A MULTIPLE SHORE-BREAKING WAVE TRANSFORMATION COMPUTER MODEL

COASTAL ZONE
INFORMATION CENTER

by

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Florida Department of Natural Resources

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FOREWORD

This work provides a description of the Multiple Shore-Breaking Wave Transformation (MSBWT) computer model. This model predicts both wave behavior (including wave impacts of of shore-breaking waves) and horizontal and vertical coastal recession (i.e., dune erosion and profile scour) for a design storm surge event due to storm or hurricane impact. The work constitutes partial fulfillment of contractual obligations with the Federal Coastal Zone Management Program (Coastal Zone Management Act of 1972, as amended) through the Florida Office of Coastal Management subject to provisions of contract CM-37 entitled "Engineering Support Enhancement Program" (DNR contract no. C0037). The work has been adopted as a Beaches and Shores Technical and Design Memorandum in accordance with provisions of Chapter 16B-33, F. A. C.

At the time of submission for contractural compliance, James H. Balsillie was the Contract Manager, and Administrator of the Analysis/Research Section, Hal N. Bean was Chief of the Bureau of Coastal Data Acquisition, Deborah E. Flack was Director of the Division of Beaches and Shores, and Dr. Elton J. Gissendanner was Executive Director of the Department of Natural Resources.

Deborah E. Flack

Deborah E. Flack, Director
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ABSTRACT

Storms and hurricanes constitute design events for the assessment of coastal vulnerability and design of coastal structures. Such events not only generate unusually large and potentially destructive waves, but also produce a significant rise in the nearshore water level (termed the storm surge and lasting for the duration of the event) allowing the waves to impact the coast at elevations not normally attained. Various models have been proposed ... commonly termed "dune erosion" models ... for predicting the response of coastal physiography to such events. A major shortcoming of these modeling attempts, however, is the failure to include consideration of wave activity and its destructive potential as the result of "dune erosion".

In this work, it is recognized that the behavior of waves, particularly shore-breaking waves, and a mobile physiography composed of unconsolidated sand, are inextricably related. A mechanism for onshore-offshore sediment transport is realized in terms of longshore bar formation which not only provides for the temporary storage of eroded sediment, but which is a bedform ubiquitously reported to be formed by storm waves. Longshore bar formation can, in turn, be related to wave conditions and an "equilibrium" bedform condition is satisfied. Further, longshore bar generation is reported to require plunging-type shore-breakers, which also produce the greatest destructive potential at the highest elevation. Therefore, a model termed the Multiple Shore-Breaking Wave Transformation (MSBWT) computer model, is presented which predicts both physiographic response (i.e., horizontal and vertical recession) and the impact of littoral wave conditions.

INTRODUCTION

In endeavors to assess design forces incident to our shores and coasts and the responses expected thereof, it becomes necessary to consider design water level extremes (e.g., storm tides, astronomical tides, and sea level rise),

wave activity, wind conditions, and the mobile character of subaerial and subaqueous coastal topographies. Such assessments might apply to the natural environment such as an isolated barrier island.

For instance, the State of Florida has recently implemented a program ("Save Our Coasts") to actively pursue purchase of coastal barriers in the interest of preservation. In view of the mobile nature of coasts comprised of unconsolidated sand-sized sediments, the value of such parcels at the time of purchase negotiations would depend upon how vulnerable such parcels are to the expected forces of nature. If the majority of a parcel under consideration was experiencing significant erosion (i.e., greater than 4 cubic yards per year loss) and is highly vulnerable to the impact of a design storm or hurricane event, the purchase might be viewed as suspect in the interests of the taxpayer.

As another example, the State of Florida through Chapter 161, Florida Statutes, and Chapter 16B-33, Florida Administrative Code, has the responsibility to review proposed development activities adjacent to Florida's coastline (see Balsillie et al. 1983). Regarding structural development activities, the following discussion is provided.

A structure that is exposed or potentially in danger of being exposed to wave action should be designed to withstand the highest design wave expected at the site, if such a design can be economically justified. Such justification will depend critically on the frequency of extreme events, such as wave height and period, and duration

of the storm or hurricane, the damage potential of the waves, and the alloted permissible risk. Wave conditions at a coastal locality also depend critically on the water level. Hence, a design still water level or mean water level or a range of levels must be established in order to determine the wave forces to which a coastal structure will be subjected. (U. S. Army, 1977).

While the preceeding is wise counsel, it is to be recognized that the advice gives much weight to hydraulic phenomena with virtually no consideration to the bathymetry and its potential mobility, in terms of other than the water depth. Noting that wave characteristics and the water depth are inextricably related, it must also be recognized that consideration of the water depth is not simply a matter of the elevation of, or changes thereto, the fluid surface . The behavior of a mobile littoral bathymetry is primarily a function of the incident wave activity. Here, again, the water level surface upon which the waves propagate is a factor but, primarily, only in-so-much as surface elevation changes affect the potential energy of the waves. The degree of distortion of waves introduces an important factor in the ability of hydraulic forces to induce modifications to a mobile littoral subaqueous topography. For example, a mobile littoral bathymetry can assume radically different geometries depending upon the type of breaking wave.

To this end, the relationship between littoral hydraulics and a mobile littoral bathymetry becomes a paramount issue. That studies are often classified in terms of "the

effect of structures on waves" or of "the effect of waves on structures" (e.g., see the organization of the indexes of the last ten years of proceedings of the international conferences on coastal engineering), testifies to the proliferation of the general lack of understanding or advancement thereof. The fact remains, regarding waves and their modifying influence on a mobile bathymetry, that any change in wave characteristics will induce an alteration in the bathymetry, but at a lag-time behind a change in the waves. In turn, because of the bathymetric lag-time, the bathymetry can impose considerable influential effect on the waves.

It is obvious, therefore, that to adequately assess design forces, both the waves (including water level changes) and bathymetry must be jointly considered.

With these considerations in mind, the Multiple Shore-Breaking Wave Transformation (MSBWT) Model has been designed primarily for those low-lying coastal areas which will be flooded by a design storm/hurricane event, in the attempt to predict expected wave activity and forces incident to and over inundated coastal barriers.

PURPOSE AND SCOPE

The purpose of this report is to document the Multiple Shore-Breaking Wave Transformation computer model recently developed and installed on and driven by the Florida Department of Natural Resources, Natural Resources Management System and Services (NRMSS) IBM 4341, Model Group II processor.

Explanation of the scientific details of the model,

other than in general descriptive terms, would take far more space than can be alloted in this report. It is to be noted, however, that most of the specific scientific details are provided in existing documents (e.g., see references).

THE MULTIPLE SHORE-BREAKING WAVE TRANSFORMATION MODEL

Background

The multiple shore-breaking hypothesis was first introduced by Balsillie (1980) and Balsillie and Carter (1980), in which it was suggested that a shore incident storm wave spectra results in a wide shore-breaking zone. It follows, since longshore bar formation is invariably associated with storms and storm waves, that the unusually wide shore-breaker zone is characterized by episodes of shore-breaking, wave reformation, and rebreaking until the shore is reached. The formation of one to several longshore bars is the result, with shore-breaking occurring over the bar crests and wave reformation occurring over the troughs.

General Considerations

In terms of force and response elements, one of the most complex environments on the earth's surface occurs at the intersection of ocean, atmosphere and lithosphere. This area may be divided into zones as illustrated in Figure 1. Four general zones may be identified as offshore, littoral, beach and coast. The offshore zone lies seaward of normally expected surf zone activity. The littoral zone encompasses the area in which surf activity (i.e., shore-breaking waves) occurs. The beach or shore is defined to lie between the line

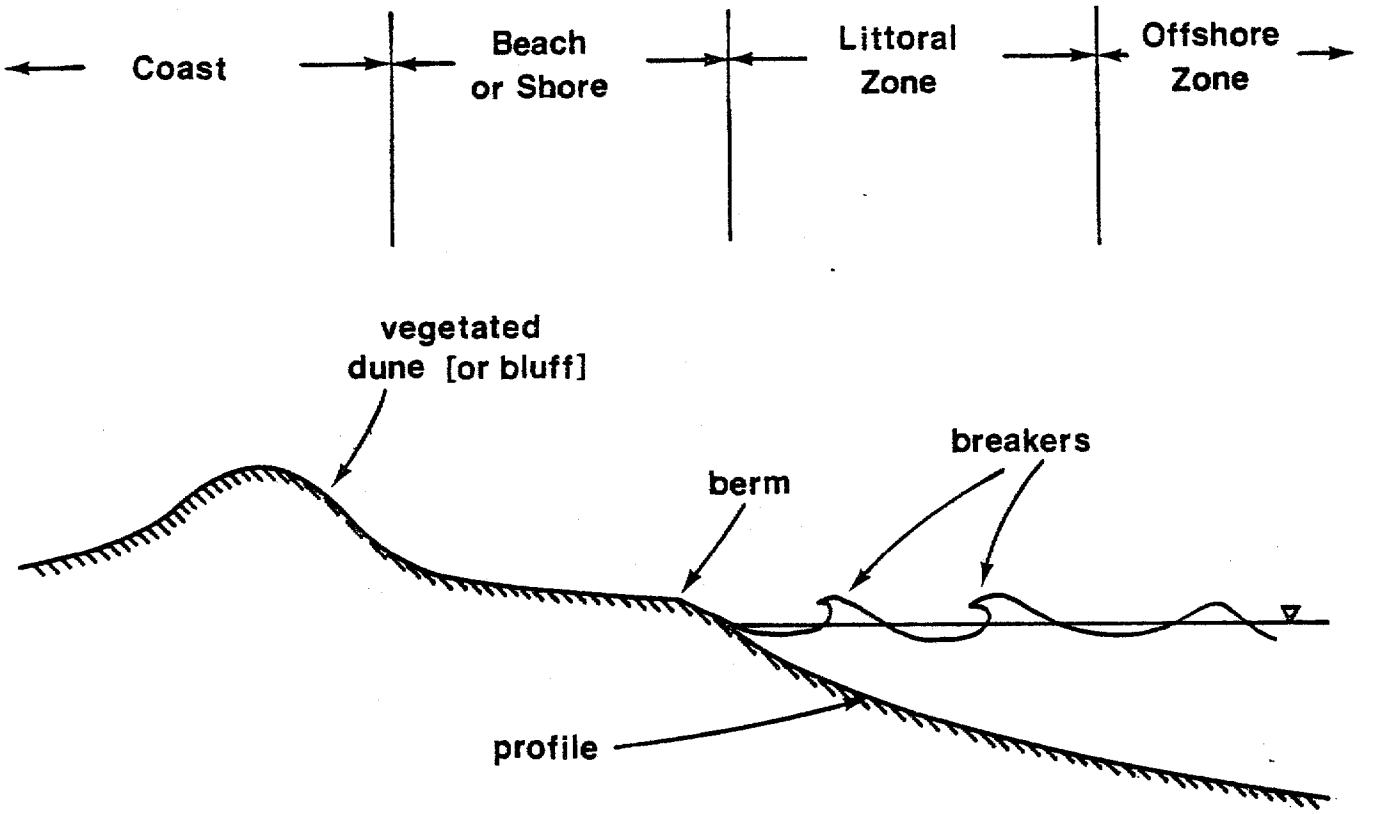


Figure 1. Cross-sectional illustration of the basic physiographic zones of a typical coastal barrier.

of mean low water and the coast. The coast lies upland of the beach defining the area of marked change in relief (e.g., bluffs and dunes) or of substantial vegetation. Offshore and littoral physiography undergo continual modifications as incident wave conditions change, with littoral changes, perhaps, the more pronounced. Where sediment is available, a beach will be present. Beach dimensions will depend upon sediment characteristics, availability of sediment, and the seasonal incident wave climate. When sediment quantities are in surplus, both beach and coast dimensions will increase. Given sufficient time, the coast through hydraulic and eolian sediment transport processes, can result in coastal configurations of formidable magnitude (e.g., high and wide dunes and/or dune ridges).

As a storm approaches the shoreline, the storm-induced rise in the nearshore water level causes storm-generated waves to strike the coast at elevations not normally attained. The net result is a redistribution of the sand stored as "coast" to some other location. This redistribution is termed horizontal and/or vertical erosion. It is to be understood, however, that the extent of such erosion following storm impact is usually less than that which occurs during the storm; that is, a certain amount of sediment recovery usually seems to occur.

For a given storm surge elevation and incident storm-generated waves, the model requires that attention is given to sediment redistribution realized in terms of a probable subaqueous equilibrium bedform. A requirement of

the model is that longshore bars constitute this bedform, thereby providing for the temporary storage of sediment eroded from the coast. Longshore bars are nature's own protection device since they cause waves to shore-break further offshore than would normally be expected, and by inducing shore-breaking cause the greatest amount of energy dissipation that waves can experience and, should wave reformation occur, significantly reduce the elevation of potentially destructive wave energy. The effect of longshore bars on reducing reformed wave characteristics has been discussed by Carter and Balsillie (1984) and Balsillie (1984b).

Longshore bar formation has been attributed to various causes (e.g., shore-breaking waves, secondary waves, standing waves, edge waves). In this work, longshore bar formation is attributed to shore-breaking wave activity. Dolan (1983, under the academic supervision of Dr. R. G. Dean at the University of Delaware) investigated the above causes of longshore bar bedform genesis for multibarred nearshores and concluded that shore-breaking wave activity constitutes the primary generating agent, noting that the others may contribute as modifying agents.

Additionally, it is a requirement of the model that plunging shore-breakers form longshore bars. The type of shore-breaker is determined from the surf similarity parameter, ξ_b (i.e., wave steepness parameter divided by the square root of the bed slope), according to the following revised scale (Balsillie, 1984c).

$$\xi_b \begin{cases} < 0.64, \text{ spilling shore-breakers} \\ 0.64 \text{ to } 5.0, \text{ plunging shore-breakers} \\ > 5.0, \text{ surging shore-breakers} \end{cases} \quad (1)$$

Longshore bars are considered to be able to form where $1.0 \leq \xi_b < 3.0$. Using the surf similarity parameter, the stoss slope of the longshore bar is evaluated in the region of critical incipient shore-breaking. Determination of the remaining segments of longshore bar geometry are discussed by Balsillie (1984b).

Plunging shore-breakers are also considered to constitute the design wave. Studies (Miller et al. 1974a; 1974b; Miller, 1976) report that impact forces from shore-breaking and broken waves significantly exceed those from non-breaking waves. Highest impact pressures occur in post-breaking bores, with greater pressures occurring for plunger-generated than for spilling-generated bores. Shore-breaking waves produce next highest impact pressures with greater pressures occurring for plunging than spilling shore-breakers. The difference between breaking and post-breaking pressures is the elevation at which the maximum horizontal impact pressure occurs. For post-breaking bores the elevation is low, occurring near the mean water level. For waves at shore-breaking, the elevation occurs in the upper portion of the wave crest, well above either the mean water level or the still water level. Because of the higher elevations associated with shore-breakers, in particular plunging shore-breakers, this breaker type defines the design wave condition.

During the course of developing the Multiple Shore-breaking Wave Transformation Model, it became clear that, for various reasons, existing wave theories do not adequately allow for the prediction of the transformation of waves during the shore-breaking process. In fact, with the recognition that the "... ultimate limitation of any wave theory based on potential wave theory is given by the condition at which the wave breaks" (Madsen, 1976), it was apparent that investigation of the shore-breaking process was needed. The need became particularly clear if secondary, tertiary, etc., shore-breaking episodes following wave reformation were to be adequately accounted for. Of importance, was the recognition of the peaking of waves during shore-breaking, termed alpha wave peaking (Balsillie, 1980). Results from the investigations (Balsillie, 1983b, 1983c, 1983d, 1984a) provide for the prediction of wave transformation (e.g., both total wave height and wave height above the still water level, wave length and wave speed) during shore-breaking. Attenuation of reformed wave characteristics (i.e., height, period and length) following bar-breaking are described by Balsillie (1984b).

While longshore sediment transport prediction seems to have reached acceptable status, the same is not true of shore-normal sediment transport prediction. Existing onshore-offshore transport models tend to assume uniform energy dissipation. Such an assumption, however, applies only to spilling shore-breakers with the additional caveat that spilling occurs across the entire littoral zone.

The approach is very attractive, since sediment transport prediction is accomodated as a function of a tractable energy dissipation rate. If, however, longshore bars form during storms, and if they must be formed by plungers, the sole consideration of uniform energy dissipation may be suspect.

In terms of sediment transport, submerged longshore sand bars are, in this work, considered to be formed due to the combination of onshore sediment transport along the bar stoss and offshore transport in the bar trough regions (Figure 2). The net result is the accumulation of sand occurring between the two processes, producing the longshore bar crest. The bars, then, not only provide the bedform for temporary storage of sediment, but provide the mechanism for wave breaking. Wave behavior landward of a bar-breaking episode is dependent, again, on the wave (i.e., whether waves reform or turbulent bores are maintained) and sediment characteristics, and on whether the shore has been reached.

The forward speed of a storm or hurricane will greatly affect the amount of coastal recession. For instance, Hurricane Eloise which struck the panhandle coast of northwest Florida in September 1975 had a forward speed of 23 knots at landfall. The average Gulf of Mexico hurricane, however, has a speed of 10 knots. Therefore, Eloise moved across the coast at a speed 2.3 times that which might be expected. While Eloise is reported (Dean, 1983) to have produced a storm surge characterized by a 75- to 100-year event, the erosion represents only a 20- to 50-year event. For this reason, various computer models (e.g., Kriebel, 1982;

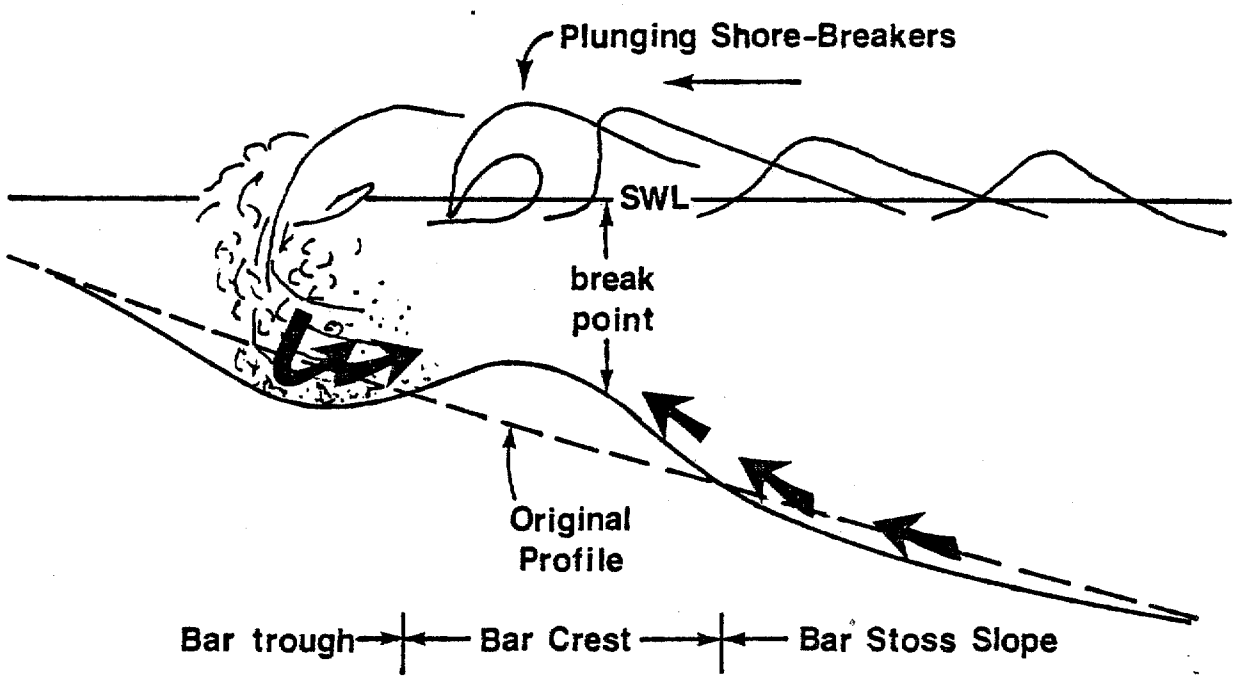


Figure 2. Cross-sectional illustration of submerged longshore bar formation. Bold arrows indicate direction of sediment transport.

Dean, 1983) have been developed incorporating a time series storm surge elevation history. Note that if Eloise had a forward speed of 10 knots, the storm surge resulting would most probably have been different. It is not possible, therefore, to simply correlate erosion quantities and storm speed, and such modeling becomes complex.

The present model assumes that as the storm surge water level accompanying a landfalling storm or hurricane rises, there is sufficient time for longshore bars to form, since the time required for storm surges to reach a peak may be measured in terms of hours. Hence, for a given peak storm surge level the offshore bedform configuration, depending on wave characteristics, has a real solution since by definition the bedform has attained equilibrium. However, coastal response to storm impact is quite a different matter since such response will be dependent on the time over which final shore-breaking, resulting runup, etc., directly impact the coast. Coastal conditions which impose significant influence on sediment redistribution are discussed in the ensuing section.

General Description

The MSBWT model requires as input a peak storm surge elevation, initial dynamic physiography (i.e., onshore coast and beach topography, and offshore bathymetry), and initial wave characteristics (i.e., wave height and period). It is assumed, based on the geology of coastal Florida, that granulometric considerations are relevant to sand-sized

sediment.

Peak storm surge elevations are available from a variety of sources. However, in Florida, the numerical storm surge modeling results of Dean and Chiu (1981a, 1981b, 1982a, 1982b, 1983a, 1983b) are recommended for use. These results represent a continuing effort funded by the Florida Department of Natural Resources to determine storm surge levels for the State on a county-by-county basis. To date, results are available for Broward, Dade, Walton, Nassau, Franklin and Charlotte Counties (Table 1). Where such studies have not yet been completed, results from other acceptable sources can be used.

Onshore profile data may be independently introduced or automatically obtained from the Beaches and Shores Profile Data Base (see Table 2). Offshore bathymetry is specified according to a mathematical representation of available measured nearshore bathymetry (Table 2). The mathematical representation (Bruun, 1954; Dean, 1977; Hughes and Chiu, 1978) is fitted to measured data to yield a smooth, concave upward profile. The relationship is given by:

$$d = a_s x^b \qquad (2)$$

where d is the water depth, x is the distance offshore, a_s is the shape coefficient (commonly ranging from about 0.12 to 0.18), and b is an exponent (demonstrated by Dean, 1977, to have a value of 2/3). The method is summarized by Balsillie (1982a) with a compilation of values for a_s and b for Florida data given by Balsillie (1982b). Newly acquired and analyzed

Table 1. Beaches and Shores Combined Total Storm Surge Values (Feet above Mean Water Level) for Various Return Periods (values include contributions of wind stress, barometric pressure, astronomical tides, and dynamic wave setup).

Return Period (years)	DNR Range Monument Number/Storm Surge Elevations					
Broward County (Dean and Chiu, 1981)						
	R-15*	R-64	R-120			
10	7.7	7.8	7.7			
20	9.0	8.9	9.0			
50	10.9	11.2	11.4			
100	12.5	13.1	13.6			
200	14.3	14.8	16.9			
500	17.1	17.2	16.9			
Dade County (Dean and Chiu, 1981)						
	R-10	R-28	R-85			
10	8.0	8.1	8.2			
20	9.3	9.5	9.8			
50	11.4	10.8	12.1			
100	13.5	13.6	14.0			
200	15.3	15.4	15.8			
500	17.6	17.7	18.0			
Walton County (Dean and Chiu, 1982)						
	R-10	R-75	R-115			
10	4.0	3.8	3.8			
20	6.9	6.5	6.2			
50	9.8	9.4	8.9			
100	11.4	11.2	10.5			
200	12.7	12.5	11.9			
500	14.2	14.1	13.6			
Nassau County (Dean and Chiu, 1982)						
	R-20	R-35	R-75			
10	5.0	5.0	4.8			
20	8.3	8.0	7.6			
50	11.9	11.6	11.1			
100	13.9	13.7	13.2			
200	16.3	15.9	15.2			
500	20.2	19.9	18.8			
Franklin County (Dean and Chiu, 1983)						
	R-1	R-20	R-80	R-130	R-170	R-210
10	2.1	2.2	2.4	2.5	2.7	3.2
20	6.1	6.1	6.2	6.3	6.5	7.3
50	10.1	10.2	10.2	10.5	11.5	12.2
100	12.0	12.1	12.3	12.6	13.0	14.7
200	13.4	13.5	13.8	14.3	14.7	16.3
500	14.7	15.1	15.4	16.0	16.4	18.7

Table 1. (cont.)

Return Period (years)	DNR Range Monument Number/Storm Surge Elevations		
Charlotte County (Dean and Chiu, 1984)			
	R-5	R-34	R-62
10	6.8	6.8	6.7
20	9.3	9.3	9.0
50	11.7	11.5	11.4
100	13.1	12.9	12.7
200	14.1	14.0	13.8
500	15.3	15.0	15.0

*See Penquite, Bean and Balsillie (1983) for location of profiles.

Table 2. Beaches and Shores Profile Inventory (after Penquite, Bean and Balsillie, 1983).

County	Survey Dates	Number of Offshore Profiles	Number of Onshore Profiles	Total* Number of Points	Survey Type
Bay	Feb 71 - Feb 73	47	143	3507	Control Line
Bay	Sep - Oct 75	34	103	2298	Post-Storm
Bay	Jan 83	0	5	138	
Brevard	Sep - Nov 72	74	219	4808	Control Line
Brevard	May 82	0	35	615	Post-Storm
Brevard	Jul 83	0	7	137	
Broward	76 - 80	127	128	5428	Control Line
Charlotte	May - Jun 74	23	68	1463	Control Line
Charlotte	Apr 82	0	19	330	Post-Storm
Charlotte	May 82	0	16	196	Condition
Charlotte	Jul 82	0	27	540	Condition
Charlotte	Nov - Dec 82	28	69	2663	Control Line
Charlotte	Sep 83	0	30	418	Condition
Collier	Mar - Apr 73	46	145	3024	Control Line
Collier	Jul 82	0	25	429	Post-Storm
Dade	Dec 76 - 79	76	76	3354	Control Line
Duval	Mar 74	21	68	1770	Control Line
Escambia	Jan - Feb 74	77	213	4946	Control Line
Escambia	Sep 79	0	14	254	Post-Storm
Flagler	Jul - Aug 72	34	99	2115	Control Line
Franklin	May - Jul 73	51	147	4142	Control Line
Franklin	Mar - Apr 76	15	46	1218	Post-Storm
Franklin	Jun - Sep 81	119	245	12641	Control Line
Franklin	Oct 82	0	31	467	Condition
Franklin	Mar 83	0	11	109	Condition
Gulf	Jul - Sep 73	53	161	4707	Control Line
Gulf	Jan 83	0	45	1365	Condition
Gulf	May 83	0	34	879	Condition
Gulf	Jul 83	0	42	1214	Condition
Indian River	72	39	116	2319	Control Line
Indian River	Oct 74	0	5	37	Post-Storm
Indian River	Aug 83	0	47	940	Condition
Lee	Feb 74	79	249	4828	Control Line
Lee	Feb 77	0	7	78	Condition
Lee	May - Dec 82	86	245	6159	Control Line
Lee	Jul - Aug 82	0	98	1658	Post-Storm

Table 2. (Cont.)

County	Survey Dates	Number of Offshore Profiles	Number of Onshore Profiles	Total* Number of Points	Survey Type
Manatee	Aug 74	22	68	1426	Control Line
Manatee	Jul 82	0	14	250	Post Storm
Martin	Oct 71 - Jan 72	44	115	2669	Control Line
Martin	Dec 75 - Feb 76	33	98	2111	Control Line
Martin	Feb - Apr 82	37	114	3190	Control Line
Martin	Mar 83	0	3	52	Condition
Martin	Feb - Mar 84	0	94	1256	Condition
Nassau	Feb 74	28	81	2201	Control Line
Nassau	Jan 79	0	4	79	Post Storm
Nassau	Sep - Dec 81	36	85	4475	Control Line
Nassau	Sep 82	0	31	475	Condition
Okaloosa	Nov - Dec 73	17	50	1273	Control Line
Okaloosa	Mar 76	16	49	1404	Post-Storm
Palm Beach	Nov 74 - Jan 75	80	227	5258	Control Line
Palm Beach	Aug 78	0	24	323	Condition
Palm Beach	Nov 81	21	21	759	Special
Pinellas	Oct - Sep 74	59	93	1860	Control Line
Pinellas	Aug 82	0	2	25	Post-Storm
Sarasota	Jun - Aug 74	63	185	3923	Control Line
Sarasota	Jul 82	0	49	271	Post-Storm
St. Johns	Aug - Sep 82	67	203	4608	Control Line
St. Johns	May 82	0	13	271	Post-Storm
St. Lucie	Jun 72	39	115	2504	Control Line
St. Lucie	Feb - Apr 83	0	36	707	Condition
Volusia	Apr - Jun 72	57	227	4863	Control Line
Walton	Oct 73	43	130	3762	Control Line
Walton	Oct 75	42	108	2426	Post-Storm
Walton	Apr - May 81	87	130	6553	Control Line
	TOTALS:	1820	5407	140168	

JHB/Apr 1984

* Total Number of Points represent elevations and distances only...I D and survey information are additional.

information related to the stability of a_s over time is presented in Appendix I.

