颱風波를 基準으로한 全設計水深의 算定에 關한 研究

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A Study on the Calculation of Total Design Water Depth from Typhoon Waves

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CONTENTS

Abstract

Various typhoon data near Youngil Bay, Korea from 1961 to 1985 were collected with some criteria and analyzed with the help of the computer. Introducing the pressure profile models and predicting the typhoon wind and wave fields, the 100-year design wave parameters were calculated. Additionally, the wave data at the southeast coast of Korea were statistically analyzed.

The deep water wave climate of this bay indicated that Typhoon Brenda, 1985 had wave

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characteristics of 100-year return period. Typhoon model and storm surge model studies were made for this typhoon.

These, including other design parmeters, were introduced into the calculation of total design water depth.

要 約

컴퓨터를 이용하여 1961년에서 부터 1985년까지 한국 영일만 부근의 여러 颱風資料를 特定 設定 基準에 따라 수집하여 분석하였다. 壓力 斷面 모델을 도입하여 태풍에 의한 바람과 波浪海域을 예측하고 100년 設計波의 파라메타를 계산하였다. 또한 한국 남동해안의 波浪에 대한 자료를 통계적으로 분석하였다.

영일만에 대한 深海波分析으로는 1985년의 颱風 Brenda가 100년 回歸週期를 가진 것으로 나타나 태풍모델과 暴風海溢 모델을 통해 이를 조사하였다. 다른 設計파라메타와 함께 조사된 자료는 全 設計水深의 算定에 도입되었다.

1. Introduction

There is no doubt as to the destructive character of tropical storms, whereas an even more destructive and significant fraction of total storm damage is the storm generated surge and waves.

Storm surge and its impact of the coastal regions have been of interests to many researchers and engineers for a long time. It is a very inportant factor in producing barrier-island washovers and breaching. Especially, the storm surges have their greatest impacts in the coastal areas that experience such storms and are topographically low lying. During periods of extreme storm activity, low lying coastal areas may be flooded and overwashed by sea water.

The reliable estimates of the water level changes during the storm conditions are essential to coastal planning and design. However, the decision of water level elevations under storms is a complicate problem which is involved in the interaction between wind, water, differences in atmospheric pressure, and other effects unrelated to the storm.

The purpose of this study is to predict storm wave conditions with a numerical model by the analysis of the past typhoon data and to calculate the total water depth for design of a shore structure at the selected site. The selected site is the Youngil Bay, Korea.

2. Equations for Typhoon Parameter

Several references are available for the development of various hurricane models and how to choose a particular model based upon certain hurricane parameters. The important parameters which had shown a good agreement among the various models are : a) R_C', the radius of maximum cyclostrophic wind, b) P_{RC}, the pressure at the radius of maximum cyclostrophic wind, and c) $\left(\frac{rdP}{dr}\right)_{max}$, the maximum value of gradient of pressure multiplied by r.

2. 1. Equation for Pressure Profile Model

There are several pressure profile models from the various sources. Those are proposed by Schloemer (1954), Fujita (1962), Jelenianski (1966), Uji (1975), Schwerdt, Ho and Watkins (1979), Holland (1980), Bretschneider (1981, 1982), and Rosendal (1982), etc.

In general, these can be summarized as two main groups : 1) the modified Rankin Vortex Model by Holland (1980), of which the Hydromet Model is a special case, and 2) the BRET-General Model of which the BRET-X Model, the Fujita model and Jelenianski Model are all special cases.

The mathematical expression of these two groups are :

$$\frac{P_r - P_o}{P_n - P_o} = Ae^{-B\frac{R_c}{r}} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots (2.1)$$

and

$$\frac{P_r - P_o}{P_n - P_o} = 1 - \frac{1}{\left\{1 + a\left(\frac{r}{R_c}\right)^2\right\}^b} \quad \cdots\cdots (2.2)$$

where,

P_r = pressure at radial distance r,

P_0 = pressure at the center of hurricane,

P_n = pressure at infinite distance,

R_C = radius of maximum cyclostrophic wind.

The constants $A = \frac{1}{B}$ and $a = \frac{1}{b}$ must always be true in order to satisfy the mathematics of the cyclostrophic wind equation. Equation 2.1, proposed by Holland (1980), becomes the original Rankin-Vortex Model when $A = B = 1$.

Equation 2.2, proposed by Bretschneider (1981) after analysis of the pressure profile data, becomes the BRET-X Model when $a = \frac{1}{b} = 1$ and the same as Fujita model (1962) when $a = \frac{1}{b} = 2$ Table 2.1 presents the theoretical constant K for four hurricane models such as Hydromet Model, NOAA Model-I, Fujita Model-J, and BRET Model-X.

The parameter used to select hurricane models is non-dimensional Rankin-Vortex number, N_{CR} (Bretschneider and Lo, 1984). The original Hydromet Model is applicable for the low valuse of N_{CR} and for the higher values of N_{CR}, other models might be accepted as shown in Table 2.2. For this study BRET-X Model will be used due to the high latitude of the study site.

Talbe 2.1 Theorectical constants for Four Hurricanse Models

(*Pa : a : r density)

Model	$K=\frac{K_0}{\sqrt{C_1}}$		C_1	K(mb/inHG)
Hydromet Model-HM	$\frac{K_0}{\sqrt{e}}$	19.26	e	*11.68(68.00)*
		18.70		*11.34(66.00)*
NOAA(Report) Model-I	$\frac{K_0}{\sqrt{\pi}}$	19.26	π	*10.87(63.25)*
		18.70		*10.55(61.39)*
Fujita Model-J	$\frac{K_0}{\sqrt{\frac{2}{3\sqrt{3}}}}$	19.26	$\frac{2}{3\sqrt{3}}$	*11.95(69.56)*
		18.70		*11.60(67.51)*
BRET Model-X	$\frac{K_0}{\sqrt{2}}$	19.26	2	*13.62(79.28)*
		18.70		*13.22(76.74)*

Table 2.2 A suuggested Guide for selection of Model

Hydromet Rankin-Vortex Model	A=B=1 A=B=1.25(app.)	0.00< NCR <0.05 0.03< NCR <0.08
BRET Models	Fujita (b=0.5) BRET-X (b=1)	0.03< NCR <0.08 0.06< NCR <0.15

Table 2.3 A suggest parameter K for $\frac{fR}{U_R}$

$\frac{fR}{U_R}$	K'	$\frac{fR}{U_R}$	K'	$\frac{fR}{U_R}$	K'	$\frac{fR}{U_R}$	K'
0.000	7.50	0.065	5.49	0.15	4.50	0.28	3.65
0.005	7.25	0.070	5.42	0.16	4.42	0.29	3.60
0.010	7.05	0.075	5.34	0.17	4.34	0.30	3.55
0.015	6.85	0.080	5.27	0.18	4.28	0.31	3.50
0.020	6.70	0.085	5.20	0.19	4.18	0.32	3.45
0.025	6.55	0.090	5.13	0.20	4.10	0.33	3.40
0.030	6.40	0.095	5.06	0.21	4.03	0.34	3.35
0.035	6.25	0.100	5.00	0.22	3.97	0.35	3.30
0.040	6.10	0.110	4.88	0.23	3.91	0.36	3.26
0.045	5.95	0.120	4.76	0.24	3.85	0.37	3.23
0.050	5.80	0.130	4.66	0.25	3.80	0.38	3.20
0.055	5.70	0.140	4.57	0.26	3.75	0.39	3.17
0.060	5.60	0.150	4.50	0.27	3.70	0.40	3.15

2.2. Equations for Prediction of Hurricane Wind Fields

With the given parameters, latitude, R_C, P_O, P_n, and V_f, the forward speed of the translation of the hurricane, the prediction equation for maximum wind speed in hurricane is derived as follows. The first part of right-hand side is for stationary hurricane and the second for additional term for moving hurricane.

$$V_{max} = (A\sqrt{\triangle P_o} - \sqrt{\triangle P_o^*} + 77.66) + \frac{1}{2}\frac{A}{K}(V_f - fR_g - 6 \pm 5) \cdots\cdots (2.3)$$

where,

$A = 0.20994102\ P_n - 197.14532507$,

$\triangle P_o$ = the central pressure reduction from normal in inches of mercury, $P_n - P_0$

$\overline{\triangle P_o^*} = 0.08723763\ P_n - 81.66318854\ \sqrt{mbs}$,

K = constant depending on the choice of model as shown in Table 2.1,

V_f = forward speed of hurricane (knots),

f = coriolis parameter, $0.525 \sin\phi$, ϕ=latitude,

R_g = radius of maximum gradient wind.

