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CHESAPEAKE BAY WAVE FORECASTS

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1. INTRODUCTION

Wave conditions on Chesapeake Bay are very important to recreational boaters, both sailing and power boat enthusiasts, and to commercial fishermen. Wave conditions are also of some importance to the larger commercial ships plying the bay. Forecasts of the wave conditions for the bay are prepared by the Weather Service Forecast Office (WSFO) in Washington, D.C. Other variables which are forecast are wind speed and direction, wind gusts, significant weather, and visibility. The forecasts are issued four times daily (0439, 1039, 1639, and 2239 EST) and may be amended at any time. The bay is divided into the following four areas for the preparation of the marine forecasts which include the wave forecasts:

1. North of Baltimore Harbor,
2. Baltimore to Patuxent,
3. Patuxent to Windmill Point, and
4. South of Windmill Point.

The Techniques Development Laboratory (TDL) plans to develop an automated wave forecast method for the Chesapeake bay similar to that which is in operation for the Great Lakes (Pore, 1979). The method will provide significant height forecasts for a number of pre-selected forecast points. The number of forecast points and their locations have not yet been decided upon. Another decision to be made, after appropriate experimentation, is on the type of wind forecasts to be used as input to drive the wave forecast model.

Wave height calculations for four points have been made for a series of wind conditions to see how the system will work for Chesapeake Bay. The four points, located at 37° 20`N, 76° 10`W; 38° 00`N, 76° 10`W; 38° 45`N, 76° 25`W; and 39° 24`N, 76° 05`W, are shown in Fig. 1. Also shown in this figure are the estimated average depths, the measured fetch lengths, and the effective fetch lengths for eight compass points. These wave height calculations may also be useful as guidance to marine forecasters in preparing wave forecasts for the bay.

2. WAVE FORECAST METHOD

The requirement for Chesapeake Bay wave forecasts is for significant wave heights. The Chesapeake Bay is rather shallow and has restricted fetches for many wind directions; it is therefore desirable to use a method which

considers the water depth and fetch length. A method, as described in the Shore Protection Manual of the U.S. Army Coastal Engineering Research Center (1977) has been adapted for use with Chesapeake Bay.

The method is based on the work of several researchers over many years. The combined theoretical-empirical procedure of Sverdrup and Munk (1947) for deep water wave forecasting is the basis. The Sverdrup-Munk procedure was modified by Bretschneider (1952, 1970) with additional observational data. This work resulted in the Sverdrup-Munk-Bretschneider (SMB) method for deep water wave forecasting in which significant wave height and period depend on wind speed, fetch length, and duration time. Because the depth is important for wave generation in shallow water, the depth should be considered in shallow water wave forecasting. Wave generation in shallow water results in smaller wave heights and shorter wave periods than wave generation in deep water. The method for shallow water wave forecasting considers that wave energy is lost due to bottom friction and percolation.

The forecast equation for wave height is:

$$H = \frac{U^2}{g}\, 0.283 \tanh\left[0.530\left(\frac{gd}{U^2}\right)^{0.75}\right] \tanh\left\{\frac{0.0125\left(\frac{gF}{U^2}\right)^{0.42}}{\tanh\left[0.530\left(\frac{gd}{U^2}\right)^{0.75}\right]}\right\} \quad (1)$$

where H is significant wave height in feet,
g is acceleration of gravity (32.2 ft/s^2),
d is depth of water in ft,
U is wind speed in ft/s, and
F is fetch length in ft.

3. FETCH AND DEPTH DETERMINATIONS

Fetch lengths were determined for eight directions at the four forecast points by direct measurement from each forecast point to land on navigation charts of the National Ocean Survey (NOS). Some of the measured fetch lengths were corrected for fetch width by the method of Saville (1954). This method considers that waves are generated not only in the exact direction of the wind but also at various angles to the wind. This results in waves at a point being the summation of wave components from the direction of the wind and other directions. Saville's correction factors for the wind being effective over 90° of a fetch, with the wind effectiveness considered to vary as the cosine of the angle of the wind component, were used. Maximum reduction of fetch length for the four forecast points was to about 40% of the measured fetch length.

The depths for the eight directions at each of the four points were estimates of the average depths over each fetch. These depths were obtained from NOS navigation charts.

4. WAVE CALCULATIONS FOR FOUR LOCATIONS

Wave height calculations were made with Eq. 1 for the four forecast points for ficticious winds from eight directions (N, NE, E, SE, S, SW, W, and NW) for wind speeds ranging from 5 to 70 knots.

Figs. 2-15 show significant wave heights for eight wind directions at the four points. Each figure is for a different wind speed ranging from 5 to 70 knots. Along each direction are shown significant wave heights in feet for winds of different durations. Significant wave heights of less than half a foot are shown by X's. The value closest to the center is for duration of 3 hours; succeeding values are for durations of 9, 15, 21, 27, and 33 hours. For example, Fig. 7 shows wave conditions for 30-kt winds over the bay. At the point located at 38° 00'N, 76° 10'W the highest waves would be generated by a south wind because of the long fetch to the south. From the south, wave height would be 2 feet for a duration of 3 hours and increase to 4 feet for a 9-hour duration. For all durations greater than 9 hours the wave height would be 5 feet.

5. FUTURE PLANS

The plan is to implement this wave forecast method on an operational basis. Additional forecast points will have to be decided upon. Fetch lengths and mean depth values will be determined for these points. A decision must be made on what wind forecasts to use with the wave forecast equation.

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_____, 1970: Forecasting relations for wave generation. Look Lab., Hawaii, 1, 31-34.

Pore, N. A., 1979: Automated wave forecasting for the Great Lakes. Mon. Wea. Rev., 107, 1275-1286.

Saville, T., Jr., 1954: The effect of fetch width on wave generation. Technical Memorandum No. 70, Beach Erosion Board, Corps of Engineers, Washington, D.C., 9 pp.

Sverdrup, H. U., and W. H. Munk, 1947: Wind, Sea, and Swell: Theory of relations for forecasting. Publication No. 601, U.S. Navy Hydrographic Office, Washington, D.C., 44 pp.

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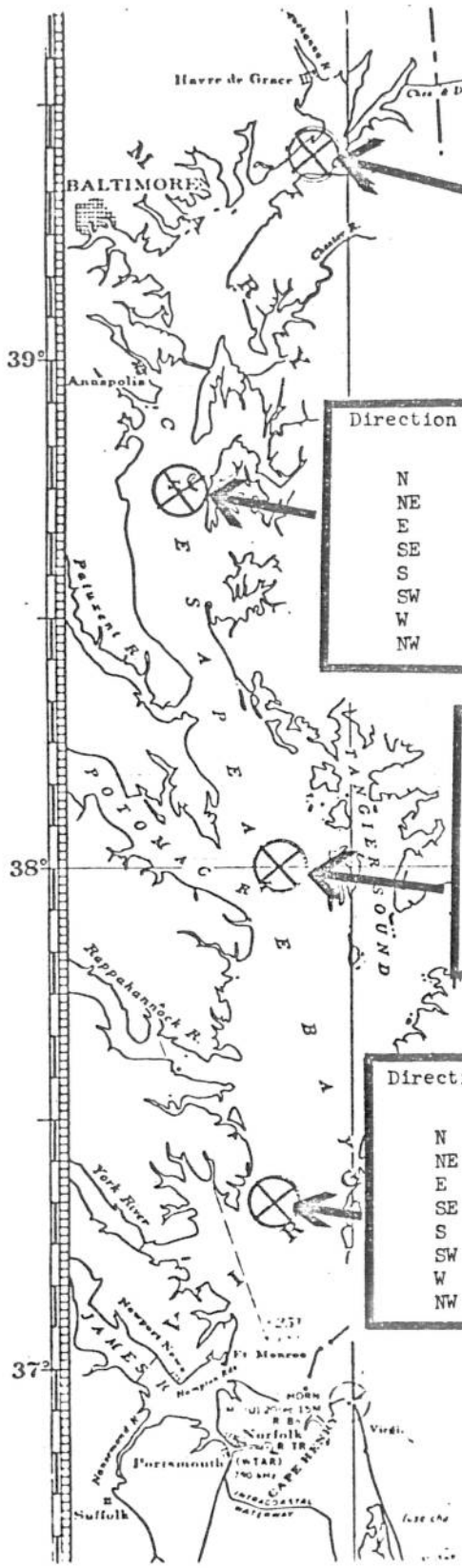

Direction	Depth	Fetch	Effective Fetch
N	10 ft	2 n mi	
NE	15	5	4 n mi
E	20	2	
SE	15	3	2
S	20	2	
SW	25	6	4
W	10	4	3
NW	10	2	

Direction	Depth	Fetch	Effective Fetch
N	45 ft	15 n mi	7 n mi
NE	30	14	6
E	5	4	
SE	20	5	
S	70	20	13
SW	35	7	
W	30	6	
NW	35	5	

Direction	Depth	Fetch	Effective Fetch
N	25 ft	14 n mi	
NE	25	8	
E	25	6	
SE	15	10	
S	40	65	26 n mi
SW	45	7	
W	40	14	7
NW	40	11	

Direction	Depth	Fetch	Effective Fetch
N	40 ft	54 n mi	28 n mi
NE	40	14	
E	45	7	
SE	40	11	
S	30	24	18
SW	25	15	
W	30	5	
NW	25	5	

Figure 1. Estimated average depths, measured fetch lengths, and effective fetch lengths for the four Chesapeake Bay points considered in this study.