Suppose, for example, that the initial wave height is 3.0 feet with a wave period of 6.0 seconds. In addition, let a surge elevation be +3.0 feet above datum, $a_s = 0.10$ and $b = 2/3$, and coastal and nearshore physiography a simple geometry as illustrated in Figure 3.

When the initial wave reaches the point of incipient shore-breaking (i.e., the bed begins to influence the waves), the method of Balsillie (1983c, 1983d) is employed to transform the waves to the point of shore-breaking (a process termed alpha wave peaking). The geometry of the ensuing longshore bar bedform, if it can form, is dependent on the shore-breaking wave characteristics, such as those considered in equation (1) and the attendant constraint that $1.0 \leq \xi_b < 3.0$ to determine the slope and shape of the seaward flank (or stoss slope) of the longshore bar, where the shore-breaker must be plunging. Other geometric characteristics of the longshore bar, based on field measurements include depth to the bar crest, depth to the bar trough fronting the crest, distance from crest to trough, bar base length and spacing, crest height, area of crest, and wave reformation distance. Each characteristic must conform to what is known about longshore bars in nature, if a bar is to be formed by the model. In addition, the disposition of the longshore bar about the original profile must meet the mass conservation constraint. This is an involved process, whereby any material eroded from below the original profile must

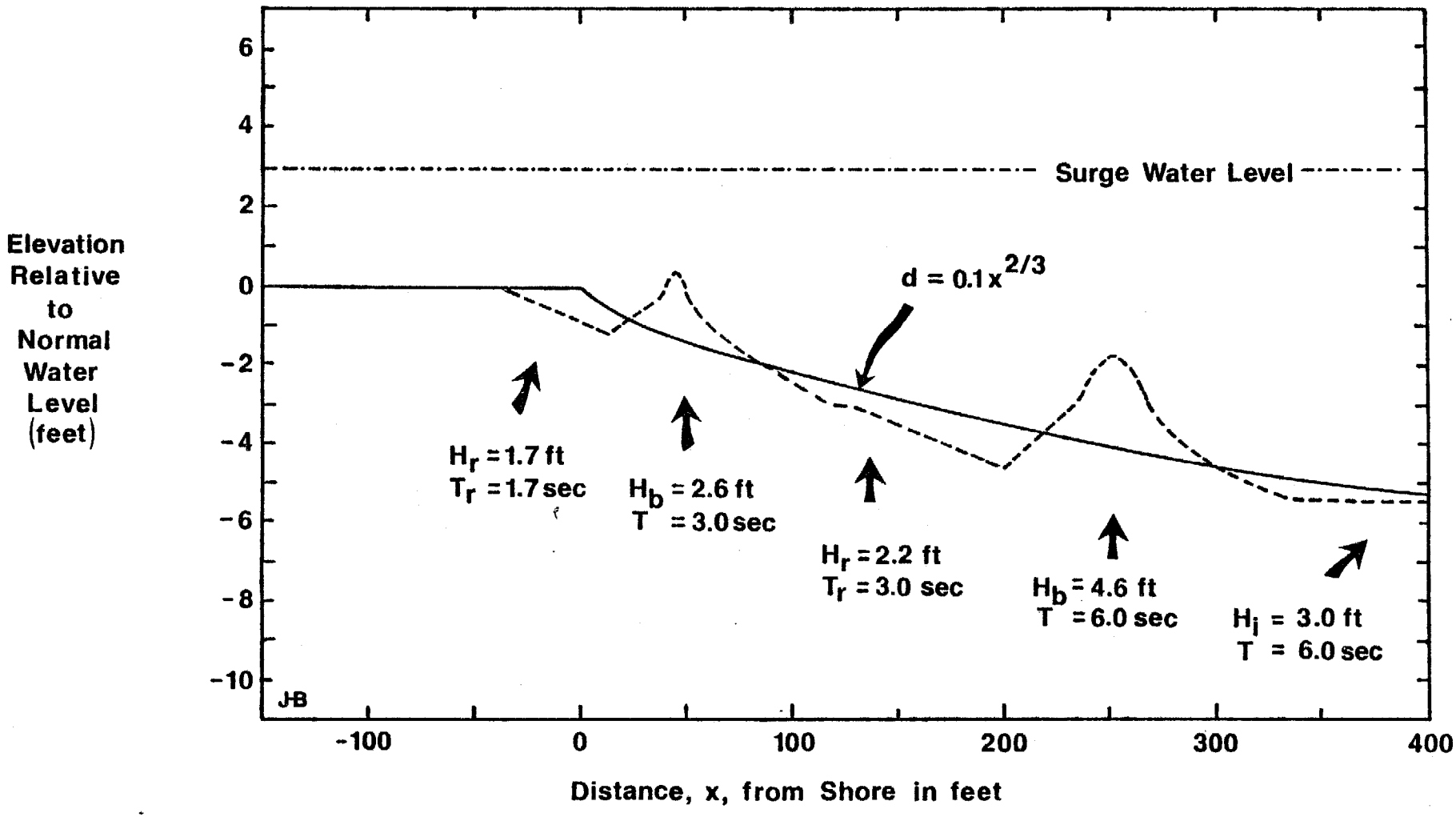


Figure 3. Example of longshore bar formation on a simple profile (surge = 3.0 feet) and resulting wave conditions (H_i = initial wave height, T = wave period, H_b = shore-breaking wave height, H_r = reformed wave height, and d = water depth).

equal the amount lying above. Hence, the volume of sand eroded from trough and bar stoss areas must be equivalent to the amount of sand contained in the bar crest.

For the above example, a longshore bar will form whose crest lies 252 feet offshore (Figure 3) at a depth of -4.65 feet. The waves plunging over the bar crest will have an average height at shore-breaking of 4.6 feet (wave period is conserved until after shore-breaking). Note that if a longshore bar had not formed, the waves would have shore-broken (according to the McCowan criterion) 200 feet closer to the shore. Reformed waves following initial bar-breaking will, from Balsillie (1984b), have a height of 2.2 feet and a period of 3.0 seconds. This wave will, in turn, produce a second longshore bar whose crest is 45 feet offshore at a depth of -2.6 feet (bar-breaking wave height of 2.6 feet), producing reformed waves with a height of 1.7 feet and period of 1.7 seconds.

It is emphasized that the example used describes a highly simplified case. Normally encountered coastal physiographies tender much more complex terminal coastal boundary conditions. Since a primary purpose of the model is to determine final shore-breaking wave conditions, it becomes important to include the various kinds of boundary conditions that will be encountered. These shall be discussed later in this section.

Field data analyzed by Balsillie (1984b) indicate that the power curve fit can be applied to longshore bars, at least in so far as delineating the depth-distance locations of the bar crest and bar trough (Figure 4). A problem occurs

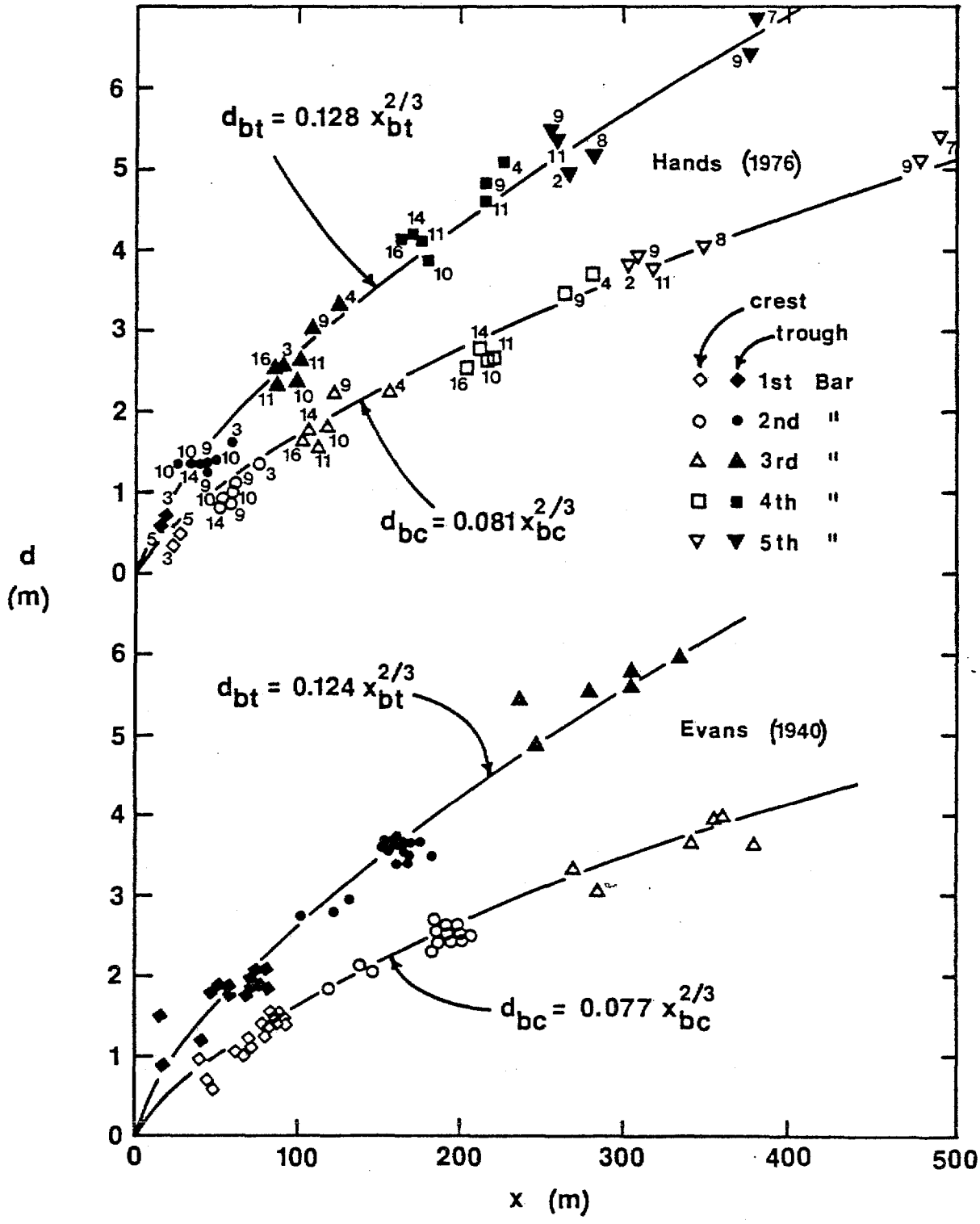


Figure 4. Illustration of power curve fits to longshore bar crests and troughs for multi-barred profiles (d is the water depth, x is the distance offshore, bc refers to the bar crest, bt refers to the bar trough). Numbers for the data of Hands (1976) refer to averages for each survey. (Figure is from Balsillie, 1984b).

with field data because initial profile conditions prior to longshore bar formation are not known. However, the MSBWT computer model, which requires initial profile specification from equation (2), was run for a significantly large range of wave height, wave period and storm surge conditions. Analyzed results suggest that where longshore bars form exclusively on an initial smooth offshore power curve profile given by equation (2), the following can be stated:

$$d_{bc} = \frac{2}{3}\left(s + a_s \, x_{bc}^{2/3}\right) \tag{3}$$

in which d_{bc} is the water depth over the longshore bar crest, x_{bc} is the distance to the crest from the shoreline, a_s is the shape coefficient for the initial smooth profile, and s is the storm surge elevation above datum, and:

$$d_{bt} = s + \frac{6}{5} a_s \left(x_{bt} + 7\,s\right)^{2/3} \tag{4}$$

where d_{bt} is the depth over the bar trough fronting (i.e., just landward) the crest, and x_{bt} is the distance to the longshore bar trough measured from the shoreline. Equations (3) and (4) are very useful in the MSBWT computer model, since they significantly reduce time requirements in fitting longshore bar bathymetry to the initial offshore bathymetry.

It is important to also realize that longshore bars are high-pass filters to incoming wave energy, and that waves with smaller heights and shorter periods than those initial waves which lead to the formation of a longshore bar, may pass over

the bar crest with significant to no change in the wave characteristics. To deal with such a situation one would, first, need to identify the storm-generated wave spectra associated with a particular hurricane and account for force and response elements of each of the individual wave energy peaks and its frequency. There is, however, a simplified alternative ... include in the analysis a significant number and range of forced wave conditions to ensure that any particular event will be represented. The MSBWT computer model is written to accomodate such an approach.

Assuming design wave conditions are coincident with the 100-year return storm surge accompanying a hurricane, the waves are considered to be forced (Mooers, 1976; Balsillie, et al. 1976). That is, they remain under the generating wind forces of the storm as it moves onshore. By specifying the initial wave height, H_i, the associated wave period, T, is given by:

$$T = 14 \ (H_i/g)^{0.5} \qquad (5)$$

in which g is the acceleration of gravity (note that the MSBWT computer model may be run using any specified wave height and period combination).

Nearshore bed response during a storm and the effect of such bed response on the incoming waves is an integral part of the MSBWT model, since an offshore incident in terms of bed-wave or wave-bed interaction will affect force-response outcomes in the shoreward direction. By employing such an

approach, the ultimate aim of the MSBWT model is to predict forces and responses occurring at and following the final shore-breaking position. At this point, however, conditions can become complex depending on the initial coastal physiography and the degree of physiographic response occurring during the course of the impacting event. This is termed the "terminal coastal boundary condition" which can generally be identified by the following categories: 1. inundated profiles, 2. breached profiles, and 3. non-flooded profiles. Each case is illustrated in Figure 5.

Inundated Profiles

Many portions of the coastal barriers of Florida will be flooded by the storm surge accompanying a design 100-year hurricane. Those low-lying coastal barriers of the lower Florida Gulf Coast are particularly vulnerable, where inundation of a substantial magnitude (from 3 to 7 feet of water, depending on local conditions) can occur. Such water depths facilitate the continued inland propagation of storm generated waves which not only result in sediment redistribution, but which can potentially impart highly destructive impacts at elevations significantly higher than the storm surge upon which they propagate. When assessing coastal vulnerability and design solutions for such areas, it becomes necessary to consider both vertical recession of the beach and coast and impact potential of wave activity.

An example of the application of the MSBWT computer

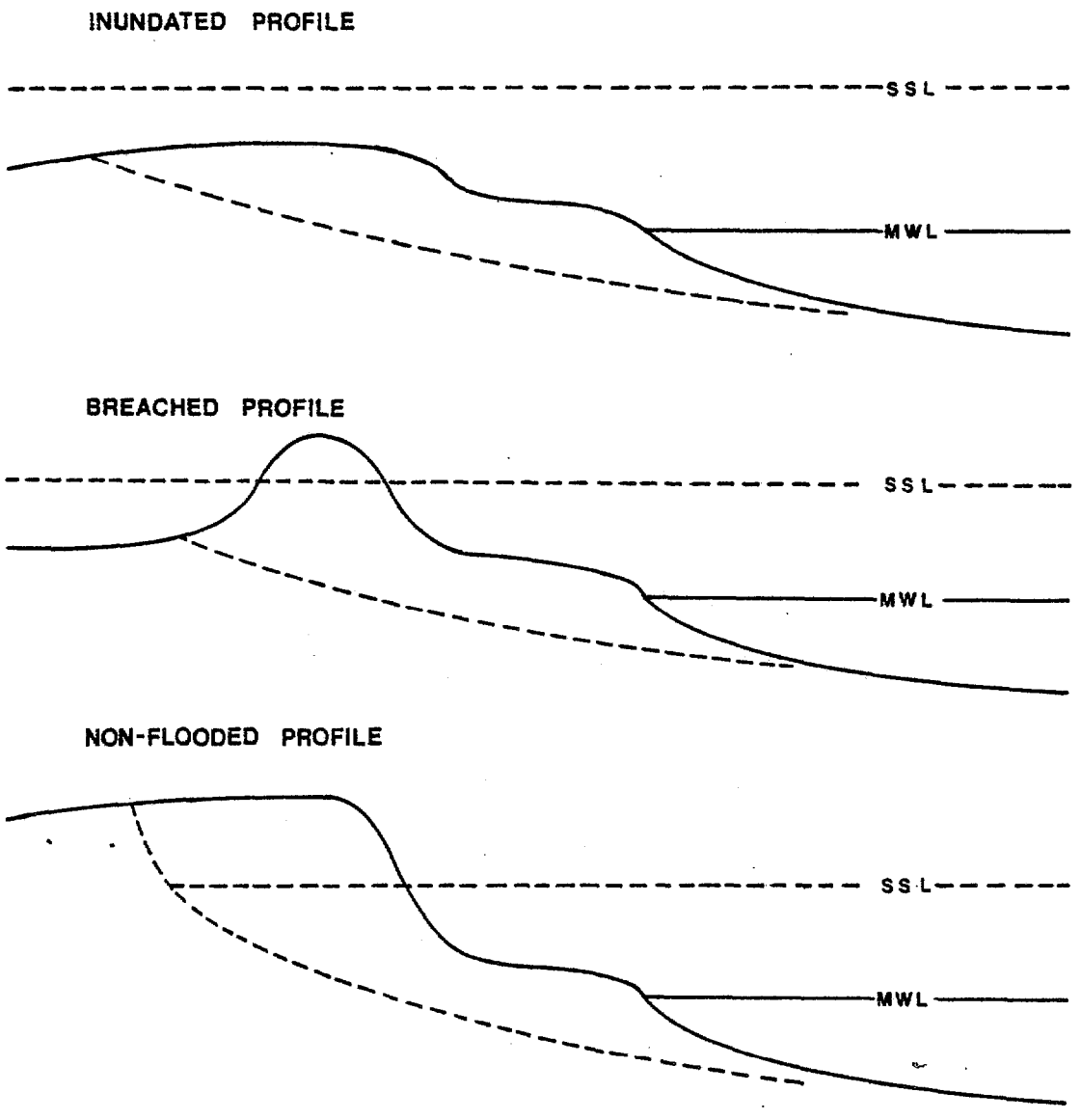
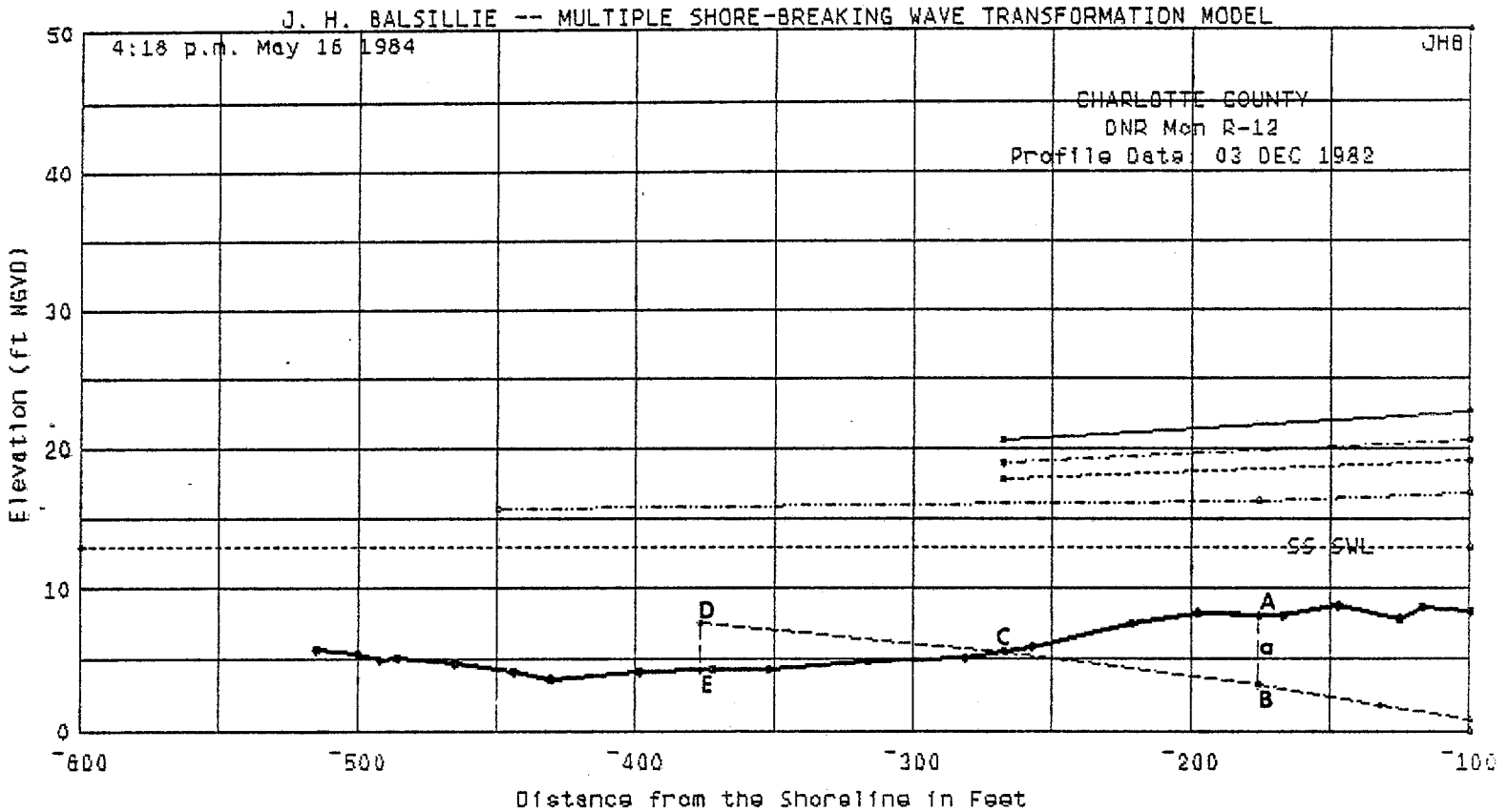


Figure 5. Cross-sectional illustration of the basic kinds of profiles resulting from storm impact, delineating the basic categories of "terminal coastal boundary conditions" considered in the present study.

model for a fully inundated profile (storm surge elevation of 13.1 feet NGVD) is given in Figure 6a. Symbols used in Figure 6 are defined in Figure 7. The eroded profile seaward of the line labeled a, represents the bar trough depth elevations. In addition, since the profile is inundated, overwash sediment transport may be expected (additional discussion of overwash processes is given in the subsection on breached profiles). In Figure 6a onshore overwash is represented by the erosion of area ABC which is deposited as area CDE. It is emphasized that the erosion profile does not represent the post-storm profile, since some recovery is expected as the storm surge recedes. Rather, the eroded profile examples of Figure 6 represents design vertical recession during impact of the event.

It is also important to realize that the eroded profiles of Figure 6, do not necessarily represent the maximum erosion possible. MacDonald's (1977) fictional account of an inlet forming along a low, narrow portion of a barrier island is not without substance. Many of Florida's natural passes have been attributed to formation by hurricane impact. Therefore, in addition to results given by analyses of Figure 6, geologic/geomorphic considerations must also be applied.

Last, and foremost, is the goal of the MSBWT model: to predict the shore-breaking wave activity (match Figures 6 and 7). The amount of the wave lying above the still water level, depicted in Figure 6, is given by Balsillie (1983d). Statistical moment shore-breaker relationships for maximum and significant wave heights are given by Balsillie and Carter



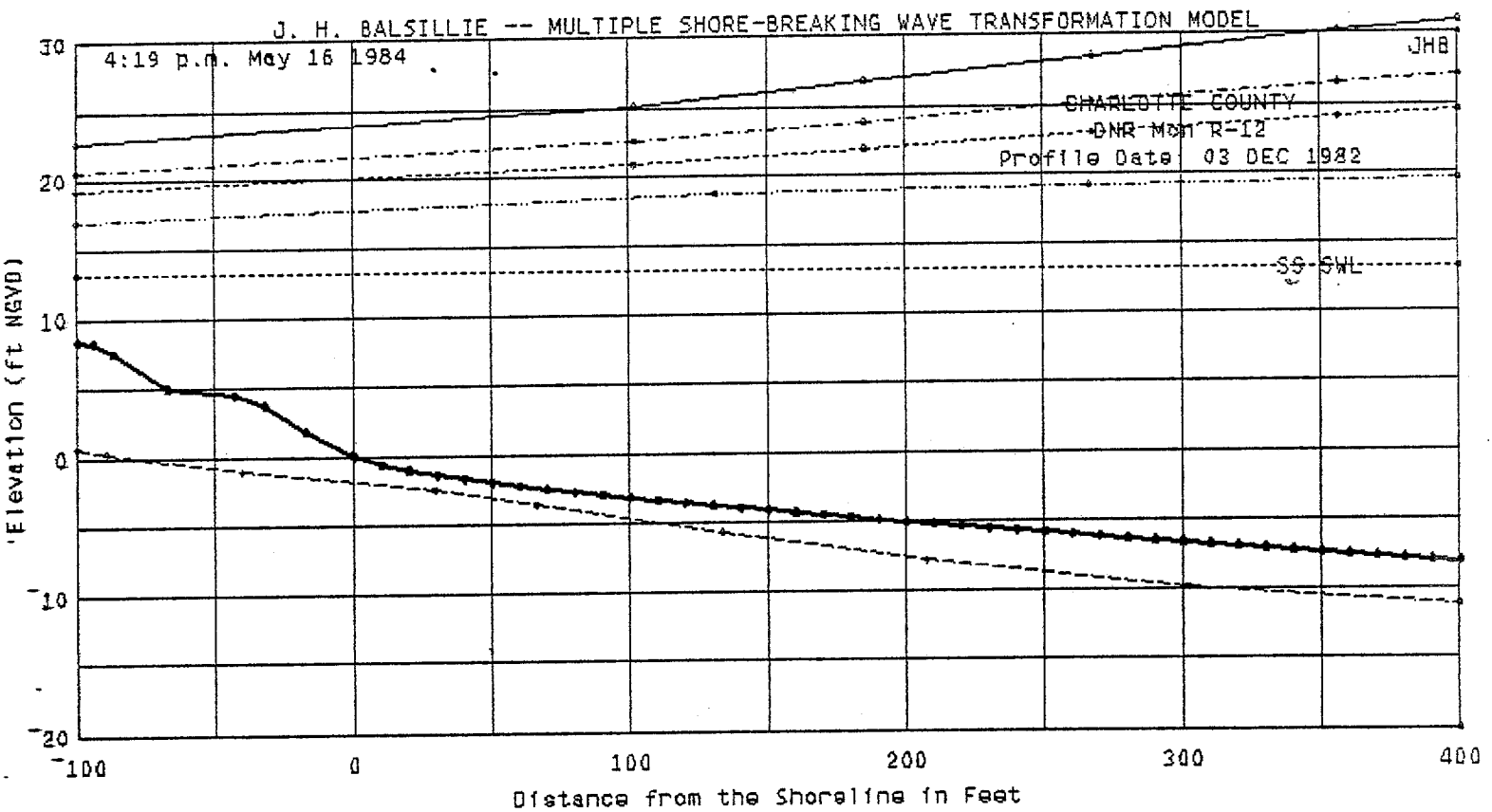
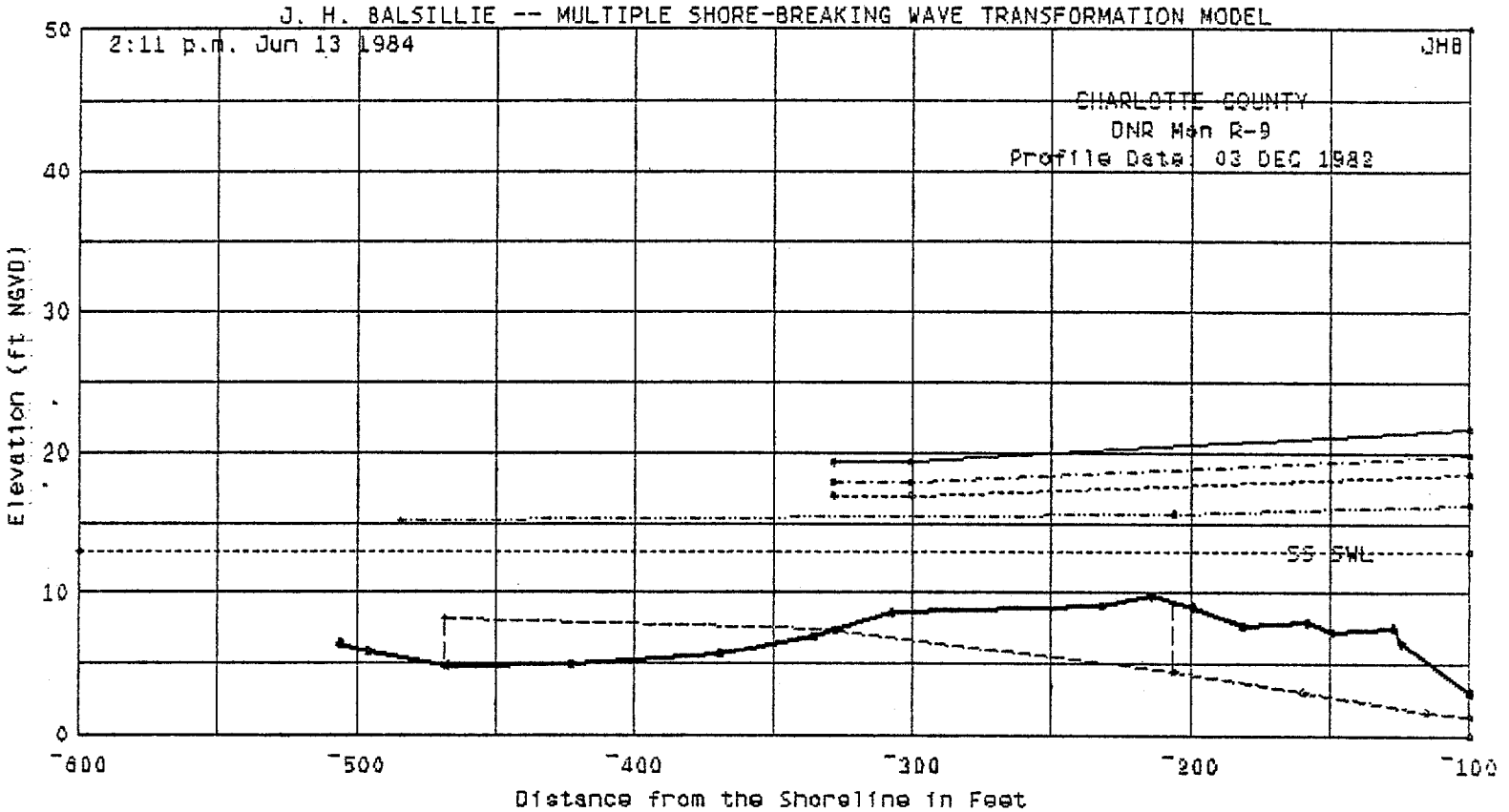


Figure 6a. Example of results from the MSBWT computer model for an inundated profile in Charlotte County, Florida.



