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**Oil, Shrimp, Mangroves:
An Evaluation of Contingency Planning
for the Gulf of Guayaquil, Ecuador**

by

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ABSTRACT

The possibility of finding oil in the Gulf of Guayaquil has led several Ecuadorian agencies to prepare contingency plans to deal with the eventuality of an oil spill in the area. This report characterizes the importance of the oil and fisheries industries to the Ecuadorian economy, and describes the region where these activities may conflict. It also elaborates on the biological effects of oil in tropical environments, and on aspects of prevention, control/clean-up and oil spill contingency planning. Compensation for oil pollution damages and methods for damage assessment are also discussed herein.

The analysis comments on specific issues of the Ecuadorian plans, such as their oil spill response organization and operational guidelines. It notes the willingness of the government and industry to handle the problem jointly and to do so prior to actual oil production. The combination of control/clean-up methods considered demonstrates the seriousness and sophistication of these plans. However, the planning process seems to overly rely on these clean-up measures as an antidote to oil spills. This report emphasizes prevention as the cheapest and the most efficient approach to protect the marine environment and resources of the Gulf of Guayaquil from oil pollution damages.

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LIST OF ACRONYMS

C/C	Control/Clean up
CEPE	Corporacion Estatal Petrolera Ecuatoriana (Ecuadorian State Petroleum Corporation)
CIMAP	Cooperative International Marine Affairs Program (Programa de Cooperacion Internacional en Asuntos Maritimos)
CLC	International Convention on Civil Liability for Oil Pollution Damage (Convenio Internacional sobre la Responsabilidad Civil por Danos Causados por la Contaminacion de las Aguas del Mar por Hidrocarburos)
COGUAR	Comando del Cuerpo de Guardacostas (Ecuadorian Coast Guard)
CRISTAL	Contract Regarding an Interim Supplement to Tanker Liability for Oil Pollution (Contrato Relativo a un Suplemento Interno para Cubrir la Responsabilidad de los Buques Tanque Nacida de la Contaminacion por Hidrocarburos)
DICAGC	Direccion de Capitanias y Guardacostas (Harbor Masters and Coast Guard Directorate)
DIGMER	Direccion General de la Marina Mercante y del Litoral (Merchant Marine and Coastal General Directorate)
DIMERC	Direccion de la Marina Mercante y del Litoral (Merchant Marine and Coastal Directorate)
ESI	Environmental Sensitivity Index (Indice de la Sensibilidad Ambiental)
FUND	Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (Convenio Internacional sobre la Constitucion de un Fondo Internacional de Indemnizacion de Danos Causados por la Contaminacion de Hidrocarburos)
INOCAR	Instituto Oceanografico de la Armada (Naval Oceanographic Institute)
INP	Instituto Nacional de Pesca (National Fisheries Institute)
JOCD	Jefe de Operaciones y Control de Derrames (Chief of Operations, or On-Scene Coordinator).

MARPOL International Convention for the Prevention of Pollution from Ships. (Convenio Internacional para Prevenir la Contaminacion por Buques)

MSI Mangrove Stress Index (Indice de la Tension en el Ecosistema del Manglar)

TOVALOP Tanker Owners Voluntary Agreement Concerning Liability for Oil Pollution (Acuerdo Voluntario de los Armadores de Buques Tanque Relativo a la Responsabilidad Nacida de la Contaminacion por Hidrocarburos)

WHOI Woods Hole Oceanographic Institution (Instituto Oceanografico de Woods Hole)

INTRODUCTION

Following a workshop on Cooperative Marine Affairs held at the Woods Hole Oceanographic Institution (WHOI) in April, 1982 (Technical Report WHOI-82-38), attended by a representative of the Ecuadorian Mission to the United Nations, members of WHOI's Cooperative International Marine Affairs Program (CIMAP) were invited by the Director of Maritime Interests of the Ecuadorian Navy in June, 1982 to verify the possibility of developing a cooperative program there. That initial invitation emphasized that:

"Ecuador is a developing country with significant marine resources. Oil and gas have been found in the Gulf of Guayaquil and actually there is an active exploration effort going on. As you well know the Gulf of Guayaquil is an area rich in living resources and the main site of the shrimp industry in our country.

At present there are some worries about the pollution that this exploration and the eventual exploitation might produce, not only damaging the marine environment of the Gulf, but deteriorating the quantity and the quality of the living resources that it produces. This will affect the economy of the country which depends on a significant percentage of the export of fishing products."

In September, 1982, a CIMAP visit to Ecuador produced a framework for a cooperative agreement that included, among other projects, the evaluation of plans related to pollution in the Gulf of Guayaquil.

Protection of the biologically-rich Gulf of Guayaquil from hydrocarbon pollution has been a major concern of the government of Ecuador. The near-term prospect for development of oil and gas could result in a classic case of oil vs. living resources conflict, which led different agencies to initiate plans to control probable spills and to monitor contamination in the area. The Merchant Marine and Coastal Directorate (DIMERC) drafted a plan of action to prevent, monitor and control hydrocarbon contamination in the Gulf; the Coast Guard (COGUAR) and the State Petroleum Corporation of Ecuador (CEPE) formulated complementary contingency plans. Further plans included two scientific monitoring projects prepared by the Naval Oceanographic Institute (INOCAR) and the National Fisheries Institute (INP). The latter also provided an environmental study for the placement of industrial complexes in the Gulf of Guayaquil.

The evaluation presented here is limited to the first three plans only, those related to contingency action to avoid oil contamination in the Gulf (Annexes I, II and III). Its objective is to offer suggestions that can be considered by affected Ecuadorian agencies in their planning process, since these plans have not yet been formally adopted by any of the above agencies and it is also our understanding that none are final drafts. In reviewing these plans, questions relating to civil liability and compensation for oil pollution damages inevitably arose and are also discussed herein.

The review included extensive literature research on the effects of oil on mangrove areas and on marine organisms; oil-spill prevention, response and contingency planning; containment and clean-up equipment; and oil pollution liability. A seminar entitled "Oil vs. Shrimp in the Gulf of Guayaquil: Devising an Adequate Monitoring Program" was held at WHOI in December, 1982 to receive comments from a wider audience; and a small work group, formed from some of the attendees to the seminar, met in January. Participants of the work group included biologists Dr. Judy Capuzzo, Dr. Howard Sanders, Dr. John Teal, all from WHOI, Dr. Carl Berg and Dr. Robert Howarth from the Marine Biological Laboratory; fisheries ecologist Dr. Michael Healey, and chemist Mr. Bruce Tripp also from WHOI. Based on these insights, a preliminary assessment report was written and presented in Ecuador by the author on February 8, 1983 at the Oceanographic Institute of the Navy, Guayaquil.

An informal agreement established with the Ecuadorian Government on the same date requested the present technical report. The scope of this report is broader than a strict analysis of the above Ecuadorian contingency plans. This is in realization that contingency plans cannot be technically evaluated outside of context, and without some knowledge of the socio-economic and physical environments where they are intended to come into effect. Sections 1 and 2 were designed to provide this essential background. The information contained in these sections is perhaps familiar to the many capable Ecuadorians from DIMERC/COGUAR, CEPE, INOCAR, INP and other agencies; to them the author hopes to have been accurate in the brief description of their dynamic country.

"Country Profile" (Section 1) characterizes the importance of the oil and fisheries industries to the Ecuadorian economy. The exploitation of these resources in the last ten years has practically rewritten Ecuador's economic history. Section 2 on the Gulf of Guayaquil offers a general picture of the area where the activities of these industries may conflict, which includes those factors that directly influence oil spill response operations, such as seasonal variation of weather (wind and temperature), waves and currents.

In the third section, the fates and consequences of oil spills, particularly in tropical environments, are approached. Sections 4, 5 and 6, respectively, elaborate on the concepts of oil spill prevention, control/clean up and contingency planning. It is only in Section 7 that DIMERC's, COGUAR's and CEPE's plans are summarized and specifically evaluated. Changes made in these plans since the initial assessment provided by the author in February, 1983, are described and commented in Section 8. Civil liability and compensation for oil pollution damages are treated in Section 9, which is followed by the report's conclusions. The annexes offer an unofficial English version of the original Ecuadorian plans. Although intended to be complementary to each other, the sections of the present report are self-contained and may be read independently.

1. COUNTRY PROFILE

Distinct patterns of human settlement and economic activities seem to characterize the three geographical regions of the Ecuadorian mainland: the coastal lowlands, the Andean highlands and the Amazon (Figure 1). Traditionally, the national economy had been supported by the agricultural output of a few major crops, with bananas, cocoa and coffee occupying the leading positions and representing most of the country's exports until the early 1970's. These products come primarily from the Guayas lowlands, situated north and east of the city of Guayaquil, and along the eastern shore of the Gulf of Guayaquil (James, 1969).

The 850-kilometer long coast of Ecuador (FAO, 1978) is one of the narrowest zones of climatic transition in South America, passing from tropical rain forest in the north at the border with Colombia, to desert a few degrees south near the border of Peru (James, 1969). Just over half of Ecuador's 8,500,000 people (U.S.D.O.S., 1982) live in this western third of the country. Concentration of people of African origin occurs in the northern part, while those of Spanish ancestry are concentrated in Guayaquil (James, 1969), but overall the population is largely mixed. The city of Guayaquil handles 95% of the country's imports and 50% of its exports. It is the largest city in Ecuador (1.2 million people) and its most important commercial center (S.A. Handbook, 1982; U.S.D.O.S., 1982).

Production from the highlands of the Andes is not as important to the export economy, even though almost half of the population is settled in the sierra. Self-sufficient Indian farmers live there in small rural communities, forming distinct clusters within ten intermont basins. Quito, the political capital of the country (population 900,000) is located in one of these basins, in the midst of the Indian communities (James, 1969; U.S.D.O.S., 1982).

A. Oil Production

The discovery of oil in the foothills of the sparsely populated Amazonic region (Figure 1), often referred to as the "Oriente", generated a major shift in the Ecuadorian economy. In August 1972 the 300-mile trans-Andean pipeline was completed, connecting the oil fields of the "Oriente", located near Lago Agrio (U.S.D.O.S., 1982), with the Pacific port of Esmeraldas (Balao Oil

Figure 1. Map of Ecuador, indicating geographic regions (shaded area was arbitrarily drawn at the 300-meter contour of the Andes, cutting across the Amazonic foothills); oilfields in the "Oriente" (located in the Amazonic foothills at the borderline with the Andean highlands) and at Punta Santa Elena; and the Gulf of Guayaquil.

Terminal). Petroleum production immediately jumped from 1.6 million barrels in the previous year to 28.6 million in only the last five months of 1972, generating \$61 million in export revenues, which then represented 19% of total exports (IDB, 1973). The production of 76.2 million barrels in 1973, aided by the quadrupling of world oil prices, quickly increased this figure to \$228 million, or 42% of all exports (IDB, 1973; IDB, 1979).

After the peak production of 1979 (78.8 million barrels), which ensured oil receipts in the order of \$1,076 million, approximately 50% of the export trade, oil production declined slightly because of governmental conservation measures since substantial new reserves had not been found (IDB, 1979; CEPAL, 1980). The 1981 production reached 77 million barrels, earning export revenues in crude and petroleum products in the order of \$1,727 million (67% of total export value). A consortium between CEPE (the state oil company) and Texaco, which operates in the "Oriente", is responsible for 98% of this production (U.S.D.O.C., 1982).

Domestic oil consumption continues to increase at rates higher than domestic production, and already represents more than half of domestic output (IDB, 1982; L.A. Reports, 1983b). Because of the growth in internal demand and the need to continue an adequate level of oil export to generate foreign revenues, CEPE turned its attention to the Gulf of Guayaquil as a potential source of oil. Several oil companies have produced and refined oil there onshore, at Punta Santa Elena (La Libertad), since 1925 (Guerra, 1983). CEPE engaged in what turned out to be a costly contract with "Perforaciones Marinas del Golfo S.A." (PERMARGO), a Mexican company, for the exploratory drilling of three wells in the external part of the Gulf, near Santa Clara Island. No oil was found in the area (L.A. Reports, 1983a), which may postpone any effective oil development there to the later future.

B. Fisheries

Fisheries have become another important factor for the economic development of Ecuador since mid-1970's. From 1975 to 1980, total catch increased three-fold from 222,000 to 671,300 metric tons, and is estimated to have reached 725,000 in 1982 (U.S.D.O.C., 1981a). Seafood now ranks third in exports, immediately after petroleum, and the traditional agricultural crops of bananas, cocoa and coffee combined (U.S.D.O.C., 1982; U.S.D.O.S., 1982). Export earnings jumped from \$6 million in 1970 to \$71.9 million in 1977, reaching \$165.6 million in 1980 (FAO, 1978; U.S.D.O.C., 1981a). The industry

is also an important source of coastal employment, both in the catching and the processing sectors.

Rapid growth in the catch of small pelagic species and increased shrimp production significantly contributed to this excellent performance. Thread herring, Pacific mackerel, sardine and anchovy, which make up about 90% of total Ecuadorian catch (U.S.D.O.C., 1983), are landed directly to processing plants near Salinas and in the Gulf of Guayaquil (Figure 1), where most of them are reduced to fish meal and oil. These landings have increased from about 35,000 metric tons in 1970 to 593,100 metric tons in 1980 (FAO, 1978; U.S.D.O.C., 1983). Intending to improve production efficiency in the existing twenty-three fish-meal plants, the government imposed a ban on expansion and on the construction of new processing plants, starting in March, 1981. This ban seems to reflect also the government's concern that continued growth of fishing for pelagic species used for meal production could result in overexploitation of the resource (U.S.D.O.C., 1981c). Recent reports indicate a severe decline in the catch of these species, but it is not known yet whether this reduction is a direct result of overfishing or the return of the warm El Niño current (U.S.D.O.C., 1983).

El Niño associated rainfall, however, may be beneficial for the shrimp industry. Shrimp are mostly found in the Gulf of Guayaquil. Penaeid shrimp spawn at sea, afterwards the larvae migrate to the mangrove swamps along the coast of the Gulf, where they feed and grow. Heavy precipitation would wash large quantities of nutrients into the coastal estuaries where the juvenile shrimp mature, thus increasing the supply available to trawling and pond operations.

Shrimp is the single most important fishery export commodity, contributing 40% of the total 1980 fisheries export value. In that year 10,200 metric tons of shrimp worth \$66.4 million were exported by twenty-one packing companies. Nearly 9,200 metric tons were sold to the United States. Total harvest has increased almost four-fold since 1975, from 5,800 to 20,100 metric tons in 1981 (U.S.D.O.C., 1981c; U.S.D.O.C., 1983). This dramatic improvement derives primarily from the harvest of cultured shrimp. Pond farming is rapidly replacing shrimp trawling as the major source of the product, and already represents approximately 70% of total production (U.S.D.O.C., 1981b).

Ecuador is considered to have the world's largest shrimp culture industry, most of which is concentrated along the Gulf of Guayaquil. In 1980 there were 32,000 hectares of shrimp ponds officially built, but this number could be as high as 80,000 hectares, since many ponds have been constructed without governmental authorization (U.S.D.O.C., 1980; U.S.D.O.C., 1981c). Six years earlier, the cultivated area was no greater than 600 hectares (Ramirez, 1982). Trawl fishermen have accused pond operators of depleting the stock of shrimp larvae and juveniles from the mangrove estuaries to supply the ponds. Scientists, however, believe that destruction of the estuaries due to pond construction and coastal development are the more probable causes behind the steady decline in trawler catches since 1977. Maritime traffic and industrial pollution also have been blamed for adversely affecting the catch in the southern part of the Gulf, off Puerto Bolivar (U.S.D.O.C., 1981c). The trawl fleet, however, concentrates along the northern coast of the Gulf, at the mouth of the Guayas river. Most of the shrimp vessels are based either at Posorja or Guayaquil (FAO, 1978).

2. GULF OF GUAYAQUIL

The Gulf of Guayaquil dominates the southern portion of Ecuador's coast. It is 160 kilometers long and covers an area of approximately 12,000 square kilometers. Water depth at the center is estimated to be 60 meters (Pesantes, 1975). Two channels are formed in the interior of the Gulf by the large island of Puna (Figure 2). Canal del Morro, the shorter, narrower channel, lies to the northwest of Puna and averages 20 meters in depth. It is 50 meters deep at its narrowest point (Cruz-Orozco, 1974). Canal de Jambeli, to the southeast, averages 12 meters in depth. A narrow continental shelf extends for 75 kilometers westward of Puna. Its outer limit borders the Peru-Chile Trench, which reaches its greatest depth (4,000 meters) only 140 kilometers offshore from the island. The shelf's slope averages 1.4m/km (Cruz-Orozco, 1975).

