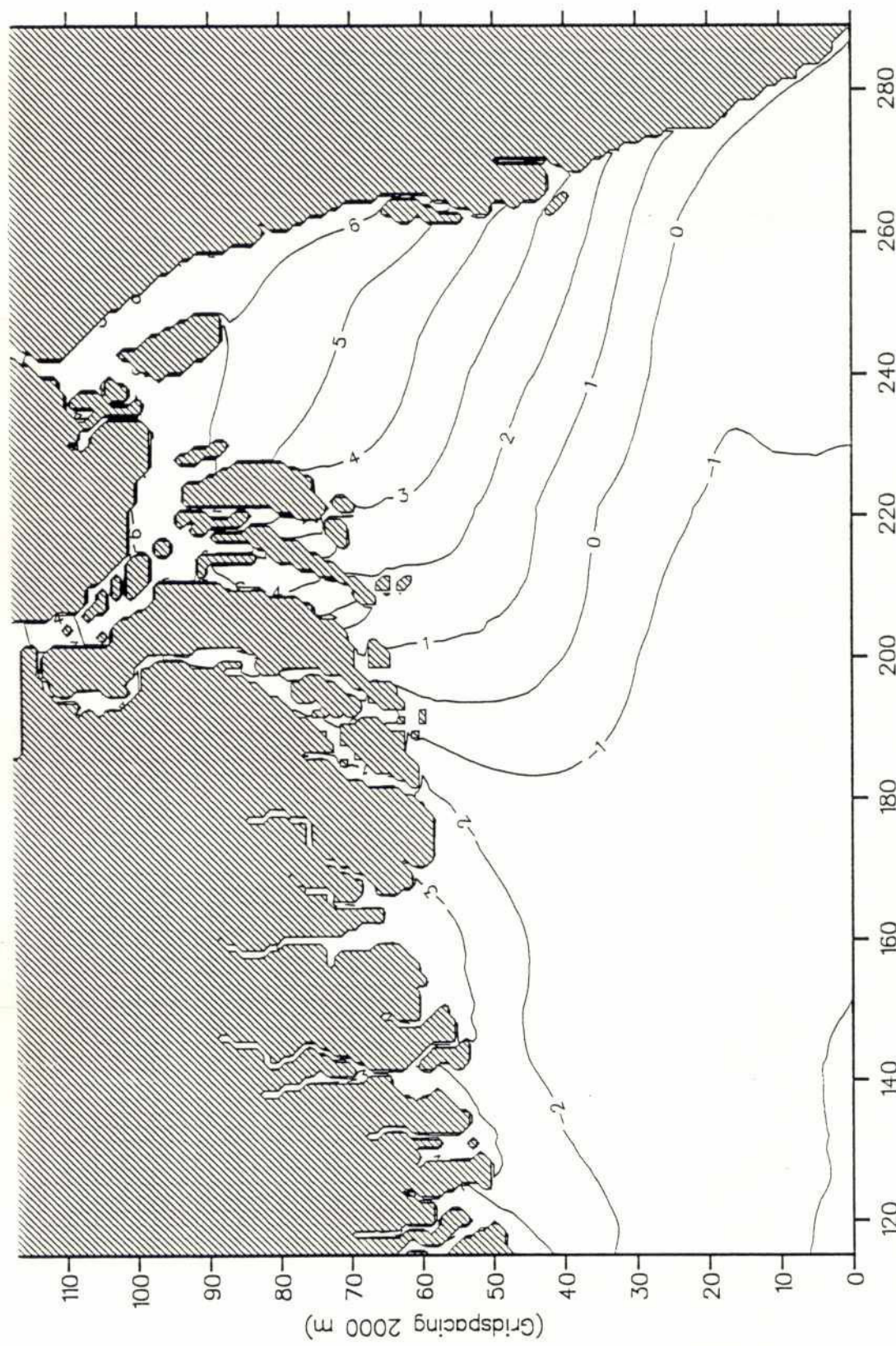
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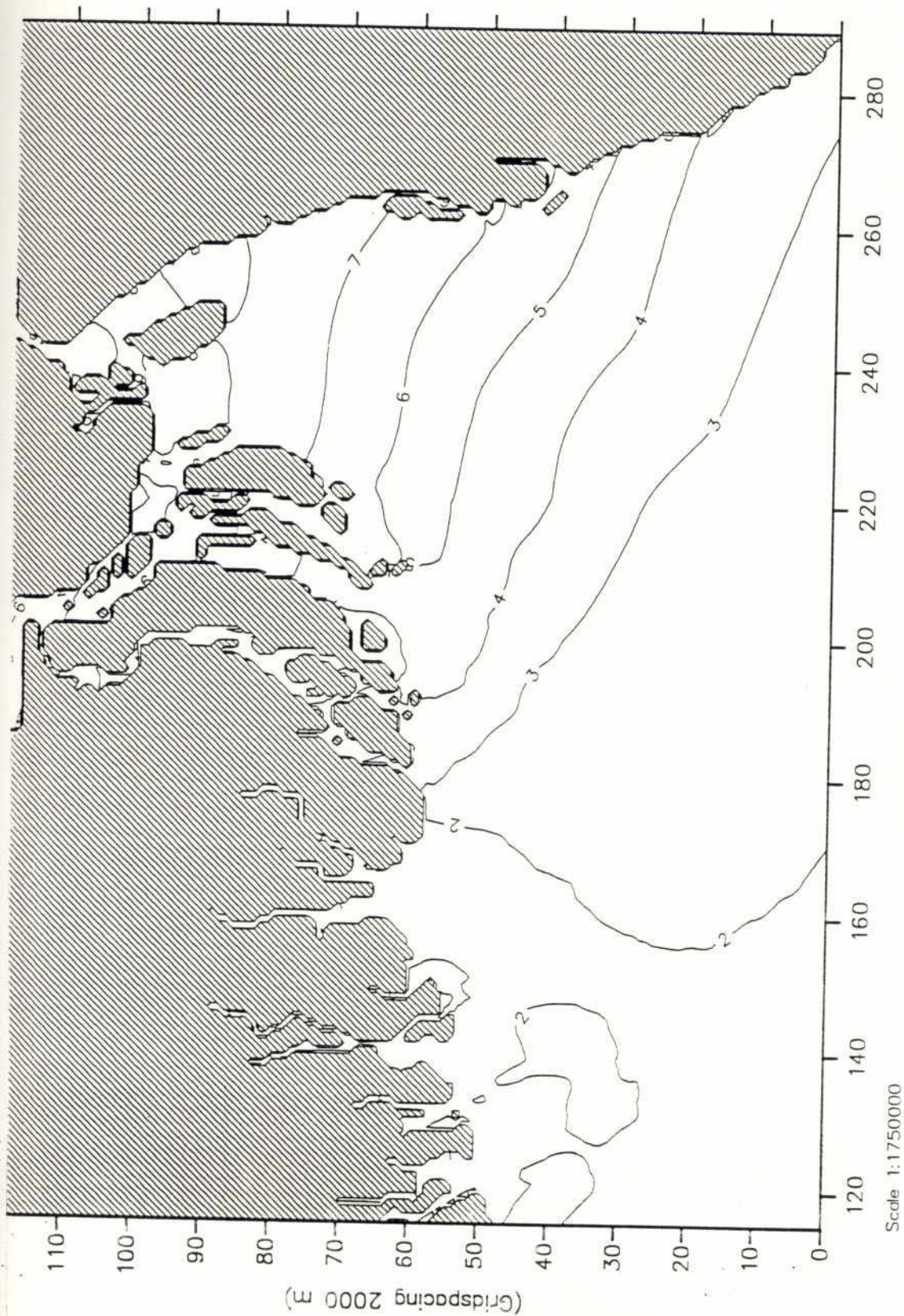
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mmr	name: out1	Surface Elevation relative to MSL		





 danish hydraulic institute	Wed Jan 29 1992	family: a9li	Maximum surge during April 1991 cyclone  Isoline values in meters	dwg. no.  3.8
		name: maxst		
Bangladesh Water Development Board			Mike 21	
Cyclone Protection Project II				



## TERMS OF REFERENCE FOR EXTENSION OF CPP II NUMERICAL CYCLONIC SURGE MODELLING

### 1. BACKGROUND

A mathematical model study of cyclonic surges along the coast of Bangladesh was carried out in 1990 as part of the hydraulic studies for the BWDB component of Cyclone Protection Project II (Feasibility and Design Studies). After the very severe cyclone of April 1991 the study was extended by simulation of this cyclone.

The conclusion from the study was, that the model complex generally is a valid tool for modelling of cyclonic surges, but that the accuracy of the model could be improved by introducing a number of modifications, especially with respect to modelling of surges in the shallow areas along the coast and in the river mouths.

The catastrophic cyclone of April 1991, emphasises the need for an Improved Early Warning System. This system would consist of a forecast model for the cyclonic winds and a numerical forecast model for the cyclonic surges, the latter of which could be based on the already existing model from CPP II and proposed improvements.

### 2. OBJECTIVES

The objectives of the services is to improve and validate the surge model established under CPP II to a standard where it can form part of an advanced Early Warning System for warning against cyclones included flooding of land areas.

The following four objectives are identified on this context:

1. The first objective of the study is to implement improvements to the existing surge model of CPP II. It is rather to make the necessary adjustments in order to make the model ready for inclusion in an Early Warning System. It should be noted that the study should prepare the model to be ready for an Early Warning System, but not extend the system itself.
2. The second objective is to examine the possibilities of creating programmes for setting up a low surge system of computer models which can deliver the surge data in a form which will be highly reliable, generated information and now severe that surge data is expected to become available.

### ANNEX B

#### Terms of Reference for Extension of CPP II Numerical Cyclonic Surge Modelling

3. Assessment of quality of data necessary for validation of model, and of meteorological data necessary for forecast of cyclonic surges.

## TERMS OF REFERENCE FOR EXTENSION OF CPP II NUMERICAL CYCLONIC SURGE MODELLING

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The catastrophic cyclone of April 1991, emphasizes the need for an Improved Early Warning System. This system would consist of a forecast model for the cyclonic winds and a numerical forecast model for the cyclonic surges, the latter of which could be based on the already existing model from CPP - II with proposed improvements.

### 2. OBJECTIVES

The objectives of the services is to improve and validate the surge model established under CPP II to a standard where it can form part of an advanced Early Warning System for warning against cyclone included flooding of land areas.

The following four objectives are identified on this context :

1. The first objective of the study is to implement improvements to the existing surge model of CPP II. It is further to make the necessary adjustments in order to make the model ready for inclusion in an Early Warning System. It should be noted that the study should prepare the model to be ready for an Early Warning System, but not establish the system itself.
2. The second objective is to examine the possibilities, and writing programme for setting up at a later stage a system of computer models which can ultimately be used to forecast which areas will be hit by cyclone generated inundation, and how severe this inundation is expected to become (duration and depth of inundation ).
3. Assessment of quality of and possibility for on-line delivery of meteorological data necessary for hindcast of cyclonic surges.



4. Assessment of the institutional set up for an Early Warning System of cyclone surges based on numerical modelling.

### 3. SCOPE OF SERVICES

#### 3.1 Improvements of the Cyclone Model

The cyclone model applied is a general parametric model which has previously been used in different areas of the world. A fine tuning of the model for the Bay of Bengal during the initial stages of the modelling would have been desirable but was not possible, as only a few parameters could be collected for each of the historical cyclones, while e.g. synoptic weather charts were not available. For the April 1991 cyclone, which is the last simulated cyclone, more information was available, and it was realized that the size of the area influenced by the cyclonic wind field was too large (at least for that cyclone).

The following study task should be carried out.

- o The cyclone model should be revised in order to establish the best possible wind and pressure fields for the April 1991 cyclone. These will then be used in the sensitivity tests described in the task below. As part of the model revision further information on the cyclone including synoptic weather charts should be collected.

The tidal variations in the surge model is driven by the tidal variation at the open model boundary, which is based on a tidal station in India (Baruva) and one in Burma/Myanmar (Searle Point). The study has proven that the tidal variation is reproduced in the model in a satisfactory way except around Hatia and Sandwip Island.

The tide in the area is very complicated with ranges of more than 6 m. A satisfactory agreement between the tide as predicted by the model and the tide as predicted from tidal constants has not been achieved in the previous study. This is assessed to be due to the following effects :

- The storage capacity of the rivers has not been included
- No storage of water on the flooded areas
- The effect of outflow from the rivers has not been included.

The following subtasks should be performed :

- o The effects from introduction of inundation of land areas and of the storage capacity of the rivers on the tidal variation should be verified (see section 3 and 3.4) . The effect of the outflow the rivers should be analyzed through a sensitivity test.

- o If a satisfactory tidal simulation around Hatia and Sandwip cannot be achieved by the above means, tidal constants from more stations in the area including stations in the mouths of the rivers should be collected and analysed in order to assess the reason for the deficiency.

### 3.2 Study of Flooding and Storage Effects

#### 3.2.1 Flooding and Drying of Land Areas in the Surge Model

In the simulations made with the surge model to date inundation of land areas has not been taken into account; not because mathematical model is incapable of doing so but because detailed information on the elevation of the land areas was not available. Secondly, the effects of the embankments protecting the low lying areas from inundation were not included.

The following subtasks should be performed :

- o Available maps showing elevations on land and showing embankment including their height should be collected from relevant authorities including all relevant data from FAP 18.
- o Sensitivity model simulation should be carried out to determine the effects from including inundation in the surge model in order to determine how the effects of embankments can be incorporated in the model.

#### 3.2.2 Introduction of the Storage Effects of Rivers in the Surge Model

In most cases, the surges computed at the river mouths were higher than the measured. This is assessed to be due to the lack of inland storage effects of the rivers in the model. As a part of the previous modelling work a simple test of this effect was made and its importance documented. However, the test could only determine that the effect was of importance, while the inclusion of the effect was not possible as part of that study.

The following subtasks are thus envisaged :

- o Data and maps should be collected upon which the storage capacity (of water from the Bay of Bengal) of the rivers emptying into the Bay of Bengal can be determined.
- Sensitivity tests should be carried out in order to determine how the rivers (and their flood plains) best can be incorporated in the surge model.



### 3.3 Study of Meteorological Data Input (Sources and Data Quality)

With the ultimate goal of setting up an Early Cyclone Warning System based on numerical modelling the form and quality of the input data in the form of synoptic weather maps and satellite images become important.

This study task should assess the data forms and their quality in cooperation with the Meteorological Office and SPARRSO to define if/how data can be delivered for online numerical modelling of the cyclone surges and their effects (flooding etc.)

### 3.5 Assessment of the Frame for Setting up of an Early Warning System

The fourth study item concentrates on assessing the possibilities within the GOB and its permanent institutions for setting up an Early Warning System.

It should for example be assessed whether such a system can be amended to the ongoing Flood Forecasting and Early Warning Project FAP 10 or whether another institutional frame is more suitable.

A number of questions consequently have to be addressed in this task. Among these are :

- Institutional frame for the model set-up
- Physical location
- Details of cyclone model to be used and of meteorological data input
- Detailed methodology

## 4. DURATION OF CONSULTANCY

The consultancy will be provided for a period of 9 months from project initiation to submission of the draft final report.

## 5. STAFFING

The staffing requirements to undertake the works as outlined in section 3 should be prepared by the Consultant.

## 6. REPORTS

The following reports shall be submitted :

**6.1 Progress Report**

During the study period the Consultant shall submit brief monthly progress reports presenting the results and progress of the study.

**6.2 Draft Final & Final Report**

The Consultant shall submit draft final report for review after 8 months study period. The report shall be modified to form the final report upon receipt of comments and suggestions from the reviewing organizations.



MIKE 21 HD - Release 1.1

HYDRODYNAMIC MODULE

**ANNEX C** DESCRIPTION

A Short Description of MIKE 21



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**MIKE 21 HD - Release 1.1**

**HYDRODYNAMIC MODULE**

**A SHORT DESCRIPTION**





# MIKE 21 HD - HYDRODYNAMIC MODULE

## SHORT DESCRIPTION

### Introduction

MIKE 21 is a comprehensive modelling system for 2-dimensional free surface flows where stratification can be neglected.

MIKE 21 HD is the basic module of the entire MIKE 21 system. It provides the hydrodynamic basis for the computations performed in most of the other modules, for example the Advection-Dispersion, Water Quality and Sediment Transport modules.

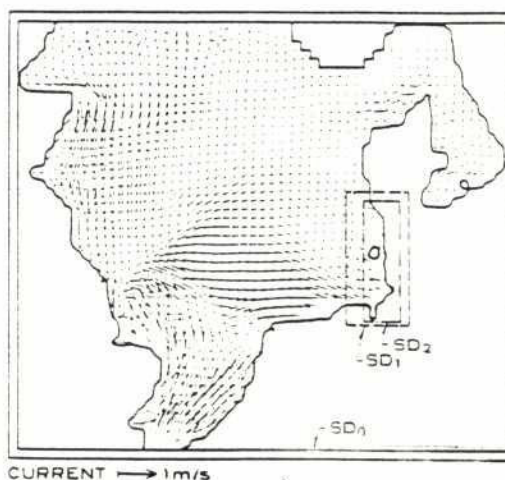
MIKE 21 HD simulates the water level variations and flows in response to a variety of forcing functions in lakes, estuaries, bays and coastal areas. The water levels and flows are resolved on a rectangular grid covering the area of interest when provided with the bathymetry, bed resistance coefficients, wind field, hydrographic boundary conditions, etc.

The system solves the equations of continuity and conservation of momentum using implicit finite difference methods.

### Applications

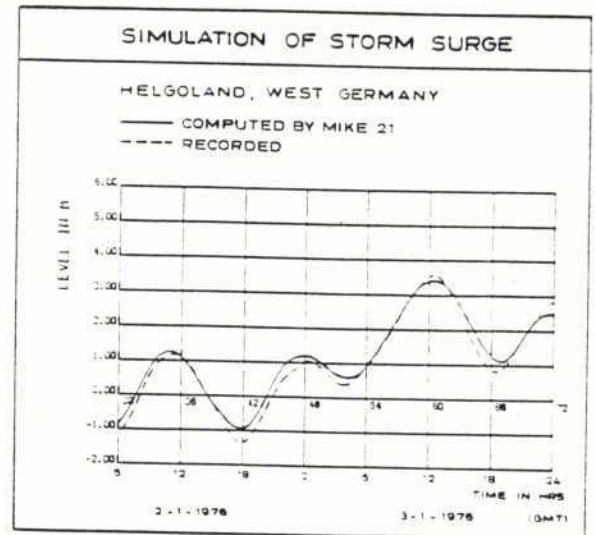
MIKE 21 HD is applicable to a wide range of hydraulic phenomena:

- Tidal exchange and currents

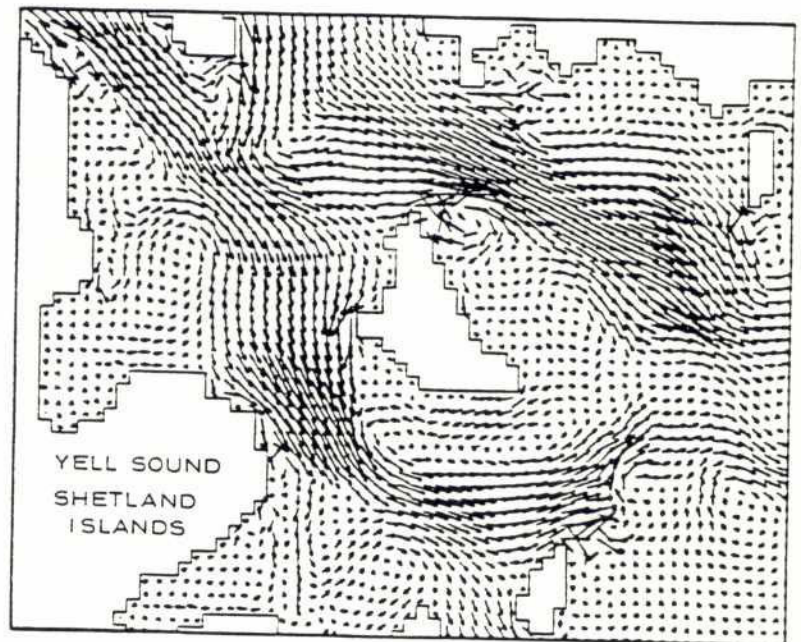




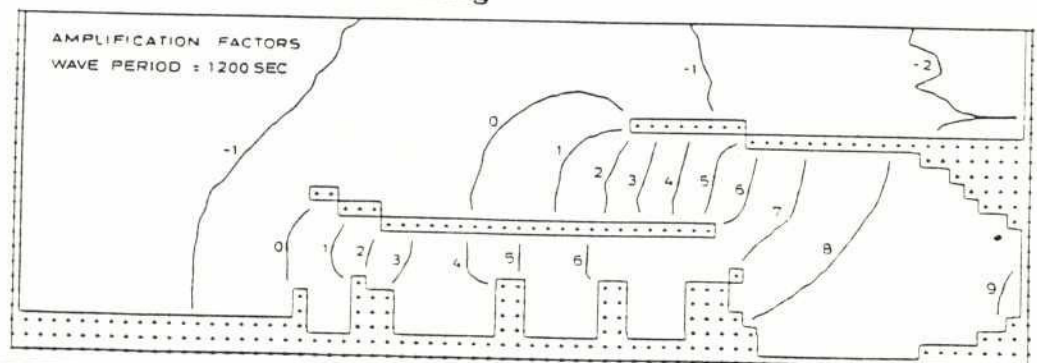
- Storm surge



- Secondary circulations, eddies and vortices



- Harbour seiching

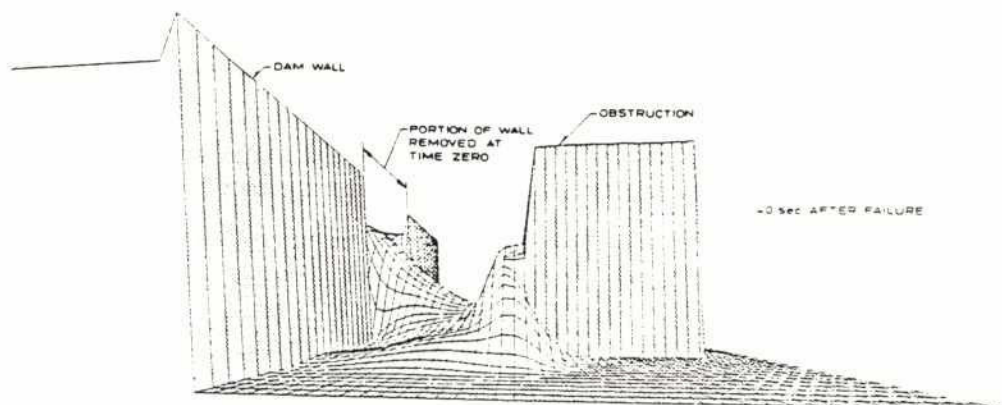


MIKE 21 HD - Short Description

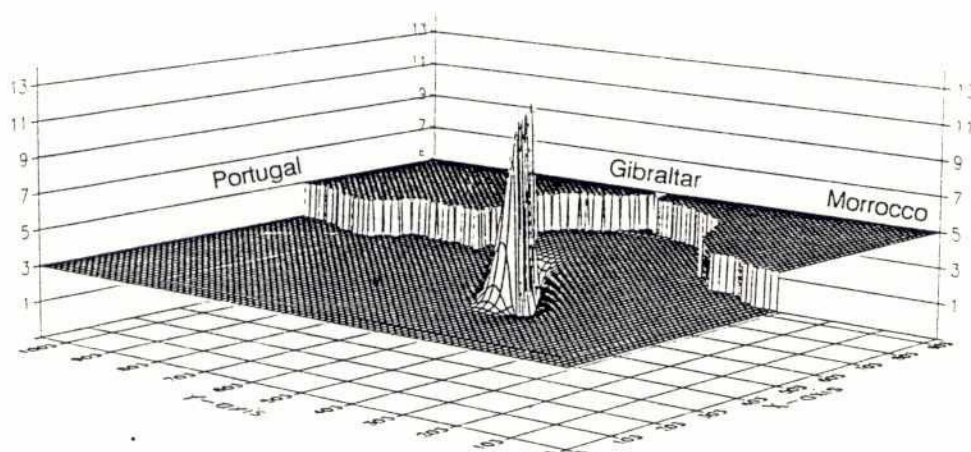




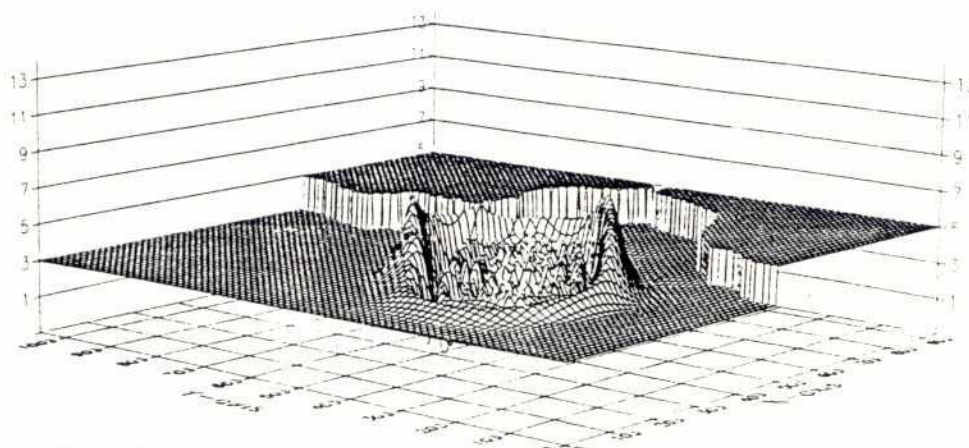
### • Dam-break



### • Tsunamis



SEA SURFACE IMMEDIATELY AFTER EARTHQUAKE



TSUNAMI AFTER 14 min.



## Equations

The hydrodynamic module of MIKE 21 solves the vertically integrated equations of continuity and conservation of momentum in two horizontal dimensions. The following effects are included in the equations:

- convective and cross momentum
- wind shear stress at the surface
- barometric pressure gradients
- Coriolis forces
- momentum dispersion ('eddy')
- sources and sinks (both mass and impulse)
- evaporation.

### Continuity

$$\frac{\partial \zeta}{\partial t} + \frac{\partial p}{\partial x} + \frac{\partial q}{\partial y} = s - e$$

### x-Momentum

$$\begin{aligned} \frac{\partial p}{\partial t} + \frac{\partial}{\partial x} \left[ \frac{p^2}{h} \right] + \frac{\partial}{\partial y} \left[ \frac{p \cdot q}{h} \right] + gh \frac{\partial \zeta}{\partial x} \\ + \frac{g}{c^2} \sqrt{\frac{p^2}{h^2} + \frac{q^2}{h^2}} \cdot \frac{p}{h} - fVv_x - \frac{h}{\rho_w} \cdot \frac{\partial p_a}{\partial x} \\ - \Omega q - \left[ \frac{\partial}{\partial x} \left( E_x \cdot h \cdot \frac{\partial u}{\partial x} \right) + \frac{\partial}{\partial y} \left( E_y \cdot h \cdot \frac{\partial u}{\partial y} \right) \right] = s_{ix} \end{aligned}$$

### y-Momentum

$$\frac{\partial q}{\partial t} + \frac{\partial}{\partial y} \left[ \frac{q^2}{h} \right] + \frac{\partial}{\partial x} \left[ \frac{p \cdot q}{h} \right] + gh \frac{\partial \zeta}{\partial y}$$





$$+ \frac{g}{c^2} \sqrt{\frac{p^2}{h^2} + \frac{q^2}{h^2}} \cdot \frac{g}{h} - f V V_y - \frac{h}{\rho_w} \cdot \frac{\partial p_a}{\partial y}$$

$$+ \Omega p - \left[ \frac{\partial}{\partial x} \left( E_x \cdot h \cdot \frac{\partial v}{\partial x} \right) + \frac{\partial}{\partial y} \left( E_y \cdot h \cdot \frac{\partial v}{\partial y} \right) \right] = S_{iy}$$

### Symbol List

$\zeta(x,y,t)$	- water surface level above datum (m)
$p(x,y,t)$	- flux density in the x-direction (m <sup>3</sup> /s/m)
$q(x,y,t)$	- flux density in the y-direction (m <sup>3</sup> /s/m)
$h(x,y,t)$	- water depth (m)
$S$	- source magnitude per unit horizontal area (m <sup>3</sup> /s/m <sup>2</sup> )
$S_{ix}, S_{iy}$	- source impulse in x- and y-directions (m <sup>3</sup> /s/m <sup>2</sup> ·m/s)
$e$	- evaporation rate (m/s)
$g$	- gravity (m/s <sup>2</sup> )
$C$	- Chezy resistance No. (m <sup>1/2</sup> /s)
$f$	- wind friction factor
$V, V_x, V_y(x,y,t)$	- wind speed and components in x- and y-directions (m/s)
$p_a(x,y,t)$	- barometric pressure (kg/m/s <sup>2</sup> )
$\rho_w$	- density of water (kg/m <sup>3</sup> )
$\Omega$	- Coriolis coefficient (latitude dependent) (s <sup>-1</sup> )
$E(x,y)$	- eddy or momentum dispersion coefficient (m <sup>2</sup> /s)
$x, y$	- space coordinates (m)
$t$	- time (s)

### Calibration Factors

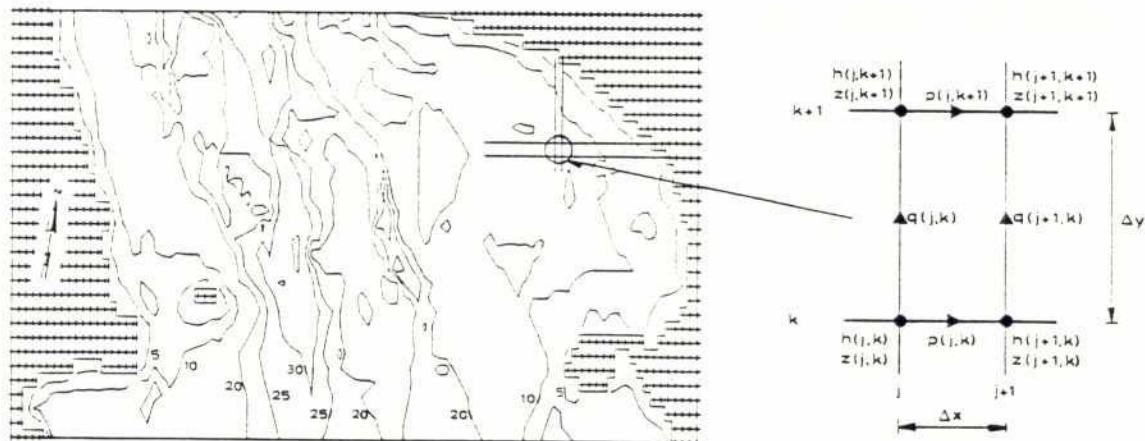
A MIKE 21 HD generated model has only three calibration factors, namely bed resistance  $C$ , wind friction factor  $f$ , and momentum dispersion coefficient  $E$  (normally called an eddy coefficient). Using these factors alone, calibration of a model is normally quite easy. In practice, the calibration of a model depends far more on the accuracy of the data, e.g. bathymetry, boundary data and wind speeds.

The bed resistance,  $C$ , and momentum dispersion coefficient,  $E$ , can both be specified as a function of space. Further,  $E$  can vary in time in accordance with a special formulation of Smagorinsky's theory for turbulence.



## Solution Technique

The equations are solved by implicit finite difference techniques with the variables defined on a space-staggered rectangular grid as shown below.



A 'fractioned-step' technique combined with an Alternating Direction Implicit (ADI) algorithm is used in the solution to avoid the necessity for iteration. Second order accuracy is ensured through the centering in time and space of all derivatives and coefficients. The ADI algorithm implies that at each time step a solution is first made in the x-direction using the continuity and x-momentum equations followed by a similar solution in the y-direction.

As a simple example, the finite difference scheme for the time derivative of flux density is shown below.

$$\frac{\partial p}{\partial t} \approx \left( \frac{p^{n+1} - p^n}{\Delta t} \right) - \frac{\Delta t^2}{24} \cdot \frac{\partial^3 p}{\partial t^3}$$

truncation error

The truncation error is of second order,  $O(\Delta t^2)$ .

The application of the implicit finite difference scheme results in a tridiagonal system of equations for each grid line in the model. The solution is obtained by inverting the tridiagonal matrix using the Double Sweep algorithm, a very fast and accurate form of Gauss elimination.





The implicit scheme is used in MIKE 21 in such a way that stability problems do not occur provided, of course, that the input data is physically reasonable, so that the time step used in the computations is limited only by accuracy requirements.

## Data Requirements

The necessary data can be divided into several groups as briefly described below.

### Basic Model Parameters:

- Model grid size and extent
- Time step and length of simulation
- Type of output required and its frequency
- Latitude and its orientation

### Bathymetry.

### Calibration Factors:

- Bed resistance
- Momentum dispersion coefficients
- Wind friction factor

### Initial Conditions:

- Water surface level
- Flux densities in x- and y-directions

### Boundary Conditions:

- Water levels or flow magnitude
- Flow direction

### Other Driving Forces:

- Wind speed and direction
- Source/sink discharge magnitude and speed.

## Pre- and Post-processing Software

The MIKE 21 HD module includes a range of pre- and post-processing software which eases the input of data and analysis of simulation results. The software can be applied to the data and results of all the MIKE 21 modules.

Some examples of the software capabilities are:

- Input of time series and 2-D data
- Isoline plots of any variable
- 2-D vector plots of current patterns
- Plots of the variation in space of a variable along any line through the model
- 3-D plots of bathymetries, surface levels, concentrations
- Statistical analysis of time or space variation of any variable.



All graphical presentations can be in colour, produced with the UNIRAS graphics package.

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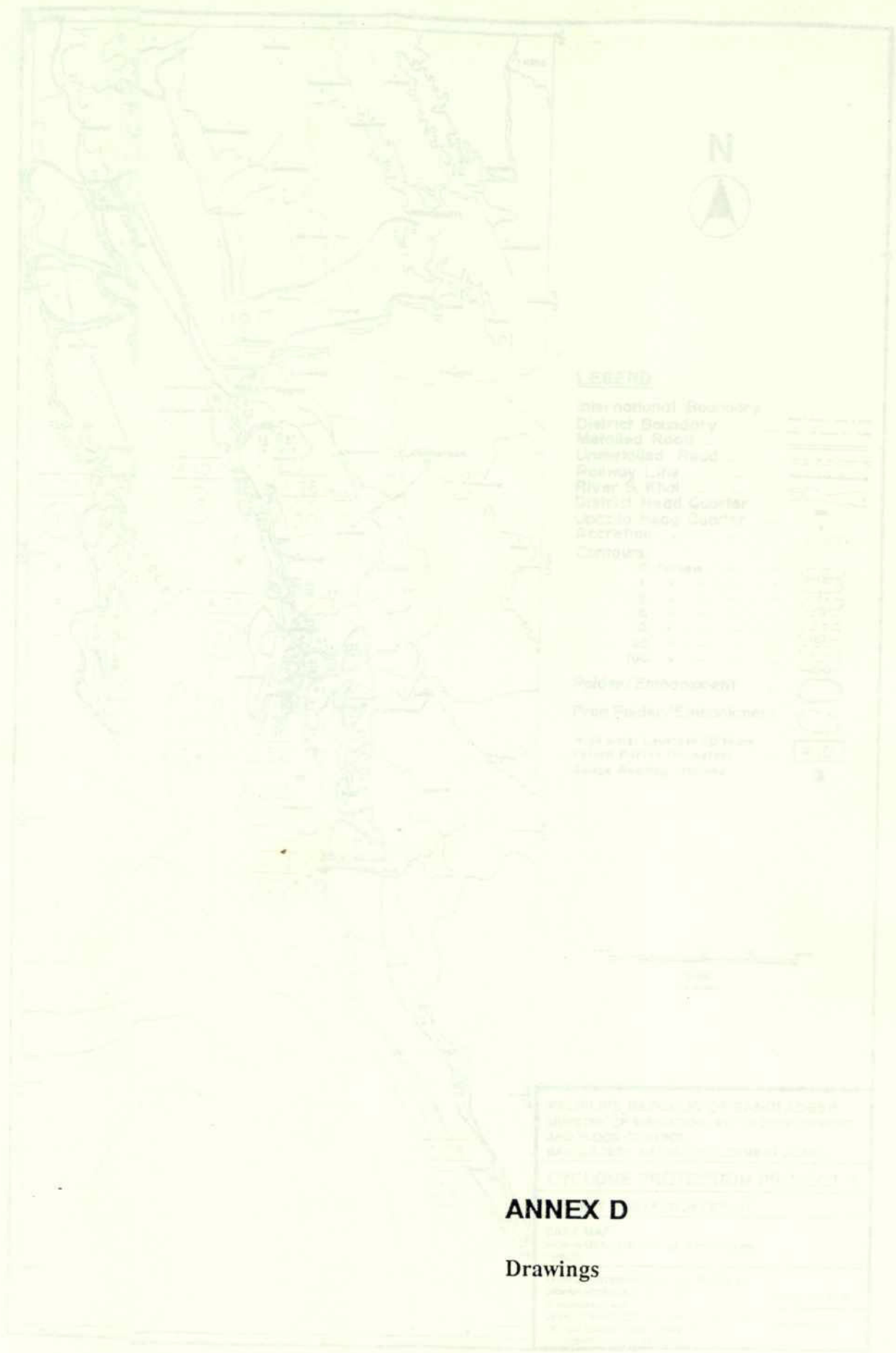




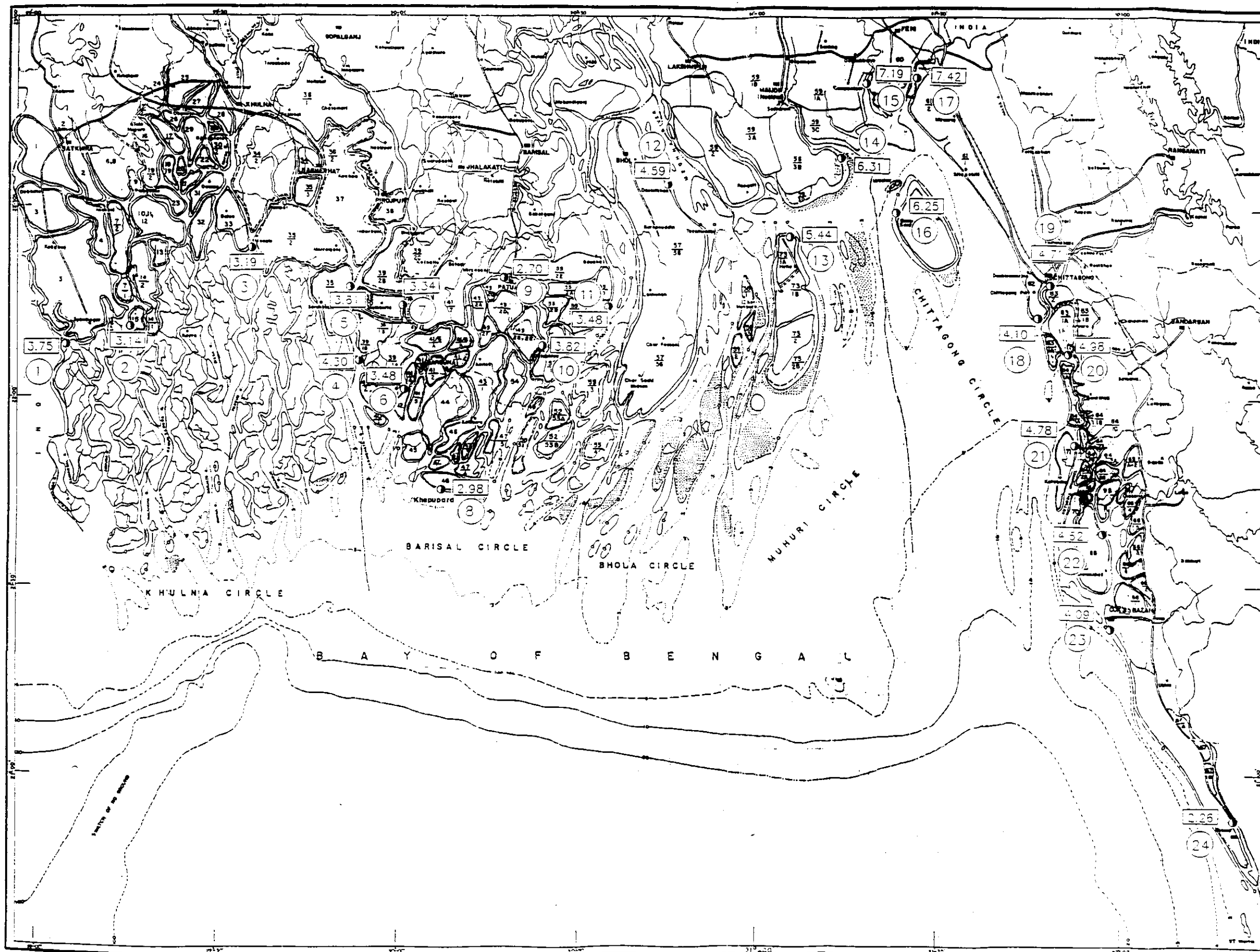
Abbott, M.B., C.H. Rasmussen, "On the numerical Modelling of Rapid Concentrations and Expansions in Models that are Two-Dimensional in Plan". Proceedings 17th Congress IAHR, 1977, Baden-Baden, 2, pp. 229-238.

Abbott, M.B., A. Damsgaard, G.S. Rodenhuis, "System 21, Jupiter, A Design System for Two-Dimensional Nearly Horizontal Flows", Journal of Hydraulic Resources, Vol. 11, 1973, pp. 1-28.

1991-01-21  
M21HD.RW/CHC9011.kin/I



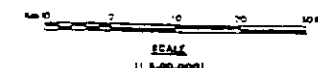




# **LEGEND**

- International Boundary
- District Boundary
- Metalled Road
- Unmetalled Road
- Railway Line
- River & Khal
- District Head Quarter
- Upazila Head Quarter
- Accretion
- Contours:
 

0	Fathom
1	"
3	"
6	"
10	"
20	"
100	"
- Polder/Embankment
- Prop. Polder/Embankment
- High water Levels of 20 Years return Period (in meter)
- Gauge Reading stations



PEOPLE'S REPUBLIC OF BANGLADESH  
 MINISTRY OF IRRIGATION, WATER DEVELOPMENT  
 AND FLOOD CONTROL  
 BANGLADESH WATER DEVELOPMENT BOARD

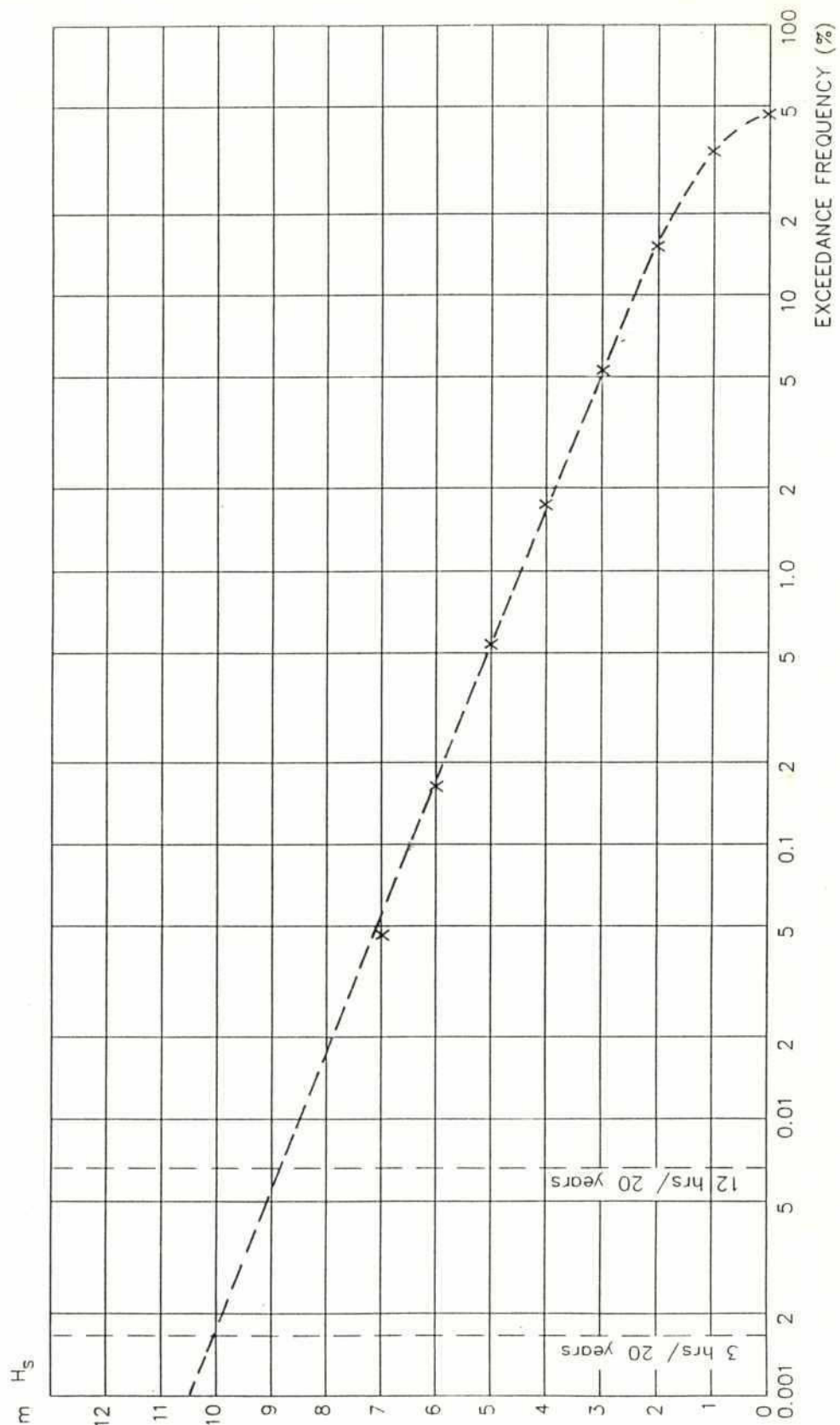
**CYCLONE PROTECTION PROJECT II**

PROJECT PREPARATION REPORT

BASE MAP  
 HIGH WATER LEVELS OF 20 YEARS RETURN PERIOD

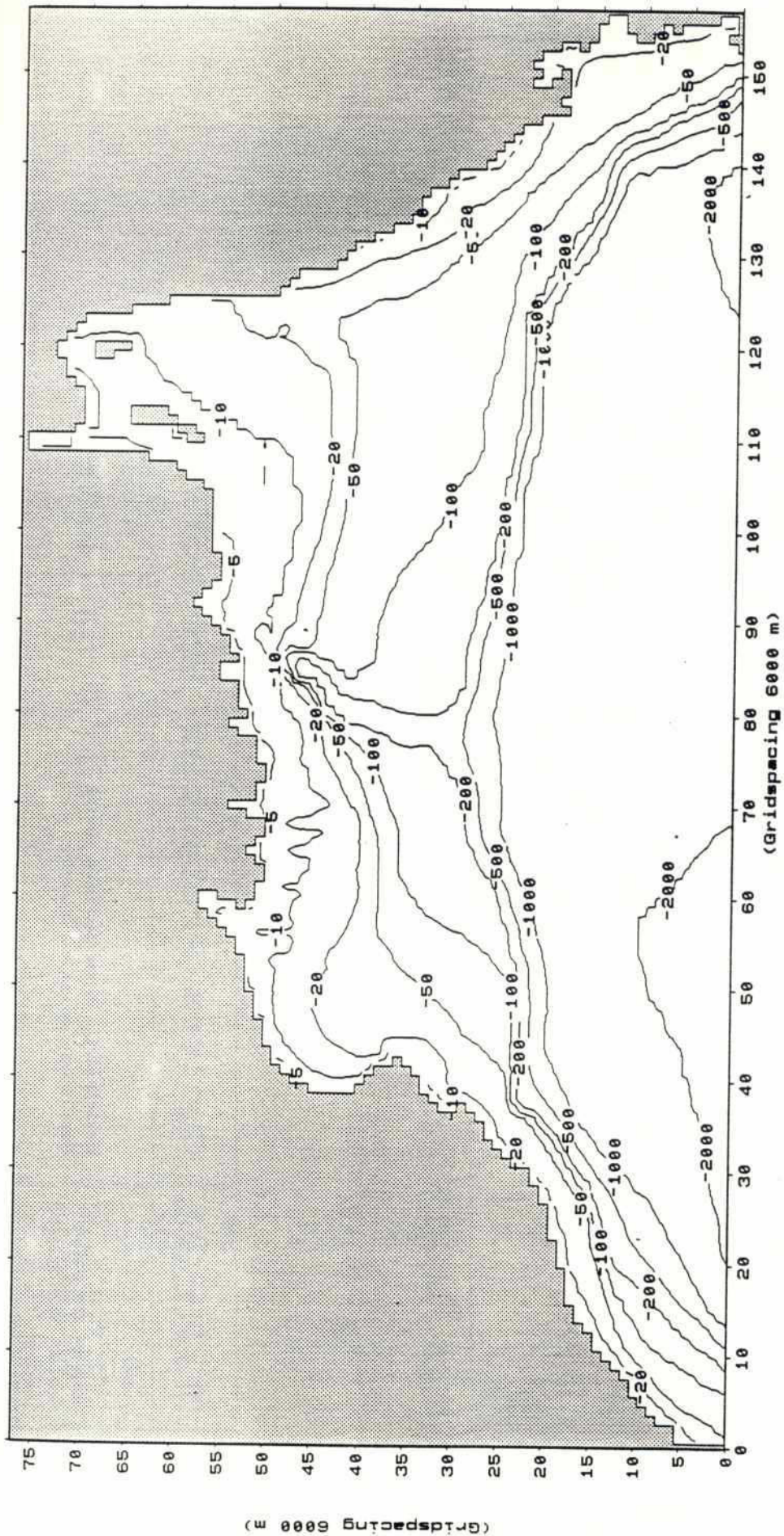
KAMPSAX INTERNATIONAL A/S, BCOEM and  
 DANISH HYDRAULIC INSTITUTE  
 in association with  
 DEVELOPMENT DESIGN CONSULTANTS LTD.  
 23, New Eskaton Road, Dhaka-1000.  
 Tel. 405477 Fax 880 02 832951

DATE 01-02-1992  
 DRAWING No.3.1



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: name : User: mnr	WAVE HEIGHT EXCEEDANCE DIAGRAM BAY OF BENGAL, DIRECTIONS SW, S AND SE	Dwg. No.  3.2

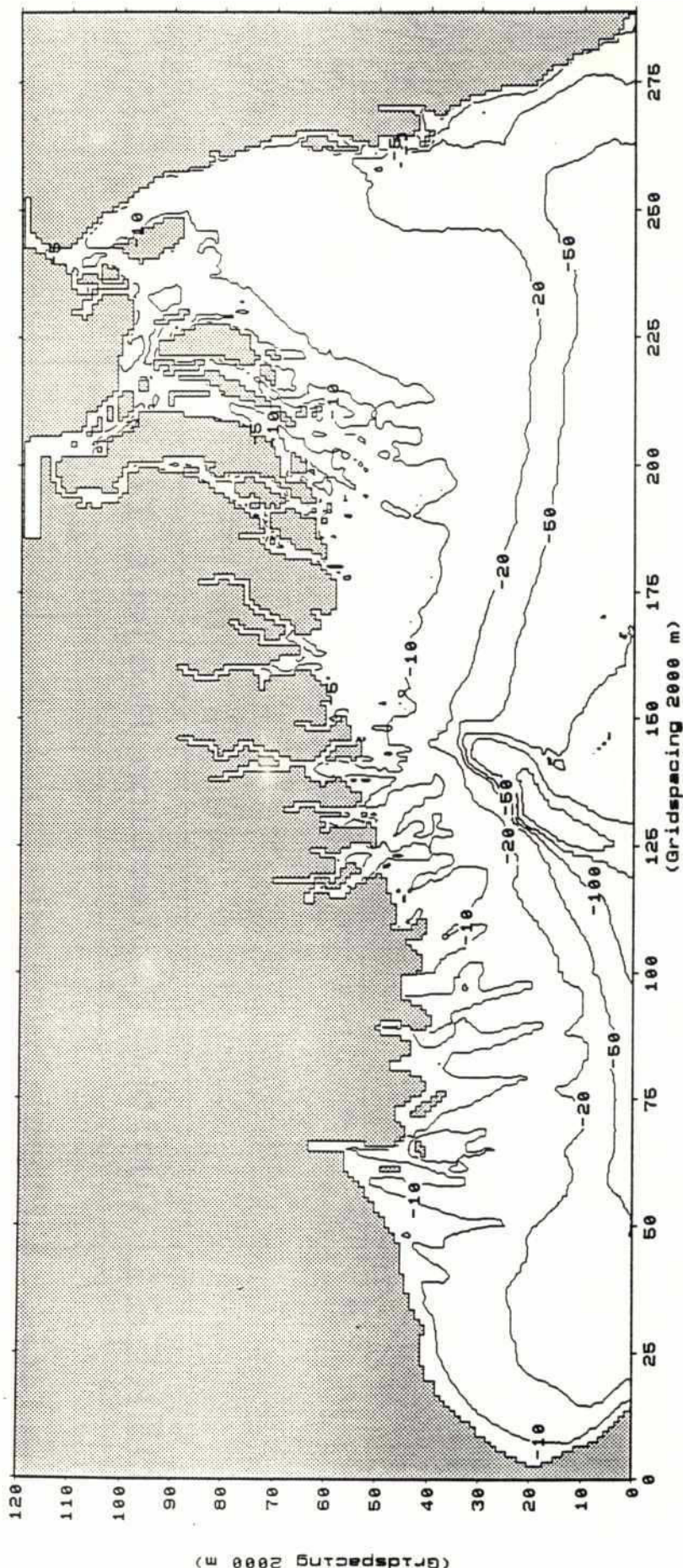




<p><b>MIKE21</b></p> <p>File: family: reg name : bathy Scale: 1:4 mill. Tue Dec 11 1990</p>	<p><b>Cyclone Protection Project II</b></p> <p>Bathymetry, Regional Model Depth (m) relative to MSL</p>	<p>Dwg. No. 4.1</p>
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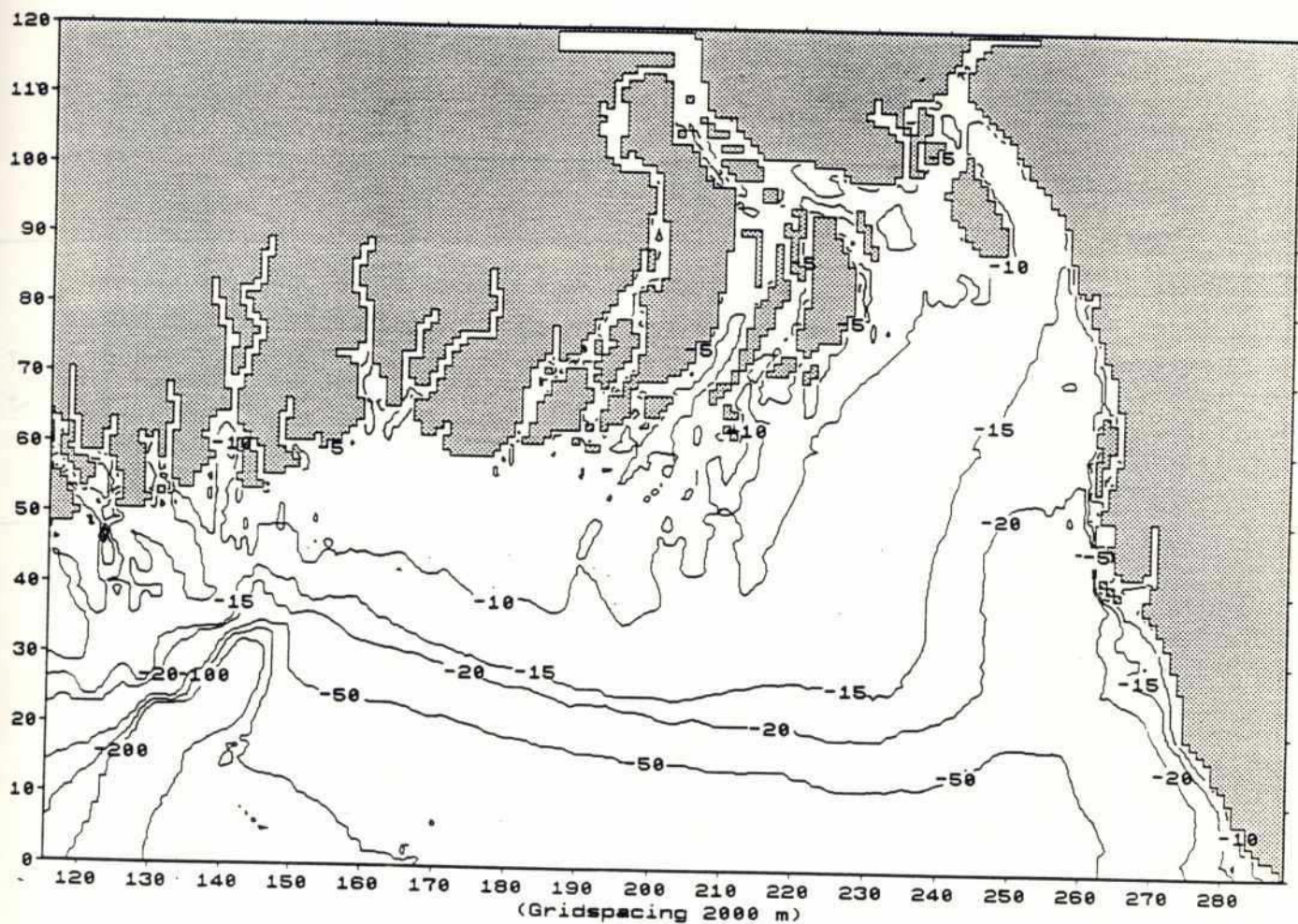


38



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: int name : bathy Scale: 1:2.5 mill Tue Dec 11 1998	Bathymetry, Intermediate Model Depth (m) relative to MSL	Dwg. No. 4.2

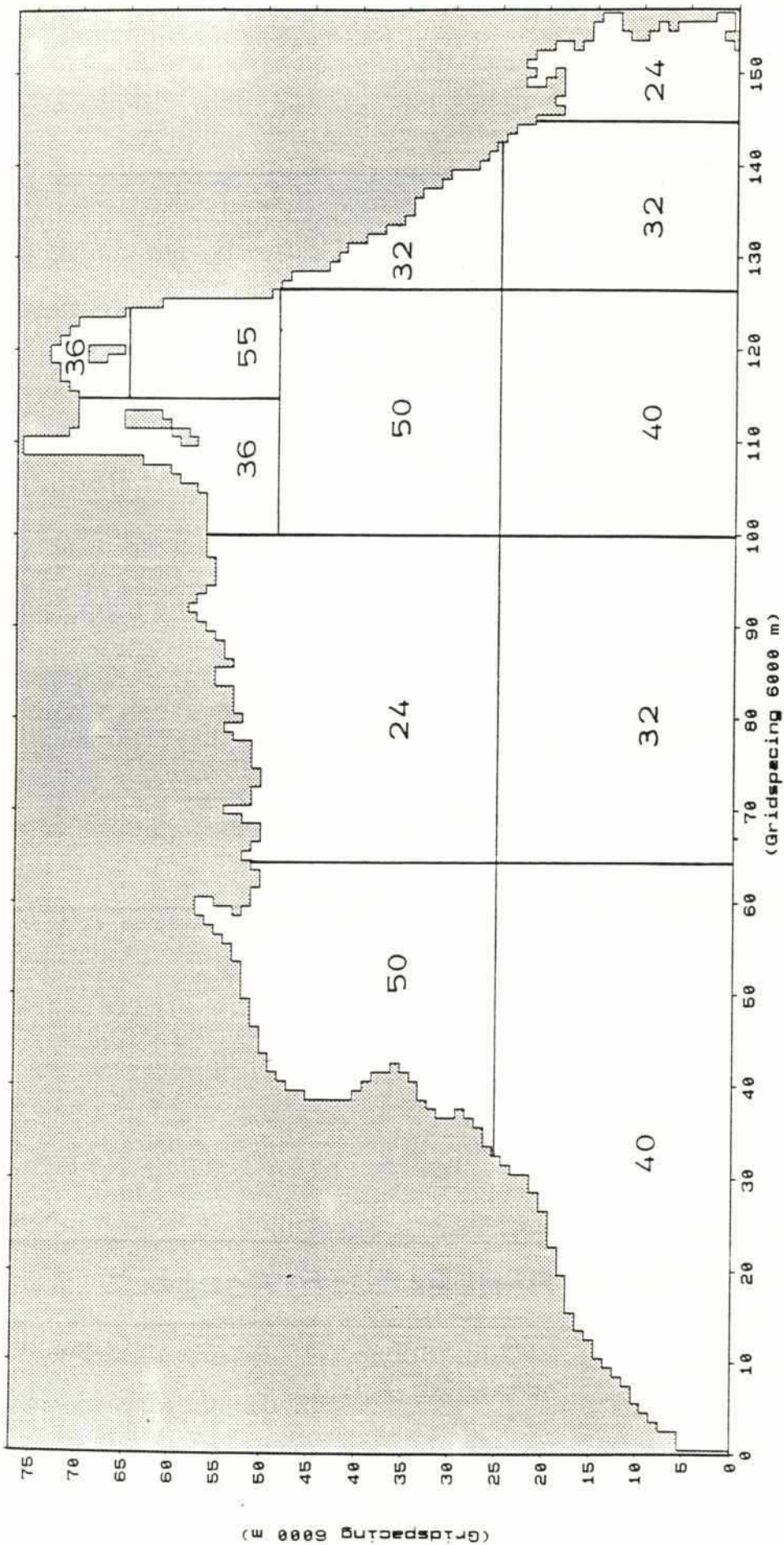




<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
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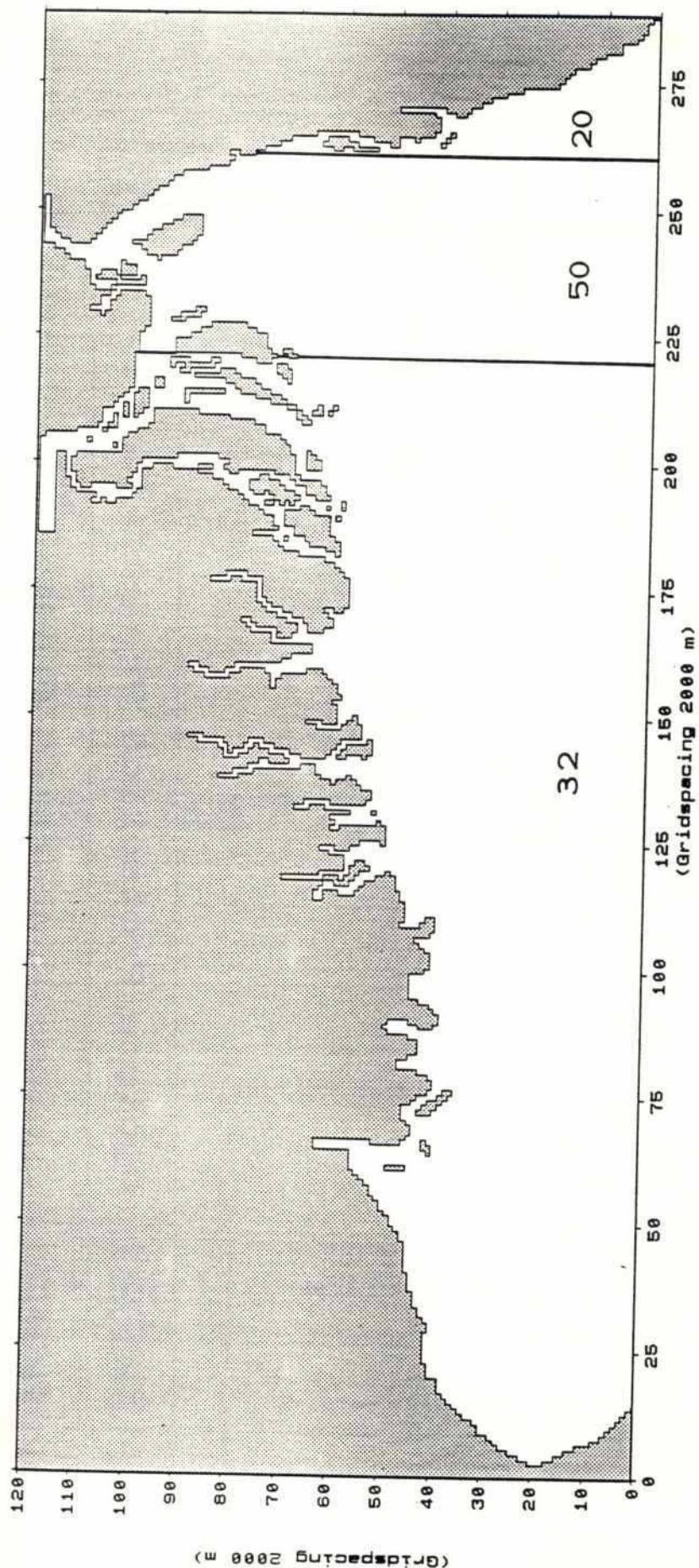


63



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: reg name : bathy Scale: 1:4 mill. Time Dec 18 1998	Resistance Map, Regional Model Manning Numbers	Dwg. No. 4.4





**MIKE21**

**Cyclone Protection Project II**

File:

family: int

name : bathy

Scale: 1:2.5 mill

Tue Dec 18 1990

Resistance Map, Intermediate Model  
Manning Numbers

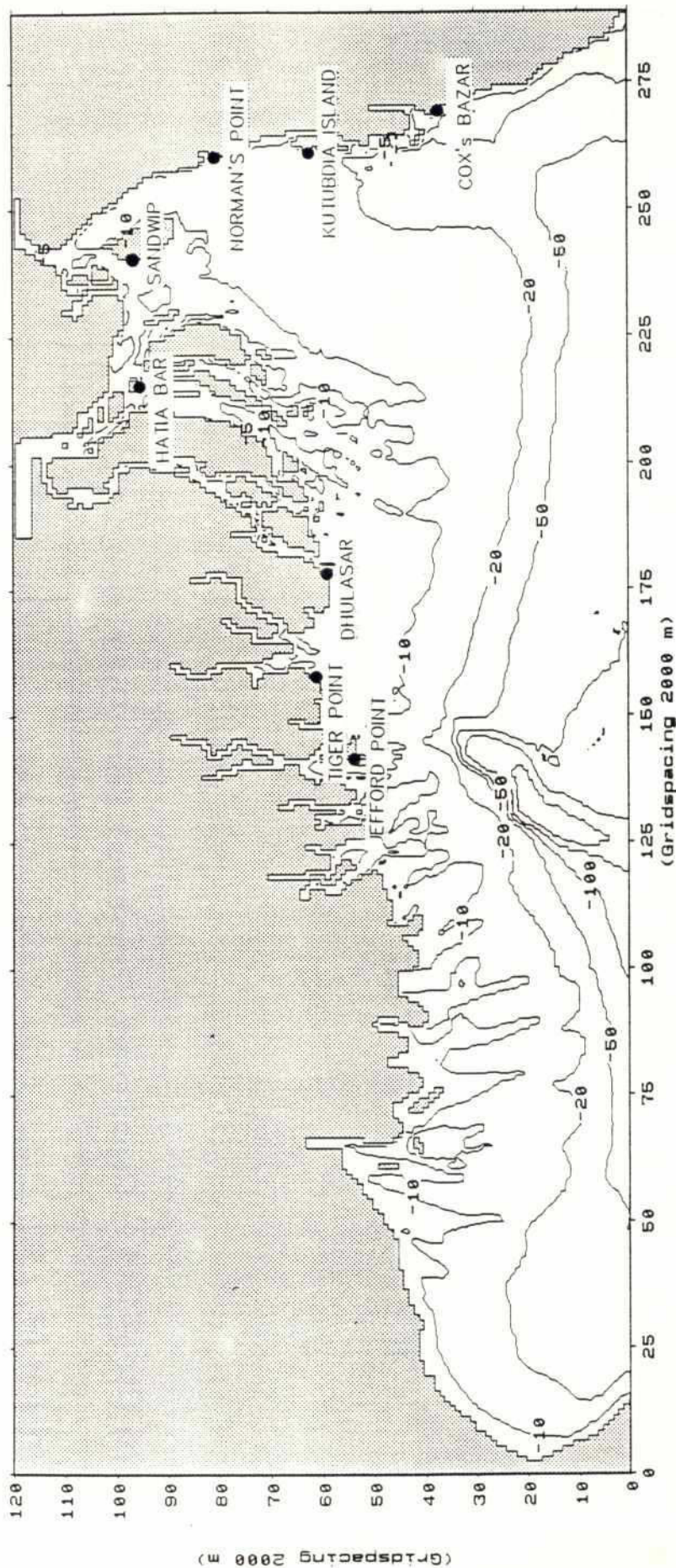
Dwg. No.

4.5

5

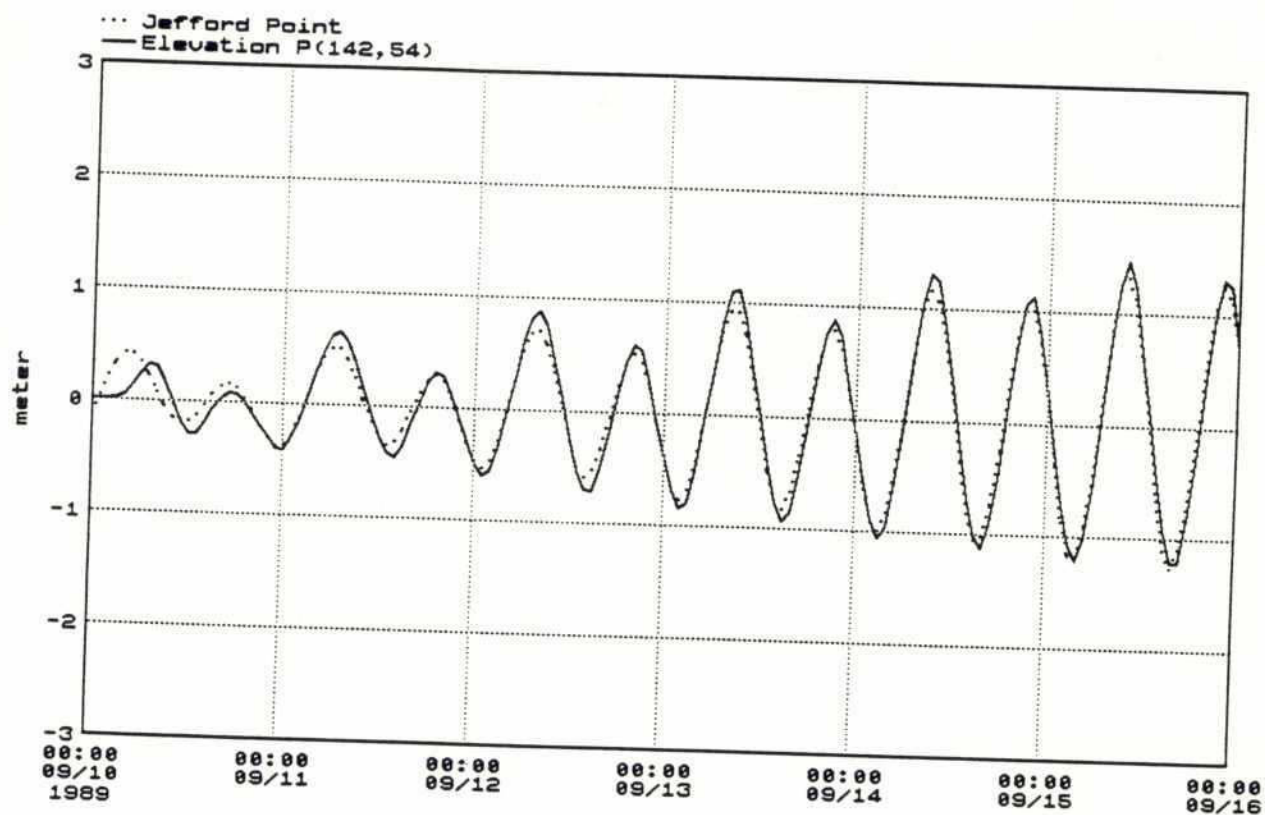


44



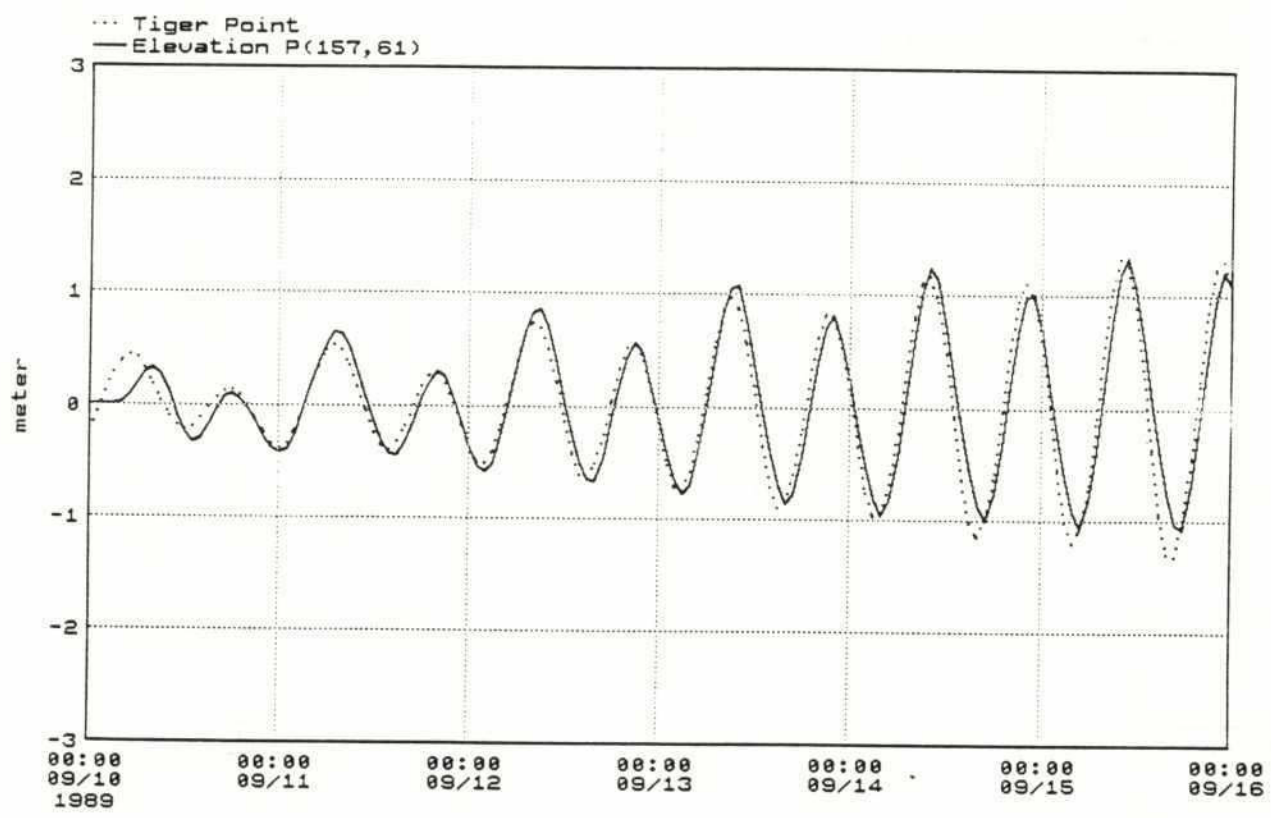
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<b>File:</b> family: int name : bathy Scale: 1:2.5 mill Tue Dec 18 1990	Tidal Validation Stations, Intermediate Model (Depth (m) relative to MSL)	
		Dwg. No.  4.6





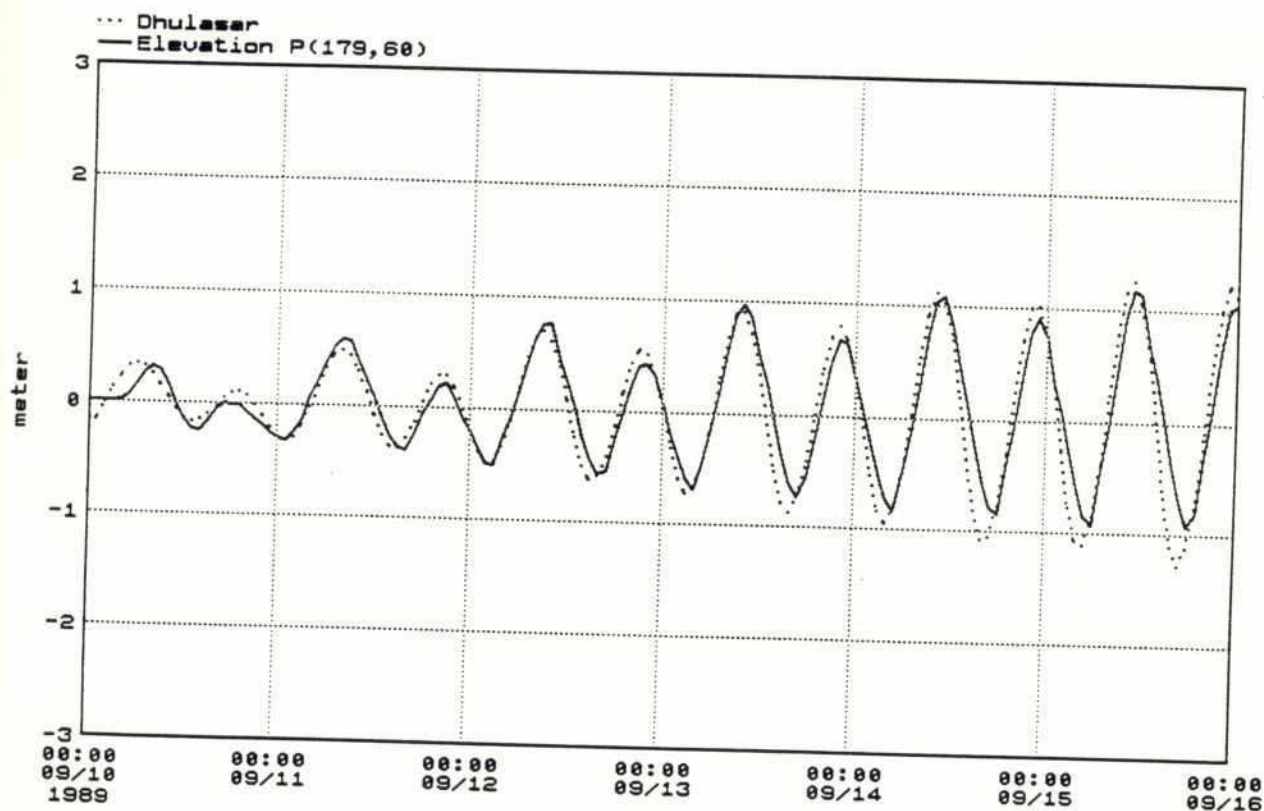
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File: family: int name : 5tsall User: mnr Tue Nov 20 1990	Tidal validation Computed elevations (full line) and Predicted elevations (dotted line)	Dwg. No.  4.7

22



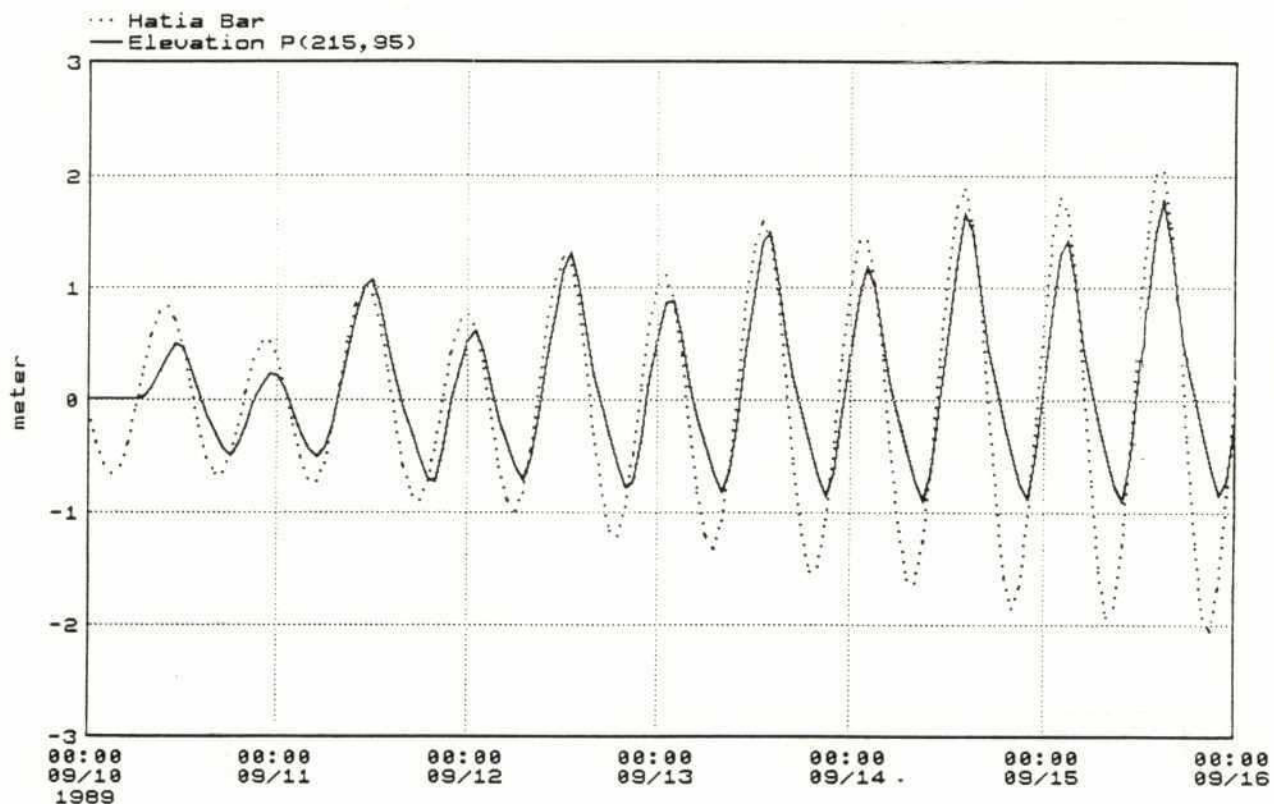
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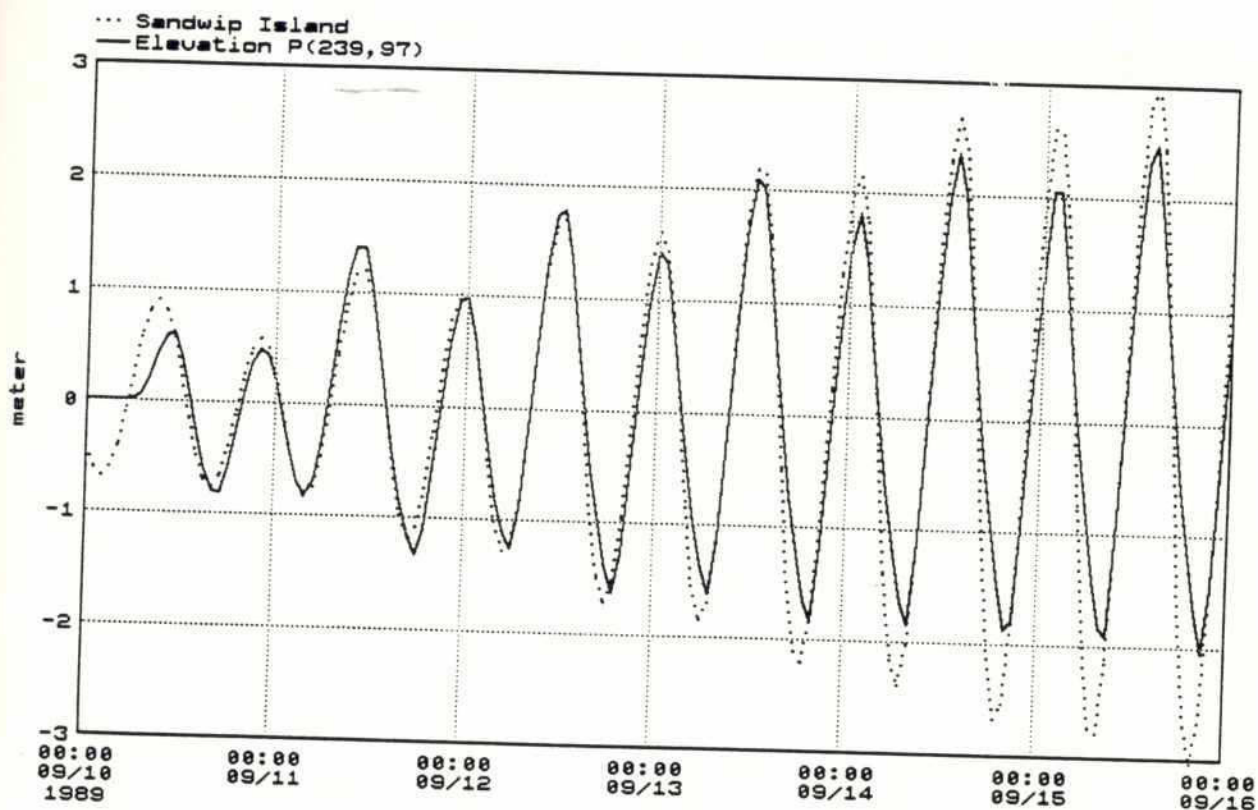
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27



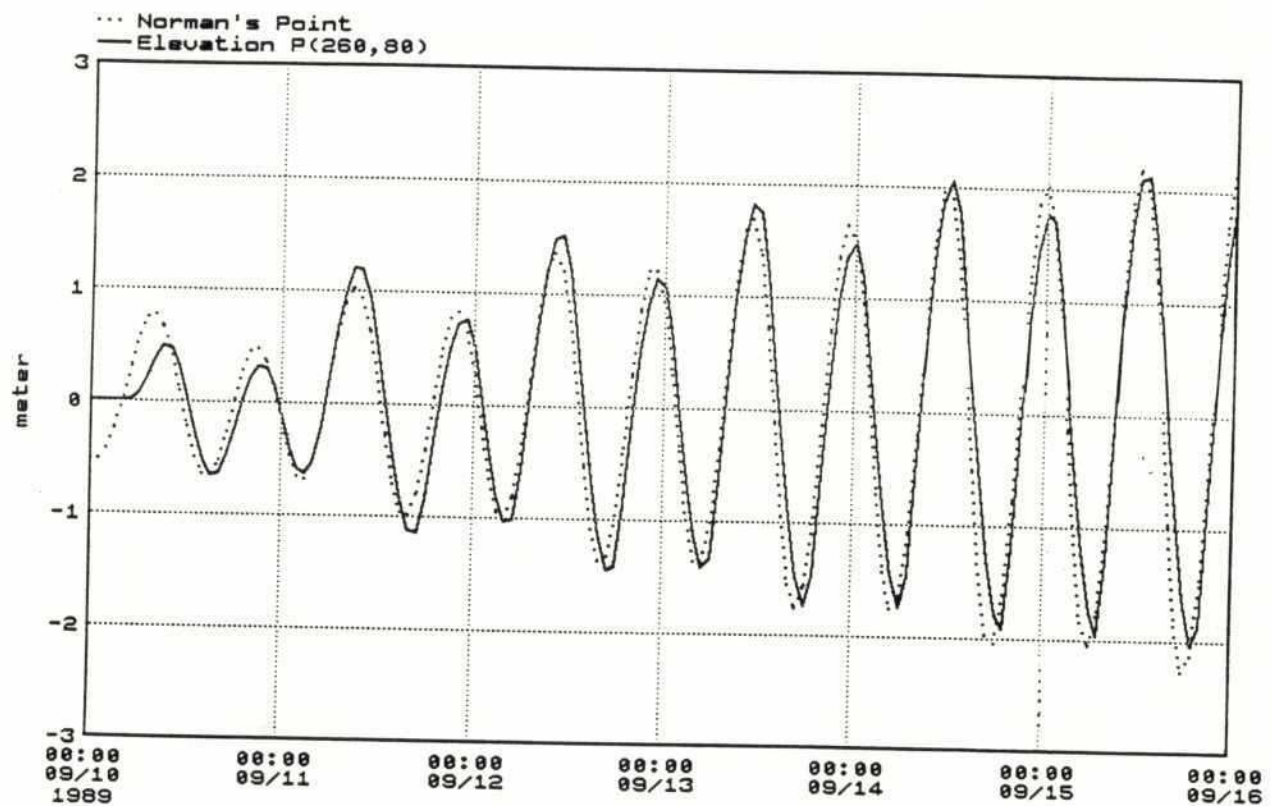
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<p>File: family: int name : Stsall User: mnr Tue Nov 20 1990</p>	<p>Tidal validation Computed elevations (full line) and Predicted elevations (dotted line)</p>	<p>Dwg. No.  4.10</p>





<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
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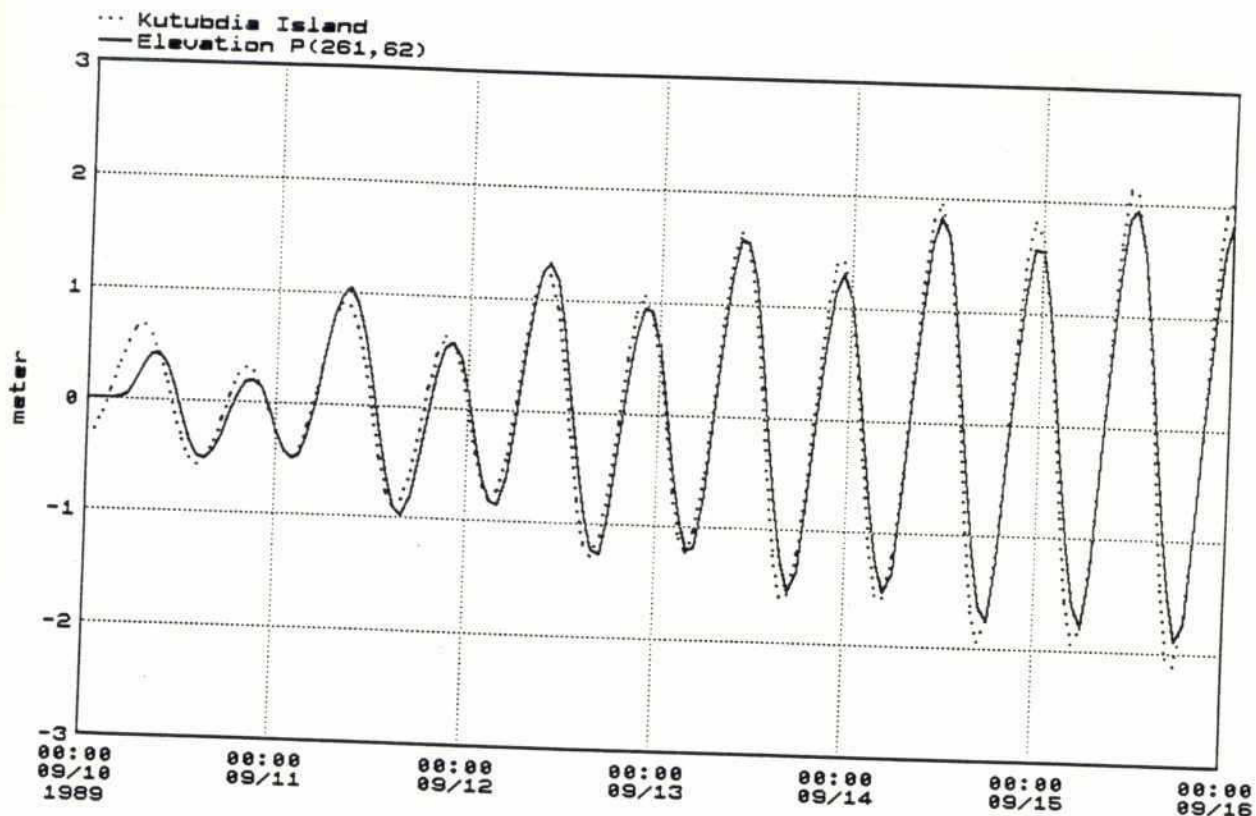
58



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
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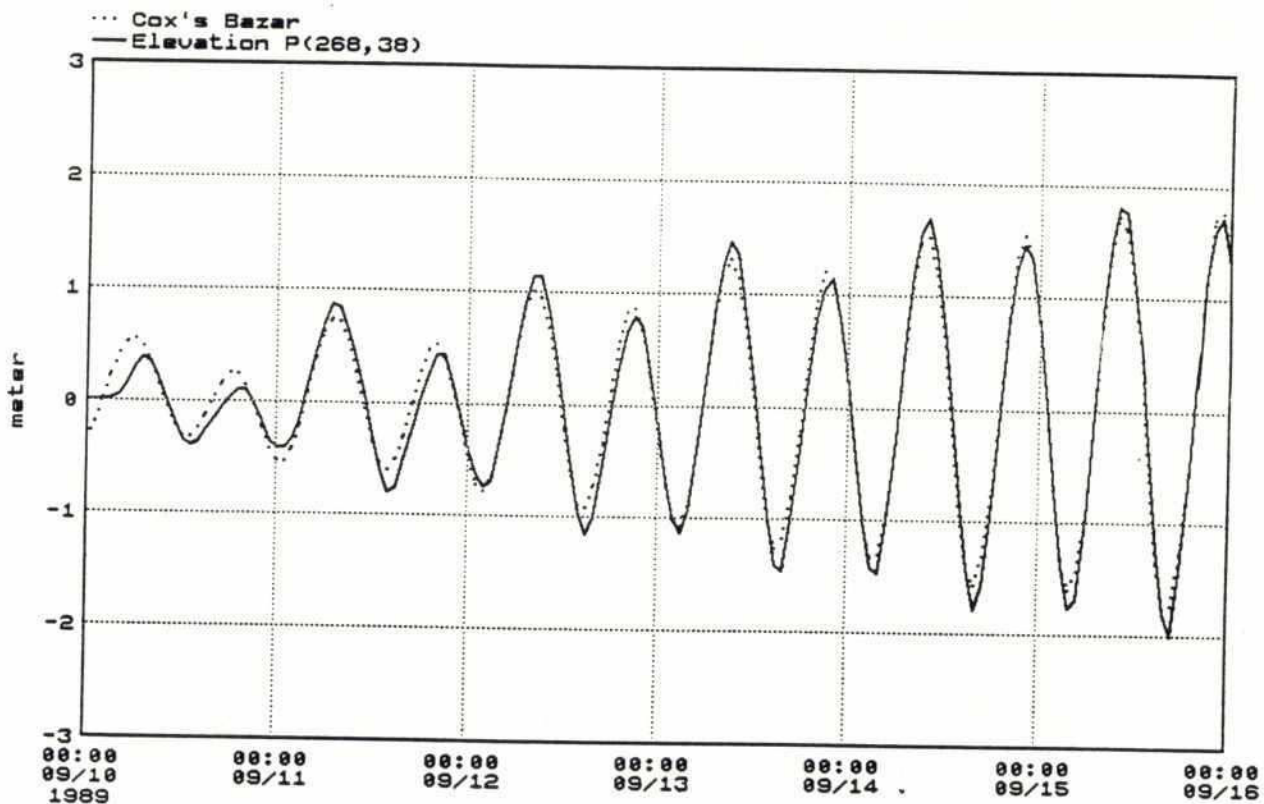


24



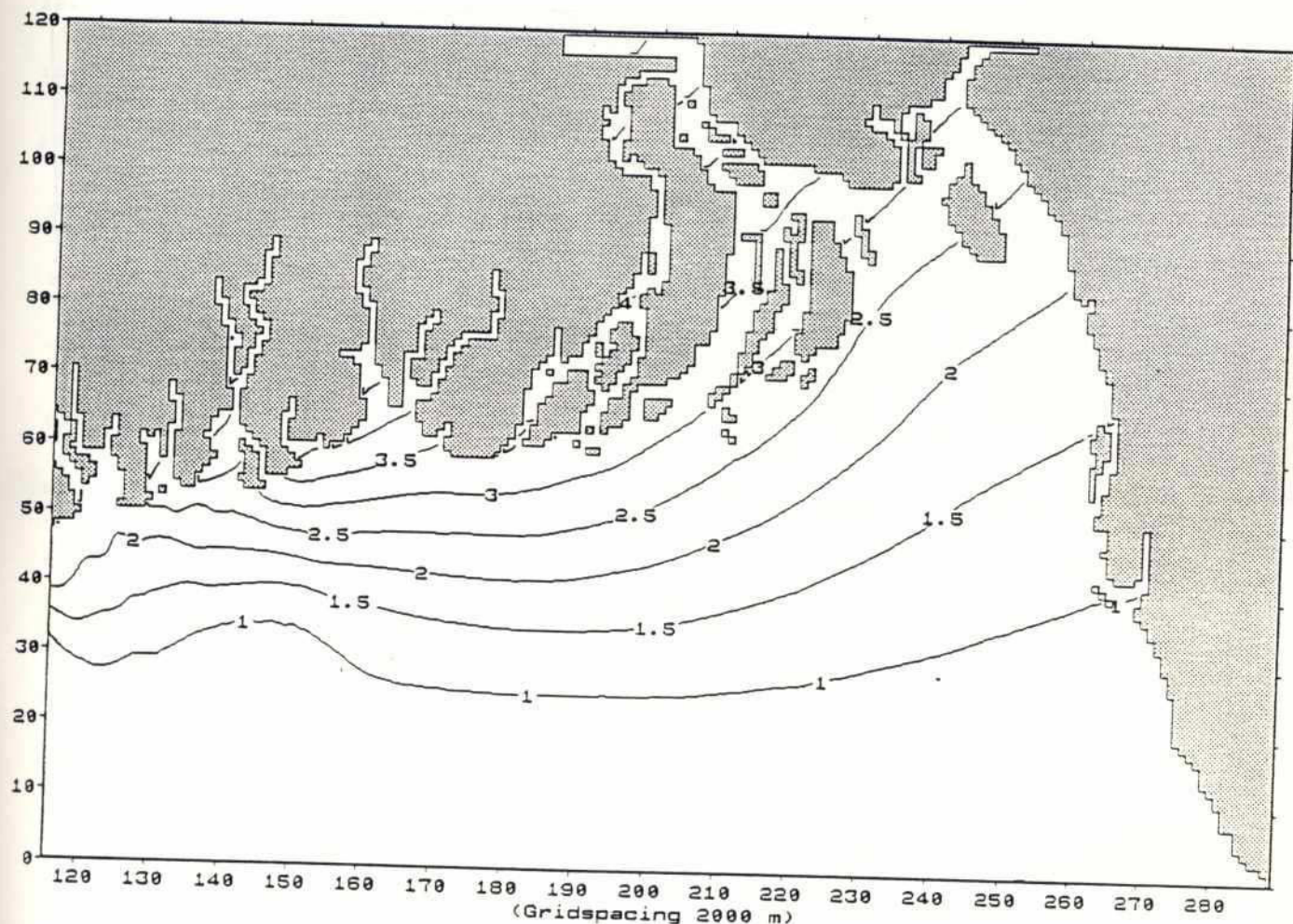
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: int name : Stsall User: mnr Tue Nov 20 1990	Tidal Validation Computed elevations (full line) and Predicted elevations (dotted line)	Dwg. No.  4.13

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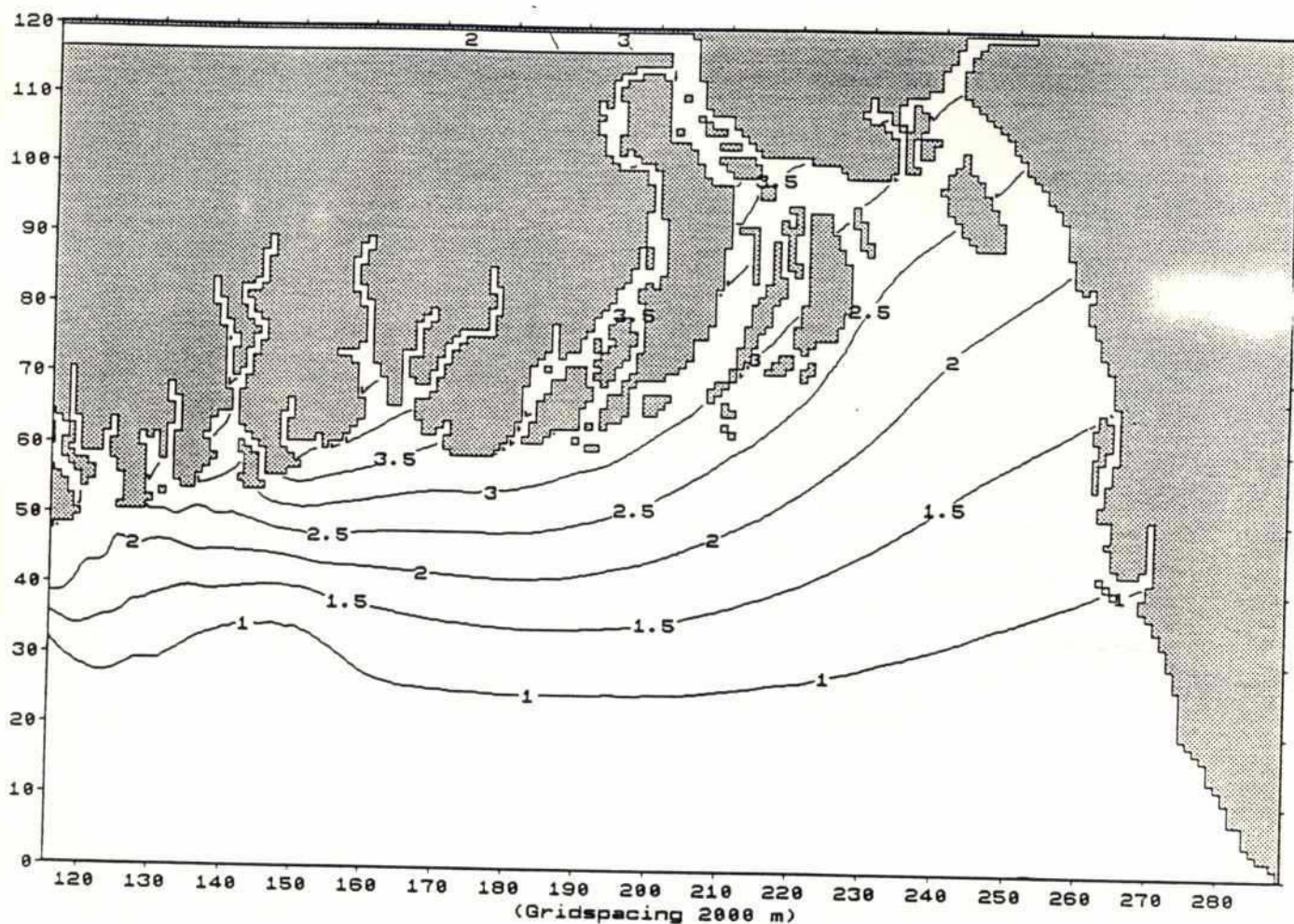


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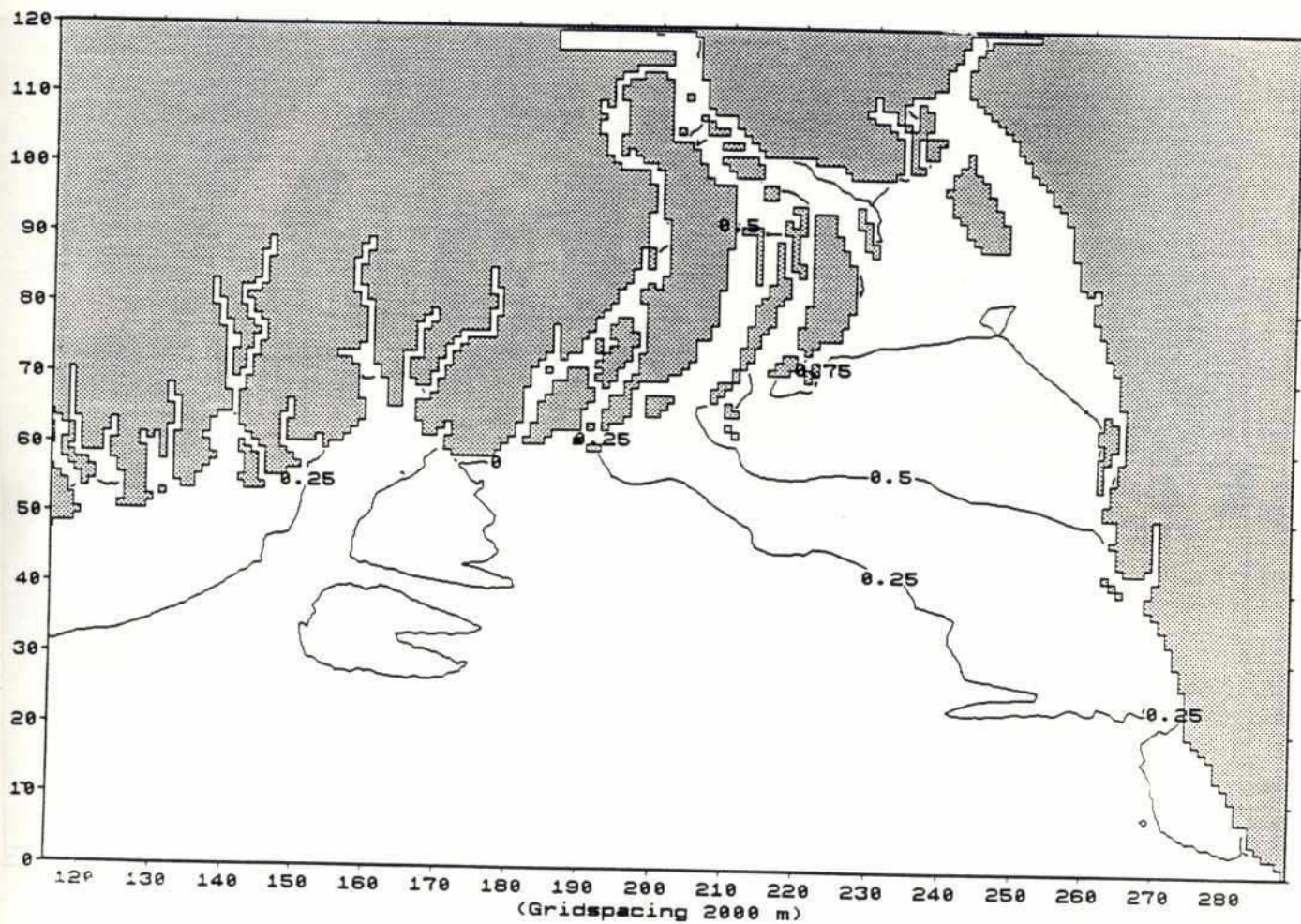


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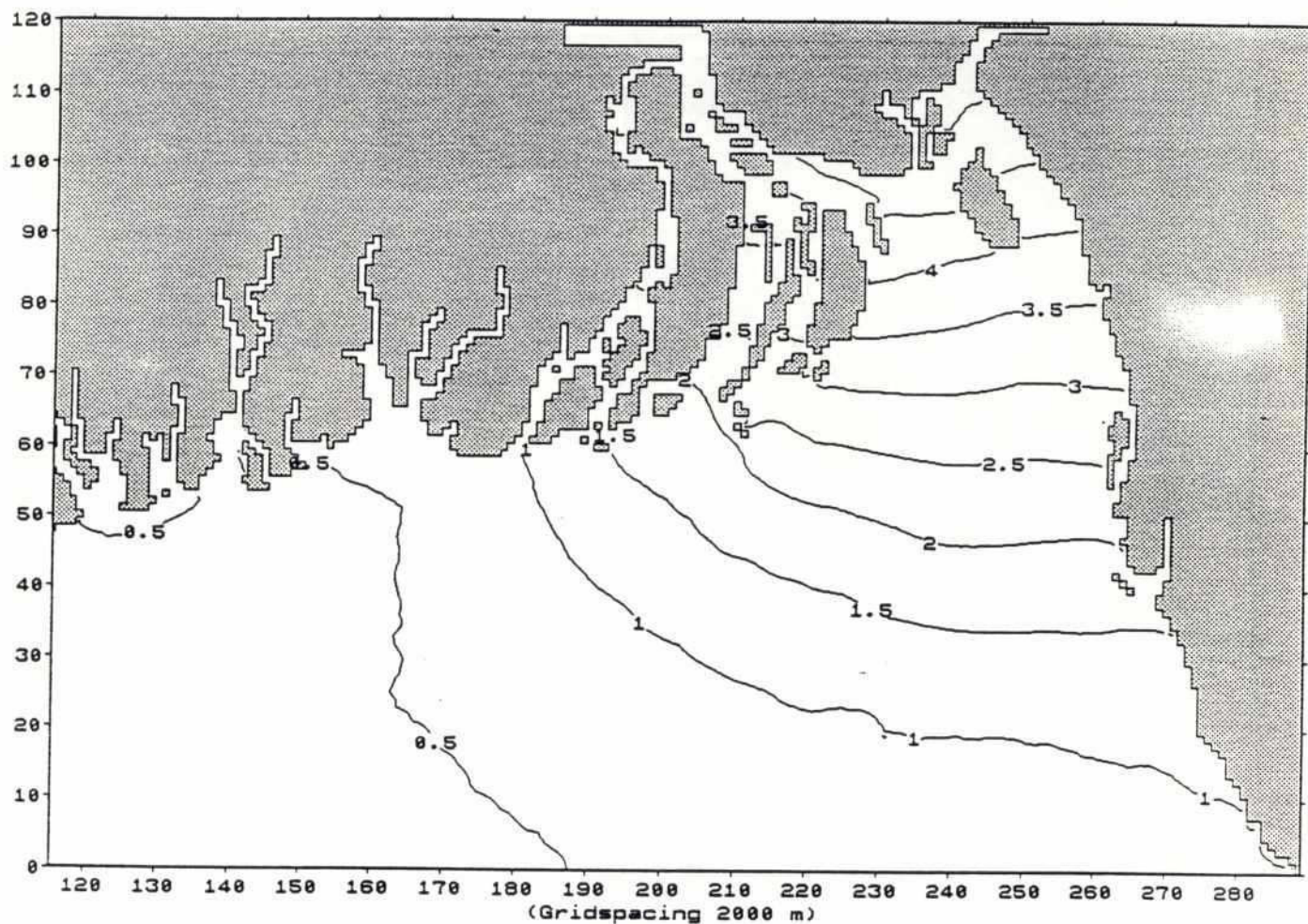
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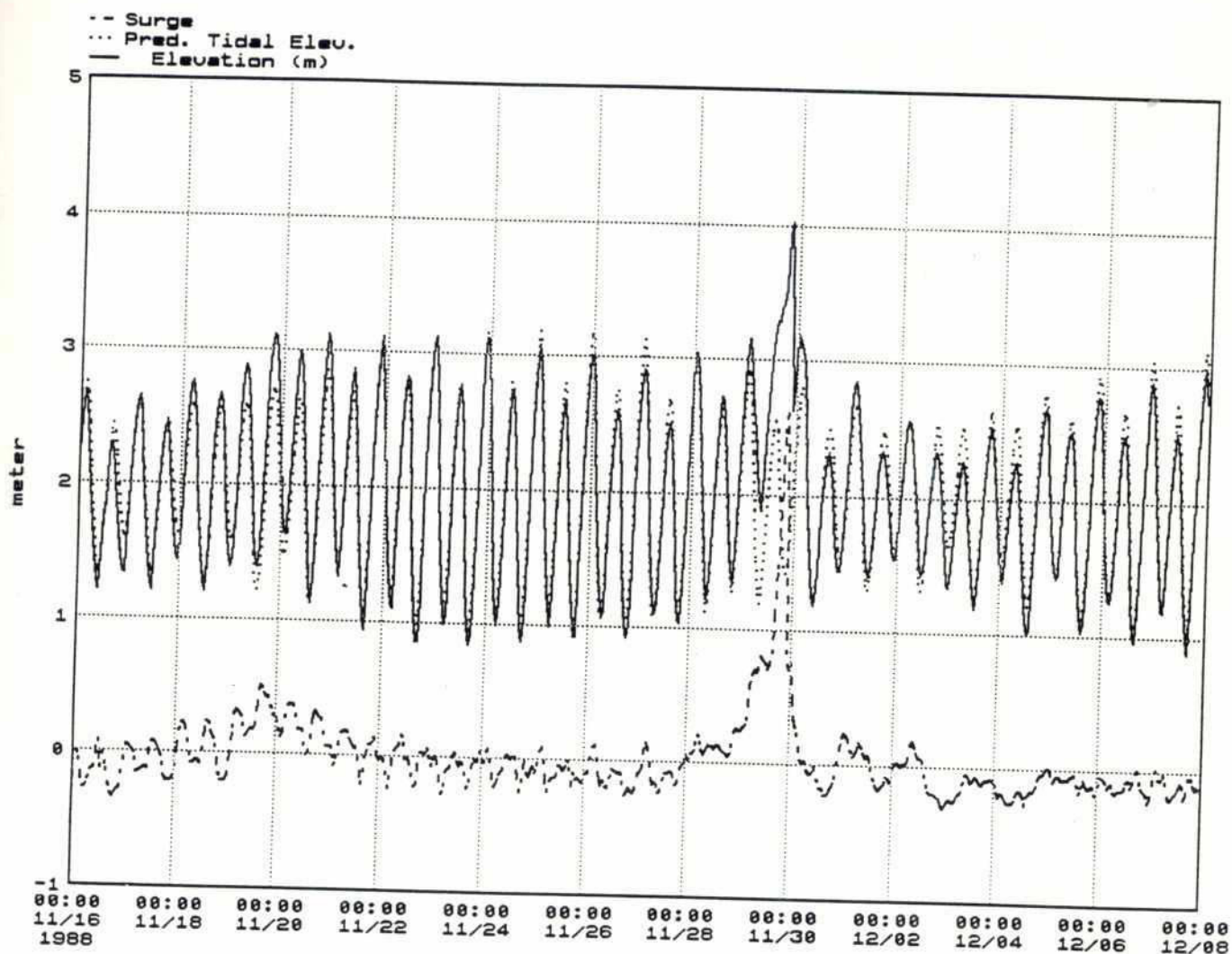
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File: family: dif name : imax User: mnr Mon Dec 3 1990	May 1977 Cyclone, Intermediate Model Difference between Maximum Surge Levels excluding Tide and including Tide	Dwg. No.  4.17

200



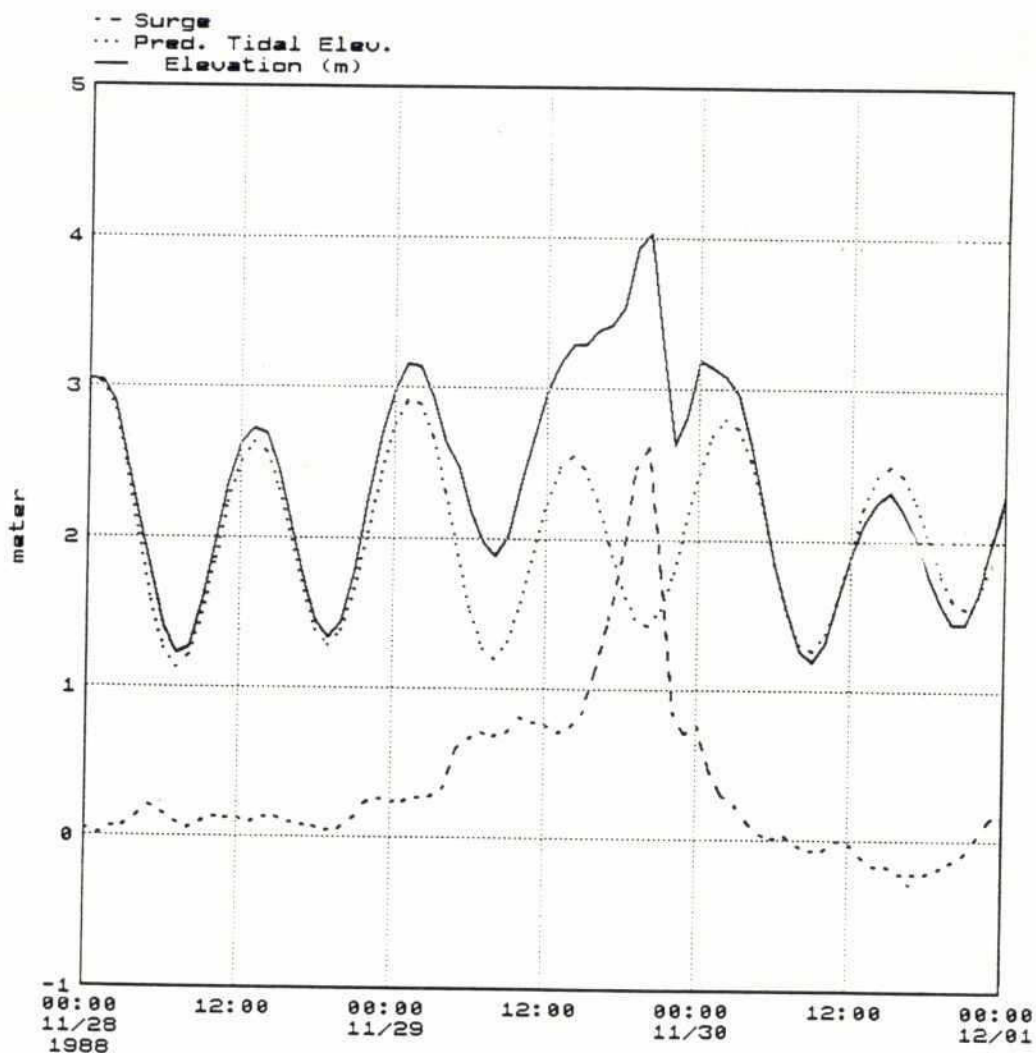
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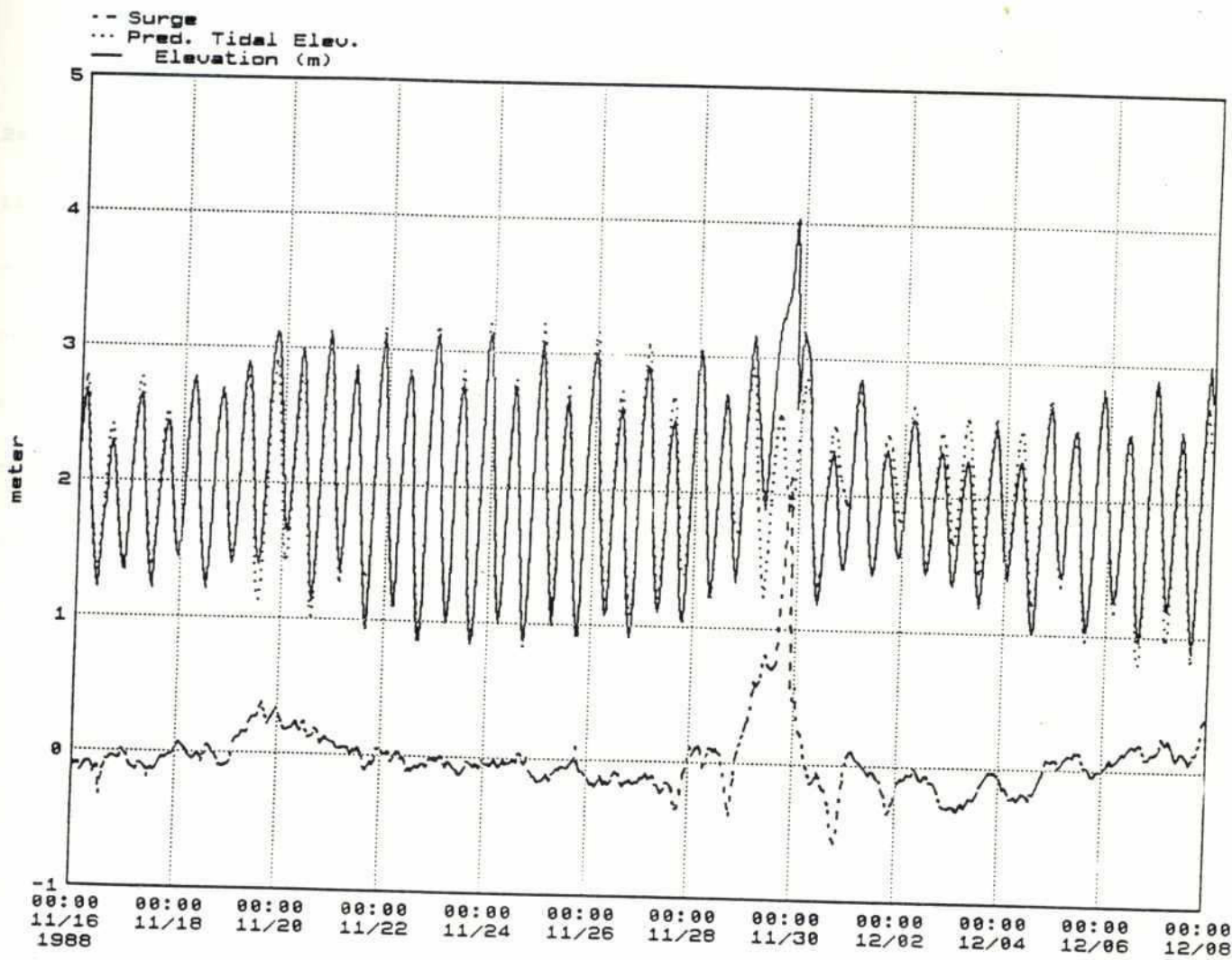
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File: family: c88 name : shir User: mnr Tue Dec 18 1990	November 1988 Measurements, Hiron Point Tide predicted from K1, O1, M2 and S2	Dwg. No.  4.19

