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The extent of microbial degradation in the sea is dependent upon water temperature and on the absence or dilution of certain volatile fractions in the spill which are bacteriocidal in high concentrations. Nutrient limitation, specifically by nitrates and phosphates, is another major factor in the effectiveness of microbial degradation of petroleum in the marine environment. This was evidently the case following the Mexican Ixtoc I spill, where biodegradation was nearly inoperative in the open ocean. The primary reason appeared to be related to the low concentration of nutrients in the underlying water. This contrasts with other spills, such as the *Amoco Cadiz* tanker incident, where microbial degradation played a significant role, removing 73,000 barrels of oil while still at sea.²⁸

Physical factors limit oil decomposing bacteria from removing more than about one-third of spilled crude oil within 100 days.²⁹ These limitations include (1) the presence of only about 10 hydrocarbon decomposing bacteria in an average liter of seawater prior to a spill, (2) the dwindling availability of oxygen as the spill area grows, and (3) the lack of oil/water boundary action (where microbial degradation occurs) in areas of low wave action. Oil decomposing bacteria multiply after a spill occurs, reaching peak densities of 50 million per liter, but growth is slow at first. Microbial degradation is also temperature dependent; it takes approximately four times longer at 4°C than at 18°C.³⁰

Uptake By Organisms

Petroleum hydrocarbons become available for uptake by marine organisms as dissolved or dispersed materials, absorbed onto particulate material, or as small floating tar balls. Hydrocarbons enter the marine food web by several routes: direct uptake of dissolved or dispersed material, ingestion of the contaminated particulate material, or passage into the gut of fish which gulp or drink water.³¹ A considerable portion of petroleum is absorbed onto particulate matter.

In some cases the biota may be severely affected by the presence of oil, but they are not a major reservoir for spilled oil. However, they may act as temporary storage sites or transfer points. Marine animals are also not major

²⁸ Gundlach, E. R. et. al. *The Fate of Amoco Cadiz Oil*, p. 122.

²⁹ LeBlanc, Leonard A. *Advanced Technology, Why Oil Decomposition Rates Are Hard to Improve*. Offshore, Apr. 1990, p. 17.

³⁰ Ibid.

³¹ IMCO/FAO/UNESCO/WMO/WHO/IAEA/UN Joint Group of Experts on the Scientific Aspects of Marine Pollution, *Impact of Oil on the Marine Environment*, p. 38.

factors in influencing the distribution of spilled oil. After petroleum hydrocarbons are taken up by an organism, they may be excreted unchanged, metabolized, or stored with possible elimination at a future time. Excreted fecal matter containing oil is generally more dense than seawater, hence there is some distribution of petroleum hydrocarbons through the water column and sedimentation from grazing organisms.

An additional concern that has been raised in association with the uptake of petroleum hydrocarbons by marine organisms is that of biological magnification. It has been suggested that petroleum hydrocarbons transfer through marine food webs, becoming more and more concentrated, in a manner similar to that of other persistent chemicals. Some researchers have found that many marine organisms may accumulate petroleum hydrocarbons in their tissues, and that a certain portion may persist throughout the life of an organism. However there is very little evidence, if any, of increased accumulation in the higher predatory members of the food web.³²

On the other hand, another aspect of oil in the marine environment is its "benefit" as a source of food. When oil is biodegraded, primarily by microorganisms, it serves as a source of nourishment at the bottom of the food chain. Other organisms grazing on the oil ingesters are nourished by them, as are further predators along the food chain. Thus, in this respect, oil is no more of a pollutant than any other organic material serving as a source of food. In fact, there are chemosynthetic ecosystems based on petroleum oozing from deepwater seeps in the Alaminos Canyon area on the Texas continental slope east of Galveston.³³ The photosynthesis that these ecosystems with their succession of predators depend on is not today's sunlight, but the photosynthesis that occurred millions of years ago, which helped create the petroleum.

THE SHORT-TERM IMPACT

A major oil spill is a major media event at the time of its occurrence. This section will examine the life cycles of six major oil spills that occurred

³² Connell, D. W. and G. J. Miller. Petroleum Hydrocarbons in Aquatic Ecosystems--Behavior and Effects of Sublethal Concentrations: Part I, CRC Critical Reviews in Environmental Control. Dec. 1980. Reported in Minerals Management Service, Final Environmental Impact Statement, Proposed Apr. 1984 North Atlantic Outer Continental Shelf Lease Offering, p. 286; and National Research Council. Oil in the Sea: Inputs, Fates, and Effects. National Academy Press, Washington, D.C., 1985, p. 6.

³³ Ocean Science News, Apr. 10, 1990, p. 6.

sufficiently long ago for their "long-term"³⁴ effects to have become apparent and for their attention from the media to have long since subsided. The six events are the Santa Barbara and Ixtoc I blowouts and the *Argo Merchant*, *Burmah Agate*, *Alvenus* and *Amoco Cadiz* tanker spills. All of these were major spills, and except for the *Amoco Cadiz*, which foundered off the coast of France, all affected U.S. waters (even though the Ixtoc I blowout occurred in Mexican waters). Each of the events received extensive press and television coverage at the time and are still widely recalled as major environmental catastrophes that caused considerable socioeconomic loss. In fact, the environmental damage and socioeconomic consequences were relatively modest, and, as far as can be determined, of relatively short duration.

The News Media and Damage Perceptions

A number of investigators have probed the influence on the public of media coverage of oil spills and other events. For example, investigators studying the Santa Barbara spill concluded that the frequency and nature of reporting an oil spill could be predicted on the basis of the geographical proximity of the media to the event.³⁵ They also showed that an occurrence receives much coverage close to its date of origin, and subsequent related happenings received comparatively little nonlocal coverage.

Initial reporting often focuses on the more "newsworthy" elements of events, e.g., the threat to the health or environmental values of society. For example, media coverage of medical wastes found on beaches on Long Island and northern New Jersey in July 1988 caused beach scares resulting in more than \$1 billion in lost revenues to other resort areas in which no wastes were found.³⁶ In the case of an oil spill, investigations and follow-up studies of actual effects take time, and results often are not available until a year or more has passed. Press coverage of these results is generally minimal and, to a large extent, confined to the more scientific literature. The *Argo Merchant* incident serves as an example.

³⁴ For the purpose of this report, "long-term" is defined to be several years or on the order of a decade or more.

³⁵ Molotch, H. and M. Lester. Accidental News: The Great Oil Spill as Local Occurrence and National Event. *American Journal of Sociology*, v. 81, no. 2, 1975, p. 235-258.

³⁶ Schmitt, Eric. A Summer to Forget on the Jersey Shore. *New York Times*, Sept. 2, 1988, p. B1, B2.

Argo Merchant

On December 15, 1976, the Liberian-registered tanker *Argo Merchant* grounded on the Nantucket Shoals off Massachusetts. Heavy seas during the subsequent week caused the ship to break up, releasing 183,000 barrels of No. 6 residual fuel oil. Attempts to burn the oil were unsuccessful. The heavy oil formed a large slick, which eventually moved out to sea and dispersed. The estimated costs of response to the accident were \$2.7 million.

In a study of media coverage of the *Argo Merchant* grounding and oil spill, researchers found that public perceptions of local damages presented an interesting and intriguing paradox. There is general agreement among post-spill investigations on the absence of serious economic damages (aside from the ship and cargo) resulting from the *Argo Merchant* incident. Persons in the area economically dependent on tourism, water transportation, and commercial fishing generally reported a good year.³⁷ Fortunately, pollution damage was also small.³⁸ There was little evidence of impact on marine fauna or phytoplankton and it was concluded that the spill had little effect on coastal and marine bird populations off the New England coast.³⁹

At the time, EPA Administrator, Russell E. Train, described the event as "the biggest oil spill disaster on the American coast in our history"⁴⁰ and Governor Michael S. Dukakis asked President Ford to declare southeastern Massachusetts a disaster area to qualify it for Federal relief funds.⁴¹ Television coverage featured the visual image of the grounded tanker and the subsequent oil slick.

As the slick broke up and moved out to sea, television coverage was greatly reduced. While a complete assessment of the environmental damage

³⁷ Rappaport, Allen, L. H. Zincone, Jr., and Peter Fricke. The Media and Oil Spills: Does the Press Influence Damage Perceptions? In Proceedings, 1981 Oil Spill Conference, sponsored by EPA, USCG, and API, American Petroleum Institute publication 4334, 1981, p. 707.

³⁸ Milgram, Jerome. Being Prepared for Future *Argo Merchants*. MIT Sea Grant Program, Report no. MITSG 77-10, Apr. 1977, p. 13; and Oil Spills: Problems and Opportunities. The MIT/Marine Industry Collegium, Opportunity Brief no. 9, July 1977, p. 9; and The Washington Post, Dec. 15, 1977, p. A 8.

³⁹ National Research Council. Oil in the Sea: Inputs, Fates, and Effects. National Academy Press, Washington, D.C., 1985, p. 557-561.

⁴⁰ The New York Times, Dec. 22, 1976, p. 1.

⁴¹ The Washington Post, Dec. 22, 1976, p. A 3.

is impossible to obtain, there seems to be general scientific consensus that classifying the incident as an ecological catastrophe had no factual basis.⁴²

The paradox that researchers found when conducting a survey of area residents approximately one year after the spill occurred was that substantially over half still believed that the *Argo Merchant* spill had caused significant economic or ecological damage.⁴³ An analysis of the press coverage showed that it had shifted from an initial position of little or modest damage to one of catastrophe or major disaster, returning to a position of modest or no damage when the oil moved out to sea. This led to the conclusion that once the press portrays a possibility for, or existence of, substantial damages, the subsequent withdrawal of such claims evidently does not alter the perceptions of extensive damage held by a large part of the population.⁴⁴

Again, it should be pointed out that the scientific literature is not without apparent contradiction. Commonly, one investigation reports findings indicating damage of one sort or another, while another study looking at other variables associated with the same event will report different conclusions. These apparent paradoxes are also illustrated in the following case examples.

Santa Barbara

On the 28th of January 1969 on Platform A in the Santa Barbara Channel about six miles southeast of Santa Barbara, California and in 190 feet of water, an incident occurred. The incident, with its widespread media coverage, did much to alter public attitudes toward offshore oil and gas development.

Four wells had already been drilled from the platform and the fifth well, A-21, was nearing completion. Federal requirements for the well had been altered to approve shorter sets of casing pipe than the minimum previously required. On the morning of January 28, the well had reached 3,479 feet and the crew began to pull the drill pipe to run a log (make down-hole instrument readings). As the crew broke out the eighth stand (segment) of drill pipe, fluids from the well blew out through the drill pipe.

The crew attempted to close the blowout preventer inside the well bore hole, but without success. The pressure was so great that some of the

⁴² See for example, Abelson, P. H. Oil Spills. *Science*, Jan. 14, 1977, p. 137.

⁴³ Rappaport, et al., *The Media and Oil Spills: Does the Press Influence Damage Perceptions?* p. 707-712.

⁴⁴ *Ibid.*, p. 711.

equipment failed and the efforts of the crew were hampered by the slick mud-oil-gas mixture and constant danger of fire. After about 15 minutes, the crew succeeded in closing the well using the blind rams of the blowout preventer. However, this was only the first stage of the blowout.

The closure of the well resulted in a huge buildup of pressure within the overlying strata above the oil formation, but where the well had not been cased. Within 30 minutes after closing the well at the top of the casing, oil and gas began to erupt from the seafloor about 800 feet east of the platform. This eruption eventually spread along a zone from 250 feet west of the platform to more than 1,000 feet east of the platform. Faults in the rock formations penetrated by oil and gas under pressure probably helped serve as a conduit. Efforts to control the spill were only marginally successful and seepage from the seafloor still continues at a rate of around 365 barrels annually (comparable to a number of natural marine seeps in the area.)⁴⁶ The initial spill was variously estimated at 10,000 to 77,000 barrels (the Minerals Management Service uses the higher figure) with subsequent seepage of over 28,000 barrels. Containment and cleanup efforts were extensive at the time and, in some cases, led to controversy regarding their overall benefit and efficacy.

The full impact of this spill on the marine and coastal environment is not possible to determine for a number of reasons including: (1) lack of pre-spill information on organisms and populations to provide a reference frame; (2) unusually high runoff from coastal areas which lowered salinity and increased turbidity, thus, masking the effects of the oil spill; (3) unseasonably low temperature further stressing the ecosystem; and (4) many natural seeps in the area which masked any potential long-term effects that could be attributed to the spill.

Among the more visible impacts were the bird mortalities. The California Department of Fish and Game reported the loss of 3,686 birds due to oiling during the first four months of the spill. This is generally regarded as a minimum figure due to unknown numbers lost at sea. Others placed the estimated bird mortality at between 6,000 and 15,000.

Other detrimental impacts were most evident in the intertidal zone where barnacles and surf grass were damaged by physical smothering. Studies indicated that damage to intertidal life was generally proportional to the amount of oil received. In some areas, the local population of acorn barnacles was destroyed, but recolonization readily occurred. Gooseneck barnacles were damaged to a somewhat lesser degree. Some algae were slightly damaged. Kelp was little harmed. However, mysid shrimp that live among the kelp may

⁴⁶ Natural seepage in the Santa Barbara Channel is estimated at 14,600 to 244,500 barrels annually from more than 2,000 seeps. See U.S. Department of the Interior, Minerals Management Service. Federal Offshore Statistics: 1988. OCS Report MMS 89-0082, p. 96.

have been harmed or caused to vacate their usual habitat during the heavy oiling.⁴⁶ Investigators noted limited damage among anemones, abalones, spiny lobsters, mussels, limpets, periwinkles, and starfish. Burrowing fauna generally escaped severe harm. Fish did not appear greatly harmed by the oil, and spawning occurred normally for most species. No fish kills were observed or reported. The limited number of mortalities of marine mammals which were observed at the time of the spill could not be conclusively attributed to effects of the oil.

Some reports suggested spiny lobster and certain finfish harvests may have been depressed for one to several years following the incident. It is difficult to ascribe a cause/effect relationship between the blowout pollution and this observation.⁴⁷ Natural variations in populations of living organisms are such that an abnormal perturbation, such as might occur in response to spilled oil, can only be detected if it is especially extreme. Some of the observed changes in marine biota populations may be more generally related to natural environmental change or reflect the effects of developmental activities onshore. Bird populations did not appear to incur any long-term changes in either behavior or habitat use and most showed signs of recovery by the summer following the event.⁴⁸

The physical impacts of the oil spill dissipated long ago, but the residual psychological scars remain for the local population, and the entire Nation as well. Environmental policy analysts have credited this spill, a discrete physical event, as a major catalyst that precipitated the "environmental decade" of the 1970s. While this attribution may be excessive, a portion of the public still associates negative aspects of offshore oil development with the Santa Barbara oil spill.

