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EXXON VALDEZ

Cleanup Technology Workshop

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Hilton Hotel,
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Hazardous Materials Response Branch
Ocean Assessments Division
Office of Oceanography and Marine Assessment
National Oceanic and Atmospheric Administration
Seattle, Washington 98115

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Introduction

On August 8, 1989, NOAA recommended a winter program to the Coast Guard that would provide a foundation for determining the nature of cleanup work to be undertaken on Alaska shorelines in the spring and summer of 1990. Although NOAA does not claim any special expertise in the technology of oil spill cleanup, such a workshop, attended by representatives of agencies involved in the EXXON VALDEZ spill response, could be a useful tool in achieving a consensus. This workshop provides a good opportunity to review the oil spill cleanup technology that might be applicable in 1990.

The objectives of this workshop are to:

- present all ideas and recommendations possible for cleanup activities in 1990;
- strive toward reaching a consensus of activities to be pursued; and
- update data on the status of the shoreline.

This workshop will be divided into three sessions: physical technologies will be discussed on the first day, chemical technologies on the second day, and biological technologies on the third day. A number of background papers have been provided to promote discussion, and approximately one hour will be devoted to open discussion among the invited participants at the end of each topic session. A panel discussion will then be convened on each topic.

Physical Technologies

The first presentation was made by Dr. Jacqui Michel, Ph.D. in Geochemistry from the University of South Carolina. She is director of the Environmental Technology Division of Research Planning Institute International. She has been a member of NOAA's Scientific Support Team since 1978, worked on the EXXON VALDEZ spill throughout the spring and summer of 1989, and is now the technical consultant directing NOAA's winter studies program.

Dr. Jacqui Michel

Dr. Michel gave a slide presentation on NOAA's study of Prince William Sound shorelines this winter. She noted that there are four other physical shoreline studies being done at this time, by the Alaska Departments of Environmental Conservation (ADEC) and Fish and Game (ADF&G), Exxon, and the National Park Service, with stations distributed within Prince William Sound and Western Alaska.

The common components among these studies include topographic profiles, which include surveys of estimated percentages of oil coverage, measurements made of sediment characteristics, trenches dug to measure oil penetration, and samples of hydrocarbon levels which are documented by photographs and videos. Some of the special studies being undertaken are:

- two-dimensional mapping of oil on the shoreline at Exxon study sites;
- surface and subsurface sampling at 33 other Exxon sites, where they are also making visual observations;
- a walking survey by ADEC in September (ADEC generated a map of oil distribution as of the end of summer 1989 and has compiled an extensive beach profile database);
- surveys anadromous stream mouths by ADF&G.

NOAA's study includes the following programs:

1. Detailed chemical characterizations are being done at every station. Two surface and two subsurface samples are been taken to be analyzed by gas chromatograph/mass spectrometry (GC/MS) at every station each month.
2. Some of the detailed chemical analyses will be conducted on samples taken in Western Alaska.
3. Collection and correlation of data on storm activity and establishment of meteorological stations.

4. Three winter study periods have been completed thus far, the last being November 7. The next study period will begin December 5; monthly surveys will continue until the first week of March.

5. The study sites are located throughout Prince William Sound to obtain a variety of different sediment characteristics, as well as different degrees of oil contamination, treatment, and exposure.

NOAA has set up meteorological stations at a variety of locations, including stations at Lone Tree Island that have been working all summer; a National Weather Service station at Seal Island, which has been operating all year; a new station on Danger Island (south of Latouche Island), which began transmitting data on November 6; and a station at Cape Resurrection station, which began transmission on November 3. All data are now being archived and maintained by the National Weather Service and can be obtained from the Alaska State Climatologist, Robert Diaz.

Dr. Michel noted that the most obvious changes in oil distribution were noted on east-facing shorelines, while inland tidal zone environments showed the least changes.

1. Latouche Station -- Heavily oiled with no treatment. Oil penetrated to approximately 50 cm. There was a significant change in October in the decrease of the thickness of oil, even though the coverage remained relatively the same; there was an oil stain versus an oil covering. In November, the surface cobbles on the shoreline were cleaner; however, oil contamination persists below that surface layer.

2. Point Helen Station -- This station was established in September following treatment of the beach; it appeared that further oil contamination of the shoreline occurred after the cleanup crews left. Oil penetration at this station was approximately 50 cm in the middle of the beach face. There was very little change in the beach profile in October or November in either the distribution of surface oil or the depth of penetration. However, there was evidence of re-oiling from the oil that had penetrated deep into the subsurface material.

3. Sleepy Bay Station -- Except for the berm, there was very little change in the beach profile over time, even though this is a fairly open area that is exposed to northeast winds and strong wave action. The September survey showed this beach to be very heavily oiled; penetration was over 50 cm. In October and November, the surface was much cleaner due to heavy mobilization of the surface material by wave action, but the oil depth was still greater than 50 cm. There was a significant reduction in the percentage of oil coverage between the September survey and the October and November surveys.

4. Perry Island Station -- This relatively exposed gravel beach showed very heavy surface oil. In all three surveys, very little change was observed in the distribution of oil.

5. Herring Bay Station -- The September survey showed heavy surface oil with penetration to a depth of 20-30 cm. The October and November surveys show very little change in either the distribution or depth of the oil.

Dr. Michel discussed the overall chemical characterization of the oil. In the September sampling, the surface oil showed weathering and biodegradation; subsurface samples showed a much lesser degree of weathering. However, this general pattern can very extensively. For example, the surface oil observed in October at the Herring Bay station showed a higher degree of weathering, but in November, samples showed much fresher-looking oil. NOAA concluded that there was a significant potential for variability in the samples, as well as a potential for re-oiling as the subsurface oil works to the surface.

Because of their high toxicity level, naphthalenes and phenanthrene are the oil compounds that are of concern biologically. These compounds showed changes in relative distribution over time in both the surface and subsurface samples due to weathering and microbial degradation of the compounds. Light-weight compounds degrade at a faster rate than the heavier carbon compounds.

Dr. Michel concluded that there has been some removal of oil from exposed shorelines and very slow removal of surface oiling on the sheltered shorelines since September. The degree of surface and subsurface removal is very limited and any change is due to direct wave action. There is a lot of evidence of biodegradation, particularly

on the surface. Monitoring will continue throughout the winter to determine the toxicity level of the oil in the surface and subsurface material in the spring of 1990, and the physical and chemical properties that will influence the effectiveness of various treatment technologies that will be evaluated in 1990.

Question: Will you be able to compare your results in Prince William Sound with studies ongoing outside the Sound that are using similar chemical analyses?

Dr. Michel: Yes, because they are using similar survey methods. NOAA offered to do the detailed chemistry on samples from Western Alaska so that we can participate in these programs.

Question: Do you have any studies ongoing at this particular time to determine the toxicity levels other than in substrata oils?

Dr. Michel: No, but many past studies and literature address that issue.

Question: Jacqui, because of the variability that you see in the oil, how many samples provide the data for the graphs that you're showing us? How many deposits or how much volume did you sample to get those figures?

Dr. Michel: Those graphs are for individual samples, but they are representative of what we have found. We have 18 stations and collect four samples per station per survey, so we'll have over 500 GC/MS data just in Prince William Sound. I hope that will give us the kind of broad coverage to extrapolate some of the more detailed work that you're doing in some of the EPA bioremediation sites.

Comment: We have 21 samples from within a small plot, and we have enough variability so that it's hard to tell any trend from within one small plot, so it's difficult to see how four samples from the site will indicate trends over time that are extremely dramatic.

Dr. Michel: It's going to be complicated, but we've seen a big difference so far if you look at all the surface and the subsurface samples.

Comment: We're seeing the same kind of trends.

Dr. Michel: That's what you would expect to happen, but we do expect to see the rate of biodegradation slow down as the microbes start trying to degrade these higher molecular weight, more resistant compounds. So, all the excitement over all the biodegradation that occurred this year -- we may be a little disappointed next year.

Question: You keep talking about biodegradation as a main cause of the change in the composition of the oil. Is it only biodegradation or can you account for change by means of other mechanisms?

Dr. Michel: Well, photo-oxidation is going to be a very important process. I don't know enough about the rates of those two to tell you which is dominant. When I say biodegradation, I probably should be saying degradation because it's biological, physical, and chemical degradation action.

Comment: It's interesting to see your observations concerning the subsurface oiling of the beaches. As part of the EPA team, we sampled one of the beaches to depths of five feet and we found little, if any, oiling at those depths. It appears that there's going to be a lot of variability in the oiling depth.

Dr. Michel: It is complex and we don't have all our data yet, but the depth of penetration does vary. The deepest that I think people had found was at Sleepy Bay, with four feet of penetration. The average penetration in other places is a function of the sorting of the sediments on the beach or at the shoreline. So, oil penetration varies from zero to four feet.

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Dr. Erich Gundlach is a consultant to the Alaska Department of Environmental Conservation. He has been active with the EXXON VALDEZ incident, advising on shoreline impacts since the second day of the spill. He has been involved with the investigation of oil spills since 1975.

Dr. Erich Gundlach

Dr. Gundlach's slide presentation compared the METULA spill in Patagonia with the studies being done in Alaska. The METULA spill was about twice the size of the EXXON VALDEZ spill. In the views of the area five years later, Dr. Gundlach observed that a subsurface band of oil still remained, indicating the longevity potential of substrata oil in the sediment itself even though the surface looks clean. The formation of asphalt or pavement slabs, where the oil and cobble have mixed and formed a hardened crust along the beach, is a common factor of the METULA spill, the AMOCO CADIZ spill, and what is now appearing in impact areas of the EXXON VALDEZ spill.

Slide views of the EXXON VALDEZ spill were shown, beginning in April with the heavy oiling; in September, which showed the areas to be cleaner, but stained; and in October at one of the salmon streams that had no cleanup activity and no wave energy to remove the oil from the sediments. Virtually no change could be detected at this site.

Dr. Gundlach discussed ADEC's program of identifying the oil locations. In September, after the cleanup activities ceased, the primary focus of attention was a detailed walking survey composed of three vessels and a crew of about 20 people. This survey concentrated primarily in Prince William Sound over a five-week period, and covered approximately 700 miles of shoreline. Detailed segment maps were produced noting oil concentrations, geomorphic beach types, and oil penetration within the sediments.

This information will be published as a map showing the oil concentrations and as a tabular summary of the observations (type of oil and depth of penetration) to delineate the areas of highest penetration for consideration of work to be done next spring. These maps, and surveys consisting of over 1,100 pages, are expected to be available in December 1989.

Another continuing ADEC survey is a detailed analysis of 22 stations within Prince William Sound. This is done by helicopter and a 30-day vessel cruise, as well as monitoring by way of biological transect, collecting chemical samples, and a diving survey. This will continue until approximately December 10, 1989. In mid-January 1990, these stations will again be observed by helicopter. Other areas of focus are Seward, Homer, and Kodiak.

The last activity being undertaken now is an aerial reconnaissance of the spill sites within Prince William Sound. Observations will include the natural cleansing process of wave activity during high tides where oil is being forced up to the surface from the subsurface concentrations. No tar balls have been detected in the hatcheries, a main source of concern, although limited tar balls have been observed in the Homer area.

Question: Can you discuss further the weathering of the asphalt?

Dr. Gundlach: I don't have specific observations from those sites in the Homer area yet, but I would suggest, based on the previous studies, that it is very difficult to weather. Essentially, the oil is not on the upper part of the beach where the wave action would break it up. In the Homer area, the oil is down in the low tide terrace; it's on one of the offshore islands, as a matter of fact, so it would make it very difficult, even though there's high wave action there to break it down. It's several inches thick which, again, makes it harder to erode. Essentially, there's an asphalt pavement on this place.

Question: Erich, have you had a chance to be out in the field the last week or two?

Dr. Gundlach: No, I have not. I'm about three weeks behind. However, in those three weeks after the storm, I've seen the breakdown of the upper berm, which is where the oil is usually the greatest. There is on the order of 30 to 50 cm penetration within the beach. Storm waves will break this berm and redistribute those sediments, which is quite common. Where it gets more complicated is when it's oil in that beach face itself, and that doesn't change much over time.

Question: Can you compare any data from the Cook Inlet spill or other spills that have happened in Alaska, or has there been any data collected on these things that you could compare?

Dr. Gundlach: The comparison mostly has been not to the Cook Inlet spill, but to the METULA and AMOCO CADIZ spills. I think they're very good comparisons.

Question: Are there any data on the Cook Inlet spill at all?

Dr. Gundlach: There is, but I'm not sure about the shoreline impact. I haven't seen the myself.

Question: In terms of the oil that is being washed off, you said there are no tar balls in the hatcheries, for example. Where is the oil? Is it ending up in the subtidal sediments?

Dr. Gundlach: Technically, we don't know. For the most part, you see a sheen coming out. In previous spills, the wave action tended to break down oil to disperse it into smaller particles and this was passed into the water column. In previous spills, we have not seen oil in the subtidal sediments. In the AMOCO CADIZ, there was substantial subtidal impact because of the tremendous wave action: 25-30 foot waves would bring this oil within the water column. We haven't seen this in Prince William Sound to date. That question may be answered by the diving survey, which is taking sediment samples. They're taking it off the primarily heavily oiled beaches now, these 22 sites.

Question: Erich, what percentage of that 700 miles that you've walked has high wave action?

Dr. Gundlach: I don't know yet. Another question is, How much is still heavily oiled, how much is moderate, and how much is light? Those sorts of analyses have to be done. Once we get the technical volume in front of us, we can start leafing through. I would like to suggest to Exxon and the other parties that not all the information is provided in the quick atlas, but as we start looking into certain areas, for instance the Upper Passage area, we might want to look at more data because we have some more subsurface penetration information there. This data could then be provided as an addendum or appendix to the atlas once we start looking at the generalized information.

Question: How long will it take you next spring, after you redo that atlas, to actually get it out on the street? Is it going to be summer before we see the spring version?

Dr. Gundlach: Well, it took five weeks to compile the data for 700 miles of shoreline, but I hope we don't have to do 700 miles again. I would imagine we'd do on the order of 50 or 60 miles, so I think we

could do it in several weeks. Especially, again, if Exxon and ADEC would jointly look at some of these beaches together so that we agree on the priorities for next year.

Question: In your beach walking survey, did you find a lot of garbage left over? A lot of manmade debris and so forth?

Dr. Gundlach: We noted a substantial amount of manmade debris left at every locality. We walked 540 segments and, out of that, I would say roughly 30% had material left. Maybe I shouldn't even say that many, but in the sections I walked there was usually some debris left, whether it was pom-poms all the way up into the trees on the upper beach or bag material. Our field crews collected a lot of it and brought it to the collection centers.

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Andy Teal discussed Exxon's view of the state of the shoreline. Mr. Teal is a biologist and physical geographer. He has been an environmental advisor with Exxon and their affiliate, Imperial Oil Company, for the past 11 years. Throughout the spill, Mr. Teal managed the Shoreline Cleanup Advisory Team (SCAT), and is presently coordinating the Shoreline Monitoring and Evaluation Team (SMET) for Exxon's winter program.

