LONG ISLAND SPILL TRAJECTORY STUDY

by

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Report to

Regional Marine Resources Council

Nassau-Suffolk Planning Board

28 February 1974

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AP - Please see that I get these before they go to CZIC. RG

attached

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April 9, 1975

Mr. Richard Gardner
Office of Coastal Zone Management
NOAA
Rockville, Md. 20852

Dear Mr. Gardner:

As a result of our Federal Project Advisory Committee Meeting on HUD Contract H-2050R held in Hauppauge on April 3, 1975, I am sending you under separate cover copies of the following reports for your information and review:

1. Long Island Spill Trajectory Study;
2. Potential Biological Effects of Hypothetical Oil Spills Occurring in the Nearshore Waters of Long Island's South Shore; and
3. Probabilistic Trajectory Assessments for Offshore Oil Spills Impacting Long Island.

These reports were produced as part of the Nassau-Suffolk Regional Planning Board's study on the implications and impacts associated with the development of potential oil and gas reserves on the Atlantic Outer Continental Shelf.

Should you have any comments on these reports, I would appreciate hearing from you.

Sincerely,

Lee E. Koppelman

Lee E. Koppelman
Executive Director

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Purpose

Oil spills can be transported many miles from the site of an accident by the action of the winds, waves, and currents found in the offshore region. Any proposal to develop petroleum deposits in the offshore region must therefore be viewed from the standpoint of the possibility of spills originating at the development site and eventually impacting the shores of nearby coastal communities. Such a possibility is of great importance to coastal communities because, as was pointed out in "The Georges Bank Petroleum Study," (Offshore Oil Task Group, 1973), these communities are in the unenviable position of bearing a potentially significant portion of the cost of the development, while the benefits will be distributed rather uniformly over a much larger group. Furthermore, the costs incident on coastal communities are typically associated with the disruption of esthetic values, or perhaps in the impaired viability of the local ecology. Schemes for rewarding due compensation for these effects are highly controversial. Many would hold that no compensation is adequate.

In view of the uncertainties and inequities involved, a key issue for coastal zone planners is therefore what are the risks involved in any particular offshore development and where are they centralized. With respect to the possible discovery of petroleum deposits in the region lying to the south of Long Island, the key questions for Long Island planners are therefore which offshore sites are likely to expose the beaches of Long Island to spills and which are not.

In order to answer this question fully, we need both a complete description of the mechanism by which oil is transported, and a statistical description of the phenomena driving this (transport) mechanism. Unfortunately, we do not at present understand either well enough to address the question except in a very approximate form. The answer to the question therefore must be phrased in light of what we do know, and how we might improve the answer if we should find the uncertainties associated with the analysis of critical importance.

Without going into great detail, this report will therefore discuss the uncertainties, present a reasonably simple model that would appear to represent all the important effects, and make some predictions of which regions in the offshore area are of interest to Long Island planners from the standpoint of oil spill exposure. As we shall see, a critical variable in the simple model proposed is the average transport imparted to an oil spill by those motions of the underlying water that are essentially uncorrelated with the wind. The sensitivity of the results to this parameter will be discussed.

Uncertainties

Despite the ten or fifteen papers available on the subject of oil spill transport on the ocean, it is fairly clear that we do not understand how the waves passing underneath an oil slick, the wind blowing over an oil slick, and the gross motions of the underlying water combine to move the oil. In fact, we find that the motions of the water lying right at the air-sea interface in the absence of oil are still the subject of much current research (Lee, 1972, and Dorman, 1971).

Some of our ignorance with respect to oil spills is no doubt attributable to the novelty of our concern about oil spillage on the seas. It wasn't until the "Torrey Canyon" grounding and subsequent sinking (1967) that oil spills became important to the world at large. Since that time the number of tests involving the planned release of oil in the offshore region has been limited to no more than twenty, and these tests have usually had very specific goals associated with immediate operational problems, e.g., can we spot the oil on the surface using remote sensing devices (infrared, ultraviolet, and microwave scanners).

The available literature has tended to attribute the velocity imparted to the slick by the wind to the formation of a simple wind-induced surface boundary layer. A number of things seem to be responsible for this. First of all, an after-the-fact analysis of the trajectories of the major oil slicks of the "Torrey Canyon" disaster showed that the path of the oil at any instant could best be estimated by taking the vectorial sum of the underlying current velocity and 3.4% of the surface wind velocity (p. 150, Smith, 1969). Secondly, Wu's (1968) laboratory studies indicate that wind blowing over a clean water surface generated surface currents ranging from 3% to 5% of the wind speed, depending on the wind speed. Moreover, Van Dorn's (1953) study of pond set-up included some data indicating that even if we suppress some of the wave motion with a surface film, we still get surface drift velocities similar to 3% of the wind speed. Finally, Hoult (1972) has presented a very simple argument that if logarithmic, constant stress boundary layer profiles are formed in the air and in the water simultaneously, then the two profiles will differ only by a scaling factor equal to the square root of the ratio of the densities of air and water. This value is also approximately 3%. Unfortunately, this conjunction of similar values may amount to little more than happy coincidence.

There can be little doubt that Hoult's argument does indeed explain a major portion of Wu's observations. Furthermore, the existence of logarithmic profiles in surface wind boundary layers and in the underlying water have been verified in field observations reported by Dorman. This is about all that is required to validate the argument as it applies to water with a clean surface. However, these results do not apply to regions in which oil films cover the surface simply because it is known that the logarithmic behavior of the surface wind boundary layer collapses (see Ruggles, 1969, p. 40). Furthermore, Van Dorn's study also demonstrated that the shear force exerted on the surface of a pond having a thin surface film is only about half that observed on a pond having a clean surface. This indicates that Wu's results probably have only a qualitative bearing on our problem. Finally, Van Dorn's observation of the surface drift may be explained by invoking the arguments of Phillips (p. 38, 1969) regarding oil slick drift as induced by the action of suppressing waves.

This leaves us with only one really hard piece of information and that is the "Torrey Canyon" analysis. This, however, is a highly empirical observation. Judging by the comparison of observed and predicted trajectories in Figure 37 of Smith (1968), we can see that on some days a wind drift factor of 2.5% might have yielded a better fit, while on others, 4.5% might have been appropriate. Without a better understanding of the transport mechanism it is speculative to choose any particular value. In short, it is not at all clear that the present literature explains oil slick drift properly.

In addition to the uncertainties surrounding our understanding of oil spill transport, we also have the problem of specifying the motions of the waters in the offshore region. A brief listing of the type of motions we should like to consider would include tidal motions, geostrophic motions, and wavelike motions of either the inertial type or the Kelvin (or Shelfwave) type. Unfortunately, we are presently just at the point of being able to identify these motions. The creation of a model in which we coupled all of them together and attempted to relate them to atmospheric driving would be an almost hopelessly speculative task.

Our approach

In view of these problems, it is clear that any sort of model we might conjure up for estimating spill trajectory probabilities in the offshore region must necessarily be a fairly humble creature. Its results must likewise be accepted with an amount of reservation commensurate with its uncertainties. Moreover, the model should at best be fairly simple so that it is possible to understand the sensitivity of the output to variations in the parameters governing the model's behavior.

An obvious candidate for the job is the simple observation by Smith that oil on the surface tends to move at a velocity approximately equal to the vectorial sum of 3% of the surface wind's velocity and the velocity of the residual currents,

$$\vec{U}_{oil} = \vec{U}_{\substack{residual \\ current}} + .03\vec{U}_{\substack{surface \\ wind}} .$$

Clearly, the definition of the residual velocity is somewhat fuzzy, but for our purposes its properties are readily understandable and we can usually determine the sort of current that makes the most sense for a given locale. With respect to the Long Island region, a study of the geostrophy of the New York Bight reveals that this current may reasonably be expected to travel from east to west down the Long Island coast and then proceed south down the New Jersey coast. While there may be some variation in the strength of the current during the year, it is simplest to consider the current as steady, and explore a variety of current speeds.

If the residual current is held steady, then all variability in the model must come from the surface wind component. Thus, the modeling of the surface wind becomes of some importance in properly simulating the oil spill motion. Under these circumstances we desire a simulation that induces the proper mean motion and introduces a dispersive component that is of approximately the right size. Due to the approximate nature of the model, the need to get a completely analytical solution (which is possible but difficult) may be dispensed with in favor of using a Monte Carlo technique that compromises the quality of the answer only slightly. In short, we end up implementing the simple spill trajectory simulation technique first used in the Georges Bank study.

The basis for accepting the results of this simple model rests on two points. First, if we apply the 3% rule to oil spills other than the "Torrey Canyon"'s, we again find reasonable agreement between observed and predicted trajectories (Stewart, 1973). Secondly, we have applied the technique extensively up and down the East Coast and compared the results for our best-guess current pattern to drift bottle launch and recovery statistics (Stewart, 1974). The quantitative agreement has been sufficiently good that we can usually rationalize mismatches, and from a quantitative standpoint, we have so far always managed to duplicate seasonal and locational trends.

Results

Figure 1 is a sketch of both the rectangular outline used to represent Long Island and the current pattern we selected for our best guess of the offshore residual current. In addition to this hypothesized current pattern, we investigated a null current hypothesis and a current hypothesis using a drift speed of .1 knot versus the .25 knot of our best-guess pattern.

The winds were modeled using the simple 9 x 9 Markov model representation developed for the Georges Bank study. The wind data was reduced on a seasonal basis, so different matrices were used for each of the four seasons. In view of the potential difference between the properties of the winds nearshore and offshore, the region was broken into three areas, and the wind properties were determined for each area based on representative wind data for the region acquired from the National Climatic Center (NCC). The matrices used to simulate the surface wind in the Long Island region were determined from a ten-year record from JFK Airport; the matrices used along the New Jersey coast were determined from ten years of weather records from Atlantic City; and the matrices used in the offshore region (more than thirty miles offshore) we determined from weather records acquired by ships stationed at Ocean Station Hotel.*

*The use of Ocean Station Hotel wind data to represent the winds in the area lying off Long Island is somewhat of a compromise because Hotel is located at 36°N, 70°W, which is about 230 nautical miles (nm) from Long Island. We did investigate using local lightship data, but we found the data unsuitable for our purposes due to the irregular sampling scheme adopted on lightships.

