APPENDIX 10

A THEORETICAL DISCUSSION OF OIL CONTAINMENT BOOMS

A. Introduction

The prime object of an oil containment boom is to influence the flow of surface water in such a way as to hold back the polluted upper layer. It is necessary to not only restrict the oil's natural spreading tendency but also to impede the environmental conditions (i.e., wind, current and seas) which favor spreading. The success of any cleanup operation will depend upon whether or not the oil can be confined quickly to a relatively small area in relatively thick films. Although this is important it is just an intermediate step in the overall operation. With a containment boom the spill can be encircled and removed from the surface, deflected to another area or to a beach for easier removal or be prevented from entering areas of value.

The physical characteristics and behavior of the pool of oil contained by an oil boom will first be discussed. This will also include a discussion of some oil boom failure mechanisms. Both wind and currents effect the behavior of this oil pool by increasing the load on the oil boom and by increasing the tendency for the oil boom to leak oil. This area will be discussed next along with the forces that are applied to an oil boom. A list of symbols with definitions is presented at the end of this appendix.

B. Physical Characteristics of an Oil Slick

The shape of an oil slick trapped behind an oil boom has been described by Wicks[1] to have three regions when acted upon by a slow current (i.e., a current of less than 0.6 ft/sec).

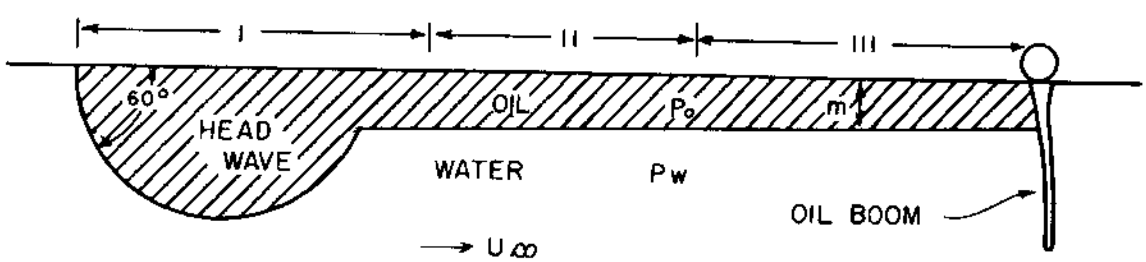

Figure 10-1

At this low velocity (less than 0.6 ft/sec) this configuration is stable. Above 0.6 ft/sec periodic traveling waves form along the oil/water interface in Region II and III. These waves travel toward the oil boom. The upper surface of the oil is quite smooth even though the lower surface is rough with these waves. Above 0.85 ft/sec oil droplets of less than 3/4" in diameter are torn off the lee side of the head wave and entrained in the flowing water. Two things can happen to these droplets. First, if they are buoyant enough, they can rejoin the oil slick before they reach Region III; second, they will be swept under the oil boom when in Region III regardless of their buoyancy. Above 1.2 ft/sec showers of droplets are torn from the lee side of the head wave. Also at these high current velocities waves begin to form at the oil/water interface of the head wave. These waves are stable in front but become unstable near the lee side of the head wave to allow droplets of oil to be torn free. There is also motion within the oil layer itself. There is a flow of oil in the direction of the current near the lower surface of the oil and a reverse flow on the upper surface.

Region I (The head wave) -

This head wave phenomenon occurs frequently in nature; it is similar to the wave shape observed when salt water is introduced into fresh water or when a submerged current of muddy water flows under clearer water.

The film thickness can be calculated from the equation:

$$m = \frac{U_\infty}{2g\ [(\rho_w/\rho_o)\ -1]}$$

at a current of about 1 ft/sec the film thickness will be 1.2 inches, and the head wave will be about twice as thick.

The rear or lee side of the head wave is the most unstable part. Waves form on the front side of the head wave and grow as they propagate to the lee side. At a critical current velocity of 0.62 ft/sec the waves become unstable and droplets begin to escape into the flowing water.

Region II -

The head wave acts as a discontinuity in the flow pattern of the current. The streamlines separate upstream of the head wave, pass under it, then reattach themselves to the surface as shown in Figure 10-2:

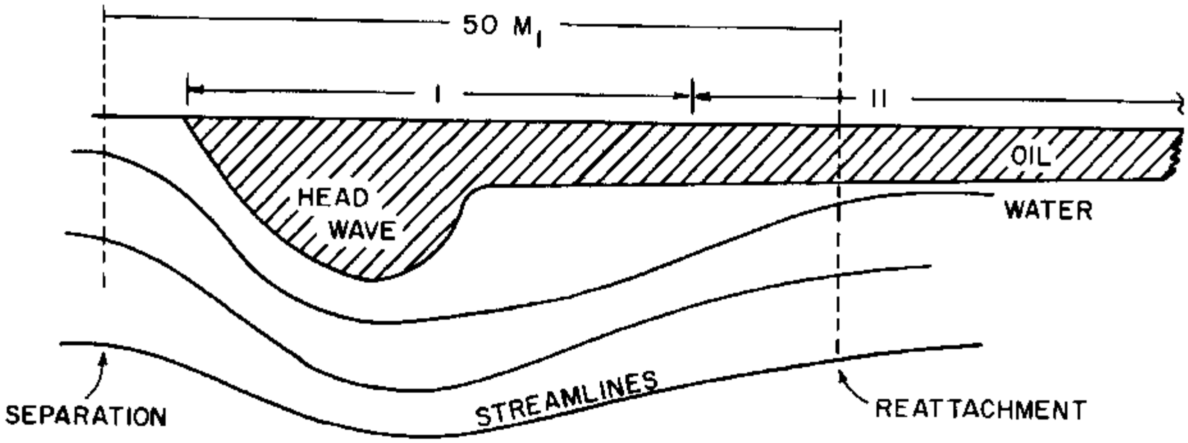

FIGURE 10-2: Boundary Layer Separation and Reattachment

Reattachment occurs about (50) (m_I) downstream. After reattachment a drag force is set up at the oil/water interface to cause circulation within the oil layer in Regions II and III.

The oil film thickness and cumulative oil slick volume are a function of the distance from the head wave. For example, in a 1 ft/sec current the slick will grow to a thickness of 8" at a distance of 20 feet from the head wave and 10" at a distance of 100 feet from the head wave.

Region III -

This region is characterized by the fact that any oil entrained in the water in this region will be swept under the oil boom regardless of the curtain's depth. As the curtain's depth increases so does Region III, although in a non-linear manner. It is usually taken to be about five times the curtain's depth beneath the oil/water interface, as shown in Figure 10-3:

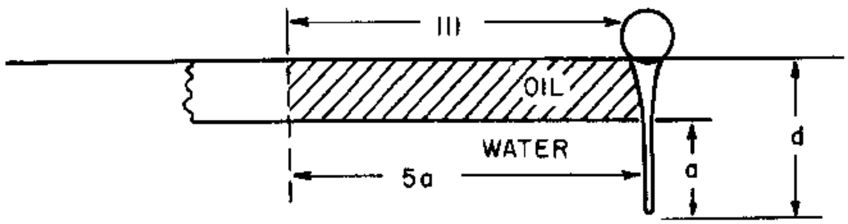

Figure 10-3

This curtain also acts as a discontinuity, so again the streamlines separate and flow under the curtain.

Now consider an oil droplet after being torn free from the lee side of the head wave. If the droplet has a large enough net upward force and sufficient time it will re-unite with the oil layer in either Region I or II. If not,it will be swept along with the water and flow under the oil boom. The terminal rise velocity, v_t can be calculated as a function of the distance downstream from the point of droplet formation. The particle will have enough time to rejoin the slick if the length of the slick in Regions I and II is longer than $2m_I U_\infty / v_t$;otherwise the droplet will be swept under the barrier.

In summary, then, there will be a velocity below which no droplets will be formed, thus, none will be entrained in the flow. At higher current velocities there may or may not be oil boom failure by droplet entrainment, depending upon the size of entrained droplets. The larger droplets with their high buoyancy force will re-unite with the oil layer, whereas the smaller droplets will be swept under the oil boom. At still higher velocities oil boom failure by droplet entrainment is certain since then even the largest particles will be swept under the oil boom.