Andy Teal

Mr. Teal began his presentation with a brief description of Exxon's winter program. This program monitors and records the physical and biological changes at the oiled areas, and is intended to provide detailed information for the strategies and decisions that must be made for spring 1990 work. There are 19 professionals on the SMET team, including eleven Ph.D.'s and seven geologists with extensive glaciated coastline and oil spill experience. Dr. Ed Owens is the senior advisor on the team. He has been involved with several oil spills and is a key member of the field program. There are a total of 64 observation sites distributed in Prince William Sound and the Gulf of Alaska: 28 sites in the Gulf of Alaska and 36 sites in Prince William Sound.

"A" Program: This is the most detailed survey being conducted. A series of transects are done along the shoreline to gather enough

information to address the variability of the sample data and create an accurate picture of present conditions. This averages out to approximately eleven transects per site for the "A" Program. Other key aspects are the surface oil coverage, subsurface observations, and test pits to determine the amount and depth of penetration. Work includes subsurface and surface sediment samples being taken for analysis of total petroleum hydrocarbons (TPH), detailed elevation profiles showing the elevation changes on the shoreline, biological surveys to evaluate the macrobiological changes and conditions, photographic and video documentation, and other general observations to help fill out the database for these sites.

"B" Program: This is a similar evaluation, although it does not include the biological component, detailed elevation, or sediment samples. The sites selected for this program do not involve as much time, and cover a broad range of energy exposures and changing conditions, with an emphasis on low-energy locations.

These teams are achieving an 80% success rate for site access on a monthly basis and are monitoring 316 transects (A and B) at this time. This creates a broad database from which to draw conclusions.

Mr. Teal continued with a slide presentation showing different aspects of the observation sites. He noted that the data sharing agreement with the State of Alaska and other agencies is not yet finalized. This agreement would enable a free exchange of data between the agencies to better reach conclusions and gain a better appreciation of changing conditions throughout the Sound.

Exxon's winter program sites are located in Prince William Sound, Kenai Peninsula, Kodiak, and Alaska Peninsula regions. Mr. Teal described some of the field observations of the high- and low energy activity sites currently being monitored.

High energy areas have shown the greatest amount of change; for example, substantial oil removal in the surface and subsurface conditions has been observed. Erosion activity is a key element in exposing and removing the subsurface oil. Some examples of total removal of visible oil in both surface and subsurface materials are in the northeast section of Little Smith Island, the north side of Smith Island, and Badger Cove and Gore Point in the Gulf of Alaska.

Slides were shown of the north side of Smith Island in the summer months and in October 1989. There has been significant erosion and removal of the sediments on this shoreline. Test pit indications showed that there is no subsurface oil along the transect area.

Low energy environments do not show as dramatic a change as the high energy areas, but there is weathering and thinning of the oil characteristics over time. Exxon has observed that the oil persists within three to six inches of the surface in these areas. There are isolated patches of asphalt, for example, on Applegate Island and in Marsha and Sleepy bays.

Asphalt formations occur where the right conditions exist, i.e., low energy, fine sediments, and sufficient remaining oil. The occurrences are infrequent due largely to the cleanup effort of the free oil. Slides were shown of asphalt patches, approximately two to four feet long, on Applegate Island.

Oil sheens along the shorelines and offshore can still be sheen. Monitoring, mapping, and trajectory models are being studied to determine the direction in which these sheens will move. At this time, it appears that any movement of the sheens and the ocean currents are in the direction of the Gulf of Alaska, into the open ocean, and should not be significant.

Observation of weathering processes, changes in the oil's physical characteristics, and thinning of the oil on the shorelines are also being monitored.

There has been a significant change in the high energy shorelines, due mostly to the storm activity in November that caused substantial removal of oil from a number of locations. Subsurface areas will continue to be monitored very closely throughout the winter. Low energy sites are showing improvement but there will be small, isolated patches of asphalt.

Mr. Robinson: Is there any reconciliation among the first three speakers [Jacqui Michel, Erich Gundlach, and Andy Teal] in terms of why we get this dramatic difference in these views of the situation? The issue boils down to subsurface oil. The first three speakers all agreed that the surface oil situation had changed fairly dramatically,

but there did seem to be quite a difference of opinion about what is happening in the subsurface. Is the difference in opinion based on the November sampling and the fact that you were in different locations? Do any of you have an explanation to offer that might help tie these three presentations together?

Mr. Teal: One of the key things that we're seeing is a high degree of variability. When you compare one transect to the next, you're going to get variability, so you need to have a series of transects in a particular area to get a good, broad perspective as to what's really happening on that shoreline. More importantly, the November storm activity did create significant change. Jacqui Michel had information for Smith Island prior to the erosion taking place on that particular site. So, the potential for variability and the November storms are keys to remember when we're comparing data.

Dr. Gundlach: I haven't got the data from November. But I think it's a very optimistic overview of what the problem will be out there in the springtime. I'd say that there are areas that are being cleaned. Smith Island was explained as a very positive and, in fact, a very high energy environment. On the other hand, I would state that there are going to be problem areas going into the springtime, and we should focus on those problem areas. A little optimism from the November survey may be warranted, but the likelihood is that there will be problem areas within Prince William Sound and other areas that we should focus on.

Comment: I've been back to some of the NOAA sites after the storm. I noticed a difference in the slides, in particular, Sleepy Bay, where I was right on the middle transect. There was a dramatic difference between her slides and what I saw last week. Obviously, the storm had a fairly major effect on the high energy areas. I visited about eight different sites in the Sound. The high energy areas, Smith most noticeably, Sleepy Bay, and the next bay over the creek, showed dramatic changes from what the slide was showing; incredible changes. It was obvious that the storm did very good work. The low energy areas, though, still showed oiling.

Question: Can you correlate the behavior of the oil and the degree of cleanup of the beaches, with the amount of treatment that was

done on those particular beaches that you showed us pictures of and which you discussed?

Mr. Teal: I think that's a key indicator that the effort that we did go through for several months of removing the free oil really did play a key role in allowing nature to remove the remaining oil. Removing as much of the free oil as possible allows the remnants to be more easily weathered, eroded, and removed. There is a correlation between intensity of effort and change in the shoreline conditions. Obviously, though, a key player is the high energy storm active areas where there is a lot of natural removal and cleansing. You can imagine the intensity from a big storm over the course of a few weeks; the resulting energy from the waves is very significant. What we're seeing now is the impact of that high energy.

It wasn't just north Smith Island where we saw these changes. In fact, Dave indicated similar kind of activity was taking place in Sleepy Bay and some other sites.

Question: How important was it to do an intensive cleanup of the beaches when nature actually accomplished more in these few weeks than expected?

Do you have any information on what the intensive cleanup did biologically? It looked good on your slides, but we didn't see what happened to the biota.

Mr. Teal: It was most important to remove the free oil to minimize the amount of oil remaining on the shoreline. One of the components of our "A" Program is the monitoring of the condition of the biota and the changes that we're seeing in that biota as far as recovery rates, etc. Obviously, we're in a winter period right now and from a biological sense it's not as active as it will be in the spring. We're seeing some rejuvenation in some of these areas. In fact, we're seeing recovery in some areas that received heavy treatment, including high energy areas where you wouldn't expect such recovery. A key issue that has to be weighed during any incident is How far do you go and when do you stop?

Question: I have a question regarding the removal of oil from the high energy areas. It appeared that the removal process was

primarily a function of erosion itself. What is the action that is responsible for the overall removal of oil from the low energy areas? You mentioned that you were very impressed with the small amount of oil that was left on these beaches.

Mr. Teal: The key is the removal of the free oil to start with. There are a number of processes obviously taking place out there from the physical, chemical, and biological perspectives. Nutrient additions also enhanced the biological activity. Obviously, there's been removal from that aspect. But when we look at those low energy environments, the remaining oil is in the surface sediments, which is the more active zone. We do get assistance from a chemical perspective as far as photolysis and chemical changes, breakdown, and weathering of the oil.

One of the keys is that we are seeing the thinning of that oil. It's not black and shiny like it used to be in the summer. Even though we call them "low energy" areas, these areas do have waves lapping in, so tidal action also assists in the washing effect in those surface sediments.

Question: A variety of speakers have compared removal by wave energy to "removal" by physically taking oil to a hazardous waste site. Coastal geomorphology typically referrs to "transport." Would you consider "transport" synonymous with what you're describing as the mechanical process of the waves?

Mr. Teal: Good point. As far as removal processes, we've got the coarse sediments moving back and forth and abrading against each other, removing the oil, and breaking it into minute particles. There's also the washing action, the exposure, and the removal and sheening that we've seen. Sheening is taking place, as well as dispersion of the oil particles throughout the water column. And, obviously, when that takes place, it is diluted very rapidly and you do get a distribution throughout the water column and, therefore, a rapid dilution effect. From a microbiological perspective, of course, that oil now becomes more biologically available for actual breakdown and assimilation. Those are two of the key things, the abrasion on the one hand and, on the other hand, the washing action, the sheening, and the dissipation of that oil throughout the water column.

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Dr. Ed Owens is a geologist from the University of South Carolina, formerly with the Geological Survey of Canada and the Coastal Studies Institute of Louisiana State University. He joined Woodward-Clyde Consultants in 1979, and became involved with oil spills when he was assigned to the Canadian Government Task Force following the ARROW spill in 1970. He is Technical Advisor to Exxon's shoreline cleanup assessment and monitoring and evaluation programs.

Dr. Ed. Owens

Dr. Owens' role in this workshop is to relate the relevance of some of his work to the Alaska situation. Dr. Owens discussed the Baffin Island Oil Spill (BIOS) experiment in which he has been involved since 1981. This experiment is part of a series of Canadian government programs related to the problem of stranded oil on shorelines in low energy, cold climate environments.

Dr. Owens gave a slide presentation on the natural degradation and persistence of oil. The processes involved are all associated with thermal, mechanical, and biological energy inputs to stranded oil. The actual processes that take place relate to evaporation, photo-oxidation, dissolution, and biodegradation. Other factors involved in the rate and importance of these changes relate to the physical and chemical properties, volume, and the surface area of the exposed oil. The factors that cause the most change in the early part of a spill are the inputs of mechanical energy, predominantly controlled by waves, tides, winds, and ice. When looking at what might happen in the future to oil from the EXXON VALDEZ, all of these processes need to be considered.

The fate of stranded oil is initially and predominantly dependent on mechanical action (waves, tides, and currents) that rapidly, in geologic terms, erodes, transports, and buries oil. This process can continue for at least a couple of years. Biochemical action becomes predominant after the mechanical action has ceased, and has a slower effect on the characteristics of the oil. The resident time of the stranded oil depends on the volume and type of oil, its location on the shoreline, mechanical wave energy levels, and rates of sediment transport of the oil.

Slides from the BIOS experiment depicted the changes measured over the period 1981-1989 at the site. Slides of the METULA spill depicted changes to stranded oil 5-1/2 and 12-1/2 years after the spill.

Dr. Owens compared data from five oil spills: the ARROW spill in Nova Scotia; the METULA spill in Patagonia, which was untreated; the AMOCO CADIZ spill; the BIOS experiment; and the EXXON VALDEZ spill. These incidents all occurred in cold weather climates and were all glaciated coast spills, with essentially the same ambient weather conditions in terms of air and water temperature, and the same sort of shoreline materials (a mixture of coarse and fine grain material).

Baffin Island is a very low energy site, with low wave activity. The stranded oil was left untreated to observe the natural effects of physical processes, and therefore, this study acts as a worst case scenario for an oil spill incident. In comparison with the AMOCO CADIZ spill, which dealt with a far greater quantity of oil, the significant amount of oil removed naturally was relatively the same.

Dr. Owens discussed the decreases in the percent of oil concentrations over time, coverage of the shoreline, and amount of oil remaining. Different parameters were used to define change, including the length of oiled shoreline, the area involved, and volume and concentration of oil. Depth of penetration into the subsurface sediments is an important issue; in Prince William Sound, shorelines characterized by fine-grained sediments (sand granules and mud) and marshes have shown low oil penetration. Below 40 cm is essentially bedrock and impermeable material, which was not expected. Permeable areas are not as extensive as first anticipated.

The data show that, even in these worst case situations, oil is removed naturally and, in the case of the Baffin Island experiment, changes are still taking place even after 17 open-water months. The AMOCO CADIZ situation is encouraging as the natural water treatment reduced 30% of the oil after about a year. Dr. Owens emphasized the need to avoid being side-tracked by anomalies; a high degree of variability is to be expected in the trend of natural oil removal. Changes in an untreated, low energy environment have been observed to be rapid and significant over a period of approximately 18 months.

Question: Was there subsurface data collection during the BIOS study?

Dr. Owens: Yes. The BIOS site is very similar to many of the low energy environments around Alaska in the sense that you have an armoring of pebbles and cobbles overlying the fine grain material; it has a low permeability. We found very little penetration in those sites, the same as we're finding around Alaska. You go down 20 cm and you're into a layer that was not oiled and is still not oiled. Early on in the BIOS experiment, in 1983 or 1985, we were getting surface concentrations of 25,000 milligrams per kilogram (mg/kg), one or two odd samples of 40,000 mg/kg surface, and under 100 mg/kg subsurface when we went down 10 cm. So, we weren't getting the penetration. What's happening now is that, although the surface of the cobbles is oiled and appears relatively clean, with just a few dots of oil, there is a one-millimeter thick layer of oil coating on the underside. So, there is a change in the way we look at things on that beach and on these beaches here. But there's not a lot of data about subsurface penetration because there wasn't a lot of penetration.

We've dug trenches and pits on all of the Gulf of Alaska sites. Our profile showed tremendous changes in elevation; we're digging pits half a meter or a meter further down than we were in the same locations in June. We're down almost two meters in some cases, as compared to when it was originally oiled. We're finding oil, of course, but we're not finding it deeply buried which is the key point.

Question: In your comparisons with BIOS, you brought out the fact that it's a very low energy environment. What role has ice gouging played in breaking pavement into patches? How might that apply to Prince William Sound where the shoreline freezes?

Dr. Owens: There's a good parallel. The beaches freeze during September and October in this geologically sheltered environment. They are now difficult to dig, but the pits are better because they're frozen. We have almost a cementation using water, which keeps the sediments bonded in place. At the BIOS site, an "ice foot" developed. This is a solid layer of ice, 20-30 cm, that can build up in low energy environments, but which acts as a protective layer. Seaward of the ice foot, there's a zone of tidal cracks between the shore-fast ice foot and the more mobile tidal sea ice. Essentially, nothing happens. The

oil is frozen, but is not gouged or otherwise reworked. Other beaches around the Canadian and Alaskan Arctic have ice push ridges, ice scour marks, ice gouge marks, and there you would have this sort of mechanical ice reworking. There was none of this at BIOS because of the cementation effect.

Question: To what level does the presence of oil affect the rate of erosion?

Dr. Owens: There tends to be a faster wave run-up. This is true of at least one site that I'm monitoring in our "B" Program. We're getting more reworking in the upper part of the inner tidal zone because the wave is no longer permeating as it runs up into the beaches, so it has a faster velocity on the higher part of the beach. This causes more reworking in the upper beach and speeding up erosion slightly on a small scale. We're only talking about sheltered environments, but it is helping.

Question: The BIOS study looks very good in that the oil has been removed from a particular beach. Do you know where the oil is going? It is my understanding that oil can be trapped either in subsurface sediments or in wind and wave action only to show up oiling another area as much as a year later. Do you have a response to that?

