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N-1819

NCEL
Technical Note

October 1990

By Jack W. DeVries

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TWO-DIMENSIONAL BEACH PROFILE RESPONSE MODEL

ABSTRACT A two-dimensional numerical beach profile response model has been developed. It is based upon the principal of conservation of mass and an energetics-based cross-shore sediment transport rate equation. The model requires minimum input, yet it simulates both onshore and offshore sediment transport for time scales ranging from hours to months. Model predictions compare favorably to the measured erosion on a natural beach due to storm waves. The model was designed to operate quickly on a personal computer.

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043-5003

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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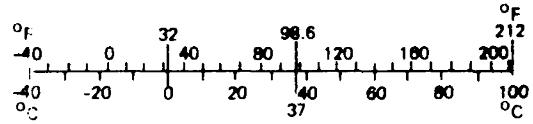
*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, *Units of Weights and Measures*, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-018*

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
October 1990

3. REPORT TYPE AND DATES COVERED
Final: Aug 1987 to Jan 1989

4. TITLE AND SUBTITLE
TWO-DIMENSIONAL BEACH PROFILE RESPONSE MODEL

5. FUNDING NUMBERS
PE - 61153N
PR - YR031.03.01
WU - DN666381

6. AUTHOR(S)
Jack W. DeVries

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESSE(S)
Naval Civil Engineering Laboratory
Port Hueneme, CA 93043-5003

8. PERFORMING ORGANIZATION REPORT NUMBER
TN - 1819

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESSE(S)
Office of the Chief of Naval Research
Office of Naval Research
Arlington, VA 22217-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

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14. SUBJECT TERMS
Model, beach, sediment transport, cross-shore transport

15. NUMBER OF PAGES
42

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UL

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INTRODUCTION

The Office of Naval Research (ONR) has requested the Naval Civil Engineering Laboratory (NCEL) to investigate the possibility of expediently modifying and controlling the shape of the beach. As part of this investigation, NCEL has developed a numerical model, based on the physics of nearshore sediment transport processes, that is capable of simulating beach profile response to waves.

Quantitative models for nearshore sediment transport processes are very useful for predicting nearshore bathymetric changes, which include changes in both the planform shape of the beach and the beach profile. Planform changes are typically associated with an interruption of the longshore littoral drift (e.g., by a groin). Beach profile changes are typically associated with variations in the cross-shore sediment transport rate which is driven by the incident wave field. Only beach profile changes will be addressed in this report.

Beach profile changes are further classified according to time scale. Short-term events range from a few hours, when associated with a single storm event, to many months, when associated with seasonal wave changes. Long-term events typically describe a rise in sea level and have a time scale measured in tens of years. The present model pertains only to short-term events, as defined above.

EXISTING SURFZONE SEDIMENT TRANSPORT MODELS

Scientists and engineers have used time-stepping line models to simulate the bathymetric evolution of the coastal zone for many years (e.g., Pelnard-Considère, 1956). These models represent the nearshore bathymetry by one or more depth contours. These contours remain constant as the model evaluates the effects of waves over a given time increment. At the end of the time increment, bathymetric changes are made. The process is repeated for each time increment for all sets of wave conditions.

The first to include cross-shore sediment transport was Bakker (1968), who developed a two-line model which utilized the shoreline and an arbitrary depth contour to represent the nearshore bathymetry. His transport relationship compares the cross-shore separation between contour lines at any given time step with the cross-shore separation at the equilibrium conditions for the given waves. The offshore transport rate per unit width, Q_x, is:

$$Q_x = q_x[x_1 - (x_2 - w)] \qquad (1)$$

where: q_x = rate constant with dimensions (L/T)

x_1, x_2 = cross-shore positions of the contours

w = distance (x_2 - x_1) for the equilibrium profile

Due to the lack of a transport relationship based upon the physics of sand transport, there are serious shortcomings in this approach. These include: (1) a lack of asymmetry in the rate of offshore and onshore sediment transport, and (2) a lack of accounting for wave height, wave period, and sediment size in the factors w and q_x.

Swart (1974) used the general form of Equation 1 in his treatment of offshore transport by incorporating both sediment and wave characteristics in his constants. Although his approach to both the equilibrium profile and the proportionality constant were more sophisticated than those used by Bakker, it was still a schematization of the profile development and not a model based on fundamental sediment transport mechanics.

Stive and Battjes (1984), on the other hand, developed an offshore sediment transport model based on an equation describing the time-averaged undertow velocity. It predicts the offshore transport of sediment during storm conditions given the height of the incident waves and the sediment load in the near-bed boundary layer. The model does not address onshore transport.

Recently, many cross-shore sediment transport models have been developed (Watanabe and Dibajnia, 1988; Kuo and Chen, 1988; Diegaard, et al., 1988; and Stive, 1988) that address both onshore and offshore transport. The application of these models, though, tends to be rather complex.

This research presents a beach profile evolution model which retains much of the simplicity of Bakker's two-line development, while incorporating several significant improvements. Rather than using a schematization of the profile development to simulate the cross-shore sediment flux, the model utilizes cross-shore sediment transport relationships (onshore and offshore) based on the fluid/sediment mechanics in the surfzone. Using a time-stepping routine, the model simulates the nearshore beach profile changes by applying these relationships.

MODEL DEVELOPMENT

For modeling purposes, the beach is divided into two regions, the nearshore region which extends from the berm crest to the inflection point, and the offshore region which extends from the inflection point to the depth of closure (see Figure 1). When the sediment transport rate is negative, the beach is eroded and sediment is transferred to the offshore region. When the transport rate is positive, sand is removed from the offshore region and deposited in the nearshore region.

The beach profile evolution model is based on three equations: (1) the continuity equation, (2) a cross-shore sediment transport relationship developed by Bailard (1981), and (3) a depth-of-cut relationship as defined by Hallermeier (1977).

Conservation of Mass Equation

The conservation of mass requirement states that sand is neither lost nor gained by the control volume enclosing the beach profile. This relationship can be expressed as:

$$\frac{\partial V}{\partial t} + \frac{\partial Q}{\partial x} = 0 \qquad (2)$$

where: V = total volume of the beach profile per unit width

Q = transport rate

x = cross-shore coordinate

Cross-Shore Sediment Transport Equation

Bailard's (1981) cross-shore sediment transport equation is based on the energetics concepts developed by Bagnold (1963). Bailard generalized Bagnold's unidirectional stream transport equation to allow for time-varying flow over an arbitrary sloping bottom. The resulting equation for the time-averaged cross-shore sediment transport rate, $<i_x>$, is:

$$<i_x> = \rho\, C_f\, u_m^3 \frac{\varepsilon_B}{\tan \phi} \left[\psi_1 + \frac{3}{2} \delta_u - \frac{\tan B}{\tan \phi} u_3^* \right]$$

$$+ \rho\, C_f\, u_m^4 \frac{\varepsilon_s}{W} \left[\psi_2 + 4\, u_3^* \delta_u - \varepsilon_s \frac{u_m}{W} \tan B\, u_5^* \right] \qquad (3)$$

where: ρ = density of water

C_f = drag coefficient for the bed

ε_B, ε_s = efficiency factors

$\tan \phi$, W = factors based on sediment characteristics

$\tan B$ = bed slope

u_3^*, u_5^* = orbital velocity moments

u_m = primary component of the oscillatory velocity field

ψ_1, ψ_2 = wave skewness parameters

δ_u = undertow

Using the Nearshore Sediment Transport Study field data sets (Gable, 1979; Gable, 1980), spatially-averaged empirical estimators were developed for the wave velocity field, its moments, the skewness parameters, and the undertow (Bailard, 1985). The resulting linear equations require only the incident significant wave height, beach slope, and median sediment diameter as input.

In principle, Equation 3 represents a balance of the offshore-directed transports imposed by the downslope component of gravity and the time-averaged undertow with the onshore directed transport imposed by the asymmetry of the wave orbital velocity field. At equilibrium, these transports exactly balance, and the beach is in dynamic equilibrium with the incident wave conditions.

Initial Conditions

Dean and Maurmeyer (1983) note that beach response time is as much as an order of magnitude larger than the duration of most hydrologic conditions. Therefore, conditions seldom persist long enough to completely dominate the development of a beach profile bringing it to equilibrium. More typically, a beach profile is the result of a long history of wave conditions. This suggests that the initial conditions of a response model must accurately convey the true state of the beach to successfully simulate its subsequent response.

The user is required to input the following values to define the initial conditions of the beach profile:

- Berm height - a constant value defined as the vertical distance from the still water line to the crest of the berm.
- Berm slope - an average value defining the ratio of the height of the berm to the horizontal distance between the mean shoreline and the crest of the berm.
- Foreshore slope - the initial slope of the submarine beach profile in the nearshore zone.
- Offshore slope - the initial slope of the beach profile in the offshore zone, excluding the horizontal portion of the bar.
- Depth of slope break - the initial depth from the still water line to the point where the foreshore slope meets the offshore slope.
- Length of bar - the initial length of the longshore bar.

Boundary Conditions

The absolute shoreward boundary of the model is the termination of the negative x-axis. This boundary is far shoreward of the mean shoreline which acts as the practical shoreward boundary of the system. The mean shoreline has one degree of freedom (x-axis), and its movement is determined by the accretion or erosion of sand in the nearshore region. The berm is of fixed height and slope. Its position is uniquely determined by that of the mean shoreline.

