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OF THE SPREAD OF POLLUTION
ON LONG ISLAND BEACHES

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ABSTRACT

In June 1976 large quantities of garbage and sewage-type debris
were washed ashore on most southern Long Island beaches. The float-
able debris, of unknown source, threatened industry and public health.
In an effort to trace the source, the trajectories of floatables from
a variety of hypothetical release points in the New York Bight were
simulated using a one-layer ocean model that computes currents, given
the bottom topography and the observed winds. It was then assumed
that the surface material moves as the vector sum of the currents
and 3% of the wind. It was found that the initial beaching was pro-
bably due to debris floating in the Bight Apex, and that material from
as far south as Atlantic City could have washed ashore during late
June. An examination of historical wind records indicated that the
persistent southwest winds observed during this period could recur
about each three years.

A Computer Analysis of the Spread of Pollution
Long Island Beaches

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I. Introduction

A computer model originally used at Brookhaven in the Regional Energy
Studies Program for assessing hazards to coastal regions from offshore
petroleum activities was used to simulate trajectories of floating debris
from a variety of hypothetical source regions in the New York Bight. The
area modeled extended from south of Atlantic City to **east** of Montauk Point.

The details of the model are available from the author. Basically,
it is a one-layer model that computes currents using the topography of the
area and observed winds as the driving force. It does not include a
"background" pressure force that causes a sluggish drift to the southwest
of a few centimeters per second. It is assumed that the surface material
moves as the vector sum of the current speed and 3% of the wind speed,
although the material could be moving at 2-5% of the wind speed. Never-
theless, comparisons with drift card data and current meter measurements
indicate that for material released south of Long Island that impacts the
beaches within a few days, the model results could be accurate within one
day and 15 kilometers. For material released within 25 kilometers of
Sandy Hook with travel times of 10 days, the error could exceed 3 days
because of the high frequency variability of currents and the effect of
the Hudson River. Several model results for this region must be rejected
because the confidence limits are unknown.

The complexity of the mechanisms involved in the transport and fate of the variety of debris found on the beaches cannot at present be simulated in detail and the effects of waves, tides and estuarine discharges were not computed. In addition, because the ocean is stratified during the summer, the model could not be used to simulate the transport of material deposited on the ocean floor.

The model serves as a useful tool for posing a large variety of questions and for selecting situations and events that merit further analysis with more comprehensive physical reasoning. Therefore, the results discussed later will be presented in terms of our confidence in the model's performance under varying circumstances.

The following questions were posed to the model:

· From assumed distributions at sea, what are the landing limits (dispersion cones), times, and probabilities associated with the wind history following the reversal from predominately northerly to predominately southerly directions (this occurred on the afternoon of June 6)?

· Assuming Hudson Estuarine sources, what distribution of material would be expected in the Bight at the time of wind reversal and the subsequent fate of such material?

· Assuming that a pulse of material from the Bay Park explosion was released through East Rockaway Inlet during Ebb Tide (00 - 0700 EST), what was the fate of such material?

· Assume that the spoils from the clean-up operations of the Bay Park explosion were deposited at the sewage sludge dump site, what is the fate of the surface material dumped (clean-up began June 3)?

We also examined the historical wind records at Brookhaven National Laboratory in order to see if there was anything particularly unusual about the meteorological situation that could have contributed to the severity of the beaching of floatable material on the Long Island beaches.

We used the observed 10 meter hourly winds from a BNL tower at Tiana Beach, just west of Shinnecock Inlet, both to drive the model and to compute the surface transport. The wind data is plotted as daily transport (KM/day) in Figure 1. This figure indicates that around June 6-7 and June 12-13 wind shifts occurred that would reduce the reliability of the model, since the data may not be representative of the true wind pattern over the entire New York Bight. The latter period, unfortunately, is when the fouling of the beaches began, but we have not yet obtained more comprehensive data.

The method of calculation was to scatter 45 hypothetical continuous sources south of Long Island, down the Jersey shore, and in the Bight Apex. Tagged particle releases were simulated each four hours from each source from 00 EST June 1 through June 28, which resulted in a data base of 7560 particles. A "hit" was counted if a particle came within 2 km of the shore and the particle was then frozen at that location, that is, the possibility that particles were floating along the shore was not considered. In addition, particles were not allowed to impact the Jersey shore within 40 KM of Sandy Hook.