There is still another method by which oil can escape past an oil boom and it is by a kind of draining action. Water flowing beneath the oil boom causes a pressure reduction which can pull or suck the oil under the oil boom. This is similar to what happens when a bathtub is emptied. When the bathtub is drained from the bottom a depression in the surface forms when the liquid depth reaches a certain critical height above the drain hole. This depression grows downward very rapidly, eventually forming a vortex as shown in Figure 10-4:

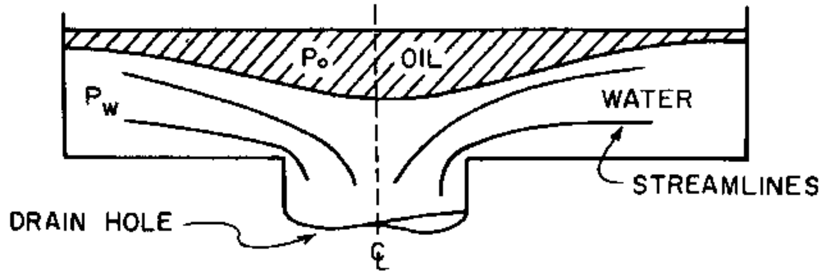

Figure 10-4

With some stretching of the imagination this radial flow into a drain hole can be re-interpreted to fit the flow of oil under an oil boom. Place the oil boom along the dotted centerline so the curtain extends into the drain hole where the streamlines will be parallel to it as shown in Figure 10-5:

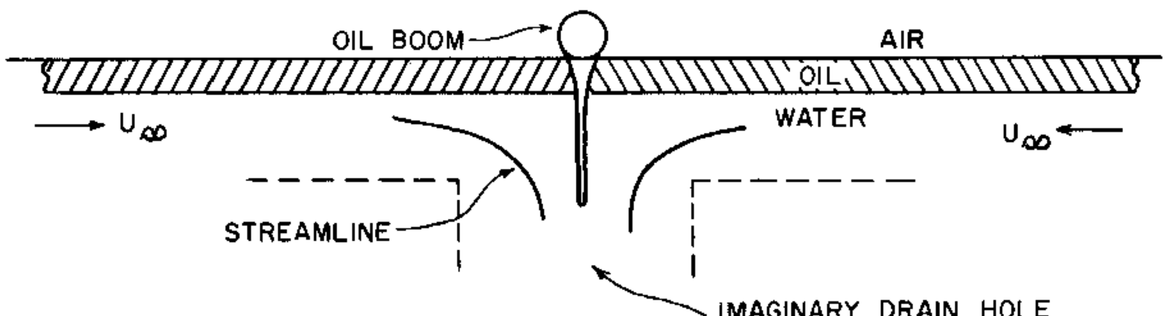

Figure 10-5

Now with an increase in the current's velocity the "critical height above the drain hole" will be reached and the oil layer will be depressed down toward the imaginary drain hole. At higher velocities a shower of droplets will be torn away from this depression and entrained into the flow, similar to the way the droplets were torn away from the lee side of the head wave in Region I. The shower of droplets will be torn away from the oil layer long before the depression shown in Figure 10-4 could have formed. Removing the imaginary drain hole and the symmetry of Figure 10-5 will lead to the method of oil boom failure by draining as shown in Figure 10-6:

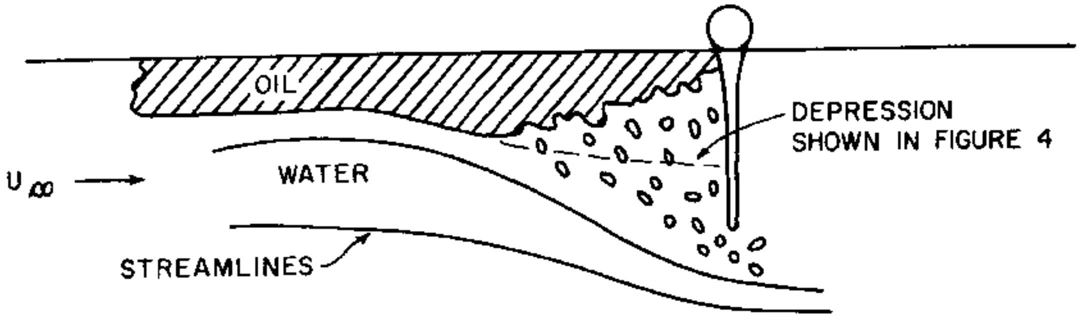

Figure 10-6

Other more obvious modes of oil boom failure include the physical destruction of an oil boom due to wind, wave or current effects; the splashing of oil over a boom by wave action and the flowing of oil under an oil boom when lifted clear of a wave trough and the flow of oil over and under an oil boom in a heavy wind.

C. The Effect of Wind

David Hoult[2] at M.I.T. looked at the problem of oil boom failure due to the action of the wind only. He looked at the effect of oil being pushed up against an oil boom's curtain of depth, d, by a wind blowing perpendicular to the oil boom as shown in Figure 10-7. With a knowledge of d the holding power of the oil boom can be determined.

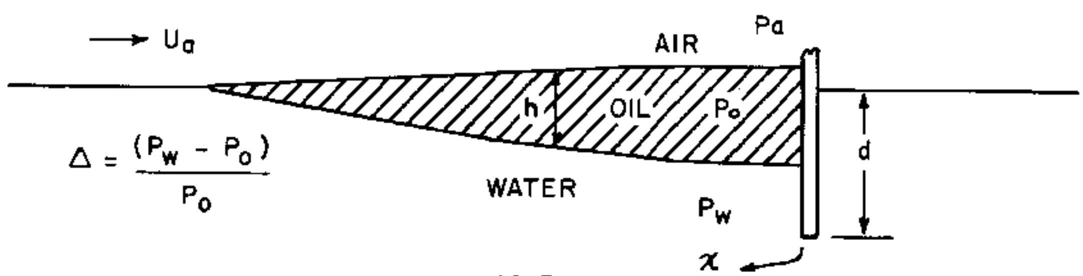

Figure 10-7

The turbulent wind stress τ acts on the oil piling it up against the oil boom until the gradient of the thickness dh/dx balances the wind stress set up. The expression relating τ to dh/dx

$$-\tau = \rho_w \Delta g h$$

The wind stress is $\tau = 1/2 \; \rho_a \; U_a^2 \; C_f$

where

$$C_f = 0.002 \text{ for oil on the open sea.}$$

The initial slope can be used to estimate the holding power of an oil boom. If Q is the volume of oil contained by an oil boom of length L, then the holding power may be expressed as:

$$\frac{Q}{L} = \frac{\rho_w \Delta g d^3}{2 \rho_a U_a^2 C_f}$$

The major point of interest here is that the oil boom's capacity increases as the cube of the effective curtain depth. In order to double the amount of oil contained by an oil boom due to the action of the wind the effective curtain depth would have to be increased by a factor of eight. This is not a very desirable situation. The presence of waves and surface water currents will make the situation even worse.

D. The Effect of Surface Currents

Ralph Cross and David Hoult[3] of M.I.T. looked into the oil holding capacity of an oil boom in a steady current.

An oil boom will be effective in holding oil against a steady current under proper conditions. The first condition is the existence of a critical Froude number above which the oil boom holds no oil. The second condition is related to the shape and behavior of the pool of oil held by the oil boom.

A quick estimate of whether or not an oil boom will hold oil at all can be made by comparing the forces acting to draw a small column of oil under the oil boom with the buoyancy of such a column of oil. The force driving the oil downward is the difference between the stagnation pressure and the free-stream pressure near the bottom of the oil boom, i.e., $1/2\ \rho_w U_\infty^2$. The net buoyancy is given by $\rho_w \nabla g d$. At incipient oil boom failure these two expressions are equal. The result will be the critical Froude number.

$$F_c = \frac{U_\infty}{\sqrt{\Delta g d}} = \sqrt{2}$$

At Froude numbers above $\sqrt{2}$ the oil boom will hold no oil. Failure will occur first near the apex of the boom which is assumed to be "U" shaped.

With a Froude number of less than $\sqrt{2}$ it is next desirable to find out just how much oil an oil boom will hold under the action of a current. First an equation relating X to h is needed.
Figure 10-8 shows how h varies with X.

