STUDY OF CURRENT CIRCULATION IN JAKARTA BAY

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ABSTRACT

Current circulation has a great influence to the existence of biota and human activities. Jakarta bay as one of the entering gate to the Jakarta, is one of the important waters in Indonesia and has too many changing in hydrodynamics conditions caused by nature and human activities.

A study of current circulation has been done in Jakarta bay to analyze the characteristic of its pattern due to season and local changing. The study shows that the current pattern in Jakarta bay generally influenced by seasonal variation.

1. Introduction

Current pattern that can describe the hydrodynamics of water condition has a great influence to the existence of biota and human activities. A Very big changing in hydrodynamics conditions will give a big change into the environment especially to the sensitive biota. Current circulation was influenced by many factors such as tides, surface wind, waves, etc.

Study about current circulation can be done by analyzing the data which are scattered in many stations in the same time and map it as general circulation. This method is very expensive because needed too many equipment and long period of observation. The alternative method can be done using the numerical modelling which is cheaper and more flexible because it needs can freely choose the time and location as we want. But in numerical modelling we also need some adjustment and preparations to set the initial values, boundary conditions and other specific parameters. And also, the result of this method should be compared and verified to the observation data.

Jakarta bay, as one of the entering gate to the Jakarta, is one of the important waters in Indonesia. According to this function, Jakarta bay has too many changing in hydrodynamics conditions caused by nature and human activities, the study of current circulation in Jakarta bay was very important.

2. Current, Wind and Tidal Data in Jakarta Bay

Current, wind and tidal data with one hour interval were collected from many stations located in Jakarta bay. The data were devided into two seasons, December - February for west monsoon and June - August for east monsoon. Some data have been already collected from Muara Karang, Pluit, Tanjung Priok, Marunda, and Karawang from different sources such as SEAWATCH buoy and manual observations.

Compilation from various data are processed using Admiralty analysis method during 15 days. From this analysis obtained tidal and non tidal current which is then compared to the observation current and wind condition.

3. Hydrodynamics Model

3.1. Governing Equations

The current circulation moddeling of Jakarta bay is done by solve the 2 dimension depth averaged-horizontal momentum and continuity equation in x and y direction as follows :

Momentum equation :

$$\frac{\partial U}{\partial t} + \frac{U}{H}\frac{\partial U}{\partial x} + \frac{V}{H}\frac{\partial U}{\partial y} + gH\frac{\partial \zeta}{\partial x} + rU\frac{\sqrt{U^2+V^2}}{H^2} - A_H\left[\frac{\partial^2 U}{\partial x^2} + \frac{\partial^2 V}{\partial y^2}\right] = \lambda\, w_x\sqrt{w_x^2+w_y^2} \qquad (4.1)$$

$$\frac{\partial V}{\partial t}+\frac{U}{H}\frac{\partial V}{\partial x}+\frac{V}{H}\frac{\partial V}{\partial y}+gH\frac{\partial V}{\partial y}+rV\frac{\sqrt{U^2+V^2}}{H^2}-A_H\left[\frac{\partial^2 U}{\partial y^2}+\frac{\partial^2 V}{\partial y^2}\right]=\lambda\, w_y\sqrt{w_x^2+w_y^2} \qquad (4.2)$$

Continuity equation :

$$\frac{\partial \zeta}{\partial t} + \frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} = 0 \qquad (4.3)$$

where :
A_H : horizontal turbulence coefficient [m^2/secon],
g : gravity acceleration [m/$secon^2$],
$H= h+\zeta$: the actual depth [m],
h : the depth of the waters which is measured from mean sea level to sea bottom [m],
r : coefficient of bottom friction,
t : time parameter [secon],
U : velocity transport in x direction = $\int_{z=-h}^{z=\zeta} u\, dz$ [m^2/secon],
u : velocity in x direction [m/secon],
V : velocity transport in y direction = $\int_{z=-h}^{z=\zeta} v\, dz$ [m^2/secon],
v : velocity in y direction [m/secon],
w_x : wind speed in x direction [m/secon],
w_y : wind speed in y direction [m/secon],
x : coordinate in west-east direction,
y : coordinate in north-south direction,
λ : coefficient of surface wind friction, and
ζ : water elevation [m].

The equations used in (4.1), (4.2), and (4.3) comprise of local change term, advection, pressure gradient, bottom friction, turbulence, and wind stress which is the assumptions used can be read completely in reference number [4].

3.2 Numerical Solution

The differential equations that described above can not be analytically solved but numerically and simulated using computer.

Equation (4.1), (4.2), and (4.3) solved using explicit method with numerical stability criterion as follows :

$$\Delta t = \frac{\Delta L}{\sqrt{gH}}\text{ , where } \Delta L = \text{minimum } [\Delta x , \Delta y] \qquad (4.4)$$

3.3. Model Design

The simulation of this hydrodynamics numerical model was done in two times, west and east monsoon respectively during 15 days tidal cycle. The model area of this simulation is Jakarta bay at 106^o 41' E to 107^o 02' E and 6^o 0' S to 6^o 08' S, with Tanjung Pasir in west boundary and Tanjung Karawang in east boundary.