The actual effects of the blowout appear to have been limited in both time and extent. Declines in local tourism, shore use, and property values were painful but transitory. Coastal uses rapidly returned to pre-spill levels after the oil was off the beaches. Tar continues to be found on beaches. Although this is known to be from marine seeps, it is frequently perceived by some to be primarily from offshore petroleum development.

⁴⁶ Dept. of Biological Sciences, University of California. Santa Barbara Oil Spill: Short-term Analysis of Macro-plankton and Fish. Prepared for Office of Water Quality Research, Environmental Protection Agency, Contract no. 14-12-534, Feb. 1971, p. 55.

⁴⁷ Mielke, James E. and Eugene H. Buck. Offshore Oil Spills: Is the Shoe Bigger Than the Foot? Congressional Research Service Review, Apr. 1985, p. 16.

⁴⁸ Easton, Robert. Black Tide: The Santa Barbara Oil Spill and Its Consequences. Delacorte Press, New York, 1972, p. 264.

Campeche Bay/Ixtoc I

On June 3, 1979, the Ixtoc I exploratory well in the Bay of Campeche, Mexico, in 167 feet of water, blew out. The trouble began on June 2 when at a depth of 11,857 feet, the well started to lose drilling mud into the rock formations being penetrated. Loss of drilling mud creates an unstable condition since the weight of the mud balances the underground pressure as a defense against blowouts. Despite this problem, the crew drilled further until circulation was totally lost at 11,890 feet.

Several unsuccessful attempts were made to regain circulation, but as the well appeared stable, the crew decided to seal it by withdrawing the drill pipe and inserting a plug. At 3:30 a.m. the well blew out crude oil and natural gas through the drill pipe and caught fire. The explosion and fire destroyed the platform and damaged the stack of drilling pipe and well casing that extended to the seafloor; thus began the largest marine oil spill in the history of offshore drilling or tanker transportation.

About three weeks after the blowout, an attempt was made to close the blowout preventer valves which were still intact on the seafloor under the ruptured pipe. The valves closed but the extremely high pressure caused oil to leak outside the well casing below the blowout preventer. Several attempts were made, with some success, to decrease the flow of oil by forcing large numbers of lead and steel balls into the well head. Next a funnel-shaped "sombrero" was placed over the well head to collect the oil, but this was not very successful, and was eventually damaged in rough seas and removed from the site. Rough seas also hindered other containment and oil recovery efforts.

The measure that finally capped the well on March 23, 1980, was the pumping of mud into two adjacent wells that were drilled directionally into the producing formation to link into the Ixtoc I well. These wells had been started in mid-June and July. After the mud caused the flow of oil and gas to cease, the Ixtoc I well was sealed with several cement plugs. During the 290 days that the spill continued, approximately 3,500,000 barrels of oil entered the Gulf of Mexico.⁴⁹

Dispersants were selectively applied by aircraft to oil masses that threatened Mexican resources. Of special concern was the area extending 20 to 25 miles from shore along 1,000 miles of Mexican coast in major shrimping locations.⁵⁰ The use of dispersants kept oil from coming ashore on Mexican

⁴⁹ Jarnelov, Arne, and Olof Linden. *Ixtoc I: A Case Study of the World's Largest Oil Spill*. *Ambio*, v. 10, no. 6, 1981, p. 299-306.

⁵⁰ Lindblom, Gordon P., Bruce D. Emery, and Ing. Miguel A. Garcia Lara. *Aerial Application of Dispersants at the Ixtoc I Spill*. In *Proceedings, 1981 Oil Spill Conference*, sponsored by EPA, USCG, and API, American Petroleum Institute publication 4334, 1981, p. 259-262.

beaches until hurricane Henri arrived in late September and grounded the aircraft. At that time, oil stranded on the Yucatan shoreline, but lagoons were protected from oiling by the rapid outflow of fresh water from heavy rains. Field investigations indicated that the chemicals effectively dispersed the oil from the surface into the upper 10 feet of the water column by which it rapidly became diluted to low concentrations below acute toxicity thresholds. Limited biological studies during and following the spill did not reveal adverse effects.⁶¹ Shrimp landings in subsequent years were unchanged or greater than previous yearly catches.

Impacts on U.S. resources were limited by the distance oil traveled from the site of the Mexican blowout. An estimated 30,000 to 70,000 barrels of the calculated 3.5 million barrels spilled reached Texas beaches.⁶² Loss of the more volatile and soluble components through extensive weathering of the oil during travel time to Texas waters decreased the potential for detrimental impacts since these components are generally more toxic. Impacts on Mexican resources are incompletely known due to limited study and availability of results from such investigations as were conducted.

Reports indicate that few shrimp in Mexican and U.S. waters were tainted by settling oil debris. Along Padre Island, Texas, the percentage of total birds with any signs of oil on their feet or plumage never exceeded 10 percent; 82 birds were found with up to 75 percent of their bodies covered with oil and judged unlikely to survive.⁶³ Studies found decreasing populations of benthic fauna following the incident, but these circumstances could not be conclusively linked to the Ixtoc accident since minimal deposits of hydrocarbons were found in associated sediments.⁶⁴ No reports of long-term impacts on resources in U.S. or Mexican waters have been identified.

Most of the impact to the Texas beaches occurred between August and mid-September 1979. During this time business in the recreational and tourist

⁶¹ National Research Council. *Using Oil Spill Dispersants on the Sea*. National Academy Press, Washington, D.C., 1989, p. 320.

⁶² Bedinger, C. A., Jr., and C. P. Nulton. *Analysis of Environmental and Tar Samples from the Nearshore South Texas Area after Oiling from the Ixtoc I Blowout*. *Bulletin of Environmental Contamination and Toxicology*, v. 28, no. 2, Feb. 1982, p. 166.

⁶³ Chapman, Brian R. *Effects of the Ixtoc I Oil Spill on Texas Shorebird Populations*. In *Proceedings, 1981 Oil Spill Conference*, sponsored by EPA, USCG, and API, American Petroleum Institute publication 4334, 1981, p. 461-465.

⁶⁴ Boehm, Paul. *Ixtoc Oil Spill Assessment: Executive Summary*. Energy Resources Co., Inc., Cambridge, Mass., Apr. 1982, p. 22-24. NTIS PB82-197773.

industries in the South Padre Island area dropped significantly.⁶⁶ Dispersants were not used by the United States. By the end of 1980, the only known remnants of oil from Ixtoc I were scattered patches of tar mats along the Texas barrier island beaches.⁶⁶ Because of the numerous natural seeps in the area similar patches appear every year, but they were more numerous and extensive in 1980, and analysis showed that some originated at Ixtoc.

Cleanup costs on the Texas beaches exceeded \$4 million. The estimated total cost of capping the well and containing the environmental damage, including lost oil revenues, amounted to \$219 million.

Burmah Agate

On November 1, 1979, a collision of the Liberian-registered tanker, *Burmah Agate*, and the Liberian-registered freighter, *Mimosa*, produced the largest oil spill in U.S. waters up to that time. The accident occurred off the coast of Texas about five miles southeast of the Galveston Entrance Channel. The *Burmah Agate* was loaded with 397,800 barrels of Nigerian crude oil. The collision ruptured the starboard midship tanks resulting in a fire and explosions that left 33 dead. The ship settled on the bottom in 44 feet of water with its deck awash. Eventually, 24 of the 36 tanks were ruptured, releasing about 250,000 barrels of oil, much of which was consumed in the fire that continued to burn out of control for over two months. Over 150,000 barrels of oil were eventually salvaged from the forward tanks before the ship was refloated and towed to Brownsville, Texas for scrap. Another 6,700 barrels of oil/water emulsion were recovered from the water. Because of the predominance of offshore winds during the first month of the spill, most of the oil not consumed by the fire was dispersed offshore. Of the approximately 62,000 barrels of oil that were released and not burned, 2,100 eventually reached shore.

Beach impacts directly attributable to the spill occurred as far as 290 miles from the wreck. Prevailing winds and currents moved the oil toward the southwest. The first oil came ashore 155 miles southwest of the wreck. The heaviest oiling occurred between November 19 and 21 when up to 1,500 barrels beached along the western half of Galveston Island. Cleanup was initially by manual labor and front-end loaders. Eventually, the primary

⁶⁶ U.S. Congress. House. Committee on Merchant Marine and Fisheries and Committee on Public Works and Transportation, Subcommittee on Water Resources. Blowout of the Mexican Oil Well Ixtoc I. Hearings, 96th Cong., 1st Sess., Corpus Christi, Texas, Sept. 8 and 9, 1979, p. 108-118.

⁶⁶ Gundlach, E. R., K. J. Finkelstein, and J. L. Sadd. Impact and Persistence of Ixtoc I Oil on the South Texas Coast. In Proceedings, 1981 Oil Spill Conference, sponsored by EPA, USCG, and API, American Petroleum Institute publication 4334, 1981, p. 477-485.

method of beach cleanup involved pooling the oil by hand and picking it up with vacuum trucks. The latter method considerably reduced the amount of sand removed from the beach. By the end of the spill, a total of 1,500 cubic meters of oiled sand and 1,930 barrels of oil, water, and sand mixture were recovered from the beaches. Coastal processes aided the rapid recovery of Galveston beaches.⁶⁷

The only known marsh impact occurred when approximately 5 barrels of oil coated about 1300 feet of marsh fringing Smith Point in Galveston Bay. Because of the relatively small area affected, no cleanup was attempted. It was thought that any human disturbance to the marsh area might be more detrimental than the relatively limited amount of oil. Over \$850,000 was spent on onshore cleanup efforts. Offshore impacts were not reported.

Alvenus

On July 30, 1984, the British-registered tanker, *Alvenus*, grounded in the Calcasieu River Channel entrance about 11 miles south-southwest of Cameron, Louisiana. The vessel's hull buckled and fractured vertically on both sides and across the cargo tank tops discharging approximately 65,500 barrels of Venezuelan crude oil over a 6-day period. The grounding was later attributed to a combination of vessel squat and isolated channel shoaling. Attempts to contain and recover the oil at sea were ineffective because of rough seas and lack of adequate equipment for the magnitude of the spill.

Precautions were taken to prevent the outbreak of fire by continuously pumping inert gas into the ruptured cargo tanks. Decks were also covered with foam, and electrical power in the damaged area was shut off. Oil continued to flow from both sides of the ship. A major concern was the numerous aircraft employed by the news media, which at times flew within 50 feet of the stricken vessel, prompting the Coast Guard to request the Federal Aviation Administration to impose a restricted airspace over the vessel.⁶⁸ Approximately 284,000 barrels of crude oil remained onboard the *Alvenus* and were salvaged.

The spilled oil formed a 75-mile-long slick that traveled west from the wreck for over 100 miles, arriving on Texas beaches on August 3 and 4 along

⁶⁷ Thebeau, Larry C. and Timothy W. Kana. Onshore Impacts and Cleanup During the *Burmah Agate* Oil Spill--November 1979. In Proceedings, 1981 Oil Spill Conference, sponsored by EPA, USCG, and API, American Petroleum Institute publication 4334, 1981, p. 144.

⁶⁸ Alejandro, Anthony C. and Jack L. Buri. *M/V Alvenus: Anatomy of a Major Oil Spill*. In Proceedings, 1987 Oil Spill Conference, sponsored by EPA, USCG, and API, American Petroleum Institute publication 4452, 1987, p. 27.

the west end of Galveston Island. Cleanup crews encountered a major problem when a large portion of the slick approached the shoreline, absorbed suspended solid particles, and sank in the nearshore surf zones. The oil became trapped between sand bars not more than 100 feet from shore, in water too deep for heavy land-based equipment and too shallow for floating recovery equipment. Cleanup crews had to wait until the oil beached, a process that took several weeks. The continued re-oiling of the beach required repeated recleaning of the beach area.

An effort was made to minimize the amount of sand removed from the beaches. Sand contaminated with an oil concentration greater than 10 percent (heavily oiled) was classified as waste and removed from the entire beach area. Moderately contaminated sand was relocated and spread in the back beach area adjacent to existing sand dunes. Lightly oiled sand was spread in the non-tidal, mid beach area. Analyses of the oil-contaminated sand indicated that the weathered oil contained no toxic components and that water-soluble fractions were no longer present, thus minimizing further leaching. There was no evidence of leaching from the oiled sand that was spread on the beaches above the tidal zone.

During the beach cleanup, conflict arose over who owned the contaminated beach sand. The State wanted the sand removed from the beach front while the land owners wanted it either left where it was or moved to the dune line seaward of the vegetation line. The amount of sand eventually removed from the beaches was roughly equivalent to the amount that would be removed by a small winter storm.

The Federal Scientific Support Group debated the merits of mechanical cleaning, which might kill organisms that survived smothering, versus letting the oil remain. From the onset of the spill, there were extensive discussions regarding the feasibility of dispersing the viscous Venezuela crude oil and the potential environmental damage, but dispersants were not used. It was concluded that available dispersants would not have significantly reduced the surface area of the spill, altered the location of the shoreline impact, or reduced the net damage to natural resources. Despite mechanical cleanup, the economic damage was great since the Galveston's resort beaches were heavily oiled during the height of the tourist season.

Booms prevented any significant quantity of oil from entering the inland hatchery environments of East Bay, Galveston Bay or West Bay. No significant lasting environmental damage was documented as a result of the *Alvenus* oil spill.⁶⁰ The oil was known to have a smothering effect on some marine organisms in the area; however, the Scientific Support Group determined that the affected organisms were a minor loss to the local ecosystem which soon recovered. Other than algae growing on rocks, most of the organisms in the area are transient and able to move to a more suitable

⁶⁰ Ibid., p. 31.

habitat. Several dead crabs, fish, and rays were found but these mortalities could not be directly attributed to the oil spill. The crabs, for example, were mostly female and may have expired normally after spawning.⁶⁰ Throughout the beach-cleaning period, fishing and shrimping activities continued offshore.

By mid-November, algae were again growing on rocks and groins and even growing over some oil that remained. Also, indigenous grasses were growing through the oiled sand in back beach areas.

Amoco Cadiz

On March 16, 1978, the Liberian-registered tanker, *Amoco Cadiz* grounded and broke up off the coast of Brittany, France and, over the next 15 days, spilled her entire cargo of 1,635,000 barrels of light Arabian crude oil. At the time of its occurrence, this was the largest oil spill the marine environment had experienced (and is over 6 times the size of the *Exxon Valdez* spill). The tanker suffered steering failure 8 miles north of the Ile d'Ouessant in the English Channel, and grounded on rocks at high tide within sight of shore. As the tide ebbed, the ship broke in two.