Dr. Owens: I only showed you one small aspect of the BIOS study, which was a very large, multi-agency international study. At times the BIOS study looked like north Smith Island in the early parts of this spill, but we did collect subtidal samples on transects out into the main part of the bay. We've taken some subtidal samples this last year as well, but I haven't got the data back from them. The 1983 and 1985 BIOS data show that, out of 18 samples in 1983, the mean concentration was 15 mg/kg (15 parts per million). The highest value was about 70 mg/kg, and of 34 samples that we collected in 1985, the mean concentration was 15 mg/kg. It was concentrated in a zone out to about the three-meter water depth, with the highest concentration at the three-meter subtidal contour line. The further out we went, the more significant the decrease in concentration levels. At a couple of hundred meters, levels were below detection limits for our methodology.

In the budgets that we developed, about four cubic meters of oil was removed from the beach between the initial oiling in 1981 and 1985. Out of that four cubic meters, we estimated that only .028 cubic meters of oil was left over an area of 37,000 square meters. The oil was transported out of the system into the larger fjord system that was getting flushed by every tidal cycle. Subtidal oil samples all showed high degrees of weathering, oxidation, and evaporation. The samples were very weathered and were all very small; there were no big patches of oil picked up, floated out, and dropped. It's particulate-sized matter. In fact, the divers didn't see any oil most of the time.

Question: What are the other aspects of the BIOS study that look at the effects of dispersant-treated oil? What was the difference between the treated oil and the untreated oil?

Dr. Owens: Our study was called Bay 11, which was the untreated site, and at the treated site on Bay 9 we stopped mapping right away because there was very little oil. The surface sediment samples from the next year, I think, showed almost negligible traces of oil in the sediments.

Gary Sergy: There was really very little dispersed oil in the tidal zone.

Dr. Owens: The oil that was released was a dispersant/oil mixture, so it didn't come onto the shoreline, which is, perhaps, more of the thrust of your question. However, we did other experiments on beaches that were treated with dispersants.

Question: How would you characterize the difference between the oil in the BIOS study and the oil spilled from the EXXON VALDEZ? What impact did that have?

Dr. Owens: The oil in the BIOS study was a lighter crude than the Prudhoe Bay crude spilled by the EXXON VALDEZ, an important difference. It was aged before we put it out there, so it was a little heavier than just the original crude, but the look and the viscosities are really not a lot different from EXXON VALDEZ oil. The mousse, where it formed again, was very similar. The difference was probably in the initial period of evaporation, dissolution, and dispersal. It was

a slightly lighter oil than the Prudhoe Bay crude, but that worked out of the system very quickly because of the heavier nature of the oil.

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Jim O'Brien is the president of O'Brien Oil Pollution Services, Inc. of New Orleans. He has been working in oil spill response since 1971, and has been involved in over 100 significant spills during that period. Mr. O'Brien is a past commanding officer of the Pacific Area Strike Team. His experience has been enhanced by response operations inside and outside the United States and includes tanker spills, pipeline ruptures, well blowouts, barge sinkings, and facility leaks. He has been the cleanup manager for numerous spill incidents that entailed shoreline cleanup and nearshore oil recovery, and has been involved in spill incidents in Alaska, including the GLACIER BAY spill.

Jim O'Brien
Following detailed literature search and interviews with other experts, Mr. O'Brien concluded that no technology, other than that which has already been considered, is available to facilitate mechanical recovery and cleanup of oiled shorelines. There is no single mechanical concept that will satisfy every situation confronting this spill or any other spill.

Mr. O'Brien discussed the necessary consideration of natural recovery when preparing a mechanical cleanup strategy. Inputs of energy and the properties of oil are critical in any type of mechanical application or physical cleanup methodology that might be approached.

Cleanup methodologies must minimize damage to the environment. The types of treatment methods that are presently available include:

- manual removal
- cold water flooding, although this method becomes impractical after time and weathering
- a combination of cold-water flooding with low pressure application to move the oil

- a combination of cold-water flooding with high pressure
- a combination of warm water with moderate to high pressure
- hot water flushing with hand equipment and vacuum;
- passive absorbents;
- vacuum systems;
- hot water injection;
- disking of sand beaches, referred to as "land farming";
- sediment removal;
- shoreline removal, cleansing, and replacement;
- relocation to the surf zone;
- burning;
- chemical treatment; and
- bioremediation.

Question: What are the passive techniques for capturing oil?

Mr. O'Brien: One of the methods that we used quite a bit during the summer was placing absorbent materials, such as the viscous sweep boom, the pom-poms, or absorbent boom, onto the shoreline or in the nearshore zone to capture the deposits of oil as they were transported from the beach. It's a limited technique.

Question: You didn't mention geotextiles. Do you have any feelings about those?

Mr. O'Brien: They are a potential tool to be evaluated.

Dr. Erich Gundlach

Dr. Gundlach gave a slide presentation depicting scenes from the AMOCO CADIZ spill in 1978 (seven times larger than the EXXON VALDEZ spill), which heavily impacted the village of Portsall, France. Trenches and pits dug to collect the oil and cart it away still show collections of oil eleven years later, and heavy use of equipment on the beach surface ground the oil deeper into the sediments. Views of Prince William Sound were shown to compare the two shoreline spill areas.

ADEC is looking at technologies and cleanup strategies for possible use in the spring, including

- reviewing types of equipment used—water pressures being used with the maxi-booms, temperatures, performance specifications, and effectiveness of the equipment;
- identifying areas where efforts should be concentrated and, once established, putting that reviewed technology to work and recommending the types of equipment to be used.
- considering appropriate treatments for these sites; and
- reviewing unsolicited proposals.

Some generalized guidelines to be considered:

- Focus on location of oil and determine areas of greatest volume.
- Determine methods for removing and capturing oil.
- Cleanup should not increase the persistence of oil.
- Review cautiously the possibility of trenching the beach or use of equipment; try to avoid mistakes made in the past.
- Try to avoid causing more biological damage than might occur if left to natural recovery.
- Removal of asphalt pavement with priority in the high recreational use areas in Prince William Sound.

Question: Why would recreation areas be selected over commercial subsistence?

Dr. Gundlach: There's not a priority. Excellent point. I think it was an oversight.

Question: Erich, can you focus on how we could gauge the effectiveness of the cleanup methodology?

Dr. Gundlach: That's a good question. I'm sure you've looked at it and we've tried it, too. The problem, like I mentioned, is that the technology has gone through different cleanups of spills that have hit the same beach. I think the quality of the crews that worked the beaches are also a very important factor.

It is possible, however, that we might be able to prioritize the technology for the different types of substrate. For instance, maxi-booms may be too much high pressure, too much flushing, and cause too many big changes of the environment. Now, we may be dealing with areas where oil is in smaller quantities and more isolated areas where smaller crews are necessary. I've tried to look back at the cleanup crews' work and analyze exactly what went on at each beach. It's a difficult task, especially once the crews went on twenty-four hour shifts.

Comment: I think there has to be some flexibility that says that's probably as good as we can anticipate we can get, and move on.

Dr. Gundlach: I agree. Inflexibility can lead to cleanup ceasing to be effective, which we did see on several beaches.

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Mr. Scott Nauman is a chemical engineer with Exxon. He graduated from the University of Southern California and started with Exxon in Los Angeles in 1979. His assignments have included Seattle, Lafayette, and New Orleans. He is currently an operations superintendent in Exxon's South Texas Production Division in Corpus Christi, Texas. This summer he served as Operations Coordinator for Prince William Sound and currently is the Winter Operations Coordinator for Exxon in Anchorage.

Scott Nauman

It is important to look back at the work accomplished this summer and put it in its proper perspective. His discussion and slide presentation focused on Exxon's experience in physical cleaning techniques as used on the EXXON VALDEZ spill.

Manual methods were applied predominantly in the Gulf of Alaska where the impact was primarily tar balls, mousse, and oil debris. This was very labor-intensive, concentrating on hand-cleaning with rakes and shovels. The debris was bagged and hauled away. Mechanical methods were also primarily used near the source of the spill in Prince William Sound.

Innovation and evolution played major roles in the use of cleanup equipment. The variety of mechanical cleanup techniques used to remove oil produced versatile equipment that very effective in the environment encountered. The integration of techniques led to the development of tools responsible for the effectiveness of three fundamental steps in the cleanup: removal, containment, and collection of the oil.

Four types of physical cleaning and equipment were used:

1. Cold water landing craft (LCV) -- Early in the shoreline cleanup, while the oil was still mobile, the first priority was to get water onto the beach and flush off the oil. This required vessels that could carry pumps, hoses, auxiliary equipment, and a 20-person crew. Because the shoreline in the Sound is rocky and often shallow, shallow-draft vessels were required. This craft permitted access to small coves, bays, and hard-to-reach areas. Over 60 civilian and military landing craft were used for this purpose.

   The deluge system was accomplished by pumps, hoses, and manifolds that flushed high volumes of water down the face of the beach. A perforated, flexible header, placed at the top of the shoreline, distributed water down across the beach. Crews worked down the beach with hoses, loosening the oil adhered to the rock and pushing it down to the water's edge. Self-contained pressure wash units provided low volume, high pressure water capability. This unit consisted of a generator,

pump, heaters, hoses, and spray wands, avoiding the need for an external power supply.

The LCV units were extremely effective and were considered to be a primary component of the cleanup effort.

2. Maxi-barge (warmwater washing) -- This concept was developed to add heat and increase the amount of water being applied to larger stretches of shoreline. There were 13 tug-assisted, oceangoing barges measuring approximately 50 feet wide and from 130 to 180 feet long, carrying a 50-person crew, and operating on a 24-hour basis.

   Some differences from the LCVs: Heat exchange units were added due to concern about scaling and corrosion by seawater in the boiler sections. Fire monitors were mounted to provide focused spray to those areas that were inaccessible to beach crews. Man-lift platforms were mounted to use equipment to increase the capability of delivering water to the shore by being able to reach 60-70 feet out from the barge.

   With the barge set up parallel to the shore, the water was heated and fed to a discharge manifold running along the barge and across the bow, using fire monitors and the man-lift with hoses attached to spray water onto the shore.

3. Omni-barge (warm water washing) -- As weathering changed the characteristics of the oil, this equipment was developed to enable application of a greater volume of hot water to the beach. This barge vividly reflected the innovation that was inherent in the development of shoreline cleanup equipment for the Sound, and was unique in that it was equipped with a hydraulic articulating arm that was installed on the bow of the barge deck and operated by remote control. This arm (typically used in construction work for pouring concrete) had a spray head nozzle attached allowing for spraying at different angles over 100 feet from the barge. As with the maxi-barge, this provided access to otherwise unreachable shoreline.

   At this stage of the cleanup, heating the water was a major priority. Initially, the omni-barges used hot oil trucks as a heat source. To increase the heat capacity, industrial direct-fire

heaters became the standard heating source throughout the cleanup.

Differences between the omni-barge and the maxi-barge were that the omnis were made by flexi-float cube construction which were joined together to form a barge. They were propelled by single or duel thrusters as opposed to being towed by a tug, and utilized a winch system enabling the barge to move in and out with the tide and move along the beach.

4. Two-pack LCV (warm water washing) -- This piece of equipment is similar to #1, but it was equipped to provide heat to the water flushing of the beach. This provided approximately half the heat capability of the omni-barge. Fire monitors with hoses were also mounted. More than 12 two-packs were involved in the cleanup over the summer.

Mr. Nauman reviewed the containment phase of the process. Once the oil was flushed into the water, primary and secondary booms were used. The primary boom was used to corral the oil as it came off the beach and herd it towards a skimmer. The secondary boom enclosed the vessel to prevent sheen from escaping and acted as a second line of defense. Absorbent booms were used with the containment booms to help reduce the loss from the primary system, reduce the sheen, and as a backup to the skimmer in recovering oil. Skiffs and beach crews deployed the booms.

The oil collection phase used several skimming devices. Skimmers were the primary means to recover the oil, as well as absorbent booms, pom-poms, and snare booms. The skimmer is a device that skims the oil from the surface of the water. There are different classifes of skimmers, e.g., absorbent, weir, and suction devices, all of which were used on this cleanup and were often used in tandem with each other. One example is the rope-mop skimmer, which is based on an absorbent principle. The rope-mop rotates around pulleys and is then squeezed through wringers that remove the oil from the rope. Vacuum skimmers were used where there was a particularly thick layer of oil and they could remove oil in bulk quantities. Regardless of the skimming method used, the goal was to capture the oil as it came off the beach into the primary boom.

Given all of the various types of equipment used, there is no one specific piece of equipment capable of handling the entire operation; it depends on the situation. From the experience gained on this spill, it was determined that a mix of equipment was needed for different areas and characteristics of the shoreline involved, and different types of equipment were deployed to match each circumstance.

In conclusion, never before has a situation occurred that required such a mixture of equipment. The combined capability of the heaters used could provide heat for a city of 500,000, and the amount of pumps used could provide enough water for a city of 1,000,000 people. Tools were developed to solve specific circumstances, born of innovation and necessity, and played a substantial role in the encouragement being noted today.

Question: What type of equipment was designed and used in the Kodiak and the Alaska Peninsula areas?

Mr. Nauman: Prince William Sound and the Gulf of Alaska are two different situations My experience was in Prince William Sound, where we relied on the mechanical cleaning, the omnis, the maxis, and the LCVs. We did not have omnis or maxis down in the Gulf of Alaska. We concentrated to a large degree on manual pickup in Prince William Sound. The effort in the Gulf of Alaska was by no means small. We did use landing craft, beach crews, and small, self-contained spray units on the landing craft. We didn't have the same type of impact in the Gulf as we found in the Sound and, therefore, we used different tools. But the difference was mainly manual pick-up as opposed to mechanical. We used both methods in both places, but outside the Sound we focused more on manual pick-up.

Question: Can you give us some detail as to what steps Exxon is going through this winter to decide what cleanup techniques to use next spring, and can you tell us whether you've done any assessment of biological damage and ecological damage associated with the various cleanup techniques, and give some idea of what the results of that assessment was?

Mr. Nauman: We're continuing to do extensive work throughout the winter. It's a misnomer to say Exxon left Alaska on September

15; there is a large number of people here and at other locations who are currently studying shoreline conditions.

It is difficult to match the tools to the job until you know what the job entails. There is a lot of work being done to assess changes in shoreline conditions. While there are some general trends that can be seen, it's evident that there's still a lot of studying that needs to be done to assess spring conditions. We've said all along that the culmination of that process will tell us what, if anything, needs to be done in terms of shoreline cleanup in the spring. I will say that there are Exxon operations people here in Alaska for the winter and I'm one of them.

We are looking at the techniques that were used in the summer. The State is studying these techniques; Exxon is trying to develop a better understanding of equipment efficiency, sorting out what was effective, and what will be effective given different circumstances. We currently have a staff here in Anchorage that is studying what we've done, and is spending time in the field looking not only at the tools I've just described, but also any technology that might be applicable. The key is to find out what's going to be there in the spring and that's something we're watching very carefully. We're encouraged by what we've seen. I don't foresee an effort like last summer.

We do have an extensive effort looking at biological impacts. We're trying to study all of the techniques that are available to us.

Question: Could you give us the name of someone at Exxon who might know more about ecological damage associated with cleanup techniques?

Mr. Nauman: I would call Al Maki.

Question: Did you have a chance to see the gravel washes that Exxon financed?