The first part of the right hand side of Equation 2.3 is based on the analysis of published data from 319 Western Pacific Cyclones from 1971 to 1982 found in the corresponding Mariners Weather Log (1972-1983) and the second part is based on the analysis of 122 U.S. East Coast and Gulf Coast, where 6 ± 5 knots are the mean of the values and standard deviation respectively of $V_f - fR_g$.

Bretschneider (1982) recommended to use the following equation for the determination of most probable radius of maximum gradient wind.

$$R_g = R^* + \alpha V_f - K_1 B + K_2 C, \cdots\cdots\cdots\cdots (2.4)$$

where,

R^* = average value of R_g from data (n. miles), 18 n. miles,

$\alpha = 0.72$ (model case = 0.7, worst case = 1.0),

$B = \tanh\{3.17(\sin 35° - \sin\phi)\}$,

$C = \triangle P_0 e^{-\frac{\pi}{4}(\triangle P_0)^2}$

$K_1 = 22.0$,

$K_2 = 6.0$.

The non-dimensional stationary hurricane wind field by the balance of the pressure gradent, Coriolis, and centrifugal forces of the equation of motion is given in the form of ratio between wind speed at radial distances r and R from the hurricane center.

$$\frac{U_r}{U_R} = -\frac{1fRr}{2U_RR} + \sqrt{\left(1 + \frac{fR}{U_R}\right)\frac{R}{r}e^{\left(1-\frac{R}{r}\right)} + \left(\frac{1}{2}\frac{fR}{U_R}\frac{r}{R}\right)^2}, \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (2.5)$$

where the geostrophic wind speed U_R and the maximum sustained 10-minute wind speed at the 10-meter reference level U_{RS} are given by

$$U_R(\text{knots}) = K\sqrt{\triangle P_o} - \frac{1}{2}fR, \cdots\cdots (2.6)$$

where,

K = constant varies with latitude from 67 at 20°~25° Lat. to 63 at 45° Lat. (Bretschneider, 1972),

$U_{RS} = k^* U_r$ (knots)

$k^* = 0.865$ (Graham and Nunn, 1959).

For a moving hurricane, the stationary wind field is directly coupled with the corresponding model hurricane wave field and the change in the wind speed component to be corrected as

$$U^*_{RS} = U_{RS} + dU, \quad \cdots\cdots\cdots\cdots\cdots\cdots (2.7)$$

where dU equals to $\frac{1}{2} V_f \cos\theta$ and θ the angle of wind deflected from the direction of the incurvature angle of the wind speed.

2.3. Equations for Prediction of Hurricane Wave Fields

In general, the wave forecasting or hindcasting can be done either the significant wave method or the wave spectrum mothod. These methods are dedicated by Bretschneider, Burling, Hasselmann (JONSWAP), James, Moskowitz, Montogmery, Munk, Neumann, Pierson, Rossby, Silvester, Sverdrup, Wilson and so on. For this study, the recent Bretschneider's wave forecasting relationships for constant wind speed and direction, fully developed sea, and deep water will be used. The significant wave height H_S and significant wave period H_S are function of wind speed U, fetch length F, and wind duration t by use of the Buckingham's PHI-theory (1914) and the dimensional analysis as follows

$$\frac{gH_s}{U^2} = A_1 \tanh\left\{B_1\left(\frac{gF}{U^2}\right)^{m_1}\right\}, \quad \cdots\cdots (2.8)$$

$$\frac{gT_s}{2\pi U} = A_2 \tanh\left\{B_2\left(\frac{gF}{U^2}\right)^{m_2}\right\}, \quad \cdots\cdots (2.9)$$

$$t_{min} = 2\int_{0}^{F_{min}} \frac{1}{C_0}\,dx, \quad \cdots\cdots\cdots\cdots\cdots\cdots (2.10)$$

where,

$A_1 = 0.283$, $B_1 = 0.0125$, $m_1 = 0.42$,
$A_2 = 1.200$, $B_2 = 0.0770$, $m_2 = 0.25$,
U = 10-minute average surface wind speed at 10-meter above the water level,
C_0 = wave celerity in deep water.

The parameters and constants are based on foot scale.

The model wave height field for stationary hurricane developed by Bretschneider (1972) shows

$$H_R = K' \sqrt{R \triangle P_o}, \quad \cdots\cdots\cdots\cdots\cdots\cdots (2.11)$$

where K' is a function of $\frac{fR}{U_R}$ and can be obtained from Table 2.3. Significant wave height for moving hurricane with forward speed V_f should be modified by

$$H_c = H_R\left(1 + \frac{1}{2}\,\frac{V_f \cos\theta}{U_{Rs}}\right)^2, \quad \cdots\cdots (2.12)$$

where, θ is an angle between the direction of wind and the forward moving direction of hurricane. The model wave period field can be derived as follows after eliminating fetch term F, using the above coefficients and expressing U in knots and g as 32.2 ft/sec^2.

$$T_R = 0.4U_{Rs} \tanh\left\{1.07\left(\tanh^{-1} 40\frac{H_R}{U^2_{Rs}}\right)^{0.6}\right\}.$$

$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (2.13)$$

Modified significant wave period for moving hurricane shows

$$T_c = T_R\left(1 + \frac{1}{2}\,\frac{V_f \cos\theta}{U_{Rs}}\right)^2 \cdots\cdots\cdots (2.14)$$

and the forward speed can vary from $V_f = 0$ to $V_f = C_g = 1.515\,T_C$, where C_g is the group velocity of the significant waves. The upper limit of $V_f = C_g = 20$ to 25 knots (Bretschneider, 1986) after the hurricane moves faster than the waves it has generated, producing very confused seas, and the results might be in doubt. Thus, for calculation by a computer program in this study it is assumed that the forward speed $V_f = C_g \leqq V_C$, the critical forward speed.

All these calculations for significant typhoons passed by the Korean Peninsula since 1947 were done by the IBM PS/2 386 (20MHz) in order to predict the 100-year typhoon characteristics and results will be discussed later.

3. Calculation of the 100-Year Design Wave Parameters

3. 1. Description of Study Area

Youngil Bay is located at southern part of the east coast of Korean peninsula (36°-03′N, 129°-23′E) and has about 10Km width of bay entrance, an open northeastly to the East Sea (Japan Sea) and 15km length and a concaved form southwestly as shown in Figure 3. 1. Inside the bay, there are two harbors, Pohang Old Harbor and Pohang New Harbor. There is a river between these two harbors. This bay includes not only the industrial complex such as the Pohang Steel Company and its sub-industrial companies which are the vital part of the heavy-chemical industry development of Korea but also Songdo Beach which gives a rest place for the civilians and a resort area for the tourists.