Approximately 90 percent of the cargo was lost in the first 11 days, during which time the winds averaged between 20 and 30 knots. The strong winds precluded most efforts at removing oil from the sea and soon drove the oil ashore along 250 miles of the French coast. The oil came ashore over a 4-week period, resulting in an almost continual oiling of the coastline. Less than 146,000 barrels were eventually recovered, most from beach and shoreline areas. A considerable portion of the oil that came ashore, and was not removed manually in the massive cleanup effort, eventually became buried in the sediments or entrapped in the low-energy salt marshes and estuaries. Efforts were made to remove oiled vegetation and sediments in some marsh areas with the expectation that recovery would be more rapid on clean subsurface sediments.

Attempts to combat the oil at sea included the use of about 3,000 tons of dispersant and some chalk, used as a sinking agent. Dispersant use was permitted only in water depths greater than 50 meters (164 feet) and only where no major marine resource would be endangered. Dispersants appeared to be used effectively in some instances and ineffectively in others. Effective use was limited by the broad aerial distribution of oil along the coast, the patchiness of the oil in windrows, and limited favorable weather conditions. The use of chalk as a sinking agent did not appear to be very effective and

⁶⁰ Ibid., p. 32.

was objectionable on environmental grounds because of the smothering effect on bottom-dwelling organisms.⁶¹

While at sea, the oil underwent extensive evaporation and biodegradation so that the petroleum that stranded had changed in character from the original cargo. All of the oil that came ashore was in the form of some type of oil-water emulsion or "mousse," with the oil content ranging from 8 percent to 48 percent.

Of the 455,000 barrels of oil estimated to be on the shore at the end of March 1978, 67,500 barrels were estimated to be remaining one month later. The reduction was due to cleanup activities and the extensive biodegradation of the stranded oil. The affected shoreline areas included rocky coasts, recreational beaches, tidal estuaries, and coastal marshes. Figure 3 is a quantitative estimate of the disposition of the oil during the first month of the spill.

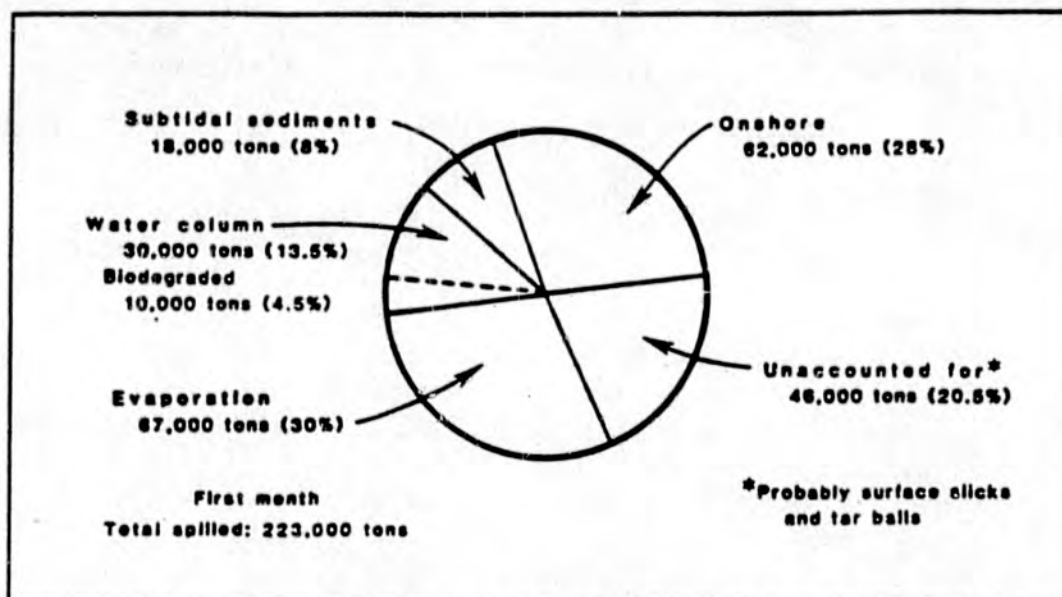


Figure 3. Distribution of *Amoco Cadiz* oil during the first month of the spill. Source: *Science*, July 8, 1983.

Since much of the coastline in the affected area is a resort area known for its beautiful pink granite, the cleaning of rocks, retaining walls, ramps, and boulders was considered of high priority for safety, aesthetic, and economic reasons. Most of this effort was accomplished through flushing with water and water-detergent mixtures under high pressure. Both hot and cold

⁶¹ Hann, Roy W., Jr. Unit Operations, Unit Processes and Level of Resource Requirements for the Cleanup of the Oil Spill From the Supertanker *Amoco Cadiz*. In Proceedings, 1979 Oil Spill Conference, sponsored by EPA, USCG, and API, American Petroleum Institute publication 4308, 1979, p. 154.

water were used, and, upon completion, the rock walls, ramps, and boulders appeared relatively clean. Sand blasting was tested, but was not recommended because of the high cost. The cleanup effort lasted several months, although some restoration activities extended into 1979 and beyond.

Because of its magnitude and impact on a range of coastal areas, including marshes in particular, the spill has been the subject of extensive ecological investigations. An initial three-year study of the effects of the spill was sponsored by Amoco Transport Company and conducted under the joint efforts of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) and the French Centre National Pour l'Exploitation Des Océans (CNEXO).⁶² These studies were subsequently followed by several others. Figure 4 is a synthesis of data indicating the relative persistence of *Amoco Cadiz* oil in various environments over the first three years. Fate and effects studies were severely complicated, however, when on March 7, 1980 the tanker *Tanio* broke up 40 miles off the Brittany coast releasing over 50,000 barrels of oil into many of the same areas affected by the *Amoco Cadiz* spill.

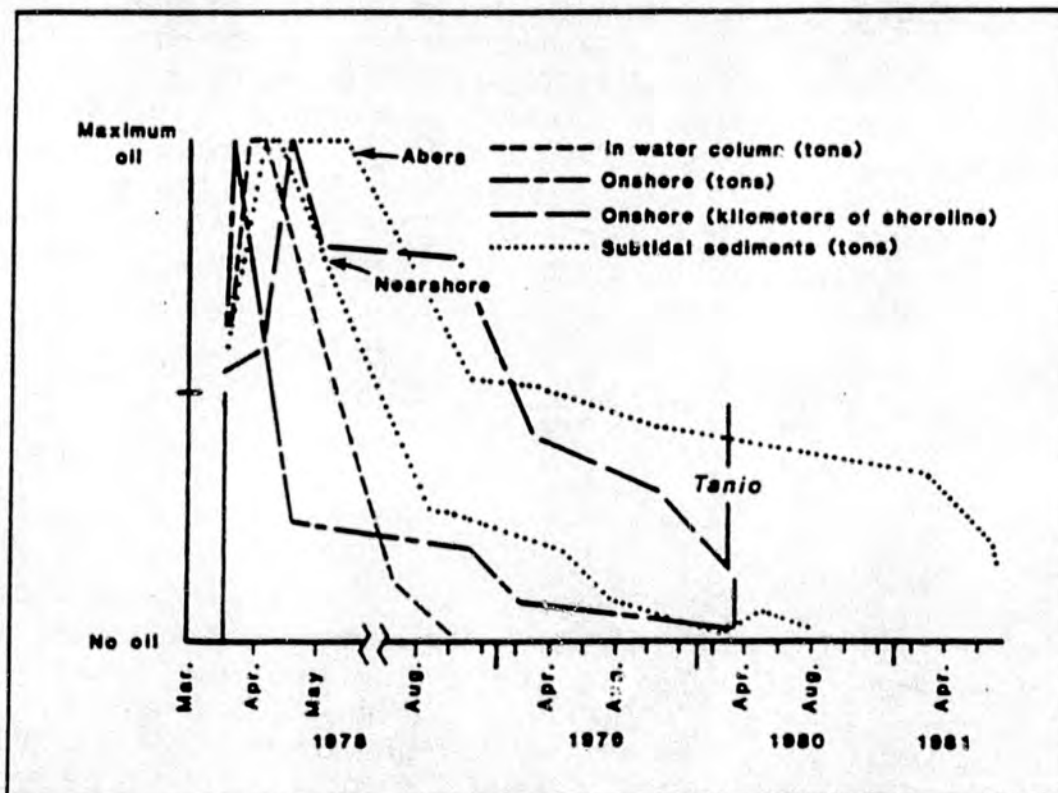


Figure 4. Relative persistence of *Amoco Cadiz* oil in various components, March 1978 through June 1981.

Source: *Science*, July 8, 1983.

⁶² Ecological Study of the *Amoco Cadiz* Oil Spill. Report of the NOAA-CNEXO Joint Scientific Commission, Oct. 1982, 419 p.

The *Amoco Cadiz* spill affected the most exposed sites, such as rocky shores, the least. A variety of intertidal rocky shore animals were killed, but in general, rocky shores suffered little damage except where they were damaged from cleanup operations.⁶³ Sandy shores retained oil as buried layers for several years, but dead animals were found only immediately after the spill. Exposed intertidal mudflats had almost their entire fauna killed by oil from the water column until recolonization could occur. Decreases in biomass of phytoplankton were observed for several weeks in the immediate vicinity of the wreck and in the highly contaminated tidal rivers. In contrast, further from the wreck phytoplankton production was elevated, perhaps stimulated by either low levels of petroleum hydrocarbons or nutrient release from dead organisms.⁶⁴ Over 4,500 oiled birds were recovered dead, presumably from physical effects of the oil. A disastrous effect on the bird population had been feared, but it did not materialize, suggesting that the survival potential of seabirds, at least for the eastern North Atlantic populations, is quite good.⁶⁵ There was some mortality of fish in the vicinity of the wreck and some bottom-dwelling species showed evidence of fin rot with the percentage of individuals affected diminishing from 80 percent after 9 months to 10 percent after 20 months. However, it was also found by comparison to control areas, that the area oiled by the *Amoco Cadiz* spill was clearly not pristine before the spill.⁶⁶ For example, investigators found that 21 months after the oil spill, hydrocarbons (not all derived from the spill) were only one of three factors (the others were silver and mercury) associated with adverse effects on oyster populations in the area.⁶⁷ Although hydrocarbons from the spill were still found in oysters up to 27 months after the spill, there was little evidence of histopathological and biochemical damage.⁶⁸ At the same time, evidence of

⁶³ National Research Council, *Oil in the Sea: Inputs, Fates, and Effects*, p. 561-566.

⁶⁴ *Ibid.*, p. 564.

⁶⁵ *Ibid.*, p. 574.

⁶⁶ Gilfillan, Edward S., David S. Page, Barbara Griffin, Sherry A. Hanson, and Judith C. Foster. *The Importance of Using Appropriate Experimental Designs in Oil Spill Impact Studies: An Example From the Amoco Cadiz Oil Spill Impact Zone*. In *Proceedings, 1987 Oil Spill Conference*, sponsored by EPA, USCG, and API, American Petroleum Institute publication 4452, 1987, p. 503.

⁶⁷ *Ibid.*, p. 507.

⁶⁸ Neff, J. M. and W. E. Haensly. *Long-term Impact of Amoco Cadiz crude oil on oysters *Crassostrea gigas* and plaice *Pleuronectes platessa* from Aber Benoit and Aber Wrac'h, Brittany, France*. In *Ecological Study of the Amoco Cadiz Oil Spill*. Report of the NOAA-CNEXO Joint Scientific Commission, October 1982, p. 269-327.

damage continued to be found in plaice (bottom-dwelling fish) in areas heavily affected by the spill, although substantial improvement was noted during that period.

Two years after the spill it was reported that there was no recovery at the most heavily oiled marsh areas. This led to predictions that several decades may be required for a return to prespill conditions by natural processes.⁶⁹ Others who studied the spill in the first 2 years suggested that if the oiled marshes were left untouched, spontaneous recovery may require centuries and recommended mass planting of marsh vegetation.⁷⁰ However, on the basis of further studies, it now appears that marshes that were oiled but had no cleanup were essentially restored by natural processes within 5 years, whereas in cleaned marsh areas, restoration took 7 to 8 years.⁷¹ Marshes that had been subjected to extensive cleanup efforts experienced increased erosion of fine sediments and despite extensive artificial plantings, their restoration was delayed by 2 to 3 years. In Aber Benoit, an estuary heavily affected by the spill, the only measurable residues of weathered petroleum remaining after 8 years were found in isolated soft sediment locations that served as repositories for fine sediment from other parts of the estuary.⁷²

In the months following the spill, journalists and individuals associated with affected localities and industries made numerous assertions about the extent of lost earnings in the fishing and tourist industries, and the extent of cleanup and restoration costs, property damage, and other effects. "Brittany will look like a desert" was one oft-repeated phrase. The magnitudes of the short-run and long-run physical, biological, and monetary damages as a result

⁶⁹ National Research Council, *Oil in the Sea: Inputs, Fates, and Effects*, p. 566.

⁷⁰ Vandermeulen, J. H., B. F. N. Long, and L. D'Ozouville. *Geomorphological Alteration of a Heavily Oiled Saltmarsh (Ile Grande, France) as a Result of Massive Cleanup*. In *Proceedings, 1981 Oil Spill Conference*, sponsored by EPA, USCG, and API, American Petroleum Institute publication 4334, 1981, p. 350.

⁷¹ Baca, Bart J., Thomas E. Lankford, and Erich R. Gundlach. *Recovery of Brittany Coastal Marshes in the Eight Years Following the Amoco Cadiz Incident*. In *Proceedings, 1987 Oil Spill Conference*, sponsored by EPA, USCG, and API, American Petroleum Institute publication 4452, 1987, p. 459-464.

⁷² Page, David S., Judith C. Foster, Paulette M. Fickett, and Edward S. Gilfillan. *Long-term Weathering of Amoco Cadiz Oil in Soft Intertidal Sediments*. In *Proceedings, 1989 Oil Spill Conference*, sponsored by EPA, USCG, and API, American Petroleum Institute publication 4479, 1989, p. 401-405.

of the spill became questions of national and international focus and interest. Thus, the social costs of this oil spill were also well studied. The total economic costs to the world were estimated to range from about \$190 million to \$290 million (1978 dollars).⁷³ The largest components of the total cost were cleanup expenditures, losses to the oyster-culturing industry, and the loss of the tanker and cargo. The loss of recreational values were estimated to range from about \$1.5 million to over \$80 million depending on the unit values of losses assumed. The French Government and others originally sought \$2 billion in damages, but Amoco's liability was considerably reduced because the judge found relatively little long-term ecological damage and recommended an award of \$115.2 million.⁷⁴

CONCLUSIONS

Since the first well was drilled over 130 years ago, petroleum has become society's major energy source. Petroleum and petroleum products have played a significant role in the progress of civilization. Materials made from petroleum are virtually everywhere. Petroleum production has been among the least damaging to the environment of any of the extractive earth resources industries. Yet no technology is without environmental cost and none is fail-safe.

