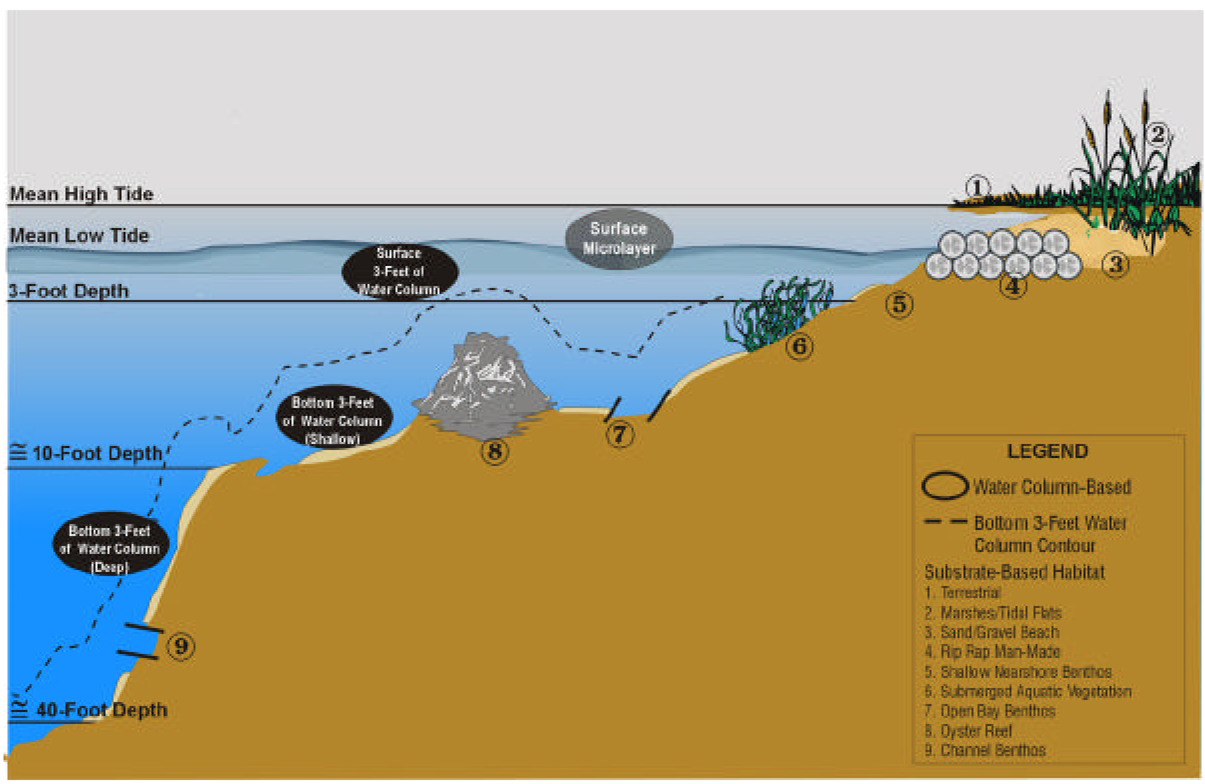
ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN THE GALVESTON BAY AREA

Report of a Consensus Risk Assessment in Galveston Bay



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Disclaimer

Report Availability

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Preface

This report describes the efforts of a group of individuals involved in or concerned with the environmental impacts of oil spills and oil spill response in Galveston Bay. Participants affiliated with various federal and state government agencies, the response industry, and environmental organizations were invited to utilize their individual familiarity with the issues in discussion and consensus-building exercises. The conclusions and recommendations do not commit any governmental, industry, or environmental organization in the Galveston Bay area to a particular course of action or policy.

This report was disseminated to participants for review, and their comments have been addressed in the final report. Some participants requested that the report be given wider dissemination in draft form to allow review by parent organizations and other non-participants. Although the sponsors agree that wide dissemination of the final document is essential, dissemination of the draft report beyond actual participants was not encouraged, since the report represents the consensus conclusions of the participants. Nevertheless, some comments were received from organizations, rather than participants. Some comments regarding style and grammar from non-participants were incorporated into the final report, but comments that altered the final consensus conclusions reached by participants were not incorporated. Those comments are relevant, however, and they serve as an excellent starting point for future discussion at the Area Committee and Regional Response Team levels of improved response capabilities in the Galveston Bay Area. They are, therefore, included as Appendix P.

This report does not endorse the use of dispersants or any other response measure on a specific spill incident in Galveston Bay or elsewhere, but it does indicate that that more emphasis on integrated response measures, including unconventional options, might be of benefit. The results of this ERA are intended as a starting point for further, more focused study by those organizations potentially benefiting from spill mitigation strategies.

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EXECUTIVE SUMMARY

There is growing interest in the United States (U.S.) for the use of a mix of countermeasures during oil spill response to achieve the highest level of environmental protection possible. This has led to concern over the potential for secondary impacts from the use of new or unfamiliar approaches. No countermeasure, e.g., natural recovery, on-water mechanical recovery, shoreline cleanup, *in situ* burning (ISB), or chemical dispersion, is risk-free or completely effective. Therefore, it is critical to have a defensible method for comparison of the risks and benefits of all. In an effort to make such comparisons, the U.S. Coast Guard (USCG), Texas General Land Office (TGLO), and American Petroleum Institute (API) agreed to co-sponsor an ecological risk assessment (ERA) of response countermeasures in Galveston Bay.

This report documents the Galveston Bay ERA and the conclusions and recommendations of the participating stakeholders. It provides background information to assist planners in the selection of appropriate response options, resulting in a higher probability of environmental protection from oil spills. This report also serves as a template for similar efforts in other regions around the country. This report was assembled by the project team on behalf of all participants in the process. It represents the consensus assessment of the participants regarding the ecological impacts of each of the potential response options.

This ERA process involved three phases: problem formulation, data analysis, and risk characterization. These activities were addressed by the participants in a series of three workshops, with the support of a project team. Participants included representatives of government agencies, industry, and community interest groups with a stake in environmental protection and oil spill response. The project team provided background information on the process and its application in Galveston Bay, facilitated each of the three workshops conducted as part of the process, and prepared the draft reports on behalf of the stakeholders.

Stakeholders were divided into two groups: risk managers and risk assessors. The risk managers provided the framework for the assessment by defining the parameters to be addressed, improving, their ability to identify and utilize all appropriate response options. In Workshop I, the risk managers described the risk of oil spills in the Galveston Bay area and the options available for response to spills (including operational capabilities and weaknesses inherent with each option). They tasked the risk assessors with building a conceptual model of the Galveston Bay environment, including identification of environmental resources at risk, as well as pathways and estimated effects of exposure on those resources.

The conceptual model constructed in Workshop I was utilized by assessors during and between Workshops II and III to analyze and characterize the ecological risks associated with the selection of various response options in Galveston Bay. At the end of Workshop III, the assessors again met with the risk managers to deliver the results of their assessment.

The final summary risk matrices included in this report (Chapter 6) represent the participants' consensus on the relative levels of risk associated with various stressors (response options) and resources or habitats in the Galveston Bay area. Certain conclusions and recommendations can be drawn from these consensus estimates. **While these estimates apply fully to the scenarios evaluated, they can only be extrapolated to other events with caution.**

- On-water recovery or ISB, used alone, offers little risk reduction over natural recovery.
- Chemical dispersion or shoreline cleanup, used alone or in combination, potentially results in greater environmental benefit than the use of natural recovery, ISB, or on-water recovery in the 4,000 barrel spill scenario. However, each technique involves trade-offs as well, e.g., dispersants shift concerns from shoreline resources to water column resources.
- The optimum response is likely to involve some combination of the response options available.

Response and resource managers need to "think tactically, not just strategically." Dispersants and ISB should not be considered for use only on major spills. Dispersants may provide critical environmental protection in nearshore areas for small spills as well.

The consensus conclusions regarding relative impacts are conservative. By design, they tend to over-emphasize the potential impact of each stressor on the environment, and under-emphasize the potential protection of sensitive resources. In an actual spill situation, participants would expect to see less injury from the oil spill than is predicted by this ERA.

Participants believe that the available data were sufficiently detailed and robust enough to allow supportable conclusions, but they recognize that there are areas where additional information would be valuable (i.e., ISB plume model, chronic oil toxicity data on reproduction). In order to validate the results of this and future ERAs, participants noted that more information is necessary regarding operational effectiveness of all response options; as well as dispersed oil plume exposure concentrations and durations in the environment.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Oil spills can have serious environmental and economic impacts, and because they are highly visible events, decisions related to oil spill response often become complex. These factors have made response planners very cautious about new or controversial response options, and, at the same time, anxious to find ways to improve oil spill response capability.

Historically, oil spill response in the U.S. has relied primarily on mechanical on-water recovery. Mechanical recovery is attractive because it is the only response option that leads to the recovery of some of the product. Experience, however, shows that it rarely results in recovery of more than 10 – 20% of the spilled oil. In and of itself, mechanical recovery does not provide the desired level of protection for sensitive resources threatened by oil slicks.

As a result, there is a strong desire on the part of many of the stakeholders to broaden the consideration of alternative countermeasures, with the objective of integrating all of the appropriate options to develop the "best" possible response. Since no countermeasure (i.e., mechanical on-water recovery, ISB, chemicals [particularly dispersants], or shoreline recovery) is risk-free or completely effective, it becomes important to have a defensible method to compare the risks and benefits of all, especially when used in combination. This approach has been viewed with suspicion by some advocacy groups, who worry that this is no more than an attempt to find "cheaper" response options at the expense of the environment. This issue can be more clearly understood by examining the status of dispersant use, one of the more controversial alternative response options.

Dispersant use provides an increased level of shoreline and surface resource protection, but does so by increasing the exposure of resources in the water column. In contrast to on-water recovery, environmental considerations rather than engineering efficiency drive decisions about dispersant use.

Historically, opponents of dispersant use have argued that dispersants simply represent an attempt by the industry to avoid more expensive response options, or to reduce the visibility of the environmental consequences of oil spills by "hiding" the oil in the water column.

Proponents respond that, while dispersant application may be cheaper, cost is not a controlling concern. Examination of environmental trade-offs indicates that dispersant use can significantly enhance the net environmental benefit in many spill situations. Proponents also argue that not only do dispersants prevent oil from entering sensitive habitats, but they mitigate the potential effects of dispersed oil in the water column by dilution and enhanced biodegradation. Furthermore, mechanical recovery is often not feasible.

The available information on dispersant use can be confusing, contradictory, and difficult to interpret. Past discussions often focused on an assessment of dispersant use consequences versus arbitrary exposure criteria. In contrast, this current, computer-assisted ERA offers a comparative review of the advantages and disadvantages of dispersant use as well as other response options. Such philosophical and technical debates can be resolved through an objective, well-documented process to evaluate the advantages and disadvantages of all response options. Side-by-side comparisons of the environmental trade-offs involved with each response option assist planners and decision-makers in developing an integrated response program.

This is not a particularly new concept, and for many years there has been discussion concerning evaluation of "environmental trade-offs" as a way to improve oil spill response planning (Baker 1997). To address this need for comparison of environmental effects, this project builds on several previous efforts (SEA, 1995; Kucklick et. al, 1997) and the ERA project begun in the state of Washington in 1998 by the current project team.

1.2 PURPOSE

The purpose of this ERA is to examine the available oil spill response options as described in the Galveston Bay Area Contingency Plan (ACP). Each option will be examined for its potential to both mitigate and aggravate environmental harm from an oil spill. Options will then be compared to each other. This side-by-side comparison will serve as the foundation for re-evaluation and realignment of response strategies in the current ACP.

1.3 ASSESSMENT OBJECTIVES

This report presents the results of developing a "cooperative ecological risk assessment (ERA)" analysis for two hypothetical spill scenarios in Galveston Bay. The objectives of the process were to:

- Demonstrate the feasibility of using this approach,
- Develop and document tools and protocols for use in future analytical efforts,
- Evaluate and compare the ecological consequences of oil spill response options in the scenarios, and
- Develop recommendations for consideration by local response organizations concerning the proper role for the response options under consideration.

1.4 ORGANIZATION OF THIS REPORT

This is a report of the ERA process as it was applied to Galveston Bay in an examination of the mix of response options available for two specific oil spill scenarios occurring at the intersection of the Gulf Intercoastal Waterway and the Houston Ship Channel. The report was assembled by the project team on behalf of all participants in the process. It represents the consensus assessment of the participants regarding the ecological impacts of each of the potential response options available in the area. The report is organized into eight basic chapters and supporting appendices.

Chapter 1 is an introduction and overview of the objectives for the Galveston Bay ERA.

Chapter 2 discusses the ERA process in general, and its adaptation for use in oil spill planning.

Chapter 3 starts with an overview of oil spill risk in Galveston Bay, describes spill response management considerations and available response options, and ends with a description of the scenarios developed for use in this assessment process.

Chapter 4 describes the process for developing the Galveston Bay conceptual model based on the scenarios described in Chapter 3. It includes identification of resources of concern, pathways of exposure and analysis endpoints.

Chapter 5 describes the risk assessment methodology and the tools used in conducting actual risk assessment, including the risk matrix, oil transport modeling, and oil budgets.

Chapter 6 details the results of the analysis by habitat type and scenario.

Chapter 7 details sources of uncertainty and data adequacy that participants dealt with in reaching their consensus decisions.

Chapter 8 summarizes conclusions and recommendations for use of this report in improving spill response in the Galveston Bay.

CHAPTER 2: ECOLOGICAL RISK ASSESSMENT PROCESS OVERVIEW

2.1 FUNDAMENTAL ELEMENTS OF AN ECOLOGICAL RISK ASSESSMENT

ERA is a process to evaluate the possible ecological consequences of human activities and natural catastrophes. ERA emphasizes the comparison of an exposure to a stressor (in this case, oil and/or a response option) with an ecological effect (e.g., population disruption, changes in ecological community structure or function, toxicological effects). This is done in a quantitative way as often as possible, and includes an estimation of the probability that an undesirable consequence will occur.

Some sort of risk evaluation occurs whenever a regulator must approve or disapprove an action with environmental consequences. An ERA brings structure and defensibility to this process through a defined methodology.

- It uses quantitative data whenever possible and defines uncertainty.
- It incorporates information into conceptual or mathematical models of the affected system.
- It interprets information against clear, consistent, predefined endpoints (action or threshold levels) related to the protection of resources.

While it is true that any assessment problem, such as the "best" mix of response options, can be formulated as a comparison of alternatives, many risk assessments tend to focus on the evaluation of one action to determine if it is acceptable. For example, when a new pesticide is proposed, the risks associated with its use will be evaluated and used to determine its acceptability. While this decision involves two options (i.e., approve or withhold approval), the focus is usually on the consequences of approval, rather than on a comparison of approval versus denial (Suter, 1993). In this study, the intent is to compare multiple response options in order to gain insight into the acceptability of each and how they might be integrated into a comprehensive response plan. The methods used for this comparative analysis are discussed in detail in Chapter 5.

It is important to note that ecological consequences are only one element that risk managers (e.g., Federal or State On-Scene Coordinators, natural resource Trustees, industry emergency response managers) must consider. The use of ERA methods helps ensure that the ecological considerations are properly analyzed and presented. However, a complete decision process must integrate these results with other factors, as illustrated in Figure 2-1.

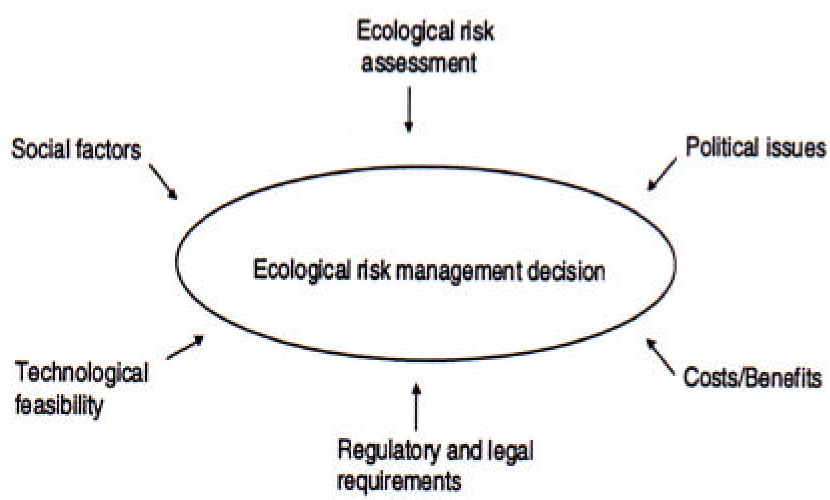


Figure 2-1: The Relationship of Ecological Risk Assessment to Management Decisions (Pittinger et. al, 1998).

Federal and state regulatory agencies and industry are all actively investigating or implementing ERA methods in support of their environmental programs. In the U.S., the primary Federal proponent of this approach is the U.S. Environmental Protection Agency (USEPA). The background and development of the ERA guidelines are discussed in detail in a series of USEPA publications (USEPA 1992a, b, c; USEPA 1993; USEPA 1994 a, b, c) and in the Proposed and Final Guidelines for Ecological Risk Assessment (USEPA 1996, 1998). The following summary is developed primarily from the latter two sources.

The ERA process (Figure 2-2) includes three primary phases - problem formulation, analysis, and risk characterization.

The first phase (problem formulation) involves identification of goals and assessment endpoints, preparation of a conceptual model, and development of an analysis plan. In this stage, the early interaction of risk managers (spill response managers) and risk assessors (ecological or natural resource technical experts) to clearly define the problem is essential. If mangers do not adequately define their concerns or assessors do not fully understand those concerns, the resulting analysis may not be sufficient to aid in management decisions.

The development of assessment endpoints is critical. These are "explicit expressions of the actual environmental value to be protected," e.g., reproductive success of anadromous fish or the size of a kelp bed (USEPA, 1998).

Endpoints can then be related to the potential stressors by developing a model that defines interrelationships between stressors, exposure, receptors, and endpoints. Selection of appropriate endpoints influences all subsequent activities.

The analytical phase involves characterization of exposure and ecological effects in the context of the conceptual model. The analysis phase must produce a summary for each component in the model, i.e., stressors, receptors, pathways, and potential exposure.

The last step in the process is the completion of a risk characterization. This involves estimating and interpreting the risks in relation to the defined endpoints. In addition, the strengths, limitations, assumptions, and major uncertainties are summarized. A report is prepared which describes the results of the analysis.

After the risk assessment is completed, the risk managers must decide on how to integrate this information into the decision process, along with other relevant considerations.

Chapters 3 through 6 of this report provide the results of applying this process to the two scenarios in Galveston Bay, and provide more details on the specific methods used.

The following discussion presents an overview of how the basic ERA process was modified to meet the requirements of this project.

2.2 ADAPTING THE ERA PROCESS TO OIL SPILL RESPONSE PLANNING

To encourage active participation by stakeholders, build consensus, and control costs, this risk assessment was conducted in a workshop environment where local technical experts and managers did much of the analytical work. The process consisted of three, multi-day workshops separated by several months (see Figure 2-3). Since the oil spill planning and response process involves a large number of organizations, including regulatory agencies, industry, natural resource trustees, and public interest groups, both risk managers and risk assessors were drawn from as many of the affected groups as possible. Oil spill response planning deals with a future, unspecified event; so participants developed scenarios that they believed offered the best general information for analysis (see Chapter 3). While the initial focus of this process was to evaluate the potential environmental risks and benefits of dispersant use, the analysis seeks to identify the "best" overall response plan for each of the scenarios studied. The approach is based on the paper prepared by Aurand (1995).

The use of workshops to complete the actual analysis is not typical for an ERA, but is well suited to the circumstances that exist in the oil spill planning community. This format facilitated participation by as many individuals as possible, and created a situation in which stakeholders (risk managers and risk assessors), with guidance from the project team (staff facilitators), were responsible for the development of the assessment. Further, involvement of participants throughout the ERA forced them to understand the totality of the options, impacts, and trade-offs beyond their particular area of expertise. That understanding led to credibility of the risk ranking, and increased stakeholder understanding of and commitment to the process.

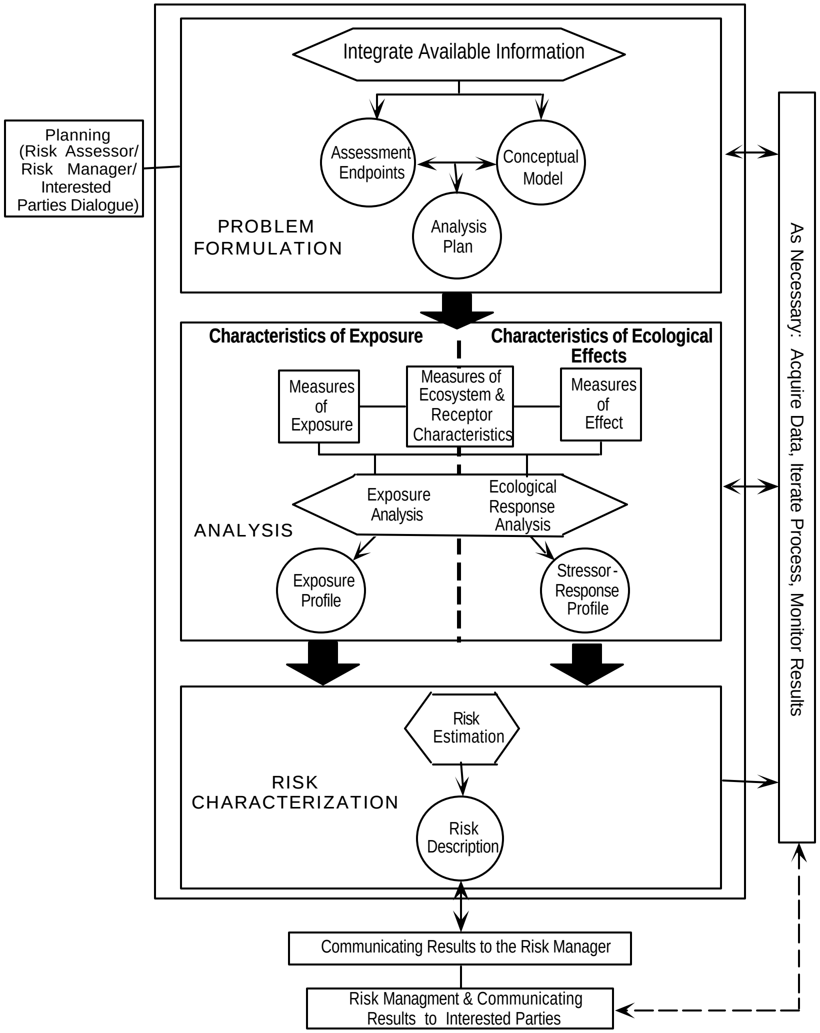


Figure 2-2: The Ecological Risk Assessment Framework (USEPA, 1998).

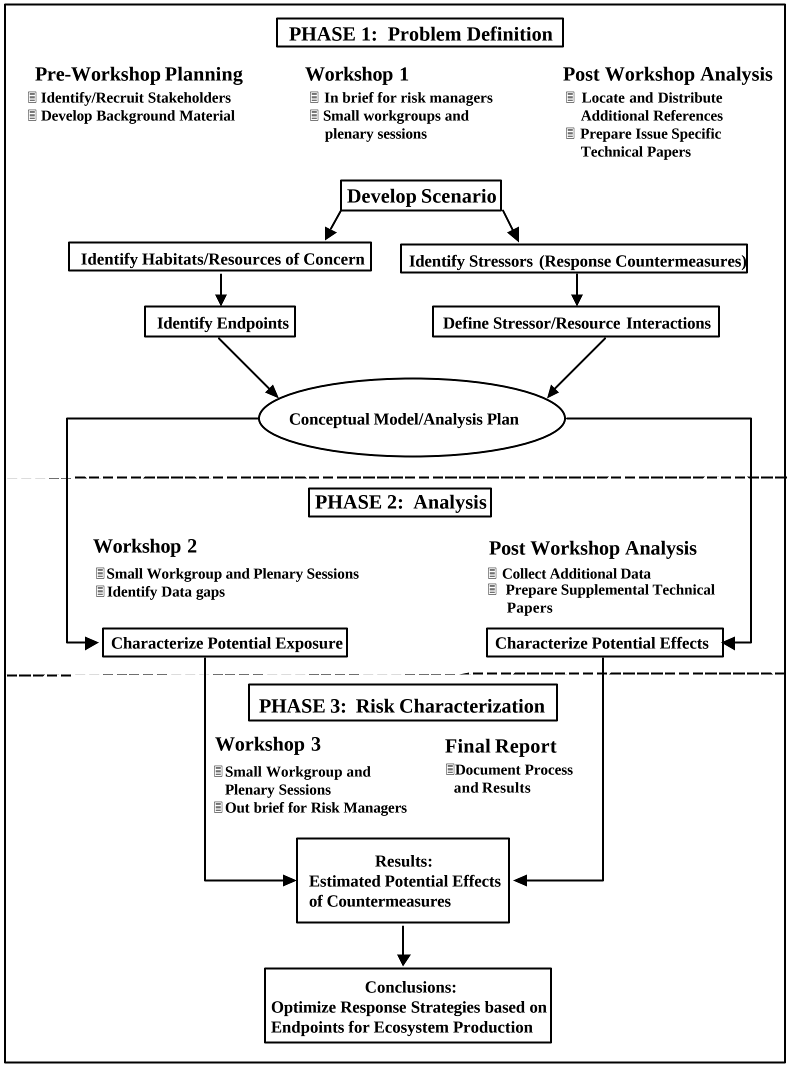


Figure 2-3: Ecological Risk Assessment Strategy Presented to Workshop Participants.

Since many of the participants are involved in oil spill response planning only as a collateral duty, the involvement of the facilitation team in both the workshops and the interim assignments helped to maintain momentum. The facilitation team assisted in the compilation and analysis of data, as well as assumed responsibility for the preparation of meeting summaries after each workshop and compilation of the final report. Facilitation team members provided technical knowledge/experience in one or more of the following:

- Oil spill planning and response,
- The ecological effects of oil in the marine environment,
- Familiarity with the ERA approach, and
- Experience in meeting management and facilitation.

At the first workshop, risk managers and assessors worked together to define the problem (Chapter 3), and then the assessment team developed the proposed endpoints, conceptual model, and analytical approach (Chapter 4). At the end of the workshop, specific assignments for data collection related to analysis of exposure and effects were given to groups of individuals for completion prior to the second workshop.

At the second workshop, participants used these data to examine exposure scenarios, agree on endpoint thresholds, and conduct a preliminary analysis of the relative risk of all of the response options under consideration. This equates to the analysis and risk characterization phases of the assessment (see Chapter 5 for more detailed background information on this process).

At the third workshop, participants were given the opportunity to review the preliminary analysis done during the second workshop, and to discuss issues of concern. When this was completed, a final analysis of relative risk was developed (Chapters 6 and 7), and used to identify management recommendations for each of the response options being considered (Chapter 8). These recommendations were presented to the risk managers at the conclusion of the workshop.

2.3 PARTICIPANTS AND RESPONSIBILITIES

In order to effectively adapt ERA protocols to oil spill response planning, it is essential that there be broad, multi-stakeholder involvement. Federal, state, and industry response managers, natural resource Trustees, environmental advocacy groups, and technical experts all need to participate. Because of the nature of oil spill response and oil spill response planning, consensus building is a critical element. In addition, other groups, such as local government, concerned private citizens, and the press, must have access to and understand the process.

Process participants were assigned to one of two categories: risk managers or risk assessors.

Risk managers included those government, industry, and community representatives who are involved in carrying out oil spill response decision-making, both during spill planning and response. They are familiar with the operational capabilities of various response options and with the personnel requirements and logistics necessary to successful spill response.

Risk assessors include government, industry, and community representatives involved in advising the risk managers on environmental and ecological considerations, both in planning and during spill response.

At the beginning of the process, risk managers outlined their response strategies and defined their concerns and questions regarding ecological impacts of specific response alternatives. Risk assessors then proceeded to analyze and characterize the potential threats and benefits in order to respond to the managers' concerns.

Individuals who agreed to participate in this project supported the process through the following:

- Their attendance at and participation in developing consensus-based "best professional judgements" at the workshop,
- The identification and summarization of appropriate technical data, and
- The preparation of analytical information or summaries needed to complete the risk assessment.

Individuals and groups prepared overview material in their area of expertise for consideration at the first workshop, as well as presented the data necessary for the risk characterization and analysis. The material presented in this report represents a compilation of the material they prepared and used during the workshops. The participants in the workshops, the expertise they provided, and the analytical groups in which they were involved are presented in Appendix A.

CHAPTER 3: PROBLEM FORMULATION

3.1 AN OVERVIEW OF OIL SPILL RISK IN GALVESTON BAY

The USCG Vessel Response Plan Rules define 14 "higher volume port areas" as having greater quantities of oil and higher amounts of vessel traffic than other port areas. The Coast Guard believes opportunity and likelihood of an oil spill occurring in those areas is greater, thereby resulting in USCG-imposed higher response standards in the form of more stringent response times. The Galveston Bay and Houston Ship Channel region is a designated higher volume port area.

More oil moves through the Houston Ship Channel/Galveston Bay area than any other port along the Texas coast. According to statistics from the Texas General Land Office, the Houston-Baytown area imported more than 941,000 barrels of Groups II, III, and IV persistent oil per day in 1997 alone. (Group II, III and IV oils have a specific gravity of less than 1.0, tend to float on the surface of the water [USCG, 1996] and are generally amenable to conventional response techniques such as mechanical on-water recovery, chemical dispersion or ISB techniques.) An additional 430,137 barrels per day of refined oils were loaded onto ships for export from the port in 1997. That totals 500,500,000 barrels of oil moving through the Galveston Bay waterway each year. In comparison, 388 million and 425 million barrels of oil move through the respective ports of Corpus Christi and Beaumont/Port Arthur, TX (Wilson Gillette & Co., 1998). Both of these ports are considered higher volume ports as well.

Galveston Bay is also one of the most heavily congested waterways in the country. Statistics provided by USCG Marine Safety Unit Galveston state that there were 129,187 vessel movements (~354 per day) in or through the Galveston Bay/Houston Ship Channel area in 1997. This total includes 104,896 tow vessels with barges, 19,051 ship movements, and 5,240 recreational, military, and other vessel movements.

Transportation of large quantities of oil in a confined waterway subject to extremely high traffic increases the potential for a major oil spill accident. This threat is offset to a certain extent by the heightened awareness of industry and government to that potential, which results in increased emphasis on prevention. Nevertheless, an accident due to human error, "act of God", untimely equipment failure, or some other cause is still very likely.

The following examples provide an indicator of the potential for major accidental spills, as well as typically response strategies, throughout Galveston Bay.

On July 28, 1990, the tank barge Apex 3417 sank and Apex 3503 was damaged in a collision with a tankship in the Houston Ship Channel in Galveston Bay. Over a two-day period, the barges spilled a total of nearly 17,000 barrels of partially refined oil into the Bay. Pushed by variable winds and tidal currents, the oil spread throughout the Bay threatening shorelines and environmentally-sensitive marshes. In addition to conventional on-water mechanical and shoreline recovery, responders experimented with bioremediation in marsh areas in responding to the spill (Wade et al., 1993).

On October 20, 1994, four major petroleum pipelines ruptured in the San Jacinto River, swollen beyond flood stage by torrential rains in the aftermath of a tropical storm. More than 432,000 barrels of gasoline, fuel oil, crude oil, and natural gas spilled into the river. Some of the oil caught fire, forcing closure of railroad and highway bridges and other oil pipelines in its path. Response options were limited to mechanical recovery and experimental trials of bioremediants and ISB techniques (Leonard, 1997).

In March 1996, the barge Buffalo 292 spilled approximately 3,000 barrels of intermediate fuel oil (IFO 380) in the Houston Ship Channel just inside the mouth of Galveston Bay. More than half the oil was swept into the Gulf of Mexico by strong northerly winds. That oil moved south and west in the Gulf and eventually formed into large tar mats and patties that threatened the barrier island beaches along the South Texas Coast. The oil weathered quickly and soon rendered conventional offshore skimmers ineffective. Responders eventually resorted to modification of shrimp boats by attaching containment boom to their nets to collect the oil on the surface of the water (Clark et al., 1997).

The Galveston Bay Area Contingency Plan (ACP) lists 18 spills of 500 barrels or greater in the Bay between 1979 and 1997. All but five of these spills were less than 4,000 barrels in size. The ACP also includes a discussion of four spill scenarios for the purpose of comparing baseline response strategies against available response resources as a measure of preparedness.

One of these scenarios is relevant to this risk assessment because it involves a vessel collision at the intersection of the Houston Ship Channel and the Gulf Intercoastal Waterway. The scenario lists sensitive areas at risk as a result of the spill, including:

1. Environmental.
    - Bird rookeries in Galveston Bay, East Bay, West Bay, and Trinity Bay.
    - Marshland and bird habitat on Pelican Island and Bolivar Peninsula.
    - Swan Lake, Dickinson Bayou, Moses Lake and Dollar Bay.
    - Possible contamination of shellfish grounds.
2. Human Use.
    - Galveston Yacht Basin.
    - Texas City Dike.
    - Recreational beaches.
    - Recreational boating in the affected areas.
3. Industrial.
    - Bolivar ferry operations.
    - Vessel traffic in Houston Ship Channel and the Gulf Intercoastal Waterway.
    - Commercial fishing in the Bay.
    - Municipal and industrial water intakes in Galveston and Texas City.

3.2 MANAGEMENT GOALS

The Galveston Bay ACP lists the safety of response personnel and the public as its first priority in managing response to an oil pollution incident. The second priority is to stop "…the economic (including environmental) loss." The ACP underscores speed of response as essential in limiting economic and environmental loss. According to the plan, rapid response is essential for several reasons:

- It is more effective to stay ahead of the rapidly spreading oil than to "chase" after it.
- Mechanical recovery operations are most efficient when the oil is concentrated over a relatively small area.
- High volume removal technologies (e.g., dispersants and ISB) work best on fresh oil.

3.2.1 Equipment Limitations

According to the ACP, the shallow water depths of the Galveston Bay estuary make deployment of small boats and conduct of open-water skimming operations difficult. Vacuum trucks or oil recovery equipment accessibility is inhibited due to the limited number of access points from shore and the predominance of salt marsh in much of the area. Therefore, response priorities focus on rapid containment and treatment of the spilled oil as close to the spill source as possible. This must be coupled with implementation of shoreline protection strategies intended to divert oil not recovered on the water away from the more sensitive areas to natural collection points.

3.2.2 Ecological Considerations

The ACP recognizes that the extent of cleanup work in certain environments in the Bay must be balanced with the possible ecological damage that may result from overly aggressive cleanup operations. It underscores that purely cosmetic cleanup must be avoided and that in some areas the most ecologically sensible course will be to allow beached oil to degrade naturally.

3.2.3 Political Considerations

Sensitive environments include aquatic and shoreline ecosystems, economic resources and activities, recreational resources, and historic cultural resources. While all are critical, it is not always possible to protect all resources equally during a response. In fact, response often involves trade-off decisions, which result in greater protection of some resources at the expense of greater damage to others. The ACP details protection priorities and those priorities have been offered for public and political review. However, planners recognize that public and political priorities may be substantially different in any given spill incident. Responders need to be sensitive to changing public and political concerns. They must be prepared to explain why a particular course is being pursued and be able to adjust response strategies to satisfy new concerns.

3.2.4 Shoreline Impact Considerations

It is not possible to prevent shoreline contamination in most spill situations in Galveston Bay. Therefore, the ACP provides detailed plans for tactical protection of the most sensitive shoreline habitats using a combination of sorbent and deflection booming. This assessment examines additional options as well.

3.2.5 Sensitive Environment Protection Considerations

Part of the ACP protection strategy focuses on protective booming of some of the salt marsh tributaries and inlets that surround the main portion of the Bay. Sorbent booming of critical tributaries is considered a priority in protecting those salt marsh habitats. The plan also acknowledges that such protective booming will be extremely labor intensive and time consuming, taking three to five days for initial installation of sufficient protective booms. Without sufficient lead time, these labor intensive operations may frustrate attempts to mount a rapid response.

3.2.6 Appropriate Countermeasures

The ACP lists a number of cleanup techniques available for response to an oil spill and acknowledges that techniques may be employed alone or in combination to optimize response. Final selection of the appropriate mix of response options is situation-dependent and varies based on a number of factors, including product spilled, quantity spilled, location, weather, political considerations, and potential site impacts. The ACP also incorporates the current recommended order in which those techniques should be considered for employment in various waterways in the Galveston Bay estuary area. Those are as follows:

A. Houston Ship Channel (West of Morgan's Point).

1. Mechanical/physical recovery.
2. Natural remediation.
3. Additives (e.g., herding agents, polymers, etc.).
4. Bioremediation.
5. ISB.
6. Dispersants.

B. Galveston Bay (Including Trinity Bay, East and West Bays).

1. Mechanical/physical recovery.
2. Natural remediation.
3. ISB.
4. Bioremediation.
5. Additives (e.g., herding agents, polymers, etc.).
6. Dispersants.

C. Gulf Intercoastal Waterway (outside the Bays).

1. Mechanical/physical recovery.
2. ISB.
3. Bioremediation.
4. Natural remediation.
5. Additives (e.g., herding agents, polymers, etc.).
6. Dispersants.

D. Nearshore/Offshore

1. Mechanical/physical recovery.
2. Dispersants.
3. ISB.
4. Natural remediation.
5. Additives (e.g., herding agents, polymers, etc.).
6. Bioremediation.

The above priorities were based on the presumption that mechanical recovery on water offers the optimum means of protecting the environment in any spill situation. One goal of this ERA process (as defined by the sponsors and participants) was to examine the adequacy of strategies in place to deal with those risks. Their ultimate goal was to provide sufficient, technically-sound information to enable a reevaluation of the above strategies that will result in reaffirmation or modification of those strategies in Galveston Bay.

3.3 SCENARIO BUILDING

3.3.1 Introduction

During Workshop I, risk managers were asked to determine spill scenarios that allowed a balanced examination of all relevant issues. Selection of scenarios is critical to the risk assessment process because the scenarios establish the spatial and temporal parameters of the risk analysis. Details of their deliberations are included in Appendix B. The final scenarios incorporated considerations of both risk and management factors detailed above. A summary of the elements of the final scenarios follows.

3.3.2 Location

The risk managers agreed that the intersection of Gulf Intercoastal Waterway/Houston Ship Channel (Figure 3-1) was the preferred scenario location based on relatively high incident probability, potential for consideration of all response options, and potential for impact on the largest number and variety of resources.

The group also considered factors other than incident probability and ecological impact in selecting the scenario. Parameters such as oil weathering, salinity of the receiving waters, water depth, and seasonal considerations were also discussed.

3.3.3 Oil Type

Arabian Medium Crude oil was chosen because it offers a significant challenge to all on–water response options for the following two reasons:

- It is transported in large quantities through the Bay.

- It emulsifies quickly and may be amenable to treatment by dispersant and ISB only on the first day of the spill.

3.3.4 Size of Spill

Participants opted to examine two spill sizes.

- A spill size of 500 barrels was chosen because a spill of less than 500 barrels might be too small to consider use of dispersants or ISB.
- A 4,000-barrel spill was also examined because one tank on a vessel can hold 4,000 to 5,000 barrels of oil, so a spill volume in that range was thought to be representative of a serious spill.
- By bounding the spill at 500 and 4,000 barrels, participants attempted to identify limits of effects from the various countermeasures in this shallow estuary system.

3.3.5 Weather Conditions

Prevailing winds in the Galveston Bay area are from the southeast. Therefore, a southeasterly wind of 12 kts for Day 1 was chosen. Storm fronts passing through the Bay often cause winds to blow from the west. Participants therefore decided to apply a westerly wind after the first 12 hours. This change redirected the oil into some of the most ecologically sensitive areas of Galveston Bay on the second day of the spill.

3.3.6 Time of Year

Spring (i.e., the month of April) was used for the following reasons:

- Shrimp migration occurs in March and April.
- Numerous organisms pass through critical life stages at that time.
- It is historically when the greatest number of vessel accidents occur (Grabowski, 1997).

3.3.7 Spill Duration

Participants reached consensus that an instantaneous discharge would be a better scenario parameter than a continuous release due to the relatively small total volumes spilled.

3.4 RESPONSE OPTIONS AS STRESSORS

The term “stress” can be defined as “The proximate cause of an adverse effect on an organism or system” (Suter, 1993). In the case of this project, the response options analyzed can be considered to be the “stressors” of concern. Ultimately, five response options were evaluated:

- Natural recovery,
- Dispersants,
- Shoreline cleanup,
- On-water mechanical recovery, and
- ISB.

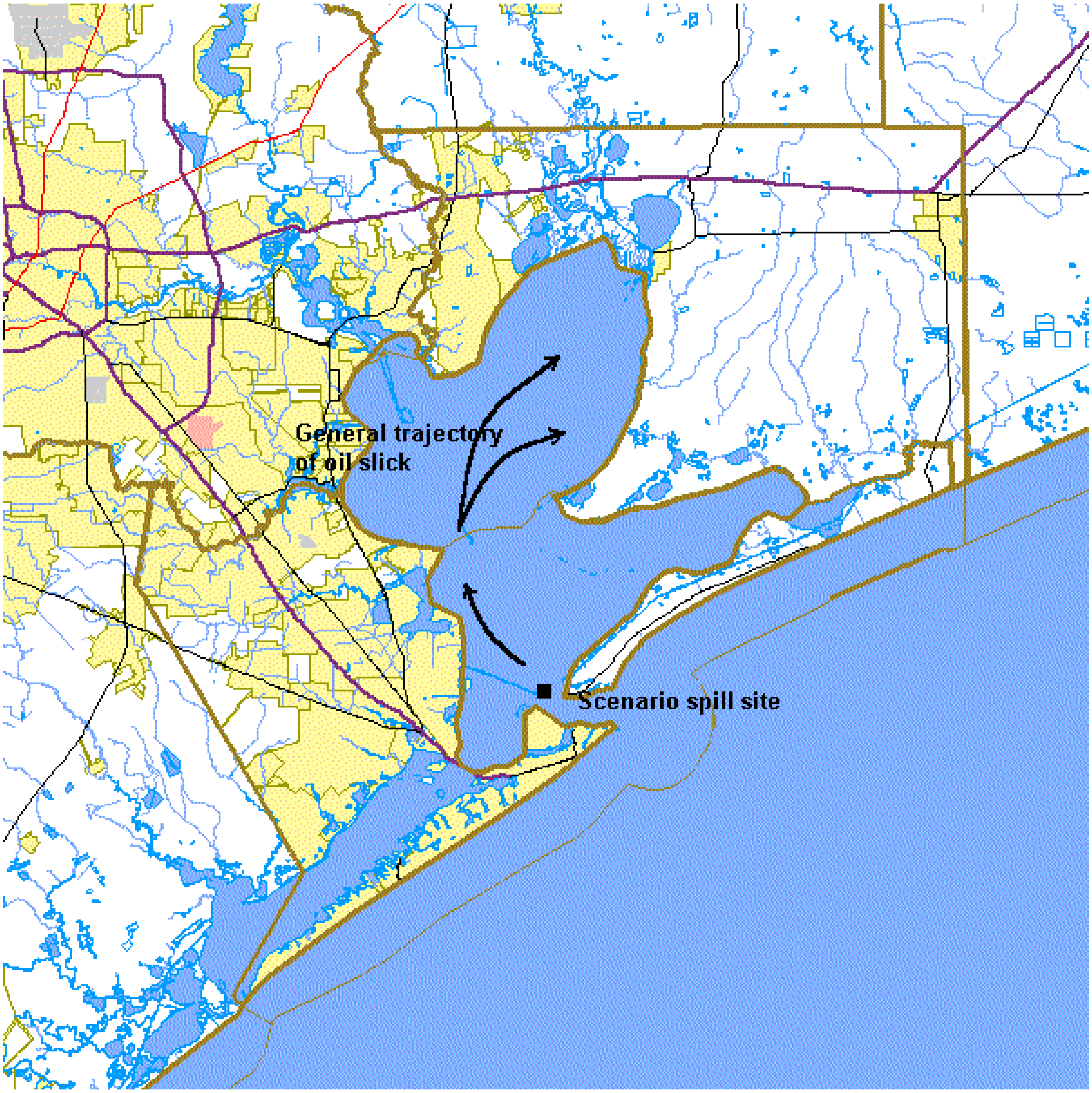


Figure 3-1: Map of Galveston Bay showing the location of scenario spill site and general surface slick trajectory (as shown by NOAA Hazmat modeling). (Map created using U.S. Census Bureau's Tiger Mapping Service located at http://tiger.census.gov.)

Two other response activities, shoreline bioremediation and protective shoreline booming, were considered but not included in the analysis. Shoreline bioremediation was eliminated because, while it can accelerate shoreline recovery under ideal circumstances, it is used as a "polishing" tool, not an immediate response. Protective shoreline booming was not included because it is a universal technique implemented regardless of other immediate response options utilized. Background information on both of these response techniques is presented in Appendix C.

While these five response options are the source of the potential ecosystem stress, the mechanisms that cause this stress are not always the same, and may differ in magnitude between options. Seven hazards which determine potential exposure pathways that link the stressors to resources were identified as follows:

- Air pollution,
- Aquatic toxicity,
- Physical trauma (a mechanical impact from people, boats, etc.),
- Oiling or smothering,
- Thermal (refers to heat exposure from ISB),
- Waste, and
- Indirect (refers to a secondary effect such as ingestion of contaminated food).

These lists of stressors and associated hazards were used to develop the conceptual model (see Chapter 4). The general characteristics of each of the stressors (response options) are described below.

3.4.1 Natural Recovery

Use: Natural recovery is defined as no human intervention to influence the fate of the spilled oil. **It represents the baseline against which all of the other response options are compared**. With natural recovery, the spilled oil will drift with the winds and currents, gradually weathering until it evaporates, dissolves, and disperses into the water column, or strands on the shoreline. Once stranded, weathering will continue and the oil will gradually biodegrade or be incorporated into the sediments. Portions of the relatively fresh oil may be released from the shoreline and redistributed several times until it finally degrades, is consumed by organisms, or is deposited permanently.

Natural recovery is considered an appropriate option for spills at sea which do not threaten shoreline or protected habitats. It is also appropriate for some sensitive shoreline habitats where intrusion by people and equipment may cause more environmental damage than allowing the oil to degrade naturally, or where recovery and cleanup are not feasible.

Logistics: Monitoring is required; recovery may take months or years.

Limitations: Does not meet public expectation that an attempt will be made to remove spilled oil from the environment. May not protect high value shoreline habitats.

Efficiency: N/A

3.4.2 On-water Mechanical Recovery

Use: Removal of oil from water for disposal and possible reuse to prevent or minimize impacts to sensitive nearshore and shoreline habitats.

Logistics: Booms, skimmers, vessels, sorbents, deflection/collection booms, oil storage devices, and/or vacuum trucks.

Limitations: Water depth is a challenge in Galveston Bay; large-capacity equipment is generally limited to waters of greater than 8 feet in depth. Although most on-water mechanical recovery operations occur in open water, some efforts extend into shallow water habitats. Shallow water operations increase opportunity for damage to resource as a result of physical contact with clean-up equipment.

Managers estimated it would take approximately 6 hours (from notification to arrival on-scene) to mount an effective response. Managers agreed that effectiveness of mechanical recovery is encounter rate-dependent.

- *Efficiency*: Estimated effectiveness of 38% for a 500-barrel spill and 27% for a 4,000-barrel spill. (See Appendix B, section 4.1) On-water recovery efficiencies were based on the following assumptions:
- Percent effectiveness is based on total volume spilled.
- Spill occurred at 0400.
- Effective cleanup involves use of skimmers, booms, and recovered oil storage equipment.
- Effective cleanup with all equipment operational at 1000.
- Day 1- Effective cleanup with all equipment continues for 8 hours until 1800.
- In an 8-hour period, all equipment will be fully operational for 6 hours, with 2 hours downtime for repositioning to new oil patches, decanting, and other miscellaneous activities.

- For the 500-barrel scenario, no on-water mechanical recovery would occur after Day 1 due to spreading.
- For the 4,000-barrel spill, mechanical recovery operations would continue at a reduced level throughout the night and the following day.

3.4.3 Oil and Dispersant

Use: Transformation of oil from a surface slick into dispersed droplets in the water column, to reduce shoreline impacts and waste disposal issues.

Logistics: Approval for dispersant application, application platform (vessel, helicopter, fixed-wing aircraft, dispersant), spotter aircraft, and monitoring.

Limitations: Dispersant use is not pre-approved in Galveston Bay. The decision to use dispersants in the Bay is dependant on incident-specific consultation with the natural resource trustee agencies and the concurrence of the EPA.

Another limitation is that of availability of Scientific Monitoring of Advanced Response Technologies (SMART), and whether or not visual observation is sufficient initially. Dispersant plans in the Galveston Bay require that all dispersant use be monitored, if possible, to assess dispersant effectiveness. If dispersant monitoring is not immediately available, decision-makers must determine whether to delay dispersant operations until monitoring capabilities are in place.

Efficiency: Chemical dispersant effectiveness estimate for the 500-barrels spill was 100% dispersion, and for the 4,000-barrels spill, 80% effectiveness (see Appendix B, section 4.2). Dispersant efficiency estimates were based on the following assumptions:

- Percent effectiveness is based on total volume spilled.
- Spill occurred at 0400.
- Window of opportunity for effective dispersant use is 0600 to 1800 on Day 1. After that, dispersant use would not be possible due to darkness and excessive weathering of the oil.
- Corexit 9500 (at a 1:20 ratio) is the dispersant used.
- Dispersant aircraft (DC-3 and DC-4) on scene applying dispersant within 5 hours of the spill.
- All oil treated is dispersed.

3.4.4 *In Situ* Burning (ISB)

Use: Removal of oil from water surface (due to burning) resulting in the minimization of storage and disposal problems.

Logistics: Fire boom, vessels, spotter aircraft, monitoring and ignition capability, and smoke-plume model.

Limitations: ISB, like dispersant use, is not pre-approved in Galveston Bay. The decision to use ISB in the Bay is dependant on incident-specific consultation with the natural resource trustee agencies and the concurrence of the EPA.

Another limitation of ISB is that of availability of SMART, and whether or not visual observation is sufficient initially. ISB plans in the Galveston Bay require that all ISB operations be monitored, if possible, to assess burn effectiveness. If monitoring is not immediately available, decision-makers must determine whether to delay ISB operations until monitoring capabilities are in place.

There is a gap between the public perceptions of potential human health effects of a smoke plume and the actual potential for effect. Although accurate predictions of smoke plume movement can be made based on wind speed and direction, conditions can change quickly, possibly impacting nearby populated areas.

For this assessment, ISB includes only on-water burns. Sandy beach and riprap habitats would not be burned, but could be affected by burning in nearby areas. Burns would not be conducted directly over oyster reefs. Thermal radiation would not further aggravate injuries to resources in the surface microlayer because the oil itself would already have killed those resources.

Efficiency: On-water ISB efficiency estimated at 40% for a 500-barrel spill and 20% efficiency for a 4,000-barrel spill (see Appendix B, section 4.3), based on the following assumptions:

- Percent effectiveness is based on total volume spilled.
- Spill occurred at 0400.
- Window of opportunity for effective on-water ISB operations is 0600 to 1800 on Day 1. After that, ISB operations would not be possible due to darkness and excessive weathering of the oil.
- Two, 500 foot sections of fire boom and all associated vessels, monitoring equipment, igniters, etc., would be on scene and operational within 6 hours (at 1000).

- Each burn cycle requires approximately 2 hours to contain and concentrate the oil to a thickness sufficient to sustain burning.
- Each actual burn lasts for one hour.

3.4.5 Shoreline Cleanup

Use: Removal of oil and debris, preventing or limiting re-oiling of intertidal areas.

Logistics: Manpower, vacuum trucks, water washing, hand tools, surface washing agents, shoreline cleaners, protection boom, and/or heavy equipment.

Limitations: The use of heavy machinery on beaches and intrusion by humans on foot can have adverse impacts on some shoreline habitats.

Adverse public reaction, restricted commercial, industrial, and recreational use or access during cleanup, high cost and difficulty in gaining access to impacted shorelines (due to property or topographical obstacles) can all make shoreline cleanup difficult operationally.

Once shoreline cleanup begins, determination of “how clean is clean” can make decisions regarding termination difficult.

Effectiveness: Cleanup effectiveness is highly dependent on shoreline type and accessibility. Participants estimated that as much as 100% (or as little as 0%) of the visible and accessible oil would be removed over time, depending on habitat type.

CHAPTER 4: CONCEPTUAL MODEL

4.1 BASIC ELEMENTS OF THE CONCEPTUAL MODEL

A key element of any ERA is the development of a conceptual model to guide the analysis. In the context of ERA procedures, USEPA (1998) defines a conceptual model as a "written description and visual representation of predicted relationships between ecological entities and the stressors to which they may be exposed." The conceptual model has two principle components, 1) risk hypotheses, which describe expected relationships between the resource(s), the stressor(s) and the assessment endpoint(s), and 2) a diagram (or diagrams) that illustrates the relationships presented by the hypotheses (USEPA, 1998). The conceptual model is important because developing the model helps ensure that the assessment team examines all of the important relationships in the analysis, and documents their approach so that it is clear to others how the analysis was conducted.

The model should focus on the ecosystem or ecosystems at risk, using individual species only as representative elements of the system. When it is applied to oil spill response planning, the model must be a comparative analysis of the risks and benefits of all of the response options, not their individual risks and benefits.

The model need only be complex enough to provide the information necessary to support informed conclusions. This does not mean that effective analysis cannot proceed without an in-depth knowledge of all components of the local environment. In fact, it means just the opposite. The affected systems must be described well enough that the major consequences of the perturbations can be defined. The planning team should focus on key components rather than exclusively on the collection of environmental or physiological data, which do not assist in facilitating the decision process.

There is no "cookbook" methodology to develop a conceptual model. However, to be effective, any model needs to address the basic characteristics of ecological systems relevant to oil spill response planning, i.e.:

Complex Linkages. Ecosystem effects may be both direct and indirect, and the response planner must be sensitive to the possibility of unexpected consequences. The best way to approach this problem is through the development of conceptual models that show the pathways connecting the various ecosystem components. There are a variety of approaches that can be used. Energy flow, food webs and nutrient or mineral cycling have all been used and are in the basic ecological literature. In oil spill response planning, it is probably most appropriate to develop a model using trophic linkages and/or physical habitat requirements.

Density Dependence. Some effects may vary depending on the population density of the species in question. More frequently, either the oil or the response countermeasure may affect the density of a particular species, with unexpected consequences for the ecosystem as a whole. The possibility and consequences of a dramatic change in population density for a particular species should always be examined.

Keystone Species. In all ecosystems, there are certain species that play a major role in the structure of the system. In some cases, this may be direct and obvious (the role of framework corals in coral reefs, or large, dominant tree species in mangrove forests). In others, it is less so (predators which limit the population of an otherwise dominant species). It is essential to identify keystone species during the analysis, because changes in the population of those species can have major effects on the rest of the ecosystem in question.