The depth is abruptly decreasing from the open sea to the bay. The average depth of the bay is 21m and the distribution of the contour lines is similar to the shape of the bay. Bottom profile at the cross-section A-A′ shows Figure 3. 2. The bottom profile had been changed significantly year by year and is still changing due to the dredging work in connection with the construction of a new harbor to assist the industrial complex. Moreover, since 1970 the site has frequently been exposed to beach erosion and damages on the shore structures from severe storms.

3. 2. Calculation of Typhoon Parameters

In order to calculate typhoon parmeters typhoon data were collected in three steps :

a) all typhoons which were within 325 n. miles (CPTT; the Closest Point of Typhoon Track) from the study site between 1961 and 1985 were collected to calculate V_C and R_C with models decided by Rankin-Vortex Number (N_{CR}) as described in Chapter 2.

b) pressure (P_0), latitude (ϕ), forward speed (V_f) and maximum wind (V_{OMAX}) were collected at locations which the closest point to the study area keeping the typhoon intensity, within 350 n. miles (CPTI; the Closest Point of Typhoon Intensity).

c) to get the worst situation from the data recorded, it is assumed that the typhoon intensity continues to CPTT.

Figures 3.3 and 3.4 show the steps a) and b) and the distribution of typhoons is shown in Figure 3.5. Calculation was performed with the computer program developed and the result shows the relationship between H_S and T_S for the stationary and moving cases in Figure 3.6. The 100-year design typhoon wave height was predicted from the typhoon data within 110 n. miles of CPTT.

There are several distributions to calculate a return period such as normal, log-normal, Weibull and Gumbel. Gumbel's first asymptotic distribution has been used extensively to forecast the extreme values of certain environmental parameters. Gumbel's first asymptotic distribution is used to determine the return period for this study.

The result of calculation is shown in Figure 3.7. The line of best fit for Gumbel's distribution by least square method shows

$$H_S = 2.405Y + 23.890, \quad Variance\ of\ Fit = 11.2581, \cdots\cdots (3.1)$$

where, $Y = -ln\{-ln\,P(H_s \le h)\}$ and $P(H_s \le h)$ is the cumulative probability of being the yearly maximum based on 13 observations in 23 years. As shown in Figure 3.6, typhoon Brenda which has 35.32 ft of significant wave height is close to the 100-year return period typhoon. Thus, all parameters of Brenda are used for the prediction of the 100-year design typhoon wave.

The observed pressure profile data of typhoon Brenda from the National Weather Service Forecast Office, Honolulu, Hawaii was introduced to draw the pressure profile P_r, pressure gradient profile $\frac{dP}{dr}$ and $r\frac{dP}{dr}$ profile. The data profiles and the model profiles with Bret-X model are compared in Figure 3.8. R_C by the Bret-X model is 35.09 n. miles and the observed R_C is 37.5 n. miles.

The predicted wind, wave height, and wave period fields for the typhoon Brenda from the computer model are shown in Figures 3.9 through 3.11. Figures 3.12 through 3.14 show the cross sectional views at some distance from the typhoon center.

3.3. Analysis of S. S. M. O. and Hogben & Lumb's Wave Data

Two sources of wave data were used in this analysis. They were the U. S. Weather Service, "Synoptic Summary of Meteorolgical Observation (S. S. M. O.)", Vol. 9, Area 29 and Hogben and Lumb's "Climatological and Oceanographical Atlas for Mariners", Vol. II, Area 13, 1961. The observed wave height data near the study site (S. S. M. O.; 2745 observations, Hogben & Lumb; 2934 observations for 8 years) were collected. The data were analyzed in terms of all seasonss and all directions.

With some calculations the significant wave height in feet, occurrence per year were derived and plot of this shows

Figure 3. 15. By Gumbel's first asymptotic distribution the 100-year return wave hight of both data shows Figure 3. 16 and the line of best fit for Gumbel's distribution by least square method shows

$H_S = 2.947Y + 18.010,$

$\text{Variance of Fit} = 84.3808.$ ···(3. 2)

These are lower than the 100-year design typhoon wave because these data were based upon the observations made by ships in passage and such ships tended to avoid the bad weather when it was possible. Thus, from now on, throughout this study, Typhoon Brenda as an example of the 100-year design typhoon will be used to calculate the design parameters.

4. Calculation of Total Design Water Depth

The total design storm water depth at the design area can be determined from the following equation

$D_t = D_{MLLW} + A_s + S_p + S_x + S_y + S_w$ ··(4. 1)

where,

D_t=total water depth,

D_{MLLW}=mean lower water level (MLLW)

A_s=astronomical tidal range,

S_p=pressure tide, $S_p = 1.12R\triangle P$ and R, the response factor,

$\triangle P$=atmospheric pressure reduction from normal, in inches of mercury,

S_x=wind tide (direct wind stress tide),

S_y=wind tide (Coriolis tide)

S_w=wave set up.

The factor *1. 14* converts in. of mercury into ft. of water and other parameters are in ft. Without various assumptions the above equation can't be solved by linear addition because of a time dependency. Some of the terms coupled with second-order effects that most have with the other terms in shallow water.

Depth at MLLW (D_{MLLW})

We assume that the location of a shore structure at the Youngil Bay is at 5m water depth in reference to a MLLW datum and 300m away from the beach through the investigation of charts.

Astronomical Tide (A_s)

The tidal tables which are published annually by the National Ocean Survey and the Hydrographic Office of Korea are showing that 8. 6cm of a mean tidal range and 10. 4cm of a spring of tidal range occur at Youngil Bay. Compared with those of the west coast of Korea, these are very low. The 10. 4cm of astronomical tide will be used in the design water level computation.

Pressure Tide (S_P)

A general rise in water level caused by atmospheric pressure reduction from normal, due to the typhoon system in this syudy, can be obtained by

$$S_p = 1.14R\triangle P\left(1-e^{-\frac{r}{R_c}}\right), \cdots\cdots\cdots\cdots\cdots(4.2)$$

where r is 45 n. miles and R_C is 35. 09 n. miles.

In case of the typhoon is moving at a forward speed V_f, and for a completely undamped system, the response factor R takes on the following form

$$R=-\frac{gh}{(V^2{}_f-g\triangle h)} \cdots\cdots\cdots\cdots\cdots\cdots (4.3)$$

The elevation becomes very great and there is a resonace. But the frictional and damping factors will prevent a complete free resonance. Thus,

$S_P=1.14(1)(1-e^{-1.28})=0.4ft\ (12.19cm)$.

From the computer simulation for typhoon Brenda this can be derived.

Wind Setup $(S=S_x+S_y)$

The rise in water level caused by the wind stress component directed perpendicular to the coast, wind tide S_x, is a function of wind speed, direction and water depth.

The most significant wind direction at Youngil Bay is WSW which is 51.7% of al wind directions. The next one is NNE direction. N, NNE and NE directions are 23.1% and the rest, 25.2%. Among the wind directions over 10m/sec of wind speed, NNE wind is 40.2% of all directions and N, NNE and NE winds, 67.8%, whereas W, WSW and SW winds are only 25.3%.

The rise (or drawdown) of water level due to the wind stress component parallel to the coast, Coriolis tide S_y, caused by a current following parallel to the coastline. S_y can exist in the absence of any wind when a hurricane has no wind.

