Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part A: Description of Models and Assumptions

by

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ASA 00-246

August 2004

Preface

This technical report is a supplement to the Programmatic Environmental Impact Statement (PEIS: US Coast Guard, 2004) in support of the US Coast Guard's (USCG) Notice of Proposed Rulemaking (NPRM, USCG, 2002) regarding Vessel and Facility Response Plan oil removal capacity (Caps) requirements for tank vessels and marine transportation-related facilities. The PEIS (USCG, 2004), in accordance with National Environmental Policy Act of 1969 (NEPA), examines a series of alternatives, including a no action alternative, which could influence the availability of oil spill response equipment around the United States.

This technical report is in six (6) parts:

1. Part A contains a description of the approach, models, methods, and underlying assumptions used in the analysis. The sources of input data and data applicable to all locations are described. Part A also contains a general description of the model outputs. References for all citations of Parts A to F are in Part A.
2. Parts B to F contain:
    a. Input data and assumptions specific to each of the 5 locations where model runs were performed
    b. Model results for each spill volume and response alternative for these 5 locations;
    c. Analysis of potential benefits and risks to resources of concern for each of these locations and various spill response alternatives.

Citation for entire report:

> French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Lord, C. Dalton, R. Levine, J. Rowe, S. Sankaranarayanan, H-S. Kim, R. Piovesan and M. Hitchings, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, March 2004, 6 volumes.

Citations for parts of the report:

Part A: Description of Models and Assumptions:

> French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Dalton, R. Levine, J. Rowe, S. Sankaranarayanan and H-S. Kim, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios, Part A: Description of Models and Assumptions. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, March 2004.

Parts B to F:

French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Lord, C. Dalton, R. Levine, J. Rowe, S. Sankaranarayanan, H-S. Kim, R. Piovesan and M. Hitchings, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios, Part B: Delaware Bay and Mid-Atlantic Shelf. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, March 2004.

Part B: Delaware Bay and Mid-Atlantic Shelf.
Part C: Galveston Bay and North Texas Shelf
Part D: Florida Straits
Part E: San Francisco Bay and Central California Shelf
Part F: Prince William Sound

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A. DESCRIPTION OF MODELS AND ASSUMPTIONS

A.1 INTRODUCTION

A.1.1 Background

This technical report was prepared to provide technical input to the Programmatic Environmental Impact Statement (PEIS: US Coast Guard, 2004) in support of the US Coast Guard's (USCG) Notice of Proposed Rulemaking (NPRM, USCG, 2002) regarding Vessel and Facility Response Plan oil removal capacity (Caps) requirements for tank vessels and marine transportation-related facilities (based on Caps review, USCG, 1999). The PEIS (USCG, 2004), in accordance with National Environmental Policy Act of 1969 (NEPA), examines a series of alternatives, including a no action alternative, which could influence the availability of oil spill response equipment around the United States. The proposed regulations would affect existing requirements for regulated vessels and facilities to contract for mechanical recovery, the use of dispersants, and the use of in-situ burning (ISB). While all of these technologies are currently available for use in all or some regions of the country, the regulated community is only required to contract for certain quantities of mechanical recovery equipment, but not for either dispersant or ISB equipment. The primary issue in the PEIS (USCG, 2004) is the potential for the regulations to change the response option mix (i.e., greater availability of both dispersant and ISB equipment), and therefore, the frequency of use of those options.

It is a matter of public policy to provide a response to spill incidents in order to mitigate the adverse environmental impacts of spilled oil. It is also true, however, that no response option can eliminate or prevent all environmental effects and that each response option may have environmental consequences of its own. Therefore, the purpose of the PEIS is to assess the potential environmental impacts for each of these options, separately and together, within the operating environments where those options are likely to be used. The NPRM and this PEIS assume that the following critical factors are necessary to determine the likelihood of use for any response alternative:

1) Range of oils for which effectiveness of the option in mitigating adverse impacts is assumed;
2) Limitations on effectiveness due to weather, current, water depth, etc.;
3) Whether use has been pre-authorized by the response community, and under what conditions; and
4) Availability of equipment to carry out the response option.

The NRPM defines the extent to which the first three critical factors have been met as a basis for proposing how the fourth one should be met. The PEIS assesses the potential impact of meeting the fourth factor in the context of the first three.

A.1.2 Role as Technical Support to the PEIS

The effects of oil spills are difficult to predict and are highly site- and event-specific. The analysis of the alternatives presented in the PEIS is based on a four-phase approach. First, generic information is developed to establish broad expectations for the effects of oil spills in general. These establish a range of expected effects for oil spills in the various geographic regions considered in the PEIS. Second, in order to develop estimates of the potential degree of exposure and effects that might result from oil spills and response activities, five representative locations around the U.S. were selected as sites of a detailed analysis using the Spill Impact Model Application Package (SIMAP) oil spill model. The SIMAP model evaluates both physical fates and biological effects of oil spills, and may be run in probabilistic mode, which is needed to evaluate environmental risks (as discussed in Section A.1.3). Third, the results of the modeling effort were evaluated using a relative risk approach (see Section A.1.5) to provide an estimate of the magnitude of the risk from two different size spills, 2,500 and 40,000 bbl (bbl), and the potential influence of various response options. Finally, all of this information was integrated to evaluate the expected regional impacts, for small (200 bbl), medium (2,500 bbl) or large (40,000 bbl) oil spill at an average location.

Since oil spills are variable in size, location, and type of product, as well as being sensitive to a wide range of environmental variables, it is necessary to provide some reasonable basis for the interpretation of potential impacts — this technical report provides such a basis. The analysis in this technical report, which documents phases two and three described above, is in several steps:

1) Oil spill modeling provided quantitative estimates for the expected impacts of various response options. Model runs were made for representative scenarios in each region considered in the PEIS (USCG, 2004). Descriptions of the models used, the locations selected, and the scenarios modeled are described in subsequent sections of Part A of this technical document.
2) The model results and other information are used to evaluate potential environmental impacts to resources in each region considered in the PEIS (USCG, 2004). These evaluations are in Parts B through F of this technical document.
3) The model results are categorized with risk scores, defining levels of concern for a resource in terms of extent of exposure and length of recovery. The risk scores were used in assessing the relative impacts to various resources in the PEIS (USCG, 2004). The methodology for the risk score matrix is described in Section A.1.5. The evaluations are in Parts B through F of this technical document.

This volume (Part A) contains (1) a description of the model algorithms and assumptions and (2) general sources and methods for compiling model input data, (3) the design of the model runs performed, and (4) an explanation of model outputs used in impact analyses. Section A.2 describes the oil spill model used for this analysis. Section A.3 describes the oil spill model input data and assumptions. (Note that assumptions used are based on best available information, such as laboratory or field data, or logic based on these data.) An explanation of oil spill model results is in Section A.4. Section A.5 describes the atmospheric dispersion model used to estimate exposure concentrations in the air immediately above the water surface in the spill area. The concepts and assumptions for the socioeconomic impacts model are in Section A.6. References cited are in Section A.7.

Subsequent volumes (Parts B to F) contain (1) descriptions of the location-specific input data, (2) results for each location where modeling was performed, and (3) analysis of potential effects for the spill scenarios examined, including the derivation of risk scores. There are numerous tables, maps and other figures output from the modeling. These are contained in appendices to Parts B to F. The main text in each of Parts B to F (sections B.1 to B.4, etc.) describes the input data, model results and impact analyses.

A.1.3 Need for Quantitative Estimates and Benefits of Model Use

The fate and effects of oil spills will vary depending on the environmental conditions at the time of the spill and the biological and socioeconomic resources exposed to the oil. The available data from real spill case studies do not sufficiently indicate what the potential effects might be in every combination of conditions that might occur. However, the information learned from past spills, as well as laboratory and tank studies, has been analyzed and synthesized into oil fates and effects models. This information represents our best understanding of the processes and potential for effects.

Modeling provides quantitative estimates of the potential pathways and fates of the oil, and thus estimates of exposure to water surface, shorelines and other habitats, water column, and sediments. These estimates may be used to evaluate potential effects on wildlife, aquatic organisms, shorelines, habitats, and socioeconomic uses of those resources. The alternative to modeling would be to make general non-quantitative statements about impacts. This would cause the distinction between dispersant versus no-dispersant-use scenarios to be imprecise, instead being based on subjective judgments and incomplete information. The modeling results provide quantitative best-estimate results that can be compared in an objective manner.

There are many possible spill scenarios that could be modeled, as well as an essentially infinite number of potential spill sites. However, this modeling was performed for a finite number of scenarios that sufficiently provides an understanding of the expected impacts resulting from spills under the various response options. A stochastic (Monte Carlo) approach was used to allow the range and frequency of possible environmental conditions to be examined for each spill site, spill volume and response option evaluated. Long term (decade or more) wind and current records were sampled at random and model runs were performed for each of the spill dates-times selected. This provided a statistical description of the environmental fate and effects that would result if a spill occurred. The alternative to using a stochastic approach is examining selected individual model runs under certain selected environmental conditions. This would not represent all possible events and would provide biased results. Moreover, it is impossible to determine *a priori* (before running many model runs) what particular environmental scenarios would be representative or worst case. In addition, what is representative or worst case varies depending on the resource examined. For these reasons, the probabilistic approach is necessary to evaluate potential environmental effects on biological and socioeconomic resources.

Stochastic modeling was performed in five geographic locations of the US to be representative of all six of the PEIS regions:

- Offshore of Delaware Bay representing the Atlantic region,
- Offshore of Galveston Bay representing Gulf of Mexico region,
- Offshore of San Francisco Bay representing Pacific region,
- Prince William Sound representing Alaskan region, and
- Offshore of the Florida Keys representing subtropical and tropical regions (Caribbean and Oceania regions).

The selected modeling locations are all at the entrances to high volume ports or in high traffic shipping lanes where the risk of oil spills is high. In order to standardize the analysis at each location, the spill was at a point 7.5 nautical miles from shore, in the shipping lane. This is the approximate midpoint of the nearshore zone for response, which extends outward 12 miles from about three miles from shore. (Current dispersant and *in situ* burn pre-authorization or expedited approval zones around the country generally extend seaward from 3 mi offshore in the coastal waters, except for Maine and New

Hampshire, where these zones start at 1.5 mi from shore). This represents a reasonable position for the use of any of the three response options under consideration, based on existing preauthorization zones.

These five sites were selected to provide a broad geographic representation of high-risk areas, not on the basis of their ecological characteristics. However, these sites also provide a sense of the risk on both a national and regional level, because they are broadly characteristic of the coast as a whole.

In evaluating the potential impacts of spills in the six regions considered in the PEIS (USCG, 2004), inferences were drawn from the modeling results from all spill locations modeled. For example, the amount of water surface oiling and the water volume contaminated is similar for a given spill volume and environmental conditions regardless of where the spill occurs. Thus, the physical fates results of a specific spill site can be extrapolated to other locations and regions.

With respect to the biological effects, the major habitats are unique to each of the five modeled geographic locations. For example, the Florida Keys location contains mangrove, tropical seagrass beds, and coral reefs typical of the Caribbean and Oceania. The Atlantic coast contains saltmarshes dominated by *Spartina* spp. and eelgrass (*Zostera marina*) beds, while the Pacific coast contains kelp beds (*Macrocystis* spp.) and wetlands dominated by species other than *Spartina*. Alaskan waters, while also unique, have ecological similarities to the areas off Maine and Washington/Oregon. The fish and invertebrates of these habitats also vary by these broad areas. In addition, the temperature and weather regimes will cover the characteristic ranges of each region considered in the PEIS. Thus, results from the modeled location may be extrapolated to other spill sites in the same region that are sufficiently similar in water depth and distance from shore.

While these five locations broadly represent major ecological systems, no single site provides specific information for an entire region. The purpose of the modeling effort is to examine generalities about the spills, based on the stochastic approach, which can then be applied more broadly. For example, if modeling results indicate that when dispersants are used the water column concentrations of concern for corals are never exceeded more than one mile away from the Florida Keys spill site, regardless of the environmental conditions, then it is reasonable to assume that in any similar location there may be a similar, limited risk to corals. It is also reasonable to assume that if the model results indicate that surface oil would significantly contaminate shorelines at significant distances, then a similar threat could exist in other areas at near equal distance from shore. These considerations were made on a resource-by-resource basis, and are discussed in Parts B through F.

A.1.4 Basic Model Scenario

Oil spill modeling was performed to assess the potential consequences of oil spills in the five representative locations in US near shore waters (described above). Various response scenarios were simulated to provide data to be used in the evaluation of potential impacts of alternative response scenarios in the PEIS (USCG, 2004). In addition to modeling of oil fates on and in water, air dispersion modeling was performed to evaluate potential impacts of spills and response actions on air quality. The objective was to provide an assessment of the potential pathways and fate of the oil, and thus estimate exposure on/in the water surface, shorelines, water column, sediments, and the atmosphere. These were used to evaluate potential effects on wildlife, aquatic organisms, habitats and socioeconomic resources on a region-by-region basis.

The oil spill modeling was performed using SIMAP (Version 4.3) developed by Applied Science Associates (ASA). In a recent review of oil spill models by the National Research Council of the National Academy of Sciences (NRC, 2002a), SIMAP was found to be the most comprehensive model available, based on the fates processes simulated, the inclusion of a biological exposure and effects model (not available in other models), and the ability to run the model in stochastic (probabilistic) mode (necessary for ecological risk assessments and also unique to SIMAP). SIMAP also makes use of the recently published oil toxicity algorithm (French McCay, 2002) that addresses the different toxicities of the various hydrocarbons in oil and their additive toxic effects.

The oil fates model in SIMAP uses wind data, current data, and transport and weathering algorithms to calculate the mass of oil components in various environmental compartments (water surface, shoreline, water column, atmosphere, sediments, etc.), oil pathway over time (trajectory), surface oil distribution, and concentrations of the oil components in water and sediments. Hourly wind speed and direction data over a long historical period were obtained from nearby meteorological stations for each representative location. Tidal and other currents were modeled based on known water heights, using a three-dimensional hydrodynamic model based on physical laws (described in Section A.3.3). Geographical data (habitat mapping and shoreline location) were obtained from existing Geographical Information System (GIS) databases based on Environmental Sensitivity Indices (ESI) that identify shore type. Water depth was available from National Oceanic and Atmospheric Administration (NOAA) National Ocean Service (NOS) soundings databases. SIMAP was used to evaluate exposure of aquatic habitats and organisms to whole oil and potentially toxic components.

The oil spill model in SIMAP provided estimates of hydrocarbon mass lost to the atmosphere by volatilization. These data were input to an air dispersion model, which is part of the chemical fate and transport model CHEMMAP (Chemical spill Model Application Package, Version 4.3, developed by ASA). The air dispersion model simulated the wind transport, turbulent dispersion and degradation rate of hydrocarbons evaporated from the spill, with an output of concentration in the lower atmosphere over time. The air emissions from ISB were evaluated with an empirical burning model (Fingas et al., 2001) that predicts air concentrations as a function of distance from the fire. The predicted air concentrations were compared to air quality criteria as part of the analysis.

The oil spill modeling was run in stochastic mode to determine the probabilities and degrees of exposure. A large number of simulations (i.e., 100) were run for a given spill site, oil release and oil response scenario, varying the spill date and time, and thus the environmental conditions, for each run. The output of the stochastic model includes time histories of a large number of spill trajectories. These distributions are used to (1) estimate the percent of runs (weather conditions) where air, water surface, water column, and shoreline areas would be affected by a release from the given site; (2) determine the highest exposure in time for each possible environmental condition (each run); and (3) identify the distribution of degrees of exposure for all runs.

In order to perform the modeling, the following input data sets were prepared for each of the five representative locations examined, as described generally in Section A.3, and specific to each modeled location in Appendix I to Parts B through F:

1) Geographical data – Shoreline location, shoreline/habitat type, and bathymetric (water depth) mapping

2) Current data – Tidal and other currents
3) Wind data – Long-term (decade or more) wind record of hourly wind speed and direction
4) Environmental data – Water salinity and temperature data by month of the year were compiled, along with estimates of suspended sediment concentration and turbulent dispersion rates

Two spill volumes were assumed for medium and large spills (2500 bbl and 40,000 bbl). Coast Guard regulations (33 CFR 155.1020) define various spill sizes, and these volumes were developed from those definitions. The regulations define the Worst Case Discharge as the loss of all cargo from a tank vessel. The use of this volume (which could exceed 200,000 bbl, depending on the vessel size) would overwhelm any of the available response options, and prevent any discrimination between the alternatives. On that basis, the "large" volume was selected to be the loss of cargo from two storage tanks, which is approximately 40,000 bbl. The Maximum Most Probable Discharge is defined as 2,500 bbl, and this volume was used to represent a "moderate" spill.

The oil types modeled were South Louisiana crude oil for the Atlantic, Gulf of Mexico, and Florida locations; and Alaskan North Slope crude oil for the Pacific and PWS locations. These oils were chosen to be representative of shipping in each region, and to be consistent from region to region to allow comparisons.

Three response scenarios were modeled for each of two spill volumes and the five geographic locations:

- mechanical removal at present levels of capability, or with some of that removal accomplished by ISB;
- the same mechanical removal response as above, or with some of that removal accomplished by ISB, plus dispersant application at 45% efficiency (based on minimum dispersant effectiveness criteria established in the National Oil and Hazardous Substances Contingency Plan, NCP – 40 CFR Part 300); and
- the same mechanical removal response as above, or with some of that removal accomplished by ISB, plus dispersant application at 80% efficiency (based on theoretically successful dispersant operation).

The modeled response scenarios apply to several of the alternatives being considered in the PEIS, depending upon the combination of response capabilities required. For example, for the no action alternative (Alternative 1) in the Atlantic, Caribbean, Pacific, and Oceania regions, only mechanical or ISB would be used, but not dispersants. Thus, the first of the three modeled response scenarios applies to Alternative 1 in these four regions. For Alternative 1 in the Gulf of Mexico and Alaska regions, where dispersant capability already exists, the modeled response scenarios involving dispersants apply. For Alternative 3, where dispersant capability would be required, the modeled response scenarios involving dispersants also apply. The applications of the modeled scenarios to the alternatives are described in Parts B through F of this technical report and Sections 4.5 to 4.9 of the PEIS (USCG, 2004).

A.1.5 Evaluation of Relative Ecological Risk

Given the inherent uncertainty associated with oil spills, it is very difficult to assess and compare the relative costs and benefits of the alternatives presented in the PEIS. There are two areas of concern. The first is the absolute potential impact, and the second is the relative risks and benefits of using various response options. In addition, the anticipated effects need to be placed in an ecological or socioeconomic context so that their significance can be estimated. The approaches used to interpret the modeling results in order to address these goals are described below.

The discussion of the affected environment (Section 3 of the PEIS) identified 24 resource categories. These same categories are used for the evaluation of potential impacts, but not all of these could be quantified using the modeling results. The objective of the analysis is to compare the overall costs and benefits of each alternative (nationally and regionally) to each of these resources. In order to make these comparisons, it is important to establish a frame of reference that provides some standard basis. Our analysis used a risk matrix approach to define levels of concern (as an indicator of significance) for the ecological impacts. The approach to the socio-economic analysis is discussed in Section A.6.2.

Risk matrices have a long history as a way to evaluate the interrelationship of scaled variables. Their use as a basic decision tool for risk analysis is discussed by Paul (1998). They have been used to support risk decisions in a wide range of areas, including such diverse subjects as business planning, engineering decisions, sales and promotion strategies, foreign policy or military strategies, to name only a few. Norton (1991) was an early proponent of the use of a risk matrix using spatial scale, temporal scale and reversibility to address relative ecological risk. In a review of analytical approaches available for ecological risk assessment, Norton (1996) reviewed the risk square approach for both economic and ecological risk evaluation. He concluded that it could be a valuable tool for both. According to Harwell *et al*. (1994), this approach is consistent with the goals and objectives of the U.S. Environmental Protection Agency's Ecology and Welfare Subcommittee of the EPA Relative Risk Reduction Project. They found that the "ecological risk square can be useful for analyzing decisions that have long-term, difficult to reverse, and spatially pervasive impacts." Foran and Ferenc (1999) reviewed available ranking methods which involve the use of matrices comparing stressors and endpoints and found them to be a useful analytical tool. The National Academy of Sciences (NRC 1992) used a risk square as a "project assessment matrix" to interrelate human and ecological value scales as a way to plan and analyze potential restoration projects for aquatic ecosystems. Their goal was to find projects which met both ecological and sociological value scales. Belluck *et al* (1993) reviewed the utility of generic risk assessments for ecological planning decisions, and concluded that a descriptive evaluation supported by qualitative data provided an appropriate level of detail.

The matrix developed for this analysis allows the evaluation of two parameters, the extent of exposure versus length of recovery time for the resource. This follows the approach described by Norton (1991) and Harwell *et al*. (1994). The proportion of the resource (spatial scale) and time of recovery provide sufficient resolution to effectively rate ecological impacts. These parameters describe the level of effect for each possible interaction between a risk factor (such as dispersed oil) and a resource under evaluation. The entire set of risk scores for each option can then be evaluated and compared. For the purpose of the analysis, the estimates of ecological risk are based on the series of oil spill scenarios described below. These scenarios were selected to be representative of conditions where spills are likely to occur beyond three nautical miles from shore, but do not represent every possible situation. The risk scores relate to those particular scenarios, and must be interpreted with care. Patterns across regions or within scenarios, however, do offer insight into the relative risks and benefits of the alternatives.

It is theoretically possible to estimate economic losses or damages associated with ecological impacts, as is often done in support of Natural Resource Damage Assessment (NRDA) or cost-benefit studies. This might involve valuation studies or costs of restoration/remediation. In the case of the PEIS, however, the risk matrix approach was selected instead of attempting to evaluate losses in monetary terms, for the following reasons:

1. While monetary valuations related to ecological loss have been attempted in a variety of contexts, the relationships are not well developed and are very site specific.
2. The locations selected for the modeling analysis are not the most sensitive areas to oil spills, but rather are representative locations where oil spills are more likely to occur. While the results at these locations can offer insight into the likely ecological consequences elsewhere in the region, calculating monetary damages for specific locations could be misleading.
3. Estimates of economic damages would vary more between modeling locations than the ecological measures of effect, making it more difficult to generalize between locations.
4. Finally, given all of the assumptions in the modeling analysis, monetary estimates of damages would be more imprecise than the ecological parameters selected for analysis. In addition, they are not critical for this analysis, where the appropriate measures of significance relate to ecological integrity and recovery.

The simplest risk matrix is a two by two square (Table A.1-1). For example, consider a matrix 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 (2 by 2) 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 (Table A.1-1). Obviously, a 2 by 2 matrix does not allow much in the way of resolution and is ineffective in rating impacts. On the other hand, if you use something like a 10 by 10 matrix, the scaling becomes challenging and the resulting 100 ranks are difficult to interpret.

Table A.1-1. Basic Ecological Risk Matrix.

		RECOVERY	
		1. Irreversible	**2. Reversible**
MAGNITUDE	**A. Severe**	1A	2A
	B. Trivial	1B	2B

The use of the "risk matrix" in the context of oil spill response planning was described in Pond et al. (2000) and Aurand et al. (2000). Since that time the process has also been used for evaluations in the Santa Barbara Channel area of California and in the middle Chesapeake Bay. Normally, four or five risk categories on each axis (Pond et al, 2000; Aurand et al, 2000) allow a reasonable degree of resolution. Once the detailed matrix has been completed, it is generally useful to establish simplified categories for comparison purposes, based on summary levels of concern.

Table A.1-2 provides the risk matrix used in this analysis. It is based on an evaluation of two factors for each resource (physical, biological or socioeconomic) included in the analysis. These factors are 1) the proportion of the resource affected by the action and 2) the time for the resource to recover. The scaling is based on the Project Team's best professional opinion as to the appropriate intervals which would allow discrimination of impacts of most concern, as well as differences between response options.

Table A.1-2. Risk Matrix and Definition of Levels of Concern.

		Time to Recovery			
		>7 years (SLOW) (1)	3 to 7 years (2)	1 to 3 years (3)	<1 year (RAPID) (4)
Percent of Resource Potentially Affected	>20% (LARGE) (A)	1A	2A	3A	4A
	10 to 20% (B)	1B	2B	3B	4B
	5 to 10% (C)	1C	2C	3C	4C
	1 to 5% (D)	1D	2D	3D	4D
	0 to 1% (SMALL) (E)	1E	2E	3E	4E

Legend: Black cells represent a "high" level of concern, medium gray cells represent a "moderate" level of concern, and light gray cells represent a "limited" level of concern.

In Section 4.3 of the PEIS (USCG, 2004), thresholds that determine the consequences of and recovery from the various risk factors (oil toxicity, dispersant toxicity, oil coating, mechanical damage, etc.) associated with each alternative were developed. The thresholds can be compared to the results of the modeling runs for the five selected locations (see Section 4.4 of the PEIS) in order to determine the relative risk to the resource under each response option, and that in turn can be summarized as a "high, moderate, or limited" level of concern.

As a simplified example of this approach, assume that a hypothetical oil spill could affect only two resources, seabirds congregating on the sea surface or a coral reef, and that there were only two response options, on-water mechanical recovery and treatment with dispersants. Further, assume that mechanical recovery is effective in removing 25% of the surface oil before the slick reaches the area where the seabirds are congregated, but that the remaining oil is still sufficient to coat a large number of birds with oil, and most subsequently die. Based on biological data, assume the loss to the population represented about 50% of the area's population, and this particular species is long-lived and has a relatively low rate of reproduction, so recovery will take seven to ten years. There is little to no oil found in the water column. This means that there will be little risk to corals, because the oil will float past the reef and not affect the coral itself or sensitive water column organisms. In the other option, assume that dispersant application is highly effective, removing enough of the surface oil so that the slick largely dissipates before reaching the seabirds and many fewer die. Recovery is still slow, based on their life history. There is also an elevated exposure to dispersed oil in the water over the coral reefs. Concentrations above ten meters in depth exceed a level that can kill coral larvae (based on continuous exposures for 96 hours in the laboratory), but those concentrations are only present for three hours. All of the coral reefs themselves are at depths below the ten-meter level.

Table A.1-3 shows, for this hypothetical example, a comparison of the two alternatives (on-water mechanical recovery and dispersants) relative to their impacts on the two resource groups. The use of mechanical recovery leads to a high level of concern for birds, based on the removal of a large portion of a population that is slow to recover. It does not, however, pose more than a low level of concern for the coral reef, since the small amount of dissolution and dispersion, which occurs as a result of natural processes, does not threaten either the reef itself or larvae in the water column. When dispersants are used, the seabirds are exposed to much less floating oil and many fewer die. The number now lost from the population is similar to natural mortality in many years, and the population can be expected to recover in three to seven years. The coral reef area is exposed to enough oil that there is a risk to larval organisms in the water column, but the area affected, relative to the area where coral larvae occur is not large. The adult corals are not affected. Dilution rapidly reduces the risk. Based on the potential loss of some larvae, but their rapid recovery, the level of concern increases slightly, but remains an overall low level of concern. Therefore, in this example, the use of dispersants reduced the level of concern for seabirds from “high” to “moderate”, while the risk to coral reefs remain unchanged as “limited”.

Table A.1-3. A Hypothetical Example of the Use of Relative Risk Scores to Compare Response Options

Response Option	Resource at Risk	
	Seabirds	**Coral Reef**
On-Water Mechanical Recovery	1B	4E
Dispersant Application	2D	4D

Obviously, the evaluation required for this analysis is much more complicated than the example; however, the principle is the same. For each modeling run the appropriate thresholds are used to estimate the potential impact to the resource group under consideration. The predicted amount of the resource affected is then compared to the total resource present in the appropriate biogeographical provinces, as delineated in Section A.4 below, and an estimate made of the time for the resource to recover. Basic biological and life history data for representative species or habitats, as well as spill studies was used to estimate recovery time. Using these data, a risk score is developed for each option for each resource. This score, along with the explanatory narrative, forms the basis for the evaluation of the modeling results (contained in Parts B through F). The modeling results, in turn, are placed in a regional context for the analyses of alternatives in Sections 4.5 through 4.9 of the PEIS (USCG, 2004).

A.2 OIL SPILL MODEL ALGORITHMS

The modeling analysis was performed using SIMAP. SIMAP includes (1) an oil physical fates model, (2) interfacing to a hydrodynamics model for simulation of currents, (3) biological exposure and effects models, (4) an oil physical, chemical and toxicological database, (5) environmental databases (winds, currents, salinity, temperature), (6) geographical data (in a GIS), (7) a biological database, (8) a response module to analyze effects of response activities, (9) graphical visualization tools for outputs, and (10) exporting tools to produce text format output.

SIMAP was developed from the oil fates and biological effects submodels in the Natural Resource Damage Assessment Model for Coastal and Marine Environments (NRDAM/CME), which ASA developed for the US Department of the Interior for use in Natural Resource Damage Assessment (NRDA) regulations under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA). The NRDAM/CME (Version 2.4, April 1996) was published as part of the CERCLA type A NRDA Final Rule (Federal Register, May 7, 1996, Vol. 61, No. 89, p. 20559-20614). The technical documentation for the NRDAM/CME is in French et al. (1996a,b,c). This technical development involved several in-depth peer reviews, as described in the Final Rule. Below are descriptions of the fates and effects models as now implemented in SIMAP. Reference is made to French et al. (1996a,b,c) where algorithms remain unchanged from the NRDAM/CME or to later papers and reports which describe more recent development.

While the NRDAM/CME is focused on natural resource damage assessment, SIMAP is designed to evaluate fates and effects of both real and hypothetical spills. SIMAP may be run in stochastic mode to evaluate a distribution of spill results, rather than just a single result for a specific hindcast. Most of the updates of the model to develop SIMAP are designed for allowing the use of site-specific data and for evaluation of the distribution of effects.

A.2.1 Physical Fates Model

The physical fates model estimates the distribution of oil (as mass and concentrations) on the water surface, on shorelines, in the water column and in the sediments. The model is three-dimensional, using latitude-longitude grids for environmental and geographical data. Algorithms based on state-of-the-art published research include spreading, evaporation, transport, dispersion, emulsification, entrainment, dissolution, volatilization, partitioning, sedimentation, and degradation. Oil mass is tracked separately for lower molecular weight aromatics (1 to 3-ring aromatics) which cause toxicity, other volatiles, and non-volatiles. The lower molecular weight aromatics dissolve from the whole oil and are partitioned in the water column and sediments according to equilibrium partitioning theory (French et al., 1996a, 1999; French McCay, 2004).

SIMAP includes the physical fates model in the NRDAM/CME (French et al., 1996a), with several changes and additions (French et al., 1999; French McCay, 2003, 2004). The additions to prepare SIMAP from the NRDAM/CME were made to increase model resolution, allow modification and site-specificity of input data, allow incorporation of temporally varying current data, evaluate subsurface releases and movements of subsurface oil, enable stochastic modeling, and facilitate analysis of results.

The consideration of the effects of subsurface oil is important, particularly in the evaluation of effects on aquatic organisms with and without dispersant use. Surface oil is not the only exposure pathway for effects, and surface oil primarily affects wildlife rather than aquatic biota. At higher wind speeds (than about 12 knots), oil will entrain into the water column, unless it has become too viscous to do so after the formation of mousse. Thus, formation of mousse and entrainment needs to be quantified. Once oil is entrained in the water in the form of small droplets, monoaromatic hydrocarbons (MAHs) and polynuclear aromatic hydrocarbons (PAHs) readily dissolve into the water column. The fate of MAHs and PAHs from surface oil is primarily to the atmosphere, rather than to the water. Entrained oil droplets and dissolved MAHs and PAHs in the water can affect water column organisms or bottom communities. The dissolved MAHs and PAHs are the most bioavailable and toxic portion of the oil.

An example of how important this process can be comes from the *North Cape* oil spill on the east coast of the U.S. in Rhode Island, January 1996. The spill occurred during a strong winter storm and in heavy surf. The No. 2 fuel oil spilled was completely entrained into the water column in the surf. During the following day, when the wind and waves calmed, the entrained oil resurfaced as sheens. However, the PAHs in the oil dissolved in the water column and caused the mortality of millions of lobsters and other near shore water column and bottom-dwelling organisms near the spill site. The oil sheens were blown offshore, but the major effect was in the water column near the beach where the PAHs dissolved (French, 1998a,b,c; French McCay, 2003).

On the other hand, for many oil spills the winds and waves are not so severe. At low wind speeds, most of the oil effect is caused by surface oil, with little effect (if any) to the water column. Thus, both surface oil and water column effects must be evaluated in order to quantify oil effects from spills.

The physical fates model has been validated with more than 20 case histories, including the *Exxon Valdez* and other large spills (French and Rines, 1997; French, 1998a,b,c; French McCay, 2003, 2004), as well as test spills designed to verify the model (French et al., 1997).

A.2.1.1 Design of and Processes in the Fates Model

The schematic in Figure A.2-1 shows oil fates processes simulated in the model. Rectangles represent oil or environmental components. Since oil contains many chemicals with varying physical-chemical properties, and the environment is spatially and temporally variable, the oil rapidly separates into different phases or parts of the environment:

- Surface slicks
- Emulsified oil (mousse) and tar balls
- Oil droplets suspended in the water column
- Oil adhered to suspended particulate matter in the water
- Dissolved lower molecular weight components (monoaromatic hydrocarbons, MAHs; polynuclear aromatic hydrocarbons, PAHs; and other soluble components) in the water column
- Oil on and in the sediments
- Dissolved lower molecular weight components (MAHs, PAHs, and other soluble components) in the sediment pore water
- Oil on and in the shoreline sediments and surfaces

Figure A.2-1 shows forces that affect the oil fate processes and that are simulated in the model:

- Spreading is the thinning and broadening of surface slicks caused by gravitational forces and surface tension. This occurs rapidly after oil is spilled on the water surface. The rate is faster if oil viscosity is lower. Viscosity decreases as temperature increases. Viscosity increases as an oil emulsifies.
- Transport is the process where oil is carried by currents.
- Turbulent dispersion: Typically there are also “sub-scale” currents (not included in the current data), better known as turbulence, which move oil and mix it both horizontally and vertically. The process by which turbulence mixes and spreads oil components on the water surface and in the water is called turbulent dispersion.

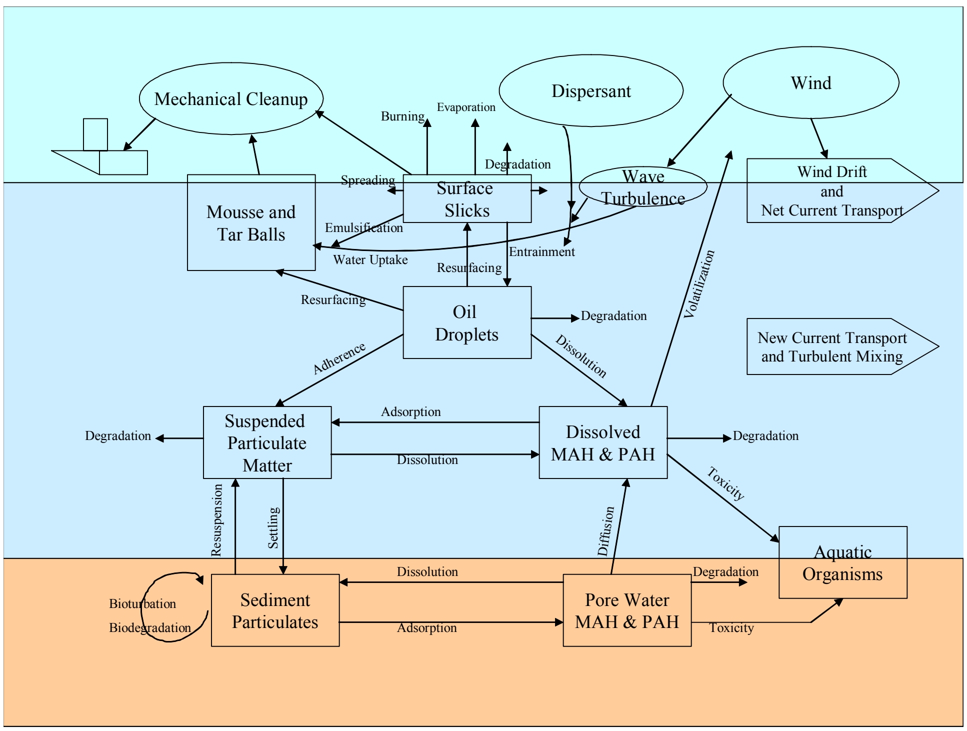

Figure A.2-1. Simulated oil fates processes in open water

- Evaporation is the process where volatile components of the oil diffuse from the oil and enter the gaseous phase (atmosphere). Evaporation from surface and shoreline oil increases as the oil surface area, temperature, and wind speed increase. As lighter components evaporate off, the remaining “weathered” oil becomes more viscous.
- Emulsification is the process where water is mixed into the oil, such that the oil makes a matrix with embedded water droplets. The resulting mixture is commonly called mousse. It is technically referred to as a water-in-oil emulsion. The rate of emulsification increases with increasing wind speed and turbulence on the surface of the water. Viscosity increases as an oil emulsifies.
- Entrainment is the process where waves break over surface oil and carry it as droplets into the water column. As wind speed increases, wave height increases up to a threshold where it breaks. Waves break beginning at about 12 knots of wind speed and wave breaking increases as wind speed becomes higher. Thus, entrainment becomes increasingly important (higher rate of mass transfer to

the water) the higher the wind speed. Below 12 knots of wind speed, very little oil is entrained. As wind and turbulence increase, the oil droplet sizes become smaller. Application of chemical dispersant increases the entrainment rate of oil and decreases droplet size at a given level of turbulence. Some wave energy is required for dispersant-treated oil to actually entrain. Entrainment rate is slower, and droplet size is larger, as oil viscosity increases (by emulsification and evaporation loss of lighter volatile components). The droplet size determines how fast and whether the oil resurfaces.

- Resurfacing of entrained oil rapidly occurs for larger oil droplets. Smaller droplets resurface when the wave turbulence decreases. The smallest droplets do not resurface, as typical turbulence levels in the water keep them in suspension indefinitely. Resurfaced oil typically forms sheens. As surface slicks are usually blown down wind faster than the underlying water, resurfacing droplets come up behind the leading edge of the oil, effectively spreading the slicks in the down-wind direction.
- Dissolution is the process where water-soluble components diffuse out of the oil into the water. Dissolution rate increases the higher the surface area of the oil relative to its volume. Since the surface area to volume ratio is higher for smaller spherical droplets, the smaller the droplets the higher the dissolution rate. The higher the wave turbulence, the smaller the droplets of entrained oil. Dissolution from entrained small droplets is much faster than from surface slicks in the shape of flat plates. The soluble components are also volatile, and evaporation from surface slicks is faster than dissolution into the underlying water. Thus, the processes of evaporation and dissolution are competitive, with evaporation the dominant process for surface oil.
- Volatilization of dissolved components from the water to the atmosphere occurs as they are mixed and diffuse to the sea surface boundary and enter the gas phase. Volatilization rate increases with increasing air and water temperature.
- Adsorption of dissolved components to particulate matter in the water occurs because the soluble components are only sparingly so. These compounds (MAHs and PAHs) preferentially adsorb to particulates when the latter are present. The higher the concentration of suspended particulates, the more adsorption. Also, the higher the molecular weight of the compound, the less soluble, and the more the compound adsorbs to particulate matter.
- Adherence is the process where oil droplets combine with particles in the water. If the particles are suspended sediments, the combined oil/suspended sediment agglomerate is heavier than the oil itself and than the water. If turbulence subsides sufficiently, the oil-sediment agglomerates will settle.
- Sedimentation (settling) is the process where oil-sediment agglomerates and particles with adsorbed semi-soluble components (MAHs and PAHs) settle to the bottom sediments. Adherence and sedimentation can be an important pathway of oil in near shore areas when waves are strong and subsequently subside. Generally, oil-sediment agglomerates transfer more PAH to the bottom than sediments with PAHs that were adsorbed from the dissolved phase in the water column.
- Resuspension of settled oil-sediment particles and particles with adsorbed semi-soluble components (MAHs and PAHs) may occur if current speeds and turbulence exceed threshold values where adhesive forces can be overcome.
- Diffusion is the process where dissolved compounds move from higher to lower concentration areas by random motion of molecules and micro-scale turbulence. Dissolved components in bottom and shoreline sediments can diffuse out to the water where concentrations are relatively low. Bioturbation can greatly increase the rate of diffusion from sediments (see below).
- Dilution occurs when water of lower concentration is mixed into water with higher concentration by turbulence, currents, or shoreline groundwater.

- Bioturbation is the process where animals in the sediments mix the surface sediment layer while burrowing, feeding, or passing water over their gills. Bioturbation effectively mixes the surface sediment layer about 10 cm thick (in non-polluted environments).
- Degradation is the process where oil components are changed either chemically or biologically (biodegradation) to another compound. It includes breakdown to simpler organic carbon compounds by bacteria and other organisms, photo-oxidation by solar energy, and other chemical reactions. Higher temperature and higher light intensity (particularly ultraviolet wavelengths) increase the rate of degradation.

For a spill on the water surface, the gravitational spreading occurs very rapidly (within hours) to a minimum thickness. Thus, the area exposed to evaporation is high relative to the oil volume. Evaporation proceeds faster than dissolution. Thus, most of the volatiles and semi-volatiles evaporate, with a smaller fraction dissolving into the water. Degradation (photo-oxidation and biodegradation) also occurs at a relatively slow rate compared to these processes.

Evaporation is more rapid as the wind speed increases. However, above about 12 knots of wind speed, white caps begin to form and the breaking waves entrain oil as droplets into the water column. The higher the wind speed (and turbulence), the more entrainment and the smaller the droplet sizes. From Stoke's Law, larger droplets resurface faster. Droplets that resurface within a time step in the model rejoin the surface slick. For smaller droplets, new subsurface spillets are created and followed in the next time step. In the future they may resurface and form surface slicks. Thus, a dynamic balance evolves between entrainment and resurfacing. As high-wind events occur, the entrainment rate increases. When the winds subside to less than 12 knots, the larger oil droplets resurface and remain floating.

The smallest oil droplets remain entrained in the water column for an indefinite period. Larger oil droplets rise to the surface at varying rates. While the droplets are under water, dissolution of the light and soluble components occurs. Dissolution rate is a function of the surface area available. Thus, most dissolution occurs from droplets, as opposed to from surface slicks, since droplets have a higher surface area to volume ratio, and they are not in contact with the atmosphere (and so the soluble components do not preferentially evaporate as they do from surface oil).

If oil is released underwater, it forms droplets of varying sizes. The more turbulent the release, the smaller the droplet sizes. From Stoke's Law, larger droplets rise faster, and surface if the water is shallow. Resurfaced oil behaves as surface oil after gravitational spreading has occurred. The surface oil may be re-entrained. The smallest droplets in most cases remain in the water permanently. Thus, dissolution is higher for a subsurface release than for a surface release.

Because of these interactions, the majority of dissolved constituents (which are of concern because of potential effects on aquatic organisms) are from droplets entrained in the water. The higher the entrainment rate and the smaller the droplets, the higher the dissolved concentrations will be after a spill of a given volume of oil. Entrainment and dissolved concentrations increase with (1) higher wind speed, (2) increased turbulence from other sources (waves on a beach, rapids, and waterfalls in rivers, etc.), (3) subsurface releases (especially under higher pressure and turbulence), and (4) application of chemical dispersants. Chemical dispersants both increase the amount of oil entrained and decrease the oil droplet size. Thus, chemical dispersants increase the dissolution rate of soluble components.

These processes that increase the rate of supply of dissolved constituents are balanced by loss terms in the model: (1) transport (dilution), (2) volatilization from the dissolved phase to the atmosphere, (3) adsorption to suspended particulate material (SPM) and sedimentation, and (4) degradation (photo-oxidation or biologically mediated). Also, other processes slow the entrainment rate: (1) emulsification increases viscosity and slows or eliminates entrainment; (2) adsorption of oil droplets to SPM and settling removes oil from the water; (3) stranding on shorelines removes oil from the water; and (4) mechanical cleanup or burning removes mass from the water surface. Thus, the model-predicted concentrations are the resulting balance of all these processes and the best estimates based on our quantitative understanding of the individual processes.

The SIMAP model quantifies, in space and over time:

- The spatial distribution of oil mass and volume on water surface over time
- Oil mass, volume and thickness on shorelines over time
- Subsurface oil droplet concentration, as total hydrocarbons, in three dimensions over time
- Dissolved aromatic concentration (which causes most aquatic toxicity) in three dimensions over time
- Total hydrocarbons and aromatics in the sediments over time

A.2.1.2 Oil Components, Fractions and Representation

The spilled substance (oil) is represented as multiple sublots (called “spillets”, Lagrangian “particles” or “elements”) of the entire mass (or volume) spilled. In the model computations, the spillet retains its identity as it is transported from the release site in three dimensions over time. For each spillet, the model tracks over time: mass by chemical component (or component category), density, water content, viscosity, location of the spillet center (latitude, longitude, and depth), thickness and radius (of a cylindrical representation on the water surface or a Gaussian cloud in the water, see “Calculation of Water Column Concentrations for Model Output” in section A.2.1.3). The model simulates weathering as a change in these characteristics. Spillets may split, as components have differing pathways and fates.

Most oil spill models use this Lagrangian approach because it allows specific weathering and other characteristics to be tracked along with the movement of the mass (e.g., American Society of Civil Engineers (ASCE), 1996; Lehr et al, 2000). In other words, specific sublots of the spilled mass are tracked wherever they go. The alternative modeling approach is to calculate concentration as a function of location (x,y,z) and time. In this so-called Eulerian approach, specific sublots are not tracked as they move; rather the mass in a given volume (i.e., grid cell) increases or decreases according to the net flux to or from neighboring volumes (grid cells). The restriction of this latter approach is that the age and weathering characteristics of portions of the oil cannot be tracked and used in such evaluations as whether the mass is dispersible at a given location and time.

Oil is a mixture of hydrocarbons of varying physical, chemical, and toxicological characteristics. Thus, oil hydrocarbons have varying fates and effects on organisms. In the model, oil is represented by component categories, and the fate of each tracked separately. The “pseudo-component” approach

(Payne et al. 1984, 1987; French et al. 1996a; Jones 1997; Lehr et al, 2000) is used, where chemicals in the oil mixture are grouped by physical-chemical properties, and the resulting component category behaves as if it were a single chemical with characteristics typical of the chemical group. (The alternative of treating oil as a single substance is much less precise as oil is not of uniform properties, but is a mixture of chemicals of widely ranging properties.)

The most toxic components of oil to water column and benthic organisms are low molecular weight compounds, which are both volatile and soluble in water, especially the aromatic compounds. It has been shown that toxicity of narcotic organic compounds, such as these low molecular weight aromatics in oil (monoaromatic and polynuclear aromatic hydrocarbons, MAHs and PAHs), is related to the octanol-water partition coefficient (K_{ow}), a measure of hydrophobicity. The more hydrophobic the compound, the more it is toxic. However, the more hydrophobic the compound, the less soluble it is in water, and so the less exposure there is to aquatic organisms. Compounds of $\log(K_{ow})>5.6$ are considered insoluble and so unavailable to aquatic biota (French McCay, 2001, 2002). Thus, effect is the result of a balance between bioavailability (exposure) and toxicity once exposed. French McCay (2002) contains a full description of the oil toxicity model in SIMAP.

Because of these considerations, the SIMAP fates model focuses on tracking the lower molecular weight aromatic components divided into chemical groups based on volatility, solubility, and hydrophobicity. In the model, the oil is treated as eight components. Six of the components (all but the residuals) evaporate in the model at rates specific to the component. The three aromatic components dissolve into the water. This number of components provides sufficient accuracy for the evaporation and dissolution calculations. The alternative of treating oil as a single compound with empirically-derived rates (e.g., Mackay et al, 1980; Stiver and Mackay, 1984) does not provide sufficient accuracy for impact analyses because the effects to water column organisms are caused by MAHs and PAHs, which have specific properties that differ from the other volatile and soluble compounds. Use of more pseudo components does not improve accuracy, as the major constituents of concern are well characterized (sufficiently similar in properties within the pseudo-component group of chemicals) by the modelled component properties used in SIMAP. The model has been validated both in predicting dissolved concentrations and resulting toxic effects, supporting the adequacy of the use of this number of pseudo-components (French, 1998a,b,c; French McCay, 2003).

The seven modeled pseudo-components are:

1) MAHs: BTEX (benzene, toluene, ethylbenzene, xylenes) and substituted benzenes;
2) 2-ring PAHs (naphthalenes);
3) 3-ring PAHs;
4) Volatile aliphatics;
5) Semi-volatile aliphatics;
6) Low volatility aliphatics; and
7) Residual fraction (aromatics); and
8) Residual fraction (aliphatics).

The residual fractions in the model are composed on non-volatile and insoluble compounds that remain in the “whole oil” that spreads, is transported on the water surface, strands on shorelines, and disperses into the water column as oil droplets or remains on the surface as tar balls. This is the fraction that composes black oil, mousse, and sheen.

Tables A.2-1 and A.2-2 define the characteristics of the eight components. Table A.2-3 lists physical-chemical characteristics of individual aromatics. These data were used to derive a mean molecular weight, boiling point, solubility, and vapour pressure for each pseudo-component (numbers 1-3 above). Components 4, 5, and 6 have the same vapour pressure and evaporation rates as components 1, 2, and 3, respectively. Dissolution of components 4, 5, and 6 are negligible. These mean characteristics are used to calculate rates of processes such as evaporation and dissolution in the model.

Note that the MAHs include benzene, toluene, ethylbenzene and xylenes, known as BTEX, as well as alkyl-substituted benzenes. The C3 benzenes (trimethylbenzenes, ethyl-methylbenzenes, and others with three carbon substitutions) are soluble and contribute to toxicity, along with the soluble PAHs and MAHs. Wang et al. (1995) have identified these as important constituents of concern in oils and fuels.

For light fuels, such as gasoline and jet fuels, MAHs account for a large percentage of the total hydrocarbon mass in the oil. For diesel, and heavier fuel oils, MAHs are a small component of the mass balance, and they evaporate quickly. For crude oils, the contribution of MAHs is variable, but typically the PAHs are more of a concern to toxicity. Thus, for light fuels, exposure and toxicity is the result of MAHs + PAHs, while PAHs are the most important fraction for diesel, heavy fuels, and crude oils. Both MAHs and PAHs are tracked in the model.

Table A.2-1. Definition of four distillation cuts in the model

All hydrocarbons	**Volatiles**	**Semi-volatiles**	**Low Volatility**	**Residual (non-volatile)**
Aromatics	MAHs (1 ring)	2 ring PAHs	3 ring PAHs	$\geq$4 ring aromatics
Non-aromatics	Volatile aliphatics	Semi-volatile aliphatics	Low volatility aliphatics	High molecular weight aliphatics
Number of Carbons	C4 – C10	C10 – C15	C15 – C20	>C20
Distillation cut #	1	2	3	4
Boiling Point (^{o}C)	<180	180 - 265	265 - 380	>380
Boiling Point (^{o}F)	<356	356 - 509	509 -716	>716

Table A.2-2. Definition of four aromatic pseudo-components in the model

Characteristic	**Volatile and Highly Soluble**	**Semi-volatile and Soluble**	**Low Volatility and Slightly Soluble**	**Residual (non-volatile and insoluble)**
Aromatic category name	MAHs (1 ring)	2 ring PAHs	3 ring PAHs	$\geq$4 ring aromatics
MAHs included	BTEX, MAHs to C3-benzenes	C4-benzenes	-	-
PAHs included	-	2-ring to C2-naphthalenes	C3-,C4-naphthalenes, 3-4 ring PAHs with log(K_{ow}) <5.6	PAHs with log(K_{ow}) >5.6 (insoluble)
Molecular Weight	50 - 125	125 - 168	152 - 215	>215
Mean Mol. Wt.	111	142	186	>215
Log(K_{ow})	2.1-3.7	3.7-4.4	3.9-5.6	>5.6
Mean Log(K_{ow})	3.3	4.0	4.9	>5.6

Table A.2-3. Physical-chemical properties for monoaromatics (MAHs) and 2 to 4-ring polynuclear aromatic hydrocarbons (PAHs). Molecular weight (MW), boiling point (BP), solubility, and vapor pressure are from Mackay et al. (1992b,c,d,e). Estimates of log(K_{ow}) are based on Mackay et al. (1992b,c) and Neff and Burns (1996). (A dash indicates no data available.)

Compound(s)	# Rings	# Cs	MW (g/mol)	Distil-lation Cut #	BP (°C)	Solubility (ppm)	Vapor Pressure (atm)	log(K_{ow})
Benzene	1	6	78	1	80	1780	0.12534	2.1
Toluene	1	7	92	1	111	515	0.03750	2.7
Ethylbenzene	1	8	106	1	136	152	0.01253	3.1
o-Xylene	1	8	106	1	144	220	0.01155	3.2
p-Xylene	1	8	106	1	138	215	0.01155	3.2
m-Xylene	1	8	106	1	139	160	0.01086	3.2
Xylenes (mixture)	1	8	106	1	140	198	0.01132	3.2
styrene	1	8	104	1	145	300	0.00868	3.1
methylstyrenes	1	9	118	1	170	100	0.00264	3.4
1,2,3-Trimethylbenzene	1	9	120	1	176	70	0.00197	3.6
1,2,4-Trimethylbenzene (pseudocumene)	1	9	120	1	169	57	0.00266	3.6
1,3,4-Trimethylbenzene	1	9	120	1	169	57	0.00266	3.6
1,3,5-Trimethylbenzene (mesitylene)	1	9	120	1	165	50	0.00321	3.6
Trimethylbenzenes	1	9	120	1	170	59	0.00262	3.6
n-propylbenzene	1	9	120	1	159	52	0.00444	3.7
iso-propylbenzene	1	9	120	1	154	50	0.00602	3.6
ethyl-methylbenzenes (cumene)	1	9	120	1	163	85	0.00367	3.6
iso-propyl-4-methylbenzene	1	10	134	2	177	34	0.00201	4.1
butylbenzenes	1	10	134	2	174	17.7	0.00225	4.1
tetramethylbenzenes	1	10	134	2	200	3.48	0.00057	4.0
tetralin	2	10	132	2	208	15	0.00052	3.8
diphenylmethane	2	13	168	2	264	16	8.73E-07	4.1
biphenyl	2	12	154	2	261	5.53	1.28E-05	3.9
naphthalene	2	10	128	2	218	31	0.00010	3.4
C1-naphthalenes	2	11	142	2	243	26.5	8.80E-05	3.9
C2-naphthalenes	2	12	156	2	254	6.4	1.98E-05	4.4
C3-naphthalenes	2	13	170	3	267	-	-	5.0
C4-naphthalenes	2	14	185	3	-	-	-	5.6

Table A.2-3, continued.

Compound(s)	**# Rings**	**# Cs**	**MW (g/mol)**	**Distil-lation Cut #**	**BP (^oC)**	**Solubility (ppm)**	**Vapor Pressure (atm)**	**log(K_{ow})**
acenaphthylene	3	12	152	3	270	16.1	8.88E-06	4.1
acenaphthene	3	12	154	3	278	3.8	2.96E-06	3.9
dibenzofuran	3	12 + O	168	3	287	4.75	2.96E-06	4.3
Fluorene	3	13	166	3	295	1.9	8.88E-07	4.2
C1-fluorenes	3	14	181	3	-	1.09	-	5.0
C2-fluorenes	3	15	196	3	-	-	-	5.2
C3-fluorenes	3	16	211	3	-	-	-	5.5
anthracene	3	14	178	3	340	0.045	9.87E-09	4.5
phenanthrene	3	14	178	3	339	1.1	1.97E-07	4.6
C1-phenanthrenes/ anthracenes	3	15	192	3	-	-	-	5.1
C2-phenanthrenes/ anthracenes	3	16	207	3	-	-	-	5.3
C3-phenanthrenes/ anthracenes	3	17	222	4	-	-	-	6.0
C4-phenanthrenes/ anthracenes	3	18	237	4	390	-	-	6.5
dibenzothiophene	3	12 + S	184	3	333	-	-	4.5
C1-dibenzothiophene	3	13 + S	199	3	-	-	-	4.9
C2-dibenzothiophene	3	14 + S	214	3	-	-	-	5.5
C3-dibenzothiophene	3	15 + S	228	4	-	-	-	5.7
fluoranthene	4	16	202	3	375	0.265	-	5.2
pyrene	4	16	202	3	404	0.013	-	5.2
C1-fluoranthenes/ pyrenes	4	17	217	4	407	-	-	5.7
Chrysene	4	18	228	4	448	0.0018	-	5.9
C1-Chrysenes	4	19	242	4			-	6.4
Mean MAHs (Distillation Cut #1)	1	8.4	111	1	149	242.4	0.01525	3.3
Mean 2-ring aromatics (Distillation Cut #2)	1.7	10.9	142	2	222	17.3	6.20E-04	4.0
Mean 3-ring aromatics (Distillation Cut #3)	3.1	14.4	187	3	324	3.2	2.65E-06	4.8

A.2.1.3 Oil Fates Algorithms

Transport

Lagrangian particles (spillets) are moved in three dimensions over time. For each model time step, the new vector position of the spillet center is calculated from the old plus the vector sum of east-west, north-south, and vertical components of advective and diffusive velocities:

$$X_t = X_{t-1} + \Delta t\ (U_t + D_t + R_t + W_t)$$

where X_t is the vector position at time t, X_{t-1} is the vector position the previous time step, Δt is the time step, U_t is the sum of all the advective (current) velocity components in three dimensions at time t, D_t is the sum of the randomized diffusive velocities in three dimensions at time t, R_t is the rise or sinking velocity of whole oil droplets in the water column, and W_t is the surface wind transport ("wind drift"). The magnitudes of the components of D_t are scaled by horizontal and vertical diffusion coefficients (Okubo and Ozmidov, 1970; Okubo, 1971). The vertical diffusion coefficient is computed as a function of wind speed in the wave-mixed layer, based on Thorpe (1984). R_t is computed by Stokes law, where velocity is related to the difference in density between the particle and the water, and to the particle diameter. The algorithm developed by Youssef and Spaulding (1993) is used for wind transport in the surface wave-mixed layer (W_t, described below).

Shoreline Stranding

The fate of spilled oil that reaches the shoreline depends on characteristics of the oil, the type of shoreline, and the energy environment. The stranding algorithm is based on work by CSE/ASA/BAT (1986), Gundlach (1987) and Reed and Gundlach (1989) in developing the COZOIL model for the U.S. Minerals Management Service. In SIMAP, deposition occurs when an oil spillet intersects shore surface. Deposition ceases when the volume holding capacity for the shore surface is reached. Subsequent oil coming ashore is not allowed to remain on the shore surface. It is refloated and carried to sea by out-going tidal currents and wind drift. The shoreline oil is then removed exponentially with time by erosion and degradation. Data for holding capacity and removal rate are taken from CSE/ASA/BAT (1986) and Gundlach (1987), and are a function of oil viscosity and shore type. The algorithm and data are in French et al. (1996a).

Spreading

Spreading determines the areal extent of the surface oil, which in turn influences its rates of evaporation, dissolution, dispersion (entrainment) and photo-oxidation, all of which are functions of surface area. Spreading results from the balance among the forces of gravity, inertia, viscosity, and surface tension (which increases the diameter of each spillet); turbulent diffusion (which spreads the spillets apart); and entrainment followed by resurfacing, which can spatially separate the leading edge of the oil from resurfaced oil transported in a different direction by subsurface currents.

For many years Fay's (1971) three-regime spreading theory was widely used in oil spill models (ASCE, 1996). Mackay et al. (1980, 1982) modified Fay's approach and described the oil as thin and thick slicks. Their approach used an empirical formulation based on Fay's (1971) terminal spreading behavior. They assumed the thick slick feeds the thin slick and that 80-90% of the total slick area is represented by the thin slick. In SIMAP, oil spillets on the water surface increase in diameter according to the spreading algorithm empirically-derived by Mackay et al. (1980, 1982). Sensitivity analyses of this algorithm led to the discovery that the solution was affected by the number of spillets used. Thus, a formulation was derived to normalize the solution under differing numbers of surface spillets (Kolluru et al., 1994). Spreading is stopped when an oil-specific terminal thickness is reached.

Evaporation

The rate of evaporation depends on surface area, thickness, vapor pressure and mass transport coefficient, which in turn are functions of the composition of the oil, wind speed and temperature (Fingas, 1996, 1997, 1998, 1999; Jones, 1997). As oil evaporates its composition changes, affecting its density and viscosity as well as subsequent evaporation. The most volatile hydrocarbons (low carbon number) evaporate most rapidly, typically in less than a day and sometimes in under an hour (McAuliffe, 1989). As the oil continues to weather, and particularly if it forms a water-in-oil emulsion, evaporation will be significantly decreased.

The evaporation algorithm in SIMAP is based on accepted evaporation theory, which follows Raoult's Law that each component will evaporate with a rate proportional to the saturation vapor pressure and mole fraction present for that component. The pseudo-component approach (Payne et al. 1984; French et al., 1996a; Jones, 1997; Lehr et al. 2000) is used, such that each component evaporates according to its mean vapor pressure, solubility, and molecular weight (Table A.2-3). The mass transfer coefficient is calculated using the methodology of Mackay and Matsugu (1973), as described in French et al. (1996a).

Entrainment

As oil on the sea surface is exposed to wind and waves, it is entrained (or dispersed) into the water column. Entrainment is a physical process where globules of oil are transported from the sea surface into the water column due to breaking waves. It has been observed that entrained oil is broken into droplets of varying sizes. Smaller droplets spread and diffuse in the water column, while larger ones rise back to the surface. Breaking waves created by the action of wind and waves on the ocean surface are the primary sources of energy for entrainment. Entrainment is strongly dependent on turbulence and is greater in areas of high wave energy (Delvigne and Sweeney, 1988).

Delvigne and Sweeney (1988), using laboratory and flume experimental observations, developed a relation for entrainment rate as a function of oil droplet size, which is in turn related to turbulent energy level and oil viscosity. Entrained droplets in the water column rise according to Stokes law, where velocity is related to the difference in density between the particle and the water, and to the particle diameter. The data and relationships in Delvigne and Sweeney (1988) are used in SIMAP to calculate mass and particle size distribution of droplets entrained. Particle size decreases with higher turbulent energy level and lower oil viscosity. The natural dispersion particle sizes observed by Delvigne and Sweeney (1988) are confirmed by field observations by Lunel (1993a,b).

Use of chemical dispersants decrease the median particle size, increasing the number of droplets in the <70 μm range (Daling et al., 1990; Lunel, 1993a,b). Particle size distributions for dispersed oil are available for several oils from these studies. When dispersant is applied, the model entrains surface oil, creating subsurface droplets in the appropriate size distribution for dispersant use. The median particle size for permanently dispersed droplets is set at 20 microns, the median size observed by Lunel (1993a,b). The fraction of oil permanently dispersed is set by the dispersant efficiency input to the model. The IKU/SINTEF studies provide data on the viscosity range where oils may be dispersed chemically. Typically, dispersants are effective up to about 10,000 cp (Aamo et al., 1993; Daling and Brandvik, 1988, 1991; Daling et al., 1997). In the model, oil is dispersed up to 10,000 cp.

Entrained oil is well mixed in (i.e., mixed uniformly throughout) the surf zone. Vertical mixing in the surf is simulated by random placement of particles within the wave-mixed layer each time step. Settling of particles does not occur in water depths where waves reach the bottom (taken as 1.5 multiplied by wave height). Wave height is calculated from wind speed, duration and fetch (distance upwind to land), using the algorithms in CERC (1984).

Emulsification (Mousse Formation)

The formation of water-in-oil emulsions, or mousse, depends on oil composition and sea state. Emulsified oil can contain as much as 80% water in the form of micrometer-sized droplets dispersed within a continuous phase of oil (Daling and Brandvik, 1988; Fingas et al., 1997). Viscosities are typically much higher than that of the parent oil. The incorporation of water also dramatically increases the oil/water mixture volume.

Mackay and Zagorski (1982) emulsification scheme is implemented in SIMAP. Water content increases exponentially, with the rate related to the square of wind speed and previous water incorporation. Viscosity is a function of water content. The change in viscosity feeds back in the model to the entrainment rate.

Dissolution

Dissolution is the process by which soluble hydrocarbons enter the water from a surface slick or from entrained oil droplets. The lower molecular weight hydrocarbons tend to be both more volatile and more soluble than those of higher molecular weight. For surface slicks, since the partial pressures tend to exceed the solubilities of these lower molecular weight compounds, evaporation accounts for a larger portion of the mass than dissolution (McAuliffe, 1989), except perhaps under ice. Dissolution and evaporation are competitive processes. The dissolved component concentration of hydrocarbons in water under a surface slick shows an initial increase followed by a rapid decrease after some hours due to the evaporative loss of components. Most soluble components are also volatile and direct evaporation (volatilization) from the water column depletes their concentrations in the water. Dissolution is particularly important where evaporation is low (dispersed oil droplets and ice-covered surfaces). Dissolution can be substantial from entrained droplets because of the lack of atmospheric exposure and because of the higher surface area per unit of volume.

The model developed by Mackay and Leinonen (1977) is used in SIMAP for dissolution from a surface slick. The slick (spillet) is treated as a flat plate, with a mass flux (Hines and Maddox, 1985) related to solubility and temperature. It assumes a well-mixed layer with most of the resistance to mass transfer lying in a hypothetical stagnant region close to the oil. For subsurface oil, dissolution is treated as a mass flux across the surface area of a droplet (treated as a sphere) in a calculation analogous to the Mackay and Leinonen (1977) algorithm. The dissolution algorithm was developed in French et al. (1996a).

Volatilization from the Water column

The procedure outlined by Lyman et al. (1982), based on Henry's Law and mass flux (Hines and Maddox, 1985), is followed in the SIMAP fates model. The volatilization depth for dissolved substances is limited to the maximum of one half the wave height. Wave height is computed from the wind speed, fetch and duration (CERC, 1984). The volatilization algorithm was developed in French et al. (1996a).

Adsorption and Sedimentation

Aromatics dissolved in the water column are carried to the sea floor primarily by adsorption to suspended particulates, and subsequent settling. The ratio of adsorbed (C_a) to dissolved (C_{dis}) concentrations is computed from standard equilibrium partitioning theory as

$$C_a / C_{dis} = K_{oc} C_{ss}$$

K_{oc} is a dimensionless partition coefficient and C_{ss} is the concentration of suspended particulate matter (SPM) in the water column expressed as mass of particulate per volume of water. The model uses a mean near shore value of total suspended solids of 10 mg/l (Kullenberg, 1982).

Sedimentation of oil droplets occurs when the specific gravity of oil increases over that of the surrounding seawater. Several processes may act on entrained oil and surface slicks to increase density: weathering (evaporation, dissolution and emulsification), adhesion or sorption onto suspended particles or detrital material, and incorporation of sediment into oil during interaction with suspended particulates, bottom sediments, and shorelines. Rates of sedimentation depend on the concentration of suspended particulates and the rates of particulate flux into and out of an area. In near shore areas with high suspended particulate concentrations, rapid dispersal and removal of oil is found due to sorption and adhesion (Payne and McNabb, 1984).

Kirstein et al. (1987) and Payne et al. (1987) used a reaction term to characterize the water column interactions of oil and suspended particulates. The reaction term represents the collision of oil droplets and suspended matter, and both oiled and unoiled particulates are accounted for. The model formulation developed by Kirstein et al. (1987) is used to calculate the volume of oil adhered to particles. In the case where the oil mass is larger than the adhered sediment (i.e., the sediment has been incorporated into the oil) the buoyancy of the oil droplet will control its settling or rise rate. The Stoke's law formulation is used to adjust vertical position of these particles. If the mass of adhered droplets is small relative to the mass of the sediment it has adhered to, the sediment settling velocity will control the fate of the combined particulate.

Bioturbation in the upper 10 cm of sediment completely mixes the sedimented oil mass at the time scales of concern so that concentration is simply mass loading per area divided by 10 cm. Contaminant concentrations in sediment are distributed between adsorbed and dissolved states by equilibrium partitioning, as in the water column. The particulate-to-interstitial water ratio is taken to be 0.45 (CERC, 1984).

Degradation

Degradation may occur as the result of photolysis, which is a chemical process energized by ultraviolet light from the sun, and by biological (bacterial) breakdown, termed biodegradation. In the model, degradation occurs on the surface slick, deposited oil on the shore, the entrained oil and aromatics in the water column, and oil in the sediments. A first order decay algorithm is used, with a specified (total) degradation rate for each of surface oil, water column oil and sedimented oil (French et al, 1999).

Calculation of Water Column Concentrations for Model Output

The physical fates model creates output files recording the distribution of a spilled substance in three-dimensional space and time. The quantities recorded are:

- area covered by oil and thickness on the water surface ("swept area");
- volumes in the water column at various concentrations of dissolved aromatics;
- volumes in the water column at various concentrations of total hydrocarbons in suspended droplets;
- total hydrocarbon concentrations and dissolved aromatic concentrations in surface sediment;
- lengths and locations of shoreline effected and volume of oil ashore in each segment.

The dissolved aromatic hydrocarbon concentration in the water column is calculated from the mass in the Lagrangian particles, as follows. Concentration is contoured on a three-dimensional Lagrangian grid system. This grid (of 200 X 200 cells in the horizontal and 5 vertical layers) is scaled each time step to just cover the volume occupied by aromatic particles, including the dispersion around each particle center. This maximizes the resolution of the contour map at each time step and reduces error caused by averaging mass over large cell volumes. Distribution of mass around the particle center is described as Gaussian in three dimensions, with one standard deviation equal to twice the diffusive distance ($2D_xt$ in the horizontal, $2D_zt$ in the vertical, where D_x is the horizontal and D_z is the vertical diffusion coefficient, and t is particle age). The plume grid edges are set at one standard deviation out from the outer-most particle. These data are used by the biological effects model to evaluate exposure, toxicity and effects.

A.2.2 Biological Exposure and Effects Model

The biological exposure model estimates the area, volume or portion of a stock or population affected by surface oil, concentrations of oil components in the water, or sediment contamination. The biological effects model estimates short-term (acute) losses resulting from a spill (i.e., losses at the time of the spill and while toxic concentrations remain in the environment) in terms of direct mortality and lost production because of direct exposure or the loss of food resources from the food web. Losses are estimated by species or species group for fish, invertebrates (i.e., shellfish and non-fished species) and wildlife (birds, mammals, sea turtles). Lost production of aquatic plants and lower trophic levels of animals are also estimated.

The area potentially affected by the spill is represented by a rectangular grid with each grid cell coded as to habitat type. The habitat grid is also used by the physical fates model to define the shoreline location and type, as well as habitat and sediment type. A habitat is an area of essentially uniform physical and biological characteristics that is occupied by a group of organisms that are distributed throughout that area. A contiguous grouping of habitat grid cells with the same habitat code represents an ecosystem in the biological model. (Pre-spill) abundance of fish, invertebrates and wildlife, and rates of lower trophic level productivity, are assumed constant for the duration of the spill simulation and evenly distributed across an ecosystem. While biological distributions are known to be highly variable in time and space, data are not sufficient to characterize this patchiness. Oil is also patchy in distribution. The patchiness is assumed to be on the same scale so that the intersection of the oil and biota is equivalent to overlays of spatial mean distributions.   This approach has proved to provide mean results that have been validated (French and Rines, 1997). As the purpose of this environmental impact assessment is to characterize the relative change in effects if response scenarios are altered, rather than the effects for a specific spill event, the use of mean abundances for biological resources is appropriate and sufficient to estimate (mean) expected effects.

Mobile fish, invertebrates and wildlife are assumed to move at random within each ecosystem during the simulation period. This is a reasonable assumption for the two-week period of the simulation. Benthic organisms may also remain stationary on or in the bottom. Planktonic stages, such as pelagic fish eggs, larvae, and juveniles (i.e., young-of-the-year during their pelagic stage(s)), move with the currents.

Habitats include open water, reef, wetland and shoreline environments. Habitat types are defined by depth, proximity to shoreline(s), bottom type, dominant vegetation type, and the presence of invertebrate reefs (simplified from the scheme of Cowardin et al., 1979, which was developed by the US Department of the Interior for classifying bio-geographical regions and habitat types). With respect to proximity to shoreline(s), habitats are designated as landward or seaward.   Landward portions are the near-shore rivers, estuaries and inlets. The seaward portion is the more oceanic or main part of the water body. This designation allows different biological abundances to be simulated in landward and seaward zones of the same habitat type (e.g., open water with sand bottom). Habitat types are described in detail in Section A.3.1.

A.2.2.1 Wildlife

In the model, surface slicks (or other floating forms such as tar balls) of oils and petroleum products effect wildlife (birds, marine mammals, sea turtles). For each of a series of surface slicks (spillets), the physical fates model calculates the location and size (radius of circular spreading spillet) as a function of time. The area swept by a surface spillet in a given time step is calculated as the quadrilateral area defined by the shaded area in Figure A.2-2. This area is summed over all time steps for the time period the slick is present on the water surface and separately for each habitat type where the oil passes. The total area swept over a threshold thickness by habitat type is multiplied by the probability that a species uses that habitat (0 or 1, depending upon its behavior) and a combined probability of oiling and mortality. This calculation is made for each surface-floating spillet and each habitat for the duration of the model simulation.

The portion of the wildlife in the area swept by the slick over a threshold thickness that are assumed to die is based on probability of encounter with the slick multiplied by the probability of mortality once oiled. The probability of encounter with the slick is related to the percentage of the time an animal spends on the water or shoreline surface. The probability of mortality once oiled is nearly 100% for birds and fur-covered mammals (assuming they are not successfully treated) and much lower for other wildlife. The products of the two probabilities for various wildlife behavior groups are in Table A.2-4. Estimates for the probabilities were derived from information on behavior and field observations of mortality after spills (French et al., 1996a). The wildlife mortality model has been validated with more than 20 case histories, including the *Exxon Valdez* and other large spills, verifying that these values are reasonable (French and Rines, 1997; French, 1998a,b,c; French McCay, 2003, 2004).