Time and Spatial Scaling. In order to characterize the ecosystem at risk, an assessor must understand the role of time and space in the system. For example, some ecosystems are naturally patchy, others are continuous. Seasonality may be an overriding consideration. Some marine and coastal communities essentially exist for only a few weeks or months and change rapidly, while others may exist for centuries with only minor modifications unless perturbed.

Uncertainty and Variability. All ecosystems contain elements of randomness and uncertainty, as well as variability, which make the prediction of exact consequences impossible. This does not mean that general trends and overall structure cannot be discerned, but it does mean that the assessor must be alert to unexpected events or consequences, and be prepared to deal with them as they are identified.

Cumulative Effects. Oil spills and oil spill responses often occur in polluted areas or in combination with other environmental stresses. Cumulative or synergistic effects are always a possibility. For example, a coral reef stressed by high sediment load, or a rocky intertidal zone subjected to thermal stress from an effluent discharge, cannot be expected to respond in the same way as a similar, unstressed community. A history of multiple spills or other sources of oil in the environment could also be a factor.

Population versus Community Dynamics. The assessor must consider both protection of valuable (for whatever reason) species and whole communities. It serves no purpose to rescue individuals of an endangered or threatened species, only to return them to a community or habitat which can no longer support them.

Definition of System Boundaries. In order to correctly characterize an ecosystem, the area that operates as a functional unit must be defined, both in space and time. If this is not done correctly, unexpected consequences are more likely to occur. It is also a crucial factor in the subsequent risk evaluation, because it places the affected resources in the appropriate context for the entire system.

4.2 DEVELOPING THE ELEMENTS OF THE CONCEPTUAL MODEL

The participants in this assessment developed the elements for the conceptual model during the first workshop. Detailed notes from their discussion are presented in Appendix B. After the scenarios were developed, the assessors discussed the basic elements of the conceptual model, and then developed the information necessary to complete a conceptual model relevant to this analysis. Initially, they reviewed the information available on the Galveston Bay ecosystem, relying heavily on GBNEP (1994), TGLO (1994) and the personal expertise of the participants to develop information of the resources of concern (Section 4.2.1). They then examined the relationships between the stressors and the resources of concern to define the basic pathways that needed to be examined (Section 4.2.2). When this was complete, endpoints were developed to use during the assessment to evaluate effects (Section 4.2.3). All of the information from these activities was used to develop the final conceptual model (Section 4.3).

4.2.1 Resources of Concern

The following actions helped participants to develop the list of resources of concern:

- Grouping of species/resources into categories (i.e., related species or habitats),
- Careful consideration of resources that might be affected by one stressor, but not another,
- Having some basis of value for that resource (e.g., ecological or economic value),
- Considering the current status of a species or condition of a population (e.g., is that community already stressed or protected?),
- Thinking about the exposure pathways that will affect a resource, and
- Keeping the spill scenario in mind.

Identification of resources of concern involved a three-step process of habitat identification, resource category identification within the habitat, and example species identification within resource categories. The participants proposed a classification of five habitats and a series of subhabitats. These are:

1. Terrestrial (Nearshore Upland).
2. Shoreline and intertidal.
    - Marsh/tidal flat.
    - Sand and gravel beach.
    - Riprap/manmade.
3. Subtidal benthic.
    - Subtidal benthic in water depths of less than or equal to 3 feet.
    - Subtidal benthic in the open bay in water depths of 3-10 feet.
    - Subtidal benthic in dredged channels in water depths of greater than 10 feet.
    - Non-intertidal oyster reefs.
    - Submerged aquatic vegetation beds (SAV).
4. Water column.
    - Upper 3 feet.
    - Bottom 3 feet in depths of 3-10 feet.
    - Bottom 3 feet in depths greater than 10 feet.
5. Surface (Surface Microlayer).

Figure 4-1 presents a visual representation of the major habitats considered in this analysis.

This information, and information from Galveston Bay National Estuary Program (GBNEP, 1994) and TGLO (1994), are summarized in the “Description of the Resource” sections found in Chapter 6 (Risk Analysis Results)(see also Appendix B, Table 1).

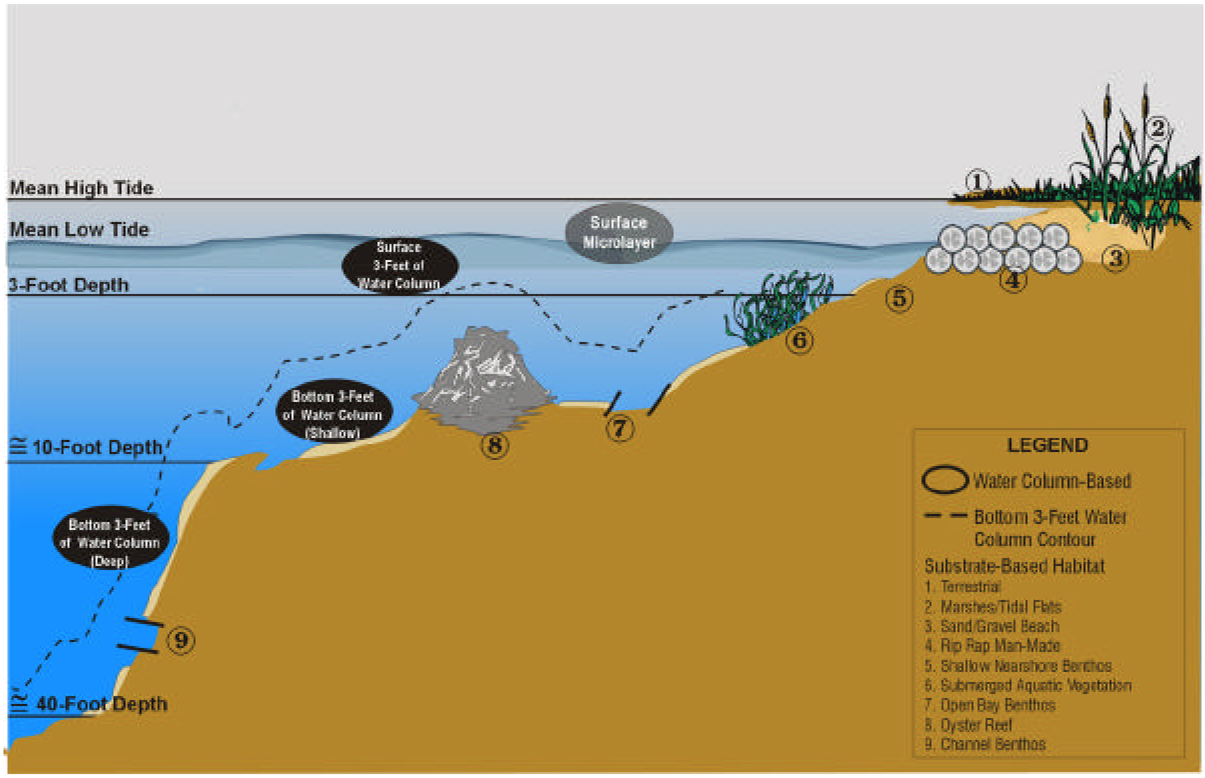


Figure 4-1: Visual representation of the major habitats considered in this analysis.

4.2.2 Potential Environmental Risks and Exposure Pathways

Once participants developed a list of resources at risk, they prepared a matrix relating the stressors (response options) to the resources at risk through the exposure pathways discussed in Section 3.4 (Response Options as Stressors). The results of this analysis are presented in Appendix D. This matrix defines all of the connections that are necessary to complete the conceptual model. When the term "N/A" is used in the analysis, it indicates that no pathways exist to link the stressor (response option) to the resource. **This does not mean that impacts do not exist**. All of the stressors were compared against the baseline of natural recovery, and since none of the response options were "immediately 100% effective", some effects always occur. This issue is discussed in more detail in Chapter 6.

4.2.3 Endpoints for Analysis

When the connections necessary to define the conceptual model were identified, the participants developed "endpoints" and "thresholds" to consider when evaluating the actual effects and consequences of response actions using the matrix presented in Appendix D. According to USEPA (1998), an endpoint is an explicit and measurable expression of an environmental value that is to be protected. The use of defined endpoints is a key element in the assessment process, and there must be agreement as to what constitutes appropriate endpoints prior to the analysis of effects based on the conceptual model.

4.2.3.1 Background

The U.S. EPA terminology recognizes one type of endpoint - assessment endpoints. "Assessment" endpoint refers to effects of ecological importance at the population level or higher within the system under evaluation. It includes both an ecological entity and specific attributes of that entity. For example, it might be determined that a reproducing population of a particular commercial fish species is a critical assessment endpoint. Some ERA literature on recognizes a second type of endpoint - the measurement endpoint. The USEPA approach defines this as one type of "measure" used to evaluate the assessment endpoint.

Assessment endpoints are often difficult or impossible to measure directly, especially in advance of the action under evaluation. In that case, "measures" must be identified to evaluate the risk hypotheses related to the assessment endpoints. These are identified in the analysis plan. Measures of effect equate to the term measurement endpoint. It refers to data that can be measured in the laboratory or the field, and then used to estimate the assessment endpoint. Toxicity data for a single species (combined with life history and distribution information to estimate population effects) is an example of a measurement of effect.

Assessment endpoints should have biological and societal relevance, an unambiguous operational definition, accessibility to prediction and measurement, and susceptibility to the hazardous substance. Assessment endpoints may include habitat loss or physical degradation of habitat below some effect threshold, as well as biological effects. All participants in the assessment process must accept the endpoint definitions for endpoints of both assessment and measurement endpoints.

Determination of the ecological significance of an event requires that it be placed in the context of the following:

- The types of other anticipated occurrences associated with the event.
- The magnitude of the other occurrences caused by the event.
- The role of the event in the structure and function of the system in question.
- The relationship of the event to other occurrences within the system (cumulative analysis).

For an entity (a receptor) to be used in an endpoint, it must be susceptible to the stressor of concern. Susceptibility has two components: sensitivity and exposure. Sensitivity refers to how readily an ecological entity is affected by a particular stressor. It is related to the proposed mode of action of the stressor, as well as to individual and life history stages. Exposure refers to co-occurrence, contact, or the absence of contact, depending on the nature of the stressor and the properties of the ecological entity in question. It is a central assumption of risk assessment that effects are directly related to exposure. Life history considerations are often very important in determining susceptibility, and can be very complex. Delayed effects must also be considered.

4.2.3.2 Endpoint Definition

Based on the context considerations previously listed, the participants identified a list of general goals that would be important response objectives from an ecological standpoint. These were as follows:

- Prevent or minimize taking of protected species,
- Prevent or minimize degradation of water quality,
- Prevent or minimize degradation of sensitive habitats, and
- Prevent or minimize the long-term disturbance of relative abundance and diversity of communities within habitats (this is a “no net loss” statement for chronic effects).

Based on these goals, the workshop participants then chose the following four endpoints for consideration during the analysis (see Chapter 6):

- The proportion of the resource within the proposed trajectory that is killed.
- The amount of exposure that leads to impaired reproductive potential of the resource.
- The proportions of resources present within the trajectory that become oiled.
- The extent of disturbance.

4.3 GALVESTON BAY OIL SPILL CONCEPTUAL MODEL

When all of the information described above was completed, the participants reviewed the purpose of the risk assessment in order to develop a risk hypothesis to guide the analysis. Galveston Bay supports a wide range of recreational activities and has economically significant commercial fisheries, especially for shrimp, crabs and oysters. It also provides habitat for a diverse community of birds, marine and estuarine organisms, including marine mammals, sea turtles, and several threatened or endangered species. Galveston Bay is also a vital commercial and industrial waterway, especially for the trans-shipment of crude oils and petroleum products. Oil spills are probable events in the Bay. While very large spills are rare, small spills are not. At present, the primary response option within the Bay is on-water mechanical recovery, followed by shoreline cleanup for removal of stranded oil. This approach does not provide reliable protection of many of the resources of concern. However, before any change in response planning can be initiated, the relative environmental costs and benefits of all possible response options need to be examined.

Based on these considerations, the following risk hypothesis was developed:

The careful integration of the five response options selected for analysis in Galveston Bay could prevent injury to resources sensitive to floating oil. This could be done without undue or new risk to other resources of concern, especially water column and benthic resources.

The conceptual model developed by the participants in this project is very similar to the conceptual model developed by the Galveston Bay National Estuary Program (GBNEP, 1994). That model is presented in Figure 4-2, for comparative and reference purposes. In the case of the GBNEP model, the primary focus is on organic productivity and the flow of energy and materials within the estuary. The conceptual model developed for this project, in contrast, focuses on the potential exposure of the resources to oil for direct effects, followed by consideration of the trophic consequences of these changes. Figure 4-3a – 4-3e presents a summary of all of the considerations developed in this chapter.

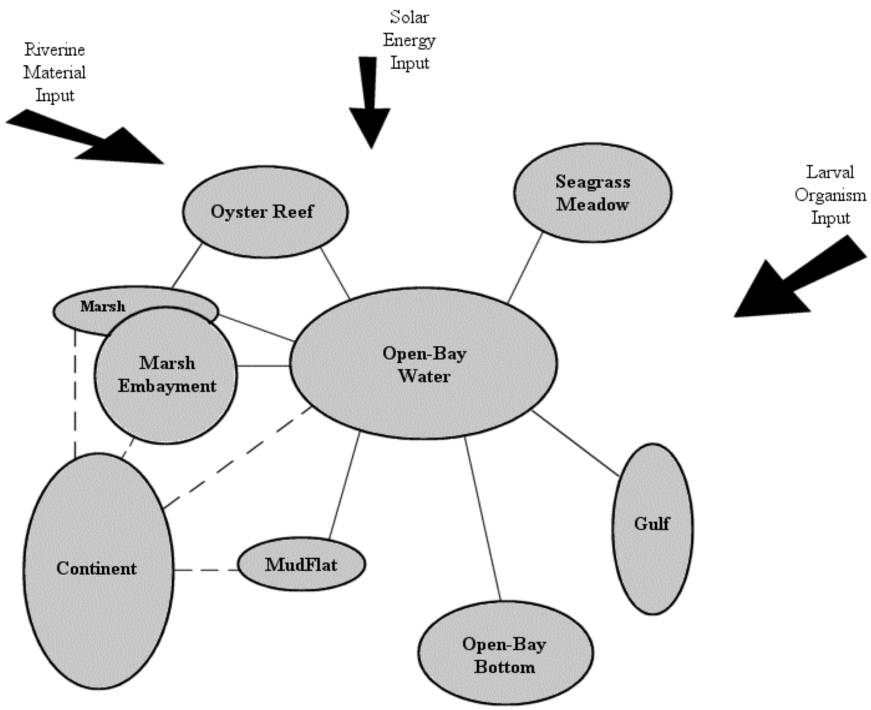


Figure 4-2: Conceptual Model developed by the Galveston Bay National Estuary Program (GBNEP) (1994).

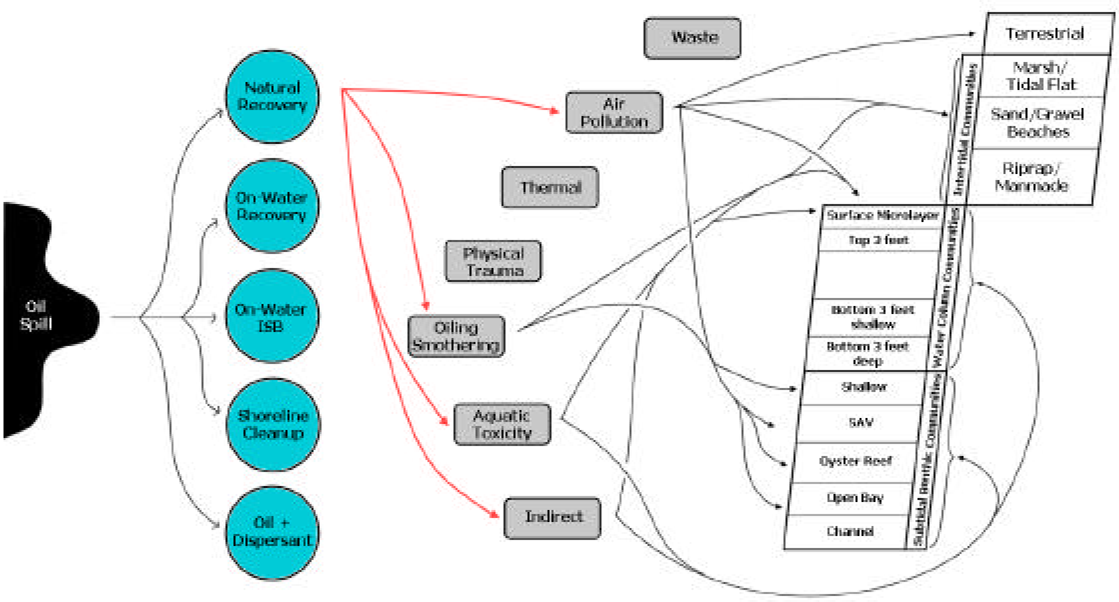


Figure 4-3a: Relationships between natural recovery and resources (exposure pathways) within the conceptual model, as developed by participants of the Galveston Bay area ecological risk assessment.

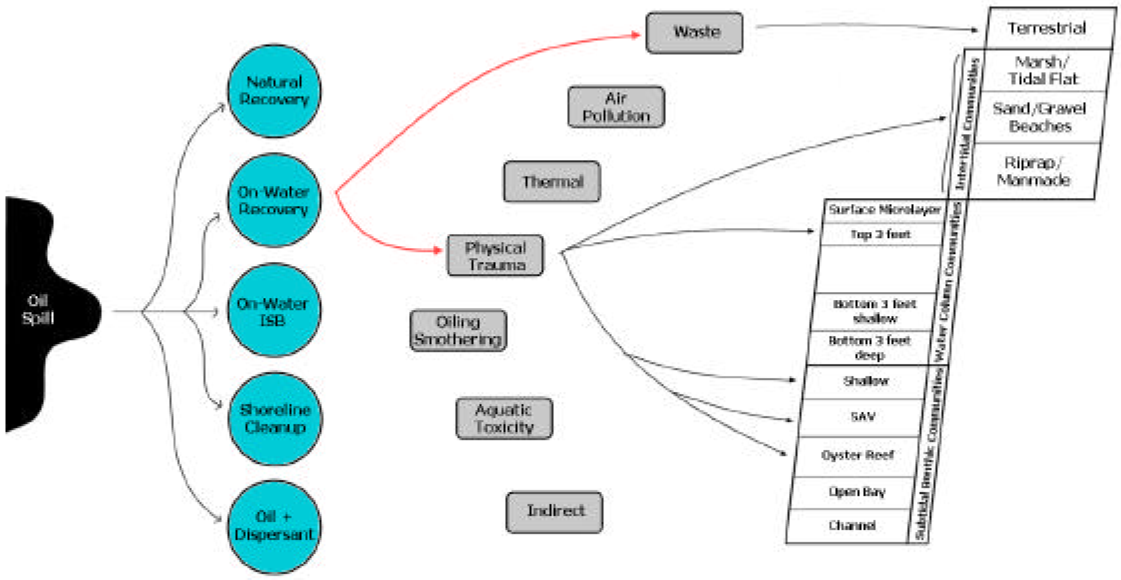


Figure 4-3b: Relationships between on-water mechanical recovery and resources (exposure pathways) within the conceptual model, as developed by participants of the Galveston Bay area ecological risk assessment.

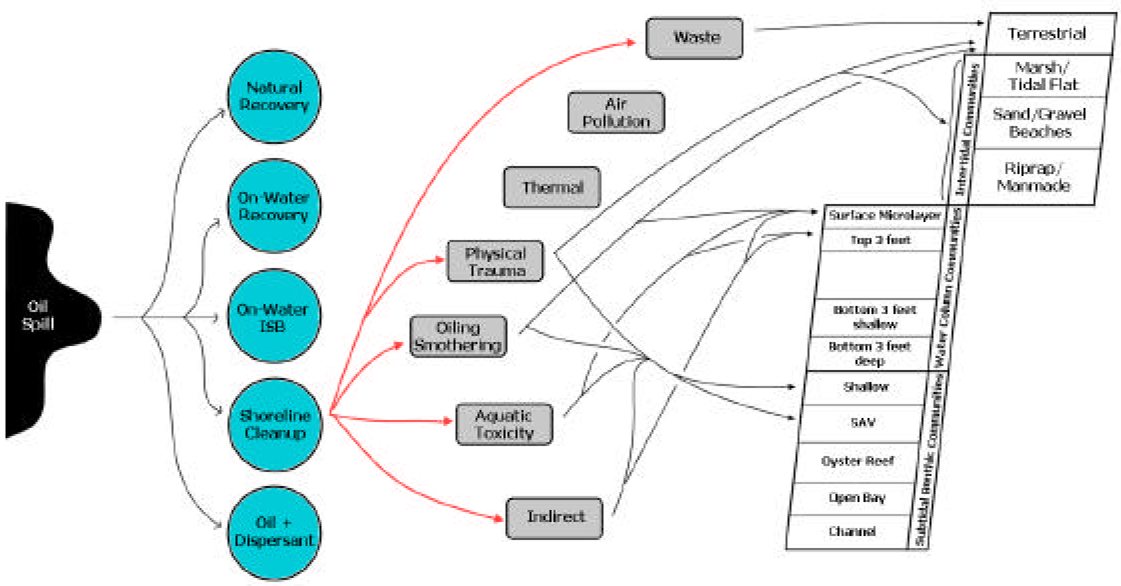


Figure 4-3c: Relationships between shoreline cleanup and resources (exposure pathways) within the conceptual model, as developed by participants of the Galveston Bay area ecological risk assessment.

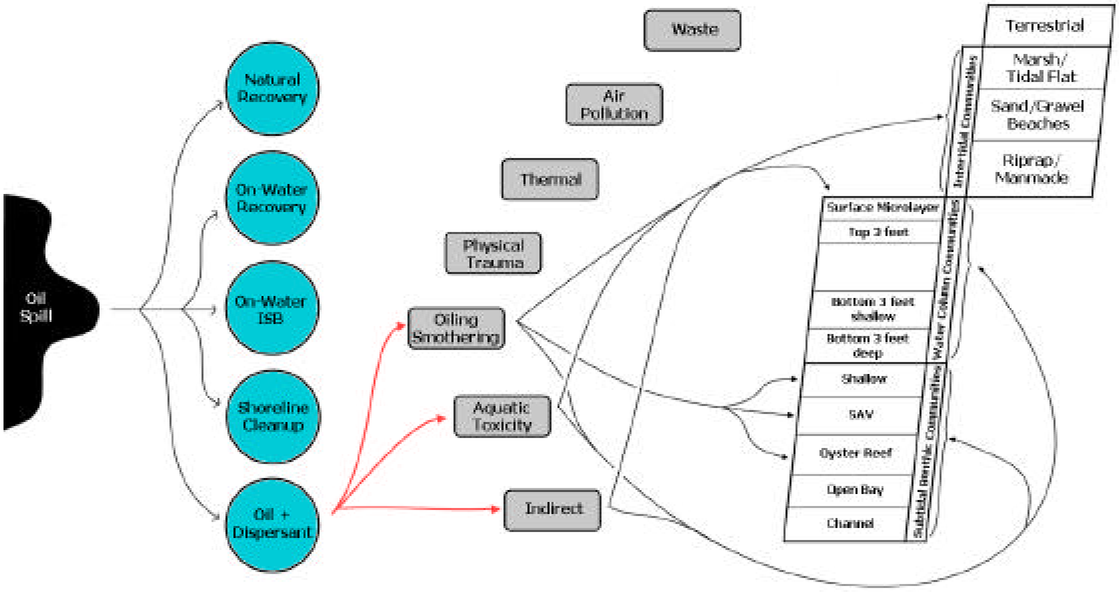


Figure 4-3d: Relationships between dispersant use and resources (exposure pathways) within the conceptual model, as developed by participants of the Galveston Bay area ecological risk assessment.

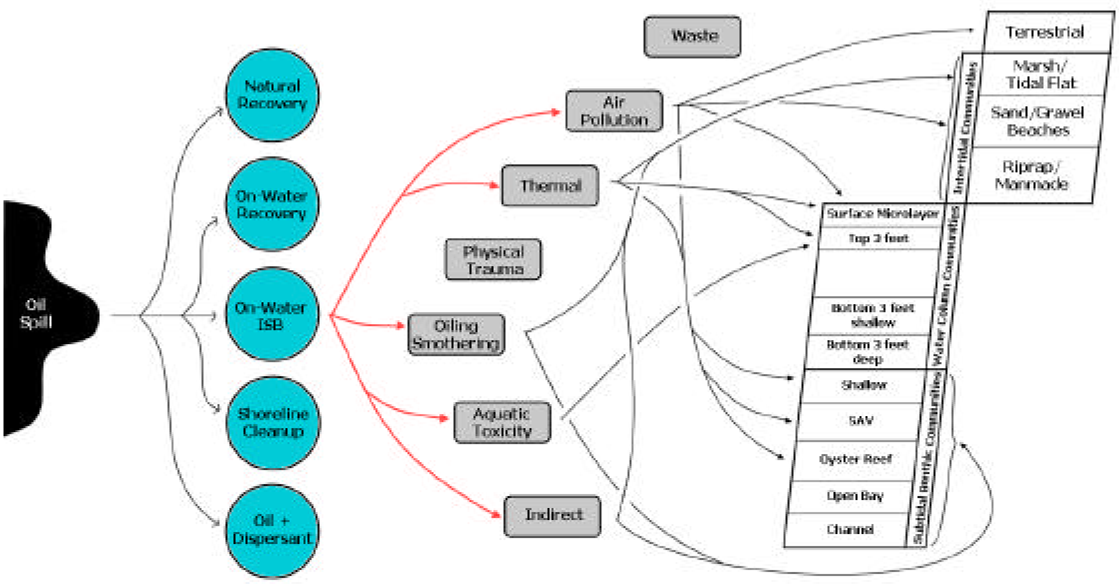


Figure 4-3e: Relationships between ISB and resources (exposure pathways) within the conceptual model, as developed by participants of the Galveston Bay area ecological risk assessment.

CHAPTER 5: RISK ANALYSIS

5.1 COMPARATIVE RISK ANALYSIS METHODOLOGY

The ERA process provides the basis for comparing and prioritizing risks. If every alternative presents some level of risk, then such an approach can provide the basis for choosing between alternatives (Suter, 1993). In this case, the goals of the analysis are to determine if the available response options offer environmental benefits and can be used in combination to improve over the situation which exists with natural recovery or on-water mechanical recovery alone.

The final activity at the first workshop was the development of an analysis approach. This defined the methods used by participants to evaluate the risk hypothesis developed in the conceptual model. The participants gathered and organized information in preparation for the risk analysis. Three workgroups were formed to gather, organize, and evaluate data. Appendix E provides more information on these discussions, and on the participants in each workgroup.

Workgroups were assigned responsibilities relating to transport, resources, and effects issues. The Transport Workgroup assumed responsibility for developing information on the surface oil trajectory, the behavior of the dispersant plume, and the behavior of the ISB smoke plume. The results of this workgroup are summarized in Section 5.2 of this chapter, and the full report is provided in Appendix F. The Resources Workgroup identified and described the resources within each habitat. They obtained information on resource distribution/location and potential sensitivity to the hazards identified in the conceptual model. They obtained information on life history stages, protected species status, and the relationship of the Galveston Bay resource to the resource as a whole, as appropriate. The primary source for this information was TGLO (1994), (document was available for review by the participants at the remaining workshops), and the subject matter experts present at the meetings. The Effects Workgroup collected data on the hazards relative to the endpoints and resources identified in the conceptual model. This included collecting existing data on toxicity and/or physical effects of the stressors relative to resources of concern. The major conclusions of that group are presented in Section 5.3 of this chapter.

5.2 OIL TRANSPORT AND EXPOSURE MODELING

ERA participants were assisted by the National Oceanic and Atmospheric Administration (NOAA) in the assessment of potential exposure. To examine oil movement and oil volume over time, NOAA provided modeled trajectories and oil budgets. The NOAA report is included in its entirety as Appendix F.

The 500 barrel and 4,000 barrel scenarios provided the base information necessary to model surface and subsurface oil trajectories (snapshots of the spilled oil in the environment at various time intervals). Each snapshot indicates the geographic location of the oil, the areal extent of the oil, and an approximation of the concentrations of oil at that geographic location. Combining trajectories for several time intervals provides a representational image of the duration and severity of exposure for every geographic point in Galveston Bay. The NOAA model assumes that the areal extent of a surface or subsurface plume is the same, regardless of quantity of oil spilled. Thus, a spill of 4,000 barrels has the same “footprint” (but a different oil distribution) as a spill of 100 barrels. When calculating the concentration of oil at any particular point in a plume, the model assumes a spill quantity of 100 barrels. To calculate point concentrations of oil for the 500-barrel spill at this ERA, participants simply multiplied the reported concentrations by 5. For the 4,000-barrel spill the concentrations reported in the model were multiplied by 40.

Volume of oil in the water is affected by weathering and by reductions in volume due to response activities. To account for this, NOAA assisted participants in building oil budgets (estimates of the fate of spilled oil over time due to weathering and human intervention) for each response option under consideration (See Section 5.2.4).

5.2.1 Surface Slick Trajectories

Surface slick trajectories were modeled from the point of discharge described in the scenarios until oil impacted shoreline areas two days following the spill incident. The location and relative density of stranded oil was used to evaluate resources at risk when response methods such as natural recovery and on-water mechanical recovery were used. In the NOAA trajectory model, surface slick movement is heavily influenced by the prevailing wind conditions.

The surface slicks for both the 500 and 4,000 barrel spill scenarios were represented by the same trajectory.

In both cases, the spilled oil followed a northwest path, so that at 6 hours following discharge the slick was in the Galveston Bay east of Texas City (Figure 5-1).

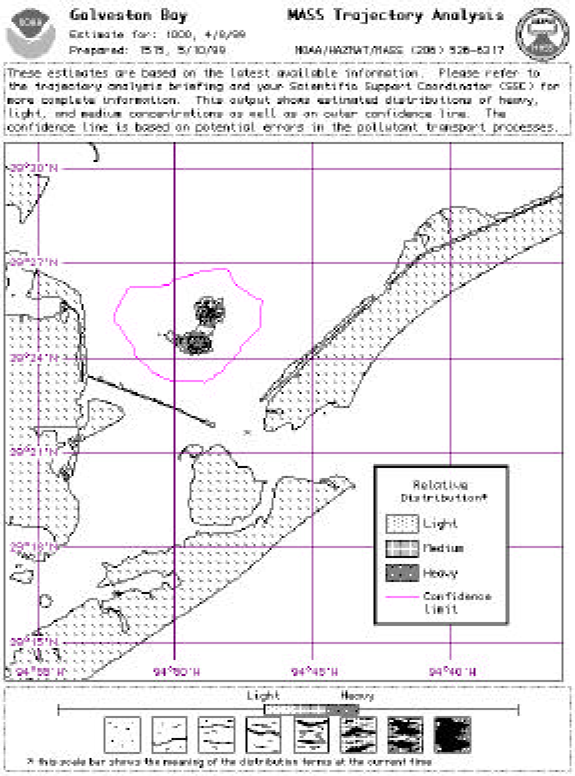


Figure 5-1: Surface slick trajectory 6 hours following discharge.

The slick extended in a north-northwest and southeast direction, so that by 12 hours post-spill, the slick had split into two major sections and flattened out. The heaviest concentrations of oil at this point were found in the most southerly portions of the slick (Figure 5-2).

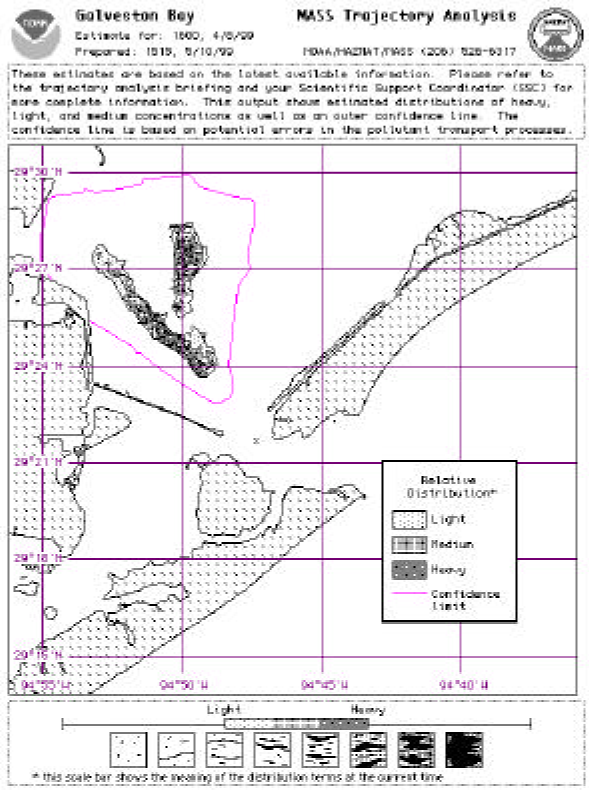


Figure 5-2: Surface slick trajectory 12 hours following discharge.

In the snapshot 24 hours after the spill, the two sections extended toward the southeast, resulting in two parallel ribbons of fairly concentrated oil with light sheening in between. The slick stretched as far south as Port Bolivar, and the first impacts to land were seen (Figure 5-3).

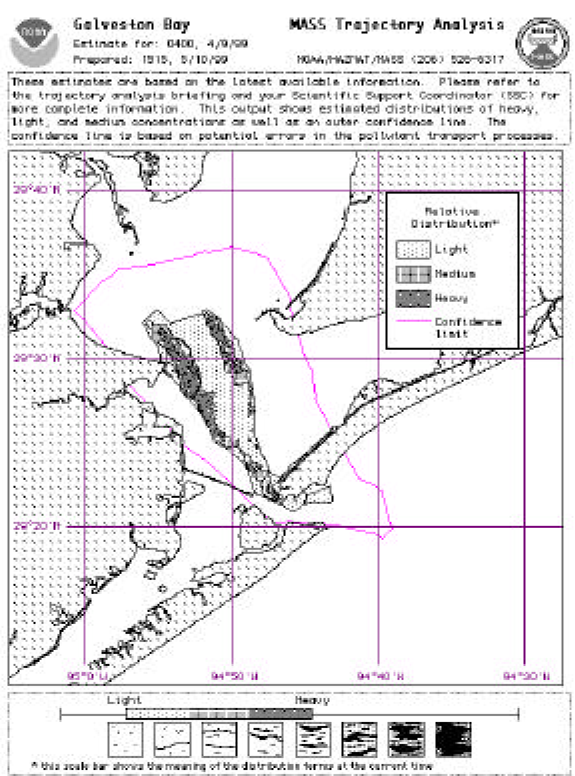


Figure 5-3: Surface slick trajectory 24 hours following discharge.

Due to the change in the wind direction as described in the scenario, by the end of Day 1 the slick began to move eastward. With the wind holding steady out of the west, by the end of Day 2, large areas of land on the east side of the Bay were impacted by the oil. The heaviest oiling of shoreline habitats occurred in the Oak Island and Lake Stephenson areas, with some oil extended across East Bay (Figure 5-4). This is a particularly sensitive area, in that the Lake Stephenson region is rich in marshland habitats and associated waterfowl, invertebrates, and fishes.

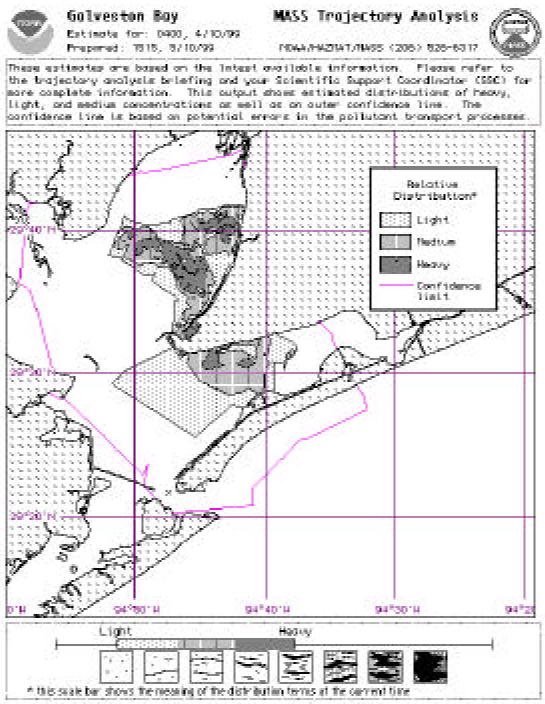


Figure 5-4: Surface slick trajectory after 48 hours following discharge.

5.2.2 Dispersed Plume Trajectories

As with the surface plume trajectories, NOAA initially modeled the dispersed oil plume concentrations based on a 100 barrel slick. NOAA assumed that the dispersed plume mixes deeper in the water column over time, e.g., the entire plume mixed to a 1-meter depth at 6 hours after dispersion, a 3-meter depth by 36 hours, and a seven-meter depth by 72 hours. The model also assumed instantaneous dispersion of the entire slick at eight hours into the spill and even mixing throughout the plume. This maximized potential concentrations of oil in the water column. According to the NOAA model, no oil was expected to escape from the Bay into the Gulf of Mexico. The trajectory indicated that the dispersed oil plume would not impact land until 48 hours after dispersing, or 56 hours after the spill.

NOAA also selected four sites from which a general exposure profile could be constructed (Figure 5-5). The location and concentration of the plume over time were used to assess potential risks to resources as the plume moved through the water.

Table 5-1: Estimated dispersed oil concentrations of the 500 barrel spill scenario at selected sites for the trajectory snapshots shown in Figure 5-5.

	Concentration (ppm)*				
D + (hrs)	Plume	Site A	Site B	Site C	Site D
1	6.28	6.28	0	0	0
6	3.87	3.87	0	0	0
12	1.99	1.99	0	0	0
18	1.11	1.11	0	1.11	0
24	0.70	0	0	0.70	0
48	0.28	0	0	0.28	0.28

***Note**: NOAA reported these values in ppb quantities. The more expansive table created by NOAA can be found in Appendix F.

Exposure concentrations were estimated for each of the four sites and within the plume for both the 500 (Table 5-1) and 4,000 (Table 5-2) barrel spill scenarios over 48 hours following dispersion. Note that no dispersed oil is predicted by the model to impact site B.

The trajectory predicted that the dispersed oil plume moved in a northerly direction between the western tip of the Bolivar Peninsula and Smith Point. Because it is located below the water surface, the dispersed plume is transported by subsurface currents and tidal influences rather than following the same path as the surface slick.

Table 5-2: Estimated dispersed oil concentrations of the 4,000 barrel spill scenario at selected sites for the trajectory snapshots shown in Figure 5-5.

	Concentration (ppm)*				
D + (hrs)	Plume	Site A	Site B	Site C	Site D
1	38.56	38.56	0	0	0
6	23.75	23.75	0	0	0
12	12.23	12.23	0	0	0
18	6.79	6.79	0	6.79	0
24	4.27	0	0	4.27	0
48	1.69	0	0	1.69	1.69

***Note**: NOAA reported these values in ppb quantities. The more expansive table created by NOAA can be found in Appendix F.

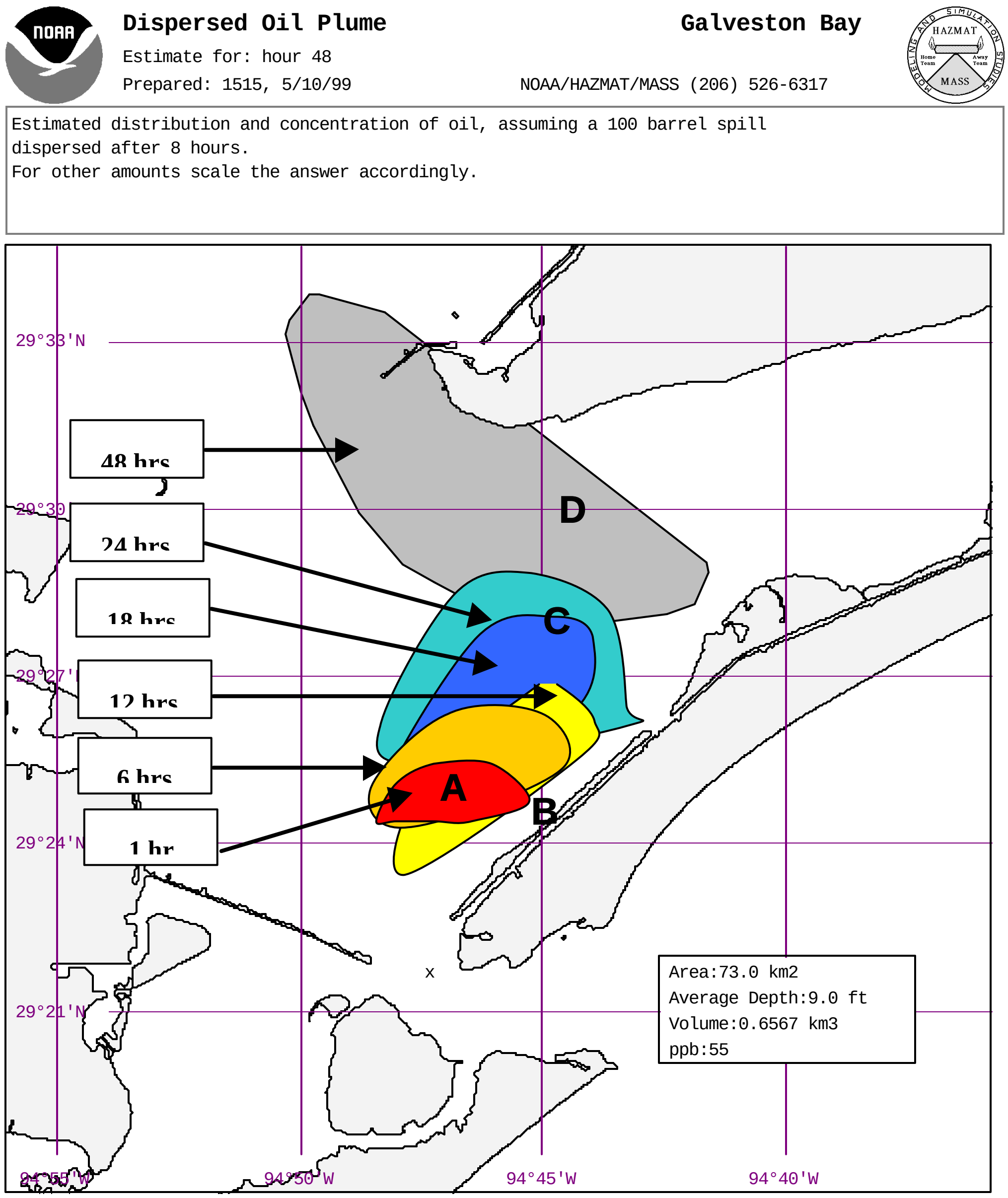
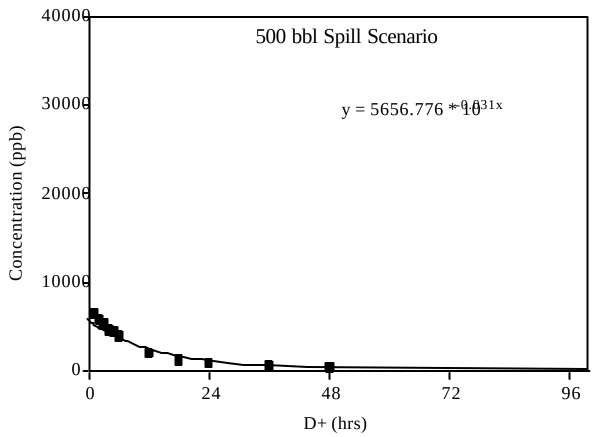
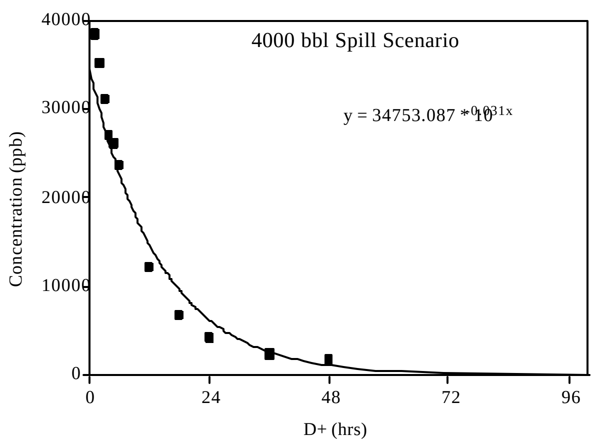


Figure 5-5: Dispersed plume trajectory over 48 hours and location of four sites (A, B, C, D); sites selected for general exposure profile analysis.

The rapid decrease in dispersed oil concentration over a 96-hour period is evident in Figure 5-6. In the 500 barrel spill scenario, dispersed oil concentrations dropped below 1 ppm around 24 hours following dispersion. In the 4,000 barrel spill scenario, the concentration dropped below 1 ppm around 72 hours.



(A)



(B)

Figure 5-6: Change in dispersed oil concentration as a function of time for both the 500 barrel (A) and 4,000 barrel (B) scenarios.

5.2.3 Smoke Plume Trajectories

Smoke plumes as a result of ISB were not modeled. NOAA estimated, however, that smoke plumes resulting from the spill scenarios would dissipate entirely within two to three miles downwind of the burn site. Therefore, no areas of human habitation would be impinged upon as a consequence of these scenarios.

5.2.4 Oil Budgets

Oil budgets for each of the four major response options (on-water mechanical recovery, dispersant application, and ISB) were prepared from the NOAA models. The budgets estimated oil volume over time as a result of the natural processes of weathering and evaporation, as well as by the application of individual clean-up techniques. For the dispersant budget of the 500 barrel spill, 100% dispersant effectiveness was assumed. For the 4,000 barrel spill, however, 80% effectiveness was assumed. Example oil budgets for natural recovery and dispersant application for the 500 barrel scenario can be found in Tables 5-3 and 5-4. The complete set of oil budgets can be found in Appendix G.

5.3 BACKGROUND INFORMATION ON DISPERSED OIL EFFECTS USED DURING THE WORKSHOPS

The issue of defining effects that might result from an oil spill is a complex issue. The approach used in the workshops was to rely on the professional experience of the participants and selected published literature. This information was used to develop consensus positions on appropriate thresholds for analysis. The participants had access to the following references, which were reviewed by the facilitators and available at the workshops: Lewis and Aurand (1997), Aurand and Coelho (1995), SEA (1995), and NRC (1989). In addition, summary presentations (based on poster presentations at the 1999 International Oil Spill Conference) were made by the facilitation team on the results of a series of mesocosm experiments on the fate and effect of dispersed oil run at the Coastal Oilspill Simulation System (COSS) Facility in Corpus Christi, TX (see Aurand et al., 1999; Bragin et al., 1999; Coelho et al., 1999; Fuller et al., 1999; Lessard et al., 1999; Page et al., 1999), and on the use of laboratory, mesocosm, and field data in the preparation of oil spill response risk assessments (see Aurand and Coelho, 1999).

The participants felt that they had a reasonable grasp of shoreline effects, based on the actual experience of many of the participants, however they were concerned about interpreting water column effects, based on toxicity. The participants worked cooperatively to prepare an exposure effects template for use in risk ranking of dispersant use (Table 5-5).

Table 5-3: Example of oil budgets prepared from the NOAA models. This budget documents the volume of oil over time when no response approach was taken in the 500 barrel spill scenario.

500 bbl Scenario: No Response								
Time:	0	6	12	24	36	48	72	96
Floating Oil	500	372	352	316	273	210	141	0
Floating Oil Emulsion	500	531	587	1265	1092	839	565	0
Evaporated	0	125	144	161	172	180	186	189
Dispersed (Natural)	0	3	4	5	5	6	6	6
Mech. Recovered (Oil)	0	0	0	0	0	0	0	0
Dispersed (Chemical)	0	0	0	0	0	0	0	0
In Situ Burned	0	0	0	0	0	0	0	0
Stranded	0	0	0	18	49	104	167	305
Stranded Oil Emulsion	0	0	0	70	197	415	667	1220
Water-In-Oil	0	159	235	1002	967	941	924	915
Emulsion Factor	0.00	0.30	0.40	0.75	0.75	0.75	0.75	0.75
% Evaporation	0.00	0.25	0.05	0.05	0.04	0.03	0.03	0.02
% Dispersion	0.000	0.006	0.003	0.002	0.002	0.002	0.001	0.001
% Stranding	0.000	0.000	0.000	0.050	0.100	0.200	0.300	0.350

Table 5-4. Example of oil budgets prepared from the NOAA models. This budget documents the volume of oil over time when dispersant was applied in the 500 barrel spill scenario.

500 bbl Scenario: Dispersant Application								
Time:	0	6	12	24	36	48	72	96
Floating Oil	500	372	0	0	0	0	0	0
Floating Oil Emulsion	500	531	0	1	1	1	0	1
Evaporated	0	125	144	144	144	144	144	144
Dispersed (Natural)	0	3	4	4	4	4	4	4
Mech. Recovered (Oil)	0	0	0	0	0	0	0	0
Dispersed (Chemical)	0	0	352	352	352	352	352	352
In Situ Burned	0	0	0	0	0	0	0	0
Stranded	0	0	0	0	0	0	0	0
Stranded Oil Emulsion	0	0	0	0	0	0	1	0
Water-In-Oil	0	159	0	1	1	1	1	1
Emulsion Factor	0.00	0.30	0.40	0.75	0.75	0.75	0.75	0.75
% Evaporation	0.00	0.25	0.05	0.05	0.04	0.03	0.03	0.02
% Dispersion	0.000	0.006	0.003	0.002	0.002	0.002	0.001	0.001
% Stranding	0.000	0.000	0.000	0.050	0.100	0.200	0.300	0.350

Table 5-5: Workshop consensus on exposure thresholds of concern for dispersed oil in the water column.

Level of Exposure	Level of Concern	Sensitive Life Stages	Adult Fish	Adult Crustacea/ Invertebrates
0-3 hours	Low	1	10	5
	Med-Low	1-5	10-50	5-10
	Med-High	5-10	50-100	10-50
	High	10	100	50
24 hours	Low	.5	.5	.5
	High	5	10	5
96 hours	High	.5	.5	.5

Notes: All numbers are in parts per million (ppm). (The numbers provided in the NOAA Trajectory report are in parts per billion.) Values are intended to indicate threshold levels of concern for resources. For example, if adult fish are exposed to a dispersed oil plume of 100 ppm for 3 hours, concern should be high. If they are exposed to a 10 ppm plume for 3 hours, concern should be low because there is little or no potential for acute effects.

The following points were also agreed upon as a result of consideration of dispersant use:

- Birds are in danger of diving through oil at the surface as well as through the dispersed oil plume. This would result in not only oiling of birds, but also in the removal of natural plumage oils and the consequent loss of buoyancy. Participants agreed that birds are endangered during the first four hours after dispersion, after which time the plume will have diluted and moved out of the area.
- Background concentrations of oil in Galveston Bay are in the range of 3 to 4 ppm.
- In the 18 to 36 hour time frame, the 4,000 barrel spill generated concentrations at fixed reference points that exceeded levels expected to cause a resource effect. In the 500 barrel spill scenario, exposure to dispersed oil is reduced to 5 ppm at hour 24, and less than 0.3 ppm by hour 48, so that no acute effects from dispersed oil were expected. This is ecologically relevant when considering exposure of planktonic organisms that would move with the plume and be exposed for a longer duration versus benthic organisms that would be exposed only as long as the plume passes over the area.

5.4 ECOLOGICAL RISK MATRIX DESIGN

The focus of the second workshop was to use the information available to the participants from the above assignments to determine the relative risks associated with each of the response options. This means that a risk rating needed to be developed for each square in the matrix presented in Appendix D for the 500 barrel spill and the 4,000 barrel spill. Given the time constraints of the workshop, this was difficult to do without some sort of standard ranking system. The participants discussed a risk ranking matrix (presented by the facilitators) that evaluates two parameters, e.g., severity of exposure versus length of recovery for the resource. This type of ranking system was used to develop a semi-quantitative evaluation of the effects of stressors on resources. Each axis of the square represents a continuum of parameters used to describe risk. For example, a square could be used in which the x-axis rates “recovery” and ranges from “reversible” to irreversible,” and the y-axis evaluates “magnitude” and ranges from “severe” to “trivial.” In its simplest form, the risk matrix is divided into 4 cells. Each cell is assigned an alphanumeric value to represent relative impact. Thus, a “1A” represents an irreversible and severe effect, while a “2B” represents a reversible and trivial effect (Figure 5-7).

Recovery

MAGNITUDE	1. IRREVERSIBLE	2. REVERSIBLE
A. Severe	1A	2A
B. Trivial	1B	2B

Figure 5-7: Basic Ecological Risk Matrix Design.

The risk square concept is similar to the approach used in a risk assessment effort in South Florida (MMS, 1989). A copy of that report was made available to all participants at the workshop for further background reading. Participants agreed that the risk square concept would serve their purposes in completing this risk assessment.

The participants went on to discuss what labels should be applied to the axes and how many gradations should be used. The details of this discussion are presented in Appendix E. Area of impact (percentage of total resource affected) was suggested for the vertical axis, expressed in percentages of individual resources affected (greater than 60% = high, 40 - 60% = moderate/high, 10 - 40% = moderate/low, and less than 10% = low). These criteria also address the level of effect, ranging from community level effects at the high level to the loss of a few individuals at the low level. For the horizontal axis, recovery, which includes both time and function expressed as lost services, was selected as an appropriate scale. Four gradations were suggested for this scale as well (recovery in greater than 10 years = high, 3 - 10 years = moderate/high, 1 - 3 years = moderate/low and less than 1 year = low).

Having outlined the risk ranking process, participants divided into three groups (see Appendix E for members in each group) to begin the process. Participants agreed to first rank natural recovery in the 500 barrel spill scenario to evaluate the approach and to provide a baseline against which the other stressors could be compared. Work groups were arranged so that each had at least two industry, two Federal, and two state representatives. Using the preliminary risk matrix values, each group scored individual resources first and then derived consolidated sub-habitat scores. The results for each group are included in Appendix H.

When all three work groups were finished the natural recovery matrix, the results were reviewed and compared. They concluded that the process was effective, and that having the three groups score the matrices separately and then examine the differences was a good way to identify issues or assumptions that needed to be discussed. They also concluded that the rate at which recovery occurred (the horizontal axis in the square) was relatively easy to complete, but the estimation of affected resource was much more challenging because of the difficulty in determining "percentages". Percentage of resource affected is a function of the size of the area under consideration. If the area is all of Galveston Bay, percent affected for a given resource is likely to be very small for these scenarios. If the area is limited to the area of the spill in the given scenario, then the percent affected would be very high. This discussion led to a revision in the vertical axis of the risk matrix based on the projected magnitude of impact on the community as a whole, without regard to numerical percentages, as follows:

- High (community change),
- Medium/high,
- Medium/low, and
- Low (loss of a few individuals).

