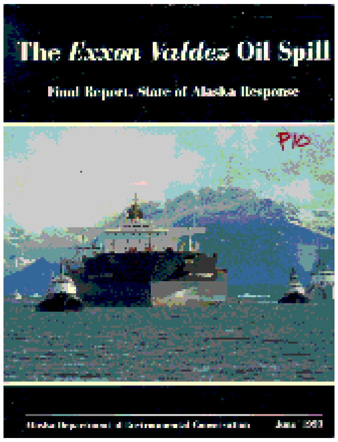

Shoreline Treatment Techniques

The *Exxon Valdez* Oil Spill:
Final Report, State of Alaska Response

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The oil started to wash ashore in large amounts, and over wide areas, beginning in early April. Throughout that month, resources and techniques were targeted mainly on the massive and expanding problem of on-the-water recovery, and on defensive booming. Although oil was weathering, breaking up, and was frequently concentrated at nearshore sites, there was no single or main "oil slick." The battle against the oil was more like a guerrilla war, fought in skirmishes on multiple fronts, rather than a concentrated attack against a massed enemy.

Yet even as on-the-water efforts expanded and Exxon mobilized more and more vessels and equipment, it was becoming clear that shoreline cleanup was about to become perhaps an even bigger priority. Oil was washing ashore at one site, only to be lifted off by the next tide cycle.

"It is discouraging for the crews to see oil come off a beach during a tide change and impact another (sometimes clean) beach," reported DEC's main contractor on April 19. The contractor added, the following day, "All attention is still directed to offshore recovery. Nothing being done to shoreline contamination."(29)

This was a major issue for state authorities and local communities. The rapidly fragmenting "fronts" and the limited recovery and storage capabilities were quickly overwhelming the response effort. Oil was not only heading out of the Sound for the outer Kenai Peninsula and Kodiak archipelago, but it was swirling throughout the Sound and hitting more and more shorelines.

"There is some kind of correlation between the tides and the movement or relocation of free-floating oil," the DEC contractor explained in that April 19 report. "The oil appears to be moving through Northwest Bay in a counter-clockwise direction, up and around Pt. Eleanor in a clockwise direction, down the east side of Knight Island and back to the west through Upper and Lower passages. Then (depending on the tide stage), when it reaches the west side, it either travels north to Northwest Bay or south to herring Bay."

A week later, on April 26, the report noted, "Lots of oil is being washed from Smith, Little Smith and Seal islands as well as the north east comer of Point Eleanor. These areas were heavily impacted during the major release of oil."(30) This scenario, occurring around northern Knight Island and the smaller islands to the east that April, suggested that much of the on-the-water recovery was really becoming an endless - and losing - game of chase with familiar oil concentrations. The only way to truly stop the recurring cycle was to break it onshore, by recovering stranded oil and preventing it from getting loose every six hours when the tide changed. And there was plenty of oil to be washed off: A number of DEC field reports noted pooled oil and stretches of greasy, brown emulsion up to and exceeding two feet deep stranded on shorelines of the area. The re-oiling problem was starting to move south, as well, as prevailing currents and changes in wind carried oil off the beaches of the Smith Islands, Seal Island, and Green Island. Two of the most heavily oiled areas of 1989 - Point Helen at the south tip of Knight Island, and at Sleepy Bay at the northern head of Latouche Island were affected largely by secondary oiling from their northern cousins. These two southern Prince William Sound sites would be the focus of some of the most intense cleanup activity well into 1991, and even 1992.

While there was little activity on the shorelines during the first weeks after the spill, by the second week in April (around the 19th-20th day of the response), the Coast Guard and DEC were putting increasing pressure on Exxon to plan for and execute a full-fledged shoreline cleanup program.

Working off the relative success of vacuum equipment to pick up weathered oil from the water, there was one attempt at Smith Island to use vacuum equipment on the shoreline. The trick was to vacuum oil without pulling up cobbles and fine sediments. Where the oil was deep and the rocks were large, vacuuming actually worked. However, recovery was slow and the areas where it might work were limited.

Exxon made one highly publicized, almost desperate effort to do shoreline cleanup with workers literally wiping rocks by hand with absorbent material. This looked ludicrous on television, and supervisors from all parties thought it useless and impractical almost as soon as they saw it. State monitors reported during 1989 that contractor crews occasionally resorted to hand-wiping when waiting to be redeployed or when equipment was down, but rock-by-rock cleanup was essentially eliminated as a realistic option after a single attempt.

Washing the beaches was generally regarded as the most practical method, but there were various theories about how to do it. Exxon tried several combinations of manpower and equipment. Under one arrangement, at the "top" of the beach (roughly the high-tide line) workers strung a perforated hose that could carry a high volume of cold sea water, which flooded the sediments at low pressure. Workers "down-beach" agitated the sediments with rakes and other hand tools to release the oil, which was lifted off by the flood and collected in front of booms strung just offshore. This worked fairly well, and DEC monitors reported that the tilling released more oil than flooding alone. However, while hand-tilling passed in and out of fashion throughout the response, it was rarely used with the flooding system after those early tests. Not all shorelines lend themselves to hand-tilling,

and the amount of labor necessary for full-scale application was, at the time, a daunting proposition. At that point, there was still no firm plan to house workers, feed them, clean them, and dispose of all the waste they would produce.
A second variation of the header flooding system added workers using moderate high-pressure hoses to wash rocks. This released more oil than the flood alone, and it covered more ground at a faster rate than the hand-tilling method. It could also be used on many types of shoreline. This variation was not without some obvious problems. Biologists were concerned about blasting animals and plants off the shorelines. Coastal geologists were concerned that high-pressure blasts would wash away the fine sediments underneath big rocks and cobbles; that, in turn, might de-stabilize the beach and trigger serious erosion.
The temperature of the water was a problem, too: The nearshore waters in the Sound, even in the summer, rarely rise much above 45-50 degrees Fahrenheit. Lots of cold water tended to make the oil thick and tarry, making it harder to move and harder to recover. This also tended to encourage workers to use higher pressure to blast the tarry oil, which made biologists and geologists more nervous than before. Cold water would not cut the oil.

Hot water and high pressure
One of the enduring images of the *Exxon Valdez* cleanup is of workers in hard-hats and yellow rain gear blasting at rocks with high-pressure hoses that fired hot water. Virtually every beach that had significant oiling (moderate to heavy, by DEC definitions) was washed with either hot-water hoses or hot-water mechanical washing devices called "omnibooms." In all, as much as 150 miles of shoreline were probably washed with hot (140-160 degrees Fahrenheit) water in 1989.(31)
In terms of shoreline ecology, hot water hurts. As early in the cleanup as July, 1991, little more than six weeks after full-scale hot-water washing became standard shoreline treatment, both the Coast Guard's scientific advisor and independent biologists expressed concern that the hot water was "cooking" the beach life and perhaps doing more harm than good.(32) This group was not solely concerned with the immediate, acute impacts of the hot water and high pressure. These scientists were also concerned that the plants and animals on the shorelines washed with hot water would actually return to normal *more slowly* than those left alone, or those treated less harshly.
In an article published in 1990, two independent Alaska biologists questioned the wisdom of the hot water wash based on information gathered from a study site they established on Green Island.(33) A second paper expanded on this hypothesis, offering data that, the authors suggested, showed that hot water and high pressure had killed more animals and plants than the oil might have. They took their analysis a step further and suggested that recovery might therefore be slower.
"Complete loss of mussels and rockweed [due to treatment] at these sites has changed or eliminated several ecological niches," the study concluded.(34) Without the cover of the mussels and seaweed, the biologists said, it was hard for the usual array of small intertidal plants and animals to establish themselves

and survive; the exposed rock surfaces were too dry, too exposed to predators, and too heavily pounded by wave action. Moreover, the normal progression of plant life was likely to be delayed because the exposed surfaces allowed so-called "opportunistic" species, such as various algae, to establish themselves in formidable and overwhelming numbers.

This paper was actually part of a larger study commissioned by the National Oceanic and Atmospheric Administration (NOAA), and financed by the EPA, the Coast Guard, the American Petroleum Institute and Exxon, among others. The NOAA study was much more forceful, and its conclusions more pointed, than the previously published work. NOAA released the paper(35) in April 1991 at a Washington, D.C. press conference. NOAA's top officials not only said hot water washing did more harm than good and set back recovery, but closed by suggesting that "sometimes the best thing to do in an oil spill is nothing."(36)

"It is clear," the study reads, "that the data ... strongly support the conclusion that hydrocarbon contamination and high-pressure, hot-water treatment each caused major adverse impacts to the intertidal biota of western Prince William Sound, but that the effects of the treatment predominated. Moreover, it appears likely that the treatment, while removing oil from the upper and mid-intertidal zone, where its effects were somewhat restricted to relatively tolerant organisms such as barnacles, rockweed, and mussels, transported the remobilized oil into the lower intertidal and shallow subtidal zones, where the oil was placed into contact with relatively more sensitive and productive organisms such as hard shelled clams and crustaceans."(37)

The authors of the study argue, in short, that a lot of the tougher shoreline organisms might have been killed by the oil, but that a fair number would survive. Therefore, while the overall health of the shoreline might suffer, populations would limp along and gradually re-establish themselves fully. Having "survivors," in other words, is an important step on the way to full recovery. But in hot-water, high-pressure treatment, there are few survivors, if any; therefore, recovery is likely to take longer.

The study also suggests that the high-pressure wash drove oil out of the upper beach, but the hoses also drove oily fine sediments into places below the tide line, thereby oiling places that would have escaped oiling otherwise

Before addressing the specific technical and scientific points raised by the NOAA study, it is helpful to look at the study first within the context of the larger technical debate about shoreline cleanup in general, and second, within the context of *Exxon Valdez spill* politics.

There has long been a debate among responders, biologists and policy-makers from industry and government about whether oil spill cleanup should proceed beyond anything more than simple pickup. Indeed, NOAA's introduction to the 1991 report cites several of the best known references on the subject from the past decade or so. The NOAA report is not necessarily an isolated analysis; rather, the conclusions (and some of the principal authors and school of thought about oil spill directors) of the study are a product of a certain cleanup.