The seaward boundary of the model is defined by a fixed depth of closure. This is the depth at which transport ceases for the median annual significant wave (Hallermeier, 1981). That is:

$$D_0 = 1.418\ (H_m)(T_m)\sqrt{g/5D}$$

where: D_0 = depth of negligible transport, meters

H_m = annual median wave height, meters

T_m = annual median wave period

g = acceleration of gravity, meters/second

D = median grain size, millimeters

Note, this is not the ultimate depth of no transport for all wave conditions, but merely a convenient average of the anticipated values, which will vary with both wave height and wave steepness. The user is required to input an annual median deep water significant wave height and wave period so that the model can define this boundary.

The horizontal position of the seaward boundary is determined by the location at which the depth of closure falls on the initial offshore slope.

Inflection Point

In the past, modelers (Bakker, 1968; Swart, 1974) have used a line of constant depth to define the division between the nearshore and offshore regions. In the present model, this inflection point is a function of both the incident wave height and the time history of the profile. The inflection point has two degrees of freedom (x,z). Its movement is defined as a function of the ratio of the volume of sand transported, Q_x, to the total volume of sand transported within a given wave regime, Q_t (see Figures 2 and 3). The incremental movement of the inflection point, d_i, is defined as:

$$d_i = (D_c - D_i)Q_x/Q_t \tag{4}$$

where: d_i = incremental movement of the inflection point at time step "i"

D_c = equilibrium depth of cut

D_i = initial depth of cut for a given wave regime

The equilibrium depth of cut is defined by Hallermeier (1977) as the limiting depth of erosion. It is a function of the incident wave height and wave steepness:

$$D_c = 2.28\,H_s - 68.5(H_s^2/gT_s^2) \qquad (5)$$

where: H_s = significent wave height, meters

T_s = significant wave period

The horizontal position of the inflection point is determined by the location at which the depth of cut, as defined by Equation 5, falls on the nearshore slope.

MODEL APPLICATION

Offshore Transport

The offshore transport mode occurs when the present nearshore beach slope is steeper than the equilibrium slope for the given set of wave conditions. In this mode, sand is transported from the nearshore region, the beach slope flattens, and the berm/mean shoreline retreats. Sand accumulates in the offshore region forming a bar whose depth is determined by the inflection point and whose width is determined by the volume of sand transported.

Figure 4 shows the evolution of a summer beach profile that is subjected to larger waves. A wave histogram is presented in Figure 5. The steep, reflective nearshore slope flattens as the berm/mean shoreline retreats and the inflection point moves offshore. As the beach continues to reform due to the new wave conditions, the volume transport rate decreases and the bar grows in smaller increments as it moves more slowly offshore.

Onshore Transport

The onshore transport mode occurs when the present nearshore beach slope is flatter than the equilibrium condition. Sand is transported from the offshore region to the nearshore as the nearshore beach steepens and the berm accumulates sediment.

Figure 6 shows the evolution of a winter beach profile that is subjected to benign conditions. A wave histogram is presented in Figure 7. The offshore bar begins to diminish in size and move shoreward as the inflection point moves to shallower water. Sand accumulates on the berm forcing the mean shoreline to advance. A steep, reflective nearshore slope is formed. The bar continues to diminish in size and move shoreward, much like a ridge and runnel system. After the bar is welded to the beach face, the nearshore slope continues to steepen as it moves slowly toward the equilibrium condition.

Storm Simulation

Both wave data and beach profile data were collected at Leadbetter Beach in Santa Barbara, California during the Nearshore Sediment Transport Study. This data set includes the beach profile response to a storm. Using the input conditions provided by the prestorm surveys and the wave data set (see Figure 8), it was possible to simulate the beach profile response using the cross-shore sediment transport model.

Figure 9 shows the measured beach profiles. The profiles, from the crest of the berm down to the minus 2-meter mark, were measured via wading profiles throughout the storm (Gable, 1980). The offshore portion of the profile was measured with a fathometer before the storm (Moore, 1982).

Note that in the field profiles shown in Figure 9, sand was removed from the beach profile and not just redistributed (as would be in keeping with the model stipulation of conservation of mass). Closer inspection reveals that the volume of sand lost came from the nearshore region (roughly corresponding to the surfzone). This suggests that the longshore transport (driven by the longshore current which is confined to the surfzone) was not constant in space, but rather has resulted in a net erosion for the measured beach.

Since this beach profile response model does not take into account sediment removed by longshore transport, compensation must be made for this net loss of sand so the field profiles can be compared with the model simulation. To accomplish this, the final field profile was shifted seaward to add back the sand that was lost to longshore current-induced erosion, assuming a triangular distribution intersecting the seafloor at the point of closure (see Figure 10). This shifted profile was then compared to that predicted by the model (see Figure 11).

The model compares reasonably well with the field profile, with the exception that it has overpredicted the erosive action of the storm. As shown in Figure 11, the length of the bar and the depth of the slope break are well predicted, yet slightly overpredicted. The flattening of the nearshore beach slope and the retreat of the mean shoreline are overpredicted due to the excess erosion.

SUMMARY AND CONCLUSIONS

The present model shows promise as a method for simulating cross-shore sediment transport. It is a simple scheme that uses only significant wave height, wave period, sediment size, and initial beach profile as input. Nevertheless, the model effectively simulates erosion as well as accretion. The model tends toward an equilibrium profile given sufficient time and a constant wave climate, but in most applications this is never realized. It handles events that have time scales ranging from hours to years.

All of the major characteristics of beach response are simulated. Offshore transport occurs very rapidly during storms causing development of a simple barred profile. Onshore movement, on the other hand, is a very slow process in relation to offshore transport. When a bar is present it depicts, in a rather simple fashion, the shoreward marching of a ridge and runnel system. When no bar is present, a narrow, steep beach is formed in response to the lower waves.

Despite its ability to simulate all of the major characteristics of beach response, there are a number of qualifications concerning this simple model that must be emphasized in order to permit its useful application as a coastal engineering tool:

1. The model assumes a conservation of mass. This implies that the longshore component of sediment transport is assumed to be constant in both time and space. This is often not the case. When longshore transport is present, it may be appropriate to use the two-dimensional cross-shore transport model in conjunction with a two-dimensional longshore sediment transport model that would predict the sediment gained or lost for a given slice of beach. There are many currently available, for example, the models by Le MéHauté and Soldate (1980), or Bailard (1985) would be adequate.

2. The model is spatially-averaged within the nearshore region. This means that the cross-shore distribution of the sediment transport rate is ignored. This eliminates the possibility of adequately simulating multiple bars.

3. The offshore region acts merely as a source/sink, driven entirely by the dynamics of the nearshore zone.

4. The empirically derived wave velocity moment equations are limited to the relatively narrow range of conditions found on the southern California coastline.

5. Due to a bias in the original cross-shore sediment transport equation, the model tends toward overpredicting erosion in the nearshore region (as defined in Figure 1).

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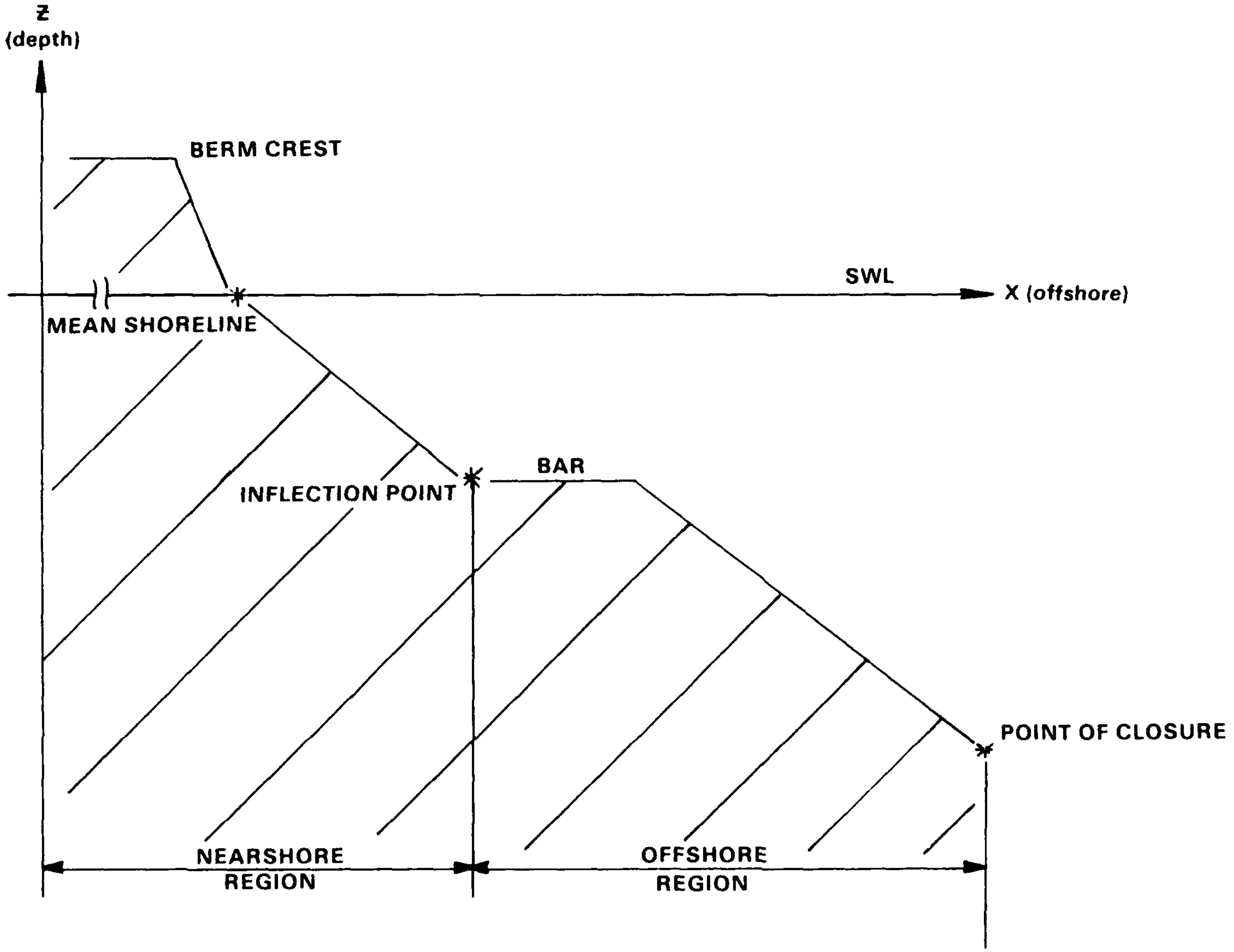

Figure 1. Beach schematic.