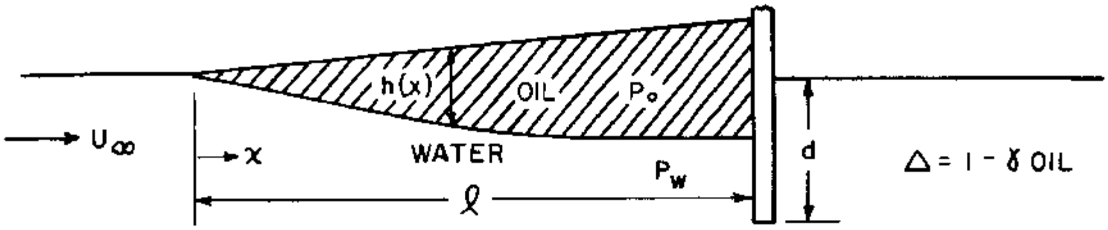

Figure 10-8

It has been shown[4] that the thickness of the oil layer, h(x), is not a strong function of the shape and construction of the oil boom. This is clearly seen by noting that the slick length may be 100 times the effective oil boom depth, d; and that the oil boom geometry can influence the motion of the oil slick up to about 5 oil boom drafts upstream. But, as a first approximation, assume only that the thickness is independent of the viscosity. This will lead to an expression relating the volume of oil held by an oil boom to the oil boom's draft, d.

The water current pushes oil up against the oil boom until the shear stress τ on the underside of the oil layer due to the current is balanced by the horizontal hydrostatic pressure gradient corresponding to an increase in thickness of the oil pool. This will result in the following equation for oil thickness as a function of slick length (h(x) vs. X):

$$h^2 = (U_\infty^2/\Delta g)\ C_f X$$

where

$$C_f = 0.008 \text{ and is independent of } X$$

Near the leading edge of the oil slick where the head wave occurs this equation does not hold, nor does the Froude number of $\sqrt{2}$ hold as a critical value for determining oil boom failure.

With this equation and an equation relating slick length, ℓ, to oil boom draft, d,

$$\ell = \frac{(d^2)\ \Delta g}{C_f\ U_\infty^{\ 2}}$$

an expression for oil volume stores per foot of oil, boom width can be obtained. This considers the boom to be perpendicular to the current which is not always the case. The oil boom will usually take on an approximate parabolic shape as shown in Figure 10-9:

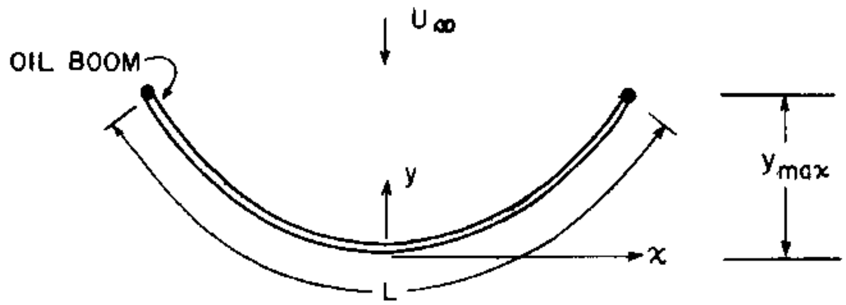

Figure 10-9

Now a more realistic calculation for the oil volume behind an oil boom can be made:

$$\text{Volume} = (1.9 \times 10^3) L d^3 \left(\frac{\lambda d}{L}\right)^{1/2} \left(\frac{\Delta g h_o}{U_\infty^{\ 2}}\right)^3$$

Where h_o is the depth of oil in the apex of the oil boom which must be less than the boom draft, d. The quantity λ is a tension factor which relates the tension in an oil boom to the normal force on a stretched-out oil boom. Values for λ are given in the following table.

$\frac{y\ max}{L}$	λ	$\frac{y\ max}{L}$	λ
.10	.028	.30	.163
.20	.078	.35	.231
.25	.115	.40	.336
		.45	.560

Again notice that if it is desired to hold twice as much oil, d will have to be increased by a factor of eight. The oil volume depends upon the cube of h_o and d. This analysis does not take into account oil boom failure by oil droplets being torn away from the oil layer. Here it is assumed that a low current drives so much oil up against an oil boom that the curtain depth d is not sufficient enough to hold it back. The combined effect of wind, waves and current on the holding capacity of a boom has not yet been investigated. Currents can be generated by both wind and waves as well as by the action of the tide.

E. Boom Forces

The mechanism of oil boom failure due to structural damage suggests that not enough information is known about the applied loads and the oil boom forces. Work done at Hydronautics Inc.[5,6] has provided basic quantitative engineering data on the performance of oil booms in a seaway. Oil boom loads (i.e., local loads and end or mooring loads) in the presence of wind current and seas and the oil boom motion (i.e., whether the oil boom will be lifted clear of a wave trough or completely immersed by a wave crest) were investigated at Hydroanutics, Inc. Their work is in the form of graphs giving forces, moments and curvatures for various oil boom configurations and mooring angles. Figure 10-10 shows the type of information available when using their data:

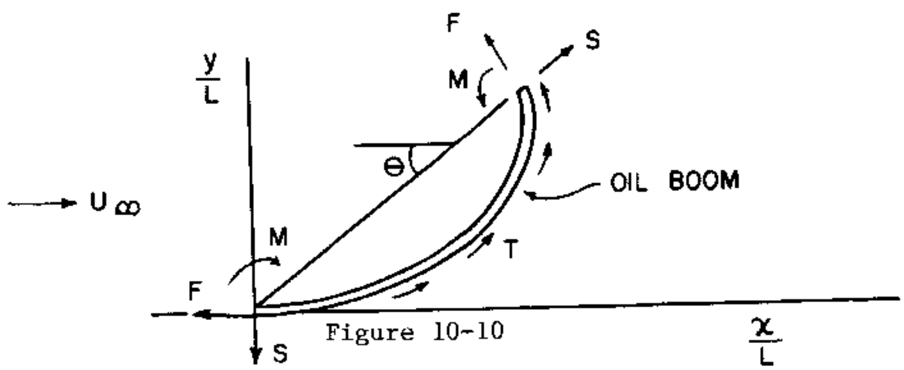

Figure 10-10

Where

Θ = Mooring Angle

F = Tension or axial force

S = Shear or normal force

M = Applied moment

T = Tangential force

When an oil boom is placed perpendicular to a current it is possible to calculate the drag force on the oil boom due to that current. This will give the minimum loads on the oil boom, loads that will tend to rip the oil boom apart or pull it free of its moorings. The equation assumes that a current piles so much oil up against an oil boom that the oil layer extends down to the curtain depth, d. Any increase in current will cause oil to flow under the oil boom. If the oil boom takes on a parabolic shape due to the current, then this equation holds near the apex of the curve. The drag force, D_F is expressed by:

$$D_F = (1/2) C_D \rho_w U_\infty^2 d\ L$$

where

C_D is the drag coefficient and is equal to $C_D = 1/F$

F is the Froude number and must be less than 1.3 in order for the oil boom to hold oil.[3] With a knowledge of U_∞, the current velocity; d, the curtain depth; and L, the oil boom length it is possible to estimate the loads on an oil boom. This equation does not take into consideration oil boom failure by oil droplet formation at the head wave or elsewhere along the oil/water interface, nor does it account for the effect of wind and waves.

F. Conclusion

In many areas of Puget Sound the combined effects of wind, waves and currents would require an extremely large oil boom to hold back the flow of the polluted surface water. However, to deflect the oil rather than stop its flow would require a much smaller oil boom. The object in deflecting the flow of oil is to save valuable property (either ecologically important or valuable man-made areas) while allowing the oil to flow into other areas. This is the concept of selectively sacrificing an area (letting the oil flow into an area where it can be easily cleaned up) in an attempt to save a more valuable area.

The problem with attempting to completely confine the oil or prevent any of it from getting into an area with an oil boom is that the oil boom does not always stay perpendicular to the current or wind direction. It will bulge out in the center and collect oil in the middle of the channel where it is difficult to remove. Also when placing an oil boom in a channel, the narrowest part might look like a good place to construct it but this area has the highest current velocity. Another consideration is the shape of the beach into which the oil is to be deflected. A gently sloping beach will have a lower current velocity along its sides than a beach with cliffs for sides, plus it will be easier to clean up and support cleanup operations.