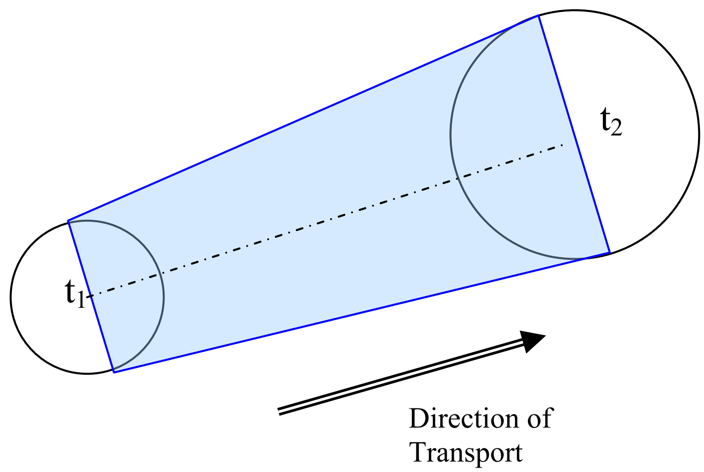

Figure A.2-2. Area swept by oil (quadrilateral area defined by the shaded area) for a spreading and moving circular-shaped spillet, depicted over a time step from time 1 (t_1) to time 2 (t_2).

Area swept is calculated for the habitats occupied by each of the behavior groups of wildlife listed in Table A.2-4. Species or species groups are assigned to behavior groups to evaluate their loss. The threshold is 10 micron (~10g/m^2) thick oil, based on data and calculations in French et al. (1996a). Wildlife mortality is directly proportional to abundance per unit area and the percent mortalities in Table A.2-4.

Table A.2-4. Combined probability of encounter with the slick and mortality once oiled, if present in the area swept by a slick exceeding a threshold thickness. Area swept is calculated for the habitats occupied.

Wildlife Group	Probability	Habitats Occupied
Dabbling waterfowl	99%	Intertidal and landward subtidal
Nearshore aerial divers	35%	Intertidal and landward subtidal
Surface seabirds	99%	All intertidal and subtidal
Aerial seabirds	5%	All intertidal and subtidal
Wetland wildlife (Waders and shorebirds)	35%	Wetlands, shorelines, seagrass beds
Cetaceans	0.1%	Seaward subtidal
Furbearing marine mammals	75%	All intertidal and subtidal
Pinnipeds, manatee, sea turtles	1%	All intertidal and subtidal
Surface birds in seaward only	99%	All seaward intertidal and subtidal
Surface diving birds in seaward only	35%	All seaward intertidal and subtidal
Aerial divers in seaward only	5%	All seaward intertidal and subtidal
Surface birds in landward only	99%	All landward intertidal and subtidal
Surface diving birds in landward only	35%	All landward intertidal and subtidal
Aerial divers in landward only	5%	All landward intertidal and subtidal
Surface diving birds in water only	35%	All subtidal
Aerial divers in water only	5%	All subtidal

A.2.2.2 Aquatic Biota

Aquatic biota include fish, invertebrates, and plants in the water column and on/in the sediments. In the model, aquatic biota are affected by dissolved aromatic concentrations in the water or sediment.
This rationale is supported by the fact that soluble aromatics are the most toxic constituents of oil (Neff et al., 1976; Rice et al., 1977, 1979; Craddock, 1977; Tatem et al., 1978; Neff and Anderson, 1981; Malins and Hodgins, 1981; National Research Council (NRC), 1985, 2002; Anderson, 1985; Anderson et al., 1987; Capuzzo, 1987; McAuliffe, 1987). Exposures in the water column are short in duration. Therefore, effects there are the result of acute toxicity. In the sediments, exposure may be both acute and chronic, as the concentrations may remain elevated for longer periods of time. In either acute or

chronic exposures, it is the aromatics, and specifically the PAHs that cause effects either directly or indirectly via bioaccumulation and uptake via the food web (NRC, 1985).

The model evaluates mortality and sublethal effects of dissolved aromatic concentrations in the water or sediment. Mortality is a function of duration of exposure – the longer the duration of exposure, the lower the threshold for effects (Sprague, 1970; Kooijman, 1981; McAuliffe, 1987; Anderson et al., 1987; French and French, 1989; McCarty et al., 1989, 1992a,b; Mackay et al., 1992a; French et al.1996a; French McCay, 2001, 2002). After a certain period of time all individuals who will die at a given concentration have done so, and no further mortality is observed. The lethal threshold concentration, also termed the incipient lethal level, is the concentration where mortality occurs after this sufficiently long exposure (Sprague, 1970; Buikema et al., 1982). The LC50 is the lethal concentration to 50% of exposed organisms. The incipient LC50 ($LC50_{\infty}$) is the LC50 asymptotic LC50 reached after infinite exposure time (or long enough that that level is approached). The standard mortality model fits log-normal relationship between percent mortality and concentration, with the LC50 the center of the distribution (Figure A.2-3).

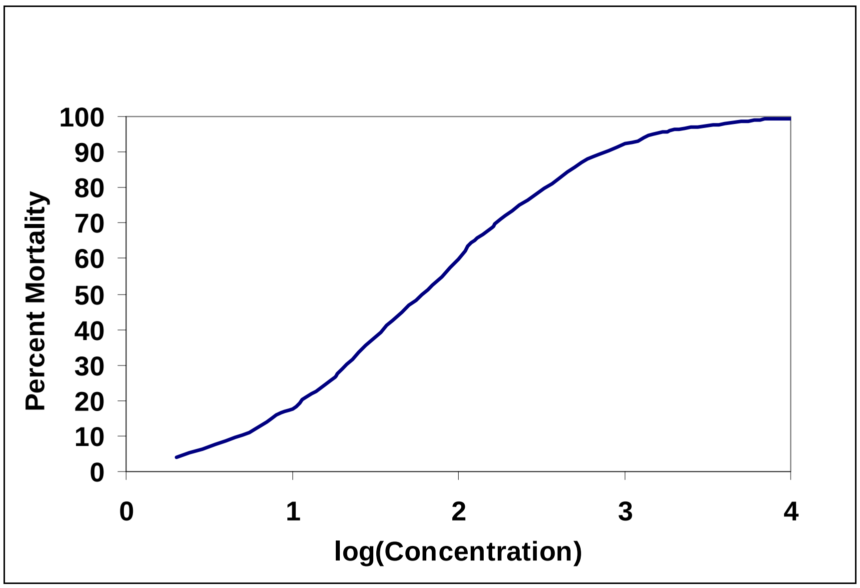

Figure A.2-3. Percent mortality as a function of concentration.

In SIMAP, $LC50_{\infty}$ is input to the model. For each of a series of aquatic biota behavior groups, the model evaluates exposure duration, and corrects the LC50 for time of exposure and temperature to calculate mortality. LC50s for the mixture of the most toxic components of oil, dissolved MAHs and PAHs, are used to define the center of the log-normal function. (See next section.)

Movements of biota, either active or by current transport, are accounted for in determining time and concentration of exposure. Lagrangian particles are used to represent schools or groups of animals. The particles move or remain stationary according to the behavior of the animal type, and concentration and duration of exposure are recorded. Exposures are integrated over space and time by habitat type to calculate a total percentage killed.

Behavior groups are used to represent species or stages within species. These behaviors cover the possible movement patterns (or lack there of) for aquatic organisms:

1) planktonic (move with currents),
2) demersal and stationary (on the bottom exposed to near bottom water),
3) benthic (in the sediments and stationary),
4) demersal fish and invertebrates (on the bottom exposed to near bottom water and moving slowly),
5) small pelagic fish and invertebrates (moving randomly and slowly in the water column), and
6) large pelagic fish and invertebrates (moving randomly and rapidly in the water column).

Pelagic fish move at about 0.5 body length per sec (Durbin et al., 1981), which amounts to 9 km/day for a 20 cm small pelagic fish and 45 km/day for a 100 cm large pelagic fish (sizes from French et al., 1996c). For demersal species, movements are much slower, assumed to be 0.5 km/day. Demersal organisms always remain in the bottom layer within 1 meter of the bottom, whereas pelagic fish move vertically within the water column. Lagrangian particles are used to distinguish organisms in six habitat types, which are indistinguishable to each of the behavioral categories. These six habitat categories account for the fact that fish and other aquatic biota tend to prefer one or more of these types (Odum, 1971; Cowardin et al., 1979; French et al., 1996a,c):

1) seaward (offshore) open water
2) landward (estuarine) open water
3) seaward (offshore) wetland and seagrass
4) landward (estuarine) wetland and seagrass
5) seaward (offshore) reef
6) landward (estuarine) reef

Mortality is calculated as percent loss in specified areas. This is translated into the equivalent area of 100% loss. That area may be divided by the total area of habitat available in the area of interest to estimate a percentage of a population affected. The percent mortality of the exposure group may be multiplied by abundance at the time exposed and in the habitat type to calculate the species' mortality as numbers or biomass (kg).

Lost production of plants and animals at the base of the food chain is also integrated in space and over time using EC50s, the effective concentration to reduce growth to 50% of normal, to parameterize a log-normal function of the same form as the mortality function (Figure A.2-3). For each time step and for each of the concentration grid cells output by the physical fates submodel, lost primary, zooplankton and benthic production (P_L) is calculated as follows:

$$PL = (1 - F_k) V/d \Delta t$$

where F_k is the fraction of the uninhibited rate of production which is realized at the contaminant concentration, V is volume contaminated (m^3), d is water depth, and Δt is the number of days contaminated. This calculation is performed for each habitat grid cell and vertical section of the water column affected by toxic concentrations, at each time step (Δt). Total production loss is summed over time and space. The integrated losses are summarized as m^2-days of equivalent 100% loss of production. These may be multiplied by production rates in g dry weight m^{-2} day^{-1} to estimate production losses.

The biological effects model has been validated using simulations of over 20 spill events where data are available for comparison (French and Rines, 1997; French, 1998a,b,c; French McCay, 2003). In most cases (French and Rines, 1997) only the wildlife effects could be verified because of limitations of the available observational data. However, in the *North Cape* spill simulations, both wildlife and water column effects (to lobsters) could be verified (French, 1998a,b,c; French McCay, 2003). Production losses of lower trophic levels are typically very small because of their short generation times and quick recovery after a spill. They have not been measured in the field because the effect is less than natural variability.

A.2.3 Oil Toxicity to Water Column and Benthic Organisms

The following summarizes the oil toxicity model, OilToxEx, used in the SIMAP exposure model and to determine thresholds of concern for aquatic biota in the impact analysis. The full development of OilToxEx and data upon which it is based are in French McCay (2001, 2002). This state-of-the-art approach is used for natural resource damage assessments (e.g., French, 1998a,b,c; French McCay, 2003) and utilizes the accepted toxic units approach for organic compounds whose primary acute effect is narcosis. The approach is being used by USEPA in the development of PAH water and sediment quality criteria (DiToro et al., 2000; DiToro and McGrath, 2000). The use of acute toxicity endpoints, such as the LC50 (lethal concentration to 50% of exposed organisms) and EC50, for evaluation of water column effects is well established and the basis of USEPA water quality criteria for aquatic life under acute exposures (USEPA, 2002; DiToro et al., 2000). As oil spills result in short-lived contamination in the water (days to weeks, NRC, 2002a), the use of acute toxicity endpoints is appropriate. The oil toxicity model has been validated using laboratory oil bioassay data (French McCay, 2002) and for lobster mortality in the case of the *North Cape* spill (French, 1998a,b,c; French McCay, 2003). Below is a summary of the oil toxicity analysis in French McCay (2001, 2002).

The most toxic components of oil to water-column and benthic organisms are lower-molecular-weight compounds, which are both volatile and soluble in water, especially the aromatic compounds (Anderson et al., 1987; French et al., 1996a; French McCay, 2001, 2002). It has been shown that toxicity of narcotic organic compounds, such as these lower-molecular-weight aromatics in oil (MAHs and PAHs), is related to the octanol-water partition coefficient (K_{ow}), a measure of hydrophobicity (Nirmalakhandan and Speece 1988; Hodson et al., 1988; Blum and Speece 1990; McCarty 1986; McCarty et al., 1992a; Mackay et al., 1992a; McCarty and Mackay 1993; Varhaar et al., 1992; Swartz et al., 1995; French et al., 1996a; French, 1998a,b; French McCay, 2001, 2002). Chemicals that have a narcotic mode of action effect organisms by accumulating in lipids (such as in the cell membranes) and disrupting cellular and tissue function. The more hydrophobic the compound, the more accumulation in the tissues and the more severe is the effect. However, the more hydrophobic the compound, the less soluble it is in water, and so the less available it is to aquatic organisms. Compounds of $\log(K_{ow})>5.6$ are insoluble, and so are not bioavailable and thus not acutely toxic to aquatic biota (French McCay, 2001, 2002). Thus, effect is the result of a balance between bioavailability (dissolved-component exposure) and toxicity once exposed.

The acute toxic effects of narcotic chemicals, including lower molecular weight aromatics, are additive (Swartz et al., 1995; French et al., 1996a; DiToro et al., 2000; DiToro and McGrath, 2000; French McCay, 2001, 2002). The Toxic Unit (TU) model is used to estimate the toxicity of a mixture of narcotic chemicals. A TU is defined as the exposure concentration divided by the LC50. For a mixture, the toxic units are additive. When Σ TU = 1, the mixture is lethal to 50% of exposed organisms.

It may be shown (French et al., 1996a; French McCay, 2001, 2002) that the LC50 of the mixture ($LC50_{mix}$) is related to the LC50 of each chemical i in the mixture and the fractional concentration of chemical i (F_i) in the total mixture:

$$F_i = C_{w,i} / (\Sigma C_{w,i}),$$

where $C_{w,i}$ is the dissolved concentration of chemical i in the water.

$$LC50_{mix} = 1 / \Sigma (F_i / LC50_i)$$

The values of F_i may be measured in the field, or if field samples are not available, F_i may be estimated from the source oil composition. It has been shown that for surface waters, where turbulent entrainment of oil has occurred, the values of F_i are nearly proportional to the source oil aromatic composition. The values of $LC50_i$ can be estimated using regression models relating LC50 to K_{ow} (French McCay, 2001, 2002). The 95% confidence range of this regression provides LC50s for average (50^{th} percentile), sensitive (2.5^{th} percentile), and insensitive (97.5^{th} percentile) species. This oil toxicity model is used to estimate the LC50 for the dissolved aromatic mixture originating from spilled oil. Only the soluble compounds of $\log(K_{ow}) \leq 5.6$ are included in the additive toxicity model.

Toxicity varies with duration of exposure, the LC50 decreasing as exposure time increases (Sprague, 1970; Kooijman, 1981; McAuliffe, 1987; Anderson et al., 1987; French and French, 1989; McCarty et al., 1989, 1992a,b; Mackay et al., 1992a; French et al., 1996a). This is due to the accumulation of toxicant over time up to a critical body residue (tissue concentration) that causes mortality. The accumulation is more rapid at higher temperature, such that LC50 at a given (short) exposure time decreases with increasing temperature.

The following algorithm was developed in French McCay (2001, 2002). The LC50 of an aromatic in the oil mixture varies with exposure time and temperature according to:

$$LC50_\infty = LC50_t (1 - e^{-\varepsilon t})$$

$$\log_{10}(\varepsilon) = \varepsilon_1 - \varepsilon_2 \log_{10}(K_{ow})$$

$$d\varepsilon / dT = \tau T$$

where t is time of exposure, $LC50_t$ is LC50 at time t, $LC50_\infty$ is LC50 at infinite time of exposure, K_{ow} is the octanol-water partition coefficient, $\varepsilon_1 = 1.47$ and $\varepsilon_2 = 0.414$, T = temperature (C), and $\tau = 0.11$.

LC50s for MAHs and PAHs from the literature were corrected for time and temperature of exposure to calculate $LC50_\infty$. The relationship is that for narcotic chemicals, including aromatics in oil:

$$\log_{10}(LC50_\infty) = \log_{10}(\phi) + \gamma \log_{10}(K_{ow})$$

For 278 bioassays on individual aromatics, the slope and intercept of the regression are: $\log_{10}(\phi) = 4.8926$ and $\gamma = -1.0878$. This regression describes the mean response for all species (i.e., the response of the average species). The slope of this relationship is constant for all species (see DiToro et al., 2000 for theory). The intercept varies by species, with 95% of species falling within the range $\log_{10}(\phi) = 3.9704$ (sensitive species) and $\log_{10}(\phi) = 5.8147$ (insensitive species). The above equation may be used to estimate $LC50_\infty$ for any aromatic, employing an appropriate intercept for the species of concern (French McCay, 2001, 2002).

The SIMAP exposure model takes into account the time and temperature of exposure, using the rearrangement of the above: $LC50_t = LC50_\infty / (1- e^{-\varepsilon t})$ to correct the LC50. Time of exposure is evaluated by tracking movements of organisms relative to toxic concentrations (greater than the concentration lethal to 1% of exposed organisms, LC1, approximated as 1% of $LC50_\infty$). Stationary or moving Lagrangian tracers that represent organisms record the concentrations of exposure over time and the dose (sum over time of concentration multiplied by duration) to an organism represented by that behavior. Exposure time is the total time concentration exceeds LC1. The concentration is the average over that time, or total dose divided by exposure time. The percent mortality may then be calculated using the log-normal function centered on $LC50_t$.

The threshold of concern for toxicity can be estimated from LC50 corrected to the expected duration of exposure. In the stochastic model results described below, the peak exposure concentrations are for brief exposures, on the order of hours. Thus, for example, a time-corrected LC50 indicates the concentration where 50% of exposed organisms would be expected to be affected. The time-corrected LC50 for sensitive species would be protective of (not have an effect on) 95% of exposed individuals of the 2.5^{th} percentile species (in rank order of sensitivity). Thus, if concentrations are less than this threshold concentration, 95% of the individuals of 97.5% of species (on a statistical basis) would not be expected to suffer an effect. This conservative threshold is used as a threshold of concern in the analysis of model results.

BTEX is very soluble in water, and so exposure concentrations in water can be high. However, BTEX is only moderately hydrophobic and so relatively low in toxicity. It is also very volatile. Thus, the BTEX rapidly volatilizes reducing exposure concentrations. For these reasons, the effect of BTEX after a spill is typically low and of short duration, except for light fuels such as gasoline which contain high percentages of BTEX (French McCay, 2002).

PAHs and many of the alkyl-substituted benzenes are less soluble than BTEX, but do dissolve in significant quantities into the water. Thus, they are bioavailable. Because they are more hydrophobic than BTEX, they more strongly partition into the lipids in membranes and tissues. Thus, they are more toxic and can have significant effects on aquatic organisms (French McCay, 2002).

Lower-molecular-weight aliphatic hydrocarbons (e.g., alkanes and cycloalkanes with boiling points less than about 380°C) may also contribute to toxicity after an oil spill. However, the aliphatics are more volatile (have higher vapor pressure) and less soluble than aromatics of the same molecular weight (Mackay et al., 1992b,c,d) and would be more readily lost to the atmosphere from surface waters. They are also less toxic than the aromatics of similar molecular weight (French McCay, 2001, 2002). Anderson et al. (1987) found that 98% of the dissolved hydrocarbons in oil and water dispersions were aromatics (MAHs and PAHs).

The residual fraction in the model is defined as the non-volatile and insoluble compounds that remain in the "whole oil" that spreads, is transported on the water surface, strands on shorelines, and disperses into the water column as oil droplets or remains on the surface as tar balls. This is the fraction that comprises black oil, mousse, and sheen. It is not bioavailable or acutely toxic to aquatic biota (fish, invertebrates, and plankton; French McCay, 2002).

The $LC50_{mix}$ of the aromatic mixture is calculated using the additive model, including those aromatics that are measured in the oil and dissolved in the water (with $\log(K_{ow}) \leq 5.6$) for long enough for exposure to aquatic organisms to be significant. Typically (except for gasoline), only the PAHs are dissolved in sufficient quantity and remain in the water long enough for their TU values to be significant. The biological effects model uses the total PAH concentration (or BTEX plus total PAH if BTEX is significant) and the estimated $LC50_{mix}$, corrected for time and temperature of exposure, to estimate mortality to aquatic biota. Typically, the appropriate $LC50_{mix}$ is for average sensitivity for most species, as specific data are not available for all species. However, for certain sensitive species the 2.5^{th} or 97.5^{th} percentile $LC50_{mix}$ is more appropriate. Categorization of species as sensitive, average or insensitive is based on bioassay data reviewed in French McCay (2001, 2002).

The dissolved concentrations are estimated by the fates model for both the water column and sediments. Dissolved concentrations the water column result mainly from dissolution of entrained oil droplets, as the soluble compounds evaporate faster from surface slicks. In the sediments, dissolved concentrations in pore waters are calculated using the equilibrium partitioning model. Exposure and mortality of benthic organisms are a function of the dissolved concentrations in pore water. This methodology has been validated by Swartz et al. (1995) and used in sediment quality criteria for PAHs (DiToro et al., 2000).

A.2.4 Stochastic Modeling

The stochastic modeling approach employed in this analysis has previously been used to estimate potential impacts as part of contingency planning, ecological risk assessments, net environmental benefit, and cost-benefit analyses (French et al. 1999; French McCay and Payne 2001; French McCay et al. 2002, 2003). The strength of the approach is that the range of possible environmental conditions is sampled randomly, providing an unbiased, quantitative estimate of the distribution of expected effects. In an environmental impact assessment under NEPA, the range of potential effects should be compared among alternatives. A Monte Carlo type approach, such as used here, is commonly used by MMS to evaluate the potential impacts of offshore oil and gas development (e.g., MMS, 2002a,b). MMS uses their Oil Spill Risk Analysis (OSRA) trajectory model to evaluate potential pathways and shoreline oiling from hypothetical spills, randomly selecting from the range of potential environmental conditions that might occur at and after the time of the release. Monte Carlo modeling approaches are also used for evaluations of the range of potential impacts of developments and discharges into water (USEPA, 1991).

In order to determine risks to ecological resources, multiple scenarios and conditions need to be evaluated to develop an expectation of risk of oil reaching each site of concern. The stochastic oil fates model in SIMAP is used to determine the range of distances and directions oil spills are likely to travel from a particular site, given historical wind and current speed and direction data for the area. To sample the universe of possible environmental conditions, long-term wind and current data are compiled. For each model run used to develop the statistics, the spill date is randomized. This provides a probability distribution of wind and current conditions during the spill. The stochastic model performs a large number of simulations for a given spill site, varying the spill time, and thus the wind and current conditions, for each run. Output of the model is the time histories of the spill trajectories. These distributions are used to estimate the percent of these hypothetical spills where water surface, water column, sediments, and shoreline areas will be affected by a release from a spill at a given site.

The 3D stochastic model quantifies the following exposure measures, in space and over time, for each individual model run:

1) oil thickness (microns or g/m2) on water surface,
2) oil thickness (microns or g/m2) on shorelines,
3) subsurface oil droplet concentration, as total hydrocarbons,
4) dissolved aromatic concentration in water,
5) total hydrocarbon loading on sediments (g/m2), and
6) dissolved aromatics concentration in sediment pore water.

The results of each model run are summarized by mapping of each of these exposure measures onto the habitat grid as:

1) the time of first exceedance of the threshold for concern (in this case that protective of 97.5% of species),
2) maximum exposure (thickness or concentration) at any time after the spill, and
3) an integrated dose measure of g/m2-hours for slicks and sediments or ppb-hrs for concentrations.

The results of multiple model runs are also evaluated to develop the following indicators of possible exposure for each location and for each of the components listed above:

1) Probability of exposure (probability that a threshold thickness or concentration will be exceeded at each location at any time following the spill).
2) Time (hours) before potential first exceedance of the threshold at each location.
3) Worst case maximum exposure (thickness, volume or concentration) at any time after the spill, at a given location (i.e., maximum peak exposure for all the model runs), calculated as follows. For each individual run (for each spill date run), the maximum amount over all time after the spill is saved for each location in the model grid. Then the runs are evaluated to determine the greatest or highest amount possible at each location.
4) Mean expected maximum exposure (thickness, volume or concentration) at any time after the spill, at a given location (i.e., mean peak exposure of all model runs), calculated as follows. For each individual run (for each spill date run), the maximum amount over all time after the spill is saved for each location in the model grid. The runs are evaluated to determine the mean expected peak exposure (mean exposure for all runs) at each location.

The SIMAP graphical user interface produces maps of these statistics, both for individual runs and summarizing possible exposures based on all runs. Mapped geographical data of resources (biological and human use) may be compared when overlaid with model results. The results are also tabulated by habitat or shore type for each of several ranges of exposure conditions (thickness, mass loading (g/m^2) or concentration intervals).

The stochastic modeling outputs provide a distribution of spill results, which may be summarized by statistics such as mean and standard deviation. The results are ordered into a probability density function (PDF) such that the 50th (median) and other percentile exposures and spill date-times are identified. Individual runs may be evaluated in greater detail to characterize the impacts of events of that probability. The worst case exposure described above is the maximum possible exposure based on the model runs performed (i.e., the 99th percentile if 100 runs are made).

A PDF of a particular exposure measure, such as area swept by oil, may be scaled to an impact measure, such as percentage of waterfowl in the area of interest which are oiled, by running the biological exposure model to estimate the effect for a specific percentile run (e.g., the 50th percentile run). The ratio of the impact measure to the exposure measure for that run is used to scale the PDF in terms of impact. For example, the PDF of area swept by oil may be multiplied by the ratio of waterfowl oiled per area swept to calculate the PDF in terms of waterfowl effect. This approach is used in the analysis of model results in this study. The effect on each resource is evaluated as proportional to the exposure measure by which the resource is most affected (such as surface area swept for waterfowl and seabirds, water column dissolved aromatic dose for fish, etc.). Table A.2-5 lists example biological resource categories and appropriate exposure measures.

Table A.2-5. Biological resource types and exposure measure by which the resource is most affected.

Resource	Exposure Measure
Waterfowl, seabirds, marine mammals, sea turtles	Water surface area swept or g/m^2-days (an index of area swept)
Waders, shorebirds	Wetland and shoreline area oiled
Fish, water column invertebrates, plankton	Dissolved aromatic dose (ppb-hours) and volume exposed
Benthic biota	Sediment concentrations (dissolved aromatic concentration in pore water)

A.2.5 Limitations of the Model and the Analysis

The model has been developed over many years to include as much information as possible to simulate the fates and effects of oil spills. However, as in all science, there are significant gaps in knowledge and the ability to simulate the detailed behavior of organisms and ecosystems. As described in the preceding sections, assumptions based on available scientific information and professional judgment were made in the development of the model, which represent our best assessment of the processes and potential mechanisms for effects that would result from oil spills.

The major sources of uncertainty in the oil fates and biological effects model are:

- Oil contains thousands of chemicals of varying physical and chemical properties that determine their fate in the environment. The model must of necessity treat the oil as a mixture of a limited number of components, grouping chemicals by physical-chemical properties.
- The fates model contains a series of algorithms that are simplifications of complex physical-chemical processes. These processes are understood to varying degrees, as described above.
- Organisms are assumed uniformly distributed in affected habitats they occupy for the duration of the spill simulation. The accuracy of this assumption varies between organisms, but the objective is to assess potential effects for an average-expected condition, which is what this assumption most closely resembles.
- Biological effects are quantified based on acute exposure and toxicity of contaminant concentrations as a function of degree and duration of exposure. The model is not designed to address long-term, chronic exposure to pollutants.
- It is assumed that the mortalities and changes in biological productivity are small enough that ecosystem structure is not significantly changed. The model does not address changes in predator-prey or competitive relationships between populations.
- The model treats each spill as an isolated event and does not account for any potential cumulative effects.

In addition, in any given oil spill, the fates and effects will be highly related to the specific environmental conditions, the precise locations of organisms, and a myriad of details related to the event. Thus, the results are a function of the scenarios simulated and the accuracy of the input data used (described in Section A.3). The goal of this study was not to capture every detail that could potentially occur, but to statistically describe the range of possible consequences so that an informed analysis could be made as to the likely effects of spills under specified response scenarios. The model inputs are designed to provide representative conditions to such an analysis. Thus, the modeling is used to provide quantitative guidance in the analysis of the scenarios considered in the PEIS (USCG, 2004).

A.3 INPUT DATA

A.3.1 Geographical Model Grid: Shoreline, Depth and Habitat Mapping

For geographical reference, SIMAP uses a rectilinear grid to designate the location of the shoreline, the water depth (bathymetry), and the shore or habitat type. The grid is generated from a digital coastline using the ESRI Arc/Info® compatible Spatial Analyst program. The cells are then coded for depth and habitat type. Note that the model identifies the shoreline using this grid. Thus, in model outputs, the coastline map is only used for visual reference; it is the habitat grid that defines the actual location of the shoreline in the model.

Preliminary model runs were made in each location to determine the extent of possible surface oil contamination. The potentially affected area was then gridded with the maximum number of grid cells (smallest grid cell size) possible within the memory limits of the computers used (Windows NT machines). The maximum possible number of cells in a grid is 540,000.

Depth data for all locations modeled were obtained from Hydrographic Survey Data supplied on CD-ROM by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Geophysical Data Center. Hydrographic survey data consist of large numbers of individual depth soundings. The data points were then interpolated into the grid, by averaging all soundings falling within a cell.

Digital shoreline data were mapped from Environmental Sensitivity Indices (ESI) coverages in Environmental Sensitivity Atlas Geographical Information System (GIS) for each area. ESI codes, which identify the shoreline substrate type and grain size, were translated to equivalent habitat codes for SIMAP. Habitat type is based on shoreline substrate type, grain size, and dominant structure-defining vegetation or fauna (based on the system of Cowardin et al., 1979 as developed in French et al., 1996a and described in Section A.2.2). Vegetated subtidal habitats (seagrass and kelp beds) were mapped from coverages also provided in Environmental Sensitivity Atlas. Other subtidal areas were assumed to be sand. (This assumption has no influence on oil fate.)

Within a grid, habitats are designated as landward or seaward. Landward portions are the rivers, estuaries and inlets. The seaward portion is the offshore (shelf) area. This designation allows different biological effects to be estimated in landward and seaward zones of the same habitat type (e.g., open water with sand bottom).

Ecological habitat types are broadly categorized into two zones: intertidal and subtidal (Table A.3.-1). Intertidal habitats are those above spring low water tide level, with subtidal being all water areas below that level. Intertidal areas may be extensive, such that they are wide enough to be represented by an entire grid cell at the resolution of the grid. These are typically either mud flats or wetlands, and are coded 20 (seaward mudflat), 21 (seaward wetland), 50 (landward mudflat) or 51 (landward wetland). All other intertidal habitats are typically much narrower than the size of a grid cell. Thus, these fringing intertidal types (indicated by F in Table A.3-1) have typical (for the location, French et al., 1996a) widths associated with them in the model. Boundaries between land and water are fringing intertidal habitat types. On the waterside of fringing intertidal grid cells, there may be extensive intertidal grid cells if the intertidal zone is extensive. Otherwise, subtidal habitats border the fringing intertidal.

Table A.3-1. Classification of habitats. Seaward (Sw) and landward (Lw) system codes are listed. (Fringing types indicated by (F) are only as wide as intertidal zone in that province. Others (W = water) are a full grid cell wide and must have a fringing type on the land side.)

Habitat Code (Sw,Lw)	Zone	Ecological Habitat	F or W
1,31	Intertidal	Rocky Shore	**F**
2,32		Gravel Beach	**F**
3,33		Sand Beach	**F**
4,34		Fringing Mud Flat	**F**
5,35		Fringing Wetland (Saltmarsh)	**F**
6,36		Macrophyte Bed	**F**
7,37		Mollusk Reef	**F**
8,38		Coral Reef	**F**
9,39	Subtidal	Rock Bottom	**W**
10,40		Gravel Bottom	**W**
11,41		Sand Bottom	**W**
12,42		Silt-mud Bottom	**W**
13,43		Wetland (Subtidal of Saltmarsh)	**W**
14,44		Macroalgal (Kelp) Bed	**W**
15,45		Mollusk Reef	**W**
16,46		Coral Reef	**W**
17,47		Seagrass Bed	**W**
18,48	Intertidal	Man-made, Artificial	**F**
19,49		Ice Edge	**F**
20,50		Extensive Mud Flat	**W**
21,51		Extensive Wetland (Saltmarsh)	**W**

The intertidal habitats were assigned based on the shore types in digital Environmental Sensitivity Index (ESI) maps. The mapping of ESI index to the SIMAP habitat/shore type was as in Table A.3-2. Open water areas were defaulted to sand bottom. Where data are missing, shore types are defaulted as in Table A.3-3.

Table A.3-2. Mapping of ESI shore type to SIMAP habitat types.

ESI Shore Type	SIMAP Habitat Type	Code
bedrock	rocky shore	1
boulder beach	rocky shore	1
exposed rocky cliffs	rocky shore	1
exposed scarps and steep slopes of clay	fringing mud flat	4
scarps and steep slopes in sand	sand beach	3
exposed tidal flats	sand beach	3, 20
gravel beach	gravel beach	2
man-made solid	intertidal artificial	18
mixed sand-gravel beach	sand beach	3
mud tidal flat	fringing or extensive mud flat	4, 20
pebble-cobble beach	gravel beach	2
salt marsh	fringing or extensive wetland	5, 21
sand beach	sand beach	3
sand tidal flat	sand beach	3
riprap and sheltered riprap	rocky shore	1
vegetated, steeply sloping bluffs	gravel beach	2
sheltered tidal flats	extensive or fringing mud flat	4, 20
vegetated low banks (estuarine or riverine)	landward fringing wetland	35
salt and brackish-water marshes	fringing or extensive wetland (saltmarsh)	5, 21
freshwater marshes and swamps	landward extensive wetland	35, 51
scrub-shrub wetlands	landward extensive wetland	35, 51

Table A.3-3. Default fringing intertidal habitat type, given adjacent subtidal or extensive intertidal habitat type.

Subtidal or Extensive Intertidal Habitat	Fringing Intertidal Habitat
Seagrass Bed (47)	Sand Beach (33)
Subtidal Sand Bottom (41)	Sand Beach (33)
Extensive Mudflat (50)	Fringing Mudflat (34)
Extensive Wetland (51)	Fringing Wetland (35)

A.3.2 Environmental Data

The model uses hourly wind speed and direction for the time of the spill and simulation. A long term wind record (>10 year) is sampled at random to develop a probability distribution of environmental conditions that might occur at the time of a spill. The model can use multiple wind files, spatially interpolating between them to determine local wind speed and direction. However, as all the locations where simulations were run were on the continental shelf, a single wind station record was used. Standard meteorological data were acquired from the National Data Buoy Center Internet site for the nearest NDBC buoy to the spill site. Hourly mean wind speed and direction were compiled in the SIMAP model input file format. Appendices B-I.1.4, C-I.1.4, D-I.1.4, E-I.1.4 and F-I.1.4 of Parts B to F of this technical report provide the sources and specifics of the wind data used.

Surface water temperature varies by month, based on data in French et al. (1996b) for the area of the spill site. The air immediately above the water is assumed to have the same temperature as the water surface, this being the best estimate of air temperature in contact with the water and floating oil. The mean salinity value for the location of the spill site is used, based on data compiled in French et al. (1996b). Variation of salinity within a few parts per thousand (over the possible range in the marine environment of the location of interest) would have little influence on the fate of the oil, as salinity is used to calculate water density (along with temperature), which is used to calculate buoyancy, and none of the oils evaluated have densities near that of the water. It is assumed that the responders will use dispersants appropriate to the salinity at the spill site. Appendices B-I.1.4, C-I.1.4, D-I.1.4, E-I.1.4 and F-I.1.4 of Parts B to F of this technical report provide the sources and specifics of the temperature and salinity data used.

Suspended sediment is set at 10 mg/l, a typical value for coastal waters (Kullenberg, 1982). The sedimentation rate is 1 m/day. These default values have no significant affect on the model trajectory. Sedimentation of oil and PAHs becomes significant at about 100 mg/L suspended sediment concentration. High suspended sediment concentrations do not occur at any of the spill sites modeled French et al. (1996b).

The horizontal diffusion (randomized mixing) coefficient is 1 m^2/sec. The vertical diffusion (randomized mixing) coefficient is 0.0001 m^2/sec. These are reasonable values for coastal waters based on empirical data (Okubo and Ozmidov, 1970; Okubo, 1971) and modeling experience.

A.3.3 Currents

A.3.3.1. Tidal and Other Currents

Currents have substantial influence on the trajectory, and are critical data inputs. Wind-driven, tidal and background currents are included in the modeling analysis. The wind driven currents are calculated within the oil spill model (as described in Section A.3.3.2). The tidal currents and background (other than tidal) currents are input to the oil fates and biological effects models from a current file that is prepared for this purpose. Sections B-I.2.1, C-I.2.1, D-I.2.1, E-I.2.1, and F-I.2.1 to Parts B through F contain specific descriptions of the current data used in the model runs. Below is a summary of the sources of those data.

For Prince William Sound and the Florida Straits, seasonal mean current data previously generated by hydrodynamic models were used. ASA had performed hydrodynamic modeling previously for Prince William Sound. For the Florida Straits, the POP (Parallel Ocean Program) model developed by the Los Alamos Laboratory has been run for mean climatic conditions. Both these current fields represent long-term climatic mean conditions. In Prince William Sound, tidal currents were also simulated and included. The sources for the currents are described in Sections D-I.2.1 (Prince William Sound) and F-I.2.1 (Florida Straits) of Parts D and F.

For Galveston, San Francisco, and Delaware Bay, current data were generated using ASA's boundary fitted coordinate hydrodynamic model (BFHYDRO) which produces applicable hydrodynamic data sets suitable for use in the SIMAP model system. The hydrodynamic model's governing equations and validation are described in detail in Muin and Spaulding (1997a, b), Spaulding et al. (1999a), and Sankaranarayanan and Spaulding (2003). The boundary-fitted grid is a mesh of quadrilateral cells of varying size and included angles, which is capable of handling variable geometry and flow regimes. The boundary fitted coordinate system in BFHYDRO uses general curvilinear coordinates to map the model grid to the shoreline of the water body being studied. It also allows enormous versatility in grid sizing so that many of the smaller features may be resolved, along with the larger, without being penalized by an excessive grid size (number of cells).

Existing sources of current data were considered for the oil spill modeling off Galveston, San Francisco, and Delaware Bay. However, we need to model spills for sample dates from at least a decade, with the tidal and other forces for those dates, and in high resolution in the area of the spill site. Thus, we applied BFHYDRO, and compared the predictions to existing current data, as well as National Oceanic and Atmospheric Administration tidal predictions, as part of the calibration and verification of the model results. The model compared well with the observational data (as described in Appendix B-I.2, C-I.2, and E-I.2 to Parts B, C, and E of this technical report). The ASA model also is compatible with the oil trajectory model SIMAP, requiring no data processing step to input the current data to SIMAP.

The boundary-fitted method uses a set of coupled quasi-linear elliptic transformation equations to map an arbitrary horizontal multi-connected region from physical space to a rectangular mesh structure in the transformed horizontal plane. The 3-dimensional conservation of mass and momentum equations, with approximations suitable for estuaries (Muin and Spaulding, 1997a, b) that form the basis of the model, are then solved in this transformed space. In addition, an algebraic transformation is used in the vertical to map the free surface and bottom onto coordinate surfaces. The resulting equations are solved using an efficient semi-implicit finite difference algorithm.

In that Galveston Bay, San Francisco Bay, and Delaware Bay (and nearby coastal waters) are highly energetic and predominantly well-mixed, BFHYDRO was applied in the two-dimensional mode, thus providing vertically-averaged currents. Known physical conditions are input to the model grid at the edges, termed "open boundaries". These inputs are described as "forcing factors". The forcing factors are water height, available from tidal height data, and river flow. Salinity driven (i.e., density driven) flows, were not considered for the present analysis. Forcing factors due to wind stress on the water surface were included in the wind drift calculation in the oil fates model.

Tidal currents are driven by a mix of forces with semi-diurnal and diurnal periodicity, causing the elevations of successive high and low tides to be unequal. The major 6 constituents are M2, S2, N2, K1, O1, and P1, where the letter and number codes for the tidal constituents are standard terminology based on harmonic analysis of tidal height data (Defant, 1961), with the number indicating the approximate frequency of the sinusoidal cycle per day (1 is diurnal and 2 is semi-diurnal). The letter indicates the sinusoidal periodicities included in the component. M2 and S2 are pure lunar and solar components, respectively. All the others are mixtures of signals resulting from various periodic changes in the position of the sun and moon relative to the earth. For more information, see Defant (1961) or similar oceanographic text book.

Tidal forcing is accomplished by defining the water height over time at the model grid boundaries. The forcing is specified for each tidal constituent. The current vectors for each constituent are computed for each model grid cell and time step based on physical laws (conservation of mass and momentum). Current vectors for non-tidal flows are computed in an analogous manner. In the oil spill model, the various tidal constituent and non-tidal current vectors are summed to determine the actual transport of oil components and plankton in the particular grid cell and time step of interest.

The hydrodynamic model (BFHYDRO) has been validated in numerous applications, including in Muin and Spaulding (1997a, b), Spaulding et al. (1999a), and Sankaranarayanan and Spaulding (2003) where the governing equations are described. Applications that have been validated include: for San Francisco Bay (French McCay et al., 2002, 2003; Sankaranarayanan and French McCay, 2003a); for the Narragansett Bay system (Swanson et al., 1998; Spaulding et al., 1999b; Kim and Swanson, 2001); for Bay of Fundy (Sankaranarayanan and French McCay, 2003b); the Savannah River (Mendelsohn et al., 1999), and Charleston Harbor, SC (Peene et al., 1997; Yassuda et al., 2000a,b; Mendelsohn et al., 2001).

Details of the current data for each location are in Sections B-I.2, C-I.2, D-I.2, E-I.2, and F-I.2. There are also current vector plots for the dominant tidal constituent, M2, at selected intervals relative to maximum flood and maximum ebb. The actual summed current vectors for all tidal and non-tidal constituents vary slightly from this dominant tidal signal for each individual model run, as the 100 spill dates run vary randomly over a long-term period. The exception is for the Florida location, where a long-term mean current field was used (as shown in D-I.2.2).

A.3.3.2. Wind-driven Surface Currents

Wind-driven surface currents are calculated within the SIMAP fates model, based on local wind speed and direction. Surface wind drift of oil has been observed in the field to be 1-6% (average 3-4%) of wind speed in a direction 0-30 degrees to the right (in the northern hemisphere) of the down-wind direction (ASCE, 1996).

Wind drift speed and angle were studied in detail by Youssef and Spaulding (Youssef, 1993; Youssef and Spaulding, 1993, 1994), finding the following. Wind drift speed as a percentage of wind speed over the water is highest at low wind speed and decreases as wind speed increases. The range of drift speed for winds up to 20 kts (averaged over time) is 2-4% of wind speed. At 10 kts or less, the percent of wind speed is about 3.5-4% at the water surface, decreasing to 2% at 0.1m below the surface. The angle to the right of down wind is highest at low wind speed, on the water surface ranging from about 20^o-30^o at 10 kts or less. The drift speed decreases, and the drift angle increases, deeper into the water column.

Youssef and Spaulding (Youssef, 1993; Youssef and Spaulding, 1993, 1994) developed a set of equations to describe the percent of wind speed and angle as functions of wind speed and depth in the water. This algorithm has been incorporated into SIMAP. The wind drift is applied to the upper 5 meters of the water column. The SIMAP algorithm was validated with observations of the drift of floating fuel and bitumen in surface water after an intentional (test) Orimulsion spill (French et al., 1997).

A.3.4 Oil Properties and Toxicity

The oil types modeled were South Louisiana crude oil for the Atlantic, Gulf of Mexico, and Florida locations; and Alaskan North Slope crude oil for the Pacific and PWS locations. Crude oil was modeled because dispersants would not normally be used on light fuels, as they evaporate and naturally disperse rapidly, and on heavy fuels, because their viscosity is too high. These crude oils are the among the most commonly shipped oils in the region: South Louisiana crude represents the Gulf of Mexico production of oils and Alaskan North Slope crude is shipped out of Valdez to the west coast in large quantities (Etkin and Michel, 2002; French McCay et al., 2002, 2003). Also, the properties of these oils have been measured in sufficient detail to allow use in the modeling. Finally, these medium viscosity oils are representative of the range of crude oils in terms of their fates and effects. The results using these crude oils are also representative of oils generally.

Physical and chemical data on these oils were taken from the NRDAM/CME database (French et al., 1996b), except for the PAH concentrations, which were based on data in French McCay (2001), the MAH concentrations, which were from Jokuty et al. (1996, 1999) and Wang et al. (1995), and the volatile aliphatic concentrations, which were calculated from boiling curves (in Jokuty et al. 1996 and 1999), subtracting the volatile aromatics. Properties used in the modeling are in Table A.3-4.

The volatile aliphatics are evaporated and volatilize from the surface water. Their mass is accounted for in the overall mass balance. However, as they do not dissolve in significant amounts, they have no influence on the biological effects on water column and benthic organisms (French McCay, 2002; see Section A.2.3).

For crude oil spills, MAHs do not have a significant effect on aquatic organisms for the following reasons. MAH concentrations are <3% in fresh fuel oils. MAHs are soluble, and so become bioavailable (dissolved). MAH compounds are also very volatile, and will volatilize (from the water surface and water column) very quickly after a spill. The threshold for toxic effects for these compounds is about 400 ppb for sensitive species (French McCay, 2001, 2002). MAHs evaporate faster than they dissolve, such that toxic concentrations are not reached. The small concentrations of MAHs in the water will quickly be diluted to levels well below toxic thresholds immediately after a spill. Thus, the MAH content of the spilled oil has little influence on model results, while the percentage of PAHs has a significant influence on the model results (French McCay, 2002; see also Section A.2.3). Thus, data for well-defined oils were used in the model runs, and the LC50s were for PAH concentrations in the water.

Table A.3-4. Properties of fuel oils used in the modeling.

Property	AK North Slope Crude	South LA Crude
Density @ 25°C (g/cm^3)	0.8761	0.8518
Viscosity @ 25°C (cp)	16	8.0
Surface Tension (dyne/cm)	27	25.9
Pour Point (°C)	-54	-28
Adsorption Rate to Suspended Sediment	0.01008	0.01008
Adsorption Salinity Coefficient (ppt^{-1})	0.023	0.023
Fraction monoaromatic hydrocarbons (MAHs)	0.030662	0.01478
Fraction polynuclear aromatic hydrocarbons (PAHs)	0.010372	0.008108
Fraction 2-ring aromatics (included in PAHs above)	0.00375	0.003104
Fraction 3-ring aromatics (included in PAHs above)	0.006622	0.005004
Fraction Non-Aromatic Volatiles: boiling point <180°C	0.18934	0.16522
Fraction Non-Aromatic Volatiles: boiling point 180-264°C	0.13325	0.18590
Fraction Non-Aromatic Volatiles: boiling point 264-380°C	0.200378	0.62711
Minimum Oil Thickness (m)	0.00005	0.00001
Maximum Mousse Water Content (%)	70	75
Mousse Water Content as Spilled (%)	0	0
Water content of fuel (not in mousse, %)	0	0
Degradation Rate (day^{-1}), Surface & Shore	0.01	0.01
Degradation Rate (day^{-1}), Hydrocarbons in Water	0.01	0.01
Degradation Rate (day^{-1}), Oil in Sediment	0.001	0.001
Degradation Rate (day^{-1}), Arom. in Water	0.01	0.01
Degradation Rate (day^{-1}), Arom. Sediment	0.001	0.001

The following data are needed to estimate a mixture LC50 for low molecular weight aromatics.

- The LC50 for each PAH in the mixture. This is available from French McCay (2001, 2002), as described in Section A.2.3.
- The relative concentrations of each PAH dissolved in water (to which organisms are exposed). Total PAH data for each oil is available. For oils in general, the relative concentrations have been shown to be equal to that in the source oil (French McCay, 2001, 2002).

To estimate $LC50_{mix}$ values for dissolved PAHs in the water, the additive model is used with LC50s calculated from the regression of LC50 versus log(K_{ow}, Section 2.3) and F_i values calculated from concentrations of PAHs (with log($K_{ow} \leq 5.6$) in typical crude and fuel oils. Three LC50s were estimated using the slope of $\gamma = -1.0878$:

- For species of average sensitivity (50th percentile), the intercept $\log_{10}(\phi) = 4.8926$
- For sensitive species (2.5th percentile), the intercept $\log_{10}(\phi) = 3.9704$
- For insensitive species (97.5th percentile), the intercept $\log_{10}(\phi) = 5.8147$

This yielded the following $LC50_{mix}$ values for infinite exposure time. In the impact assessment, the sensitive species value was used as a conservative (protective) value.

- For species of average sensitivity (50th percentile), $LC50_{mix}$ = 48 ppb
- For sensitive species (2.5th percentile), $LC50_{mix}$ = 6 ppb
- For insensitive species (97.5th percentile), $LC50_{mix}$ = 400 ppb

The LC50s above are for the concentration of *dissolved* PAHs that would be lethal to 50% of exposed organisms for a long enough times of exposure for mortality to occur. For PAHs, this is for at least 2 weeks of exposure at warm temperature. For chemicals in general, toxicity is higher, and the LC50 lower, at longer time of exposure and higher temperature (French et al, 1996a; French McCay, 2001, 2002).

The literature shows that, for most organic and inorganic chemicals, the threshold for sublethal effects is approximately 10 times lower than the 96-hour LC50 (Call et al., 1985; Gobas, 1989; Giesy and Graney, 1989). The only chemicals where higher ratios occur are those that have very high log(K_{ow}), and so bioaccumulate. PAHs have ratios of up to 10. Thus, the sublethal effect threshold for PAHs in oils would be about 5-7 ppb for average species and about 1 ppb for sensitive species. Dissolved PAH concentrations below 1 ppb would not be expected to have any toxic effects on aquatic organisms. Note that exceedance of the chronic threshold would need to be for long time periods (>1 week) for effects to occur.

The model results show that the duration of water column exposures are on the order of hours. Thus, the exposures are acute rather than long-term, and the LC50 for infinite exposure time is very conservative in considering potential for effects. Sublethal effects would also be expected to vary by duration of exposure. Table A.3-5 lists acute toxicity values for each fuel component, and for sensitive (5th percentile) and average (50th percentile) species, at different durations of exposure at 25°C (based on equations in Section 2.3 and from French McCay, 2002). The LC50s for short exposure times are higher at colder temperatures. Figure A.3-1 plots LC50s for species of average sensitivity for a range of exposure durations and temperatures. The data are based on the oil toxicity model that has been validated using laboratory oil bioassay data (French McCay, 2002) and for lobster mortality in the case of the *North Cape* spill (French, 1998a,b,c; French McCay, 2003).

Table A.3-5. LC50s for oil PAHs (μg/l) and varying exposure times (French McCay, 2002).

Exposure Time (hours)	Sensitive Species (2.5th percentile)	Average Species (50th percentile)
6	99	789
96	9	76
(infinite exposure)	6	48

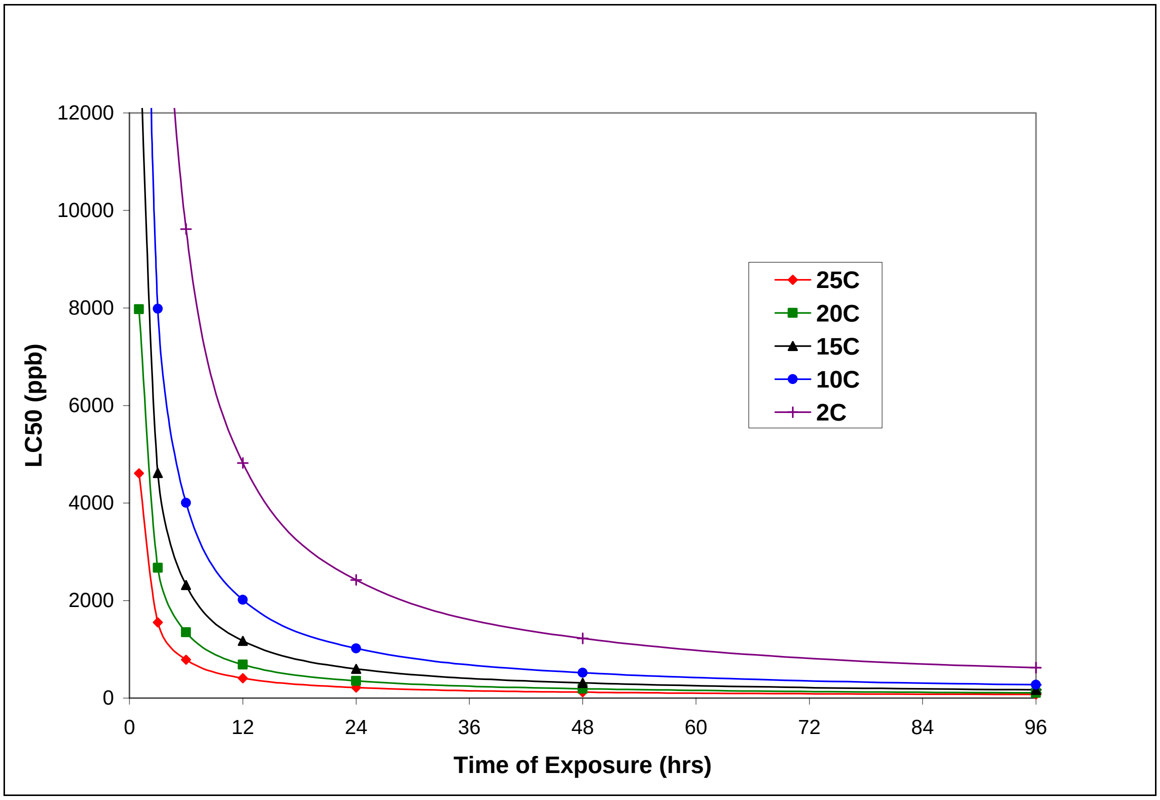

Figure A.3-1. Effect of time of exposure and temperature on LC50, for PAHs in oil (based on equations in Section A.2.3 and from French McCay, 2002).

For PAHs, the LC50 for six hours of exposure for the 2.5th percentile species is 100 µg PAH/L (Table A.3-5). The exposure dose threshold for sensitive species is 600 ppb-hrs. Thus, to the nearest half order of magnitude, short-term PAH concentration doses below 500 ppb-hrs would have no significant effect on aquatic organisms.

In the stochastic model analysis to determine potential for effects, the chronic threshold of 1ppb total PAH was used. This threshold is conservative, in that 97.5% of species would not be affected by concentrations of 1ppb under long-term exposure. Based on the above discussions, the threshold for acute effects for short-term exposures in the water column is 600-ppb-hrs. Individual model runs, with the LC50 corrected for temperature and time of exposure, were used to evaluate acute effects of each spill scenario. Thus, potential for both short- and long-term effects was evaluated.

A.3.5 Shoreline Oil Retention

Retention of oil on a shoreline depends on the shoreline type, width and angle of the shoreline, viscosity of the oil, the tidal amplitude, and the wave energy. In the NRDAM/CME (French et al., 1996a,b), shore holding capacity was based on observations from the *Amoco Cadiz* spill in France and the *Exxon Valdez* spill in Alaska (based on Gundlach, 1987) and later work summarized in French et al., 1996a). These data are used here (Table A.3-6). The shore (intertidal zone) widths used were typical widths for the location, based on French et al. (1996a). Shore widths for each location are listed in the model input tables of Parts B to F (Sections B-I.4, C-I.4, D-I.4, E-I.4, and F-I.4).

Table A.3-6. Maximum surface oil thicknesses for various beach types as a function of oil viscosity (from French et al., 1996a, based on Gundlach, 1987).

	Oil Thickness (mm) by Oil Type		
Shore Type	Light (<30 cSt)	Medium (30-2000 cSt)	Heavy (>2000 cSt)
Rocky shore	1	5	10
Gravel beach	2	9	15
Sand beach	4	17	25
Mud flat	6	30	40
Wetland	6	30	40
Artificial	1	2	2

A.3.6 Modeled Scenarios

Current approvals for dispersant application limit their use to specific offshore distances (usually greater than 3 nautical miles) and water depths (usually greater than 10 meters). Therefore, dispersants are not likely to be applied in coastal waters or marine waters shallower than 10 meters or closer than 3 nautical miles from shore. The spill sites for modeled scenarios were chosen to be 7.5 nautical miles (nmiles) from port (Table A.3-7), which is the approximate midpoint of the nearshore zone for response, which extends outward 12 miles from about three miles from shore. This area is the worst case location for dispersant use, as dilution there would be less than the dilution that would occur in waters farther from shore. Results from the selected spill sites may be used to infer potential effects in the entire marine environment.

Oil spills in the areas covered in the PEIS (USCG, 2004), especially larger ones, are rare events. In addition, the timing, location and conditions at the time of the spill, as well as the type of oil and the ecological resources of concern are all variables that will influence the selection of response options. In order to deal with the inherent complexity, the analysis in the PEIS examines the probable impacts of a small (200 bbl), moderate (2,500 bbl) and a large (40,000 bbl) oil spill. Coast Guard regulations (33 CFR 155.1020) define various spill sizes, and the volumes given above were developed from these definitions. The regulations define the Worst Case Discharge as the loss of all cargo from a tank vessel. The use of this volume would overwhelm any of the available response options, and prevent any discrimination between the alternatives. On that basis, the "large" volume was selected to be the loss of cargo from two storage tanks, which is approximately 40,000 bbl. The Maximum Most Probable Discharge is defined as 2,500 bbl, and this volume was used to represent a "moderate" spill. Finally, the regulations define the Average Most Probable Discharge as 50 bbl. In order to make a conservative estimate of the potential impacts from such spills, a volume four times larger, or 200 bbl, was selected. The relative frequency of such events varies around the country, but the small spill is representative of the more common spill sizes, while the moderate or large spills happen only rarely and represent extreme events (see Section 2.7 and Appendix C of the PEIS, for a discussion of the relative sizes and frequency of oil spills). In the PEIS, the use of these three different spill volumes allows for a more accurate assessment of the potential consequences of events which may be of concern.

In the modeling, which is used to inform the analysis in the PEIS (USCG, 2004), the two larger spill volumes were simulated, i.e., the medium and large spills (Table A.3-8). The potential impacts of small spills were inferred from the modeling results of the medium spill scenarios, along with other information available in the literature.

The release simulated is one occurring at a constant rate (for simplicity), over 4 hours for the large spill and 1 hour for the medium spill. These spill durations are based on opinions on tanker captains (Captain Biff Holt, personal communication, October 2002) of the approximate minimum time it would take for a spill of these volumes to be released. The durations are conservatively small in order to evaluate maximum possible effects. Effects would be less if the release occurs over a longer time. Whether the release is constant or intermittent during these release times has little influence on the model results, as randomized mixing quickly smoothes oil distribution.

Table A.3-7. Modeled spill sites and oil types.

Region	Spill Location	Latitude (N)	Longitude (W)	Oil Type
Atlantic	Delaware Bay	38° 47.46’	74° 54.02’	So. LA crude
Straits of Florida	7.5 nmiles from coral reef area along Florida Keys	24° 39.2’	80° 54.74’	So. LA crude
Gulf of Mexico	Galveston Bay	29° 18.124’	94° 35.86’	So. LA crude
Pacific	San Francisco Bay	37° 44.958’	122° 40.216’	AK No. Slope crude
Alaska	Prince William Sound	60° 34.728’	147° 4.41’	AK No. Slope crude

Table A.3-8. Simulated spill volumes and duration of release.

Spill Size	Spill vol. (bbl)	Spill vol. (gal)	Duration of Release (hrs)
Large	40,000	1,680,000	4
Medium	2,500	105,000	1

The model inputs for each location and scenario are summarized in tables in Parts B to F (Sections B-I.4, C-I.4, D-I.4, E-I.4, and F-I.4). These data inputs include mapping of the habitat and shore types, water depths, winds, currents, temperature and salinity. All inputs are listed along with the sources of the information.

Table A-3.9 lists the model inputs common to all scenarios. Surface spills are the most common, and would result in the maximum impact from floating oil. Also, dispersant would more likely be applied after surface spills, rather than subsurface spills where some of the oil is naturally dispersed as it rises to the water surface. Thus, surface releases are simulated. The model was run for 14 days, which has proven sufficient to track the oil from near shore spills until it reaches shore or disperses below levels that would cause effects. One hundred runs have proven sufficient to characterize environmental variability of effects (French McCay et al., 2002, 2003). The thresholds listed are at or below those determined to potentially cause effects (French et al., 1996a; French McCay et al., 2002, 2003). Thresholds used in the impact analysis are described in Section 4.3 of the PEIS (USCG, 2004).

Table A-3.9. Inputs to the Fates Model for Stochastic Scenarios.

Name	Description	Units	Source(s) of Information	Value(s)
Spill Site	Location of the spill site	-	(Chart)	Spill site 7.5 nmiles from entrance to port
Depth of release	Depth below the water surface of the release or 0 for surface release	m	(most likely to occur)	0 m
Start time and date	Randomized over selected months of the year	Date, hr, min	(randomized over all months)	Jan-Dec
Spill duration	Hours over which the release occurs	Hours	(based on likely durations)	Large – 4 Small – 1
Total spill amount	Total volume (or weight) released	bbl	-	Large – 40,000 Small – 2,500
Model duration	Length of each model simulation	Days	-	14 days
Number of model runs	Number of random start times to run in stochastic mode	#	-	100
Fates Output Threshold: floating on water surface	Slick or surface mass thickness passing through a grid cell	g/m^2 (microns)	Minimum thickness of oil sheens (NRC, 1985)	0.01
Fates Output Threshold: shoreline	Total hydrocarbons deposited on shorelines, averaged over each habitat grid cell.	g/m^2 (microns)	Minimum thickness of oil sheens (NRC, 1985)	0.01
Fates Output Threshold: dissolved aromatics in water or sediment	Dissolved concentration of aromatics with $\log(K_{ow}) \leq 5.6$ (bioavailable fraction)	mg/m^3 = $\mu g/L$ = ppb	Below minimum for effects to sensitive species exposed for at least two weeks (Section A.3.4)	1
Fates Output Threshold: Subsurface (water) total hydrocarbons	Concentration of total hydrocarbons in droplets	mg/m^3 = $\mu g/L$ = ppb	(Minimum value with no potential for effect, Section A.3.4 and ratio of PAHs to total hydrocarbons)	10

Table A-3.9. Inputs to the Fates Model for Stochastic Scenarios (continued).

Name	Description	Units	Source(s) of Information	Value(s)
Fates Output Threshold: Sediment total hydrocarbons	Total hydrocarbon loading to sediments, averaged over each habitat grid cell.	g/m^2	(Minimum value with no potential for effect, Section A.3.4)	0.0001 g/m^2 (which is 1.0 mg/m^3 = 1ppb averaged over the top 10cm)
Salinity	Surface water salinity	ppt	French et al. (1996b)	(by location)
Surface Water Temperature	Water temperature at the sea surface	Degrees C	French et al. (1996b)	monthly means (by location)
Subsurface Water Temperature	Water temperature for subsurface	Degrees C	French et al. (1996b)	monthly means (by location)
Air Temperature	Air water temperature at water surface	Degrees C	(= water temperature)	(= water temperature)
Fetch	Fetch = distance to land to N, S, E, W (if landfall not within model domain)	km	-	(calculated from chart)
Wind drift speed	Speed oil moves down wind relative to wind	% of wind speed	Youssef (1993); Youssef and Spaulding (1993)	(model calculated)
Wind drift angle	Angle to right of wind (in northern hemisphere) that oil drifts	Degrees to right of down wind	Youssef (1993); Youssef and Spaulding (1993, 1994)	(model calculated)
Horizontal turbulent diffusion coefficient	Randomized turbulent mixing parameter in east-west and north-south directions	m^2/sec	French et al. (1996a, 1999) based on Okubo (1971)	1 m^2/sec (estuaries and low energy coastal areas)
Vertical turbulent diffusion coefficient	Randomized turbulent mixing parameter in vertical direction	m^2/sec	French et al. (1996a, 1999) based on Okubo (1971)	0.0001 m^2/sec
Suspended sediment concentration	Average suspended sediment concentration during spill period	mg/l	French et al. (1996b)	10 mg/l
Suspended sediment settling rate	Net settling rate for suspended sediments	m/day	French et al. (1996b)	1 m/day

A.3.7 Model Inputs for Response Scenarios

The PEIS (USCG, 2004) considers alternatives involving mechanical recovery, ISB and dispersant use. Because it is proposed to allow ISB to offset the existing mechanical requirements by 25%, ISB is assumed to remove 25% of the available oil each hour while the amount removed using mechanical recovery is reduced by 25%. Thus, ISB is assumed to replace 25% of the mechanical removal when it applies, and both response options remove oil from the water surface with equal effectiveness. The amount burned is assumed 25% of model estimate of the amount cleaned up in a given scenario. Burning is assumed to occur at a location greater than 3 nmiles from shore. Given these assumptions, the oil fates and effects to the water and shoreline environments are the same regardless of whether ISB is used. Thus, only one model scenario is used to represent either mechanical alone or the combination of mechanical recovery and ISB. In the scenarios involving dispersants, mechanical removal or mechanical removal in combination with ISB are modeled in the same manner as removal of mass.

Only chemical dispersants that are listed on the current USEPA National Contingency Plan (NCP) Product Schedule may be used to treat oil spills in US waters. Manufacturers who want to list their chemical dispersants on the NCP must complete specific tests demonstrating effectiveness of at least 45%, aquatic toxicity, and identify ingredients. The results of these tests are sent to the U.S. Environmental Protection Agency for evaluation (FDEP, 2001). The August 2001 edition of the NCP Product Schedule includes seven dispersants from five manufacturers (USEPA, 2001).

Three response scenarios were modeled (Table A.3-10) for each of the two spill volumes in Table A.3-8:

1) mechanical removal at present levels of capability, or with some of that removal accomplished by ISB;
2) the same mechanical removal response as in (1), which may include some of that removal accomplished by ISB, plus dispersant application at 45% efficiency (based on minimum dispersant effectiveness criteria established in the National Oil and Hazardous Substances Contingency Plan, NCP – 40 CFR Part 300); and
3) the same mechanical removal response as in (1), which may include some of that removal accomplished by ISB, plus dispersant application at 80% efficiency (based on theoretically successful dispersant operation).

Table A.3-10. Response scenarios modeled in the SIMAP model runs.

Response	Mechanical + ISB	Dispersant
R1	Removal @50%	none
R2	Removal @50%	45% efficiency
R3	Removal @50%	80% efficiency

The dispersant efficiency of 45% or 80% refers to *the percent of oil treated* by dispersant that is in fact dispersed in the water column. Thus, it is assumed, as a worst case for oil contamination into the water, that if dispersant is applied in the appropriate amount relative to the amount of floating oil, it disperses the oil at the assumed efficiency. If dispersant efficiency is in practice lower than the assumed efficiency, less oil would be dispersed into the water column per volume of dispersant applied. In other words, the lower the efficiency, the more dispersant must be applied to disperse the same amount of oil.

The modeled response scenarios apply to several of the alternatives being considered in the PEIS (Section 2.6 of the PEIS, USCG, 2004), depending upon the combination of response capabilities required. For example, for the no action alternative (Alternative 1) in the Atlantic, Caribbean, Pacific, and Oceania regions, only mechanical or ISB would be used, but not dispersants. Thus, the first of the three modeled response scenarios applies to Alternative 1 in these four regions. For Alternative 1 in the Gulf of Mexico and Alaska regions, where dispersant capability already exists, the modeled response scenarios involving dispersants apply. For Alternative 3 considered in the PEIS, where dispersant capability would be required, the modeled response scenarios involving dispersants also apply. The applications of the modeled scenarios to the alternatives are described in Sections 4.5 to 4.9 of the PEIS.

The specific details of the response scenarios modeled were developed by the US Coast Guard, based on existing and proposed planning factors, as described in Appendix B of the PEIS. The selected input parameters for the model are described below.

Mechanical removal (i.e., skimming) occurs in all water locations where surface oil is present and from hour 12 until hour 96 during daylight only. The light period is assumed 6AM-6PM, i.e., a 12-hour day. Hourly mechanical recovery rate is 50% of the total oil available on the water at the beginning of that hour divided by 48 (the total number of cleanup hours in the 4 day response). Thus, the amount removed is 0.50/48 = 0.0104167/hour multiplied by the amount of oil floating that hour, summed over 12-96 hours after the spill (during daylight only). This is the maximum possible amount that would be removed if conditions are appropriate, i.e., removal may occur if the oil thickness exceeds 0.0005 inch (13 microns) and wave height does not exceed 3.5 ft (based on guidance in API et al. 2001).

Because it is proposed to allow ISB to offset the existing mechanical removal requirements by 25%, ISB is assumed to remove 25% of the available oil each hour while the amount removed using mechanical recovery is reduced by 25%. Thus, ISB is assumed to replace 25% of the mechanical removal when it applies, and both response options remove oil from the water surface with equal effectiveness. The amount burned is 25% of model estimate of the amount cleaned up in a given scenario. Burning is assumed to occur at a location greater than 3 nmiles from shore. It is assumed that the burn volume is available in the region greater than 3 nmiles from shore. Thus, for those runs where >75% of the cleanup would occur closer to shore (in the absence of burning), the burned volume would be over-estimated and provide a conservative (high) estimate of effect on air quality. The water surface, shoreline and water column effects are assumed the same, whether the oil is mechanically removed or burned.

Dispersant application also occurs only in the light period (6AM-6PM) and within location-specific pre-approval zones (see maps in Sections C-I.1.4, D-I.1.4, E-I.1.4 and F-I.1.4). For all locations, dispersants may be applied in waters greater than 10m deep that are at least 3 nmiles from shore. No dispersant is assumed applied within Galveston Bay, San Francisco Bay (inside the Golden Gate), Delaware Bay, or within coastal inlets and estuaries near the modeled spill sites. Dispersants are only assumed applied and/or effective if the oil thickness exceeds 0.0005 inch (13 microns), if the wind speed is between 3 and 27 kts, and if wave height does not exceed 10 ft (based on guidance in API et al. 2001).

Based on USCG existing or proposed planning factors, dispersants are assumed applied in three tiers involving several aircraft sorties (flights without re-loading). For all tiers, application will be assumed to be made using one or more C-130 aircraft. According to the Caps Report (USCG, 1999) the C-130 is capable of delivering 5,495 gallons of dispersant per sortie. In the Gulf of Mexico, Tier 1 would require delivery of 8,250 gallons of dispersant in two sorties over the course of 5 hours starting at hour 7 or at the first hour of daylight. The first sortie is 5,495 gallons, followed by a second sortie beginning 5 hours later of 2,756 gallons. Outside the Gulf of Mexico, Tier 1 would require delivery of 4,125 gallons in one C-130 sortie at hour 7 or at the first hour of daylight. Tier II and III each require delivery of 23,375 gallons of dispersant in 4 sorties of 5,495 gallons each and one sortie of 1,395 gallons. Sorties occur at tier start time +1, 3, 5, 7, and 9 hours. When sorties from two tiers overlap due to darkness, both sorties will be assumed to occur simultaneously.

The schedule of dispersant application, without accounting for darkness, is in Table A.3-11. If darkness intervenes at the scheduled time, dispersant application is delayed until light. Delay of either of the two Tier 1 dispersant applications does not affect Tier 2, but delay in Tier 2 sets back the rest of the schedule. The amount of oil that can be dispersed in an hour (O_d) is calculated as:

$$O_d = 20 \, D \, E_d$$

where D is the amount of dispersant applied per hour and E_d is the assumed efficiency (0.45 or 0.80). The factor 20 is the generally accepted ratio of oil to dispersant needed for the dispersant to be effective (French and Payne, 2001; Appendix B of the PEIS, USCG, 2004). If O_d exceeds the amount of floating oil present at a given time in the simulation, all the floating oil is dispersed.

Thus, the lower the efficiency, the more dispersant must be applied to disperse the same amount of oil. The implication of this is that if the total amount of dispersant used, with 45% efficiency, in a given time period is sufficient to disperse the amount of floating oil present, the increased efficiency of 80% may not disperse more oil. However, if additional dispersant is needed at 45% as opposed to 80% efficiency, it takes longer to apply, during which time oil may affect resources, come ashore, or spread to less than the minimum of 13 microns thickness needed for dispersant application to be effective. Thus, the effects of surface oil may or may not be reduced if efficiency is increased from 45% to 80%.

This is born out by the model results (see Parts B to F of this Technical Report). In comparing model results for the mechanical only (or in combination with ISB) scenario to that including dispersant use at 45% removal efficiency, the effect of dispersants on the oiled area proves to be dramatic in many of the cases presented. In comparison, however, the improvement from 45% to 80% removal efficiency is less impressive. This result is less a reflection of the efficacy of the dispersant than the fact that the 45% removal efficiency leaves little work to be done. Therefore, marginal effect of the dispersants above the 45% removal efficiency is quite small.

Additionally, dispersant is assumed not to be applied until after 7 hours of oil weathering has occurred. The components of oil that are toxic to plankton and fish are both volatile and soluble. Much of the contamination that affects plankton and fish dissolves before 7 hours after the spill, (French and Payne, 2001). The dispersant application adds more contamination to the water. However, the difference in effects on plankton and fish between 45% and 80% efficiency is small because the assumed amount of dispersant applied is sufficient to disperse most of the floating oil at 45% efficiency.