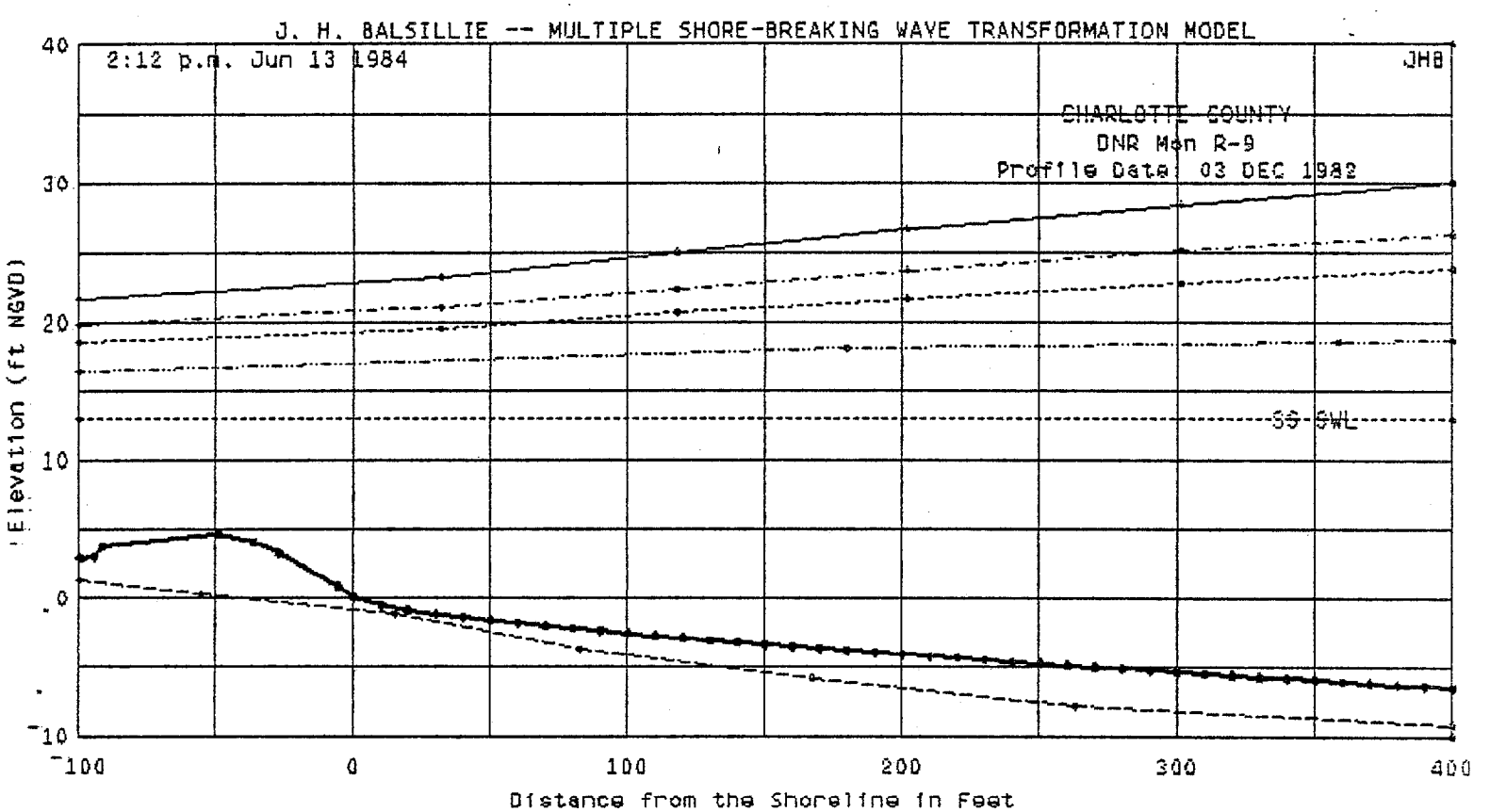
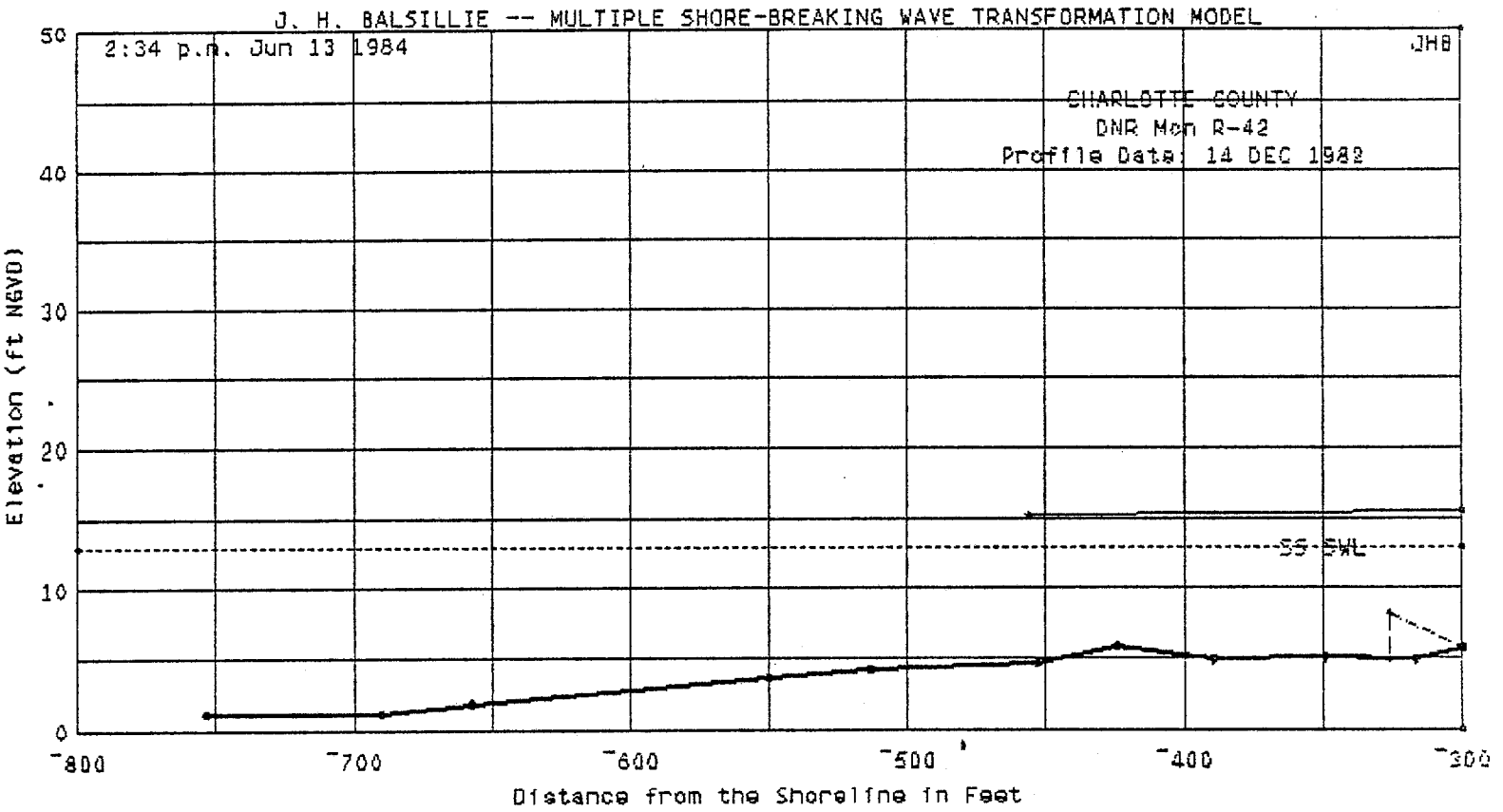


Figure 6b. Example of results from the MSBWT computer model for an inundated profile in Charlotte County, Florida.



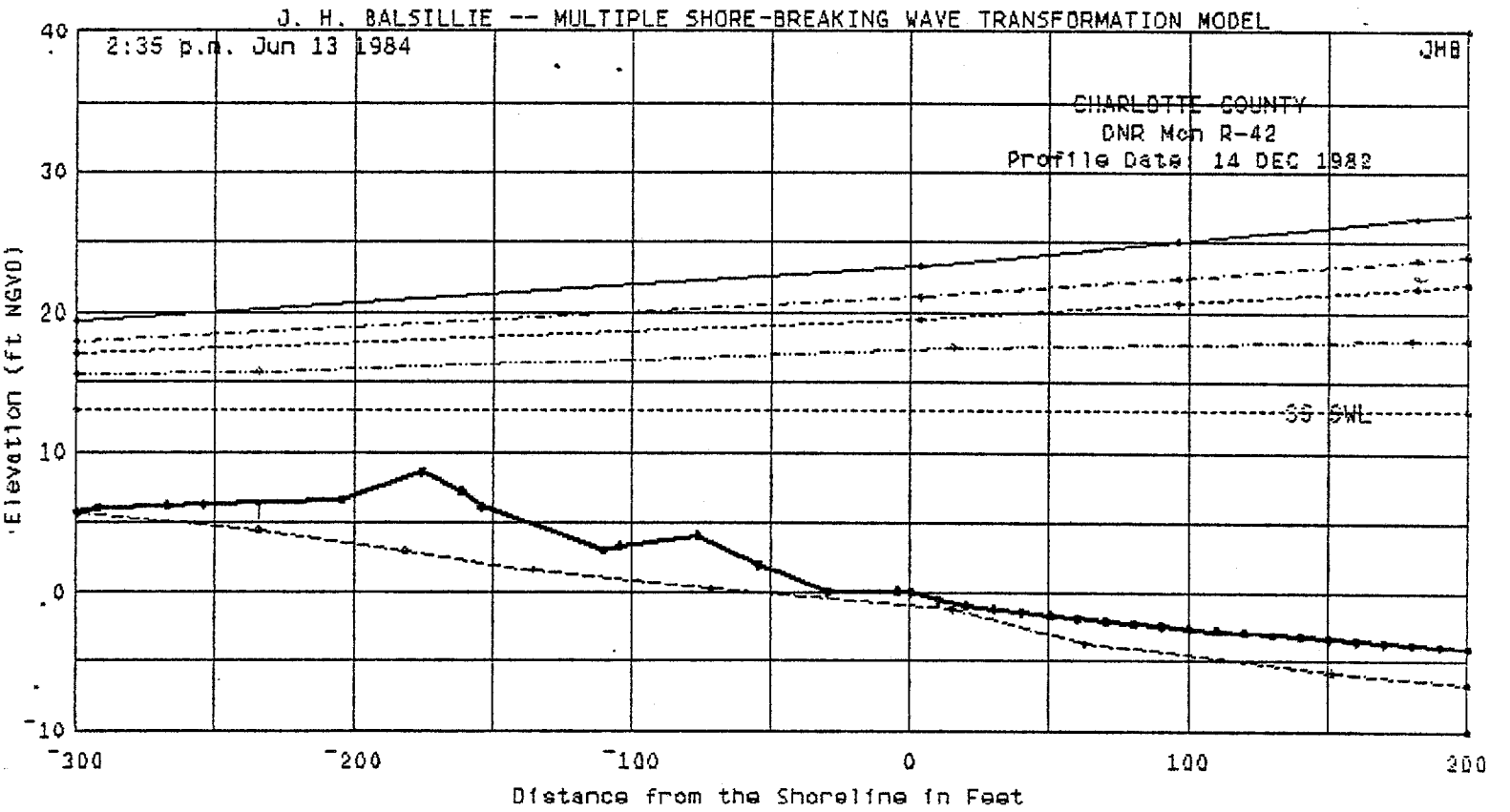


Figure 6c. Example of results from the MSBWT computer model for an inundated profile in Charlotte County, Florida.

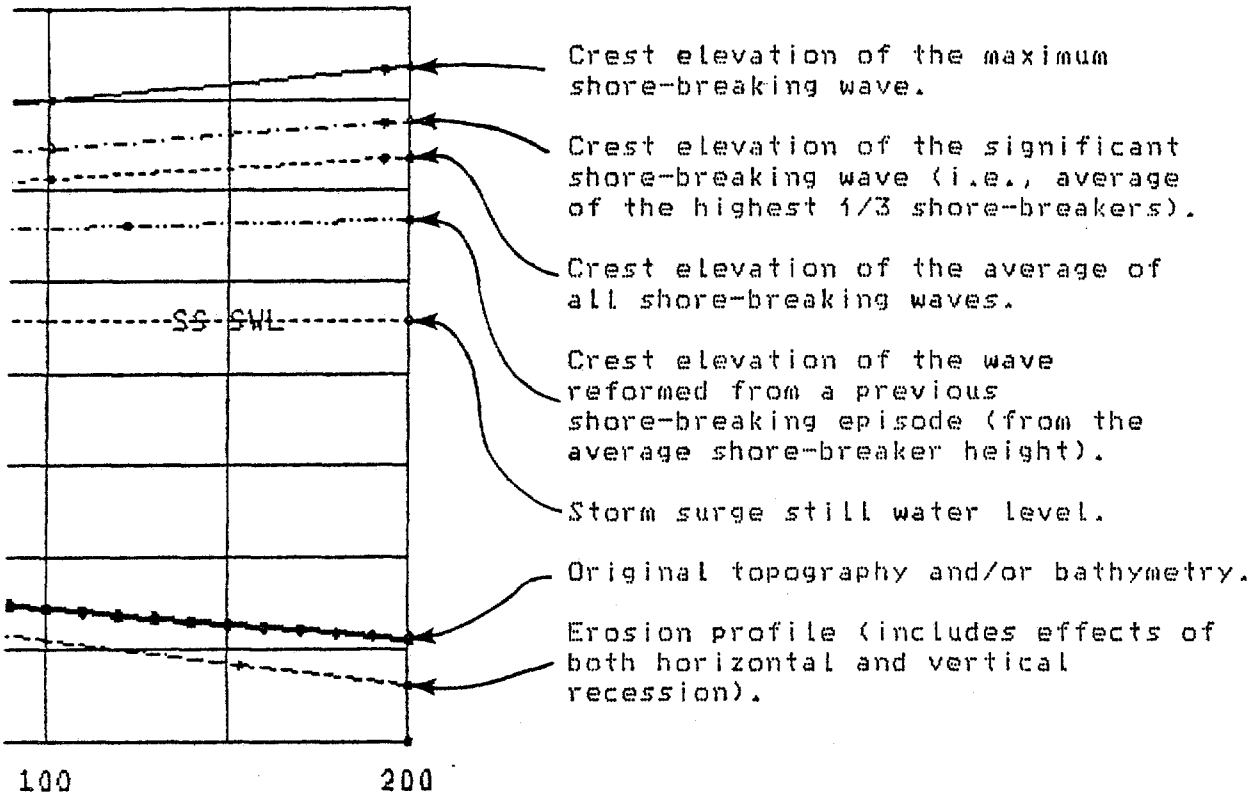


Figure 7. Explanation of symbols used in plotted results from the Multiple Shore-Breaking Wave Transformation computer model.

(1984).

Non-Flooded Profiles

Dune erosion, more nearly defined by the term horizontal recession, occurs where the coastal profile is not inundated by the storm surge. This situation is clearly different from the case of profile inundation and vertical recession previously discussed. In the present case, a portion of the coast remains above the storm surge level. Hence, gravitational forces are introduced and one must deal with geological topographic mass wasting processes. With the assumption that one is dealing with highly mobile, unconsolidated, sand-sized sediment comprising the coastal dunes or bluffs, and that the natural angle of repose of sand is about 30 degrees (steeper if the sand is fully saturated, but certainly no steeper than the vertical), then one can easily understand that only relatively few shore-breaking waves or broken bores need impact the base of an exposed sediment escarpment to cause mass wasting. The result is a local topographyically derived contribution of sand into the water column, which then becomes subject to redistribution by the waves and wave-generated currents.

For a given peak storm surge water level increase, the MSBWT model predicts horizontal recession of the coast (i.e., of the dune or bluff) based on joint consideration of allowable coastal erosion and wave runup. For purposes of discussion (i.e., modeling procedures are rather more complicated in replicating actual processes), the "sink" for sand eroded from the coast is the bar trough lying between

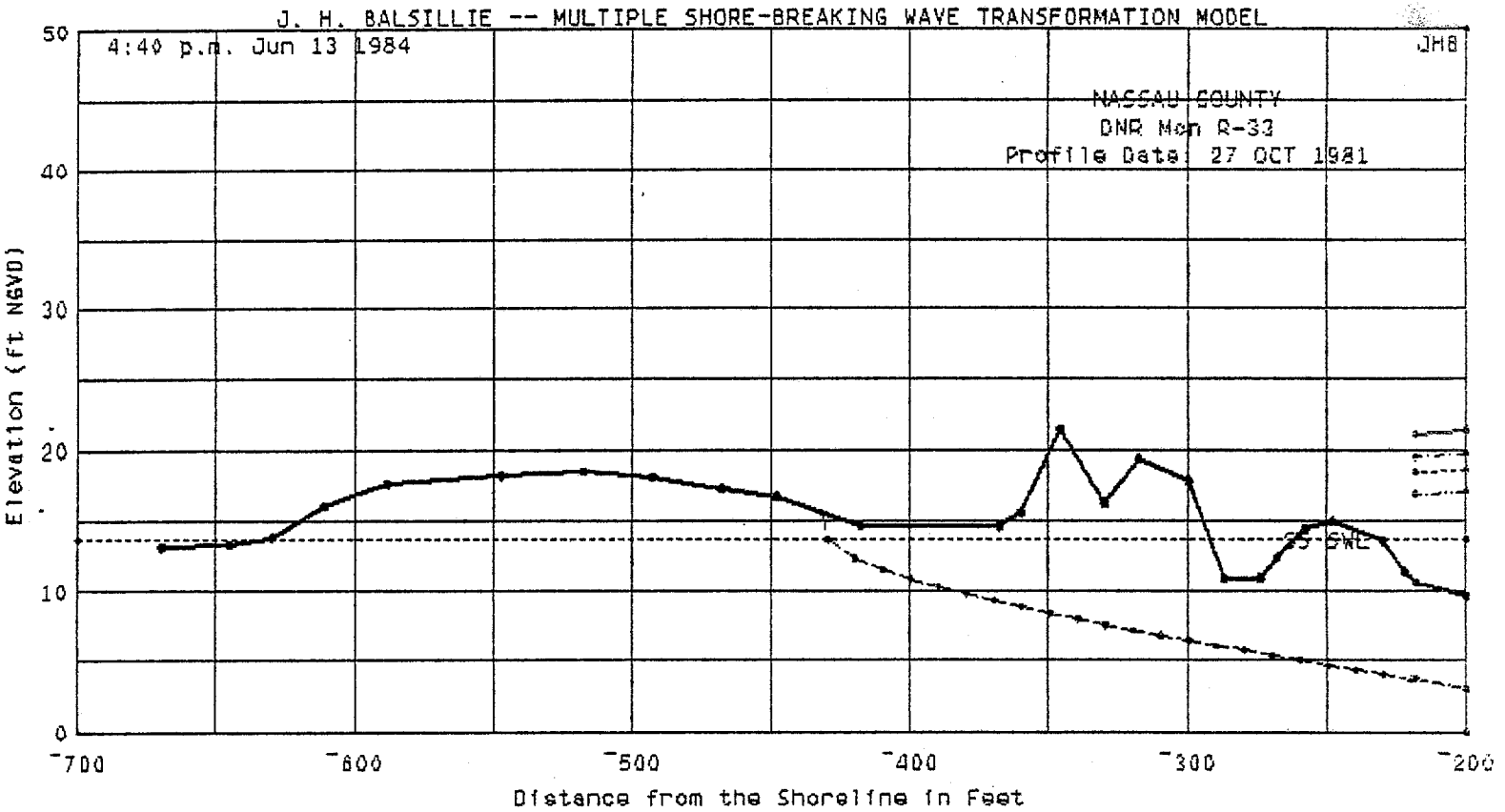
the storm shoreline and the first longshore bar crest. The bar trough area, then, constitutes a measure for the allowable amount of material that can be eroded from the coast. Wave runup is dependent on the final shore-breaking wave characteristics (Balsillie and Carter, 1980).

Dune/bluff horizontal recession prediction is based on the assumption that there is sufficient time for the profile to attain an equilibrium configuration (refer to earlier discussion of Hurricane Eloise). Examples of horizontal recession of non-inundated coastal profiles, representing a range of coastal topographic scenarios, are illustrated in Figure 8.

Breached Profiles

This profile category (see Figure 5) includes aspects considered for both flooded and non-flooded profiles. Once a dune (or other vulnerable coastal feature) has been breached due to horizontal recession in which sand is transported offshore, onshore sediment transport may occur due to overwash (or washover) processes (e.g., Schwartz, 1975; Leatherman, 1976, 1977; Leatherman, Williams and Fisher, 1977; Leatherman, 1979, 1981).

Overwash transport is considered in the model to be due largely to wave and bore activity. The amount of sediment that may be involved in overwash is dependent upon a number of factors including the amount of sediment and wave energetics at the site. Several examples resulting from the MSBWT model are illustrated in Figure 9.



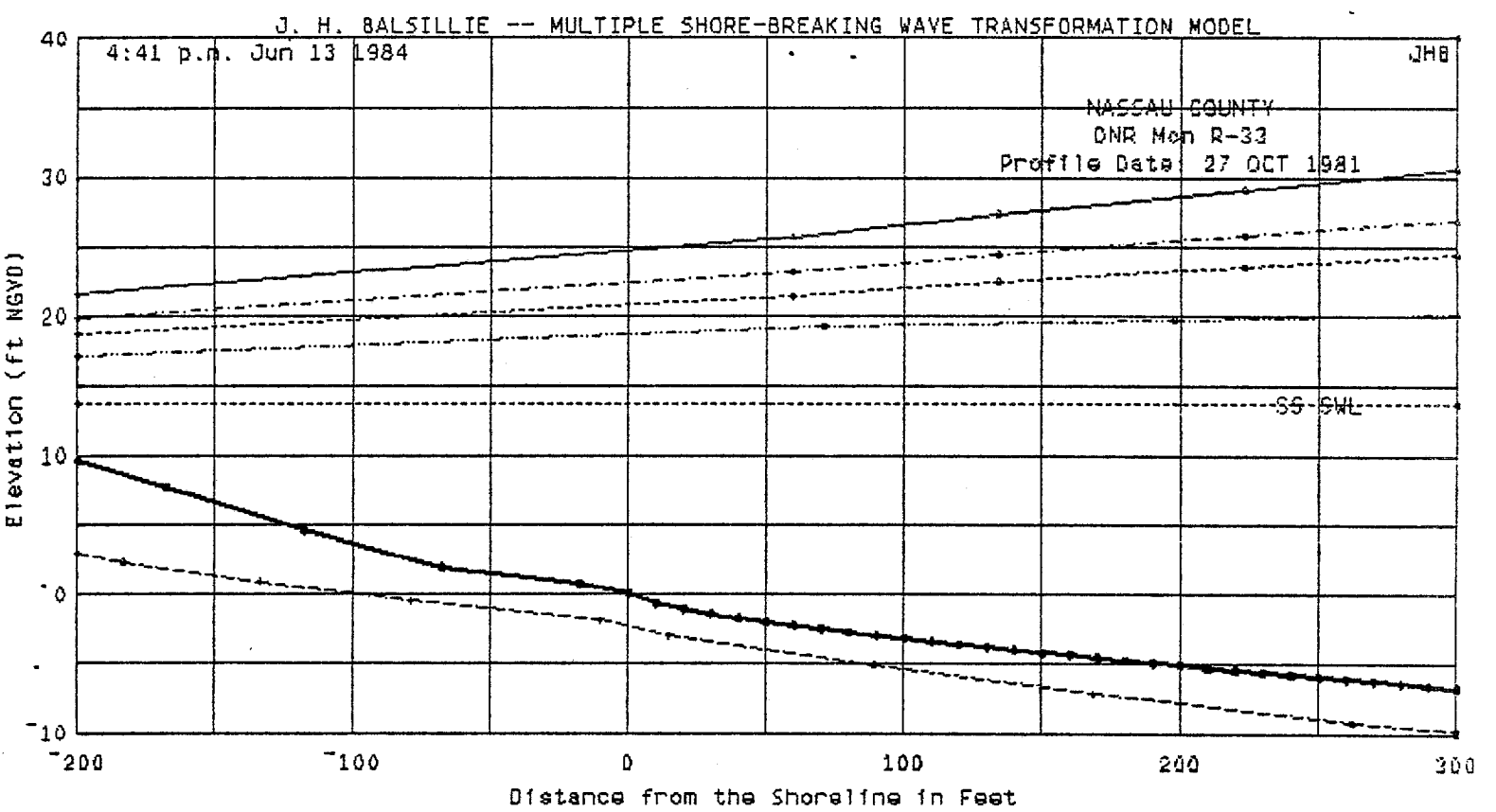
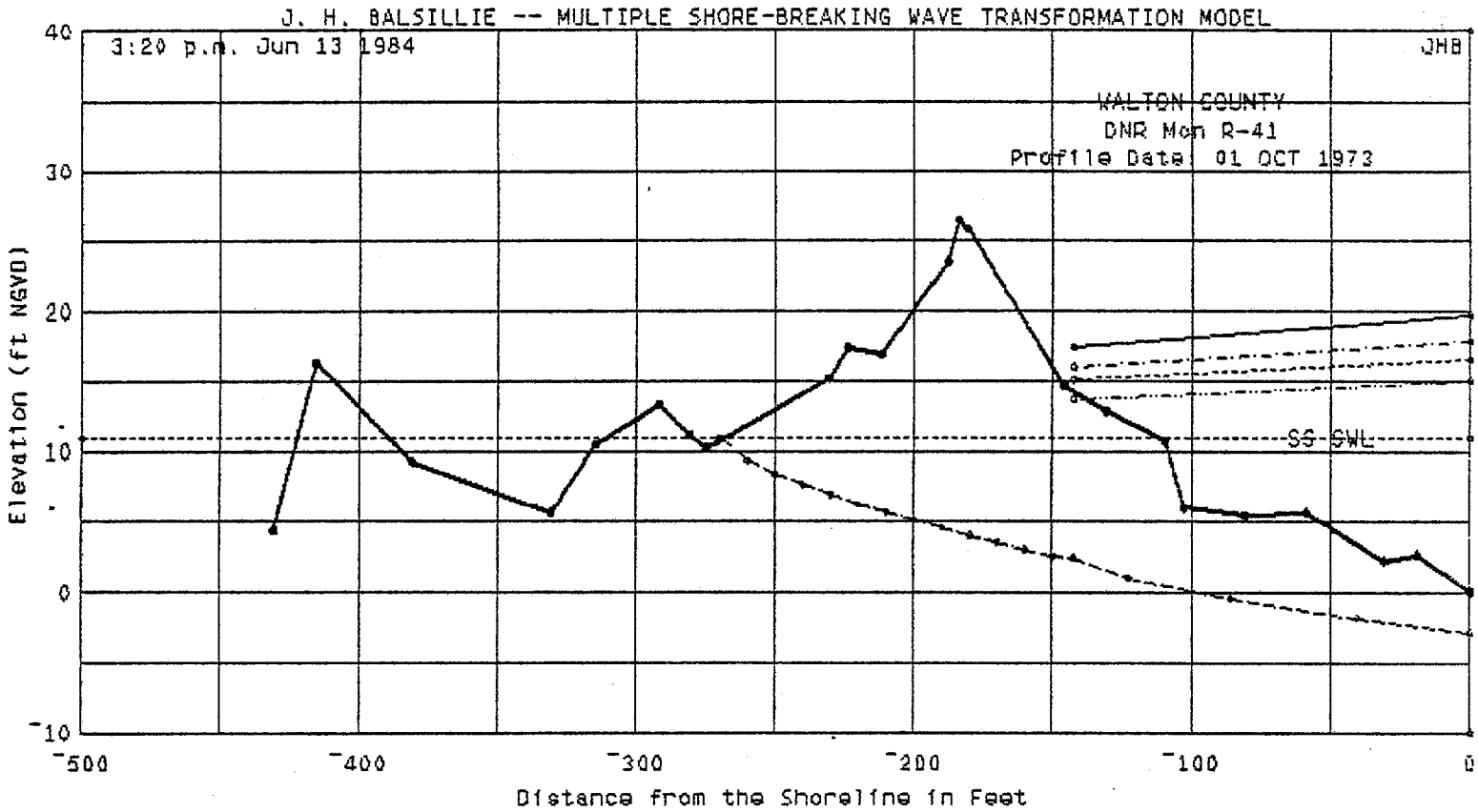


Figure 8a. Example of results from the MSBWT computer model for a non-flooded profile in Nassau County, Florida.