Research conducted by Milz[7] has provided some current and wind velocities necessary to cause oil to flow under an oil boom. At current velocities of over 12 ft/sec and in sea states of over 2 to 4 feet oil booms have been observed to fail. At high current velocities, above 2.0 to 3.0 ft/sec oil booms become very ineffective because most of the oil is swept under the oil boom. As mentioned before, oil booms fail by having water splash over their tops;this happens when the ratio of the wave height to the wave length is greater than 0.08. Surface winds above about 12 knots were observed to force oil to flow under an oil boom.

It might be appropriate to mention two disadvantages of oil booms. First, they prevent surface craft movement, and second, they confine volatile materials which can create a fire hazard.

G. List of Symbols

ρ_o = Oil density

ρ_a = Air density

ρ_w = Water density

Δ = $(\rho_w - \rho_o)/\rho_o$
defined as (1 - Specific gravity of oil) or as the fractional density difference between the oil and the water.

U_∞ = Water current velocity, ft/sec

U_a = Air current velocity, ft/sec

g = Local acceleration of gravity, 32.2 ft/sec^2

m = Film thickness, ft

d = Oil boom draft (curtain depth), ft

a = Curtain's depth below oil water interface, ft

h = Variable film thickness away from curtain, ft

C_f = Friction coefficient

Q = Volume of oil held by boom, ft^3

L = Total boom length, ft

F_c = Froude number

λ = A tension factor

C_D = Drag coefficient

l = Slick length

H. Endnotes for Appendix 10

1. M. Wicks, Fluid Dynamics of Floating Oil Containment by Mechanical Barriers in the Presence of Water Currents, API/FWPCA Joint Conference on Prevention and Control of Oil Spills, December 15-17, 1969.

2. D. Hoult, Containment and Collection Devices for Oil Slick, Department of Mechanical Engineering, M.I.T., 1969.

3. D. Hoult and R. Cross, Oil Booms in Tidal Currents, M.I.T., 1970.

4. D. Hoult, Containment of Oil Spills by Physical and Oil Barriers, M.I.T., 1970.

5. J. Scherer, Design Requirements for Booms, Hydronautics, Inc., Washington, D.C., 1969.

6. W. Lindenmuth, J. Scherer and P. Van Dyke, Analysis and Model Tests to Determine Forces and Motions of an Oil Retention Boom, Hydroanutics, Inc., Washington, D.C., January 1970.

7. E. Milz, An Evaluation-Oil Spill Control Equipment and Techniques, Research Development Laboratory, Shell Pipe Line Corporation, Houston, Texas, April 1970.

APPENDIX 11

EVALUATION OF POLLUTION ABATEMENT PROPOSALS

A. Introduction

There currently is no shortage of anti-pollution proposals with regard to improvements in ship design and operation.[1] Equally obvious should be the fact that the proposals are, in themselves, not an adequate solution to the oil spill prevention problem. Some will ultimately prove to be more effective than others, or perhaps a combination of two or three or more may provide the best answer under the existing constraints. These constraints presently take two forms. One is the technical ability of meeting the requirements set forth by the various proposals. The second constraint is the endowment available with which to work. Although it is desirable, the economic constraints on proposed solutions are not infinite. There is a definite amount of funds available determined primarily through a complex ordering of priority according to the perceived need. Any discussion which neglects economic constraints is not realistic and thus should not be seriously considered. For the most part, technical ability is the least imposing of the two constraints.

This leads to the following: some means must be developed to effectively evaluate proposed prevention techniques. That is, some framework needs to to be established so as to allow for an analysis of the incremental costs of each proposal or combination of proposals as opposed to the incremental benefits derived therefrom. Little work has been done in this area as specifically applied to marine casualties that result in oil pollution.

Any analysis of marine casualties is a difficult problem, primarily because of the inadequate and inconsistent collection of experience. This absence of an adequate management control and information system is what leads to the accident-related response proposals presently used for correction of marine related problems.[2] With no means to consider marine accidents from a systems point of view, a suboptimal solution is generally reached; one in which there are no supporting quantitative means available with which to evaluate the effectiveness of the change.

In this era of giant supertankers where the potential for damage to the environment from these vessels and others is significant, the present system for response to an evaluation of solutions to marine problems is grossly inadequate.

Some work has been initiated to help close the gap. Stratton and Silver present a conceptual model of an operational research and cost benefits analysis of navigation proposals toward reducing marine accidents through their implementation.[3] The Coast Guard is presently developing a comprehensive management information system utilizing the abilities of modern computers. Paralleling this information system, they are developing a model of casualty situations from which it will be possible to evaluate various proposals as solutions to reduce or minimize further casualties. At the printing date of this report, it was learned that this project was stalled as the result of the untimely death of its leading proponent two years ago. Since then the project has not been actively pursued because of the press of other requirements. However, some indication of the direction the work was assuming can be gathered from an outline prepared by the planning staff of the Office of Merchant Marine Safety, July 7, 1969.

A brief discussion of both the Stratton and Silver, and Coast Guard models follows.

B. Stratton-Silver Model

The model discussed by Stratton and Silver is aimed at determining an optimal solution to the reduction of marine casualties through analyzing how changes in navigational procedures (technical advances) will affect the incremental costs and related incremental benefits. They maintain a view of the complex interaction between navigation, vessel operation and the world at large in their model. Their ideas are equally adaptable to other proposals for maritime casualty reduction and should not be construed as being confined strictly to navigational proposals. The model forms a conceptual base which can be expanded to accommodate other casualty reduction proposals as well.

The relationship of the various costs resulting from efforts to reduce, through technology, maritime casualties is shown in Figure 11-1. The