An oil spill can be a devastating occurrence. However, past spills have not been long-lived events. For the most part, the longest residence time that spilled oil appears to have had in the marine and coastal environment was generally less than a decade--often much less. The major ecological impact has come at the time of the spill or within the first few months. Beyond a few months, most oil has been reduced to tarry residues or was chemically detectable in sediments and resident organisms, which may be of scientific interest, but in terms of further ecological impact, has proved to be fairly insignificant overall. Public impressions of socioeconomic and environmental damage that occurred and concerns over further ecological impacts have lasted much longer. The life span of the media coverage has been shorter than the major ecological impact of the spill, but probably of greater significance. With the possible exception of special environments, predictions of long-term effects have been largely unsubstantiated. Based on the evidence available, there has been no evident irrevocable damage to marine resources on a broad scale to justify serious allegations of unknown, but significant, long-term effects.

The short-term impact of a major spill can be devastating to the organisms in the immediate vicinity, including shellfish, finfish, marine

⁷³ U.S. Department of Commerce, National Oceanic and Atmospheric Administration. *Assessing the Social Costs of Oil Spills: The Amoco Cadiz Case Study*. July 1983, 144 p.

⁷⁴ Wall Street Journal, Mar. 28, 1989, p. A13.

mammals and waterfowl. Experience, thus far, however, would indicate that this has not made a noticeable impact on world population levels of any species. For species of shellfish, finfish, and waterfowl that are harvested, the mortality from an oil spill, so far as is known, has never come close to approaching the magnitude of the annual harvests.⁷⁶ Recolonization of an area temporarily polluted from oil appears to be rapid for most species.

A major short-term impact of a major spill is the visual impact created by an oiled shoreline and featured by the media coverage of the event. The media coverage typically includes heartrending scenes of oiled or dead birds and sea life, and oiled beaches. The portrayal is generally one of a major catastrophe.⁷⁶ While not minimizing the effect of an oil spill, it appears that the environmental damage has been less than one would surmise from immediate visual appearances or media coverage.

Nearly one year after the grounding of the *Exxon Valdez* the city of Valdez issued a press release appealing to the world's press "to avoid repeating errors and myths" in covering the spill anniversary. The press release noted that the loss of wildlife was a small fraction of existing populations in the sound and that most of the affected shoreline is remote and outside the area likely to be seen by seaborne tourists. On the other hand, the Alaska Coalition, an environmental group, marked the anniversary by calling on Congress to establish a memorial for the wildlife lost in the accident by declaring the entire Arctic National Wildlife Refuge a wilderness area.

Based on the record of past spill events, it would also appear that beyond a moderate human effort to clean up an oil spill, nature does a much better job than humans. In fact, in some instances, it would appear that massive physical cleanup efforts delayed the natural ecological restoration of the affected area although the appearance, particularly of rock and beach areas, may be improved sooner. This might raise the question of whether the cost to society of massive physical cleanup efforts is equal to the social and environmental benefit. In the case of the *Exxon Valdez* spill, the cost of cleanup to date has exceeded \$2 billion (far more than has been expended on any previous spill), where most of the affected shoreline is "remote and outside the area likely to be seen by seaborne tourists." The unfortunate spill in Prince William Sound will, however, offer an opportunity to study the effects of a large oil spill in a subarctic environment. Whether the effects of the *Exxon Valdez* spill will match the experiences of spills in more temperate environments remains to be seen.

⁷⁶ For example, about 300,000 waterfowl are taken each year during hunting season on Maryland's "eastern shore" alone.

⁷⁶ Yen, Marianne. Judge Sets \$500,000 Bail for Disaster Unequaled 'Since Hiroshima'. Washington Post, Apr. 6, 1989, p. A1, A11.

Oil spills are not new events and many have been studied. Obviously, all of the possible physical oceanographic, socioeconomic, and environmental effects of an oil spill are not known, and further scientific study will be of value. On the other hand, from a public policy perspective, the major socioeconomic and environmental impacts of an oil spill are reasonably well known, and, on the basis of that knowledge, the major effects of a future spill should be fairly predictable.

Public policy decisions have to balance the overall needs and benefits to society of a particular action versus its costs and risk. For example, public policy decisions, such as whether to permit offshore drilling in a particular area, are properly based in part on a scientific assessment of the probability of spills from offshore production versus imported oil and the severity of the consequences. The experience of the past 50 years and the careful research of marine scientists now provide the basis for realistic estimates.

EPILOGUE

The oceans are ancient and throughout the course of time many sea-dwelling species have flourished and faded while new species have evolved. Now, for the first time, there is broad human concern for the well-being of the seas because, as no other creature before, human beings have the ability to alter a wide range of marine ecosystems dangerously and quickly. In the pursuit of food and living resources, humans have even threatened the survival and caused the extinction of many species. Fortunately, however, the oceanic environment is not fragile;⁷⁷ in fact, it is extraordinarily resilient. It has evolved through ice ages, global warming, bombardments of cosmic radiation, fluctuations of the sun, massive volcanic eruptions, and collisions of comets and meteors. Mass extinctions of species were associated with some of these events, but life forms continued to adapt, evolve, become more complex, and flourish.

Many physical and biological processes in the marine and coastal environment are only poorly understood. For these reasons, it is particularly difficult for scientists to measure the full impact of an oil spill and sometimes the results appear contradictory. To date, pollution from offshore petroleum activities has not appeared to be a significant threat to the survival of the various species. Nor is it, if compared to other activities and possible pollutants, likely to be ranked as a leading threat in this regard. Despite short-term media attention to the catastrophic nature of major spill events, the chemicals contained in petroleum have long been part of the marine environment and physical impacts are likely to be temporary in the dynamic natural flux of the coastal environment.

⁷⁷ Fragile and environment are commonly linked together in media accounts of spill events.

MARINE OPERATIONS AND LOGISTICS DURING THE EXXON VALDEZ SPILL CLEANUP

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ABSTRACT: The Exxon Valdez oil spill required unprecedented marine operations and logistics support for cleanup. At the peak of operations, more than 11,000 people, 1,400 vessels and 85 aircraft were required.

Due to the remoteness of the spill location and the absence of land access, virtually all cleanup was conducted from vessels. Three types of vessels were used: landing craft and barges for oil recovery and shoreline treatment; berthing vessels for housing offshore workers; and support vessels for transporting personnel and materials.

Major logistic challenges in the oil spill response included providing offshore housing; replenishing food, water, and fuel for the offshore operations; establishing a large aircraft operation; installing a telecommunications network that was essentially built from scratch; providing onshore support; handling and disposing of more than 25,000 tons of oily solid waste and several hundred thousand barrels of oily liquid waste; and safely demobilizing the effort.

The March 24, 1989 grounding of the tank vessel *Exxon Valdez* on Bligh Reef resulted in an oil spill of approximately 258,000 barrels that began in Prince William Sound and later impacted portions of the southern Alaska shorelines in the Gulf of Alaska, as shown in Figure 1. The resulting cleanup operations were spread over an area more than 500 miles long, although less than 15 percent of the shoreline in this area was impacted by the oil spill. The areas impacted were remote in that virtually all of them required access by water or air, few could be served by existing communications, little housing was available, and the entire operation was distant from most sources of cleanup equipment and materials.

The remoteness combined with the magnitude of the task and limited weather window in which to conduct the work resulted in very high marine operations and logistics requirements. At the peak of operations, more than 11,000 personnel, 1,400 vessels, and 85 aircraft were working on the cleanup. Figure 2 shows the personnel buildup and illustrates the high support requirements of the operations. Of the more than 11,000 total personnel, about 3,400 worked on shoreline treatment and the remaining were onshore and offshore. Figure 3 shows the buildup of vessels. In order to utilize all available vessels in the response and to quickly mobilize and construct specialized vessels, it was necessary to obtain a number of waivers from normal Coast Guard requirements.

Overall operations were coordinated out of the Valdez Command Center and were geographically divided into Prince William Sound (PWS) and Gulf of Alaska (GOA) areas. PWS operations were also

coordinated from Valdez while GOA operations were coordinated out of satellite command centers in Seward, Homer, and Kodiak (Figure 1).

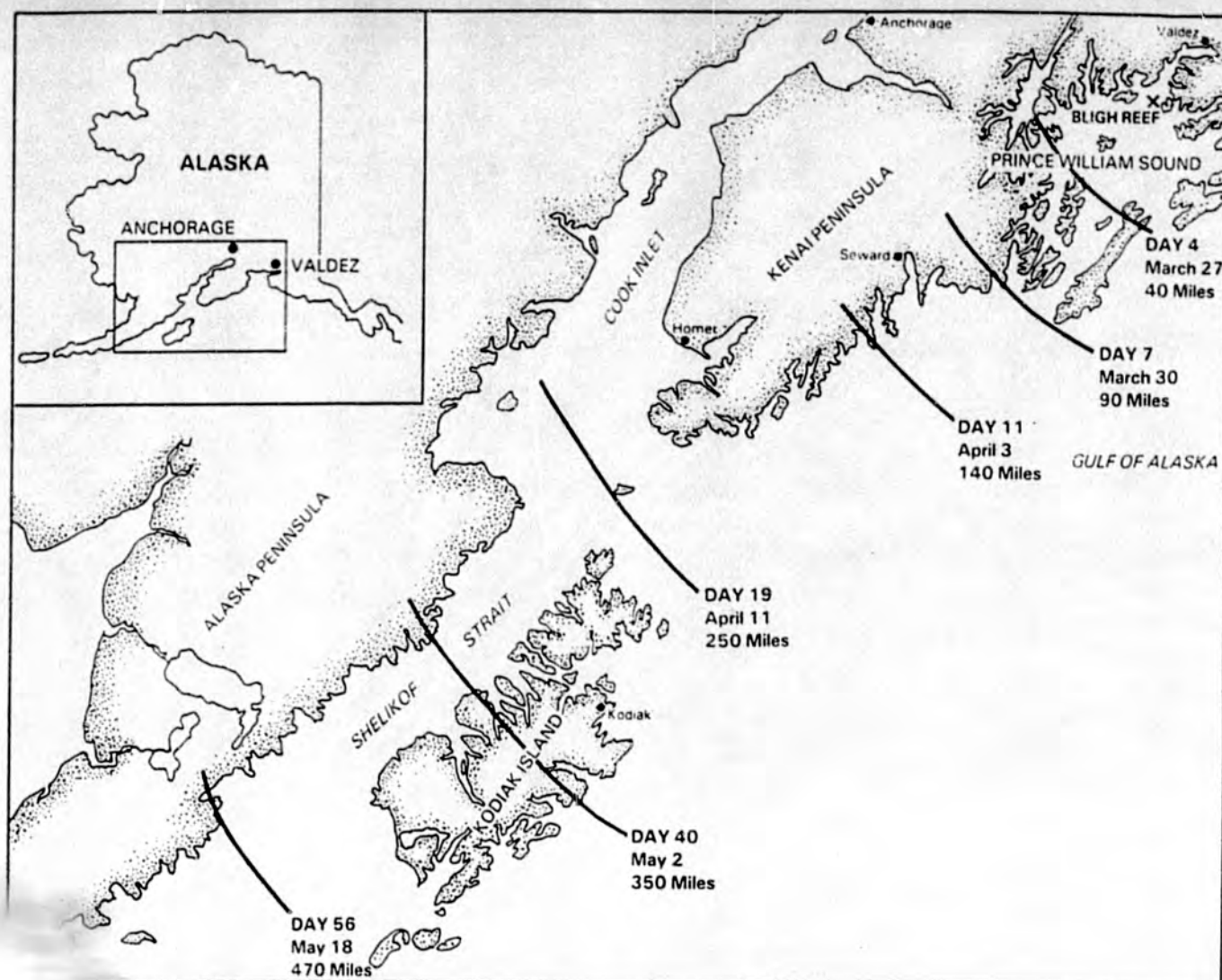
From the onset, safety was a major priority. The first formal safety training was performed on day nine of the cleanup effort. The cleanup methods changed throughout the effort and the safety programs changed in concert. In spite of the massive personnel buildup and inherently difficult working conditions, the safety program showed continual improvement and the total number of lost time incidents averaged 34 percent less than heavy construction over the same period (Figure 4).

This paper describes the approach to the cleanup of the remoteness factors so that the necessary personnel and equipment could be mobilized and supported to effect the cleanup of the 1989 oil spill response. Since the spill occurred in the areas of largest impacts occurred there and the concentration of personnel and equipment was high, the cleanup of the 7,000 total offshore workers were in the PWS area. The cleanup was generally similar to PWS but on a lesser scale. The cleanup of the 1989-90 Winter Operations and 1990 activities are not included in this report.

PWS marine operations and logistics

Six large task forces were assembled for Prince William Sound operations, with each composed of about 400 to 700 people and 70 to 100 vessels. As shown in Figure 5, approximately one-half were direct cleanup personnel, either oil spill response technicians (OSRTs) or treatment vessel crews, and the remaining were support personnel. Common logistics vessels, animal rescue operations and other support also required more than 1,000 offshore people. The vessels in a typical task force included barges, landing craft, skimmers, cruisers, skiffs, and numerous fishing boats such as bowpickers, seiners, and tenders. Their functions are shown in Table 1. Task Force 2's support complex, consisting of a berthing barge, supply barge, shower/wash barge, and associated operations and support vessels is shown in Figure 6. In addition to the task forces, a number of vessels and personnel provided common support to all task forces and smaller units.

Berthing vessels. All of the shoreline cleanup and offshore support personnel had to be housed on the water. To meet the large requirements, several different types of vessels were used. At first, fishing boats and other readily available marine craft were used. These small vessels continued to be used for smaller teams after larger units were available.

Figure 1. Chronology of oil movement from the *Exxon Valdez*

excursion boats and fish processing ships were the fastest way to obtain larger numbers of berths, but they were still a limited source. Navy transport ships quickly provided a larger number of berths but the quarters were cramped for extended operations. The majority of the long-term berths were provided by camps on eleven conventional

deck barges. The camp housing was installed on the barges in shipyards, where plumbing and electrical work was also done. Because berthing barges were considered facilities and not vessels, they were subject to largely the same food service, fresh water and wastewater permitting requirements as permanent onshore commercial facilities.