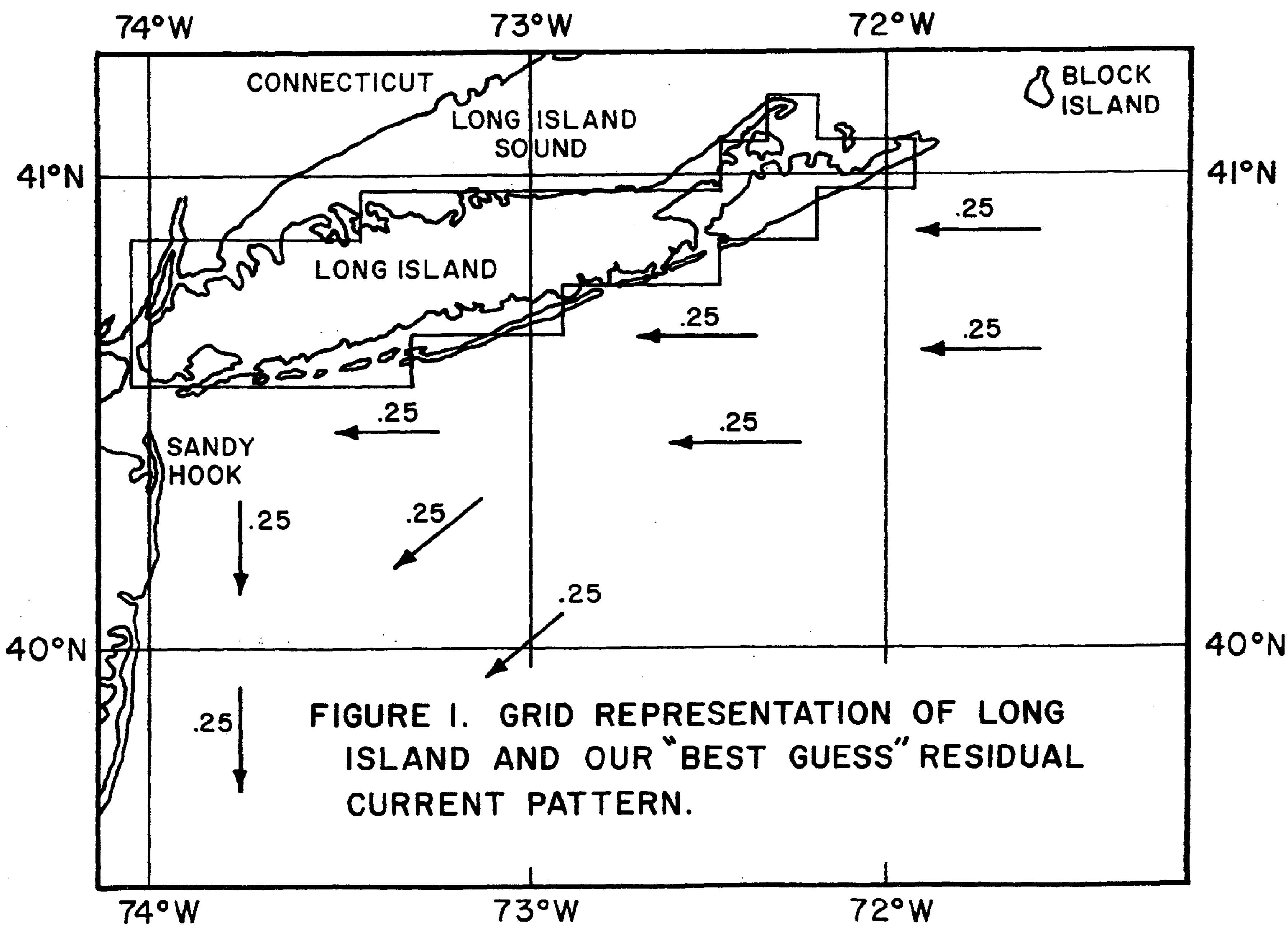

FIGURE I. GRID REPRESENTATION OF LONG ISLAND AND OUR "BEST GUESS" RESIDUAL CURRENT PATTERN.

We were motivated to investigate the best-guess current pattern through a discussion with Dr. E. R. Baylor of SUNY at Stony Brook in which he described the preliminary results of a current study performed by EG&G in the region just to the south of Long Island.

It was found that the principal difference between the behavior of the model when using the .25 knot current value versus the lower value of .1 knot lay in the spatial distribution of impact zones. There was very little difference in the total percentage ashore. The explanation is straightforward. Lower current values reduce the average westerly drift and allow a larger proportion of the simulated spills to be transported to the more easterly areas. Since the flow is not offshore, the total number of spills hitting shore remains about the same. It was found that the best-guess current gave us a better qualitative fit to drift bottle records and this observation in conjunction with the fact that the EG&G data represented our best hard information regarding offshore currents, led us to select it.

The following figures present a more detailed description of the trajectory probabilities for this best-guess current. Figure 2a-d summarizes the seasonal dependency of the probability of impacting Long Island's shores upon launch point location in the offshore region. Notice that the contours of equal probability are rather similar in all seasons except the summer. In summer it appears that there is a large region lying southeast of Shinnecock Inlet where the probability is higher than .9 that a spill will come ashore on Long Island.

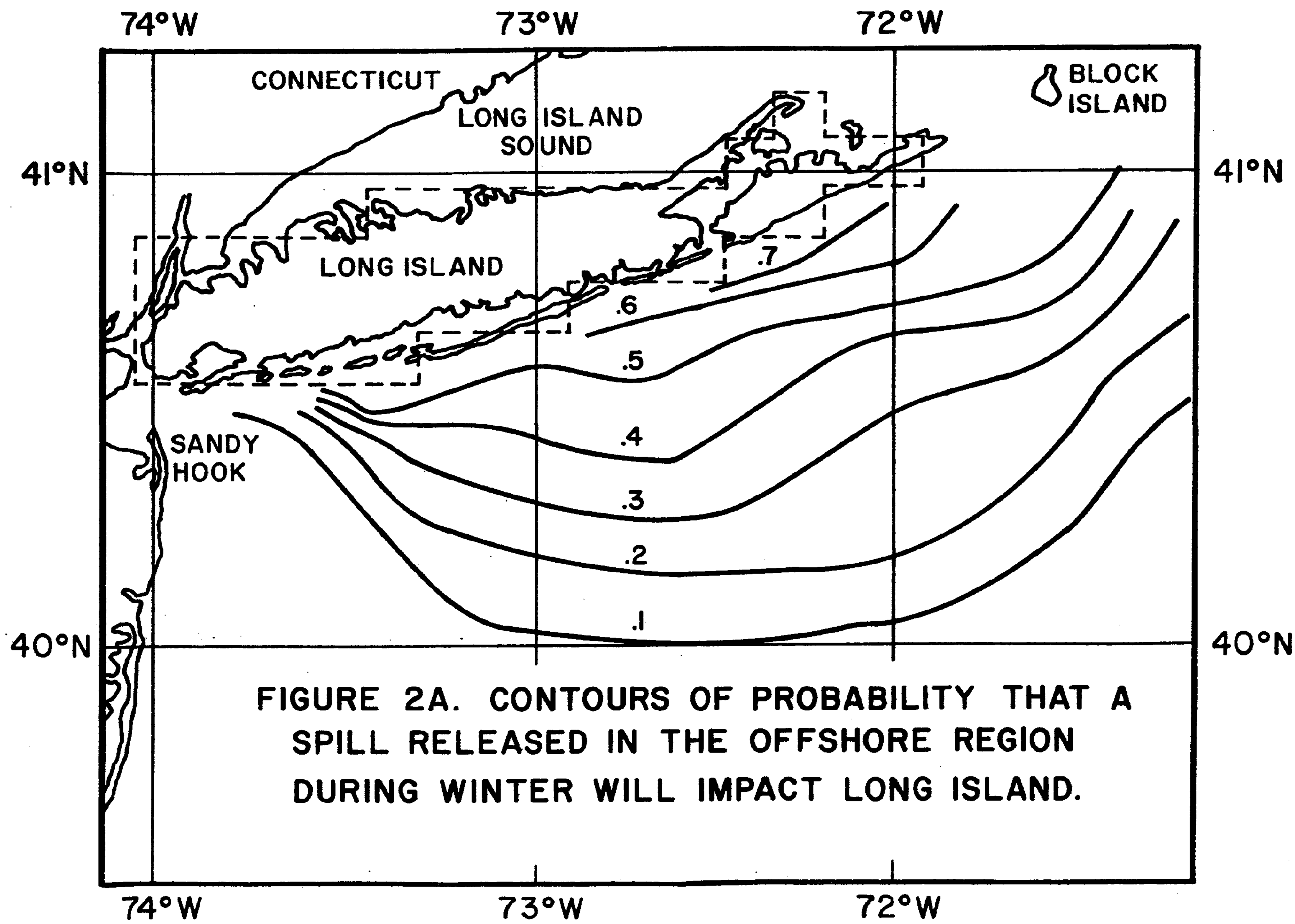

FIGURE 2A. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING WINTER WILL IMPACT LONG ISLAND.

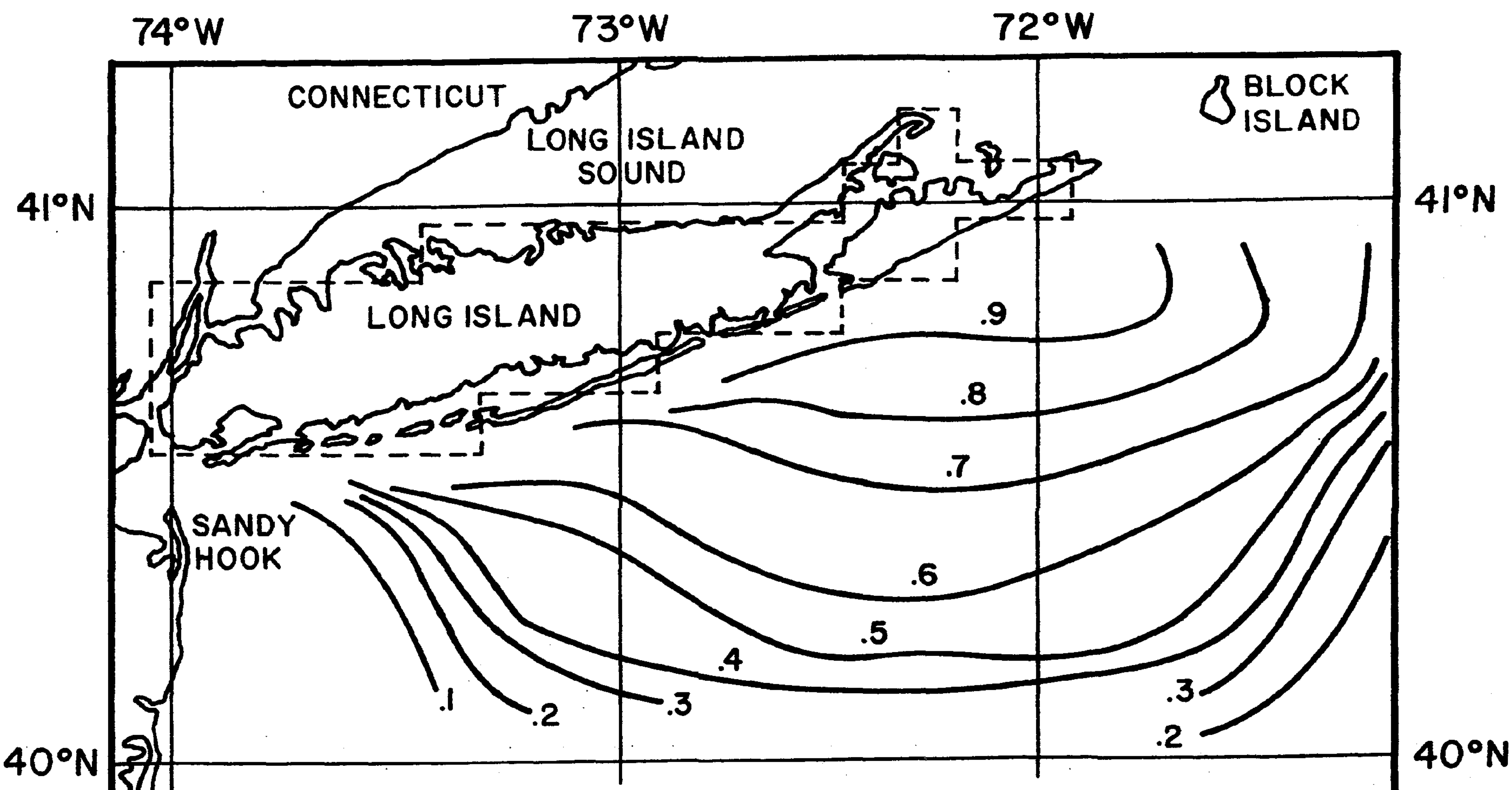

FIGURE 2B. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING SPRING WILL IMPACT LONG ISLAND.