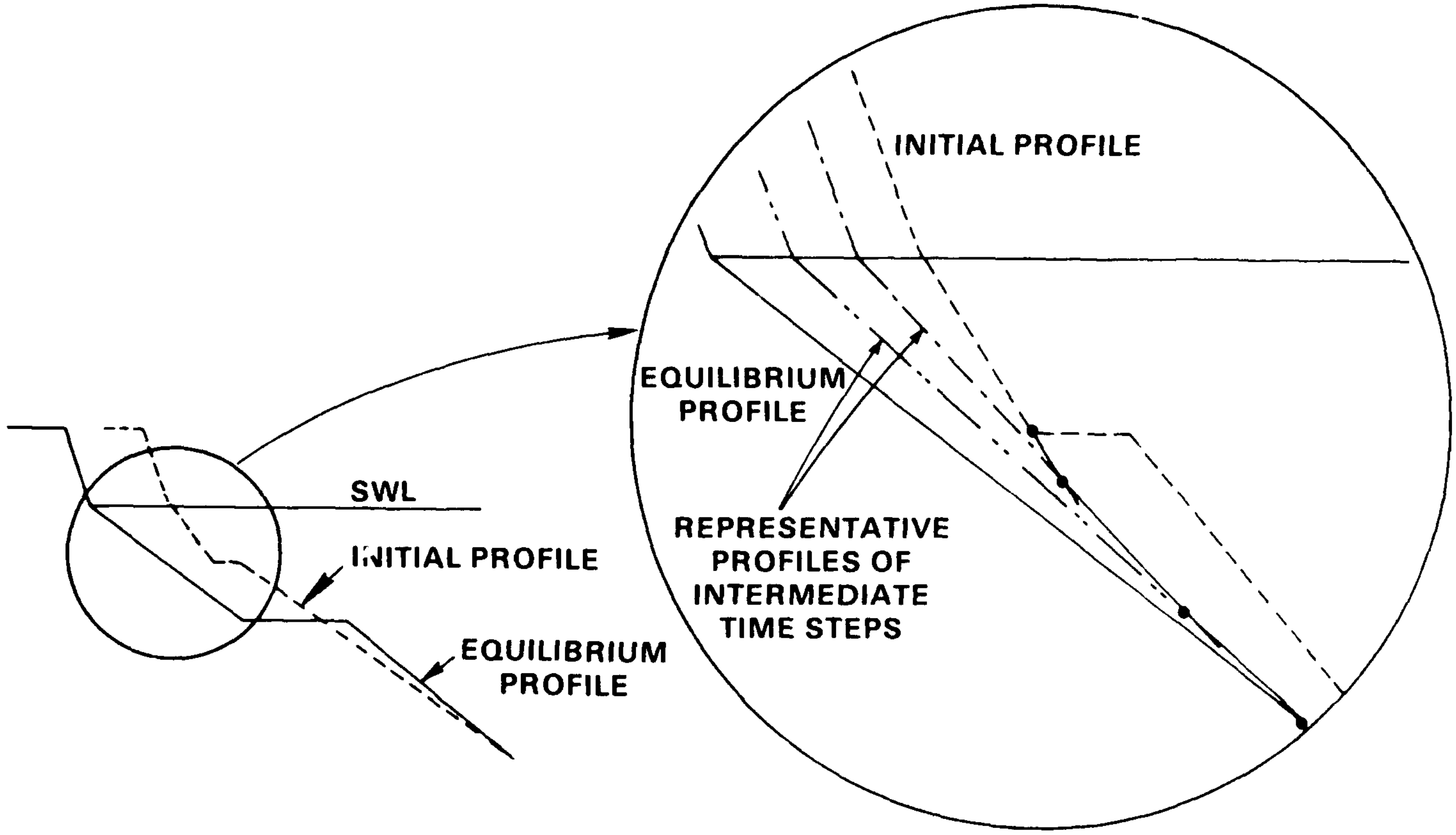

Figure 2. Movement of the inflection point during erosion of the nearshore region.

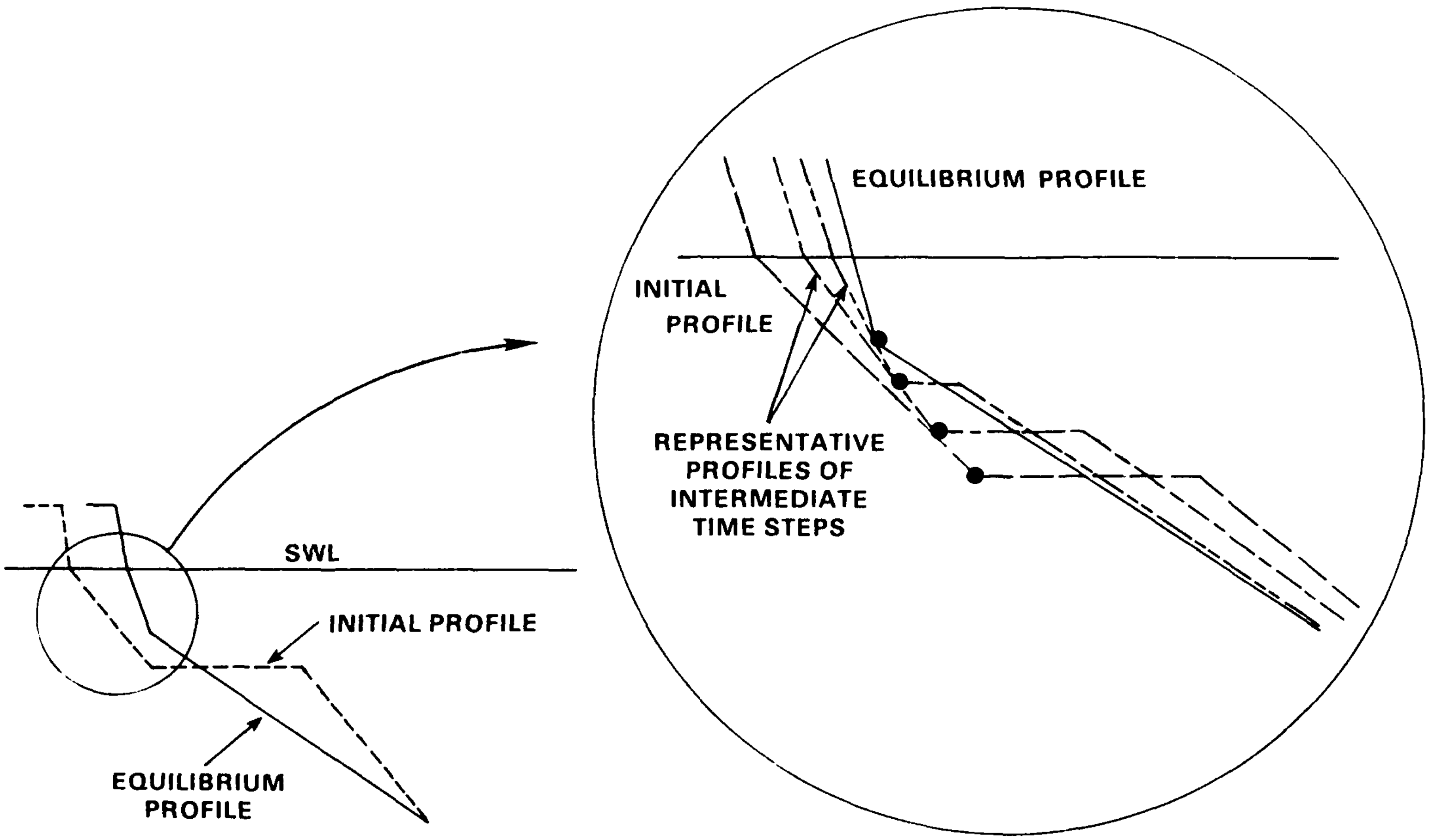

Figure 3. Movement of the inflection point during accretion in the nearshore region.

