Report On

Task 4

Possible Physical Impact of Dredging at Sandbridge Shoal

of the 1993-1995 U.S. Minerals Management Service - Commonwealth of Virginia Cooperative Project

INVESTIGATION OF ISOLATED SAND SHOALS ON THE INNER SHELF OF VIRGINIA RELATIVE TO THE POTENTIAL FOR AGGREGATE MINING

Submitted to

U.S. Department of the Interior
Minerals Management Service
Office of International and Marine Minerals
381 Elden Street
Herndon, Virginia 22070-4817

by

School of Marine Science
Virginia Institute of Marine Science
College of William & Mary
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Gloucester Point, Virginia 23062-1346

Jerome P. -Y Maa
Principal Investigator

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INTRODUCTION

The Virginia Institute of Marine Science, together with other state agencies, has a continuing interest in preserving the coastline of Virginia, particularly, the Atlantic coastline in the vicinity of the resort city of Virginia Beach. Because a well maintained beach can serve several purposes, e.g., (1) providing public recreational areas, (2) protecting valuable properties that are located near coastline, and (3) reducing the rate of land loss, a great deal of efforts has been devoted to understand the processes that affect the change of shoreline. Among several erosion forces, waves are especially important elements as they can alter the shoreline significantly.

To have a beach properly maintained, one may use several approaches, and perhaps use all available approaches in parallel to obtain the best results. In the costal sector of Virginia Beach, beach nourishment using material from inland borrow pit have been done constantly during last two decades. The ability to find land sources of good beach-quality sand has become more difficult. The sand loss due to both shore normal and longshore transport creates the need to find a reliable source of good quality sand for future supply.

Sandbridge Shoal (see Fig. 1) located approximately 20 miles south of Virginia Beach and 3 miles offshore, has been identified as the potential source of good beach-quality sand (Kimball and Dame 1989). Use of the sand resources there, however, causes a great deal of concern that dredging may cause severe beach

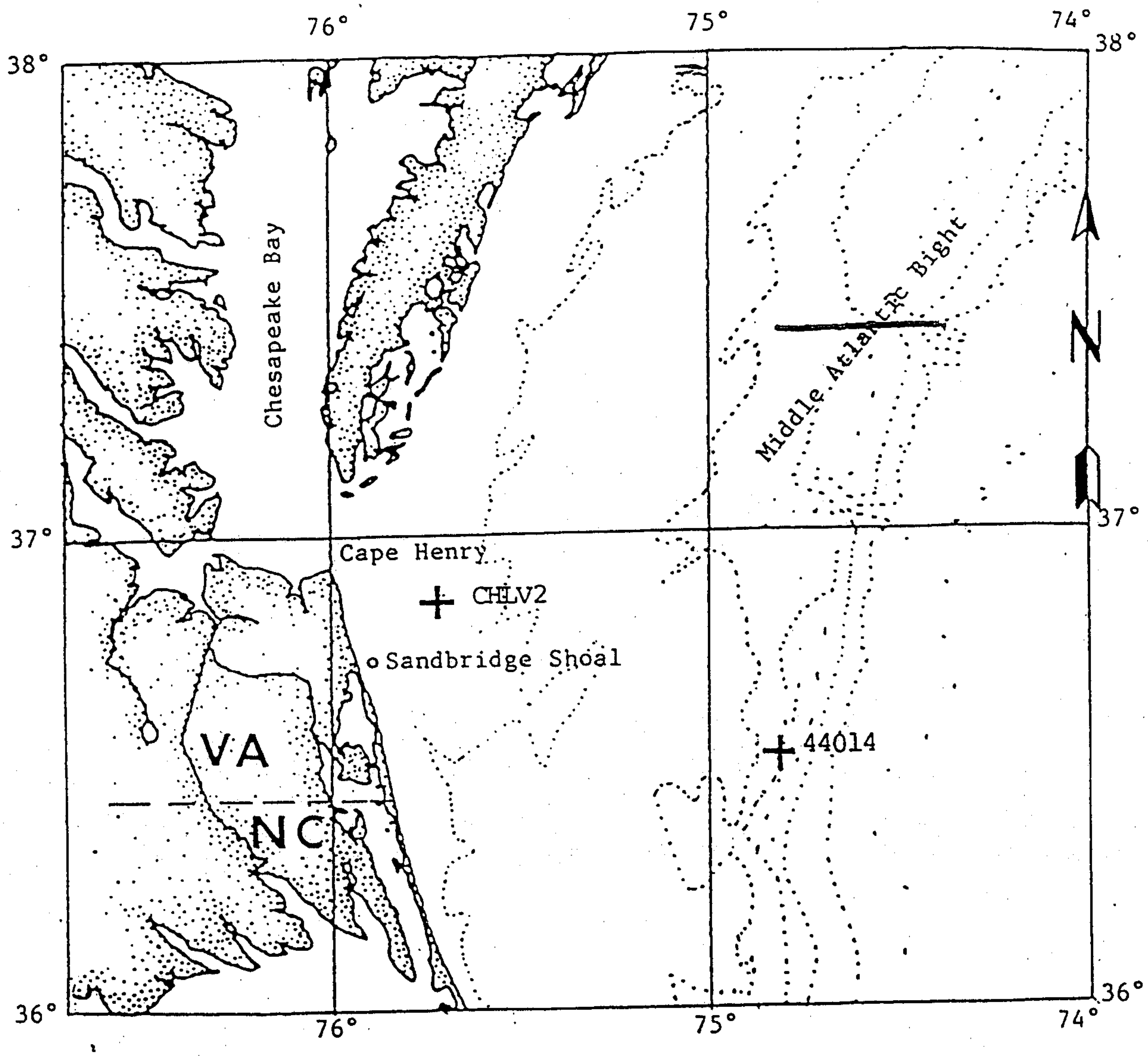


Fig. 1. Location Map of Wave Stations and Study Area

erosion at Sandbridge due to alternation of wave transformation process. To understand the possible change of shoreline due to dredging at the shoal requires a comprehensive understanding of the wave climate, the wave transformation process, and the associate shoreline responses.

From other studies of wave transformation (e.g., Berkhoff et al. 1982), we understand that a shoal may functional as a convex lens that tends to converge wave energy and cause more beach erosion. The degree of convergence, however, depends on the size, shape, and location of a shoal as well as the wave conditions. Thus, we proposed to do a basic statistical analysis of the wave climate using nearly seven years (from Feb. 1985 to Dec. 1992) wave records from a nearby wave station CHLV2 and 1.6 years wave records from another station 44014. We also proposed to examine the possible effects of dredging at Sandbridge Shoal on the wave transformation process and associated impact on the nearby shoreline stability. The followings are results from this study.

WAVE STATISTICS

Data Sources

The National Data Buoy Center (NDBC) has 16 stations located along the east coast of the United States (Wang and Mettlach 1992). There are two wave stations off the Virginia coast: A moored buoy station, 44014 (sponsored by the U.S. Army, Coastal Engineering Research Center), located near the continental shelf break with water depth of 48 m (Latitude 36°34'59", Longitude

74°50'01"), and a Coastal-Marine Automated Network (C-MAN) station, CHLV2, located on a shoal approximately 25 km east of the Chesapeake Bay mouth (Latitude 36°54'18", Longitude 75°42'48") with water depth of 12 m. Around the shoal, the ambient water depth is about 20 m. Fig. 1 shows the locations of these two stations.

The wave measurement system at station 44014 used accelerometer to record the buoy's heave, pitch, and roll motions. A NDBC onboard Wave Data Analyzer computed the wave spectral information from the time series of buoy motion and transmitted the results to the Stennis Space Center in Mississippi for further analysis and quality assurance. This station also provided wave directional information by using the approach proposed by Longguet-Higgins et al. (1963).

Wave measurements at station CHLV2 were carried out with the Infrared Laser Wave Height Sensor, which measured the surface displacement. The overall accuracy of all systems for significant wave height, wave period, and wave direction is 0.2 m (or 5%), 1.0 s., and ±5°, respectively (Meindl and Hamilton 1992). Details of the NDBC wave measurement system and data processing technique can be found in Steele et al. (1990). All processed data were achieved in National Oceanic Data Center (NODC) in Washington, D.C. using a special ASCII format. These data were stored in CD-ROM and are easily retrieved.

We developed computer software to analyze the data and stored the basic information such as date, time, significant wave heights, zero cross periods, peak energy wave periods, and wave spectrum information into separate disk files for later uses.

Statistical Analysis

We studied the joint distribution of significant wave height and peak energy wave period for the two stations. Because of the short record duration at station 44014 and far away from the project site, we could not use the statistics of wave height and period from that station. We used the wave direction information from station 44014 only for guidance.

Figure 2 shows the joint distribution of significant wave height and peak energy period at station CHLV2. Unfortunately, we have to point that data from station CHLV2 are not available for 1993 and 1994 because of instrument and data quality problems. The available information indicates that the most frequent wave has a wave height of 0.7 meter and wave period of 9 seconds. Notice that there is a lot of swell (small wave heights with long wave period) at this station. The same data are also displayed in Table 1. To understand the distribution of recorded significant wave height and peak energy period, we plot the last row and last column data from Table 1 to show the relative abundance of each wave height and period. Fig. 3 shows the results. Based on this diagram, we can determine the design waves for fair weather and northeaster storm wave conditions.

We do not have a long enough wave record to accurately estimate the most severe hurricane wave condition for a return

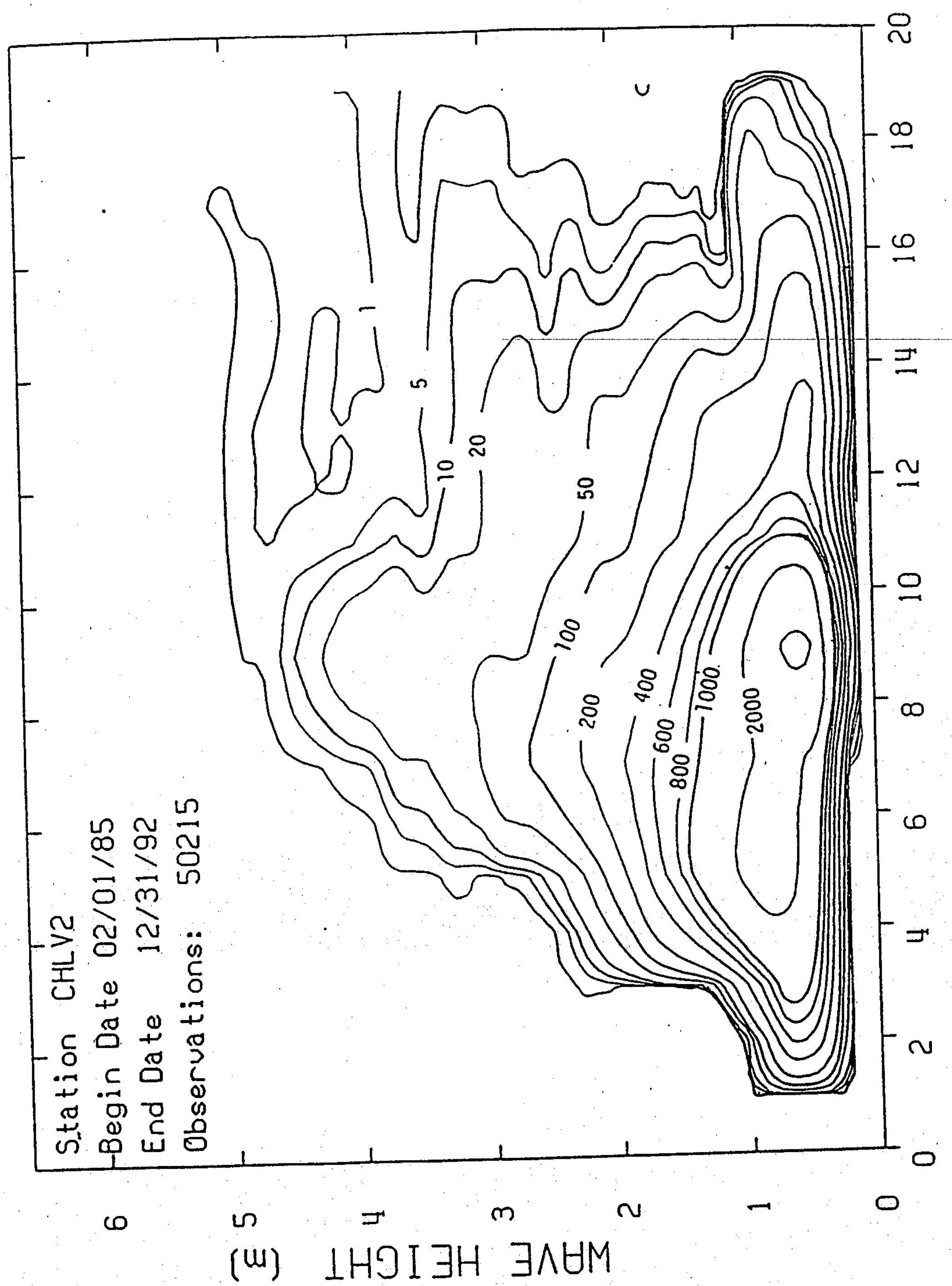


Fig. 2. Joint Distribution of Significant Wave Height and Peak Energy Wave Period at Station CHLV2. Contours are in number of occurrence.

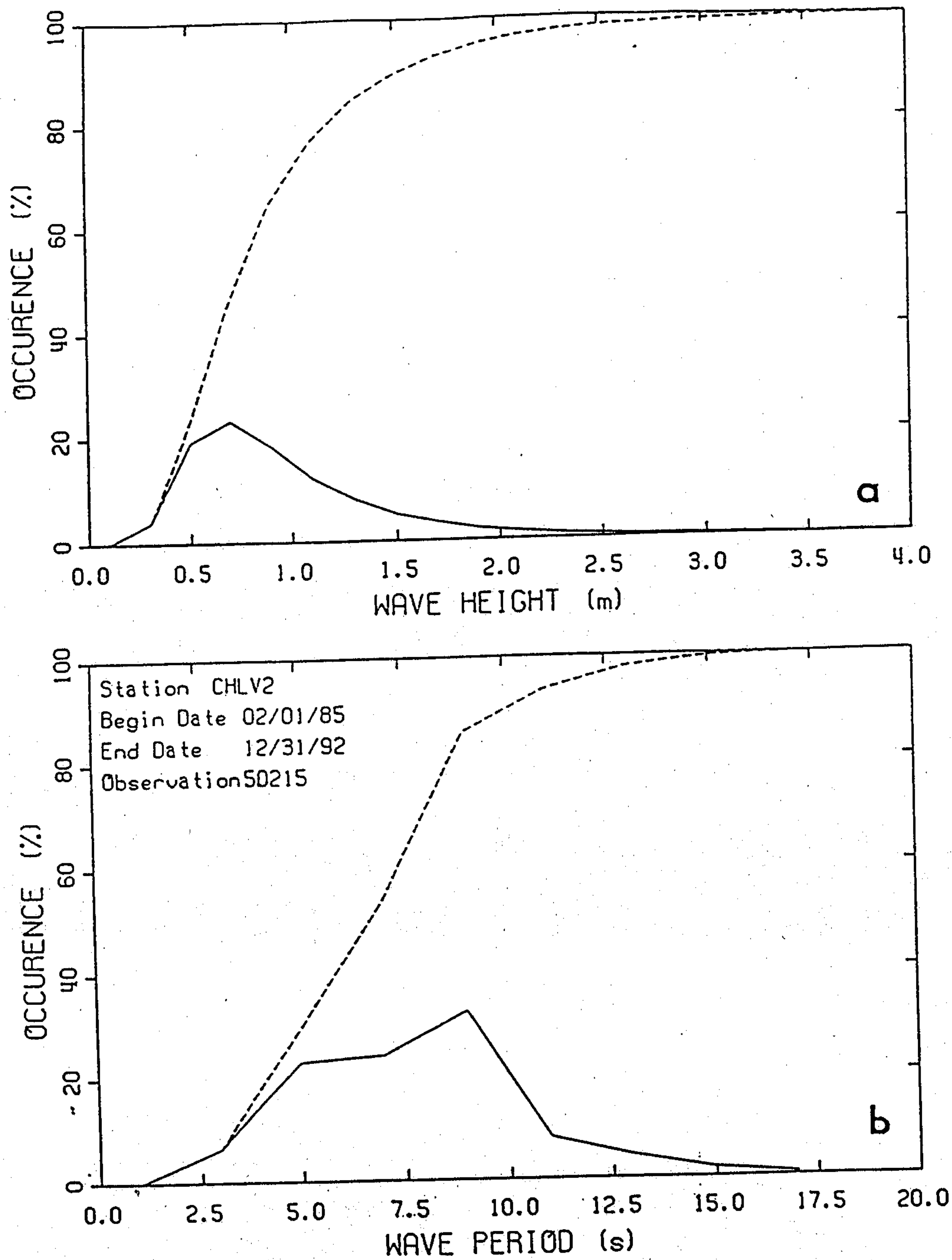


Fig. 3. The percentage of occurrence for (a) Wave Period of Peak Energy and (b) Significant Wave Height at CHLV2. The Dashed Lines are Accumulated Occurrence.

Table 1. Joint distribution of Significant Wave Height and Peak Wave Energy Period at Wave station CHLV2.