With the assumption for bathystrophic approximation, quasi-steady state (nearly constant wind speed) and constant bottom slope, the following equations for S_x and S_y devleloped by bretschneider (1967) are applicable to determine the wind setup near the coastline.

$$S_x=kU^2\frac{\cos\theta'}{g}G_o, \cdots\cdots\cdots\cdots\cdots\cdots (4.4)$$

$$S_y=\frac{6}{7}\frac{fUF}{g}\sqrt{\frac{k}{K'\sin\theta'}}D_o^{\frac{1}{6}}, \cdots (4.5)$$

where,

$$G_o=\frac{F}{D_o-(D_c+S)}\ln\left(\frac{D_o}{D_c+S}\right),$$

k=surface wind stress parameter, 3.0×10^{-6} (Saville)

K'=bottom friction parameter, 10^{-2} (shallow water),

θ'=direction of wind, angle from the line perpendicular to the coast,

S=total wind setup,

D_0=breakoff end of the slope at the edge of the continental shelf,

D_C=depth at the coast.

G_0 is solved as a function of fetch distance offshore, corresponding water depth, and an arbitrary water depth near the shoreline. Based on the bottom profile as Figure 3.2, it was assumed that $D_0+S=1.5m$. computation of G_0 shows Figure 4.1 and a maximum G_0 of 0.232(n. miles/ft) was determined at a distance offshore of 13n. miles corresponding to a water depth D_0 of 66m (216.5ft).

Computer program uses above equations for S_x and S_y to calculate the wind setup (S). However, we can use modified equations

$$S_x = 6080\frac{h}{g}\,\frac{U^2}{30}\cos\theta\, G_o$$

$$= 1.456\frac{U^2}{30}\cos\theta\, G_o$$

and

$$S_y = 0.05490\frac{U}{30}\sin\phi\, D_o^{\frac{1}{6}}\sqrt{\sin\theta}$$

$$= \pm 0.1940\frac{U}{30}\sqrt{\sin\theta},\ at\ \phi = 36.0°N$$

$$= \pm 0.1719\frac{U}{30}\sqrt{\sin\theta},\ at\ \phi = 31.4°N.$$

The value of S_y differed slightly for two different latitudes and the value for 31.4°N was chosen to calculate wind setup. Calculated manimum wind setups by the computer at 45n. miles of CPTT for Brenda are 41.64cm for S_x and -7.96cm for S_y.

Wave Setup (S_W)

As deep water waves encounter a sloping shelf, they become short, steep and finally break, while travel forward after breaking. The increase in the mean stil water near the beach due to the effect of breaking waves is known as wave setup. The computer simulation shows the maximum wave setup at the study srea as 137.16cm (4.5ft) as shown in Figure 4.2.

Summary of Total Design Water Depth (D_t)

Again the resultant total design water depth is

$$D_t = D_{MLLW} + A_s + S_p + S_x + S_y + S_w;$$

$$= 5.0000 + 0.1040 + 0.1219 + 0.4164 - 0.0796 + 1.3716 \approx 6.93m.$$

Figure 4.3 shows the observed sea surface fluctuation during the passage of typhoon Brenda. The mean tide level at Youngil Bay is 12.0cm from the datum level. On October 6, the maximum storm surge was recorded with 32.0cm from the mean tide level. If this was recorded at the ebb tide, the maximum will be 42.4cm. This value is very close to the value of the predicted storm surge, 45.1cm. Table 4.1 shows an example of the calculation of the storm surge.

5. Summary and Discussions

Various typhoon data since 1961 for the study site were collected and analyzed with some criteria. Derived parmeters were introduced into calculation of total design water depth. The method used in this study for determination of typhoon parameters is limited to a hurricane or typhoon intensity whose moving speed equals to or less than its critical forward speed. Thus, those typhoons faster than this limit need further study.

Storm surge inside the Youngil Bay will be higher than the calculation because of the concaved shape of the bay and the seiche motion.

This study gives the methods for calculating typhoon winds, waves and total design water depth. In order to create a final and optimum design, more study on the environmental condition such as the current and near shore littoral process supported by the hydraulic model experiment, and a rigorous economic analysis should be followed. Moreover, we need steps for shallow water design wave and wave run up calculations. This is beyond the scope of this study and this will be followed by the next paper.

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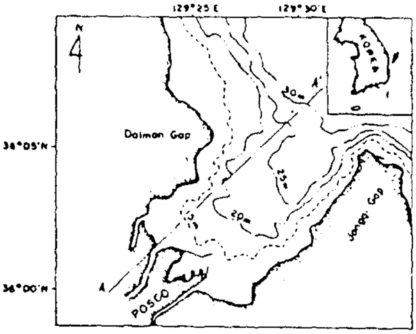


Figure 3.1 Location of the Study Site and Depth Profile

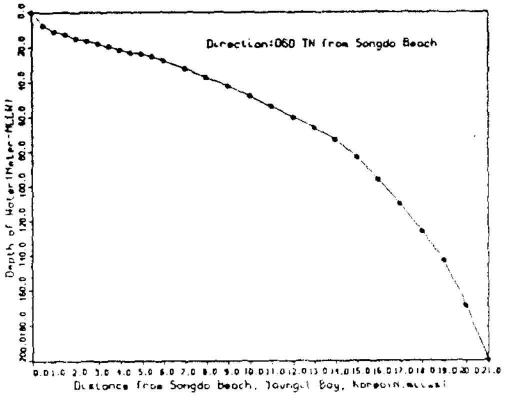


Figure 3.2 Bottom Profile in and Out of Youngil Bay, Korea

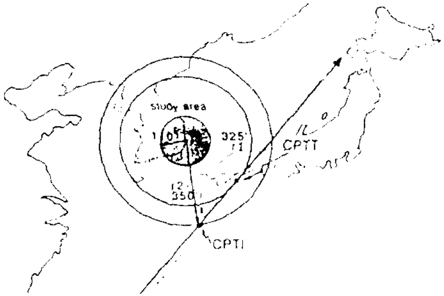


Figure 3.3 Typhoon Data Collection from 1961 to 1985

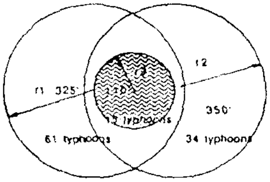


Figure 3.4 Selection of Typhoons to Calculate the Return Period

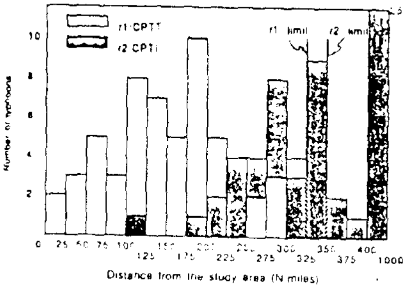


Figure 3.5 Distribution of 61 Typhoons

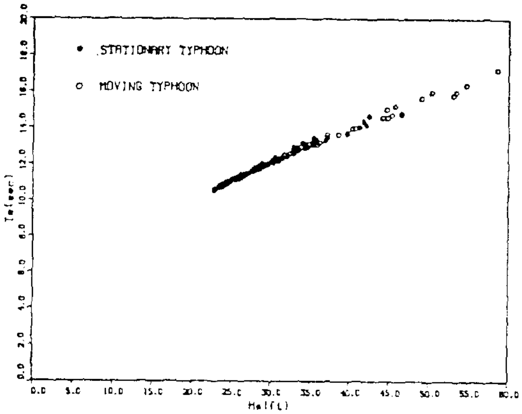


Figure 3.6 Relationship between H_S and T_S for Stationary Case and Moving Case

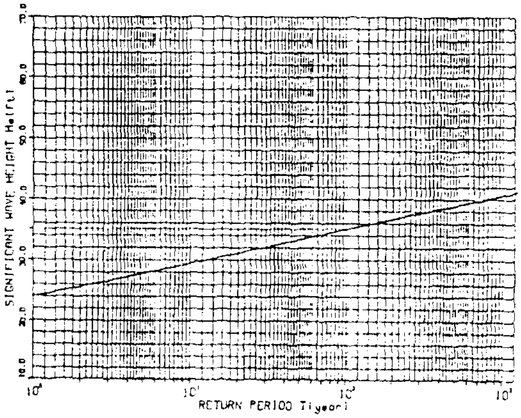


Figure 3.7 Plot of the Significant Wave Height versus Return Period from Analysis of Typhoon Data