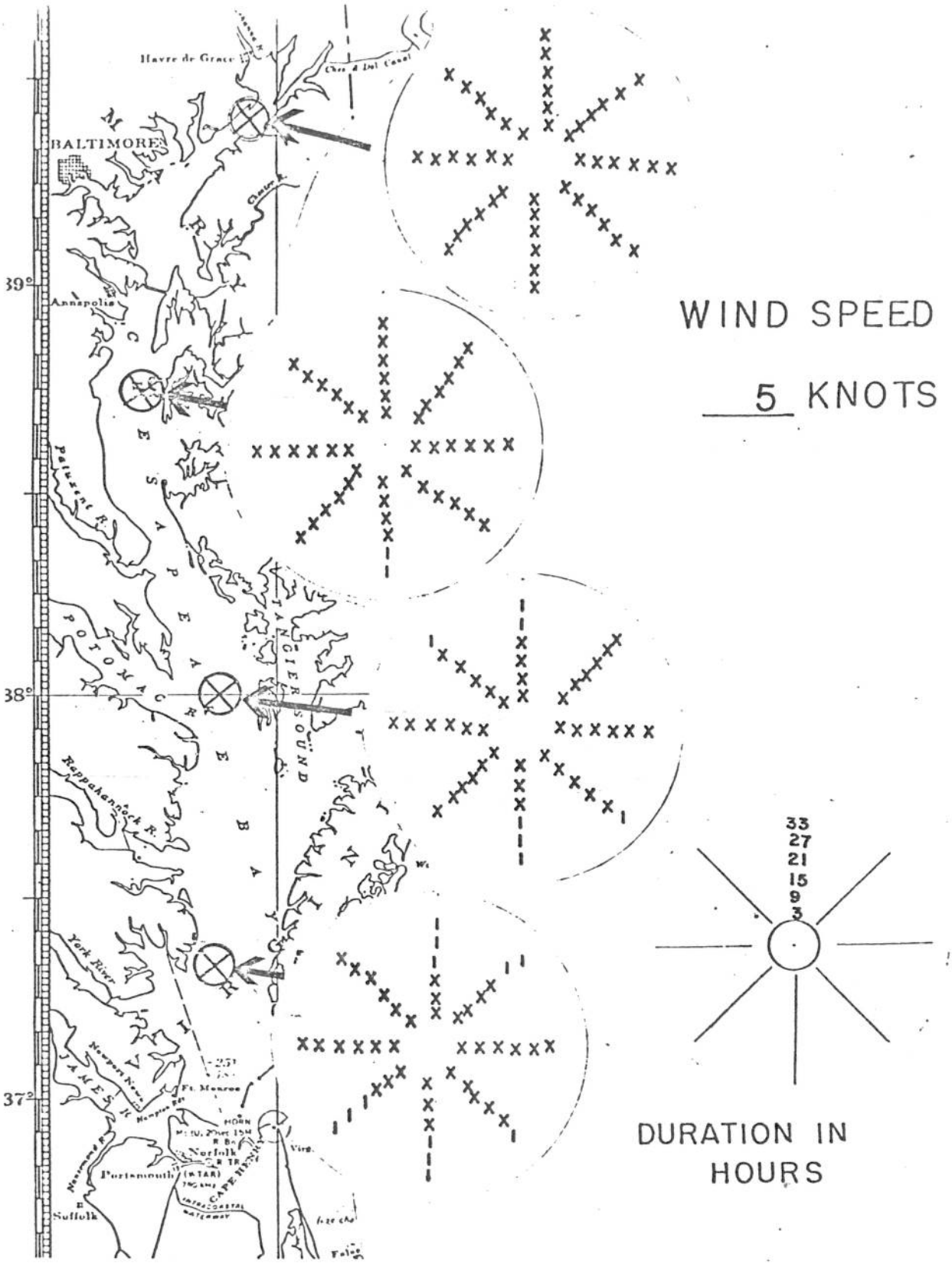

Figure 2 . Significant wave heights at four points for wind of 5 knots from eight directions. For each direction wave heights are presented for wind durations of 3, 9, 15, 21, 27, and 33 hours. Wave heights are shown in feet. Wave heights of less than 0.5 feet are shown by X's.

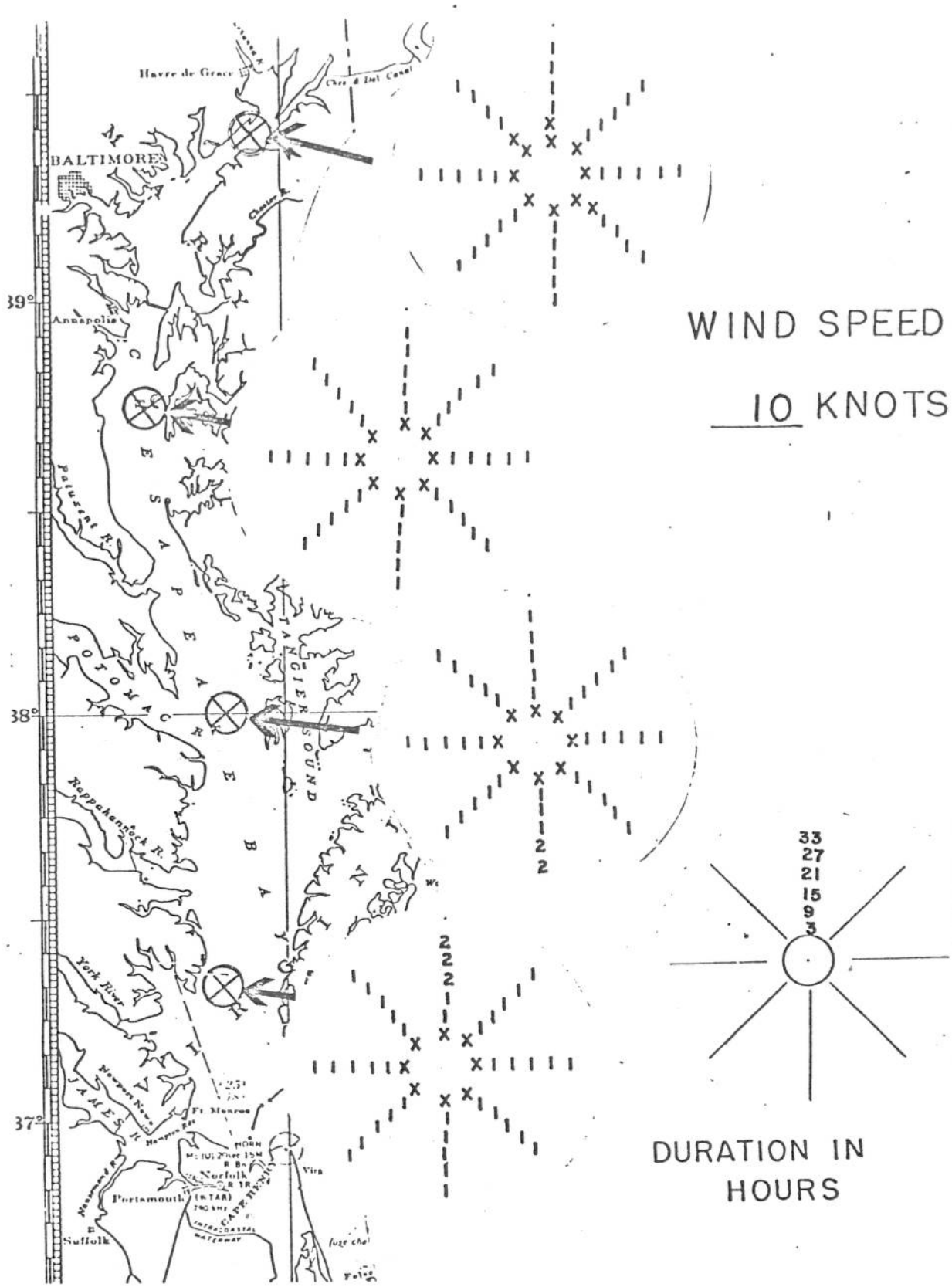

Figure 3 . Significant wave heights at four points for wind of 10 knots from eight directions. For each direction wave heights are presented for wind durations of 3, 9, 15, 21, 27, and 33 hours. Wave heights are shown in feet. Wave heights of less than 0.5 feet are shown by X's.