Start date = 02/01/85
End date = 12/31/92
Total observations = 50215

Wave H_1/3 (m)	Wave peak-energy period (s) 0 2	 2 4	 4 6	 6 8	 8 10	 10 12	 12 14	 14 16	 16 18	 18 20	Sum
0.0-0.2:	0	4	0	1	4	1	0	0	0	0	: 10
0.2-0.4:	0	115	166	314	1013	160	123	70	14	0	: 975
0.4-0.6:	0	886	1286	1774	4064	769	477	262	57	1	: 9576
0.6-0.8:	0	1218	2320	2387	4132	910	356	213	63	13	:11612
0.8-1.0:	0	694	2595	2116	2677	650	282	78	87	2	: 9181
1.0-1.2:	0	262	1961	1593	1490	469	225	28	5	0	: 6033
1.2-1.4:	0	39	1371	1125	885	326	203	45	1	0	: 3995
1.4-1.6:	0	7	840	759	569	191	133	34	1	0	: 2534
1.6-1.8:	0	2	515	610	350	143	86	29	1	1	: 1737
1.8-2.0:	0	0	237	434	222	86	62	14	0	0	: 1055
2.0-2.2:	0	1	111	281	185	77	62	11	0	0	: 728
2.2-2.4:	0	1	47	197	130	47	27	15	3	0	: 467
2.4-2.6:	0	0	18	139	93	29	22	7	2	0	: 310
2.6-2.8:	0	0	6	99	49	22	33	16	2	0	: 227
2.8-3.0:	0	0	1	92	48	31	28	12	6	0	: 218
3.0-3.2:	0	0	0	46	49	17	16	12	5	0	: 145
3.2-3.4:	0	0	2	32	39	16	8	8	6	0	: 111
3.4-3.6:	0	0	0	19	35	6	5	3	0	0	: 68
3.6-3.8:	0	0	0	17	49	11	1	3	2	2	: 85
3.8-4.0:	0	0	0	6	37	7	2	0	1	1	: 54
4.0-4.2:	0	0	0	3	31	4	1	1	0	1	: 41
4.2-4.4:	0	0	0	1	19	2	2	1	0	0	: 25
4.4-4.6:	0	0	0	0	10	2	0	0	0	0	: 12
4.6-4.8:	0	0	0	0	2	1	0	3	0	0	: 6
4.8-5.0:	0	0	0	0	1	2	2	1	1	0	: 7
5.0-5.2:	0	0	0	0	0	0	0	0	1	0	: 1
5.2-5.4:	0	0	0	0	0	0	0	0	0	0	: 0
5.4-5.6:	0	0	0	0	0	0	0	0	0	0	: 0
5.6-5.8:	0	0	0	0	0	0	0	0	0	0	: 0
5.8-6.0:	0	0	0	0	0	0	0	0	1	0	: 1
6.0-6.2:	0	0	0	0	0	0	0	0	0	0	: 0
6.2-6.4:	0	0	0	0	0	0	0	0	0	1	: 1
6.4-6.6:	0	0	0	0	0	0	0	0	0	0	: 0
6.6-6.8:	0	0	0	0	0	0	0	0	0	0	: 0
SUM	0	3229	11476	12045	16183	3979	2156	866	259	22	

period of 20 years or more. Table 2 shows the maximum significant wave heights that occurred during each of the 7 years. The recorded maximum significant wave height (6.2 m with a peak wave period of 20 seconds, occurred on 9/27/85) probably qualifies as the most severe storm wave.

Table 2

Date	Time	H_significant (m)	T_Peak (sec)
9/27/85	10:00	6.2	20
12/02/86	21:00	4.2	10
3/10/87	15:00	4.5	10
2/19/88	20:00	3.3	5.6
2/24/89	22:00	4.9	12.5
10/26/90	17:00	4.0	10
11/10/91	03:00	4.6	10
1/04/92	11:00	4.9	14.3

<u>Model Waves</u>

Based on the measurements at station CHLV2, Table 3 shows the total hours (and percentage) in each year that the measured wave height exceeded 2 and 3 m.

Table 3

Year	Hours (percentage) that H_sign >=2.0m	>=3.0m
85	350 (4.0%)	34 (0.4%)
86	229 (2.6%)	55 (0.6%)
87	341 (3.9%)	73 (0.8%)
88	129 (1.5%)	4 (0.0%)
89	568 (6.5%)	166 (1.9%)
90	216 (2.5%)	20 (0.2%)
91	510 (5.8%)	118 (1.3%)
92	542 (6.2%)	150 (1.7%)
average	2885 (4.1%)	77 (0.9%)

This table indicates an average about 5% of the total time in each year that the wave height exceeds 2 m. The percentage decreases to only about 1% if the selected wave height is 3 m.

Table 4

Year	Hours (percentage) that T_peak >=12 s	>=14 s
85	483 (5.5%)	262 (3.0%)
86	406 (4.6%)	173 (2.0%)
87	254 (2.9%)	14 (0.2%)
88	254 (2.9%)	89 (1.0%)
89	331 (3.8%)	114 (1.3%)
90	581 (6.6%)	184 (2.1%)
91	1069 (12.2%)	116 (1.3%)
92	506 (5.8%)	195 (2.2%)
average	485 (5.5%)	143 (1.5%)

Table 4 indicates an average about 5% of the total time in each year that the wave period exceeds 12 s. This ratio also decreases to about 1% if the selected wave period is 14 s.

From Fig. 3a, we can identify that a significant wave height of 1.9 m exceeds 95% of the observations (50215 records), and thus may be selected to represent the Northeast storm wave condition. From Fig. 3b, we found the corresponding wave period (11.8 s) that also exceeds 95% of the observed wave periods. This selection is very close to that given in Table 3 and 4.

If we select a representative wave that occurred only 1% of the total time in a year, a wave height of 3 m and period of 14 sec. can be picked from Fig. 3. This result also is close to that shown in Tables 3 and 4. This wave condition can be classified as a severe sea which occurred only 1% (88 hours) of the total time in one year.

For the fair weather condition, we selected a significant wave height of 0.72 m as 50% of the total observed wave heights are less than this value. The corresponding wave period is 6.7 seconds. Table 5 shows all the four wave conditions.

Table 5

Wave Height (m)	Wave Period (sec)	Remark
6.2	20	Most severe sea
3.0	14	Severe sea
1.9	12	Northeaster
0.72	6.7	Fair weather wave

Wave Direction

Although we have the above stated wave height and period information, we do not have the direction information because the measurement system at station CHLV2 is not capable of measuring wave direction. From the wave measurements at station 44014, however, a best estimation can be made.

Figs. 4 and 5 show the wave height and wave period roses for station 44014. The orientation of the coastal line at Sandbridge is also plotted as a reference. The wave height rose indicates that wave height's directional distribution is relatively uniform from SSE to NNE, and the most common wave direction is ESE. The waves coming from NNE to ENE are mainly large waves caused by Northeasters. Their wave period, however, are not long except the ENE direction. Most of the waves in

NNE and NE are less than 8 sec. Long period waves are mainly came from ENE and E because of the long fetch length. Thus, waves coming from ENE are most important because of the possible large wave height and long wave period. Waves coming from SSE to ESE directions could have all kind of wave heights, but their wave periods were rather short. Considering the water depth at Sandbridge Shoal is more than 10 meter, it's influence to short period waves is minimal and may be ignored.

Notice that the wave height and period distributions at station 44014 are mainly from ESE with a large spread from S and N. Waves from the other side are negligible because of the limited fetch. When closer to the Virginia coast at station CHLV2, we can assumed that waves are more concentrated in ESE direction. As indicated before, however, waves coming from ESE are mainly short period waves. We need to concentrate on large waves that have a longer wave period. For this reason, we selected ENE as the main direction of the threatening waves. The next two important directions are E and NE. At Sandbridge, the shore normal direction is 73 degrees (counted clockwise from true north). For waves coming from this direction, however, we referred as waves go toward 253 degrees from true north. This direction is only 5.5 degrees different from ENE. Considering the accuracy of wave direction measurement is ±5 degrees, there is almost no difference between ENE and 73 degrees. For convenience, we selected the shore normal direction as the main direction for the threatening waves. The next two important wave directions are 53 and 93 degrees from true north, or moving toward 233 and 273 degrees. In the wave modeling study below, the wave directions given are the direction that waves are traveling toward.

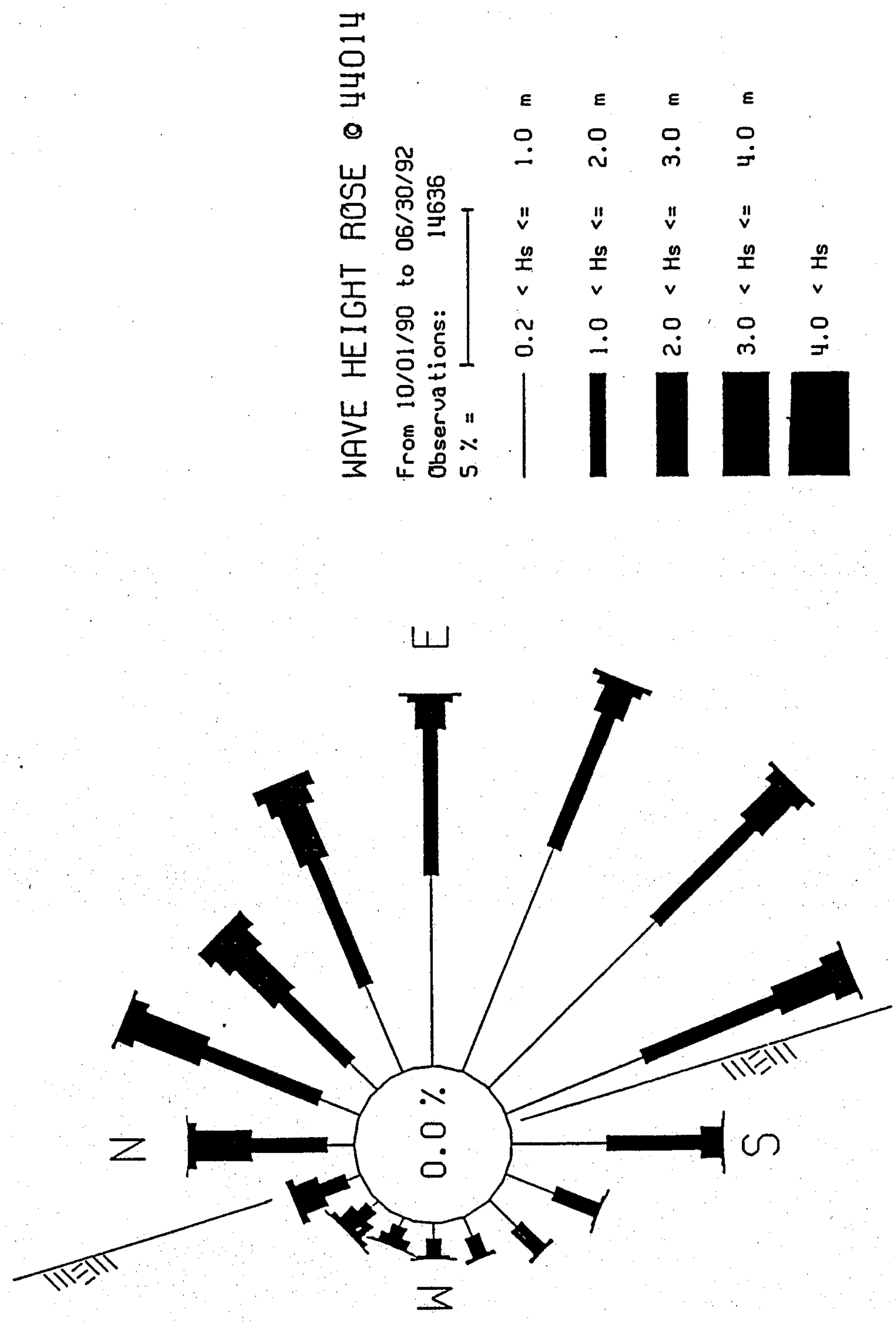


Fig. 4. Wave Height Rose from Station 44014. The scale of 5% occurrence is plotted in the legend.

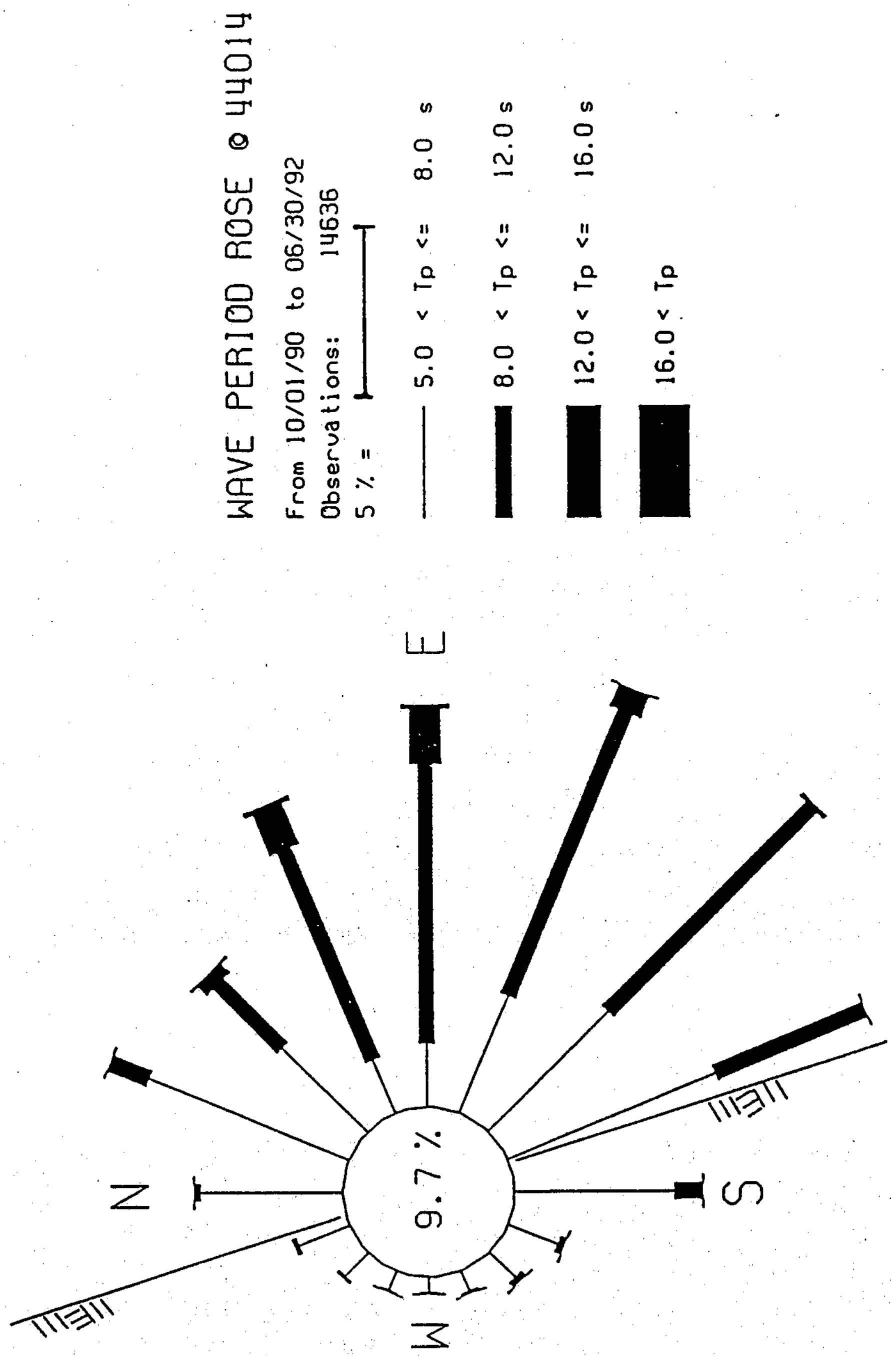


Fig. 5. Wave Period Rose from Station 44014. The scale of 5% occurrence is plotted in the legend.

POSSIBLE PHYSICAL IMPACT ON WAVE TRANSFORMATION

Wave rays tend to concentrate at the lee side of a shoal because of the wave refraction and diffraction processes. A typical example of these two processes can be found from Berkhoff el al.'s (1982) laboratory experiment, see Fig. 6. The concentration of wave rays means wave energy is higher and may cause severe beach erosion if the shoal is close to the beach. Because of the size, shape, and location of Sandbridge Shoal, the response of wave transformation may not be as clear as that shown in Berkhoff et al.'s experiment. We may assume, however, the dredging would reduce the wave convergence because the shoal could be flattened. However, the actual responses need to be studied carefully. First, we need to examine the wave transformation process for the existing bathymetry and the associated longshore sediment transport. Then we will assume the bathymetry is changed by dredging and do the same exercises again. Notice that examining all possible waves is not necessary because only the severe sea with a longer wave period may be affected by the dredging at Sandbridge Shoal which is located in a relatively deep water, 10 m. For this reason, the selected fair-weather wave condition will not be examined. Only the northeaster, the severe sea, and the most severe sea conditions will be examined with and without dredging.