The NOAA Hazardous Materials section, which is the designated scientific support coordinator for the federal on-scene coordinator, leans towards the

approach taken by the school of limited cleanup. John Robinson, who led much of NOAA's work on the *Exxon Valdez spill,* was not generally in favor of aggressive cleanup. He took direct control of the controversial Net Environmental Benefit Analysis study of 1990, which concluded that rock-washing or sediment excavation was ill-advised. It became the federal government's official policy. Robinson's position was largely based on concern for intertidal communities, and the technical literature has a number of references to support his position. In addition to those cited in the NOAA report, other studies - including one conducted in part by DEC's chief technical consultant (Erich Gundlach, now of the Arthur D. Little Co.) suggest that most oiled shorelines exposed to wind and weather have a good chance of recovering their biological health within periods often measured in years, not decades.(38) So, given the facts that Prince William Sound's ecosystems were largely not exposed to other external environmental stresses, that the weather is harsh, that ocean conditions are generally high energy, and that there are a lot of nutrients flushing into the marine ecosystems to aid recovery, it would not necessarily be unreasonable to suggest that minimal shoreline cleanup might be better than aggressive cleanup in such a situation.
This raises serious questions about the cleanup: Is the NOAA study accurate in its picture of hot-water, high-pressure washing during the *Exxon Valdez* cleanup? Are the results strong enough to prompt a conclusion that the technique should not have been used in Alaska, and should not be used in the future? These questions address both scientific and strategic issues.
The data collected by the NOAA researchers is thought-provoking, but it suffers from a certain imprecision - no fault of the researchers, really - because of the working conditions on the shorelines in 1989. It is impossible to generalize too broadly about hot-water, high-pressure washing, since that meant different things at different sites, with different heaters, different crew chiefs, different external pressures (meeting goals in scheduling, for example), and differing levels of fidelity to proper procedures. While this might have affected some of the data, this also might affect the general conclusions about washing mentioned by NOAA officials when the report was released.
Some washing crews were careful and some were not. Some basic problems in variability of performance included:

Uncoordinated spraying

State monitors often observed Exxon crews spraying hoses randomly on the shorelines, rather than working systematically down a beach. This often meant that some people put more hot water and more pressure on a given area than others. Some workers were allowed to point hoses directly into fine sediments, which mobilized oil and sand and allowed it to be transported into the lower intertidal. In short, treatment was uneven, not just from site to site, but within sites themselves.

Ignorance or carelessness in application of treatment

Everyone agreed that it was important for crews to avoid spraying the so called "green zone," the rich, lower intertidal area characterized frequently by the presence of filamentous green algae.

"Generally, a cleanup squad was to wash a beach by following the tidal waters down the beach on the ebb tide and moving back up the shore with the flood tide, stopping intrusive treatment if the green zone were exposed. However, many crews ignored these restrictions, insisting on working the area rather than shutting down or moving to a less sensitive location," the DEC's cleanup monitoring section reported in its 1992 summary.(39)

Also, once oil was released from the beach into the containment zone for a skimmer to retrieve, workers were supposed to turn down the pressure on their hoses and gently push the floating oil towards the skimmer.

"Unfortunately, despite repeated explanations of this method, crews were often allowed to turn most if not all of their hoses on the oil without reducing the intensity of their spray," DEC's monitors reported.(40) This not only caused a lot of mixing and turbulence, but dumped a good deal of warm water into the nearshore area, which could affect the survival and recovery of the extreme lower intertidal areas.

Scheduling and reporting of results

Throughout 1989, DEC pointed out to both federal and Exxon authorities that too much time and effort was being spent on shorelines that were not as heavily oiled as others. Crews were often deployed on moderately oiled shorelines that could be completed quickly, rather than on more heavily oiled shorelines that might take more time, and therefore throw off the crews' scheduled goals, and reports of progress, for shoreline miles treated.

From the standpoint of the NOAA study, this issue raises questions about whether the damage from hot water washing could have been minimized throughout the region by concentrating the harsh technique only on the most heavily oiled sites, using milder techniques on others.

Poor choices or combinations of equipment

Shore washing was more effective at releasing oil when hoses and the omnibooms were used in conjunction with a low-pressure beach deluge system (such as the perforated hoses). However, some places used it and some did not, which meant that more work was done with the most powerful equipment. In addition, the omnibooms were originally intended to work primarily on steep, rocky faces and some large boulder beaches. However, Exxon gradually began using them on almost all kinds of beaches, with the exception of low-energy, fine sediment shorelines.

NOAA's data did not, and probably could not, correct for these important variables. The study's model for hot-water washing was based on one actual observed test of the technique; the rest relied on imprecise or incomplete documentation. Records may show that a beach was washed with hot water, but the records used by NOAA did not show where on the beach the hot water and high pressure were applied.(41) There are some ways to reconstruct this,(42) but to DEC's knowledge NOAA did not know about them or chose not to use them. From the standpoint of science, this is a real problem: Data based on imprecise sources weakens the data and the conclusions based on them.

Biologists from the Alaska Department of Fish and Game (ADF&G) remarked, "The NOAA report attempts to circumvent this problem by relying on general segment reports and from observations by 'individuals working in the field (e.g. field bosses for specific locations).' While this may provide additional detail on beach cleanup efforts, one must question the ability of such individuals to recall the exact treatment that occurred (temperature, duration, number of passes, etc.) on a specific location where the NOAA transects were conducted. Where multiple treatments occurred, different individuals were involved." (43)

Hot water and high pressure are harsh treatments, and the data gathered by NOAA give us a better idea of how harsh they might be. However, because of the variability of the treatment from site to site, coupled with the scientific unreliability of some of the sources used, the conclusions NOAA reaches about setbacks to recovery caused by treatment are closer to hypothesis than proof. One year's data based on observations immediately after the spill makes for an incomplete data set, state reviewers suggested; several years of recruitment and recolonization data are needed to reach the kind of conclusions the report's authors suggested.(44)

NOAA was working under difficult circumstances, and it is not surprising that its data would suffer from the weaknesses described above. The state, in reviewing the report and in responding to questions from the press, tried to make clear that it did not dismiss NOAA's findings out-of-hand.

The state's reviewers agreed generally that the NOAA report's conclusions, especially estimates of rates of recovery, are not fully supported by the study's data. However, it would be imprudent to ignore the general picture the report draws about the harshness of hot water and high pressure on intertidal life. Applying this piece of science to oil spill shoreline cleanup strategy, one might conclude that:

a) Hot water and high pressure can be extremely harsh on intertidal communities.

b) Such treatment probably has implications for recovery as well as initial acute effects.

c) Therefore, before choosing such a technique, responders must make sure any damage from the treatment is acceptable based on the potential threat from the oil.

It was well known from the start that hot water and high pressure were a potentially harsh combination for shoreline treatment.

"[T]esting done on Block Island by Exxon and the USCG have demonstrated that water flushing and hydro blasting are both effective removal methods," wrote DEC's main contractor on May 3. "The only thing to determine now is the temperature range of the water. Admiral Yost seems to think that a clean, dead beach (using hot water) is better than a live, semi-oiled beach (using cold water)."(45)

In fairness, Yost, the Coast Guard commandant, was not alone in this assessment. The state's spill officials agreed that hot water flush had a role - perhaps a significant one - in shoreline cleanup. State and federal officials agreed that the potential damage of treatment was acceptable based on the potential threat from the oil.

And here is precisely where opinions separate, not just in this instance, but in the larger and more common debate about conducting shoreline treatment after an oil spill: Who defines terms such as "threat" and "harm?' What resources, values, economies, and uses are most important and deserve protection - especially when protection for some may have negative results for others?

For the State of Alaska, the bottom line was that cleanup policy was a complex matter of public policy, not merely a scientific consideration. However, science provided the starting point.

First, the spill was enormous, and the shoreline impacts were unprecedented. The 11 million gallons lost from the tanker washed into hundreds of salmon streams, estuaries, bird-nesting areas, marine mammal haulout and rearing zones, and other critical habitat. The oil was not affecting a limited habitat for a single major species; it was coating tremendously large sections of habitat for a number of important species, some of which do not survive in large numbers outside of Alaska. Nothing in the literature gave clear guidance about what might happen to species that suffered widespread disruption due to oil over massive areas that supported them.

Second, the amount of oil that was spilled - and later, it was determined, the amount of oil that was locked underneath rocky shorelines and buried on other beaches - raised serious questions about the potential for sublethal effects due to longterm, low-level exposure to hydrocarbons.

Third, despite the general impression that Alaska is a rich paradise for wild things, it must be remembered that Alaska's subarctic climate puts most species on a razor's edge of survival. A tropical climate with endless summer has more energy, more diversity, better conditions for recovery, generally speaking. Prince William Sound is rich, compared to other areas, largely because it is not subject to the same barrage of environmental insults as other, more populated and industrialized areas

However in Alaska, any disruption - natural or man-made - has the potential for driving a given animal population below the levels necessary for survival. Cold water, harsh weather, and limited solar energy at high latitudes can all combine to make recovery in such an area less dependable than recovery in a more temperate climate. This spill was so large, and its initial effects so widespread, anything less than a fullscale attempt at cleanup seemed like a biological gamble.

Last, the timing of the spill, in biological terms, was especially critical. Prince William Sound, the Copper River delta, the Kenai Peninsula Coast, the Barren Islands and the Kodiak Archipelago - all these areas were on the verge of the massive m i g rations of birds, marine mammals, and fish that begin in April and extend through the northern summer. The beaches and islands of the region are primary stops on migration routes, and preferred sites to nest, give birth, and raise young for many species. The oil, quite literally, was in the way, or on its way to vast stretches of critical habitat.