Figure 2. Map of the Gulf of Guayaquil, indicating the Guayas River estuary and mangrove areas.

The Guayas River is formed five kilometers upstream from the city of Guayaquil (Murray, 1975), and flows for approximately 60 kilometers to empty into the Gulf. The river is five kilometers wide at its mouth. The Gulf's land-water interface throughout the Guayas delta and in the southeastern coast is composed mostly of mangroves (Figure 2). Cliffs and sandy beaches are found in the northwestern coast from Punta Santa Elena to Punta del Morro, and Puna Island, and constitute perhaps a third of the Gulf's coastline (CEPE, 1982; Cruz-Orozco, 1974). The Gulf's economic importance lies mainly in terms of port facilities, its potential for oil and gas, and fisheries. The country's most important fishery resources (Jimenez, 1983, Ramirez, 1982), including ten species of Penaeid shrimp, are concentrated there. In 1976, for example, 170,000 tons of fin-fish and shrimp were caught within the Gulf area, which represented 65% of Ecuador's total catch (Hallberg, 1977). Ramirez (1982) describes these commercial fisheries, and estimates the present annual catch of pelagic species in the Gulf of Guayaquil to be greater than 600,000 metric tons.

A number of oceanic currents influence the region: the near-shore Humboldt current, and the Equatorial and Tropical surface currents. This mix produces strong upwelling and temperature gradient. Equatorial waters move further southward when the northward-flowing Humboldt current weakens (Cruz-Orozco, 1974; Pesantes, 1975). Another input to the mix is fresh water from the Guayas River. Discharge varies from approximately $200 \text{ m}^3/\text{sec}$ in the dry season to over $1,600 \text{ m}^3/\text{sec}$ during the rainy season (Pesantes, 1975). These water masses, particularly the cold Humboldt current, are largely responsible for the richness of the Gulf. The water is rich in chlorophyll and nutrients. Concentrations of phytoplankton may exceed 300,000 cells/liter (INP, 1980). Large concentrations of fish eggs and larvae are also found in the Gulf, primarily to the Northwest vicinity of Santa Clara Island (Ramirez, 1982).

The currents are also the greatest determinant of climate. The Gulf is located in the zone between tropical conditions to the north and desert conditions to the south, which follows an east-west trend in the region. Desert conditions prevail west of the Gulf, and again to the southeast. On the delta itself, and its eastern flank, tropical conditions predominate (Cruz-Orozco, 1974). Accordingly, Punta Santa Elena, to the west, has very low levels of precipitation. Playas, farther east, averages 254mm annually,

while Guayaquil experiences an average of 885mm per year. On the southern coast of the Gulf, at Puerto Bolivar, precipitation drops to about 438mm (CEPE, 1982).

When the Humboldt current predominates, the weather is dry; air temperatures average 22 degrees Celsius, and surface-water temperatures average 21 degrees Celsius. Winds are strongest from August to November, averaging about seven knots* (Pesantes, 1975). Usually winds measured in the dry season vary from five knots in the morning up to eleven knots in the afternoon (Cruz-Orozco, 1974). As warmer waters invade the area, through February-March, air temperatures increase to an average of 26 degrees Celsius, and water temperatures to about 25 degrees Celsius (during El Niño years it can exceed 27 degrees). The wind falls to an average of four knots during the rainy season (Pesantes, 1975), from January to April. The area of the coast most exposed to wind and swell is the stretch from Punta Santa Elena to Punta del Morro, since the prevailing winds from the west-southwest are nearly perpendicular to the coast there. Low to moderate wave energy affects the remainder of the Gulf (Cruz-Orozco, 1974).

In general, water temperatures increase by three or four degrees Celsius from the external to the internal part of the Gulf, while the salinity drops slightly. There are two horizontal water masses: the surface layer down to 20 meters has an average temperature greater than 20 degrees Celsius and an average salinity less than 34.5 parts per thousand; the deeper layer has an average temperature below 20 degrees Celsius and salinity in excess of 34.5 parts per thousand (Pesantes, 1975).

Tides in the estuary are relatively strong, which allow mangroves to flourish despite relatively low precipitation. Tidal progression is approximately from south to north. Tides are amplified by oceanic currents, winds, and waves that flow in the same general direction, and dominate over riverine forces (Cruz-Orozco, 1974; Murray, 1975). They average 1.8 meter at the entrance to the channels, but exceed three meters near the city of Guayaquil. Tidal currents vary in the channels. Recorded mean current speeds (July) for the Canal de Jambeli are 1 knot (flood), 0.3-0.6 knot (ebb), at its narrowest point, and 0.2-0.7 knot (flood) and 0.85 knot (ebb) at its mouth; for Canal del Morro, 1.8 knot (ebb). In the Guayas river, maximum flood

* 1 knot = 1 nautical mile/hr = 1.8 km/hr = 50 cm/sec

velocity exceeds 2.0 knots and ebb velocity is 1.5 knot. Off the Punta Santa Elena-Punta del Morro coast, currents average 0.3-0.45 knot, in an east-west, southeast-northwest flow; off Puerto Bolivar, they average 0.6-0.8 knot in a west-east flow (INP, n. d.). Flushing time of the Gulf is about 21 days (Murray, 1975).

3. BIOLOGICAL EFFECTS OF OIL

A. Mangrove Areas

Mangrove ecosystems are typically found on intertidal zones of high annual precipitation, and often form the borderline between the oceans and tropical rain forests. These systems may cover areas of just a few meters in width to sometimes several kilometers. Their value to man includes protection against shoreline erosion, and enhanced productivity of estuarine and marine organisms. It has been estimated, for example, that "80-90% of commercial fisheries in the Gulf of Mexico were dependent on mangroves at one or more stages of their life cycles" (Cintron et al., 1981). A study conducted by Heald and Odum (1970) in the mangrove forests of southern Florida revealed that commercial and game fisheries are directly related to these areas, and will decline in proportion to mangrove destruction.

Mangroves are salt-tolerant plants well adapted to undiluted seawater. Some species have a salt excretion mechanism with salt glands in the epidermal layer of the leaves, while other species, lacking salt glands, prevent salt from entering by the roots. Besides salinity and high precipitation, mangrove habitats are also characterized by a thick layer of loose, rich organic soil, which is anaerobic from a few centimeters below the sediment surface. The unique mangrove root system plays a major role in its ability to stay planted and cope with the anaerobic soil. Complex anchoring and aeration systems have been developed (Figure 3), the latter being either in the form of aerial roots from the main trunks and lower branches as in the red mangroves (*Rhizophora*), or in the form of pneumatophores from cable roots as in the black mangrove types (*Avicennia*, *Sonneratia*, etc.) (Getter et al., 1981; Linden and Jernelov, 1980; Snedaker et al., 1981). Oil can smother these root systems affecting the respiratory and osmoregulatory capability of the plants, which results in oxygen starvation, excessive absorption of salt and subsequent death (Getter et al., 1981; Gilfillan, 1983; Linden and Jernelov, 1980; Lugo et al., 1981).

Oil may cause acute or chronic damage to mangrove communities, depending on the intensity and the duration of exposure. Acute, short-exposure damage normally follows immediate impact from large oil spills; while chronic, long-exposure damage is the result of persistent contamination from operational discharges, or substrate oiling after a major accident. Mortality of birds, turtles, fish, and invertebrates are usual signs of acute damage, which may be followed by defoliation and death of young mangrove trees. According to R. Lewis (Getter et al., 1982b), during the Howard Star (Florida, 1979) and the Peck Slip (Puerto Rico, 1978) spills, this stage lasted thirty days and caused no further impact since the oil was removed naturally. In other spills, chronic contamination may take place for many months or years. Depending on the oil concentration, chronic damage may be lethal or sublethal. This varies according to the degree of substrate oiling (Getter et al., 1982a). Common occurrences have been high tree mortality; defoliation, leaf deformation and stunting; seedling (Figure 4) deformation and mortality; dismorphic propagules; abnormal pneumatophore growth; and changes in the density and distribution of plants and animals (Getter et al., 1981; Lugo et al., 1981).

Figure 3. Schematic diagram of the rooting systems of the two major types of mangroves (Linden and Jernelov, 1980).

Figure 4. Propagule = mangrove seed; seedling = germinated propagule. (A) *Rhizophora* propagule; (B) *Rhizophora* seedling; (C, D, and E) *Avicennia* propagules shortly after release from the adult tree; (F) *Avicennia* seedling (Getter et al., June 1982).

In areas where damage persists, there often is visual evidence of retained oil in the sediments, where removal is difficult. Penetration of oil into the substrate may be facilitated by burrowing crabs and shrimp (Cintron et al., 1981). While oil in exposed areas with few burrows can be naturally removed within a few weeks, sheltered areas with extensive burrows may suffer extensive damages (Getter et al., 1982a). Chronic toxic releases of persistent substrate oiling directly affect mangrove propagules and seedlings inhibiting the mangrove potential to colonize new areas. Even the propagules still attached to adult trees are affected by chronic toxicity through the display of dismorphic shapes. Oiled seedlings have shown toxic effects as well, including smaller size, reduced leaf and root development, and curvatures in hypocotyls (Getter et al., June 1982; Lugo et al., 1981). Responses to sublethal stress by mangrove communities are still poorly understood, but it is believed that the long-term weathering and chronic release of oil from sediments may represent consequences equal to or worse than accute effects.

Assessments of oil impact on mangroves have been made by comparison of areas of similar ecological parameters. Because the presence of oil is the only difference between impacted and comparison stations, any other differences are assumed to be due to the existence of oil. This technique was designed by the Research Planning Institute, Inc., from South Carolina, to assess biological change in areas without prior environmental data. Several parameters are utilized to determine natural variability, the extent of oiling, and the resulting biological change between stations. "Independent variables", e.g., slope of shoreline, exposure to wave activity, tidal water flow, and the movement of detrital debris, are used to examine natural differences between impacted and comparison stations. These variations are independent from the effects of oiling. "Dependent variables", on the other hand, are specifically utilized to determine the extent of oil between stations, by measuring adult tree oiling, seedling oiling, substrate oiling and chemical samples. Since impacted and comparison sites should share similar "independent variables", significant difference between "dependent variables" should reflect biological damage related to oiling, such as mangrove mortality or abnormal behavior, and decrease in faunal density and diversity. When applied to areas affected by the Howard Star (Florida, October 1978) and the Peck Slip (Puerto Rico, December 1978) oil spills, this

method revealed and quantified significant damage caused by oil to mangrove habitats (Getter et al., February 1980; Getter et al., April 1980).

S. Snedaker and M. Brown from the University of Miami, Florida, have classified the symptoms of adverse impacts caused by oil on mangrove forests into five stress categories: Cryptic Stress (MSI=1), Slight Stress (MSI=2), Moderate Stress (MSI=3), Intense Stress (MSI=4), and Mortality (MSI=5) (Getter et al., April 1980). This "Mangrove Stress Index" varies according to the capacity of survival of impacted trees. The first three categories require close examination to detect stress. Trees under "cryptic stress", for example, exhibit an overall healthy appearance with only negligible stress symptoms. In the "slight stress" category, they show more evident signs of damage, such as air holes and cracks in the bark, and might not recover if submitted to other stresses. Characteristics of "moderate stress" include leaf yellowing, death of terminal shoots and partial defoliation of the canopy. Only the most severe stress categories, i.e., "intense stress" and "mortality", are readily identified by superficial examination of mangrove forests because of aberrations in the mangrove morphology, heavy mortality, and the absence of natural recovery.

Several key factors seem to affect the quality and quantity of biological damage in mangrove forests. The variation in oil impact appears to be related to differences in the physical environment where the spill occurs, such as, the topography of the shoreline, waves, currents, and depositional cycles, which control the distribution and persistence of the spilled oil (Getter et al., 1981; Getter et al., 1982a; Getter et al., June 1982; Lugo et al., 1981). The varying sensitivity of mangrove forests may also be a relevant factor, even though present concepts imply that all mangrove areas are uniformly sensitive to oil and should be treated similarly (Getter et al., June 1982; Getter et al., 1983; Jernelov and Linden, 1981; Lugo et al., 1981). Another factor is the nature of the spill itself, i.e., the type and amount of oil that will ultimately reach vulnerable areas (Cintron et al., 1981).

The duration of oil exposure appears to be the most crucial issue. Riverine and overwash mangrove forests seem to have the lowest potential for biological damage because of their high exposure to flushing, either by the predominant seaward flow of freshwater in riverine forests, or by waves and tides in overwash mangroves. Dwarf and outer fringe mangrove forests have a moderate potential for biological damage, again due to the exposure to waves

and tides, which decrease oil permanency. Inner fringe and basin mangroves, on the other hand, have the highest potential for biological damage, which is attributed to their low exposure to waves and tides, thus facilitating the retention of oil (Cintrón et al., 1981; Getter et al., 1981; Getter et al., 1982a; Getter et al., 1982b; Lugo et al., 1981). The heaviest defoliation of trees, mortalities of seedlings and of canopy-dwelling animals are found where the heaviest oiling is concentrated (Getter et al., 1982a).

Laboratory tests conducted on seedlings of red mangrove (Rhizophora mangle) and black mangrove (Avicennia germinans), species of the two dominant genera in most tropical and subtropical regions, have indicated varying degrees of toxic effects from all fuel types tested (light Arabian crude, No. 2 fuel oil, and Bunker C) and at a range of concentrations, with or without a chemical dispersant added (Getter et al., June 1982). Seedlings of Avicennia proved to be more sensitive to oil, dispersants, and to oil-dispersant combinations than Rhizophora seedlings. Unlike Rhizophora, the osmoregulatory mechanism of black mangroves seems to facilitate the uptake of oil, by passing it through the roots to be deposited in the leaves (Getter et al., 1983).

Mangrove responses are also dependent on the amount and type of oil. Lighter substances have been the most toxic. No. 2 fuel appears to be very toxic to seedlings even at moderate concentrations, while Bunker C has been the least toxic, and indicated a lowered toxicity when dispersed (Getter et al., 1983). All others increased in toxicity when mixed with dispersants. In general, both Avicennia and Rhizophora mangroves appeared to have a much lower toxic threshold to dispersed oils than to oils alone.

Mapping of mangrove-dominated regions should therefore consider the location of mangrove forests as to their exposure to kinetic forces and differing species sensitivity to spilled oil. Planning should also consider that responses of mangroves to oil may not be generic but may vary according to the type of oil.

B. Marine Organisms

Marine organisms, like mangrove forests, may suffer lethal or sublethal effects from oil contamination. Also, similarly to mangroves, these effects may be acute or chronic. Acute, lethal effects are often caused by the

smothering of marine organisms with oil, combined with its chemical toxicity (NAS, 1975). This usually happens after an accidental spill, such as a tanker collision, grounding, or a well blowout. If shore bound, these spills may bring catastrophic consequences to the habitat of coastal waters, where most fish spawn and shellfish live. In these cases, damage to finfisheries and shellfisheries are both obvious and widespread (Howarth, 1981). Gradual damage from chronic pollution, however, is more difficult to attribute to oil alone, since chronic operational discharges often occur adjacent to urban areas, where a variety of other pollutants are also present (Olsen et al., 1982).

Four major processes affect the presence of oil in the marine environment: evaporation, dissolution, degradation (chemical and biological), and sedimentation (Howarth, 1981; IMCO, 1980; McManus, 1982; NAS, 1975; Olsen et al., 1982). Their relative importance to the disappearance of an oil slick will depend on a number of circumstantial variables, such as weather conditions (temperature and wind); sea conditions (waves, tides and currents); and oil composition, that is, the many types of crude oils and petroleum products. Evaporation, for example, is thought to be an important factor at warm southern oceans, principally on light, refined oils (Olsen et al., 1982). Howarth (1981), however, points out that even though evaporation may be important in warmer weather, the chemical compounds that entered the atmosphere would eventually rain back into the ocean.

Oil dissolves in the marine environment either through the spreading of the surface slick, or by mixing into the water column. Lighter fuels will spread on the surface forming a thin film of oil, whereas heavier fuels tend to thicken and move as floating islands of several centimeters thick (IMCO, 1980). The toxicity of surface slicks may cause significant impact to eggs, larvae and young fish life (Hall et al., 1978), resulting in significant mortalities (McManus, 1982). Adult fish seem to suffer less harm, as most species avoid contaminated regions. Lethal effects on adult fish, however, have been high in enclosed coastal areas (McManus, 1982).

The immediate widespread mortality caused by the surface slick may also have long-term consequences to future catches of commercial fisheries. Being especially destructive to young forms of fish life, a large oil spill could severely reduce the replenishment capacity of commercially important species for several years (Hall et al., 1978).