Bathymetric Data

The first step in analyzing the wave transformation processes is to obtain accurate bathymetric data. We obtained all available digital bathymetric data for this area from NOAA Data Center. After examining

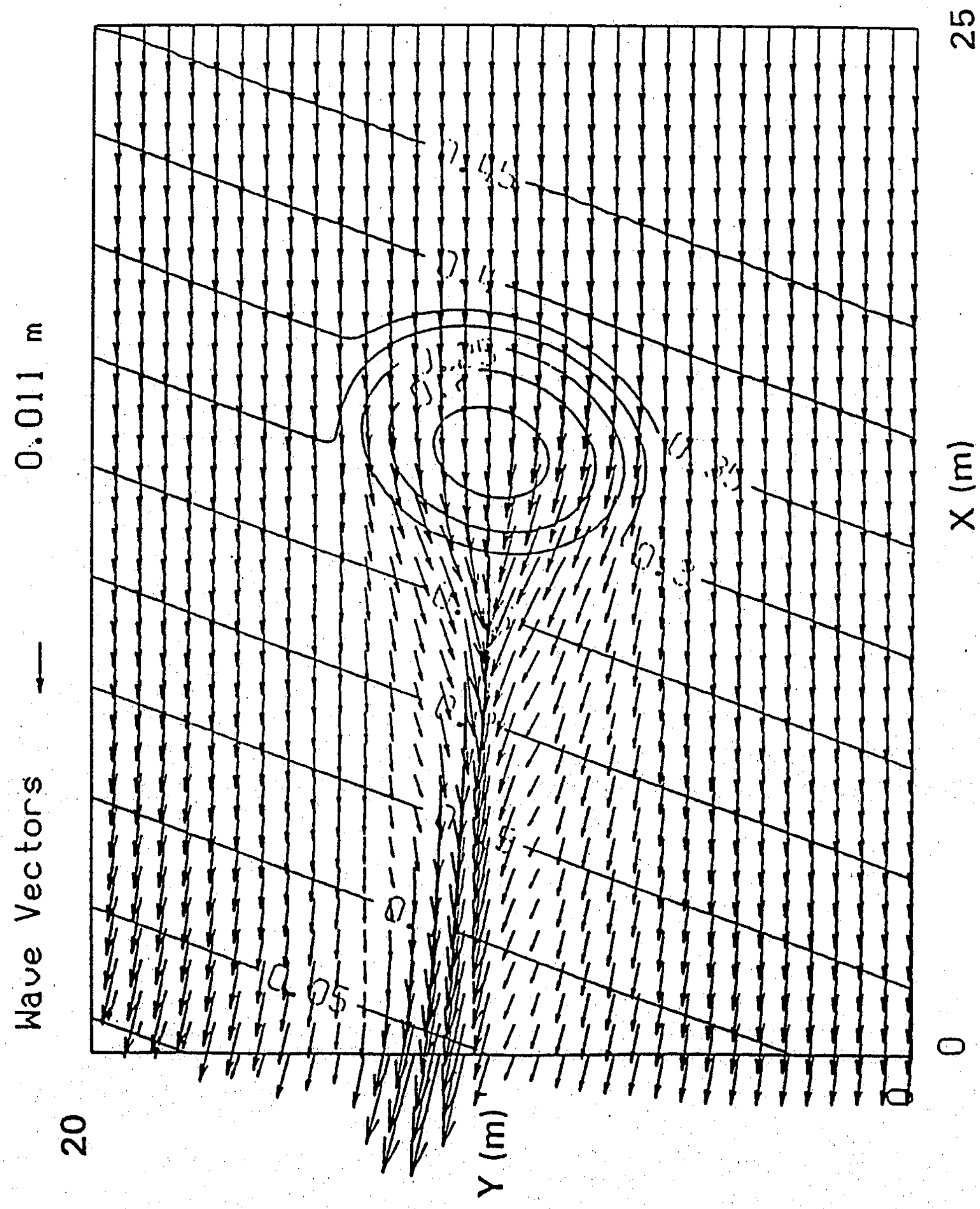


Fig. 6. Berkhoff's (1982) Laboratory Experiment Shows the Wave Energy Concentrated after an Elliptic shoal. Waves coming from top with 1 s. period, the shoal is located at x=15 m and y = 10 m. The depth contours are also plotted

these data, we found several small areas for which digital data are not available. Fortunately, we were able to obtain original survey charts, digitized them, and converted the digitized data to NOAA format for further processing.

After we collected sufficient digital data to cover the study area, we developed a computer program to convert these randomly spaced data into regularly spaced data that are suitable for a wave refraction and diffraction model. We need a large enough spatial domain and a small enough grid size to analyze wave transformation process. Fig. 7 shows the bathymetry within the entire grid system. The size of each cell for this grid is 30 m in the x direction and 60 m in the y direction, respectively. In Fig. 7, the small subarea enclosed by dashed line is replotted in Fig. 8a to show the detail water depth contours at the vicinity of Sandbridge Shoal. In Fig. 8a, the proposed dredging area was identified by a dashed rectangular with 500 m wide and 1500 m long. The coordinates for the lower-right corner of the rectangular are x = 5.08 km and y = 10.335 km. The water depth within this rectangular are at least shallow than 11 meters, with some place are shallow than 9 m. The proposed dredge would be a uniform two meters in this rectangular. After dredging, the possible water depth contours are displayed as Fig. 8b. It can be seen that the original two 10-meter contour lines was replaced by one much smaller 10 m contour line, which may be targeted for next stage dredging.

Wave Refraction and Diffraction Models

There are two numerical models available at VIMS for simulating wave refraction and diffraction. They are RCPWAVE and REFDIF-1. The first one was developed by Ebersole (1985) and the second one was developed by Kirby and Dalrymple (1991). Both models solve the mild slope equation given by Berkhoff (1972). The differences are the computing algorithm and some enhancements. These two models both have some advantages and disadvantages. It is out of scope of this study to discuss which model is the better one. Our objective is to employ a model and examine the possible difference caused by the dredge at Sandbridge shoal. We chose RCPWAVE model because of the following two reasons: (1) It considered wave energy loss caused by bottom friction, which is important for estimating breaking wave height when there is a long wave travel distance, about 10 km; (2) We already have all the computer codes for analyzing RCPWAVE output files to study longshore sediment transport.

Wave Pattern for the Original Bathymetry

Although we have emphasized four wave conditions, the fair-weather waves are not important. It has been demonstrated in our early study that Sandbridge shoal will not affect waves with a period shorter than 9 seconds.

For the other three wave conditions (the most severe sea, the severe sea, and the northeaster wave), we ran the RCPWAVE model with six possible wave directions; 223, 233, 233, 253, 263, and 273 degrees. Again these angles are the directions that wave trains move toward.

Figures 9a, b, and c show the calculated wave rays for the Northeaster waves coming from NE, ENE, and E directions, respectively.

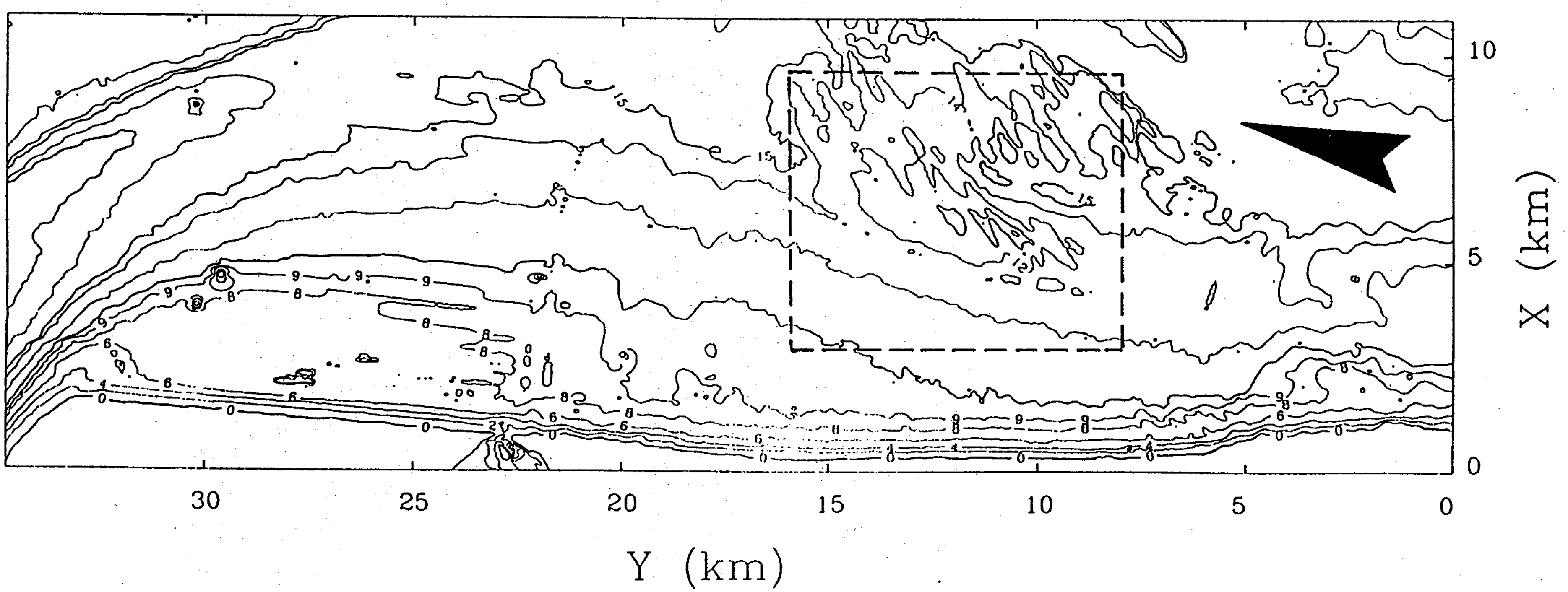
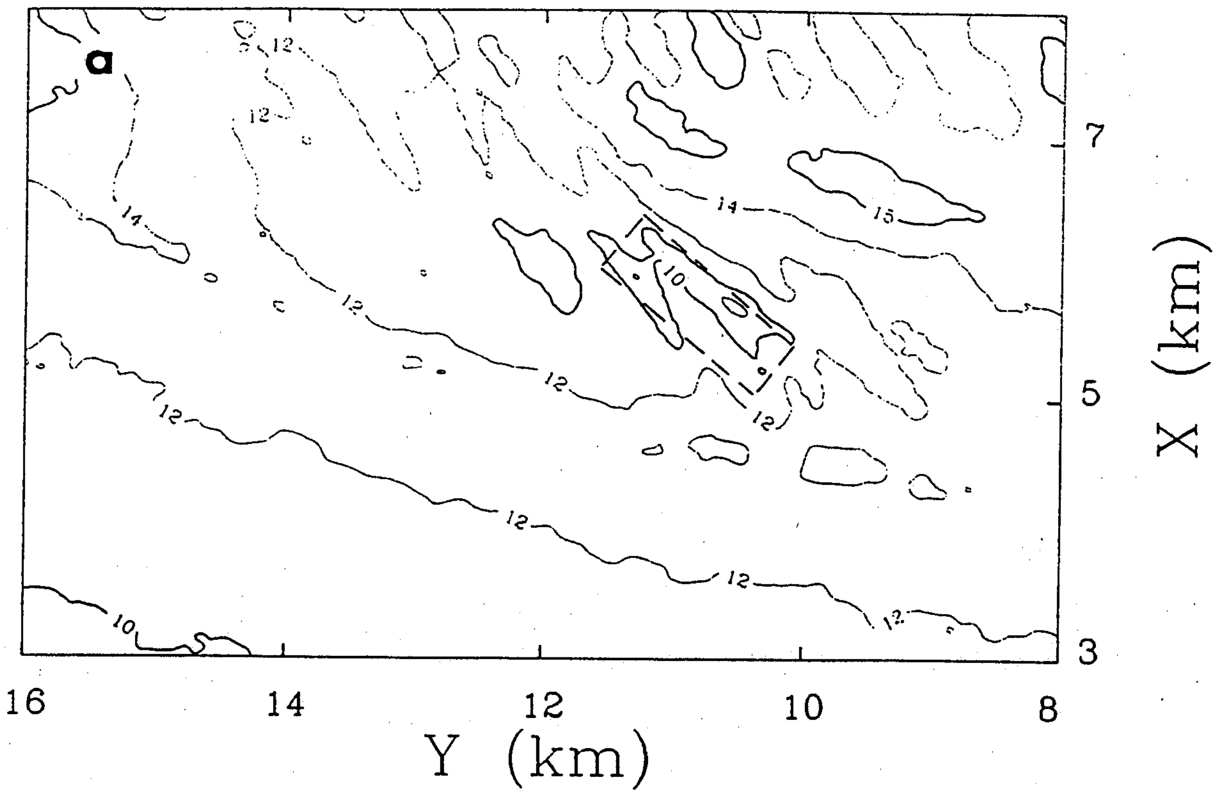


Fig. 7. Water Depth Contours for the Entire Study Domain. The area with the dashed box will be replotted in Fig. 8.



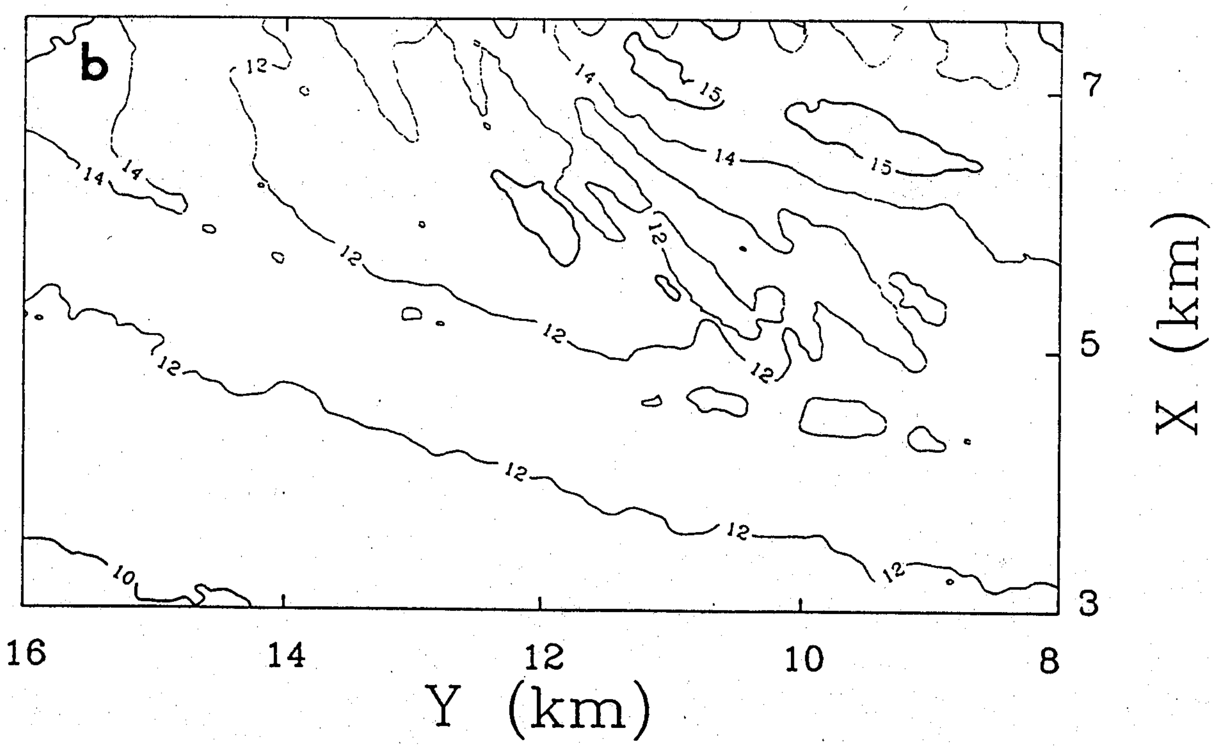


Fig. 8. Detail Bathymetry at the Vicinity of Sandbridge Shoal. (a) Original with the proposed dredging area enclosed by a dashed rectangular; (b) After Dredging.

Only the section from y = 5 to 20 km are presented here for a clear view. Figures 10 and 11 show similar plots for the severe sea and the most severe sea that waves coming from NE, ENE, and E directions, respectively. In general, waves tend to converge around the coast section near Sandbridge without regard to the wave directions. As waves are higher in the zone of convergence, this might explain the severe beach erosion at Sandbridge. Notice that as the wave period decreases, the wave ray convergence also decreases.

Among the six important directions, the most severe sea with waves come from NE direction (waves go toward 223 degrees) has the most convergence at the coastal section of Sandbridge. That is why we see a large breaking wave height near Sandbridge (see Fig. 15). This trend holds for the other two wave periods (12 and 14 sec.), but the rate of convergence decreases as the wave period decreases.

Wave Pattern after dredging

As has been discussed, wave convergence after an offshore shoal is expected because of wave refraction. The offshore shoal studied here roughly covers a 5 km x 10 km area. The effect of wave refraction caused by the targeted dredge area (about 0.5 km x 1.5 km), however, seems not significant. This can be seen by observing that wave rays do not have a significant convergence or divergence at or after the targeted dredge area.

Examples of the plot of wave rays for the most severe sea coming from NE, ENE, and E directions for the case that dredging has been completed are given in Fig. 12. This diagram depicts only a minor change of wave rays after dredging. To further clarify the changes in breaking wave height and breaking wave angle before and after dredging, they were plotted in Figs. 13, 14, and 15 for all the important wave directions along this section of the Virginia coast, y = 5 to 20 km. The proposed dredge area is located approximately between y = 10 to 12 km. The solid line in these figure represents the breaking wave height or breaking angle before dredging, and the dashed line represents the same parameter after dredging.

From Fig. 13 (the Northeaster waves), it can be seen clearly that the maximum breaking wave height does not changed along this section of the Virginia coast. Their locations and breaking angles do change a little.

For the severe sea, see Fig. 14, waves coming from the NE seem not affected by the dredging. Although the breaking wave angles changed a little, the maximum breaking wave height does not change. Waves coming from ENE and E are affected a little by the dredging, i.e., their maximum breaking wave height increases from 3.37 m to 3.45 m, about a 2% increase.

For the most severe sea, except for the normally incident waves (waves going to 253 degrees), waves come from all other directions are affected a little, see Fig. 15. The change of maximum breaking wave height varies with the direction, i.e.,

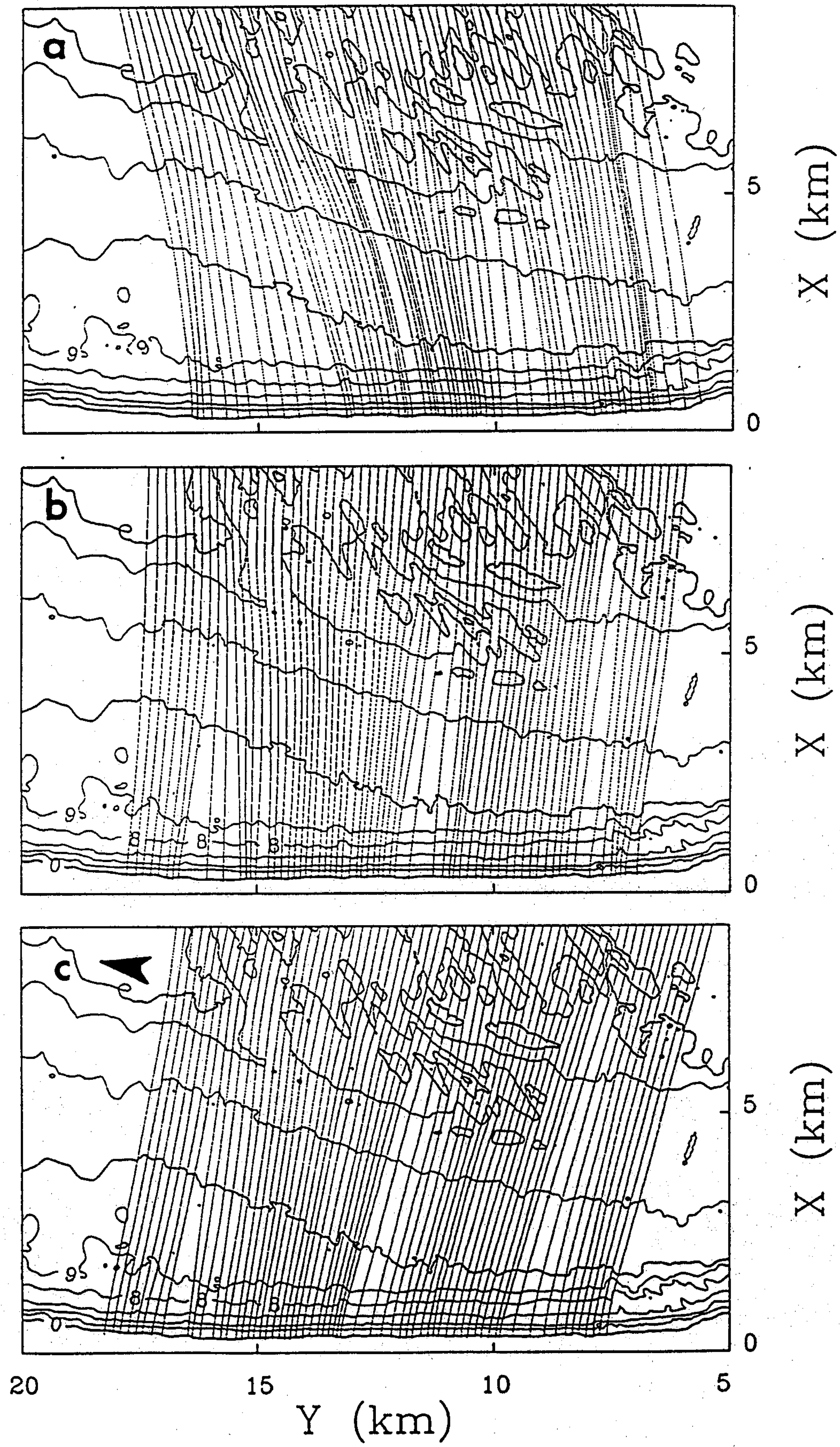


Fig. 9. Wave Rays for the Northeaster (H=1.9 m, T=12 s, original bathymetry) that comes from (a) NE; (a) ENE; and (b) E.