Table A.3-11. Schedule of dispersant application, without accounting for darkness

		Gulf of Mexico			Other areas		
Hour	**Tier**	**Gal Dispersant**	**bbl oil @ 80%**	**bbl oil @ 45%**	**Gal Dispersant**	**bbl oil @ 80%**	**bbl oil @ 45%**
0-6	0	0	0	0	0	0	0
7	1	5,495	2093	1178	4125	1571	884
8	1	0	0	0	0	0	0
9	1	0	0	0	0	0	0
10	1	0	0	0	0	0	0
11	1	0	0	0	0	0	0
12	1	2,756	1050	591	0	0	0
13	2	0	0	0	0	0	0
14	2	5,495	2093	1178	5,495	2093	1178
15	2	0	0	0	0	0	0
16	2	5,495	2093	1178	5,495	2093	1178
17	2	0	0	0	0	0	0
18	2	5,495	2093	1178	5,495	2093	1178
19	2	0	0	0	0	0	0
20	2	5,495	2093	1178	5,495	2093	1178
21	2	0	0	0	0	0	0
22	2	1,395	531	299	1,395	531	299
23	2	0	0	0	0	0	0
24	2	0	0	0	0	0	0
25	2	0	0	0	0	0	0
26	3	0	0	0	0	0	0
27	3	5,495	2093	1178	5,495	2093	1178
28	3	0	0	0	0	0	0
29	3	5,495	2093	1178	5,495	2093	1178
30	3	0	0	0	0	0	0
31	3	5,495	2093	1178	5,495	2093	1178
32	3	0	0	0	0	0	0
33	3	5,495	2093	1178	5,495	2093	1178
34	3	0	0	0	0	0	0
35	3	1,395	531	299	1,395	531	299
36	3	0	0	0	0	0	0

A.4 EXPLANATION OF OIL SPILL MODEL OUTPUTS

A.4.1 Fates Model Output to Estimate Exposure

For each individual model run, the model evaluates area exposed over a minimum threshold thickness and exposure mass per unit area or concentration, recording exposure by grid cell as an average over each individual cell. Exposure indices and minimum thresholds (i.e., levels less than or equal to those that might have an effect on any resource, based on the discussions above) used in the modeling were:

- Surface slick or floating oil: ≥0.01 g/m^2 (average thickness ≥0.01 micron, i.e., sheen or thicker oil)
- Shoreline: average mass loading over the shore segment (length of one grid cell, calculated as the cell diagonal length, multiplied by the typical width for the habitat type) ≥0.01 g/m^2 (i.e., the same threshold as surface oil)
- Dissolved aromatics: average over the water cell ≥1 ppb (1 mg/m^3), based on the PAH toxicity threshold
- Subsurface oil (entrained in water): average over the water cell ≥10 ppb (10 mg/m^3), based on the maximum possible percentage of PAH in whole oil (French McCay, 2002) and the PAH threshold
- Sediment dissolved aromatic concentrations: average over the cell ≥0.0001 g/ m^2 (which is 1.0 mg/m^3 = 1ppb averaged over the top 10 cm, the bioturbation zone)
- Sediment total hydrocarbons: average over the cell ≥0.001 g/ m^2, based on the maximum possible percentage of PAH in whole oil (French McCay, 2002) and the PAH threshold of 1ppb

The thresholds used for the effect evaluations (in Parts B to F) were either at or greater than these minimum thresholds, depending on the resource of concern. For each model run, the model evaluates the maximum exposure for any one hour in each grid cell of the habitat grid (averaged over the area of the cell). Note that these data are the maximum exposure at any time after the spill. For water surface and water column exposures, the time of exposure may be as short as 1 hour or potentially longer. Exposure time was considered in the evaluation of water column effects (as described in Section A.2.2 and A.2.3), such that the minimum threshold above was less than that actually used in the evaluation. For shorelines and sediments, the hydrocarbons accumulate over the model run and so the exposures are for weeks or more, until (in the case of the shoreline) the oil is cleaned up (as is normal practice in a spill). The removal of mass by cleanup was not included in the model simulations.

Floating oil is mapped in g/m^2, where 1 g/m^2 is about 1 micron thick oil. Table A.4-1 gives approximate thickness ranges for surface oil of varying appearance. Dull brown sheens are about 1000 mg/m^2. Rainbow sheen is about 200-800 mg/m^2 and silver sheens are 50-800 mg/m^2 (NRC, 1985). Floating oil will not always have these appearances, however, as weathered oil would be in the form of scattered floating tar balls and tar mats where currents converge.

Fates model results are presented in Appendices II.1 to II.4 to each of Parts B to F. Appendix II.1 of each Part (i.e., B.II.1, C.II.1, D.II.1, E.II.1, and F.II.1,) contains maps of exposure probability, time of first exposure for each medium (water surface, shorelines, water column, and sediments) and location surrounding the spill site, and maximum possible mass or concentration at each location at any time after a spill. These maps are gridded, presenting the average amount of contamination over the entire grid cell (which for water cells is about 0.04-1 km^2 in area) at any time after a spill. The grid average is calculated from the mass passing through the cell, divided by the area or volume of the cell. Note that if the mass is concentrated in patches much smaller than the area of the grid cell, as is often the case over open water, the gridded data will average out the patches and not resolve small concentrations of oil. Thus, the gridded data are used as indices of exposure, rather than areas exposed at specific levels. (See below for methods used to more accurately evaluate exposure of biota to surface floating oil and dissolved aromatic hydrocarbons.)

Tables summarizing areas and volumes potentially affected using gridded exposure indices specific to water surface, shorelines, water column, and sediments are in Appendix II.2. Average, standard deviation, and the maximum of the 100 simulations performed for each scenario are presented. The 95th percentile conditions used in the risk analysis were calculated as the mean plus two times the standard deviation. The mean results are used in most of the analyses, while the extreme event (95th percentile) is evaluated for some resources. Appendix II.3 contains rank order distributions of results for all 100 model runs, from which 50th and 95th percentile of exposure index areas and volumes were derived. Mass balance information, such as percent of the oil mechanically removed, dispersed in the water column, and eventually going ashore or to the sediments, is also included in Appendices II.2 and II.3. Appendix II.4 contains the results for the 50th percentile runs for surface oiling, shoreline oiling, water column effects, and sediment contamination, presented as plots of various measures of exposure. These figures show the oil exposure for a single run, while those in II.1 are composites over all runs. Note that the areal extent of oiling is never as much as shown in II.1 in any individual spill.

Table A.4-1. Oil thickness (microns, 1 μm thick is approximately 1 g/m^2) and appearance on water (NRC, 1985).

Minimum	Maximum	Appearance
0.05	0.2	Colorless and silver sheen
0.2	0.8	Rainbow sheen
1	4	Dull brown sheen
10	100	Dark brown sheen
1,000	10,000	Black oil

In addition to the maximum exposure thickness or concentration at any time after the spill, total dosage measures were also calculated for each grid cell for contamination that changes rapidly in time:

- Water surface oiling: Slick mass per unit area multiplied by time present (mass per area - time) for each run and by dosage level (g-m^{-2}-hrs)
- Dissolved aromatic contamination in water: Water area (entire water column) exposed at each dosage level (concentration-time, i.e., ppb-hrs)
- Total hydrocarbon contamination in water: Water area (entire water column) exposed at each dosage level (concentration-time, i.e., ppb-hrs)

Floating oil and contamination in the water column change rapidly in space and time, such that a dosage measure, as the integrated product of concentration and time, is a more appropriate index of effects than simply peak concentration. As described above, toxicity to aquatic organisms increases with time of exposure, such that organisms may be unaffected by brief exposures to the same concentration that is lethal at long times of exposure. Toxicity data indicate that the 96-hour LC50 (which may serve as an acute lethal threshold) for dissolved aromatics (primarily PAHs) averages about 6 μg/l (ppb) for sensitive species. Thus, this exposure dosage is 600 ppb-hours. The threshold for chronic and tainting effects is about 10% of the LC50 for sensitive species, or 0.6 ppb (60 ppb-hours). Contamination in sediments remains longer than 100 hours, such that the use of 6 ppb for acute effects, and 0.6 ppb for chronic effects, is appropriate as an index.

For floating oil, effects to birds and other wildlife would be proportional to area swept above a threshold and how long the oil would remain in the area. Thus, g/m^2-hrs of floating oil exposure, or area oiled above a threshold thickness integrated over time (m^2-hours), serve as an indices to effects by floating oil.

The tabular results for each oil exposure measure (water surface oil, shoreline, etc.) and resource (habitat or shore) type are analyzed over all runs to determine the probability distribution of model results (i.e., a PDF, as described above), which is plotted in a histogram chart format. The distribution of model results for all runs within a scenario indicates the range of possible effects depending on the weather conditions and currents at the time of the spill. The following impact indices are plotted as rank order distributions:

- Shoreline area (m^2) exposed to hydrocarbons of various threshold thicknesses (>1, 10, 100, and 1000 g/m^2)
- Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 (which is sheen) multiplied by duration of exposure (in m^2-hrs)
- Water volume exposed to >1 ppb of dissolved aromatic concentration at some time after the spill
- Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to >1 ppb of dissolved aromatic concentration at some time after the spill
- Percent of spilled hydrocarbon mass eventually going ashore
- Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats)
- Maximum percent of spilled hydrocarbon mass in the water column at any time after the spill, and
- Percent of spilled hydrocarbon mass mechanically removed.

In most cases, there is a smooth frequency distribution about the median case. However, occasionally extreme events occur, i.e., the weather conditions are just right to cause the most adverse effects. These figures indicate the median and distribution of impact indices, including the degree of variability and likelihood of extreme events.

From the rank order distributions, the median (50^{th} percentile) and 95^{th} percentile conditions (using the above impact measures) were identified for that scenario. The runs producing the median percentile result were subject to further impact analysis to refine the measurements of exposure and effect. The 95^{th} percentile result indicates the variability due to weather and current conditions, as it is approximately equivalent to the mean plus two standard deviations (using a Gaussian distribution).

Note that the same model run is not the median or worst case for water surface, shoreline, and water column effects. In fact, when shoreline effects are highest, water column effects tend to be relatively low, and *vice versa*. The impact measures from the stochastic modeling provide a quantitative method for determining which run is the median percentile for the resource of interest.

The appendices show summary graphics for individual model runs for each scenario. The results for the 50th percentile cases for surface oiling, shoreline oiling, water column effects, and sediment contamination are shown as plots of the following measures of exposure:

- Water surface exposure to floating hydrocarbons (g/m^2)
- Water surface exposed to floating hydrocarbons, as the sum of area covered by more than $1g/m^2$ multiplied by duration of exposure
- Shoreline exposure to hydrocarbons (g/m^2)
- Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill
- Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill
- Water column exposure dose of dissolved aromatic concentration (ppb-hours)
- Sediment pore water exposure of dissolved aromatic concentration (ppb)
- Sediment exposure to total hydrocarbons (g/m^2)

A.4.2 Exposure Modeling to Scale Effects from Exposure Indices

To obtain better accuracy in estimating exposure of biota to floating oil and dissolved aromatic concentrations in the water than the above gridded averages would indicate, the 50th percentile runs of each of the six scenarios (two volumes and three dispersant conditions) were examined individually and run through the biological exposure model. The biological exposure model produced the following types of outputs:

- Area swept by surface oil multiplied by probability of wildlife being oiled, for each behavior category in Table A.2.4. This is summarized as an equivalent area of 100% mortality by behavior group. The equivalent area for 100% mortality is the integrated sum of area swept by individual spillets representing surface floating oil multiplied by probability of mortality. The mean equivalent area killed for all possible environmental conditions is calculated using the gridded index of surface oil exposure exceeding $0.01g/m^2$ (described in Section A.4.1), which is the integrated area swept by oil sheen or thicker oil multiplied by the duration that oil is present, in m^2-hours. The equivalent areas of 100% mortality (in km^2) for the six 50th percentile runs were regressed against m^2-hours based on the gridded outputs of the 100 model runs to obtain an equation for each behavior group that was used to scale from m^2-hours to area killed.
- Mortality of water column and demersal (on the bottom) organisms of each behavior type is estimated as described in Section 2.2. To perform the exposure calculations, each time step of the fates model a small-scale high-resolution grid is laid over the model dispersed mass in the water column and concentration calculated for each cell. Exposure is recorded for individual organisms by tracking their movements relative to the plume. Resulting fractional mortalities are summarized as an equivalent area of 100% mortality by behavior group. The equivalent area for 100% mortality is the integrated sum of equivalent area affected multiplied by percent mortality. For water column and demersal species, the equivalent area affected is calculated as water

volume affected multiplied by the fraction of the water depth zone the behavior group occupies that the affected volume encompasses. For pelagic species, the depth zone occupied is the entire water column. For demersal species (on the bottom sediments, exposed to bottom water), the depth zone occupied is the bottom 1 meter of the water column. For water column and demersal species, the mean equivalent area killed for all possible environmental conditions is calculated using the gridded index of water volume (m^3) exposed to greater than 1 mg/m^3 (1 ppb) dissolved aromatic concentration at any time after the spill (described in Section A.4.1). The equivalent areas of 100% mortality (in km^2) for the six 50th percentile runs were regressed against the gridded index of water volume exposed (m^3) to obtain an equation for each behavior group that was used to scale from volume exposed to area killed.

- Benthic effects are related to the bottom sediment area exposed to oil exceeding a threshold of concern. For most species, the dissolved aromatic concentration in the pore water of the sediments is what is bioavailable and causes toxicity. A threshold of 6 ppb dissolved aromatic concentration could cause effects to sensitive (2.5% of) species; whereas the threshold for average species is 50 ppb (see Section A.3.4).

Equivalent areas killed were estimated for mean environmental conditions (i.e., the arithmetic average of the results for 100 runs) and used in further analysis of the impacts of response alternatives. The areas affected were compared to the total area of habitat in a representative area of concern for each location modeled. The reference areas of concern were based on the biogeographical “province” or provinces that included the modeled location, using the biogeographical provinces delineated in French et al. (1996a), which were based on the ecoregion (province) concept outlined in Cowardin et al. (1979) and used by the US Department of the Interior. The divisions into provinces are based on the distributions of and natural boundaries between marine populations. The biota within a province are exposed to similar environmental factors and the populations typically cover the entire province (as appropriate habitat is available). Thus, the effects are evaluated as percentages of the province or group of neighboring provinces occupied by the populations of concern. Table A.4-2 lists the biogeographical provinces that contain the five modeled locations in this study. Figures A.4-1 to A.4-5 contain maps of the biogeographical provinces. Tables A.4-3 lists the areas of each province.

The model results for each model location were evaluated in the context of an area of concern, based on the biogeographical provinces (Tables A.4-4 to A.4-6). The reference area of concern used in the analysis varies depending on the resource considered. For example, for the Delaware location, if an estuarine species or coastal area is considered, the area of interest is Delaware Bay, which is used as a representative estuary in the analysis. For the Florida, Galveston, San Francisco and Prince William Sound locations, the reference areas are Florida Bay, Galveston Bay, San Francisco Bay and Valdez Arm. Areas of the coastal reference areas are in Table A.4-2, except for Valdez Arm, which is 108.9 km^2 (42 mi^2). If an offshore species is considered, the shelf area (e.g., NY-NJ shelf and DelMarVa shelf; i.e., Delaware, Maryland and Virginia Peninsula) is the area of interest representing a typical shelf area of the Atlantic region. In the analysis sections of parts B to F, percentage effects are estimated for the reference areas of concern in Table A.4-4, unless otherwise noted.

Table A.4-2. Biogeographical provinces from French et al. (1996a) that contain or surround the modeled locations.

Modeled Location	Biogeo-graphical Province #	Biogeographical Province Name	Biogeographical Province Boundaries
Delaware	13	NY-NJ Shelf	NY-NJ Shelf (ICNAF 6A) (west of 71° 52'W, north of Cape May at 39° N, <200m)
Delaware	14	Delaware Bay	Delaware River and Delaware Bay (inside line from Cape May to Cape Henlopen)
Delaware	15	Delmarva Shelf	Delmarva Shelf (ICNAF 6B) (Cape Henlopen to Cape Henry, 37° N - 39° N, <200m)
Florida	26	Straits of Florida	Straits of Florida (Cape Canaveral to Key West, 23° 30'N - 28° 30'N, east of 82° W, >200 m deep)
Florida	28	Florida Bay	Florida Bay and Everglades (east of line from Cape Romano to Key West, incl. shelf of Fla. Keys <200m)
Galveston	37	Louisiana-No. Texas Shelf	La.-No. Texas coast and shelf (Miss. R. Delta to Port Aransas, TX)
Galveston	39	Galveston Bay	Galveston Bay, Houston
San Francisco	44	Central Calif. Coast	Central Calif. coast and shelf (Point Conception to Cape Mendocino, 34° 27'N - 40° 30'N, <200m)
San Francisco	46	San Francisco Bay	Sacramento River Delta to San Francisco Bay (inside Golden Gate Bridge)
PWS	55	Prince Wm. Sound	Prince William Sound

Table A.4-3. Biogeographical provinces areas (km^2, by province number, #) from French et al. (1996a).

Modeled Location	#	Biogeographical Province Name	Total Area (km^2)
Delaware	13	NY-NJ Shelf	36353
Delaware	14	Delaware Bay	2669
Delaware	15	DelMarVa Shelf	29519
Florida	26	Straits of Florida	132000
Florida	28	Florida Bay (includes Florida Keys)	16288
Galveston	37	Louisiana-North Texas Shelf	113412
Galveston	37 (in part)	North Texas Shelf	37813
Galveston	39	Galveston Bay	1786
San Francisco	44	Central Calif. Coast	14906
San Francisco	46	San Francisco Bay	1733
PWS	55	Prince William Sound	10,080

Table A.4-4. Biogeographical provinces used in the analysis of percentage effects.

Modeled Location	Province #s Included	Reference Area Name	Total Area (km^2)	Wetlands and Flats (km^2)	Other Shoreline (km^2)	Hard Bottom (km^2)	Coral Reef (km^2)	Seagrass (km^2)
Delaware	13, 14, and 15	Mid-Atlantic Shelf	68,541	3,384	14.8	na	na	na
Florida	28 and part of 26 (area covered by model grid)	Florida Straits	42,689	1272	1.5	992	222	4246
Galveston	39 plus the North Texas portion of 37	North Texas Shelf	39,602	1356	4.2	na	na	na
San Francisco	44 and 46	Central California Shelf	16,639	568	10.2	na	na	na
PWS	55	Prince William Sound	10,080	864	34.4	na	na	na

Table A.4-5. Shoreline areas (km^2) for biogeographical provinces used in the analysis of percentage effects. (Seaward is outer coast or facing main water body, see Section A.3.1.)

Modeled Location	Reference Area Name	Rocky Shore	Gravel Beach	Sand beach	Artificial (man-made)	Total
Delaware	Mid-Atlantic Shelf	1.105	0.025	12.988 (6.047 seaward)	0.723	14.841
Florida	Florida Straits	0.261	0.001	1.199 (all seaward)	0	1.461
Galveston	North Texas Shelf	0.128	2.102	1.726 (1.374 seaward)	0.253	4.209
San Francisco	Central California Shelf	1.47	0.42	8.02 (7.85 on outer coast = seaward)	0.29	10.19
PWS	Prince William Sound	7.466	24.178	2.756 (all seaward)	0.008	34.408

Table A.4-6. Shoreline lengths (km) for biogeographical provinces used in the analysis of percentage effects. (Seaward is outer coast or facing main water body, see Section A.3.1.)

Modeled Location	Reference Area Name	Rocky Shore	Gravel Beach	Sand beach	Artificial (man-made)	Total
Delaware	Mid-Atlantic Shelf	552.5	5.0	1299 (604.7 seaward)	361.5	2218
Florida	Florida Straits	261.0	0.2	239.8 (all seaward)	0.0	501.0
Galveston	North Texas Shelf	128.0	420.4	345.2 (274.7 seaward)	253.0	1147
San Francisco	Central California Shelf	733	123	621 (604 on outer coast = seaward)	143	1620
PWS	Prince William Sound	2489	2418	137.8 (all seaward)	2.7	5047

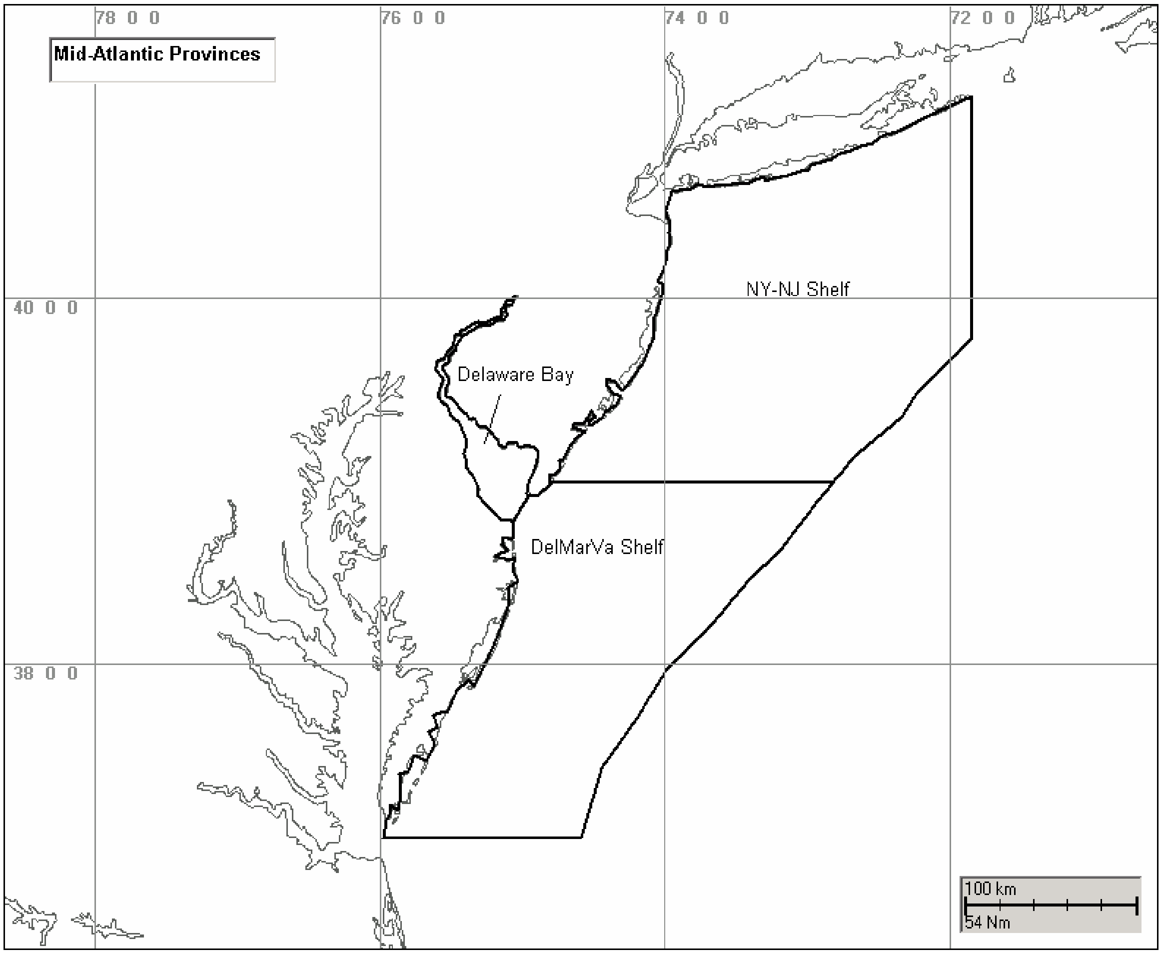

Figure A.4-1. Biogeographical provinces from French et al. (1996a) for the Delaware (Atlantic) model location.

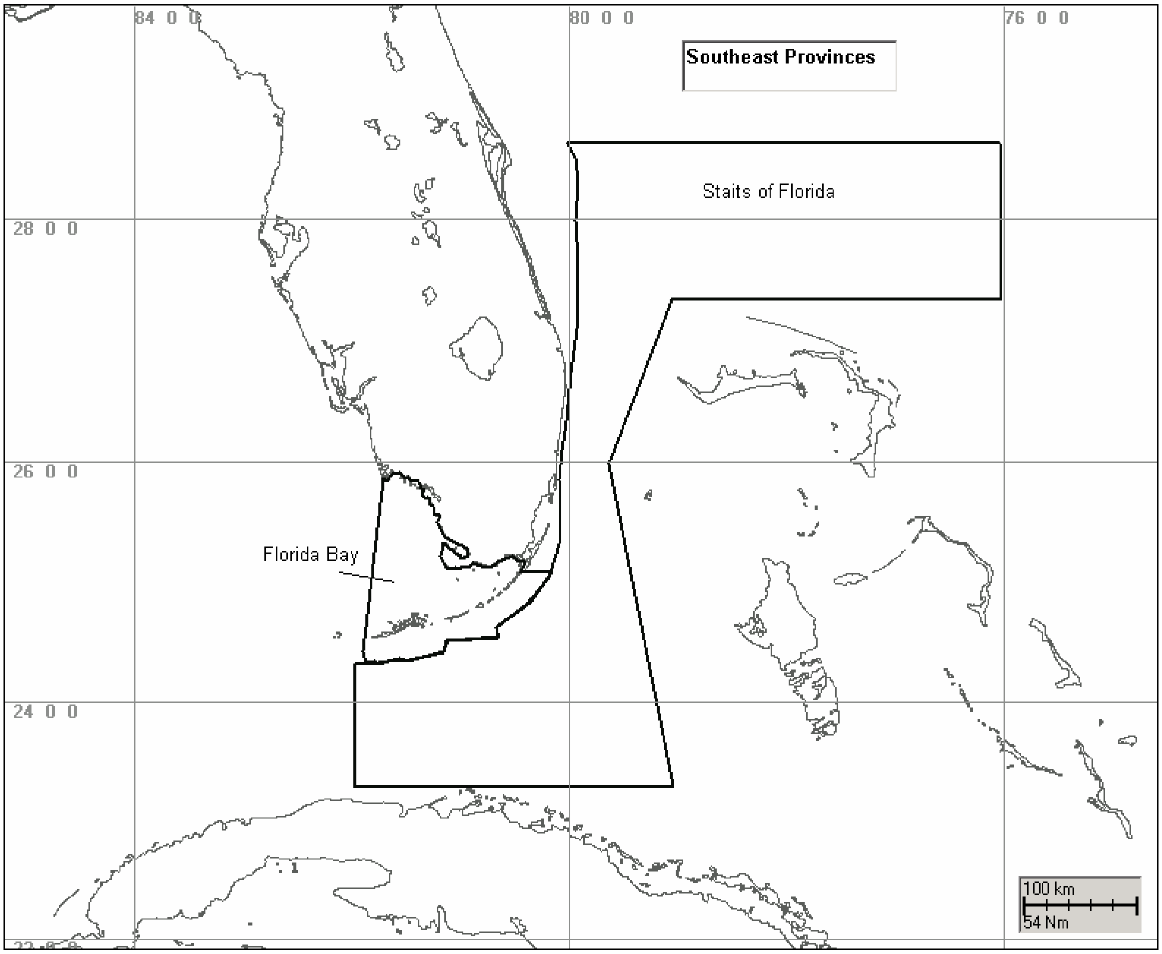

Figure A.4-2. Biogeographical provinces from French et al. (1996a) for the Florida Keys model location.

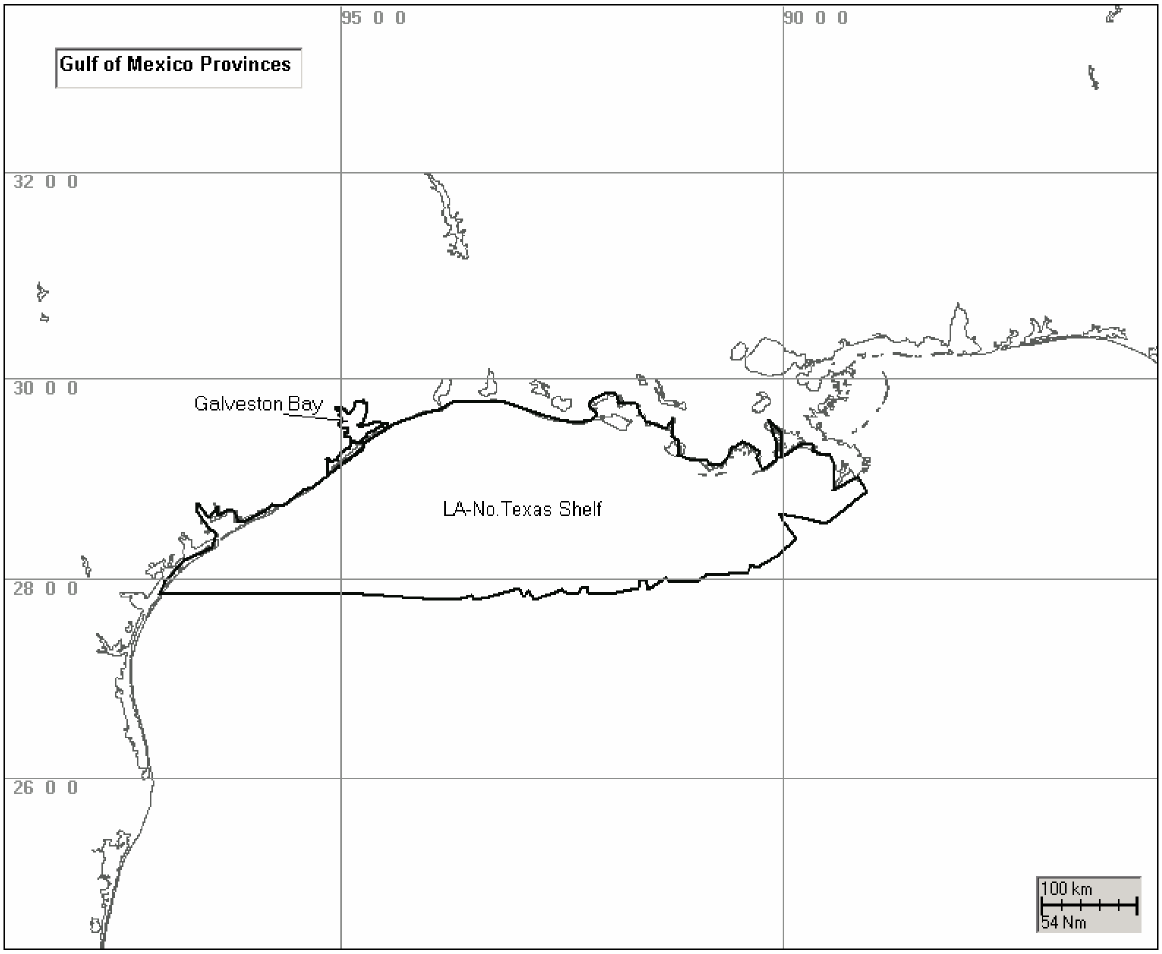

Figure A.4-3. Biogeographical provinces from French et al. (1996a) for the Galveston (Gulf of Mexico) model location.

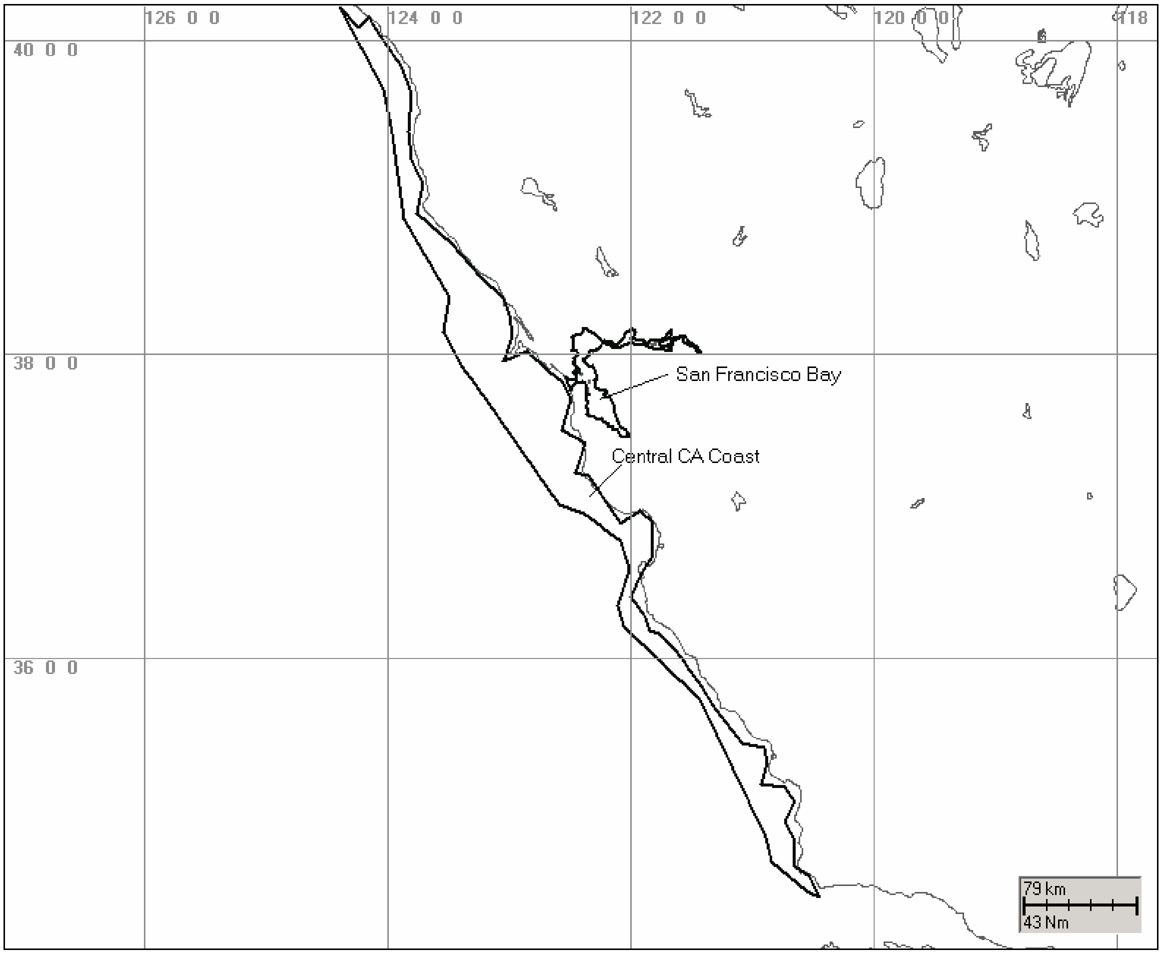

Figure A.4-4. Biogeographical provinces from French et al. (1996a) for the San Francisco (Pacific) model location.

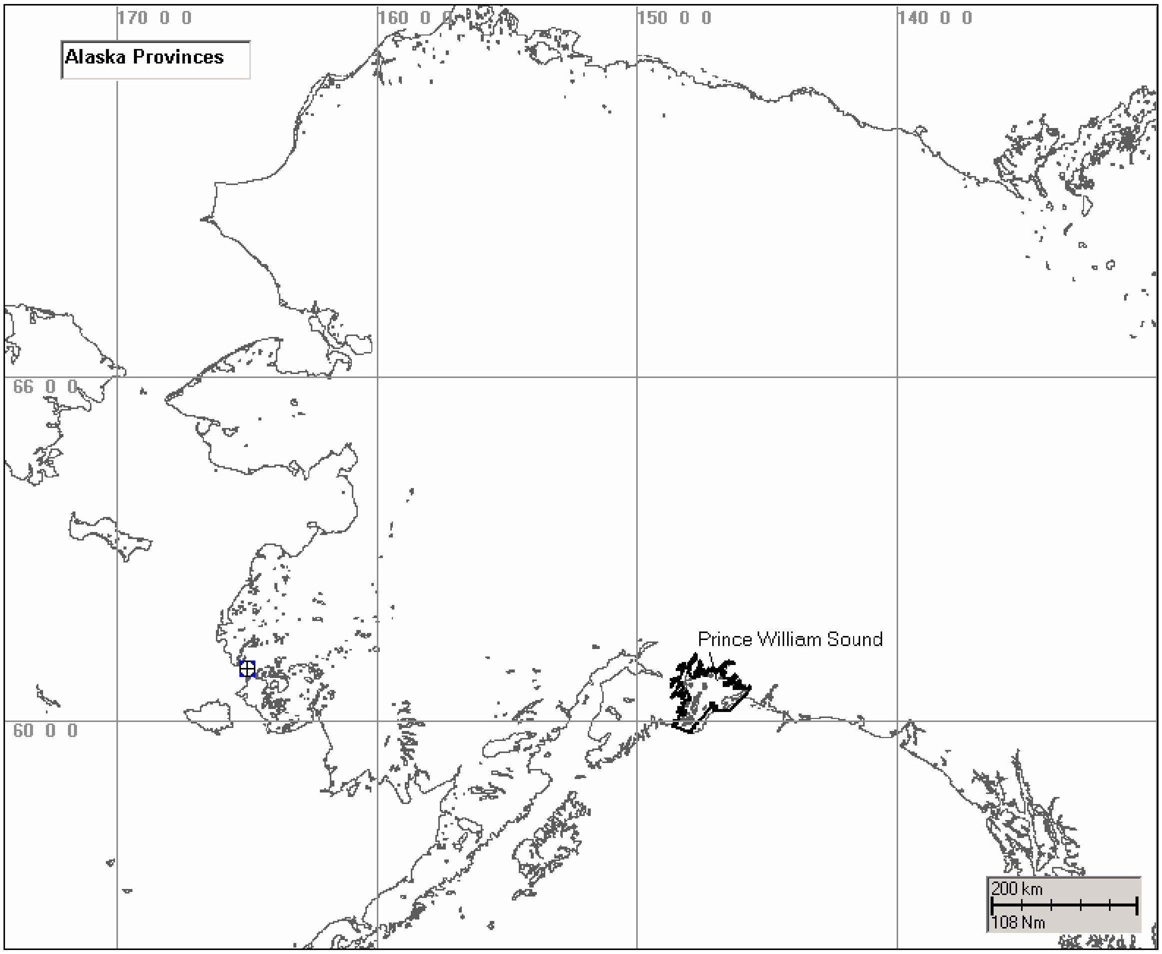

Figure A.4-5. Biogeographical province from French et al. (1996a) for the Prince William Sound model location.

A.5 ATMOSPHERIC DISPERSION MODELING

A.5.1 Atmospheric Model for Volatiles Released by Unburned Oil

The atmospheric concentrations of volatilized hydrocarbons released by unburned oil as it weathers were modeled using an atmospheric dispersion model, AIRMAP (Air Model Application Package), which is part of the chemical fate and transport model CHEMMAP (developed by ASA). AIRMAP accounts for transport and dilution of hydrocarbons in the local area around the spill site, and provides estimates of air concentrations in the air layer within 100 m of the water surface. The concentrations in the lowest 2 m of the atmosphere (i.e., at the water surface within the approximate height of a person who might be exposed and where concentrations would be the highest were compared to air quality standards to evaluate the potential for human health and wildlife effects. The amount of volatilized mass entering the atmosphere for each chemical (or chemical class) of concern was estimated using oil spill modeling (SIMAP). SIMAP also provided the time frame over which the emissions occur.

Section A.5.1.1 describes the air dispersion model, AIRMAP. Section A.5.1.2 describes the modeled scenarios used in the analysis. Results are in Parts B through F, for each of the modeled locations. Appendix III to each of Parts B through F contains the model output data, and discussions of the results are in Sections 3.1 and 4.1 of the main text of each of Parts B-F.

A.5.1.1. Atmospheric Dispersion Model

The mass in the atmosphere was tracked using a Lagrangian approach analogous to the in-water transport model for oil. In the model, the chemical is transported by the wind. Degradation is included for volatilized hydrocarbons at an empirical rate estimated for in air (French et al., 1999, based on Mackay et al. 1992 b,c,d,e). The atmospheric dispersion model provided estimates of air concentrations in the air layer within 2 m of the water and land surface (i.e., within the approximate height of a person who might be exposed).

The mass is dispersed horizontally by turbulence following the algorithm from Gifford (1961), as described in Csanady (1973). The model-calculated horizontal dispersion coefficient is a function of wind speed and air stability. Stability is defined as:

- Moderately stable
- Slightly stable
- Neutral
- Slightly unstable
- Moderately unstable

The USEPA and NOAA (2002) offer the following guidance (based on Turner, 1970, Table A.5-1) in the Aloha model regarding atmospheric stability.

> "The atmosphere may be more or less turbulent at any given time, depending on the amount of incoming solar radiation as well as other factors. Meteorologists have defined six atmospheric stability classes, each representing a different degree of turbulence in the atmosphere. When moderate to strong incoming solar radiation heats air near the ground, causing it to rise and generating large eddies, the atmosphere is considered 'unstable', or relatively turbulent. Unstable

conditions are associated with atmospheric stability classes A and B. When solar radiation is relatively weak, air near the surface has less of a tendency to rise and less turbulence develops. In this case, the atmosphere is considered ‘stable’, or less turbulent, the wind is weak, and the stability class would be E or F. Stability classes D and C represent conditions of more neutral stability, or moderate turbulence. Neutral conditions are associated with relatively strong wind speeds and moderate solar radiation.”

Table A.5-1. Stability Classes (from Turner, 1970)

Surface Wind Speed (units below)	Day			Night	
	Incoming Solar Radiation			Greater than 0.5 Cloud Cover	Less than 0.5 Cloud Cover
	Strong	Moderate	Slight		
(meters/second)					
<2	A	A-B	B	E	F
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
>6	C	D	D	D	D
(knots)					
<3.9	A	A-B	B	E	F
3.9-5.8	A-B	B	C	E	F
5.8-9.7	B	B-C	C	D	E
9.7-11.7	C	C-D	D	D	D
>11.7	C	D	D	D	D
(miles/hour)					
<4.5	A	A-B	B	E	F
4.5-6.7	A-B	B	C	E	F
6.7-11.2	B	B-C	C	D	E
11.2-13.4	C	C-D	D	D	D
>13.4	C	D	D	D	D

NOTES:
Stability is D for completely overcast conditions during day or night.
"Night" is the time period from 1 hour before sunset until 1 hour after sunrise.
"Strong" solar radiation corresponds to clear skies with the sun high in the sky (solar angle greater than 60 degrees).
"Slight" solar radiation corresponds to clear skies with the sun low in the sky (solar angle between 15 and 35 degrees).

Stability class has a large effect on the modeled dispersion of a gas. Under unstable conditions, for example, a dispersing gas will mix rapidly with the air around it and the pollutant will be diluted more quickly below levels of concern than it would for more stable conditions. In the analysis of the scenarios in this study, the worst case of a stable atmosphere was simulated.

The mass is also dispersed upward by turbulence, which is a function of wind speed. The basic approach used is the planetary boundary layer and mixing length theory (described in fluid dynamic text books, e.g., Holton, 1979). According to the theory, the vertical change of velocity and shear is defined by the log law. This also provides the eddy viscosity relationship,

$$D_z = L^2 \, du/dz$$

where D_z is the vertical mixing rate, L is mixing length, and du/dz is the vertical velocity shear. This is approximated as

$$D_z = z\,U^* \qquad \text{and} \qquad U^* = (F_b / \rho_a)^{-1/2}$$

where F_b is bottom stress and ρ_a is air density. In short,

$$D_z = z * W_v * (C_d)^{1/2}$$

where W_v is wind speed (at 10m), and C_d bottom friction (0.0013).

This provides a continuous Eddy viscosity diffusion coefficient, from ground zero to approximately 10 meters. Once the diffusion coefficient is calculated from wind speed, we can solve the diffusion term,

$$D_z * d(dC/dz)/dz$$

where C is concentration of chemical in the air. C values are specified at the interface by the flux from the water.

It is assumed that the upper atmosphere does not contain any substance and transport is always out of the surface layer. At each model time step, concentration is calculated in a grid sized to just cover the extent of the plume. Concentration in each cell (C_i) is calculated as:

$$C_i = (M_{air}) / (A * H)$$

where M_{air} = mass in the air within the grid cell, A = area of the cell, and H = height of the cell. The maximum 30-minute and 8-hour averages are calculated by scanning the concentration data each time step and for every 30-minute or 8-hour time period. Similar calculations are made for other time periods of interest.

A.5.1.2. Estimation of Air Emissions and Concentrations

Volatilization of hydrocarbons from oil includes two processes: (1) evaporation from surface floating oil and from oil stranded on shorelines, and (2) volatilization of soluble hydrocarbons (aromatics) from the dissolved state in the upper wave-mixed layer of the water column. (The term volatilization is used as a general term for both processes.) Volatilization is faster the higher the vapor pressure of the compound. Thus, for example, MAHs are volatilized faster than PAHs.

The volatilization rate of hydrocarbons varies with environmental conditions, including increasing with temperature and wind speed. For wind speeds less than about 12 kts, evaporation from surface floating oil is the dominant process and evaporation is faster the higher the wind speed (Mackay and Matsugu, 1973). Entrainment of oil into water increases rapidly as winds increase above 12 kts, removing oil from the water surface and slowing evaporation. However, dissolved hydrocarbon components volatilize directly to the atmosphere under these high wind conditions. Thus, the balance between evaporation and entrainment, followed by volatilization from the water column, determines the net emission rate of volatiles to the atmosphere.

As a screening analysis, SIMAP runs were performed for both the medium (2,500 bbl) and large (40,000 bbl) spill volumes of the representative oil for each region under varying environmental conditions to determine the highest possible hydrocarbon emissions from unburned oil to the atmosphere. Emissions were estimated using SIMAP for the warmest water temperature in the region and for varying wind speeds from 3 to 25 kts. (Evaporation is very slow in conditions of no wind, so this case was not included.) As will be seen in the results (Appendices III.1 in Parts B to F), emission rate increases as wind speed increases.

As a worst case, these model runs were performed assuming no dispersants are applied, since the use of dispersants would reduce emissions to the extent that volatile components are permanently mixed into the water. It is also assumed that any mechanically-removed oil still volatilizes, so no correction for removal was made to the volatilized mass. Likewise, no correction for amount burned was made to the rate of unburned oil emission. Thus, the screening model runs estimated the maximum rate and amount of emissions which would be expected under any environmental conditions and response scenario for the location.

In the next step of the analysis, the atmospheric concentrations of volatilized hydrocarbons released by unburned oil were modeled using AIRMAP, which accounts for transport and dilution of hydrocarbons in the local area around the spill site. Each hydrocarbon constituent was modeled separately, releasing the mass of the constituent emitted from the oil over time from the area covered by surface floating oil (as estimated by SIMAP). AIRMAP was run for each constituent and wind speed condition, from 3 to 25 kts. The atmospheric dispersion model provided estimates of air concentrations in the air layer within 2 m of the water surface. The estimated concentrations were then compared to air quality standards to evaluate the potential for human health effects.

In the atmospheric dispersion model, the chemical is transported by wind and diluted by turbulence. To provide conservatively high estimates of concentrations, the atmosphere was modeled as stable (as opposed to turbulent). These conditions resulted in the slowest dispersion of the volatilized hydrocarbons. Degradation was also included at an empirical rate specific to the chemical or chemical class. Degradation is very slow relative to atmospheric dispersion by wind and turbulence, and so had little influence on the results. Since the emissions were more rapidly dispersed in the atmosphere the higher the wind speed, the conditions where concentrations of volatiles in air were at maximum were those where winds were assumed light (3 kts). This is demonstrated in the results, as described in Appendices III.1 of Parts B to F.

Atmospheric dispersion was modeled for the major volatile compounds released from unburned oil that would be of concern to human health and where human health standards are available (as described in Section A.5.3). Table A.5-2 contains the list of chemicals and chemical classes in oil that were considered in the analysis of air emissions from volatilization. Heptane is used as representative of the volatile aliphatic VOCs. Its air quality standards are the lowest of those available for this group of chemicals (see Section A.5.3), so comparison to the standards for heptane is conservative.

Table A.5-2 Chemicals considered in the analysis of air emissions from volatilization.

Chemical Class	Chemical	CAS # of Modeled Chemical	Degradation Rate in Air (day^{-1})
MAHs	Benzene	71-43-2	0.978
	Toluene	108-88-3	0.978
	Ethylbenzene	100-41-4	0.978
	Xylenes	1330-20-7	0.978
PAHs	Biphenyls	92-52-4	0.302
	Naphthalene	91-20-3	0.978
	Phenanthrene	85-01-8	0.978
Volatile Aliphatic VOCs	Aliphatics VOCs with boiling points <180°C	142-82-5 (heptane)	0.113

The model estimates of concentrations were made in a grid sized to just cover the dimensions of the air plume where concentrations exceeded thresholds of concern. This grid was divided into 200 by 200 cells horizontally (55m by 55m each) and a 2-m thick layer just above the water surface. The maximum concentration averaged within any single grid cell was compared to the thresholds of concern, and areas where the thresholds were exceeded were tabulated by constituent.

A.5.2 Atmospheric Concentrations Resulting From ISB

For scenarios involving ISB, the maximum potential amount of oil burned was assumed to be 25% by volume of the amount of oil mechanically removed (see Section A.3.7). The amount burned was calculated for each scenario since the percent of oil mechanically removed varies for each of the 100 stochastic runs. The 50th and 95th percentiles of the volumes mechanically cleaned up (for the 100 stochastic runs) were multiplied by 0.25 to calculate the 50th and 95th percentile volumes burned by ISB.

The atmospheric concentrations of compounds and particulates released by an in-situ burn of a particular volume of oil were estimated using the models developed by Fingas et al. (2001). Atmospheric emission concentrations are dependent upon both the distance from and the area of the fire. Such predictions equations have been generated by Fingas et al. (2001) for more than 150 individual compounds. All chemicals in the emissions that might be of concern are considered in the analysis.

The following is a summary of the approach of Fingas et al. (2001), which includes extensive sampling data from over 45 mesoscale burns. The mesoscale oil burns and emission measurement tests began in Mobile, Alabama, in 1991 with several controlled burns designed to measure a series of physical parameters as well as emissions. Further tests have been conducted in 1992, 1993, 1997 and 1998. The emphasis on sampling was at typical receptor heights for humans, usually 5 feet or 1 meter. Sampling locations were typically placed at downwind stations, at upwind stations, and in the smoke plume.

A full analysis of emissions from an oil burn entails measuring a number of components, including the smoke plume, particulate matter precipitating from the smoke plume, combustion gases, unburned hydrocarbons, organic compounds produced during the burning process and the residue left at the burning pool site. Soot particles also have a variety of chemicals absorbed and adsorbed (Fingas et al., 2001).

The compounds analyzed are either known or likely (based on similar chemistry to those known) to have effects on humans and wildlife in sufficient concentrations. Fingas et al. (2001) have identified ten substances of possible concern to human and environmental health. They are: particulates, PAHs, VOCs, dioxins and dibenzofurans, carbonyls, carbon dioxide, carbon monoxide, sulphur dioxide, other gases (oxides of nitrogen) and "hidden" compounds. Fingas et al. (2001) summarize the measured concentration data from the mesoscale test burns for 150 specific compounds. They also calculate safe distances from the burn site for these compounds for various burn sizes.

Fingas et al. (2001) also draw on the results of the Newfoundland Offshore Burn Experiment (NOBE), conducted 42 km east of St. John's, Newfoundland (Fingas, et al., 1995a,b), and the United Kingdom in-situ burn trials conducted 40 km offshore Lowesoft (Thornborough, 1997). The NOBE project studied two controlled spills of approximately 50 m^3 of crude oil. Numerous vessels and aircraft were stationed throughout the 34-km^2 area with equipment to sample the fire and smoke plume (Fingas et al., 1995a,b). The UK burn experiment also studied two controlled spills in a 25 square mile area, but the emphasis was on determining the operational practicalities of ISB as a cleanup option, with only peripheral emphasis on emission sampling (Thornborough, 1997).

Correlating emission data results with spatial and burn parameters, Fingas et al. (2001) derive the following relationship for predicting emissions:

$$C = a + b*A_{fire} - c*\ln(d)$$

where C is concentration in the air, A_{fire} is the area of the fire, d is distance from the fire, and a, b and c are constants determined by the best-fit to the data. The constants a, b and c vary by compound. This equation shows that, for each compound, the predicted concentration is a function of the fire size and the distance from the fire.

It has been found that a minimum oil thickness of 1 mm to 5 mm is required for ignition depending on the nature of the oil (Buist et al., 1994). However, 10 cm is a more preferable oil thickness for burning (personal communication, A. Allen, Spiltec, Woodinville, WA, June 2002) and is used for cases where such a thickness might be obtainable given the oil volume. A volume equal to 25% of the mechanical recovery volume is assumed contained by fire-resistant booming and burned.

For smaller burn volumes, one fire might be used. However, for larger burn volumes, multiple fires would likely be used, as there would be a logistical limit to the size of a burn. Burn size for a single burn was calculated by dividing the volume of oil burned (in m^3) by the minimum thickness of the oil (3 mm, or 0.003 m, the midpoint of the cited range by Buist et al., 1994). It is assumed that the maximum feasible burn size is 500 m^2. Any burn sizes calculated to be larger than 500 m^2 are assumed to be gathered within an area of 500 m^2, which would increase the thickness of the oil.

The maximum burn size of 500 m^2 was derived from two considerations. First, there are limitations to the test data and approach used to calculate the distance to each concentration threshold. Using data from 30 test burns, Fingas et al. (2001) correlated atmospheric emissions data with distance from the fire and the size of the fire. The largest of the test burns from which these data were obtained was 450 m^2. Therefore, we restrict burn sizes to 500 m^2, for without empirical data, the calculations for burns larger than 500 m^2 are merely mathematical predictions with large uncertainty. Second, we queried ISB expert Alan Allen (Spiltec, Woodinville, WA, June 2002, personal communication) regarding the logistical or reasonable limit to a burn area. His estimate of what was a reasonable burn area was about 5,000 to 6,000 $feet^2$ (465-557 m^2), which is a typical area that could be contained for a sustained burn with fire boom in a U-configuration (boom being about 500 feet in length).

Therefore, the burn area used to estimate the distance to the threshold concentration is the minimum of: (1) the oil volume burned divided by 3 mm, assuming a worst case of a single burn, or (2) the maximum possible burn area of 500 m^2. It is assumed that if multiple burns are needed, the burns are separated in time and space such that each burn can be considered separately.

For each model scenario for a given spill volume and location (i.e., no dispersant, dispersants at 45% efficiency, and dispersants at 80% efficiency), the distance where concentrations would fall below a threshold of concern is made for each constituent in the ISB emissions, as follows.

$$B_v = 0.25\, f_M$$

$$B_a = A_{\mathrm{fire}} = \mathit{Minimum}\ [\ (B_v\ /\ th_{min}),\ A_{max}\ ]$$

$$D_{\mathrm{th}} = \exp[\ (a + b\ A_{\mathrm{fire}} - D_{\mathrm{th}})/c\ ]$$

where B_v is the burned volume, f_M is fraction mechanically removed, B_a is the burn area, th_{min} is the minimum burn thickness (=3mm), A_{max} is the maximum burn area (=500 m^2), and D_{th} is the distance to the concentration threshold. The parameters a, b, and c are provided by Fingas et al. (2001, Tables A.5-3 and A.5-4).

Table A.5-3. Values of a, b, and c for the in-situ burn emissions model developed by Fingas et al. (2001): total particulates, fixed gases, carbonyls, and PAHs.

Substances	Equation Parameters		
	a	b	c
Total Particulates			
10-um particle	12.7	0.0347	4.79
2.5-um particle	12.7	0.0347	4.79
Fixed gases			
Sulphur Dioxide	19.4	0.0266	5.29
Carbon Dioxide	520	0.523	81.5
Carbon Monoxide	7.72	0.00124	1.56
Carbonyls			
Acetaldehyde	23.3	0.115	12.9
Acetone	11.3	0.0445	5.11
Formaldehyde	58.4	0.103	20.1
PAHs			
1- Methylnaphthalene	1.01	0.00424	0.381
1-Methylphenanthrene	0.115	0.00000483	0.0192
2,3,5-Trimethylnaphthalene	0.286	0.00053	0.08
2,6-Dimethylnaphthalene	0.614	0.0025	0.249
2-Methylnaphthalene	1.4	0.00397	0.462
Acenaphthene	0.0673	0.0000213	0.00989
Acenaphthylene	0.0673	0.0000213	0.00989
Anthracene	0.32	0.000189	0.0653
Benz(a)anthracene	0.14	1.43E-09	0.398
Benzo(a)pyrene	0.617	0.000361	0.145
Benzo(b) fluoranthene	0.108	0.00000998	0.0229
Benzo(e) pyrene	0.108	0.0000998	0.0229
Benzo(g,h,I) perylene	0.228	0.000091	0.0479
Biphenyl	0.507	0.0000127	0.0708
Chrysene	0.1224	0.000127	0.0305
Dibenz(a,h)anthracene	0.0189	0.00000297	0.00227
Dimethylnaphthalenes	1.75	0.000804	0.257
Fluoranthene	0.851	0.00000297	0.1523
Fluorene	0.299	0.000309	0.0716
Indenol(1,2,3-cd)pyrene	0.161	0.000145	0.0394
Methylphenanthrenes	0.322	0.000244	0.075
Naphthalene	1.86	0.00226	0.385
Perylene	0.0675	0.0000709	0.0152
Phenanthrene	0.787	0.000224	0.141
Pyrene	0.542	0.000226	0.117
Trimethylnaphthalenes	0.856	0.000891	0.21

Table A.5-4. Values of a, b, and c for the in-situ burn emissions model developed by Fingas et al. (2001): volatile organic compounds (VOCs).

Substances	Equation Parameters		
	a	b	c
1,2,3-Trimethylbenzene	11.4	0.0106	2.53
1,2,4-Trimethylbenzene	22.4	0.0239	4.58
1,3,5-Trimethylbenzene	17.3	0.0191	4.28
1,4-Diethylbenzene	4.66	0.00529	0.947
2,2,3-Trimethylbutane	25	0.0256	7.49
2,2,4-Trimethylpentane	5.41	0.0131	1.66
2,2,5-Trimethylhexane	8.49	0.00806	2.58
2,2-Dimethylbutane	61	0.105	19.3
2,2-Dimethylpropane	25.2	0.0271	7.93
2,3,4-Trimethylpentane	14	0.0249	4.53
2,3-Dimethylbutane	168	0.308	57
2,3-Dimethylpentane	173	0.294	56.8
2,4-Dimethylhexane	72.2	0.109	22.7
2,4-Dimethylpentane	99	0.164	32
2,5-Dimethylhexane	40.5	0.0787	14.3
2-Ethyltoluene	5.98	0.00826	1.47
2-Methylbutane	2221	4.58	821
2-Methylheptane	240	0.384	77.4
3-Methylhexane	526	0.896	175
3-Methylpentane	822	1.41	272
4-Ethyltoluene	4.79	0.0051	0.85
4-Methylheptane	30.1	0.063	9.44
Benzene	72	0.0242	14.1
Butane	1700	3.31	604
c-1,3-Dimethylcyclohexane	82.4	0.21	28
c-1,4/t-1,3-Dimethylcyclohexane	22.4	0.0626	6.74
c-2-Butene	4.73	0.0108	1.6
Cyclohexane	726	1.43	256
Cyclopentane	262	0.526	93.8
Decane	97	0.0899	24.5
Dodecane	27.1	0.0368	7.43
Ethylbenzene	25	0.0391	6.69
Heptane	1170	2.11	400
Indan (2,3-Dihydroindene)	2.64	0.00305	0.557
Isobutane (2-Methylpropane)	414	1.05	165
m,p-xylene	88.6	0.109	20.8
Methylcyclohexane	1660	3.03	571
Methylcyclopentane	2090	2.9	713

Table A.5-4. Values of a, b, and c for the in-situ burn emissions model developed by Fingas et al. (2001): volatile organic compounds (VOCs) (continued).

Substances	Equation Parameters		
	a	b	c
Naphthalene	5.92	0.00991	1.7
n-Butylbenzene	3.28	0.003	0.806
Nonane	232	0.328	70.5
n-Propylbenzene	6.85	0.0073	1.52
Octane	513	0.776	162
o-Xylene	26	0.0186	5.38
p-Cymene (1-Methyl-4-iso-propylbenzene)	2.52	0.0055	0.0125
Pentane	2590	5.05	920
Propane	733	0.789	236
Propene	21.8	0.062	8.28
2,2-Dimethylpentane	52.3	0.0799	16.5
iso-Butylbenzene	3.48	0.00574	1.06
Isoprene (2-Methyl-1,3-Butadiene)	17.4	0.0314	5.51
iso-Propylbenzene	21.4	0.0178	6.41
Undecane	50	0.0525	12.4

A.5.3 Thresholds of Concern

For burn emissions, the thresholds of concern are for short term exposures, such as the Immediate Danger to Life and Health (IDLH) value, because the burn is typically of short duration (less than 1.5 hours) and the IDLH is for exposures of 30 minutes. Thresholds of concern (IDLH and others) were compiled from several sources: the National Institute for Occupational Safety and Health (NIOSH), the Occupational Safety and Health Administration (OSHA), the American Conference of Governmental Industrial Hygienists (ACGIH), and USEPA. Thresholds are shown for chemicals contained in crude oil (Table A.5-5), as identified by Fingas et al. (2001) as of concern in crude oil. There are some chemicals for which threshold values were not available and no data are listed. For the safe distance calculations of these chemicals during a burn, the threshold values were set to zero, so that the resulting distance calculation is the distance from the fire at which the concentration would be insignificant.

The NIOSH thresholds values are IDLH and Recommended Exposure Limit - Time Weighted Average (REL-TWA). The IDLH values represent a level at which the concentration of the chemical is high enough to immediately cause danger to human health if exposed for 30 minutes. The REL-TWA is the recommended exposure limit for a time weighted average of 10-hours.

OSHA PEL-TWA is the permissible exposure limit time weighted average for air contamination for 8-hours according to OSHA. The ACGIH TLV-TWA is the threshold limit value time weighted average for 8-hours according to the ACGIH. TLV-TWA is usually more restrictive than the OSHA PEL or NIOSH REL.

The USEPA values are National Ambient Air Quality Standards (NAAQS). NAAQS values are provided by USEPA for several time periods, from 1-hour averages to annual means. NAAQS values are shown for both the primary and secondary standards. Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings.

As discussed above, volatile chemicals released after a spill from unburned oil may affect air quality, as may other additional chemicals emitted during an in-situ oil burn. The PAHs and VOCs volatize from the slick and surface water mixed layer. For an oil burn, PAHs, VOCs and all other chemicals contained in Table A.5-5 may be emitted and of concern.

Table A.5-5. Air quality standards.

Substances	NIOSH – IDLH (ppm)[1]			TWA (ppm)[2]			USEPA NAAQS (ug/m3)[3]	
	(ppm)	(mg/m3)	Conversion ppm to mg/m3 (1 ppm = x mg/m3)	ACGIH TLV	OSHA PEL	NIOSH REL	Primary Standard (ug/m3)	Secondary Standard (ug/m3)
Total Particulates								
10-um particle							150 (24-hr average), 50 (annual mean)	150 (24-hr average), 50 (annual mean)
2.5-um particle							65 (24-hr average), 15 (annual mean)	65 (24-hr average), 15 (annual mean)
Fixed gases								
Sulphur Dioxide	100		2.62	2	5	2	80 (annual mean), 365 (24-hr average)	1300 (3-hr average)
Carbon Dioxide	40000		1.8	5000	5000	5000		
Carbon Monoxide	1200		1.15	25	50	35	10000 (8-hr average), 40000 (1-hr average)	
Carbonyls								
Acetaldehyde	2000		1.8	100	200			
Acetone	2500		2.38		1000	250		
Formaldehyde	20		1.23		0.75	0.016		
PAHs								
1- Methylnaphthalene								
1-Methylphenanthrene								
2,3,5-Trimethylnaphthalene								
2,6-Dimethylnaphthalene								
2-Methylnaphthalene								
Acenaphthene								
Acenaphthylene								
Anthracene								
Benz(a)anthracene								
Benzo(a)pyrene		80						
Benzo(b) fluoranthene								
Benzo(e) pyrene								
Benzo(g,h,I) perylene								
Biphenyl		100	6.31		0.2	0.2		
Chrysene		80						
Dibenz(a,h)anthracene								

1 - NIOSH; March 2002; 2 - NIOSH; June 2002; 3 - USEPA, 1990; Primary standards protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly; Secondary standards protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings

Table A.5-5. Air quality standards (continued).

Substances	NIOSH – IDLH (ppm)[1]			TWA (ppm)[2]			USEPA NAAQS (ug/m3)[3]	
	(ppm)	(mg/m3)	Conversion ppm to mg/m3 (1 ppm = x mg/m3)	ACGIH TLV	OSHA PEL	NIOSH REL	Primary Standard (ug/m3)	Secondary Standard (ug/m3)
Dimethylnaphthalenes								
Fluoranthene								
Fluorene								
Indenol(1,2,3-cd)pyrene								
Methylphenanthrenes								
Naphthalene	250		5.24		10	10		
Perylene								
Phenanthrene		80						
Pyrene		80						
Trimethylnaphthalenes								
VOCs								
1,2,3-Trimethylbenzene			4.92	25		25		
1,2,4-Trimethylbenzene			4.92					
1,2-Diethylbenzene			5.33			10		
1,3,5-Trimethylbenzene			4.92			25		
1,4-Diethylbenzene			5.33			10		
2,2,3-Trimethylbutane								
2,2,4-Trimethylpentane								
2,2,5-Trimethylhexane								
2,2-Dimethylbutane			3.53					
2,2-Dimethylpropane								
2,3,4-Trimethylpentane								
2,3-Dimethylbutane			3.53					
2,3-Dimethylpentane								
2,4-Dimethylhexane								
2,4-Dimethylpentane								
2,5-Dimethylhexane								
2-Ethyltoluene								
2-Methylbutane								
2- and 4-Methylheptanes								
3-Methylhexane								

1 - NIOSH; March 2002; 2 - NIOSH; June 2002; 3 - USEPA, 1990; Primary standards protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly; Secondary standards protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings

Table A.5-5. Air quality standards (continued).

Substances	NIOSH – IDLH (ppm)[1]			TWA (ppm)[2]			USEPA NAAQS (ug/m3)[3]	
	(ppm)	(mg/m3)	Conversion ppm to mg/m3 (1 ppm = x mg/m3)	ACGIH TLV	OSHA PEL	NIOSH REL	Primary Standard (ug/m3)	Secondary Standard (ug/m3)
3-Methylpentane								
4-Ethyltoluene								
Benzene	500		3.19	10	1	0.1		
Butane			2.38			800		
c-1,3-Dimethylcyclohexane								
c-1,4/t-1,3-Dimethylcyclohexane								
c-2-Butene								
Cyclohexane	1300		3.44	300	300	300		
Cyclopentane			2.87	600		600		
Decane								
Dodecane								
Ethylbenzene	800		4.34	100	100	100		
Heptane	750		4.1		500	85		
Indan (2,3-Dihydroindene)								
Isobutane (2-Methylpropane)			2.38			800		
m,p-xylene	900		4.34	100	100	100		
Methylcyclohexane	1200		4.02		500	400		
Methylcyclopentane								
n-Butylbenzene								
Nonane			5.25	200		200		
n-Propylbenzene								
Octane	1000		4.67		500	75		
o-Xylene	900		4.34	100	100	100		
p-Cymene (1-Methyl-4-iso-propylbenzene)								
Pentane	1500		2.95		1000	120		
Propane	2100		1.8		1000	1000		
Propene								
2,2-Dimethylpentane								
iso-Butylbenzene								
Isoprene (2-Methyl-1,3-Butadiene)								
iso-Propylbenzene	900		4.92		50	50		
Undecane								

1 - NIOSH; March 2002; 2 - NIOSH; June 2002; 3 - USEPA, 1990; Primary standards protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly; Secondary standards protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings.

A.6 MODEL OF ECONOMIC AND SOCIAL EFFECTS OF OIL SPILLS

A.6.1 Introduction

Oil spills generate a wide range of economic and social effects. This section provides a description of the methods used for the quantitative assessment of the degree to which the various response techniques considered in the PEIS (USCG, 2004) can mitigate the risk of economic and social effects. The modeled spill scenarios are used for this assessment.

The potential economic and social impacts of spills are modeled by considering several important and visible effects of oil spills: reduced recreational activity due to beach closures, limited accessibility, or reduced demand for local recreational facilities due to the perception of taint; closure of commercial fishing grounds or hatcheries; and oiling of marine resources important to indigenous peoples and subsistence cultures. The change in the risk of such outcomes under a variety of hypothetical spill scenarios is used to quantify the implications of the spill response alternatives considered in the PEIS. It is clear that oil spills can also generate secondary economic and social effects, such as impacts on employment, income, business revenues in local communities, and changes in environmental justice. While these and other types of impacts are not quantified through this analysis, the results of the risk analysis provide proxy measures of the overall change in economic and social impacts resulting from changes in spill response activities. To augment the quantitative analysis and shed light on the wider economic and social benefit that can result from enhanced spill response activities, the impacts of response scenarios on coastal communities, demography and employment, and environmental justice are addressed qualitatively.

This section begins with general discussions of various categories of impact resulting from oil spills. It then describes the approach used to model risk of economic and social impact given spill response scenarios as defined by the alternatives considered in the PEIS. The results of the modeling efforts for each of five study sites, each under two spill-size scenarios, are in Parts B through F of this technical report.

A.6.1.1 Recreation and Tourism

Recreation and tourism in coastal areas include visitation to developed and undeveloped landscapes and recreational boating excursions (e.g., marine fishing and other pleasure craft use). Expenditures for recreation and tourism can be a significant component of the coastal economy. For example, in 1998 beach recreation in the state of California generated $14 billion in direct revenue and $73 billion through indirect and induced benefits (King 1999).

Beach closures and moratoria on recreational fishing and/or boating activity can be among the most visible effects of oil spills. These effects reduce the number of visitors to a given area and the corresponding revenues generated from recreational activities and tourist facilities. The longer the period of closures and moratoria and the more extensive the affected geographic area, the greater the losses will be to those who participate in or derive their income from such activities. Further, perceptions of the degree to which a location has been affected by an oil spill can impact tourism and recreational activities. To the extent that dispersants and/or ISB protect shorelines from spilled oil, minimize closures or moratoriums on recreational activity, and address individual concerns about taint, these spill response options will reduce effects on users and minimize economic and financial impacts (King, 1999; NOAA, 1983). However, there are limitations to the application of these spill response techniques. Specifically, dispersants cannot be used on oil that comes within three miles of shore or in waters less than 10 meters deep. Similarly, ISB reduces sheen and surface oil, but it produces large quantities of black smoke that is potentially harmful to humans (NOAA 2002c) and may drive recreators from an area following a spill.

A.6.1.2 Commercial Fisheries

Commercial fishing is an important economic activity in many coastal communities. In Texas, for example, approximately 73.8 million pounds of shrimp, valued at $210 million, were landed in 2000. The inability to work a fishery due to an oil spill can lead to significant losses in revenue for the commercial fishery as well as related industries, including those who supply equipment to and purchase products from commercial fleets. Oil spills can lead to the closure of fisheries, a decrease in demand for fish from affected waters (i.e., due actual or perceived product taint), and the need to alter fishing practices in a manner that increases operating costs and/or decreases revenues. The longer a commercial fishery is affected by a spill, and the larger the geographic area affected, the greater the economic impact to coastal communities.

Both dispersants and ISB are effective countermeasures used to reduce the effect of oil spills on commercial fisheries. While ISB is as effective as mechanical recovery, the use of dispersants can reduce sheen and oil volume more rapidly, allowing for a faster resumption of commercial fishing activities. Dispersants also reduce the effects of spilled oil on surface and shoreline organisms. However, the aforementioned limitations on and implications of their use indicate that neither dispersants nor ISB are viable means of mitigating the impact of oil once it comes within 3 miles of shore and affects shore-line fishing operations. Furthermore, ISB can lead to moratoria on commercial fishing activities due to the human health risk associated with the smoke plume generated by the burning (NOAA 2002a, 2002b, 2002c).

A.6.1.3 Coastal Communities

Coastal communities benefit from and rely upon the marine environment to provide them with sustenance, livelihoods, and shipping avenues. Individuals in close proximity to the coast derive pleasure from the natural beauty, recreational opportunities, quality of life, and cultural attributes associated with such locations. Oil spills can affect multiple aspects of a coastal community's economy, culture, and quality of life. The reliance of these communities on marine-related industries, activities, and foods means that an oil spill can lead to disruptions in employment, business revenue, import and export of materials, as well as degradation in social welfare and the ability to live a healthy life. Activities necessitated by the clean-up of oiled coastal areas can also affect the well-being of coastal populations by disrupting resident's daily lives (e.g. increased traffic, noise pollution, and aesthetic impacts). In some cases, residents may benefit from these additional activities. For example, clean-up efforts may generate additional employment opportunities. The benefits of such jobs, however, may be short lived, while the stigma associated with the spill may remain after the cleanup is complete. [1]

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[1] For example, net regional economic benefit would result from the creation of clean-up related jobs only to the extent that such jobs reduce net regional unemployment and increase total wages (i.e., fully off-set jobs and wages lost as a result of the spill).

To the extent that dispersants and/or ISB can reduce shoreline oiling and minimize the impact on coastal communities, these spill response techniques will reduce impacts on coastal communities, both short and long term.

A.6.1.4 Environmental Justice

In some coastal areas, low-income, indigenous, and minority sub-populations may rely on local fisheries and other marine species for subsistence, as part of an artisinal economic system (i.e., a system in which resources are harvested, sold, and consumed within the local community), or in the context of participation in a commercial fishery. These groups may experience the effects of a spill more severely than the general population, which relies on a more diverse economic base for their livelihoods and a widespread and commercially available selection of foods. Additionally, subsistence use of natural resources and employment in marine resource related industries may have value beyond the importance these resources hold as a food source or employment opportunity. Many communities associate their reliance on natural resources with their ethnic and cultural identities, subscribing to a unique lifestyle built around the same natural resources that are susceptible to impact from oil spills. Thus, damage to these resources can cause a loss of cultural identity.

Regardless of the specific nature of the interaction between a community and a resource injured by an oil spill, disproportionate effects on any of the sub-populations highlighted above may merit special attention. Specifically, if a group is disproportionately at risk of the effects of oil spills, they will likely disproportionately benefit from response actions intended to mitigate the impacts of such spills. Consideration of this type of effect is mandated by Executive Order 12898, which defines environmental justice as the need to take special care that actions do not have "disproportionately high or adverse human health or environmental effects on minority populations and low-income populations."

A.6.2 Methodology

The impacts of oil spills on coastal locations and the economic damages associated with these impacts are often expressed in dollar terms. While monetary measures of spill-related economic losses could be developed for each of the spill scenarios modeled in this analysis, this analysis does not attempt to express damages in monetary terms for several reasons:

1) There is good reason to believe that monetary damages are linearly related to the physical risk measures used in this analysis, and thus results based on monetary measures of damage would not be expected to differ significantly from those presented in this analysis (NRC, 2002b).
2) Monetary measures of ecological and other damages resulting from the modeled hypothetical spills are not developed.
3) The case study sites chosen for this analysis are not areas considered to be the most vulnerable to oil spills. Instead, they were chosen because they are considered representative of the diverse sites at which oil might be released into the environment. In fact, shifting a case study site a few miles could result in a significantly different pattern of modeled economic losses. Thus, consideration of case-specific monetary losses could lead to assigning disproportionate weight to the specifics of a modeled location (NRC, 2002b).

4) Estimates of economic damage would vary significantly across case study sites, making it difficult to draw comparisons and/or generalizations about the harm caused by oil spills and the benefits of spill response.
5) Given data availability and various assumptions made in the context of the modeling exercise, any monetary estimates of economic damage would be imprecise. For example, determining the effects of a beach closure requires information on the weather conditions at the time of the spill and the numbers of visitors during the season in which the spill occurred. Weather and seasonality will affect both the volume of visitors to a beach as well as the movement of oil in the water. The dollar value of damage will likewise fluctuate with these factors. Since these factors can cause the economic damage to vary substantially, assigning a single dollar value would be misleading.

Therefore, instead of using a monetary metric, this analysis has chosen to identify the level of economic and social risk to physical assets. For example, at some locations, the length of sandy shoreline (i.e., beach) oiled as a result of a modeled spill is used to indicate the risk of impact on recreational activity rather than dollars lost from a decrease in beach visitation.