Mixing of toxic oil compounds into the water column facilitates their uptake by marine organisms and may increase the toxic effects of these compounds (Howarth, 1981; IMCO, 1980). Oil in the water column will continue to poison biotic communities perhaps more than the slick itself, and will result in acute, short-term effects to pelagic species (Hall et al., 1978; McManus, 1982). Chemical degradation seems to help the dissolution process by transforming oil hydrocarbons, through oxidation, into more soluble substances. Whereas this contributes to the disappearance of the oil slick, it may potentially increase the toxicity of the original product (Hall et al., 1978). Microorganisms also cause hydrocarbon degradation. The level of microbial activity, however, is conditioned to the available supply of nutrients and oxygen, which may not always be adequate in the marine environment, and may be hindered by other natural factors not yet fully understood. Hall et al. (1978) indicates that this process, similarly to that of chemical degradation, may create more toxic compounds than originally existed.

Field studies have suggested that most oil compounds are rapidly removed from the water column, taking only a few days, or weeks, to disappear. It has been estimated, however, that most of the oil spilled in temperate estuaries become incorporated into the bottom sediments (Olsen et al., 1982), where it can persist for years, or decades (Howarth, 1981). Oil reaches the bottom primarily by zooplankton ingestion and fecal elimination, or by adsorption to suspended particles in the water column. Several tons of oil per day can be transported to marine sediments by the activity of typical populations of zooplankton (McManus, 1982). Even though they are able to process oil fractions, zooplanktons are sensitive to oil, more than phytoplanktons, and experience extensive mortality.

Sinking oil is fatal to benthic communities, particularly to those species that are not able to relocate to uncontaminated areas (McManus, 1982), due to the physical coating of these organisms with oil, and the disruption of their normal feeding and burrowing behavior. The number of species and their total densities seem to decrease substantially as the concentration of petroleum hydrocarbons increase in the sediments (Olsen et al., 1982; Sanders, 1981). Because oil degrades very slowly in sediments, chronic mortality of marine organisms may persist as weathered oil is continuously rereleased from

the substrate. Disruption of benthic communities by long-lasting sediment recontamination seems to be more serious than immediate impacts caused by the initial sedimentation, and can be aggravated if chronically refueled by operational discharges from the oil industry (Vergara, 1983).

Although the toxicities of crude oils from different locations and fuel oils from different refineries vary to a great extent, refined products are generally more harmful than crudes. Oil toxicity also varies according to the sensitivity of the organisms exposed. Juveniles are usually more sensitive than adults. Adult fish are among the most resistant forms of marine life, whereas larval crustaceans are among the most sensitive (Howarth, 1981; Olsen et al., 1982). Laboratory observations have shown that lethal toxicity of crude oils and No. 2 fuel oil range from 0.1 parts per million to 20 parts per million. Mortality of crustacean larvae and adults occurred at the lowest concentrations, generally below five parts per million (Olsen et al., 1982).

Oil hydrocarbons are more soluble in fatty tissues (blood, liver, reproductive organs) than in water. For this reason, Howarth (1981) suggests that they may accumulate in marine organisms in concentrations higher than those found in the water. Because some of the components are carcinogens, fish and shellfish contaminated with oil hydrocarbons could pose a serious public health hazard. Even when the taste is not tainted, there is the possibility of contamination (Hall et al., 1978; Howarth, 1981).

Sublethal effects from oil contamination are not yet fully understood. Besides carcinogenic implication, low-level contamination may also interfere with reproduction, feeding, predation survival, and migration of species (Hall et al., 1978; McManus, 1982). Persistent low-level pollution, either from chronic discharges or from oiled sediments, as low as 20 parts per billion, may also trigger the replacement of large species of phytoplankton by smaller ones. This may induce a shift in the whole food chain, whereby animals of no direct use to humans would take the place of important commercial fisheries (Howarth, 1981).

Considering the circumstances of the Gulf of Guayaquil, such scenarios of drastic or chronic pollution would be particularly disastrous to its multi-million dollar fisheries industry and, therefore, should be prevented.

4. OIL SPILL PREVENTION

There are two major approaches to minimize environmental damage from oil pollution: prevention and control/clean up (c/c). Governments quite often seem to overlook the need for effective preventative efforts and rely extensively on c/c response. This is usually done under the assumption that accidental spillage, because of its abrupt and massive disruption of the environment, is the villain of the oil problem.

Public attention is also more easily drawn to the occurrence of major accidents, but most oil that enters the environment is intentionally and/or routinely introduced through normal operations of the oil industry, such as offshore drilling and production, transportation (transfer operations, deballasting and/or fuel tank cleaning), and refining; municipal and industrial wastes; coastal urban runoff; river runoff; atmospheric rainout; and natural seeps (Hall et al., 1978; IMCO, 1976; Olsen et al., 1982), and receive no clean-up considerations. Accidental oil spillage has been estimated by the U.S. National Academy of Sciences (Olsen et al., 1982) to account for only 5% of the total annual inputs to the oceans. Furthermore, because of costs and the limitations of present c/c technology, most of this spilled oil cannot be recovered (Hall et al., 1978). To increase this capability would require having trained crews on constant alert on every 100-mile stretch of coastline, and massive investment of capital on equipment and maintenance (Milgram, 1977).

For these reasons, the trend in recent years has been for stringent governmental regulations demanding safer operations from the oil industry, which has continuously been required to improve its training, as well as its operating standards, procedures, and equipment. These measures require a two-prong approach: minimization of operational discharges and accident avoidance, which provide greater economic and ecological payoffs than the remedial c/c approach. Considering its present market value, oil is an expensive commodity to be wasted due to negligence or outdated practices. To these savings, it must also be added those from reduced c/c investment and costly operations; undamaged property; and avoided depletion of marine resources.

A. Operational Discharges

Stringent regulations of offshore production, maritime transportation, and refineries, have already resulted in a substantial decrease of discharges from these sources. According to the U.S. National Academy of Sciences, these discharges represented 39% of the global oil input into the oceans as recently as the mid-seventies, but account for only 22.4% today (Olsen et al., 1982). The International Maritime Organization estimates that a 30% reduction in oil discharges from shipping alone within the last decade occurred as a direct result of preventative efforts.

Chronic spills from platforms, oil terminals, storage areas, refineries, pipelines, vessels, and land transportation are best prevented through a reliable deterrence mechanism, that is, strict regulations and strong enforcement with regard to permissible discharges, maintenance of equipment and the procedures utilized for the handling of oil. Operational discharges represent a constant means of contamination in the region of the Gulf of Guayaquil, primarily due to deballasting, bilge cleaning, and transfer operations (Gomez, 1983).

International standards for tanker and cargo transportation, as well as drilling platforms, have been set by the 1973 International Convention for the Prevention of Pollution from Ships and its 1978 Protocol, which have been joined together as a single document - MARPOL 73/78 (OSIR, August 1982). Upon its entry into force, this convention (Article 9) will supersede the 1954 International Convention for the Prevention of Pollution of the Sea by Oil along with its amendments, and is expected to "eliminate almost all operational pollution" (Anderson, 1976). MARPOL (Article 17) promotes technical cooperation among its Parties with the assistance of the United Nations Environment Programme, for the training of personnel, supply of equipment, and arrangements that will facilitate prevention or mitigation of pollution from vessels and platforms into the marine environment. Much of this assistance is carried out through the technical cooperative program of the International Maritime Organization (Hayes and Okamura, 1983).

Laws and regulations promulgated by national governments to carry out the provisions of MARPOL (Article 11) are communicated to the International Maritime Organization to be circulated to all Parties. Specific regulations for the prevention of pollution by oil are contained in its Annex I (the

remaining annexes deal with other harmful forms of contamination from ships and platforms). This Annex establishes systematic inspections of ships to ensure that their structure, equipment, and associated pumping, piping and discharge systems fully comply with applicable requirements. Operational discharges of oil from tankers and other ships can generally be made when such vessels are, respectively, a minimum of 50 or 12 nautical miles away from the nearest land, and not within a special area. Oil residues which cannot be released because of these limitations must be retained on board or discharged into reception facilities onshore.

A key element of this system is the provision by the Parties of reception facilities (Hayes, 1983) at all necessary ports and terminals to receive oily residues and mixtures (MARPOL, Annex I, Regulation 12). Uniform dimensions have been set (Regulation 19) to enable pipes at these facilities to be connected with the discharge pipelines from ships.

Special requirements are also fixed for drilling rigs and other platforms, since they utilize fuel oils for power generation and helicopter operations. As far as practicable, they are required to be equipped with oily - water separating equipment, an oil filtering system, and a holding tank for oily residues. They must also keep a record of all operations involving oil or oily mixture discharges (Hayes, 1983c). According to Hayes (1983c), many governments have applied "Special Area" requirements to fixed and floating platforms, whereby the oil content of the discharge is restricted to 15 parts per million.

These international standards set by MARPOL, however, must be incorporated and enforced by national governments, which are in turn urged to set their own strict standards for coastal shipping as well. Fines, prison, revoking of licenses, and liability for clean-up and removal costs should be enough to discourage polluters from all sources within their maritime jurisdiction, if the enforcement agency is allotted an appropriate number of qualified personnel to carry out its duty in a visible manner. This need cannot be overemphasized. Special consideration should also be given to sewage (MARPOL, Annex IV) and garbage pollution (MARPOL, Annex V) from vessels and offshore rigs and platforms.

Several manuals (IMCO, 1976; Smith, 1975) give detailed information of what should be inspected and how inspection should be conducted. Check lists (IMCO, 1976) should be utilized. In general, regulations should cover surveillance of oil transfer operations offshore and at all dock areas for

defective loading arms, hoses, valves and flanges, and inappropriate procedures. Drip trays of appropriate size should be used under hose couplings and flanges during loading or unloading (IMCO, 1976; Smith, 1975). Regulations should also comprise ships and barges to avoid overfill or open scuppers during transfer operations. General maintenance against corrosion and for adequate lubrication of equipment (Smith, 1975) is another item of concern. Corrosion can pose a serious hazard to the marine environment for it may cause the rupture of pipelines, particularly of subsea pipelines. Such occurrences can be prevented by periodic pressure testing for thinned pipe walls (Hayes, 1983a).

Concerning land-based operations, these regulations should deal with the oil recovery systems of tank racks; well points and drain systems (holding lagoons or separator basin dikes) of tank farms; security codification and maintenance of valves, pipes and flanges from storage areas and refineries; maintenance of tank trucks; and maintenance of gas stations' underground storage tanks, collecting sumps, and the periodic disposal of waste oils (Smith, 1975). These often trivial separate losses of oil add up, as mentioned before, to significant collective amounts.

B. Accidental Spills

Major accidental spills result primarily from vessel transportation and offshore oil installations. Modern drilling techniques that allow overpressured formations to be anticipated and counteracted, along with additional safety devices have substantially reduced the pollution hazard from exploratory drilling. A combination of blowout preventers may be utilized to seal a drilling well at the surface of the hole on the sea floor, thus preventing unwanted flow. The blowout preventer stack does not seem to provide the same degree of protection when located on board of the drilling platform (Hayes, 1983b).

During production, a set of valves known as "Christmas Tree" controls the flow of oil or gas from the well. All wells should also be equipped with subsurface shut-off valves, which close automatically when hydraulic pressure is lost due to rupture or manual closure of the line (Collins et al., 1983; Hayes, 1983b). Hayes (1983b) considers these subsurface valves to be superior to the storm chokes utilized in the Gulf of Mexico for they prevent fire from an uncontrolled blowout to spread to other wells, which storm chokes have

sometimes failed to do. As to safety on the platforms themselves, malfunction sensors should be connected to alarms to indicate liquid or pressure levels at critical installations, such as gas-liquid separators, gas compressors, pipeline pumps, pipelines entering and leaving platforms, pressure vessels, etc. (Collins et al., 1983).

Transportation-related spills account for a volume four times greater than that of production (Hileman, 1981), and studies have also shown that most tanker groundings and collisions happen close to shore, either in the coastal zone or within harbors (Anderson, 1976). Prevention of such occurrences are usually attained by making navigation safer and/or decreasing the volume of traffic in the area.

Navigational aids (lighthouses, buoys, pilots and charts) fall in the first category, and can largely reduce the risk of groundings. States that fail to provide adequate aids to navigation may, in some cases, be liable for damages (Anderson, 1976). A further step is the establishment of a vessel traffic separation scheme to eliminate most collisions. Under such a system, "all traffic headed in a given direction is routed through one corridor and the traffic in the opposite direction through another corridor with as much physical separation between them as is practical" (Anderson, 1976). The advantage of a separation scheme is that it makes coastal transportation less dependent on the crews' competence in handling their vessels and utilizing navigational aids.

Apart from these safety precautions, damage to valuable resources can also be prevented by directing the tanker traffic to less congested or less vulnerable areas, which can be achieved by placing storage tanks and refineries there. Finally, the utilization of pipelines would greatly contribute to the reduction of tanker traffic. Pipelines are considered to be the safest and usually the most economic way to transport oil and gas (Baker et al., 1983).

A decision to build a pipeline versus tanker transportation, however, must carefully consider several factors. How far does the oil have to be carried? Does the estimated production justify its construction? What are the constraints placed by depth, topography, and geology of the seafloor where the pipeline is expected to be laid or buried? What kinds of environmental impacts may occur? How will it affect present activities in the area, such as trawling? Pipeline interference with fishing activities can be solved by

burying it, but this generally costs as much or more than the installation of the line itself (Collins, et al., 1983). Pipe-laying activities sometimes require temporary closing of fishing grounds near the construction site, and may cause severe damage to spawning and nursery areas, as well as to benthic plant and animal life (Collins et al., 1983). Pipelines further need to be periodically checked to prevent spillage from fractures or corrosion.

5. OIL SPILL CONTROL/CLEAN UP

Mechanical removal and utilization of chemical dispersants seem to be the principal methods for dealing with spilled oil at sea. When the slick reaches the shoreline, other alternatives may also be available, as discussed below.

A. Mechanical Removal

The advantage of the mechanical removal approach is the elimination of the danger without causing further biological damage, but its effectiveness depends on a rapid human response to deploy the necessary equipment close to the source, and on favorable water and weather conditions. Present clean-up technology is largely ineffective otherwise.

Since many spills occur during poor conditions, that is, waves greater than two meters, winds greater than 20 knots, and currents greater than one or two knots, oil containment is frequently difficult and sometimes impossible (Bell, 1981; Hall et al., 1978; Poley, 1981). Deployment of equipment in rough seas is not only ineffective, but may also endanger the lives of the response personnel and should, therefore, be avoided (IMCO, 1980). It is generally more difficult to respond to open ocean spills than to those in sheltered waters, for appropriate equipment has not yet been perfected to face the adverse conditions frequently encountered offshore (IMCO, 1980). Most of the existing equipment was designed for moderate sea conditions, or for protected calm waters.

Booms are normally the first type of equipment to be deployed. These are "mechanical barriers that extend above and below the water surface to contain and concentrate spilled oil for recovery and to herd spilled oil into

areas where recovery is easier to conduct" (OSIR, 1983). They can also be used to block off the entrance to bodies of water such as marinas, inlets, and small bays; or to prevent the surface slick from reaching commercially valuable or environmentally vulnerable shorelines by diverting the path of the oil (IMCO, 1980). Booms, however, are not very efficient when wave heights exceed one meter, and even in better conditions much oil escapes from under and over them (Bell, 1981). Heavy duty booms are used primarily for oil containment offshore. Lighter duty booms are appropriate only for calm waters and for shallow areas nearshore. They have been very effective in preventing spilled oil from spreading in sheltered waters (IMCO, 1980). Their use is, for instance, common in oil terminals to control accidental spillage during tanker transfer operations. Whatever the intended application, they require specially trained personnel to achieve successful results.

A variety of skimming equipment, such as floating suction heads and floating weirs which require the use of pumps, and rotating disc and belt skimmers which are motor driven, can then be used to remove surface oil contained within booms (Bell, 1981; Hayes, 1983a; IMCO, 1980). Oil collected in this manner is deposited in tankers, barges, or onshore trucks to be stored for later refining or disposal. If the weather is right and skimmers are employed as soon as the spill occurs, they can be very effective (Bell, 1981).

Regardless of the type and severity of an oil spill, mechanical recovery demands a great deal of technical expertise, manpower and equipment investment to adequately clean it up. The separate pieces of highly specialized clean-up equipment required to respond to an oil spill must be operationally compatible for proper recovery of oil to occur throughout all phases: containment, skimming, storage, and disposal. If the skimming capacity, for example, is greater than available storage, skimmers will be underutilized and recovery will proceed inefficiently. Mechanical recovery further requires extreme coordination of vessels, booms, skimmers, and related devices (pumps, oil-water separators, storage tanks, etc.). Usually, while booms are being towed, a third vessel behind the center of the barrier needs to position (utilizing a crane) the skimmer at the oil pool. Vessels, booms, and skimmers must be constantly repositioned to guarantee maximum recovery from the highest concentrations of oil. This is not a simple task, principally in adverse weather.

