orderly arrangement of marked parking spaces would provide useful practice in estimating per cent coverage. Once over the ocean, there was usually nothing against which to calibrate pancake sizes. Per cent coverage would be estimated by looking through a plexiglass eyepiece with a grid marked on it and an inclinometer to measure its tilt. Often, however, Deaver did not bother to use the device, relying instead on his own experienced estimates.

In a subsequent interview, Deaver expressed great faith in his visual estimation abilities, but the SOR team was not so sure. One day after a particularly complete map had been made, the SOR team tried to use it, plus its own knowledge of the oil's thickness, to estimate the volume of oil on the surface. The result, Mattson said, was enough oil to fill 10 Argo Merchants. A combination of errors in percent coverage and thickness estimates led to an error of an order of magnitude. At one time, Mattson also said, the SOR team thought of trailing Deaver to check his estimates, but then decided that this might cause Deaver to subconsciously modify his estimates. The important thing, both parties realized, was consistency. If observations and estimates were consistent, then all could be corrected on the basis of photographs or other observations made on a single day.

Flights would begin in the morning and end late in the afternoon if all went well. Deaver would land, brief Morgan and Hein, give Morgan a map for the model, and the cycle could continue. It was something of a self-sustaining cycle — the overflights would provide verification of the model and the model would guide the overflights. Then
Deaver would return to his hotel, the Holiday Inn in Hyannis, and brief the SOR team.

From December 17 to January 3, Deaver made 15 such overflights, one every day, except December 28 and 29, when weather prevented it, and December 30, when the engine broke down.

4.5 Enter EPA

If December 21 was a day for crisis alarm, December 22 was a day of activity and movement. There was more scientific activity on this day than on any other. Some of it was the direct response to the breakup of the vessel. Some of it was ongoing activity. And some of it represented the fruition of efforts that had begun days before the breakup. To be specific, on December 22, the following things happened:

- The Coast Guard research vessel Evergreen began its cruise, ordered the day before, to survey the fate and effects of the oil. It was to be the first cruise in which water column and sediment samples were taken in oil-infested waters.

- The Delaware II, a NMFS research vessel also began a cruise. It was the start of the effort to assess the effect of the oil on the ecosystem, particularly on the Georges Bank fisheries. At the same time, NMFS port agents began canvassing returning fishermen to learn if the spill had caused any damage to fish or fishing equipment.

- The USGS began sampling sand for baseline hydrocarbon level measurements from the intertidal regions along the coasts of Nantucket and Cape Cod. The sampling was initiated by Robert Miller and David
Schultz of the Branch of Atlantic and Gulf Coast Marine Geology in Reston, Va. Miller had first proposed measuring intertidal hydrocarbon levels as part of the USGS's BLM contract for the Mid-Atlantic Region. Here was the perfect opportunity, explained Schultz, to start this sampling and at the same time to "answer the call," in that the samples would provide baseline data in case the oil reached shore. From Dec. 22 to Dec. 24, a USGS sample collector hopped by helicopter to 53 sites shown in Figure 4.5-1, disembarking at each site to scoop about 1000 grams of sediments into solvent-rinsed quart jars. Schultz himself was to come from Virginia shortly after Christmas to resample some of the sites.

- The Coast Guard and SOR team made its usual mapping overflight.
- The SOR team, on a separate helicopter flight, made its fourth set of leeway measurements.
- NASA made one of the five overflights it was to make during the incident and took 172 frames of high-altitude (2500 ft) vertical false color infrared photos.
- A NASA Landsat II satellite took imagery of a 100 x 150 mile area immediately to the southeast of the wreck. Unfortunately, much of the area was obscured by clouds.
- EG&G, BLM's contractor for physical oceanography, made its first flight in conjunction with Raytheon, the other contractor, and Aero-Marine Surveys, Inc. The purpose of this and subsequent EG&G flights was to photograph and map the oil, perform ART measurements of surface temperatures and to experiment with the drogues that were to be used to measure surface currents in the upcoming BLM study.
- Howard Winn of URI made an overflight to observe marine mammals.

- And for those scientists who still were unoccupied, EPA held a meeting.

We have so far not heard much from EPA, the group which, with NOAA, is responsible for scientific input into the spill response. EPA had sent representatives to the NRT and RRT and had conducted high altitude overflights on December 18 and December 19, but had otherwise maintained a low profile. But when Russell Train flew over the spill on December 21, he had asked EPA's Environmental Research Laboratory in Narragansett, R.I. to take a part in studying the spill's effects. The result was a meeting in Boston's John F. Kennedy federal office building. Just about every group involved in the scientific response sent at least one representative.

The purpose of the meeting was to plan a program to assess the ecological damage from the spill. EPA announced it would coordinate the program and help procure money for it. After each group discussed its own activities to date, the meeting broke up into several discipline-oriented skill sessions to draw up a rough outline of goals and methods. Attention was paid to the projected costs of the various activities as well as to purely scientific aspects.

To help the scientists, EPA had passed out a list of suggested goals and activities. Its longer-term goals included assessing the effects on fish and shellfish, in economic terms if possible, and monitoring the degradation and migration of oil in the sediments.
Immediate goals were to develop a budget of the oil's fate and to assess the immediate impacts on birds, mammals, plankton and benthos.

EPA placed heavy emphasis on studies of oil reaching the sediment and affecting the benthos. As its outline put it, "Much oil is apparently sinking. This will have a major impact on the fish and shellfish in the area... (The benthic region) is where the major impact will be and it must be investigated for both scope and impact."

It has already been discussed why it was thought that oil might sink. But it is interesting to ask on what basis EPA could say that much oil was sinking. Essentially, there wasn't any. The only evidence seemed to be visual evidence that oil pancakes were floating slightly beneath the surface, though not necessarily sinking. There had as yet been no sampling of the water column or sediment in oiled areas. In fact, it has been mentioned that the evidence was beginning to point in the opposite direction, though this evidence had not reached EPA or many others. It was at this meeting that Milgram first reported the results of his tests. And while there had been no measurements of suspended sediments following the spill, a USGS survey south of the shoals on December 9 had found suspended sediment levels of 1.3 mg/l, not very high at all (although levels could have been much higher on the shoals themselves). The SOR team's Jim Mattson in a later interview said that by December 22 he was fairly certain that the oil was not sinking in large amounts. Mattson, though, did not attend the EPA meeting.

In fact, at 10:10 a.m., 10 minutes into the EPA meeting, Mattson was talking on the phone to John Robinson of NOAA's Environmental
Research Laboratory in Boulder. Earlier that morning, Robinson had talked to lab director Wilmot Hess about conducting long-term assessment studies when the SOR team had finished its short-term work. On the phone he told Mattson that Lou Butler, also of the Boulder Lab, would arrive in Hyannis shortly to help coordinate such ecological studies. EPA and NOAA were headed toward a confrontation over coordination of studies that neither agency necessarily wanted.

4.6 Oil in Water: December 23 - 25

The chemical phase of the study — concerned with oil weathering and particularly with the transport into the water column, begins to accelerate a little now.

On December 23, Navy divers, requested by the SOR team two days earlier, conducted a dive below the slick and added another piece of evidence to the conclusion that oil was not sinking in massive doses. According to Grose and Mattson (1977), the location of the dive, though not known precisely, was under the path of the slick in an area that had been oiled by tides twice a day for seven days. Yet the divers found the bottom of white sand covered with clams not visibly contaminated. The divers took films of the bottom and of the underside of the oil, which included both sheens and pancakes estimated to be 1 1/2 to 2 inches thick. The bottom of the pancakes were flat and no oil was noticed breaking off from them.