The most striking feature of the results was the extreme variability of the currents throughout the period. We believe that this is real in the sense that nature behaves this way, but it also means that each trajectory must be treated as a statistic and not as an individual event.

In fact, it may be impossible to trace the exact particle path from a source. Our examination of the computer results to date, however, leads us to believe that this is not important, since all particles floating in a large area southeast of New York on June 3 and 4 impacted Fire Island in a week or so. We do not see how the errors in the model could alter this conclusion. A few samples of the computer output should put the analysis in perspective.

Examples of the computed current patterns are shown in Figures 2 and 3. On June 13 the currents were generally flowing to the southwest except for a clockwise gyre in the Bight Apex. However, by June 15, the pattern had completely reversed, with currents along the south shore of Long Island flowing to the east at about 10-15 cm/sec. These figures illustrate the variability discussed above and also the scale of the computer resolution. The grid spacing is 5.6 KM with N. Y. at the upper left and the shelf break at lower right. Examples of the computed trajectories are shown in Figures 4 and 5. Particles floating in the Apex at 00 EST June 5 circulated around to impact Fire Island about June 11. However, some material would have missed the Island altogether. The picture is quite different on June 21. Here, particles close to Long Island impacted within a day and particles 80 KM south could have hit Fire Island within 5 days.

II. Analysis of Results

Assumed Sea Distributions

The results are summarized in Figure 6. The code for the plot is at the upper right. The times shown are hours from 00 EST June 1. Anything floating in the shaded area from June 1 to June 24 would have hit Long Island. The travel times are interesting in that even for sources close

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to shore the times range from less than one to more than ten days, although 90% hit within three days. The release times of particles that hit also varied over a wide range. For example, nothing released at the position southwest of Montauk Point before June 12 hit the Island, but then 71% impacted. The percentages shown refer only to the particles released during the indicated interval. The dispersion cones were too wide to plot, but even particles released at closer positions were scattered over about 1/3 of the Island. This will be discussed in more detail below.

Another way of summarizing the results is shown in Figure 7. All hits for each 12-hour period from all points are plotted against the 12 hour resultant Winds. The hits prior to June 6 were those released near the Jersey coast that hit New Jersey. The hits around the 8th were those that were released after June 5. The hits beginning June 9 and 10 were those released on June 1-4. The break at June 12 is very important. We noted previously that the model winds may not be representative of those over the Bight. Since the observations were taken on the eastern end of Long Island the winds could have shifted a day later than at New York. This would have kept the particles released on June 1-4 floating for another day. During the period June 14-25, particles from nearly all sources were hitting with short travel times. The figure also shows that the problem dissipated after June 26, even though particles were still being released. These plots were done for each release point and could be restricted to any area of the coast.

Sludge Dump Site

All particles released from the afternoon of June 2 through June 23 in the vicinity of the sludge dump site landed on the south shore of Long Island, scattered from East Rockaway Inlet to Watch Hill. Material

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released on June 3 landed on a line 30 kilometers long from Sailors Haven east on June 10 and 11. Material released on June 4-7 arrived earlier, mostly before June 9 and tended to concentrate near Sailors Haven. Material released on June 11-17 landed on Jones Beach within 1-2 days. Material released after this landed from East Rockaway Inlet to Fire Island Inlet within 1-3 days. The model results indicate that floating material at the dump site in early June could have circulated for 7-10 days before impacting Fire Island. Because of the short travel distances and times from mid-June on, we do not believe that the model is seriously in error during this period. Thus, if floating material was at the dump site during this period, it should have been found closer to New York. For the entire period about 40% of the material released near the dump site impacted Fire Island.

The Bay Park Explosion

Possible paths from East Rockaway Inlet into the ocean could not be tracked. Instead, releases were made at 20 points in a 300 KM^2 area. All the particles released on June 3 and 4 ended up scattered along Fire Island in a week or so. For example, all particles from a release point 7 KM southwest of the Inlet landed within 15 KM of Sailors Haven on June 9 and 10. The uncertainties in an interpretation of this kind of detail are large, as discussed in the introduction. The particles were floating down the Jersey coast for a couple of days and took 5 or 6 days after the wind shift to reach Fire Island. Thus many of the particles were floating in the area of the "no hit" boundary condition. The trajectories look smooth, so it is possible that the wind transport was dominating the current variability. The model results imply that a more comprehensive analysis is required.