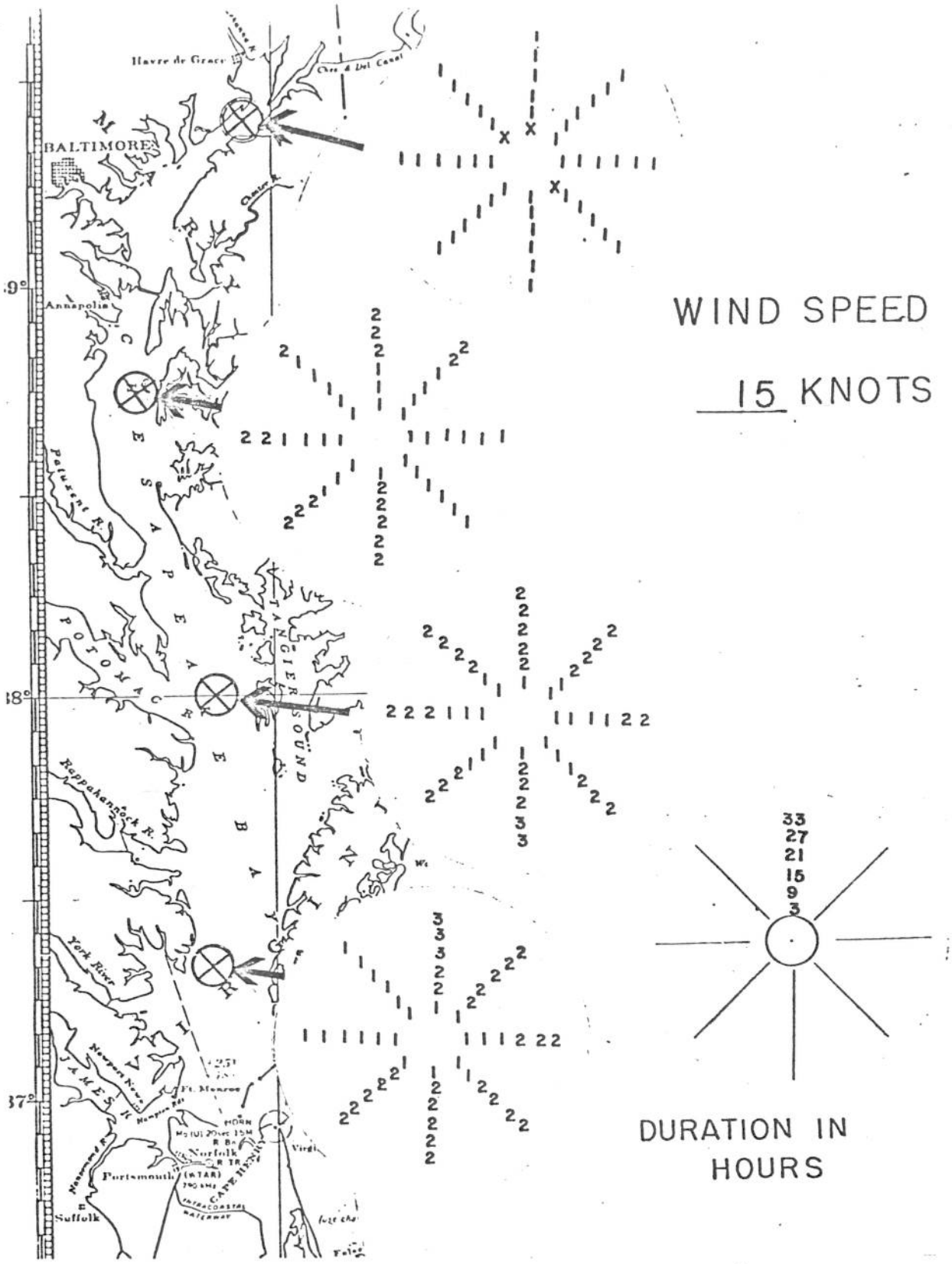

Figure 4 . Significant wave heights at four points for wind of 15 knots from eight directions. For each direction wave heights are presented for wind durations of 3, 9, 15, 21, 27, and 33 hours. Wave heights are shown in feet. Wave heights of less than 0.5 feet are shown by Xs.

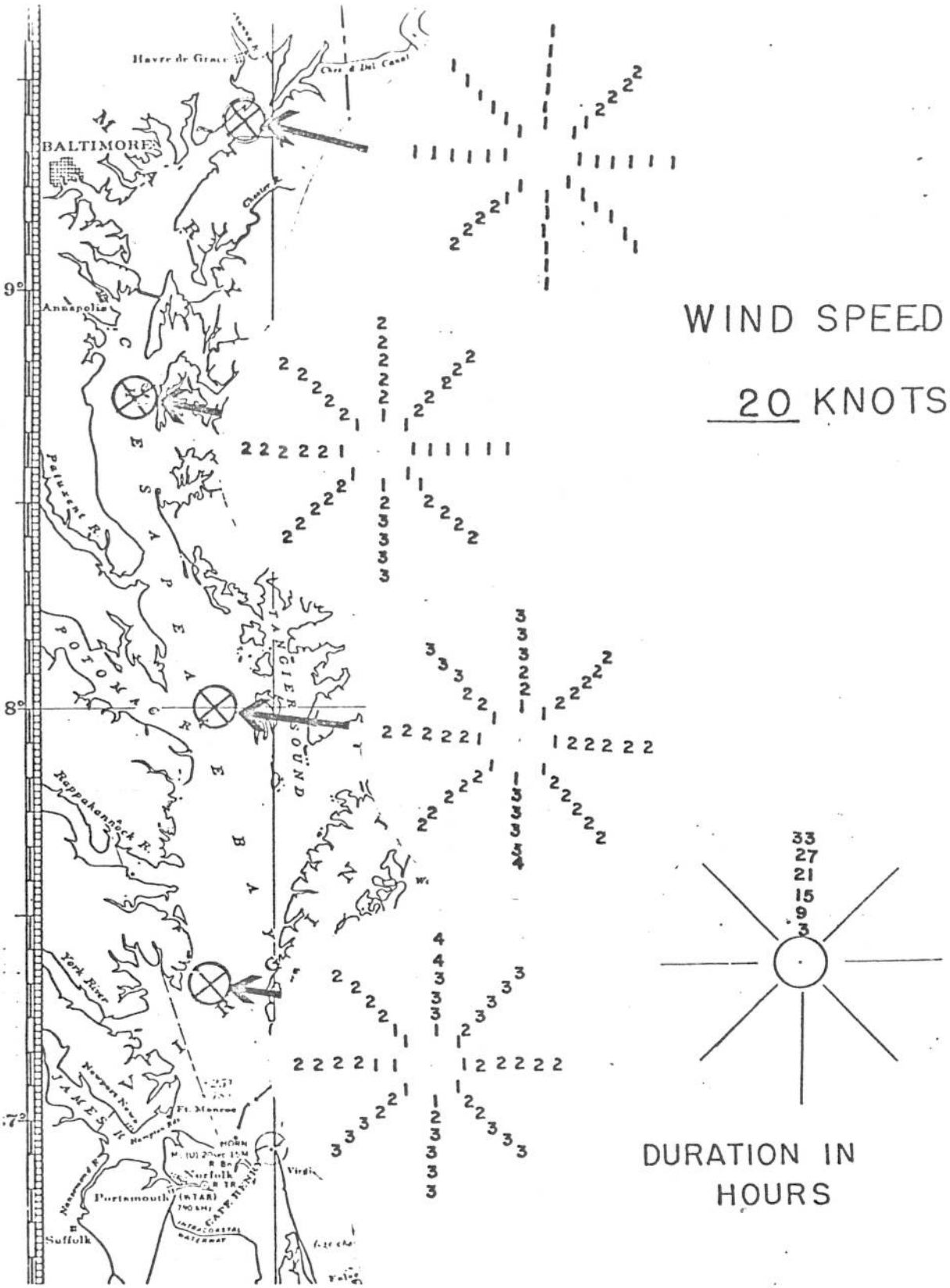

Figure 5 . Significant wave heights at four points for wind of 20 knots from eight directions. For each direction wave heights are presented for wind durations of 3, 9, 15, 21, 27, and 33 hours. Wave heights are shown in feet.