202



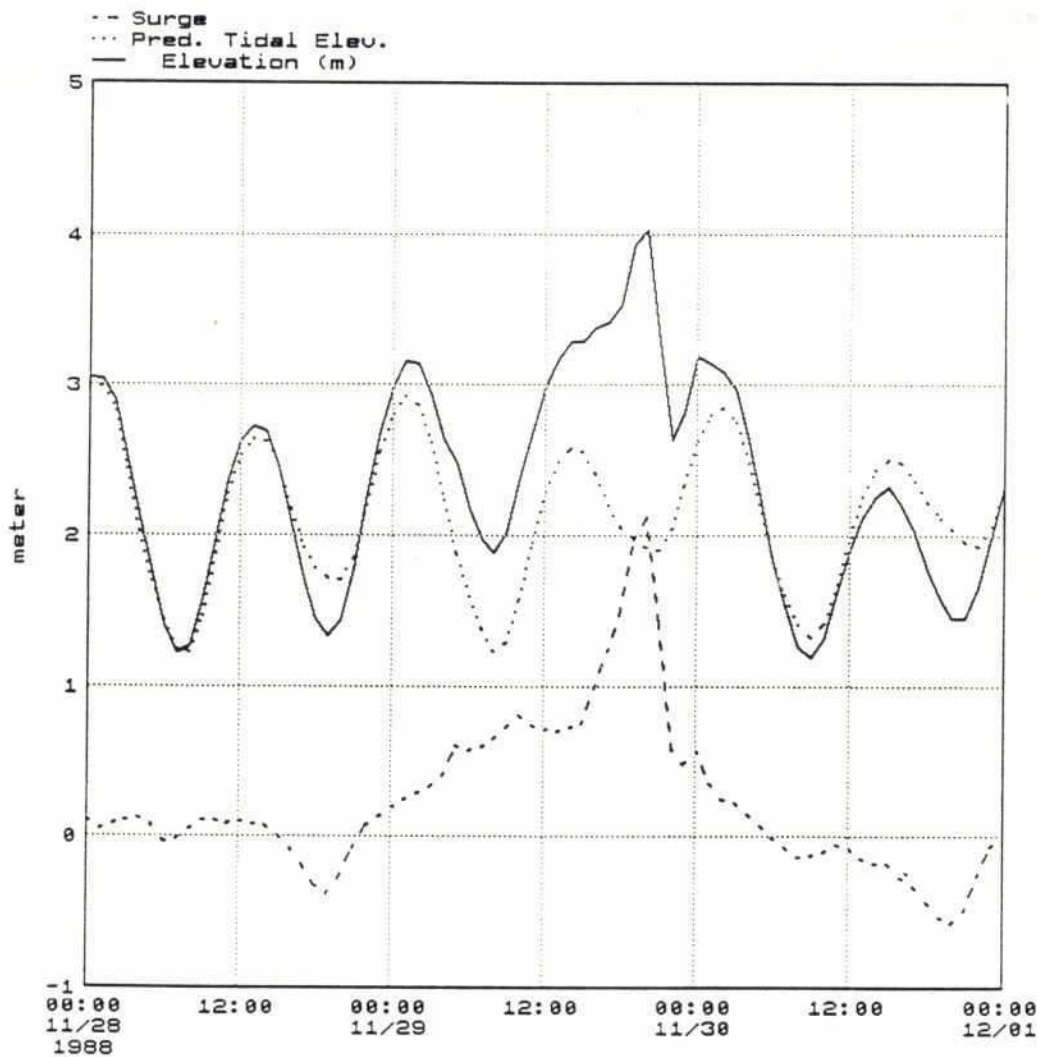
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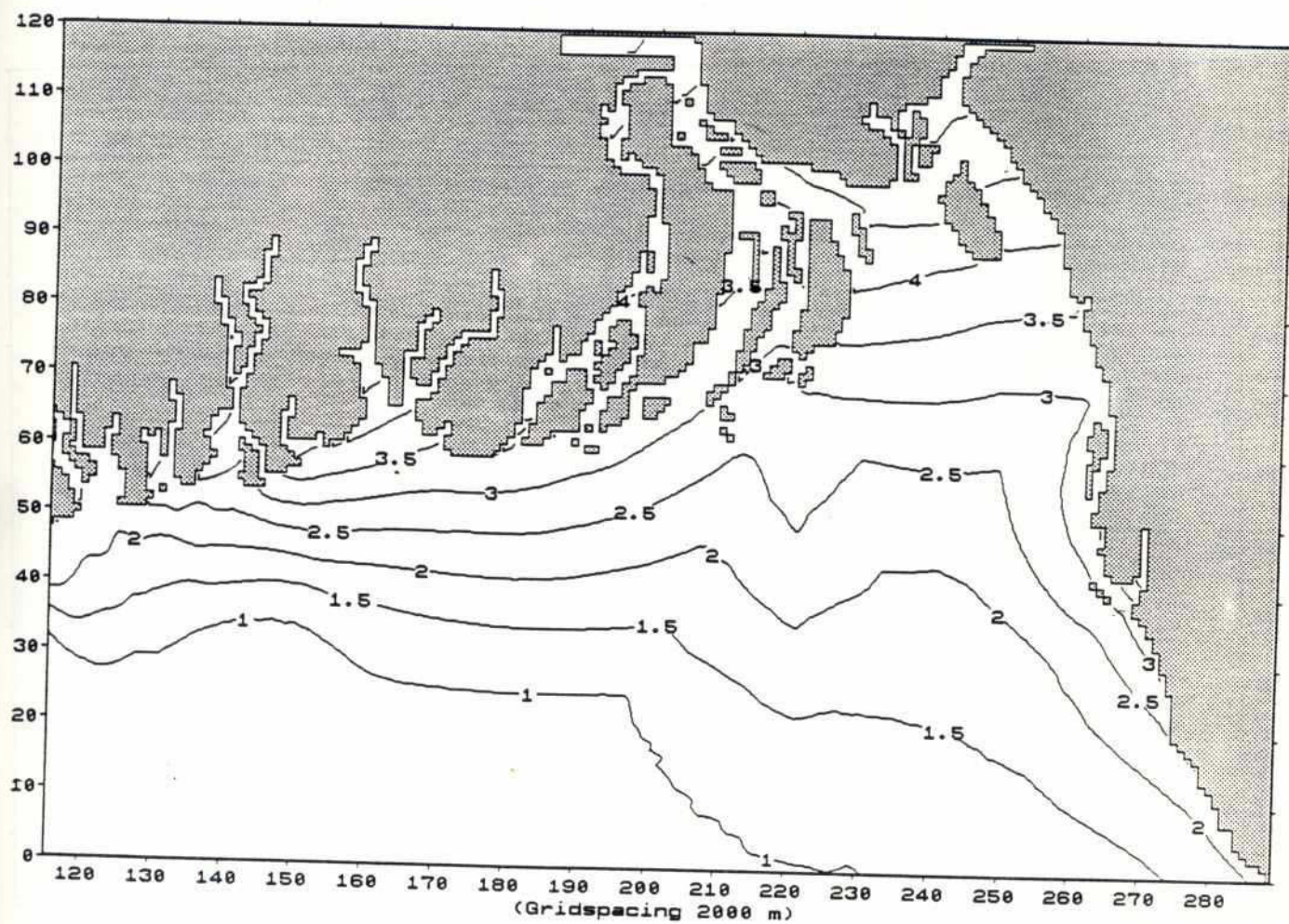
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208

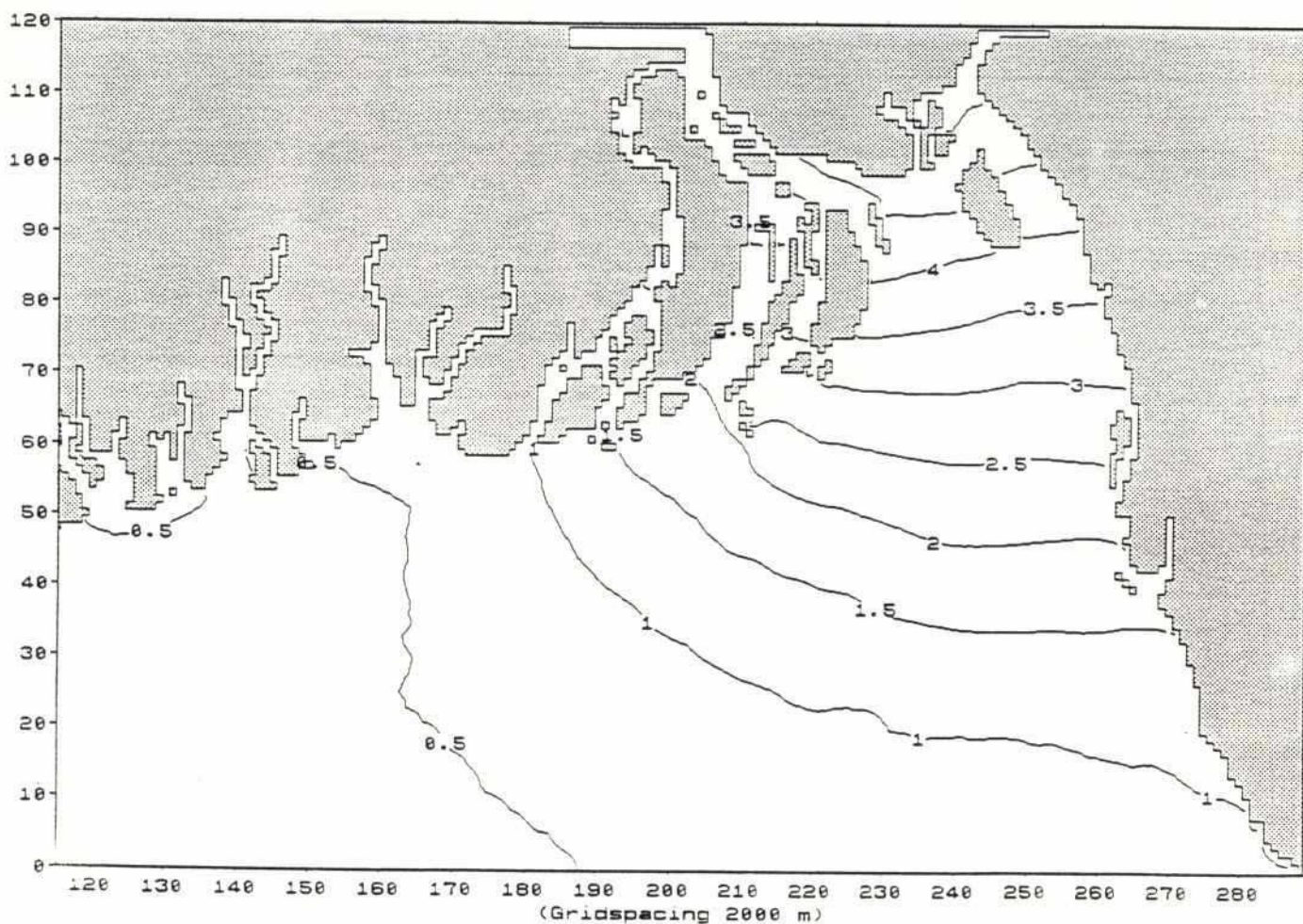


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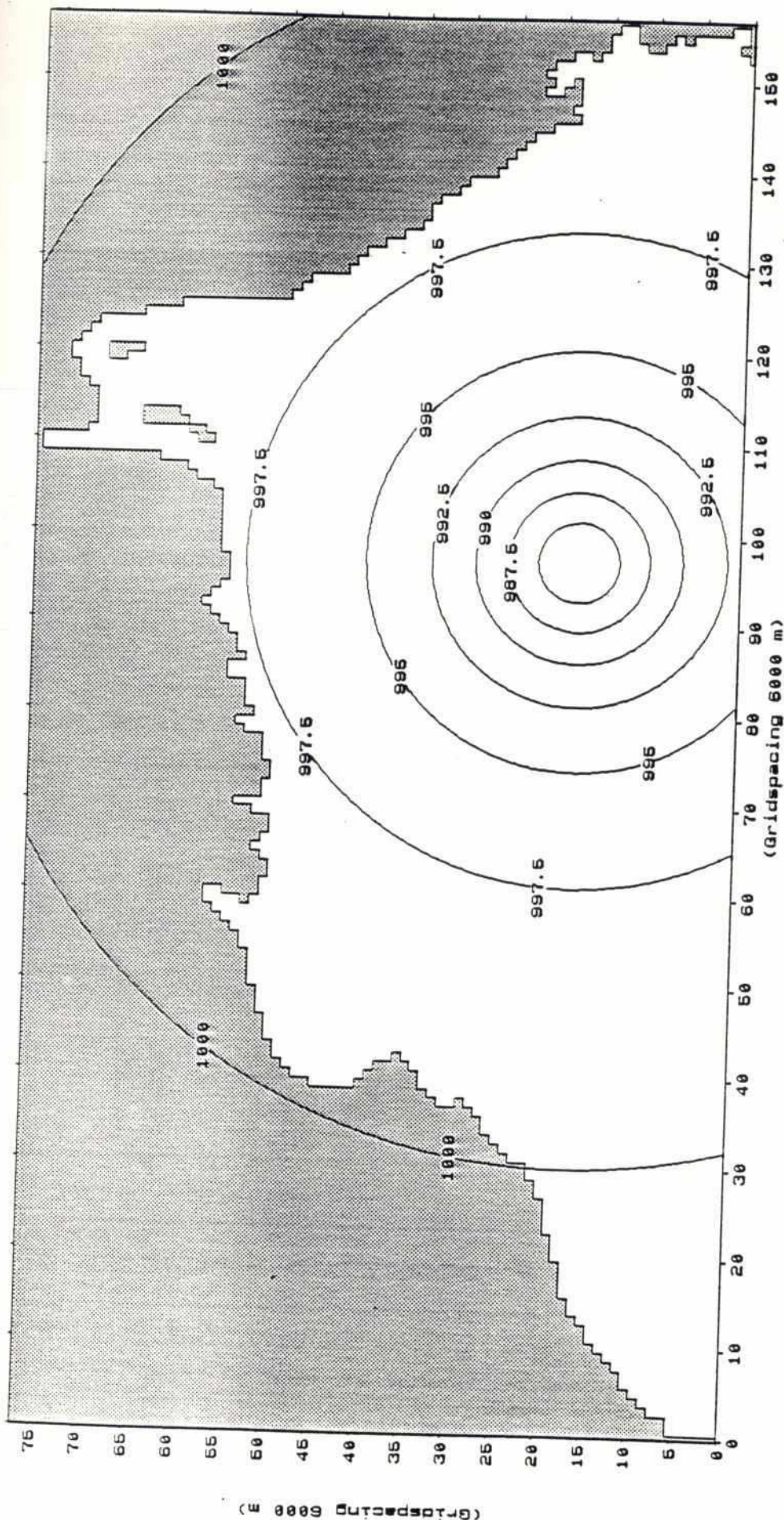


<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: all name : imax Scale: 1:2 mill Sat Dec 1 1990	All 7 Cyclones Simulation Results, Intermediate Model Maximum Surge Levels	Dwg. No.  4.23



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
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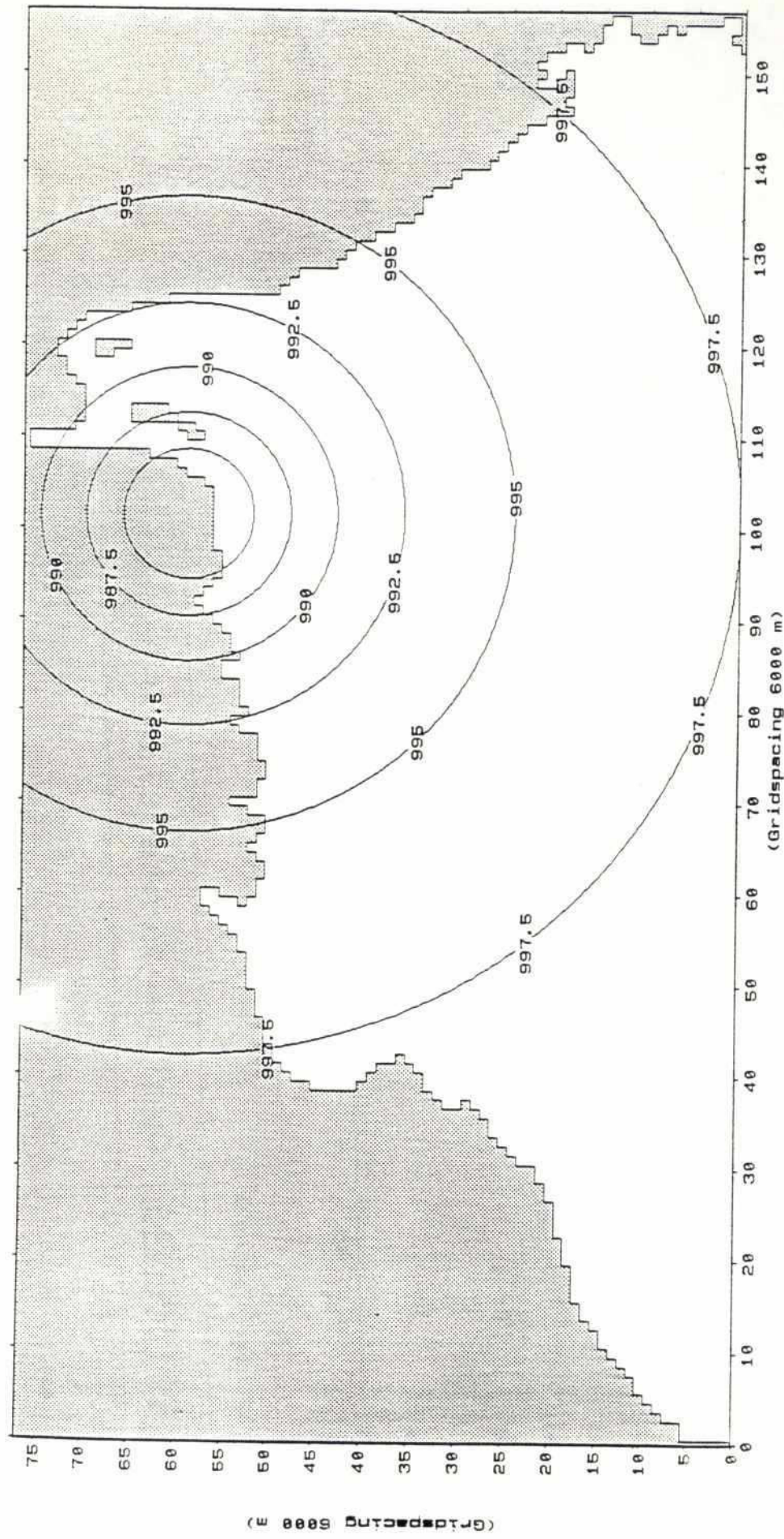


1977/05/12 12:00:00

<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: m77 name : rwind Scale: 1:4 mill Thu Nov 29 1990	May 1977 Cyclone Pressure Field (mb)	
		Dwg. No. 4.25



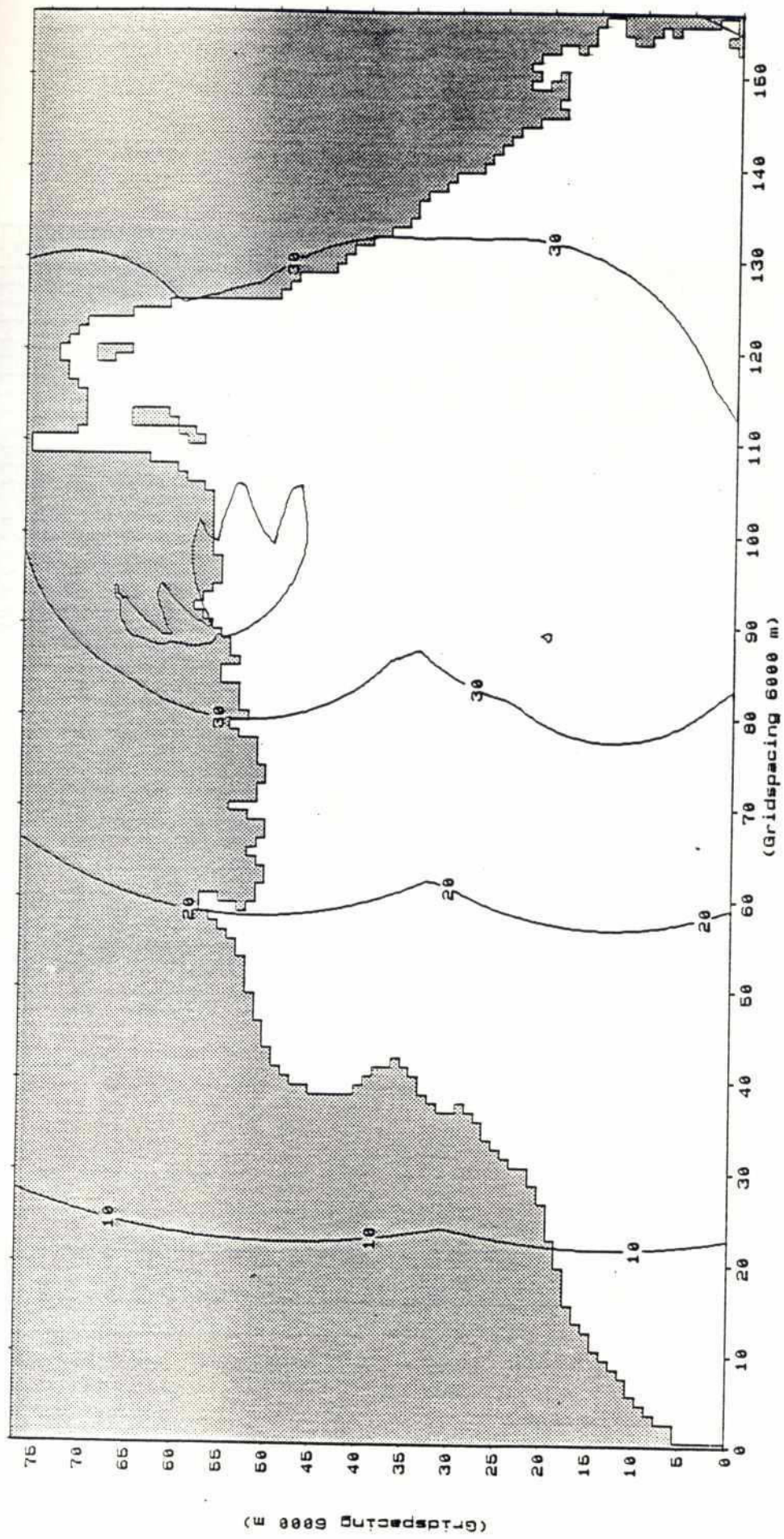
2008



1977/05/13 00:00:00

MIKE21 Cyclone Protection Project II	
File: family: m77 name : rwind Scale: 1:4 mill Thu Nov 29 1990	Dwg. No.  4.26





MIKE21

Cyclone Protection Project IT

File:  
family: m77  
name : rmwind  
Scale: 1:4 mill  
Thu Dec 29 1999

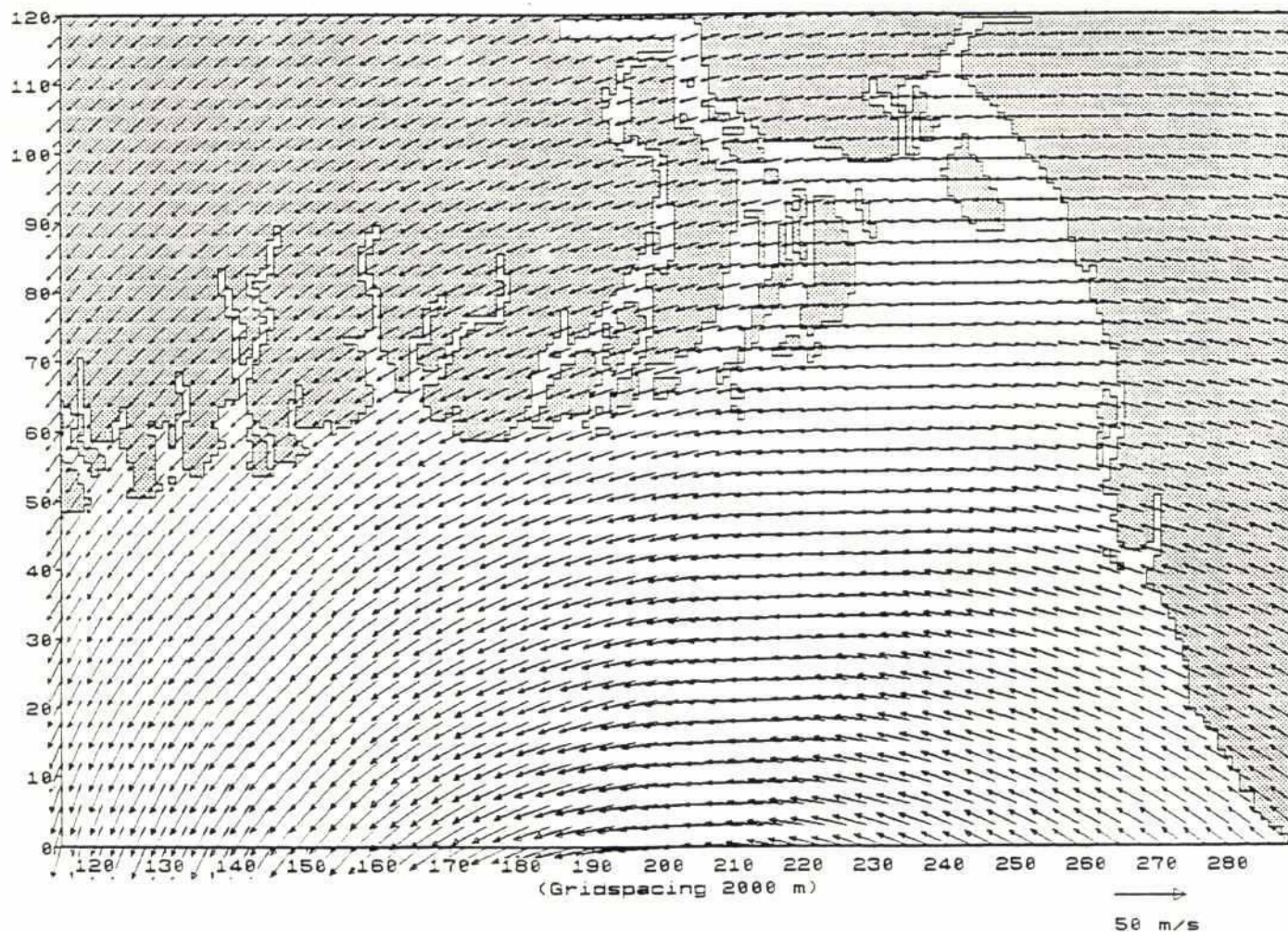
May 1977  
Maximum occurring Wind Speed (m/s)

Dwg. no.

4.27



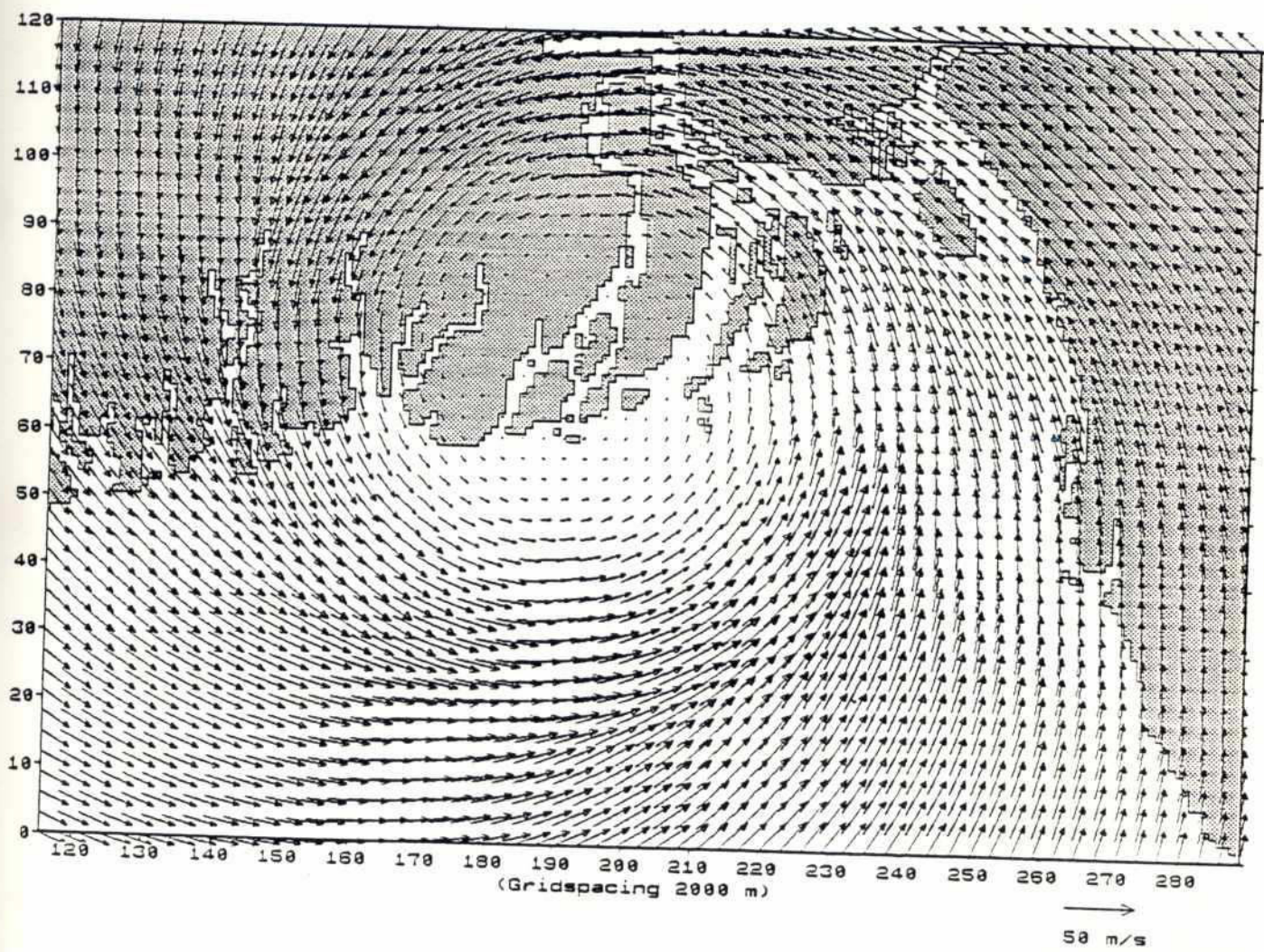
220



1977/05/12 12:00:00

MIKE21	Cyclone Protection Project II	
File: family: m77 name : iwind Scale: 1:2 mill Thu Nov 29 1990	May 1977 Cyclone Wind Field	Dwg. No.  4.28

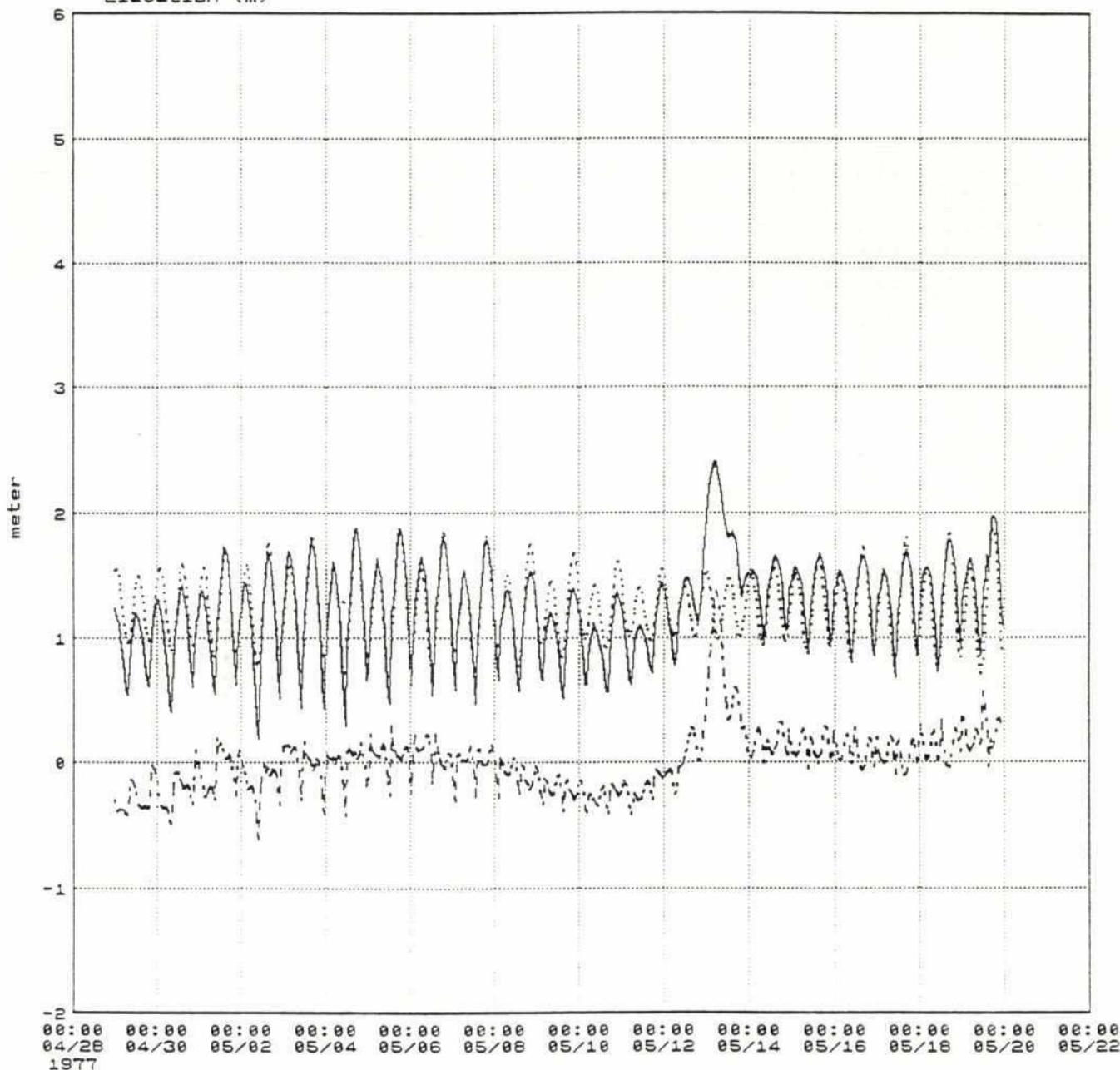




1977/05/13 00:00:00

<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: m77 name : iwind Scale: 1:2 mill Thu Nov 29 1990</p>	<p>May 1977 Cyclone Wind Field</p>	<p>Dwg. No.  4.29</p>

-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



MIKE21

Cyclone Protection Project II

File:

family: m77

name : sbar4

User: mnr

Sat Dec 15 1990

May 1977

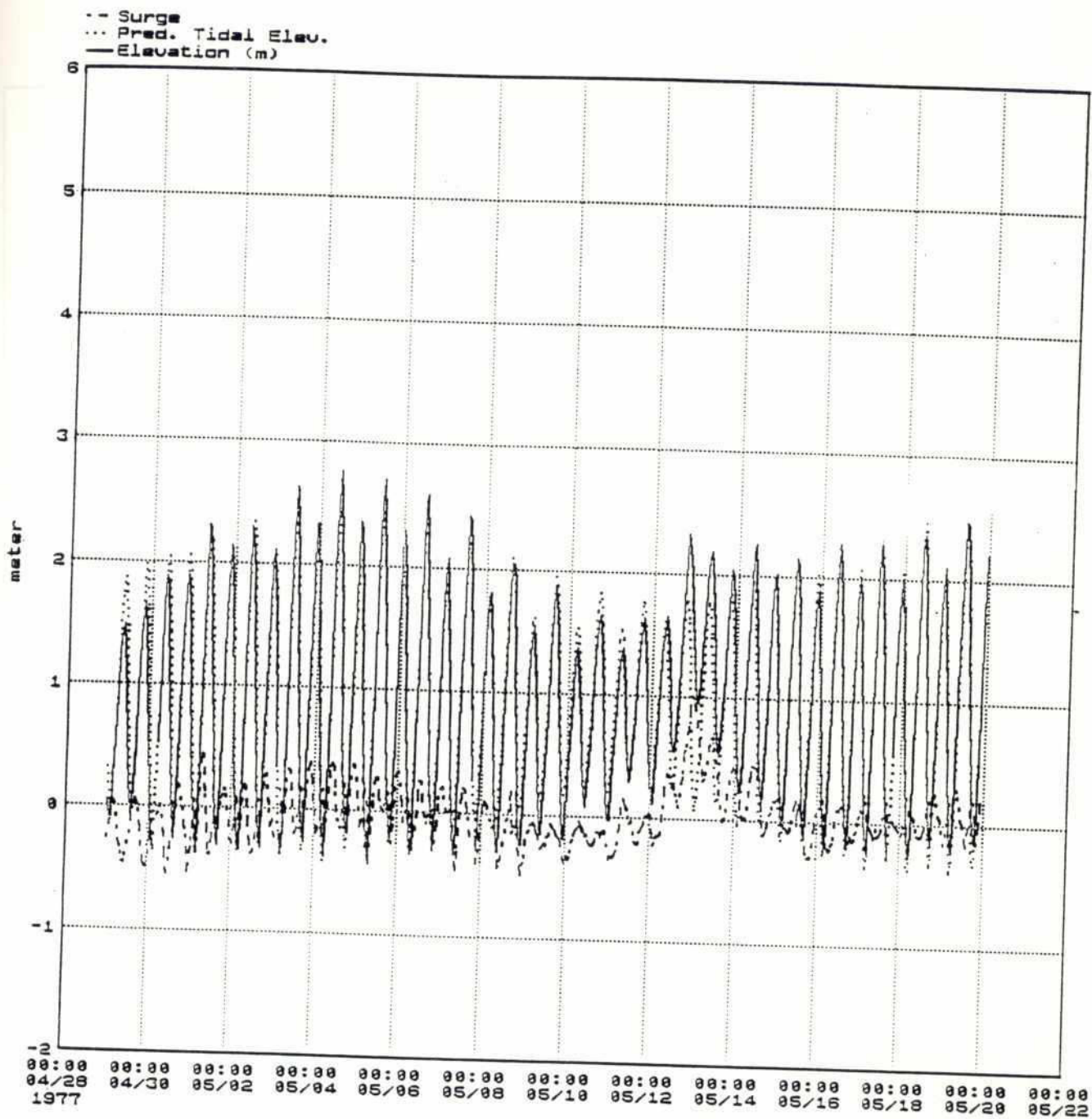
Barisal

Measurements

Dwg. No.

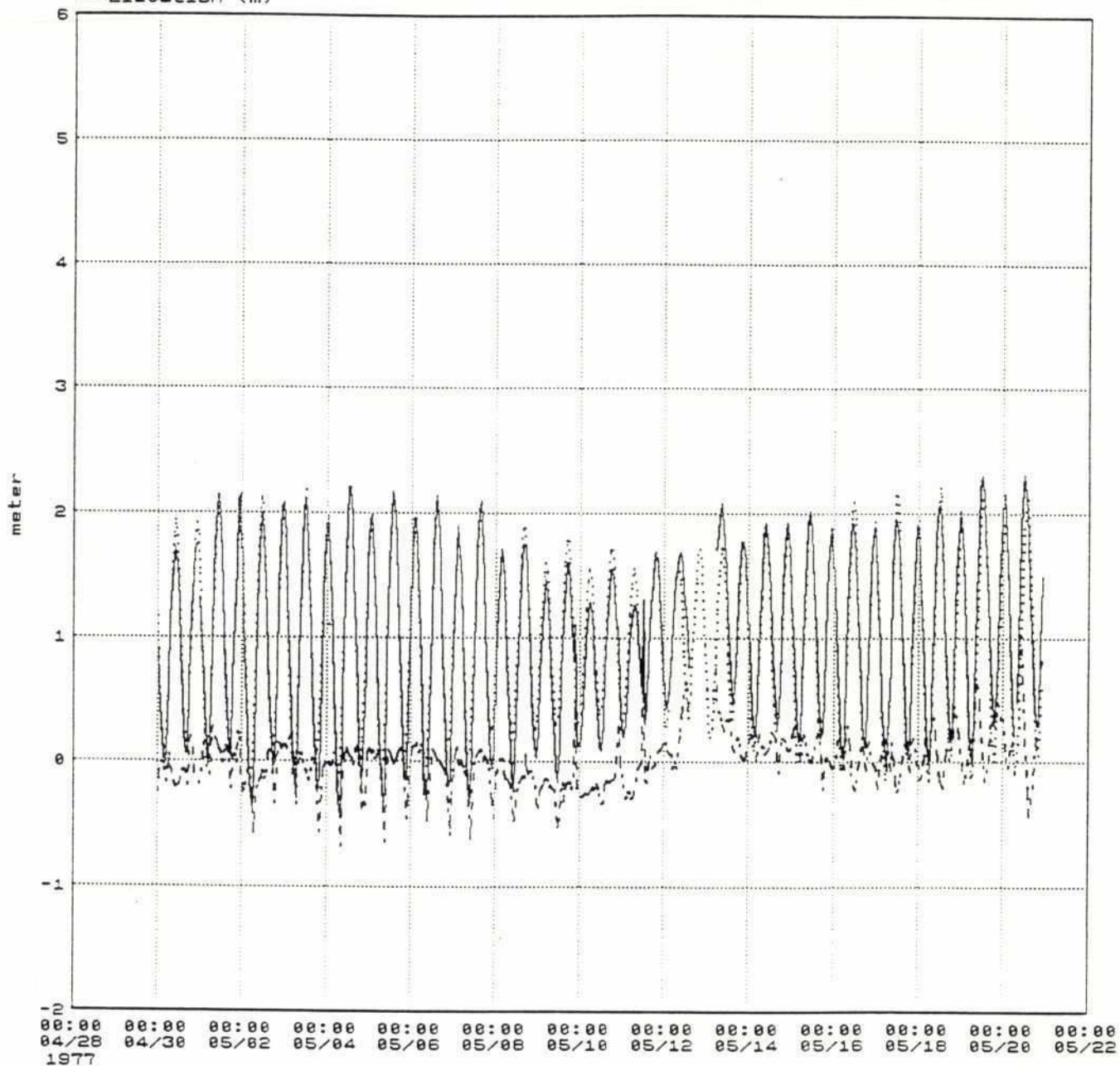
4.30





<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
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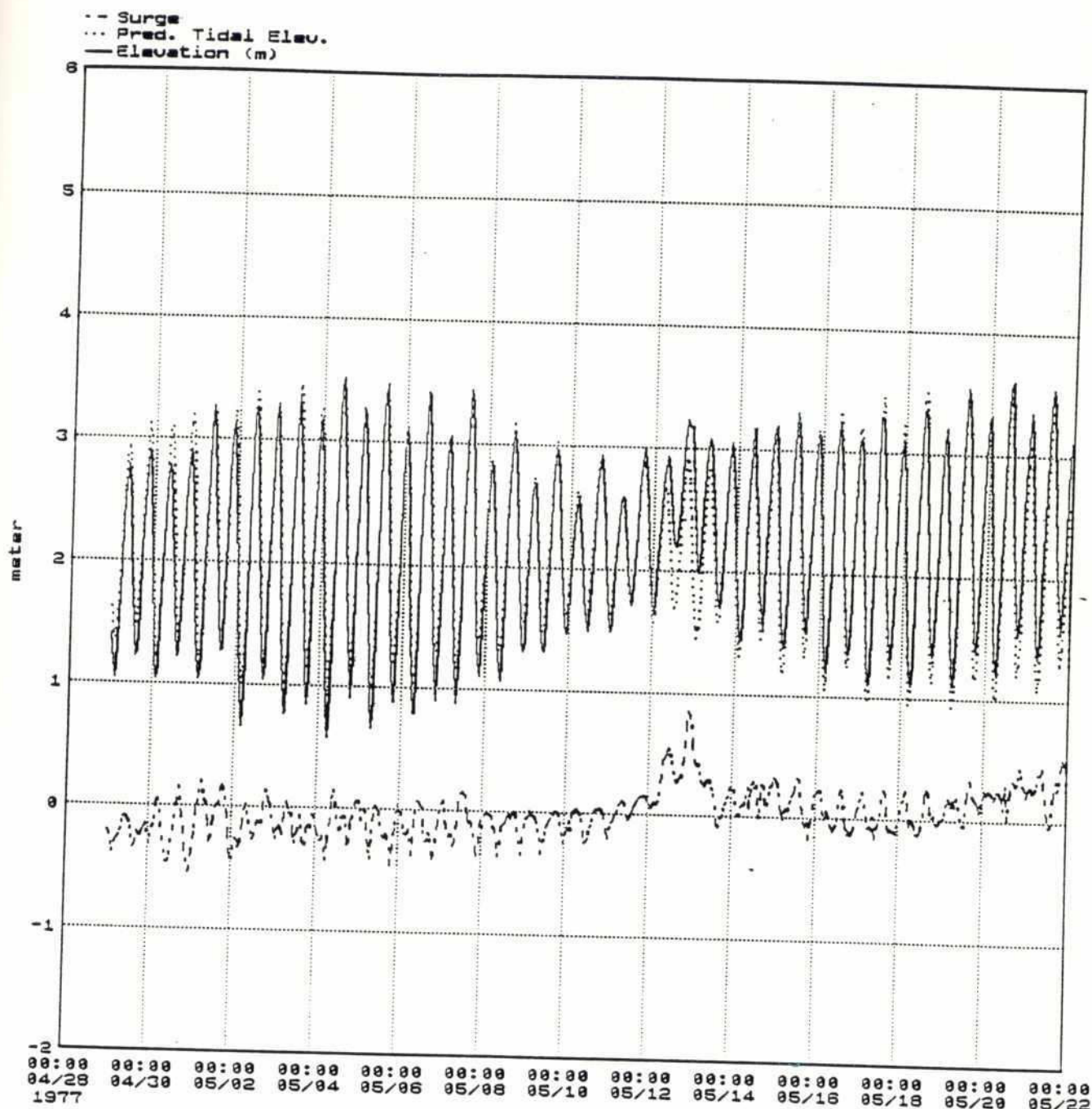
-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: m77 name : sg14 User: mnr Sat Dec 15 1990	May 1977 Galachipa Measurements	Dwg. No.  4.32

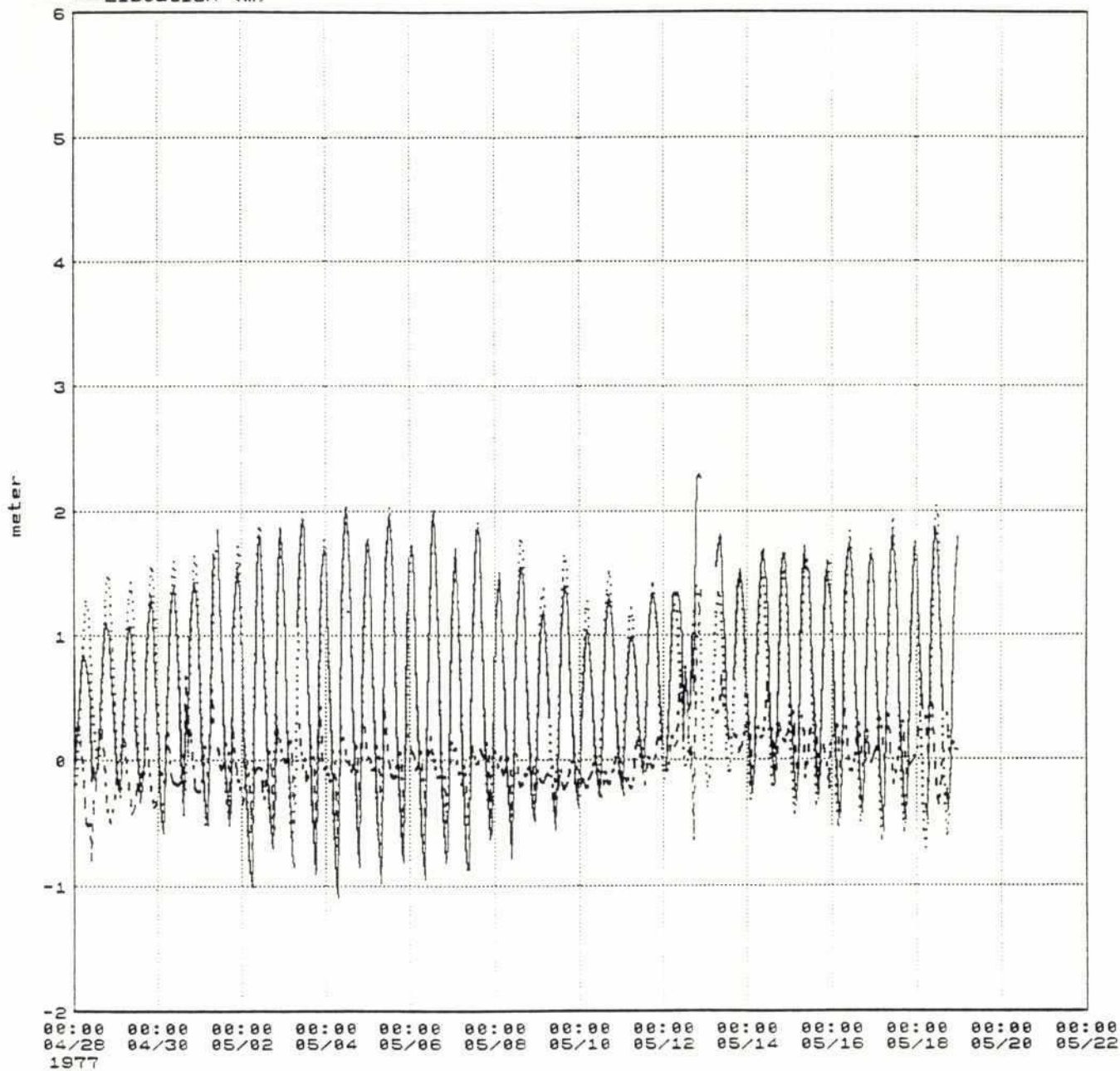


228



MIKE21		Cyclone Protection Project II	
File:			
Family: m77	May 1977		Dwg. No.
name : shir4	Hiron Point		
User: mnr	Measurements		
Sat Dec 15 1990			4.33

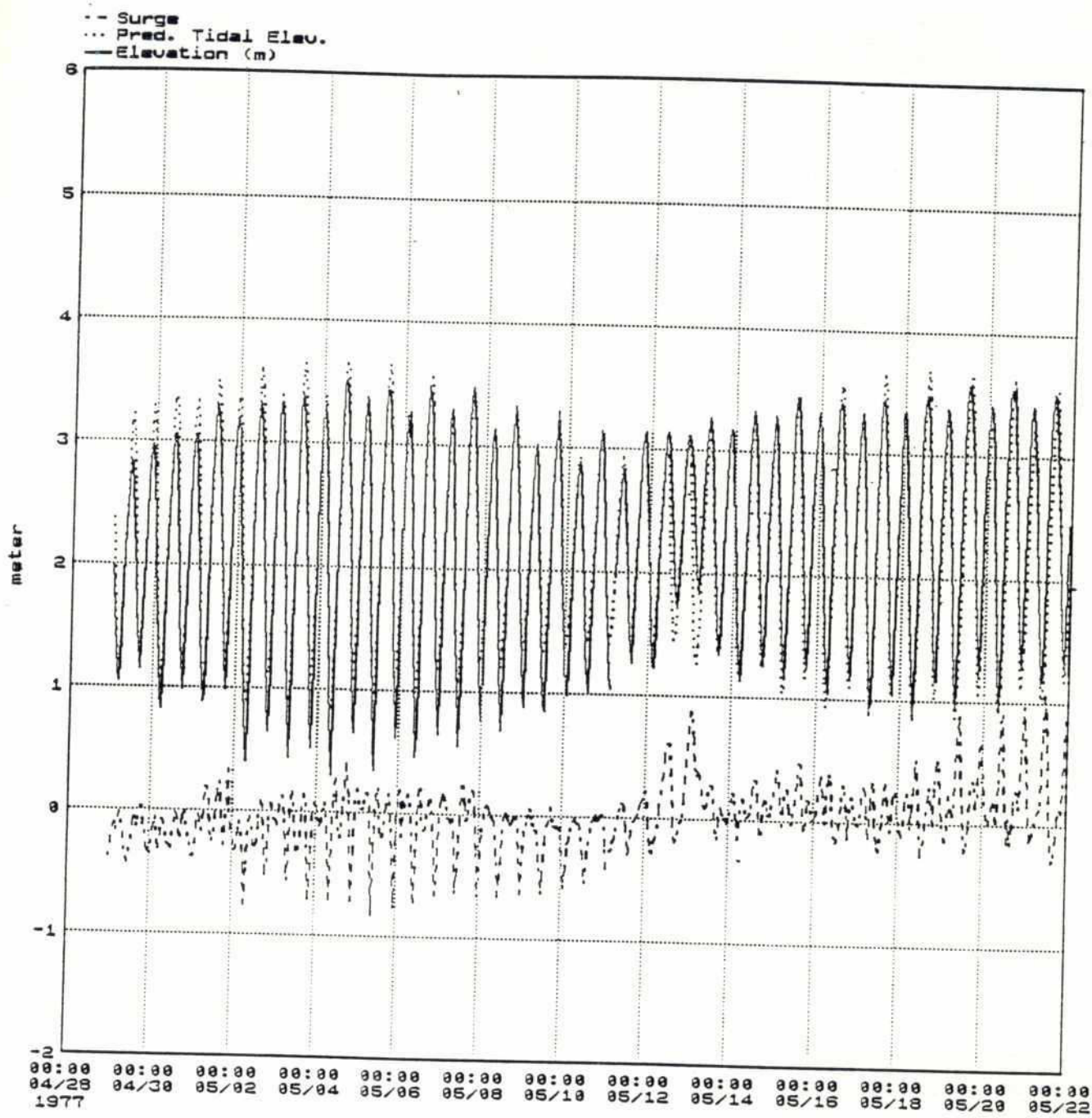
-- Surge  
 ... Pred. Tidal Eleo.  
 — Elevation (m)



MIKE21	Cyclone Protection Project II	
File: family: m77 name : skhe4 User: mnr Sat Dec 15 1990	May 1977 Khepupara Measurements	Dwg. No.  4.34

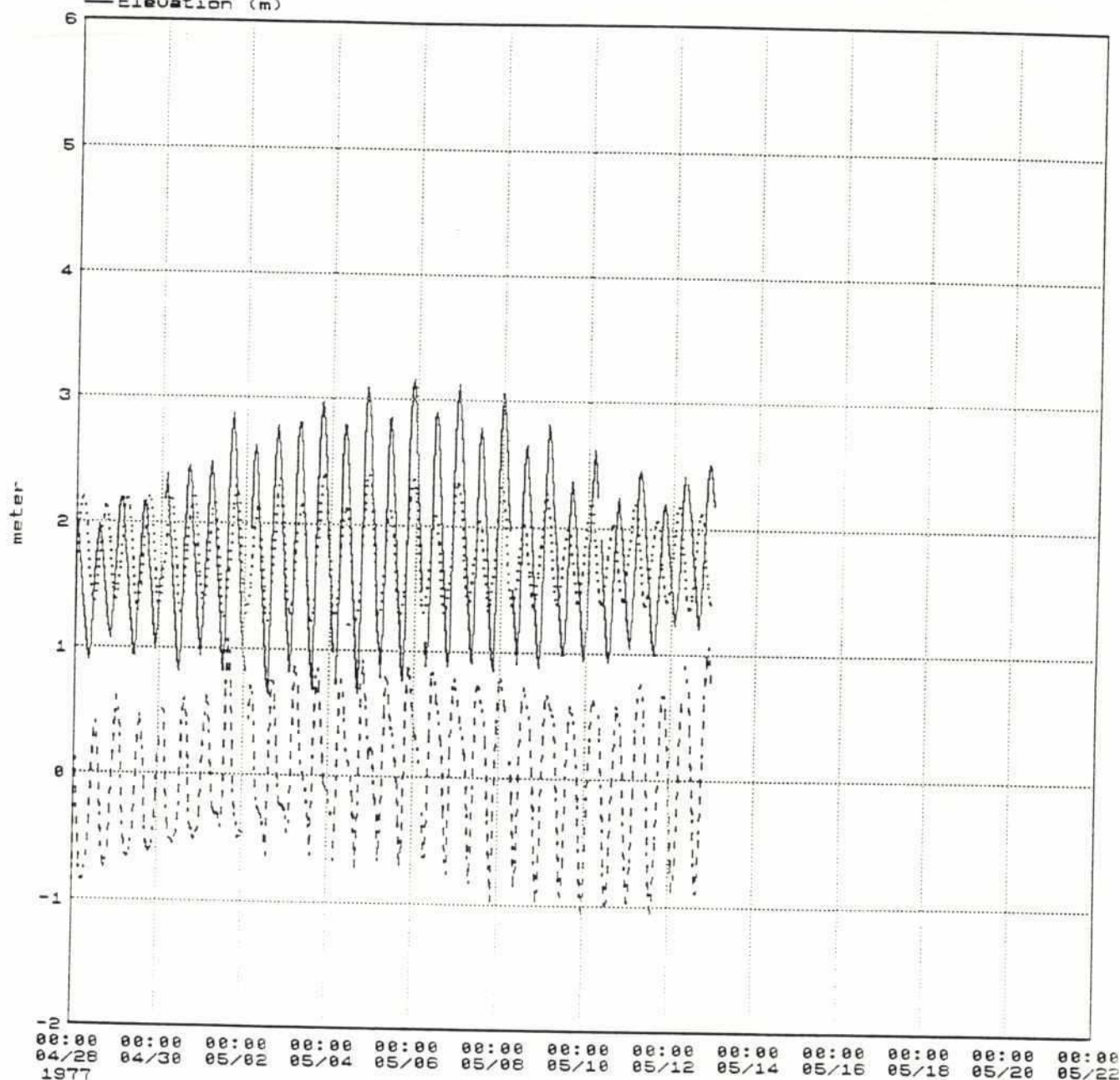


229



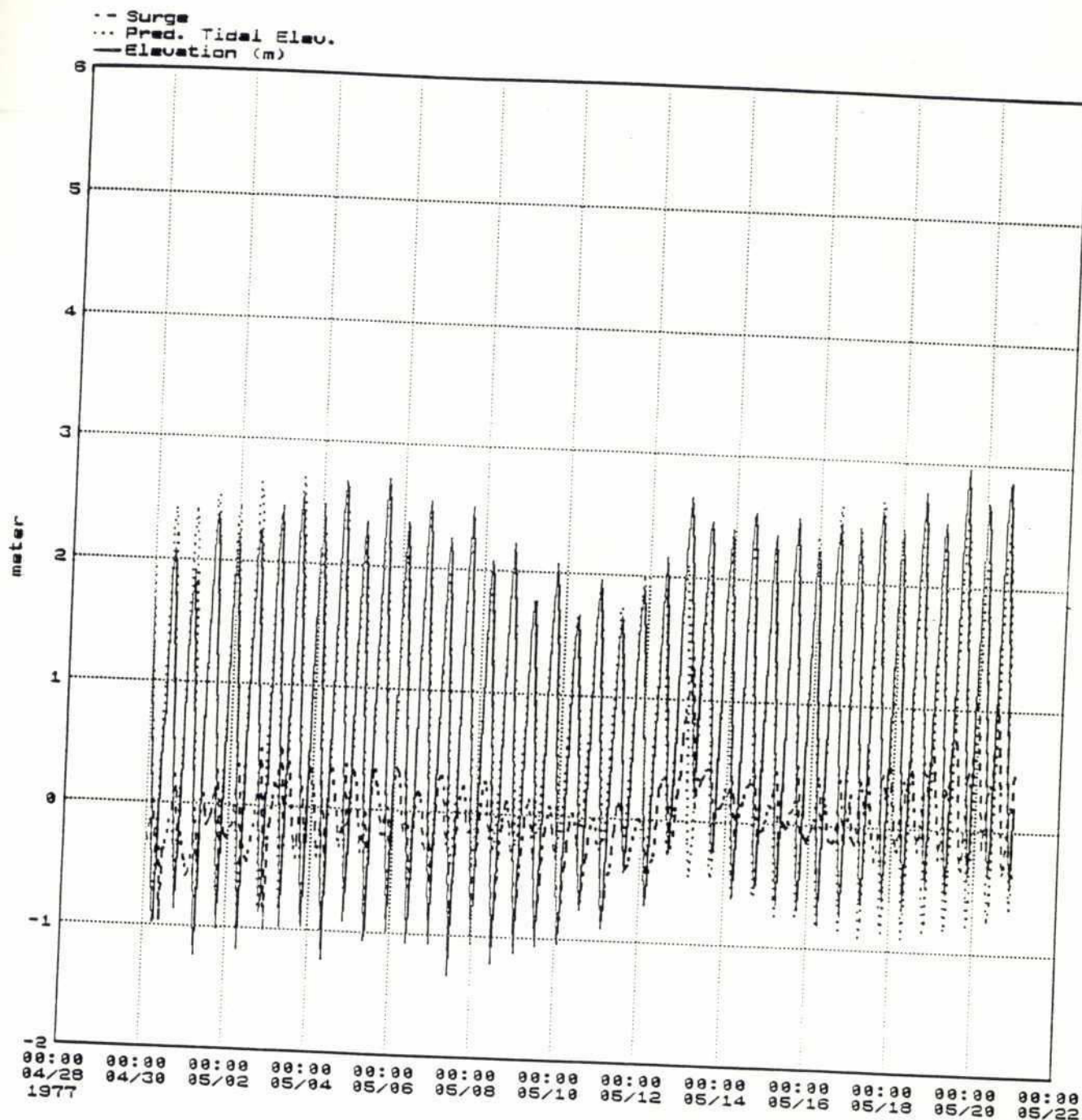
MIKE21		Cyclone Protection Project II	
File:			Dwg. No.
family: m77	May 1977		
name : smon4	Mongia		
User: mnr	Measurements		
Sat Dec 15 1990			4.35

-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



MIKE21		Cyclone Protection Project II	
File:			
family: m77	May 1977		Dwg. No.
name : sram4	Ramdaspur		
User: mnr	Measurements		
Sat Dec 15 1990			4.36

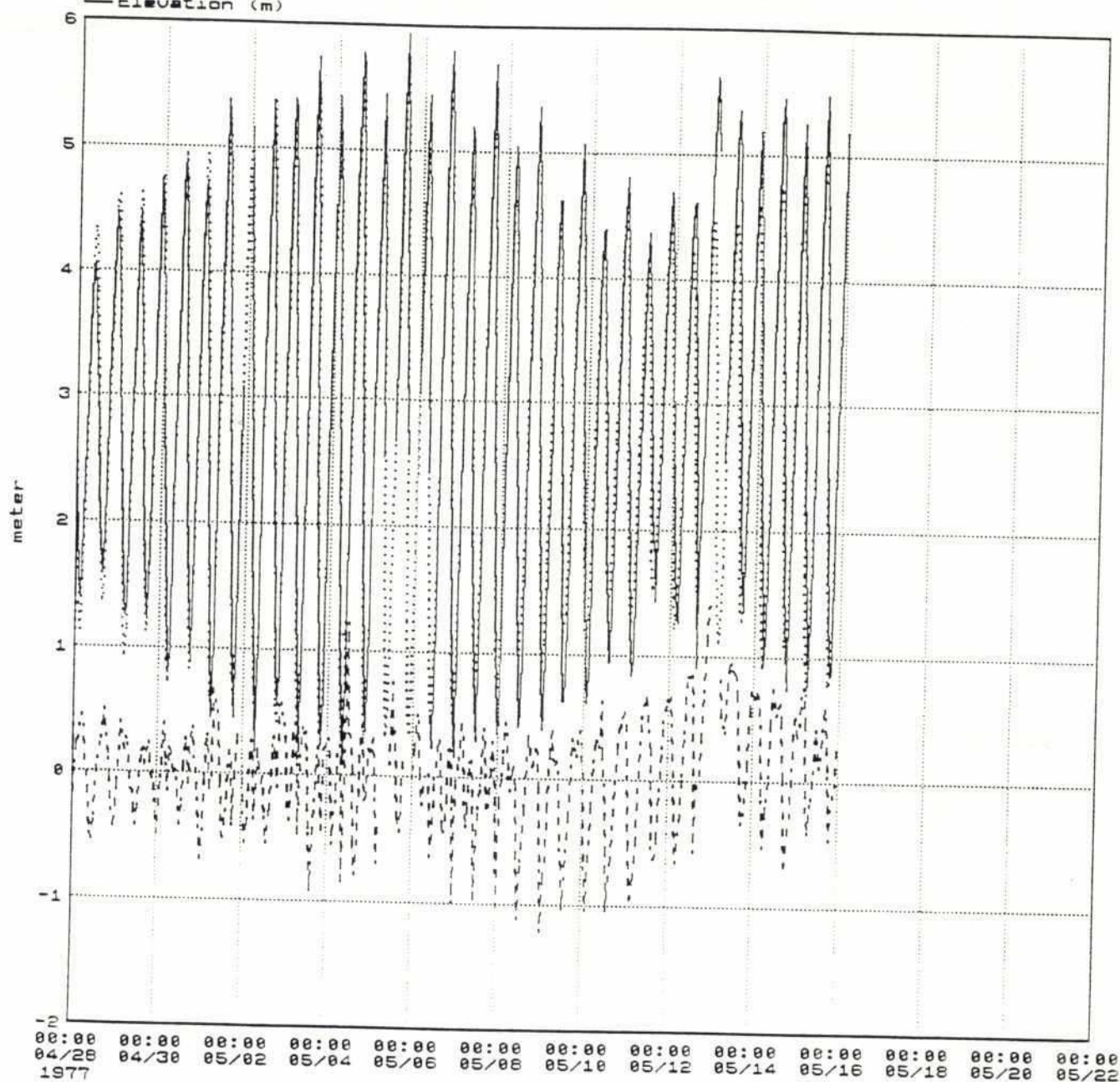




<b>MIKE21</b>	Cyclone Protection Project II	
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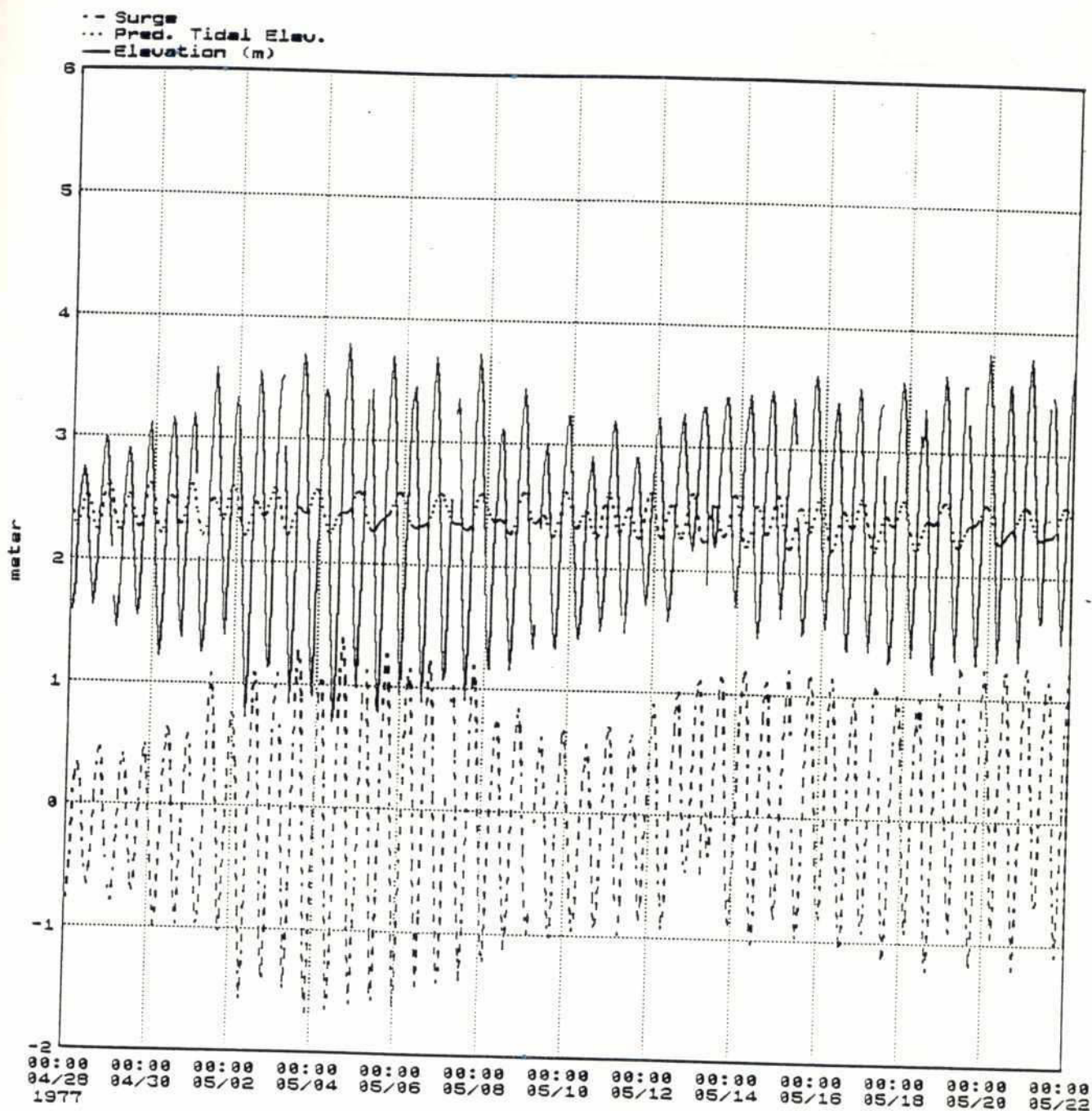
220

-- Surge  
 ... Pred. Tidal Eleo.  
 — Elevation (m)



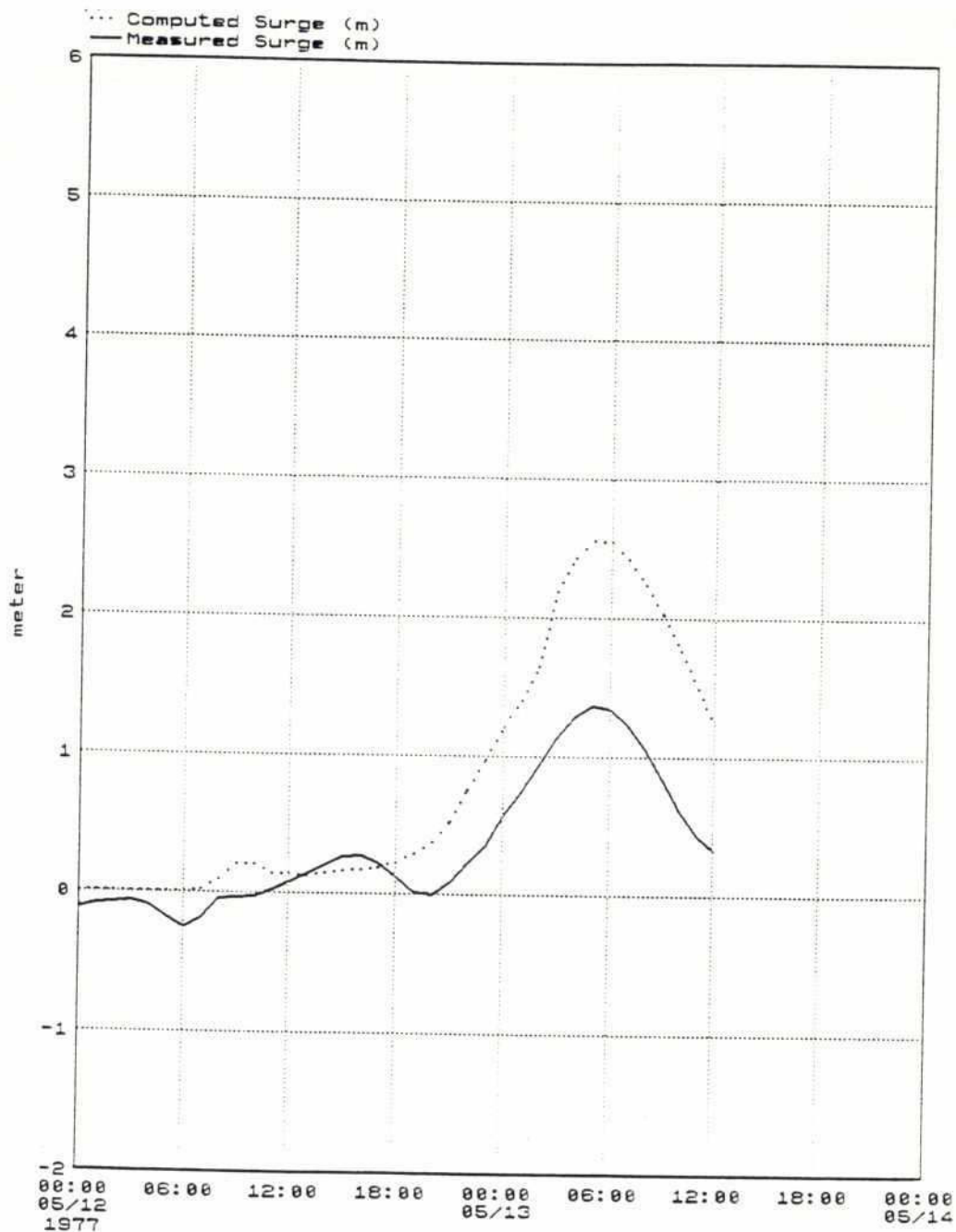
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
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MIKE21	Cyclone Protection Project II	
File: family: m77 name : ssun4 User: mnr Sat Dec 15 1998	May 1977 Sundarikota Measurements	Dwg. No.  4.39

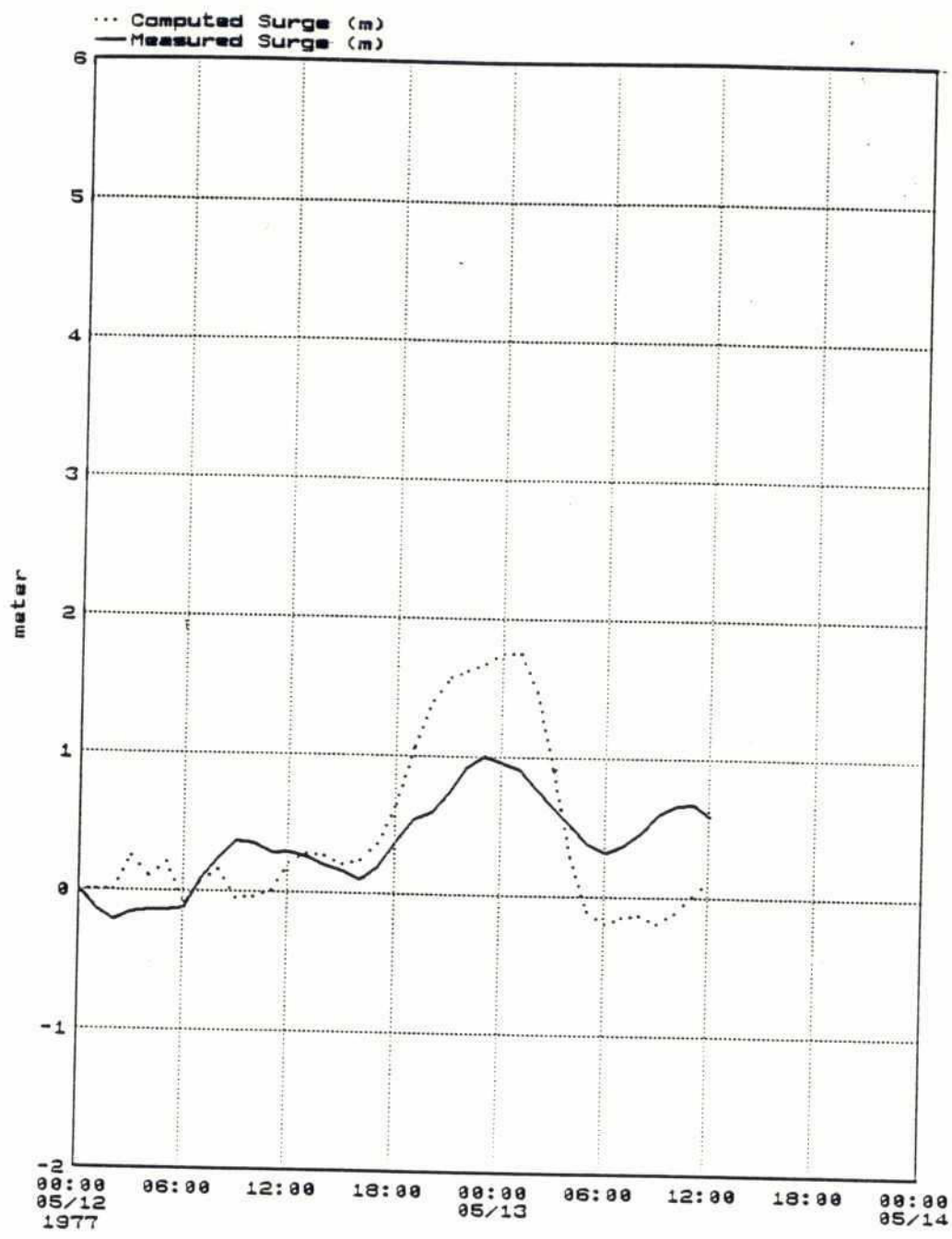
222



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: m77 name : cbar4 User: mnr Sat Dec 15 1990	May 1977 Barisal Measured and computed surge	Dwg. No.  4.40

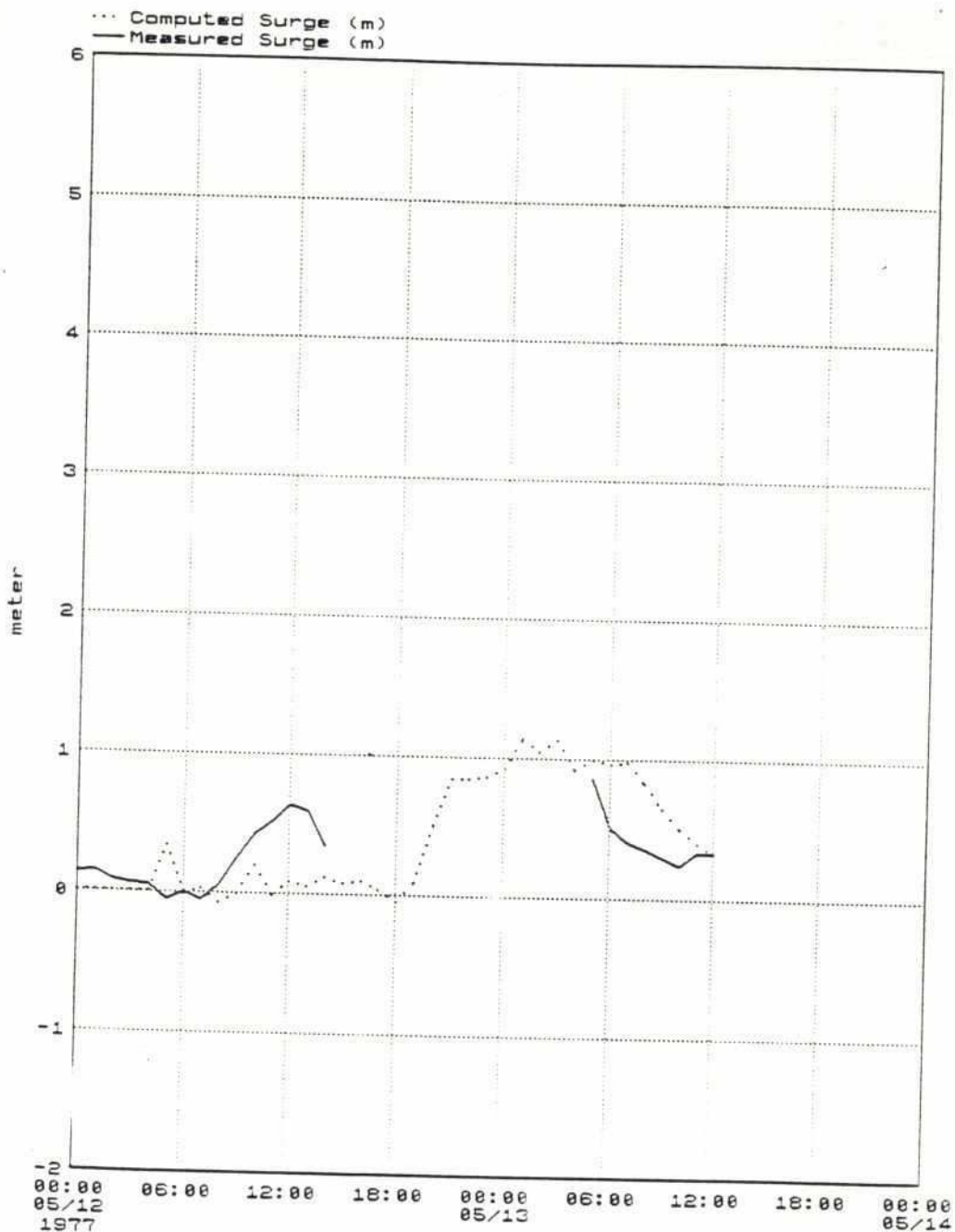


326



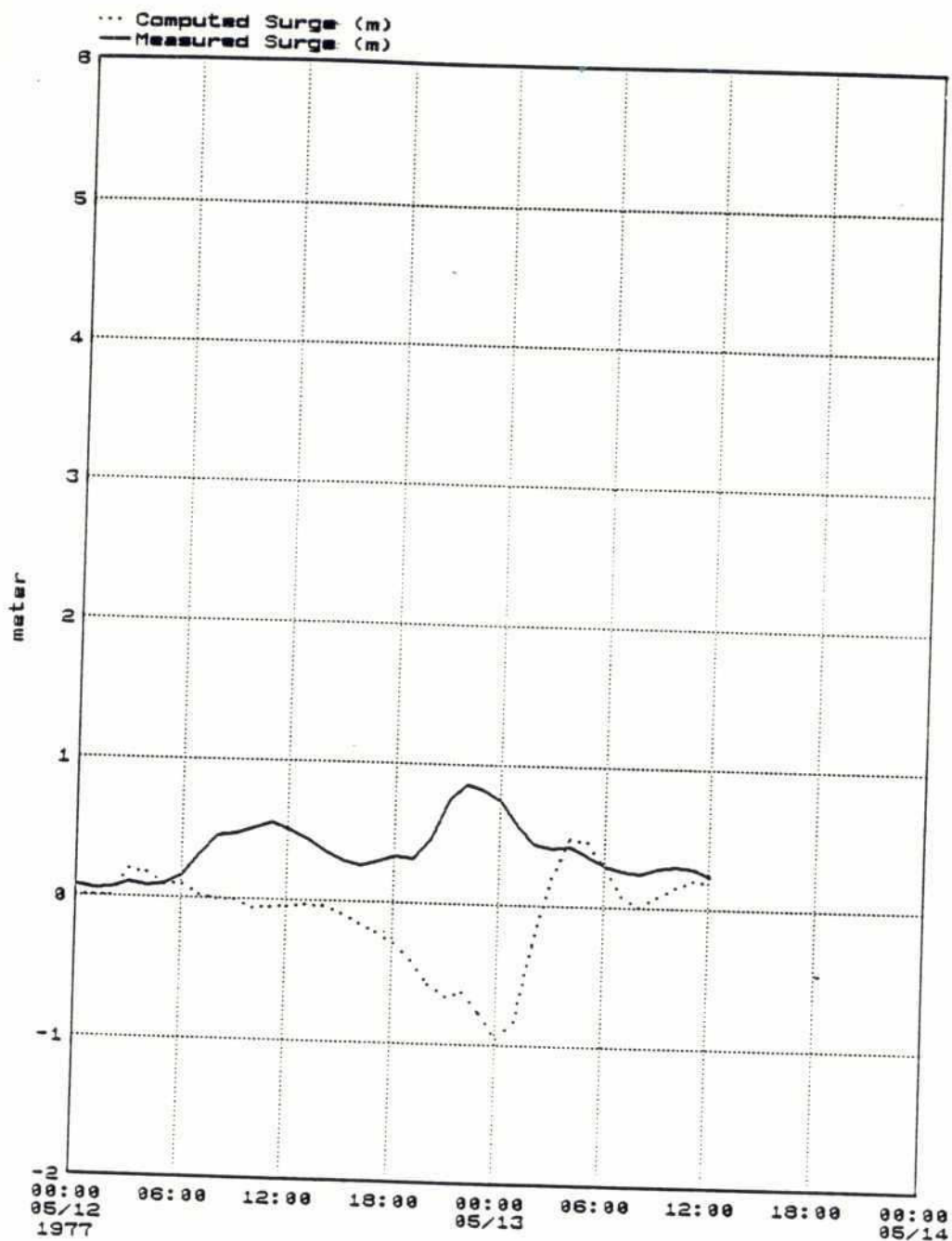
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<p>File: family: m77 name : ccox4 User: mnr Sat Dec 15 1998</p>	<p>May 1977 Coxs Bazar Measured and computed surge</p>	<p>Dwg. No.  4.41</p>

228



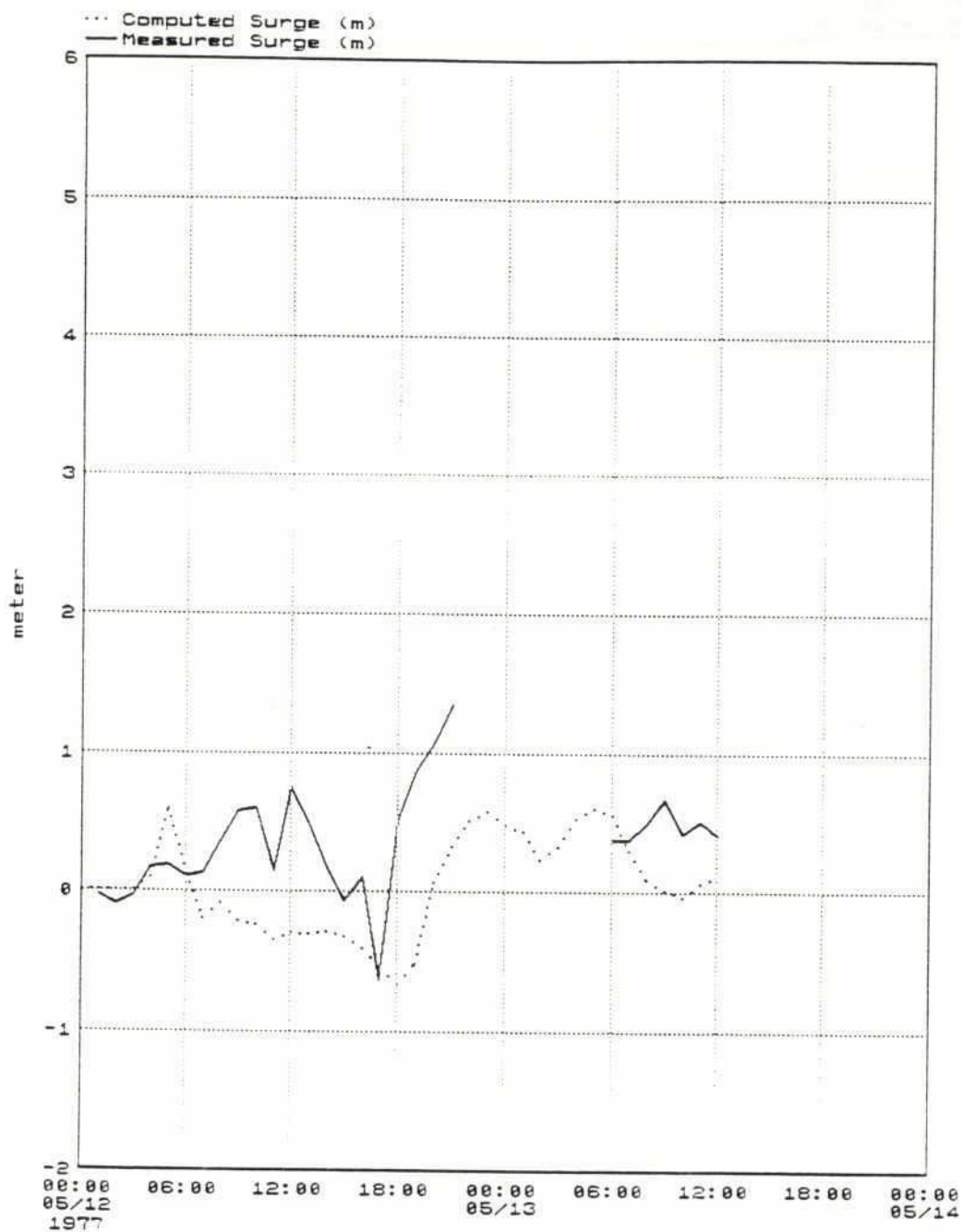
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: m77 name : cgal4 User: mnr Sat Dec 15 1996	May 1977 Galachipa Measured and computed surge	Dwg. No.  4.42





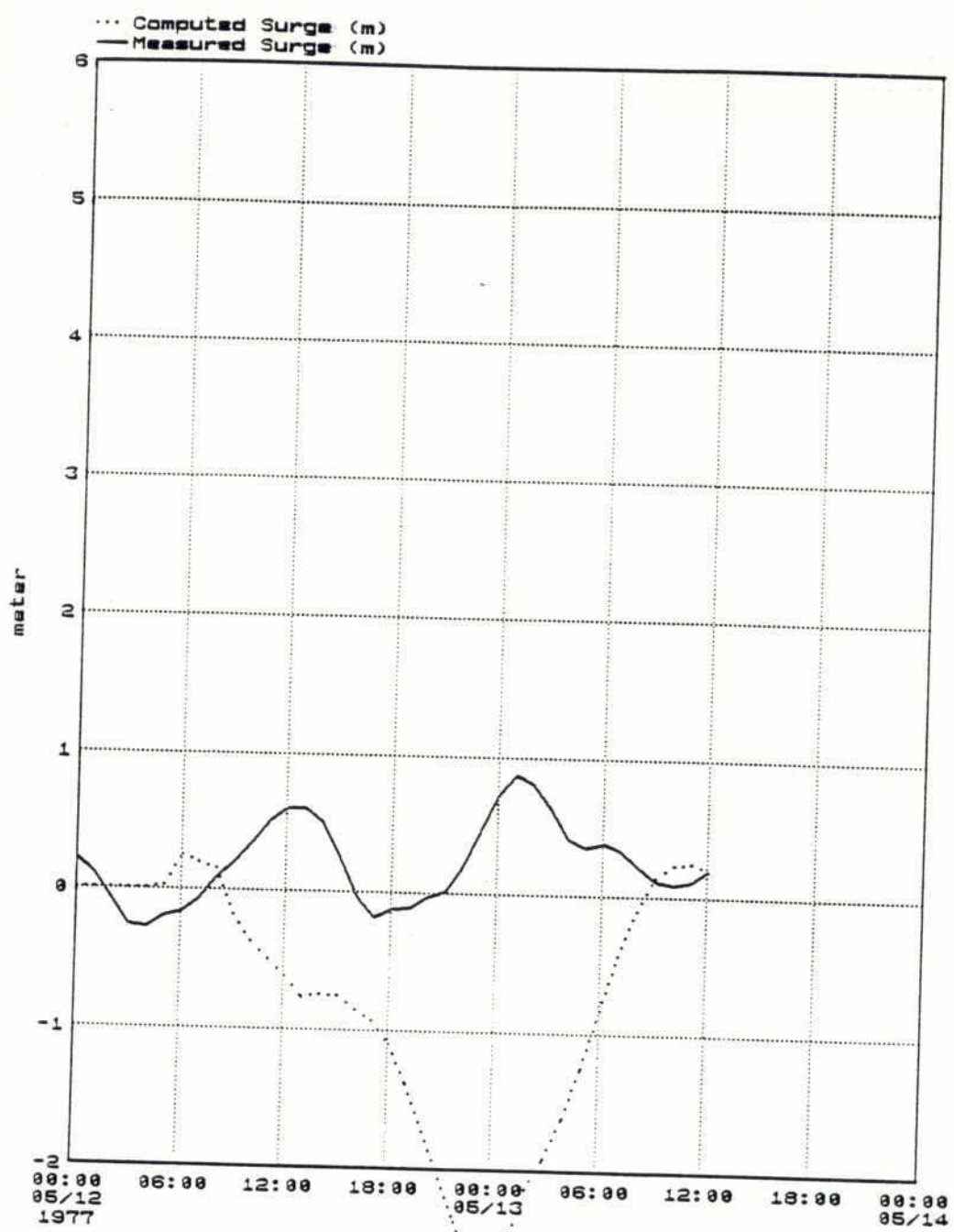
MIKE21	Cyclone Protection Project II	
File: family: m77 name : chin4 User: mnr Sat Dec 15 1990	May 1977 Hiron Point Measured and computed surge	Dwg. No.  4.43

224



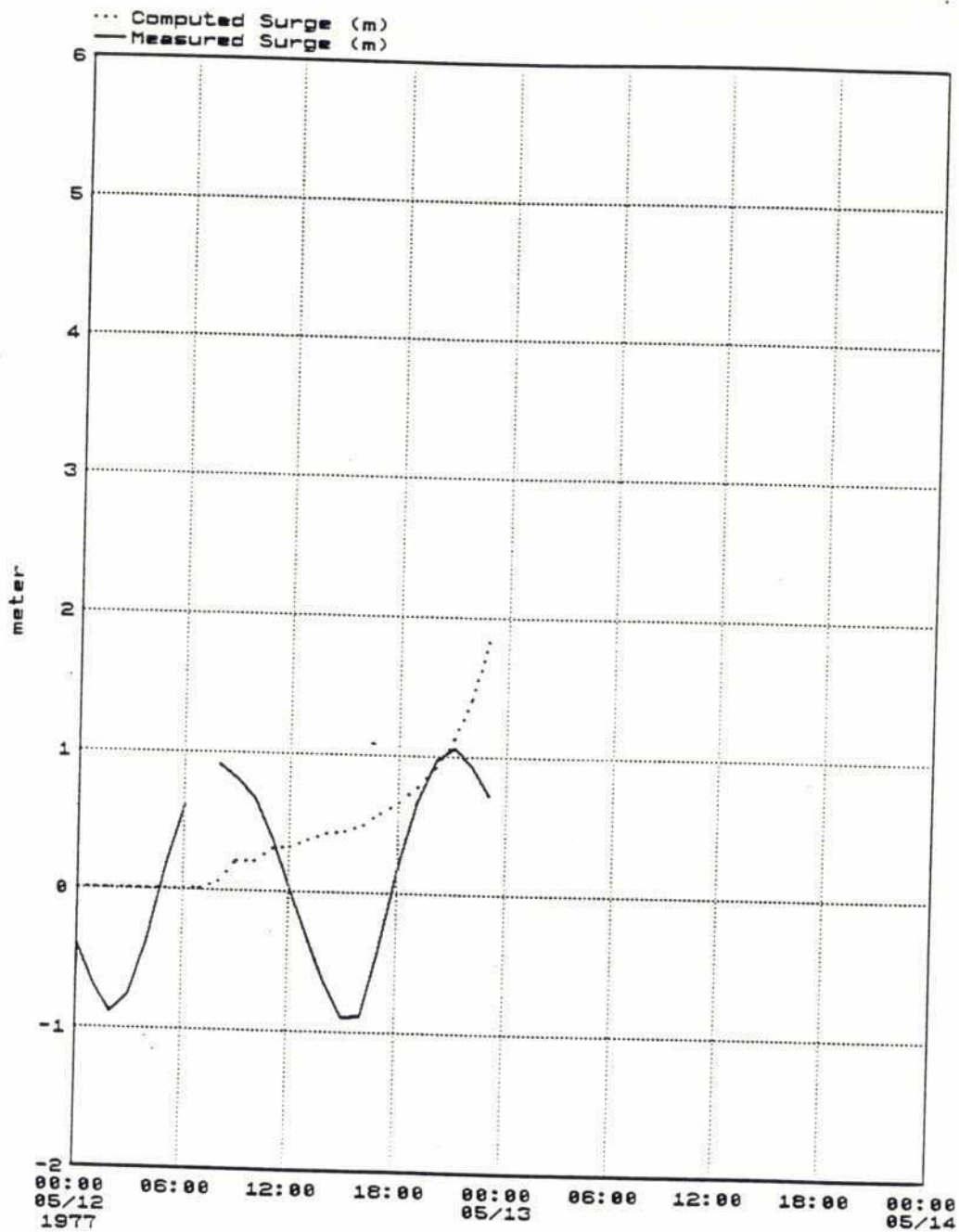
MIKE21	Cyclone Protection Project II	
File: family: m77 name : ckhe4 User: mnr Sat Dec 15 1990	May 1977 Khepupara Measured and computed surge	Dwg. No.  4.44





<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> Family: m77 name : cmon4 User: mnr Sat Dec 15 1990	May 1977 Mongla Measured and computed surge	<b>Dwg. No.</b>  4.45

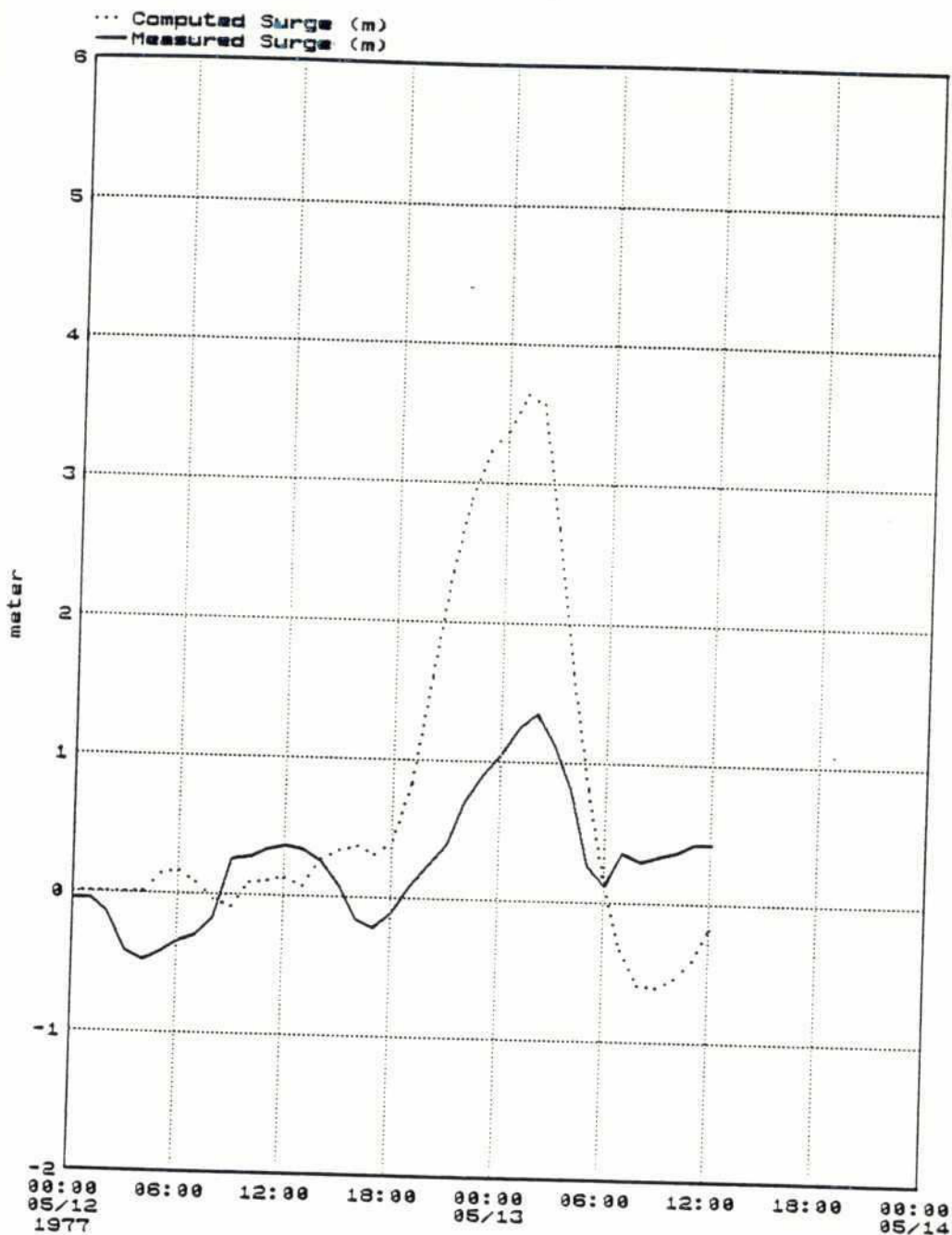
226



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: m77 name : cram4 User: mnr Sat Dec 15 1990	May 1977 Ramdasapur Measured and computed surge	Dwg. No.  4.46

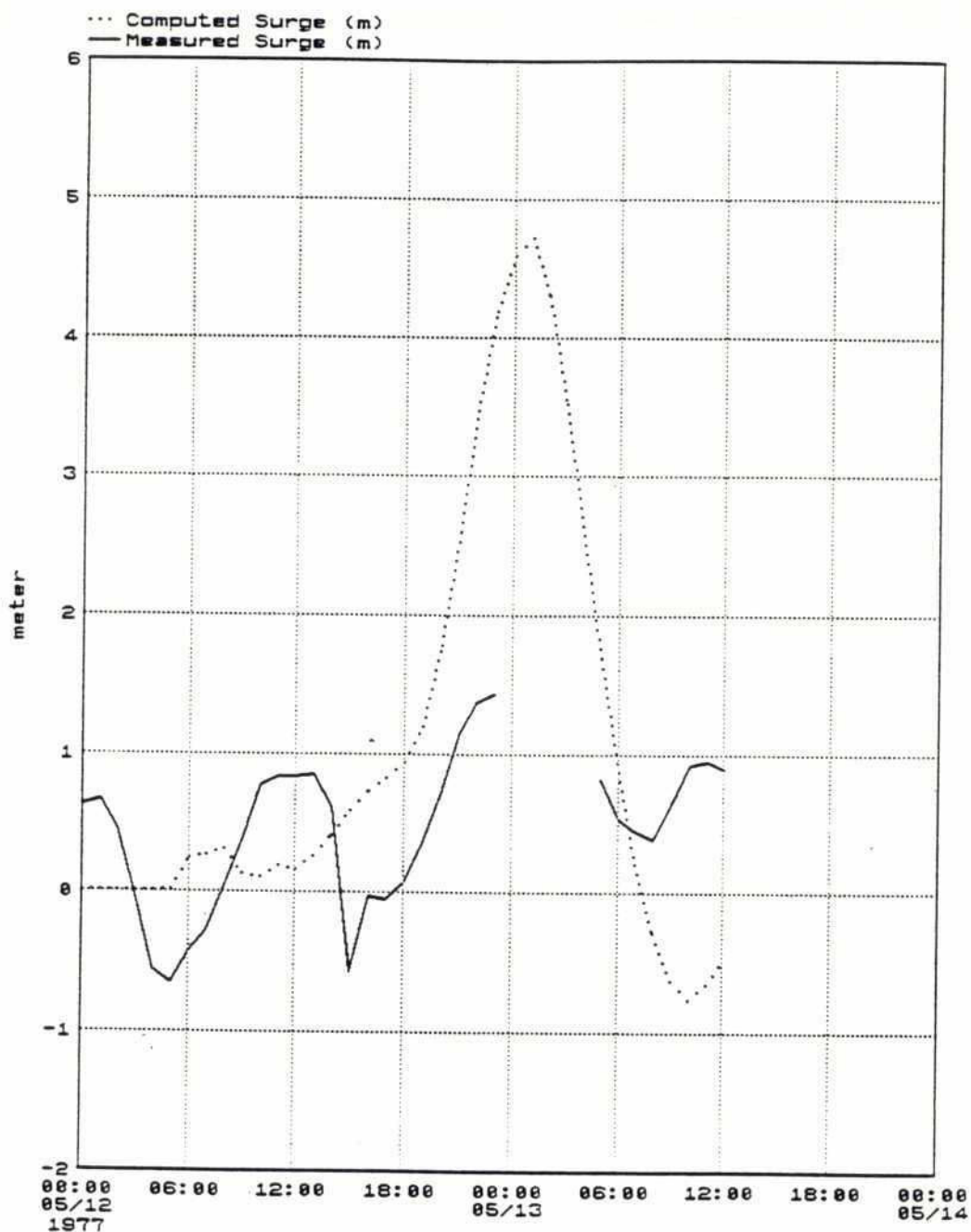


222



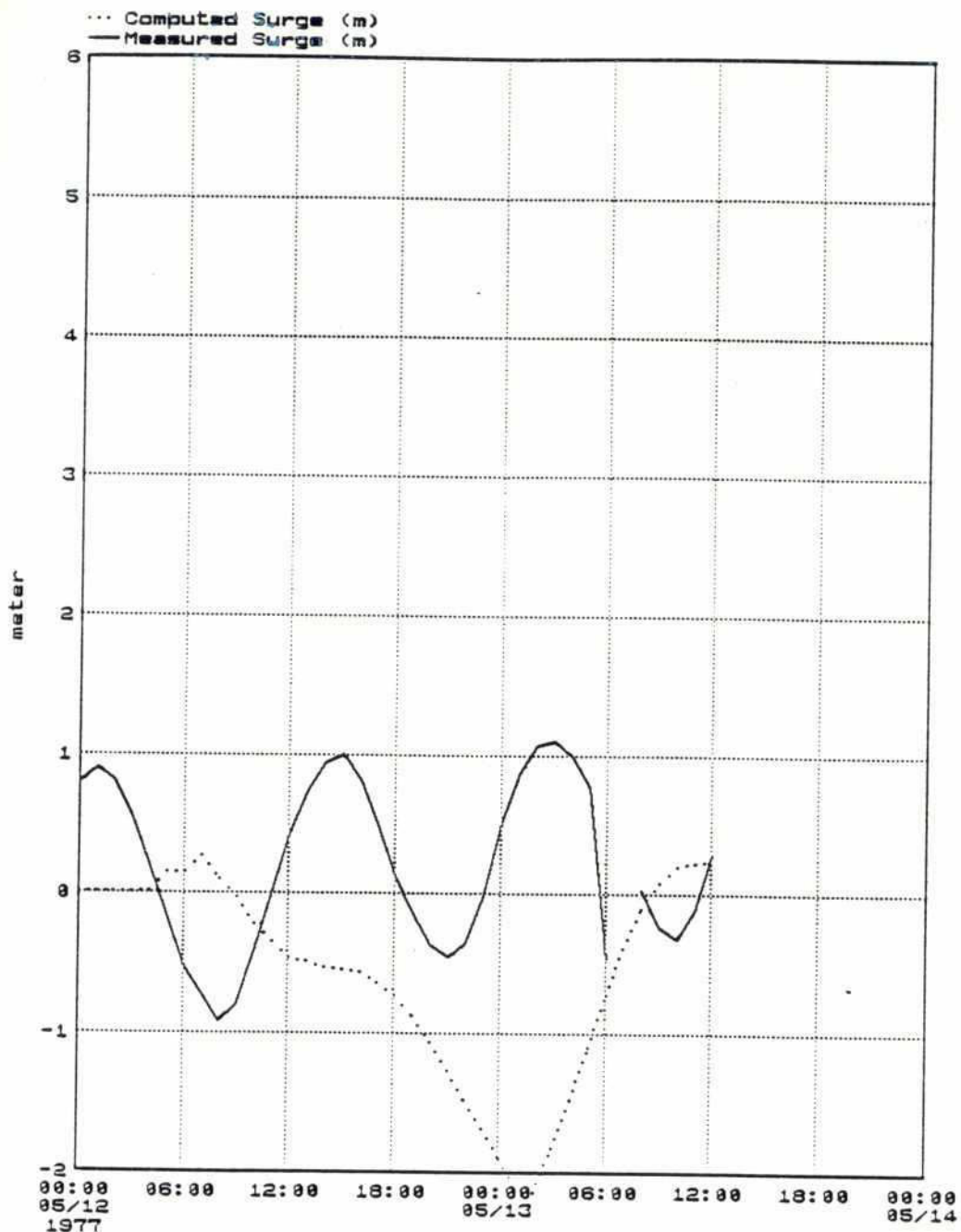
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: m77 name : csad4 User: mnr Sat Dec 15 1990	May 1977 Sadarghat (CTG) Measured and computed surge	Dwg. No.  4.47

220



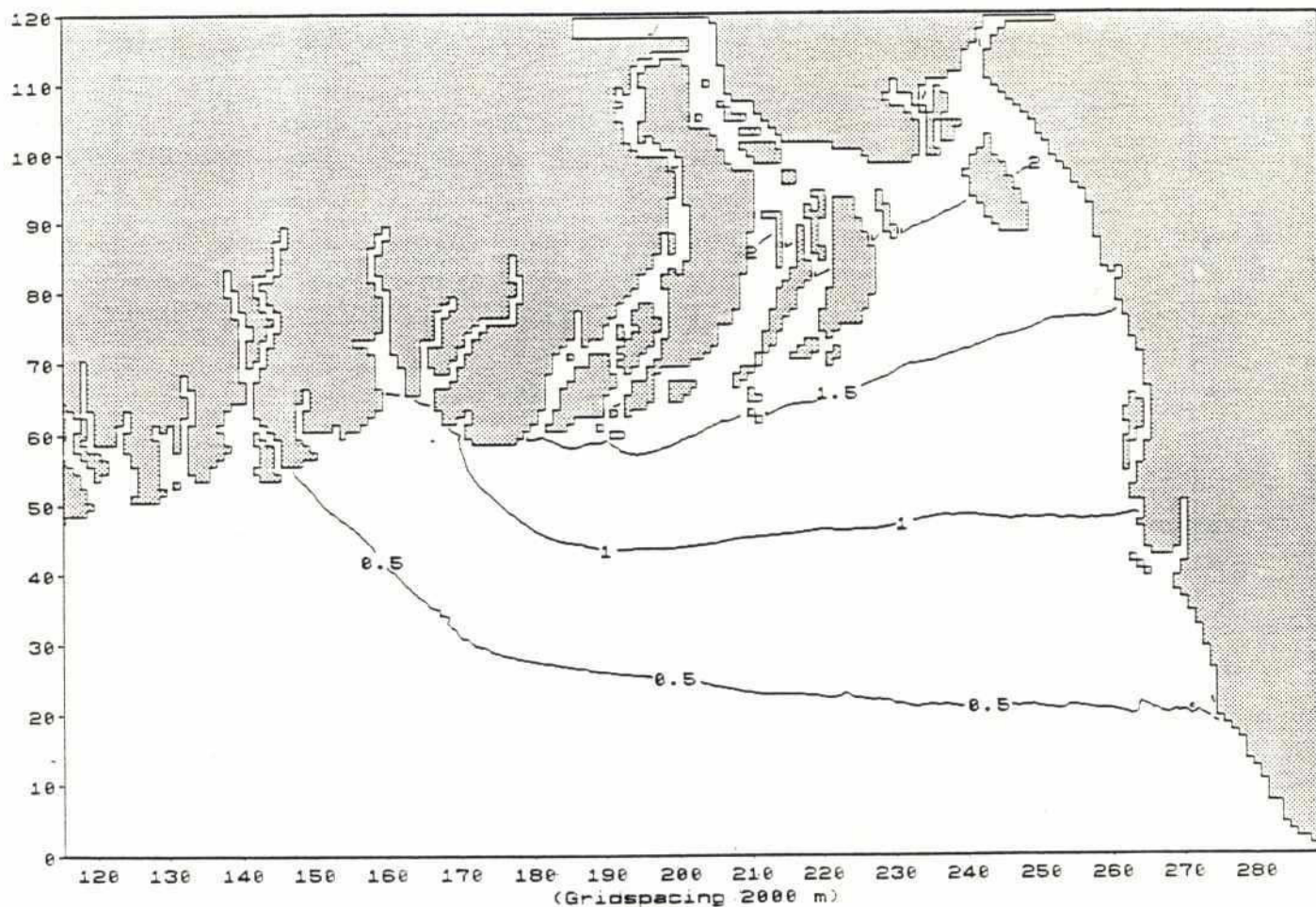
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: m77 name : csan4 User: mnr Sat Dec 15 1990	May 1977 Sandwip Measured and computed surge	<b>Dwg. No.</b>  4.48





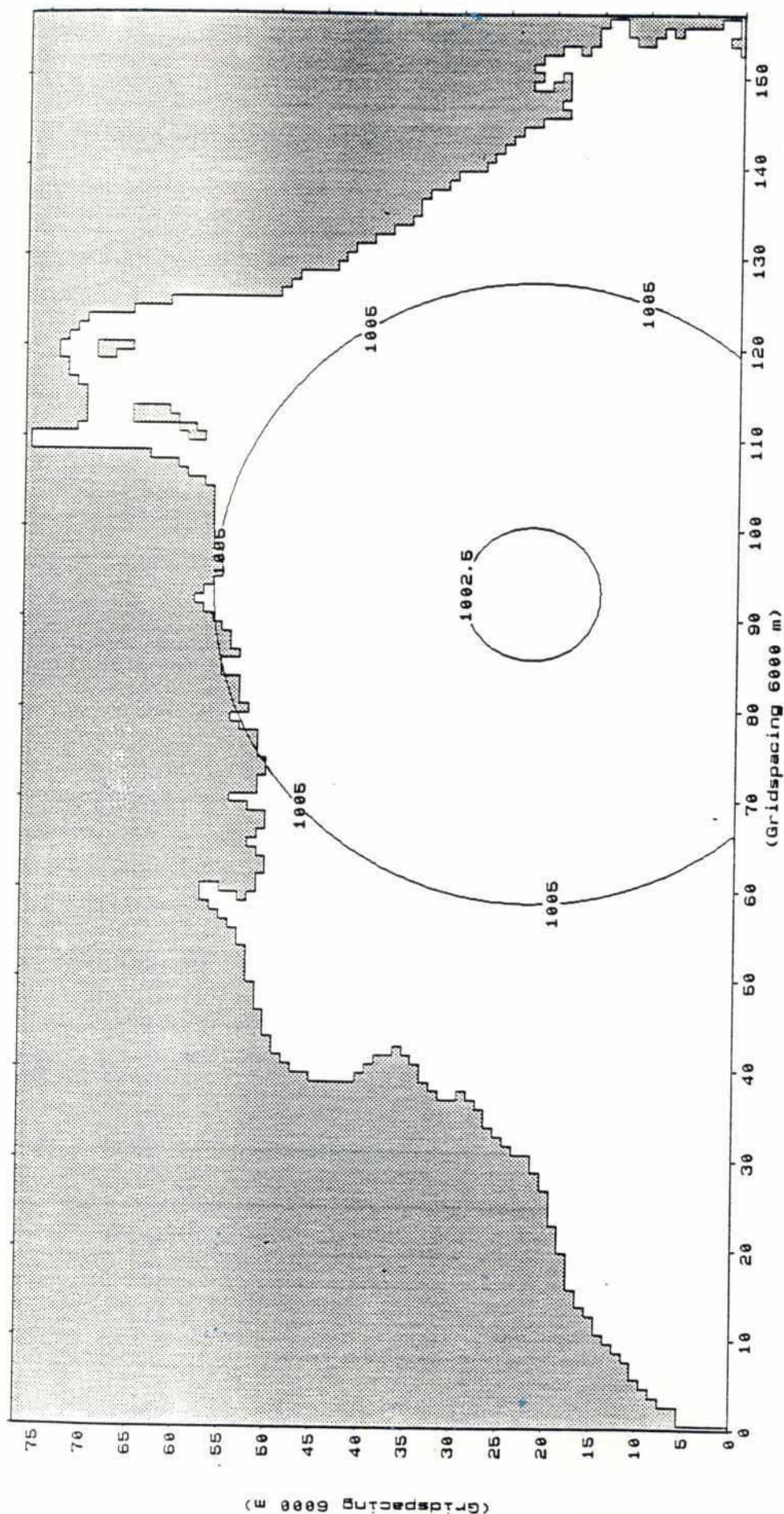
<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: m77 name : csun4 User: mnr Sat Dec 15 1990</p>	<p>May 1977 Sundarikota Measured and computed surge</p>	<p>Dwg. No.  4.49</p>

202



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o78 name : imax Scale: 1:2 mill Thu Nov 29 1990	October 1978 Cyclone Simulation Results, Intermediate Model Maximum Surge Levels	Dwg. No.  4.50



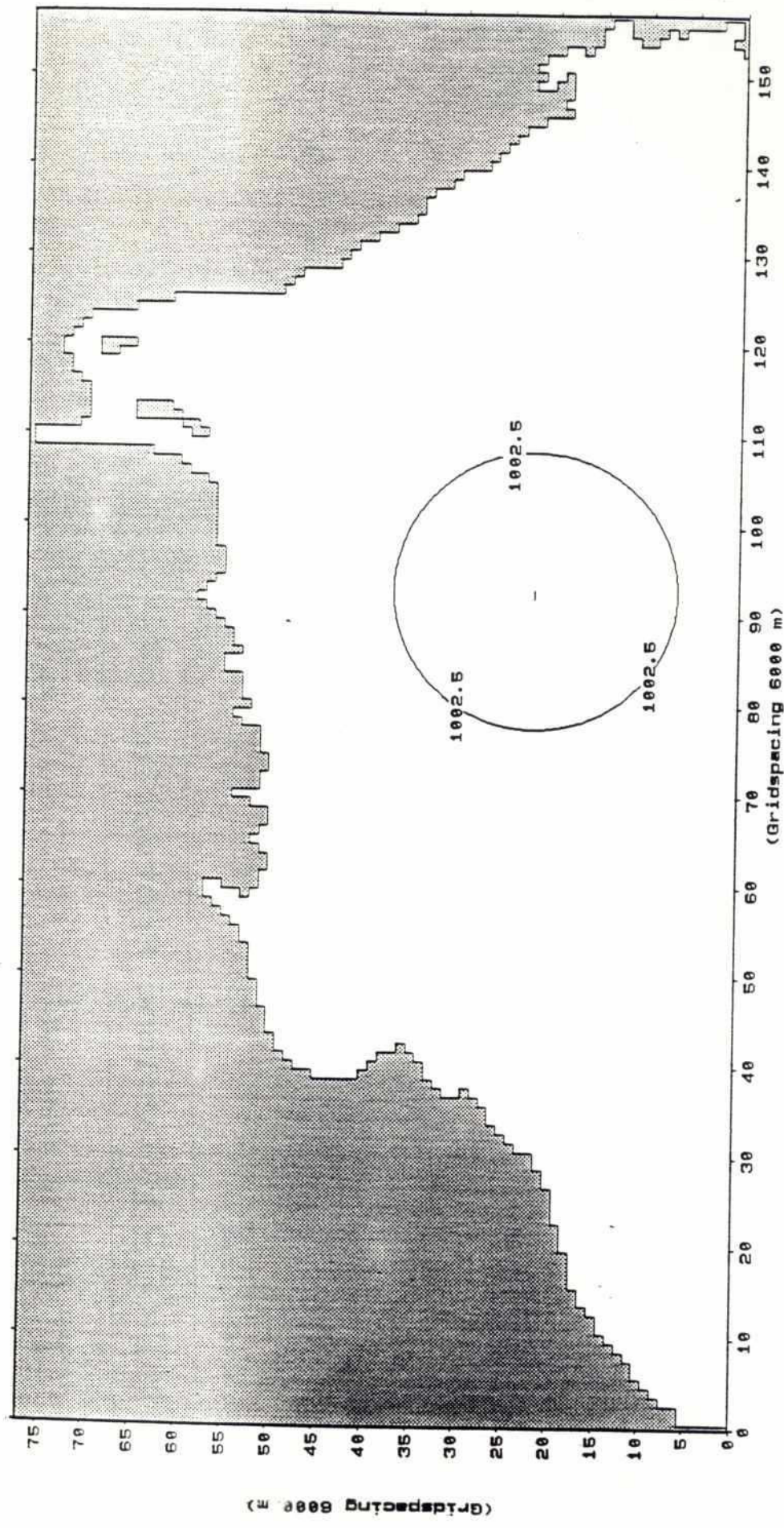


1978/10/02 12:00:00

<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: 078 name : rwind Scale: 1:4 mill Thu Nov 29 1990	October 1978 Cyclone Pressure Field (mb)	
	Dwg. No.	4.51



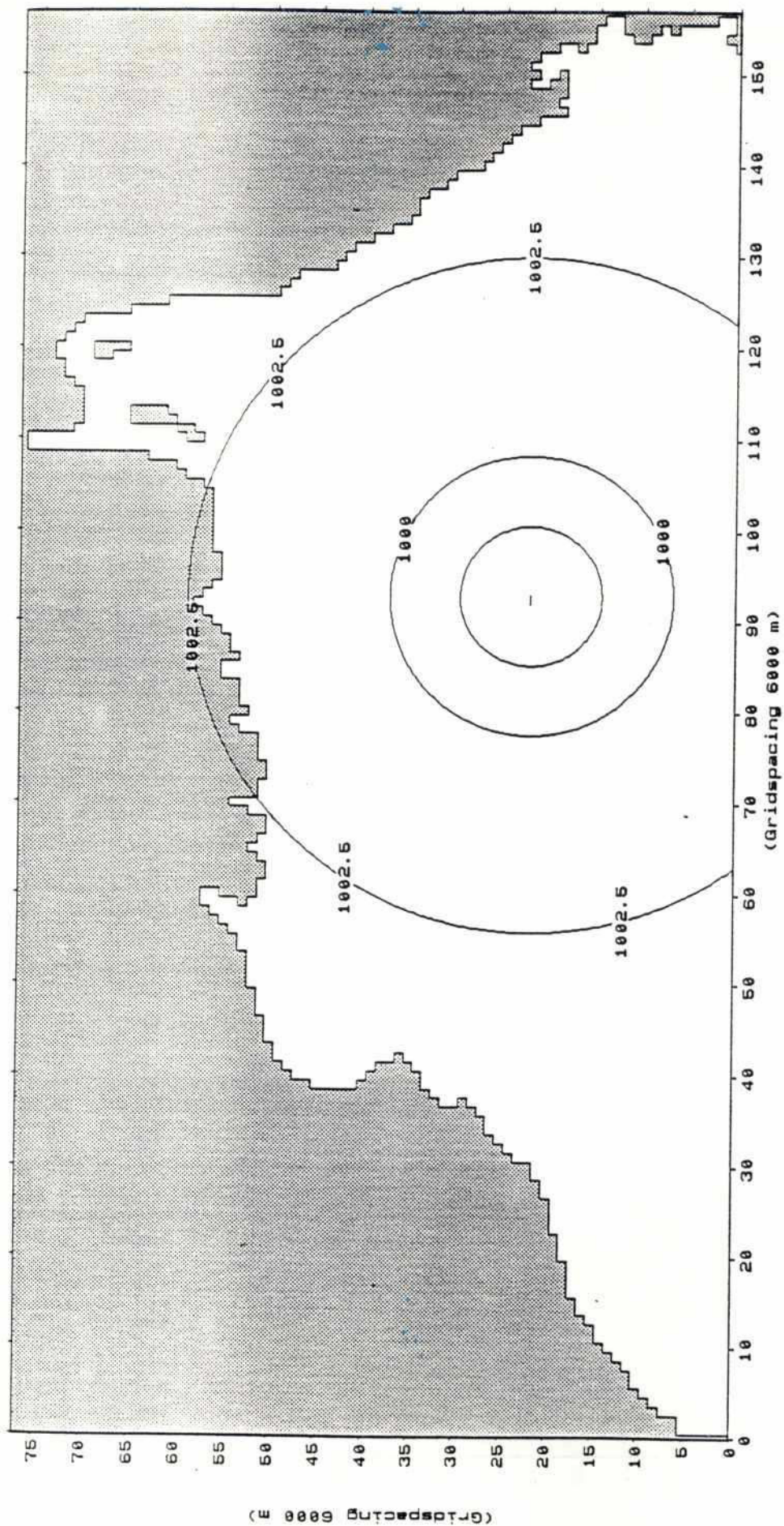
268



1978/10/03 00:00:00

<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: a78 name : rwind Scale: 1:4 mill Thu Nov 29 1990	October 1978 Cyclone Pressure Field (mb)	Dwg. No.  4.52





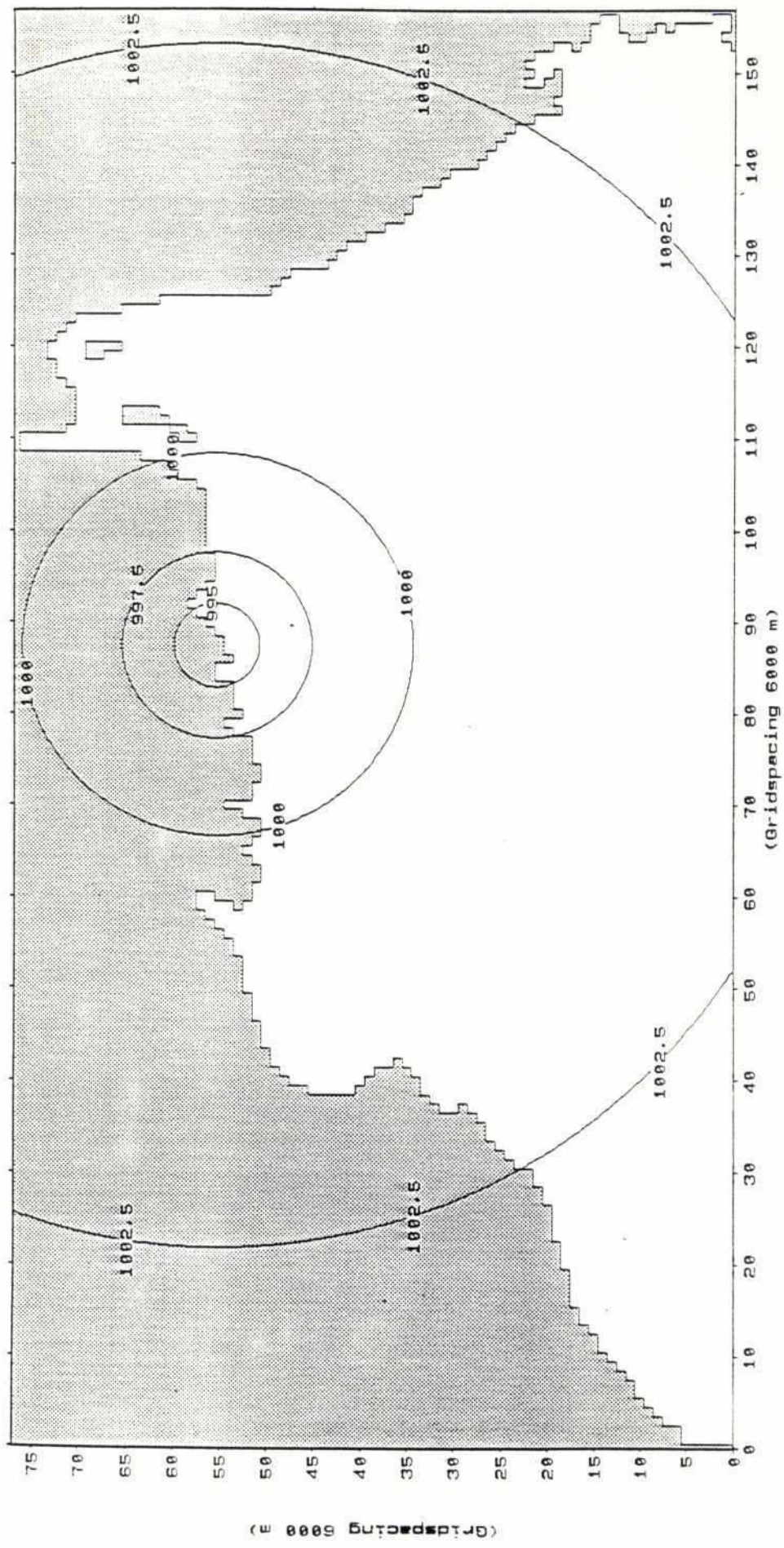
1978/10/03 12:00:00

<p><b>MIKE21</b></p>	<p><b>Cyclone Protection Project II</b></p>	
<p>File: family: o78 name : rwind Scale: 1:4 mill 10/10/77 1900</p>	<p>October 1978 Cyclone Pressure Field (mb)</p>	<p>Dwg. No.  4.53</p>