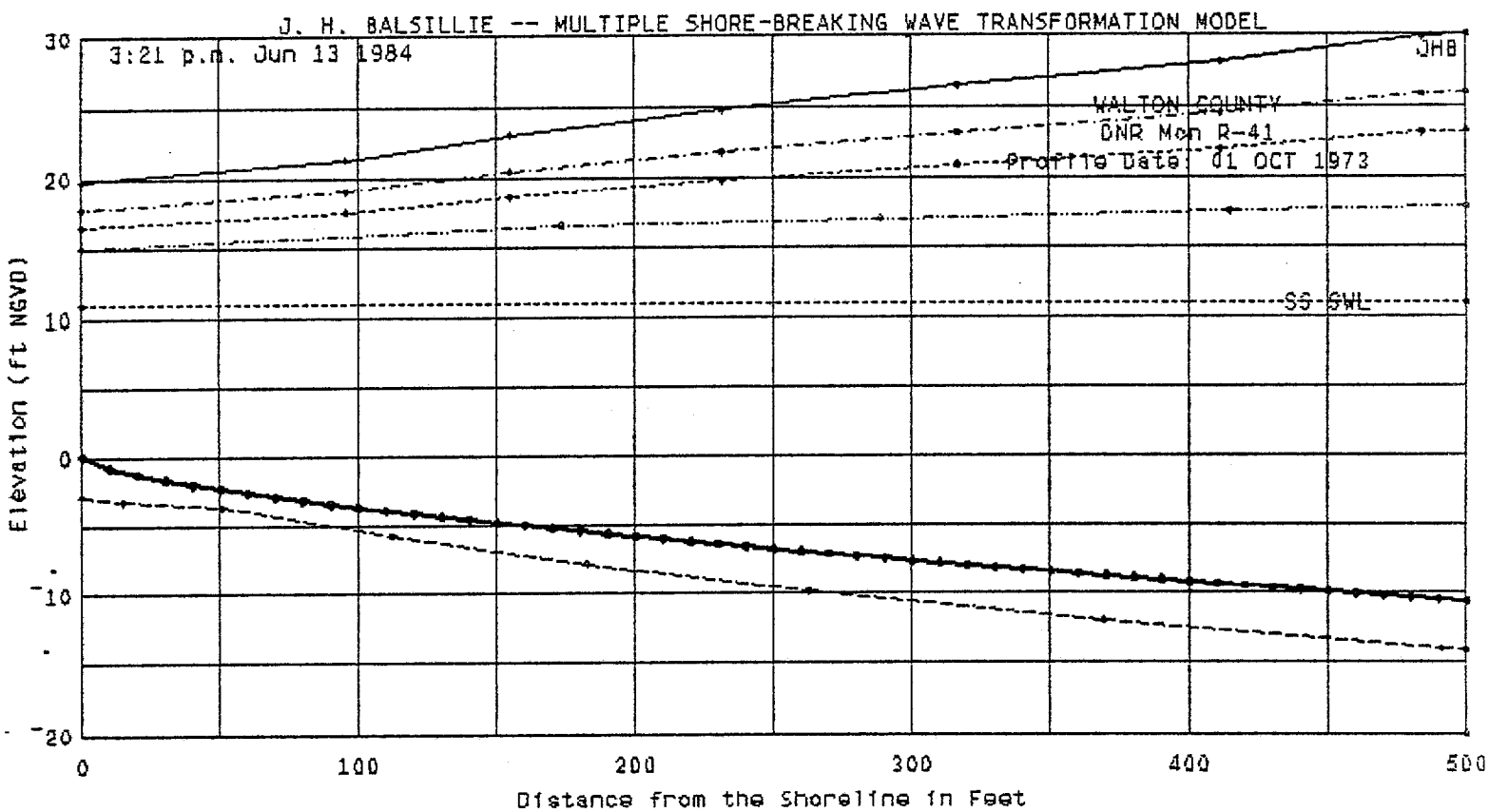
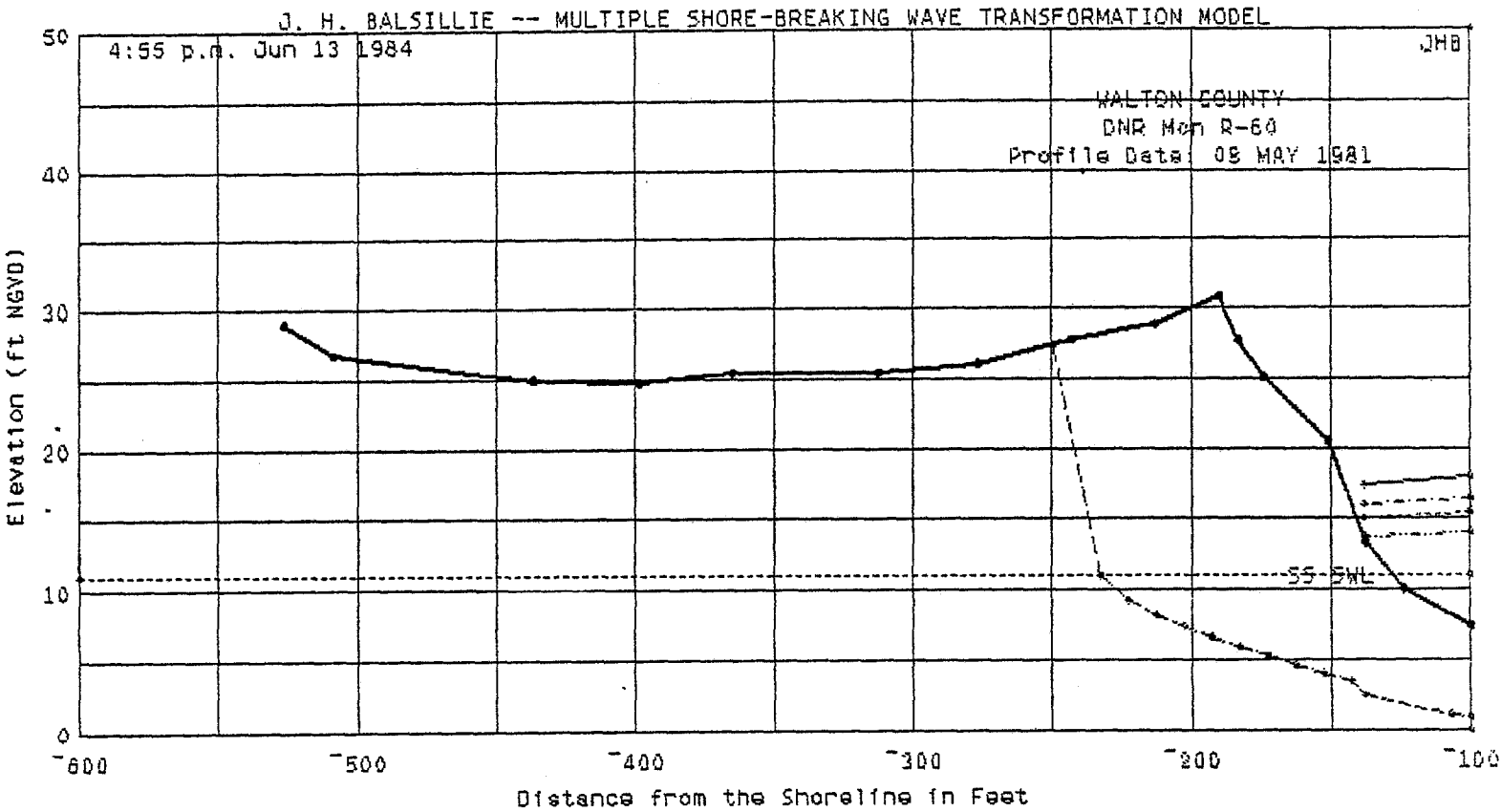


Figure 8b. Example of results from the MSBWT computer model for a non-flooded profile in Walton County, Florida.



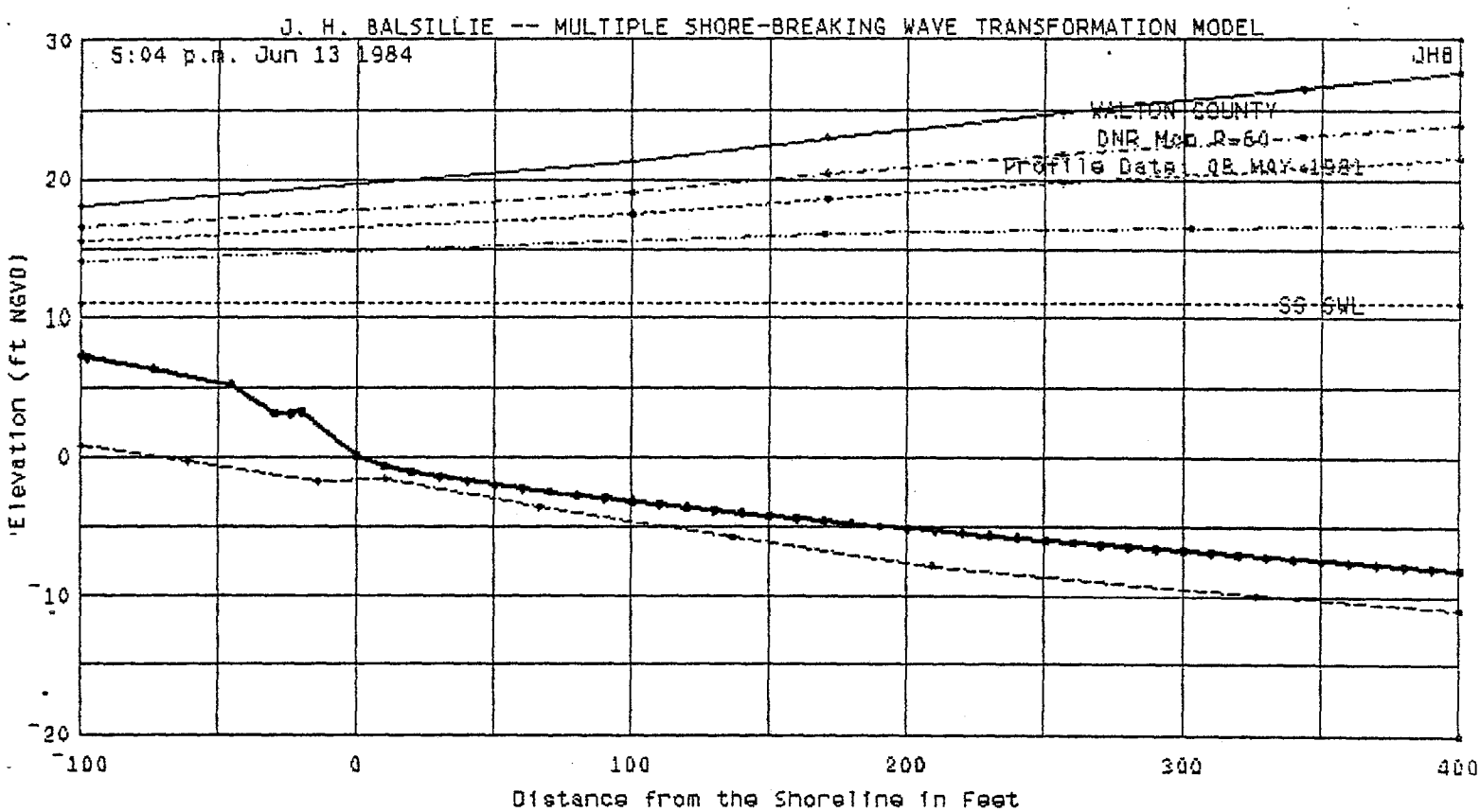
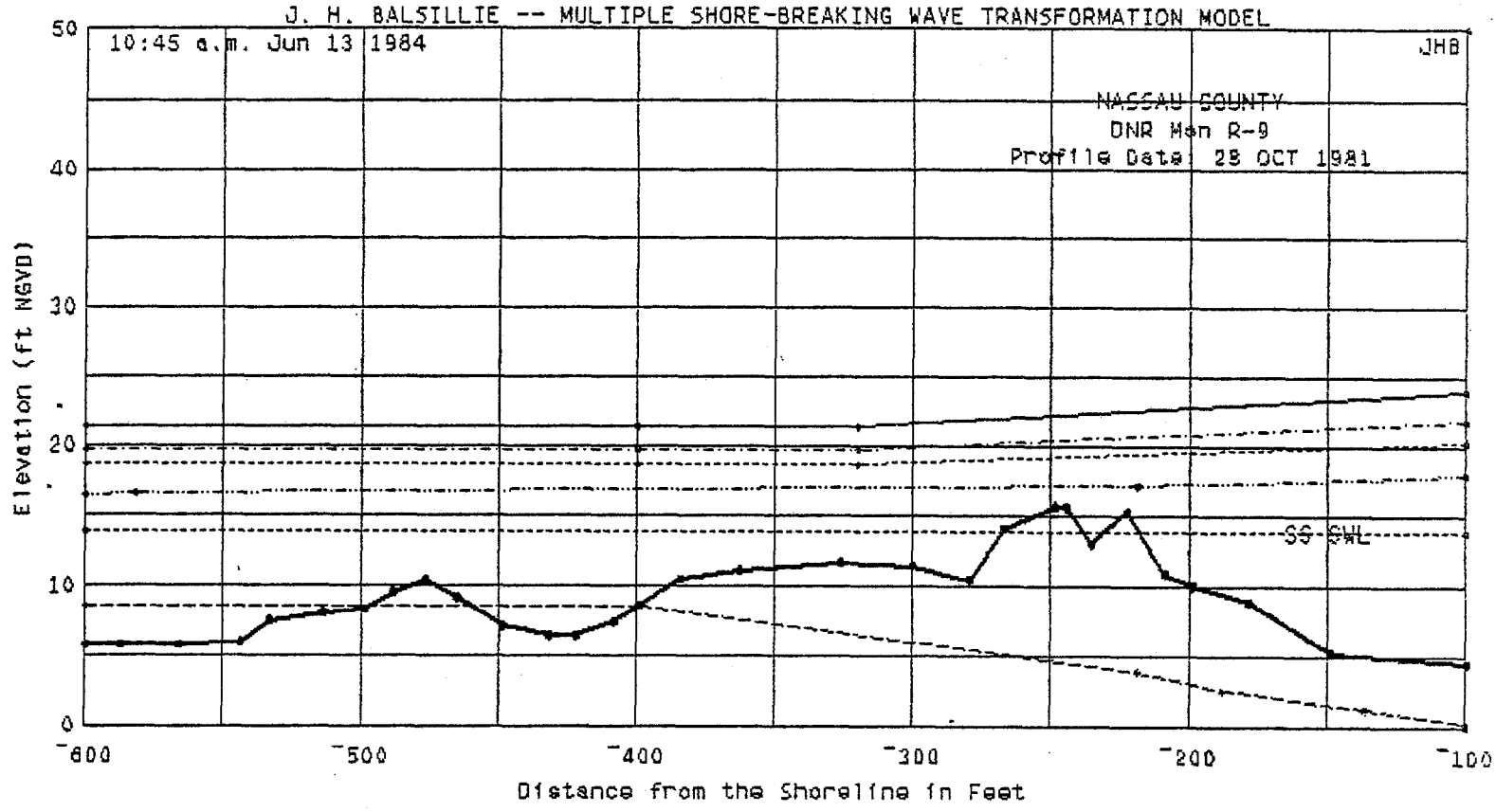


Figure 8c. Example of results from the MSBWT computer model for a non-flooded profile in Walton County, Florida.



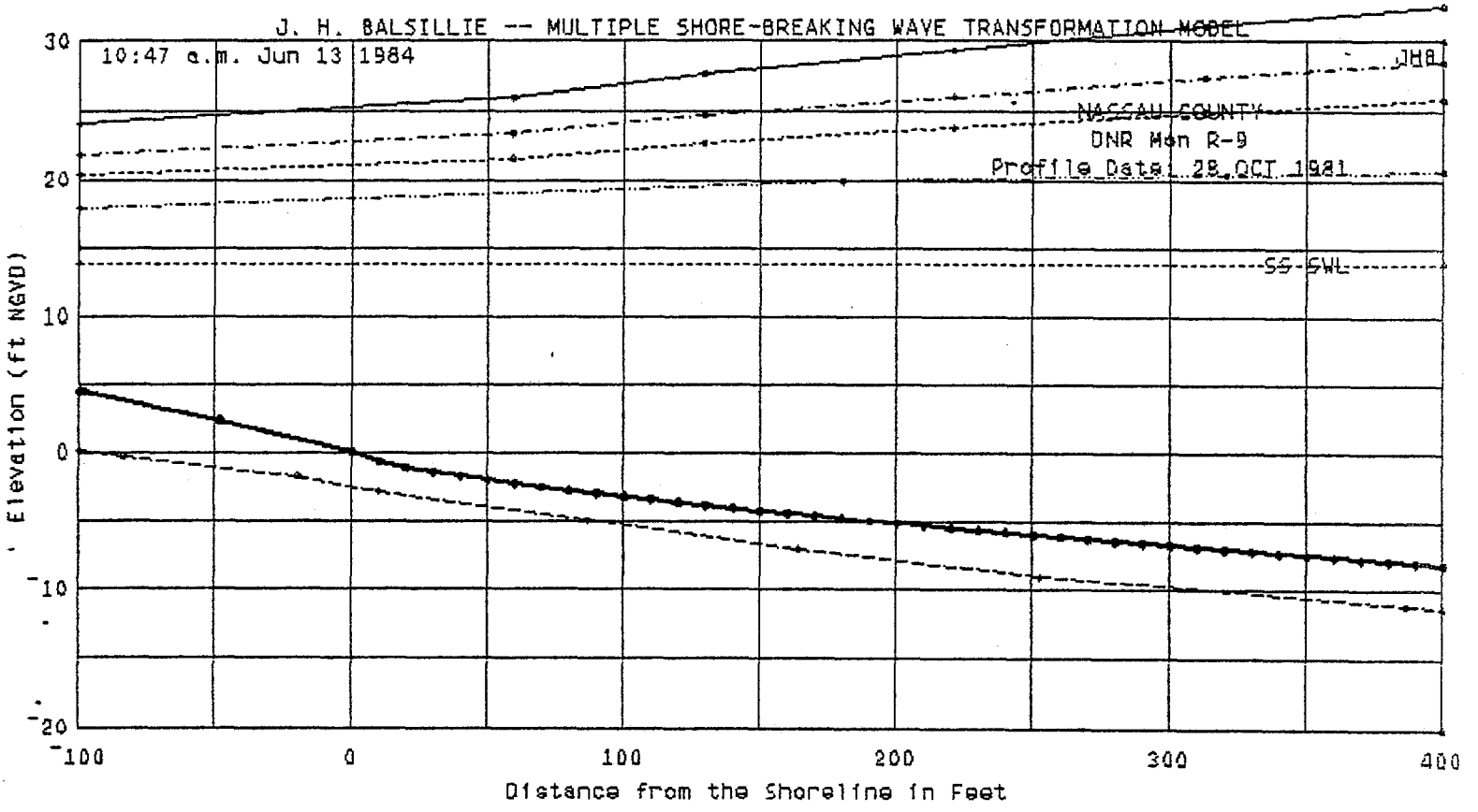
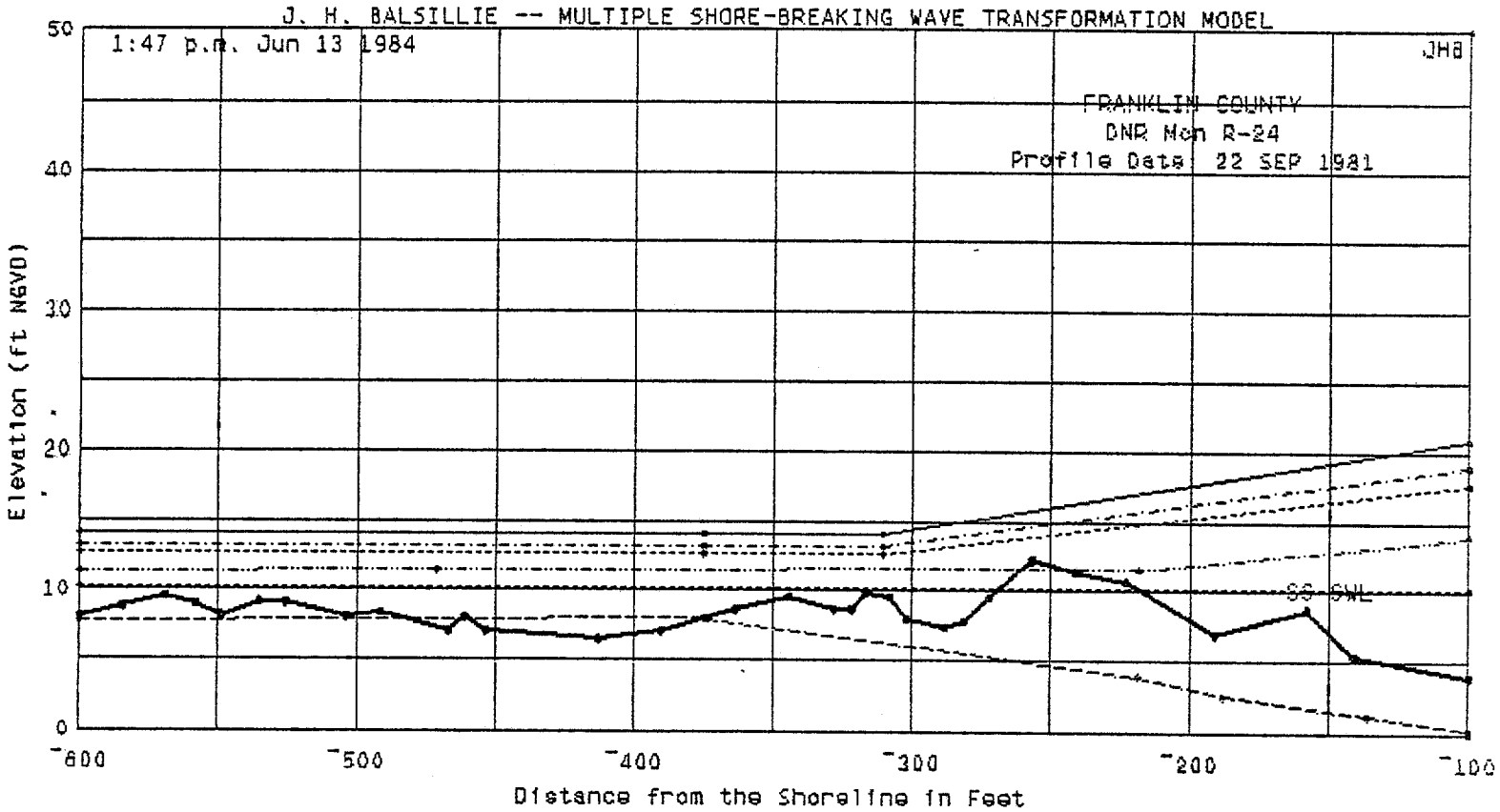


Figure 9a. Example of results from the MSBWT computer model for a breached profile in Nassau County, Florida.



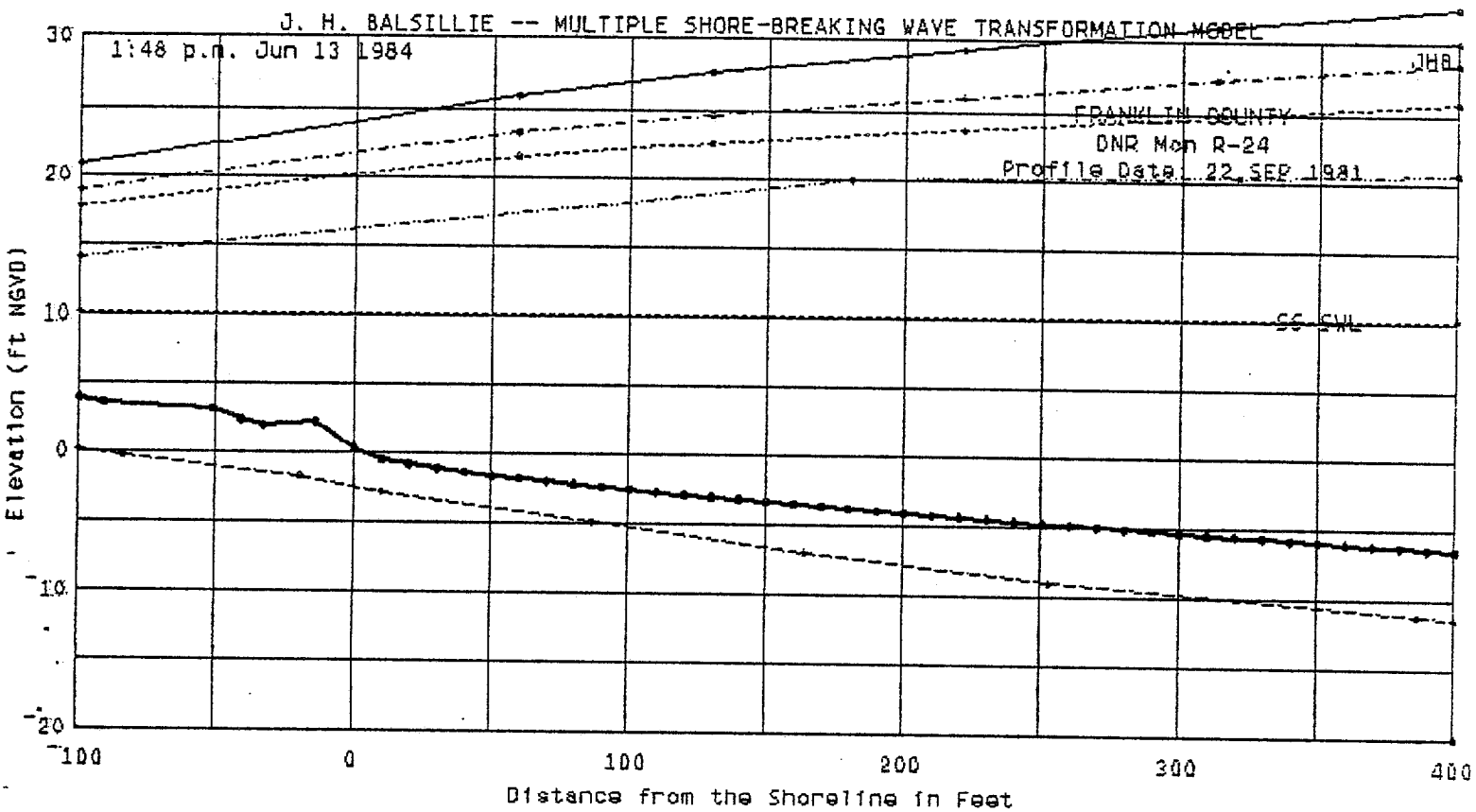


Figure 9b. Example of results from the MSBWT computer model for a breached profile in Franklin County, Florida.