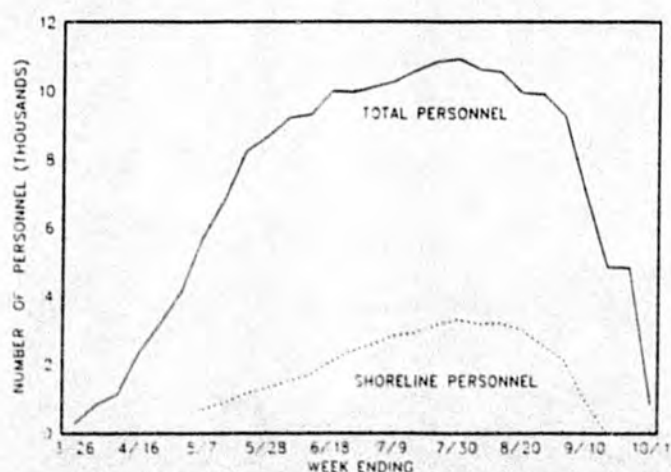


Figure 2. Number of shoreline and total personnel for oil spill response

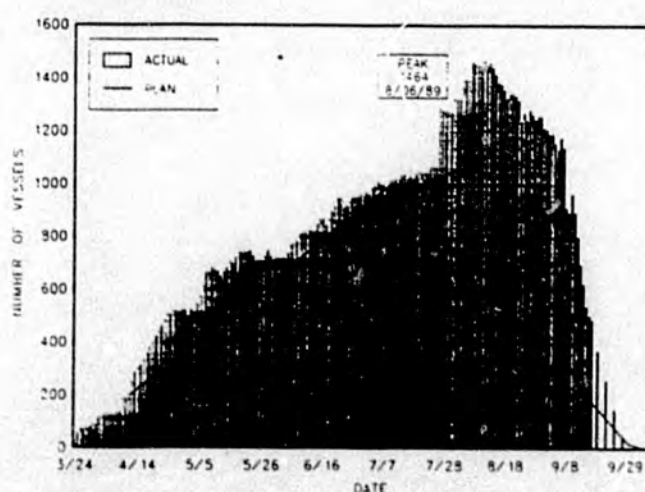


Figure 3. Number of vessels utilized in oil spill response

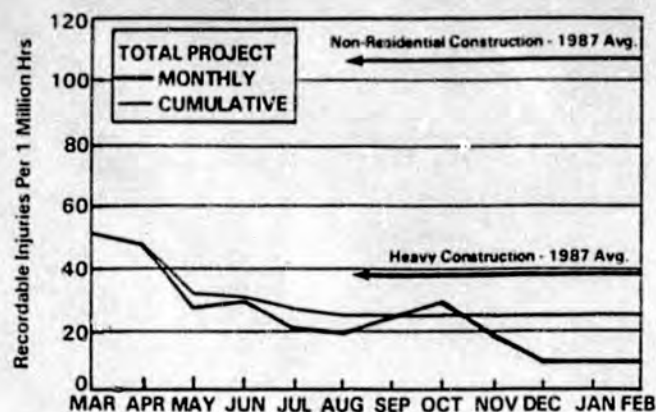


Figure 4. Safety performance during oil spill response

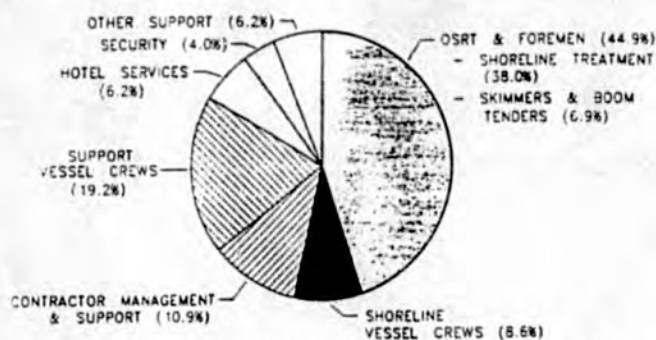


Figure 5. Functions of task force personnel (excluding Exxon and Crawford)

A self-contained semi-submersible derrick barge was able to provide the largest number of berths in a single vessel. Table 2 compares the key characteristics of the major berthing vessel types.

The berthing vessels and other barges were moored in sheltered bays and coves within Prince William Sound to reduce their exposure to extreme weather conditions. Local fishermen were consulted as to the best sites for the moorings based on their knowledge of winds, seas, and underwater hazards. All mooring systems were designed as single point moorings (SPM) with a design basis of 50 knot winds and ten-foot seas. A tug was assigned to each barge or cluster of barges to assist in the event of a storm in excess of the design conditions.

Crew transfer vessels. A large number of vessels were needed for crew transfers between the command center cities, berthing vessels, production and support vessels, and the shoreline work sites. The

Table 1. Typical task force vessels,

Logistics vessels	
Berthing vessels	3
Crew transfer	18
Storage/supply	11
Waste handling	8
Safety/medical	4
Other	9
	53
Cleanup vessels	
Shoreline treatment	17
Boom tending	14
Crew transfer	20
	51

1. Numbers reflect the average composition of the fleet. Vessel types and numbers varied from task force to task force and from day to day.



Figure 6. Task Force 2 support complex

Table 2. Berthing vessels

Vessel type	Beds	Days to outfit	Comments
Excursion boats	25-100	4-9	Quickly mobilized, limited mooring systems, require support barge with gear washing, potable water, and sewage handling
Fish processors	50-200	2-5	Largely self-sufficient, good propulsion and mooring systems
Navy ships	500	1-2	Quickly mobilized, large capacity but cramped berthing, good propulsion and mooring, require support barge with gear washing and sewage storage
Camp barges	50-250	7-29	Slower mobilization, large capacity, no mooring systems, require support barge, most weather sensitive
Derrick barge	548	1-2	Large capacity, slow mobilization, existing mooring system but lengthy installation, self-sufficient

majority of these were 24- to 40-ft fishing boats, although they varied from small inflatables to large ocean-going crew boats. Many functioned in multiple roles such as tending boom, transporting supplies, and transferring trash.

Shoreline treatment vessels. At the peak, 87 vessels were outfitted with equipment for treating the shorelines: 61 landing craft and 26 barges. Construction was performed in Valdez, Seattle, and Ketchikan. A number of skimmers and small pontoon barges were also used. The primary types were:

- **Miri-vessels.** The 61 landing craft equipped with both cold and hot water washing equipment were referred to as mini production vessels. These were the smallest shoreline treatment vessels, and their self propulsion, shallow draft, and bow ramps facilitated their ability to maneuver and access shorelines. Many were readily available in Alaska, and they could be mobilized the soonest; outfitting time was less than one day. About 40 percent came from military sources.

- **Maxi-barges.** Conventional barges outfitted to provide larger quantities of heated water were called maxi-barges. The time to outfit these barges was typically 6 days. The maxi-barges varied in length from 128 to 180 feet, and in width from 33 to 54 feet. Their higher freeboards and deeper drafts, combined with the need for a tug to maneuver them, made the Maxis best suited for treating longer sections of impacted shorelines.

- **Omni-barges.** The omni-barges were equipped with industrial heaters and an articulating arm to allow delivering heated water to hard-to-reach areas. They were 115 feet to 140 feet long and about 40 feet wide, with drafts of 2.5 to 4 feet. All but one were self-propelled and constructed of interlocking sectional barge components as shown in Figure 7. The Omnis required five to seven days for assembly. An

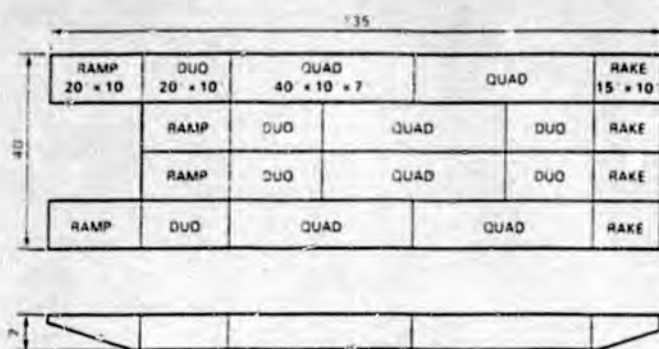


Figure 7. Interlocking float pattern for one Omni-barge configuration

additional 4-5 days were required to install the shoreline cleanup equipment.

• **Bioremediation vessels.** To apply the liquid fertilizer used in the shoreline bioremediation process later in the cleanup, water washing equipment was removed from six cold water mini vessels, and bioremediation application tanks and sprayers were installed. To access shallow areas that the minis couldn't reach, small pontoon vessels were similarly outfitted.

Resupply in Prince William Sound. At the peak of offshore operations, the six task forces required about 100,000 gallons of fuel, 30 tons of food, 150,000 gallons of fresh water, and 18 tons of materials on a daily basis. Additional supplies were required for the vessels and personnel providing common offshore logistic support and government agency operations. Even larger quantities of waste were hauled back daily.

To expedite the fueling of vessels and helicopters, two fuel depots were set up in Prince William Sound. Motor gasoline, aviation gasoline, jet fuel, diesel fuel, lube oil, and hydraulic oil were available. Food, water, and materials were delivered on ocean-going workboats on a regular schedule to each task force. In addition, smaller boats delivered fresh groceries and specialty items on an as-needed basis. Later, fresh water sources were developed in PWS to reduce logistical needs.

Other support vessels. Barges were particularly important in meeting the various marine support needs. Due to limited availability in Alaska, most of these vessels were mobilized from the lower 48 states. Some of the support vessel requirements were:

- **Skimmed oil/water storage.** Five large (25-50,000 barrels) tank barges were used for storing and transporting oil and water from skimming operations.
- **Boat and boom cleaning vessels.** It was necessary to clean response vessels before they left the cleanup areas and to clean other vessels that incidentally became oiled before they could enter harbors. Boat washing stations were established that generally consisted of a work barge, pontoon floats, and associated pumping, washing, and oil containment equipment. Boom washing stations were set up on barges to clean oiled boom.
- **Repair vessels.** Two major repair facilities were set up in Prince William Sound. One facility consisted of three barges moored together, including a crane barge. A second facility consisted of two floating dry docks, a crane barge, a slop barge, and an accommodations barge as shown in Figure 8. The floating dry docks were also used for boat cleaning.
- **Clinic barge.** A fully staffed medical clinic was established on a barge to provide medical services in the vicinity of the operations.
- **Kelp/popweed washer.** During the early days of the spill response there was concern that major quantities of oiled kelp and popweed would be encountered. In response, a hot water washing system was constructed on a barge and a series of collection and disposal vessels were mobilized. Ultimately, little oiled kelp was found.

Aircraft and onshore support

Aircraft operations. At the peak, 85 fixed wing aircraft and helicopters were used in support of the cleanup and animal rescue operations. During these peak months, five thousand to six thousand flight hours

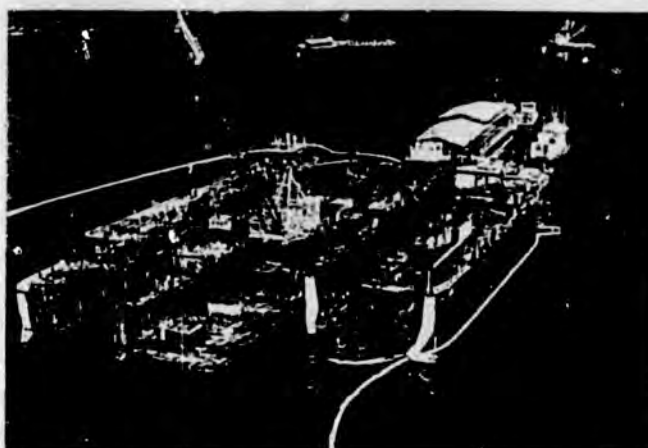


Figure 8. Dry dock repair facility

were required to transport about 20,000 passengers and 800,000 pounds of cargo. Over 20,000 total flight hours were experienced in 1989. Exxon weather criteria (flight minimums) were established to ensure safety and uniformity of air operations. Operations offices were established at the Valdez, Cordova, Homer, Seward, and Kodiak airports. A floatplane base was established on a lake near Valdez. Flight following was employed to monitor aircraft positions and thereby reduce the time required to locate and rescue the crew and passengers in the event an aircraft went down. Fuel caches were provided in remote areas for helicopter refueling.

Telecommunications. Extensive telecommunications facilities were required because of the large operating area, limited existing facilities, and mountainous terrain. Locations of telecommunications facilities changed throughout the operating period in response to the changing spill response needs.

Major fixed repeater stations were established on mountain peaks or other locations to provide broad coverage. These fixed repeaters were supplemented with small solar-powered, mobile repeaters that were moved many times during the spill response to reach specific bays or locations. VHF-UHF translator repeaters (Figure 9) were developed to reduce frequency crowding and meet special frequency needs. Ultimately, the telecommunications network included UHF, VHF, and HF radio systems, microwave stations, satellite stations (INMAR-SAT), and improved mobile telephone service (IMTS) as summarized in Table 3. Exxon was authorized to use all available frequencies, including the entire business radio spectrum.

Onshore berthing, offices, and food. Approximately 4,000 onshore support personnel were involved, with the majority located in Valdez.

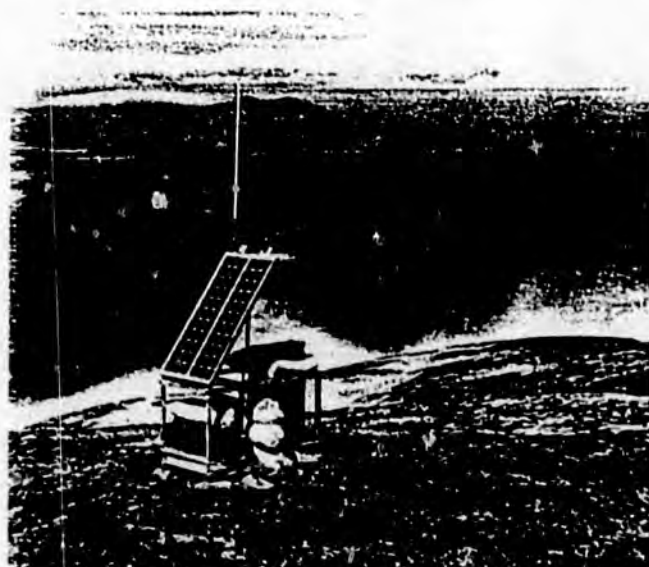


Figure 9. Translator-repeater on Kodiak island

Table 3. Telecommunication equipment used during spill response

Systems	Number used
Wide area UHF radio system	50 fixed repeaters 600 mobile radios 2,040 hand-held radios
VHF—AM and FM radio systems	15 base stations 200 mobile radio 1,150 hand-held radios
Translator repeaters	15 repeaters
HF—single sideband	30 radios
Microwave radio stations	4 fixed stations
Satellite communications	5 earth stations 15 INMARSAT terminals
Improved mobile telephone service (IMTS)	3 systems
Telephone systems	5 PBXs 27 key systems 517 lines and trunks

Housing for these personnel was provided by a number of means including all available hotel/motel space, private homes functioning as "bed and breakfasts," portable camps, and mobile homes. Food catering was provided to accommodate the expanded population in Valdez. Exxon's Valdez Command Center began in a hotel conference room. It later moved into available office space and then into a dedicated building erected by Exxon.