On the SOR team's helicopter flight the same day, Scott Fortier of the Coast Guard R&D Center took 3 surface slick samples using a sampler capable of picking up thin sheens. Also on December 23, Jim
Quinn of URI performed the first gas chromatographic analysis of the Argo Merchant oil using part of Milgram's cargo sample and part of his sample collected from the thick part of the surface slick on December 19. Milgram had given the oil to Robert Sexton of URI at the EPA meeting. The chromatograms (Figure 4.6-1) confirmed the presence of the lighter, cutter stock, which was still not widely known at that time.

On December 24, the SOR team discovered that the means for sampling oil in the water column beneath the slick had been sitting right under its nose all the time. With the Argo Merchant essentially a lost cause, the on-scene cutter Vigilant was standing idly by and was not afraid to go into the slick. The SOR team gained permission for the Vigilant to take water column samples. Elaine Chan of the SOR team was airlifted to the Vigilant to instruct the crew in the use of the sterile-bag sampler. The sampler, the most widely used in the Argo Merchant response, is a 1-liter plastic bag that passes through the air-sea interface closed, opens at depth and closes again before returning to the surface. It leaves the sample uncontaminated by surface organics and oil.

Between 12:45 p.m. that day and 8:45 a.m. the next the Vigilant sampled 12 stations in the immediate proximity of the Argo Merchant. At each site it took a near surface sample (1-2 feet) and one at 10 feet. All these were flown to Cape Cod at 9 a.m. on Christmas Day, and eventually picked up by NOAA and frozen. When eventually screened by Richard Jadamec of the Coast Guard R&D Center, some of the 10-foot samples contained the highest hydrocarbon concentrations (250 ppb)
FIGURE 4.6-1: Gas chromatograms of cargo sample (top) and surface slick sample taken December 19. (from Grose and Mattson, 1977)
found by anyone in the water column after the spill. These are still very low levels. Whether this was because the oil did not enter the water column in large quantities or because the investigators did not look hard enough will be discussed in Chapter 7.

Meanwhile, by December 24 the Coast Guard vessel Evergreen had completed its sampling program. The original plan was to take water column and sediment samples and bottom photographs at each of 5 stations which lay in varied directions from the Argo Merchant (stations A through E in Figure 4.6-2). En route the Evergreen added 2 additional water sampling stations. Four water column samples were taken at each lettered station using sterile bag samplers. Sediment samples (2–4 per site) were taken at A through D. In contrast to the Oceanus cruise, some of the Evergreen’s sampling stations were chosen to be in contaminated areas. Station C in particular was selected for maximum pollution. The surface there was 100% covered by a sheen, with heavy concentration of slicks, clumps and tar balls present. Oil droplets were clearly visible in the water samples — most in the 1–2 meter sample, somewhat less in the 7–10 m sample and almost none in the 20 m sample. The bottom samples (70 m), however, looked free of oil.

4.7 The Cruising of the Delaware

The National Marine Fisheries Service’s Delaware II also departed on a short cruise December 22 for an initial survey of the effects of oil on fish and marine biota. NMFS, part of NOAA, is responsible for monitoring and maintaining the health of U.S. fisheries. For the area
FIGURE 4.6-2: Evergreen cruise stations, Dec. 22-24. Also shown is Dec. 23 slick map.
from Cape Hatteras to the Gulf of Maine, this responsibility was handled by the Northeast Fisheries Center (NEFC), comprised of six laboratories from Oxford, Maryland in the south, to Gloucester, Mass., just north of Boston. For 15 years NEFC had been conducting standard surveys of groundfish as part of a program called MARMAP (Marine Resources Monitoring, Assessment and Prediction). It had been sampling ichthyoplankton (fish eggs and larvae) since 1971 and had several other ongoing programs. Most of these programs were directed mainly at determining fish population changes resulting from fishing, to be used to regulate fishing. NMFS was somewhat less concerned with evaluating the effects of an acute pollution event on fish stocks, but seemed unable to avoid it. In the year preceding the Argo Merchant spill, NEFC had been requested by various government officials to assess the impact of three major pollution events. Finding it extremely difficult to do this, NEFC had been considering, for about a year before the spill, the development of a massive program to monitor the health of the fisheries in such a manner as to permit the assessment of the effects of chronic and acute pollution (NOAA, 1977).

Essentially, the program was to consist of regularly monitoring both polluted sites and control sites on the Atlantic Shelf. Measurements at each site were to include overall population by species, pollutant concentrations, and various biochemical and physiological indices of organism health. An attempt was to be made to correlate the three types of indices. However, the program was still largely an idea when the Argo Merchant ran aground.
One of the six laboratories of the NEFC is in Woods Hole, only a block from WHOI, and it was here that the response of NMFS originated. George Kelly and several others had attended the Woods Hole meeting on December 17, at which the SOR team and local scientists had all agreed that a boat was needed immediately.

Kelly recalled that he had first thought of using the George Kelez, a vessel, assigned to another NOAA group, which was sitting idly in a dock on Long Island. Kelly called Long Island that same day, only to find the crew had just been released for the Christmas holiday.

So Kelly next thought of the Delaware II, which was trawling in the Mid-Atlantic. The night after the WHOI meeting Kelly called NEFC Director Robert Edwards, who was in Boulder at the time, to advise him a vessel might be needed. Edwards said not to commit any vessels just yet. When the SOR team's Craig Hooper tried later, Edwards said the Delaware was to finish its trawl surveys before doing anything else. So the Delaware did not get to Woods Hole until Dec. 20, and only then after Richard Hennemuth, director of the Woods Hole lab, ordered it there. As it turns out, the delay was probably very fortunate, in that the Delaware II missed the weather that had forced the earlier Oceanus cruise to return.

With ship in hand, the next question was what to do with it. The SOR team desperately wanted water column samples taken for hydrocarbon analyses. Other than that, the Woods Hole NMFS group was mostly on its own. "There was no text, no guidelines as to how to go about it,"
explained Kelly. So the group decided to use the techniques it knew best — those of the standard MARMAP trawl and ichthyoplankton surveys which the crew had performed dozens of times. In addition, it was decided to take samples for two other of NMFS/Wood Hole’s ongoing projects — a study of benthic invertebrates and of fish feeding habits.

There was a problem, however, in that the MARMAP surveys were not designed to be conducted in oil spills. There is no method of catching fish or towing for water column plankton with a net beneath a slick without contaminating the samples and ruining the net. So the NMFS scientists decided to first get control samples from outside the spill area, without contaminating ship and gear, then to move into the oiled area and take only those samples that would not subject the gear to massive contamination.

The stations sampled are shown in Figure 4.7-1. They were chosen with the help of the December 22 slick map. Stations 1, 2,3,10 and 11 were strictly meteorological and oceanographical stations. Biological, sediment and water column samples were restricted to stations 4-9, three of which were inside the contaminated area and three just outside it. Sediment samples were taken at 6 stations using various dredges. Water column samples were taken using sterile bag samplers at 4 stations and 2 depths per station. Water column plankton samples were taken using standard MARMAP tows of 2 bongo nets. Bongo nets are so called because they consist of 2 circular nets side by side, resembling a bongo drum. The smaller bongo net had "drums" 20 cm in diameter with net mesh sizes of 0.165 and 0.253 mm. The other bongo had drums 61 cm
FIGURE 4.7-1: Delaware cruise stations, December 22-24. The slick shown is for December 22, the one used in cruise planning to demarcate oiled vs. clean stations.
in diameter and nets with mesh sizes of .333 and .505 mm. The .333 mm mesh was used primarily for zooplankton samples, the .505 mm primarily for eggs and larvae. Additional neuston (surface plankton) tows were made at all six stations using .505 mm nets. At stations 7 and 8 the net became soaked with oil and was saved in a can.