The hydrodynamics parameter used in this simulation are coefficient of bottom friction (r) 0.1, coefficient of turbulence (A_H) calculated by total depth (H) and grid size $\Delta x=\Delta y=$, with time step (Δt) 4.0 secon based on the numerical stability criterion (4.4).

The initial values and boundary conditions used in this simulation are :

3.3.1. Initial Values

Initial values used in this simulation are assumption of calm condition without changing and disturbing in water surface and no current speed. Mathematically can be expressed as :

$$u = v = \zeta = 0 \qquad (4.5)$$

3.3.2. Boundary Conditions

The boundary conditions used are elevation at Tanjung Pasir in the west boundary, Untung Jawa island in the north west part, Damar island in the north middle part and Tanjung Karawang in the east boundary. And for velocity values at open boundary used the boundary condition below :

$$\frac{\partial \vec{V}}{\partial n} = 0 \qquad (4.6)$$

At close boundary along the coast line used semi slip condition. The normal velocity is equal to zero, whereas the tangential is calculated. Mathematically can be expressed as

$$\vec{V}_n = 0 \qquad (4.7)$$

4. Analysis

4.1. Tidal Current

From the analyzing of current data at Pluit on 7 - 21 January 1997 (Figure 3.1), non tidal current more dominant than the tidal current. This result can be shown from the comparison of current velocity component in x and y direction which is have significant different in amplitude and phase. In this case, the non tidal current has to be analyze to determine what kind of forces is dominant.

At Karawang on 2 -16 January 1997 (Figure 3.2a and 3.2b) seen that the tidal current has same direction as the total current with smaller magnitude. The x component of current velocity is more dominant compare to the y direction.

At Muara Karang on 3 - 17 August 1996 (Figure 3.3) seen that non tidal current more dominant compare to tidal current with the x component of current velocity is more dominant compare to the y direction.

In the west monsoon (December - February) which is represented by data processing on January seen that the current flows from southwest to the northeast with current speed 0.8 until 1.4 m/s. This condition was agreed with the wind direction from west to east with magnitude between 1 - 4.5 m/s.

On the other side, during the east monsson {June - August}, where the wind blow from east to west, the current flows from east to northwest with magnitude between 0.8 until 1.2 m/s. At Karawang shown that the dominant wind was blown from north-northeast to southwest with magnitude between 4.5 until 6 m/s. In the inner part of bay, which is represented by data from Muara Karang, seen that the influence from tides and wind is not too big. This condition might be happened because of the influence of the wave reflection from the shore line or might be because of the entering of the long wave to the bay. Other possibility is because of the density current from the Muara Karang power plant.

The interesting data shown in Figure 3.2b where the wind direction during the month almost the same to the south. This phenomena also happen to the current vector, where the dominant direction is to the west-northwest.

4.2. Simulation Result

The simulation result shown that the tidal current during spring flood condition flow from north of Tanjung Pasir to east with magnitude between 0.005 until 0.001 m/s (Figure 4.1). During spring ebb the current flow from offshore entering the bay with (Figure 4.2) with magnitude between 0.008 until 0.012 m/s. Figure 4.3 shown the current pattern during neap flood, where the current flow from north border of west part and turn left to the west pass trough Untung Jawa island with magnitude between 0.005 until 0.01 m/s. The same pattern occurs during neap ebb (Figure 4.4.) with magnitude 0.008 - 0.01 m/s.