Integrated recovery systems designed and built by Offshore Devices, Inc., in Massachusetts, seem to eliminate the incompatibility aspect and much of the deployment difficulties from the separate vessel/boom/skimmer operation (Cohen and Dalton, 1983; Doherty et al., 1980; Jensen, 1976). These systems consist of "skimming barriers," and may be utilized both in the high seas and in protected waters (Cohen and Dalton, 1983). Several weir skimmers are built into the center of self-inflatable curtain barriers, where most oil collects. A waterfall effect is formed at the lower edge of the slots where the skimmers are located, which takes the oil/water combination into sump tanks. The mixture is then pumped onboard, separated, and the oil stored into floating storage containers or, preferably, into barges. A barge towed behind these skimming barriers would offer the greatest collecting capacity (Figure 5).

These integral systems are presently considered to be the state of the art by the U.S. Coast Guard (Dalton, 1983). Although skimming barrier systems simplify c/c deployment and operation, the success of mechanical recovery is still largely dependent on favorable weather conditions and the fast response of an experienced crew. Since a fast response is crucial to remove the oil, and this may not be achieved within the length of time that takes for onshore response units to reach the spill site, it might be helpful to have some equipment stored on platforms or at other probable spill source to immediately attempt to contain the rapid spread of oil.

B. Dispersion

When c/c equipment cannot be utilized and the direction of the spill threatens economically valuable or environmentally sensitive areas, the best alternative to not doing anything often seems to be the use of chemical dispersants (IMCO, 1980). These products break up the oil into small droplets causing it to spread over a larger area, which facilitates its biodegradation. Because the oil slick is removed from the surface and dispersed through the water column, the use of chemical agents reduce the risk of fire or explosion and damage to sea birds. Dispersants further prevent oil from adhering to beach sands, boats and manmade structures (Cintron et al., 1981); do not depend on the weather; and can be applied quickly (Poley, 1981). According to J. O'Brien (1983), dispersants can be expensive, but price only should not deter their application because, most of the time, they are very cost effective.

Figure 5. Skimming-barrier test configuration, (Jensen, 1976).

Dispersants, however, have been inoperative on some crude oils, heavy fuel oils, stable emulsions and weathered crudes (Hayes, 1983a; OSIR, January 1982). Another drawback is their toxic effects in the water column. As Howarth (1981) has stated, just because dispersants make an oil slick less visible, this does not mean that the danger from oil has disappeared, for once dissolved in water these chemicals are still present and available for uptake by living organisms.

Government and industry have adopted standard test procedures to determine the chemical toxicity of dispersants. According to these tests, the dispersant given concentration represents that 50% of the tested organisms die in a specified amount of time, usually 48 hours (OSIR, 1983). Newer products have shown marked improvement over the years. While the lethal concentration (LC) of the dispersants used in the Torrey Canyon incident (1967), for instance, was in the range of one to ten parts per million (IMCO, 1980), the most recent generation of these chemical agents is in the range of hundreds and, quite often, several thousands parts per million (OSIR, 1983). This is the case of COREXIT 7664, a water-based Exxon oil dispersant that has been tested on Penaeid shrimp: LC50 (48 hours) - 10,000 parts per million (OSIR, 1983). The type of oil must be known beforehand for the selection of appropriate dispersants.

Although modern dispersants seem to have lower toxicity and pose less danger to the environment as compared to earlier products, their use should continue to be restricted in shallow waters of limited circulation and in areas of large biological activity (Hayes, 1983a; IMCO, 1980; OSIR, January, 1982). Their application must occur "while the oil slick is still far enough from shore so that the concentrations of the oil/dispersant mixture is quickly diluted below its toxic level" (NAS, 1975). Several nations (Canada, Japan, Norway, Sweden, the United Kingdom and the United States) have developed specific criteria for the licensing and use of these chemicals. It is recommended that a potential buyer verify beforehand whether a desired product has been approved. In this regard, criteria from the U.S. Environmental Protection Agency are among the strictest.

C. Absorption

The use of absorbents is a third alternative to deal with oil spills. Absorbents, however, are primarily used on small spills, on oiled shorelines, on final clean-ups of oil films after skimming, and where the use of skimmers

is difficult (Bell, 1981; Hayes, 1983a; IMCO, 1980). They are marketed in many physical forms: powder, pellets, chips, fibers, belts, mops, pillows, ropes, booms, and sheets. These products can be of vegetable origin, such as bark, corncob grindings, sawdust, and straw; mineral, such as chalk, clays, and ash; or synthetic, such as polyester plastic shavings, and resin-type foams (IMCO, 1980; OSIR, 1983). A good absorbent should pick up oil 20 to 60 times its weight by surface sorption and by entrapment within its pores or fibers, but there is no "best" material since its effectiveness depends on availability and cost (IMCO, 1980).

D. Shoreline Clean up

Oil removal from shorelines can be just as complex as in water. Because of the variety of coastal areas, there is no universal method and the clean-up activity itself may, in some cases, cause more damages than the original spill. In mangrove-dominated regions (such as the Gulf of Guayaquil), the most recommended methods seem to be either low-pressure flushing (Getter et al., 1982b; Hayes, 1983a), or leaving the oil alone. Oil left alone is likely to degrade in a relatively short time under tropical conditions (IMCO, 1980). Low-pressure flushing utilizes pumped seawater to clean oiled sediments and mangrove roots. Oil washed off in this manner must be recovered to avoid reentry into adjacent environments (Getter et al., 1982b). According to C. Getter (1983b), the application of low-toxicity dispersants may, under certain conditions, also be desired. Although the oil/dispersant combination is usually more harmful to mangrove communities, in areas of high wave activity this procedure may decrease the long-term persistency of the contaminant, thus allowing the mangrove environment to recover sooner.

Other methods have resulted in a number of detrimental effects. The utilization of heavy equipment for mechanical removal, for example, causes oil to be buried into deeper sediment layers; alteration of drainage patterns, forming stagnant pools; breakage and removal of plants - all of which augment the stress on mangroves and animals (Getter et al., 1982b). The use of absorbents can help reduce the impact of an oil spill, but harvesting them with rakes tends to facilitate oil penetration into the substrate. Another negative effect of this method is the intense traffic from the large labor force that is required for the application and recollection of sorbent

materials. When not removed, the oil-soaked absorbents also act as a source of contamination.

Because of the limitations of mechanical clean-up at sea, the constraints on dispersant utilization in areas of high biological sensitivity, and the difficulty of shoreline clean-ups, it seems that there is little that can be done to save the environment from damage once oil enters the water. A very important first step is the recognition that oil spill control/clean-up operations are not necessarily the best approach to reducing the risk of oil development. This should be made very clear throughout the entire planning process, otherwise a false sense of security might exist based on the belief that oil is only dangerous when catastrophic spills occur, and that even in those situations equipment could be deployed to successfully clean it up. On the contrary, experience worldwide has proven that c/c technologies are not very effective. Above all, focus on spill clean-ups alone tends to overlook the more pervasive low-level, chronic contamination mentioned earlier (Section 3.B.). Yet, again experience has shown that this type of contamination is likely to be more significant in the long run.

Because accidental spillage, though a small part of the problem, brings drastic and immediate consequences, control/clean-up operations are necessary in order to minimize damages. These operations, however, will not work unless there is a careful response plan, trained personnel and appropriate equipment. These plans should contain maps of biologically sensitive or valuable coastal areas to be protected, together with site-specific recommendations on clean-up methods to be used or avoided. After planning, training is the most important procedure for the effectiveness of clean-up efforts.

6. OIL SPILL CONTINGENCY

A contingency plan is primarily a practical decision-making tool. For this reason, it should be realistic and simple, avoiding long prologues or unnecessary data. It should be designed around a clear set of objectives, and must contain two separate parts: (1) an administrative organizational structure to facilitate coordination; and (2) operational guidelines to know beforehand what technical options might be available.

A. Administrative Organization

The administrative contingency plan should stress competence in decision-making and not simply reinforce authority, that is, the on-scene coordinator should be someone completely familiar with the operational guidelines of the contingency plan and the specific circumstances of the region where c/c operations will take place. He should be knowledgeable of the best available c/c techniques, especially with regard to dispersants, in order to take prompt and appropriate decisions on the scene of a spill. Further, he must be activated immediately. If the chain of command does not allow a quick response, the plan is nothing more than an administrative burden.

The administrative plan should also encourage inter-agency cooperation and facilitate coordination. A joint oil industry/government participation is desirable to develop the necessary c/c strategies, and adequate communication networks must be established between all units, agencies and companies involved.

B. Operational Guidelines

An operational contingency plan must attempt to facilitate rational decisions and avoid improvisation. Although the variety and conditions under which an oil spill can occur is almost infinite, it is valid and useful to consider possible site specific response options. Recognizing that the on-scene-coordinator must have great latitude to make decisions concerning c/c strategies, a contingency plan, nonetheless, should provide enough background information to facilitate rational decision-making, and should contain recommendations to initiate response activities.

Ideally c/c operations should be attempted near the source of the spill, most likely at sea, but there can be cases where such a response may not be warranted either because the spill is moving offshore or because the sea state does not permit an effective c/c action. In the latter case, as well as in other situations, the spilled oil may eventually threaten shorelines.

Because of limited resources, it is not usually possible to protect the shoreline completely. Some coastal areas must be protected first. This decision should not be made on a trial-error basis at the moment an emergency occurs, but it must be planned beforehand. To be effective, the plan must identify vulnerable coastal features and provide c/c strategies to protect

them. In this regard, pre-spill operational contingency planning should encompass three major aspects: (1) identification and classification of sensitive areas; (2) determination of likelihood of an oil impact; and (3) cost assessment for the intended protection. An Environmental Sensitivity Index (ESI) to determine the first aspect has been developed by the Research Planning Institute, Inc., in the state of South Carolina, and applied to extensive mapping of U.S. coastal areas (including the State of Massachusetts), as well as those of France, Germany, and New Zealand (Davis et al., 1980; Gumlach et al., 1981). It allows clean-up efforts to be prioritized, starting with the most sensitive areas, and ending with the least susceptible environments, although public agencies have the duty to protect as much of the coast as possible.

This index uses geomorphic, biological and socioeconomic criteria to establish the priority of mapped areas. The potential for oil retention on the shoreline is considered to be a relevant geomorphic factor. A factor that influences the biological criterion is the potential for long-term damage to migratory and the area's living resources; while the major socioeconomic factors are recreational beaches, parks, etc. In the case of the Gulf of Guayaquil, the latter should also include other factors, such as fishermen's incomes, and operations of processing and packaging plants, the shrimp pond industry and the boat construction industry. Shorelines are then ranked in terms of their respective sensitivity on a scale from one to ten, where one would represent the least probable negative impact, and ten would suffer the most long-term damage. Biologic information is conveyed to the maps by symbols and colored circles to facilitate prompt identification of the resource, such as, yellow=mammals, green=birds, blue=fish, orange=shellfish. An illustrative example is attached (Figure 6). Depending on the seasonal migration, reproduction and feeding behavior of marked species, a particular shoreline type may increase in value over adjacent shores of similar characteristics. Socioeconomic resources are also indicated by special symbols; and spill response methods included on the map will show the deployment positions of booms, skimmers, dispersants, and areas designated for enclosure.

The second aspect of pre-spill planning is the designation of potential spill sources, e.g., platforms, terminals, tank routes, and pipelines; and potential impact areas. Potential impacts could be determined by starting a

Figure 6. Example of the application of the Environmental Sensitivity Index to a hypothetical, mangrove-dominated shoreline, indicating ranked shoreline types, biologically important areas, and priority boom locations. Maps are usually prepared in color to aid rapid understanding of the presented information (Gundlach et al., 1981).

computer model at probable spill locations, through various weather and current patterns, to reach shorelines that are likely to be impacted; or utilizing a reverse model to determine where a spill would have to occur to reach a designated sensitive area. This way, expenditures to protect unlikely spill scenarios are not necessary. Finally, the third aspect would be a cost analysis of the degree of c/c response based on the previously identified sensitive areas and their vulnerability to an oil impact. Expenditures for equipment that would be ineffective at certain locations and conditions should be avoided.

An Oil Spill Contingency Guide prepared by the Coastal Resources Center of the University of Rhode Island for the state of Rhode Island, U.S.A. (Olsen, 1983), identifies vulnerable coastal features and provides site-specific operational information to protect these identified coastal areas. It follows a slightly different technique from the ESI mapping to classify vulnerable areas. In many ways, the two systems could complement each other. The guide also identifies important recreational and scenic resources, as well as valuable natural habitats. It utilizes four major factors to select these areas according to: (1) risk of spill damage, such as, proximity to oil routes, and proximity to transfer and storage areas (proximity to production platforms would be of significant consideration for the Gulf of Guayaquil); (2) ability to protect, such as, accessibility from land and water, size and type of shore opening; (3) value (ecological, economic, social, and aesthetic considerations); and (4) recoverability, which would include besides ability for natural recovery of impacted area, the difficulty in protecting and/or cleaning it up.

The guide provides maps and sheets of site-specific information for the selected vulnerable areas. The information sheets are divided into four sections: Identification, Characteristics, Site-specific factors, and Contingency Plan. The section on site-specific factors is not supposed to be an exhaustive description of the area, but rather a selective presentation of useful data to the on-scene-coordinator. The "Contingency Plan" section should contain general guidelines to enable the beginning of a site-specific oil spill response action. Ecuador, perhaps, should consider developing a similar approach as a next stage in the evolution of the contingency planning process. Bell (1981) illustrates this format by utilizing the following example from the Rhode Island Guide (Figure 7):

Figure 7. Map of Winnepaug Pond.

I. Identification

Site name: Winnapaug Pond
Water body: Block Island Sound
Municipality: Westerly (Police Dept. 596-2022)

II. Characteristics

Size: approximately 440 acres
Ecosystem type: coastal lagoon/salt marsh
Water quality: SA
Vulnerability: breachway approximately 110 to 130 ft wide with slight dogleg of 25 degrees to the left. Breachway is approximately 1/2 mi long.

III. Site-specific factors

- Entrance to the breachway is exposed to extremely high SE-S-SW winds and wave action due to unlimited fetch across Block Island Sound.
- Currents range up to 4.0 kt in the breachway at maximum ebb and flood.
- Mean tidal range in breachway is approximately 2 ft.
- The roads on both sides of the breachway have moderate to heavy private development, although access points are available.
- The salt marsh extending west from breachway on the side of the pond is especially fragile.
- The pond is considered an important natural resource in Rhode Island because it supports numerous fish and wildlife.
- Recreational shellfishing is a significant activity in the pond.
- Recreational boating facilities, including launching, are located in the breachway.

IV. Contingency plan

The same general situation prevails in the Winnapaug Breachway as in other south shore ponds. Conducting C/C operations outside the breachway is likely to be difficult in most conditions. Inside the breachway the currents are swift, leading to an entrainment problem. The open area (A in hexagon) on the east side of the breachway is accessible and might be used to slow down the oil flow and to start collecting it. Location B in hexagon, which is adjacent to the road, might be used as an oil-collection point, as the wind conditions and flooding tide would drive oil up into the pond and tend to pile it up there.

The primary objective should be to contain the oil before it turns the corner and threatens the salt marsh. There is a culvert (B in hexagon) leading into a marsh on the eastern side of the access road which should also be closed.

Launching facilities are available at the point indicated by r in an arrowhead. The large salt marsh along the pond's southern shoreline should be boomed off at tidal creeks and mosquito ditches, if a threat should develop.

Access 1 (in circle) is the best route for getting to the several locations along the breachway where C/C operations can be conducted."

C. Control

The basis of an effective response is a combination of good organization (administrative contingency plan), technical planning (offshore and site-specific operational contingency plan), and control; the latter being the ability to take correct strategic actions at the moment of the spill. Sophisticated equipment alone cannot compensate for a lack of any of these qualities.

Monitoring the movement of the oil slick at sea is essential for an effective control. This is best achieved by utilizing aerial surveillance (a small aircraft or, preferably, a helicopter) (Farrington, 1983).

7. SUMMARY AND ANALYSIS OF CONTINGENCY PLANS

The Merchant Marine and Coastal Directorate (DIMERC), the agency responsible for the prevention, monitoring and control of marine pollution in Ecuador, developed a plan of action for the Gulf of Guayaquil (see Annex I). Concerned with the possibility of gas leaks, oil spills, increased traffic and the possibility of collisions in this biologically rich region, DIMERC has set its objective the constant monitoring of possible sources of oil pollution and enforcement of regulations.