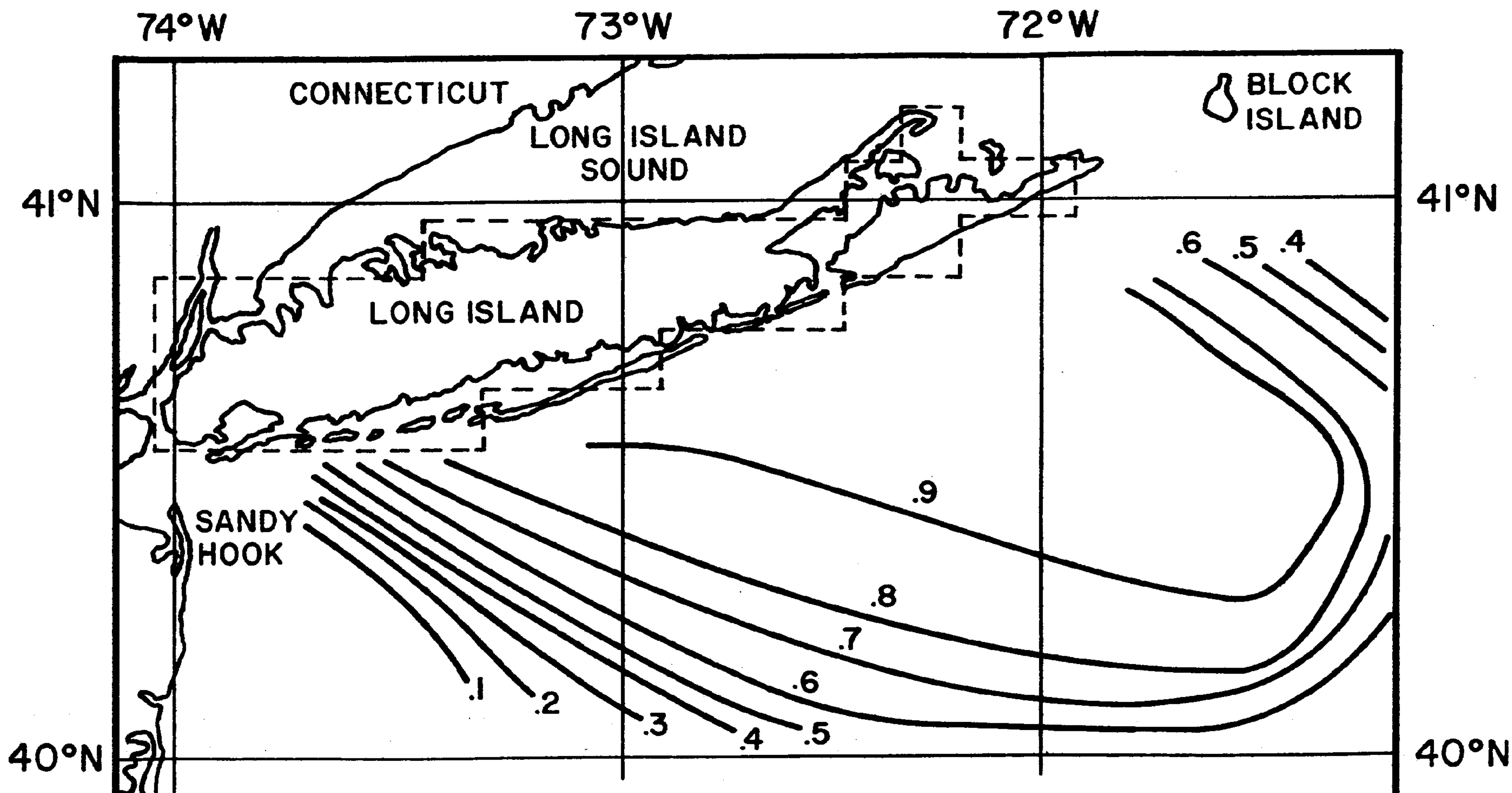

FIGURE 2C. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING THE SUMMER WILL IMPACT LONG ISLAND.

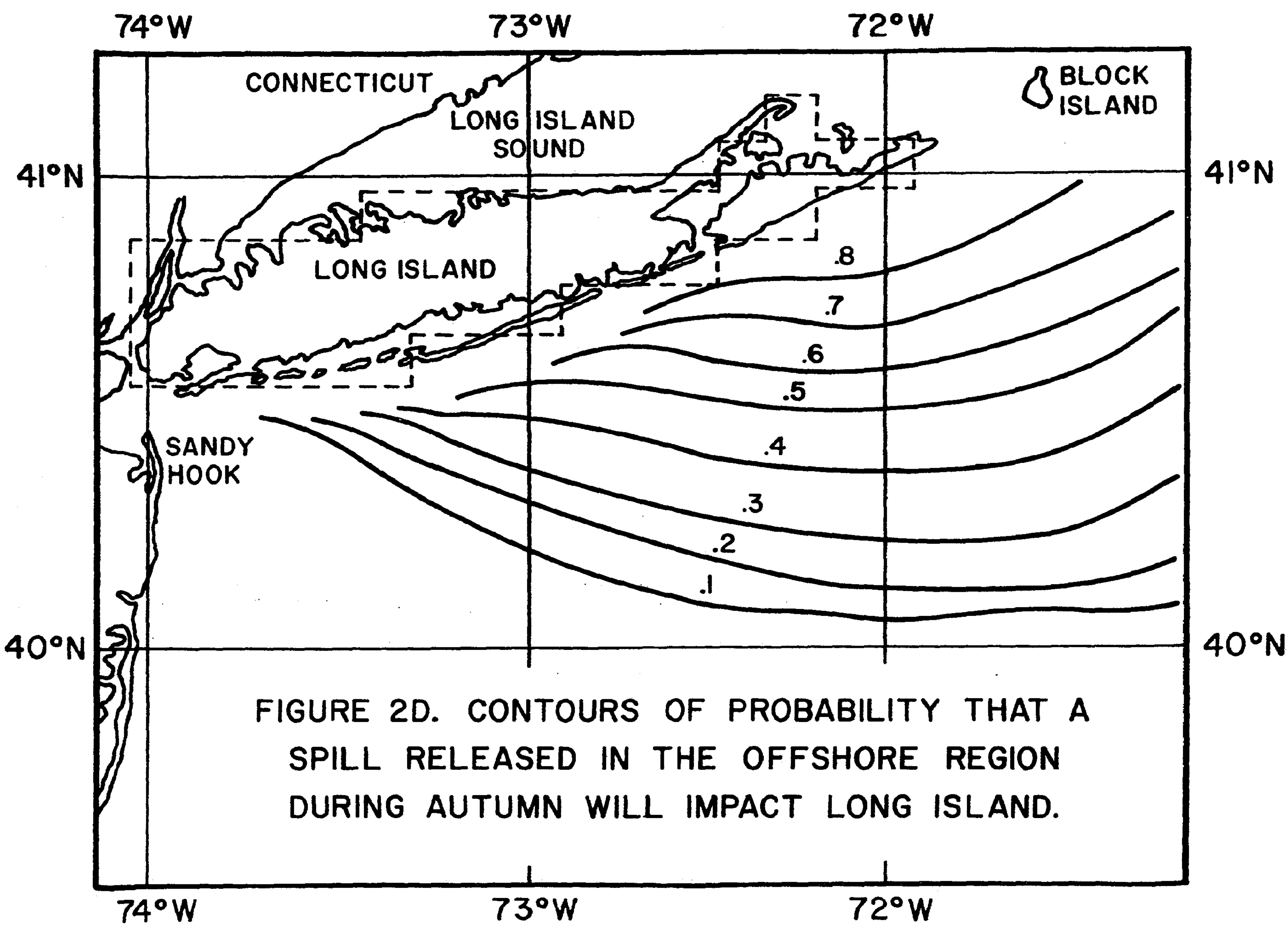

FIGURE 2D. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING AUTUMN WILL IMPACT LONG ISLAND.

Figure 3a-d shows the variation in the average time to shore with distance from shore. Figures 4a-d, 5a-d, and 6a-d show the specific launch regions in the offshore area that have a high probability of impacting the Amityville region, the eastern portion of Fire Island, and the Montauk Point area respectively. Notice that the Amityville and eastern Fire Island areas are threatened primarily by spills lying to the east, while the Montauk Point region is threatened by spills to the southeast. One explanation for this behavior is that spills in the waters lying south of western Long Island will be subjected to both beaching on the New Jersey shore and to the southerly transport of our hypothesized current in this area.

The generation of these figures was quite expensive due to the number of points involved, so it was judged inadvisable to create similar plots for the other current hypotheses. However, based on our preliminary results we can be reasonably confident that the principal changes would be to shift the regions of high probability slightly to the southwest. This would be of rather little consequence with two major exceptions:

1. In the region centered about 40°N, 72°W we might find a substantial change in the summer trajectory behavior. Specifically, the chance of impact might increase from .5 or .6 to .8 or .9.

2. A review of Figures 2a-d reveals that there is a sharp dropoff in the probability of a spill impacting Long Island along a line running about southeast

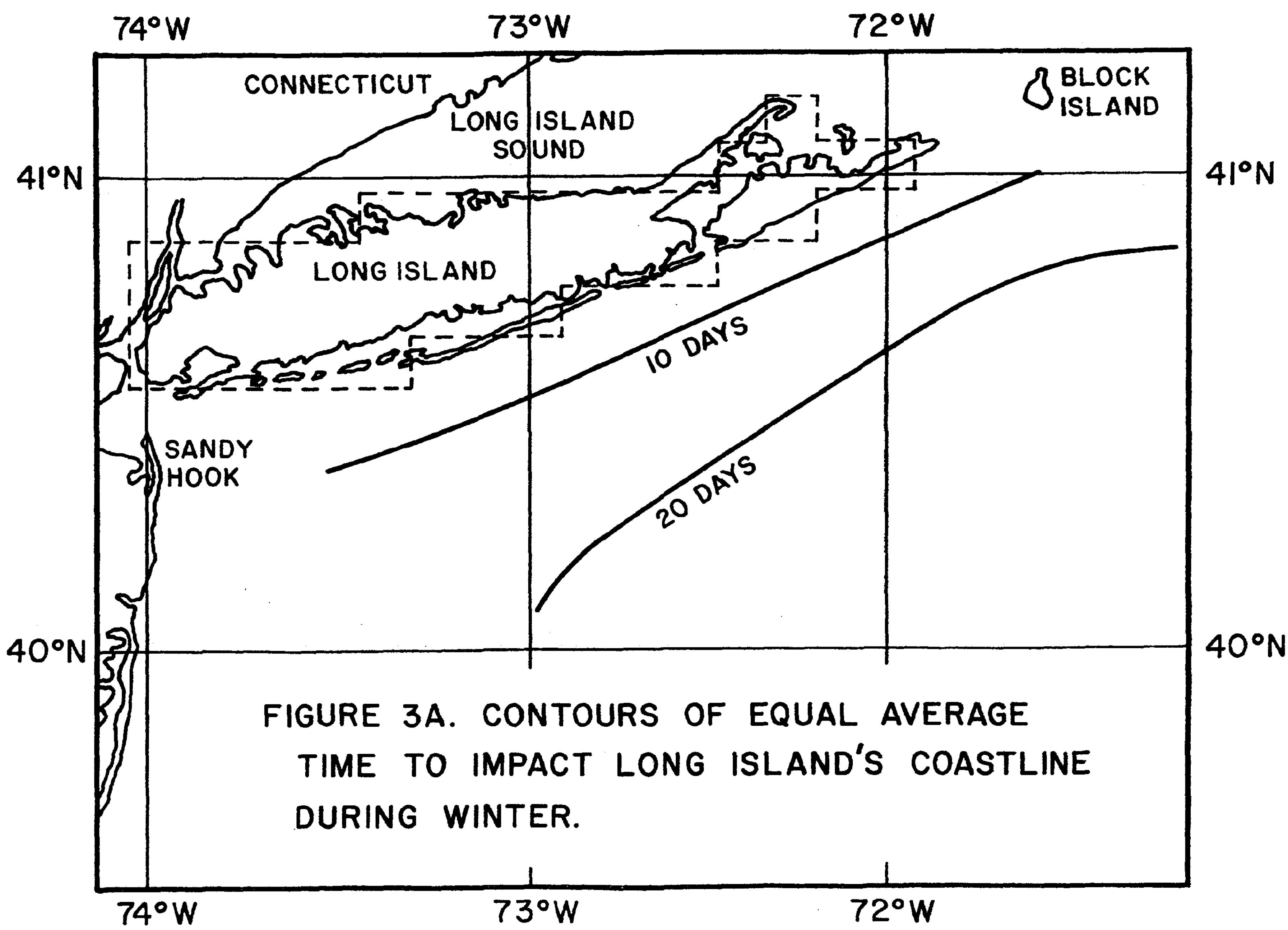

FIGURE 3A. CONTOURS OF EQUAL AVERAGE TIME TO IMPACT LONG ISLAND'S COASTLINE DURING WINTER.