5. Bibliography

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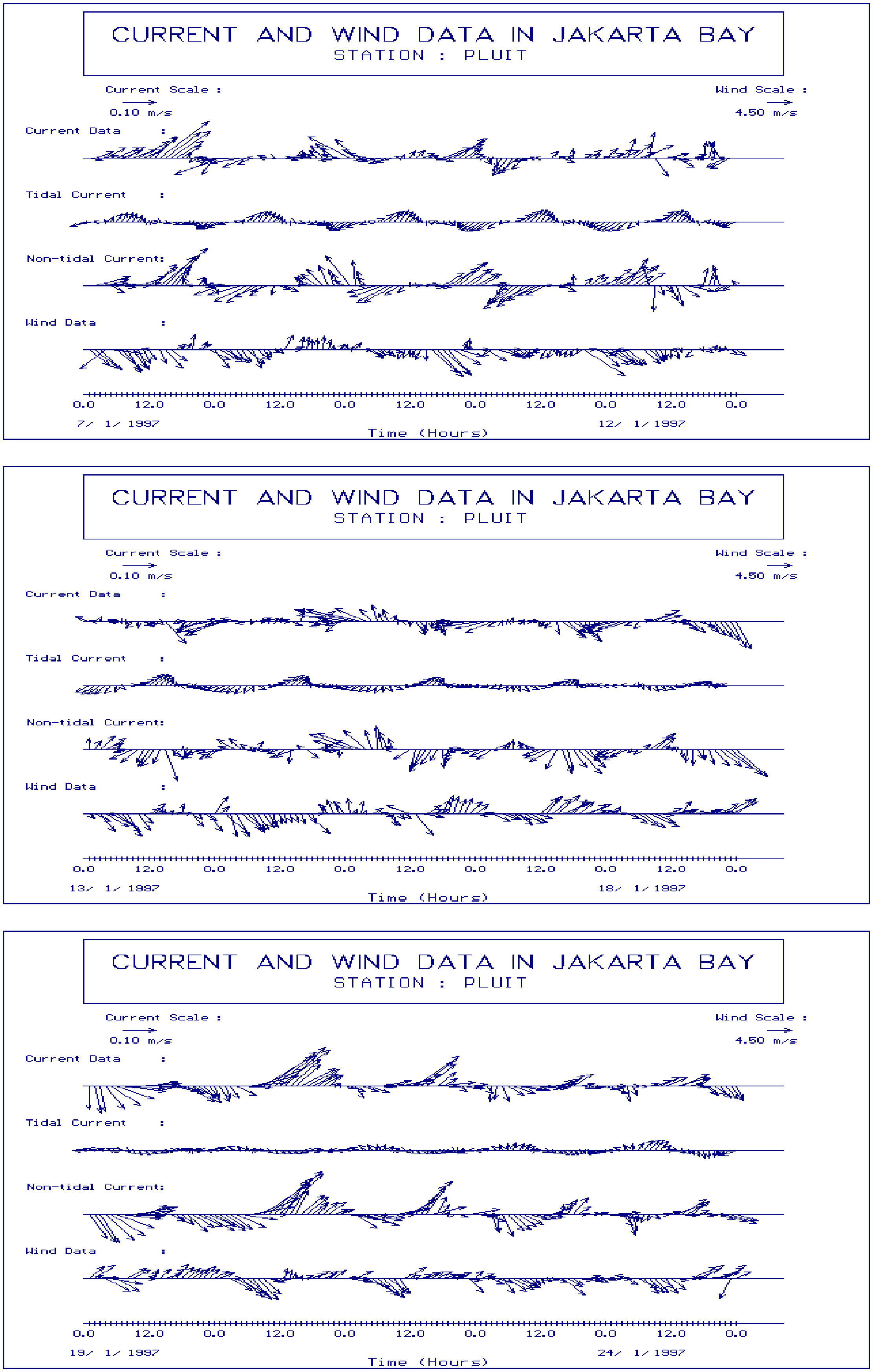


Figure 3.1 Vector of current data, tidal current, non-tidal current, and wind data in Jakarta Bay (a) January 7 - 12, 1997; (b) January 13 - 18, 1997; (c) January 19 - 24, 1997