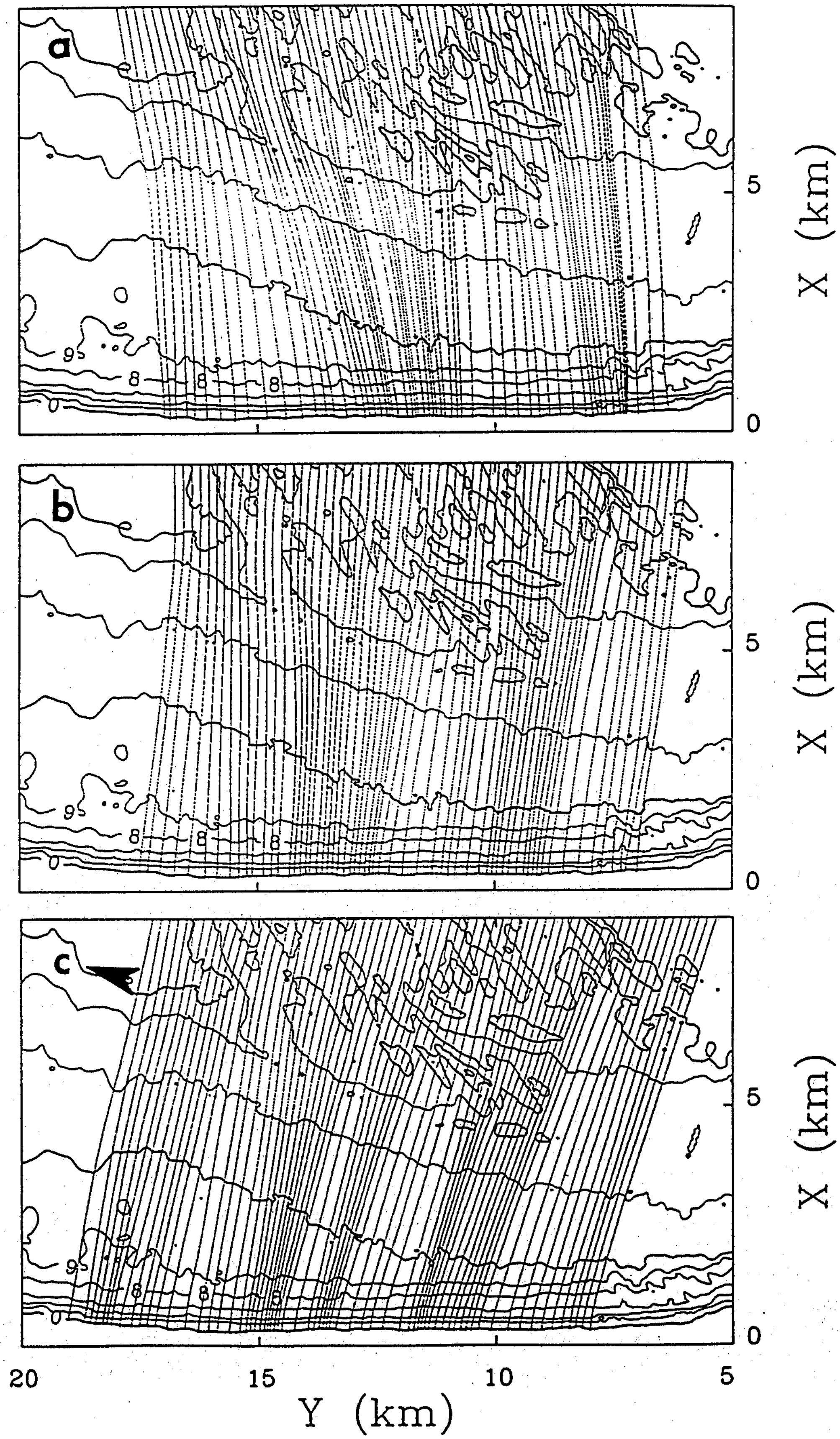


Fig. 10. Wave Rays for the Severe Sea (H=3 m, T=14 s, original bathymetry) that comes from (a) NE; (a) ENE; and (b) E.

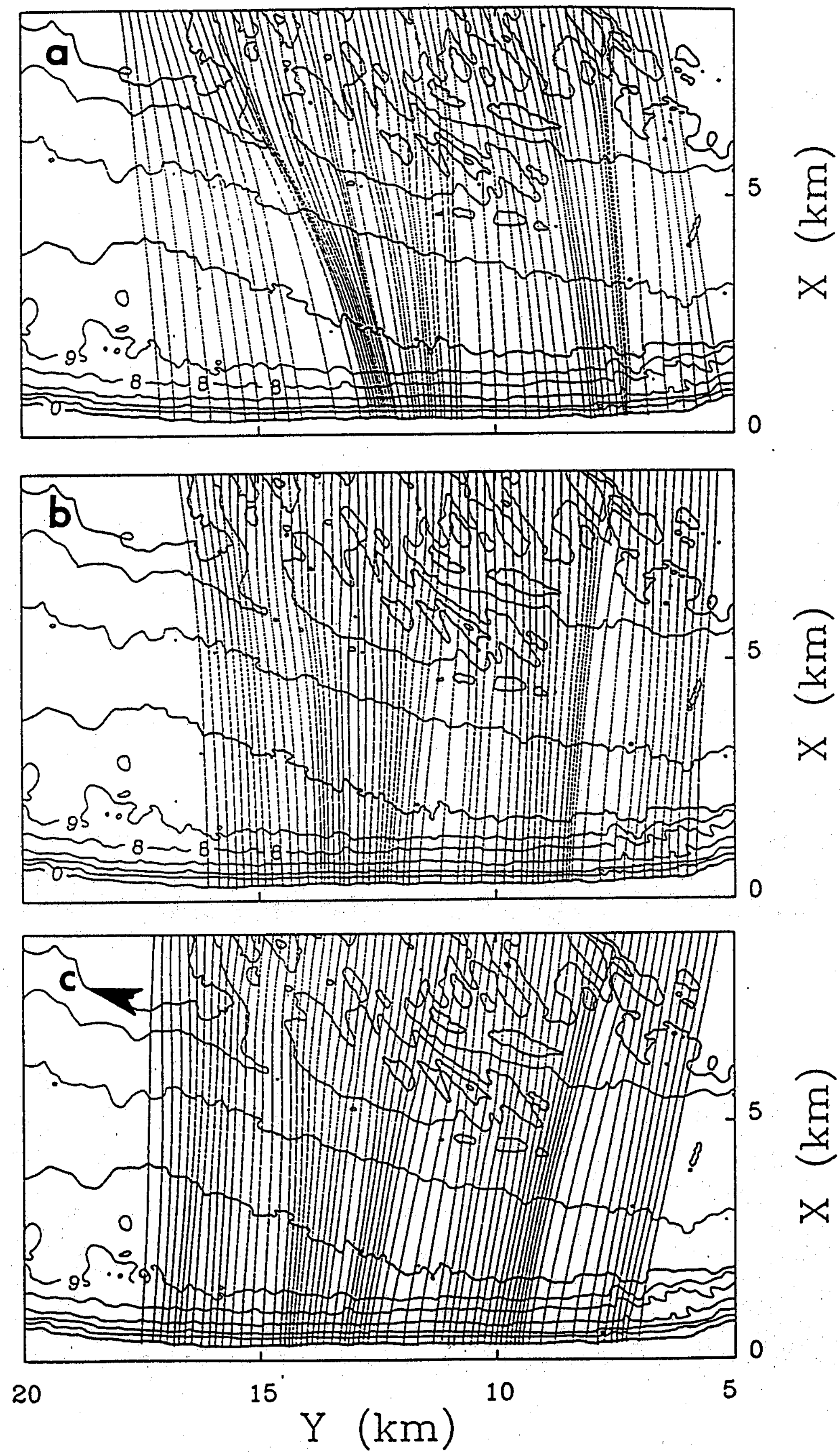


Fig. 11. Wave Rays for the Most Severe Sea (H=6.2 m, T=20 s, original bathymetry) that comes from (a) NE; (a) ENE; and (b) E.

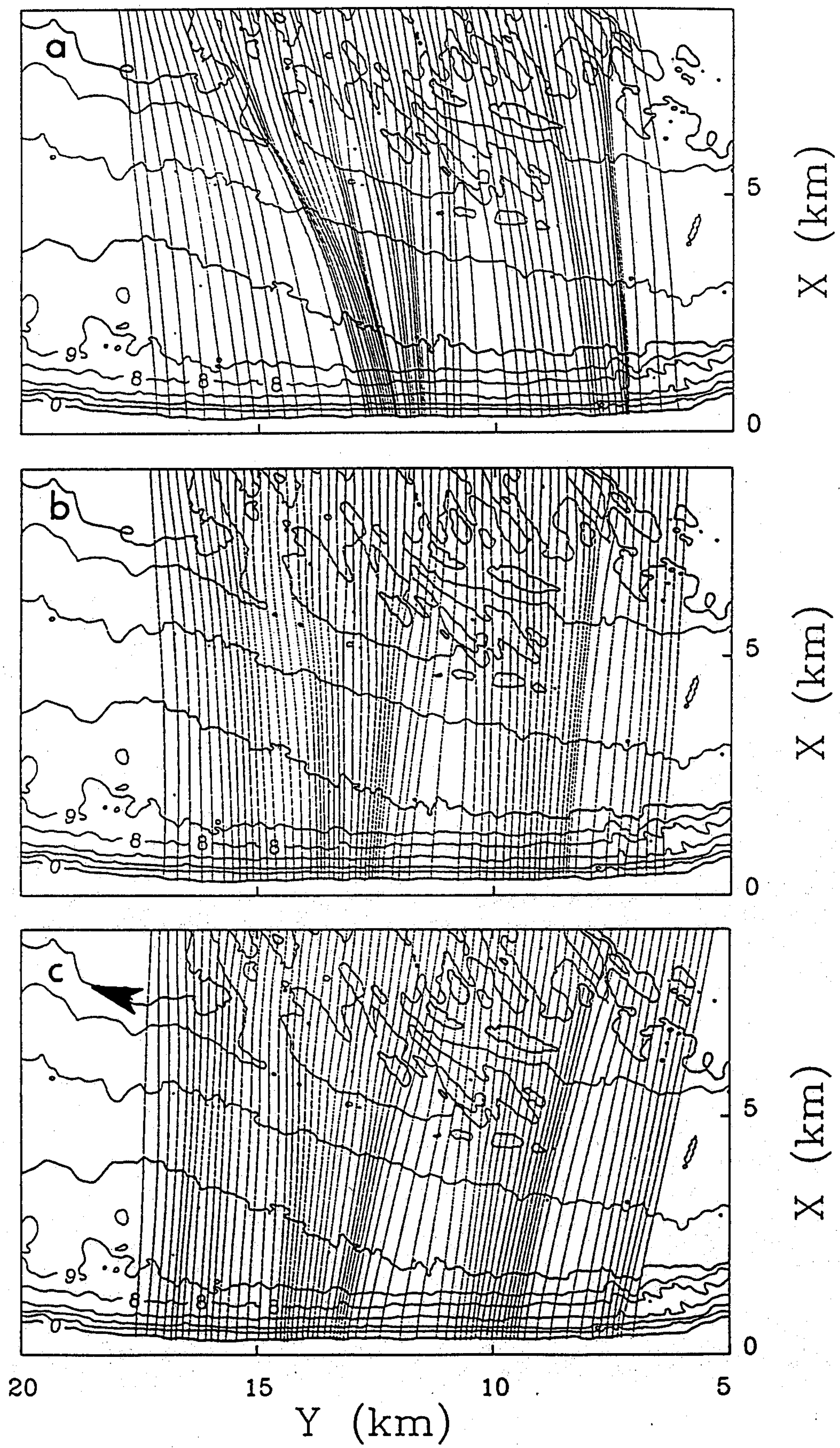


Fig. 12. Wave Rays for the Most Severe Sea (H=6.2 m, T=20 s, after dredging) that comes from (a) NE; (a) ENE; and (b) E.

from 2% to 7%. Notice that, however, the maximum change is only 7% for the waves going toward 233 degrees.

It is worth mentioning that the overall accuracy of NOAA's wave height measurement is 5%. Our calculation indicates that the proposed dredging at Sandbridge shoal may only cause a change of 2 - 7% on the breaking wave height. This is an indication that the effect of proposed dredge on wave transformation is insignificant. Thus, we may expect that the longshore sediment transport process will not be affected significantly either. The following are a further verification of this conclusion.

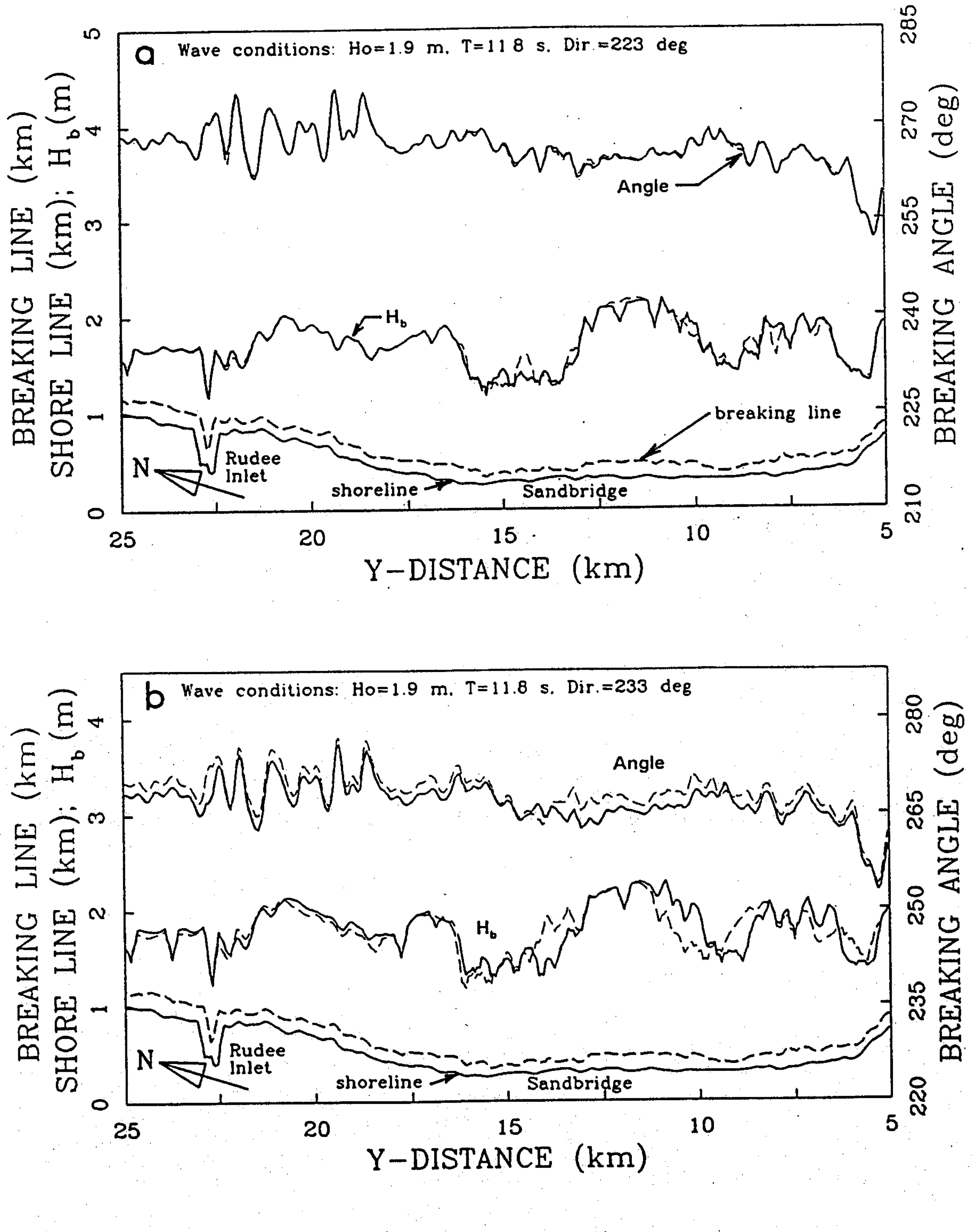


Fig. 13. Comparison of the Breaking Wave Heights, Breaking Angles, Breaking Locations for the Northeaster. Solid lines are before dredging, Dashed lines are after dredging.