Remarks

Several comments regarding the MSBWT model would appear to be appropriate. The best information from which to calibrate numerical modeling of the type presented in this work, would be actual field measurements. Unfortunately, except for Hurricane Eloise of 1975 (Chiu, 1977; Balsillie, 1983a; discussed earlier), there is virtually no such data of the variety and type suited for calibration purposes. There are, however, alternatives. In this work, onshore-offshore sediment transport is realized in terms of bedform genesis (i.e., longshore bars) due to wave activity. Hence, sand is redistributed in aggregate rather than using an onshore-offshore transport approach which has, as yet, not reached acceptable status. The additional advantage to this approach is that wave activity (particularly, shore-breaking wave activity) can be assessed for design purposes.

Various processes are not presently or extensively considered in the MSBWT model. In part, the lack of consideration is due to the lack of quantification required for installation into the model. These include, for example, washover processes (e.g., Leatherman, 1977, 1979, 1981), sediment liquefaction (e.g., Zeevaert, 1983, 1984), and attenuation of wave height and current speed due to coastal frictional elements (e.g., Christensen and Walton, 1980; Wang, 1983). Existing programming will need to be updated as new advancements quantifying coastal processes such as these become available.

It is necessary to again stress that the erosion profiles

predicted by the model (as presently depicted on the plots) REPRESENT PRE-RECOVERY STORM IMPACT CONDITIONS. That is, some post-impact recovery is to be expected for most profiles as the storm produced water level recedes. The eroded profile configuration does represent, however, a design surface in terms of a predicted "stable bed elevation".

THE COMPUTER MODEL

The Multiple Shore-Breaking Wave Transformation computer model is written in the APL language. This language is especially suited to numerical approaches required in scientific and engineering applications. While APL has been variously reported to require additional mainframe resources relative to other languages such as FORTRAN, it is more robust and straightforward in dealing with sophisticated mathematical applications.

Organization

The general organization of the MSBWT computer model is illustrated in the flow chart of Figure 10. Programming is organized at four levels: 1. input functions, 2. data management functions, 3. coastal processes functions, and 4. output functions. A complete listing of functions written by the author is given in Appendix II.

Input Functions

Three types of data input options are available. Execution of the function INPUT allows the user to input new onshore profile topography. Other information requested by

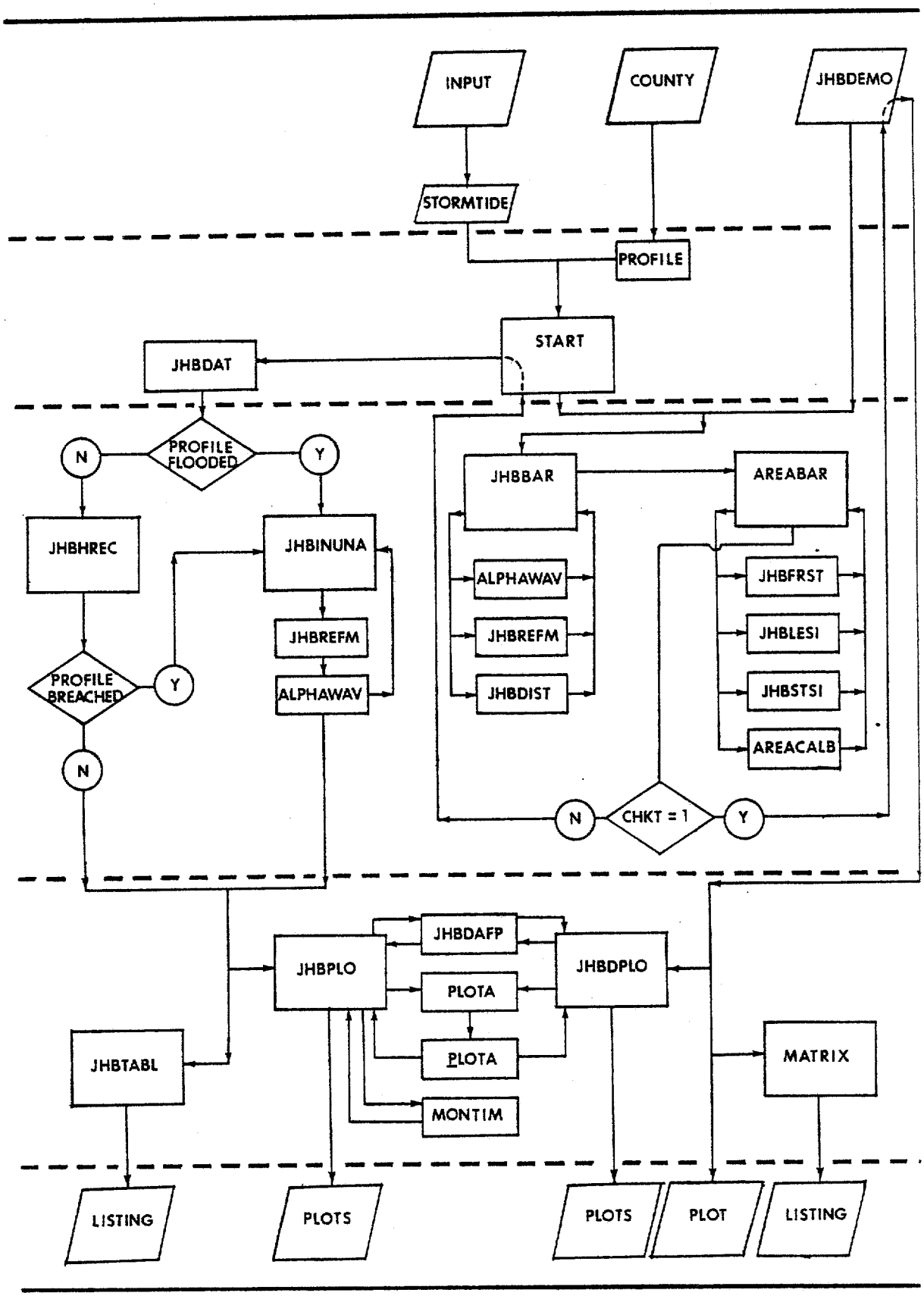


Figure 10. General flowchart of the Multiple Shore-Breaking Wave Transformation (MSBWT) computer model.

the function, for computational and administrative purposes, is provided by preparing a specially designed data input form (Figure 11). The function INPUT has been designed to specifically address the needs of the regulatory engineering staff in assessing coastal construction permit applications pursuant to Florida regulations (Chapter 16B-33, Florida Administrative Code).

The function COUNTY allows the user to automatically access profile data maintained on the Beaches and Shores data bank (see Table 2 for inventory). The data is accessed by specifying the county, profile number, year of survey, and survey type (control line survey = CCCL, post-storm survey = POST, condition survey = COND, and special survey = SPEC), and executed by specifying a storm surge.

The preceding input functions accomodate a wide range of incident wave conditions (i.e., wave height-period combinations) for a given storm surge. The function JHBDEMO, however, is a demonstration function for a single incident wave height and period, and storm surge condition. The function is particularly useful to demonstrate how the MSBWT model works, and for inspecting model behavior where coastal profile terminal boundary conditions may be uniquely complex. The MSBWT computer model could not have been developed without JHBDEMO; its use will be required for future enhancement and debugging of functions.

Data Management Functions

Little needs to be stated about these functions, other than that they are necessary for obtaining and organizing

BEACHES AND SHORES COMPUTER DATA INPUT FORM

OFFSHORE PROFILE INFORMATION

Exponent: _____ Scale Factor _____ Survey Date ___/___/___
da mo yr

ONSHORE PROFILE DATA
(List data from the shoreline upland.)

	Dist (ft)	Elev (ft NGVD)		Dist (ft)	Elev (ft NGVD)		Dist (ft)	Elev (ft NGVD)
1	0	0	11	____	____	21	____	____
2	____	____	12	____	____	22	____	____
3	____	____	13	____	____	23	____	____
4	____	____	14	____	____	24	____	____
5	____	____	15	____	____	25	____	____
6	____	____	16	____	____	26	____	____
7	____	____	17	____	____	27	____	____
8	____	____	18	____	____	28	____	____
9	____	____	19	____	____	29	____	____
10	____	____	20	____	____	30	____	____

Survey Date: __/__/__/ Profile Type: _____
da mo yr

LOCATION INFORMATION

DNR Ref Mon: _____ County Name: _____

Distance range is from the Ref Mon
(e.g., W145 -- the range is located _____
145 ft west of specified ref mon)

Distance from Shoreline to CCCL: _____

ADMINISTRATIVE INFORMATION

File I.D.: _____ Engineer Responsible for Input Data _____

STORM SURGE INFORMATION

	Storm Surge Elevation (ft NGVD)	Return Period (Years)	Source
1	_____	____	_____
2	_____	____	_____
3	_____	____	_____
4	_____	____	_____
5	_____	____	_____

Figure 11. Data input form where new profile data is to be assessed by the MSBWT computer model.

data arrays for use by other functions.

Coastal Processes Functions

This class of functions describe the various coastal processes related to the model. The attempt has been made to isolate each component process and boundary condition, by making each an individual function. This approach has been followed to facilitate future programming modifications as new scientific advancements become available. The functions are described in Appendix II.

Output Functions

These functions prepare the final data for plotting and listing. In order to obtain final results, additional IBM graphic and file management systems software is utilized (see Appendix II).

Remarks

It is to be noted that because the MSBWT computer model has very recently been installed in production mode (in February 1984), it shall remain in "debug" and research/development status for months to come. While the APL language is capable of being very efficiently written, reassessment and rewriting of functions will not be realized until after debugging has been completed. Some functions (e.g., coastal processes functions) will remain perpetually in research/development status in anticipation of future scientific advancements. They should remain logically simple and straightforward to facilitate modification, rather

than written so efficiently as to become intractable code.

Results

The following output formats are available from the MSBWT computer model. The format of final plotted results has been illustrated in Figures 6, 8 and 9, with a standardized key to symbols given in Figure 7. Actual-size plots have a set size where the horizontal axis scale is set at 1 inch = 50 feet, and the vertical axis scale is 1 inch = 10 feet (with extended tic marks every 1/2 inch). This format is designed to facilitate drafting of additional engineering considerations, such as project dimensions and elevations. Listed output (pertinent input information, administrative data, and recession results) are printed in standard format (Figure 12). Onshore profile data are listed in a third report (Figure 13), and are referenced to both the shoreline and to Florida's Coastal Construction Control Line (CCCL).

An example of results from the demonstration function JHBDEMO are illustrated in Figure 14, with numerical values listed in Figure 15. Figure 14 depicts the original measured profile. The particular case illustrated in Figure 14 is for Hurricane Eloise (Walton County, Florida, September 1975).

NOTE: The citation of trade names in this document does not constitute an official endorsement or approval of the use of such commercial products.

FLORIDA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF BEACHES AND SHORES
BUREAU OF COASTAL DATA ACQUISITION

MULTIPLE SHORE-BREAKING WAVE TRANSFORMATION MODEL
(J. H. Balsillie)

ADMINISTRATIVE INFORMATION

File Number .....Test
Responsible for data input .....J. H. Balsillie
Initials .....
Date Job Compteted (mo/da/yr) 3 28 1984

INPUT INFORMATION

A. OFFSHORE PROFILE DATA
Exponent (i.e., scale coefficient) 0.6667
Shape Coefficient 0.162
Date of Profile Survey 2/82

B. ONSHORE PROFILE SURVEY
Date of Profile Survey 0/0/00
Profile Type .....Post-Const

C. STORM SURGE DATA
Storm Surge Elevation (ft NGVD) 7
Storm Surge Return Period (years) 30
Source of Information .....U of F

D. DNR REFERENCE MONUMENT INFORMATION
DNR Reference Monument I.D. R-6
County .....Martin
Range to Mon Distance (ft) .....S 236
CCCL to Shoreline Distance (ft) 114

Figure 12. Example of an output listing for retention as a record of input for verification and legal purposes.

ONSHORE PROFILE SURVEY DATA

COUNTY: Martin

PERMIT I.D.: Test

PROFILE LOCATION: S 236 ft from R-6

PROFILE SURVEY DATE (DA/MO/YR): 0/0/00

DISTANCE UPLAND FROM SHORELINE (FEET)	DISTANCE FROM THE CCCL (FEET)	ELEVATION (FEET NGVD)
.00	114.00	.00
31.00	83.00	3.00
42.00	72.00	4.00
52.00	62.00	5.00
62.00	52.00	7.50
87.00	27.00	16.00
90.00	24.00	16.60
92.00	22.00	16.30
96.00	18.00	13.00
102.00	12.00	12.50
114.00	.00	12.00
164.00	50.00	8.00
204.00	90.00	6.00

NOTE: -ve distances denote locations upland of the CCCL.

Figure 13. Example of an output listing for retention as a record of input profile information.

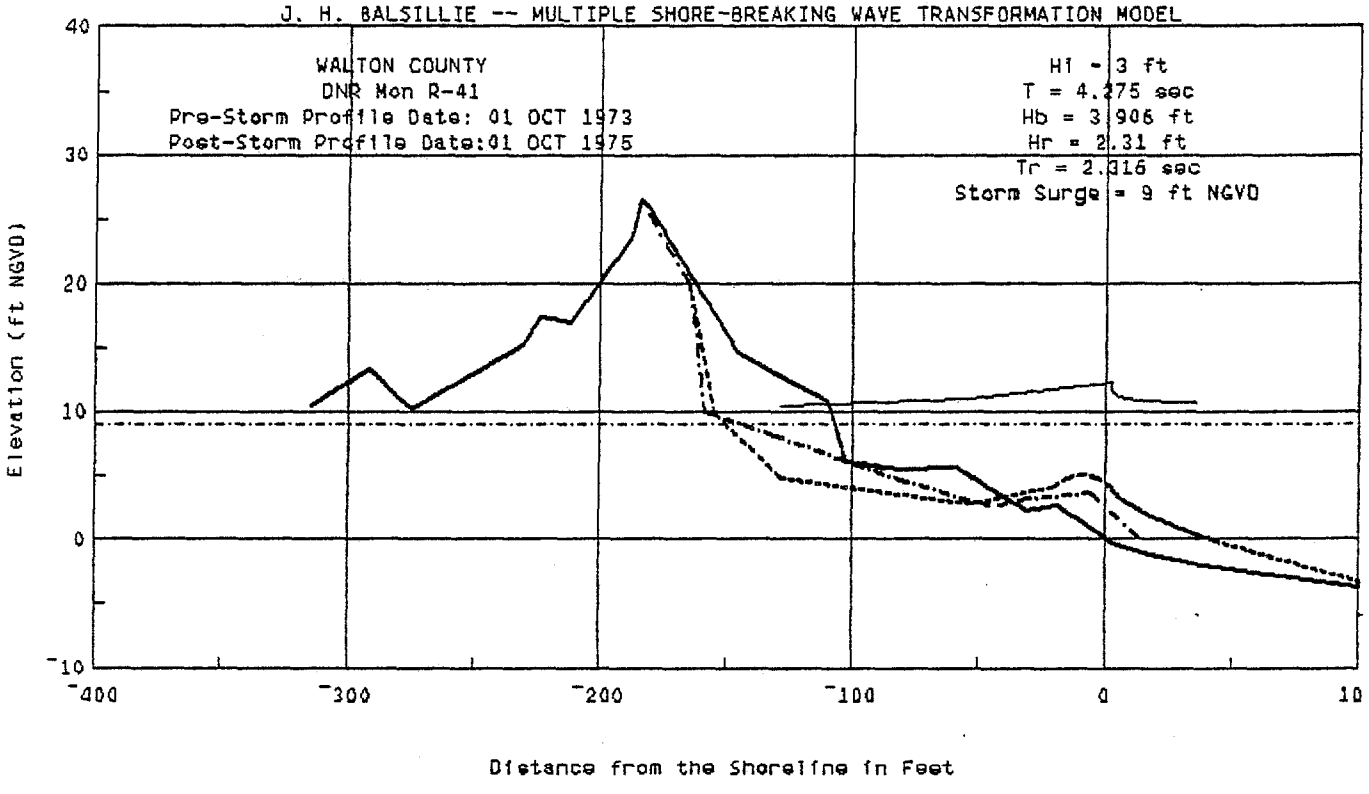


Figure 14. Example of results from the demonstration function JHBDEMO. The bold solid line represents the measured pre-storm profile, the bold dash-dot-dash line the measured post-storm profile, the bold dashed line the predicted erosion profile (during storm impact prior to any post-storm recovery) from the MSBWT computer model for a storm surge given by the single dash-dot-dash line (in this case the storm surge level does not include effects of the dynamic setup which is computed suing additional considerations). The remaining line represents the crest elevation of the wave as alpha wave peaking over the longshore bar crest occurs and the wave reforms following bar-breaking. Example is for data from Hurricane Eloise of September, 1975.

MATRIX

BAR NUMBER (OFF TO ONSHORE):	1
INITIAL WAVE HEIGHT (FT) =	3
INITIAL WAVE PERIOD (SEC) =	4.275
SHORE-BREAKER HEIGHT (FT) =	3.906
BAR CREST SPACING (FT) =	156.2
WAVE REFORMATION DISTANCE =	125
SHAPE COEFFICIENT =	0.2557
INITIAL WAVE STEEPNESS =	0.005102
BREAKING WAVE STEEPNESS =	0.006642
BREAKER STEEPNESS * 0.5 =	0.0815
REQUIRED STOSS SLOPE FOR PLUNGING =	0.2557
ADJUSTED STOSS SLOPE FOR PLUNGING =	0.6667
AREA UNDER BAR CREST (SQ FT) =	286.9
AREA UNDER BAR TROUGH (SQ FT) =	¯293.7
AREA UNDER BAR STOSS (SQ FT) =	¯9.528
COMPUTED BAR BASE LENGTH (FT) =	190.4
REQUIRED BAR BASE LENGTH (FT) =	179.7
ORIGINAL PROFILE POWER CURVE FIT =	0.175
STOSS POWER CURVE FIT FOR PLUNGING =	0.163
ADJUSTED STOSS POWER CURVE FIT =	0.348
SEDM TRANSPORT PARTITIONING COEFF =	0.3
DEPTH TO BAR TROUGH (FT NGVD) =	¯6.249
DISTANCE TO BAR TROUGH (FT) =	¯55.09
DEPTH TO BAR CREST (FT NGVD) =	¯3.906
DISTANCE TO BAR CREST (FT) =	¯10.37
STORM SURGE ELEVATION (FT NGVD) =	9
WATER DEPTH OVER BARRIER ISLAND (FT) =	¯9
CREST HEIGHT ABOVE BAR BASE (FT) =	4.188
CREST DEPTH ÷ BAR BASE HEIGHT =	0.9327
REFORMED WAVE HEIGHT (FT) =	2.31
REFORMED WAVE PERIOD (SEC) =	2.316
REFORMED WAVE LENGTH (FT) =	19.15

Figure 15. Listing of numerical results describing the plot from function JHBDEMO.

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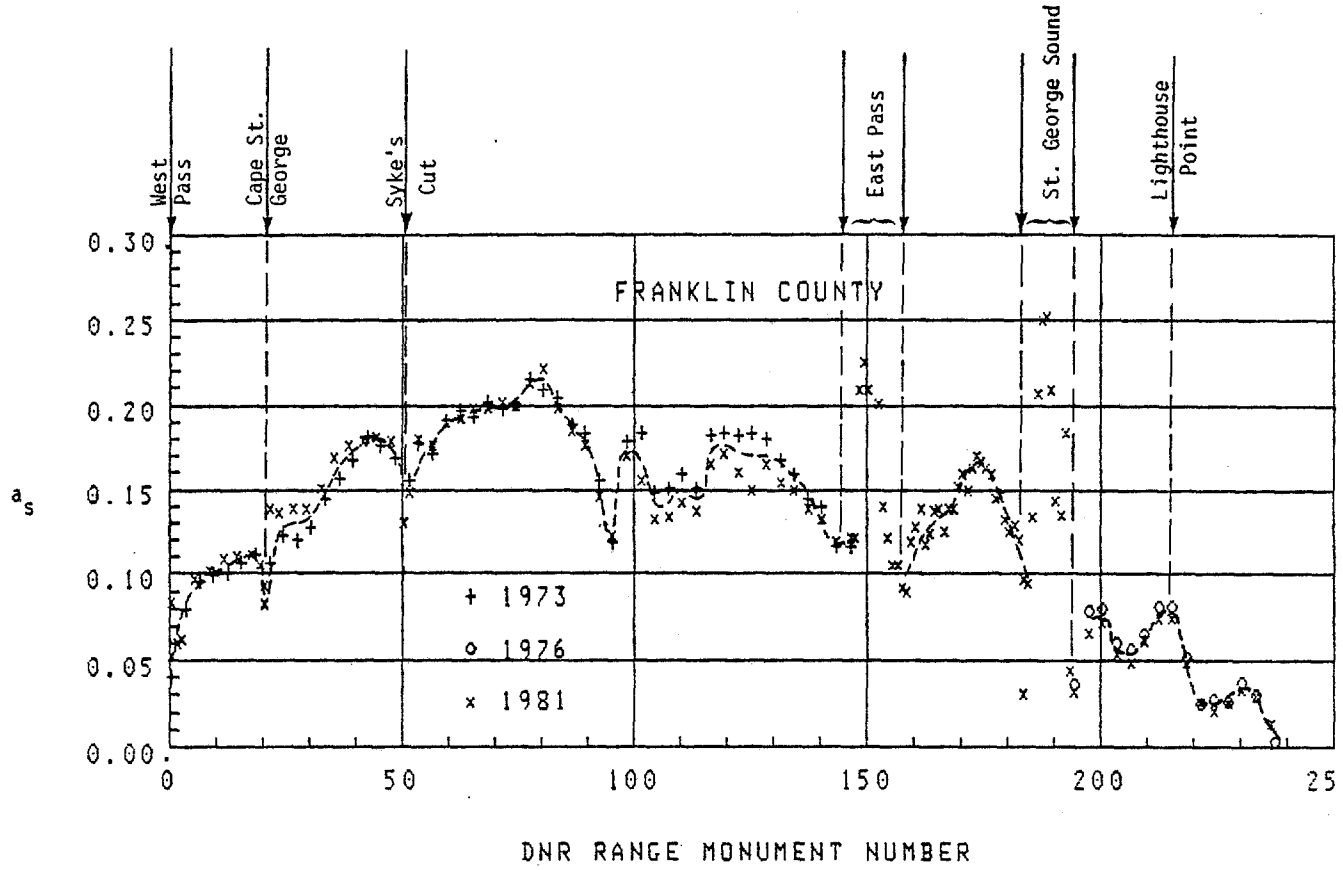
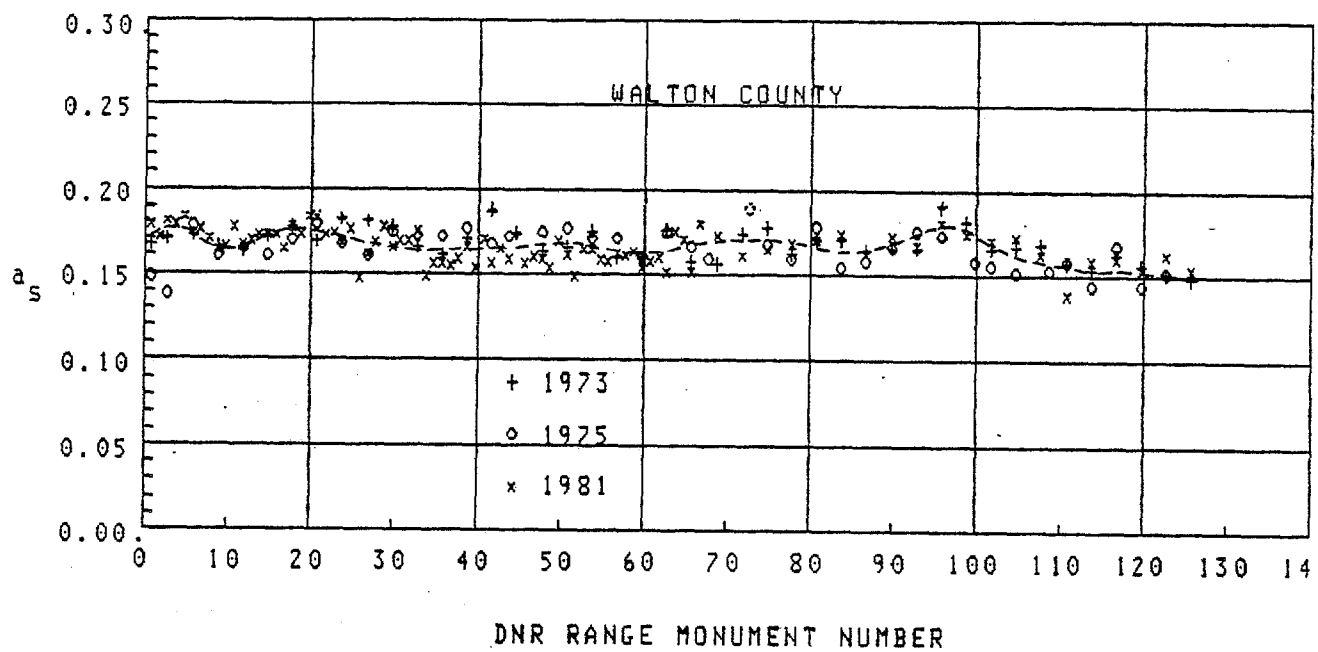

West Pass
Cape St. George
Syke's Cut
East Pass
St. George Sound
Lighthouse Point
FRANKLIN COUNTY
+ 1973
o 1976
x 1981
a_s
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
50
100
150
200
250
DNR RANGE MONUMENT NUMBER


WALTON COUNTY
+ 1973
o 1975
x 1981
a_s
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
DNR RANGE MONUMENT NUMBER

APPENDIX I

Preliminary Investigation of Shape Coefficient (a_s) Behavior Over Time.

Power curve representation of equilibrium offshore profile geometry has received considerable attention (Bruun, 1954; Dean, 1977), particularly in Florida (Dean, 1977; Hughes and Chiu, 1978; Balsillie, 1982a, 1982b). The mathematical representation is given by:

$$d = a_s x^b$$

in which d is the water depth, x is the distance offshore, a_s is the shape coefficient, and b is an exponent termed the scale coefficient. Dean (1977) found that the scale coefficient, b, has a theoretical value 2/3, which is supported by physical data. Hughes and Chiu (1978) found that for Florida, the equation adequately represents profiles to about 1200 feet offshore. Using this methodology, Balsillie (1982a, 1982b) compiled standard offshore profile tables for Florida, for use in scientific and engineering applications.

Despite this work, nothing is known about how the values of a_s and b might behave as a function of time because of the lack of repeated profile surveys. However, a considerable amount of such data is now available. This data has been been measured, reduced and computerized as a part of the continuing field data collection effort of the Bureau of Coastal Data Acquisition, Division of Beaches and Shores, Florida Department of Natural Resouces.

Since this is a first analytical attempt, it is assumed that b = 2/3, so that the only variable to be inspected is a_s.