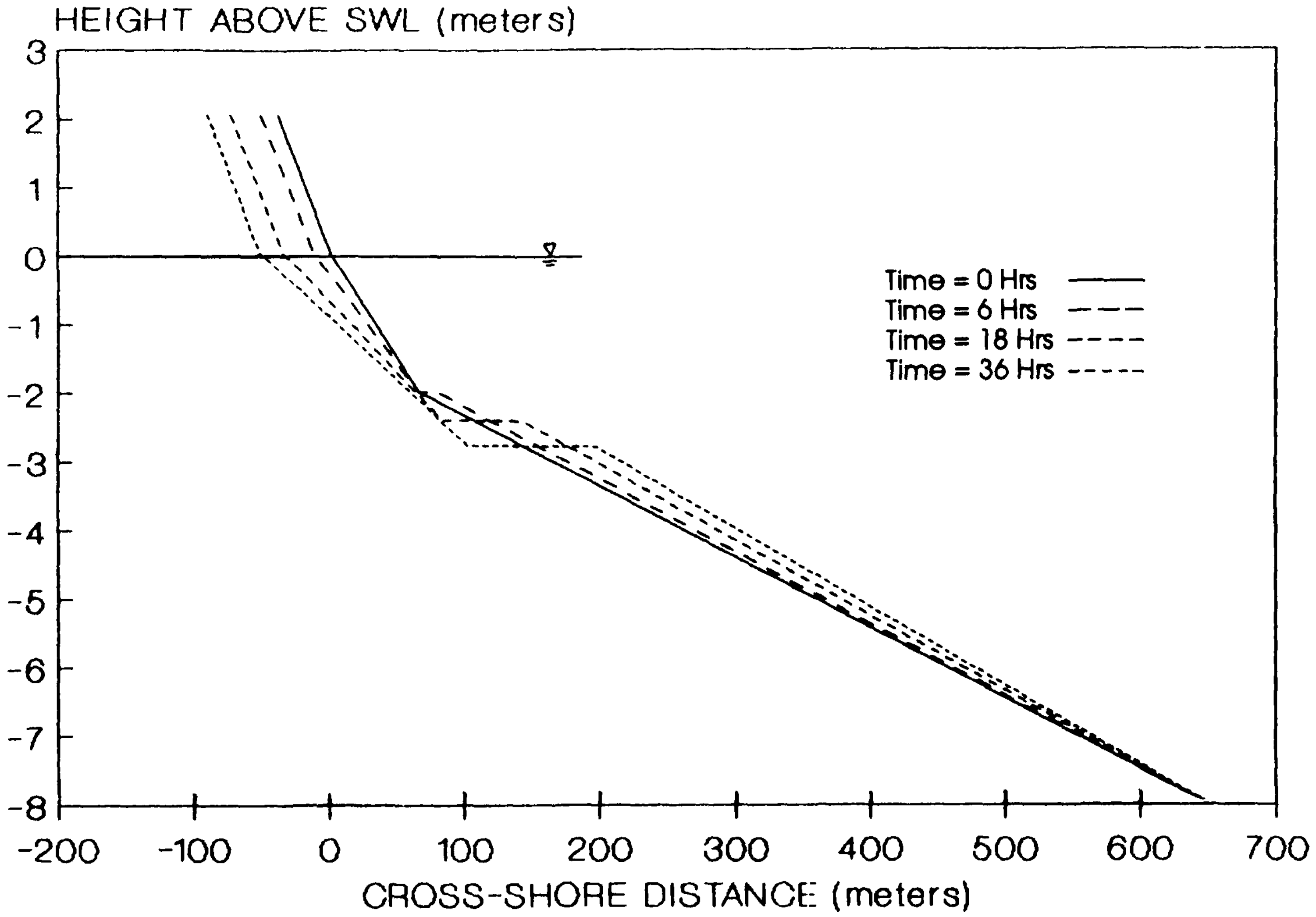

Figure 4. Evolution of the beach profile: reflective profile subjected to large waves.

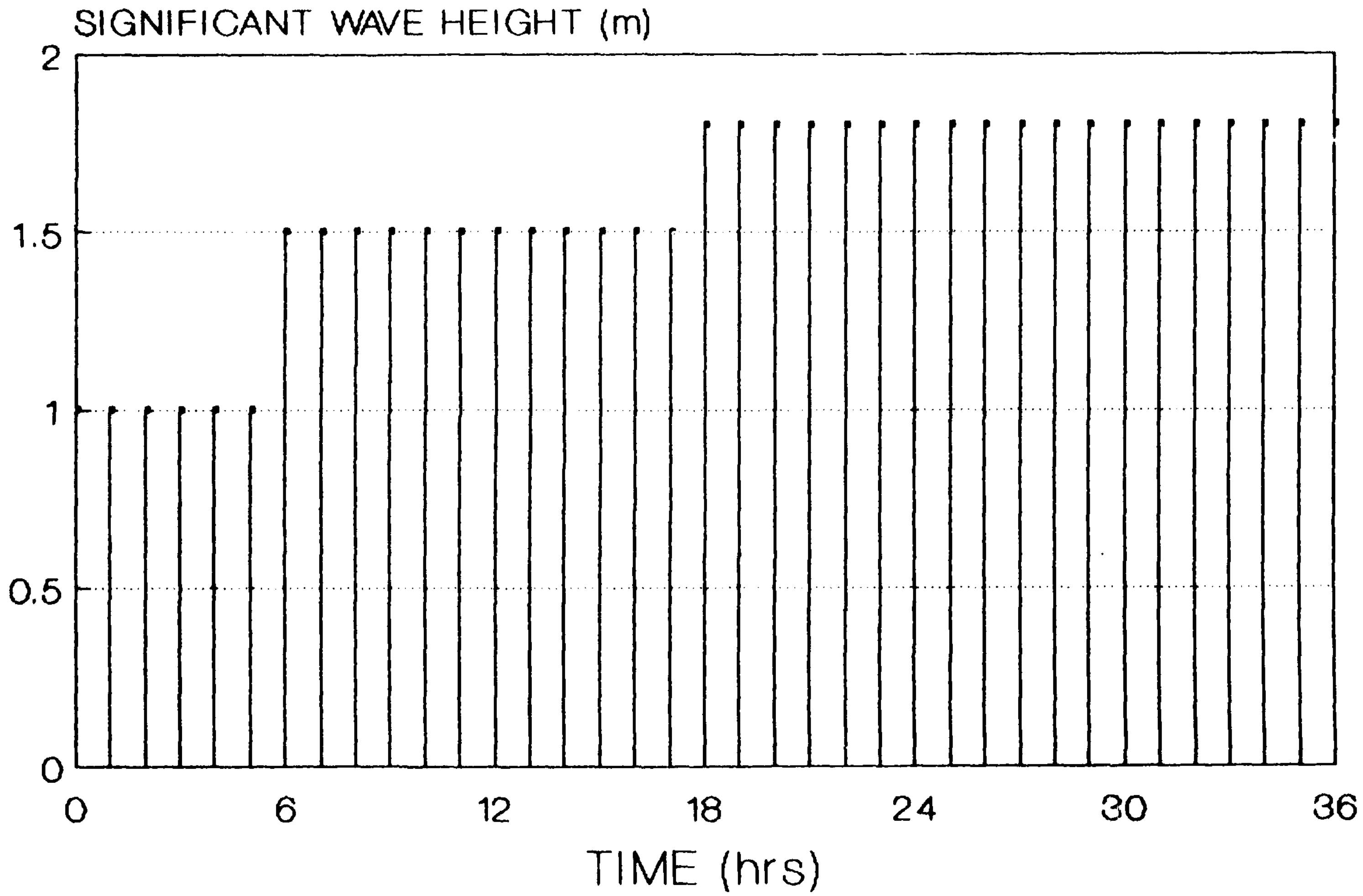

Figure 5. Wave histogram for evolution of the beach profile due to large waves.

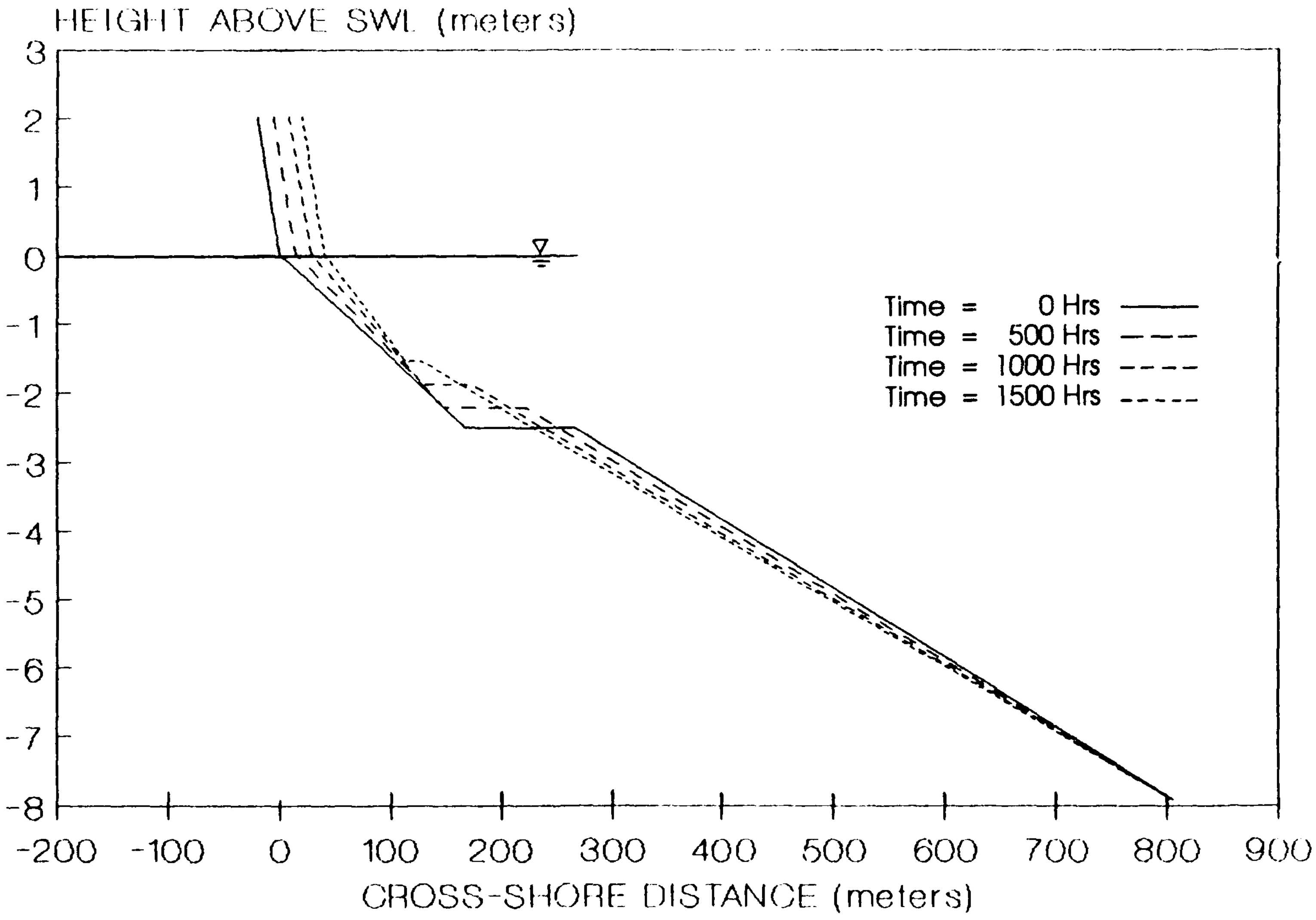

Figure 6. Evolution of the beach profile: barred profile subjected to small waves.