260



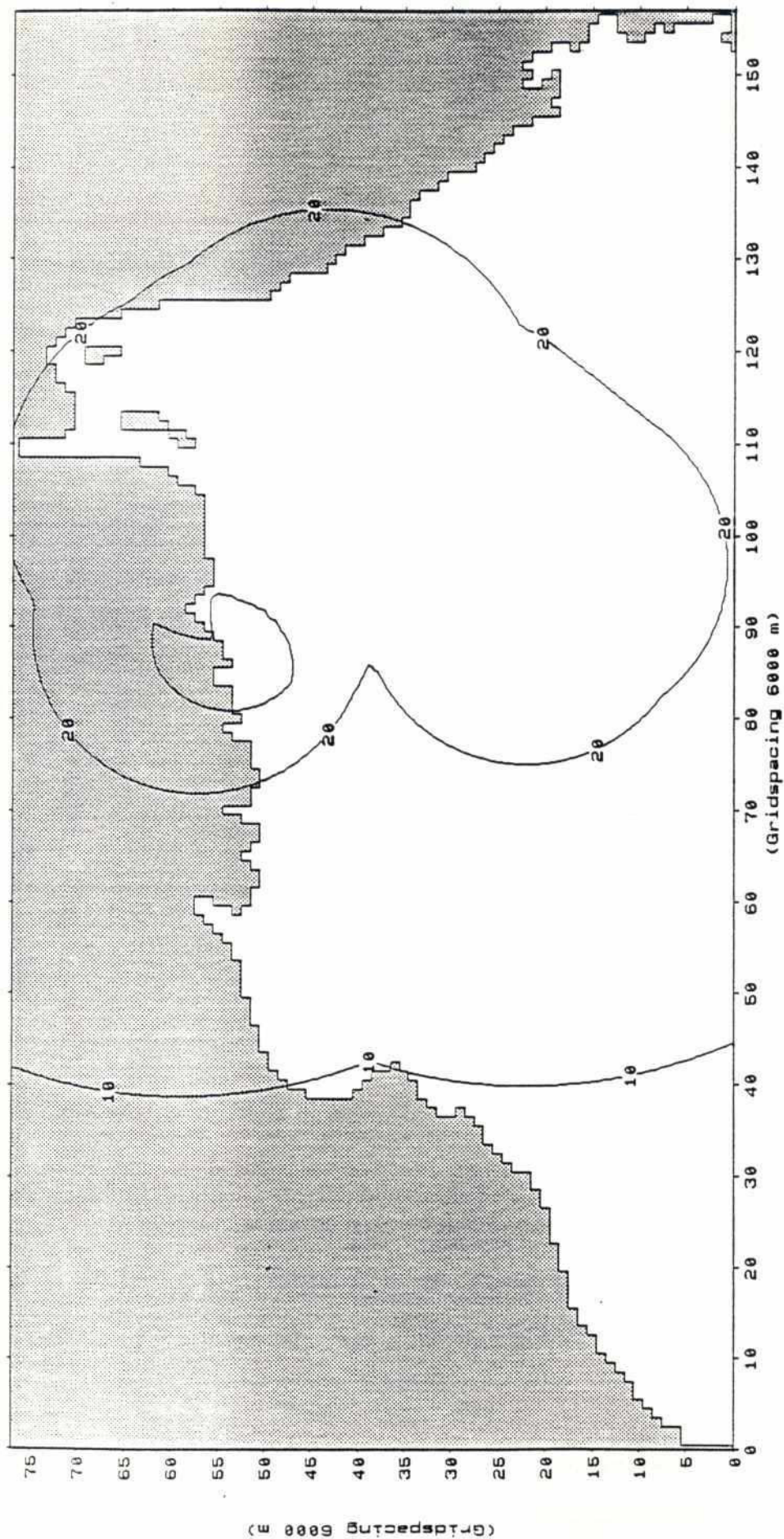
267



1978/10/04 00:00:00

<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: 078 name : rwind Scale: 1:4 mill Thu Nov 29 1990</p>	<p>October 1978 Cyclone Pressure Field (mb)</p>	<p>Dwg. No.  4.54</p>

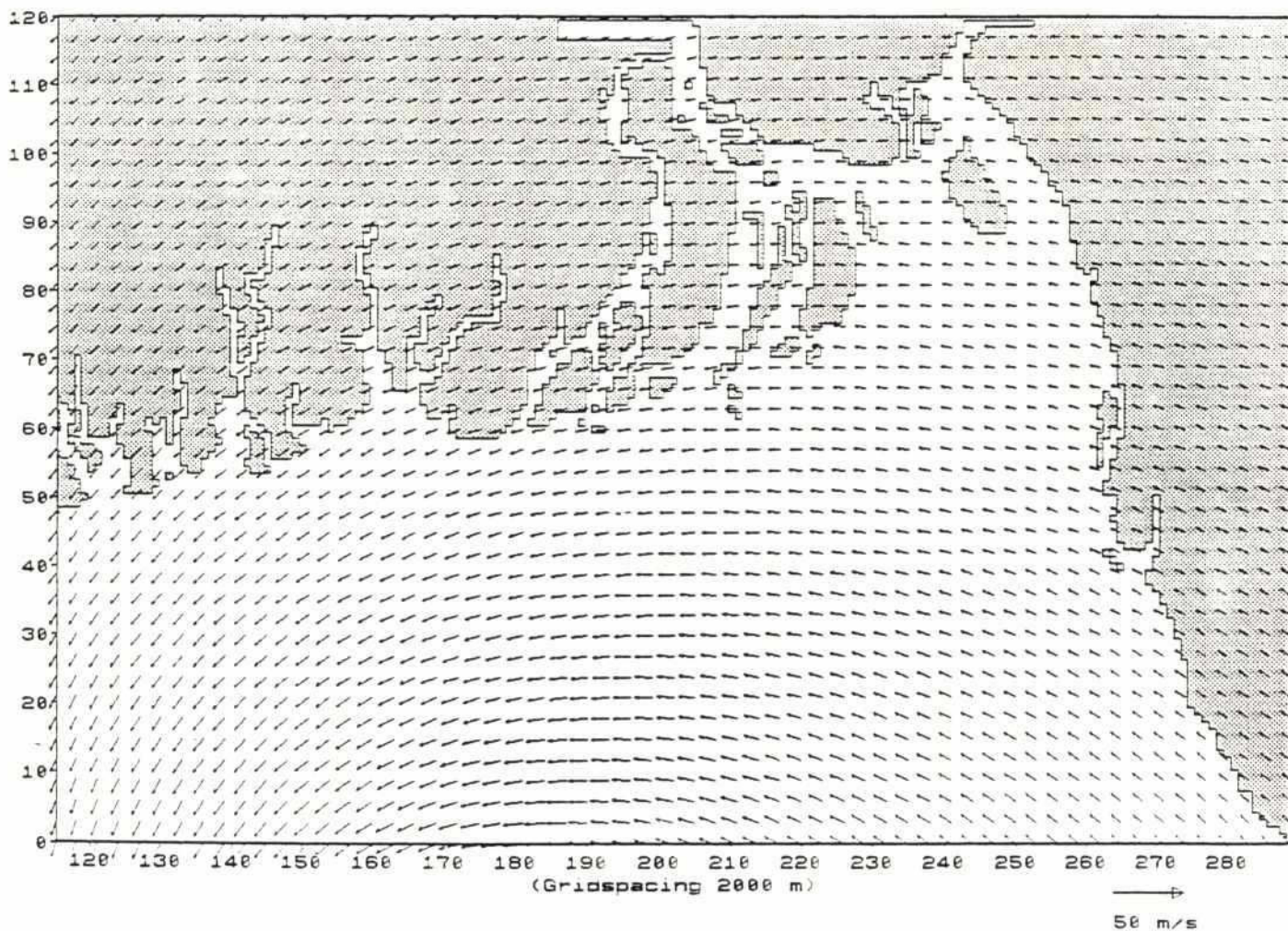




<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: 078 name : rmwind Scale: 1:4 mill Thu Nov 20 1998	October 1978 Maximum occurring Wind Speed (m/s)	Dwg. No. 4.55



268

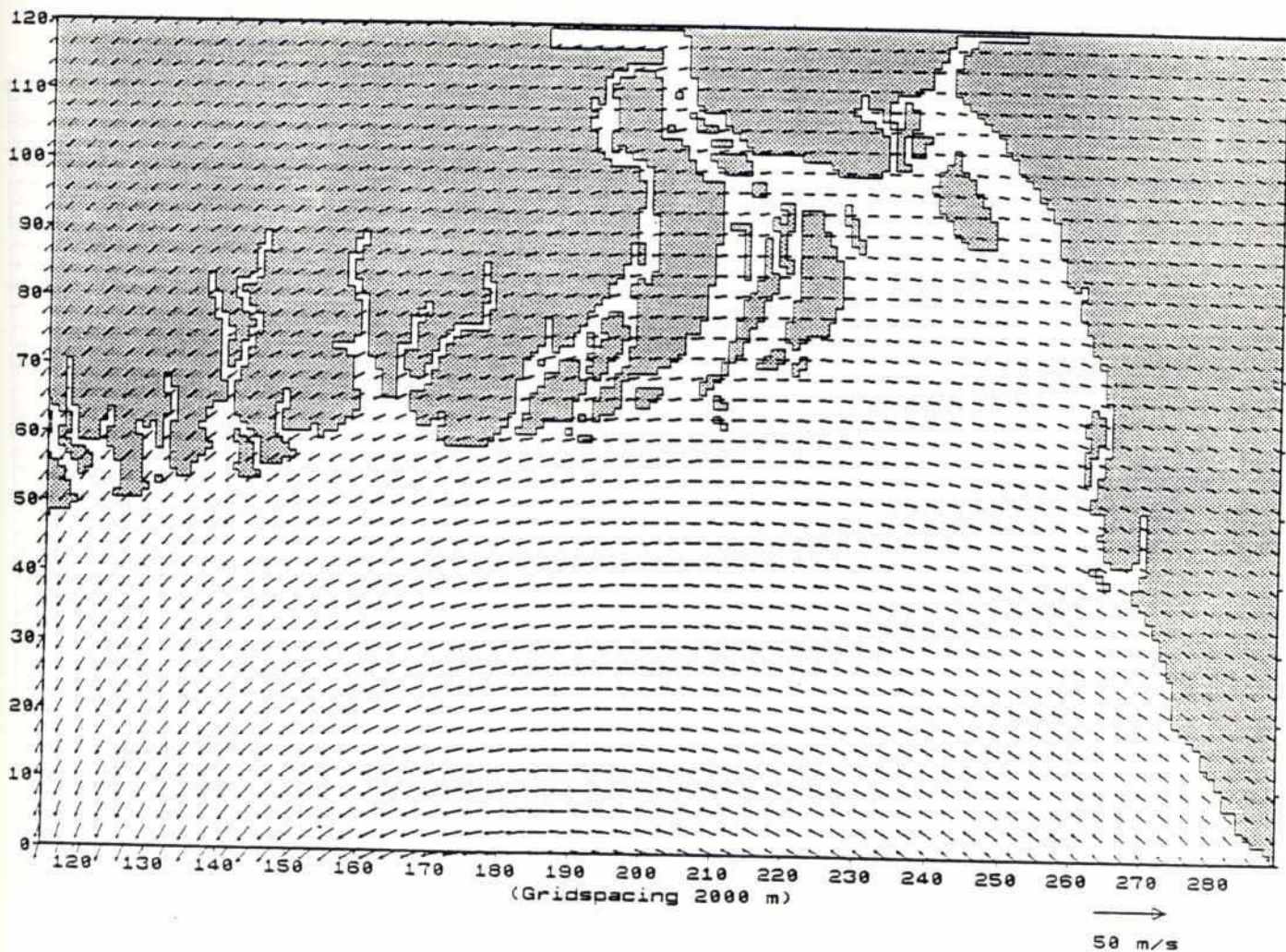


1978/10/02 12:00:00

<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: o78 name : iwind Scale: 1:2 mill Thu Nov 29 1990</p>	<p>October 1978 Cyclone Wind Field</p>	<p>Dwg. No.  4.56</p>



707

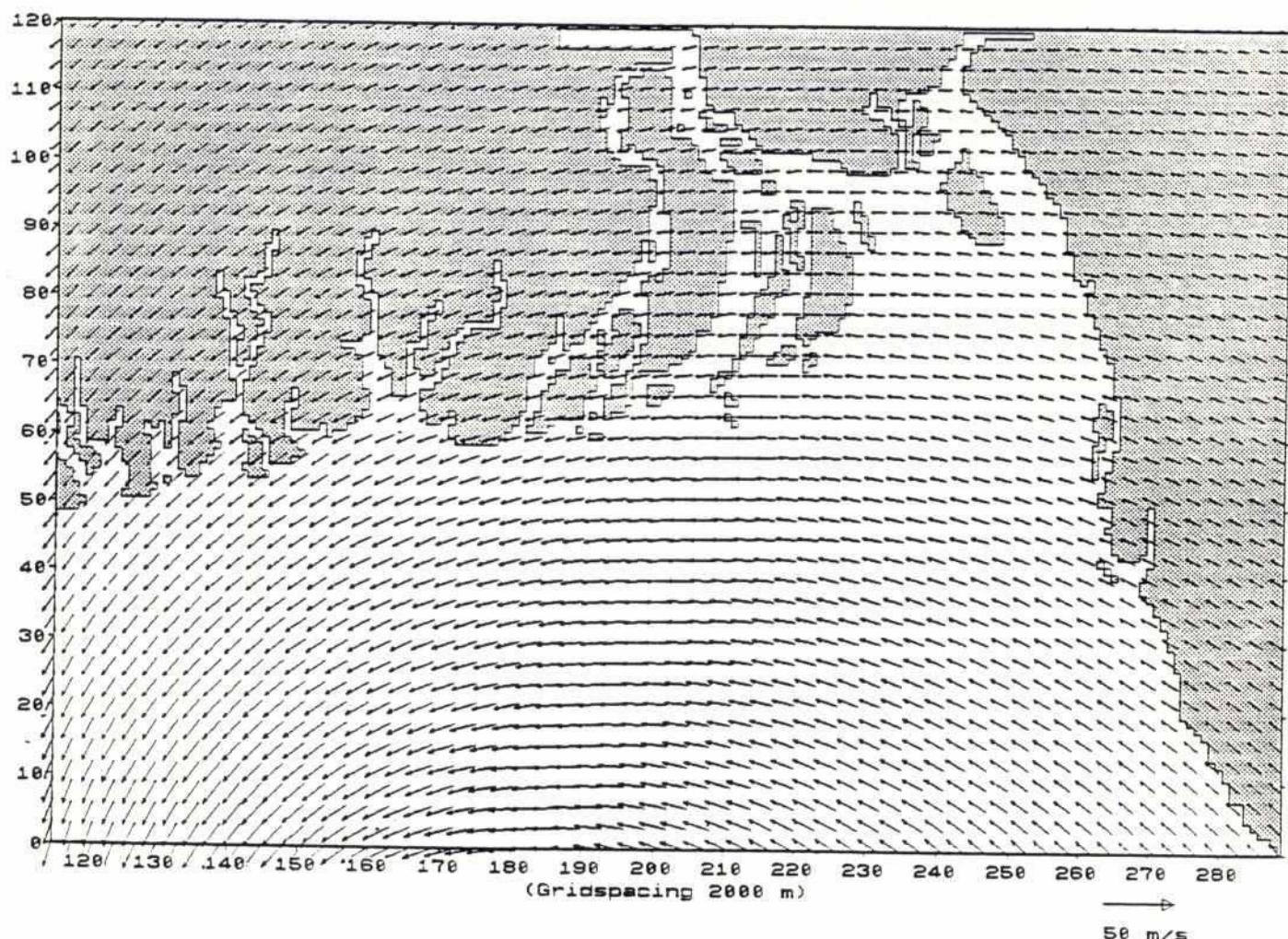


1978/10/03 00:00:00

<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: o78 name : iwind Scale: 1:2 mill Thu Nov 29 1990</p>	<p>October 1978 Cyclone Wind Field</p>	<p>Dwg. No.  4.57</p>



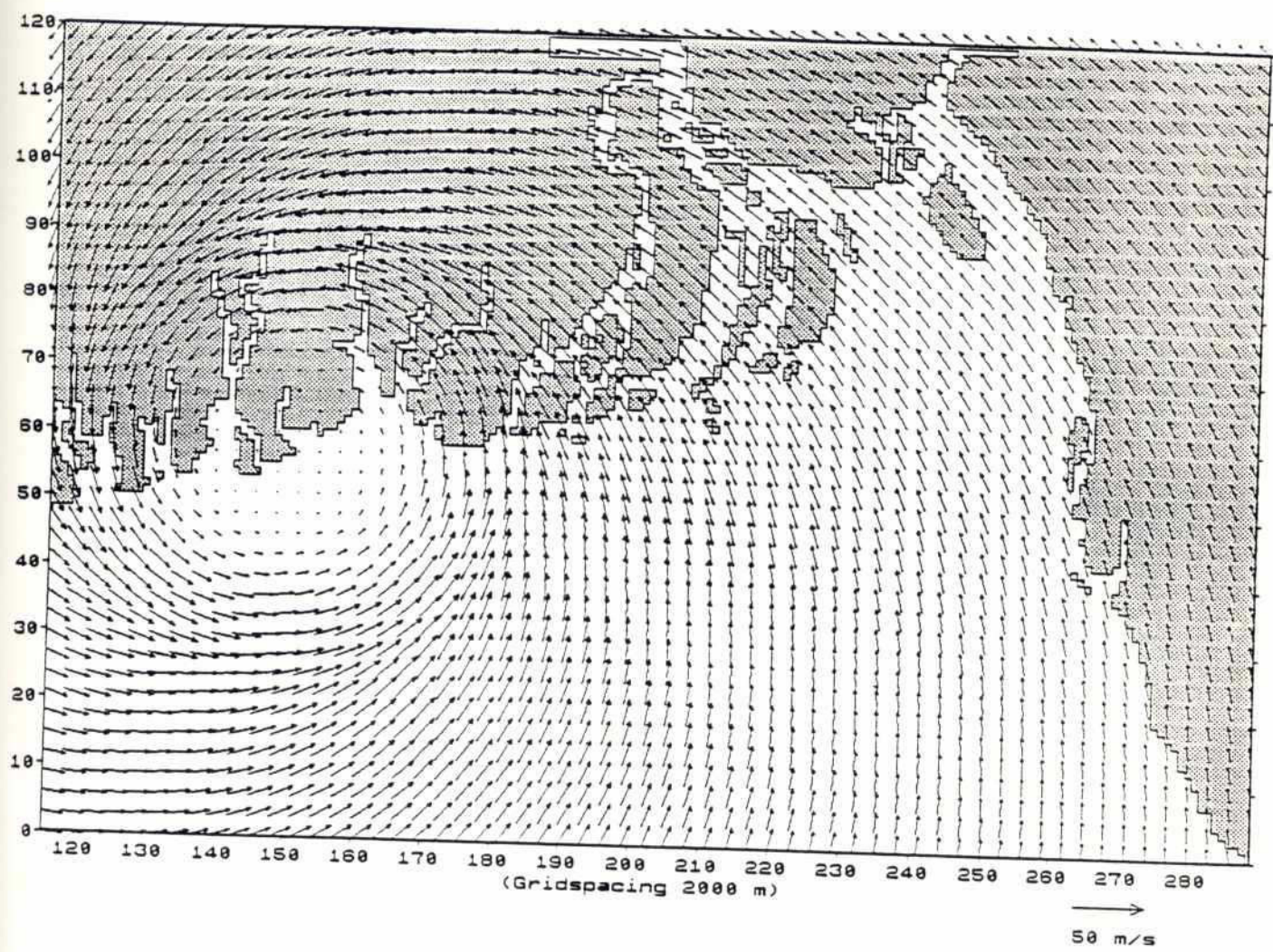
280



1978/10/03 12:00:00

<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: o78 name : iwind Scale: 1:2 mill Thu Nov 29 1990</p>	<p>October 1978 Cyclone Wind Field</p>	<p>Dwg. No.  4.58</p>

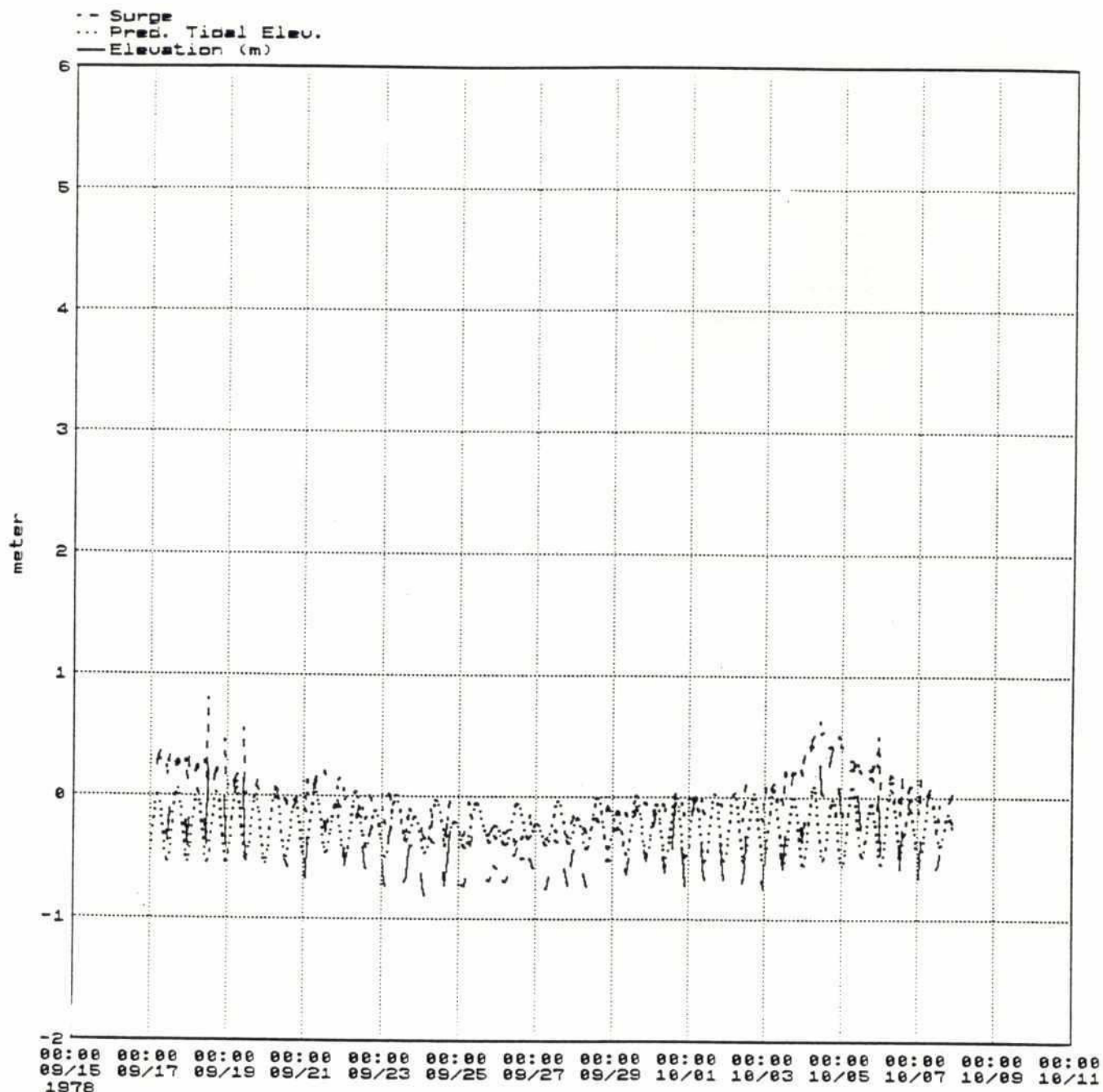




1978/10/04 00:00:00

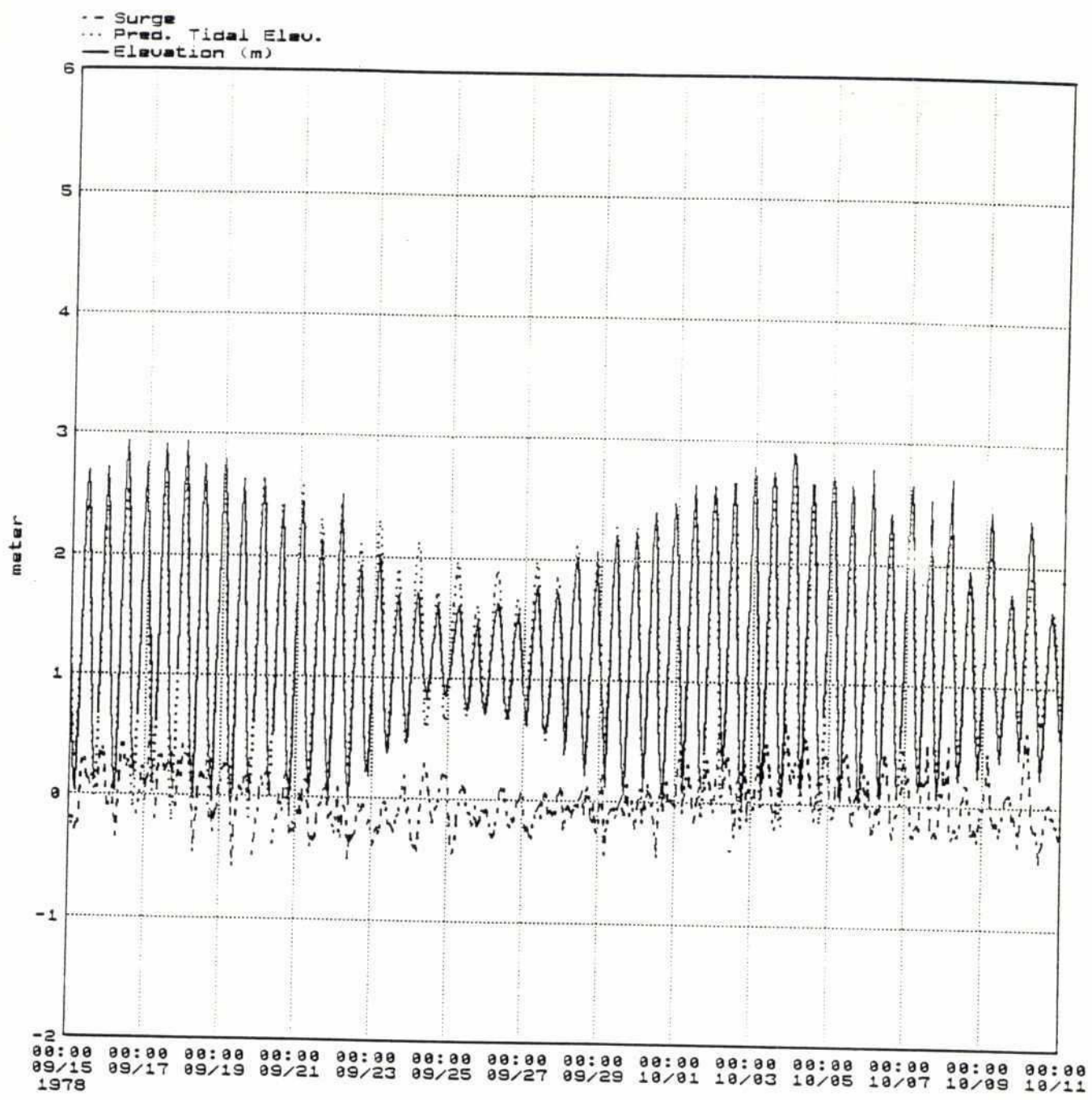
<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: o78 name : iwind Scale: 1:2 mill Thu Nov 29 1990</p>	<p>October 1978 Cyclone Wind Field</p>	<p>Dwg. No.  4.59</p>

082



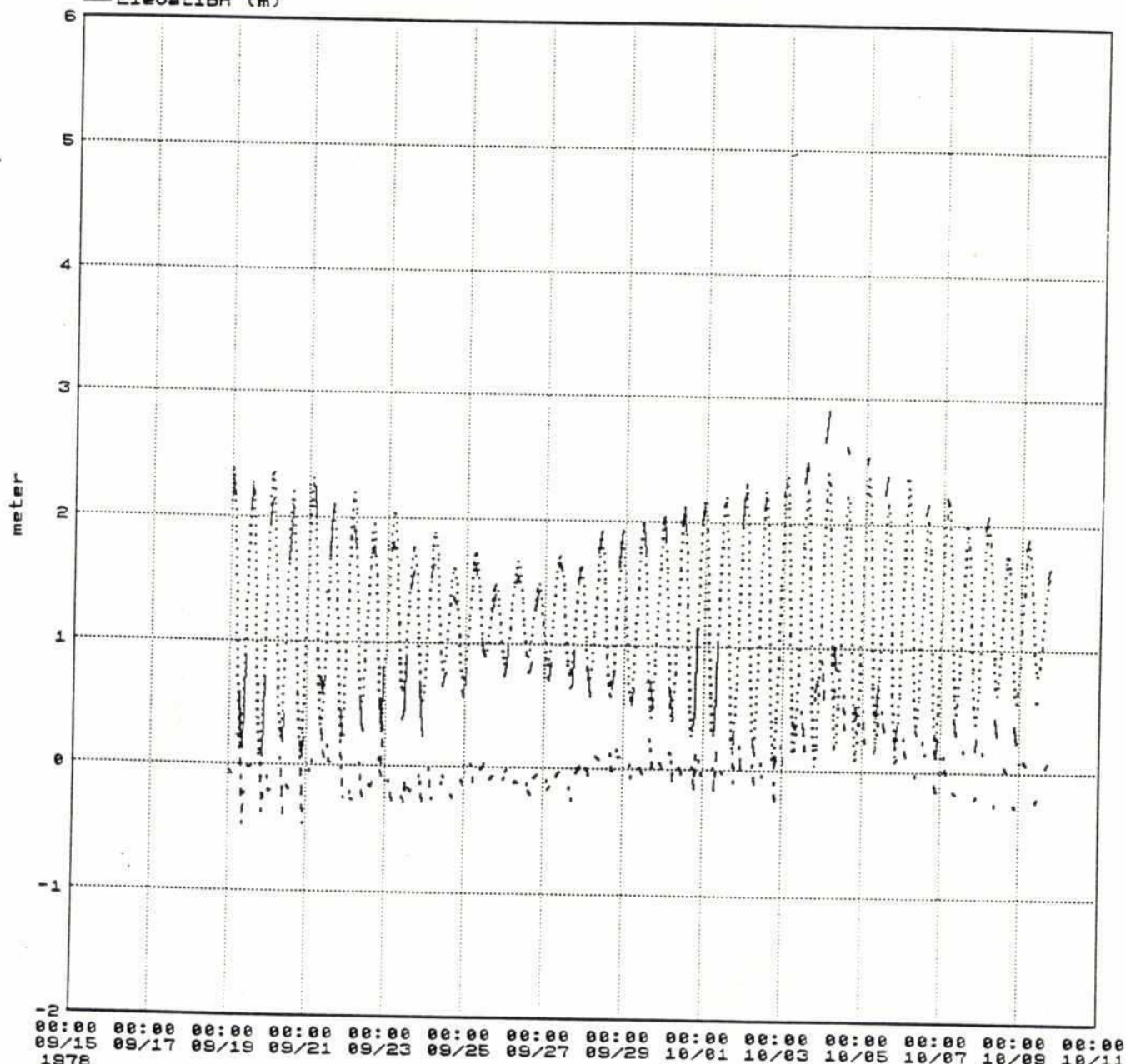
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o78 name : sbar4 User: mnr Sun Dec 16 1990	October 1978 Barisal Measurements	Dwg. No.  4.60





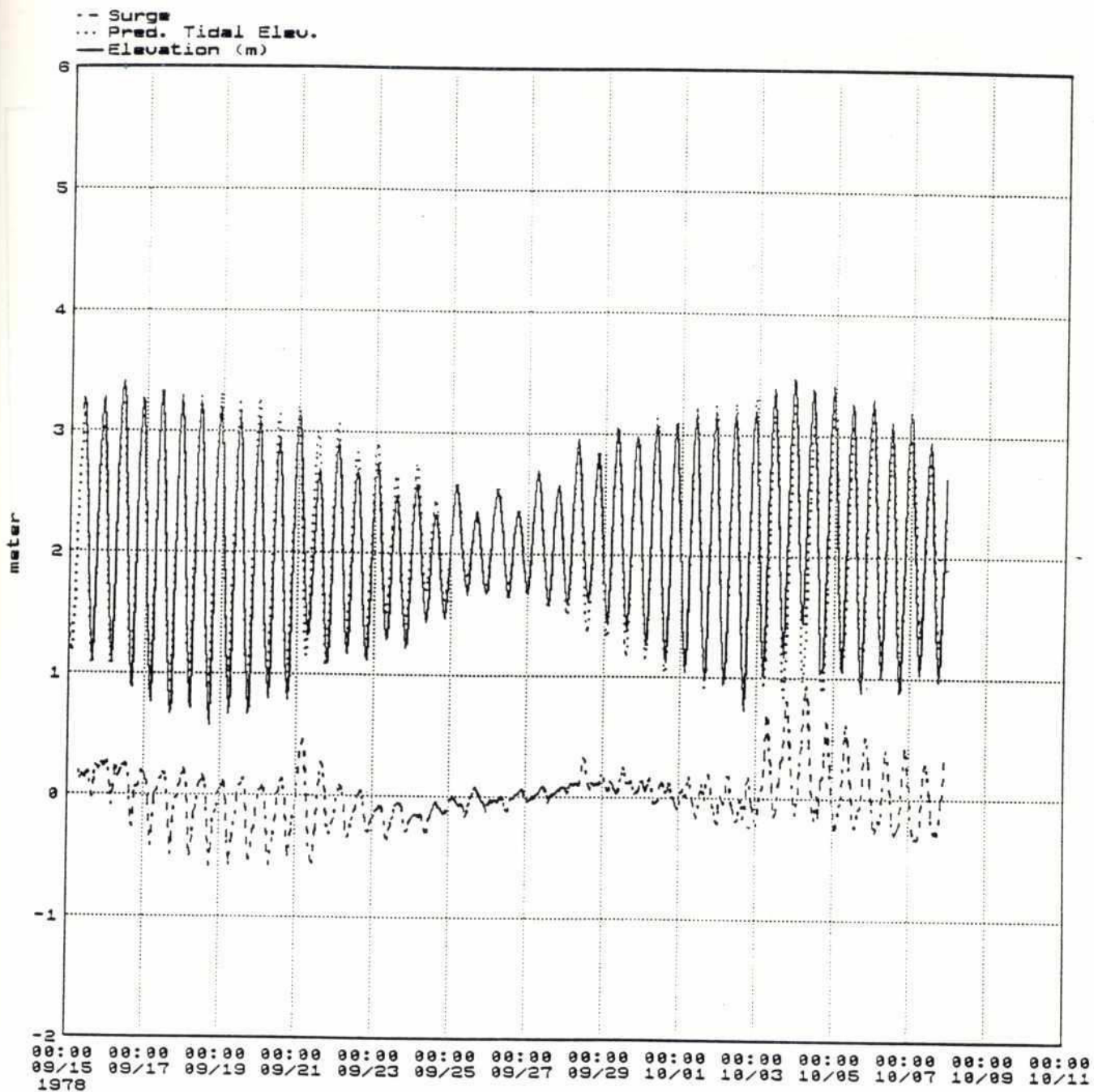
<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File:            family: o78            name : scox4            User: mnr            Sun Dec 16 1990</p>	<p>October 1978            Coxs Bazar            Measurements</p>	<p>Dwg. No.             4.61</p>

-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



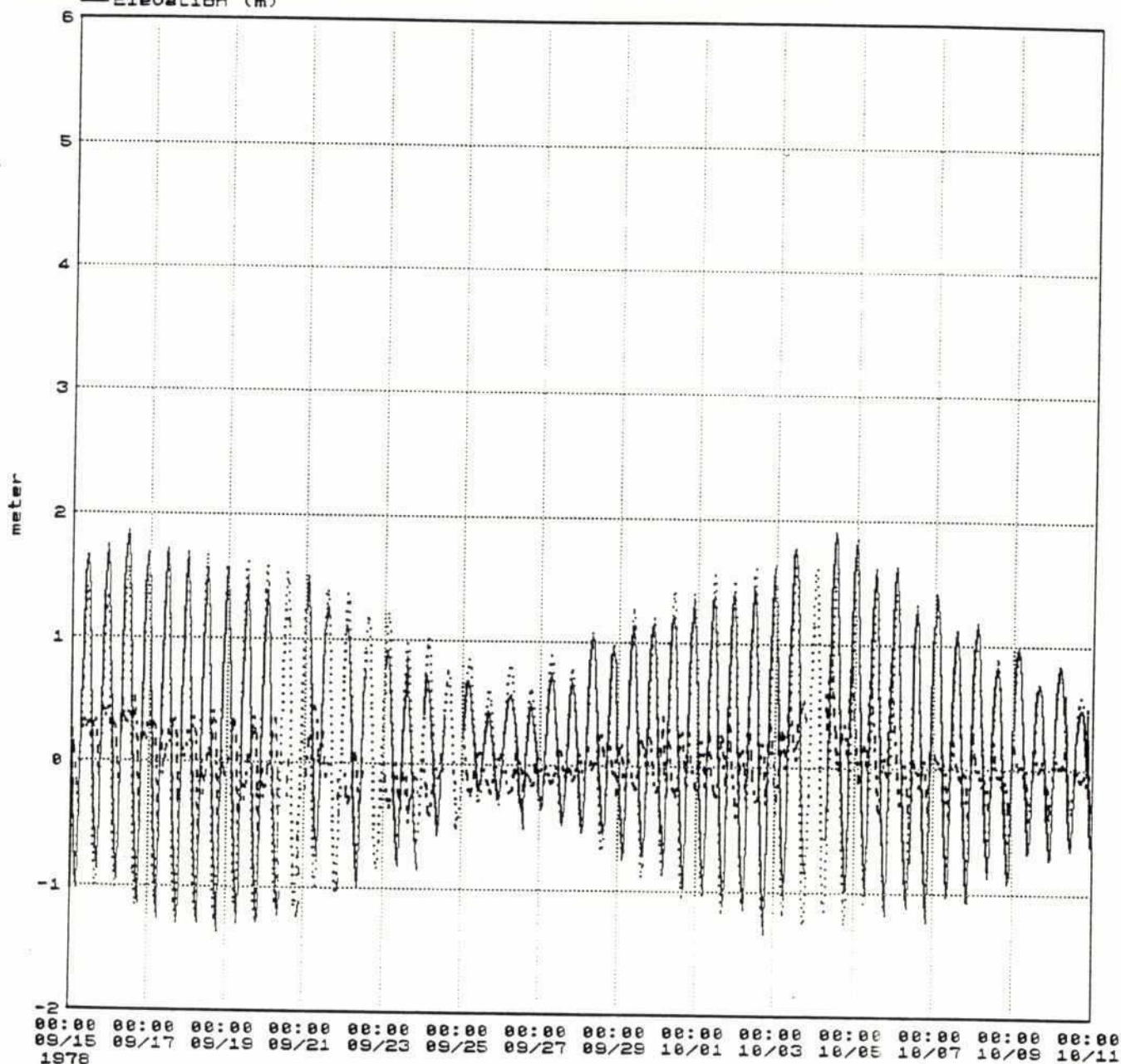
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o78 name : spal4 User: mnr Sun Dec 16 1990	October 1978 Galachipa Measurements	Dwg. No.  4.62





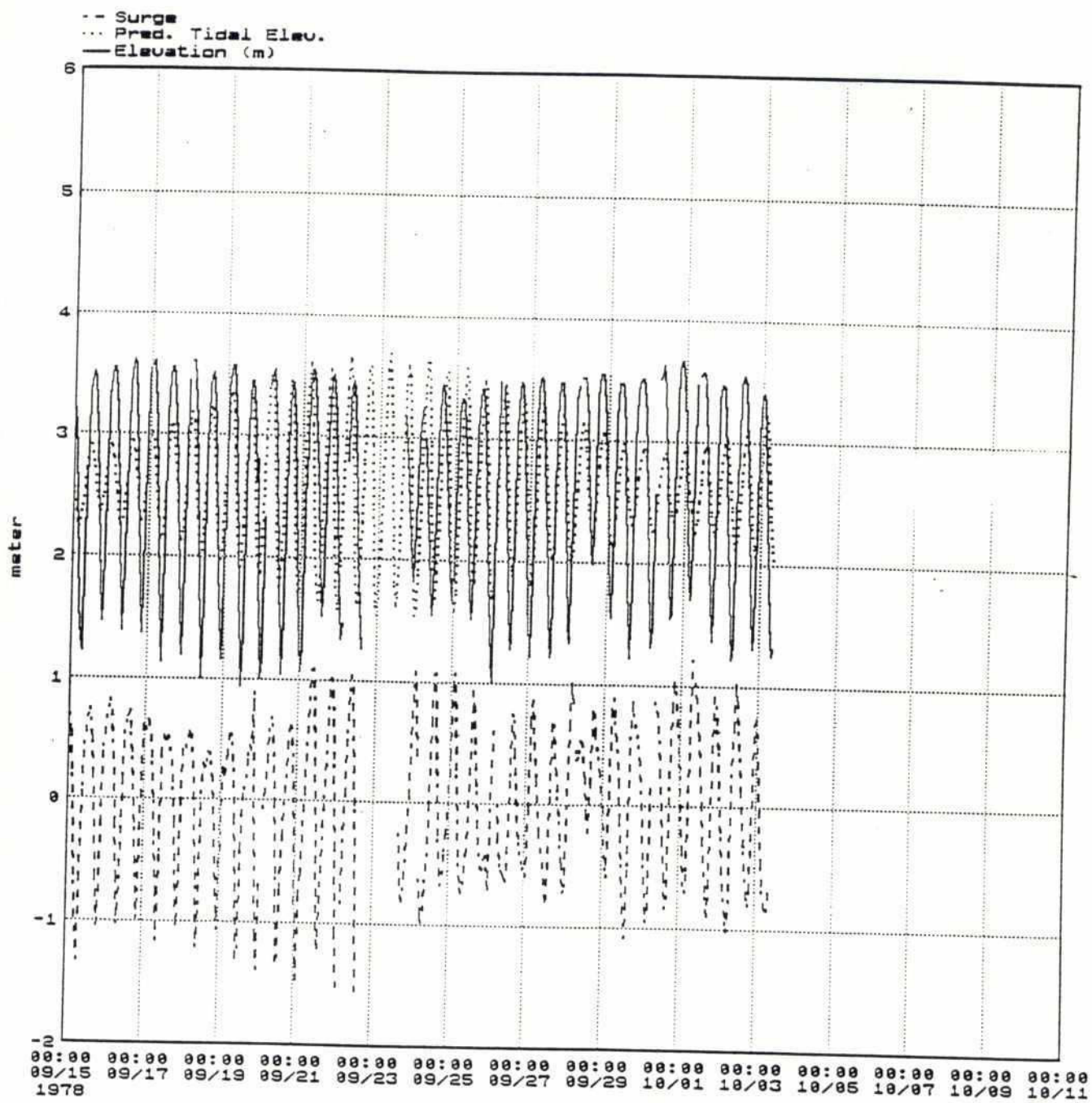
MIKE21	Cyclone Protection Project II	
File: family: o78 name : shir4 User: mnr Sun Dec 16 1990	October 1978 Hiron Point Measurements	Dwg. No.  4.63

-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



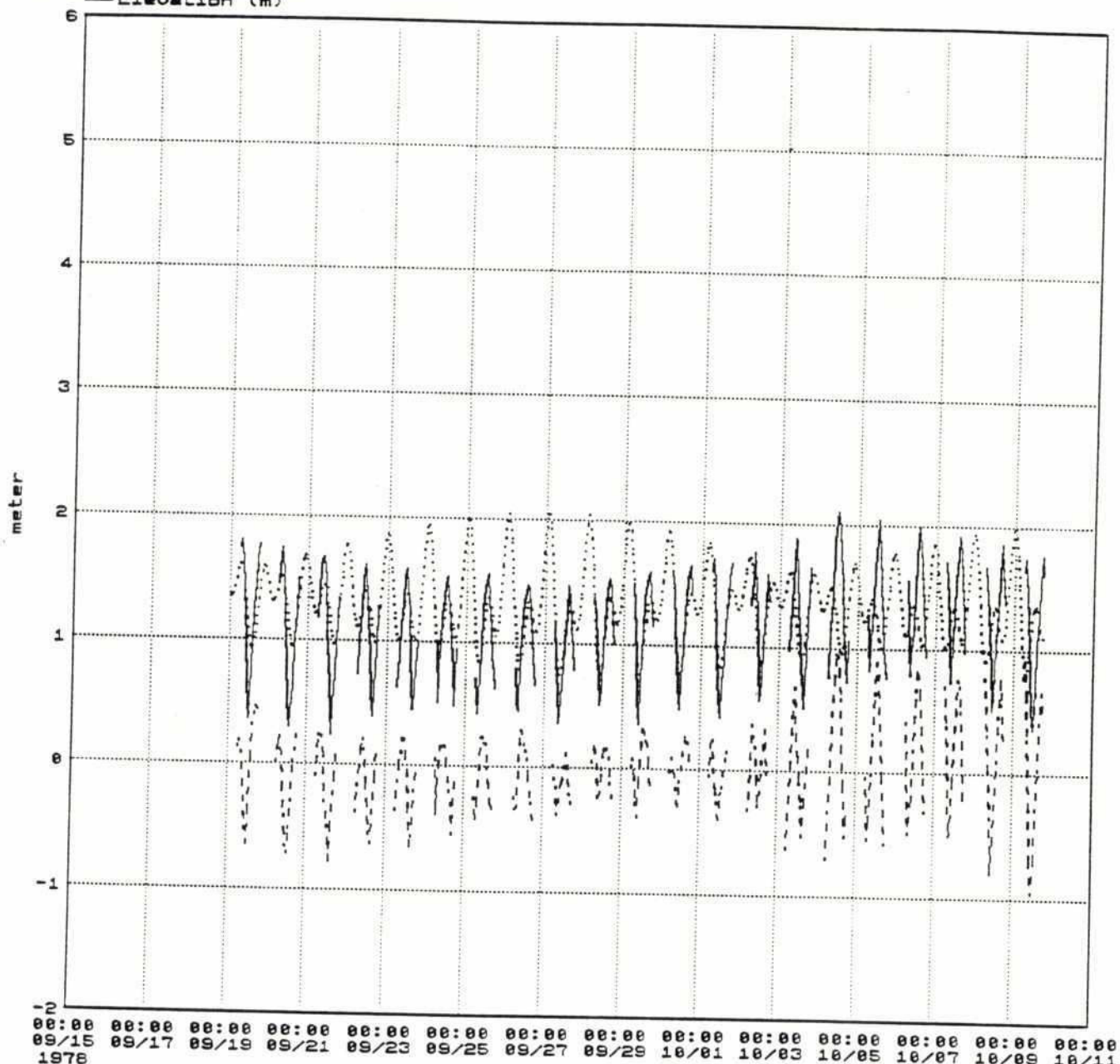
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o78 name : skhe4 User: mnr Sun Dec 16 1998	October 1978 Khepupara Measurements	Dwg. No.  4.64





<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o78 name : smon4 User: mnr Sun Dec 16 1998	October 1978 Mongla Measurements	Dwg. No.  4.65

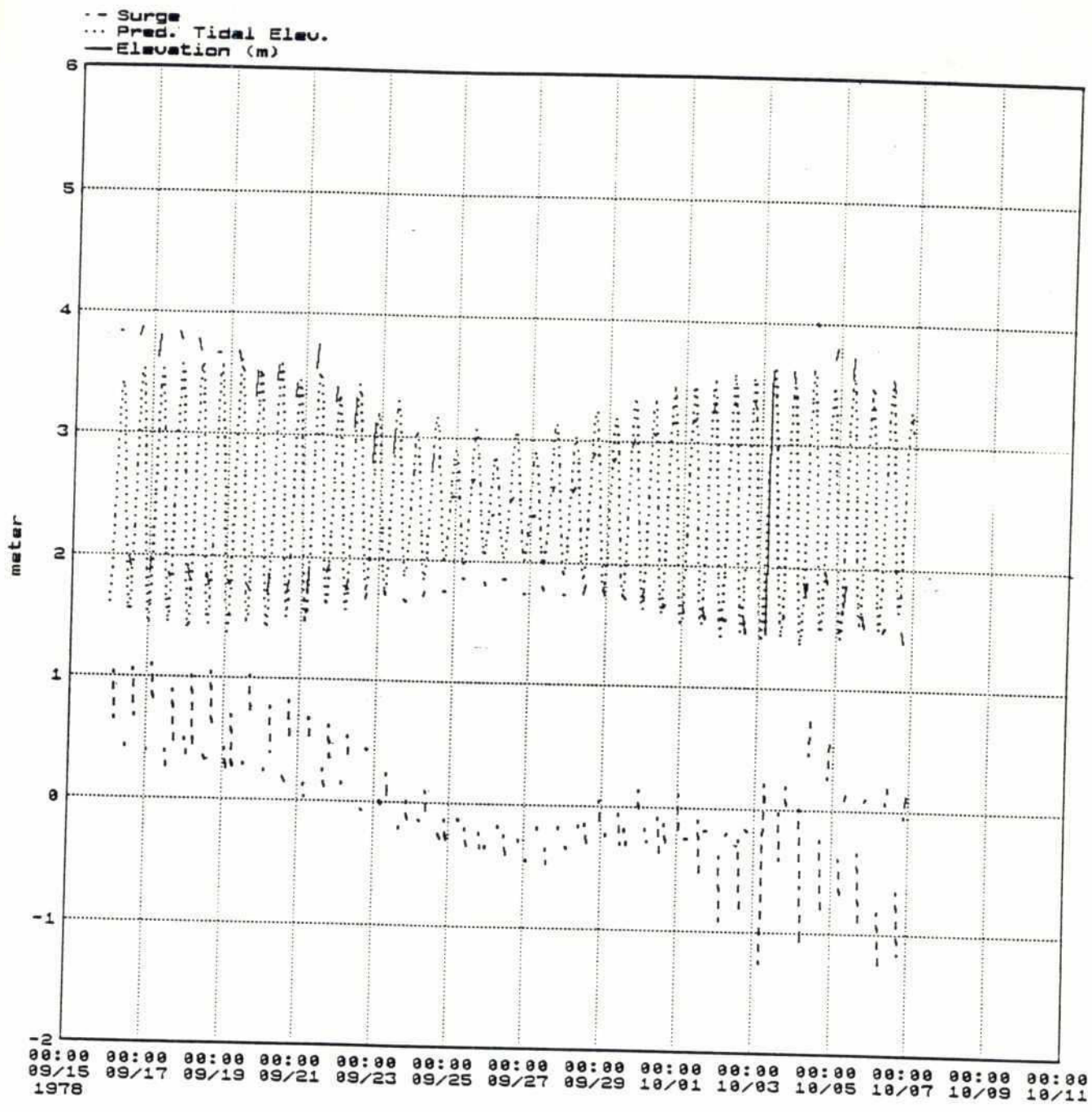
-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o78 name : spat4 User: mnr Sun Dec 16 1990	October 1978 Patuakhali Measurements	Dwg. No.  4.66



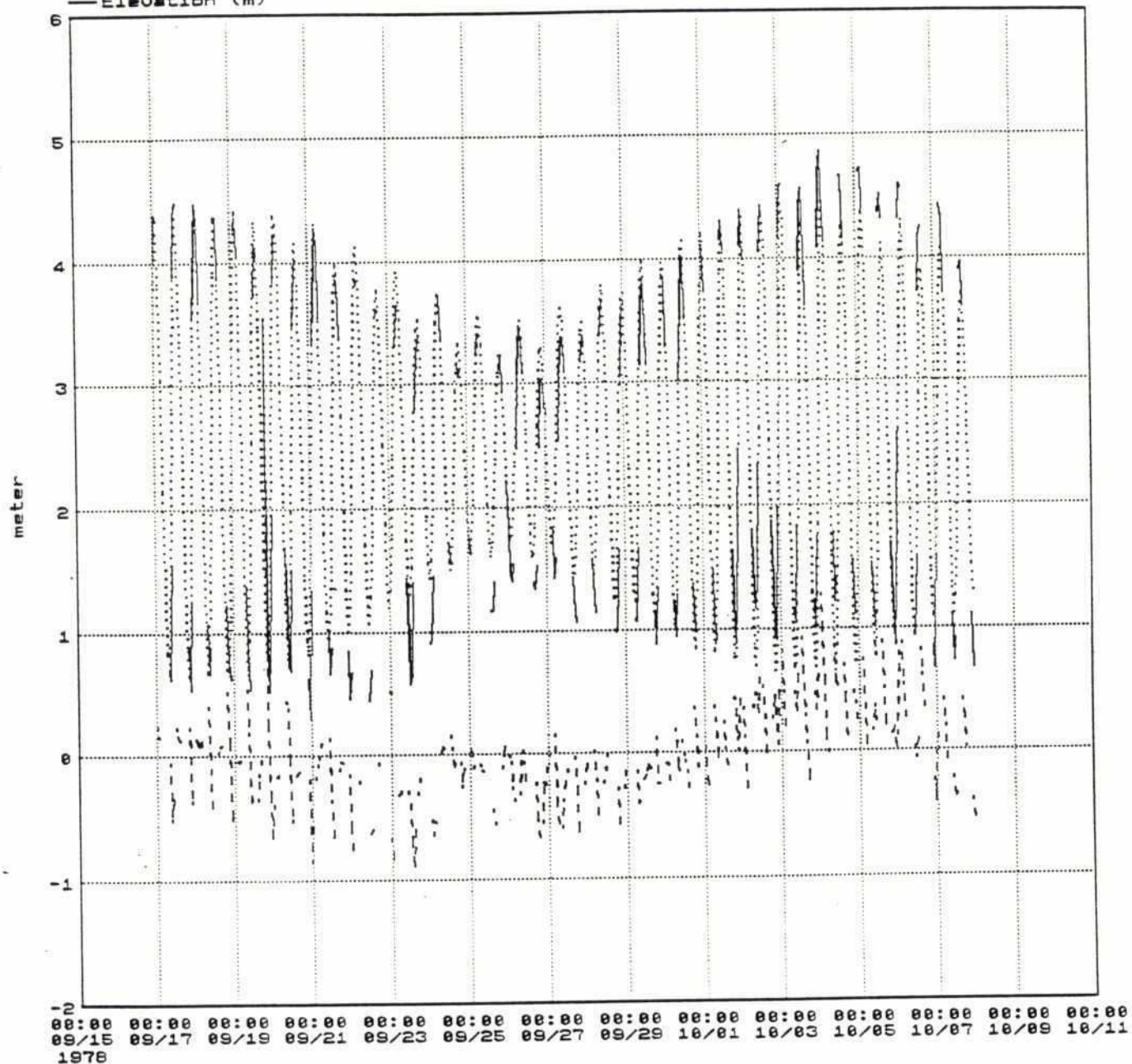
280  
280



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o78 name : sram4 User: mnr Sun Dec 16 1990	October 1978 Ramdaspur Measurements	Dwg. No.  4.67

280

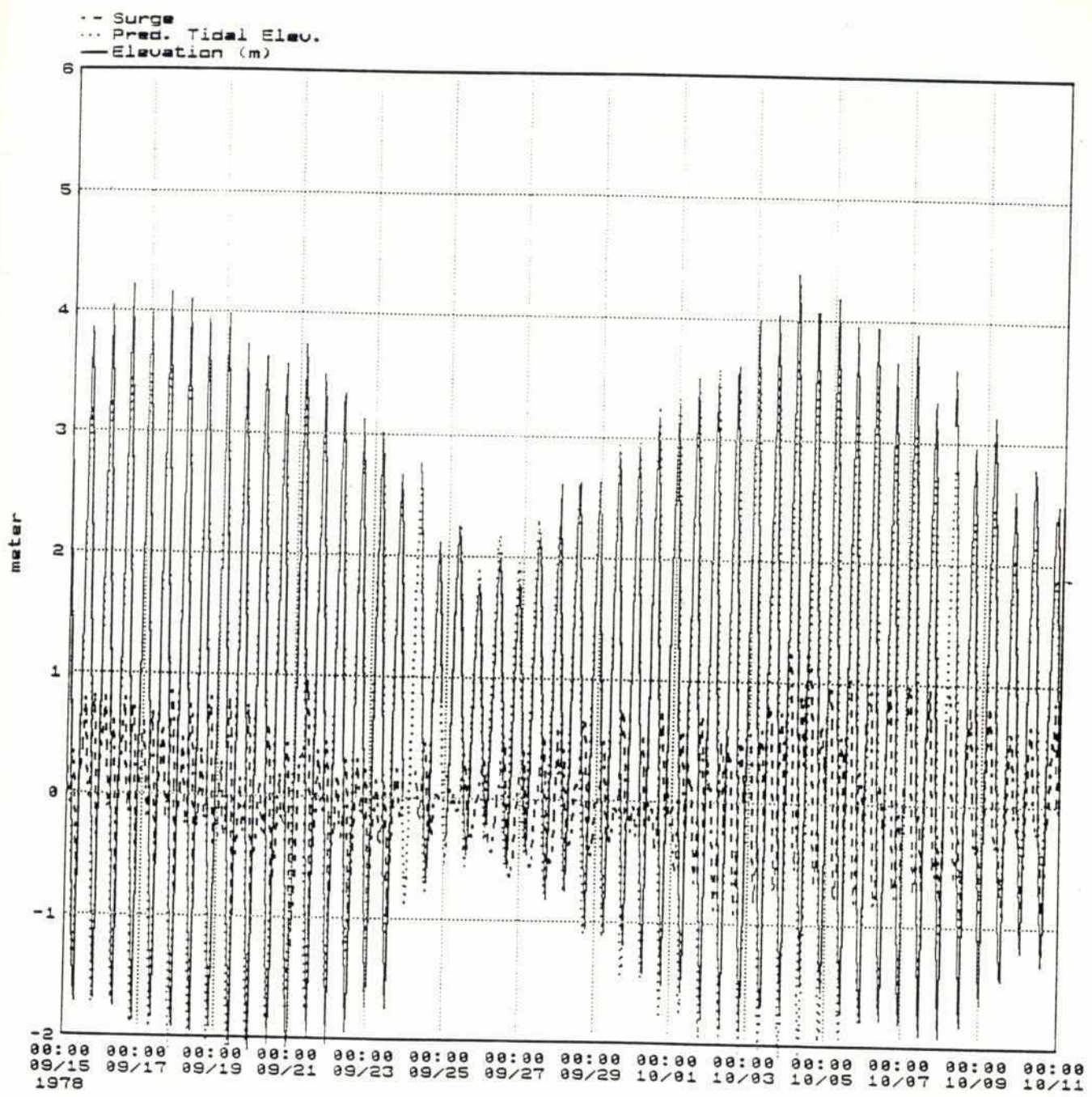
-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: p78 name : ssad4 User: mnr Sun Dec 16 1990	October 1978 Sadarghat (CTG) Measurements	Dwg. No.  4.68

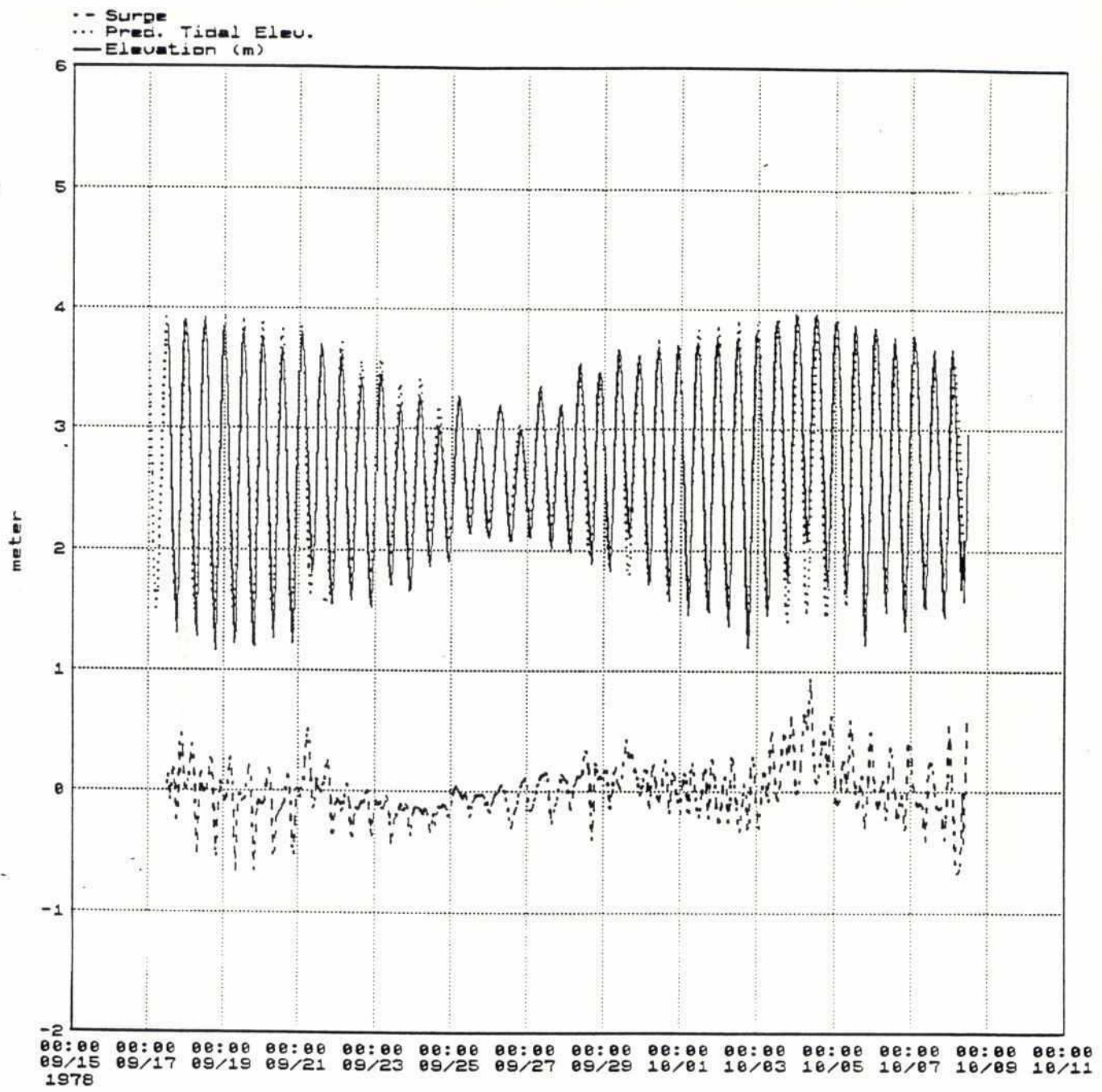


222



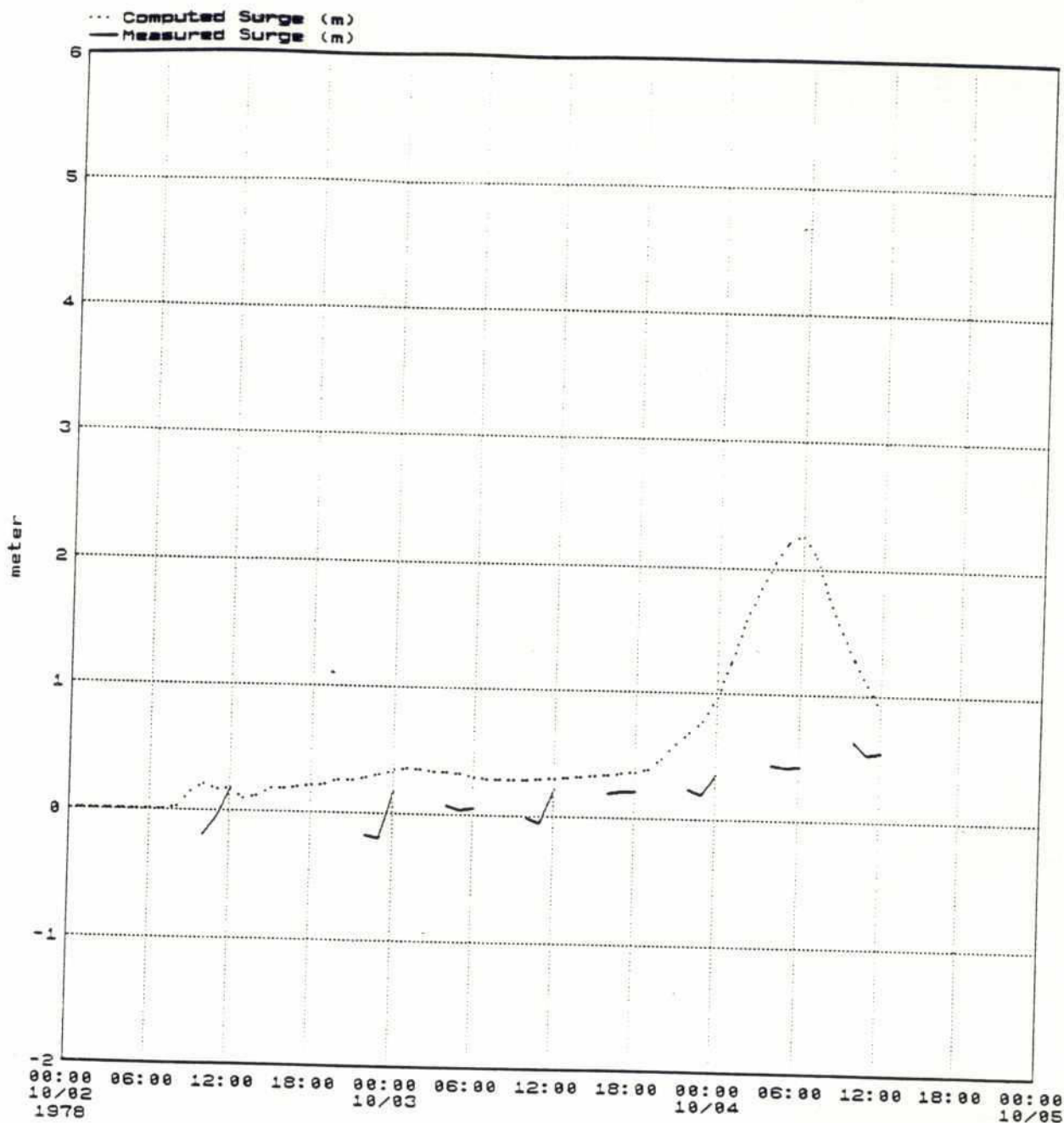
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o78 name : ssan4 User: mnr Sun Dec 16 1990	October 1978 Sandwip Measurements	Dwg. No.  4.69

202



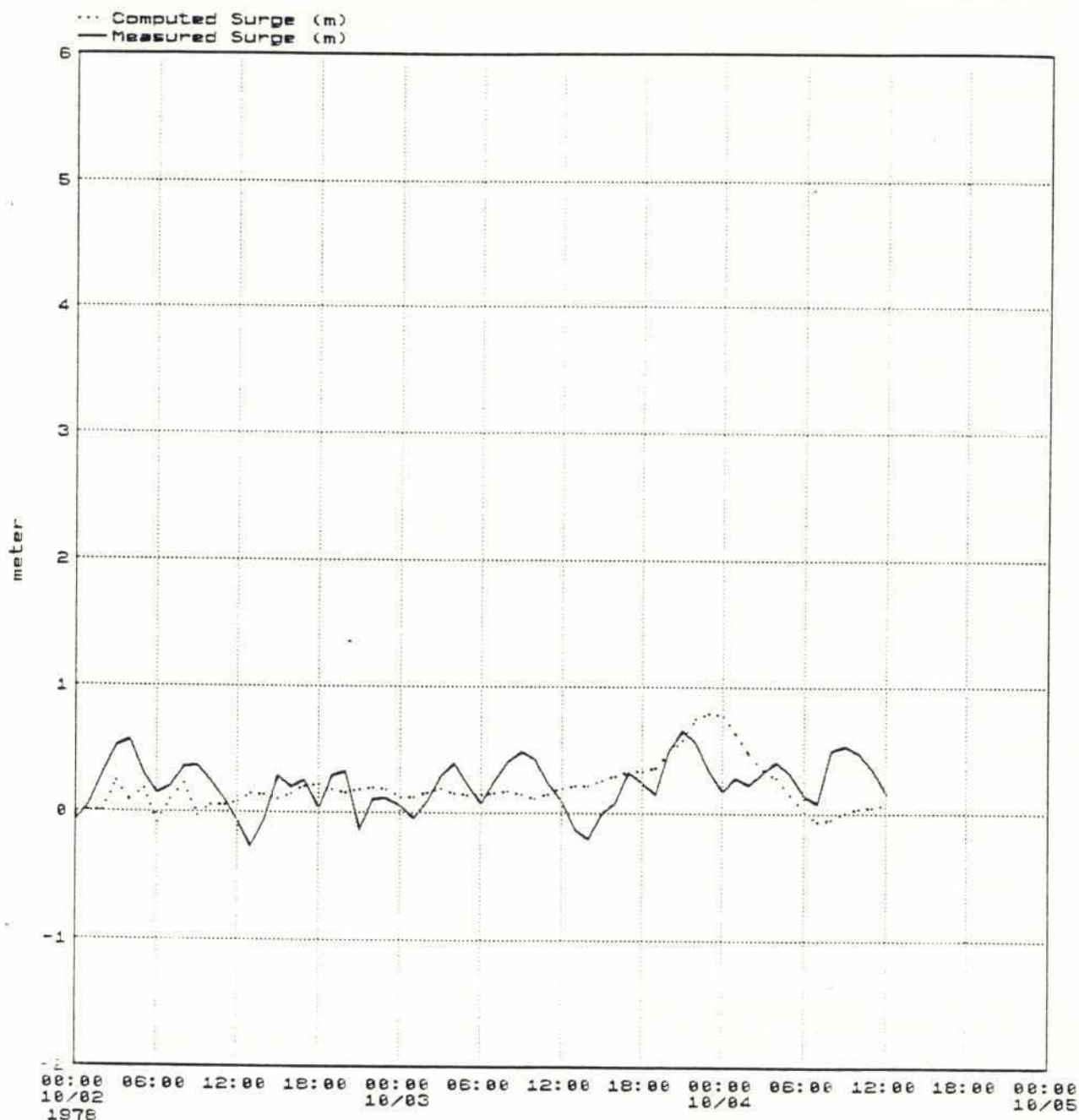
<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File:            family: o78            name : ssun4            User: mnr            Sun Dec 16 1990</p>	<p>October 1978            Sunderikota            Measurements</p>	<p>Dwg. No.             4.70</p>





MIKE21	Cyclone Protection Project II	
File: family: o78 name : cbar4 User: mnr Sun Dec 16 1990	October 1978 Barisal Measured and computed surge	Dwg. No.  4.71

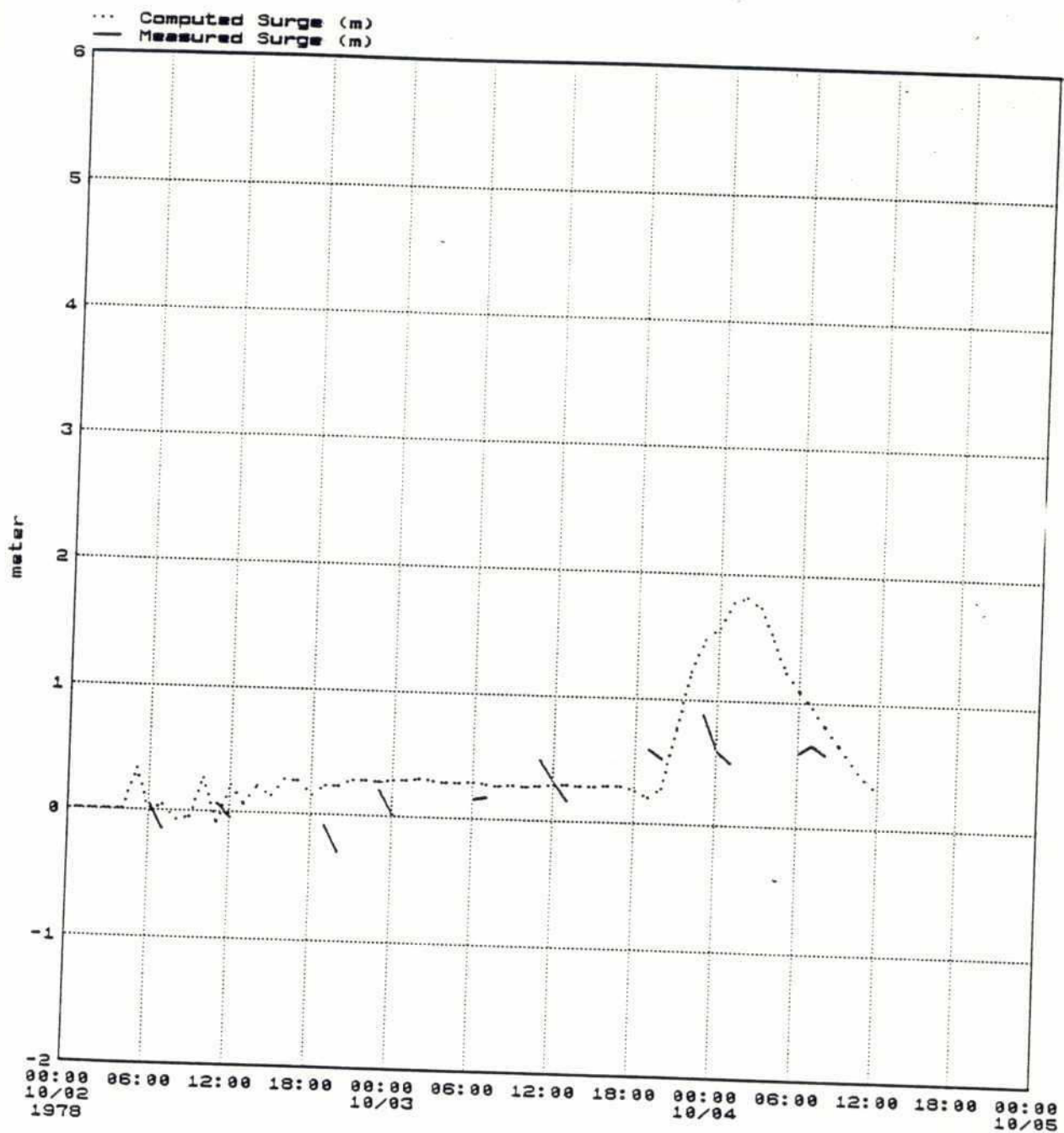
208



<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: o78 name : ccox4 User: mnr Sun Dec 16 1990</p>	<p>October 1978 Coxs Bazar Measured and computed surge</p>	<p>Dwg. No.  4.72</p>

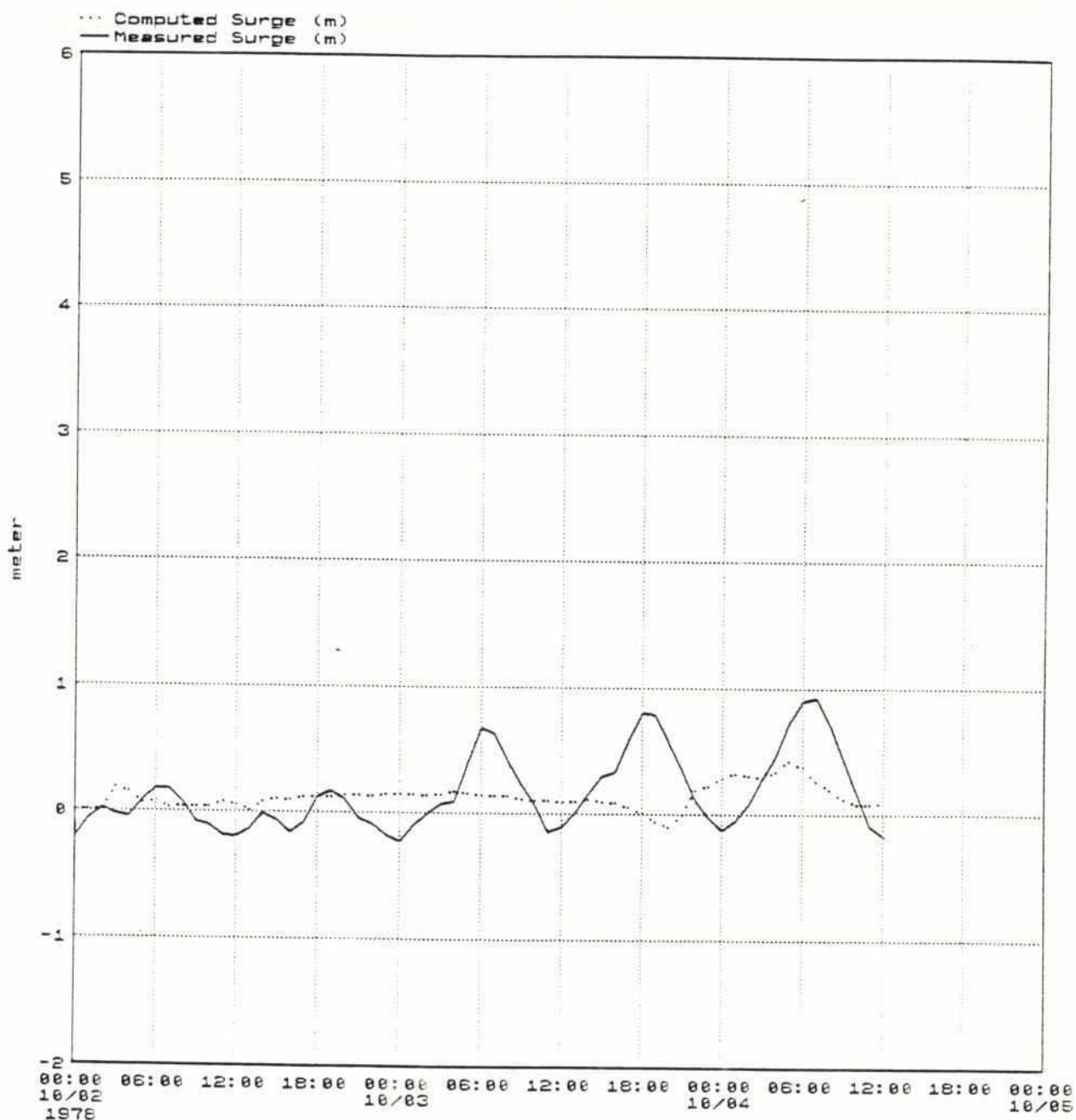


200



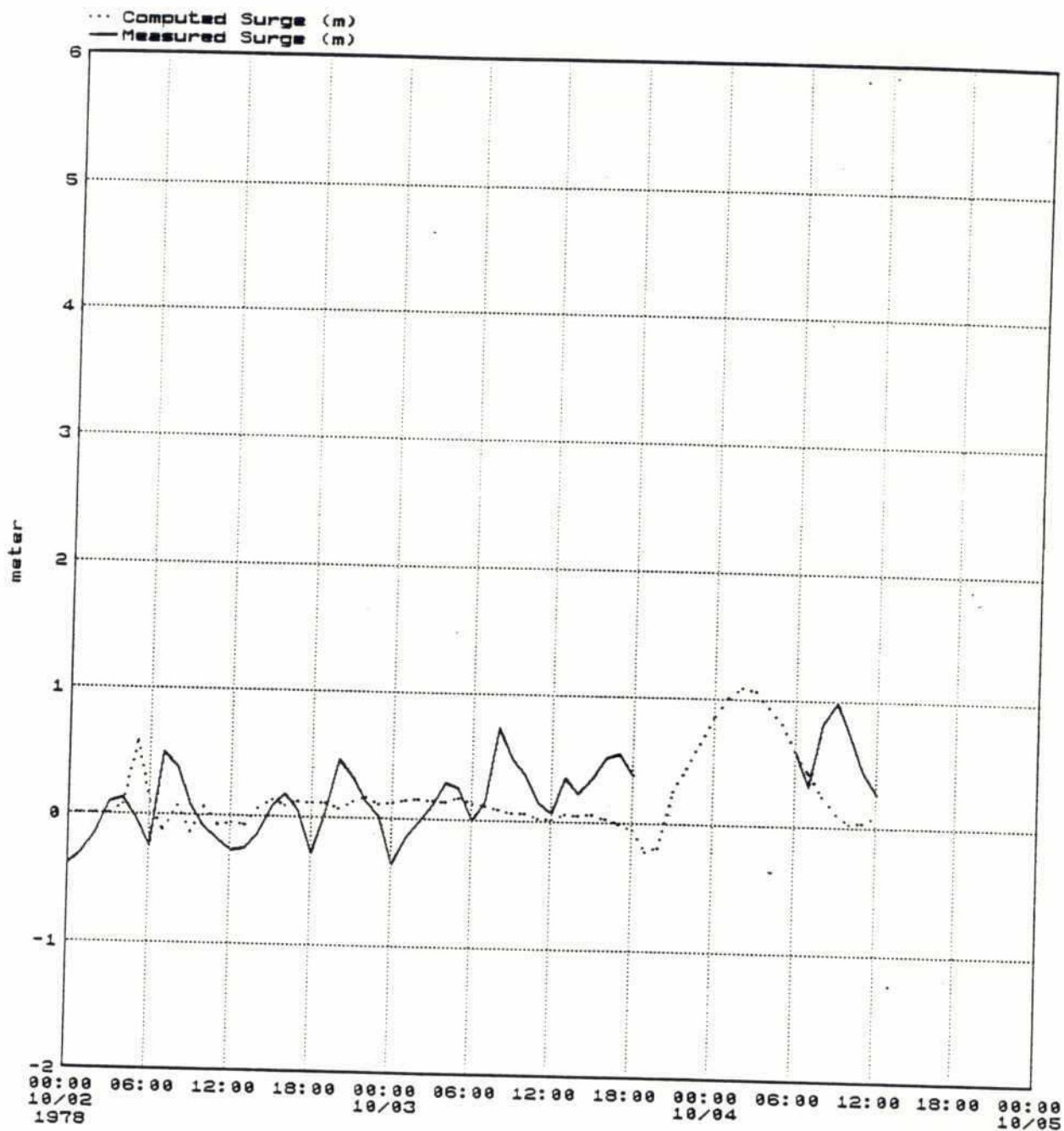
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o78 name : cgal4 User: mnr Sun Dec 16 1990	October 1978 Galachipa Measured and computed surge	Dwg. No.  4.73

283



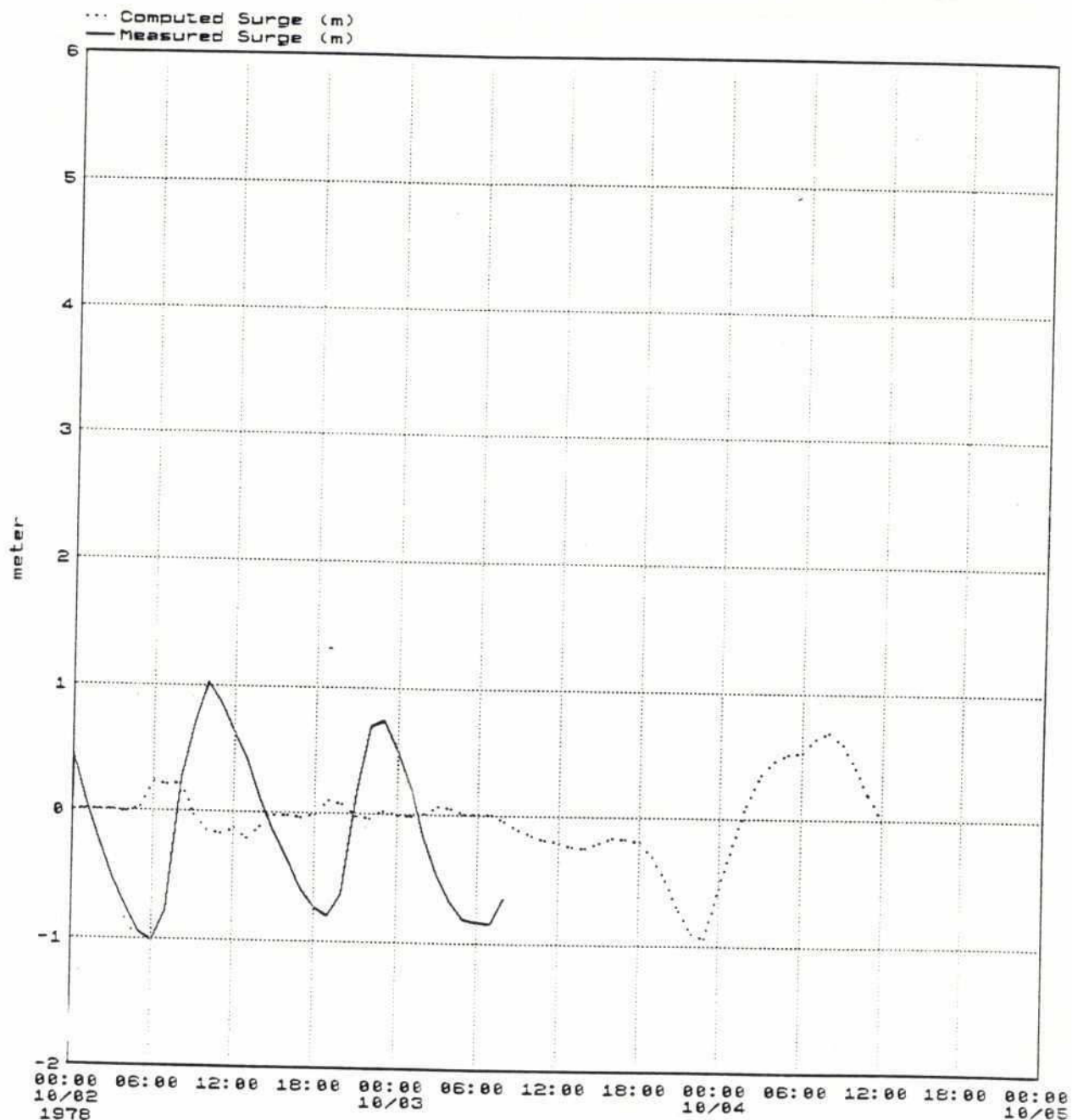
<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: o78 name : chir4 User: mnr Sun Dec 16 1990</p>	<p>October 1978 Hiron Point Measured and computed surge</p>	<p>Dwg. No.  4.74</p>





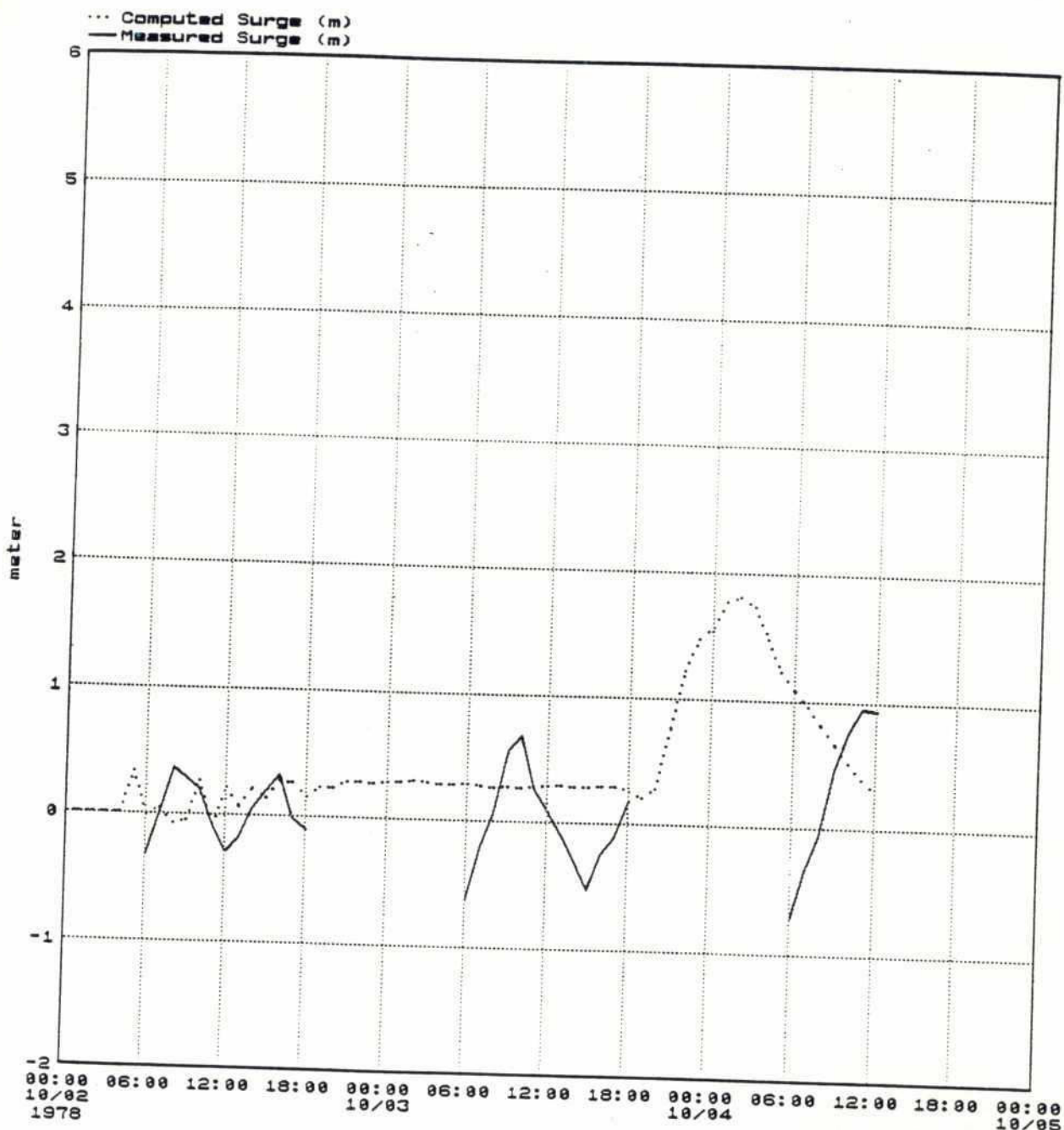
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: o78 name : ckhe4 User: mnr Sun Dec 16 1990	October 1978 Khepupara Measured and computed surge	Dwg. No.  4.75

224



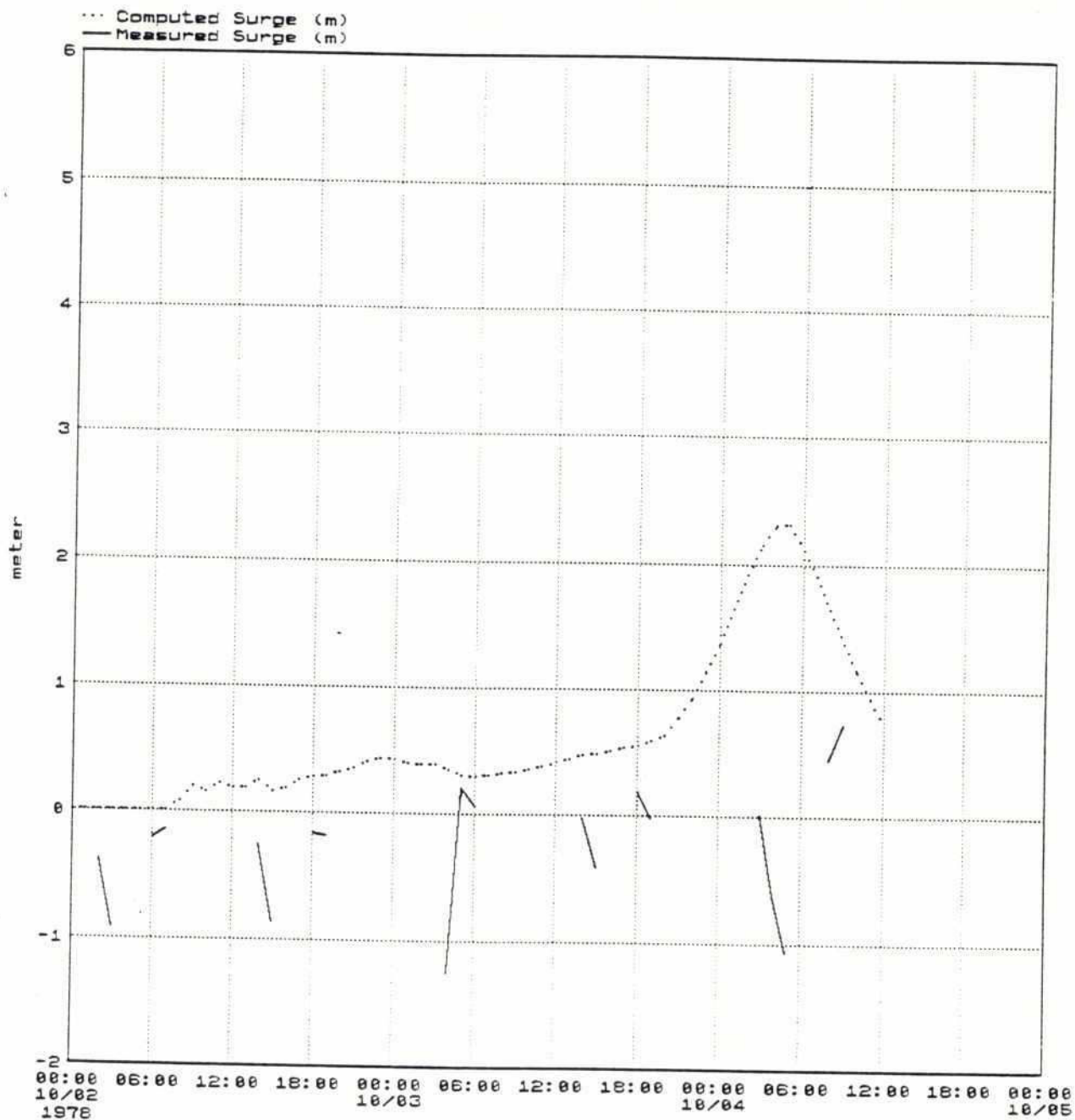
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: c78 name : cmon4 User: mnr Sun Dec 16 1990	October 1978 Mongla Measured and computed surge	Dwg. No.  4.76





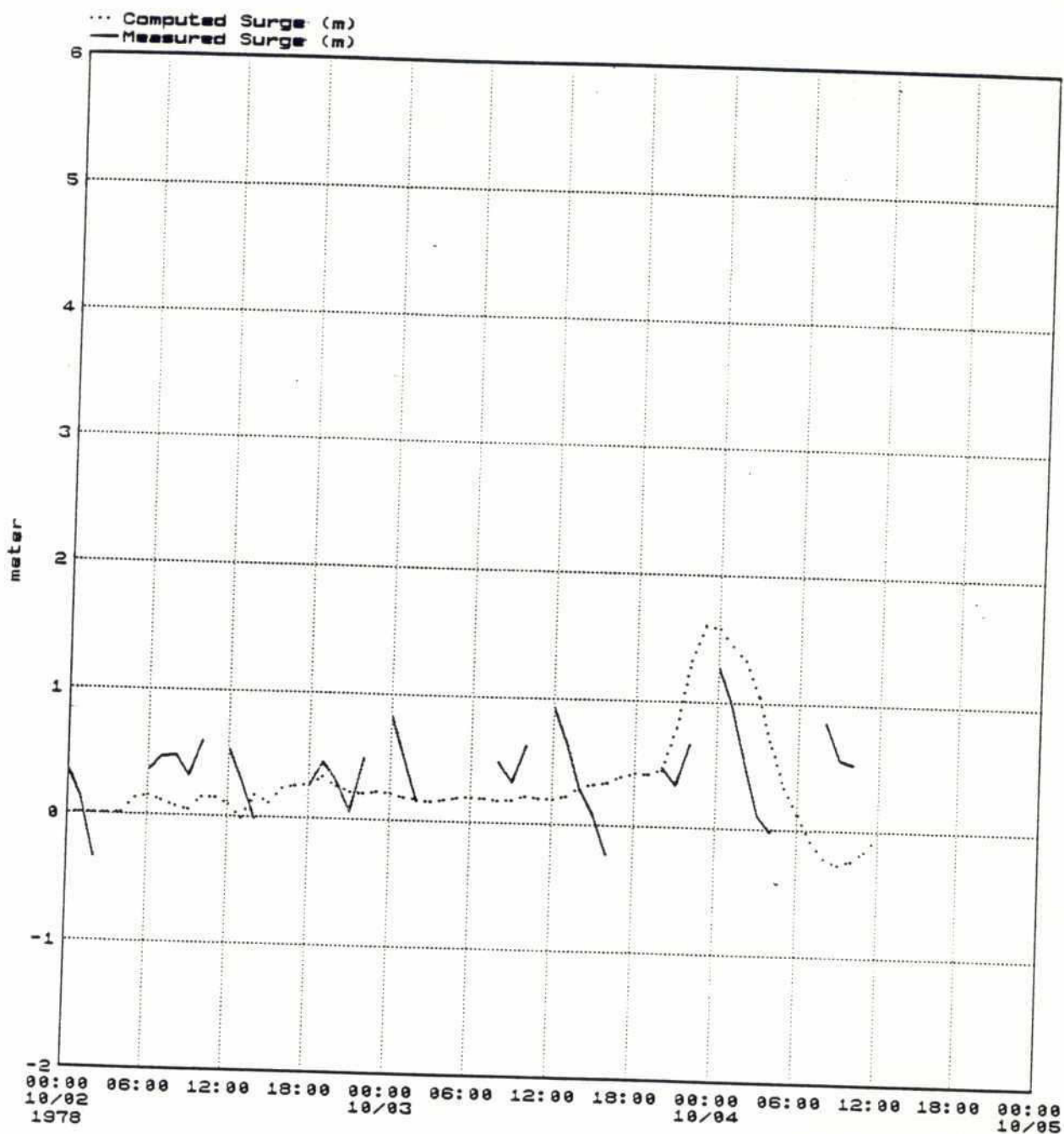
<b>MIKE21</b>  File: family: o78 name : cpat4 User: mnr Sun Dec 16 1990	<b>Cyclone Protection Project II</b>  October 1978 Patuakhali Measured and computed surge		Dwg. No.  4.77
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248



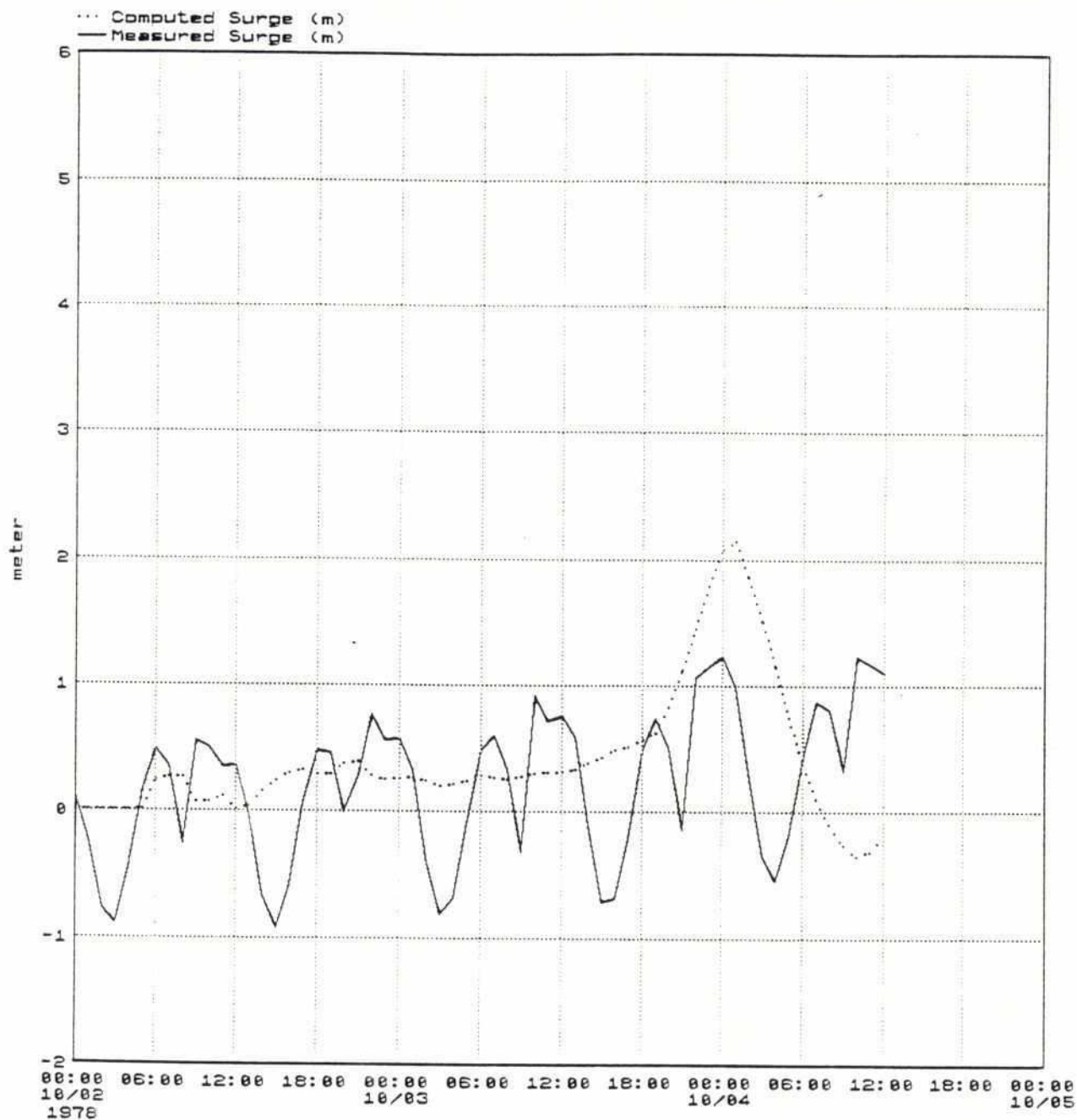
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o78 name : cram4 User: mnr Sun Dec 16 1990	October 1978 Ramdasapur measured and computed surge	Dwg. No.  4.78





<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o78 name : csad4 User: mnr Sun Dec 16 1990	October 1978 Sadarghat (CTG) Measured and computed surge	Dwg. No.  4.79

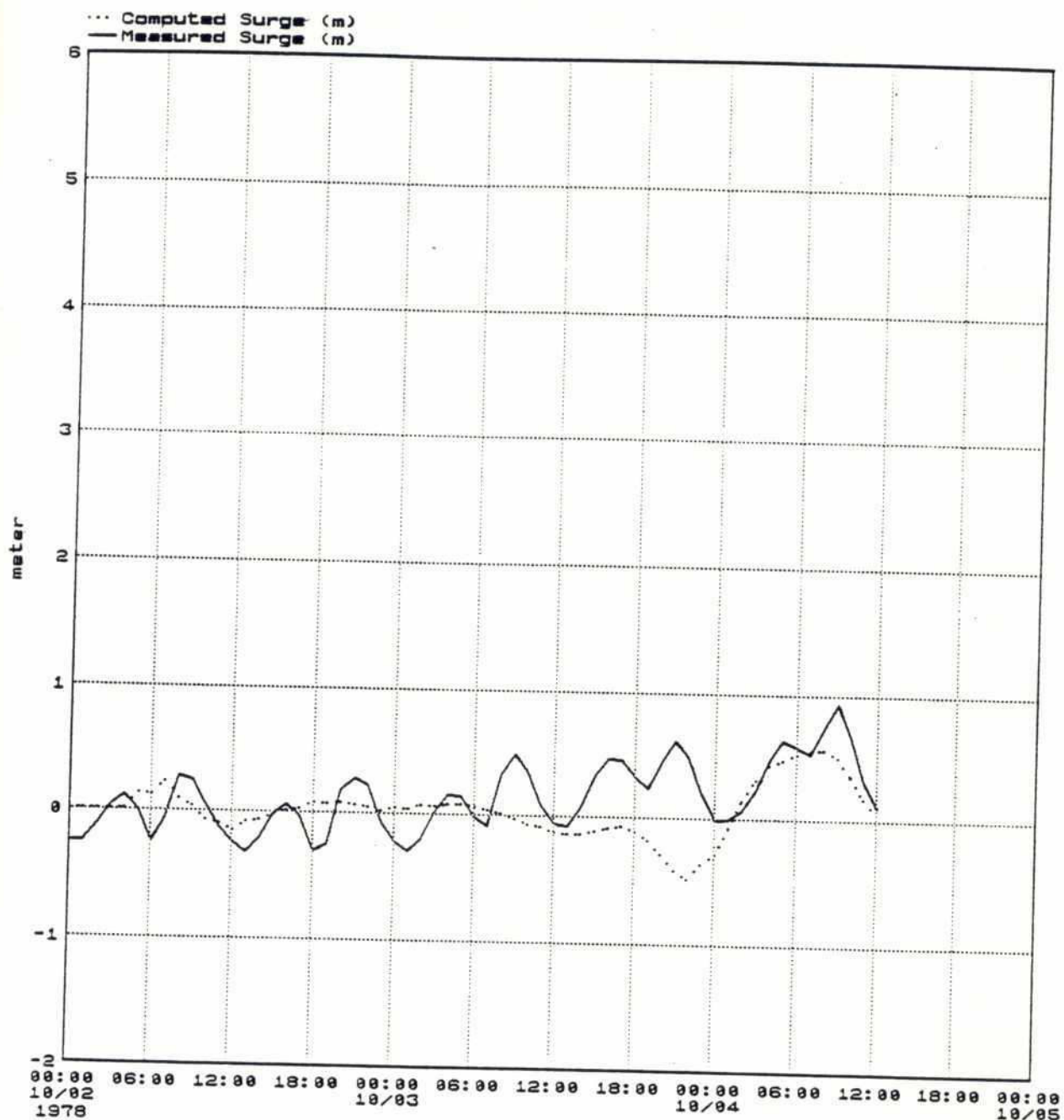
202



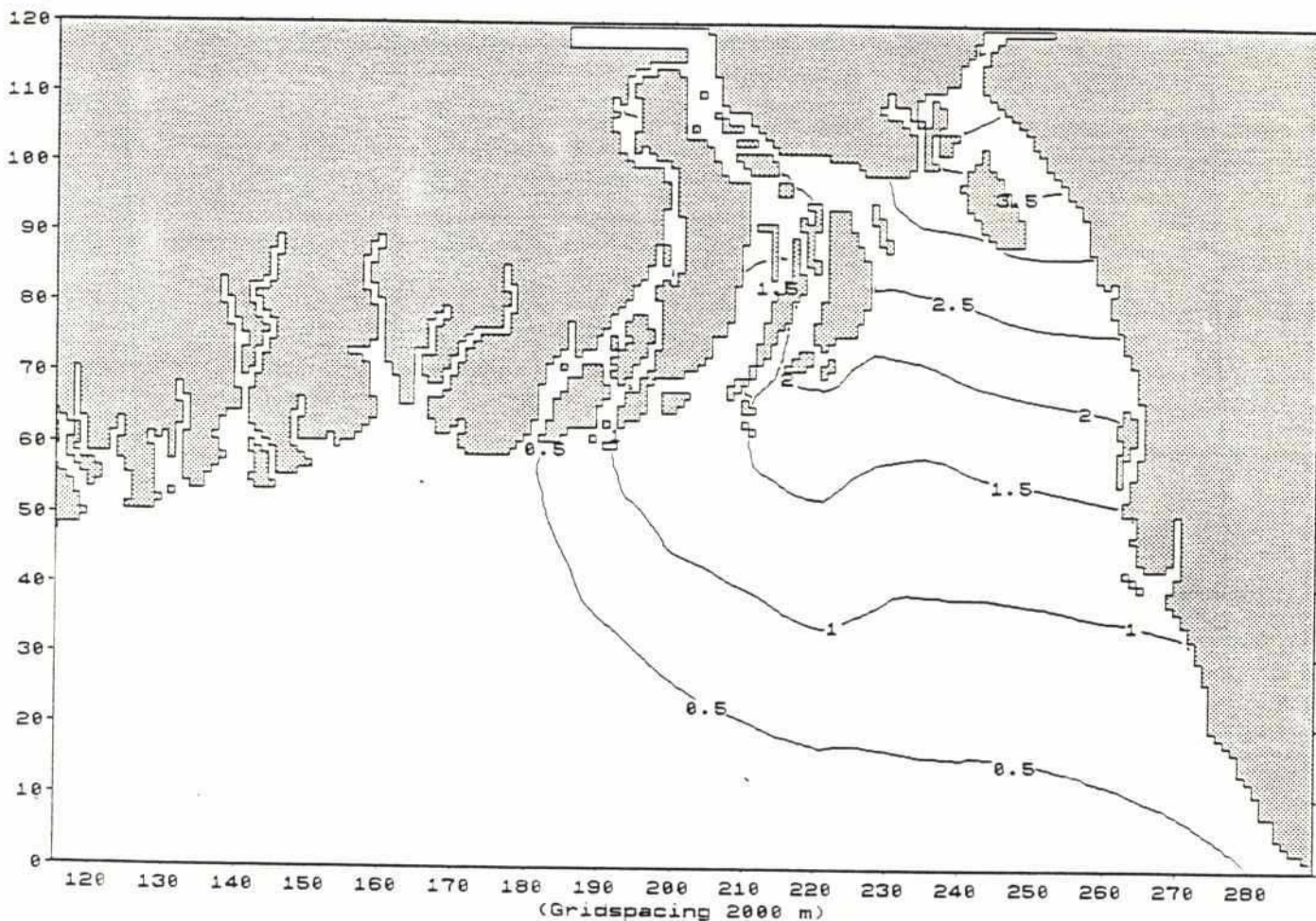
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o78 name : csan4 User: mnr Sun Dec 16 1990	October 1978 Sandwip Measured and computed surge	Dwg. No.  4.80



056

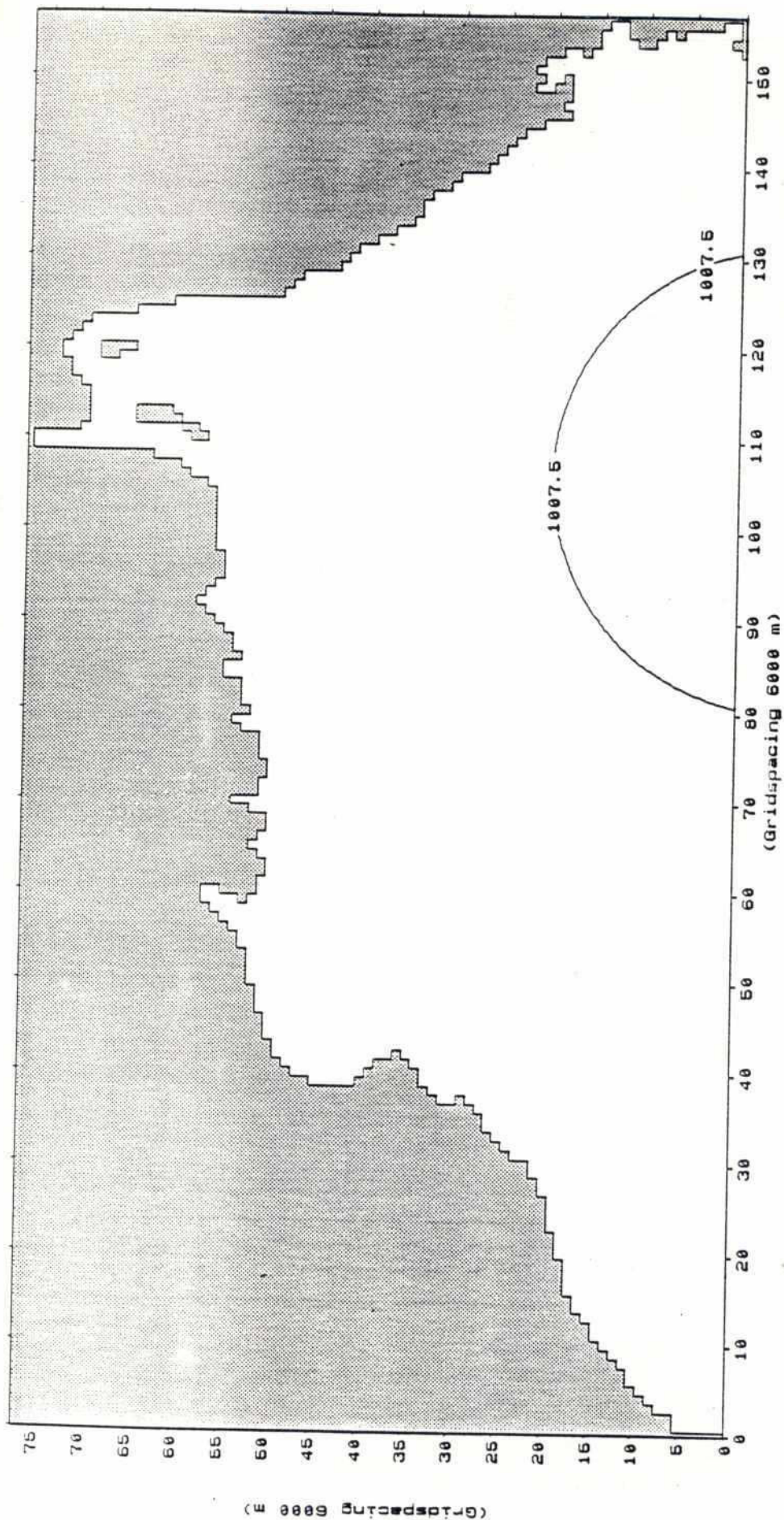


<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: o78 name : csun4 User: mnr Sun Dec 16 1990	October 1978 Sundarikota Measured and computed surge	Dwg. No.  4.81



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: 083 name : imax Scale: 1:2 mill Thu Nov 29 1990	October 1983 Cyclone Simulation Results, Intermediate Model Maximum Surge Levels	Dwg. No.  4.82



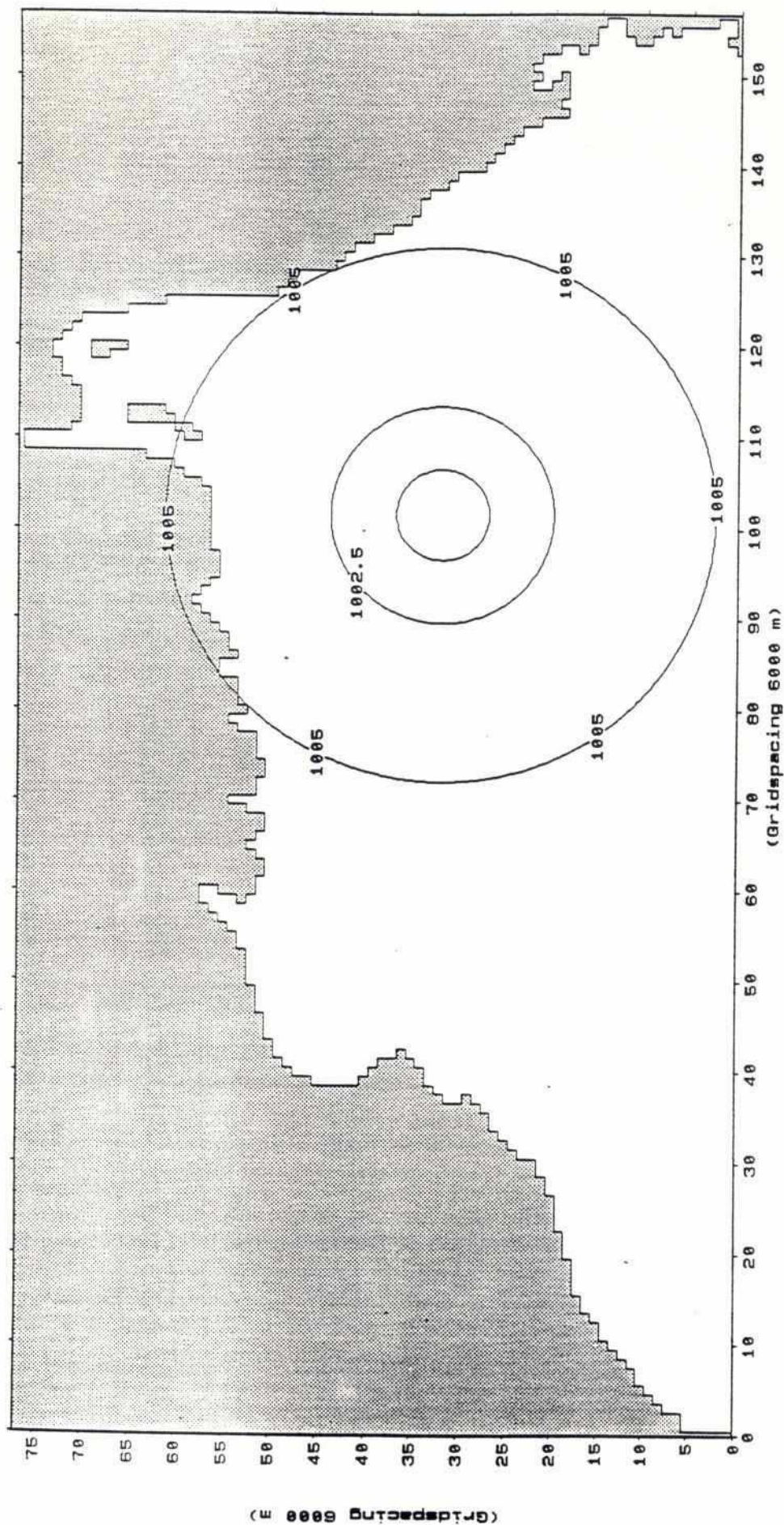


1983/10/14 12:00:00

<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: 083 name : rwind Scale: 1:4 mill Thu Oct 29 1983	October 1983 Cyclone Pressure Field (mb)	Depth (m) 4.83

230





1983/10/15 00:00:00

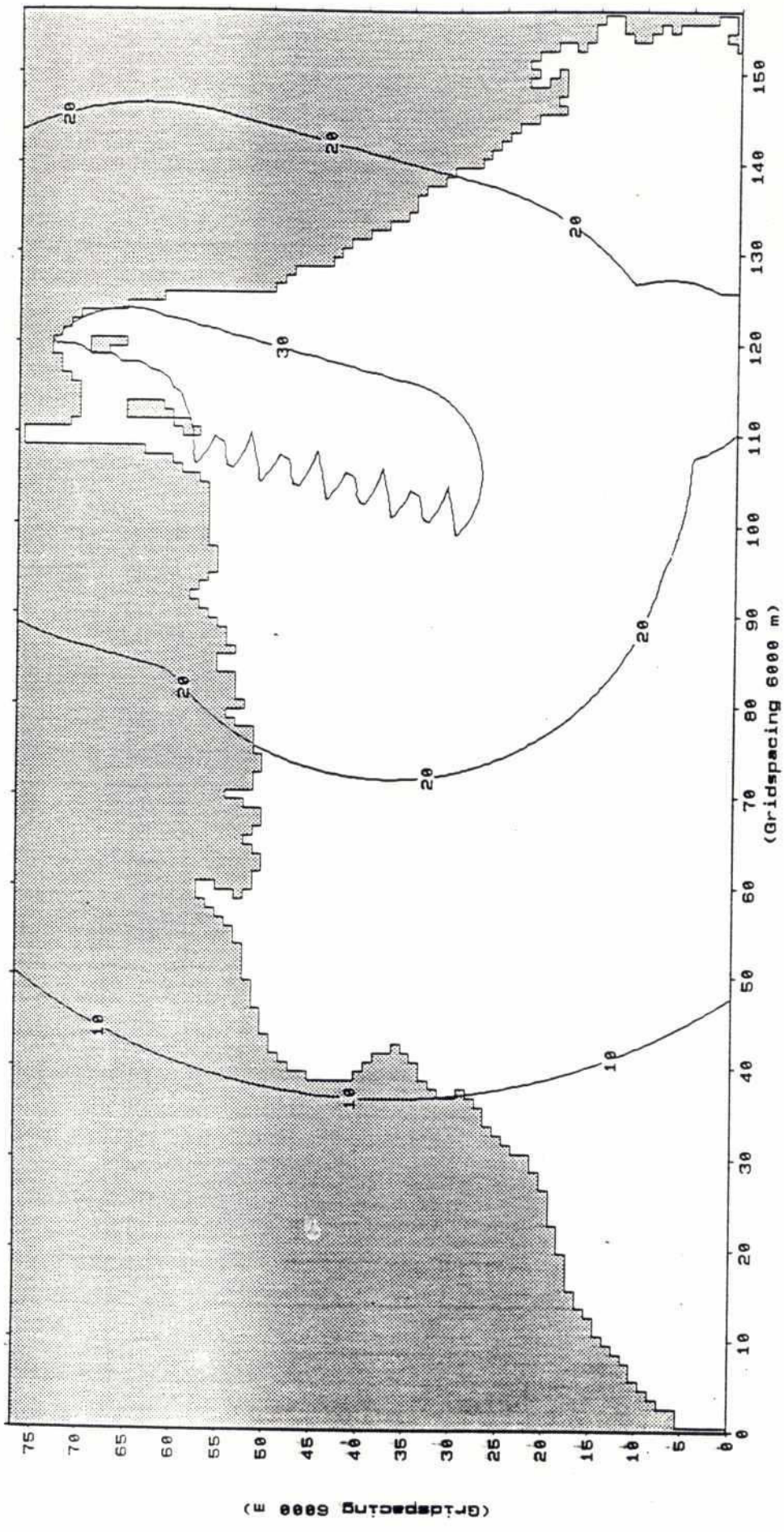
MIKE21	File: family: o83 name : rwind Scale: 1:4 mill Thu Nov 29 1990
Cyclone Protection Project II	October 1983 Cyclone Pressure Field (mb) Dwg. No. 4.84