The steps followed in modeling the economic and social effects of oil spills and response include:

1) Inventory and describe the economic resources at risk in the modeled area and determine the best physical metric to act as a proxy for economic damages (e.g., shoreline length oiled, surface water area oiled);

2) Establish oil coverage thresholds above which the effects on the chosen physical resources are likely to be significant (i.e., the thickness of oil on a beach that mandates its closure);

3) Run SIMAP for each of the five modeled locations given large (40,000 bbl) and medium (2,500 bbl) sized spills under three response scenarios: mechanical and/or ISB methods only (baseline scenario), mechanical and/or ISB methods plus dispersant use at 45% removal efficiency, and mechanical and/or ISB methods plus dispersant use at 80% removal efficiency.

4) Use the length of sandy shoreline or surface area of water swept by oil, above the chosen threshold, as a measure of the absolute risk of economic and social impact in the modeled area under each scenario.

5) Determine the relative risk of economic and social damage by expressing the area affected under each of the dispersant use scenarios (dispersant use at 45% and 80% efficiency) as a percentage of the area affected under the baseline scenario (i.e., the “risk factor”).

For each modeled location the physical metrics that best reflect the economic and social resources likely to be disrupted by an oil spill are identified. Given the diverse nature of the case study sites, site-specific definitions of each metric are used. For example, various forms of recreational activity undertaken within the modeled areas of the Florida Keys were investigated to determine the resource base upon which these activities most heavily rely. Aquatic-based recreational activities both within and adjacent to waters in the Florida Keys National Marine sanctuary constituted the majority of recreation in the area. Therefore, surface water was determined to be the resource of concern. Similarly, the Texas shrimp industry was determined to be the key sector of commercial fishing along the Texas Gulf coast. The shrimp harvest represents 91% of the value of all commercial marine products landed in the state. Therefore, this analysis uses shrimping waters as the critical physical metric of spill-related impacts to the commercial fishery in the Texas Gulf Coast case study.

Having identified critical resources, a risk measure relevant to SIMAP was chosen. Since the area swept by oil in the wake of a spill is determined by a variety of weather and current-related conditions, proximate locations may be affected differently by the same spill depending on wind directions, tides, and currents. With specific information on the location and size of the resources at risk, SIMAP can generate data relevant to a comparison of the benefits of spill response scenarios. For example, the location and length of major beaches was determined for the mid-Atlantic case study. The SIMAP model was then used to generate the average beach area affected above the selected threshold under the various spill and response scenarios.

As previously discussed, oil spills have implications for coastal communities that may be qualitatively assessed. An oil spill that initially decreases revenue for tourism, maritime commerce, and commercial fishing industries will have a subsequent detrimental effect on other sectors of the local economy. Industries within any geographic area are interdependent in the sense that they purchase output from various industries and sectors, while supplying inputs to other businesses. In addition, coastal areas offer environmental amenities, recreational activities, and distinct job opportunities that many residents value highly. Therefore, the economic loss associated with an oil spill includes both decreased revenue generated by specific industries (e.g., commercial fishing), as well as impacts to the associated coastal community (e.g., effects on employment, quality of residential life, recreation, and appreciation of coastal areas).

As with coastal communities, the implications of an oil spill for environmental justice are difficult to quantify. In particular, environmental justice involves issues of equity: the distribution of impacts due to a spill and likewise the distribution of benefits when enhanced spill techniques are employed. Low income, minority, and indigenous communities may rely more heavily on coastal or ocean resources than other sub-sections of the coastal populations and therefore may face more severe consequences from the contamination of those resources. Because the extent of loss in these communities is intimately connected to the degree to which key resources are oiled, evaluating relative risk offers the opportunity to identify any disproportionate benefit gained from the use of enhanced spill remediation techniques.

While it is possible to estimate the monetary economic losses sustained by a particular industry due to an oil spill, there are limitations inherent in attempting to place a dollar value on other impacts (e.g., social impacts) to an entire coastal community or to a sub-population of that community. It is feasible, however, to examine the effects of oil spills on both coastal communities and environmental justice in terms of relative risk. For each of the modeled sites this is done by:

1) assuming the relative risk of impacts to coastal communities and environmental justice is similar to that of the modeled risk to recreational and commercial fishing resources (i.e., use of these measures of impact as proxy measures), or
2) modeling the effect of a range of spills on resources identified as significant to specific sub-populations. For this modeling effort, it is assumed that the relative risk measures developed serve as accurate proxy for the relative risk of regional socio-economic impacts.

As noted above, in addition to identifying resources at risk, the degree of oiling must be considered. For example, small amounts of oil are assumed to have a negligible impact on given economic or social assets, and may not require the closure of fisheries or beaches. At some point, however, the degree of oiling becomes significant, generating an economic and/or social impact. Thus, a threshold of oil density above which economic and social damages are substantial and clean-up is warranted must be identified.

Where beaches and/or surface water were determined to be the representative resource(s) for recreational activity, commercial fishing, coastal communities, and/or environmental justice, thresholds above which some economic or social risk is expected were determined. There are no promulgated thresholds for beach and fishery closures. Thus, thresholds applied in other studies and expert opinion were considered in establishing the thresholds used in this analysis. The socio-economic impacts of oil spills are both a function of resource management decisions (e.g., a formal decision by the National Park Service to close a national seashore) and public perceptions (e.g., an individual recreator's decision not to go to the beach). Perceptions of risk can exist even at very low exposure levels (e.g., just noticeable sheen). For example, the public may choose not to visit an area given the presence of oil even in the absence of a formal beach closure. Similarly, commercial fisheries managers may choose to close a fishery in order to protect the integrity of the fishery in the market, even in cases in which oil is present at very low levels. Thus, relatively low effects thresholds were selected for this analysis.

While specific thresholds were used for this analysis, we expect that the results would be similar given alternate modeled thresholds. This analysis applies a modeling approach that considers the relative risk of socioeconomic impacts under a variety of spill scenarios. This approach is consistent with that developed by an expert committee established by the Transportation Research Board of the National Academy of Sciences to evaluate the environmental performance of double-hull tanker design alternatives (NRC, 2002b). While alternative thresholds could be applied for purposes of this analysis, the double-hull design alternatives committee found modeling results to be insensitive to a range of assumed risk thresholds. This committee also found that results obtained using a range of thresholds were generally consistent with those based on the most conservative (i.e., low) thresholds.

Impacts to beaches and surface water resources are modeled by considering the area of sandy beach or surface water potentially used for a given activity. While other metrics are available (linear meters of shoreline oiled; time period over which surface water is oiled above a threshold), the NRC double-hull design alternatives committee (NRC, 2002b) found the results using square meters of shore and square meters of slick were consistent with results using other metrics.

In this analysis, beaches are assumed closed when the shoreline is covered by 100 g/m^2 of oil, and fishing waters when there is a visible sheen greater than 0.05 g/m^2 (Michel, 2002). Table A.4-1 indicates that the minimum threshold for visible sheen is 0.05 g/m^2. However, key coastal resources are often affected at levels below these thresholds. As noted above, the closure of beaches or fishing grounds, changes in subsistence consumption patterns, or the level at which the perception of taint affects recreation habits all involve complex management and community considerations. Based on these considerations, this analysis uses more conservative thresholds than those used in some other analyses.

This analysis uses the following effects thresholds:

- **Recreational beach shoreline oiled exceeding 10 g/m^2** (i.e., one order of magnitude lower than the assumed closure threshold of 100 g/m^2 for sandy beaches; this threshold is set lower than the assumed closure thresholds to account for public perceptions of risk);
- **Surface area of recreational waters and access points oiled exceeding 10 g/m^2 for waters where surface-based water recreation (e.g., boating) dominates** (i.e., one order of magnitude lower than the threshold of 100 g/m^2 for beach closures). Because there is no level of oiling that can be assumed to cause shipping and boating lanes to be closed or that prompts the closure of channels, harbors, and ports, surface based water recreation in these areas is assumed to be affected when waters are oiled above 10 g/m^2, reflecting a public perception threshold;
- **Surface area of recreational waters oiled exceeding 0.01 g/m^2 for waters where in-water recreational activities (e.g., snorkeling, diving) dominate** (i.e., one order of magnitude lower than the threshold of 10 g/m^2 for fishery closures, again reflecting a public perception threshold);
- **Surface area of fishing grounds oiled exceeding 0.01g/m^2** (i.e., one order of magnitude lower than the threshold of 10 g/m^2 for fishery closures, reflecting a public perception threshold); and
- **Surface area of subsistence harvest areas exceeding 100 ppb of dissolved aromatics for one hour or more** (reflecting an empirical threshold where tainting tends to occur; See Section 4.3.5.6 of the PEIS, USCG, 2004). This threshold is based on studies that show tainting in fish and shellfish occurs rapidly (within hours) and in salmon at exposures to the water-soluble fraction of a crude oil equal to 0.4 ppm total hydrocarbons (which included both MAH and PAH) (Yender et al., 2002). Laboratory studies have shown that, for short-term exposures, tainting occurs before mortalities (e.g., Ernst et al., 1989). Also, Figure A.3-1 shows the correlation of toxicity with time of exposure, with very short times having higher toxicity thresholds. Thus, the 1 hour maximum concentrations of total aromatics from the model were used as the threshold for tainting impacts to subsistence resources.

Below these levels the impact to the resource is considered to be negligible and the corresponding economic and/or social risk assumed to be zero.

A.6.3 Results as Relative Measures of Risk

The results generated by SIMAP include data describing the surface area swept or the length of shoreline contaminated by oil above the modeled thresholds, given large and medium sized-spills occurring during one-hundred modeled weather events under each of three modeled response scenarios. The analysis then reports the average for all runs of each selected risk metric. That is, the model considers a variety of likely weather conditions in the spill area and presents results for each individual event, which are then averaged for comparison across scenarios.

The impacts under each oil spill scenario are described using both absolute and relative data. The absolute measures indicate the area affected by a modeled oil spill above the selected thresholds. Baseline results (assuming mechanical response only) indicate the average area oiled above the threshold assuming dispersants are not applied. The 45% and 80% dispersant efficiency scenarios indicate the average area (i.e., surface water) or length (i.e., shoreline) of the resource oiled above a threshold when spill response involving dispersant use is assumed. The effects of dispersant use can be estimated by directly comparing the results of the baseline analysis with the two dispersant use scenarios. The difference between the scenarios reflects the change in absolute and relative risk to economic and social factors as a result of spill response using dispersants.

The relative measure of risk expresses the relative economic and social impact expected given spill response using dispersants as compared to baseline conditions. In this case, baseline results (i.e., modeled scenarios in which dispersants are not applied, and mechanical recovery and/or ISB are assumed when feasible) represent the maximum potential risk under each scenario. The results of both the 45% and 80% dispersant efficiency scenarios are expressed in terms of the degree of risk under these scenarios relative to the baseline. For example, consider a case where the results indicate that applying dispersants with 45% removal efficiency, when feasible, reduces the risk of economic and social impact to 89% of the baseline risk. This infers that, by applying dispersants with 45% removal efficiency, the risk of economic and social impact is reduced by 11%. Comparisons between the two responses can also be made. For example, while the 45% removal efficiency scenario may yield an 11% reduction in risk, the 80% removal efficiency scenario may yield a greater percentage reduction in relative risk.

A.6.4 Limitations of the Analysis Related to Model Assumptions

In order to assist in interpretation of the results presented for each site, several issues regarding limitations of the analysis, which are related to model assumptions, are highlighted below.

- The modeling approach used assumes a risk of economic and social effect when the concentration of oil in the media of concern (e.g., surface slick, beach oiling) exceeds a selected threshold. The economic and social impacts of spills may also be a function of the intensity of oiling at a given location. This assumption may lead the analysis to understate or overstate the change in impacts resulting from changes in response actions.
- The modeling approach used makes very general assumptions regarding the relevant geographic areas at risk of social or economic effect. For example, for the San Francisco Bay site, it assumes that commercial fisheries will be affected by any slick that enters within 20 miles of the coast. To the extent that these simple assumptions misrepresent the true areas at risk of the effects of spills, the model may over or understate the change in impacts resulting from changes in response actions.
- The modeling approach used takes advantage of wind and current data for each modeled site, and thus reflects the variation in weather conditions experienced across seasons. However, the risk calculations assume that resources are at equal risk under all seasons and weather conditions. For example, a spill that oils a given length of shoreline above a threshold in January is considered to present the same risk of economic and social effect as one that oils the same area of shoreline in August. This modeling approach was selected given a lack of detailed data on beach use and commercial fish landings by date, and the assumption that a given weather condition could occur in any season. To the extent that spill response involving dispersant use is more effective during seasons that are more important to recreation, commercial fishing, and other marine related activities, the model may understate the change in impacts resulting from changes in response actions.
- The approach used does not consider the secondary effects of spill response involving dispersant use. That is, it simply assumes that there is some degree of oil removal efficiency (from the water surface) following a spill, given appropriate conditions. The effects of dispersants (and of dispersed oil) on commercial and recreational fisheries, and the effects of residuals and smoke from ISB on all activities, are not considered. As a result, the analysis likely over-states the benefits of spill response involving dispersants.

- The analysis may underestimate the benefits of using dispersants to recreation and tourism when shoreline is the key recreation and tourism resource in the area. The estimated reduction in sandy shoreline oiled is based on 100 runs of the SIMAP model. Of these 100 runs, only a portion affects the shoreline, other spills are directed away from the shore. As a result, there are a number of spills in the simulation for which the removal scenarios have no impact on the shoreline. For an outward spill, the use of dispersants in the spill response would indicate no improvement to the selected resource at risk--i.e., sandy shoreline--and therefore no decrease in relative risk.
- For the model runs that only have a small effect on the shoreline, the model result may indicate a level of risk reduction that underestimates the efficiency of the dispersant. For example, removing oil by using dispersant may reduce the baseline impact of five miles of shoreline to zero. However, the same dispersant may also reduce a greater baseline impact of ten miles to zero. Thus, the results reflect conservative estimates of the benefits of dispersants due to the specific spill impact scenarios used to generate the average reduction in risk.
- The surface area must be oiled at a level of 13 microns or higher for dispersants to be used in clean-up efforts. From the baseline scenario to 45% removal efficiency, the impact of dispersants on the oiled area proves to be dramatic in many of the cases presented. In comparison, however, the improvement from 45% to 80% removal efficiency is less impressive. This result is less a reflection of the efficacy of the dispersant than the fact that the 45% removal efficiency leaves little work to be done, reducing the oil below 13 microns. Therefore, marginal impact of the dispersants above the 45% removal efficiency is quite small.
- Weather and currents affect the movement of oil within the site area. Although the average weather condition was chosen on a site-specific basis, this average condition remains variable across sites and may contribute to the differences in results presented below.
- This analysis models five sites, each with a different area appropriate for the application of dispersant (i.e., the rules governing dispersant application may eliminate large portions of the spill area from this type of remediation). Therefore, locations with greater areas of acceptable dispersant application may display greater risk reduction. For example, dispersants prove far more effective in the Mid Atlantic region, than in the Gulf of Mexico. Although the oil spill originates in the mouth of a bay for both sites (i.e., Galveston Bay, Gulf of Mexico site and Delaware Bay, Mid Atlantic site), the area to which dispersant may be applied includes the waters inside Delaware Bay but not the waters inside Galveston Bay. Direct comparisons of risk reduction across sites may, therefore, inaccurately represent relative dispersant efficiency.

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A.8 LIST OF ACRONYMS

ACGIH – American Conference of Governmental Industrial Hygienists

ADC&ED – Alaska Department of Community and Economic Development

ADF&G – Alaska Department of Fish and Game

ADLWD – Alaska Department of Labor and Workforce Development

ADIOS – Automatic Data Inquire for Oil Spill (model developed and distributed by NOAA)

ADOT – Alaska Department of Transportation

ADOTPF – Alaska Department of Transportation and Public Facilities

AGDC – Alaska Geospatial Data Clearinghouse

AIRMAP – Air Model Application Package (model developed by ASA)

AMOP – Arctic and Marine Oil Spill Program

ANCSA – Alaska Native Claims Settlement Act

API – American Petroleum Institute, Washington, D.C., USA

ASA – Applied Science Associates, Inc., 70 Dean Knauss Drive, Narragansett, Rhode Island, USA

ASCE – American Society of Civil Engineers, Reston, Virginia, USA

ASOT – American Samoa Office of Tourism

ATIA – Alaska Travel Industry Association

BaP – benzo[a]pyrene

BAT – Battelle New England Research Laboratory, Upton, New York

BFHYDRO – Boundary Fitted Coordinate Hydrodynamic Model (model developed by ASA)

BIOS – Baffin Island Oil Study

BTEX – benzene, toluene, ethylbenzene, xylenes

Caps – Vessel and Facility Response Plan oil removal capacity

CERC – Coastal Engineering Research Center, US Army Corps of Engineers, Fort Belvoir, Virginia

CERCLA – Comprehensive Environmental Response, Compensation and Liability Act of 1980

CSE – Coastal Science & Engineering, Inc., Columbia, South Carolina

CHEMMAP – Chemical spill Model Application Package (model developed by ASA)

DEDO – Delaware Economic Development Office

DENIX – Defense Environmental network & Information Exchange

DOT – Department of Transportation

EPA – United States Environmental Protection Agency

ESI – Environmental Sensitivity Index

ESRI – Environmental Systems Research Institute, Inc., Redlands, California

FDEP – Florida Department of Environmental Protection

FHA – Federal Highway Administration

FLN – Family Learning Network

FTA – Federal Transit Administration

GICVB – Galveston Island Convention & Visitors Bureau

GIS – Geographical Information System

HSDBEDT – Hawaii State Department of Business, Economic Development & Tourism

HSDOT – Hawaii State Department of Transportation

IDLH – Immediate Danger to Life and Health

ISB – In-Situ Burning

K_{ow} – Octanol-water partition coefficient

LC50 – Lethal Concentration to 50% of exposed organisms

$LC50_\infty$ – Incipient LC50, asymptotic LC50 reached after infinite exposure time (or long enough that that level is approached)

MAH – Monoaromatic Hydrocarbons

MSRC – Marine Spill Response Corporation

NDBC – National Data Buoy Center, NOAA

NEPA – National Environmental Policy Act

NIOSH – National Institute for Occupational Safety and Health

NMFS – National Marine Fisheries Service, NOAA

NMS – National Marine Sanctuary

NOAA – National Oceanic and Atmospheric Administration, U.S. Department of Commerce

NOBE – Newfoundland Offshore Burn Experiment

NOS – National Ocean Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce

NPRM – Notice of Proposed Rulemaking

NPS – National Park Service

NRC – National Research Council, National Academy of Sciences, Washington, D.C.

NRDA - Natural Resource Damage Assessment

NRDAM/CME – Natural Resource Damage Assessment Model for Coastal and Marine Environments (developed by French et al. 1996)

NWF – National Wildlife Service

OSHA – Occupational Safety and Health Administration

OilToxEx – Oil Toxicity and Exposure model (French McCay 2002)

PAH – Polynuclear Aromatic Hydrocarbon

PAOG – Port Authority of Guam

PEIS – Programmatic Environmental Impact Statement (USCG, 2004)

PEL-TWA – Permissible Exposure Limit Time Weighted Average for air contamination for 8-hours according to OSHA.

POP – Parallel Ocean Program developed at Los Alamos National Laboratory

PRNS – Point Reyes National Seashore

PWS – Prince William Sound

PWSAC – Prince William Sound Aquaculture Association

QSAR – Quantitative Structure Activity Relationship

RAMSAR site – indicates wetland site of international importance

RDA – Recommended Dietary Allowance

REL – Recommended Exposure Limit

SFCVB – San Francisco Convention and Visitors Bureau

SIMAP – Spill Impact Model Application Package (model developed by ASA)

TED – Texas Economic Development

TLV-TWA – Threshold Limit Value Time Weighted Average for 8-hours according to the ACGIH.

TU – Toxic Unit

TWA – Time Weighted Average

USCG – U.S. Coast Guard, Department of Homeland Security

USDOI MMS – U.S. Department of Interior, Minerals Management Service

USDOIUSVI – U.S. Department of Interior, Office of Insular Affairs USVI

USEPA – United States Environmental Protection Agency

VFDA – Valdez Fisheries Development Association

VMRC – Virginia Marine Resources Commission

VTS – Vessel Traffic Service

WHSRN – Western Hemispheric Shorebird Reserve Network

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part B: Delaware Bay and Mid-Atlantic Shelf

by

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ASA 00-246

August 2004

Preface

This technical report is a supplement to the Programmatic Environmental Impact Statement (PEIS: US Coast Guard, 2004) in support of the US Coast Guard's (USCG) Notice of Proposed Rulemaking (NPRM, USCG, 2002) regarding Vessel and Facility Response Plan oil removal capacity (Caps) requirements for tank vessels and marine transportation-related facilities. The PEIS (USCG, 2004), in accordance with National Environmental Policy Act of 1969 (NEPA), examines a series of alternatives, including a no action alternative, which could influence the availability of oil spill response equipment around the United States.

This technical report is in six (6) parts:

1. Part A contains a description of the approach, models, methods, and underlying assumptions used in the analysis. The sources of input data and data applicable to all locations are described. Part A also contains a general description of the model outputs. References for all citations of Parts A to F are in Part A.
2. Parts B to F contain:
   a. Input data and assumptions specific to each of the 5 locations where model runs were performed
   b. Model results for each spill volume and response alternative for these 5 locations;
   c. Analysis of potential benefits and risks to resources of concern for each of these locations and various spill response alternatives.

Citation for entire report:

French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Lord, C. Dalton, R. Levine, J. Rowe, S. Sankaranarayanan, H-S. Kim, R. Piovesan and M. Hitchings, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, March 2004, 6 volumes.

Citations for parts of the report:

Part A: Description of Models and Assumptions:

French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Dalton, R. Levine, J. Rowe, S. Sankaranarayanan and H-S. Kim, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios, Part A: Description of Models and Assumptions. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, March 2004.

Parts B to F:

French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Lord, C. Dalton, R. Levine, J. Rowe, S. Sankaranarayanan, H-S. Kim, R. Piovesan and M. Hitchings, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios, Part B: Delaware Bay and Mid-Atlantic Shelf. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, March 2004.

Part B: Delaware Bay and Mid-Atlantic Shelf.
Part C: Galveston Bay and North Texas Shelf
Part D: Florida Straits
Part E: San Francisco Bay and Central California Shelf
Part F: Prince William Sound

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B. DELAWARE BAY AND MID-ATLANTIC SHELF

B.1 INTRODUCTION

This report deals with the modeling results for a location near the entrance to Delaware Bay, one of the two sites selected by the U.S. Coast Guard (USCG) for analysis in the Atlantic region. It is one of five locations used to develop modeling data to analyze the regional and national implications of potential changes in oil spill response requirements. The results and a summary of the assumptions are discussed in a separate volume for each of these locations, while details on the methodology are presented in Part A of this Technical Report. The results of the site specific modeling analyses were used to develop the discussions about the impacts of the various alternatives under consideration in the Programmatic Environmental Impact Statement.

All of the sites were selected because they are either located in the approaches to "higher volume ports" as defined in the Code of Federal Regulations (33 CFR 154.1020) or because they are in an area of high vessel traffic. In either case, they are considered to be areas where congestion could increase the risk of oil spills.

B.1.1 Selection of the Location

The location discussed in this volume is located 7.5 miles offshore in the approach channel for Delaware Bay (Figure B.I.1.1-1). This is the approximate mid-point of the nearshore zone as defined in 33 CFR 155.1020 and represents a location where an open water oil spill could threaten shore resources, and where on-water mechanical recovery, in-situ burning (ISB), or dispersant use could be considered. The specific coordinates are given in Table B.I.4-1.

Over 70% of all oil entering the eastern United States comes through the Delaware Bay (USCG Marine Safety Office (MSO), Philadelphia, 1998), and the Delaware Bay and Delaware River up to Philadelphia, PA is designated as a higher volume port. Over 43% of all the vessel traffic in the bay consists of vessels carrying crude oil upriver. In 2000, almost 74 million tons of oil and oil products moved through Delaware Bay. This is equivalent to an average of almost 1.3 million barrels (bbl) of oil per day. Approximately 71 million tons of the total volume was crude oil inbound for refineries. Much more oil travels upriver than down, and in 2000 only 239,000 tons of oil products left the bay, all of it refined products. The remainder of the total consisted of oil moving to and from locations within the bay and river (U.S. Army Corps of Engineers, 2000). In addition to a very large number of refineries (including seven major facilities) in the northern end of the bay and Delaware River, the Big Stone Beach anchorage area in the lower bay is the site of lightering operations to bring deep-draft vessels up to the controlling draft of 39 feet saltwater or 40 feet freshwater (MSO, Philadelphia, 1998).

Because so much oil enters Delaware Bay, the modeled spill site is among the most likely locations for spills in the Atlantic region. Given this and that the release site is near the midpoint of the nearshore zone where dispersant use and ISB might be used along with on-water mechanical recovery, it is a representative location with which to perform the analysis of potential impacts for various response alternatives.

B.1.2 Description of the Local Study Area

The study area for this analysis consists of three biogeographical provinces, as defined in Table A.4-2 of Part A of this Technical Report. The three provinces are: the New York-New Jersey Shelf (Province 13), the Delaware Bay (Province 14), and the Delmarva Shelf (Province 15). Collectively, these areas are referred to in this report as the Mid-Atlantic Shelf. On occasion, Delaware Bay (Province 14) provides a reference area for potential effects of spills into coastal areas. The boundaries of the provinces were delineated in French et al. (1996) and are based on the ecoregion (province) concept outlined in Cowardin et al. (1979) used by the Department of the Interior. The divisions into provinces are based on the distributions of, and natural boundaries between, marine populations. Biota within a province are exposed to similar environmental factors and the populations typically cover the entire province (as appropriate habitat is available). Thus, effects can be evaluated as percentages of the province(s) occupied by the populations of concern. A map of the three provinces used to analyze the offshore Delaware Bay scenario is presented as Figure A.4-1 in Part A of this Technical Report. The total areas of the provinces are presented in Table A.4-3. The areas of various habitats and shoreline types in the Mid-Atlantic Shelf reference area are given in Tables A.4-4 and A.4-5, and shoreline lengths for various shoreline types are given in Table A.4-6.

B.1.3 Modeling Input Assumptions

Part A of this Technical Report provides details on the modeling approach used in the analysis of all of the five locations. In summary, for each of the locations the Spill Impact Model Application Package (SIMAP) oil spill model was run in a probabilistic mode (100 simulations) to evaluate both physical fate and biological effects. Running the model in probabilistic mode allows the estimation of the variance due to random circumstances, such as weather, time of day, and hydrographic conditions. The basic model scenario is described in Section A.1.4, while the specific model algorithms are presented in Section A.2, and details on model input parameters are presented in Section A.3. Air quality effects, which are not directly evaluated by SIMAP, were estimated using the Air Model Application Package (AIRMAP) and then estimated concentrations at the water surface were compared to air quality standards (see Section A.5).

The results of the model runs consist of a series of tables and figures which summarize areas or linear distances, by habitat type and/or location, which exceed thresholds of concern (see Section A.4). These results were compared to information on the distribution and abundance of various resources in appropriate geographic areas to estimate the percentage of habitats or biological resources that are potentially affected, and the results were then scored using a relative risk matrix which included proportion of the resource affected and time of recovery (see Section A.1.5). Socioeconomic effects could not be evaluated with the same risk matrix, since the concept of recovery time was not appropriate. The method used for those elements is described in Section A.6 and is based strictly on the magnitude of the effect on the resource of concern relative to the total resource that is available.

The input parameters which were specific to the offshore Delaware Bay study location are presented in Appendix B.I (this volume). Appendix B.I.1 presents a series of maps which define the basic geographic data input into the model; Appendix B.I.2 discusses the development of current (hydrodynamic) data used in the model runs; Appendix B.I.3 presents the properties for South Louisiana crude oil (the oil used in the analysis); and Appendix B.I.4 summarizes all of the input parameters and the sources of the information that were used to run the model.

B.2 MODELING RESULTS

Two spill volumes and three response scenarios were simulated using modeling and the results are provided in Appendices B-II and B-III. Section A.1.4 of Part A contains a description of the rationale for running these scenarios to provide the needed information for evaluating the alternatives being considered in the PEIS. The two spill volumes were for medium (2,500 bbl) and large spills (40,000 bbl). Oil properties used were for South Louisiana crude oil, as representative of oils shipped in the Atlantic region. The three response scenarios modeled for each of two spill volumes were:

- mechanical removal at present levels of capability, or with some of that removal accomplished by ISB;
- the same mechanical removal response as above, or with some of that removal accomplished by ISB, plus dispersant application at 45% efficiency (based on minimum dispersant effectiveness criteria established in the National Oil and Hazardous Substances Contingency Plan, NCP – 40 CFR Part 300); and
- the same mechanical removal response as above, or with some of that removal accomplished by ISB, plus dispersant application at 80% efficiency (based on theoretically successful dispersant operation).

Appendices B-II.1 to B-II.6 contain results of the SIMAP oil spill model simulations that estimate oil hydrocarbon exposure on/in the water surface, shorelines, water column, and sediments. Each of these appendices contains results for all six volume-response scenario combinations. Appendix B-II.1 contains maps of exposure probability, time of first exposure for each medium (water surface, shorelines, water column, and sediments) and location surrounding the spill site, and maximum possible mass or concentration at each location at any time after a spill. These maps are gridded, presenting the average amount of contamination over the entire grid cell (which for water cells is 1.01 km^2 in area) at any time after a spill. The grid average is calculated from the mass passing through the cell, divided by the area or volume of the cell. Note that if the mass is concentrated in patches much smaller than the area of the grid cell, as is often the case, the gridded data will average out the patches and not resolve small concentrations of oil. Thus, the gridded data are used as indices of exposure, rather than areas exposed at specific levels. (See Section A.4.2 in Part A and Sections B.II.5 and B.II.6 for the methods used to more accurately evaluate exposure of biota to surface floating oil and dissolved aromatic hydrocarbons.)

Tables summarizing areas and volumes potentially affected using gridded exposure indices specific to water surface, shorelines, water column, and sediments are in Appendix B-II.2. Average, standard deviation, and the maximum of the 100 simulations performed for each scenario are presented. The 95^{th} percentile conditions used in the risk analysis were calculated as the mean plus two times the standard deviation. Appendix B-II.3 contains rank order distributions of results for all 100 model runs, from which 50th and 95th percentile of exposure areas and volumes were derived. Mass balance information, such as percent of the oil mechanically removed, dispersed in the water column, and eventually going ashore or to the sediments, is also included in Appendices B-II.2 and B-II.3. Appendix B-II.4 contains the results for the 50th percentile cases for surface oiling, shoreline oiling, water column effects, and sediment contamination, presented as plots of various measures of exposure.

In Appendix B-II.5, estimates of the mean (for all 100 runs of varying environmental conditions) equivalent area of 100% mortality are listed for each of several wildlife behavior categories. The equivalent area for 100% mortality is the integrated sum of surface water area swept by oil multiplied by probability of mortality, which varies by foraging behavior and whether the animal has feathers or fur. Appendix B-II.6 contains estimated mean mortality of water column, demersal (on the bottom) and benthic (in the bottom) organisms, summarized as an equivalent area of 100% mortality by behavior group and habitat type. The equivalent area for 100% mortality is the integrated sum of equivalent area affected times percent mortality. For water column and demersal species, the equivalent area affected is calculated as water volume affected times the fraction of the water depth zone the behavior group occupies that the affected volume encompasses. For pelagic species, the depth zone occupied is the entire water column. For demersal species (on the bottom sediments, exposed to bottom water), the depth zone occupied is the bottom 1 meter (3.3 feet) of the water column. The methods and assumptions for these calculations are described in Part A and Sections B-II-5 and B-II-6.

Appendices B-III.1 and B-III.2 contains the model results of atmospheric exposure to volatilized oil hydrocarbons and soot from ISB, relevant to air quality evaluations. Appendix B-III.1 contains model results used to evaluate volatile hydrocarbon emissions from unburned oil and resulting air quality effects. The amount of volatilized mass entering the atmosphere, and the time frame for those emissions, was estimated for each chemical (or chemical class) of concern using oil spill modeling (SIMAP). The atmospheric concentrations of volatilized hydrocarbons were modeled using AIRMAP (as described in Part A, Section A.5.1). The estimated concentrations at the water surface were compared to air quality standards to evaluate the areas exceeding the standards. Section A.5.2 of Part A describes the methods used to evaluate emissions from ISB and their potential effects on air quality. The results for ISB are in Appendix B-III.2.

The model results in Appendices B-II and B-III are summarized in Sections B.3 and B.4, and were used in the analysis of potential impacts for the various alternatives being considered in the PEIS. All summary risk rankings are based on the average results. In some sections, the results of the 95th percentile calculation are also presented to illustrate the variability for that particular resource. Section B.3 contains the discussion of potential effects for medium volume spills (2,500 bbl), and Section B.4 contains that for large volume spills (40,000 bbl). Sections B.3 and B.4 are organized by each of the physical, biological and socioeconomic resource categories evaluated in the PEIS. Section B.5 contains a summary of all the risk scores and conclusions. References are in Section B.6.

B.3 ENVIRONMENTAL CONSEQUENCES BASED ON THE MEDIUM VOLUME SPILL MODELING SCENARIOS

B.3.1 Effects on the Physical Environment

B.3.1.1 Air Quality

In the event of a spill, there are two possible sources of contamination to the atmosphere: volatilization of hydrocarbons from unburned oil and emissions produced ISB. The hydrocarbon and ISB emissions are of concern for both human health and wildlife that may be exposed. Concentrations in the lowest 2 m (6.6 ft) of the atmosphere were estimated for both unburned and burned oil using modeling and observational data from test burns, as described in Part A, Section A.5. Distances from the spill or burn site to thresholds of concern and areas affected above these thresholds were calculated for each of a number of chemicals. The thresholds of concern are air quality standards for human health (IDLH (Immediate Danger to Life and Health) for ½ hour exposure and minimum TWA (Time Weighted Average) for an 8-hour exposure, Table D.1-1 in Appendix D of the PEIS and Table A.5-5 in Part A).

Emissions from unburned oil were estimated using SIMAP, assuming the warmest (monthly mean) water temperature in the reference area and for varying wind speeds from 3 to 25 kts. As a worst case, these model runs were performed assuming no response, which would otherwise reduce emissions to some degree. Atmospheric concentrations of volatilized hydrocarbons were estimated using AIRMAP, which accounts for transport and dilution of hydrocarbons in the local atmosphere around the spill site. The worst case of a stable atmosphere was assumed for these calculations. Area and the down-wind distance affected above the thresholds were calculated from the model results, as described in Section A.5.1 of Part A.

For emissions from ISB, the maximum potential amount of oil burned was assumed to be 25% by volume of the amount of oil mechanically removed (see Section A.3.7, Part A). The 50^{th} and 95^{th} percentiles of the cleanup volumes (for the 100 stochastic runs) were multiplied by 0.25 to calculate the 50^{th} and 95^{th} percentile volumes burned by ISB. The atmospheric concentrations of compounds and particulates released by an in-situ burn of a particular volume of oil were estimated using the models developed by Fingas et al. (2001), as described in Section A.5.2 of Part A. The number of burns needed was estimated from the total volume burned and a maximum burn size. The burn model provides concentration as a function of distance down wind from the fire. Distances were translated to areas of potential effect, assuming the air plume could move in any direction depending on the wind direction, such that the area of a circle of this radius could be affected for each of the burns.

The area potentially contaminated was divided by the area of the Mid-Atlantic Shelf (68,541 km^2 or 26,463 mi^2, Table A.4-4) to estimate the percentage affected by the scenario. Appendices B-III.1.1 and B-III.2.1 provide data for unburned and burned oil, respectively, from medium volume spills into the Mid-Atlantic Shelf.

Results of On-Water Mechanical Recovery Only
Under the medium volume spill scenario with no dispersant response, volatilized hydrocarbons would not exceed air quality standards for human health at ≥0.7 km (0.4 mi) from the spill site, with a maximum of 0.08 km^2 (0.03 mi^2) adversely affected. While this would be of concern for personnel close to the spill site within the first few hours after emissions are released, it is a very small percentage of the area of the Mid-Atlantic Shelf. Evaporation and dispersion in the air would be very rapid after a spill, and recovery time would be less than 1 day. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
For the medium volume spill scenario with 45% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
For the medium volume spill scenario with 80% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would also be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, the worst case for air quality would be a single large burn 500 m^2 in area at one location. Based on model results described in Appendix B-III.2.1 and areas affected as summarized in Table B-III.2.1-4, air quality would be affected up to 710 m (2,329 ft) downwind of the burn site, assuming a stable atmosphere and light wind at the time of the burning (environmental conditions that would inhibit dispersion of the plume and induce the highest adverse effects to air quality). Thus, the area potentially affected is a 1.6 km^2 (0.6 mi^2) circular area around the burn site. This represents 0.002% of the Mid-Atlantic Shelf. Thus, the percent of the resource affected is <1%. The recovery time for the atmosphere after ISB would be on the order of hours. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Summary of the Consequences for Air Quality in the Medium Volume Scenarios
The consequences of the three response options for medium spills (1) on-water mechanical recovery only, (2) on-water mechanical recovery plus dispersants at 45% efficiency, and (3) on-water mechanical recovery plus dispersants at 80% efficiency are all essentially the same with respect to air quality. Evaporation off the water surface and volatilization from the water column creates a plume of volatile hydrocarbon gases that disperses quickly after a spill. The concentrations in the atmosphere at the water surface would exceed human health thresholds up to 0.7 km (0.4 mi) from the spill site. Dispersant use would reduce the evaporation rate, but dissolved hydrocarbons would still volatilize, although dispersed over a wider area. Thus, atmospheric concentrations would be slightly less under the dispersant use options. In all three options, the effect would be small, affecting much less than 1% of the reference area (i.e., the Mid-Atlantic Shelf in Table A.4-4), and the recovery time for the atmosphere would be on the order of hours. The alternatives involving on-water mechanical recovery plus ISB (whether or

not dispersants are used) could increase atmospheric pollutants by the amount injected via burning.

Table B.3.1.1-1 indicates risk scores for air quality for all response options for a medium volume spill. Both the area affected and the recovery times are assigned the lowest risk score for all the response options. These results would apply to any spill site at least 3 miles from shore.

Table B.3.1.1-1. Air quality risk scores for medium spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB, With or Without Dispersant Application	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

B.3.1.2 Water Quality

The lowest water quality thresholds of concern are those concentrations of dissolved aromatics that could have effects on sensitive species in the water (see Section 4.3.1.1 of the PEIS). These thresholds are much lower than human health thresholds. The threshold for effects on water column organisms would be 5 ppb for at least 4 days of exposure. As an exposure dose, the threshold would be 500 ppb-hours. (See Part A, Section A.3.4 for development of these thresholds.)

The volume affected by greater than 500 ppb-hours was estimated by the model. Table B.3.1.2-1 summarizes the mean and 95th percentile values of the water volume affected by >1 ppb for at least 1 hour and the average exposure dose in that volume of water. These data are the mean and the mean plus 2 standard deviations of the model results for all 100 runs performed for each scenario (Appendix B-II.2). The average exposure doses in the volumes are at or greater than the 500 ppb-hour threshold. Thus, the volume exposed to >1 ppb for at least 1 hour is an appropriate criterion for identifying water volumes exceeding the exposure dose threshold of 500 ppb-hours.

The percentages affected of total water volumes in coastal and marine reference areas of interest were calculated using the biogeographical province areas in Tables A.4-3 and A.4-4 for Delaware Bay (coastal) and the Mid-Atlantic Shelf (marine). The total coastal volume was the area of Delaware Bay times a mean depth of 10 m (33 ft). In this calculation it is assumed that the entire contaminated volume would be located in the coastal reference area (Delaware Bay) after a spill, a worst case assumption for a spill in that estuary. The total marine volume was the area of the entire reference area times the depth at the spill site, 18 m (59 ft). Thus, only the surface water volume was considered in the marine estimation. Risk scores for potential effects were assigned for each of coastal and marine areas.

Table B.3.1.2-1. Estimation of adverse effects on water quality for medium volume spills by dispersant scenario, based on mean and 95th percentile water volumes exceeding 1 ppb dissolved aromatic concentration.

Dispersant % Efficiency		**0**	**45**	**80**
Volume (millions of m^3) Exposed to >1 ppb	mean	129.6	230.0	229.6
	95^{th}	321.1	409.4	401.4
Average ppb-hrs in Volume	mean	500	3070	3008
	95^{th}	1054	5940	5694
Percent of Reference Area, coastal	mean	0.5	0.9	0.9
	95^{th}	1.2	1.5	1.5
Percent of Reference Area, marine	mean	0.01	0.02	0.02
	95^{th}	0.03	0.03	0.03

Results of On-Water Mechanical Recovery Only
For the medium volume spill in Delaware Bay and no dispersant response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be <1% on average. For 5% of spills, the percentage affected would exceed 1.2% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days, the time for concentrations to disperse to background levels. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions and coastal spills under average conditions. Extreme (95^{th} percentile) events, expected to occur for <5% of spills in coastal areas, were assigned a risk matrix ranking of **4D**.

Results of the Addition of a Dispersant Response at Low Efficiency
For the medium volume spill scenario and 45% dispersant efficiency response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be <1% on average. For 5% of spills, the percentage affected would exceed 1.2% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions and coastal spills under average conditions. Extreme (95^{th} percentile) events, expected to occur for <5% of spills in coastal areas, were assigned a risk matrix ranking of **4D**. Note that dispersants would not be applied in coastal waters under the alternatives considered in the PEIS that include dispersant use.

Results of the Addition of a Dispersant Response at High Efficiency
For the medium volume spill scenario and 80% dispersant efficiency response, the volumes affected are nearly the same as for 45% dispersant efficiency (because more than sufficient dispersant would be available to disperse the floating oil, see Section A.3.7 of Part A). Thus, the risk matrix rankings assigned to water quality for this scenario were the same as for the 45% dispersant efficiency case.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, the water quality effects would be slightly less, by the amount removed by burning. Thus, the percent of the resource affected is slightly less for on-water mechanical and both dispersant response scenarios when ISB is included. The recovery time for water quality would be on the order of days. Thus, the risk matrix rankings assigned to water quality for scenarios involving burning were the same as those assigned for scenarios without burning.

Summary of the Consequences for Water Quality in the Medium Volume Scenarios
Table B.3.1.2-2 summarizes risk scores for water quality for all response options for a medium volume spill in coastal waters under average and extreme (95^{th}) environmental conditions. Table B.3.1.2-3 summarizes risk scores for medium volume spills in marine waters. The coastal results would apply to similar volume coastal areas and the marine results would apply to any spill site at least 3 miles from shore.

Table B.3.1.2-2. Water quality risk scores for medium spills in coastal areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: E 95^{th}: D	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: E 95^{th}: D	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: E 95^{th}: D	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

Table B.3.1.2-3. Water quality risk scores for medium spills in marine areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

B.3.2 Effects on the Biological Environment

B.3.2.1 Intertidal Habitats

The intertidal habitats in the Mid-Atlantic Shelf are dominated by beaches, tidal flats, and wetlands (NOAA, 1996). Beaches are important nesting habitats for piping plovers and least terns; the tidal flats of Delaware Bay are critical habitat for migratory shorebirds; and wetlands provide wintering habitat for many species of ducks and nursery habitat for fish and shellfish (NOAA, 1996). The threshold concentration of concern for intertidal habitats is 10 g/m^2 (~10 microns) oil thickness (see Section A.4 in Part A). Table B.3.2.1-1 shows the outputs of the different scenarios in terms of the area and/or length of shoreline habitat affected, for the major shoreline habitat types for the medium spill volume (shoreline classifications are defined in NOAA, 2000b). Shoreline oiling is reported in kilometers for linear features such as beaches, and in square meters for wide habitats such as tidal flats and wetlands.

Table B.3.2.1-1. Mean area and length of shoreline habitats oiled above a threshold of ~10 micron oil thickness for the medium volume scenarios. The numbers are summarized from Appendix B Tables B-II.2-1 through B-II.2-3.

Response Option	Total Oiled Shoreline Area (m^2)	Total Oiled Shoreline Length (km)	Sand Beach Length (km)	Tidal Flats Area (m^2)	Wetlands Area (m^2)
On-Water Mechanical Recovery (with or without ISB)	99,900	11.6	8.0	2,800	11,300
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	13,600	2.0	1.3	0	0
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	11,800	1.8	1.1	0	0

Results of On-Water Mechanical Recovery Only
Under the medium volume spill scenario and no dispersant response option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs would be about 100,000 m^2 (1.1 million ft^2) or about 11.6 km (7.2 mi) of shoreline. Most of the habitats oiled under the worst-case environmental conditions would be outer sand beaches on both sides to the entrance to Delaware Bay and a smaller length of shoreline in lower Delaware Bay (Figure B-II.1.1.2-3). The mean oiled shoreline areas represents less than 1 percent of the shoreline area in the Mid-Atlantic Shelf reference area, which covers 3,400 km^2 (Table A.4-4 and A.4-5) or 1,330 mi^2. Outer sand beaches would account for nearly 70 percent of the affected shoreline length. Sand beaches would be expected to recover within 1-3 years (NRC, 2003). Tidal flats and wetlands habitat would account for about 14 percent of the shoreline habitats oiled above the threshold. Adverse effects to tidal flats and wetlands would be expected to last up to 7 years (Sell et al., 1995), but the area potentially affected is so small (0.0004 percent of the total tidal flats and wetlands in the reference area) that the predicted recovery rate for sand beaches is used to determine the risk. Thus, a risk matrix ranking of **3E** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs would be reduced by over 85 percent, compared to mechanical alone (Table B.3.2.1-1). The oiled shoreline

represents much less than 1 percent of the shoreline in the reference area. Most of the shoreline oiling would be very light and restricted to the outer sand beaches (Figure B-II.1.2.2-3). Most shoreline habitats would be expected to recover within 1 year (NRC, 2003). Thus, a risk matrix ranking of **4E** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron oil threshold for all model runs would be slightly reduced, compared to the low dispersant efficiency (Table B.3.2.1-1). The extent of shoreline oiling would be much less than 1 percent of the shoreline in the reference area. Most of the effect would occur as light oiling along the outer sand beaches (Figure B-II.1.3.2-3), which would be expected to recover within 1 year (NRC, 2003). Thus, a risk matrix ranking of **4E** was assigned to intertidal habitats for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, adverse effects to intertidal habitats would be similar to the on-water mechanical recovery only response option, since the pattern of oil stranding would remain unchanged. When considering the areas of the different shoreline habitats affected under these spill conditions, a risk matrix ranking of **3E** was assigned to intertidal habitats for this scenario.

Summary of the Consequences for Intertidal Habitats in the Medium Volume Scenarios
Under the medium volume scenario and under the on-water mechanical recovery only and use of ISB, adverse effects to intertidal habitats would occur primarily as light to moderate oiling or oiling of mostly sand beaches, where recovery would be expected to be 1-3 years. The area of tidal flats and wetlands, where recovery may take up to 7 years, would always be small under the medium volume spill scenario. The use of dispersants would likely lessen the area of adverse shoreline effect by about 85 percent. The dispersant efficiency does not affect the level of concern for intertidal habitats in this spill scenario because sufficient dispersant is assumed applied to disperse available floating oil assuming 45% efficiency.

B.3.2.2 Marine and Coastal Birds

The Mid-Atlantic Shelf, and particularly Delaware Bay, provides important habitat for migrant and resident coastal birds, including: migratory shorebirds that utilize beaches, tidal flats, and marshes; migratory and resident waterfowl that utilize wetlands and open water habitats; migratory and resident raptors and diving birds that feed in open water and along the shoreline and roost in various habitats, and nesting wading birds that utilize marshes (Section 3.2.2.2 of the PEIS). Gulls, terns, and seabirds also occur in the Mid-Atlantic Shelf and utilize shoreline, offshore, and wetland habitats.

Of particular importance are the Delaware Bay hemispheric WHSRN (Western Hemispheric Shorebird Reserve Network) and Delaware Bay Wetlands RAMSAR (indicating wetlands of international importance) sites. From 0.95 to 1.3 million shorebirds have been observed on beaches and tidal marsh habitats in the area, the second largest stopover location in the Western Hemisphere during spring migration. Delaware Bay hosts 80% of the hemisphere's red knots

(*Calidris canutus*) and ruddy turnstones (*Arenaria interpres*), 80% of Atlantic flyway snow geese (*Chen caerulescens),* and 30% of the hemisphere's sanderlings (*Calidris alba*). Several federally and state threatened and endangered raptor, wading bird, and shorebird species occur in the area.

Also of importance is the Barrier Islands international WHSRN site, the Edwin B. Forsythe National Wildlife Refuge regional WHSRN site, and the Chincoteague National Wildlife Refuge. The wetlands, beaches, and open water habitats in these areas provide abundant habitat for shorebirds, raptors, diving birds, and waterfowl. Important nesting habitat for piping plovers (federally threatened), terns, skimmers, and brown pelicans occurs here.

It is important to note that the species groups being considered are not normally distributed equally throughout the Mid-Atlantic Shelf, and that effects may not be proportional to the total amount of shoreline or water surface area oiled. In the Mid-Atlantic Shelf reference area, waterfowl and diving birds are concentrated primarily in bays and inshore of barrier islands. Some species of wintering waterfowl (e.g. sea ducks) and diving birds (e.g. pelicans) utilize the nearshore area within approximately 10 km of shore, with a few species ranging to up to 40 km offshore in limited areas (Ray et al., 1980). The offshore boundary of the biogeographical lies between approximately 125 and 250 km offshore, therefore considering the surface area of bays and inshore waters, we assume that water associated species are only utilizing approximately 10 percent of the reference area area. Therefore, we used a multiplier of 10 when calculating risk to open-water associated species.

When calculating the risk scores to include shoreline associated species, we took into account the fact that shorebirds, wading birds, and waterfowl concentrate in wetlands and on sand beaches and tidal flats, but are not distributed evenly throughout these habitats spatially or seasonally (Ray et al., 1980). The current body of data available for these species in the Mid-Atlantic Shelf does not allow for quantifying the "level of concentration", as was possible for open-water species. We used a multiplier of 5 to account for the importance of these key shoreline habitats, which when oiled, particularly in the case of marshes, are difficult to clean and oil exposure can persist for months to years. Effects of seasonal concentrations of particular species in high-use areas need to be considered (NOAA, 1996).

Birds would likely be affected if a threshold of 10 g/m^2 (~10-micron) thickness of oil is exceeded on the shoreline or on the water surface (see Section A.4 in Part A).

Results of On-Water Mechanical Recovery Only

Under the medium volume spill scenario and no dispersant response option, some areas of important shorebird and waterbird habitat would be oiled above the 10-micron threshold. Oiled areas could include: the entrance to Delaware Bay; Cape Henlopen, DE, an important colonial waterbird nesting area; the Barrier Islands WHSRN site, and along Cape May and Brigantine in south Jersey, which are important nesting areas for state and federally listed waterbirds (Figure B -II.1.1.2-3). The mean area of shoreline oiled above a threshold of 10 g/m^2 would be about 100,000 m^2 (1,076,391ft^2), most of which would be outer sand beaches (Table B.3.2.1-1). Important wetland and tidal flat areas would also be oiled, potentially affecting wading birds and waterfowl.

Surface water oiling above the 10-micron threshold in the modeled area would be restricted to central portions of Delaware Bay and immediately outside of the bay entrance (Figure B-II.1.1.1-3). The total mean surface water area oiled above the threshold would be about 94 km^2 (36 mi^2, Table B-II.5-2). Some diving bird and waterfowl habitat may be affected.

When considering all species groups together (e.g. shorebirds, waterfowl, diving birds, etc.), it is possible that 1 to 5 percent of the marine and coastal bird population of the Mid-Atlantic Shelf may be affected under these spill conditions. Recovery would likely occur in 1 to 3 years for most species, as was the case following the Exxon Valdez oil spill (Kuletz, 1993; Boersma et al., 1995; Erikson, 1995, and Wiens, 1995). A risk matrix ranking of **3D** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and the low efficiency dispersant response option, the mean area of shoreline oiled above a threshold of 10 g/m^2 was reduced by over 85 percent (Table B.3.2.1-1). Areas oiled could include Cape Henlopen and Cape May, which may potentially affect important waterbird nesting areas, but adverse effects on birds utilizing the Delaware Bay WHSRN and RAMSAR sites should be reduced (Figure B-II.1.2.2-3).

Surface water oiling above the 10-micron threshold in the modeled area would be reduced and restricted to directly outside of Delaware Bay and along the Bay entrance on the Delaware side (Figure B-II.1.2.1-3). The mean surface water area oiled above the threshold was 31 km^2 (12 mi^2) (Table B-II.5-2). Limited diving bird and waterfowl habitat may be affected.

Due to the estimated decrease in shoreline and surface water oiling compared to when no dispersants were used, particularly inside of Delaware Bay, it is possible that adverse effects on birds would be reduced, and that less than one percent of the marine and coastal bird population may be affected under these spill conditions. Recovery would likely occur in 1 to 3 years for most species. A risk matrix ranking of **3E** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and the high efficiency dispersant response option, total shoreline oiling would be similar to when low efficiency dispersants were used (Table B.3.2.1-1). Areas oiled could include Cape Henlopen and Cape May, and effects on important waterbird nesting areas are likely (Figure B-II.1.3.2-3).

Surface water oiling should be similar with high efficiency dispersant use, and limited diving bird and waterfowl habitat may be affected (B-II.1.3.1-3).

When considering all species groups together, it is possible that less than one percent of the total bird population of the Mid-Atlantic Shelf may be affected under these spill conditions. Recovery would likely occur in 1 to 3 years for most species. A risk matrix ranking of **3E** was assigned to birds for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, adverse effects on birds would be similar to the on-water mechanical recovery only response option. When considering all species groups together, 1 to 5 percent of the Mid-Atlantic Shelf population may be affected under these spill conditions, and recovery would likely occur in 1 to 3 years for most species. A risk matrix ranking of **3D** was assigned to birds for this scenario.

Summary of the Consequences for Marine and Coastal Birds in the Medium Volume Scenarios
Under the medium volume scenario and under the on-water mechanical recovery only and use of ISB response option, adverse effects on birds are likely to be of moderate concern when no dispersants are used due to the high probability of important staging and nesting concentration areas being oiled. The use of dispersants is projected to likely lessen the water surface and shoreline effects enough to lower the percentage of birds adversely affected, thus reducing the risk to a low level.

B.3.2.3 Marine Mammals

The marine and coastal waters of the Mid-Atlantic Shelf support a relatively limited variety of marine mammals (Section 3.2.2.1 of the PEIS). Pinnipeds are infrequent visitors to the area, but there are a number of cetaceans which may be found offshore. These include right whales (*Eubalaena glacialis*), humpback whales (*Megaptera novaeangliae*), fin whales (*Balaenoptera physalus*), sei whales (*Balaenoptera borealis*), and sperm whales (*Physeter catodon*), which are all endangered. In addition, there are a variety of other, non-endangered cetacean species, including smaller whales and porpoises, found in the area. Within the estuaries and coastal marshes, terrestrial mammals, such as otters, are occasionally present.

Marine mammals may be at risk from either floating oil, or from oil which strands in coastal shoreline areas that are used as haul out or breeding areas. The latter concern is not important in the Mid-Atlantic Shelf, since there are no species which use such areas. There is, however, a risk to terrestrial species in marshes and along the shore, particularly in Delaware Bay.

For this analysis, marine mammals are assumed to be at risk if a threshold of 10 g/m^2 (~10-micron) thickness of oil is exceeded on the shoreline or on the water surface (see Section A.4 in Part A), however the level of risk varies by the behavior group. Potential adverse effects on marine mammals (i.e., terrestrial wildlife, cetaceans, furbearing marine mammals, pinnipeds, manatees, and sea turtles were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the medium volume Mid-Atlantic Shelf spills are in Appendix B-II.5, Table B-II.5.2. The equivalent areas of 100% mortality for all response options are summarized in Table B.3.2.3-1 as percentages of the Mid-Atlantic Shelf (defined in Tables A.4-4 and A.4-5 of Part A). In addition to this calculation, which is based on the mean result, the mean length of shoreline oiled and the surface oil exposure exceeding 0.01 g/m^2 (in m^2-hrs) based on all model runs was also compared between the treatment options (Tables B-II.2-1 through B-II.2-3).

Table B.3.2.3-1. Percentage of reference area adversely affected for medium spills, by dispersant option and behavior group (assuming Mid-Atlantic Shelf area in Tables A.4-4 and A.4-5).

Behavior Group (Habitat Occupied)	0	45	80
Terrestrial wildlife (wetlands, sea grass beds and shoreline)	0	0	0
Cetaceans (seaward subtidal)	<0.001	<0.001	<0.001
Furbearing marine mammals (all intertidal and subtidal)	0.10	0.03	0.03
Pinnipeds and manatees (all intertidal and subtidal)	0.001	<0.001	<0.001

Results of On-Water Mechanical Recovery Only
In the Mid-Atlantic Shelf, the only marine mammals at risk are cetaceans, an occasional pinniped from outside of the area, and terrestrial mammals along the shore. The resistance of cetaceans to oiling coupled with the very small percentage of affected area creates a very minimal risk to cetaceans under the on-water mechanical recovery only option for the medium volume spill scenario. The cetaceans that are oiled as a result of contact with floating oil would most likely recover within a few days, if not hours, of the spill (**4E**), (RPI, 1987). Similarly, terrestrial mammals are at very low risk, but if an individual were killed or reproductively impaired by contact with oil on the shoreline, the recovery period could exceed one year (**3E**). The higher score is reported for marine mammals overall.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and the 45% efficiency dispersant option, the areas of equivalent mortality are slightly reduced in absolute area, and are still very small relative to the reference areas. Even though the use of dispersants would reduce the amount of surface oil entering the Delaware Bay, the change would not affect the recovery time and so the risk score of **3E** remains the same. There is no evidence that cetaceans are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality are essentially the same as those for the 45% option, as is the extent of shoreline oiled, thus the risk score remains unchanged.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in addition to on-water mechanical recovery is projected to not change the effects on marine mammals (**3E**), since the amount of floating oil remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to marine mammals.

Summary of the Consequences for Marine Mammals in the Medium Volume Scenario
The results indicate that on average for medium volume spills in the Mid-Atlantic Shelf adverse effects on marine mammals would be negligible with or without the use of dispersants. Dispersant use would potentially reduce the possibility of terrestrial mammals being affected, but

this risk would already be very low. The absence of furbearing marine mammals and pinnipeds in the area, and the low sensitivity of cetaceans are the major contributing factors to this conclusion. These results are consistent with experience with spills of this size in areas where marine mammals are uncommon.

B.3.2.4 Sea Turtles

Sea turtles are only occasional visitors to the Mid-Atlantic Shelf, and there are no nesting beaches in the area (Section 3.2.3 of the PEIS). The primary risk to sea turtles is from exposure to shoreline oiling in areas where they breed, however adult turtles do have a low sensitivity to floating oil and they could ingest tar balls.

Sea turtles are assumed to be at risk when a threshold of 10 g/m^2 (~10-micron) of oil is exceeded on the shoreline or the water surface (see Section A.4 in Part A). Potential adverse effects on sea turtles were estimated using the modeling (SIMAP) and summarized as the mean equivalent area of 100% mortality (i.e., under average environmental conditions). The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the medium volume Mid-Atlantic Shelf spills are in Appendix B-II.5, Table B-II.5.2. The equivalent areas of 100% mortality for all response options are summarized in Table B.3.2.3-1 as percentages of the Mid-Atlantic Shelf (defined in Tables A.4-4 and A.4-5 of Part A). The sensitivity of sea turtles is assumed to be the same as that for pinnipeds and manatees, and the area of equivalent mortality never exceeds 0.001% of the total reference area, regardless of the response option (see Table B.3.2.3-1).

Results of On-Water Mechanical Recovery Only
Under the medium volume scenario with only on-water mechanical recovery, the area of equivalent mortality is 0.001% of the total reference area. If an individual were to be oiled, the result would probably be only minor physiological effects, but it is conceivable that it could interfere with reproductive capacity, thus a risk ranking of **3E** was assigned. There are no nesting beaches in the area, so that is not a consideration.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and the 45% efficiency dispersant option the area of equivalent mortality is slightly reduced in absolute area, and is still very small relative to the reference areas. Even though the use of dispersants would reduce the amount and duration that surface oil was present, it does not change the recovery time, thus the score remains **3E**. There is no evidence that sea turtles are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality are essentially the same as those for the 45% option, thus the risk score remains unchanged.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in addition to on-water mechanical recovery should not change the effects on sea turtles (**3E**), since the amount of floating oil remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to sea turtles.

Summary of the Consequences for Sea Turtles in the Medium Volume Scenarios
The results indicate that on average for medium volume spills in the Mid-Atlantic Shelf the level of concern for sea turtles would be low with or without the use of dispersants. Dispersant use would potentially reduce the possibility of turtles coming into contact with floating oil, but this risk would already be very low. These results are consistent with experience with spills of this size in areas where sea turtles are uncommon and do not nest.

B.3.2.5 Plankton and Fish

Adverse effects on plankton and fish are of high concern, particularly when dispersants are potentially considered as a response alternative. As described in Part A (Section A.2), plankton and fish are adversely affected either directly or via the food web by the toxic effects of oil components that enter the water column: the soluble compounds (i.e., MAHs (monoaromatic hydrocarbons) and PAHs (polynuclear aromatic hydrocarbons)) and microscopic oil droplets mixed by waves into the water. Overall, adverse effects increase the larger the spill size. However, there is great variability related to the environmental conditions after the spill: plankton and fish suffer much more adverse effect under storm conditions where high waves mix unweathered oil into the water than in calm weather (French et al., 1999; French McCay et al., 2002; French McCay, 2003). Species and life stages vary considerably in sensitivity to the toxic components, with species from relatively unpolluted and environmentally stable locations more sensitive than those from polluted and environmentally variable areas (French McCay, 2002).

Potential adverse effects on water column organisms (i.e., plankton and fish, as well as pelagic invertebrates such as squid) were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. Estimated water volumes where adverse effects could occur were converted to equivalent areas of 100% loss by integrating percentage losses over all affected volumes and multiplying by water depth at the spill site, allowing comparison to other resources that are distributed on a per area basis (e.g., mammals, shorelines). In the near shore areas modeled, effects were nearly evenly distributed throughout the water column because of water column mixing and vertical movements of animals. If these results are used to infer potential for adverse effects in deeper waters, the areas of effect would only apply to surface waters up to on the order of 30-50 m (98-164 ft) deep (during strong wind conditions). The modeling methods are described in Part A and Section B-II.6, and the results of the calculations for the medium volume Mid-Atlantic Shelf spills are in B-II.6, Tables B-II.6-2 to B-II.6-5.

For these calculations, the toxicity parameter for sensitive species (i.e., two standard deviations more sensitive than the average of all species tested, which is the 2.5th percentile in rank order of sensitivity) was assumed. Thus, the volumes and areas potentially affected would only apply to 2.5% of species (based on a Gaussian distribution of species sensitivities, see also Part A, Section A.2.3), and adverse effect areas to 97.5% of species would be smaller than the volumes and areas of effect estimated by the model. Thus the model estimated areas should not be interpreted as experiencing 100% mortality of all plankton and fish. They are conservative estimates used for comparative purposes among response scenarios.

Table B-II.6-2 lists the average equivalent areas projected to be killed (for sensitive species) for medium volume spills. These areas are based on the mean of all 100 runs, and so represent an average of all environmental conditions that may occur after a spill (see explanation in Section B-II.6). Table B-II.6-4 lists the 95th percentile equivalent areas where sensitive species would be adversely affected. This maximum potential effect is calculated as the mean plus two standard deviations, using the statistics of all 100 model runs for the scenario, and assuming the toxicity values for sensitive species.

The mean areas adversely affected for all response options are summarized in Table B.3.2.5-1 as percentages of the Mid-Atlantic Shelf (defined in Table A.4-4 of Part A). The maximum areas (95th percentile) for sensitive species are summarized in Table B.3.2.5-2 (also as percentages of the Mid-Atlantic Shelf).

Table B.3.2.5-1. Average percentage of reference area adversely affected for medium spills, by dispersant option and behavior group (assuming Mid-Atlantic Shelf area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.000	0.000	0.000
Small pelagic fish & invertebrates	0.0054	0.012	0.012
Large pelagic fish	0.000	0.013	0.013
Demersal (stationary on bottom)	0.000	0.000	0.000
Planktonic (drift with currents)	0.0004	0.010	0.010

Table B.3.2.5-2. Maximum (95th percentile) percentage of reference area adversely affected for medium spills, by dispersant option and behavior group (assuming Mid-Atlantic Shelf area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.00	0.02	0.02
Small pelagic fish & invertebrates	0.02	0.03	0.03
Large pelagic fish	0.03	0.06	0.06
Demersal (stationary on bottom)	0.00	0.01	0.01
Planktonic (drift with currents)	0.02	0.04	0.04

Results of On-Water Mechanical Recovery Only

Under the medium volume spill scenario and no dispersant response option, the area adversely affected would be negligible (<0.005% of the Mid-Atlantic Shelf) for spills under average environmental conditions. For 5% of spills, the area affected would be 0.02-0.03% of the Mid-Atlantic Shelf, depending on the behavioral group of the organism. Because the adverse effects are very small, much less than the range of natural variability, the recovery time would be <1 year (given the short generation time of many species and annual reproduction of others). Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45% dispersant efficiency response option, the area adversely affected would be 0.01% of the Mid-Atlantic Shelf for spills under average environmental conditions. For 5% of spills, the area affected would be 0.1-0.6% of the Mid-Atlantic Shelf, depending on the behavioral group of the organism. Because the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80% dispersant efficiency response option, the area adversely affected would be 0.01% of the Mid-Atlantic Shelf for spills under average environmental conditions. For 5% of spills, the area affected would be 0.1-0.6% of the Mid-Atlantic Shelf, depending on the behavioral group of the organism. These results are not very different from the low-efficiency dispersant response because approximately the same amount of oil is dispersed in either case (i.e., more than sufficient dispersant is available to disperse available oil for such activity in the low efficiency case). Since the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario, if ISB is effectively used in the response, the adverse effects on water column organisms would be slightly less than otherwise by the amount removed by burning. Thus, the percent of the resource affected is <1% for on-water mechanical and both dispersant response scenarios when ISB is included. Since the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Summary of the Consequences for Plankton and Fish in the Medium Volume Scenarios
The results indicate that on average for medium volume spills, adverse water column effects would be negligible without the use of dispersants. With dispersants, and on average, up to 9 km^2 (3.5 mi^2) of water could be toxic to the most sensitive species (Table B-II.6-2). Exposure for larger fish is higher because they are more mobile, and new animals move into the dissolved aromatic plume over time (assuming they do not avoid hydrocarbon contamination). Under worst case conditions for sensitive species, the potentially affected areas for no dispersants and dispersant use are on the order of 18 and 39 km^2 (7 and 15 mi^2), respectively (Table B-II.6-4). Thus, the extreme event assuming no dispersant use adversely affects more area than the average area affected with dispersant use. In other words, use of dispersants would not turn an average spill into an extremely adverse event for water column organisms. The increase in water column effect is smaller than natural variability for spill effects.

It should be emphasized that the areas affected are those where there is a potential to affect the most sensitive species. Areas adversely affected would be much less for species of average sensitivity. These areas should not be interpreted as experiencing 100% mortality. They are used for comparative purposes among response scenarios.

The mean areas adversely affected for all response options are <0.01% of the Mid-Atlantic Shelf (Table B.3.2.5-1). Thus, the risk scores for these effects are "**E**" (<1%, Table B.3.2-.5-3). The maximum areas (95th percentile) for sensitive species are also <1% of the Mid-Atlantic Shelf (Table B.3.2.5-2). Because the effects are small, much less than the range of natural variability, the recovery time would be <1 year.

These results are consistent with experience for oil spills of about 2500 bbl generally (French McCay and Payne, 2001; French McCay et al., 2002; and as discussed in Part A). In the Mid-Atlantic Shelf in the warmer months, the high temperatures facilitate rapid evaporation and volatilization of the toxic fraction, the soluble aromatics. Also, winds are typically light to moderate, except in infrequent storm events. Thus, natural dispersion into the water is typically low, while evaporation is rapid. Because of logistical constraints, in the scenarios examined the dispersion by chemical dispersants begins 12 hours after the spill. By this time, most of the toxic components have volatilized (see Section B.3.1), such that dissolved aromatic concentrations resulting from dispersant use are only slightly elevated over the no-dispersant option. The adversely affected water column would be a small area around the spill site, and recovery of affected biota would be rapid (weeks to months).

Table B.3.2.5-3. Risk scores for plankton and fish for medium spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB, With or Without Dispersant Application	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

B.3.2.6 Subtidal Benthic Habitat

In deeper water, subtidal habitats are relatively protected from exposure to oil by the overlying water column. It is possible for extreme storm events to mix oil with sediments which then settle to the bottom, but this is a rare event. The use of dispersants can also transport oil into the water column, but dilution usually reduces concentrations to levels that are not of a concern when the water column is more than 30 feet deep, and in any case dispersed oil is less adhesive than untreated oil. In shallow, nearshore water, the risk of contamination of the sediments increases, and may either occur by mixing into the water column due to wave action, or to erosion of contaminated shoreline sediments (Section 4.3.2.5 of the PEIS).

Benthic habitat was assumed to be at risk when a threshold of 0.10 g/m^2 of total hydrocarbon loading was exceeded in the sediment or 0.0001 g/m^2 of dissolved aromatic hydrocarbons was exceeded in the pore water (see Section A.4 of Part A). These concentrations are approximately equivalent to 1 ppm of total hydrocarbons or 1 ppb of dissolved aromatic hydrocarbons, when a sediment mixing depth of 10 cm is assumed. The area was estimated using SIMAP and the modeling methods are described in Part A. The area estimates of sediment loading for the medium volume Mid-Atlantic Shelf spills are presented in Table B-II.6.6. The area estimates for dissolved aromatic hydrocarbons in sediment pore water are in Table B-II.6.7. Regardless of the treatment option, the sediment thresholds were not exceeded under average conditions.

Benthic habitat was also assumed to be at risk if epiflora and epifauna (demersal) organisms were affected by dissolved aromatic concentrations in the bottom water just above the sediments. The percentage of benthic habitat where stationary demersal biota would be affected, assuming the toxicity parameter for sensitive species (i.e., two standard deviations more sensitive than the average of all species tested), was estimated using SIMAP and the modeling methods described in Part A and Section B.II.6. As indicated in Table B.3.2.5-1, <0.001% of the reference area was affected, regardless of treatment option.

Results of On-Water Mechanical Recovery Only
In the on-water mechanical recovery only option for the medium volume spill scenario, the model results indicate that the threshold concentrations were never exceeded, thus there is no effect on the benthic habitat, and the risk ranking is **4E**.

Results of the Addition of a Dispersant Response at Low Efficiency
Use of a dispersant at 45% efficiency in the medium spill scenario still does not result in measurable hydrocarbon contamination in subtidal habitat, thus the risk score remains at **4E**.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and the 80% efficiency dispersant option, bottom water and sediments are still not exposed to hydrocarbons in excess of the threshold levels, thus the risk ranking remains at **4E**.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in the medium spill scenario should have no additional effect when combined with mechanical recovery on benthic habitats, since ISB takes place on the water's surface and results in the removal of an equivalent amount of oil (**4E**). The only concern associated with ISB is the chance of heavy burn residues sinking and mixing with sediments, but this risk is minimal based on both the toxicity of the material and on the amount that would be produced from the limited burning possible in the scenarios.

Summary of the Consequences for Subtidal Habitat in the Medium Volume Scenarios
Oil spills and oil-spill response activities could potentially affect benthic habitats. Floating oil does not pose a great level of concern unless sufficient wave energy exists to mix the surface oil

into the water column, or sediments contaminated with oil are transported from the intertidal zone into subtidal habitats. Mechanically dispersed oil could reach bottom water and adhere to sediments, flora and fauna in benthic habitats, and could cause potentially adverse effects. However, in this simulation, essentially no hydrocarbon exposure is expected on or in the sediments, even near shore. Given the limited length of shoreline oiled, regardless of response option, the small spill volume, the distance of the spill offshore, and the relatively deep water in the area of dispersant operations dispersant use would not change the results. Regardless of the response option, the risk to benthic habitat is low.

B.3.2.7 Biological Areas of Special Concern

The Mid-Atlantic Shelf has numerous areas of special concern (Section 3.2.2.6 of the PEIS). They include both coastal and subtidal areas, and a number are susceptible to the effects of an oil spill. The risk to such areas is clearly site specific and highly dependant upon the location and trajectory of the slick. In general, the greatest risk to the majority of the areas of concern is from floating oil, but areas such as marine sanctuaries are also at risk from dispersed oil. For the purposes of this evaluation, the average risk to such areas is assumed to be defined by the higher of the risks to intertidal (Section B.3.2.1) or subtidal (Section B.3.2.6) habitats, adjusted for the type, abundance and distribution of areas of special concern, if appropriate. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
For the on-water mechanical recovery option under the medium spill scenario, floating oil poses a moderate risk (**3E**) to intertidal habitat, while subtidal habitat was at minimal risk (**4E**). Therefore, coastal areas of special concern are the only areas at risk. Since the area affected is already low, and there is no reason to assume areas of special concern would recover more quickly, the score of **3E** is used. The concerns for intertidal habitat were discussed in Section B.3.2.1.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency in the medium spill scenario reduced the risk to intertidal habitat by reducing the amount of surface oil which reaches shore. The fact that the oiling would be very light and mostly restricted to sand beaches means recovery should be fairly rapid, resulting in a risk score of **4E** (see Section B.3.2.1). The risk to subtidal habitats does not increase (**4E**), because of the limited extent of the dispersed oil plume and rapid dilution.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at an efficiency of 80% in the medium spill scenario does not change the scores from the application at 45% efficiency, based on the results for intertidal and subtidal habitat.

Results of the Addition of an On-Water ISB Response
ISB should produce a black smoke plume that could pass over an area of special concern if the proper weather conditions exist. In this case, however, the burning can only occur three miles or more offshore, and the results for air quality (Section B.3.1.1) indicate that the plume should not

travel that far. The use of ISB in addition to on-water mechanical recovery is not expected to increase the risk to these resources (**3E**).