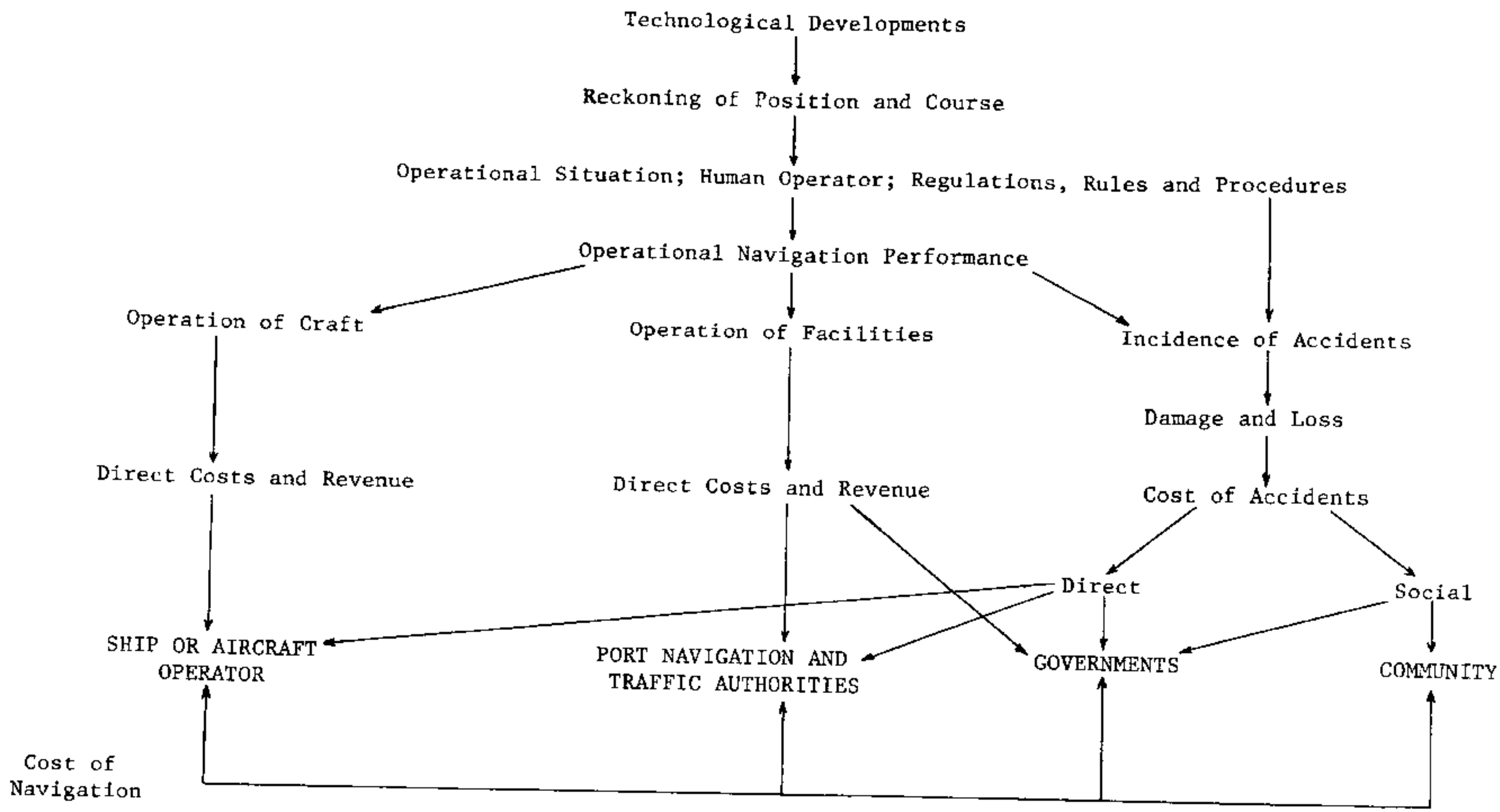

Figure 11-1: Relationship of Costs to Reduce Maritime Casualties[4]

operational performance is a function of the technical improvement and is determined in part by the interaction between the ability to effectively utilize the benefits of a design change, the operational situation and the operator's interpretation of the situation in relation to the control procedure that has been established.

The operational performance, in turn, influences the operation of the vessel, of supporting facilities, the incidents of accidents, and hence the costs and revenues associated with these happenings. Casualty costs fall on operators through loss of revenue and increased insurance rates and on society through the loss of life, property damage, loss of earnings, damage to the environment, etc. Some of this social cost falls on the government while the rest is borne directly by the community. The government also receives a load of the direct costs associated with a casualty which may somewhat offset the community cost. These costs to the government are in the form of direct payments to the injured community from insurance or damage claims. Thus, the total cost of changes in vessel operational performance as a result of technical proposals falls on the vessel operators/owners, the various operating authorities and the government. The end result cost to society is not so measurable in dollars as it is in the loss of amenity of life. Costs will be transferred among these various sectors only in relation to the extent of the external penalty imposed.

Because of complexity of these various interactions, quantification of these relationships is necessary to avoid a high degree of subjective judgement in the decision making process. This involves two related areas of study. First, it is necessary to apply operational research techniques to relate the operation of the vessel and supporting facilities and the incident of casulaties to the operational performance and situation resulting from a technological change. That is, the effectiveness of any technological change must be evaluated. An extensive data base is necessary for this type of analysis and must include such parameters as the number and size of ships lost or damages, the degree of damage, fuel consumption, time of voyage, etc. Secondly, these parameters must be translated into economic costs.

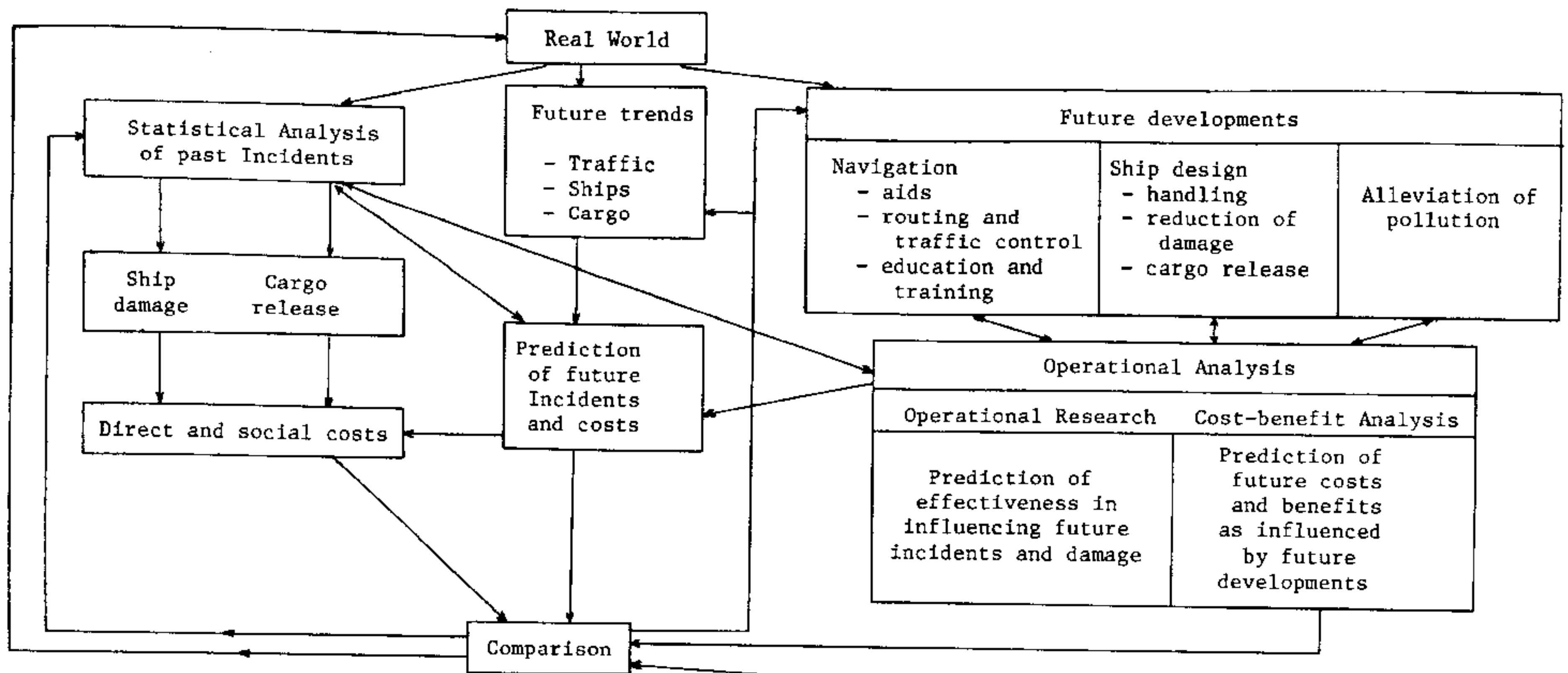

Figure 11-2: The method of conducting an operational analysis on marine accidents with particular reference to navigation[5]

The application of the overall system analysis to marine casualties is shown in Figure 11-2 in block diagram form. This diagram shows a method of conducting an analysis by abstracting the real world sufficiently to predict the effect of introducing any changes. The basis of the model is historical data and known physical laws.

C. Coast Guard Model

The Coast Guard Model is in conceptual form. The purpose of it is to compare the relative effectiveness of measures proposed to prevent or minimize potential oil pollution of the sea from ship casualties.

The basis of the model involves a consideration of the circumstances in which oil may be released, taking into account the degree of pollution which may occur and the likelihood of the incident.

Elements Involved:

I. Alternative Measures: (not a complete list)

1. Training of Ship's Officers
2. Installation of Radar
3. Tank Size Limit
4. Tank Arrangement
5. Backing Power Requirement
6. Decreased Turning Circle
7. Sea Lanes

II. Potential Pollution Incidents: (not a complete list)

a. Collision with Ship - Busy Populated Port
b. Stranding - Populated Area
c. Collision with Ship at Sea < 10 miles
d. Collision with Ship 10-100 miles at Sea
e. Collision with Ship - Small Unpopulated Port
f. Stranding - Isolated Area
g. Collision with Ship > 100 miles at Sea
h. Collision with Offshore Structure
i. Collision in Port with Dock

III. Severity Power

R is a factor to take cognizance of the seriousness of any one of the potential polluting incidents, as regards the quantity of oil which may be released, the difficulty of controlling the released oil, problem of cleaning up, and the extent of damage ensuing.

Thus, R_a is the severity of the incident "Collision with Ship-Busy Populated Port."