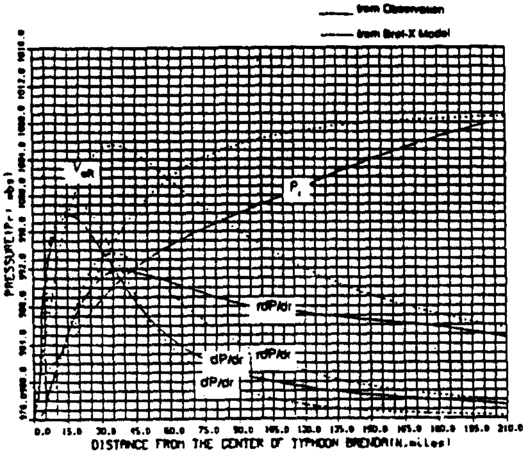


Figure 3.8 Plot of Typhoon Brenda (1985) Parameters from Observation and Bret-X Model

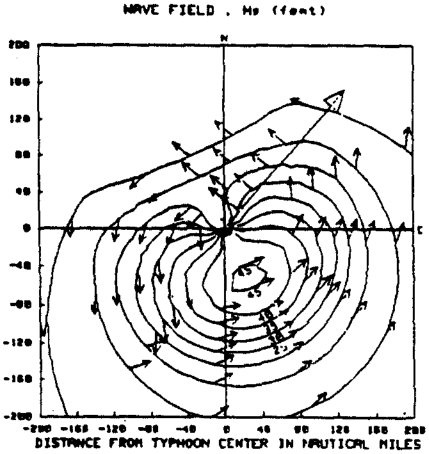


Figure 3.10 Calculated Wave Height Field for Typhoon Brenda

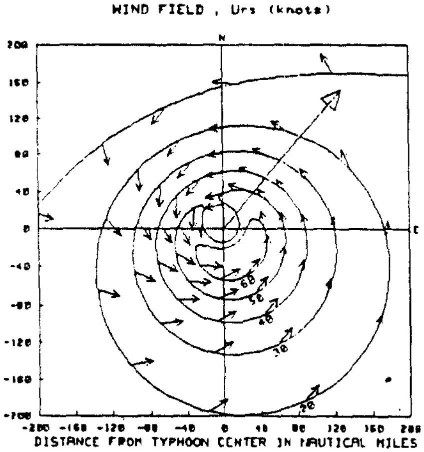


Figure 3.9 Calculated Wind Field for Typhoon Brenda

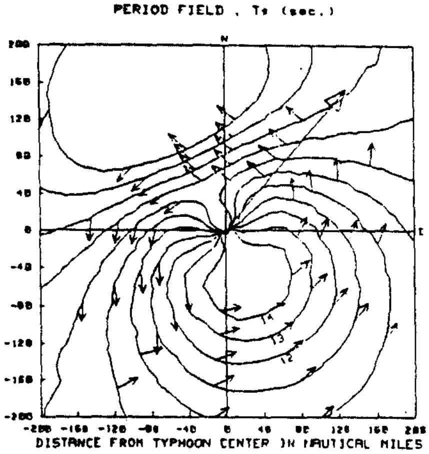
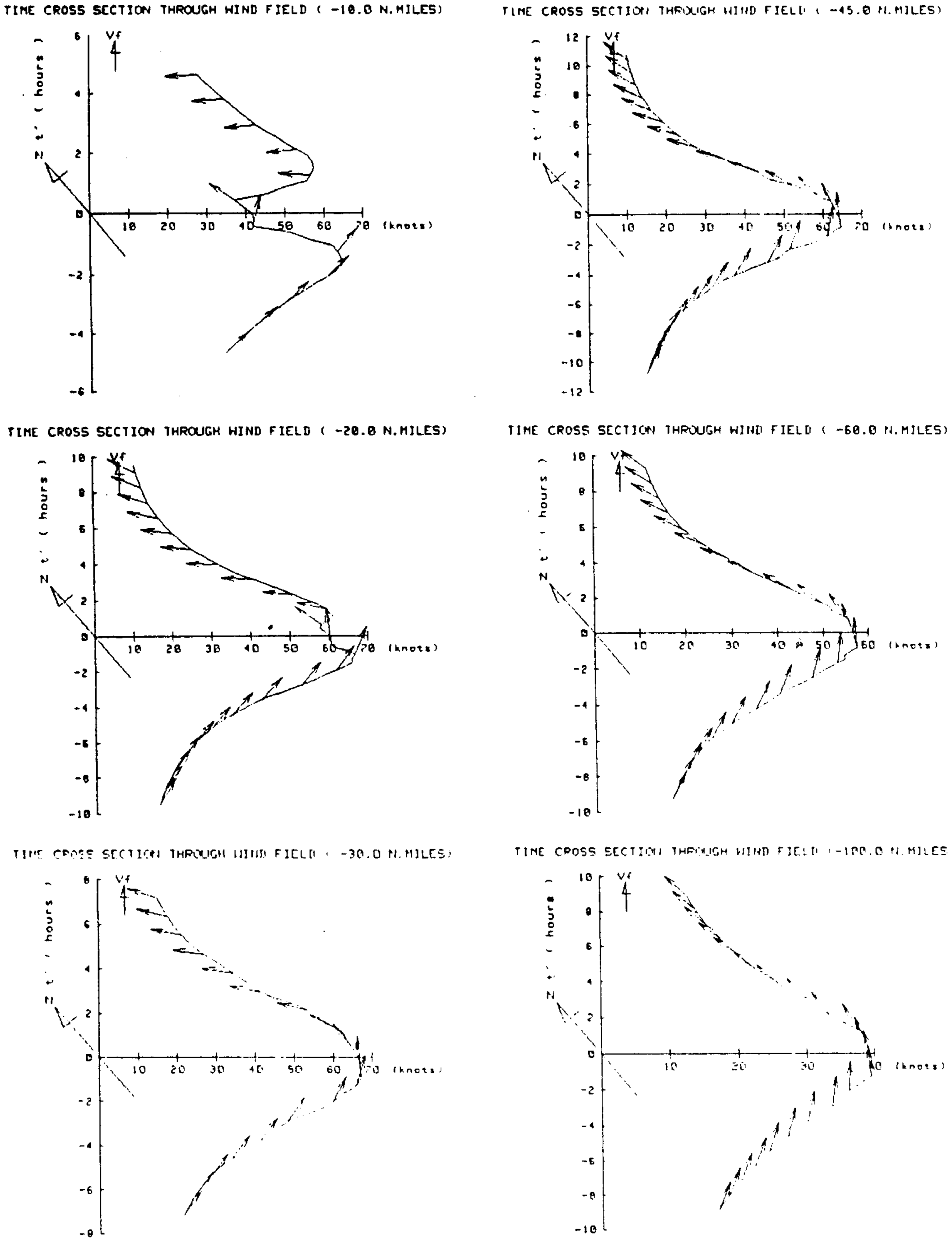