Participants further agreed that issues to be considered in establishing magnitude of impact should include the following:

- Presence of a value resource (e.g., threatened or endangered species) in the spill trajectory area;
- Percent of the resource affected locally (in the spill trajectory area);
- Percent of the resource affected in the Bay;
- Type and level of effect (e.g., death, reproductive impairment, etc.); and
- Oil type, condition (weathering), quantity and distribution/coverage.

Participants also adjusted the horizontal axis of the square based on the concept that 10 years was too long a time frame for consideration and establishment of the significance of effects. Therefore, they opted to label the horizontal axis as follows:

- Recovery is probable in greater than 6 years (long term),
- Recovery is probable in 3 to 6 years (medium),
- Recovery is probable in 1 to 3 years (short term), and
- Recovery is probable in less than 1 year (rapid).

Based on these considerations, the final risk matrix used in this analysis was developed (Figure 5-8).

	> 6 years (1)	3 to 6 years (2)	1 to 3 years (3)	< 1 year (4)
A. High	A1	A2	A3	A4
B. Med/High	B1	B2	B3	B4
C. Med/Low	C1	C2	C3	C4
D. Low	D1	D2	D3	D4

Figure 5-8: Final Ecological Risk Ranking Matrix.

When this was completed, the three groups finished all of the interim risk ranking matrices for each of the response options (this included a reevaluation of the 500 barrel natural recovery matrix, based on the preliminary discussions). Prior to starting work on a matrix, the three workgroups met in plenary session to discuss any special issues related to the response option under consideration. The resulting matrices are presented in Appendix I and J.

The final task of the second workshop was to define relative levels of concern in the risk ranking matrix. This was done to provide a method of grouping stressor effects in terms of a "high," "medium," or "low" level of concern, based on the alphanumeric codes described earlier (Figure 5-8). At this time, the participants could not agree on the relative levels for three cells, which are shown as divided cells on the chart.

Figure 5-9: Preliminary Definition of Levels of Concern within the Risk Matrix.

	> 6 years (1)	3-6 years (2)	1-3 years (3)	< 1 year (4)
High (A)	**1A**	**2A**	**3A**	**4A**
Moderate/High (B)	**1B**	**2B**	**3B**	**4B**
Moderate/Low (C)	**1C**	**2C**	**3C**	**4C**
Minimal (D)	**1D**	**2D**	**3D**	**4D**

Legend: Cells shaded dark gray represent a high level of concern, cells shaded medium gray represent a moderate level of concern, and cells not shaded represent a minimal level of concern.

Between the second and third workshops, the facilitation team combined individual workgroup matrices into a preliminary summary matrix for the 500 and 4,000 barrel scenarios (Appendix K). This allowed the participants to examine differences between groups in scoring the matrices. While the scores were relatively consistent, there were areas in which there were some noticeable differences. The areas generating the greatest concern were group scores that differed between summary levels of concern. The participants reviewed all of the risk ranking matrices before the third workshop and came prepared to discuss and resolve any differences in the relative risk rankings.

The third workshop began with a review of the preliminary definition of levels of concern (Figure 5-9) in order to resolve ratings in the split cells. The participants also decided to use the designations high ecological concern, moderate ecological concern, and minimal ecological concern when discussing the results of the analysis. After discussion, a final definition of the levels of concern was developed for use in the final ranking process (Figure 5-10).

Figure 5-10: Final definition of Levels of Concern.

Magnitude of Impact*	Recovery Time: > 6 years (1)	3-6 years (2)	1-3 years (3)	< 1 year (4)
High (A)	**1A**	**2A**	**3A**	**4A**
Moderate/High (B)	**1B**	**2B**	**3B**	**4B**
Moderate/Low (C)	**1C**	**2C**	**3C**	**4C**
Low (D)	**1D**	**2D**	**3D**	**4D**

Legend: Clear cells represent a "high" level of concern, light gray cells represent a "moderate" level of concern, and dark gray cells represent a "minimal" level of concern.

***Note**: Magnitude of Impact is based upon percentage of resource affected.

The facilitators then led a plenary discussion on group differences in the 500 and 4,000 barrel preliminary summary matrices in an effort to come to consensus. This was important because these summary matrices represent participant consensus on the relative environmental effects of each response option. Where consensus could not be reached in ranking individual cells, outstanding issues were identified and presented to the risk managers. No attempt was made to reconcile individual risk scores within the same level of concern. While this was desirable, the time constraints of the process did not allow that level of detail. The revised risk ranking matrices are presented in Chapter 6, and the discussions regarding changes to the individual risk scores are summarized in the third workshop report (Appendix L). The revised risk ranking matrices were used to develop the discussions in Chapter 6.

When the risk matrices were completed, participants organized into three new groupings. Each group prepared "habitat summary worksheets," identifying the critical points discussed at the three workshops for each of the habitats of concern. They provided brief statements on the following topics:

- Habitat distribution (regionally and locally),
- Key species,
- Key ecological role,
- Sensitivity to oil,
- Key assumptions in the risk ranking (for each response),
- Consequences of incorrect assumptions (if critical),
- Adequacy of data for the analysis, and

- Data needs.

These notes were combined with the other data resources and the notes generated at the various meetings to prepare the final analysis in Chapter 6.

The third workshop concluded with a plenary session to develop final recommendations for presentation to the risk managers (see Workshop III meeting notes in Appendix L and Chapter 8).

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CHAPTER 6: RISK ANALYSIS RESULTS

This section of the report describes the results of the comparative risk assessment conducted by the participants, based on the ranking process described in Section 5.4. They are presented by habitat type, and the reasons for the various rankings are discussed. At the end of the section, the relative risk rankings are compared between habitats in order to integrate the results of the analysis.

These final rankings were prepared at the third workshop, after the participants had the opportunity to review and compare the rankings developed by the three evaluation panels at the second workshop. Interim matrices can be found in Appendices I and J. Preliminary summary matrices following any changes that were made can be found in Appendix K. Reasons for any changes can be found in Appendix L, and final summary matrices can be found at the end of this chapter.

For discussion purposes within this chapter, three risk scores are presented for each spill volume and response option, representing the conclusions of the three rating groups. When interpreting the tables, it is appropriate to refer to Figure 5-10, which presented the final levels of concern developed by the participants. In an ideal situation, participants would have continued to review and discuss the available information until they could agree on a single alphanumeric ranking. Given that there are 16 possible rankings, this was not practical within the time limits of this process. Instead, the group focused on achieving consensus on the three summary levels of concern of "high," "moderate," and "minimal." This was achieved in most cases, but not in all. Even when there was agreement on the summary level of concern, there were still differences of opinion amongst the three groups as to the actual score in some cases. It is also important to remember that, when comparing results for the various response options, actual scores may improve or become worse without a change occurring in the summary (high/moderate/ minimal ranking. For some resources, the participants felt that under most circumstances a minimal ranking would be appropriate, but if threatened or endangered species, species of concern, or sensitive life history stages were present, then the level of concern would increase for that hazard. It was agreed that resource managers could usually resolve such issues quickly if contacted. Situations where this was determined to be important are marked on the tables with the symbol (•) to indicate that "consultation with resource managers is required." Finally, in some cases a score of "NA" is presented. In the earliest discussions (at the first workshop), this term was defined as a situation in which no pathway could be developed between the stressors resulting from the response options and the resources in the particular habitat. In practice, however, the term also came to include situations where the level of concern was so low (even though a pathway might exist) that the group felt that using even the lowest ranking in the matrix was inappropriate. All scores are based on the change in ranking relative to the natural recovery option, which was always completed first.

6.1 TERRESTRIAL HABITATS

6.1.1 Nearshore Upl and Terrestrial

6.1.1.1 Description of the Resource

Terrestrial upland habitat, *per se*, is not directly threatened by an oil spill in the Galveston Bay. Indirectly, however, terrestrial habitat adjacent to the shoreline may be affected, and on that basis this habitat type is included in this analysis. For this report, terrestrial habitat is defined as all land areas above the high tide/spray zone, including the dunes on the back beach. In many areas around Galveston Bay, this area has been developed, while in others it may represent valuable upland wildlife habitat.

Terrestrial habitat is found adjacent to all shoreline areas. In Galveston Bay, there is little ecologically valuable upland habitat because much of the shoreline area is developed or cultivated. In the area affected by this scenario (the eastern side of the Bay) upland habitat is of concern because of its close association with bird rookery areas. This is particularly true in the Smith Point area.

This habitat is home to mammals and birds that might be disturbed by response activities, or come into contact with oil transported into this habitat on animals contaminated in another location. There are also a variety of common reptiles that may be present. Common mammals include opossum, raccoon, coyote, and deer. Birds include cattle egret, rails, Attwater prairie chicken, snipe, and killdeer. Of particular concern is the reddish egret, which is the world's most geographically restricted heron (National Audubon Society, 1999). While not endangered or threatened in the U.S., it is on the National Audubon Society's Watchlist, and the coastal marshes of Texas are a primary habitat. Typical vegetation in this area would include wiregrass, shrubs, and deciduous trees.

6.1.1.2 Sensitivity to Oil

All of the concern over effects in this habitat is based on indirect effects. Oil can be transported into the habitat on waste material from the response operation, debris from the cleanup, or on animals moving into the area. Responders seeking access to the shoreline could also damage vegetation, and disturb the animals living in the area.

6.1.1.3 Relative Risk Evaluations – Terrestrial

The final risk scores developed for each of the response options in this habitat are presented in Table 6-1. For the 500 barrel scenario, all of the risk ratings fell into the minimal risk category, and for the 4,000 barrel scenario they were of minimal to moderate risk. The basic differences are related to the volume of the spill.

Table 6-1: Risk Scores for Terrestrial Habitat, Relative to Natural Recovery.

Response Action	500 barrel Spill			4,000 barrel Spill		
Natural Recovery	4D	4D	NA	3C	4D	4C
On-water Recovery	4D	4D	NA	3C	4D	4D
Shoreline Cleanup	4D •	4D •	3D •	3C	4C	3C
Oil & Dispersant	4D	4D	NA	4D	4D	4D
On-Water ISB	4D	4D	NA	3C	4D	4D

Legend: Dark gray cells represent a "high" level of concern, gray cells represent a "moderate" level of concern, and clear cells represent a "minimal" level of concern.

For natural recovery, the 500 barrel spill was judged to have minimal impact, since there would be only indirect exposure, no collateral damage, and given the limited volume likely to come ashore, little transport into terrestrial habitats. The level of concern increased with the 4,000 barrel spill, based on the assumption that indirect exposure was more likely to occur.

For on-water recovery, the indirect effects were unlikely to change significantly compared to natural recovery (only a fraction of the oil was recovered). On-water operations lead to very little interaction with terrestrial habitat. This is true as long as there is proper use of boat ramps and other access points. If this were not the case, then disturbance impacts could increase.

The shoreline cleanup option had the highest probability of causing upland habitat disturbance in addition to indirect effects. This option ranked equally with natural recovery for the 500 barrel spill, but slightly higher than the other response options for the 4,000 barrel spill scenario, where the probability of disturbance is the greatest. The participants felt that an effective shoreline cleanup effort reduced the concern over indirect effects, but increased the likelihood of disturbance. Since there is a possibility of the presence of threatened or endangered species in this habitat, (e.g., the reddish egret), the minimal rankings for the 500 barrel spill are predicated on consultation with the resource manager.

For dispersant use in the 500 barrel spill, the upland habitat risk scores were similar to the other response options, but for the 4,000 barrel spill the dispersant option resulted in lower scores. This was based on the assumption that this response option was the only one likely to significantly decrease the amount of oil coming ashore; therefore, the likelihood of resulting disturbance is minimal.

The results for ISB were judged to be the same as for on-water recovery, based on the assumption that ISB prevented at least some oil from entering the habitat, and that the smoke plume did not impact the shore. The participants felt that, even if the plume did contact the shore, the effects were minimal due to the limited duration and area affected.

6.2 SHORELINE AND INTERTIDAL HABITATS

This broad habitat category contains three sub-habitats: Marsh/Tidal Flat, Sand/Gravel Beaches and Riprap/ Man Made. Protection of shoreline habitat is a primary concern during an oil spill, especially in a relatively small, enclosed system like Galveston Bay.

6.2.1 Marsh/Tidal Flat

6.2.1.1 Description of the Resource

This subhabitat includes three habitats described in the Upper Texas Coast Oil Spill Planning and Response Atlas (TGLO, 1994) using the NOAA Environmental Sensitivity Index (ESI) categories, " exposed tidal flats" (ESI = 7), "sheltered tidal flats" (ESI = 9) and "salt and brackish water marshes" (ESI = 10A). Exposed tidal flats are primarily sand, whereas sheltered tidal flats are mostly silt and clay. The exposed flats are subjected to a higher level of energy and are usually associated with tidal inlet systems, while the sheltered flats are present in calm water habitats and are frequently associated with marshes. Sheltered mud flats are common in the eastern half of the estuary affected by these scenarios. The shoreline in this portion of the Bay also contains significant areas of salt marsh. Overall, approximately 61% of the shoreline [There are over 100,000 acres of wetlands in the immediate bay watershed.] of the Bay is wetlands (GBNEP, 1994). These include several types of freshwater wetlands, as well as the salt marshes that are most at risk in the spill scenarios in this report. As is true in many estuaries, marshes and tidal flats represent some of the most important habitat present in the Galveston Bay. Their important role in the Galveston Bay ecosystem was described by GBNEP (1994) and is summarized below.

Intertidal mud flats can be highly productive habitats. Primary production occurs in the form of benthic microalgae (primarily diatoms), macroalgae and, at high tide, phytoplankton. Imported organic matter from other habitats is also an important energy source. Infaunal and epifaunal organisms, such as small crustaceans, various polychaete worms and mollusks, are common and form an important food resource for both fish and birds that forage in the area at high and low tide, respectively.

Wetlands are transitional areas between terrestrial and aquatic systems. Salt or brackish water wetlands dominate in the immediate vicinity of Galveston Bay. Salt marshes serve a variety of important functions within the Bay ecosystem. They filter runoff from the land, removing pollutants, nutrients and sediments, and protect the shoreline from erosion. They are highly productive and export large amounts of organic matter to the rest of the Bay, mostly as detritus. They are also valuable wildlife and fish habitat. Many of the most important aquatic commercial species in the Bay rely on marshes during some stage of their life, including brown shrimp, white shrimp, blue crab, red drum, spotted sea trout, southern flounder, and Gulf menhaden (GBNEP, 1994). A myriad of other species that are not commercially important but are critical to the estuarine food web also use marshes as nurseries or primary habitat. Other organisms include the grass shrimp, fiddler crabs, killifish, sheepshead minnow, blue and ribbed mussels, periwinkles, diamondback terrapins, polychate worms, and amphipods. Terrestrial mammals, such as raccoons and otters, also use this habitat. Many bird species such as the American avocet, American oyster-catcher, black-necked stilt, great blue heron, snowy egrets, roseate spoonbills, mottled duck, blue and green-winged teal, and widgeon either forage here or utilize the habitat in some other way.

Salt marshes are dominated by a small number of emergent grasses, particularly the genus *Spartina*. Smooth cordgrass (*S. alterniflora*) dominates the low marsh community, which is the most likely to be exposed to oiling. At higher elevations and lower salinity, marsh hay (*S. patens*) and Gulf cordgrass (*S. spartinae*) are common. Other common marsh plants include saltwort, saltgrass, and glasswort. In addition, there is a significant benthic diatom population in many salt marshes.

Historically, the wetland acreage in the Bay has been declining. Since the 1950s over 33,000 acres of vegetated wetlands have been lost. While most of this loss has been freshwater wetlands, rather than salt marsh, the loss of wetlands habitat is considered the highest priority issue in the Bay (GBNEP, 1994). Wetlands are a key component in the overall productivity of the Bay, so protection of the wetlands that remain is an important management consideration.

6.2.1.2 Sensitivity to Oil

Floating oil does not adhere readily to either type of tidal flat (exposed sand or protected mud) and tends to accumulate at the high tide line. If enough oil is present it may coat the flat, but it usually does not penetrate the wet sediments. It will penetrate burrows or dry, cracked sediment. Oil may be sorbed to suspended sediments (particularly clay particles), which can then be deposited on the flats. Both algae and animals on the surface and the infauna may be coated with oil and/or exposed to dissolved hydrocarbons. If oil accumulates in the high tide zone or in adjacent habitats, exposure may continue for an extended period. This is especially important for birds foraging in the area. Biological damage may be severe, depending on the degree of exposure and the type of oil.

Salt marshes (as well as other wetlands) can be seriously affected by floating oil, which adheres readily to marsh vegetation. The degree to which the vegetation will be oiled varies widely, depending on the water level when the oil reaches the marsh. If oil moves into the area over several tidal cycles, the plants may be entirely coated. The extent of the oiling within the marsh also depends on a variety of factors, including the thickness of the vegetation, the tides and winds, and the amount of oil. If left untreated, the oiled leaves will die and the oil may be transported to other areas in detritus or will accumulate in the marsh. Usually, the plants will regrow the next year, unless there were extensive surface accumulations of oil. Small organisms that live on or near the vegetation will be exposed to the oil, resulting in either lethal or sub-lethal effects. Birds and mammals that utilize the habitat are particularly vulnerable to oiling as a result of contact with oil floating in the marsh and coating marsh vegetation.

Medium to heavy oils will not penetrate or adhere to the muddy sediments but will penetrate burrows and may pool on the surface as the tide recedes. Penetration into burrows, especially fiddler crab burrows, may be highly significant in some situations. Light oils may penetrate the top few centimeters of the sediments and may get as deep as one meter in burrows. Invertebrate infauna and epifauna may be seriously affected, as may birds and mammals utilizing the marsh. If enough oil accumulates in the marsh, it will gradually be incorporated into the sediments and may remain, poorly weathered, for long periods (20 years or more). The ecological consequences of such long-term accumulations are not well understood, but the weathered, buried oil is much less of a hazard than exposure to the oil when it is still on the surface.

Both of these habitats are very sensitive to physical disruption, which means they may be adversely affected by intrusive response activities. In the case of the salt marsh, the alterations may lead to permanent habitat loss. In all areas, physical disturbance may lead to the mixing of oil into the substrate to a greater extent than if it were left undisturbed.

6.2.1.3. Relative Risk Evaluations – Marsh/Tidal Flat

The final risk scores developed for each of the response options in this subhabitat are presented in Table 6-2. The projected trajectory for these scenarios moves the surface oil into areas where highly valuable marsh and tidal flats are common. For the 500 barrel scenario, all of the risk ratings, with the exception of natural recovery, fell into the minimal risk category. However, the level of concern was much higher in the 4,000 barrel scenario, due to the larger amount of oil likely to enter the subhabitat.

For natural recovery, the 500 barrel spill was judged to have moderate impact, since the scenario indicated that the oil came ashore, but with limited volume. The level of concern increased with the 4,000 barrel spill to moderate-high, because the volume of emulsified oil predicted to reach the shore was so much greater.

For on-water recovery, where a portion of the oil was recovered, the rating for the 500 barrel spill was reduced to minimal. For the 4,000 barrel spill, the amount recovered relative to the amount reaching shore was not considered to be enough to make any significant difference (although one group did feel there would be a slight improvement), and the ranking remained unchanged.

Table 6-2: Risk Scores for Marsh/Tidal Flat Subhabitat, Relative to Natural Recovery.

Response Action	500 barrel Spill			4,000 barrel Spill		
Natural Recovery	2C	3C	3C	2B	3A	3B
On-water Recovery	3D	3D	4C	2B	3A	3C
Shoreline Cleanup	4C •	4C •	4C •	3B	3B	3B
Oil & Dispersant	4D	4D	4D	3C	3B	3C
On-Water ISB	3D	3D	3D	2B	3A	3C

Legend: Dark gray cells represent a "high" level of concern, gray cells represent a "moderate" level of concern, and clear cells represent a "minimal" level of concern.

The shoreline cleanup option had the highest probability of causing disturbance in addition to the effects of the oiling. On this basis, the participants deemed consultation with resource managers necessary in order to determine if shoreline cleanup was appropriate. Based on the definition of shoreline cleanup in marshes presented in Section 4.3, the response was limited to the fringes of the marsh and was largely non-intrusive. This response method collected only easily recoverable oil and involved no heavy equipment. For the 500 barrel spill, the participants felt that this resulted in some improvement, but not enough to lower the general rating of moderate concern. Many of the impacts occur before the cleanup begins, and a significant fraction of the oil cannot be removed using techniques that are ecologically acceptable. For the 4,000 barrel scenario, the participants lowered the natural recovery score from high/moderate to moderate, assuming that the cleanup was still useful, but significant amounts of oil remained in the habitat. These ratings are very sensitive to the assumed effectiveness of the cleanup effort and to the avoidance of intrusive techniques. If an aggressive cleanup effort occurred throughout the habitat, then risk scores could increase rather than decrease.

When dispersants were considered, the risk scores declined more than for any other response option. For the 500 barrel spill, all three groups rated the risk as 4D, based on the assumption that if the oil could be dispersed before it came ashore, the threat was removed (in this scenario the assumption was that dispersant effectiveness was at or close to 100%).

A major reduction in risk was also anticipated for the 4,000 barrel spill, but in this scenario the dispersant efficiency was assumed to be 80%, rather than 100%. Therefore, the amount of oil reaching the habitat, while much less, is still enough to cause undesirable consequences.

The presumed efficiency of the dispersant is the key factor in these risk scores, as well as the greatest uncertainty. If the dispersant effectiveness is lower, then scores will be similar to natural recovery. If dispersant effectiveness is higher, however, the possibility of preventing any impacts does exist. In the scenarios of this study, dispersant operations were presumed to occur at some distance from the shoreline. Participants, therefore, did not feel that the dispersed oil plume was likely to affect these marsh/tidal flat habitats adversely (see Figure 2 and Table 2 in Appendix F).

The results for ISB were judged equal to on-water recovery, based on the assumption that ISB prevented at least some oil from entering the habitat, and that the smoke plume did not impact the shore. The participants felt that, even if the plume did contact the shore, the effect would be minimal due to the limited duration and area affected.

6.2.2 Sand/Gravel Beaches

6.2.2.1 Description of the Resource

This subhabitat includes two habitats described by TGLO (1994) using the NOAA ESI categories: fine-grained sand beaches (ESI= 3A) and mixed sand and shell beaches (ESI = 5). Beaches are constantly undergoing cycles of erosion and replenishment and may change significantly seasonally. For the purposes of this analysis, these were considered to be similar enough to be discussed together.

Fine-grained sand beaches are generally flat and hard-packed. In the Bay, the beaches are usually about 45 feet wide. Mixed substrate beaches contain a mixture of sand and shell. They are usually slightly higher energy environments. They may contain considerable accumulations of beach wrack. Mixed substrate beaches occur on the Bolivar Peninsula, between High Island and Sea Rim State Park, and along spoil islands.

Sandy beaches are common along south Galveston Bay, East Bay, and around large spoil islands near the Houston Ship Channel. Sandy beaches are not highly productive, but they are used heavily by birds for nesting, foraging, and resting. Wading birds in general are very common. Typical avian species include the American oyster catcher, black skimmers, terns, gulls, piping plovers, and white and brown pelicans. Terrestrial mammals, such as coyotes, skunks, opossum, and raccoons may be present occasionally. There is a distinctive, if somewhat limited, upper beach invertebrate fauna, consisting primarily of ghost crabs and amphipods. The lower intertidal fauna (ghost crabs, *Rangia*, amphipods, nematodes) can be much more dense, but is highly variable. The presence of large amounts of shell makes the beach dry out faster, and lessens its value as useable benthic habitat.

6.2.2.2 Sensitivity to Oil

If a small amount of oil is present, it will tend to accumulate as oily swatches or bands in the upper intertidal zone. If a lot of oil is present, the entire intertidal zone may be coated, with oil that relocates as the tide rises and falls. The more shell present on the beach, the greater the potential for oil penetration into the substrate. In fine sand, penetration is usually 10 cm or less. In shelly areas, penetration may be as much as 50 cm. Natural wave action will remove much of the oil, but without cleanup, some oil is likely to be buried on the beach.

Organisms found on or in the beach may be smothered by oil or exposed to lethal or sublethal concentrations of hydrocarbons in the interstitial water. Birds may become oiled. In addition to the direct effects suffered by the oiled individual, they may transport oil back to the nest or into other habitats. Any decline in infaunal populations is usually only temporary, but this can also affect foraging birds.

While sandy beach is relatively easy to clean, the response operations impact the habitat and the fauna in the area. If not properly managed, cleanup operations can lead to shoreline profile changes, the presence of oily waste, and the disturbance of animals, particularly birds.

6.2.2.3 Relative Risk Evaluations – Sand/Gravel Beaches

The final risk scores developed for each of the response options in this subhabitat are presented in Table 6-3. The projected trajectory for these scenarios moves the surface oil into areas where some beach habitat is present. For the 500 barrel scenario, the natural recovery rating was moderate, and all of the other response option risk ratings were minimal. For the 4,000 barrel scenario, the level of concern was higher, related to the larger amount of oil likely to enter the habitat. All of the rankings for all response options were moderate.

Table 6-3: Risk Rankings for Sand/Gravel Beach Subhabitat, Relative to Natural Recovery.

Response Action	500 barrel Spill			4,000 barrel Spill		
Natural Recovery	3C	3C	3C	3C	3B	3B
On-water Recovery	3D	4D	3D	3C	3B	3B
Shoreline Cleanup	3D •	4D •	3D •	3C	3C	3C
Oil & Dispersant	4D	4D	4C	3C	3C	3C
On-Water ISB	3D	4D	3D	3C	3B	3B

Legend: Dark gray cells represent a "high" level of concern, gray cells represent a "moderate" level of concern, and clear cells represent a "minimal" level of concern.

For both the 500 and 4,000 barrel spills, the natural recovery risk ranking was determined to be moderate, although two of the three groups did increase the severity of the risk for the larger spill. The rating was based on the probability that some oil would strand on beaches in the area, resulting in a larger impact with the larger spill volume. The larger volume of oil leads to more area impacted, more indirect exposure, and more direct exposure along the tide line. The risk ratings were not higher because natural recovery processes for this habitat are relatively rapid.

For on-water recovery, the risk associated with the 500 barrel spill was rated as minimal, based on the low initial volume and the recovery of at least some of the product. For the 4,000 barrel spill, the larger volume leads to more opportunity for both direct and indirect exposure. The increased response activity leads to greater use of access points and, therefore, more habitat disruption. Even though the amount of oil stranding was reduced by nearly 50%, there is still enough oil to cause a moderate level of concern.

For shoreline cleanup, the rating for the 500 barrel spill was conditionally minimal, since the presence or absence of bird rookeries must be confirmed with the resource manager prior to cleanup. The reddish egret and other threatened and endangered species are particularly critical. For the 4,000 barrel spill, the risk rating remained moderate because of the greater quantity of oil and more collateral damage than in the 500 barrel spill.

When dispersants were considered, the ranking for the 500 barrel spill was minimal. This was the lowest ranking of any response option. This was based on the assumed efficiency of 100% for the small spill scenario, meaning that no floating oil reached the habitat. For the 4,000 barrel spill, the ranking was moderate because the participants felt that sufficient surface oil remained to be of concern.

The results for ISB were judged equal to on-water recovery, based on the assumption that the activity prevented at least some oil from entering the habitat, and that the smoke plume did not impact the shore. The participants felt that even if the plume did contact the shore, the effect would be minimal due to the limited duration and area affected.

6.2.3 Riprap/Manmade

6.2.3.1 Description of the Resource

This subhabitat includes NOAA ESI category 1, "exposed walls and other solid structures made of concrete, wood or metal", ESI category 6B, "exposed riprap structures, ESI category 8A, "sheltered solid man-made structures" and ESI category 8B, "sheltered riprap structures." Included in this category are structures such as seawalls, groins, revetments, piers/pilings, and riprap. Riprap structures are composed of cobarrele- to boulder-sized blocks of rock or concrete. There may or may not be any exposed beach in front of the structure at low tide. The purpose of most of these structures is to protect the shoreline from erosion, or to provide access to or from the shore. In many instances, the currents or wave action are relatively high, which means that natural removal is expected to be more rapid than in nearby low energy areas. In cases of low energy, especially where the structure is protecting only a local area of shoreline, oil may be more persistent. Many of these areas are utilized by the public for fishing or access. This type of habitat is somewhat limited in the area affected by these spill scenarios, but is relatively common in other areas of the Bay. It is not a high-value habitat.

The animal and plant community depends heavily on the particular substrate involved. Attached algae (such as sea lettuce) and sessile animals such as barnacles and mollusks are sparsely distributed on solid structures. Crabs, amphipods, bottom-swelling fish, and polychaetes are found in habitats with crevasses. Birds, such as pelicans, cormorants and gulls, rest or feed in this habitat.

6.2.3.2 Sensitivity to Oil

Since these structures tend to be built in higher energy areas to protect the shoreline, natural removal of oil is relatively rapid. Oil will coat the flat surfaces, but tends to accumulate in the upper intertidal zone. If the substrate is porous, like riprap, oil may accumulate in the spaces between the rocks and cause chronic leaching until the oil hardens or is removed. Organisms found in the area can be smothered by oil and be exposed to lethal or sublethal concentrations of hydrocarbons. Birds using the area could become contaminated and transport oil out of the habitat to other areas.

6.2.3.3 Relative Risk Evaluations – Riprap/Manmade

The final risk scores developed for each of the response options in this subhabitat are presented in Table 6-4. There is little of this subhabitat type in the path of the projected trajectory for these scenarios. For both the 500 and 4,000 barrel scenarios, all of the risk ratings fell into the minimal risk category. The risk scores are slightly higher for the 4,000 barrel spill, but not enough to change the rankings. None of the response options result in any major change to the rankings relative to natural recovery for either scenario.

Table 6-4: Risk Analysis for Riprap/Manmade Subhabitat, Relative to Natural Recovery.

Response Action	500 barrel Spill			4,000 barrel Spill		
Natural Recovery	4D	4D	4D	4C	4C	4C
On-water Recovery	4D	4D	4D	4C	4C	4C
Shoreline Cleanup	4D	4D	4C	4C	4C	4D
Oil & Dispersant	4C	4C	NA	4C	4C	4D
On-Water ISB	4D	4D	4D	4C	4C	4C

Legend: Dark gray cells represent a "high" level of concern, gray cells represent a "moderate" level of concern, and clear cells represent a "minimal" level of concern.

6.3 SUBTIDAL BENTHIC HABITATS

This habitat category consists of five subhabitats. The first three (benthic subtidal habitat in less than three feet of water, benthic subtidal habitat in three to ten feet of water, and benthic subtidal habitat in channels greater than ten feet) relate to the GBNEP (1994) categories of marsh embayment and open-bay bottom. The two remaining categories, subtidal oyster reefs and SAV beds, were also identified by the GBNEP (1994) as distinct and important habitat categories. None of the five are included in the NOAA ESI shoreline categories, but the latter two are identified as significant resources on the habitat maps (TGLO, 1994).

6.3.1 Subtidal Benthic Habitat in Water 3 Feet Deep or Less

6.3.1.1 Description of the Resource

Most of Galveston Bay is less than ten feet deep, and large portions of it are even shallower. Nearshore, and in the vicinity of dredge spoil areas and oyster reefs, significant areas may be three feet deep or less. The subhabitat is primarily mud and silt.

The benthic fauna and flora found in this area (and in deeper water) are important to the estuarine food chain and are closely linked to the water column. While diatoms and macroscopic algae can be found in these shallow areas, much of the food chain is detrital-based. Plankton also provides food for the benthic fauna, which at the same time provides food for fish and birds. Typical organisms present in this habitat include a wide variety of crustaceans (grass shrimp, brown shrimp, amphipods, crabs), mollusks (snails, bivalves), and polychaete worms. Birds such as the roseate spoonbill and the great blue heron forage in these areas, as do fish such as the southern flounder and drum. Both the infaunal and epifaunal communities are well-developed and extensive.

6.3.1.2 Sensitivity to Oil

The benthic areas of the Bay less than three feet deep were identified as a separate habitat category because of the participants' belief that the potential for long-term exposure, and the possibility for short-term, acute exposure in some situations, could be more significant here than in deeper water. Much of the shallow water benthic habitat is adjacent to shoreline areas which could become oiled and contribute contaminated sediment to the habitat, especially during periods of high wind and wave action. In addition, it was felt that response activities could result in the transport of oil into this habitat. This was of particular concern with dispersant use, but it was also true with shoreline cleanup, where the re-release of oil is always a concern. Since the water is so shallow in these areas, exposure due to physical dispersion and hydrocarbons entering solution was also a consideration. If oil did become incorporated into the habitat, then long-term exposure to hydrocarbons would increase. This is already an important issue in the Bay because of hydrocarbon pollution from other sources, such as non-point source pollution and storm water runoff.

6.3.1.3 Relative Risk Evaluations – Subtidal Benthic Greater Than 3 feet

The final risk scores developed for each of the response options in this habitat are presented in Table 6-5. The projected trajectory for these scenarios moves both the surface oil and dispersed oil plumes into areas where this habitat is common. For the 500 barrel scenario, all of the risk ratings fell into the minimal risk category. For the 4,000 barrel scenario, the level of concern was somewhat higher, with natural recovery, on-water recovery, and ISB receiving a moderate rating.

Table 6-5: Risk Ratings for Subtidal Benthic Subhabitat in Water 3 Feet Deep or Less, Relative to Natural Recovery.

Response Action	500 barrel Spill			4,000 barrel Spill		
Natural Recovery	4D	3D	4D	3C	3B	3C
On-water Recovery	4D	3D	4D	3C	3C	3C
Shoreline Cleanup	4D	3D	4D	4C	4C	4C
Oil & Dispersant	4D	4D	4C	4D	4C	4C
On-Water ISB	4D	3D	4D	3C	3C	3C

Legend: Dark gray cells represent a “high” level of concern, gray cells represent a “moderate” level of concern, and clear cells represent a “minimal” level of concern.

For natural recovery, the participants decided that for a 500 barrel spill, the potential to affect a significant portion of the habitat was low, since most of the oil collected on the shoreline. There was concern regarding oil erosion from the shoreline, but participants felt that any such contributions would be below thresholds of concern for such a small spill. Physical dispersion and dissolution were examined and rejected as serious concerns based on the low efficiencies of these processes and the likelihood of rapid dilution. The level of concern increased for the 4,000 barrel spill, where the participants felt the potential for transport was greater.

For on-water recovery and for ISB, similar considerations prevailed, since the participants did not believe the limited success of these response options led to any real reduction of the risk.

For shoreline cleanup in the 500 barrel scenario, the risk was judged to be low because very little of the habitat was affected. For the 4,000 barrel scenario, the scores were somewhat higher, but still in the minimal concern level. This was based on the conclusion that even a partially successful shoreline cleanup lessened the potential secondary contamination of this habitat. In both scenarios, the appropriate use of shoreline cleanup options, including preventing the loss of contaminated sediment, is a key assumption.

For dispersant use, the participants concluded that for both the 500 and 4,000 barrel spill, the risk was minimal. This was based on several factors. In the 500 barrel spill, as for other options, only a limited amount of the resource could be affected. In the 4,000 barrel spill, the participants felt that preventing oil from stranding lessened the possibility of secondary contamination. Even though the dispersed oil plume impinged on the bottom, it was felt that the dispersed oil particles were less likely to adhere to the sediments than oil alone, and the rapid dilution of the dispersed oil plume (Appendix F, Figure 1) was a positive factor. Finally, the possibility that the dispersed oil would biodegrade more rapidly in the water column was considered to be a benefit.

6.3.2 Subtidal Benthic Habitat in the Open Bay in Water Depths of 3 to 10 Feet

6.3.2.1 Description of the Resource

This subhabitat is very similar to that described above. This zone covers large areas of the open bay and is highly productive and important to the Bay’s overall well-being. There are some differences in the flora and fauna in the two areas. Since Galveston Bay is quite turbid, micro- and macroscopic algae are less significant in this area, although still present. The greater water depths exclude wading birds, but diving birds (such as some ducks, grebes and coots) feed in the area. Larger fish, and more fish species, are likely to be present. As was true for the shallower areas, this habitat is a key feeding area for many important species.

6.3.2.2 Sensitivity to Oil

The concerns regarding oil exposure here are similar to those for benthic habitat in less than three feet of water depth, except that the greater extent of the overlying water column provides additional protection. This means that dilution reduces exposure to physically (or chemically) dispersed oil. Dissolved hydrocarbons are not a significant concern for the same reason.

6.3.2.3 Relative Risk Evaluations – Subtidal Benthic Habitat, Open Bay, 3 to 10 Feet

The final risk scores developed for each response option in this subhabitat are presented in Table 6-6. The projected trajectory for these scenarios passes through areas where this habitat type is extensive. For both the 500 barrel and 4,000 barrel scenarios, all of the risk ratings were in the minimal risk category. There were no consistent differences between the response options or the two scenarios that were notable. The rankings were based on the conclusions that 1) the quantities of oil which might enter the habitat were extremely small given the extent of the resource, 2) dilution would be sufficient to limit exposure, and 3) indirect transport into these areas was unlikely since they are not immediately adjacent to the shoreline.

Table 6-6: Risk Ranking for Subtidal Benthic Habitat in the Open Bay in Water Depths of 3 to 10 Feet, Relative to Natural Recovery.

Response Action	500 barrel Spill			4,000 barrel Spill		
Natural Recovery	4D	4D	NA	4D	4C	4D
On-water Recovery	4D	4D	NA	4D	4C	4D
Shoreline Cleanup	4D	4D	NA	4D	4C	4D
Oil & Dispersant	4D	4D	4C	4D	4C	4C
On-Water ISB	4D	4D	4D	4D	4C	4D

Legend: Dark gray cells represent a "high" level of concern, gray cells represent a "moderate" level of concern, and clear cells represent a "minimal" level of concern.

6.3.3 Subtidal Benthic Habitat in Dredged Channels in Water Depths Greater Than 10 Feet

6.3.3.1 Description of the Resource

Prior to the initiation of dredging activities in the mid- to late 1800s, there were essentially no "deep water" habitats in Galveston Bay. The earliest dredging activities focused on the Galveston area, and later extended toward Houston. The completion of the Houston Ship Channel in 1914 was tremendous incentive for industrial growth in the area. Most of these early channels were only ten to twelve feet deep. Since then, however, channels have been widened and deepened throughout the Bay so that the main shipping channels are now 40 feet deep. This represents a habitat type which did not exist prior to industrialization of the area and which can only be maintained through constant dredging. These channels represent sedimentary basins for fine particulate materials and related pollutants. The upper Houston Ship Channel has a continuing problem with low dissolved oxygen concentrations in the bottom water, but the situation is steadily improving (there was essentially zero oxygen in areas in the 1960s). In the rest of the Bay, water quality in the dredged channels is similar to that in shallower areas. In these areas, this habitat supports a diverse fauna (no plants exist at these depths in the Bay), including crustaceans (blue crab, pink, brown and white shrimp, amphipods), polychaete worms, and a variety of mollusks. Fish, including southern flounder, drum, and hardhead, are present. The channel bottoms are not utilized by diving birds.

6.3.3.2 Sensitivity to Oil

The concerns over oil exposure here are similar to those for shallow water benthic habitats, except that the greater extent of the overlying water column and the limited extent of the habitat make it even less likely that oil will be able to enter the habitat. The most significant issue is the accumulation of contaminated sediments entering from another source.

6.3.3.3 Relative Risk Evaluations – Subtidal Benthic, Dredged, Less Than 10 Feet

The final risk scores developed for each of the response options in this subhabitat are presented in Table 6-7. The projected trajectory for these scenarios affects channel habitat only briefly at the beginning of the scenarios. For both 500 and 4,000 barrel scenarios, all of the risk ratings are minimal. The only variation from the lowest possible concern was a minor increase with dispersant use suggested by one group. The basic reasons for these low ratings are the same as for the benthic subtidal habitat in three to ten feet of water. There is no mechanism to transport floating oil into the habitat effectively. In the case of dispersed or dissolved oil dilution, the concentrations are reduced to such an extent that they are not an issue. While the accumulation of pollutants in channel sediments is a concern, any contribution from oil spills of the type in these scenarios is essentially undetectable against the background pollution in the Bay.

Table 6-7: Risk Rankings for Benthic Subtidal Habitat in Dredged Channels in Water Depths Greater than 10 Feet, Relative to Natural Recovery.

Response Action	500 barrel Spill			4,000 barrel Spill		
Natural Recovery	4D	4D	NA	4D	4D	4D
On-water Recovery	4D	4D	NA	4D	4D	4D
Shoreline Cleanup	4D	4D	NA	4D	4D	4D
Oil & Dispersant	4D	4D	4C	4D	4D	4C
On-Water ISB	4D	4D	4D	4D	4D	4D

Legend: Dark gray cells represent a "high" level of concern, gray cells represent a "moderate" level of concern, and clear cells represent a "minimal " level of concern.

6.3.4 Non-Intertidal Oyster Reefs

6.3.4.1 Description of the Resource

This subhabitat is one of the two habitats of special concern identified by the GBNEP (1994), the other being wetlands. In 1991, there were 26,700 acres of reef and unconsolidated shell sediments in Galveston Bay that could be classified as naturally occurring reefs and reefs originating through human activities (GNEP, 1994). The natural reefs include longshore reefs, reefs extending perpendicular to the shoreline, patch reefs, and barrier reefs. Reefs resulting from human activity include those associated with dredged material disposal banks, oil and gas development, commercial oyster leases, and new natural beds in areas where currents have been modified by human activity. Galveston Bay, unlike many estuaries, has a thriving oyster industry. The general habitat increased in area over the last 20 years, although there have been declines in specific reefs. There are significant areas of reef habitat in the portion of the Bay affected by these scenarios.

An oyster reef consists of clusters of oyster shells, live oysters, and a distinct commensal community associated with the reef. In the Bay, oyster reefs are generally subtidal, although the depth at low tide may be quite shallow. They form wherever there is suitable hard bottom and enough current to provide planktonic food and remove sediment and waste products. The reef community is very diverse. Oysters are the dominant (keystone) species, but a variety of other mollusks (both bivalves and gastropods) are present. In addition, crabs, barnacles, amphipods, isopods, and polychaete worms are usually abundant. Secondary consumers, such as the black drum, stone crabs, and blue crabs are abundant. Small fish and crustaceans are found in the shelter of the oyster shells. Birds such as the American oyster-catcher, gulls, terns, white and brown pelicans, and wading birds may forage in the area.

In addition to being a valuable commercial resource, the sheer number of filter-feeding oysters present is very important of the Bay in influencing water clarity and planktonic populations.

6.3.4.2 Sensitivity to Oil

Oysters (and bivalves in general) are considered to be good indicator species of chronic pollution levels in a given location because they cannot move rapidly and tend to bioaccumulate some pollutants, including hydrocarbons. On the other hand, they can respond to short term exposure to adverse conditions by simply closing their shells and ceasing to filter until water quality improves. All of the organisms present on the oyster reef can be affected either by smothering or toxicity, if sufficient oil is present. Since the reefs are subtidal, smothering is less of a concern. Even if toxic effects do not occur, tainting is a concern for commercial harvesting.

6.3.4.3 Relative Risk Evaluations – Oyster Reefs

The final risk scores developed for each of the response options in this subhabitat are presented in Table 6-8. The projected trajectory for these scenarios moves the surface oil into areas where oyster reefs are common. For the 500 barrel scenario, all of the risk ratings fell into the minimal risk category. For the 4,000 barrel scenario, all of the scores remained essentially unchanged except when dispersants were used. In that case, the rankings given by all three groups increased to a moderate level of concern. The low scores are based on the low probability of floating oil contacting the reefs, and the limited extent of the area of exposure relative to the entire resource. In addition, the concentrations of dissolved hydrocarbons or physically dispersed oil in the vicinity of the reefs is not expected to approach levels of concern. When dispersants are used, concentrations could occur which would be of concern if the exposure were long enough. Since the reefs are stationary, the fleeting exposure would (see Table 2 in Appendix F) not be long enough to cause serious concern.

Table 6-8: Risk Rankings for Non-Intertidal Oyster Reefs, Relative to Natural Recovery.

Response Action	500 barrel Spill			4,000 barrel Spill		
Natural Recovery	4D	4C	NA	4D	4C	4D
On-water Recovery	4D	4C	NA	4D	4C	4D
Shoreline Cleanup	4D	4D	NA	4D	4C	4D
Oil & Dispersant	4C	4D	4C	4B	3C	4B
On-Water ISB	4D	4C	4D	4D	4C	4D

Legend: Dark gray cells represent a "high" level of concern, gray cells represent a "moderate" level of concern, and clear cells represent a "minimal" level of concern.

6.3.5 Submerged Aquatic Vegetation (SAV) Beds

6.3.5.1 Description of the Resource

SAV beds are highly productive and valuable habitat. They are made up of marine (or freshwater) plants (keystone species) and their associated epiphytic plant and animal community. They form "meadows" in shallow water areas that provide food and protective cover for an extensive array of organisms, many of commercial importance. Small fish and crustaceans are particularly abundant in such areas, where the threat of predation is much less than in open water. When present in sufficient extent, the community also contributes substantially to the detrital food web, sediment stabilization, and shoreline protection. Unfortunately, only 700 acres of this habitat remain in Galveston Bay, mostly in the western areas (GBNEP, 1994).

6.3.5.2 Sensitivity to Oil

Subtidal seagrasses are relatively unaffected by either floating or dispersed oil. However, animals present within the community may be seriously affected by dissolved hydrocarbons or dispersed oil if they are present at high concentrations for a long enough period.

6.3.5.3 Relative Risk Evaluations – Submerged Aquatic Vegetation

The final risk scores developed for each of the response options in this category are presented in Table 6-9. The projected trajectory for these scenarios does not affect areas where SAV is common. Consequently, the risk scores for both scenarios are minimal. Since this result is based entirely on non-occurrence of the resource rather than a discussion of the potential effects of exposure, it cannot be applied to areas where SAV beds are present.

Table 6-9: Risk Rankings for Submerged Aquatic Vegetation (SAV) Beds, Relative to Natural Recovery.

Response Action	500 barrel Spill			4,000 barrel Spill		
Natural Recovery	4D	NA	NA	4D	4D	NA
On-water Recovery	4D	NA	NA	4D	4D	NA
Shoreline Cleanup	4D	4D	NA	4D	4D	NA
Oil & Dispersant	4D	4D	NA	4D	4D	NA
On-Water ISB	4D	NA	NA	4D	4D	NA

Legend: Dark gray cells represent a "high" level of concern, gray cells represent a "moderate" level of concern, and clear cells represent a "minimal" level of concern.

6.4 WATER COLUMN RESOURCES

This broad habitat category contains three subhabitats: the upper three feet of the water column, the bottom three feet of the water column in depths of three to ten feet, and the bottom three feet of the water column in depths greater than ten feet. The participants selected these categories to provide a comprehensive view of potential water column exposures throughout the Bay.

6.4.1 Upper 3 Feet of the Water Column

6.4.1.1 Description of the Resource

This subhabitat includes all of the surface water of the Bay down to a depth of three feet, but excludes the surface microlayer, which is considered separately. This subhabitat was selected because planktonic primary productivity is greatest in this zone and it is the most vulnerable to floating oil.

Phytoplankton and zooplankton are the dominant organisms in this subhabitat. The zooplankton community includes egg, larval, and juvenile stages of many important organisms, both vertebrate and invertebrate, as well as fully planktonic species such as copepods. The larval forms, or meroplankton, are often highly seasonally abundant based on reproductive patterns of the adults. A key characteristic of the holoplanktonic species is their rapid reproductive rates. This is true for both phytoplankton, with generation times of hours or days, and the dominant zooplankters, copepods, with generation times of days or weeks. In addition to these planktonic organisms, larger organisms, especially fish (bay anchovy, gulf menhaden, red drum, inland silversides, striped mullet, and drum) and birds (osprey, gulls, terns, cormorants, diving ducks, common loon), feed in this area. Coelenterates and ctenophores are common. There is a small population of bottlenose dolphin within the Bay, and low numbers sea turtles may be present.

6.4.1.2 Sensitivity to Oil

Acute or sublethal toxic effects caused by exposure to either dissolved or dispersed hydrocarbons in the water column are the key concerns in this area. If exposure was high enough to cause an effect and occurred at a time when sensitive life history stages were present in the plankton, it could have an effect on a year-class for the species. With respect to the holoplanktonic species, such exposure could lead to a temporary decline in primary productivity and the loss of some zooplankton production, which would potentially affect the rest of the food chain.

6.4.1.3 Relative Risk Evaluations – Upper 3 feet of Water Column

The final risk scores developed for each of the response options in this category are presented in Table 6-10. Field research in other areas has demonstrated that toxic effects beneath floating oil are very localized, unless there is sufficient mixing to physically disperse the oil into the water column.

For both the 500 and 4,000 barrel scenario, all of the risk ratings were in the minimal risk category, but for the use of dispersants, this was a “conditional” rating, requiring consultation with the resource manager. For the other options, the participants felt that only very low levels of exposure would occur, based on limited physical dispersion and low levels of dissolved hydrocarbons. The participants anticipated a slight increase in potential effects from the 4,000 barrel spill, but the small area affected, relative to the entire resource, and the rapid recovery rates for the plankton, limited this concern. When the participants compared the information presented in Section 5.4 on toxicity thresholds to the results of the oil spill modeling effort (Appendix F), they concluded that the potential for acute or sublethal effects, if any, was limited to a very localized volume of water. Exposures were not high enough to cause direct toxic effects on adult fish, and effects on larval or juvenile fish were considered unlikely. Levels of exposure for birds and mammals were low and geographically and temporally limited, so it was not a significant concern.

The conditionally-minimal rating and slightly increased levels of concern for dispersant operations were related to the higher exposure that results if the response is effective. Even so, for both of these scenarios, the participants felt that the concentrations fell to levels below the thresholds of concern rapidly enough that the community as a whole was not greatly affected (see Section 5.4, and Table 2 and Figure 2 in Appendix F). The presence of sensitive life history stages could increase the risk, but consultation with the appropriate resource manager could rapidly determine if this was a consideration in an actual event. It should be noted that, as discussed in Section 5.3, the toxicity thresholds of concern developed for this analysis are conservative, and it is likely that the actual effects within the water column would be less than that assumed during this analysis.

Table 6-10: Risk Rankings for the Upper 3 Feet of the Water Column, Relative to Natural Recovery.

Response Action	500 barrel Spill			4,000 barrel Spill		
Natural Recovery	4D	4D	4D	4C	4C	4C
On-water Recovery	4D	4D	4D	4C	4D	4C
Shoreline Cleanup	4D	4D	4D	4D	4C	4C
Oil & Dispersant	3D •	4D •	4C •	4C •	4C •	4C •
On-Water ISB	4D	4D	4D	4C	4C	4C

Legend: Dark gray cells represent a “high” level of concern, gray cells represent a “moderate” level of concern, and clear cells represent a “minimal” level of concern.

6.4.2 Bottom Three Feet of the Water Column in Depths of Three to Ten Feet

6.4.2.1 Description of the Resource

This subhabitat category was developed to evaluate water column exposure below the immediate zone of influence of the oil slick, but still in shallow water. By focusing on water depths of ten feet or less, the conclusions drawn by the participants apply to essentially all areas of the Bay except for dredged channels and the areas near the entrance to the Bay.

Since the Bay is shallow and generally well-mixed, the organisms present in this subhabitat are very similar to those found near the surface. The variety of birds that feed in the area is limited to loons and diving ducks because of the increased depth. Some of the fish species found near the surface are less likely to be present in this area. Phytoplankton and zooplankton populations may be lower, but will certainly still be present. Shrimp, which prefer to stay near the bottom, would be a key species in this area.

6.4.2.2 Sensitivity to Oil

Acute or sublethal toxic effects caused by exposure to either dissolved or dispersed hydrocarbons in the water column remain the key concern. However, the greater depth means that dilution is more effective in limiting exposure.

6.4.2.3 Relative Risk Evaluations – Bottom 3 Feet in Depths of 3 to 10 Feet

The final risk scores developed for each of the response options in this category are presented in Table 6-11. The results and the reasons are essentially the same as for the surface three feet. During their deliberations, the participants recognized that the increased potential for dilution meant that exposures to dissolved or physically dispersed oil in this area were reduced over those in the surface water, but the risk was already so low that the change was not important to the score. In the case of dispersant application, it was assumed that mixing carried the plume at least this deep, but the exposures were still slightly less than at the surface. Again, the reduction, while recognized, had limited effect on the scores.

Table 6-11: Risk Rankings for the Bottom 3 Feet of the Water Column in Depths of 3 to 10 Feet, Relative to Natural Recovery.

Response Action	500 barrel Spill			4,000 barrel Spill		
Natural Recovery	4D	4D	4D	4D	4C	4C
On-water Recovery	4D	4D	4D	4D	4C	4C
Shoreline Cleanup	4D	4D	NA	4D	4C	4C
Oil & Dispersant	3D ●	4D ●	4C ●	4C ●	4C ●	4C ●
On-Water ISB	4D	4D	4D	4D	4C	4C

Legend: Dark gray cells represent a “high” level of concern, gray cells represent a “moderate” level of concern, and clear cells represent a “minimal” level of concern.

6.4.3 Bottom Three Feet of the Water Column in Depths Greater Than Ten Feet

6.4.3.1 Description of the Resource

This subhabitat was included to allow consideration of possible water column effects in the very deepest portions of the Bay and in or near dredged channels. In these areas, plankton is likely to be reduced over the populations down to ten feet, but otherwise the communities are similar.

6.4.3.2 Sensitivity to Oil

Acute or sublethal toxic effects caused by exposure to either dissolved or dispersed hydrocarbons in the water column remain the key concern. However, the greater depth means that dilution is more effective in limiting exposure.

6.4.3.3 Relative Risk Evaluations – Bottom 3 Feet in Depths Less Than 10 Feet

The final risk scores developed for each of the response options in this category are presented in Table 6-12. The results and the reasons are essentially the same as for the preceding two subhabitat categories. Once again, the participants recognized that the now significantly increased potential for dilution meant that exposures to dissolved or physically dispersed oil in this area was greatly reduced, but the risk was already so low that the change was not important to the risk score. In the case of dispersant application, it was assumed that mixing probably did not carry the plume to this depth until the concentrations were significantly reduced. Again, the reduction, while recognized, had limited effect on the scores. The participants still felt the potential presence of sensitive life history stages meant that resource managers must be consulted before dispersant application.

Table 6-12: Risk Rankings for the Bottom Three Feet of the Water Column in Depths Greater Than Ten Feet, Relative to Natural Recovery.

Response Action	500 barrel Spill			4,000 barrel Spill		
Natural Recovery	4D	4D	4D	4D	4D	4C
On-water Recovery	4D	4D	4D	4D	4D	4C
Shoreline Cleanup	4D	4D	NA	4D	4D	4C
Oil & Dispersant	3D •	4D •	4C •	4C •	4D •	4C •
On-Water ISB	4D	4D	4D	4D	4D	4C

Legend: Dark gray cells represent a "high" level of concern, gray cells represent a "moderate" level of concern, and clear cells represent a "minimal" level of concern.