Transportation. Although truck and sea transport were used where feasible, the need for speed led to air shipment of most equipment and materials. At one point, all available commercial cargo flights were on contract to Exxon. Additionally, Exxon used the maximum military airlift capability possible while still allowing for national defense. Because of restrictions at the Valdez airport, most of the equipment delivered by air was flown to Anchorage and transferred to smaller aircraft. Air shipment continued to be the primary means of transport throughout the cleanup, since equipment and materials were needed as soon as they could be manufactured. More than 15,000 tons was shipped by air.

Weather forecasting. Throughout most of the oil spill cleanup operation, weather forecasts were provided by the National Oceanic and Atmospheric Administration (NOAA) and supplemented by local observations. Special forecasting arrangements were made for work on the Barren Islands due to the variability and potential severity of wind and sea conditions in that area. To enhance safety during the period of typically worsening weather leading up to September 15, a specialized contractor was hired to provide more frequent weather monitoring and forecasting within Prince William Sound.

Security. Almost 400 personnel were employed for security in Alaska at the peak of operations. Security functions included controlling access to facilities, providing bear guards on the shorelines, monitoring for alcohol and drugs, and safeguarding personnel and equipment.

Contracting and procurement. Contracting and procurement functions were performed both by Exxon and prime contractor personnel. Vessel contracting was complicated by the speed of mobilization, limited availability of vessels, and the need for some Jones Act waivers for foreign flag vessels. Approximately 1,000 separate contracts were involved and literally thousands of purchase orders were issued, which led to creation of a major data base.

Waste management

The cleanup effort generated quantities of both oily and non-oily liquid and solid wastes. Management of these wastes required extensive facilities for collection, temporary storage, transport, processing, and safe disposal. Final waste disposal methods included landfill, incineration, treatment, or recycling.

Solid waste handling and disposal. Oily solid waste from Prince William Sound, where shoreline cleanup techniques focused on water

washing, consisted mainly of oiled sorbent materials and shoreline debris. In the Gulf of Alaska, the wastes were primarily oily sand and gravel collected as a result of removing mousse patties and tarballs from the shoreline. The initial plan was to incinerate most oily solid wastes offshore on two specially constructed barges. Due to delays in permitting, however, an alternative plan for secure landfill disposal was implemented. Table 4 summarizes the disposal quantities by method. In addition, there was a considerable amount of non-oily solid waste, which included household refuse as well as wood and metal waste, that was sent to municipal landfills in Alaska. The major steps and facilities included:

- **Waste handling.** Oily materials from shoreline cleanup were put in plastic bags and taken to central storage or staging barges equipped with cranes and watertight containers. "Circuit" barges and vessels transported the waste containers to shore. Facilities in Valdez and Seward were constructed to receive, separate/sort, store, transship and/or incinerate oily solid waste. The layout of the Valdez site is shown in Figure 10.

- **Repackaging and landfill operations.** Oily solid waste was transported to repackaging sites in Anchorage and Seward. These facilities reduced the waste volume by shredding, added absorbent material to stabilize free liquids, and packaged it into one and one-half cubic yard bags called "supersacks" for disposal in an out-of-state landfill.

- **Incineration.** To begin disposing of the anticipated large quantity of oily solid waste, Exxon utilized five small onshore incinerators until higher capacity waste handling facilities were available. Two air curtain incinerators were tested, but standard air emission limits on particulates could not be applied to an incinerator without an exhaust stack, and operating permits were not issued.

One of the two incinerator barges (Figure 11) had a silo hearth incinerator with an operating capacity of about 40–70 tons per day. It was chosen for its early availability, positive emissions control system, simple and reliable operation, ability to directly feed large waste materials, and ability to burn high-BTU waste. Although startup was delayed by permitting until nearly the end of the operating season, the unit did operate long enough to conduct air emissions tests. It burned about 500 tons of waste, which was a fraction of its intended use. The other incinerator barge had a rotary kiln incinerator with a projected disposal capacity of 120 tons per day for oil sand and gravel. Permitting also delayed startup of this barge, and further permitting and mechanical problems prevented its use.

Liquid waste handling and disposal. Several hundred thousand barrels of liquid wastes, with the largest amount of this being skimmed oil and water, were generated and disposed of.

- **Skimmed oil and oily water.** Free water from skimming activities and other oily waters were transported to Alyeska Pipeline Service Company's Valdez terminal for processing through its ballast water treating system. Emulsified oil and water from skimming operations were transported to Seattle or to Exxon's Baytown refinery for processing, oil recovery, and waste water treating.

- **Sanitary waste.** Offshore discharge of untreated sanitary wastes from berthing vessels was not allowed, and this waste was transported to the Valdez municipal treatment system. Later, a barge was modified to serve as an offshore treatment facility.

Table 4. Summary of oily solid waste disposal

Processing facility	Tons processed
Incineration	
Onshore incinerators	2,100
Silo incinerator barge	500
Total incineration	2,600
Lower 48 landfill	
Anchorage repackaging facility	15,900
Seward repackaging facility	6,500
Subtotal	22,400
Absorbent added in processing	8,000
Total landfill	30,400
Total oily solid waste disposal	33,000

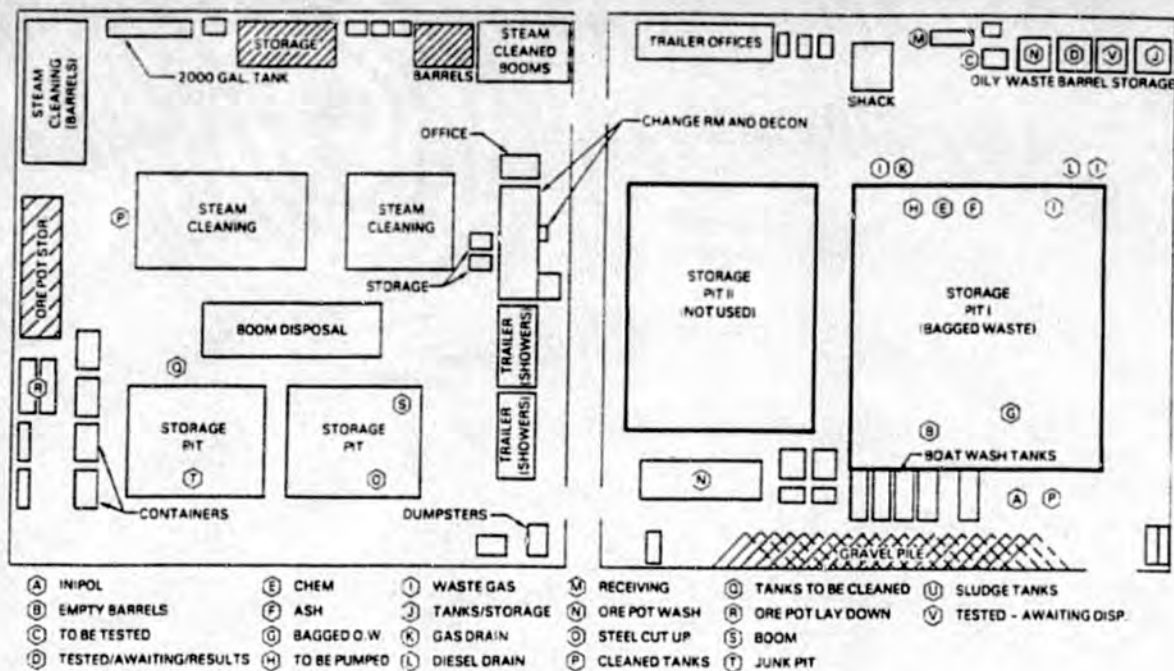


Figure 10. Layout of Valdez waste handling site

• **Cleaning waters.** Oily washwater generated from cleaning boats, protective gear, or booms, was pretreated to reduce the oil and grease to levels acceptable for treatment in the Valdez municipal treatment facility.

Hazardous wastes. The spill cleanup wastes were not classified as hazardous under state and federal laws, but some associated wastes were and required special handling and disposal in out-of-state facilities.

Demobilization

During early June, Exxon began to plan the demobilization of the cleanup operations and the transition to the 1989-1990 Alaska winter program. A review of historical weather patterns showed that by the middle of September offshore operations would have to cease because deteriorating weather conditions would seriously impact the safety of

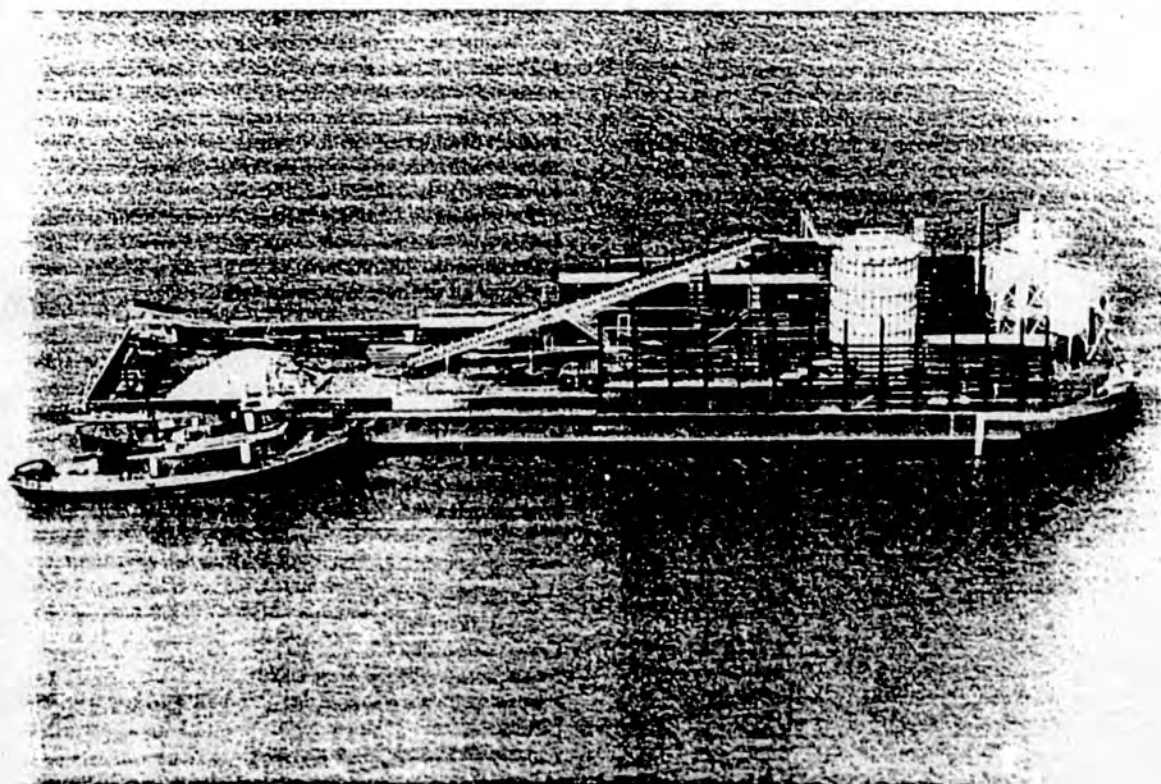


Figure 11. Barge mounted silo incinerator

the cleanup. A demobilization schedule was prepared that permitted work to continue as long as possible and still allow vessels to transit safely to their home ports before the forecasted onset of weather conditions that would exceed each vessel's operating limits. Vessel demobilization was complete in late October.

Vessel data base. The large number of vessels involved in the cleanup operation and the short demobilization period made it imperative for the supervisors of this operation to have an accurate knowledge of the vessels, owners, charter terms, and off-hire redelivery ports with which they would be dealing. A demobilization vessel data base was put together from several operating data bases to meet this need. This data base was used to schedule sailing plans for vessels and to monitor status of the program.

Vessel preparation and cleaning. All vessels were cleaned of oil as part of demobilization; additional vessel cleaning stations were established to meet this need.

Within Valdez harbor, demobilization facilities for equipment removal included three shore sites, three crane barges, and two staging areas with moorings. A separate complex in Louis Bay, including a derrick barge, was used for dismantling sectional barge assemblies.

Transit to home port. For the transit to home port, the larger barges were used to transport equipment and smaller vessels. A tow survey was conducted prior to departure to ensure that the vessels and tow hardware were safe and seaworthy. When the vessel reached its home port and was ready to go off-hire, a surveyor representing Exxon and a representative of the owner inspected the vessel.

AN OVERVIEW OF THE EXXON VALDEZ OIL SPILL

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ABSTRACT: While the Exxon Valdez oil spill had a significant and far-reaching impact, important progress has been made since the massive cleanup operation was launched in the spring of 1989. In 1989, Exxon treated almost 1,100 miles of shoreline identified to be impacted. This effort involved more than 11,000 people and 1,400 marine vessels. Environmental recovery is well under way in areas impacted by the spill, thanks to nature's own cleansing power and man's efforts. The 1990 cleanup primarily used nonintrusive techniques and addressed 10 to 15 percent of the shoreline treated in 1989. Much has been learned about how to prevent and respond to such an incident in the future.

Early in the morning on Friday, March 24, 1989, the *Exxon Valdez*, a 987-foot, state-of-the-art tanker carrying 1.25 million barrels of North Slope crude oil, ran hard aground on Blight Reef in Alaska's Prince William Sound. The grounding left 8 of the vessel's 11 cargo tanks and 3 of its 5 ballast tanks holed extensively, causing some 258,000 barrels of crude to spill into the water, most of it within the first few hours.