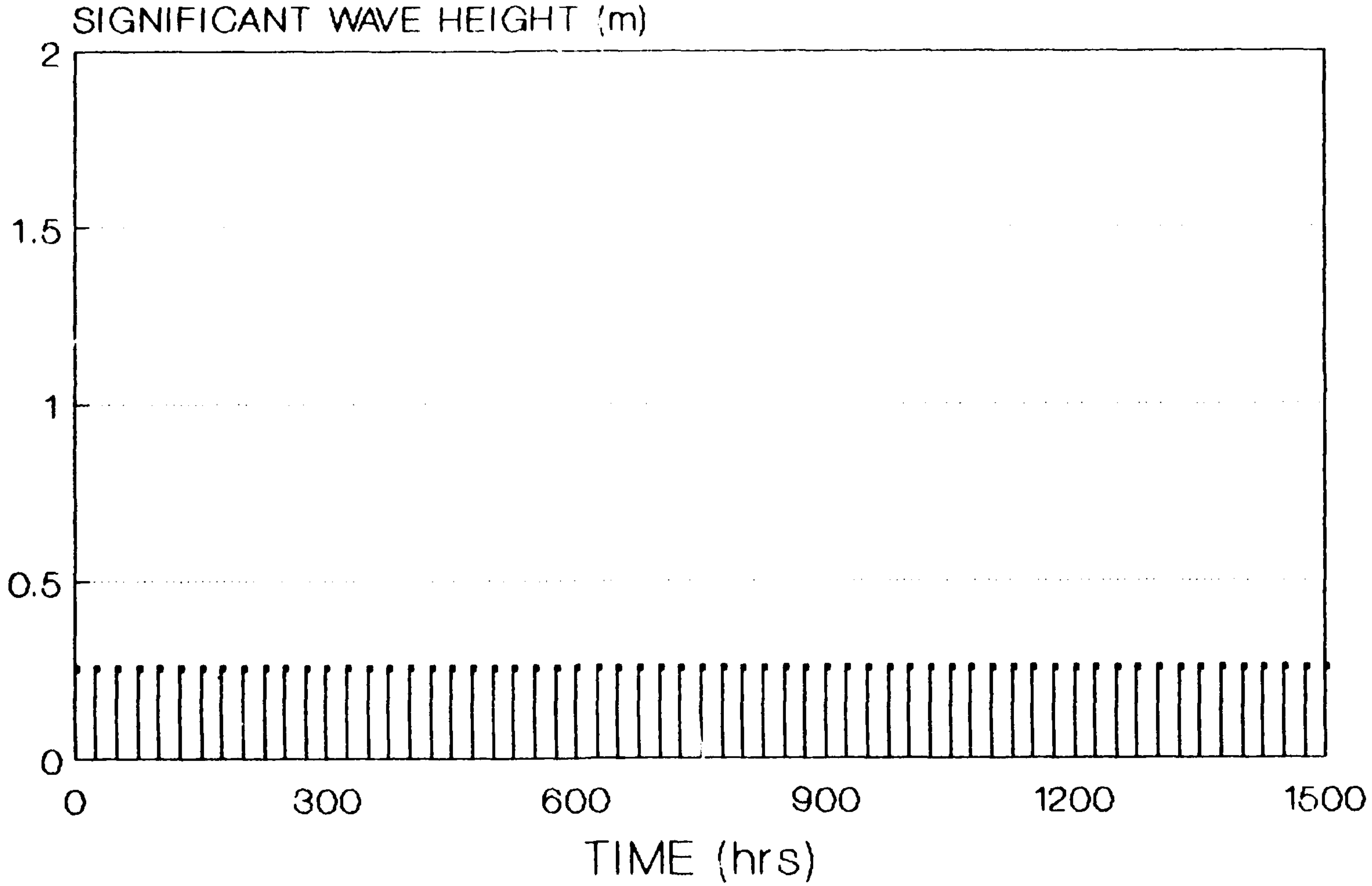

Figure 7. Wave histogram for evolution of the beach profile due to small waves.

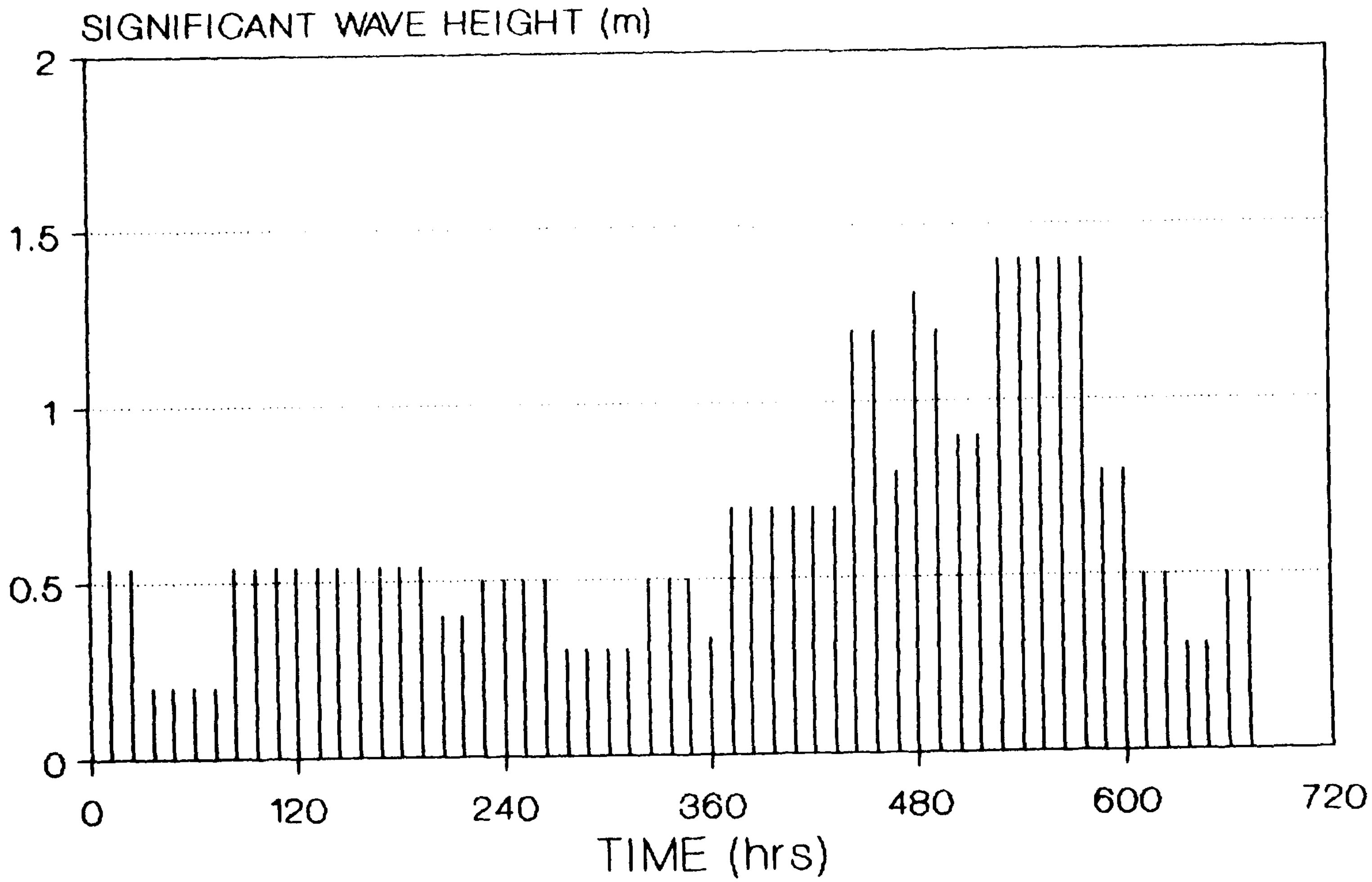

Figure 8. Wave histogram for storm (28 January 1980 to 25 February 1980) at Leadbetter Beach, CA.