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The Hudson Estuary

The model says that material at the time of the wind reversal was scattered down the Jersey coast and in a large area of the Bight Apex. Particles released on June 3 and 4 impacted Fire Island in a week or so. Particles released after this hit the city beaches. Since this did not happen, the model cannot be used with any credibility for Hudson Estuarine sources without additional information on transport out of the estuary.

III. The Meteorological Analysis

Thirteen previous years of hourly wind data from the 355' Ace Tower at Brookhaven National Laboratory were analyzed for persistence to see if there was anything particularly rare about June 1976. Briefly, the situation prior to June 14 was not found to be particularly infrequent. However, during the period June 13 - 26 the winds had a steadiness that occurred only four times in the thirteen year sample.

Frequency distributions of

1) direction vs. the steadiness of the wind speed,

2) direction vs. the wind speed,

3) direction vs. the steadiness of the stress,

4) direction vs. stress

were calculated for 3, 6, 12, 18, and 24-day averages. In computing an "N" day period, a new "N" day was computed every day. The steadiness is the ratio of the vector wind and the wind speed summed for each hour of the period. (A mathematical transformation was used here in order to give enhanced resolution near unity.) If the vectors are random its value is zero, and if there is no change its value is one. The stress is the

mean of the square wind speed and is a measure of the strength of the wind to drive currents.

We selected the 6 and 12 day "steadiness of the stress" for illustration. Seven years of summer data are summarized in Table 1. The winds are generally southwesterly over 60% of the time and a six-day steadiness of up to 0.7 is not unusual. The results for June 1976 are shown in Table 2. The steadiness did not reach a high value until June 18 and then it remained high through the 25th. The 12-day steadiness is shown in Table 3 for the dates of similar events in the past. The events are not independent. For example, in June 1967, the steadiness remained above 0.7 for 4 days in a row. It is interesting that July 1975 was "worse" than June 1976. We are not aware of any problem with the beaches either then, or for the other three cases.

Table 1.　Six-day Steadiness of the Stress for Seven Years of Summer (SSW through WSW direction).

Steadiness interval	0-0.1	0.1-0.2	0.2-0.3	0.3-0.4	0.4-0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-0.10
Percent Occurrence	1.2	5	11	15.8	13	8.3	4.4	0.8	0.5	0.3

Total Percent of All Directions - 60.3%

Table 2. Six-day Steadiness of the Stress for June 1976.

Ending Day	Steadiness	Direction (degrees)
7	.07	50
8	.10	247
9	.18	257
10	.35	252
11	.56	246
12	.44	246
13	.36	235
14	.41	230
15	.47	226
16	.50	222
17	.51	218
18	.80	216
19	.78	215
20	.76	210
21	.76	206
22	.76	200
23	.78	199
24	.76	202
25	.75	212
26	.60	223
27	.50	240

Table 3. Southwest Events with 12-day Steadiness of the Stress
          Greater than 0.7 (not independent).

Year Analyzed	Events	Month	Direction
1960	0		
1961	0		
1964	0		
1965	0		
1966	0		
1967	4	June	209°-213°
1968	0		
1970	0		
1971	1	July	212°
1972	4	July	209°-211°
1973	0		
1974	0		
1975	4	July	195°-203°
1976	2	June	211°-215°