6.5 WATER SURFACE

6.5.1 Surface Microlayer

6.5.1.1 Description of the Resource

This subhabitat category consists of the actual surface of the water and the one or two centimeters of water immediately below the surface. This area, while very restricted, is important to many species. Sargassum is present in this habitat, along with a unique assemblage of crustaceans and fish. Many birds, including cormorants, terns, gulls, ducks and pelicans, rest on the surface. Marine mammals and turtles break the surface to breathe. Finally, certain types of fish eggs and larvae are present in this habitat on a seasonal basis.

6.5.1.2 Sensitivity to Oil

This is the primary feeding zone for many organisms. Organisms in or on the surface microlayer may come into direct contact with floating oil, or with high concentrations of dissolved hydrocarbons or physically dispersed oil droplets immediately beneath the slick. The potential for contamination or exposure is quite high in the immediate vicinity of the slick. Organisms found in the microlayer tend to concentrate in convergence zones, as does floating oil.

6.5.1.3 Relative Risk Evaluations – Surface Microlayer

The final risk scores developed for each of the response options in this category are presented in Table 6-13.

For the 500 barrel scenario, the risk ratings are low to moderate. For the 4,000 barrel scenario, the level of concern was much higher, related to the larger amount of oil likely to enter the subhabitat.

Table 6-13: Risk Rankings for the Water Surface (Surface Microlayer), Relative to Natural Recovery.

Response Action	500 barrel Spill			4,000 barrel Spill		
Natural Recovery	2C	3C	3C	2B	4B	4B
On-water Recovery	3C	3C	3D	2C	4B	4B
Shoreline Cleanup	2C	3C	3C	2B	4B	4B
Oil & Dispersant	4D	4D	4D	3C	4C	4C
On-Water ISB	3C	3C	3D	2C	4B	4B

Legend: Dark gray cells represent a "high" level of concern, gray cells represent a "moderate" level of concern, and clear cells represent a "minimal" level of concern.

For natural recovery, the 500 barrel spill was determined to represent a moderate risk to this subhabitat. The risk level increased to moderate to high for the 4,000 barrel spill, based on the increase in the actual area covered by the oil slick (see Appendix F). The participants felt that birds were particularly vulnerable to oil in this area, and, in most cases, concern over that resource determined the score. Even limited oiling can cause birds to die and lead to secondary exposure in other habitats. Concerns over microscopic organisms or the Sargassum community were lower, based on the broad distribution of the resource. The participants were concerned that, while much of the oil came ashore, enough remained on the water to cause a problem for several days. There was also concern over longer term exposure as oil refloated or leached from shoreline areas where it stranded.

In both the 500 and 4,000 barrel scenarios, some participants felt the risk was lessened slightly by on-water recovery or ISB, based on their ability to eliminate some of the floating oil.

In both scenarios, no improvement was attributed to shoreline cleanup, because most of the damage already occurred. While shoreline cleanup would remove oil and, to some degree, prevent the release of oil from the shoreline, participants were also concerned about the possible release of floating oil during cleanup operations. These considerations essentially canceled each other out.

The use of dispersants yielded the only noticeable reduction in risk, occurring in both scenarios. The improvement was most dramatic in the 500 barrel scenario, where 100% efficiency was assumed. For the 4,000 barrel scenario, the use of dispersant led to a reduction in the risk by removing much of the oil from the surface. However, since the efficiency was assumed to be only 80%, some oil still affected this subhabitat.

6.6 RELATIVE RISK SUMMARY

While the results for the individual habitats are important, the real focus of this assessment examination of the ability of response options, alone or in combination, to reduce or minimize the overall risk to each habitat. Tables 6-14 and 6-15 summarize the risk scores for all habitats and response options for the 500 and 4,000 barrel scenarios, respectively. The scores for natural recovery represent the baseline against which the participants evaluated the other options. The risk ranking matrix (Table 5-10), which was used to rate the level of concern, is resource independent. In other words, the matrix is driven by considerations that apply equally well to all resources (recovery time and level of effect from individual to community). This provides, to some degree, a common basis for comparison between habitat types.

6.6.1 Summary for 500 barrel Scenario

For the 500 barrel spill scenario, no risk scores exceeded the moderate level. This reflects the conclusion of the participants that a spill of this size, while important, was likely to have mostly local, rather than regional effects. Ecological effects in the terrestrial habitat, the riprap/manmade subhabitat, and the various benthic subtidal habitats were not likely to be important enough to influence response decisions. The areas that were seriously affected were the two high value shoreline subhabitats (marsh/tidal flat and sand/gravel beaches) and the surface microlayer subhabitat. The participants felt shoreline cleanup or on-water recovery (and possibly ISB) could lessen effects on the shoreline resources, but these responses were unlikely to benefit the surface microlayer. The response option which offered the greatest degree of protection to these habitats was dispersant use.

While dispersant use increased water column exposures and led to slightly increased risk scores in those subhabitats, overall dispersant risk ratings remained minimal, provided sensitive life history stages were not present. None of the other response options led to increased risk scores in comparison to natural recovery. Further, the assumptions used by participants to estimate exposure to dispersed oil and the thresholds for effects are very conservative. Thus, actual exposure and effects stemming from dispersant operations is probably less than assumed.

6.6.2 Summary for 4,000 barrel Scenario

For the 4,000 barrel scenario, the pattern for natural recovery was essentially the same, but the level of concern was greatly increased, because of the increased volume of oil. For marshes/tidal flats and for the surface microlayer, some of the risk scores moved into the high risk category, and the others moved higher within the moderate risk category. The participants concluded that some risk was now present for the terrestrial habitat and the shallow (less than three foot deep) benthic subtidal habitat, based on indirect effects. The general risk categories for the remaining habitats remained unchanged. The only response options that resulted in lower risk scores for marshes/tidal flats were shoreline cleanup and dispersant use. None of the response choices resulted in an improvement for sand/gravel beaches (based on the assumed efficiencies) and only dispersants made a serious improvement in the risk to the surface microlayer. Both shoreline cleanup and dispersant use reduced risk to the shallow subtidal zone.

Dispersant use in the 4,000 barrel spill slightly increased risk scores within the water column habitats, but the scores were still conditionally minimal. These increases were not nearly as dramatic as the reduction in risk with dispersant use seen in other habitats. In this scenario, the participants felt that there was an increased risk to oyster reefs, based on the higher water column concentrations of dispersed oil.

6.6.3 Summary Conclusions

These results for these spill scenarios suggest that, for small spills, all of the response options evaluated here could be used without being concerned about serious adverse ecological consequences. At the 4,000 barrel spill size, the possible exposure to dispersed oil in the water column becomes an issue for oyster reefs, but overall is still much less of a concern than the consequences of oil stranding on the shoreline.

It is not appropriate to extend the results of this analysis to significantly larger spills, or spills of different oils, without further analysis. The results suggest, however, that it would be prudent to examine additional spill scenarios to see how widely the results can be applied.

Of the four active techniques evaluated, on-water recovery and ISB produced the least environmental benefit, while shoreline cleanup and dispersant use produced the most when compared to natural recovery for a 4,000 barrel spill. This is primarily the result of the assumptions made about the efficiencies associated with the various response options. While the participants felt that the assumptions were reasonable, it is also true that such numbers are highly variable. Since all of the response options (when they are effective) appear to lead to a net benefit, the appropriate planning strategy is to use a mix of all of the options, based on the circumstances, providing greatly needed flexibility for the response planner. The issue of efficiency is particularly important for dispersant use, where actual field data is the least reliable. If dispersants have a high efficiency, as some recent events suggest, then they appear to offer the best means of providing rapid protection to sensitive shoreline habitats. They do not need to be applied to an entire slick to accomplish this objective, but could be used selectively within the Bay. This could reduce the concerns associated with dispersed oil in the water column.

Table 6-14: Summary of risk scores for 500 barrel spill scenario.

Habitats	**Terrestrial**	**Shoreline/Intertidal**			**Benthic Subtidal**					**Water Column**			**Surface**
SUBHABITATS:	Terrestrial	Marsh/Tidal Flat	Sand/Gravel Beaches	Riprap Manmade	Shallow <3 feet	Open Bay 3 to 10 feet	Channel >10 Feet	Reef (not intertidal)	SAV	Top 3 feet	Bottom 3 feet (in depths of 3 to 10 feet)	Bottom 3 feet (in depths greater than 10 feet)	Surface (microlayer)
Natural Recovery													
On-Water Recovery													
Shoreline Cleanup	c	c	c										
Oil + Dispersant										c	c	c	
ISB													

Legend: Dark gray cells represent a "high" level of concern, gray cells represent a "moderate" level of concern, and clear cells represent a "minimal" level of concern. Cells with lines indicate concern with intermediate between moderate and low. Note that there were no high concern ratings in this scenario. Cells with a "c" indicate normally minimal concern, but incident specific circumstances need to be examined.

Table 6-15: Summary of risk scores for 4,000 barrel spill scenario.

Habitats:	Terrestrial	Shoreline/Intertidal			Benthic Subtidal					Water Column			Surface
SUBHABITATS:	Terrestrial	Marsh/Tidal Flat	Sand/Gravel Beaches	Riprap Manmade	Shallow <3 feet	Open Bay 3 to 10 feet	Channel >10 Feet	Reef (not intertidal)	SAV	Top 3 feet	Bottom 3 feet (in depths of 3 to 10 feet)	Bottom 3 feet (in depths greater than 10 feet)	Surface (microlayer)
Natural Recovery													
On-Water Recovery													
Shoreline Cleanup													
Oil + Dispersant										c	c	c	
ISB													

Legend: Cells shaded gray represent a "moderate" level of concern and clear cells represent a "minimal" level of concern. Cells with lines indicate concern with intermediate between moderate and low. Cells with cross-hatches indicate concern intermediate between high and moderate. Cells with a "c" indicate normally minimal concern, but incident specific circumstances need to be examined.

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CHAPTER 7: SOURCES OF UNCERTAINTY AND DATA ADEQUACY

7.1 BACKGROUND

Uncertainty can enter into all phases of an ERA. In detailed risk analyses, considerable effort is spent trying to quantify the sources of uncertainty. In oil spill planning applications, however, this analysis must remain qualitative because the events cannot be defined precisely. The major areas of uncertainty are as follows:

- Conceptual model formation,
- Information and data,
- Natural variability, and
- Mistakes by participants.

It is important to include natural variability in the analysis because it determines limits for the reliability of the assessment. Reliability can be overwhelmed if natural variability is high.

The development of the conceptual model early in the process requires that the assessors identify the various components of the ecosystem in question and define their function. Since the data for this process is always incomplete, it involves summarizing information, making choices, and then defining the uncertainty associated with this process. The development of the conceptual model is one of the most important sources of uncertainty in the process. It is fundamental to the risk assessment that the conceptual model be defensible, and part of this defense is a discussion of the uncertainties related to the factors important to the model.

During the analysis phase, the two main components of error are 1) the definition and modeling of exposure, and 2) the definition of the ecosystem effects after an exposure or exposure regime has been defined. Estimating the error inherent in the exposure process is particularly difficult because of the range of factors involved. These factors include frequency, duration and intensity of exposure, synergism or antagonism, and secondary effects. Inaccuracy in measuring the stressor (in this case, the active components in oil) may be a significant source of error. Using this information in a sensitivity analysis of the model is also an important consideration.

In an oil spill planning situation, it is unlikely that anything better than qualitative measures of uncertainty will be available. This can involve subjective measures such as the following:

- Lists of uncertainties with a rough estimate of magnitude,
- Expert opinion or delphic analyses,
- Cause and effects relationships and their reliability, and
- Importance of each factor (sensitivity analysis).

A finished assessment should represent the best estimate of the ecological risk. It is also important that the uncertainties associated with the estimate be explicitly discussed in the report. In order to address those concerns in this assessment, the participants were asked to address the following four issues when they developed their subhabitat assessment summaries:

- What were the key assumptions behind the risk rating?
- What would be the consequences if these assumptions were incorrect?
- What was the overall data adequacy for determining the risk rating?
- Were there any recommendations for data collection that will improve the analysis?

7.2 GENERAL DATA ADEQUACY AND CRITICAL ASSUMPTIONS

While there were specific concerns about data elements in the analysis, the participants felt that they had sufficient information to complete the analysis. This was based, in large part, on the fact that conservative estimates for exposure and adverse effects were made, when appropriate. This means that, in some instances, adverse effects were overestimated and the benefits underestimated, in order to minimize inappropriate conclusions. It should also be emphasized that predicting the course of events for a hypothetical oil spill involves uncertainties at least as significant as the concerns over the effects data. With those concerns in mind, the following general concerns were identified.

7.2.1 Assumptions about Efficiency

The risk scores are highly dependent upon the efficiencies that were assigned to the various response options, because they define the oil which remains in the environment. This is especially true for on-water mechanical recovery, ISB, and dispersant application. For the first two, the participants were relatively comfortable with the efficiencies used. For dispersants, however, there was a considerable range of opinion as to the expected efficiency. This has a tremendous influence on the perceived benefits for dispersant use. Better data on dispersant efficiencies from actual field trials are important to future planning efforts.

7.2.2 Modeling the Fate of Oil and Dispersed Oil in the Environment

While the participants were comfortable with the results of the surface oil trajectory model, there was concern over the less developed dispersed oil plume model. This is a critical concern because it defines the extent and duration of exposure in the water column. The calculations used in this assessment were considered conservative, but an improved plume model would allow a more accurate analysis. The fact that shoreline loading rates cannot be accurately modeled was also noted, but there are serious difficulties in resolving this concern. It should be possible to produce rough estimates of a real loading, however.

7.2.3 Uptake of Dispersed Oil by Sediments

The available laboratory and mesocosm information suggests that dispersed oil is less likely to adhere to intertidal sediments than crude oil. This is an important issue and needs better definition. Data also suggest that dispersed oil will not accumulate in benthic sediments if the plume reaches those sediments. This is a critical assumption in a shallow system like Galveston Bay.

7.2.4 Effect of Dispersed Oil on Birds

There are inadequate data to determine what happens if a bird comes in contact with a plume of dispersed oil in the water column or with dispersants. For purposes of this analysis, it was assumed to be just as detrimental as crude oil, which is very conservative. Additional data may lower the concern over this issue.

7.3 SPECIFIC DATA ADEQUACY AND CRITICAL ASSUMPTIONS

Table 7-1 summarizes the participants' conclusions about data adequacy. There were no categories in which the participants felt that the adequacy of the available data was poor and only three instances in which the data adequacy was judged to be moderate. These three instances all related to the use of dispersants. All of the information on the four questions listed above is summarized in the following sections.

7.3.1 Terrestrial Habitats

The analysis of terrestrial impacts was only based on limited movement of oil or responders into the area. Based on previous response operations, there is little reason to question these assumptions. Overall, the participants felt the adequacy of data available for their analysis was either good or very good. This is partly a refection of the fact that the potential for exposure in this habitat was very low, and there were only a limited number of pathways. Even if the estimates of exposure were inaccurate, it was clear to all participants that the actual exposure is very limited, and will not affect a large area. Important data needs were identified; however, the value of examining shoreline access points for proximity to high value resources was mentioned, as was the possibility of evaluating the effects of disturbance caused by activities at such sites.

7.3.2 Shoreline and Intertidal Habitats

7.3.2.1 Marsh/Tidal Flat

The conclusions concerning this subhabitat for all response options were particularly dependent upon the surface oil trajectory and on the estimates of efficiency for the various response options. For dispersant use, the accuracy of the plume trajectory and water column concentrations of dispersed oil was also critical. For shoreline cleanup activities, it was assumed that only non-intrusive techniques were used, and that they were not particularly effective in removing the oil. If more aggressive techniques were used, collateral damage to the marsh greatly increased. The participants rated data adequacy as either good or very good for all stressors except for dispersant use, where the ranking was moderate. This was based on concern over the fate of dispersed oil if it entered the marsh or the tidal flat.

7.3.2.2 Sand/Gravel Beaches

The conclusions concerning this subhabitat for all response options were particularly dependent upon the surface oil trajectory and on the estimates of efficiency for the various response options. For dispersant use, it was assumed that there was no overspray. For shoreline cleanup activities, it was assumed appropriate removal techniques were used, substrate was replaced, and that sensitive habitat was avoided. The participants rated data adequacy as either good or very good for all stressors.

7.3.2.3 Riprap/Manmade

The conclusions concerning this subhabitat for all response options were particularly dependent upon the surface oil trajectory and on the estimates of efficiency for the various response options. For dispersant use, it was assumed there was no overspray. For shoreline cleanup activities, it was assumed that steam cleaning or pressure washing was not used. The participants rated data adequacy as either good or very good for all stressors.

Table 7-1: Estimations of Data Adequacy (4 = very good, 3 = good, 2 = moderate, and 1 = poor).

Habitat	Response Action				
	Natural Recovery	On-water Recovery	Shoreline Cleanup	Oil & Dispersant	On-Water ISB
Terrestrial	4	3	4	3	4
Marsh/Tidal Flat	4	3	4	2	4
Sandy Beach	4	4	3	3	4
Riprap/Manmade	4	4	4	3	4
Subtidal benthic (< 3 foot water depth)	4	3	4	2/3	4
Subtidal benthic (3 to 10 foot water depth)	3	3	3	3	3
Subtidal benthic (> 10 foot water depth)	4	4	4	3	4
Non-intertidal oyster reefs	4	4	4	2/3	4
SAV	3	3	3	3	3
Water column (top three feet)	3	3	3	3	3
Water column (bottom three feet) in 3 to 10 foot water depths	4	4	4	3	4
Water column (bottom three feet) in water depths > 10 feet	3	3	3	3	3
Surface microlayer	4	4	4	3	4

7.3.3 Subtidal Benthic Habitats

7.3.3.1 Subtidal Benthic Habitat in Water 3 Feet Deep or Less

The conclusions for this subhabitat were mostly dependent upon the estimates of dispersant efficiency and behavior of the dispersed oil plume because dispersant use was the most significant exposure source. For floating oil, it was assumed that very little physical dispersion occurred. For shoreline cleanup activities, it was assumed that care was taken to prevent the loss of oil contaminated sediment to the nearshore area. The participants rated data adequacy as either good or very good for all stressors, except dispersant use, which was rated as moderate to good. This rating was based on a concern over whether or not the modeled characteristics of the dispersed oil plume were adequate to define exposure, concern about the adsorption of dispersed oil to sediment, and concern regarding the rate of biodegradation of dispersed oil.

7.3.3.2 Subtidal Benthic Habitat in the Open Bay in Water Depths of 3 to 10 Feet

The conclusions for this subhabitat were mostly dependent upon the estimates of dispersant efficiency and behavior of the dispersed oil plume because dispersant use was the most significant exposure source. The concern was less because of the increased water depth, but it was still considered critical. For floating oil, it was assumed that very little physical dispersion occurred. For shoreline cleanup activities, it was assumed that care was taken to prevent the loss of oil-contaminated sediment to the nearshore area and that these areas were far enough away to avoid contamination. The participants rated data adequacy as either good or very good for all stressors.

7.3.3.3 Subtidal Benthic Habitat in Dredged Channels in Water Depths Greater Than 10 Feet

The conclusions for this subhabitat were mostly dependent upon the estimates of dispersant efficiency and behavior of the dispersed oil plume because dispersant use was the most significant exposure source. The concern was minor because of the increased water depth, but it was still considered important. Assumptions about shoreline cleanup and floating oil mentioned in other subhabitats in this category were not considered critical here because of the distribution of the habitat and the increased water depth. The participants rated data adequacy as either good or very good for all stressors.

7.3.3.4 Non-Intertidal Oyster Reefs

The conclusions for this subhabitat were mostly dependent upon the estimates of dispersant efficiency and behavior of the dispersed oil plume because dispersant use was the most significant exposure source. The conclusions were influenced by the surface oil trajectory and it was assumed that very little physical dispersion or dissolution of floating oil occurred. For shoreline cleanup activities, it was assumed that care was taken to prevent the loss of oil-contaminated sediment near oyster reefs. The participants rated data adequacy as either good or very good for all stressors, except dispersant use, which was rated as moderate to good. This rating was based on a concern over whether the modeled characteristics of the dispersed oil plume were adequate to define exposure and the rate of biodegradation of dispersed oil.

7.3.3.5 Submerged Aquatic Vegetation (SAV) Beds

The ratings for this habitat were all based on the assumption that, given this trajectory, there were no sea grass beds present in the study area.

7.3.4 Water Column Habitats

7.3.4.1 Upper 3 Feet of the Water Column

The conclusions for this subhabitat were mostly dependent upon the estimates of dispersant efficiency and behavior of the dispersed oil plume because dispersant use was the most significant exposure source. For floating oil, it was assumed that very little physical dispersion occur. For shoreline cleanup activities, it was assumed that care was taken to prevent the loss of oil-contaminated sediment to the nearshore area. The participants rated data adequacy as good for all stressors. This rating was based on a concern over whether or not the modeled characteristics of the dispersed oil plume were adequate to define exposure, concern about the adsorption of dispersed oil to sediment, and the rate of biodegradation of dispersed oil. The assumption that the toxicity thresholds were truly conservative was also listed as an important consideration. The conservative assumption that diving birds exposed to dispersed oil are uniformly at risk needs to be investigated.

7.3.4.2 Bottom 3 Feet of the Water Column in Depths of 3 to 10 Feet

The conclusions for this subhabitat were mostly dependent upon the estimates of dispersant efficiency and behavior of the dispersed oil plume because dispersant use was the most significant exposure source. The concern was less because of the increased water depth, but it was still considered critical. For floating oil, it was assumed that very little physical dispersion occurred. For shoreline cleanup activities, it was assumed that care was taken to prevent the loss of oil-contaminated sediment to the nearshore area and that these areas were far enough away to avoid contamination. The participants rated data adequacy as very good for all stressors, except dispersant use, where it was rated as good. The assumption that the toxicity thresholds were truly conservative was also listed as an important consideration. The conservative assumption that diving birds exposed to dispersed oil are uniformly at risk needs to be investigated.

7.3.4.3 Bottom 3 Feet of the Water Column in Depths Greater Than 10 Feet

The conclusions for this subhabitat were mostly dependent upon the estimates of dispersant efficiency and behavior of the dispersed oil plume because dispersant use was the most significant exposure source. The concern was minor because of the increased water depth, but it was still considered important. Assumptions about shoreline cleanup and floating oil mentioned in other subhabitats in this category were not considered critical here because of the distribution of the habitat and the increased water depth. The participants rated data adequacy as good for all stressors. This is based on the belief that there was more uncertainty about exposure and on the fate of the oil at the greater depth. The conservative assumption that diving birds exposed to dispersed oil are uniformly at risk needs to be investigated.

7.3.5 Water Surface (Microlayer) Habitats

The key assumptions here were the surface oil trajectory and the efficiencies of the various response options, especially dispersants. The percentage of the surface area of the Bay actually affected by surface oil is also important. The participants rated data adequacy as very good for all stressors, except dispersant use, where it was rated as good.

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CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

The final summary risk matrices included in this report (Chapter 6) represent the consensus estimate of the participants regarding the potential impacts of various stressors on resources and habitats in the Galveston Bay area. Certain conclusions and recommendations can be drawn from those consensus estimates.

The replicable process used herein should be adapted as a regular part of the statewide area contingency planning process.

During the process, several tools were developed which enabled participants to work through the risk assessment process, applying scientific data and conservative assumptions to model relative impacts. These tools, particularly the risk square and the habitat/stressor matrices, can be applied to other scenarios at the local level on a continuing basis.

The potential impact estimates contained in the summary matrices are directly applicable only to the scenarios described herein. The results are not directly transferable to any other spill situation in the Bay. However, the results do indicate the need for more information regarding the potential for broader application of certain response options (i.e., dispersants and ISB) in Galveston Bay.

Development of similar assessments using this process will increase the knowledge base regarding stressor impacts on key resources and habitats in Galveston Bay. In the short-term, this will result in an improved incident-specific decision process because decision-makers will have a standardized set of tools (with which they are familiar) to use in evaluating response options.

In the longer term, the decision making process could be shortened, as more scenarios are worked in different locations and using different oils, patterns of potential stressor impacts will emerge which could ultimately provide a database which is extractable for use with minor modification in various spill situations.

Specific information regarding response options in Galveston Bay was generated as a result of this ERA.

The following response-specific points were agreed upon by participants:

- On-water recovery or ISB, used alone, offer little risk reduction over natural recovery.
- For larger spills (in the 4,000 barrel range) chemical dispersion and shoreline cleanup, used in combination and/or used alone, indicate improved environmental benefits over the use of natural recovery, ISB or on-water recovery. However each of those techniques involves trade-offs as well, e.g., dispersants shift concerns from shoreline resources to water column resources.
- The optimum response is likely to involve some combination of the response options available.
- Resource managers in the response option selection process need to "think tactically, not just strategically." Historically, planners tended to focus on conventional recovery techniques as the only options for most spill incidents. Use of alternative technologies, especially dispersants, ISB, and natural recovery, is often reserved for major incidents. This ERA has shown that these tools may play a significant role in enhancing environmental protection in smaller spills. Planners should consider tactical application of these tools.
- Dispersants and ISB may provide critical environmental protection in nearshore areas and therefore should be considered for use on small spills in Galveston Bay.

This ERA is not an evaluation of all habitats.

An evaluation of all habitats was not done. For example, an evaluation of the impacts of various stressors on submerged aquatic vegetation (SAV) was not performed because there is no SAV in the scenario area. Habitats not addressed herein should be evaluated in future assessment exercises.

This ERA does not encourage use of dispersant on every small spill.

As noted above, although dispersants were estimated to minimize environmental harm in this assessment, results might be different with different oil types, spill locations, or other variables. More information in needed on operational effectiveness of dispersants and exposure concentrations and duration in the environment.

“Small spill” dispersant use parameters were discussed in this ERA.

Participants discussed the concept of a reasonable lower limit spill size, below which dispersant use is less practical due to the rapid natural weathering of oil. Participants were comfortable that a 500-barrel spill was a reasonable dispersant use candidate. However, while spills smaller than 500 barrels were not specifically discussed, participants generally agreed that spills smaller than 200 or 300 barrels are likely to dissipate too rapidly to attempt an effective dispersant operation. This would be an important consideration if existing dispersant use decision protocols are reexamined.

Results of this ERA are conservative.

Participants are confident that the consensus conclusions regarding relative impacts are conservative; that is, they tend to over-emphasize the potential impact of each stressor on the environment. In an actual spill situation, participants expect to see less injury than predicted in the ERA. Participants acknowledge that their conclusions are based on incomplete data, but that available data was sufficiently detailed and robust to support the group’s conclusions. In order to add validity to the results of the current ERA, as well as future assessments, participants noted that they need more information on the operational effectiveness of dispersants and their exposure concentration and duration in the environment.

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Appendix A

List of Invitees, Participants, and Facilitators

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Appendix A. List of Invitees, Participants, and Facilitators.

INVITEE	WORKSHOPS ATTENDED
Acker, Bob Manager MSO Houston-Galveston P.O.Box 446, Gelena Park, TX 77547-0446 Response Operations	1, 2
Anbar, Hasan Assessor Aramco Services Company Environmental Services Unit, 9009 West Loop South, Houston, TX 77096-1799 Scientific Support to Responsible Party	
Anderson, Steven Assessor Texas Natural Resources Conservation Commission 711 West Bay Area Blvd., Suite 210, Webster, TX 77598 Invertebrates, Fish, Plant, Community Ecology, Benthic Ecology, Plankton, Physical Oceanography	1
Arnhart, Rich Assessor Texas General Land Office 11311 N. D Street, La Porte, TX Response Operations	1
Aurand, Don Facilitator Ecosystem Management & Associates, Inc. P.O. Box 1199, Purcellville, VA 20134 Ecology	1, 2, 3
Balboa, Bill Assessor Texas Parks and Wildlife Department Coastal Fisheries, 2200 Harrison, Palacios, TX 77465 State Agency Resource Protection	
Barker, David Assessor Texas Natural Resources Conservation Commission P.O. Box 13087, Austin, TX 78711 Response Operations	1, 2, 3
Broach, Linda Assessor Texas Natural Resources Conservation Commission Field Operations, 5425 Polk Ave., Suite H, Houston, TX 77023-1423 State Agency Resource Protection	

INVITEE	WORKSHOPS ATTENDED
Buie, Greg Manager MSU Galveston 601 Rosenberg, Rm 309, Galveston, TX 77550 Risk Assessment, Response Operations	1
Burch, Denise Manager Equiva 12700 Northborough, Houston, TX 77251-1380 Response Operations	1
Buzan, David Assessor Texas Parks and Wildlife 3000 South IH - 35, Suite 320, Fountain Park Plaza, Austin, TX 78704 State Agency Resource Protection	1, 2
Cain, Brian Assessor US Fish and Wildlife Service 17629 El Camino Real, Suite 211, Houston, TX 77058 Federal Agency Resource Protection	2
Caplis, John Manager US Coast Guard Headquarters G-MOR, 2100 2nd St SW, Washington, DC 20593 Response Operations	1, 2, 3
Clark, Jim Assessor Exxon Biomedical Sciences, Inc. P.O. Box 2954, 2800 Decker Dr., Baytown, TX 77521 Risk Assessment, Toxicity, Oil Chemistry, Fate and Transport, Invertebrates, Fish, Plant, Community Ecology, Benthic Ecology, Plankton	1, 2, 3
Coelho, Gina Facilitator Ecosystem Management & Associates, Inc. P.O. Box 1209, Solomons, MD 20688 Marine Toxicology	1, 2, 3
DeLong, Greg Manager MSU Galveston Post Office Bldg. RM 313, 601 Rosenberg,Galveston, TX 77550-1705 Response Operations	1

INVITEE	WORKSHOPS ATTENDED
Denton, Winston Assessor Texas Parks and Wildlife Fish & Wildlife Service Bldg., 17629 El Camino Real, Houston, TX 77058 Risk Assessment, Response Operations, Invertebrates, Fish	1, 2
Desmond, Chris Manager MSO New Orleans Hale Boggs Federal Bldg., RM 138, 501 Magazine St., New Orleans, LA 70130-3396 Response Operations	
Drummond, Helen Assessor Galveston Bay Estuary Program 711 West Bay Area Blvd., Suite 210, Webster, TX 77598 Non-governmental Organization, Environmental Perspective	2
Duncan, Welcome Manager MSO New Orleans Hale Boggs Federal Bldg., RM 1328, 501 Magazine Street, New Orleans, LA 70130-3396 Response Operations	1
Fritz, David Assessor Amoco Oil Company 200 East Randolph Drive, Chicago,IL 60601 - 7125 Response Operations, Fate and Transport	1, 2
Gahn, Julie Manager MSU Galveston Post Office Bldg. RM 313, 601 Rosenberg,Galveston, TX 77550-1705 Response Operations	3
Gazda, Charlie Assessor U.S. Environmental Protection Agency Response and Prevention Branch (6SF-R), 1445 Ross Ave., Dallas, TX 75202 EPA Regional Response Policy	
Glenn, Phil Manager Clean Channel Association 111 East Loop, Rm. 270, Houston, TX 77029 Response Operations, Toxicity	1

INVITEE	WORKSHOPS ATTENDED
Goldberg, Alisha/ Sipocz, Marissa Assessor Galveston Bay Foundation 17324-A Highway 3, Webster, TX 77598 Non-governmental Organization, Environmental Perspective	1, 2, 3
Grimes, Bill Assessor Texas General Land Office Natural Resource Damage Assessment, 1700 North Congress Ave., Austin. TX 78701 Risk Assessment, Response Operations, Marine Mammals, Birds, Fish, Plants, Community Ecology	1, 3
Gusman, Wayne Manager MSO Houston-Galveston P.O.Box 446, Gelena Park, TX 77547-0446 Response Operations	1, 3
Hamm, Steve Assessor Texas Natural Resource Conservation Commission OCE/FO/R-12-Houston, 5425 Polk Ave. Suite H, Houston, TX 77023-1486 Response Operations, Fish, Community Ecology	1
Henry, Charles Assessor National Oceanic and Atmospheric Administration Scientific Support Coordinator's Office, 501 Magazine St., New Orleans, LA 70130-3396 Scientific/Technical Advisor to OSC	1, 2, 3
James, Bela M. Assessor Environmental Sciences Westhollow Technology Center, 3333 Hwy 6 South (EC-375), Houston, TX 7082 Industry Scientific Advisor	2, 3
Kaser, Rick Manager MSU Galveston 601 Rosenberg, Rm 309, Galveston, TX 77550 Response Operations	3
Kern, John Assessor NOAA- Damage Assessment Center Southeast Region, 9721 Executive Center Drive, St. Petersburg, FL 33702 Federal Agency Resource Protection	

INVITEE	WORKSHOPS ATTENDED
King, Charles H. Jr Manager Buffalo Marine Service, Inc. P.O. Box 5006, Houston, TX 77262 Risk Assessment, Response Operations	1
Kraly, Jen Facilitator Soza and Company, Ltd. 8550 Arlington Blvd., Fairfax, VA 22031 Environmental Science	1
Kuhn, Linda Assessor ENTRIX 5252 Westchester, Suite 160, Houston, TX 77005 Risk Assessment, Response Operations	1, 2
Martin, Buzz Assessor Texas General Land Office Oil Spill Prevention & Response, 1700 North Congress Ave., SFA Bldg., Rm. 340, Austin, TX 78701-1495 State Agency Scientific Support to OSC	1, 2, 3
Moore, Richard Assessor PISCES Rte. 3, Box 789, Dickinson, TX 77539 Response Operations, Invertebrates	
Nelson, Doris Assessor Galveston Bay Estuary Committee Rte. 2, Box 754, Anahuac, TX 77514 Invertebrates	
Nichols, William (Nick) Assessor Oil Program Center 401 M St. SW, Mail Code 5203G, Washington, DC 20460 EPA National Response Policy	1
O'Brien, Cherie Assessor Texas Parks and Wildlife Department Resource Protection Division, Fish & Wildlife Service Bldg., 17629 El Camino Real, Suite 175, Houston, TX 77058 Fish, Plants, Community Ecology	1, 2

INVITEE	WORKSHOPS ATTENDED
Ordner, Mike Assessor Texas Department of Health Seafood Safety, 1100 West 49th St., Austin, TX 78756 State Agency Resource Protection	
Ormond, Bess Assessor Texas Department of Health Seafood Safety, P.O. Box 8748, Bacliff, TX 77518 Invertebrates, Community Ecology, Benthic Ecology	1, 2
Pond, Bob Facilitator Soza and Company, Ltd. 8550 Arlington Blvd., Fairfax, VA 22031 Spill Response	1, 2, 3
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Appendix B

Workshop One Meeting Summary

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FIRST WORKSHOP: Building the Conceptual Model Framework

1.0 FRAMING THE ASSESSMENT PROCESS

1.1 Conceptual Background Discussion

At the opening of the first workshop, the facilitation team presented an overview of the process proposed for preparing the Ecological Risk Assessment (ERA). The approach used in this project is based on the paper prepared by Aurand (1995), and is discussed in general terms in the discussion paper distributed to all participants prior to the first workshop.

The ERA process, as defined by the US Environmental Protection Agency (EPA), has a series of specific activities.

- Problem Formulation – the Conceptual Model.
- Analysis.
- Risk Characterization.

These activities, and the rationale behind the ERA guidelines, are discussed in detail in a series of USEPA publications (USEPA 1992a, b, c; USEPA 1993; USEPA 1994a, b, c) and in the Guidelines for Ecological Risk Assessment, which were issued by USEPA in May of 1998.

The use of workshops is not typical for an ERA, which generally uses an assigned project staff, but this approach is well suited to the circumstances that exist in the oil spill planning community in the Galveston Bay area. This format is intended to foster participation by as many individuals as possible, and create a situation where the stakeholders (risk managers and risk assessors), with guidance from the project team (staff facilitators), are responsible for the development of the assessment. Their direct involvement facilitates stakeholder understanding of, and commitment to, the process. Finally, since many of the participants are involved in oil spill response planning only as a collateral duty, the involvement of the facilitation team in the workshops and during the interim assignments helps to maintain momentum and assist in the compilation and analysis of data.

As an introduction for the first workshop, the critical activities to be addressed were described.

- Problem Definition.
    - 5 Scenario building.
    - 5 Response measures.
    - 5 Resources of concern.
    - 5 Stressors.
    - 5 Endpoints.
- Conceptual Model.
- Analysis Plan.

All of these were discussed on fact sheets provided prior to the workshop. The initial presentation about problem definition emphasized that it is practical to evaluate only one or two scenarios, due to the complexity added to the ERA process with each additional scenario. The chosen scenarios need to represent good decision situations as well as create situations in which the issues of concern to resource managers could be realistically addressed.

Once the scenarios (Section 2) were completed, risk managers were tasked with identification of response measures (Section 3), as well as estimation of effectiveness of each response measure (Section 4). Concurrently, the resources of concern were identified by risk assessors (Section 5) based on consideration of the following:

- Basis for its value in the analysis.
- Current status (with respect to management).
- Preferred habitat or location of the resource.
- Role in the ecosystem.
- Presumed exposure pathways.

Stressors associated with the scenarios that would impact resources of concern were identified (Section 6). Just as the oil alone impacts the environment, so do each of the response options. All potentially have adverse as well as beneficial environmental effects. Therefore, after identifying the full suite of possible options, participants were tasked with examining impacts of each of these options.

Once the resources of concern and potential stressors were identified, endpoints to be used in the analysis were developed (Section 7). Assessment endpoints refer to specific statements pertaining to the resource to be protected (e.g., survival of individuals of an endangered species), which may not be directly measurable. Measures of effect (formerly referred to as measurement endpoints) refer to characteristics that can be measured directly and used to evaluate an assessment endpoint (e.g., stressor toxicity to a surrogate species). For the first workshop, the participants were asked to focus initially on assessment endpoints.

The development of a conceptual model, a key element in any ERA, ties together the resources of concern, the stressors, and potential impacts on those resources (Section 8). The facilitation team emphasized that the purpose of the model was to guide the analysis, and that the level of detail and complexity should be based on practical considerations. Detailed, mathematical models are not a requirement.

Finally, the last activity of the first workshop was to apply this information to develop an assessment plan (Section 9). The assessment plan is used to the analyses that will occur between the first two workshops.

1.2 Sponsors' expectations

Sponsors of the Houston/Galveston area ERA were given the opportunity to voice their objectives in supporting the ERA process. The following goals were expressed:

- Encourage responders to use all the possible "tools" in all areas of the country.
- Help people to make educated decisions.
- Execute a rigorous examination of "alternative technologies" for accurate evaluation.
- Provide a good forum for exchange of information.
- Focus on nearshore response.

2.0 SCENARIO BUILDING

2.1 Introduction

Workshop participants were asked to determine spill scenarios that would allow a balanced examination of all relevant issues. Selection of scenarios is critical to the risk assessment process because they establish the spatial and temporal parameters of the risk analysis. Participants decided to focus on one scenario. In this scenario, they would attempt to encompass the critical concerns of the group by using two spill volumes and both ebb and flood tide scenarios.

The various scenario parameters considered include the following:

- Spill location.
- Oil type.
- Size of spill.
- Weather conditions.
- Time of year.
- Spill duration (instantaneous release or continuous discharge over some period of time).

2.2 Location

The participants, risk managers, and risk assessors, focused first on identifying the potential scenario locations. The Galveston Bay Habitat Conservation Blueprint was suggested as one source that could identify not only locations that would be maximally impacted by a worst case discharge, but also locations with the highest probability for impact. In this plan, the intersection of the Intercoastal Waterway (ICW) and Galveston Bay Channel is identified as a "hot-spot" for collisions. The Conservation Blueprint identifies priority areas of ecological importance. A scenario at the ICW/ Galveston Bay Channel Intersection is a locale of high potential for an incident and high potential for environmental impact.

Other suggestions for the scenario included the following:

- Selection of one scenario within Galveston Bay and one scenario outside the Bay.
- Selection of a spill that occurs outside the 3-mile line and drifts into the nearshore areas.
- Selection of a pipeline spill to generate discussion about ISB.
- Selection of the Opportunity Bay area, due to the presence of shellfish, recreational fishermen, and vessel traffic.

The group also considered factors other than incident probability and ecological impact in selecting the scenario. Parameters such as salinity, water depth, and seasonal considerations were also discussed. One goal in scenario development is to maximize the potential for use of as many response options as possible. With this in mind, the group decided to limit the spill to location within the Bay to assure that excessive weathering of the oil discharged will not occur. Excessive weathering severely limits potential for both dispersant use and ISB. A suggestion was made to choose only one location for the scenario, but examine it by changing other parameters, such as volume and type of oil discharged, season in which the spill occurred, and salinity.

The group arrived at three location options:

- ICW/Galveston Bay Channel.
- Galveston Bay Entrance Channel.
- Upper Part of Galveston Bay.

A final vote identified the ICW/Galveston Bay Channel location (Figure 1) as the preferred scenario location based on relatively high incident probability, potential for consideration of all response options, and potential for impact on the largest number and variety of resources.

2.3 Oil Type

The type of oil discharged in the spill scenario would ideally be one that was amenable to all of the response options. Some participants argued that a medium to light crude product would be a good choice due to a lower emulsification factor, extending the window of opportunity for dispersant and ISB use. Although the local Area Contingency Plan (ACP) uses No. 6 fuel oil in its worst-case discharge scenario, the frequency of crude oil spills is much greater than that of refined product. Two candidate oil types, Arabian Medium and High Island crude oil, were suggested. Despite the fact that Arabian Medium emulsifies quickly and is only amenable to treatment by dispersant and ISB on the first day of the spill, it was selected for the scenario because it is more likely to be transported through the area by vessel.

2.4 Size of Spill

A spill size of 500 barrels was first suggested using the rationale that even a response to a small spill in a sensitive environment would allow examination of trade-offs between response options. However, one tank on a vessel can hold 4,000 to 5,000 barrels of oil, so a spill volume in that range was thought to be more representative of a serious spill in that area. The consensus was reached to discuss two spill volumes in the spill scenario: 500 barrels and 4,000 barrels.

2.5 Weather Conditions

Participants decided that, in general, weather conditions should not limit the use of any response options. Within that bound, wind speed, and direction must be defined because they have the greatest influence on the movement of spilled oil on the surface. Prevailing winds in the Houston/Galveston area are out the southeast. This would tend to drive the oil from the spill location, up the ship channel toward commercial and/or industrial areas. Participants favored this trajectory of a southeasterly wind of 12 kts for Day 1 because it would allow full consideration of both dispersants and ISB by keeping the surface oil in the center of the bay. When passing fronts cause winds shift in this area, winds tend to blow from the west. Participants therefore decided to apply a westerly wind after the first 12 hours. This change would redirect the oil into some of the most ecologically sensitive areas of Galveston Bay on the second day of the spill. No other weather factors were considered relevant for this scenario. In a related discussion, tidal movements were also considered. To avoid the problems associated with an incoming or outgoing tide, the facilitation team suggested that the spill be timed so that the tide moves in both directions during the response.

2.6 Time of Year

Seasonal changes in the resources were discussed to determine the time of year in which the spill scenario should occur. Seasonal migrations of local animals tend to occur in the spring and fall; in particular, the shrimp migration occurs in March and April. Numerous organisms pass through critical life stages during these seasons as well. Spring also tends to be the season with the greatest number of vessel accidents, so was selected as being ideally suited for use in the spill scenario. Spring was later refined to be the month of April.

2.7 Spill Duration

Participants reached consensus that an instantaneous discharge would be a better scenario parameter than a continuous release due to the relatively small total volumes spilled.

3.0 IDENTIFICATION OF RESPONSE MEASURES

While the risk assessors discussed resources of concern (Section 5), the risk managers identified response measures in a concurrent session. The managers assumed that all contracted resources were available for call-out at the time of the spill, and that the spill occurred at a time of day (approximately 4 a.m.) that allowed the entire response effort a maximum of daylight hours.

3.1 On-Water Mechanical Recovery

Logistical considerations: Booms, skimmers, vessels, sorbents, deflection/collection booms, oil storage devices, and vacuum trucks.

Use: Removal of oil from water for disposal and possible reuse to prevent impacts.

Obstacles to on-water recovery were discussed. Water depth is a challenge in Galveston Bay, a body of water that has many shallow areas, because large-capacity equipment is generally limited to waters of greater than 8 feet in depth. Managers estimated it would take approximately 6 hours (from notification to arrival on-scene) to mount an effective response. Managers agreed that effectiveness of mechanical recovery is encounter-rate dependent.

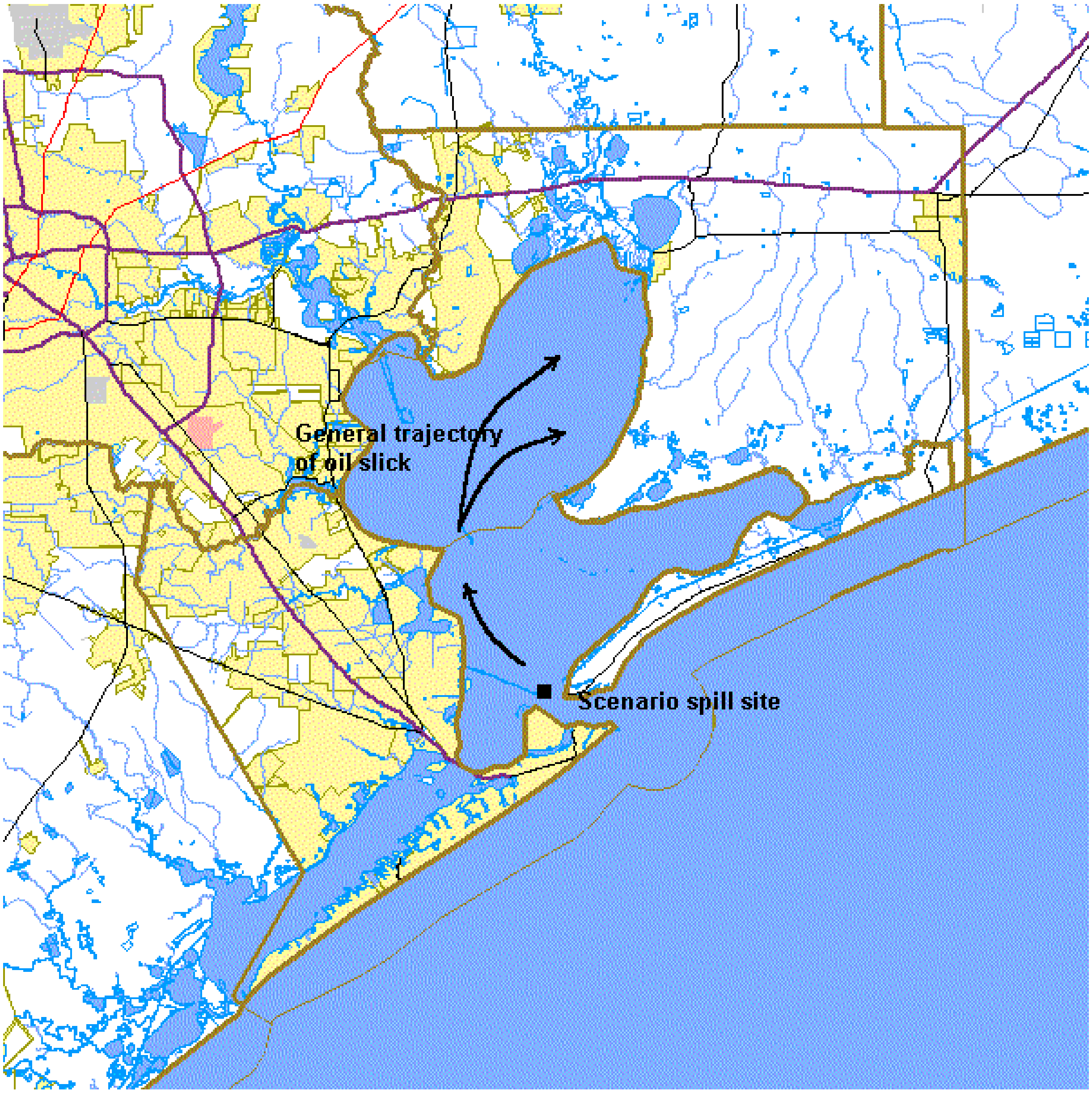

Figure 1. Map of Galveston Bay showing the location of scenario spill site and general surface slick trajectory (as shown by NOAA Hazmat modeling). (Map created using US Census Bureau's Tiger Mapping Service located at http://tiger.census.gov.)

3.2 Dispersant Use

Logistical considerations: Approval for dispersant application, application platform (vessel, helicopter, fixed-wing aircraft), spotter aircraft, and monitoring.

Use: Transformation of oil from a surface slick into the water column as dispersed droplets, preventing impacts, and eliminating disposal issues.

Issues that were raised in the dispersant use discussion included the use of Scientific Monitoring of Advanced Response Technologies (SMART), and whether or not visual observation was sufficient initially. Some participants felt there is a predisposition toward non-approval in nearshore areas. The prime concern over dispersing (rather than mechanically recovering) oil is the perception that increased oil in the water column equates to increased environmental impact. State stakeholder support is important in getting the necessary RRT approval. The prime benefit is reduced exposure to water surface and shoreline habitats. Regarding dispersant use, managers need better understanding/ clarification of several issues, including:

- Is it possible to quantify the environmental trade-offs between dispersing oil and the other potential response options?
- Does dispersant alone in the water column measurably increase toxicity of the oil dispersed in the water column? Managers didn't think this occurred.
- Is there case history information on specific shallow water, nearshore incidents of dispersant use? (Specifically, reporting on both effectiveness and effects).
- If insufficient data exists to make definitive recommendations regarding dispersant use, could planning for experimental use at "spills of opportunity" help fill information gaps?

3.4 ISB

Logistical considerations: Fire boom, vessel, spotter aircraft, monitoring and ignition capability, and smoke-plum model.

Use: Removal of oil from water surface resulting in the minimization of storage and disposal problems.

One of the concerns of ISB use in nearshore areas is the gap between the public perception of potential human health effects of a smoke plume versus the actual potential for effect. Although accurate predictions of smoke plume movement can be made based on wind speed and direction, conditions can change quickly, possibly impacting nearby, populated areas. Vessel traffic impacts of ISB were also discussed. Managers raised several issues that required further input from risk assessors:

- Should particulate fallout (PM10) be used as a tool for development of ISB approval?
- Does the potential for a lesser ecological impact of ISB relative to mechanical recovery exist (due to reduced involvement of machinery and manpower)?
- What are the effects of the post-burn residue remaining after conclusion of a burn?

3.5 Shoreline Cleanup

Logistical considerations: Manpower, vacuum trucks, water washing, hand tools, surface washing agents, shoreline cleaners, protection boom, and heavy equipment.

Use: Removal or oil and debris, preventing or limiting re-oiling of intertidal areas.

Adverse public reaction to shoreline cleanup was one of the major concerns brought up in the managers' discussion. Restricted commercial, industrial, and recreational use or access during cleanup was another negative aspect. The high cost and difficulty in reaching the shoreline (due to property or topo-graphical obstacles) can make shoreline cleanup difficult operationally, and the sensitivity of some shoreline intertidal areas can reduce its appeal for ecological reasons. Once shoreline cleanup begins, determination of "how clean is clean" can make termination difficult. Questions raised for further discussion with risk assessors were as follows:

- Can bioremediation be classified as a subset of shoreline cleanup activities? None of the managers thought there was any legitimate on-water bioremediation currently occurring.
- Can no action/natural recovery be viewed as natural remediation? Although this is not an on-water alternative, it could be a substitute for shoreline cleanup.
- Should the goal of response always be to minimize shoreline impacts? This was not thought to be absolutely true, and the question was rephrased as "the goal of response is to minimize environmental or ecological impact." Although some participants felt that shoreline impacts were often the most severe, others didn't feel there was sufficient data to make that assessment. For example, they were unclear as to whether there was sufficient field data to define the effects of dispersants on fishes.

4.0 EFFECTIVENESS OF RESPONSE MEASURES

Having defined the response options and several issues of concerns, risk managers were asked to develop effectiveness estimates for on-water mechanical recovery, chemical dispersant use, and on-water ISB operations. The intent was to estimate the amount of oil physically removed from the water, dispersed into the water column, or burned on the water as a percentage of the total volume spilled. The presumption is that oil not recovered, dispersed, or burned on the water will ultimately move to other areas of the environment and ultimately arrive on shore.

Consideration was given to adjusting the volume of oil spilled for evaporation and/or emulsification as predicted by ADIOS data. Evaporation reduces the volume of spilled oil in the water and emulsification increases the volume of "mousse", the result of mixing of water into the oil. The managers decided that precise calculations for either of these weathering effects would be highly speculative and that as a practical matter they tend to cancel each other out in determining oil volumes spilled and recovered. Therefore the managers decided to base their percentages solely on total volume spilled.

4.1 On-water Mechanical Recovery Effectiveness Estimate

4.1.1 Assumptions

- Spill occurred at 0400.
- Effective cleanup involves use of skimmers, booms, and recovered oil storage equipment.
- Effective cleanup with all equipment operational at 1000.
- Day 1- Effective cleanup with all equipment continues for 8 hours until 1800.
- In an 8-hour period, all equipment will be fully operational for 6 hours, with 2 hours downtime for repositioning to new oil patches, decanting, and other miscellaneous activities.
- For the 500-barrel scenario, no on-water mechanical recovery would occur after Day 1.
- For the 4,000-barrel spill, mechanical recovery operations would continue at a reduced level throughout the night and the following day.

4.1.2 Equipment recovery and efficiency calculations for the 500-barrel spill

- Four large oil spill recovery vessels (OSRVs). OSRV optimal recovery capacity in barrels per hour (bph) was calculated as follows :

  Nominal pump rate of 400 gallons per minute X 60 minutes X .20 (regulatory nameplate de-rating factor in the regulations)/ 42 (conversion from gallons to barrels) = 114 bph per OSRV X 4 OSRVs = 456 bph.
- Two LORI and 1 Marko Skimmers. LORI and Marko skimmer optimal recovery capacities in bph were calculated as follows :

  Nominal pump rate of 200 gallons per minute X 60 minutes X .20 (regulatory nameplate de-rating factor in the regulations)/ 42 (conversion from gallons to barrels) = 57 bph per skimmer X 3 skimmers = 171 bph.
- Total optimal recovery capacity of OSRVs and skimmers 456 + 171 = 627 bph. Recovery capacity was further reduced by an encounter rate factor of 0.05.

  627 bph X 0.05 = 31.35 bph effective removal capacity per hour for all equipment deployed.