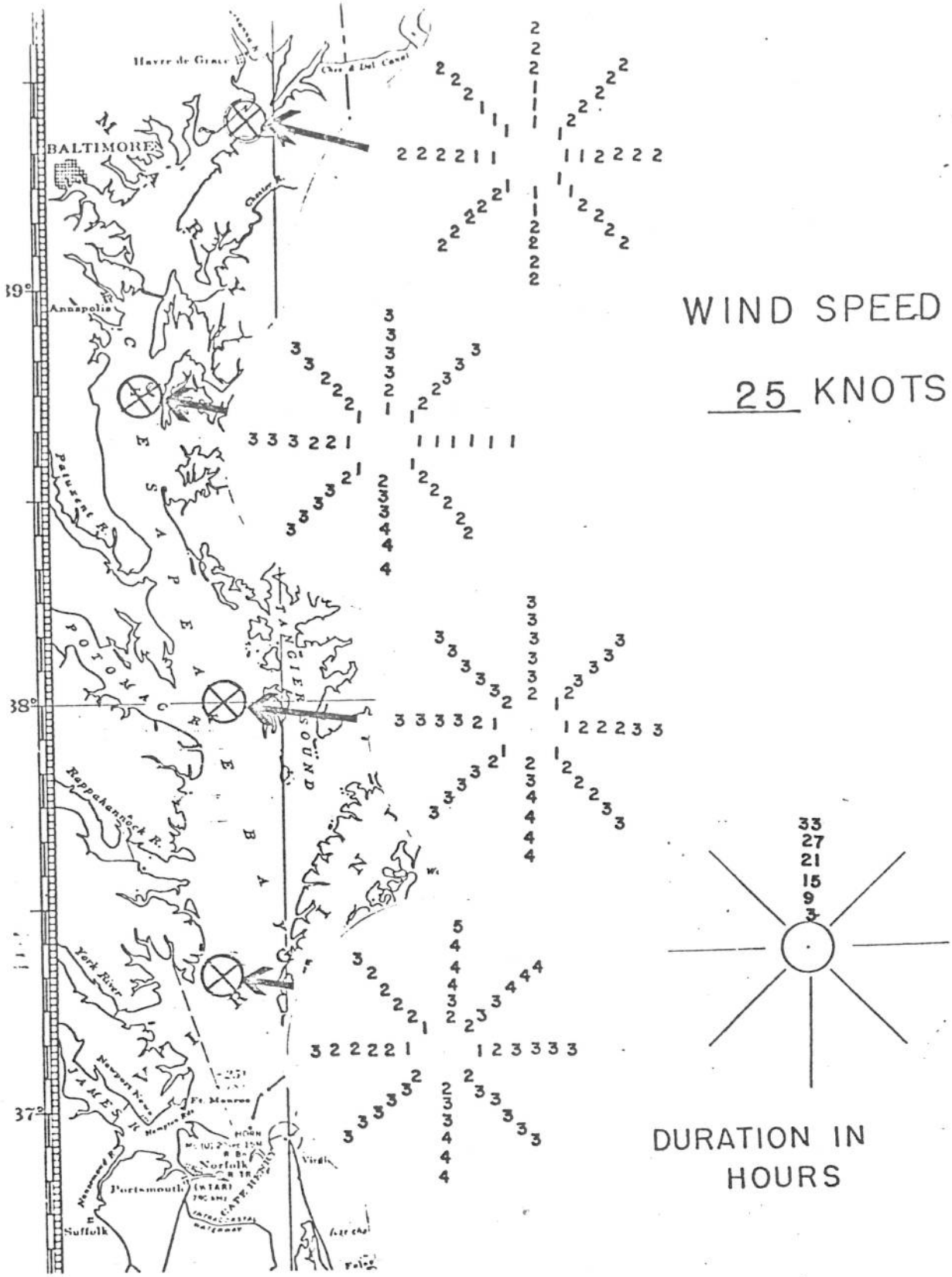

Figure 6 . Significant wave heights at four points for wind of 25 knots from eight directions. For each direction wave heights are presented for wind durations of 3, 9, 15, 21, 27, and 33 hours. Wave heights are shown in feet.

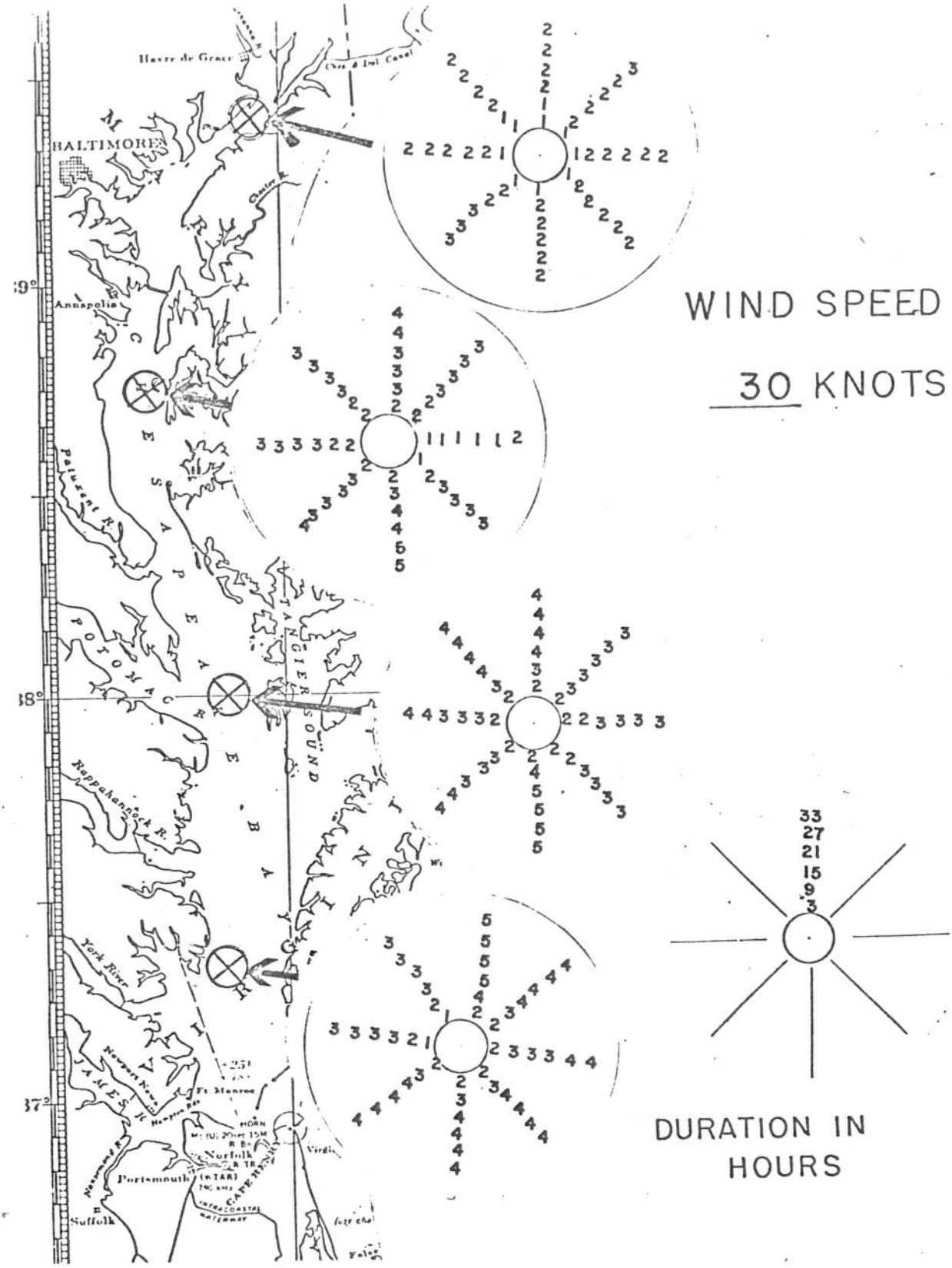

Figure 7 . Significant wave heights at four points for wind of 30 knots from eight directions. For each direction wave heights are presented for wind durations of 3, 9, 15, 21, 27, and 33 hours. Wave heights are shown in feet.