Figure 3.11 Calculated Wave Period Field for Typhoon Brenda


TIME CROSS SECTION THROUGH WIND FIELD (-10.0 N.MILES)

TIME CROSS SECTION THROUGH WIND FIELD (-45.0 N.MILES)

TIME CROSS SECTION THROUGH WIND FIELD (-20.0 N.MILES)

TIME CROSS SECTION THROUGH WIND FIELD (-60.0 N.MILES)

TIME CROSS SECTION THROUGH WIND FIELD (-30.0 N.MILES)

TIME CROSS SECTION THROUGH WIND FIELD (-100.0 N.MILES)

Figure 3.12 Time Cross Sections through the wind Field

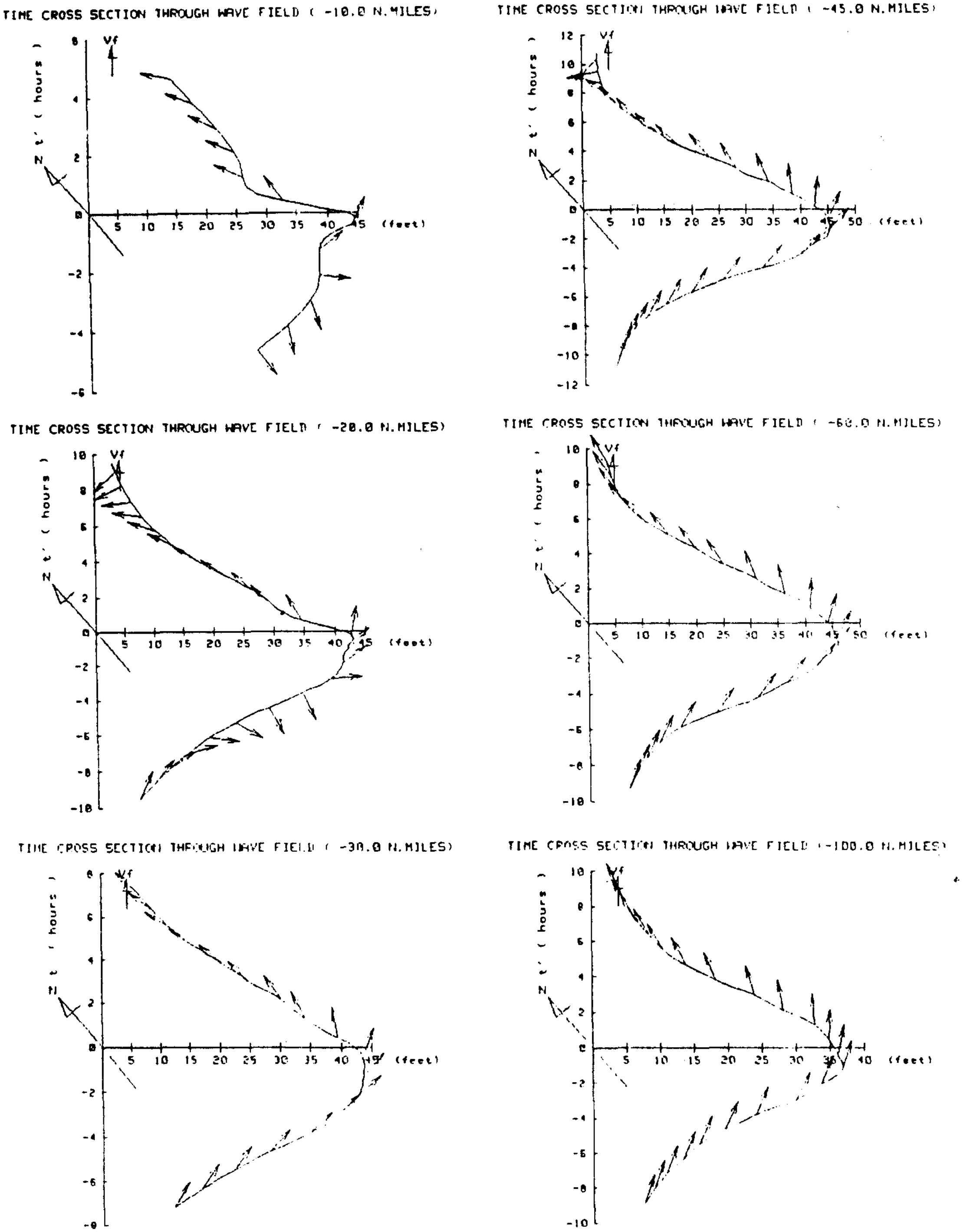
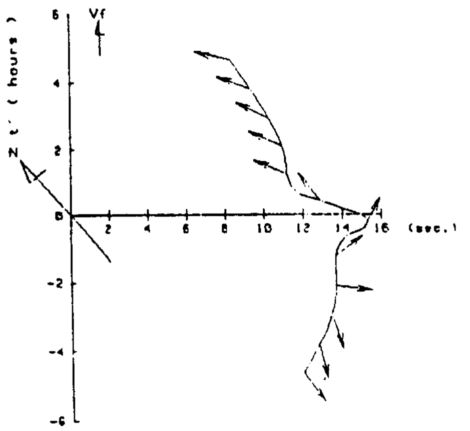
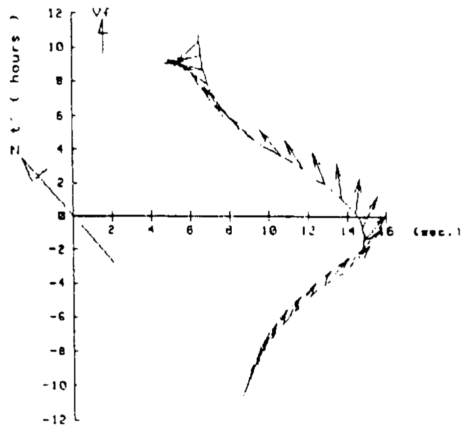


Figure 3. 13 Time Cross Sections through the wave Height Field

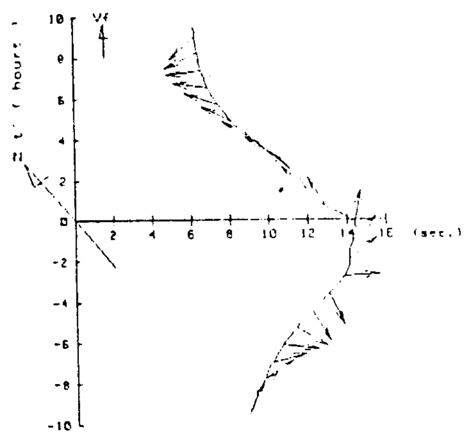
TIME CROSS SECTION THROUGH PERIOD FIELD (-10.0 N.MILES)



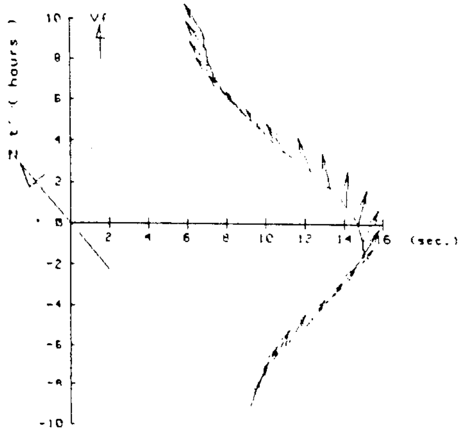
TIME CROSS SECTION THROUGH PERIOD FIELD (-45.0 N.MILES)