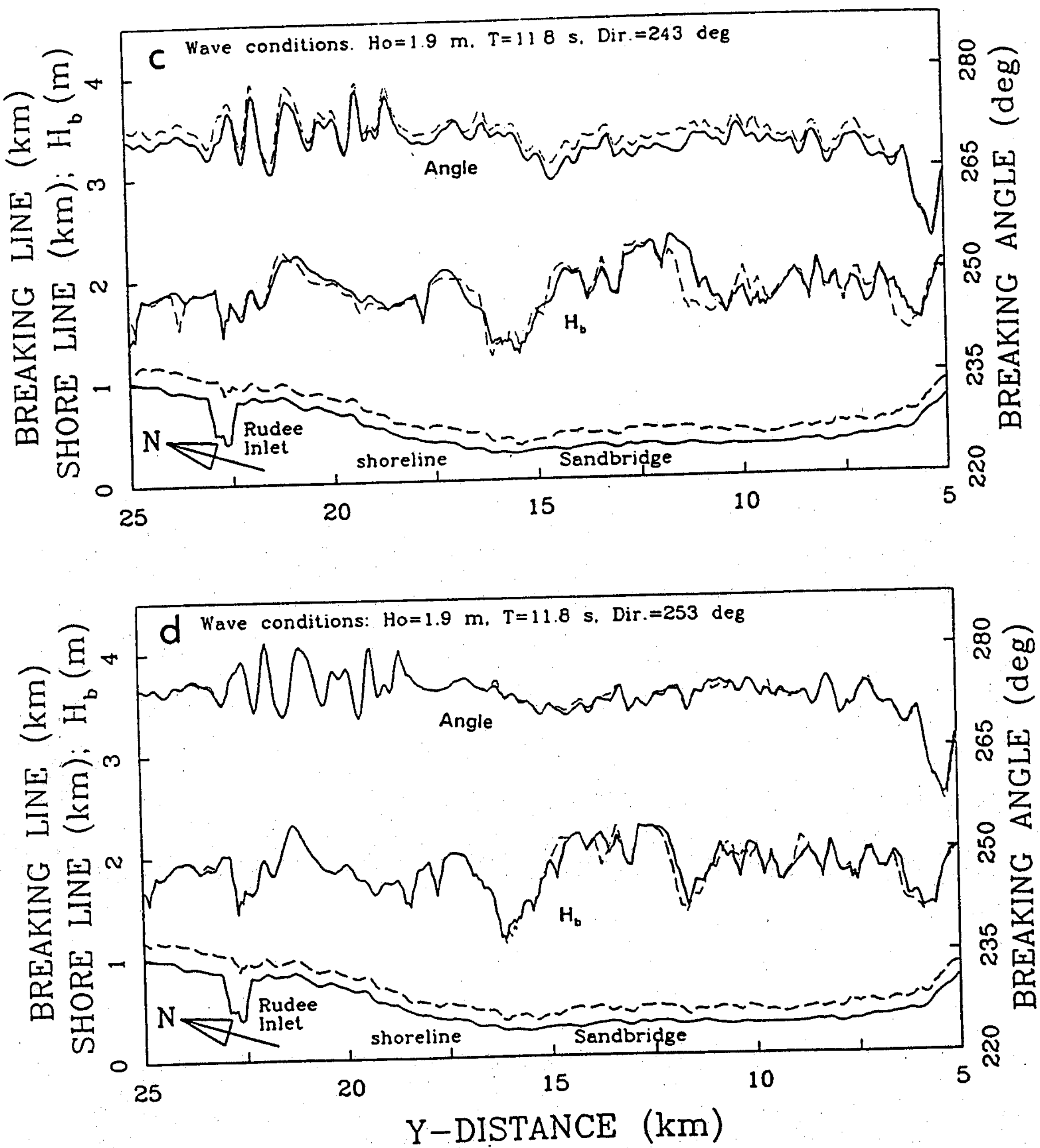


Fig. 13. (continue) Comparison of the Breaking Wave Heights, Breaking Wave Angles, Breaking Locations for the Northeaster.

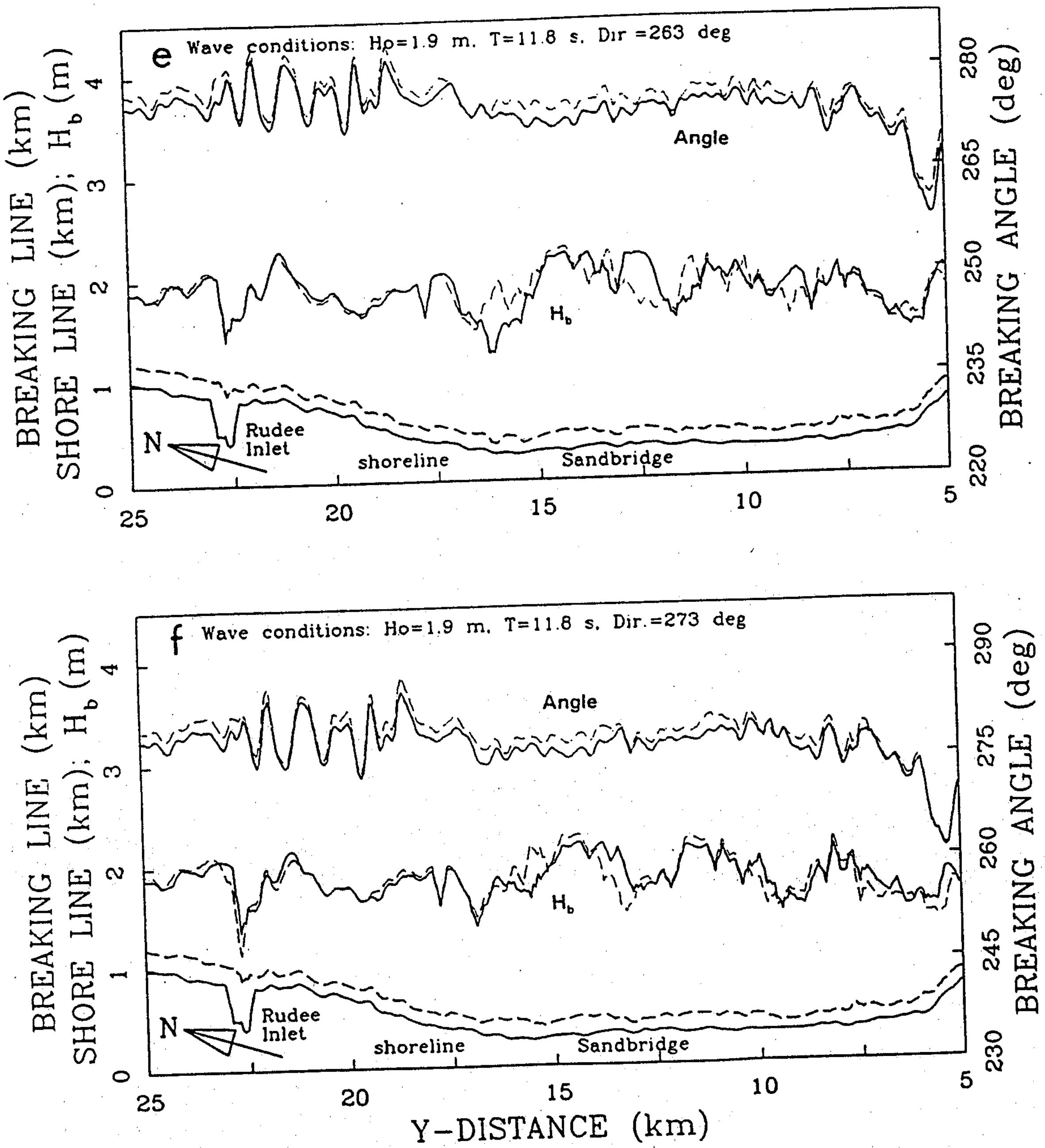


Fig. 13. (continue) Comparison of the Breaking Wave Heights, Breaking Wave Angles, Breaking Locations for the Northeaster.

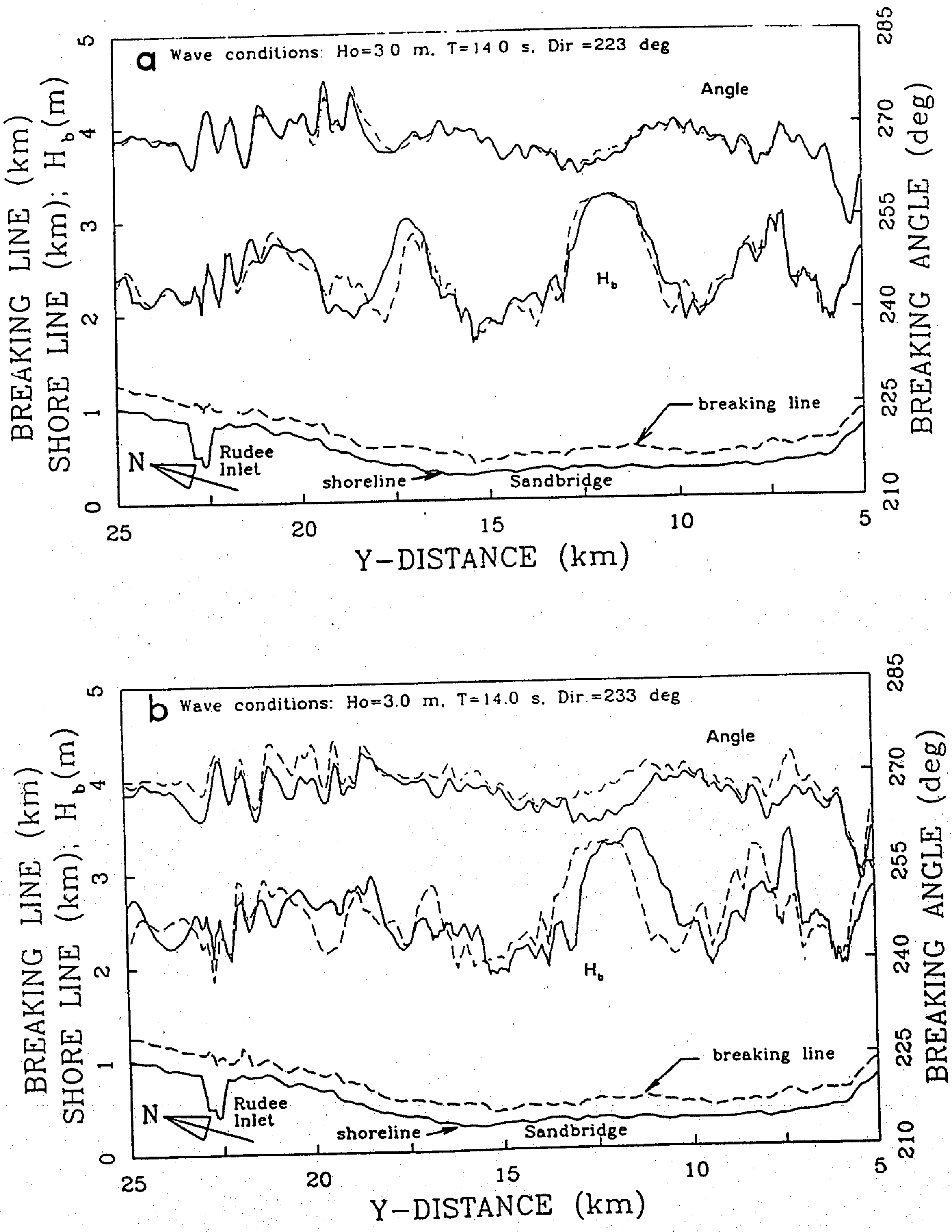


Fig. 14. Comparison of the Breaking Wave Heights, Breaking Wave Angles, Breaking Locations for the Severe Sea. Solid lines show the results before dredging. Dashed lines show the results after dredging.

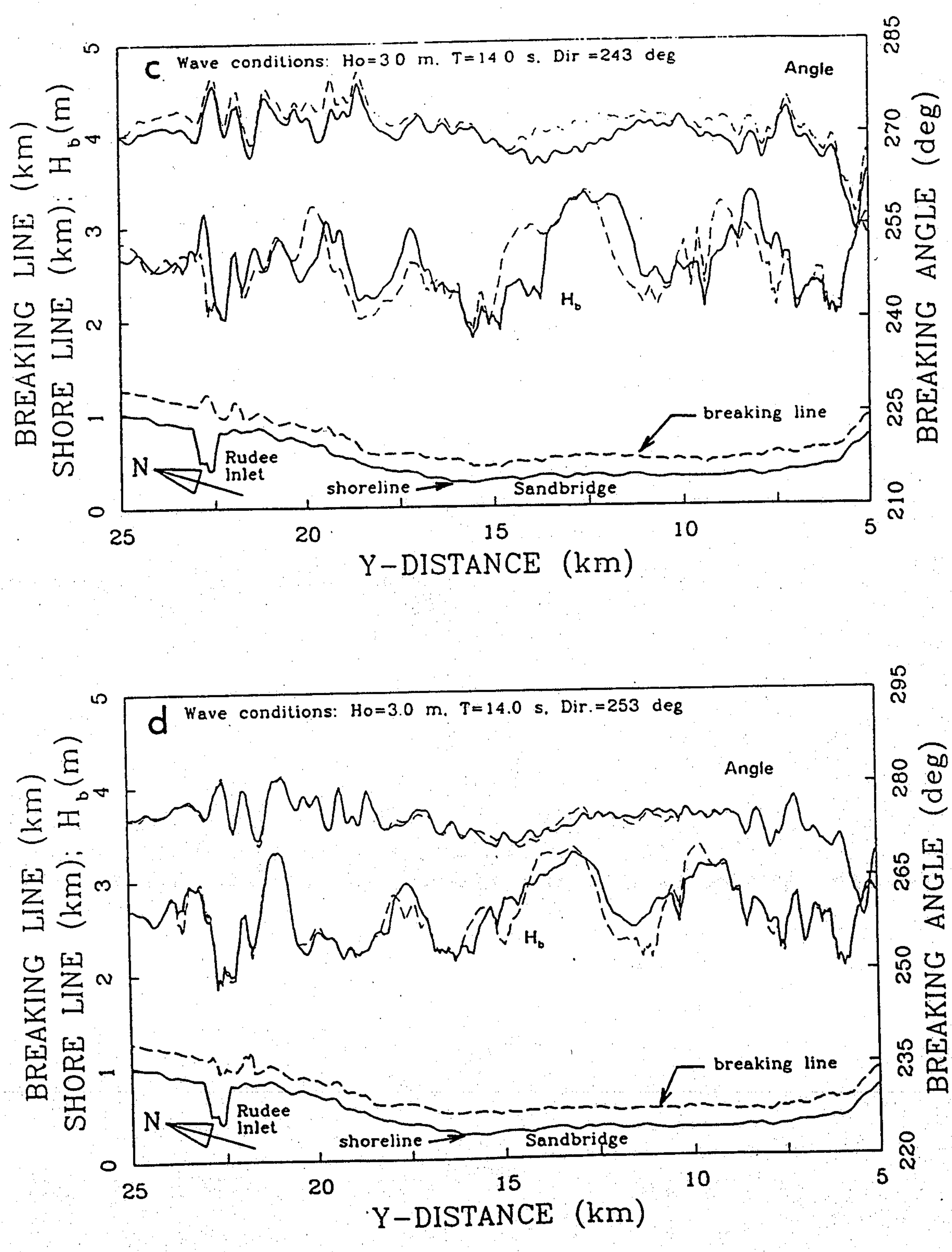
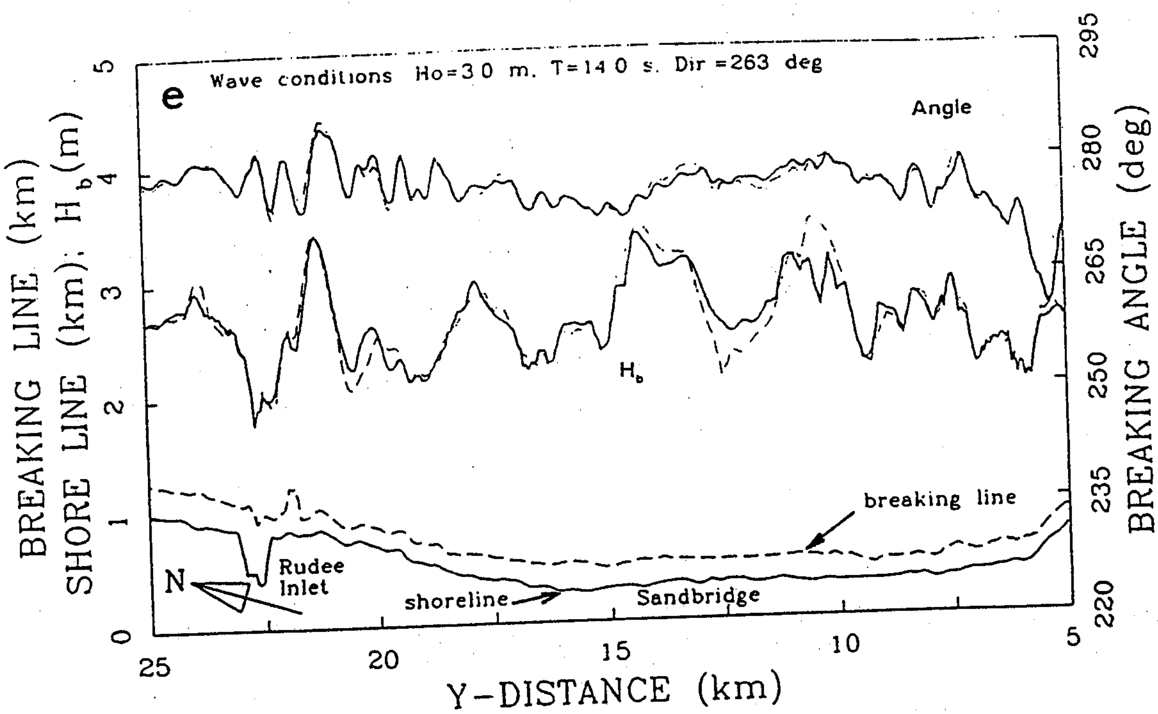


Fig. 14. (continue) Comparison of the Breaking Wave Heights, Breaking Wave Angles, and Locations for the Severe Sea.