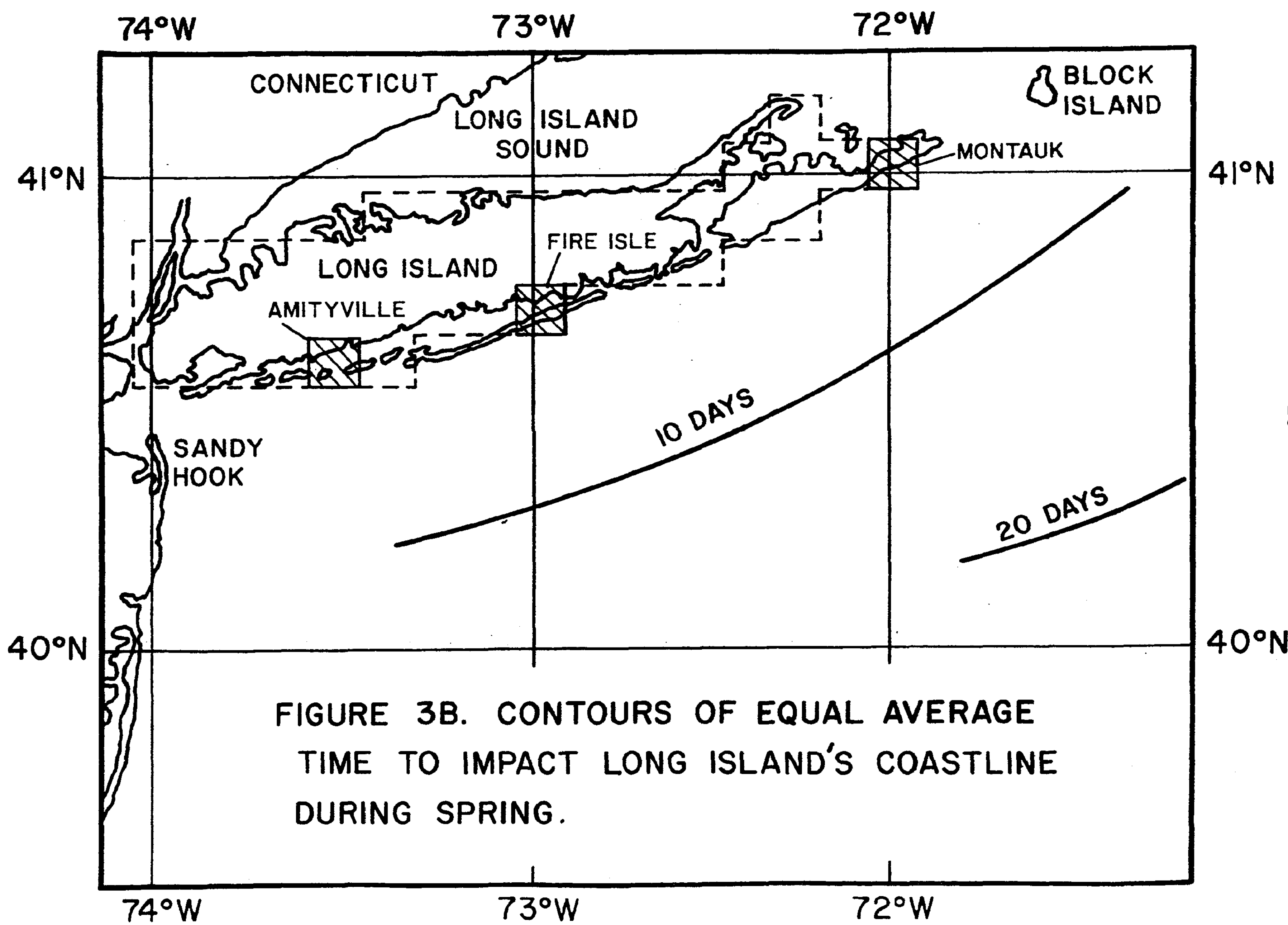

FIGURE 3B. CONTOURS OF EQUAL AVERAGE TIME TO IMPACT LONG ISLAND'S COASTLINE DURING SPRING.

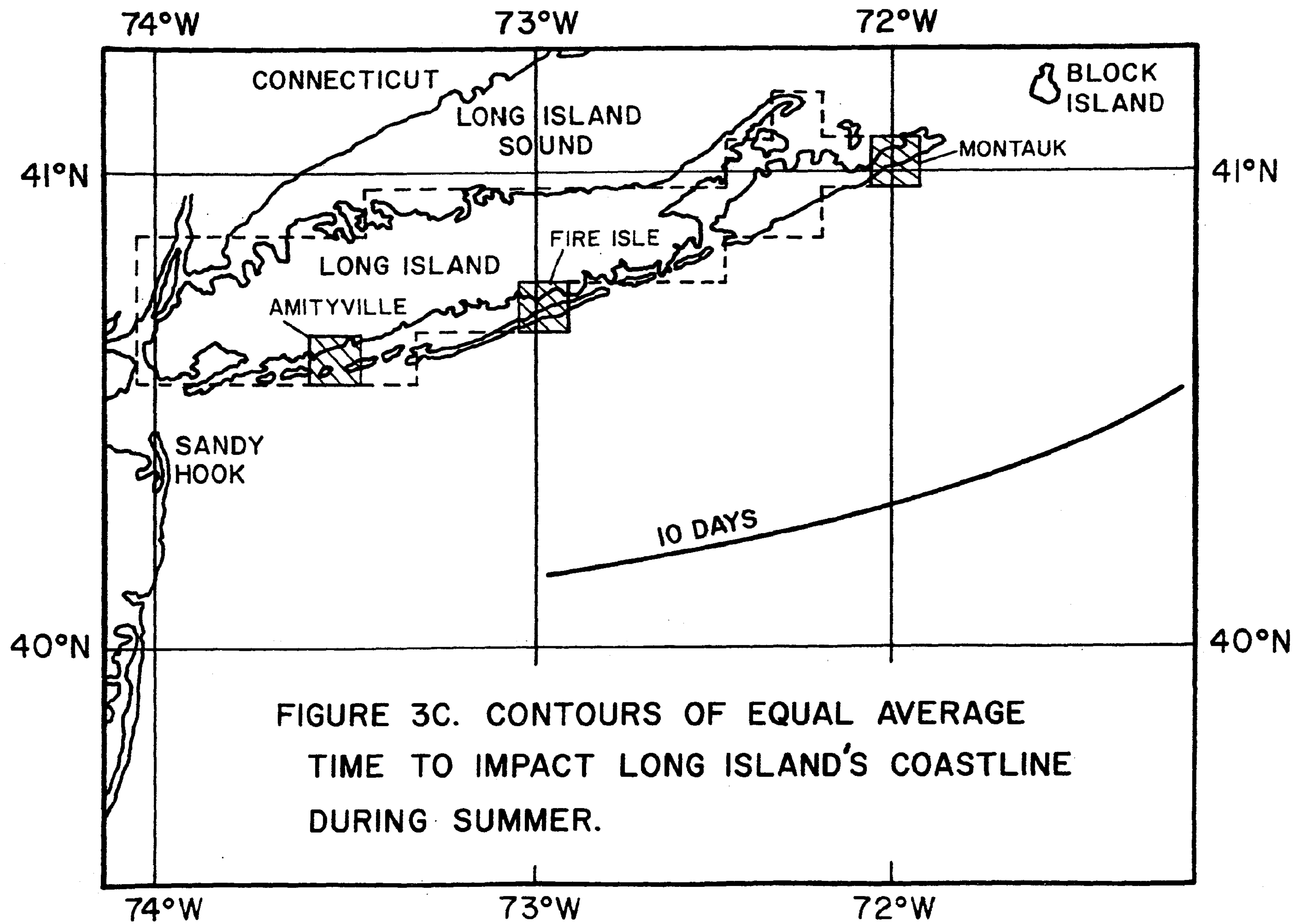

FIGURE 3C. CONTOURS OF EQUAL AVERAGE TIME TO IMPACT LONG ISLAND'S COASTLINE DURING SUMMER.

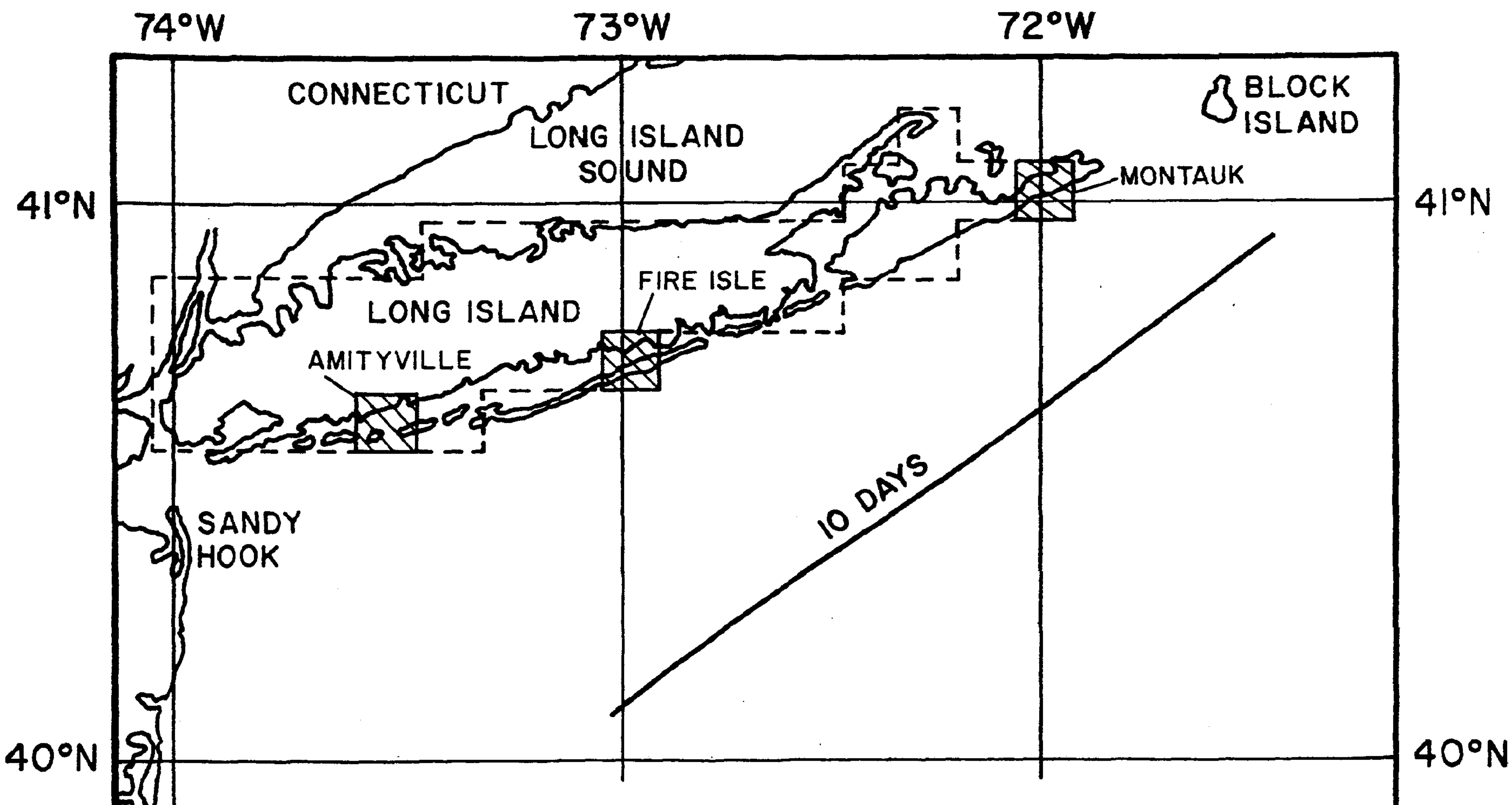

FIGURE 3D. CONTOURS OF EQUAL AVERAGE TIME TO IMPACT LONG ISLAND'S COASTLINE DURING AUTUMN.