  The actual ability of mechanical recovery equipment to remove oil is affected by the actual amount of oil encountered which in turn is affected by the quantity of oil spill, wind, currents, sea states, water depth, human factors, etc. The encounter rate factor was devised based on the experience of the response managers in previous spills occurring in the Houston ship channel and elsewhere in the Gulf of Mexico and around the world.
- Total oil recovery for Day 1 = 31.35 bph X 6 = 188.1 barrels recovered.
- No further mechanical recovery would be effective due to on-water spreading and beaching of oil onshore.
- **Estimated effectiveness for on-water mechanical recovery = 188.1 oil recovered /500 oil spilled = 37.6 % effectiveness for a 500 barrel spill.**

4.1.3 Equipment recovery and efficiency calculations for the 4,000-barrel spill

- Four large OSRVs. OSRV optimal recovery capacity in bph was calculated as follows :

  Nominal pump rate of 400 gallons per minute X 60 minutes X .20 (regulatory nameplate de-rating factor in the regulations)/ 42 (conversion from gallons to barrels) = 114 bph per OSRV X 4 OSRVs = 456 bph.
- One Large OSRV with similar pumping rate but limited oil storage capacity. Managers decided that the optimal recovery capacity for

this OSRV should be reduced to 57 bph due to necessity for frequent decanting.

- Two LORI and 1 Marko Skimmers. LORI and Marko skimmer optimal recovery capacities in bph were calculated as follows :

  Nominal pump rate of 200 gallons per minute X 60 minutes X .20 (regulatory nameplate de-rating factor in the regulations)/ 42 (conversion from gallons to barrels) = 57 bph per skimmer X 3 skimmers = 171 bph.

- Total optimal recovery capacity of OSRVs and skimmers 456 +57 = 171 = 684 bph. Recovery capacity was further reduced by an encounter rate factor of 0.15.

  684 bph X 0.15 = 102.6 bph effective removal capacity per hour for all equipment deployed.

  The encounter rate factor for Day 1 of the 4,000-barrel spill was set higher than for the 500-barrel spill because the greater volume of oil in the water provides greater opportunity to encounter larger and thicker patches of oil.

- Total oil recovery for Day 1 = 102.6 bph X 6 = 615.6 barrels recovered.
- Nighttime operations (1800 to 0600) would be limited to two OSRVs for safety reasons. Two hand-held infrared cameras on board spotter aircraft would be used to locate oil on the surface of the water. Managers estimated the encounter rate factor would be reduced to 0.05 and that each OSRV would spend 6 hours downtime for repositioning.

  Estimated recovery = 2 (OSRVs) X 114 bph X 6 hours X 0.05 (encounter rate factor [because darkness limits effectiveness]) = **68.4 barrels recovered during night operations**.

- Day 2 operations (0600 to 1800) would include 2 OSRVs (114 bph each), 6 LORI skimmers and 4 Marko skimmers (57 bph each) because the oil would move in to waters too shallow for 2 of the OSRVs to operate effectively. All skimmers would spend 2 hours downtime during the 12-hour operational period. The encounter rate factor would again be 0.05 because the oil would have spread over a much greater area by this time.

  Estimated recovery = (114 bph*2 + 57 bph X 10) X 10 hours x 0.05 = 399 barrels of oil recovered during day 2.

- No further mechanical recovery would be effective due to on-water spreading and beaching of oil onshore.
- **Estimated effectiveness for on-water mechanical recovery = 615.6+68.4+399 = 1183 barrels rocovered/4,000 barrels spilled = 27% effectiveness for a 4,000-barrel spill.**

4.2 Chemical Dispersant Operations Effectiveness Estimate

4.2.1 Assumptions

- Spill occurred at 0400.
- Window of opportunity for effective dispersant use is 0600 to 1800 on Day 1. After that, disperant use would not be possible due to darkness and excessive weathering of the oil.
- Corexit 9500 (at a 1:20 ratio) would be the dispersant used.
- Dispersant aircraft (DC-3 and DC-4) would be on scene applying dispersant within 5 hours of the spill.
- DC-3 carries 24 barrels of dispersant, which can be used to treat 480 barrels of oil.
- DC-4 carries 48 barrels of dispersant, which can be used to treat 960 barrels of oil.
- Spill volumes were not adjusted for evaporation or emulsification.

4.2.2 Dispersant equipment and efficiency calculations for the 500-barrel spill:

- Using one DC-3, the response managers estimated that 480 barrels of the 500 barrels would be treated. Dispersant effectiveness factor was set at .80 because of overdosing, under-dosing etc. Total estimated oil dispersed 480 X 0.80 = 384 barrels dispersed/500 barrels spilled.
- Using one DC-4, the response managers estimated that the 500 barrels of the 500 barrels would be treated on the initial pass. Dispersant effectiveness factor was set at .80 because of overdosing, under-dosing etc. Total estimated oil dispersed 500 X 0.80 = 400 barrels dispersed. The plane would then make additional passes as necessary over the remaining oil 100 barrels of oil to achieve **100% dispersion**.

4.2.3 Dispersant equipment and efficiency calculations for the 4,000-barrel spill:

- One DC-3 would conduct sorties to treat 960 barrels of oil at a 1:20 ratio and one DC-4 would make 2 sorties to treat 1,920 barrels. Total oil treated 960 + 1920 = 2,880 X **80% effectiveness = 2304 barrels** dispersed.
- Managers speculated that it might be possible to conduct a third DC-4 sortie during Day 1. A third DC-4 sortie would result in treatment of an additional 960 barrels of spilled oil X **80% effectiveness = 768 barrels**, raising the total dispersed to 3072 barrels.

4.3 On-water ISB Operations Effectiveness Estimates

4.3.1 Assumptions:

- Spill occurred at 0400.
- Window of opportunity for effective on-water ISB operations is 0600 to 1800 on Day 1. After that, ISB operations would not be possible due to darkness and excessive weathering of the oil.
- Two, 500 foot sections of fire boom and all associated vessels, monitoring equipment, igniters, etc., would be on scene and operational within 6 hours (at 1000).
- Each burn cycle requires approximately 2 hours to contain and concentrate the oil to a thickness sufficient to sustain burning.
- Each actual burn would last for one hour.

4.3.2 ISB equipment and efficiency calculations for the 500-barrel spill:

- OSRV skimming operations would not occur to allow sufficient oil to be collected for burning.
- Each burn boom package would collect and concentrate 100 barrels of spilled oil for burning resulting in 200 barrels burned/500 barrels spilled = **40% efficiency for a 500 barrel spill**.

4.3.3 ISB equipment and efficiency calculations for the 4,000-barrel spill:

- OSRV skimming operations would continue because there would be sufficient oil in the water to allow collections for removal by skimmers and for removal by burning.
- Each burn boom package would collect and concentrate 200 barrels of spilled oil in two burn cycles during the first operational period. These 4 burns would result in 800 barrels burned/4,000 barrels spilled = **20% efficiency for a 4,000 barrel spill.**

5.0 RESOURCES OF CONCERN

While risk managers were identifying response measures, risk assessors began the process of identifying those resources that could be impacted by the spill described in the scenario. Facilitators provided a list of considerations to assist participants through developing the list of resources. These included the following:

- Group species/resources into categories (e.g., -related species or habitats).
- Don't overlook a resource that might be affected by one stressor, but not another.
- Have some basis of value for that resource (e.g., ecological or economic value).
- Consider the current status of a species or condition of a population (e.g., is that community already stressed or protected?).
- Think about the exposure pathways that will affect a resource.
- Keep the spill scenario in mind.

The groups were reminded that there is limited data available, and eventually they will be forced to extrapolate that data to assess the risk to other species. Participants felt it was important to use the current maps and classifications already set up by the Texas General Land Office (TGLO) Resource Atlas and the standard NOAA ESI groups. The four basic ESI habitats used in the Bay were as follows:

- *Spartina* marshes.
- Sandy beaches.
- Riprap.
- Manmade structures.

The participants wanted to consider broader habitats, however, and proposed a classification of five habitats. These are listed below, with some further classification of subhabitats:

- Shoreline (intertidal).
  - Marsh/tidal flat.
  - Beach (sand).
  - Riprap/man made.
- Benthic (subtidal).
  - Shallow < 3 feet.
  - Open bay 3 - 10 feet.
  - Channel > 10 feet.

  5 Reef.

  5 SAV.

- Water column.

  5 Top 3 feet

  5 Bottom 3 feet (in depths of 3 - 10 feet)

  5 > 10 feet (to accommodate offshore movement)

- Surface.
- Terrestrial.

The habitat classifications were further divided into resource categories, within which individual "example organisms" were identified. This resulted in construction of a matrix of resources of concern (Table 1).

6.0 STRESSORS

In the next step toward building the conceptual model, workshop participants were asked to define the various stressors associated with spill countermeasures. Six stressors were identified:

- Natural Recovery.
- Dispersed Oil.
- Shoreline Cleanup.
- On-Water Mechanical Recovery.
- ISB.
- Shoreline Bioremediation.

In addition, seven hazards were identified which determine potential exposure pathways that link stressors to resources:

- Air Pollution.
- Aquatic Toxicity.
- Physical Trauma (refers to a mechanical impact from equipment, people, boat bottoms, etc.).
- Oiling or smothering.
- Thermal (refers to heat exposure from ISB).
- Waste.
- Indirect (indicates a secondary effect on a resource, such as ingestion of a contaminated food source).

A summary of discussion points raised in defining the hazards of each stressor is presented below. Construction of a matrix further illustrating the linkages is discussed as part of development of the conceptual model (Section 8.0). The completed matrix can be seen in Appendix D.

6.1 Natural Recovery

All of the Houston/Galveston habitats that come in contact with discharged oil were highlighted as areas of concern. Only the benthic habitats of Open Bay 3 – 10 feet and Channel > 10 feet, and the water column habitats of bottom 3 feet (in depths of 3 – 10 feet), and bottom 3 feet (in depths of > 10 feet) were not of high concern with this countermeasure.

6.2 Dispersed Oil

Effects of dispersed oil on surface microlayer communities are minimal because the oil is no longer at the surface. However, dispersed oil droplets are a potential problem for all of the other habitats. The toxicity of dispersed oil to fur-bearing animals comes indirectly in the form of oil licked off the body and ingested. Although the magnitude of the effects of dispersed oil on these communities is unclear, participants felt it should be further evaluated.

6.3 Shoreline Cleanup

Shoreline cleanup can involve the use of sorbents, beach skimmers, power-washers, and, if approved, other mechanical methods. Effects of this stressor are of concern to terrestrial and marsh/tidal flats because of physical impact by trucks and equipment. Shallow water habitats and SAV's may be of concern because oil can sometimes refloat and move back into the shallow water.

6.4 On-Water Mechanical Recovery

Although most on-water mechanical recovery operations occur in open water, some efforts extend into shallow water habitats and may be of concern.

6.5 ISB

ISB includes both on-water and shoreline burns. Sandy beach and riprap habitats would not be burned, but could be affected by burning in nearby areas. Discussion was raised regarding burning over an oyster reef or in an SAV bed, and although it is probably not operationally feasible if they are close to the surface, it is possible that responders might not be aware of their presence, and proceed with the burn. The workgroup decided that although those cells should not be termed "NA", they are not of high concern. The surface microlayer was not highlighted as of high concern because it was assumed that the oil would have already done damage prior to the start of the burn.

Table 1. Resources of concern identified by risk assessors.

BROAD HABITATS	SUB-HABITATS	RESOURCE CATEGORY	EXAMPLE ORGANISMS
Terrestrial (includes dunes)	N/A	arthropods	insects; spiders
		birds	bald eagle; cattle egret; rail; Attwater prairie chicken; snipe; killdeer
		mammals	opossum; raccoon; coyote; deer
		reptiles/ amphibians	Gulf coast toad; pygmy rattlesnake; western rattlesnake
		vegetation	wire grass; shrubs, deciduous trees
Shoreline (intertidal)	marsh/ tidal flat	birds	American avocet; American oyster-catcher; black-necked stilt; great blue heron; mottled duck; roseate spoonbill; blue and green-winged teal widgeon; shovelers
		crustaceans	blue crab; grass shrimp; fiddler crab; brown, white and pink shrimp; hermet crabs
		fish	killifish; sheepshead minnow; spot; gobies; flounder
		infauna	polychaetes, amphipods
		mammals	river otter, raccoon
		molluscs	blue mussel; ribbed mussel; periwinkle; Donax
		reptiles/ amphibians	diamondback terrapin; American alligator; saltmarsh snake
		vegetation	salt marsh cord grass; wire grass
	sandy beach	birds	American oyster-catcher; black skimmer; terns; gulls; piping plover; white and brown pelicans
		crustaceans	mole crab, ghost crab
		infauna	amphipod; nematodes
		mammals	coyote; skunk, opossum; raccoon
		molluscs	common rangia
	riprap/ man made	algae	Sea lettuce;
		birds	brown pelican; double-crested cormorant; laughing gull;
		crustaceans	stone crab; blue crab; hermit crab
		fish	blennies; gobies; sheepshead; mullet
		infauna	amphipods, polychaetes
		mammals	rats
		mollusc	blue mussel; barnacle; oyster

* Indicates organism is a keystone species.

Table 1. Resources of concern identified by risk assessors. (Continued)

BROAD HABITATS	SUB-HABITATS	RESOURCE CATEGORY	EXAMPLE ORGANISMS
Benthic (subtidal)	shallow (< 3 feet)	algae	Grassaleria; Ruppia
		birds	roseate spoonbill; great blue heron;
		crustaceans	grass shrimp; brown shrimp; hermit crabs
		fish	southern flounder; drum
		infauna	amphipods; polychaetes
		molluscs	lightening whelk; snails; quahog; oysters
	open bay (3-10 feet)	algae	benthic diatoms
		birds	diving ducks; grebes; coots
		crustaceans	white, pink and brown shrimp; blue crab;
		fish	southern flounder; drum; mullet; hardhead
		infauna	amphipods; polychaetes
		molluscs	lightening whelk; snails; northern quahog; oysters; clams
	channel (> 10 feet)	crustaceans	blue crab; pink, brown and white shrimp
		fish	southern flounder; drum; Spanish mackerel; bluefish; pinfish; sheepshead
		infauna	amphipods; polychaetes
		molluscs	oysters
Benthic (subtidal) (cont.)	reef	algae	benthic diatoms
		birds	American oyster-catcher; gulls; terns; white and brown pelicans; wading birds
		crustaceans	stone crab
		fish	pinfish; sheepshead; flounder; gobies; blennies
		infauna	amphipods; polychaetes
		molluscs	oyster*; oyster drills; barnacles
	SAV	algae	??
		birds	great blue heron; diving ducks;
		crustaceans	white shrimp; blue crab;
		fish	killifish; sheepshead; sheepshead minnow; spotted seatrout; spot; seahorse; pipefish
		infauna	amphipods; polychaetes
		molluscs	northern quahog; lightening whelk; snails
		seagrass*	eelgrass; American seagrass; ruppia

* Indicates organism is a keystone species.

Table 1. Resources of concern identified by risk assessors. (Continued)

BROAD HABITATS	SUB-HABITATS	RESOURCE CATEGORY	EXAMPLE ORGANISMS
Water column	top 3 feet	algae	??
		birds	osprey; gulls; terns; cormorants; diving ducks; common loon; migratory water fowl
		crustaceans	blue crab; white, brown and pink shrimp
		fish	bay anchovy; gulf menhaden; redrum; inland silverside; striped mullet; drum
		jellyfish	cabbage head; sea comb; sea nettle; man-o-war
		mammals	bottlenose dolphin; stennelid dolphin
		phytoplankton	diatoms; dinoflagelates
		reptiles	American alligator; Kemp's ridley seaturtle; loggerhead seaturtle;
	top 3 feet (cont.)	zooplankton	larval crustaceans; larval molluscs; copepods; fish eggs and larvae
	bottom 3 feet (in depths of 3-10 feet)	birds	loons; diving ducks
		crustaceans	blue crab; white, brown and pink shrimp
		fish	black drum; redrum; sand seatrout;
		reptiles	American alligator; Kemp's ridley seaturtle; loggerhead seaturtle;
		zooplankton	larval crustaceans; larval molluscs; copepods; fish eggs and larvae
	Bottom 3 feet (in depths > 10 feet)	birds	loons; diving ducks
		crustaceans	blue crab; white, brown, pink shrimp
		fish	black drum; redrum; sand seatrout;
		mammals	bottlenose dolphin; stennelid dolphin
		reptiles	Kemp's ridley seaturtle; loggerhead seaturtle;
Surface	N/A	algae	sargassum
		birds	olivaceous cormorant; least tern; herring gulls; mallard; brown pelican; white pelican
		crustaceans	sargassum shrimp*, sargassum crabs*
		fish	sargassum fish*, file fish; sea horse
		mammals	bottlenose dolphin; stennelid dolphin
		microlayer associated plankton	fish eggs and larvae
		reptiles/ amphibians	sea turtles

* Indicates organism is a keystone species.

6.6 Shoreline Bioremediation

Bioremediation can accelerate shoreline recovery and is used as a "polishing" tool, not an immediate response. As a result, it is always used in combination with some other form of response, and must be repeated for extended periods of time. The concern with bioremediation is that nutrients added to the water via run-off from shore will degrade water quality. Furthermore, the requirement for repeated treatments can cause increased physical disruption to habitats.

7.0 ENDPOINTS

Facilitators provided a brief overview on endpoints to assist the participants in developing a list of endpoints tailored to the Houston/Galveston area.

The trajectory and ADIOS model will provide spill information regarding time and duration, concentration, location, and weathering. Specifically, the following information will be provided:

- Percent loading on the shoreline.
- Area of water surface affected.
- Concentration and duration in the water column.

There is not much information in the literature on sediment effects, so the issue of accumulation in the sediment will be dealt with through discussions among the risk assessors.

The facilitation team showed the workshop participants one possible format of a risk ranking system that evaluates two parameters (e.g., occurrence of exposure versus length of recovery for the resource). This type of ranking system provides a semi-quantitative evaluation of the effects of stressors on resources. This risk ranking system will be discussed during Workshop 2. Before this type of ranking system could be used, the participants first needed to identify their overall goals of the analysis.

The following general goals were defined:

- Prevent or minimize taking of protected species.
- Prevent or minimize degradation of water quality.
- Prevent or minimize degradation of sensitive habitats.
- Prevent or minimize the long-term disturbance of relative abundance and diversity of communities within habitats (this is a "no net loss" statement for chronic effects).

The group decided that the third goal mentioned above should be revisited to determine whether or not prevention or minimization of the degradation of wetlands should be identified separately because of its importance as a unique habitat. By defining their goals in this way, the workshop participants considered individual species as being protected within their respective ecosystem communities. Based on these goals, the workshop participants then chose the following four endpoints for consideration:

- The proportion of the resource within the proposed trajectory that are killed.
- The amount of exposure that leads to impaired reproductive potential of the resource.
- The proportions of the resource present within the trajectory that becomes oiled.
- The extent of disturbance.

8.0 CONCEPTUAL MODEL

The next step in the ERA process is development of the conceptual model. The conceptual model defines interrelationships between stressors and resources. This was accomplished by constructing a matrix in which the resources of concern are linked to stressors by a numbering code that referenced the seven hazards. If the resource and the stressor had no potential for contact, an "NA" was placed in the cell, rather than a number corresponding to a hazard. To complete the matrix, workshop participants highlighted particular habitats for which there was a concern that may affect response options. For example, the group worked through the stressor "dispersant + oil" and debated whether or not each habitat (terrestrial, marsh/tidal flat, sandy beach, etc.) was an important consideration in the decision to use dispersants. The completed matrix can be seen in Appendix D. A diagram illustrating relationships of stressors, hazards, and resources is being prepared and will be sent at a later date.

9.0 OUTLINE OF ANALYSIS PLAN

On the third day of the workshop, the participants addressed how information would be gathered and organized in preparation for the risk analysis that will be conducted during the second workshop. Three workgroups were formed to gather, organize, and evaluate data. These workgroups were assigned responsibilities relating to transport, resources, and effects issues.

9.1 Transport Workgroup

Prior to the second workshop, the Transport Group will develop surface oil, dispersed plume, and smoke plume trajectories with support from NOAA Hazmat. This group will be coordinated by Charlie Henry, and includes Bob Pond (project team contact), Bea Stong, Buzz Martin, Chris Ponthier, and Dave Fritz.

9.1.1 Surface Oil Trajectory

Two-dimensional surface oil trajectories will include "snapshots" of the surface oil over the spill duration (as often as is necessary or practical), showing areal extent and relative concentrations. For each snapshot, oil volume will be adjusted for evaporation, emulsification, natural dispersion, and other weathering effects. Snapshots will continue for 72 hours after the time at which the spill occurred.

9.1.2 Dispersant Plume Model

For the dispersed oil plume model, surface oil will be dispersed in pulses starting at hour 5. For the 500-barrel spill, 100% dispersion of the surface oil (adjusted for weathering) will be assumed at the first application. For the 4,000-barrel spill, dispersant would be applied every 2 hours as follows: 960 barrels (of oil treated), 400 barrels, 960 barrels, 400 barrels, and 960 barrels for a total of 3072 barrels of oil treated in five pulses. It will be assumed that 80% of the oil treated will be dispersed in each sortie.

Snapshots of dispersed plumes will be provided at each application interval and as often as is necessary or practical for the first 72 hours of the spill. Snapshots will indicate areal extent and relative concentration of surface oil (adjusted for weathering and chemical dispersion). The trajectory of the dispersed oil plume will include average water column concentrations at selected depths in the plume.

9.1.3 Smoke Plume Model

For the smoke plume, ISB operations will begin at hour 8. For the 500-barrel spill, the first burn will occur at hour 8 and a second burn will occur at hour 12. Each burn removes 100 barrels of oil. For the 4,000-barrel spill, two burns will occur at hour 8, and two burns will occur at hour 12. Each burn will remove 200 barrels of oil.

Snapshots for both the 500 barrel and 4,000 barrel spills will be constructed at the time of each burn and will show areal extent and relative concentration of surface oil. The three-dimensional trajectory of the smoke plume will yield approximate PM10 concentrations, adjusted for weathering and ISB.

9.2 Resources Workgroup

Participants from the resources workgroup were tasked with identifying and describing all of the resources within each habitat. This will include obtaining information on distribution/location and its potential sensitivity to the hazards identified in the conceptual model. Where appropriate, information on life history stages, protected species status, and the relationship of the Galveston Bay resource to the resource as a whole should be obtained. The resources workgroup will be coordinated by Winston Denton, and includes Gina Coelho (project team contact), Bill Grimes, Ken Rice, Bess Ormond, Cherie O'Brien, Steve Anderson, Marissa Sipocz, Page Williams, Jim Staves, and Brian Cain.

9.3 Effects Workgroup

Participants from the effects workgroup were tasked with collecting data on the hazards relative to the endpoints and resources identified in the conceptual model. This will include collecting existing data on toxicity and/or physical effects of the stressors relative to resources of concern. The group will then review these data to obtain information that will be needed to develop the endpoint thresholds at the next meeting. The effects workgroup will be coordinated by Jim Clark, and includes Don Aurand (project team contact), Andy Tirpak, Bob Acker, Galveston Bay Foundation (GBF) representatives, Linda Kuhn, Dave Barker, and Nick Nichols.

9.4 Scheduling

Workshop participants scheduled the second workshop for Monday, June 7th (1 p.m. to 8 p.m.), Tuesday, June 8th (8 a.m. to 8 p.m.), and Wednesday, June 9th (8 a.m. to 5 p.m.). Workshop III was scheduled for the week of July 26th.

10.0 REFERENCES

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U.S. Environmental Protection Agency (USEPA). 1992b. Report on the Ecological Risk Assessment Guidelines Strategic Planning Workshop. USEPA/630/R-92/002. Washington, DC.

U.S. Environmental Protection Agency (USEPA). 1992c. Peer Review Workshop Report on a Framework for Ecological Risk Assessment. USEPA/625/3-91/022. Washington, DC.

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U.S. Environmental Protection Agency (USEPA). 1994c. Ecological Risk Assessment Issue Papers. USEPA/630/R-94/009. Washington, DC.

U.S. Environmental Protection Agency (USEPA). 1998. Guidelines for Ecological Risk Assessment. USEPA/630/R-95/002Fa. Washington, DC.

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Appendix C

Supplementary Information

1. Ecological Risk Assessment Principles Applied to Oil Spill
2. Response Planning: A Project Overview
3. Developing the Analysis Plan
4. Monitoring and Long-Term Data Gathering
5. The Use of Conceptual Models
6. Dealing With Uncertainty
7. The Use of Endpoints
8. Natural Recovery/No Response
9. On-Water Mechanical Recovery
10. Dispersants
11. *In Situ* Burning
12. Shoreline Cleanup
13. Evaluation of Protective Booming
14. Bioremediation

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DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING: A PROJECT OVERVIEW

Project Team
SOZA & Company, Ltd.,
Ecosystem Management & Associates, Inc., and Scientific and Environmental Associates, Inc.

Sponsors
U.S. Coast Guard, Texas General Land Office, American Petroleum Institute.

What is Meant by the Expression "Ecological Risk Assessment"?

Ecological Risk Assessment (ERA) is a process to evaluate the possible ecological consequences of human activities and natural catastrophes. An ERA emphasizes the comparison of an exposure to a stressor (in this case, oil) with an ecological effect (e.g. population disruption, changes in ecological community structure or function, toxicological effects) in as quantitative a way as possible, and including an estimation of the probability that an undesirable consequence will occur.

Some sort of risk evaluation occurs whenever a regulator must approve or disapprove an action with environmental consequences. An ERA brings structure and defensibility to this process by a defined methodology. It uses quantitative data whenever possible, defines uncertainty, incorporates information into conceptual or mathematical models of the affected system, and interprets information against clear, consistent, predefined endpoints (action levels) related to the protection of resources.

How Can it Benefit Oil Spill Response Planning?

After protection of human health and safety, oil spill response planning should focus on minimizing ecological impacts. Response planners often base risk perceptions on the expected consequences of individual response actions, rather than on an analysis of how response options could be combined to minimize ecological effects. ERA offers a mechanism for this comparison.

How does Ecological Risk Assessment Relate to Other Oil Spill Planning Considerations?

Ecological consequences are only one element that risk managers (e.g. Federal or State On-Scene Coordinators, natural resource Trustees, industry emergency response managers) must consider. The use of ERA methods helps ensure that the ecological considerations are properly analyzed and presented, but they still must be integrated with other factors (social, economic, aesthetic, legal).

What are the Necessary Steps to Conduct an Ecological Risk Assessment?

Federal and state regulatory agencies and industry are all actively investigating or implementing ERA methods in support of their environmental programs. In the U.S., the primary Federal proponent of the approach is the U.S. Environmental Protection Agency (EPA). In 1998, EPA published "Guidelines for Ecological Risk Assessment", which is the basis for the following summary.

An ERA includes three primary phases - problem formulation, analysis, and risk characterization. The first (problem formulation) involves identifying goals and assessment endpoints, preparing a conceptual model, and developing an analysis plan. In this stage, the early interaction of risk managers (spill response managers) and risk assessors (ecological or natural resource technical experts) to clearly define the problem is essential. Without this interaction, the results of the analysis may not be appropriate to aid in the management decisions. The development of assessment endpoints is critical. These are "explicit expressions of the actual environmental value that is to be protected" (e.g. reproductive success of anadromous fish or the size of a kelp bed). These can then be related to the potential stressors (in this case oil or response options, either alone or in combination) by developing a conceptual (or general) model which defines interrelationships between stressors, exposure, receptors and endpoints. Selection of appropriate endpoints influences all subsequent activities.

The analytical phase involves characterization of exposure and ecological effects. The conceptual model is used to direct the analysis. The result is a series of short reports

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which define and summarize the analysis for each component in the model.

Finally, a risk characterization is completed. This involves estimating and interpreting the risks in relation to the defined endpoints. In addition, the strengths, limitations, assumptions, and major uncertainties are summarized. A report is prepared which describes the results of the analysis.

After the risk assessment is completed, the risk managers must decide on how to integrate this information into the decision process, along with other relevant considerations.

How Can This be Adapted to Support Oil Spill Response Planning?

Conceptually, there are a number of ways to develop an ERA in support of oil spill planning. To encourage active participation by stakeholders, build consensus, and control costs, our approach is to develop the risk assessment in a workshop environment where much of the analytical work can be conducted by local technical experts and managers. The process consists of three multi-day workshops separated by several months. At the first workshop, risk managers and assessors work together to define the problem, and then the assessment team will develop the proposed endpoints, conceptual model and analytical approach. At the end of the workshop, specific analytic assignments will be given to individuals for completion prior to the second workshop.

At the second workshop, the participants will undertake the analysis phase, base on the material on exposure and effects they have developed since the last workshop. This will lead to preparation of a draft risk characterization for review and discussion. Additional analytical assignments may be given in order to refine the analysis or clarify issues.

At the third workshop any remaining analytical concerns will be resolved and a final risk characterization prepared. This will then be used to develop recommendations for the risk managers to consider at the end of the meeting.

This entire process will be facilitated by a management team which also coordinates the exchange of technical information and the development of working documents and the final report.

Who Needs to be Involved?

In order to effectively adapt ERA protocols to oil spill response planning, it is essential that there be broad, multi-stakeholder involvement. Because of the nature of oil spill response and oil spill response planning, consensus-building is a critical element. This means that Federal, State and industry response managers, natural resource Trustees, environmental advocacy groups, and technical experts all need to participate. In addition, other groups, such as local government, concerned private citizens, and the press, must have access to and understand the process.

What are Their Responsibilities?

Individuals who agree to participate in this project will be expected to support the process through:

1. Their attendance and participation at the workshop.
2. The identification and summarization of appropriate technical data.
3. The preparation of analytical papers or summaries needed to complete the risk assessment.

This means that individuals, or groups, will prepare overview material in their area of expertise for consideration at the first workshop, and will also prepare the data necessary for the risk characterization in the interval between the two workshops.

Where Can I Find More Information?

There are many excellent references on ecological risk assessment, its benefits, limitations, and procedures. A few which were used as the basis for this summary are listed below.

American Industrial Health Council. Undated. Ecological Risk Assessment: Sound Science Makes Good Business Sense. Washington, D.C. 13 p.

Aurand, D. 1995. The application of ecological risk principles to dispersant use planning. Spill Sci. Tech. Bull. 2 (4): 241-247.

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DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

DEVELOPING THE ANALYSIS PLAN

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What is the Analysis Plan?

The final activity in the Problem Formulation Phase is the development of an analysis plan. It summarizes what has been done during problem formulation, shows how the plan relates to management decisions, and indicates how data and analyses will be used to estimate risks. The analysis plan provides a summary of the methods that the assessment team will use to evaluate the risk hypothesis developed in the conceptual model. It provides the basis for making selections of data sets that will be used, and how they support the proposed methods

What Does it Contain?

The analysis plan begins with an evaluation of the risk hypotheses from the conceptual model to determine how they will be assessed using either available or new data. It can also present the assessment design, data needs, measures and the methods to be used in the Assessment Phase. It includes the most important pathways and relationships identified in the conceptual model, and how they support the risk hypotheses. In addition to outlining what will be done, it should explicitly identify possible activities that will not be included in the assessment.

How are Decisions Made on What to Include in the Analysis Plan?

The selection of what elements of the conceptual model will be analyzed is based on:

- Availability of information.
- Strength of the information about cause and effect relationships.
- Selected assessment endpoints and their functional role in the ecosystem.
- The mode of action of the stressors.
- The completeness of information on exposure pathways.

In many assessments, including one for oil spill response planning, it is not feasible to collect large amounts of new data. Assessors should concentrate on combining existing local data with extrapolation models to allow the use of alternative data sources. For example, if toxicity information is not available for a particular species of concern, it may be possible to adapt information on another, similar species. When this is done, the source of the data, the method of extrapolation and the justification must be clearly presented.

How are the Risk Hypotheses Evaluated?

Since direct information on assessment endpoints can rarely be obtained, measures are identified to evaluate the risk hypotheses. There are three types:

- Measures of effect - evaluate the response of the assessment endpoint when exposed to a stressor (also known as measurement endpoints).
- Measures of exposure - measures of how exposure may be occurring.
- Measures of ecosystem and receptor characteristics - characteristics of the ecosystem that influence or modify assumptions in the conceptual model.

The analysis plan presents a discussion of all of the measures that will be used in the analysis.

How do Analysis Plans Relate to Decisions?

After the analysis plan is completed, it is appropriate for the risk managers and risk assessors to review their progress. This helps ensure that the analyses will provide information that the managers can use in making decisions. By setting thresholds, the team can define conditions under which the decision-maker should choose alternative options. When it is determined that the problem is clearly defined, that there is enough data available, and that the approach is relevant to the decisions to be made, analysis can begin.

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Discussion Paper

Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in Texas Waters

Monitoring and Long-term Data Gathering

Project Team
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What is Monitoring?

According to Webster's Dictionary (1991), "monitor" means "to watch, observe, or check especially for a special purpose" and "to keep track of, regulate, or control the operation of (a process)." "(Marine) environmental monitoring is conducted to assess the status of the marine environment, detect changes in its status, and guard against the deleterious effects of special activities." The ultimate goal of environmental monitoring of all kinds is protection of the environment, living resources, and human health. Monitoring can provide information that is useful in managing the environment, its resources, and the human activities affecting them.

In general, there are two types of monitoring: real-time observations and long-term information collection. Monitoring to provide a qualitative estimate on the effectiveness of a response method (e.g., dispersants; whether the addition of a dispersant has increased the amount of oil being dispersed into the water column compared to natural dispersion) is referred to as ***operational monitoring***.

Data Gathering is a quantitative measurement often involving complex, and time-consuming steps which can include developing a sampling design, the actual information collection, and subsequent analysis. In this definition, data gathering is not a useful tool for incident-specific decision-making. Rather, these efforts focus on obtaining better data to be applied during the subsequent planning process in assessing the adequacy of response assumptions in general.

What is Operational Monitoring?

Operational monitoring is a real-time evaluation process which provides measurement or observation activity (using trained observers) to ensure the success of a response and, in particular to direct or redirect the response decision. Operational monitoring can provide information that, if used properly, provides support for more effective management decisions. Operational monitoring is not an isolated activity, nor one that should focus on a single response operation (e.g., dispersant use). It should be a part of the management process that provides feedback confirming the intended actions not only took place, but also resulted in the claimed or desired benefit.

When applying dispersants, real-time operational monitoring can supply/obtain additional information important during a response to better inform the decision-making, including but not limited to:

- Monitoring (using trained observers) to determine that the dispersant was applied at the appropriated dispersant-to-oil ratio to the correct locations.
- Monitoring (using trained observers and/or fluorometric measurement) to determine whether the dispersant is working effectively.
- Monitoring the obvious ecological effects (e.g., large flocks of birds or mammals on the surface) of the dispersant application through visual observations.

Operational Monitoring Limitations

- Dispersion may not be an instantaneous process and visible changes to a slick may not be apparent, especially to an untrained observer, for several

This discussion sheet was prepared from Pond, R., J.H. Kucklick, and A.H. Walker, 1997. Dispersant Use: Real-time Operational Monitoring and Long-term Data Gathering. Prepared by Scientific and Environmental Associates, Inc., Alexandria, VA. Prepared for the Marine Preservation Association, Scottsdale, AZ. 23 p.

hours.

- Visual observations are qualitative; they do not offer quantitative effectiveness results.
- Fluorometry readings can provide a qualitative measure of dispersant effectiveness, however they offer no indication of the chemical composition of the dispersed oil.
- Absence of visual evidence does not mean the dispersant is not working.

What is Data Gathering?

Policy-makers, planners, and decision-makers want to gather data during a response in order to understand the effect of a dispersant application on the marine environment, as a way of confirming or revising their knowledge and assumptions about dispersants. Generally, sampling (of water column and organisms in the affected area(s) compared to background/baseline data) is the method used to obtain this kind of information. The results of sample analysis, which take anywhere from days to weeks or months to obtain, are not typically available during real-time response. It is a research activity and is not operational monitoring. Data gathering results can be used in pre-spill planning to help refine dispersant use assumptions in the long-term. Data gathering (validation and verification studies) examines real-world results against the predictive results gathered from past use and conceptual models, enabling validation and adjustment to those models.

Data Gathering Limitations

- Incident-specific studies are designed and implemented without advance notice; "on the spot" plan development and implementation is often considered the cause for limited value of results.
- Experimental spills and the use of mesocosm facilities offer an opportunity to gather data on effects and effectiveness of response options, including the use of dispersants, in a controlled, but real-word setting.

Design and Implementation of an Effective Operational Monitoring and Data Gathering Protocol

Cooperative efforts between decision-makers and technical experts are required to design an effective operational monitoring program. Consideration must be given to what can and cannot be done during real-time and what the information tells you. The National Research Council (NRC) recommended 10 steps for developing and improving any monitoring process.

DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

THE USE OF CONCEPTUAL MODELS

Project Team

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What is a Conceptual Model?

A conceptual model is a written and diagrammatic description of the predicted responses by ecological resources of concern after exposure to stressors. The model must include ecosystem processes that influence the potential responses. Conceptual models consist of two principal products:

- A set of risk hypotheses that describe predicted relationships between stressor, exposure, and assessment endpoint response.
- A diagram that illustrates the relationships defined above.

What Should it Focus On?

The model should focus on the ecosystem or ecosystems at risk, using individual species only as representative elements of the system. When it is applied to oil spill response planning, the model must be a comparative analysis of the risks and benefits of all of the response options, not individual risks and benefits.

How Detailed is it?

The model need only be complex enough to provide the information necessary to support informed conclusions. The systems which are to be affected must be well enough described so that the major consequences of the perturbations can be defined. This does not mean that effective analysis cannot proceed without an in-depth knowledge of all components of the local environment, in fact it means just the opposite. It is the primary responsibility of the planning team to develop a conceptual understanding of the basic structure and functioning of the systems so that research can focus on key components rather than just on the collection of environmental or physiological data which will not facilitate the decision process.

What Factors Need to be Considered?

While there is no "cookbook" methodology to develop a conceptual model, a list of basic characteristics of ecological systems relevant to oil spill response planning follows:

- **Complex Linkages.** Ecosystem effects may be both direct and indirect, and the response planner must be sensitive to the possibility of unexpected consequences. The best way to approach this problem is through the development of conceptual models, which show the pathways connecting the various ecosystem components. There are a variety of approaches which can be used. Energy flow, food webs and nutrient or mineral cycling have all been used and are in the basic ecological literature. In oil spill response planning, it is probably most appropriate to develop a model using trophic linkages and/or physical habitat requirements.
- **Density Dependence.** Some effects may vary depending on the population density of the species in question or, more frequently, either the oil or the response countermeasure may affect the density of a particular species, with unexpected consequences for the ecosystem as a whole. The possibility for and consequences of a dramatic change in population density for a particular species should always be examined.
- **Keystone Species.** In all ecosystems there are certain species which play a major role in the structure of the system. In some cases this may be direct and obvious (the role of framework corals in coral reefs, or large, dominant tree species in mangrove forests), in others less so (predators which limit the population of an otherwise dominant species). It is essential to identify such species during the analysis, because changes in the population of keystone species can have major

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effects on the rest of the ecosystem in question.

- **Time and Spatial Scaling.** In order to characterize the ecosystem at risk an assessor must understand the role of time and space in the system. For example, some ecosystems are naturally patchy, others are continuous. Seasonality may be an overriding consideration. Some marine and coastal communities essentially exist for only a few weeks or months and change rapidly, while others may exist for centuries with only minor modifications unless perturbed.
- **Uncertainty and Variability**. All ecosystems contain elements of randomness and uncertainty as well as variability, which make the prediction of exact consequences impossible. This does not mean that general trends and overall structure cannot be discerned, but it does mean that the assessor must be alert to unexpected events or consequences, and be prepared to deal with them as they are identified.
- **Cumulative Effects.** Oil spills, and oil spill response often occur in polluted areas or in combination with other environmental stresses and cumulative or synergistic effects are always a possibility. This must be considered before models are developed. For example, a coral reef stressed by high sediment load, or a rocky intertidal zone subjected to thermal stress from an effluent discharge, cannot be expected to respond in the same way as a similar, but unstressed community. A history of multiple spills or other sources of oil in the environment could also be a factor.
- **Population versus Community Dynamics.** The assessor must consider both protection of valuable (for whatever reason) species and whole communities. It does no good to rescue individuals of an endangered or threatened species, only to return them to a community or habitat which can no longer support them.
- **Definition of System Boundaries.** In order to correctly characterize an ecosystem, the area that operates as a functional unit must be correctly defined, both in space and time. If this is not done correctly, unexpected consequences are more likely to occur. It is also a crucial factor in the subsequent risk evaluation, because it places the affected resources in the appropriate context for the entire system.

Who Should Participate?

Common sense limits the model to the information that is essential to the analysis, and the best way to ensure that this occurs is to involve a wide spectrum of individuals in the process. In addition, the model will be of little value if it is incomprehensible to the planning community, and so the needs of the risk managers must be considered throughout the model's development.

DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

THE USE OF ENDPOINTS

Project Team
SOZA & Company, Ltd.,
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What is an Endpoint?

An endpoint is an explicit and measurable expression of an environmental value that is to be protected. The use of defined endpoints is a key element in the assessment process, and must be agreement as to what constitutes an appropriate endpoint prior to the development of the conceptual model.

What Types of Endpoints are There?

The U.S. EPA terminology recognizes one type of endpoint, assessment endpoints. "Assessment" endpoint refers to effects at the population level or higher that are of ecological importance within the system under evaluation. It includes both an ecological entity and specific attributes of that entity. For example, it might be determined that a reproducing population of a particular commercial fish species is a critical assessment endpoint. Some literature on ecological risk assessment recognizes a second type of endpoint, the measurement endpoint. The EPA approach defines this as one type of "measure" used to evaluate the assessment endpoint.

How are Data Used to Evaluate Endpoints?

Assessment endpoints are often difficult or even impossible to measure directly, especially in advance of the action under evaluation. In that case, "measures" must be identified to evaluate the risk hypotheses related to the assessment endpoints. These are identified in the analysis plan. One of these, measures of effect, equates to the term measurement endpoint. It refers to data that can be measured in the laboratory or the field, and then used to estimate the assessment endpoint. Toxicity data for a single species (which can then be combined with life history and distribution information to estimate population effects) is an example of a measurement of effect.

What Factors Enter into Assessment Endpoint Selection?

Assessment endpoints should have biological and societal relevance, an unambiguous operational definition, accessibility to prediction and measurement, and susceptibility to the hazardous substance. Assessment endpoints may include habitat loss or physical degradation of habitat below some effects threshold, as well as biological effects. All participants in the assessment process must accept the endpoint definitions for endpoints of both types.

How do you Determine if a Proposed Endpoint is Really Ecologically Significant?

Determination of the ecological significance of an event requires that it be placed in the context of:

- The types of other anticipated events associated with the stressor.
- The magnitude of the other events caused by the stressor.
- Its role in the structure and function of the system in question.
- Its relationship to other events within the system (cumulative analysis).

What Is Meant By Susceptibility?

Susceptibility has two components, sensitivity and exposure. Sensitivity refers to how readily an ecological entity is affected by a particular stressor. It is related to the proposed mode of action of the stressor as well as to individual and life history stages. Exposure refers to co-occurrence, contact, or the absence of contact, depending on the nature of the stressor and the properties of the ecological entity in question. It is a central assumption of risk assessment that effects are directly related to exposure. Life history considerations are often very important in determining susceptibility, and can be very complex. Delayed effects must also be considered.

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How Are Management Goals Considered?

Consideration of management issues is critical because, ultimately, the value of the risk assessment is determined by its ability to support quality management decisions. Managers find it easier to use the information if it is based on values or entities that people know about and understand. With planning, such considerations can be integrated into the assessment without compromising its relevance to the ecological system in question.

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DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

NATURAL RECOVERY/NO RESPONSE

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What is Natural Recovery and/or the "No Response" Option?

The natural recovery and/or "no response" cleanup strategy is just that–the oil is left to weather naturally; no attempt is made to remove/recover any of the floating or stranded oil. This is considered the response option of choice when there is a need to minimize the environmental impact of human intervention in a particular habitat. It is used when other response options are considered to cause more damage than the oil itself. It is also an option when there is no effective method for cleanup or the existing environmental conditions do not allow the use of existing response technologies. Although no cleanup action is taken, monitoring of the contaminated areas or resources is required.

This response strategy is applicable for all habitat types. The primary reason for using the "no response" strategy is when:

- Spills occur a great distance from shore.
- Natural removal rates are fast (e.g., the evaporation of gasoline or oil along highly exposed coastlines).
- The degree of oiling is light.
- Cleanup actions will do more harm than natural removal (as is primarily the case with salt marshes and sheltered tidal flats).
- The spilled oil is inaccessible.

In general, oil that is not recovered using conventional response techniques is left in the environment and can be considered to undergo natural recovery, whether it continues to weather, in sediments, is consumed, or undergoes natural biodegradation.

Effectiveness

Effectiveness of the natural recovery/no response option is dependent upon many factors:

- Volume of oil spilled.
- Type of oil spilled.
- Depth of penetration.
- Habitat type.
- Season.
- Climate.

The effects of the "no response" option has been studied for several large spills, e.g., the *Metula* spill in Chile, the *Exxon Valdez* spill in Prince William Sound, Alaska, and the Gulf War spill in Saudi Arabia. In each of these cases, significant quantities of oil were left to weather naturally. In the cold, temperate environment of Chile, the heavily oiled marshes where the oil was not removed by tidal/rain action are expected to be affected for decades. This is an extreme example of a slow recovery; after 20 years, little change has occurred. Sites left to natural recovery during the *Exxon Valdez* spill are considered to have nearly returned to background levels less than 10 years later.
Seven years following the Gulf War, Saudi Arabia's climate has rapidly weathered the extremely thick layers of oil coating the entire shoreline, detoxifying it and allowing for the beginnings of what is expected to be a rapid recovery.

In general, the lighter the oiling, the more rapid the recovery. Conversely, an area covered with a thick layer of oil will take longer to recover. Recovery may be on the order of several months (light oiling) to many decades (extensive oiling or penetration deep into the sediments).

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What are the Potential Opportunities/ Benefits?

- Reduces the potential impact to the habitat from other, more conventional response techniques.
- Reduces the chance for mixing the oil deeper into the sediments where it can remain relatively unweathered for many decades.
- Can be used for spills of very light oils and oil products (e.g., gasoline and jet fuel) that are not easily recovered using conventional cleanup technologies.

What are the Potential Challenges/ Tradeoffs?

- Leaves the oil in the environment for a longer period than if recovered, thus increasing the chance for resource impacts.
- May be inappropriate for areas used by high numbers of mobile animals (birds, marine mammals) or endangered species.

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DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

ON-WATER MECHANICAL RECOVERY

Project Team

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What is On-Water Mechanical Spill Response?

Mechanical oil spill response uses physical barriers and mechanical devices to redirect and remove oil from the surface of the water. Where feasible and effective, this technique may be preferable to other methods, since spilled oil is removed from the environment to be recycled or disposed of at appropriate facilities. Because effective mechanical containment and removal is severely restricted by wind, waves, and currents, only a small percentage of spilled oil has historically been recovered in this manner. Mechanical removal of oil utilizes two types of equipment: booms and skimmers.

Oil Containment Booms: Spilled oil floating on the water's surface is affected by wind, currents, and gravity, all of which cause it to spread. This oil may be concentrated or redirected by deploying floating barriers, called booms. Booms come in many different shapes, sizes, and styles. They are used for concentrating oil so that it is thick enough to be skimmed, for keeping oil out of sensitive areas, or for diverting oil into collection areas. The success of booming as a strategy is dependent on currents, wind, and waves. Currents can draw the oil under the booms; waves may cause oil splashover; wind and currents may cause the booms to sink or plane; and currents or debris may damage the boom.

Skimmers: These devices remove oil from the water's surface. They are typically used with booms that concentrate the oil, making it thick enough to be skimmed efficiently. The effectiveness of the skimmer is determined by how quickly it can collect the oil, and how much water is mixed in with it. The oil collected by the skimmer is stored in a containment tank. A wide variety of skimmers are available that use different methods for separating oil from water. Skimmer operating time is limited by the size of the storage tank, and skimmer effectiveness can be hampered by debris. Vessel-based skimming systems are utilized to remove oil from open water, while vacuum trucks are often used to remove oil that has collected near the shoreline.

Effectiveness

Boom and Skimmer Operations: Typically, estimated recovery rates range from 10 to 15% of the total spill volume with little opportunity for higher rates due to containment limitations in open water. If a boom and skimming operation is working successfully, 75 to 90% of the oil contained within the boom will be recovered by the skimmer.

What are the Potential Opportunities/ Benefits?

- Physically removes oil from the environment.
- Allows recycling or proper disposal of recovered oil.
- Minimizes direct environmental impacts in open water areas.

What are the Potential Challenges/ Tradeoffs?

- Adequate storage capacity for recovered oil is often limited.
- Spreading of oil on the surface of the water; inability to contain the oil.
- Wind, waves, and currents may allow only a fraction of the spilled oil to be contained and recovered.
- Booms may fail and skimmers may clog.

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DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

DISPERSANTS

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What Are Dispersants?

Dispersants are specially designed oil spill products composed of detergent-like surfactants in low toxicity solvents. Dispersants do not actually remove oil from the water. Instead, they break the oil slick into small particles, which then permanently mix (or disperse) into the water column where they are further broken down by natural processes. During periods of heavy wind and wave activity, spilled oil will often get mixed naturally into the water column, only to resurface at a later time as a surface slick when the natural mixing forces have been reduced.

By removing oil from the water surface and diluting oil concentrations in the water column, chemical dispersion:

- Prevents the small oil droplets from coming together again and forming another surface slick (re-coalescence).
- Reduces the ability of the oil to attach to birds and other animals, shoreline rocks, and vegetation.
- Reduces evaporation of volatile oil components thus reducing fire and explosion hazards.
- Provides a cleanup option when other response techniques are not effective (e.g., waves too high for booms and skimmers).
- Enhances natural weathering and biodegradation of the oil droplets.
- Removes the oil from the action of the wind that may ultimately bring a slick ashore.
- Prevents the formation of tarballs and mousse.

Dispersants may be applied to surface slicks from airplanes, helicopters, or vessels. Dispersant spray systems are designed to provide the correct droplet size and dosage, as both are important factors in effective oil dispersal. The volume of dispersant applied is a fraction of the volume of oil treated, with a typical dispersant to oil ratio of 1:20.

Where the Oil Goes

When the oil is treated with dispersants, it initially disperses within the upper 10 meters (30 feet) of the water column due to natural mixing processes. If these dispersed oil droplets are small enough (generally less than 0.01-0.02 mm diameter) the droplets will remain dispersed in the water column. The dispersed oil will be rapidly diluted due to spreading both horizontally and vertically by tides and currents. Historically, dispersed oil concentrations of 20 to 50 parts per million (ppm) have been reported in the upper 10 meters of the water column directly under the slick. These concentrations dilute rapidly as the oil moves through time and space in the water column. Within 2-4 hours, concentrations are typically below 10 ppm, which is the threshold limit below which adverse ecological effects are not anticipated. Typically, pre-authorization of dispersant use is reserved for deeper (>10 meters) waters to ensure sufficient dilution of the oil and to prevent impacts on bottom-dwelling organisms. Dispersant use can also be considered in shallower environments to minimize impacts on highly sensitive surface, shoreline, and intertidal areas that are difficult to otherwise protect.

Dispersant Effectiveness

Dispersant effectiveness is dependent on the type of oil and environmental conditions. Areas where dispersants are applied can reach 100% effectiveness in dispersing surface oil, but often this effectiveness cannot be verified because the dispersant action may occur over a long period of time, and wind and currents carry the oil from the application area. Trained observers must be used to verify effectiveness.

Approval for Dispersant Use

Because of the tradeoffs involved (i.e., relative benefits and potential negative effects), the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) sets limitations on dispersant use. Dispersants must be on a national list maintained by the Environmental Protection Agency. Federal and state agency agreements establish areas where rapid decisions on dispersants may be made by the Federal On-Scene Coordinator. Use outside these areas requires the approval of additional agencies identified in the NCP.

Studies of Dispersants

The evidence from six spills treated with dispersants in United Kingdom waters since 1980 is that dispersion of oil (natural or chemical) into the water column can minimize overall environmental impacts by reducing damage to the shoreline and sea surface ecosystems. The limited environmental damage from the 1993 *Braer* incident, where large volumes of oil were dispersed naturally, provides particularly strong evidence that dispersion of oil can minimize the overall effects of a spill. Chemical dispersion in the *Sea Empress* spill in 1996 was found to reduce environmental damages and cleanup intrusiveness, cost, and duration.

What are the Potential Opportunities/ Benefits?

- Reduced impact of surface oil on shorelines, sensitive habitats, birds, mammals, and other wildlife.
- Rapid treatment of large areas.
- Reduced oil storage and disposal problems.
- Accelerated natural degradation processes.
- Use in high seas and currents is feasible.

What Are the Potential Challenges/ Tradeoffs?

- Increased oil impacts on organisms in the upper 10 meters of water column.
- Time frame for effective use may be short.
- Application equipment may be unavailable.
- Personnel trained in proper dispersant equipment use may be unavailable.

DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

IN-SITU BURNING

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What is In-Situ Burning?

In-situ burning means the controlled burning of oil "in place." On open water, burning requires specialized fire resistant boom because uncontained oil rapidly spreads too thin to sustain combustion. *In-situ* burning can be applied in some inland areas where other methods cannot be used because of limited access to the spill location or ice conditions. Since a fire boom behaves much like a standard containment boom, it is subject to some of the same wind and sea limitations as mechanical removal. However, burning rapidly removes large quantities of oil and, minimizes the need for recovery and storage.

Where the Oil Goes

The primary products of *in-situ* burning of oil are carbon dioxide and water vapor. About 90% to 95% of the carbon product is released to the atmosphere as carbon dioxide, while particulates commonly account for only about 5% to 10% of the total volume burned. In addition, about half of the particulates are soot, which is responsible for the black appearance of the smoke plume. Minor amounts of gaseous pollutants are emitted, such as carbon monoxide, sulfur dioxide, and nitrogen oxides. In addition, some polynuclear aromatic hydrocarbons (PAHs) are emitted, but the amount released is less than the amount that would be released if the oil had not undergone burning.

Field experiments have shown that most air pollutants of concern produced by an *in-situ* burn are concentrated around the area of the fire. Only one pollutant, the fine particles in the smoke, is of concern beyond the immediate area of the fire. If inhaled in high concentrations, these particulates can cause respiratory distress in the elderly or those with impaired lung function. Although these small particles from an *in-situ* burn will typically remain suspended and dilute high above the human breathing zone, monitoring plans have been established so responders can monitor particulate levels to ensure the protection of public health.

The decision to use *in-situ* burning must consider the tradeoffs involved, including:

- Impact on air quality.
- Benefit of rapid oil removal.
- Safety of the response workers.
- Risk of secondary fires.

Effectiveness

Burning is efficient. Consistently, it has been found to remove more than 90% of the oil held inside a fire boom during numerous experiments and accidental burns of petroleum on water. The small percentage of the original oil volume left unburned is typically a viscous, taffy-like material that floats for long enough to be manually removed. Because of the containment challenge, like mechanical recovery, it is unlikely that *in-situ* burning will be able to affect more than 10-15% of the total spill volume.