Fish trawls were made at only two stations, 4 and 6, both outside the oil limits. Each otter trawl was conducted for 15 minutes traveling at 3.5 knots. A .25 cm ring net with a 1-mm mesh size was attached to the trawl headrope to catch smaller invertebrates that escaped the nets. In all, 20 species of fish and 10 of invertebrates were collected. Some of each species were frozen for hydrocarbon analyses. Stomachs were removed from other fish, labeled and preserved in formalin for the food habit studies. The level of maturity was logged for all fish on standard forms. Live samples from station 9 were held in running water until the ship's return to Sandy Hook, N.J. From Sandy Hook, the samples were parcelled out to the various NEFC labs for analysis.

4.8 Joe Deaver's Christmas Present

Christmas brought with it a lull in the scientific activity, a time for taking stock. To summarize, while there had been no cruises before the ship broke up on December 21 (with the partial exception of the Oceanus), there had been 3 research cruises since then plus a sampling trip by the cutter Vigilant. As best as can be estimated, by Christmas morning there had been ten samples of oil taken, one
from the cargo and nine from the water's surface.* One or more water column samples had been taken at one or more depths at 26 stations, about 17 of them in areas that had been oiled at one time.** In addition to the near-surface sampling at these stations, the Delaware II took surface water samples at 7 sites. One or more sediment samples had been taken at 12 stations, 5 of which were below areas covered by the surface slick.***

Visual observations and preliminary screening of some of the water and sediment samples failed to detect massive quantities of oil, and the suspicion that oil was not getting below the surface in large amounts was backed by the observations of Navy divers. Biological investigations were somewhat farther behind, with extensive sampling having been done at only 2 stations on the Delaware cruise.

On Christmas Day the cutters Vigilant and Bittersweet stood by and watched the Atlantic Strike Team write Merry Christmas in oil on the remains of the stricken tanker. About the only scientific activity was Deaver's overflight, for which he was amply rewarded.

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*Sources of Samples: Two slick samples by Milgram on December 17, 2 on December 19; one cargo sample by Milgram on December 19. One slick sample from helicopter by SOR team on December 19; three by Scott Fortier of the Coast Guard R&D Center on December 23; one by the Delaware on December 23.

**These are: 3 Oceanus stations; 4 Delaware II stations (2 contaminated); 7 Evergreen stations (5 contaminated); and 12 Vigilant stations (assume all contaminated at one time or another).

***The count is: Oceanus—2 stations; Delaware II—6 stations (3 in areas of surface contamination); Evergreen—4 stations (2 in surface-contaminated areas).
For while flying on his fifth trackline of the day, Deaver noticed a most extraordinary glob of oil, which he estimated as 700 feet by 300 feet. The Vigilant was guided to the pancake, took a sample of it, and observed it to be between 4 and 6 inches thick. On this basis, it was estimated that "Pancake 1," as it was named, contained about half a million gallons of oil.

The pancake in the next few days served as an easily identifiable landmark of the oil and made tracking and modeling somewhat easier. "Pancake 1 was a great breakthrough for me," Deaver explained. "I could spot that thing in a snowstorm." When he discovered it, Deaver said, he dropped a radio beacon in it, but it was removed that night. The next day the SOR team dumped 100 drift cards on it to mark it even better. Eventually, on December 31, a satellite trackable buoy was dropped on the pancake and it was tracked remotely after that.

The sample of Pancake 1 that was taken on Christmas Day, incidentally, was the last surface slick sample taken of the Argo Merchant spill for research purposes, upping the count to 10 surface samples. Like the very first sample, some of it was given to Jerry Milgram for determination of its physical properties in an effort to see what changes weathering had wrought.
CHAPTER 5

LATE DECEMBER: LATE RESPONSES

5.1 Oil Ashore That's Going Ashore

The Christmas truce had no sooner ended than the battle began again. The wind, that gracious wind which had until now spared both beach and bank, pulled a doublecross. It happened between 2 and 3 a.m. on Sunday, December 26, when a 5-knot wind from the southwest flipped around to a 10-knot wind from the southeast. The shoreward winds persisted all night, nudging the oil toward Nantucket.

Warning of the shift had actually come during Christmas Day with the NWS wind forecasts, and the Oceanographic Unit's forecast predicted the oil would move within five miles of Nantucket by the next afternoon, Dec. 26.

Armed with the forecasts, Cmdr. Morgan of the Oceanographic Unit met with the SOR team late Christmas afternoon and it was decided that it would be important to launch drift cards ahead of the oil to warn of the time and location of landfall and help position cleanup crews and equipment. Unfortunately, the SOR team had used up its available cards and the only others were in Boulder. So a call was made to Craig Hooper, who had returned home to Boulder for Christmas, asking him to ship all the available cards, some 20,000 of them, to Hyannis. According to an article which later appeared in NOAA magazine (Paine, 1977) what happened next was this:

Hooper worked all evening to locate a commercial flight that could get the drift cards to Boston; the Coast Guard had pledged that it would meet
any commercial flight and get the drift cards into the water. Finally he called to say that Continental Air Lines has just cancelled its 4 a.m. flight from Denver, the last hope, because of the weather. At his request, Mattson and Lt. Cdr. Roger Cawley, who was responsible for coordinating beach cleanup, conferred. They decided that the cards were indeed badly needed; word was passed back to Hooper.

The night stretched on like a bad dream, with appalling weather and events appearing to conspire to frustrate the shipment while threatening the coast. At one point Hooper had to have a telephone call routed through London, as all domestic lines were hopelessly tied up.

He then left his family dinner, collected assistance from some of the Boulder staff of MESA (Marine Ecosystems Analysis group), and loaded a jet - chartered a short time before - with the cards.

At 5:30 a.m. the jet appeared over Otis [Air Force Base, on Cape Cod], asking for permission to land. Once on the ground, the MESA people who had come along pitched in and helped unload the cargo. By 9 a.m. and HU-16 Albatross seaplane took off with the cards, which were deployed successfully between the then menacing oil slick and the land.

The locations of the drift card drops made that day and the next are shown in Figure 5.1-1. Each drop consisted of 1000 cards.

5.2 Emergency Science, Part 2

Hooper wasn't the only one working through the night in response to the sudden event. Herb Curl of NOAA's MESA program in Boulder, hearing the forecast, decided that baseline data should be collected on the beaches before the oil's arrival, to allow eventual assessment
FIGURE 5.1-1: Drift card drops to warn of oil approaching shore. Each symbol represents 1000 cards. Also shown are mapped slick and forecasted limits for each day.
of the effects of the oil. From Boulder, Curl telephoned fellow 
microbiologist Stan Watson of WHOI and George Woodwell of the Marine 
Biological Laboratory in Woods Hole and asked them to help. A meeting 
was called for the next morning.

Here, again is the epitomy of emergency science. Some middle-of-
the-night phone calls (Woodwell remembers being called by Curl at 
1:30 a.m.), followed by a quick summoning of colleagues to a hastily 
arranged planning session. As WHOI's Howard Sanders later put it, 
"A panic button was pushed in Boulder. In an act of desperation 
they gave us a plea to try to do something."

The meeting convened at 9 a.m., Dec. 26, in Hyannis and was 
attended by NOAA's John Robinson as well as by the local scientists 
recruited by Watson and Woodwell. The day was spent designing a 
baseline sampling program and rounding up equipment. There seemed 
to be little time to lose.