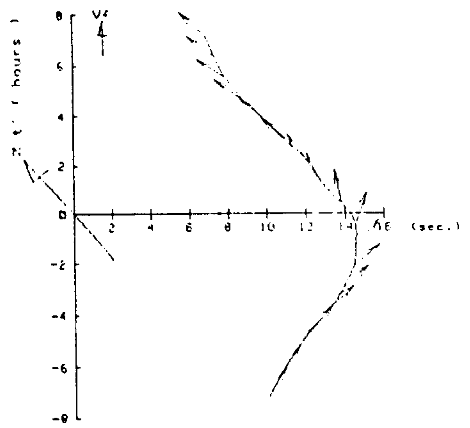
TIME CROSS SECTION THROUGH PERIOD FIELD (-20.0 N.MILES)



TIME CROSS SECTION THROUGH PERIOD FIELD (-60.0 N.MILES)



TIME CROSS SECTION THROUGH PERIOD FIELD (-30.0 N.MILES)



TIME CROSS SECTION THROUGH PERIOD FIELD (-100.0 N.MILES)

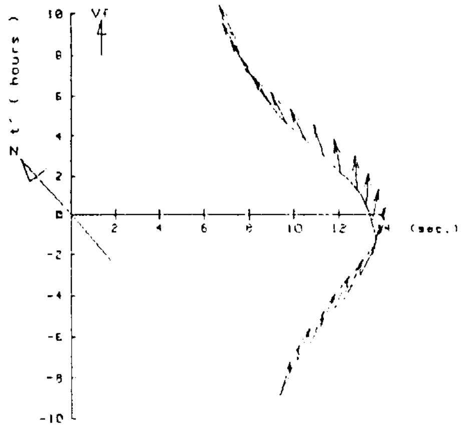


Figure 3.14 Time Cross Sections through the wave Period Field

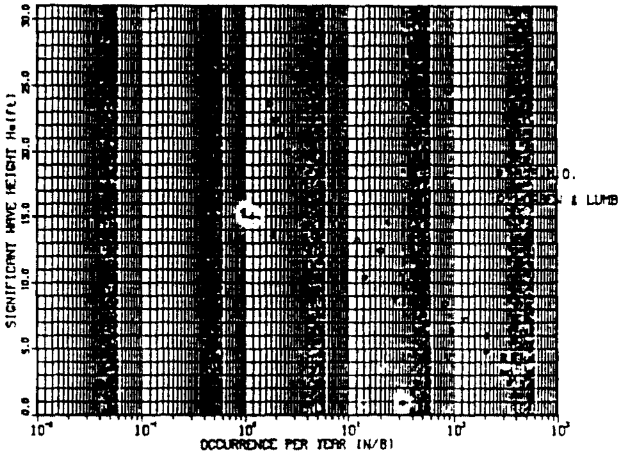


Figure 3.15 Occurrence per Year versus Significant Wave Height from S.S.M.O. and Hogben & Lumb's Data

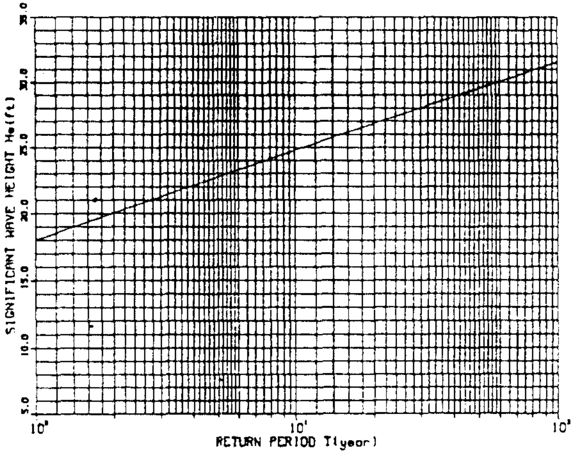


Figure 3.16 Plot of the Significant Wave Height Versus Return Period from S.S.M.O. and Hogben & Lumb's Data