Approval of In-Situ Burning

Because of the tradeoff decisions involved, certain approvals must be obtained prior to use of *in-situ* burning. Use of burning agents to increase oil combustibility is regulated by Subpart J of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The State Implementation Plans required by the Clean Air Act are the primary plans that regulate air quality and pollutant sources. Agreements between state and federal regulatory authorities establish areas and necessary conditions where rapid decisions on *in-situ* burning may be made by the Federal On-Scene Coordinator and/or the State On-Scene Coordinator(s).

What are the Potential Opportunities/ Benefits?

- Reduces impact of surface oil on shorelines, sensitive habitats, birds, mammals, and other wildlife.
- Rapidly consumes oil in the burn.
- Reduces oil storage and disposal problems.
- Eliminates the air quality impacts of the volatile hydrocarbons that would otherwise evaporate.
- The products of combustion are diluted in the air above and downwind of the burn, dispersing rapidly at ground level to background concentrations.

What are the Potential Challenges/Trade-offs?

- Use limited to correct atmospheric and sea conditions or offshore areas to protect public health.
- Equipment required for burning may not be readily available.
- Time frame for effective use may be short due to difficulty of igniting weathered oil.
- Post-burn cleanup operations may be hampered if booms fail or skimmers clog with the burn residue.
- Black Smoke.

DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

SHORELINE CLEANUP

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What is a Shoreline Cleanup?

The shoreline acts as a natural containment barrier for oil spilled on water. Given the right current and wind conditions, even a spill 25 or 50 miles at sea can wash ashore if not recovered or removed by on-water spill response technologies (mechanical recovery, dispersants, *in-situ* burning). On shore cleanup is very labor intensive and tends to be more acutely environmentally intrusive than any of the on-water response options. Listed below are examples of shoreline cleaning methods, many of which are used concurrently.

1. **Natural Recovery**–no action is taken, the oil is left to weather naturally.
2. **Manual Removal**–removal of surface oil by manual means (hands, rakes, shovels, buckets, scrappers, sorbents, etc.)
3. **Mechanical Removal**–removal of oil from water surface, bottom sediments and shorelines using backhoes, graders, bulldozers, dredges, draglines, etc.
4. **Passive Collection and Sorbents**–removal of floating oil by absorption onto oleophilic material placed in the water or at the water line.
5. **Vacuum**–mechanical removal of free oil pooled on the substrate or from relatively calm water.
6. **Debris Removal**–manual or mechanical removal of debris (oiled and unoiled) from the shore or water surface to prevent additional sources of contamination.
7. **Sediment Reworking/Tilling**–reworking sediments to break up subsurface oil deposits, both manually and mechanically, to expose the oil to natural processes and enhance the rate of oil degradation.
8. **Vegetation Cutting/Removal**–removal and disposal of portions of oiled vegetation or oil trapped in vegetation to prevent oiling of wildlife or chronic oil releases.
9. **Flooding (deluge)**–removal by water washing oil stranded on the land surface to the water's edge for collection and disposal.
10. **Ambient Water Washing (low and high pressure)**–removal of liquid oil that has adhered to the substrate of man-made structures, pooled on the surface, or become trapped in vegetation using ambient-temperature water sprayed at low or high pressures.
11. **Warm Water Washing (<90°F)**–removal of non-liquid oil that has adhered to the substrate or man made structures, or pooled on the surface using warm water.
12. **Hot Water Washing (> 90°F)**–removal of weathered and viscous oil strongly adhered to surfaces using hot water.
13. **Slurry Sand Blasting**–removal of oil from solid substrates or man-made structures using sandblasting equipment.
14. **Solidifiers**–chemical formulations which change the physical state of the spilled oil from a liquid to a solid for easier recovery and disposal.
15. **Shoreline Cleaning Agents**–chemical formulations applied to the substrate to increase the efficiency of oil removal from contaminated substrates using other response methods (flushing, pressure washing, etc.).
16. **Nutrient Enrichment**–a bioremediation technique that involves adding nutrients to the environment to stimulate the growth of naturally occurring oil-eating

bacteria.

17. **Burning**–removal of oil from the water surface or habitat by burning the oil.

Options 14 through 17 require special approval under federal laws.

In order to determine the proper cleanup method, responders and planners consider cleanup methods in advance of a moving oil slick. Several considerations must be made before a proper cleanup plan can be initiated. First, the type and quantity of oil must be determined. Oil types vary greatly and have a major influence on the degree of impact, ease of cleanup, and persistence of the contamination. For example, lighter fuels (diesel, home heating fuel, and light crude oils) will evaporate quickly, but tend to be more toxic and penetrate the shoreline sediments to a greater degree. Heavy oils (bunker C, No. 6 fuel, and heavy crude oils) are less toxic to shoreline ecosystems and do not penetrate finer sediments, but they are very persistent, difficult to clean and may smother shoreline organisms.

Second, the type of shoreline which is predicted to be impacted must be identified, mapped, and ranked in terms of its relative sensitivity to oil spill impacts, the predicted rates of natural removal of stranded oil by processes such as waves and currents which naturally clean the shoreline, and ease of cleanup.

Additionally, the shoreline cleanup strategy may need to be revised in response to changing conditions or as the oil weathers.

Cleanup Effectiveness

1. The success of the shoreline cleanup response is dependent on several factors, including but not limited to the type of affected shoreline;
2. The type of oil spilled;
3. The availability of the equipment;
4. The technical experience of the cleanup personnel; and
5. Weather and sea state conditions.

Depending on the spill conditions and the response operation used, the cleanup strategy can range from 100 percent effective (e.g., manual removal) to minimally effective initially (as can often be the case in marshes and sheltered tidal flats). In marsh habitats, the activity associated with the cleanup can often be more damaging than the oil itself; the cleanup operations can drive the contaminants below the surface and make them available to the root systems of the plant and the organisms that burrow into the sediments. It is common in these environments for oil to be allowed to remain on the surface of the sediments with sorbents being placed at the edge of the water line in an effort to passively collect any oil that refloats.

What are the Potential Opportunities/ Benefits?

Examination of the benefits and tradeoffs of shoreline cleanup are different than examining the benefits and tradeoffs of on-water response. Given the option, on-water cleanup will almost always be environmentally preferable to on-shore recovery. Therefore the potential benefits here apply to employment of one or more of the shoreline recovery options versus allowing the oil to degrade naturally on the shoreline without human intervention.

- Reduced impact on shorelines, sensitive habitats, birds, mammals, and other wildlife.
- Physically removes oil from the environment.
- Allows recycling or proper disposal of recovered oil.

What are the Potential Challenges/Tradeoffs?

- Reduced impact on shorelines, sensitive habitats, birds, mammals, and other wildlife.
- Often labor and manpower intensive.
- Adequate storage capacity for recovered oil is often limited.
- May require special approvals under federal law.

DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

EVALUATION OF PROTECTIVE BOOMING

Project Team

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Background

Protective booming was not included in the matrix of response options evaluated for this exercise. The workshop participants are aware of the potential impacts associated with implementation of protective booming along shorelines and shallow water habitats. However, the group felt that protective booming would be deployed in highly sensitive areas under any oil spill response option, thus the risks would be present in all response activities considered.

When is protective booming appropriate?

Protective booming is seen as an integral part of dealing with unexpected events associated with any type of oil spill response (i.e., on water recovery, dispersant use, on-water or in-situ burning, natural dispersion without recovery). This characterization is consistent with its intended role as a contingency in case oil moves to new areas unexpectedly. It also is deployed in case planned recovery operations are not as efficient as desired or as timely as expected in deployment. The workshop participants recognized that response options that leave small residuals of oil on the water surface due to operational inefficiencies may provide a greater overall level of environmental protection when paired with protective booming. The environmental risks of those response options might indeed be unfairly characterized by leaving out the benefits of protective booming, compared to greater residual risks associated with response options that leave relatively greater residuals of oil in the water surface. For those less efficient response options, protective booming may not be sufficient to eliminate impacts of residual surface oil.

Efficiency

Workshop participants recognized that the efficiency and effectiveness of protective booming is highly variable. The degree of protection afforded depends on factors such as the type of oil, local currents and wave conditions, installation methods, boom maintenance, and the degree to which a shoreline is accessible with equipment and amenable to placement of protective booming. An additional consideration is that the efficiency of protection commonly decreases as the duration of oiling and amount of oil impinging on the boom increases. Oily boom that is not serviced on a regular basis can become a source of oil for the local area it was intended to protect. When oil does pass behind the boom, the boom can then serve as a barrier to slow the rate of oil release from the shoreline area.

Risks

Protective booming brings about a certain degree of risk of collateral damage do to physical disturbance by work crews installing, maintaining and dismantling the boom. Additionally, there are impacts of disturbance and scaring from anchoring the materials to soils, sediments or plants, along with increased erosion of shoreline and sediments while the boom jostles in place. Finally, oily booming materials that are not retrieved when the response is completed become shoreline or wetland debris.

The potential ecological risks from protective booming are considerable. However, the risks are nearly the same for any and all the response options considered in the course of the workshop, since booming would be deployed as a contingency in all cases. Therefore, it was left off the risk assessment matrix.

This discussion sheet was prepared by Jim Clark, with assistance from Buzz Martin and Chris Ponthier.

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DISCUSSION PAPER

ECOLOGICAL RISK ASSESSMENT PRINCIPLES APPLIED TO OIL SPILL RESPONSE PLANNING IN TEXAS WATERS

BIOREMEDIATION

Project Team
SOZA & Company, Ltd.,
Ecosystem Management & Associates, Inc., and Scientific and Environmental Associates, Inc.

Sponsors
Texas General Land Office, United States Coast Guard, American Petroleum Institute

Background

Bioremediation was not included as a response option for the Galveston Bay Ecological Risk Assessment since bioremediation is considered a final cleanup consideration or "polishing" tool.

The biodegradation process is simply microbial respiration. The end products of this natural process are carbon dioxide and water. Some bioremediation products contain surfactants to break up the oil into tiny droplets, increasing the surface area of the residual oil and thus enhancing the rate of microbial degradation by enhancing interfacial exposure between oil and the microbial community. For bioremediation to be considered, incident-specific and product-specific RRT approvals are required. Given the limitations of bioremediation use, it would not be used widely in any of the defined habitats and was not included in this risk assessment.

When bioremediation appropriate?

Bioremediation is not an appropriate strategy in dealing with heavy oiling. Light to moderate residual oiling in low energy environments are potential candidates for bioremediation. Generally, some form of shoreline cleanup would be required prior to bioremediation. Workshop participants considered the application of bioremediation outside the current risk assessment matrix. That does not suggest that the workshop participants considered bioremediation inappropriate for use in the Galveston Bay.

Efficiency

Biodegradation was demonstrated in Galveston Bay during the Apex Oil spill in 1990, but observations related to effectiveness were mixed. Very little change in oil concentration appeared to be related to the addition of bioremediation agents.
The objective of bioremediation is to accelerate the rate of hydrocarbon (oil) degradation by natural microbial processes to include the addition of nutrients and/or the addition of oil degrading microorganisms. Bioremediation is generally a slow process and is limited by many factors including oil concentration. For bioremediation to be effective, the oil concentration must be below the level which is toxic to the microbial community, as well as below the concentration level which inhibits appreciable biodegradation due to limited interfacial exposure between oil and oil degraders.

This discussion sheet was prepared by Charlie Henry.

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Appendix D

Matrix Linking Resources of Concern to Specific Stressors

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Appendix D. Matrix linking resources of concern to specific stressors via hazards defined by workshop participants.

Habitats:	Shoreline (intertidal)																								
Subhabitats:	**Terrestrial (supratidal)**					**Marsh/Tidal Flat**								**Sand/Gravel Beaches**					**Rip Rap/Man Made**						
RESOURCES:	arthropods	birds	mammals	reptiles/ amphibians	vegetation	birds	crustaceans	fish	infauna	mammals	molluscs	reptiles/ amphibians	vegetation	birds	crustaceans	infauna	mammals	molluscs	algae	birds	crustaceans	infauna	fish	mammals	molluscs
Stressors:																									
Natural Recovery	1	1	1	1	NA	1,4,7	1,2,4,7	2,4,7	2,4,7	1,4,7	2,4,7	1,2,4,7	2,4	1,4,7	1,2,4,7	2,4,7	1,4,7	2,4,7	2,4	1,4,7	1,2,4,7	2,4,7	2,4,7	1,4,7	2,4,7
On-Water Recovery	6	6	6	6	NA	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Shoreline Cleanup	3,4,6	4,6	4,6	4,6	3,4,6	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Oil + Dispersant	NA	NA	NA	NA	NA	4,7	2,7	2,7	2,7	4,7	2,7	2,7	2	4,7	2,7	2,7	7	2,7	2	4,7	2,7	2,7	2,7	7	2,7
ISB	1	1	1	1	1	1,4,5,7	1,4,5,7	5,7	4,5,7	1,4,5,7	4,5,7	1,4,5,7	4,5	1	NA	NA	1	NA	NA	1	NA	NA	NA	1	NA
Shoreline Bioremediation	3	3	3	3	3	3,7	2,3,7	2,3,7	2,3,7	3,7	2,3,7	3,7	2,3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

These hazards represent changes from oil-only scenario.

Note: Bioremediation is not an immediate response, but is a polishing response.

Note: Both Surface water (<3 feet and surface microlayer were not differentiated between nearshore and offshore, but we applied the hazards to them as if they were close to shore in fairly shallow water.

NA: Resource and stressor do not come in contact with each other.

Shading indicates stressor-resource interactions of concern.

Hazards:

1. Air Pollution
2. Aquatic Toxicity
3. Physical Trauma (mechanical impact from equipment, people, boat bottoms, etc.)
4. Oiling/Smothering
5. Thermal (heat exposure from ISB)
6. Waste
7. Indirect (food web, etc.)

Habitats:	Benthic (subtidal)																												
Subhabitats:	**Shallow < 3 feet**						**Open Bay 3-10 feet**						**Channel > 10 feet**				**Reef (not intertidal)**						**SAV**						
RESOURCES:	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	seagrass
Stressors:																													
Natural Recovery	2	1,4,7	2,7	2,7	2,7	2,7	2	1,4,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2	1,4,7	2,7	2,7	2,7	2,7	2	1,4,7	2,7	2,7	2,7	2,7	2,4
On-Water Recovery	3	3	3	3	3	3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3	3	3	3	3	3	3	3	3	3	3	3	3
Shoreline Cleanup	2,3	3,4,7	2,3,7	2,3,7	2,3,7	2,3,7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2,3	3,4,7	2,3,7	2,3,7	2,3,7	2,3,7	2,3,4
Oil + Dispersant	2	4,7	2,7	2,7	2,7	2,7	2	7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2,7	2	4,7	2,7	2,7	2,7	2,7	2	4,7	2,7	2,7	2,7	2,7	2,4
ISB	4,5	1,5,7	5,7	5,7	4,5,7	4,5,7	4	7	7	7	4,7	4,7	7	7	4,7	4,7	4,5	1,5,7	5,7	5,7	4,5,7	4,5,7	4,5	1,5,7	5,7	5,7	4,5,7	4,5,7	4,5
Shoreline Bioremediation	2	7	2,7	2,7	2,7	2,7	2	7	2,7	2,7	2,7	2,7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	7	2,7	2,7	2,7	2,7	2

These hazards represent changes from oil-only scenario.

Note: Bioremediation is not an immediate reponse, but is a polishing response.

Note: Both Surface water (<3 feet and surface microlayer were not differentiated between nearshore and offshore, but we applied the hazards to them as if they were close to shore in fairly shallow water.

NA: Resource and stressor do not come in contact with each other.

Shading indicates stressor-resource interactions of concern.

Hazards:

1. Air Pollution
2. Aquatic Toxicity
3. Physical Trauma (mechanical impact from equipment, people, boat bottoms, etc.)
4. Oiling/Smothering
5. Thermal (heat exposure from ISB)
6. Waste
7. Indirect (food web, etc.)

Habitats:	Water column																				Surface (microlayer)					
Subhabitats:	**Top 3 feet**									**Bottom 3 feet (in depths of 3-10 feet)**						**Bottom 3 feet (in depths > 10 feet)**										
RESOURCES:	algae	birds	crustaceans	fish	jellyfish	mammals	phytoplankton	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	algae	birds	fish	mammals	microlayer associated plankton	reptiles/amphibians
Stressors:																										
Natural Recovery	2	7	2,7	2,7	2,7	7	2	7	2,7	7	2,7	2,7	7	7	2,7	7	2,7	2,7	7	7	2,4	1,4,7	4,7	1,4	2,4	1,4,7
On-Water Recovery	3	3	3	3	3	NA	3	NA	3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Shoreline Cleanup	2	7	2,7	2,7	2,7	7	2	7	2,7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2,4	4,7	4,7	4	2,4	4,7
Oil + Dispersant	2	4,7	2,7	2,7	2,7	4,7	2	4,7	2,7	4,7	2,7	2,7	4,7	4,7	2,7	4,7	2,7	2,7	4,7	4,7	2,4	4,7	4,7	4	2,4	4,7
ISB	2,5	5	2,5	2,5	2,5	5	2,5	5	2,5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	5	1,5	5	1,5	5	1,5
Shoreline Bioremediation	2	7	2,7	2,7	2,7	7	2	7	2,7	7	2,7	2,7	7	7	2,7	NA	NA	NA	NA	NA	2	7	2,7	7	2,7	7

These hazards represent changes from oil-only scenario.

Note: Bioremediation is not an immediate reponse, but is a polishing response.

Note: Both Surface water (<3 feet and surface microlayer were not differentiated between nearshore and offshore, but we applied the hazards to them as if they were close to shore in fairly shallow water.

NA: Resource and stressor do not come in contact with each other.

Shading indicates stressor-resource interactions of concern.

Hazards:

1. Air Pollution
2. Aquatic Toxicity
3. Physical Trauma (mechanical impact from equipment, people, boat bottoms, etc.)
4. Oiling/Smothering
5. Thermal (heat exposure from ISB)
6. Waste
7. Indirect (food web, etc.)

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Appendix E

Workshop Two Meeting Summary

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SECOND WORKSHOP: Preliminary Risk Analysis

1.0 FRAMING THE RISK ANALYSIS PROCESS

1.1 Background

The second Houston/Galveston Bay Area Ecological Risk Assessment (ERA) Workshop convened at the Houston Hobby Hilton Hotel beginning at 1:00 p.m. on June 7, 1999. Participants are listed in Appendix A.

The workshop began with a review of the first workshop report that was distributed to all participants via e-mail or regular mail at the beginning of May. The first workshop generated the conceptual model to be used by participants during this ecological risk assessment. During the first workshop, participants established:

- A realistic and practical scenario.
- Response measures that might be suitable in that scenario.
- Resources of concern in the scenario impact area.
- Spill response related stressors that might impact those resources.
- Exposure pathways (mechanisms by which those stressors might interact with the resources).
- Endpoints of concern (measures of the severity of stressor impacts on resources).

The resulting conceptual model of the environment and matrix of stressor/resource interactions served as the basis for the risk analysis in the second workshop. At the first workshop, a matrix was developed to indicate all environmental stressors potentially present during an oil spill incident and the habitats and individual resources those stressors may impact. Stressors were listed vertically down the side and habitats and example resources across the top of the matrix. Participants filled out the blocks in the matrix with numbers indicating the potential routes of exposure (interaction) between each stressor and each resource (See First Workshop Report for more details.)

The following three points of clarification were sought regarding the first workshop report:

A comment was made regarding whether the 6-hour response time attributed to spill response resources in the Galveston area was realistic. It was suggested that response might take place more quickly in a “spill ready” area like Galveston. Participants at the second workshop decided that the 6-hour response time was reasonable. The logistics of moving large numbers of personnel and equipment make response in less time improbable.

A second comment stated that the first workshop assumption of 100% dispersion was unrealistic because there is no proof from a real spill incident that 100% dispersion is achievable. Second Workshop participants pointed to recent incidents in the Gulf of Mexico where 100% dispersion was achieved. Participants decided that 100% dispersion of the 500-barrel spill is achievable but that the more conservative estimate of 80% dispersion of the 4,000-barrel spill should be used. Participants agreed that assuming a high rate of dispersion was desirable for the purposes of this ERA because it would result in maximum dispersed oil concentrations in the water column, thus maximizing potential adverse effects from the dispersed oil. The assumption of a high dispersion rate for the ERA should not be construed as an endorsement of the efficiency of dispersant use compared to other response options.

Regarding the ISB scenario described in the report, a workshop participant asked why only 100 barrels could be corralled by boom in each burn cycle during the 500-barrel spill while the same boom was estimated to corral 200 barrels in the 4,000-barrel spill. Participants at the second workshop stated that the reason for the difference is that in both spills oil would spread over the same area in the same amount of time. However, it would be eight times more concentrated in the 4,000-barrel spill and therefore more oil could be collected in the boom.

Participants accepted the first workshop report as written without further comment.

1.2 Modeling Results

Charlie Henry summarized the results of the surface oil and subsurface dispersed oil plume models prepared by the National Oceanic and

Atmospheric Administration (NOAA) modelers. A copy of his report can be found as Appendix F. Participants discussed the trajectory development process and details of how the information might be used in the risk assessment. The following are key points regarding the modeling process and results.

1.2.1 Dispersed Oil Plume Trajectory Model

- Instantaneous dispersion of the entire slick was estimated to have occurred at 8 hours into the spill. This conservative estimation maximizes potential concentrations of oil in the water column. In an actual response, dispersion would be more gradual resulting in lower average water column concentrations.
- Given the currents that exist in the area, surface and subsurface plume trajectories indicate that little or no oil would exit the Houston Ship Channel to the Gulf of Mexico.
- The NOAA modeling team assumed that the dispersant plume would be evenly distributed in the water column from the surface to the channel floor due to the shallow water depths in the area.
- The trajectories reflect tidal influences, but currents are the dominant movers of the oil in this environment.
- In these trajectories, oil concentrations are strictly linear. For example, the NOAA report records oil concentrations in parts per billion (ppb) for a 100-barrel spill. To determine concentrations for a 500-barrel spill, multiply the reported ppb by 5, and to convert for a 4,000-barrel spill multiply by 40.
- At any one time in any one spot in the dispersed oil plume, oil concentrations may by higher or lower by a factor of 2 or 3. For example, in the 4,000-barrel spill the initial concentration is estimated to be 38,000 ppb in the plume. Charlie Henry stated during the workshop that in actuality, at any point in that plume, the concentration might be as high as 114,000 ppb or as low as 13,000 ppb. Over time this variation decreases and by hour 48, concentrations are approximately the same throughout the plume.

1.2.2 Smoke Plume Trajectory Model

Smoke plumes for ISB were not modeled, but NOAA estimates that smoke plumes in these scenarios would dissipate entirely within 2-3 miles downwind of the burn site and that the smoke plumes would not impinge on areas of human habitation.

1.2.3 Surface Slick Trajectory Model

During the Workshop, oil slick trajectories were used to indicate percentage of shoreline oiled and relative severity of oiling.

1.3 Risk Ranking Process

1.3.1 Overview

The basic goal of the risk ranking process is to define the relative impacts of the stressors (oil recovery operations) on resources of concern. The first step involves development of a “risk square”, which is a tool used by group members to assess not only the severity of the effect, but also the value of the resource. This requires that the relative impacts of the stressors on resources be commonly defined. This is achieved by examining ecological information and toxicological endpoints, and discussing any issues that group members feel will become important in the scoring process. Finally, participants are divided into groups diverse in expertise and background for the actual scoring process. The stressor/resource interaction matrix developed in Workshop I was used as a template for the scoring matrix. Each group was required to examine individual cells in the matrix and decide which cell of the risk square was the most accurate assessment of that particular stressor’s impact on that particular resource. The end result from each group was compiled in a summary risk-ranking matrix allowing side-by-side comparison of stressor impacts on the environment.

1.3.2 The Risk Square

Don Aurand led a discussion of the development of the risk square. Each axis of the square represents a continuum of parameters used to describe risk. Don described a square, in which the horizontal axis ranges from “reversible” to irreversible,” and the vertical axis ranges from “severe” to “trivial.” In its simplest form, the risk square is divided into four cells. Each cell is assigned an alphanumeric value to represent relative impact. Thus, a “1A” represents an irreversible and severe effect, while a “2B” represents a reversible and trivial effect (Figure 1).

Figure 1. The "risk square".

	1. Irreversible	2. Reversible
A. Severe		
B. Trivial		

Note: The risk square concept and the parameters for both axes are similar to those used in a risk assessment effort in South Florida as reported in Southwest Florida Outer Continental Impact Assessment Task Force Report, which was prepared jointly by Florida and Mineral Management Service in October 1989. A copy of that report was made available to all participants at the workshop for further background reading.

1.3.2 Labeling of Risk Axes

Participants agreed that the risk square concept would serve their purposes in completing this risk assessment. The issue then turned to what labels should be applied to the axes and how many gradations should be used. The suggestion was made that there are three axes of significance to the assessment process – temporal, spatial and functional. The use of a square would require one of these three functions to be subordinated into the other two functions. Some consideration was given to using a three dimensional matrix rather than a square for ranking. However, the use of a cube instead of a square cubes the number of potential outcomes, significantly complicating the process with only marginal benefit. Group consensus was to retain the square with time and function as the two most important aspects. (Spatial concerns can be rolled into function.)

1.3.3 Parameters of Concern

Discussion moved to the appropriate parameters of concern to be represented by the axes. Area of impact (percentage of total resource affected) was suggested for the vertical axis, expressed in percentages of individual resources affected, e.g., 10% resource affect might be considered small or moderate; 60-70% resource affect may be unacceptable. Group consensus was that area should be expressed in four gradations:

- Greater than 60 % of resource affected – high.
- 40 to 60 % of resource affected – moderate/high.
- 10-40 % of resource affected – moderate/low.
- Less than 10 % of resource affected – low.

In working through the matrix, participants agreed that the area affected by the spill could be estimated by the NOAA trajectories discussed above.

For the horizontal axis, recovery, which includes both time and function expressed as lost services, was selected as an appropriate scale. Four gradations were suggested for this scale as well:

- Level 1. An effect that results in changes for periods of greater than 10 years at the community level of organization is likely.
- Level 2. Recovery is probable in 3 to 10 years. A significant interference with ecological relationships is likely. This usually involves mortality or a biological alteration of the population, community, or assemblage.
- Level 3. Recovery is probable within 1 to 3 years. A short-term interference with ecological relationships is likely with a few species sustaining low losses.
- Level 4. Recovery is probable in less than 1 year. Loss of a few individuals is likely but with no interference with ecological relationships.

The proposed risk square for this ERA is shown in Figure 2.

Figure 2. Proposed risk square for risk ranking process.

	> 10 years (1)	3 to 10 years (2)	1 to 3 years (3)	< 1 year (4)
A. High				
B. Med/High				
C. Med/Low				
D. Low				

1.3.4 Estimating Resource Impact

To conclude the risk ranking process discussion, Winston Denton gave an overview of resources in the Galveston Bay area, as reported in Natural Resource Habitat Maps prepared by the Texas General Land Office. Denton brought fisheries maps and made copies of the habitat maps available for participants to use in working through the risk ranking matrices. The maps did not include fisheries data but were useful in determining fish habitat locations. It was determined that in Galveston Bay, fish tend to rely on wetlands and shallow unvegitated areas during juvenile life stages.

2.0 RISK RANKING

2.1 Natural Recovery

Having outlined the risk ranking process, participants were divided into three groups to begin the process. Participants agreed to rank natural recovery in a 500-barrel spill first. This provided a baseline against which the other stressors could be compared, all of which involve some form of response, thereby altering impact on the environment.

Participants were divided into three subgroups as defined in Table 1.

Table 1. Subgroups for risk ranking process.

Group 1	Group 2	Group 3
James *(coordinator)*	Fritz *(coordinator)*	Clark *(coordinator)*
Stong	Ponthier	Kuhn
Henry	Cain	Acker
Caplis	Thumm	Staves
Denton	Buzan	Barker
Ormond	O'Brien	Martin
Williams	Tirpak	Rice
Grimes	Sipocz	Drummond
	Hamm	Nichols

Note: Sub-groups were arranged so that each had at least two industry, two federal, and two state representatives. Stong was unable to participate in the workshop. Kuhn participated on Day 1 only; Drummond and Sipocz participated on Days 2 and 3 only; Henry, Thumm and Cain departed at 11 a.m. on Day 3. All others were present for the entire workshop. (Grimes, Hamm, and Nichols were not able to attend Workshop II).

Participants spent the remainder of the first day working through the natural recovery risk ranking. Results for each workgroup are included in Appendix H. Note that each workgroup scored individual resources first and then derived consolidated sub-habitat scores.

2.2 Ranking Scheme Adjustments

On Day 2, the morning session began with discussion regarding lessons learned from using the risk square to rank natural recovery for a 500-barrel spill. Participants stated that they needed more detailed information on oil volume over time, as it is reduced by weathering and by the application of individual clean-up techniques. This concern was addressed by the development of several "oil budgets" using the data in the NOAA trajectory analysis and various NOAA electronic databases. Charlie Henry, Steve Thumm, and Bob Pond constructed a separate budget for each of the four major response options under consideration. The budget for the 500-barrel spill assumed 100% dispersion. For the 4,000-barrel spill, two dispersion budgets were prepared, one assuming 100% dispersion and the other 80% (Appendix G).

Participants debated dispersant effectiveness and determined that while 100% dispersion is feasible for a 500 barrels spill, it is unlikely at 4,000 barrels even under optimum conditions. Participants opted to use the 80% dispersion budget during the assessment.

While the oil budgets were being developed the other participants discussed the scoring process itself, generating comments such as the following:

- The rate at which recovery would occur (the vertical axis in the square) was relatively easy to complete.
- The resource affect estimation was much more difficult because of the difficulty in determining "percentages" of resources affected.

Percentage of resource affected is a function of the size of the area under consideration. If the area is all of Galveston Bay, percent affected for a given resource is likely to be very small for these scenarios. If the area were limited to the area of the spill in the given scenario then the percent affected would be very high. This discussion led to a revision in the vertical axis of the risk square based on the projected magnitude of impact on the community as a whole, as follows:

- High (community change).
- Medium/high.
- Medium/low.
- Low (loss of a few individuals).

Participants further agreed that issues to be considered in establishing magnitude of impact should include the following:

- Presence of a value resource (e.g., threatened or endangered species) in the spill trajectory area.
- Percent of the resource affected locally (in the spill trajectory area).
- Percent of the resource affected in the Bay.
- Type and level of effect (e.g., death, reproductive impairment, etc.).
- Oil type, condition (weathering), quantity, and its distribution/coverage.

Participants also adjusted the horizontal axis of the square based on the concept that 10 years was too long a time frame to consider in establishing significance of affects. Therefore, they opted to label the horizontal axis as follows:

- Recovery is probable in greater than 6 years (long term).
- Recovery is probable in 3 to 6 years (medium).
- Recovery is probable in 1 to 3 years (short term).
- Recovery is probable in less than 1 year (rapid).

Thus the final risk square used in risk ranking all habitats is depicted in Figure 3.

During this session participants also agreed that "Sandy Beaches" should be changed in all workshop 2 matrices to read "Sand/Gravel Beaches" (to be consistent with TGLO EIS classification).

Figure 3. Finalized "risk square".

	> 6 years (1)	**3 to 6 years (2)**	**1 to 3 years (3)**	**< 1 year (4)**
A. High	**A1**	**A2**	**A3**	**A4**
B. Med/High	**B1**	**B2**	**B3**	**B4**
C. Med/Low	**C1**	**C2**	**C3**	**C4**
D. Low	**D1**	**D2**	**D3**	**D4**

3.0 COMPLETING THE RISK ASSESSMENT MATRICES

The remainder of Day 2 and most of Day 3 was devoted to working through the risk assessment matrices for each of the response options. Prior to starting work on a matrix, the three workgroups met in plenary to discuss any special consideration related to the response options. The workgroups would then work through each matrix, completing both individual resource scores and sub-habitat scores for each response option and spill size. Facilitators collected the matrices from each group and developed a master matrix, showing group scores by resource and sub-habitat for each response option and spill size (Appendix I and J). Note that the natural recovery matrix was rescored to reflect the new parameters used in the risk square.

Key discussion points related to various response options are summarized below.

Participants agreed that no blocks in the matrix should be filled in using NA (meaning there is no connection between the stressor and the habitat). The participants scored each matrix in comparison to the baseline natural recovery matrix. In other words, even if there is no direct resource impact with a given response option, there still may be an indirect net benefit.

3.1 Shoreline Cleanup

When considering shoreline cleanup, more precise definitions of various shoreline response procedures were discussed:

- Marsh/tidal flat – protective booming, low pressure washing, clipping, sorbents and manual pick-up on fringes (all activities take place only on the fringes), Invasive technologies are not going to be used typically, largely natural recovery. (ISB accounted separately)
- Gravel/Sand Beach (course sand beach including gravel, gravel sized shells.) – protective booming, mechanical/manual pick-up (people with buckets, shovels, front–end loader), low/high pressure washing, sediment removal, and berm relocation.
- Riprap/Man-made – protective booming, low/high pressure washing, consider use of cleaners, and sorbents.

3.1.1 Protective Booming

Participants agreed that protective booming effectiveness for these wide-ranging shorelines is difficult to estimate since there are no standard planning numbers for it. It will not be included in the shoreline cleanup option. The group felt it was better addressed in a separate evaluation of ecological risks from protective booming (Appendix C).

3.2 Dispersant Application

Jim Clark presented an overview of effect information, providing a framework for estimating resource impacts of exposure to dispersed oil. Citing a variety of source data, he offered an exposure effects template for consideration by the group in risk ranking of dispersant use (Table 2).

Several overheads were pieced together using the NOAA trajectory data (Appendix F) to show dispersant plume locations and approximate in-water concentrations during the first 48 hours after dispersant application.

Concentrations for the 500-barrel spill scenario were reported as follows:

Hour 1 concentration – 6 ppm
Hour 6 concentration – 4 ppm
Hour 24 concentration – 1 ppm
Hour 48 concentration – .3 ppm

For the 4,000-barrel spill, concentrations were as follows:

Hour 1 concentration – 39 ppm
Hour 6 concentration – 24 ppm
Hour 24 concentration – 5 ppm
Hour 48 concentration – 2 ppm

The following points were agreed upon as a result of consideration of dispersant use:

- Birds are in danger of diving through oil at the surface as well as through the dispersed oil plume. This would result in not only oiling of birds, but also in the removal of natural plumage oils and the consequent loss of buoyancy. Participants agreed that birds are endangered during the first four hours after dispersion, after which time the plume will have diluted and moved out of the area.
- Background concentrations of oil in Galveston Bay are in the range of 3 to 4 ppm.

Table 2. Overview of effect information.

Level of Exposure	Level of Concern	Sensitive Life Stages	Adult Fish	Adult Crustacea/ inverte-brates
0-3 hours	Low	1	10	5
	Med-Low	1-5	10-50	5-10
	Med-High	5-10	50-100	10-50
	High	10	100	50
24 hours	Low	.5	.5	.5
	High	5	10	5
96 hours	High	.5	.5	.5

Notes: All numbers are in parts per million (ppm). (The numbers provided in the NOAA Trajectory report are in parts per billion.) Values are intended to indicate threshold levels of concern for resources. For example, if adult fish are exposed to a dispersed oil plume of 100 ppm for 3 hours, concern should be high. If they are exposed to a 10 ppm plume for 3 hours, concern should be low because there is little or no potential for acute effects. These ranges were also used in the ecological risk assessment process currently underway in Washington.

- In the 18 to 36 hour timeframe, the 4,000-barrel spill generated concentrations at fixed reference points that exceeded levels expected to cause a resource effect. In the 500-barrel spill scenario, exposure to dispersed oil is reduced to 5 ppm at hour 24, and less than 0.3 ppm by hour 48, so that no acute effects from dispersed oil were expected. This is ecologically relevant when considering exposure of planktonic organisms that would move with the plume and be exposed for a longer duration versus benthic organisms that would be exposed only as long as the plume passes over the area.

3.3 ISB

When considering ISB, participants agreed to limit consideration to on-water *in situ* burn operations only. The following points were raised:

- Shoreline ISB would not be used given the spill location and oil type. If ISB were used in these scenarios, there would be no mechanical recovery because the two operations would interfere with one another in the confined waters of the Channel.
- After the first half mile the smoke plume generated by the burn will rise well above the surface and will not affect human health.
- Given the anticipated trajectory and elevation of the smoke plume, participants assumed that an ISB operation in this scenario would not adversely impact air quality or compliance with air quality standards for the Houston/Galveston area.
- Principal concern from ISB in these scenarios would be public perception of harm due to the appearance of the heavy black smoke plume. Even this concern would be minimal because the plume would likely dissipate more than three miles from shore and should never be visible from land.
- The biggest ecological concern is the potential for impacting submerged oysters reefs in the vicinity.
- In the given scenarios, burn residues will not sink because of oil type.
- Heat generated by the fire does not have a significant impact on resources in the water column underneath the burn. There is sufficient heat transfer in a large volume of water that heat generated in a burn only heats the first inch or so of the water column. While the fire might incinerate most of the organisms in the surface microlayer, it is likely that all of these organisms were already dead from contact with the oil.

4.0 WORKSHOP WRAP-UP

Workgroups completed all preliminary matrices, which were consequently put into summary form (Appendices I and J).

The final task of the second workshop was categorizing the risk square into sections of relative magnitude (Figure 4). This provided a method of grouping stressor effects in terms of a “high”, “medium”, or “low” effect on the resource, based on the alphanumeric codes described earlier. The resulting matrices provided an instant visual summary of relative effects. Levels of magnitude were not given formal definitions.

Figure 4. Levels of concern within the finalized risk square.

	> 6 years (1)	3-6 years (2)	1-3 years (3)	< 1 year (4)
High (A)	1A	2A	3A	4A
Moderate/High (B)	1B	2B	3B	4B
Moderate/Low (C)	1C	2C	3C	4C
Low (D)	x 1D	2D	3D	4D

Legend: Cells shaded red represent a “high” level of concern, cells shaded yellow represent a “medium” level of concern, and cells shaded green represent a “low” level of concern. (If viewing the table in black and white, red, yellow, and green corresponds to dark gray, light gray, and medium gray, respectively.)

The third workshop will begin with reconciliation of individual workgroup matrices into a single summary matrix for each spill size. These summary matrices will represent participant consensus on the relative environmental impacts of each response option. Where consensus can not be reached, outstanding issues must be identified so that they can be presented to the risk managers. Risk assessors will also be asked to complete definitions/ descriptions of each sub-habitat. The workshop will conclude with a presentation of the risk assessor results to the risk managers and a discussion of the application of the results in future planning and response activities.

Activities between now and the next workshop:

- All participants should review this report and the matrices generated from Workshop 2. Participants are invited to e-mail concerns now and to come to the third workshop prepared to discuss unresolved issues.
- If time permits, group spokespersons (Bela James, Dave Fritz, and Jim Clark will convene via conference call with the project team to resolve as many differences between group scores as possible prior to the third workshop.
- Protective booming: Jim Clark, Chris Ponthier, and Buzz Martin will describe protective booming at the next workshop. Protective booming was considered an adjunct response procedure necessary regardless of whether ISB, dispersants, on-water recovery, or shoreline cleanup was the primary response options. Therefore, participants elected to address the impacts of protective booming in narrative form, describing its uses, and potential impacts in all situations (Evaluation of protective booming included in Appendix C).
- Bioremediation: Charlie Henry, Jim Staves, and Bea Stong will produce a narrative description of the use and potential impacts of bioremediation for distribution and discussion at the next workshop. Bioremediation is not considered an immediate response option (and is therefore not in the matrix), but needs to be addressed and will require a more detailed write-up.

The third workshop will take place on July 26-28 at ARAMCO Services in Houston, Texas, starting at 8:00 a.m. each day. Details on lodging and specific agenda for the workshop will be forwarded by separate e-mail.

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Appendix F

Complete National Oceanographic and Atmospheric Administration (NOAA) Modeling Report

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Appendix F. NOAA modeling report (courtesy of Charlie Henry).

Correspondence

6 June, 1999

To: Transport Evaluation Team

From: Charlie Henry
NOAA SSC

Re.: Estimated Dispersed Oil Transport and Exposure Concentrations

The NOAA Oceanographers/Modelers have provided me a CD full of surface oil and dispersed plume trajectory data. Trajectory maps, which illustrate these data, are attached. The results are essentially two dimensional, but considering the shallow water depths present in the lower Galveston Bay, this should cause no significant problem for our evaluation of dispersed oil transport and exposure. For our scenario, the dispersed plume follows the surface oil since the currents in Lower Galveston Bay are essentially wind driven. Very little dispersed oil (the model predicts none) is lost through the pass due, in part, to flood/slack tide conditions. The model assumes that all of the oil was dispersed at a single point in time. I was given the choice of when this occurred. I used the median time value of 8 hours after the spill (4 hours after we began the dispersant operations which were to last approximately 8 hours). The model assumed 100% effectiveness, I modified the results to fit the effectiveness predicted in our scenario. The model did allow for some evaporation (25%).

Table 1 is the estimated or predicted dispersed oil concentrations for the dispersed oil plume as it moves in Lower Galveston Bay; the values do not reflect exposure at a single point. The data in Table 1 would be valid to evaluate the exposure of small animals such as zooplankton which might be transported by normal bay circulation patterns. To evaluate single point exposure four locations were chosen (Figure 1). An exposure profile was generated for each (Table 2 and Figure 2). A single fixed point might be representative of bivalves on a small shell reef. Have a great day...

Table 1. Estimated Dispersed Oil Concentrations.

D+ (hrs)	A (Km sq.)	Depth (m)	Vol. (Km cu.)	Concentration (ppb) 100 bbl (1)	500 bbl (2)	3072 bbl (3)
1	9.6	1.0	0.023	1,255	6,277	38,563
2	10.6	1.0	0.032	1,148	5,741	35,273
3	11.9	1.0	0.036	1,019	5,094	31,298
4	13.7	1.0	0.041	886	4,431	27,221
5	14.2	1.0	0.043	851	4,257	26,152
6	15.7	1.0	0.047	773	3,865	23,747
12	18.2	1.7	0.091	398	1,990	12,227
18	23.4	2.3	0.164	221	1,105	6,789
24	37.1	2.3	0.260	139	695	4,270
36	51.6	3.0	0.464	78	390	2,396
48	73.0	3.0	0.657	55	275	1,690
72(4)	nd	nd	nd	7	33	203
96(4)	nd	nd	nd	1	6	37

(1) Dispersed oil concentration for 100 bbls scenario (complete dispersion).
(2) Dispersed oil concentration for 500 bbls scenario (complete dispersion).
(3) Dispersed oil concentration for 4000 bbls scenario (incomplete dispersion).
(4) Extropolated concentration values for 72 and 96 hours.

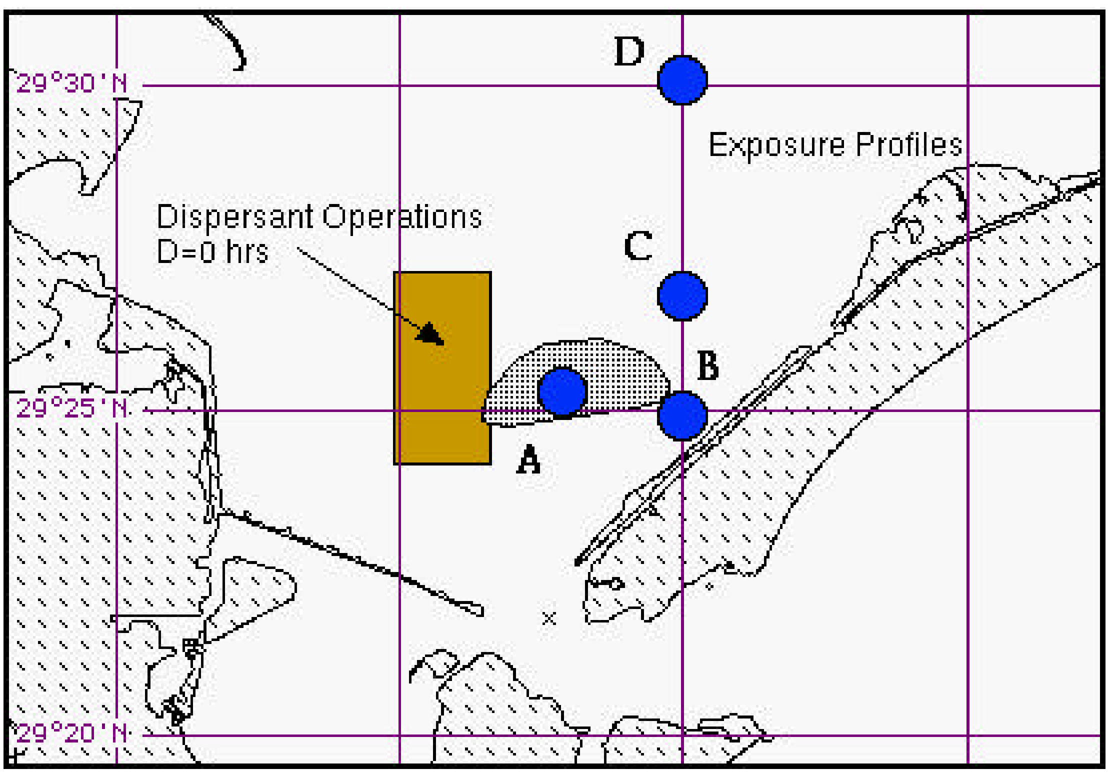


Figure 1. **Location of sites selected for general exposure profile analysis.**

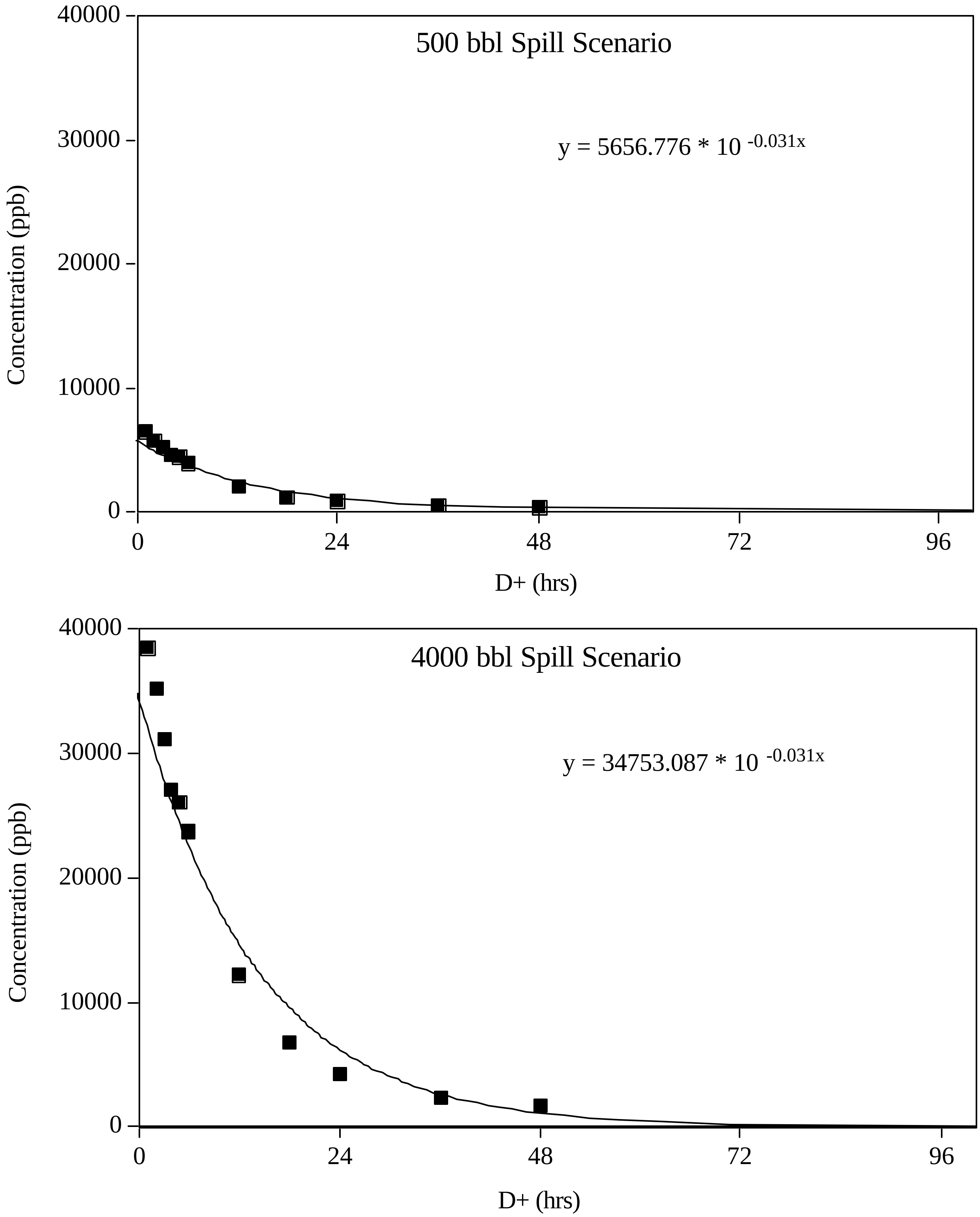


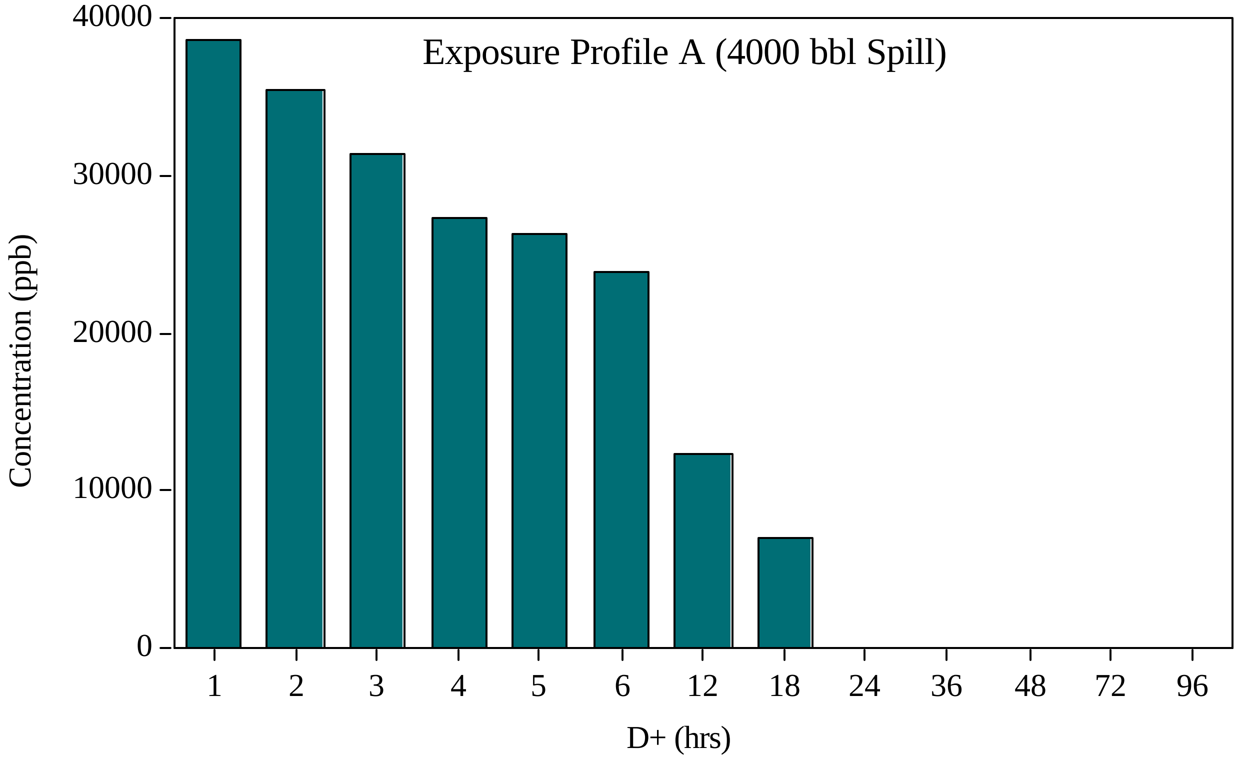
Figure 2. **Change in dispersed oil concentration as a function of time for both the 500 bbl (top) and 4000 bbl (bottom) scenarios.**

Table 2. Estimated Dispersed Oil Concentrations at Selected Sites.

500 bbl Spill Scenario:			Concentration (ppb)		
D+ (hrs)	Plume	Site A (1)	Site B	Site C	Site D
1	6,277	6,277	0	0	0
2	5,741	5,741	0	0	0
3	5,094	5,094	0	0	0
4	4,431	4,431	0	0	0
5	4,257	4,257	0	0	0
6	3,865	3,865	0	0	0
12	1,990	1,990	0	0	0
18	1,105	1,105	0	1,105	0
24	695	0	0	695	0
36	390	0	0	390	0
48	275	0	0	275	275
72	33	0	0	33	33
96	6	0	0	6	6

4000 bbl Spill Scenario:			Concentration (ppb)		
D+ (hrs)	Plume	Site A	Site B	Site C	Site D
1	38,563	38,563	0	0	0
2	35,273	35,273	0	0	0
3	31,298	31,298	0	0	0
4	27,221	27,221	0	0	0
5	26,152	26,152	0	0	0
6	23,747	23,747	0	0	0
12	12,227	12,227	0	0	0
18	6,789	6,789	0	6,789	0
24	4,270	0	0	4,270	0
36	2,396	0	0	2,396	0
48	1,690	0	0	1,690	1,690
72	203	0	0	203	203
96	37	0	0	37	37

(1) See Figure 2 for site locations.