Mr. Nauman: Yes. I went into the field nearly every day. There are varied opinions on the rock washer. We didn't use rock-washing technology much in the Sound because of the physical nature of the shorelines. Perhaps the rock washer concept would be applicable to a

long stretch of cobble beach or smaller gravel type. However, it is very difficult to get rock washers and ATVs pulling plows on rocky cliff face, which constitutes most of the type of shoreline that we cleaned.

Comment: The use of rock washers was suggested in the Homer area, and in that area they also removed sediment. They obviously got their ATVs and their plows and their hand labor out there to move the rocks and they took them away.

Mr. Nauman: Yes, I'm aware of that. I think we share everyone's interest in evaluating all the methods, and those are methods that will be looked at.

Question: Do you anticipate, with the knowledge that you will be gaining on what worked best in different situations, that you could have a team which could visit any site and help anybody out and say, Here you should do this, here you should do that, or this is likely to work best?

Mr. Nauman: I think everyone who has been involved in the spill response has gained a lot of experience. I don't envision an Exxon response team being on call but there are things that we can share.

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Dr. Bob Hiltabrand is a Ph.D. in Geochemistry who graduated from Louisiana State University. He has 19 years with the U.S. Coast Guard Research and Development Center at Groton, Connecticut, in environmental law enforcement projects dealing with oil and hazardous chemical spills.

Dr. Bob Hiltabrand

In his presentation, Dr. Hiltabrand noted that it became apparent soon after the EXXON VALDEZ spill that various government agencies were concerned that none of the suggestions and proposals that were being received be overlooked. The Coast Guard Research and Development Center at Groton, Connecticut, was chosen as the clearinghouse for the incoming information and proposals being received from both state and Federal agencies. The Center's main function was to review the proposals and forward them to the

appropriate committees for evaluation, separating those with engineering and scientific merit. Originally, the R&D Center expected to receive approximately 200 proposals. However, as of November 14, 1989, 625 proposals, letters, and suggestions on how to handle oil spills have been received, and the database is not yet complete since information is still being received.

Each proposal received a control sheet that contained the address information, the originating point, the agency from which it was received, date received, category assigned, and a brief description of the proposal.

The different categories for response were:

Category A:

* A-1 letter. Review by interagency team for possible application to the EXXON VALDEZ. A letter was sent to the author advising where the proposal would be routed.

* A-2 letter. Review by interagency team for future research and development work; short term and long term.

* A-3 letter. All bioremediation or bio-related work went to the U.S. Environmental Protection Agency.

* B letter. Letters or proposals received that did not contain enough information for evaluation.

* C letter. Indicating a previous research application involving methods of research not feasible for the EXXON VALDEZ spill.

Category B:

* Forward to Exxon for action.

Category C:

* Letters of general concern.

Of the 625 proposals that have been received, 25% of the database (160 proposals) went into committee for future government investigation

and review; 22% of the database (139 proposals) was forwarded to Exxon. No single cleanup cure was determined from the proposals received.

At the same time, the R&D Center has been working with ADEC, who has also received proposals. Dr. Hiltabrand introduced Ed Meggert from ADEC to comment on the proposals being received in Alaska. Mr. Meggert said that ADEC uses the same guidelines as the Coast Guard. One hundred and one applications have been received and placed in the categories below:

6	Biological
27	Chemical
6	Consultant
14	General
43	Physical
3	Unknown

These are all in the process of being forwarded to the proper committees.

Question: What does Exxon do with these proposals?

Comment: Exxon also has a database of approximately 1,300 unsolicited proposals, which may include those from the Coast Guard. We have screened whatever is available. There was a big effort in that field to continue to look at that list. We've written letters back to the applicants telling them whether we're going to use it, whether it's applicable for this year's cleanup, or whether it's something that looks like it has potential for long-term research. Much of it was of that nature, but being applicable for this year's cleanup was the criteria.

Comment: I was part of the team in the early part of the work, and I'm sure that every one of the proposals was reviewed by a team of experts.

Question: How do you determine which proposals would be forwarded to government agencies for investigation, and which would be forwarded to Exxon?

Dr. Hiltabrand: As far as the Exxon proposals were concerned, they involved engineering and commercial capabilities that could be applied in a short period of time. Exxon may have had a need for it over the last three or four months. It wasn't a product that might require testing or an R&D effort. As far as the other agencies are concerned, it was quite evident that the bioreview and bioremediation-related proposals would go to the EPA. The long-range R&D and possibly even short-range R&D committee or agency would be composed of EPA, NOAA, the Minerals Management Service, and the Coast Guard, to review a wide description of those proposals that you see up there. A cross-section of interagency scientists will review the proposals.

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CDR Gary Reiter is currently the Commanding Officer of the Coast Guard Pacific Strike Team, his second assignment with the Strike Team (his first position was as Executive Officer). He was also Assistant Chief of the Coast Guard Pollution Response Branch in Washington, D.C. CDR Reiter holds a Master's degree in Marine Affairs from the University of Rhode Island.

Gary Reiter

CDR Reiter discussed the Coast Guard's perspective on the technology used during the cleanup. He began with a chronology and review of the use of equipment as the cleanup progressed.

Offloading from the EXXON VALDEZ. The offloading from the EXXON VALDEZ was handled in an excellent manner, although this was mostly overlooked in the total picture, as was the entire salvage project. The size of the spill was greatly reduced due to the efforts in offloading the remaining oil from the EXXON VALDEZ and the subsequent salvage operation.

Offshore skimming operations. During the actual event, skimming operations were highly criticized. CDR Reiter spent most of the first week after the spill occurred deploying the skimmers and getting the operation underway. The Coast Guard operated a barge that serviced other skimmers in the area by offloading oil they had gathered. The skimmers' efforts in maximizing the recovery greatly decreased the volume of oil that eventually came ashore. The actual recovery of approximately 15-20% was substantial compared to other spills with

more available equipment and less logistical problems, where only one or two percent of the oil was recovered (specifically, the Gulf of Mexico spill). Although not perfect, the overall skimming operations were successful.

Some of the problems with the skimmers were not enough knowledge and experience among operators, especially in later stages of the skimming operations; ignorance of skimmer capabilities (ancillary equipment was needed); most skimmers were vessel-of-opportunity skimmers, usually used aboard fishing vessels with minimal onboard tankage; slow offloading capability; untrained vessel operators; and limited accommodations for personnel.

Shoreline operations. The main turning point in shoreline operations was the decision limiting cleanup to treatment by removing the free oil rather than trying to clean shorelines to pre-spill conditions. If not for this decision, the area ultimately covered would have been greatly reduced, thus requiring more work this winter and possibly next spring. Exxon's shoreline operation was an impressive mobilization of personnel and equipment. Even more so was the logistical support system Exxon put in place for maintaining the shoreline cleanup operation.

CDR Reiter expressed some criticisms of Exxon's efforts. Perhaps less cleanup resources would have been more productive. In some instances, it appeared that more sheen was created by the hundreds of cleanup boats than from the oil spill itself. Another area of criticism was in the skimming and booming operations. He feels there needs to be some training done prior to their deployment both for operators and those responsible for oversight.

The Coast Guard's inspections of the shorelines throughout the cleanup were an effort to standardize the visual observations of the cleanup.

CDR Reiter feels that all parties involved in spring 1990 cleanup should have negotiations and decisions completed before work is commenced, and be ready to get the work done as soon as conditions permit.

Question: You said you recovered 15-20%.

CDR Reiter: That's a figure used during the oil spill. I think that's Exxon's figure. You recovered 15-20%?

Mr. Nauman: That was asked earlier and I don't have the exact figures, but I know it was over 10% early in June.

CDR Reiter: I think even at 10% it would be a lot better than the norm for most spills.

Comment: I just wanted to say that I appreciate that you praised the people involved in the salvage. It certainly was a mess, but they kept three times as much oil out of the Sound as there was in the Sound. I think they deserve a lot of praise.

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Gary Sergy is the manager of the Western Regional Office of the Environmental Emergencies Technology Division of Environment Canada. Mr. Sergy has been in oil spill research and development for the past ten years, and managed the Baffin Island Oil Spill project. He is now working in the area of effects of oil on shorelines, and was involved in the EXXON VALDEZ spill in April and in August in the SCAT office.

Gary Sergy

Mr. Sergy gave a slide presentation on activities in Canada related to further developing shoreline cleanup and spill response techniques, and suggestions for further activities for Prince William Sound.

Environmental issues have a very high profile in Canada right now. Oil spills were in the limelight in the spring of 1989, at which time the Prime Minister appointed a public review panel on tanker safety and marine spill response capability. There is also an ongoing internal review by the Canadian Coast Guard, Departments of Environment and Fisheries and Oceans. A great deal of effort is being expended on these activities to come up with recommendations to improve oil spill response capabilities in Canada.

The Environmental Emergencies Technology Division is planning a number of projects to be conducted in 1990 to develop and evaluate cleanup techniques and assessment procedures for oiled shorelines.

A project to modify the reciprocating kiln incinerator will begin shortly. This is a portable unit developed about ten years ago in Canada to burn oiled beach sand. They are looking at redesigning this unit to expand its versatility to handle larger material like oily gravel, to increase its burning efficiency to handle a wider range of oil contamination levels, and to construct and test this modified version.

There will be a cleaning and restoration project to design and test a practical, portable technique to remove, wash, and replace larger, oil-contaminated cobble-size material.

A third project will be to produce a Shoreline Cleanup Advisory Team (SCAT) manual for coastal oil spills in British Columbia. Mr. Sergy feels the SCAT process in Valdez worked very well and was very beneficial in providing direction to the cleanup crews.

Another ongoing project is toxicity testing on spill-treating agents to support the development of a standardized approach to assess the agents' potential hazards and effectiveness. Mr. Sergy developed standard toxicity testing procedures both for oil and chemicals.

The first stage of the Pacific Coast Oil Spill Project has been completed. This stage was a scoping exercise to assess the oil spill countermeasure techniques and equipment that were potentially applicable to specific Pacific Coast oil spill scenarios, and identifying information deficiencies to be remedied by field research and evaluation.

This study highlighted specific technical, advisory, and operational issues related to oil spill response:

- Deficiencies in detection and tracking of oil spills with emphasis on further development of sensors;

- In the area of offshore containment and recovery, there was major interest in being able to demonstrate the feasibility and acceptability of burning as a countermeasure tool;

- Shoreline cleanup cannot be viewed in terms of a dominant technique; there is no single solution;
- Need for shoreline cleanup manuals based on recent experiences which detail the effect of the application of different techniques and their limitations with respect to environmental problems;
- Lack of knowledge of shoreline cleanup effectiveness;
- Need for better data on relative ecosystem recovery rates with different cleanup techniques, including the no cleanup option;
- Problems with shipping and disposal of oil cleanup debris;
- Interim storage;
- Need for practical incineration units that can be transported to remote sites and can remove significant volumes of oily debris with acceptable levels of air emissions;
- Concern over lack of agreement among various levels of government on location and nature of acceptable disposal sites and techniques;
- Need of studies to assess and compare the most effective cleanup techniques for different settings with emphasis on measuring net environmental damage;

The study recommended:

- Exploring the merit of burning heavily oiled shorelines within the first ten days;
- Looking at commercial vacuum systemg
- Developing and testing techniques for removal of subsurface oil, such as those of the "remove and replace" variety.
- Studying mechanical mixing.
- Determining the true effectiveness of bioremediation.

- Developing and testing nearshore herding devices.
- Developing and testing incineration disposal systems.

The Baffin Island project has been monitoring stranded oil on Arctic shorelines for the past nine years. Other cold climate spill sites have been, and will continue to be, monitored to build up the understanding of long-term effects on oil stranded on shorelines. Similarly, Mr. Sergy would like to support long-term monitoring of such effects in Prince William Sound.

Using the information gathered from Canada and the new data from Prince William Sound, it would be possible to make more accurate predictions about self-cleaning rates on shorelines. He feels that natural cleaning is an option that requires a greater level of acceptability by the public, especially in cases where it would be the more ecologically preferable solution.

He would like to see an upgrading of training in shoreline-related oil spill response issues that may be encountered by staff who would be providing advice to the Canadian Coast Guard. Experienced personnel are invaluable, especially in the first phases of an oil spill when there is no time for training exercises.

In conclusion, Mr. Sergy suggested further work on Prince William Sound:

- Identify the nature and distribution of the residual oil. Develop oil characterization methodology.
- Survey beaches relatively quickly and accurately between now and next spring and make decisions on treatment.
- Select and refine appropriate techniques.
- Aid research and development in this area and so better prepare for the next oil spill event. Document and monitor observations on shoreline cleanup performance.

Question: Gary, have you looked at any of the techniques that might be recommended for surveying residual oil?

Mr. Sergy: No.

Question: For treating it?

Mr. Sergy: Cleaning the oil? The first step in what we're doing was to gather some opinions on the types of techniques that might be looked at.

Question: I thought that the focus of your presentation was about a year one-type problem. What would you try to look at in year two cleanup problems?

Mr. Sergy: We looked at trying to identify techniques that we feel need further evaluation in the field. It could be year one or year two. We really didn't get that many suggestions as to what you would call your year two-type cleaning up old residual oil. That's not to say that we aren't open to investigating those if we can come up with some ideas. Perhaps Prince William Sound is the better proving ground for those types of experiments.

Question: Did I hear you recognize burning oiled shorelines?

Mr. Sergy: Yes. Several suggestions were made that it may be feasible to burn oil on the shorelines when it is still fresh.

Question: What about the biological effects?

Mr. Sergy: Well, obviously, burning is going to kill anything that's living on the shorelines, but then it's probably already dead if it's been smothered with oil. Certainly, the heavily oiled shorelines that I observed on Prince William Sound last year had very few remaining living organisms. You want to select the option that causes the least environmental damage in the long run.

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Dr. Bernard Fichaut has a Ph.D. in shoreline morphology. He was born in Brittany, France, and was living there when the AMOCO CADIZ spill came ashore. From 1982 to 1987, he worked with the French parties to the lawsuit with Amoco to prepare a statement on

the residual pollution on the coast. Presently, he is a consultant for the Nature Conservancy Trust in Brest, France.

Dr. Bernard Fichaut

Dr. Fichaut's presentation focused on the recovery of the Brittany coast more than 11 years after the AMOCO CADIZ oil spill occurred.

Summary of the spill: The AMOCO CADIZ spill occurred in March 1978, dumping 220,000 tons of oil, of which 60,000 to 80,000 tons polluted 200 miles of shoreline. A continuous layer of oil remained on over 100 miles of intertidal zone. As the slick came in on the highest spring tides, it was distributed on the highest points of the coast, splashing high above the high tide mark. In many cases, oil was distributed in tidal marshes where no natural removal was possible.

Cleanup activities: The oil company did not pay for the cleanup. It was not clear who owned the tanker at the time. The army came in with heavy equipment and private citizen volunteers arrived with their own equipment, such as teaspoons and brooms. Bulldozers were used on Ile Grande marshes (approximately 40 acres), which received 7,000 tons of oil, creating a very thick layer of oil.

The cleanup lasted three months, through June 1978. Some beaches were still heavily contaminated and, as the summer vacation season was about to begin, decisions were made to clean the beaches by any means possible, culminating in removal and disposal of tons of sediments. No further cleanup was undertaken after June 1978. In 1980, the TANIO spill added 6,000 tons of oil along stretches of shoreline already contaminated by the AMOCO CADIZ spill.