The spill occurred in a remote location in open water, in an undeveloped area of rugged terrain where boats and aircraft provided the only access to the impacted areas (Figure 1). The site was far from major population areas—about equidistant from New York and Tokyo and more than 3,000 miles from Exxon USA's principal operations along the Gulf coast of the United States. Exxon is not an operator in Alaska, and at the time of the accident, only a couple of dozen Exxon employees were in the entire state.

Immediately following the accident, the tanker captain notified the U.S. Coast Guard. Consistent with the oil spill contingency plan developed by the Alyeska Pipeline Service Company (operator of the marine terminal in Valdez) and approved by both federal and state authorities in 1977, and again as recently as January 1987, the initial spill response was carried out by Alyeska and the U.S. Coast Guard. It is important to note that the contingency plan focused on spill sizes of 1,000 or 2,000 barrels, in the belief that these were "most likely" to occur. It specifically recognized that a spill in the 200,000-barrel range could not be fully contained, and that a significant amount of oil would reach shore.

Exxon's response

From its offices in Exxon USA's headquarters building in Houston, Exxon Shipping Company began to mobilize the Exxon response team. A command center was established in Houston before dawn, and phone calls were placed around the world to locate and assemble needed materials and equipment. Arrangements were made for the first of many flights to Alaska to airlift equipment from oil spill cooperatives and other organizations. The Exxon response team left Houston by air before 8:30 a.m., arriving in Valdez by 5:20 p.m. on the

day of the spill. Dozens more trained people and tons of supplies began arriving that same day.

When Exxon's team arrived, they found the *Exxon Valdez* impaled precariously on a reef, in imminent danger of capsizing. The threat to the crew and the remaining cargo—another million barrels of oil, four times the amount spilled—was an immediate concern. One of the most pressing tasks was clear: to transfer—or lighten—the remaining crude to other tankers and keep the ship afloat.

Lightering operations began the morning after the spill. Transferring the million barrels of crude oil that remained in the *Exxon Valdez* to other tankers was an extremely delicate operation. Three tankers were diverted to the site and each was carefully maneuvered alongside the grounded vessel to offload the oil. Every barrel of oil removed was replaced with sea water to avoid potentially disastrous shifts in weight. Within 10 days, a small group of Exxon Shipping Company employees, displaying superb seamanship and on-the-spot technical innovation, successfully removed all the remaining cargo—and with it the threat of a much greater spill.

Simultaneously, the effort began to contain and clean up the oil that had already spilled.

To reduce substantially the volume of oil that might reach land, the contingency plan stressed the importance of the early use of dispersants and open burning. Unfortunately, there were inordinate delays in obtaining approval from the authorities for these methods.

A severe storm at the end of the third day following the spill spread the oil slick over a distance of 40 miles and onto island shorelines. At that point, containment was no longer possible, and cleanup became a key priority.

Wildlife. Another concern was the rescue and treatment of animals affected by the spill, and Exxon immediately committed extensive resources to this effort. From March through September of 1989, Exxon organized the largest and most comprehensive bird and sea otter rescue and rehabilitation program ever attempted. Facilities for holding, cleaning, and caring for oiled birds and otters were built in Valdez, Seward, Homer, Kodiak, and Anchorage. The rescue and rehabilitation efforts were overseen by established experts in the field, who arrived in Alaska within days of the spill.

More than 140 boats were used to retrieve oiled birds and otters from remote locations throughout Prince William Sound and the Gulf of Alaska. More than 700 specialists and volunteers were involved in the rescue and rehabilitation effort. Expenditures for the bird and sea otter programs exceeded \$45 million.

Claims. Exxon also moved quickly to establish claims offices to work with hatcheries, canneries, fishermen's groups, and many individuals to assure their financial viability through a system of advance payments.

The first claims office opened in Valdez on March 31, 1989, a week after the spill, and funds were available locally that same day. By the end of the summer of 1990, Exxon had paid over \$230 million to more than 12,000 fishermen and other claimants.

Mobilization. At the same time that Exxon was removing oil from the vessel, caring for wildlife, and launching a claims program, inten-



Figure 1. Map of Exxon Valdez oil spill site

sive efforts were under way to assemble the personnel, equipment, and supplies needed to implement the cleanup.

Bringing about this mobilization required a tailor-made organization that addressed every aspect of the cleanup effort, including planning and coordination, logistics, operations, technical and accounting, public affairs, and telecommunications.

Assembling the necessary people was the key to this mobilization, and that effort accelerated rapidly over time. Twenty-four hours after the spill, Exxon had 35 employees on the scene, and had hired 200 others. After one week, 800 people were dedicated to the effort; after one month, 3,000—and that number nearly quadrupled at the height of activity in the summer of 1989 (see Figure 2).

People were added as quickly as equipment arrived to support their activities. Most of the needed equipment had to be transported from the Lower 48 states, Canada, and several European countries.

Techniques. While this huge mobilization progressed, Exxon began to focus on what was needed to treat the affected shorelines. It became clear that two different kinds of operations had to be mounted because two different sets of cleanup problems existed.

In Prince William Sound, the shoreline is largely a collection of rocks of varying sizes, and this effectively determined what cleanup methods would be developed and tried. The principal cleaning method was to wash the oil from the rocks, using warm or cold water, or both (see Figure 3). The oil loosened by this washing was flushed into the sound, where it was contained by booms, picked up by skimmers, and held for subsequent treatment in onshore separation facilities.

In time, Exxon had to find innovative methods to bring more water for use on the shorelines. Accordingly, what came to be the workhorse piece of equipment for this phase of the cleanup—the maxi-barge—was developed. These custom-built barges had a crew of about 50, some 10,000 feet of boom, a couple of oil skimmers, fuel and storage tanks, a 225 kw generator, and several water heaters (Figure 4).

Many of the maxi-barges had a piece of equipment that made it possible to treat shorelines that could not be reached by foot. This device was called an "omni-boom," a hydraulically articulated delivery

system normally used for pumping concrete on construction projects (Figure 5).

At the peak of operations, systems capabilities were substantial: the ability to heat enough water to serve a city of half a million people. Overall, some 200 million gallons were delivered daily—enough to meet the needs of a city of one million persons.

Operations varied somewhat in the Gulf of Alaska, where the terrain was different and the impacts of the spill were less severe. There, the shorelines are less rocky and more sandy than those in the sound; more like what most people envision when they think of beaches.

Largely, the cleanup job entailed collecting, by rake and shovel, oily sand and tar balls, and disposing of the debris in plastic bags. In about six months, workers collected some 25,000 tons of solid wastes. Most of this waste material was sent to a landfill in the Lower 48 states.

Bioremediation. One of the most promising cleanup methods developed to deal with the spill was bioremediation. It has long been known that certain microbes have a taste for the complex hydrocarbons that make up crude oil. They ingest these hydrocarbons and break them down into harmless water and carbon dioxide.

The Environmental Protection Agency, working jointly with Exxon, undertook a test program that was encouraging. It led to using bioremediation on selected areas of shorelines. In all, in 1989 about 70 miles were treated with nutrients that supported these microorganisms.

Results. In the spring and summer of 1989, Exxon treated a total of nearly 1,100 miles of shoreline identified to be impacted—about 360 miles in Prince William Sound and more than 730 miles in the Gulf of Alaska—leaving them in an environmentally stable condition, safe for wildlife (see Figure 6 for cleanup timetable). While this was a major undertaking, it is important to bear in mind that the oil spill affected less than 15 percent of the total shoreline in these two areas.

At the peak of activity, the cleanup effort involved more than 11,000 workers—of whom about 3,500 were working directly on the beach—as well as some 84 aircraft and more than 1,400 vessels of all types.

In such a labor-intensive operation, safety was of the highest prior-

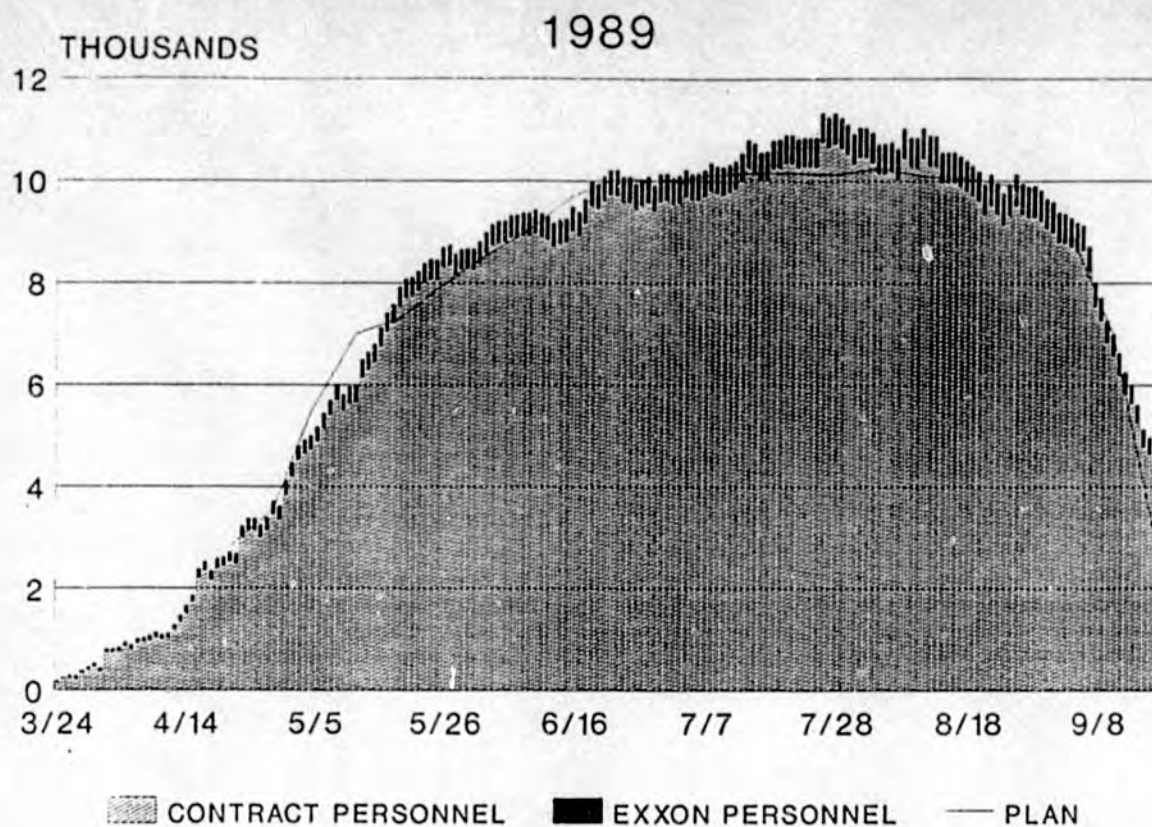


Figure 2. Personnel employed in oil spill response effort

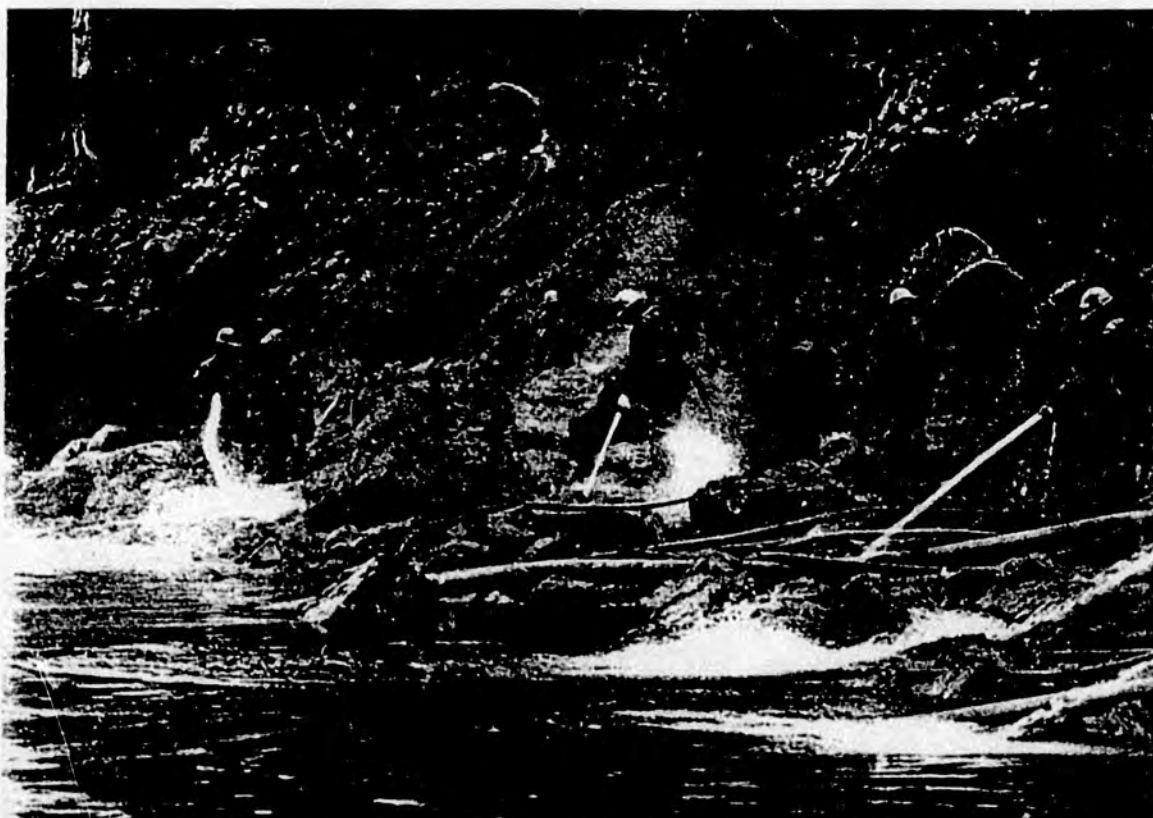


Figure 3. Washing oil from rocks in Prince William Sound



Figure 4. Maxi-barge working at shoreline

ity, and Exxon was pleased with its performance. There were 24.9 total recordable accidents per million manhours, which compares to 38 for heavy construction in general and 107 for non-residential construction.

Winter 1989-90

By mid-September, weather conditions required that shoreline activities be phased down because of the serious risk of life posed by the onset of the arctic winter. In Prince William Sound, winter gales can create waves 10 to 15 feet high, while 30-foot waves are common in the Gulf of Alaska. Wind speeds in the area are shown in Figure 7. Temperatures plunge well below freezing, and daylight diminishes to five hours per day by the time of the winter solstice.