The following day a field party assembled on Nantucket to complete 
the planning and begin the surveying. The party consisted of Woodwell 
and three others from MBL, Sanders and George Hampson from WHOI, and 
Tom Novitsky of BLiM contractor ERCo., who had been recruited by Watson, 
his former professor. The team also included two Nantucket-based 
researchers — Wes Tiffney of the University of Massachusetts' Nantucket 
Field Station and W. Patricia Morse of Northeastern University's Marine 
Science Institute.

The sampling scheme was chosen to suit the circumstances — it 
was designed to be implemented quickly yet to be as thorough as possible.
Sampling was restricted to four transects in areas either likely to be oiled or ecologically important (Figure 5.2-1). Accessibility was another factor in choice of sites. As is usually the case, no site combined all the desirable features. Nantucket Harbor was extremely valuable for its shellfish beds but was not as likely to be oiled. South Beach was the most likely to be oiled. It was the part of the island directly facing the Argo Merchant and was an area of rapidly shifting sands, on which organic debris was known to accumulate. On the other hand, Novitsky pointed out, this rapid movement would make follow-up sampling somewhat meaningless unless done frequently. Eel Point salt marsh was chosen both because it was thought likely to be contaminated and because of its ecological value. The North Shore beach was chosen largely for its accessibility and representativeness, the field party reported.

The transects themselves spanned the extent of the intertidal zone from the high strandline (thought a likely place for oil to accumulate) to the low tide zone. Samples were taken for various biological tests including bacterial counts, measurement of bacterial metabolism using labeled amino acids, measurement of chlorophyll content as an indication of algal biomass, and population and species counts on benthic fauna. Sediment and water samples for the determination of background hydrocarbon levels were taken adjacent to the biological samples. In addition, a visual survey was made to detect oil and tar on the beach.

The sampling effort was meticulously documented. Transects
FIGURE 5.2-1: MBL-WHOI-ERCO intertidal baseline sampling stations on Nantucket, December 27-28.
referenced to fixed landmarks and photographically recorded.

Most of the actual sampling was done on December 28, a day after
the team's arrival on Nantucket. The weather that day was so cold and
rough that Joe Deaver's overflight was cancelled for the first time.
The weather made the intertidal sampling operations extremely difficult.
The scientists often had to poke through ice to get samples. And
while it was realized that more water samples would have been desirable,
only George Hampton and Howard Sanders braved the icy choppy waters to
take samples at two stations in Nantucket Harbor.

Nevertheless, members of the field party who were later interviewed
expressed satisfaction with the sampling scheme, saying it would have
been useful for crude before-after studies. The main reason the studies
need be crude, they said, was the absence of a longer time series of
data. Sampling each location only once does not allow any accounting
for tidal, diurnal, seasonal or longer-term fluctuations, Woodwell
explained. For instance, the data collected would not be sufficient,
hisaid, to distinguish between the effects of the oil, had any come
ashore, and the effects of the storm.*

Both Woodwell and Sanders agreed that the team had had enough time
to plan and prepare. "If we had had more time to plan," explained
Sanders, "we might have done one or two things more, not a great deal."

However, it seems that the problem was entirely the opposite — not a matter of too little time to prepare, but of too much. In the

*Interestingly, distinguishing between the effects of a storm and a spill
was a major problem confronting those studying the effects of the
Santa Barbara Spill (Straughan and Kolpack, 1971).
field party's subsequent report (Grose and Mattson, 1977), they write:

"The challenge was two fold: first to obtain data from Nantucket immediately, because there was a real possibility that the oil would wash ashore within hours." Dave Frydenlund, who ran the Oceanographic Unit's model, said in a later interview that if the forecasted winds had persisted for 6 to 10 more hours, the forecasted slick limits would have reached the island. This would have put the landfall sometime during the late afternoon of December 26, the day of the planning session in Hyannis.

Of course that scenario never materialized. The wind shifted back to the west and northwest very shortly after the start of the Hyannis meeting. But had it not, the baseline sampling would have been largely useless (for baseline information, that is), despite the midnight phone calls, the hastily convened meeting and the ready response of several very able biologists. On the other hand, a quicker response would have required a shoddier survey.

5.3 Not-So-Current Meters

While Woodwell, Sanders et al. were struggling in a storm on Nantucket, two vessels were struggling with it on Nantucket Shoals.

One was WHOI's Oceanus, out for its second cruise. Again it collected water and sediment baseline data, again near sediment depositional areas, this time to the west of the wreck site (see Figure 5.3-1). Basic procedures were the same as on the first cruise. In spite of the weather and seas, the Woods Hole researchers managed to sample 8 stations. Also, the Oceanus crew deployed two current meter
FIGURE 5.3-1: Sediment and water column sampling stations of Oceanus cruise. Also shown is forecast limits for December 28.
moorings at the request of Brad Butman of the U.S. Geological Survey.

Butman himself was on the other vessel, the tug Whitefoot, deploying two other arrays. Of the four moorings emplaced on December 28, three contained only current meters of various makes, whatever Butman had been able to round up. The fourth was a bottom-monitoring tripod capable of measuring pressure (at wave frequencies or lower) and light transmission (an indicator of suspended solids load) as well as current speed and direction and temperature. The tripod also contained a camera which took a bottom photograph every four hours. And when the current speed exceeded a certain level, the camera was automatically triggered to take two photos in 32 seconds in hopes of capturing any quick sediment movement generated by the currents.

In addition to the moorings deployed December 28, an array containing two current meters and a bottom tripod were already operating on the southern flank of Georges Bank, put there by Butman on December 5 as part of the BLM Georges Bank study. Hence by December 28, there were five current monitoring stations in the vicinity of the Argo Merchant oil spill, which were hopefully to supply data for later use in studies of oil and water movement and for model verification. Their locations are shown in Figure 5.3-2.

In positioning the arrays, Butman's goal was to bracket the Argo Merchant. Particularly needed was a station to the southeast, where the oil had gone, and one to the west or southwest, in the believed direction of bottom flow. The specific locations surrounding the tanker,
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<tr>
<td>GS-2</td>
<td>Dec. 28</td>
<td>Tripod</td>
<td>70</td>
<td>70</td>
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<td>GS-3</td>
<td>Dec. 38</td>
<td>One Geodine</td>
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<td>40</td>
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<tr>
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<td>20.28</td>
<td>60</td>
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<tr>
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<td>Two Amp Vane's</td>
<td>45.75, 85</td>
<td>85</td>
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<td>Dec. 29</td>
<td>Three Ineeco Current Meters</td>
<td>5, 5.25, 50</td>
<td>50</td>
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</table>

**FIGURE 5.3-2: Current meter deployments**
however, were determined by a number of constraints. One, for instance, was scientific — the need to avoid severe local effects (non-representative sampling) caused by the shoals and the constrictions between them. Another constraint was purely logistical. Because of the short notice, Butman had been able to find only two surface markers for the four moorings. Therefore, he said, two of the moorings had to be positioned next to already existing surface markers. So the southernmost array went next to the Nantucket Light Ship and the westernmost one next to a Coast Guard buoy.

Positioning the tripod was even more problematical because of its wider usefulness, and decision-making on this question continued right up until the Whitefoot sailed. The decision to put it southeast of the wreck in the Great South Channel was made on two bases. First, the oil had moved in that direction and it was hoped to catch some bottom oil with the tripod’s camera. Secondly, said Butman, the USGS had been intending to put the tripod in the Great South Channel in January anyway, as part of the BLM study.