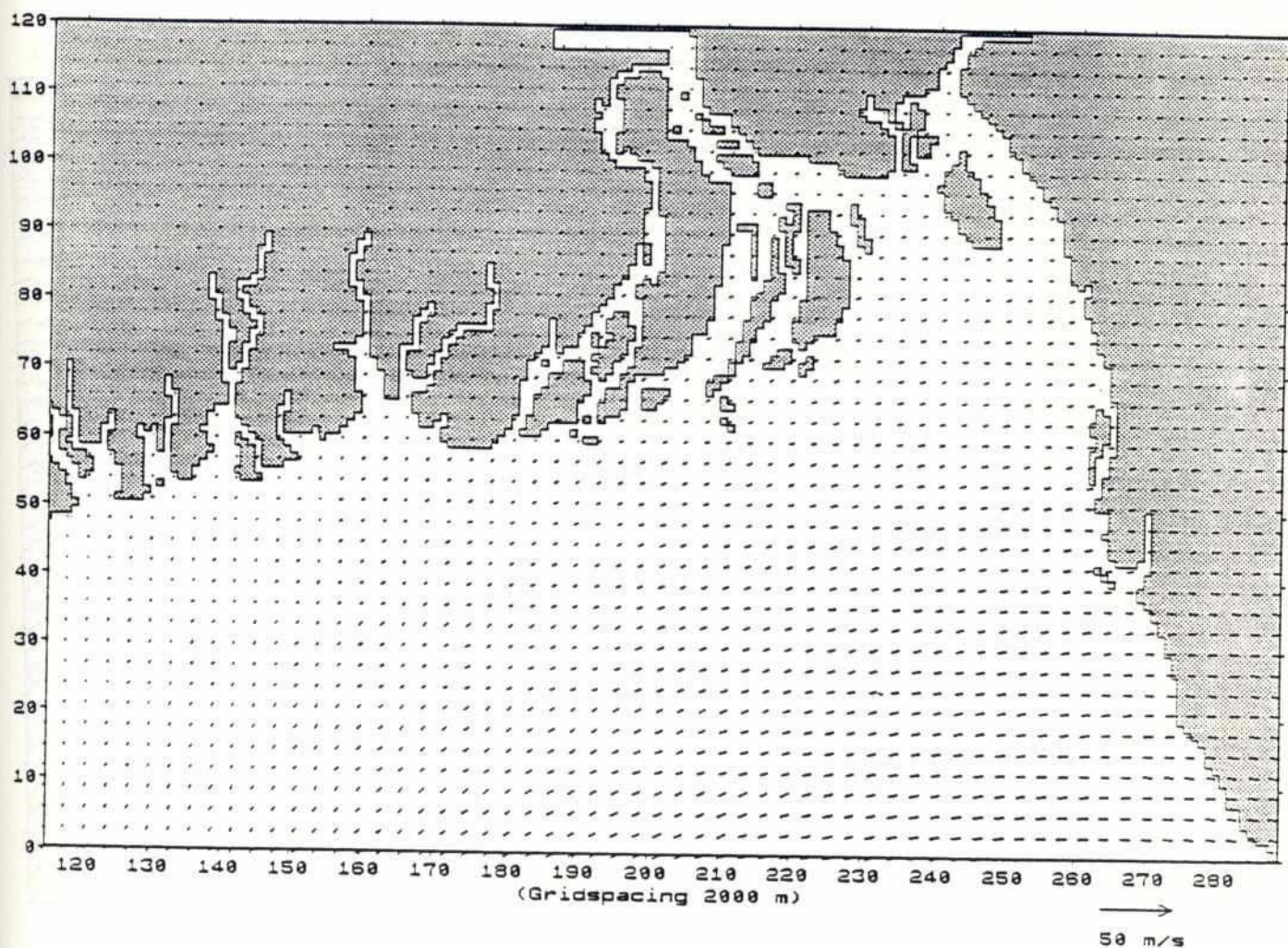


234



<p><b>MIKE21</b></p>	<p><b>Cyclone Protection Project II</b></p>	
<p>File: family: o83 name : rmwind Scale: 1:4 mill Thu Nov 29 1990</p>	<p>October 1983 Maximum occurring Wind Speed (m/s)</p>	<p>Dwg. No.  4.86</p>

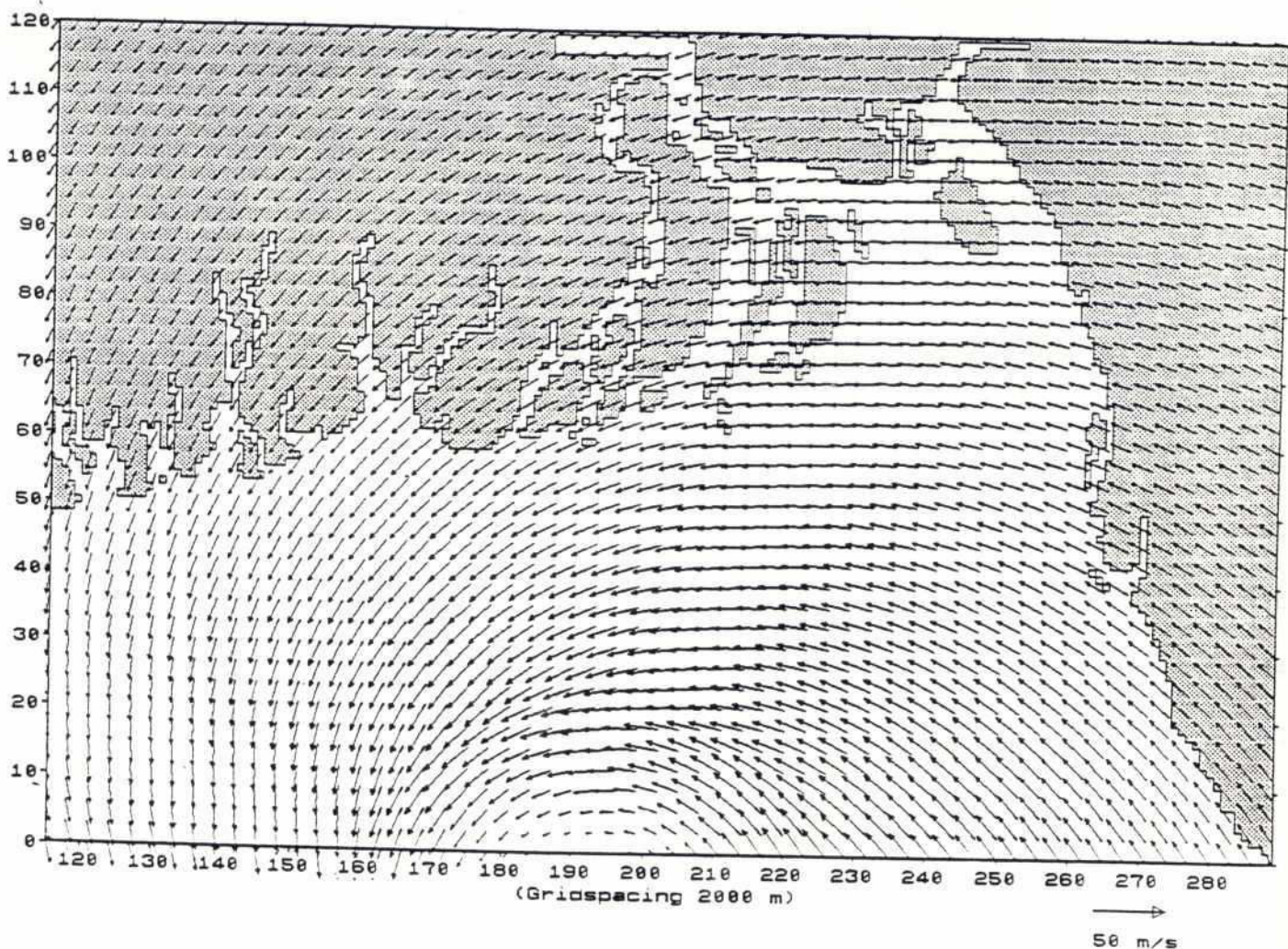




1983/10/14 12:00:00

<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o83 name : iwind Scale: 1:2 mill Thu Nov 29 1990	October 1983 Cyclone Wind Field	Dwg. No.  4.87



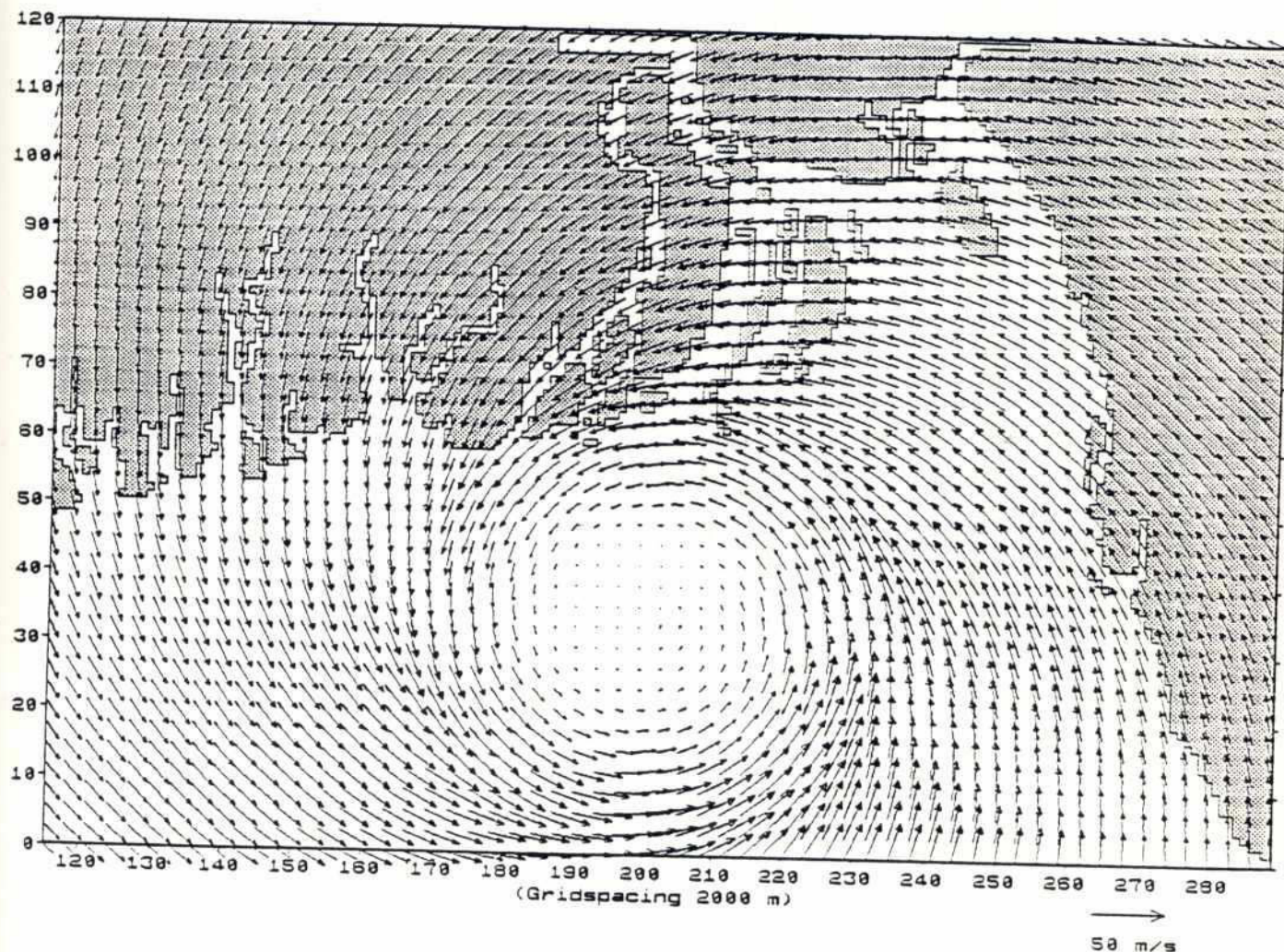


1983/10/15 00:00:00

<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: o83 name : iwind Scale: 1:2 mill Thu Nov 29 1990</p>	<p>October 1983 Cyclone Wind Field</p>	<p>Dwg. No.  4.88</p>



092

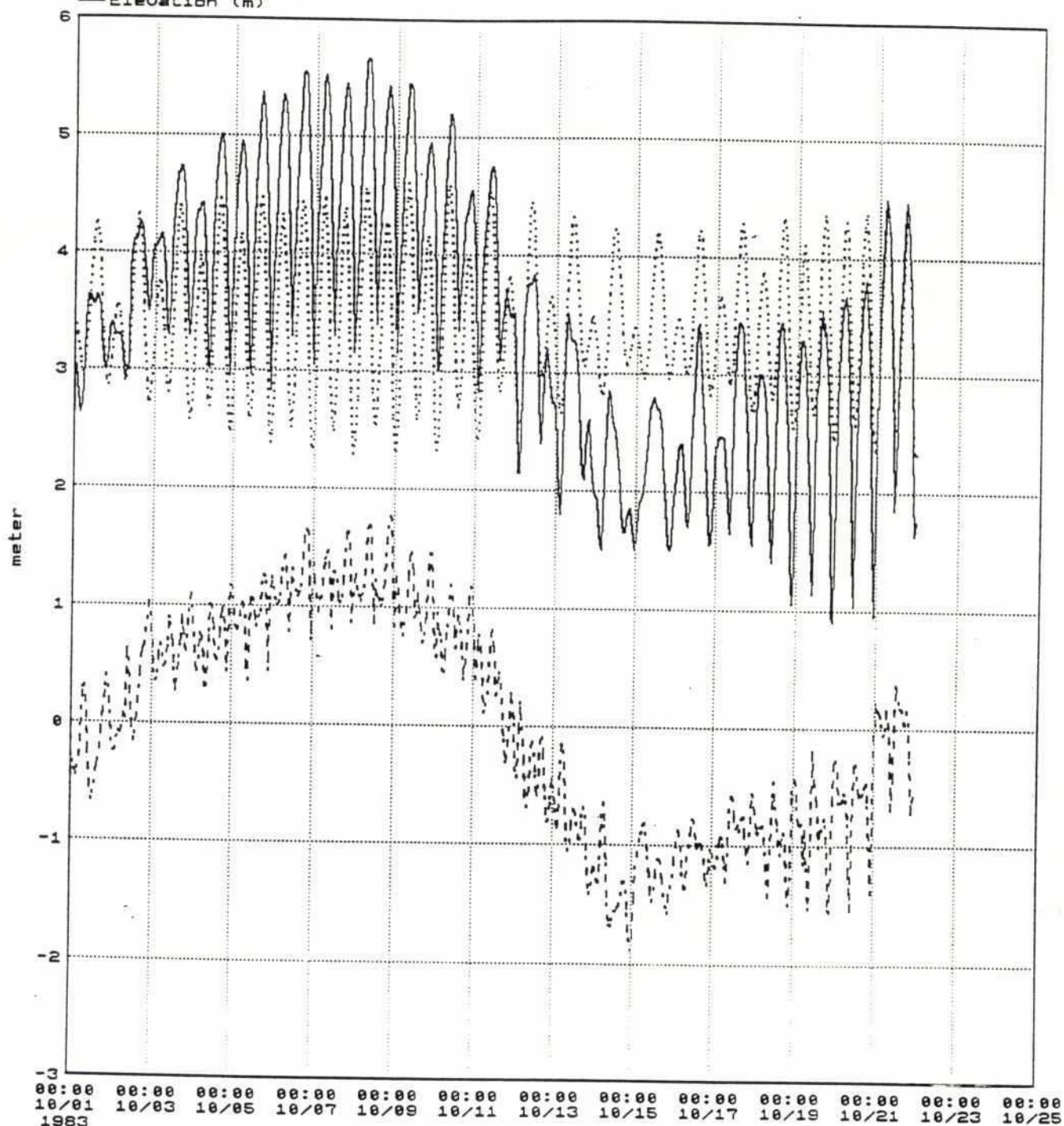


1983/10/15 12:00:00

<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: 083 name : iwind Scale: 1:2 mill Thu Nov 29 1990</p>	<p>October 1983 Cyclone Wind Field</p>	<p>Dwg. No.  4.89</p>

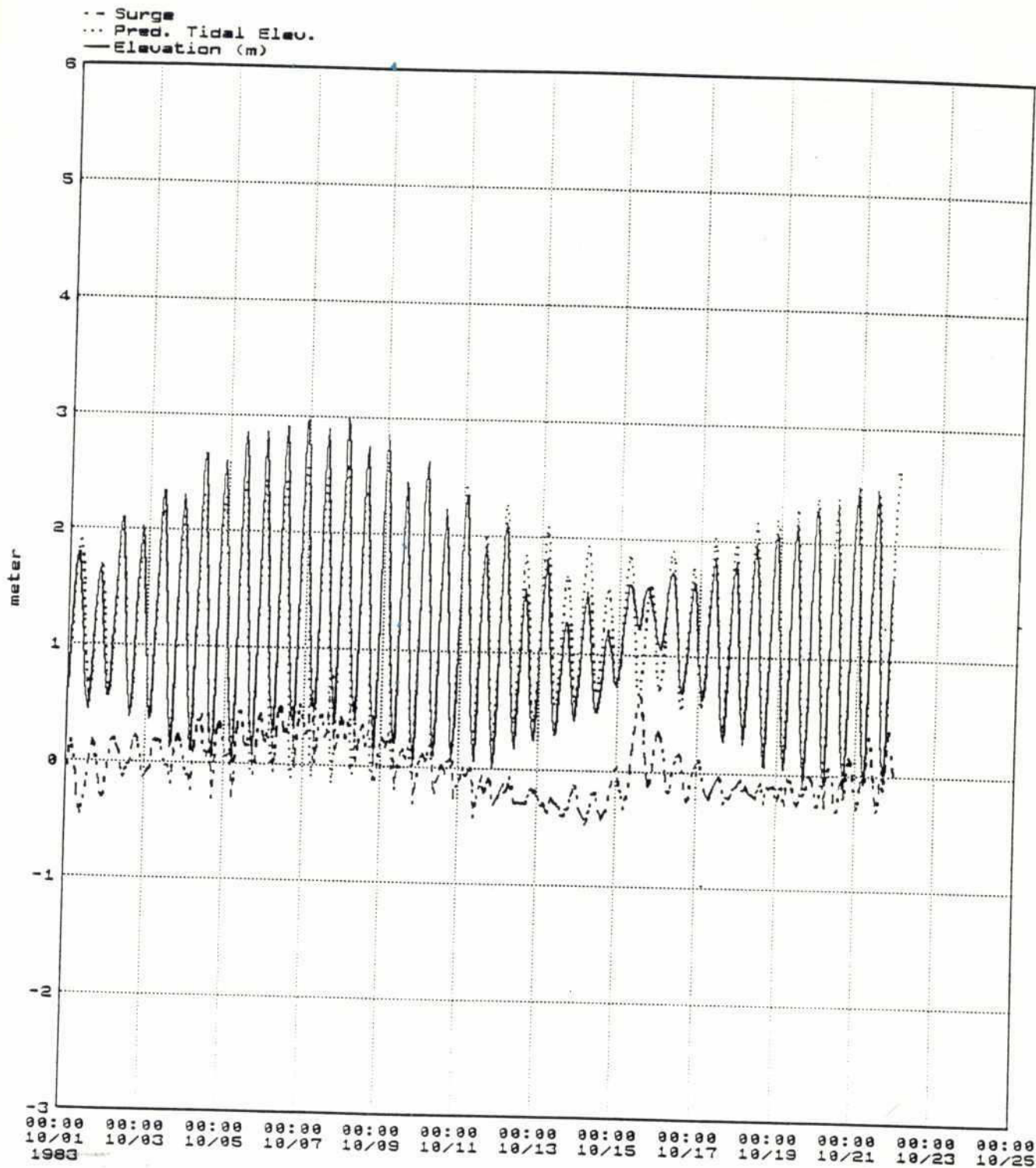
292

-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



MIKE21		Cyclone Protection Project II	
File:			Dwg. No.
family: o83	October 1983		
name : sbar4	Barisal		
User: mnr	Measurements		
Sun Dec 16 1990			4.90

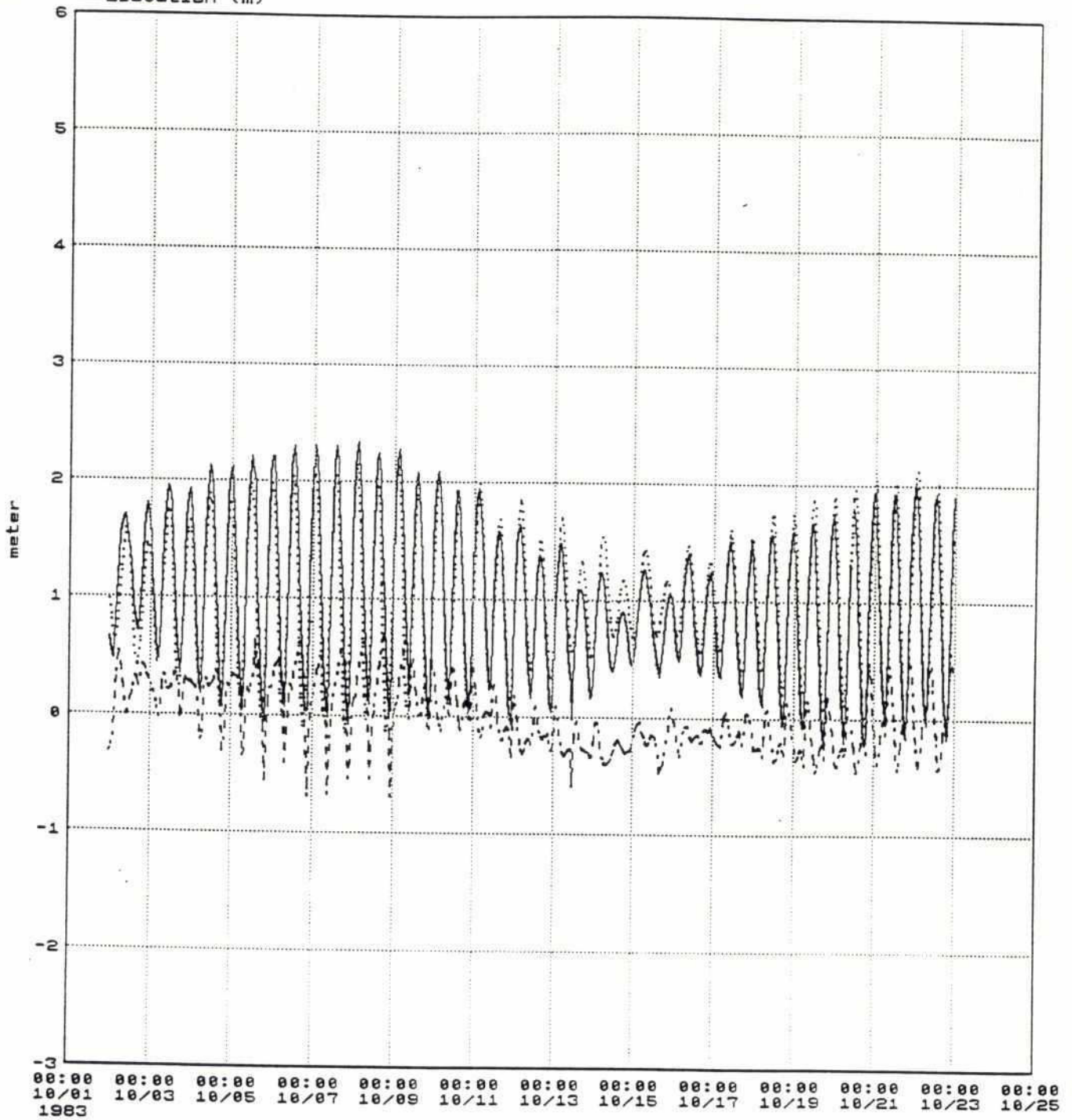




MIKE21		Cyclone Protection Project II	
File:			
Family: o83	October 1983		Dwg. No.
name : scox4	Coxz Bazar		
User: mnr	Measurements		
Sun Dec 16 1990			4.91

298

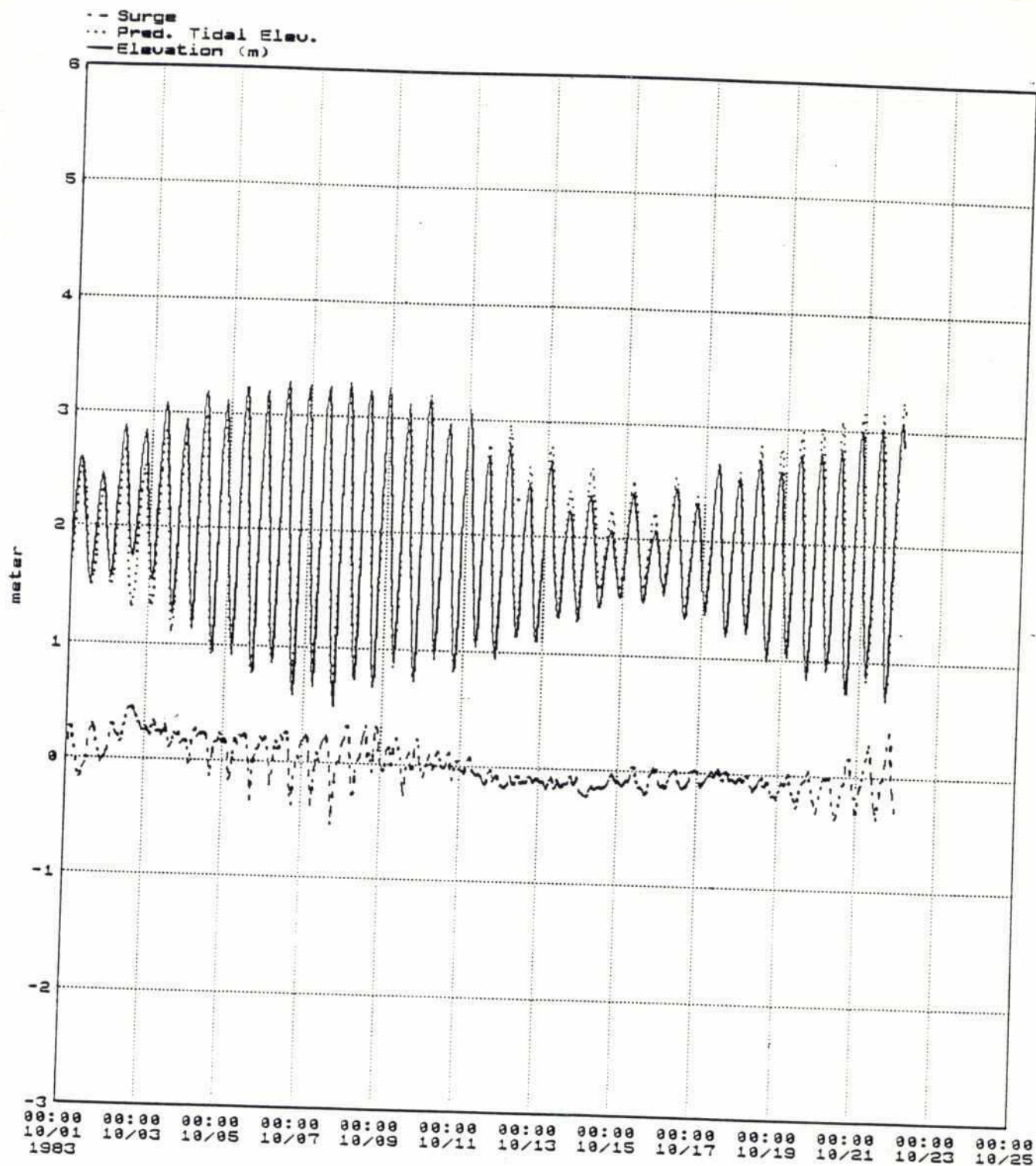
-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o83 name : sgsl4 User: mnr Sun Dec 16 1990	October 1983 Galachipa Measurements	Dwg. No.  4.92

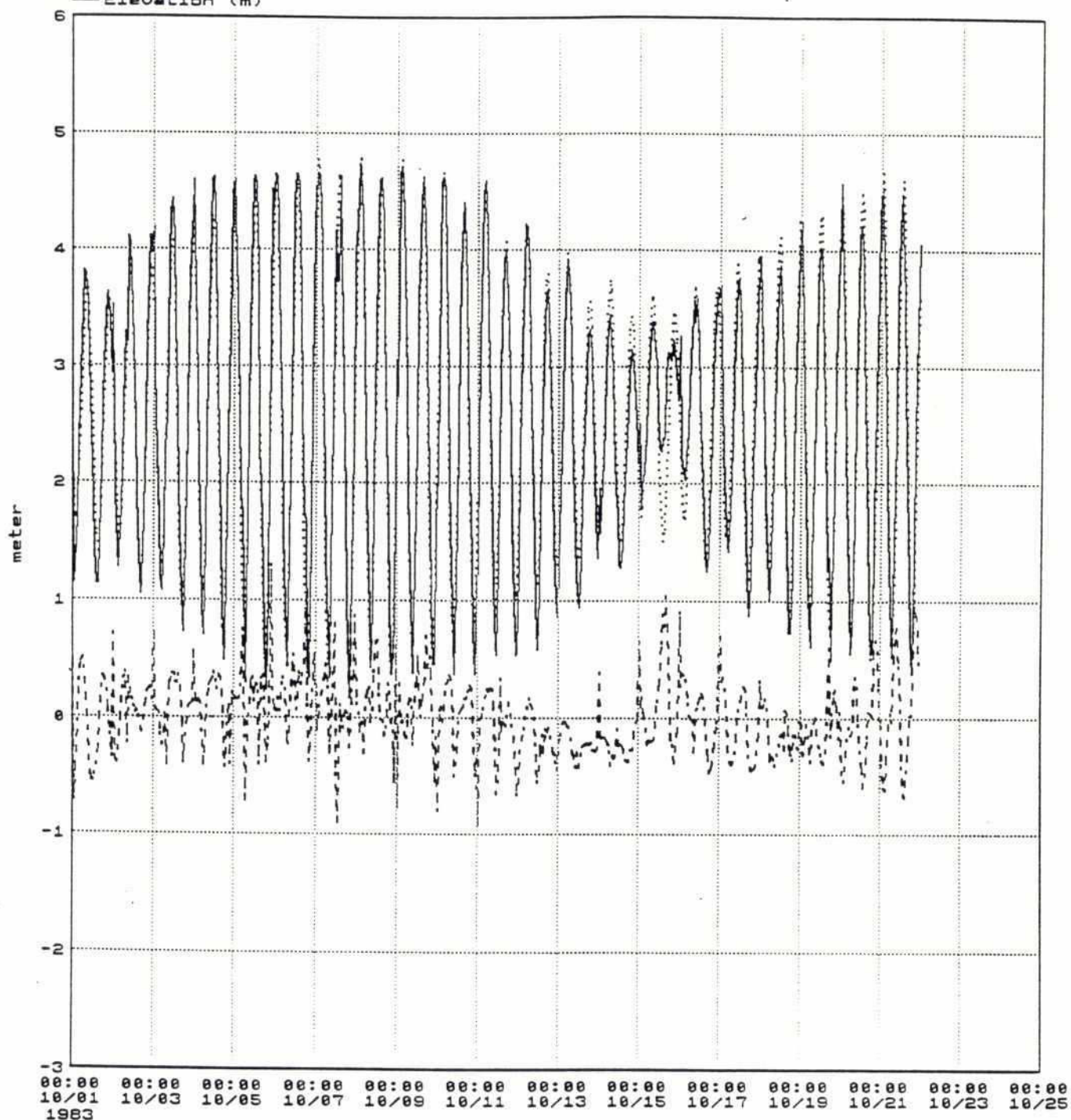


290



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: 083 name : shir4 User: mnr Sun Dec 16 1990	October 1983 Hiron Point Measurements	Dwg. No.  4.93

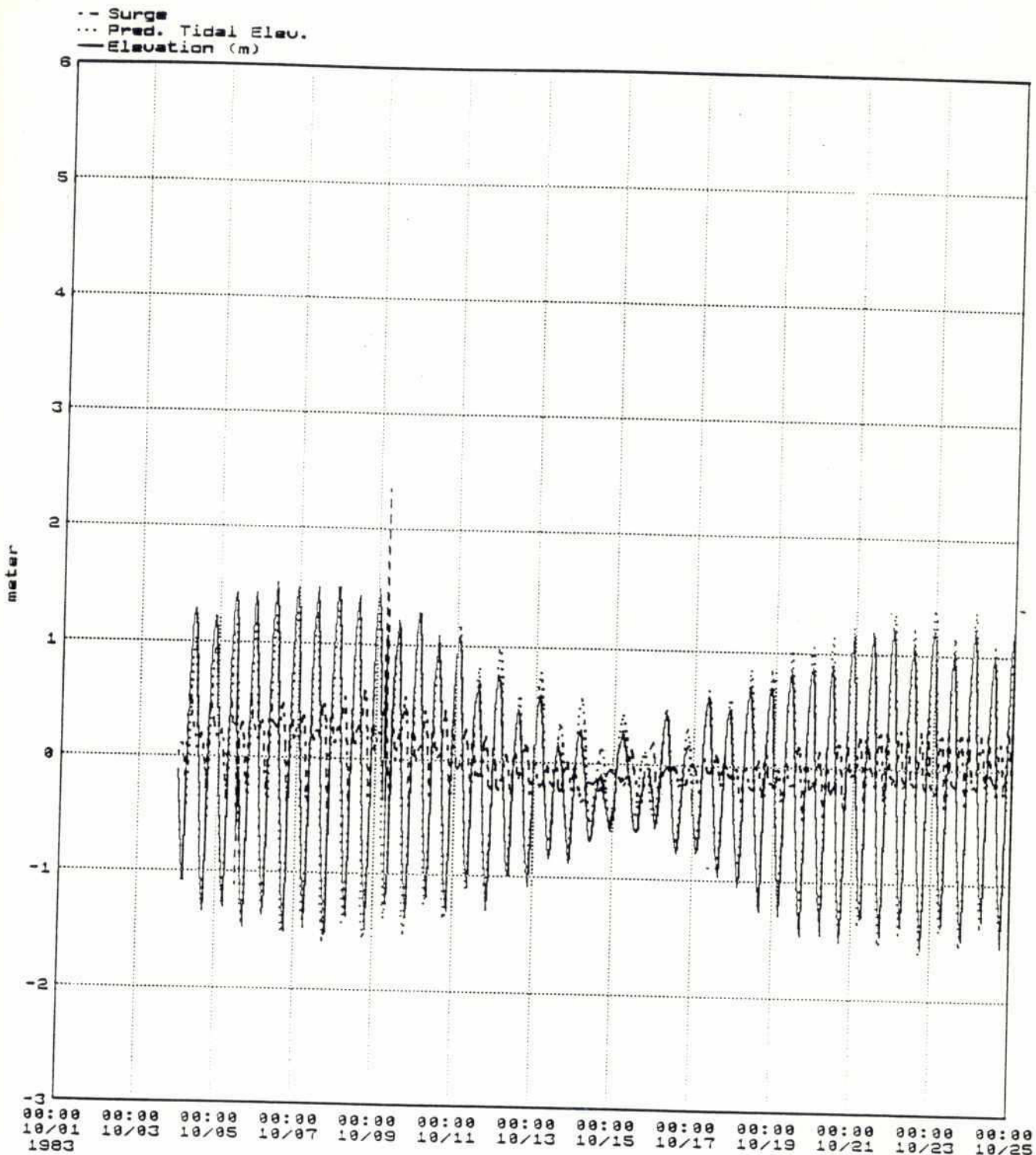
293  
 -- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



<b>MIKE21</b>	Cyclone Protection Project II	
File: family: o83 name : skha4 User: mnr Sun Dec 16 1990	October 1983 Khal No. 10 Measurements	Dwg. No.  4.94



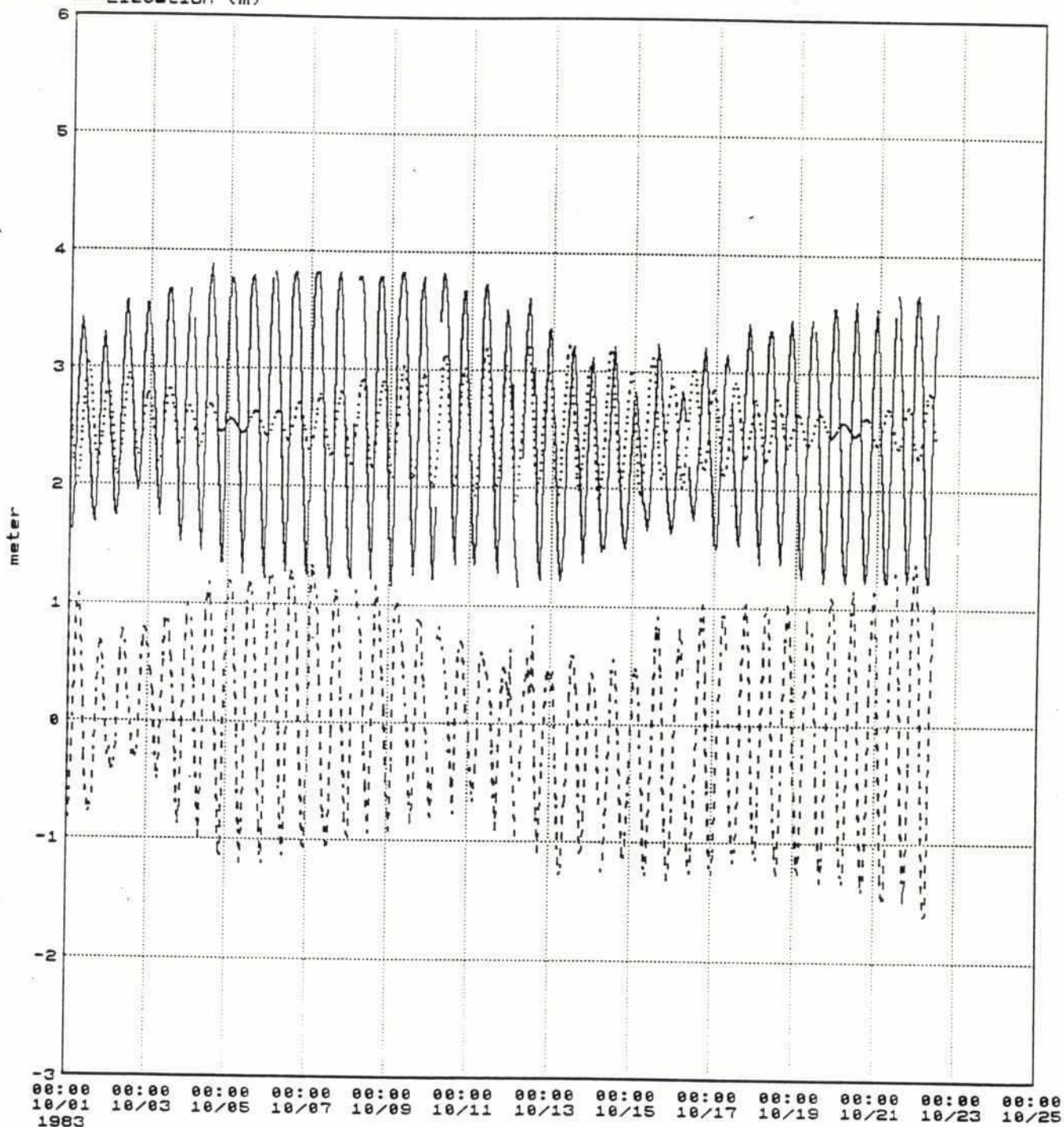
294



MIKE21	Cyclone Protection Project II	
File: family: 083 name : skhe4 User: mnr Sun Dec 16 1990	October 1983 Khepupara Measurements	Dwg. No.  4.95

298

-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)

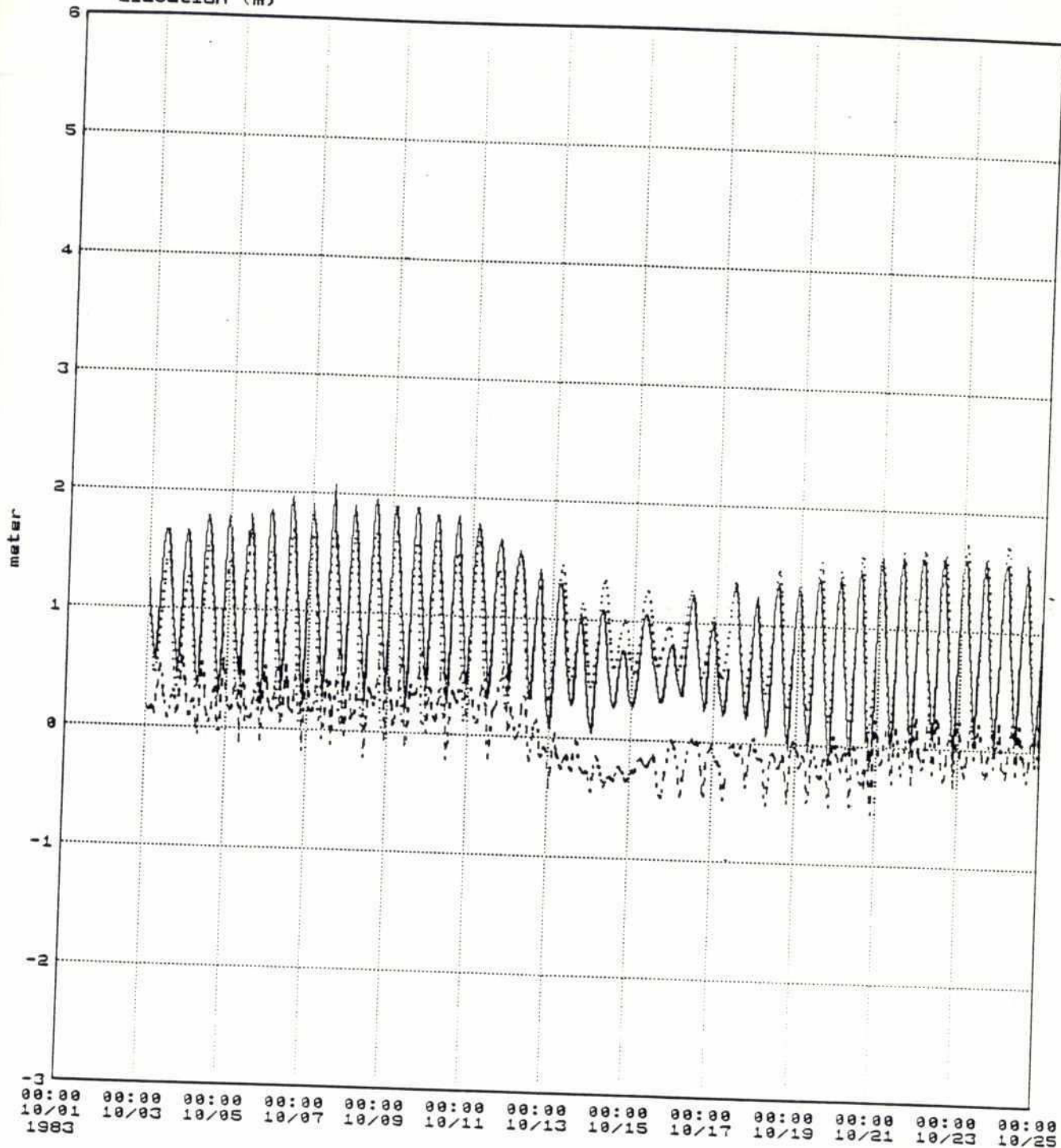


MIKE21		Cyclone Protection Project II	
File:			Dwg. No.
family: o83	October 1983		
name : smon4	Mongla		
User: mnr	Measurements		
Sun Dec 16 1990			4.96



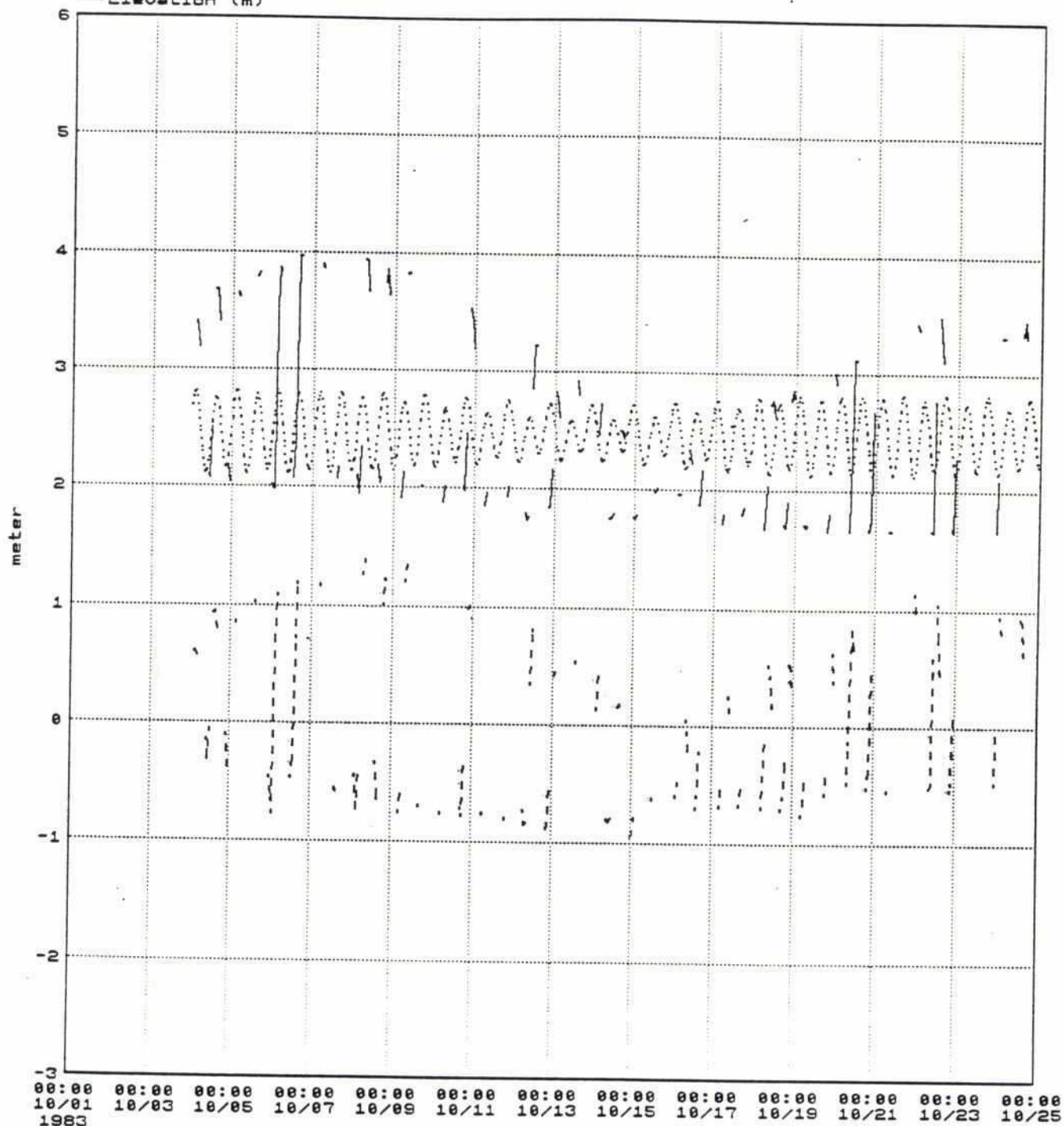
292

-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o83 name : spat4 User: mnr Sun Dec 16 1990	October 1983 Patuakhali Measurements	Dwg. No.  4.97

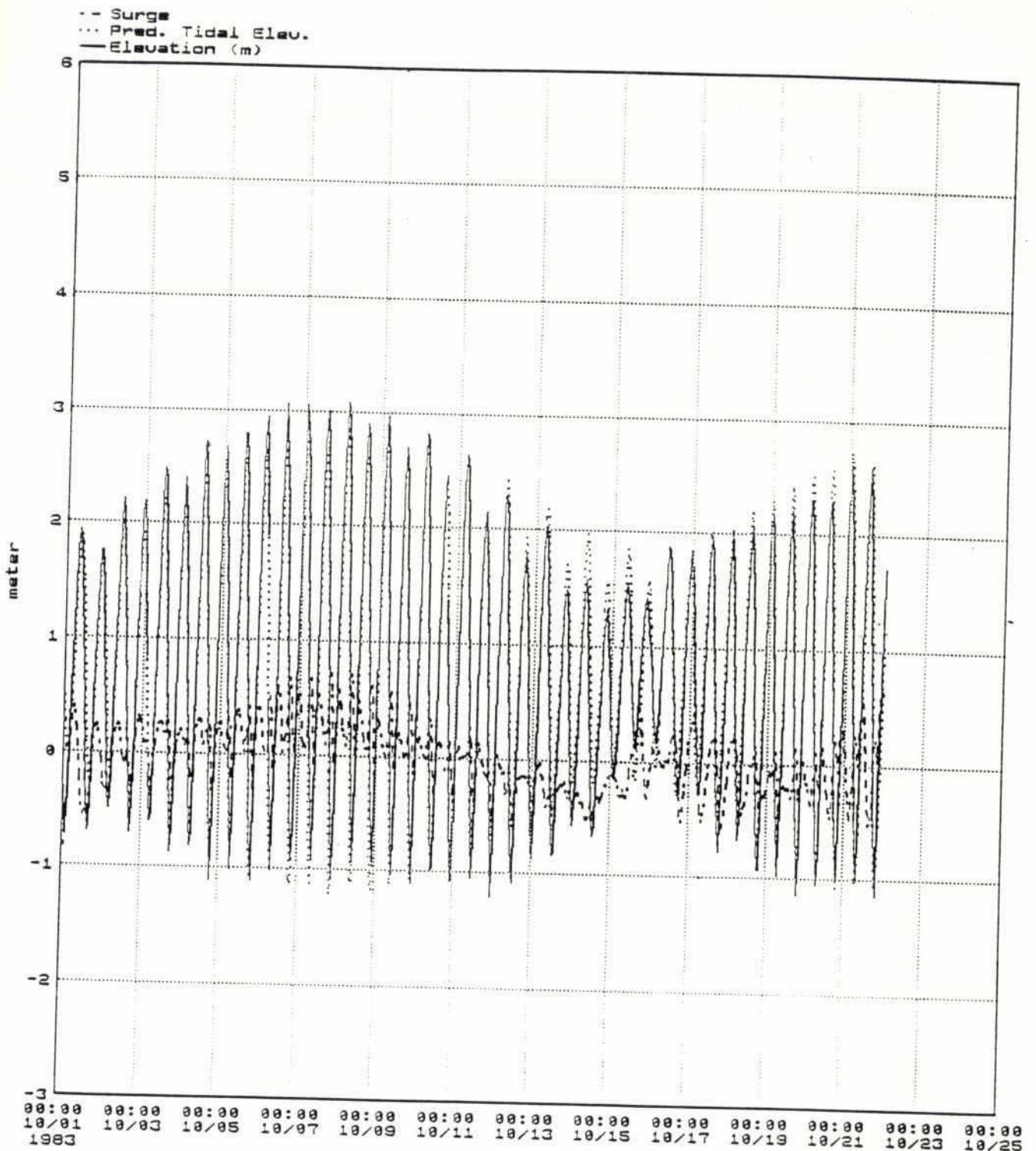
-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



MIKE21	Cyclone Protection Project II	
File: family: o83 name : sram4 User: mnr Sun Dec 16 1990	October 1983 Ramdasapur Measurements	Dwg. No.  4.98



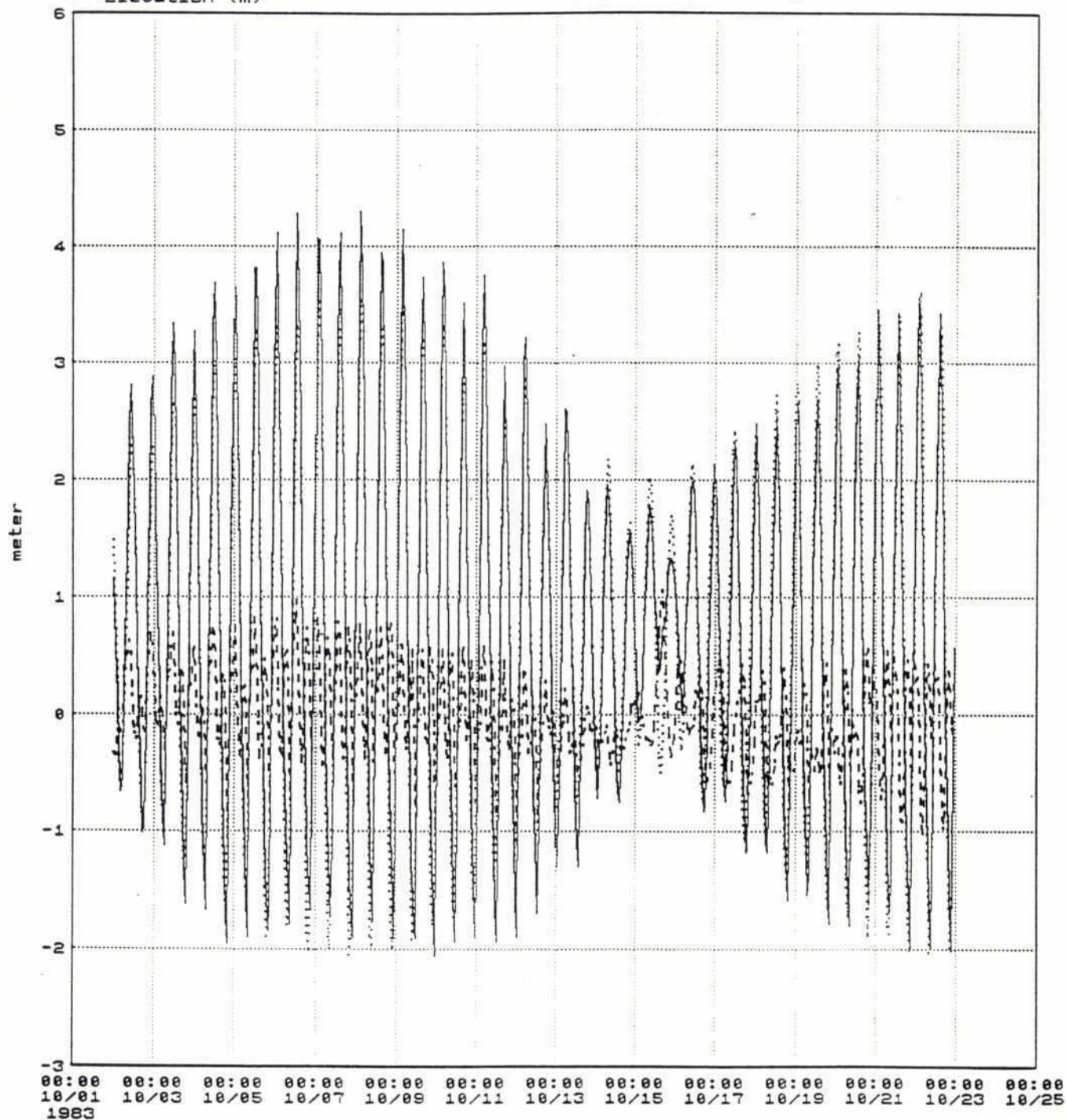
565



<b>MIKE21</b>	Cyclone Protection Project II	
File: family: 083 name : ssad4 User: mnr Sun Dec 16 1990	October 1983 Sadarghat (CTG) Measurements	Dwg. No.  4.99

262

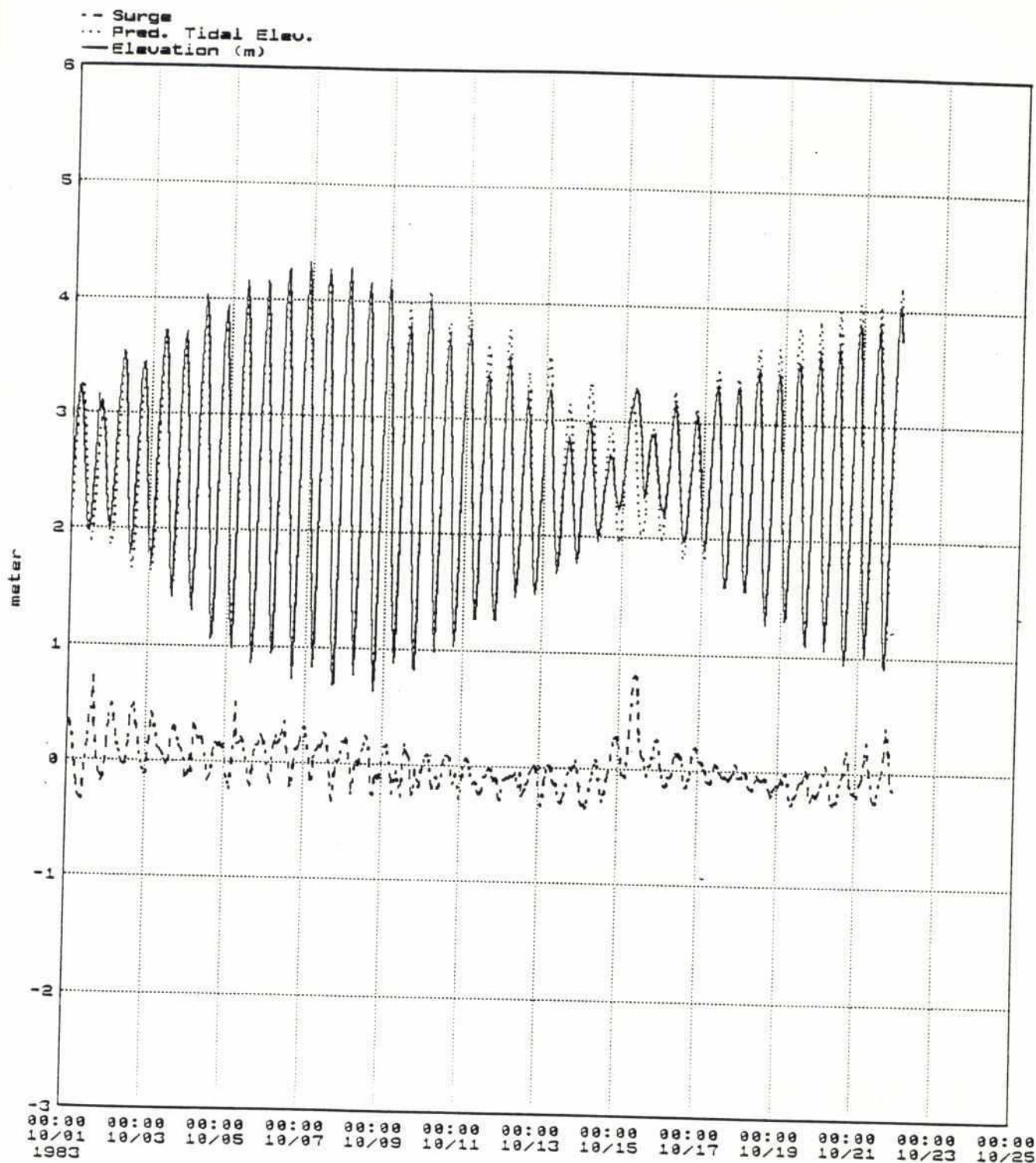
-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o83 name : ssan4 User: mnr Sun Dec 16 1990	October 1983 Sandwip Measurements	Dwg. No.  4.100

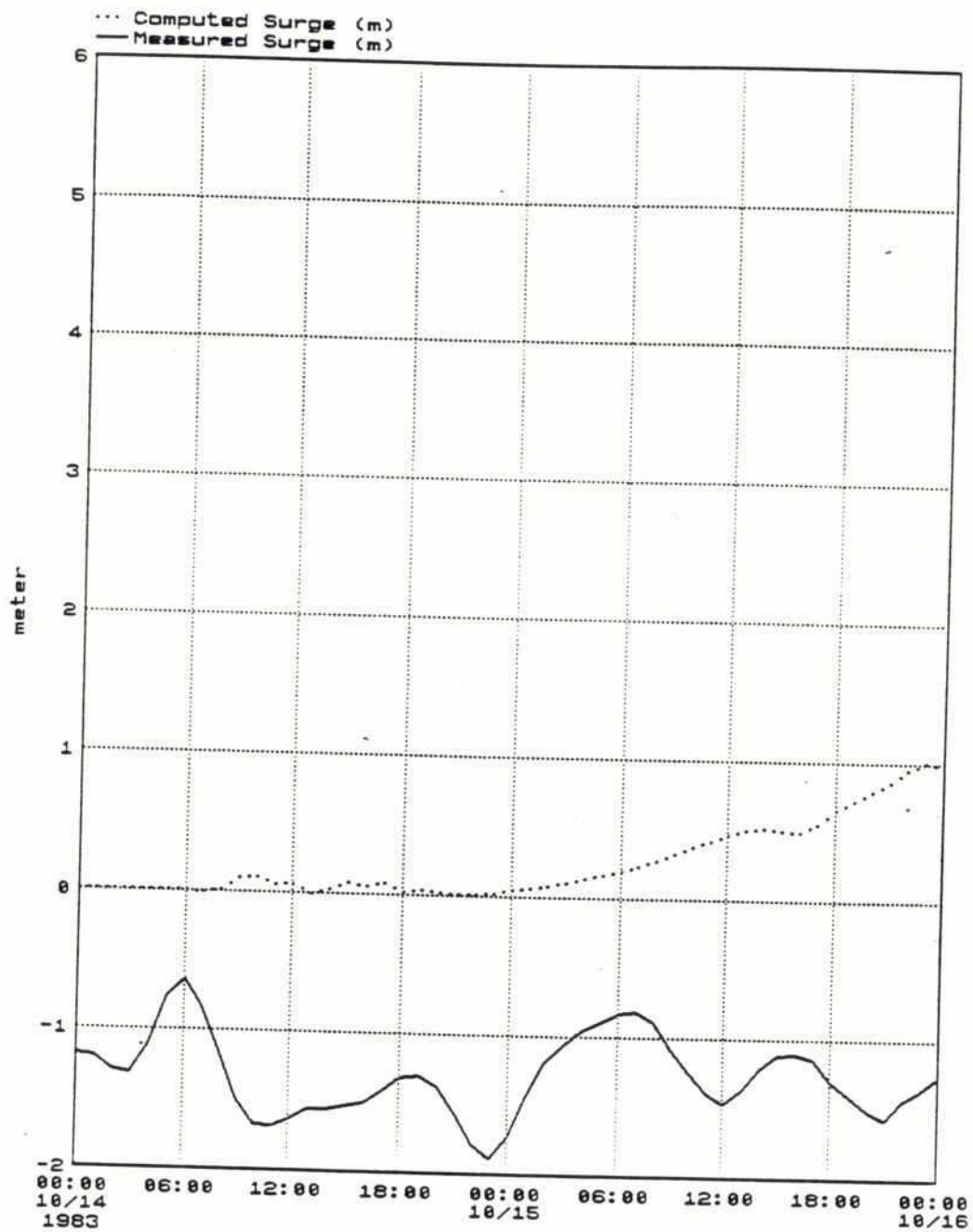


260



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: 083 name : stak4 User: mnr Sun Dec 16 1990	October 1983 Teknaf (Shapuri) Measurements	Dwg. No.  4.101

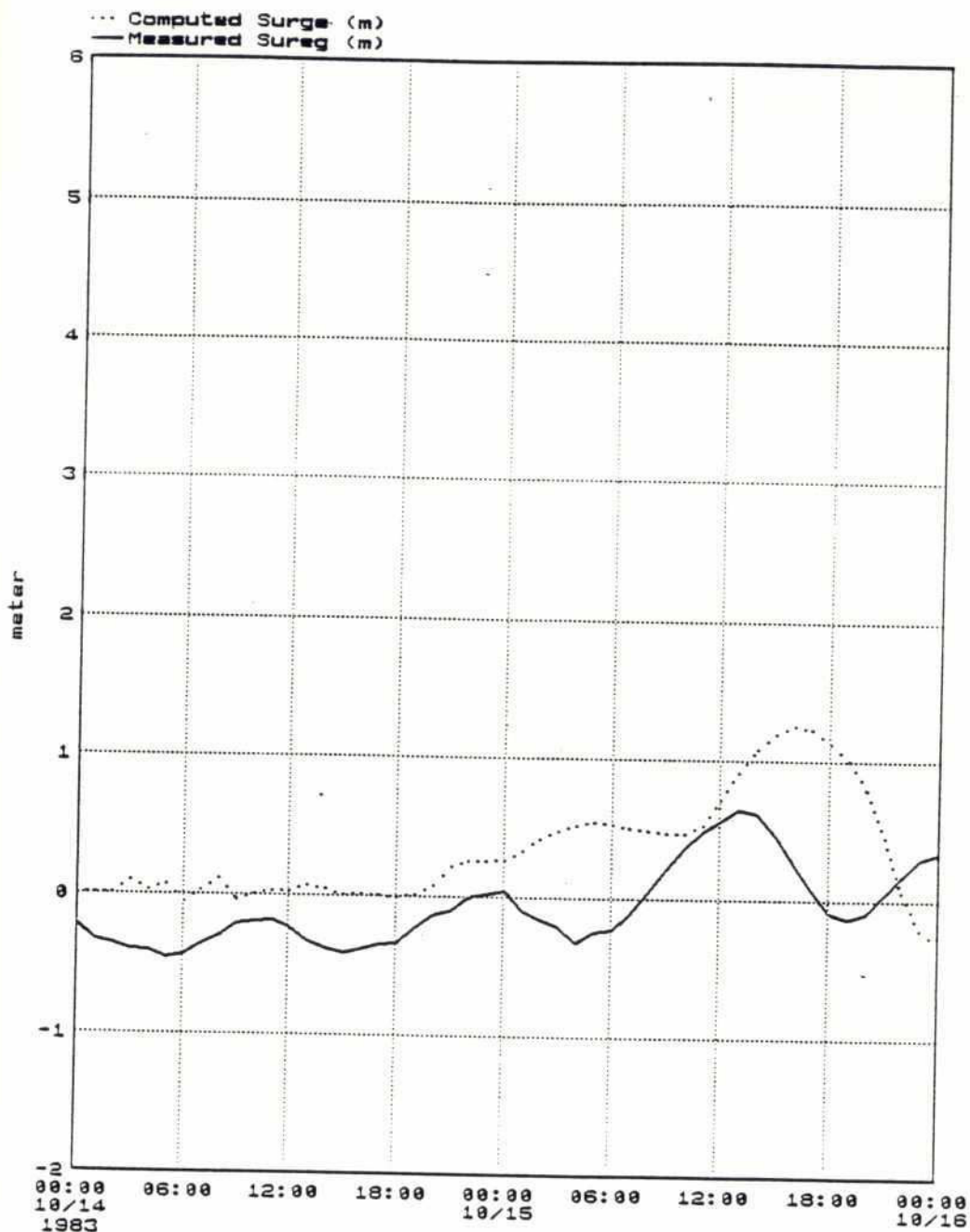
268



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o83 name : cbar4 User: mnr Sun Dec 16 1990	October 1983 Barisal Measured and computed surge	Dwg. No.  4.102

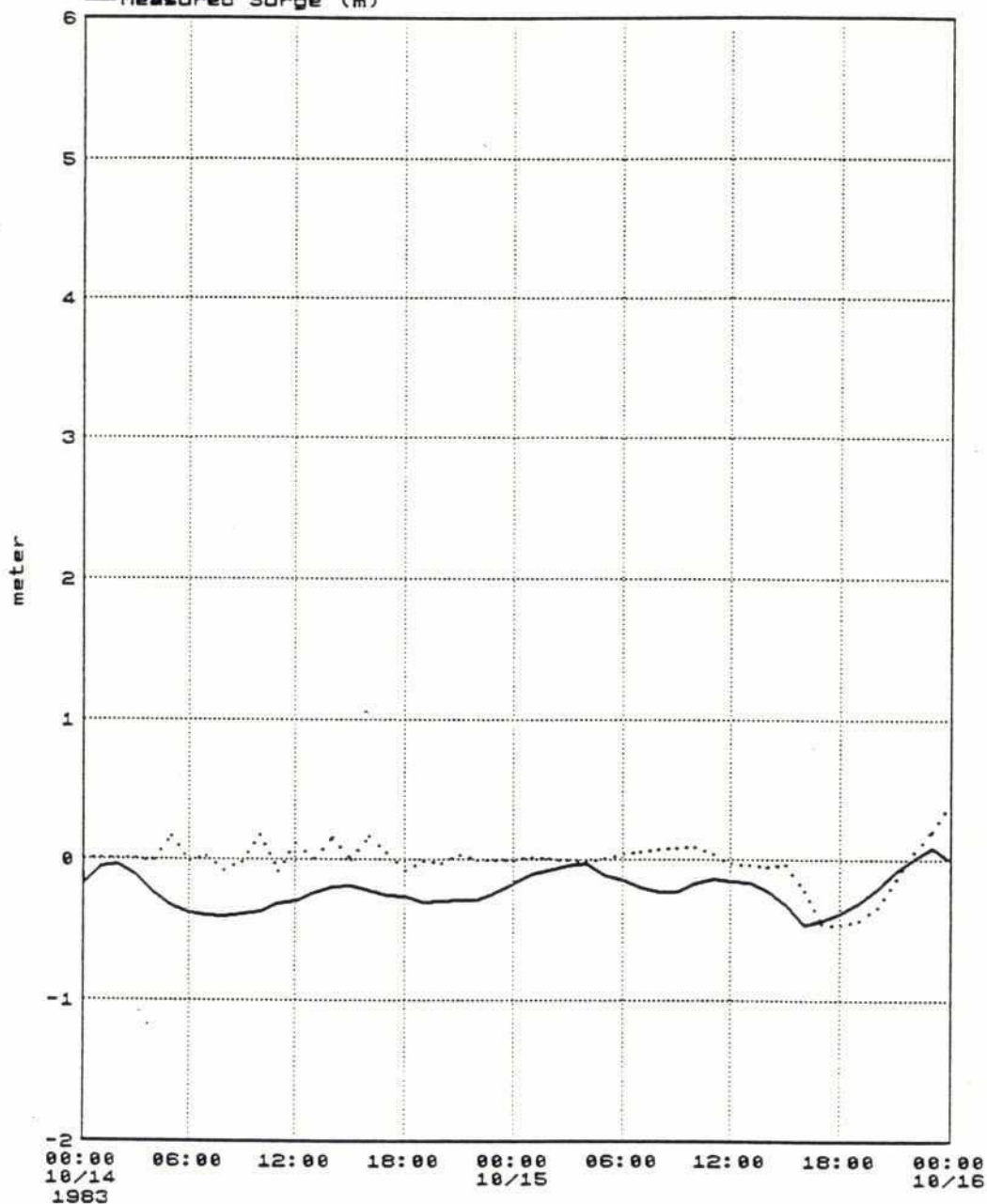


368



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o83 name : ccox4 User: mnr Sun Dec 16 1990	October 1983 Cox's Bazar Measured and computed surge	Dwg. No.  4.103

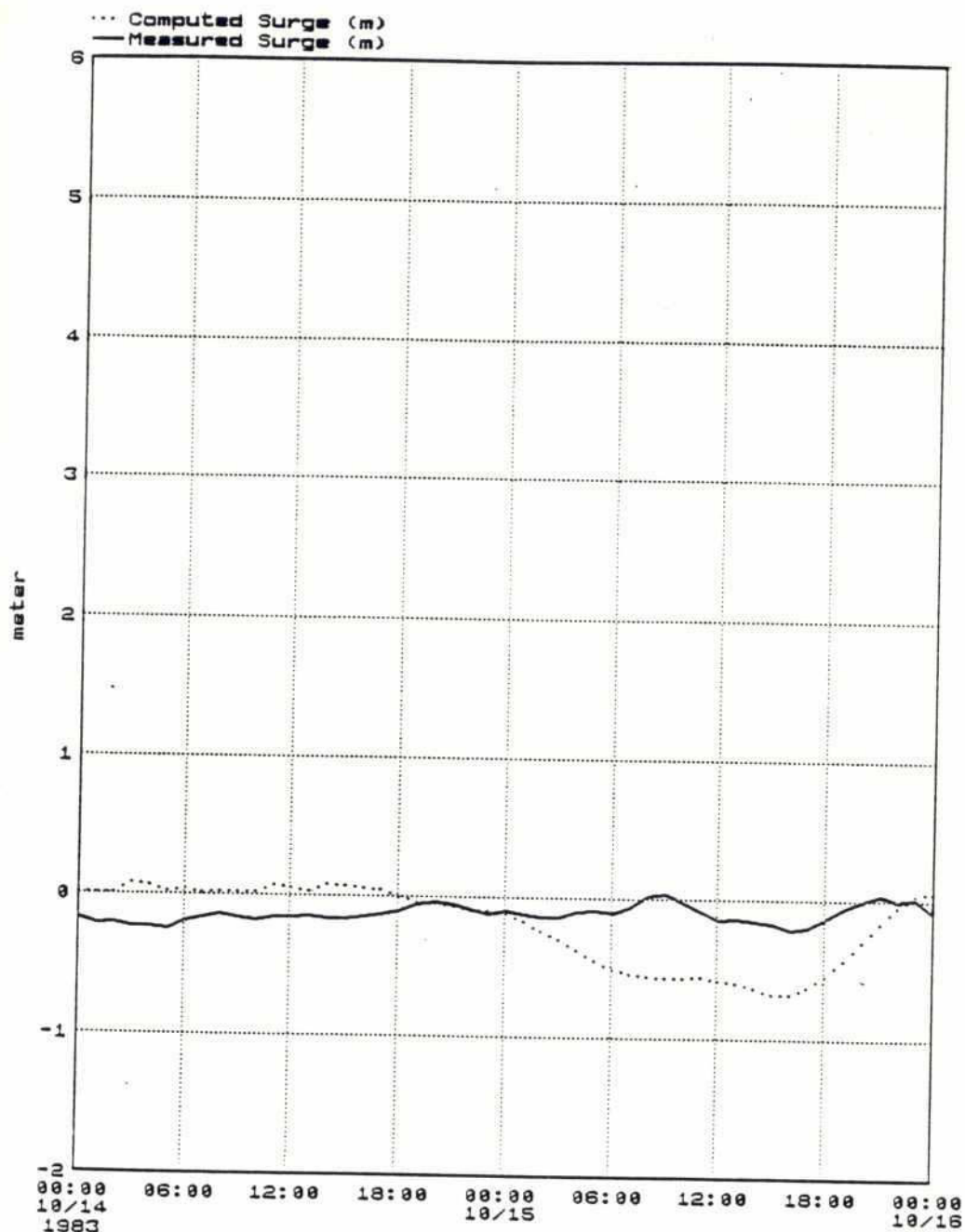
... Computed Surge (m)  
 — Measured Surge (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: o83 name : cgal4 User: mnr Sun Dec 16 1990	October 1983 Galechips Measured and computed surge	<b>Dwg. No.</b>  4.104

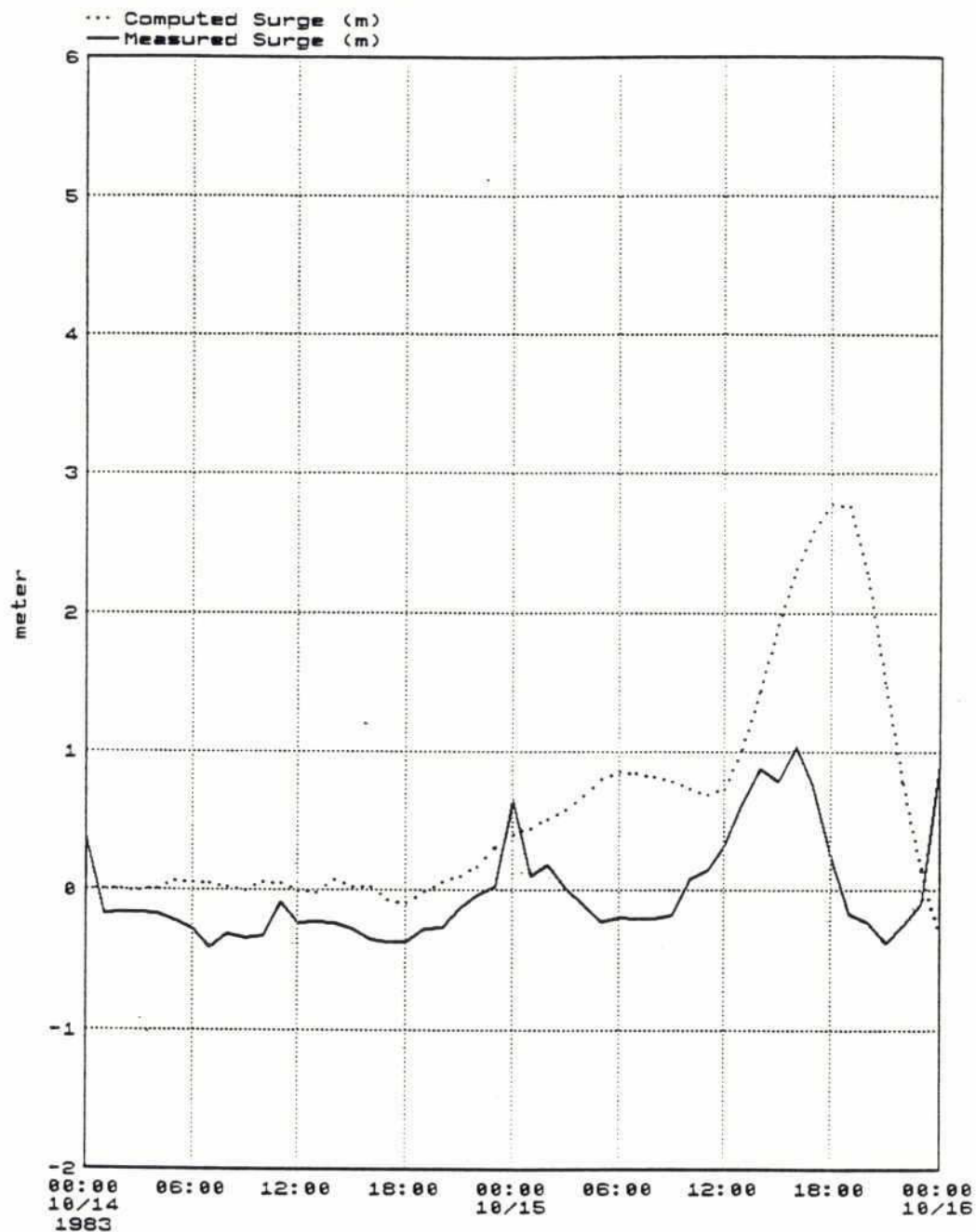


209



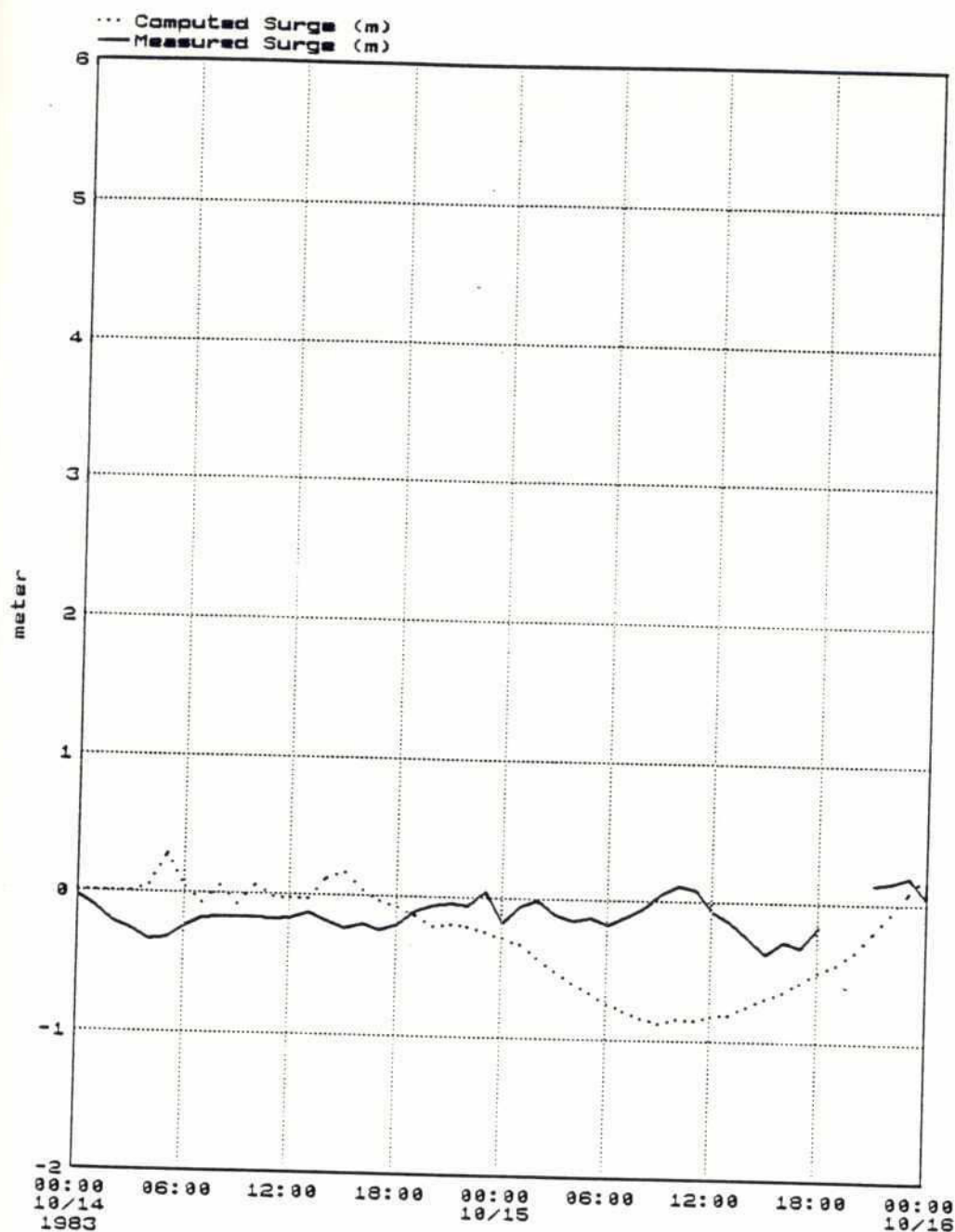
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: o83 name : chir4 User: mnr Sun Dec 16 1990	October 1983 Hiron Point Measured and computed surge	<b>Dwg. No.</b>  4.105

284



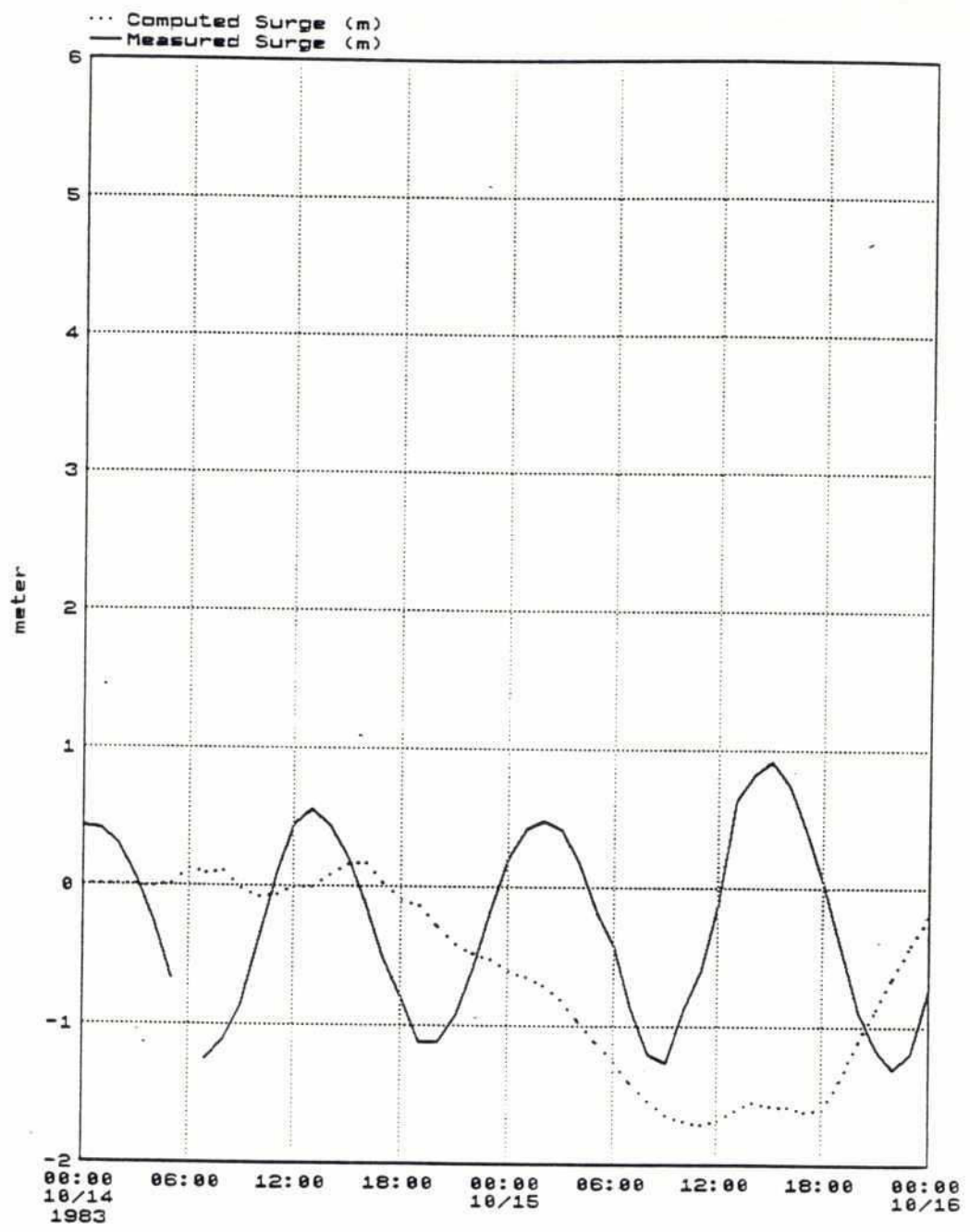
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: o83 name : ckha4 User: mnr Sun Dec 16 1990	October 1983 Khal No. 10 Measured and computed surge	<b>Dwg. No.</b>  4.106





<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: o83 name : ckhe4 User: mnr Sun Dec 16 1990	October 1983 Khepupara Measured and computed surge	Dwg. No.  4.107

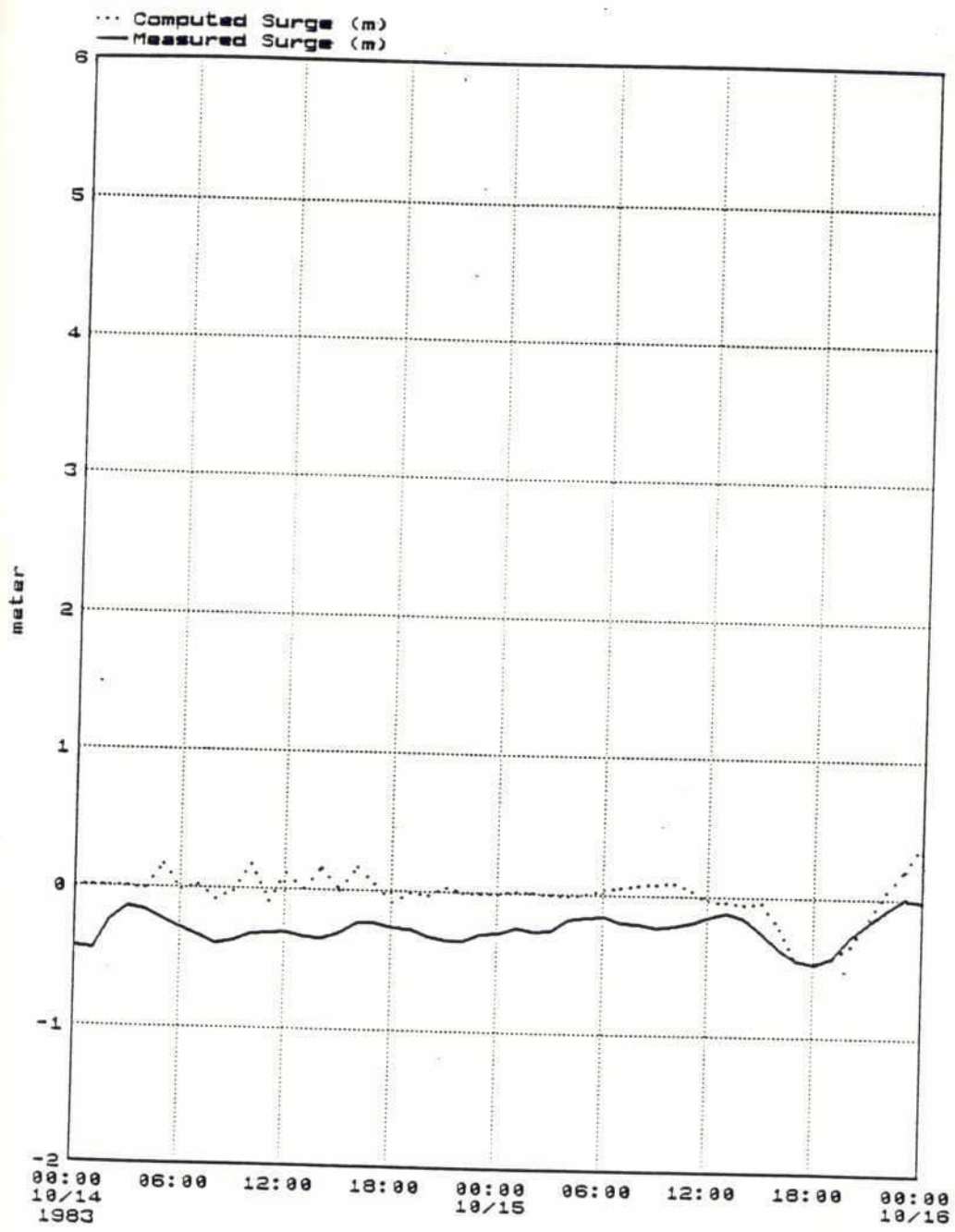
2020



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: o83 name : cmon4 User: mnr Sun Dec 16 1990	October 1983 Mongla Measured and computed surge	Dwg. No.  4.108

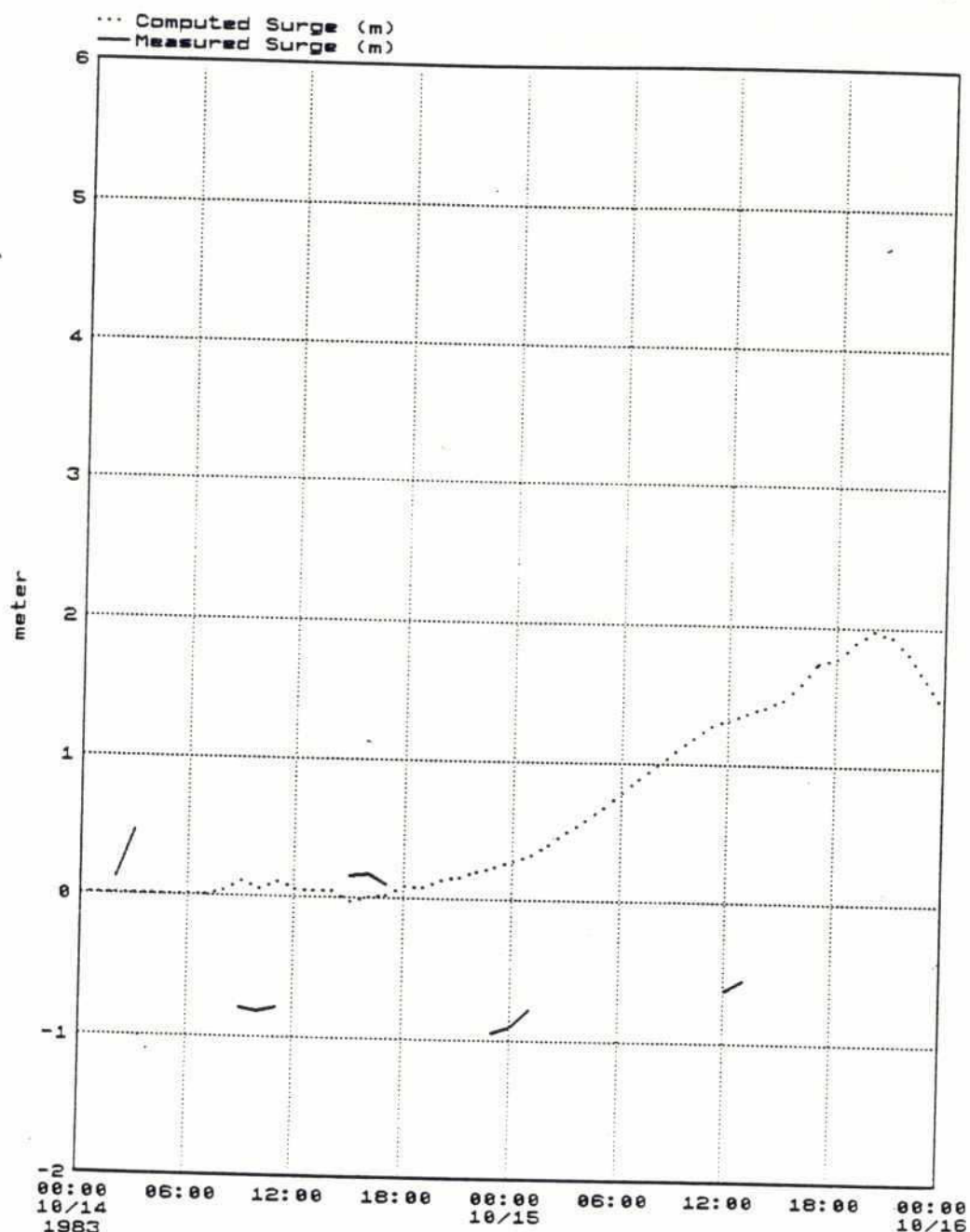


732  
C-17



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: o83 name : cpat4 User: mnr Sun Dec 16 1990	October 1983 Patuakhali Measured and computed surge	Dwg. No.  4.109

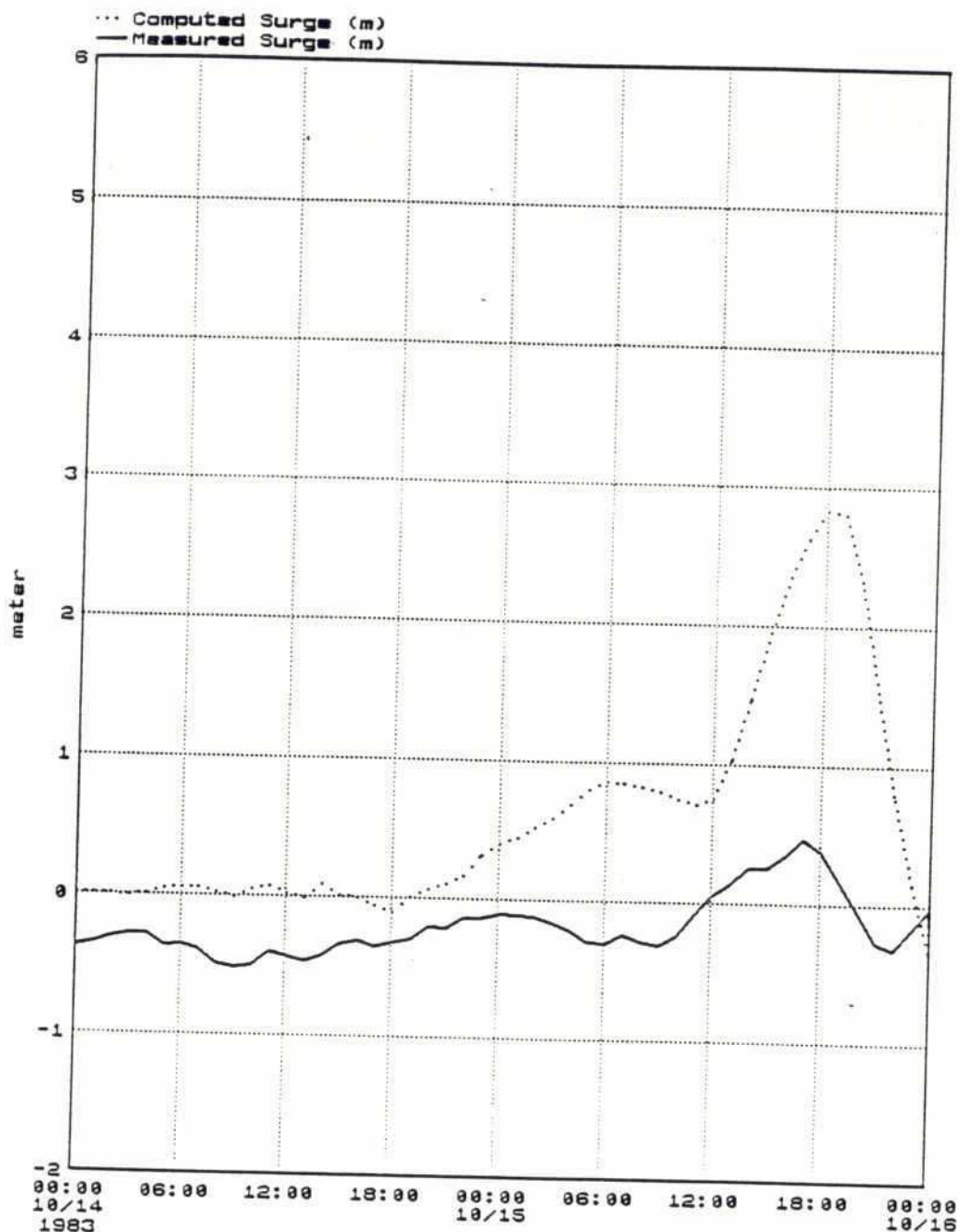
222



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: o83 name : cram4 User: mnr Sun Dec 16 1990	October 1983 Ramdaspur Measured and computed surge	Dwg. No.  4.110

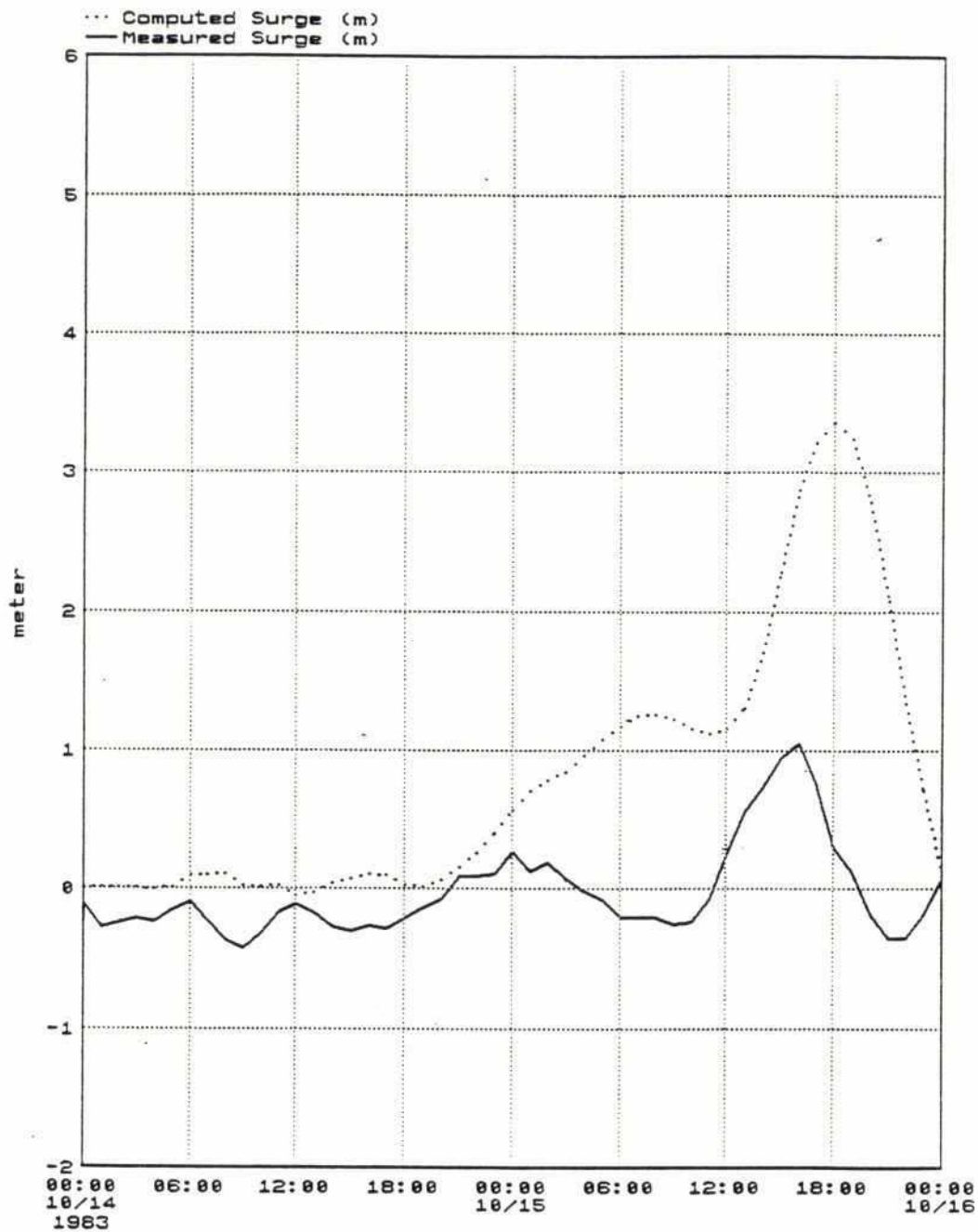


206



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: o83 name : csad4 User: mnr Sun Dec 16 1990	October 1983 Sadarghat (CTG) Measured and computed surge	Dwg. No.  4.111

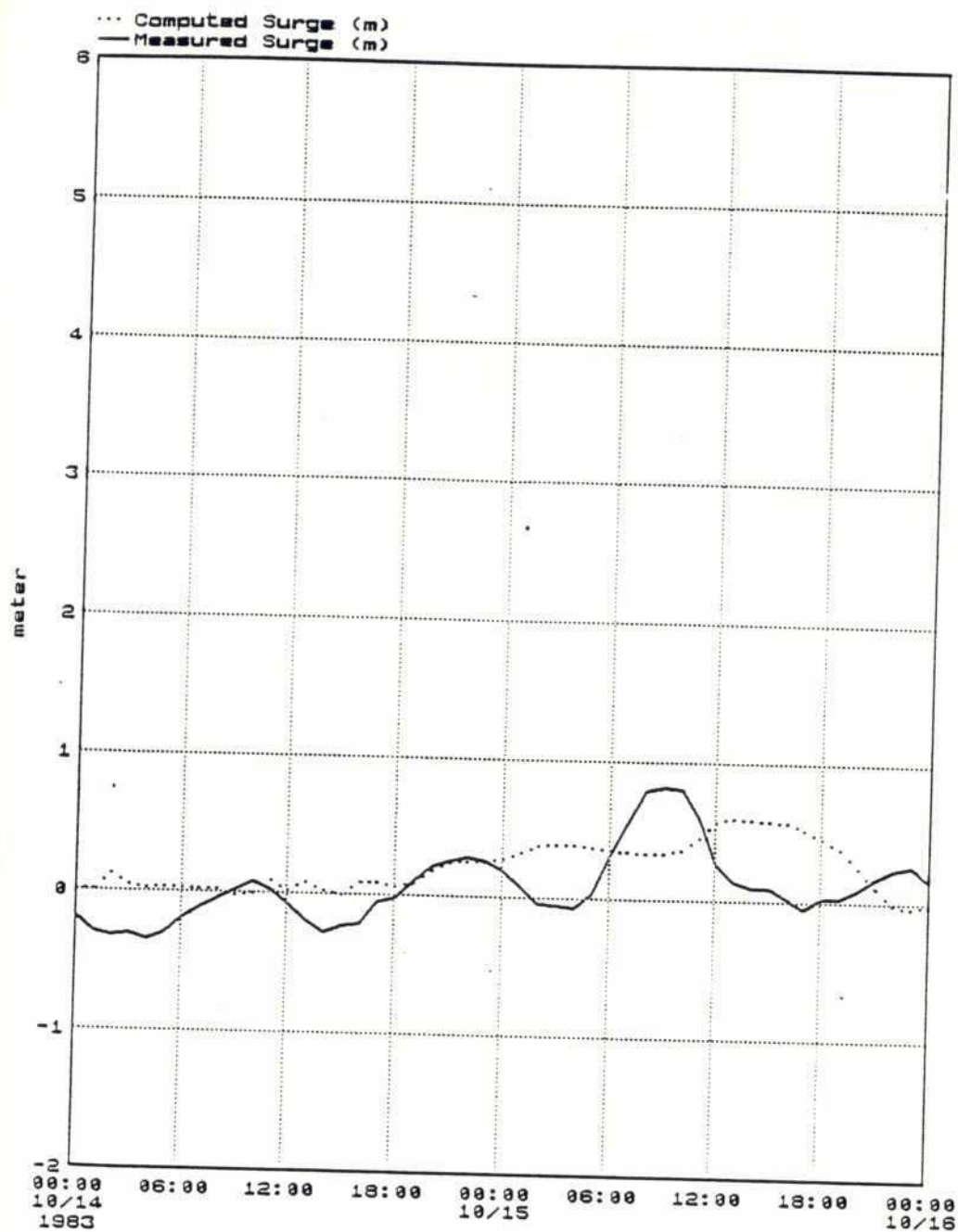
728



<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: o83 name : csan4 User: mnr Sun Dec 16 1990</p>	<p>October 1983 Sandwip Measured and computed surge</p>	<p>Dwg. No.  4.112</p>

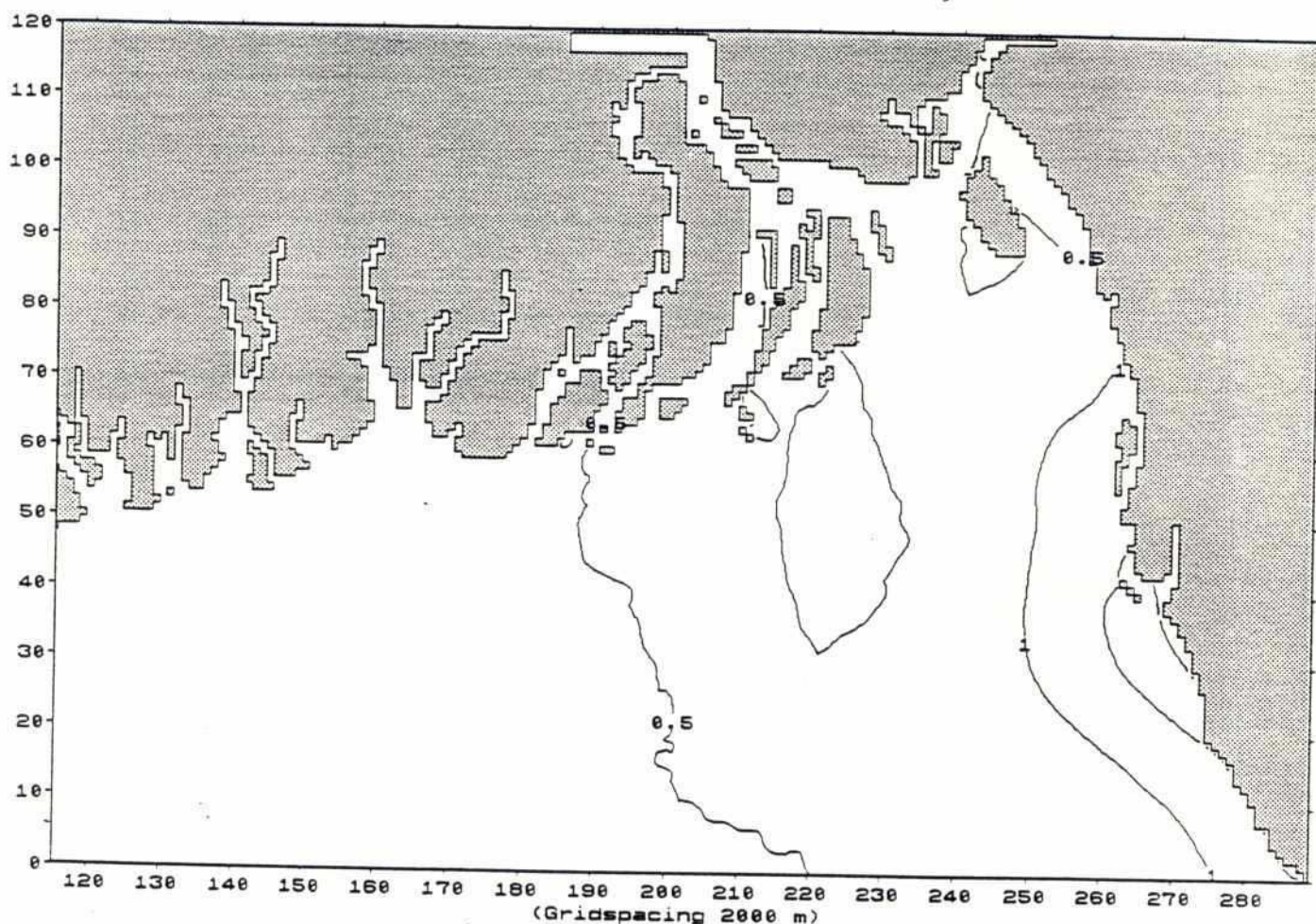


222



<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: o83 name : cta4 User: mnr Sun Dec 16 1990</p>	<p>October 1983 Teknaf (Shapuri) Measured and computed surge</p>	<p>Dwg. No.  4.113</p>

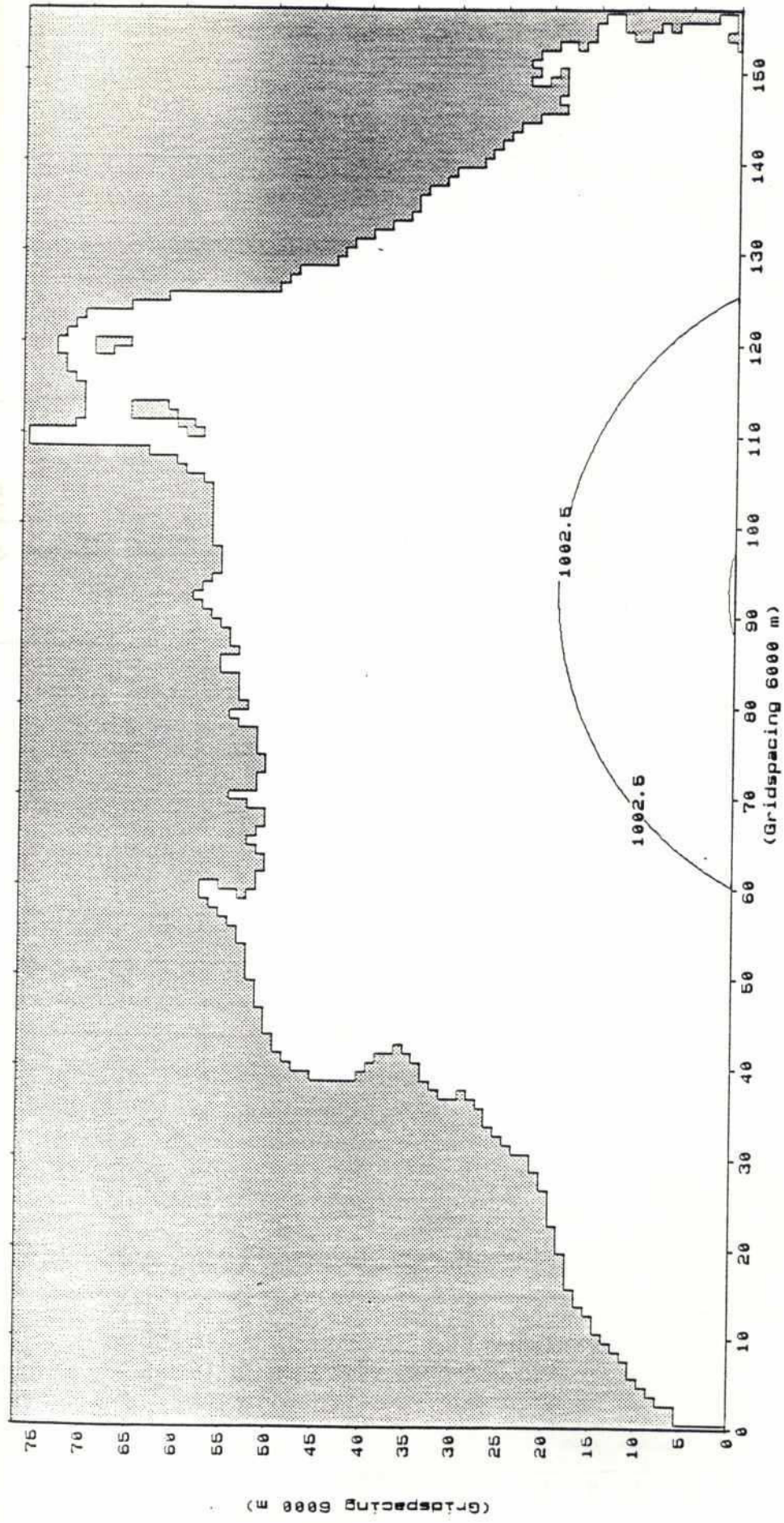
703



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : imax Scale: 1:2 mill Tue Nov 27 1990	November 1983 Cyclone Simulation Results, Intermediate Model Maximum Surge Levels	Dwg. No.  4.114



209

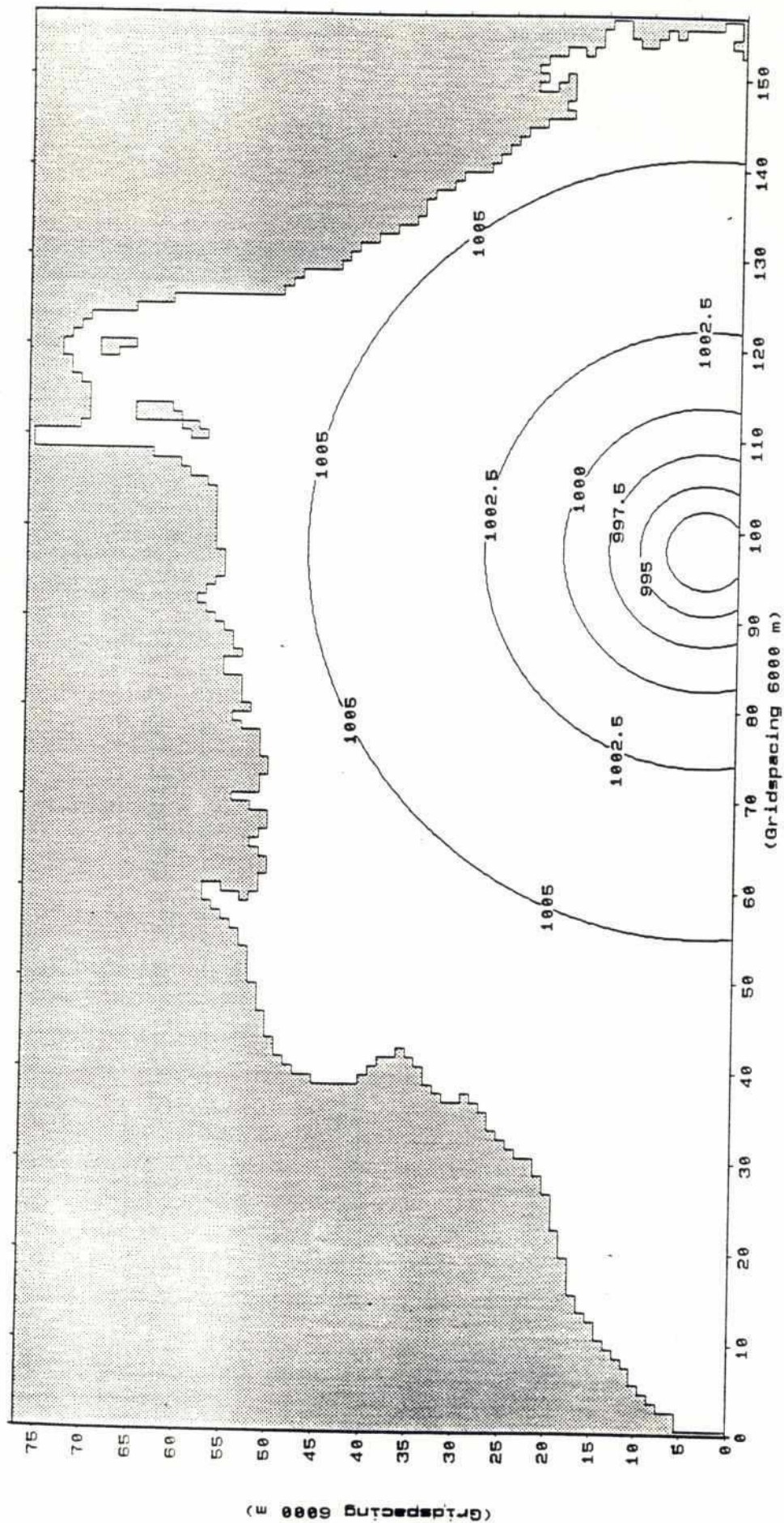


1983/11/08 12:00:00

<b>MIKE21</b> Cyclone Protection Project II		
File: family: n83 name : rwind Scale: 1:4 mill Tue 27	November 1983 Cyclone Pressure Field (mb)	Dwg. No. 4.115



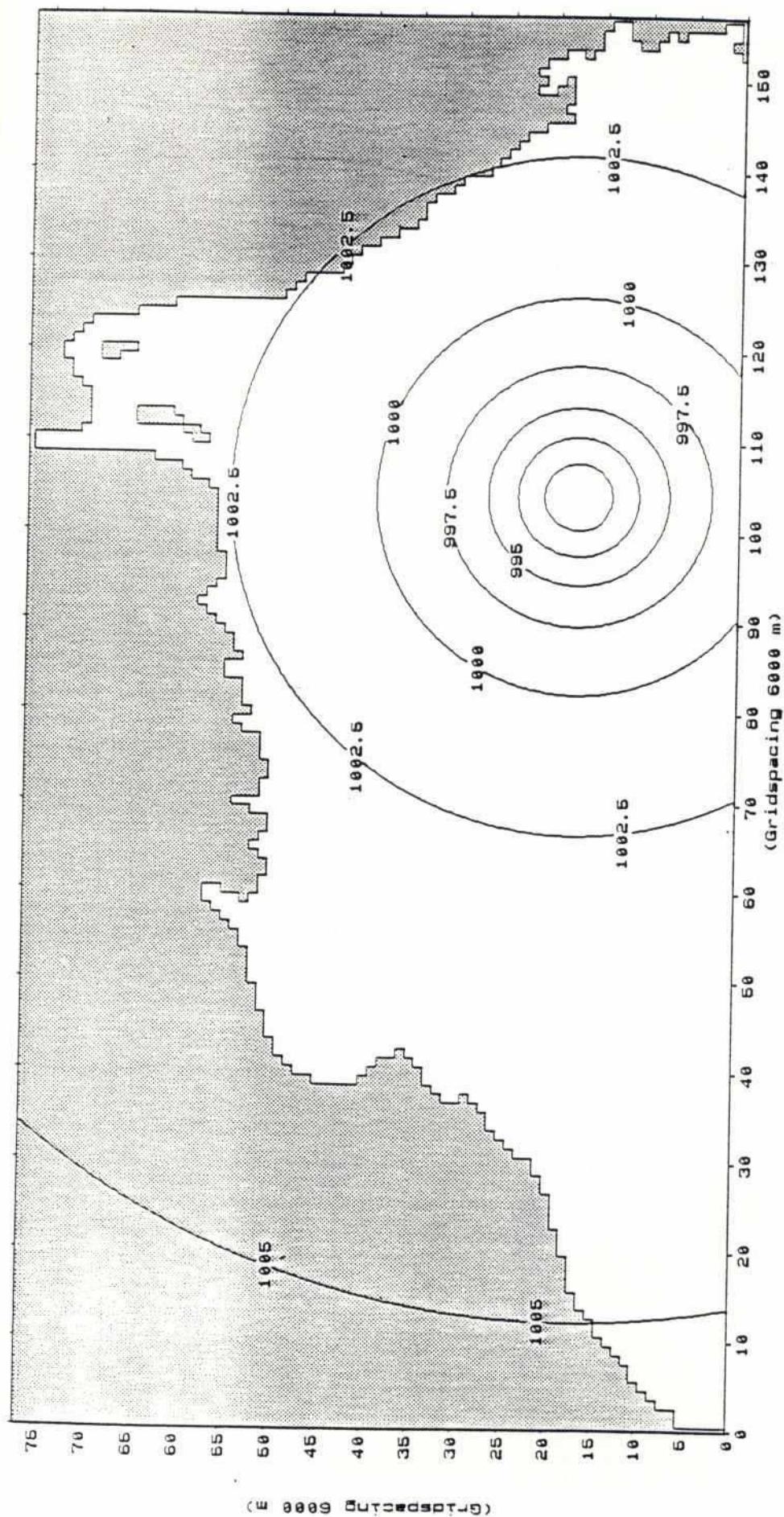
337



1983/11/09 00:00:00

<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : rwind Scale: 1:4 mill Tue Nov 27 1990	November 1983 Cyclone Pressure Field (mb)	
	Dwg. No.	4.116





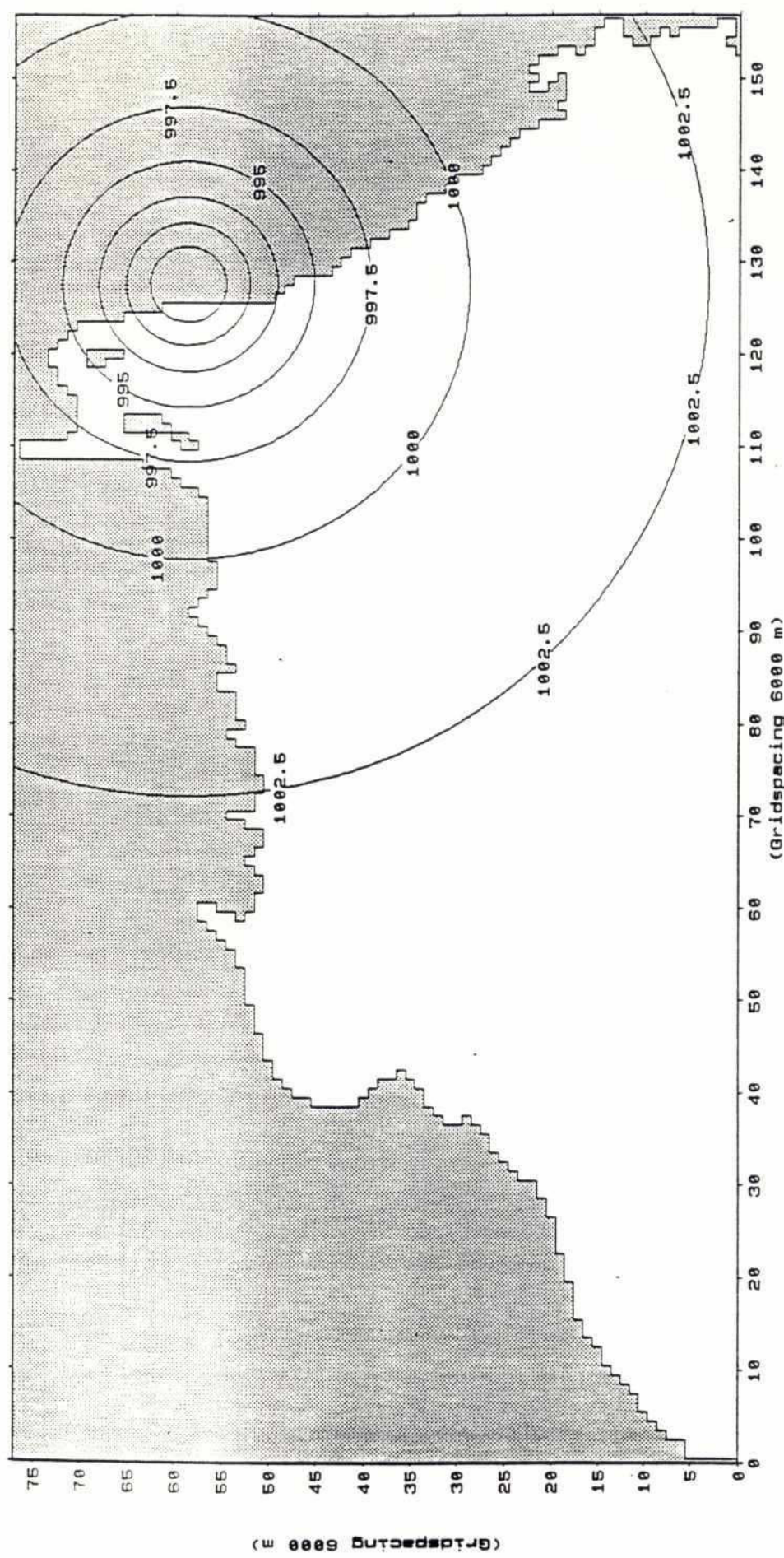
1983/11/09 12:00:00

<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : rwind Scale: 1:4 mill Tue Nov 27 1990	November 1983 Cyclone Pressure Field (mb)	
		Dwg. No. 4.117

cell



200



1983/11/10 00:00:00

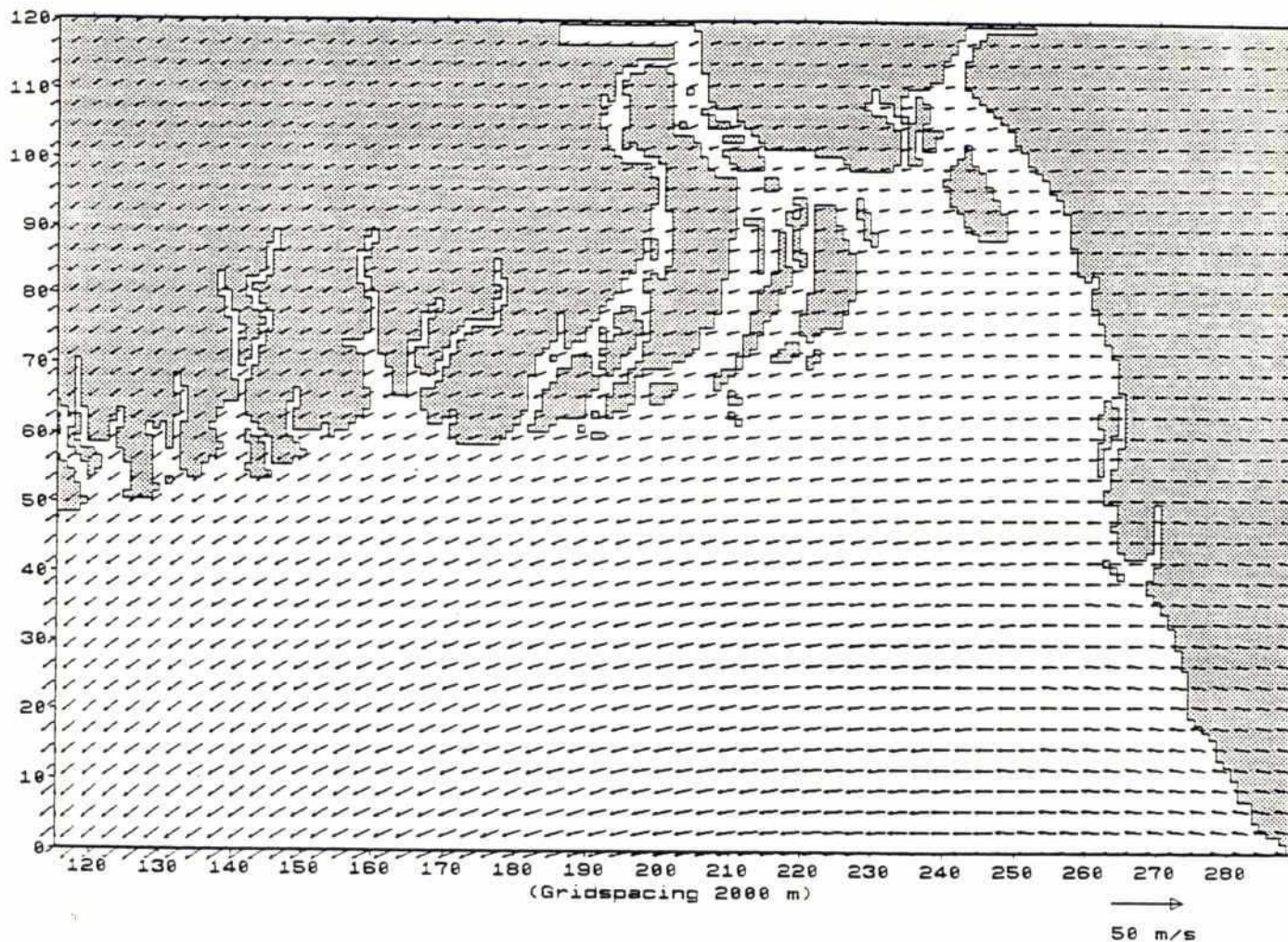
MIKE21		Cyclone Protection Project II	
File: family: n83 name : rwind Scale: 1:4 mill Tue Nov 27 1990		November 1983 Cyclone Pressure Field (mb)	
		Dwg. No.	4.118