Exxon maintained a large presence in Alaska over the winter and carried on a multifaceted program. More than 700 Exxon and contract employees remained at work, most based in Anchorage, where equipment also was maintained. Ships, aircraft, and other materials were strategically deployed in Anchorage, Valdez, and other communities. A number of people residing in Alaskan villages, who worked in the summer cleanup effort, were retained on "call up" status as a contingency strike force. Sixteen villages were under contract to Exxon to conduct winter shoreline monitoring of designated beach areas.

In addition, Exxon's comprehensive winter science program encompassed more than two dozen environmental field studies, involving some 300 scientists and technicians from all over the United States.

As anticipated, both in Prince William Sound and the Gulf of Alaska, fierce winter storms made major improvements on high- and moderate-energy shorelines. In the areas where it was applied, bioremediation enhanced those natural processes. As a result, the condition of the shorelines continued to improve.

Environmental recovery

By the spring of 1990, it was clear not only that shoreline conditions had markedly improved, but also that environmental recovery was well under way (see Figure 8).

In April, three distinguished scientists from the United Kingdom visited Alaska to conduct field observations on the environmental impacts of the spill. One of their principal observations was: "Only a portion of the shoreline had been oiled, and, as with most other oil spills, the bulk of the damage had disappeared during the first year. The area has retained its natural beauty; there are abundant signs of plant and animal life, and recovery is well under way on even the most severely impacted beaches."¹

Equally encouraging results were seen in studies of water quality. In the spring of 1990, findings were published based on water quality studies conducted by four prestigious research organizations: Arthur D. Little Marine Sciences, Battelle Ocean Sciences, Kinetic Laboratories, Inc., and America North, Inc.

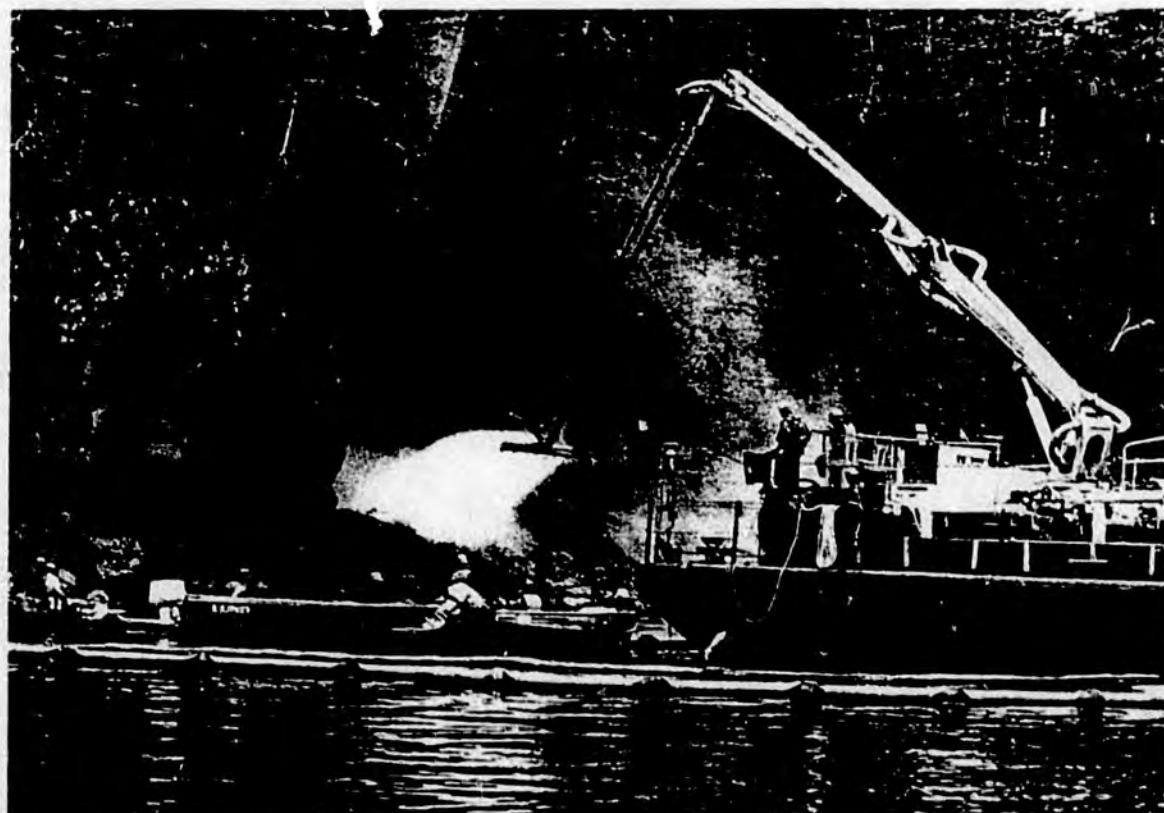


Figure 5. Omni-boom spraying water on shoreline

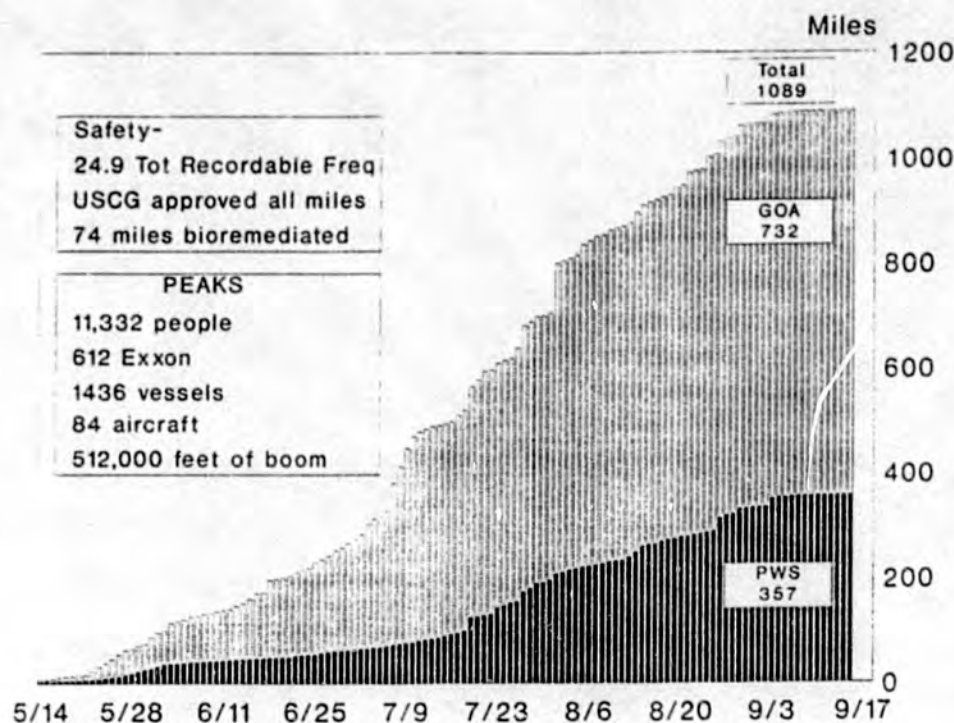


Figure 6. Graph of 1989 shoreline cleanup progress

Dr. Jerry M. Neff, a Battelle scientist, reported that average aromatic hydrocarbon concentrations in the waters of Prince William Sound had remained well below State of Alaska standards. Over 2,300 water samples were taken from the sound and all had shown consistently low hydrocarbon levels since April of 1989. In most cases, the levels were 10 to 1,000 times below the concentrations found to cause harm to marine animals. In addition, he concluded, "It is extremely unlikely that hydrocarbon concentrations resulting from the spilled oil have had or will in the future have any adverse effects on plants and animals living below the surface in the water column of Prince William Sound, including commercial fishery species."²

This judgment was confirmed by the fact that commercial fishermen realized highly successful catches in 1990, including a record-setting pink salmon harvest in Prince William Sound. Moreover, field observations confirmed a large number and diversity of birds, otters, and other mammals thriving in the spill-impacted area. Given the 10 million seabirds and 12,000 otters in the affected area and their natural resiliency, all species were expected to recover rapidly.

Spring and summer 1990

The major objective of studies conducted over the winter was to assess the need for additional work and to make plans to conduct whatever activities were needed in the spring and summer of 1990. While winter storms and tidal actions further cleaned the shorelines, particularly those exposed to higher and moderate wave energy, some areas required additional cleaning and Exxon performed that task over the summer.

The 1990 cleanup focused on techniques that were least intrusive to the recovering environment while achieving the desired results. Over-

all, the objective was to complete the appropriate cleanup work in a way that provided a further net benefit to the environment, minimized the negative impacts on wildlife, did not interfere with fishing, and enhanced the natural recovery that had already begun.

Consistent with these goals, principal cleanup methods used in 1990 included manual oil removal, tar mat removal, spot washing, tilling and raking, and bioremediation. Some 1,000 people and 70 vessels were involved in the 1990 cleanup operation, which re-treated 10 to 15 percent of the total shoreline mileage treated in 1989.

The U.S. Coast Guard monitored day-to-day shoreline operations, with extensive technical support from the National Oceanic and Atmospheric Administration (NOAA). The professionalism and technical and operating expertise provided by these key government agencies were an important factor in the success of the 1990 effort.

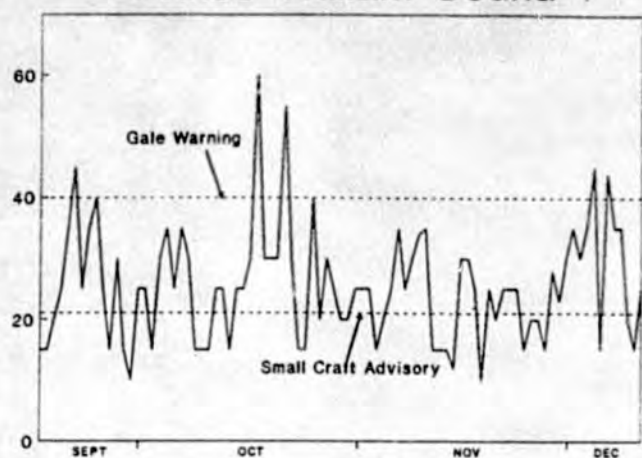
A joint shoreline assessment program was conducted in August 1990 to identify sites for possible re-treatment in 1990 and to recommend priority sites for reassessment in 1991.

It's expected that by the spring of 1991, few areas will remain with any significant oil and there will be no visible oil or stains on areas treated in 1990. Isolated pockets of subsurface oil will likely still remain, particularly in wave-sheltered areas. However, NOAA concluded in July 1990 that "deeply buried subsurface oil . . . poses little risk of causing further significant environmental injury."³

Lessons learned

As difficult as the spill and cleanup experience has been, it has yielded some important lessons about the management of such a crisis. That better advance preparation is needed for what to do when such an emergency occurs is obvious. The American petroleum industry has

Prince William Sound



Gulf of Alaska

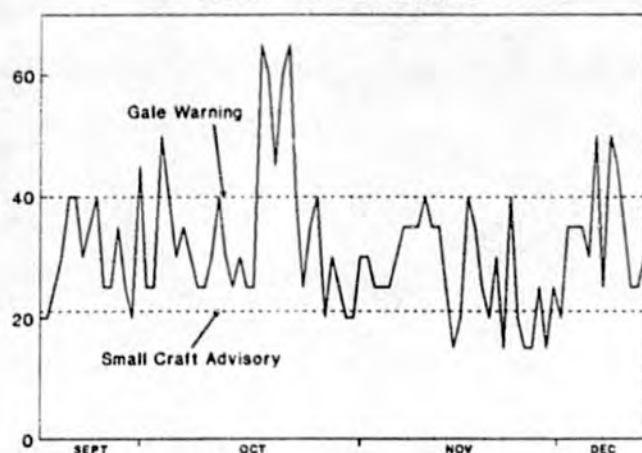


Figure 7. Graphs of 1989 winter wind speeds in knots

already taken this to heart in a plan for a series of response bases located along the coasts of the United States—the Petroleum Industry Response Organization, or PIRO. The proposed equipping and manning of these bases will be at a level far exceeding anything seen before.

Similar measures are adopted at the terminal operator Valdez, which as stockpiled additional boom, barges, and other spill-related equipment.

In addition, interim steps have been taken regarding vessel transit in and out of the port of Valdez. These include escorts and extending the distance from port during which a pilot must be onboard.

In the event of a spill, however, putting added resources to effective use is not an automatic process. Timely, effective action—the kind needed in an emergency—cannot be taken by committees. When several groups with different priorities and differing views about what should be done jointly face an urgent need for action, too often the outcome is conflict and no action at all—or, at best, a lowest common denominator approach. The larger interest tends to get lost in the give and take. Someone who can weigh the issues, cut through the disagreements, and force timely action must clearly be in charge. Most logically, that someone should be the U.S. Coast Guard.

Another area for close examination is the pre-approval of cleanup technology. Clearly, dispersants are the key to responding to a large spill, and their use must be cleared *in advance*—as if often done in Europe—if timely and effective action is to be taken. The same is true concerning the use of chemical cleaners, and even the more basic methods such as warm-water washing. Unfortunately, in the case of the Valdez spill, chemical cleaners were approved only in tests, and heated wash water temperatures were approved only in increments.

While speed and decisiveness are critical to effective spill response, the procedures in place in the United States are hardly conducive to either. Federal, state, and local authorities—as well as industry—have to develop a more effective response procedure in the event of an emergency. When it comes to a crisis, the federal government, which is best positioned to have the necessary technical expertise and to balance the diverse interests of the myriad of local, state, and national agencies involved, must have clear authority and the confidence to act decisively.



Figure 8. Seagulls off Green Island, April 1990

Changes within Exxon

Exxon has taken a number of specific steps to reduce the risk of oil spills and to strengthen cleanup capabilities.

Procedures have been revised concerning employee substance abuse to require random testing of employees in designated safety-sensitive positions, such as certain refinery and chemical plant operators, tanker officers, aircraft pilots, and tank truck drivers. No one who has, or has had, a dependency will be permitted to occupy such a position.

Exxon operating units in the United States and foreign affiliates have reviewed their oil spill prevention plans and response capabilities and have increased the amount of response equipment at their marine terminals. Collision warning systems for tankers are being upgraded with more sophisticated, integrated bridge navigation systems. Additional remotely-operated pipeline block valves have been installed where lines cross rivers or sensitive areas. Oil storage has been eliminated in exposed wing tanks of the Exxon offshore processing vessel in

California. And the frequency of vessel inspections of Exxon's fleet has been increased to as much as twice per year.

In addition, a new senior executive level position of Corporate Vice President, Environment and Safety, has been created to further assure that Exxon's environmental responsibilities are fulfilled.

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