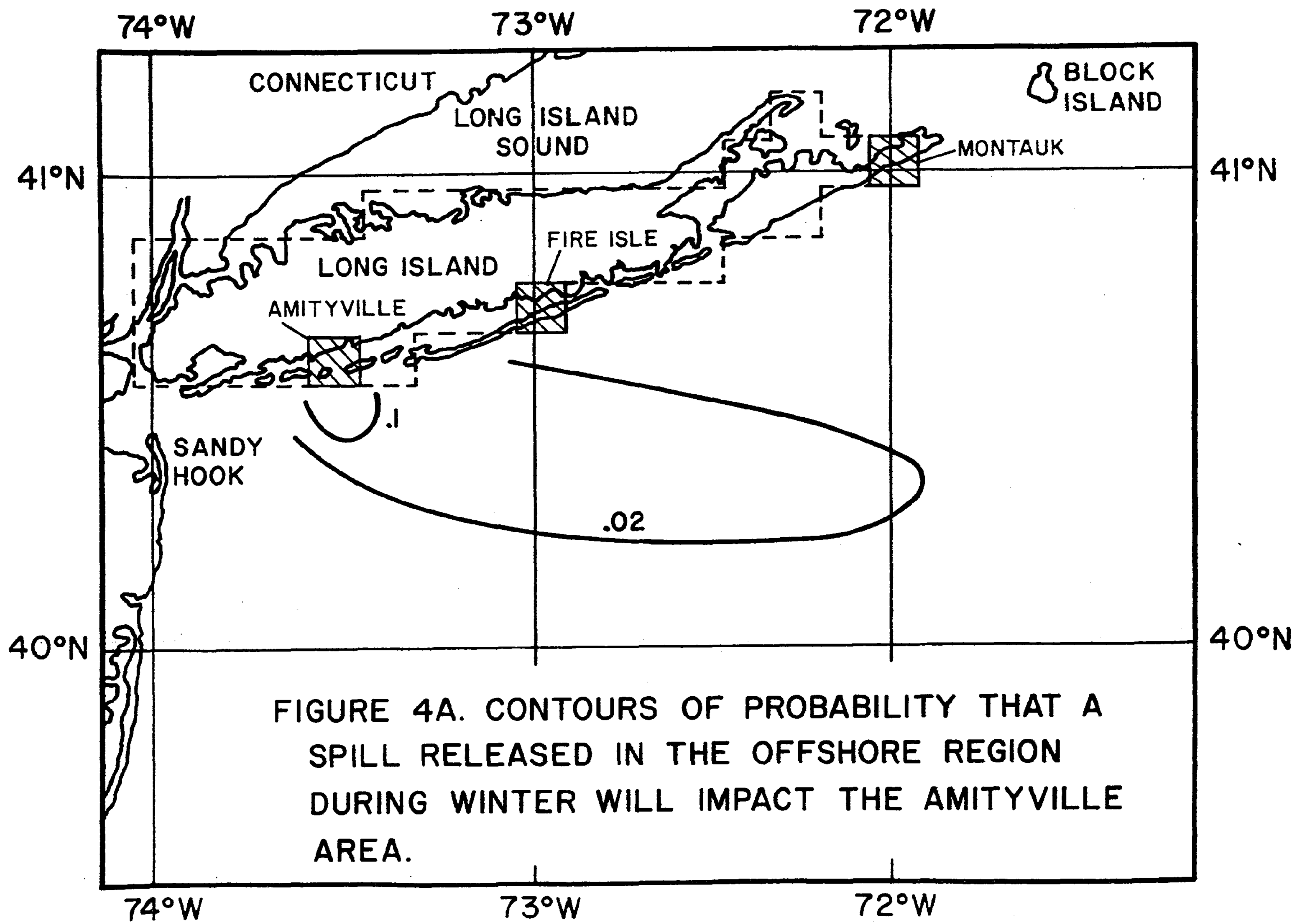

FIGURE 4A. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING WINTER WILL IMPACT THE AMITYVILLE AREA.

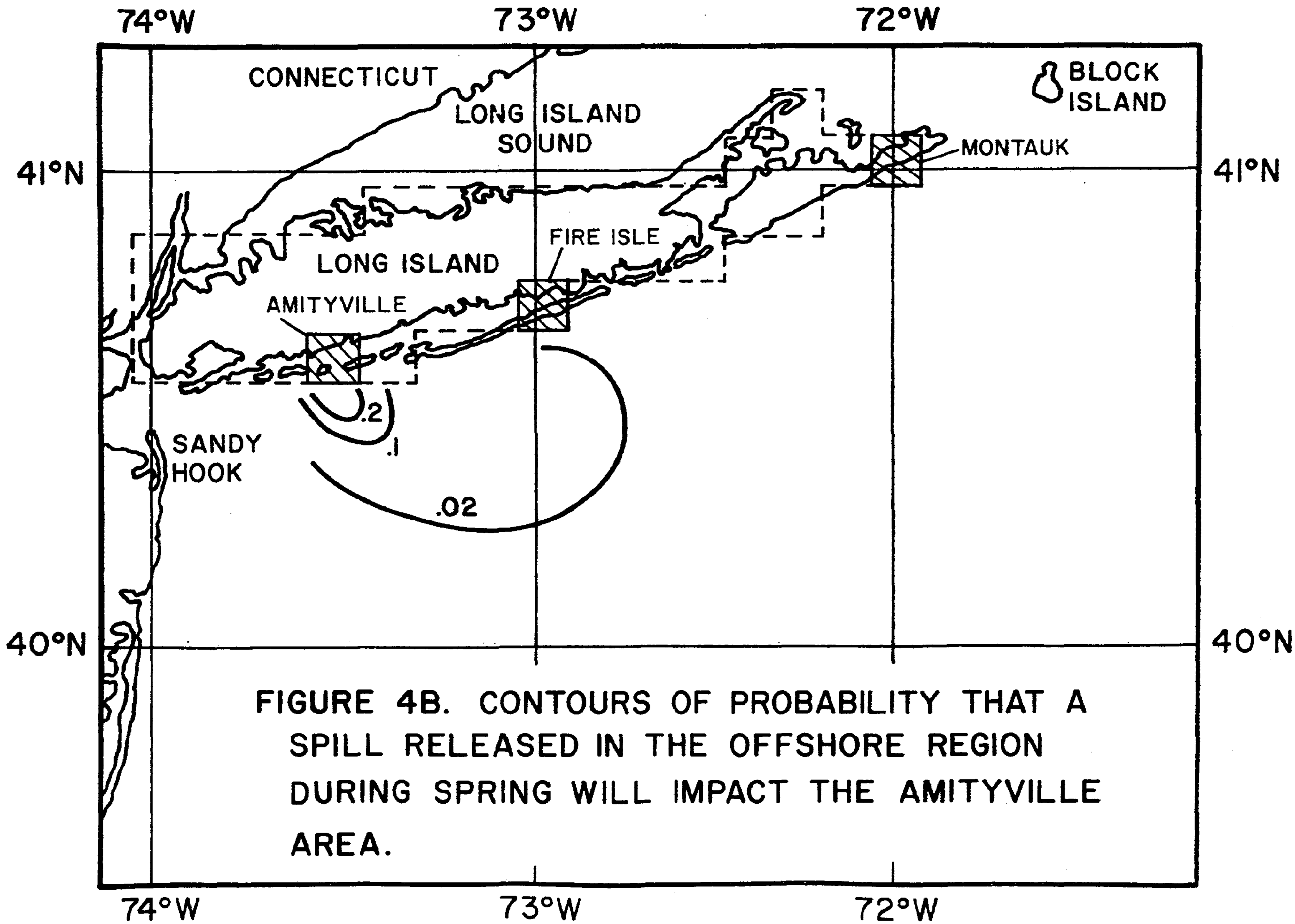

FIGURE 4B. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING SPRING WILL IMPACT THE AMITYVILLE AREA.

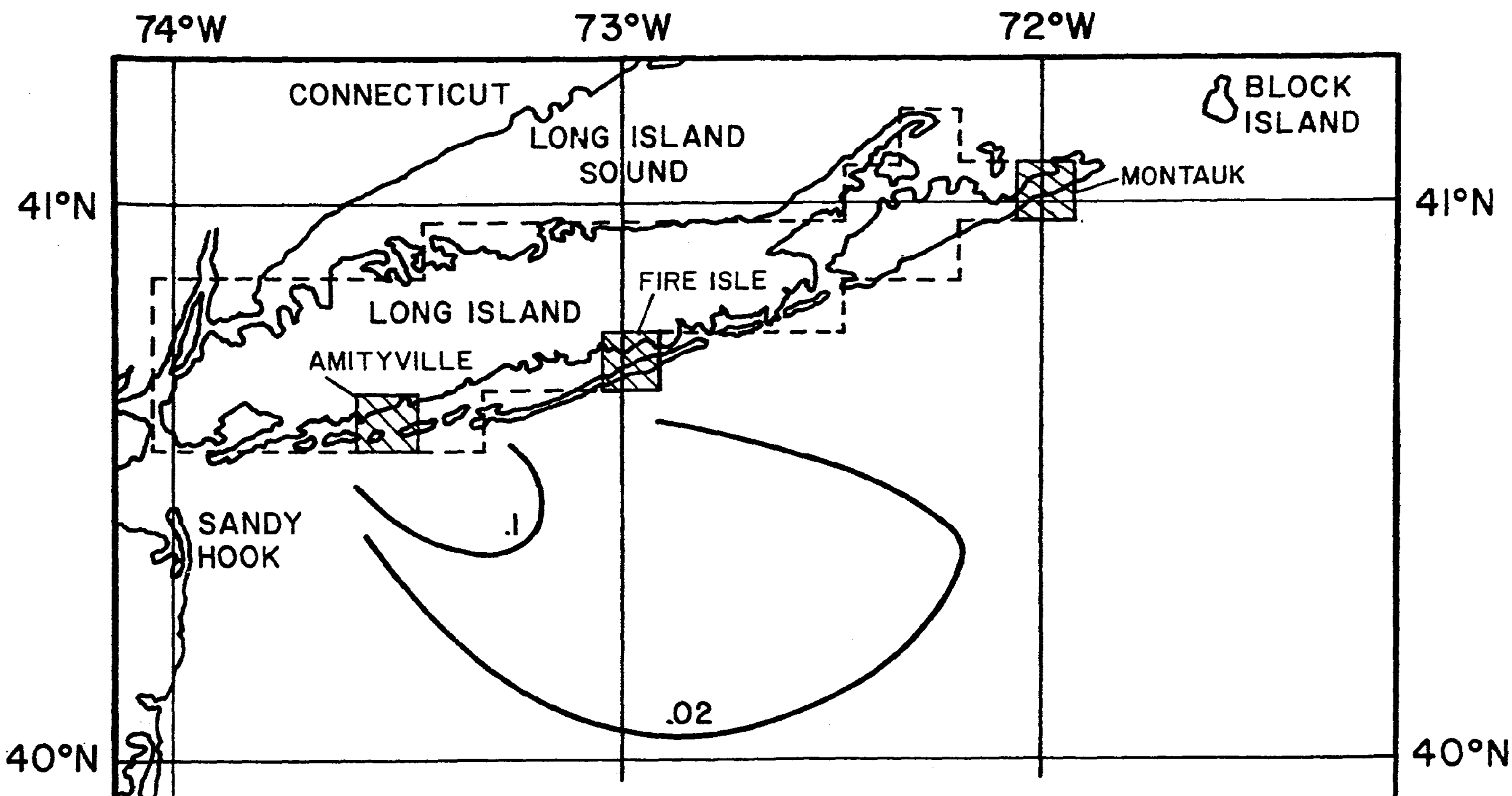

FIGURE 4C. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING SUMMER WILL IMPACT THE AMITYVILLE AREA.