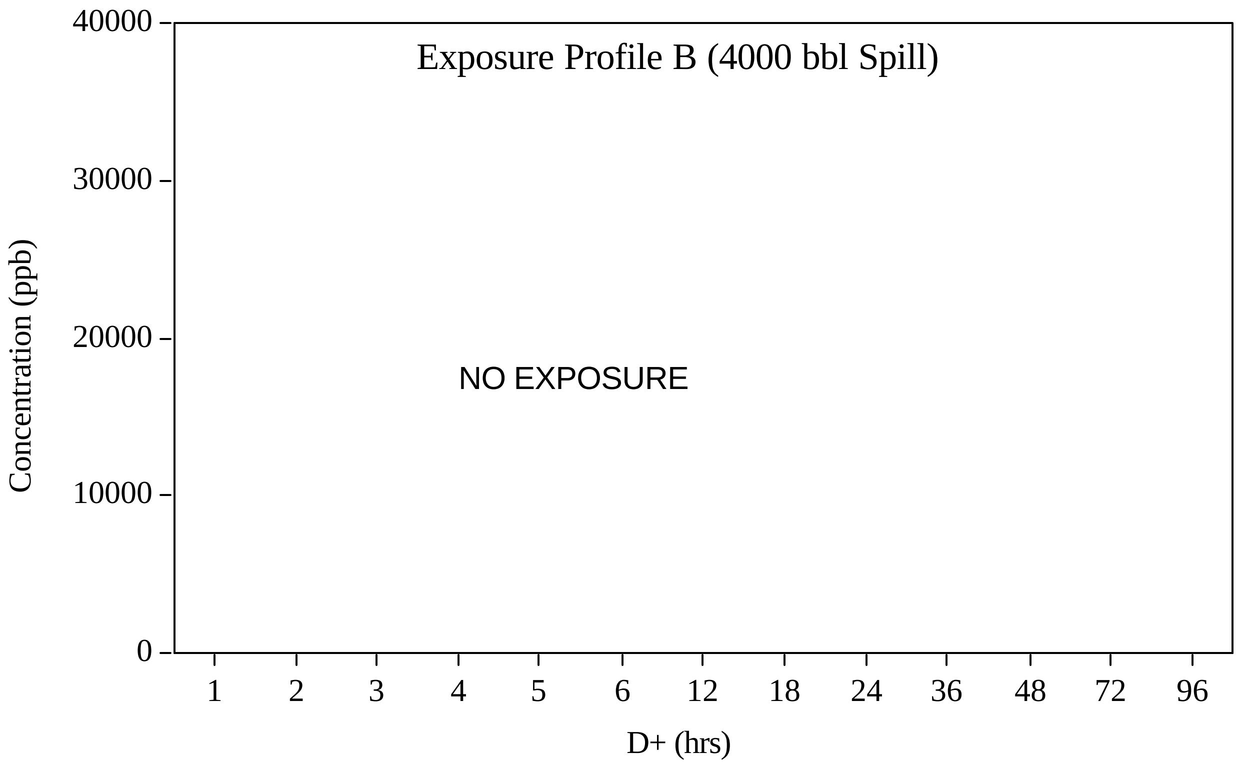


Figure 3. **Exposure profile for 4,000 bbl scenario at Site A and B. Note, no dispersed oil is predicted by the model to impact in Site B.**

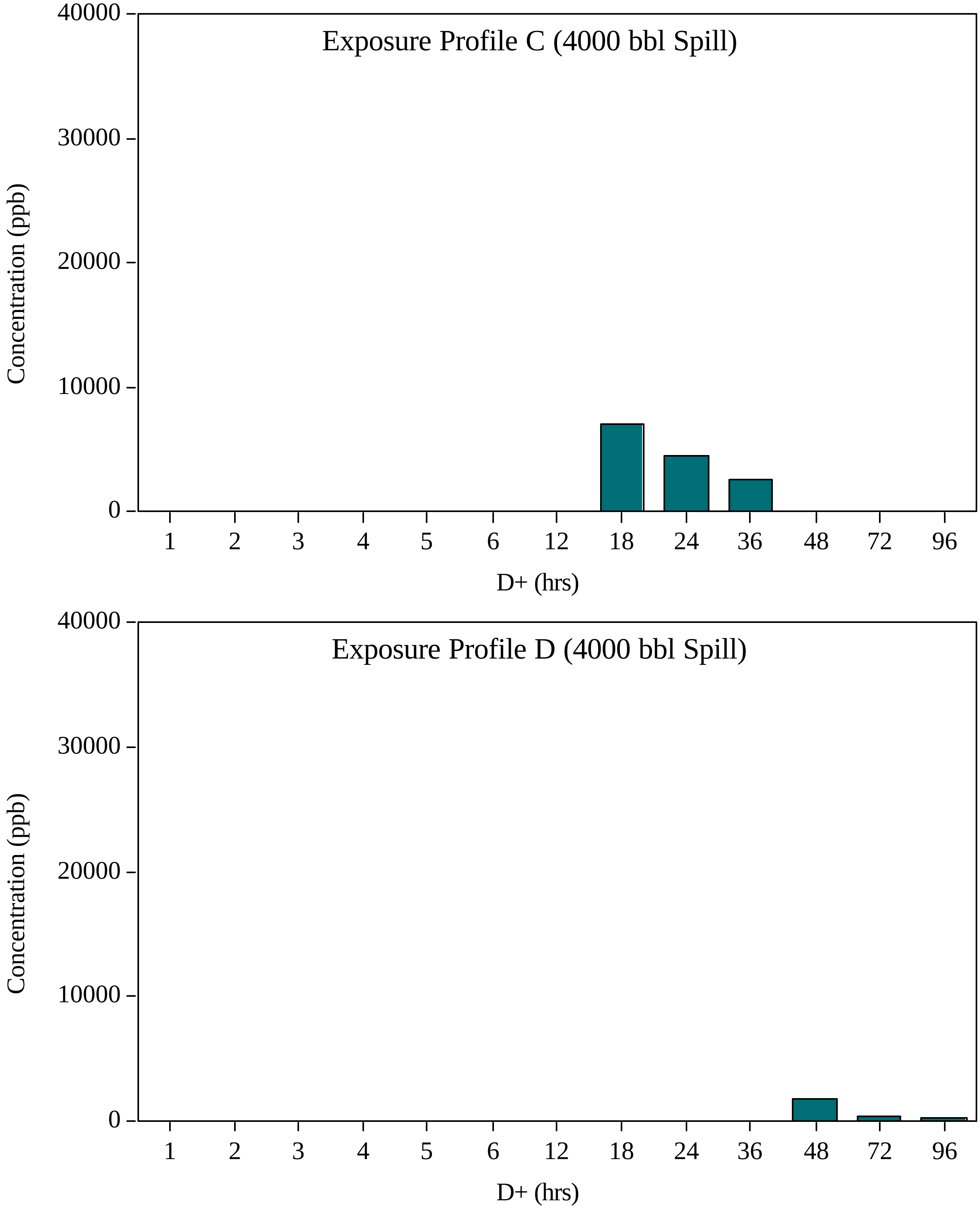
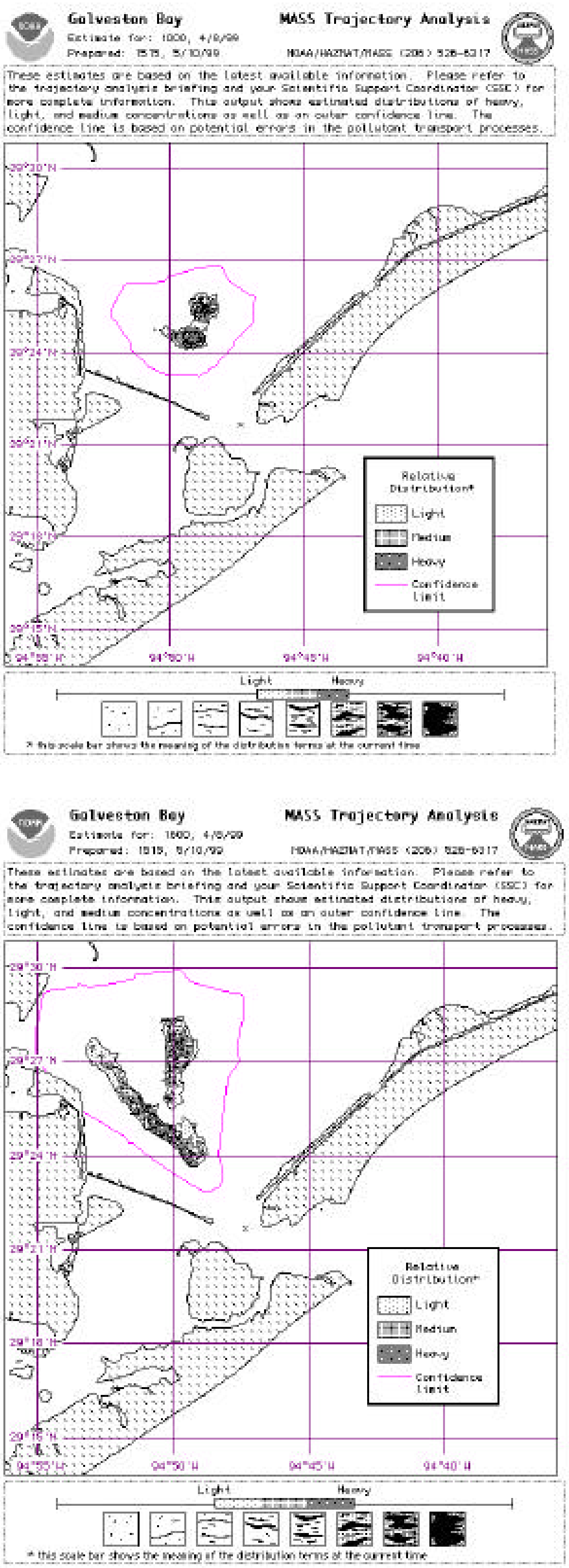
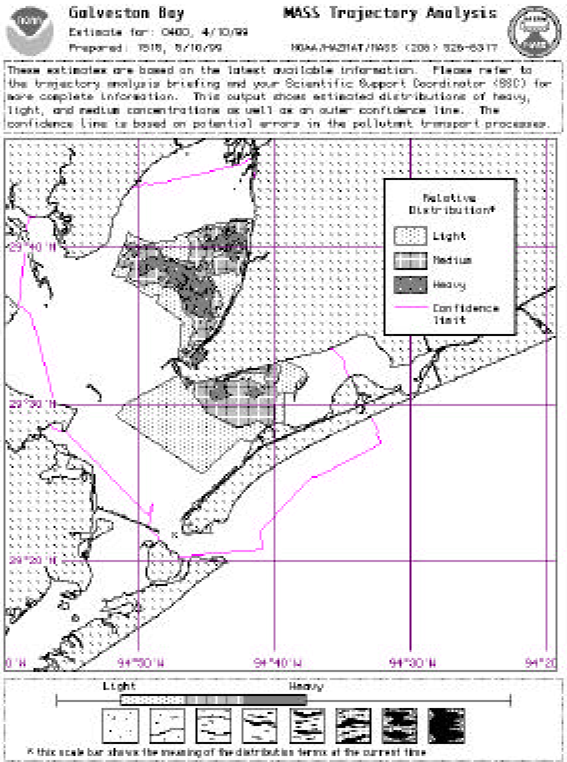


Figure 3. Exposure profile for 4000 bbl scenario at Site C and D.

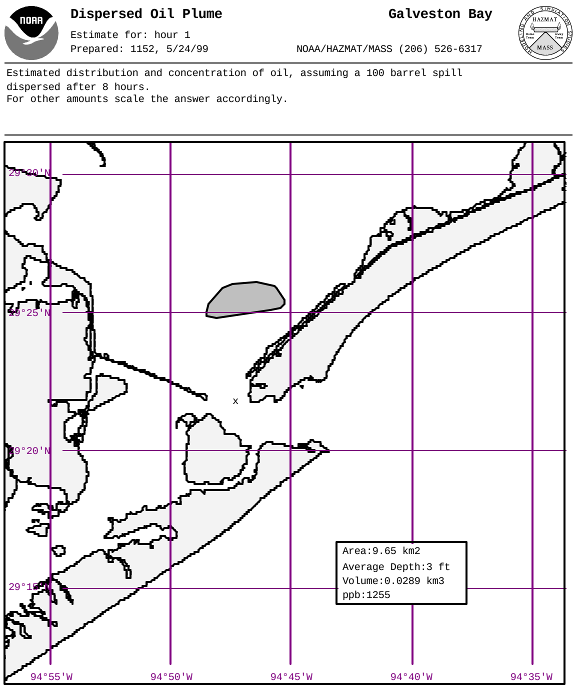
Appendix F-1. Surface Oil Slick Trajectory.

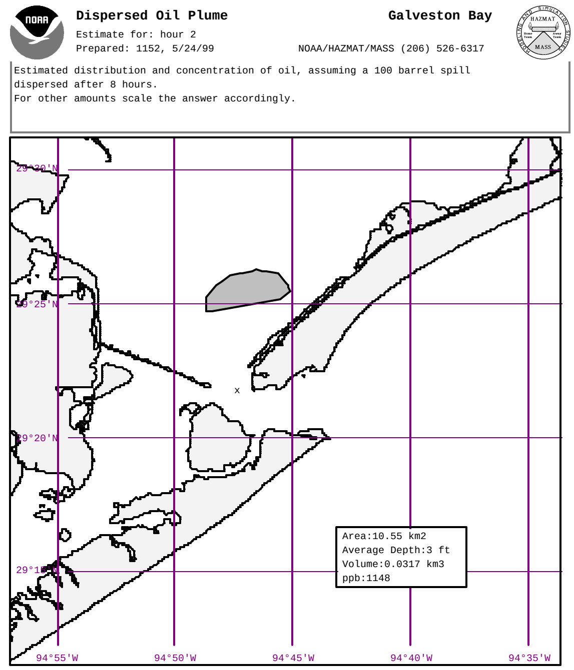


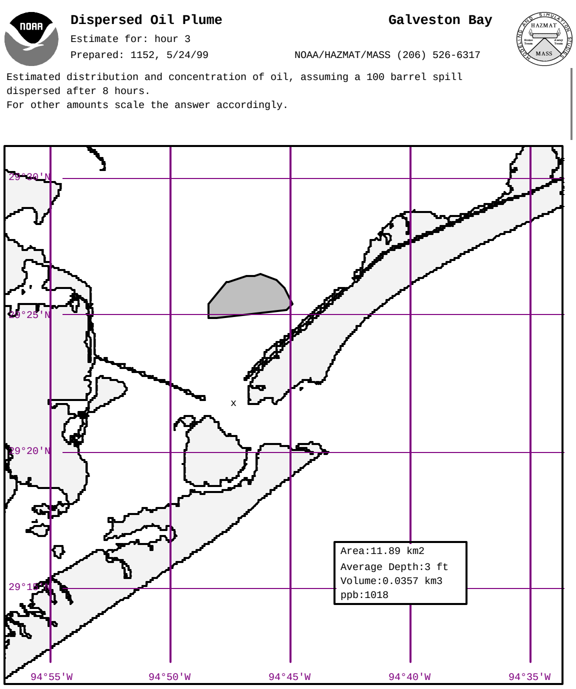
Appendix F-1. Surface Oil Slick Trajectory (Continued).

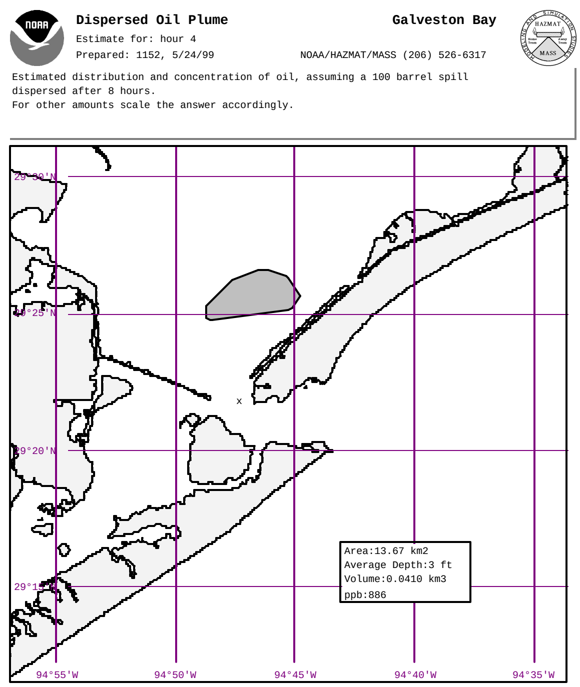


Appendix F-2. Dispersed Oil Plume Trajectory.

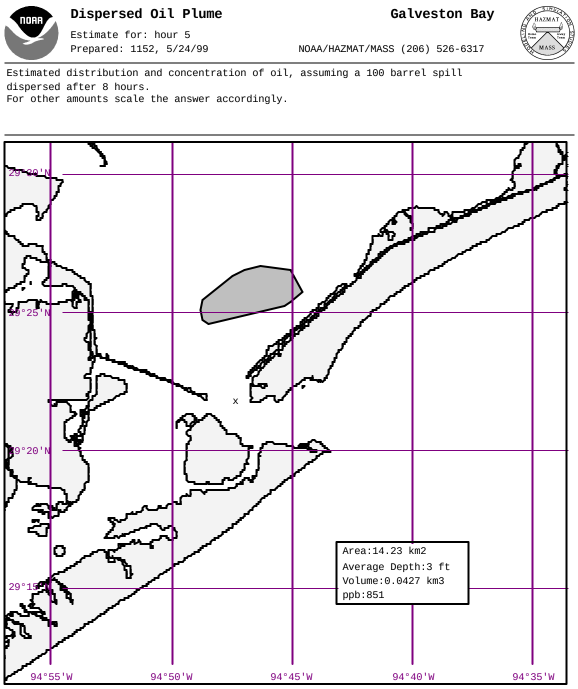


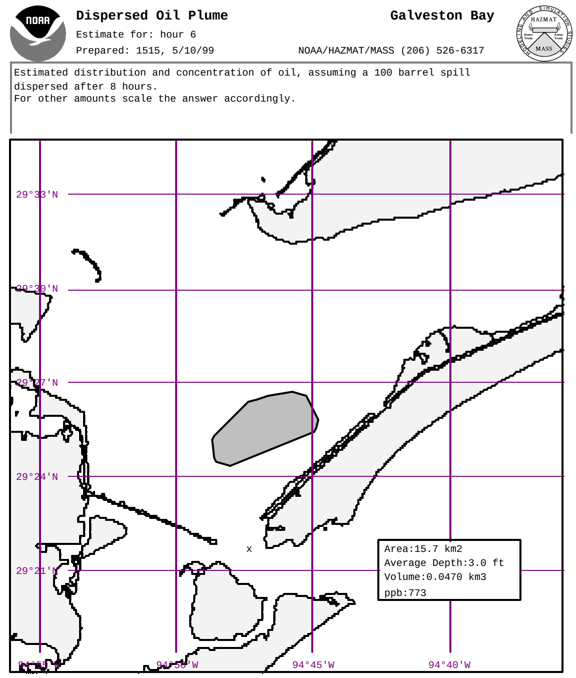


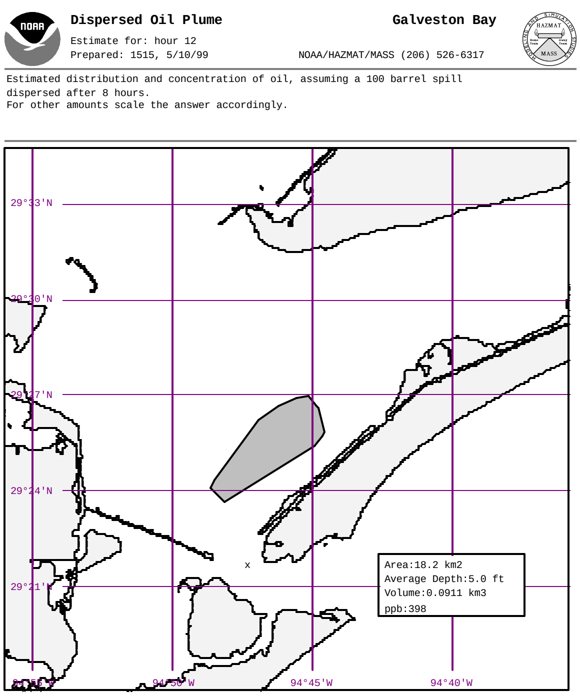


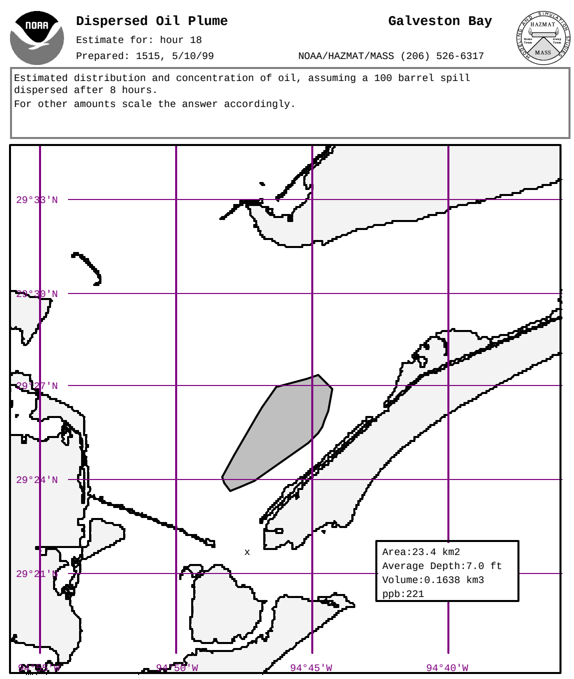


Appendix F-2. Dispersed Oil Plume Trajectory (Continued).

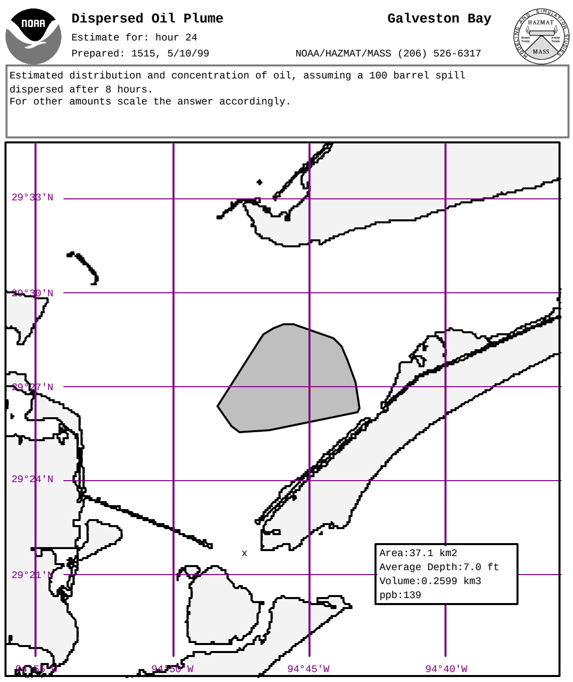


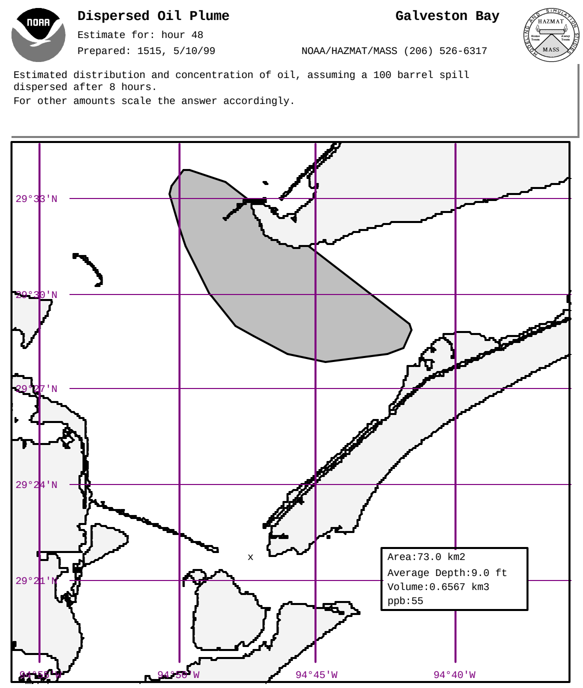






Appendix F-2. Dispersed Oil Plume Trajectory (Continued).





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Appendix G

Oil Budgets for 500 and 4,000 bbl Spill Scenarios

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Appendix G-1. Oil budgets for the 500 bbl spill scenario.

500 bbl Scenario: No Response								
Time:	0	6	12	24	36	48	72	96
Floating Oil	500	370	350	320	270	210	140	0
Floating Oil Emulsion	500	530	590	1300	1100	840	570	0
Evaporated	0	130	140	160	170	180	190	190
Dispersed (Natural)	0	3	4	5	5	6	6	6
Mech. Recovered (Oil)	0	0	0	0	0	0	0	0
Dispersed (Chemical)	0	0	0	0	0	0	0	0
In-Situ Burned	0	0	0	0	0	0	0	0
Stranded	0	0	0	18	49	100	170	300
Stranded Oil Emulsion	0	0	0	70	200	420	670	1200
Water-In-Oil	0	160	240	1000	1000	940	920	920
Emulsion Factor	0.00	0.30	0.40	0.75	0.75	0.75	0.75	0.75
% Evaporation	0.00	0.25	0.05	0.05	0.04	0.03	0.03	0.02
% Dispersion	0.000	0.006	0.003	0.002	0.002	0.002	0.001	0.001
% Stranding	0.000	0.000	0.000	0.050	0.100	0.200	0.300	0.350

500 bbl Scenario: Mechanical Recovery								
Time:	0	6	12	24	36	48	72	96
Floating Oil	500	370	160	150	130	98	66	0
Floating Oil Emulsion	500	530	270	590	510	390	260	0
Evaporated	0	130	140	150	160	160	160	160
Dispersed (Natural)	0	3	4	4	5	5	5	5
Mech. Recovered (Oil)	0	0	190	190	190	190	190	190
Dispersed (Chemical)	0	0	0	0	0	0	0	0
In-Situ Burned	0	0	0	0	0	0	0	0
Stranded	0	0	0	8	23	48	78	140
Stranded Oil Emulsion	0	0	0	33	92	190	310	570
Water-In-Oil	0	160	110	470	450	440	430	430
Emulsion Factor	0.00	0.30	0.40	0.75	0.75	0.75	0.75	0.75
% Evaporation	0.00	0.25	0.05	0.05	0.04	0.03	0.03	0.02
% Dispersion	0.000	0.006	0.003	0.002	0.002	0.002	0.001	0.001
% Stranding	0.000	0.000	0.000	0.050	0.100	0.200	0.300	0.350

Appendix G-1. Oil budgets for the 500 bbl spill scenario (Continued).

500 bbl Scenario: Dispersant Application								
Time:	0	6	12	24	36	48	72	96
Floating Oil	500	370	0	0	0	0	0	0
Floating Oil Emulsion	500	530	0	0	0	0	0	0
Evaporated	0	130	140	140	140	140	140	140
Dispersed (Natural)	0	3	4	4	4	4	4	4
Mech. Recovered (Oil)	0	0	0	0	0	0	0	0
Dispersed (Chemical)	0	0	350	350	350	350	350	350
In-Situ Burned	0	0	0	0	0	0	0	0
Stranded	0	0	0	0	0	0	0	0
Stranded Oil Emulsion	0	0	0	0	0	0	0	0
Water-In-Oil	0	160	0	0	0	0	0	0
Emulsion Factor	0.00	0.30	0.40	0.75	0.75	0.75	0.75	0.75
% Evaporation	0.00	0.25	0.05	0.05	0.04	0.03	0.03	0.02
% Dispersion	0.000	0.006	0.003	0.002	0.002	0.002	0.001	0.001
% Stranding	0.000	0.000	0.000	0.050	0.100	0.200	0.300	0.350

500 bbl Scenario: *In-Situ* Burn Application								
Time:	0	6	12	24	36	48	72	96
Floating Oil	500	370	150	140	120	91	61	0
Floating Oil Emulsion	500	530	250	550	470	360	240	0
Evaporated	0	130	140	150	160	160	160	160
Dispersed (Natural)	0	3	4	4	5	5	5	5
Mech. Recovered (Oil)	0	0	0	0	0	0	0	0
Dispersed (Chemical)	0	0	0	0	0	0	0	0
In-Situ Burned	0	0	200	200	200	200	200	200
Stranded	0	0	0	8	21	45	72	130
Stranded Oil Emulsion	0	0	0	30	85	180	290	530
Water-In-Oil	0	160	100	430	420	410	400	400
Emulsion Factor	0.00	0.30	0.40	0.75	0.75	0.75	0.75	0.75
% Evaporation	0.00	0.25	0.05	0.05	0.04	0.03	0.03	0.02
% Dispersion	0.000	0.006	0.003	0.002	0.002	0.002	0.001	0.001
% Stranding	0.000	0.000	0.000	0.050	0.100	0.200	0.300	0.350

Appendix G-2. Oil budget for the 4,000 bbl spill scenario, assuming 80% dispersion.

4000 bbl Scenario: No Response								
Time:	0	6	12	24	36	48	72	96
Floating Oil	4000	3000	2800	2600	2200	1700	1100	0
Floating Oil Emulsion	4000	4300	4700	10000	8700	6700	4500	0
Evaporated	0	1000	1150	1300	1400	1400	1500	1500
Dispersed (Natural)	0	24	33	39	44	48	50	51
Mech. Recovered (Oil)	0	0	0	0	0	0	0	0
Dispersed (Chemical)	0	0	0	0	0	0	0	0
In-Situ Burned	0	0	0	0	0	0	0	0
Stranded	0	0	0	140	400	830	1300	2400
Stranded Oil Emulsion	0	0	0	560	1600	3300	5300	10000
Water-In-Oil	0	1300	1900	8000	7700	7500	7400	7300
Emulsion Factor	0.00	0.30	0.40	0.75	0.75	0.75	0.75	0.75
% Evaporation	0.00	0.25	0.05	0.05	0.04	0.03	0.03	0.02
% Dispersion (natural)	0.000	0.006	0.003	0.002	0.002	0.002	0.001	0.001
% Stranding	0.000	0.000	0.000	0.050	0.100	0.200	0.300	0.350

4000 bbl Scenario: Mechanical Recovery								
Time:	0	6	12	24	36	48	72	96
Floating Oil	4000	3000	2400	1900	1100	870	590	0
Floating Oil Emulsion	4000	4300	4000	7600	4500	3400	2300	0
Evaporated	0	1000	1100	1300	1300	1400	1400	1400
Dispersed (Natural)	0	24	33	38	42	44	45	45
Mech. Recovered (Oil)	0	0	400	680	1200	1200	1200	1200
Dispersed (Chemical)	0	0	0	0	0	0	0	0
In-Situ Burned	0	0	0	0	0	0	0	0
Stranded	0	0	0	120	310	540	800	1400
Stranded Oil Emulsion	0	0	0	480	1200	2100	3200	5500
Water-In-Oil	0	1300	1600	6000	4300	4200	4100	4100
Emulsion Factor	0.00	0.30	0.40	0.75	0.75	0.75	0.75	0.75
% Evaporation	0.00	0.25	0.05	0.05	0.04	0.03	0.03	0.02
% Dispersion (natural)	0.000	0.006	0.003	0.002	0.002	0.002	0.001	0.001
% Stranding	0.000	0.000	0.000	0.050	0.100	0.200	0.300	0.350

Appendix G-2. Oil budget for the 4,000 bbl spill scenario, assuming 80% dispersion.

4000 bbl Scenario: Dispersant Application								
Time:	0	6	12	24	36	48	72	96
Floating Oil	4000	3000	560	500	440	340	230	0
Floating Oil Emulsion	4000	4300	940	2000	1700	1300	900	0
Evaporated	0	1000	1100	1200	1200	1200	1200	1200
Dispersed (Natural)	0	24	33	34	35	36	36	37
Mech. Recovered (Oil)	0	0	0	0	0	0	0	0
Dispersed (Chemical)	0	0	2300	2300	2300	2300	2300	2300
In-Situ Burned	0	0	0	0	0	0	0	0
Stranded	0	0	0	28	80	170	270	490
Stranded Oil Emulsion	0	0	0	113	315	665	1068	1952
Water-In-Oil	0	1300	380	1600	1500	1500	1500	1500
Emulsion Factor	0.00	0.30	0.40	0.75	0.75	0.75	0.75	0.75
% Evaporation	0.00	0.25	0.05	0.05	0.04	0.03	0.03	0.02
% Dispersion (natural)	0.000	0.006	0.003	0.002	0.002	0.002	0.001	0.001
% Stranding	0.000	0.000	0.000	0.050	0.100	0.200	0.300	0.350

4000 bbl Scenario: *In-Situ* Burn Application								
Time:	0	6	12	24	36	48	72	96
Floating Oil	4000	3000	2000	1800	1600	1200	810	0
Floating Oil Emulsion	4000	4300	3400	7300	6300	4800	3200	0
Evaporated	0	1000	1100	1300	1300	1400	1400	1400
Dispersed (Natural)	0	24	33	37	41	44	45	46
Mech. Recovered (Oil)	0	0	0	0	0	0	0	0
Dispersed (Chemical)	0	0	0	0	0	0	0	0
In-Situ Burned	0	0	800	800	800	800	800	800
Stranded	0	0	0	100	280	600	1000	1700
Stranded Oil Emulsion	0	0	0	400	1100	2400	3800	7000
Water-In-Oil	0	1300	1300	5700	5500	5400	5300	5300
Emulsion Factor	0.00	0.30	0.40	0.75	0.75	0.75	0.75	0.75
% Evaporation	0.00	0.25	0.05	0.05	0.04	0.03	0.03	0.02
% Dispersion (natural)	0.000	0.006	0.003	0.002	0.002	0.002	0.001	0.001
% Stranding	0.000	0.000	0.000	0.050	0.100	0.200	0.300	0.350

Appendix H

Preliminary Risk Ranking Matrix for Natural Recovery

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Appendix H. Risk ranking matrix for natural recovery in the 500 bbl spill scenario (original matrix, before ranking system was finalized).

	Terrestrial (supratidal)					Shoreline (intertidal)																			
						Marsh/Tidal Flat								Sand/Gravel Beaches					Rip Rap/Man Made						
RESOURCES:	arthropods	birds	mammals	reptiles/amphibians	vegetation	birds	crustaceans	fish	infauna	mammals	molluscs	reptiles/amphibians	vegetation	birds	crustaceans	infauna	mammals	molluscs	algae	birds	crustaceans	infauna	fish	mammals	molluscs
1	4D	4D	3D	4D		3C	3C	3C	3C	3C	4D	3C	3C	3C	3C	3C	3C	4C	4D	3D	3D	4D	4D	4D	4D
	4D					3C								3C					4D						
2	4D	4D	4D	4D		3A	3A?	4A	3A?	3A	3A?	3A	3A	4A	3A	2A	4A	3A	4A	4A	3A	4A	4A	4A	3A
	4D					3A								3A					4A						
3	4D	4D	4D	4D		3D	4D	4D	4D	4D	4D	4D	4D	3D	4D	4D	4D	4D	4D/NA	4D/NA	4D/NA	4D/NA	NA	NA	NA

	Benthic (subtidal)																												
	Shallow < 3 feet						Open Bay 3-10 feet						Channel > 10 feet				Reef (not intertidal)						SAV						
RESOURCES:	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	seagrass
1	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	4D						4D						4D				4D						4D						
2	4C	4C	3C	4C	3C	3C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4C	4C	3C	4C	4C	4C	X	X	X	X	X	X	X
	3C						4D						4D				4C						X						
3	4C	4C	4C	4C	4C	4C	4B	4B	4B	4B	4B	4B	4D	4D	4D	4D	4C	4C	4C	4C	4C	4C	NA	NA	NA	NA	NA	NA	NA

	Water column																				Surface (microlayer)					
	Top 3 feet									Bottom 3 feet (in depths of 3-10 feet)						Bottom 3 feet (in depths > 10 feet)										
RESOURCES:	algae	birds	crustaceans	fish	jellyfish	mammals	phytoplankton	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	algae	birds	fish	mammals	microlayer associated plankton	reptiles/amphibians
1	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	2C	4C	4D	4C	4C
	4D									4D						4D					2/3C					
2	4A	4A	4A	4A	4A	4A	4A	4A	4A	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4A	4A	4A	4A	4A	4A
	4A									4D						4D					4A					
3	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	4B	3B	4B	4B	4B	3B

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Appendix I

Interim Risk Ranking Matrices – 500 bbl Spill Scenario

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Appendix I-1. Risk ranking matrix for natural recovery in the 500-bbl spill scenario (original matrix, following finalization of ranking system).

	Terrestrial (supratidal)					Shoreline (intertidal)																			
						Marsh/Tidal Flat								Sand/Gravel Beaches					Rip Rap/Man Made						
RESOURCES:	arthropods	birds	mammals	reptiles/amphibians	vegetation	birds	crustaceans	fish	infauna	mammals	molluscs	reptiles/amphibians	vegetation	birds	crustaceans	infauna	mammals	molluscs	algae	birds	crustaceans	infauna	fish	mammals	molluscs
1	4D	4D	4D	4D	4D	3C	3C	3C	3C	3C	3D	2C	3C	3C	3C	3C	3C	3C	4D	3D	3D	4D	4D	4D	4D
	4D					2C								3C					4D						
2	4D	4D	4D	4D	x	3C	3C	4C	3D	3D	3C	3C	3C	4D	4D	4D	4D	4D	4D	4D	3D	4D	4D	4D	3D
	4D					3C								4D					4D						
3	NA	NA	NA	NA	x	3B	4C	4C	4C	4D	4D	4C	4B	3B	4D	4D	4D	4D	4D	4D	4C	4D	4D	4D	4D
	NA					3C								3C					4D						

	Benthic (subtidal)																												
	Shallow < 3 feet						Open Bay 3-10 feet						Channel > 10 feet				Reef (not intertidal)						SAV						
RESOURCES:	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	seagrass
1	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	4D						4D						4D				4D						4D						
2	4C	4C	3C	4C	3C	3C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4C	4C	3C	4C	4C	4C	NA	NA	NA	NA	NA	NA	NA
	3C						4D						4D				4C						NA						
3	4D	4D	4D	4D	4D	4D	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	4D						NA						NA				NA						NA						

	Water column																				Surface (microlayer)					
	Top 3 feet									Bottom 3 feet (in depths of 3-10 feet)						Bottom 3 feet (in depths > 10 feet)										
RESOURCES:	algae	birds	crustaceans	fish	jellyfish	mammals	phytoplankton	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	algae	birds	fish	mammals	microlayer associated plankton	reptiles/amphibians
1	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	2C	4C	4D	4C	4C
	4D									4D						4D					2C					
2	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4B	4C	4D	4D	4D
	4D									4D						4D					4B					
3	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	3B	4C	4D	4C	4C
	4D									4D						4D					4C					

Appendix I-2. Risk ranking matrix for mechanical recovery in the 500-bbl spill scenario.

	Terrestrial (supratidal)					Shoreline (intertidal)																			
						Marsh/Tidal Flat								Sand/Gravel Beaches					Rip Rap/Man Made						
RESOURCES:	arthropods	birds	mammals	reptiles/amphibians	vegetation	birds	crustaceans	fish	infauna	mammals	molluscs	reptiles/amphibians	vegetation	birds	crustaceans	infauna	mammals	molluscs	algae	birds	crustaceans	infauna	fish	mammals	molluscs
1	4D	4D	4D	4D	4D	3D	3C	3C	3D	3D	3D	2C	3D	3D	3D	3D	3D	3D	4D	3D	3D	4D	4D	4D	4D
	4D					3C								3D					4D						
2	4D	4D	4D	4D		3C	3D	4C	3D	3D	3D	3D	3C	4D	4D	4D	4D	4D	4D	4D	3D	4D	4D	4D	3D
	4D					3D								4D					4D						
3	NA	NA	NA	NA		3C	4C	4C	4C	4D	4D	4C	4C	3B	4D	4D	4D	4D	4D	4D	4C	4D	4D	4D	4D
	NA					4C								3C					4D						

	Benthic (subtidal)																												
	Shallow < 3 feet						Open Bay 3-10 feet						Channel > 10 feet				Reef (not intertidal)						SAV						
RESOURCES:	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	seagrass
1	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	4D						4D						4D				4D						4D						
2	4C	4C	3C	4C	3C	3C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4C	4C	3C	4C	4C	4C	NA	NA	NA	NA	NA	NA	NA
	3C						4D						4D				4C						NA						
3	4D	4D	4D	4D	4D	4D											NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	4D																NA						NA						

	Water column																				Surface (microlayer)					
	Top 3 feet									Bottom 3 feet (in depths of 3-10 feet)						Bottom 3 feet (in depths > 10 feet)										
RESOURCES:	algae	birds	crustaceans	fish	jellyfish	mammals	phytoplankton	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	algae	birds	fish	mammals	microlayer associated plankton	reptiles/ amphibians
1	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	3C	4C	4D	4C	4C
	4D									4D						4D					2D					
2	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4B	4C	4D	4D	4D
	4D									4D						4D					4B					
3	4D	4D	4D	4D	4D		4D		4D												4D	3C	4D	4D	4D	4D
	4D									4D						4D					4C					

Appendix I-3. Risk ranking matrix for shoreline cleanup in the 500-bbl spill scenario.

	Terrestrial (supratidal)					Shoreline (intertidal)																			
						Marsh/Tidal Flat								Sand/Gravel Beaches					Rip Rap/Man Made						
RESOURCES:	arthropods	birds	mammals	reptiles/ amphibians	vegetation	birds	crustaceans	fish	infauna	mammals	molluscs	reptiles/ amphibians	vegetation	birds	crustaceans	infauna	mammals	molluscs	algae	birds	crustaceans	infauna	fish	mammals	molluscs
1	4D	4D	4D	4D	3D	3C	3C	3C	3C	3C	3D	2C	3C	3D	4C	4C	4C	4C	4C	3D	4C	4D	4D	4D	4D
	4D					2C								3D					4D						
2	4D	4D	4D	4D	4D	3C	3C*	4C	3C*	3D	3D	3D	3B*	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	4D					3B								4D					4D						
3	4D	3C	4D	4D	4C	3C	4C	4C	4C	4D	4D	4C	4B	3B	4D	4C	4D	4D	4C	4D	4C	4D	4D	4D	4D
	3C					4C								3C					4C						

	Benthic (subtidal)																												
	Shallow < 3 feet						Open Bay 3-10 feet						Channel > 10 feet				Reef (not intertidal)						SAV						
RESOURCES:	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	seagrass
1	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	4D						4D						4D				4D						4D						
2	4C	4C	3C	4C	3C	3C	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4D	4D	4D	4D	4D	4D	4D
	3C						4D						4D				4D						4D						
3	4D	4D	4D	4D	4C	4D	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	4D						NA						NA				NA						NA						

	Water column																				Surface (microlayer)					
	Top 3 feet									Bottom 3 feet (in depths of 3-10 feet)						Bottom 3 feet (in depths > 10 feet)										
RESOURCES:	algae	birds	crustaceans	fish	jellyfish	mammals	phytoplankton	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	algae	birds	fish	mammals	microlayer associated plankton	reptiles/ amphibians
1	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	2C	4C	4D	4C	4C
	4D									4D						4D					2C (they want NA)					
2	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	4D									4D						4D					4D					
3	4D	4D	4D	4D	4D	4D	4D	4D	4D	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4D	4D	4D	4D	4D	4D
	4D									NA						NA					4D					

Appendix I-4. Risk ranking matrix for dispersant use in the 500-bbl spill scenario.

	Terrestrial (supratidal)					Shoreline (intertidal)																			
						Marsh/Tidal Flat								Sand/Gravel Beaches					Rip Rap/Man Made						
RESOURCES:	arthropods	birds	mammals	reptiles/amphibians	vegetation	birds	crustaceans	fish	infauna	mammals	molluscs	reptiles/ amphibians	vegetation	birds	crustaceans	infauna	mammals	molluscs	algae	birds	crustaceans	infauna	fish	mammals	molluscs
1	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	4D					4D								4D					4D						
2	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	4D					4D								4D					4D						
3	NA	NA	NA	NA	NA	4D	4D	4D	4D	4D	4D	4D	4D	4C	4D	4D	4D	4D	NA	NA	NA	NA	NA	NA	NA
	NA					4D								4C					NA						

	Benthic (subtidal)																												
	Shallow < 3 feet						Open Bay 3-10 feet						Channel > 10 feet				Reef (not intertidal)						SAV						
RESOURCES:	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	seagrass
1	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4C	4C	4C	4C	4D	4D	4D	4D	4D	4D	4D
	4D						4D						4D				4C						4D						
2	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	4D						4D						4D				4D						4D						
3	4D	4D	4C	4C	4C	4B	4D	4D	4C	4C	4C	4B	4C	4C	4C	4C	4D	4D	4C	4C	4C	4C	NA	NA	NA	NA	NA	NA	NA
	4C						4C						4C				4C						NA						

	Water column																				Surface (microlayer)					
	Top 3 feet									Bottom 3 feet (in depths of 3-10 feet)						Bottom 3 feet (in depths > 10 feet)										
RESOURCES:	algae	birds	crustaceans	fish	jellyfish	mammals	phytoplankton	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	algae	birds	fish	mammals	microlayer associated plankton	reptiles/ amphibians
1	4D	3C	3C	4D	4D	4D	4D	4D	4C	3C	3C	4D	4D	4D	4C	3C	3C	4D	4D	4D	4D	3D	4D	4D	4D	4D
	3C									3C						3C					4D					
2	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	4D									4D						4D					4D					
3	4C	4C	4C	4C	4C	4D	4C	4D	4C	4D	4C	4C	4C	4D	4C	4C	4C	4C	4C	4C	4D	4D	4D	4D	4D	4D
	4C									4C						4C					4D					

Appendix I-5. Risk ranking matrix for ISB in the 500-bbl spill scenario.

RESOURCES:	Terrestrial (supratidal)					Shoreline (intertidal)																			
						Marsh/Tidal Flat								Sand/Gravel Beaches					Rip Rap/Man Made						
	arthropods	birds	mammals	reptiles/amphibians	vegetation	birds	crustaceans	fish	infauna	mammals	molluscs	reptiles/amphibians	vegetation	birds	crustaceans	infauna	mammals	molluscs	algae	birds	crustaceans	infauna	fish	mammals	molluscs
1	4D	4D	4D	4D	4D	3D	3C	3C	3D	3D	3D	2C	3D	3D	3D	3D	3D	3D	4D	3D	3D	4D	4D	4D	4D
	4D					3C								3D					4D						
2	4D	4D	4D	4D	4D	3C	3D	4C	3D	3D	3D	3D	3C	4D	4D	4D	4D	4D	4D	4D	3D	4D	4D	4D	4D
	4D					3C								4D					4D						
3	NA	NA	NA	NA	NA	3C	4C	4C	4C	4D	4D	4C	4C	3B	4D	4D	4D	4D	4D	4D	4C	4D	4D	4D	4D
	NA					4C								3C					4D						

RESOURCES:	Benthic (subtidal)																												
	Shallow < 3 feet						Open Bay 3-10 feet						Channel > 10 feet				Reef (not intertidal)						SAV						
	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	seagrass
1	4D	4D	4D	44D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	3C	4D	4D	4D	4D	4D	4D	4D
	4D						4D						4D				4D						4D						
2	4C	4C	3C	4C	3C	3C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4C	4C	3C	4C	4C	4C	NA	NA	NA	NA	NA	NA	NA
	3C						4D						4D				4C						NA						
3	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	NA	NA	NA	NA	NA	NA	NA
	4D						4D						4D				4D						NA						

RESOURCES:	Water column																				Surface (microlayer)					
	Top 3 feet									Bottom 3 feet (in depths of 3-10 feet)						Bottom 3 feet (in depths > 10 feet)										
	algae	birds	crustaceans	fish	jellyfish	mammals	phytoplankton	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	algae	birds	fish	mammals	microlayer associated plankton	reptiles/amphibians
1	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	3C	4C	4D	4C	4C
	4D									4D						4D					2D					
2	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4B	4C	4D	4D	4D
	4D									4D						4D					4B					
3	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	3C	4D	4D	4D	4D
	4D									4D						4D					4C					

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Appendix J

Interim Risk Ranking Matrices - 4,000 bbl Spill Scenario

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Appendix J-1. Risk ranking matrix for natural recovery in the 4,000-bbl spill scenario (original matrix, following finalization of ranking system).

	Terrestrial (supratidal)					Shoreline (intertidal)																			
						Marsh/Tidal Flat								Sand/Gravel Beaches					Rip Rap/Man Made						
RESOURCES:	arthropods	birds	mammals	reptiles/amphibians	vegetation	birds	crustaceans	fish	infauna	mammals	molluscs	reptiles/amphibians	vegetation	birds	crustaceans	infauna	mammals	molluscs	algae	birds	crustaceans	infauna	fish	mammals	molluscs
1	4D	3C	3C	4C	3D	2B	2C	2C	2C	3B	2C	2B	2B	3B	3C	2B	3C	3C	4C	3C	3C	4C	4C	4C	4C
	3C					2B								3C					4C						
2	4D	4D	4D	4D	NA	3A	3A	3A	3A	3C	3B	3A	3A	3A	3A	3A	3C	3B	3C	3A	3C	3D	3D	4D	4D
	4D					3A								3A					3C						
3	4D	4C	4C	4D	4D	3A	3B	3B	3B	3C	3C	3C	3B	3A	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C
	4C					3B								3B					4C						

	Benthic (subtidal)																												
	Shallow < 3 feet						Open Bay 3-10 feet						Channel > 10 feet				Reef (not intertidal)						SAV						
RESOURCES:	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	seagrass
1	4C	4C	3C	4D	3C	3C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	3C						4D						4D				4D						4D						
2	4C	3A	3A	3C	3B	3B	4D	3A	4C	4C	4D	4D	4D	4D	4D	4D	4C	3A	3A	3C	4D	4D	4D	4D	4D	4D	4D	4D	4D
	3B						4C						4D				4C						4D						
3	4C	3C	3C	3C	3C	3C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	NA	NA	NA	NA	NA	NA	NA
	3C						4D						4D				4D						NA						

	Water column																				Surface (microlayer)					
	Top 3 feet									Bottom 3 feet (in depths of 3-10 feet)						Bottom 3 feet (in depths > 10 feet)										
RESOURCES:	algae	birds	crustaceans	fish	jellyfish	mammals	phytoplankton	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	algae	birds	fish	mammals	microlayer associated plankton	reptiles/amphibians
1	4C	4C	4C	4C	4C	4C	4C	4C	4C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4C	2B	4B	4C	4C	4C
	4C									4D						4D					2B					
2	4C	3A	3A	4C	4C	4D	4C	3C	4C	3A	3A	4D	4D	4D	4D	3B	4D	4D	4D	4D	4C	3A	4C	4D	4D	4D
	4B									4C						4D					4C					
3	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	3A	4B	4C	4B	4B
	4C									4C						4C					4B					

Appendix J-2. Risk ranking matrix for mechanical recovery in the 4,000-bbl spill scenario

	Terrestrial (supratidal)					Shoreline (intertidal)																			
						Marsh/Tidal Flat								Sand/Gravel Beaches					Rip Rap/Man Made						
RESOURCES:	arthropods	birds	mammals	reptiles/amphibians	vegetation	birds	crustaceans	fish	infauna	mammals	molluscs	reptiles/amphibians	vegetation	birds	crustaceans	infauna	mammals	molluscs	algae	birds	crustaceans	infauna	fish	mammals	molluscs
1	4D	3C	3C	4C	3D	2B	2C	2C	2C	3B	2C	2B	2B	3B	3C	2B	3C	3C	4C	3C	3C	4C	4C	4C	4C
	3C					2B								3C					4C						
2	4D	4D	4D	4D	NA	3A	3A	3B	3B	3C	3C	3A	3A	3A	3A	3B	3C	3B	3C	3B	3C	3D	3D	4D	4D
	4D					3A								3A					3C						
3	4D	4D	4D	4D	NA	3B	3C	3C	3C	3D	3D	3D	3B	3A	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C
	4D					3C								3B					4C						

	Benthic (subtidal)																												
	Shallow < 3 feet						Open Bay 3-10 feet						Channel > 10 feet				Reef (not intertidal)						SAV						
RESOURCES:	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	seagrass
1	4C	4C	3C	4D	3C	3C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	3C						4D						4D				4D						4D						
2	4C	3A	3C	3C	3C	3C	4D	3A	4D	4D	4D	4D	4D	4D	4D	4D	4D	3A	3C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	3C						4C						4D				4C						4D						
3	4C	3C	4C	4C	4C	4C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	NA	NA	NA	NA	NA	NA	NA
	3C						4D						4D				4D						NA						

	Water column																				Surface (microlayer)					
	Top 3 feet									Bottom 3 feet (in depths of 3-10 feet)						Bottom 3 feet (in depths > 10 feet)										
RESOURCES:	algae	birds	crustaceans	fish	jellyfish	mammals	phytoplankton	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	algae	birds	fish	mammals	microlayer associated plankton	reptiles/amphibians
1	4C	4C	4C	4C	4C	4C	4C	4C	4C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4C	2B	4B	4C	4C	4C
	4C									4D						4D					2C					
2	4C	3A	3C	4C	4C	4D	4C	4D	4C	3A	4D	4D	4D	4D	4D	3C	4D	4D	4D	4D	4D	3A	4D	4D	4D	4D
	4D									4C						4D					4C					
3	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	3A	4B	4C	4B	4B
	4C									4C						4C					4B					

Appendix J-3. Risk ranking matrix for shoreline cleanup in the 4,000 bbl spill scenario.

	Terrestrial (supratidal)					Shoreline (intertidal)																			
						Marsh/Tidal Flat								Sand/Gravel Beaches					Rip Rap/Man Made						
RESOURCES:	arthropods	birds	mammals	reptiles/amphibians	vegetation	birds	crustaceans	fish	infauna	mammals	molluscs	reptiles/amphibians	vegetation	birds	crustaceans	infauna	mammals	molluscs	algae	birds	crustaceans	infauna	fish	mammals	molluscs
1	4D	3C	3C	4C	3C	2B	3C	3C	3C	3B	3C	2B	3B	3C	3C	3B	4C	3C	4D	4D	4B	4B	4D	4D	4B
	3C					3B								3C					4C						
2	4D	4D	4D	4D	4D	3B	3B	3B	3B	3C	3B	3B	3A	4D	4C	4C	4D	4C	4D	4C	4C	4D	4D	4D	4D
	4D					3B								4C					4C						
3	4C	3B	4C	4C	4B	3A	3B	3B	3B	3C	3C	3C	3A	3A	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	4C					3B								3C					4D						

	Benthic (subtidal)																												
	Shallow < 3 feet						Open Bay 3-10 feet						Channel > 10 feet				Reef (not intertidal)						SAV						
RESOURCES:	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	seagrass
1	4C	4C	3C	4D	3B	3C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	3C						4D						4D				4D						4D						
2	4C	3B	4C	4C	3D	3D	4D	3A	4C	4C	4D	4D	4D	4D	4D	4D	4C	3A	3A	3C	4D	4D	4D	4D	4D	4D	4D	4D	4D
	4C						4C						4D				4C						4D						
3	4D	3C	4C	4C	4C	4C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	NA	NA	NA	NA	NA	NA	NA
	4C						4D						4D				4D						NA						

	Water column																				Surface (microlayer)					
	Top 3 feet									Bottom 3 feet (in depths of 3-10 feet)						Bottom 3 feet (in depths > 10 feet)										
RESOURCES:	algae	birds	crustaceans	fish	jellyfish	mammals	phytoplankton	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	algae	birds	fish	mammals	microlayer associated plankton	reptiles/amphibians
1	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4C	2B	4B	4C	4C	4C
	4D									4D						4D					2B					
2	4C	3A	3A	4C	4C	4D	4C	3C	4C	3A	3A	4D	4D	4D	4D	3B	4D	4D	4D	4D	4C	3A	4C	4D	4D	4D
	4B									4C						4D					4C					
3	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	3A	4B	4C	4B	4B
	4C									4C						4C					4B					

Appendix J-4. Risk ranking matrix for dispersant use in the 4,000 bbl spill scenario.