But biology was only part of the decision. The people and the economies of the region depend on the health of resources, the seasonal abundance of game and fish, clean water and wilderness islands. Subsistence, commercial fishing tourism, sport hunting and fishing, and recreation are the foundation of the local economies, and the very reasons the communities of the region exist. Commercial fishing seasons were on the verge of opening, and the concern was not just over the 1989 season, but the 1990 season as well. Not only was it important to clear spawning beds from oil contamination, but it was just as important to clean beaches that held the potential for leaking oil into the bays and coves where fishermen made their living. Alaska tourism at virtually every level is based on pristine wilderness. Subsistence users demanded that oil be removed from their hunting and fishing areas as best as possible. It was simply not acceptable or practical to put these economies on hold for some period of years while oil degraded naturally.

And as a practical matter, a minimal cleanup raised the distinct possibility that oil being lifted off beaches and moved elsewhere would oil and re-oil many areas that had escaped the initial impacts, as described in field reports and overflights by state and federal agencies.

The threat from the oil extended far beyond the intertidal communities of the affected shorelines the potential harm to limpets and rockweed from hot water seemed acceptable, based on the potential harm to the region's economies and communities, and to higher trophic species such as fish, seals, and seabirds. Arguments for limited or light cleanup, based on concerns about immediate intertidal impacts, lacked the perspective of both the broader ecological implications and important public policy considerations.

Did the hot water treatment work? Hot water and high pressure did, indeed, remove relatively large amounts of weathered oil from rocky shorelines. It did, however, suffer from serious drawbacks. It was probably harsh on intertidal creatures and plants that survived the oiling itself, and it probably drove some oil at some sites deeper into the fine sediments. In addition, variability in the way crews conducted the treatment caused secondary problems, some of which the NOAA 1991 study points out.

On balance, state officials were willing to accept some of this damage in exchange for removing the heaviest concentrations of oil from shorelines as much as possible, as fast as possible. The benefits to commercial fishing, tourism, and other human uses of the shorelines outweighed the potential damage and disruption caused by the treatment.

The treatment was most effective, and most acceptable, on shorelines that were heavily oiled. As soon as the heaviest oiling - the so-called "gross contamination" was removed by the hoses and omnibooms, the balance tipped away from high pressure and hot water. By the middle of 1989, it was obvious that some other method would have to be used if the cleanup was to continue past the initial, rough washing program.

Solvents and chemical cleaners

Exxon's first attempt to get past the limitations of hot water washing (and perhaps, some of its harsh effects), was to propose the use of a chemical cleaner called Corexit 958OM2. This was, essentially, kerosene with most of the aromatics (the most toxic components of petroleum products) removed, plus some detergents. The substance was a modification of the dispersant that Exxon had attempted to apply during initial on-the-water response. Exxon said it looked at 40 potential chemical cleaners from several different manufacturers before settling on Corexit, which is manufactured by Exxon.

Corexit never got past the testing stage, for many of the same reasons that relegated hundreds of other products to the file cabinets during the *Exxon Valdez* response. It had not been tested, scientific data on its toxicity were either thin or incomplete, and it had operational problems. In addition, public acceptance of a new, widespread chemical treatment was lacking. To landowners, fishing groups, and conservation organizations, the idea of dumping chemicals on hundreds of miles of shorelines that had just been oiled seemed much too risky - especially when there were other alternatives.

Like the earlier public flap over dispersants in April and May, the bitter arguments about Corexit were based, in part, on Exxon's insistence that it had an answer to the oil spill and the government was obstructing progress. A high-ranking Exxon executive bitterly complained to a U.S. Senate subcommittee in July that despite overwhelming evidence of Corexit's effectiveness, the State of Alaska would not allow the chemical to be sprayed. The executive said he wasn't sure Alaska even wanted the spill to be cleaned up quickly,(46) since the DEC wouldn't grant approval to use Corexit.

Again, like the dispersant debate, the issues and facts about Corexit were not as clear and easily defined as any side would have liked.

Exxon's experts stated that the toxicity was low, the cleaning efficiency was high, and their ability to recover the chemical and oil was good. State and federal environmental scientists (including DEC, Fish and Game, and EPA) felt that the toxicity information was limited and incomplete. Both governments agreed that Corexit took oil off the rocks, but neither felt that Corexit was much more efficient or less disruptive than hot water. And most observers had serious questions about the ability of Exxon crews to contain and collect the oil-water-Corexit mixture that washed off the rocks into the water. In most of the 1989 tests, Exxon used more chemical - in at least one case, twice as much chemical - as it could actually recover.

Did Corexit get oil off the rocks? The answer, according to state and federal observers, was yes, although it worked better under dry conditions.(47) Could Exxon recover the mix of water, oil and Corexit once it was in the water? Not so well, the government observers said. "There is little evidence to indicate that an appreciable amount of washed oil (let alone the applied Corexit) was recovered after the test applications," the EPA reported.(48) State and federal observers reported that Corexit tests generated a reddish-brown plume that sneaked outside containment and absorbent booms and was difficult to recover.

Federal and state agency staff, including EPA and the state Department of Fish and Game, were not satisfied with the limited information available on the toxicity of Corexit. The existing tests told regulators something about the acute effects of Corexit, but they were silent on the effects of longer-term exposure - a critical point if Corexit were to be used in large quantities covering hundreds of miles of various wildlife habitat. There was also little firm information about the longer-term effects of a mix of Corexit and oil on wildlife - again, a critical point, considering that Exxon had not demonstrated its ability to contain and recover what it washed off; the elusive reddish brown plume was troubling.

In short, the public and the governments were uncomfortable with allowing a chemical dispersant to be sprayed throughout hundreds of miles of the spill area because no one could prove that the chemical could be recovered. Crews would have to be retrained, a monitoring program had to be developed and implemented, and a new concern about worker safety would enter the picture.

No one, on either side, could claim that the existing test data in 1989 supported his position without equivocation. But like most major cleanup decisions, this one hinged on more subtle, less technical points. It was part science, part risk assessment, part operational, and part practicality. Test data were just a part of a complicated judgment call.

From the standpoint of operations, Corexit was far from a sure thing. When the chemical-oil-mix came off the beach and went into the water, conventional skimming equipment had difficulty picking it up and absorbent booms didn't necessarily soak it up. On August 28, Exxon applied 73.8 gallons of chemical to a test area and could recover less than 42 gallons of oil-water-Corexit mix; the next day, Exxon applied almost 60 gallons of chemical and could retrieve less than 42 gallons of mix. In both cases, the reddish-brown plume escaped from the testing area, and no one could tell how much of what got free into the ocean was chemical and how much was oil.

"Another disturbing observation was that [Corexit] appeared to carry oil into the water column ... and we have little assurance about its toxicity and/or knowledge of its ultimate fate in the marine environment," EPA's observers wrote.(49)

And it didn't seem to work well when it was raining - a serious drawback in rainy Prince William Sound.

NOAA maintained that washing with Corexit would be less harmful than washing alone, since the solvent worked at lower water temperatures. It was an interesting theory, but there was nothing in the science that suggested that hitting marine life with a solvent and 100-degree water was significantly less harmful that hitting the animals with 160-degree sea water alone.

And finally, from the standpoint of public policy, allowing a company to introduce many, many thousands of gallons of chemicals over many hundreds of miles of Alaska shorelines - based on limited scientific and public review - seemed irresponsible, especially when there was nothing to suggest the chemicals worked any better than sea water.

The question came down to this: If hot water washing, manual pickup, and other existing methods did an acceptable job of cleaning within an acceptable range of side effects, why gamble the rest of the cleanup on a chemical that hadn't been shown to be much less damaging or much more effective?

Exxon never retreated from its position that Corexit should have been used. The Coast Guard, meanwhile, sent mixed messages. On September 10, 1989, the federal on-scene coordinator told Exxon that he wasn't convinced Corexit was effective,(50) yet within a few months, the Commandant of the Coast Guard would lobby the Alaska Governor directly to approve Corexit in 1990. Federal on-scene coordinator Ciancaglini was also quoted in a March news story urging use of Corexit during 1990 cleanup.(51)

Exxon continued to press its case for using Corexit in 1990. The debate stumbled along on the same legs as before: toxicity and operational efficiency. The toxicity argument against Corexit got somewhat weaker and Exxon's ability to recover the stuff got somewhat stronger.(52) DEC approved limited testing at five sites that summer, with the intent of finding out whether Corexit could be used as a spot washer, rather than a blanket treatment.

The 1990 tests provided little new information to decision-makers. The state's observers of a July 14, 1990 test reported that a Corexit-and-water wash again proved to remove more weathered oil than washing with water alone.

DEC's Judy Kitagawa observed in a memo to her supervisor that "this is the seventh Corexit 9580 demonstration I have observed" since 1989. She reiterated her observations of the chemical's effectiveness in a brief passage that betrays some weariness with the exercise.

"We already learned from the 1989 trials that COREXIT plus hot water removes oil better than hot water alone and that COREXIT/oil mixtures are difficult to contain and collect from water. All agencies agreed with this last year. The demonstrations of spot washing with COREXIT in July, 1990 have reconfirmed this," she wrote.(53)

A second DEC monitor agreed with Kitagawa's evaluation, writing that "Corexit was unquestionably superior in removing oil from the bedrock surface." (54)

But each monitor made additional observations that suggest, once again, that decisions about technology and evaluations of effectiveness in oil spill response are made within the context of conditions and risks existing at a given point in time.

State monitors observed that applying Corexit, followed by a wash with hot water, was certainly a good cleaning combination. However, it took a long time. A Corexit application, followed by a waiting period (the stuff had to soak in to be effective) and a wash, took about 90 minutes; washing alone took 15. Was it worth the wait?

And Kitagawa observed that using Corexit to spot-wash tarry oil took oil off rocks, but it put oil and chemical into the nearshore area - in short, it took a stable environmental problem and made it a mobile environmental problem. Was it worth it, in environmental terms?