The story, by the way, of how these current meters finally came to be emplaced is worthy of telling in its entirety. For in one 12-day episode it illustrates many of the pitfalls that befell the scientific response to the Argo Merchant spill. As reconstructed from interviews with Butman and Richard Scarlett of EG&G, the story — and the problems — are as follows:

THE MIX UP: The idea to install current meters was first discussed independently by the USGS in Woods Hole and EG&G in Waltham on
December 16, the day after the grounding. Like the USGS, EG&G was a contractor to BLM for physical oceanographical studies of the Georges Bank, which were to begin in several months. Scarlett, coordinator of the OCS effort for the consulting firm, thought it would be a good idea to test out some of the equipment and techniques in advance, while helping the Argo Merchant response in the bargain. That day, EG&G called BLM's New York OCS office and asked for funding to deploy current meters and to test the air-deployable drogues which were to be used for Lagrangian current measurements. The New York office passed the word to Bob Beauchamp in Washington, who gave an initially positive reaction. EG&G also called Butman and the groups agreed to collaborate.

The following day, December 17, Butman attended the meeting at Woods Hole, in which the desirability of current meter data was commented upon. In the afternoon, Butman told Mattson of his plans, apparently including EG&G's current meters among his own without explicitly saying so. Mattson subsequently mentioned Butman's plan to Dave Allen, a BLM oceanographer, and the word trickled through BLM.

Later that afternoon, BLM called EG&G approving $7,500 for surface current studies to be drawn from EG&G's OCS funding. But it denied the firm funding for current meters on the grounds that someone else was already doing it, not realizing the someone else included EG&G itself. It wasn't until December 19th that the matter was straightened out in a conference call involving Scarlett, Butman, and the New York OCS office.

**THE FUNDING PROBLEM:** With the mixup untangled, EG&G still had to final-
ize funding for the effort. This was done Tuesday, December 21 when Scarlett and Dave Cook of Raytheon, EG&G's partner in the physical oceanographical benchmark study, went to Washington. Butman meanwhile had to round up equipment and load the Whitefoot. He had the mooring hardware and an old current meter on hand, plus another which had just been removed from Georges Bank. To make sure he had EG&G's two meters, the USGS arranged to pay EG&G, if necessary, until the company arranged matters with BLM.

**THE WEATHER:** The Whitefoot left Woods Hole on December 22 and experienced bad weather. The tug took refuge for the day at Nantucket.

**BREAKDOWN:** The seas calmer, the Whitefoot departed Nantucket at midnight on December 23. Three hours out, the tug's furnace broke down and the boat was forced to return.

**CHRISTMAS:** By then it was just about Christmas. Nobody really wanted to be at sea on Christmas. So current meters initially thought of on December 16 were not deployed until December 28, though it was really nobody's fault.

This lag, unfortunately, caused a decline in the value of the current meter data. The data would have been most useful for physical oceanographical and modeling studies in conjunction with the wind data and slick maps. But the period for which the slick was at its prime and well-mapped ended December 28.* It will still be possible, said

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*To be sure, mapping did continue well into January. But by January the slick had started to disperse and the maps were not as easy to use for model verification.
Butman, to get a general idea of what the currents were during the course of the spill. This can be done by examining the January data to get an idea of the current field as a function of wind conditions, then extrapolating backwards to December, using known wind conditions. But even this task, he said, will be difficult because the on-scene wind measurements by the Coast Guard cutter ended December 31. "I think we will be able to say something about what the currents were like during the spill," said Butman, "but it will be nowhere near as good as if we had the data for the time."

5.4 A Short-Lived Endeavor

The Endeavor, the brand new research vessel of URI's Graduate School of Oceanography made the first of four Argo Merchant-related cruises on December 28 and December 29. While the decision to use the ship had been finalized on December 20, it had taken a week to get it into commission. By all rights, the Endeavor was not ready for a research cruise. Its first cruise was not to have been until April. Temporary clearance to sail had to be obtained from the Coast Guard. A new captain had to be hired because the regular one was on vacation. But this was an emergency.

Once out at sea, numerous problems arose, as expected, with the scientific equipment. The Loran antenna froze at first; the winch broke; the laboratory had no plumbing. But what hurt the cruise most, in the eyes of the crew, was the weather. This was the same weather which grounded Deaver, rocked the Oceanus and hindered the efforts of
Woodwell et al. on Nantucket.

The weather limited the crew of 18 to three stations shown in Figure 5.4-1. Station 1, near the Davis Shoal buoy, was picked as an uncontaminated station. Station 2 was chosen as a contaminated station although there was no evidence of oil's presence at the time. This is just as well because the Endeavor did not want to sail into the slick for fear of gumming up its engines. Station 3 was chosen as being potentially in the path of the oil. The crew spent about 6 hours at the first station, 3 hours at the second and a shorter time at the third.

The crew included oceanographers, chemists and biologists. Three water column samples (near surface, 6m, near bottom) were taken at Station 1 using 5-liter Niskin bottles, the kind that enter the water open. Two samples (near surface, 6m) were obtained at the second station and a surface sample using a bucket was obtained at the third. Sediment samples for benthic population analysis and hydrocarbon determinations were obtained at the first two stations. Plankton net and bongo net tows were also conducted at the first two stations and the samples analyzed for species abundance and diversity.

At Station 2, a current meter array was deployed by David Shonting of the Naval Underwater Systems Center in Newport, R.I. Shonting, an adjunct professor at URI's Graduate School of Oceanography, said he was first called around December 21 by URI and asked if he had a wave buoy, which he didn't. But it was decided that current measure-
FIGURE 5.4-1: Endeavor cruise stations, December 29.
ments would be useful anyway.

The array consisted of 3 Endeeco self-recording meters placed at 5, 25, and 50 meters, the latter depth being just above the bottom. The devices had horizontal-axis rotors, which average out wave orbits better than the vertical-axis rotors used by Butman. Unlike Butman, Shonting did not think hard about where to best deploy the meters. That decision was made by others in the choice of Station 2. Shonting said there was no coordination between him and Butman, and, in fact, Station 2 turned out to be close to Butman's tripod station.

One purpose of the cruise was to aid in URI's ERDA-funded study concerning dispersants. This was done by trying to take an oil budget approach in determining the fate of the oil. In addition to water and sediment samples, an attempt was made to measure concentrations of airborne hydrocarbons using a device that continuously sucked in air. But the cruise was too late and too far from the oil to have realistically expected to catch any evaporated oil. Evaporation generally occurs within the first few days of the oil's life and the airborne hydrocarbons are likely to be dispersed quickly by the wind.

The same was true of attempts to measure the natural dispersion of oil by measuring concentrations of oil droplets in the water column, a key aim of the cruise and of the ERDA project's field program. "By the time we got there, all the oil that you'd expect to be in the water column had drifted away," said Peter Cornillon, the ocean engineering professor in charge of this phase of the cruise. Nevertheless, Cornillon painstakingly passed parts of all six water samples through a .45 micron
filter and scrutinized the filters under a microscope for the presence of oil droplets. He found only one droplet larger than 10 microns, a 155-micron x 300 micron globule from Station 3's bucket sample. To check that it was really oil and not some other particle, Cornillon injected it with carbon tetrachloride and the pellet dissolved. Cornillon never bothered to determine whether the droplet was indeed oil from the Argo Merchant.

5.5 Political Science

With the return of the Endeavor and the Oceanus and the changing of December into January, the scientific response began to enter into a transition period. With the initial sorties completed and most of the oil already spilled, it was clear that the next task was to be the assessment of the long-term fate and effects of the spill.

It was also clear that the new phase would require a new supervisory framework. While the SOR team was still in charge of day-to-day operations as January began, it had completed most of what it had come to do. The new response was to be more biologically oriented than the SOR team was and would probably require substantial amounts of funding over a long period of time. A new leader was needed to fill the gap which for the short-term studies had been filled ad hoc by the SOR team.