Figure 1.   Total wind transport for each day as observed
            at 10 meters at Tiana Beach (Eastern Long Is-
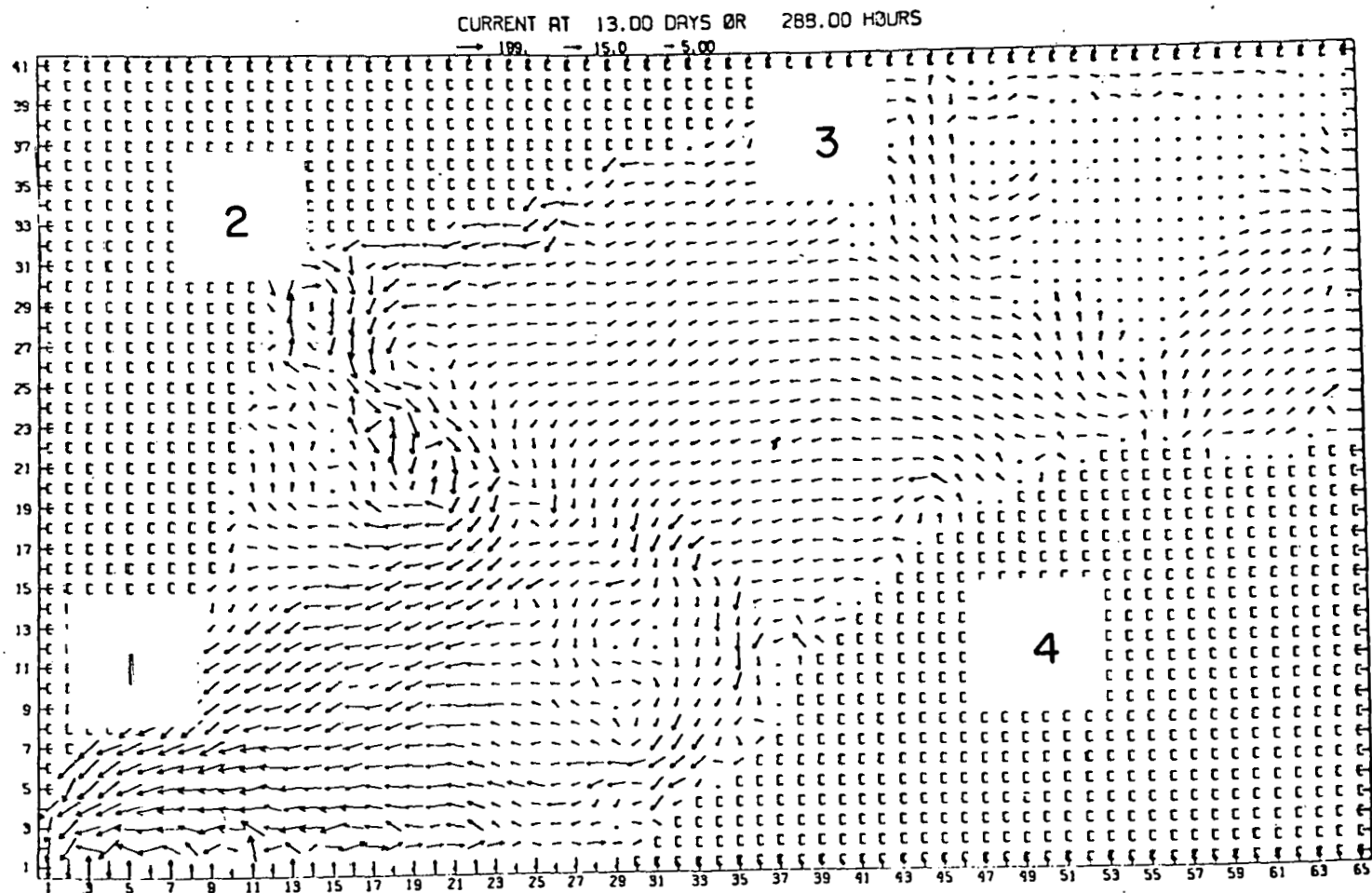   land).   Each day is marked with a +.