There was never much of a doubt that Corexit could remove oil from oiled shore lines. There were doubts about whether it could be contained and recovered, and there were doubts about whether it was toxic to marine animals, and if so, to what degree. Given this set of facts, different government observers came to very different conclusions about whether Corexit should be used on the *Exxon Valdez* cleanup.(55)

State agencies shared both operational and ecological concerns. Fish and game officials were wary about introducing the chemical into nearshore areas without a better handle on its shortand long-term effects. DEC had similar concerns, but based its decision primarily on the fact that Exxon used too much chemical to recover too little oil; Corexit didn't appear any better than washing.

Federal government's officials had mixed opinions. The Coast Guard wasn't sure the Corexit was much better than hot water washing, and the EPA was concerned that Exxon's inability to contain Corexit and clean it up could put oil and chemical into the water. NOAA's John Robinson in 1989 vigorously promoted the use of Corexit, which in his judgment would speed up the response. He was concerned that the slow-moving cleanup effort would leave oil to harden and weather over the winter, making it difficult to clean.(56)

But really, the differing opinions were not really based on whether the chemical was or was not a good cleaner. Rather, each observer was heavily influenced by individual assessments of risks (from the oil as well as the chemical), the range of other choices that were available (hot water and high pressure vs. the chemical), assumptions about time (whether all cleanup would end in September), public accountability (whether the emergency allowed the governments to circumvent their responsibility to consult the public about putting a chemical into the environment), and other public policy issues.

Cleanup decisions have a context beyond science and technology, and the Corexit issue was no different. In 1989, the public agencies directing the cleanup concluded that Exxon's chemical was not a better alternative than the methods available at the time. In 1990, they reached the same conclusion. Nothing in the tests suggested to the state agencies that dousing beaches with a kerosene-based solvent was any better than washing (1989) and mechanical and manual removal (1990). It wasn't any faster, and no one could prove that it was any less harsh than washing. It added something new to the environment, and presented additional containment problems. It raised more questions than it resolved.

Mechanical treatment

Backhoes, tractors, front-end loaders and other small and large mechanized units were used on shorelines primarily in 1990, and to a limited degree in 1991. In most cases, there was nothing especially complicated about the work; it was generally a mechanized magnification of what workers were doing by hand. Front-end loaders scraped up and removed large tar and asphalt patches (such as at Aialik Glacier Beach on the outer Kenai Peninsula coast); tractors pulled thick, steel tines through concentrations of buried oil to release them (an excellent example was the work at beach segment LA20,(57) in Sleepy Bay, on Latouche Island); backhoes dug up pockets of heavy, buried oil or pulled oiled sediments from high intertidal areas to mid-intertidal areas for either removal or bioremediation (KN405, on Point Helen, on Knight Island and other places).

There was little dispute about the crude effectiveness of mechanical equipment: It moved a lot of material that could not otherwise be moved by hand. The state favored wider use of mechanical equipment based on the risk-benefit analysis that has been discussed throughout this report. The federal government (and to some degree, Exxon) began resisting wider use of mechanical equipment in mid- to late summer of 1990, largely based on the risk-benefit conclusions reached by NOAA.

However, there was some agreement about what the machines could do well, assuming one accepted the short-term disruption the machines caused.

On cobble beaches with moderate slope (such as the LA20 example), a small tractor pulling steel tines of various depths could agitate the sediments and release large amounts of buried oil, particularly if the tilling was done on a rising tide, when water lifted the oil out and made it easier to collect. On beaches dominated by small or midsize boulders,(58) a backhoe was very effective at pulling back larger rocks so workers could either scoop or shovel mousse into buckets or bags for removal.

Backhoes and other equipment were used to "pull down" oil and oily rocks that were stranded in the high upper intertidal areas where storms and high tides had left berms far up the beach. The method became known as "storm berm relocation," and was generally accepted as a good way to expose oil to weathering or bioremediation [see next section]. The oil had wound up in these upper beach areas largely as a result of high tides and storms that occurred in 1989, when oil was on the water.

There were ways of increasing the efficiency of a mechanical operation - such as tilling on a rising tide only - but Exxon and the Coast Guard thought this impractical, since staying at a site and waiting for the right tide cycle prevented a crew from moving to a new site. In addition, in some cases, oil was stranded so high on a beach that tilling on a rising tide could only be done during the few times during a month that tides were running higher than average. This, as well, was viewed by Exxon and the Coast Guard as an unacceptable scheduling and logistics problem.

Storm berm relocation, while generally accepted as a legitimate method by all parties, occasionally highlighted differences in approach between the state and federal governments. The state sometimes favored mechanical treatment that removed the oil: As long as one was going to send a piece of heavy equipment to a shoreline, why not make it one that could remove the pollution?

Exxon and the Coast Guard preferred an approach that simply exposed the oiled sediments for limited removal, weathering, bioremediation, or all three. They argued against large-scale removal first because of fears that the removal would promote erosion. When that proved later not to be a problem, they argued against it because it caused logistical and disposal problems they found unacceptable.

And overarching all these operational arguments were the concerns about mobilizing oil into the environment by tilling it with heavy equipment. NOAA, in particular, thought that heavy tilling could take an unacceptable, but relatively stable problem (buried oil stranded below the surface) and turn it into an unacceptable, mobile problem. The concern was that oil could be released into the water where it could, for example, disrupt an area fishery, or cause fine, oily sediments to migrate down into the lower, unoiled intertidal zone.

The state viewed all the counter arguments - logistics, oil mobilization, etc. - as valid concerns, but generally DEC and other state officials felt that quality work and good timing could alleviate some of the more pressing environmental concerns. In some cases, the state and federal government found common ground; in others, it didn't. Generally, everyone viewed mechanical treatment as a high-impact treatment that made sense at some sites based on which risk-benefit conclusion one tended to favor.

Bioremediation (59)

The limitations of large-scale washing and the shortcomings of solvents like Corexit highlighted the emerging fact in 1989 that if an extensive and area-wide cleanup program were to continue, some other technique would be necessary. The U.S. Environmental Protection Agency (EPA) proposed in May and June of 1989 to try and speed up the natural rate of degradation of the oil by applying fertilizers to rocky shorelines. The general term for this type of cleanup is bioremediation.

The idea of using some kind of artificial stimulus to speed up the natural breakdown of pollutants had been around for some time, although the idea began to have some limited application in the 1960s and early 1970s. In 1967, the famous cruise liner Queen Mary was permanently moored in Long Beach California. At the time, it contained about 800,000 gallons of oily waste water in its bilge. Contractors used bioremediation techniques to break down the hydrocarbons in the bilge water, and the owners received approval to discharge the bilge tanks after six weeks of treatment.(60) Other field experiments and trial applications over the course of the next 20 years included efforts to improve the quality of underground water sources and contaminated soils by applying biotechnology.

Most of these early efforts had one major thing in common: The work was done largely within the confines of a closed or controlled system. Under those kinds of conditions, a scientist or contractor or engineer could tinker with the variables that optimize the effectiveness of the treatment. Controlling temperature, nutrient levels, and other physical factors can have a tremendous effect on the results. The *Exxon Valdez oil spill* was a very different matter. Prince William Sound was anything but a controlled system. It was a wild, remote marine environment subject to extreme weather, big seas, 10-foot tidal changes four times a day, and seasonal swings in solar energy, temperature, and nutrient availability. The Alaska Bioremediation Project, as EPA called it, was an unprecedented exercise in applied biotechnological research, even if judged on nothing more than the area that was treated and the amount of fertilizer that was applied.

As noted before, the *Exxon Valdez oil spill* was hardly the best time to embark on a broad program of research and development of oil spill response technology. However, a targeted program for a specific technique or product was possible. At the EPA's urging, and with funding from Exxon under a special technology development agreement, bioremediation became the focus of the effort.

There is nothing magic about bioremediation, especially in the form it took during the *Exxon Valdez.* Crude oil was a good candidate for bioremediation, primarily because of its chemistry. In terms of volume, about a third of the oil is made up of light, volatile gasses that evaporate fairly quickly; the middle third (or more, in some crudes) is made up hydrocarbons that can be broken down relatively easily by natural forces, and the last third or so is made up of compounds that are more resistant to quick degradation: waxes, asphalts, and so on.

Chemically, the oil breaks down naturally for several major reasons. Exposure to sunlight and air causes some degradation, and some is the result of microbial activity. The microbes don't actually "eat" the oil; the image of bugs chewing up chains of molecules and spitting out the leftovers is not quite right. It is more like they make the chains "rust out." The microbes use carbon in various biochemical ways; as they pull carbon out of the chains of molecules that make up the different parts of the oil, the chains fall apart. They break down into their basic elements. So the theory behind bioremediation of crude oil is simple: If you put more microbes to work on this process, you will get faster degradation.(61)

To test this theory, EPA put up about $5 million, Exxon committed additional funding, and the state threw its staff and support into a high-speed research project.

The project could take one of two basic approaches: a) inoculation, in which vast numbers of oil-degrading bacteria would be introduced into the ecosystem, or b) enhancement, in which the existing microbial population would be boosted by the addition of various nutrients.

The process was neither well-explained nor well-understood, particularly by the public, and particularly at the outset. Most people envisioned a kind of biological warfare, in which new, engineered bacteria would be unleashed on the environment. To the public, this conjured up the image of the Mutant Microbe That Ate Prince William Sound, as out-of-control bacteria overwhelmed an already-stressed environment. Even as late in the spill response as the spring of 1991, a national news reporter would describe the bioremediation effort as a process of spraying millions of oil-eating microbes on the shores of Prince William Sound.(62)

That was not really what was proposed in 1989. Although EPA considered inoculation, researchers rejected the idea primarily because Prince William Sound already seemed to have a good population of oil-eating bacteria. Not all kinds of bacteria are hydrocarbon degraders, but it turned out that Prince William Sound had the right bugs - about five percent of the basic microbial population.(63) This relatively high level of degraders in the "unfertilized" population was there, researchers think, because of natural drips of turpentine-like hydrocarbons coming from the spruce-hemlock evergreen forest of the Sound. It was a fairly good scientific bet that the increase in available carbon - the spilled oil - would cause a jump in the hydrocarbon-degrader population in the area anyway. But if the overall population of bacteria could be multiplied exponentially, then the modest, natural increase in oil-degraders could be turned into a population boom. The EPA-DEC-Exxon project would not use artificial means to put more oil degraders into the existing population. Instead, crews would simply boost the overall bacterial population; five percent of a billion bacteria is much more than five percent of a million.