Summary of the Consequences for Areas of Special Concern in the Medium Spill Scenarios
The effects on areas of special concern in this scenario are focused on the potential risk to shoreline habitats. The use of dispersants can reduce the risk to such areas without increasing the minimal risk to subtidal areas. In this analysis the risk to such areas is defined as equivalent to the risk to intertidal habitat in general. While this accurately reflects the ecological consequences of the event, it does not account for the social values which may be attached to such areas. If the spill trajectory of an actual event did threaten such areas, special attention would be given to their protection.

B.3.2.8 Essential Fish Habitat

Areas of essential fish habitat are extensive in the Mid-Atlantic Shelf (Section 3.2.4 of the PEIS). Included are numerous estuaries, especially the Delaware and Chesapeake Bays, as well as coastal and offshore areas. The Mid-Atlantic Shelf is an area of transition and seasonal migration for a number of species. Many boreal species, such as the Atlantic cod (*Gadus morhua*), move from northern waters down into the Mid-Atlantic Shelf during the winter. Conversely, warm-temperate fish from the south, such as menhaden (*Brevoortia tyrannus*) and bluefish (*Pomatomus saltatrix*), move into the Mid-Atlantic Shelf during the summer months. In addition to north-south migrations, many species, such as the Atlantic mackerel (*Scomber scombrus*) and the American lobster (*Homarus americanus*), exhibit an onshore-offshore movement with the seasons. Because of the complexity of the Mid-Atlantic Shelf ecosystem, fish species distribution, abundance, and community composition vary greatly during the year (MMS, 1996). In the entire Atlantic region, approximately 45 species of finfish and shellfish are managed under the Magnuson-Stevens Fishery Conservation and Management Act.

For this evaluation, the effects on essential fish habitat are assumed to be reflected by the risk to plankton and fish (Section B.3.2.5) and subtidal habitat (Section B.3.2.6), since they define the risk to the majority of fish habitat. Intertidal habitats, such as marshes, are also important habitat for fisheries resources, but were considered separately. The average risk to essential fish habitat is assumed to be defined by the higher of the risk scores for plankton and fish or subtidal habitat. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
In the medium spill scenario, with the use of on-water mechanical recovery only, the risk to both plankton and fish and subtidal habitat was minimal, resulting in a risk score for both habitats of **4E**. This is a reflection of the relatively small volume of oil, the large volume of water for dilution, and the areal extent of the habitats.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency did not change the risk score for either plankton or fish or for subtidal habitat, thus the scores remained **4E**. The dispersed oil plume produced was not large enough to have any effect on the exposure levels for these resources. However, dispersant

use did reduce effects on intertidal habitat, which includes areas that are also important for fisheries resources and EFH.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at 80% efficiency in the medium spill scenario resulted in no change to the risk to plankton and fish or subtidal habitat, and the score remains **4E**. Again, dispersant use does benefit intertidal habitat, some of which are also important to EFH.

Results of the Addition of an On-Water ISB Response
The addition of ISB to mechanical recovery in the medium spill scenario did not change the evaluation for either plankton or fish or for subtidal habitat, and the score remains **4E**.

Summary of the Consequences for Essential Fish Habitats in the Medium Volume Scenarios
Overall, the risk to essential fish habitat is low for the medium spill scenario, regardless of the response option employed. This is a reflection of the relatively small area of the spill, the volume and depth of water available for dilution, and the large area of habitat present in the area.

B.3.3 Effects on the Socio-Economic Environment

B.3.3.1 Human Health

Operation of the type of equipment associated with oil spill response can be dangerous. This is well recognized and is the basis for the worker certification and training requirements that are now in place. There are also protocols in place for the proper application and handling of dispersants. The safety risk is greater as the spill size, and thus the intensity and duration of operations increases, but is minimized if safety standards are followed. There is a health risk from inhalation of hydrocarbon fumes for first responders, which is recognized in current safety protocols. Exposure to hydrocarbon fumes is the only health risk that can be directly estimated in the SIMAP model, and the results are presented in Section B.3.1.1.

B.3.3.2 Subsistence

Information on subsistence use of fish and shellfish in the Mid-Atlantic Shelf is limited. While some residents may supplement their diets with these resources, subsistence is not known to be a prominent activity in this area, as compared to Alaska, where Native communities may suffer substantial economic and cultural losses due to contamination of subsistence seafood during an oil spill.

Results of On-Water Mechanical Recovery Only
Under the medium volume spill scenario and no dispersant response option, water column exposure of dissolved aromatics between 1-100 ppb should be localized to directly outside and inside the entrance to Delaware Bay (Figure B-II.1.1.4-3). Tainting of fish and invertebrates

becomes a concern when water concentrations exceed approximately 100 ppb in a brief (order of hours) exposure (See Section 4.3.5.6 of the PEIS). Sediment exposure was estimated to be negligible (Figure B-II.1.1.5-2). Therefore, at most a very small percentage of subsistence resources are likely to be adversely affected, and recovery would be rapid (<1 year). A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and low efficiency dispersant response option, water column exposure of dissolved aromatics between 1-100 ppb for one hour or more would cover a larger area outside Delaware Bay than when no dispersants were used, and dissolved aromatic concentrations between 100-10,000 ppb would occur in localized areas (Figure B-II.1.2.4-3). Sediment exposure was expected to be negligible (Figure B-II.1.2.5-2). Although a larger water column area may be affected under these spill conditions, it is still likely that only a small percentage of subsistence resources would be adversely affected, and recovery should be rapid. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and high efficiency dispersant response option, water column exposure of dissolved aromatics was estimated to be similar compared to when low efficiency dispersants were used (Figure B-II.1.3.4-3). Sediment exposure was expected to be negligible (Figure B-II.1.3.5-2). It is still likely that only a small percentage of subsistence resources would be adversely affected, and recovery should be rapid. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, adverse effects on subsistence resources would be similar to the on-water mechanical recovery only response option. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Summary of the Consequences for Subsistence in the Medium Volume Scenarios
Because subsistence use of resources is not a prominent activity in this area, and because water column effects were localized, adverse effects on subsistence resources in the Mid-Atlantic Shelf are expected to a low concern.

B.3.3.3 Cultural Resources

Archaeological sites are potentially present along the shoreline from the mean low tide line seaward in the Mid-Atlantic Shelf. Historic sites are present onshore, and shipwrecks are present in Atlantic coast waters, mostly submerged and landward of 10 fathoms. Results from several studies indicated that direct oiling caused negligible effects on cultural resources following the Exxon Valdez oil spill (Reger et al., 1992; Dekin, 1993; Wooley and Haggarty, 1995; Bittner, 1996). Therefore, open water response options, such as the use of dispersants, ISB, and on-water mechanical recovery, may help reduce the amount of oil that strands on the shoreline, which would also reduce the amount of shoreline clean up and disturbance of sensitive cultural resources. For these reasons, a risk matrix ranking of **4E** was assigned to cultural resources for all response options under this scenario.

B.3.3.4 Coastal Communities

Oil spills affect the pleasure that coastal residents and visitors derive from coastal activities and the economic contribution that natural resources make to local income and employment. Spills are likely to have effects on water- and shore-based recreation, fisheries (recreational and commercial), marine transportation, and tourism. The effects on these activities are described in more detail in subsequent sections.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to coastal communities in the Mid-Atlantic Shelf under various spill response options. The model results are presented in Appendix B-II.2, Tables B-II.2-1 to B-II.2-3, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to coastal communities of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the Mid-Atlantic Shelf would be expected to adversely affect approximately 7.1 km (4.5 mi) of sandy shoreline and sweep approximately 810 km^2 (313 mi^2) of surface water above recognized effect thresholds (Table B-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by more than 80 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by almost 90 percent (Table B-II.2-2). This results in risk factor ratings of 0.18 and 0.11 (effected length or area with dispersants divided by that for mechanical only) for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 10 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by more than 15 percent as compared to the low efficiency dispersant response option (Table B-II.2-3). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.17 and 0.09, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on coastal communities would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to coastal communities for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Coastal Communities in the Medium Volume Spill Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 1.2 to 1.4 km (0.75 to 0.84 mi) of sandy shoreline and 75 to 90 km^2 (29 to 35 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 82 and 90 percent, respectively, the dispersant efficiency does not greatly affect the level of concern about coastal communities in this spill scenario.

B.3.3.5 Economic Status

The overall economic status of communities, industries and individuals that rely on coastal resources for sustenance, revenue and quality of life can be affected by an oil spill. As noted above, coastal communities can suffer direct and indirect economic effects due to an oil spill, as beach and fishery closures decrease revenues, eliminate jobs, and adversely affect subsistence users of the resources.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to economic status in the Mid-Atlantic Shelf under various spill response options. The model results are presented in Appendix B-II.2, Tables B-II.2-1 to B-II.2-3, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to economic status of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the Mid-Atlantic Shelf could be expected to adversely affect approximately 7,1 km (4.5 mi) of sandy shoreline and sweep approximately 810 km^2 (313 mi^2) of surface water above recognized effect thresholds (Table B-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by more than 80 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was

reduced by almost 90 percent (Table B-II.2-2). This results in risk factor ratings of 0.18 and 0.11 for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 10 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by more than 15 percent compared to the low dispersant efficiency option (Table B-II.2-3). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.17 and 0.09, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on economic status would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to economic status for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Economic Status in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 1.2 to 1.4 km (0.75 to 0.84 mi) of sandy shoreline and 75 to 90 km^2 (29 to 35 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 82 and 90 percent, respectively, the dispersant efficiency does not greatly affect the level of concern about economic status in this spill scenario.

B.3.3.6 Vessel Transportation and Ports

Marine transportation is of paramount importance for many industries along the Atlantic Coast. Any interruption in the standard use of vessels or increase in travel times over water can result in hardship for coastal communities and businesses as fewer goods are exchanged, transportation costs rise, and the revenue streaming through the local economy falls.

As described in Part A, the amount of total surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to marine transportation and ports in the Mid-Atlantic Shelf under various response options. The model results are presented in Appendix B-II.2, Tables B-II.2-1 to B-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to the marine transportation industry of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the Mid-Atlantic Shelf would be expected to adversely affect approximately 810 km^2 (313 mi^2) of surface

water used by the marine transportation industry above recognized effect thresholds (Table B-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by almost 90 percent as compared to on-water mechanical recovery alone (Table B-II.2-2). This results in a risk factor rating of 0.11 for the marine transportation industry under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by more than 15 percent as compared to the low dispersant efficiency response option (Table B-II.2-3). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for the marine transportation industry decreases to 0.09 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on the marine transportation industry would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to the marine transportation industry for this scenario.

Summary of the Consequences for Vessel Transportation and Ports in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 75 to 90 km^2 (29 to 35 mi^2) of surface water. While the use of dispersants is projected to likely lessen the area of surface water affected by approximately 90 percent, the dispersant efficiency does not greatly affect the level of concern about vessel transportation and ports in this spill scenario.

B.3.3.7 Fisheries (Commercial and Recreational)

Commercial and recreational fishing and related industries are vulnerable to oil spills, due to closures as well as market perceptions surrounding taint of the catch. In addition, recreational anglers, who fish for pleasure or sport, as opposed to monetary gain, may experience a reduced quality of experience. Large-scale spills also hold the potential to injure nursery grounds and impose other effects that could reduce fish harvests in the longer run.

As described in Part A, the amount of total surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to commercial and recreational fishing in the Mid-Atlantic Shelf under various response options. The model results are presented in Appendix B-II.2, Tables B-II.2-1 to B-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to commercial and recreational fishing of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the Mid-Atlantic Shelf would be expected to adversely affect approximately 810 km^2 (313 mi^2) of surface water used for commercial and recreational fishing above effect thresholds (Table B-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by almost 90 percent as compared to on-water mechanical recovery alone (Table B-II.2-2). This results in a risk factor rating of 0.11 for commercial and recreational fishing under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by more than 15 percent as compared to the low dispersant efficiency response option (Table B-II.2-3). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for commercial and recreational fishing decreases to 0.09 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on commercial and recreational fishing would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to commercial and recreational fishing for this scenario.

Summary of the Consequences for Commercial and Recreational Fishing in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 75 to 90 km^2 (29 to 35 mi^2) of surface water. While the use of dispersants is projected to likely lessen the area of surface water affected by approximately 90 percent, the dispersant efficiency does not greatly affect the level of concern about commercial and recreational fishing in this spill scenario.

B.3.3.8 Recreation and Tourism

An oil spill would be expected to cause local decreases in tourism, recreation, associated business revenues and the quality of coastal living. Similar to recreational fishing effects, an oil spill would also be expected to affect recreationalists' overall social welfare.

As described in Part A, the amount of total sandy shoreline oiled above selected thresholds is used to represent the risk of socioeconomic effects to recreation and tourism in the Mid-Atlantic

Shelf under various spill response options. The model results are presented in Appendix B-II.2, Tables B-II.2-1 to B-II.2-3, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns). From the model results, risk is then expressed in terms of the length of shoreline affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to recreation and tourism of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the Mid-Atlantic Shelf could be expected to adversely affect approximately 7.1 km (4.5 mi feet of sandy shoreline used for recreation and tourism above recognized effect thresholds, Table B-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by more than 80 percent as compared to on-water mechanical recovery alone (Table B-II.2-2). This results in a risk factor rating of 0.18 for recreation and tourism under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 10 percent as compared to the low dispersant efficiency response option (Table B-II.2-3). Because the adverse effect on sandy shoreline resources is less with higher dispersant efficiency, the risk factor rating for recreation and tourism decreases to 0.17 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on recreation and tourism would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to recreation and tourism for this scenario.

Summary of the Consequences for Recreation and Tourism in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 1.2 to 1.4 km (0.75 to 0.84 mi) of sandy shoreline. While the use of dispersants is projected to likely lessen the length of sandy shoreline affected by approximately 80 percent, the dispersant efficiency does not greatly affect the level of concern about recreation and tourism in this spill scenario.

B.3.3.9 Environmental Justice

Low-income, indigenous, and minority sub-populations in some coastal areas may rely on local fisheries for subsistence or on tourism, recreation or other marine-resource related industry for employment. These groups may experience the effects of a spill more severely than the general population, which relies on a more diverse economic base for their livelihoods and on the availability of a widespread and commercially available selection of foods.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to environmental justice in the Mid-Atlantic Shelf under various spill response options. The model results are presented in Appendix B-II.2, Tables B-II.2-1 to B-II.2-3, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to environmental justice of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only

Given the use of on-water mechanical recovery only, the average medium size spill in the Mid-Atlantic Shelf would be expected to adversely affect approximately 7.1 km (4.5 mi) of sandy shoreline and sweep approximately 810 km^2 (313 mi^2) of surface water above recognized effect thresholds (Table B-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency

Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by more than 80 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by almost 90 percent (Table B-II.2-2). This results in risk factor ratings of 0.18 and 0.11 for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 10 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by more than 15 percent as compared to the low dispersant efficiency response option (Table B-II.2-3). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.17 and 0.09, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response

Under the medium volume spill scenario and the ISB response option, effects on environmental justice would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to environmental justice for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Environmental Justice in the Medium Volume Spill Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 1.2 to 1.3 km (0.75 to 0.84 mi) of sandy shoreline and 75 to 90 km^2 (29 to 35 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 82 and 90 percent, respectively, the dispersant efficiency does not greatly affect the level of concern about environmental justice in this spill scenario.

B.4 ENVIRONMENTAL CONSEQUENCES BASED ON THE LARGE VOLUME SPILL MODELING SCENARIOS

B.4.1 Effects on the Physical Environment

B.4.1.1 Air Quality

There are two possible sources of contamination to the atmosphere: volatilization of hydrocarbons from unburned oil and emissions produced by ISB, both of which are of concern for both human health and wildlife that may be exposed. Concentrations in the lowest 2 m (6.6 feet) of the atmosphere, as well as distances to and areas above thresholds of concern, were estimated for both unburned and burned oil. The thresholds of concern are air quality standards for human health (IDLH for ½ hour exposure and minimum TWA for an 8-hour exposure, Table D.1-1 in Appendix D of the PEIS and Table A.5-5 in Part A). The area potentially contaminated was divided by the area of the Mid-Atlantic Shelf (68,561 km^2 or 26,471 mi^2, Table A.4-4) to estimate the percentage affected by the scenario. Appendices B-III.1.2 and B-III.2.2 provide data for unburned and burned oil, respectively, from large volume (40,000 bbl) spills into the Mid-Atlantic Shelf.

Results of On-Water Mechanical Recovery Only
Under the large volume spill scenario with no dispersant response, volatilized hydrocarbons would not exceed air quality standards for human health at ≥7.4 km (4.6 mi) from the spill site, with a maximum of 3.4 km^2 (1.3 mi^2) adversely affected. While this would be of concern for personnel close to the spill site within the first few hours after emissions are released, it is a very small percentage of the area of the Mid-Atlantic Shelf. Evaporation and dispersion in the air would be very rapid after a spill, and recovery time would be less than 1 day. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
For the large volume spill scenario with 45% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would be similar or slightly less than for on-water mechanical recovery only. Thus, a risk ranking **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
For the large volume spill scenario with 80% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would also be similar or slightly less than for on-water

mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, the worst case for air quality would result from the 95th percentile of volume burned (estimated as 25% of the mechanically-removed oil) for the no-dispersant scenario. The volume to be burned in this case would require 10 large burns, each 500 m^2 in area. The 50th percentile burn volume would require 8 large burns, each 500 m^2 in area. If dispersant is used, the amount burned would be less, requiring fewer burns (See Appendix B-III.2.2).

Air quality would be affected up to 710 m (2,329 ft) downwind of *each* burn site, assuming a stable atmosphere and light wind at the time of the burning. Accounting for the worst case of 10 burns in different locations, the area potentially affected is a 15.84 km^2 (6.1 mi^2) area. This represents 0.023% of the Mid-Atlantic Shelf. Thus, the percent of the resource affected is <1%. The recovery time for the atmosphere after ISB would be on the order of hours. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Summary of the Consequences for Air Quality in the Large Volume Scenarios
The consequences of the three response options for large spills (1) on-water mechanical recovery only; (2) on-water mechanical recovery plus dispersants at 45% efficiency, and (3) on-water mechanical recovery plus dispersants at 80% efficiency are the same with respect to air quality. Evaporation off the water surface and volatilization from the water column creates a plume of volatile hydrocarbon gases that disperses quickly after a spill. For the large volume spill, the concentrations in the atmosphere at the water surface would exceed human health thresholds of concern at a maximum of 7.4 km (4.6 mi) from the spill site. Dispersant use would reduce the evaporation rate, but dissolved hydrocarbons would still volatilize, although dispersed over a wider area. Thus, atmospheric concentrations would be somewhat less under the dispersant use options. In all three options for the large spill, the effect would be small, affecting much less than 1% of the area of interest (i.e., the Mid-Atlantic Shelf in Table A.4-4), and the recovery time for the atmosphere would be on the order of hours.

The alternatives involving on-water mechanical recovery plus ISB (whether or not dispersants are used) should increase atmospheric pollutants by the amount injected via burning. The maximum area potentially affected is 15.84 km^2 (6.1 mi^2). However, this represents much less than 1% of the Mid-Atlantic Shelf.

Table B.4.1.1-1 indicates risk scores for air quality for all response options for a large volume spill. Both the area affected and the recovery times are assigned the lowest risk score for all the response options. These results would apply to any spill site at least 3 miles from shore.

Table B.4.1.1-1. Air quality risk scores for large spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB, With or Without Dispersant Application	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

B.4.1.2 Water Quality

The lowest water quality thresholds of concern are those concentrations of dissolved aromatics that could have effects on sensitive species in the water (see Section 4.3.1.1 of the PEIS). These thresholds are much lower than human health thresholds. The threshold for effects on water column organisms would be 5 ppb for at least 4 days of exposure. As an exposure dose, the threshold would be 500 ppb-hours. (See Part A, section A.3.4 for development of these thresholds.)

Table B.4.1.2-1summarizes the mean and 95th percentile values of the water volume affected by >1 ppb for at least 1 hour and the average exposure dose in that volume of water. These data are the mean and the mean plus 2 standard deviations of the model results for all 100 runs performed for each scenario (Appendix B-II.2). The average exposure doses in the volumes are at or greater than the 500 ppb-hour threshold.

The percentages affected of total water volumes in coastal and marine areas of interest were calculated using the biogeographical province areas in Tables A.4-3 and A.4-4 for Delaware Bay (coastal) and the Mid-Atlantic Shelf (marine). The total coastal volume was the area of Delaware Bay times a mean depth of 10 m (33 ft). In this calculation it is assumed that the entire contaminated volume would be located in the coastal reference area (Delaware Bay) after a spill, a worst case assumption for a spill in that estuary. The total marine volume was the area of the entire reference area times the depth at the spill site, 18 m (59 ft). Thus, only the surface water volume was considered in the marine estimation. Risk scores for potential effects were assigned for each of coastal and marine areas.

Table B.4.1.2-1. Estimation of adverse effects on water quality for large volume spills by dispersant scenario, based on mean and 95th percentile water volumes exceeding 1 ppb dissolved aromatic concentration.

Dispersant % Efficiency		0	45	80
Volume (millions of m^3) Exposed to >1 ppb	mean	698.1	1797.	1781.
	95th	1628.	3308.	3345.
Average ppb-hrs in Volume	mean	1869	8297	9643
	95th	3983	18289	20993
Percent of Reference Area, coastal	mean	2.6	6.7	6.7
	95th	6.1	12.4	12.5
Percent of Reference Area, marine	mean	0.06	0.15	0.14
	95th	0.13	0.27	0.27

Results of On-Water Mechanical Recovery Only
For the large volume spill scenario in Delaware Bay and no dispersant response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 2.6% on average. For 5% of spills, the percentage affected would exceed 5% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days to weeks, the time for concentrations to disperse to background levels. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions. For coastal spills under average conditions, the risk score is **4D**. Extreme (95th percentile) events, expected to occur for <5% of spills in coastal areas, were assigned a risk matrix ranking of **4C**.

Results of the Addition of a Dispersant Response at Low Efficiency
For the large volume spill scenario and 45% dispersant efficiency response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 6.7% on average. For 5% of spills, the percentage affected would exceed 10% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days to weeks, the time for concentrations to disperse to background levels. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions. For coastal spills under average conditions, the risk score is **4C**. Extreme (95th percentile) events, expected to occur for <5% of spills in coastal areas, were assigned a risk matrix ranking of **4B**. Note that dispersants would not be applied in coastal waters under the alternatives considered in the PEIS that include dispersant use.

Results of the Addition of a Dispersant Response at High Efficiency
For the large volume spill scenario and 80% dispersant efficiency response, the volumes affected are nearly the same as for 45% dispersant efficiency (because more than sufficient dispersant would be available to disperse the floating oil, see Section A.3.7 of Part A). Thus, the risk matrix rankings assigned to water quality for this scenario were the same as for the 45% dispersant efficiency case.

Results of the Addition of an On-Water ISB Response

Under the large volume spill scenario and the ISB response option, the water quality effects would be slightly less, by the amount removed by burning. Thus, the percent of the resource affected is also slightly less for the on-water mechanical recovery only response scenario when ISB is included. The risk matrix rankings assigned to water quality for scenarios involving burning were the same as those assigned for scenarios without burning.

Summary of the Consequences for Water Quality in the Large Volume Scenarios

Table B.4.1.2-2 summarizes risk scores for water quality for all response options for a large volume spill in coastal waters under average and extreme (95^{th}) environmental conditions. Table B.4.1.2-3 summarizes risk scores for large volume spills in marine waters. The coastal results would apply to similar volume coastal areas and the marine results would apply to any spill site at least 3 miles from shore.

Table B.4.1.2-2. Water quality risk scores for large spills in coastal areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: D 95^{th}: C	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: C 95^{th}: B	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: C 95^{th}: B	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%

** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

Table B.4.1.2-3. Water quality risk scores for large spills in marine areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%

** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

B.4.2 Effects on the Biological Environment

B.4.2.1 Intertidal Habitats

The intertidal habitats in the Mid-Atlantic Shelf are dominated by beaches, tidal flats, and wetlands (NOAA, 1996). Sand beaches are important habitats for nesting piping plovers, and the tidal flats of Delaware Bay are critical habitat for migratory shorebirds. The threshold concentration of concern for intertidal habitats is 10 g/m^2 (~10 microns) oil thickness (see Section A.4 in Part A). Table B.4.2.1-1 shows the outputs of the different scenarios in terms of the area and/or length of shoreline habitat affected, for the major shoreline habitat types for the large spill volume (shoreline classifications are defined in NOAA, 2000b). Shoreline oiling is reported in kilometers for linear features such as sand beaches and in square meters for wide habitats such as wetlands and tidal flats.

Table B.4.2.1-1. Mean area and length of shoreline habitats oiled above a threshold of ~10 micron oil thickness for the large volume scenarios. The numbers are summarized from Appendix B Tables B-II.2-4 through B-II.2-6.

Scenario	Total Oiled Shoreline Area (m^2)	Total Oiled Shoreline Length (km)	Sand Beach Length (km)	Tidal Flats Area (m^2)	Wetlands Area (m^2)
On-Water Mechanical Recovery (with or without ISB)	426,000	29.2	21.1	16,800	187,000
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	73,300	7.8	5.6	0	12,700
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	153,000	8.6	5.6	0	92,800

Results of On-Water Mechanical Recovery Only

Under the large volume spill scenario and no dispersant response option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs was estimated to be 426,000 m^2 (4.6 ft^2) and the mean oiled shoreline length was estimated as 29.2 km (18.2 mi). Affected habitats for the worst-case environmental conditions extended along the outer coast from Little Egg Inlet to the north to well into Maryland to the south (Figure B-II.1.4.2-3). The oiled shoreline area represents less than 1 percent of the shoreline area in the reference area (Table A.4-4), but 3.5 percent of the total length of outer sand beaches (Table A.4-6). About 10-20 percent of the outer sand beaches and much of lower Delaware Bay would be affected for the model run with the highest degree of shoreline effect. Sand beaches would account for 73 percent of the shoreline oiled under these highest shoreline effect conditions, and many areas would be exposed to oil loadings of 10,000-100,000 g/m^2. Effects resulting from oiled wetlands and tidal flats could be larger than the simple percent of shoreline length in the reference area affected, because of the numbers of animals that could be present, depending on the season. Recovery of oiled wetlands could take 3-7 years. Thus, a risk matrix ranking of **2D** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs would be reduced by 83 percent, compared to mechanical alone (Table B.4.2.1-1). Less than 1 percent of the shoreline length and area in the reference area would be oiled above the threshold. The extent of heavy shoreline oiling under the highest-effect conditions would be greatly reduced (Figure B-II.1.5.2-3), and there would be no or minor oiling of tidal flats and wetlands. Sand beaches would be expected to recover from heavy oil exposures within 1-3 years (NRC, 2003), thus a risk matrix ranking of **3E** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron oil threshold for all model runs would be reduced by 64 percent compared to on-water mechanical recovery only. However, it would be about double the shoreline effects of the low efficiency model output (Table B.4.2.1-1). The oiling would affect about the same area and length of sand beaches but much more wetlands (Figure B-II.1.6.2-3). However, only 0.3 percent of the tidal flat and wetland area in the reference area would be affected. Thus, a risk matrix ranking of **2E** was assigned to intertidal habitats for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on intertidal habitats would be similar to the on-water mechanical recovery only response option. When considering the areas of the different shoreline habitats affected under these spill conditions, a risk matrix ranking of **2D** was assigned to intertidal habitats for this scenario.

Summary of the Consequences for Intertidal Habitats in the Large Volume Scenarios
Under the large volume scenarios, outer beaches would be heavily oiled but recovery would be expected to occur within 1-3 years for all response options. The use of dispersants would likely lessen the area of shoreline affected by 64-83 percent, greatly reducing the extent of oiling of tidal flats and wetlands. The increase in wetland effects from the high dispersant efficiency reflects the different model inputs.

B.4.2.2 Marine and Coastal Birds

The Mid-Atlantic Shelf, and particularly Delaware Bay, provide important habitat for migrant and resident coastal birds. Refer to Section B.3.2 for additional information on important bird habitats in the Mid-Atlantic Shelf and factors considered in risk score calculations.

Results of On-Water Mechanical Recovery Only

Under the large volume spill scenario and no dispersant response option, many areas of important shorebird and waterbird habitat would be oiled above the 10-micron threshold. Oiled areas could include: the entrance to Delaware Bay; Cape Henlopen, DE, an important colonial waterbird nesting area; the Maryland and Virginia Barrier Islands WHSRN site; and along the south Jersey coast from the Edwin B. Forsythe National Wildlife Refuge to Cape May, an area which includes important nesting habitat for state and federally listed shorebirds and waterbirds (Figure B-II.1.4.2-3). The mean area of shoreline oiled above a threshold of 10 g/m^2 was estimated to be 426,000 m^2 (4.6 million ft^2) and included sand beaches, wetlands, and tidal flats (Table B.4.2.1-1).

Surface water oiling above the 10-micron threshold is estimated to occur along the shoreline in similar outer coast areas to those described above, and throughout Delaware Bay (Figure B-II.1.4.1-3). The total mean surface water area oiled above the threshold was estimated as 1,370 km^2 (530 mi^2, Table B-II.5-3). Waterfowl, raptor (e.g. feeding osprey, *Pandion haliaetus*), and diving bird habitat may be affected within this area.

When considering all species groups together (e.g. shorebirds, waterfowl, diving birds), it is possible that 10 to 20 percent of the marine and coastal bird population of the Mid-Atlantic Shelf may be affected under these spill conditions. Recovery could likely occur in 1 to 3 years for most species, as was the case following the Exxon Valdez oil spill (Kuletz, 1993; Boersma et al., 1995; Erikson, 1995, and Wiens, 1995). A risk matrix ranking of **3B** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency

Under the large volume spill scenario and the low efficiency dispersant response option, total shoreline oiling would be reduced by 83 percent compared to when no dispersants were used (Figure B-II.1.5.2-3). Important waterbird nesting areas along the Cape Henlopen and the Cape May areas could still be heavily oiled, although effects on birds utilizing the Delaware Bay WHSRN and RAMSAR sites would likely be reduced.

Surface water oiling above the 10-micron threshold would also be reduced, and possibly restricted to the Delaware Bay entrance and along Cape Henlopen and Cape May (Figure B-II.1.5.1-3). The total mean surface water area oiled above the threshold was estimated at 248 km^2 (96 mi^2, Table B-II.5-3). Some waterfowl, raptor, and diving bird habitat may be affected in these areas.

Due to the estimated decrease in shoreline and surface water oiling compared to when no dispersants were used, particularly inside of Delaware Bay, it is probable that effects on birds would be reduced, and that 1 to 5 percent of the marine and coastal bird population of the Mid-Atlantic Shelf may be affected under these spill conditions. Recovery would likely occur in 1 to 3 years for most species. A risk matrix ranking of **3D** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the large volume spill scenario and the high efficiency dispersant response option, total shoreline oiling would be almost double the area as compared to when low efficiency dispersants were used, and a larger wetland area would be affected (Figure B-II.1.6.2-3). Wading birds and waterfowl utilize these areas in high concentrations at certain times of year. The mean area of shoreline oiled above a threshold of 10 g/m^2 was 153,000 m^2 (1.6 million ft^2) (Table B-II.2-6). Oiled areas along Cape Henlopen and Cape May and in the Delaware Bay wetlands may potentially affect important waterbird nesting areas.

Surface water oiling above the 10-micron threshold would be reduced, and possibly restricted to inside the entrance of Delaware Bay and along Cape Henlopen and Cape May (Figure B-II.1.6.1-3). The total mean surface water area oiled above the threshold was estimated at 239 km^2 (92 mi^2, Table B-II.5-3). Some waterfowl, raptor, and diving bird habitat may be affected in these areas.

Due to the estimated increase in oiling of Delaware Bay marshes compared to when low efficiency dispersants were used, when considering all species groups together, it is possible that greater 5 to 10 percent of the marine and coastal bird population of the Mid-Atlantic Shelf may be affected under these spill conditions. Recovery would likely occur in 1 to 3 years for most species. A risk matrix ranking of **3C** was assigned to birds for this scenario.

Results of the Addition of an On-Water ISB Response

Under the large volume spill scenario and the ISB response option, adverse effects on birds would be similar to the on-water mechanical recovery only response option. When considering all species groups together, greater than 20 percent of the population may be affected under these spill conditions, and recovery would likely occur in 1 to 3 years for most species. A risk matrix ranking of **3B** was assigned to birds for this scenario.

Summary of the Consequences for Marine and Coastal Birds for the Large Volume Scenarios

Under the large volume scenario, adverse effects on birds are likely to be of concern when no dispersants are used, regardless of the use of ISB, due to the high probability of important concentration areas being oiled. The use of low efficiency dispersants would likely lessen the water surface and shoreline effects enough to lower the percentage of birds affected, and adverse population effects would probably be decreased, but not enough to reduce the overall moderate risk ranking. The use of high efficiency dispersants did not decrease shoreline effects, particularly in wetlands, as much as when low efficiency dispersants were used, although shoreline oiling was reduced. The level of concern about potential adverse effects on birds for these spill conditions compared to when no dispersants were used remained moderate. The increase in wetland effects from the high efficiency dispersants reflects the different model inputs.

B.4.2.3 Marine Mammals

The Mid-Atlantic Shelf has a limited population of marine mammals. Refer to Section B.3.2.3 for additional information on marine mammal populations in the Mid-Atlantic Shelf. Marine mammals are assumed to be at risk when a threshold of 10 g/m^2 (~10-micron) of oil is exceeded on the shoreline or the water surface (see Section A.4 in Part A), however, the level of risk varies by the behavior group. Potential adverse effects on marine mammals (i.e., terrestrial wildlife, cetaceans, furbearing marine mammals, pinnipeds, manatees, and sea turtles were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the large volume Mid-Atlantic Shelf spills are in Appendix B-II.5, Table B-II.5.3. The equivalent areas of 100% mortality for all response options are summarized in Table B.4.2.3-1 as percentages of the Mid-Atlantic Shelf (defined in Tables A.4-4 and A.4-5 of Part A). In addition to this calculation, which is based on the mean result, the mean length of shoreline oiled and the surface oil exposure exceeding 0.01 g/m^2 (in m^2-hrs) based on all model runs was also compared between the treatment options (Tables B-II.2-4 through B-II.2-6).

Table B.4.2.3-1. Percentage of reference area adversely affected for large spills, by dispersant option and behavior group (assuming Mid-Atlantic Shelf area in Tables A.4-4 and A.4-5).

Behavior Group (Habitat Occupied)	0	45	80
Terrestrial wildlife (wetlands, sea grass beds and shoreline)	<0.001	<0.001	<0.001
Cetaceans (seaward subtidal)	<0.001	<0.001	<0.001
Furbearing marine mammals (all intertidal and subtidal)	1.49	0.27	0.26
Pinnipeds and manatees (all intertidal and subtidal)	0.02	0.004	0.004

Results of On-Water Mechanical Recovery Only

In the Mid-Atlantic Shelf, the only marine mammals at risk are cetaceans, occasional stray pinnipeds and terrestrial mammals along the shore. The resistance of cetaceans to oiling coupled with the very small percentage of habitat affected yields a minimal risk to cetaceans under the on-water mechanical recovery only option even for the large volume spill scenario. The cetaceans that are oiled as a result of contact with floating oil would most likely recover in within a few days, if not hours, of the spill (**4E**), (RPI, 1987). Potential effects on the occasional pinniped also increase, but the proportion of the area remains well below 1% of the total habitat. Similarly, terrestrial mammals are at very low risk, but even though the area of equivalent mortality is still below 1%, the length of shoreline oiled is considerably higher than in the medium spill scenario (see Section B.4.2.1) and now just exceeds 1% of the total shoreline. Assuming an area where terrestrial animals were present was affected, with a combination of mortality and sublethal effects on reproduction, the recovery time would be 1 to 3 years (**3E**). This higher score is reported for marine mammals overall.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and the 45% efficiency dispersant option the areas of equivalent mortality for the groups of concern are slightly reduced in absolute area, and are still very small relative to the reference areas. The use of dispersants would reduce the amount of surface oil entering the Delaware Bay and the length of shoreline oiled, but would not reduce the risk ranking since the recovery time does not change. There is no evidence that cetaceans are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality and shoreline oiling are essentially the same as those for the 45% option, thus the risk score remains unchanged.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in addition to on-water mechanical recovery should not change the effects on marine mammals (**3E**), since the amount of floating oil remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to marine mammals.

Summary of the Consequences for Marine Mammals in the Large Volume Scenarios
The results indicate that on average for large volume spills in the Mid-Atlantic Shelf, adverse effects on marine mammals would be low with only on-water mechanical recovery, and that this risk could be reduced somewhat by the use of dispersants. Dispersant use would provide this benefit by potentially reducing the possibility of terrestrial mammals being affected, which is the primary concern in the area. The absence of furbearing marine mammals, the fact that pinnipeds are only rare visitors in the area, and the low sensitivity of cetaceans are the major contributing factors to this conclusion. These results are consistent with experience with spills of this size in areas where marine mammals are uncommon.

B.4.2.4 Sea Turtles

Sea turtles are only occasional visitors to the Mid-Atlantic Shelf, and there are no nesting beaches in the area (Section 3.2.3 of the PEIS). The primary risk to sea turtles is from exposure to shoreline oiling in areas where they breed, however, adult turtles do have a low sensitivity to floating oil and they could ingest tar balls.

Sea turtles are assumed to be at risk when a threshold of 10 g/m^2 (~10-micron) is exceeded on the shoreline or the water surface (see Section A.4 in Part A). Potential adverse effects on sea turtles were estimated using the modeling (SIMAP) and summarized as the equivalent area of 100% mortality. The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the large volume Mid-Atlantic Shelf spills are in Appendix B-II.5, Table B-II.5.3. The equivalent areas of 100% mortality for all response options are summarized in Table B.4.2.3-1 as percentages of the Mid-Atlantic Shelf (defined in Tables A.4-4 and A.4-5 of Part A). The sensitivity of sea turtles is assumed to be the same as that for pinnipeds and manatees, thus the area of equivalent mortality never exceeds 0.02%, regardless of the response option (see Table B.4.2.3-1). The area of surface oil exposure in m^2-hrs (see Tables B-II.2-1 and B-II.2-4), however, is increased 16-fold over that in the medium spill scenario and the area in m^2 is roughly 3% of the total reference area (about a 50% increase over the medium spill scenario). The increase in duration increases the potential for contact if a sea turtle were to be in the area, and therefore, increases the risk of sublethal effects.

Results of On-Water Mechanical Recovery Only
Under the large volume scenario with only on-water mechanical recovery, the area of equivalent mortality is less than 0.02% of the total reference area, but the surface slick is much larger. This increases the potential area where an individual could be oiled. The slick is, however, not continuous and since turtles are so rare in the area there is no increase in the area of effect. Contact with floating oil would probably only result in minor physiological effects, but it is conceivable that it could interfere with reproductive capacity or even the loss of an individual, thus a risk ranking of **3E** was assigned.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and the 45% efficiency dispersant option the area of equivalent mortality is slightly reduced in absolute area, and is still very small relative to the reference areas. Furthermore, the use of dispersants would greatly reduce the area of the surface slick, however, this change is not enough to change the score of **3E**. There is no evidence that sea turtles are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality are essentially the same as those for the 45% option, thus the risk score remains **3E**.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in addition to on-water mechanical recovery should not change the effects on sea turtles (**3E**), since the amount of floating oil remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to sea turtles.

Summary of the Consequences for Sea Turtles in the Large Volume Scenarios
The results indicate that on average for large volume spills in the Mid-Atlantic Shelf adverse effects on sea turtles would be low with the use of only on-water mechanical recovery, and that the use of dispersants would reduce the possibility of turtles coming into contact with floating oil. Oil on the shoreline is not a concern since sea turtles do not nest in the area. Since sea turtles are not common in the area, it is difficult to accurately assess the risk to this group.

B.4.2.5 Plankton and Fish

Potential adverse effects on water column organisms (i.e., plankton and fish, as well as pelagic invertebrates such as squid) were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. Estimated water volumes where adverse effects could occur were converted to equivalent areas of 100% loss by integrating percentage losses over all affected volumes and multiplying by water depth at the spill site, allowing comparison to other resources that are distributed on a per area basis (e.g., mammals and shorelines). In the near shore areas modeled, effects were nearly evenly distributed throughout the water column because of water column mixing and vertical movements of animals. If these results are used to infer potential for adverse effects in deeper waters, the area of effect would only apply to surface waters up to on the order of 30-50 m (98-164 ft) deep (during strong wind conditions). The modeling methods are described in Part A and Section B-II.6, and the results of the calculations for the large Mid-Atlantic Shelf spills are in B-II.6. For these calculations, the toxicity parameter for sensitive species was assumed. Thus, the areas affected would only apply to 2.5% of species (based on a Gaussian distribution of species sensitivities), and areas of adverse effect for 97.5% of species would be smaller.

Table B-II.6-3 lists the average equivalent areas projected to be killed (for sensitive species) for large volume spills. These areas are based on the mean of all 100 runs, and so represent an average of all environmental conditions that may occur after a spill (see explanation in Section B-II.6). Table B-II.6-5 lists the 95th percentile equivalent areas where sensitive species would be adversely affected. This maximum potential effect is calculated as the mean plus two standard deviations, using the statistics of all 100 model runs for the scenario, and assuming the toxicity values for sensitive species.

The mean areas adversely affected for all response options are summarized in Table B.4.2.5-1 as percentages of the Mid-Atlantic Shelf (defined in Table A.4-4 of Part A). The maximum areas (95th percentile) for sensitive species are summarized in Table B.4.2.5-2 (also as percentages of the Mid-Atlantic Shelf reference area).

Table B.4.2.5-1. Average percentage of reference area adversely affected for large spills, by dispersant option and behavior group (assuming Mid-Atlantic Shelf area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.022	0.073	0.073
Small pelagic fish & invertebrates	0.045	0.121	0.120
Large pelagic fish	0.077	0.228	0.226
Demersal (stationary on bottom)	0.014	0.052	0.051
Planktonic (drift with currents)	0.053	0.156	0.154

Table B.4.2.5-2. Maximum (95th percentile) percentage of reference area adversely affected for large spills, by dispersant option and behavior group (assuming Mid-Atlantic Shelf area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.077	0.156	0.157
Small pelagic fish & invertebrates	0.113	0.229	0.232
Large pelagic fish	0.223	0.453	0.458
Demersal (stationary on bottom)	0.055	0.113	0.114
Planktonic (drift with currents)	0.152	0.309	0.312

Results of On-Water Mechanical Recovery Only
Under the large volume spill scenario and no dispersant response option, the area adversely affected would be 0.01-0.08% of the Mid-Atlantic Shelf for spills under average environmental conditions. For 5% of spills, the area affected would be 0.1-0.2% of the Mid-Atlantic Shelf, depending on the behavioral group of the organism. As the percentage affected is <1%, it is less than the range of natural variability and would not be perceptible at the population level. Given this, the short generation time of many species, and annual reproduction of others, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45% dispersant efficiency response option, the area adversely affected would be 0.1-0.2% of the Mid-Atlantic Shelf for spills under average environmental conditions. For 5% of spills, the area affected would be 0.1-0.5% of the Mid-Atlantic Shelf, depending on the behavioral group of the organism. The adverse effects are slightly higher than the on-water mechanical recovery only response but still relatively small, and, for the reasons stated above, the affected species would require less than a year to replace the missing individuals. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% dispersant efficiency response option, the area adversely affected would be 0.1-0.2% of the Mid-Atlantic Shelf for spills under average environmental conditions. For 5% of spills, the area affected would be 0.1-0.5% of the Mid-Atlantic Shelf, depending on the behavioral group of the organism. These results are not very different from the low-efficiency dispersant response because approximately the same amount of oil is dispersed in either case (i.e., more than sufficient dispersant is available to disperse available oil for such activity in the low efficiency case). As for the low dispersant efficiency scenario, the effects are slightly greater than the mechanical-only response. The adverse effect is relatively small on the scale of the populations involved, and the affected species would require less than a year to replace the missing individuals. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario, if ISB is effectively used in the response, the adverse effects to water column organisms would be slightly less than otherwise by the amount removed by burning. Thus, the percent of the resource affected is <1% for on-water mechanical and both dispersant response scenarios when ISB is included. The adverse effects are relatively small on the scale of the populations involved, and the affected species would require less than a year to replace the missing individuals. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Summary of the Consequences for Plankton and Fish in the Large Volume Scenarios
The results indicate that on average for large volume spills, adverse water column effects for sensitive species could affect 10-53 km^2 (4-20 mi^2) without the use of dispersants. With dispersants, and on average, up to 156 km^2 (60 mi^2) of water could be toxic to the most sensitive

and mobile species (Table B-II.6-2). Exposure for larger fish is higher because they are more mobile, and new animals move into the dissolved aromatic plume over time (assuming they do not avoid hydrocarbon contamination). Under worst case conditions, the potentially affected areas for sensitive species and for no dispersants and dispersant use are on the order of 153 and 314 km^2 (59 and 121 mi^2), respectively (Table B-II.6-5).

The mean areas adversely affected for all response options are <1% of the Mid-Atlantic Shelf (Table B.4.2.5-1). Thus, the risk scores for these effects are "**E**" (Table B.4.2.5-3). The maximum areas (95^{th} percentile) for sensitive species are also <1% of the area of concern (Table B.4.2.5-2). The effects are relatively small on the scale of the populations involved, and the affected species would require less than a year to replace the missing individuals.

It should be noted that these results are assuming toxicity threshold for sensitive (2.5^{th} percentile) species. The average species would not be so sensitive, and these estimated adverse effects would not apply to most or average species. The effect estimates are used in a comparative manner, comparing potential areas of concern to the most sensitive species.

These results are consistent with experience for large oil spills of about 40,000 bbl (about 1 million gallons or more; French McCay and Payne, 2001; French McCay et al., 2002, and as discussed in Part A). In the Mid-Atlantic Shelf in summer, high temperatures facilitate rapid evaporation and volatilization of the toxic fraction, the soluble aromatics. Also, winds are typically light to moderate, except in infrequent storm events. Thus, natural dispersion into the water is typically low, while evaporation is rapid. Because of logistical constraints, in the scenarios examined the dispersion by chemical dispersants begins 12 hours after the spill. By this time, most of the toxic components have volatilized (Section B.4.1), such that dissolved aromatic concentrations resulting from dispersant use are only slightly elevated over the no-dispersant option.

Only in rare storm events where high waves entrain fresh un-weathered oil, such as in the *North Cape* oil spill (French, 1998a,b; French McCay, 2003), would the concentrations of toxic components be high enough to cause concern about effects on water column communities. The 95^{th} percentile case assuming no dispersant use would be the analogous case to the *North Cape* situation for sensitive species (analogous to the lobster affected in the *North Cape* spill). It should be noted that dispersants would not be likely to be used in such a situation. Thus, the 95^{th} percentile result for the dispersant option scenarios are unlikely to ever occur, based on probability of the event and likelihood that dispersants would actually be used in a storm situation.

Table B.4.2.5-3. Risk scores for plankton and fish for large spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

B.4.2.6 Subtidal Benthic Habitat

Subtidal benthic habitat in the Mid-Atlantic Shelf, and its susceptibility to oil was discussed in Section B.3.2.6. Benthic habitat was assumed to be at risk when a threshold of 0.10 g/m^2 of total hydrocarbon loading was exceeded in the sediment or 0.0001 g/m^2 of dissolved aromatic hydrocarbons was exceeded in the pore water (see Section A.4 in Part A). These concentrations are approximately equivalent to 1 ppm of total hydrocarbons or 1 ppb of dissolved aromatic hydrocarbons, when a mixing depth of 10 cm is assumed. The area was estimated using SIMAP and the modeling methods are described in Part A. The area estimates of sediment loading for the large volume Mid-Atlantic Shelf spills are in Appendix B-II.6, Table B-II.6.6. The area estimates for dissolved aromatic hydrocarbons in sediment pore water are in Table B-II.6.7. Regardless of the treatment option, the 0.10 g/m^2 total hydrocarbon threshold was exceeded in an area totaling approximately 7 km^2 (2.7 mi^2), while the dissolved aromatic concentrations never exceeded the sediment threshold. This is much less than 1% of either the total area or the area just in Delaware Bay.

Benthic habitat was also assumed to be at risk if epiflora and epifauna (demersal) organisms were affected by dissolved aromatic concentrations in the bottom water just above the sediments. The percentage of benthic habitat where stationary demersal biota would be affected, assuming the toxicity parameter for sensitive species (i.e., two standard deviations more sensitive than the average of all species tested), was estimated using SIMAP and the modeling methods described in Part A and Section B.II.6.

Results of On-Water Mechanical Recovery Only
In the on-water mechanical recovery only option for the large volume spill scenario, the model results indicate that for sediments only the total hydrocarbon threshold was exceeded, and then only in a very small area. As indicated in Table B.4.2.5-1, 0.014% of the reference area was affected by bottom water concentrations when no dispersants were assumed used. Since the overall area of effect on the benthic habitat is low and recovery would be rapid, the risk ranking is **4E**.

Results of the Addition of a Dispersant Response at Low Efficiency
Use of a dispersant at 45% efficiency in the large spill scenario does not change the level of sediment contamination in subtidal habitat. As indicated in Table B.4.2.5-1, 0.052% of the reference area was affected by bottom water concentrations when dispersants were assumed used at low efficiency. Thus, the ranking remains at **4E**.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and the 80% efficiency dispersant option potential effects are essentially unchanged from the 45% efficiency dispersant option, therefore, the risk ranking remains at **4E**.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in the large spill scenario should have no additional effect when combined with on-water mechanical recovery on benthic habitats, since ISB takes place on the water's surface and results in the removal of an equivalent amount of oil (**4E**). The only concern associated with ISB is the chance of heavy burn residues sinking and mixing with sediments, but this risk is minimal based on both the toxicity of the material and on the amount that would be produced from the limited burning possible in the scenarios.

Summary of the Consequences for Subtidal Benthic Habitat in the Large Volume Scenarios
Oil spills and oil-spill response activities could potentially affect benthic habitats. Floating oil does not pose a great level of concern unless sufficient wave energy exists to mix the surface oil into the water column, or sediments contaminated with oil are transported from the intertidal zone into subtidal habitats. Mechanically dispersed oil could reach bottom water and adhere to sediments, flora and fauna in benthic habitats and could cause potentially adverse effects. However, in this simulation, only very low levels of hydrocarbon exposure are expected on or in the sediments, even near shore. Dispersant use could increase this risk slightly, especially if a large portion of the dispersed oil plume were to enter Delaware Bay. With on-water mechanical recovery only, the risk to benthic habitat is low, and even though dispersant use increased the amount of oil in the water column, it did not lead to additional accumulation in the sediments.

B.4.2.7 Biological Areas of Special Concern

The Mid-Atlantic Shelf has numerous areas of special concern which were described in Section B.3.2.7. As discussed in that section, the average risk to such areas is assumed to be defined by the risk to intertidal (Section B.4.2.1) or subtidal habitats (Section B.4.2.6), adjusted for the extent of areas of special concern which occur in the Mid-Atlantic Shelf, if appropriate. The higher of the risk scores for these two resource groups is used as the starting point to define the risk to areas of special concern. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
For the mechanical response option under the large volume spill scenario, floating oil poses a high risk (**2D**) to intertidal habitat, while subtidal habitat was at minimal risk (**4E**). Therefore, coastal areas of special concern are the only areas which require consideration. The concerns for intertidal habitat were discussed in Section B.4.2.1. Since areas of special concern occupy only

selected locations, the probability of contact is less than for intertidal habitat as a whole, but probably not enough to reduce the areal estimate. If contact did occur, recovery times would be as estimated for intertidal habitat. Therefore, the estimated score remains **2D.**

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency in the large spill scenario reduced the risk to intertidal habitat by reducing the amount of surface oil which reaches shore, decreasing the probability of contacting an area of concern. While the likelihood of contact is reduced, more marshes were contacted, which have a longer recovery, resulting in a risk score of **3E**. The risk to subtidal habitat remains low (**4E**) because of the limited extent of the dispersed oil plume and rapid dilution, so the score of **3E** is used.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at an efficiency of 80% in the large spill scenario does not reduce shoreline oiling over that for dispersant use at 45% efficiency by much, but the amount of wetland contamination is reduced, and most of the shoreline effects occur on sand beaches, so the risk score was reduced to **2E** because recovery should be more rapid.

Results of the Addition of an On-Water ISB Response
ISB should produce a smoke plume that could pass over an area of special concern if the proper weather conditions exist. In this case, however, the burning can only occur three miles or more offshore, and the results for air quality (Section B.4.1.1) indicate that the plume should not travel that far. The use of ISB in addition to on-water mechanical recovery is not expected to change the risk to these resources (**2D**).

Summary of the Consequences for Biological Areas of Special Concern in the Large Volume Scenarios
The effects to areas of special concern in this scenario are focused on the potential risk to shoreline habitats. The use of dispersants can reduce the risk to such areas without increasing the minimal risk to subtidal areas. In this analysis the risk to such areas is defined as equivalent to the risk to intertidal habitat, in general. While this accurately reflects the ecological consequences of the event, it does not account for the social values which may be attached to such areas. If the spill trajectory of an actual event did threaten such areas, special attention would be given to their protection.

B.4.2.8 Essential Fish Habitat

Areas of essential fish habitat are extensive in the Mid-Atlantic Shelf (Section 3.1.6 of the PEIS). Included are estuaries, especially the Delaware Bay, as well as coastal and offshore areas. The Mid-Atlantic Shelf is an area of transition and seasonal migration for a number of species. Many boreal species, such as the Atlantic cod (*Gadus morhua*), move from northern waters down into the Mid-Atlantic Shelf during the winter. Conversely, warm-temperate fish from the south, such as menhaden (*Brevoortia tyrannus*) and bluefish (*Pomatomus saltatrix*), move into the Mid-Atlantic Shelf during the summer months. In addition to north-south migrations, many species, such as the Atlantic mackerel (*Scomber scombrus*) and the American lobster (*Homarus americanus*), exhibit an onshore-offshore movement with the seasons. Because of the complexity of the Mid-Atlantic Shelf ecosystem, fish species distribution, abundance, and community composition vary greatly during the year (MMS, 1996).

The area functions as a valuable spawning and nursery ground for many species. Fish eggs and larvae can be found in the offshore waters of this area throughout the year. Most of the species support commercial and/or recreational fisheries or constitute major forage for other marine carnivores (MMS, 1996).

In the Mid-Atlantic Shelf, the diversity of taxa is usually greatest during the spring and summer period. Although ichthyoplankton are present year-round, the annual distribution and abundance of eggs and larvae are highly variable. The barrier island sounds and estuaries in the Mid-Atlantic Shelf, in addition to the offshore waters, afford a highly protective and productive environment for the juvenile stages of many marine fish (MMS, 1996).

For this evaluation, the effects to essential fish habitat are assumed to be reflected by the risk to plankton and fish (Section B.4.2.5) and subtidal habitat (Section B.4.2.6) since they define the risk to the majority of fish habitat. Intertidal habitats, such as marshes, are also important habitat for fisheries resources, but were considered separately. The average risk to essential fish habitat is assumed to be defined by the higher of the risk scores for plankton and fish or subtidal habitat. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
In the large spill scenario, with the use of on-water mechanical recovery only, the risks to plankton and fish and to subtidal habitat were **4E**, resulting in a risk score for EFH of **4E**. The areal extent of effects on fish was higher than for subtidal habitat but remained well below 1%. Recovery time should be less than 1 year, based on natural variability and the fecundity of most groups.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency increases the possibility of exposure for both plankton and fish and subtidal habitat. The dispersed oil plume produced was not large enough to change the risk scores for plankton and fish or for subtidal habitat, therefore, the risk score remains **4E** for EFH. Dispersant use did reduce effects on intertidal habitat, which includes areas that are important for fisheries resources and EFH.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at 80% efficiency in the large spill scenario resulted in no change to the risk to plankton and fish or subtidal habitat from the 45% efficiency scenario and the score remains **4E**. Again, dispersant use does benefit intertidal habitat, some of which are also important to EFH.

Results of the Addition of an On-Water ISB Response
The addition of ISB to on-water mechanical recovery in the large spill scenario did not change the evaluation for either plankton or fish or for subtidal habitat, and the score remains **4E**.

Summary of the Consequences for Essential Fish Habitat in the Large Volume Scenarios
Overall, the risk to essential fish habitat is low for the large spill scenario regardless of what response option is used. The risk score is determined by the potential risk to plankton and fish, rather than subtidal habitat, but in this case both were a low concern.

B.4.3 Effects on the Socio-Economic Environment

B.4.3.1 Human Health

Operation of the type of equipment associated with oil spill response can be dangerous. This is well recognized and is the basis for the worker certification and training requirements that are now in place. There are also protocols in place for the proper application and handling of dispersants. The safety risk is greater as the spill size, and thus the intensity and duration of operations increases, but is minimized if safety standards are followed. There is a health risk from inhalation of hydrocarbon fumes for first responders, which is recognized in current safety protocols. Exposure to hydrocarbon fumes is the only health risk that can be directly estimated in the SIMAP model, and the results are presented in Section B.4.1.1.

B.4.3.2 Subsistence

Information on subsistence use of fish and shellfish in the Mid-Atlantic Shelf is limited. While some residents may supplement their diets with these resources, subsistence is not known to be a prominent activity in this area, as compared to Alaska, where Native communities may suffer substantial economic and cultural losses due to contamination of subsistence seafood during an oil spill.

Results of On-Water Mechanical Recovery Only
Under the large volume spill scenario and no dispersant response option, water column exposure of dissolved aromatics between 10-100 ppb was estimated to occur in a large area from inside Delaware Bay to approximately 116 km (72 mi) offshore, and from Maryland to southern New Jersey (Figure B-II.1.4.4-3). Sediment exposure was expected to be negligible (Figure B-II.1.4.5-2). Tainting of fish and invertebrates becomes a concern when water concentrations exceed approximately 100 ppb in a brief (order of hours) exposure (See Section 4.3.5.6 of the PEIS). Therefore, at most a small percentage of subsistence resources would be affected, and recovery would be rapid (<1 year). A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and low efficiency dispersant response option, water column exposure of dissolved aromatics between 1-100 ppb were estimated to cover a smaller area outside of Delaware Bay than when no dispersants were used, and dissolved aromatic concentrations between 100-10,000 ppb were estimated to occur directly outside the bay (Figure B-II.1.5.4-3). Sediment exposure was expected to be negligible (Figure B-II.1.5.5-2). It is possible that a small percentage of subsistence resources would be adversely affected under these

conditions, and recovery would be rapid. A risk matrix ranking of **4D** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and high efficiency dispersant response option, water column exposure of dissolved aromatics covered a larger area than when low efficiency dispersants were used, but adverse effects to subsistence resources would likely be similar (Figure B-II.1.6.4-3). Sediment exposure is negligible (Figure B-II.1.6.5-2). It is still likely that only a small percentage of subsistence resources would be adversely affected, and recovery would be rapid. A risk matrix ranking of **4D** was assigned to subsistence resources for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, adverse effects to subsistence resources would be similar to the on-water mechanical recovery only response option. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Summary of the Consequences for Subsistence in the Large Volume Scenarios
Because subsistence use of resources is not a prominent activity in this area, and because high concentrations of dissolved aromatics in the water column were not expected to cover a large percentage of the total area in the Mid-Atlantic Shelf, adverse effects to subsistence resources are expected to be a low concern.

B.4.3.3 Cultural Resources

Archaeological sites are potentially present along the shoreline from the mean low tide line seaward in the Mid-Atlantic Shelf. Historic sites are present onshore, and shipwrecks are present in Atlantic coast waters, mostly submerged and landward of 10 fathoms. Results from several studies indicated that direct oiling caused negligible effects to cultural resources following the Exxon Valdez oil spill (Reger et al., 1992; Dekin, 1993; Wooley and Haggarty, 1995; Bittner 1996). Therefore, open water response options, such as the use of dispersants, ISB, and on-water mechanical recovery, may help reduce the amount of oil that strands on the shoreline, which would also reduce the amount of shoreline clean up and disturbance of sensitive cultural resources. For these reasons, a risk matrix ranking of **4E** was assigned to cultural resources for all response options under this scenario.

B.4.3.4 Coastal Communities

Oil spills affect the pleasure that coastal residents and visitors derive from coastal activities and the economic contribution that resources make to local income and employment. Effects are likely to include effects on water- and shore-based recreation, fisheries (recreational and commercial), marine transportation and tourism. The effects on these activities are described in more detail in subsequent sections.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds in Delaware Bay is used to represent the risk of socioeconomic effects to coastal communities in the Mid-Atlantic Shelf under various spill response options. The model results are presented in Appendix B-II.2, Tables B-II.2-4 to B-II.2-6, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to coastal communities of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Mid-Atlantic Shelf would be expected to adversely affect approximately 17.5 km (9,9 mi) of sandy shoreline and sweep approximately 1,155 km^2 (446 mi^2) of surface water above recognized effect thresholds (Table B-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 70 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by more than 75 percent (Table B-II.2-5). This results in risk factor ratings of 0.29 and 0.23 for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 4 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced more than 15 percent as compared to the low dispersant efficiency response option (Table B-II.2-6). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.28 and 0.19, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on coastal communities would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to coastal communities for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Coastal Communities in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 5.0 to 5.3 km (3.1 to 3.3 mi) of sandy shoreline and 220 to 270 km^2 (85 to 104 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 70 and 80 percent,

respectively, the dispersant efficiency does not greatly affect the level of concern about coastal communities in this spill scenario.

B.4.3.5 Economic Status

The overall economic status of communities, industries and individuals that rely on coastal resources for sustenance, revenue and quality of life can be affected by an oil spill. As noted above, coastal communities can suffer direct and indirect economic effects due to an oil spill, as beach and fishery closures decrease revenues, eliminate jobs, and adversely affect subsistence users of the resources.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to economic status in the Mid-Atlantic Shelf under various spill response options. The model results are presented in Appendix B-II.2, Tables B-II.2-4 to B-II.2-6, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to economic status of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Mid-Atlantic Shelf would be expected to adversely effect approximately 17.5 km (9.9 mi) of sandy shoreline and sweep approximately 1,155 km^2 (446 mi^2) of surface water above recognized effect thresholds (Table B-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 70 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by more than 75 percent (Table B-II.2-5). This results in risk factor ratings of 0.29 and 0.23 for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 4 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by more than 15 percent compared to the low dispersant efficiency response option (Table B-II.2-6). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.28 and 0.19, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on economic status would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to economic status for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Economic Status in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 5.0 to 5.3 km (3.1 to 3.3 mi) of sandy shoreline and 220 to 270 km2 (85 to 104 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 70 and 80 percent, respectively, the dispersant efficiency does not greatly affect the level of concern about economic status in this spill scenario.

B.4.3.6 Vessel Transportation and Ports

Marine transportation is of paramount importance for many industries along the Atlantic Coast. Any interruption in the standard use of vessels or increase in travel times over water can result in hardship for coastal communities and businesses as fewer goods are exchanged, transportation costs rise, and the revenue streaming through the local economy falls.

As described in Part A, the amount of total surface water oiled above selected thresholds in Delaware Bay is used to represent the risk of socioeconomic effects to marine transportation and ports in the Mid-Atlantic Shelf under various response options. The model results are presented in Appendix B-II.2, Tables B-II.2-4 to B-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to the marine transportation industry of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Mid-Atlantic Shelf would be expected to adversely effect approximately 1,155 km^2 (446 mi^2) of surface water used by the marine transportation industry above recognized effect thresholds (Table B-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by more than 75 percent as compared to on-water mechanical recovery alone (Table B-II.2-5). This results in a risk factor rating of 0.23 for the marine transportation industry under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was

reduced more than 15 percent as compared to the low dispersant efficiency response option (Table B-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for the marine transportation industry decreases to 0.19 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on the marine transportation industry would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to the marine transportation industry for this scenario.

Summary of the Consequences for Vessel Transportation and Ports in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 220 to 270 km^2 (85 to 104 mi^2) of surface water. While the use of dispersants is projected to likely lessen the area of surface water affected by approximately 80 percent, the dispersant efficiency does not greatly affect the level of concern about vessel transportation and ports in this spill scenario.

B.4.3.7 Fisheries (Commercial and Recreational)

Commercial and recreational fishing and related industries are vulnerable to oil spills, due to closures as well as market perceptions surrounding taint of the catch. In addition, recreational anglers, who fish for pleasure or sport, as opposed to monetary gain, may experience a reduced quality of experience. Large-scale spills also hold the potential to injure nursery grounds and impose other effects that could reduce fish harvests in the longer run.

As described in Part A, the amount of total surface water oiled above selected thresholds in Delaware Bay is used to represent the risk of socioeconomic effects to commercial and recreational fishing in the Mid-Atlantic Shelf under various response options. The model results are presented in Appendix B-II.2, Tables B-II.2-4 to B-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to commercial and recreational fishing of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Mid-Atlantic Shelf would be expected to adversely affect approximately 1,155 km^2 (446 mi^2) of surface water used for commercial and recreational fishing above recognized effect thresholds (Table B-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was

reduced by more than 75 percent as compared to on-water mechanical recovery alone (Table B-II.2-5). This results in a risk factor rating of 0.23 for commercial and recreational fishing under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced more than 15 percent as compared to the low dispersant efficiency response option (Table B-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for commercial and recreational fishing decreases to 0.19 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on commercial and recreational fishing would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to commercial and recreational fishing for this scenario.

Summary of the Consequences for Commercial and Recreational Fishing in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 220 to 270 km^2 (85 to 104 mi^2) of surface water. While the use of dispersants is projected to likely lessen the area of surface water affected by approximately 80 percent, the dispersant efficiency does not greatly affect the level of concern about commercial and recreational fishing in this spill scenario.

B.4.3.8 Recreation and Tourism

An oil spill would be expected to cause local decreases in tourism, recreation, associated business revenues and the quality of coastal living. Similar to recreational fishing effects, an oil spill would also be expected to affect recreationalists' overall social welfare.

As described in Part A, the amount of total sandy shoreline oiled above selected thresholds in Delaware Bay is used to represent the risk of socioeconomic effects to recreation and tourism in the Mid-Atlantic Shelf under various spill response options. The model results are presented in Appendix B-II.2, Tables B-II.2-4 to B-II.2-6, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns). From the model results, risk is then expressed in terms of the length of shoreline affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to recreation and tourism of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Mid-Atlantic Shelf would be expected to adversely affect approximately 17.5 km (9.9 mi) of sandy shoreline used for recreation and tourism above recognized effect thresholds (Table B-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 70 percent as compared to on-water mechanical recovery alone (Table B-II.2-5). This results in a risk factor rating of 0.29 for recreation and tourism under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 4 percent as compared to the low dispersant efficiency response option (Table B-II.2-6). Because the adverse effect on sandy shoreline resources is less with higher dispersant efficiency, the risk factor rating for recreation and tourism decreases to 0.28 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on recreation and tourism would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to recreation and tourism for this scenario.

Summary of the Consequences for Recreation and Tourism in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 5.0 to 5.3 km (3.1 to 3.3 mi) of sandy shoreline. While the use of dispersants is projected to likely lessen the length of sandy shoreline affected by approximately 70 percent, the dispersant efficiency does not greatly affect the level of concern about recreation and tourism in this spill scenario.

B.4.3.9 Environmental Justice

Low-income, indigenous, and minority sub populations in some coastal areas may rely on local fisheries for subsistence or on tourism, recreation or other marine-resource related industry for employment. These groups may experience the effects of a spill more severely than the general population, which relies on a more diverse economic base for their livelihoods and on the availability of a widespread and commercially available selection of foods.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds in Delaware Bay are used to represent the risk of socioeconomic effects to environmental justice in the Mid-Atlantic Shelf under various spill response options. The model results are presented in Appendix B-II.2, Tables B-II.2-4 to B-II.2-6, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to environmental justice of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only

Given the use of on-water mechanical recovery only, the average large size spill in the Mid-Atlantic Shelf would be expected to adversely affect approximately 17.5 km (9,9 mi) of sandy shoreline and sweep approximately 1,155 km^2 (446 mi^2) of surface waters above recognized effect thresholds (Table B-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency

Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 70 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by more than 75 percent (Table B-II.2-5). This results in risk factor ratings of 0.29 and 0.23 for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 4 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by more than 15 percent as compared to the low dispersant efficiency response option (Table B-II.2-6). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.28 and 0.19, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response

Under the large volume spill scenario and the ISB response option, effects on environmental justice would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to environmental justice for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Environmental Justice in the Large Volume Scenarios

Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 5 to 5.3 km (3.1 to 5.3 mi) of sandy shoreline and 220 to 270 km^2 (85 to 104 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 70 and 80 percent, respectively, the dispersant efficiency does not greatly influence the level of concern about environmental justice in this spill scenario.

B.5 Summary Conclusions

For the moderate (2500 bbl) spill (Table B.5-1) the level of concern for all environmental resources remains low except for marine and coastal birds, which were determined to be at moderate risk without dispersant use. When dispersants were used, regardless of the efficiency, the model suggests that the reduction in shoreline oiling and on-water exposure will be reduced enough to lower the overall level of concern to low, which also lowers the risk for biological areas of special concern. The use of ISB does not change the predicted risk to the environment when compared to on-water mechanical recovery alone, because it results in the treatment of an equivalent volume of spilled oil.

When the spill size increases to 40,000 bbl (large spill scenario, Table B.5-2) the expected impacts also increase. The average model results now suggest that with on-water mechanical recovery only there is a moderate risk to intertidal habitat, marine and coastal birds, and biological areas of special concern (due to the risk to intertidal habitat). The overall risk to other resources is low. These results can generally be explained by the greatly increased level of stranded oil, the extent and duration of the surface oil slick, and the low levels of exposure in the air or water, regardless of response option. Dispersant use is predicted to reduce the risk to all three resources, but not always by enough to change the overall level of concern. In this case, the average effects for a high efficiency dispersant application were somewhat higher than for the low efficiency option. This is partly a result of the stochastic approach used, but also reflects the fact that, under the assumed conditions, sufficient supplies of dispersant are available to achieve the maximum level of dispersion, regardless of which efficiency is assumed. Again, the use of ISB does not change the results from those predicted with only on-water mechanical recovery.

Examination of the entire suite of model runs indicates that the range of impacts to resources of concern is highly variable, which reflects the dynamic nature of oil spills. For example, for the medium spill no oil reaches the shore at all with only on-water mechanical recovery (22 out of 100 runs), and this value increases to 64 out of 100 with dispersant use at low efficiency. Alternatively, also for the medium spill, the maximum shoreline oiling length predicted was slightly more than 41 km, nearly four times the average. Similar observations can be made for other exposure indices. The same pattern exists for the large spill results, and in many cases the relative relationships are quite similar. These model results are consistent with observed impacts from spills that originate offshore and with the expected impacts described in Section 4.3 of the PEIS.

With respect to socioeconomic resources, the use of dispersants would limit the effects of the spill in all cases.

Table B.5-1 Risk Ranking for Medium (2,500 bbl) Spills at the Mid-Atlantic Shelf Location.

	Physical Environment			Biological Environment								Socioeconomic Environment			
Response Option	Coastal Water Quality	Marine Water Quality	Air Quality	Intertidal Habitat	Marine and Coastal Birds	Marine Mammals	Sea Turtles	Plankton and Fish	Subtidal Benthic Habitat	Biological Areas of Special Concern	Essential Fish Habitat	Subsistence	Cultural Resources	Shoreline Oiling Index	Surface Water Oiling Index
On-Water Mechanical Recovery	4E	4E	4E	3E	3D	3E	3E	4E	4E	3E	4E	4E	4E	1.0	1.0
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	4E	4E	4E	4E	3E	3E	3E	4E	4E	4E	4E	4E	4E	0.18	0.11
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	4E	4E	4E	4E	3E	3E	3E	4E	4E	4E	4E	4E	4E	0.17	0.09
On-Water Mechanical Recovery and In-Situ Burning	4E	4E	4E	3E	3D	3E	3E	4E	4E	3E	4E	4E	4E	1.0	1.0

Legend: Black cells represent a “high” level of concern, medium gray cells represent a “moderate” level of concern, and light gray cells represent a “limited” level of concern.

Table B.5-2 Risk Ranking for Large (40,000 bbl) Spills at the Mid-Atlantic Shelf Location.

	Physical Environment			Biological Environment								Socioeconomic Environment			
Response Option	Coastal Water Quality	Marine Water Quality	Air Quality	Intertidal Habitat	Marine and Coastal Birds	Marine Mammals	Sea Turtles	Plankton and Fish	Subtidal Benthic Habitat	Biological Areas of Special Concern	Essential Fish Habitat	Subsistence	Cultural Resources	Shoreline Oiling Index	Surface Water Oiling Index
On-Water Mechanical Recovery	4D	4E	4E	2D	3B	3E	3E	4E	4E	2D	4E	4E	4E	1.0	1.0
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	4C	4E	4E	3E	3D	3E	3E	4E	4E	3E	4E	4D	4E	0.29	0.23
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	4C	4E	4E	2E	3C	3E	3E	4E	4E	2E	4E	4D	4E	0.28	0.19
On-Water Mechanical Recovery and In-Situ Burning	4D	4E	4E	2D	3B	3E	3E	4E	4E	2D	4E	4E	4E	1.0	1.0

Legend: Black cells represent a "high" level of concern, medium gray cells represent a "moderate" level of concern, and light gray cells represent a "limited" level of concern.

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Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part B: Delaware Bay and Mid-Atlantic Shelf

Sections B-I.1 – B-I.4

by

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ASA 00-246

August 2004

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B-I. OIL SPILL MODEL INPUT DATA

This appendix contains model input data (in maps, figures and tables) for the modeled location in the mid-Atlantic (near the entrance of Delaware Bay) and the sources for that information. The approach and sources applicable to all modeled locations are described in Part A, Section A.3 of this technical report. Specifics to this model location are below. Thus, the reader should refer to Part A, Section A.3 for background and the context within which these data are used.

B-I.1 Geographical Data Input to the Model

Geographic data for the modeled location are presented in this section. The sources for these data are described in Part A, Section A.3.1. A map is also presented below showing areas where dispersant application was assumed in model simulations. The assumptions for the dispersant application scenarios are in Part A, Section A.3.7. The crosshair mark (⊞) in the figures below represents the assumed oil spill site for the model simulations.