With the help of American scientists, 160 study sites were established along the shoreline for research on profiles, sedimentology, and pollution levels. Studies of rates of natural cleanup were conducted by the French Oceanographic Institute, which produced a precise report used as a guideline for further studies on the Brittany coast.

The lawsuit filed against Standard Oil regarding the AMOCO CADIZ spill had two objectives: (1) declare Amoco responsible for the pollution, and (2) order Amoco to pay for the expenses of the cleanup effort. Dr. Fichaut was responsible for determining whether any oil remained and, if so, where it was located and the best methods for

removing any residual contamination. Some of the steps taken and conclusions made were: In January 1982, Dr. Fichaut walked the 200 miles of oiled coastline, taking over 2,500 photographs. He transferred the information gained on the walking survey to large scale aerial view maps to represent the extent and concentrations of oil throughout the involved areas. Files were created for each site giving the characterization of the pollution and the recommended operations for cleanup. This study was conducted over a period of five months in preparation for presentation to the court, however, was not entered into evidence until 1987.
During this time, a second survey was conducted in 1986 to update the information from 1982, culminating in a new report. Based on the findings of this report, the lawsuit claim amount was decreased from $31,000,000 in 1982 to $11,000,000 in 1986. This reduction was due to the decrease over time by natural removal in oil contaminating the beaches.

Long-term effects: High-energy cobble beaches had oil permeated down to 50 cm or more in the upper portions of the intertidal zone. In 1982 (four years after the spill), most of these beaches were clean; however, some have never been completely cleaned.

In Alaska, if the high energy beaches are not naturally cleaned this winter, it will occur in following years. Oil trapped in the beach will become more sticky and asphalt-like, and will break up with wave action. Dr. Fichaut's opinion on the treatment of this type of beach is avoid further treatment and let the natural cleaning process proceed on its own.

Low-energy, sheltered areas create a different set of considerations. In Brittany, the most important residual oil problem remaining is in the form of pavements. There are several acres of pavement after 11 years, some in blocks of several square meters. Pavements form when the oil reaches an impenetrable layer and no wave activity is present, combine with the sediment and solidify. Cleanup operations can often contribute to the forming of pavements. In Brittany, the flushing of the shoreline with high pressure hoses "glued" the oil to the gravel, enhancing the pavement effect. Where pavements occur, erosion is heightened around and underneath them, creating a small cliff effect.

The pavements have enabled the recovery of algae growth. Depending on the consistency of the oil that created the pavements, they can be removed with mechanical means by breaking up the hardened crust. One other point is that the pavement crust loses its toxicity after time.

Suggestions concerning Alaska: Not knowing how the pavement phenomenon will occur, Dr. Fichaut feels that, possibly due to the colder climate, the hardening process may not be completed by next spring. He feels that this will be one of the most important occurrences facing the Prince William Sound area in the future.

Question: What are the long term effects of the hydrocarbons on the fishing areas? Did you have a lot of fish kills? Did you have a lot of wildlife killed?

Dr. Fichaut: I do not know much concerning biological effects of the spill. The University of Brest did long-term studies on crabs, and they found that we had some kinds of long-term effects. The crabs in Brittany live in deep water, but they come near the shoreline to lay eggs in the spring. So, in the spring of 1978, when the crabs came to the shoreline area and laid eggs, all the eggs were killed by the oil. I don't know how long it takes for the maturation of crabs, but it is like two, three, or four years for the kind we have. And two, three, or four years later, they had a big decrease of crab caught in traps, and this was related to the fact that the eggs and the young were killed in 1978.

Question: Do you have a fishing industry that was affected? Were you still able to buy the fish from that area?

Dr. Fichaut: I know that we had problems with oysters. Fish from the sea in Brittany was still bought and sold. I continued eating fish in 1978, maybe because I knew that some scientists said that the white fish just went away during the oil spill and that they were away from the slick, so there was no oil in the fish.

Question: Can you tell us what the disposal method was for the oil that you picked up and carried off?

Dr. Fichaut: There were many solutions; some were good, but some were really bad. I can discuss some of them. As I said, there was some panic. For instance, of the oil that was removed from the inland marsh, 7,000 tons entered the marsh and 6,000 tons were removed by mechanical processes. They built a riprap on one part of the marsh, put all the trash behind it, and then left it there. I mean they just killed a few acres of marshes to get rid of the oil. This is not very smart, of course. Most of the oil that was on the western point of Brittany was picked up on the coast and then dumped in huge gas trucks and transported to the harbor at the Port of Brest where it was treated—there are industries that treat the ballasting from boats. Some of the oil was dumped in sites at Brest, and covered with quicklime on it, which neutralized the effects of the oil. Some marshes were probably destroyed, but most of the oil came to Brest and was treated there.

Question: Do you still find any unweathered oil underneath the crust or the asphalt?

Dr. Fichaut: The last unweathered oil I found in gravel or cobble beach, was in 1984, and that was under a berm on top of the beach. The oil was still liquid and was leaking from underneath a pavement that was in the berm of the cobble beach. But, as I said, I dug thousands of oil samples even in the cobble beaches and by 1984, whatever the oil was, either AMOCO or other, underneath the crust there was almost no fresh oil left.

Question: So what you're saying is that in a period of a year or two years from now, we could have a pavement layer four inches under the beach?

Dr. Fichaut: Yes. Still, I do not know the effects of the cold weather on the hardening process. I'm not good in that, but I think that, yes, if the natural removal of the oil goes slowly, there is a competition which is going on which is the hardening process of the oil. It turns into stained rocks in some places or into a crust in other places if you have enough oil to fill up the space which is left between each of the grains of the beach. And I think some time, I don't know if next year or the year after, you shall have crusts in a number of places.

Question: Did I understand you to say that you're working on breaking up the asphalt or that you've noted that it does break up naturally?

Dr. Fichaut: I selected a few spots where I tried to break up the crusts, but in Brittany since the lawsuit started, the policy is not to touch the AMOCO oil left because this is a kind of proof against Standard Oil. We are not doing anything to the oil left and that's why I said that it was kind of a laboratory of long-term effects. I think that it was very traumatic for French people to have tons of oil coming on the beaches like this and to be left with the oil everywhere. We did not know who the owner of the oil was; they were never there and we have never seen Standard Oil be responsible on the coast. This is like being treated like the Third World; we were the Third World of Standard Oil. So, this was so traumatic that we made plenty of mistakes after that.

Question: Are there areas where the cleanup processes carried out led to the formation of the pavement or the hard crust, or was it more of a natural phenomenon?

Dr. Fichaut: I think it's a more natural phenomenon. I know that you have cleaned up your coast here, but I've seen that you had some argument last summer about whether the beaches were "clean" or "treated." I saw that in the newspaper. When you have cleaned them up, they are still not completely clean, if I understand the issue correctly, so there is some oil left on the beaches and on the sheltered beaches. So, I think you will have thick accumulations of pavement and thin pavements, but the hardening process, cleanup or not, is going to occur. We have very large pavements in every instance that were treated, not cleaned. If there is some oil left, the hardening process is going to start.

Question: What was the effect of putting lime on waste oil?

Dr. Fichaut: Lime neutralizes waste oil. The oil becomes hard first and it is neutralized so that, when it's dumped at some site, it won't leak or pollute the waters. Sometimes they used to mix oil and lime and then put it as a form of pavement on the roads. I haven't seen much criticism concerning the use of lime on waste oil in Brittany. This was not a point of argument.

Question: For how many years did sheen come off the beaches?

Dr. Fichaut: I cannot answer that precisely. I said that there was a study of different sites from 1978 to 1981. The studies mentioned sheens several times, but since I started the study myself in 1982, two years after the TANIO spill, I have never seen a sheen coming out of the beaches. I was spending all day on the beaches, even when it was very windy and stormy, and I have seen the process of cobbles being turned over on beaches. I was there to check it and I had seen no sheens coming out. To be more precise, we could say that there will be sheens coming out until the oil becomes tar and thus, pavement. But I think this process of becoming tar is rapid. You should have sheens coming out all winter long here if there are enough storms, but next year I would doubt that you would have sheens coming out of your beaches. Let's say in two or three years there should not be sheens coming out.

Comment: Bernard, there were still sheens coming out of the salt marsh by Ile de Grande when we were there in October.

Dr. Fichaut: Yes. But this is a very particular instance. We have seen that on Erich Gundlach's slides yesterday. In Brittany, the beach very often has two kinds of slopes. The upper part of the beach has a steep slope and then you have the intertidal flats and the low tide flats or low tide terrace. At the meeting between this low tide terrace and the upper part of the face of the beach, they used to dig trenches and pits. They used to push the oil down in the pits and then pump it into honey wagons. Plenty of these pits and trenches were left like this once the cleanup ended and then some sand coming from the upper part of the beach, some silty sediment, came into the trenches and covered the oil that was still in it. In these very localized areas, you can still find very, very fresh oil because oil was in the pit and water and this was slowly buried by sediments which are kind of airproof, so this is an anaerobic environment and there is no biological long-term effect of oxygenation of the sediment and of the oil.

It is true that, one month ago, we were able to dig in the trench and get some oil that was still smelly. Since I have been working on the coast, I have never seen this kind of problem on a beach that was not treated. This was in sandy and silty sediment, not at all the same

kind of problem as what we were talking about this morning. On the sandy beaches, we had layers of oil four, five, six years after the pollution and on many acres in only one block, but this is sandy and silty.

Question: How do you pick a candidate for pavement? To form an actual crust where you have 100% saturation in the pore space between the grains? If you are in an area where you still have some subsurface oil but have low saturation or residual saturation, do you expect that to migrate up?

Dr. Fichaut: Yes, I think that to form a pavement, you need a continuous layer. But, as I said, a continuous layer can be on top of the beach. If the first layer is kind of salted with only big cobbles and then you have different kinds of gravels right underneath, the pavement will be formed there. If you have oil percolating inside the sediment, that is to say, if it is a much better sorted sediment, it will hit an oil-proof layer somewhere anyway, even if it is 10 or 20 cm below the surface. It will hit something and stay there. As long as the sediment we are talking about is permeable, the air effect will play a role as well 20 cm below the surface as it does on top of the sediment. So, crust can get formed on top, 20 cm below, or wherever. I've seen crust that I was unable to see in 1982, 1984, but by 1986 after a huge storm, a berm had been destroyed on the beach and the crust was there where it had formed deep inside the beach and was exposed to the air at one exceptional occasion. So, I think that the problem is just that the oil has to hit some oil-proof sediment layer and there will be a crust formed.

AMOCO CADIZ Spill Site Revisited, October 1989

Steve Provant and David Kennedy discussed their October trip to France to study the effects of the AMOCO CADIZ spill in relation to what might be expected to occur in Alaska.

It appeared that the rapid response by French officials was effective in recovering oil, which may have helped the long-term impacts on the beaches. There is still evidence of impact on some low energy shorelines, e.g., asphalt crust formation created changes in beach morphology, damage from heavy equipment, the warmer coastline promoting biological degradation, and natural and man-caused disruptions may effect the long-term ecological recovery.

Mr. Kennedy described the areas visited on the trip. He was encouraged by what they saw, albeit there were problems and mistakes made from which Alaska can learn.

Question: Were there any beaches that you saw that had been recovered and were going through a restoration phase? It might not be a restoration to what it originally was. You said that cleanup basically stopped in light of legal aspects of the spill, but I was just curious if anything had gone through to a recovery stage or restoration.

Dr. Fichaut: You mean by itself, after the stop of the cleanup operations?

Question: Either by itself or if it had been helped along before people were told to stop?

Dr. Fichaut: We have plenty of beaches that are completely restored in Brittany now. I mean that most of the entire coast can be considered clean. I do not have in mind the exact number of acres of this that is left on the coast, but I would say that, apart from the crusts, which is quite an important problem, some collection pits and trenches that are still more or less containing fresh oil, and some muddy, silty sediments in coastal marshes in some areas, all the rest is literally clean. Cobble beaches with a very high energy level are clean, except some places on the ridge on top of the beach because of the splashing; otherwise they are completely restored. I think that there is not much left. As I said, in 1986 we were claiming $11,000,000 to get rid of the oil left. I think that, compared to the input that you have, this is not much. There is some left from the second spill and there is more that came from another spill two years ago because we are near the most important merchant ship route in the world. But from the AMOCO, there is not much left now. Many people would not be able to find what is left.

Question: Would you consider, or is it a consensus, that those areas that are clean are biologically restored also?

Dr. Fichaut: Again, I don't like to go into areas that I don't know very well. I'm trying to think of my last meeting with others. It can

be more or less considered as restored, yes. There was a big shock with the AMOCO. In some places, every single living organism was just wasted; sometimes in square kilometers. And the comeback was quite slow. We had some problems related, as I said, to the problem of crabs laying eggs, but then a comeback was achieved in many places. In the muddy environments and coastal marshes, we are still facing the problem that mainly opportunistic fauna is back, that is to say, the fauna that is able to cope with some amounts of oil. Some worms eat a mixture of sediment and oil, and their feces are often full of digested oil that is removed by the limited wave action in the tidal marshes. Even most of the marshes are clean except in some locations, and the long-term biological effects are not that bad now.

Mr. Provant: We met with Dr. Cabioch and Dr. Glemarec. Essentially, the biota along the beaches was heavily impacted early on in the spill and it has pretty much come back now. I think some studies showed where some species were entirely wiped out and where there was an upstream source to replenish that or recolonize in those areas once the oil was removed. In most cases, the high energy beaches were clean in three to four years. After that time period, they did reestablish themselves. Also, the oyster population was heavily impacted and now they're serving oysters from some of those areas that were impacted. It's my understanding, too, that they did close down the fishery there for one season due to gear oiling. The major impact seemed to be just that one-year period that they didn't fish.

Question: You talked about the exposed areas. Did you look at any sheltered areas? What was showing there?

Mr. Provant: Well, most of the sheltered areas we looked at were the salt marsh around Ile Grande. There was the one location that we went to with Bernard where they had dug the trench and the oil was in there at depth, and it's still there; very liquid, gooey, and smelly. On the other side of that salt marsh where there was some heavy equipment, I'm not sure it was used as extensively, and Erich or Bernard could correct me on this, but there's still oil in there, too, and that was the area where we saw sheening. As the tide comes in and fills over the sediments, you could see a sheen coming out onto the water. I really looked at that carefully to make sure it wasn't an organic sheen and, digging down, you could find the oil in the

sediments there. You could see where the oil was just sheening out of the banks and so on.

Question: Do you have any information on the persistence of oil in subtidal sediments off the coast?

Dr. Fichaut: No, and I think nobody has.

Mr. Kennedy: I believe, in talking to Dr. Cabioch, that there were some locations off the coast that were sumps. There are strong currents that run along and some eddies that come off from the sumps. In those kinds of areas, depressions where some of the finer sediments dropped out from the strong current, during the spill and for about two to three years afterward, they were able to detect some very hot spots within those sumps where those fine sediments were collecting. Interestingly, there was a lot of variability there. Essentially, from one year to the next almost a dramatic, complete change down to background levels. The following year they went back and sampled and it was clear back up almost as hot as the previous year. So, there's a good deal of migration in there. But, once again, after about the third year, they did not see any more of a problem. There have been several studies done in those areas because of those hot spots that they found, and certainly there was a lot of damage there, and the recovery was about five to six years. It was not the same, but they have a way to study this, a quadrant, that shows the migration back to almost a normal diversity.