Figure 2. Computed currents on June 13 showing a south-west flow with a clockwise gyre near New York. The locations are 1) Atlantic City, 2) New York, 3) Montauk Point and, 4) deep ocean.
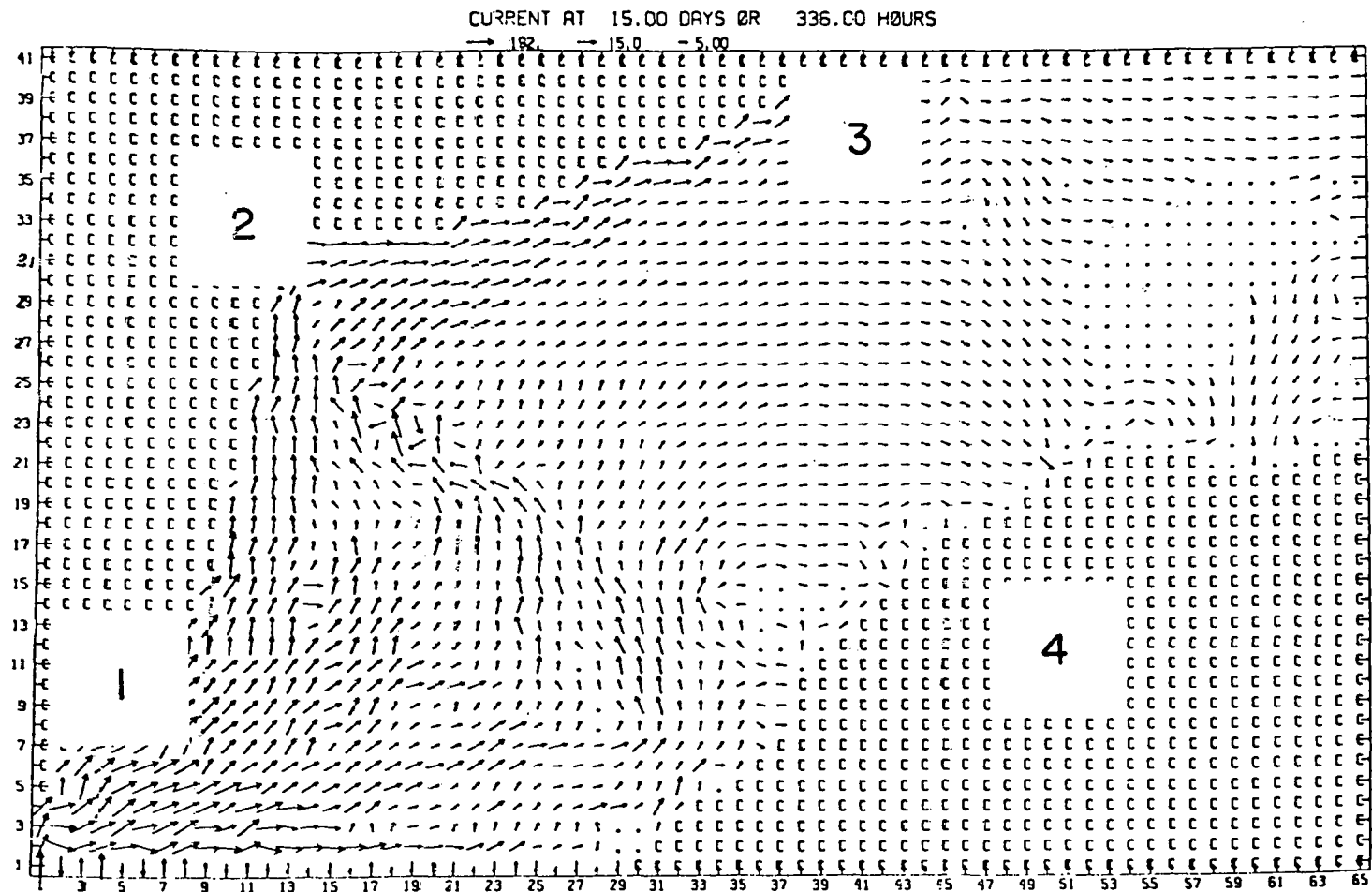
CURRENT AT 15.00 DAYS OR 336.CO HOURS