B-I.1.1 Maps of the Vicinity of the Spill Site

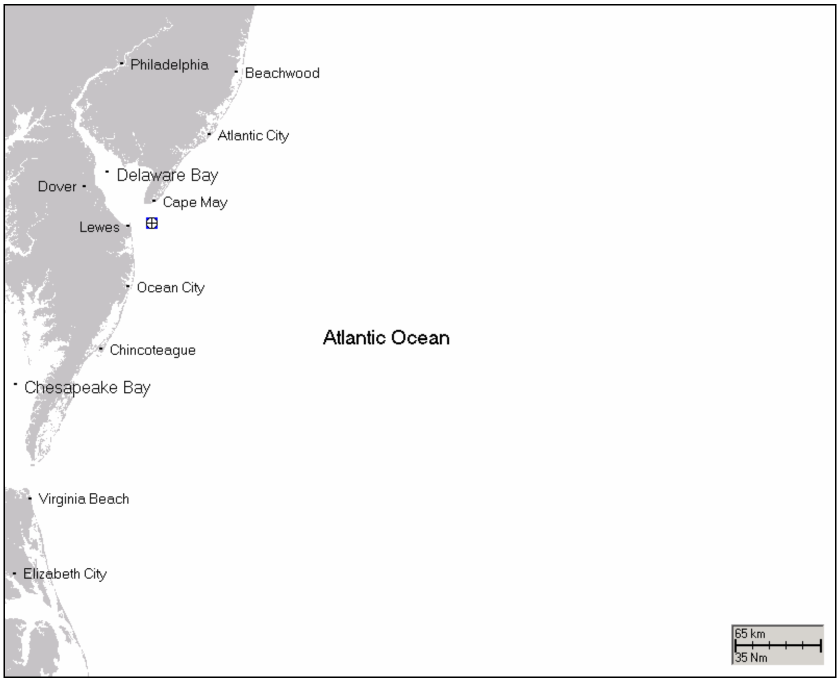

Figure B-I.1.1-1 Map of spill site and location names used in the text (entire grid).

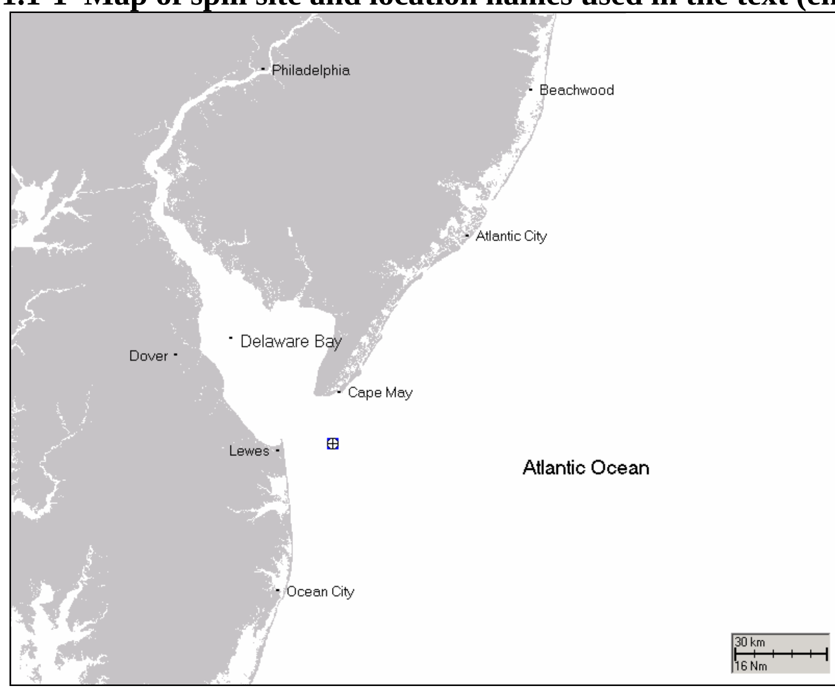

Figure B-I.1.1-2 Map of spill site and location names used in the text (Delaware Bay).

B-I.1.2 Gridded Depth Data

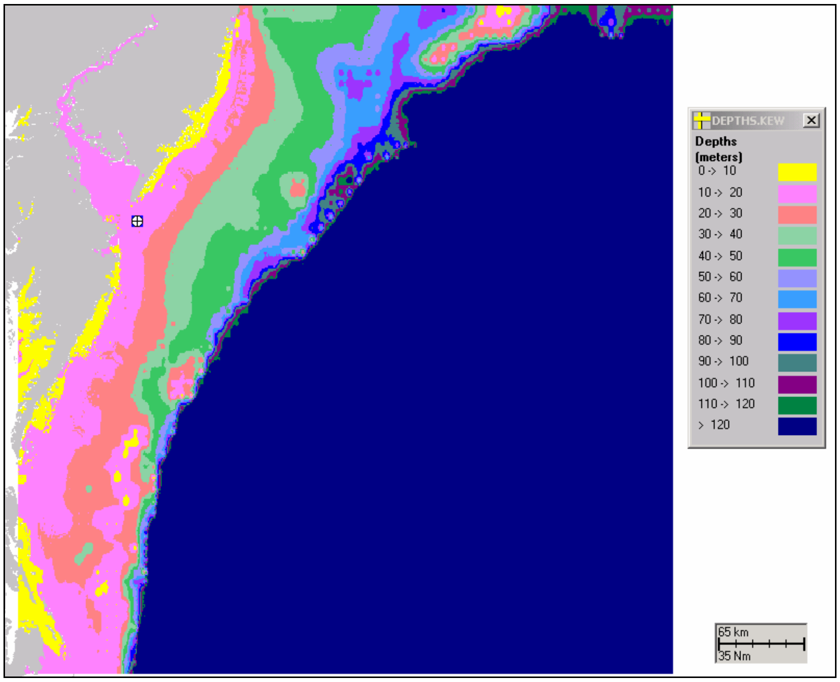

Figure B-I.1.2-1 Gridded depth data used in model runs (entire grid).

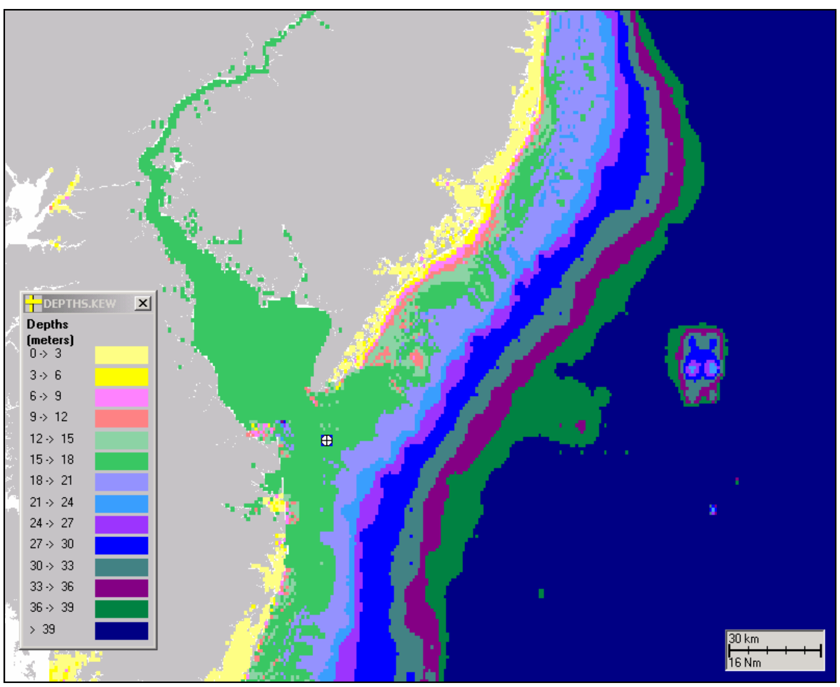

Figure B-I.1.2-2 Gridded depth data used in model runs (Delaware Bay).

B-I.1.3 Gridded Habitat Mapping

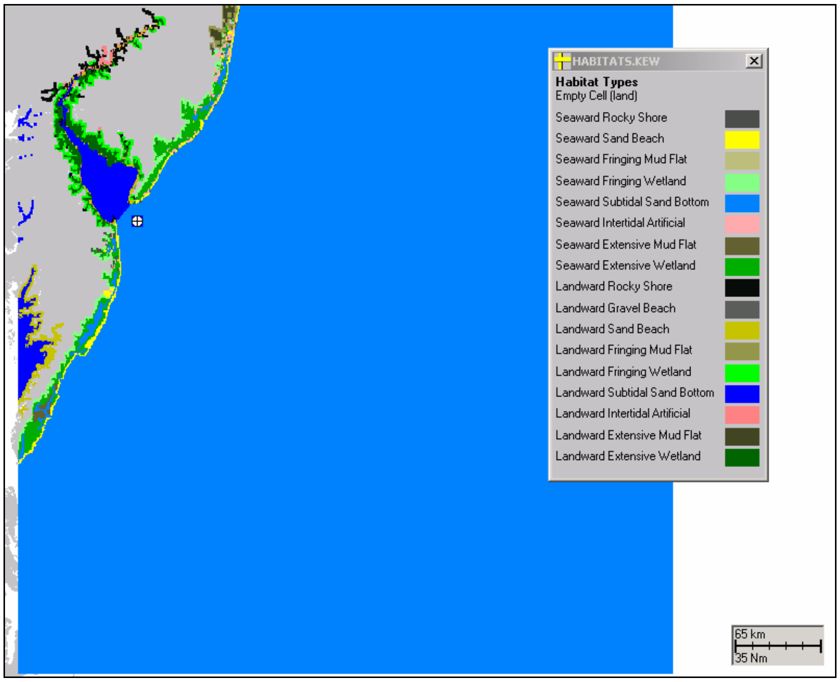

Figure B-I.1.3-1 Gridded habitat map used in model runs (entire grid).

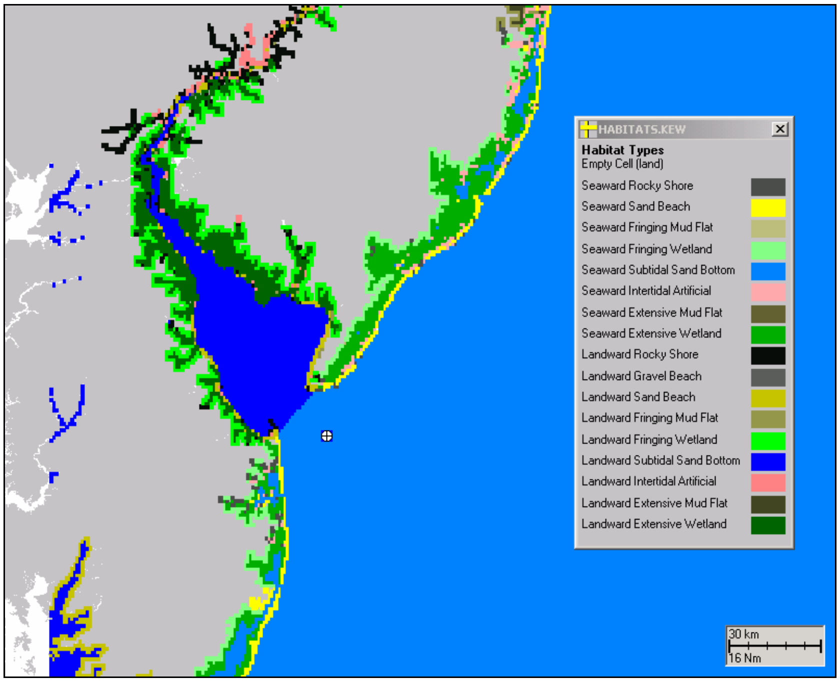

Figure B-I.1.3-2 Gridded habitat map used in model runs (Delaware Bay).

B-I.1.4 Dispersant Application Areas for Response

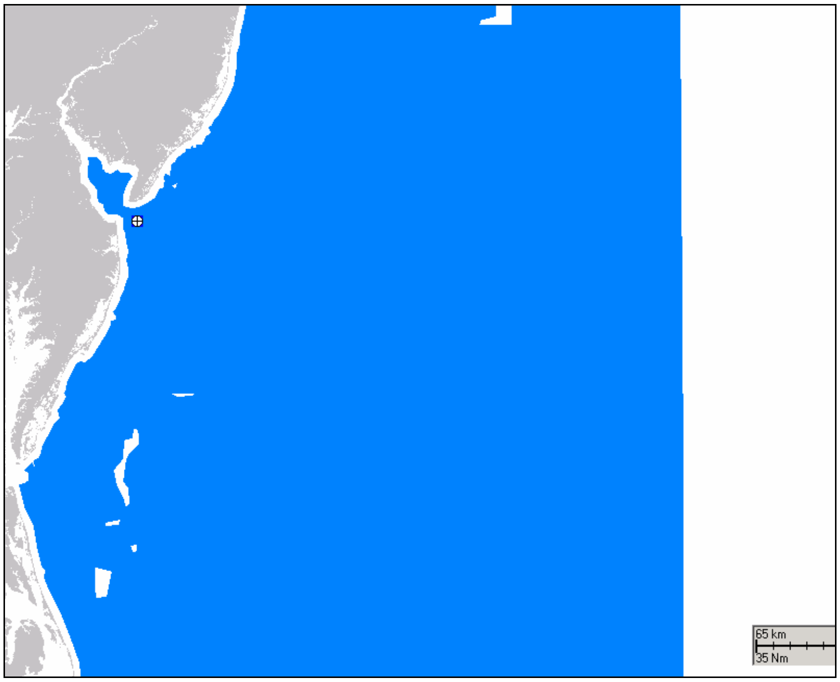

Figure B-I.1.4-1 Map of dispersant application areas (blue shaded area is where dispersants are assumed applied).

B-I.2 Current Data

ASA's boundary fitted coordinate hydrodynamic model (BFHYDRO, see Part A, Section A.3.3) was used to generate an applicable current data set for the Delaware River (from Trenton seaward), Delaware Bay, and nearby coastal waters. The 2-D, (vertically averaged) model is driven with freshwater river flow and tidal forcing, to predict the currents over tidal cycles and time. The river is tidal all the way up to the dam at Trenton. The USGS stream flow gauging station above the dam (http://waterdata.usgs.gov/) was used to estimate annual mean river flow. The tidal forcing functions applied were the 6 major harmonic constituents (M_2, S_2, N_2, K_1, O_1 and P_1) derived from Tides and Currents time series (Tides & Currents Pro for Windows, Version 3.0. Nautical Software Inc.).

The currents of the Delaware River and Bay system are complex mixtures of river flow and tidal vectors. The peak flood currents in the river are not at the same time as the peak flood currents at the mouth of Delaware Bay. In fact, the tidal currents are moving in opposite directions at Philadelphia and at the mouth. The figures below show currents relative to maximum flood and ebb at the mouth of Delaware Bay. Note that 0.5 m/sec = 1 knot.

The crosshair mark (⊞) in the figures below represents oil spill site.

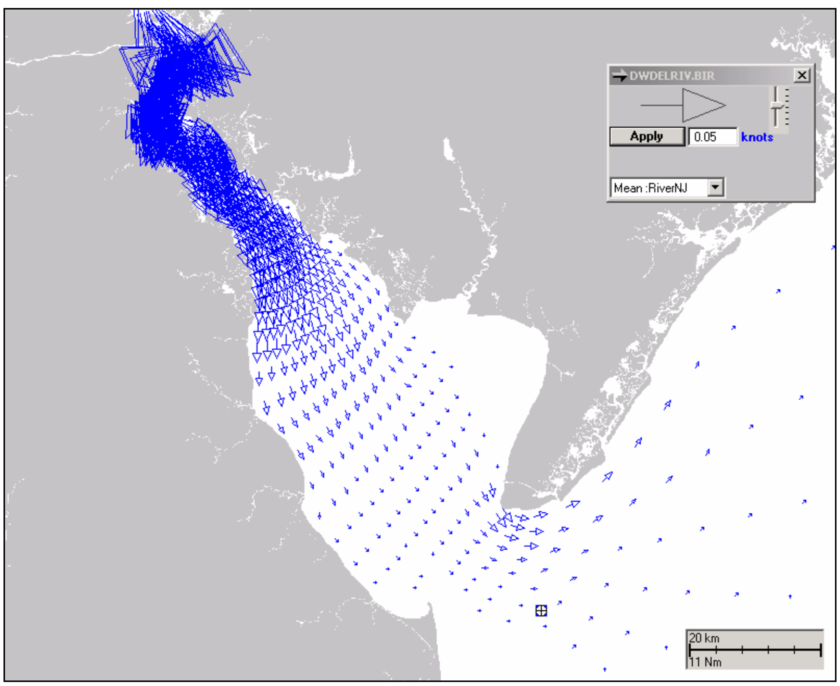

Figure B-I.2-1. Non-tidal current component (freshwater river flow) used in oil model runs (annual mean for Delaware River).

B-I.2.1 Current Vector Plots at Selected Times

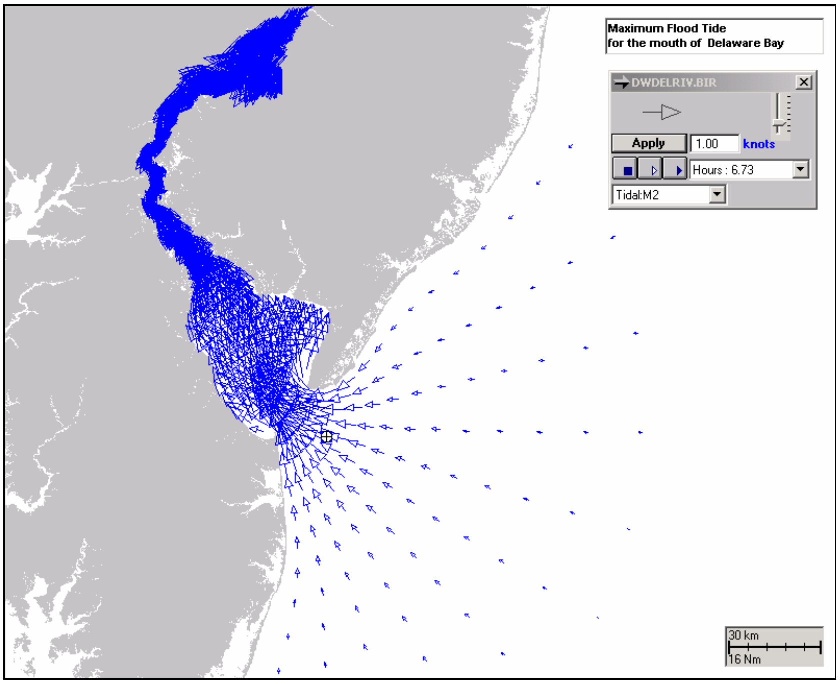

Figure B-I.2.1-1 Current vectors at maximum flood tide (Delaware Bay).

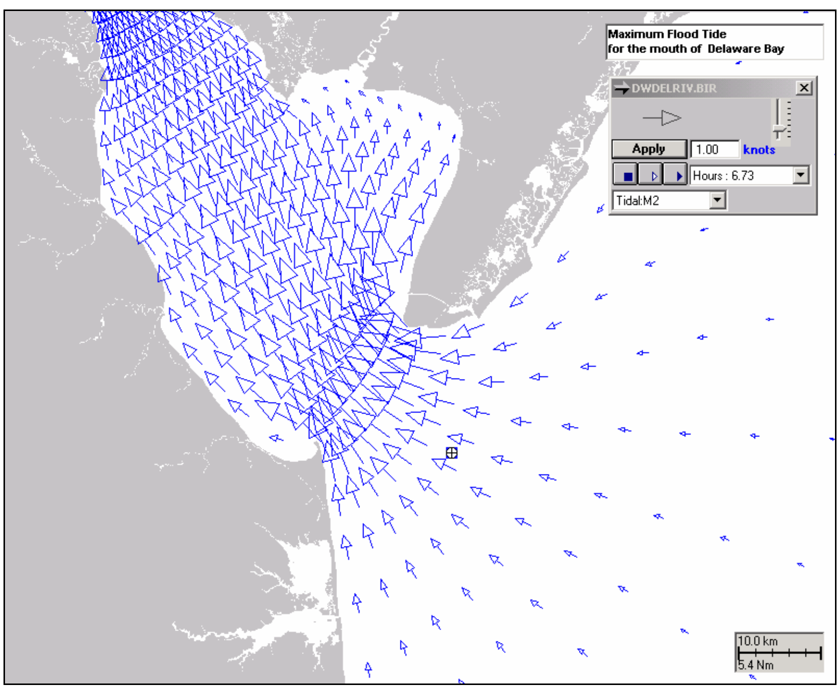

Figure B-I.2.1-2 Current vectors at maximum flood tide (Mouth of Delaware Bay).

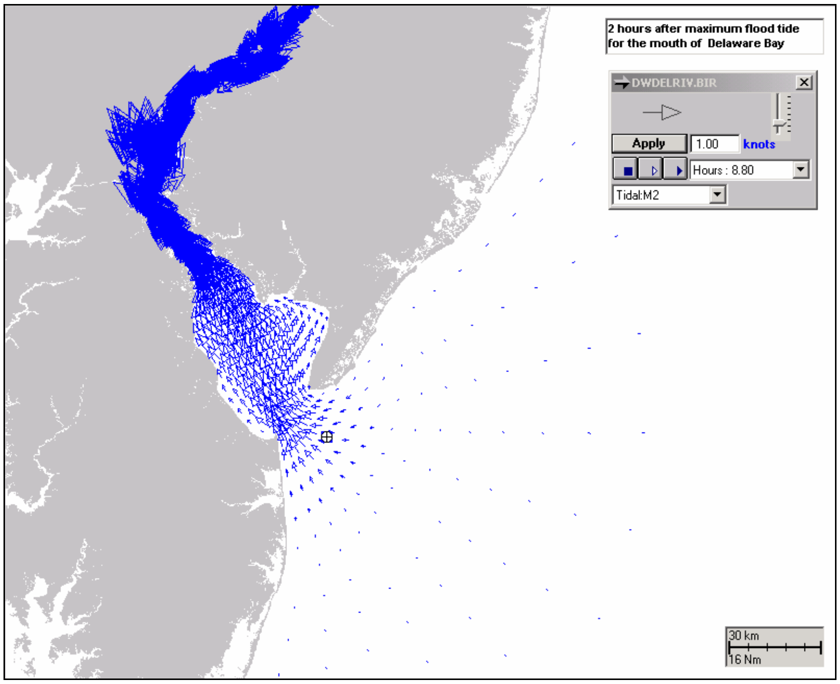

Figure B-I.2.1-3 Current vectors at 2 hours after maximum flood tide (Delaware Bay).

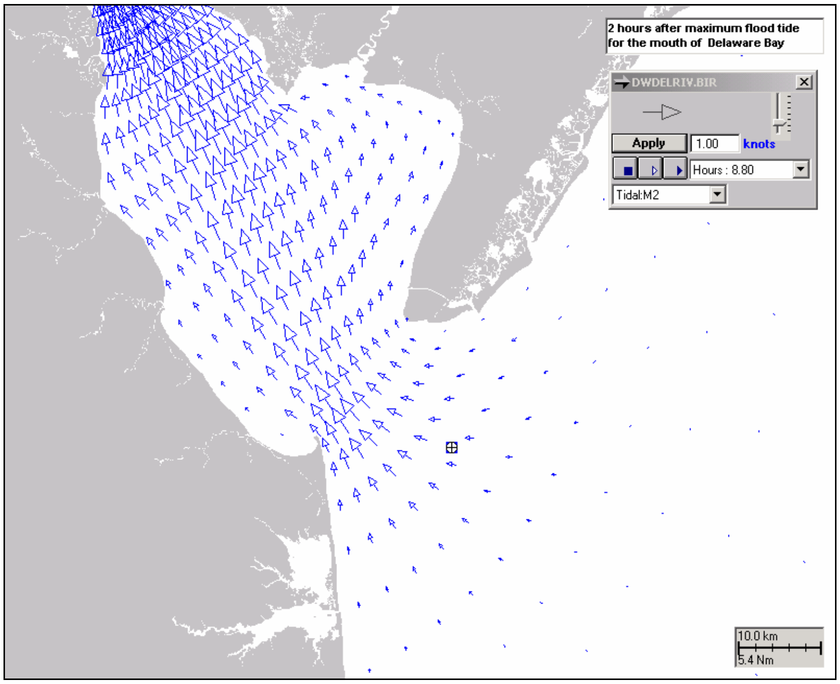

Figure B-I.2.1-4 Current vectors at 2 hours after maximum flood tide (Mouth of Delaware Bay).

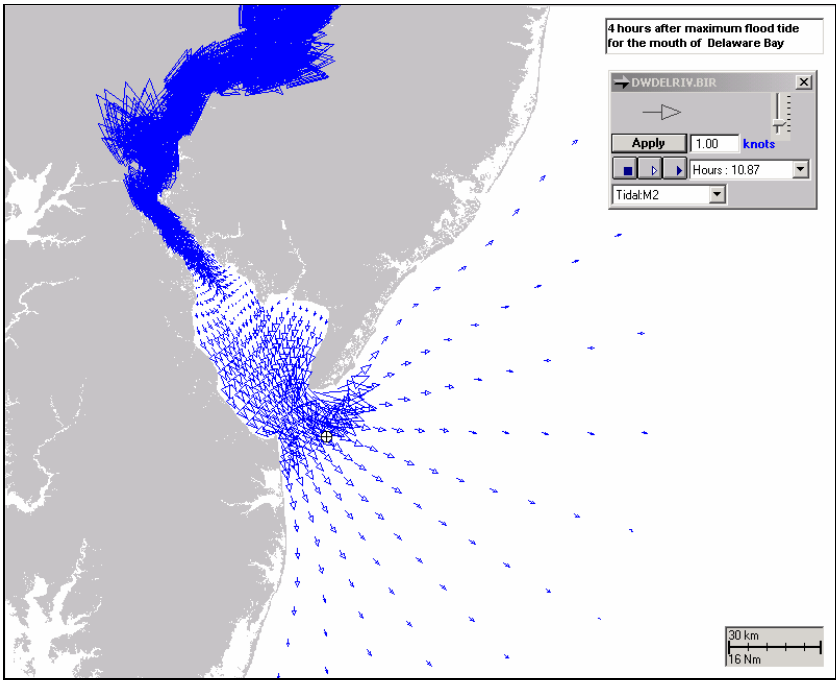

Figure B-I.2.1-5 Current vectors at 4 hours after maximum flood tide (Delaware Bay).

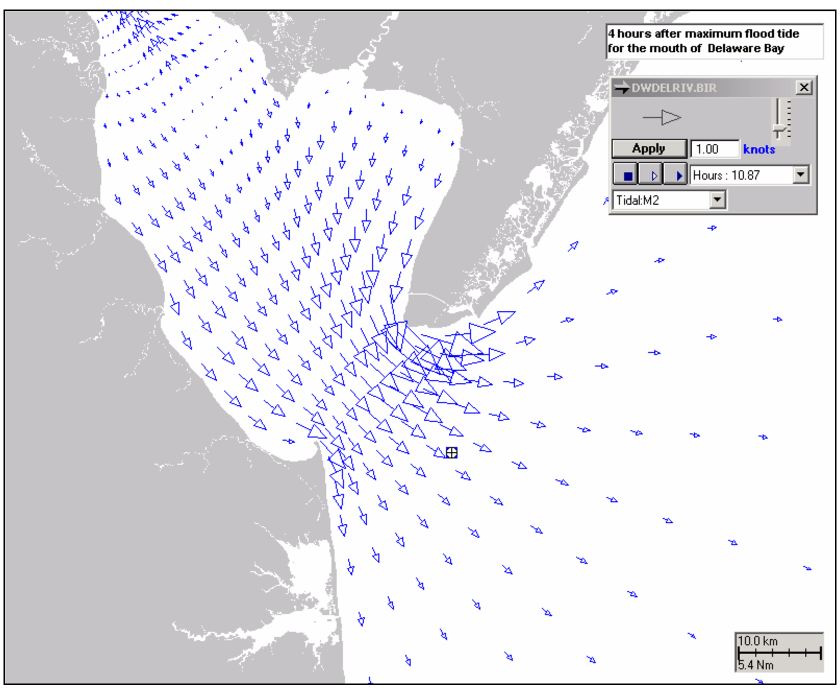

Figure B-I.2.1-6 Current vectors at 4 hours after maximum flood tide (Mouth of Delaware Bay).

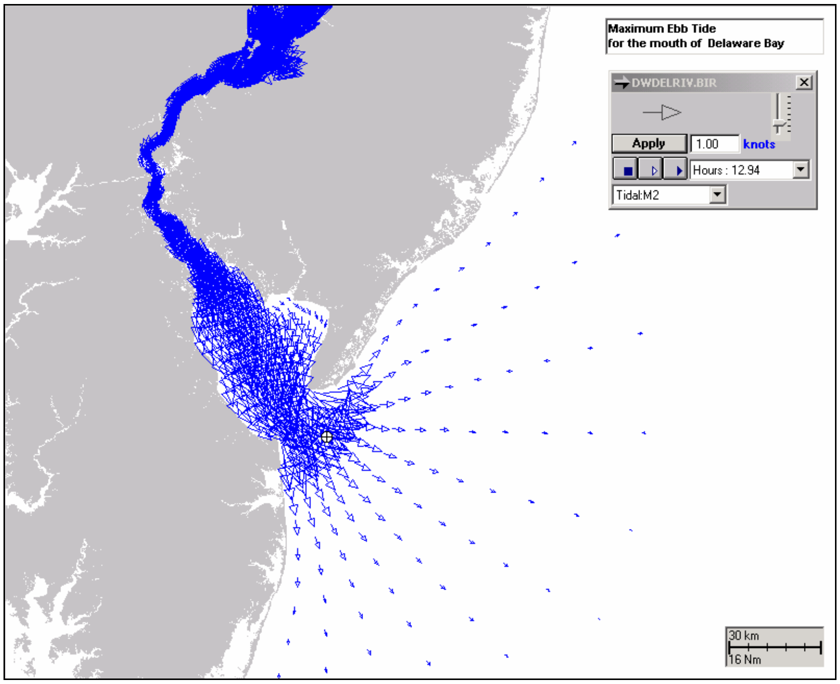

Figure B-I.2.1-7 Current vectors at maximum ebb tide (Delaware Bay).

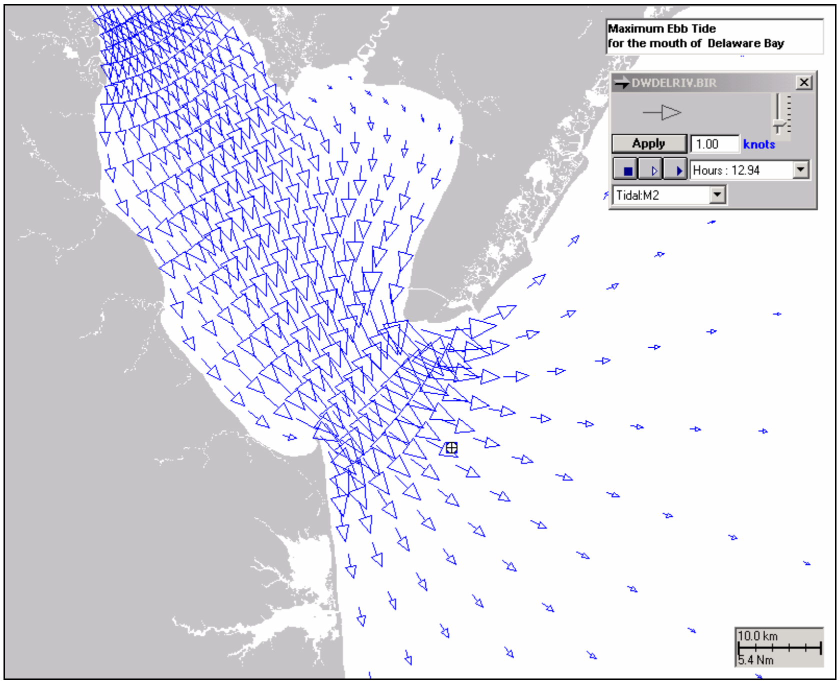

Figure B-I.2.1-8 Current vectors at maximum ebb tide (Mouth of Delaware Bay).

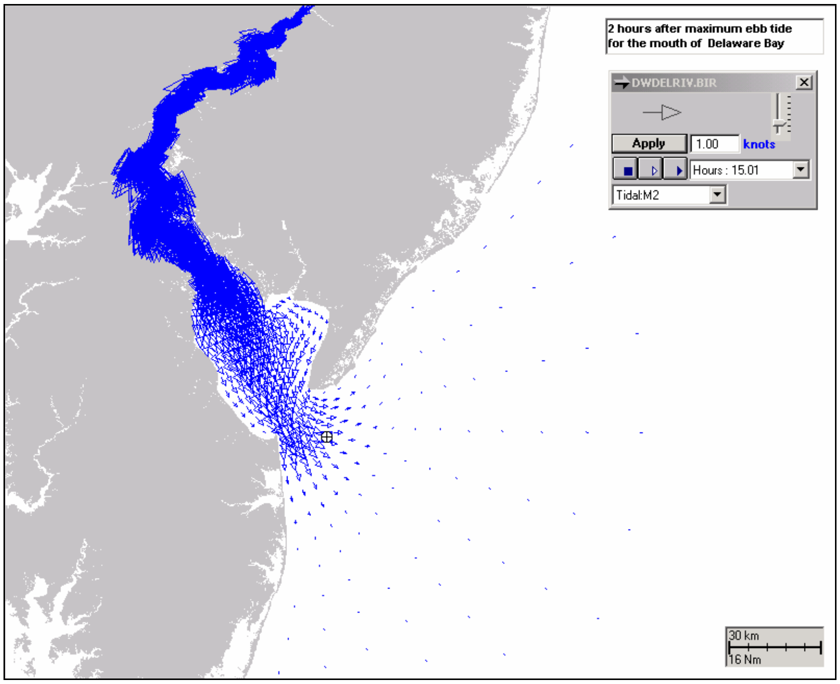

Figure B-I.2.1-9 Current vectors at 2 hours after maximum ebb tide (Delaware Bay).

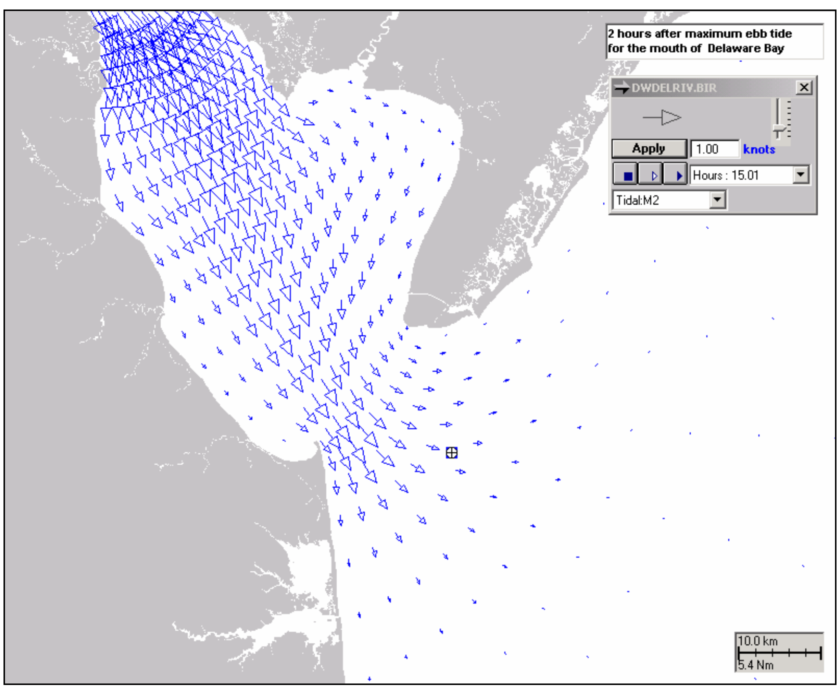

Figure B-I.2.1-10 Current vectors at 2 hours after maximum ebb tide (Mouth of Delaware Bay).

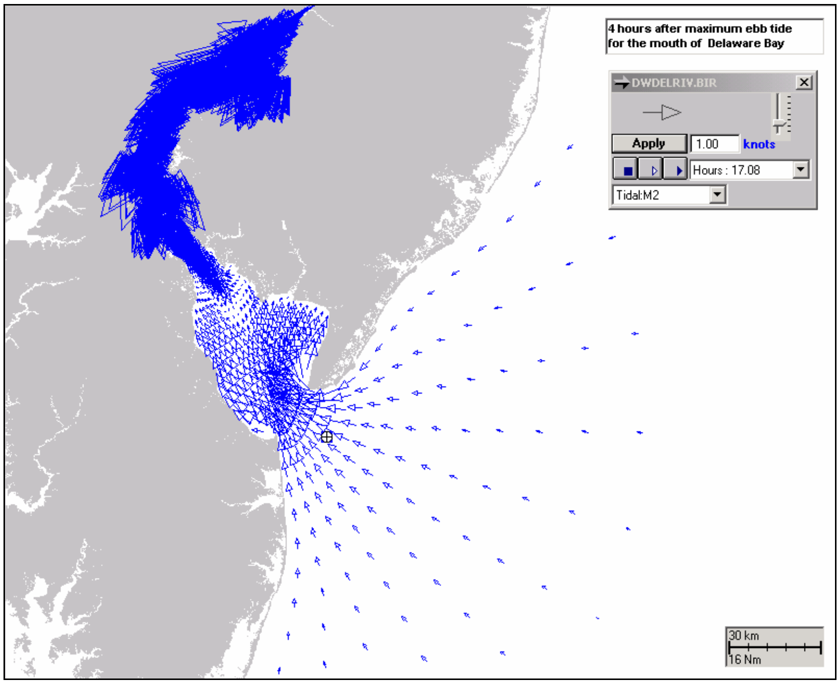

Figure B-I.2.1-11 Current vectors at 4 hours after maximum ebb tide (Delaware Bay).

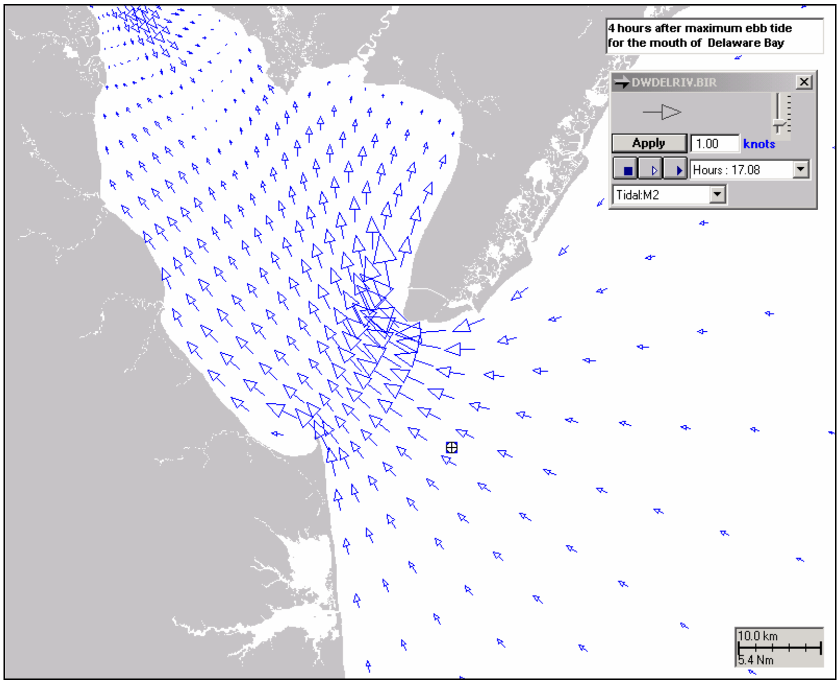

Figure B-I.2.1-12 Current vectors at 4 hours after maximum ebb tide (Mouth of Delaware Bay).

B-I.3 Oil Properties

Table B-I.3-1. Oil properties for South Louisiana crude oil.

Property	**Value**	**Reference**
Density @ 25 deg. C (g/cm3)	0.8518	Jokuty et al. (1999)
Viscosity @ 25 deg. C (cp)	8.0	Jokuty et al. (1999)
Surface Tension (dyne/cm)	25.9	Jokuty et al. (1999)
Pour Point (deg. C)	-28	Jokuty et al. (1999)
Adsorption Rate to Suspended Sediment	0.01008	Kolpack et al. (1977)
Adsorption Salinity Coef.(/ppt)	0.023	Kolpack et al. (1977)
Fraction monoaromatic hydrocarbons (MAHs)	0.01478	Jokuty et al. (1999)
Fraction polynuclear aromatic hydrocarbons (PAHs)	0.008108	French (1998c)
Fraction 2-ring aromatics (included in PAHs above)	0.003104	French (1998c)
Fraction 3-ring aromatics (included in PAHs above)	0.005004	French (1998c)
Fraction Non-Aromatic Volatiles: boiling point < 180^{o}C	0.16522	Jokuty et al. (1999)
Fraction Non-Aromatic Volatiles: boiling point 180-264^{o}C	0.18590	Jokuty et al. (1999)
Fraction Non-Aromatic Volatiles: boiling point 264-380^{o}C	0.62711	Jokuty et al. (1999)
Minimum Oil Thickness (m)	0.00001	McAuliffe (1987)
Maximum Mousse Water Content (%)	75	NOAA (2000a)
Mousse Water Content as Spilled (%)	0	French et al. (1996b)
Water content of fuel (not in mousse, %)	0	French et al. (1996b)
Degradation Rate (/day), Surface & Shore	0.01	National Research Council (1985)
Degradation Rate (/day), Hydrocarbons in Water	0.01	National Research Council (1985)
Degradation Rate (/day), Oil in Sediment	0.001	Haines and Atlas (1982)
Degradation Rate (/day), Aromatics in Water	0.01	French et al. (1996b)
Degradation Rate (/day), Aromatics in Sediment	0.001	French et al. (1996b)

[1] – Jokuty et al. (1999) provided total hydrocarbon data. The aromatic hydrocarbon fraction was subtracted from the total hydrocarbon fraction to obtain the aliphatic fraction.

Table B-I.3-2. Aromatic concentrations (mg/kg) for South Louisiana crude oil.

Aromatic	**Log(K_{ow})***	**Concentration (mg/kg)**
benzene	2.13	800
toluene	2.69	2190
ethylbenzene	3.13	710
o-xylene	3.15	0
p-xylene	3.18	0
m-xylene	3.2	0
xylenes	3.18	5360
1,2,3-trimethylbenzene	3.55	0
1,3,4-trimethylbenzene	3.6	0
1,3,5-trimethylbenzene	3.58	0
trimethylbenzenes	3.58	0
n-propylbenzene	3.69	0
iso-propylbenzene	3.63	0
ethyl-methylbenzenes	3.63	0
iso-propyl-4-methylbenzene	4.10	0
butylbenzenes	4.12	0
tetramethylbenzenes	4.01	0
styrene	3.05	0
methylstyrenes	3.35	0
tetralin	3.83	0
diphenylmethane	4.14	0
naphthalene	3.37	364.0
C1-naphthalenes	3.87	1400.0
C2-naphthalenes	4.37	1340.0
C3-naphthalenes	5.00	1200.0
C4-naphthalenes	5.55	637.0
acenaphthylene	4.07	11.4
acenaphthene	3.92	9.0
biphenyls	3.9	68.5
dibenzofuran	4.31	0.0
fluorene	4.18	34.4
C1-fluorenes	4.97	60.2
C2-fluorenes	5.20	223.0
C3-fluorenes	5.50	227.0

*Estimates of log(K_{ow}) are from Mackay et al. (1992a,b) and Neff and Burns (1996).

Table B-I.3-2. Aromatic concentrations (mg/kg) for South Louisiana crude oil (continued).

Aromatic	Log(Kow)*	Concentration (mg/kg)
anthracene	4.54	2.5
phenanthrene	4.57	90.2
C1-phenanthrenes/ anthracenes	4.49	278.0
C2-phenanthrenes/ anthracenes	5.14	327.0
C3-phenanthrenes/ anthracenes	5.25	254.0
C4-phenanthrenes/ anthracenes	6.00	104.0
dibenzothiophene	6.51	79.9
C1-dibenzothiophene	4.49	315.0
C2-dibenzothiophene	4.86	570.0
C3-dibenzothiophene	5.50	513.0
fluoranthene	5.73	0.0
pyrene	5.22	0.0
Total $\log(K_{ow}) \leq 5.6$	5.18	22037.1

*Estimates of $\log(K_{ow})$ are from Mackay et al. (1992a,b) and Neff and Burns (1996).

B-I.4 Inputs to the SIMAP Oil Spill Model

This section summarizes the model input data for the scenarios run and the sources for that information. The approach and sources applicable to all modeled locations are described in Part A, Section A.3 of this technical report. Specifics to this model location are below. Thus, the reader should refer to Part A, Section A.3 for background and the context within which these data are used.

The model grid and cell size (Table B-I.4-4) were set to provide the maximum resolution (minimum cell size) possible within the memory constraints of the model, while also providing sufficient geographic coverage to encompass the maximum extent of oiling possible for a large volume scenario. Test runs (randomizing weather conditions) were made with the largest spill volume simulated (40,000 bbl) and assuming no dispersant application. The maximum extent of surface oiling was determined and the grid size set to cover that area (Figure B-I.1.3-1).

Table B-I.4-1. Inputs to the Fates Model for Stochastic Scenarios.

Name	Description	Units	Source(s) of Information	Value(s)
Spill Site(s)	Location of the spill site	-	(Part A, Section A.3.6)	Spill site 7.5 nmiles from entrance to port
Spill Latitude	Latitude of the spill site	Degrees	Chart (Part A, Section A.3.6)	38^{o} 47.46' N
Spill Longitude	Longitude of the spill site	Degrees	Chart (Part A, Section A.3.6)	74^{o} 54.0198' W
Depth of release	Depth below the water surface of the release or 0 for surface release	m	assumed (Part A, Section A.3.6)	0 m
Start time and date	Randomized over selected months of the year	Date, hr,min	randomized (Part A, Section A.2.4)	Jan-Dec
Spill duration	Hours over which the release occurs	Hours	(Part A, Section A.3.6)	Large – 4 Small – 1
Total spill amount	Total volume (or weight) released (maximum if range)	bbl	(Part A, Section A.3.6)	Large – 40,000 Small – 2,500
Randomize spill amount	Volume spilled is constant or maximum of range	-	-	Constant
Model time step	Time step used for model calculations	Hours	(Part A, Section A.2.1)	0.2
Model duration	Length of each model simulation	Days	(Part A, Section A.3.6)	14 days
Number of runs	Number of random start times to run in stochastic mode	#	(Part A, Section A.2.4)	100
Number of surface spillets	Number of Lagrangian elements used to simulate mass floating on the surface	#	(Part A, Section A.2)	500
Number of aromatic spillets	Number of Lagrangian elements used to simulate dissolved aromatics in the water	#	(Part A, Section A.2)	2000

Table B-I.4-1. Inputs to the Fates Model for Stochastic Scenarios (continued).

Fates Output Threshold: floating on water surface	Slick or surface mass thickness passing through a grid cell	g/m^2 (microns)	Minimum value for sheens (Part A, Section A.4.1)	0.01
Fates Output Threshold: shoreline	Total hydrocarbons deposited on shorelines, averaged over each habitat grid cell.	g/m^2 (microns)	Minimum value for sheens (Part A, Section A.4.1)	0.01
Fates Output Threshold: dissolved aromatics in water or sediment	Dissolved concentration of aromatics with $\log(K_{ow}) \leq 5.6$ (bioavailable fraction)	mg/m^3 = μg/L = ppb	Below minimum for effects to sensitive species exposed for at least two weeks (Part A, Section A.4.1)	1
Fates Output Threshold: Subsurface (water) total hydrocarbons	Concentration of total hydrocarbons in droplets	mg/m^3 = μg/L = ppb	Minimum value with no potential for impact (Part A, Section A.4.1)	10
Fates Output Threshold: Sediment total hydrocarbons	Total hydrocarbon loading to sediments, averaged over each habitat grid cell.	g/m^2	Minimum value with no potential for impact (Part A, Section A.4.1)	0.0001 g/m^2 (which is 1.0 mg/m^3 = 1ppb averaged over the top 10cm)
Salinity	Surface water salinity	ppt	French et al. (1996b) province 15	32

Table B-I.4-1. Inputs to the Fates Model for Stochastic Scenarios (continued).

Surface Water Temper-ature	Water temperature at the sea surface	Degrees C	French et al. (1996b) province 15	monthly means (see Table B-I.4-5)
Subsurface Water Temper-ature	Water temperature for subsurface	Degrees C	French et al. (1996b) province 15	monthly means (see Table B-I.4-5)
Air Temper-ature	Air water temperature at water surface	Degrees C	(assume = water temperature; Part A, Section A.4.1)	(= water temperature)
Fetch	Fetch = distance to land to N, S, E, W (if landfall not in model domain)	km	Chart	N & W: (calculated from model grid) E: 1,000 S: 1,000
Wind drift speed	Speed oil moves down wind relative to wind	% of wind speed	Youssef (1993); Youssef and Spaulding (1993)	(model calculated)
Wind drift angle	Angle to right of wind (in northern hemisphere) that oil drifts	Deg. to right of down wind	Youssef (1993); Youssef and Spaulding (1993, 1994)	(model calculated)
Horizontal turbulent diffusion coefficient	Randomized turbulent mixing parameter in x & y	m^2/sec	French et al. (1996a, 1999) based on Okubo (1971)	1 m^2/sec (estuaries and low energy coastal areas)
Vertical turbulent diffusion coefficient	Randomized turbulent mixing parameter in z	m^2/sec	French et al. (1996a, 1999) based on Okubo (1971)	0.0001 m^2/sec
Suspended sediment concentrati on	Average suspended sediment concentration during spill period	mg/l	French et al. (1996b)	10 mg/l
Suspended sediment settling rate	Net settling rate for suspended sediments	m/day	French et al. (1996b)	1 m/day
Density change	Rate of change of droplet density due to adsorption of sediment	g/cm^3/hr	(data not available – fuel oil algorithm used)	0

Table B-I.4-2. Description of scenario runs.

Scenario Name	Description
MATL-Lrg-50-0	Large Spill; Removal at 50%; No Dispersant;
MATL-Lrg-50-80	Large Spill; Removal at 50%; Dispersant at 80% efficiency;
MATL-Lrg-50-45	Large Spill; Removal at 50%; Dispersant at 45% efficiency;
MATL-Med-50-0	Medium Spill; Removal at 50%; No Dispersant;
MATL-Med-50-80	Medium Spill; Removal at 50%; Dispersant at 80% efficiency;
MATL-Med-50-45	Medium Spill; Removal at 50%; Dispersant at 45% efficiency;

Table B-I.4-3. Matrix of scenarios run.

Scenario Name	Fuel	Latitude, Longitude	Depth (m)	Duration (hr)	Volume (bbl) Released	Mechanical Removal Efficiency	Dispersant Efficiency
MATL-Lrg-50-0	South Louisiana crude	38.791 N 74.90033 W	0 m (surface)	4	40,000	50%	none
MATL-Lrg-50-80	South Louisiana crude	38.791 N 74.90033 W	0 m (surface)	4	40,000	50%	80%
MATL-Lrg-50-45	South Louisiana crude	38.791 N 74.90033 W	0 m (surface)	4	40,000	50%	45%
MATL-Med-50-0	South Louisiana crude	38.791 N 74.90033 W	0 m (surface)	1	2,500	50%	none
MATL-Med-50-80	South Louisiana crude	38.791 N 74.90033 W	0 m (surface)	1	2,500	50%	80%
MATL-Med-50-45	South Louisiana crude	38.791 N 74.90033 W	0 m (surface)	1	2,500	50%	45%

Table B-I.4-4. Dimensions of the habitat grid cells used to compile statistics for multiple fates model runs.

Item	Value
Grid W edge	75.9561°W
Grid S edge	35.59°N
Cell size (°longitude)	0.010035
Cell size (°latitude)	0.010035
Cell size (m) west-east	905.81
Cell size (m) south-north	1113.89
# cells west-east	581
# cells south-north	468
Water cell area (m^2)	1,008,972
Shore cell length (m)	1,004.48
Shore cell width – Rocky shore (m)	2.0
Shore cell width – Artificial shore (m)	2.0
Shore cell width – Gravel beach (m)	5.0
Shore cell width – Sand beach (m)	10.0
Shore cell width – Mud flat (m)	140.0
Shore cell width – Wetlands (fringing, m)	140.0

Table B-I.4-5. Water temperature by month of the year (from French et al., 1996b).

Month	Surface Water Temperature (°C)	Bottom Water Temperature (°C)	Pycnocline Depth (m)
January	9	4	20
February	7	4	20
March	7	4	20
April	9	7	20
May	12	7	20
June	18	7	20
July	23	10	10
August	24	10	10
September	22	10	10
October	16	7	20
November	14	7	20
December	11	7	20

Table B-I.4-6. Wind data sources and records used.

File Name	Location	Latitude Longitude	Dates	Data Source
44009 90-2002.WNE	Station 44009 - Delaware Bay 26 nmiles southeast of Cape May, NJ	38.46 N 74.7 W	August 1990 to April 2002	National Data Buoy Center

The 44009 90-2002.WNE wind data was downloaded from buoy Station 44009, 26 nmiles southeast of Cape May, NJ. Figure B-I.4-1 displays where the buoy is located along with surrounding buoys. Winds were for the period 9 August 1990 to 30 April 2002. Gaps in buoy 44099 data were preferentially filled with data from nearby buoy 44014 (12/31/90-5/1/91, 10/28/92-5/17/93, 5/25/93-6/29/93, 9/23/95-11/20/95, 5/20/97-6/24/97, 4/14/98-4/30/98). Buoy 44014 is located at 36.58^{o} N 74.83^{o} W (64 nmiles east of Virginia Beach, VA). Where data was also unavailable from buoy 44014, gaps were filled with buoy 44099 data from the same day and month of a different year (5/1/98-5/7/98). The wind data contains one gap larger than a day, 16 May 1995 to 21 June 1995.

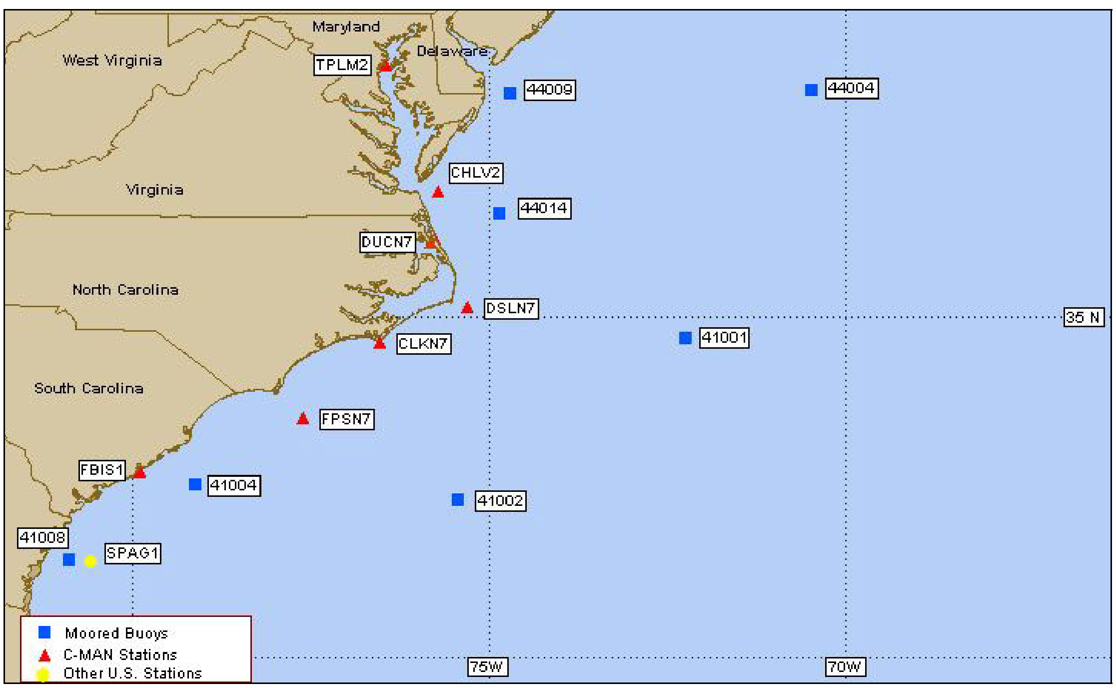

Figure B-I.4-1. Wind Station Locations

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part B: Delaware Bay and Mid-Atlantic Shelf

Section B-II.1

by

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ASA 00-246

August 2004

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B-II.1 Results of the Stochastic Modeling: Maps of Exposure Probability, Time and Maximum Possible Mass and Concentration

The results of multiple model runs are evaluated to develop the following statistics, for each location (cell in the model grid) and for each exposure index. Maps of the results are contained in this section.

- Probability of exposure greater than the minimum threshold (probability that the minimum threshold thickness or concentration will be exceeded at each location at any time following the spill). For surface oil, the model records if any oil of greater than that thickness passes through the grid cell, regardless of the areal coverage of the oil. For concentrations, the average concentration in the grid cell is used to determine if the threshold is exceeded.
- Time (hours) to first exceedance of the minimum threshold at each location
- Worst-case maximum exposure (thickness, volume or concentration) at any time after the spill, at a given location (peak exposure at each location delineated by the grid cells). The amounts are averaged over the area of the model grid cell. The worst-case maximum amount is for all possible releases (i.e., maximum peak exposure for all the model runs). This is calculated in two steps: (1) For each individual run (for each spill date run), the maximum amount over all time after the spill is saved for each location in the model grid. (2) The runs are evaluated to determine the highest amount possible at each location. Note that these *worst-case maximum* amounts are not additive over all locations. These represent maximum possible amounts of oil that could ever reach each site (grid cell), considered individually, and based on the model runs performed. Thus, "worst-case" represents the highest exposure of the most adverse of the runs performed.

Exposure indices and minimum thresholds (i.e., those less than values that might have an impact on any resource) used in the modeling were:

- Surface slick or floating oil: $\geq$ 0.01 g/m^2 (average thickness $\geq$ 0.01 micron)
- Shoreline: average mass loading over the shore segment (length of one grid cell, calculated as the cell diagonal length, times the typical width for the habitat type) $\geq$ 0.01 g/m^2
- Dissolved aromatics: average over the water cell $\geq$ 1 ppb (1 mg/m^3)
- Subsurface oil (entrained in water): average over the water cell $\geq$ 10 ppb (10 mg/m^3)
- Sediment total hydrocarbons: average over the cell $\geq$ 0.0001 g/ m^2
- Sediment dissolved aromatic concentrations: average over the cell $\geq$ 0.0001 g/ m^2 (which is 1.0 mg/m^3 = 1ppb averaged over the top 10 cm, the assumed bioturbation zone)

Discussion of exposure indices and minimum thresholds are described in Part A: Description of Models and Assumptions and Section 4.3 of the PEIS.

The Crosshair mark (⊞) in figures below represents oil spill site.

B-II.1.1. Scenario: Medium Volume, No Dispersant

B-II.1.1.1 Surface Floating Total Hydrocarbons. Scenario: Medium Volume, No Dispersant

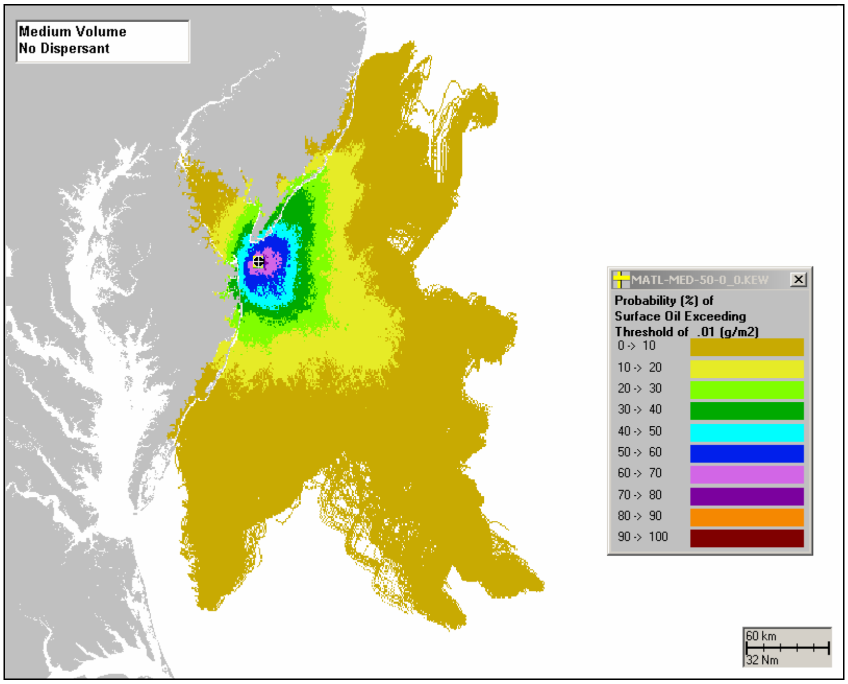

Figure B-II.1.1.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Medium Volume, No Dispersant.

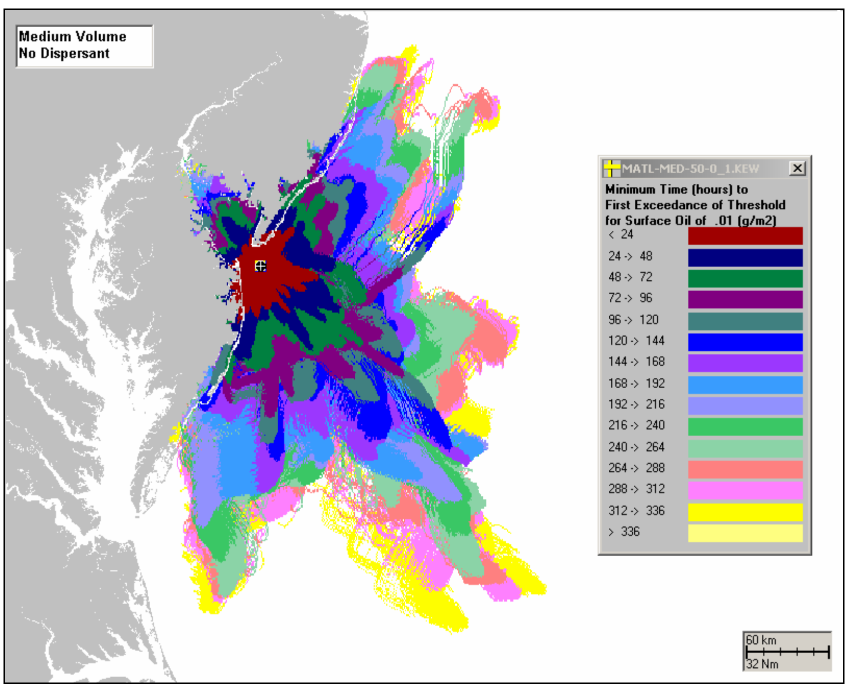

Figure B-II.1.1.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Medium Volume, No Dispersant.

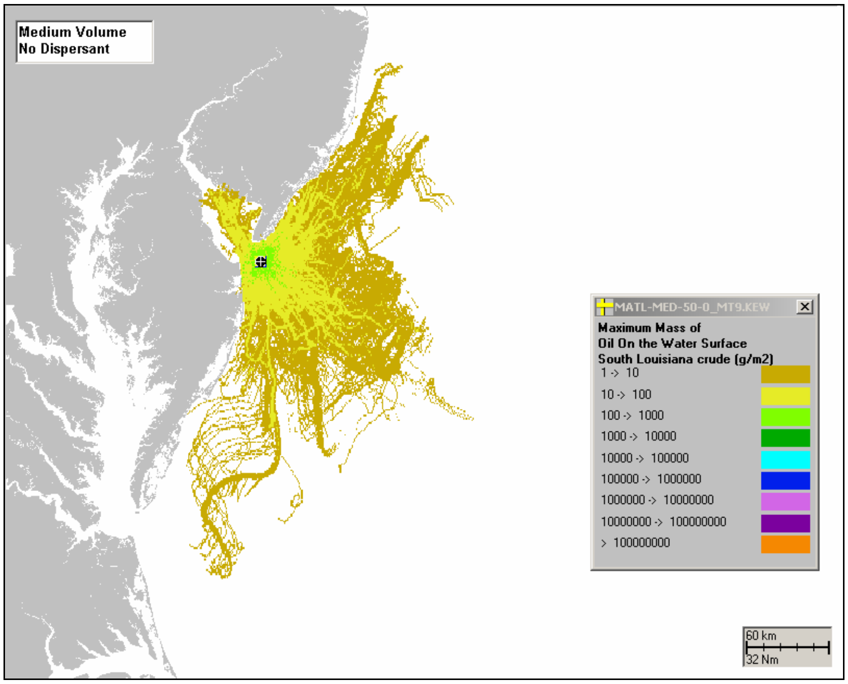

Figure B-II.1.1.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

B-II.1.1.2 Shoreline Oiled. Scenario: Medium Volume, No Dispersant

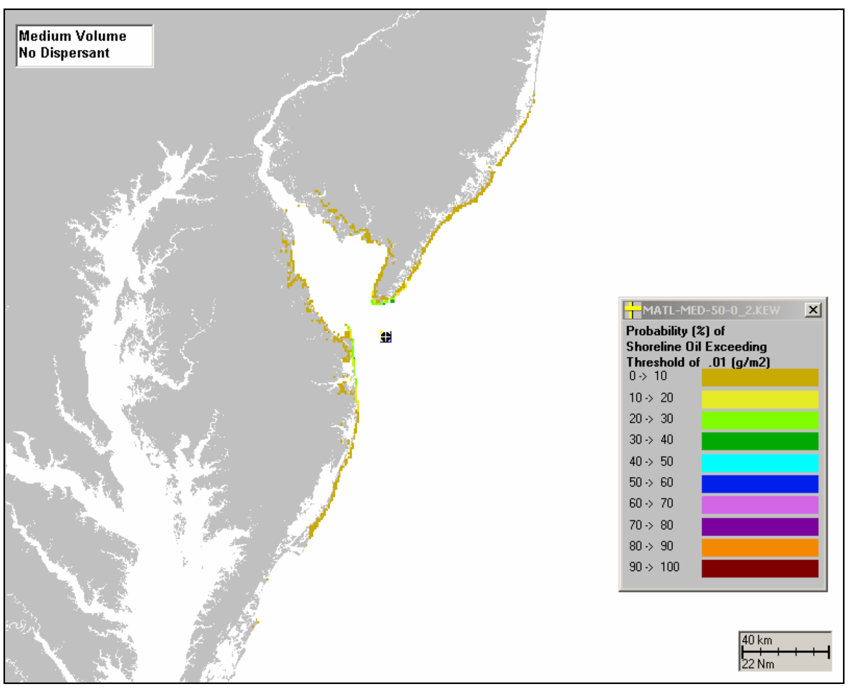

Figure B-II.1.1.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Medium Volume, No Dispersant.

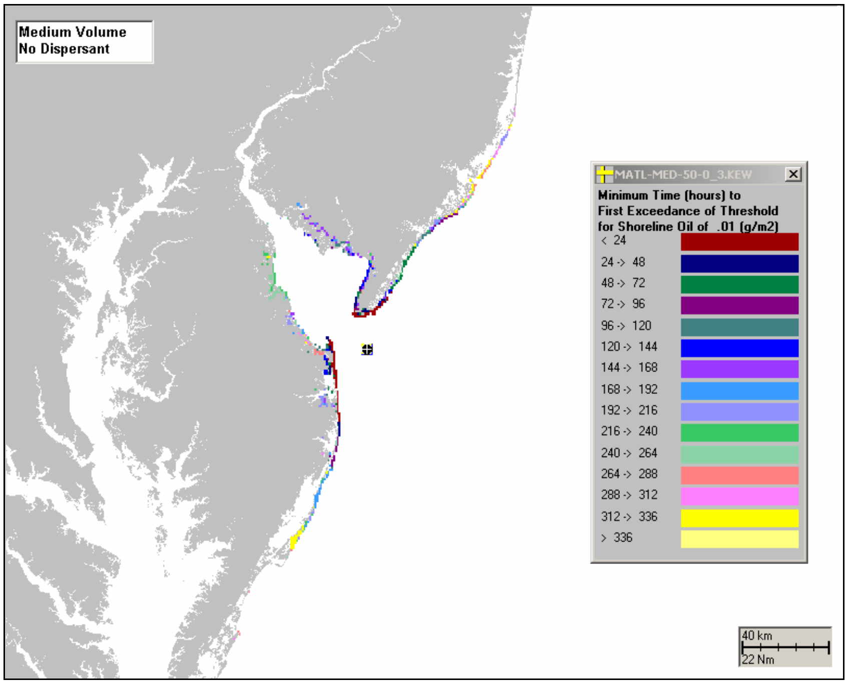

Figure B-II.1.1.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Medium Volume, No Dispersant.

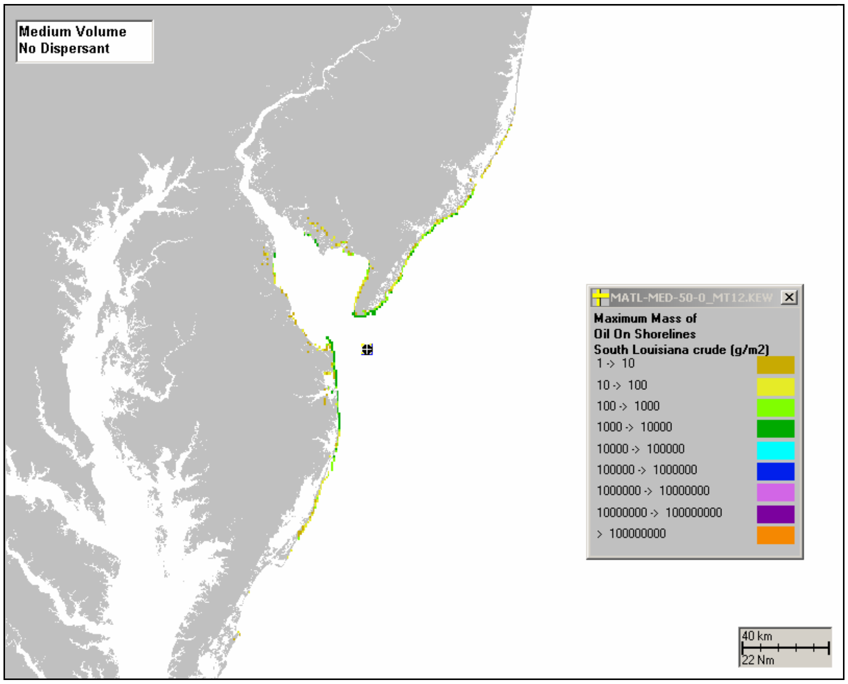

Figure B-II.1.1.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

B-II.1.1.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Medium Volume, No Dispersant

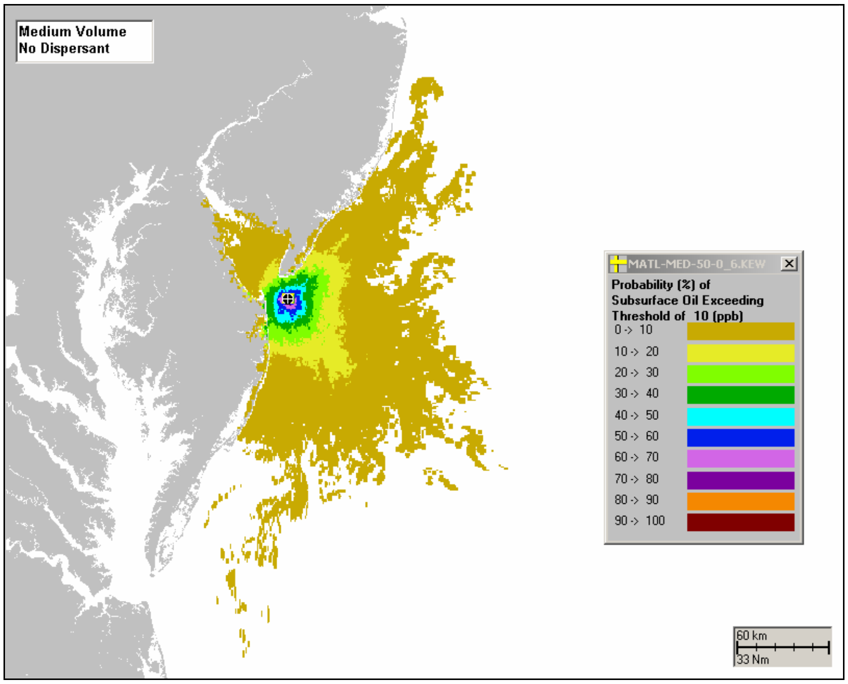

Figure B-II.1.1.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Medium Volume, No Dispersant.

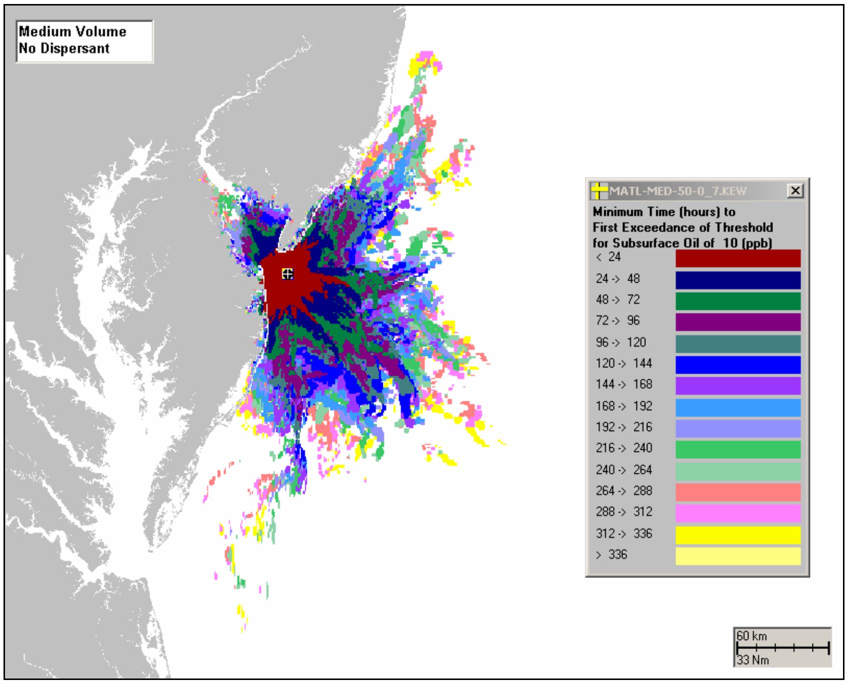

Figure B-II.1.1.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Medium Volume, No Dispersant.