Question: Mr. Kennedy, would you consider that some of our glacial silts could create the same pattern in creating these sumps?

Mr. Kennedy: The suspended particulate matter issue was brought up quite early. Dr. Jim Payne, who has done a great deal of work on this issue, concluded that there was not enough particulate matter here to cause that problem. Erich mentioned that there are some diving surveys going on. There there may be some residual oil sediment coming off the beaches after heavy storms.

Question: On a more basic level, it was said that a third of the oil reached the shoreline. What was the fate of the other two-thirds?

Dr. Fichaut: When I said one-third, I was talking in weight, 220,000 tons. A lot of it just evaporated. There were a lot of aromatic components in the oil. Quite a lot of it sank because of storms and was released in the form of a sheen that covered huge areas, but was mixed in the water column in the first stages of the pollution. I think there was also some kind of treatment made by the Navy that consisted of throwing chalk on the oil in order to make it aggregate and sink. I know that this was kind of a big argument because they did it once before and, of course, fishermen and fishing people were angry because they did not want oil in their nets. But I know they did some of it for the AMOCO oil and there was argument about it.

Mr. Provant: I might add one piece of information. They estimate that half of the oil that hit the beaches along the Brittany coast was recovered. Because they were able to get at it quickly and it was accessible, they were able to remove a lot of the oil. I don't think we're facing the same situation here where we can remove quite that quantity of oil. I don't think we have yet had those kinds of recovery rates.

General Discussion

Mr. Sergy described the impact of fresh water on the overall cleanup of the shoreline. In a study of a test beach this summer, it was observed that, when a continuous flow of fresh water was present before the oil reached the area, the oil did not contaminate the subsurface strata of the beach, except superficially. It is believed that fresh water intrusion might have a significant role in overall cleanup techniques.

Dr. Gundlach explained that, when fresh water is present as the oil is coming in, it circulates through the beach and does not allow the oil to settle. If the fresh water supply was initially frozen or otherwise not flowing before the oil reached the shoreline, then thawed and began flowing through the beach, the oil has already had a chance to attach itself to the surface, making it more difficult for water removal.

Mr. Kennedy responded to a question of whether the freezing process would encapsulate the oil and hold it at least until the spring thaw. He stated that he felt that condition would be present, but was not sure what could be accomplished and asked for any recommendations.

Mr. Tom Newbury added that he felt the winter should be considered as a time to research the possibility of removing frozen or encapsulated oil from the beach by mechanical means to prevent any further penetration into the subsurface.

Mr. O'Brien stated that consideration of safety factors must be considered in an operation of this nature.

Mr. Stylianos Plakakis described a process used in Greece in a 1961 spill. Here, salt was removed from seawater and a formula of one part vinegar to 2,000 parts hot water was mixed. This solution was then applied to the shoreline in a flushing process which was very successful.

Ms. Trisha Gartland from Kodiak commented that she felt a walking survey was needed in order to make a responsible decision for spring cleanup in the Kodiak area.

Ms. Joanna Fugimoto commented that she was disappointed in this conference because she has not learned any new technological information.

Mr. Kennedy responded that, generally, it is true that no new technologies have been implemented. However, in preparation for this conference, all available resources were explored to obtain new information on techniques being developed or that had been developed in response to other spills throughout the world. The consensus of this research was that any viable technique that had been tried elsewhere had been tried here as well. However, another function of this meeting is to provide a forum so that a wide cross-section of individuals who may not have the benefit of the inside information being considered by all the groups involved, would get a better understanding of their purposes as this information is shared between them.

Ms. Fugimoto asked whether other techniques for removing oil from the water other than booming and skimming had be considered.

Mr. O'Brien responded that techniques such as burning and use of chemical or biological agents had been considered, but the dominant consideration in reviewing these techniques is the environmental

trade-offs to be accepted. He commented that he is not as discouraged today as he would have been five years ago because of the improvement and enhancement of techniques that have evolved and will continue to evolve as experience is gained.

Mr. Kennedy commented on an organization in France that was established after the AMOCO CADIZ spill. Its only purpose is research and development of cleanup techniques. Every procedure that this organization suggested be attempted in the EXXON VALDEZ spill had, in fact, been used here.

Mr. Tom Gosink of the University of Alaska in Fairbanks described a bolsing lime process for possible bioremediation purposes. When applied, it produces a dry powder. Nutrients can be added to the agent and, even if it should sink, the half-life of the product is less than a week. He was concerned because no one has allowed further development or use of this product.

Mr. Kennedy responded that ADEC, the Coast Guard, and Exxon have reviewed the process and are considering it in detail. He explained that there is a protocol that must be followed in order to proceed with this type of proposal. The presentation to be given by Alex Viteri later in the conference will elaborate on that aspect.

Mr. Andy Spear of the Governor's Office added that the Governor does not approve or disapprove any specific process or product.

Ms. Bridget Milligan, the Kodiak Island Borough Coordinator, presented the concerns of the Kodiak Island inhabitants regarding the removal of residual oil and the effects of aromatic hydrocarbon levels in the fish. She discussed the techniques the Kodiak people are intending to utilize next spring to proceed with cleanup efforts.

Mr. Sergy commented that it is important to consider the effectiveness of the techniques and to decide where to draw limits for continued effort.

Mr. Kennedy responded that limit standards have not yet been established because the information gathering phase is not complete. Spring 1990 is fast approaching and there is still a long way to go in the decision-making process.

Mr. Newbury requested any input on experience with underwater blasting, and possible consideration of this technique to prevent the formation of pavements in those areas with subsurface layers of oil.

Mr. Kennedy commented on one experience with this technique in Puget Sound that was very successful.

Mr. Nauman stated that Exxon has experimented with this process with limited success. Consideration must be given to the consistency of the subsurface strata. One of the problems with the Prince William Sound and the Gulf of Alaska is the region's rocky coastline. Also, electrical problems in developing a boom that can control the conductivity of salt water were a major consideration.

Ms. Nancy Lethcoe from the Prince William Sound Conservation Alliance commented that they are most concerned with the conceptual approach to physical cleanup of the shoreline, such as the limitation of efforts to spring, summer, and fall and the lack of emphasis on lightly oiled areas.

Mr. Bud Rice with the National Park Service discussed the possibility of enhancing the freeze-thaw process for breaking up and removing oil, keeping beaches in a flooded state throughout the winter which might remove oil particles.

Mr. Alex Eskandor from the Cold Region Research Laboratory in Hanover, New Hampshire, described a technique they have been working on with EPA over the last five years. The technique deals with slow soil freezing to decontaminate the soil, uses liquid nitrogen to stop the migration of the contamination, and then slow freezing to contain it.

In response to a question about the effects of freezing on the oil, Mr. Hans Jahns of Exxon responded that field crews have not found any evidence that oil consistency changes dramatically with freezing, such as becoming brittle or cracking.

Mr. Provant commented that the State's survey has shown that the oil tends to cement itself to the sediments as opposed to separating.

Ms. Frankie Cofan with the Alaska Department of Natural Resources expressed her concern that the low energy beaches have not had high emphasis. Not much information seems to be forthcoming on them.

Mr. Kennedy responded that the low energy areas are not showing as much improvement as the high energy areas and it is felt that these areas are not going to recover very quickly.

Mr. Provant added that the intent this spring is to identify these problem areas and focus on them.

Stewart Elgie from the Sierra Club Legal Defense Fund commented that hard decisions need to be made now, such as whether further effort would be more disruptive than leaving it alone. He is concerned that no decisions have actually been made.

Mr. Kennedy responded that unresolved legal aspects cannot be discussed at this time, but efforts are being undertaken to make decisions, and this forum is expected to be used as a springboard to encourage the resolution of these issues.

Mr. Jim Heinzen asked for consideration of the problem of plastics entanglement, which has greatly compounded the oil problem.

Panel Discussion

Members:
- Erich Gundlach, E-Tech (Chairman)
- John Bauer, ADEC
- Hans Jahns, Exxon
- Jack Lamb, Cordova District Fishermen United
- Bernard Fichaut, Nature Conservancy
- Jim O'Brien, O'Brien Oil Pollution Services
- Pamela Bergmann, U.S. Department of the Interior

The first point of discussion was the different techniques to be considered in the removal of subsurface oil from the sediments.

Excavation and Removal of Sediments

Positive -- Excavation and removal of contaminated materials and replacement of clean material will restore the shoreline to the

condition it was in prior to the spill as opposed to a chemical treatment that will not be completely effective.

Negative -- From a geologic standpoint, it is almost impossible to find grain size similar to that of the material removed from the beach. Disturbance of cultural resources, archaeological sites, and biological impacts on wildlife and habitats may occur.

Procedures -- Consideration of the variety of shoreline compositions is imperative to determine the capacity to deliver the cleanup devices as well as the transport of replacement materials.

Alternatives -- Disposal problems generated by this type of operation could involve use of a rock washer could minimize the amount of solid waste. The waste material could possibly be used in building roads.

Dr. Fichaut noted that, during the AMOCO CADIZ spill, it was recommended that removal and replacement be limited to localized areas, such as trenches and pits that were dug as oil gathering sites. He does not feel that there are areas in Prince William Sound where the removal and replacement technique should take place.

Discussion -- Setting environmental limitations on the removal and replacement technique. Ranking of habitat based on sensitivity of environment. Timing of the work with respect to habitat, e.g., spawning grounds, archaeological sites, was suggested. Setting priorities and generating criteria was stressed.

Tilling and Reworking Sediments

Description -- This is commonly referred to as land farming and involves the use of agricultural equipment to break the surface of the shoreline.

Positive -- Would allow the aerating of the sediments to prevent anaerobic conditions and would allow natural degradation by exposing sediments, enabling oil removal by the flushing system. This would also break apart pavement layers.

Negative -- Would mainly involve the culture resource problem and biological impacts.

Flushing and Washing Shorelines

Description -- Move the oil down the surface of the shoreline to a collection point by a combination of pressure and heat or application of volumes of water.

Positive -- Experience this summer has shown that this technique can be accomplished successfully and on a grand scale.

Negative -- Possibly have reached a point of diminishing returns; mobilization involved is extensive in resuming this activity, there is disruption of biological recolonization, environmental damage due to heat in the green zone, sediment washing off the beaches. Flushing and washing would need to be timed carefully in relation to seasonal sea life activity.

Alternatives -- Regarding the environmental damage due to hot water, a cold water header could be placed at the bottom of the wash zone. With respect to the sediment removal, a sediment curtain or trap could be placed to catch sediment before they blanket the lower inner tidal area.

Discussion -- Temperature of water to be used this spring.

Water Injection

Description -- The technique is concentrated in the substrate areas. Water is introduced into the subsurface sediments below the oil line in an attempt to move it in a certain direction. The water would be injected either through perforated pipe or sunken rods.

Positive -- Oil is released and wave and tidal action refloat it out of the sediments. Water injection does not disrupt and destabilize the beach as excavation or flushing does, and could allow the use of other methodology, such as bioremediation or chemical treating agents.

Negative -- Cultural resource problems, water pressure and temperature considerations, variance in beach profiles as to location of the oil. Water injectionis not recommended for use near anadromous habitat because of the inability to forecast migration of oil. The process is considered inefficient due to the variability of the shoreline.

Procedures -- Two-pack concept would be the best option to keep manpower requirements to a minimum.

Discussion -- Use of rods and placement in areas of possible pavement formation. Concern over biological effects of disturbing subsurface strata, and if it is necessary to continue subsurface work; let natural processes remove residual subsurface oil. Releasing and recapturing oil problems and concerns.

Summary
Removal of asphalt pavement can be accomplished by pickup and removal and rototilling to break up the pavements, which allows wave action and biological degradation to occur. Surface oiling of boulders, rocks, and vertical cliff walls would have to be accomplished by a washing and flushing operation combined with temperature and biological considerations.

Chemical Technologies

Dr. Bob Fiocco is a Senior Engineering Associate with Exxon Research and Engineering Co. His background is in chemical engineering and surface chemistry. He has a Ph.D. from Stevens Institute of Technology.

Dr. Bob Fiocco

Dr. Fiocco's presentation described the laboratory and field-testing work on shoreline chemical cleaners carried out over the summer in Alaska and the Lower 48.

A chemical shoreline cleaner is usually comprised of surfactant materials based in either a water or solvent carrier. This reduces the adhesion forces between the oil and the water surface, and allows the oil to be flushed away with water. The disposition of the oil in the flush water depends to a large extent on the surfactant system. In some cases, dispersant systems promote breakup of the oil into fine droplets that disperse into the water column, become diluted, and biodegrade. However, shoreline cleaners do not necessarily have to act as dispersants; they can also be used in a manner to avoid dispersion. Shoreline cleaners and dispersants are not the same.

Dr. Fiocco discussed the historical background of chemical cleanup technology, highlighting occasions where chemicals were used for shoreline cleanup, such as at the TORREY CANYON spill in England in 1967 and at Tampa Bay, Florida in 1970.

After the EXXON VALDEZ spill, a task force was established by Exxon to develop technical options for the cleanup, including the use of chemicals, absorbents, and bioremediation. As time progressed and the characteristics of the oil began to change, options formulated earlier had to be revised and redeveloped.

The criteria used to develop a chemically enhanced operation included low toxicity, the ability to clean weathered oil from rocks and allow physical removal of the oil from the environment. Before applying a chemical to the spill, it had to be listed in the EPA's National Contingency Plan Product Schedule. To meet these criteria, chemical screening capabilities were established by means of a laboratory rock-washing apparatus.

Dr. Fiocco described the field-testing sites established and the results achieved from different chemicals throughout the summer. The sites involved were at Ingot, Knight, Eleanor, Disk, and Smith islands.

Dr. Fiocco stated that the technology continually improved as the summer progressed and the weather worsened. He feels that Exxon conducted an extensive, accelerated, and environmentally responsible program on this chemical cleaner. Exxon was pleased with the performance of the Corexit 9580 product. Chemically enhanced shoreline cleaning remains a viable option.

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Alex Viteri is the manager of the Treatment Technology Division of the State of Alaska's Oil Spill Response Center. He has been a Senior Environmental Engineer with the Department of Environmental Conservation for the last ten years. He is the author of the last comprehensive revision of the State's Water Quality Standards and Wastewater Disposal Regulations. He has led numerous special environmental projects, such as the water quality assessment of polluted shoreline areas, and has been working on the spill since about May 1.

Alex Viteri

Mr. Viteri discussed the current activities of ADEC's Treatment Technology Division in Valdez and presented a new protocol advocating the State's method for approving different mechanical, chemical, and bioremediative enhancement agents, or any combination thereof. The Division's function is to identify and document effective, cost-efficient, and environmentally safe methods for shoreline cleanup next year.

The protocol is established to facilitate an understanding of the effectiveness and the toxicological consequences of using a newly proposed method. The outline of the protocol is as follows:

* Tier 1: Preliminary information—evaluating and identifying the characteristics and toxicity of the agent by literature review and laboratory bioassay tests.

* Tier 2: Small-scale field testing—determine ethical nature of the product by applying agent to small beach plot and conducting laboratory bioassays.