NOAA had made the motions to fill this gap. Around Christmas, John Robinson and Lou Butler, biologists from Boulder, had visited Hyannis to help determine what was needed in the way of a long-term ecological assessment. But this alone did not yet constitute a NOAA

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commitment to long-range studies and long-range funding.

There was also the question of EPA's role. In hosting the
December 22 meeting, EPA had implied that it would at least coordinate
the ecological assessment studies, and perhaps help fund them as well.
But the agency had done little in this regard since the meeting. The
person who was to head the Argo Merchant effort for the Narragansett
lab, in fact, did not even arrive in Narragansett from EPA's Washington
Office until December 27.

His name was Paul Lefcourt and he later explained that EPA never
intended to launch a full-scale study on its own. "This lab is a
research lab," he said. "It does not respond to oil spills. The
only reason the lab is involved is because Train asked the director
of the lab to get involved. EPA doesn't have the resources to go
offshore and do a long-term study. We have to rely on NOAA and the
Coast Guard."

This is only a partial answer, but seems to point at two of the
underlying reasons for EPA's sudden entry and quick withdrawal from
the coordination of the response. One reason is political. EPA, as
Lefcourt said, had become involved after an essentially political visit
by Russell Train at the height of the panic. Within a few days, however,
it had become increasingly clear that the spill was not going to be, at
least outwardly, the great ecological disaster that some had feared.
The public and politicians began to breathe easier. With the
pressure off, EPA might have become hesitant to commit itself to the
work and money that a full-scale assessment would require.
The other reason points back to something mentioned in Chapter 2 -
the division of responsibility under the National Contingency Plan.
As mentioned, there is no lead scientific agency; both NOAA and EPA
have their roles. And while EPA might have the stated responsibility
for damage assessment, NOAA has the oceanic expertise. Moreover,
the plan does not say how extensive an assessment is required. It
does not require a long-term program, since the plan is not really
concerned with the long-range aftermath of the spill.

Whatever the reason, EPA's behavior was to draw the ire of others
involved in the scientific response. It angered NOAA, which claimed
that it had held back on some activities thinking EPA would handle them.
It also angered many academic scientists, particularly at Woods Hole
and MIT.

The root of the scientists' complaints, however, was not only
that no one was clearly in charge, even weeks after the grounding.
Academic scientists were also somewhat upset that no agency was taking
the lead in financing post-spill studies. With the crisis upon them,
academic, government and private scientists had agreed to help when
asked, or even volunteered to help, with no guarantee of payment. Woods
Hole had conducted 2 cruises on faith. Milgram had performed his
analyses on his own. Others had managed to tap their existing projects
- URI its ERDA project, EG&G and the USGS their BLM projects. But with

* The National Contingency Plan says the following: "(EPA) provides
expertise regarding environmental effects or pollution discharges and
environmental pollution control techniques, including assessment of
damages."
the immediate emergency over, these scientists were becoming more reluctant to continue their post-spill investigations and take time out from their own projects without assurance of payment.
CHAPTER 6

JANUARY AND BEYOND: WINDING DOWN

6.1 The Coast Guard 'Bows' Out—Slowly

For the purpose of categorizing and classifying events into periods, ages and eras, as historians are wont to do, it can be said that the Coast Guard's wind-down phase began December 28 or thereabouts. Actually, a clever historian might claim to be able to trace this period back another whole week, almost to the time the ship split apart. For it was then that Capt. Hein, looking ahead, requested advice on the weathering and breakup of oil. Hein wanted a forecast made of when the oil would no longer be a threat—when it would lose its toxicity, when it would break up into tarballs, and how far from land the oil would have to travel before being considered beyond return.

The reason Hein was so concerned with this was that there was little else the Coast Guard could do but maintain the costly cleanup crews on Nantucket and wait for the threat to subside. The Coast Guard's booms and other cleanup equipment were not effective in the rough seas over the shoals. It was suggested that the Coast Guard attempt to burn the oil using a chemical wicking agent to help ignite it. So in late December, the Coast Guard conducted two burning tests. In both cases the oil failed to ignite sufficiently.

No one would give Hein the predictions he requested on the breakup of the oil because no one knew that much about weathering in general or about the Argo Merchant's cargo in particular. We have already seen
this in the mass puzzlement over whether the oil would sink. But surface
trajectory models—both on-line and probabilistic—were to become
Captain Hein's allies in the attempt to wrap things up. It was the
use of these models that began Dec. 28 or thereabouts.

Hein's first use of a model was in releasing most of the cleanup
crews on Nantucket for New Year's Day weekend. As Hein later explained,
the crews could have been mobilized in 22 hours and he relied on the
Oceanographic Unit's model, plus wind forecasts, to give him at least
that much notice.

The real use of the models, however, came in the decisions to
be made about the fate of the bow section of the Argo Merchant. All
this time the bow had been dancing around Nantucket Shoals and disposing
of it was to occupy much of the Coast Guard's attention through
January. On Dec. 30, Hein once again asked the District One commander
to permit the bow to be sunk with gunfire. He argued that little oil
would be released by the bullets and that sinking would stabilize the
bow on the bottom, making it easier to determine how much oil was left
inside it.

The bow section contained the first 3 or 4 rows of tanks, and
an analysis of how the tanker grounded and broke apart led the Coast
Guard to believe that oil might still remain in some of them. During
the grounding and breakup, water had risen in the cargo holds, forcing
oil out the top through holes called ullage gaps. But the ullage gaps
in the first four rows had not blown. Nor had the breakup obviously
affected the first two rows, the first break occurring between rows 7
and 8 and the second between rows 3 and 4. The number 1 port and
starboard tanks had never had oil in them to begin with, and a
subsequent inspection showed them to be dry. If they had remained
intact, it was conceivable that the 1 center tank and the three number
2 tanks, which did contain oil, were also still intact. These tanks
had a combined capacity of 1.5 million gallons.

This time permission was granted and at 11:32 a.m. on Dec. 31
the cutter Bittersweet opened fire on the skin of the bow, releasing
trapped air and a little oil. After 520 rounds the shelling stopped
and the bow settled, with about 10 feet remaining above the surface.

By January 3 or 4 it was clear that Captain Hein wanted to phase
out the full Coast Guard response and rely on occasional overflights
to keep watch on the oil. On January 4 he asked the Regional Response
Team to meet to consider whether the Coast Guard should continue to
track the oil and what should be done about the bow. He met the same
day with the SOR team to discuss further scientific efforts.

On January 5 Commander Morgan returned to Washington to help
improve the Oceanographic Unit's modeling. Hein requested the Unit
to continue its 24-hour forecasts, and in addition to provide 3-5 day
assessments of the chances of oil reaching land and a long-range
(6-month)outlook. At about this time, with the oil clearly moving off-
shore, the Oceanographic Unit ceased its sophisticated computer modeling
and began to make forecasts with a hand calculator using 3% of the wind
speed plus a residual current.

But political forces prevented a more rapid phaseout. Massachusetts
officials, in particular, did not want the Coast Guard to lower its
guard, not while there still might have been 1.5 million gallons of oil
in the bow. And the Coast Guard, still stung by the charges that it had
bungled the whole affair, was not willing to take unnecessary risks.
On January 7, the commandant's office advised Hein to continue tracking
the oil as long as it remained in some discernible form. That same day
the Atlantic Strike Team, after 4 days of standing by on the tug
Whitefoot waiting for good weather, dove down to inspect the bow.
But currents were too strong for the divers, who were still not able
to determine how much oil was left in the tanks. On January 9,
Admiral Stewart, first district commander, assured Massachusetts
officials that cleanup crews would be maintained on Nantucket until
the bow issue was settled.