Figure 3. Computed currents on June 15. The flow has
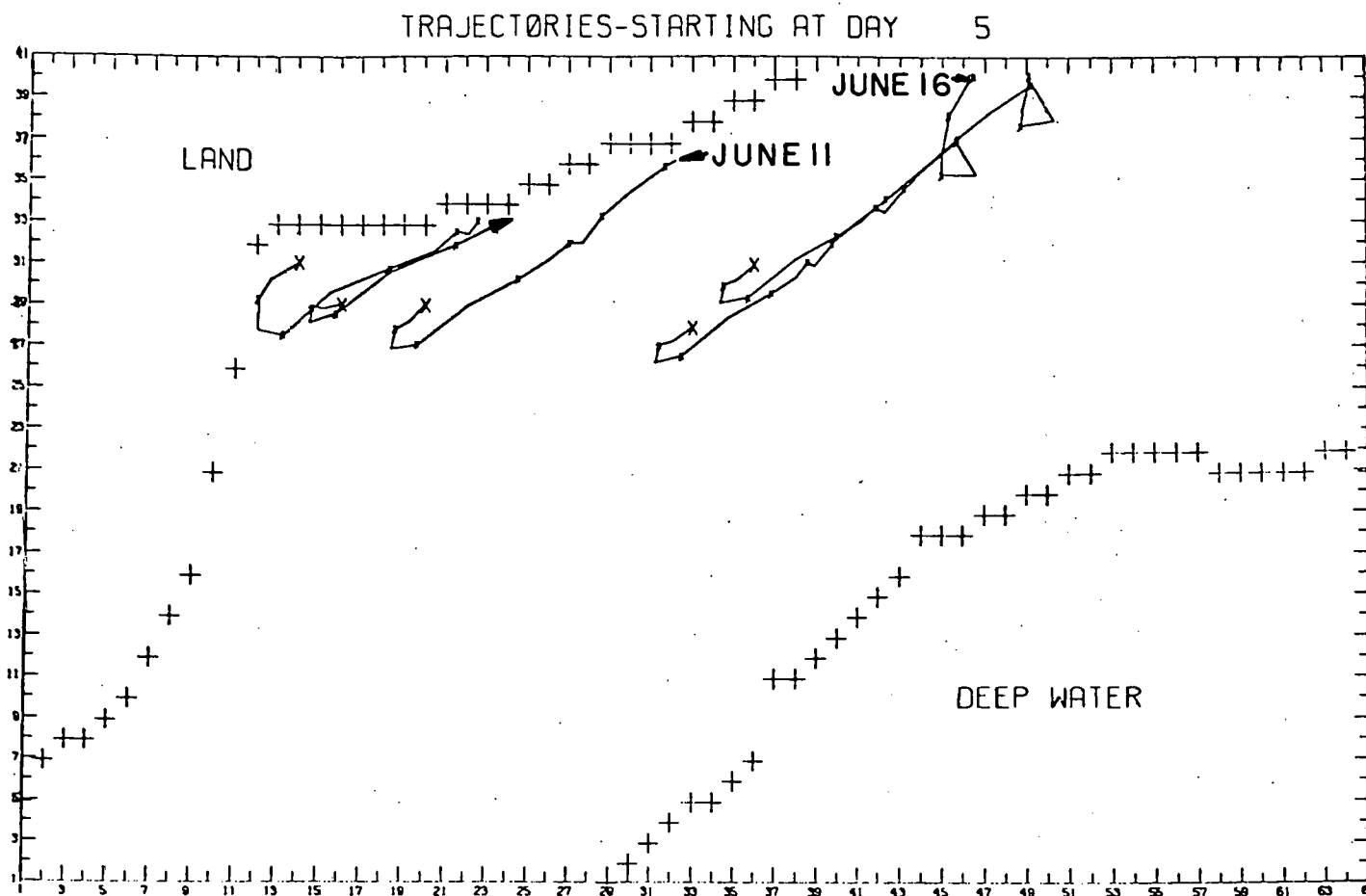changed to easterly. Locations are the same
as in Figure 2.