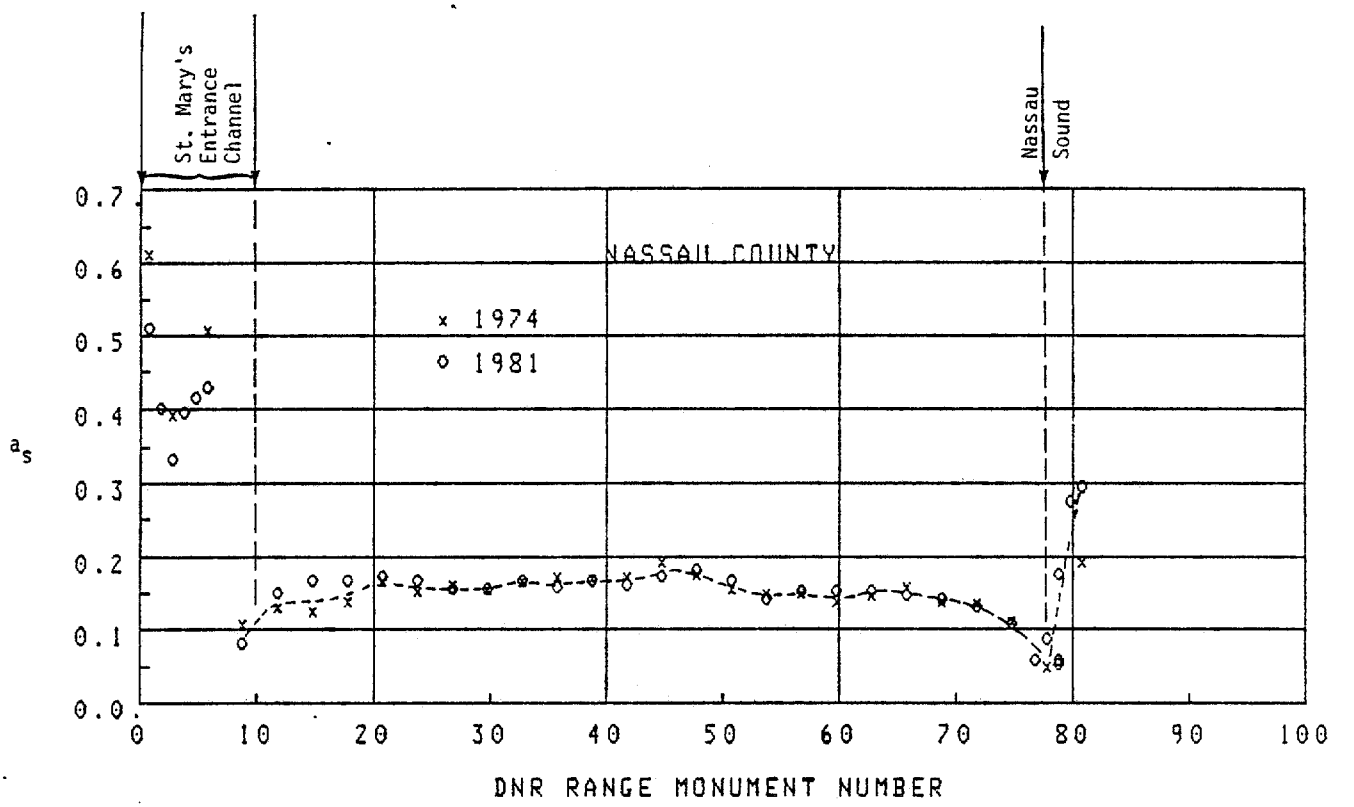
The shape coefficient is calculated using the "direct method" (i.e., equation (4) of Balsillie, 1982a), and only offshore profiles with lengths extending at least 800 feet offshore (cutoff point of 1200 feet) were selected for analysis. Twelve surveys are now available for comparison, representing over 400 profile pairs; the time between surveys ranges from 2 to 11 years. Analytical results are listed in the Table. Data are plotted in the figures for surveys in Nassau, Martin, Charlotte, Lee, Franklin, and Walton Counties, Florida. A most striking feature of the plots is that radical changes and behavior of the value of a_s occurs at inlets, and at capes or points where the shoreline azimuth changes significantly. Hence, a_s appears to correlate well with plan-view shoreline physiography. Additionally, the average absolute difference of a_s between surveys is quite small at 0.018 which is an order-of-magnitude less than the observed range in a_s (from about 0.05 to 0.25 for ocean fronting beaches). The standard deviation of the absolute differences is also small. One might expect such value to be even smaller should data around the inlets not be included in analysis. It is suggested, therefore, that the value of a_s between surveys does not significantly change for surveys up to a decade apart (note that the affect of storms are to some extent included in the data).

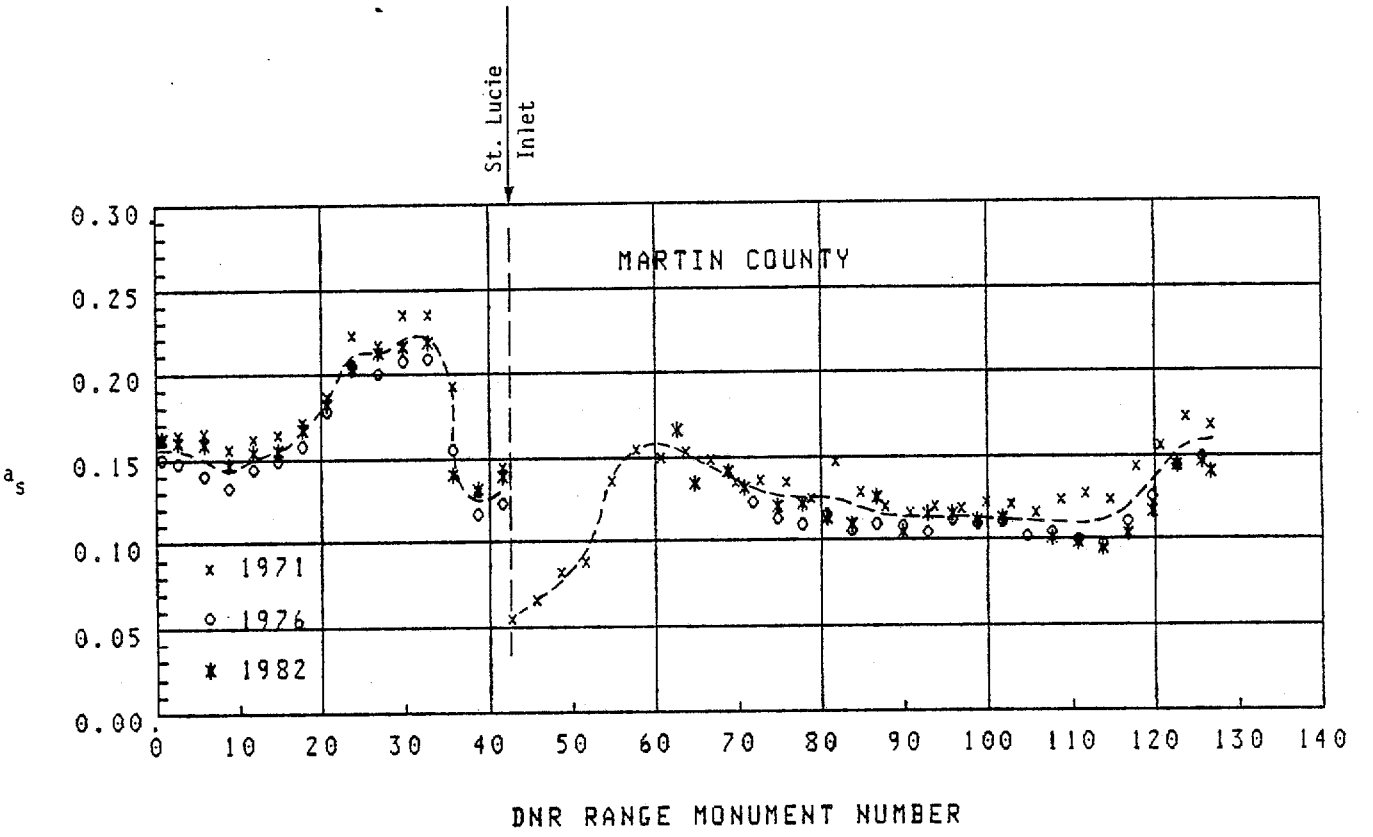
The results of this investigation are certainly preliminary. Additional statistical analysis is needed. The results are optimistic, particularly because of the apparent correlation between plan-view shoreline physiography and a_s. Regarding these issues, further study is warrented.

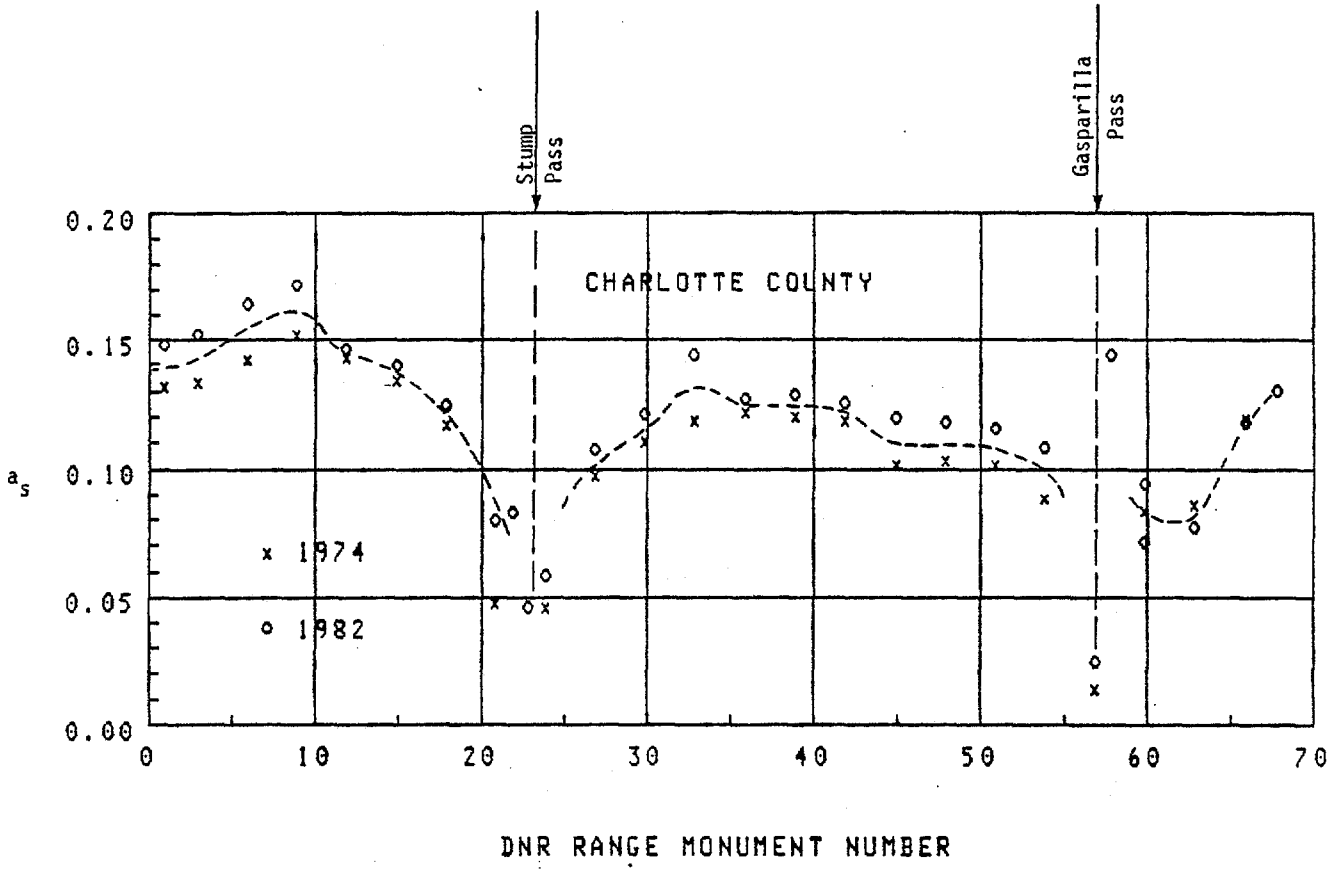
Table. Shape Coefficient Analysis Results.

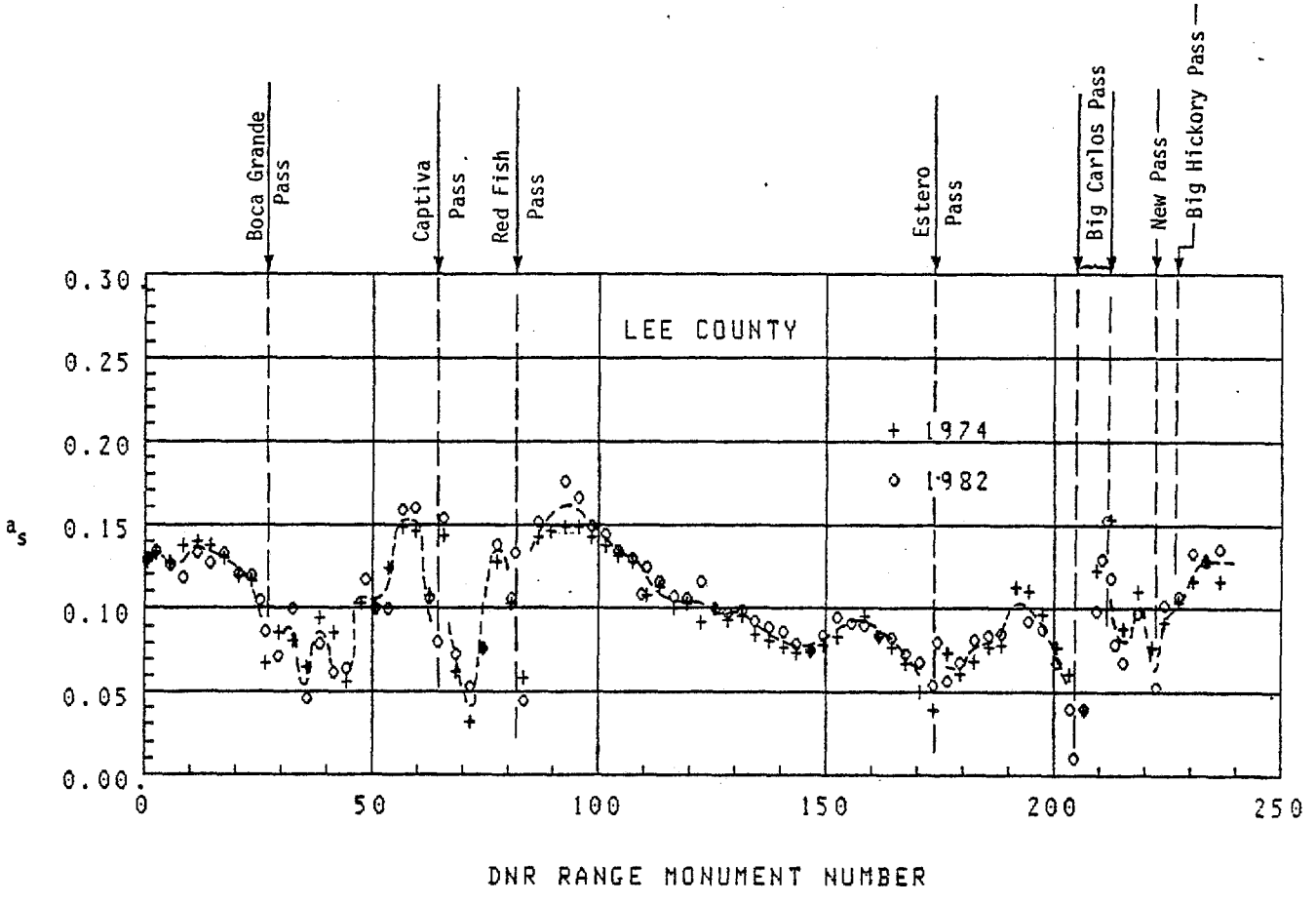
County	Years of Surveys	No. Years	n	Average Absolute Difference	Std Dev
		UPPER EAST COAST			
Nassau	1974-1981	8	28	0.023	0.03
		LOWER EAST COAST			
Martin	1971-1976	5	15	0.012	0.008
Martin	1976-1982	6	32	0.008	0.006
Martin	1971-1982	11	16	0.013	0.013
		LOWER GULF COAST			
Charlotte	1974-1982	8	23	0.012	0.007
Lee	1974-1982	8	76	0.010	0.008
		PANHANDLE COAST			
Franklin	1973-1976	3	13	0.046	0.032
Franklin	1976-1981	5	14	0.004	0.003
Franklin	1973-1981	8	78	0.060	0.041
Walton	1973-1975	2	37	0.010	0.007
Walton	1975-1981	6	38	0.012	0.009
Walton	1973-1981	8	42	0.008	0.007
TOTAL NUMBER OF PROFILES			412		
AVERAGES		6.5		0.018	0.014

NOTES:
1. n = number of profile pairs used in analysis.
2. std dev = the standard deviation.
3. The 1976 Franklin Co. and 1975 Walton Co. surveys are post-storm surveys.


St. Mary's Entrance Channel
Nassau Sound
NASSAU COUNTY
× 1974
○ 1981
a_s
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
10
20
30
40
50
60
70
80
90
100
DNR RANGE MONUMENT NUMBER


St. Lucie Inlet
MARTIN COUNTY
× 1971
○ 1976
✱ 1982
a_s
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
DNR RANGE MONUMENT NUMBER


Stump Pass
Gasparilla Pass
CHARLOTTE COUNTY
0.20
0.15
0.10
0.05
0.00
a_s
x 1974
o 1982
0
10
20
30
40
50
60
70
DNR RANGE MONUMENT NUMBER


Boca Grande Pass
Captiva Pass
Red Fish Pass
Estero Pass
Big Carlos Pass
New Pass
Big Hickory Pass
LEE COUNTY
0.30
0.25
0.20
0.15
0.10
0.05
0.00
a_s
+ 1974
o 1982
0
50
100
150
200
250
DNR RANGE MONUMENT NUMBER

APPENDIX II

APL Programming

(APL functions and variables listed in full have been written by the author. All other functions and variables are copyrighted property of IBM and are not listed.)

LIST OF FUNCTIONS FOR THE MULTIPLE SHORE-BREAKING WAVE TRANSFORMATION MODEL:

AGAIN	ALPHAWAV		AND	ANNX	ANNY	AREABAR	AREACALB		AVG
AXES	AXIS	AXS	A3D	BOX	BY	CDE	CGWRT	CHART	
CHECKNAME		CHK	CLEAR	CLIP	CLOSE	CLOSEALL		CLOSEGP	CMS
COIBM	COLOR	CONTOUR	COPY	COPYID	COPYN	COUNTY	CP	CSINIT	
DECOMMENT		DOUBLE	DRAW	ENCODE	ERASE	ERF	EXP	FILL	
FILLENCODE		FIT	FITFUN	FITFN	FIXVP	FMT	FRAME	FREQ	FRME
FSSAVE	FSSHOW	FTCF	GEP	GET	GETDAT	GETDATA	GETFILE	GRFIELD	HCHART
HIDE	HOR	INDEV0	INDEV1	INDEV3	INPUT	INTERPOLATE		INTERSECTIONS	
INTO	ISOMETRIC		J	JHBBAR	JHBCALI	JHBDAFP	JHBDAT	JHBDEMO	JHBDIST
JHBDPLO	JHBFRST	JHBHREC	JHBHRECA		JHBINUNA		JHBLESI	JHBLIN	JHBONAR
JHBPLO	JHBREFM	JHBSTSI	LABEL	LBLX	LBLY	LINEAR	LOADSSAUX		LOG
LOGLOG	LOC	MAGNIFY	MATORD	MATRIX	MEMBER	MODE	MONTIM	MSG	OBLANKS
OBLIQUE	OF	ONAREA	OPEN	OPENGP	OUTPUT	PERSPECTIVE		PIECHART	
PIELABEL		PIELAB	PLOT	PLOTA	POLY	POWER	PREPARSE		PROC
PROFILE	PUT	PUTFILE	READ	RESTORE	RETICLE	RETRACT	RNG	ROTATE	SAXES
SAXISX	SAXISY	SAXISZ	SCALE	SCISSOR	SCRATCH	SHARES	SHRFSM	SKETCH	SL
SLABEL	SLBLX	SLBLY	SLBLZ	SM	SMFIELD	SORTALF	SORTALFV		SPL
SPLINE	SPLOT	SS	START	STEP	STEREO	STITLE	STORMTIDE		STYLE
SURFACE	SURVEY	SXFM	SZSF	THREEVIEWS		TITLE	TM	TRANSLATE	
TRAVERSE		TYPE	UCTRANS	USE	USING	VCAT	VER	VIEW	
VIEWPORT		VMG	VS	WIDTH	WITH	WRDG	WRITE	WSID	W3D
XBLANKS	XFM	PLOT	PLOTA	PLOTINIT		PLINSI	PIOV	RELATIVE	
STEP	WI								

```
      ∇INPUT[⎕]∇
       ∇ INPUT
[1]    CHKT←CHKTT←0
[2]   ⍝ Requests input data except for storm surge information.
[3]    '*****************************************************************************'
[4]    ''
[5]    'OFFSHORE PROFILE:'
[6]    'Enter Exponent:'
[7]    POW←⎕,2÷3
[8]    'Enter Shape Factor:'
[9]    POW[1]←⎕
[10]   'Date of Survey:'
[11]   OFFDATE←⎕
[12]   '-----------------------------------------------------------------------'
[13]   ''
[14]  L2:'ONSHORE PROFILE DATA:'
[15]   'Enter distances measured from orignal shoreline at 0 NGVD'
[16]   '(Enter in ascending numerical order in feet):'
[17]   XOP←XORG←⎕
[18]   XOP←¯1×⍋XOP
[19]   XORG←¯1×⍋XORG
[20]   'Enter elevation corresponding to distances just specified (Ft NGVD):'
[21]   YORG←⎕
[22]   YORG←⍋YORG
[23]   →L1×⍳(⍴XORG)≠⍴YORG
[24]   'Date of Survey:'
[25]   ONDATE←⎕
[26]   'Profile Type (Pre-Const or Post-Const):'
[27]   TYPEPR←⎕
[28]   '-----------------------------------------------------------------------'
[29]   ''
[30]   'DNR REFERENCE MONUMENT INFO:'
[31]   'Enter DNR reference monument number (e.g., R-26):'
[32]   RANGE←⎕
[33]   'County Name:'
[34]   CO←⎕
[35]   'Enter distance that range line is from the reference monument:'
[36]   '(e.g., N300 indicates range is 300 feet north of specified monument):'
[37]   DNR←⎕
[38]   'Enter distance from the normal existing shoreline to the CCCL in feet:'
[39]   DIST←⎕
[40]   '-----------------------------------------------------------------------'
[41]   ''
[42]   'ADMINISTRATIVE INFO:'
[43]   'Enter File Number:'
[44]   FILE←⎕
[45]   'Full name of the engineer responsible for the input data:'
[46]   NAME←⎕
[47]   STORMTIDE
[48]   →0
[49]  L1:'HEY ..... YOU HAVE NOT ENTERED THE SAME NUMBER OF'
[50]   '   DISTANCES AND ELEVATIONS.'
[51]   →L2
       ∇
```

```
      ∇STORMTIDE[⎕]∇
      ∇ STORMTIDE
[1]   ⍝ PURPOSE OF FUNCTION:  REQUEST STORM SURGE INFORMATION.
[2]   '-----------------------------------------------------------------------'
[3]   ''
[4]   'STORM SURGE INFO:'
[5]   'Enter storm surge elevation in feet NGVD:'
[6]   S←⎕
[7]   'Enter the return event which this storm surge represents'
[8]   '(e.g., 100 for the 100-year return event):'
[9]   RETPER←⎕
[10]  'Source of storm surge information (e.g., NOAA, U of F, etc.,):'
[11]  SOURCE←⎕
[12]  '***********************************************************************'
[13]  SEQNO←SEQNO+1
[14]  START
      ∇


      ∇COUNTY[⎕]∇
      ∇ COUNTY
[1]   CHKTT←1
[2]   'County Name:'
[3]   CO←⎕
[4]   'Year of Survey:'
[5]   YR←⎕
[6]   'Profile Number:'
[7]   P2←⎕
[8]   'Shape Coefficient:'
[9]   POW←⎕,2÷3
[10]  FN1←(3↑CO),2↓YR
[11]  FT1←'CCCL B1'
[12]  PROFILE
[13]  DIST←AA
[14]  XORG←XOP←X
[15]  YORG←Y
[16]  CO←(16↑TITL1≠' ')/16↑TITL1
[17]  RANGE←(P1[⍳8]≠' ')/P1[⍳8]
[18]  DATE←P1[88+⍳7]
[19]  'STORM SURGE ELEVATION:'
[20]  S←⎕
[21]  START
      ∇


      ∇PROFILE[⎕]∇
      ∇ PROFILE
[1]   CLOSEALL
[2]   FN1 OPEN FT1,'( FIX 370'
[3]   TITL1←GET FN1
[4]   X1←X11←Y1←Y11←⍳0
[5]  L1:P1←(GET FN1),(GET FN1)
[6]   P1←(80↓P1),80↑P1
[7]   PRO1←PROF1←⍳0
[8]   I←1
[9]   NOFNS1←⌈0.2×⍎N1←P1[105 106 107]
```

```
[10] L2:PRO1←PRO1,GET FN1
[11]  PRO1←⌽5↓⌽PRO1
[12]  I←I+1
[13]  →L2×⍳I<NOFNS1+2
[14]  PRO1←75↓PRO1
[15]  N←1
[16] L4:PROF1←PROF1,(⍎PRO1[⍳7]),(⍎PRO1[8+⍳7])
[17]  PRO1←15↓PRO1
[18]  N←N+1
[19]  →L4×⍳N<(⍎N1)+1
[20]  DATA1←(((⍴PROF1)÷2),2)⍴PROF1
[21]  →L1×⍳(RNG P1[⍳8])<P2
[22]  I←⍴X←(DATA1[;2]≥0)/DATA1[;1]
[23]  Y←(DATA1[;2]≥0)/DATA1[;2]
[24]  DATA1[I,I+1;2] LINEAR DATA1[I,I+1;1]
[25]  X←-(|(X-AA),0)
[26]  Y←(Y,0)
[27]  →L1×⍳(RNG P1[⍳8])<P2
     ∇


     ∇START[⎕]∇
     ∇ START;II;DOHI;WSTT;XBCO;XBTO;XIIO
[1]   YOP←YORG-S
[2]   CHKT←0
[3]   DREL←(1↑YORG[⍒YORG])-S
[4]   DFIF←DXFIF←BRDAT←INDAT←TRDAT←ONDAT←ERDAT←RFDAT←FBDAT←⍳0
[5]   HBDAT←RRDAT←MAX←SIG←AVR←HIO←⍳0
[6]   ZZZ←0
[7]   '∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇∇'
[8]   '                         ',CO,' COUNTY; DNR Monument ',RANGE
[9]   '                  BARRIER ISLAND CREST ELEVATION = ',(⍕DREL+S),' FT NGVD.'
[10]  '                       STORM SURGE = ',(⍕S),' FT NGVD; As = ',⍕POW[1]
[11]  '∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆∆'
[12]  T←14×((HI←⌽(I←0)↓⍳20)÷32.17)*0.5
[13] LX:HB←HI[I]×1-0.4×⍟7○100×HI[I]÷32.17×T[I←I+1]*2
[14]  HIP←HI←1↑I↓HI
[15] LWR:T←14×(HI÷32.17)*0.5
[16]  →LP3×⍳T<2
[17]  ZZZ←ZZZ+1
[18]  '***************************************************************************'
[19]  'WAVE RUN NUMBER: ',(⍕ZZZ),' ⍟⍟⍟⍟ Hi = ',(⍕HI),' ft ⍟⍟⍟⍟ T = ',(⍕T),' sec
      '
[20]  '                                Hb          T          Lb         Xbt        dbt'
[21]  '                               (ft)       (sec)       (ft)       (ft)       (ft)'
[22]  →LP3×⍳(HB<|DREL)∧(DREL<0)
[23]  ZZ←0
[24] ⍝********** WAVES ACTIVE ON POWER CURVE OFFSHORE PROFILE ***********
[25] ⍝***************** USE PARAMETRIC PROCEEDURES ************************
[26] LP1:ALPHAWAV
[27]  ZZ←ZZ+1
[28]  →LP2×⍳(HB+(2÷3)×-S)≤0
[29]  XBCO←((|HB+(2÷3)×-S)÷(2÷3)×POW[1])*1÷POW[2]
[30]  →LP2×⍳(XBCO-32×HB)<0
[31]  BRDAT←XBCO,(XBCO+0.25×HB÷WSTB*0.5),(-HB),(HB×1,1.23,1.37,1.57),T,LB,HI,
       BRDAT
```