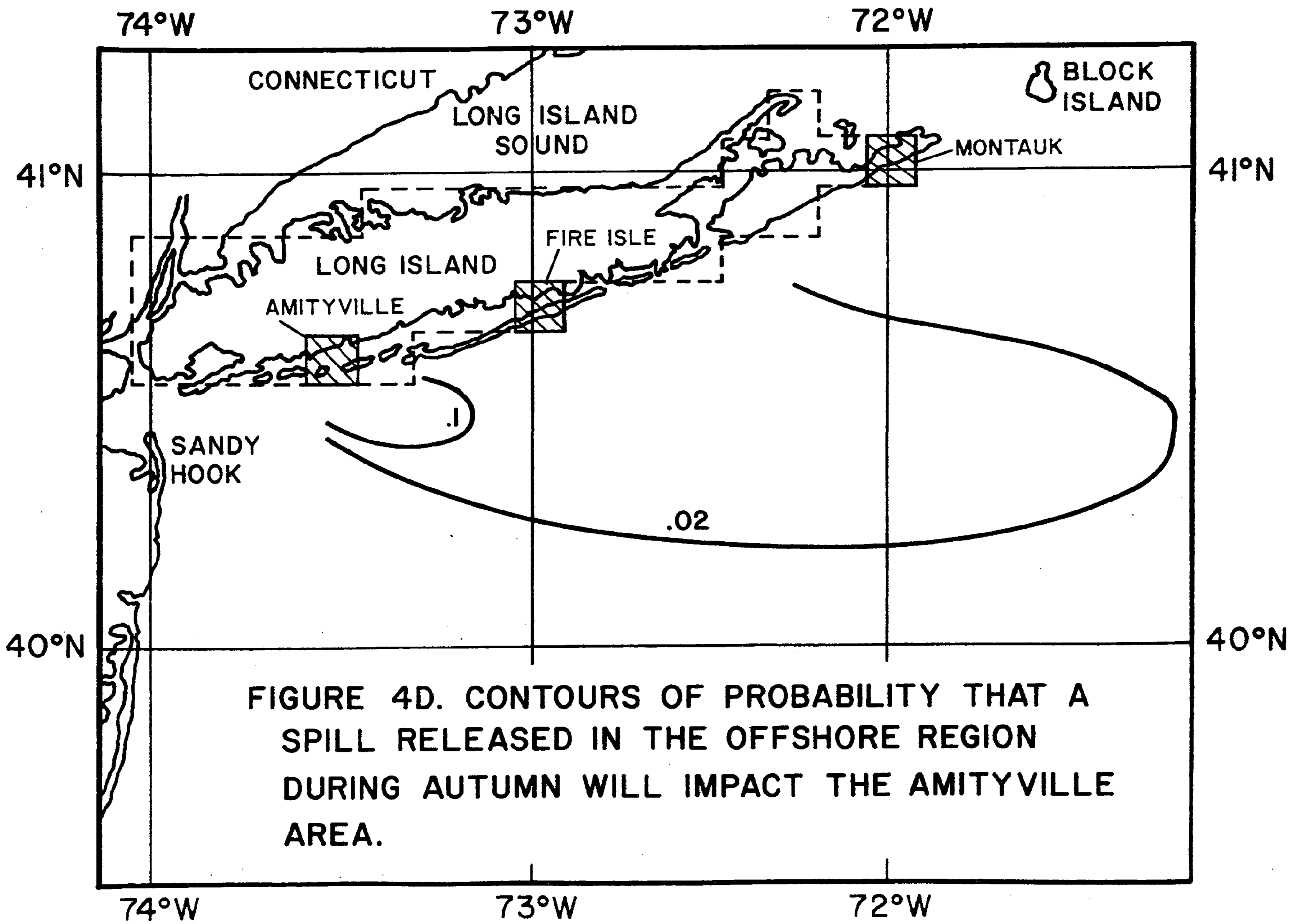

FIGURE 4D. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING AUTUMN WILL IMPACT THE AMITYVILLE AREA.

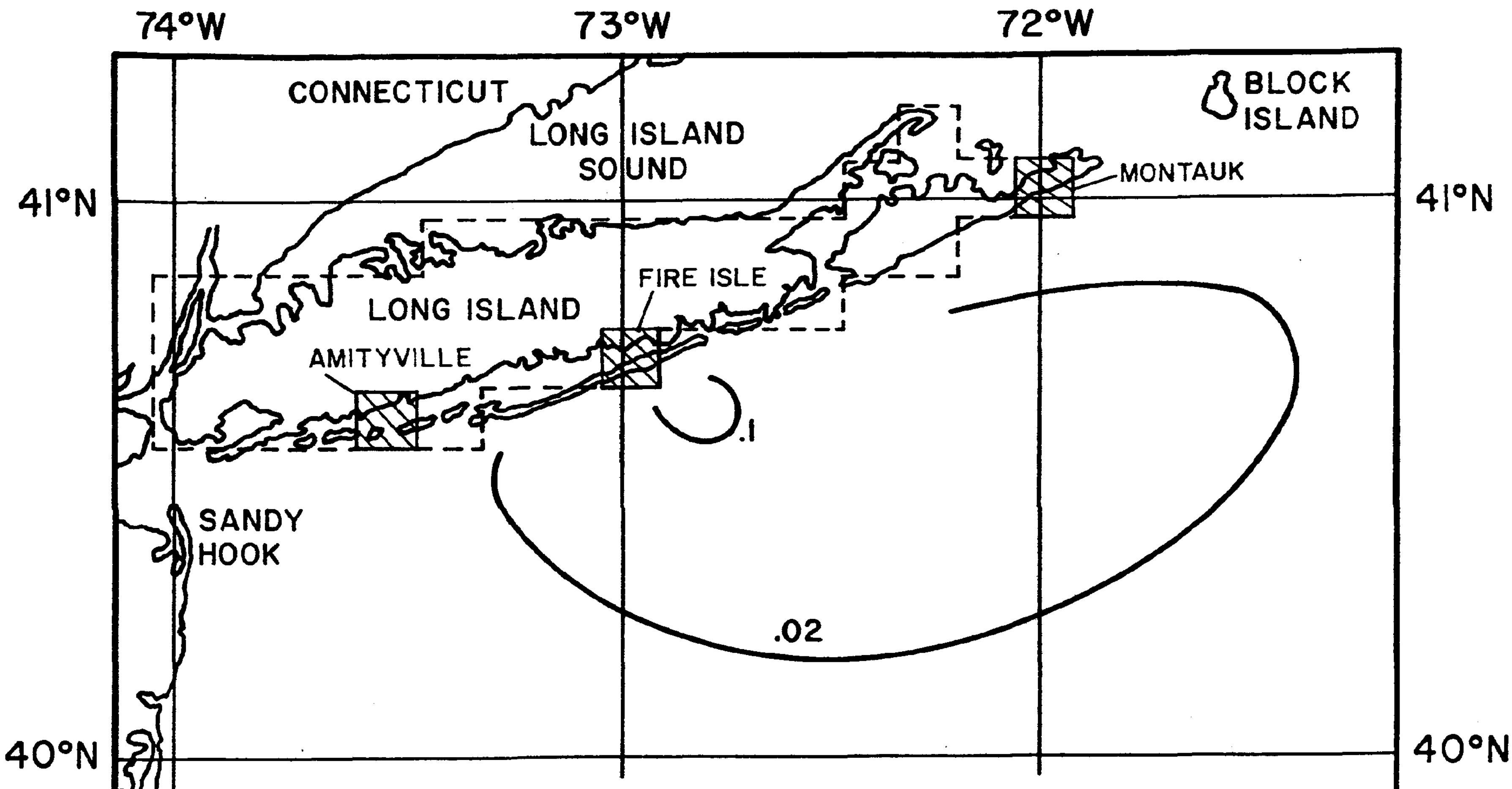

FIGURE 5A. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING WINTER WILL IMPACT EASTERN FIRE ISLAND.

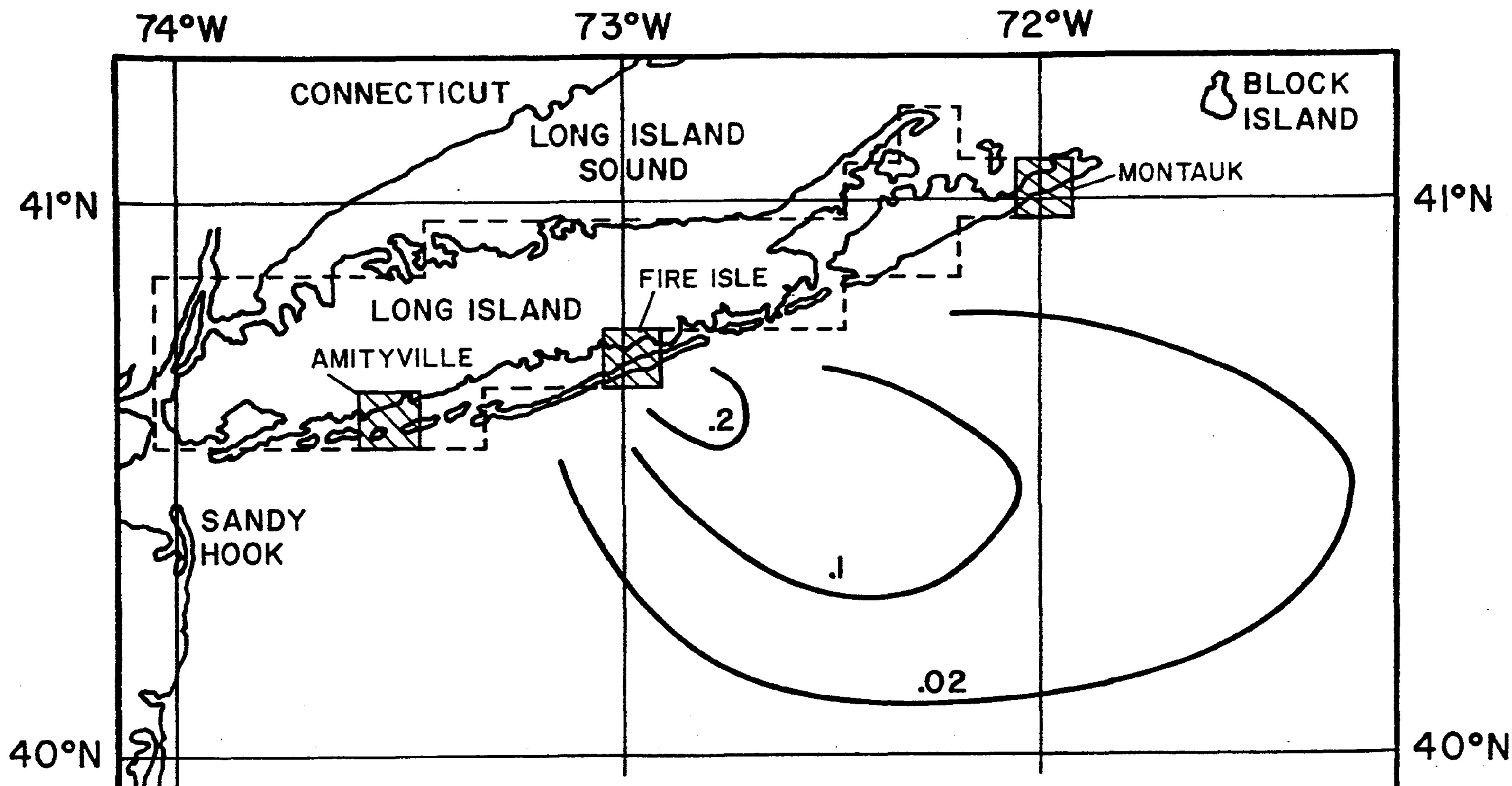

FIGURE 5B. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING SPRING WILL IMPACT EASTERN FIRE ISLAND.