The best way to stimulate microbial growth was to add nitrogen and phosphorus to the available nutrient mix; the best way to put nitrogen and phosphorus out there was to spread fertilizer. The research team narrowed the choices down to Inipol EAP22, a French-manufactured liquid fertilizer, and several kinds of slow-release pellets or briquettes. On July 31, 1989, Exxon began applying fertilizers to oiled beaches at Green Island. By the end of the cleanup season, somewhere between 74 and 110 miles of shoreline had been sprayed or peppered with fertilizers.(64)

The three months from conception to widespread approval and application for a new oil spill cleanup technique was extremely brief - especially one that introduced chemicals and massive doses of additional nutrients to an open environment. EPA started scouting for field test sites in May and conducted lab tests in June. It started a 90-day field test at Snug Harbor, Knight Island, on June 8 - but approval for widespread use of fertilizers came barely halfway through the test to determine whether fertilizers worked.

In fact, when both the state and federal government gave tentative approval to the use of fertilizers, the program stood on a few lab tests, thin field test data, and literature searches that gave only limited evidence about whether the fertilizers were toxic. There was virtually no broader ecological analysis about what the addition of all those nutrients might do. There had been no public hearings and no real opportunities for independent scientific review of the data. On the day Exxon submitted its proposal for area-wide use, there were not even any accepted guidelines for application.

This was an unusual process for approval, to be sure, but the state and federal governments were operating in interesting times. The alternatives, beyond hot water washing, were limited. The oiling, even after washing, was substantial. Frustration was high, and expectations were low. Suddenly, it appeared someone had found the answer to the problem.

In July, after a month or so of treatment at Snug Harbor, the EPA project leaders produced what has become known as the "postage stamp" photo, an aerial shot of a clean rectangle stamped on a black background of oiled beach. While EPA could not conclusively prove that this "striking disappearance" of the oil from the rocks was due to bioremediation, they found 30 to 100 times more microorganisms on the treated plots than on the unfertilized plots.(65)

A second field test was conducted in July at Passage Cove. On July 25, following application of Inipol, EPA toxicologists collected water samples and brought them back to the lab. There, they ran standard acute toxicity tests on several kinds of marine animal larvae (a stage of development at which one would expect animals to be most sensitive to pollution). The preliminary results from the toxicity tests suggested that Inipol could be harmful to small marine animals, but it could be mixed in weaker solutions. So, the conclusion was not that Inipol was "safe," in the broad sense of the word; the conclusion was that one could apply the chemical in solutions weak enough to both accelerate degradation and minimize harm to marine life. In addition, the EPA data suggested the risk to animals would disappear fairly shortly after application perhaps a day or two. The relative risk was high immediately after application, but dropped off steeply after that.

What decision-makers had, therefore, was another incarnation of the same basic cleanup balancing act: Most methods (including leaving the oil alone) had risks that accompanied the benefits. How badly one wanted or needed results drove one's judgment about how much risk was acceptable.

State and federal scientists on a joint research and development team sat down with Exxon to come up with guidelines for a large-scale field trial of bioremediation. The group decided that fertilizers should be applied only to certain kinds of shorelines, primarily those where beach hydraulics and tidal flush provided a good opportunity for the runoff to be diluted.

They also made some practical decisions about application methods. The sprinkler system used at Snug Harbor appeared to deliver the best results; the slow, steady, light wetting of the surface by the sprinkler allowed a slow and steady release of nutrients from the solid fertilizers. The group decided, however, that this was impractical on a large scale. They settled on two basic methods. The first was application of Inipol using backpack tanks and spray wands; the second was spreading of Customblen pellets using the kind of hand-held whirler used to spread fertilizer on suburban lawns. These methods would be refined over time, but they stayed basically the same.

The next step was to train supervisors to make sure the Customblen was properly weighed and measured, that Inipol solution was properly mixed and maintained, and that workers knew what they were doing and were properly protected. The Customblen didn't present much of a problem, since the pellets could be easily weighed and workers simply needed to spread the stuff evenly within a specified area (essentially "x" pounds of Customblen over "y" square feet of shoreline). Worker safety was primarily a matter of keeping the pellets from direct contact with the skin, since Customblen, like most garden fertilizers, irritates the skin and can cause a fertilizer "bum."

The Inipol was more of a problem. The solution included more than just a nitrogen- and phosphorus-based fertilizer, because there was more to bioremediation than simply delivering more bugs to the work site. The foundation of the process was the increase in the microbial population, but the additional components of the Inipol were needed to keep the microbes on the oil.(66) These additional components included butoxyethanol, which when fresh can be harmful to both marine life and humans. The butoxyethanol evaporated relatively quickly (within about 24 hours), but it was important to keep wildlife away from it during that period. Workers had to avoid breathing or absorbing the fumes through the skin.

The solution also included the surfactant laurel phosphate, sort of a detergent,.that tended to produce a dispersant-like effect if the Inipol were sprayed too heavily or mixed too "rich." When workers applied the Inipol improperly, it would actually wash oil off the rocks. A telltale sign of this mistake would be clean streaks striping down an otherwise oily rock. During the 1989 trial application program, some poorly trained work crews didn't understand how and why bioremediation was supposed to work, treating the Inipol as a beach cleaner instead of an additive.

Inipol also had to be kept flowing at the right level of viscosity. In the cool climate of Prince William Sound, left to itself the Inipol would get thick. It had to be heated gently and its temperature and mix maintained.

The R&D committee considered these scientific and operational questions, and put the proposal before the Interagency Shoreline Cleanup Committee, the interagency review group that included fishing and conservation public interest groups. The ISCC approved the guidelines, as did the Regional Response Team. Exxon received formal authorization from the Coast Guard to proceed on August 1, although Coast Guard officials had already told Exxon the federal on-scene coordinator would approve bioremediation as quickly as possible.(67)

It is important to note that no one had confirmed that bioremediation was effective on the rocky shorelines of Prince William Sound. Both the state and the federal government expressed their intention to revisit the bioremediation issue in 1990. A decision to put fertilizers "in the toolbox" (to use the response vernacular) would be based on whether the 1989 trial program produced data that supported the hypothesis that fertilizers were both safe and effective. The burden of proof -and the responsibility for collecting the necessary data - would be on Exxon.(68) EPA would also be involved to a large degree, since more complete analysis of the Snug Harbor and Passage Cove studies during the 1989 season would be available over the winter of 1989-90.

However, the momentum behind bioremediation grew considerably after the 1989 trial application. By January, even without complete reports on 1989 activities, the Coast Guard and NOAA were banking on bioremediation, as was Exxon. The materials prepared by all these organizations for the principal winter planning meeting in February, 1990, made strong claims about the effectiveness of bioremediation (Exxon and EPA), dismissed most concerns about the possibility of any adverse ecological effects (Exxon and EPA), or identified bioremediation as the best treatment option because of it was assumed to cause little disruption to shorelines (NOAA).

Exxon's researchers claimed, based on their laboratory studies, that Inipol worked not only on surface oiling, but also on subsurface oiling as deep as one foot into the beaches.(69) NOAA recommended that bioremediation be a "primary option" for treatment, especially in sheltered areas that could suffer the most ecological disruption from "overly aggressive" cleanup.(70) Hap Pritchard, one of EPA's lead researchers on the project, concluded from the 1989 field tests that there was only one reason to explain the differences between test plots and (unfertilized) control plots, and the reason was that the added nutrients enhanced degradation .(71) Shortly thereafter, Pritchard and a colleague, Chuck Costa, began a speaking tour of the major communities in the spill area. They expressed their enthusiasm about the 1989 tests and advocated for use of bioremediation in the coming season.

It was clear that the state and general public had a different understanding than the federal government and Exxon about the status of bioremediation as an approved cleanup technique for widespread use in Prince William Sound. The state expected both Exxon and the EPA to produce for review - not only for principal agencies, but also for the Regional Response Team and the public - completed reports on effectiveness and toxicity. At the time that EPA's Pritchard was calling bioremediation "the only reasonable response technique" for the 1990 season (72) DEC had not received the information it had requested.

This presented a significant communications problem. The public was being presented with bioremediation as *afait accompli* for 1990, a primary treatment that would be used throughout the spill area. However, DEC insisted that the issue had not yet been resolved. Members of the public, including commercial fishing groups, Alaska Native landowners and subsistence users, local governments, and conservation groups, were confused. Some were outright skeptical. It appeared to them that a decision had been made with no more information than before, and no consultation with affected resource users. State agencies became concerned that the bioremediation bandwagon was rolling forward without stopping to properly consider the problems and the questions from 1989.

"Whereas NOAA identified bioremediative treatment as a primary option for the 1990 cleanup, the state considers bioremediation as only one option that may be useful and that treatment decisions will have to be made on a site-specific basis," state on-scene coordinator Steve Provant wrote to his federal counterpart on Feb. 15. "NOAA's recommendations should acknowledge that land owners, land managers, resource managers and user groups, including state and federal agencies, do play a legitimate role in making site-specific assessments and decisions on the treatment methods.(73)

The state and public concerns about bioremediation could be separated into three categories: procedural problems regarding the approval process, differences in approach to the cleanup, and gaps in the scientific knowledge about bioremediation.

The state still expected the bioremediation question to come before two important committees: a) the Interagency Shoreline Cleanup Committee, which had reviewed and approved the previous year's bioremediation program, and b) the Alaska Regional Response Team (RRT), which, under the National Contingency Plan, had to be consulted about the use of new technologies by the federal on-scene coordinator. It should also be noted that in the RRT, the state had critical authority regarding the approval and use of chemical cleaners such as dispersants or Inipol, the fertilizer. As plans for the 1990 cleanup season unfolded, the state was concerned that the federal government was, by design or by misunderstanding, going around two critical groups of resource users and owners.