* Tier 3: Full-scale toxicity and field testing—final phase before approval. Use of liquid and solid toxicity tests. Large-scale field-testing involves:

  - ☐ collecting intertidal water samples prior to the application of the agent;
  - ☐ establishing transects along the shoreline where the area is to be treated which will be measure both pre and post-application for determination of the chemical changes in the oil, as well as any potential toxic effects;
  - ☐ applying the agent in a prescribed manner, and collecting the effluent water and sediment samples for analysis;
  - ☐ monitoring and collection of oil off the beach and monitoring test species; and
  - ☐ monitoring treatment of the area for up to six weeks.

After an agent has passed these criteria and has gained approval by ADEC and EPA, it is then submitted to the Regional Response Team (RRT) for approval.

Question: Some of the species you listed are only available at certain times of the year.

Mr. Viteri: Yes. We have the ability to put in target species when one is not available. There are some minimum requirements that I didn't mention before. For example, you need to be on the EPA products list and you have to use positive control toxins.

Question: Who bears the cost of Tier 2 and 3? Is it the person who manufactured the chemical, the State, or the spiller? Who's going to pay that cost?

Mr. Viteri: The manufacturer or the solicitor of the product is responsible for bearing the cost.

Question: Do you have any idea what that cost might be?

Mr. Viteri: No. It's very difficult to come up with a cost at Tier 2. I can quantify a cost for Tier 1 because I think I have a feel for what the cost of those two bioassay tests are, and the bioassay tests at Tier 2 are probably the same. Maybe there's someone in the audience here who can help. Jim O'Brien, can you tell me what the cost of those two tests might be?

Mr. O'Brien: We decided that the first two tests in Tier 1 could be done for less than $5,000.

Mr. Viteri: Does the $5,000 include the chemistry involved with that, too?

Mr. O'Brien: Yes.

Mr. Viteri: So, that includes a total petroleum hydrocarbons (TPH) analysis?

Mr. O'Brien: The most extensive toxicity test is probably less than $50,000. It depends on the type of analytical procedures used.

Mr. Viteri: It's really hard to determine an effectiveness test for a product you haven't seen yet. At both Tier 2 and Tier 3 we will provide an outline of the key elements that we think are essential for a proper study plan. The State feels that it is the responsibility of the product's proponent to provide us with the necessary information for the protocol. We will establish the outline of the key elements and the product's proponent will then come to us, based on their various techniques, with evidence of how they intend to show us the product's efficacy. We'll review it in conjunction with other resource agencies, and then, if we're sure that it's a proper method, we'll approve it and wait for their results.

At Tier 2, the sample that we're looking at is the effluent that's taken out of the transect. That's the sample that we're using to retest the shrimp and the mussels. So, in the water column, we're just looking for TPH, not necessarily toxicity, and that's the standard we're looking at using GC/MS analysis.

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Mr. Merv Fingas is the head of the Chemistry and Physics Section of Environment Canada's Environmental Emergencies Technology Division. He has worked in spill research for the past 16 years, focusing on spill behavior and dynamics, oil spill treating agents, and remote sensing. He has Masters degrees in chemistry, mathematics, and business.

Merv Fingas

Mr. Fingas's slide presentation stressed differences between dispersants and surface-washing agents or beach-cleaning agents. Environment Canada is developing guidelines for spill-treating agents.

Development of the testing process began approximately two years ago as a means to develop guidelines for the acceptability of the agents for testing. Testing involved immersion, overwashing, and simple rinsing over a variety of substrates, including concrete, stone, carborundum, wood, porcelain, and steel. Acceptability of a product had to yield fairly consistent results.

Procedures involved placing Bunker C oil in a metal trough, applying the agent to the oil and soaking it for ten minutes, followed by rinsing. The trough was then reweighed and the amount of oil removal calculated.

Positive aspects of the test were that the test is repeatable up to plus or minus five percent, it allows for rapid change of oils, involves relatively simple equipment, similar to actual beach cleaning methods, and allows for condition changes. Negative aspects were that, because the test is new, its results are difficult to compare with other data. Overall results showed that Corexit 9580 was the most effective and with low toxicity, consistently removing approximately 40% of the oil.

Different tests of variances showed that the angle of the trough made little change in the results; removal rates increased as temperatures were increased, and rinsing was effective for about the first hour and a half.

Mr. Fingas stated that the chemical agent Corexit 9580 may be effective in some field situations. He feels that agents should be tested for toxicity, dispersant, and surface washing effectiveness before being considered for use in the field.

Question: What is the nature of your dispersant test?

Mr. Fingas: It's a swirling flash test that is published in a number of papers, including the 1989 American Petroleum Institute oil spill conference.

Question: You indicated that you suspected that there's a difference in mechanism between a chemical that acts as a dispersant versus one that works as a surface washing agent. I'm curious as to what those mechanisms might be and, in fact, is that related at all to the concentration of the agent?

Mr. Fingas: It's not related to the concentration at all. That is a different mechanism. In the case of the surface-washing agent, you're talking about a detergent removing an oil from a solid interface. With a dispersant, you're removing an oil from a liquid interface (the water) and there is no solid interface along which to act.

The oil solubility versus water solubility (hydrophilic lipophilic balance, or HLB) of the products are different, of course. So actually, you can also have quite different surfactants in both cases.

Question: How does the chemistry of surfactants work? Are those surfactants different in the way they work?

Mr. Fingas: Surfactants are different in the way they work; there are about 20 different mechanisms by which a surfactant can work, and some of those mechanisms are actually in competition with each other.

Question: Can you try the solvents without the surfactants?

Mr. Fingas: Oh, yes. We tried several of your solvents, as a matter of fact, but they had little effect. They were one of the first things we tried. We use Isopar a lot in our laboratory for the simple reason that it's got a very low aquatic toxicity. It's a kerosene solvent with essentially all the aromatics removed. And it, by itself, had zero effectiveness.

Question: I'd like to make something clear. When you say 42% of the surface oil was removed, 42% of what?

Mr. Fingas: The test is on the surface. It removed 42% of the oil that was put on that trough.

Question: Can one use treating agents in Canada once they pass the tests?

Mr. Fingas: Once you get your product on our list, you still have to ask to use it.

Question: Do you think that a surface-washing agent would also be effective in keeping oil off the pom-poms and the skimmers?

Mr. Fingas: Yes, in some cases, such as if you're involving a surface that is non-absorbent. We found, for example, that the reason a lot of these surfaces didn't work before was that there's a bit of a competition between taking it off and actually putting it deeper into the interface.

Question: How would you explain an observation of Corexit 9580 in a field test last summer that created a large plume that escaped underneath the boom and was washed out further?

Mr. Fingas: I understand that that was not the observation. My understanding was that the plume occurred with the BP 1100, which is a bit of a dispersant.

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General Discussion

Products were discussed that EPA has approved but that are not on their standard list. EPA stated that were was no mechanism for establishing this kind of list and no products have EPA approval that are not on their technical products list.

Jack Lamb with Cordova District Fishermen United represented his organization's opinion against any use of chemicals in Prince William Sound. He expressed his dissatisfaction with the conference in that no technologies have been introduced that have not been tried previously, and stated that there are products that have not been tested by any organization. There was discussion regarding the processes and protocols that are necessary to approve products, reasons for delays in testing based on seasonal complications and manpower limitations. Possibilities for streamlining the process, how test sites are selected, developing a matrix system for test results, and literature research were also discussed, as well as the need to conduct a diversity of tests. Concern was expressed that it would be in the State's best interest to promote new technology, and that funding for research and development is crucial.

Response to a concern expressed about the problems encountered with early containment resulted in discussion. Unavailability of equipment was the foremost problem. The opinion was expressed that, if the correct equipment had been immediately available and mobilized as soon as the spill was reported, 40% of the oil could have been contained. It was noted that attention is being given to new technology with extreme caution to prevent costly mistakes.

There was discussion regarding the effectiveness of dispersants in the recovery of oil and its biological and ecological effects. In compiling data, it was suggested there should be a way to factor in public review.

Panel Discussion

Members:
Sharon Christopherson, NOAA
Alex Viteri, State of Alaska DEC
Hans Jahns, Exxon
Royal Nadeau, U.S. EPA
Jeff Short, National Marine Fisheries Service
Bela James, Continental Shelf Associates, Inc.
Gary Reiter, U.S. Coast Guard
Merv Fingas, Environment Canada

Dr. Christopherson explained that this panel would expand on the physical technologies panel because the use of chemicals should only be considered as an adjunct to the physical methods available. There has not been a chemical method proposed in this conference that can be used strictly by itself. The panel will concentrate on possibilities for chemical enhancement of the physical processes already proposed.

Pickup and Removal

Description -- Use of chemical agents to aid in recovery of oil, especially as it enters the water. Products considered included elastizers, gelling agents, and herders.

Positive -- May enhance the recovery efficiency of the skimmers and other collection methods.

Negative -- These would be new chemicals added to other agents already applied in other types of treatment.

Procedures -- Initial physical recovery limited to mechanical means, with chemical agents added to facilitate recovery of the oil as it reenters the water after physical shoreline treatment.

Excavation and Replacement

Description -- Use of chemical agents to enhance cleaning of substrate that has been excavated.

Positive -- Chemical enhancement could make the cleaning process quicker, more efficient, and more effective.

Negative -- In addition to those discussed for the physical processes in the previous panel, possibility of disposal problem of used chemical agent.

Procedures -- Rocks are brought into washing equipment or vat of recirculating solvents, rinsed off, and replaced. New definition of replacement as treating the material and returning it to the area versus removing and replacing with new material.

Tilling and Reworking

Description -- Use of chemical agents to enhance breakdown or washing of contaminated substrate once tilling has brought it to the surface.

Positive -- Chemical enhancement could speed up removal or degradation of the oil after it is brought to the surface.

Negative -- In addition to those discussed for physical processes in the previous panel, potential toxic effects of chemical enhancers.

Flushing and Washing

Description -- Use of chemical agents (beach cleaners) to presoak substrate prior to hot water flushing to enhance the removal of weathered oil.

Positive -- Penetrates into the substrate and loosens the oil or makes it more liquid, decreases mechanical energy necessary to remove oil from the beach.

Negative -- Potential toxic effects of chemical agent; possible problems in recovery of oil from water; lengthy approval process; no product to propose at this time.

Procedure -- Applied to the beach and allowed to soak in for a short period of time prior to the physical flushing of beach.

Water Injection
Description -- Adding chemical to water and forcing it through piping into the substrate. Water-soluble products most promising.

Positive -- Treatment makes oil more mobile and easier to remove.

Negative -- Possible retention of treating agent in the beach material; potential toxicity of chemical agent; potential for increase in erosion of beach material due to the physical process. Lengthy approval process; no product to propose at this time.

Procedure -- Chemical agent is added to water and injected into subsurface areas of contamination through injection probes pounded down into the substrate; very labor-intensive, requiring large volumes of water and/or source of hot water; placement of injection probes may be complicated by uncertainty in location of subsurface oil.

Summary
Overall advantage of using chemical enhancers is that they increase the mobility of oil and effectiveness, decreasing either the time or mechanical energy required in accomplishing generally accepted physical processes. Disadvantages are added risk of using a chemical, possible residual retention of agents, and the lengthy approval process required for any new chemicals that might be proposed.

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There was extended discussion during the question and answer session on the consequences of leaving the oil in the subsurface to be removed naturally. This is being studied by many agencies but no conclusion has yet been reached.

The controversy on the use of dispersants was addressed, and concern expressed over the new proposed testing protocol being an excuse to avoid making decisions. Opposing argument was that risk to the environment is too great to apply unproven and untested theories and products without knowing the consequences.

Biological Technologies

Dr. Hap Pritchard, is chief of the Microbial Ecology and Biotechnology Branch of EPA's Research Laboratory in Gulf Breeze, Florida. He has a Ph.D. in Microbiology and has research interests in biodegradation and microbial ecology.

Dr. Hap Pritchard

Dr. Pritchard gave a slide presentation describing the oil spill bioremediation project. After the spill occurred, a group of experts with experience in oil degradation were gathered together to attempt developing a bioremediation program for cleanup activities. The consensus was that bioremediation was a definite possibility. They expected that oil, having many very degradable components in it, will enrich microorganisms naturally that will carry out that degradation, and studies have shown that the addition of nitrogen and phosphorus in many cases stimulates the degradation in laboratory experiments because bacteria grow on hydrocarbons. When bacteria metabolize and decompose these hydrocarbons, they are multiplying cells, which requires nitrogen and phosphorus to produce proteins and nucleic acids.

It was also determined that bioremediation could be used as a finishing step after the bulk of the oil has been removed. Bacteria will degrade components of the oil, such as aliphatic materials and some aromatic and asphaltene materials, but as a tar residue is left as they degrade these materials.

A variety of time-release fertilizers were reviewed and it was determined that briquettes, fertilizer bricks, and granules held the greatest potential for success.

EAP-22 is produced in France and comes in a liquid form that dissolves nutrients into the oil. This causes immediate residual change.

Dr. Pritchard described different test sites, how they were selected, and corresponding results.

Natural biodegradation is the most preferred system of treatment. Any addition of nitrogen and phosphorus would serve to further stimulate that natural process. Observations and test results have

shown success in removing residual oil from beaches by biodegradation processes.

In response to a question regarding whether other methods are being considered, Dr. Pritchard said that they are open to reviewing other kinds of products to help in the cleanup effort.

It was suggested that further experiments be conducted to determine what exactly is happening to the oil that is not biodegraded; that it might be returning to the water column in a different form.

There was discussion on the depth of sampling, checking for accumulation of hydrocarbons in offshore areas, and studies of rates of carbon dioxide production with the application of the fertilizers.

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Mr. Fred Kaiser is Engineering Advisor to Exxon Research and Engineering in New Jersey. He is a chemical engineer from Lafayette College and has been responsible this past summer for transfer of the bioremediation technology from the EPA tests to the large-scale field application.

Fred Kaiser

Mr. Kaiser discussed the properties of the fertilizers applied to the beaches, the application criteria and techniques developed, purchasing, transport to Alaska, and the success achieved in meeting the application targets.

He described the physical and chemical properties of the two products used, EAP-22 and Customblen. The application criteria for the fertilizers was an important consideration. Test work was done on porous-type beach structures, i.e., sand, gravel and cobble, and lightly oiled or previously treated areas. Special consideration was given to poorly flushed bays, fish streams, and other sensitive areas.

Over 500 metric tons of EAP-22 were purchased, airlifted to Anchorage from France, and then trucked to Valdez, where the material was shipped by supply boat to the treatment site.

Customblen, produced in California in a slow release granule form, was sent by container ship to Anchorage and distributed to the treatment site in the same fashion as the EAP-22.

Application systems used for EAP-22 were comprised of hand- and motor-pumped backpacks, hand-pulled carts, ATVs with spray trailers, and industrial airless paint sprayers. Customblen was applied by shoulder-mounted, hand-cranked rotary broadcast spreader and a rotary spreader on an ATV.

Mr. Kaiser described the actual application treatment coverage for the two products and gave a time line of the testing process that took place. Total cost of the program was $11.2 million, not including support costs.

Common sense health and safety factors were followed, such as not ingesting the product, avoiding eye and skin contact, and not breathing vapors, mist, or dust. EAP-22 can be absorbed through the skin and damage red blood cells. Special precautions were taken for worker safety, including medically screening workers, conducting urine tests to determine overexposure, and requiring breathing masks and face shields to be worn near spraying operations.