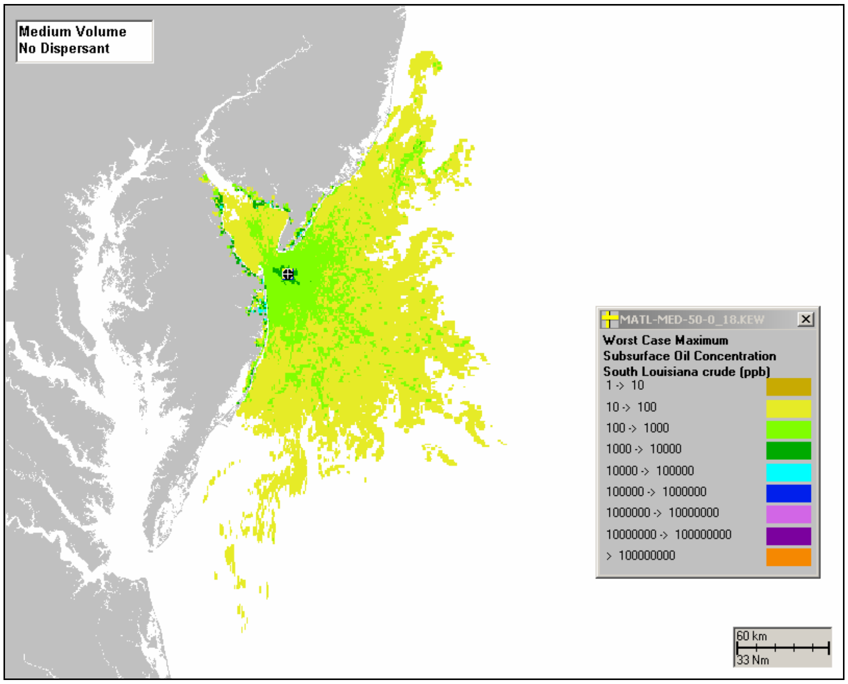

Figure B-II.1.1.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

B-II.1.1.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Medium Volume, No Dispersant

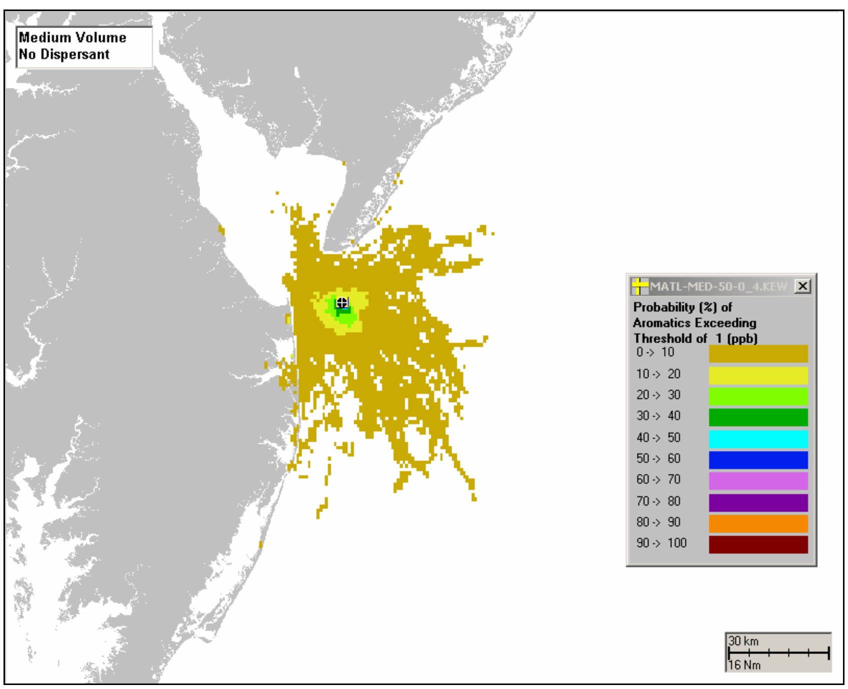

Figure B-II.1.1.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, No Dispersant.

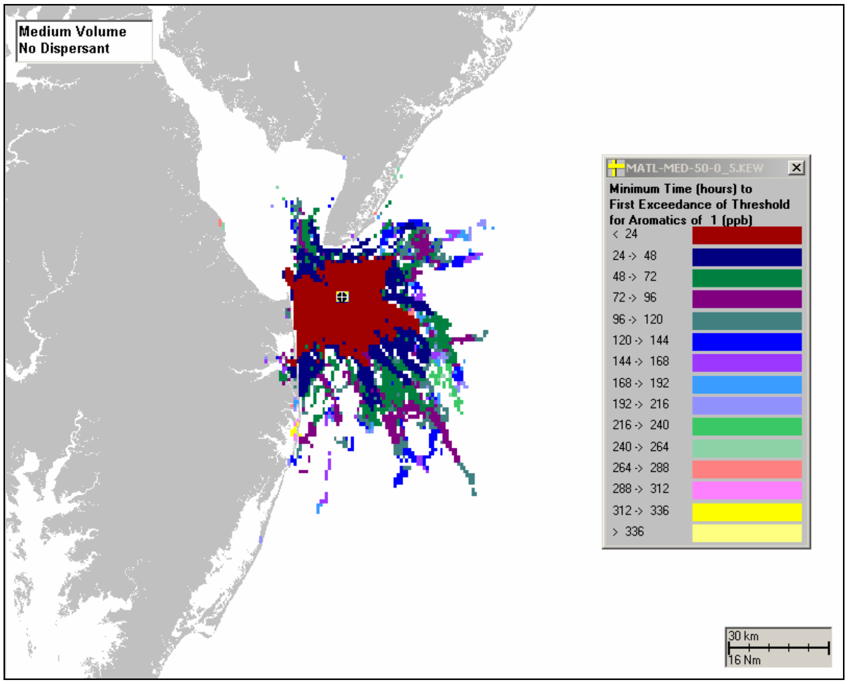

Figure B-II.1.1.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Medium Volume, No Dispersant.

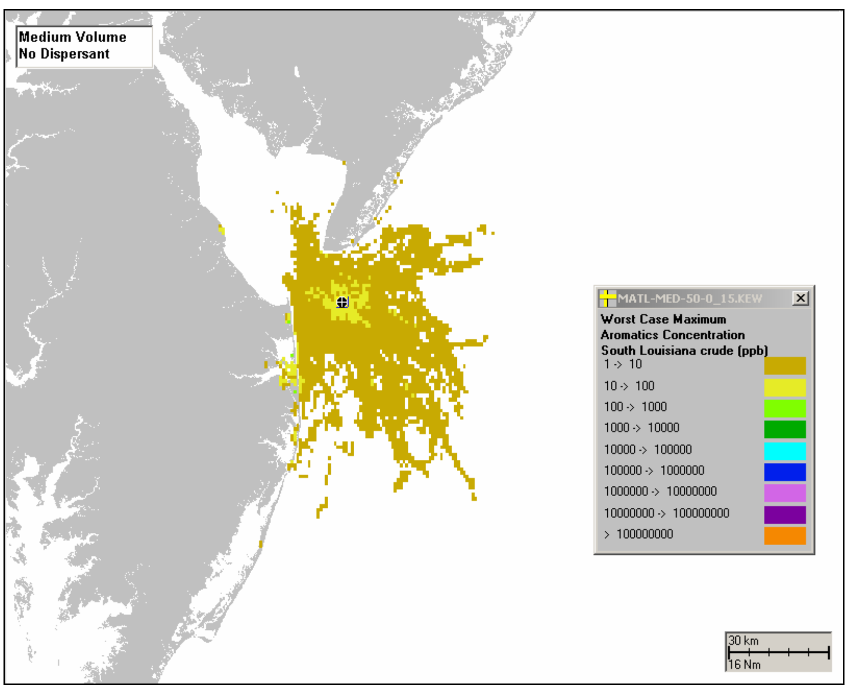

Figure B-II.1.1.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

B-II.1.1.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Medium Volume, No Dispersant

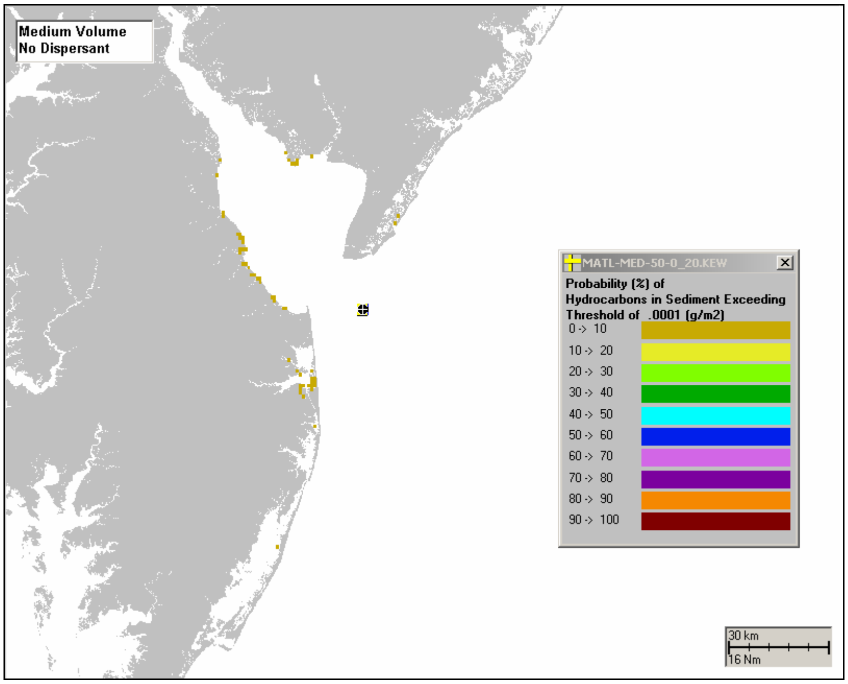

Figure B-II.1.1.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Medium Volume, No Dispersant.

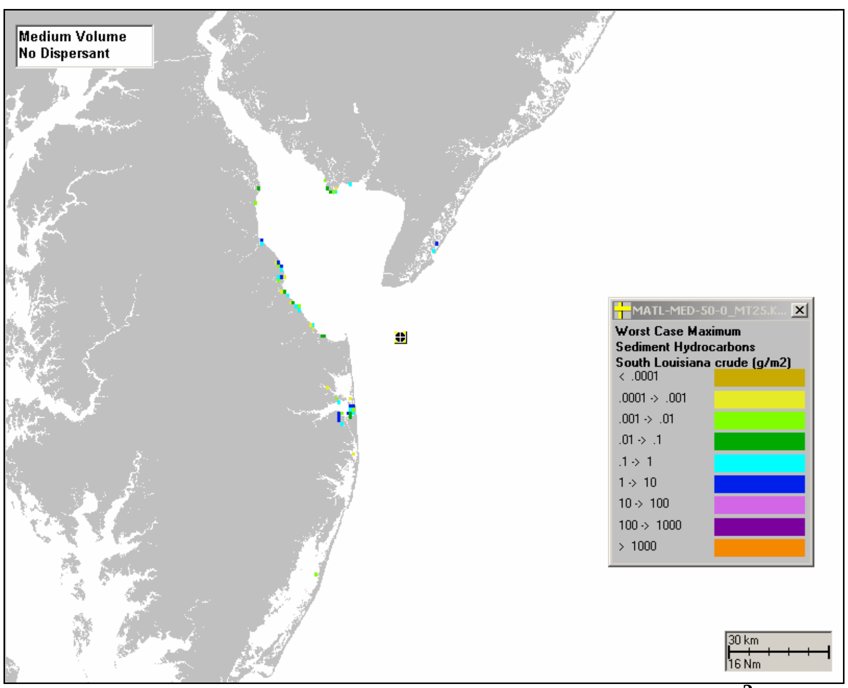

Figure B-II.1.1.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

B-II.1.1.6 Sediment pore water dissolved aromatic concentrations. Scenario: Medium Volume, No Dispersant

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time and for any of the 100 runs) does not exceed threshold of 1 ppb. Scenario: Medium Volume, No Dispersant.

B-II.1.2. Scenario: Medium Volume, 45% Dispersant Efficiency

B-II.1.2.1 Surface Floating Total Hydrocarbons. Scenario: Medium Volume, 45% Dispersant Efficiency

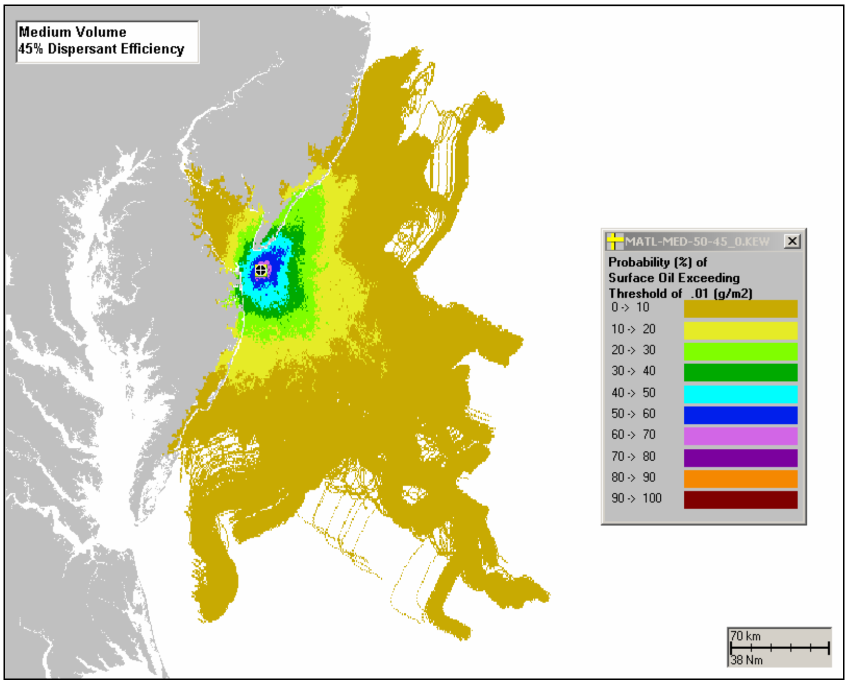

Figure B-II.1.2.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

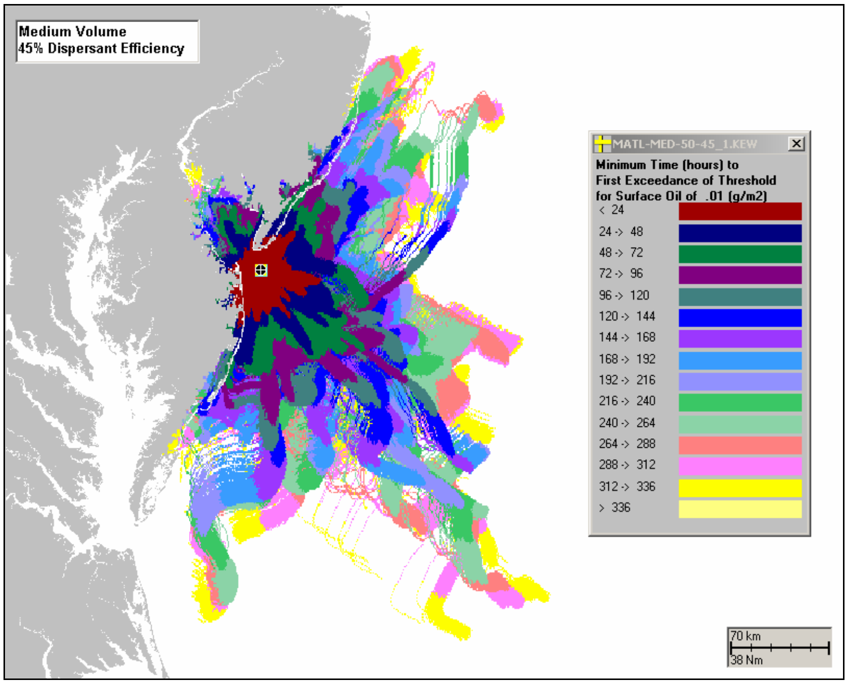

Figure B-II.1.2.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

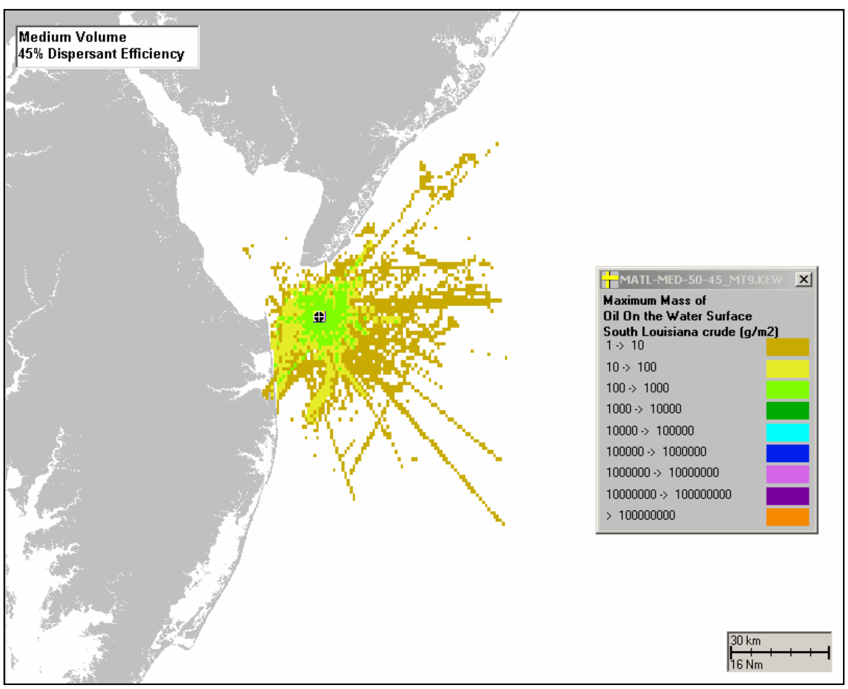

Figure B-II.1.2.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

B-II.1.2.2 Shoreline Oiled. Scenario: Medium Volume, 45% Dispersant Efficiency.

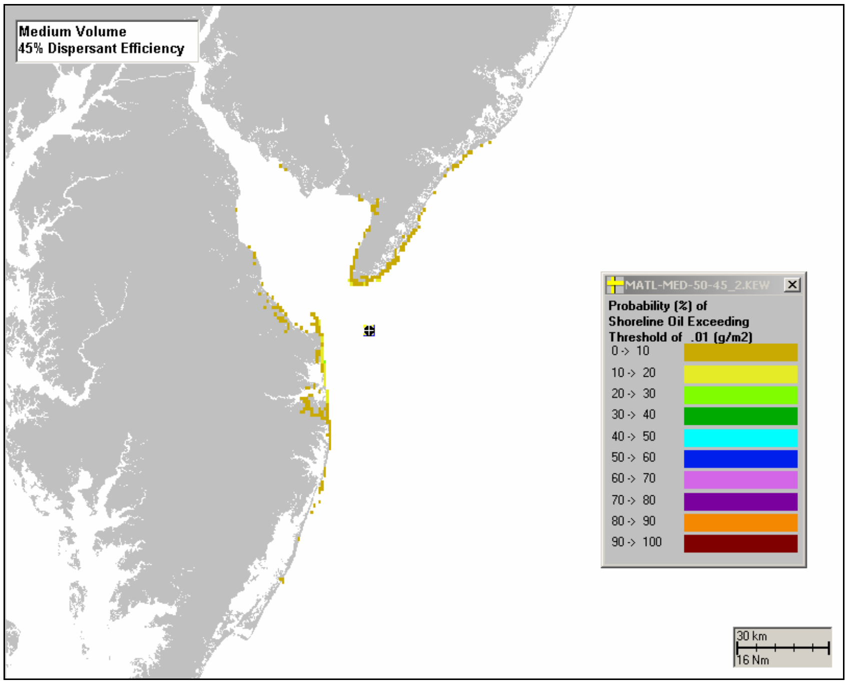

Figure B-II.1.2.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

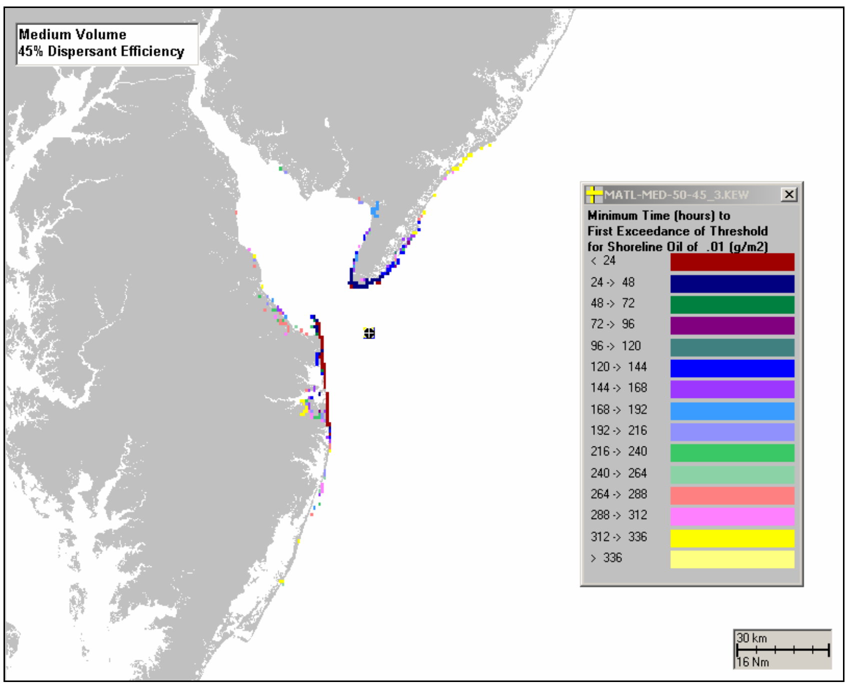

Figure B-II.1.2.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

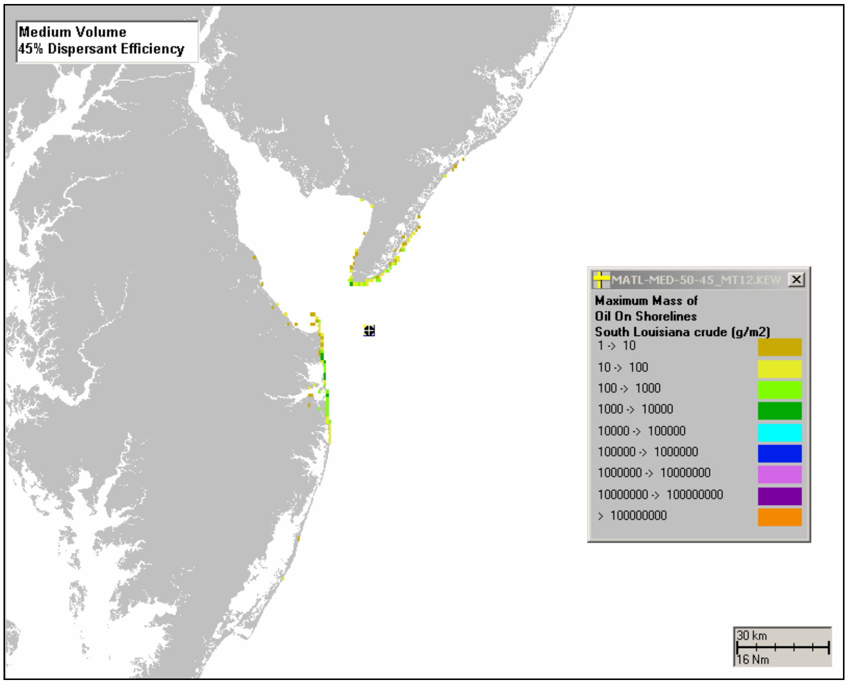

Figure B-II.1.2.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

B-II.1.2.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Medium Volume, 45% Dispersant Efficiency

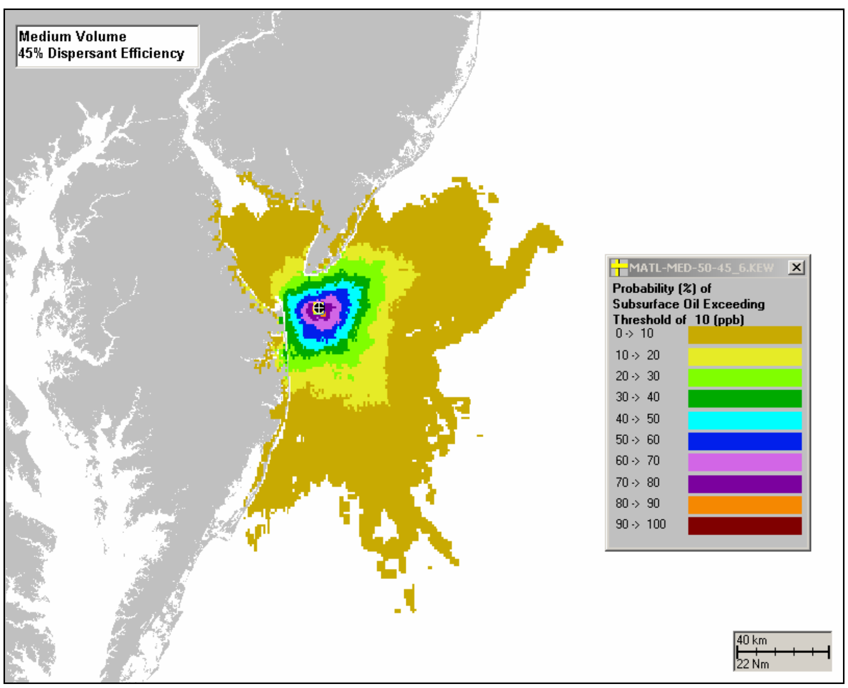

Figure B-II.1.2.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

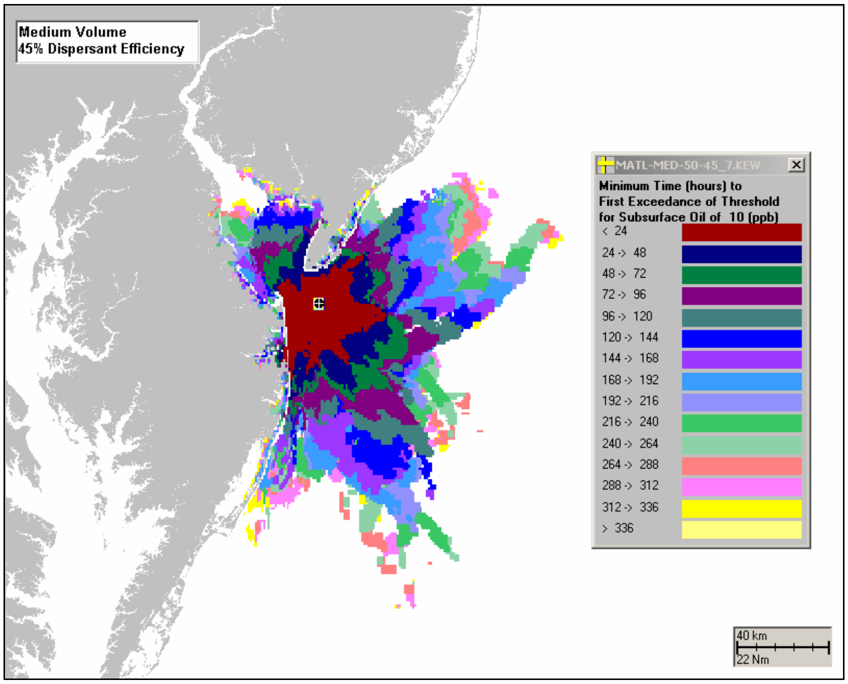

Figure B-II.1.2.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

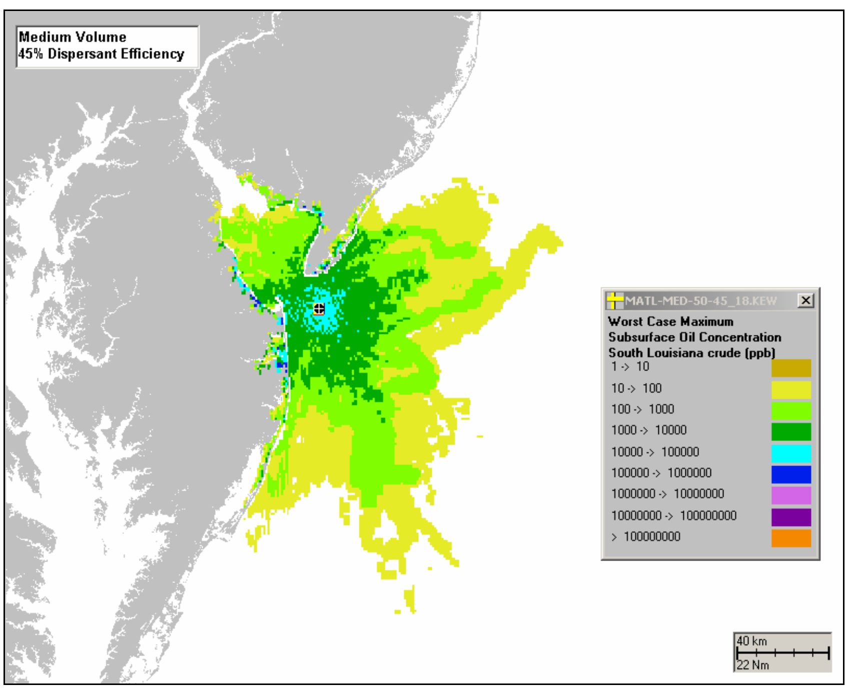

Figure B-II.1.2.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

B-II.1.2.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Medium Volume, 45% Dispersant Efficiency

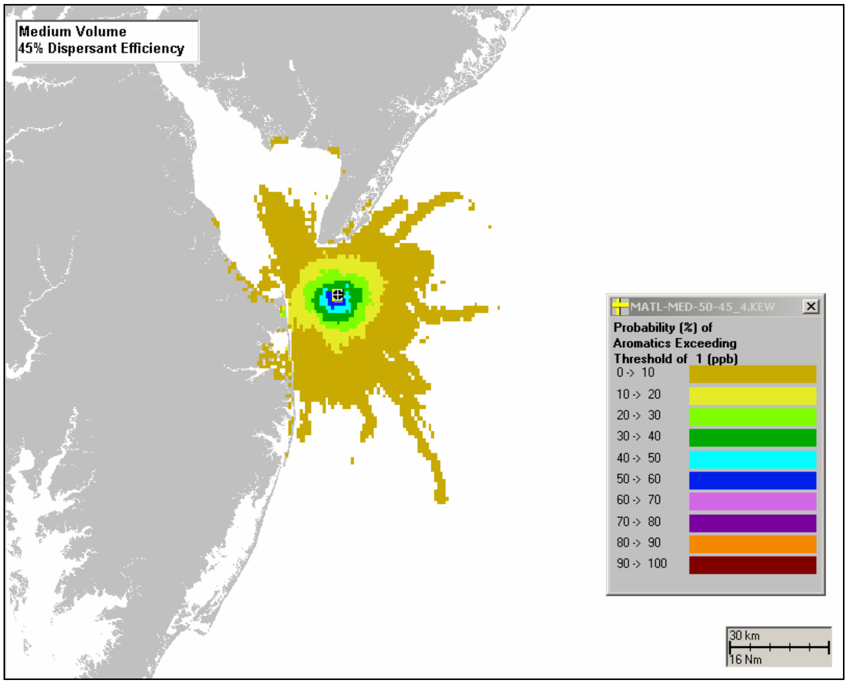

Figure B-II.1.2.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

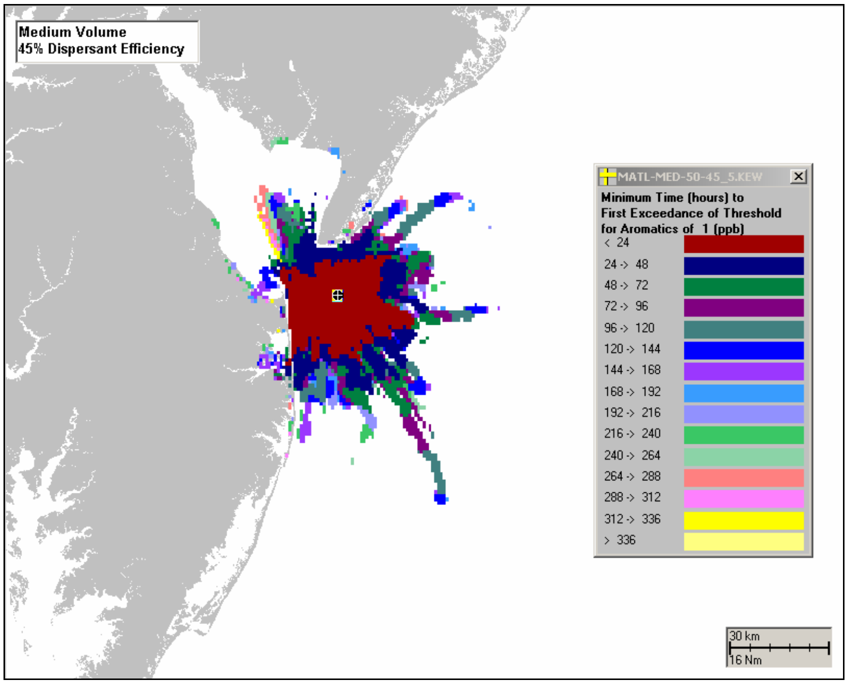

Figure B-II.1.2.4-2 Time (hrs) after spill when Dissolved Aromatic Concentrations could first exceed 1ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

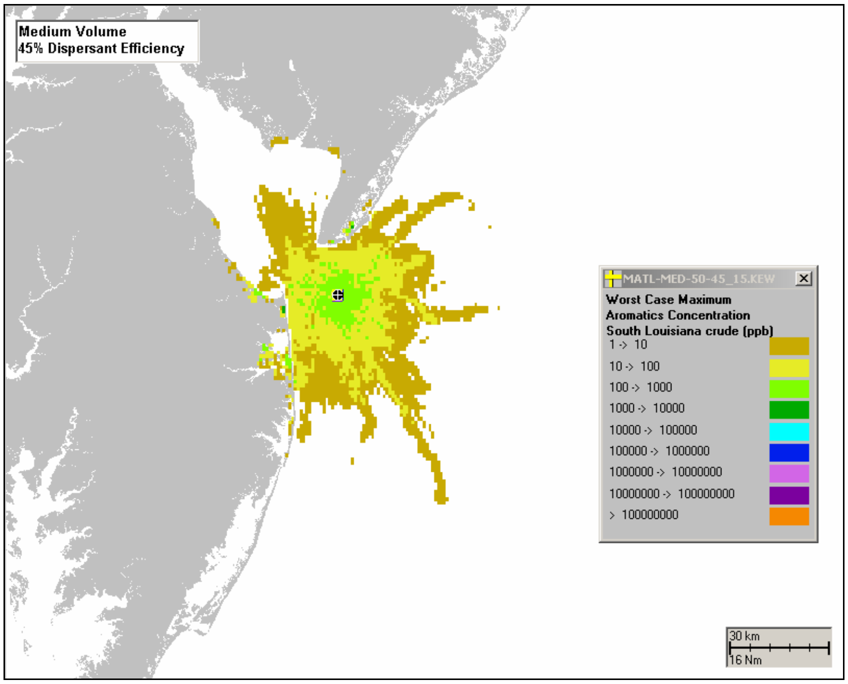

Figure B-II.1.2.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

B-II.1.2.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Medium Volume, 45% Dispersant Efficiency

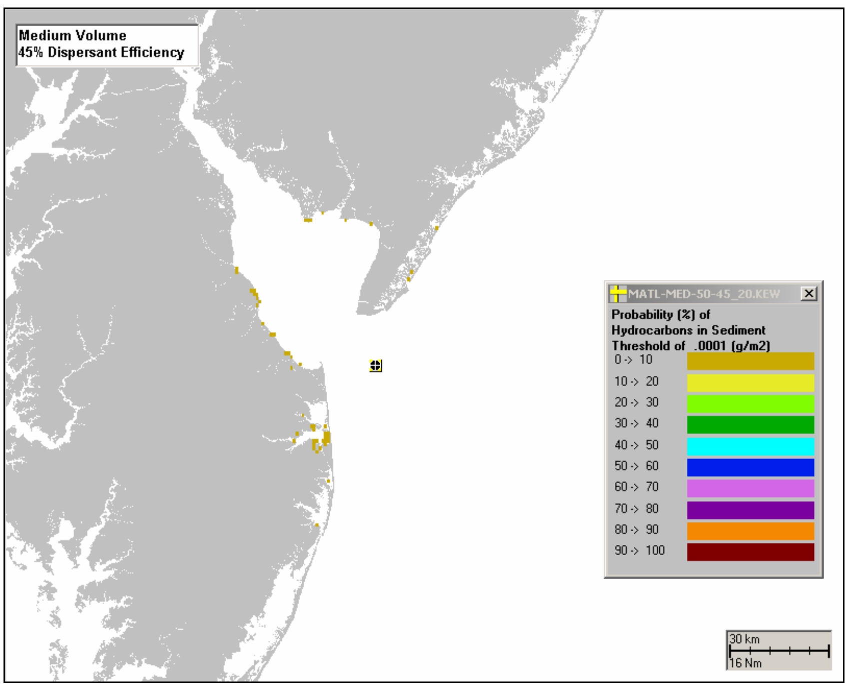

Figure B-II.1.2.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

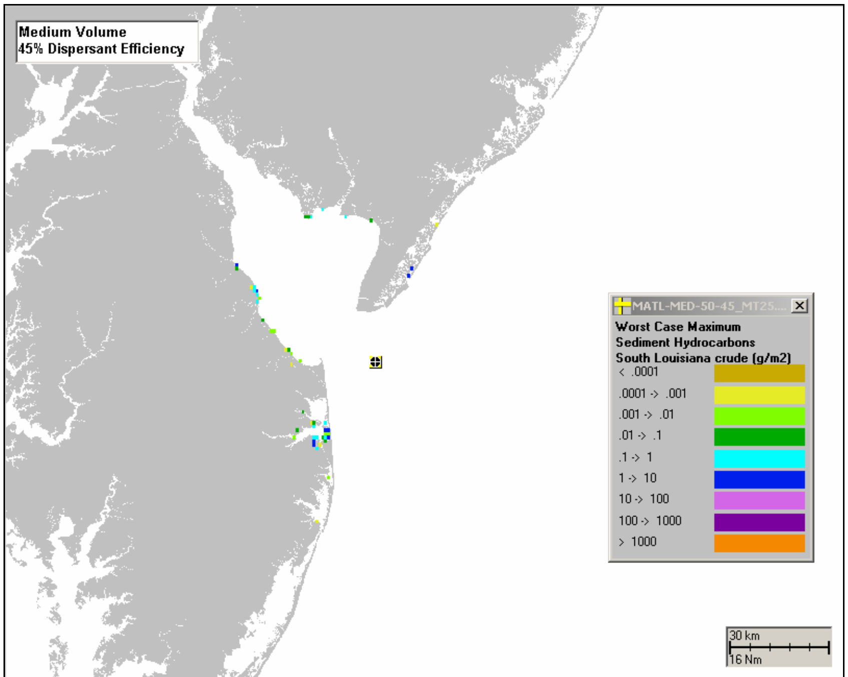

Figure B-II.1.2.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

B-II.1.2.6 Sediment pore water dissolved aromatic concentrations. Scenario: Medium Volume, 45% Dispersant Efficiency

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time and for any of the 100 runs) does not exceed threshold of 1 ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

B-II.1.3. Scenario: Medium Volume, 80% Dispersant Efficiency

B-II.1.3.1 Surface Floating Total Hydrocarbons. Scenario: Medium Volume, 80% Dispersant Efficiency.

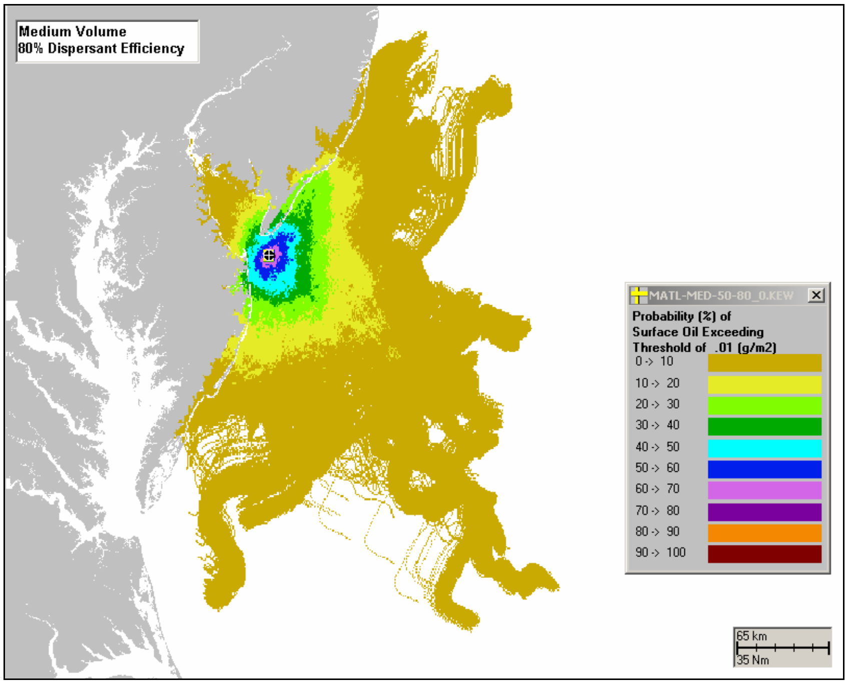

Figure B-II.1.3.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

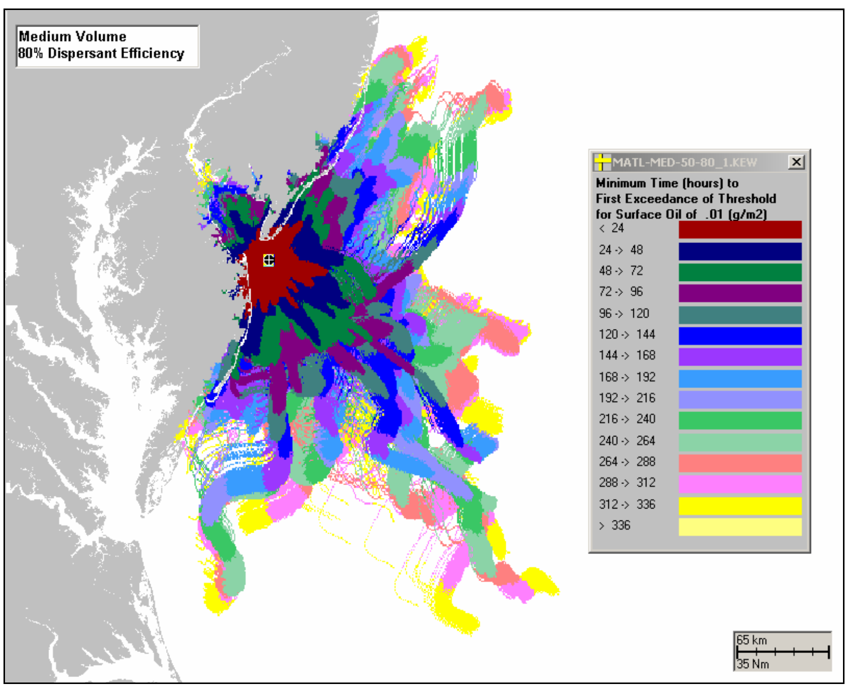

Figure B-II.1.3.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

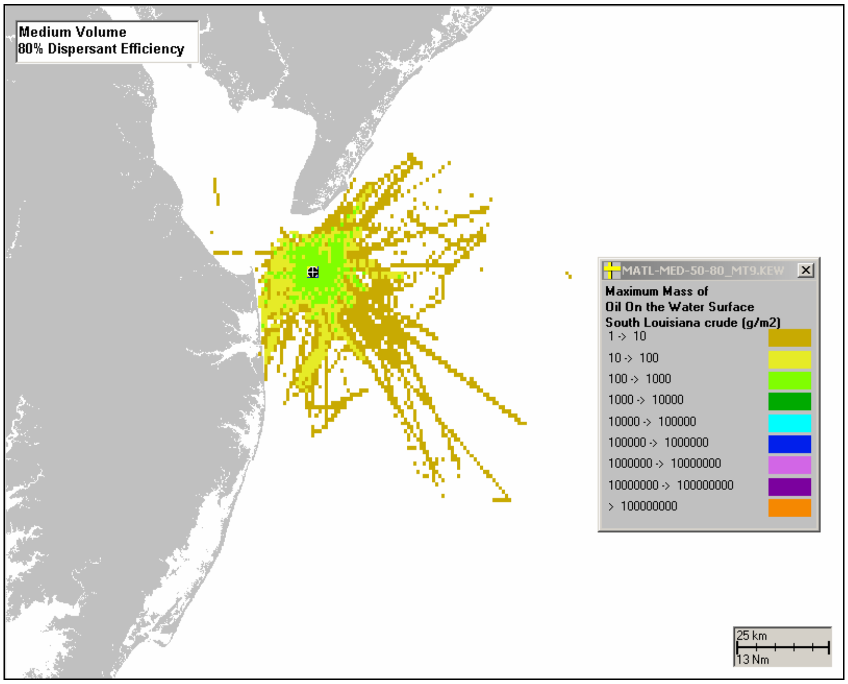

Figure B-II.1.3.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

B-II.1.3.2 Shoreline Oiled. Scenario: Medium Volume, 80% Dispersant Efficiency

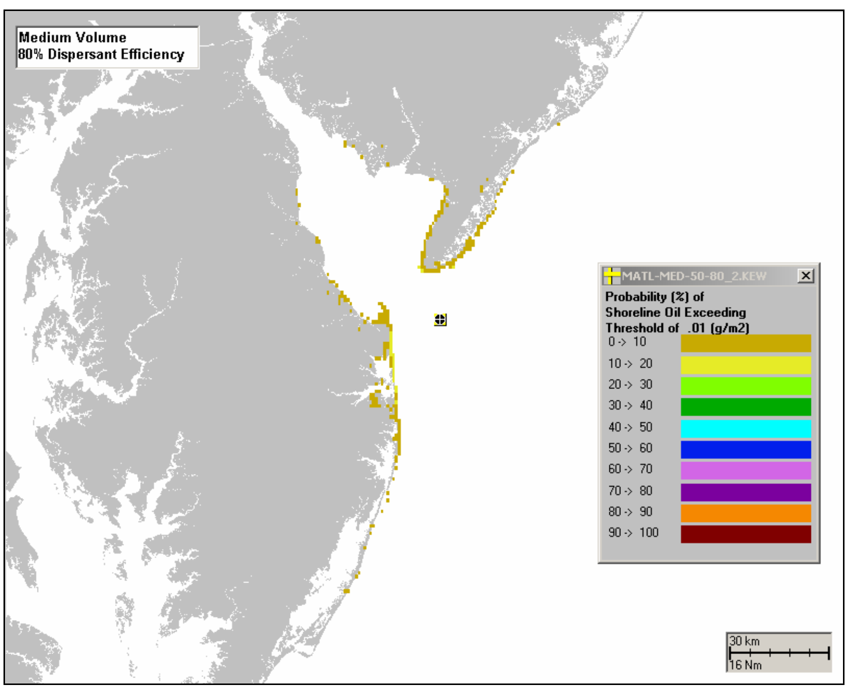

Figure B-II.1.3.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

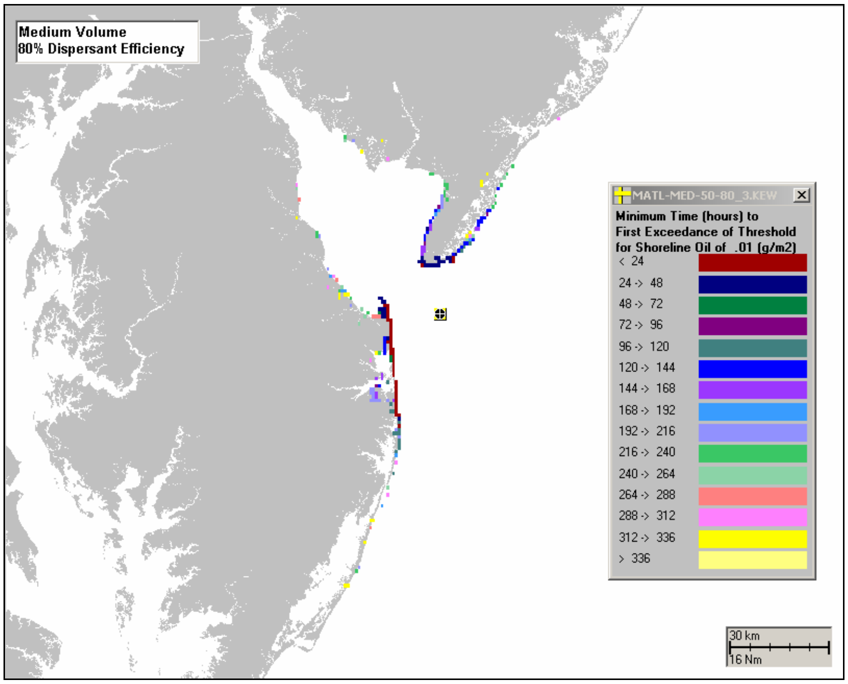

Figure B-II.1.3.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

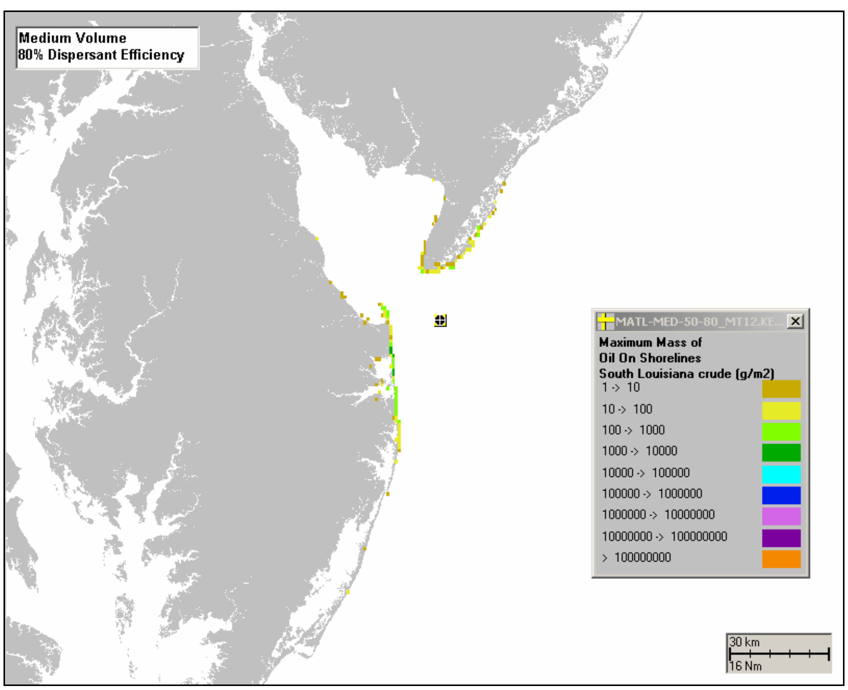

Figure B-II.1.3.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

B-II.1.3.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Medium Volume, 80% Dispersant Efficiency

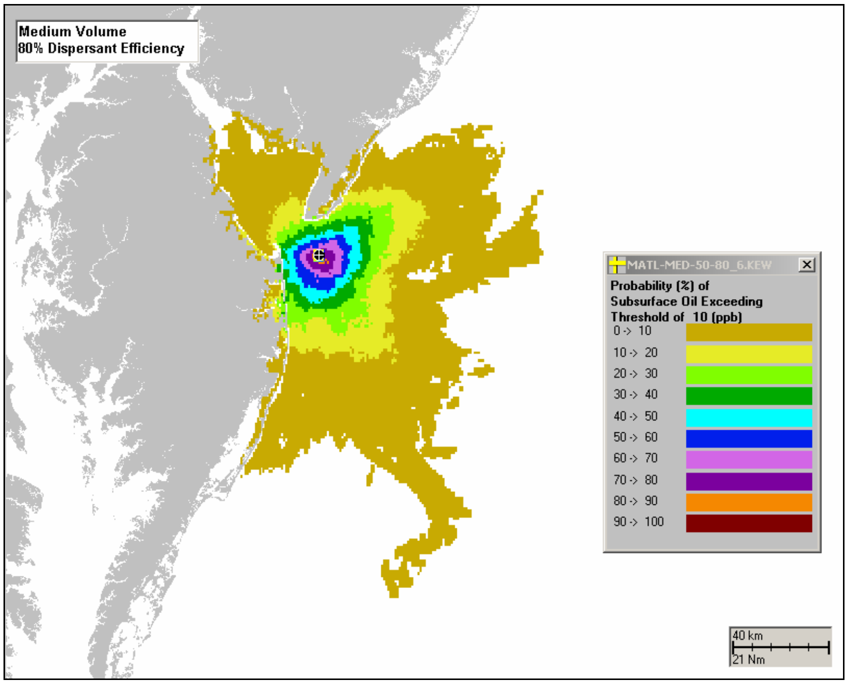

Figure B-II.1.3.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

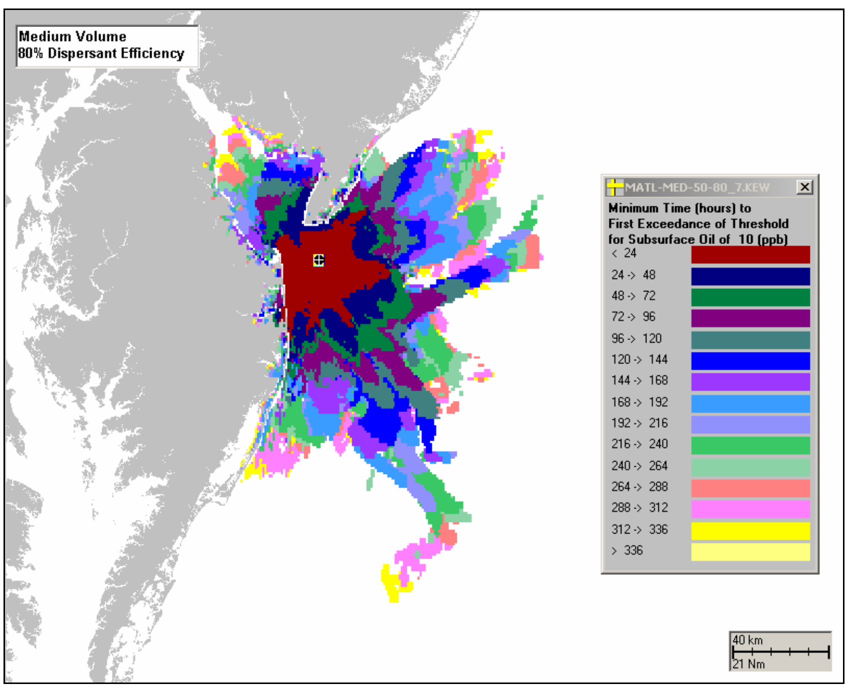

Figure B-II.1.3.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

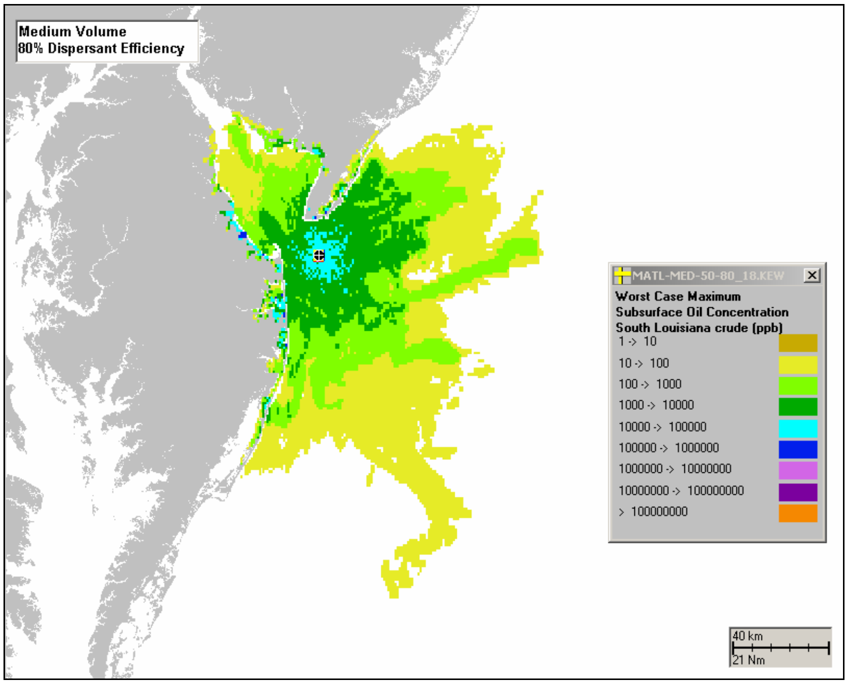

Figure B-II.1.3.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

B-II.1.3.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Medium Volume, 80% Dispersant Efficiency

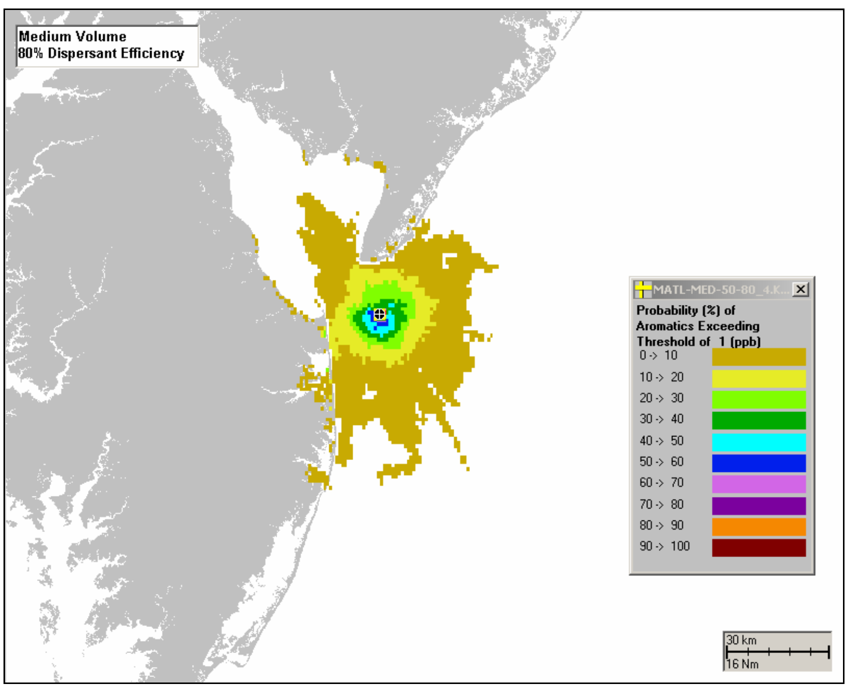

Figure B-II.1.3.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

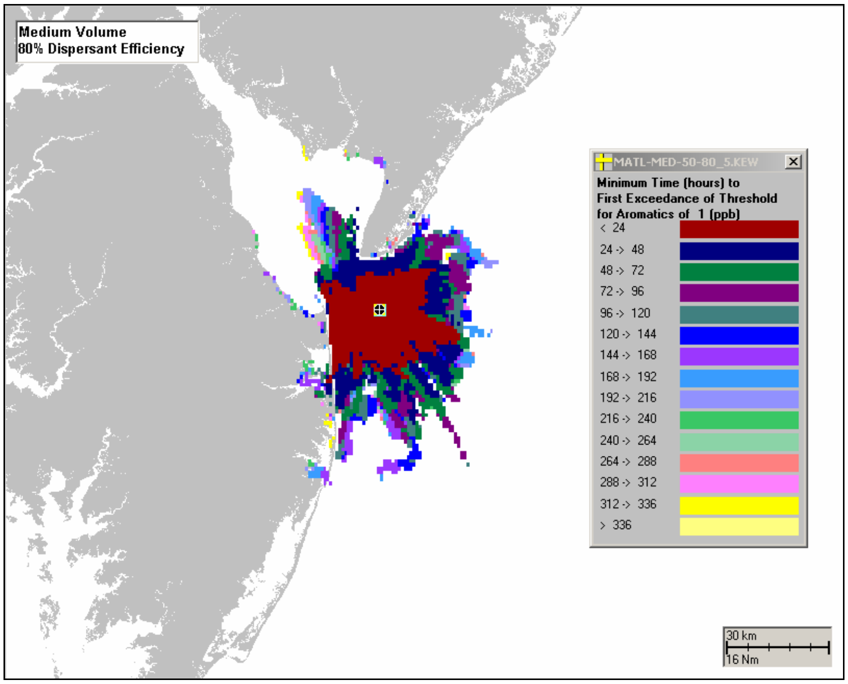

Figure B-II.1.3.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

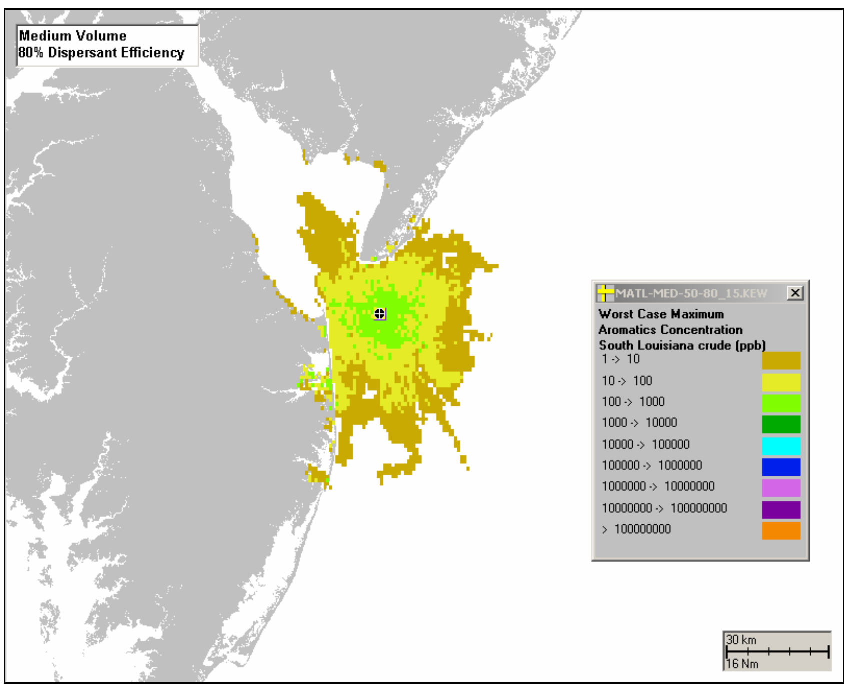

Figure B-II.1.3.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

B-II.1.3.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Medium Volume, 80% Dispersant Efficiency

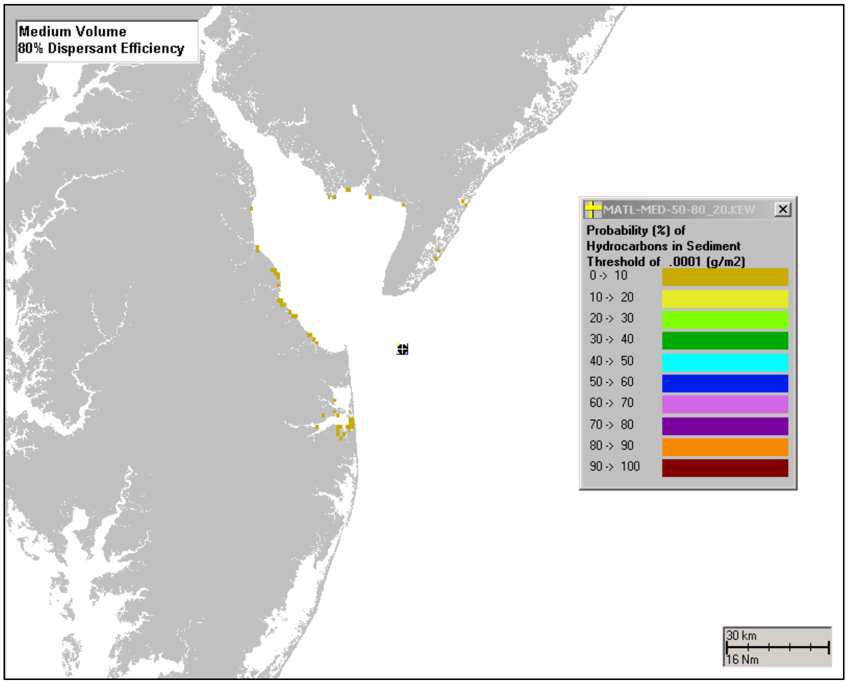

Figure B-II.1.3.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

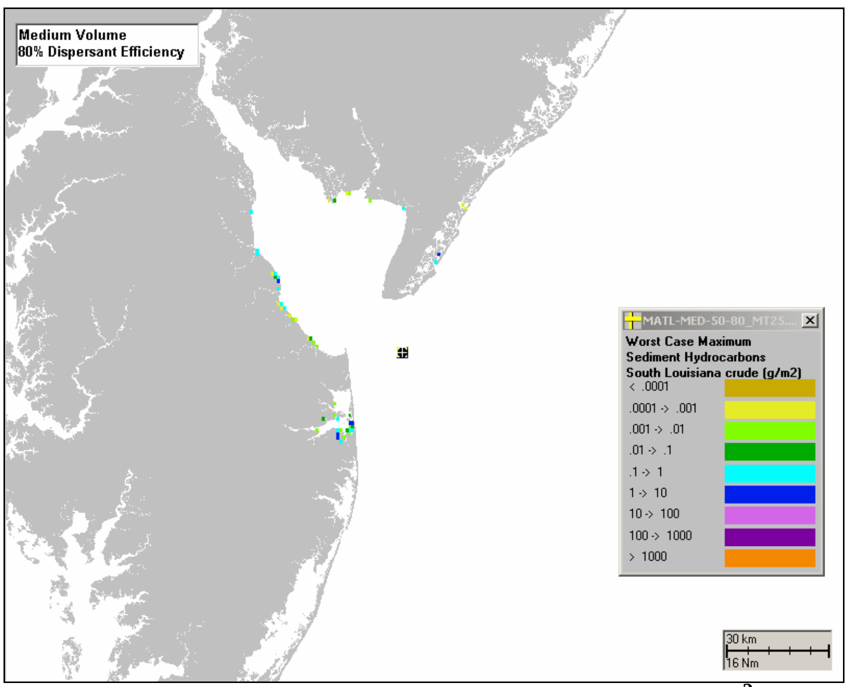

Figure B-II.1.3.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

B-II.1.3.6 Sediment pore water dissolved aromatic concentrations. Scenario: Medium Volume, 80% Dispersant Efficiency

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time and for any of the 100 runs) does not exceed threshold of 1 ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

B-II.1.4. Scenario: Large Volume, No Dispersant

B-II.1.4.1 Surface Floating Total Hydrocarbons. Scenario: Large Volume, No Dispersant

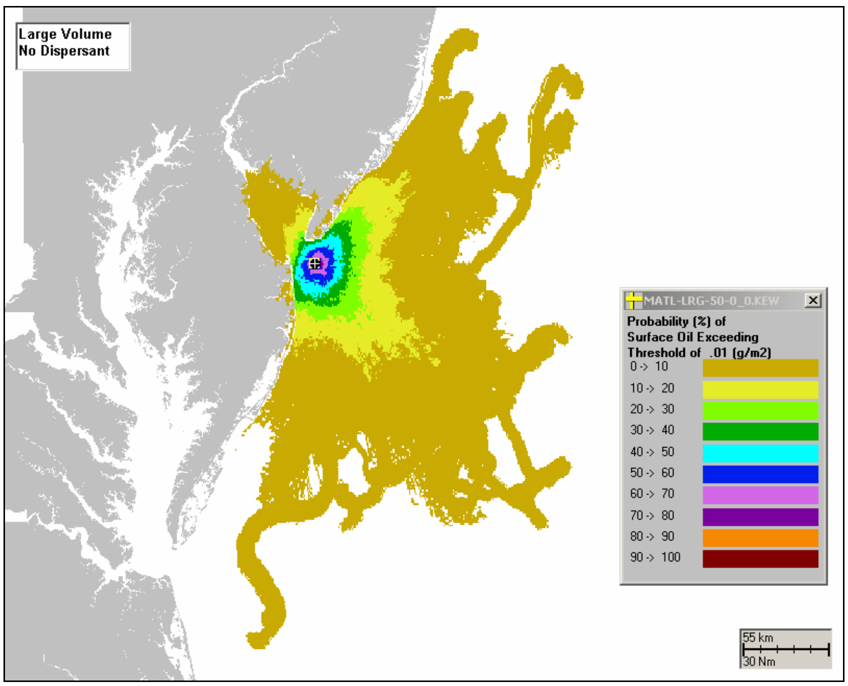

Figure B-II.1.4.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Large Volume, No Dispersant.

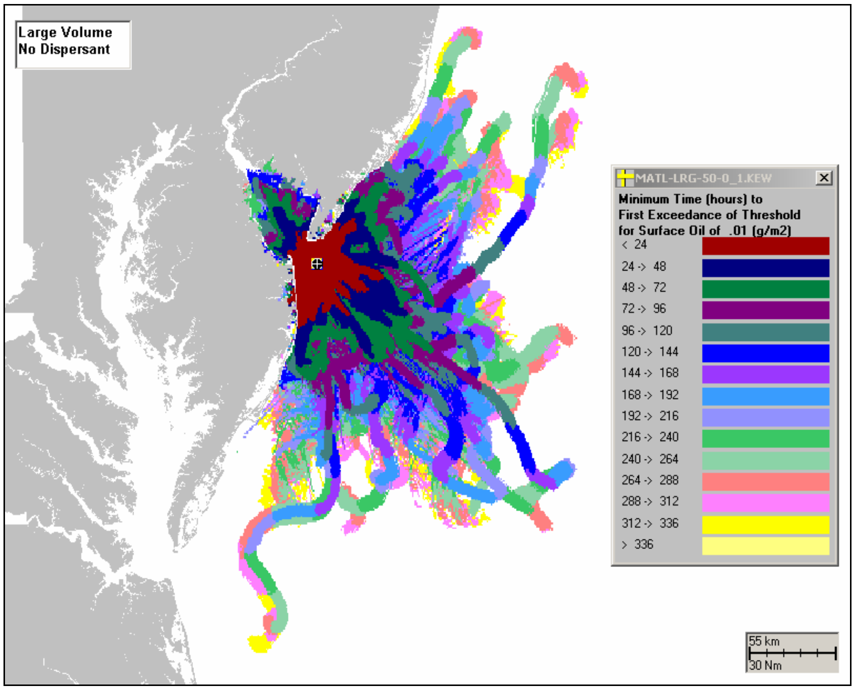

Figure B-II.1.4.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Large Volume, No Dispersant.

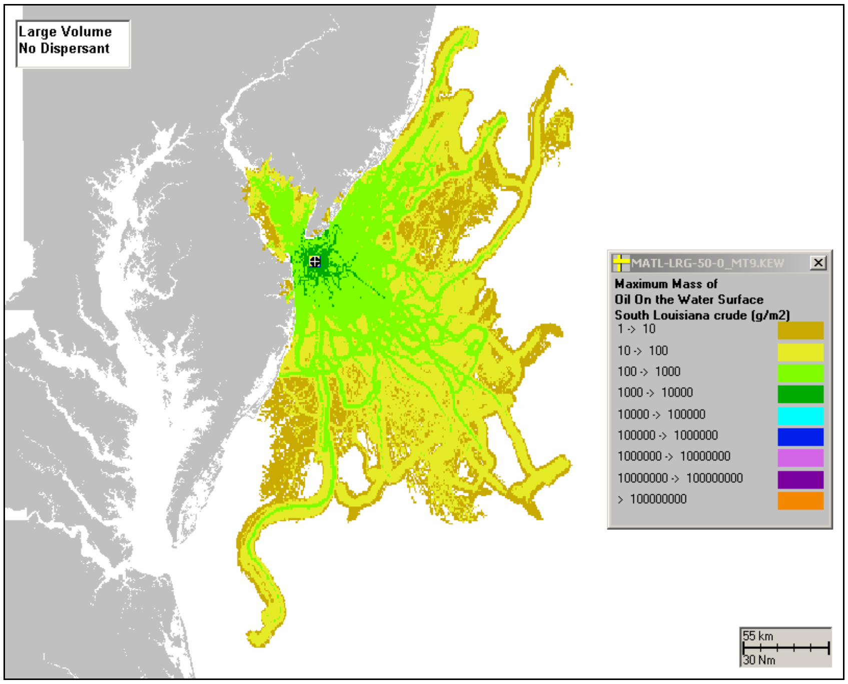

Figure B-II.1.4.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

B-II.1.4.2 Shoreline Oiled. Scenario: Large Volume, No Dispersant

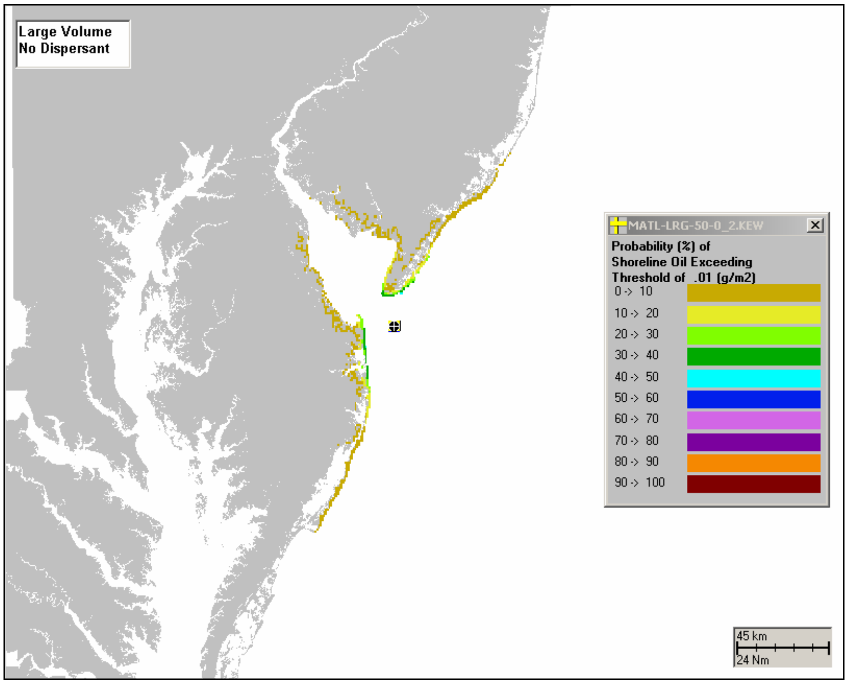

Figure B-II.1.4.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Large Volume, No Dispersant.