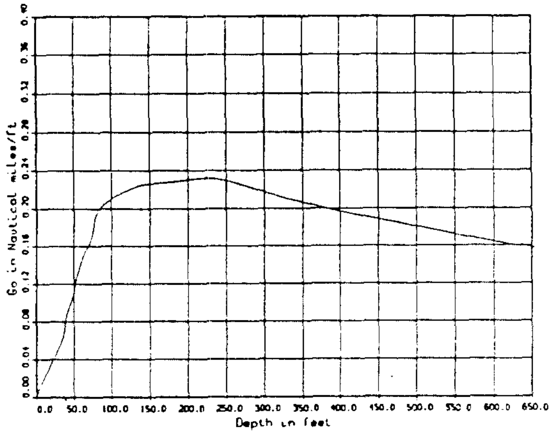


Figure 4.1 Plot of G_0 versus D_0 for the Traverse A-A' of Youngil Bay, Korea

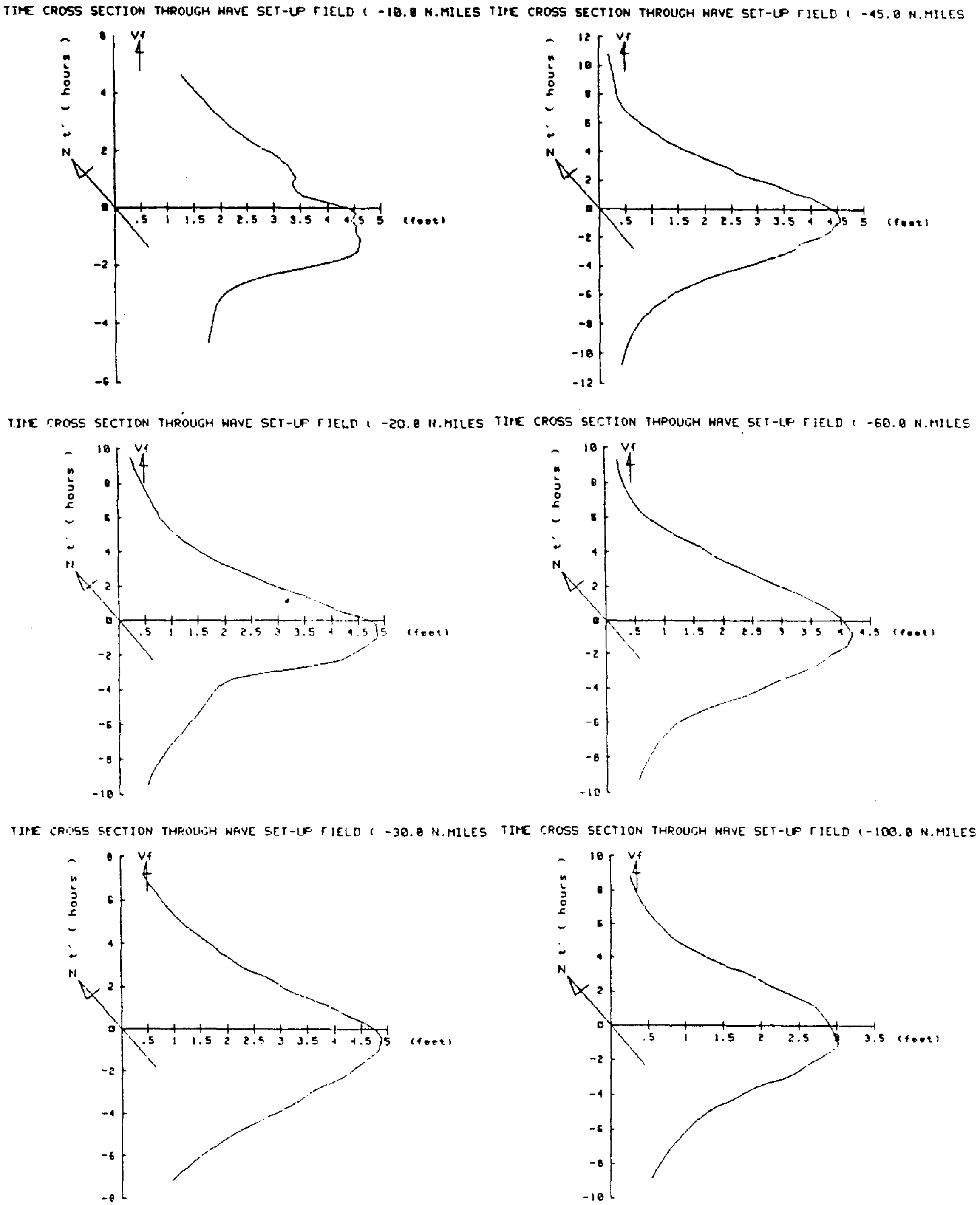


Figure 4.2 Time Cross Sections through the Wave Setup Field

Table 4.1 Storm Surge Calculation

TYPHOON : BRENDA

Lat.= 31.4 deg.; Rc= 35.09 n.mi.; Po= 33.3 mbs; Vf= 23.68 knts; Dir.= 40 deg.

X N.M.	t' HOURS	Urs KNOTS	Bu DEG	Bh DEG	Pr '' Hg	Sp FEET	Sx FEET	Sy FEET
-165.0	-6.968	22.1	252.0	249.7	29.880	.045	.183	.026
-160.0	-6.757	22.8	252.2	250.4	29.878	.047	.196	.023
-155.0	-6.546	23.6	252.4	251.3	29.876	.050	.209	.019
-150.0	-6.334	24.4	252.6	252.1	29.873	.053	.223	.013
-145.0	-6.123	25.2	252.7	252.8	29.870	.056	.239	-.007
-140.0	-5.912	26.1	252.8	253.6	29.867	.060	.256	-.018
-135.0	-5.701	27.0	252.8	254.4	29.864	.064	.274	-.026
-130.0	-5.490	28.0	252.8	255.1	29.860	.068	.294	-.032
-125.0	-5.279	29.0	252.7	255.8	29.856	.072	.316	-.038
-120.0	-5.068	30.1	252.6	256.4	29.851	.077	.339	-.044
-115.0	-4.856	31.2	252.4	257.0	29.847	.083	.365	-.051
-110.0	-4.645	32.5	252.1	257.7	29.841	.089	.394	-.058
-105.0	-4.434	33.9	251.8	258.4	29.835	.096	.427	-.066
-100.0	-4.223	35.4	251.4	259.2	29.829	.103	.467	-.075
-95.0	-4.012	37.2	250.9	260.2	29.821	.111	.513	-.086
-90.0	-3.801	39.2	250.4	261.4	29.813	.120	.567	-.098
-85.0	-3.590	41.3	249.7	262.5	29.804	.131	.626	-.111
-80.0	-3.378	43.5	248.8	263.4	29.795	.142	.688	-.125
-75.0	-3.167	45.6	247.8	263.9	29.784	.154	.751	-.138
-70.0	-2.956	47.5	246.6	264.0	29.772	.168	.809	-.149
-65.0	-2.745	49.0	245.1	263.6	29.758	.183	.854	-.158
-60.0	-2.534	49.9	243.4	262.7	29.743	.200	.882	-.165
-55.0	-2.323	51.2	241.4	262.1	29.727	.218	.921	-.174
-50.0	-2.111	54.0	239.3	262.3	29.710	.238	1.006	-.193
-45.0	-1.900	57.0	237.0	262.3	29.691	.259	1.103	-.214
-40.0	-1.689	58.9	234.2	260.5	29.671	.282	1.165	-.225
-35.0	-1.478	61.1	231.0	259.2	29.650	.305	1.233	-.241
-30.0	-1.267	62.3	227.5	258.4	29.629	.329	1.250	-.256
-25.0	-1.056	62.7	223.5	254.8	29.608	.352	1.261	-.259
-20.0	-.845	64.7	219.1	248.8	29.589	.374	1.366	-.261
-15.0	-.633	64.5	214.3	245.4	29.572	.393	1.336	-.265
-10.0	-.422	64.4	209.2	241.2	29.559	.408	1.320	-.268
-5.0	-.211	64.2	203.9	236.8	29.551	.417	1.297	-.271
0.0	0.000	63.8	198.4	232.1	29.548	.420	1.272	-.273
5.0	.211	63.4	192.8	227.4	29.551	.417	1.244	-.274
10.0	.422	63.0	187.4	222.6	29.559	.408	1.217	-.274
15.0	.633	62.4	182.2	218.0	29.572	.393	1.185	-.274
20.0	.845	62.1	177.2	213.0	29.589	.374	1.172	-.272
25.0	1.056	59.5	172.9	212.8	29.608	.352	1.019	-.273
30.0	1.267	58.6	168.7	210.2	29.629	.329	.967	-.273
35.0	1.478	57.0	165.1	204.7	29.650	.305	.939	-.261
40.0	1.689	54.4	161.9	200.9	29.671	.282	.865	-.248
45.0	1.900	52.3	159.1	198.9	29.691	.259	.790	-.240
50.0	2.111	49.0	156.9	195.3	29.710	.238	.707	-.221
55.0	2.323	46.1	155.0	191.7	29.727	.218	.639	-.204
60.0	2.534	44.6	153.0	189.5	29.743	.200	.601	-.197
65.0	2.745	43.5	151.2	188.1	29.758	.183	.569	-.193
70.0	2.956	42.0	149.8	187.0	29.772	.168	.526	-.187
75.0	3.167	40.0	148.7	185.7	29.784	.154	.478	-.178
80.0	3.378	37.8	147.9	183.8	29.795	.142	.433	-.166
85.0	3.590	35.5	147.3	181.5	29.804	.131	.392	-.153
90.0	3.801	33.3	146.9	178.9	29.813	.120	.354	-.139
95.0	4.012	31.3	146.7	176.4	29.821	.111	.320	-.126
100.0	4.223	29.5	146.6	174.5	29.829	.103	.289	-.116
105.0	4.434	27.9	146.6	173.2	29.835	.096	.261	-.107
110.0	4.645	26.5	146.6	172.4	29.841	.089	.237	-.100
115.0	4.856	25.3	146.7	172.1	29.847	.083	.216	-.095
120.0	5.068	24.1	146.9	172.2	29.851	.077	.198	-.090
125.0	5.279	23.1	147.2	172.8	29.856	.072	.180	-.087
130.0	5.490	22.1	147.6	173.6	29.860	.068	.164	-.084
135.0	5.701	21.1	148.1	174.7	29.864	.064	.150	-.081
140.0	5.912	20.2	148.6	175.8	29.867	.060	.136	-.078
145.0	6.123	19.3	149.3	176.8	29.870	.056	.124	-.075
150.0	6.334	18.5	150.0	177.6	29.873	.053	.114	-.072
155.0	6.546	17.8	150.7	178.0	29.876	.050	.105	-.069
160.0	6.757	17.0	151.5	178.0	29.878	.047	.098	-.065
165.0	6.968	16.4	152.4	177.4	29.880	.045	.091	-.061