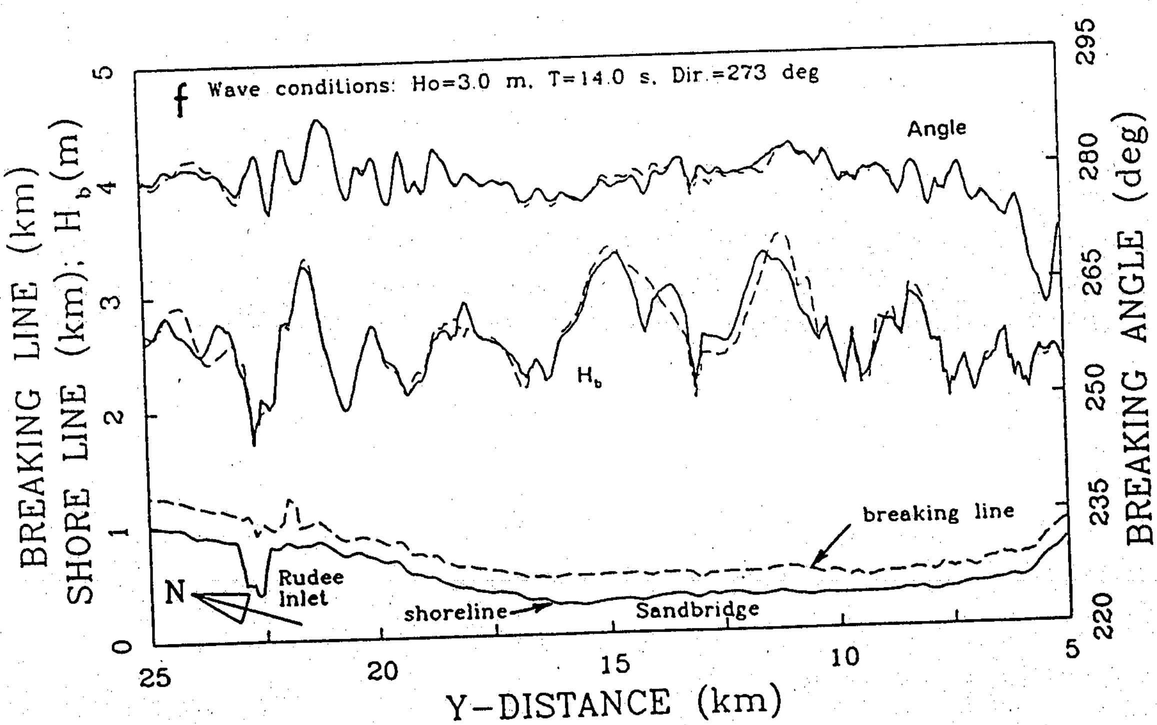


Fig. 14. (continue) Comparison of the Breaking Wave Heights, Breaking Wave Angles, and Locations for the Severe Sea.

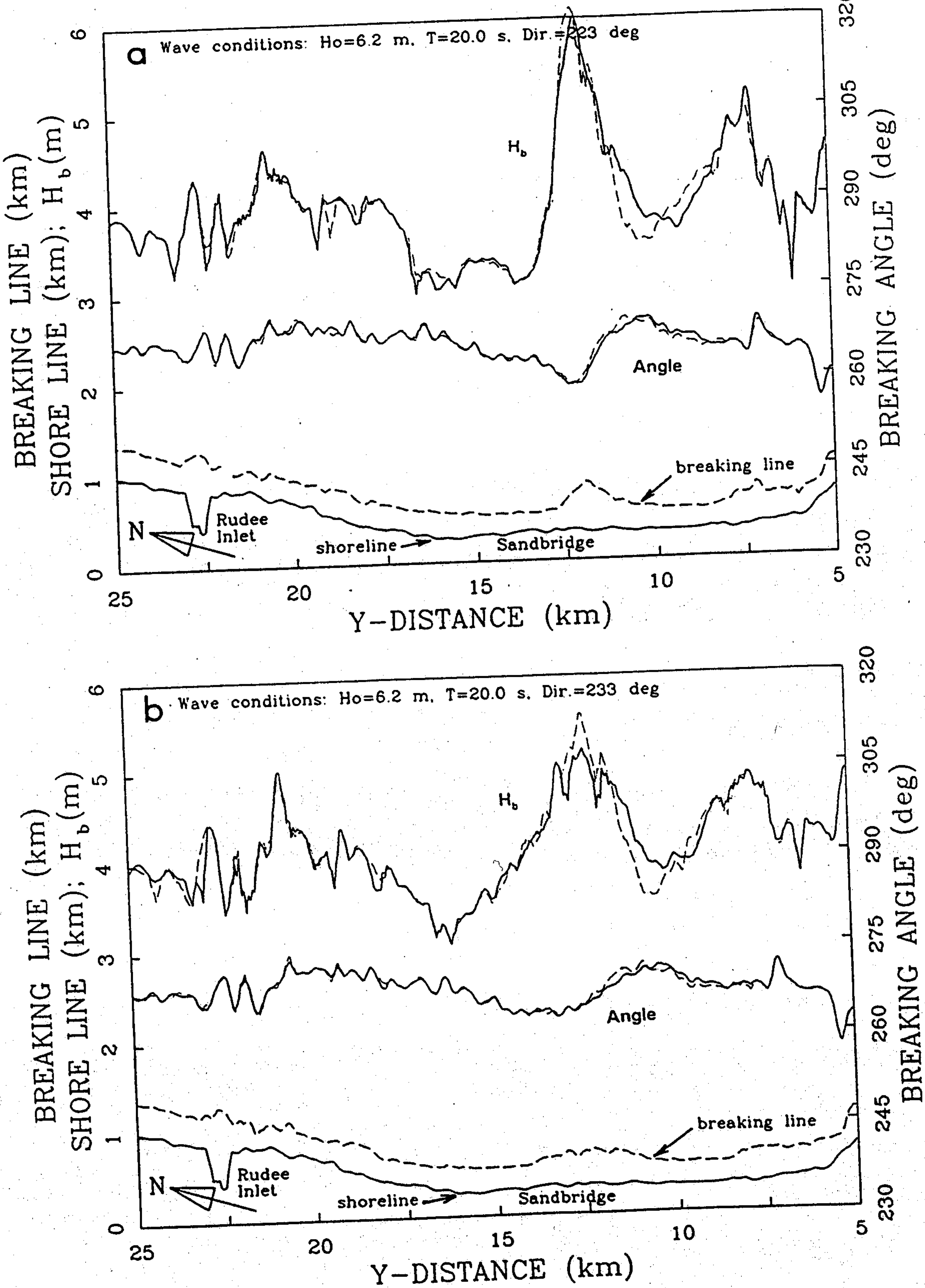
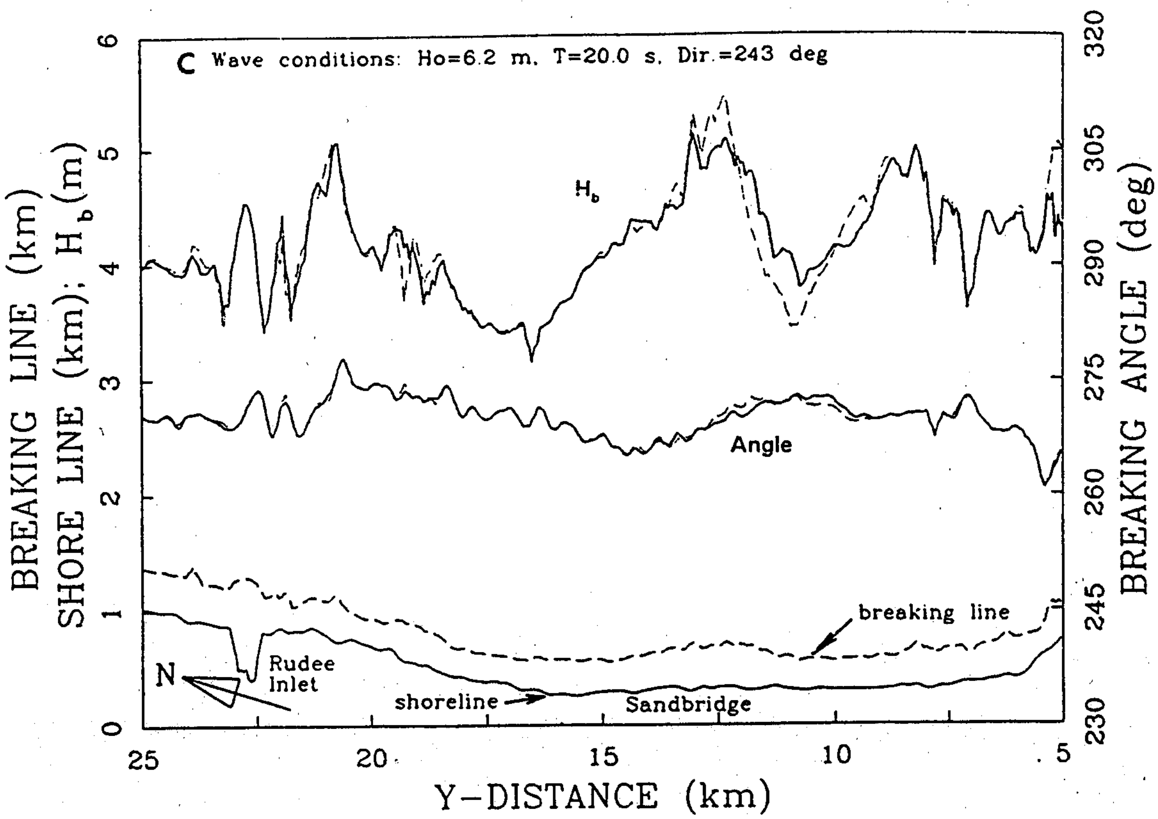


Fig. 15. Comparison of the Breaking Wave Heights, Breaking Wave Angles, Breaking Locations for the Most Severe Sea. Solid lines show the results before dredging. Dashed lines show the results after dredging



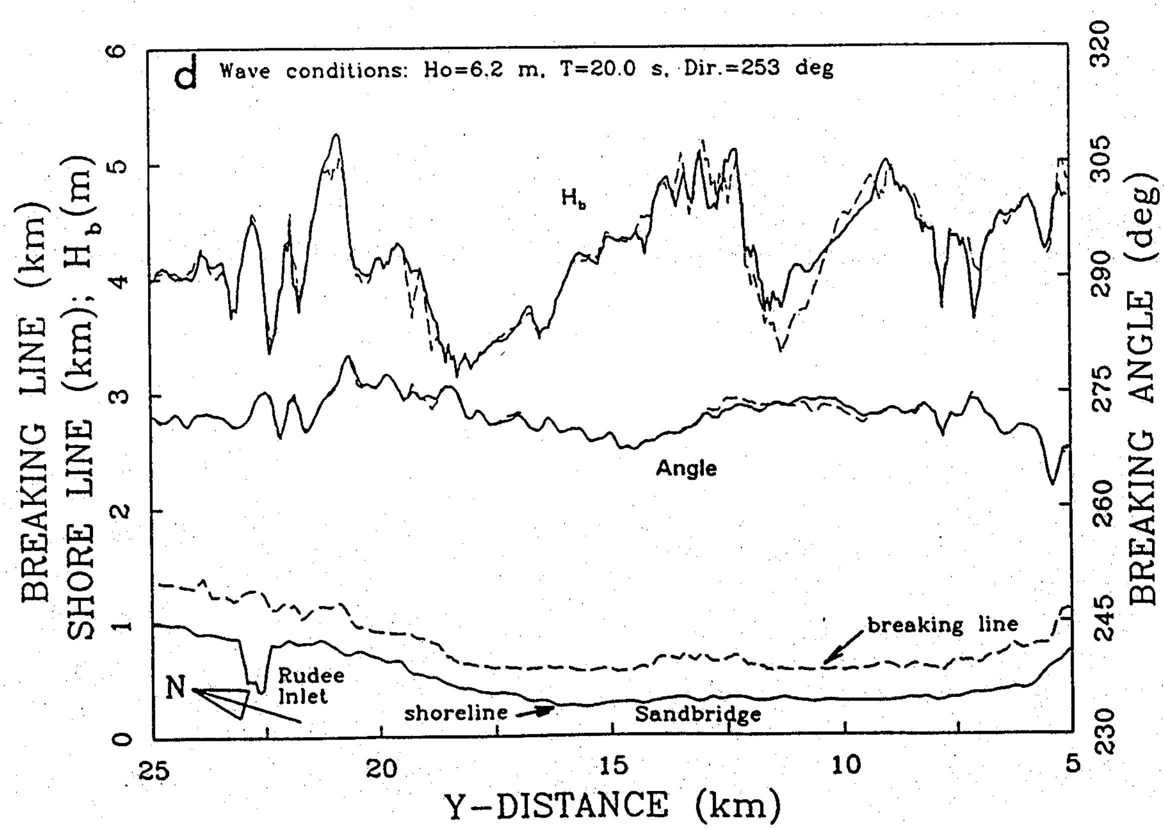
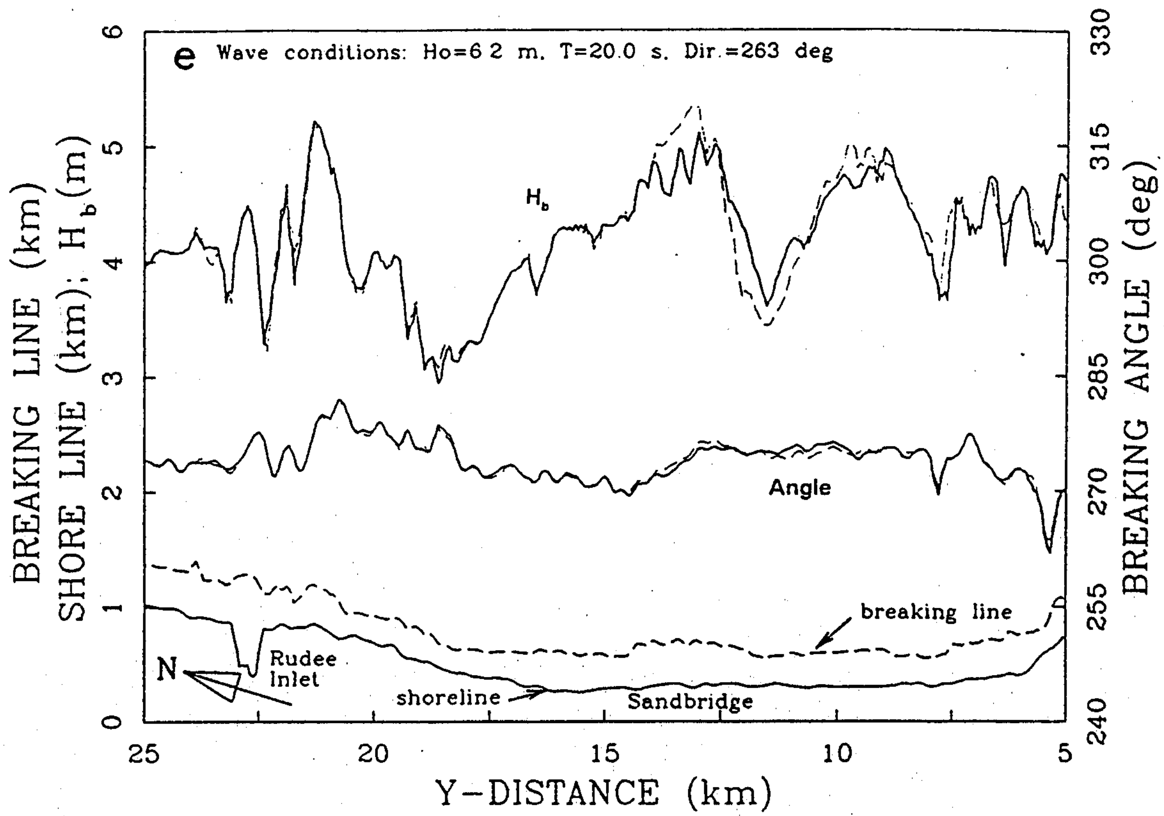


Fig. 15. (continue) Comparison of the Breaking Wave Heights, Breaking Wave Angles, and Locations for the Most Severe Sea.



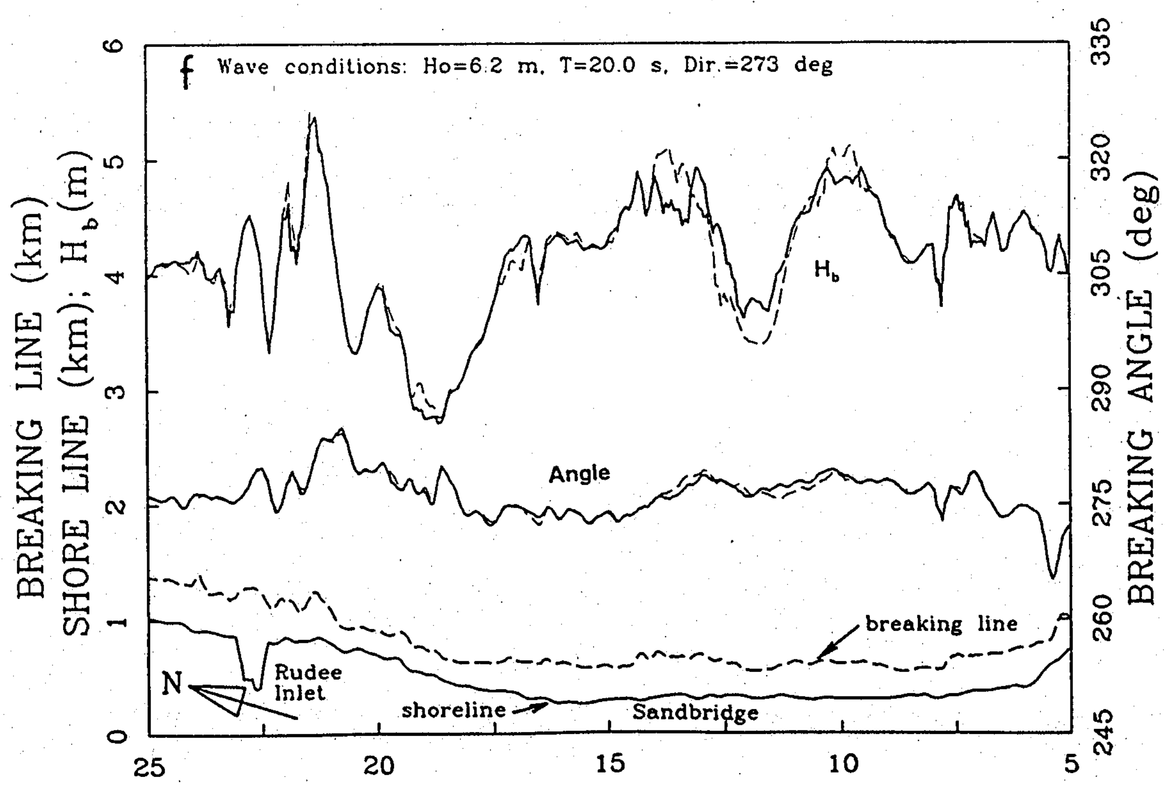


Fig. 15. (continue) Comparison of the Breaking Wave Heights, Wave Angles, and Locations for the Most Severe Sea.