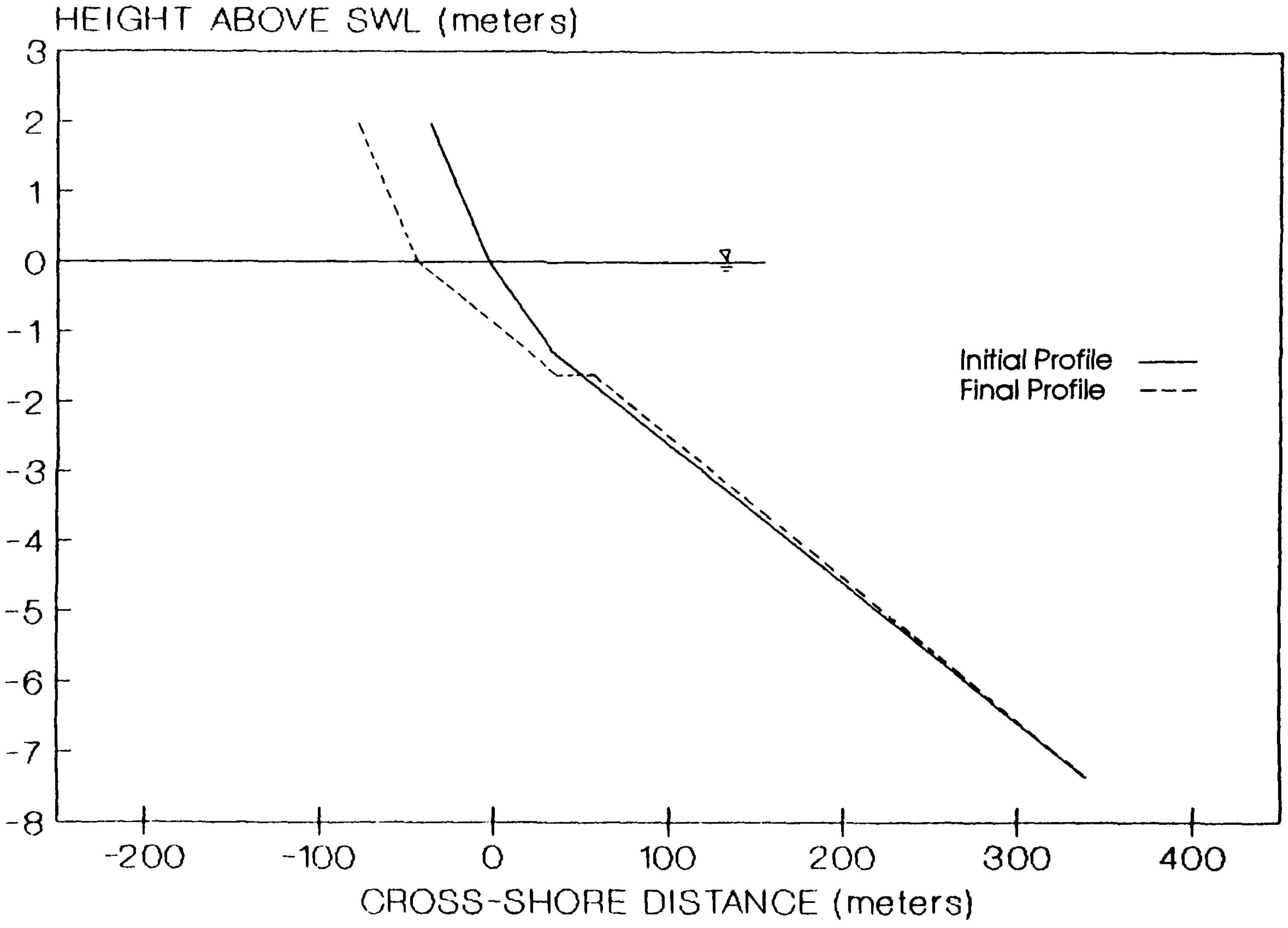

Figure 9. Measured beach profiles, Leadbetter Beach, CA.

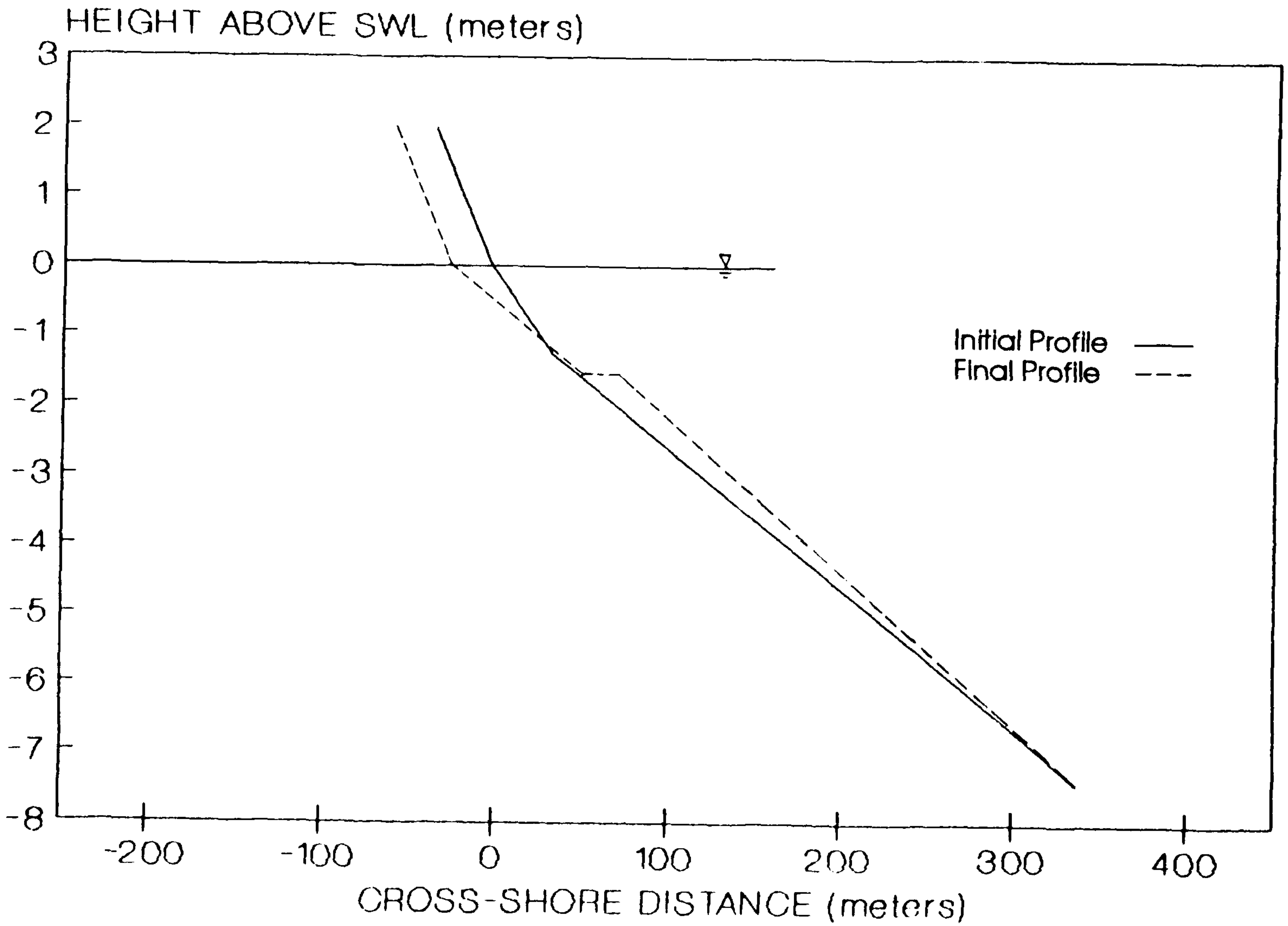

Figure 10. Measured beach profiles, Leadbetter Beach, CA. Final profile has been shifted seaward to compensate for the sand removed by the longshore transport.