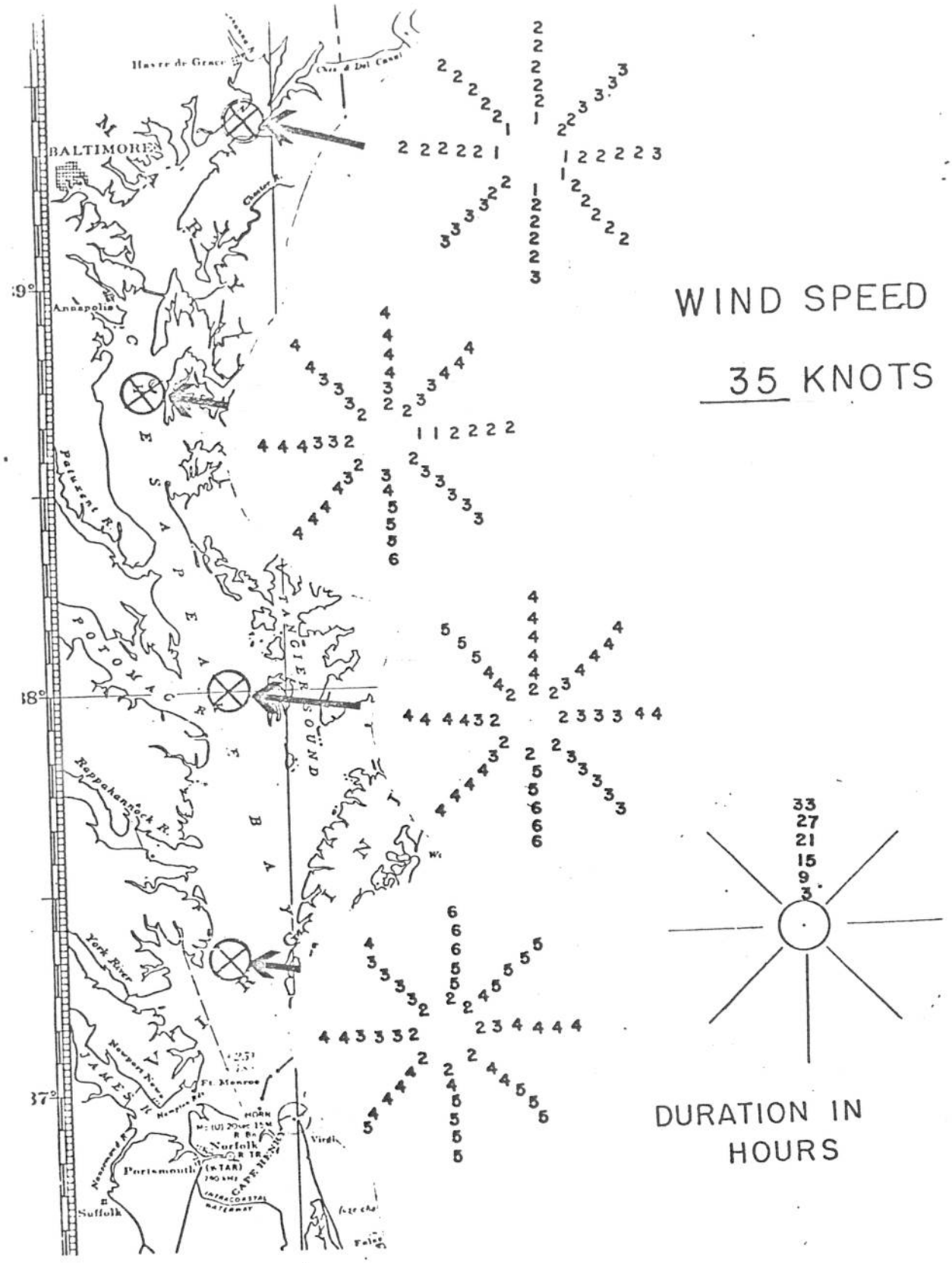

Figure 8 . Significant wave heights at four points for wind of 35 knots from eight directions. For each direction wave heights are presented for wind durations of 3, 9, 15, 21, 27, and 33 hours. Wave heights are shown in feet.

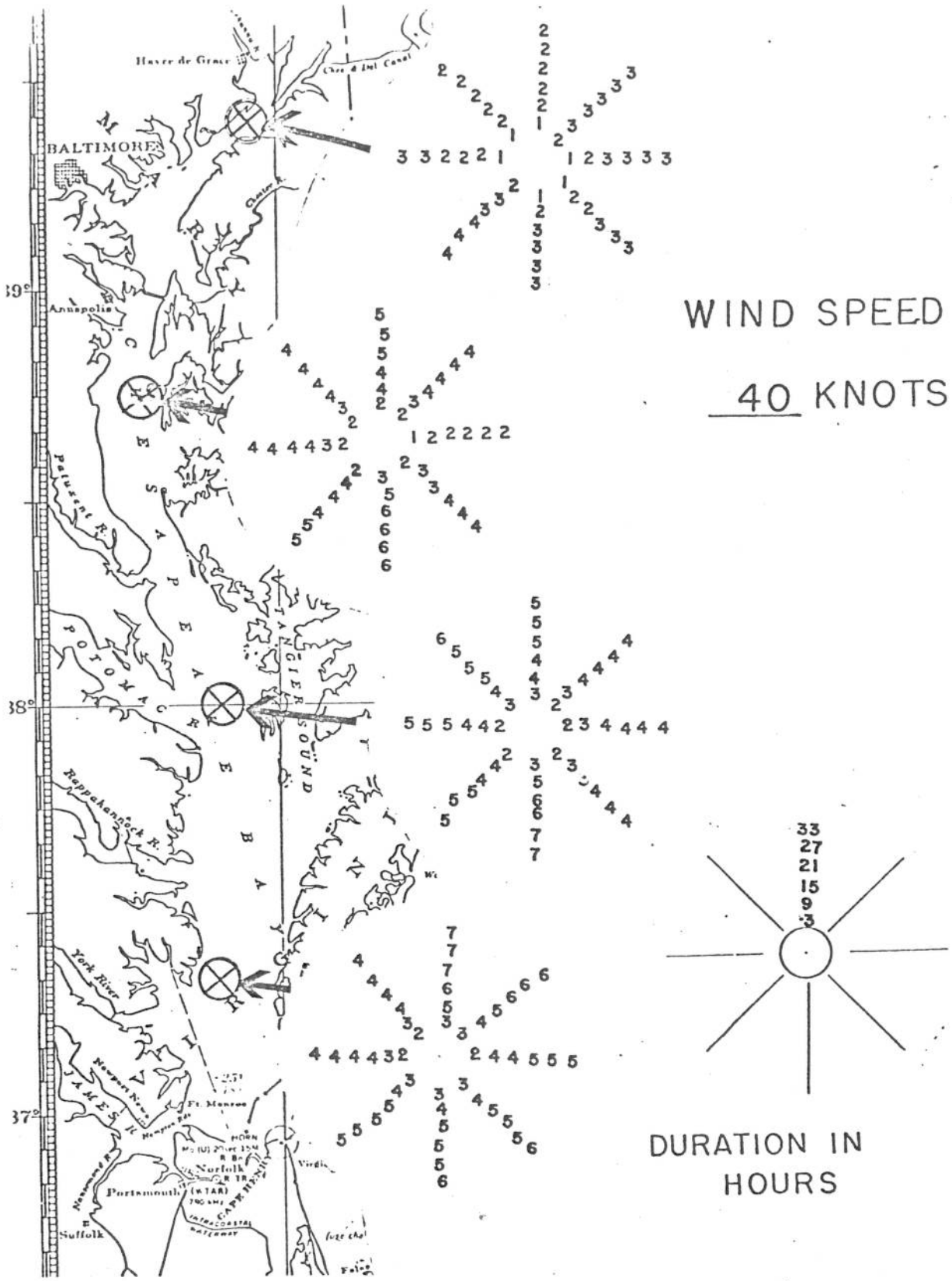

Figure 9 . Significant wave heights at four points for wind of 40 knots from eight directions. For each direction wave heights are presented for wind durations of 3, 9, 15, 21, 27, and 33 hours. Wave heights are shown in feet.