POSSIBLE IMPACT ON SEDIMENT TRANSPORT

We used an advanced longshore sediment transport model to examine the possible impact of dredging at Sandbridge Shoal. It is necessary to point out that the absolute volume of sediment transport is irrelevant. Although some models gave the same trend of longshore transport, their absolute value of sediment transport can be quite different (Wright et al. 1987). What we want to examine is the difference before and after the proposed dredging has been done.

Longshore Sediment Transport Model

The most straight-forward approach to estimate the total shore-parallel sediment transport rate (ether in mass, J, or in volume, Q) in the surf zone was simply related to the long shore breaking wave energy flux, I, as follows:

$$I = K\ (EC_g)_b \sin \alpha_b \cos \alpha_b \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where $(EC_g)_b$ is the wave energy flux at the breaking point, C_g is wave group velocity, $E = (1/8)\rho g H^2$ is wave energy, $\rho = 1020\ kg/m^3$ is water density, $g = 9.8\ m/s^2$ is the gravitational acceleration, H is wave height, the subscript b stands for breaking wave condition, α_b is the breaking wave angle between x direction (also represent the shore normal direction) and the incoming breaking wave ray, and K is an empirically determined constant. The volume transport rate and mass transport rate are related as

$$I = g(\rho_s - \rho)\ (1 - p)\ Q \quad (2)$$

where $\rho_s = 2.65$, is the sediment density, $p = 0.4$, is the pore ratio.

Although Eq. 1 has been widely used in the past two decades (Watts 1953; Savage 1962; Bagnold 1963; Komar and Inman 1970; Komar 1983) and also selected in the Shore Protection Manual (CERC, 1984). It is necessary to point out that this formulation assumes breaking wave energy is totally dissipated in the surf zone, and the gradient of radiation stress, $\partial S_{xy}/\partial x$, is the only force that drives longshore current. Thus, Eq. 1 is good for an ideal coast with straight shoreline and parallel depth contours from coast to far offshore.

If we only consider sediment transport process for a simple straight shoreline, parallel depth contours from coast to further offshore, and assume wave energy is totally dissipated in the surf zone, then Eq. 1 is a good start because H_b and α_b are the same along the coast. In reality, however, wave breaking condition (H_b and α_b) always changes along a coast because of the irregular bathymetry, e.g., see Figs. 12-15. For this reason, wave set-up induced by another component of the radiation stress (Longuet-Higgins and Steward 1962), $\partial S_{xx}/\partial x$, at the coast will not be the same. This varying wave set-up (i.e., water surface elevation) along a coast can induce longshore current even for a normally incident wave (i.e., $S_{xy} = 0$). This second component of longshore current can either enhance or diminish the first component. Therefore both the long shore energy flux (caused by oblique waves) and the gradient of wave set-up (caused by changing breaking wave height) should contribute to the longshore current, i.e., longshore sediment transport.

The three radiation stress components (S_{xy}, S_{xy}, and S_{yy}), which are second order wave properties that are responsible for driving long shore current, can be calculated as follows:

$$S_{xy} = S_{yx} = \frac{1}{2} En \sin 2\alpha \quad \ldots\ldots\ldots \quad (3)$$

$$S_{xx} = E[\, n \, (\cos^2\alpha + 1) - \frac{1}{2} \,] \quad \ldots\ldots\ldots \quad (4)$$

$$S_{yy} = E[\, n \, (\sin^2\alpha + 1) - \frac{1}{2} \,] \quad \ldots\ldots\ldots \quad (5)$$

where

$$n = \frac{1}{2} \left(1 + \frac{2kd}{\sinh(2kd)} \right) \quad \ldots\ldots\ldots \quad (7)$$

where E is wave energy, k is wave number, d is water depth, and α is wave angle defined similar to α_b given in Eq. 1.

Based on the above stated principal, attempts have been made to extend Eq. 1 to include the influence of nonuniform breaking wave height along a coast (Komar and Inman 1970). Gourlay (1982) modified Komar and Inman's model and proposed the following equation:

$$I = K^{*} \, (EC_g)_b \cos \alpha_b \, [\, \sin 2\alpha_b - \frac{K_{\Delta H}}{\mathrm{Tan}\, \beta} \frac{\partial H_b}{\partial x} \,] \quad \ldots\ldots\ldots \quad (8)$$

where Tan β is the average beach slope between the breaking point and the shoreline , $K_{\Delta H} = 23.7$, $K^{*} \approx 0.385 K_b$, and K_b depends on the Irribaren number, ξ, given by

$$\xi = \frac{2\pi \text{ Tan } \beta}{H_b \text{ g } T^2} \quad \text{.......................................} \quad (9)$$

When $\xi \geq 1.7$, $K_b = 1$, but when $\xi < 1.7$ then $K_b = 0.45\xi/K^*$

Model Results

Based on the Gourlay's model (Gourlay 1982) for longshore sediment transport, we calculated the amount of longshore sediment transport based on the calculated breaking wave heights and breaking angles (using the RCPWAVE model with modification on counting the effects of bottom friction) before and after the proposed dredge were made.

Figure 16 shows the calculated longshore sediment transport rate, Q, in M^3/hr for the Northeaster waves that coming from NE to E direction. In the figure, the legend 'a12.223' stands for Northeaster wave with representative wave period 12 s. (11.8 s.) and traveling 223 azimuth degree (i.e., coming from the NE). The solid line represents calculated longshore transport rate before dredging, and the dashed line is for after dredging. The phase 'y+ transport' represents north-going transport, and 'y- transport' represents south-going transport. Fig. 16 indicates that the Northeaster waves coming from NE and ENE directions don't have any significant effect on the changing of longshore sediment transport. The results from waves that go to 233 and 243 degrees were altered in such a manner that the south-going sediment transport rate will be reduced. The amount of north-going sediment transport, caused by waves that go to 263 and 273 degrees, increases a little after dredging. In combining the results from Northeaster waves, the net amount of south-going sediment will be reduced by the dredging. Notice that, however, the possibly affected area is located on the north of Sandbridge. On the south side, the influence is insignificant.

For the severe sea, Fig. 17 shows the calculated transport rate. The legend 'b14.223' stands for the severe sea with representative wave period 14 s. and traveling toward 223 azimuth degrees. It reveals that for waves going toward 233 and 243 degrees, the south going amount has been reduced. For other directions, there are only minor local changes. Again, the affected area is located on the north side of Sandbridge.

For the most severe sea, Fig. 18 shows the results. The legend 'c20.233' stands for the most severe sea with a wave period of 20 s. and traveling toward 233 azimuth degrees. Notice that there are only small local change and no significant difference for all directions between before and after dredging.

Considering the fact that there is only about 5% of the total time in a year that waves may reach the level of the Northeaster waves, and only about 1% of the total time in which waves reach the level of the severe sea, the calculated possible change of longshore sediment transport may be considered insignificant. If affected, the area would be 2 to 5 km north of Sandbridge.

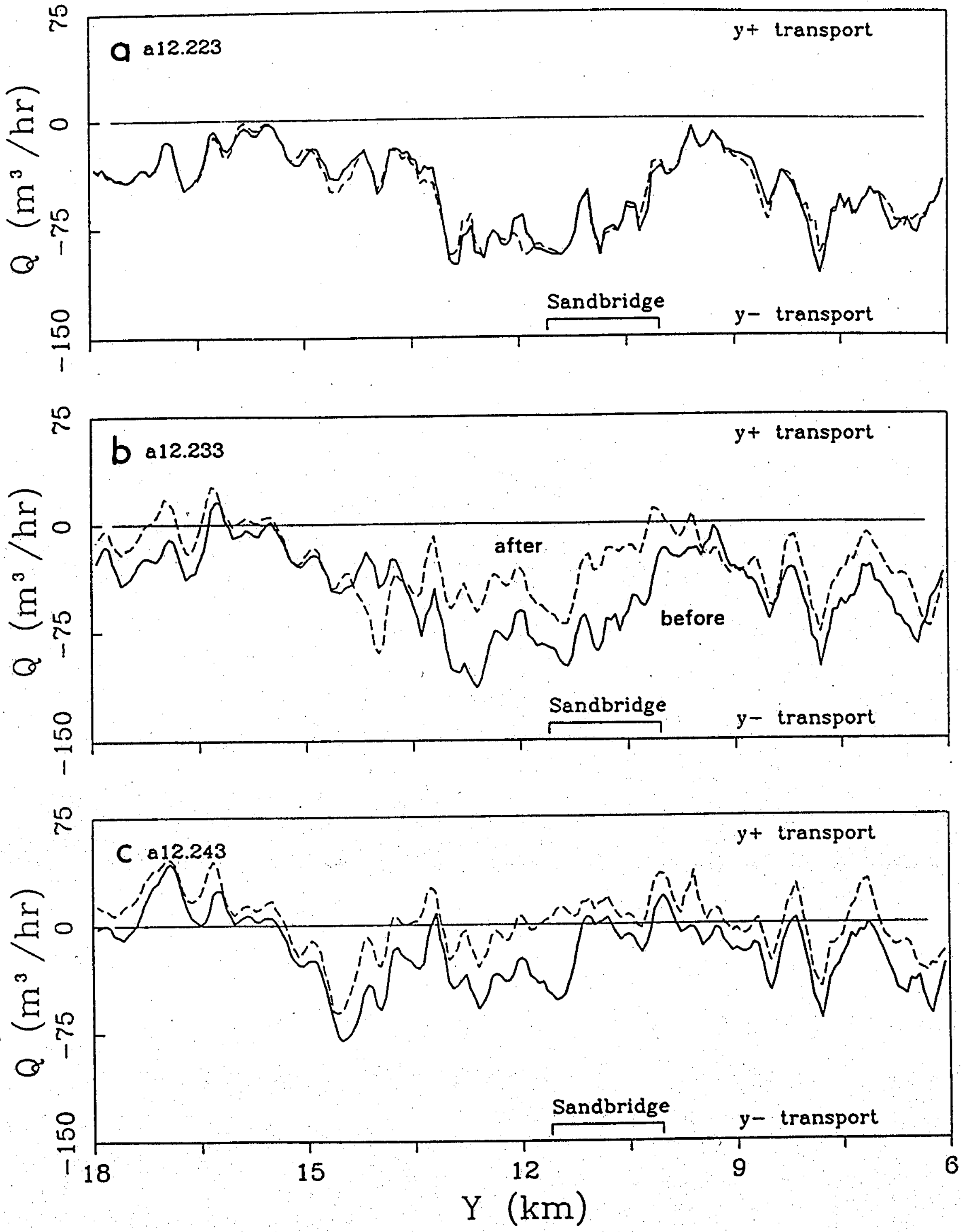


Fig. 16. Comparison of Longshore Sediment Transport Before and After the Proposed Dredging at Sandbridge Shoal for Northeaster waves.

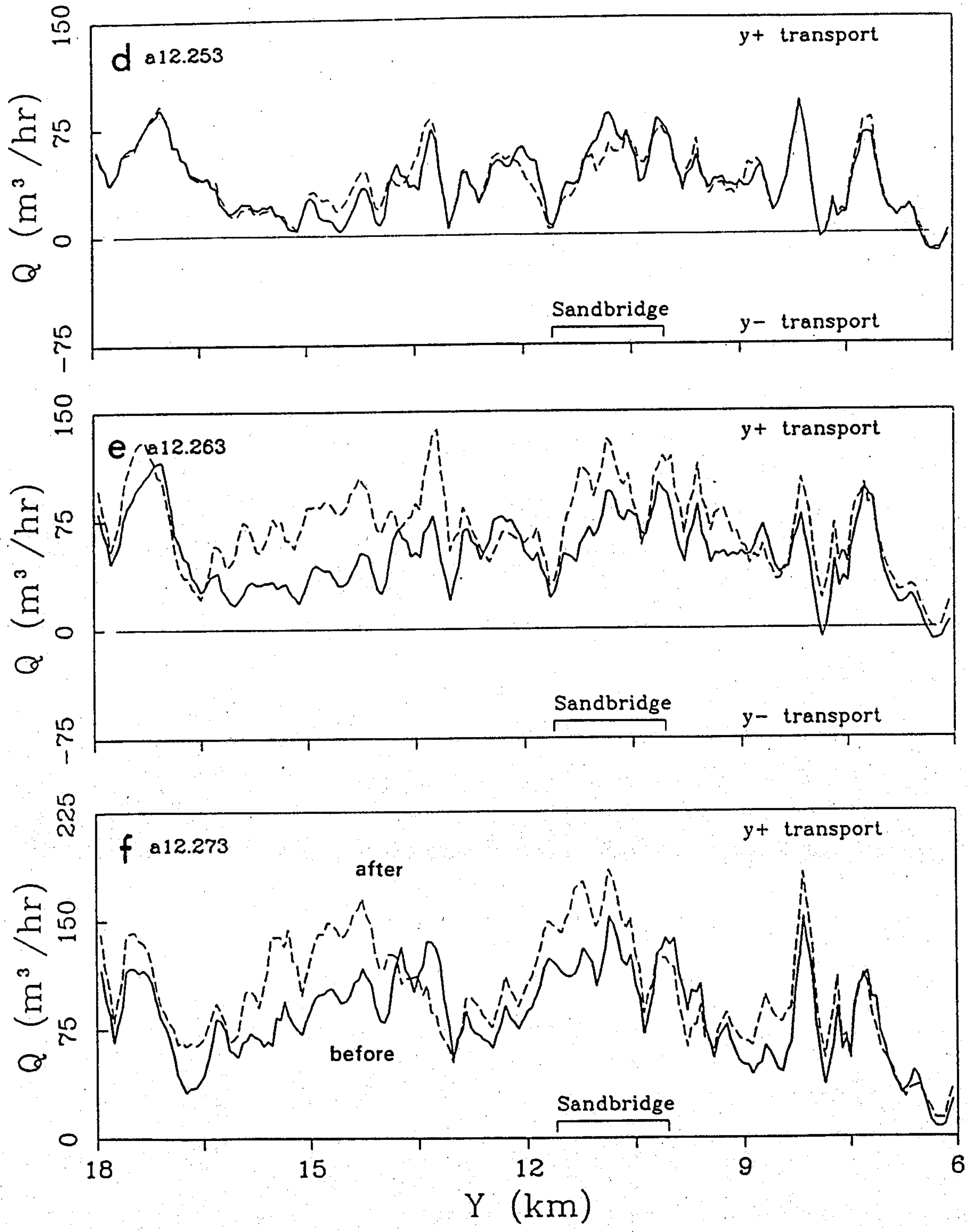


Fig. 16. (continue) Comparison of Longshore Sediment Transport Before and After the Proposed Dredging at Sandbridge Shoal for Northeaster waves.

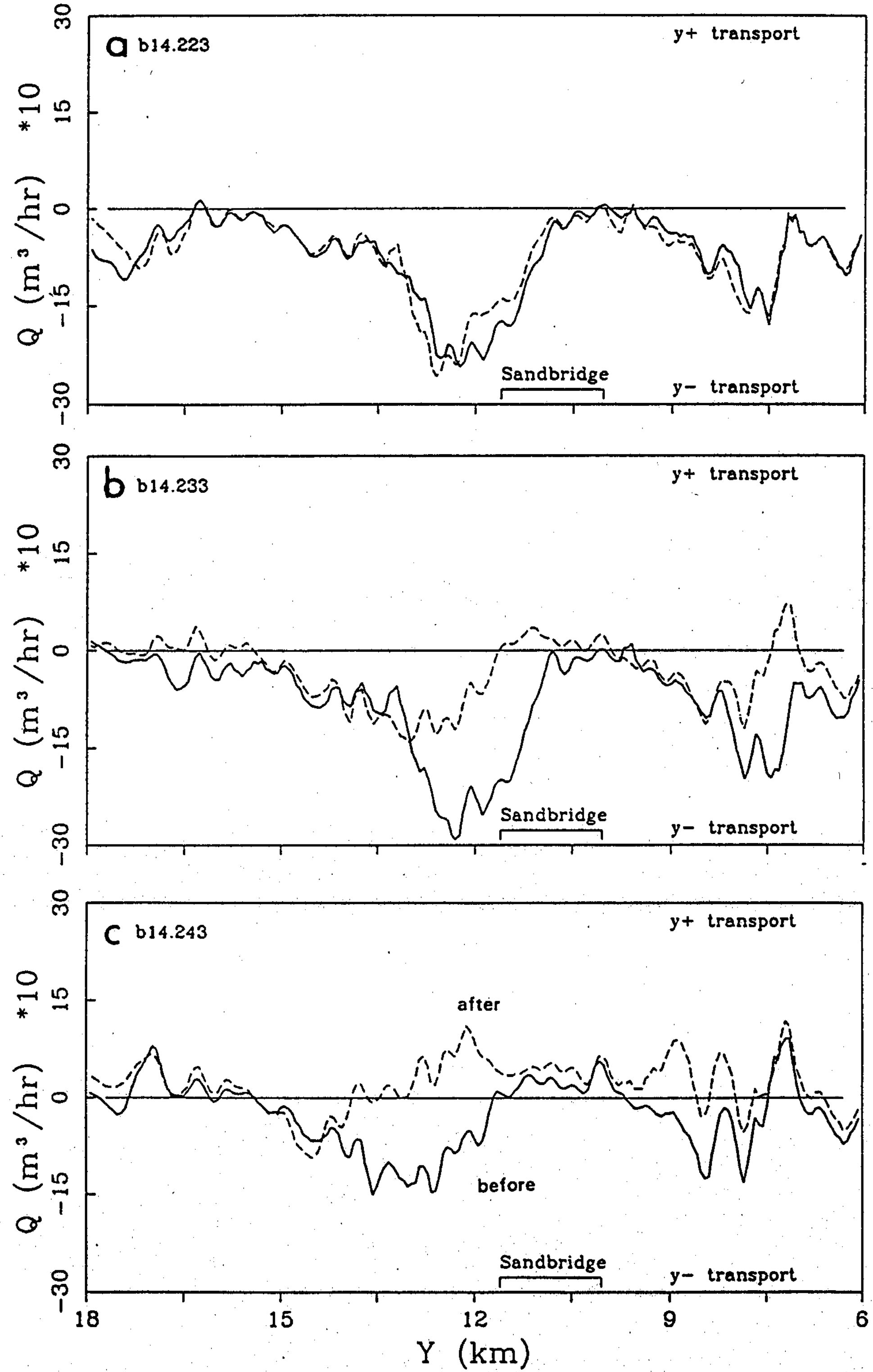


Fig. 17. Comparison of Longshore Sediment Transport Before and After the Proposed Dredging at Sandbridge Shoal for the Severe Sea.