There were, essentially, 3 options for dealing with the bow.
One was to do nothing except monitor the bow and be prepared to accept
a slow leakage of any remaining oil. The second was to try to pump
the oil out of the submerged bow. The third was to blow up the bow,
releasing all the oil at once at the most opportune time. Very early
Hein had realized that this opportune time was in the winter when
prevailing winds were offshore. But to back himself up, Hein, with
Morgan's aid, enlisted the help of risk assessment models. This
enlistment began December 28 or thereabouts, at the very beginning of
what we are calling the Coast Guard's wind-down period. Here's what
happened:

The Coast Guard called the USGS in Reston, VA. and asked it to rerun
its risk assessment model on a month-by-month basis. Richard Smith and Tim Wyant ran 300 trajectories for each month using the month's current and seasonal winds (Wyant et al., 1977). Of the 300 imaginary trajectories launched for December, 10% came ashore in the U.S. and none in Nova Scotia. For January, 8% came ashore, but then the figures started to climb. For February it was 16% (U.S. and Canada combined), for March 41%, April 52% and so on. The highest overall probability ashore was estimated at 92% for oil released in June. Considering the U.S. shoreline alone, the highest probability of impact was for April at 40%.

Bumpus, meanwhile, went back to his drift bottle data and compiled statistics on percentage of recoveries by month of release for the 1° longitude by 1° latitude rectangle which encompassed the wreck site. In 11 Januaries, 1960 through 1970 inclusive, 133 bottles had been released between 69°W and 70°W and between 41°N and 42°N. Only 3 of these were recovered, a rate of 2.3%. Some 166 bottles were released in Februaries and only one recovered - overseas. For Marches it was 242 launched and 10 recovered for 4.1%; for Aprils, 135 launched, 13 recovered for 9.6%; for Mays, 167 launched, 22 recovered for 13.2%. Interestingly, while Smith's figures continued to increase in the summer, Bumpus' figures dropped below May levels.

Morgan also commissioned an assessment from a former member of the Oceanographic Unit, Joe Bishop, now with NOAA's Center for Experimental Design and Data Analysis (CEDDA). As Bishop recalled, it took about an hour for him and Fred Godshall to get the first set of probabilities
from their model, which had originally been developed to compare the risks to several states posed by a deepwater port. The reason it went so quickly, a reason which by now rings a familiar bell, was that Bishop and Godshall happened to have recently obtained historical wind records from Nantucket Light Ship in preparation for doing some modeling connected with the OCS development.

Between Dec. 28 and Dec. 31, Bishop and Godshall did four runs for Morgan—two risk assessments for winter and two for spring. One run for each season used only winds, the other wind plus some average current.

Instead of using a transition matrix as the USGS had done, or a wind rose like URI had done, Bishop's model used the historical three-hour wind record directly. Fifteen years' worth of seasonal data proved ample enough for a generation of a sizeable number of trajectories. Oil was moved at 3% of the windspeed at 15° to the right of the wind direction. For the average current, Bishop and Godshall used one of .25 knots directly to the west for both seasons. This was estimated from readings at WHOI's permanent monitoring Station D, located off the coast of New Jersey at 39°20'N, 70°00'W, about 100 miles south of the wreck site (Bumpus, 1973). "I don't think it holds," Bishop said later about using this current for the Argo Merchant site. But it was the best that could be done on short notice.

Trajectories were followed for 1200 hours (50 days). A new spill was dropped onto the running historical record 72 hours after the previous one had finished. Bishop and Godshall divided the ocean into
10 mile x 10-mile squares and computed the probability of the oil impacting each square. They then plotted the results as probability contours, as shown in Figure 6.1-1. Considering, for simplicity's sake, the impact on Nantucket alone, the model for spring with current considered showed a 30% chance of impact. Next was a 10% chance of impact in winter with the current considered. Interestingly, when the current was not used a smaller probability of impact was estimated for spring (1%) than for winter (5%).

Finally, to top it all off, the Oceanographic Unit did its own probability estimates based on the method of Lissauer, Welsh and Hufford (1976). The probability of oil reaching shore was equated to the probability of wind blowing toward shore from a locus of release points. The locus was chosen to correspond to the maximum tidal excursion, an area 3 nm by 18 nm, oriented 30° - 210° and centered on the wreck. The source of wind data was the Navy Summary of Synoptic Meteorological Observations for the Quonset Point area and was based on 112 years of data reported by ships passing through.

The Oceanographic Unit realized that this model would produce erroneous and very high estimates of the probability of landfall. It assumes that oil released when the wind is blowing onshore will reach the shore, ignoring the very high probability that the wind would reverse itself before then. The Oceanographic Unit argued that the forecasts would serve as a worst-case estimate. Once again probability of landfall was higher for the spring than for the winter.

The Regional Response Team meeting took place January 11 and
CLIMATOLOGICAL OIL SPILL MODEL
(Percent Impact for 10 mile Square Areas)
CEDDA, EDS, NOAA

1. Wind-driven current only
2. Wind record for winter (1955–1970) months Nantucket Island

FIGURE 6.1-1: Example of CEDDA model output.
a unanimous conclusion was reached that it would be best to explode the bow before February 1, either from the air or, failing that, by demolition divers. The second-best option, the RRT decided, was to try to offload the oil. Last on the list was to do nothing.

Several factors played a role in this decision. For one, trying to offload the oil would have been extremely difficult and possibly even foolhardy. The oil would have had to have been heated so that it could be pumped, meaning heaters as well as pumps would have had to have been placed in the sunken bow, a hazardous task for divers in the winter waters. This "hot-tap" method would also have been extremely expensive. Murphy Pacific, a private salvage firm consulted by Capt. Hein, estimated a cost exceeding $600,000 for a removal of 100,000 gallons. It would also, the firm said, have required 21 days of good weather to remove these same 100,000 gallons. If there was one thing nobody was willing to gamble on, it was on getting 21 fairly continuous days of good weather during the winter on Nantucket Shoals.

Several considerations made immediate demolition of the bow preferable to slow leakage. One was that oil would likely do less ecological harm if released in the winter, when populations were lower. The other considerations were the seasonal wind pattern and the risk assessment models. The models clearly played a large part in the decision to explode the bow in winter. Captain Hein said later that they were "the biggest factor." This, clearly, was the finest hour.

*No doubt a fourth reason was that this would allow the response to end sooner. The day after the meeting, the District One Commander wired Washington: "Concur with RRT priorities except want to bomb stern and midsection as well. As long as oil is believed still in ship,[there is] pressure on us to continue monitoring and cleanup readiness."
for oil spill models, an official tribute of the highest kind. The models were trusted enough by Captain Hein and the RRT to support a decision which might have meant the deliberate spilling of 1.5 million gallons of oil, a major spill in and of itself.

Not everyone believed in models, however. The National Response Team met on January 13. It was far more cautious, requesting further information on historical weather data and on the possibility of quantifying the amount of oil in the bow. The RRT said it would meet again on January 21 and recommended no bombing in the meantime.

The State of Massachusetts in particular did not like the RRT's decision, despite the fact that its own RRT representative had voted for it. Evelyn Murphy, executive secretary for environmental affairs, and Lt. Gov. Thomas O'Neill, Jr. started active lobbying against bombing the bow. Senator Edward Brooke asked the Coast Guard to consider views of local citizens, and a public hearing was called for January 19 in a public school auditorium in Falmouth. Few of the speakers actually addressed the matter at hand, preferring rather to blast the Coast Guard's handling of the response or the flag-of-convenience system. Those who did address the proper question — mostly representatives of environmental or fisherman's groups or of towns in the area — were virtually all opposed to bombing the bow. They cited the damage the explosion itself might cause, the fact that some fish species were spawning, and the opinion that it was poor policy to deliberately pollute without exhausting all other possibilities.
When the NRT met again January 21, O'Neill and Murphy sat in. The NRT decided further study was warranted. In particular the committee thought it necessary to know how much oil remained and to analyze samples to predict its fate and toxicity should it be released. It also suggested a survey of the bow section to determine its structural integrity.