202

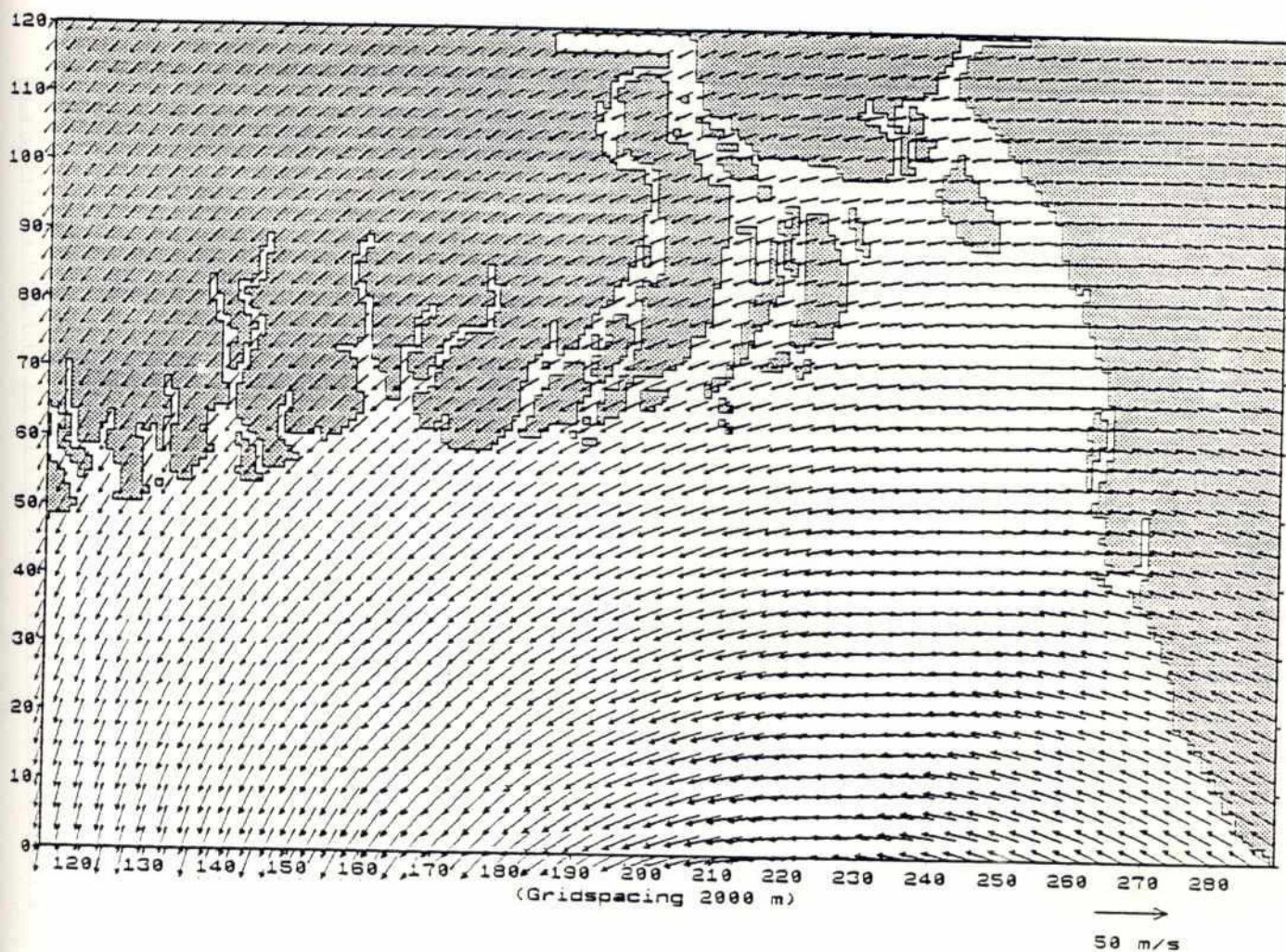


1983/11/08 12:00:00

<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: n83 name : iwind Scale: 1:2 mill tue Nov 27 1990</p>	<p>November 1983 Cyclone Wind Field</p>	<p>Dwg. No.  4.120</p>



206

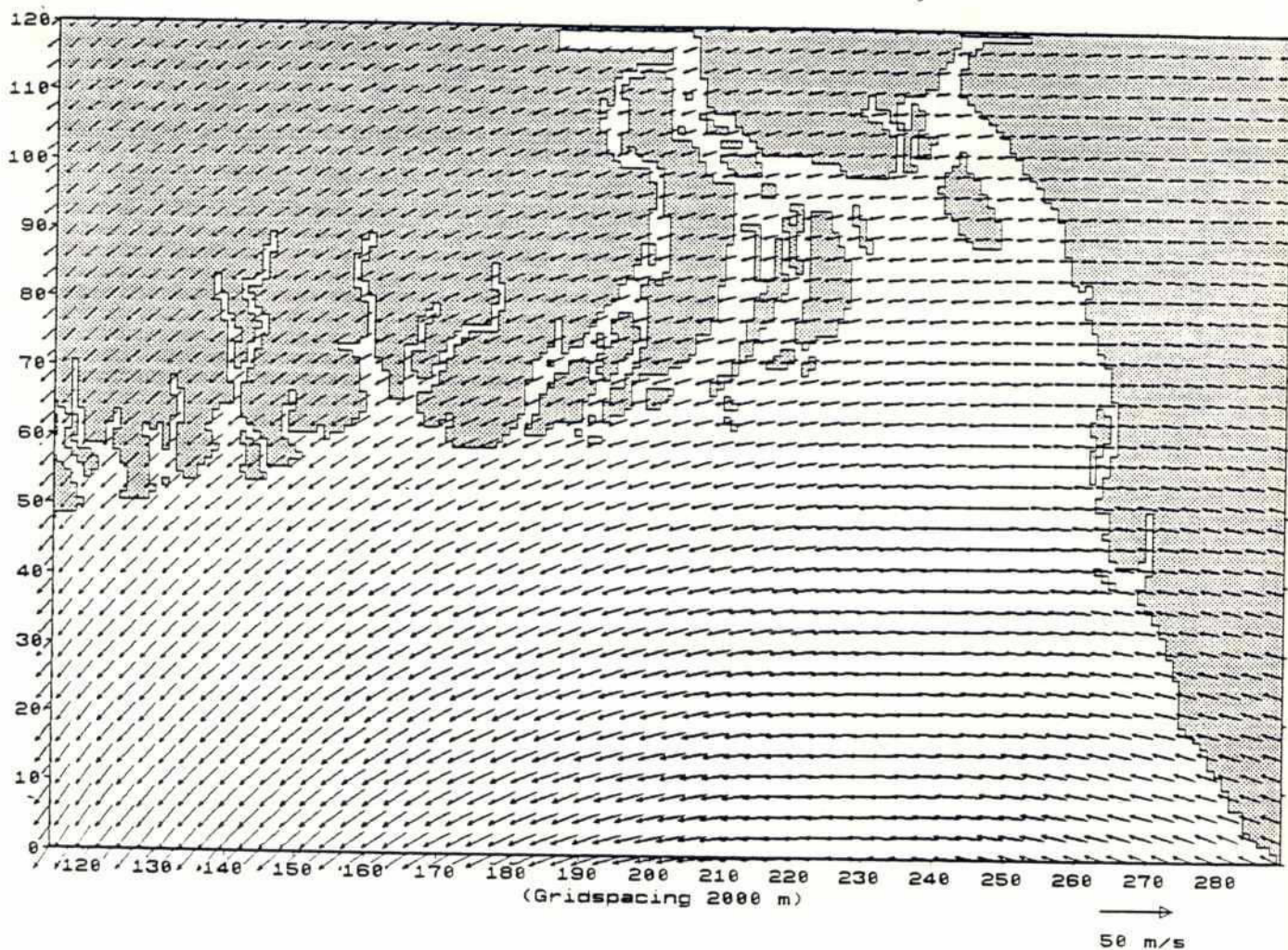


1983/11/09 12:00:00

<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: n83 name : iwind Scale: 1:2 mill tue Nov 27 1990</p>	<p>November 1983 Cyclone Wind Field</p>	<p>Dwg. No.  4.121</p>



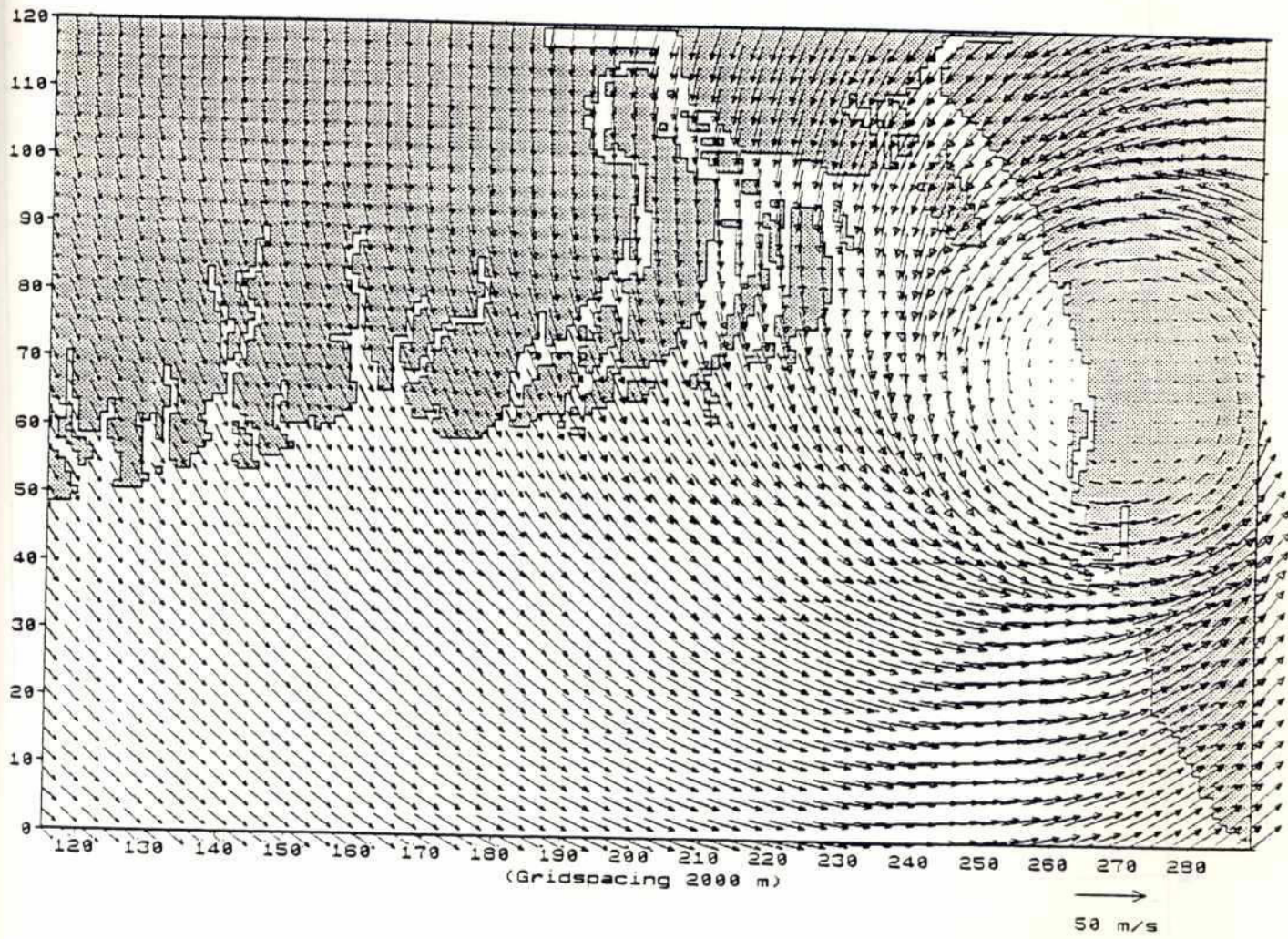
208



1983/11/09 00:00:00

<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: n83 name : iwind Scale: 1:2 mill tue Nov 27 1990</p>	<p>November 1983 Cyclone Wind Field</p>	<p>Dwg. No.  4.122</p>



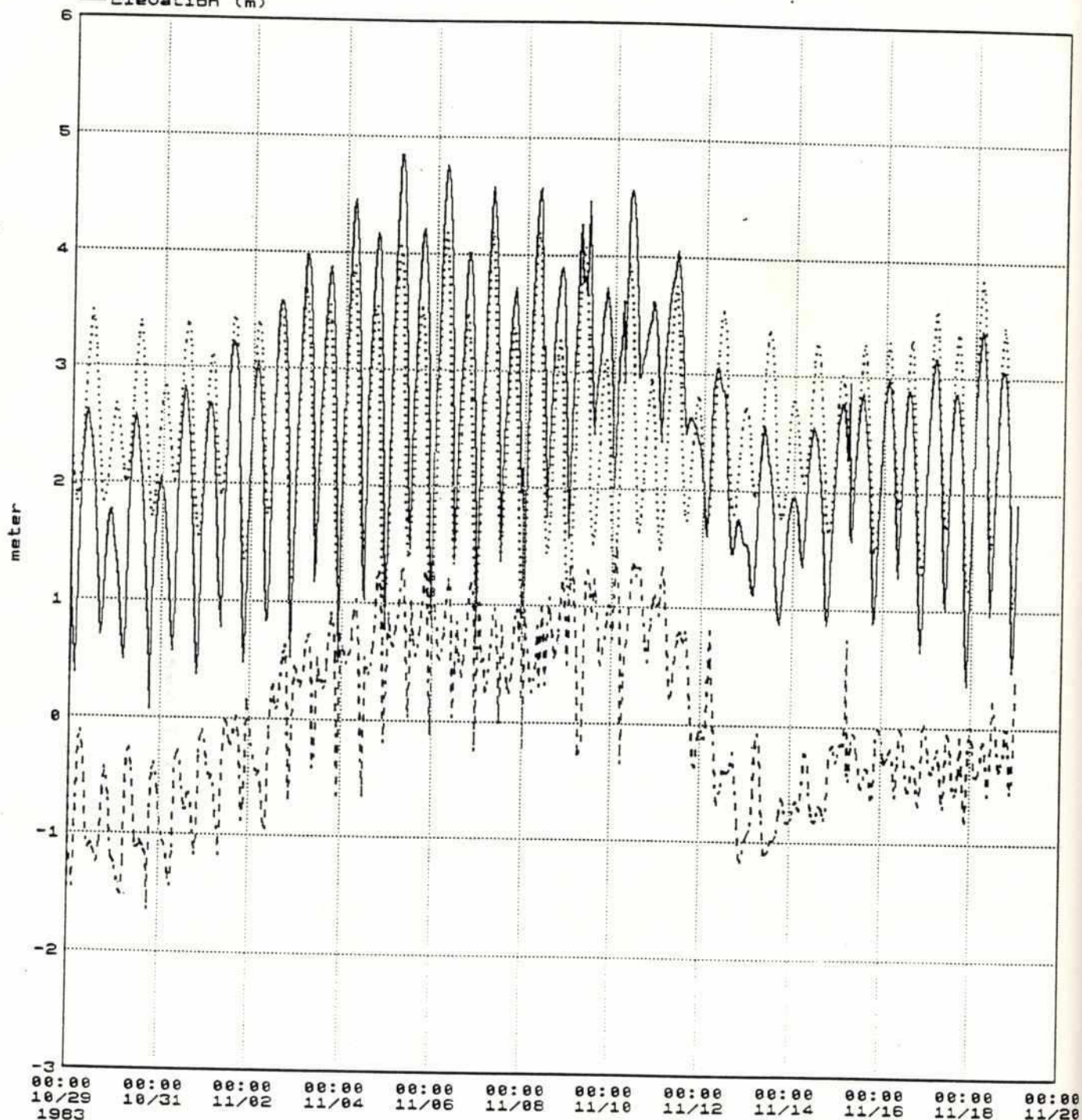


1983/11/10 00:00:00

MIKE21	Cyclone Protection Project II	
File: family: n83 name : iwind Scale: 1:2 mill tue Nov 27 1990	November 1983 Cyclone Wind Field	Dwg. No.  4.123

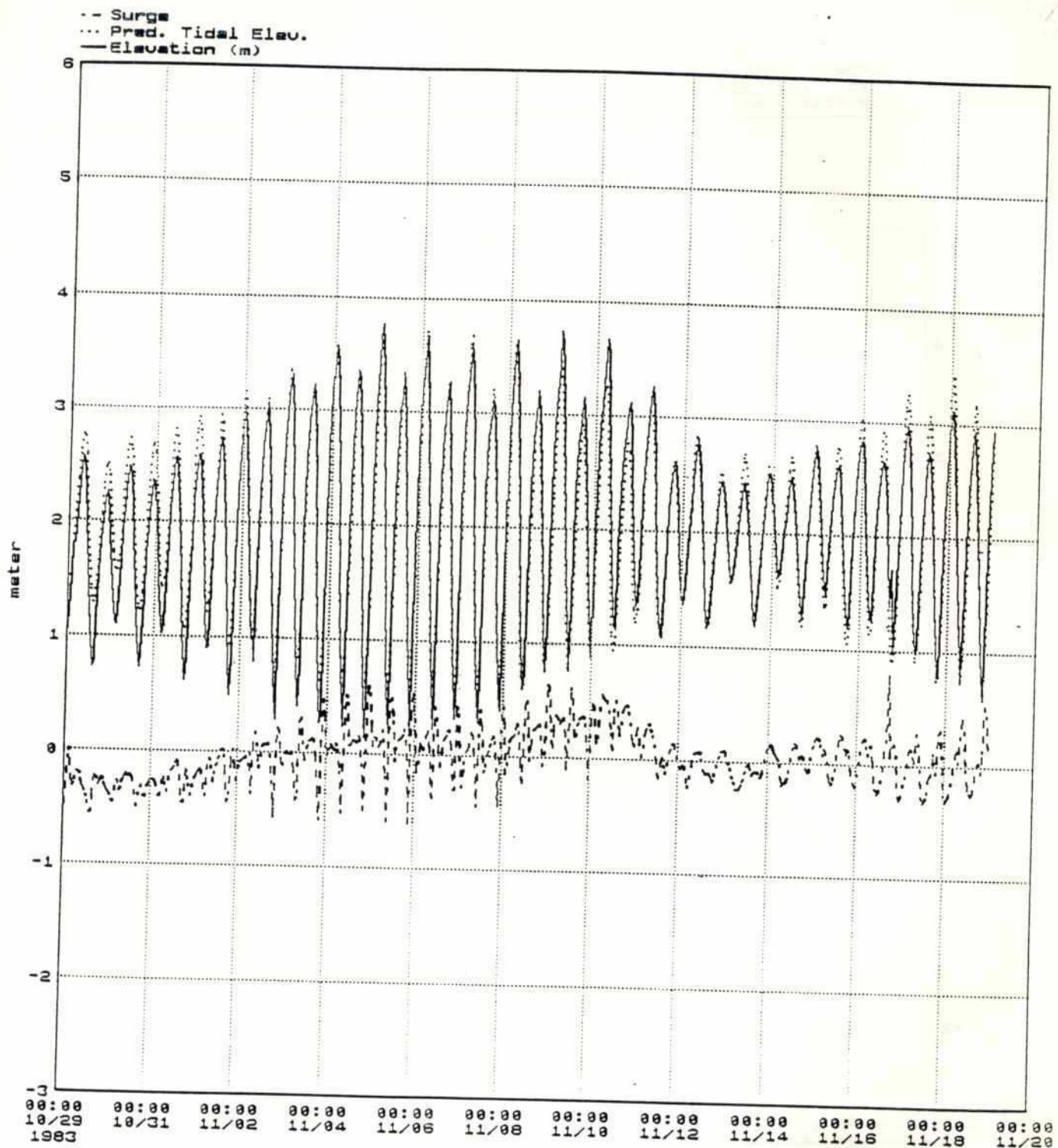


-- Surge  
 ... Pred. Tidal EleU.  
 — Elevation (m)



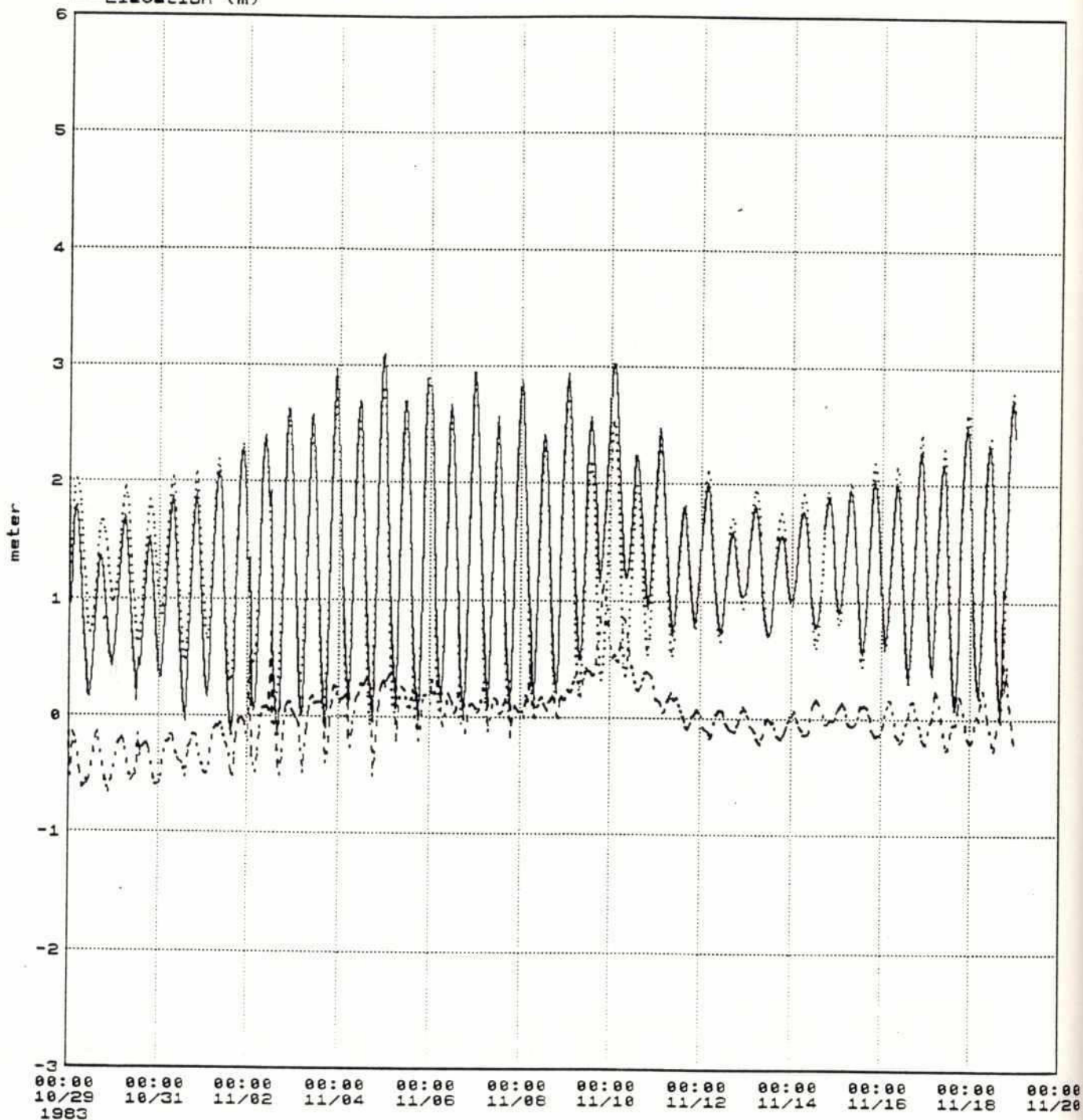
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : sbar4 User: mnr Sun Dec 16 1990	November 1983 Barisal Measurements	Dwg. No.  4.124





<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : schr4 User: mnr Sun Dec 16 1990	November 1983 Char-Chenga Measurements	Dwg. No.  4.125

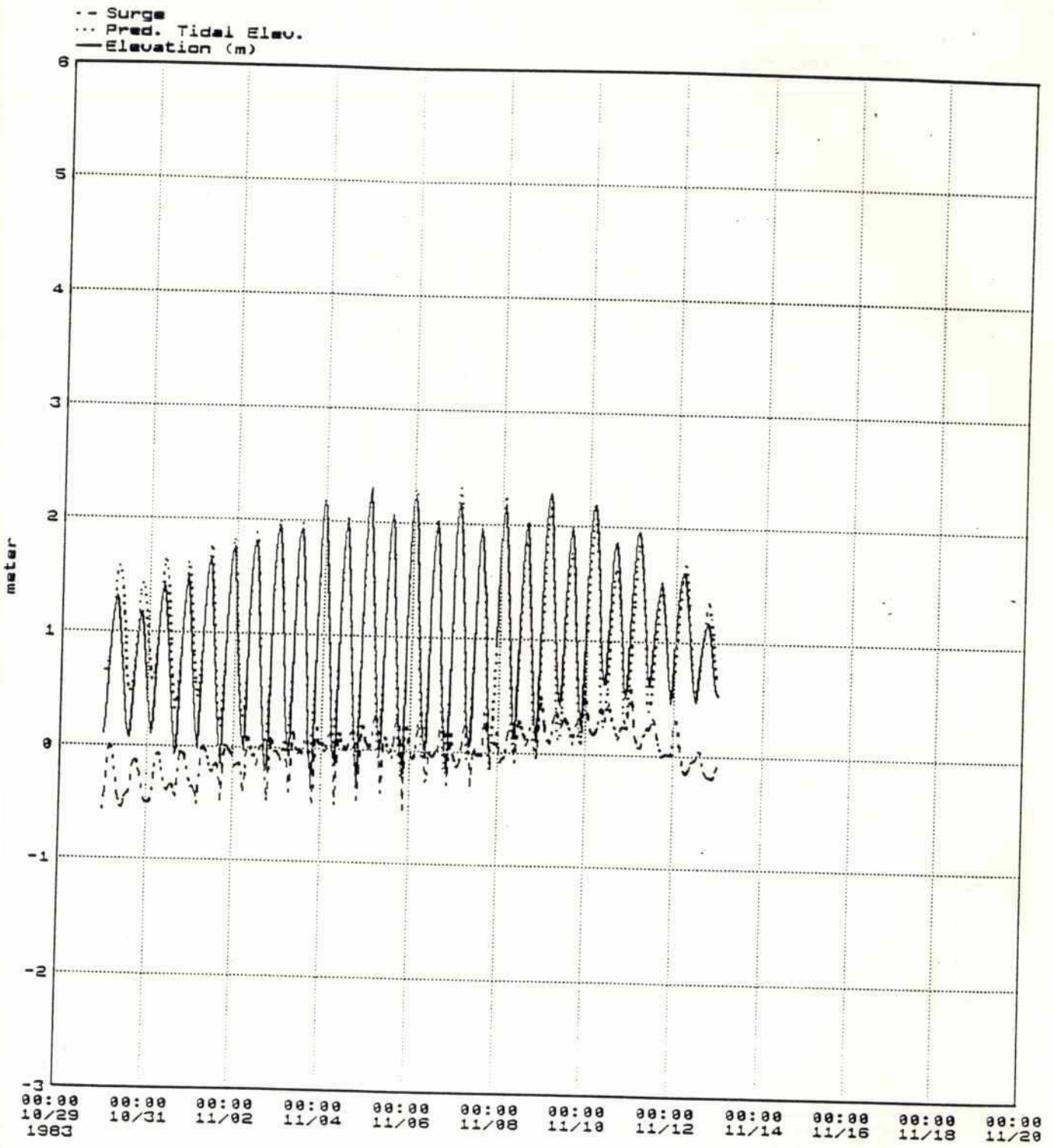
-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : scox4 User: mnr Sun Dec 16 1990	November 1983 Cox's Bazar Measurements	Dwg. No.  4.126



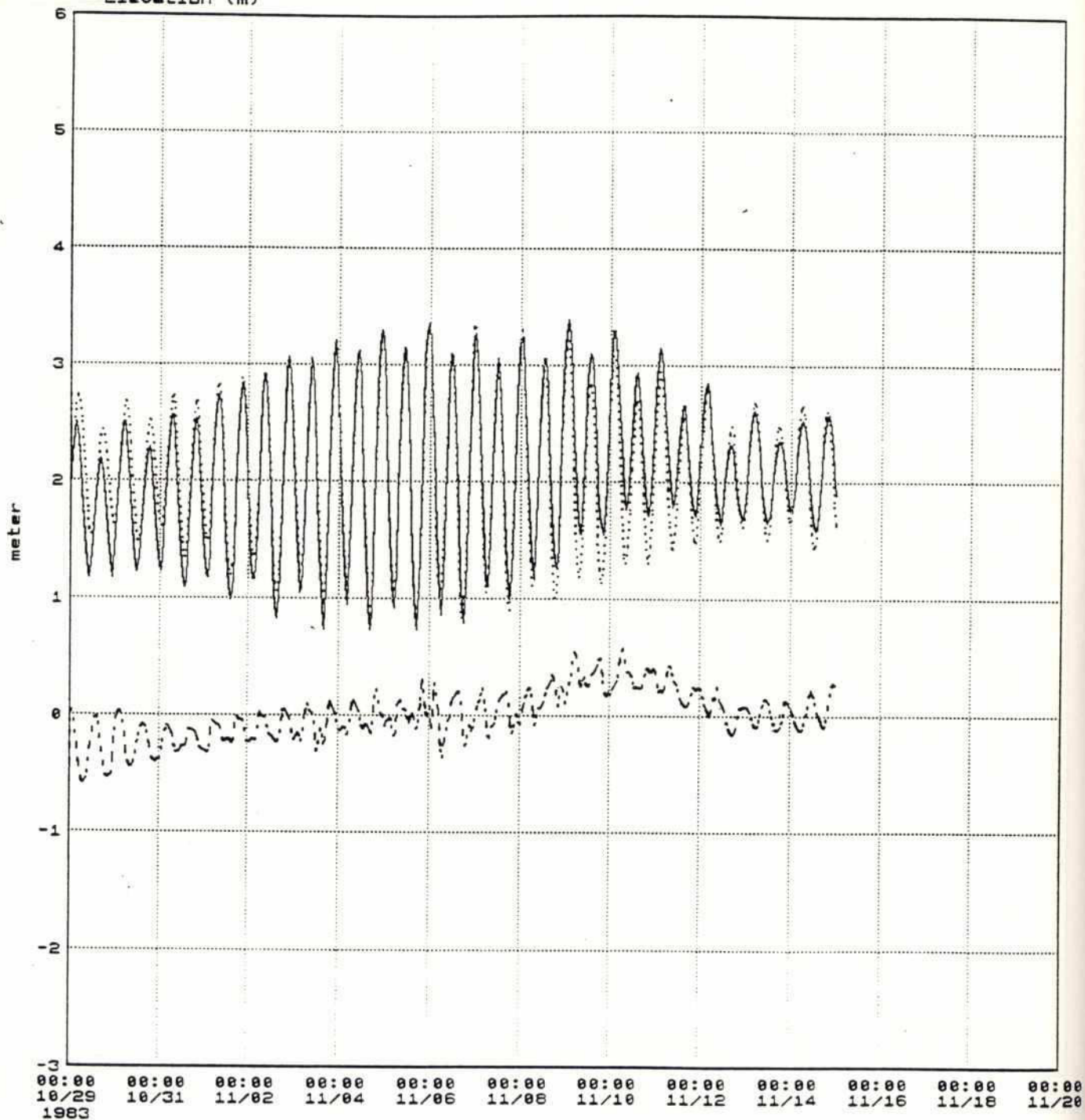
202



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : sgal4 User: mnr Sun Dec 16 1990	November 1983 Galachipa Measurements	Dwg. No.  4.127

220

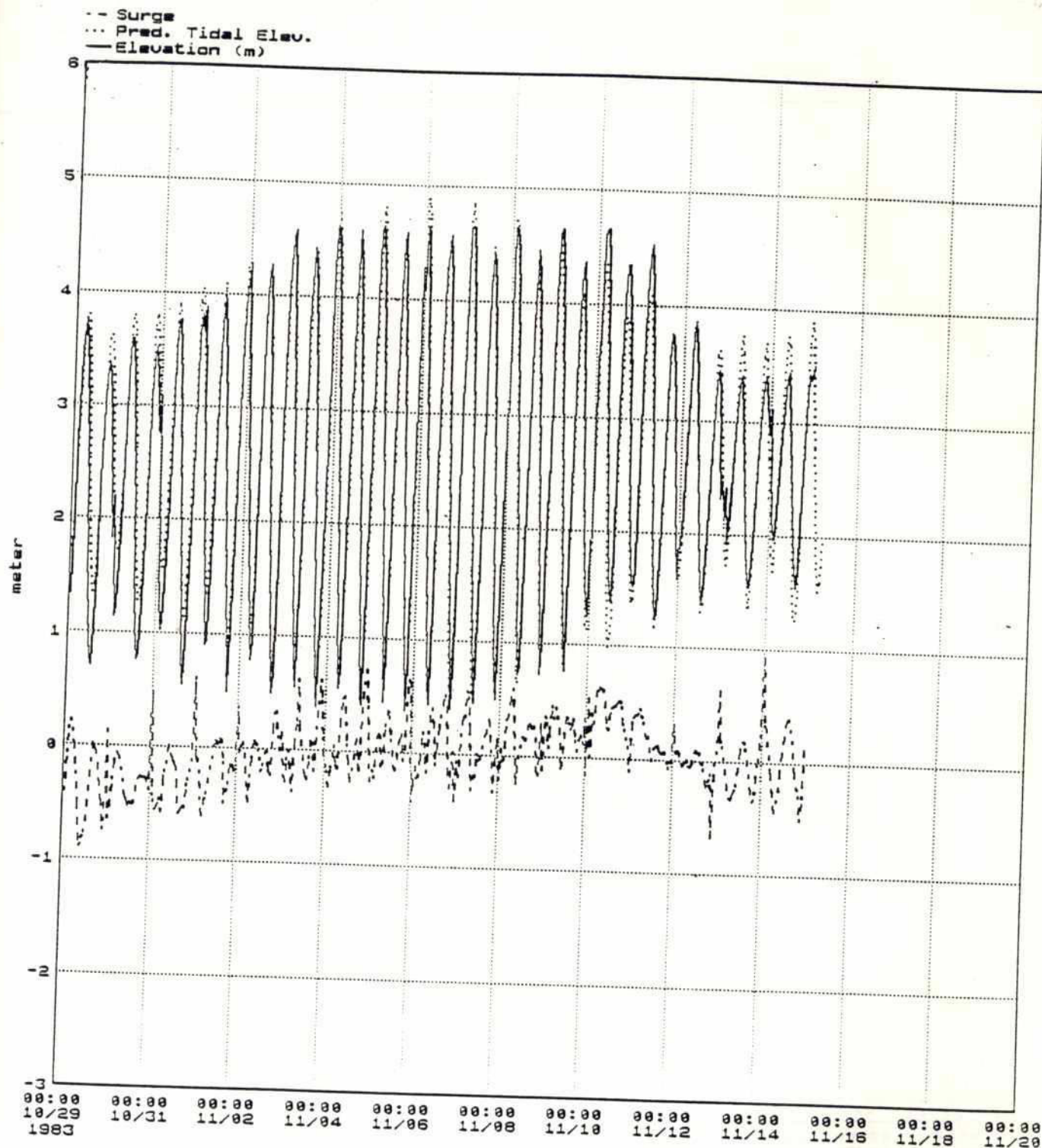
-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



MIKE21	Cyclone Protection Project II	
File: family: n83 name : shir4 User: mnr Sun Dec 16 1998	November 1983 Hiron Point Measurements	Dwg. No.  4.128



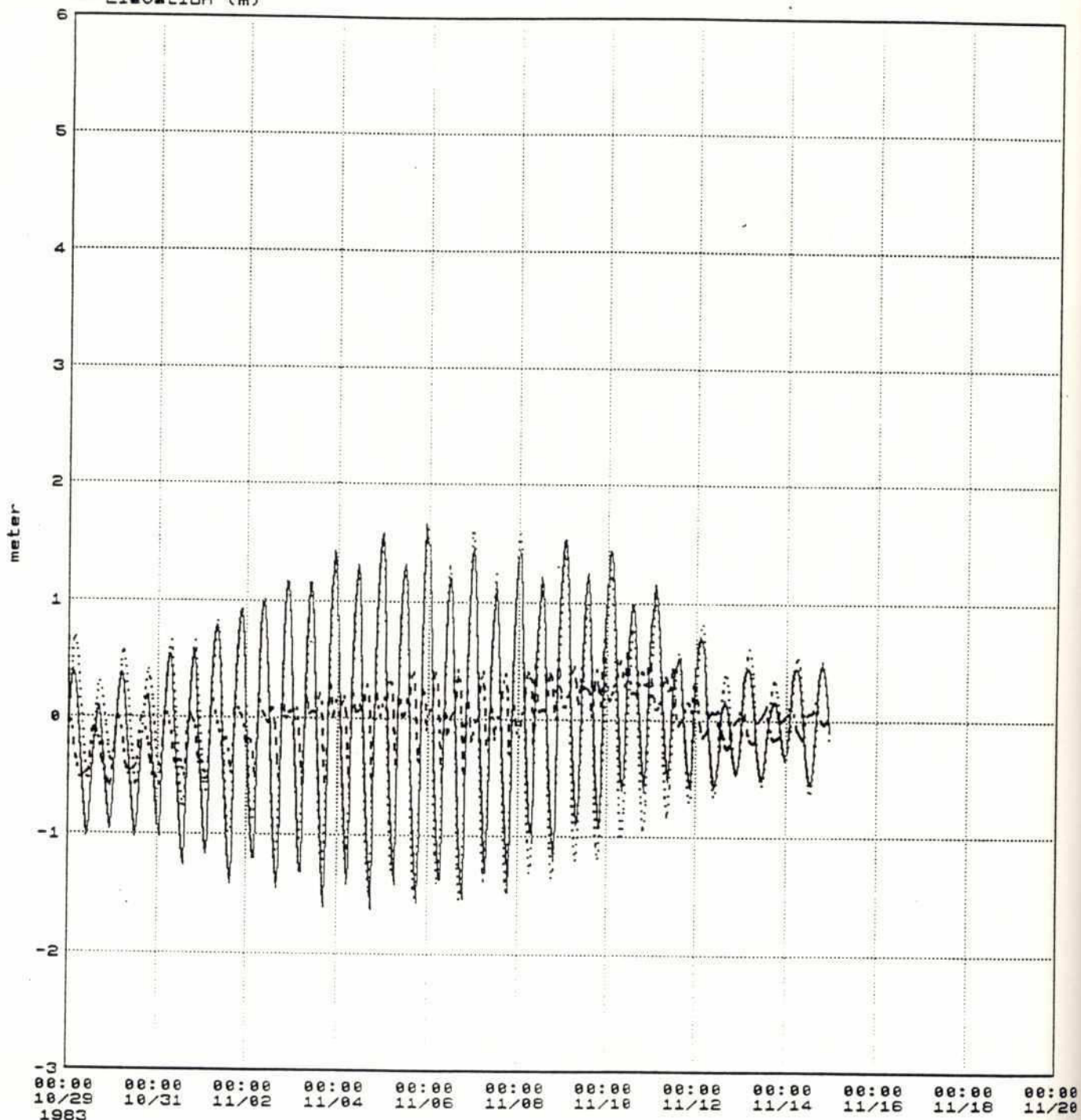
203



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : skha4 User: mnr Sun Dec 16 1990	November 1983 Khal No. 10 Measurements	Dwg. No.  4.129

222

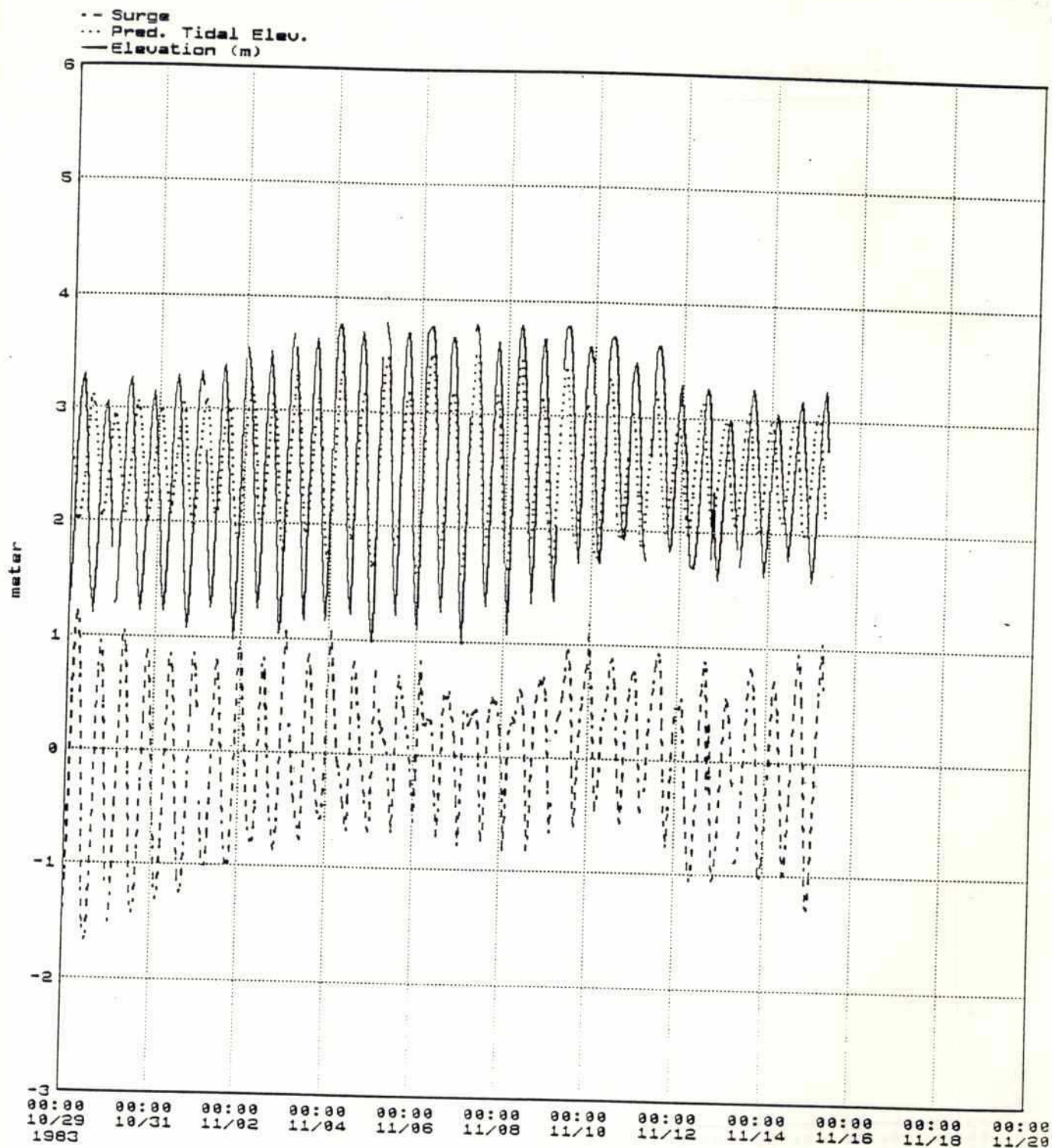
-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : skhe4 User: mnr Sun Dec 16 1990	November 1983 Khapupara Measurements	Dwg. No.  4.130



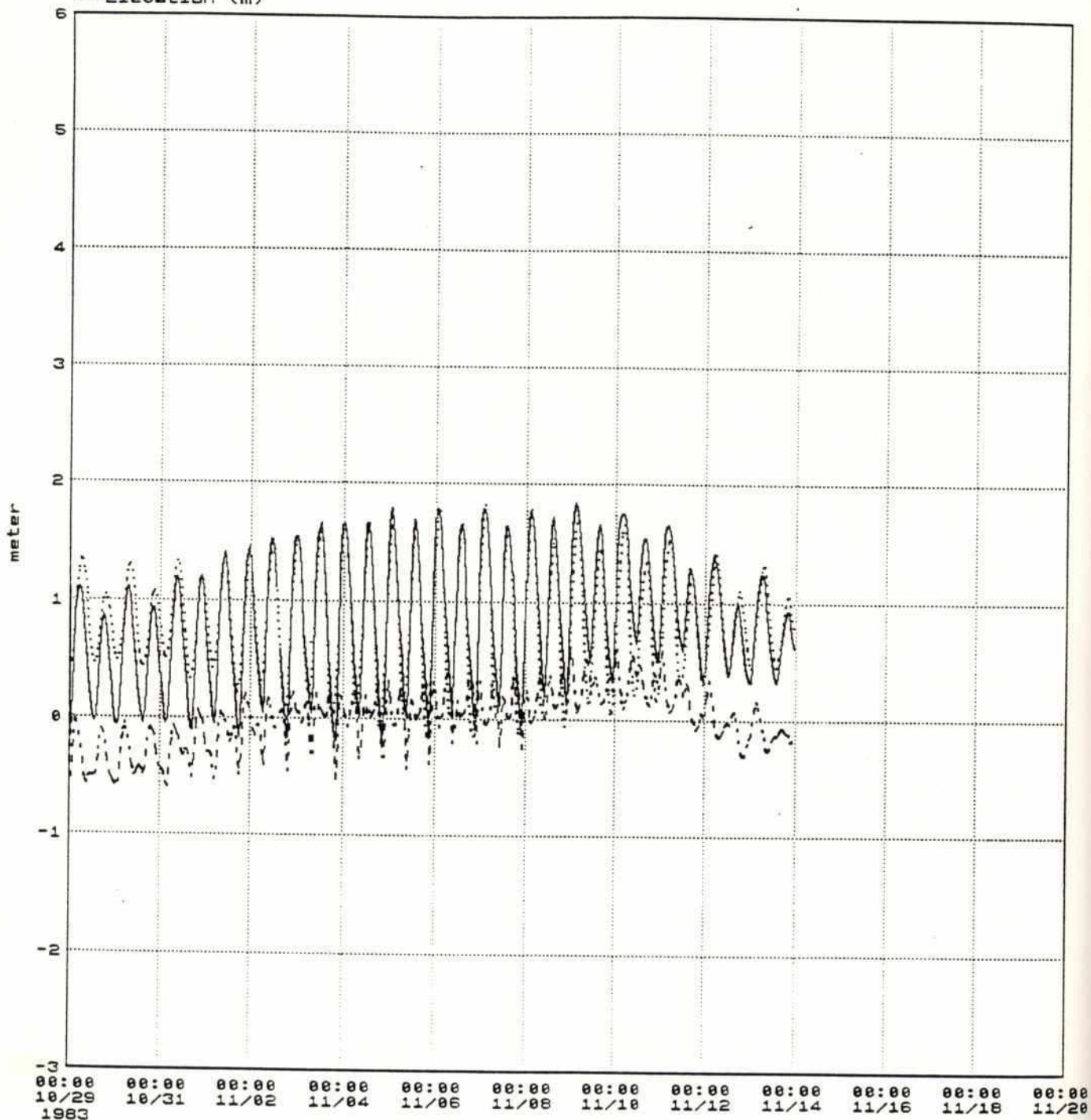
206



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : smon4 User: mnr Sun Dec 16 1990	November 1983 Mongia Measurements	Dwg. No.  4.131

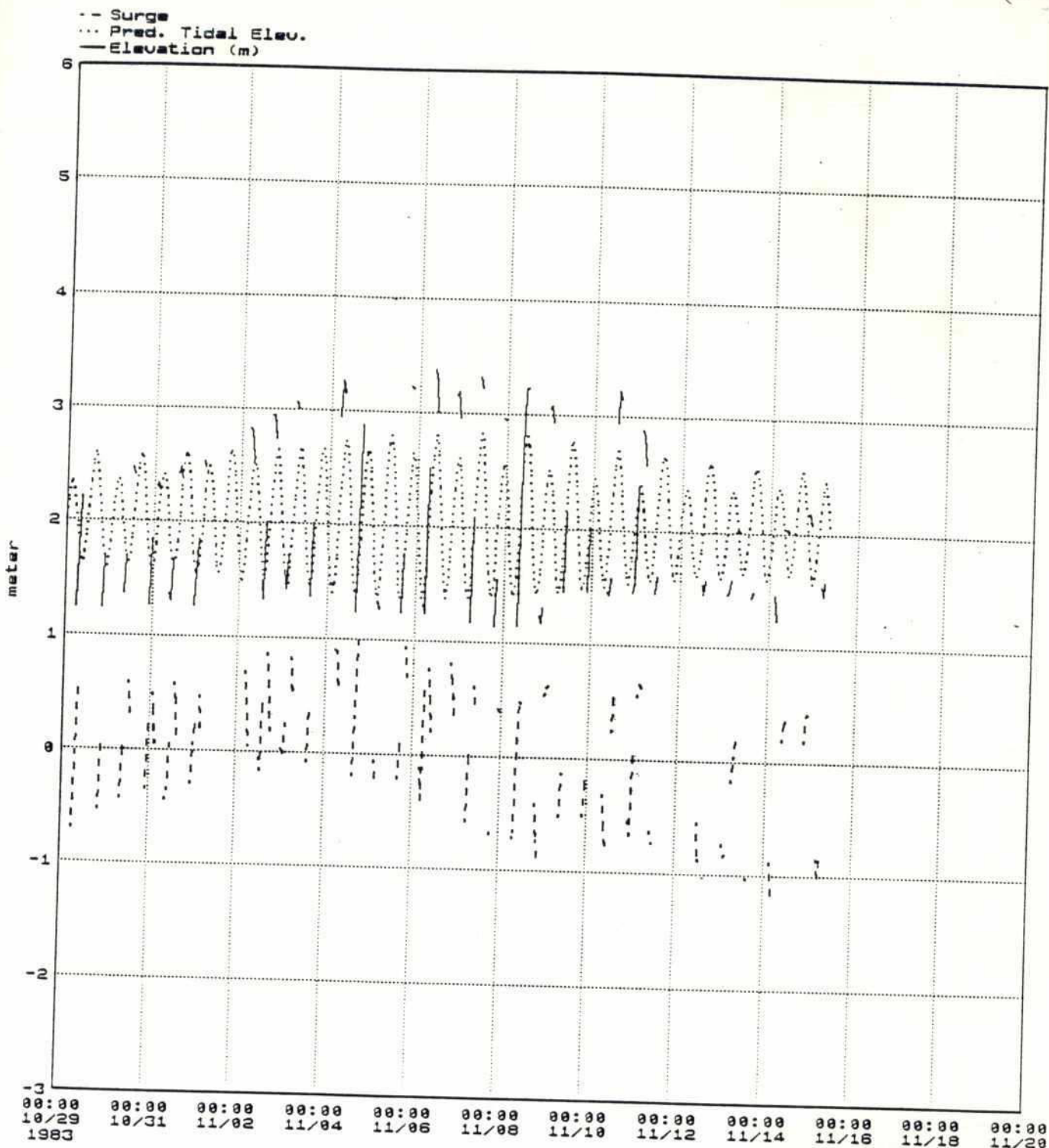
228

-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



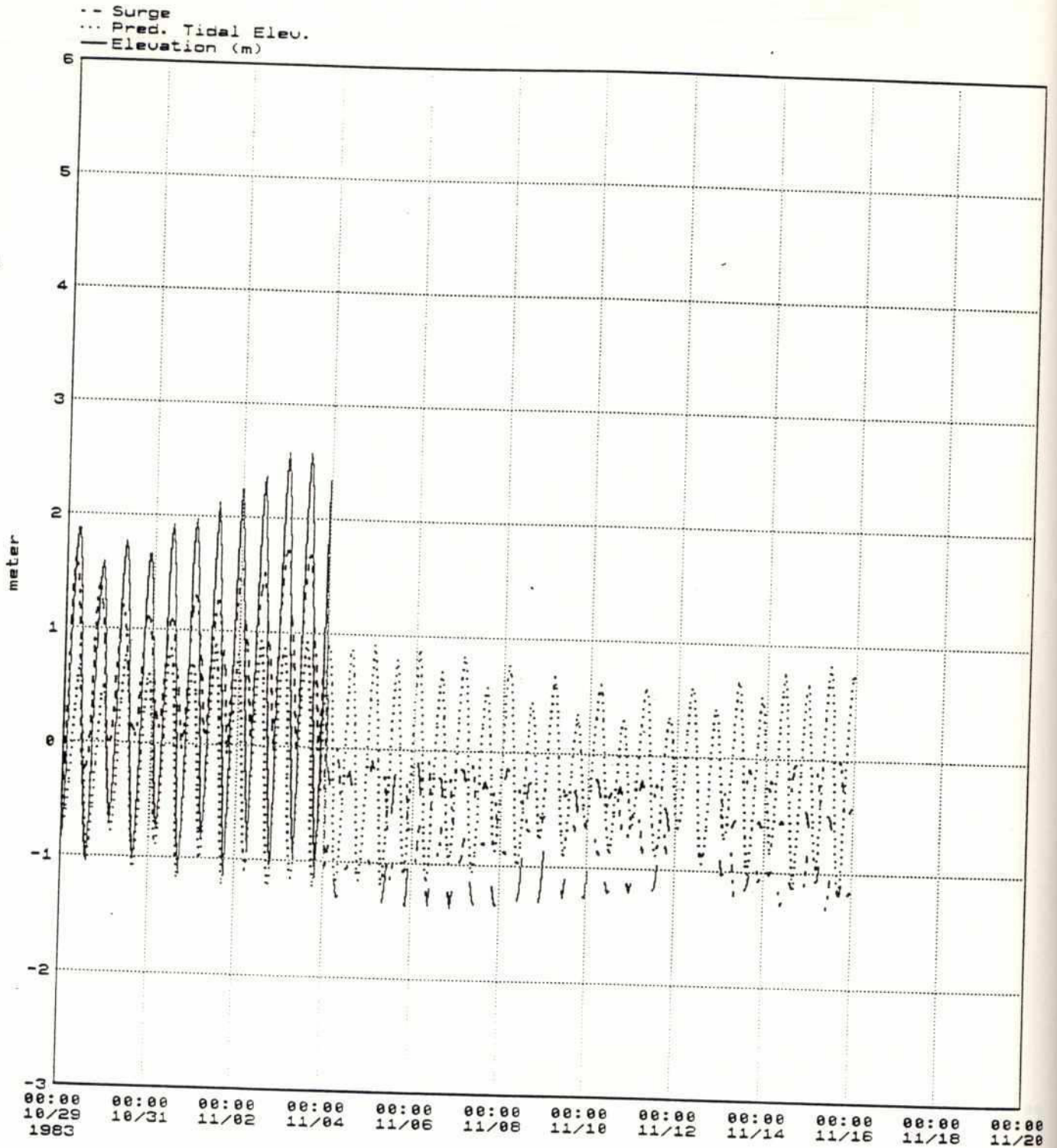
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : spat4 User: mnr Sun Dec 16 1990	November 1983 Patuakhali Measurements	Dwg. No.  4.132





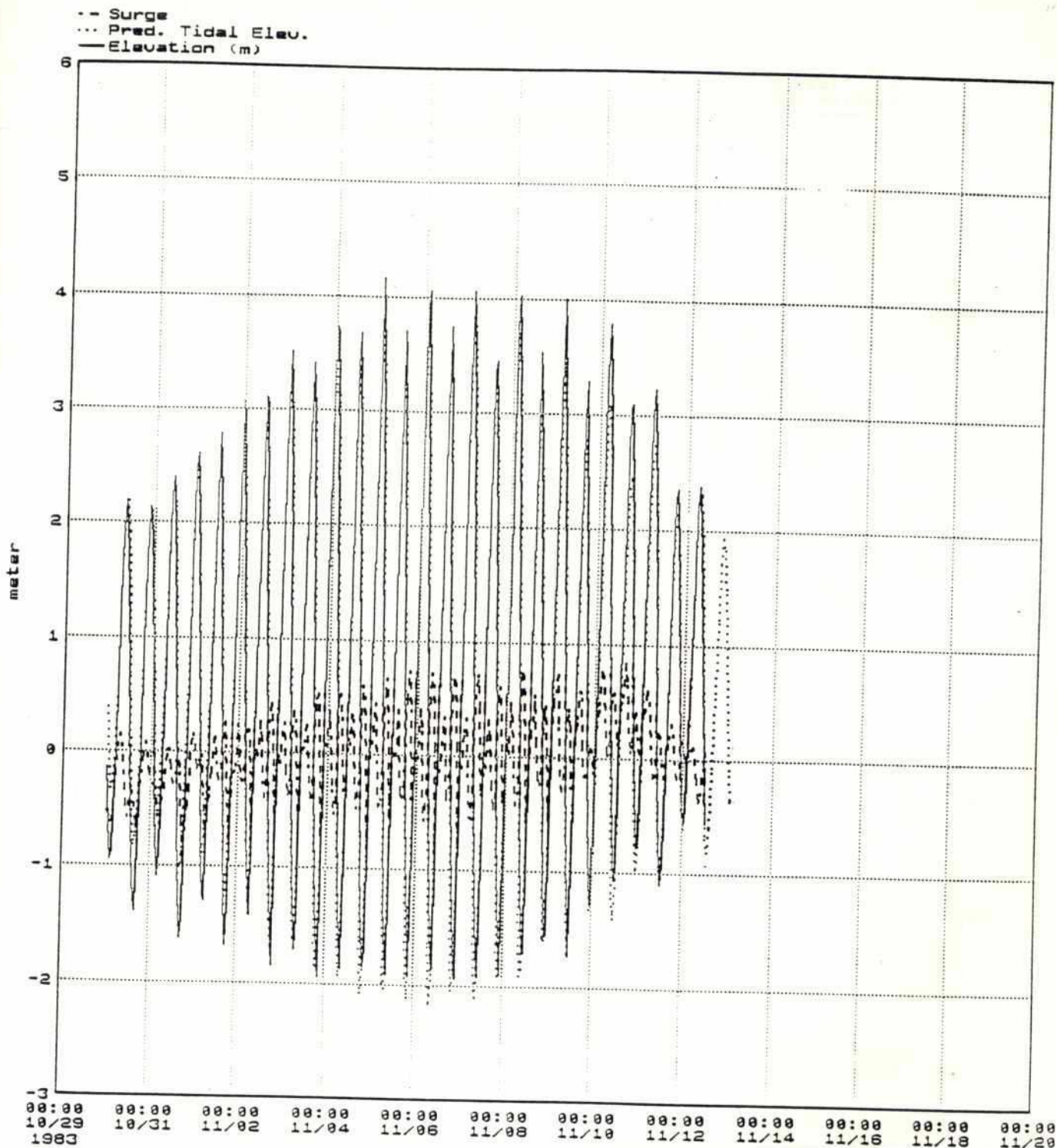
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : sram4 User: mnr Sun Dec 16 1990	November 1983 Ramdaspur Measurements	Dwg. No.  4.133

220



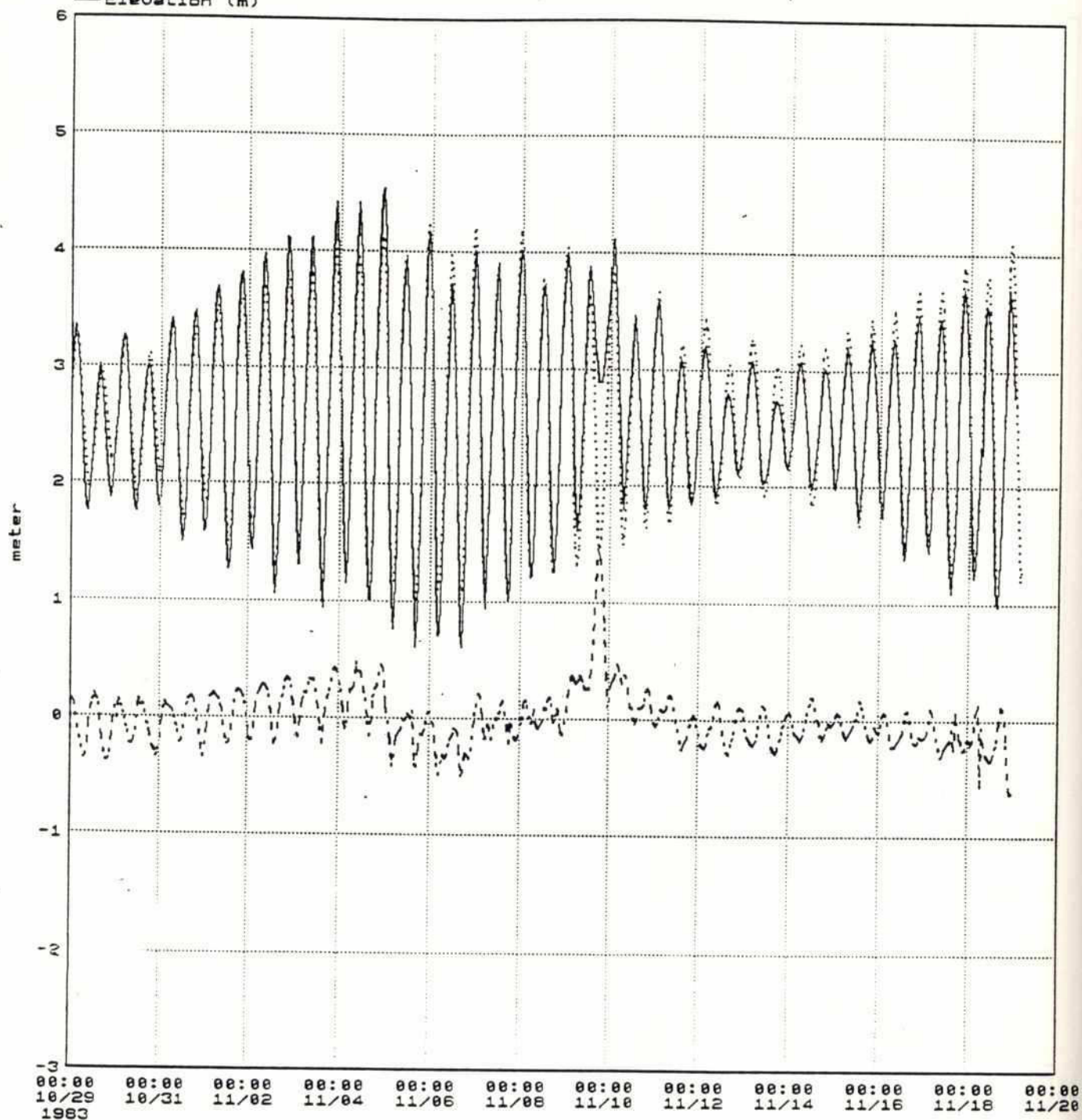
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : ssad4 User: mnr Sun Dec 16 1990	November 1983 Sadarghat (CTG) Measurements	Dwg. No.  4.134





<b>MIKE21</b>	Cyclone Protection Project II	
File: family: n83 name : ssan4 User: mnr Sun Dec 16 1990	November 1983 Sandwip Measurements	Dwg. No.  4.135

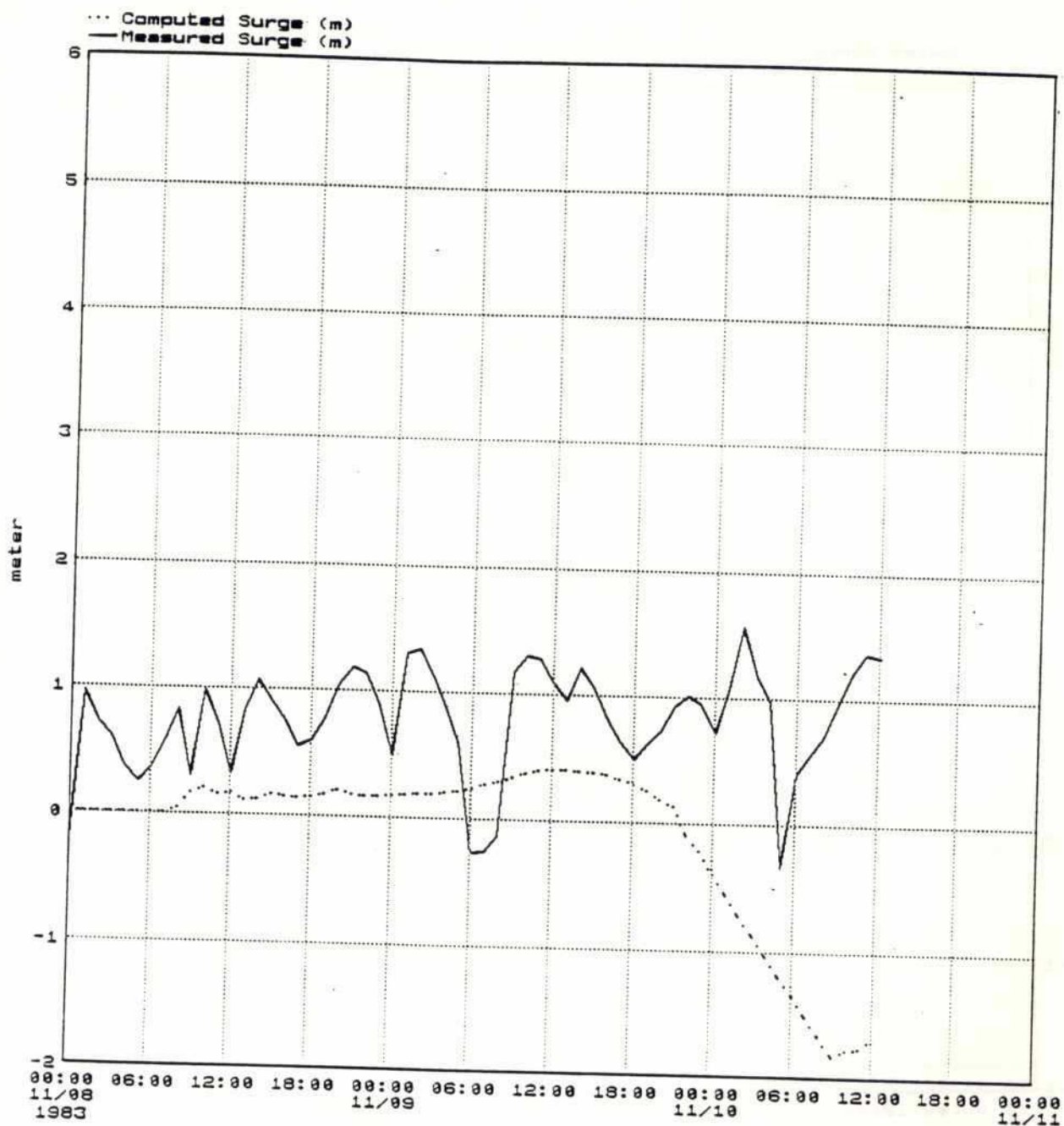
-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : stak4 User: mnr Sun Dec 16 1990	November 1983 Teknaf (Shapuri) Measurements	Dwg. No.  4.136

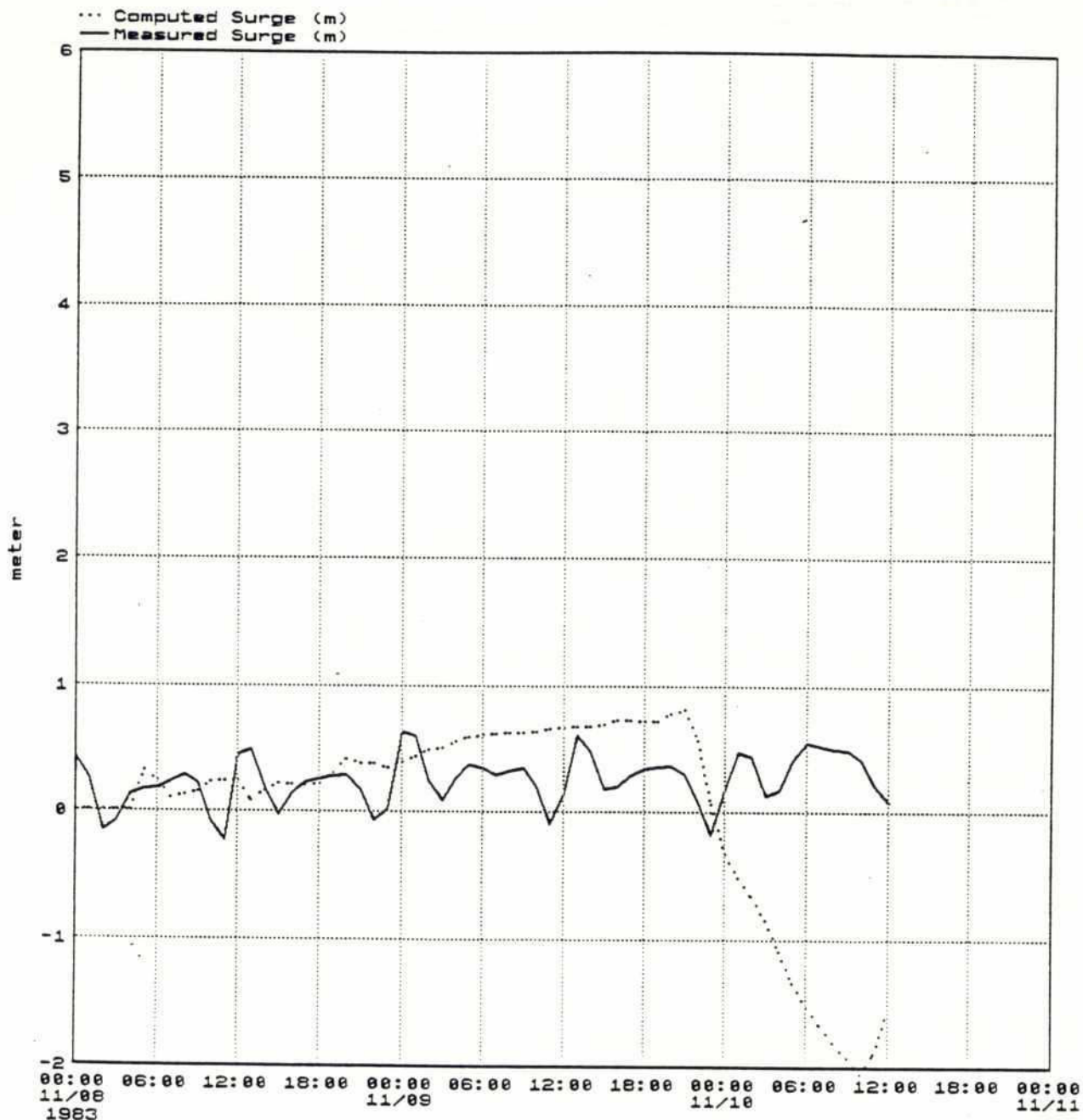


272



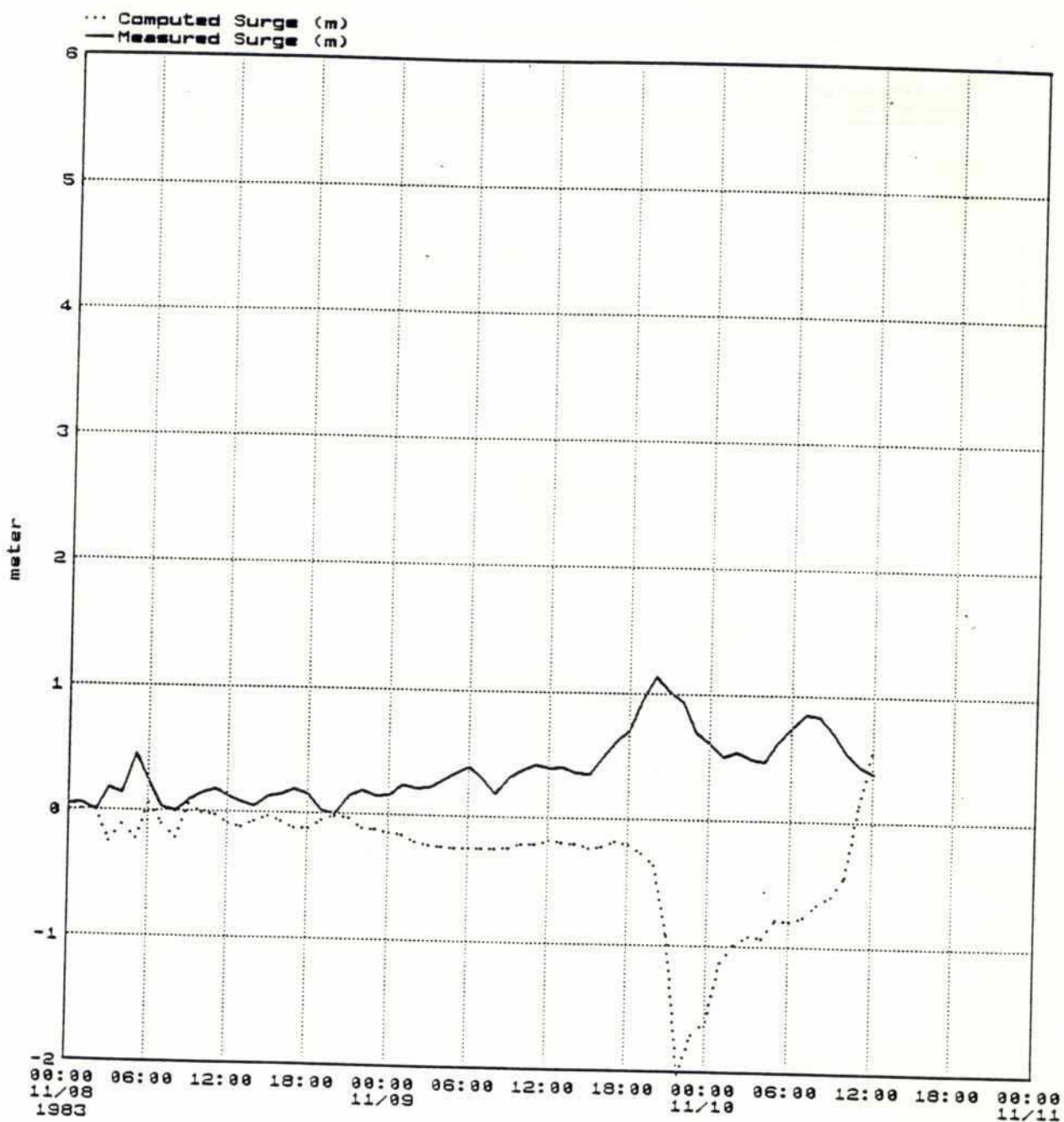
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n83 name : cbar4 User: mnr Sun Dec 16 1990	November 1983 Barisal Measured and computed surge	Dwg. No.  4.137

220



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : cchr4 User: mnr Sun Dec 16 1990	November 1983 Char-Cheng Measured and computed surge	Dwg. No.  4.138

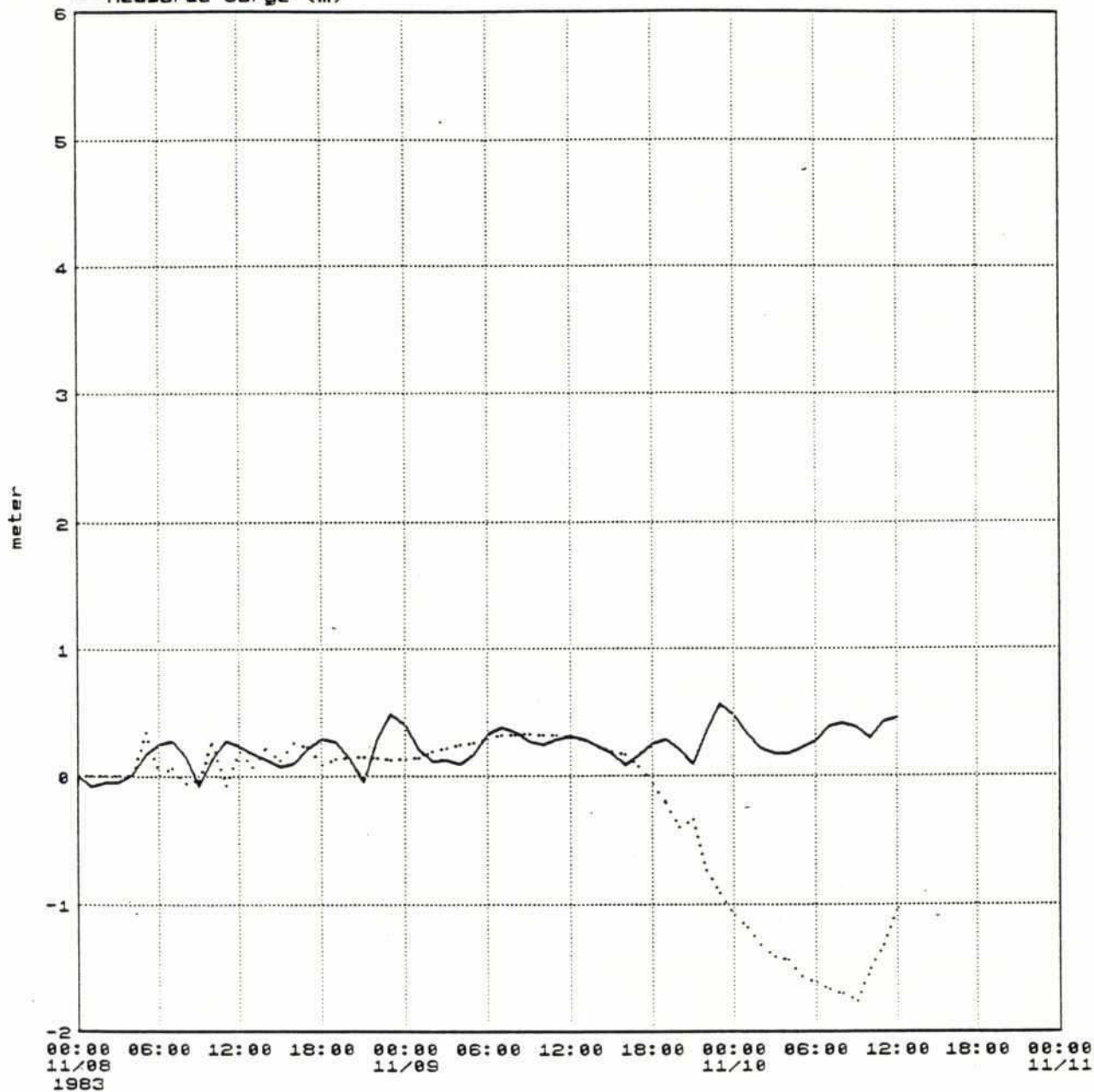




<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n83 name : ccox4 User: mnr Sun Dec 16 1990	November 1983 Coxs Bazar Measured and computed surge	Dwg. No.  4.139

222

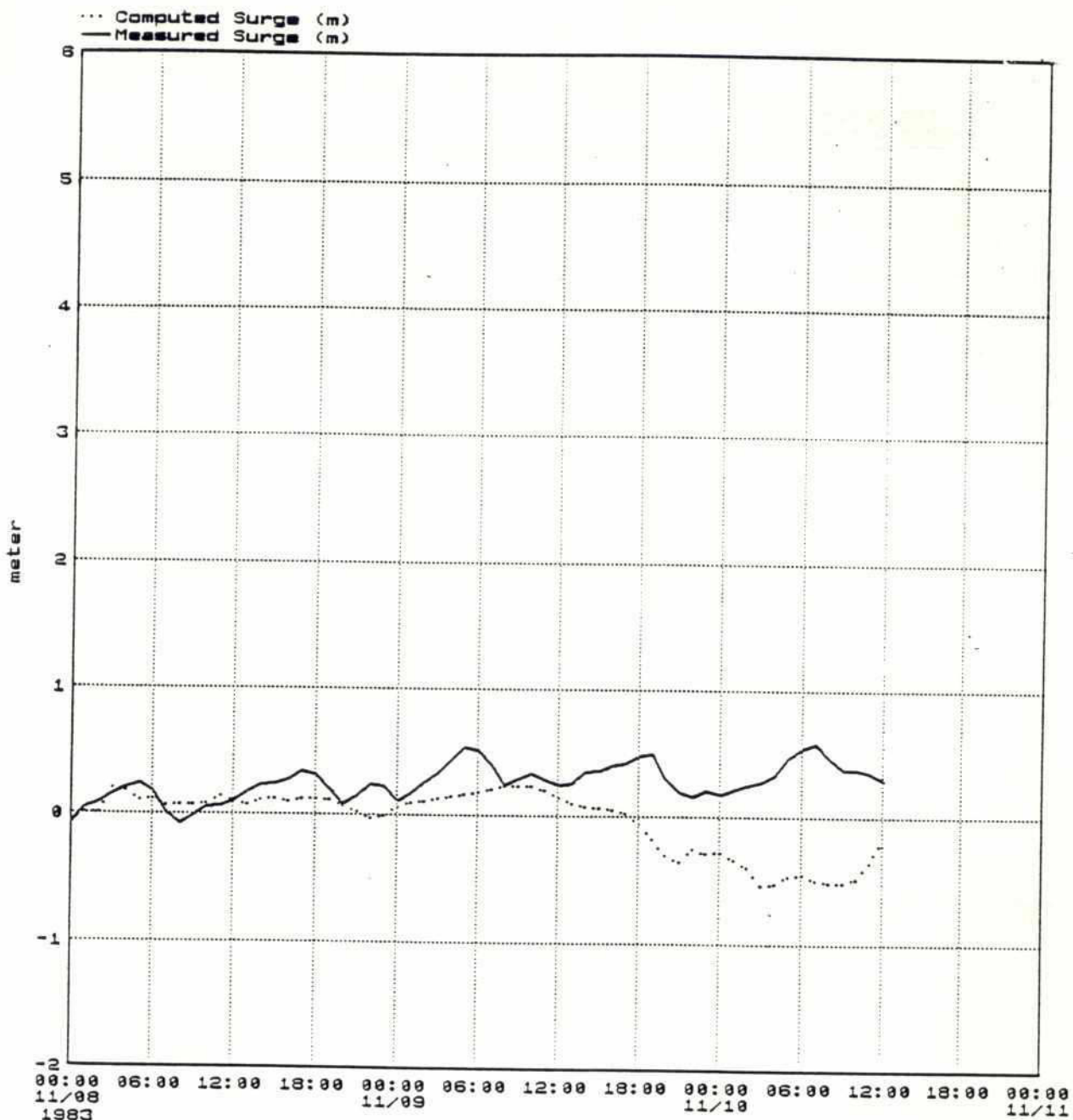
... Computed Surge (m)  
 — Measured Surge (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : cgal4 User: mnr Sun Dec 16 1990	November 1983 Galachipa Measured and computed surge	Dwg. No.  4.140

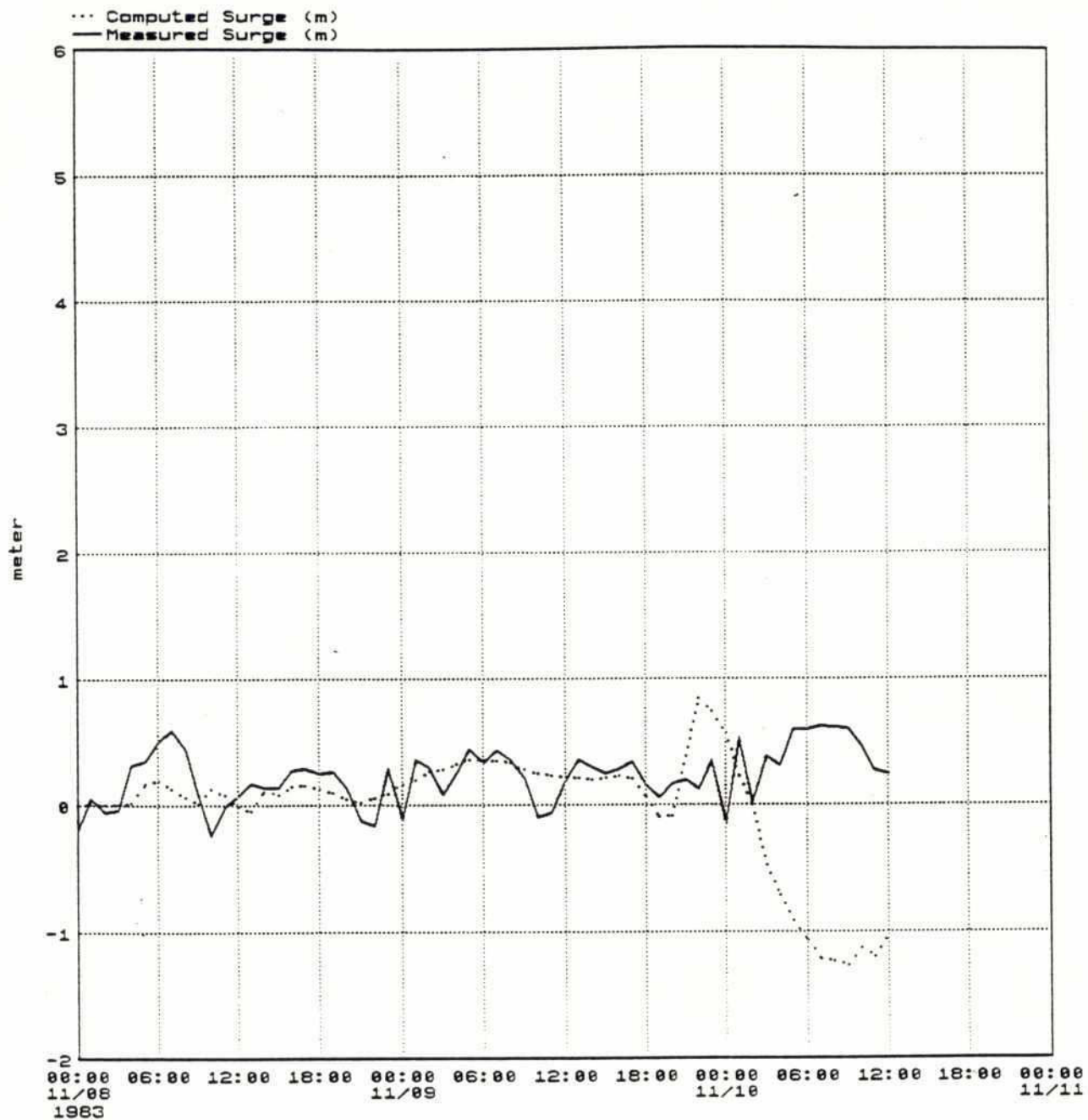


228  
226



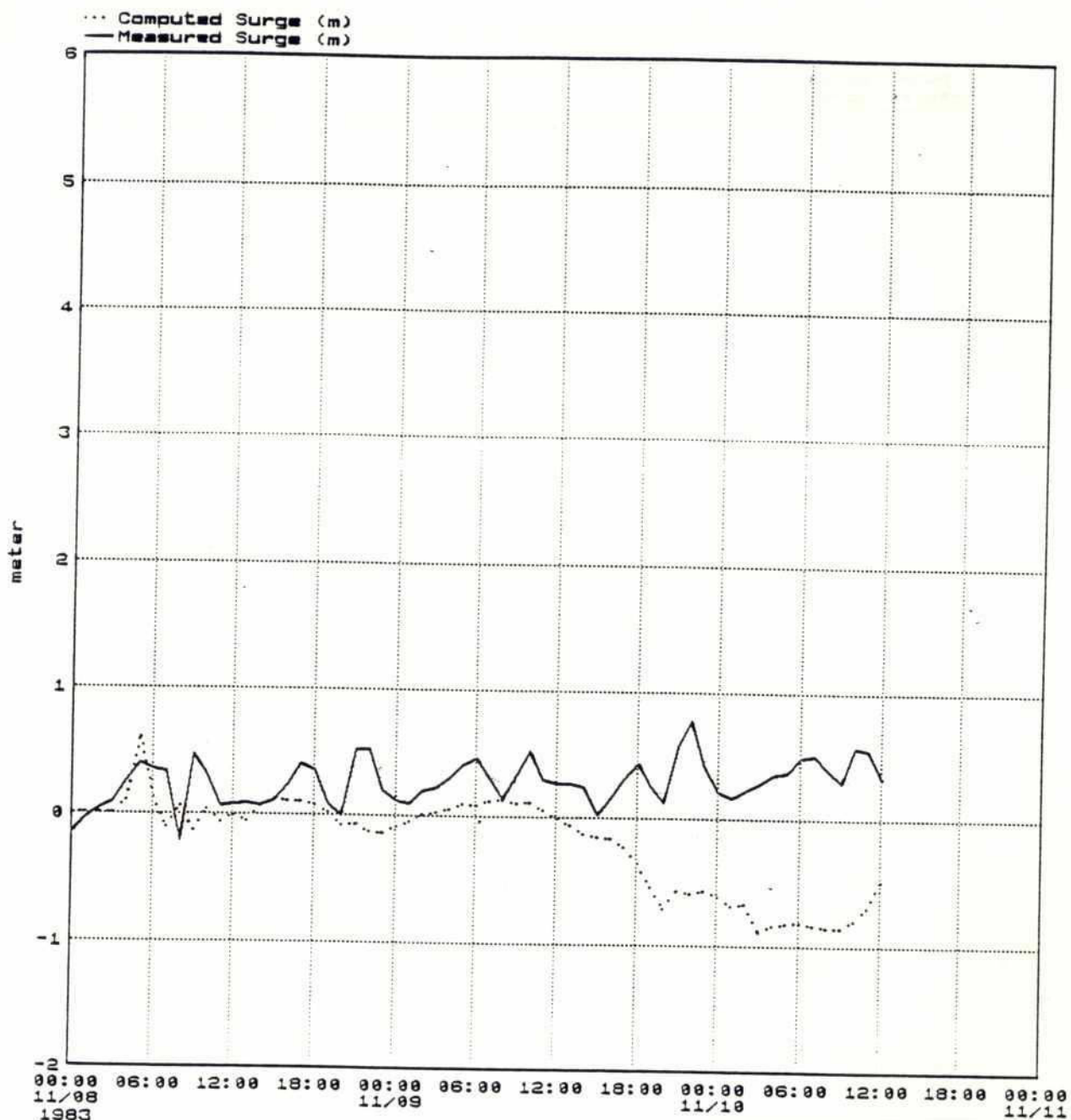
<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: n83 name : chir4 User: mnr Sun Dec 16 1990</p>	<p>November 1983 Hiron Point Measured and computed surge</p>	<p>Dwg. No.  4.141</p>

228



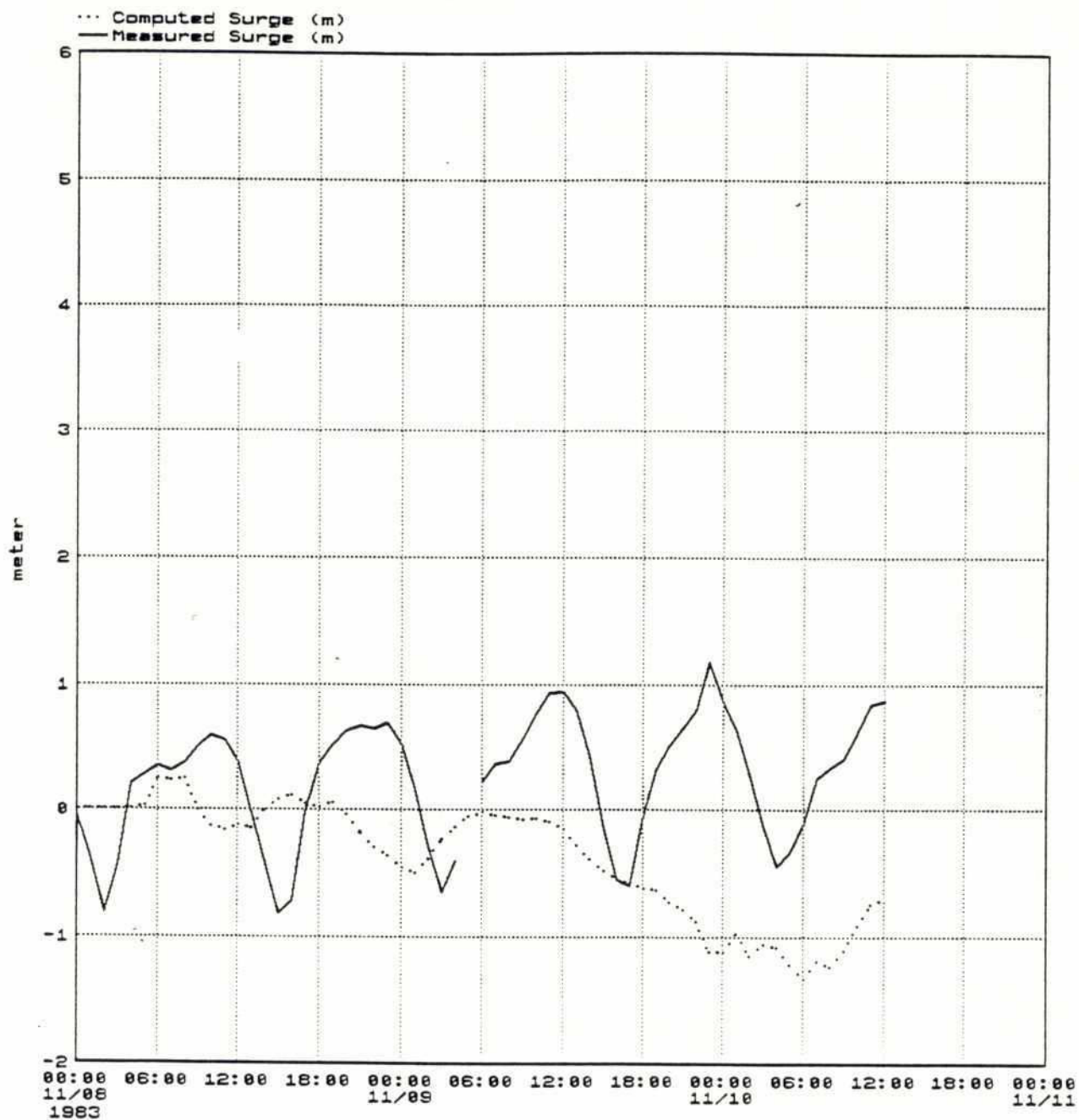
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n83 name : ckha4 User: mnr Sun Dec 16 1990	November 1983 Khal No. 10 Measured and computed surge	Dwg. No.  4.142





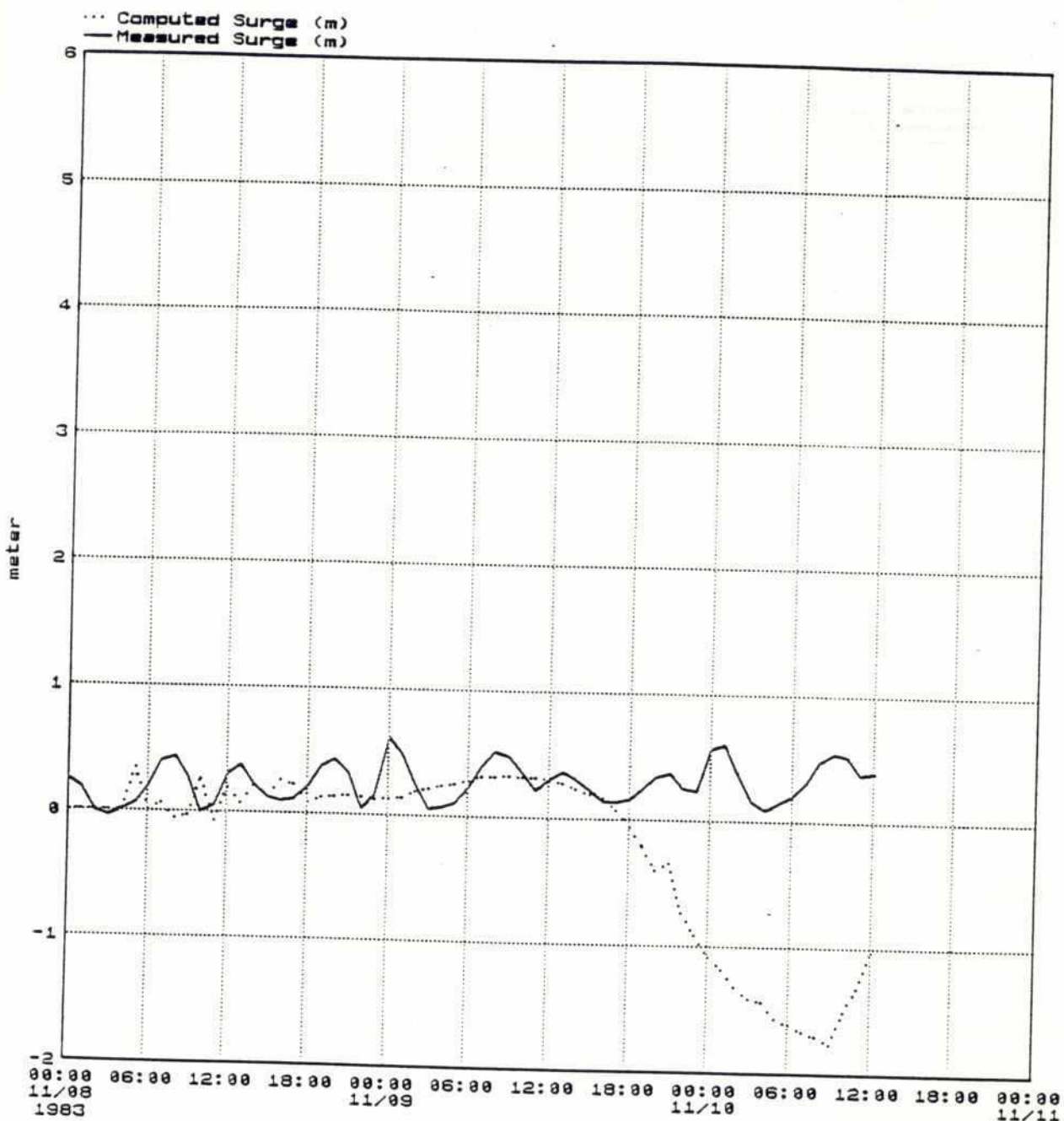
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n83 name : ckhe4 User: mnr Sun Dec 16 1990	November 1983 Khepupara Measured and computed surge	Dwg. No.  4.143

229



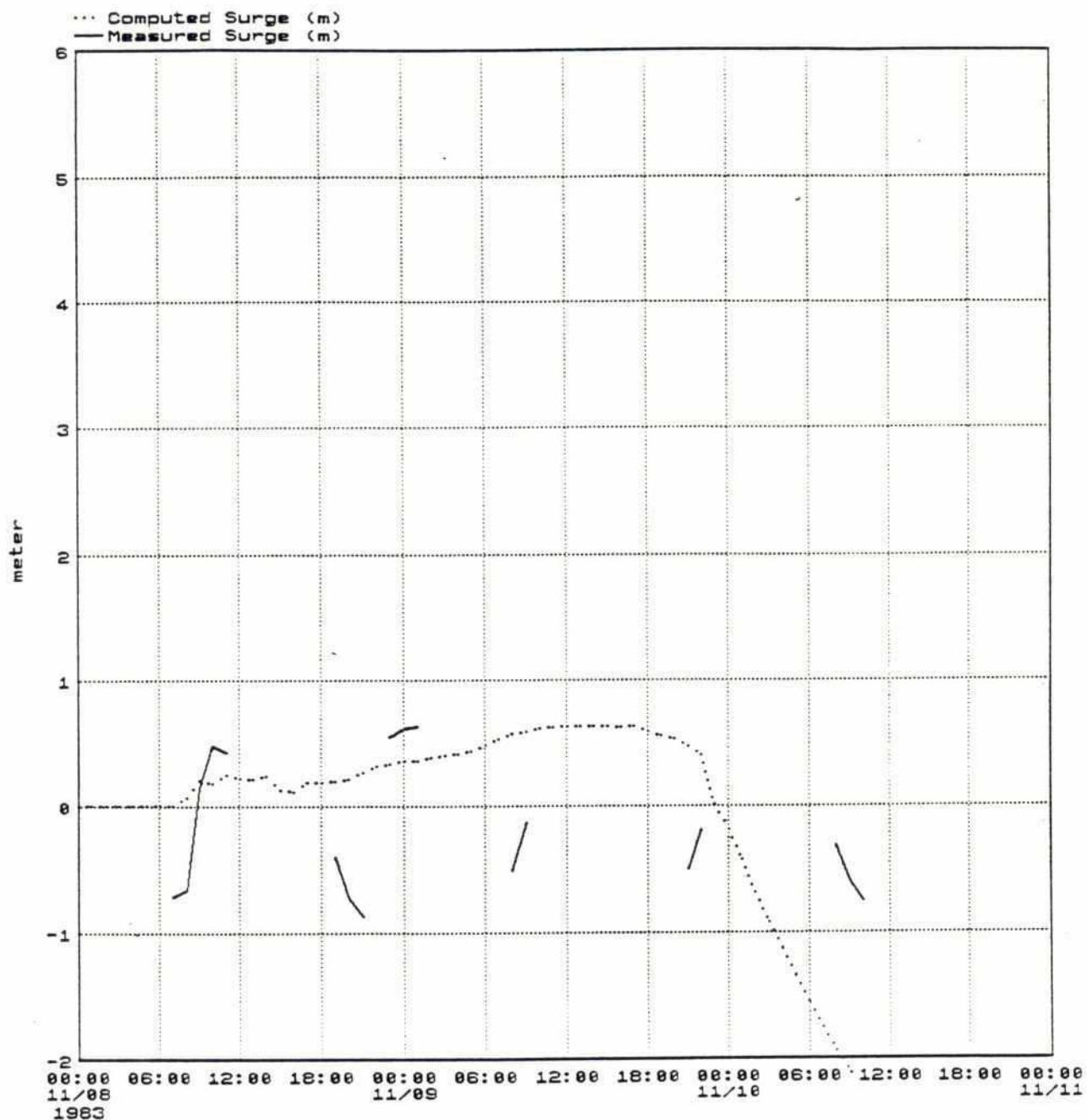
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : cmon4 User: mnr Sun Dec 16 1990	November 1983 Mongla Measured and computed surge	Dwg. No.  4.144





<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n83 name : cpat4 User: mnr Sun Dec 16 1990	November 1983 Patuakhali Measured and computed surge	Dwg. No.  4.145

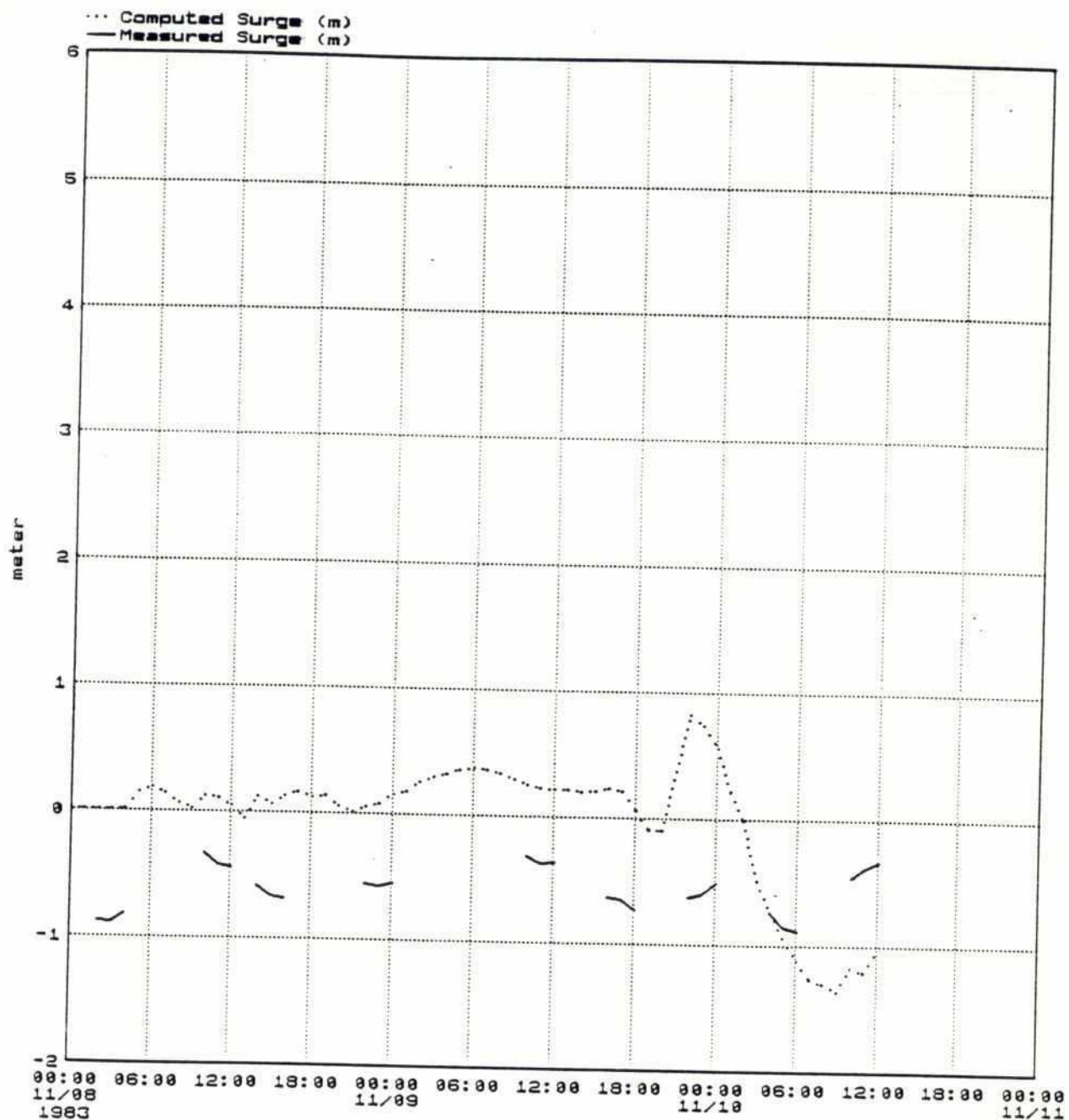
221



<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: n83 name : cram4 User: mnr Sun Dec 16 1990</p>	<p>November 1983 Ramdasapur Measured and computed surge</p>	<p>Dwg. No.  4.146</p>

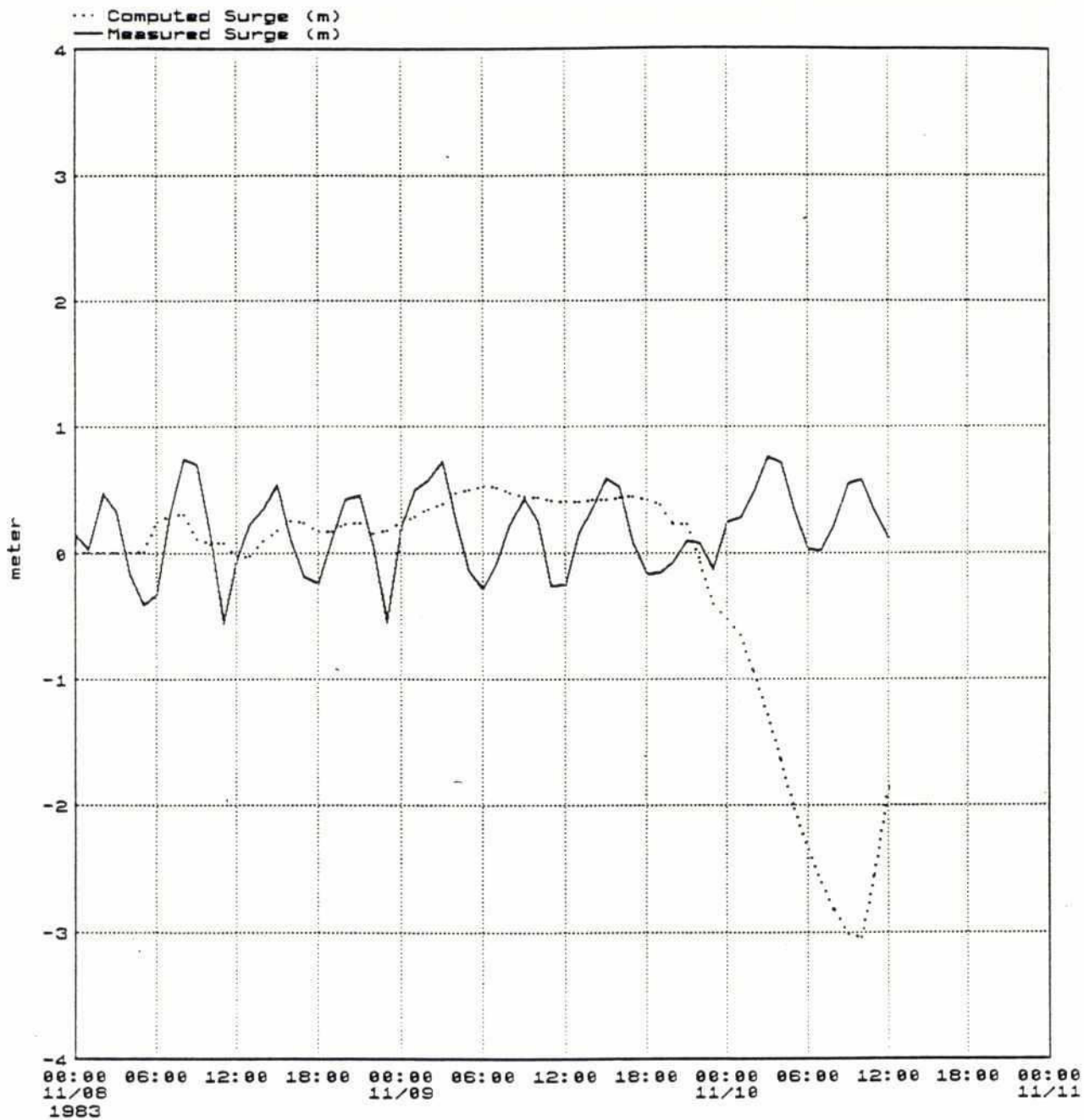


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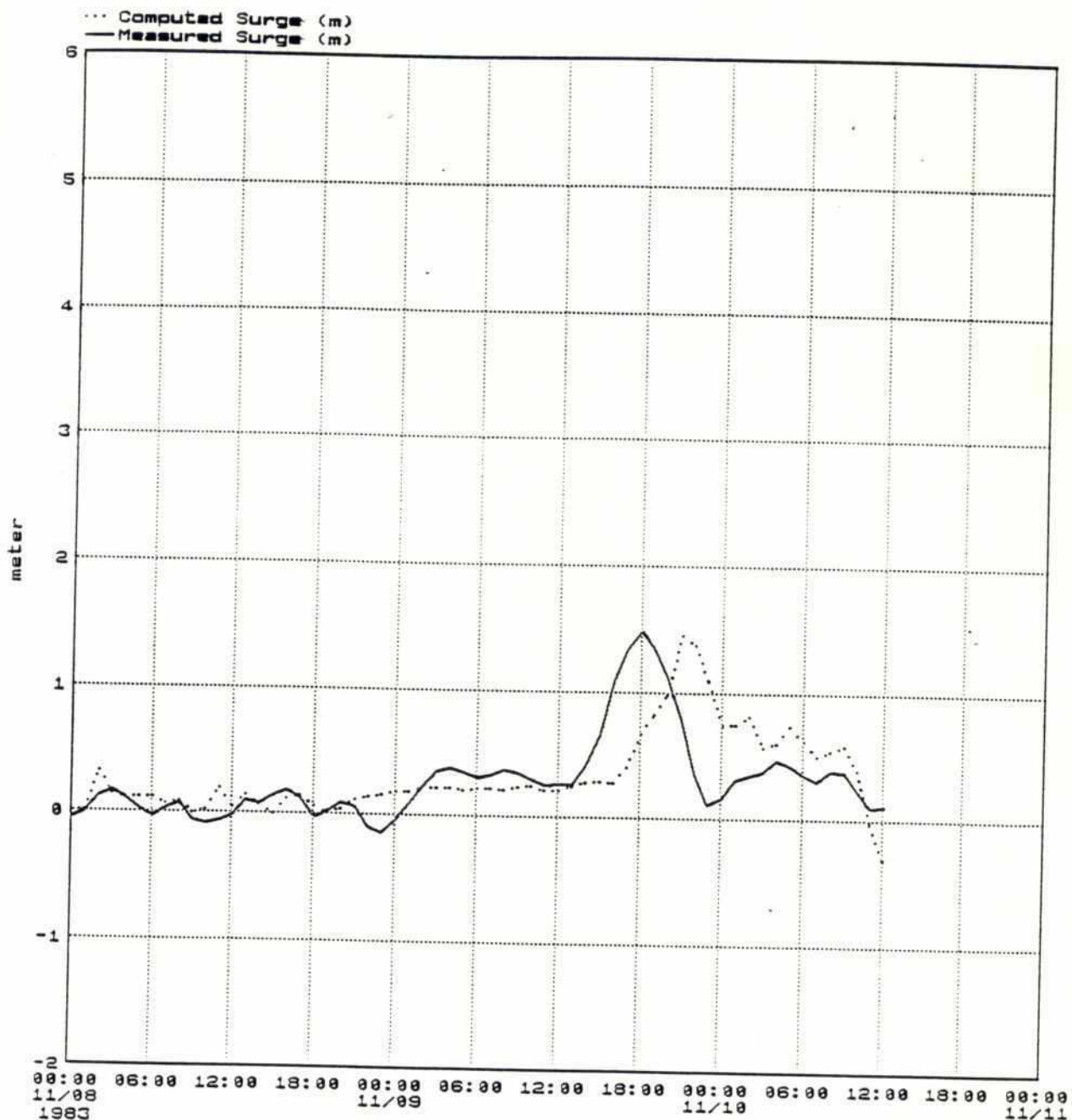
<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: n83 name : csad4 User: mnr Sun Dec 16 1990</p>	<p>November 1983 Sadarghat (CTG) Measured and computed surge</p>	<p>Dwg. No.  4.147</p>

260



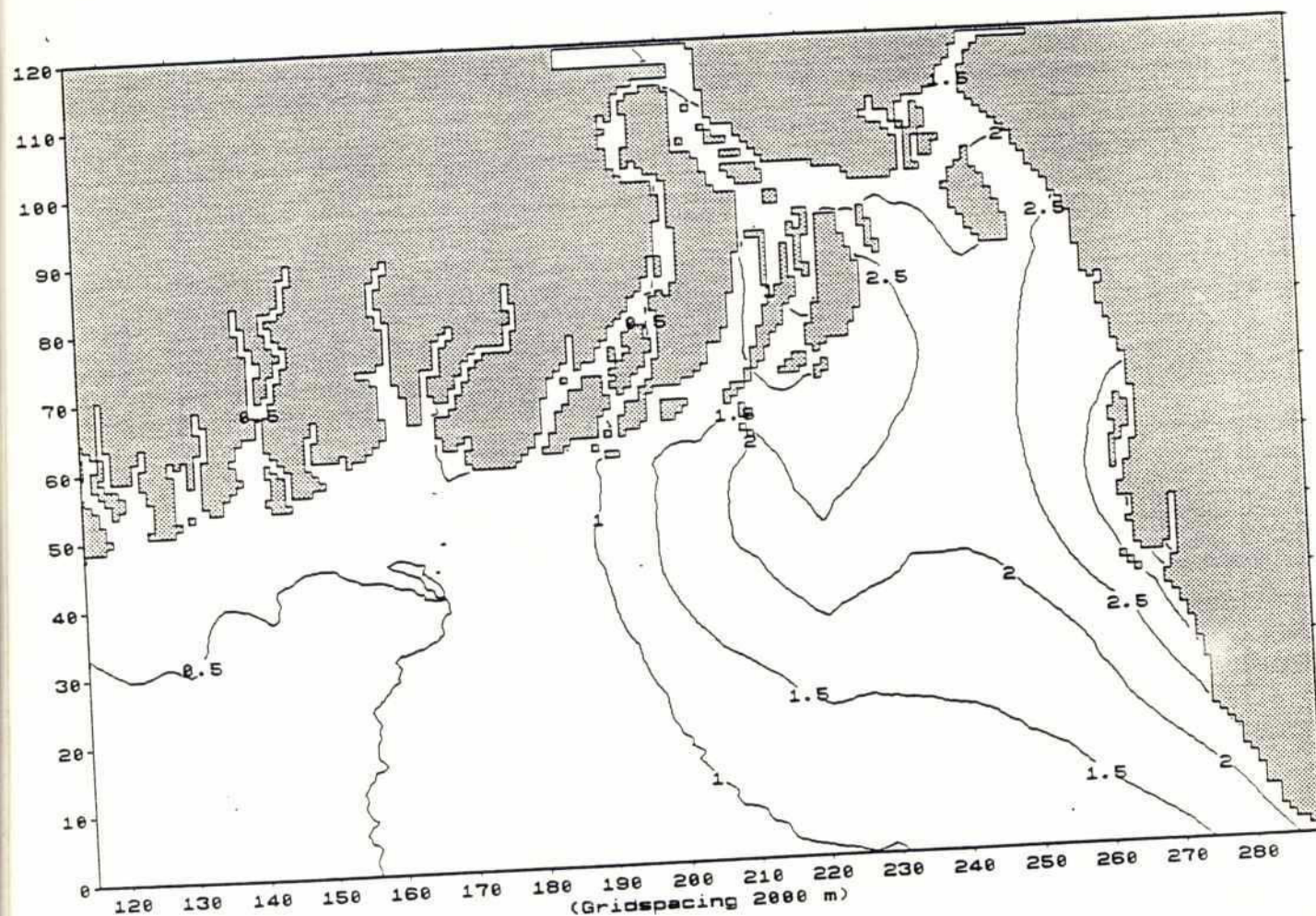
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n83 name : csan4 User: mnr Sun Dec 16 1990	November 1983 Sandwip Measured and computed surge	Dwg. No.  4.148





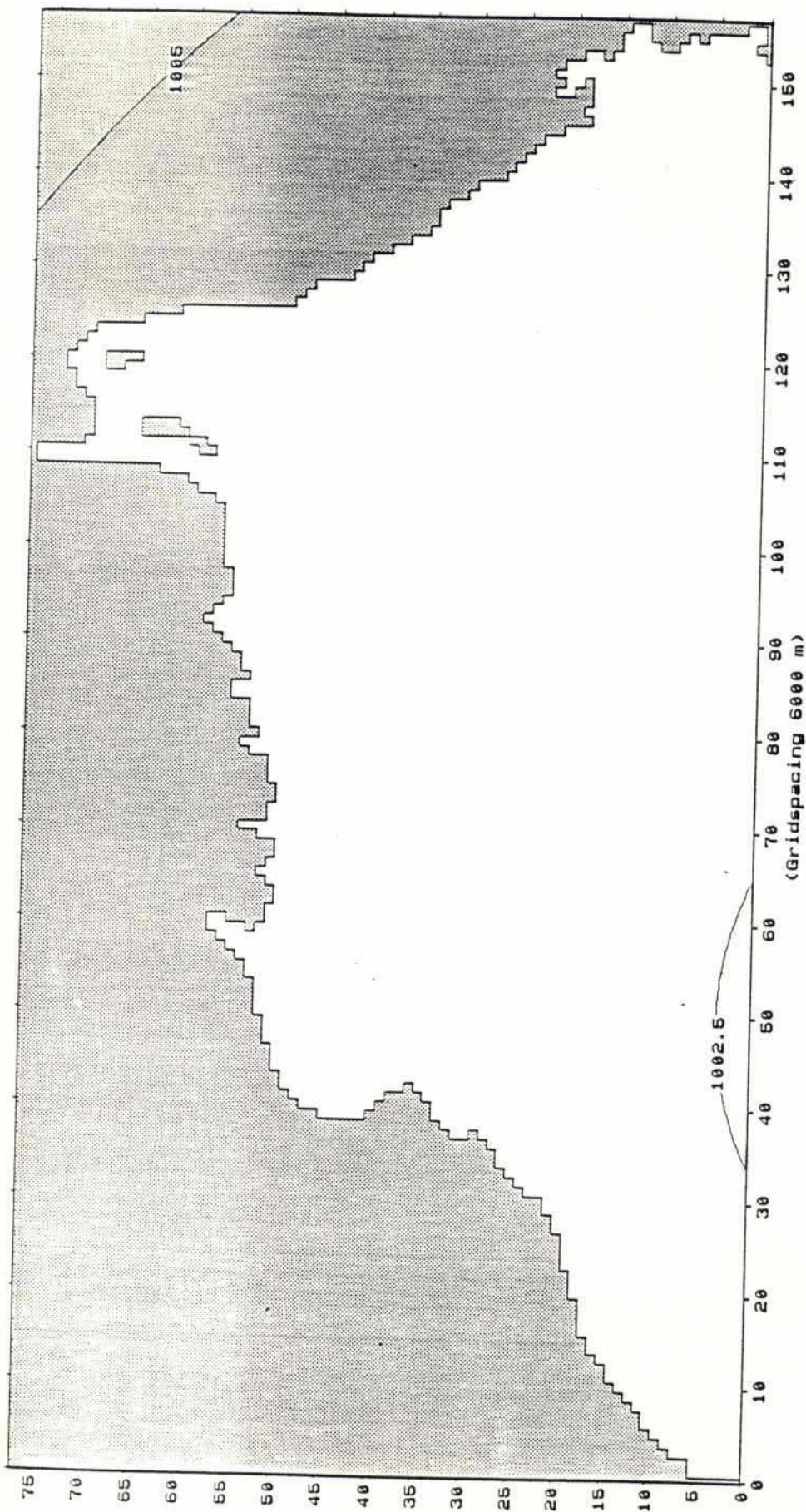
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n83 name : ctek4 User: mnr Sun Dec 16 1990	November 1983 Teknaf (Shapuri) Measured and computed surge	Dwg. No.  4.149