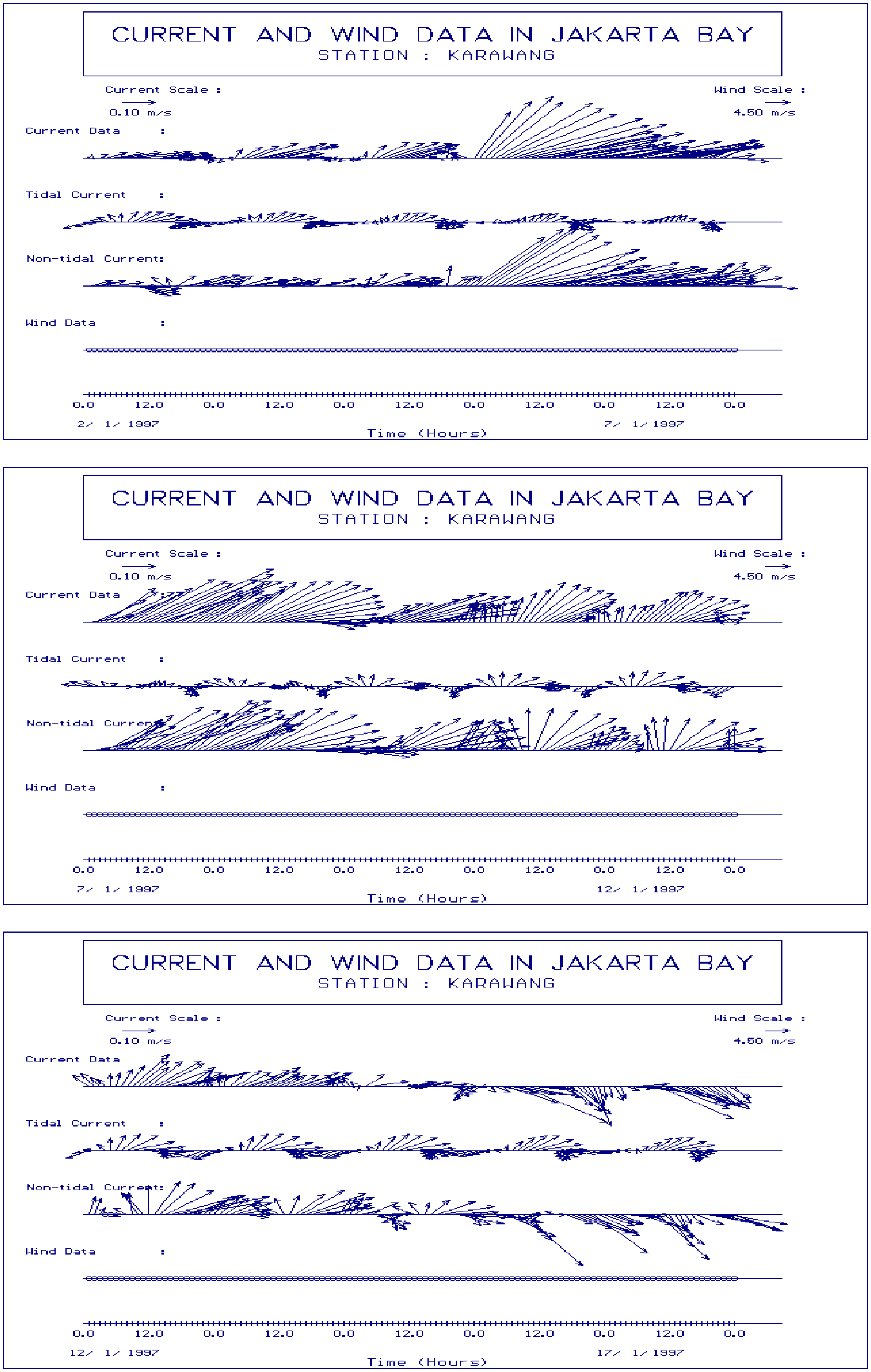
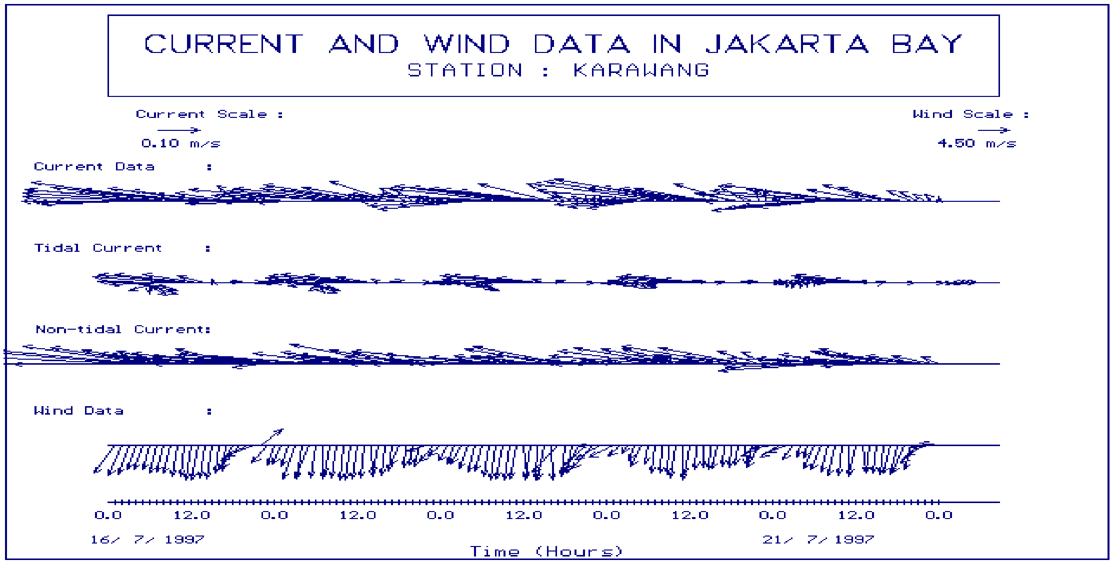
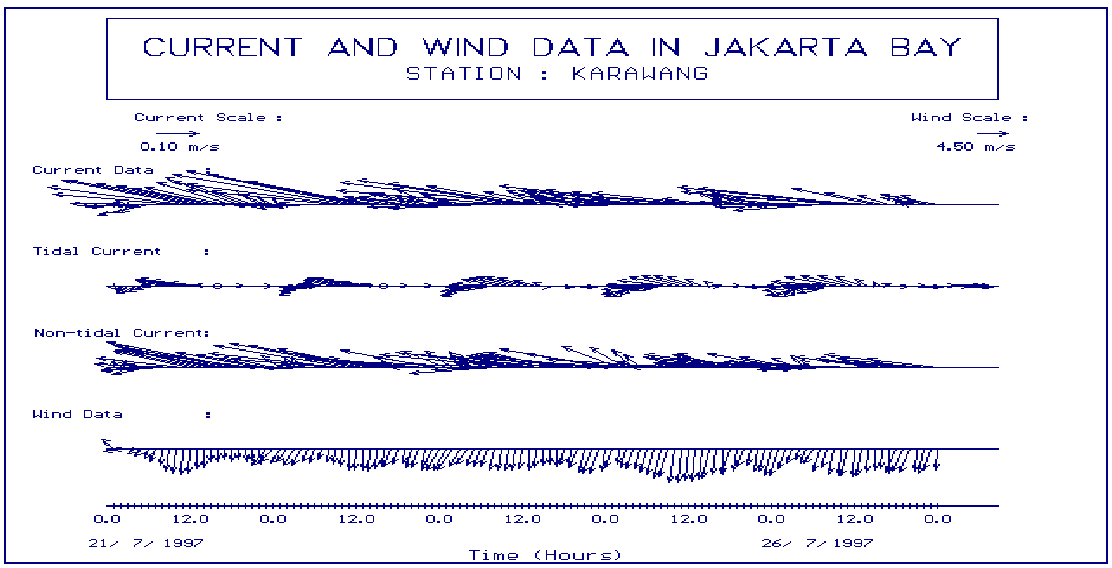