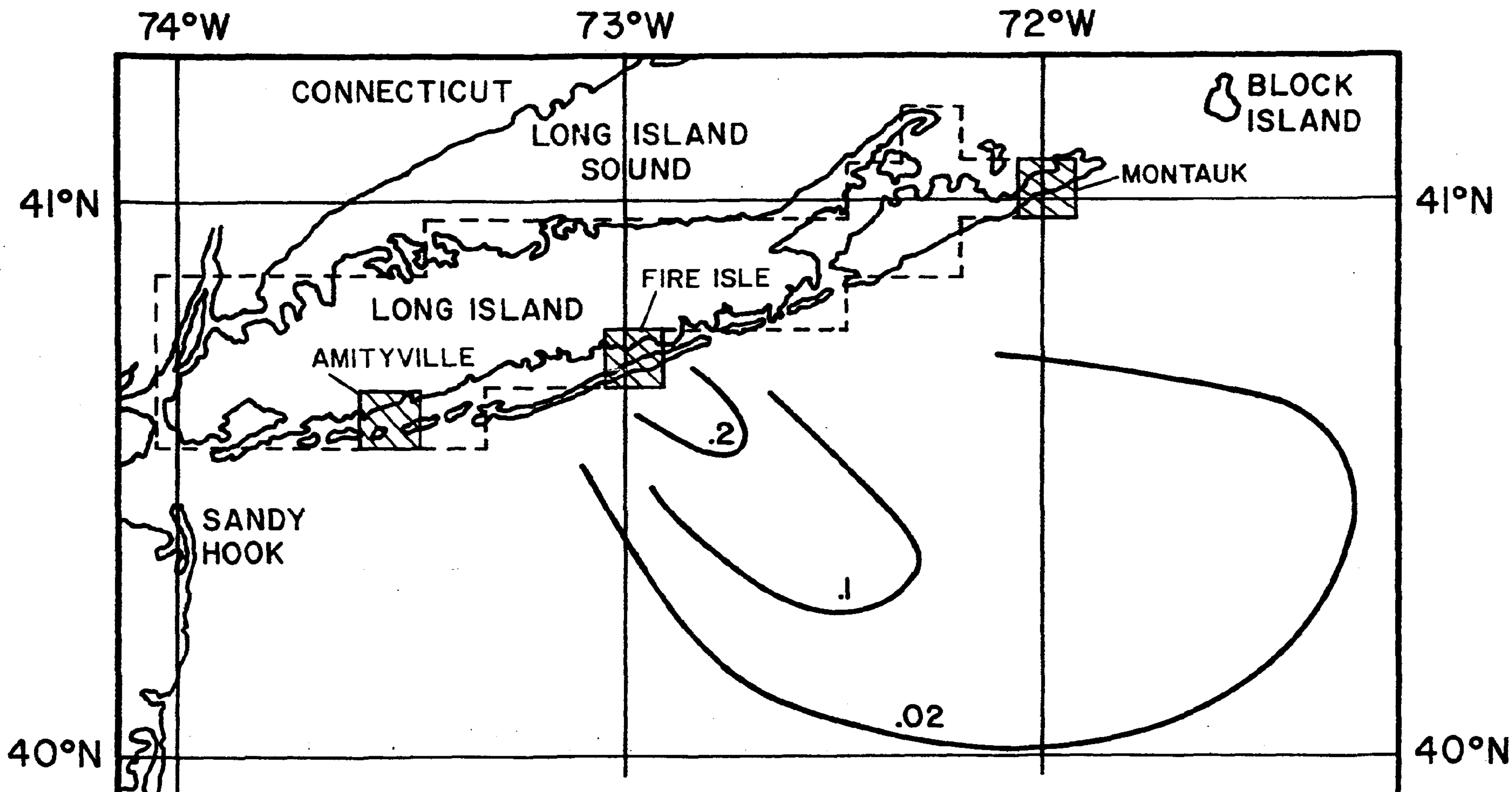

FIGURE 5C. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING SUMMER WILL IMPACT EASTERN FIRE ISLAND.

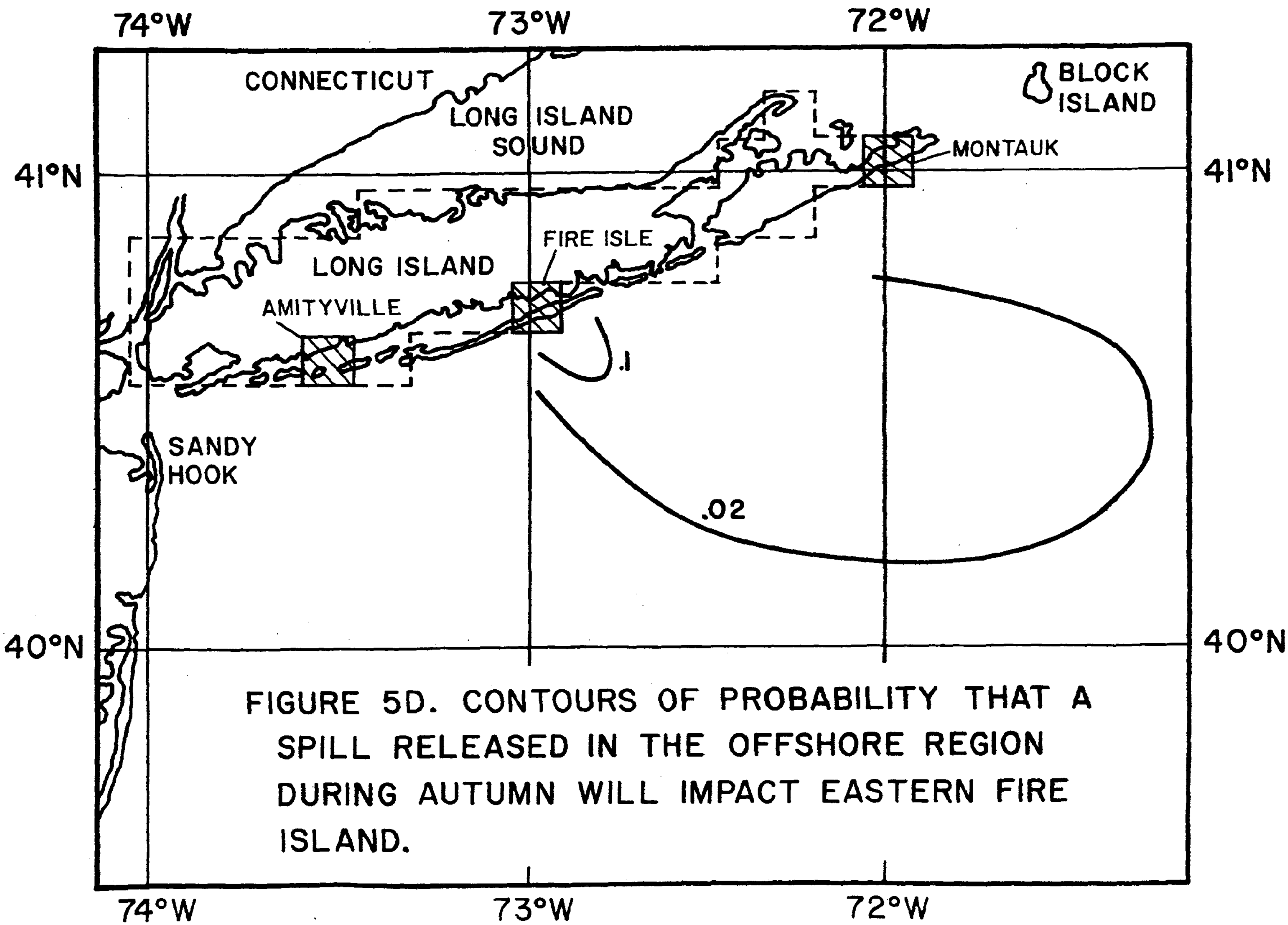

FIGURE 5D. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING AUTUMN WILL IMPACT EASTERN FIRE ISLAND.

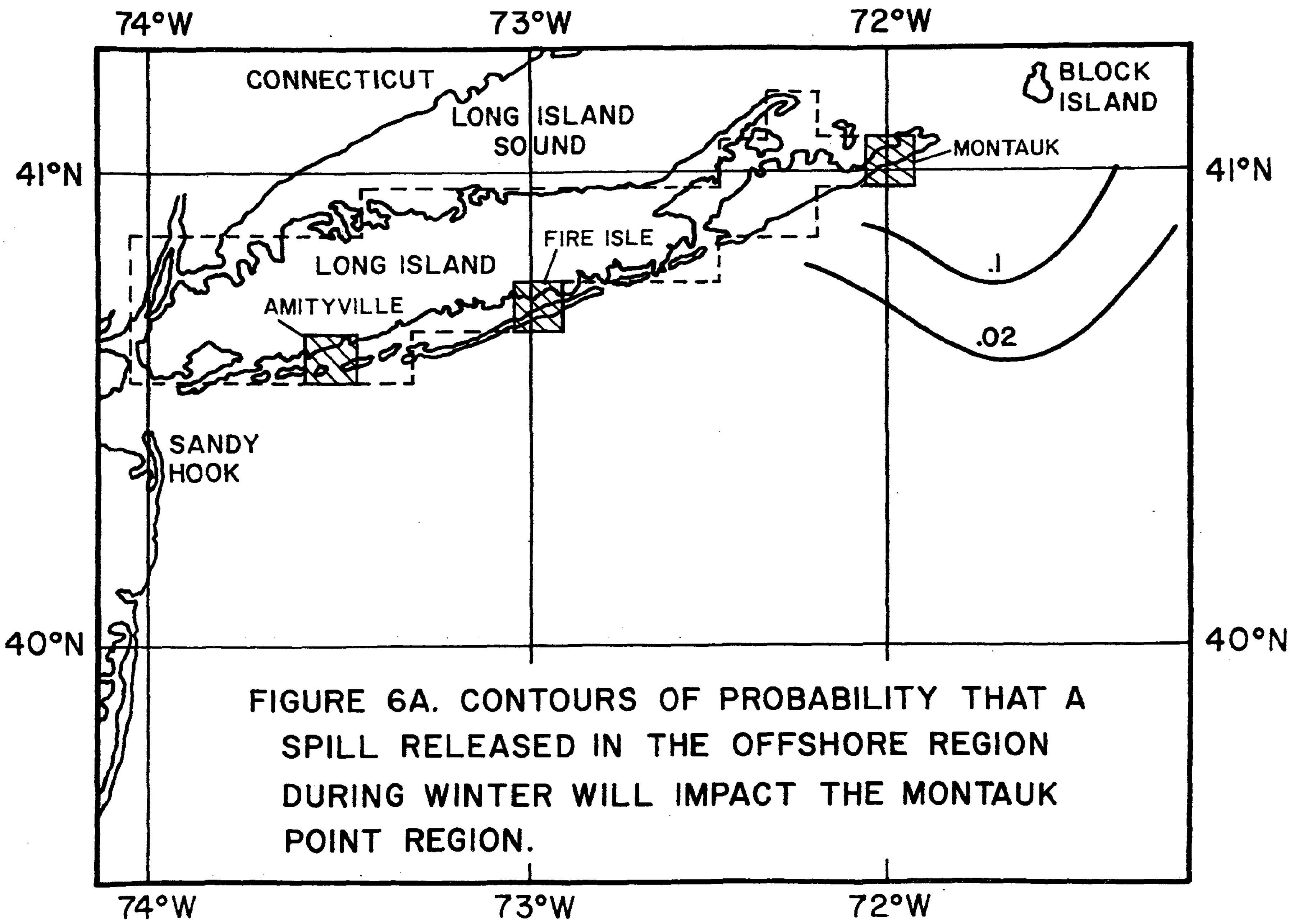

FIGURE 6A. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING WINTER WILL IMPACT THE MONTAUK POINT REGION.