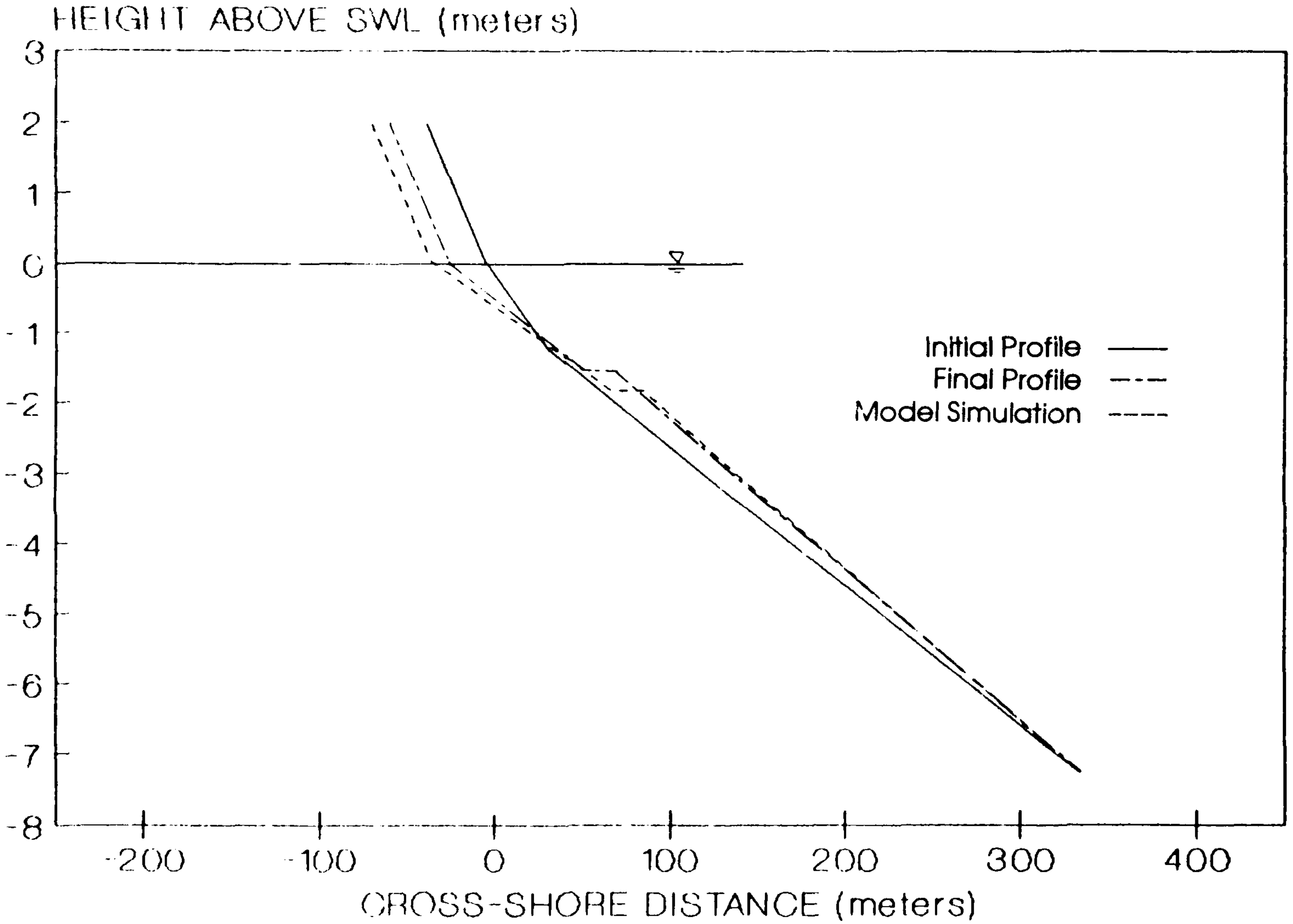

Figure 11. Comparison of cross-shore sediment transport model simulation and actual beach profile response.

Appendix A

COMPUTER CODE FOR BEACH PROFILE RESPONSE MODEL

The numerical model, CROSHORE, is a two-dimensional beach profile response model. It requires the user to supply an input file, entitled WAVES.DTA (see Appendix B), that contains wave and wave condition duration information. All other input information that is required is specifically requested by CROSHORE at the beginning of a run. All requested information must be supplied.

The numerical model "CROSHORE" was written in BASIC, specifically, TurboBasic which is a compiled basic program published by Borland. Since most of the commands in TurboBasic are similar to those in interpretive basic, translation, if necessary, should be fairly easy. To facilitate the person who wishes to "get inside" of the model, every effort was made to add comments describing each variable. Also, comments describe the overall function of each loop.

The program was written for use on an IBM-AT compatible personal computer. All of the applications described in this report were run on a Zenith 286 (AT compatible) personal computer with a math coprocessor. The longest application took less than 2 minutes.

```
'BEACH PROFILE RESPONSE SIMULATION MODEL - "CROSHORE"
'
'This program begins with an initial beach profile and
'wave conditions and determines the beach response to the waves.
'
'All units used in this program are metric (meters-kilogram-second).
'
'ESTABLISH INITIAL CONDITIONS
'
CLS
PRINT "ENTER MEDIAN GRAIN DIAMETER IN MILLIMETERS"
INPUT D
PRINT "ENTER INITIAL FORESHORE SLOPE IN DEMICAL FORM"
INPUT Tanfo
PRINT "ENTER INITIAL OFFSHORE SLOPE IN DECIMAL FORM"
INPUT Tanoff
PRINT "ENTER INITIAL DEPTH OF SLOPE BREAK"
INPUT Dsb
PRINT "ENTER INITIAL BAR LENGTH"
INPUT Lbar
PRINT "ENTER HEIGHT OF BERM"
INPUT Dbf
PRINT "ENTER SLOPE OF BERM FACE IN DECIMAL FORM"
INPUT Tanbf
PRINT "ENTER NUMBER OF WAVE CONDITIONS TO BE RUN"
INPUT N
PRINT "ENTER ANNUAL MEDIAN WAVE HEIGHT AND PERIOD"
INPUT Hm,Tm
PRINT "IF OUTPUT AT CHANGE OF WAVE CONDITIONS ONLY, ENTER 1"
INPUT A
IF A<>1 THEN INPUT "ENTER NUMBER OF HOURS BETWEEN OUTPUTS",Hours
'
Cf=0.0009                      'DRAG COEFFICIENT
Eb=0.13                        'COEFFICIENT OF BEDLOAD TRANSPORT
Es=0.032                       'COEFFICIENT OF SUSPENDED LOAD TRANSPORT
Ss=2.65                        'SPECIFIC GRAVITY OF SAND
G=9.8                          'ACCELERATION OF GRAVITY (meters/sq-sec)
No=0.6                         'AT REST VOLUME CONCENTRATION OF BEACH
Tanar=0.63                     'ANGLE OF REPOSE OF SAND IN DECIMAL FORM
Dt=3600                        'TIME STEP INTERVAL IN SECONDS
'
Quw=G*(Ss-1)*No                                'SUBMERGED UNIT WEIGHT OF BEACH SAND
W=(8.925/1000*D)*(SQR(1+95*(Ss-1)*D^3)-1)      'FALL VELOCITY OF SAND GRAINS
Dc=1.418*Hmn*Tmn*SQR(G/(5*D))                   'DEPTH TO NEGLIGIBLE TRANSPORT
Xc=Dsb/Tanfo+(Dc-Dsb)/Tanoff+Lbar              'DISTANCE TO Dc
'
'
Xms1=0                                         'DISTANCE TO THE MEAN SHORELINE
Xbf=Xms1-Dbf/Tanbf                             'DISTANCE TO THE CREST OF THE BERM
Xsb=Dsb/Tanfo                                  'DISTANCE TO THE SLOPE BREAK
KKK=1                                          'GRAPHICS COUNTER
'
```

```
DIM H(100), S(100)                           'WAVE HEIGHT AND SPAN OF DURATION
OPEN "WAVES.DTA" FOR INPUT AS #1
OPEN "PROFILE.DTA"  FOR OUTPUT AS #3
CALL Grapher
CALL Plotter
'
'
'
'
'
'
CALCULATIONS LOOPS - TOTAL VOLUME TRANSPORTED AND BEACH TRANSFORMATION
'
FOR L=1 TO N
INPUT #1, H(L),S(L)
IF A=1 THEN Hours=S(L)
Sumqt=0                       'SUM OF VOLUME TRANSPORTED FOR H(L)
Time=0                        'TIME COUNTER
Dsb2=2*H(L)                   'EQUILIBRIUM SLOPE BREAK DEPTH FOR H(L)
Knt=0                         'TOTAL VOLUME TRANSPORTED LOOP COUNTER
I=0                           'BEACH TRANSFORMATION LOOP COUNTER
'
'TOTAL VOLUME TRANSPORTED LOOP
'
Qyt=1
DO UNTIL Qyt<0.0001
Knt=Knt+1
Lknt=0.001*Knt                               'SMALLER ITERATIVE COUNTER
B=0.1-Lknt                                   'ITERATIVE BEACH SLOPE
Psi1=(2.27*B-0.141)*H(L)-12.7*B+0.547        'WAVE VELOCITY MOMENT 1
Psi2=(3.52*B-0.287)*H(L)-25*B+1.13           'WAVE VELOCITY MOMENT 2
Deltau=(-6.5*B-0.0158)*H(L)-4.29*B+0.138     'MEAN WATER VELOCITY
Um=(28.5*B-0.288)*H(L)+1.29*B+0.283          'PRIMARY COMPONENT OF WAVE VELOCITY
Qybt=Cf*Um^3*Eb/(Quw*Tanar)*(Psi1+1.5*Deltau-0.6*B/Tanar)
Qyst=-Cf*Um^4*Es/(Quw*W)*(Psi2+2.4*Deltau-1.25*Es*Um*B/W)
Qyt=Qybt+Qyst  'ADDITION OF BEDLOAD AND SUSUPENDED LOAD VOLUME TRANSPORT RATES
LOOP
Qt=ABS((Dbf+0.5*Dsb)*(Dsb/B-Dsb/Tanfo))           'TOTAL VOLUME TRANSPORTED FOR EQUIL.
'
'BEACH TRANSFORMATION LOOP
'
Timestepping:
DO UNTIL (I>=Hours OR Time>=S(L))
Sumq=0
Psi1=(2.27*Tanfo-0.141)*H(L)-12.7*Tanfo+0.547     'WAVE VELOCITY MOMENT 1
Psi2=(3.52*Tanfo-0.287)*H(L)-25*Tanfo+1.13        'WAVE VELOCITY MOMENT 2
Deltau=(-6.5*Tanfo-0.0158)*H(L)-4.29*Tanfo+0.138  'MEAN WATER VELOCITY
Um=(28.5*Tanfo-0.288)*H(L)+1.29*Tanof+0.283   'PRIMARY COMPONENT OF WAVE VELOCITY
Qyb=-Cf*Um^3*Eb/(Quw*Tanar)*(Psi1+1.5*Deltau-0.6*Tanfo/Tanar)
Qsy=-Cf*Um^4*Es/(Quw*W)*(Psi2+2.4*Deltau-1.25*EsUm*Tanfo/W)
Qy=+Qyb+Qys    'ADDITION OF BEDLOAD AND SUSPENDED LOAD VOLUME TRANSPORT RATES
'
Sumq=Sumq+Qy*Dt
```

```
Sumqt=Sumqt+Qy*Dt
I=I+1
Time=Time+Dt/3600
'
IF   Lbar>0 OR Sumqt>0 THEN                'POSITIVE TRANSPORT IS OFFSHORE
     Deldsb=(Dsb2-Dsb)*ABS(Sumq/Qt)         'CHANGE IN Dsb
     Dsb=Dsb+Deldsb                         'NEW Dsb
     Xsb=Xsb+Deldsb/Tanfo                   'NEW Xsb
     Deslxmsl=-(Sumq-0.5*Deldsb*(2*Xbar-Deldsb*(Tanfo-Tanoff)))/(Dbf+0.5*Dsb)
                                            'CHANGE IN Xmsl
     Xmsl=Xmsl+Delxmsl                      'NEW Xmsl
     Xbf=Xmsl-Dbf/Tanbf                                     'NEW Xbf
     Dellbar=(Deldsb/Tanoff-Deldsb/Tanfo)+2*Sumq/(Dc-Dsb)   'CHANGE IN Lbar
     Lbar=Lbar+Dellbar                                      'NEW Lbar
     Tanfo=Dsb/(Xsb-Xmsl)                                   'NEW Tanfo
     Tanoff=(Dc-Dsb)/(Xc(Xsb+Lbar))                         'NEW Tanoff
     IF Lbar<0 THEN Lbar=0
'
'
'
'
'
'
'
ELSE
     Adi=1/2
     Bdi=-(Dbf+Dsb+Dc)
     Cdi=Dsb*Dc
     Di=(-Bdi-SQR(Bdi^2-4*Adi*Cdi))/(2*Adi)  'DEPTH OF PROFILE INTERSECTION
     Delxmsl=-Sumq/(Dbf+Di/2)               'CHANGE IN Xmsl
     Xmsl=Xmsl+Delxmsl                      'NEW Xsml
     Delxsb=Sumq/(Dc-Di)                    'CHANGE IN Xsb
     Xsb=Xsb+Delxsb                         'NEW Xsb
     Xbf=Xmsl-Dbf/Tanbf                     'NEW Xbf
     Tanfo=Dsb/(Xsb=Xsml)                   'NEW Tanfo
     Tanoff=(Dc-Dsb)/(Xc-Xsb)               'NEW Tanoff
END IF
LOOP
'
I=0
CALL Plotter
IF Time<S(L) THEN GO TO Timestepping
NEXT L
CLOSE #1
CLOSE #3
END
'
'SUB PROGRAM THAT DRAWS THE GRAPHICS
'
SUB Grapher
screen 9
SHARED Xc,Dc,Dbf,Swl,ENDX, ENDY
```

```
'
'DRAW THE BOX
'
line (80,56)-(600, 306),,B
'
'PRINT THE TITLES
'
locate 24,30
print "CROSS SHORE DISTANCE (m)
LOCATE 1,31
PRINT "BEACH PROFILE CHANGES"
LOCATE 3,11
PRINT "DEPTH FROM SWL (m)
'
'X AXIS TICK MARKS AND LABELS
'
ENDX=INT(Xc/100+1)+2
X=1
DO UNTIL X=ENDX+1
Xx=520*(X/ENDX)+80
LINE (Xx,292)-(Xx,287)
Labelx=(X-3)*100
X1=2*INT(X/2)
IF X1<>X THEN
LOCATE 22,65*(X-1)/ENDX+9
PRINT Labelx
END IF
X=X+1
LOOP
'
'
'
'
'
'
'
'
'
'Y AXIS TICK MARKS AND LABELS
'
ENDY=INT((Dbf)+(Dc+2))
Y=1
DO UNTIL Y=ENDY
Yy=250*(Y/ENDY)+42
Dcr=INT(Dc+2)
Ly=(Dcr-ENDY)-1
Labely=-(Ly+Y)
LINE (80,Yy)-(85,Yy)
IF Labely=0 THEN
     LINE (80,Yy) - (600,Yy)          'MARKS THE POSITION OF THE SWL
     Swl=Yy                           'SAVES THE POSITION OF THE SWL
END IF
Y1=2*INT(Y/2)
```

```
IF Y1<>Y THEN
LOCATE 17.5*(Y-1)/ENDY+5,8
PRINT Labely
END IF
Y=Y+1
LOOP
END SUB
'
'SUB PROGRAM THAT PLOTS THE PROFILES
'
SUB Plotter
screen 9
SHARED Xbf,Dbf,Xmsl,Swl,Xsb,Dsb,Xc,Dc,Lbar,ENDX,ENDY,KKK
'
'CONVERTING TO GRAPHICS UNITS
'
Dbfp=Swl-250*(Dbf/ENDY)
Dsbp=Swl+250*(Dsb/ENDY)
Dcp=Swl+250*(Dc/ENDY)
Xbfp=520*((Xbf/100+2)/ENDX+80
Xmslp=520*((Xmsl/100+2)/ENDX+80
Xsbp=520*((Xsb/100+2)/ENDX+80
Xbarp=520*(((Xsb+Lbar)/100+2)/ENDX)+80
Xcp=520*((Xc/100+2)/ENDX)+80
'
'PLOTTING
'
LINE (Xbfp,Dbfp) - (Xmslp,Swl),KKK
LINE (Xmslp,Swl) - (Xsbp,Dsbp),KKK
IF Lbar>0 THEN
     LINE (Xsbp,Dsbp) - (Xbarp,Dsbp),KKK
     LINE (Xbarp,Dsbp) - (Xcp,Dcp),KKK
ELSE
     LINE (Xsbp,Dsbp) - (Xcp,Dcp),KKK
END IF
IF KKK=1 OR KKK=13 THEN Mask=&HAAA
IF KKK=5 THEN Mask=&HBBB
IF KKK=9 THEN Mask=&HCCC
KKK=KKK+4
END SUB
```