The plan has three major components: prevention, through the circulation of information and inspections of platforms, tankers, and other ships; monitoring, through the enforcement of regulations, detection of pollution, and collection of samples; and control. DIMERC has established three control zones - platforms, shipping traffic, and beaches/mangroves. These zones, along with prevailing conditions and other considerations, will determine the best course of action in combatting the spill. The alternatives are: a) containment and recovery through the use of booms and skimmers (the preferred method); b) chemical dispersion; c) absorption through the use of soybean dust and cellulose barriers; and d) clean-up along the coast. Natural degradation may be preferred near the vulnerable mangroves and beaches.

Actual implementation of this three-pronged plan falls on the Coast Guard. The Ecuadorian State Petroleum Corporation (CEPE), by agreement with DIMERC, will also share the responsibility for the prevention and control of oil pollution in the Gulf. DIMERC's timetable for implementation covers the

period from 1982 to 1985, when all preparation and studies should be completed and equipment obtained. The plan calls for compilation of information on the Gulf's environment; study of different methods and ways to combat oil spills; designation of priority areas of vulnerability and of sites for oil disposal; training of personnel; and the installation of three spill response units strategically located in the Gulf. It also lists equipment and materials worth \$2.8 million that may be required.

Following DIMERC's directives, the Coast Guard (COGUAR) formulated an organizational contingency plan (see Annex II). The plan assigns responsibilities and duties, and establishes communications links between organizations involved. The Merchant Marine and Coastal General Directorate (DIGMER), which is ultimately responsible for the plan, will mobilize the Coast Guard, which is to be in charge of operations. After a tortuous chain-of-command authorization procedure, the head of the Department of Pollution Prevention of the Coast Guard will be appointed Chief of Operations, and will take command of activities to combat an occurring spill, including taking charge of CEPE personnel and equipment. CEPE is responsible for taking immediate action to control a spill before the Chief of Operations arrives on scene. The plan also provides for logistical, administrative, scientific, legal, and other support structures. Finally, the Coast Guard will establish three spill response units on the Gulf to store equipment and serve as operations bases.

The Ecuadorian State Petroleum Corporation elaborated a plan to mobilize personnel and equipment, and train personnel to deal with the eventuality of an oil spill or other accident in the Gulf (see Annex III). The emergency procedure section of the plan was drafted for dealing with well blow-outs and outlines steps to be taken by the on-site drill supervisor; the chief of the drilling division; the Environmental Advisory Office, which will offer recommendations on the best course of action in combating spills; and the director and assistant director of oil-spill control. The assistant director of oil-spill control is the CEPE official responsible for operations and, along with his or her team of technical advisers, will choose priorities in terms of cleaning up and the best methods to contain and combat a spill. The plan also details the responsibilities of advisors and support personnel.

CEPE's plan focuses on the possibility of an accident at the drill-site. It considers a 90-day blow-out that would cause a total of

450,000 barrels of oil to escape. Assuming favorable conditions, 30% of this would burn, evaporate, or dissolve; 50% of the remainder would be recovered; and 80% of what was left would be removed with dispersants, leaving 31,500 barrels to potentially affect the coast. CEPE is responsible for protecting and cleaning up coastal areas.

The plan revolves around four response areas: offshore drill-site, intermediary waters, coastal waters, intertidal zone or onshore. Immediate containment and recovery is emphasized. Dispersants could be used on the oil that escaped the initial control. The decision on whether or not to use dispersants would primarily rest on the principal objective of protecting the mangroves. Booms should be deployed along the coastline to collect any oil reaching the shore. Depending on the coastal area affected (mangroves, beaches, or cliffs), cleaning-up techniques could be by absorption, and by mechanical or manual means. The plan also calls for studies to be made for the development of a handbook on coastal protection and clean-up strategies.

A. Plan of Action Guidelines

DIMERC's plan of action can be considered to be an umbrella plan that offers guidelines for the development of regulations and contingency plans for the Gulf of Guayaquil. These guidelines are sound, and take into consideration the need to balance oil development with the protection of the Gulf's environment. They cover, in a general form, aspects of prevention, monitoring, and control of oil pollution. In the latter, the plan suggests appropriate methods to deal with spills (recovery, dispersion, absorption, and clean-up), with proper considerations given as to the use of chemical dispersants.

The plan, however, fails to consider the possibility of spills at oil terminals and refineries, which can also cause significant damage to the marine environment. The guidelines appear to be only platform and tanker traffic oriented. This limited focus, if not corrected, will certainly hinder effective prevention and control of oil pollution from all probable sources.

Operational contingency planning did not seem to have been addressed in the Plan, either. Under the heading of "control", the Plan only indicates that after an oil spill occurs, an "operational phase" takes place to combat contamination, which will take into consideration physical and biological characteristics of the Gulf, as well as circumstantial aspects of the

accident. Because prompt responses are fundamental to an effective control/clean-up result, there is not enough time for full decision-making, which often involves several departments and agencies, in the course of an oil-spill emergency. Operational pre-planning is therefore necessary (see Section 6.B).

Implementation of DIMERC's guidelines should occur according to a four-year timetable, within which environmental data for the Gulf should be compiled and interpreted; three spill response units should be placed at strategic places; equipment purchased for these units and a laboratory; communications between participating agencies improved; disposal sites established; prioritization of vulnerable areas determined; as well as monitoring of platforms and traffic routes, training of personnel, and drills with control/clean-up equipment should be performed. These are all valuable objectives, and will certainly represent a significant accomplishment if finalized within the time allotted. DIMERC's plan does not determine, however, who will share the costs of these activities, which can adversely affect their due completion.

B. Prevention

Although contingency plans are tailored for remedial action only, to respond to oil that has already been spilled and not to prevent its spillage, it is important to consider during the contingency planning process what measures can be taken to reduce these occurrences for the reasons described earlier in Section 4. Protection of the Gulf of Guayaquil's rich environment, its fish, shrimp and mangroves can best be achieved with a strong emphasis on preventative efforts. Indeed, prevention was the first concern of DIMERC's plan of action (Annex I). In this regard, an agreement was also signed with CEPE. The 1978 Law of Hydrocarbons, Article 31 (s), (t), and the 1974 Law of Hydrocarbon Contamination, particularly Articles 3 and 12, have also realized the need to avoid oil contamination.

The Law of Hydrocarbon Contamination deals with operational discharges and seems to be the major legal instrument for oil spill prevention in Ecuador. Its enforcement depends on the Ecuadorian Coast Guard (Gomez, 1983), under the overall jurisdiction of DIMERC. Platforms, terminals and refineries must not release oil or its residues in the marine environment without prior treatment (Law of Hydrocarbon Contamination, Article 4). Ships can only

discharge oil residues at onshore reception facilities; 15 miles offshore, for those engaged in cabotage; or beyond 50 miles, for international shipping (Article 5). An exception is made for vessels that utilize the "load on top" system, which may deballast as close as five miles from shore (Article 6). A gradation of fines is established according to the source and area where infringement may take place, and infractors are also liable for damages and clean-up costs. The Law of Hydrocarbon Contamination does not elaborate on what kinds of damages can be recovered (see Section 9 below) and how they will be calculated (Articles 14, 15 and 17). In cases where fines are not applicable, those responsible for the spill must mitigate its damage (Article 21). There are also provisions in the Law to bring about voluntary reporting of a spill, as well as its clean up (Articles 7 and 8).

Compliance to the above provisions would certainly reduce the level of operational pollution along the Ecuadorian coast and in the Gulf of Guayaquil, where most fishing and shrimping is conducted. According to Gomes (1983), however, deballasting, tank and engine cleaning continue to occur routinely at short distance from the coast, along with frequent failures in the transfer of petroleum and its products at terminals, or when refueling cargo ships.

As discussed in Section 4.A., prevention of operational oil pollution can be achieved through a reliable deterrence mechanism. Since the regulations are already available, the enforcement agency, in this case, should attempt to increase its monitoring capability as regards to inspections of transfer operations, and its patrolling capability along the coast to inhibit vessel discharges. Because the oil terminal of La Libertad does not have reception facilities (Gomes, 1983), vessel discharges are frequent in the Guayaquil-La Libertad route. The absence of such facilities seriously hampers the prevention of this source of contamination as urged by the law, therefore steps should be taken to correct this need.

A final suggestion on enforcement is for the introduction of more positive incentives in the law to encourage voluntary clean up and/or reporting of spills to DIMERC. This could be attained, for example, by reducing applicable fines by 50% when reporting is made within 24 hours of a spill. Failure to report could be considered a criminal offense. In this situation, the infractor would not only pay the entire amount of the penalty but could also face prison.

Petroleum hydrocarbon concentrations measured in 1978 (sampling and

analytical procedures were not described, but this report assumes that biogenic hydrocarbons were excluded from the measurement) at port and terminal areas of the Guayas estuary and Punta Santa Elena registered levels of up to 60 parts per million (Gomez, 1983), with the 20-40 parts per million range being the most common, which are all lethal levels to marine organisms (see Section 3.B). Approximately two-thirds of this chronic contamination seem to originate from transfer operations (Gomez, 1983), related to hose break-ups, valve failures, etc., and can be substantially reduced by effective surveillance of these operations (see Section 4.A).

Monitoring of hydrocarbon concentrations in the Gulf of Guayaquil should perhaps be expanded to water beyond the immediate vicinity of ports and terminals, so that a better determination of the Gulf's overall health can be made. Measurements from stations located throughout the highly industrialized New York harbor, as an example for comparison, revealed a mean concentration of nonvolatile hydrocarbons in the order of .04 ppm and a .27 ppm maximum (Searl et al., 1977).

Accidental spills in the Gulf could be largely prevented, as follows: (1) utilization of pipelines to transport oil from platform to shore; (2) maintenance of adequate navigational aids; (3) creation of a vessel-traffic separation scheme; (4) installation of storage tanks, refineries, and other oil-related industries outside or in the external part of the Gulf as recommended in a study prepared by the National Fisheries Institute (INP, 1980); (5) employment of higher technological standard for oil production; and (6) improvement of personnel training, the most significant factor in accident prevention.

C. Equipment

Several lists of response and laboratory equipment to be purchased by CEPE and DIMERC were attached to DIMERC's plan. These lists were comprehensive and presented quantities and prices for the equipment. Nonetheless, it seems to be premature to put numbers at this moment, when no pre-spill survey of the Gulf has been made, vulnerable areas have not been classified, and no operational contingency plan developed. Purchasing equipment without this information would be unwise. It should be known "where" and "how" equipment is to be used, to exactly determine "what" to buy.

The final shopping lists should be more explicit than the present ones to include specifications and manufacturers of desired equipment. The Oil Spill Intelligence Report has recently published the third edition of its International Directory of Oil Spill Control Products, which provides detailed information concerning booms, dispersant and herding chemicals, pumps, skimmers, sorbents, dispersant spray systems, boom cleaning systems, mobile beach cleaners, oil storage containers, and transportable oily debris incinerators. Additional information concerning these and other products can also be obtained by contacting individual manufacturers directly.

DIMERC and CEPE should expect some price adjustment when more specific lists are developed. Present lists have underpriced some items in the general CEPE budget (Annex I), such as the communications system and the large scale dispersion equipment; while overpricing others, such as the ocean-going motorboat (O'Brien, 1983).

Because an incredible variety of sophisticated hardware is available in the market, one should be cautious in selecting the most appropriate equipment, and make sure that the manufacturer will also supply training and spare parts.

D. Organization Framework

COGUAR's and CEPE's plans provide an administrative framework for mobilization of personnel, and rely heavily on determining the hierarchy of authority. This is certainly an important aspect to assure appropriate responses, but besides telling "who" should react, an effective contingency plan must also say "when" to react, and "what" the correct action should be.

Related to "who" should react, these plans should attempt to improve their response mechanisms. Combining the chain of command described in both plans, for example, from the person that detects and reports a spill at the platform to the Chief of Operations (JOCD), not less than ten people from different offices and agencies would have to be contacted (not clear whether by phone or all in written form) before the JOCD takes charge of the

emergency. This definitely needs to be rearranged so that the JOCD is the first to be contacted. His office should be on duty on a 24-hour basis, for oil emergencies can occur at any time of day or night, and weekends. Besides his authority to mitigate the effects of an oil spill, the JOCD should also be empowered to initiate investigation on the causes of the occurrence, to collect evidence for subsequent legal action by the Harbormaster's Office (Annex I, No. 5).

"When" to react is another relevant factor. The classification of emergencies (Annex III, No. 3.1) does not seem to be appropriate for oil spill emergencies. This classification should, perhaps, cover different sizes of spills instead, from small to medium, and large; or the type and location of spills. The size of an oil spill to make reporting mandatory to the Merchant Marine and Coastal General Directorate (DIGMER) must also be determined. It is not clear how DIGMER will receive information of an emergency that occurs outside CEPE's platforms, since CEPE's plan seems to be platform oriented only. CEPE should be required to protect the Gulf of Guayaquil to the extent of its activities there, including tanker transportation, transfer operations at terminals, storage tanks, and future refining. It is also unclear what size of a spill from any of these sources for example, would trigger a response from DIGMER. According to COGUAR's Plan, the Coast Guard seems to be tied to initial authorization from DIGMER to the Harbor Masters and Coast Guard Directorate (DICAGC), before the JOCD can be sent to the scene of a spill. Even if COGUAR detects oil in its monitoring mission, it will probably be unable to respond immediately without DIGMER's permission.

The plan should also suggest "what" appropriate actions might be taken at sea or site-specific. In accordance to the area to be protected, the latter should contain basic information concerning what equipment and where it should be deployed. A format could be followed, as described earlier, to include identification of vulnerable areas, their characteristics, site-specific factors and actions. In this regard, decisions from CEPE's Technical Advisers (Annex III, No. 3.4.j) and respective maps should be incorporated into the plan as soon as they are available. This basic information should be flexible enough to allow adaptation depending on prevailing circumstances at the moment of an oil spill. It is unclear in the

plans whether CEPE will still cooperate with COGUAR, and whether it will still be held responsible for clean-up operations in the area of the Gulf if an accident does not occur at a platform, and is not directly related to CEPE's oil exploration and exploitation.

E. Pre-spill Survey

Specific data are necessary prior to drafting any adequate operational contingency plan. Part III of CEPE's plan seems to have been an attempt in that direction, but it needs more data for the Gulf of Guayaquil. The shoreline of the Gulf of Guayaquil must be fully classified and coastal zones that may require special protection properly identified. Further studies must show the location of possible sources of contamination, related oil movement patterns, distance to the previously identified sensitive zones, and time estimates of probable impact. Sites where onshore recovery may take place should be designated, along with disposal sites. The objectives of CEPE's plan (Annex III, No. 1.3), for example, can not be fully attained, unless the Environmental Advisory Office (Annex III, No. 2.0) determines the areas of economic/ecological value and specifies the best methods to deal with spills in those areas. Some basic scientific data related to currents, tides, and wind will be crucial for these studies. Much of these data seems to be already available, as demonstrated by INP's Environmental Study for the Placement of Industrial Complexes in the Gulf of Guayaquil, and M. Ayoub's review of oceanographic aspects (1982). As related to living resources, an important survey has already been conducted by C. Ramirez (1982).

F. Site-specific Contingency Planning

Present contingency plans need to provide more objective, operational information, instead of leaving full decision-making for when an emergency occurs. A meaningful site-specific operational contingency plan must describe what measures to take at the site of probable impact (see Section 6), and present this information with corresponding maps.

G. Scenarios

The probable scenario portrayed in CEPE's plan (Annex III, 4.0) was of a general nature and overly optimistic. It assumed that booms and skimmers will work properly, that dispersants will "remove" the oil from the water, and that only a small percentage of oil needed to be recovered from shore. This is not likely to happen in reality. Experience shows that booms and skimmers are effective only in the calmest waters, and that the use of dispersants will be very limited in the Gulf's shallow waters or near its mangrove areas.

As a preliminary step, at least two scenarios should have been described to represent the best and worst possible situations. When more information is available and modeling expertise developed, scenarios within these two extremes and with more specific focus can then be made.

H. Dispersants

The concern shown by CEPE as to the application of dispersants in the Gulf was based on correct assumptions (Annex III, No. 5.1). Their use should continue to be restricted to special cases and always taking into consideration the mangroves, shrimp hatching areas, and the sensitive habitat of the Gulf. Besides, the overall water and weather conditions in the Gulf of Guayaquil (Section 2 above) seem to favor mechanical removal. The plan should further specify the areas and circumstances where dispersants cannot be applied.