In conclusion, the airless sprayers were very successful in achieving high productivity and uniform coverage. The Customblen application was less successful due to the later start date and an inadequate delivery system. In addition, the nutrient release from Customblen occurred faster than specified.

Question: I would like a quick clarification of the word "labor-intensive."

Mr. Kaiser: Labor-intensive is not a dirty word, certainly, but it is an expensive word from our standpoint. It cost Exxon something on the order of $450 a day to maintain a worker in the field, so, although it's not a dirty word, we sure want to minimize it wherever we can and that's the purpose for saying it.

Comment: I object to Exxon even qualifying their costs. They have made a fortune in the oil price increases. If they had kept up the

safeguards they had in the first place, Alaska wouldn't have these kinds of problems.

Mr. Kaiser: The purpose for talking about the costs was to indicate how effective a treatment like this might be relative to the tremendous cost that was spent in mechanical cleaning of the beaches. That was really the intent.

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Dr. Jon Lindstrom is a chemist with ADEC at their oil spill center in Valdez. He has been working on chemistry and microbiological studies, and has Bachelor degrees in chemistry and philosophy from the University of California and a Master's Degree in Environmental Science from the University of Alaska.

Dr. Jon Lindstrom

Dr. Lindstrom's presentation focused on the results of the study funded by NOAA to enumerate hydrocarbon-degrading bacteria. He described the procedures involved in taking samples, such as transect sites on beaches, water and sediment samples, and subtidal samples collected by divers. Microbiological tests were then conducted and a direct bacteria count made. Two factors in the tests were considered: (1) changes in the proportion of hydrocarbon-degraded bacteria to the total bacteria population, and (2) the state of acclimation. Dr. Lindstrom gave a detailed description of the testing statistics and results achieved.

In conclusion, the number of hydrocarbon-degrading bacteria make up a small proportion of total bacteria, even for heavily oiled sites. Half the beaches sampled had microbial populations that were acclimated to linear alkanes. One-quarter of the beaches sampled had microbial populations that were acclimated to polynuclear aromatic hydrocarbons (PAHs), such as naphthalene.

Essentially, pore water populations seemed to acclimate to hydrocarbons more quickly than sediment populations. All beach populations became acclimated to linear alkanes within ten days, which suggests that they are easily degraded and were acclimated in culture. Microbial populations in pore water acclimate more quickly as a function of the sediment content, and in fact, there may be a physical effect of the interaction between the hydrocarbons and the

sediment particles that restricts bioavailability, creating a concentration effect that reduces the degradation rate.

Finally, the nutrient-amended pore water samples seemed to show no enhanced degradation over the straight pore water samples, which indicates that nutrient limitation did not seem to be a factor.

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Before the panel began its presentation, Jack Gould from the American Petroleum Institute (API) briefly discussed the petroleum industry's research and development program.

After the EXXON VALDEZ spill, API organized a task force that met for a number of months. Their objectives were to develop 1) a plan to respond to a catastrophic oil spill and 2) a research and development program.

It was concluded that, right now, the industry is unable to respond to a catastrophic oil spill situation. A new organization will be established, called the Petroleum Industry Response Organization (PIRO). Five response centers will be established: New York; Norfolk, Virginia; New Orleans; Long Beach, California; and Seattle, Washington.

The research and development program would span five years at a cost of $30-$35 million, which would cover aspects of oil spill prevention, control, cleanup, bioremediation, and mammal impacts.

Some of the projects in progress and proposed are:

* Continued planning for dispersant work to protect the ecological system.

* A workshop has been held and a manual written addressing the marine environment. This workshop culminated in development of a field kit to determine the effectiveness of dispersants.

* The biennial oil spill conference jointly sponsored with the EPA and the Coast Guard will be in 1991.

- A number of workshops are planned, such as communications at an oil spill site, and in relation to a mutual assistance program.

- Planning fresh water studies.

Jack Lamb with Cordova District Fishermen United addressed developments occurring with respect to early response planning and techniques. He wanted to encourage fishermen that work is progressing on developing a skimmer as well as a super pump in order to remove the oil out from the water before it hits the beaches.

Don Jensen of the U.S. Coast Guard discussed two bills recently passed by the U.S. House of Representatives and Senate, which anticipate a large research and development budget. The Coast Guard will be looking again at proposals as situations evolve encompassing new ideas that were rejected during the initial screening. Mr. Jensen wished to stress that there is a coordinated effort to attempt to set national goals.

Panel Discussion and General Discussion Combined

Panel Members:

Hap Pritchard, U.S. EPA (Chairman)
John Wilkinson, Exxon
Mark Kuwada, ADF&G
Jacqui Michel, Research Planning Institute International
Jon Lindstrom, ADEC
Judy Kitagawa, ADEC

Bioremediation methods were reviewed and brief analysis of their potential was addressed.

Oleophilic Fertilizers

Positive -- EAP-22 is available, has been tested in the field, holds nutrients in the oil, possibly acts to soften the oil and change its consistency slightly (allowing the bacteria to more quickly degrade the oil), and provides a visual improvement of the beaches.

Negative -- Need to know more about the mechanism of action; fertilizer has a mild toxicity, questionable effectiveness in the subsurface, and there is concern about worker protection.

Comments -- Concerned about effectiveness on weathered oil; may be possible, through some sort of engineering, to treat subsurface areas; and possibility of a problem with public concern about application in commercial, subsistence, or recreational areas.

Slow-Release Fertilizers

Positive -- Relatively easy to apply, good potential for getting nutrients input into subsurface, and coatings can be designed to control release rates.

Negative -- Easily available to wildlife; steady, continuous contact of oil with nutrients; briquettes can be moved around like small stones and can accumulate in areas; and difficult solid waste cleanup problem with briquette debris.

Comments -- Possibility of localized burning of vegetation due to corrosive nature of fertilizers on the beaches needs to be researched.

There was discussion on the problems of nutrient penetration into beach material as a result of fertilizer application.

Solutions

Description -- Mixing inorganic fertilizers in seawater or fresh water and applying to the beaches using a spraying device (e.g., sprinklers).

Positive -- Good for penetration to the subsurface, less impact on wildlife, and shown to provide visual improvement of oil-contaminated beaches.

Negative -- Potential for releasing significant quantities of ammonia, which is mildly toxic, and logistics of application.

Comments -- Need more information on the rate of uptake of nutrients by the microbial communities associated with the rock surfaces in order to assess how much to be applied. Need to study wastewater treatment systems as models for nutrient dynamics as water moves nutrients down to the rock.

There was discussion regarding nutrient penetration into the substrate.

Inoculation

Description -- Different choices available, such as mixed or pure cultures of bacteria, fungi and yeast cultures, and possibly, enzymes. Other products, such as chemicals, surfactants, and dispersants, or powders, absorbents, and particulate material to increase the amount of surface area; or mechanical agitation of beach material, may have to be used in conjunction with inoculation.

Positive -- Increased biomass, can focus activities, decreased acclimation time, and specialized cultures to increase bacteria tolerance of different environmental conditions.

Negative -- Becomes competitive with natural populations, selecting application procedure, and public acceptance.

Comments -- Must consider when there is an actual need to inoculate, when to use foreign bacteria relative to indigenous bacteria, use of genetically engineered organisms. Public acceptance and education is a critical area to consider.

There was further discussion on genetically engineered organisms and the EPA testing methods and regulations being developed.

Bio-availability

Description -- Increase availability of oil to bacteria through use of chemicals and surface area-increasing materials.

Positive -- Enhances degradation rates, could be very effective on weathered oil, and can incorporates nutrients into the chemicals.

Negative -- Potential side effects, requires a lot of research and development, particularly in application to the intertidal zone, and concern over chemicals releasing the oil into the environment.

Comments -- Once oil has reached a particular weathered stage, it may be ecologically insignificant in terms of possible toxic effects. Decisions on the use of chemicals would reside possibly with a shoreline committee working in conjunction with the Coast Guard or a multi-agency, multi-public forum. Additional testing that might

be necessary to approve fertilizer products for use next spring was discussed.

Summary
The issues of importance to be addressed:

- Extent of degradation and how far it is to proceed.
- Measures of degradation.
- Release of partially degraded oil.
- Environmental effects of biodegradation products.
- Surface/subsurface options.
- Application technology.
- Enhancement of natural processes versus inoculation; feasibility.
- Time allowed to show effectiveness.
- Long-term monitoring.
- Field-testing protocols.
- Timing of application in consideration of seasonal wildlife priorities.

It was suggested that some research and development effort should be required to get the best information in the shortest amount of time for potential use in spring 1990.

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Workshop Summary

Hap Pritchard
I think we agree that bioremediation has a high potential for application next spring. There are a number of research questions that have to be answered as a result of the bioremediation experience this past summer. That research is definitely going to take place this winter and will be available for use with further decisions next spring.

Bioremediation, of course, is going on naturally at a very significant rate in Prince William Sound. I think it is definitely a legitimate question to ask, Can compete with Mother Nature? This question must be evaluated within the context of the environmental situations facing us next summer. Is man's involvement really going to do any better than nature is going to do?

Oil contamination will probably be localized and could present fairly unique situations. We have all talked about the subsurface and how to get to the oil there. Conceptually, bioremediation potentially is one of the best options for removing that oil. The question is still out, however. There are still a lot of data to be analyzed before we make any final decision.

In terms of the restoration process, I think that biodegradation will continue, to some extent, this winter. Once the waters begin to warm up this spring, accelerated degradation can be expected. By the end of next summer, there is probably not going to be too much more that can be done in terms of bioremediation. The oil may be weathered to such an extent that doing bioremediation is unreasonable. We heard discussion about the potential crusting and tar formations that will eventually occur, and it is not clear how soon these processes will cause the oil to become completely unavailable for biological degradation.

I appreciate the opportunity of being able to present our results on the oil spill bioremediation project and I hope everyone gained further insight into our operations and successes. This has been a timely workshop and it looks like, based on the discussions we have had, that we need a lot more discussion in the future.

Speaker for Erich Gundlach
The physical treatment panel evaluated five different treatment techniques and assessed the pros and cons for each one of them. We divided the oiling into surface, subsurface, and asphalt formation. We decided that each method has its own site-specific applicability, and that we are going to have to develop our treatment plans based on the shoreline type and the amount of oil that is out there.

Our next step will be to develop a systems approach to treating the oil that is out there. We cannot look at any one technique as being the answer for treating all of the oil on the beaches. That is not only the case with physical treatment, but also within the biological and the chemical sections as well. We are going to have to look at a systems approach that takes a total step of looking at treating the oil.

We are going to need good monitoring data to show the condition of the beaches. We have some data now that we will transfer to Exxon and also to the Coast Guard. We are also going to have to look at the impacts of winter storms on the beaches. We will do a post-winter assessment, possibly in April, and get that data to different agencies so we can evaluate the impacts of winter storms and nature on the oil. Then we can use a systems approach to develop some method to treat the remaining oil out there.

What is nature going to do to the oil from a physical treatment standpoint? I believe that everybody is in agreement that high energy beaches are going to get washed and tumbled this winter and there is not going to be much surface oil out there. As far as subsurface oil, I do not think anyone knows. From a subsurface standpoint on the low energy beaches, the oil is still going to be there next year and we are going to have to develop some methods to get that oil out.

Sharon Christopherson
The chemical treatment panel concluded that, with the current or proposed approval process required for the use of chemicals in the environment, it will be very difficult to incorporate or even plan on using chemicals in the spring. To date, only two chemical treatments (bioremediation and the use of a chemical presoak prior to washing) have been through the approval process, and this took most of the summer. Bioremediation was approved, while the use of chemical presoaks was disapproved. If there were some way to streamline the

approval process and develop criteria to measure quantitatively effectiveness, the panel felt that chemical treatment might be a valuable tool in our response arsenal The reason for this being that we are going into the second year of the spill. The oil is either more weathered or it is in inaccessible areas, such as the subsurface.

The question we need to address before deciding to use any treatment method is, How well is natural recovery occurring? To remove surface oil, given the increased weathering and the difficulty we had getting it off in the past, we will have to use very aggressive means, going to higher pressures and higher temperatures. We will, therefore, physically disturb environments that may or may not be recovering. If the use of a chemical to enhance that process can result in less physical disruption of the environment while we are trying to get that oil out, it should possibly be considered.

In the case of the subsurface contamination, we really do not have a chemical enhancement that we think would work in situ. In order to get at the subsurface with physical methods, we are talking about either tilling and reworking; or excavating, treating the contaminated substrate, and returning it. As long as you are going to disturb the environment that much to get at that oil, you may want to use a chemical to maximize the amount of oil that you are going to be able to get off that system. We do not have any specific chemicals to recommend, but they are options to keep in mind.

I would like to look at where we are at right now in reference to both chemical and physical technologies. Through this workshop, we have tried to list the methods that we think are going to be available in the spring. If there are others under development, we can only hope that we will be able to add them as the process goes forward.

We need to review what is going on out in the field. We need to review the natural cleaning that is going on, the monitoring results that are coming in, and we have to review the available data; we cannot wait until the end. We have to then look at these data with reference to what we can learn from historical spills in similar environments. By comparing the rate of natural cleaning in both protected and exposed areas with similar spills, where at all possible, can we begin to predict how long natural cleaning will take for this spill? We need to look at our methods and at how we perceive these methods as being able to increase the rate of cleanup and recovery.

We need to come up with specific criteria for assessing the environmental tradeoffs. This is not just chemicals or bioremediation that we talking about. This also applies to physical treatment methods where we are going to go in and disrupt the environment again to try and speed up this process. If we are going to go in and dig up the soil to treat it and put it back, how long is it going to take for that area to recover versus leaving the oil there and letting it naturally weather over a certain period of time? Do we really increase the recovery by going in? These are effects that we really have not had the chance to look at in the past, but we must begin making those decisions.

Within the next month, we really ought to be sitting down and coming up with criteria, so that we have some kind of an idea of what our strategy is going to be in the spring. We can modify it as we go, if necessary, but we can't wait until the end of the spring, when all the data are in, to begin. We have already seen how long it takes us to begin to identify and weigh all the issues. Not until we can agree on what the issues are and which criteria we will use, can we be plan what is to be done in the spring. If we have to re-evaluate our plans because conditions have changed in the environment or have not developed exactly as predicted, we will be able to go through the process much more rapidly by using these issues and criteria to make a decision.

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General Discussion

Comments were addressed to the emphasis placed on the two chemical products and the lack of attention to any other product on the EPA list. It was suggested that individual vendors be permitted to show their products.

A representative from Greenpeace presented concerns on human impacts on the environment due the cleanup efforts. She commended members of the meeting for developing criteria to follow in the coming months. She asked what measures were being considered to determine cumulative impacts of chemicals, noise and air pollution, and other human pollution. Response to this question was that it was a good point that needs consideration. Further discussion on this issue was heard.

There was discussion on the need for pollution centers to treat recovered oil. An Exxon representative stated that it does not support any State-sponsored or individually-sponsored programs to recover oil spill related debris. Exxon retains responsibility for this type of recovery due to the safety hazards involved. He invited reports on locations of this debris for Exxon to begin the recovery effort.

Pamela Bergmann of the U.S. Department of the Interior stated that the U.S. Coast Guard should take the lead over the next few weeks to develop a detailed schedule and work plan that delineates how decisions will be made on additional cleanup activities. The work plan should identify the Federal and state agencies and interest groups to be involved in the decision-making process, and how they will be involved.

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