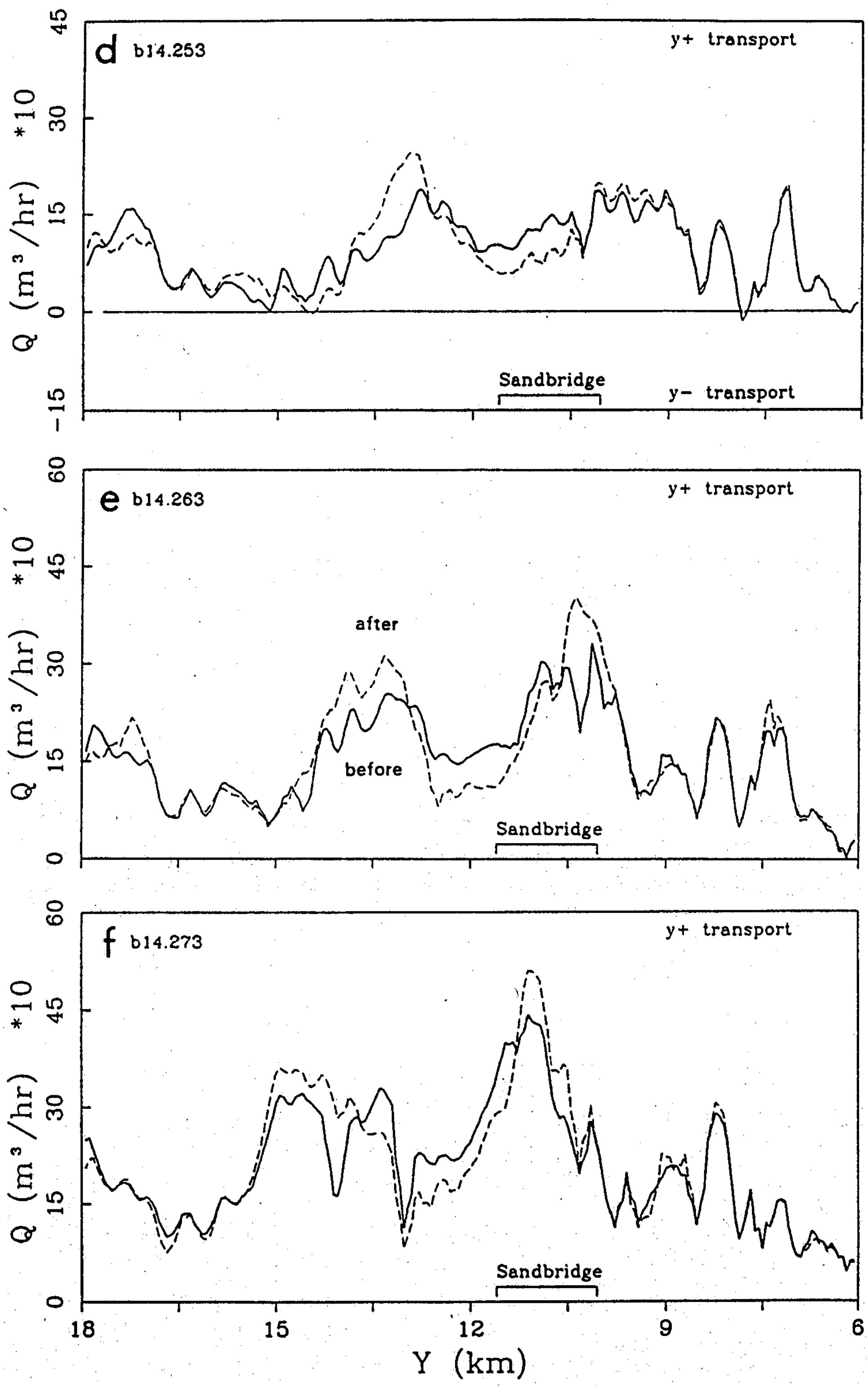


Fig. 17. (continue) Comparison of Longshore Sediment Transport Before and After the Proposed Dredging at Sandbridge Shoal for the Severe Sea.

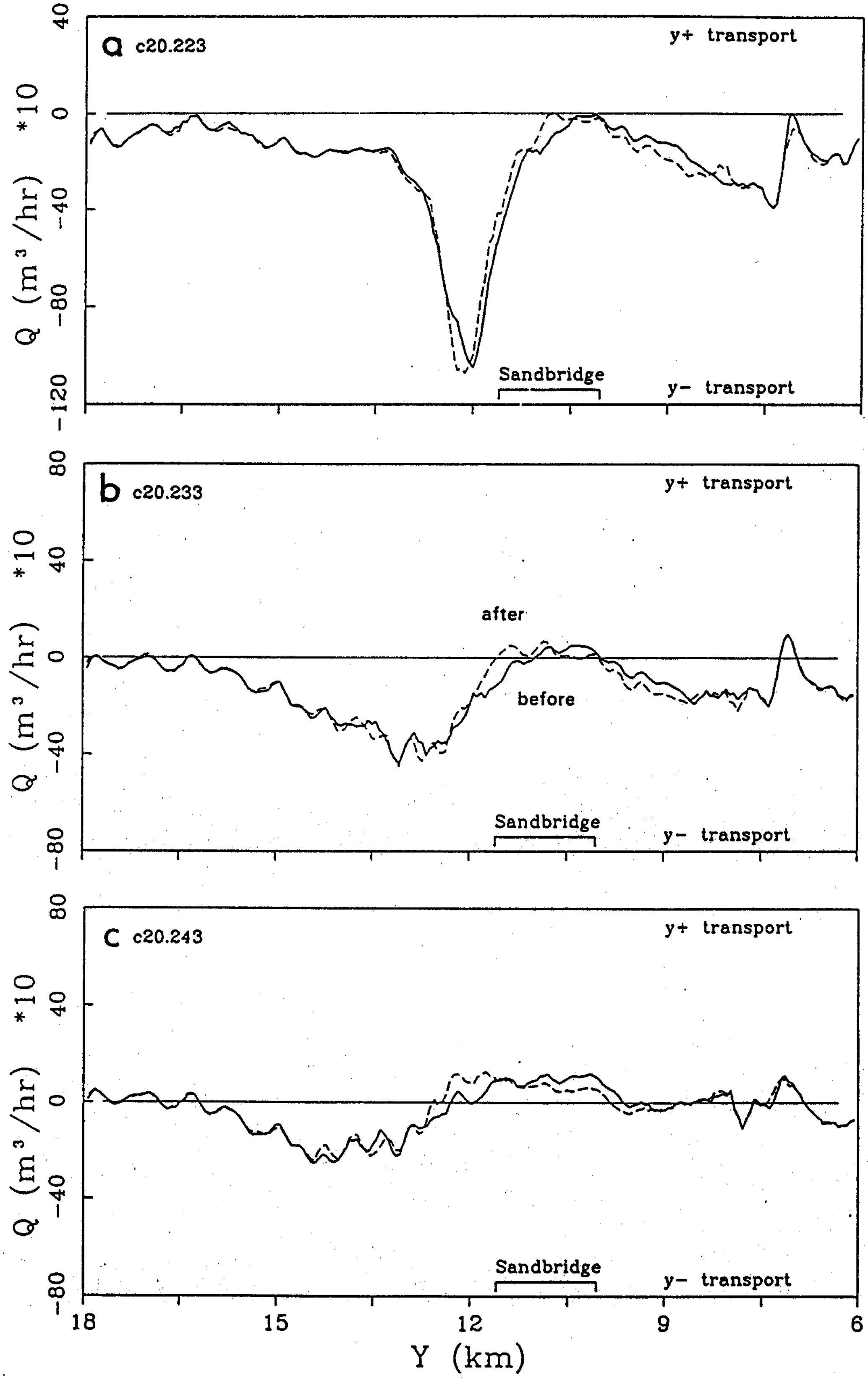


Fig. 18. Comparison of Longshore Sediment Transport Before and After the Proposed Dredging at Sandbridge Shoal for the Most Severe Sea.

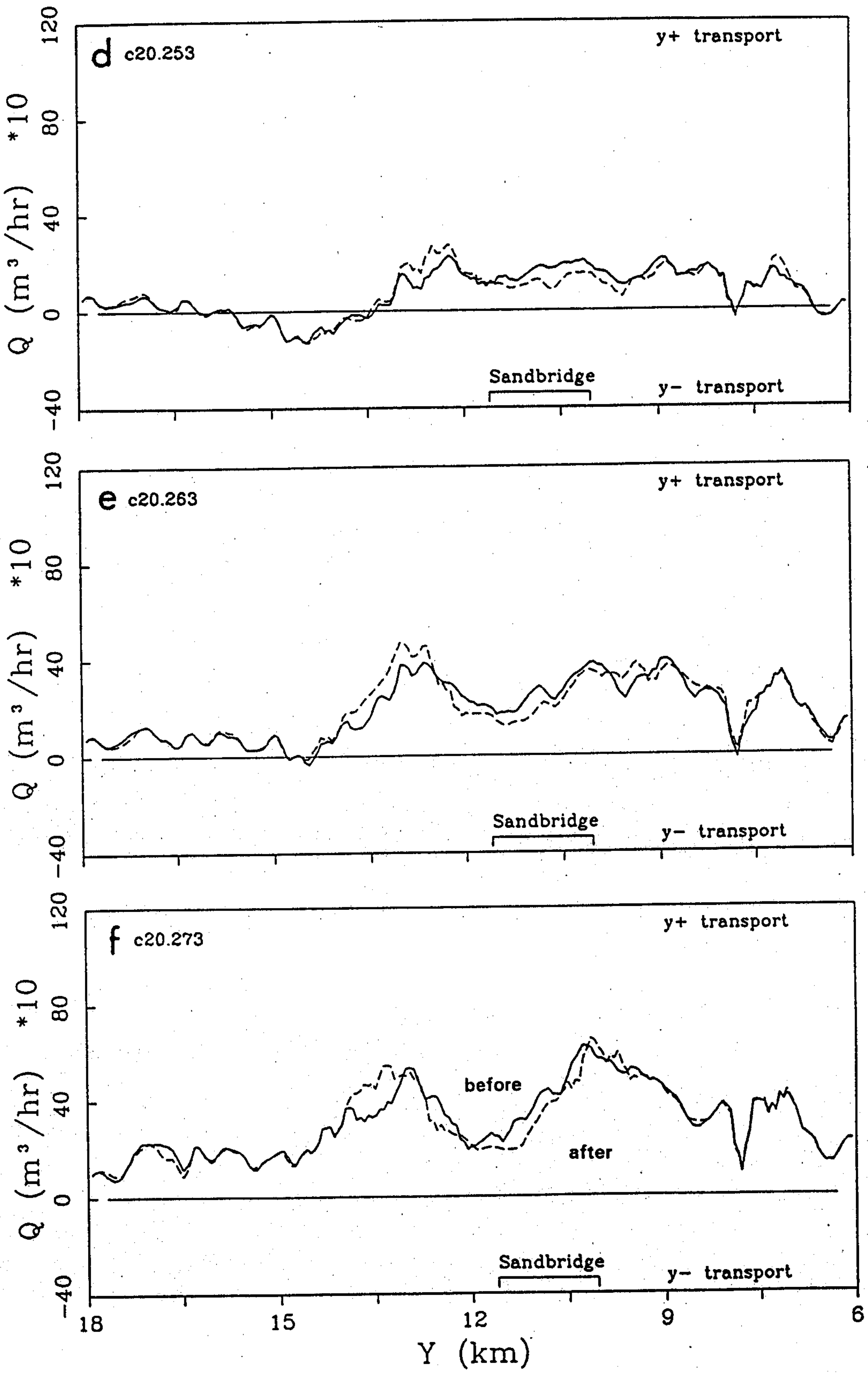


Fig. 18. (continue) Comparison of Longshore Sediment Transport Before and After the Proposed Dredging at Sandbridge Shoal for the Most Severe Sea.

CONCLUSIONS

The study of near seven years wave records from station CHLV2 indicates that long period waves (period T > 12 s.) mainly come from NE to E Directions. Because short period waves will not be affected by the presence of the Sandbridge Shoal, they are not studied. Three categories of wave conditions were examined in this report, and the possible influence by the proposed dredging are evaluated as follows.

The responses (on the longshore sand transport) to the proposed dredging at Sandbridge Shoal for the most severe sea (Wave Height H = 6.2 m and T = 20 s.) are insignificant for all the selected six directions, from NE to E.

For the severe sea (H = 3 m and T = 14 s.), which has a 1% chance of occurrence every year, the shoreline change will be reduced by the dredging for waves coming from ENE direction. The change for this kind of wave that comes from other 5 directions are insignificant. Thus, the dredging actually protects the beach behind the shoal, although only on the north side of Sandbridge.

For the Northeaster waves (H = 1.9 m, T = 11.8 s), which has a 5% chance of occurrence every year, the dredging decreases the longshore sediment transport rate for these waves that come from ENE direction, and thus, is favorable. For the waves coming from E direction, the dredging increases the north-going sand transport, which is not favorable. Notice that, however, the change occurred mainly at the north side of Sandbridge, and thus, the impact on the south side beach of Sandbridge is insignificant.

REFERENCES:

Bagnold, R.A. (1963). "Beach and Nearshore Processes: Part I: Mechanics of Marine Sedimentation," in The Sea, Hill, M.N. (ed.), Wiley-Interscience, (3), 507-528.

Berkhoff, J. C. W. (1972). "Computation of Combined Refraction-Diffraction." Proceedings, 13th International Conf. on Coastal Engrg., ASCE, 1, 471-490.

Berkhoff, J. C. W., Booy, N, and Radder, A.C. (1982). "Verification of Numerical Wave Propagation Models for Simple Harmonic Linear Water Waves," Coastal Engrg., 6, 255-279.

CERC Shore Protection Manual (1984). 4th Ed., U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Vicksburg, Miss.

Ebersole, B. A. (1985). "Refraction-Diffraction Model for Linear Water Waves," J. of Waterway, Port, Coastal, and Ocean Engrg., ASCE, 111(6), 939-953.

Gourlay, M.R. (1982). Nonuniform Alongshore Currents and Sediment Transport - A One-dimensional Approach, Civil Engrg. Research Report, No. CE31, Dept. of Civil Engrg., Univ. of Queensland, St. Lucia, Queensland.

Kimball S. M. and Dame, J. K. (1989). Geotechnical Evaluation of Sand Resources on the Inner Shelf of Southern Virginia, Vol. 1: Report and Appendices A-B, Final Report to the City of Virginia Beach, Virginia, Virginia Institute of Marine Science, College of William and Mary.

Kirby, J.T., and Dalrymple, R.A. (1991). User's Manual, Combined Refraction/Diffraction Model, REF/DIR 1, Version 2.3, Center for applied Coastal Research, Dept. of Civil Engineering, Univ. of Delaware, Newark, DE 19716.

Komar, P.D. (1983). "Nearshore Currents and Sand Transport on Beaches," in Elsevier, New York, NY, 67-109.

Komar, P.D. and Inman, D.L. (1970). "Longshore Sand Transport on Beaches, Journal of Geophysical Research, 70(30), 5914-5927.

Longuet-Higgins, M.S. and Stewart, R.W. (1962). "Radiation Stress and Mass Transport in Gravity Waves, with Application to Surf Beats," J. of Fluid Mechanics, 13, 381-504

Longuet-Higgins, M.S., Cartwright, D.E., and Smith, N.D. (1963) "Observations of the Directional Spectrum of Sea Waves Using the Motions of a Floating Buoy." in Ocean Wave Spectra, Prentice-Hill 111-136.

Meindl. E.A., and Hamilton, G.D. (1992) "Programs of the National Data Buoy Center." Bulletin of the American Meteorological Society, 73(7), 985 - 993.

Savage, R.P. (1962). "Laboratory Determination of Littoral Transport Rates," J. of Waterway and Harbor Div., ASCE, 88(WW2), 69-92.

Steele, K.E., Wang, D. W.-C., Teng, C.C., and Lang, N. (1990). "Direction Wave Measurement with NDBC 3-meter Discus Buoys." NDBC Report No. 1804-01.05.

Wang, D. W.-C., and Mettlach, T. (1992) "The Halloween Storm: Data Observations from NDBC Stations." Proceedings, 3rd International Workshop on Wave Hindcasting and Forecasting, Environment Canada Atmospheric Environment Service, Downsview, Ontario, Canada, M3H 5T4, 383-400.

Watts, G.M. (1953). "A Study of Sand Movement at South Lake Worth Inlet, Florida," Tech. Memo. No. 42, Beach Erosion Board.

Wright, L.D., Kim, C.S., Hardaway, C.S., Kimball, S.M., and Green, M.O., (1987). Shoreface and Beach Dynamics of the Coastal Region from Cape Henry to False Cape, Virginia," Technical Report, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA 23062.