In some occasions, dispersants, preferably of low toxicity, may be utilized. These include cases of imminent risk to human life, such as fire or explosion; or when the use of dispersants may result in the least overall environmental damage, such as to avoid the longer and perhaps more detrimental, persistency of the contaminant in areas of high wave activity (Section 5.D above), as well as when mechanical recovery is impossible to attempt or has not been very effective. The strong currents of the Guayas river, for example, can be a major obstacle to boom containment and skimming, which are not fully efficient where currents are greater than one knot. Except for when there is a non-controversial risk of fire or explosion, authorization for the use of dispersants should be beyond the original powers of the Chief

of Operations and result from a joint decision of the JOCD with environmental experts from another agency. In this regard, the National Fisheries Institute, which has the primary responsibility over the living resources of the Gulf, seems to be the most appropriate organization.

I. Training

The need for adequate training cannot be overemphasized. Just as much as the spill response units are considered to be the foundation of the emergency infrastructure, training is the foundation of an effective response. Drills, particularly in-water drills, should be conducted on a regular basis, at least twice a year. Because the number of personnel available at the response units (one expert and three crewmen) is not enough to respond to a large oil emergency, it is advisable that sufficient training be given to people from other public services, such as, the Fire Department and the Police, and other groups, like fishermen, that might be called to help in the event of a large spill.

J. Contractors

Contracts with private companies that specialize in oil spill response are necessary, principally while the initial phase of a local response mechanism is being set up. It is essential that these commitments with clean-up contractors and contractors of auxiliary equipment be made before spilling occurs to avoid "emergency rates." Written agreement should be made with at least three contractors in advance as one or two could be busy with other spills at the same time, and might not be able to provide their services. These agreements should show all rates and charges.

K. Oil Disposal

This is often overlooked in contingency planning. Disposal of oil, oily mixtures and absorbents create a serious problem in the aftermath of a catastrophe. The operational plan must say exactly what to do with the recovered oil and debris in specific terms: where to store, burn or bury them, otherwise emergency disposal might cause further or even more serious

contamination, such as to ground water. Having noted this need (Annex II, No. 6), the Coast Guard must now press for the prompt designation of these disposal sites.

8. RECENT DEVELOPMENTS

As mentioned in the introduction of this report, these Ecuadorian contingency plans are still in the process of evolution. As a result of this, some of the aspects commented on here, as well as some of the problems pointed out in Ecuador last February, may have been modified.

One such case concerns the reporting of a spill to the Chief of Operations (see Section 7.D). A recent chart developed by CEPE shows a significant change in the chain of command to enable a faster response by the JOCD. Reporting of an oil spill emergency now is to be made directly to the Office of Contamination Control which, in turn, immediately activates the clean-up crew.

9. LIABILITY AND COMPENSATION

Liability and compensation for oil pollution damage involve a complex relationship of national laws with rules of international origin, including compensatory insurance schemes. Although not a part of a contingency plan, this issue must be addressed simultaneously by the overall planning effort. The primary objective of this section is to describe the two international systems of liability and compensation, the related procedures to file an indemnization claim, and methods for oil pollution damage assessment.

The two separate compensation systems were created after the 1967 Torrey Canyon incident off the British coast as a realization that the traditional maritime law relating to oil pollution by international shipping was inadequate. A voluntary system was initially set up by the tanker and oil industries and immediately followed by a conventional system established under the auspices of the International Maritime Organization. Both systems only cover tanker pollution.

Each system consists of two parts, a basic shipowners' liability and an additional oil industry fund to supplement the shipowners' compensation. TOVALOP (Tanker Owners' Voluntary Agreement Concerning Liability for Oil Pollution) and its counterpart - the 1969 International Convention on Civil Liability for Oil Pollution Damage (CLC) - are complemented by CRISTAL (Contract Regarding an Interim Supplement to Tanker Liability for Oil Pollution) and the 1971 Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (FUND), respectively. Although of similar format, the voluntary and conventional regimes vary in content and amount of coverage. Unlike the voluntary agreements, the international conventions do not apply to vessels in ballast, only to loaded tankers. The total amount of compensation is, however, greater under the conventional system. For these reasons, both regimes are likely to continue to operate simultaneously for some time (Nichols, 1983).

A. The International Voluntary System

TOVALOP has been in operation since 1969 and provides compensation for damages caused by oils, transported as cargo or in ballast, up to U.S. \$16.8 million per incident. The tanker owner, who is member to the Agreement, may either undertake the c/c response or reimburse governments for incurred damages and reasonable clean-up costs (Nichols, 1983). Claims must be filed to the shipowner or directly to his insurer, either the International Tanker Indemnity Association or the Protection Indemnity Associations (P & I Clubs), within one year of the incident (Nichols, 1983). Disputes may be resolved by arbitration by the International Chamber of Commerce (TOVALOP, Section VII. (K)).

CRISTAL supplements the amount available from TOVALOP up to U.S. \$36 million per incident. This amount may be doubled to U.S. \$72 million when total compensation from all sources available to claimants is significantly lower than the damages incurred by them (RPI, 1983). CRISTAL also provides coverage to supplement the Civil Liability Convention when the Fund Convention is not applicable "provided the tanker is entered in TOVALOP, and the cargo owner is a party to CRISTAL" (Nichols, 1983).

Additional purposes of this Agreement are to provide compensation in limited situations where TOVALOP would not be applicable, and to partially

reimburse tanker owners for their initial liability under TOVALOP or CLC. Tanker owners may receive indemnification under CRISTAL up to U.S. \$40 per vessel ton, or up to \$6.8 million, whichever is less (RPI, 1983).

CRISTAL does not compensate for noncommercial natural resource damages, but it covers third-party economic losses and governmental preventive measures and clean-up costs. Claims under this regime can be made through the tanker owner, his insurer, or the Marine Pollution Compensation Services Ltd., a London-based organization that handles CRISTAL's claims.

B. The International Conventional System

There is no liability under TOVALOP when CLC applies (Nichols, 1983). The scope of this convention, which has been in force since 1975, is limited to damage caused by oils when transported as cargo only. Damages from deballasting is not covered (Ganten, 1981). The criterion used to determine its applicability is solely territorial, that is damage must occur at the territory of a signatory nation, including its territorial sea. It also covers preventive measures taken to avoid or minimize territorial damage (CLC, Article II). As pointed out by Ganten (1983), neither the nationality of the tanker owner nor the ship's registry is additionally required to be from a contracting state for the convention to apply.

Maximum shipowner liability under CLC is U.S. \$ 18.5 million (Nichols, 1983). Shipowners, however, lose the right to limit their liability if the incident occurred as a result of their actual fault or privity (Ganten, 1983; Sielen and McManus, 1983). Owners are not liable if the incident resulted from an Act of God or War, willful action or omission of a third party, or governmental negligence in maintaining navigational aids (CLC, Article III. 2).

CLC claims must be filed within three years of the date when the damage occurred, and in the courts of the contracting State that suffered the injuries (CLC, Articles VIII and IX). The amount of the award will be determined by these courts according to their definition of what constitutes pollution damages, and such a judgement shall be recognized in any contracting state (CLC, Article X). This is particularly important to Ecuador, since it is a party to CLC (OSIR, August 1982).

FUND supplements the Civil Liability Convention up to U.S. \$ 59 million per incident, with option to increase this sum to a total of U.S. \$79 million (Ganten, 1981). FUND pays this additional compensation when damages exceed the liability limits established under CLC; when the owner or his insurer is unable to meet his obligation; and when there is no liability for damage under CLC (FUND, Article 4; Sielen and McManus, 1983). Exception to these obligations are damages caused by an act of war or other hostilities, or if the claimant cannot prove that the injury resulted from an incident involving one or more ships (FUND, Articles 4.2. (a) and (b)). The tanker owners' liability under CLC is also relieved by FUND, which may indemnify them an amount of US \$44 per vessel ton, up to a maximum of US \$7.4 million (Ganten, 1981).

Compensation may be sought by suing the International Oil Pollution Compensation Fund, as a juridical person, in any national court having original CLC jurisdiction over the shipowner (Sielen and McManus, 1983). So far no compensation for damages to noncommercial resources has been provided by the FUND (Ganten, 1981; RPI, 1983). This Convention also defers to the national laws of a signatory nation to determine acceptable claims.

Ecuador is not a member of the Fund convention (Ganten, 1983). Compensation under the four instruments described here (TOVALOP, CRISTAL, CLC, and FUND) is indicated in a simplified flow chart (Figure 8).

C. Claim Procedure

As shown above, the initial liability for oil pollution damage and clean-up costs under either the voluntary or the conventional system rests with tanker owners. Ninety-five per cent of these tanker owners are insured by Protection and Indemnity Associations (Goldie, 1983), also known as P & I Clubs. Claimants seeking damage compensation will, therefore, most likely deal with a P & I representative. Besides insuring owners according to TOVALOP and CLC, the International Group of P & I Clubs has entered into agreements with CRISTAL and the International Oil Pollution Compensation Fund to facilitate the processing of claims that exceed tanker owners liability (Ganten, 1981; Nichols, 1983). P & I Clubs will act on the behalf of these

Figure 8. Flow Chart indicating oil pollution compensation under TOVALOP, CRISTAL, CLC, FUND (Nichols, 1983).

Cargo Owners (oil companies funds) throughout the incident as well (Nichols, 1983). In this manner, while negotiating the settlement of claims, the victims will only have to deal with the P & I insurer, instead of making separate claims. Each claim must contain: (1) the name and address of the claimant; (2) the identity of the ship involved in the incident; (3) the date, the place and specific detail of the incident; (4) the type of oil, the kind of pollution damage, and the place of occurrence; and (5) the amount of the claim (Nichols, 1983).

Claim assessment is often performed for the P & I Clubs by the International Tanker Owners Pollution Federation, TOVALOP'S Administrator, regardless of whether the claim is made under TOVALOP (Goldie, 1983; Nichols, 1983). Furthermore, Nichols (1983) explains that in case an oil spill emergency occurs in a country without the necessary c/c expertise, the Federation often arranges, with the joint consent of the insurers, for equipment and materials to be sent to the location of the incident. It also sends a technical staff to assist in the c/c operation. Because of this close assistance and follow up, the Federation can better estimate the total cost of damage, thus avoiding unnecessary disputes.

Assessment of the amount of damage by the victims must be based on facts and documentation. Claims are often broken down into three categories: (1) prevention and clean-up costs; (2) replacement and repair costs; and (3) economic loss (Nichols, 1983). It is extremely important to maintain a comprehensive record of all prevention and clean-up expenditures. Nichols (1983) recommends to make daily note of "the operations in progress, the equipment in use, where it is being used, the number of men employed, how and where they are deployed and the materials consumed". These can be broken down as follows:

- "i) Delineation of the area affected describing the extent of pollution and identifying those areas most heavily contaminated. This may be best presented as a map or chart accompanied by photographs.
- ii) Summary of events including a description of the work carried out in different areas and of the working methods chosen in relation to the circumstances prevailing during the incident.
- iii) Analytical and/or circumstantial evidence linking the oil pollution with the ship involved in the incident (e.g. chemical analysis, relevant wind and current data, observations of floating oil movements).

- iv) Dates on which work was carried out (weekly or daily costs).
- v) Labor costs (number and categories of laborers, rates of pay, days/hours worked, total costs).
- vi) Material costs.
- vii) Transport costs (number and types of vehicles used, number of days/ hours operated, rate of hire or cost of purchase, total costs).
- viii) Costs of final disposal of recovered oil " (Nichols, 1983).

Replacement and repair costs should include:

- "i) Extent of pollution damage to property.
- ii) Description of the item written off or damaged and needing replacement or repairs (e.g. fishing net, sail, boat), including description of its location at the time of oil pollution damage.
- iii) Cost of replacement or of repair work.
- iv) Age of item to be replaced.
- v) Labor costs incurred " (Nichols, 1983).

Finally, economic loss ought to describe:

- "i) Nature of loss, including demonstration that loss resulted directly from the incident.
- ii) Comparative figures for profits earned in previous periods and for the period during which damage was suffered.
- iii) Method of assessment of loss" (Nichols, 1983).

Assessment of economic loss and of environmental damage seem to be the area where most disputes over the amount of compensation occur (Goldie, 1983). Some of this can be alleviated by governments establishing close cooperation with P & I representatives. P & I Clubs may also provide letters of undertaking (Goldie, 1983) as security to victims' claims in order to obtain the release of ships from arrest or to avoid the threat of arrest.

The extent of liability is generally covered by the law of the country in which damage occurred. Clean-up costs, direct and indirect damage or financial loss are all recoverable under CLC (Goldie, 1983). Both the CLC and FUND conventions cover any reasonable measures taken to prevent or minimize

pollution damage after an incident has occurred. Although the meaning of "pollution damage" is yet to be determined, a resolution from the Fund's Assembly established that assessment of compensation is not to be made "on the basis of an abstract quantification of damage calculated in accordance with theoretical models" (Ganten, 1981).

The Director of the International Oil Pollution Compensation Fund has the authority to make provisional payments to victims when needed "to mitigate undue financial hardship" (Ganten, 1981), up to an amount of US \$2.2 million. This may be done without prior approval of the Fund's Assembly or its Executive Committee, but it is restricted to exceptional cases only.

D. Calculation of Damages

A uniform, ideal method to assess and compensate for damages to natural resources does not seem to exist. In many legal jurisdictions, environmental damages are not even the object of compensation, since only direct injury to the person or person's property are compensable, not damages to common resources. Only indirectly does destruction of fishing grounds, for example, impose "economic loss" to fishermen. The immediate damage is caused to the medium - the environment - from which many people draw their livelihood.

Further, uncertainty over appraising the value of these resources has proved to be a difficult barrier to overcome. The United States has attempted for some time to calculate the environmental costs from pollution and to provide redress to states and individuals that suffer environmental damage. Most states have developed tables placing a monetary value on a limited number of commercial or sport species, and seek only the replacement value of those species actually killed by a spill. These approaches focus on quantifiable body counts, instead of the less predictable, long-term wildlife and habitat damage (RPI, 1983). Some states further attempt to place a monetary value to damaged or destroyed ecosystems, and a few also include the use of these ecosystems in the calculation. At the federal level, the United States became the first nation to create a comprehensive program for damage assessment and compensation of natural resources (RPI, 1983) with the passage, in December 1980, of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), widely known as the Superfund Act. This Act mandates that

federal regulations be promulgated following the best available procedures to determine both direct and indirect injury, taking into consideration, but not limited to, "replacement value, use value and ability of the ecosystem or resource to recover" (CERCLA, Section 301 (c) (1) and (2)). The President and other public officials, as public trustees, are mandated to recover damages to natural resources within their respective jurisdiction, which sums will be used to restore or replace such resources. When damages cannot be recovered, a U.S. \$1.6 billion "superfund" will provide the funds for assessing, restoring, replacing, or acquiring the equivalent to the damaged or destroyed natural resource. The mechanism created by the Superfund Act for the assessment and recovery of environmental damages applies to oil and other hazardous substances, even though the Act itself does not cover releases of oil (CERCLA, Section 101 (14)).

Only a few Nations have sought compensation for environmental damages. Most successful efforts have been in the United States, often as a result of pre-trial settlements (Halter and Thomas, 1982). A survey of other legal systems conducted by RPI (1983) revealed that the Soviet Union seems to be the only other country that has so far attempted to develop any procedures to recover monetary compensation for damaged or destroyed ecosystems, going beyond clean-up costs and economic losses to include non-commercial injuries. Government clean-up costs and fishermen economic losses were generally protected in the countries surveyed (Canada, Denmark, France, Japan, Netherlands, Norway, Sweden, USSR, U.K. and Germany). But if polluters are not liable to pay for all resulting environmental damage, then there will not be enough economic incentive to prevent marine life and habitat losses. Without adequate liability, the cost of prevention to polluters will always be greater than the value of natural resources, since the public will bear the costs of remaining damages.

According to Getter et al. (April 1980), the least favored method among ecologists - the "dead body count" (or replacement value) - seems to be the most successful in litigation. The principal strength of this method lies in its simplicity (Halter and Thomas, 1982). Individual replacement cost for each species has been estimated by statute (Florida) or by fisheries price lists (American Fisheries Society) based on hatchery production costs (RPI, 1983). Calculating damages, then, becomes a simple matter of multiplying the replacement cost by the number of animals lost from affected species.

These price lists, however, have the disadvantage of being restricted to commercial and recreational species. Prices for rare, endangered and non-commercial species, including many that play relevant roles in the food chain of commercial and recreational fisheries, are not available. An additional disadvantage is the fact that hatchery prices do not necessarily reflect the market value of the species listed. They also do not take into account the disproportionate mortality of hatchery-reared stock after being placed in open and unprotected conditions (Bey and Fidell, 1979; RPI, 1983).