Figure 3.2a Vector of current data, tidal current, non-tidal current, and wind data in Jakarta Bay (a) January 2 - 6, 1997; (b) January 7 - 11, 1997; (c) January 12 - 16, 1997





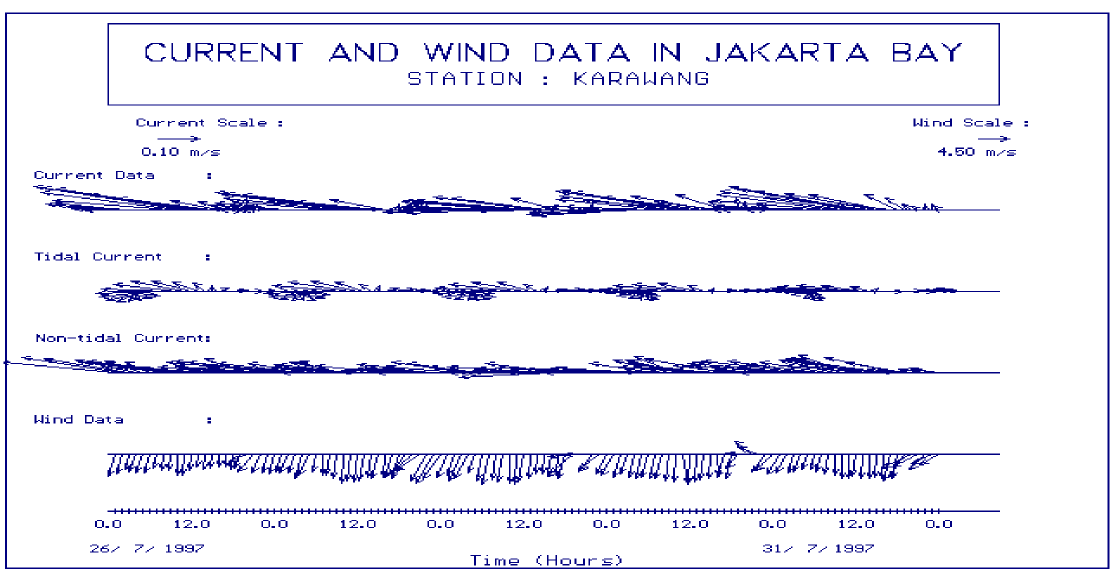


Figure 3.2b Vector of current data, tidal current, non-tidal current, and wind data in Jakarta Bay (a) July 16 - 20, 1997; (b) July 21 - 25, 1997; (c) July 26 - 30, 1997