RESOURCES:	Terrestrial (supratidal)					Shoreline (intertidal): Marsh/Tidal Flat								Shoreline (intertidal): Sand/Gravel Beaches					Shoreline (intertidal): Rip Rap/Man Made						
	arthropods	birds	mammals	reptiles/amphibians	vegetation	birds	crustaceans	fish	infauna	mammals	molluscs	reptiles/amphibians	vegetation	birds	crustaceans	infauna	mammals	molluscs	algae	birds	crustaceans	infauna	fish	mammals	molluscs
1	4D	4D	4D	4D	4D	3C	3C	3C	3C	3C	3D	2C	3C	3C	3C	3C	3C	3C	4D	3D	3D	4D	4D	4D	4D
	4D					3C								3C					4C						
2	4D	4D	4D	4D	4D	3B	3B	3B	3B	3C	3B	3B	3B	3B	3C	3C	3D	3C	3D	3C	3D	4D	4D	4D	4D
	4D					3B								3C					4C						
3	4D	4D	4D	4D	4D	3B	4C	4C	4C	4D	4D	4C	4B	3B	4D	4D	4D	4D	4D	4D	4C	4D	4D	4D	4D
	4D					3C								3C					4D						

RESOURCES:	Benthic (subtidal): Shallow < 3 feet						Open Bay 3-10 feet						Channel > 10 feet				Reef (not intertidal)						SAV						
	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	seagrass
1	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	3C	4C	4C	4B	4D	4D	4D	4D	4D	4D	4D
	4D						4D						4D				4B						4D						
2	4C	3B	3C	3D	3C	3C	4D	3A	4B	4C	4C	4C	4D	4D	4D	4D	4D	3A	3B	4C	4C	4C	4D	4D	4D	4D	4D	4D	4D
	3C						4B						4D				3C						4D						
3	4D	3C	4B	4B	4B	3B	4D	4B	4B	4B	4B	4B	4C	4C	4C	4C	4D	4B	4B	4B	4B	4B	NA	NA	NA	NA	NA	NA	NA
	4B						4B						4C				4B						NA						

RESOURCES:	Water column: Top 3 feet									Bottom 3 feet (in depths of 3-10 feet)						Bottom 3 feet (in depths > 10 feet)					Surface (microlayer)					
	algae	birds	crustaceans	fish	jellyfish	mammals	phytoplankton	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	algae	birds	fish	mammals	microlayer associated plankton	reptiles/amphibians
1	4C	3C	4B	4C	4D	4D	4C	4D	4B	3C	4B	4C	4D	4D	4B	3C	4B	4C	4D	4D	4C	2C	4C	4D	4C	4C
	4C									4C						4C					3C					
2	4C	3A	3B	4C	4C	4D	4C	4D	4C	3A	4C	4C	4D	4D	4D	3B	4D	4D	4D	4D	4D	3A	4D	4D	4D	4D
	4C									4C						4D					4C					
3	4B	3C	4B	4B	4B	4B	4B	4B	4B	3C	4B	4B	4B	4B	4B	4C	4B	4B	4C	4C	3B	3B	4C	4C	4C	4C
	4B									4B						4B					4C					

Appendix J-5. Risk ranking matrix for ISB in the 4,000-bbl spill scenario.

	Terrestrial (supratidal)					Shoreline (intertidal)																			
						Marsh/Tidal Flat								Sand/Gravel Beaches					Rip Rap/Man Made						
RESOURCES:	arthropods	birds	mammals	reptiles/ amphibians	vegetation	birds	crustaceans	fish	infauna	mammals	molluscs	reptiles/ amphibians	vegetation	birds	crustaceans	infauna	mammals	molluscs	algae	birds	crustaceans	infauna	fish	mammals	molluscs
1	4D	3C	3C	4C		2B	2C	2C	2C	3B	2C	2B	2B	3B	3C	2B	3C	3C	4C	3C	3C	4C	4C	4C	4C
	3C					2B								3C					4C						
2	4D	4D	4D	4D	4D	3A	3A	3B	3B	3C	3C	3A	3A	3A	3A	3B	3C	3B	3C	3B	3C	3D	3D	4D	4D
	4D					3A								3A					3C						
3	4D	4D	4D	4D	4D	3B	3C	3C	3C	3D	3D	3D	3B	3A	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C
	4D					3C								3B					4C						

	Benthic (subtidal)																												
	Shallow < 3 feet						Open Bay 3-10 feet						Channel > 10 feet				Reef (not intertidal)						SAV						
RESOURCES:	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	algae	birds	crustaceans	fish	infauna	molluscs	seagrass
1	4C	4C	3C	4D	3C	3C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D
	3C						4D						4D				4D						4D						
2	4C	3A	3B	3C	3C	3C	4D	3A	4D	4D	4D	4D	4D	4D	4D	4D	4D	3A	3B	4C	4D	4D	4D	4D	4D	4D	4D	4D	4D
	3C						4C						4D				4C						4D						
3	4C	3C	4C	4C	4C	4C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	NA	NA	NA	NA	NA	NA	NA
	3C						4D						4D				4D						NA						

	Water column																				Surface (microlayer)					
	Top 3 feet									Bottom 3 feet (in depths of 3-10 feet)						Bottom 3 feet (in depths > 10 feet)										
RESOURCES:	algae	birds	crustaceans	fish	jellyfish	mammals	phytoplankton	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	zooplankton	birds	crustaceans	fish	mammals	reptiles	algae	birds	fish	mammals	microlayer associated plankton	reptiles/ amphibians
1	4C	4C	4C	4C	4C	4C	4C	4C	4C	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4D	4C	2B	4B	4C	4C	4C
	4C									4D						4D					2C					
2	4C	3A	3B	4C	4C	4D	4C	4D	4C	3A	4D	4D	4D	4D	4D	3C	4D	4D	4D	4D	4D	3A	4D	4D	4D	4D
	4C									4C						4D					4C					
3	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	4C	3A	4B	4C	4B	4B
	4C									4C						4C					4B					

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Appendix K

Preliminary Summary Risk Ranking Matrices for 500 and 4,000 bbl Spill Scenarios

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Appendix K-1. Summary sheet of risk scores for the 500 bbl spill scenario.

SUBHABITATS:	Terrestrial			Shoreline/Intertidal									Benthic Subtidal														
	Terrestrial			Marsh/Tidal Flat			Sand/Gravel Beach			Riprap Manmade			Shallow <3 feet			Open Bay 3 to 10 feet			Channel >10 Feet			Reef (not intertidal)			SAV		
Natural Recovery	4D	4D	NA	2C	3C	3C	3C	4D	3C	4D	4D	4D	4D	3C	4D	4D	4D	NA	4D	4D	NA	4D	4C	NA	4D	NA	NA
On-Water Recovery	4D	4D	NA	3C	3D	4C	3D	4D	3C	4D	4D	4D	4D	3C	4D	4D	4D		4D	4D		4D	4C	NA	4D	NA	NA
Shoreline Cleanup	4D	4D	3C	2C	3B	4C	3D	4D	3C	4D	4D	4C	4D	3C	4D	4D	4D	NA	4D	4D	NA	4D	4D	NA	4D	4D	NA
Oil + Dispersant	4D	4D	NA	4D	4D	4D	4D	4D	4C	4D	4D	NA	4D	4D	4C	4D	4D	4C	4D	4D	4C	4C	4D	4C	4D	4D	NA
ISB	4D	4D	NA	3C	3C	4C	3D	4D	3C	4D	4D	4D	4D	3C	4D	4D	4D	4D	4D	4D	4D	4D	4C	4D	4D	NA	NA

SUBHABITATS:	Water Column									Surface		
	Top 3 feet			Bottom 3 feet (in depths of 3 to 10 feet)			Bottom 3 feet (in depths greater than 10 feet)			Surface (microlayer)		
Natural Recovery	4D	4D	4D	4D	4D	4D	4D	4D	4D	2C	4B	4C
On-Water Recovery	4D	4D	4D	4D	4D	4D	4D	4D	4D	2D	4B	4C
Shoreline Cleanup	4D	4D	4D	4D	4D	NA	4D	4D	NA	2C	4D	4D
Oil + Dispersant	3C	4D	4C	3C	4D	4C	3C	4D	4C	4D	4D	4D
ISB	4D	4D	4D	4D	4D	4D	4D	4D	4D	2D	4B	4C

Legend: A "high" level of ecological concern is indicated by cells shaded in dark gray, a "medium" level of concern is indicated by light gray shading, and a "low" level of concern is indicated by no shading. Cells containing cross-hatch marks are intermediate between "medium" and "low". Note: No high concern ratings were recorded for the 500 bbl spill scenario.

Appendix K-2. Summary sheet of risk scores for the 4000 bbl spill scenario.

SUBHABITATS:	Terrestrial			Shoreline/Intertidal									Benthic Subtidal															Water Column									Surface		
	Terrestrial			Marsh/Tidal Flat			Sand/Gravel Beaches			Riprap Manmade			Shallow <3 feet			Open Bay 3 to 10 feet			Channel >10 Feet			Reef (not intertidal)			SAV			Top 3 feet			Bottom 3 feet (in depths of 3 to 10 feet)			Bottom 3 feet (in depths greater than 10 feet)			Surface (microlayer)		
Natural Recovery	3C	4D	4C	2B	3A	3B	3C	3A	3B	4C	3C	4C	3C	3B	3C	4D	4C	4D	4D	4D	4D	4D	4C	4D	4D	4D	NA	4C	4B	4C	4D	4C	4C	4D	4D	4C	2B	4C	4B
On-Water Recovery	3C	4D	4D	2B	3A	3C	3C	3A	3B	4C	3C	4C	3C	3C	3C	4D	4C	4D	4D	4D	4D	4D	4C	4D	4D	4D	NA	4C	4D	4C	4D	4C	4C	4D	4D	4C	2C	4C	4B
Shoreline Cleanup	3C	4D	4C	3B	3B	3B	3C	4C	3C	4C	4C	4D	3C	4C	4C	4D	4C	4D	4D	4D	4D	4D	4C	4D	4D	4D	NA	4D	4B	4C	4D	4C	4C	4D	4D	4C	2B	4C	4B
Oil + Dispersant	4D	4D	4D	3C	3B	3C	3C	3C	3C	4C	4C	4D	4D	3C	4B	4D	4B	4B	4D	4D	4C	4B	3C	4B	4D	4D	NA	4C	4C	4B	4C	4C	4B	4C	4D	4B	3C	4C	4C
ISB	3C	4D	4D	2B	3A	3C	3C	3A	3B	4C	3C	4C	3C	3C	3C	4D	4C	4D	4D	4D	4D	4D	4C	4D	4D	4D	NA	4C	4C	4C	4D	4C	4C	4D	4D	4C	2C	4C	4B

Legend: A "high" level of ecological concern is indicated by cells shaded in dark gray, a "medium" level of concern is indicated by light gray shading, and a "low" level of concern is indicated by no shading.

Appendix L

Workshop Three Meeting Summary

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THIRD WORKSHOP:
Completion of Risk Analysis and Risk Characterization
(*preliminary meeting minutes*)

1.0 DISCUSSION/REVIEW

- Don Aurand gave an overview of progress made during the second meeting. None of the participants had comments on the workshop #2 progress report. Facilitators presented the 500 and 4000 bbl matrices and explained that the participants were to try to come to consensus on ranking the individual cells, with highest priority on cells that currently cross two levels of concern (i.e., medium/low scores from different groups).
- Participants first had to decide what "high", "medium" and "low" meant. The group was concerned with the color-coding, due to universal connotation of the color green as that of "go" or "proceed". It was decided that all tables and matrices would be changed so that the green became yellow, and the yellow became orange.
- Definitions of the Levels of Concern within the Risk Matrix:

  HIGH (red) – high ecological concern

  MEDIUM (orange) – moderate ecological

  concern

  LOW (yellow) – minimal ecological concern
- The group then decided that Charlie Henry would be the group spokesperson on Wednesday for the risk assessors' presentation to the risk managers describing what has been developed over the past three workshops.

2.0 REVISION OF RESOURCE TABLES

NOTE: A **patterned box** in the table indicates that for that habitat there is a resource present that could change the level of concern and may require site inspection (by resource manager) before making a decision.

2.1 CHANGES TO CELLS IN THE 500 BBL SPILL MATRIX AND RATIONALE FOR CHANGE

1. **Resource:** Terrestrial.

   Stressor: Shoreline Cleanup.

   Problem: Group 3 ranked their cell as 3C (moderate concern) because of concern for reddish egret bird at rookeries around Smith Point.

   Change Made: Group 3 score changed to 3D.

   Rationale for the Change: The concern for this bird is only in certain areas at certain times; the cells for all three groups will be hashed (see explanation of above).

2. **Resource:** Shoreline/Intertidal - Marsh/Tidal Flat.

   Stressor: On-Water recovery.

   Problem: Group 1 ranked their cell as 3C (moderate concern) because of concern for diamond back terrapin.

   Change Made: Group 1 score changed to 3D.

   Rationale for the change: Even if you send someone out in the field to inspect the field site, there is no way to make a call to protect the terrapin.

3. **Resource:** Shoreline/Intertidal - Marsh/Tidal Flat.

   Stressor: Shoreline Cleanup.

   Problem: Group 3 ranked their cell as 4C (low concern) because the group defined cleanup as "non-intrusive" cleanup (see write up of Sect. 3.1 of mtg 2 notes) that would only involve the fringe of the marsh. Group 1 and 2 thought there would be longer recovery times because they considered cleanup of whole marshes, which tends to be very intrusive from trampling by personnel.

   Change Made: Change group 1 and 2 scores to 4C since the cleanup would be on the fringe only.

   Rationale for the change: the cells for all three groups will be hashed meaning that someone needs to go out and look at the distribution of the oil. How much improvement would depend on how much oil you would get by cleaning up the fringe.

4. **Resource:** Shoreline/Intertidal - Marsh/Tidal Flat.

   Stressor: ISB.

   Problem: Group 3 ranked their cell as 4C because they were optimistic about the amount of oil burned. Note that the budget shows that 200 bbls were burned (less than half).

Change Made: Change Group 3 score to 3C.

Rationale for the change: Not enough oil was recovered to have all recovery occur in one year.

5. **Resource:** Shoreline/Intertidal – Sand/gravel Beach.

   Stressor: Natural Recovery.

   Problem: Group 2 ranked their cells 4D for the resource for all of the stressors because the trajectory did not seem to impact sand/gravel beach areas.

   Change Made: Change Group 2 score to 3C.

   Rationale for the change: If oil does impact sand/gravel beaches (even though there are not many within the trajectory), the habitat is very important to birds.

6. **Resource:** Shoreline/Intertidal – Sand/gravel Beach.

   Stressor: On-Water Recovery.

   Problem: Group 3 ranked their cell as 3C because the advantage of removing the oil is offset by disturbances to bird rookeries, since the scenario is during nesting season.

   Change Made: Change Group 3 score to 3D.

   Rationale for the change: On-water recovery would decrease the amount of oil stranding.

7. **Resource:** Shoreline/Intertidal – Sand/gravel Beach.

   Stressor: Shoreline Cleanup.

   Problem: Group 3 ranked their cell as 3C because the advantage of removing the oil is offset by disturbances to bird rookeries, since the scenario is during nesting season.

   Change Made: Change Group 3 score to 3D.

   Rationale for the change: shoreline cleanup would remove some of the oil; the patterned boxes indicate the need to ensure that collateral damage does not cause more disturbance.

8. **Resource:** Shoreline/Intertidal – Sand/gravel Beach.

   Stressor: ISB.

   Problem: Group 3 ranked their cell as 3C because the advantage of removing the oil is offset by disturbances to bird rookeries, since the scenario is during nesting season.

   Change Made: Change Group 3 score to 3D.

   Rationale for the change: ISB would remove some of the oil.

9. **Resource:** Benthic Subtidal – Shallow Water.

   Stressor: Natural Recovery.

   Problem: Group 2 ranked their cell as 3C because of a concern for infauna, molluscs and crustaceans.

   Change Made: Change Group 2 score to 3D.

   Rationale for the change: Oil on the surface of the water is not going to affect that much of the resource with this size spill.

10. **Resource:** Benthic Subtidal – Shallow Water.

    Stressor: On-Water Recovery.

    Problem: Group 2 ranked their cell as 3C because of a concern for infauna, molluscs and crustaceans.

    Change Made: Change Group 2 score to 3D.

    Rationale for the change: Oil on the surface of the water is not going to affect that much of the resource with this size spill.

    Resource: Benthic Subtidal – Shallow Water.

    Stressor: Shoreline Cleanup.

    Problem: Group 2 ranked their cell as 3C because of a concern for infauna, molluscs and crustaceans.

    Change Made: Change Group 2 score to 3D.

    Rationale for the change: Oil on the surface of the water is not going to affect that much of the resource with this size spill.

11. **Resource:** Benthic Subtidal – Shallow Water.

    Stressor: ISB.

    Problem: Group 2 ranked their cell as 3C because of a concern for infauna, molluscs and crustaceans.

    Change Made: Change Group 2 score to 3D.

    Rationale for the change: Oil on the surface of the water is not going to affect that much of the resource with this size spill.

12. **Resource:** Water column – Top 3 feet.

    Stressor: Oil + Dispersant.

    Problem: Group 1 ranked their cell as 3C primarily because of a concern for diving birds.

    Change Made: Change Group 1 score to 3D.

    Rationale for the change: The patterned boxes indicate that it is unclear what level of concern to should attach to birds diving through dispersed oil, since the concentrations dilute out quickly.

13. **Resource:** Water column – Bottom 3 feet (in depths of 3-10 feet).

    Stressor: Oil + Dispersant.

    Problem: Group 1 ranked their cells as 3C primarily because of a concern for diving birds.

Change Made: Change Group 1 score to 3D.

Rationale for the change: The patterned boxes indicate that it is unclear what level of concern to should attach to birds diving through dispersed oil, since the concentrations dilute out quickly.

14. **Resource:** Water column – Bottom 3 feet (in depths of greater than 10 feet).

    Stressor: Oil + Dispersant.

    Problem: Group 1 ranked their cell as 3C primarily because of a concern for diving birds.

    Change Made: Change Group 1 score to 3D.

    Rationale for the change: The patterned boxes indicate that it is unclear what level of concern to should attach to birds diving through dispersed oil, since the concentrations dilute out quickly.

15. **Resource:** Surface (microlayer).

    Stressor: Natural Recovery.

    Problem: Group 3 ranked their cell as 4C (low concern); Groups 1 and 2 considered rafting/swimming birds so ranked their cells in the moderate range.

    Change Made: Change Group 3 score to 3C; Change Group 2 score to 3C.

    Rationale for the change: Although bird populations will not probably recovery fully in one year is, but not too many individuals will be affected.

16. **Resource:** Surface (microlayer).

    Stressor: On-Water Recovery.

    Problem: Group 3 ranked their cell as 4C (low concern); Group 2 ranked their cell as 4B (meaning that a high/moderate population affect), but they had problems with the concept of "surface microlayer"; Group 1 ranked their cell as 2D, which was a scribe mistake.

    Change Made: Change Group 3 score to 3D; Change Group 2 score to 3C; Change Group 1 score to 3C.

    Rationale for the change: Although bird populations will not probably recovery fully in one year is, but not too many individuals will be affected. There will be some improvement over natural recovery.

17. **Resource:** Surface (microlayer).

    Stressor: Shoreline Cleanup.

    Problem: Group 1 ranked their cell as 2C because they were comparing the response to "natural recovery", and argue that shoreline cleanup will not help reduce this effect.

    Change Made: Change Group 2 and 3 scores to 3C.

    Rationale for the change: The damage was already done to this resource prior to shoreline cleanup, so the scores would be the same as they were for the "natural recovery" baseline.

18. **Resource:** Surface (microlayer)*.

    Stressor: ISB.

    Problem: Group 3 ranked their cell as 4C; Group 1 ranked their cell as 2D, even though none of their individual scores were that high (scribe error?); Group 2 ranked their cell as 4B.

    Change Made: Change Groups 1 and 2 scores to 3C and Group 3 score to 3D.

    Rationale for the change: Although bird populations will not probably recovery fully in one year is, but not too many individuals will be affected. There will be some improvement over natural recovery. The scores were changed to be the same as for "on-water recovery".

NOTE: SURFACE MICROLAYER: There was a lot of discussion about the scores for this resource. Consensus was that there would be some improvement for on-water recovery and ISB, but no agreement on how much improvement, or whether it would actually change from moderate level of concern (as was the case for natural recovery) to low level of concern.

2.2 Changes to Cells in the 4000 bbl spill Matrix and Rationale for Change

1. **Resource**: Terrestrial.

   Stressor: Natural Recovery *and* On-Water Recovery *and* ISB.

   Problem: Group 1 ranked their cell as 3C because they were thinking about collateral damage since this is a larger spill. They don't want to change.

   Change Made: None.

   Rationale for the change: The participants did not come to consensus on this. Final summary sheet represent this as cells split between orange and yellow.

2. **Resource:** Terrestrial.

   Stressor: Shoreline Cleanup.

   Problem: Group 2 ranked their cell as 4D; Group 3 ranked their cell as 4C.

   Change Made: Change Group 2 score to 4C; Change Group 3 score to 3C.

Rationale for the change: Increased activity in the terrestrial zone for beach cleanup will cause more damage. The participants did not come to consensus on this. Final summary sheet represent this as cells split between orange and yellow.

3. **Resource:** Shoreline/Intertidal – Marsh/Tidal Flat.

   Stressor: Natural Recovery *and* On-Water Recovery *and* ISB.

   Problem: Group 3 is in "moderate" level of concern whereas Groups 1 and 2 are in "high" level of concern.

   Change Made: None.

   Rationale for the change: The cells are adjacent, even though the colors change. The participants did not come to consensus on this. Final summary sheet represent this as cells split between orange and red.

4. **Resource:** Shoreline/Intertidal – Sand/gravel Beach.

   Stressor: Natural Recovery *and* On-Water Recovery *and* ISB.

   Problem: Group 2 ranked their cells as 3A.

   Change Made: Change Group 2 scores to 3B.

   Rationale for the change: The score of 3A is "very catastrophic" for this size spill. The 4000 bbl spill would affect a larger amount of the local resource than the 500 bbl spill, but not to the degree reflected by a score of 3A.

5. **Resource:** Shoreline/Intertidal – Sand/gravel Beach.

   Stressor: Shoreline Cleanup.

   Problem: Group 2 ranked their cell as 4C.

   Change Made: Change Group 2 score to 3C.

   Rationale for the change: The recovery time would probably be more than one year.

6. **Resource:** Shoreline/Intertidal – Riprap/Manmade.

   Stressor: Natural Recovery *and* On-Water Recovery *and* ISB.

   Problem: Group 2 ranked their cells as 3C.

   Change Made: Change Group 2 scores to 4C.

   Rationale for the change: The main driver for this score was a rating of 3A given to birds.

7. **Resource:** Benthic Subtidal- Shallow < 3feet.

   Stressor: Shoreline Cleanup.

   Problem: Group 1 ranked their cells as 3C.

   Change Made: Change Group 1 score to 4C.

   Rationale for the change: Recovery time would probably be within one year.

8. **Resource:** Benthic Subtidal- Shallow < 3feet.

   Stressor: Oil + Dispersant.

   Problem: Group 2 ranked their cell as 3C; Group 3 ranked their cell as 4B.

   Change Made: Change Group 2 score to 4C; Change Group 3 score to 4C.

   Rationale for the change: Recovery would probably be within one year, and would not cover a major portion of the population.

9. **Resource:** Benthic Subtidal- Open Bay 3-10 feet.

   Stressor: Oil + Dispersant.

   Problem: Groups 2 and 3 ranked their cells as 4B.

   Change Made: Change Group 2 and 3 scores to 4C.

   Rationale for the change: Group 2 scores were based on water column effects (of diving birds) which is not a correct definition of the benthic resource; Group 3 lowered their score to be consistent with shallower water.

10. **Resource:** Water Column – Top 3 feet.

    Stressor: Natural Recovery *and* Shoreline Cleanup.

    Problem: Group 2 ranked their cells as 4B.

    Change Made: Change Group 2 scores to 4C.

    Rationale for the change: Group 2 was interpreting the "environment" differently (i.e.,- oil was coming from the surface when birds were diving into the water column). Surface oiling will be considered separately.

11. **Resource:** Water Column – Top 3 feet *and* Bottom 3 feet (in 3-10 feet) *and* Bottom 3 feet (in greater than 10 feet).

    Stressor: Oil + Dispersant.

    Problem: Group 3 ranked their cells as 4B.

    Change Made: Change Group 3 scores to 4C.

    Rationale for the change: There are some resources which might have concentrated larvae in the area. Patterned boxes indicate because you need to ensure that a resource manager is contacted.

12. **Resource:** Surface (microlayer)

    Stressor: Natural Recovery *and* On-Water Recovery *and* Shoreline Cleanup *and* ISB.

    Problem: Group 2 ranked their cell as 4C.

Change Made: Change Group 2 score to 4B.

Rationale for the change: Group 2 change is because they had not considered that this is the location where the birds are going to be oiled (rather than in the water column).

NOTE: FOR SURFACE MICROLAYER: For On-Water Recovery *and* ISB, there is a wide range of scores because the recovery time depends on what resources are present. For Natural Recovery *and* Shoreline Cleanup *and* Oil + Dispersant, we will represent these as cells split two colors.

3.0 ASSESMENT OF ADEQUACY OF DATA

Participants were again divided into sub-groups and asked to assess the adequacy of available data in aiding completion of risk matrices. Groups rated data for each habitat and resource by stressor and provided input on the adequacy of some of the overall support data including modeling data, information on dispersed oil uptake by sediments and effect of dispersed oil on diving birds.

NOTE: Adequacy of Data: Each group scored data adequacy as: 1=poor; 2=moderate; 3=good; 4=very good. Results of scoring will be included in final summary report.

Group 1 [Marsh/Tidal Flat; Benthic Subtidal-Shallow <3 ft; Benthic Subtidal-Reef; Water Column- Bottom 3 feet (in depths of 3-10 ft)]

- C. Henry*
- J. Caplis
- Tirpak
- D. Barker

Group 2 [Sand/gravel Beach; Benthic Subtidal-Open Bay 3-10 ft; Benthic Subtidal – SAV; Water Column- Bottom 3 feet (in depths of >10 ft)]

- C. Ponthier
- P. Williams
- B. Martin*
- B. Grimes

Group 3 [Riprap/Manmade; Benthic Subtidal-Channel >10 ft; Water Column – Top 3 ft; Surface Microlayer]

- B. Powell*
- K. Rice
- M. Sipocz
- J. Staves (late arrival on day 2)

4.0 RISK ASSESSOR PRESENTATION TO THE MANAGERS

Charlie Henry and Buzz Martin were chosen to be the risk assessor representatives. The following points were made:

What does risk assessment say about use of response options in Galveston Bay?

- On water recovery and ISB offer little risk reduction over natural recovery.
- Dispersion and shoreline cleanup show some benefits but also involve tradeoffs (e.g. Dispersants shift concerns from shoreline resources to water column resources).

What these results are <u>not</u>:

- An evaluation of all habitats, e.g., not a lot of submerged aquatic vegetation (SAV) in the scenario area.
- Permission to use dispersant on every small spill.
- E.g., can't apply to West Bay or Christmas Bay. While there may be common elements for these areas, you can't rubber stamp it and you need to do site-specific adjustments. Maybe use as a incident-specific template to see what to change for that incident. But does open door to using dispersants on small spills (concentrations of dispersed small spills are low enough to not be a significant concern) in Galveston Bay if it is operationally feasible.

What the results are:

- Incentive to explore and prepare for dispersant use as an acceptable method to mitigate the environmental threat of an oil spill in Galveston Bay and other similar inshore areas.
- Strong advertisement for the value of geographic area preplanning.
- A demonstration of the value of the process to address other issues.
- In the bay, things happen quickly so need to plan ahead, maybe plan for dispersant use in Galveston Bay. Also, could use this process to address other tools, e.g., marsh burning, solidifiers, surface washing agents.

Consider using these in context of other tools. Involve resource managers in your decision process (maybe keep list of people involved on this process with the decision checklist). Think tactically not just strategically. Not just wide scale for big spills but on portions of spills. Consider air tractors and vessels for these kinds of environments.

What is the bottom limit for "small?" Maybe 200-300 bbls. If it is a manageable spill and you want to eliminate a small amount of oil from impacting a specific, small area, consider using it. Remember to think tactically and practically – have we reached a threat threshold where we want to do something to reduce/eliminate the risk. If you're going to act on this recommendation, then RRT and AC need to figure out how to work with exiting protocols to facilitate this implementing this tactical approach. Maybe identify high probability, high ecological risk to identify expedited implementation procedures.

Information needs:

- Operational effectiveness of dispersants.
- Exposure concentration and duration in the environment.
- In making these decisions, ranked our knowledge. One gap is operational effectiveness for dispersants, salinity issues and mixing energy, implications for resulting concentrations in shallow water. Also need to know more about exposure concentrations and duration in the sallow water environments by doing some field-level experiments. We want to validate the numbers we're using.

Suggestions:

- Prepare for tactical use of dispersant at suitable spill, (make sure data collection needs are simple so that you maximize opportunities for data collection).
- Collect relevant data.
- Review conclusions.
- Want to obtain measurements on small to medium sized spill to add to base and build on the process.

What is a suitable spill? 1,000 bbls or less, dispersible oil type, location - response time to mobilize and apply resources in a bay, not near a shoreline (although this is not as valuable an application because no new information is gained, that is not to say do not do any nearshore spills).

5.0 MANAGERS' RESPONSE

Managers were asked how they might utilize the results of this ERA:

Outreach

- RRT Industry Workgroup can do some outreach.
- Could do more to present for "peer review" like to the Galveston Bay Foundation and Brian Cain. Get validation of the process, then validate data via spill of opportunity.
- Environmental club newsletters – Page Williams drafting article for Sierra Club.

Area Level:

- Consideration for adjustment to the ACP.
- Push the envelope on related issues, e.g., political and social issues.

Regional Level

- Get regional buy-in on need for spill of opportunity – locate capabilities to carry it out, including gathering data (logistics). Get regional consensus that this is a good thing to do.
- Go to RRT for them to recommend this. Initiate via Science and Technology Committee that Buzz (head of that committee) and Charlie are on. They don't expect easy buy-in from RRT. Buzz will make full presentation on this at the next meeting, which is in January.

National Level

- Interest from CG as to equipment requirements at national level – this will factor in. Provide input to national regulatory process.
- Note in SMART the need to facilitate use on these spills of opportunity. Charlie will coordinate, beginning next week at SMART meeting in Elizabeth City.

What do you do in preparation for use of dispersants on small spills?

- Would industry be supportive of data gathering? Participants thought the Strike Team might be set up to do it. Infrastructure is there as the firehouse. Industry can help design studies. Resist the temptation to make this more complicated than it needs to be. One question to get data to answer for design - How much of the oil did you disperse? – get a credible mass balance. Design only for data gathering on spills of opportunity. Not for every spill in the future.

- Commitment to design data gathering protocol. Define who will maintain equipment and pay for the data gathering. Both industry and government are committed to do something reasonable and practical.

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Appendix M

Presentation of Risk Assessors to Risk Managers in Workshop Three

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Slide 1

Galveston Bay Ecological Risk Assessment

Slide 2

Environmental Management Goal:

- Reduce injury to the environment by:
  - keeping oil out of sensitive habitats
  - removing oil from the water surface
  - reducing oil concentration and enhance biodegradation
  - minimizing the time oil is in the environment

Slide 3

Definitions of the Levels of Concern within the Risk Matrix

- HIGH (red) – high ecological concern
- MEDIUM (orange) – moderate ecological concern
- LOW (yellow) – minimal ecological concern

Risk Matrix

Summary Chart

Slide 4

What does this risk assessment say about the use of various response options inside Galveston Bay ?

- On water recovery and ISB offer little risk reduction over natural recovery
- Dispersion and shoreline cleanup show some benefits but also involve tradeoffs
  - e.g. Dispersants shift concerns from shoreline resources to water column resources

Slide 5

What these results are not:

- An evaluation of all habitats, e.g., not a lot of submerged aquatic vegetation (SAV) in the scenario area…..
- permission to use dispersant on every small spill

Slide 6

What the results are:

- Incentive to explore and prepare for dispersant use as an acceptable method to mitigate the environmental threat of an oil spill in Galveston Bay and other similar inshore areas.
- Strong advertisement for the value of geographic area preplanning
- A demonstration of the value of the process to address other issues

Slide 7

Limitations on extending these conclusions

- Doesn't apply to all oil types or all spills
- Not blanket permission to use dispersants

Slide 8

Think tactically not just strategically

- Consider the use of dispersants for small spills
- Involve resource managers in your decision process

Slide 9

Information Needs

- Operational effectiveness of dispersants
- Exposure concentration and duration in the environment

Slide 10

Suggestions:

- Prepare for tactical use of dispersant at suitable spill, (make sure data collection needs are simple so that you maximize opportunities for data collection)
- Collect relevant data
- Review conclusions

Slide 11

What is a suitable spill:

- Size: 1,000 bbls or less
- Oil type: dispersible
- Location: adequate response time to mobilize and apply resources, in a bay – not near a shoreline

Appendix N

Agendas from Ecological Risk Assessment Workshops One, Two, and Three

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Ecological Risk Assessment for Galveston Bay Area
Workshop 1 – Agenda

Building the Conceptual Model Framework

April 6 – April 8, 1999

Day 1 – Tuesday, April 6, 1999

Scenario development; Identification of available response measures; Identification of ecological resources of concern; Identification of endpoints

8:00 Registration

8:30 Welcome and Introduction
- Workshop organization and goals
- Overview of the Ecological Risk Assessment Process

9:00 Scenario Development
- Proposed scenarios
- Discussion
- Selection

9:30 Break

9:45 Risk Managers- Identification of Response Measures
- What are our options?
- Questions and answers on response measures

Risk Assessors – Resources of Concern
- Proposed resources of concern
- Discussion/evaluation
- Develop consensus on resources of concern

11:45 Lunch (on your own in the cafeteria)

1:00 Plenary Discussion

2:00 Break (Risk manager attendance optional beyond this point)

2:15 Identification of Resources of Concern
- Discussion of resources
- Resource characteristics
- Stressor effects on resources

3:45 Break

4:00 Define Endpoints for Assessment

- Discussion
- Endpoints for assessment
- Consensus on endpoints for assessment process

5:30 Summary

5:45 Adjourn

Day 2 – Wednesday, April 7, 1999

Identification of potential effects from spill and spill countermeasures; Development of conceptual model

8:30 Overview

8:45 Identification of Effects of Spill and Countermeasures: Boundaries and Options

- Discussion
- Hazard/Exposure

10:00 Break

10:15 Identification of Effects - continued

- Consensus on potential effects
- Discussion
- Develop consensus on effects of concern

11:45 Summary

12:00 Lunch (on your own in the cafeteria)

1:00 Conceptual Model

- Overview and role of conceptual model
- Examples
- Discussion of conceptual model components
- Discussion of routes of exposure and effects

2:45 Break

3:00 Conceptual Model - continued

- Strawman model

5:00 Summary

5:30 Adjourn

Day 3 – Thursday, April 8, 1999

Development of assessment plan; Handout of assignments; Briefing of risk managers

8:30 Process Review

9:00 Assessment Plan
- Discussion – purpose and format of the plan
- Issues for resolution through the plan
- Data needs

10:00 Break

10:15 Assessment Plan – continued
- Assignments
- Expectations

12:30 Lunch (on your own in the cafeteria)

1:30 Plenary session
- Overview: scenarios
- Overview: resources
- Overview: effects
- Overview: model
- Overview: assessment plan

2:45 Break

3:00 Plenary Discussion – continued
- Process to date
- Steps remaining
- Open discussion

4:30 Summary

5:00 Adjourn

Ecological Risk Assessment for Galveston Bay Area
Workshop 2 – Agenda

Preliminary Risk Analysis

June 7-8, 1999

<u>DAY 1 – MONDAY, JUNE 7, 1999</u>

REVIEW AND DISCUSSION OF FIRST WORKSHOP; PROPOSED FORMAT FOR ANALYSIS SECTION OF REPORT; RISK RATING SYSTEM; PRELIMINARY DISCUSSION OF MEASURES OF EFFECTS

1:00	Welcome and Introduction
1:15	Review of Last Meeting and Discussion of Draft Report
2:00	Presentation and Discussion of the Exposure Working Group Modeling Results
3:00	Overview of the Proposed Analysis Section Format
3:30	Introduction to Risk Matrix Approach
4:00	Break
4:30	Discussion of Risk Matrix Parameters (based on exposure and effects)
6:00	Develop Exposure Criteria for Effects (action levels)
7:30	Initial Ratings for Risk Matrix (Natural Recovery Only)
8:00	Adjourn

<u>DAY 2 – WEDNESDAY, APRIL 7, 1999</u>

RE-EVALUATION OF THRESHOLDS AND COMPLETION OF RISK MATRIX

8:00	Overview - Review Yesterday and Discuss Expectations for Today
8:15	Review of Initial Ratings (Natural Recovery Only)
8:30	Develop Preliminary Concern Levels for Risk Matrix
9:00	Review and Discussion of Exposure and Effects Data
11:00	Complete Initial Ratings (All)
12:30	Lunch *on your own*
2:00	Review of Risk Ratings (All)
2:30	Discussion of Risk Ratings and Assumptions
5:00	Break
6:00	Discussion of Risk Ratings Continued
7:30	Develop Draft Risk Table
8:00	Adjourn

DAY 3 – THURSDAY, APRIL 8, 1999

DEVELOPMENT OF FINAL DRAFT RISK MATRIX; DISCUSSION OF REPORT SECTIONS ON "RESOURCES AND ENVIRONMENTAL RISK"; ASSIGNMENTS

8:00	Overview - Review Yesterday and Discuss Expectations for Today
8:15	Review of Risk Matrix and Levels of Concern
9:00	Discussion of Risk Matrix
10:00	Break
10:15	Discussion of Risk Matrix
12:00	Lunch *on your own*
1:00	Develop Final Draft Risk Matrix
2:00	Discussion of Report Sections on "Resources and Environmental Risk
3:00	Break
3:15	Develop and Complete Outline for Sample Section
4:30	Assignments and Expectations for Workshop 3
4:45	Summary
5:00	Adjourn

Ecological Risk Assessment for Galveston Bay Area
Workshop 3 – Agenda

Completion of Risk Analysis and Risk Characterization

July 26 – 28, 1999

Day 1 – Monday, July 26, 1999

8:30	Review of ERA Workshop 2 and Workshop 2 Report
9:30	Discussion of Risk Matrix
10:30	Break
10:45	Final Risk Definitions
12:00	Lunch *(on your own)*

1:00	Review of Risk Scores
2:45	Break
3:00	Review of Risk Scores (continued)
4:00	Finalization of Risk Scores
4:45	Wrap-up

Day 2 – Tuesday, July 27, 1999

8:30	Review and Reconfirmation of Risk Scores
9:30 Basis for	Define Basis for Risk Scores (Resource, Sensitivity, Exposure, Effects, Concern)
12:00	Lunch *(on your own)*
1:00	Address Protective Booming and Bioremediation
1:30	Develop Report and Briefing Assignments
2:45	Break
3:00	Develop Report and Briefing Assignments (continued)
4:45	Wrap-up

Day 3 – Wednesday, July 28, 1999

8:30	Risk Assessors - Review Presentation Points Risk Managers - ERA Process Review
10:00	Break
10:15	Risk Assessor Presentations to Risk Managers
12:00	Lunch *(on your own)*
1:00	Plenary Discussion

Appendix O

Composition of Workgroups in Workshops One, Two, and Three

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Appendix O. Workgroup Composition for each workshop session.

WORKSHOP 1

Transport Workgroup	Resources Workgroup	Effects Workgroup
Charlie Henry*	Winston Denton*	Jim Clark*
Bob Pond**	Gina Coelho**	Don Aurand**
Bea Stong	Bill Grimes	Andy Tirpak
Buzz Martin	Ken Rice	Bob Acker
Chris Ponthier	Bess Ormond	Galveston Bay Foundation
Dave Fritz	Cherie O'Brien	Linda Kuhn
	Steve Anderson	Dave Barker
	Marissa Sipocz	Nick Nichols
	Page Williams	
	Jim Staves	
	Brian Cain	

* Indicates group coordinator
** Indicates project team contact

WORKSHOP 2

Group 1	Group 2	Group 3
Bela James*	Dave Fritz*	Jim Clark*
Bea Stong	Chris Ponthier	Linda Kuhn
Charlie Henry	Brian Cain	Bob Acker
John Caplis	Steve Thumm	Jim Staves
Winston Denton	David Buzan	David Barker
Bess Ormond	Cherie O'Brien	Buzz Martin
Page Williams	Andy Tirpak	Ken Rice
Bill Grimes	Marissa Sipocz	Helen Drummond
	Steve Hamm	Nick Nichols

* Indicates group coordinator

WORKSHOP 3

Group 1 Marsh/Tidal Flat; Benthic Subtidal-Shallow <3ft; Benthic Subtidal-Reef; Water Column-Bottom 3 ft (in depths of 3-10 ft)	Group 2 Sandy Beach; Benthic Subtidal-Open Bay 3-10 ft; Benthic Subtidal-SAV; Water Column-Bottom 3 ft (in depths greater than 10 ft)	Group 3 Riprap/Manmade; Benthic Subtidal-Channel >10 ft; Water Column-Top 3 ft; Surface Microlayer
Charlie Henry	Chris Ponthier	Billy Powell
John Caplis	Page Williams	Ken Rice
Andy Tirpak	Bill Grimes	Marissa Sipocz
David Barker	Buzz Martin	Jim Staves

* Indicates group coordinator

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Appendix P

Non-Participant Comments

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GALVESTON
BAY
FOUNDATION

December 6, 1999

Dr. Buzz Martin
TGLO
1700 N. Congress Avenue
Austin; TX 78701-1495

Dear Dr. Martin:

Enclosed are our proposed revisions to the draft of the Executive Summary and Introduction of the *Ecological Risk Assessment Principles Applied to Oil Spill Response Planning in Texas Waters*. As you can see, the revisions are extensive, and reflect our concern that the draft does not accurately characterize the purpose or the conclusions of the ERA.

The Galveston Bay Foundation has a keen interest in ensuring effective response to oil spills within the Bay system, and we appreciate this opportunity to comment on the draft report. We are currently editing the remainder of the report, focusing mostly on the conclusions in Chapter 8. We hope to have comments on the conclusions to you by 12/10/99. Based on our review thus far, we believe considerable additional re-writing is needed of the main body of the report. If you have any questions, please call our office at (281) 332-3381.

Very truly yours,

Linda Shead

Linda R. Shead
Executive Director

17324-A HIGHWAY 3 • WEBSTER, TX 77598 • (281) 332-3381

EXECUTIVE SUMMARY

There is growing interest in the United States ~~for the use of a mix of~~ countermeasures during oil spill response ~~to~~ will achieve the highest level of environmental protection possible. ~~This has led to~~ concern over ~~the~~ potential ~~for~~ secondary impacts from the use of new or unfamiliar approaches. No countermeasure, e.g., natural recovery, on-water mechanical recovery, shoreline cleanup, *in situ* burning, or chemical dispersion, is risk-free or completely effective. Therefore, it is critical to have a defensible method for comparison of the risks and benefits of all, especially when used in combination. In an effort to make such comparisons, the U.S. Coast Guard, Texas General Land Office and American Petroleum Institute agreed to co-sponsor an ecological risk assessment of ~~the~~ response countermeasures ~~in~~ Galveston Bay.

This report documents the Galveston Bay ecological risk assessment (ERA) and the conclusions and recommendations of the participating stakeholders. It ~~provides~~ background information ~~to assist planners in the~~ selection of ~~appropriate~~ response options ~~resulting in a higher probability of~~ environmental protection from oil spills. This report also serves as a template for similar efforts in other regions around the country. This report was assembled by the project team on behalf of all participants in the process. It represents the consensus assessment ~~of the participants~~ regarding the ~~ecological impacts of each of the potential response options.~~

~~This~~ ERA process involved three phases: problem formulation, data analysis and risk characterization. These activities were addressed by the participants in a series of workshops, with the support of the project team. Participants included representatives of government agencies, industry and community interest groups, with a stake in environmental protection and oil spill response. The project team provided background information on the process and its application ~~in~~ Galveston Bay, facilitated each of the three workshops conducted as part of the process and prepared the draft reports on behalf of the stakeholders.

Stakeholders were composed of two groups: risk managers and risk assessors. ~~The risk managers provided the framework for the assessment by defining the parameters to be addressed to improve their ability to identify and utilize all appropriate response options.~~ In workshop I, the risk managers described the risk of oil spills in the Galveston Bay area and the options available for response to spills (including operational capabilities and weaknesses inherent with each option). They tasked the risk assessors with building a conceptual model of the environment in Galveston Bay, including identification of environmental resources at risk, as well as pathways and estimated effects of exposure on those resources.

The conceptual model constructed in workshop I was utilized by assessors during and between workshops II and III to analyze and characterize the ecological risks associated with the selection of various response options in Galveston Bay. At the end of workshop III, the assessors again met with the risk managers to deliver the results of their assessment.

The final summary risk matrices included in this report (chapter 6) represent the participants' consensus estimate of the relative levels of risk associated with various ~~[illegible]~~ response options ~~and resources or habitats in the Galveston Bay area~~. Certain conclusions and recommendations ~~can be~~

drawn from those consensus estimates. While these apply fully to the scenarios evaluated, they can only be extrapolated to other events with caution.

- On-water recovery or ISB, used alone, offer little risk reduction over natural recovery.
- Dispersion or shoreline cleanup used alone or in combination, indicate improved environmental benefit over the use of natural recovery, ISB, or on-water recovery. However, each technique involves tradeoffs as well, e.g. dispersants shift concerns from shoreline resources to water column resources.
- The optimum response is likely to involve some combination of the response options available.

Response and resource managers need to "think tactically not just strategically." Dispersants and ISB should be considered for use just on major spills. Dispersants may provide critical environmental protection in near-shore areas for small spills as well.

Participants are confident that the consensus conclusions regarding relative impacts are conservative, they tend to over-emphasize the potential impact of each stressor on the environment, and underemphasize the potential protection of sensitive resources. In an actual spill situation, participants would expect to see less damage than is predicted by this ERA.

Participants believe that the available data was sufficiently detailed and robust to allow supportable conclusions, but they recognize that there are areas where additional information would be valuable. In order to validate the results of this ERA and to add further validity to future assessments, participants noted that more information is needed on both operational effectiveness of dispersants and exposure concentration and duration in the environment.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Oil spills are often contentious and sometimes economically or environmentally serious pollution events. Because oil spills are highly visible and potentially harmful to valuable species or habitats, decisions related to oil spill response often become controversial. This "outrage" factor varies geographically and is related to the size of the spill, but it has made response planners very cautious about new or controversial response options, and at the same time anxious to find ways to improve oil spill response capability.

Historically, oil spill response in the United States (US) has relied primarily on mechanical on-water recovery. On-water mechanical recovery is attractive because it is the only response option that leads to the recovery of at least some of the product. Experience, however, shows that mechanical recovery rarely results in recovering more than 10–20% of the spilled oil. In and of itself, mechanical recovery does not provide the desired level of protection for sensitive resources threatened by oil slicks.

One consequence of this situation has been a strong desire on the part of many of the stakeholders to broaden the consideration of alternative countermeasures, with the objective of integrating all of the appropriate options to the develop the "best" possible response. Since no countermeasure, i.e. mechanical on-water recovery, *in situ* burning (ISB), chemicals (particularly dispersants), or shoreline recovery is risk-free or completely effective, it becomes important to have a defensible method to compare the risks and benefits of all, especially when used in combination. This approach has been viewed with suspicion by some advocacy groups, who worry that this is no more than an attempt to find "cheaper" response options at the expense of the environment. This issue can be more clearly understood by examining the status of dispersant use, one of the more controversial alternative response options.

Dispersant use provides an increased level of shoreline and surface resource protection, but does so by increasing the potential exposure of resources in the water column. In contrast to on-water recovery, environmental considerations rather than engineering efficiency drive decisions about dispersant use.

Opponents of dispersant use often argue that dispersants simply represent an attempt by the industry to avoid "better" but more expensive response options, or to reduce the visibility of the environmental consequences of oil spills by "hiding" the oil in the water column where its adverse effects cannot be seen.

Proponents respond that, while dispersant application may be cheaper, that should not be a predominant issue. Examination of environmental tradeoffs demonstrates that dispersant use can significantly enhance net environmental benefit in many spill situations. Proponents also argue that dispersant use may prevent oil from entering sensitive habitats, that the potential effects of dispersed oil in the water column are mitigated by dilution and enhanced biodegradation, and that mechanical recovery is often not feasible.

The available information on dispersant use can be confusing, contradictory, and difficult to interpret. Past discussions often focused on an assessment of dispersant use consequences against arbitrary exposure

~~criteria, rather than as part of a~~ comparative review of the advantages and disadvantages ~~relative to other~~ response options ~~(e.g., mechanical recovery). Such philosophical and technical debates are often best resolved~~ through an objective, well documented process ~~to evaluate the advantages and disadvantages of all response options.~~ Side-by-side comparisons of the environmental tradeoffs involved with each response option ~~should~~ assist planners and decision-makers in developing an integrated response program.

This is not a particularly new concept, and for many years there has been discussion concerning "environmental trade offs" as a way to improve oil spill response planning (Baker 1997). To date, however, there has been limited success in applying any systematic approach.

1.2 ASSESSMENT OBJECTIVES

This report presents the results of developing a "cooperative ecological risk assessment (ERA)" analysis for two hypothetical spill scenarios in Galveston Bay. The objectives of the process were to:

- ~~Demonstrate the feasibility of using this approach;~~
- Develop and document tools and protocols that could be used in future analytical efforts;
- Evaluate and compare the ecological consequences of oil spill response options in the scenarios;
- ~~Develop recommendations for consideration by local response organizations concerning the proper role for the response options under consideration.~~

1.3 ORGANIZATION OF THIS REPORT

This is a report ~~to~~ the ERA process as it was applied ~~in~~ Galveston Bay Texas to examine the mix of response options available ~~to~~ ~~respond~~ to two specific oil spill scenarios occurring at the intersection of the Gulf Intercoastal Waterway and the Houston Ship Channel. The report was assembled by the project team on behalf of all participants in the process. It represents the consensus assessment of the participants regarding the ecological impacts of each of the potential response options available in the area. The report is organized into seven basic chapters and supporting appendices.

Chapter 1 is an introduction and overview of the objectives for the Galveston Bay ERA.

Chapter 2 discusses the ERA process in general and its adaptation for use in oil spill planning.

Chapter 3 starts with an overview of oil spill risk in Galveston Bay, describes spill response management considerations and available response options and ends with a description of the scenarios developed for use in this assessment process.

Chapter 4 describes the process for developing the Galveston Bay conceptual model based on the scenarios described in chapter 3. It includes identification of resources of concern, pathways of exposure and analysis endpoints.

Chapter 5 describes the risk assessment methodology and the tools used in conducting actual risk assessment, including the risk matrix, oil transport modeling, and oil budgets.

Chapter 6 details the results of the analysis by habitat type and scenario.

Chapter 7 details sources of uncertainty and data adequacy that participants dealt with in reaching their consensus decisions.

Chapter 8 summarizes conclusions and recommendations for use of this report in improving spill response in the Galveston Bay.

CHAPTER 8: CONCLUSIONS AND RECOMMENDATIONS

The final summary risk matrices included in this report (Chapter 6) represent the consensus estimate of the participants regarding the potential impacts of various stressors on resources and habitats in the Galveston Bay area. Certain conclusions and recommendations can be drawn from those consensus estimates.

The process used herein ~~is replicable, and~~ should be adapted as a regular part of the area contingency planning process.

During the process, several tools were developed which enabled participants to work through the risk assessment process, applying scientific data and ~~conservative~~ assumptions to model relative impacts. These tools, particularly the risk square and the habitat/stressor matrices, can be ~~replicated for~~ other scenarios at the local level on a continuing basis.

The potential impact estimates contained in the summary matrices are directly applicable only to the scenarios described herein. The results are not directly transferable to any other spill situation in the Bay. However, the results do ~~provide an~~ indicat~~or of~~ the potential for broader application of certain response options (~~particular~~ dispersants and *in situ* burning) in Galveston Bay.

Development of similar assessments using this process ~~will~~ increase the knowledge base regarding stressor impacts on ~~all~~ resources and habitats in Galveston Bay. In the short-term, this ~~will~~ result in an improved incident-specific decision process because decision-makers will have a standardized set of tools (with which they are familiar) to use in evaluating response options.

In the longer term, the decision making process ~~will~~ be shortened, as more scenarios are worked in different locations and using different oils, patterns of potential stressor impacts will emerge which ~~will~~ ultimately provide a~~n~~ data base which is extractable for use with minor modification in various spill situations.

Specific information regarding response options in Galveston Bay was generated as a result of this ERA.

The following response-specific points were agreed upon by participants:

- On-water recovery or ISB, used alone, offer ~~little~~ risk reduction over natural recovery.
- Dispersion and shoreline cleanup, used in combination and/or used alone, indicate improved environmental benefits over the use of natural recovery, ISB or on-water recovery. However each of those techniques involves tradeoffs as well, e.g. dispersants shift concerns from shoreline resources to water column resources.
- The optimum response is likely to involve some combination of the response options available.
- ~~Resource managers in the response option selection process. Response and resource managers need to "think tactically not just strategically."~~
- ~~Dispersants and ISB should not be considered solely for use on major spills, as they may provide critical environmental protection~~

in near shore areas for small spills as well.

This ERA is not an evaluation of all habitats, nor is it permission to use dispersants on every spill.

An evaluation of all habitats was not done. For example, an evaluation of the impacts of various stressors on submerged aquatic vegetation (SAV) was not performed because there is no SAV in the scenario area. Habitats not addressed herein should be evaluated in future assessment exercises.

This ERA does not encourage use of dispersant on every small spill. As noted above, although dispersants were estimated to minimize environmental harm in this assessment, results might be different with different oil types, spill locations or other variables.

"Small spill" guidelines for dispersant use resulted from this ERA.

An oil spill of 200-300 barrels represents the practical lower limit for dispersant and ISB use. Spills smaller than that are likely to dissipate too rapidly to allow for mounting an effective dispersant operation.

For spills in the 200-300 barrel range, dispersant use should be considered if it offers the potential to prevent oil from impacting a specific, highly sensitive area.

In order to implement a "small spill" dispersant plan in the Galveston Bay area, Regional Response Team and Area Committee members will have to assess existing dispersant use decision processes and develop an expedited decision process for inshore areas.

Results of this ERA are conservative.

Participants are confident that the consensus conclusions regarding relative impacts are conservative; that is, they tend to over-emphasize the potential impact of each stressor onto the environment. In an actual spill situation participants would expect to see less damage than was predicted. Participants acknowledge that their conclusions are based on incomplete data, but that available data was sufficiently detailed and robust to support the groups' conclusions. In order to add validity to the results of the current ERA as well as future assessments, participants noted that more information is needed on operational effectiveness of dispersants and exposure concentration and duration in the environment.