Replacement cost has, in some cases, been established by values other than hatchery costs, such as the commercial wholesale or retail price, and prices from biological supply house catalogs. The latter reflect the cost of rearing, capturing, marketing and distributing the animals for research or educational purposes (RPI, 1983). In a famous Puerto Rican case (Zoe Colocotroni), the catalog values for the species to be replaced were averaged and multiplied by the estimated body count. This averaged value, however, did not seem to have been fully tested in the courts since the parties reached a settlement.

Other valuation methods exist to complement or supercede replacement cost. The "habitat evaluation method," for example, attempts to calculate damages by comparing "measurable changes in the quality and quantity of habitat available to wildlife before and after a spill incident" (RPI, 1983). This is, however, an expensive method. It requires extensive computer assistance, field surveys and mapping, along with the application of complex quantification formulas.

A third method estimates environmental damage by converting the amount of oil spilled to a figure that represents the volume of water affected. This model was utilized by the Soviet Union to recover damages from the International Oil Pollution Compensation Fund but was rejected for being too arbitrary (RPI, 1983). A tri-dimensional variant of this method has been adopted by the state of Alaska. It takes into consideration the type of oil spilled and the nature of the impacted ecosystem in addition to the quantity of spilled oil. This Alaskan method also provides specific adjustment factors to reflect low, moderate and high degrees of toxicity, degradability and dispersability of the pollutant. Value of damage to the least sensitive environments is set at U.S. \$1.00 per barrel of spilled oil. This value increases for areas of greater sensitivity. The total value of damages is

obtained by multiplying this unit value (based on the nature of the impacted ecosystem) by the arithmetic mean of the adjustment factors (based on the type of oil), and the product further multiplied by the amount of oil spilled (RPI, 1983). This method is easy to apply because relevant data (amount and type of oil, and kind of ecosystem) are easily accessible; however it has never been tested in a court of law. Its major weaknesses concern the arbitrary value applied to environmental damage per barrel of oil and the gradation of the adjustment factors, along with not accounting for varied species responses to an oil spill.

Other methods consider the economic loss from the human use value of these affected ecosystems. The basic assumption behind these methods is that environmental damage from an oil spill is greater than the cost of simply replacing the animals and restoring the impacted habitat - it also represents a reduction of consumer expenditures. Several methods attempt to estimate these values. The Travel Cost Method (TCM) uses transportation expenditures and time cost. The Gross Expenditure Method (GEM) considers a combination of travel, time and equipment costs. The Unit Day Value Method (UDV) assigns values to fishing and hunting days, and other recreation days (Halter and Thomas, 1982; RPI, 1983). The state of Washington utilizes five components to measure economic loss: park land closure or reduced utilization; public lands closure or reduced utilization; reduction of recreational fishing; reduction of commercial fishing; and reduction of state revenues from taxes, licenses and fees (RPI, 1983). Commercial fishing losses are determined by measuring the difference between catch per unit of effort before and after the spill incident.

Halter and Thomas (1982) suggest the best approach to be a combination of several of these methods. Some of them could be of direct application to Ecuador. The Alaskan tri-dimensional method, for example, could be an attractive method due to its simplicity and data accessibility, but it would be advisable to consult its adequacies with the International Oil Pollution Compensation Fund. A complementary or parallel approach to the Alaskan method could be the utilization of replacement costs based on hatchery and market values of the species, especially as it concerns the valuable Ecuadorian shrimp industry. Assessment procedures, in any case, ought to be clearly laid out by law or regulation.

E. Offshore Installations

Offshore oil rigs and platforms usually operate within specific national jurisdictions and, therefore, are subject to domestic laws. Liability, whether limited or unlimited, whether strict or based on fault, is a prerogative of the concerned state to determine.

The difference between a system of liability based on fault and a system of strict liability, as discussed by Fleischer (1976), "is to be found where there is no person to blame for the accident, or where the person to be blamed has not acted within the organization of the licensee or operator." In these cases, the owner, who is ordinarily liable for his own faults and for those of his employees, would not be liable and the victims would be without redress. The advantage of strict liability is clearly on the side of the victims. As long as the injury originated from his activity, the owner (licensee or operator) is liable for damages. Fault does not need to be proven.

Again, from the victims standpoint, a system of unlimited liability seems to be the most desirable. Limitation of liability often amounts to having the victims, including governments, bear the cost of damages in excess of the fixed limit (Fleischer, 1976). Even though States could appear to have a direct interest in no fixed limitation, so that expenditures for the restoration of the environment would be guaranteed in full, this is not always the case. Unlimited liability may also decrease taxable revenues from oil companies, which often prompts governments to establish some limitation to compensation.

These questions, in turn, bring to fore the additional questions of how the liability will be guaranteed. Governments may require some form of security, either in the form of insurance or indemnity bonds (Fleischer, 1976; Hayes, 1983b). Compulsory insurance is considered by Fleischer (1976) to be costly and unnecessary. A guarantee by the oil company based on its financial resources, including the value of the oil fields, should be sufficient to cover possible damages.

This is a matter to be resolved by Ecuador within its own legal and political system. Protection of its natural resources (fish, shrimp, etc.) in the Gulf of Guayaquil can be achieved effectively through an appropriate system of civil liability. Such a system should offer sufficient and explicit coverage to potential victims, without causing an unjustifiable burden to the oil industry.

10. CONCLUSIONS

Oil production from the Ecuadorian Amazonic region and fisheries in the Gulf of Guayaquil have become increasingly important to the national economy as major earners of foreign revenue. The possibility of oil development in the region of the Gulf of Guayaquil may come into conflict with the marine resources found there, which represent a diversified multi-million dollar industry.

Protection of these resources, fish and shrimp, also involves the need to protect their natural habitat (the mangroves) from oil contamination. This can be accomplished by preventing accidental and reducing operational discharges of oil into the environment. This need for prevention cannot be overemphasized. Clean-up operations or the use of dispersants are also important to minimize damages, but it will not function as an antidote to the problem.

The preliminary oil contingency plans drafted by several government agencies in Ecuador and the state oil company have both strengths and weaknesses. An essential positive aspect is the willingness on the part of the government and the industry to cooperate and to handle the problem jointly. This is demonstrated by the DIMERC-CEPE agreement and the contents of all three plans discussed in this report. Another positive indicator is the fact that planning is taking place prior to actual oil exploitation.

As to the plans themselves, their general guidelines are basically sound. The combination of c/c methods considered indicates the intended sophistication of the response mechanism.

Weaknesses, however, do exist but they can easily be eliminated as planning progresses. The plans seem to overly rely on clean-up operations. Such an optimistic approach may shadow the emphasis on preventative measures. The author has not received any indication that "prevention" is actively being pursued separately.

Coordination of the inter-agency implementation of the plans could be another problem. The Chief of Operations must not only be activated immediately, but he must also have latitude for decision-making. Too much inter-agency decision-making at the time of a spill is undesirable.

Furthermore, existing environmental data needs to be analyzed and presented in clear, practical form. Vulnerable coastal sites must be

designated. Operational guidelines on how to combat a spill at sea and site-specific should be developed with foremost urgency and introduced, to complement the organizational framework. Designation of disposal sites, selection and purchase of equipment, installation of response units, and realistic training of personnel should follow.

Prompt access to relevant environmental and technical information will enable the Chief of Operations to make a rapid evaluation of the oil spill threat, and take more effective action. Ecuador's future as an oil and fish exporting country depends on careful planning conducted today.

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ANNEX I

MERCHANT MARINE AND COASTAL DIRECTORATE (DIMERC) PLAN OF ACTION TO PREVENT, MONITOR AND CONTROL HYDROCARBON CONTAMINATION IN THE GULF OF GUAYAQUIL

1. REFERENCES

- Maritime Police Code /29
- Law of Hydrocarbon Contamination /74, Annex No. 1 to Title III of the Maritime Police Code
- Law of Environmental Pollution /76, Annex No. 2
- International Convention for the Prevention of Oil Pollution in the Ocean/54, Including 62 Amendments (OILPOL)
- International Convention on Civil Liability For Oil Pollution Damage /79
- DIMERC-CEPE Agreement (CEPE - State Oil Corporation)

2. RESPONSIBILITY

DIMERC is responsible for the prevention, monitoring and control of contamination through the Coast Guard, but has reached an agreement with CEPE for the prevention and containment of oil pollution.

3. JUSTIFICATION

The Gulf of Guayaquil is a source of renewable resources that represents a large share of the economy. It is vital to constantly monitor the entire area

and follow the precepts of this Plan in order to prevent or combat major incidents. Exploitation of and exploration for gas and oil may have serious consequences:

- Accidents in the recovery of gas, while more likely to contaminate the air, can if they occur under the surface alter the surrounding waters and their ecology.

- The possibility exists of oil extraction, which would require that the Plan be intensified.

- There will be an increase in maritime traffic, washing of tanks bearing combustibles, and emergencies resulting from collisions and leaks.

4. OBJECTIVES

Preservation of the ecological balance through constant monitoring of all possible sources of hydrocarbon contamination, and compliance with all DIMERC-COGUAR regulations and the Law of Hydrocarbon Contamination.

5. PLAN OF ACTION

The Plan will be enforced and security measures taken on the platforms and the entire Gulf. Moreover, attempts will be made to determine the source and the infractor in case of a spill, and legal action taken by the Harbor Master's Office.

- Prevention

To inform people as to regulations, directives, etc:

- (a) letters and pamphlets will be circulated to shipowners, crewmembers and all others who use the ports;

(b) inspections will be carried out on platforms, tankers and other ships traveling in areas near the platforms or fishing zones.

-Monitoring

The Coast Guard will be responsible for patrols of the Gulf, especially in drilling and fishing zones, and will:

- (a) enforce regulations;
- (b) detect and report contamination;
- (c) take samples of contamination;
- (d) serve notice to infractors for court appearance.

-Control

In the event of a spill or contamination, note will be taken of its location, the extent of the spill, winds, tides, proximity to biologically productive areas, etc. to determine the best method of action. There will be three zones: platforms; shipping zones; beaches and mangrove swamps.

Plans to deal with spills are:

- (a) recovery (enclose the spill with booms or barriers, collect the oil using pumps or a skimmer, and dispose of it);
- (b) dispersion (chemicals);
- (c) absorption (soybean dust, cellulose barriers);
- (d) cleaning.

DIMERC and CEPE are responsible for combatting spills. Proximity to mangroves and beaches will be taken into consideration when selecting methods, since in many cases natural decomposition is preferable.

6. LEGAL ACTION

Compliance with this plan does not exempt CEPE or those that work for CEPE.

7. TIMETABLE (4 years)

1982: First stage. Compilation of information of Gulf's environment; application of data we presently have to prevention, monitoring and control programs; education of CEPE and other personnel; installation of three spill response units with CEPE in strategic areas; acquisition of equipment; control of increases in maritime traffic; monitoring of platforms; establishment of priorities based on areas' vulnerability to contamination; increased communications between organizations involved (CEPE, UEGG-CEPE, Coast Guard); designation and preparation of sites for the disposition of oil recovered from a spill; study of different methods and ways to combat spills; training in the use of equipment.

1983-1984: Second stage. Participation in planning and operation of CEPE pollution control stations; training in use of equipment; coordination in the implementation of equipment for the three units; seminar on prevention and combatting of spills and contamination; monitoring of areas where drilling and exploration are occurring; completion of any unfinished business from the previous stage.

1985: Third stage. Continued monitoring; annual evaluation of equipment; continuation of joint programs to preserve the marine environment with INOCAR (Naval Oceanographic Institution) and INP (National Fisheries Institute); development of annual seminars on prevention and control of pollution; evaluation of information on pollution that has occurred.

8. NECESSARY EQUIPMENT

Equipment is necessary for monitoring activity, and to combat spills. It is also required for the creation of a Contamination Division Laboratory, which will carry out analysis and quantification of any contamination and deal with chemicals to be used in decontamination.

9. PERSONNEL

CEPE will provide any personnel needed to supplement DIMERC and the Coast Guard.

<u>EQUIPMENT</u>	<u>UEGG-CEPE</u>	<u>BUDGET</u>	<u>Amount</u>	<u>Sucres</u>	<u>(US\$)</u>
(1) <u>Prevention and Vigilance</u>					
- High-potency Searchlights			6	250,000	7,540
- Binoculars			3	12,000	360
- Communications System			1	1,000,000	30,170
- Gas Detectors			3	39,000	1,177
- Van			1	800,000	24,136
- Truck			1	1,500,000	45,255
(2) <u>Decontamination and Clean-up</u>					
- Large Scale Dispersion Equipment			2	700,000	21,120
- Sea Mop or Sausage Boom			1	750,000	22,620
- Heavy-Liquid Suction Pumps			2	800,000	24,136
- Self-propelled Lighter w/Crane and Skimmer			1	8,000,000	241,360
- Ocean-going Motorboat			1	14,000,000	422,380
- Floating Barrier 30"		4000 ft.			
- Dispersants (55 gallon drums)			150	2,000,000	60,340
- Tridents			100	30,000	905
- Shovels			100	15,000	450
- Straw Bundles or Bales			200	10,000	300
(3) <u>Laboratory</u>					
- Gas Chromatograph			1	800,000	24,136
- Viscosity Meter			1	60,000	1,810
- Kiln			1	45,000	1,360

(3) Laboratory (con't.)

Oxygen Meter	2(1)	50,000	1,510
Salinity Meter (portable)	1	24,900	750
Fusion-point Meter	1	24,000	725
Pipette-Cleaner	1	7,600	230
Glass-ware	S/N	50,000	1,510
Reagents	S/N	50,000	1,510

(4) Security and Personal Protection (15 Persons)

- Divers			
- Helmets			
- View-finders			
- Masks			
- Gloves			
- Boots			
- Rain gear		200,000	6,035

(5) Other

- Tools and Accessories		100,000	3,000

<u>Total</u>		31,377,500	946,660

CEPE ANNUAL CONTRIBUTIONS

1982

(1) Prevention, Monitoring and Decontamination

	<u>Amount</u>	<u>Sucres</u>	<u>(US)</u>
Binoculars	3	12,000	360
High-potency Searchlights	6	250,000	7,540
Large scale Dispersion Equipment	1	350,000	10,560
Floating Barrier	2000 ft	1,500,000	45,255
Heavy-liquid Suction Pump	1	400,000	12,070
Motor boat	1	600,000	18,100
Dispersants	100bb1	1,200,000	36,200
Van	1	800,000	24,135
Communications System	1	1,000,000	30,170
Maintenance and Equipment	-	500,000	15,100
Fuel and lubricants	-	1,000,000	30,170
Personal Protective Equipment	-	100,000	3,020
Truck	1	1,500,000	45,255
Ocean-going Motorboat	1	1,500,000	45,255
Lighter equipped with Skimmer and Crane	1	8,000,000	241,360
Aerial Surveillance	-	1,000,000	30,170

(2) Laboratory Equipment and Materials

Gas Chromatograph	1	800,000	24,135
Viscosity meter	1	60,000	1,810
Oxygen meter	1	25,000	755
Salinity meter (fixed)	1	60,000	1,810
Fusion point meter	1	24,000	725

(2) Laboratory Equipment and Materials (Con't.)