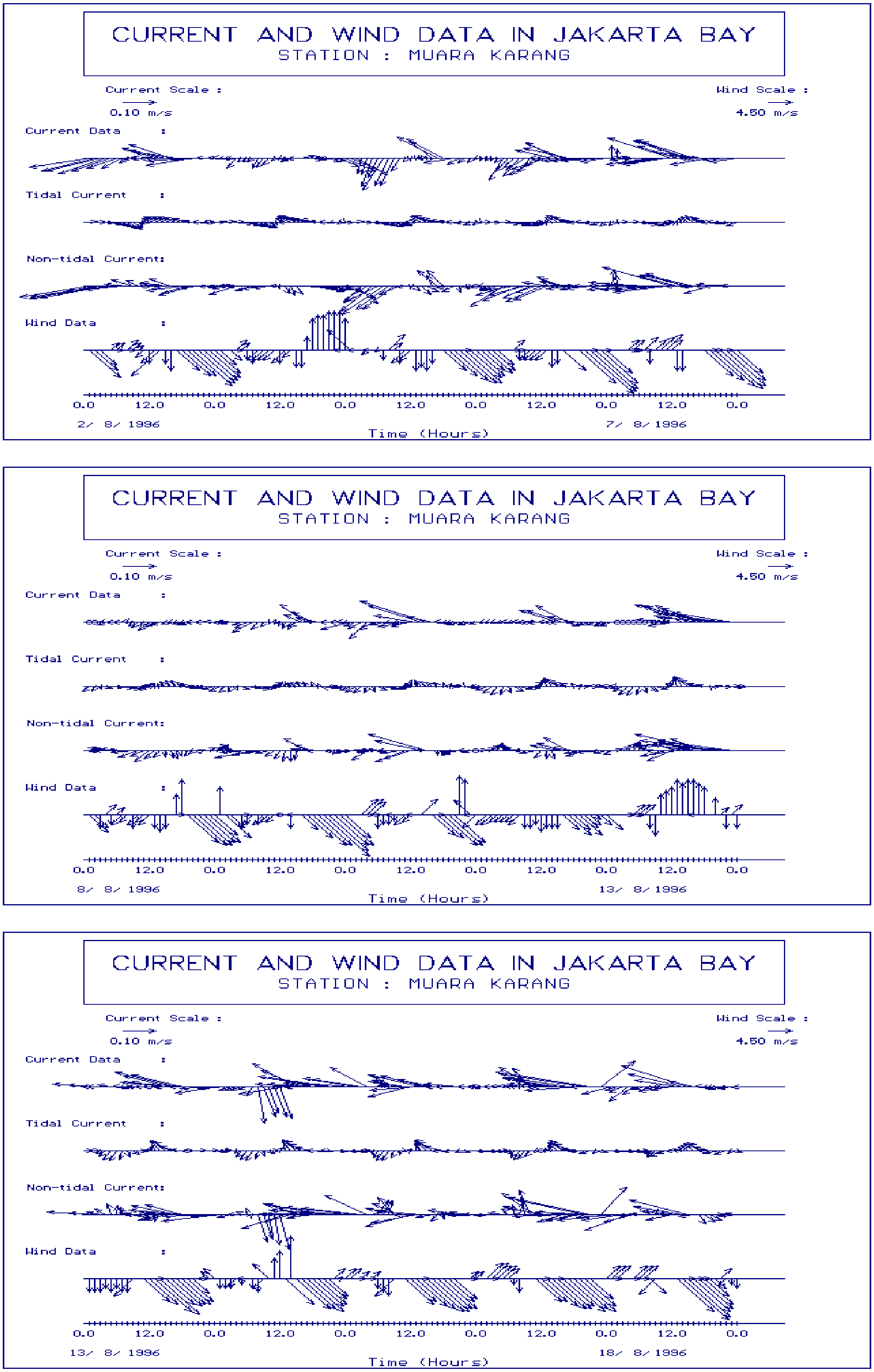


Figure 3.3 Vector of current data, tidal current, non-tidal current, and wind data in Jakarta Bay (a) August 2 - 7, 1996; (b) August 8 - 12, 1996; (c) August 13 - 17, 1996