202



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: m85 name : imax Scale: 1:2 mill Mon Nov 26 1990	May 1985 Cyclone Simulation Results, Intermediate Model Maximum Surge Levels	
		Dwg. No.  4.150





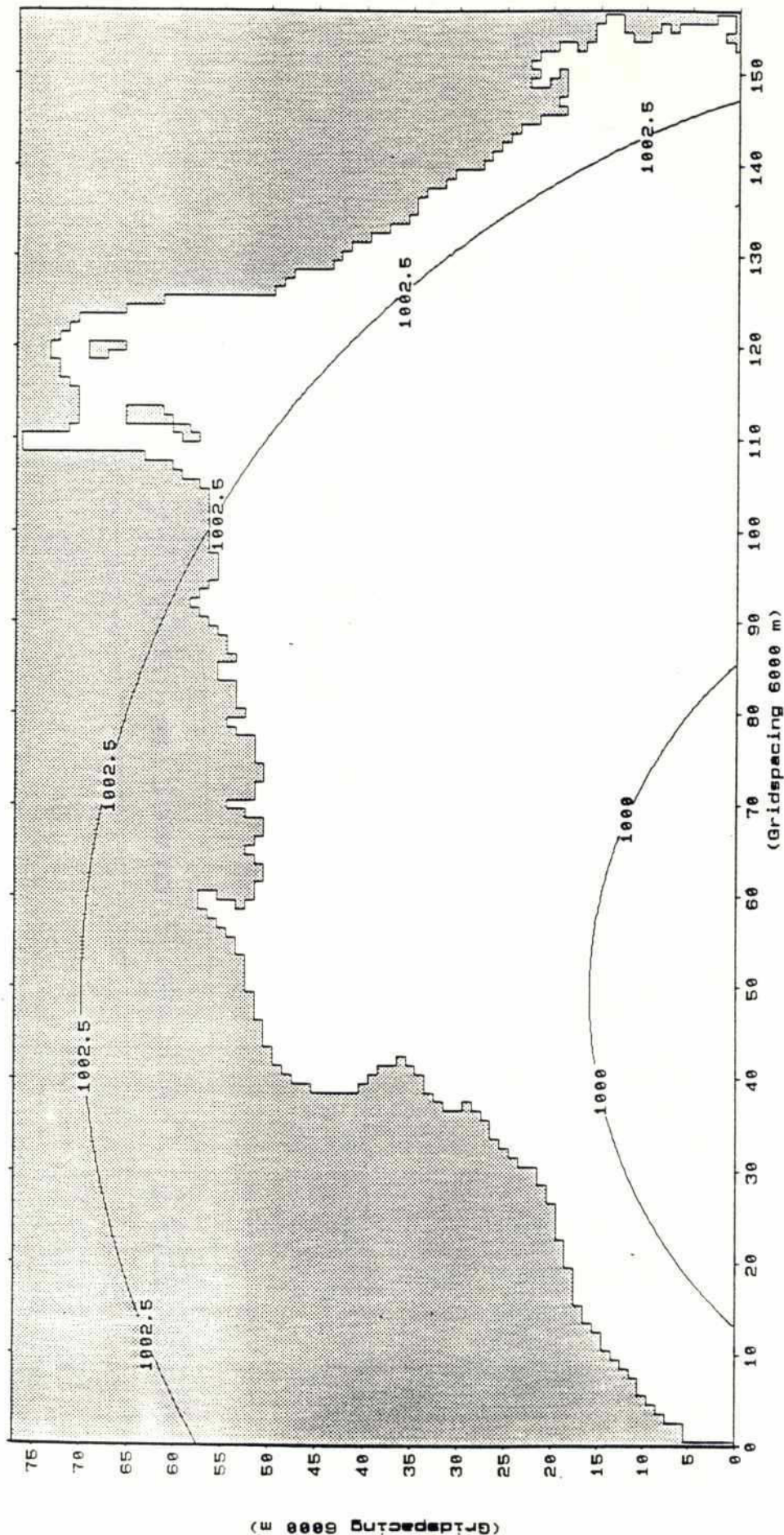
(E 0000 AUTOMATED)

1985/05/23 12:00:00

MIKE21 Cyclone Protection Project II		
File: family: m85 name : rwind Scale: 1:4 mill Mon time 26 1984	May 1985 Cyclone Pressure Field (mb)	Dwg. No.  4.151



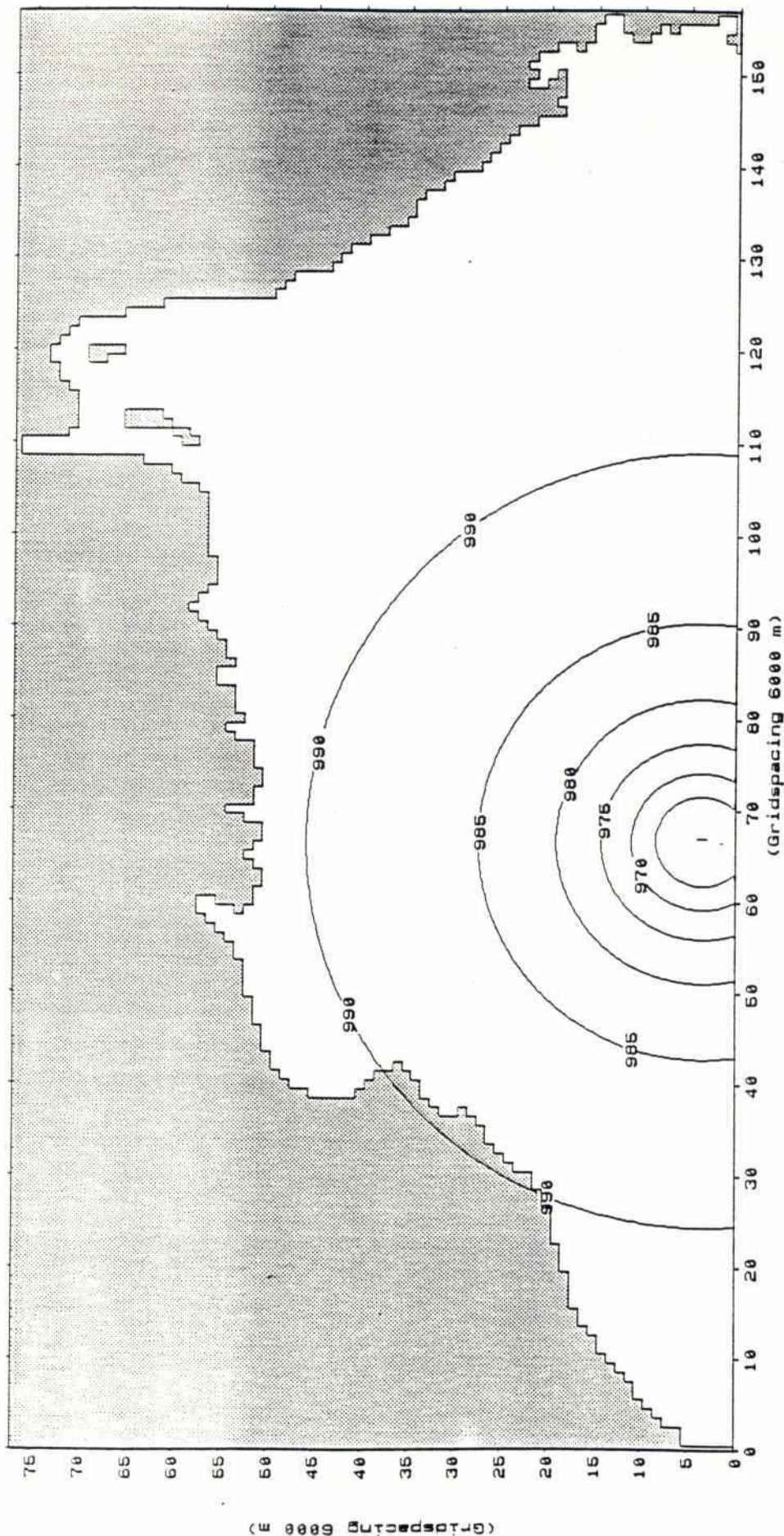
208



1985/05/24 00:00:00

<p><b>MIKE21</b></p>	<p><b>Cyclone Protection Project II</b></p>	
<p>File: family: m85 name : rwind Scale: 1:4 mill Mon Nov 26 1990</p>	<p>May 1985 Cyclone Pressure Field (mb)</p>	
<p>Dwg. No.</p>		<p>4.152</p>



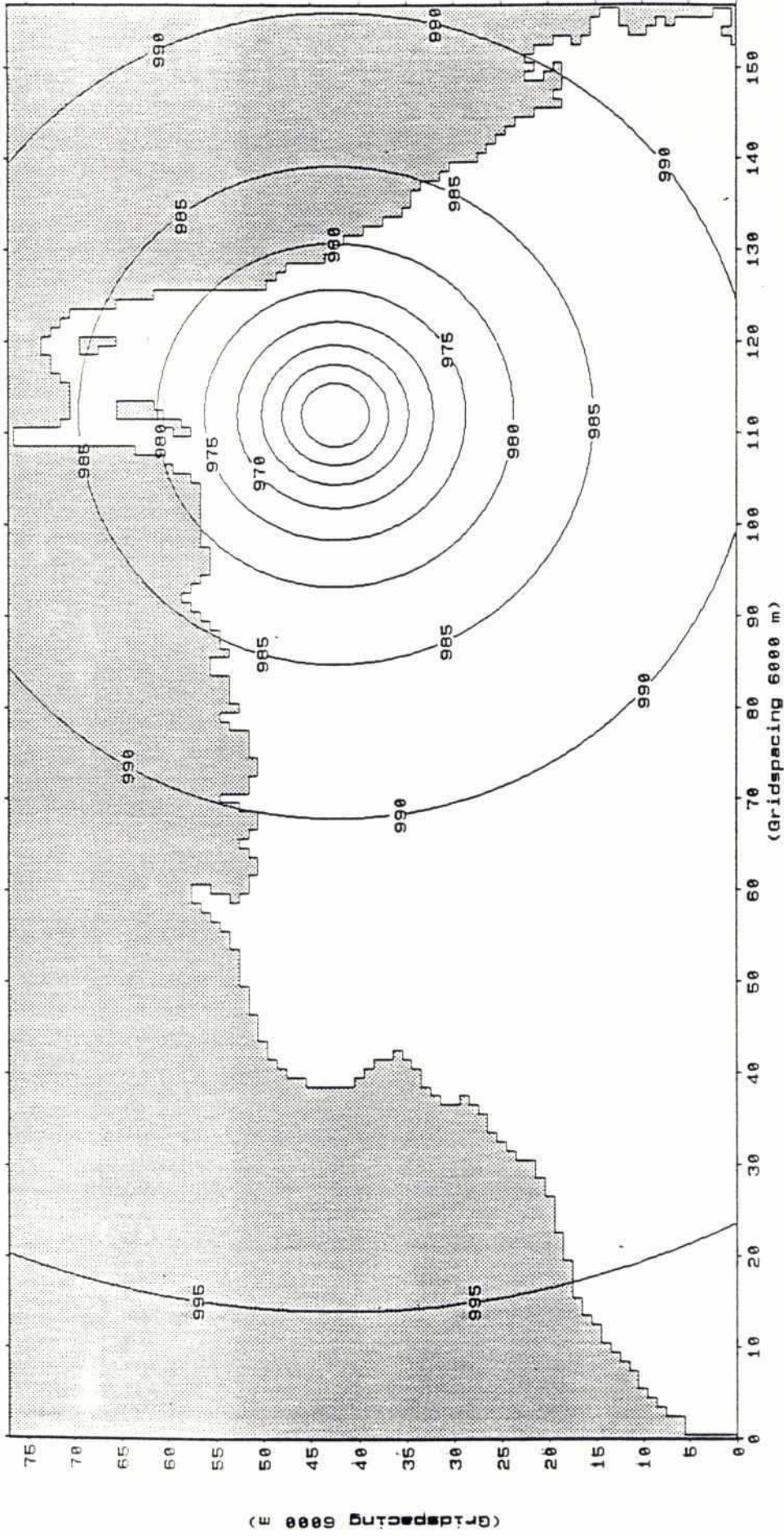


1985/05/24 12:00:00

<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: m85 name : rwind Scale: 1:4 mill Mon Nov 26 1990	May 1985 Cyclone Pressure Field (mb)	
		Dwg. No.  4.153



200

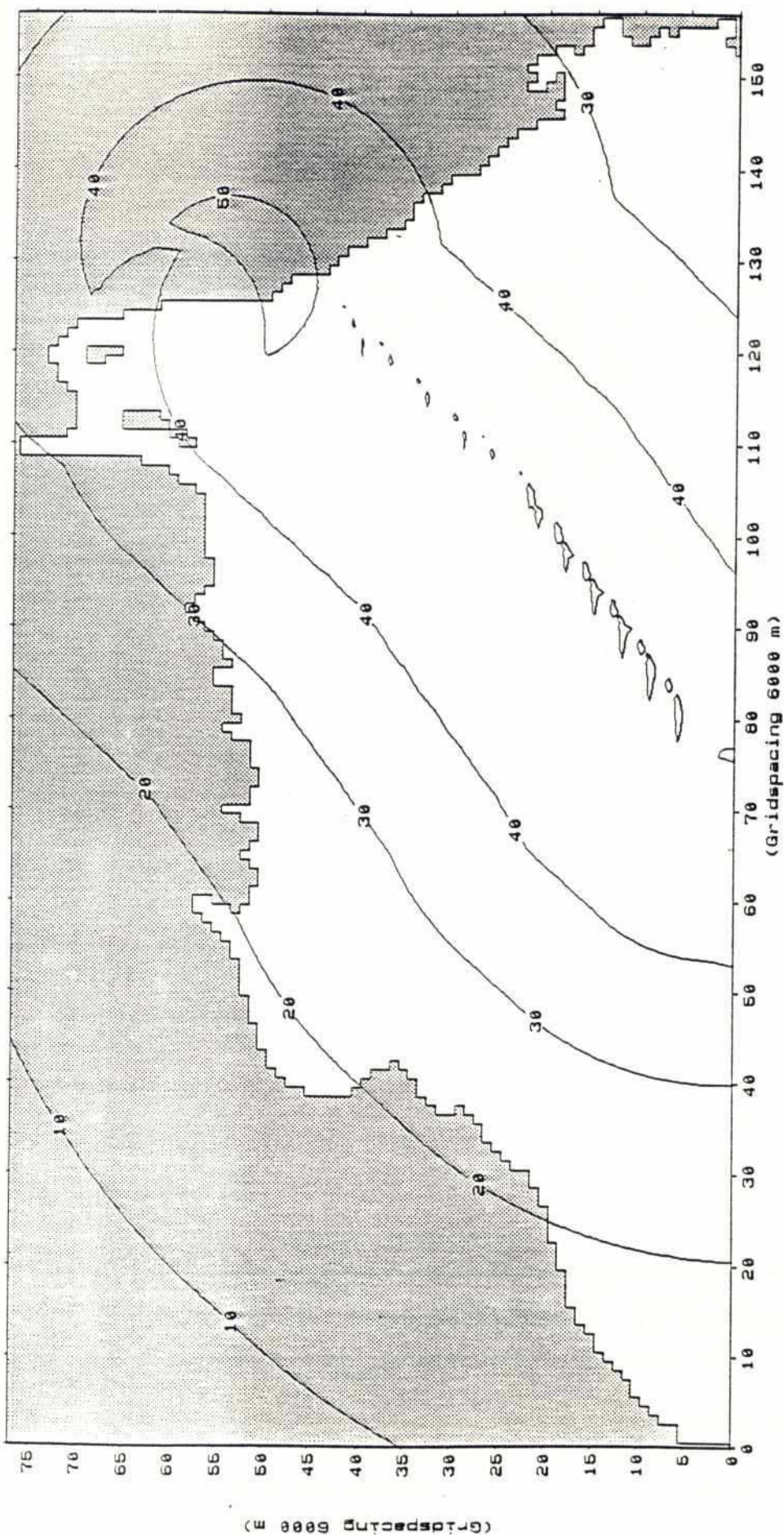


1985/05/25 00:00:00

<p><b>MIKE21</b></p>	<p><b>Cyclone Protection Project II</b></p>	
<p>File: family: m85 name : rwind Scale: 1:4 mill Mon Nov 26 1990</p>	<p>May 1985 Cyclone Pressure Field (mb)</p>	
	<p>Dwg. No.</p>	<p>4.154</p>



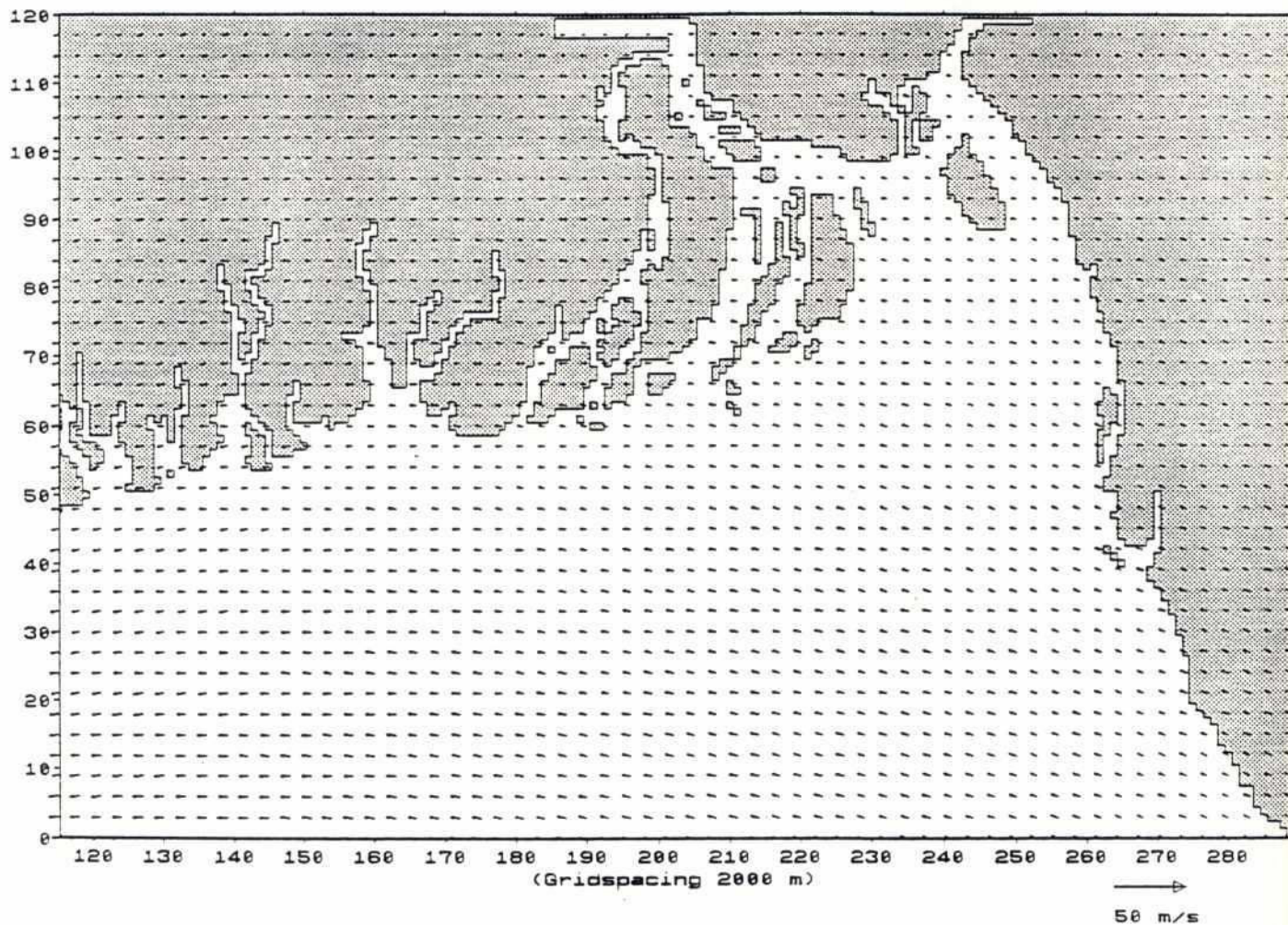
269



<p><b>MIKE21</b></p>	<p><b>Cyclone Protection Project II</b></p>	
<p>File: family: m85 name : rmwind Scale: 1:4 mill Mon Nov 26 1990</p>	<p>May 1986 Maximum occurring Wind Speed (m/s)</p>	<p>Dwg. No.  4.155</p>



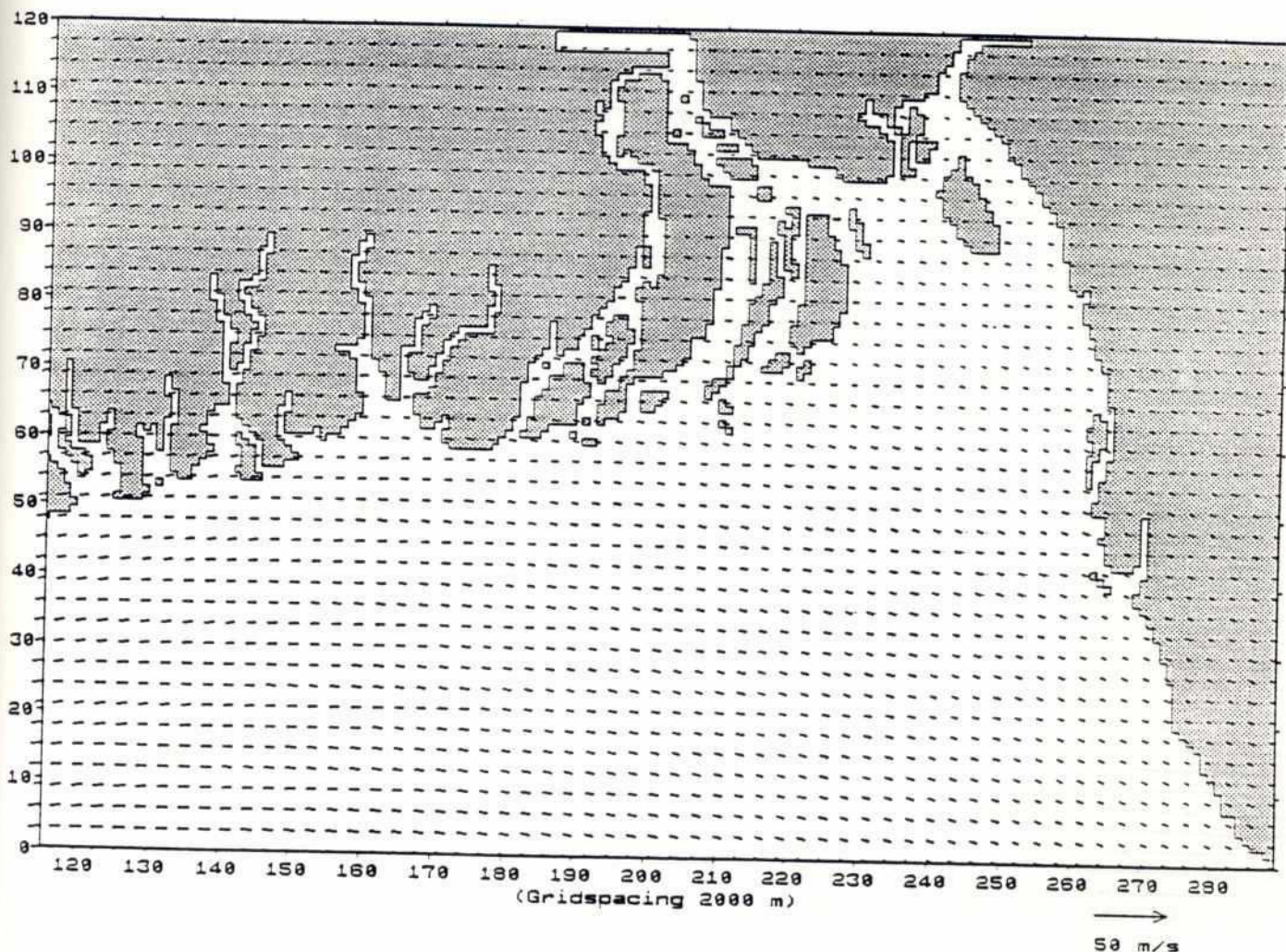
264



1985/05/23 12:00:00

<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: m85 name : iwind Scale: 1:2 mill Mon Nov 26 1990</p>	<p>May 1985 Cyclone Wind Field</p>	<p>Dwg. No.  4.156</p>



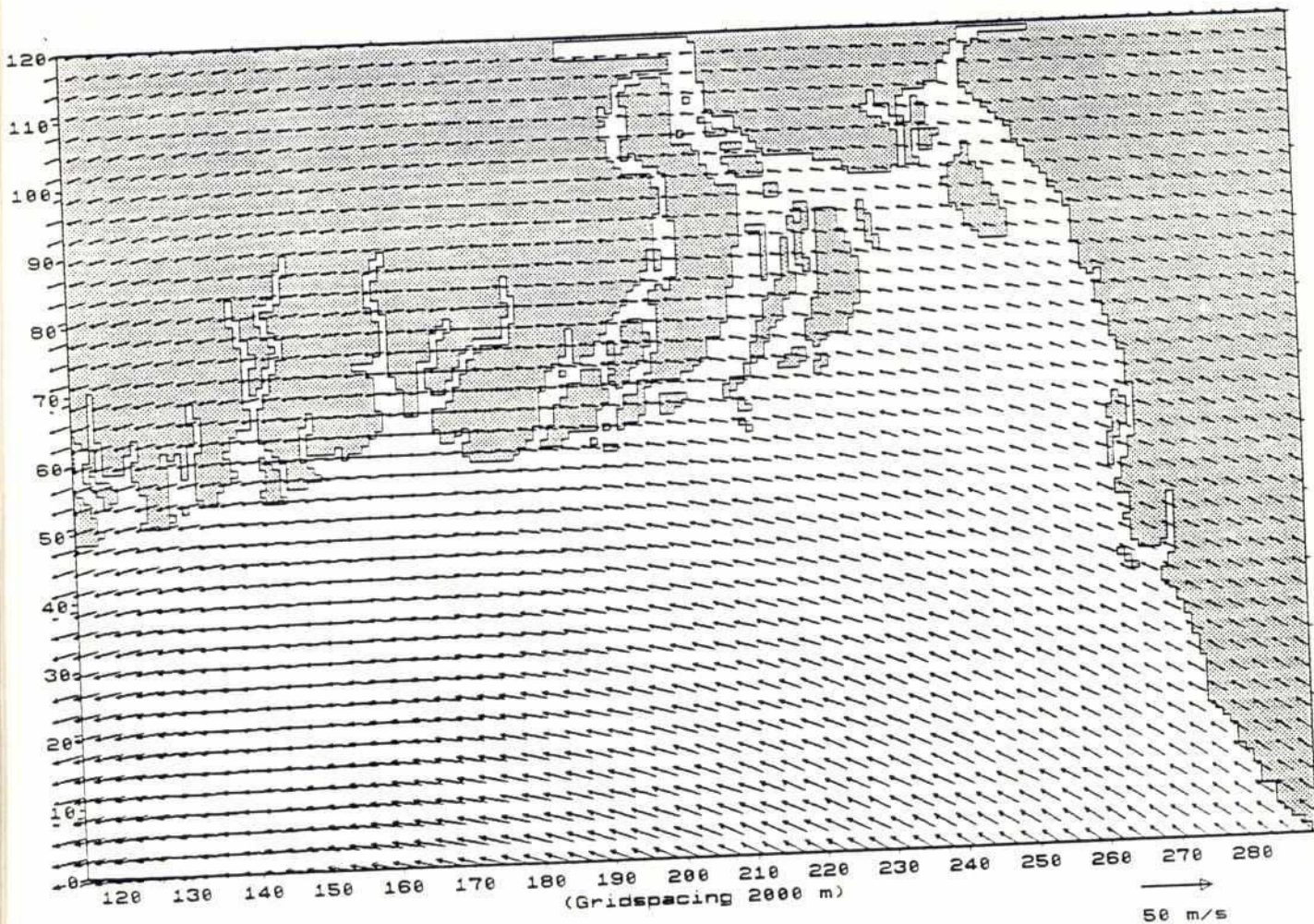


1985/05/24 00:00:00

<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: m85 name : iwind Scale: 1:2 mill Mon Nov 26 1990	May 1985 Cyclone Wind Field	Dwg. No.  4.157



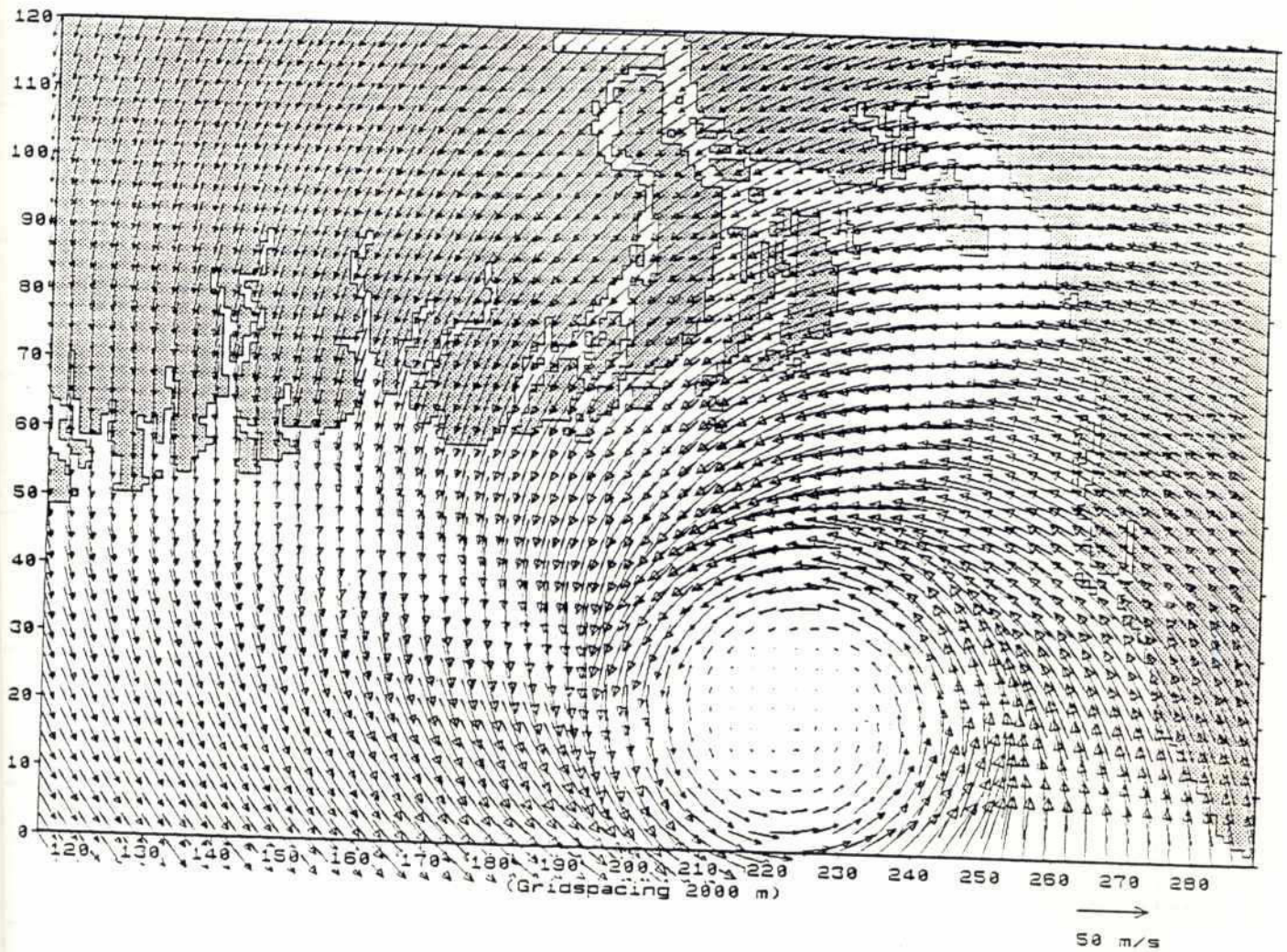
280



1985/05/24 12:00:00

<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: m85 name : iwind Scale: 1:2 mill Mon Nov 26 1990</p>	<p>May 1985 Cyclone Wind Field</p>	<p>Dwg. No.  4.158</p>



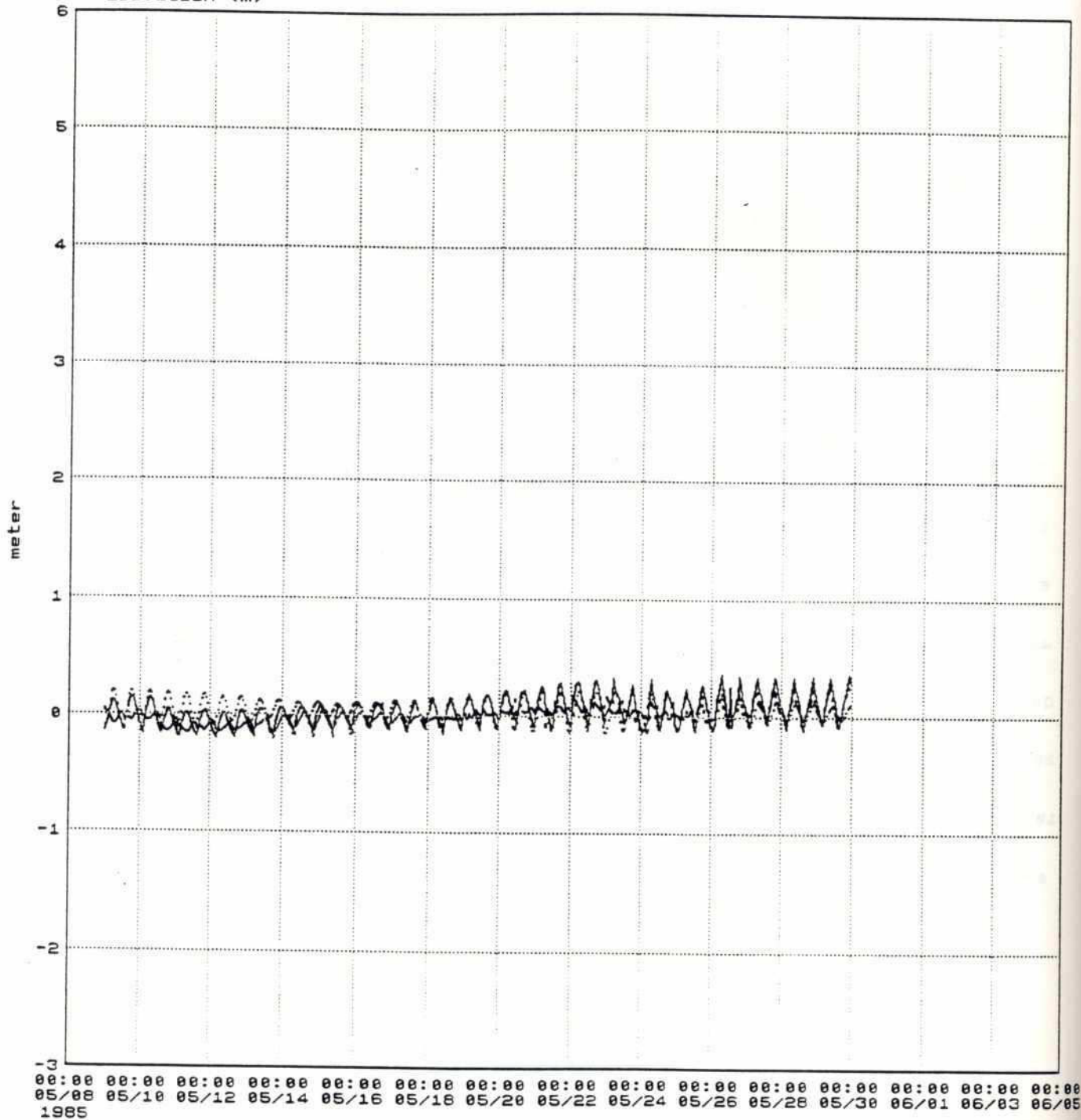


1985/05/25 00:00:00

<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: m85 name : iwind Scale: 1:2 mill Mon Nov 26 1990</p>	<p>May 1985 Cyclone Wind Field</p>	<p>Dwg. No.  4.159</p>

282

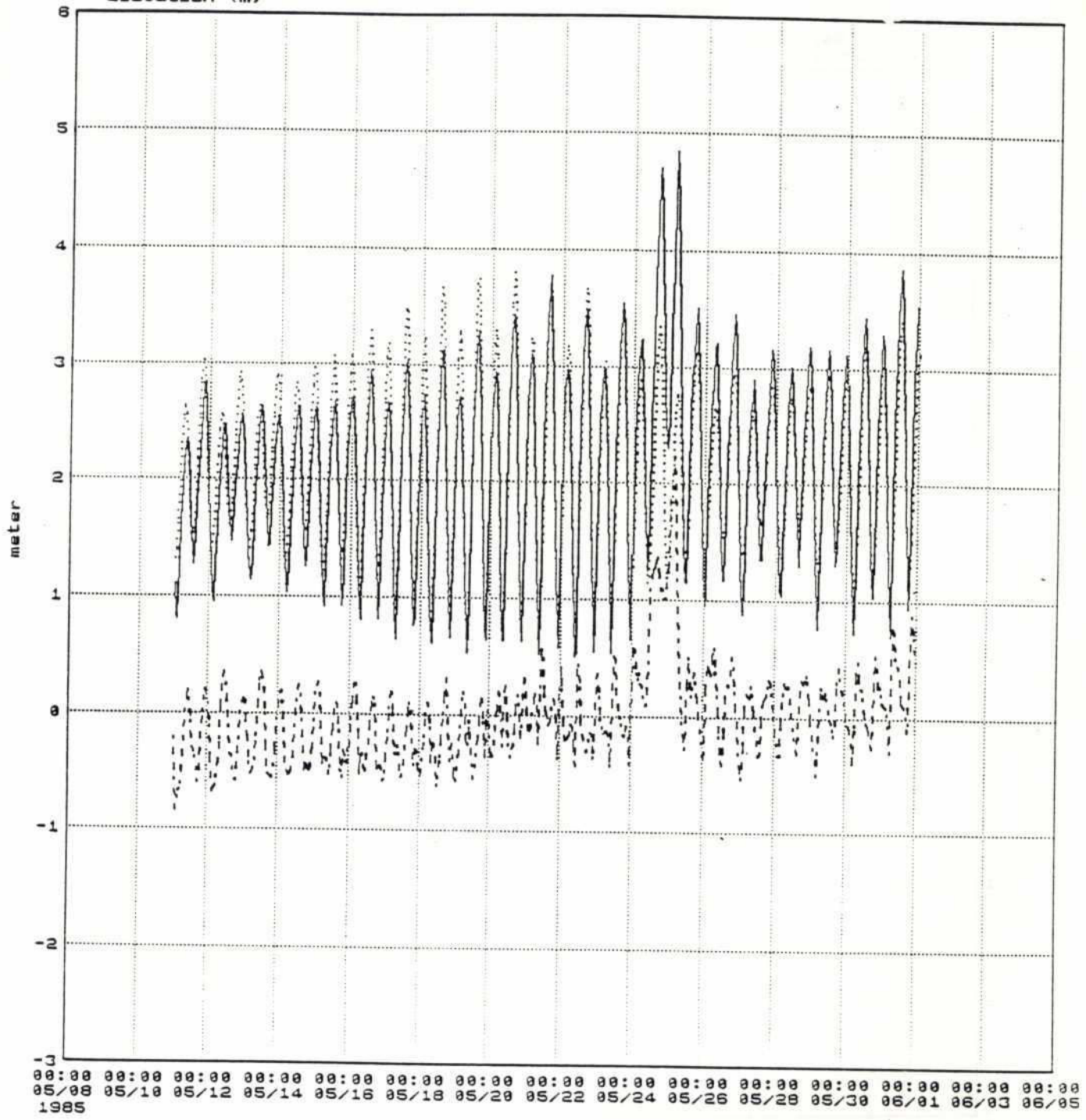
-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File:            family: m85            name : sbar4            User: mnr            Mon Dec 17 1990</p>	<p>May 1985            Barisal            Measurements</p>	<p>Dwg. No.             4.160</p>



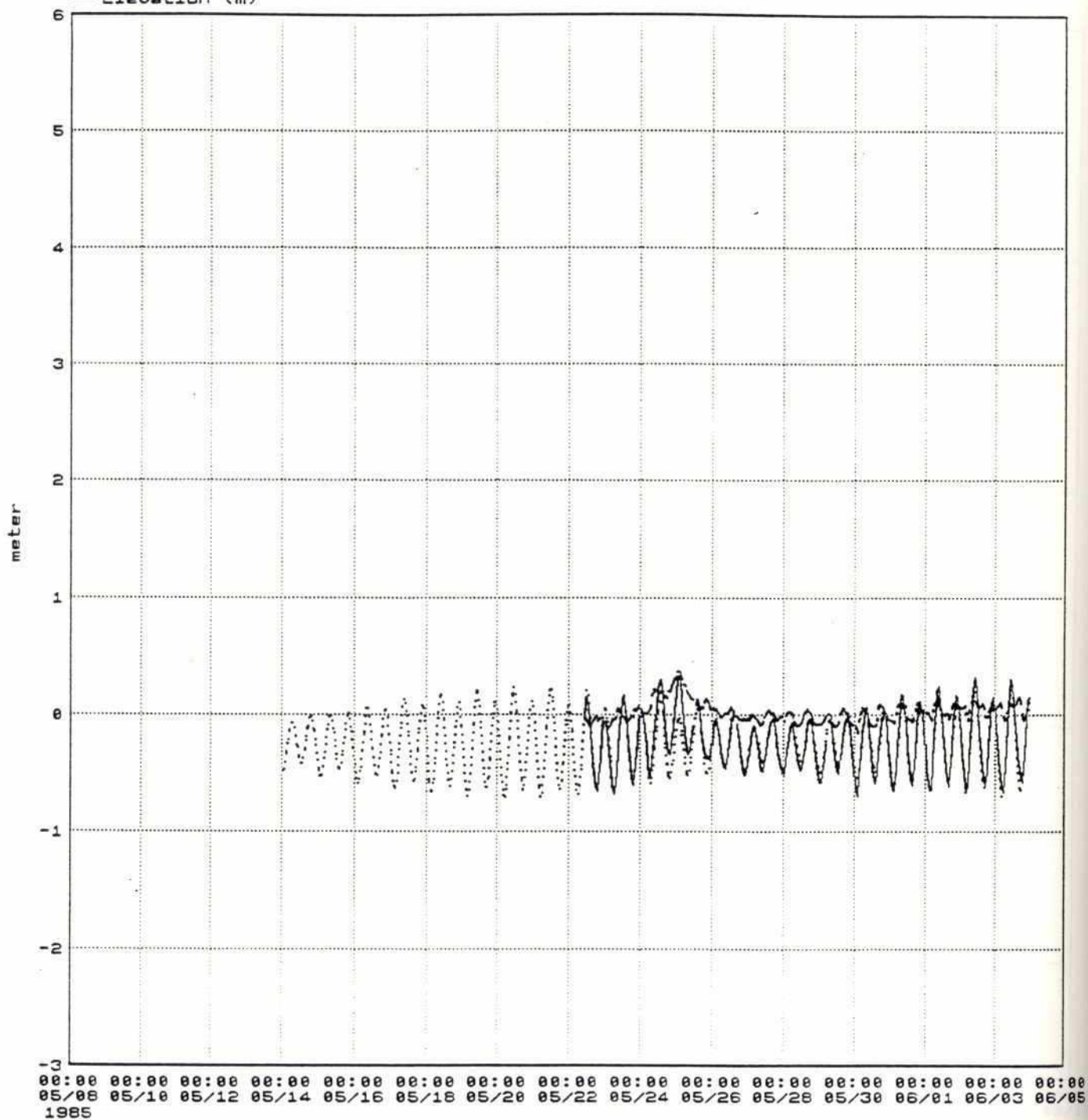
-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File:            family: m85            name : schr4            User: mnr            Mon Dec 17 1998</p>	<p>May 1985            Char-Chenga            Measurements</p>	<p>Dwg. No.             4.161</p>

288

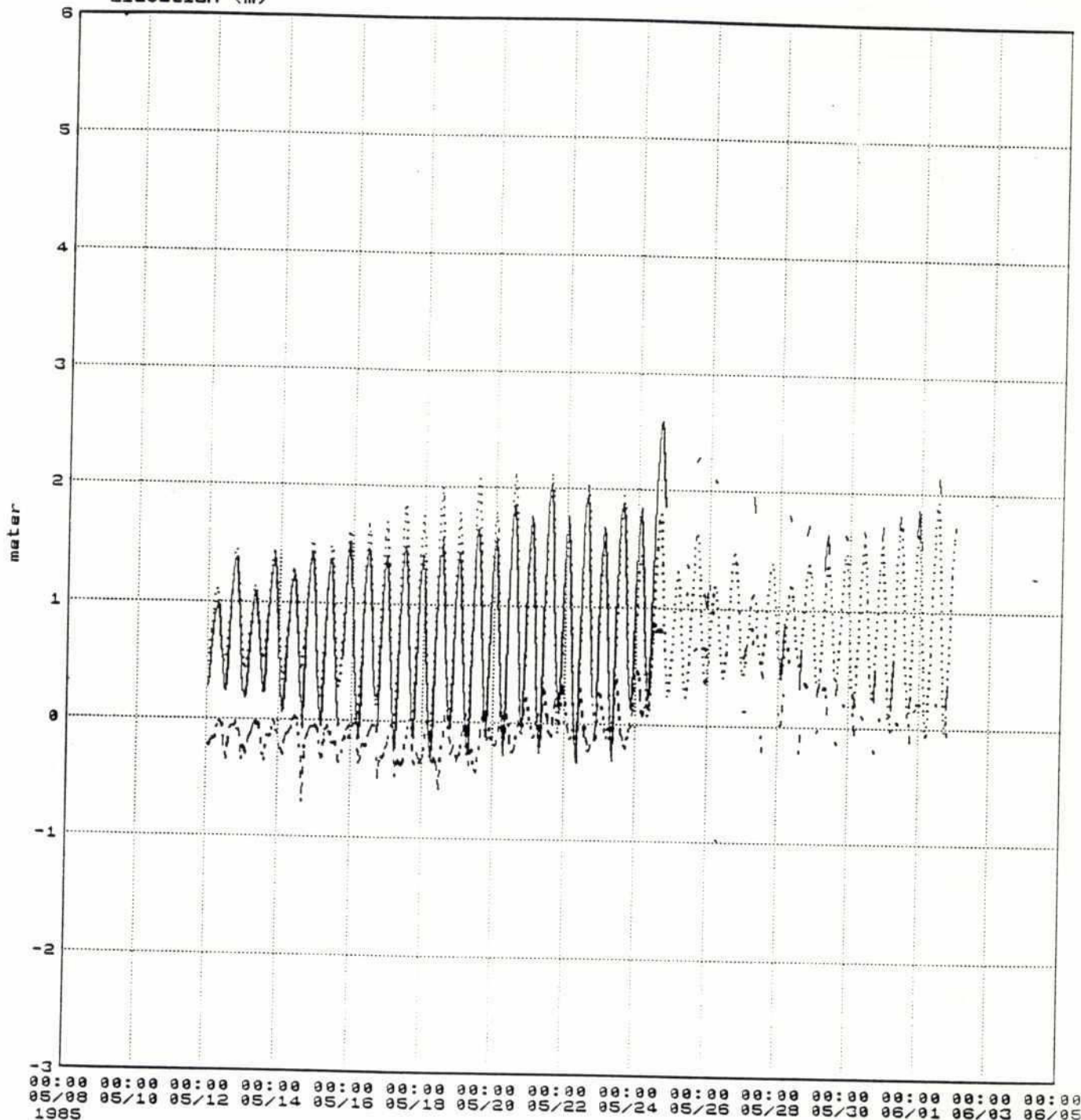
-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: m85 name : scox4 User: mnr Mon Dec 17 1990	May 1985 Cox Bazar Measurements	Dwg. No.  4.162



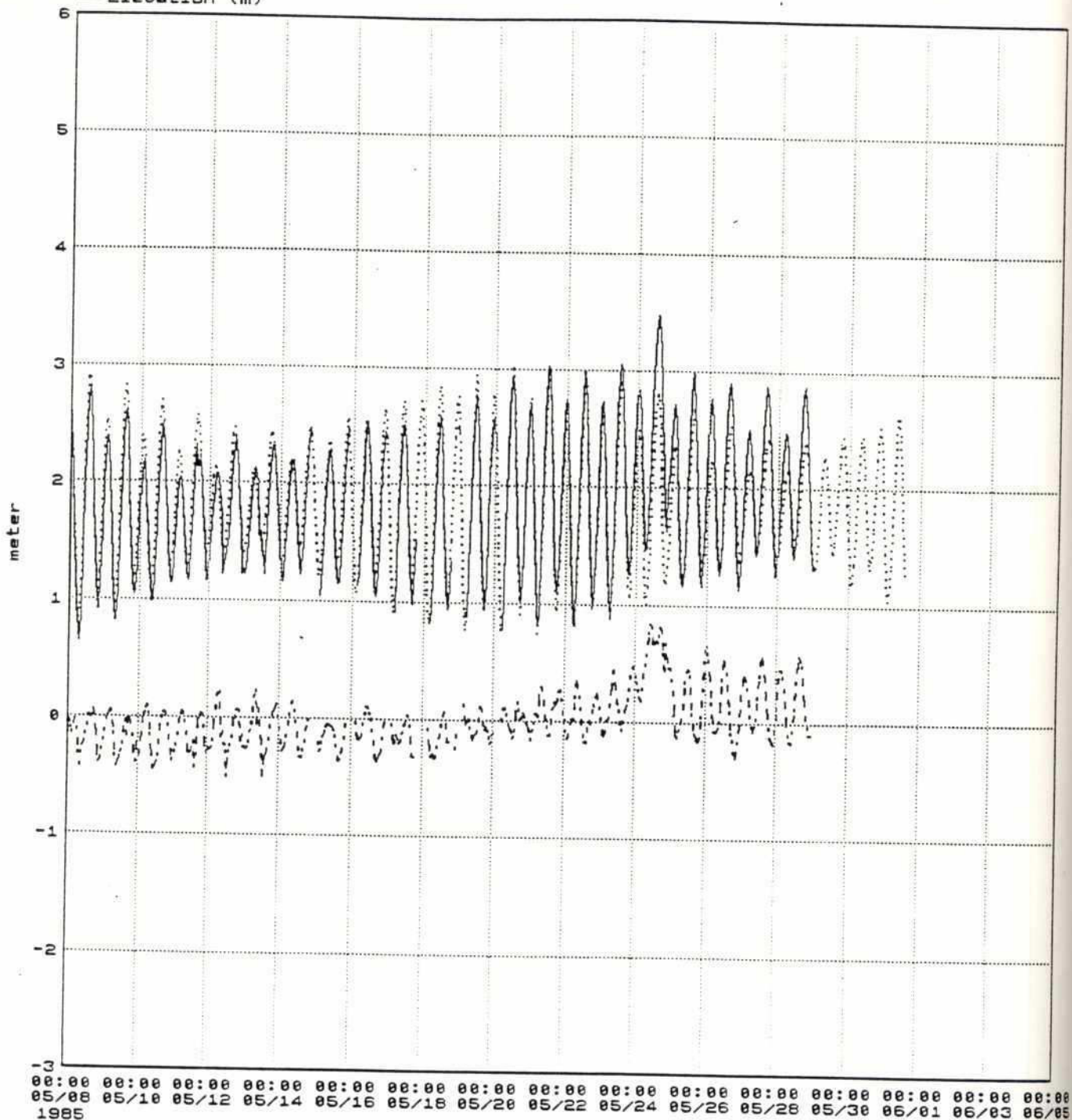
-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: m85 name : sgsl4 User: mnr Mon Dec 17 1998	May 1985 Galachipa Measurements	Dwg. No.  4.163

289

-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)

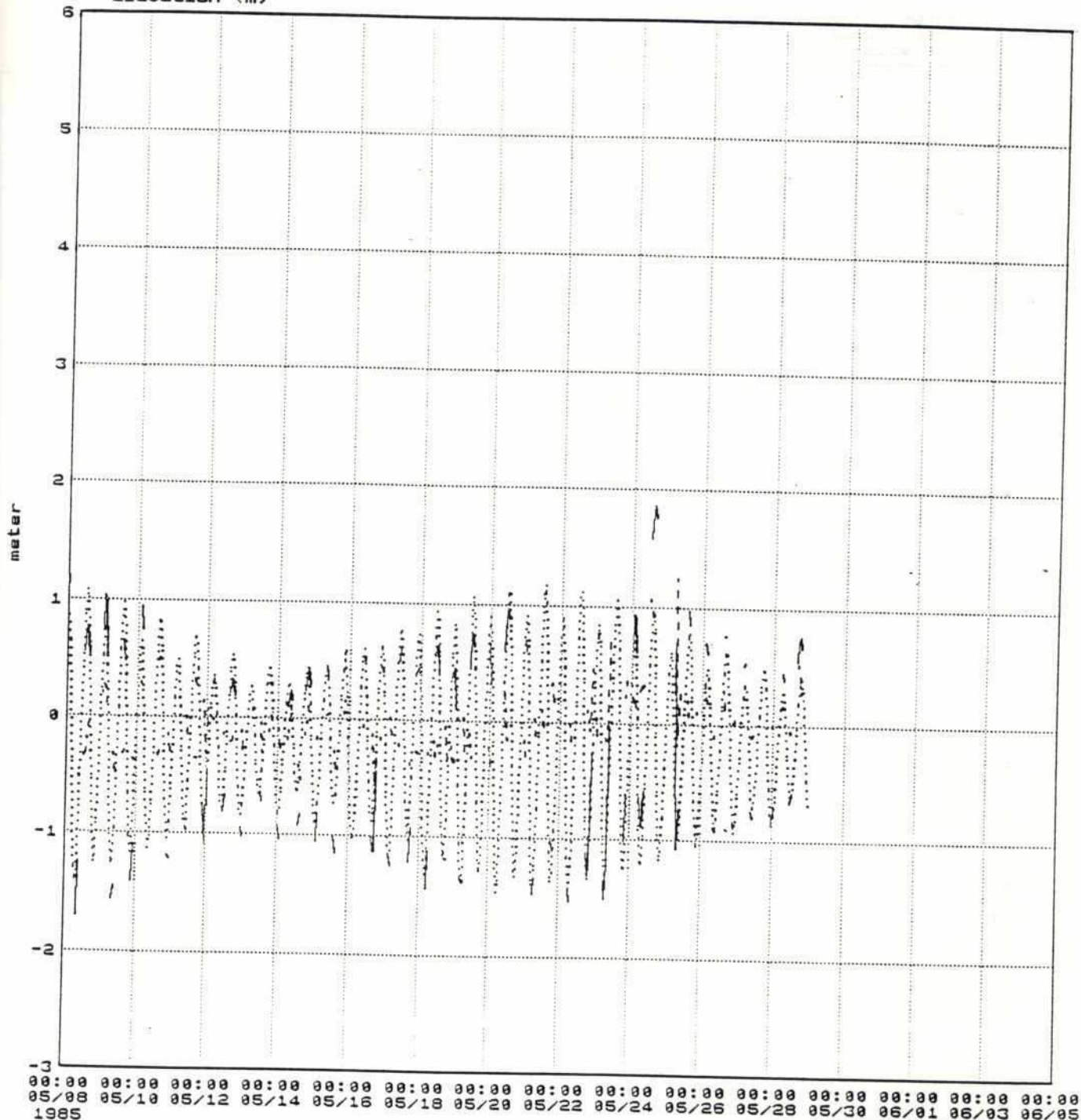


MIKE21	Cyclone Protection Project II	
File: family: m85 name : shir4 User: mnr Mon Dec 17 1990	May 1985 Hiron Point Measurements	Dwg. No.  4.164



289

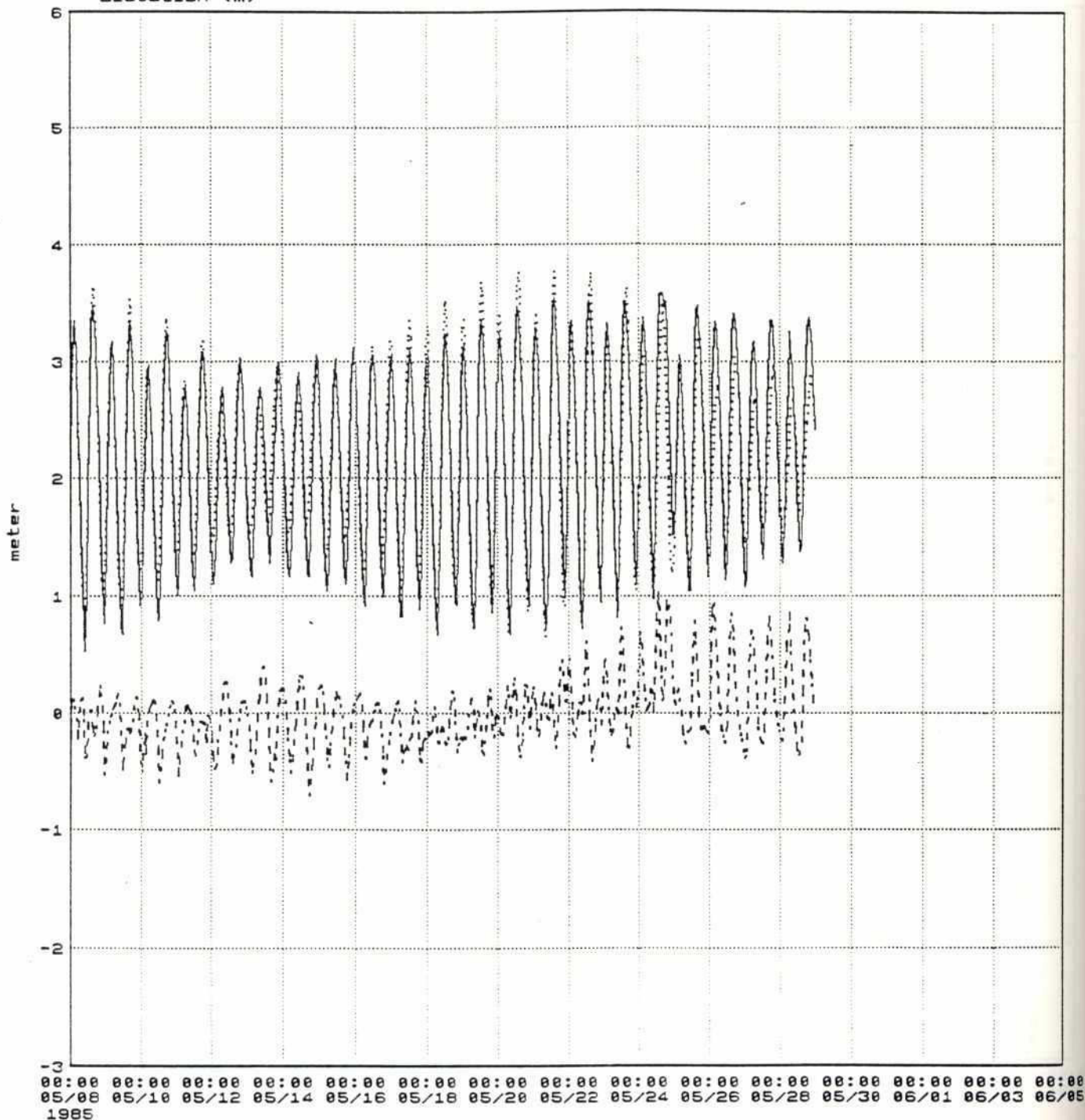
-- Surge  
 ... Pred. Tidal Elau.  
 — Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: m85 name : skhe4 User: mnr Mon Dec 17 1990	May 1985 Khepupara Measurements	Dwg. No.  4.165

284

-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)

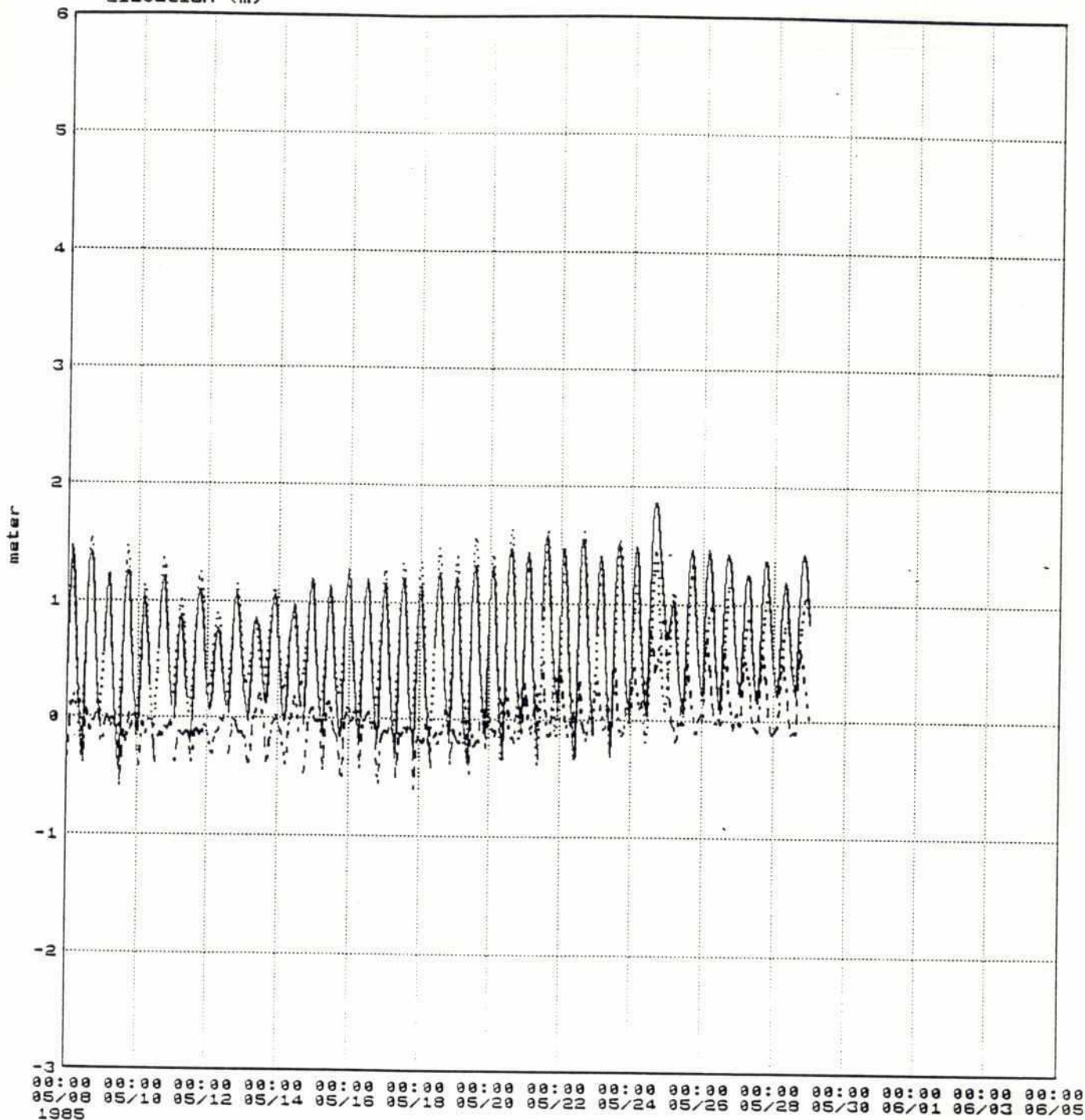


<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: m85 name : smon4 User: mnr Mon Dec 17 1990	May 1985 Mongla Measurements	Dwg. No.  4.166



287

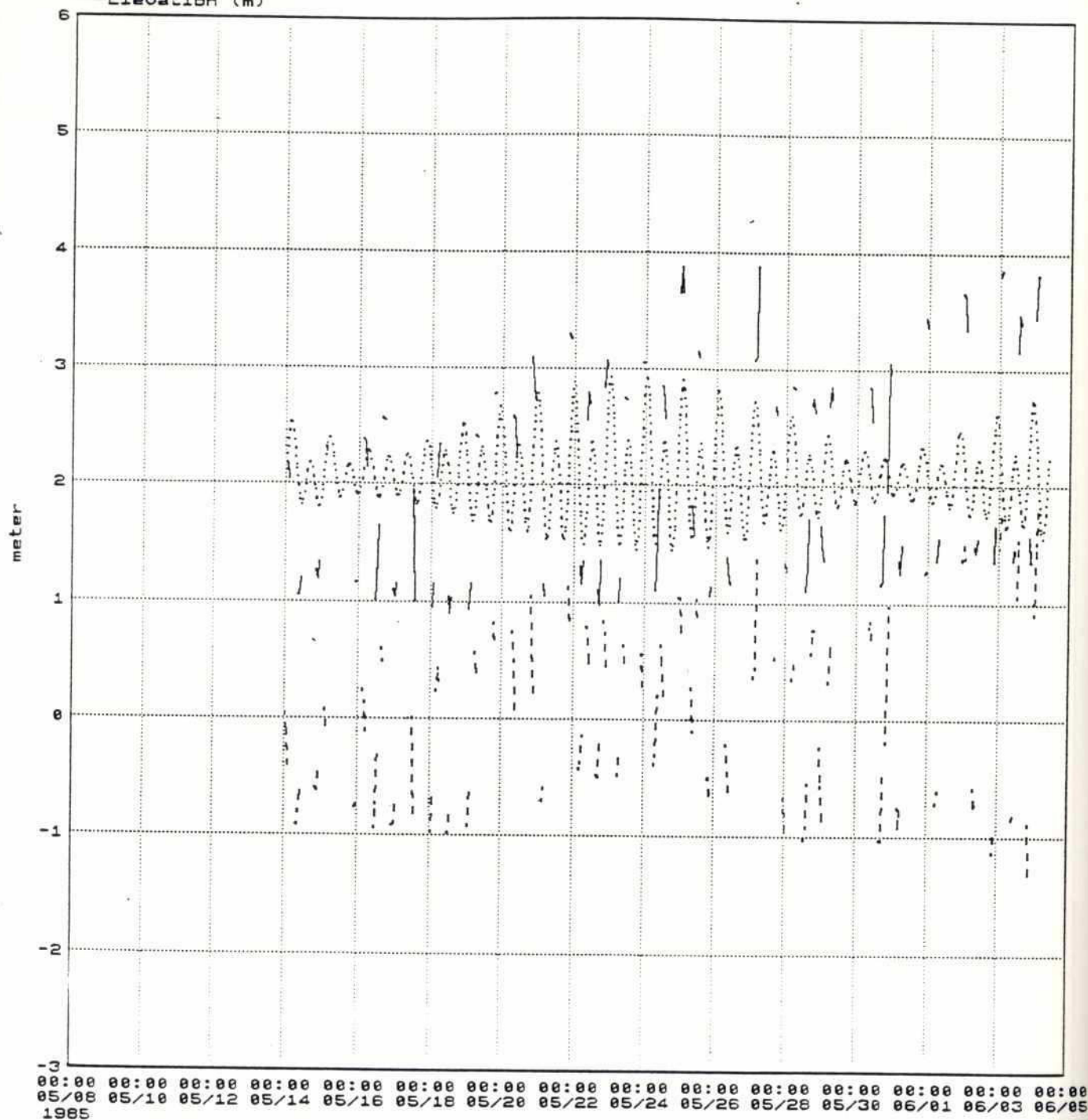
-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



<p>MIKE21</p>	<p>Cyclone Protection Project II</p>	
<p>File:            family: m85            name : spat4            User: mnr            Mon Dec 17 1990</p>	<p>May 1985            Patuakhali            Measurements</p>	<p>Dwg. No.              4.167</p>

200

-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)

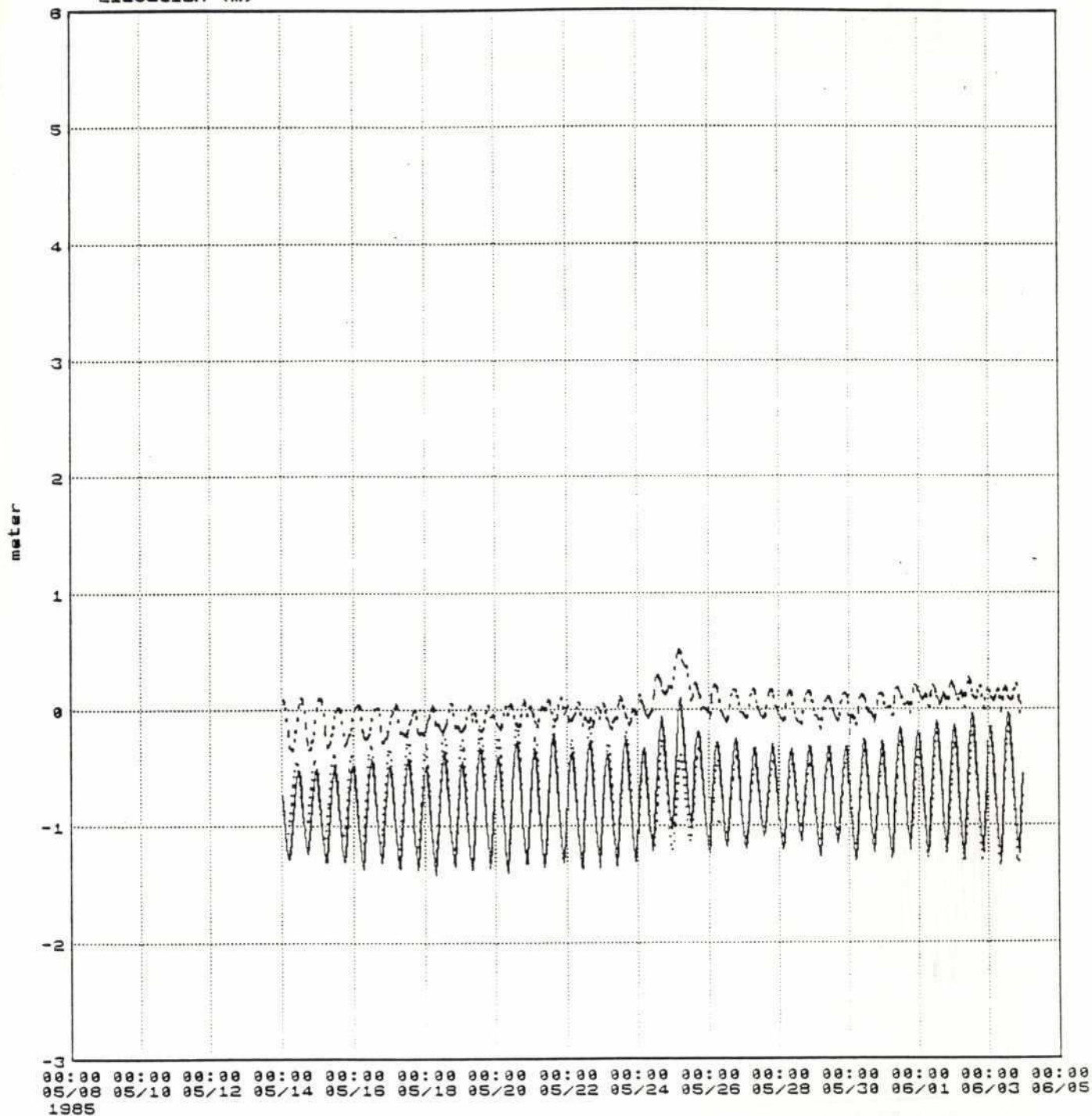


<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: m85 name : sram4 User: mnr Mon Dec 17 1990	May 1985 Ramdaspur Measurements	Dwg. No.  4.168



242

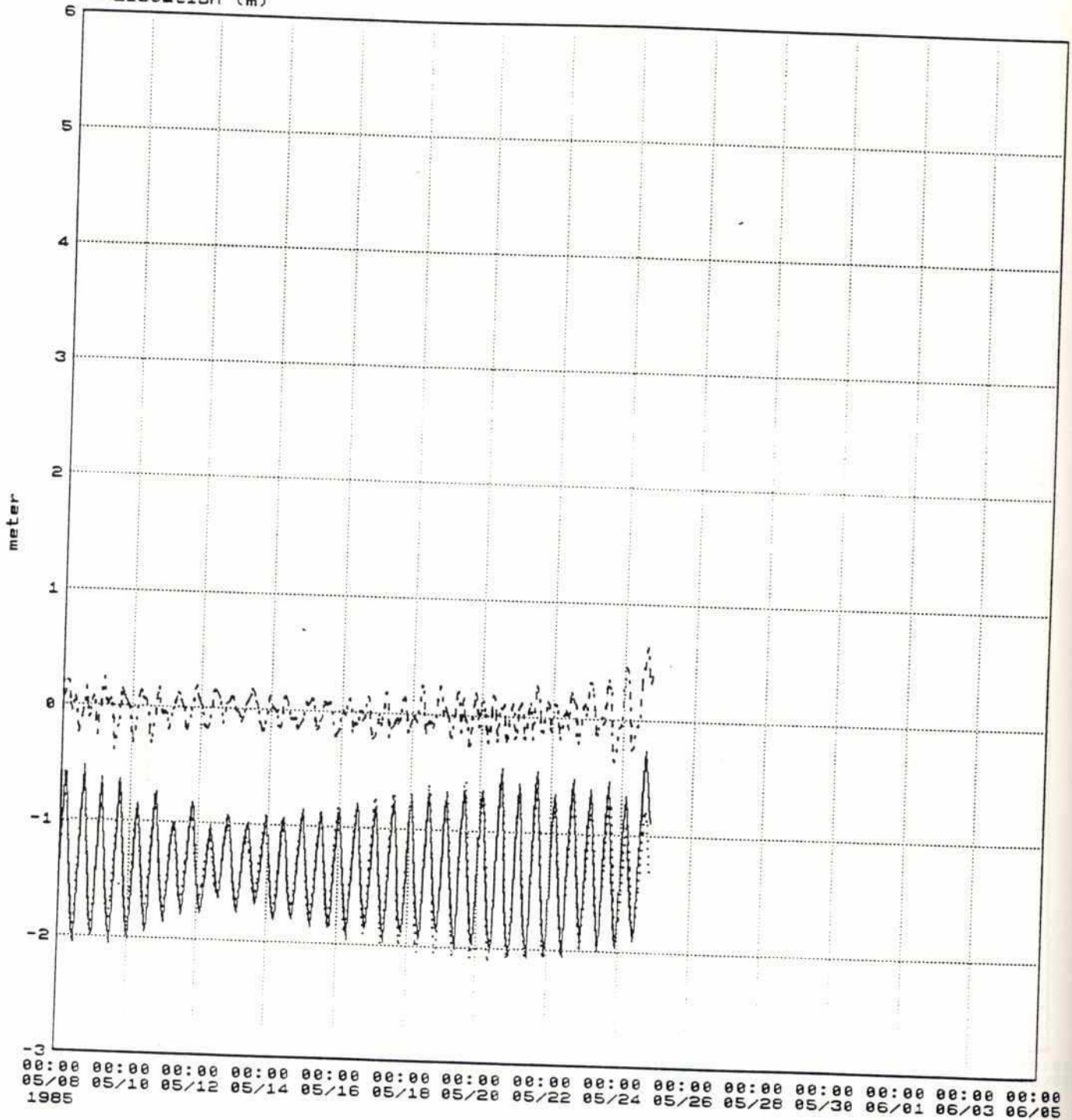
-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



MIKE21	Cyclone Protection Project II	
File: family: m85 name : ssad4 User: mnr Mon Dec 17 1998	May 1985 Sadarghat (CTG) Measurements	Dwg. No.  4.169

2d<sup>2</sup>

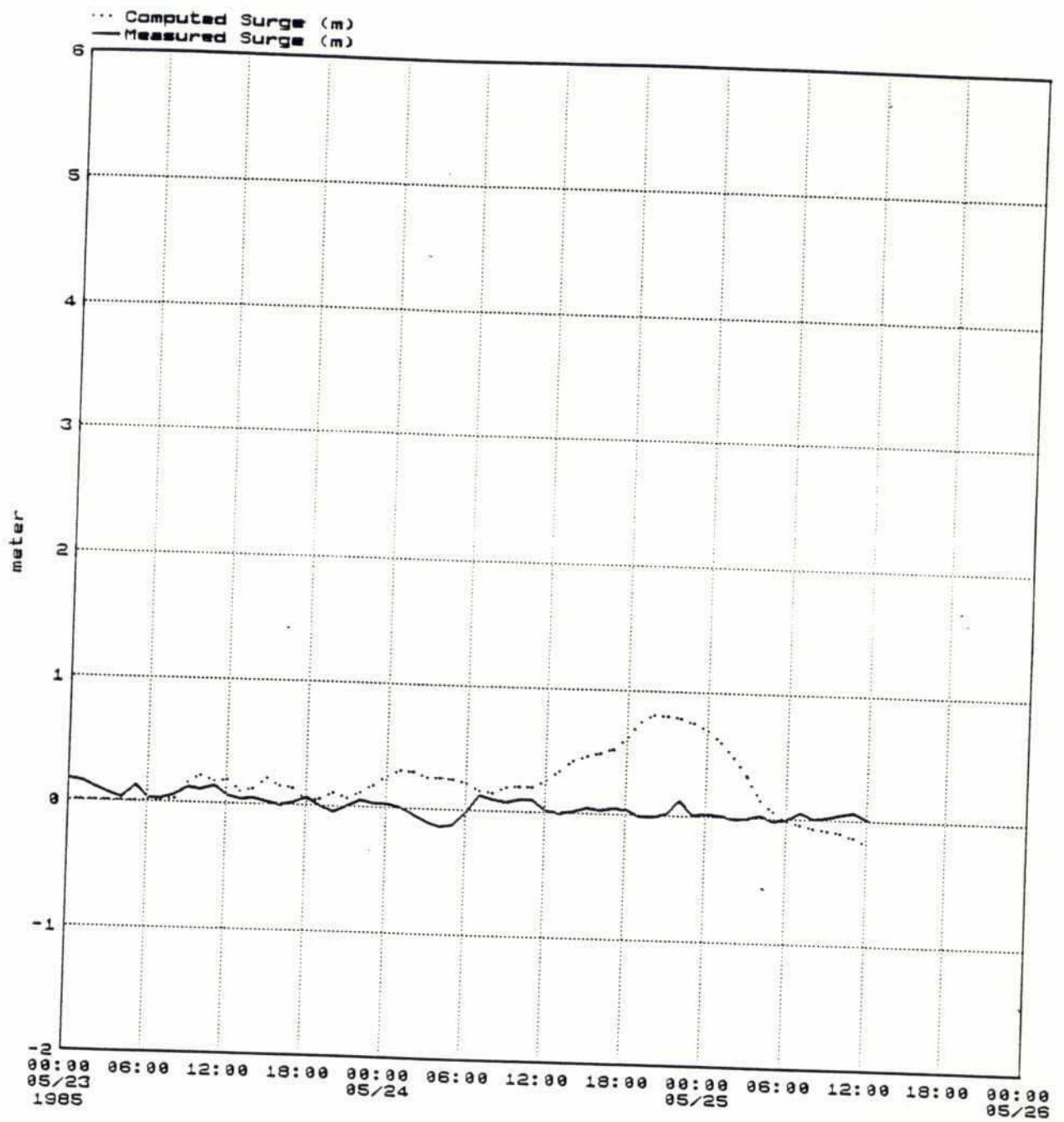
-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File:            family: m85            name : ssan4            User: mnr            Mon Dec 17 1990</p>	<p>May 1985            Sandwip            Measurements</p>	<p>Dwg. No.             4.170</p>

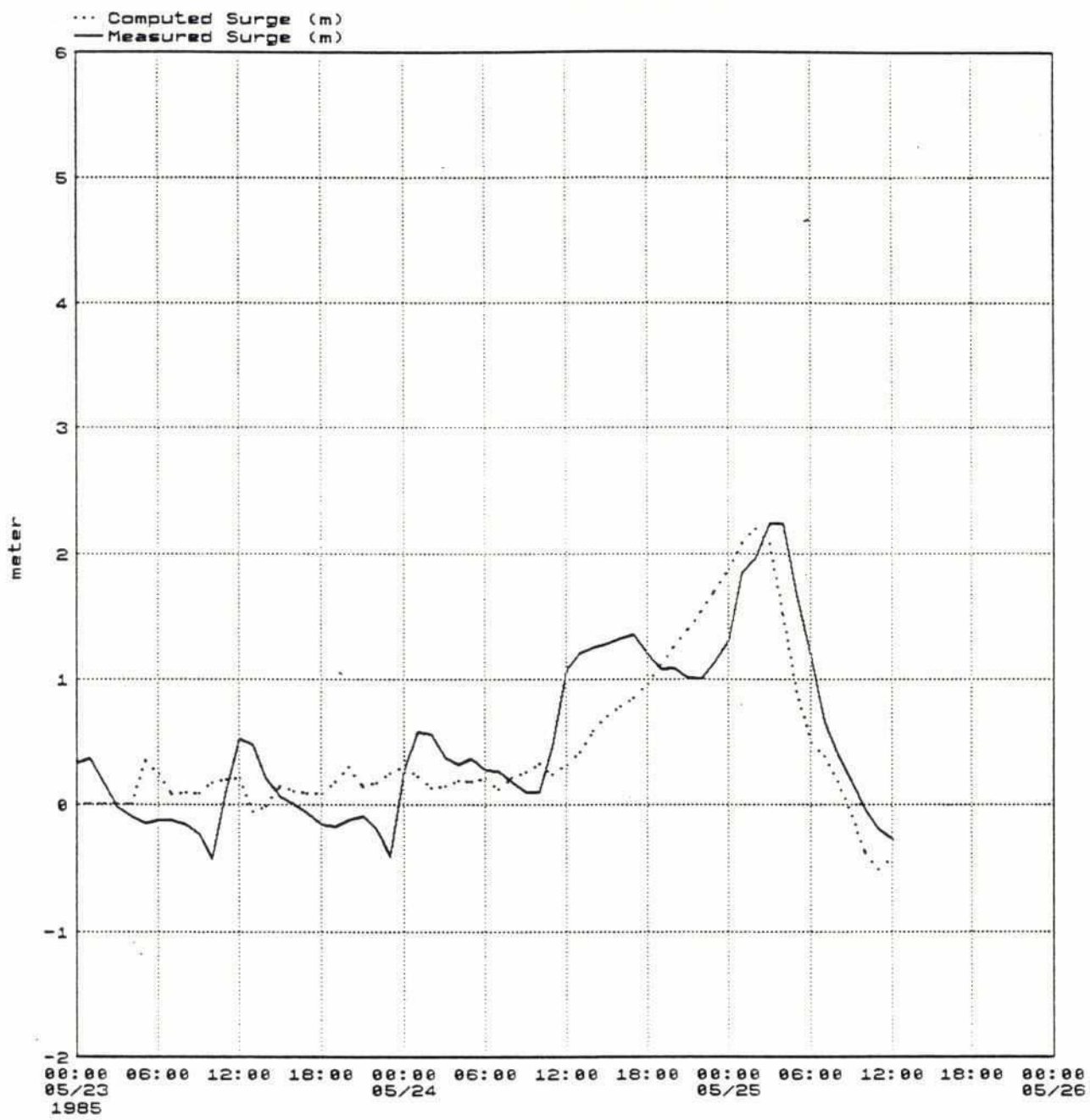


206



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: m85 name : cbar4 User: mnr Mon Dec 17 1998	May 1985 Barisal Measured and computed surge	Dwg. No.  4.171

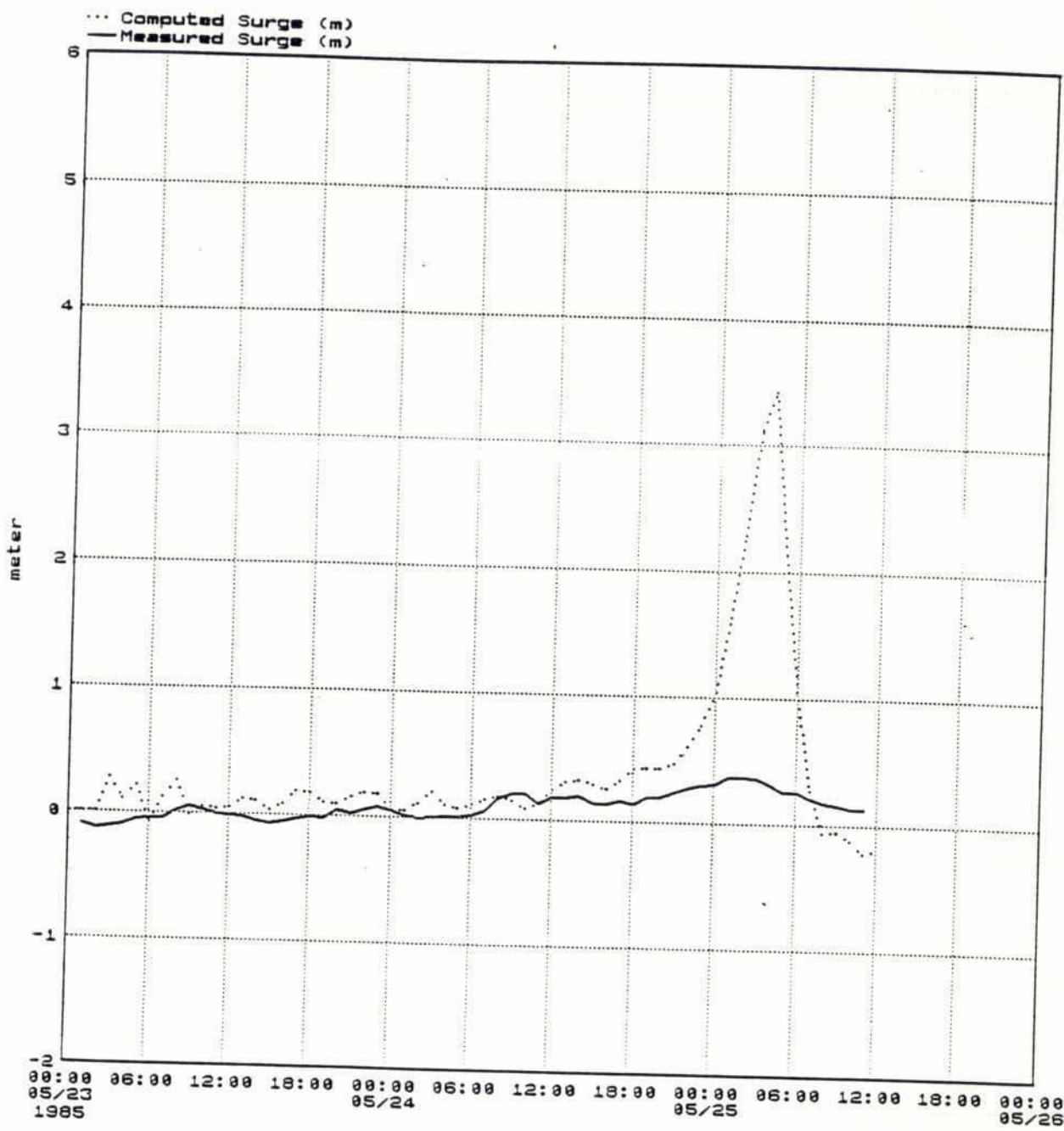
2558



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: m85 name : cchr4 User: mnr Mon Dec 17 1990	May 1985 Char-Chenga Measured and computed surge	Dwg. No.  4.172

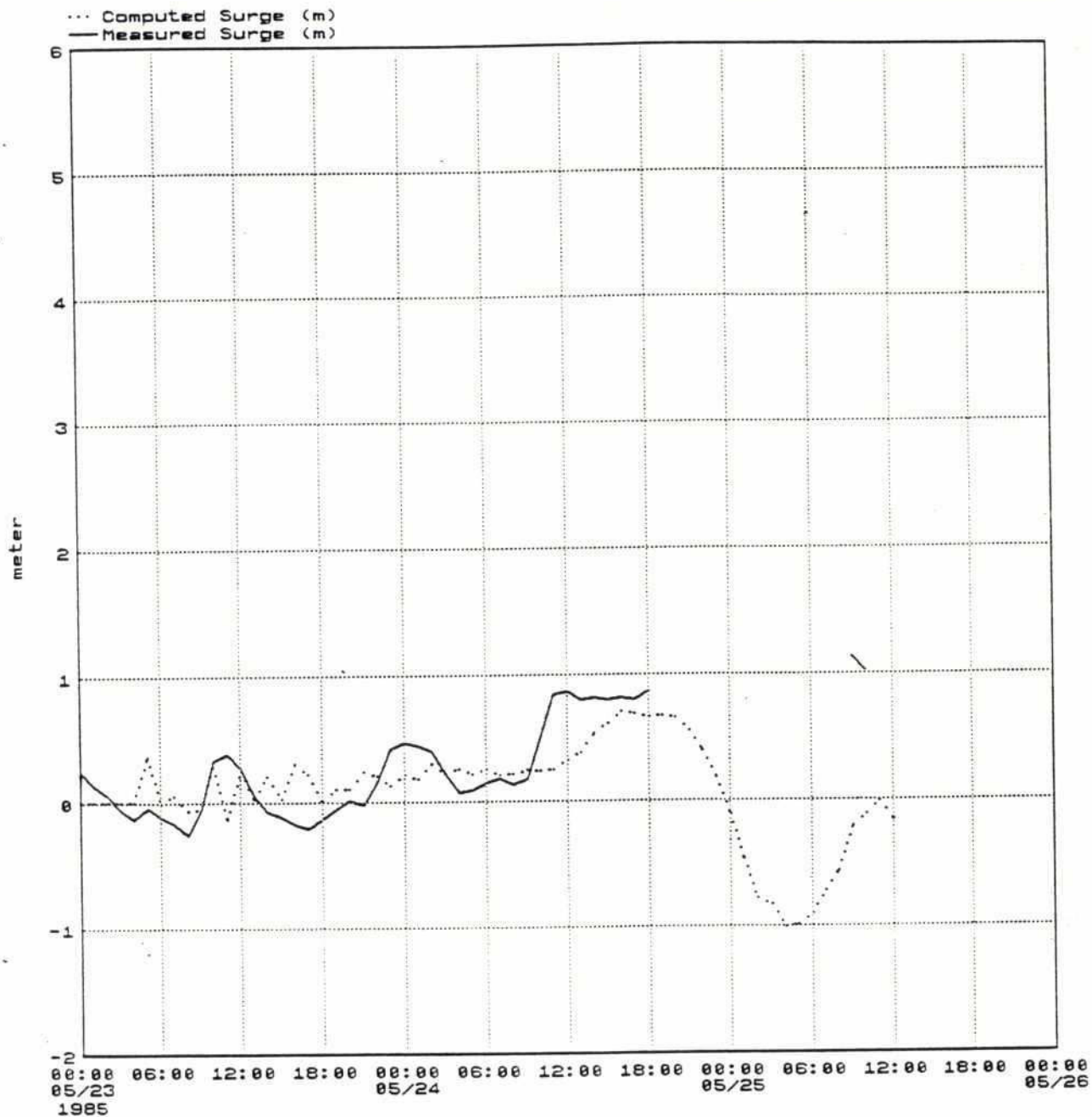


208



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: m85 name : ccox4 User: mnr Mon Dec 17 1990	May 1985 Coxs Bazar Measured and computed surge	<b>Dwg. No.</b>  4.173

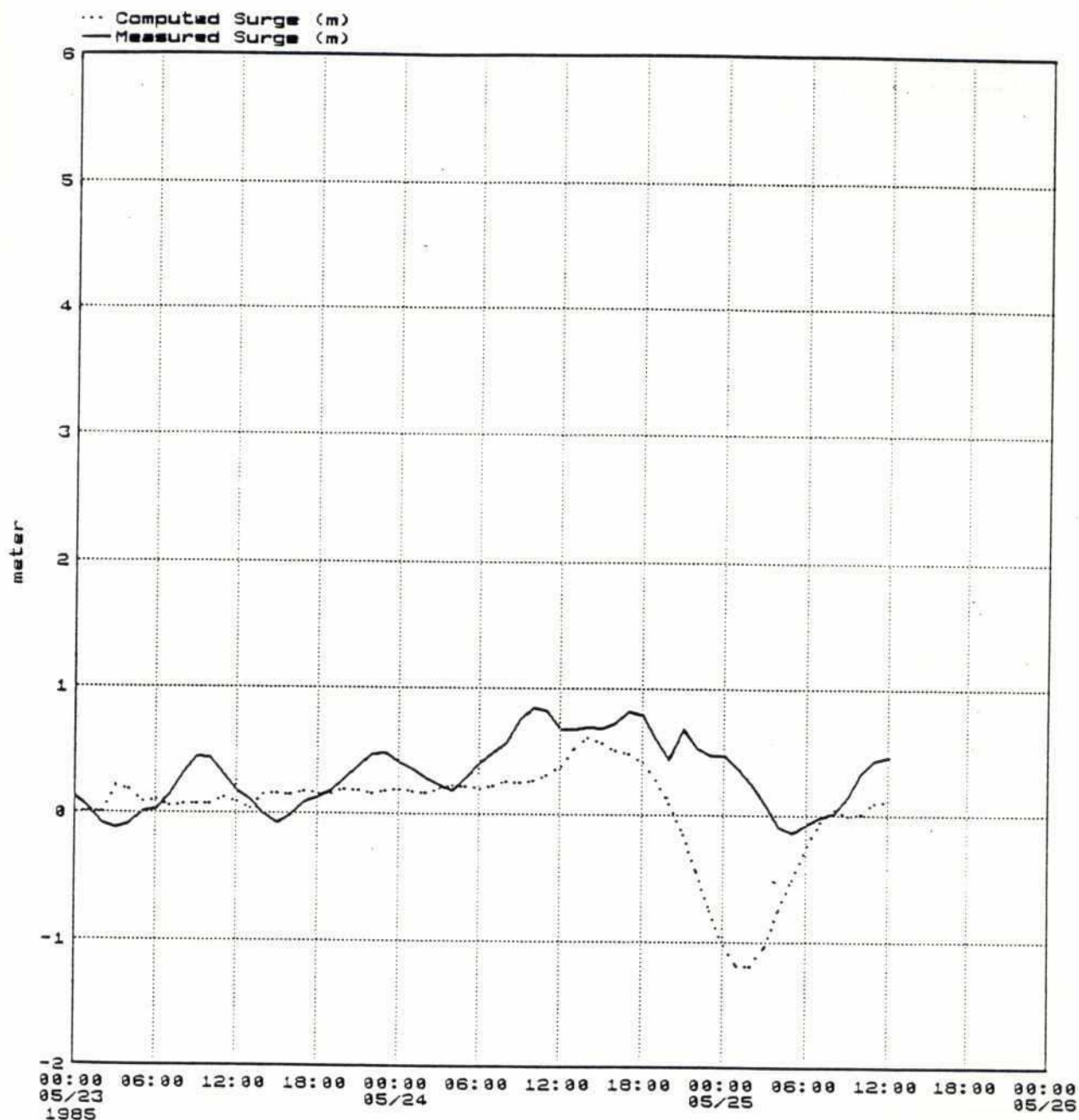
204



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: m85 name : cgal4 User: mnr Mon Dec 17 1990	May 1985 Galachipa Measured and computed surge	Dwg. No.  4.174



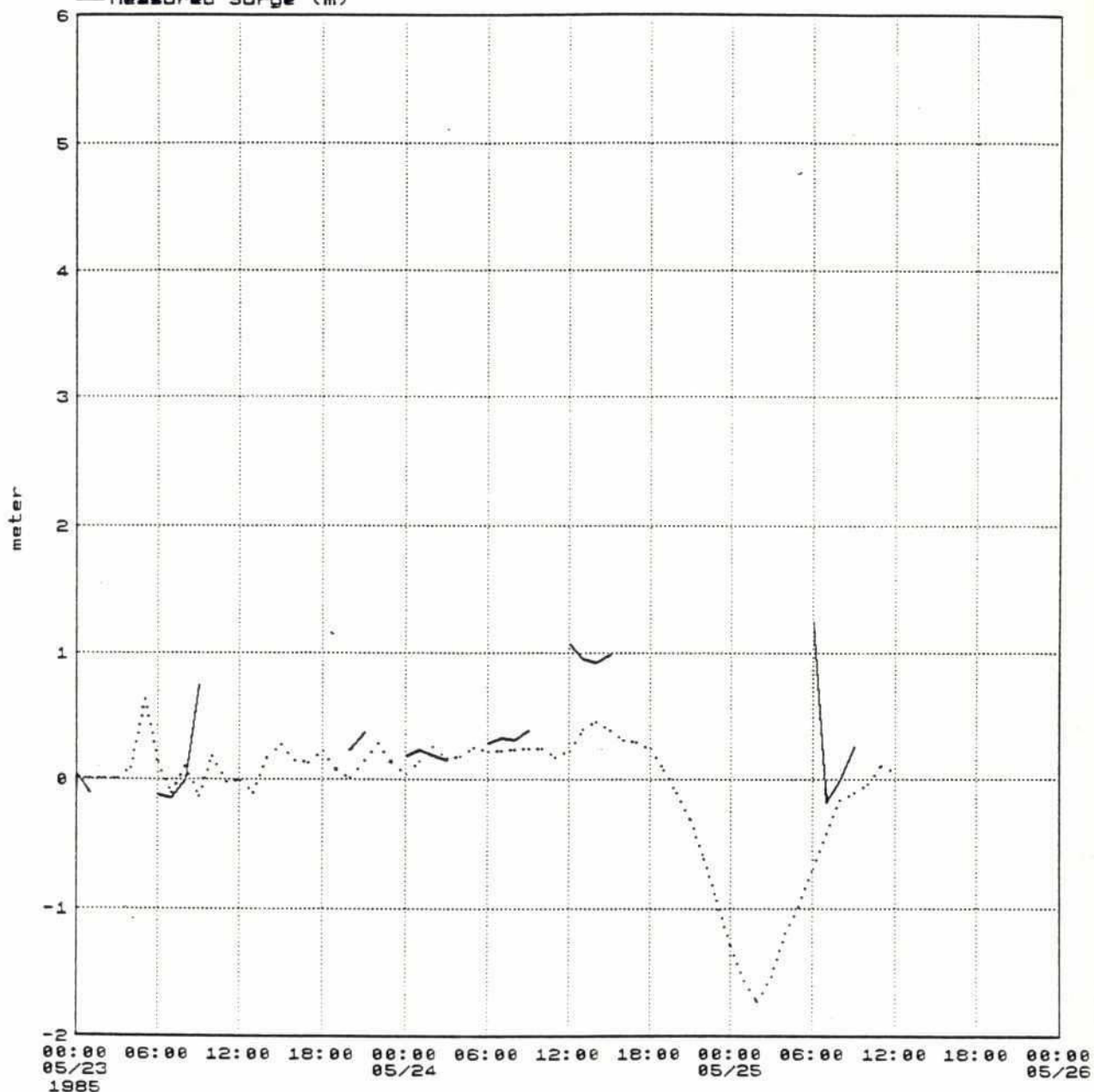
209



MIKE21	Cyclone Protection Project II	
File: family: m85 name : chir4 User: mnr Mon Dec 17 1990	May 1985 Hiron Point Measured and computed surge	Dwg. No.  4.175

248

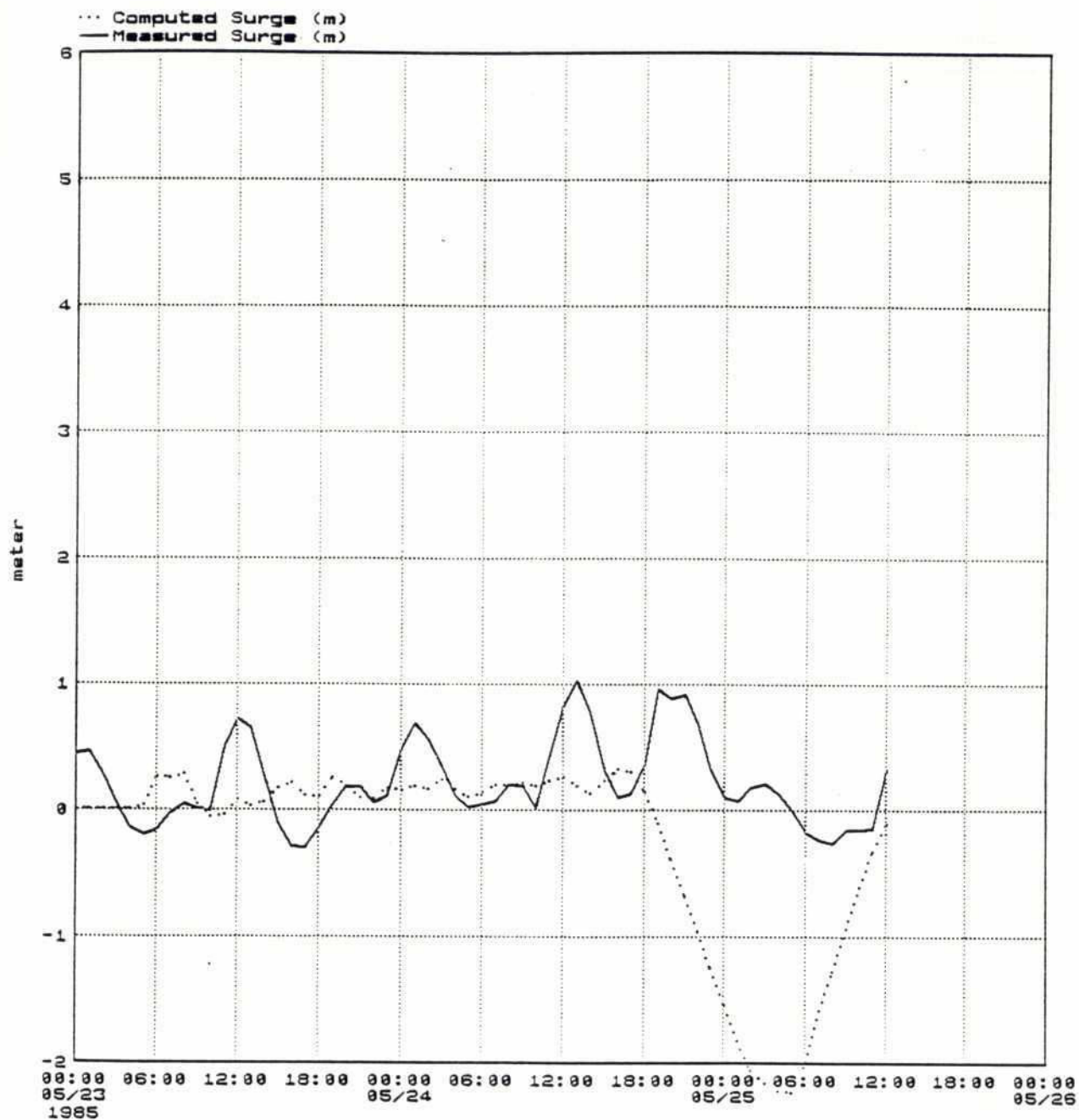
... Computed Surge (m)  
 — Measured Surge (m)



MIKE21	Cyclone Protection Project II	
File: family: m85 name : ckhe4 User: mnr Mon Dec 17 1990	May 1985 Khepupara Measured and computed surge	Dwg. No.  4.176

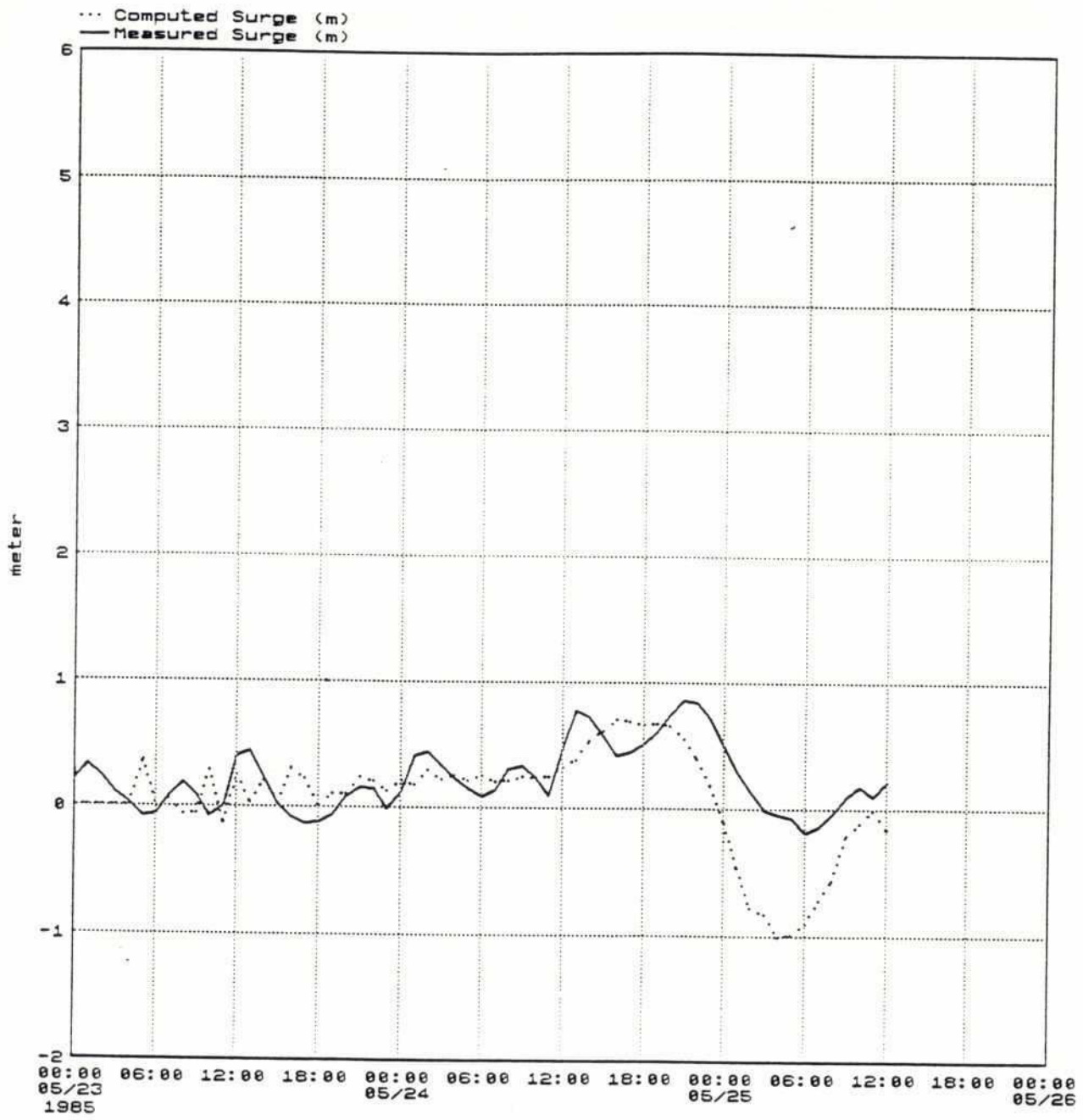


299



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: m85 name : cmon4 User: mnr Mon Dec 17 1998	May 1985 Mongla Measured and computed surge	Dwg. No.  4.177

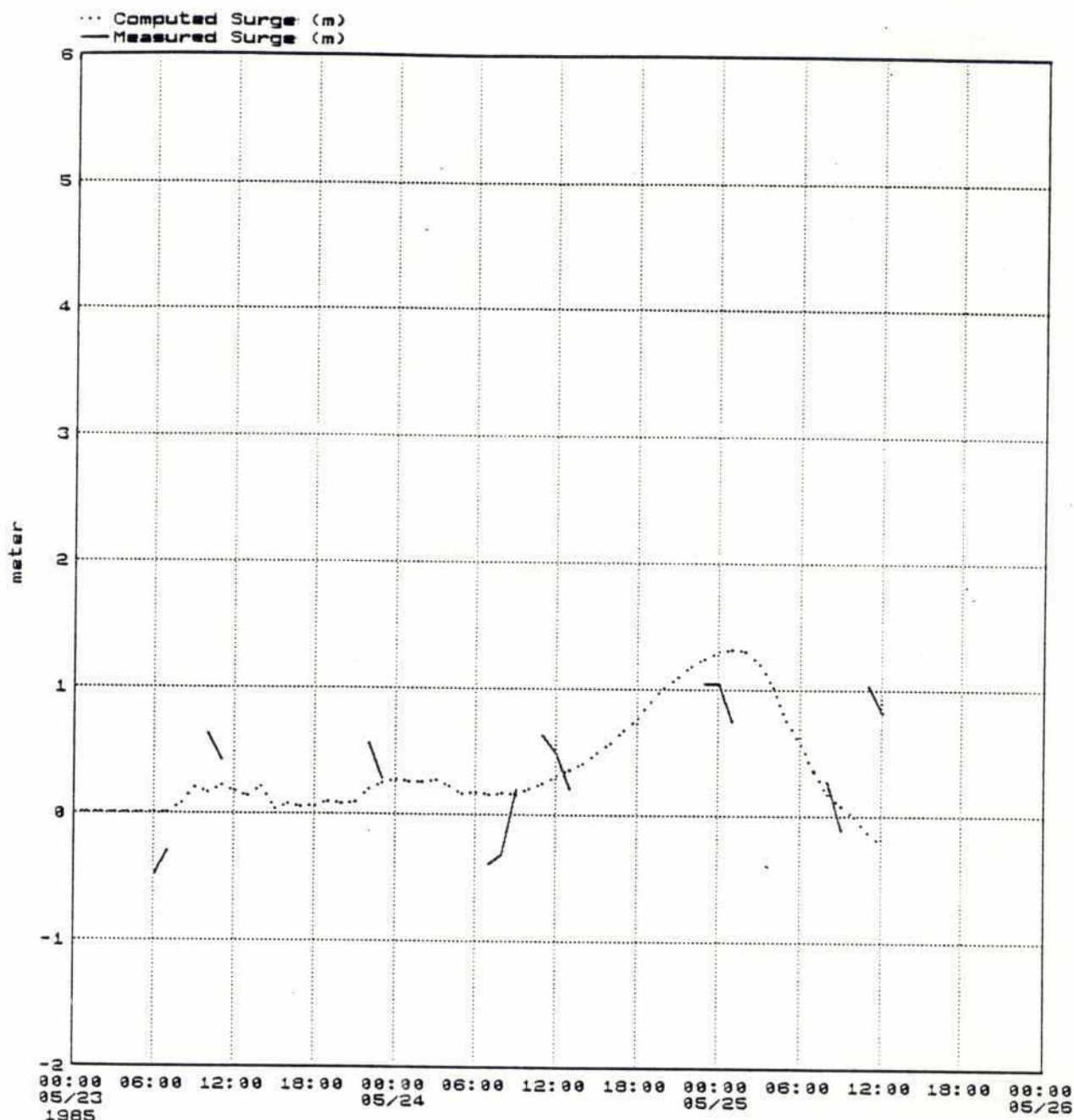
240



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: m85 name : cpat4 User: mnr Mon Dec 17 1990	May 1985 Patuakhali Measured and computed surge	Dwg. No.  4.178

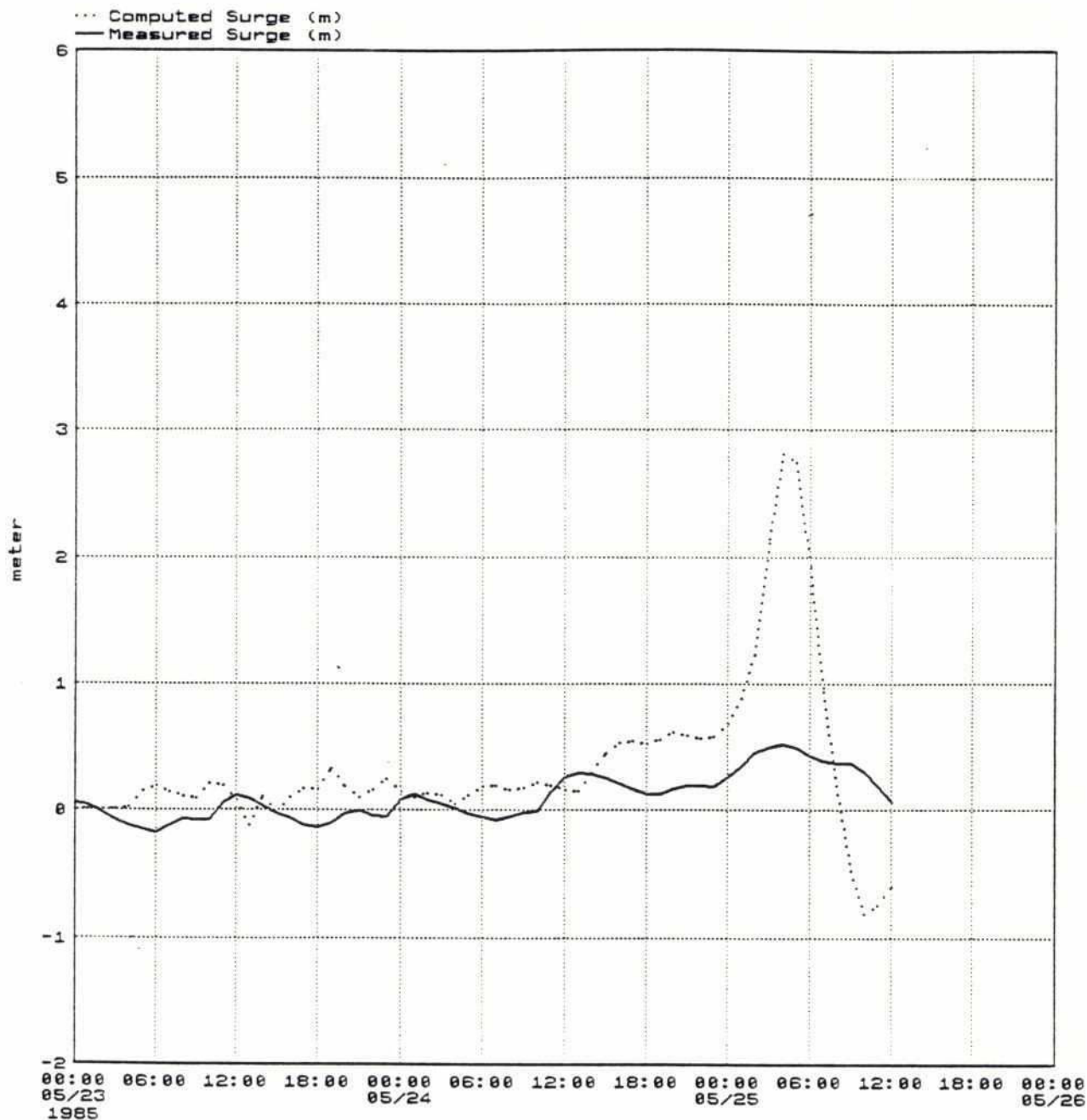


250



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: m85 name : cram4 User: mnr Mon Dec 17 1990	May 1985 Ramdasapur Measured and computed surge	Dwg. No.  4.179

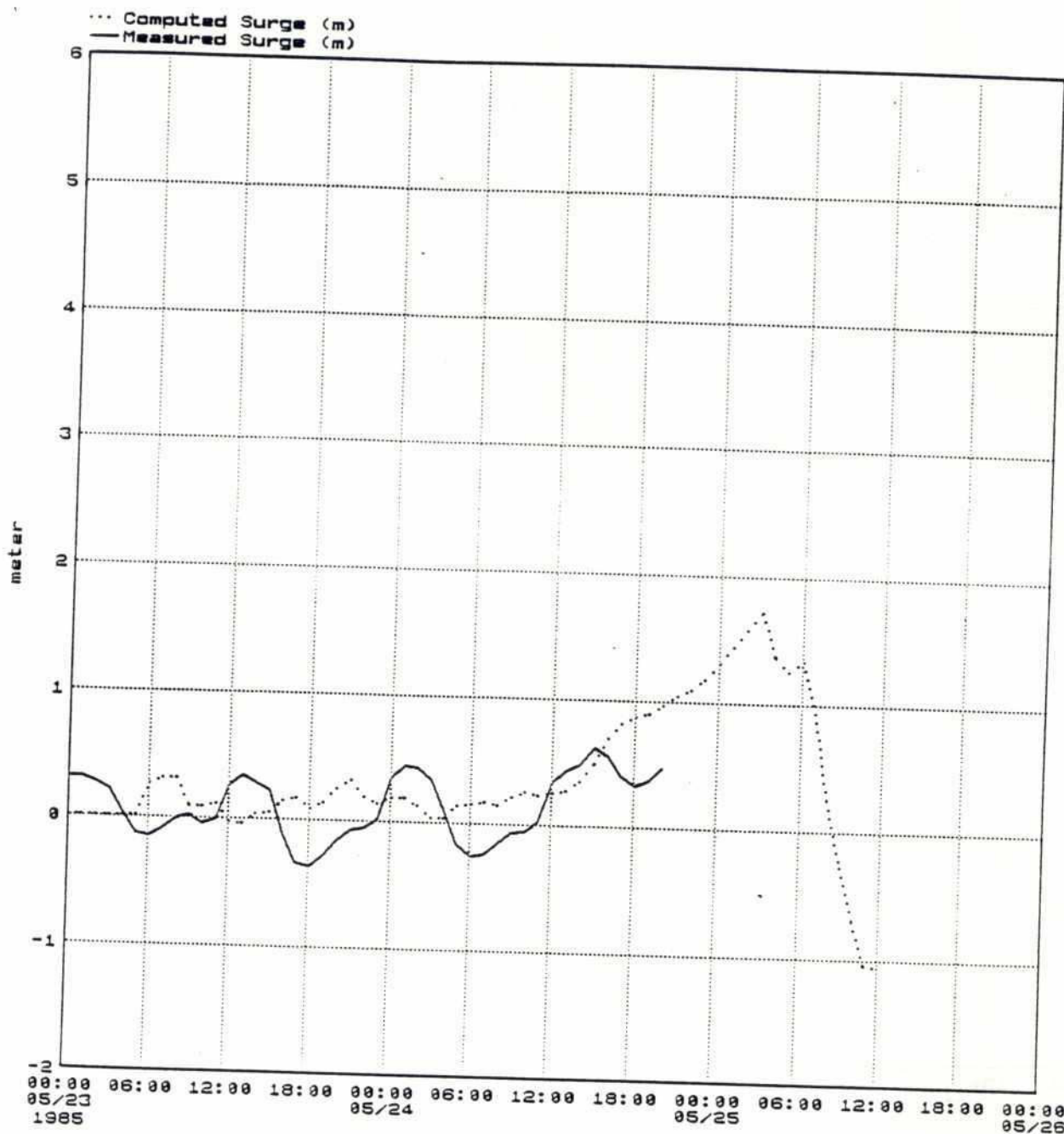
242



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: m85 name : csad4 User: mnr Mon Dec 17 1990	May 1985 Sadarghat (CTG) Measured and computed surge	<b>Dwg. No.</b>  4.180

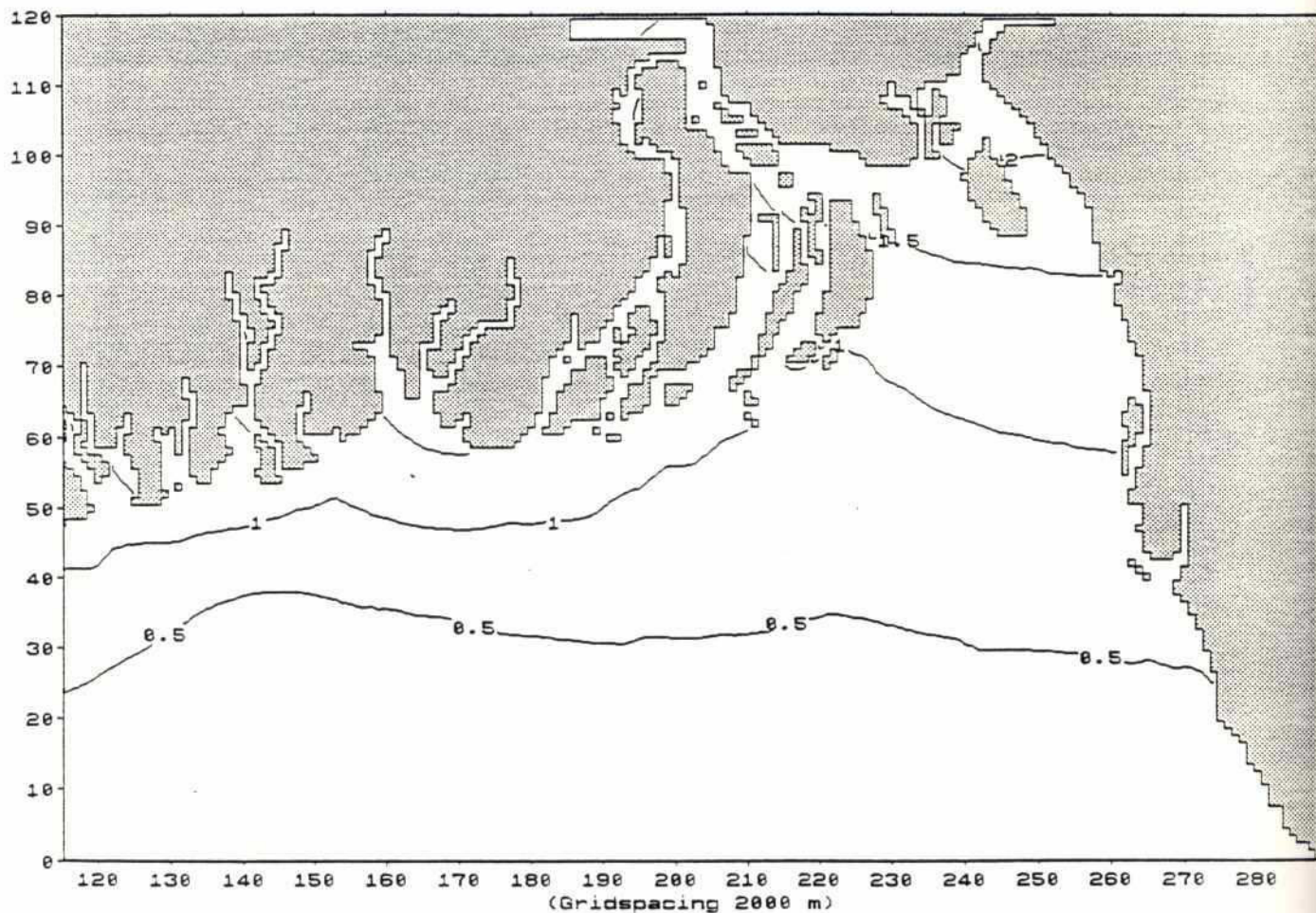


226



<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: m85 name : csan4 User: mnr Mon Dec 17 1990</p>	<p>May 1985 Sandwip Measured and computed surge</p>	<p>Dwg. No.  4.181</p>