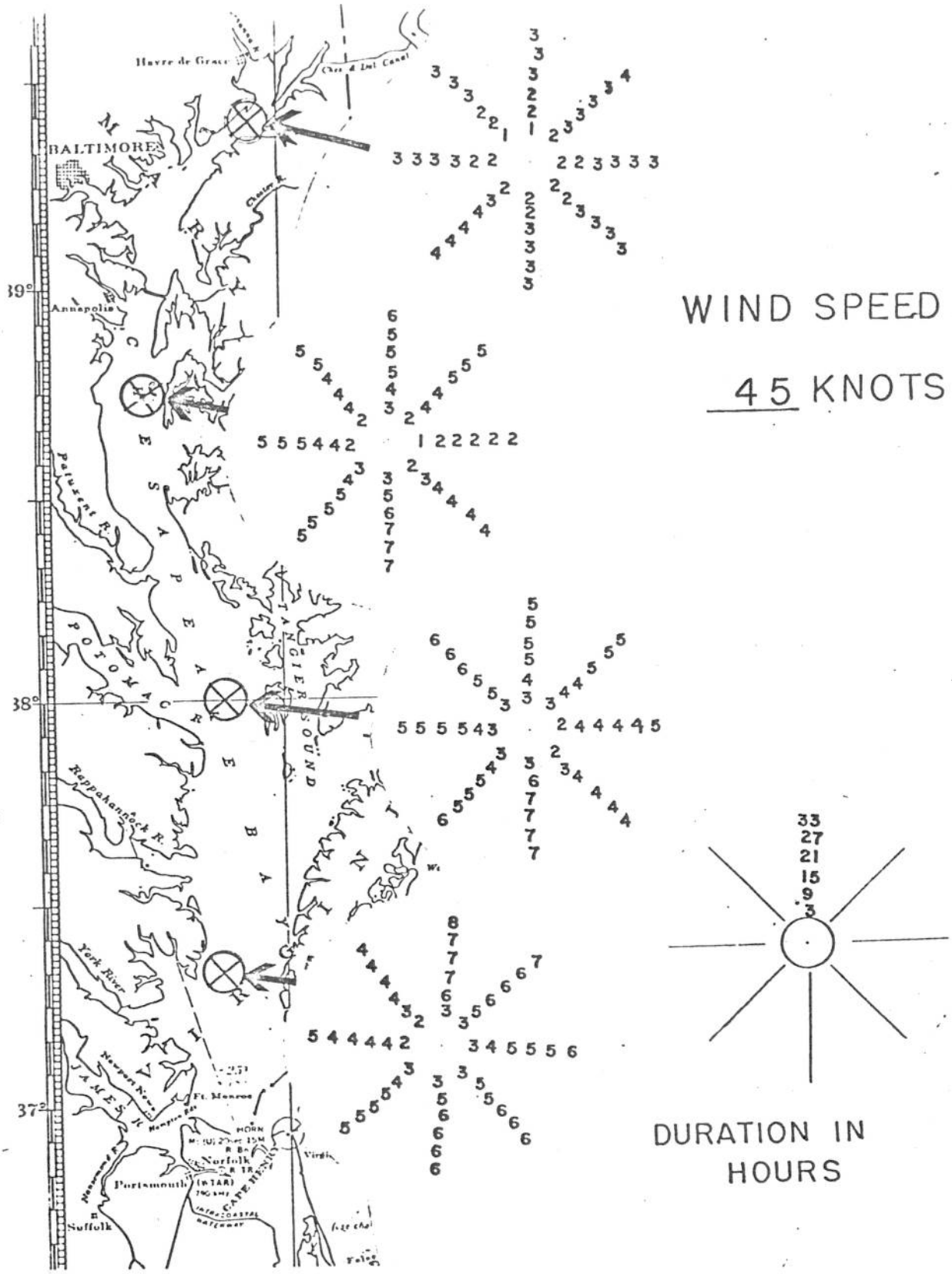

Figure 10 . Significant wave heights at four points for wind of 45 knots from eight directions. For each direction wave heights are presented for wind durations of 3, 9, 15, 21, 27, and 33 hours. Wave heights are shown in feet.

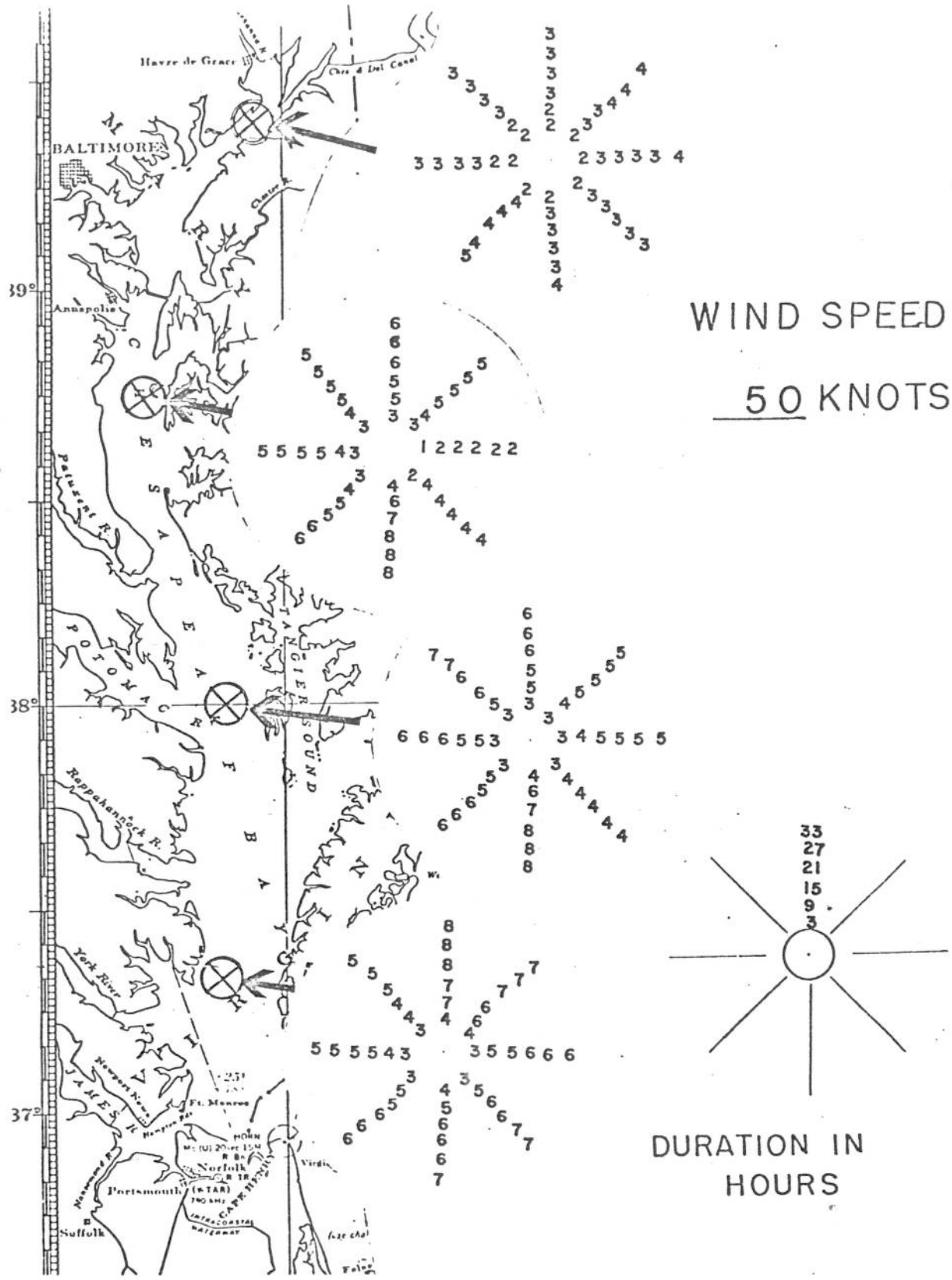

Figure 11 . Significant wave heights at four points for wind of 50 knots from eight directions. For each direction wave heights are presented for wind durations of 3, 9, 15, 21, 27, and 33 hours. Wave heights are shown in feet.