Figure 4.   Hypothetical trajectories starting 00 EST
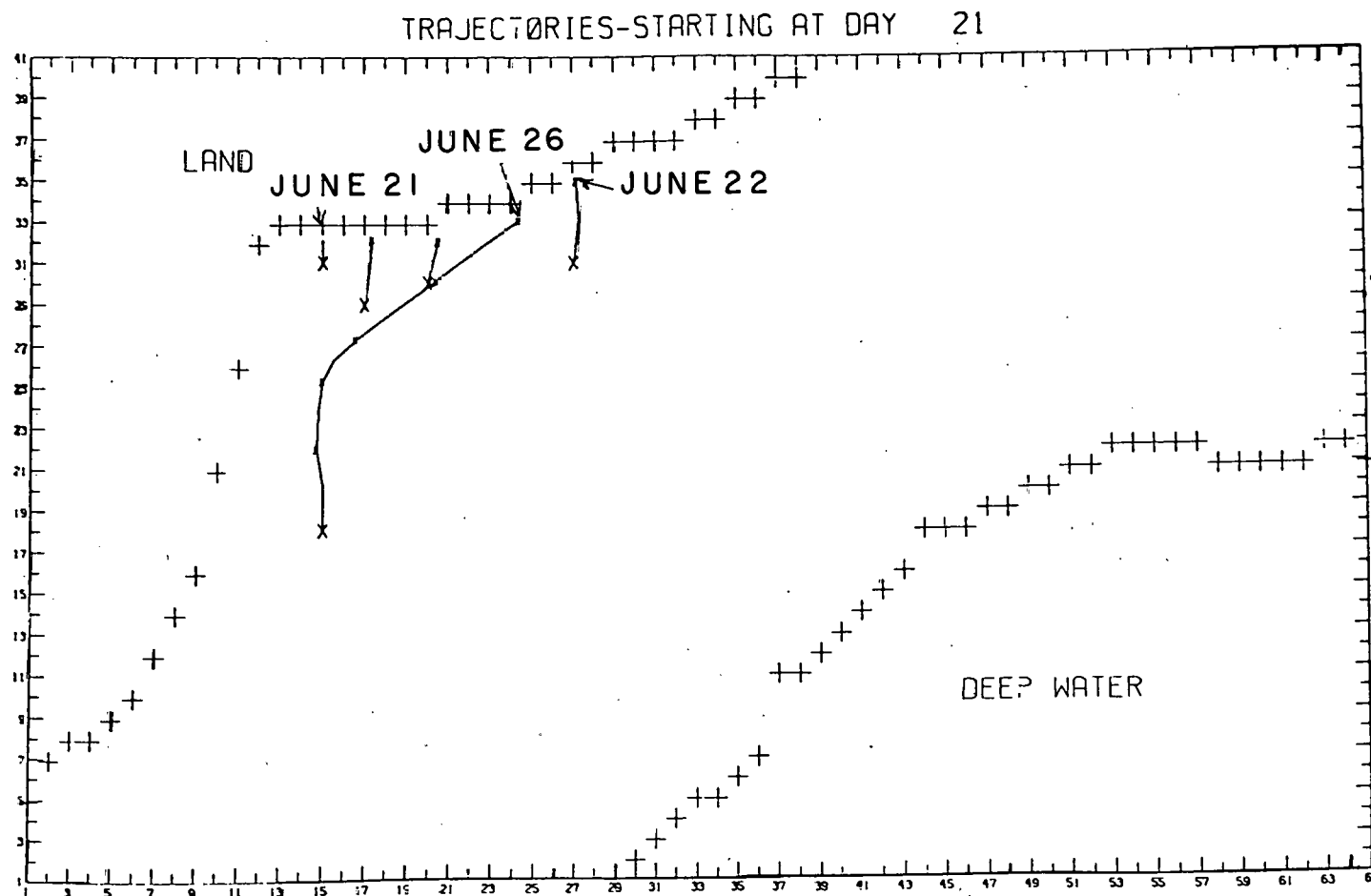June 5 for sample release points. Each
day is marked with a +.

Figure 5. Hypothetical trajectories starting 00 EST
June 21. Floatable 80 KM south of New York
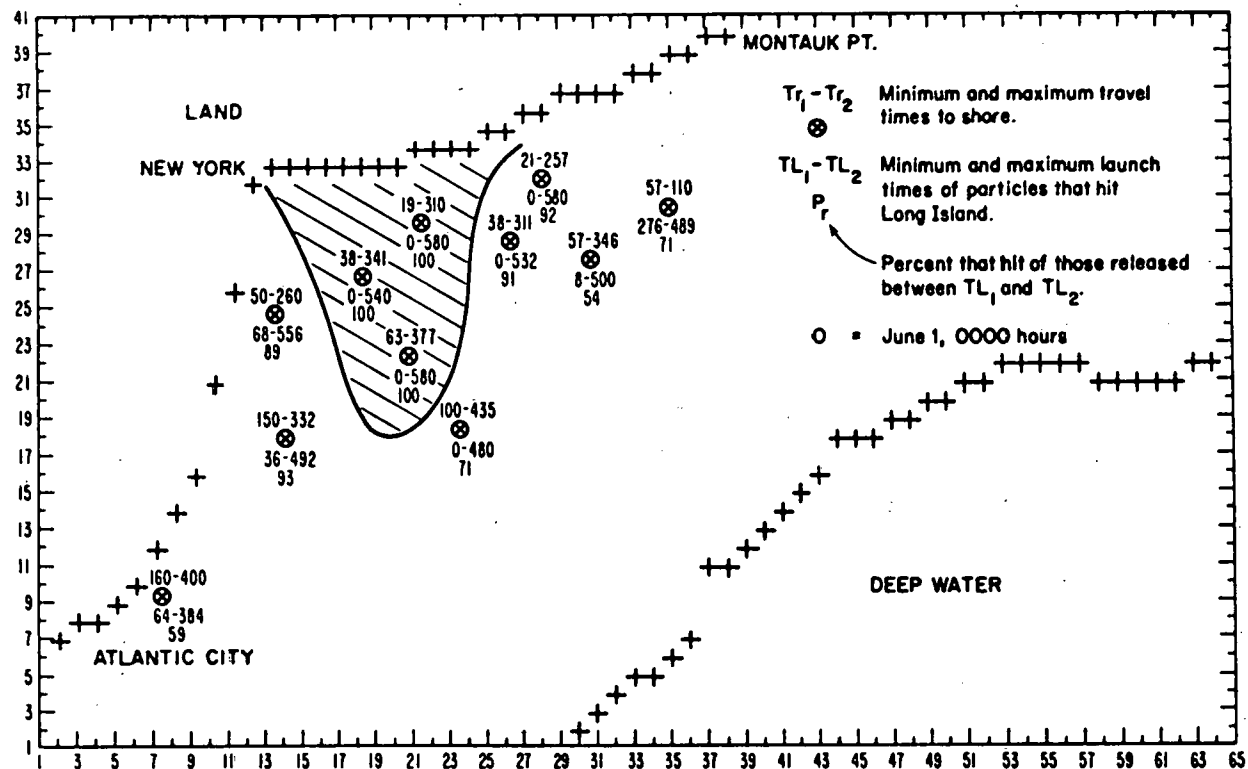could have hit Fire Island in 5 days.