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[32]  →LP2×⍳((1.6×HB)-S)<0
[33]  XBTO←(((|(1.6×HB)-S)÷1.2×POW[1])*1÷POW[2])+7×-S
[34]  TRDAT←XBTO,(-1.6×HB),TRDAT
[35]  HI←HR←HB×0.26×*7○175×WSTB
[36]  TR←T×(7○5×WSTB)*0.18
[37]  DOHI←1.28-1.57×⍟7○65×WSTT←HI÷32.17×TR*2
[38]  HPR←HI×0.5+(1.25×(1÷DOHI)×1.462×WSTT*1.055)*0.5
[39]  LR←LB×(7○0.95×WSTB*0.5)*0.45
[40]  XIIO←(((|(|DI)-S)÷POW[1])*1÷POW[2]
[41]  INDAT←XIIO,HP[⍴HP],T,L[⍴L],INDAT
[42]  →LLP×⍳ZZ≠1
[43]  RFDAT←((XBCO+0.25×HB÷WSTB*0.5)-32×HB),HPR,HR,TR,LR,HB,HI,RFDAT
[44] LLP:'          OFFBAR: ', 10 1 ⍕BRDAT[4 8 9],TRDAT[1 2]
[45]  T←TR
[46]  →LP1×⍳ZZ=1
[47]  →LP1×⍳((BRDAT[1]-XBCO)≥40×BRDAT[10])
[48]  BRDAT←10↓BRDAT
[49]  INDAT←8↓INDAT
[50]  TRDAT←2↓TRDAT
[51]  HI←HIP←HIP-CONST
[52]  →LWR×⍳HI>0
[53]  →LP3
[54] LP2:→LP5×⍳((XBCO-40×HB)<0)∧ZZ≠1
[55] ⍝************* WAVE REACHES ONSHORE BATHYMETRY ********************
[56] ⍝****************** PROCEED WITH TOTAL PROCESS ************************
[57]  JHBBAR
[58]  →LP3×⍳(HB<|DREL)∧DREL≤0
[59]  →LP4×⍳ZZ=1
[60]  →LP5×⍳(BRDAT[1]-DXFI[6])<1.1×40×BRDAT[4]
[61] LP4:BRDAT←DXFI[6 8],DFI[6],(HB×1,1.23,1.37,1.57),T,LB,HI,BRDAT
[62]  TRDAT←DXFI[3],DFI[3],TRDAT
[63]  '          ONBAR: ', 10 1 ⍕BRDAT[4 8 9],TRDAT[1 2]
[64]  INDAT←DXFI[⍴DXFI],HP[⍴HP],T,L[⍴L],INDAT
[65]  'Hr = ',(⍕HR),' Tr = ',(⍕TR),' YHr = ',(⍕DR+S),' Ytopo = ',⍕YFIR+S
[66]  RFDAT←DXFI[1],HRP,HR,TR,LR,HB,HI,RFDAT
[67]  ONDAT←XFRST,YFRST,HI,ONDAT
[68]  ERDAT←XFRST,YFRST,ALEE,ABAR,ASTS,HB,DXFI[3 4 5],DFI[3 4 5],T,ERDAT
[69]  →LP3×⍳(HB≤|DREL)∧DREL<0
[70] LP5:HI←HIP←HIP-CONST
[71]  →LWR×⍳HI>0
[72] LP3:'*************************************************************************
      '
[73]  'Hi = initial wave height.  T = wave period. Hb = shore-breaker height.'
[74]  'Lb = breaker wave length. Xbt = distance from shore to bar trough.'
[75]  'dbt = water depth from storm surge to bar trough.'
[76]  '*************************************************************************'
[77]  JHBDAT
      ∇


      ∇JHBDAT[⎕]∇
      ∇ JHBDAT
[1]   BRDATT←BRDAT←(((⍴BRDAT)÷10),10)⍴BRDAT
[2]   TRDATT←TRDAT←MATORD(((⍴TRDAT)÷2),2)⍴TRDAT
[3]   INDAT←MATORD(((⍴INDAT)-4),4)⍴INDAT
[4]   RFDATT←RFDAT←(((⍴RFDAT)÷7),7)⍴RFDAT
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[5]    ONDATT←ONDAT←(((ρONDAT)÷5),5)ρONDAT
[6]    ERDATT←ERDAT←(((ρERDAT)÷15),15)ρERDAT
[7]    BRDATT[; 4 5 6 7]←BRDAT[; 4 5 6 7]←S+0.84×BRDAT[; 4 5 6 7]
[8]    BRDATT[;3]←BRDAT[;3]←S+BRDAT[;3]
[9]    TRDATT[;2]←TRDAT[;2]←S+TRDAT[;2]
[10]   INDAT[;2]←S+INDAT[;2]
[11]   RFDATT[;2]←RFDAT[;2]←S+RFDAT[;2]
[12]   ONDATT[; 3 4]←ONDAT[; 3 4]←S+ONDAT[; 3 4]
[13]   →LLL×⍳DREL≥0
[14]   JHBINUNA
[15]   →0
[16] LLL:JHBHREC
      ∇


      ∇JHBINUNA[⎕]∇
      ∇ JHBINUNA
[1]   ⍝********** HORIZONTAL/VERTICAL RECESSION DETERMINATION **********
[2]   ⍝ Determine the eroded topography/bathymetry, final bar-breaking wave,
[3]   ⍝ reformed wave, and ensuing shore-breaking wave conditions (the last
[4]   ⍝ two are dependent on the eroded topographic conditions).
[5]    NOTAK←2
[6]   LP1:CF1←(NOTAK↑X←⌽ONDAT[;1]) JHBLIN(NOTAK←NOTAK+1)↑Y←⌽ONDAT[;4]
[7]    ID←1↑⌽NOTAK↑⌽ONDAT[;5]
[8]    →LP3×⍳(NOTAK+1)>ρX
[9]    DEV←(|Y[NOTAK+1])-|CF1[1]+CF1[2]×X[NOTAK+1]
[10]   →LP1×⍳(DEV≤1)∧ONDAT[(1↑ρONDAT)-NOTAK;3]>ONDAT[(1↑ρONDAT)-NOTAK;4]
[11] LP3:N←(N-1),N←1+ρ(XORG<ONDAT[NOTAK;1])/XORG
[12] LP2:CF2←XORG[N] LINEAR YORG[N←N-1]
[13]   YOVR←CF1[1]+CF1[2]×XOVR←(-CF1[1]-CF2[1])÷CF1[2]-CF2[2]
[14]   →LP2×⍳((XOVR<XORG[N[1]])∨(XOVR>XORG[N[2]]))∧(N[1]-1)≠0
[15]   XX←(⌽NOTAK↑⌽ONDAT[;1]),(TRDAT[;1]>ONDAT[1↑ρONDAT;1])/TRDAT[;1]
[16]   YY←(⌽NOTAK↑⌽ONDAT[;4]),(TRDAT[;1]>ONDAT[1↑ρONDAT;1])/TRDAT[;2]
[17]   TRDAT←(XOVR,YOVR),[1]⍉(2,ρXX)ρXX,YY
[18]   →LP10×⍳NOTAK=1↑ρONDAT
[19]   ONDAT←ONDAT[(+/ONDAT[;5]<ID)+⍳|(1↑ρONDAT[;1])-(+/ONDAT[;5]<ID);⍳5]
[20] LP10:ONDAT←(ONDAT[1; 1 1 3 3 5]),[1] ONDAT
[21]   BRDAT←BRDAT[(+/BRDAT[;10]<ID)+⍳+/BRDAT[;10]≥ID;⍳10]
[22]   RFDAT←RFDAT[(+/RFDAT[;1]<BRDAT[1;1])↓⍳1↑ρRFDAT;⍳7]
[23]   HB←S-BRDAT[1;3]
[24]   T←BRDAT[1;8]
[25]   JHBREFM
[26]   RFDAT←((RFDATT[+/RFDATT[;7]≤ID;1]),(S+HRF),HR,TR,LR,HB,HI),[1] RFDAT
[27]   HI←RFDAT[1;3]
[28]   T←RFDAT[1;4]
[29]   ALPHAWAV
[30]   →LP4×⍳(S-TRDAT[1;2])>1.28×HB
[31]   CF4←TRDAT[⍳2;1] JHBLIN S-TRDAT[⍳2;2]
[32]   X←((1.28×HB)-CF4[1])÷CF4[2]
[33]   BRDAT←(X,X,(S-1.28×HB),(S+0.84×HB×1,1.23,1.37,1.57),T,LB,HI),[1] BRDAT
[34] ⍝********************** OVERWASH SIMULATION**************************
[35] ⍝ Determine the area of material to be overwashed.
[36] LP4:X←XOVR,(XX≥XOVR)/XX←((XORG<TRDAT[2;1])/XORG),TRDAT[2;1]
[37]   Y←(YOVR,((XX≥XOVR)/Y←((XORG<TRDAT[2;1])/YORG),TRDAT[2;2]))-S
[38]   XP←TRDAT[⍳2;1]
[39]   YP←(TRDAT[⍳2;2])-S
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[40]  →LPDx⍳(⍴X)=1
[41]  ONAR←AREACALB
[42] LP5:XOVP←XOVR
[43]  YOVPP←XOVPP←⍳0
[44] ⍝ Determine displacement and distribution of the overwash material.
[45] LPA:Y←((CF1[1]+CF1[2]×XOVP←XOVP-1),YOVPP,YOVR)-S
[46]  X←XOVP,XOVPP,XOVR
[47]  XP←XOVP,(XX≥XOVP)/XX←((XORG<XOVR)/XORG),XOVR
[48]  N←⍬(N+1),N←⍴(XORG<XOVP)/XORG
[49]  →LPCx⍳X[1]<XORG[1]
[50]  CF3←XORG[N] LINEAR YORG[N]
[51]  YP←CF3[1]+CF3[2]×XOVP
[52]  YP←(YP,((XX≥XOVP)/((XORG<XOVR)/YORG),YOVR))-S
[53]  AOVR←¯1×AREACALB
[54]  →LPBx⍳CF1[2]=0
[55]  →LPAx⍳((|AOVR)<ONAR)∧(S+Y[1])<S+DR
[56]  TRDAT←(⍉ 2 2 ⍴XP[1],X[1],(YP[1]+S),Y[1]+S),[1] TRDAT
[57]  BRDAT←(XOVP,XOVP,YOVR,(S+0.84×HBx1,1.23,1.37,1.57),T,LB,HI),[1] BRDAT
[58]  JHBREFM
[59]  RFDAT←((BRDAT[1;1]-XBR),(S+HRP),HR,TR,LR,HB,HI),[1] RFDAT
[60] LPB:CF1←(YOVPP←S+DR),0
[61]  XOVPP←XOVP
[62]  →LPAx⍳((|AOVR)<ONAR)
[63] LPC:TRDAT←(⍉ 2 2 ⍴XP[1],X[1],(YP[1]+S),Y[1]+S),[1] TRDAT[1↓⍳1↑⍴TRDAT;⍳2]
[64] ⍝ Eventually determine if shore-breaking can occur upland of the
[65] ⍝ overwash ... if not determine where Hr and the post-shore-broken
[66] ⍝ wave crest elevation merge.
[67] ⍝************* DATA MANAGEMENT FOR FINAL PLOTTING*****************
[68] LPD:YOFF←-POW[1]×(XOFF←10×⍳⌊(1↑⍬TRDAT[;1])÷10)*POW[2]
[69]  X←((XORG≤ONDAT[1;1])/XORG),(XORG≤ONDAT[1;1])/YORG
[70]  ONDAT←((⍉(4,(⍴X)÷2)⍴X),[2]((⍴X)÷2)⍴ONDAT[1;5]),[1] ONDAT
[71]  X←((XORG≤TRDAT[1;1])/XORG),(XORG≤TRDAT[1;1])/YORG
[72]  TRDAT←(⍉(2,(⍴X)÷2)⍴X),[1] TRDAT
[73]  →LSTx⍳CHKTT=1
[74]  ONDAT[;1]←DIST+ONDAT[;1]
[75]  TRDAT[;1]←DIST+TRDAT[;1]
[76]  BRDAT[;1]←DIST+BRDAT[;1]
[77]  RFDAT[;1]←DIST+RFDAT[;1]
[78]  XOFF←XOFF+DIST
[79]  XORG←XORG+DIST
[80] LST:JHBPLO
      ∇


      ∇JHBREFM[⎕]∇
      ∇ JHBREFM
[1]  ⍝ Determines the reformed wave characteristics following shore-breaking
[2]  ⍝ over longshore bars.  This function utilizes data created by function
[3]  ⍝ ALPHAWAV.
[4]   SSL←(XBCP←40×HB)-XBR←32×HB
[5]   HR←HB×0.26×*7○175×WSTB←HB÷32.17×T*2
[6]   TR←T×(7○5×WSTB)*0.18
[7]   DR←-HR×1.28-1.57×⍟7○65×HR÷32.17×TR*2
[8]   HRP←HR×0.5+(1.25×(HR÷|DR)×(1.462×(HR÷32.17×TR*2)*1.055))*0.5
[9]   LR←LB×(7○0.95×WSTB*0.5)*0.45
      ∇
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```
      ∇JHBHREC[⎕]∇
      ∇ JHBHREC
[1]   ⍝************ HORIZONTAL/VERTICAL RECESSION DETERMINATION *************
[2]   ⍝ Determine the eroded topography/bathymetry, final bar-breaking wave,
[3]   ⍝ reformed wave, and ensuing shore-breaking wave conditions (the last
[4]   ⍝ two are dependent on the eroded topographic conditions).
[5]    NOTAK←2
[6]   LP1:CF1←(NOTAK↑X←⌽ONDAT[;1]) JHBLIN(NOTAK←NOTAK+1)↑Y←⌽ONDAT[;4]
[7]    ID←1↑⌽NOTAK↑⌽ONDAT[;5]
[8]    →LP3×⍳(NOTAK+1)>⍴X
[9]    DEV←(|Y[NOTAK+1])-|CF1[1]+CF1[2]×X[NOTAK+1]
[10]   →LP1×⍳(DEV≤1)∧ONDAT[(1↑⍴ONDAT)-NOTAK;3]>ONDAT[(1↑⍴ONDAT)-NOTAK;4]
[11]  LP3:N←(N-1),N←1+⍴(XORG<ONDAT[NOTAK;1])/XORG
[12]  LP2:CF2←XORG[N] LINEAR YORG[N←N-1]
[13]   YOVR←CF1[1]+CF1[2]×XOVR←(-CF1[1]-CF2[1])÷CF1[2]-CF2[2]
[14]   →LP2×⍳((XOVR<XORG[N[1]])∨(XOVR>XORG[N[2]]))∧(N[1]-1)≠0
[15]   XX←(⌽NOTAK↑⌽ONDAT[;1]),(TRDAT[;1]>ONDAT[1↑⍴ONDAT;1])/TRDAT[;1]
[16]   YY←(⌽NOTAK↑⌽ONDAT[;4]),(TRDAT[;1]>ONDAT[1↑⍴ONDAT;1])/TRDAT[;2]
[17]   TRDAT←(XOVR,YOVR),[1]⍉(2,⍴XX)⍴XX,YY
[18]   →LP10×⍳NOTAK=1↑⍴ONDAT
[19]   ONDAT←ONDAT[(+/ONDAT[;5]<ID)+⍳|(1↑⍴ONDAT[;1])-(+/ONDAT[;5]<ID);⍳5]
[20]  LP10:ONDAT←(ONDAT[1; 1 1 3 3 5]),[1] ONDAT
[21]   BRDAT←BRDAT[(+/BRDAT[;10]<ID)+⍳+/BRDAT[;10]≥ID;⍳10]
[22]   RFDAT←RFDAT[(+/RFDAT[;1]<BRDAT[1;1])↓⍳1↑⍴RFDAT;⍳7]
[23]   HB←S-BRDAT[1;3]
[24]   T←BRDAT[1;8]
[25]   JHBREFM
[26]   RFDAT←((RFDATT[+/RFDATT[;7]≤ID;1]),(S+HRP),HR,TR,LR,HB,HI),[1] RFDAT
[27]   HI←RFDAT[1;3]
[28]   T←RFDAT[1;4]
[29]   ALPHAWAV
[30]   CF4←TRDAT[⍳2;1] JHBLIN S-TRDAT[⍳2;2]
[31]   X←((1.28×HB)-CF4[1])÷CF4[2]
[32]   BRDAT←(X,X,(S-1.28×HB),(S+0.84×HB×1,1.23,1.37,1.57),T,LB,HI),[1] BRDAT
[33]  ⍝****************** FINAL SHORE-BREAKING AND RUNUP ********************
[34]   'Is Dynamic Setup Included in the Storm Surge Level ?'
[35]   ANS←⎕
[36]   FAC←0
[37]   →LP6×⍳ANS[1]='Y'
[38]   FAC←0.3×HB
[39]  LP6:TRDAT←TRDAT[1↓⍳1↑⍴TRDAT;]
[40]   RDIST←TRDAT[1;1]-1
[41]  LP4:RDIST←RDIST-1
[42]   LR←6.66×((HB*2)÷RSLP←(S-TRDAT[1;2])÷|RDIST-TRDAT[1;1])*0.5
[43]   →LP4×⍳(|RDIST-TRDAT[1;1])<LR
[44]   BRDAT[1;1]←TRDAT[1;1]
[45]   JHBONAR
[46]   TRDAT←((0.5×RDIST+XB),S+FAC),[1] TRDAT
[47]   X←((TRDAT[;1]<0)/TRDAT[;1])-TRDAT[1;1]
[48]   Y←(S+FAC)-(TRDAT[;1]<0)/TRDAT[;2]
[49]   AF←(+/Y×X*2÷3)÷+/X*4÷3
[50]   X←TRDAT[1;1]+XX←0,10×⍳L(TRDAT[2;1]-TRDAT[1;1])÷10
[51]   Y←(S+FAC)-AF×XX*2÷3
[52]   TRDAT←(⍉(2,⍴X)⍴X,Y),[1] TRDAT[1↓⍳1↑⍴TRDAT;]
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[53]  FINX←TRDAT[1;1]
[54] LP5:X←XORG[⌽(N+1),(N←⍴(XORG<FINX←FINX-1)/XORG)]
[55]  CF5←X JHBLIN YORG[N,N+1]
[56]  →LP5×⍳(|((S+FAC)-(FINY←|CF5[1]+CF5[2]×FINX))÷|TRDAT[1;1]-FINX)>1
[57]  TRDAT←(FINX,FINY),[1] TRDAT
[58] LPD:YOFF←-POW[1]×(XOFF←10×⍳⌊(1↑⌽TRDAT[;1])÷10)*POW[2]
[59]  X←((XORG≤ONDAT[1;1])/XORG),(XORG≤ONDAT[1;1])/YORG
[60]  ONDAT←((⍉(4,(⍴X)÷2)⍴X),[2]((⍴X)÷2)⍴ONDAT[1;5]),[1] ONDAT
[61]  X←((XORG≤TRDAT[1;1])/XORG),(XORG≤TRDAT[1;1])/YORG
[62]  TRDAT←(⍉(2,(⍴X)÷2)⍴X),[1] TRDAT
[63]  →LST×⍳CHKTT=1
[64]  ONDAT[;1]←DIST+ONDAT[;1]
[65]  TRDAT[;1]←DIST+TRDAT[;1]
[66]  BRDAT[;1]←DIST+BRDAT[;1]
[67]  RFDAT[;1]←DIST+RFDAT[;1]
[68]  XOFF←XOFF+DIST
[69]  XORG←XORG+DIST
[70] LST:→LAST×⍳TRDAT[1+.5×⍴X;2]<S
[71]  JHBPLO
[72]  →0
[73] LAST:JHBINUNA
      ∇


     ∇JHBONAR[⎕]∇
      ∇ JHBONAR
[1]   I←0
[2]  LOOP:DATX←ERDAT[I←I+1;]
[3]   →LOOP×⍳ERDAT[I;8]≠(BRDAT[2;4]-S)÷0.84
[4]   ERDAT← 1 15 ⍴DATX
[5]  ⍝************ CALC AREA AVAILABLE FOR OFFSHORE DEPOSITION *************
[6]   XB←ERDAT[1;1]
[7]  LP1:CF←((XB←XB-1),ERDAT[1;11]) JHBLIN(YB←S+FAC),S+ERDAT[1;14]
[8]   XSS←XP←(1↑XS←X←ERDAT[1;1],ERDAT[1;11]),ERDAT[1; 9 10 11]
[9]   YSS←YP←(S+ERDAT[1; 4 12 13]),1↓(YS←Y←(CF[1]+CF[2]×ERDAT[1;1]),S+ERDAT[1;
       14])
[10]  ONARA←AREACALB
[11] ⍝***************** CALC ONSHORE AREA THAT IS ERODED *********************
[12]  NN←⌽(NN+1),NN←1+⍴(XORG<XB)/XORG
[13]  CF1←(XB,XB-1) JHBLIN YB,YB+1
[14] LP2:CF2←XORG[NN] JHBLIN YORG[NN←NN-1]
[15]  YBB←CF2[1]+CF2[2]×XBB←(-CF2[1]-CF1[1])÷CF2[2]-CF1[2]
[16]  →LP2×⍳XBB<XORG[1↑NN]
[17]  X←XBB,((XP>XBB)/XP←(XORG<ERDAT[1;1])/XORG),ERDAT[1;1]
[18]  Y←YBB,⌽((⍴X)-1)↑⌽((XORG<ERDAT[1;1])/YORG),S+ERDAT[1;3]
[19]  →LP3×⍳Y[1]<YB
[20]  YP←YB,CF[1]+CF[2]×ERDAT[1;1]
[21]  XP←XB,ERDAT[1;1]
[22]  →LP4
[23] LP3:CF3←(X[1],ERDAT[1;11]) JHBLIN(Y[1],S+ERDAT[1;14])
[24]  YP←Y[1],CF3[1]+CF3[2]×ERDAT[1;1]
[25]  →LP5
[26] LP4:YP←(S+FAC),YS[1]
[27] LP5:XP←X[1],ERDAT[1;1]
[28]  ONARB←AREACALB
[29]  →LP1×⍳ONARB<ONARA
```

```
[30]  DATZ←DATZ,[1] 1 4 ρERDAT[1;8],HB,ONARA,XB
      ∇


      ∇JHBPLO[⎕]∇
      ∇ JHBPLO
[1]   N←ρXORG
[2]   ORIGDAT←⍉(2,ρXORG)ρXORG,YORG
[3]   ORIG←SURGE←BRKEV←TRELV←HIELV←PLGHT←⍳0
[4]   CNT←1
[5]   MAX←500+MIN←⌈100×¯1+⌈ORIGDAT[1;1]÷100
[6]  LP1:MAX←MIN+500
[7]   ERASE
[8]   SVP← 10 10 86 48
[9]   DD[5 6 7 8 9]← 0.8 1.7 0.6 0.8 1
[10]  IM← 1 1
[11]  PA←COLOR 7 7 7 7 7 7 7 7 ,STYLE 6 1 3 1 1 4 3 7 ,WIDTH 1 2 1 1 1 1 1 1
[12]  COPYCIL← 0 0 1 80 0 0 0 80 0 80 132
[13]  PC←'∘∘∘∘∘∘∘∘∘∘∘∘∘∘'
[14]  ORIG←JHBDAFP ORIGDAT,[1]⍉(2,ρXOFF)ρXOFF,YOFF
[15]  SURGE←⍉ 2 2 ρMIN,MAX,S,S
[16]  BRKEV←JHBDAFP BRDAT[; 1 4]
[17]  SIGEV←JHBDAFP BRDAT[; 1 5]
[18]  MAXEV←JHBDAFP BRDAT[; 1 7]
[19]  TRELV←JHBDAFP TRDAT
[20]  RFELV←JHBDAFP RFDAT[; 1 2]
[21]  →LP7×⍳(1↑ρTRELV)=0
[22]  PLHGT←⍉ 2 2 ρMAX,MAX,(50+PLHGT),PLHGT←10×⌊(⌊TRELV[1↑ρTRELV;1↓ρTRELV])÷10
[23]  →LP9
[24] LP7:PLHGT←⍉ 2 2 ρMAX,MAX,(50+PLHGT),PLHGT←10×⌊(⌊ORIG[1↑ρORIG;1↓ρORIG])÷10
[25] LP9:→LP5×⍳DREL≥0
[26]  PA←COLOR 7 7 7 7 7 7 7 7 7 ,STYLE 6 1 6 3 1 1 4 3 7 ,WIDTH 1 2 1 1 1 1 1
       1 1
[27]  ONELV←JHBDAFP ONDAT[; 1 4]
[28]  PLOTA TRELV AND ORIG AND ONELV AND SURGE AND PLHGT AND MAXEV AND SIGEV
       AND BRKEV AND RFELV
[29]  'P' SPLOT TRELV AND ORIG AND ONELV AND SURGE AND PLHGT AND MAXEV AND
       SIGEV AND BRKEV AND RFELV
[30]  (W[1],W[1]+50×⍳10) AXIS W[2],W[2]+5×⍳10
[31]  →LP6
[32] LP5:PLOTA TRELV AND ORIG AND SURGE AND PLGHT AND MAXEV AND SIGEV AND BRKEV
       AND RFELV
[33]  'P' SPLOT TRELV AND ORIG AND SURGE AND PLGHT AND MAXEV AND SIGEV AND BRKE
       V AND RFELV
[34]  (W[1],W[1]+50×⍳10) AXIS W[2],W[2]+5×⍳10
[35] LP6:((MAX-10),PLHGT[1;2]-1) TITLE 'JHB'
[36]  ((MAX-50),S) TITLE 'SS SWL'
[37]  ((MAX-100),PLHGT[1;2]-5) TITLE CO,' COUNTY'
[38]  ((MAX-100),PLHGT[1;2]-7) TITLE 'DNR Mon ',RANGE
[39]  ((MAX-100),PLHGT[1;2]-9) TITLE 'Profile Date: ',DATE[⍳2],' ',DATE[3 4 5],
      ' ',(⍕19),DATE[6 7]
[40]  ((MIN+65),PLHGT[1;2]-1) TITLE MONTIM
[41]  ((0.5×MIN+MAX),PLHGT[1;2]+1) TITLE 'J. H. BALSILLIE -- MULTIPLE SHORE-BRE
      AKING WAVE TRANSFORMATION MODEL'
[42]  ¯15 ANNY 'Elevation (ft NGVD)'
[43]  →LP3×⍳CHKTT=1
```

```
[44]  ¯3 ANNX 'Distance from the CCCL in Feet'
[45]  →LP4
[46] LP3:¯3 ANNX 'Distance from the Shoreline in Feet'
[47] LP4:VIEW
[48]  'Do you want a copy?'
[49]  ANS←⎕
[50]  →LP2×⍳ANS[1]='N'
[51]  COPYN 'PLOTJIM'
[52]  CMS 'GPRINT PLOTJIM'
[53] LP2:'Do you want to continue to the next screen print? (YES OR NO)'
[54]  ANS←⎕
[55]  →0×⍳ANS[1]='N'
[56]  CNT←CNT+1
[57]  MIN←MAX
[58]  →LP1×⍳(250+(TRDAT[;1])[⍴TRDAT[;1]])≥MIN
      ∇


      ∇PLOTA[⎕]∇
      ∇ PLOTA B;A;IO
[1]   A←'L'
[2]   IO←⎕IO
[3]   PLOTA
      ∇


      ∇PLOTA[⎕]∇
      ∇ PLOTA;P;R;U;V;AS;CI;PA;XA;⎕IO
[1]   ⎕IO←1
[2]   →(0=×/⍴B)↑0
[3]   →PLOTINIT/0
[4]   →A[13]/ER2
[5]   ⍎A[3]/'→(∨/B[;1]≤0)↑ER1'
[6]   ⍎A[3]/'B[;1]←10⍟B[;1]'
[7]   ⍎A[4]/'→(∨/B[;2]≤0)↑ER1'
[8]   ⍎A[4]/'B[;2]←10⍟B[;2]'
[9]   →(2≠⎕NC 'W')/WI
[10]  →(A[1]∧4=⍴W)/DR
[11] WI:M←(L≠B),[0.1]⌈≠B
[12]  W←MIN,((,PLHGT)[4]),MAX,(,PLHGT)[2]
[13]  ⍎'W←',(A[1]/'W,(⍴W)↓'),'W'
[14] DR:→A[7 9]/AX
[15]  B←((~U)×CI),B
[16]  →(⍱/A[10 11])/L1
[17]  →A[12]↓L3
[18]  RELATIVE
[19]  →L4
[20] L3:P←W[2]⌈0⌊W[4]
[21]  U←U\R←(V≠B[;2])≠U≠B[;2]
[22]  V←V\R
[23]  XA←B,[1](V≠XA),[1] U≠XA←CI,B[;,2],P
[24]  XA←XA[⍋(⍳⍴U),V,V←V/⍳⍴V;]
[25] L4:XA[;1]←(0,PA)[1;1+(0,AS)[1+XA[;1]]]
[26]  FILL(W INTO SVP) XFM XA
[27] L1:B←(W INTO SVP) XFM B
[28]  →(A[10 5]>A[8 11])/L2
```

```
[29]  B[;1]←(0,PA)[2;1+(0,AS)[1+B[;1]]]
[30]  DRAW B
[31] L2:→(∨/A[5 8])↓AX
[32]  B←B[; 2 3]-((1↑ρB),2)ρDD[7 8]÷2
[33]  B←B,(((1↑ρB),3)ρ0),PA[1;AS[CI]]
[34]  B WRITE(,EC)[((ρ,EC)|AS[CI]-1)∘.+,1]
[35] AX:⍎(A[7]∨⍱/A[2 9])/'⍬ AXIS ⍬'
[36]  →(⍱/A[6 9])/⍬
[37]  ⍬ LBLX ⍬
[38]  ⍬ LBLY ⍬
[39]  →⍬
[40] ER1:A←2 ERF 14
[41]  →⍬
[42] ER2:A←2 ERF 15
      ∇