IV. Frequency: (F)

F is the relative likelihood that any potential polluting incident will occur. Because the data available to evaluate the probability of a casualty is quite limited a possible weakness may exist as to the relevance of the model.

V. Effectiveness: (E)

E is a factor to evaluate the utility of any Alternative Measures as applied to any potential polluting incident.

Thus, E_{1a} is defined as follows:

$$E_{1a} = \frac{\left(\text{Number of incidents of Type a in which Alternative 1 might be beneficial}\right)}{\left(\text{Number of Incidents of Type a}\right)}$$

VI. Comparative Worth: (W)

W is the comparative worth of any Alternative Measure. Thus, the worth of Alternative Measure 1 through m is:

$$W_1 = (R_aF_a \cdot E_{1a} + R_bF_b \cdot E_{1b} + \ldots + R_hF_hE_{1n})$$

$$W_2 = (R_aF_a \cdot E_{2a} + R_bF_b \cdot E_{2b} + \ldots + R_nF_nE_{2n})$$

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$$W_m = (R_aF_a \cdot E_{ma} + R_bF_b \cdot E_{mb} + \ldots + R_nF_nE_{mn})$$

VIII. Other Factors:

It is conceivable that in some Alternative Measures there may be inherent an increase in risk of pollution. Such a factor would have to be separately identified and a means found for judging the negative contribution to Worth.

D. Summary

Two facts should become evident as a result of the implications of the Stratton-Silver Model and the C.G. work.

1. A quantitative systematic analysis of marine casualties is necessary if the potential gains from casualty reduction proposals are to be optimized.

2. A satisfactory statistical analysis of historical incidents is necessary to the relevance of the model and at present is hampered by the lack of a sufficient data base.

E. Endnotes for Appendix 11

1. See Section III-C, Part 1, for discussion of policies related to ship's design and operation standards.

2. Marine disasters where loss of life or a significant loss of property is involved are reviewed by a board to determine the cause of the disaster. Once a determination is made, effort is directed through the regulatory process to "legislate" against another accident occurring from the same cause.

3. A. Stratton and W.E. Silver, "Operational Research & Cost Benefit Analysis on Navigation with Particular Reference to Marine Accidents," Journal of the Institute of Navigation, July 1970, pp. 325-340.

4. Ibid., p. 326.

5. Ibid., p. 328.

APPENDIX 12

ANACORTES OIL SPILL

While onloading 20,000 barrels of #2 diesel fuel at the Texaco Refinery dock at Anacortes, Washington, United Transportation (UT) Barge 17 discharged approximately 5,500 barrels (232,000 gallons) of its cargo into Padilla Bay, Washington on April 26, 1971. The following paragraphs describe the events subsequent to discovery of the oil spill. Topics covered include response, surveillance, cleanup techniques, resource protection, and the damage assessment. The information utilized in this appendix has been provided by Washington Department of Ecology, U.S. Coast Guard, and United Transportation Company.[1,2,3] All times used in the discussion are designated on a 24-hour clock basis.

A. Notification

Loading operations for Barge 17 were initiated at 2030 hours on April 25. At 0130 hours Texaco notified the tankermen of Barge 17 that the amount transferred was approaching 20,000 barrels; a check of the barge revealed that space was still available. A visual inspection of the water around the vessel indicated oil in the water. At 0135 hours Texaco shut down the loading opeation. After evaluation of the source of the spill and approximate quantity discharged, the tankermen notified the home office in Seattle that approximately 1,000 gallons had been discharged. This information was relayed to the duty officer, USCG, 13th district, at 0245 hours. Under the Coast Guard contingency plan, this quantity is classified as a moderate spill.[4] USCG initiated a routine investigation, and dispatched the Captain of the Port (COTP) Pollution Officer to the scene.

At 0800 hours COTP issued a press release stating that about 5,000 gallons of oil had been spilled and closed its case on the incident at 1110 hours.[5] A radio broadcast at 1200 hours reporting a larger slick being sighted in Rosario Strait prompted COTP to reopen the case at 1556 hours. Not until 1600 hours, April 27 (over 40 hours after the spill incident) did COTP confirm that over 5,000 barrels was discharged.[6] A statement in the United Transportation report suggested that the misunderstanding between the terms "gallons" and "barrels" impaired response capability.[7]

B. Surveillance

Based on the information available, the only technique utilized in the tracking of this oil spill was visual. Aerial surveillance, supplemented by waterborne observations, and beachcombing were the primary methods. The behavior of this oil spill is shown in Figure 12-1, based on inputs from USCG and UT. By 0730 hours, April 26 (six hours after the spill), oil was sighted throughout Guemes Channel. The slick then spread into Rosario Strait, where oil was reported in the 1200 hours radio broadcast. By 1800 hours, April 26, the oil had spread as far south as Smith Island, a distance of 24 statute miles from the source. Oil had also travelled as far north as Sinclair Island, moving on both the east and west shores of Guemes Island. Aerial reconnaissance inspection on April 27 indicated oil had spread west of Smith Island, and even extended to San Juan Channel by 1900 hours.

All sightings after April 27 were of oil patches inside the 1900 hour perimeter shown on Figure 12-1. Based on the characteristics of #2 diesel fuel and the water condition of that spill area, it is surmised that the visual components of the oil had dissipated by this time.