Pipette Cleaner	1	7,600	230
Glassware	-	25,000	755
Reagents	-	25,000	755
Training of Personnel	-	200,000	6,035
Books, Magazines	-	20,000	600

(3) Personnel

Oceanographer	1	150,000	4,525
Biologist	1	150,000	4,525

<u>Total - 1982</u>		33,758,600	1,018,495
		(21,158,600)	(638,355)

CEPE ANNUAL CONTRIBUTIONS

1983

Amount   Sucres   (US\$)

(1) Prevention, Monitoring and Decontamination

Gas Detectors	3	39,000	1,180
Large scale Dispersion Equipment	3	350,000	10,560
Sea Mop or Sausage Boom	1	750,000	22,620
Floating Barrier	2000 ft	1,500,000	45,255
Heavy-liquid Suction Pump	1	400,000	12,070
Tridents	100	30,000	905
Lamps	100	15,000	450
Straw bundles	200	10,000	300
Tools and Accessories	-	60,000	1,810
Maintenance and Equipment	-	500,000	15,100
Fuel and Lubricants	-	1,000,000	30,170
Protective Equipment (personal)	-	100,000	3,020
Aerial Surveillance	-	1,000,000	30,170

(2) Laboratory Equipment & Materials

Kiln	1	45,000	1,360
Oxygen Meter	1	25,000	755
Salinity Meter (portable)	1	24,960	750
Glassware	-	25,000	755
Reagents	-	25,000	755
Books, magazines, etc.	-	20,000	600
Training of Personnel	-	100,000	3,020

CEPE ANNUAL CONTRIBUTIONS 1983 (Con't)

(3) Personnel

Industrial Engineer	1	150,000	4,525
Chemist	1	150,000	4,525
<u>Total</u>		6,318,860	190,643

EQUIPMENT - DIMERC

Amount Sucres (US\$)

(1) Prevention and Vigilance

- Patrol Boats	6	8,000,000	241,350
- Binoculars	6	24,000	725
- Gas Detectors	2	26,000	785
- Van	2	1,500,000	45,255

(2) Decontamination and Clean-up

- Portable Self-propelled pumps	4	376,000	11,345
- Heavy-liquid Suction Pump	1	395,000	11,920
- Water Suction Pumps	6	500,000	15,100
- Tug equipped for decontamination (Sirius)	1	45,000,000	1,357,650
- Dispersants (55 gallon drums)	100	5,000	150

(3) Laboratory

- Analytical balance or scales	1	50,000	1,510
- Distiller	1	41,000	1,240
- Ph Measurer	1	16,000	485
- Salinity Meter (portable)	1	24,900	750
- Spectronic (20)	1	26,000	785
- Centrifuge (8 Tubes)	1	25,000	755
- Current Stabilizer	1	10,000	300
- Microscope	1	43,000	1,300
- Scales	1	3,000	90
- "Dryer" for glass materials	1	18,900	570
- Double Boiler	1	7,670	230
- Chromatographic Chambers (or Columns)	4	10,000	300

Laboratory (Con't)

- Ultra-violet Lamp	1	1,800	55
- Glassware	-	50,000	1,510
- Reagents	-	40,000	1,200

(4) Security and Personal Protection

- Divers			
- Helmets			
- View-finders			
- Masks			
- Gloves			
- Rain-gear		100,000	3,020

(5) Personnel

- Technicians	5	750,000	22,620
- Secretary	2	144,000	4,345
- Helmsmen, Mechanics and Crewmembers	20	2,000,000	60,340

<u>Total</u>		60,187,270	1,815,850

ANNEX II

COAST GUARD (COGUAR) ORGANIZATION OF LOCAL CONTINGENCY PLAN FOR THE GULF OF GUAYAQUIL.

1. Ruling Body - DIGMER (Merchant Marine and Coastal General Directorate) exercises administrative control of this plan; DICAGC (Harbor Masters and Coast Guard Directorate) is charged with operations. On receiving word of an emergency DIGMER will:

- mobilize DICAGC;
- will put the plan in operation;
- tightly coordinate operations with the CEPE Executive Office of the Gulf of Guayaquil (UEGG-CEPE);
- arrange to be kept fully informed regarding operations.

2. Operational Arm - DICAGC - will delegate responsibilities to the Coast Guard, and will:

- direct efforts to combat an oil spill through the Coast Guard and its Office of Pollution Prevention and Control;
- work directly with the UEGG-CEPE Environmental Advisory Office in combatting the contamination;
- keep DIGMER informed of activities;
- enforce DIGMER's stipulations and directives.

3. Secondary Operational Arm - COGUAR - will be under DICAGC's direction, and in direct coordination with the Chief of Operations on the scene.

4. Chief of Operations - JOCD - will be the head of the Department of Pollution Prevention and Control of COGUAR. He is responsible for dealing with emergencies, will take charge on the scene of the accident and will mobilize personnel. The Chief must:

- establish command posts in strategic locations;
- keep COGUAR - DICAGC informed;
- arrange for the temporary storage and the transportation of required equipment, as well as its use;
- direct ships and airplanes performing support functions;
- supervise personnel cleaning up any coastal damage;
- direct final disposition of recovered material.

DIGMER funds will be used. The Chief can delegate authority to an Operations Assistant.

5. JOCD Personnel - The Chief of Operations will have a small staff assigned to deal with specific emergency operations.

6. Arrangements will be made to protect and clean beaches and coastal areas, including mangroves. The types of beaches or coastline threatened will be considered in combatting the spill. Recovered contaminants will not be disposed of in areas linked to subterranean waters or water tables.

7. Support Operations - Monitoring will be conducted by air and sea to determine the extent and direction of the spill. Logistical support (communications, transportation, etc.) will be arranged. Communications will be via a special channel to prevent interference.
8. Administrative Support - There will be close contact with the Finance Department regarding costs, bookkeeping and accounting of expenses, etc. Detailed records will be kept for publication and future reference.
9. Scientific Support - Scientific groups such as INOCAR and INP will provide the most up-to-date technology regarding methods to combat contamination; information regarding currents, winds and other factors; and data on environmental concerns, which may dictate priorities. UEGG-CEPE scientists will evaluate this information along with DIGMER, which will in turn pass it to JOCD.
10. Legal Counsel and Public Relations - These will be connected with the Plan on both the administrative and operational level. Legal aspects of the Plan will be assessed and advice given to any persons involved in the plan. P.R. people will gather detailed information about the sequence of events, and submit them to JOCD, DIGMER and UEGG-CEPE for analysis and approval.

Specific Functions of UEGG-CEPE

The Executive Unit:

- is responsible for avoiding any hydrocarbon contamination or any other damage as a result of its exploration-exploitation activities;

- will take precautions on platforms, working in coordination with the Environmental Advisory Office;
- will, in the case of an emergency, take action based on its own plan (produced by the Environmental Advisory Office) and simultaneously advise DIGMER of these actions;
- must join its personnel and equipment to those utilized under Coast Guard;
- will, in coordination with DIGMER, contract foreign firms to help deal with an emergency should available resources prove insufficient.

Spill Response Units

- Spill Response Units will be located in Puerto Bolivar, Puna and Posorja. They will constitute the foundation of the basic emergency infrastructure. They will be run by an expert on pollution prevention control and decontamination and three Coast Guard crewmen. The equipment listed in this Plan will be stored in these units, and in the case of an emergency, transported by the unit crews to the scene of the spill for use in control operations. There will be periodic drills in different areas of the Gulf to improve response.

Features of the Coastal and Maritime Zones of Ecuador

(4 pages of general description, including beaches and other types of coastline, oceanographic aspects, and biological resources)

ANNEX III

ECUATORIAN STATE PETROLEUM CORPORATION (CEPE) PRELIMINARY CONTINGENCY PLAN TO
CONTROL OIL SPILLS IN THE GULF OF GUAYAQUIL

I. Organization and Planning of the Response

1.1 ANTECEDENTS - DIMERC (Merchant Marine and Coastal General Directorate) is charged with preventing, controlling and combatting pollution. DIMERC and CEPE will work together to monitor and control activities in the Gulf in order to preserve the ecological equilibrium during drilling.

CEPE, which is drilling in the Gulf, has been working on a Contingency Plan to deal with spills. Present drilling has reached a depth of 4,850 meters. The type of platform being used is "UXMAL-1."

1.2 DEFINITION - The Contingency Plan is a set of organizational measures on the institutional level, including allocation of responsibility, and utilization of human, technical and economic resources in case of a spill.

1.3 OBJECTIVES - to set up a system for mobilization of personnel and equipment and to train the necessary personnel.

2.0 ORGANIZATION - The Environmental Advisory Office will determine which areas are of great economic or ecological value, and also exposed to

pollution. It will specify the best method to deal with each spill according to the zone.

2.1 DUTIES AND RESPONSIBILITIES

The Office will instruct key personnel regarding environmental conditions and control, and will work with CEPE planners and other environmental groups.

3.0 EMERGENCY PLAN

3.1 Classification of the emergency - (1) injury or death; (2) blow-outs; (3) damage to drilling platform; (4) loss or damage of supply ships, helicopters, planes; (5) oil spill.

3.2 Reporting - Drill supervisor must take the appropriate emergency measures; complete emergency forms, and notify the chief of the Guayaquil Drilling Division or a substitute (names and phone numbers listed), who will inform key personnel and put the CEPE Contingency Plan in motion.

3.3 Specific Course of Action

(a) the Drill Supervisor must inform the Chief of the Drilling Division regarding the cause of the accident; size of the spill; its thickness; prevailing conditions (currents, wind speed, etc.); distance from shore; type of contamination; and available equipment to combat it (including dispersants, helicopters, vessels, etc.). The Supervisor must also take necessary steps to reduce the risk of fire; continue to report to the Chief on the situation; and prepare a written statement.

(b) The Chief of the Drilling Division must notify the Director of Production and the Environmental Advisory Office, and assign available equipment and personnel as needed.

(c) The Environmental Advisory Office will confer with the Director of Oil-Spill Control (DICOD), activate the Plan, designate a substitute for the Sub-Director of Oil-Spill Control, and notify DICOD as to possible impacts of the spill, corrective measures and priorities regarding clean-up.

(d) The Assistant Director of Oil-spill Control (S.DICOD) will substitute for the DICOD, and keep him informed; coordinate and supervise on-site activities; be responsible for accounting of costs and logistical support, and public relations; inform and maintain close contact with DIMERC regarding the emergency; and monitor the spill.

Responsibility for action taken in the ocean in case of a spill is DIMERC's; for protecting and cleaning the coast and disposing of oil, CEPE's. This will require studies into the classification of coastal areas (based on structural, sedimentary and other characteristics), as well as land-use, population distribution, etc. Oil collected after a spill will be reprocessed, buried or burned.

3.4 Responsibility

(a) DICOD will be responsible for all aspects of the response to a spill. DICOD will appoint a Sub-Director (S. DICOD), notify the press as needed, and receive all legal and insurance advice.

(b) The Legal Adviser will provide advice to DICOD, S. DICOD and other necessary personnel; should be familiar with CEPE's civil responsibilities arising from a spill and action taken to control it; work with the insurance adviser to deal with payment in case of damages; and examine all contracts.

(c) The Insurance Adviser must work with the legal adviser on payment of claims for damages, and serve as a link to the insurance agencies.

(d) S. DICOD is the CEPE official responsible for operations, and will have a team of technical advisers working in conjunction with CEPE's Environmental Advisory Office, DIMERC, and other relevant agencies to advise on methods to be used in an emergency.

(e) The Financial Adviser will be able to authorize the large expenditures involved in combatting spills, removing and disposing of oil.

(f) The Public Relations Adviser will keep the media informed, prepare CEPE press releases, and work with S. DICOD to develop a public appreciation for the nature and the purpose of the Emergency Plan.

(g) The Logistics Supervisor is responsible for transportation, personnel, communication, equipment and materials, food and shelter, etc., to allow the S. DICOD to order whatever type of operation is necessary (examples provided).

(h) The Director of Coastal Protection will act as one of S. DICOD's technical advisers, and will arrange to have any coastal damage cleaned up, and reclaimed oil disposed of.

(i) Director of Reclaiming Operations is under the supervision of S. DICOD and the Technical Advisory Group of which he (or his substitute) will be a member. This office can be held by a DIMERC official until CEPE develops its own capability.

(j) S. DICOD's Technical Advisers will choose priorities in terms of cleaning up and the best methods to contain and combat the spill. They will take part in planning emergency operations. The group includes a biologist (who will have access to information as to the sensitivity of the coast to oil spills and response measures), an oceanographer (who will devise a mathematical model of possible oil spill trajectories in the Gulf), and experts in meteorology, coastal zones, equipment utilization, etc.

(k) Foreign contractors can fulfill two functions - as advisory or operational. The authority to decide which contractors to contact will lie with S.DICOD.

3.5 Presently, a full response to an oil spill would be beyond DIMERC's capabilities; as a result, foreign contractors from Europe (such as British Petroleum) or the United States would be called in. The decision to bring in contractors will be made by CEPE after consultation with DIMERC. It is specifically stated that experts on clean-up operations will be contracted.

II. Scenario - Strategy and Equipment

4.0 PROBABLE SCENARIO

The most probable location of an accident is at the drilling sites, at a depth of between 49 and 68 meters. Oil is expected to escape at a rate of 5,000 barrels a day, and gas at 2,000 cubic feet per barrel of oil. Light oil (35° API) will rise to the surface as drops mixed with gas. A portion will be consumed by fire maintained for security reasons. A portion will mix with water and form "Mousse," while a considerable part will form a thin layer composed mostly of oil. This distribution can be described by FANNELOP's mathematical model. Calculations are based on an average depth of 60 meters. Currents in this zone average half a knot in speed, and in combination with the wind push scattered oil on a brisk parabolic course.

From this we can estimate that a small area of ebullition would occupy a surface area of 10 to 11 meters in diameter, the zone in which most of the gas would be released and the Mousse ignited. The width of the layer of oil

decreases as speed increases, so it is most manageable when it achieves a speed of 1 knot. In sum, the oil should be contained immediately around its source if security and environmental factors permit it, though some oil will inevitably seep past barriers. Currents, winds, tides and influences from the Guayas make the direction of the spill variable.

Should a spill prove impossible to contain, at the end of 90 days a total of 450,000 barrels of oil will have been lost. Approximately 30%, or 135,000 barrels, will have burned, evaporated or been dissolved in the water.

If the spill reaches a significant thickness, it would be necessary to employ a number of counter-measures to contain it. Probably 50% of the remaining oil, or 157,000 barrels, could be recovered. Dispersants could remove 80% of the oil which still remains, or 126,000 barrels. This would leave about 31,500 barrels to be recovered in waters closer to the coast or near beaches. These figures assume the most favorable possible conditions.

5.0 STRATEGIES AND EQUIPMENT

Response to a spill would take place over 4 zones:

- 1) off-shore drill-site;
- 2) "intermediary" waters;
- 3) coastal waters (near-shore)
- 4) intertidal zone or on-shore.

5.1 Operations at the Drill-Site

The following actions will be taken:

- containment of the oil by mechanical means;
- activation of removal operations (collection and disposal).

The goal is to remove as much oil as possible while the spill is fresh. At this point, large-scale recovery equipment and conventional barriers should be enough. A 600 m. length of barrier would probably be put in a chain directly in the path of the spill, a few hundred meters from the drill-site. A second barrier should be placed nearby to prevent spreading due to a change in wind direction or to tides. A small tanker to deal with the petroleum recovered would be ideal. Concerns include conditions on the ocean, mechanical difficulties, the presence of gas, currents and the need to drill a relief well.

Since some oil will escape the barriers, dispersants will be applied in the second phase, and aerial surveillance will be used to monitor spills which have gotten past barriers. However, dispersants will not be employed if the petroleum is very viscous or if there is an emulsion of water. The prevention of long-term damage to mangroves, and their survival, will be the principal factor in determining whether or not to use dispersants.

5.2 Operations in Intermediary Waters

Powerful mobile systems to recover oil, should be obtained to manage oil on an independent, erratic course. These would deal with spills before they head towards the Island of Puna and the Gulf's coastal zones, and become an environmental hazard.

5.3 Nearshore Activities

Planning should cover the possibility of a major spill along the coast. Again, barriers must immediately be set up. Mangroves could not be completely protected. Key factors in each circumstance would determine the course of

action. As preventive measures, we would consider setting up a barge with recovery equipment, 200 ft. of barrier, a storage tank, and a pump. It should be capable of speeds of 20 to 30 knots, fully loaded.

5.4 Cleaning up Coastal Damage

The coast has been divided into 3 zones - mangrove swamps, beaches, and cliffs. The mangroves would be protected using containment equipment and absorption techniques during high tide in order to reduce the amount of oil reaching the root systems. In the case of badly contaminated beaches, the polluted sand could be removed mechanically or taken to an area where wave activity would break up the oil naturally. Oil reaching cliff areas should be removed during high tide, and where it has reached the rocks should be cleaned manually.

5.5 Oil Disposal

If recovered oil can be reprocessed, it will be taken to a refinery. If not, it can be burned or buried.

III. Preliminary studies for the development of a handbook for coastal protection and clean-up strategies.

6.1 Introduction

The response in the face of a spill depends fundamentally on the area affected, on prevailing conditions, on resources available in the zone - unknowns which must be reduced as much as possible to permit rapid and

efficient action. For this reason, a study has been undertaken of the coast and its resources in order to evaluate areas vulnerable to damage to the ecology and economy.

6.2 Basic Information

The first phase would be a study of geological, oceanographic and meteorological factors, and an evaluation of the logistics in key areas, such as access roads, land-use, resources, and others.

6.3 Physical factors

- climate (pluviometric data provided)
- tides (over five meters for the Gulf of Guayaquil, where highest tides are in February)

6.4 Geologic Factors

- Mangroves (extensive information)

6.5 Types of coastline in the Province of Guayas (beaches, cliffs, etc.).

This plan also includes:

- emergency questionnaires
- map of Drill-Site I
- Chart of Environmental Advisory Office organization
- Chart of CEPE emergency response organization
- diagrams of on-site action
- 3 charts on the placement of barriers
- graph of precipitation
- map of mangroves (locations)
- map of coast-line
- map of estimated spread of contamination.

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