Figure 6. A statistical summary of all trajectories
for 11 of the 45 release points. Time is
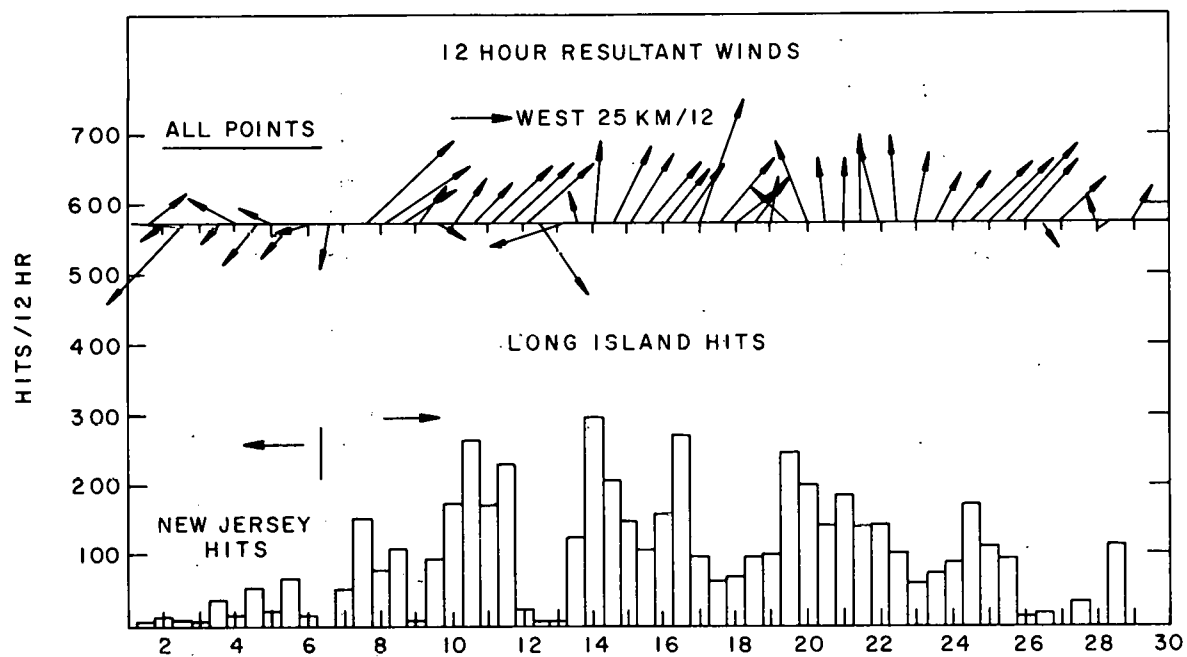in hours for 00 EST June 1. The code is
at the upper right.

Figure 7.   A summary of all hits from all locations
            plotted against the wind vector. The in-
            terpretation of this figure is discussed
            in the text.