NOAA's recommendation that bioremediation be a "primary treatment" had more to do with the agency's basic approach to cleanup than with any specific claims about the effectiveness of the fertilizers. The agency generally favored a strategy of leaving stranded oil to weather naturally (with some exceptions), but if various parties preferred to go ahead and actively treat a site, the relatively light touch of bioremediation was best. NOAA's 1990 cleanup recommendation specified that fertilizer treatment should cease if it turned out that the boost from fertilizers was no better, or only marginally better, than natural rates of degradation.

This was another example of a basic difference between state and federal responders: Based on its priorities, NOAA felt it acceptable to leave more stranded oil than did the state, based on its priorities.(74)

"It is apparent from this recommendation that NOAA does not support actual oil recovery ... but instead recommends that oil be merely exposed to microbial degradation or the effects of future storms," the state Fish and Game department wrote in its comments on the NOAA plan. "The state should clearly object to this proposal on the basis that significant quantities of oil still remain, and treatment should continue if technologies exist to allow further recovery without undue harm to the environment."(75)

This position is one of the first hints of what would become a major cleanup disagreement over bioremediation in 1990. The state would insist that bioremediation was a finishing step, the last treatment after all other efforts to remove the oil had been exhausted, either because the technology was played out or the removal was becoming too disruptive. By establishing bioremediation as the "primary. treatment throughout the spill area, the spill responders would miss an opportunity to get the pollution out of the environment altogether, the state felt. The state resource agencies agreed unanimously that agreeing to this federal policy would mean agreeing to do less than state regulations required.

As a technical and scientific matter, there were still large gaps in what was known about bioremediation, and major questions that had not been addressed. Both Exxon and EPA said repeatedly that no adverse ecological effects had been "observed," but visual observation was not the same thing as scientific inquiry. Fish and Game noted that the existing data did not even begin to address questions about long-term effects of dumping thousands of gallons of liquid fertilizer and thousands of pounds of solid fertilizer into the Prince William Sound ecosystem.

Finally, the federal government was assuming approval of bioremediation without considering a detailed set of operational and wildlife protection guidelines. NOAA and Exxon were offering up fertilizers as the treatment of choice, but they hadn't demonstrated that they could get the fertilizers to the oil. The public, particularly commercial fishing groups, were especially concerned about what they considered a high-speed rush to use fertilizers.

The state didn't oppose bioremediation, but it certainly favored a more cautious approach. State officials also felt that any major policy choice, such as this one, had to include the fishing groups and subsistence users of the spill area.

Federal officials appeared to construe the state's caution as potential obstruction or opposition. On March 23, Coast Guard Commandant Admiral Paul Yost met with Governor Steve Cowper to press for state approval of both bioremediation and Corexit. Cowper said the state would make its decision by May 1, in time to make plans for the 1990 cleanup.(76)

Misunderstandings had risen to such a level that on March 30, 1990, state and federal officials called a kind of summit meeting in Anchorage to discuss bioremediation policy. The meeting included some of the highest-ranking public officials working on the spill: DEC Commissioner Kelso, Deputy Federal On-scene Coordinator Captain Dave Zawadski, and Dr. John Skinner, deputy assistant EPA administrator. Also present was Jack Lamb, a leader of the Cordova fishermen's union.

Kelso laid out the state's position. No, Alaska did not object to bioremediation; the state merely needed all the available information, it needed time to review it, and it needed to include key public interest groups in the decision.

EPA agreed to provide all its toxicity testing information in time for the state to meet its May 1 decision deadline; one of the most important toxicity analyses was then in progress. Exxon agreed to provide the state with all its study papers; several were not complete at that time. The most important study concerned effectiveness of bioremediation on subsurface oil - a critical piece of the puzzle, since Exxon and the Coast Guard were, at that time, widely assuming that bioremediation would be the treatment of choice for subsurface oiling.(77)
Kelso said that based on what the state knew at that point, he was assuming bioremediation would be in the toolbox for 1990. However, he added, the state would require better operational guidelines - before application started - and it would also require a scientific monitoring program.
During April, DEC, working with the University of Alaska Fairbanks, convened a group of independent reviewers to look at the available information on the Alaska bioremediation project. The reviewers generally felt that the technique was still worth pursuing, and that it could probably go ahead safely with good operational and monitoring controls.
On April 26, Governor Cowper gave the go-ahead for state approval of bioremediation for 1990, but the decision was contingent on the development of the monitoring and operational guidelines DEC had suggested. After six weeks, he said, the state would reassess both the performance of the application teams and any new scientific information that had become available. The state felt this approach balanced the need for new approaches to dealing with the stubborn oiling conditions with the need to assure the public that the product was safe.
At the end of the six-week "conditional" application program, DEC gave approval to continue applications on July 20,1990. However, the DEC approval was largely a formality, as fertilizers had become a common and accepted part of the treatment program. Bioremediation would, however, remain controversial.
Throughout the 1990 season, state monitors clashed repeatedly with the Coast Guard and Exxon over the issue of when a shoreline was ready for fertilizers. The rule was that bioremediation was primarily a finishing technique, to be applied when conventional removal efforts were complete; the work orders from the federal on-scene coordinator usually followed that general rule. However, in the field, monitors battled with each other's somewhat subjective assessment of when conventional removal was "complete." This on-going struggle led to higher-level consultations and an aborted effort by the DEC to set a standard that was more scientific and less subjective. The state eventually found a way around this problem, and there were few conflicts about fertilizers in 1991.
But for all the assurances that bioremediation caused no adverse ecological effects, and for all the claims that fertilizers had worked in 1989 and would work on subsurface oil in 1990, both the state and federal governments gave their approvals based on very limited scientific data. It was not until the winter of 1990-91 - nearly two years into the project - that the governments began to assemble more convincing scientific justifications for actions they had already taken.
As time went by and more scientific monitoring was done, the toxicity question would be answered fairly definitively. Dr. James Clark of EPA concluded, based on his field tests, that the acute toxicity of the fertilizers (Inipol, particularly) was

limited, and that the pulses of ammonia released by the fertilizers, and mixed in the nearshore waters, were well within established EPA water quality standards. Clark's conclusions were backed up by independent reviewers hired by DEC in 1990-91.(78)

However, the state Fish and Game Department still favored a cautious approach to using bioremediation in and around salmon streams, and other fisheries habitat. The toxicity tests and literature search done by Clark gave a general picture of the problems one might expect, however, they did not (and could not, really) draw an accurate picture of how bioremediation might affect eggs, fry, and so on at different critical times in the growth cycle. They also could not take into account the margin of error presented by variabilities in the training of crews, their efficiency and their accuracy during application. For these and other reasons, Fish and Game continued to take a conservative approach to bioremediation near critical habitat and set up buffer zones around streams. Treatment could generally be timed to coincide with the narrow windows of time when fish and fry weren't coming or going. The department preferred to use those windows to get rid of the oil by removing it, rather than simply spreading fertilizers.(79) Actual removal was, theoretically, the best choice, since it removed one potential toxicity problem (oil) and eliminated the possibility of a second one (Inipol and Customblen).

EPA's Science Advisory Board, in reviewing the data from the Alaska bioremediation project in June 1992, came to similar conclusions regarding environmental safety of the project:

"Given the site-specific conditions of this Alaskan ecosystem, the timing of the onset of bioremediation, the limited areas of application and the limited application rates, adequate field information was gathered to conclude that the bioremediation effort would not negatively impact the Prince William Sound ecosystems.(80)

The next question is, of course: Did the stuff work?

The answer is probably yes, based on the assembled science. There is not widespread agreement, however, on whether it worked everywhere equally, whether it worked equally as well from year to year, and whether the rate of degradation achieved through the use of fertilizers was significantly higher than the natural rate of degradation.

First, let's deal with the general question of whether fertilizers worked, the definition of "worked" being determined by whether the addition of fertilizers accelerated degradation beyond naturally-occurring levels.

Everyone agreed that putting fertilizers on a beach caused a population boom for the microbes who already lived on the beach. The University of Alaska Fairbanks scientists doing the microbiology work on the joint research project were satisfied that boosting the overall population also boosted the population of hydrocarbon degraders. So far, so good.

The next part of the analysis was considerably trickier: Now that you had all these microbes, did they attack and break down the oil, according to the hypothesis?

The most convincing answer to this question would lie in an analysis of the changes in the chemical composition of the oil. If one could show that over the same period of time, oil on an unfertilized beach showed less chemical change than oil on a fertilized beach, one might be able to link the change to the microbes.

This was not so easy to do, for several reasons. First, there was a lot of "noise" to deal with, in terms of collecting and analyzing data. This science was being conducted in the middle of a treatment zone, so while scientists tried to start their analysis using oiling conditions that were similar to each other, there was a certain unavoidable imprecision in making that call. Next, while work crews were supposed to stay away from the bioremediation study sites, it isn't certain that they stayed away completely, or that their treatment of one section of beach didn't stray too close to the study sites. And as a practical matter, the control sites and the study sites were close to each other.

The bottom line in this regard is that any analysis of chemical degradation had to assume that the chemical composition (and concentration of oil) in any given of set of samples might not have exactly the same baseline. This is not a fatal flaw by itself, since all scientific studies have to deal with some assumptions of variability. Scientists get around this by taking enough samples that, based on standard statistical formulas, they have neutralized or minimized the chances that one set of samples will throw the whole thing off.

The researchers generally acknowledged in their monitoring study that, given the variables on the shorelines, a statistically bomb-proof result would have required many, many more samples from the study and control sites. This was judged to be physically impractical, especially given the time constraints under which they were working. It is important to note here that the state-federal-Exxon study was not intended as a research project for publication in a professional journal, but rather as a tool to give reasonable guidance to responders working under time and emergency deadlines.

Next, the laboratory techniques for chemical analysis (primarily gas chromatography) could not pin down the changes in the particular hydrocarbon - hopane - that would be the best "marker" of any true chemical changes.(81) Again, not a fatal flaw, since there are other hydrocarbons that can give reasonable indications of what might have been going on.