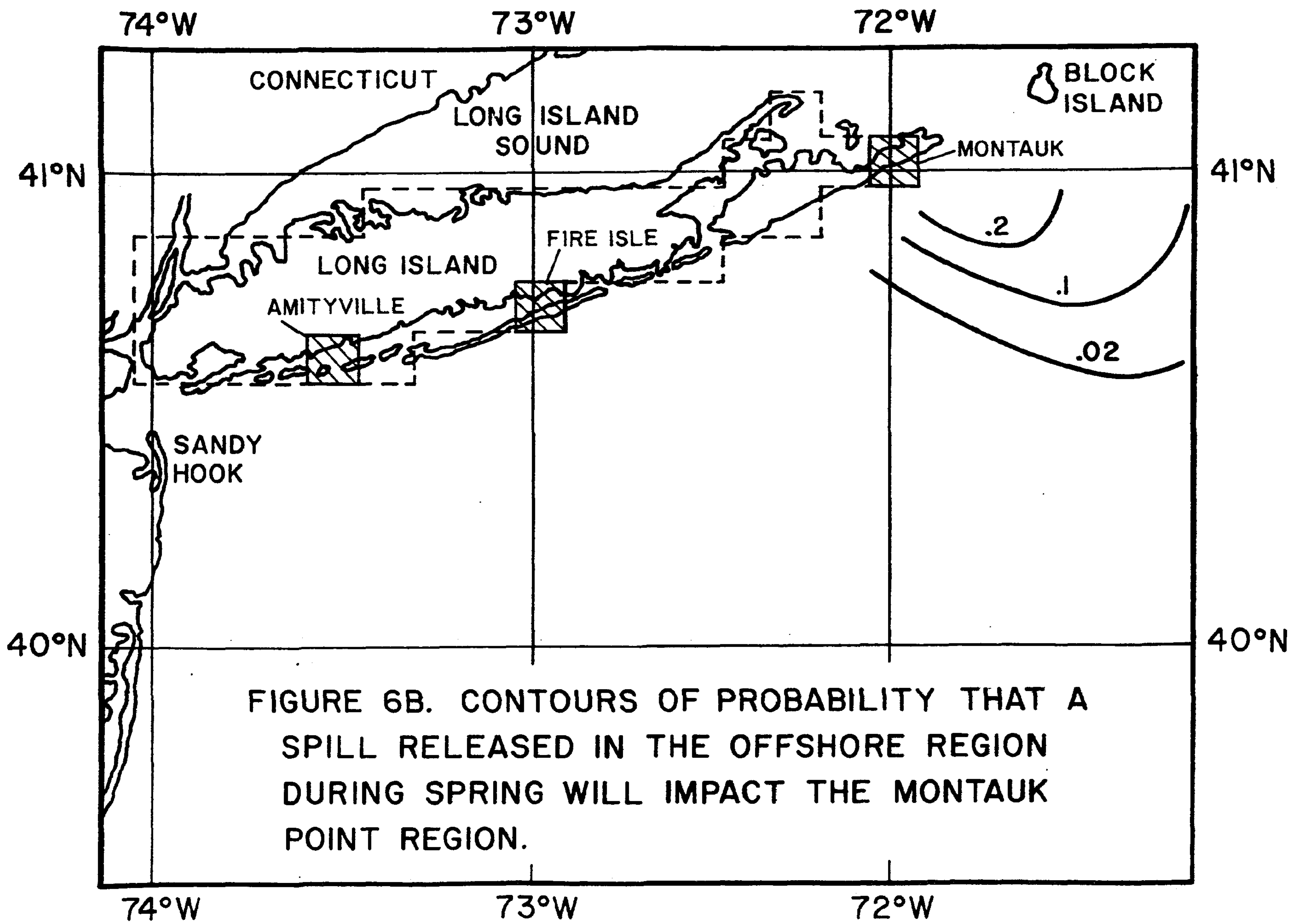

FIGURE 6B. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING SPRING WILL IMPACT THE MONTAUK POINT REGION.

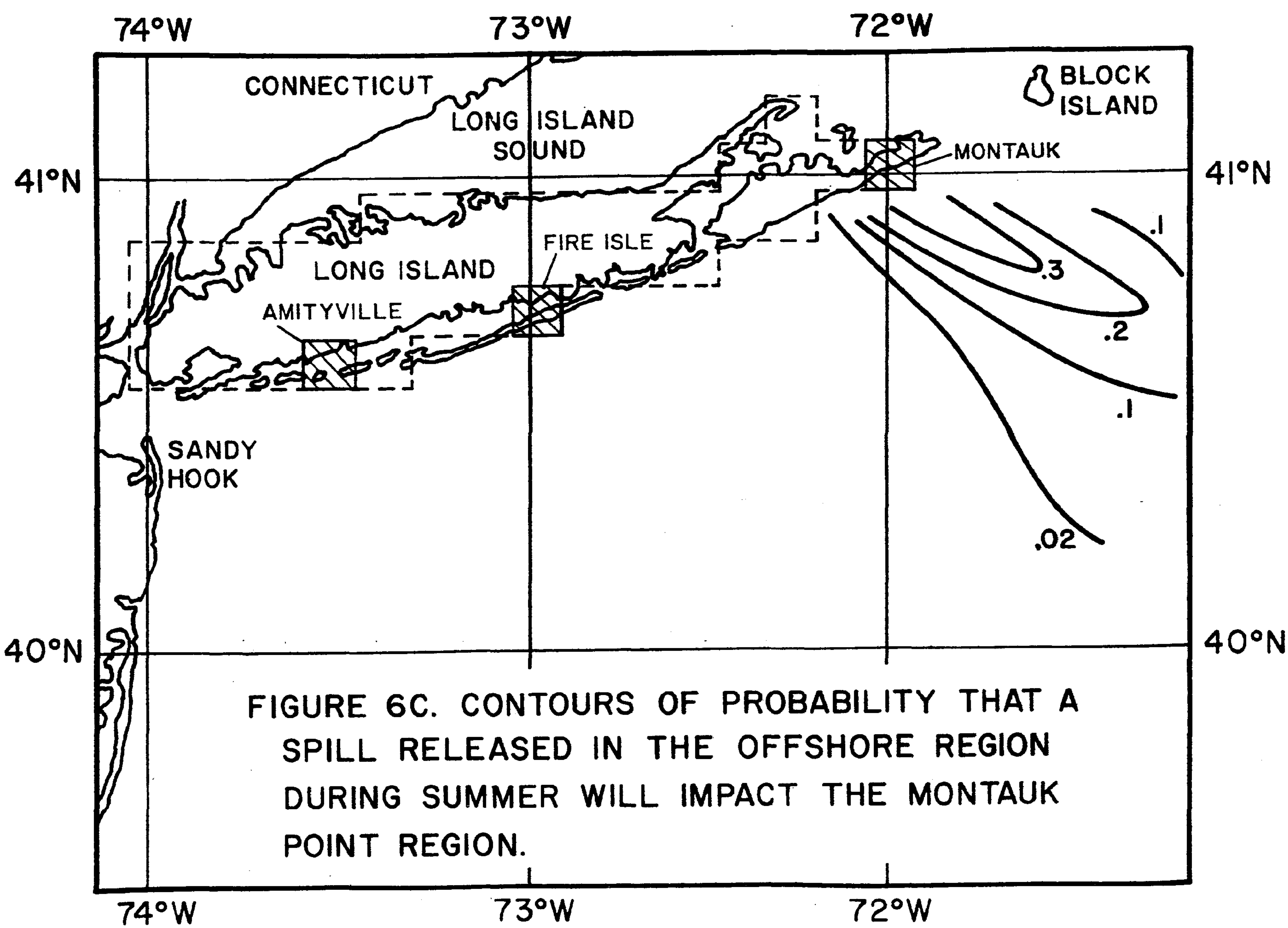

FIGURE 6C. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING SUMMER WILL IMPACT THE MONTAUK POINT REGION.

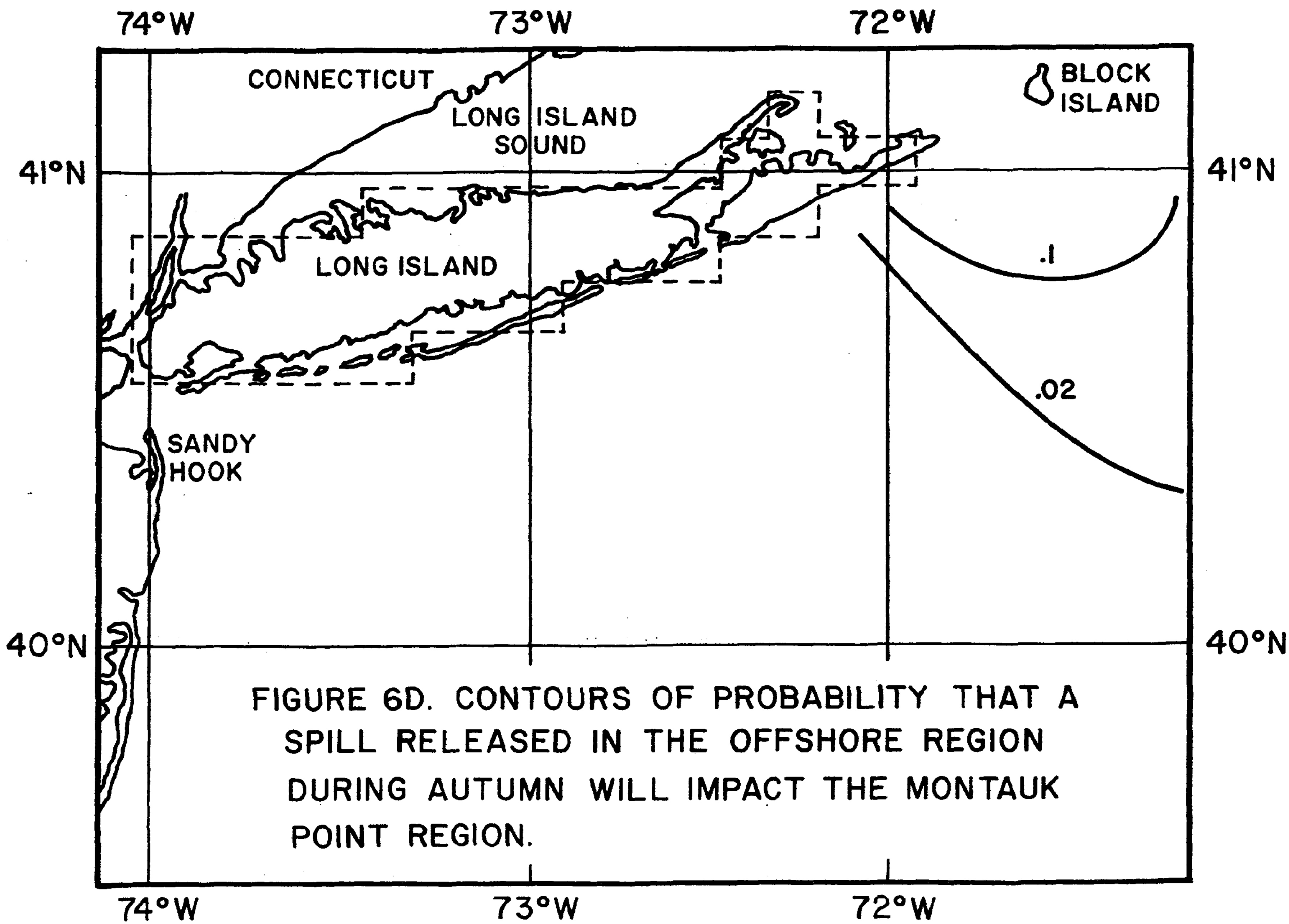

FIGURE 6D. CONTOURS OF PROBABILITY THAT A SPILL RELEASED IN THE OFFSHORE REGION DURING AUTUMN WILL IMPACT THE MONTAUK POINT REGION.

from Long Beach. Under lower residual current hypotheses we can expect this line to swing to the south.

Another point of uncertainty in the model is the wind drift coefficient (here set at .03) as mentioned above. Based on our prior experience with the model, we know that the principal effects in changes to this coefficient show up in two places. First, increasing the coefficient will increase the wind-induced dispersion. Secondly, this increase will also amplify that portion of the average velocity attributable to the wind. Decreasing the coefficient's value will cause the controverse effects. Thus, this coefficient determines both the average direction of drift and the dispersion. The effects with respect to Long Island of increasing this coefficient will be to rotate the basic patterns of the contours of equiprobability to the south, and to smear out the regions where there is now a strong gradient in this probability. The former effect may be shown to be rather small, while the latter is large. Decreasing the value of the coefficient will swing the pattern in the reverse direction and increase the probability gradients.

Conclusion

Despite the uncertainties, several features emerge from the analysis. First of all, in the offshore area bounded approximately by 40°N latitude in the south, 71°W longitude on the east, and a line running about southeast from Long Beach on the west, we can expect a high percentage of all oil spills to come ashore during at least one season. The season offering the greatest exposure is quite clearly summer. Additionally, the time to shore averages around 10 to 20 days over the whole region. This is sufficient time so that most of the low boiling fractions will have been lost to evaporation. However, it is not sufficient time so that we would expect a great deal of turbulent dispersion to have taken place. It is likely that the oil would still be in the form of large contiguous patches. These results are reasonably independent of the current presumption or the specification of the wind drift coefficient.

If we believe in the validity of selecting .03 as the wind drift coefficient and in the validity of our best-guess current hypothesis, then the contours of Figure 2a-d may be used to further specify the regions of greatest exposure.

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