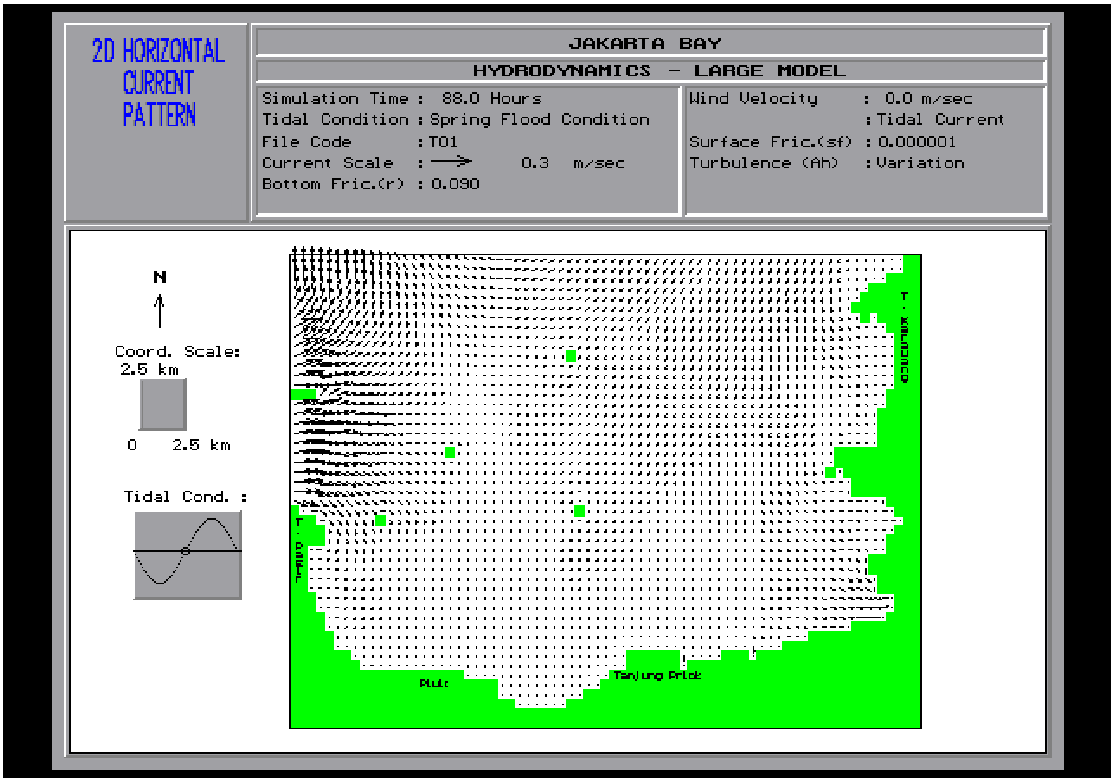


Figure 4.1 Tidal Current Simulation of Jakarta Bay 1 - 15 August 1994, Spring Flood Condition.

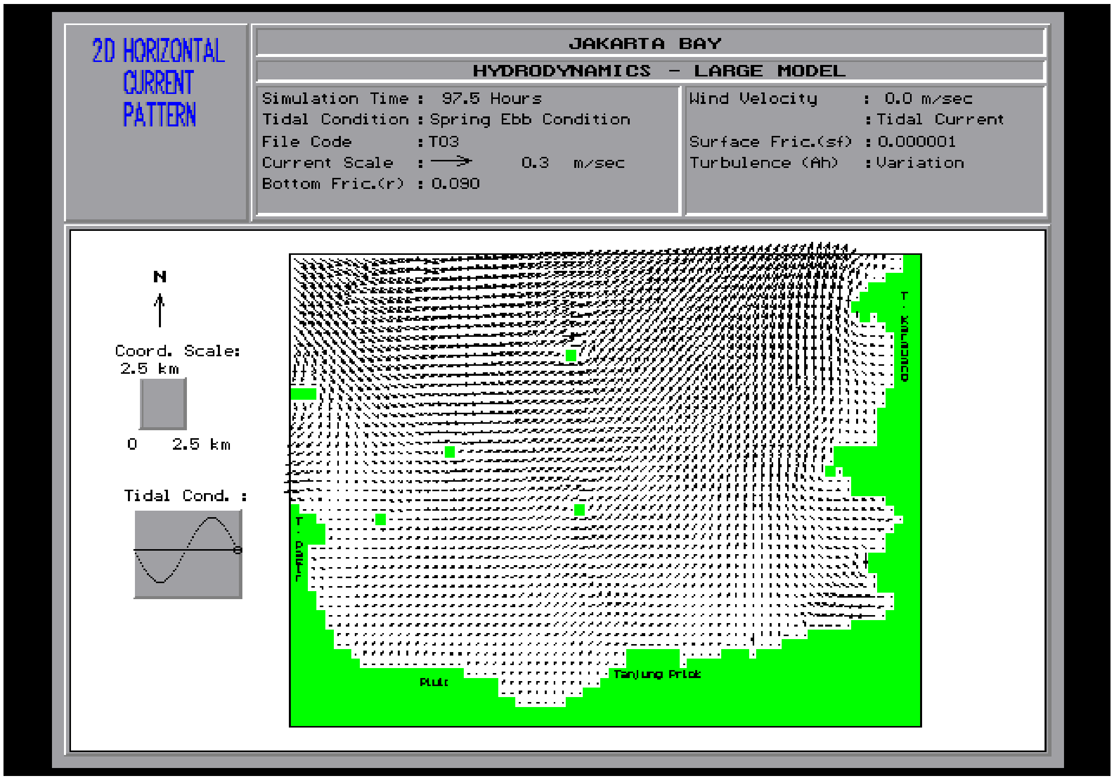


Figure 4.2 Tidal Current Simulation of Jakarta Bay 1 - 15 August 1994, Spring Ebb Condition.