Researchers in the joint study, as well as the EPA Snug Harbor and Passage Cove studies, looked at other chemical hints that increased degradation might be taking place.(82) For example, they measured the levels of "by-products" of degradation - such as carbon dioxide - and compared results from test and control sites.

As time and analysis went on, scientists added up all the different hints from all the different studies and concluded there was a pretty good chance that fertilizers t made more microbes and more microbes meant faster breakdown of the oil. Policymakers looked at this information at various stages and, given the fact there weren't a lot of other available options, gave the go-ahead for the program.

The most optimistic supporters of bioremediation on the *Exxon Valdez* response say the fertilizers speeded up the process at least three-to-five times over naturally-occurring levels.(83) The lower-end estimates put the rate at one-to-two times faster.(84) And some reviewers looked at the DEC-EPA-Exxon study and said they could find no statistically significant difference between the data collected at fertilized and unfertilized beaches.(85)

An additional, extremely important question from an operational perspective was whether the rate was constant over time. Microbes take the path of least resistance, so to speak; they work first on those hydrocarbon fractions that are most amenable to degradation. As the chemical composition of the weathered oil begins to be dominated by waxes and asphalts, it is more resistant to degradation. That is not to say that it won't eventually break down. However, it is a reasonable hypothesis that since all fractions of the hydrocarbons do not biodegrade at an equal rate (pretty easy to prove, since the ratio of asphalts to total mass is higher in old, weathered oil than in fresh crude), one should not expect bioremediation of old asphalts to go as quickly as bioremediation of oil with more medium-weight residues.

The testing and research done on bioremediation should not be viewed as a quest to find the silver bullet for oil spills. If judged by that criterion, it fails. What we found is that bioremediation is a realistic option under certain conditions, and within certain windows of chemical opportunity. It has the best chance to give the best results under controlled circumstances, and on hydrocarbons in their fresher states. Interestingly, the research in Alaska also showed that at least in Prince William Sound, natural degradation rates could be higher than we ever suspected, thanks to the relatively large population of resident hydrocarbon-degraders.(86)

The rush to bioremediation in Alaska was a function of the size of the problem and limited availability of options. The EPA, the Coast Guard, and Exxon tended to overstate the results and benefits of bioremediation from time to time. Yet as time passes and reviewers sit back for less hurried analysis of the situation, a more conservative view of the project is taking shape.

The EPA's Scientific Advisory Board, a group of independent scientists from universities and laboratories around the country, takes a view of the Alaska Bioremediation Project that is roughly consistent with that of the state.

The board points out that the project produced a great deal of new knowledge, and provided some confirmation that bioremediation can work. However, the board cited in its report many of the same gaps identified by the state.

Specifically, the review board noted the problems in gathering data during the emergency response, the variability of sites and oiling conditions, and the ability to draw firm and broad conclusions.

"A large amount of useful data was collected by the Alaska Oil Spill Bioremediation Project," the reviewers wrote in 1992. "If these data are to be used to their fullest extent, rigorous interpretation is essential. Only in some of the field studies was convincing evidence of bioremediation obtained, yet many of the summaries and conclusions read the same."(87)

The Science Advisory Board concluded, however, that at least two of the four EPA Alaska studies proved that bioremediation worked to some degree. The board noted that it is difficult to pin down actual rates of degradation because the condition of the oil varied from site to site at the beginning of treatment. In addition, it was weathering all the while, and not necessarily at a rate equal among all sites. The EPA review is a cautious endorsement of the potential for bioremediation to work in marine oil spill shoreline cleanup. However, the results of the study do not necessarily prove that adding fertilizers to oiled shorelines speeded up the cleanup.

"The conclusion that bioremediation reduced cleanup time must be qualified in view of the high variability in oil chemistry at the sites, the fact that some beaches were prewashed and the fact that the oil was continuously aging and weathering during the bioremediation period. Moreover, the specific estimates of cleanup time in this report have considerable statistical uncertainty. Quantification of the effect of bioremediation is difficult because of the limited number of sites that received different treatments and the fact that the sites had different geological characteristics."(88)

The board further speculated that bioremediation has, perhaps, more promise as a treatment for subsurface oiling than for surface oiling conditions.

What all this means is that bioremediation was the subject of intense debate, some study, and probably yielded some results at some sites. It did not turn out to be the silver bullet that many hoped it would be.

Notes, Chapter 2

1 The State of Alaska, through DEC, has been one of the principal participants on an EPA sponsored task force designed to develop a national strategy for testing and approving a class of oil spill response products falling under the loose heading of "bioremediation. " See p. 73, this chapter for a more complete discussion of this technique and its possible future application.

2 Governor Steve Cowper, Testimony before the U.S. Senate Subcommittee on Environmental Protection, Washington, D.C., April 19, 1989.

3 Alaska Oil Spill Commission, "Spill: The Wreck of the Exxon Valdez, " January 1990, p. 56.

4 The Alaska Oil Spill Commission recommended in its report that a state research center be established within the University of Alaska system.

5Alaska Oil Spill Commission report, p. 5.

6 National Response Team report, The Exxon Valdez Oil Spill: A Report to the President, May 1989, pp. 8-9.

7Mousse is an emulsion of oil and water, the general consistency and color of its chocolate namesake.

8 Noerager, J.A., and Goodman, R.H., "Oil Tracking, Containment, and Recovery During the Exxon Valdez Response," Proceedings of the 1991 International Oil Spill Conference, at pp. 193-203.

9 Hull, R., Northwest EnviroService Inc., Final report, December 1990, p. 25

10 Bayliss, R., Janssen, J.H., Kegler, A., Kendziorek, M., Lawn, D., and Gundlach, E., "Initial State of Alaska Response to the Exxon Valdez Oil Spill, Proceedings of the 1991 International Oil Spill Conference," pp. 321-323. (Hereafter this paper is referred to as "Bayliss and others. ")

11 Various state, Coast Guard and Exxon documents.

12 The National Response Team report of May, 1989, relates as an example that a skimmer with a gear box problem had to be towedfor 12 hours to Valdez, where it joined two other skimmers in the shop as mechanics worked all night to repair the vessels.
13 Gardner, D., unpublished DEC internal report on cleanup operations, Exxon Valdez Oil Spill Response Center, 1991. Other DEC reports cite shorter waits for off-loading sometimes five or six hours - but the problem, from most accounts, was endemic.
14 There is widespread agreement among state and Exxon reports on the effectiveness of the Egmopol skimmer.
15 Various state and Exxon estimates say that pom-poms, the shredded plastic absorbents that look like things cheerleaders use, absorbed anywhere from 5 to 20 times their weight in oil and mousse.
16 The RRT is described in Section 1.1, p. 10 of this report.
17 Estimates such as these are not precise, but when properly computed they can give a reasonably accurate figure. To arrive at a figure like this, one first does a series of calculations to determine the area covered by the slick, the thickness of the slick, and the volume of oil contained in the slick. These calculations are based on observation, sampling, and known characteristics of crude oil. Variables can include the freshness of the oil (a third of afresh crude's volume can be made up by volatile gasses that evaporate quickly), the percentage of the slick that is watery emulsion, and any other physical factor that might affect the volume, area, or composition of the slick. From there, a simple multiplication exercise produces the estimate.
18 National Research Council, "Using Oil Spill Dispersants on the Sea, " National Academy Press, 1989, p. 4.
19 A ARCO A Alaska's Rill Wade, quoted in the April 18 issue of The Anchorage Times.
20 *Lawrence Rawl, interviewed in the May 8, 1989 issue of* Fortune *magazine, pp. 50-51. The magazine appeared on newsstands on April 24-25*
21 *Manuel Lujan, interviewed in the April 26, 1989 issue of* USA Today *p. I 1A. All quotes above come from that article.*
22 *Governor Steve Cowper letter to Lawrence Rawl, April 28, 1989.*
23 Lawrence Rawl letter to Governor Steve Cowper, April 28, 1989.
24 National Research Council, Committee on Effectiveness of Oil Spill Dispersants, Using Oil Spill Dispersants on the Sea, (Washington, D.C: National Academy Press, 1989), p. 4. More detailed discussion of this issue at pp 81-164.
25 Environment Canada, "Acute Lethal Toxicity of Prudhoe Bay Crude Oil and Corexit 9527 to Arctic Marine Fish and Invertebrates, " Report EPS 4-EC-82-3.
26 Hahn, B., memorandum to Commissioner Dennis Kelso, May 1, 1989.
27 Lawn quoted in Bridgman, J., unpublished department draft of DEC response history, Feb.1990.
28 The figures on available dispersant come partly from the National Response Team report to The President in May 1989, and partly from DEC records. Federal and state records agree that no aircraft or equipment were available in Valdez.
29 Hull, P. 24.