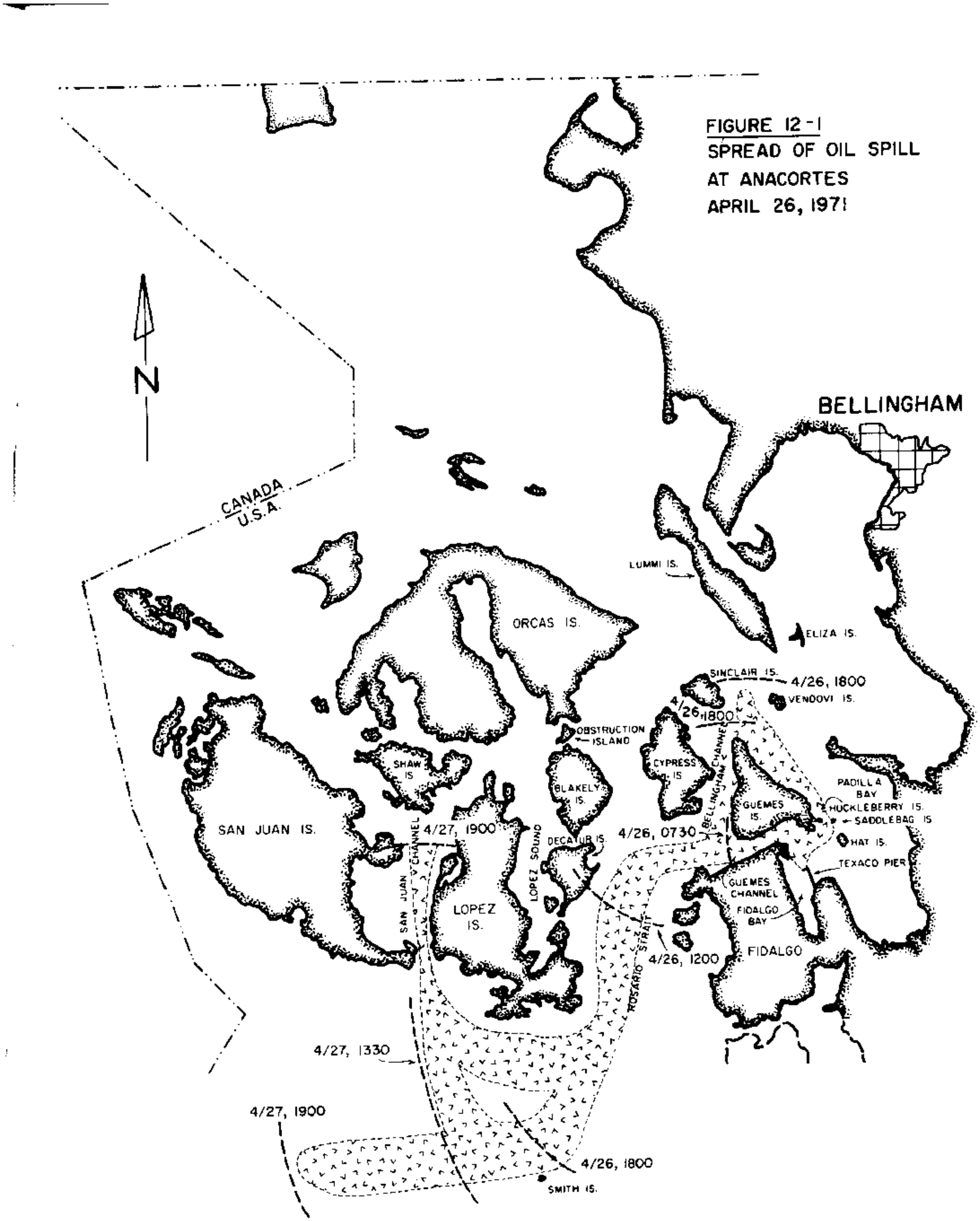

FIGURE 12-1
SPREAD OF OIL SPILL
AT ANACORTES
APRIL 26, 1971
N
CANADA
U.S.A.
BELLINGHAM
LUMMI IS.
ELIZA IS.
ORCAS IS.
SINCLAIR IS.
4/26, 1800
VENDOVI IS.
4/26, 1800
OBSTRUCTION ISLAND
CYPRESS IS.
BELLINGHAM CHANNEL
SHAW IS.
BLAKELY IS.
GUEMES IS.
PADILLA BAY
HUCKLEBERRY IS.
SADDLEBAG IS.
SAN JUAN IS.
4/27, 1900
SAN JUAN CHANNEL
LOPEZ SOUND
DECATUR IS.
4/26, 0730
HAT IS.
TEXACO PIER
GUEMES CHANNEL
FIDALGO BAY
LOPEZ IS.
ROSARIO STRAIT
4/26, 1200
FIDALGO
4/27, 1330
4/27, 1900
4/26, 1800
SMITH IS.

C. Response

At the time of the spill, the tug Sea Breeze was onsite, and was activated by 0300 hours, April 26, to breakup and disperse the slick. UT management arrived on scene by 0500 hours and immediately combed Guemes Channel for evidence of oil. By 0730 surveillance by tug had been completed. Not until after the noon radio broadcast was MOPS activated. DOE personnel also reached the scene about this time.

At 1600 hours on April 26, bird care supplies were dispatched to Guemes Island. At this time, the first wave of cleanup equipment arrived at Anacortes. This included one Mop Cat, 300 feet of 6" rubberized boom, 200 sacks of Fiber-Perl absorbent, pitchforks, shovels, and mesh screens. In addition, a work force of 25-30 men was included.[8] 100 bags of chopped straw were also secured from the Texaco Refinery. Two tugs with 1000 ft. of log booms were deployed into Bellingham Channel.

At 0600 on April 27, the tug Spartan arrived on-scene with 150 sacks of Fiber-Perl. Also on-scene was the tug Put River with 300 feet of rubberized boom. A team of out-of-town Texaco officials arrived at 0930 hours to survey this spill. The USCG arrived at 1130 hours with a COTP representative. A conference with UT at 1235 hours was the first on-site coordination effort in this spill incident.[9] At 1300 the DOE representative arrived at the spill site. COTP arrived on scene at 1400 hours, and called a meeting of the subregional response team (SRT) and the regional response team (RRT) at 1600 hours. A command post, with a mobile communications center and helicopter as support, was established at the Texaco Refinery at March Point. Concurrently, ARCO and Mobil deployed equipment to fence off Lummi Island.

On the morning of April 28, Texaco scientists inspected the site and theorized that the oil slick off Lopez Island had dissipated by natural action of micro-organisms.[10] At noon a contingent of personnel from Washington, D.C. arrived, stayed one hour and then departed, except for the EPA representative. In the afternoon, the U.S. Navy supplied 50 men to aid in the cleanup activities. Also at this time, COTP and DOE staffs departed from the scene. At 1800 hours, a team of EPA biologists completed an inspection tour of the marine life and expressed their concern for the lack of effort to cleanup beach areas.[11] A request for increased cleanup efforts was initiated, though USCG implied that complete beach cleanup efforts was improbable without removal of tons of sand and gravel.[12] At 0930 April 29, COTP received a report confirming the increased cleanup action requested by EPA. Sometime during the morning of April 29, a conflict of opinion arose between EPA and COTP with respect to the cleanup efforts.[13]

At 1700 on April 29, representatives of USCG, EPA, DOE, and UT discussed cleanup status and decided to continue for one more day. At 1130 April 30, a second meeting concluded that further activities were unwarranted. Operations were demobilized at 1400, and the command headquarters at Texaco were closed.

Apparently, the COTP, as on-scene commander, was satisfied with the response and cleanup, since there is no documented evidence of making "recommendations as to the action and type of resource to be used."[14] The Coast Guard contingency plan also specifies protection of "critical water use areas."[15] It appears that no preventive efforts were made to deflect oil from areas such as Lummi Island, Bellingham Channel, or San Juan channel until <u>after</u> oil had been sighted in those areas. Given the deployment capability and the effectiveness of booms, any action initiated after sighting a slick would be almost too late to stop the oil from entering the critical area. True, the efforts probably averted further consequences, but the purpose of defining critical regions is to protect them from potential oil slicks.

The referenced reports indicate that communications networks, especially inter-agency, were far below optimum. The small number of SRT meetings may be attributed to this factor.

With respect to mobilization time, about 6 hours elapsed from the Rosario Strait report until the arrival of the first equipment. The 10.5 hours prior to the radio report are not allocated to this figure. But it must be remembered what parties were involved. The oil was spilled by UT and UT is also an integral member of MOPS, the third party contractor. What happens next time if some other party outside MOPS is responsible for a spill? A conservative estimate of adding another 2 hours for communication seems to be in line, resulting in an 8 hour mobilization time.

Lastly, all agencies involved should critically examine their standards for judging adequacy of cleanup operations. "Out of sight, out of mind" is a poor criterion.

D. Cleanup

To minimize belaboring an already long discussion, the following statement by USCG will suffice:

> "The major effort of cleanup was concentrated on the residual light slicks with the cleanup of these light slicks by MOPS being effective. Puget Sound Tug and Barge estimated the entire cleanup operation recovered only 10 barrels of oil."[16]

USCG also concluded that the cleanup action on the beaches was considered more than adequate.[17] One must ask, how much is adequate, and by whose standards? Only time will tell in this case, since there was no scientific basis used at the time of the spill.

E. Damage Assessment

The Environmental Protection Agency (EPA) awarded $45,000 to Texas Instruments (TI) to make damage assessment studies, including chemical, biological and other types of analyses on water affected by the April 26 Anacortes spill.[18] Unfortunately, the firm was not notified by EPA until May 3, 1971 - one full week after the spill incident. By that time, the immediate short-term effects of the oil on the biota and other marine life had already been established. Without a baseline definition of this marine life, TI had no basis to assess the extent of short-term damage attributed to the oil spill.

1. Sampling Techniques

A study plan prepared by TI indicated that they would take approximately 20 samples for chemical analysis.[19] The following is quoted as guideline for their techniques.[20]

"A recent report by Dr. Max Blumer on a diesel spill on the east coast will* be examined for new analytical approaches to determine content and concentration of hydrocarbon in the samples."

It would appear from the foregoing statement that, at the time the study plan was written TI had no definite plan on how samples were to be analyzed nor how they were to be prepared. This is further indicated by their sampling techniques.

Water samples taken by the TI team were made up in polyethylene bottles.[21] An organic material such as polyethylene, contacting an oily substance, can alter the contents of the container and invalidate any analytical results. The Coast Guard contingency

*Underlining by coordinator.

plan includes the following warning:

"Glass containers always must be used because plastic containers, with the exception of teflon, have been found in some cases to absorb organic materials from water and in other cases compounds have been dissolved from plastic containers."22

It is known that oil, being lighter than water, will float on top. Thus, when taking bottom samples, care must be taken to isolate the container from the surface waters when immersing it in the water column. It is not clear how TI obtained their bottom samples; however it is known that standard bottom water sample bottles were used, they were lowered remotely, and the stoppers were pulled when the desired depth was reached.[23] No mention is made on how the bottle was lowered, or whether it was recapped in the water column or at the surface. Such information is vital to the integrity of an analysis.