278



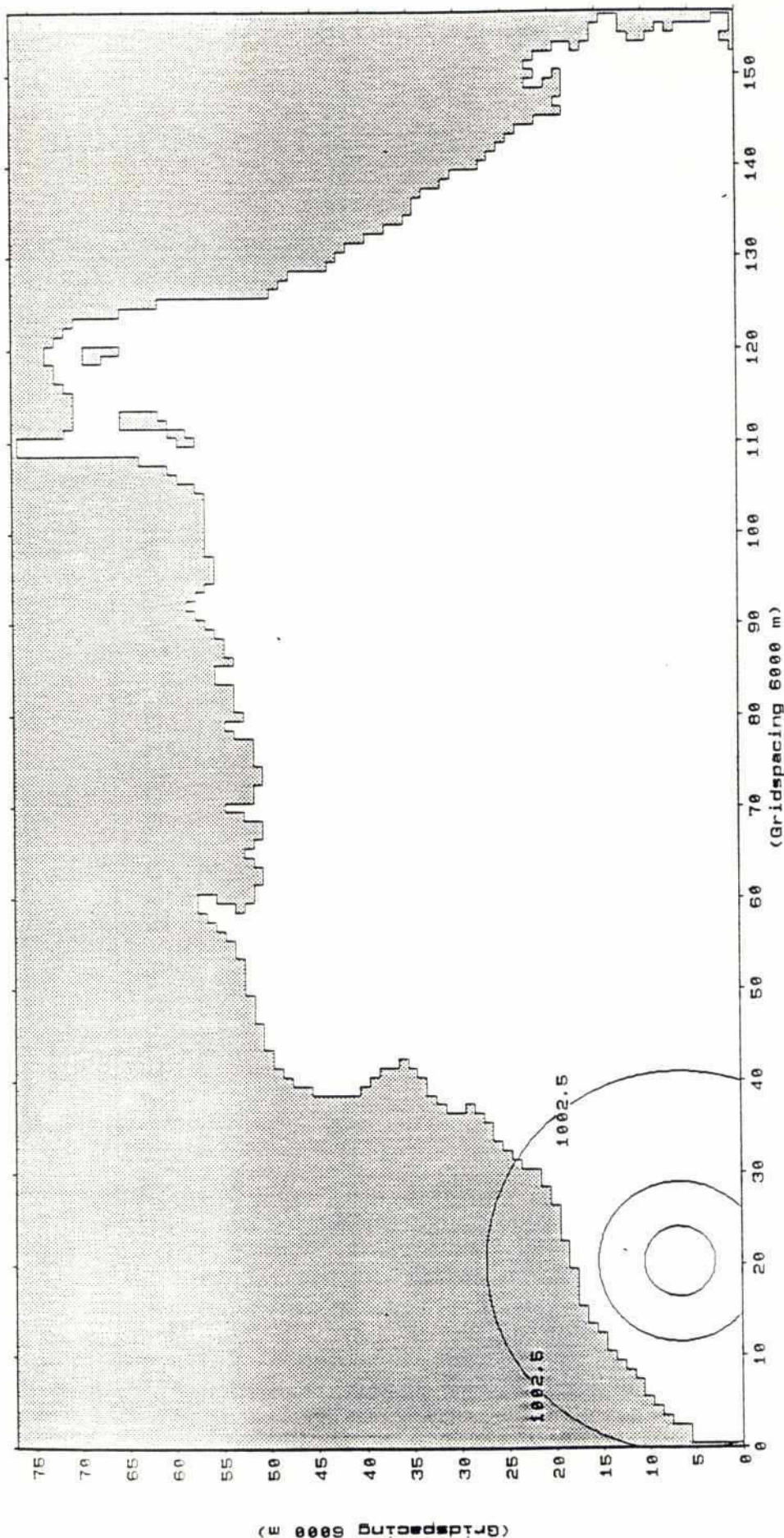
MIKE21	Cyclone Protection Project II	
File: family: n86 name : imax Scale: 1:2 mill Mon Nov 26 1990	November 1986 Cyclone Simulation Results, Intermediate Model Maximum Surge Levels	Dwg. No.  4.182







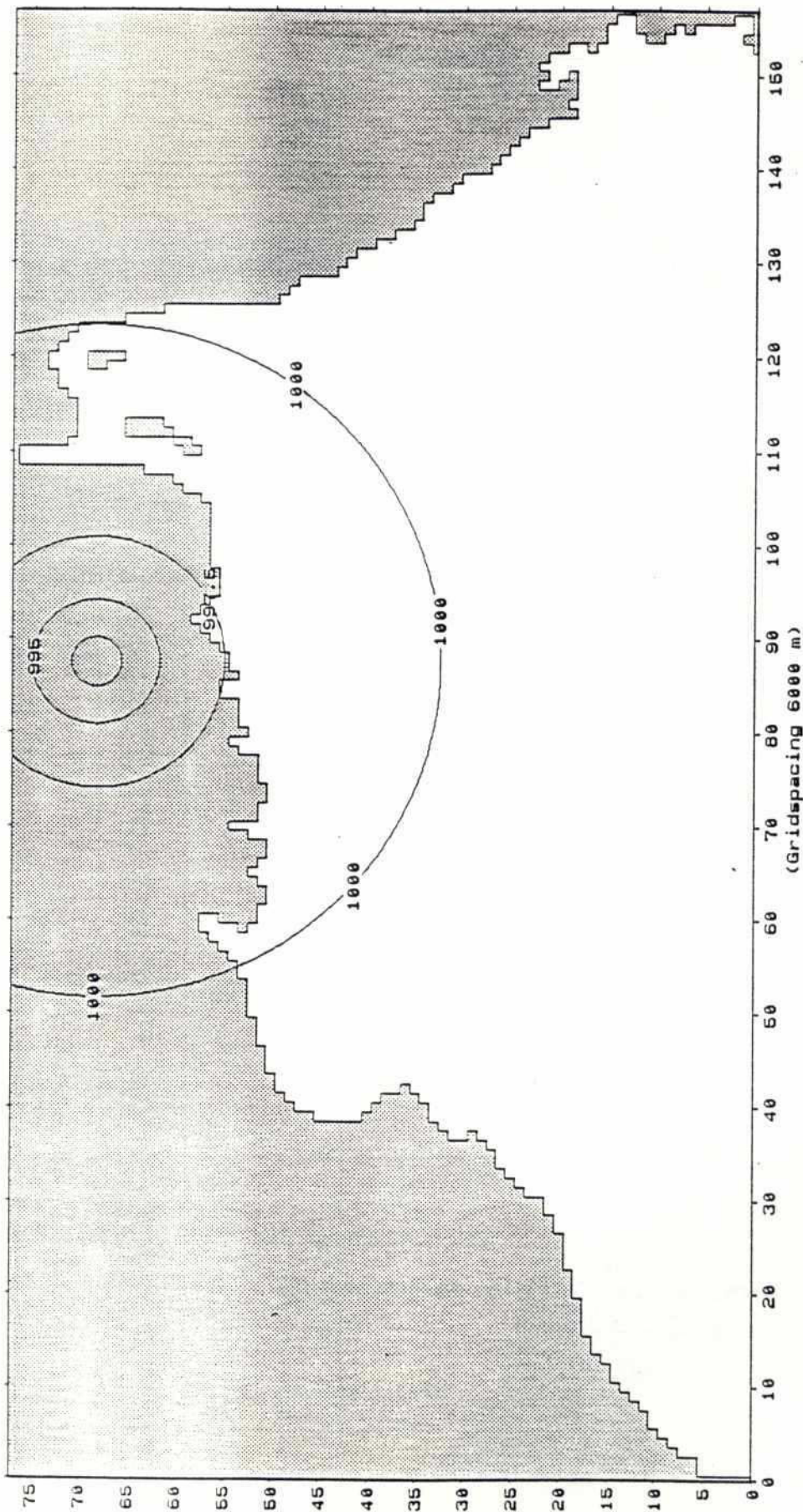
244



1986/11/09 00:00:00

<p><b>MIKE21</b></p>	<p><b>Cyclone Protection Project II</b></p>	
<p>File: family: n86 name : rwind Scale: 1:4 mill Tue Nov 27 1990</p>	<p>November 1986 Cyclone Pressure Field (mb)</p>	<p>Dwg. No.  4.184</p>



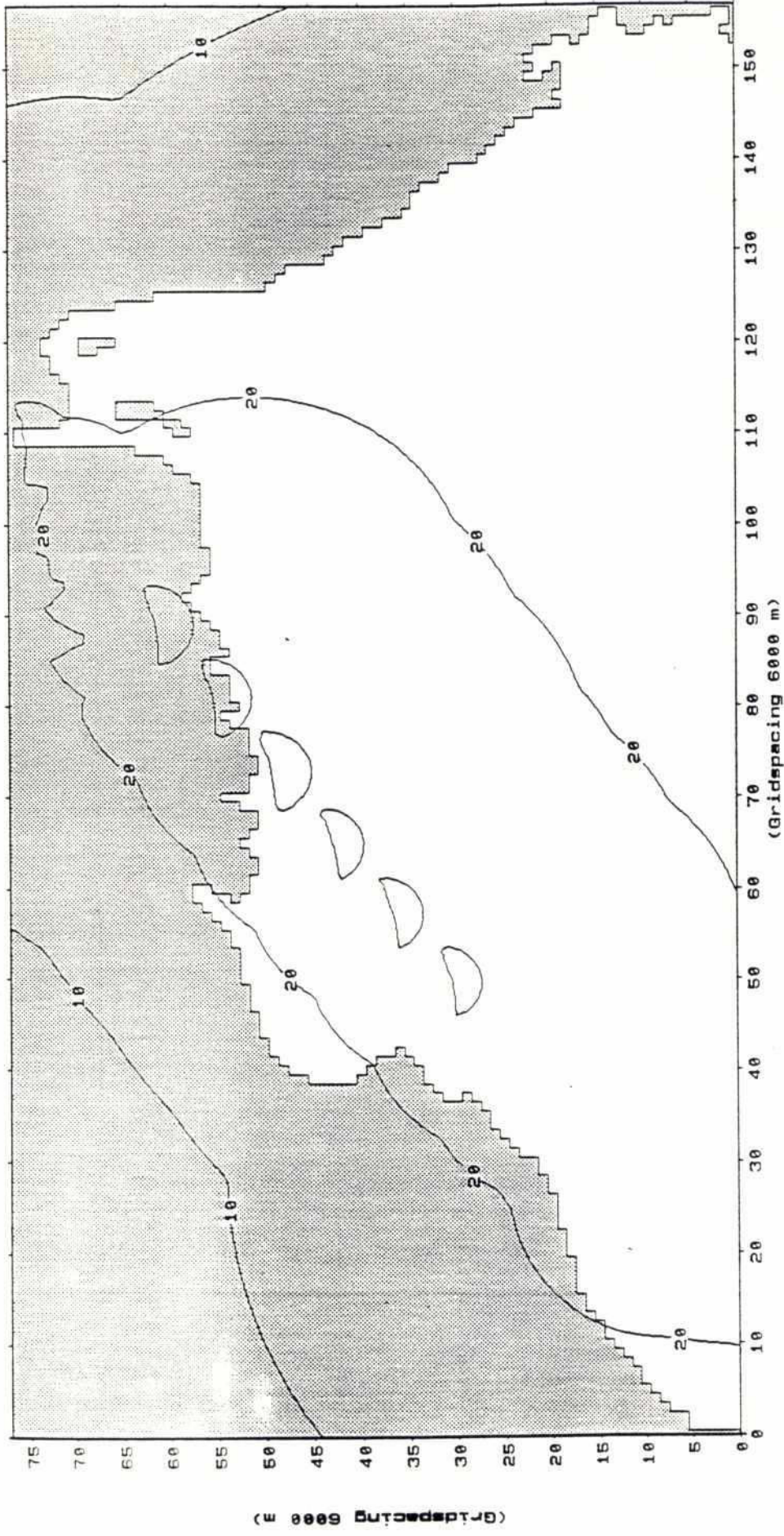


1986/11/09 12:00:00

<p><b>MIKE21</b></p>	<p><b>Cyclone Protection Project II</b></p>	
<p>File: family: n86 name : rwind Scale: 1:4 mill Mon Nov 26 1990</p>	<p>November 1986 Cyclone Pressure Field (mb)</p>	<p>Dwg. No.  4.185</p>

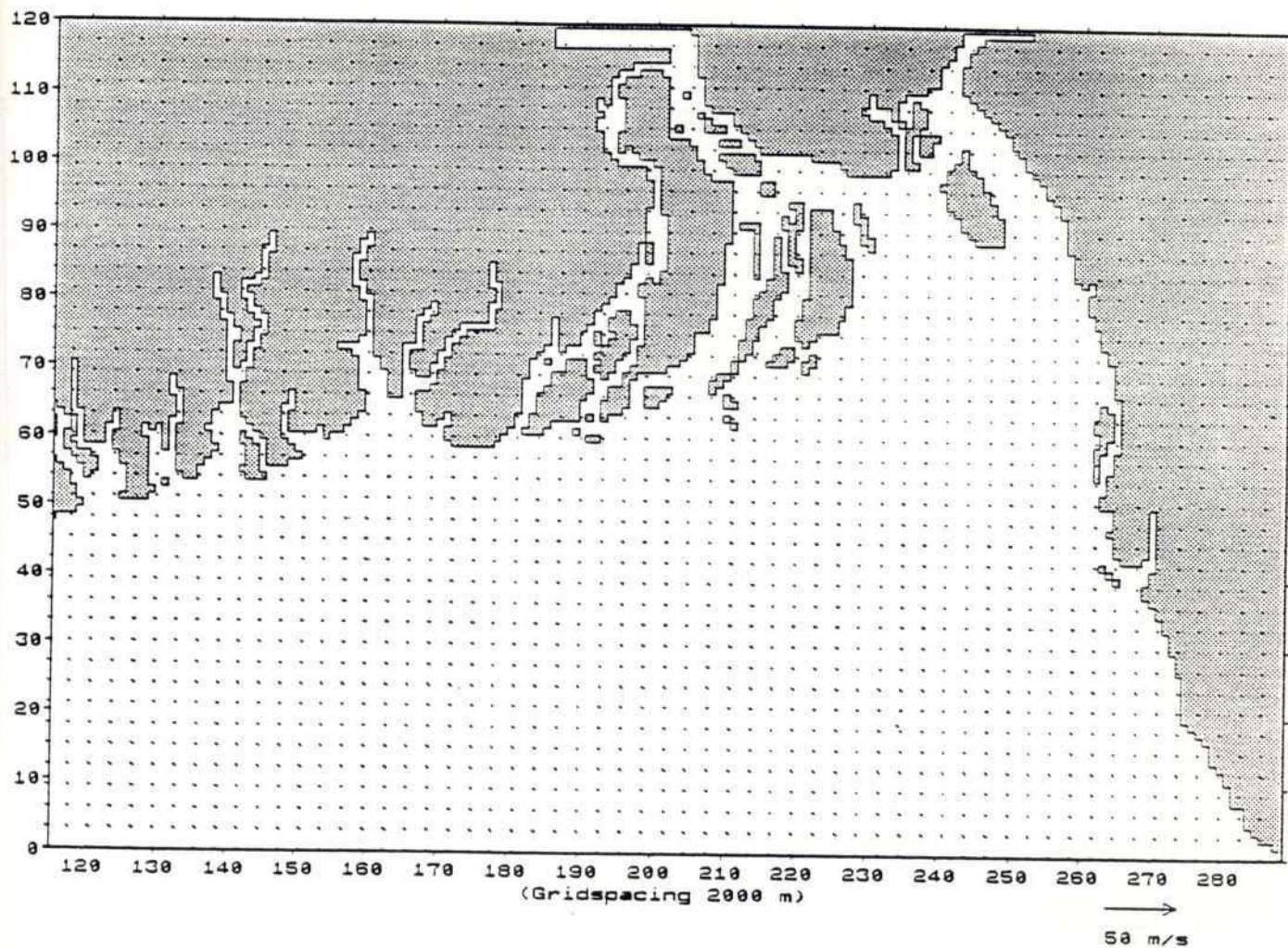


248



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n86 name : rmwind Scale: 1:4 mill Sun Nov 25 1990	November 1986 Maximum occurring Wind Speed (m/s)	
		Dwg. No. 4.186



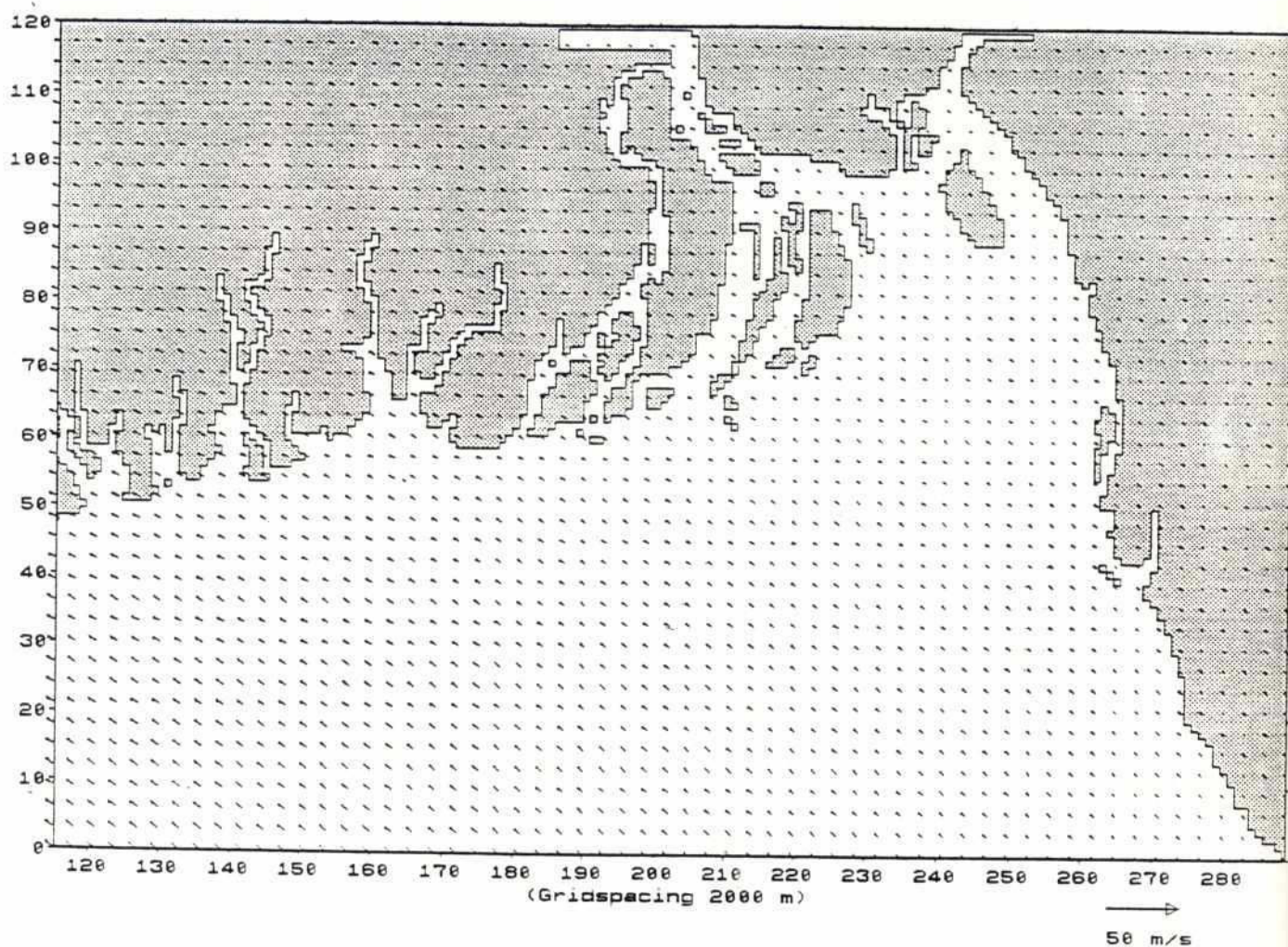


1986/11/08 12:00:00

<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n86 name : iwind Scale: 1:2 mill Mon Nov 26 1990	November 1986 Cyclone Wind Field	<b>Dwg. No.</b>  4.187



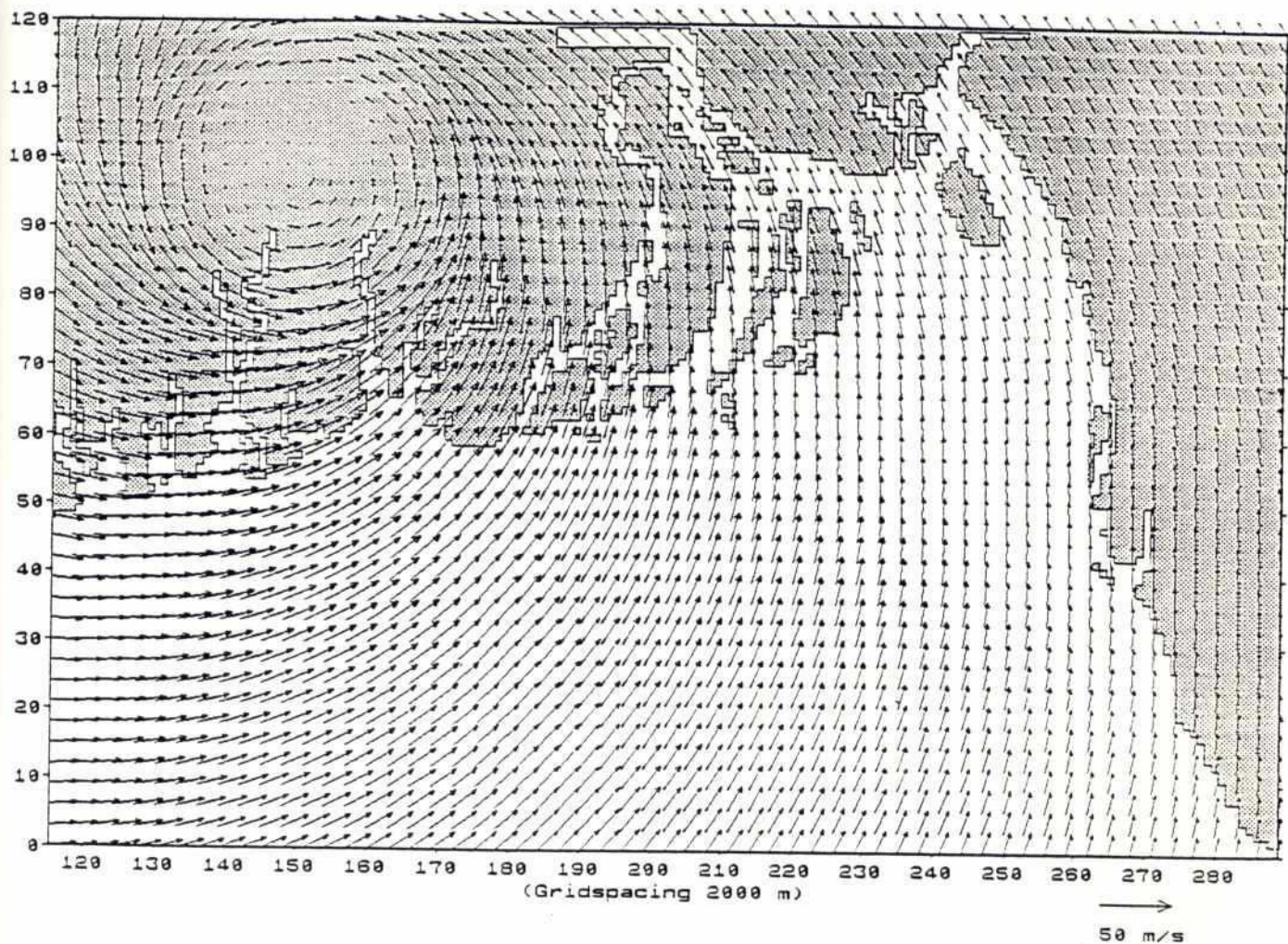
290



1986/11/09 00:00:00

MIKE21	Cyclone Protection Project II	
File: family: n86 name : iwind Scale: 1:2 mill Mon Nov 26 1990	November 1986 Cyclone Wind Field	Dwg. No.  4.188



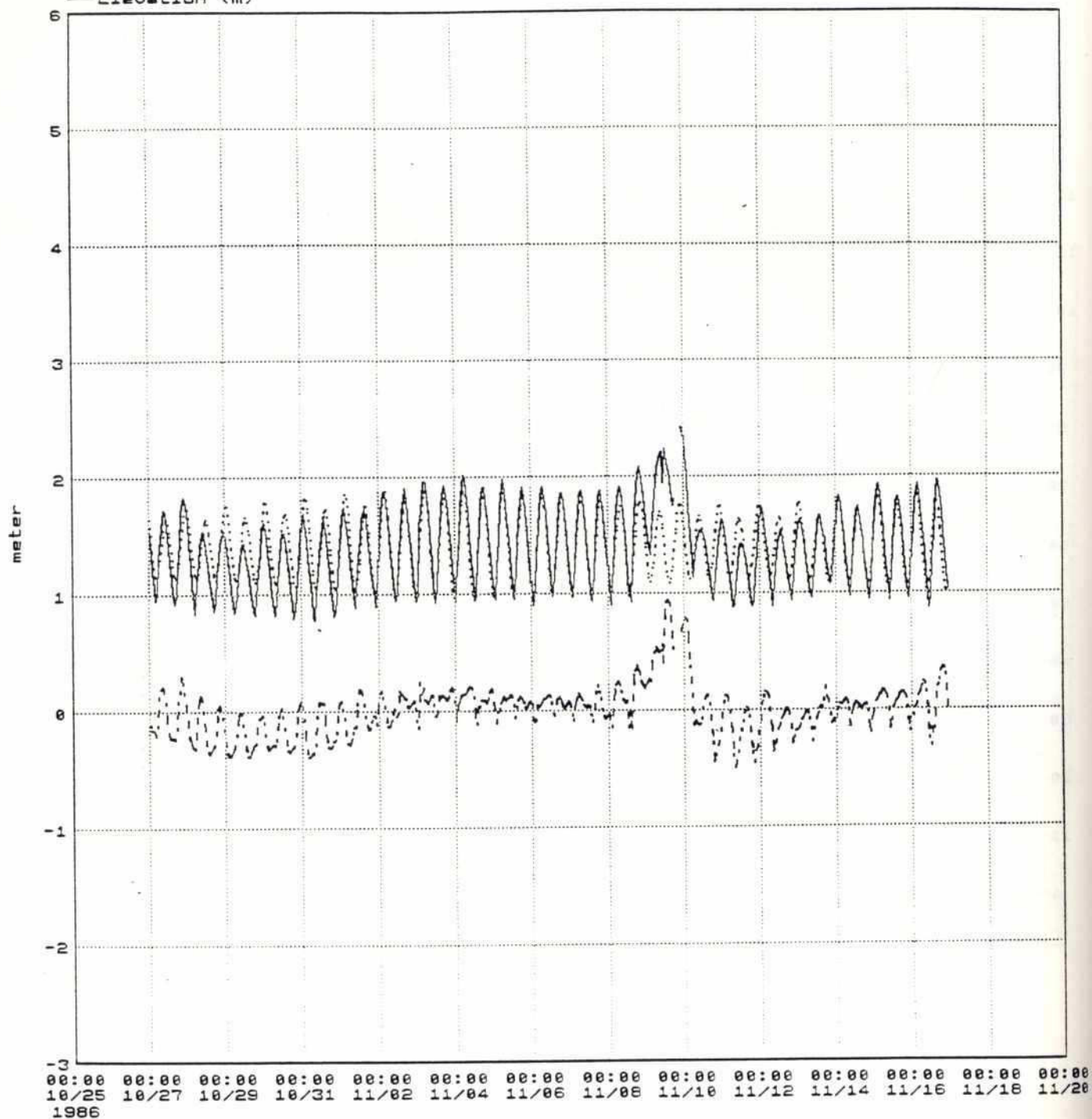


1986/11/09 12:00:00

<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: n86 name : iwind Scale: 1:2 mill Mon Nov 26 1990</p>	<p>November 1986 Cyclone Wind Field</p>	<p>Dwg. No.  4.189</p>

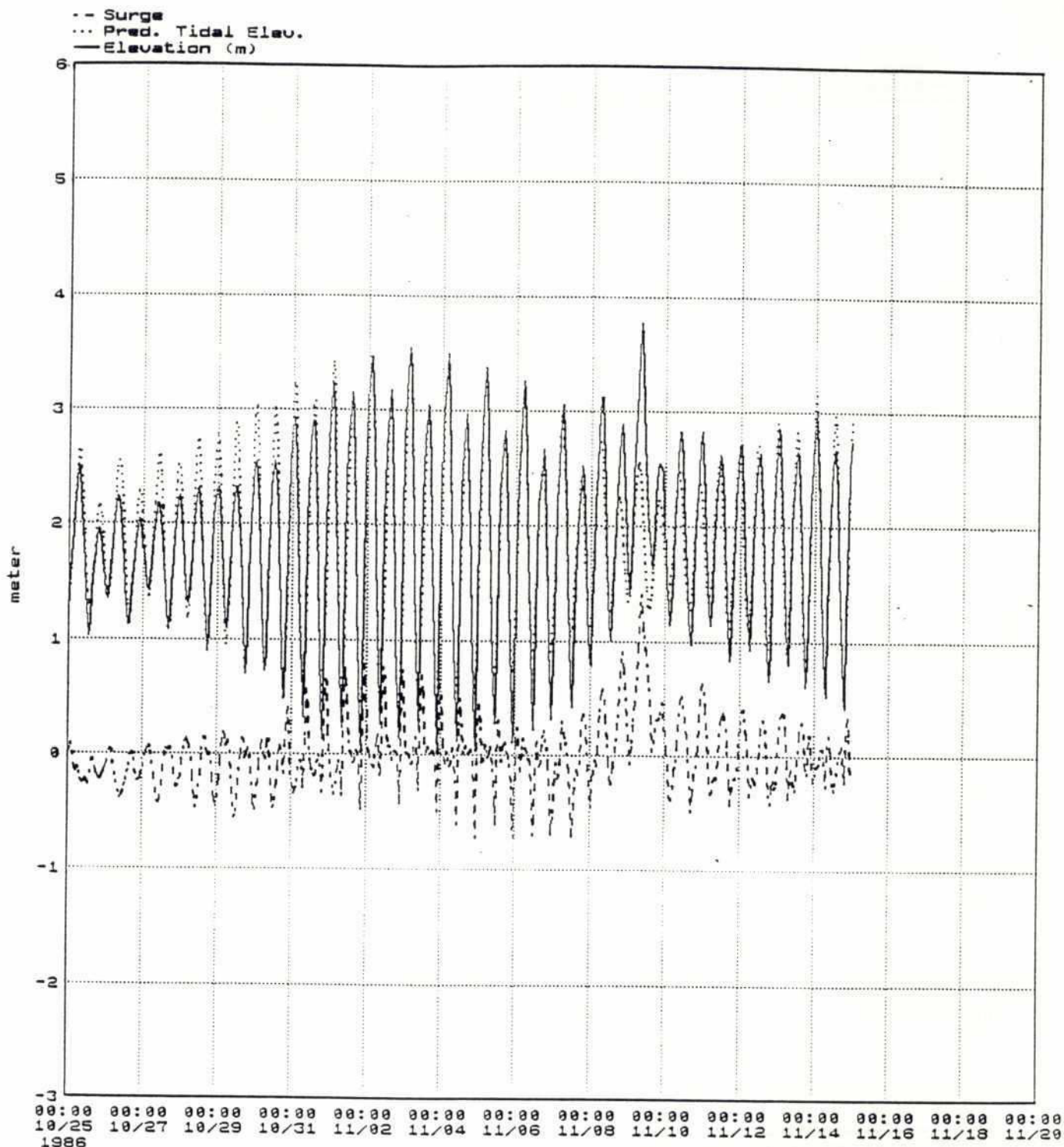
292

-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



MIKE21	Cyclone Protection Project II	
File: family: n86 name : sbar4 User: mnr Mon Dec 17 1990	November 1986 Barisal Measurements	Dwg. No.  4.190

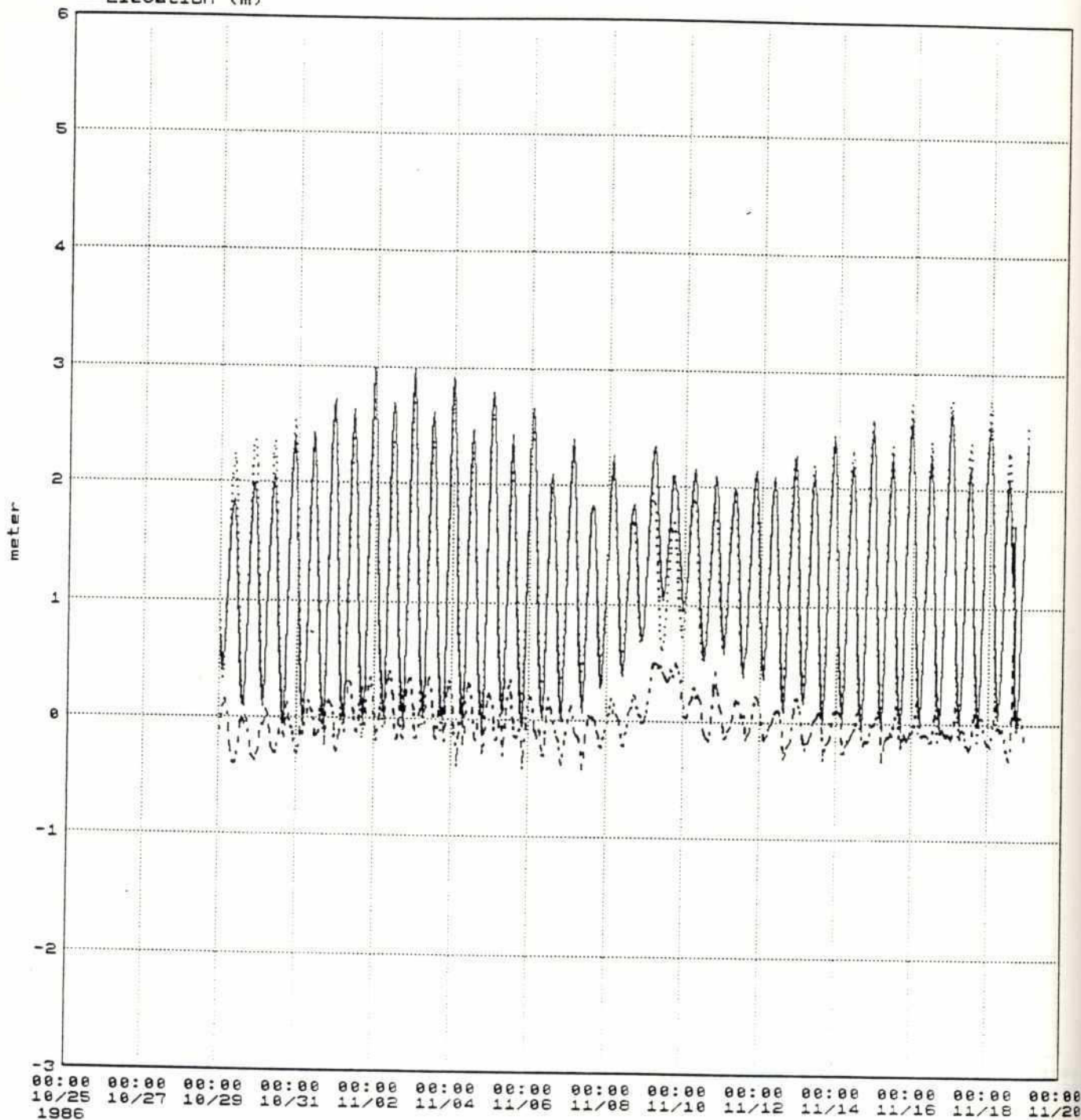




<p>MIKE21</p>	<p>Cyclone Protection Project II</p>	
<p>File:            family: n86            name : schr4            User: mnr            Mon Dec 17 1990</p>	<p>November 1986            Char-Chenga            Measurements</p>	<p>Dwg. No.             4.191</p>

298

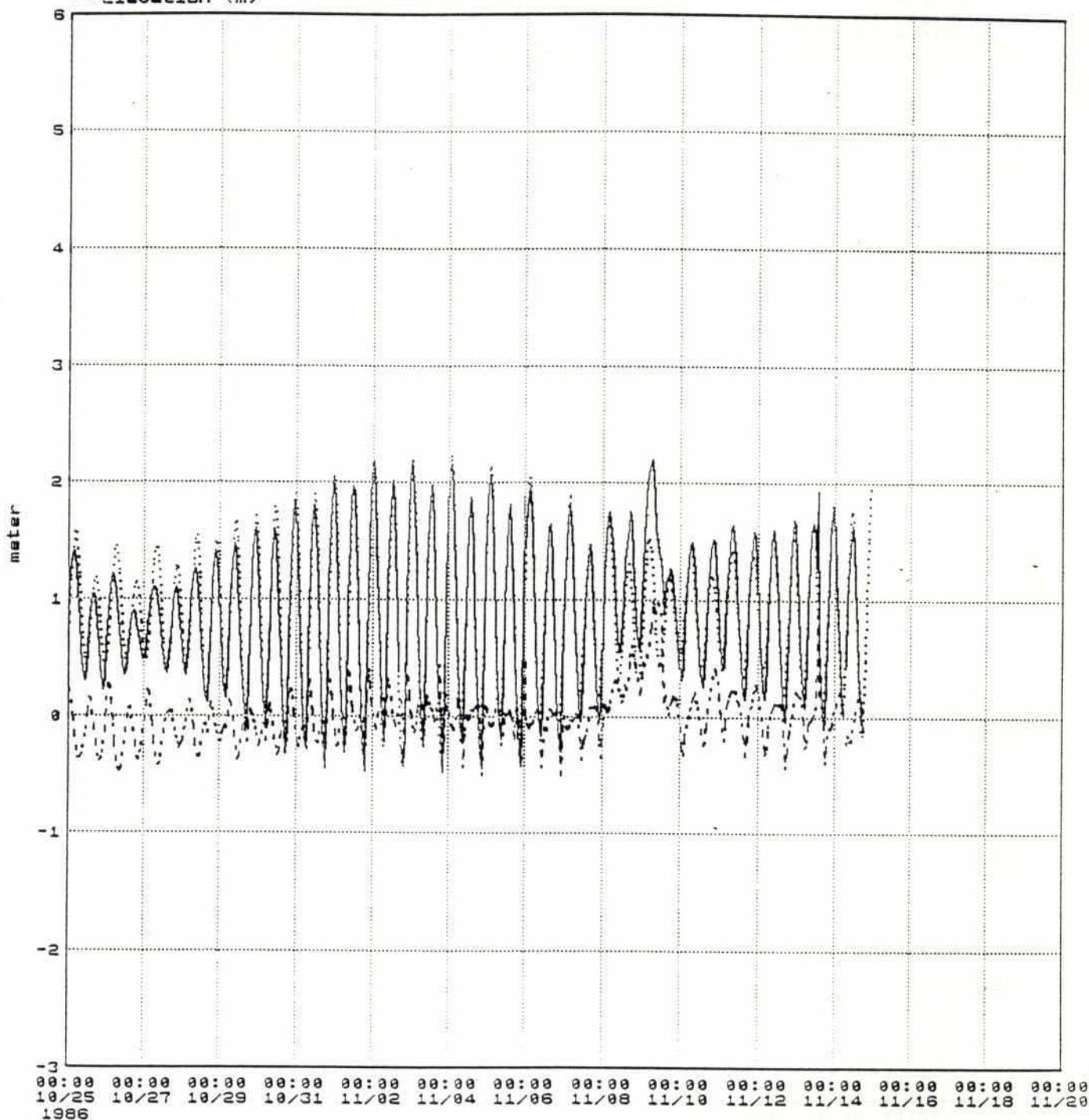
-- Surge  
 ... Pred. Tidal Eleu.  
 — Elevation (m)



<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File:            family: n86            name : scox4            User: mnr            Mon Dec 17 1990</p>	<p>November 1986            Coxs Bazar            Measurements</p>	<p>Dwg. No.             4.192</p>



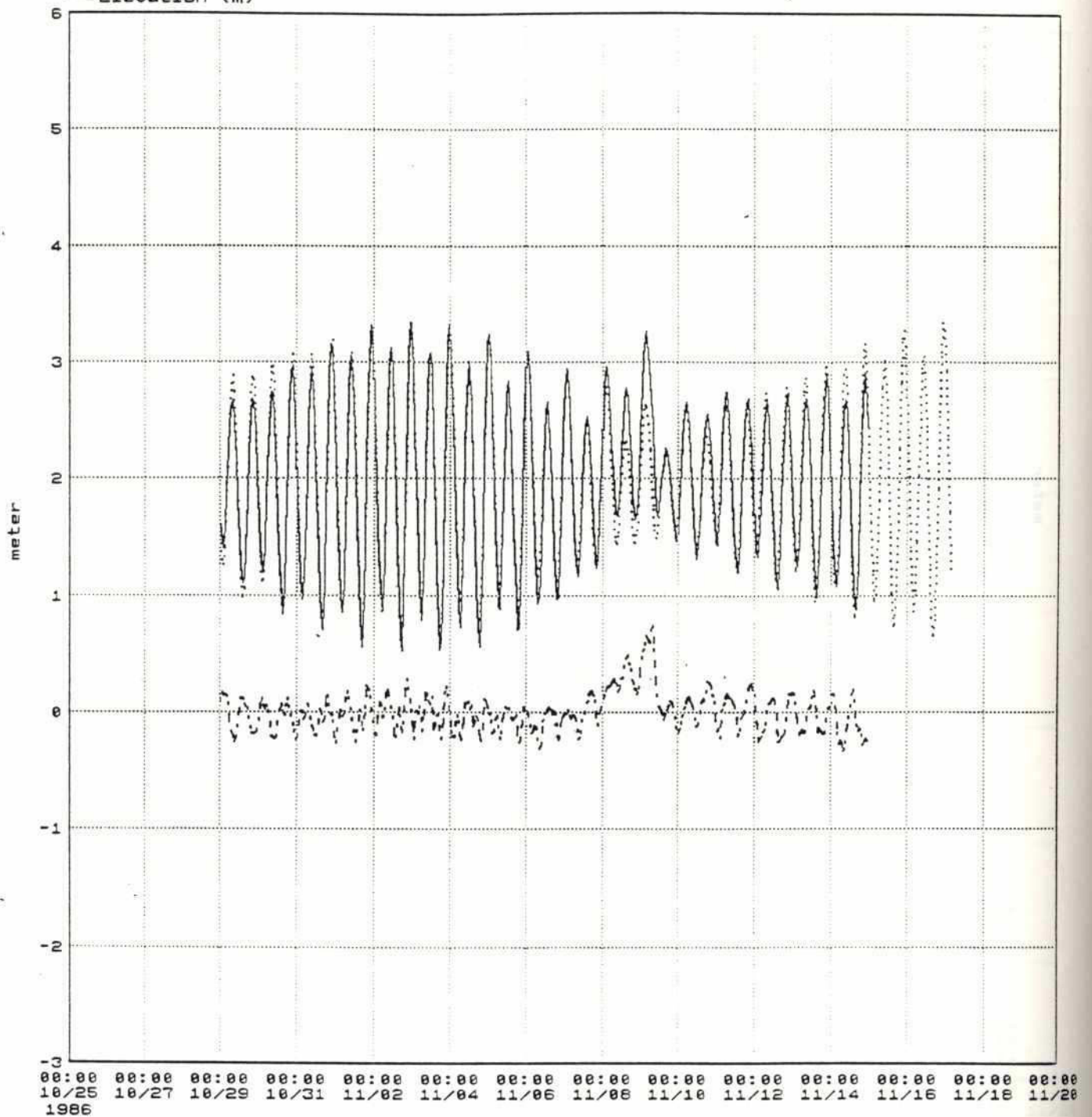
-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n86 name : sg14 User: mnr Mon Dec 17 1998	November 1986 Galachipa Measurements	Dwg. No.  4.193

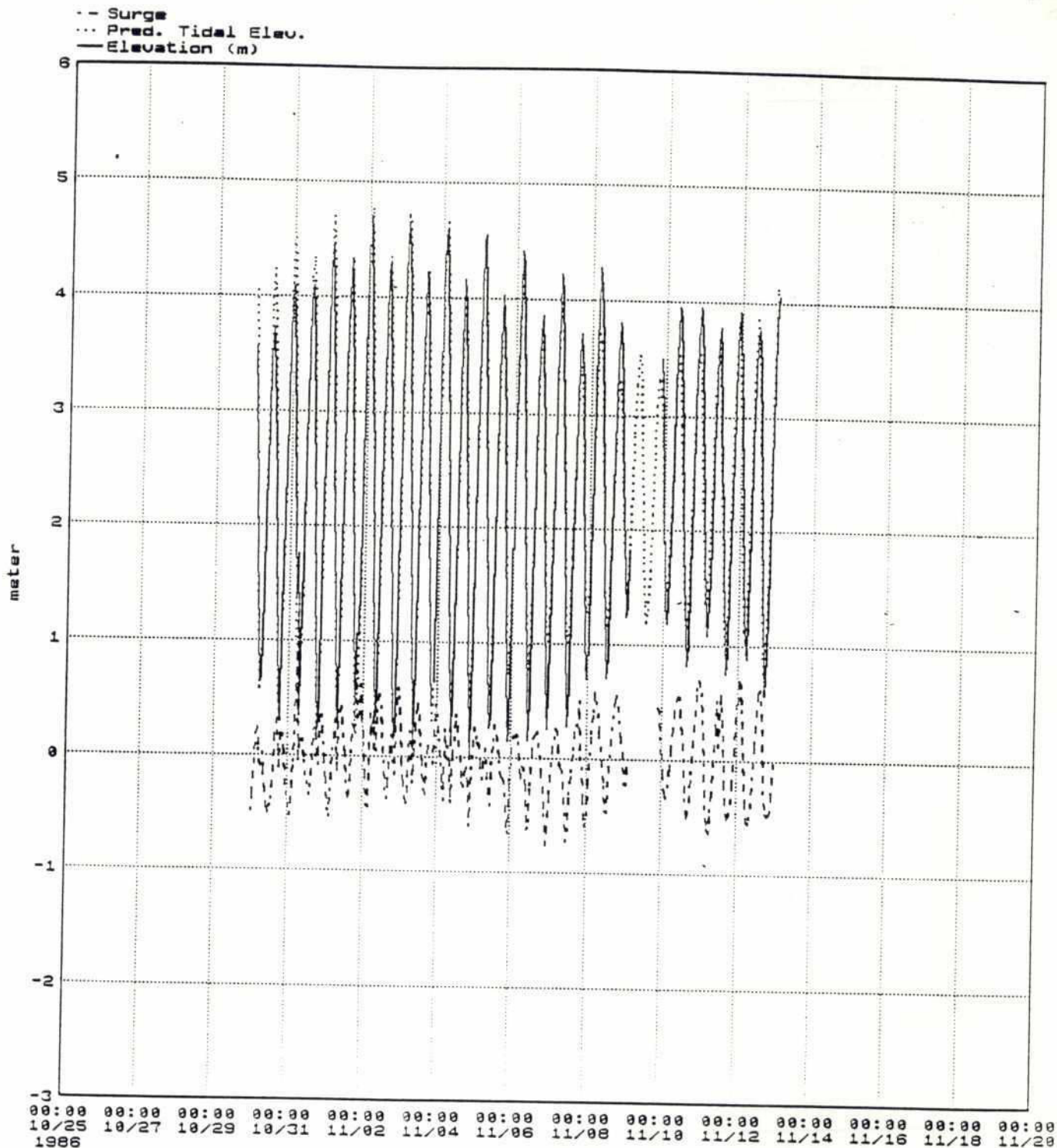
293

-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



<p>MIKE21</p>	<p>Cyclone Protection Project II</p>	
<p>File:            family: n86            name : shir4            User: mnr            Mon Dec 17 1990</p>	<p>November 1986            Hiron Point            Measurements</p>	<p>Dwg. No.             4.194</p>

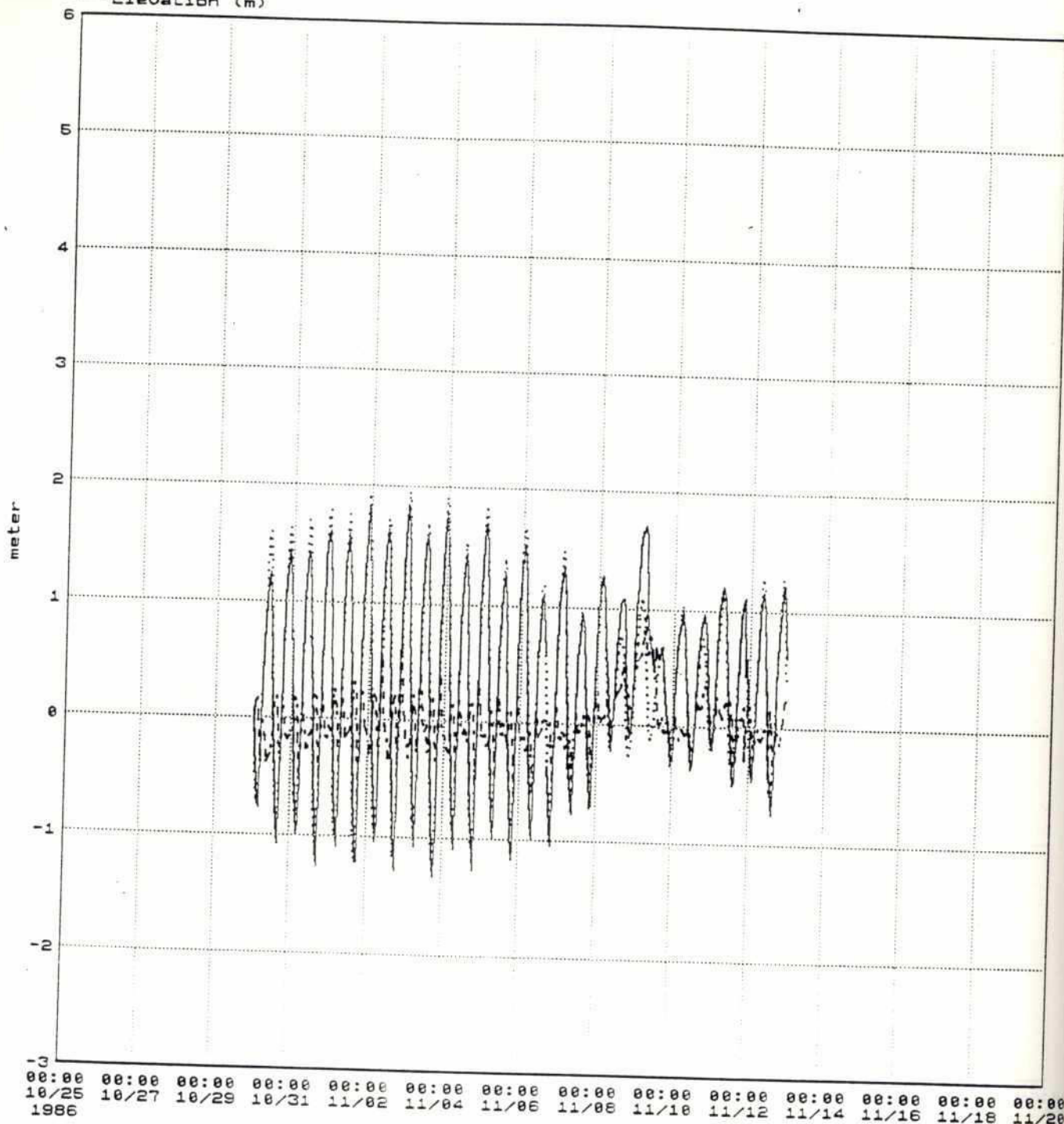




<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n86 name : skha4 User: mnr Mon Dec 17 1990	November 1986 Khal No. 10 Measurements	<b>Dwg. No.</b>  4.195

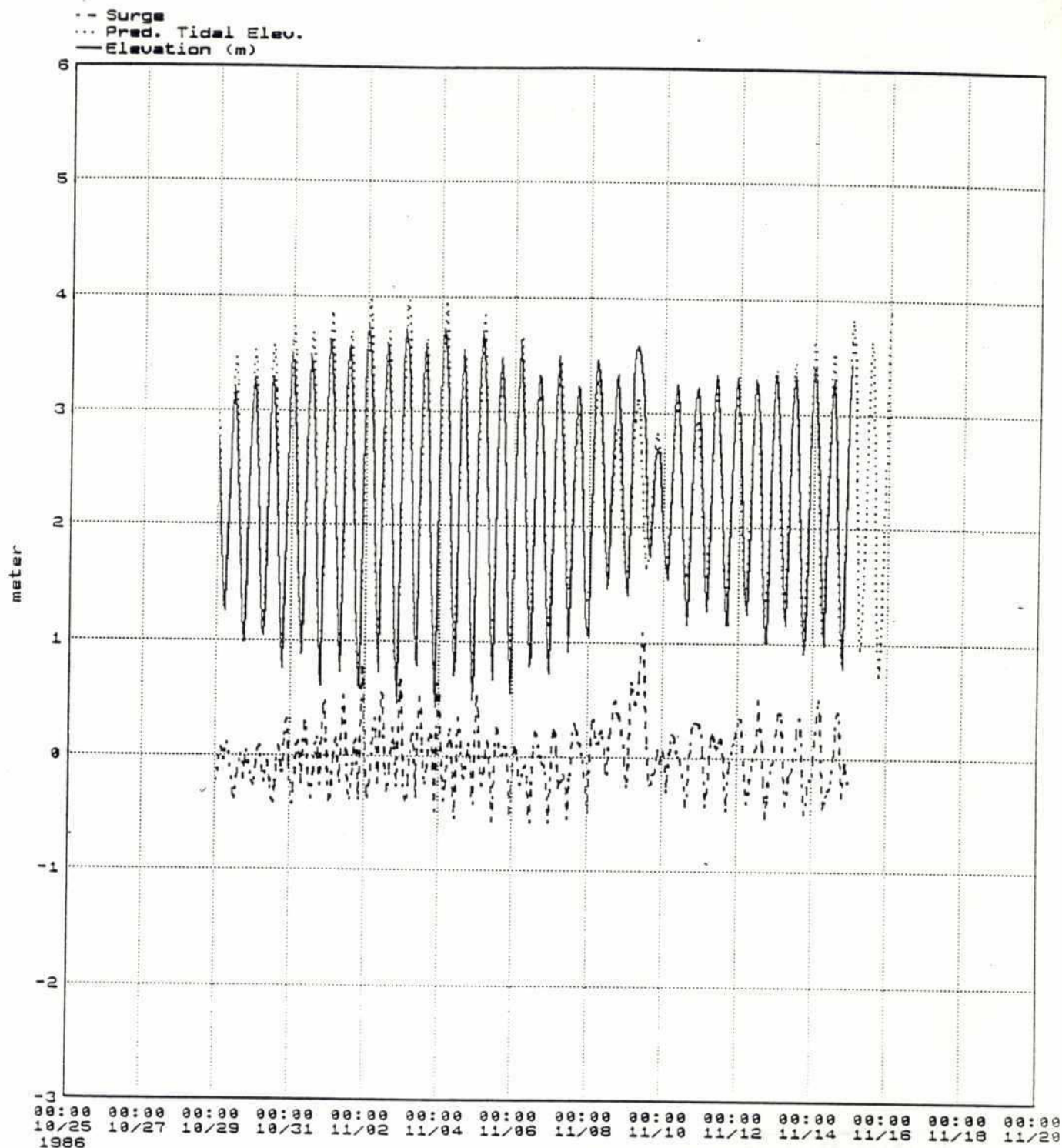
298

-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



<b>MIKE21</b>	Cyclone Protection Project II	
File: family: n86 name : skhe4 User: mnr Mon Dec 17 1990	November 1986 Khepupara Measurements	Dwg. No.  4.196

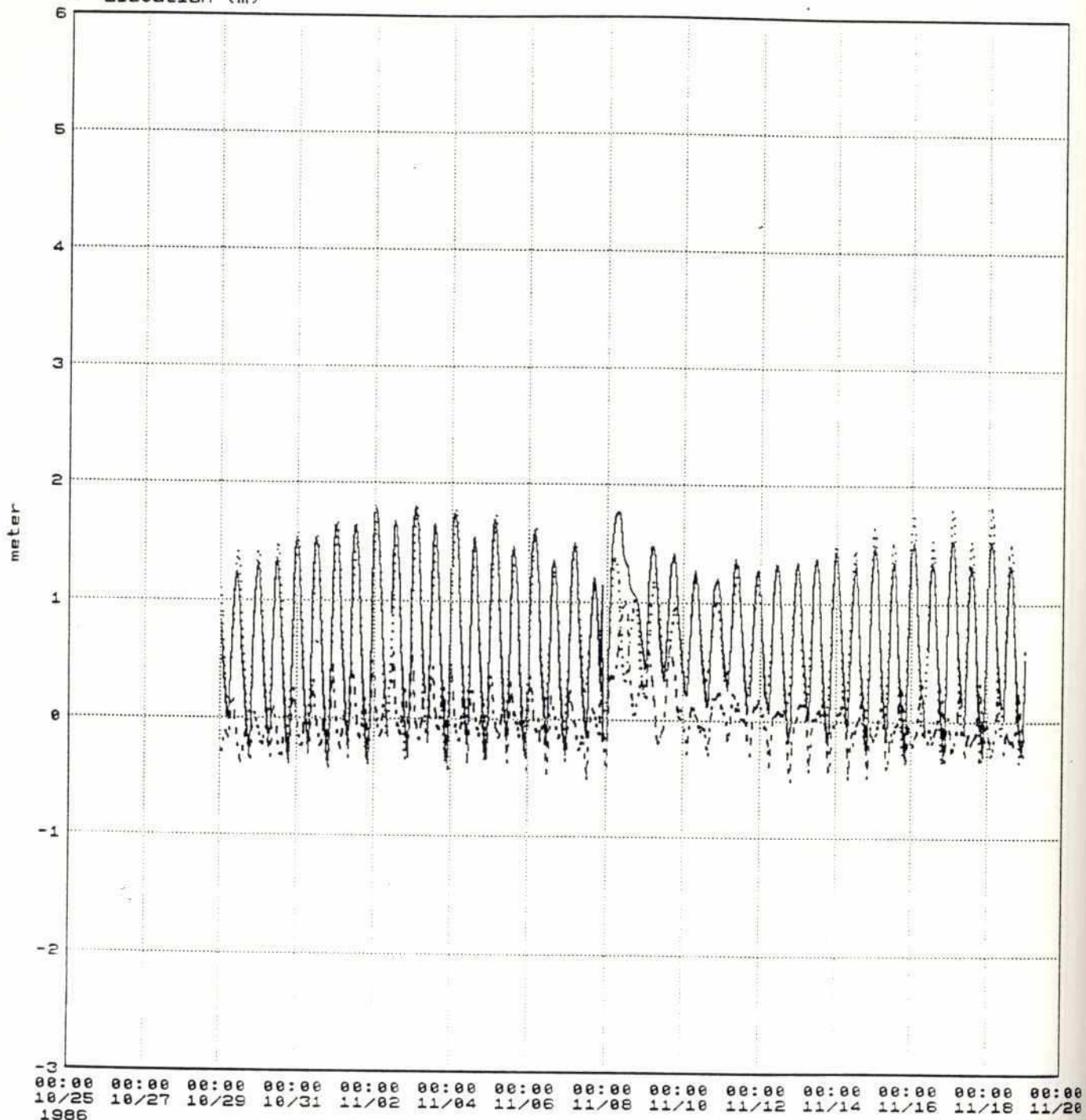




MIKE21	Cyclone Protection Project II	
File: family: n86 name : smon4 User: mnr Mon Dec 17 1998	November 1986 Mongia Measurements	Dwg. No.  4.197

270

-- Surge  
 ... Pred. Tidal Eleo.  
 — Elevation (m)

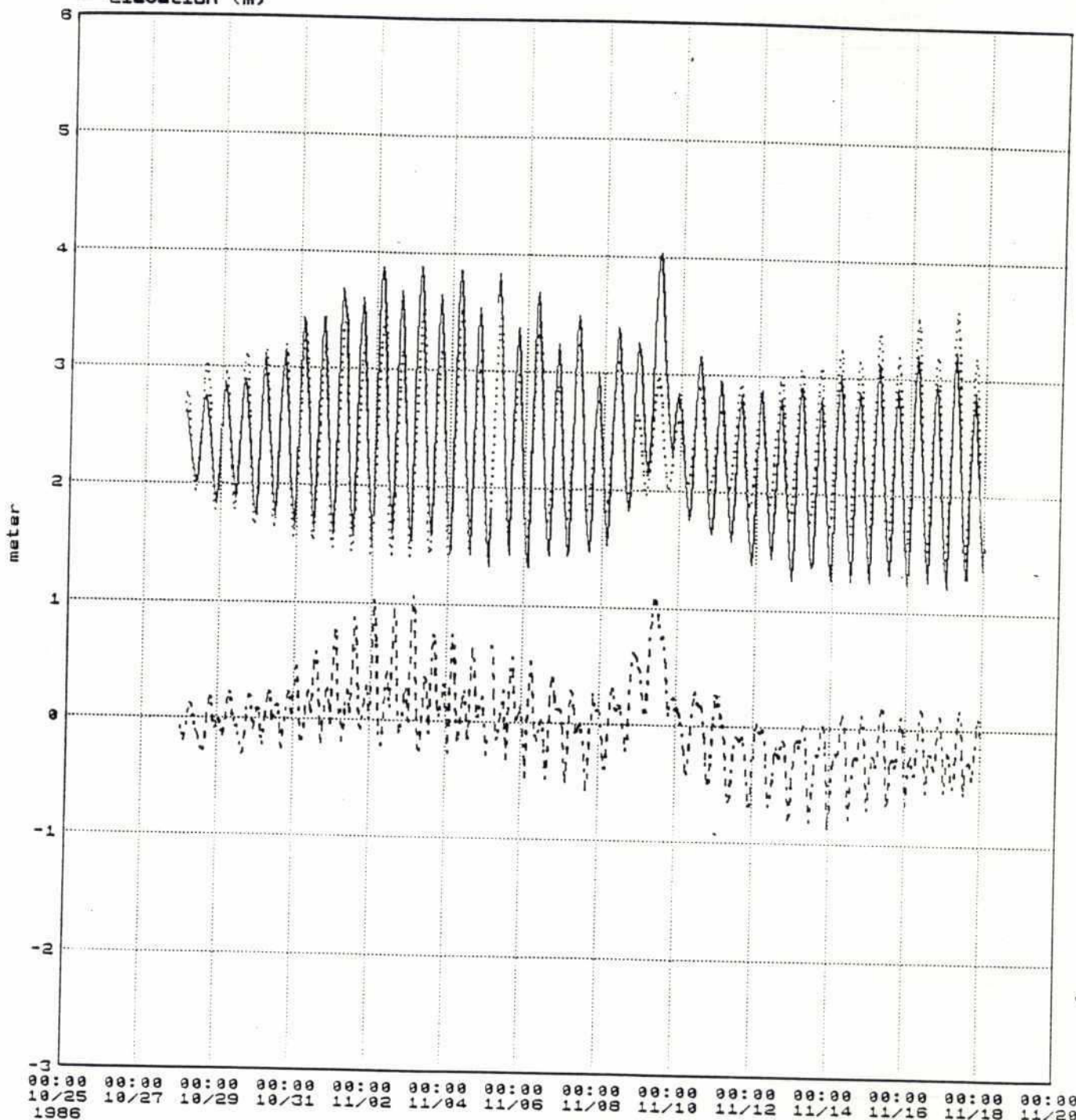


MIKE21	Cyclone Protection Project II	
File: family: n86 name : spat4 User: mnr Mon Dec 17 1990	November 1986 Patuakhali Measurements	Dwg. No.  4.198



280

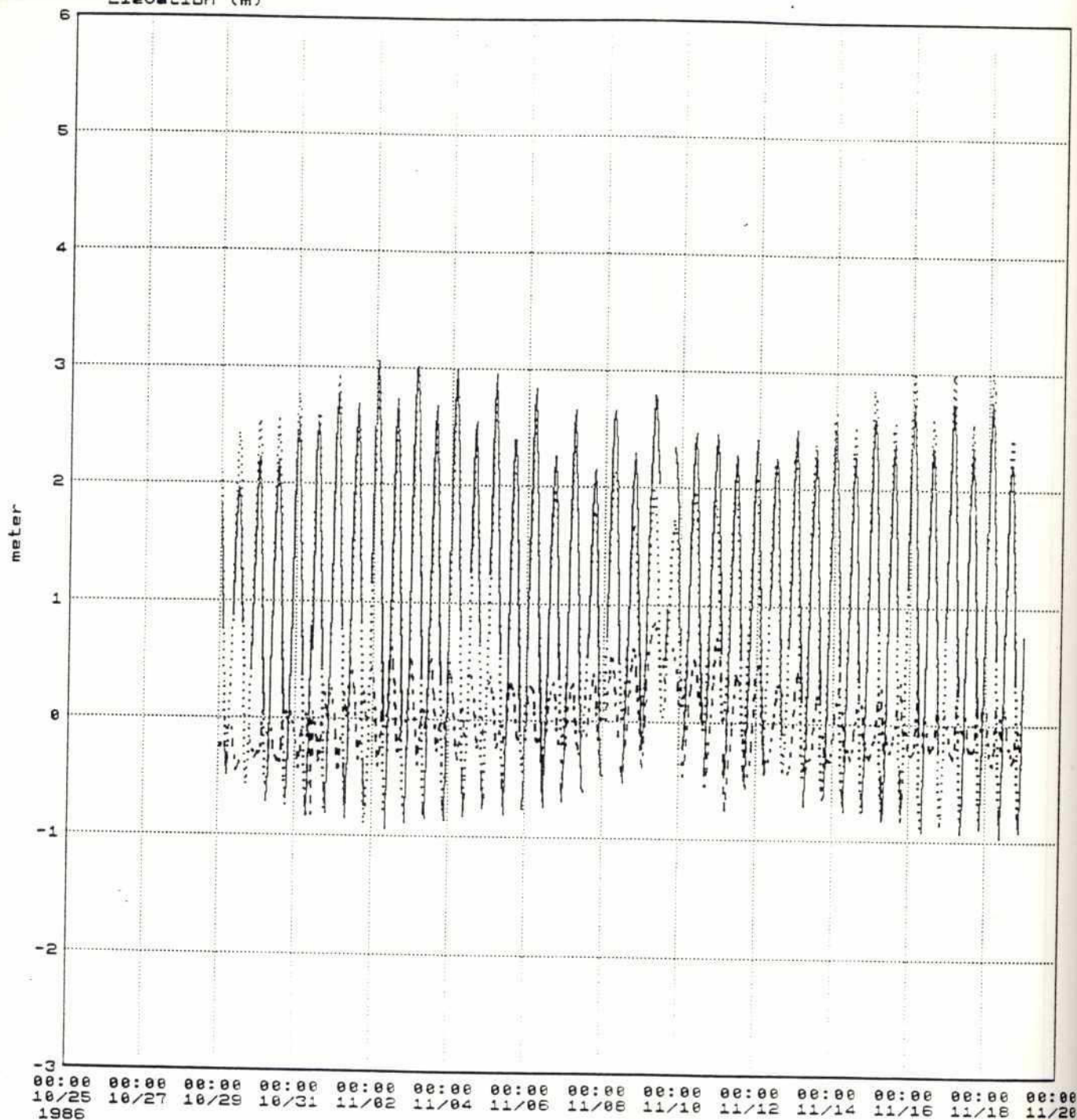
-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n86 name : sram4 User: mnr Mon Dec 17 1990	November 1986 Ramdaspur Measurements	Dwg. No.  4.199

24

-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)

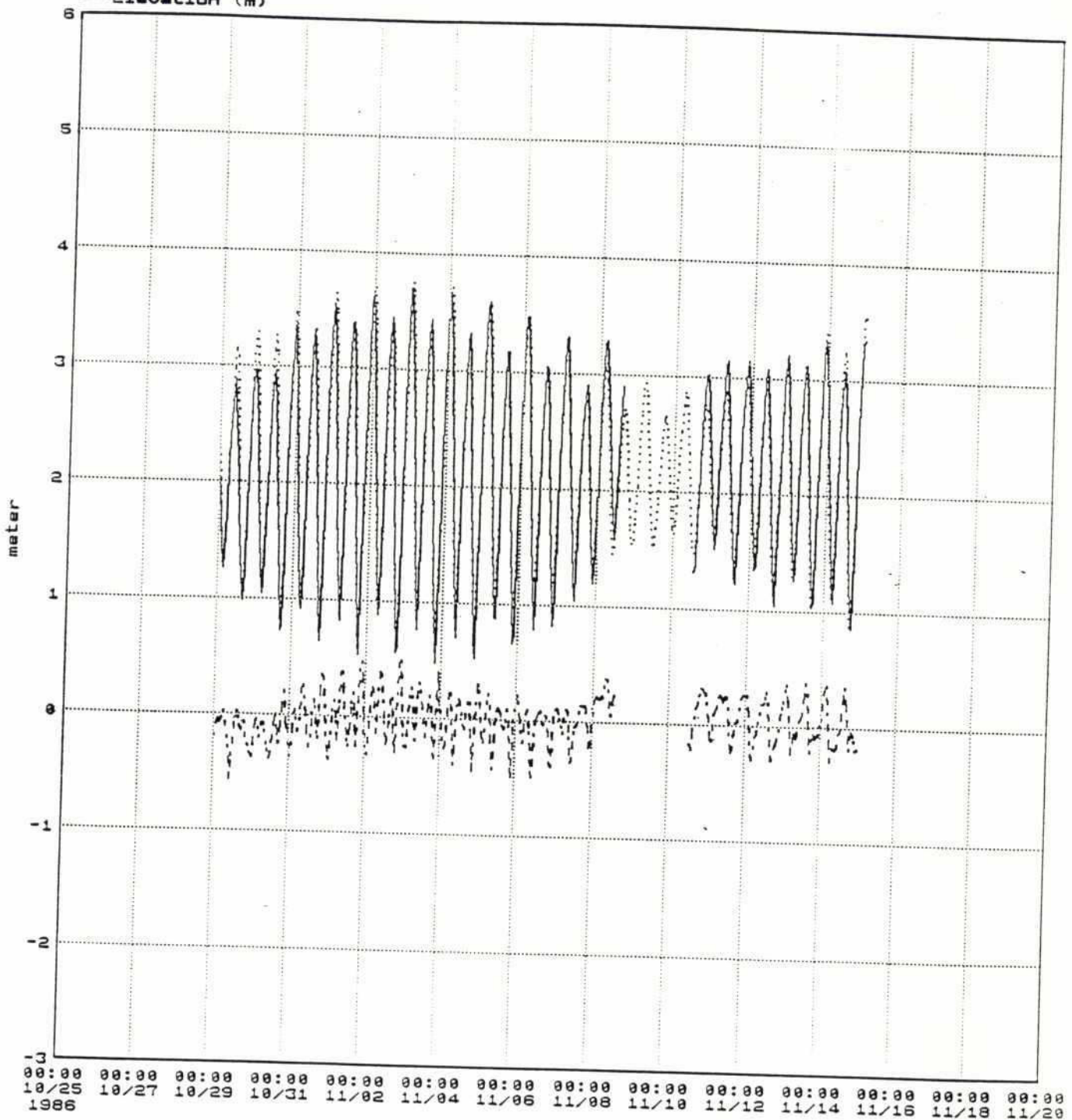


<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n86 name : ssad4 User: mnr Mon Dec 17 1996	November 1986 Sadarghat (CTG) Measurements	Dwg. No.  4.200



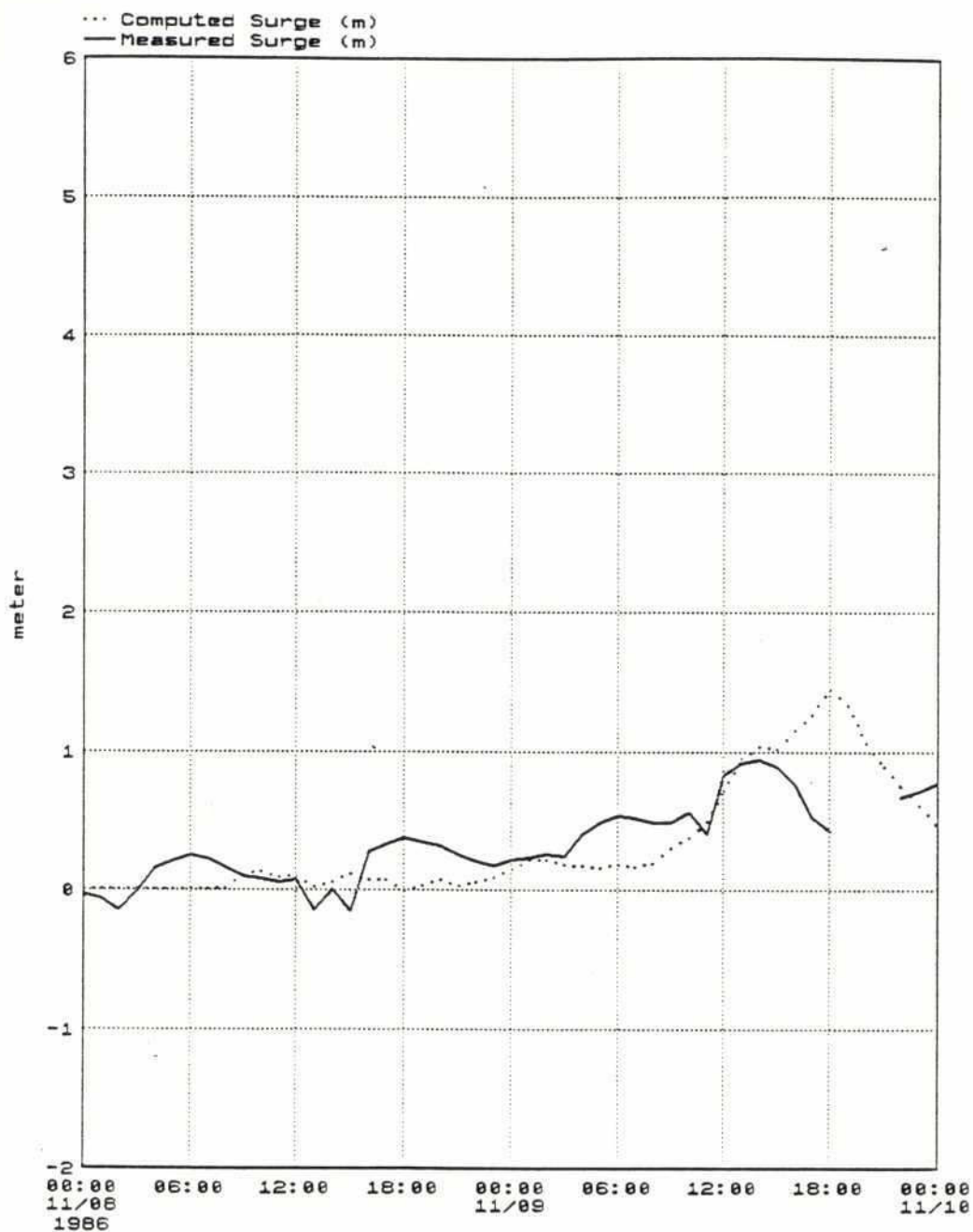
260  
15

-- Surge  
... Pred. Tidal Elev.  
— Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n86 name : ssun4 User: mnr Mon Dec 17 1990	November 1986 Sundarikota Measurements	Dwg. No.  4.201

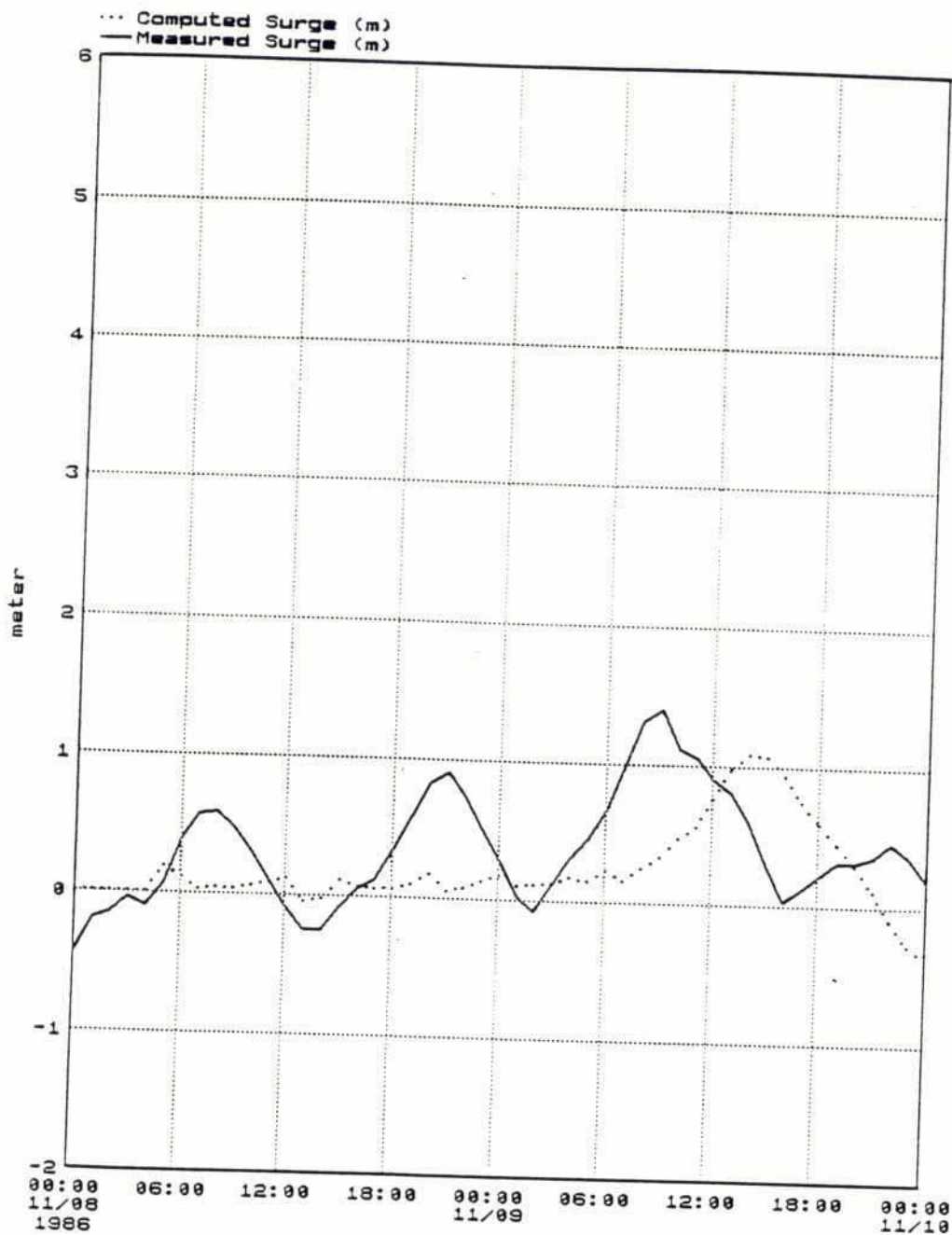
288



<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: n86 name : cbar4 User: mnr Mon Dec 17 1990</p>	<p>November 1986 Barisal Measured and computed surge</p>	<p>Dwg. No.  4.202</p>

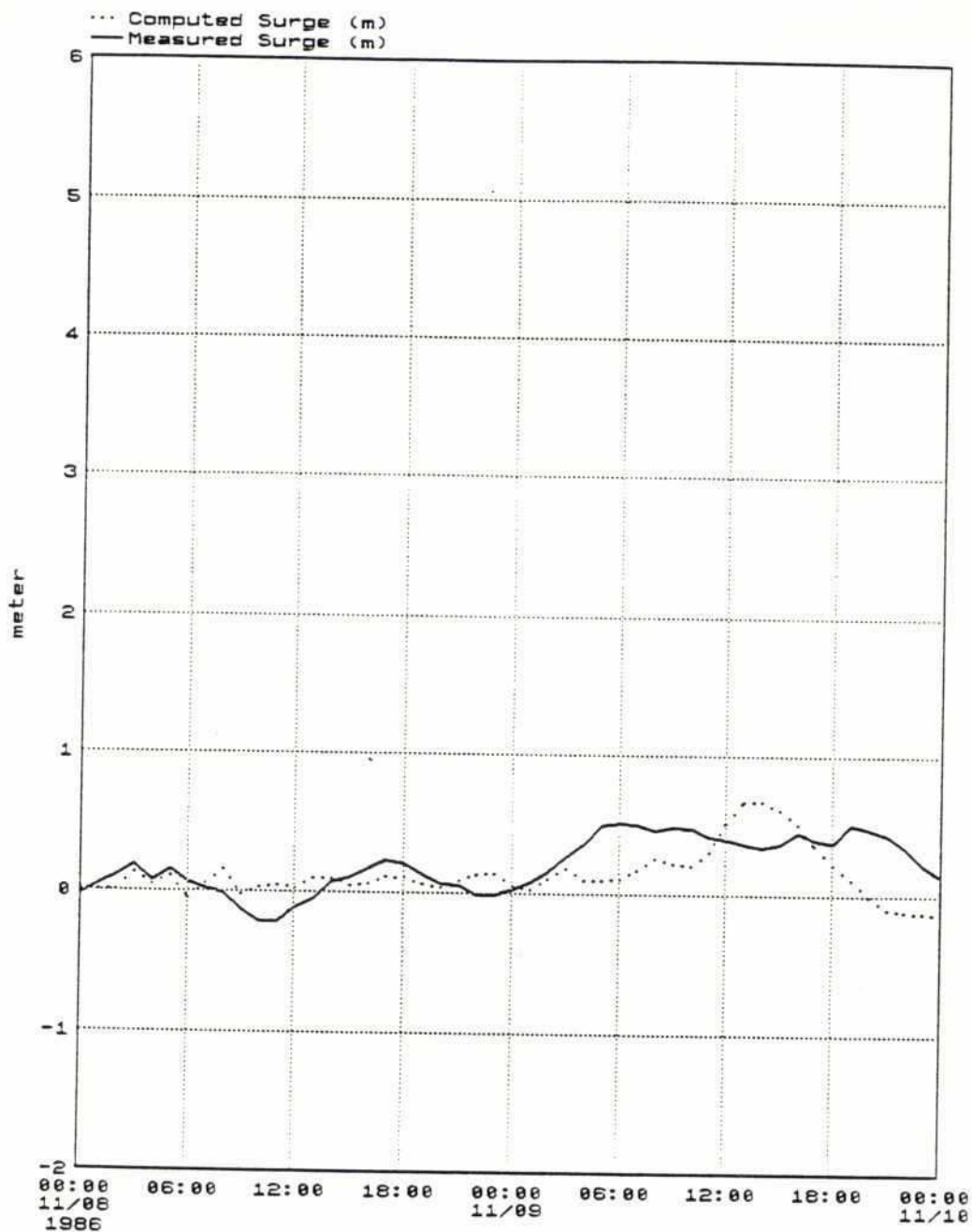


262



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n86 name : cchr4 User: mnr Mon Dec 17 1990	November 1986 Char-Chenga Measured and computed surge	Dwg. No.  4.203

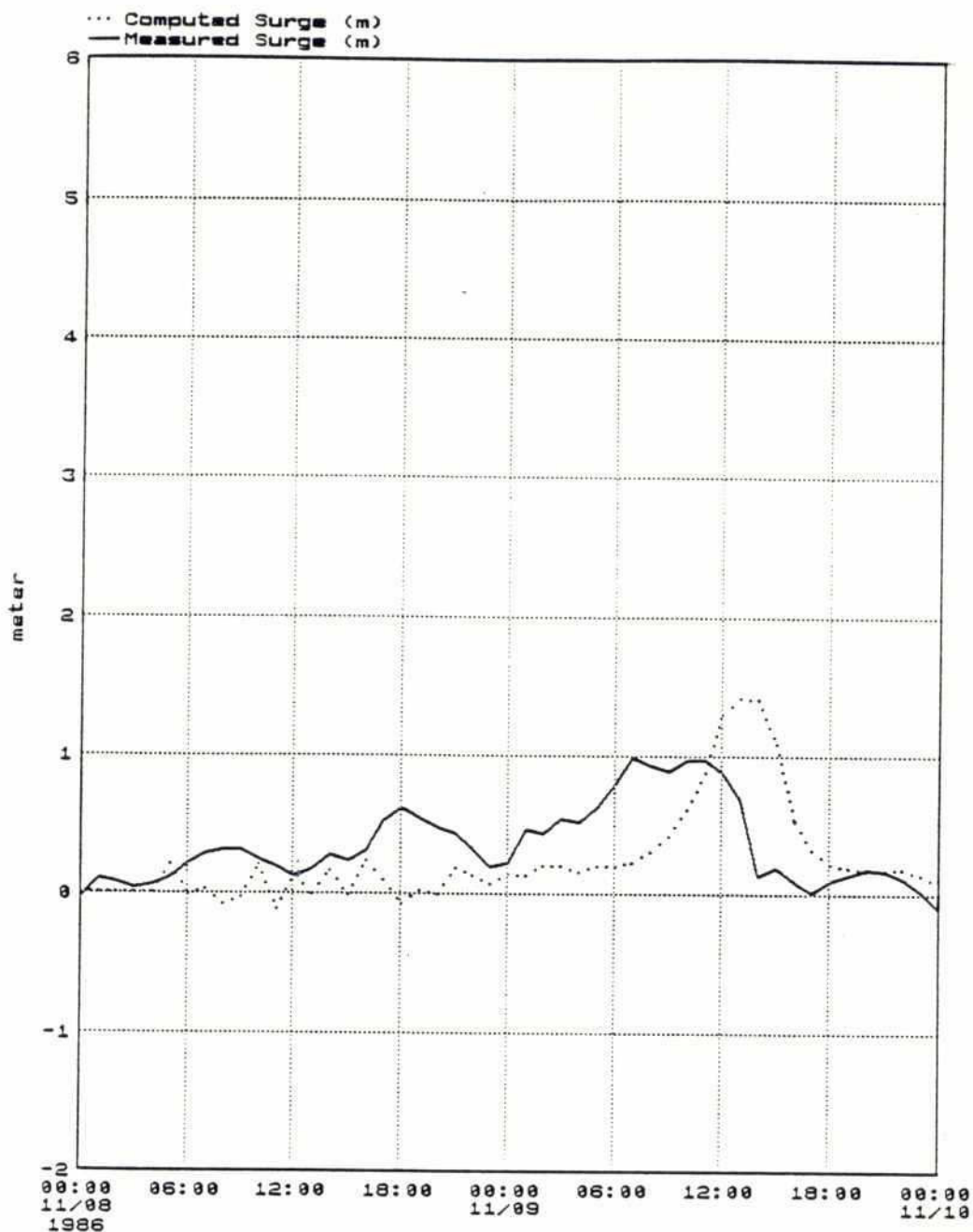
213



<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: n86 name : ccox4 User: mnr Mon Dec 17 1998</p>	<p>November 1986 Coxs Bazar Measured and computed surge</p>	<p>Dwg. No.  4.204</p>

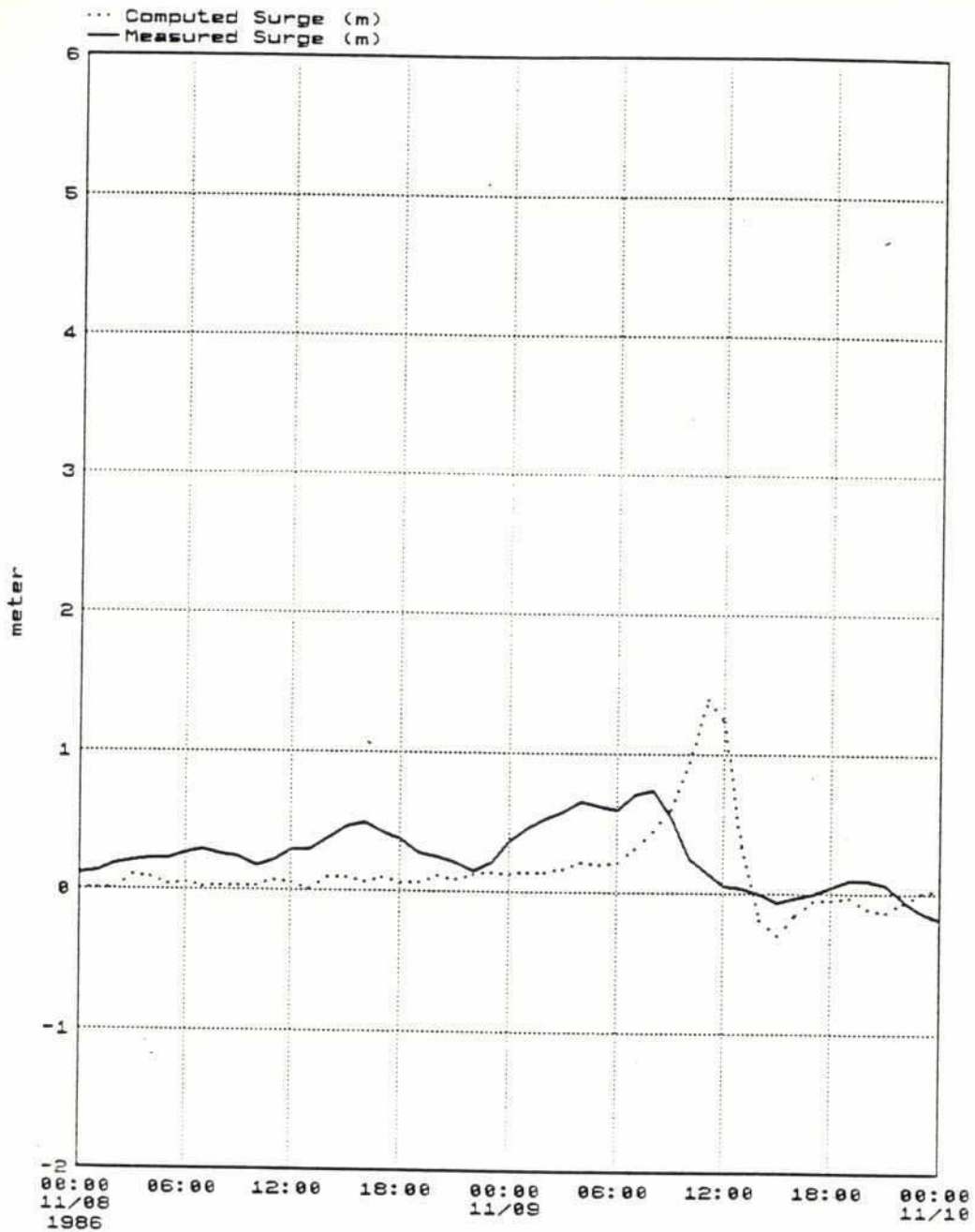


269



MIKE21	Cyclone Protection Project II	
File: family: n86 name : cgal4 User: mnr Mon Dec 17 1990	November 1986 Galachipa Measured and computed surge	Dwg. No.  4.205

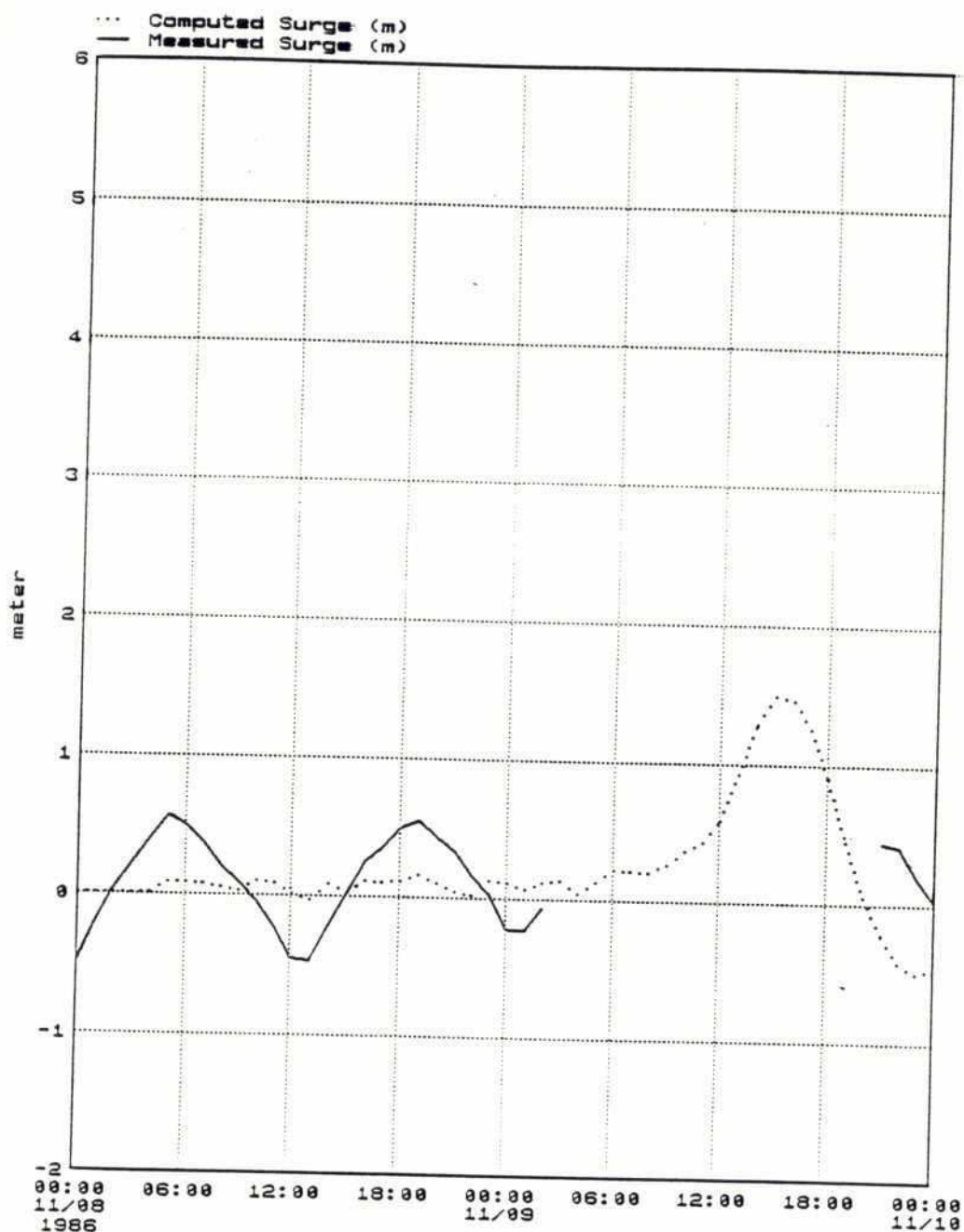
218



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n86 name : chir4 User: mnr Mon Dec 17 1990	November 1986 Hiron Point Measured and computed surge	Dwg. No.  4.206

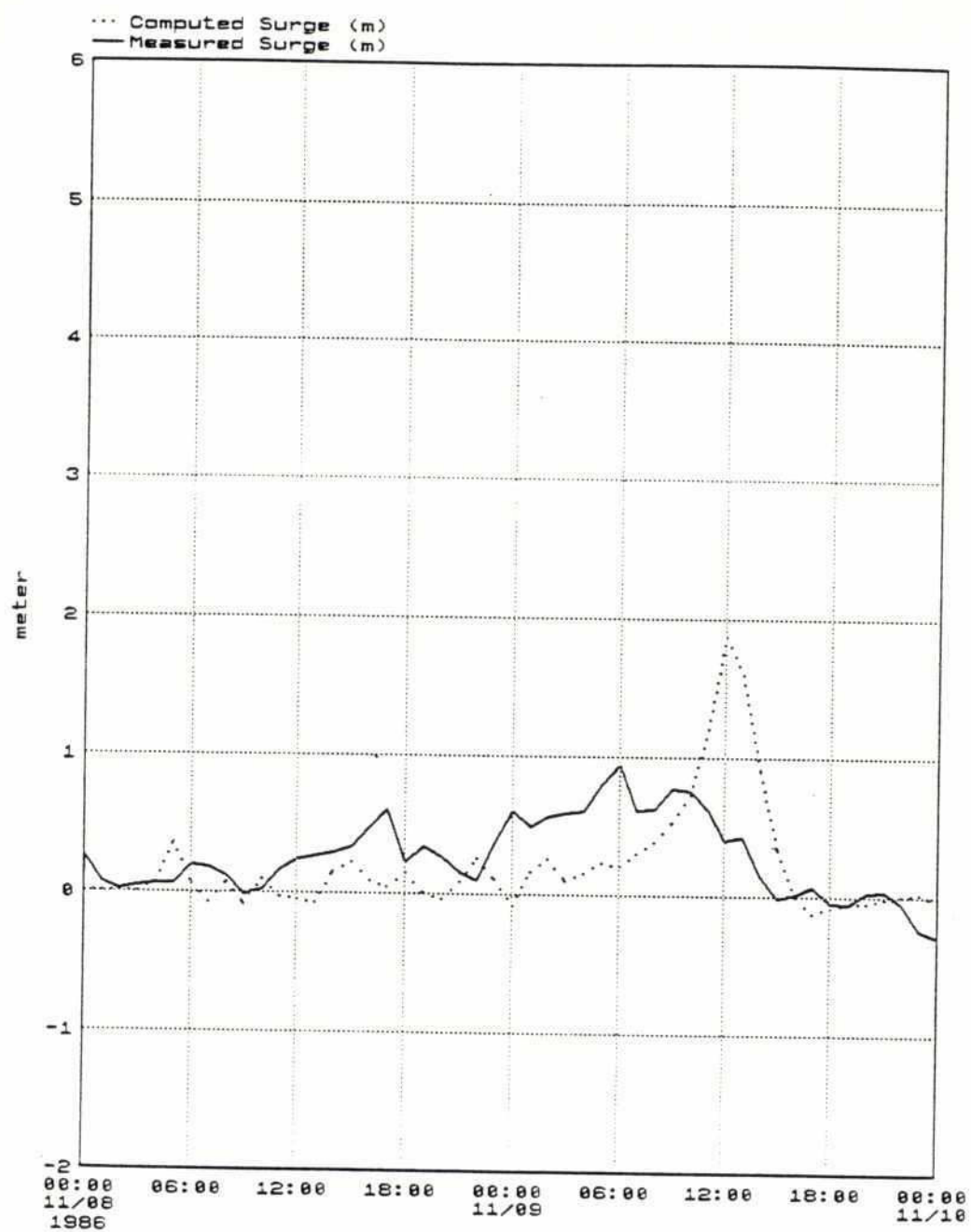


217



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n86 name : ckha4 User: mnr Mon Dec 17 1990	November 1986 Khal No. 10 Measured and computed surge	Dwg. No.  4.207

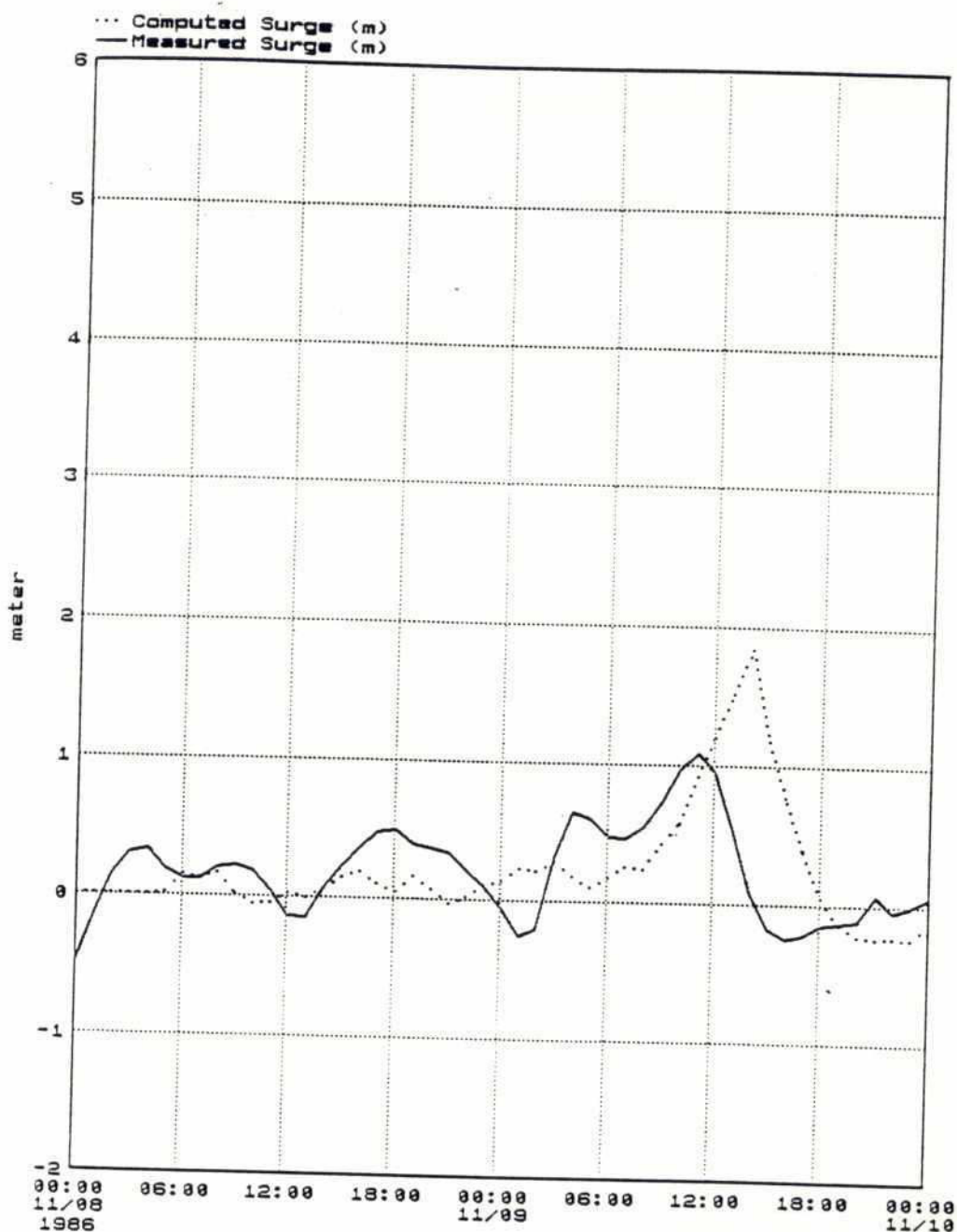
220



<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: n86 name : ckhe4 User: mnr Mon Dec 17 1998</p>	<p>November 1986 Khepupara Measured and computed surge</p>	<p>Dwg. No.  4.208</p>

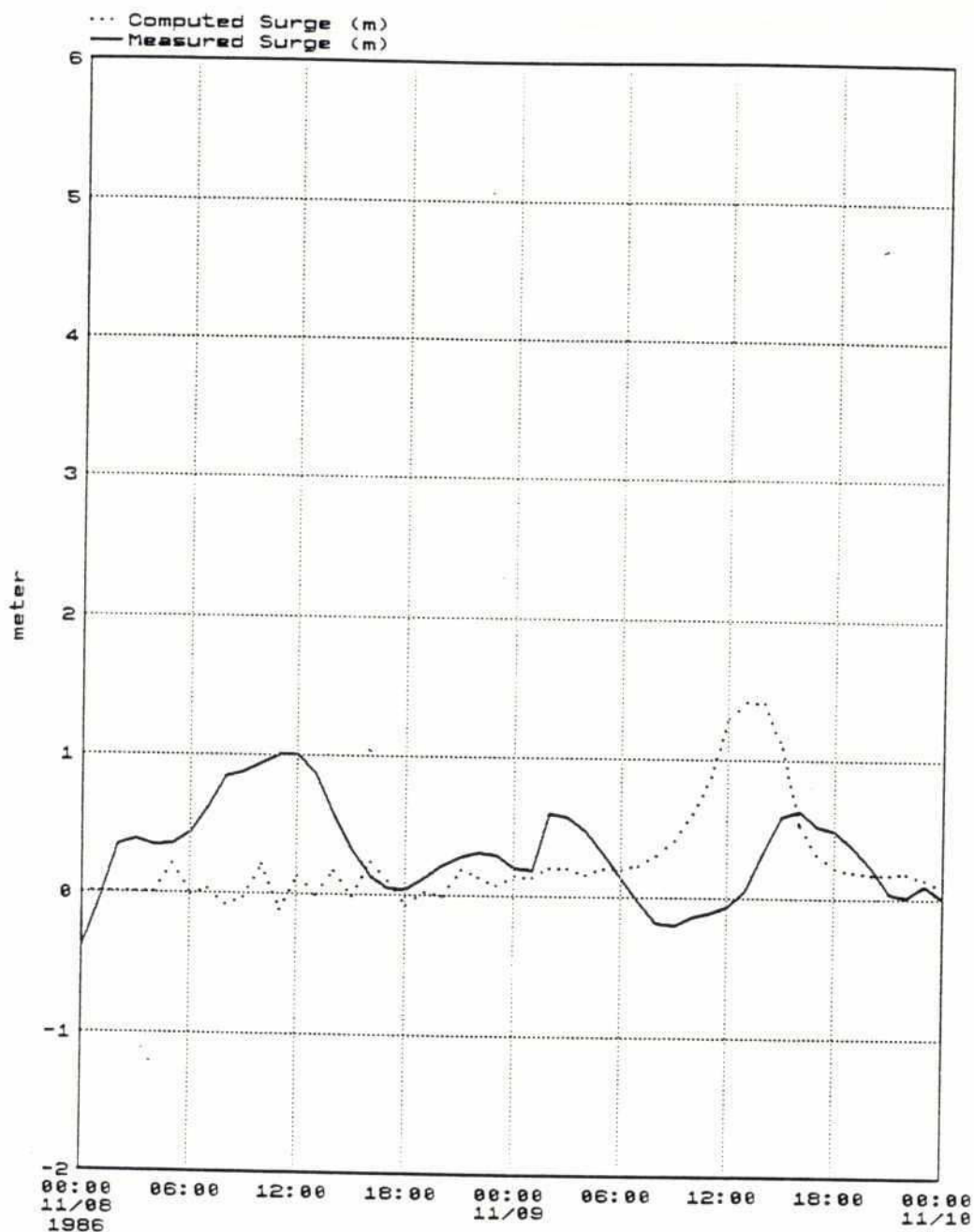


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<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: n86 name : cmon4 User: mnr Mon Dec 17 1998</p>	<p>November 1986 Mongla Measured and computed surge</p>	<p>Dwg. No.  4.209</p>

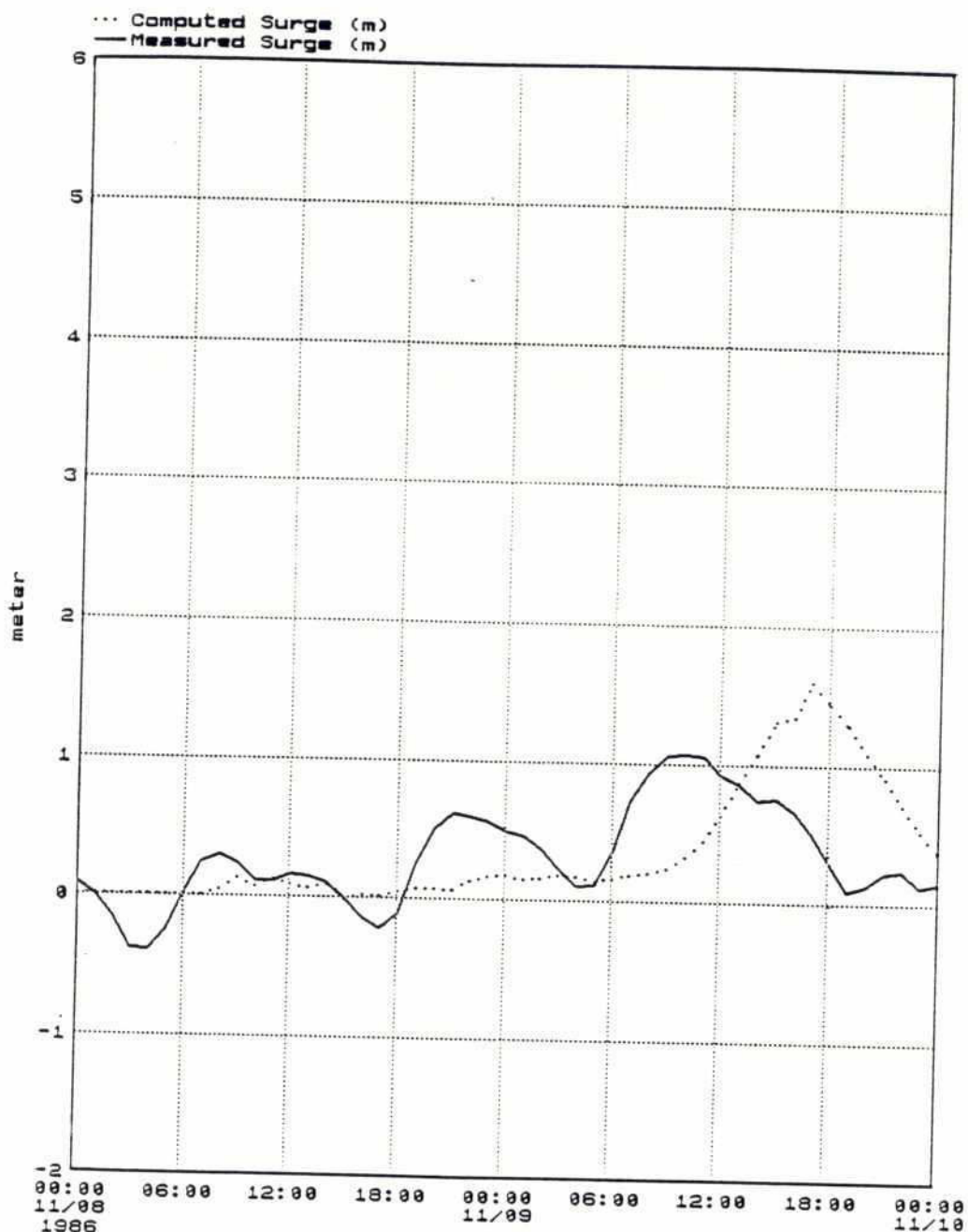
202



<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: n86 name : cpat4 User: mnr Mon Dec 17 1990</p>	<p>November 1986 Patuakhali Measured and computed surge</p>	<p>Dwg. No.  4.210</p>

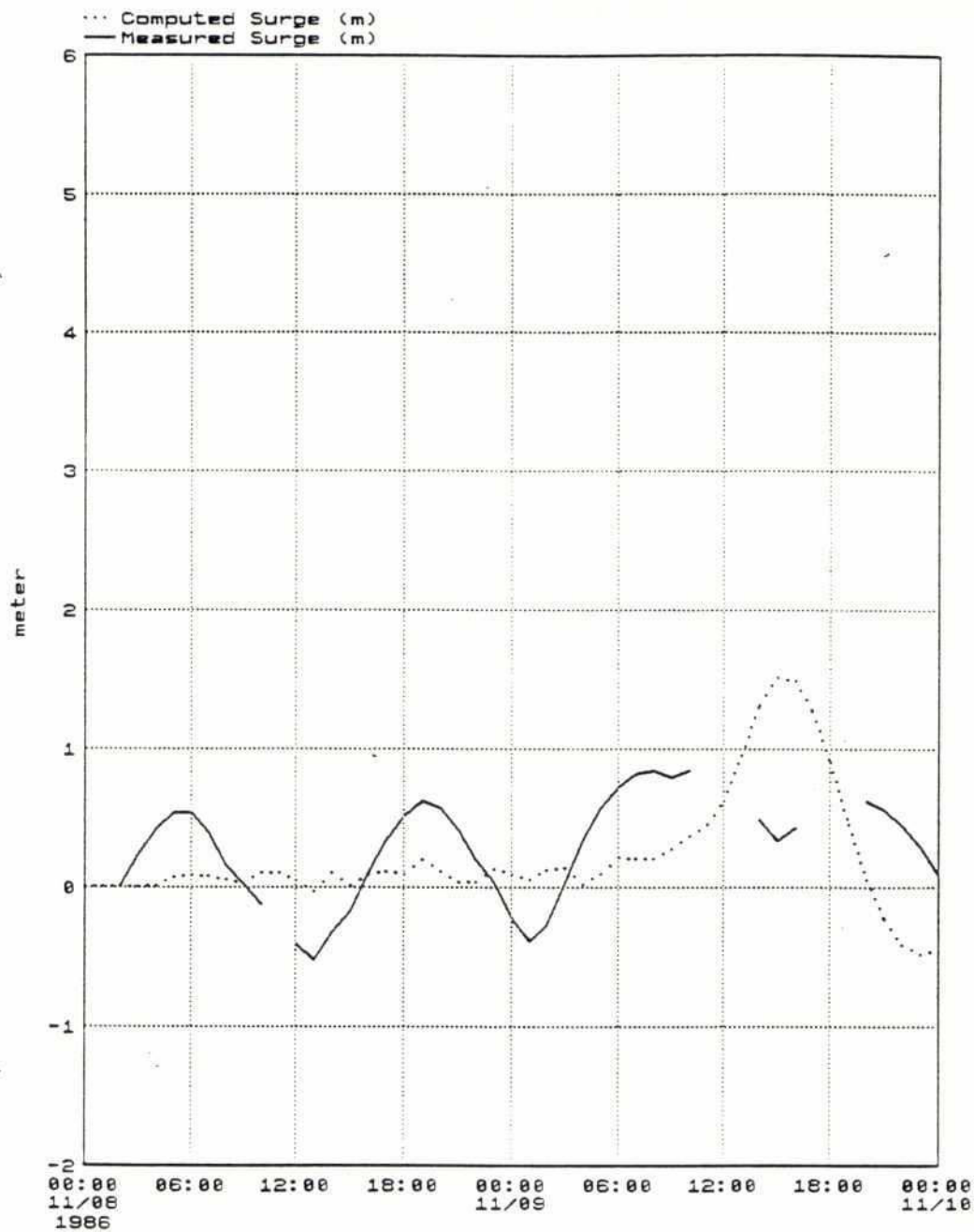


920



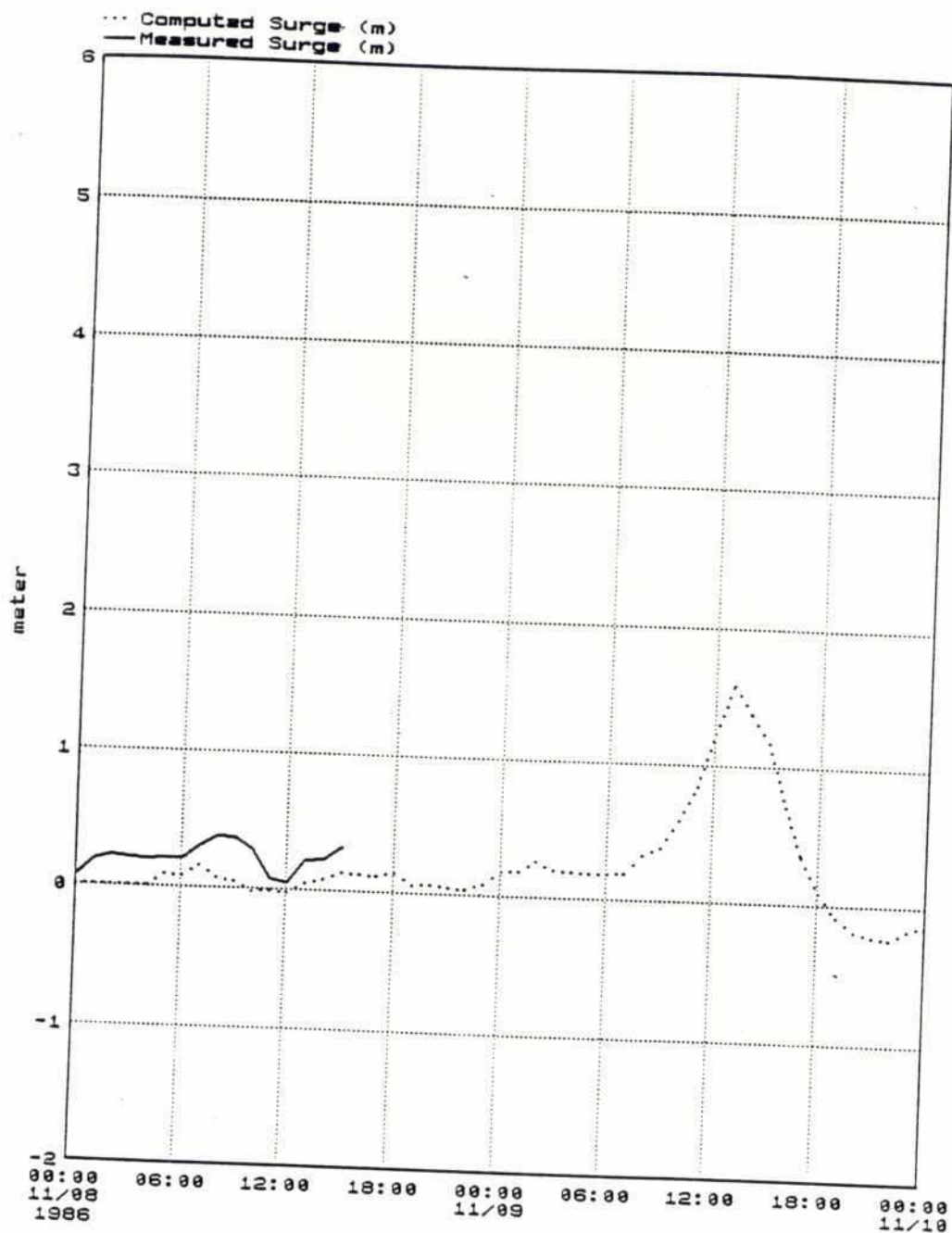
<b>MIKE21</b>	Cyclone Protection Project II	
File: family: n86 name : cram4 User: mnr Mon Dec 17 1990	November 1986 Ramdaspur Measured and computed surge	Dwg. No.  4.211

228



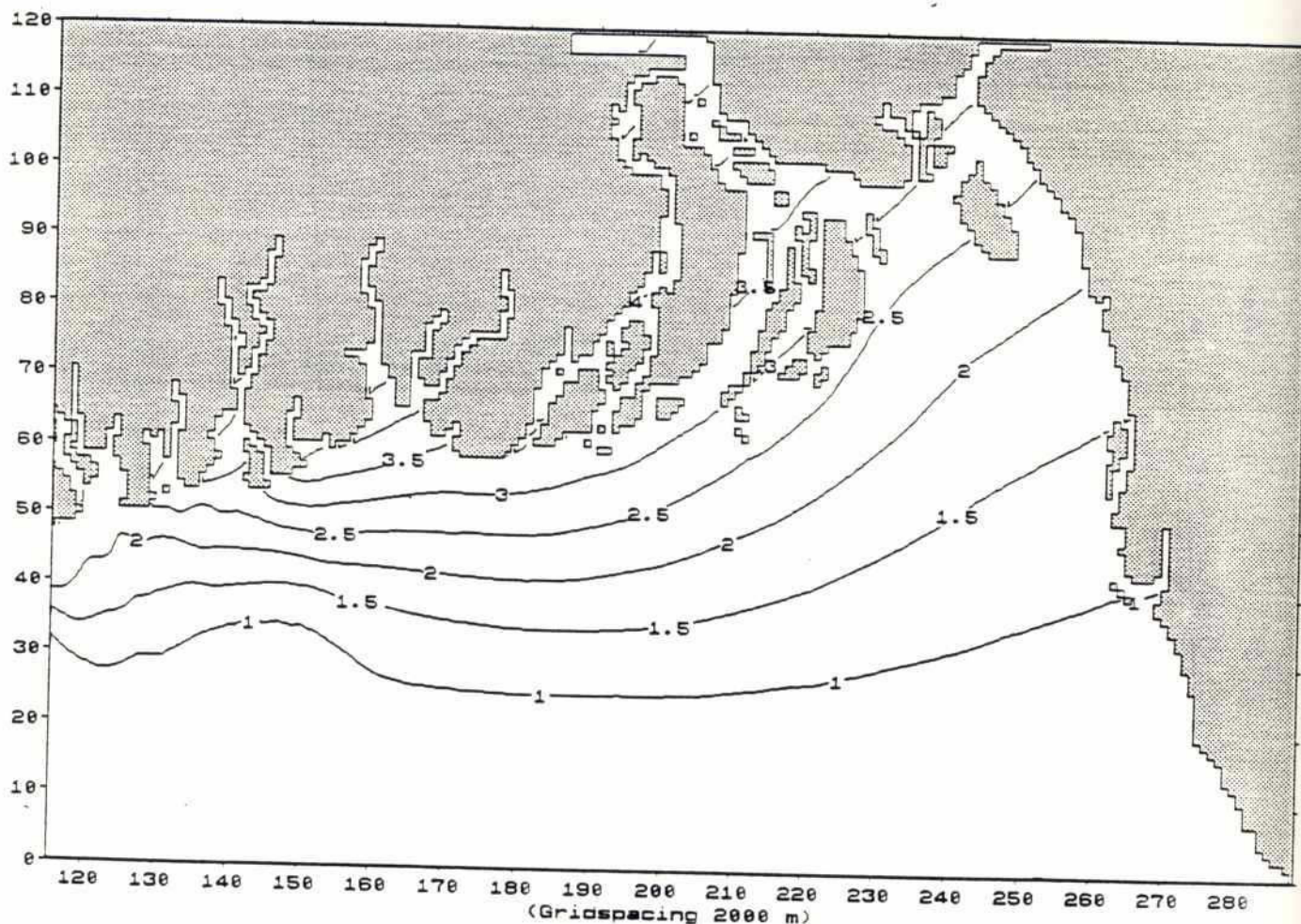
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n86 name : csad4 User: mnr Mon Dec 17 1990	November 1986 Sadarghat (CTG) Measured and computed surge	Dwg. No.  4.212





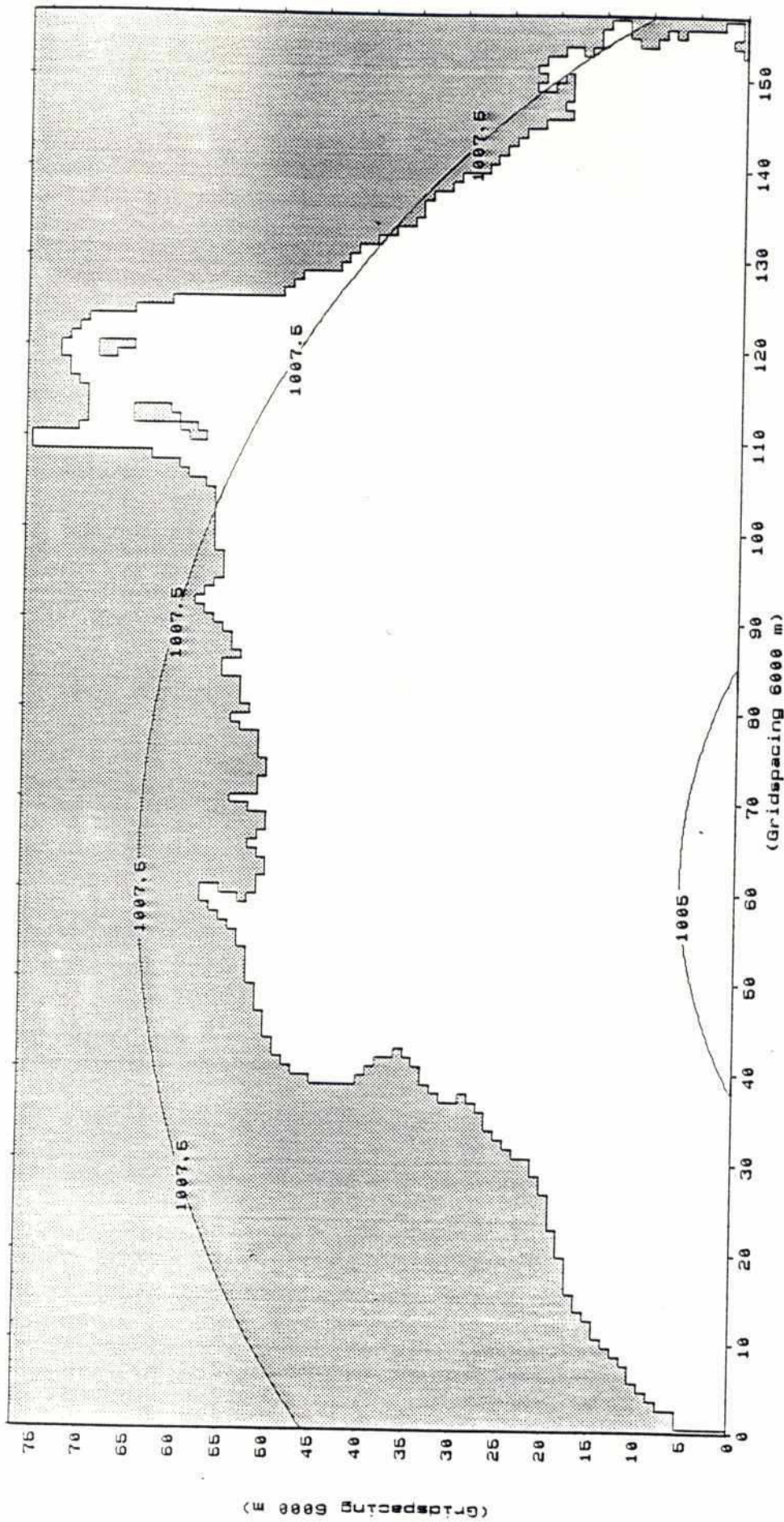
MIKE21	Cyclone Protection Project II	
File: family: n86 name : csun4 User: mnr Mon Dec 17 1998	November 1986 Sunderikota Measured and computed surge	Dwg. No.  4.213

224



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n88 name : imax Scale: 1:2 mill Sun Nov 25 1990	November 1988 Cyclone Simulation Results, Intermediate Model Maximum Surge Levels	Dwg. No.  4.214