30 Hull, P. 30
31 "Valdez oil *Spill Technology: 1989 Operations," Exxon Production Research Company,1990.*
32 Robinson, J., NOAA scientific support coordinator, to members of the Alaska Regional Response Team, July 21, 1989. Robinson wasn't alone. A number of other coastal biologists were expressing informally that they had concerns about it and were getting this information back to the State scientists.
33 Juday, G, and Foster, N., "A preliminary look at effects of the Exxon Valdez oil *spill* on *Green Island Research Natural Area," Argoborealis University of Alaska Fairbanks, vol. 22, pp. 10-17.*
34 Houghton, I., *Lees, D., Driskell, W., and Mearns, A., "Impacts of the Exxon Valdez Spill and Subsequent Cleanup on Intertidal Biota - I Year Later," Proceedings of the 1991 International Oil Spill Conference, March 1991.*
35 Houghton, J., Lees, D., and Ebert, T., "Evaluation of the Condition of Intertidal and Shallow Subtidal Biota in Prince William Soundfollowing the Exxon Valdez Oil Spill and Subsequent Shoreline Treatment," NOAA Report No. HMRB 91-1, March 1991.
36Anchorage Daily News, April 10, 1991, page B 2, also "Report: Spill cleanup *method was harmful, " Associated Press report, Anchorage Times April 10, 1991, page* A 10.
37 Houghton, Lees, Ebert, p. ES-5.
38 This is somewhat of a generalization. A lot of factors can affect recovery, such as the health of the shorelines before the spill, the amount of oil spilled, the wave and wind action, the weather, and so on. The point, however, is that the extant literature includes a number of reputable sources that suggest an oil spill is not necessarily the ecological equivalent of a nuclear explosion.
39 Gardner, D., and others, "Review of field activities during the Exxon Valdez shoreline the treatment operations." Unpublished DEC review, Spring 1992, p. 17. Gardner was principal author, although all the monitors who worked from 1989 through 1991 provided field notes, observations, and general comments for the review.
40 Gardner and others, p. 18. the same kinds of
41 A massive state-federal coastal habitat damage assessment study ran into problems. In some cases, the researchers on this $19 million study cannot establish whether damage is from oil or oil and treatment together
42 *The most reliable would be the individual field notes of DEC monitors and the Daily Shoreline Assessment reports they filled out.*
43 *Kuwada, M- Alaska Dept. of Fish and Game Habitat Division, memorandum to Piper, E., Alaska Dept. of Environmental Conservation, Jan. 30,1991. Kuwada provided his department's comments on a draft of the report reviewed by ADF&G biologists several months before NOAA released the report.*
44 Kuwada memorandum, Jan. 30, 1991.
45 *Hull, Northwest EnviroServices, p. 35.*
46 *Testimony of William K. Stevens, Exxon USA president, before the U.S. Senate commerce committee's subcommittee on the environment.*

47 *Viteri, A., DEC, memorandum to Provant, S., DEC on-scene coordinator, August 12,1989. Also, Glasser, W. and Gangmark, C., EPA, memorandum to Vice Admiral Clyde Robbins, September 5, 1989.*
48 *Glasser and Gangmark, ibid.*
49 *Glasser and Gangmark, Ibid.*
50 *Vice Admiral Clyde Robbins, letter to Otto Harrison, Exxon, Sept. 10, 1989. Robbins disagreed with the state and other federal agency conclusions that Exxon hadn't shown it could contain and pick up Corexit as it washed* off *the beach. The language in his letter is interesting because it hints at the way many of these decisions hinged on various thresholds. Robbins wrote that Corexit wasn't a good alternative because, "there are no further heavily oiled beaches in suitable locations" for using the chemical, and that he couldn't tell from the tests whether the chemical was really effective. In other words, under different circumstances - i.e., a more desperate situation of widespread heavy oiling - the uncertainties about Corexit might be outweighed by the magnitude of the problem.*
51 Admiral Paul Yost lobbied Governor Cowper in person and in a letter in April 1990. Rear Admiral Ciancaglini was quoted in the Anchorage Daily News, March 31, 1990, supporting use of Corexit, "Beaches May Get Excavated," page A 1.
52 *See DEC's June 14, 1990 summary of the issue and discussion of all relevant facets; of the debate, signed by state on-scene coordinator Randy Bayliss.*
53 Kitagawa, J. memorandum to Kendziorek, M., July 16, 1990.
54 *Vincent, J., memorandum to Bauer, J., July 17, 1990.*
55 *Exxon's position never changed. The company simply maintained that the chemical was safe, that it was effective, and that containment and recovery were not a problem.*
56 *Robinson, J., memorandum to Vice Admiral Robbins, July 21, 1989.*
57 *Uniform abbreviations such as this were used for mapping purposes by the participating response agencies. The lengths of beach segments varied but were generally several hundred yards long.*
58 For some reason, the accepted unit of measurement for "moderate" boulders was the standard office desk chair.
59 This section looks at bioremediation primarily as it related to critical decisions about the cleanup. Many of the footnotes in this section give the reader some sources of more complete technical analysis of bioremediation.
60 *This is a second-hand citation from a federal report on bioremediation: U.S. Congress, Office of Technology Assessment, "Bioremediation for Marine Oil Spills - Background Paper," OTA-BP-0-70, Washington, D.C. 1991. p. 2. The original citation comes from Applied Biotreatment Association, "Case History Compendium," November 1989.*
61 *This is a grossly simplified statement of the theory, but it suffices as a preliminary introduction to the idea.*
62 *John Enders, Associated Press, in the Anchorage Times, May 15, 1991, page A 1.*
63 Dr. Ed Brown and Jon Lindtrom, University of Alaska Water Research Center, personal communication.

64 *It is extremely hard to come up with an exact "number of miles" treated with fertilizers in 1989, primarily because different mapping and recording systems counted a "mile of beach" in different ways. DEC's number is 74, and probably comes closer to the actual distance covered than the Exxon and EPA number of 110 miles. In any case, it was afield trial of unprecedented proportions.*
65 EPA Fact Sheet, Alaska Bioremediation Project, July 6, 1989.
66 A more technical description of this process would be "sequestering nutrients at the oil-water i . nterface," but basically it means using various chemical processes to optimize the effectiveness of the microbes once their population has been stimulated. To use a crude metaphor, Inipol is designed not only to create more microbes, but to make sure they keep their food right in front of them.
67 Letter, U.S. Coast Guard Captain Zawadski to Bob Mastracchio of Exxon, dated July 26, 1989.
68 Vice Admiral Clyde Robbins, letter to Otto Harrision, August 1, 1989. See also Viteri, A., and Kitigawa, J., DEC, "The Development of Policy to Review and Approve Bioremediation Enhancement Methods, etc." June 1990.
69 Exxon workshop materials, Newport Beach treatment workshop, February 1-2, 1990.
70 NOAA, "Recommendation to the Federal On-Scene Coordinator for 1990 Cleanup of the Exxon Valdez Oil Spill" January 25,1990, p. 9.
71 ADF&G notes, Newport Beach meeting, February 1, 1990.
72 Piper, E., memorandum to Governor Steve Cowper, April 26, 1990. Pritchard made this statement at a briefingfor state personnel in mid-February at DEC's Anchorage spill response headquarters.
73 *S. Provant, DEC, letter to Rear Admiral D.E. Ciancaglini, Feb. 15, 1990.*
74 See section 1.4, pages 30-32 of this reportfor a better idea of the role of the Interagency Shoreline Cleanup Committee on the cleanup, and on the basic differences in cleanup philosophy between the state and federal governments.
75 Kuwada, M., ADF&G, memorandum to Provant, S., DEC, January 29,1990. This statement from Fish and game is a good example of the different interpretations of pollution cleanup requirements described in Chapter 1.
76 Cowper did not make any commitments about Corexit. Also, Yost may have misunderstood the Governor's promise about bioremediation. On March 30, Yost wrote a letter to Cowper to recap the conversation between the two men. The Commandant thanked Cowper for agreeing to authorize *bioremediation by May 1, as opposed to the Governor's actual promise to render a decision by that date.*
77 EPA did not deliver the toxicity analysis until May 1; by that time the slate had gone ahead and made its decision without the promised information. Exxon did not deliver its third, and last, study paper on the topic until April 26, which was actually the day the issue came before Governor Cowper.
78 *Clark's basic conclusions were drawn from standard toxicity tests using water samples in the nearshore area of a bioremediation test site in 1989. His secondary conclusions were based largely on literature searches conducted over the winter of 1989-90. These analyses were not exhaustive, nor were they intended to examine the full range of broader ecological questions. However, for*

purposes of designing a controlled, conditional program *of fertilizer use, state and federal officials felt they had enough information to reasonably make a decision. Dr. Judith Capuzzo of Woods Hole Oceanographic Institute reviewed Clark's data (which appeared in a larger, joint EPA-Exxon-DEC study) and came to the same general conclusions. Capuzzo did her review at DECs request.*
79 On those occasions when Fish and Game felt bioremediation was the best option available, they would sometimes allow fertilizers to be applied right up to stream banks, as long as the application occurred during one of the "open" windows for treatment.
80 EPA Science Advisory Board, "Review of the Alaskan Bioremediation Oil Spill Project," Washington D.C., August 11, 1992.
81 Exxon took the data back to the computer in 1992 and produced what company researchers feel is confirmation that the hopane ratio did change significantly at fertilized sites vs. unfertilized sites. But this information was unavailable at the earlier, critical decision points on bioremediation.
82 *Exxon also conducted some laboratory studies using various simulations of beach conditions, which lent some support to field data from other studies.*
83 *Roger Prince of Exxon and Hap Pritchard of the EPA take this position. At times, each has hypothesized that the rate might have been even higher at certain sites, and under certain conditions.*
84 *Brown and Lindstrom of UA-Fairbanks generally hold to a more conservative estimate than their colleagues at Exxon and EPA. A number of reviewers we consulted at a 1991 EPA symposium in Las Vegas leaned towards more conservative estimates, as well.*
85 Dr. Scott Kellogg of the University of Idaho and Dr. John Farrington of Woods Hole, whom DEC asked to review the study, came to somewhat similar conclusions in this regard. They were not asked, however, to review all available data and give DEC a recommendation about whether it was a good idea or bad idea to bioremediate. What we wanted from them was a realistic look at the single study, so that the state could keep its conclusions in perspective, and so that the joint study alone was not presented as definitive "proof' of certain rates of degradation.
86 *Lindstrom, of UA-Fairbanks, also suggested that the seasonal fluctuations of nutrient levels in the Sound might be a factor in deciding when to bioremediate. In the spring and early summer, when the flush of mountain snowmelt carries high concentrations of organic nutrients into the system, natural degradation rates might be very high. As an operational issue, that may mean it is an excellent time to bioremediate, or it may mean there's no need to bioremediate; it would depend on the oiling conditions and other factors. In the late summer and fall, when nutrients levels drop, fertilizers might provide an important boost, but one might not expect even a fertilizer-aided rate to be very high.*
87 U.S. EPA Science Advisory Board, "Review of the Alaskan Bioremediation Oil Spill Project," June 1992.
88 Ibid., p. 3.