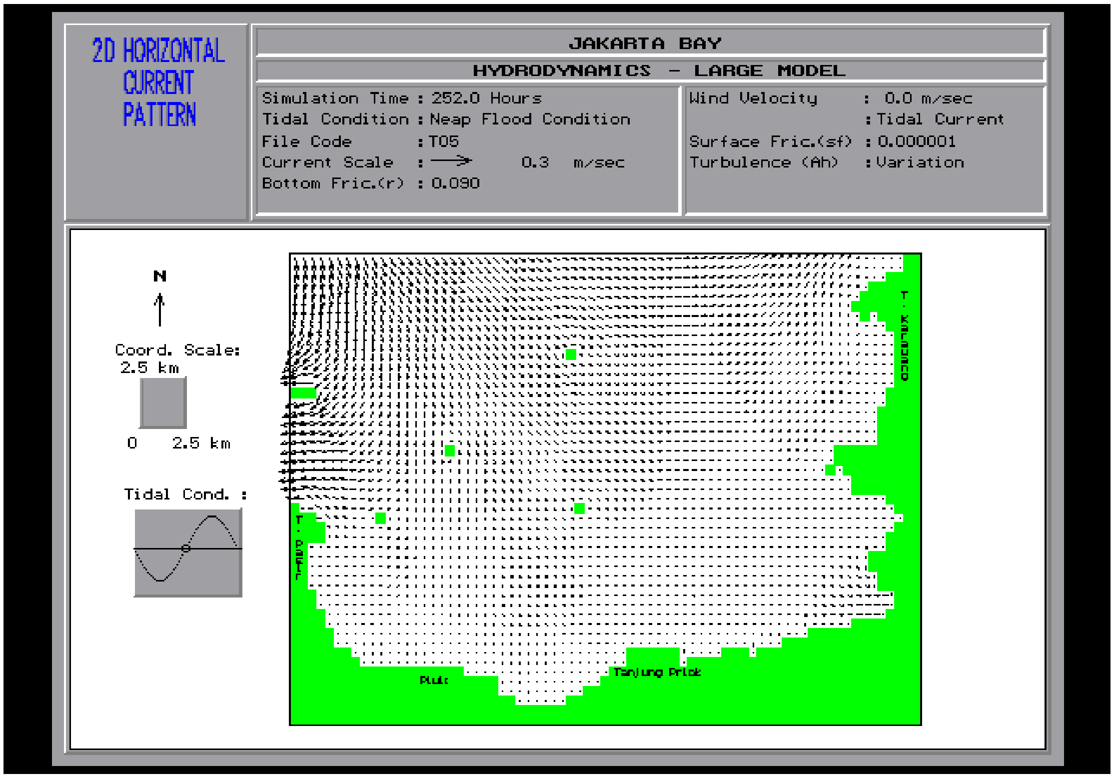


Figure 4.3 Tidal Current Simulation of Jakarta Bay 1 - 15 August 1994, Neap Flood Condition.

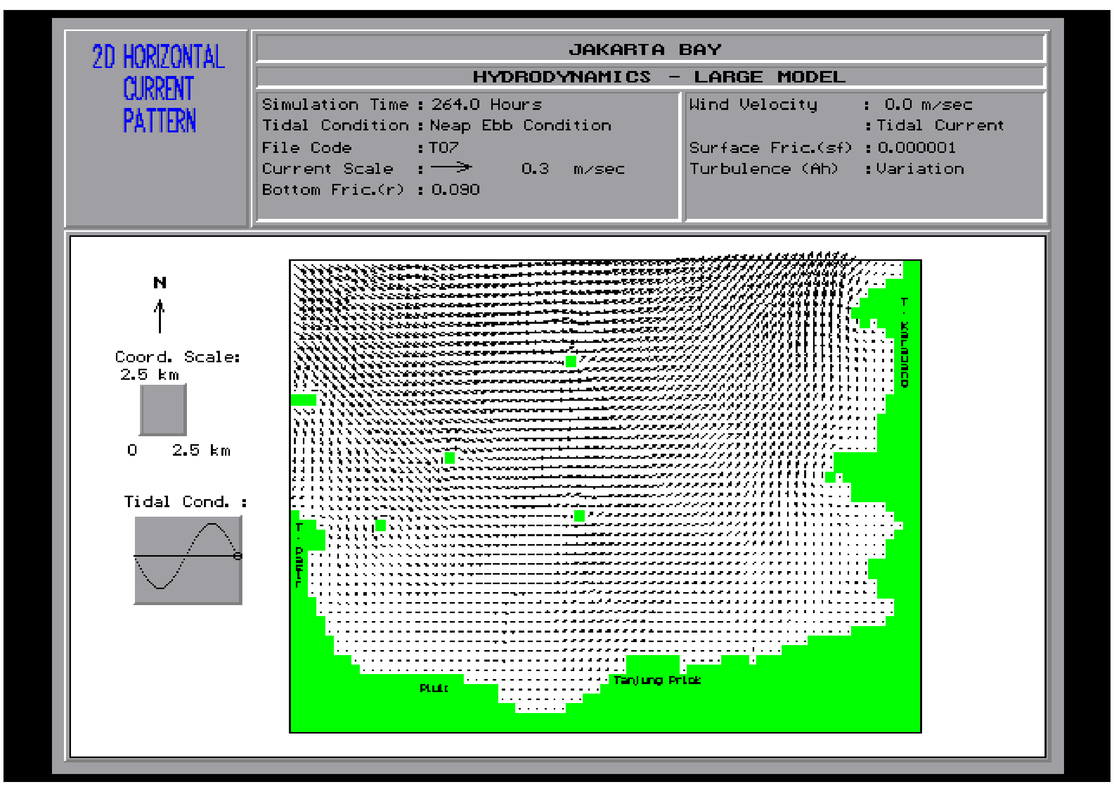


Figure 4.4 Tidal Current Simulation of Jakarta Bay 1 - 15 August 1994, Neap Ebb Condition.