      ∇JHBDAFP[⎕]∇
      ∇ Y←JHBDAFP X;SHP;I;N;XA;YA;MINX;MINY;CF1;CF2;CF3
[1]   ⍝ Function prepares data for plotting.  It is dependent on the values
[2]   ⍝ MIN and MAX given in the plot function JHBPLO, and on a counter CNT.
[3]    SHP←ρX
[4]    →LP1×⍳CNT=1
[5]    MINX←MIN
[6]    N←+/X[;1]≤MIN
[7]    →LP6×⍳N=0
[8]    →LP5×⍳(X[;1])[ρX[;1]]≤MIN
[9]    CF1←X[N,N+1;1] LINEAR X[N,N+1;2]
[10]   MINY←CF1[1]+CF1[2]×MIN
[11]   →LP7
[12] LP6:CF2←X[1 2 ;1] LINEAR X[1 2 ;2]
[13]   MINY←CF2[1]+CF2[2]×MIN
[14] LP7:→LP3×⍳(X[;1])[ρX[;1]]<MAX
[15]   →LP2×⍳CNT≠1
[16] LP1:MINX←MINY←⍳0
[17] LP2:→LP3×⍳(X[;1])[ρX[;1]]≤MAX
[18]   XA←MINX,((X1≥MIN)/X1←(X[;1]≤MAX)/X[;1]),MAX
[19]   N←ρX1
[20]   →LP5×⍳N=0
[21]   CF3←X[N,N+1;1] LINEAR X[N,N+1;2]
[22]   YA←MINY,((X1≥MIN)/Y1←(X[;1]≤MAX)/X[;2]),CF3[1]+CF3[2]×MAX
[23] LP4:Y←⍉(2,ρXA)ρXA,YA
[24]   →⍬
[25] LP3:XA←MINX,(X1≥MIN)/X1←(X[;1]≤MAX)/X[;1]
[26]   YA←MINY,(X1≥MIN)/Y1←(X[;1]≤MAX)/X[;2]
[27]   →LP4
[28]   →⍬
[29] LP5:Y←⍳0
      ∇


      ∇MATORD[⎕]∇
      ∇ Y←MATORD X;Y;I;SHP;Y
[1]   ⍝ Reorders a 2×2 array in descending order (top to bottom) according to
[2]   ⍝ the 1st column represent the distance offshore.
[3]    Y←⍳0
```

```
[4]    I←1
[5]    SHP←⍴X
[6]   LOOP:Y←Y,(X[;I])[⍋X[;1]]
[7]    I←I+1
[8]    →LOOP×⍳I≤SHP[2]
[9]    Y←⍉(⌽SHP)⍴Y
       ∇


       ∇MONTIM[⎕]∇
       ∇ MT←MONTIM;MAT;MIN;TIME
[1]   ⍝ Builds a date/time vector for plotting purposes.
[2]    MAT← 12 3 ⍴'JanFebMarAprMayJunJulAugSepOctNovDec'
[3]    MIN←⍕⎕TS[5]
[4]    →LP1×⍳(⍴⍕⎕TS[5])=2
[5]    MIN←'0',⍕⎕TS[5]
[6]   LP1:TIME←(⍕⎕TS[4]),':',MIN,' a.m.'
[7]    →LP2×⍳⎕TS[4]≤12
[8]    TIME←(⍕⎕TS[4]-12),':',MIN,' p.m.'
[9]   LP2:MT←TIME,' ',MAT[(⎕TS[2]);⍳3],' ',(⍕⎕TS[3]),' ',⍕⎕TS[1]
[10]   AA←MAT[(⎕TS[2]);⍳3],' ',(⍕⎕TS[3]),' ',⍕⎕TS[1]
       ∇


       ∇JHBDEMO[⎕]∇
       ∇ JHBDEMO
[1]   ⍝ A demonstration function for building longshore bars for a single
[2]   ⍝ incoming, initial wave condition.
[3]    CHKT←1
[4]    DFIF←DXFIF←XOFF←XBC←HU←HA←DAT←HAF←XHAF←DXF←⍳0
[5]    ZZ←1
[6]    'DO YOU WISH TO HAVE A STORM WAVE ?'
[7]    ANS←⎕
[8]    'INITIAL WAVE HEIGHT (FT):'
[9]    HI←⎕
[10]   →LP5×⍳ANS[1]='Y'
[11]   'INITIAL WAVE PERIOD (SEC):'
[12]   T←⎕
[13]   →LP6
[14]  LP5:T←14×(HI÷32.17)*0.5
[15]  LP6:'STORM SURGE ELEVATION (FT NGVD):'
[16]   YOP←YORG-S←⎕
[17]  LP1:JHBBAR
[18]   →0×⍳(YSTS+S)>0
[19]   DFIF←DFI,DFIF
[20]   DXFIF←DXFI,DXFIF
[21]   HAF←HA,HAF
[22]   XHAF←XHA,XHAF
[23]   CF1←(DXFI[3],DXFI[¯1+⍴DXFI]) LINEAR DFI[3],DFI[¯1+⍴DFI]
[24]   RBB←(|DFI[6])÷RB←(|AA+BB×DXFI[6])-|DFI[6]
[25]   DATB←ZZ,HI,T,HB,XBCP,XBR,TANABSI[1],WSTI,WSTB,(WSTB*0.5),TANABSI[1]
[26]   DATB←DATB,TANABSI[2],ABAR,ALEE,ASTS,LBB,(46×HB),POW[1],POWST[3],POWST[1]
[27]   DATB←DATB,PRTCOF,DFI[3],DXFI[3],DFI[6],DXFI[6],S,1↑YOP[⍋YOP]
[28]   DATB←DATB,RB,RBB,HR,TR,LR
[29]   DAT←DATB,DAT
[30]   ZZ←ZZ+1
```

```
[31]  HI←HR
[32]  T←TR
[33]  →LP2
[34]  →LP1×⍳(T>2)∧((HR×1-0.4×⍟7○100×HR÷32.17×T*2))|YFRST[1])∧(DXFI[6]-XFRST[1])
      >XBCP
[35]  →LP2×⍳(⍴DXFIF)=⍴DXFI
[36]  DXFIF←(⍴DXFI)↓DXFIF
[37]  DFIF←(⍴DFI)↓DFIF
[38]  HAF←(⍴HA)↓HAF
[39]  DATB←32↓DATB
[40] LP2:ERASE
[41]  COPYCTL← 0 0 1 47 0 0 0 80 0 47 90
[42]  SVP← 10 10 90 40
[43]  IM← 1 1
[44]  PA←COLOR 7 7 7 7 ,STYLE 1 8 1 1 ,WIDTH 1 2 1 1
[45]  XO←XOP,(DXFIF>XOP[⍴XOP])/DXFIF
[46]  YO←(S+YOP),-POW[1]×((⍴XOP)↓XO)*POW[2]
[47]  PLOT((DFIF+S) VS DXFIF) AND(YO VS XO) AND((HAF+S) VS XHAF) AND S VS XO
[48]  W←⍉ 2 2 ⍴W
[49]  ((0.5×+/W[1;]),W[2;2]+2) TITLE CO,' CO. ',YR,' ',P1[⍳8]
[50]  VIEW
[51]  'DO YOU WANT A COPY ?'
[52]  ANS←⎕
[53]  →0×⍳ANS[1]='N'
[54]  COPYN 'PLOTJIM'
[55]  CMS 'GPRINT PLOTJIM'
      ∇


      ∇MATRIX[⎕]∇
      ∇ MATRIX
[1]   ⎕PP←4
[2]   DATA←(32,(2↓⍴⍉DATA))⍴,⍉DATA←⍉(((⍴DAT)÷32),32,1)⍴DAT
[3]   DATA←(32 5 ⍴' '),[2] LAB,[2] DATA
[4]   '     XFRST,YFRST,S+YFRST : ',(⍉XFRST,YFRST,S+YFRST)
[5]   DATA
      ∇


      ∇JHBDPLO[⎕]∇
      ∇ JHBDPLO
[1]   CNT←1
[2]   Y←(XORG>DXFI[1]-300)/YORG
[3]   XX←(XORG>DXFI[1]-300)/XORG
[4]   ORIGDAT←⍉(2,⍴XX)⍴XX,Y
[5]   ORIG←SURGE←BRKEV←TRELV←PLGHT←⍳0
[6]   MAX←500+MIN←⌊100×¯1+⌈ORIGDAT[1;1]÷100
[7]  LP4:MAX←MIN+500
[8]   ERASE
[9]   SVP← 10 10 86 48
[10]  DD[5 6 7 8 9]← 0.8 1.7 0.6 0.8 1
[11]  IM← 1 1
[12]  PA←COLOR 7 7 7 7 ,STYLE 9 8 1 7 ,WIDTH 2 2 1 1
[13]  COPYCTL← 0 0 1 80 0 0 0 80 0 80 132
[14]  PC←'∘∘∘∘∘'
[15]  XO←XX,(DXFIF>XOP[⍴XOP])/DXFIF
```

```
[16]  YO←Y,-POW[1]×((ρXX)↓XO)*POW[2]
[17]  ORIG←JHBDAFP⍉(2,ρXO)ρXO,YO
[18]  SURGE←⍉ 2 2 ρMIN,MAX,S,S
[19]  BRKEV←JHBDAFP⍉(2,ρXHAF)ρXHAF,S+HAF
[20]  →LP5×⍳DREL<0
[21]  ONAREA
[22]  TRELV←JHBDAFP⍉(2,1+ρDXFIF)ρ(XBB,XB,1↓DXFIF),YBB,YB,S+1↓DFIF
[23]  →LP6
[24] LP5:TRELV←JHBDAFP⍉(2,ρDXFIF)ρDXFIF,DFIF+S
[25] LP6:→0×⍳(1↑ρTRELV)=0
[26]  PLHGT←⍉ 2 2 ρMAX,MAX,(50+PLHGT),PLHGT←10×⌊(LTRELV[1↑ρTRELV;1↓ρTRELV])÷10
[27]  'DO YOU WANT TO ALSO PLOT POST-STORM TOPOGRAPHY ?'
[28]  →LP1×⍳(⎕[1])='N'
[29]  'COUNTY:'
[30]  CO←⎕
[31]  'YEAR:'
[32]  YR←⎕
[33]  'PROFILE NUMBER:'
[34]  P2←⎕
[35]  FN1←(3↑CO),2↓YR
[36]  FT1←'REFORM B1'
[37]  PROFILE
[38]  DATD←P1[88+⍳7]
[39]  Y←((X+AA-DIST)>XX[1])/Y
[40]  X←((X+AA-DIST)>XX[1])/X
[41]  POST←⍉(2,ρX)ρ(X+AA-DIST),Y
[42]  →LP2
[43] LP1:PLOTA TRELV AND ORIG AND BRKEV AND SURGE
[44]  (W[1],W[1]+50×⍳10) AXIS W[2],W[2]+5×⍳10
[45]  →LP3
[46] LP2:PA←COLOR 7 7 7 7 7 ,STYLE 10 8 1 4 11 ,WIDTH 2 2 1 1 2
[47]  PLOTA TRELV AND ORIG AND BRKEV AND SURGE AND POST
[48]  ((MIN+120),PLHGT[1;2]-9) TITLE 'Post-Storm Profile Date:',DATD[1 2],' ',
       DATD[3 4 5],' ',(⍕19),DATD[6 7]
[49] LP3:((MIN+120),PLHGT[1;2]-3) TITLE CO,' COUNTY'
[50]  ((MIN+120),PLHGT[1;2]-5) TITLE 'DNR Mon ',RANGE
[51]  ((MIN+120),PLHGT[1;2]-7) TITLE 'Pre-Storm Profile Date: ',DATE[1 2],' ',
       DATE[3 4 5],' ',(⍕19),DATE[6 7]
[52]  ((MAX-100),PLHGT[1;2]-3) TITLE 'Hi = ',(⍕DAT[2]),' ft'
[53]  ((MAX-100),PLHGT[1;2]-5) TITLE 'T = ',(⍕DAT[3]),' sec'
[54]  ((MAX-100),PLHGT[1;2]-7) TITLE 'Hb = ',(⍕DAT[4]),' ft'
[55]  ((MAX-100),PLHGT[1;2]-9) TITLE 'Hr = ',(⍕DAT[30]),' ft'
[56]  ((MAX-100),PLHGT[1;2]-11) TITLE 'Tr = ',(⍕DAT[31]),' sec'
[57]  ((MAX-100),PLHGT[1;2]-13) TITLE 'Storm Surge = ',(⍕S),' ft NGVD'
[58]  ((MIN+250),PLHGT[1;2]+1) TITLE 'J. H. BALSILLIE -- MULTIPLE SHORE-BREAKIN
      G WAVE TRANSFORMATION MODEL'
[59]  ¯3 ANNX 'Distance from the Shoreline in Feet'
[60]  ¯3 ANNY 'Elevation (ft NGVD)'
[61]  VIEW
[62]  'DO YOU WANT A COPY?'
[63]  ANS←⎕
[64]  →LP2×⍳ANS[1]='N'
[65]  COPYN 'PLOTJIM'
[66]  CMS 'GPRINT PLOTJIM'
[67] LP2:CNT←CNT+1
[68]  MIN←MAX
```

```
[69]   →LP4×⍳(250+DXFIF[⍴DXFIF])≥MIN
       ∇


       ∇JHBCALI[⎕]∇
       ∇ JHBCALI
[1]    CFS←DXFIF[⍳2]
[2]    XFIR←1.1×XSEC←DXFIF[2]
[3]    NN←⍬(NN+1),NN←1+⍴(XO(1.1×XSEC)/XO
[4]   LP1:CF1←XO[NN] LINEAR YO[NN←NN-1]-S
[5]   LP2:YFIR←CF1[1]+CF1[2]×(XFIR←XFIR-0.1)
[6]    →LP2×⍳(((1.1×XSEC)-XFIR)(YFIR-DFIF[2])∧XFIR≥XO[NN[1]]
[7]    →LP1×⍳(((1.1×XSEC)-XFIR)(YFIR-DFIF[2])∧XFIR≤XO[NN[1]]
       ∇


       ∇JHBBAR[⎕]∇
       ∇ JHBBAR
[1]    DXF←DX←DF←HA←HU←⍳0
[2]    DREL←(1↑YORG[⍋YORG])-S
[3]    POWST←TANABSI←0,(2÷3),0
[4]    ALPHAWAV
[5]    JHBREFM
[6]    HA←HP,HA
[7]    HU←TP,HU
[8]   ⍝******* CALCULATE THE INITIAL STOSS BATHYMETRY FOR PLUNGING **********
[9]   LP1:DX←(|TD÷1↑POWST[1 3]←POWST[1 3]+0.001)*1÷POW[2]
[10]   →LP1×⍳(TANABSI[1]←(+/(1↓|TD)÷1↓DX)÷50)(WSTB*0.5
[11]   DF←DFF←-(HB×1.6,1.28,1.1,1,1.1),D
[12]   DX←(14.5×HB)+(-14.5×HB),((HB÷TANABSI[1])×-0.25,0.125),DX
[13]   DXF←DXFF←(1↑DX),(DX[2]-(HB÷TANABSI[1])×0.25,0.125),1↓DX
[14]   XO←XOP,DXX←((⌊DXF[⍴DXF]÷50)×⍳50),DXF[⍴DXF]
[15]   YO←YOP,(-S)+-POW[1]×DXX*POW[2]
[16]   →0×⍳JHBDIST=0
[17]   DXF←DXFF←DXF+JHBDIST
[18]   XO←XOP,DXX←((⌊DXF[⍴DXF]÷50)×⍳50),DXF[⍴DXF]
[19]   YO←YOP,(-S)+-POW[1]×DXX*POW[2]
[20]   XLAST←DXF[⍴DXF]
[21]   YLAST←DF[⍴DF]
[22]   →LP2×⍳DF[⍴DF]<YO[⍴YO]
[23]  LP4:POWST[1]←POWST[1]+0.001
[24]   YLAST←(¯1.28×HB)-POWST[1]×(XLAST-DXFF[6])*POWST[2]
[25]   DXF←((|6↓DF+1.28×HB)÷POWST[1])*1÷POWST[2]
[26]   TANABSI[1]←((+/(6↓|DF+1.28×HB)÷DXF)÷⍴DXF)
[27]   →LP4×⍳YLAST≥YO[⍴YO]
[28]   DXF←(6↑DXFF),(DXFF[6]+DXF),XLAST
[29]   DF←DF,YLAST
[30]  LP2:→LP3×⍳CHKT=0
[31]   ERASE
[32]   EA←COLOR 1 2 4 7 ,STYLE 1 1 1 1
[33]   PLOT((DF+S) VS DXF) AND((YO+S) VS XO) AND(DFF+S) VS DXFF
[34]   VIEW
[35]  LP3:AREABAR
       ∇
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      ∇ALPHAWAV[⎕]∇
      ∇ ALPHAWAV;PHI1;PHI2
[1]   ⍝ REVISION DATE:  June, 1983
[2]   ⍝ PROGRAMMER:  James H. Balsillie
[3]   ⍝ DESCRIPTION:  This standardized, interactive function transforms
[4]   ⍝ wave characteristics during alpha wave peaking in the shore-breaking
[5]   ⍝ process.  Transformed characteristics include the wave height both
[6]   ⍝ absolute and above and below the still water level (SWL), wave speed
[7]   ⍝ and wave length.
[8]   ⍝ REQUIRED INPUT:
[9]   ⍝ HI = initial incident wave height in feet.
[10]  ⍝ T = initial incident wave period in seconds.
[11]  ⍝ COMPUTED OUTPUT:
[12]  ⍝ WSTI = initial wave steepness for alpha wave peaking.
[13]  ⍝ DI = water depth at which alpha wave peaking is initiated.
[14]  ⍝ HB = shore-breaking wave height.
[15]  ⍝ WSTIP = initial wave steepness for predicting the amount of the wave
[16]  ⍝          lying above and below the SWL.
[17]  ⍝ H = local wave height during alpha wave peaking.
[18]  ⍝ HP = amount of the wave height lying above the SWL.
[19]  ⍝ TP = amount of the wave lying below the SWL.
[20]  ⍝ CB = wave speed at the shore-breaking position.
[21]  ⍝ CI = wave speed at initiation of alpha wave peaking.
[22]  ⍝ C = local wave speed during alpha wave peaking.
[23]  ⍝ L = local wave length during alpha wave peaking.
[24]  ⍝
[25]  ⍝ ALPHA WAVE PEAKING CALCULATIONS.
[26]   DI←HI×DIOHI←1.28-1.57×⍟7○65×WSTI←HI÷32.17×T*2
[27]   HB←HI×HBOHI←1-0.4×⍟7○100×WSTI
[28]   DOH←1.28+(0,⍳50)×(DIOHI-1.28)÷50
[29]   H←HI×HOHI←HBOHI-(HBOHI-1)×(7○((*1)÷(DIOHI-1.28))×DOH-1.28)*0.7
[30]  ⍝ CALCULATE WAVE HEIGHT TRANSFORMATION ABOVE AND BELOW SWL.
[31]   HPOHI←0.5+(1.25×(1÷DOH)×WSTIP←1.462×WSTI*1.055)*0.5
[32]   PHI1←(*1)÷(3×(*1)*0.153×DOH)-1.28
[33]   PHI2←¯0.384+¯0.2×⍟WSTIP
[34]   TP←(-H)+HP←H×HPOH←0.84-(0.84-HPOHI)×((7○PHI1×DOH-1.28)*PHI2)
[35]   TD←(-D[1])+D←H×DOH
[36]  ⍝ CALCULATE WAVE SPEED AND WAVE LENGTH TRANSFORMATIONS.
[37]   CB←(1.6×32.17×HB)*0.5
[38]   HPOHIA←0.84-0.307×7○0.3×DIOHI-1.28
[39]   CI←CB×1.84×(0.7078×DIOHI*0.4353)×(1+HPOHIA)*¯1
[40]   L←T×C←CI-(1-(DOH-1.28)÷DIOHI-1.28)×CI-CB
[41]   LB←T×(1.6×32.17×HB)*0.5
[42]   WSTB←HB÷32.17×T*2
      ∇


      ∇JHBDIST[⎕]∇
      ∇ X←JHBDIST;X;N;CF
[1]   ⍝ Finds the initial position of the longshore bar for determination of
[2]   ⍝ the bar stoss slope bathymetry.
[3]    N←¯1+⍴YO
[4]   LP1:N←N-1
[5]    →LP×⍳N[1]=0
[6]    CF←XO[N,N+1] LINEAR YO[N,N+1]
[7]    →LP1×⍳DF[1]>YO[N]
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[8]    X←(DF[1]-CF[1])÷CF[2]
[9]    →0
[10] LP:X←0
       ∇


       ∇AREABAR[⎕]∇
       ∇ AREABAR;I
[1]    XBC←⍳0
[2]    I←1
[3]    XLAST←((|S+YLAST)÷POW[1])*1÷POW[2]
[4]   LP2:→LPA×⍳(XFRST[1]≤0)∧DREL≥0
[5]    DXF←DXF-DT←2
[6]    →LPB
[7]   LPA:DXF←DXF-DT←1
[8]    →LPB×⍳(I=1)∨(ABAR÷|ALEE+ASTS)<2
[9]    DXF←DXF-9
[10] LPB:JHBFRST
[11]   I←I+1
[12]   DXFI←XFRST,DXF,XLAST
[13]   DFI←YFRST,DF,YLAST
[14]   JHBLESI
[15]   JHBSTSI
[16]   →0×⍳(YSTS+S)>0
[17] ⍝ ******************* CALCULATE BAR CREST AREA ***************************
[18]   X←XLEE,((XA>XLEE)/XA←(DXFI(XSTS)/DXFI),XSTS
[19]   Y←YLEE,((XA>XLEE)/YA←(DXFI(XSTS)/DFI),YSTS
[20]   XP←XLEE,((XA>XLEE)/XA←(XO(XSTS)/XO),XSTS
[21]   YP←YLEE,((XA>XLEE)/YA←(XO(XSTS)/YO),YSTS
[22]   ABAR←AREACALB
[23] ⍝ ******************* CALCULATE BAR TROUGH AREA **************************
[24]   X←XFRST,((XA>XFRST[1])/XA←(DXFI(XLEE)/DXFI),XLEE
[25]   Y←YFRST,((XA>XFRST[1])/YA←(DXFI(XLEE)/DFI),YLEE
[26]   XP←XFRST[1],((XA>XFRST[1])/XA←(XO(XLEE)/XO),XLEE
[27]   YP←YFRST[1],((XA>XFRST[1])/YA←(XO(XLEE)/YO),YLEE
[28]   ALEE←AREACALB
[29] ⍝ ****************** CALCULATE BAR STOSS AREA ****************************
[30] LP1:X←XSTS,(XSTS+DT←DT+2),XLAST
[31]   Y←YSTS,((¯1.28×HB)-POWST[1]×(X[2]-DXFI[8])*POWST[2]),YLAST
[32]   XP←XSTS,((XA>XSTS)/XA←(XO(XLAST)/XO),XLAST
[33]   YP←YSTS,((XA>XSTS)/YA←(XO(XLAST)/YO),YLAST
[34]   ASTS←AREACALB
[35] ⍝ ********** TESSELATION OF RESULTS FOR AREAS ASTS AND ALEE ************
[36]   →LP1×⍳(ASTS>PRTCOF×ALEE)∧((X[2]+2)<XLAST)∧(Y[2]≥YLAST)
[37] ⍝ ****************** DETERMINE IF ABAR = ALEE + ASTS *******************
[38]   DFI←((DXFI(X[2])/DFI),Y[2],YLAST
[39]   DXFI←((DXFI(X[2])/DXFI),X[2],XLAST
[40]   →LP2×⍳(ABAR>|ALEE+ASTS)∨ALEE>0
[41]   LBB←DXFI[¯1+⍴DXFI]-DXFI[3]
[42]   XBC←(DXFI[6]-XBCP),XBC
[43]   CF1←DXFI[3 8] LINEAR HB×(0.5,0.84)
[44]   HA←HAI,(CF1[1]+CF1[2]×DXFI[3 4 5 6 7]),HP
[45]   XHA←XHAP,(⍴HP)↑2↓DXFI
[46]   HA←Φ((⍴HA)-⍴XHA)↓ΦHA
[47]   →LP3×⍳CHKT=1
[48]   →0
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[49] LP3:ERASE
[50]  ⍷⍺← 1 2 4 7 ,STYLE 1 1 1 1
[51]  PLOT((DFI+S) VS DXFI) AND((YO+S) VS XO) AND S VS XO
[52]  VIEW
      ∇


      ∇JHBFRST[⎕]∇
      ∇ JHBFRST;I;N;CF1;CF2;CF3
[1]   ⍝ Finds the first two values of the bar trough bathymetry,
[2]   ⍝ and post-bar breaking wave characteristics for final shore-breaking.
[3]   ⍝ ********************* Coast Inundated ***************************
[4]    XSEC←DXF[5]-32×HB
[5]    NN←1+N←⍋(N+1),N←⍴(XO<XSEC)/XO
[6]    CF2←XO[N] LINEAR YO[N]
[7]    XFRST←XSEC,XSEC
[8]    YFRST←(YFIR←CF2[1]+CF2[2]×XSEC),DR
[9]    XHAP←XFRST
[10]   HAI←HRP,HRP
[11]   →0×⍳YFIR≥DR
[12]   YFRST[2]←YFIR
[13]   →0
[14]  ⍝ ********************* Coast Not Inundated ***************************
[15] LP3:XFIR←XSEC
[16] LP1:CF1←XO[NN] LINEAR YO[NN←NN-1]
[17] LP2:YFIR←CF1[1]+CF1[2]×(XFIR←XFIR-0.1)
[18]   →LP2×⍳((XSEC-XFIR)<(YFIR-0.3×HB)∧XFIR≥XO[NN[1]]
[19]   →LP1×⍳((XSEC-XFIR)<(YFIR-0.3×HB)∧XFIR≤XO[NN[1]]
[20]   YFRST←YFIR,0.3×HB
[21]   XHAP←XFRST←XFIR,XSEC
[22]   HAI←0.3×HB,HB
      ∇


      ∇JHBLESI[⎕]∇
      ∇ JHBLESI
[1]   ⍝ Finds the LEE BAR SLOPE INTERCEPT (i.e., common point of bar lee
[2]   ⍝ slope bathymetry and original bathymetry) given by (XLEE,YLEE).
[3]    CF1←DXFI[3 4] LINEAR DFI[3 4]
[4]    N←¯1+⍋(N+1),N←⍴(XO<DXFI[3])/XO
[5]   LP1:CF2←XO[N] LINEAR YO[N←N+1]
[6]    YLEE←CF1[1]+CF1[2]×XLEE←(-CF1[1]-CF2[1])÷CF1[2]-CF2[2]
[7]    →LP1×⍳XLEE>XO[N[2]]
      ∇


      ∇JHBSTSI[⎕]∇
      ∇ JHBSTSI;N;CN;CF1;CF2
[1]   ⍝ Finds the BAR STOSS INTERCEPT (i.e., common point of the bar stoss
[2]   ⍝ slope bathymetry and original bathymetry) given by (XSTS,YSTS).
[3]    N←¯1+⍋(N+1),N←⍴(XO<DXFI[8])/XO
[4]   LP1:→0×⍳(N[2]+1)>⍴XO
[5]    CF1←XO[N] LINEAR YO[N←N+1]
[6]    →LP1×⍳YO[N[2]]<(CN←(¯1.28×HB)-POWST[1]×(|XO[N[2]]-DXFI[8])*POWST[2]
[7]    CF2←XO[N] LINEAR(¯1.28×HB)-POWST[1]×(XO[N]-DXFI[8])*POWST[2]
[8]    →0×⍳CF1[2]=CF2[2]
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[9]    XSTS←(-CF1[1]-CF2[1])÷CF1[2]-CF2[2]
[10]   YSTS←CF2[1]+CF2[2]×XSTS
[11]   →LP1×⍳(YSTS+S)>0
       ∇


       ∇LINEAR[⎕]∇
       ∇ Z←X LINEAR Y;Y;X
[1]    X←X
[2]    Y←Y
[3]    BB←(Y[2]-Y[1])÷X[2]-X[1]
[4]    AA←Y[1]+BB×-X[1]
[5]    Z←AA,BB
       ∇


       ∇JHBLIN[⎕]∇
       ∇ Z←X JHBLIN Y;Y;X
[1]    BB←(+/((X-((+/X)÷⍴X))×Y))÷(+/((X-((+/X)÷⍴X))*2))
[2]    AA←((+/Y)÷⍴Y)-(BB×((+/X)÷⍴X))
[3]    Z←AA,BB
       ∇


       ∇AREACALB[⎕]∇
       ∇ AREA←AREACALB
[1]    AX←AY←⍳0
[2]    I←1
[3]   L1:AX←AX,(0.5×Y[I+1]+Y[I])×X[I+1]-X[I]
[4]    I←I+1
[5]    →L1×⍳I≤(⍴X)-1
[6]    I←1
[7]   L2:AY←AY,(0.5×YP[I+1]+YP[I])×XP[I+1]-XP[I]
[8]    I←I+1
[9]    →L2×⍳I≤(⍴XP)-1
[10]   AREA←(+/AX)-+/AY
       ∇
```