It is interesting to note where TI set up their sampling stations. Figure 12-2 depicts the areas where TI conducted their study.[24] When compared to Figure 12-1, it is questioned why TI evidently did not include Lopez, San Juan, and Cypress Islands. (See Section II-A of this report for a pictoral view of the location of marine resources in this region.)

2. Coordinated Activities

Under the terms of the contract, TI was required to respond within 48 hours of notification by EPA.[25] The team did not arrive at the spill site until May 8, 1971, five days after receiving notice. Data was finally collected almost two weeks after the spill incident, May 9 through May 12.

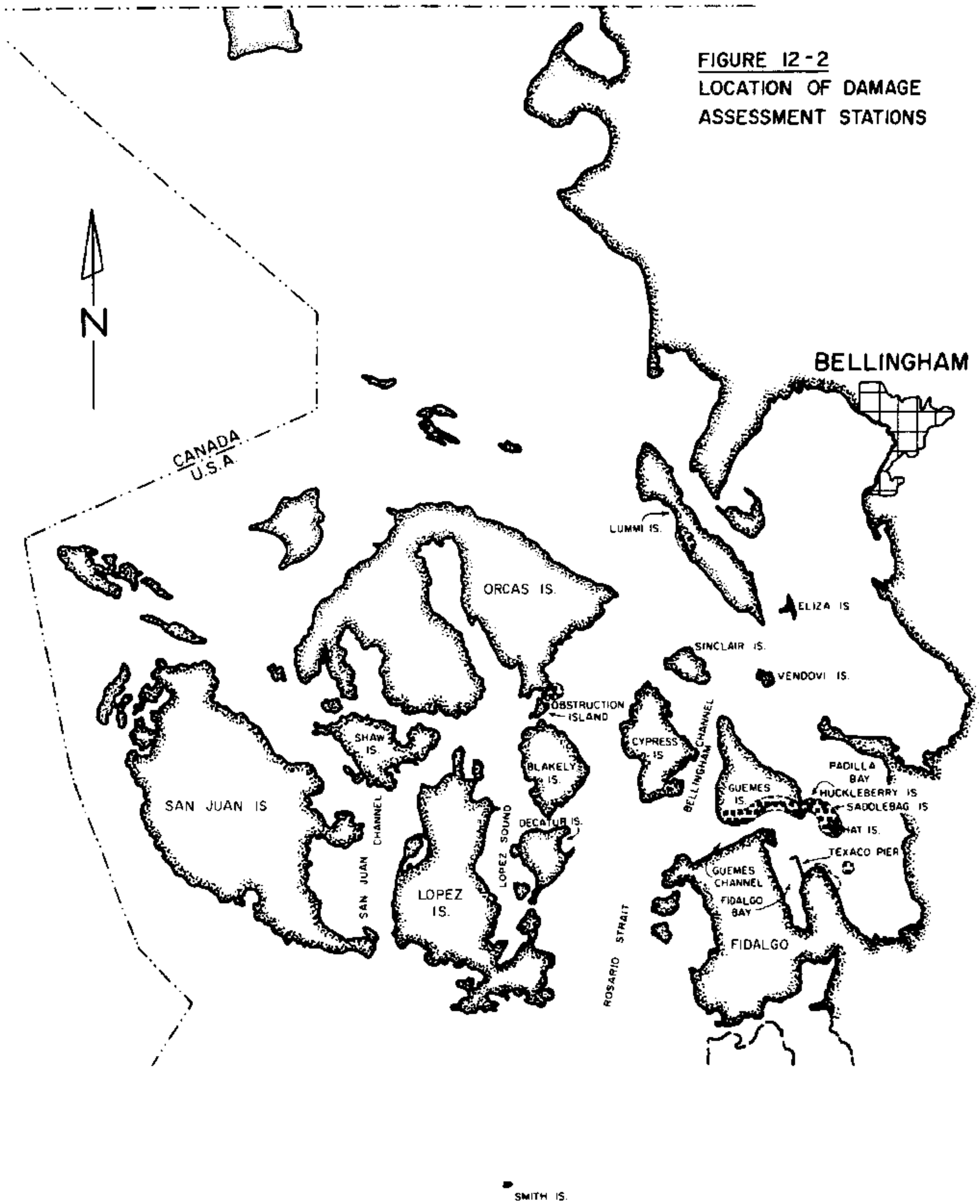

FIGURE 12-2
LOCATION OF DAMAGE ASSESSMENT STATIONS

In the area of coordination, the following are quoted from the TI study plan:

"TI will coordinate with area institutions and agencies to arrange for exchange of technical data concerning the subject spill, if available."[26]

"Additional scientific data on the spill as may be acquired for institutions and agencies (and will be included in the report)."[27]

In the preliminary report, it is stated:

"Other academic personnel from the University of Washington at Seattle carried out a subtidal inspection of the Guemes Island area by diving; they believed, however, that there was no need to return for detailed studies."[28]

Neither in the preliminary nor final reports is there further substantiation nor explanation of the results of the noted subtidal inspection. The "academic personnel" are not identified nor their credentials established.

Moreover, TI did not contact Robert C. Clark, a noted marine biologist for the National Marine Fisheries Service in Seattle, and co-author with Dr. Blumer on studies of effects of hydrocarbons on marine life.[29] The TI report did refer, however, to studies by Berg and Webber of Western Washington State College[30] and quoted some results.

F. Recommendations

Let us hope that the techniques and procedures utilized to combat and assess the Anacortes oil spill do not become standard operations for solving the oil-on-water problem in Puget Sound. But to alter these operations or to revise procedures requires evidence that changes will bring home some tangible benefit. It is not an overstatement to say that society in Puget Sound has not only incurred a loss from the spill itself, but also by the subsequent expenditures for control and assessment. Once the attitude for change is positive among responsible parties, then the mechanisms of a coordinated improvement program can be initiated. Society should insure that such improvement will be implemented if and when another oil spill occurs.

G. Endnotes for Appendix 12

1. Department of Ecology memorandum from H. B. Tracy to J. Behlke on the Anacortes spill, dated May 10, 1971.
2. Captain of the Port, Station Seattle Pollution Report #43-071, Captain of the Port, USCG, Seattle, Washington.
3. R. W. Roe, Report on Barge 17 Oil Spill, United Transportation Company.
4. U. S. Coast Guard, Seattle Coastal Region Oil and Hazardous Materials, Pollution Contingency Plan, December 1, 1970, p.5.
5. Report #43-071, Enclosure (1), p.1.
6. Ibid., p.2.
7. Roe, p.2.
8. Ibid., pp.3-4.
9. Report #43-071, Enclosure (1), p.2.
10. Roe, p. 11.
11. Ibid., p. 12.
12. Report #43-071, Enclosure (1), p. 3.
13. Tracy, p. 4.
14. Seattle Coastal Region, Annex XX, Appendix 1, Paragraph 3100.2.
15. Ibid., p. 14, paragraph 306.1-2.
16. Report #43-071, Enclosure (1), p. 6.
17. Ibid.
18. Seattle Post Intelligencer, August 15, 1971, p. 1.
19. Texas Instruments, Study Plan Anacortes Spill Survey, Texas Instruments Study Proposal, p. 5.
20. Ibid., p. 5.
21. Texas Instruments, Inc., Biological Assessment of Diesel Spill, Anacortes, Washington, May 1971 Preliminary Report, Texas Instruments, Inc., June 14, 1971, p. II-11.
22. Coast Guard Plan, p. VIII-5, paragraph 1804.2-5.
23. Preliminary Report, p. II-19.
24. Ibid., p. I-5.
25. EPA contract no. 68-01-0017.
26. Study Plan, p. 6.
27. Ibid.

28. Texas Instruments preliminary report, p. II-17.

29. Texas Instruments preliminary report lists the following document in their bibliography:

R. C. Clark and M. Blumer, "Distribution of h-parrafins in Marine Organisms and Sediments: Limnology and Oceanography," Vol. 12, 1967, pp. 79-87.

30. H. H. Webber, Survey of Mortality at Two Areas of the South Beach of Guemes Island between April 28 and May 15, 1971, Huxley College of Environmental Studies.