Appendix B

INFORMATION CONCERNING INPUT FILES

INPUT FILES

Input files can be created with any line editor. The file, entitled WAVES.DTA, must be in ASCII format with two, comma delimited fields per line. The first field should be wave height, in meters; the second field should be duration of wave conditions, in hours.

WAVEMAKER PROGRAM

For those not familiar with line editors and/or file structure, a simple program, WAVEMAKER, has been written. It provides a simple, but slightly cumbersome, method of creating a suitable input file, WAVES.DTA. Note that each time WAVEMAKER is run it automatically deletes the previous input file. To avoid deleting previous input files one must rename the files not being used in the present application.

```
'"WAVEMAKER"
'
'This program inputs and stores (and edits, minimally) the wave
'conditions required to run the program "CROSHORE."
'
'JUST IN CASE LOOP
'
CLS
PRINT "THIS PROGRAM WILL ERASE FILESPECS WAVES.DTA AND WAVES.XXX"
PRINT "IF THIS IS NOT ALRIGHT WITH YOU, ENTER 9"
INPUT Ers
IF Ers=9 THEN
     GOTO Bye
ELSE
     KILL "WAVES.*"
END IF
'
'INPUT INSTRUCTIONS LOOP
'
CLS
PRINT "ENTER THE NUMBER OF WAVE CONDITIONS TO BE USED"
INPUT N
DIM H(100), S(100), E(100)
'
'DATA INPUT
'
OPEN "WAVES.DTA" FOR OUTPUT AS #1
FOR I=1 TO N
     PRINT "ENTER WAVE HEIGHT AND DURATION OF CONDITION"I "OF" N
     INPUT H(I),S(I)
     WRITE #1,H(I),S(I)
NEXT I
CLOSE #1
'
'CHECKING DATA BY REVIEWING SCREEN OUTPUT
'
Pagain:
PRINT "PLEASE CHECK DATA SET FOR ERRORS"
PRINT " "
PRINT "CONDITION     HEIGHT     DURATION"
OPEN "WAVES.DTA" FOR INPUT AS #1
FOR J=1 TO N
     INPUT #1, H(J),S(J)
     PRINT J,H(J),S(J)
NEXT J
CLOSE #1
PRINT "IF DATA REQUIRES EDITING, ENTER 1"
INPUT Checkdat
IF Checkdat=1 THEN
     CALL Editor
     GOTO Pagain
END IF
```

```
Bye:
PRINT "YOUR DATA SET IS NOW STORED IN WAVES.DTA"
END


'SUB-PROGRAM THAT ALLOWS EDITING OF DATA
'
SUB Editor
CLS
SHARED N,H(),S()
PRINT "DATA WILL BE CHANGED IN ASCENDING ORDER OF CONDITION NUMBER"
PRINT " "
PRINT "ENTER NUMBER OF CONDITIONS TO BE EDITED"
INPUT Ne
NAME "WAVES.DTA" AS "WAVES.XXX"    'PUTS PREVIOUS DATA SET INTO A DUMMY FILE
OPEN "WAVES.XXX" FOR INPUT AS #2
OPEN "WAVES.DTA" FOR OUTPUT AS #3
FOR Con=1 TO Ne
     PRINT "ENTER" Con "OF" Ne "CONDITIONS TO BE EDITED
     INPUT E(Con)
NEXT Con
Knt=1
     PRINT Knt,E(Knt)
DELAY 10
FOR C=1 TO N                       'LOOP WHERE THE EDITING TAKES PLACE
     INPUT #2, H(C), S(C)
     IF C=E(Knt) THEN
        Knt=Knt+1
        PRINT "WAVE HEIGHT = " H(C), "DURATION =" S(C)
        PRINT "ENTER APPROPRIATE DATA"
        INPUT Hn(C),Sn(C)
        H(C)=Hn(C)
        S(C)=Sn(C)
     END IF
     WRITE #3, H(C),S(C)           'PUTS NEW INFO. INTO OLD FILE
NEXT C
CLOSE #2
CLOSE #3                           'ELIMINATES THE DUMMY FILE
KILL "WAVES.XXX"
END SUB
```

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