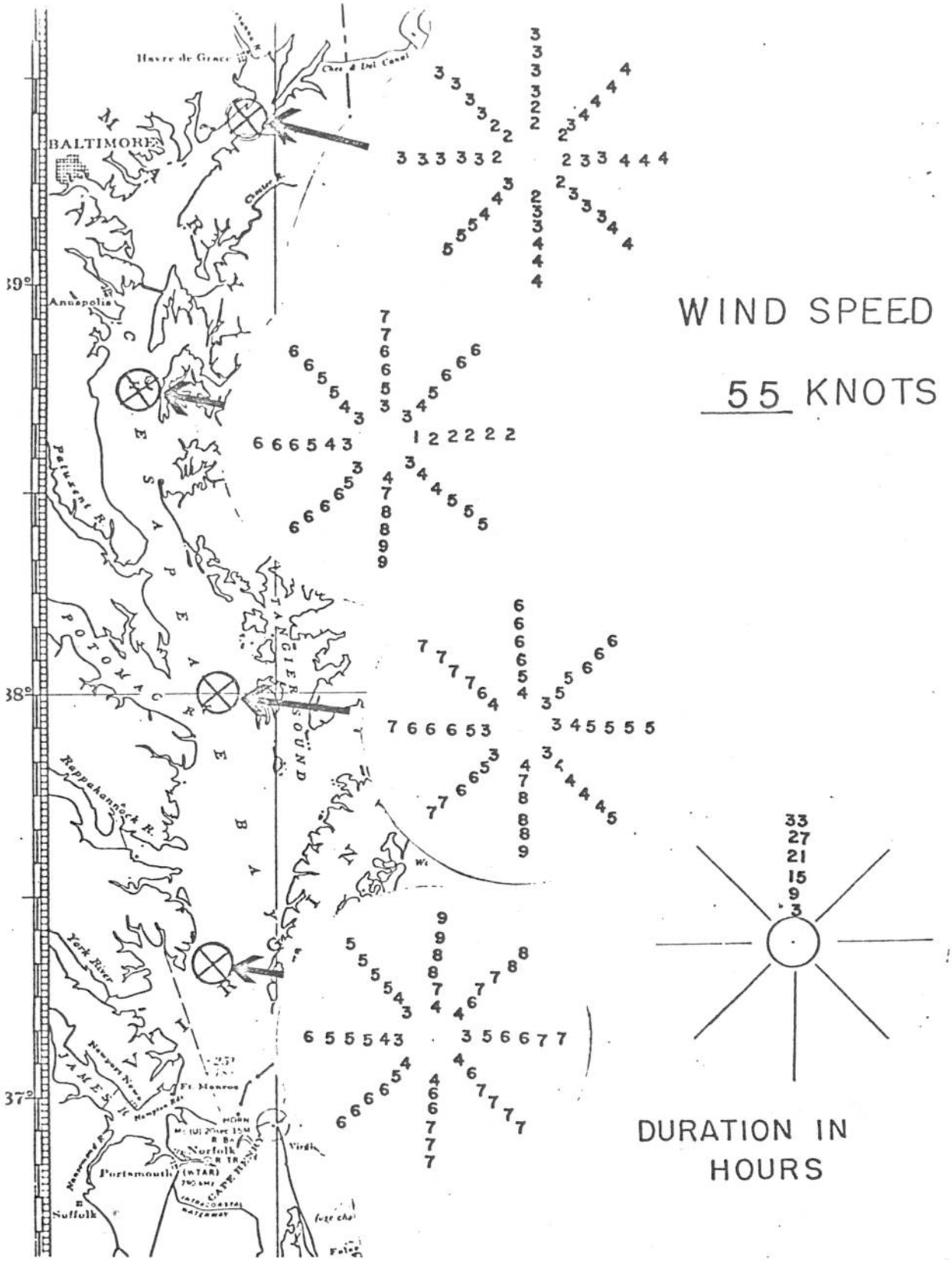

Figure 12 . Significant wave heights at four points for wind of 55 knots from eight directions. For each direction wave heights are presented for wind durations of 3, 9, 15, 21, 27, and 33 hours. Wave heights are shown in feet.

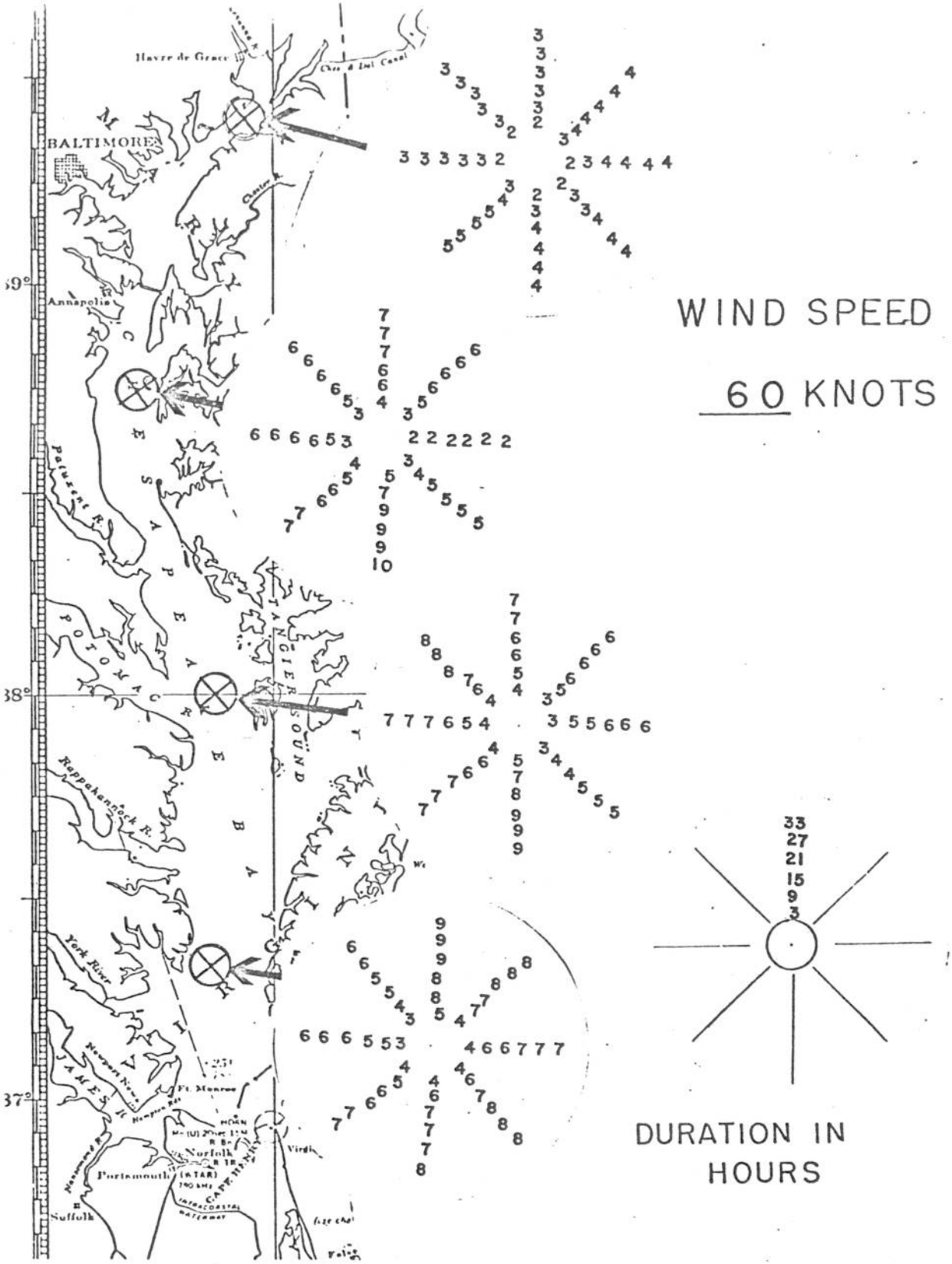

Figure 13. Significant wave heights at four points for wind of 60 knots from eight directions. For each direction wave heights are presented for wind durations of 3, 9, 15, 21, 27, and 33 hours. Wave heights are shown in feet.