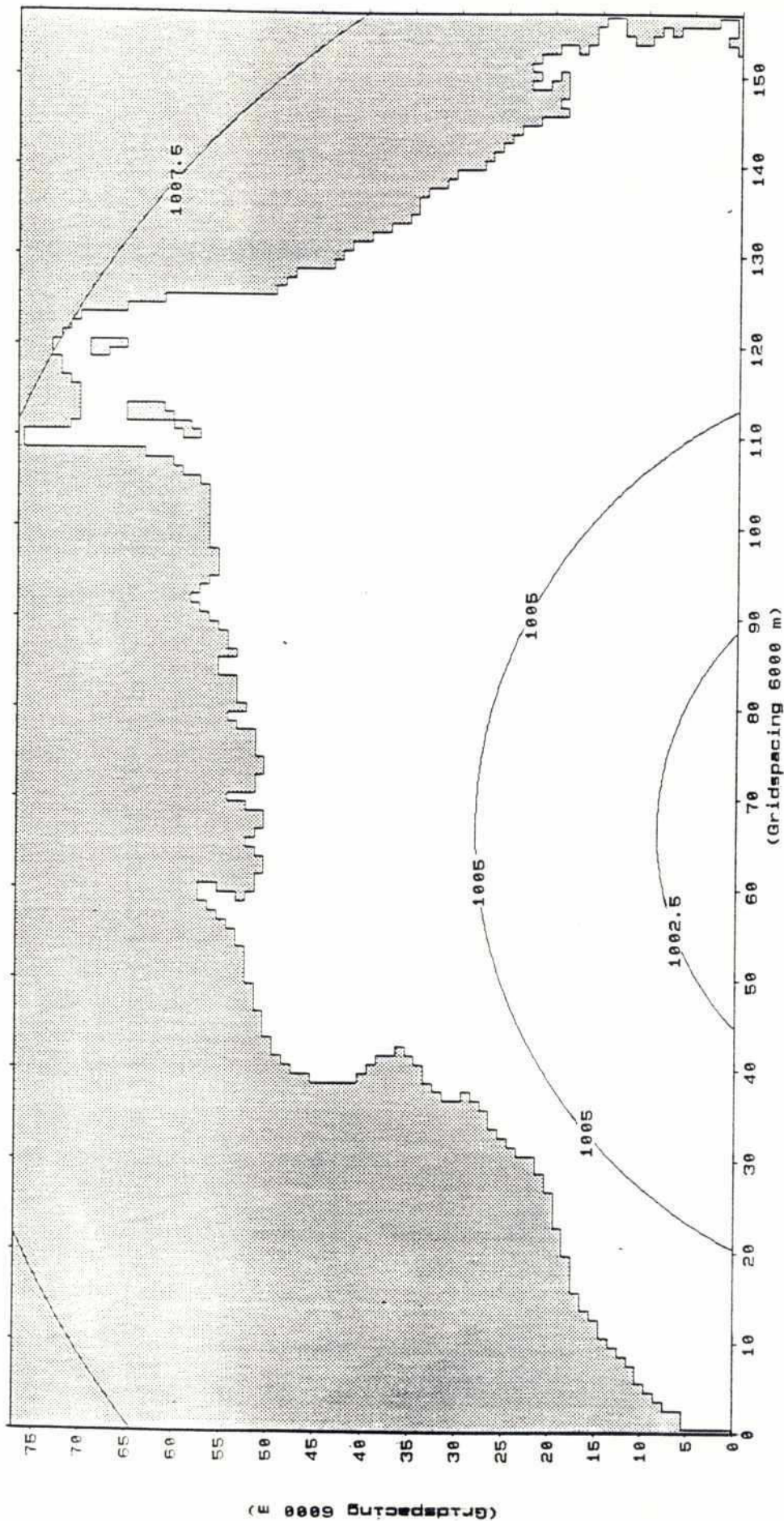
1988/11/28 12:00:00

<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n88 name : rwind Scale: 1:4 mill Mon Nov 26 1990	November 1988 Cyclone Pressure Field (mb)	
	Dwg. No.	4, 215

229



208



1988/11/29 00:00:00

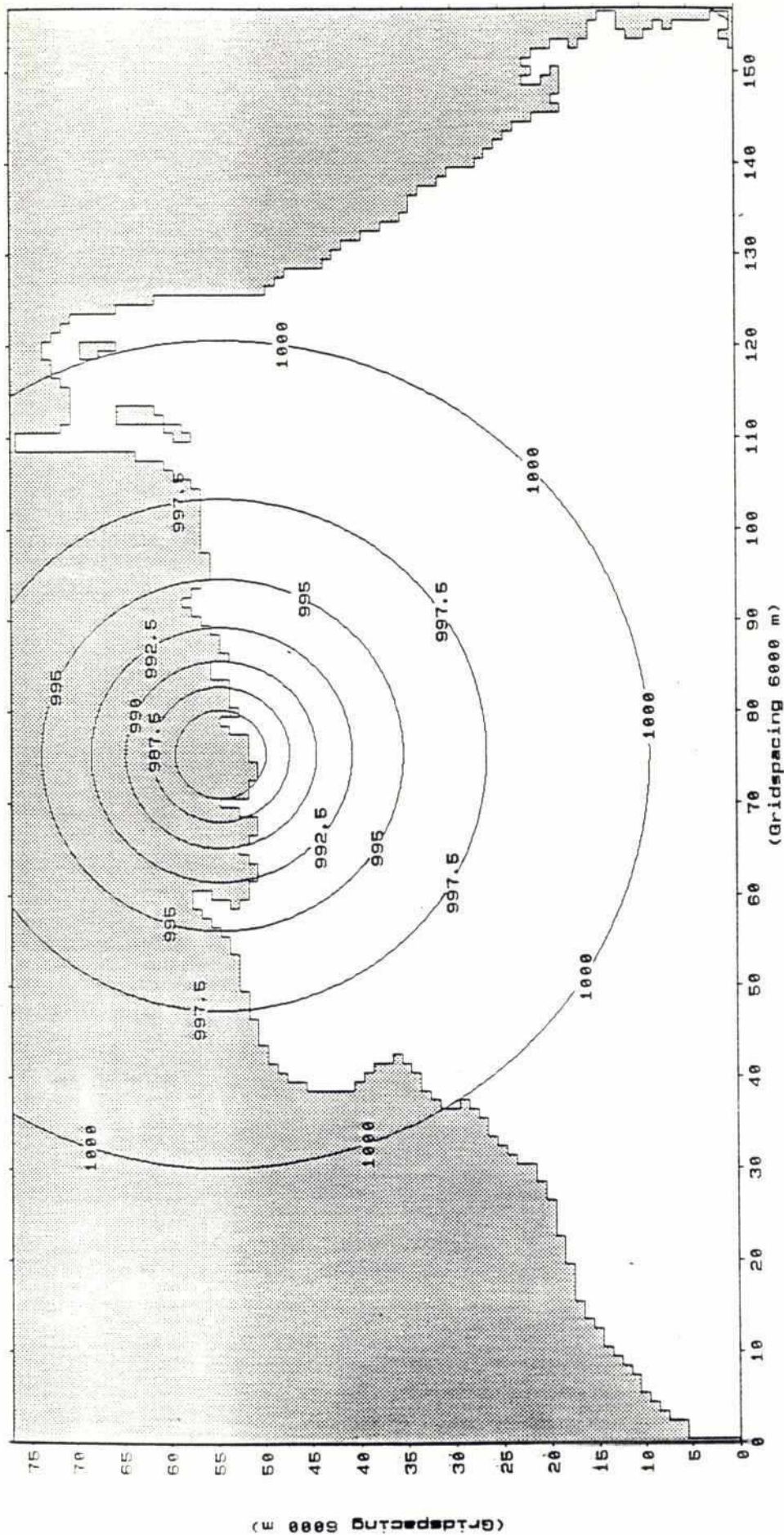
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n88 name : rwind Scale: 1:4 mill Mon Nov 26 1990	November 1988 Cyclone Pressure Field (mb)	
		Dwg. No.  4.216







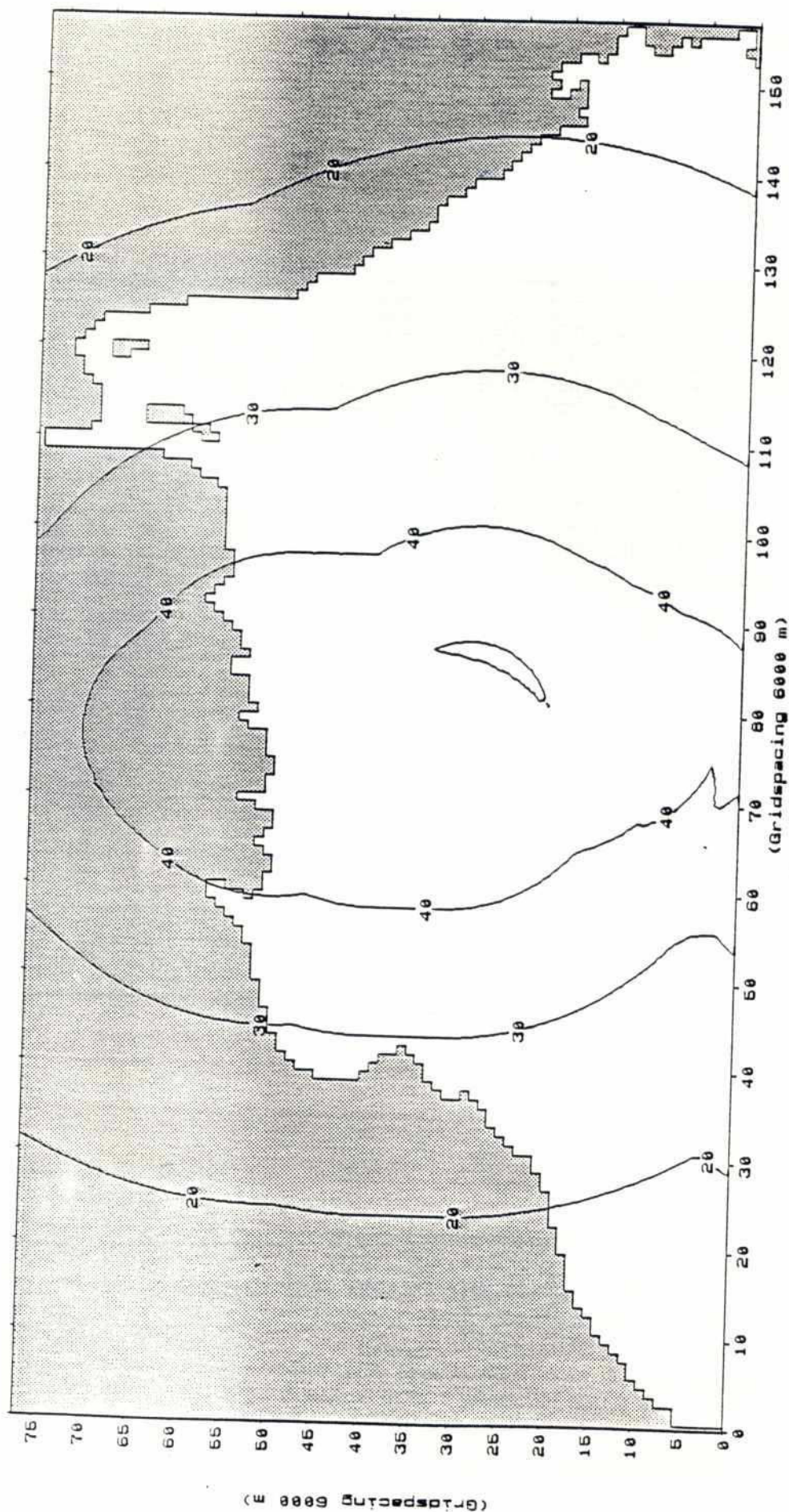
21000



1988/11/30 00:00:00

<p><b>MIKE21</b></p>	<p><b>Cyclone Protection Project II</b></p>	
<p>File: family: n88 name : rwind Scale: 1:4 mill Mon Nov 26 1990</p>	<p>November 1988 Cyclone Pressure Field (mb)</p>	<p>Dwg. No.  4.218</p>



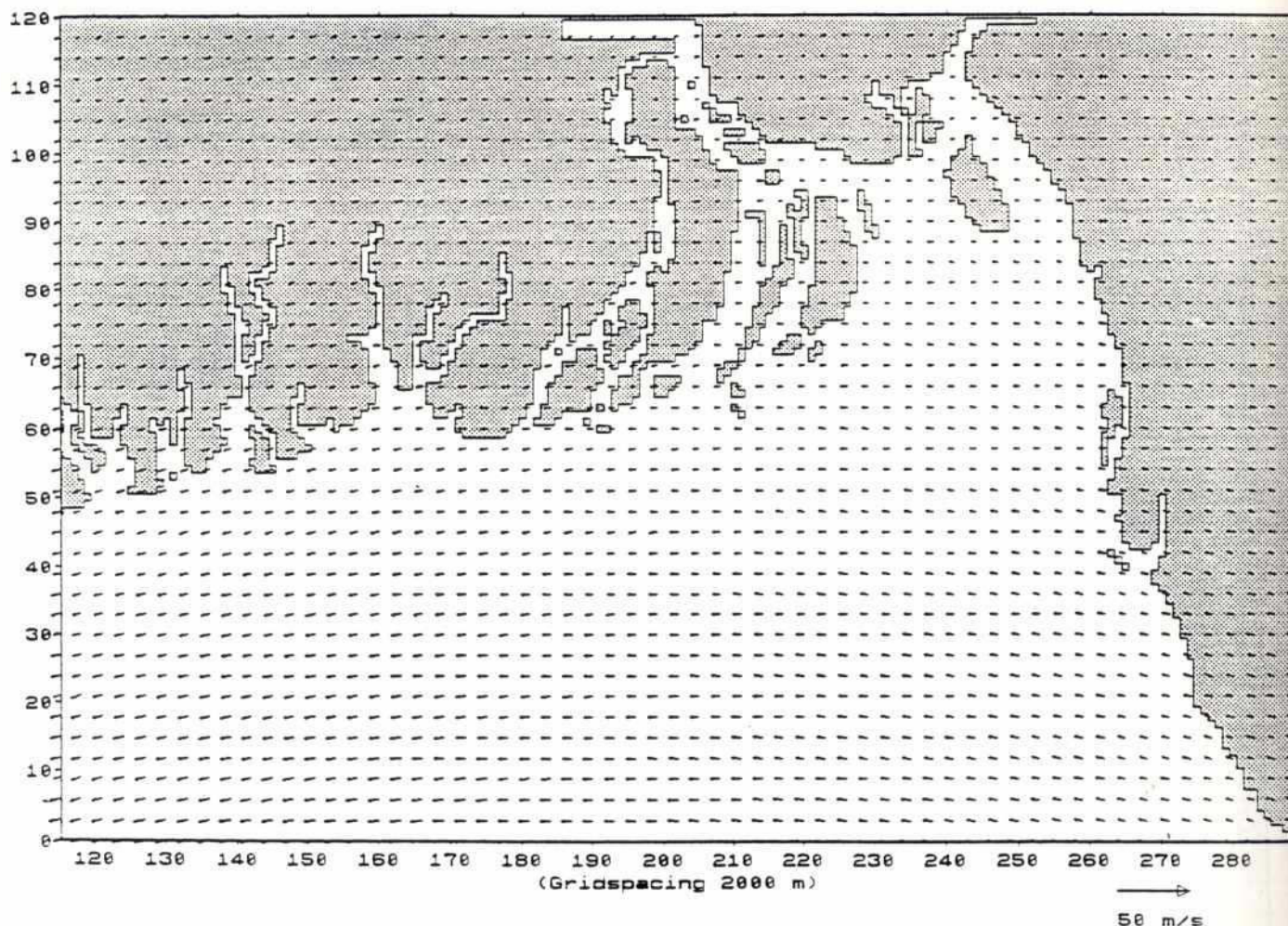


<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n88 name : rmwind Scale: 1:4 mill Sun Nov 25 1990	November 1988 Maximum occurring Wind Speed (m/s)	
	Dwg. No.	4.219

002



602

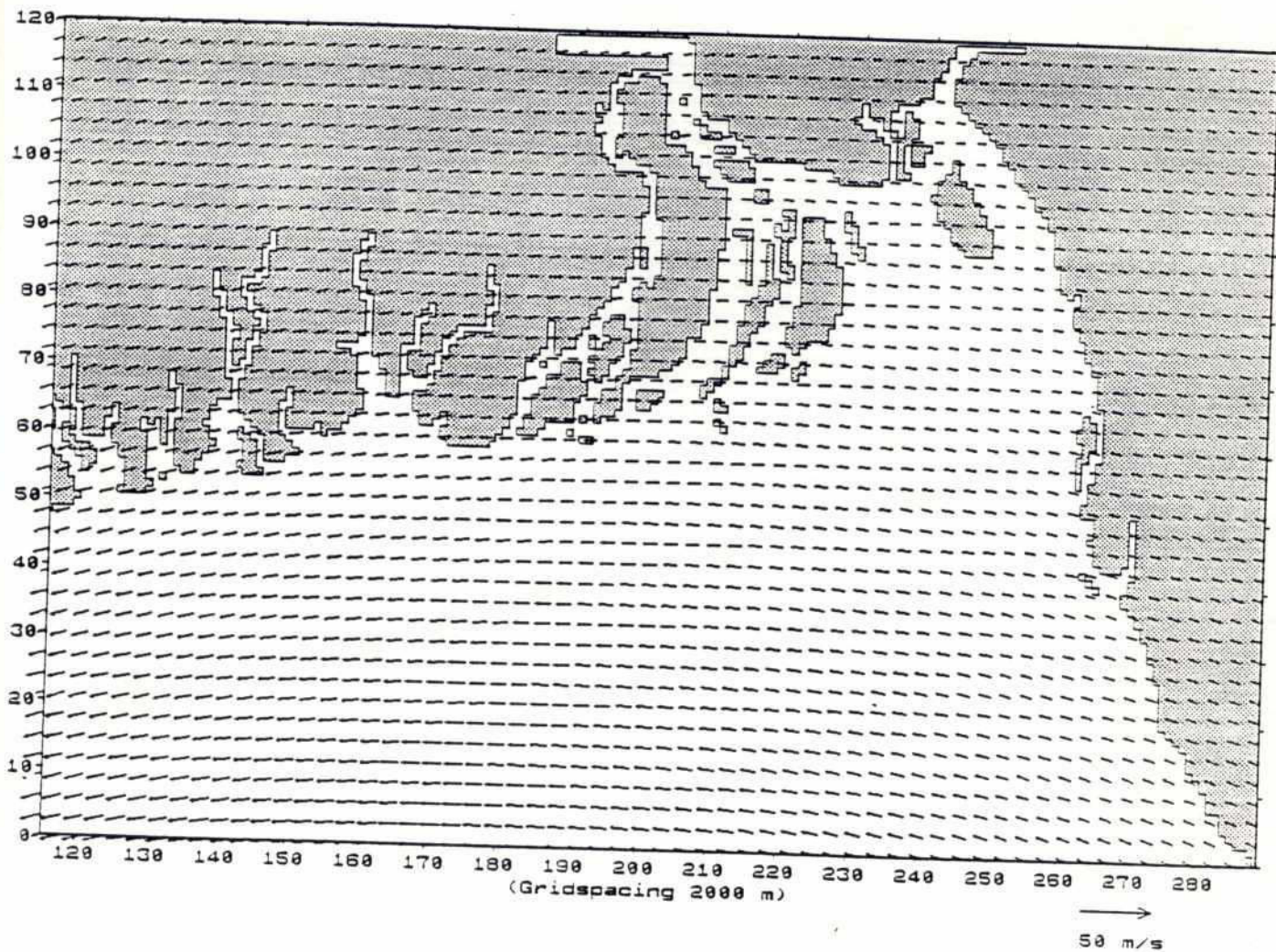


1988/11/28 12:00:00

MIKE21	Cyclone Protection Project II	
File: family: n88 name : iwind Scale: 1:2 mill Sun Nov 25 1990	November 1988 Cyclone Wind Field	Dwg. No.  4.220



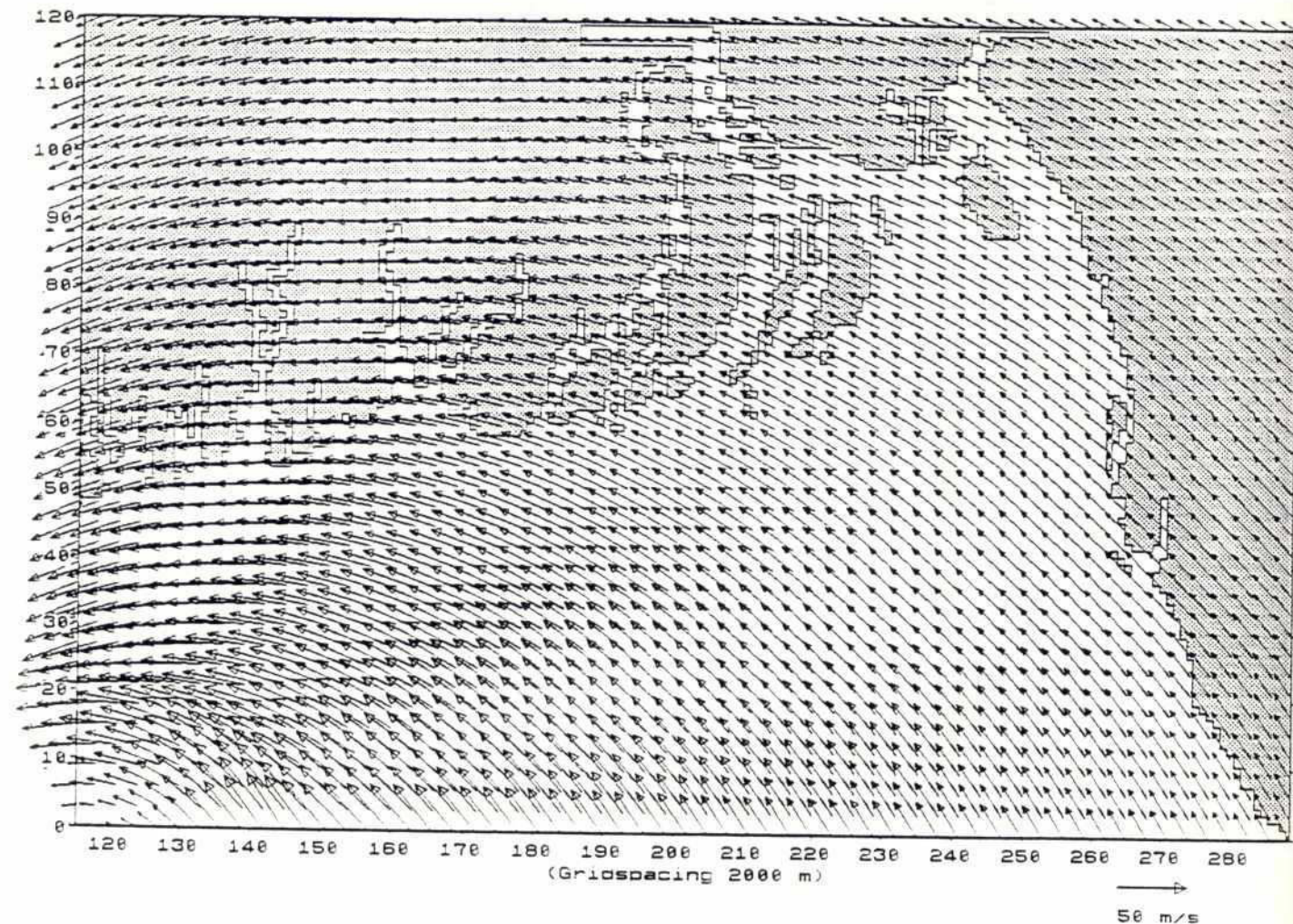
1006



1988/11/29 00:00:00

<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n88 name : iwind Scale: 1:2 mill Sun Nov 25 1990	November 1988 Cyclone Wind Field	Dwg. No.  4.221

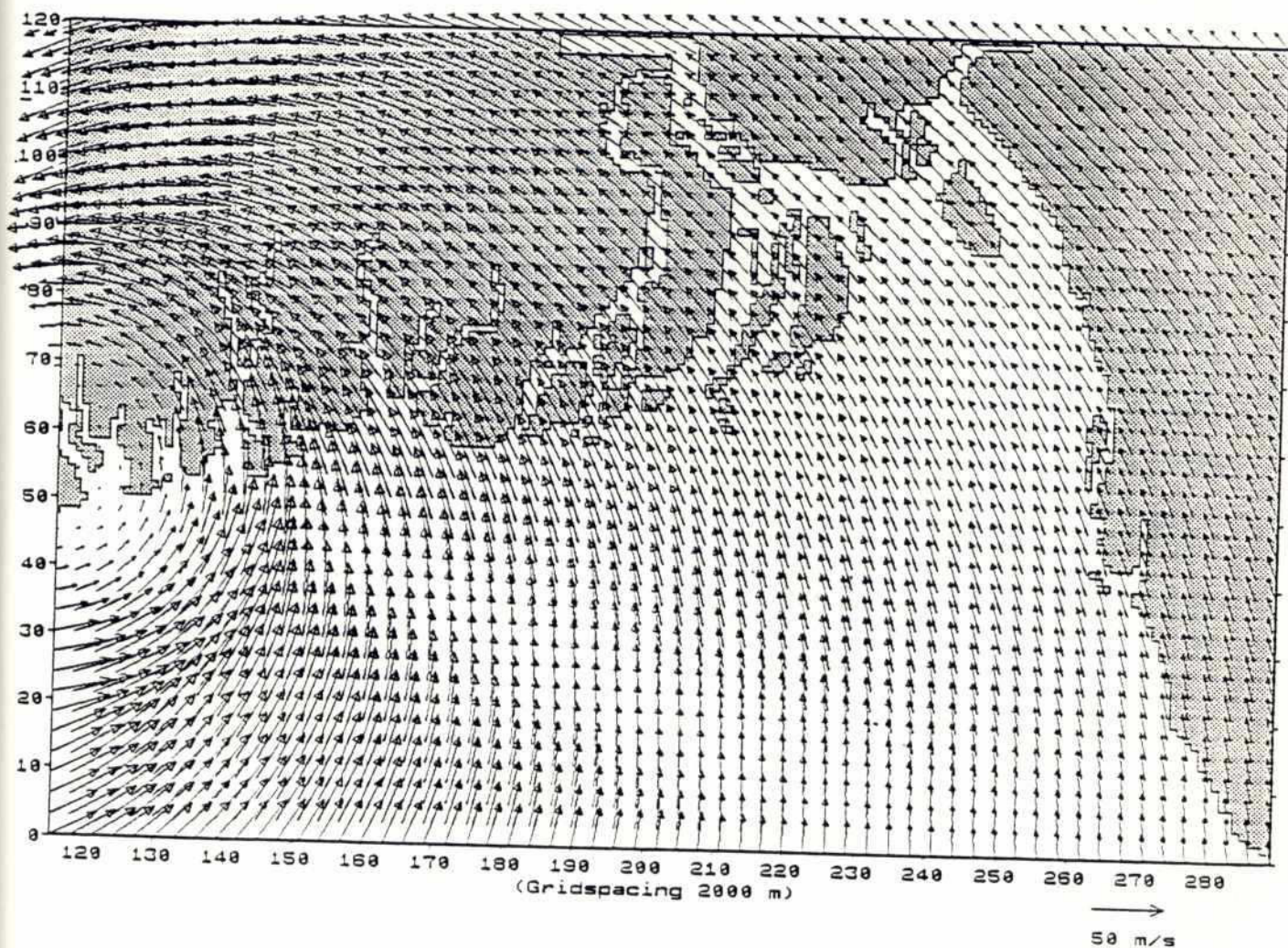




1988/11/29 12:00:00

<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n88 name : iwind Scale: 1:2 mill Sun Nov 25 1990	November 1988 Cyclone Wind Field	Dwg. No.  4.222

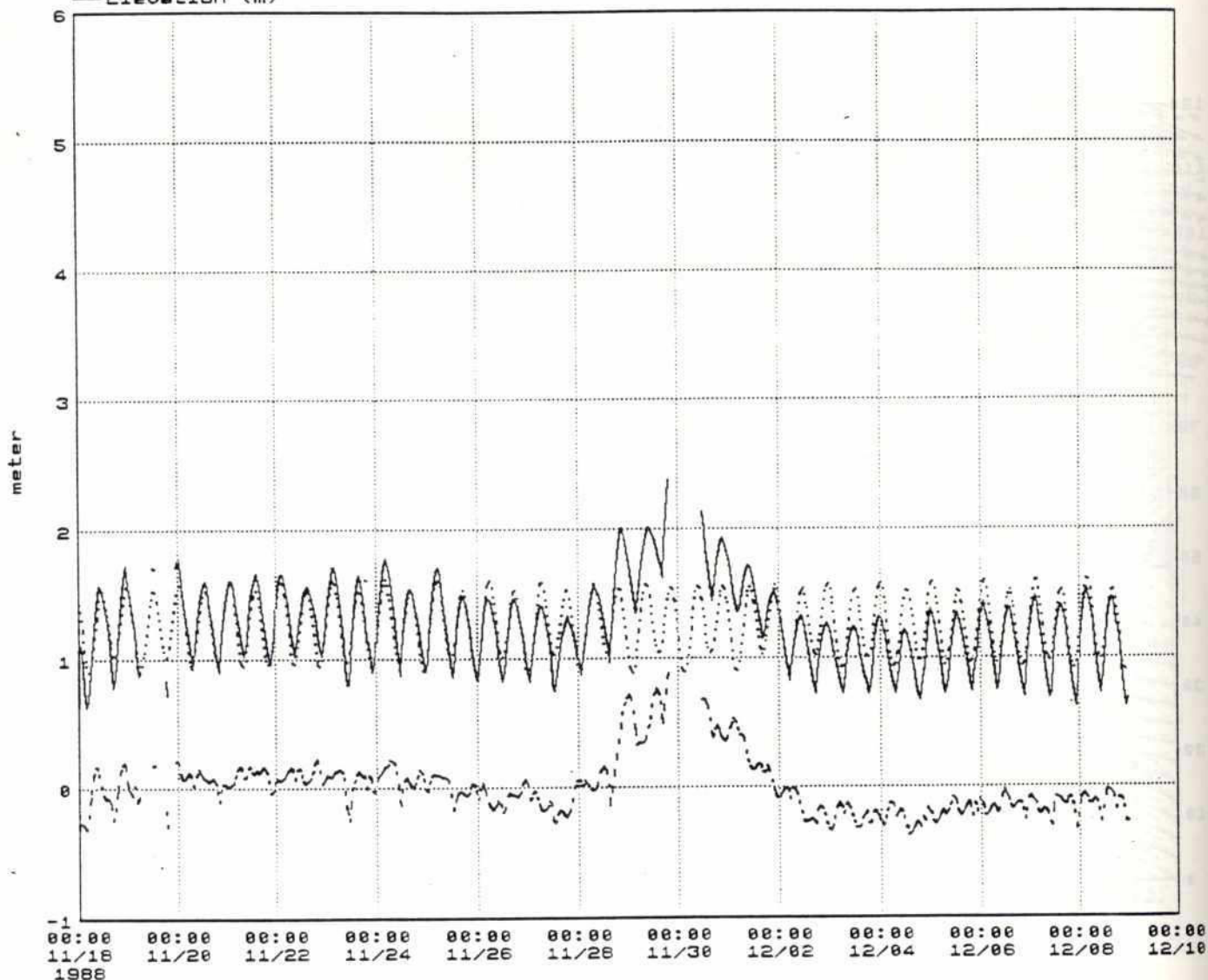




1988/11/30 00:00:00

MIKE21	Cyclone Protection Project II	
File: family: n88 name : iwind Scale: 1:2 mill Sun Nov 25 1998	November 1988 Cyclone Wind Field	Dwg. No.  4.223

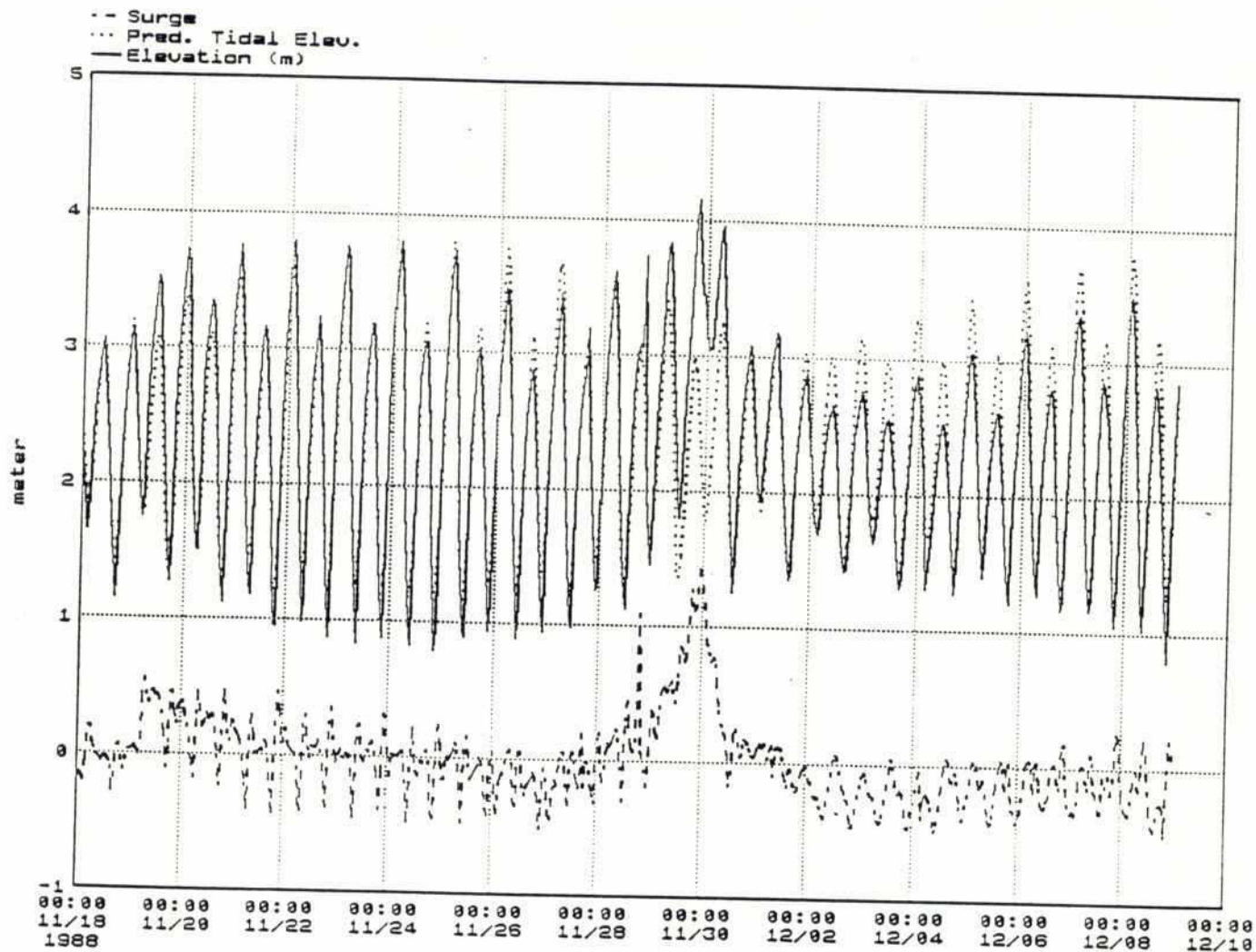
-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n88 name : sbar4 User: mnr Sat Nov 24 1990	November 1988 Barisal Measurements	Dwg. No.  4.224

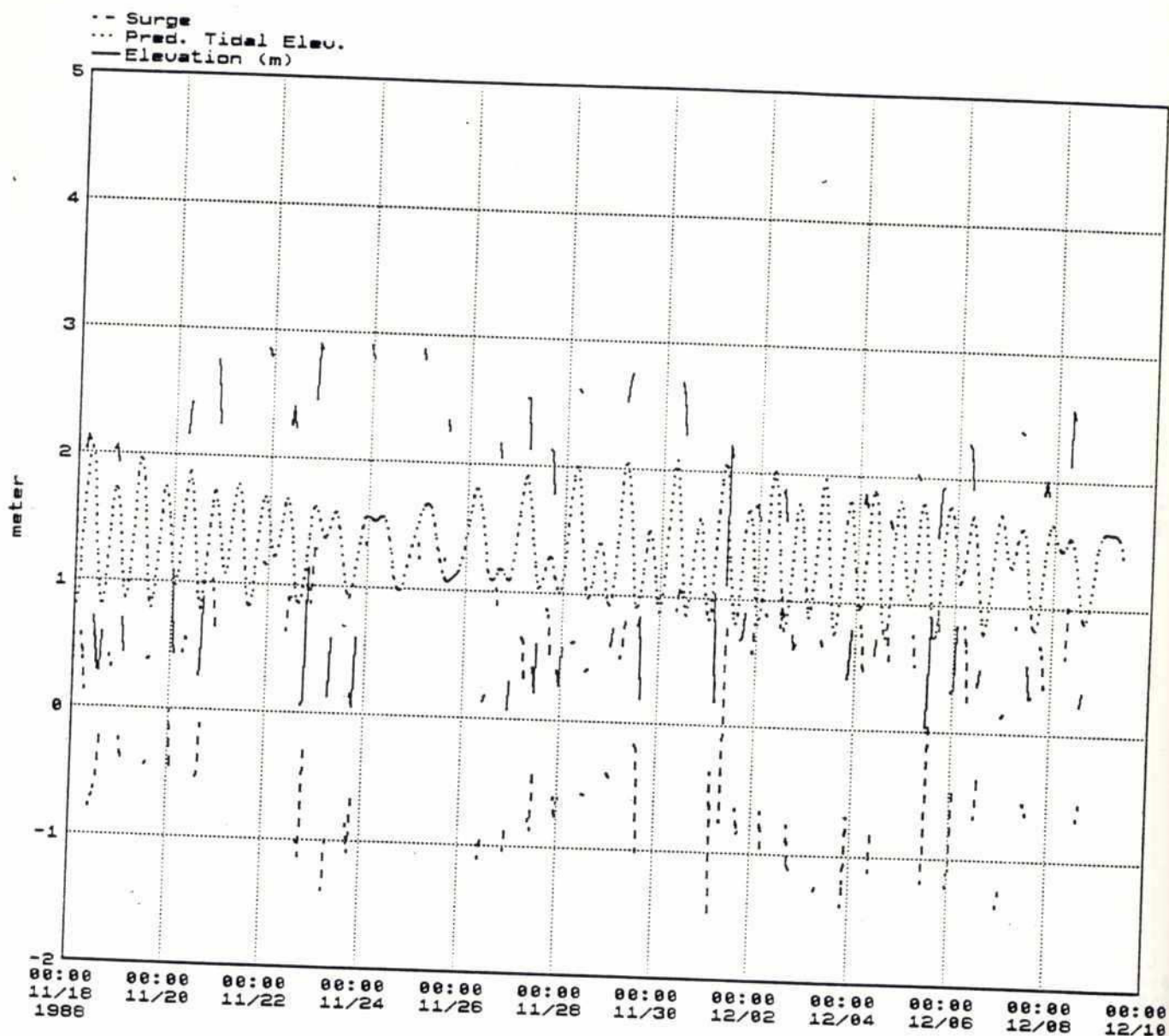


009



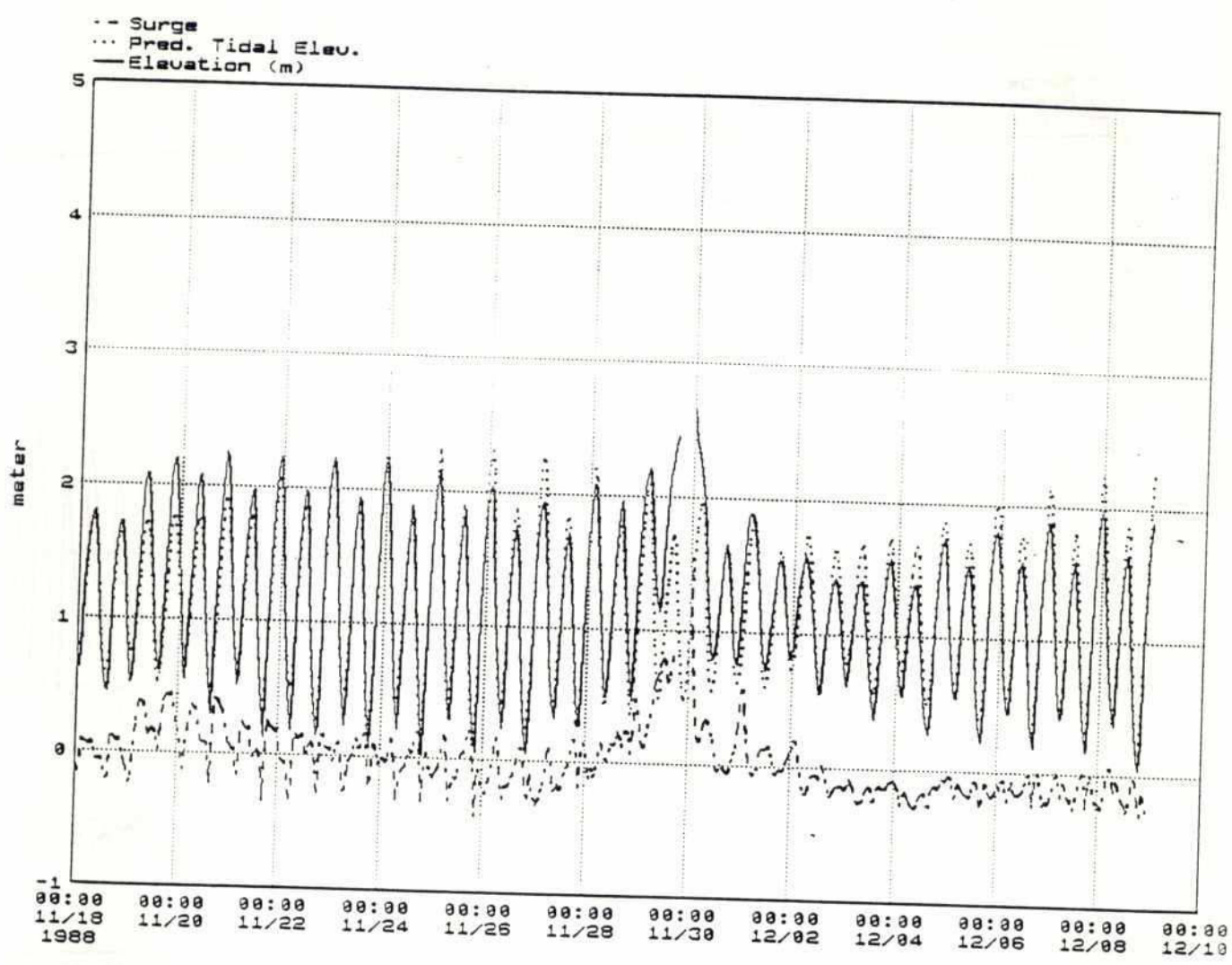
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n88 name : schr4 User: mnr Sat Nov 24 1990	November 1988 Char-Changa Measurements	Dwg. No.  4.225

lost



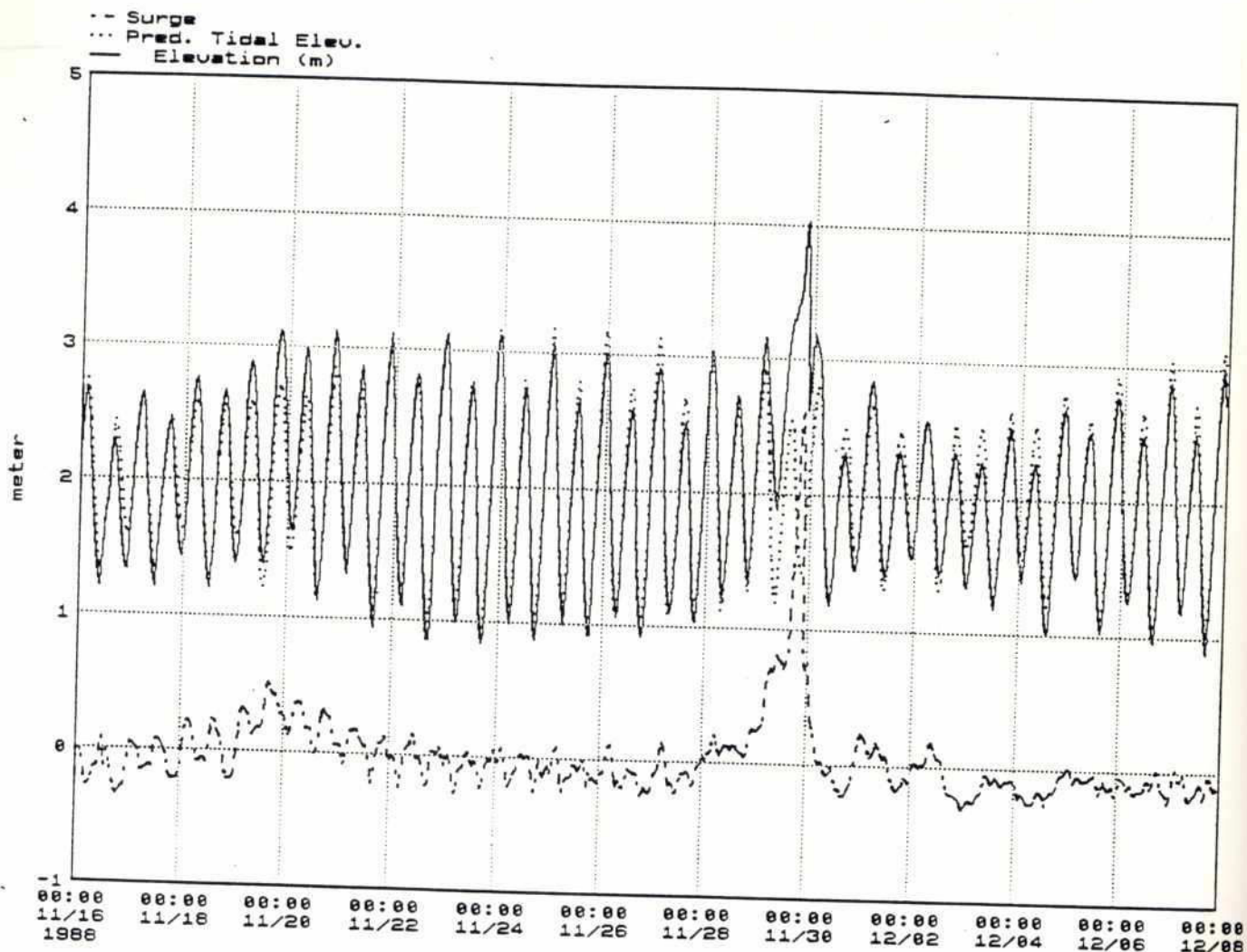
MIKE21	Cyclone Protection Project II	
File: family: n88 name : scox4 User: mnr Sat Nov 24 1998	November 1988 Cox's Bazar Measurements	Dwg. No.  4.226





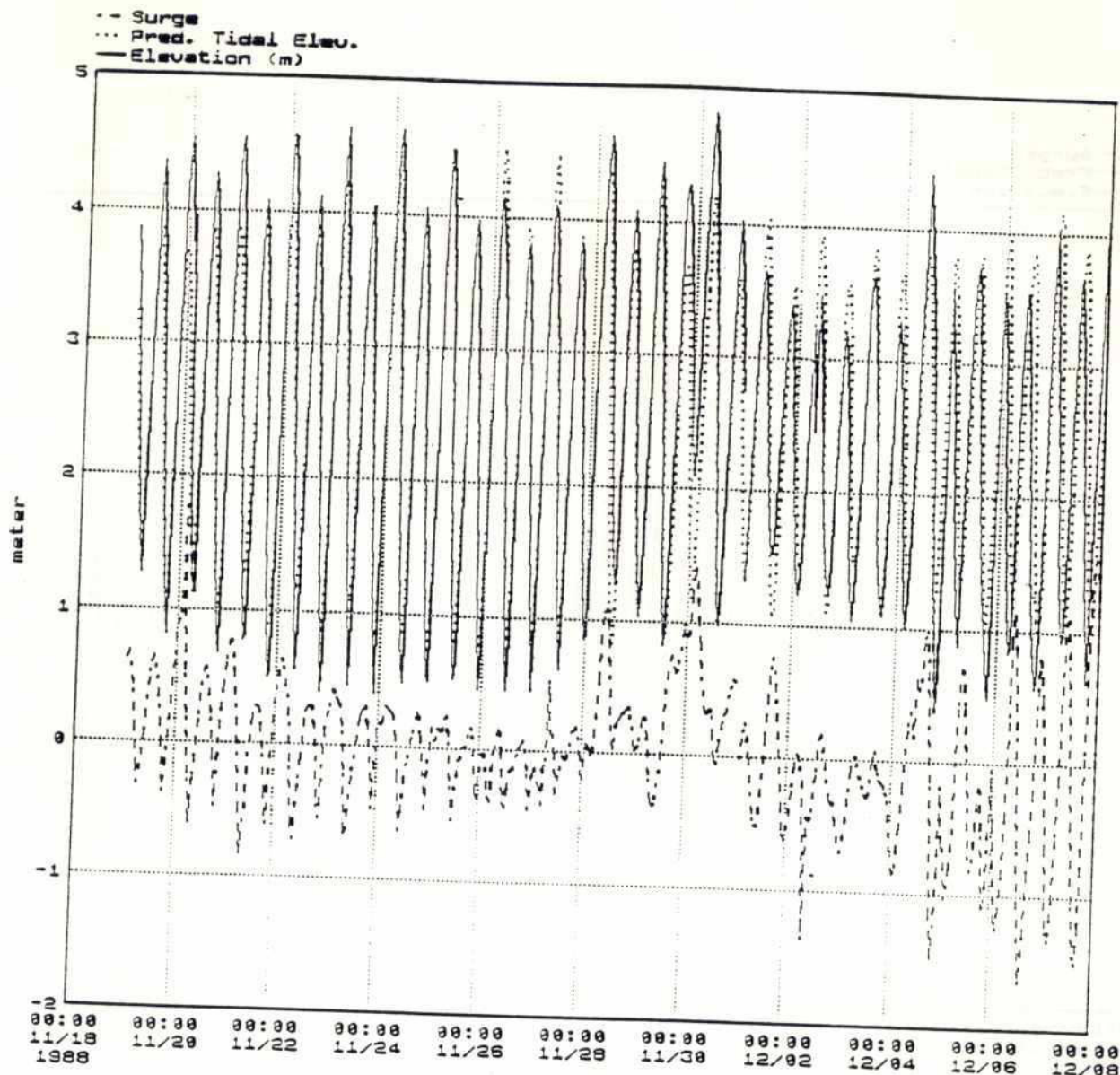
MIKE21		Cyclone Protection Project II	
File: family: n88 name : sgai4 User: mnr Sat Nov 24 1998	November 1988 Galachipa Measurements		Dwg. No.
			4.227

920



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n88 name : shir4 User: mnr Sat Nov 24 1990	November 1988 Hiron Point Measurements	<b>Dwg. No.</b>  4.228

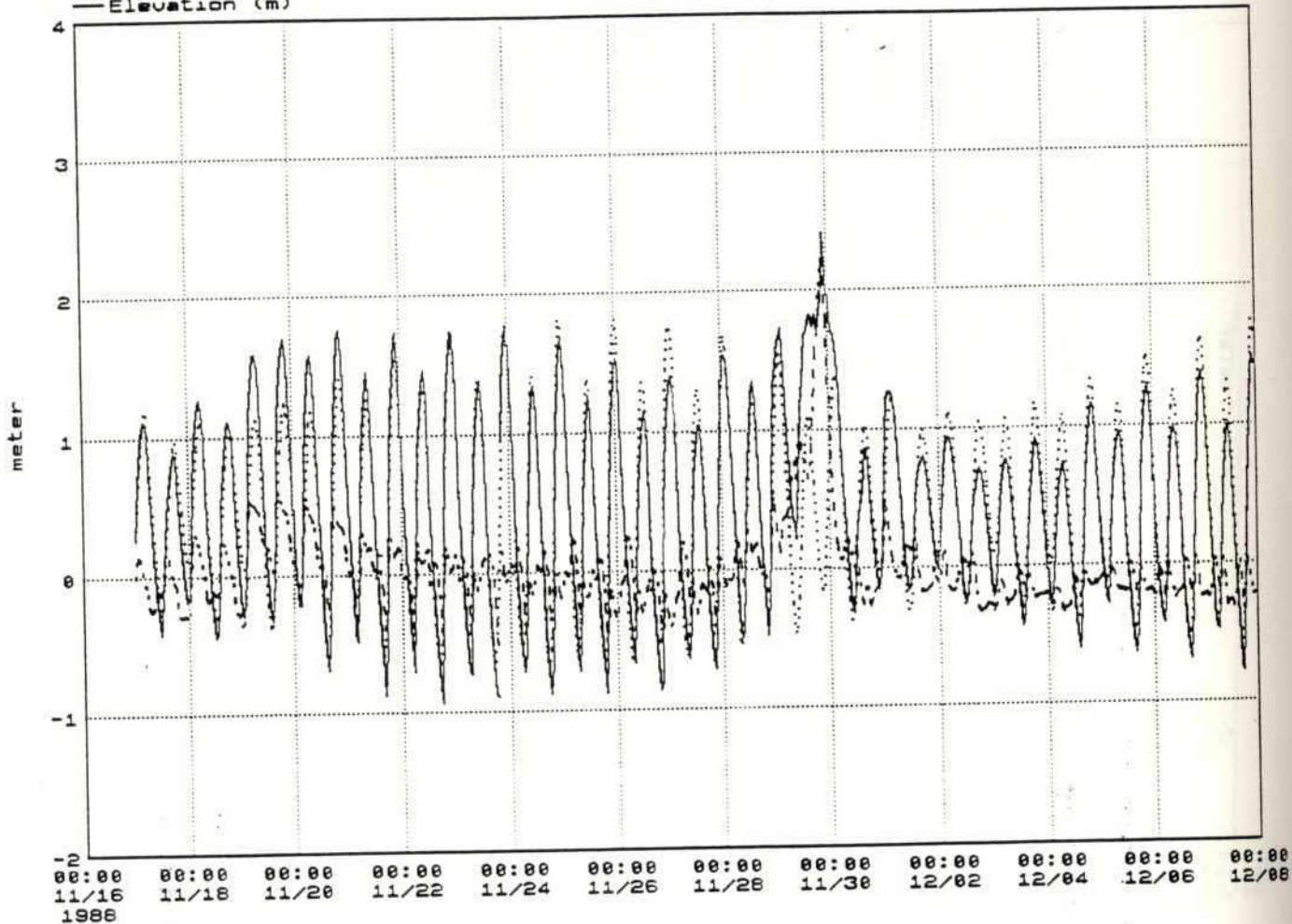




<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File:            family: n88            name : skha4            User: mnr            Sat Nov 24 1998</p>	<p>November 1988            Khal No. 10            Measurements</p>	<p>Dwg. No.              4.229</p>

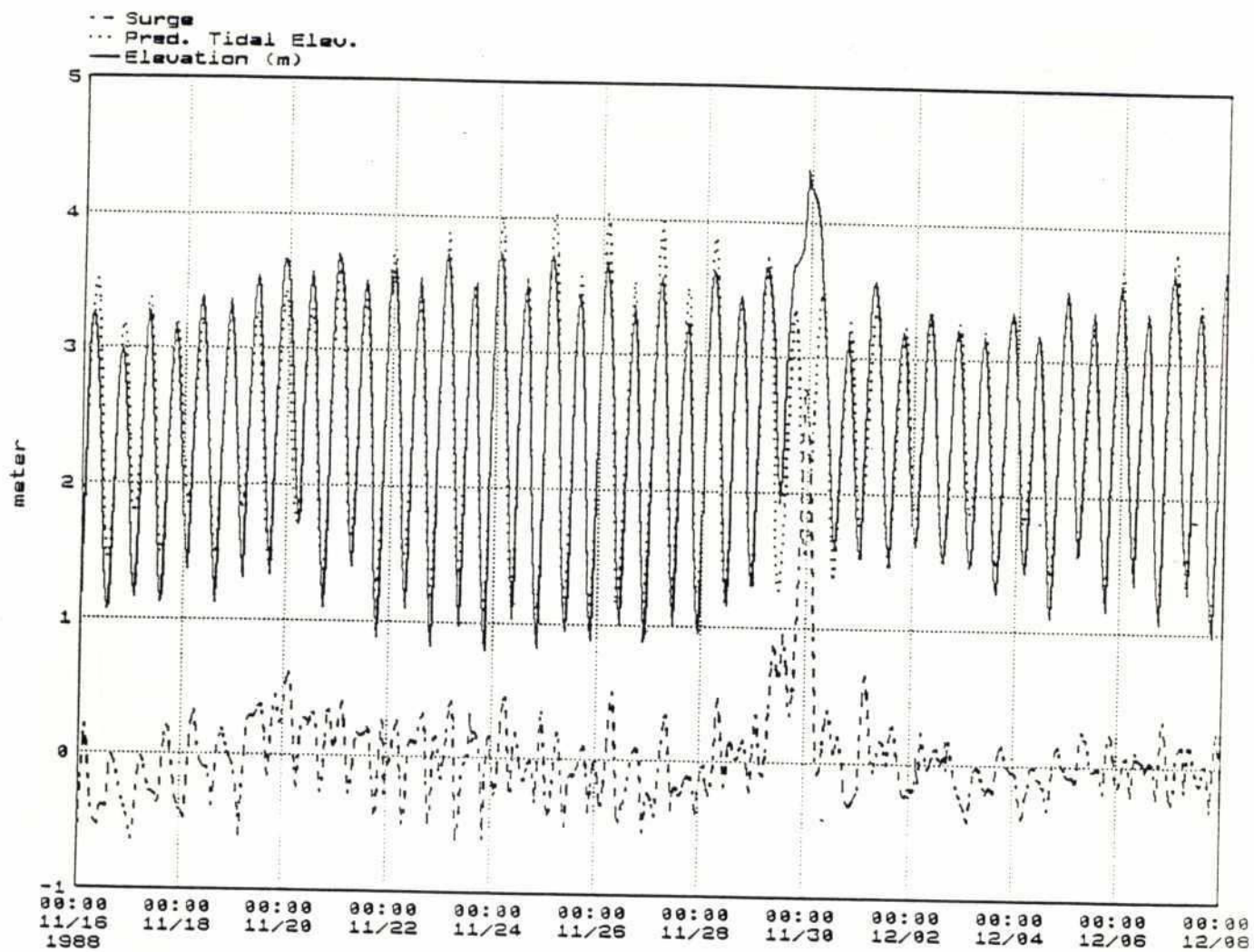
922

-- Surge  
 ... Pred. Tidal Elev.  
 — Elevation (m)



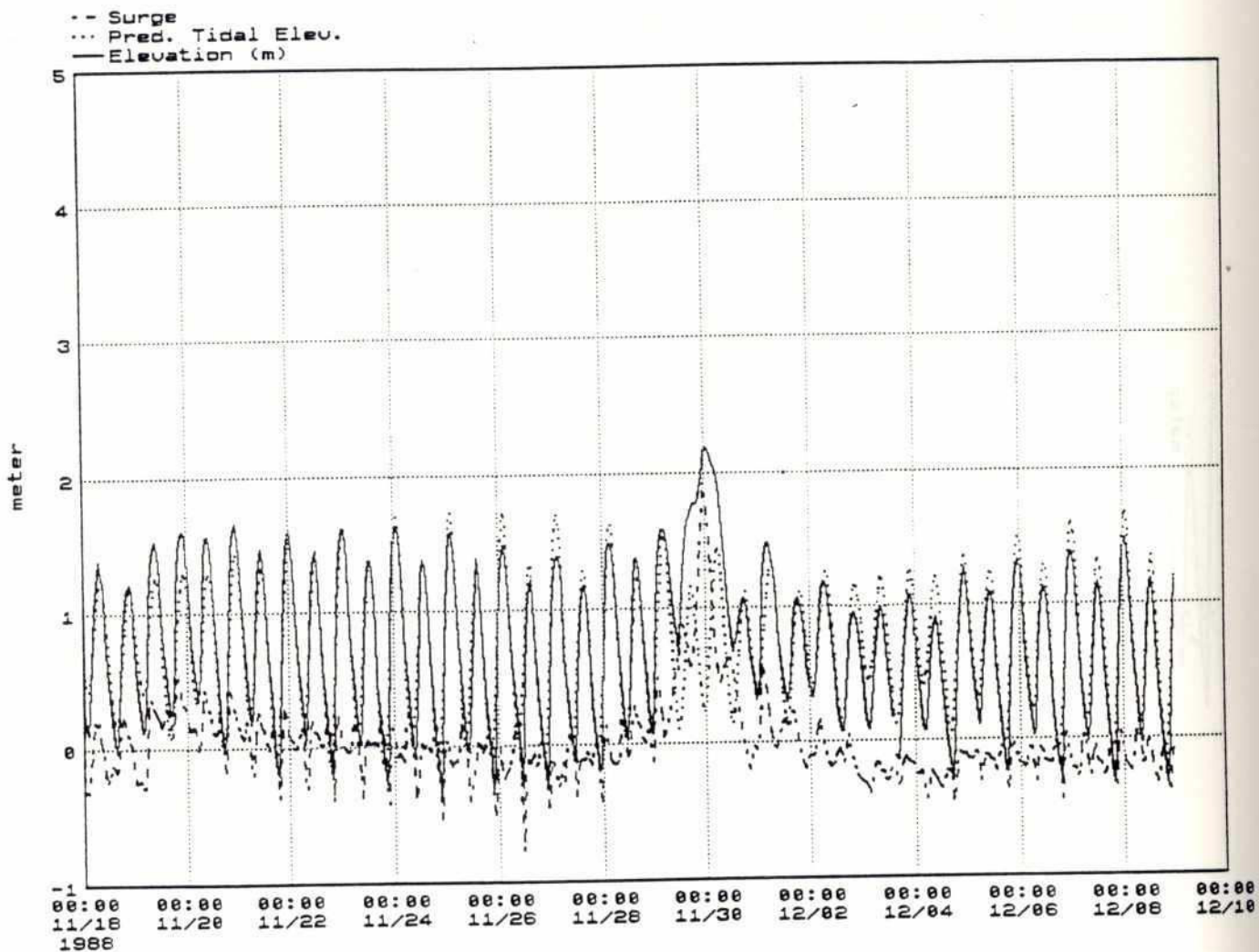
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n88 name : skhe4 User: mnr Sat Nov 24 1990	November 1988 Khepupara Measurements	Dwg. No.  4.230





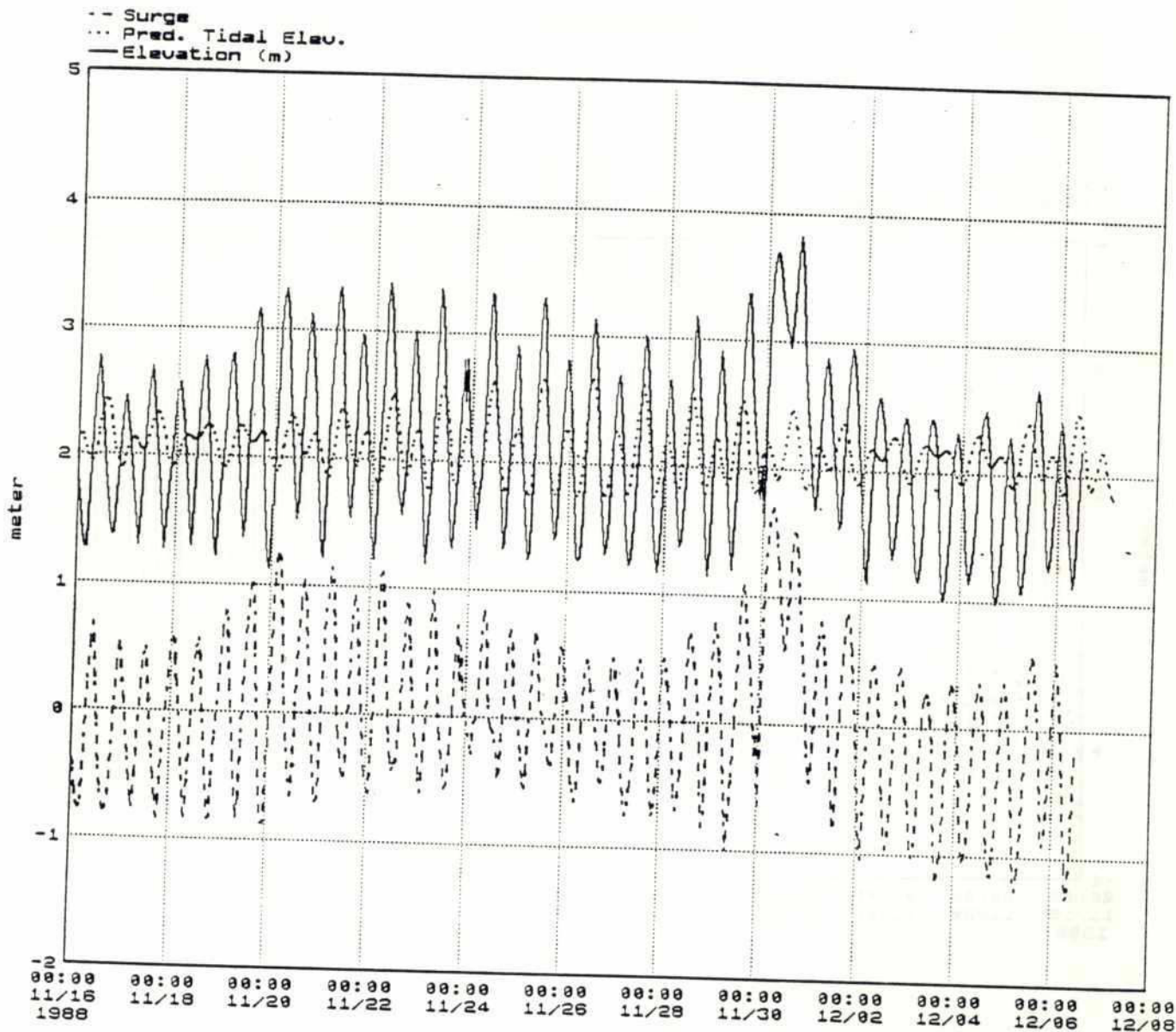
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n88 name : smon4 User: mnr Sat Nov 24 1998	November 1988 Mongia Measurements	<b>Dwg. No.</b>  4.231

028



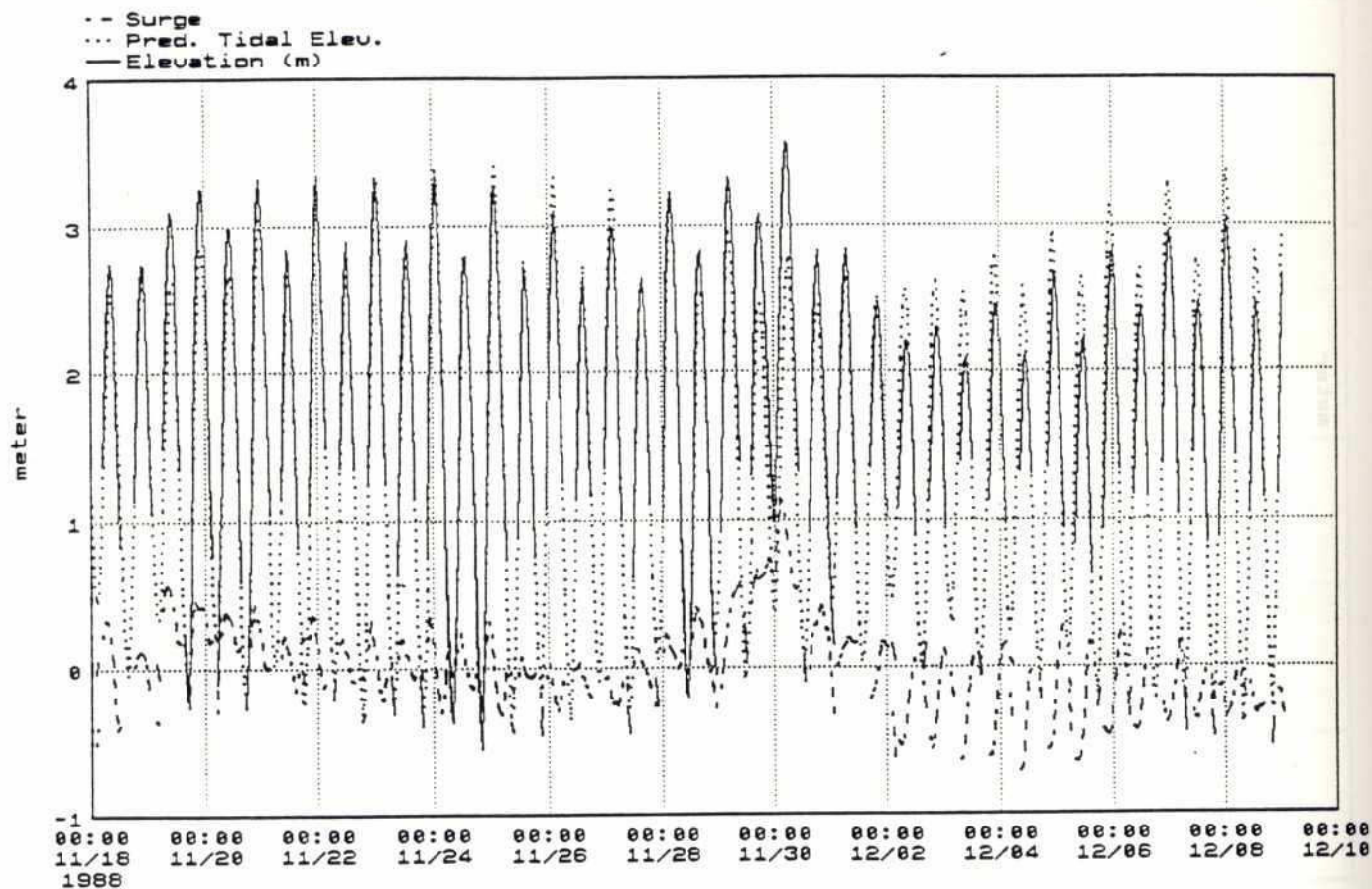
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n88 name : spat4 User: mnr Sun Nov 25 1990	November 1988 Patuakhali Measurements	Dwg. No.  4.232





MIKE21 Cyclone Protection Project II		
File: family: n88 name : gram4 User: mnr Sun Nov 25 1990	November 1988 Ramdaspur Measurements	Dwg. No.  4.233

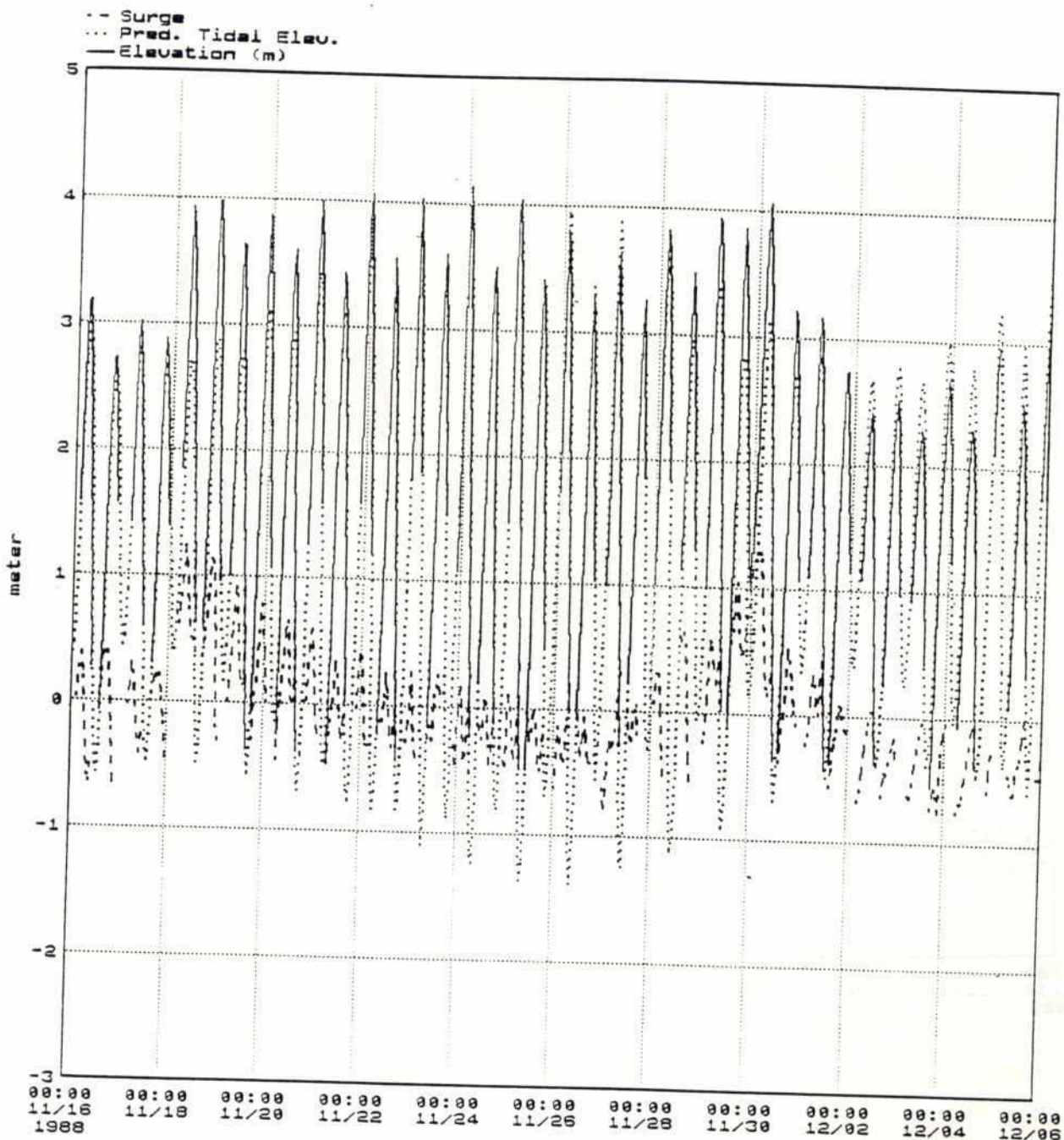
929



MIKE21	Cyclone Protection Project II	
File: family: n88 name : ssad4 User: mnr Sun Nov 25 1990	November 1988 Sadargath (CTG) Measurements	Dwg. No.  4.234

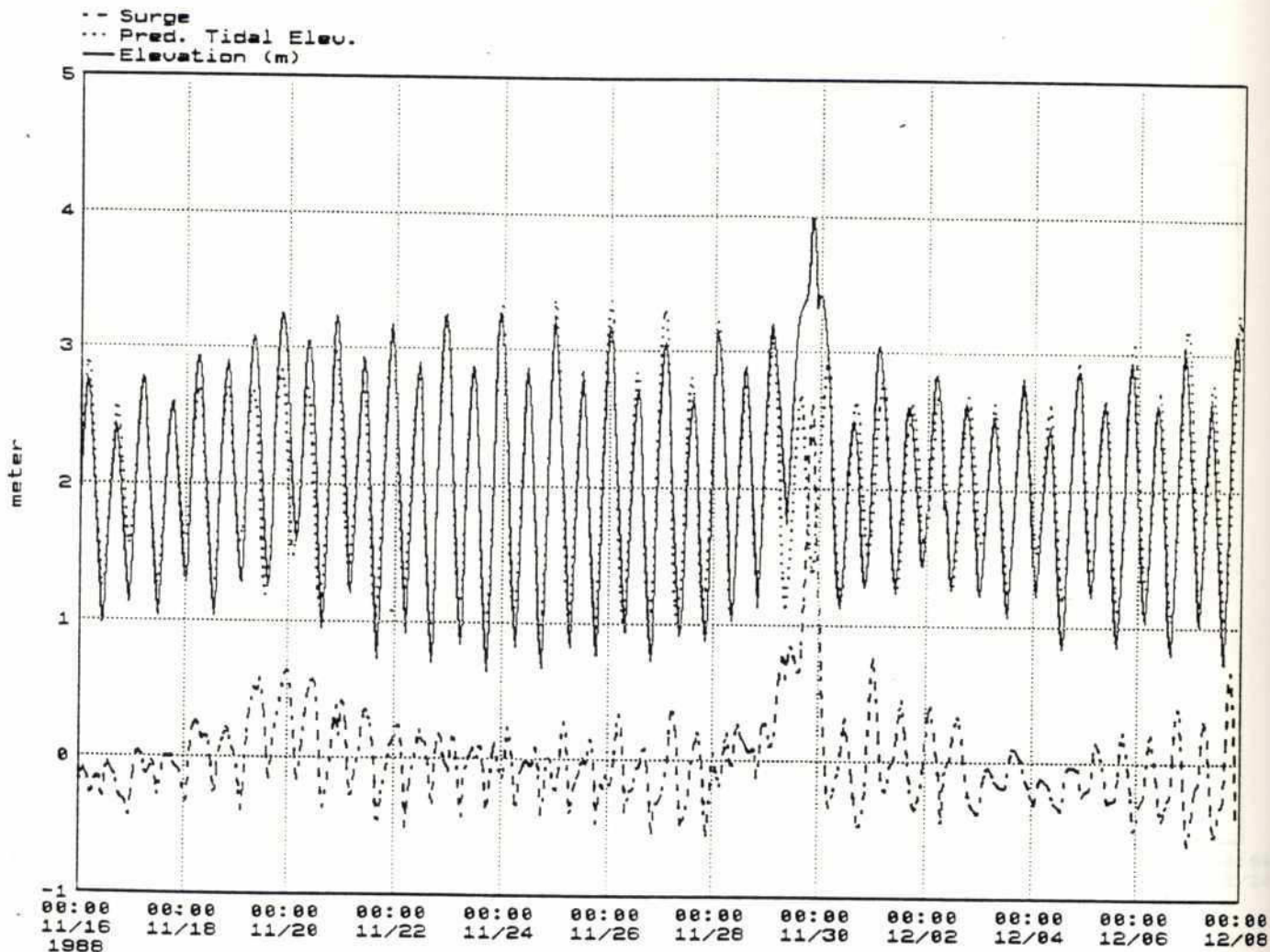


009



<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File:            family: n88            name : ssan4            User: mnr            Sun Nov 25 1998</p>	<p>November 1988            Sandwip            Measurements</p>	<p>Dwg. No.             4.235</p>

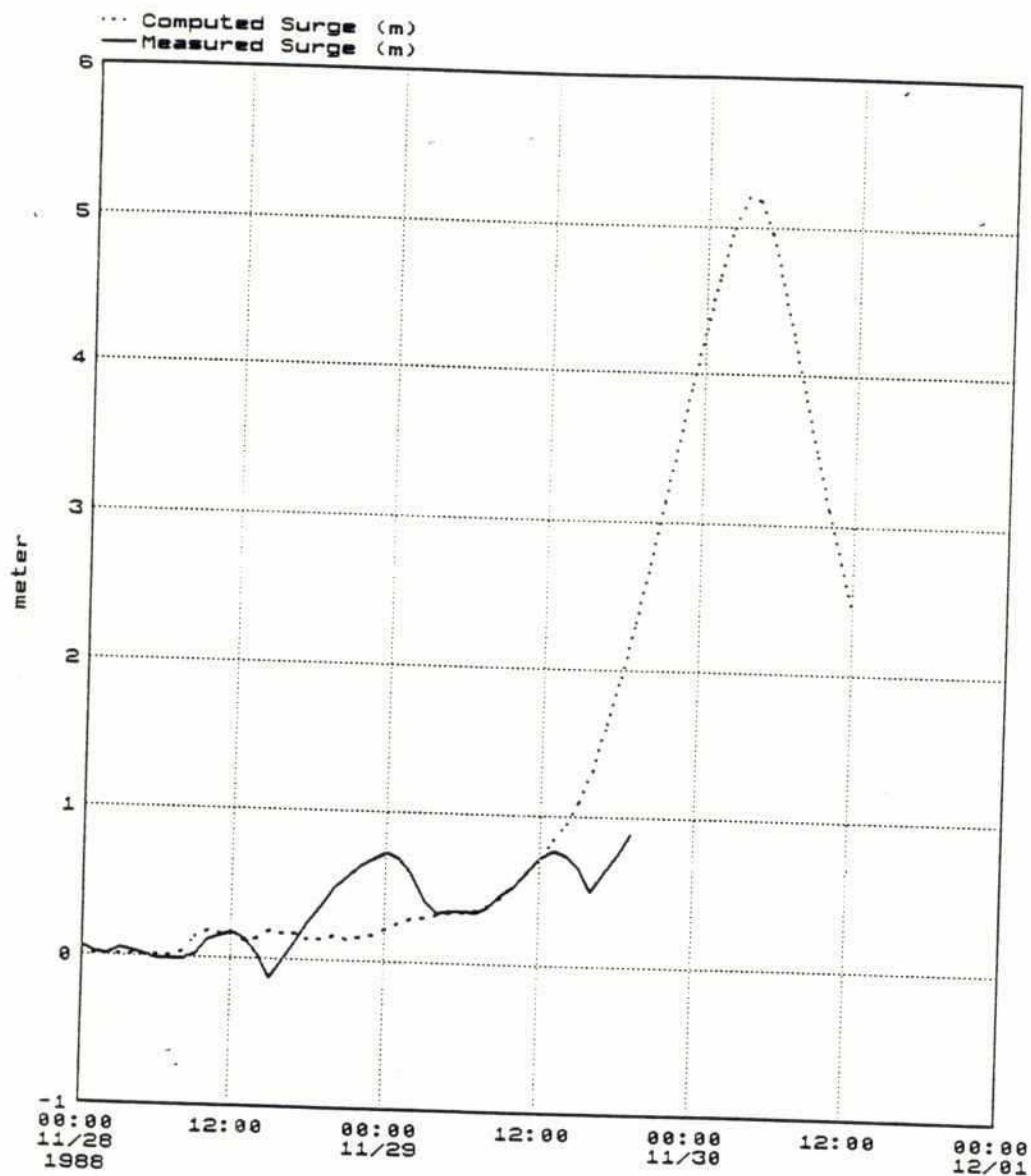
626



<p>MIKE21</p>	<p>Cyclone Protection Project II</p>	
<p>File:            family: n88            name : ssun4            User: mnr            Sun Nov 25 1990</p>	<p>November 1988            Sunderikota            Measurements</p>	<p>Dwg. No.             4.236</p>

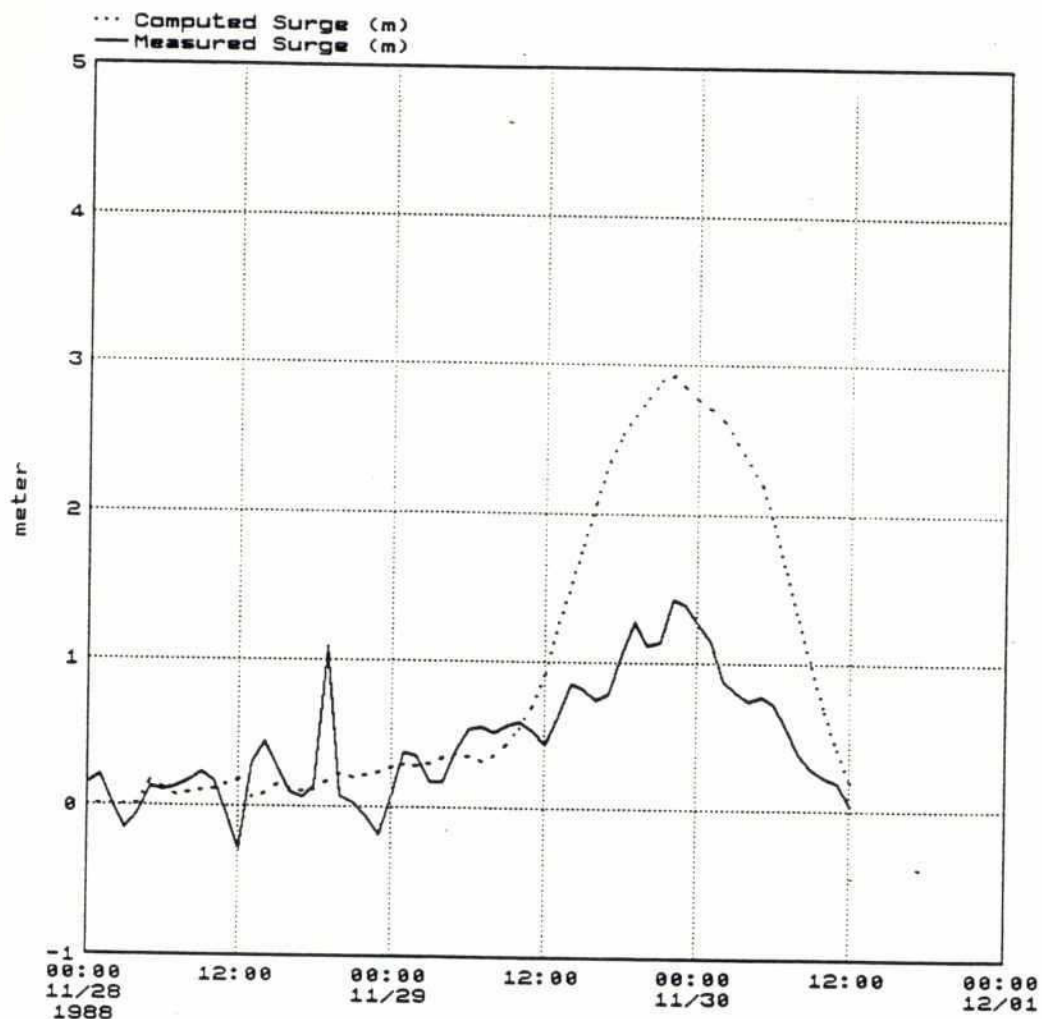


020



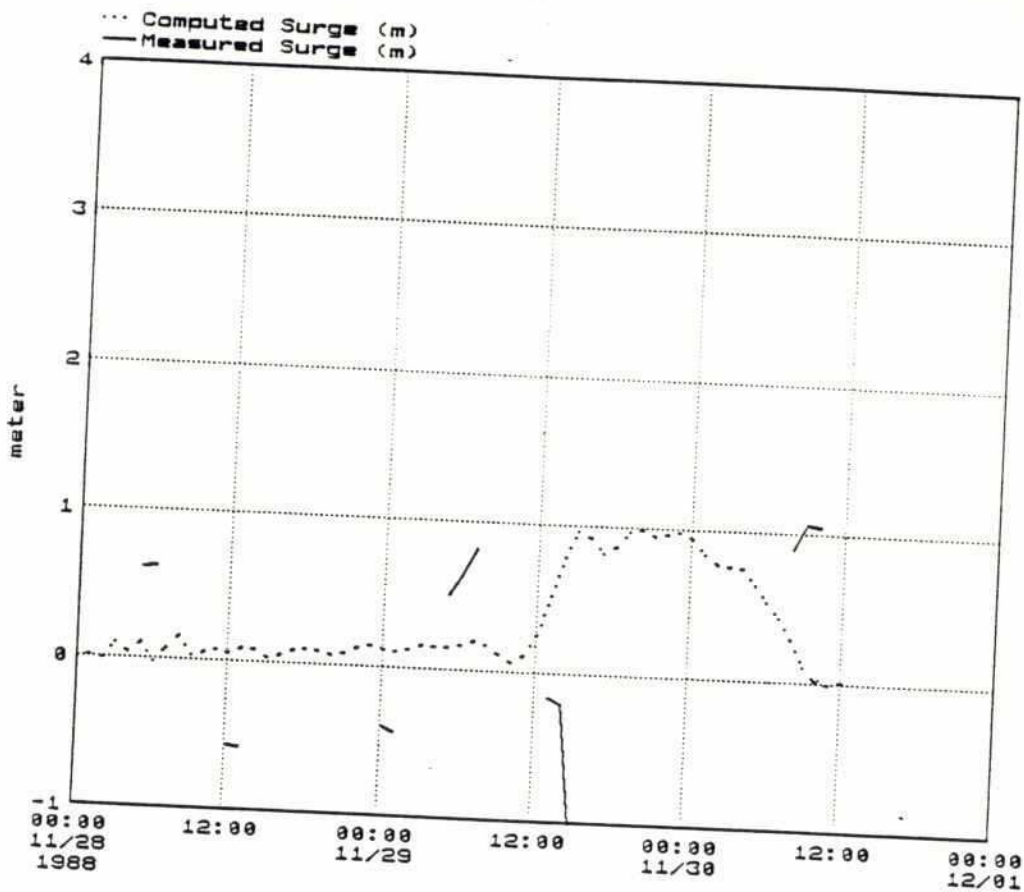
MIKE21	Cyclone Protection Project II	
File: family: n88 name : cbar4 User: mnr	November 1988 Barisal Measured and computed surge	Dwg. No.  4.237

220



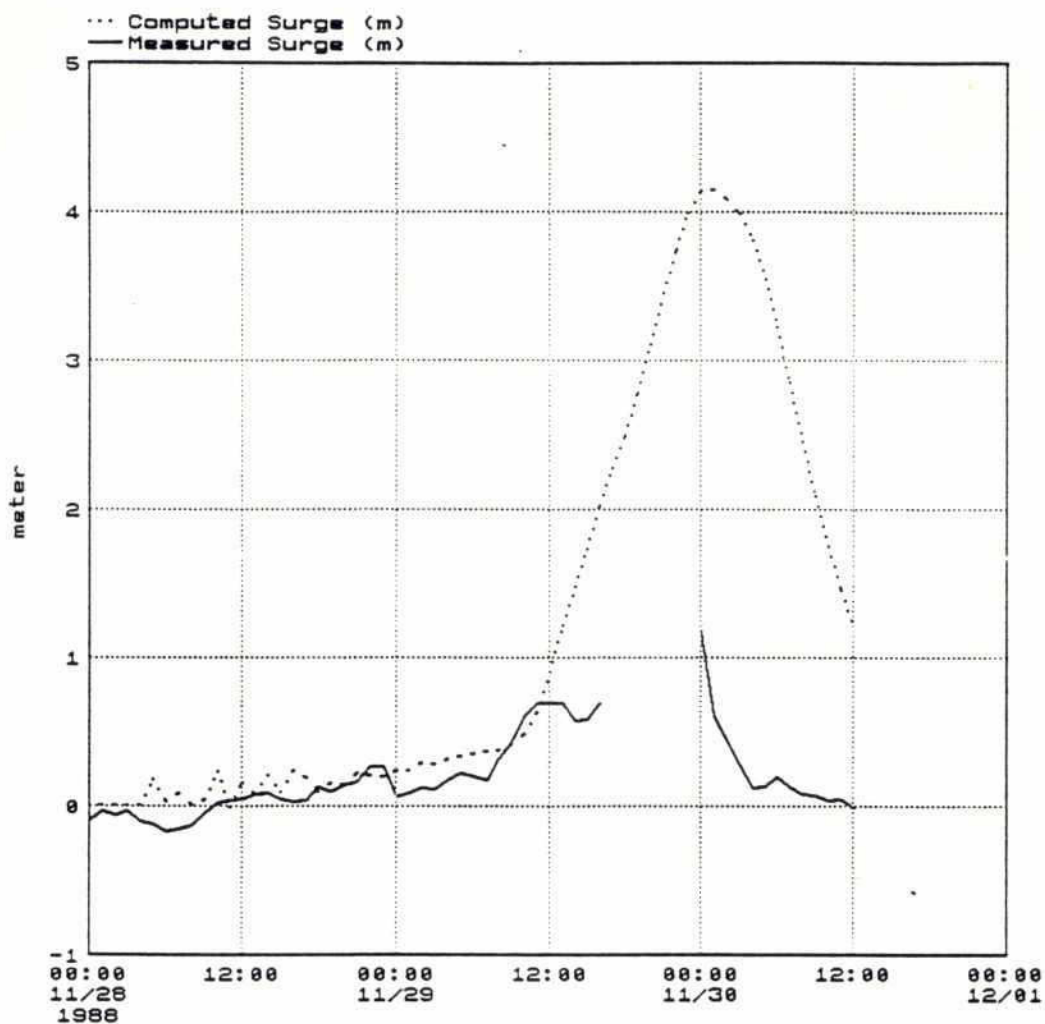
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n88 name : cchr4 User: mnr	November 1988 Char-Change Measured and computed surge	Dwg. No.  4.238





<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: n88 name : ccox4 User: mnr Sat Nov 24 1998</p>	<p>November 1988 Coxs Bazar Measured and computed surge</p>	<p>Dwg. No.  4.239</p>

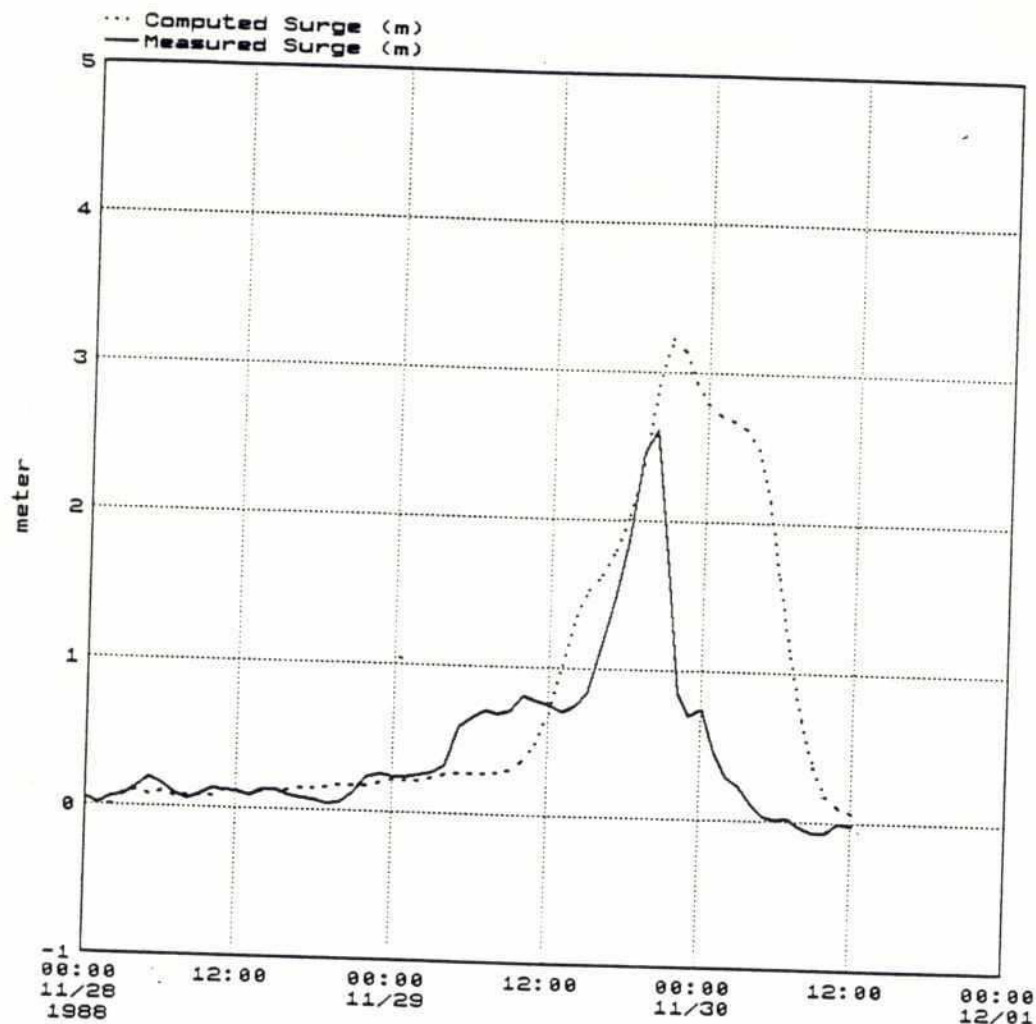
622



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n88 name : cgal4 User: mnr Sat Nov 24 1990	November 1988 Galachipa Measured and computed surge	Dwg. No.  4.240

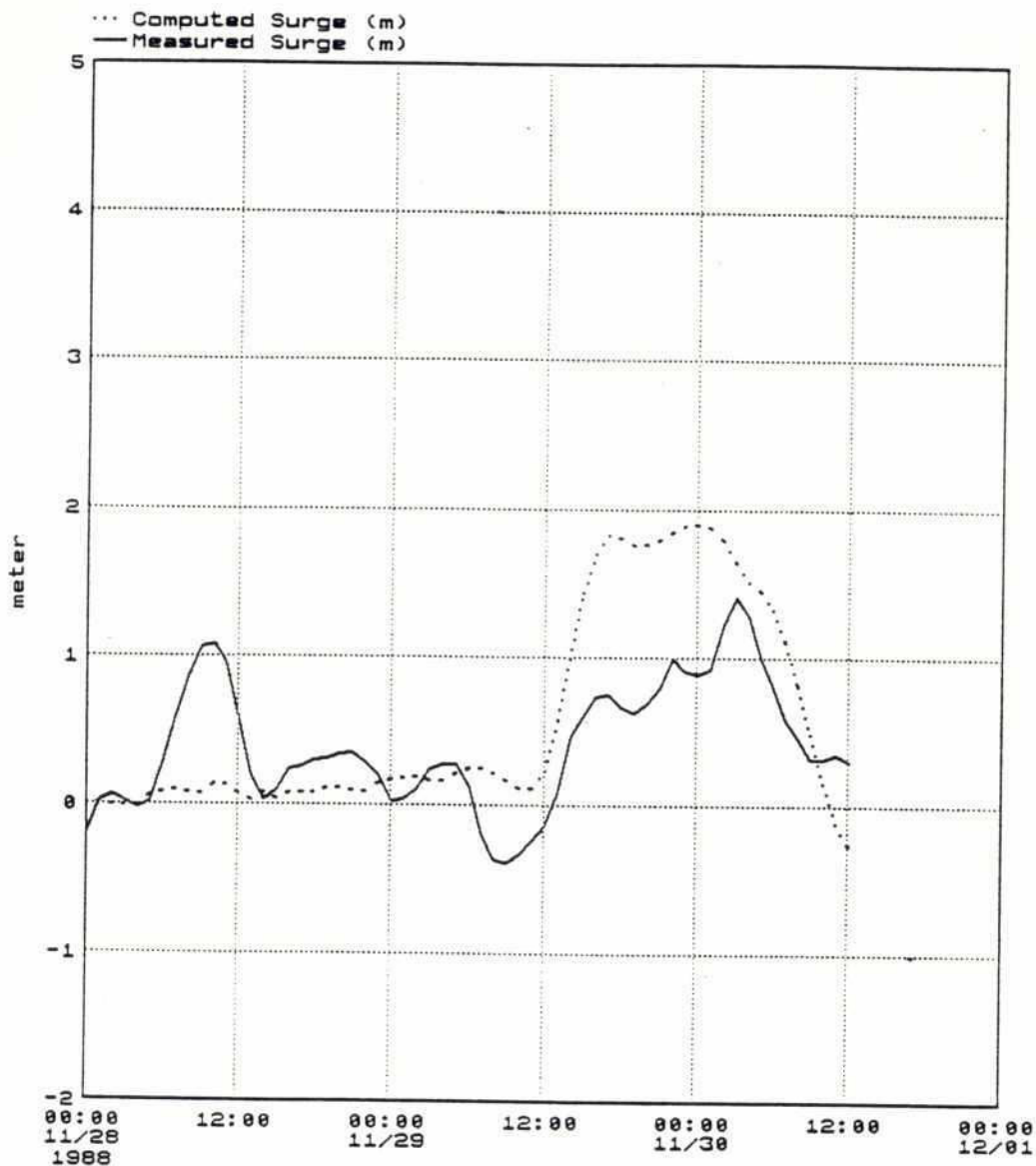


026



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n88 name : chir4 User: mnr Sat Nov 24 1990	November 1988 Hiron Point Measured and computed surge	Dwg. No.  4.241

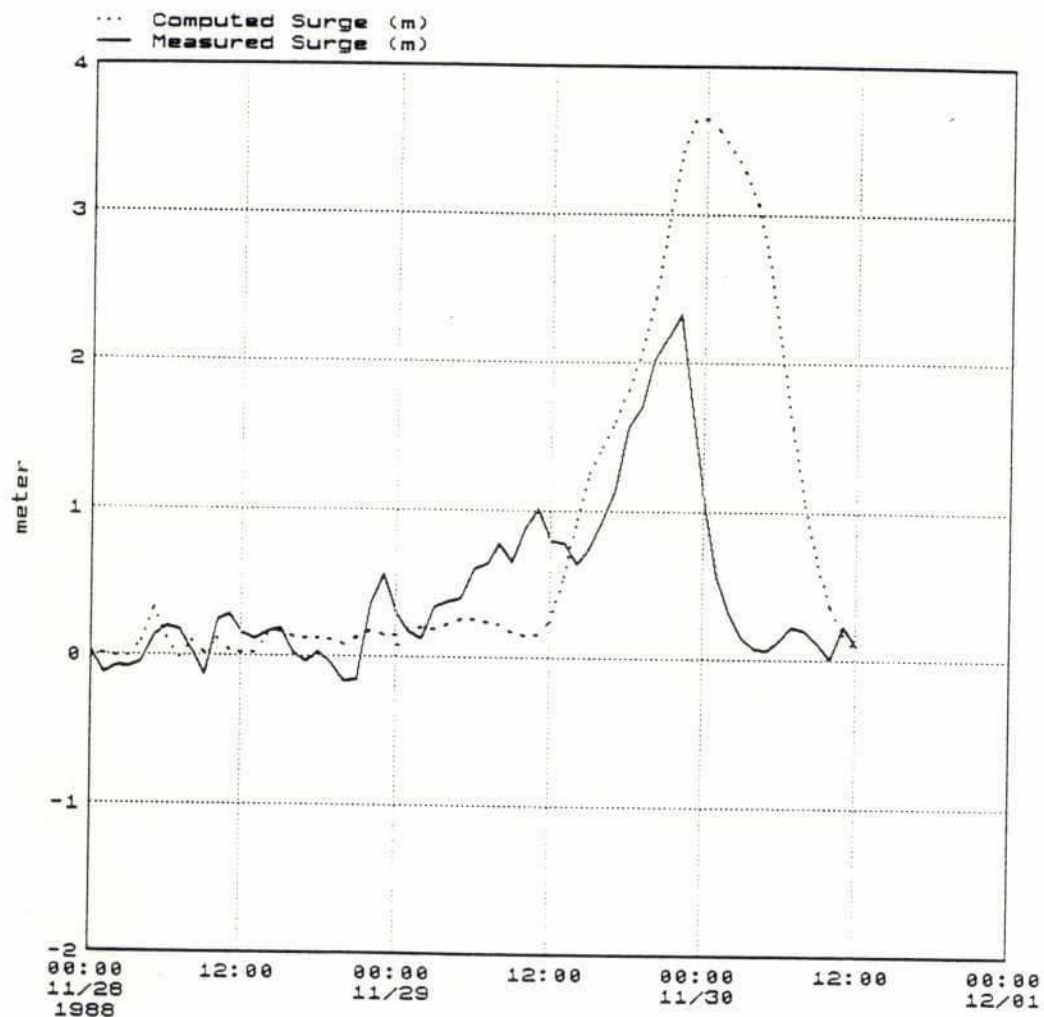
025



<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n88 name : ckha4 User: mnr Sat Nov 24 1990	November 1988 Khal No. 10 Measured and computed surge	<b>Dwg. No.</b>  4.242

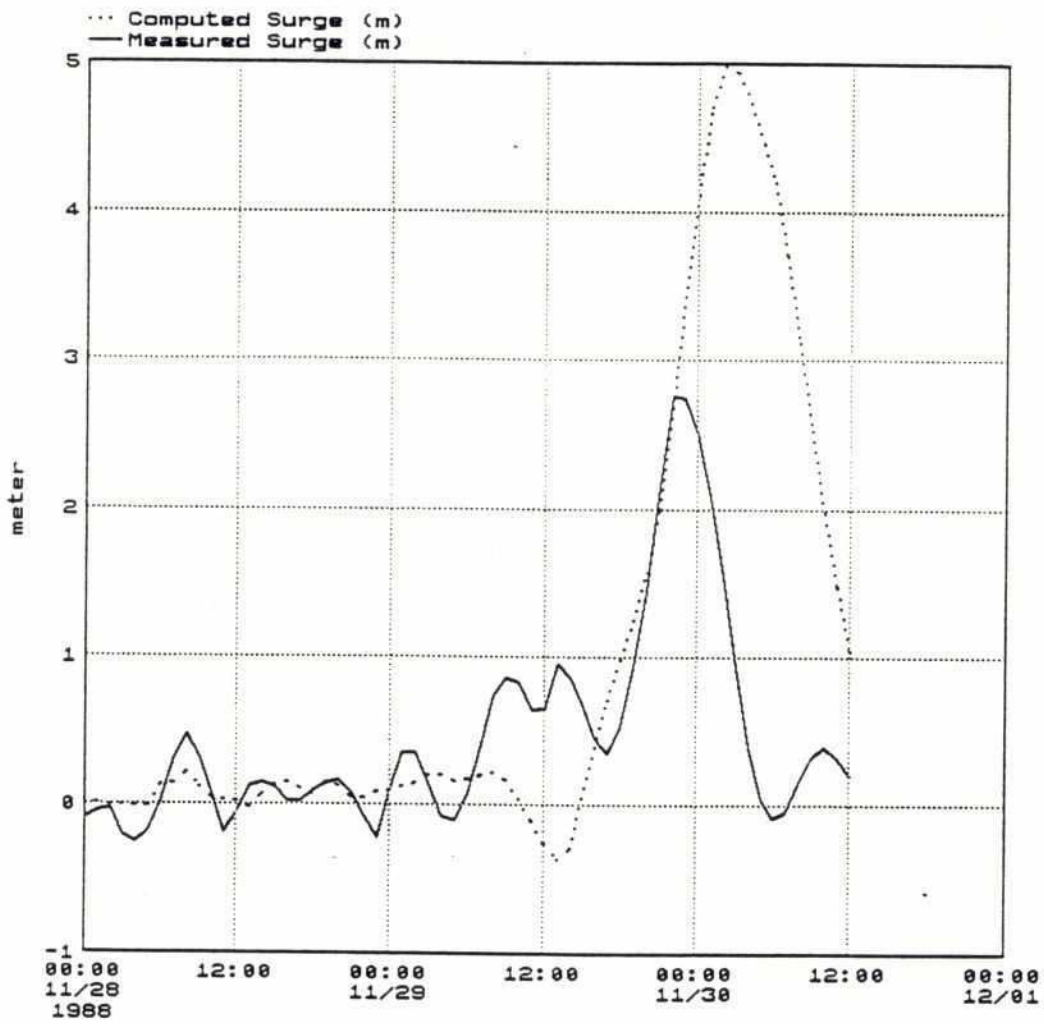


028



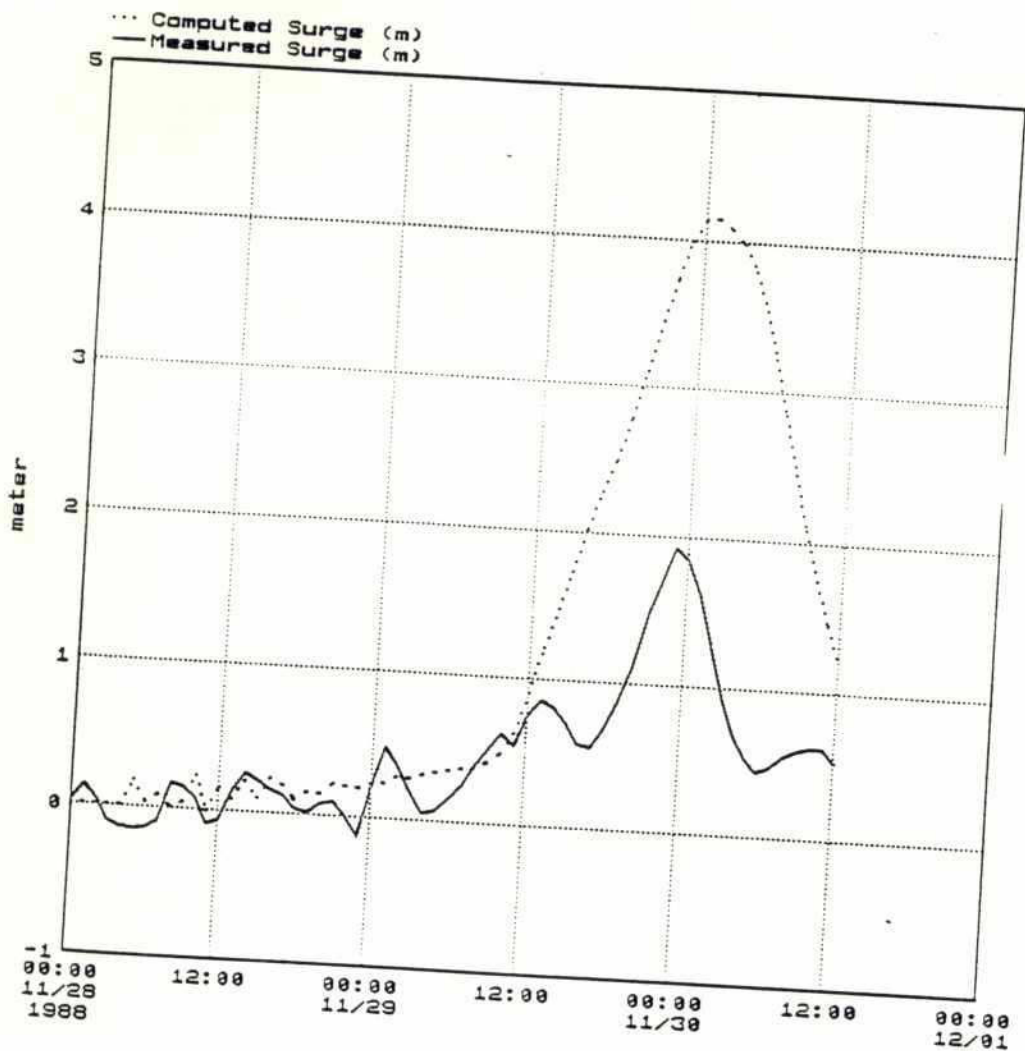
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n88 name : ckhe4 User: mnr Sat Nov 24 1990	November 1988 Khecupara Measured and computed surge	Dwg. No.  4.243

029



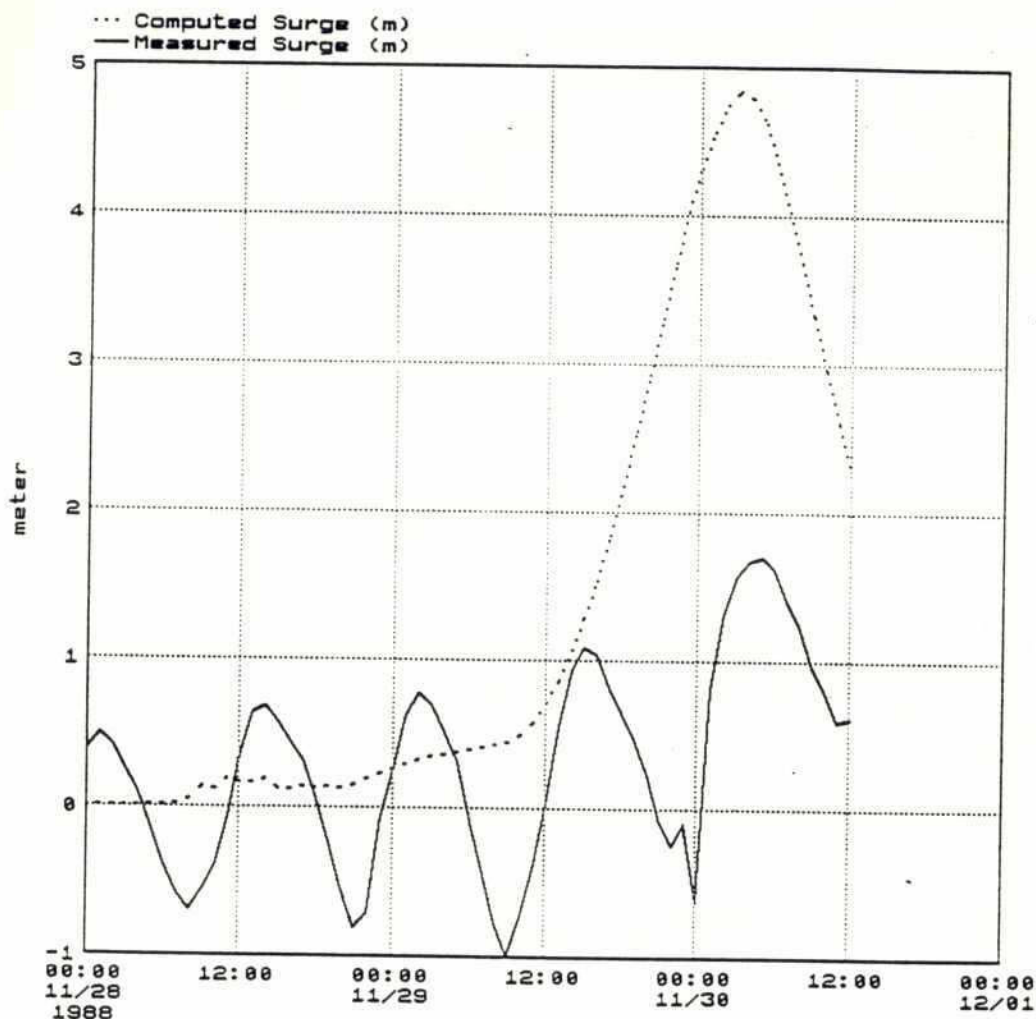
<p><b>MIKE21</b></p>	<p>Cyclone Protection Project II</p>	
<p>File: family: n88 name : cmon4 User: mnr Sat Nov 24 1998</p>	<p>November 1988 Mongla Measured and computed surge</p>	<p>Dwg. No.  4.244</p>





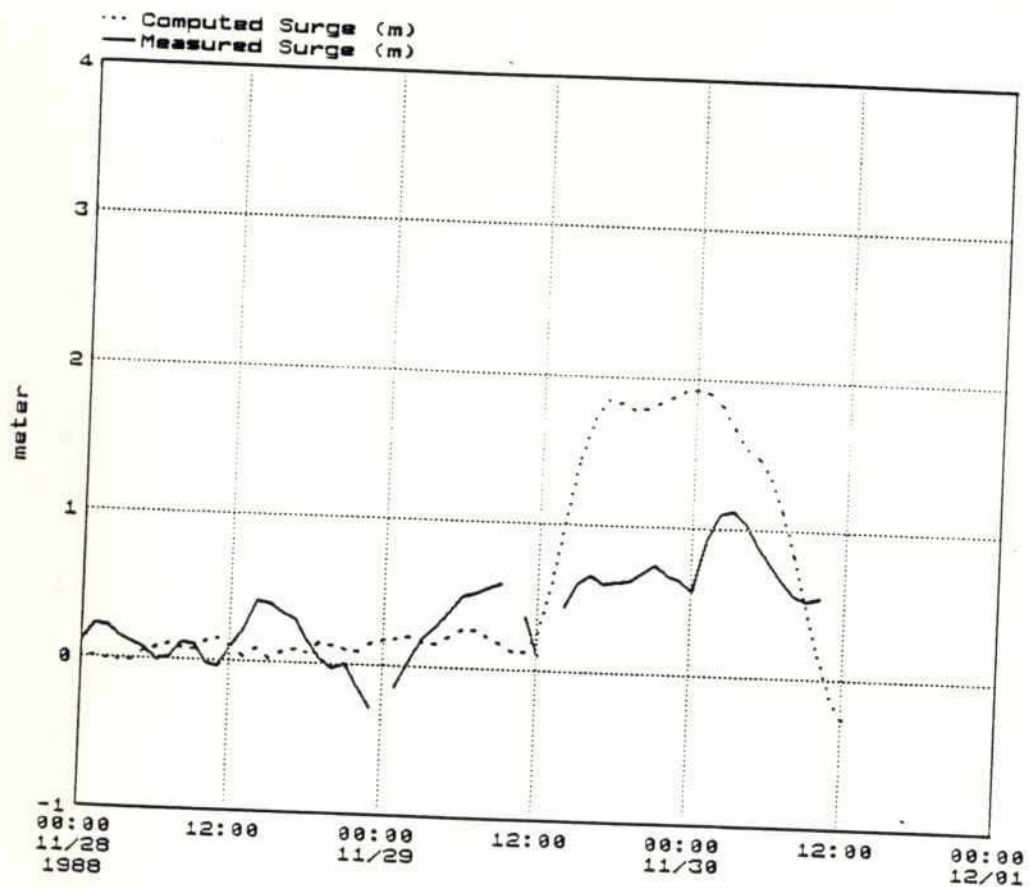
MIKE21 Cyclone Protection Project II		
File: family: n88 name : cpat4 User: mnr Sun Nov 25 1990	November 1988 Patuakhali Measured and computed surge	Dwg. No.  4.245

224



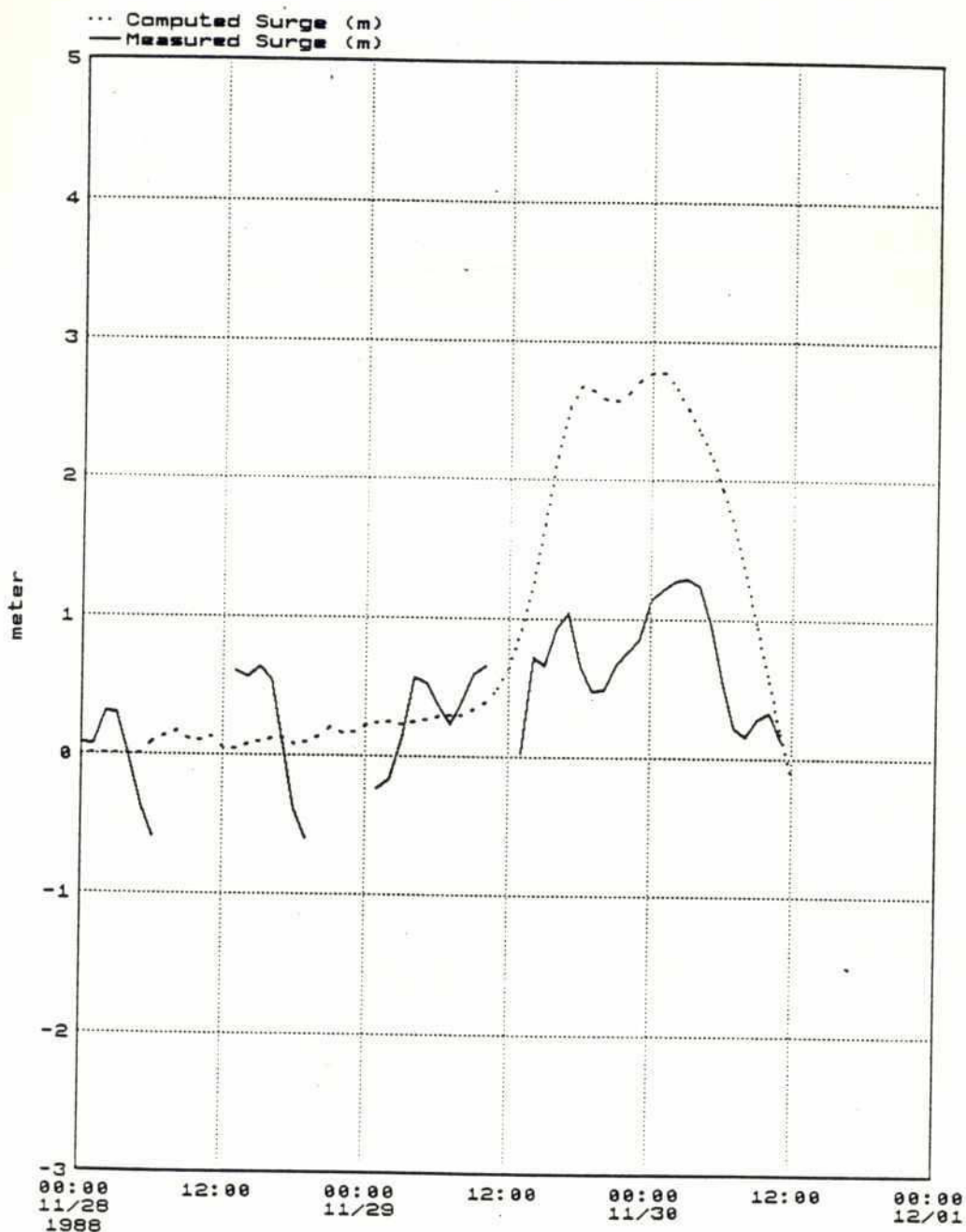
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n88 name : cram4 User: mnr Sun Nov 25 1998	November 1988 Ramdaspur Measured and computed surge	Dwg. No.  4.246





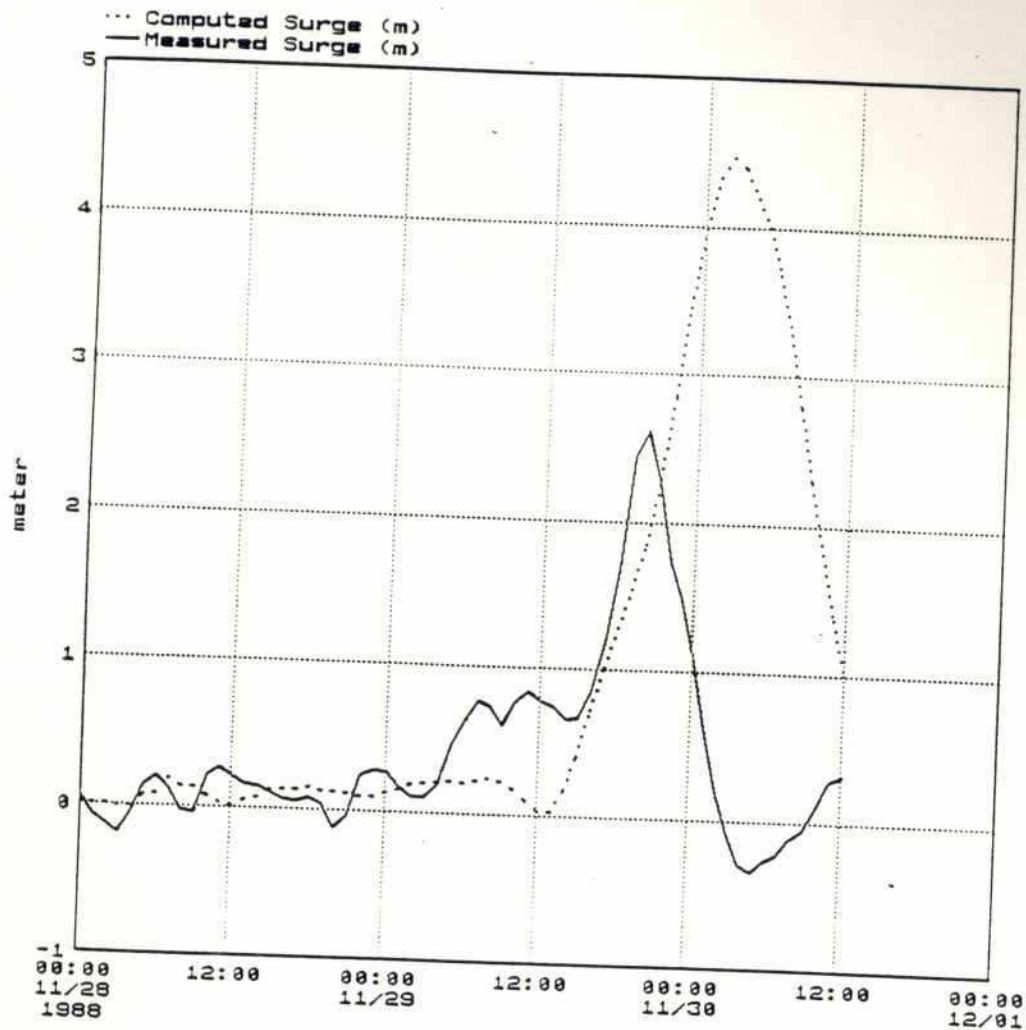
<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
File: family: n88 name : csad4 User: mnr Sun Nov 25 1998	November 1988 Sadargath (CTG) Measured and computed surge	Dwg. No.  4.247

1000



MIKE21	Cyclone Protection Project II	
File: family: n88 name : csan4 User: mnr Sun Nov 25 1998	November 1988 Sandwip Measured and computed surge	Dwg. No.  4.248





<b>MIKE21</b>	<b>Cyclone Protection Project II</b>	
<b>File:</b> family: n88 name : csun4 User: mnr Sun Nov 25 1990	November 1988 Sundarikota Measured and computed surge	<b>Dwg. No.</b>  4.249