Nothing could be done immediately, however—neither bombing nor studying—because the bow had disappeared. During a storm earlier in January it had rolled over and bounced away along the bottom, and had so far eluded all attempts to find it.

6.2 Committees

Planning for the long-range phase of the scientific response, while it had begun in December, was formally initiated with a two-day meeting on January 3 and 4 at Woods Hole, convened by Jim Mattson. It can be said that this was the point at which the scientific community started to get formally organized, for indeed, the scientific effort was to emerge from the following week in a much more orderly and unified state.

The purpose of the meeting was to plan a NOAA-sponsored cruise to take place later in the month to assess the fate and effects of the oil. To help in the planning, the SOR team brought in Ronald Kolpack of USC as a consultant to chair the meeting. Kolpack, who had previously advised the SOR team, had for years been working on a three-dimensional model of the fate of oil spills.

The scientists at the meeting recommended that emphasis be put
on determining the amount of oil in the bottom sediments. A thorough sampling program was recommended, consisting of 50 stations along 6 north-south transects. Stations were to be located in the projected path of southwestward moving bottom oil as well as in the area covered by surface oil, and each transect was to extend beyond oiled areas to clean areas. Box cores were the recommended sampling technique because only they could sample deep enough (at least 10 cm) to determine the depth of contamination. In addition, according to Kolpack, they do not disturb the surface layer of the sediments as much as other methods. Those attending the meeting also recommended the cruise vessel have onboard hydrocarbon screening capability, so that the sampling program could be modified en route.

Biological sampling was also to take advantage of the quick screening results. Investigators were to concentrate on bottom sampling for benthos and bacteria, and on bird and mammal observations.

The cruise and subsequent analyses were projected to cost $225,000. The cost was written into the suggested plan along with the recommendations for transect locations and box cores. Funding, as has been mentioned, was becoming a salient issue.

One thing the plan did not specify, however. Who -- which crew using what vessel -- was going to do all this? At the time, no one knew.

Perhaps the most notable event of January 3, however, was the establishment of a single, uniform network to handle all water column and sediment samples. In December, samples had been taken by various techniques and each participating institution had analyzed its samples.
largely on its own, using its own methods. It was thought that a uniform method would make it easier to compare data from different laboratories.

The new system was to work this way: All samples were to be collected and catalogued by George Heimerdinger, a NOAA liaison stationed at WHOI. Heimerdinger was in turn to see that all samples were delivered to Richard Jadamec, a chemist at the Coast Guard R&D Center in Groton. Jadamec was to screen all water samples (including as many as possible taken before Jan. 3) using ultraviolet fluorescent spectroscopy and all sediment samples using that technique and thin layer chromatography. Both methods were under development as part of the Coast Guard's forensic oil identification system (Clow, 1977). As used by Jadamec, the thin layer chromatographic technique could give an indication of the presence or absence of oil but could not tell what type of oil.

The ultraviolet fluorescent technique provided a characteristic spectrum produced by excitation of the aromatics in the oil. It could give a crude indication of the type of oil. It could also give a rough idea of oil concentrations by comparing the samples with known concentrations of a reference sample. Jadamec never received any of Milgram's cargo sample, so for his reference he used the surface slick sample taken on Dec. 19 by Galt and Mattson from a helicopter. Since this oil had already lost some of its hydrocarbons, concentrations referenced to this sample tended to be somewhat misleading. How much this was so could not be determined since it was not known how much the reference sample had
weathered.

Based on Jadamec's screening, samples that seemed to contain oil or were otherwise interesting were to be sent for complete analysis by gas chromatography and mass spectroscopy to NOAA's brand new National Analytical Facility in Seattle, a facility built with the same $28 million in Alaskan OCS money which underwrote the SOR team. A committee was formed to determine which samples were to be sent to Seattle. Chaired by Mattson, the group included Jadamec, Farrington of WHOI, James Quinn and Chris Brown of URI and several NOAA scientists.

According to George Heimerdinger, the NOAA liaison in charge of sample cataloguing, it was about a week after that that NOAA's Boulder office decided it would also be necessary to establish a legal chain of custody for all samples, so that they could be used as evidence in court proceedings. Essentially, this was to insure that samples were not exchanged or tampered with between the time they were taken and the time the results got to court. Heimerdinger was also put in charge of this. Since NOAA did not have its own guidelines for this, those promulgated by EPA's Region I were used. EPA had long recognized the importance of the legal aspects. In its manual for post-spill investigators (EPA, 1972) it had written:

Your investigation and response may be discredited even though you do a competent job by ordinary standards. Questions like these may be asked: Is it possible that sample labels were accidently interchanged? Could someone have accidentally contaminated a sample with the chemical that was found after by analysis? What proof is there that this photograph was taken where and when you say?...Failure to have an adequate answer for just one such question may seriously weaken the value of your report, or destroy it entirely.
The guidelines were accordingly stringent, according to Heimerdinger. In the field the sampler and a witness had to identify and tag each sample and sign the tag. Each time a sample was transferred from person to person, it had to be signed for. Heimerdinger stored the samples in a locked freezer and he or an assistant personally escorted all samples to Croton for Jadamec's screening. Shipments of samples to Seattle were perhaps the biggest nuisance. Flights had to be non-stop; the samples had to travel in sealed freight containers, the plane had to leave on schedule and be met at the other end by someone who would again sign for the samples.

And so on.

On January 5 the scientific response became even more coordinated when confusion over the lead agency was officially ironed out. Ecological damage assessment studies were to be directed by an inter-agency committee of four consisting of Paul Lefcourt of EPA, John Robinson of NOAA, Gary Hufford of the Coast Guard R&D Center, and Robert Beauchamp of BLM. Robinson was to be actual director of the field investigations since NOAA had the expertise and, more important, the momentum. But the actual environmental assessment reports were to be prepared by EPA, which had the responsibility for them. The information collected by NOAA was to be used for an assessment by a contractor hired by EPA. BLM was to provide some money, as it had been doing all along.

With the stage now set for the long-term investigations, the field work of the SOR team was essentially complete. On January 9
the team vacated its headquarters at the Holiday Inn in Hyannis, leaving only a skeleton crew. The new team from Boulder, meanwhile, began moving into the Sheraton Inn in Falmouth, a few towns away.

6.3 Long-Range Tracking

Oil continued to be tracked throughout January and into February, but the job was becoming more difficult. The surface area inside the slick limits was getting extremely large, yet the fraction of this surface area actually covered by oil was diminishing far below 1%. In late December, the oil had reached the edge of the continental shelf. By January 3, the day of Joe Deaver's last overflight (his work was continued by others), the oil stretched 200 miles southeast of the wreck and the forecasted limits covered more than 10,000 square miles.* This was too large an area to cover by the regular zig-zag pattern, so flights either flew around the perimeter or covered only part of the area. By January 10, the limits covered more than 30,000 square miles.

Throughout January, visual tracking was supplemented by remote tracking with the aid of a NOAA drifting buoy. The buoy had been dropped into a pancake thought to be "Pancake 1" on Dec. 31. The buoy reported its position to a Nimbus-F satellite, which in turn reported to NASA's Goddard Space Flight Center, which in turn reported it to the Coast Guard.

It is not known how long the buoy actually stayed in the 75' x 35'

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* Slick maps and limits for all days until Jan. 9 are contained in the Appendix.