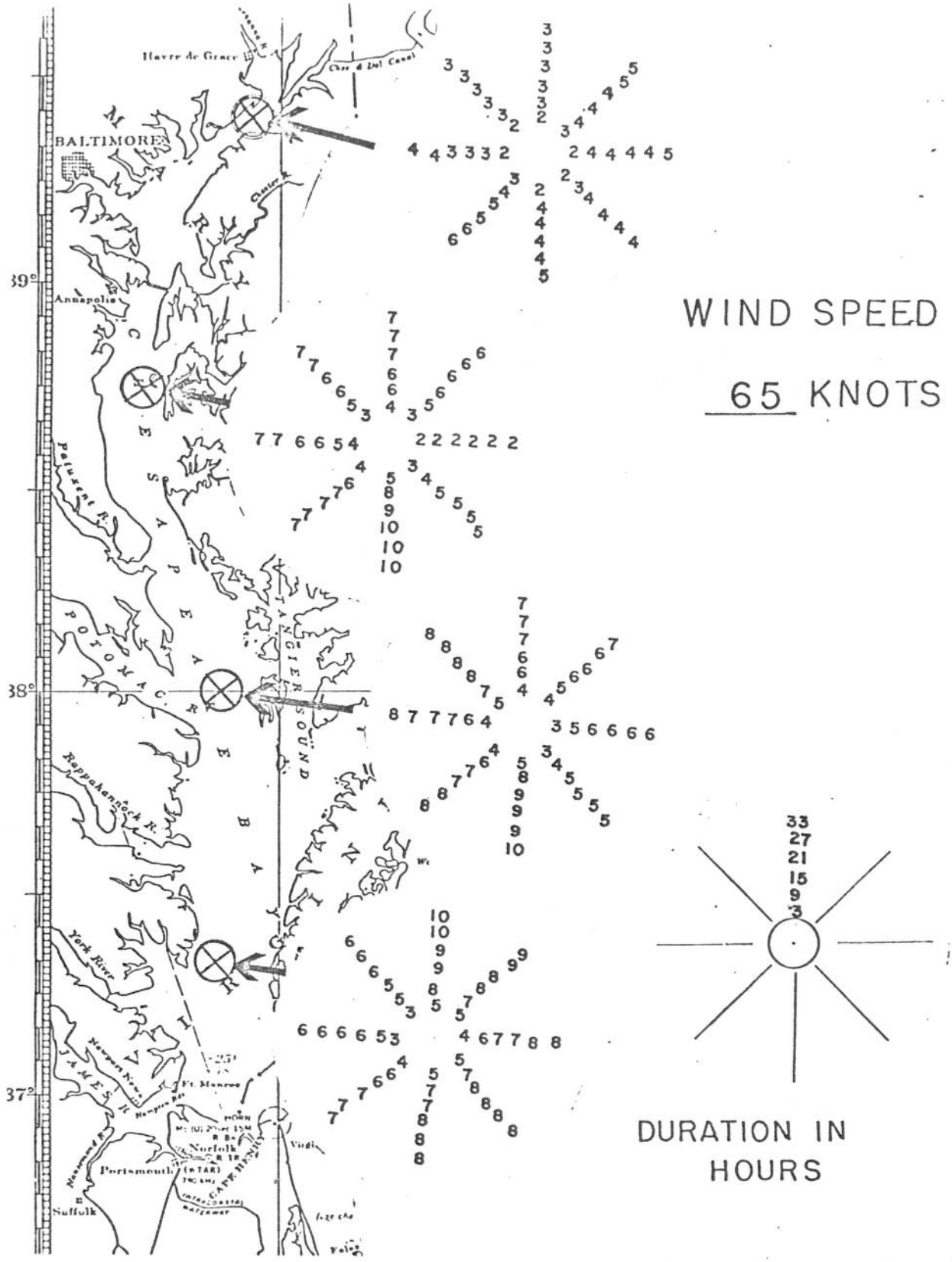

Figure 14 . Significant wave heights at four points for wind of 65 knots from eight directions. For each direction wave heights are presented for wind durations of 3, 9, 15, 21, 27, and 33 hours. Wave heights are shown in feet.

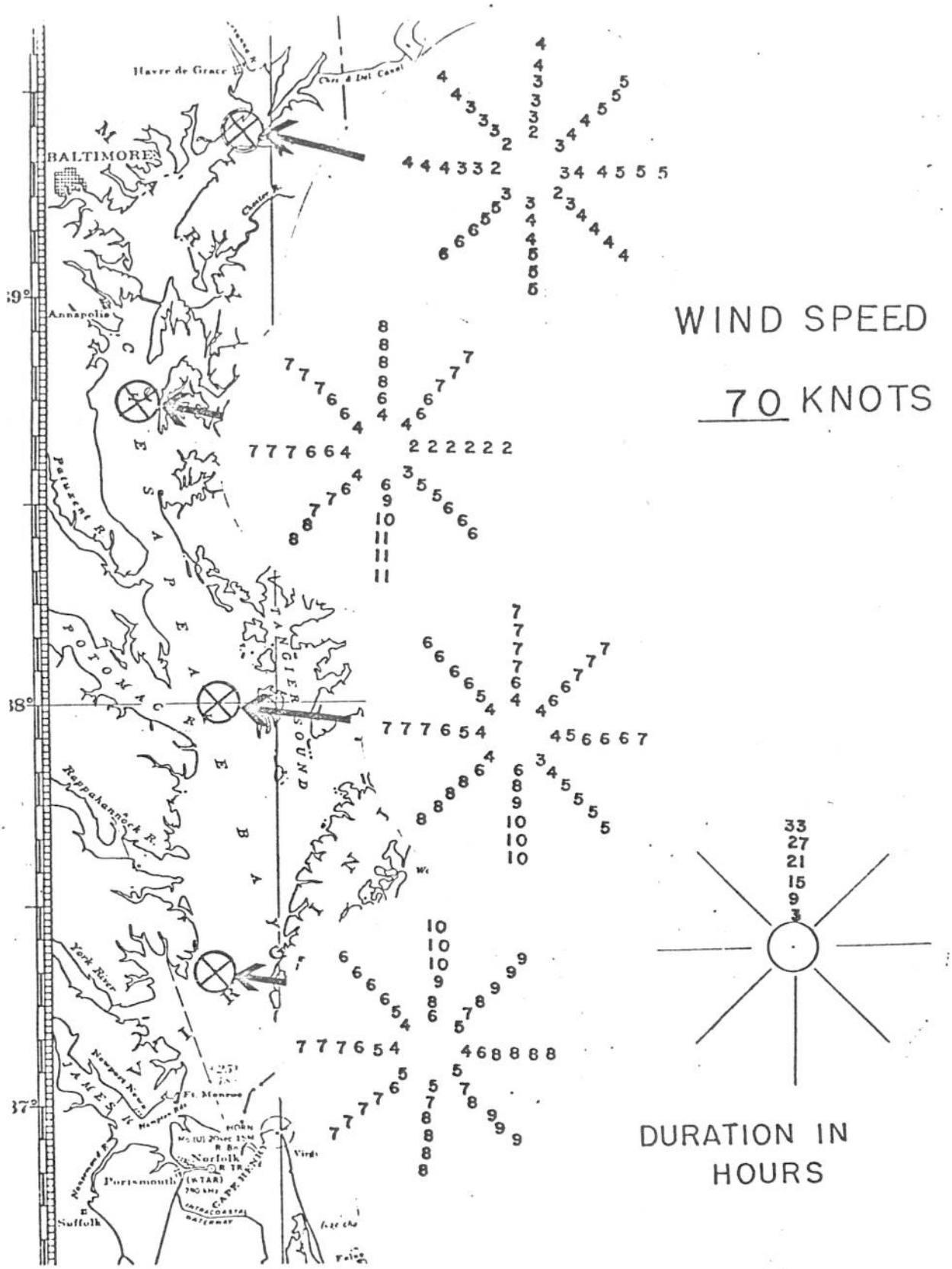

Figure 15. Significant wave heights at four points for wind of 70 knots from eight directions. For each direction wave heights are presented for wind durations of 3, 9, 15, 21, 27, and 33 hours. Wave heights are shown in feet.