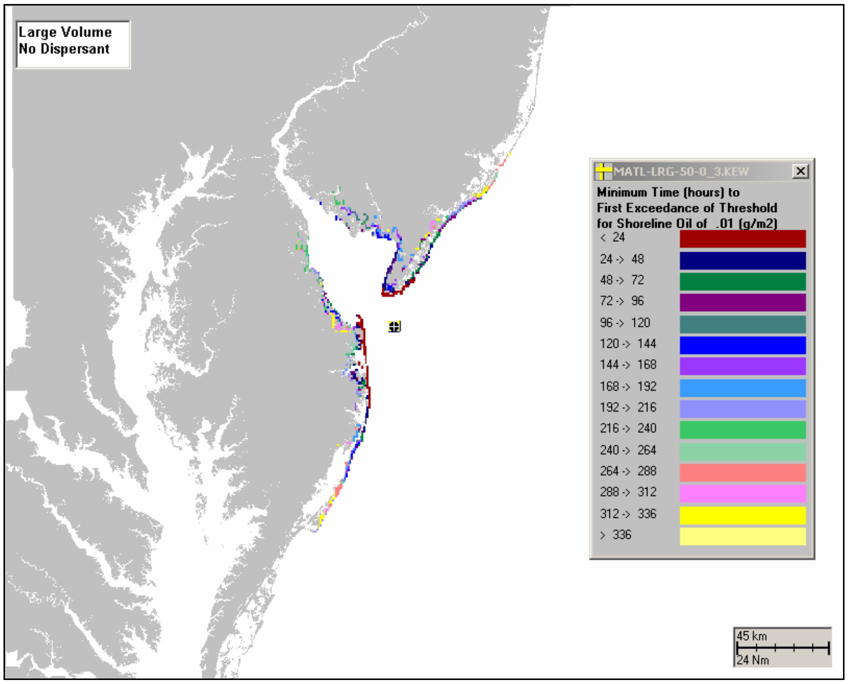

Figure B-II.1.4.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Large Volume, No Dispersant.

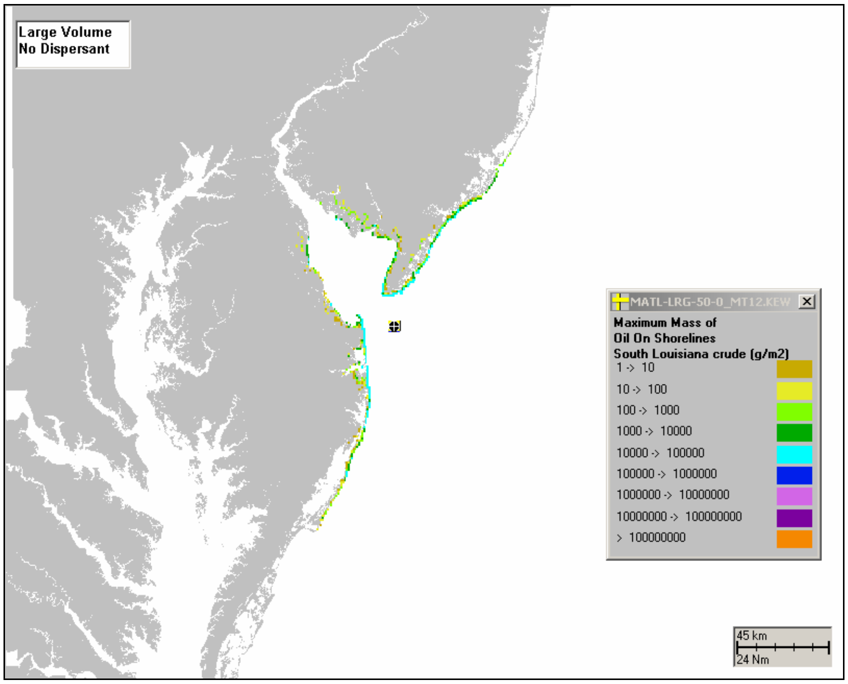

Figure B-II.1.4.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

B-II.1.4.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Large Volume, No Dispersant

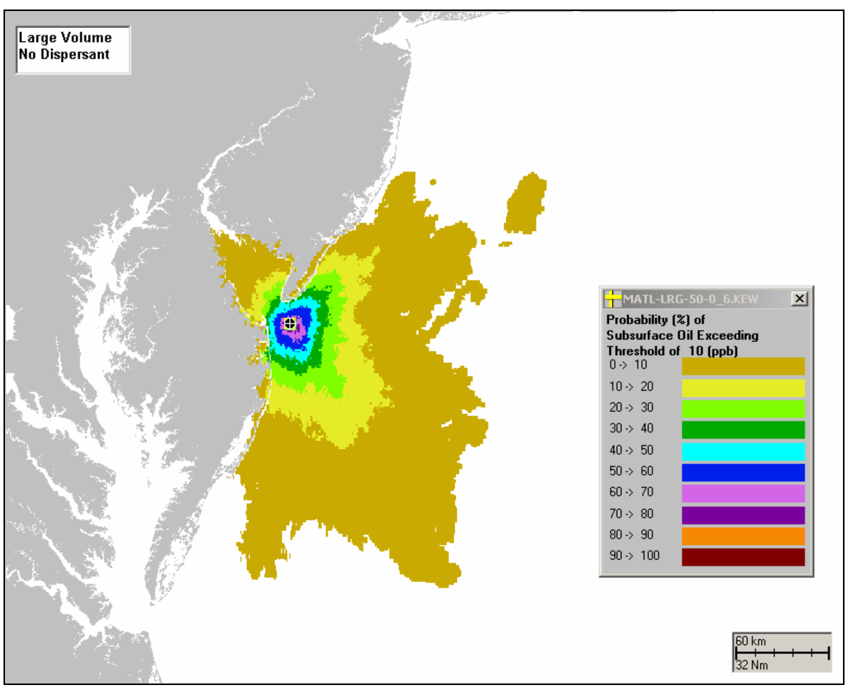

Figure B-II.1.4.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Large Volume, No Dispersant.

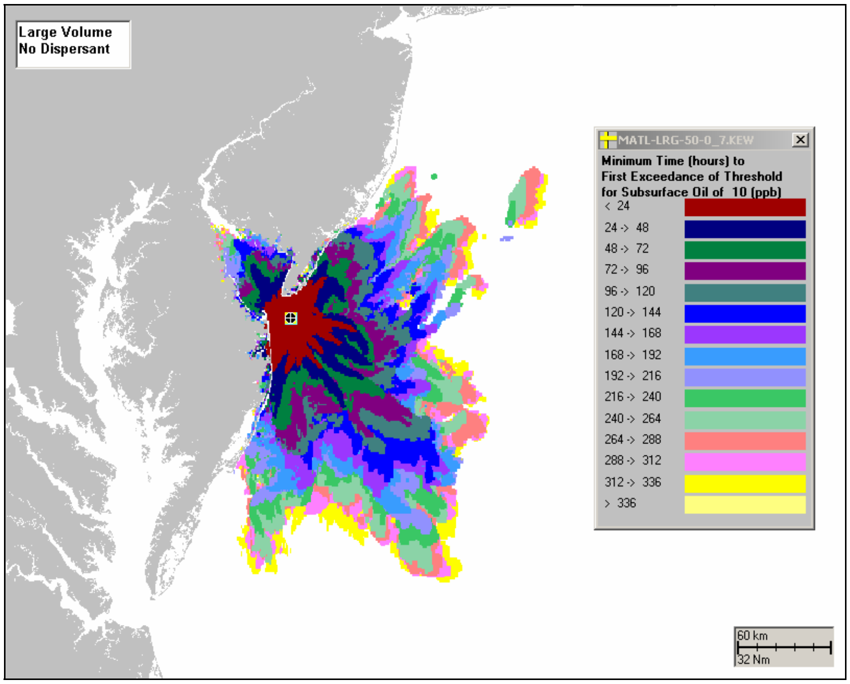

Figure B-II.1.4.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Large Volume, No Dispersant.

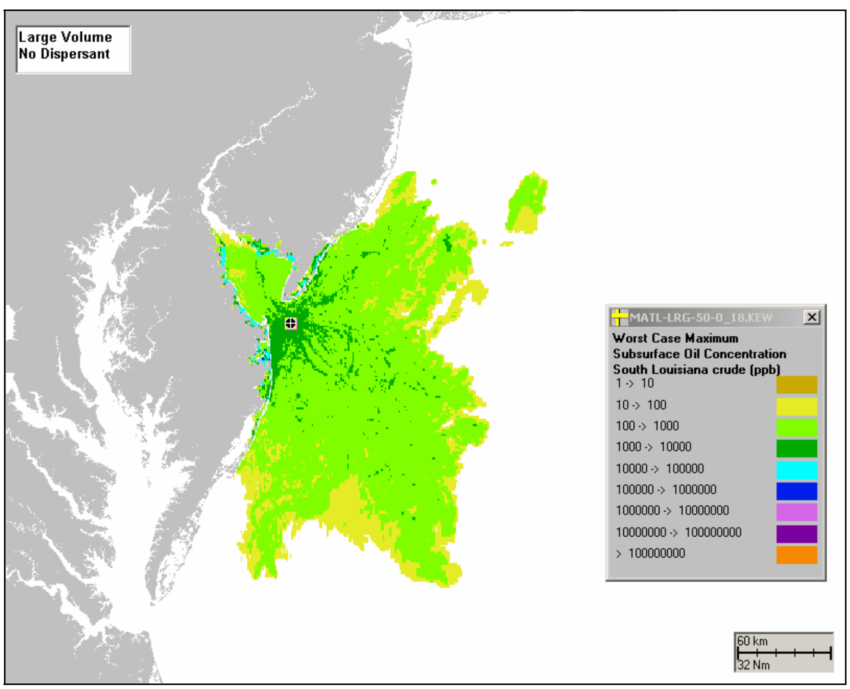

Figure B-II.1.4.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

B-II.1.4.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Large Volume, No Dispersant

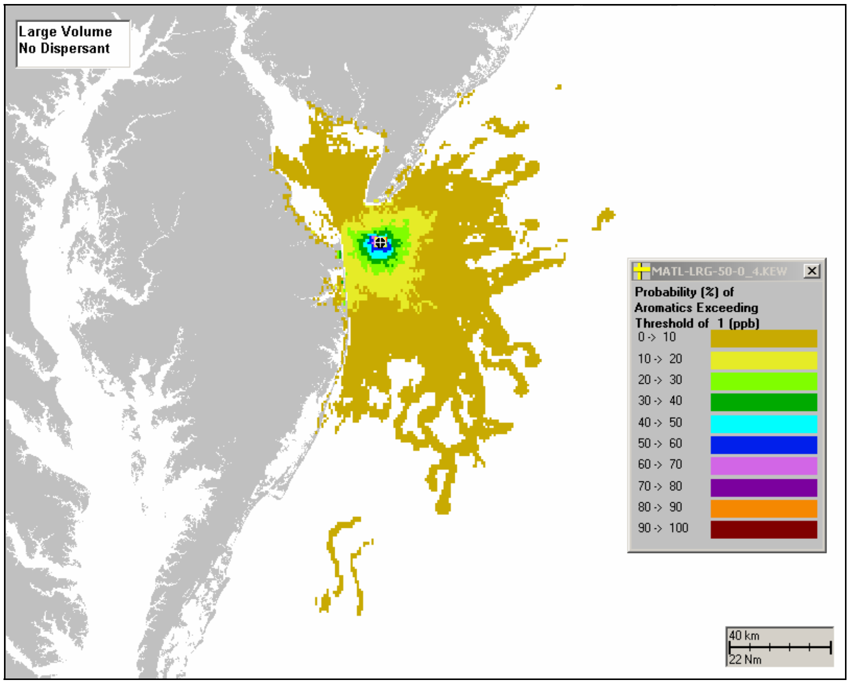

Figure B-II.1.4.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, No Dispersant.

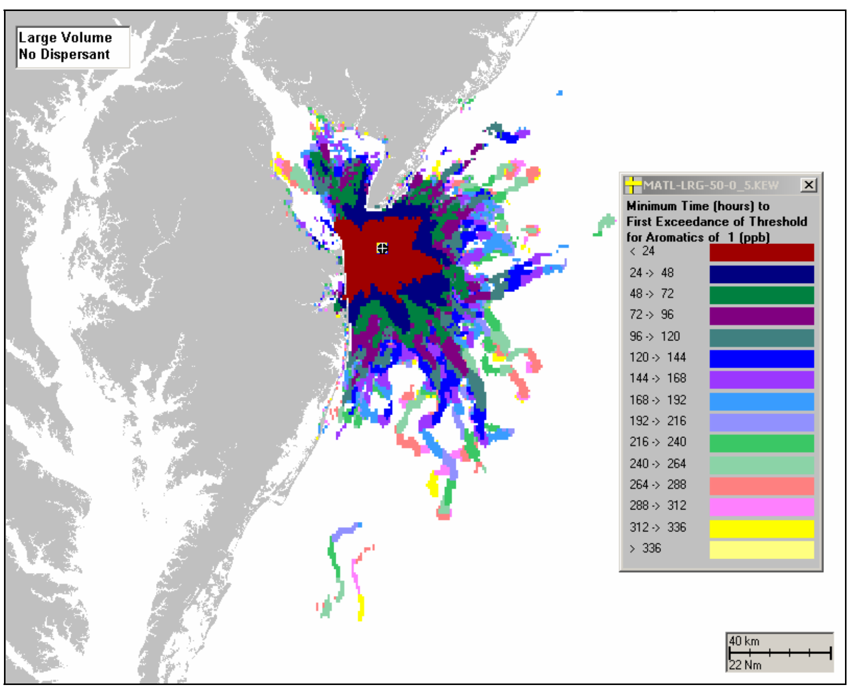

Figure B-II.1.4.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Large Volume, No Dispersant.

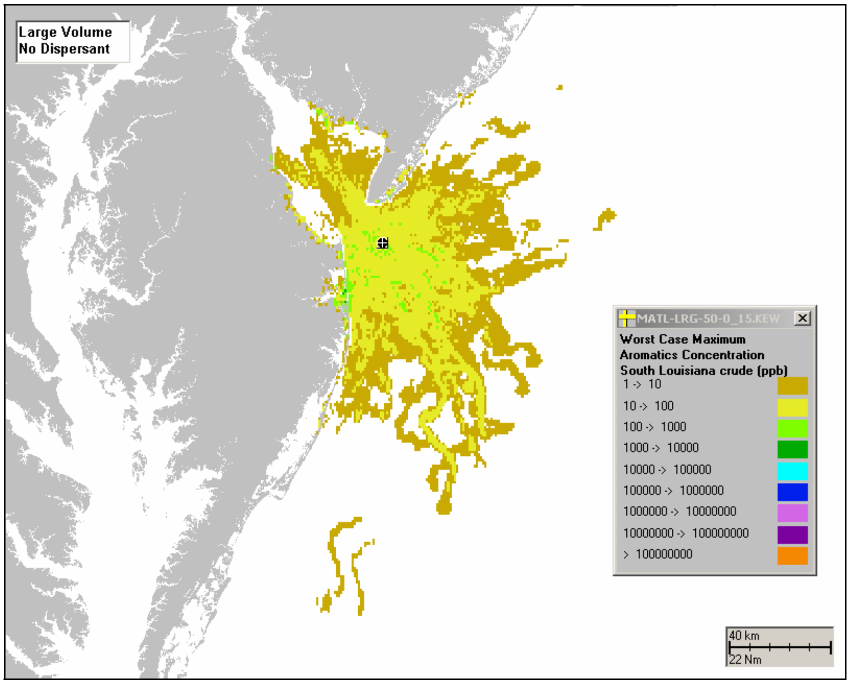

Figure B-II.1.4.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

B-II.1.4.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Large Volume, No Dispersant

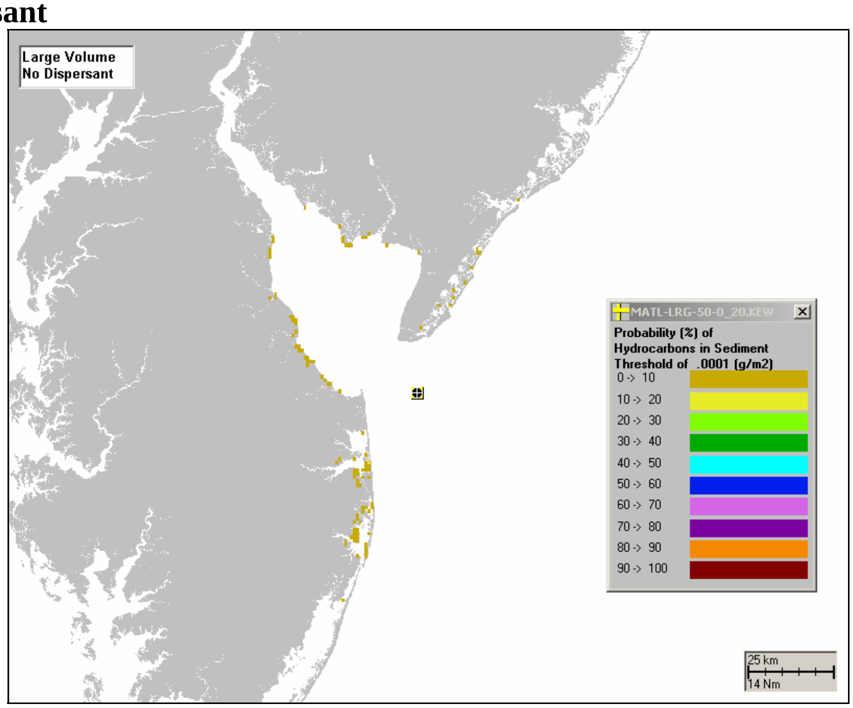

Figure B-II.1.4.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Large Volume, No Dispersant.

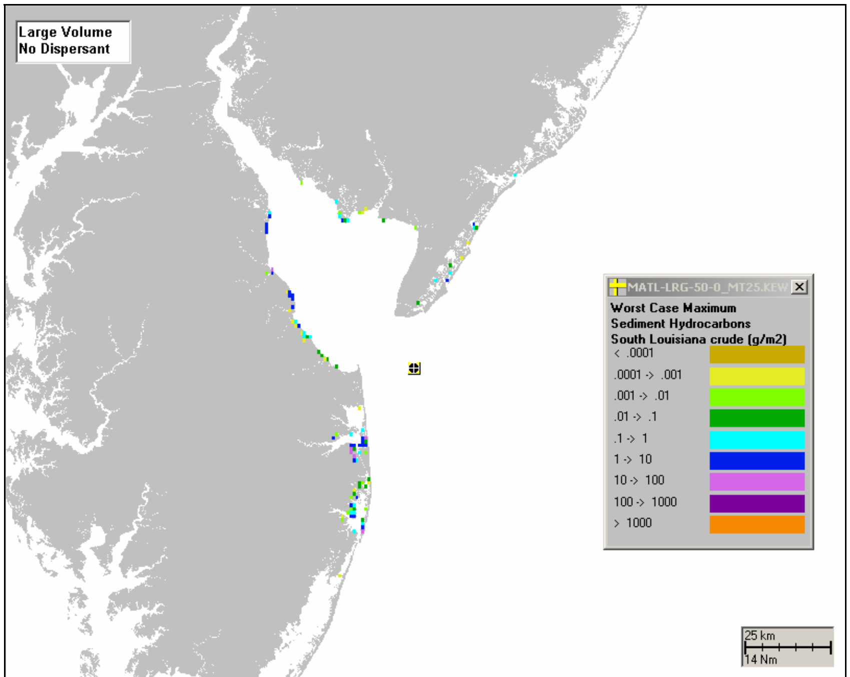

Figure B-II.1.4.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

B-II.1.4.6 Sediment pore water dissolved aromatic concentrations. Scenario: Large Volume, No Dispersant

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time and for any of the 100 runs) does not exceed threshold of 1 ppb. Scenario: Large Volume, No Dispersant.

B-II.1.5. Scenario: Large Volume, 45% Dispersant Efficiency

B-II.1.5.1 Surface Floating Total Hydrocarbons. Scenario: Large Volume, 45% Dispersant Efficiency

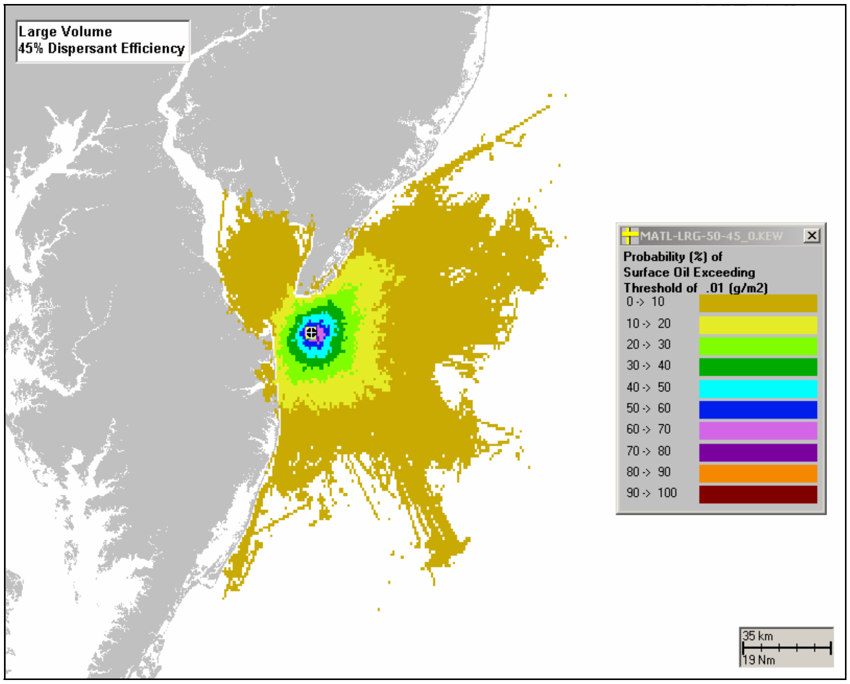

Figure B-II.1.5.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

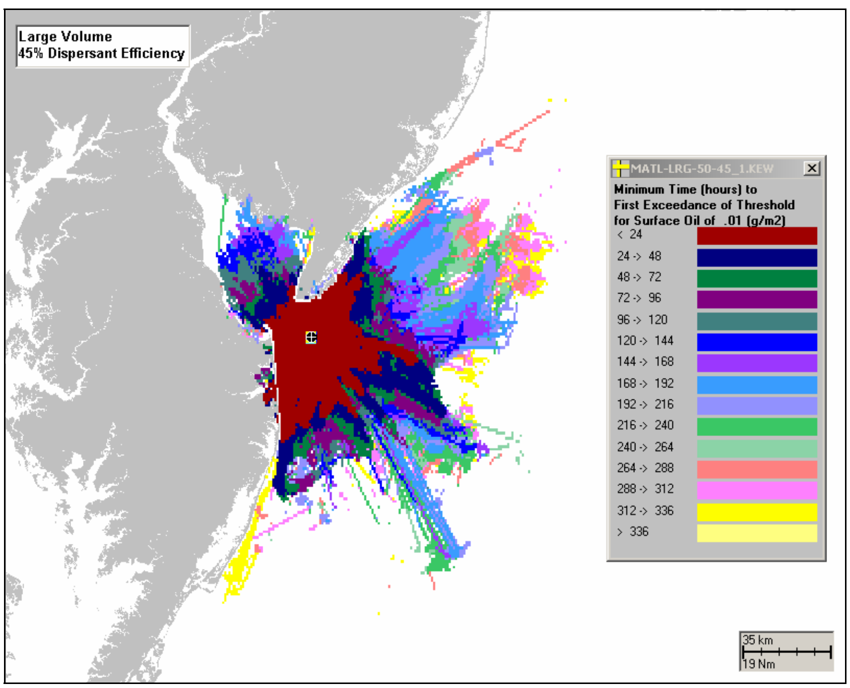

Figure B-II.1.5.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

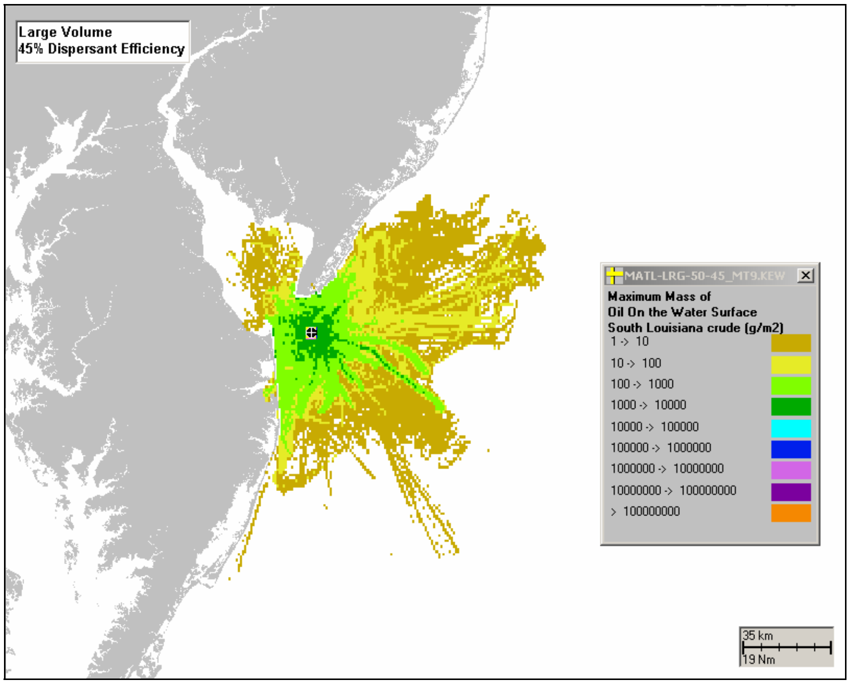

Figure B-II.1.5.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

B-II.1.5.2 Shoreline Oiled. Scenario: Large Volume, 45% Dispersant Efficiency

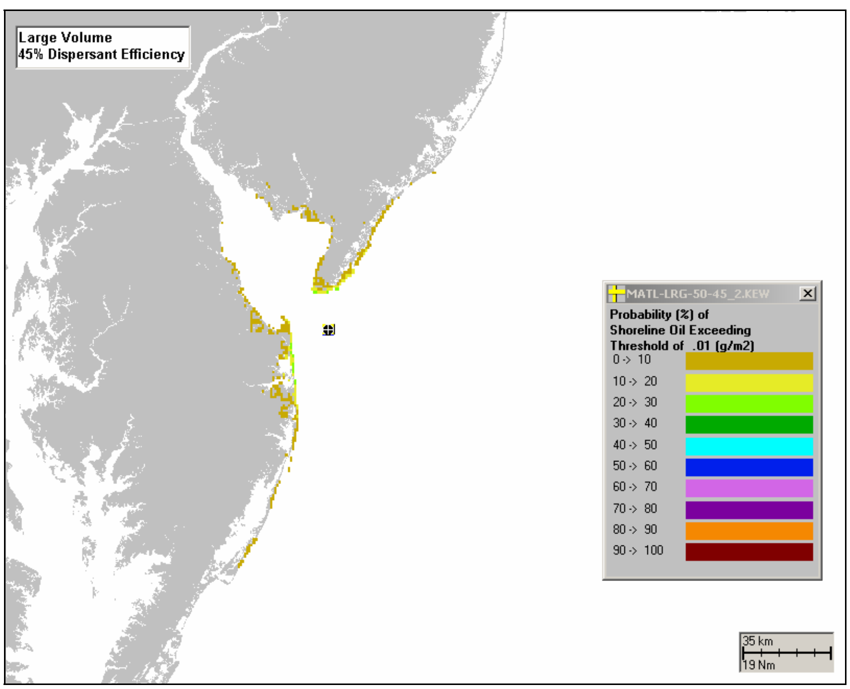

Figure B-II.1.5.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

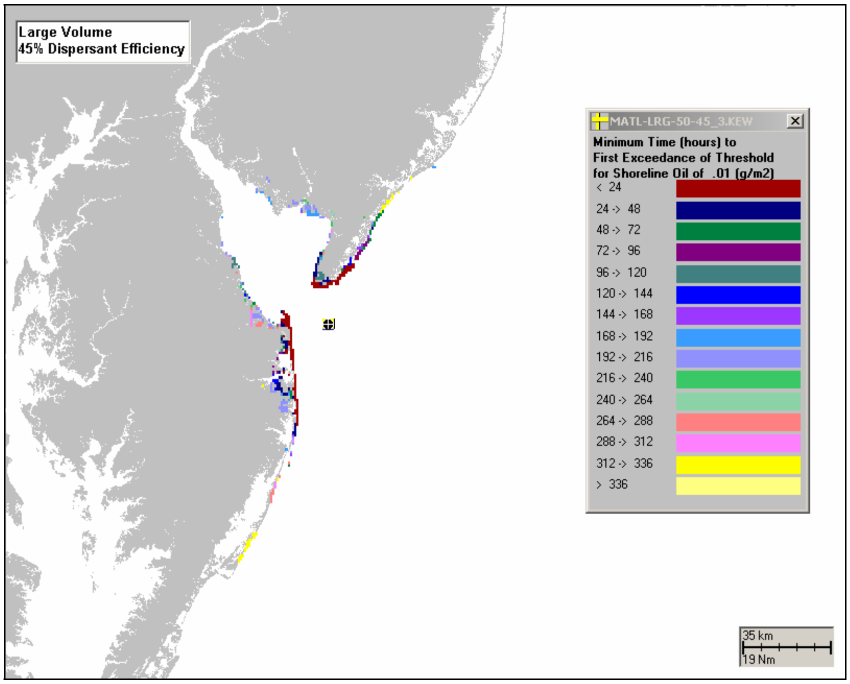

Figure B-II.1.5.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

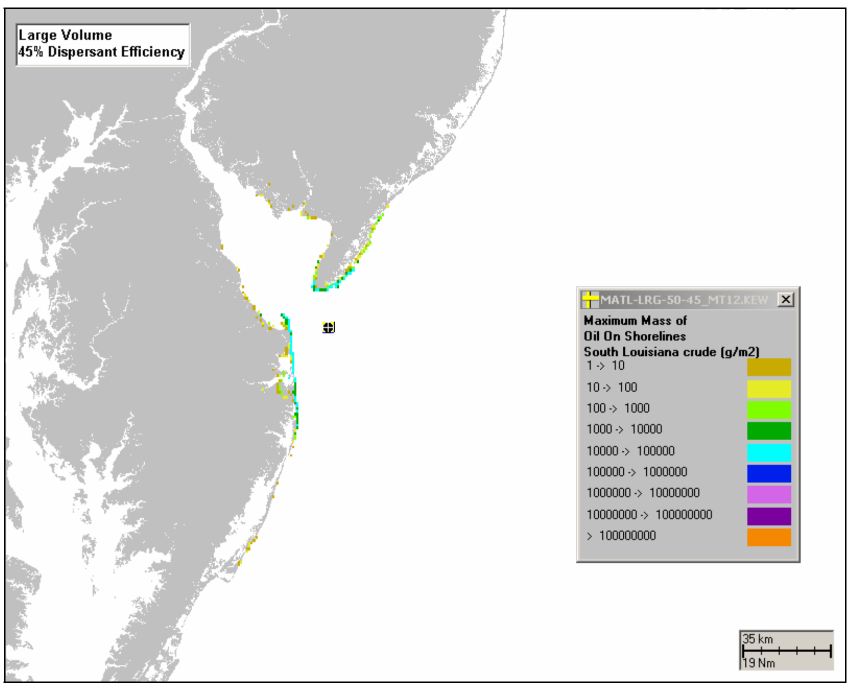

Figure B-II.1.5.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

B-II.1.5.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Large Volume, 45% Dispersant Efficiency

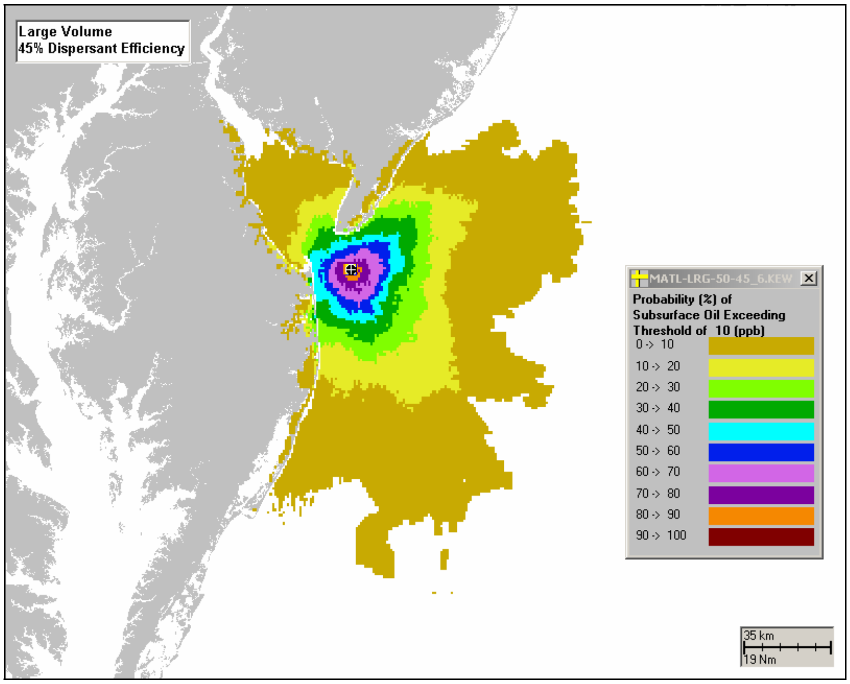

Figure B-II.1.5.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

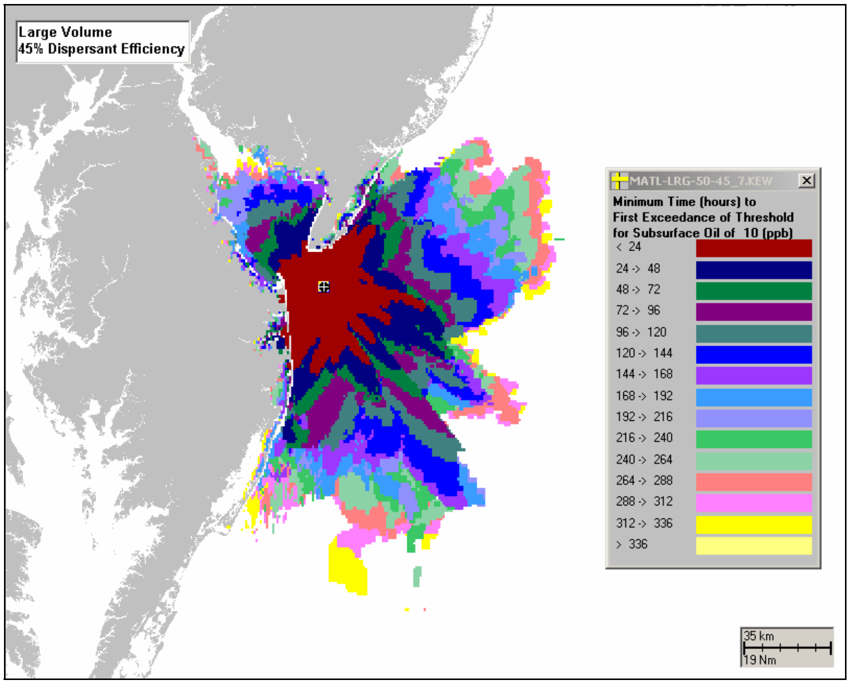

Figure B-II.1.5.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

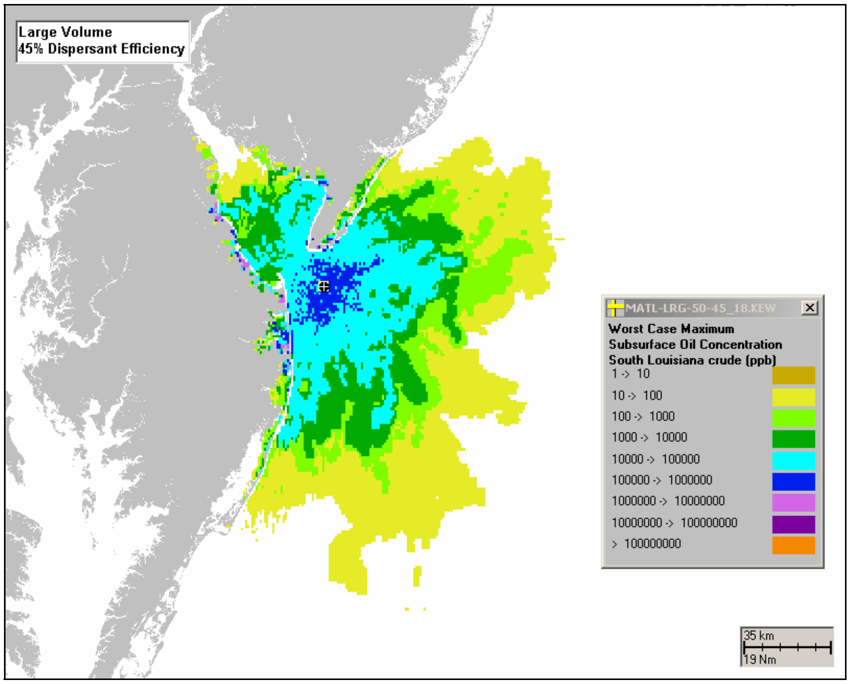

Figure B-II.1.5.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

B-II.1.5.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Large Volume, 45% Dispersant Efficiency

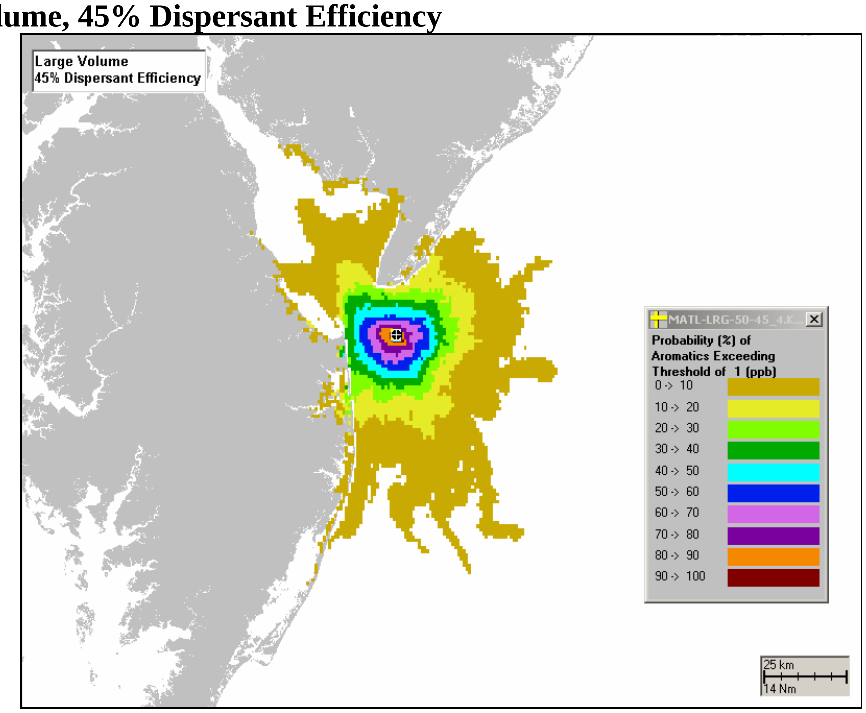

Figure B-II.1.5.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

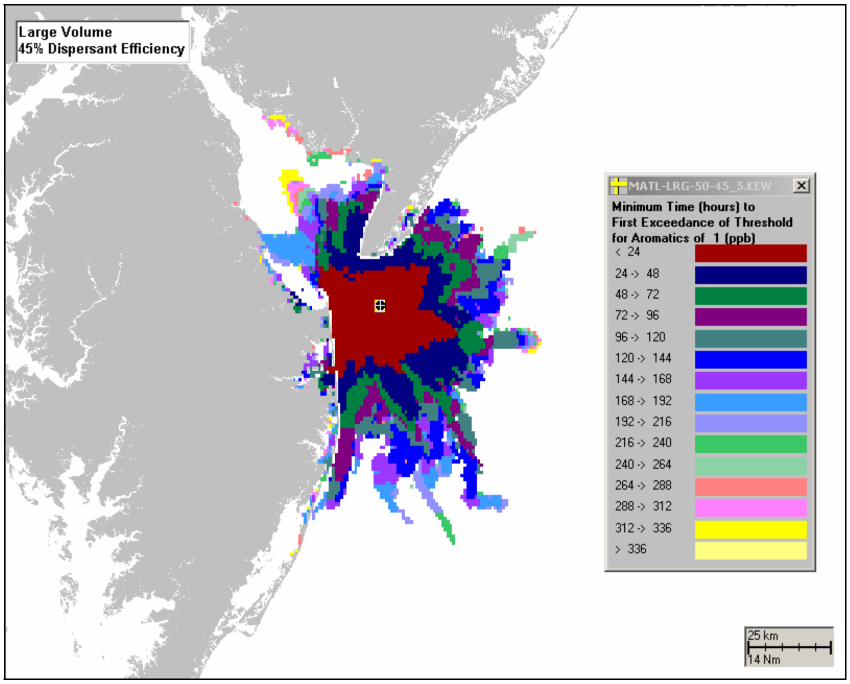

Figure B-II.1.5.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

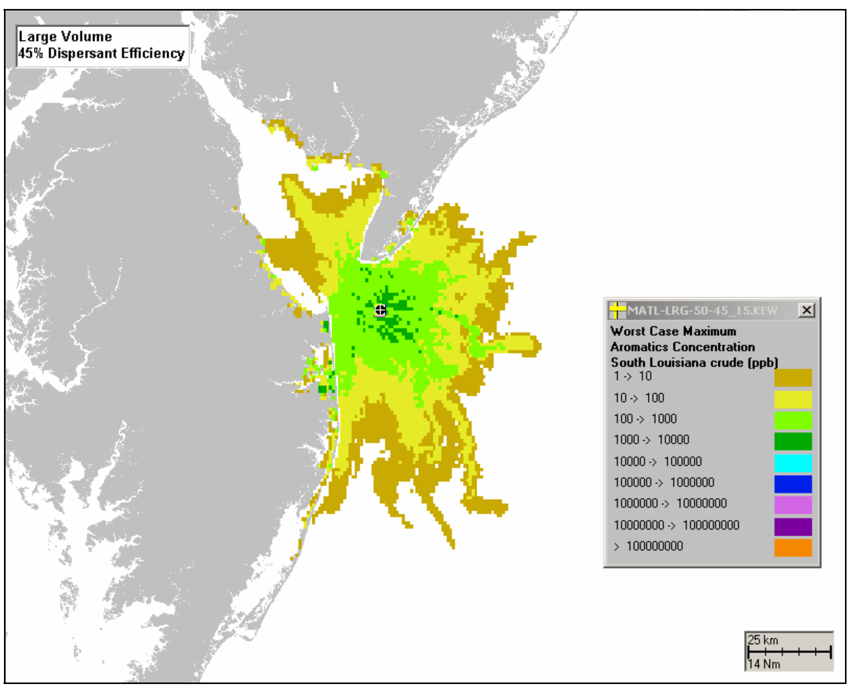

Figure B-II.1.5.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

B-II.1.5.5 Sediment exposure to total hydrocarbons (g/m²). Scenario: Large Volume, 45% Dispersant Efficiency

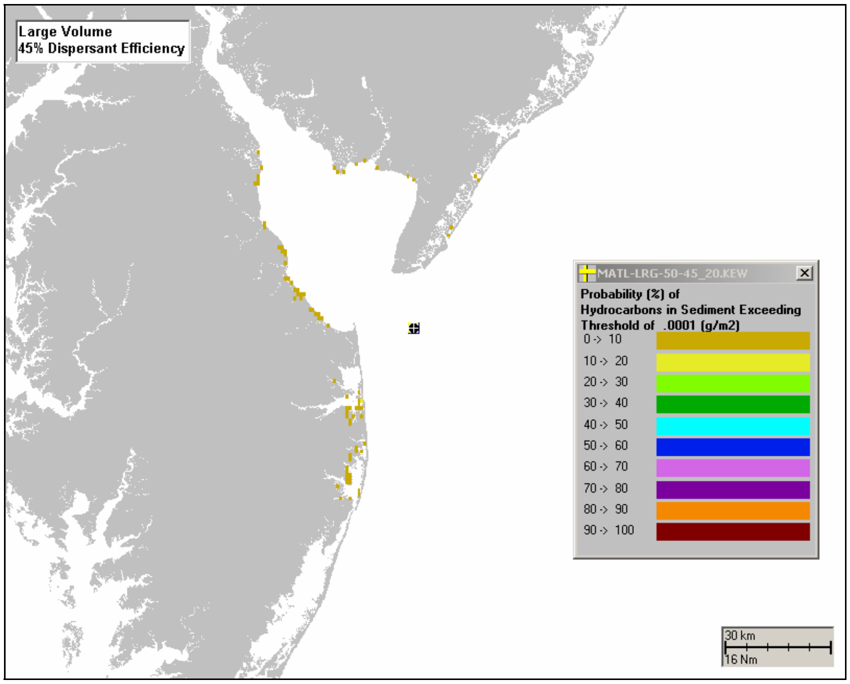

Figure B-II.1.5.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

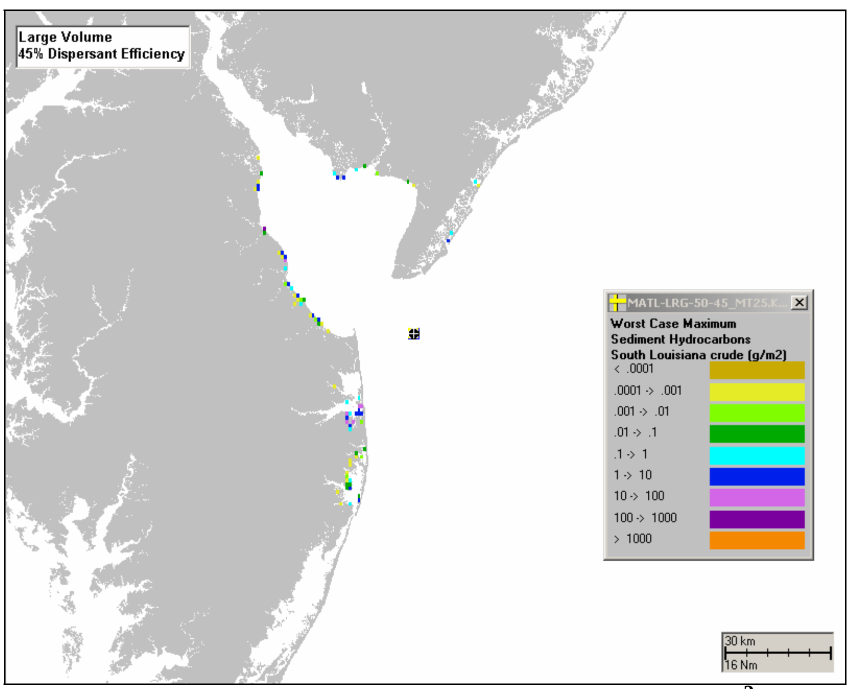

Figure B-II.1.5.5-2 Sediment exposure to total hydrocarbons (g/m²) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

B-II.1.5.6 Sediment pore water dissolved aromatic concentrations. Scenario: Large Volume, 45% Dispersant Efficiency

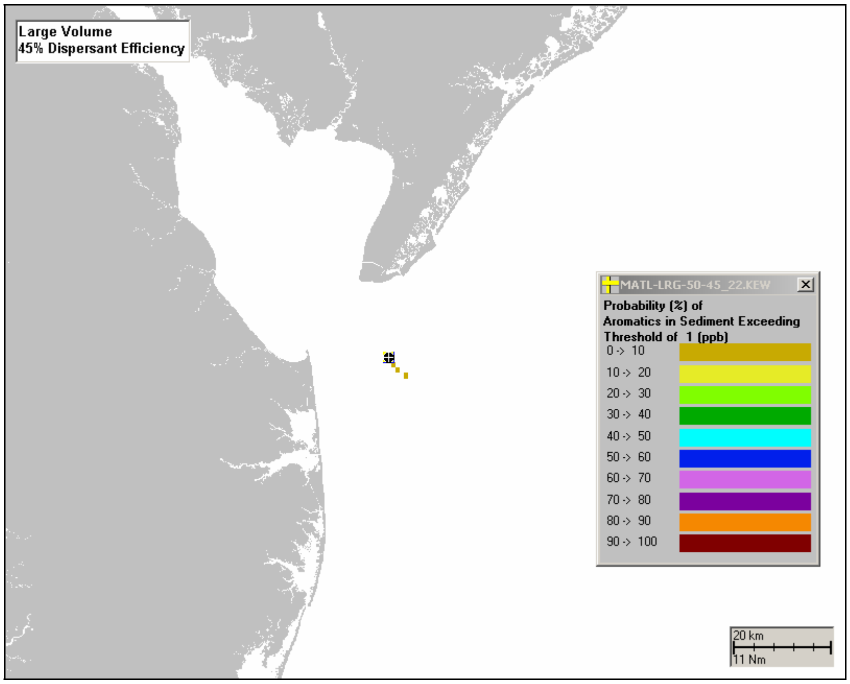

Figure B-II.1.5.6-1 Probability (%) of sediment pore water concentrations exceeding 1ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

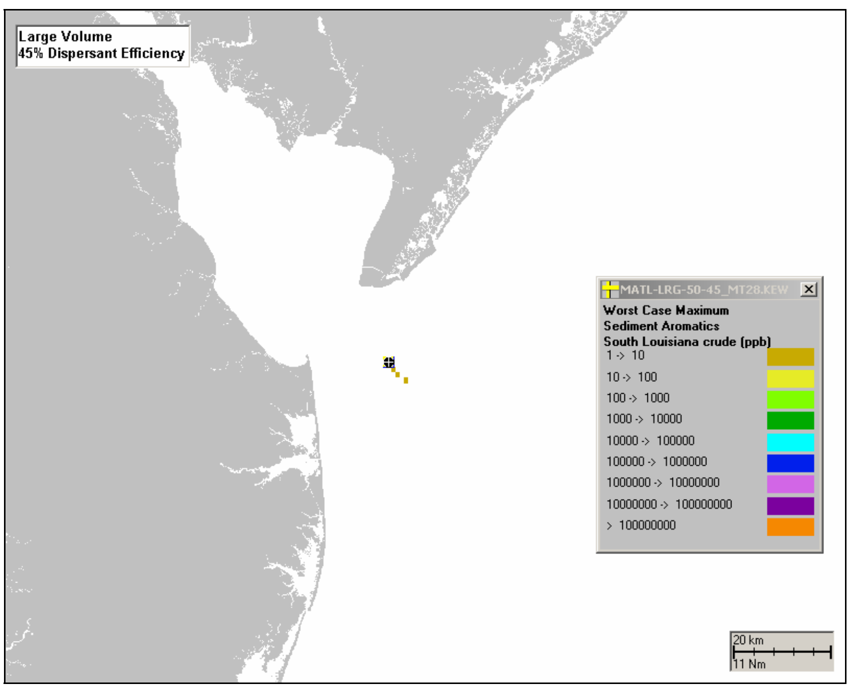

Figure B-II.1.5.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

B-II.1.6. Scenario: Large Volume, 80% Dispersant Efficiency

B-II.1.6.1 Surface Floating Total Hydrocarbons. Scenario: Large Volume, 80% Dispersant Efficiency.

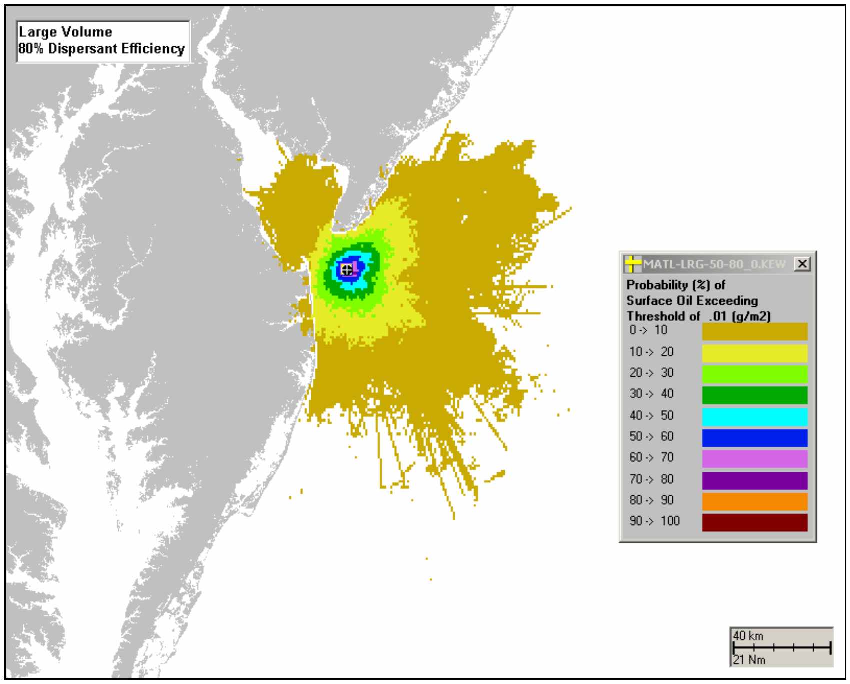

Figure B-II.1.6.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

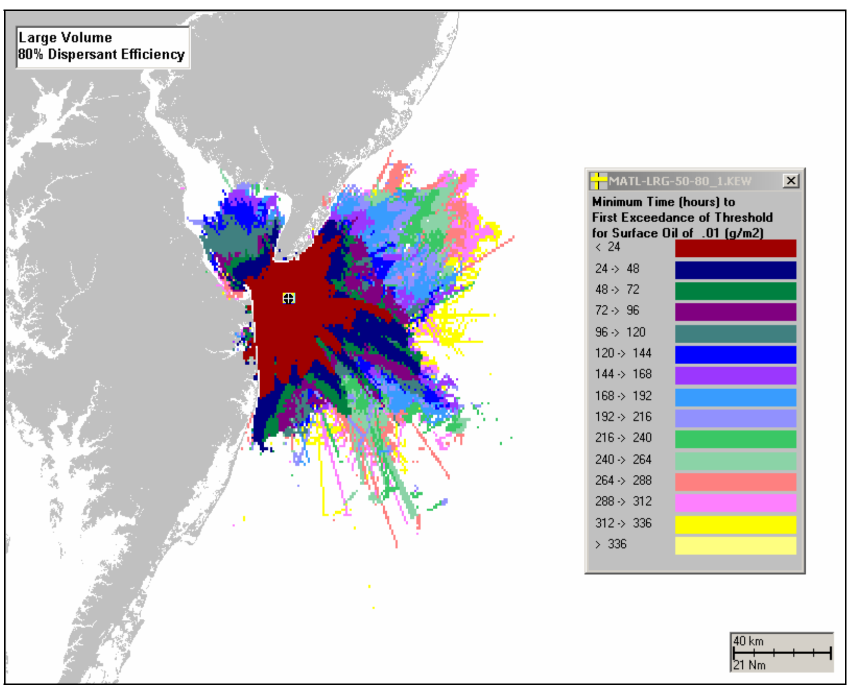

Figure B-II.1.6.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

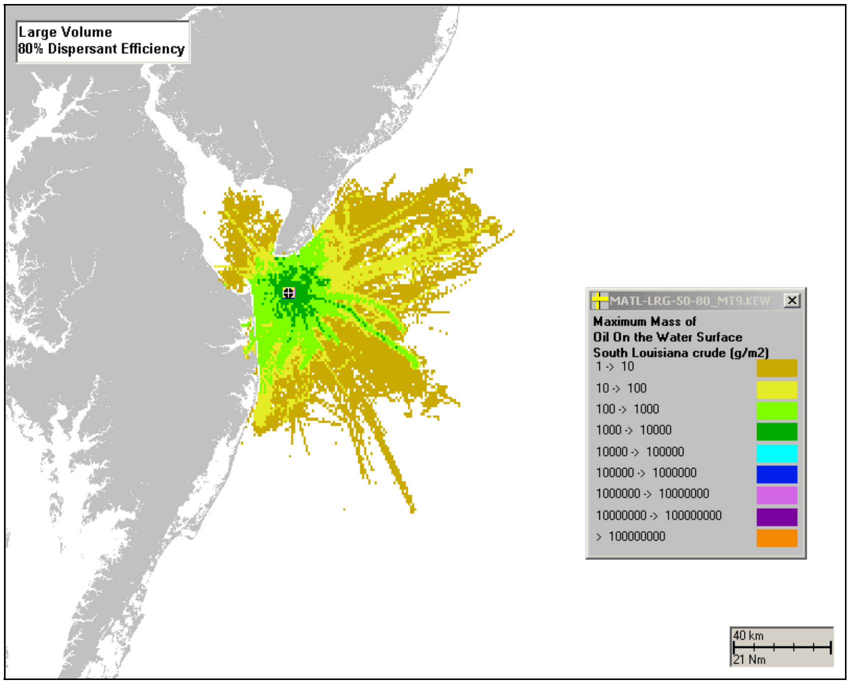

Figure B-II.1.6.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

B-II.1.6.2 Shoreline Oiled. Scenario: Large Volume, 80% Dispersant Efficiency

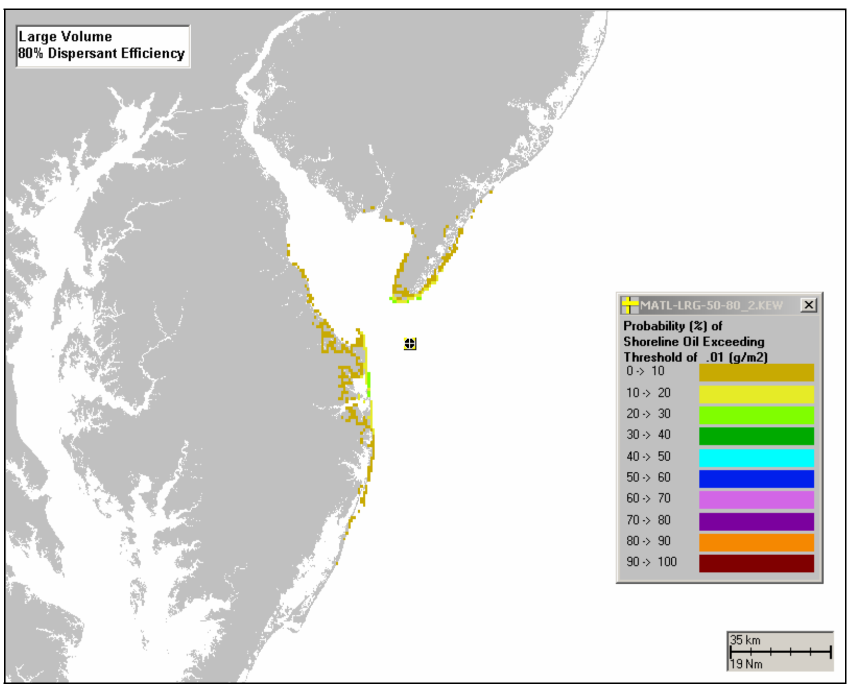

Figure B-II.1.6.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

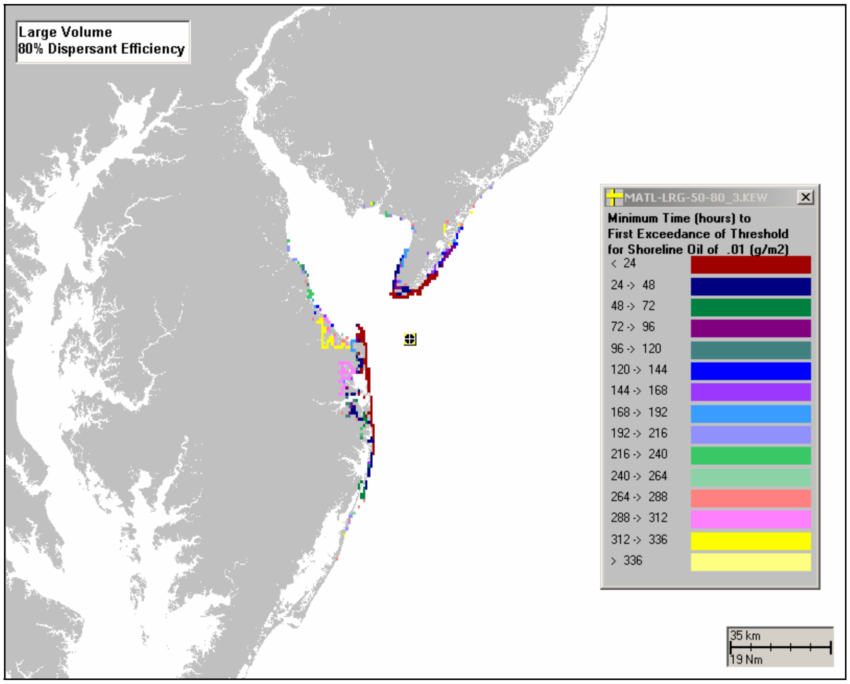

Figure B-II.1.6.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

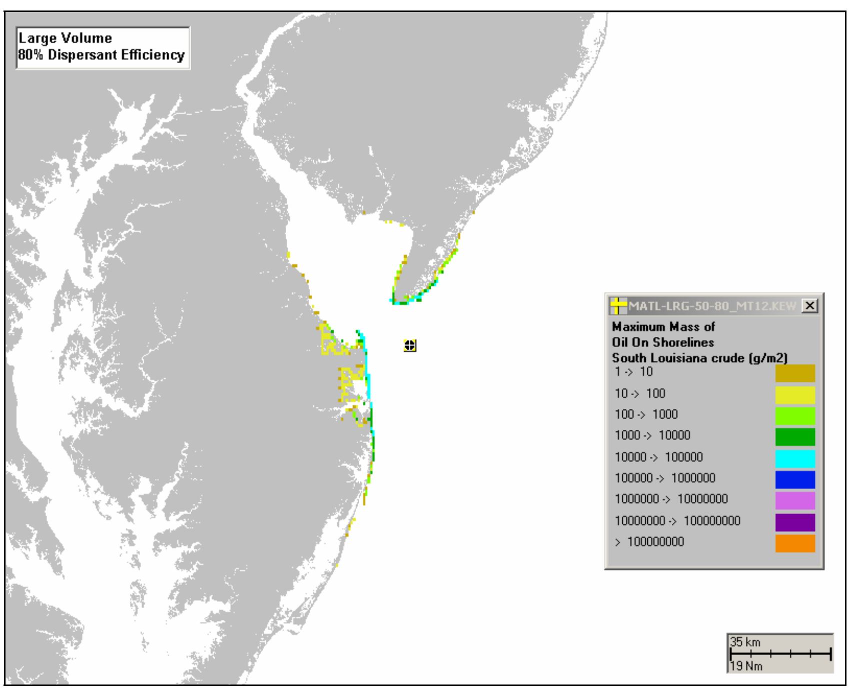

Figure B-II.1.6.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

B-II.1.6.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Large Volume, 80% Dispersant Efficiency

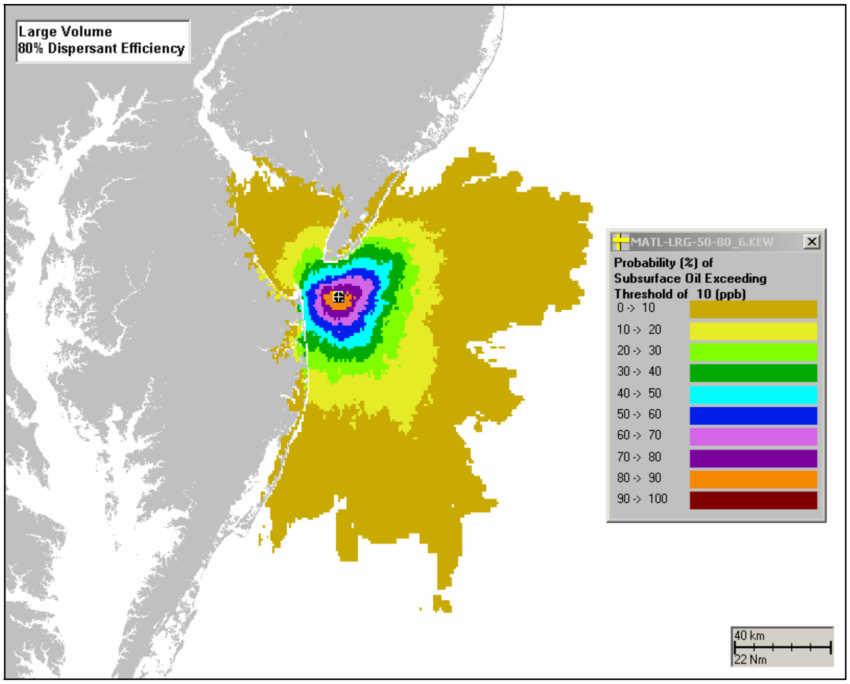

Figure B-II.1.6.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

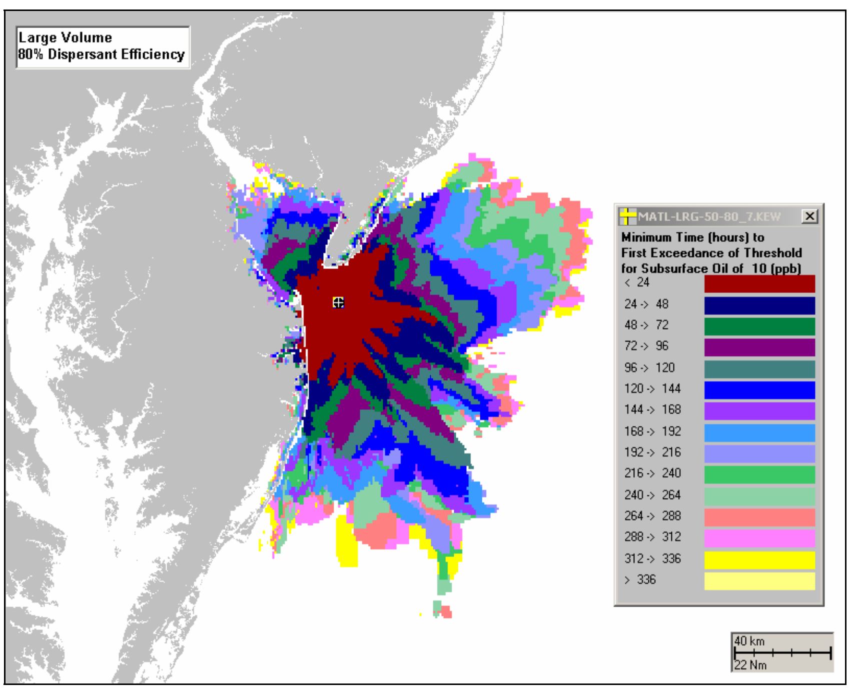

Figure B-II.1.6.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

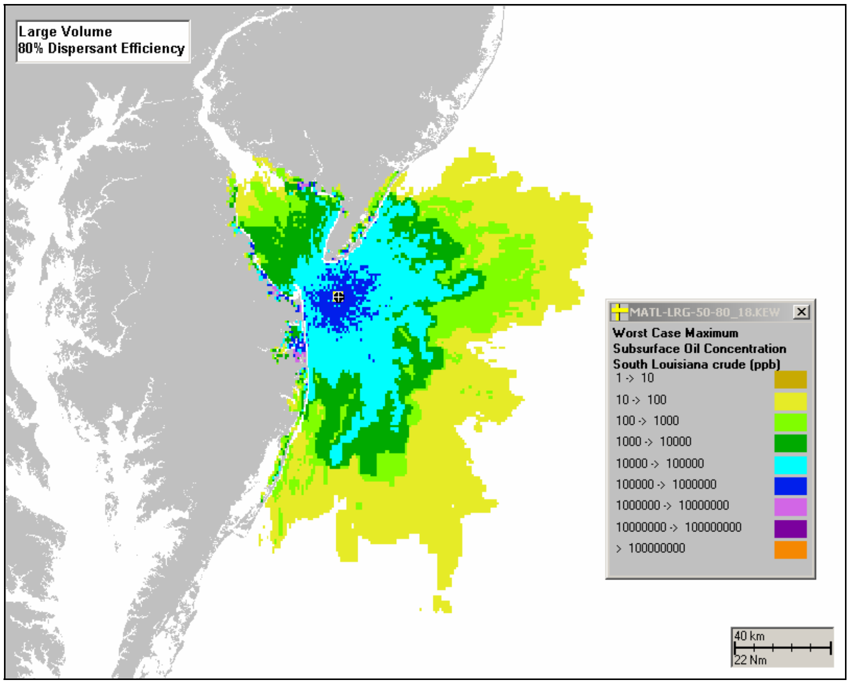

Figure B-II.1.6.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

B-II.1.6.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Large Volume, 80% Dispersant Efficiency

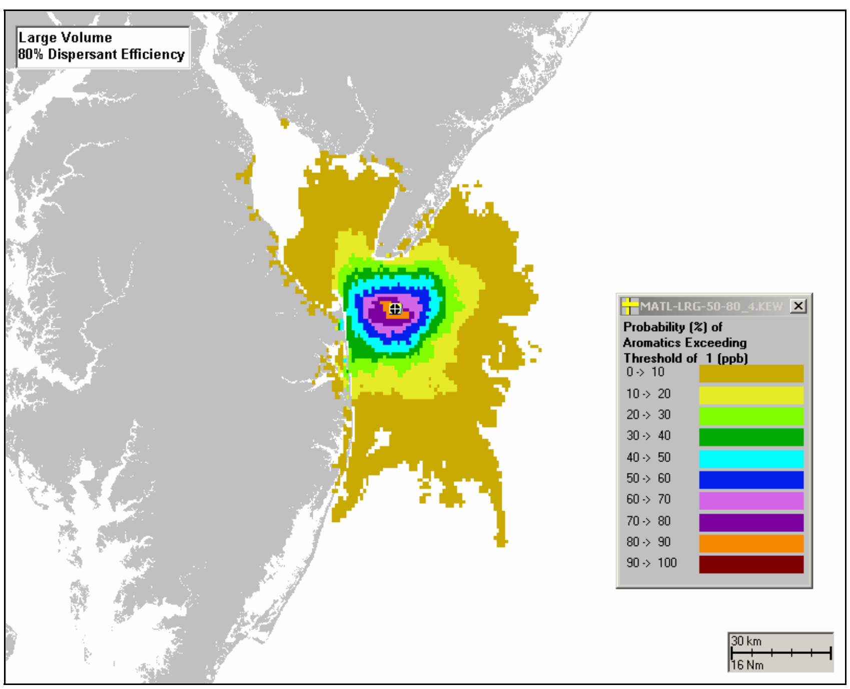

Figure B-II.1.6.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

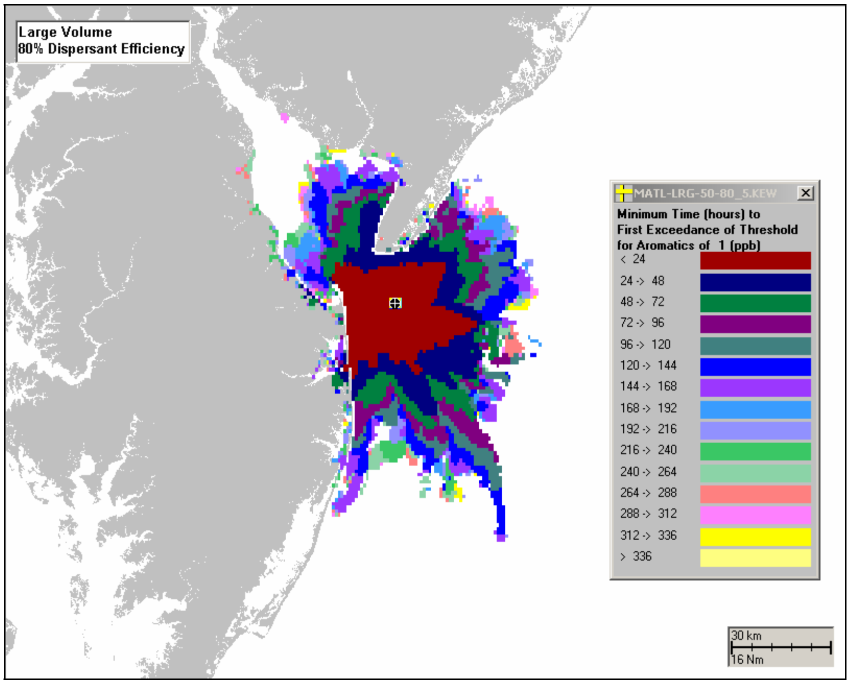

Figure B-II.1.6.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

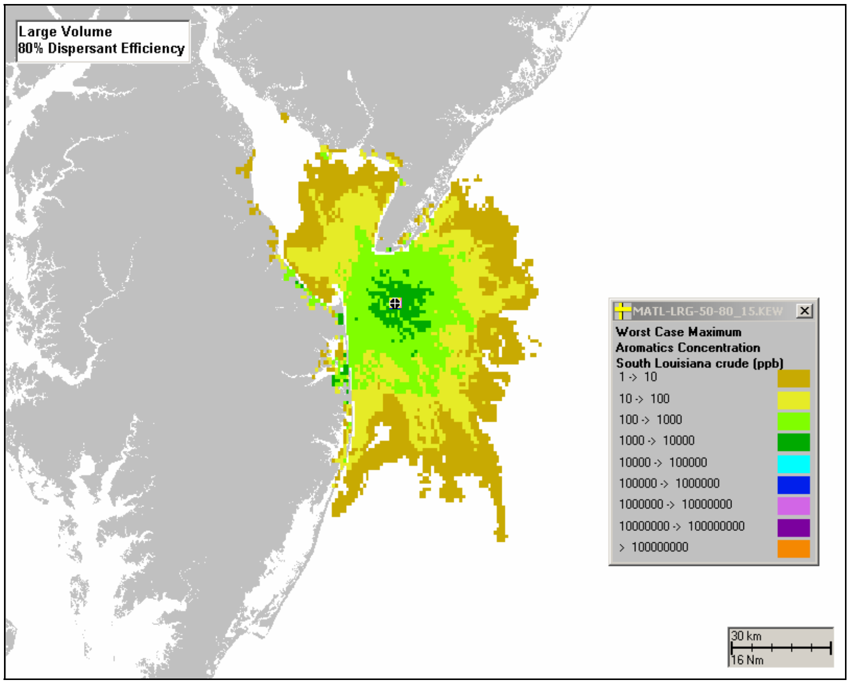

Figure B-II.1.6.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

B-II.1.6.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Large Volume, 80% Dispersant Efficiency

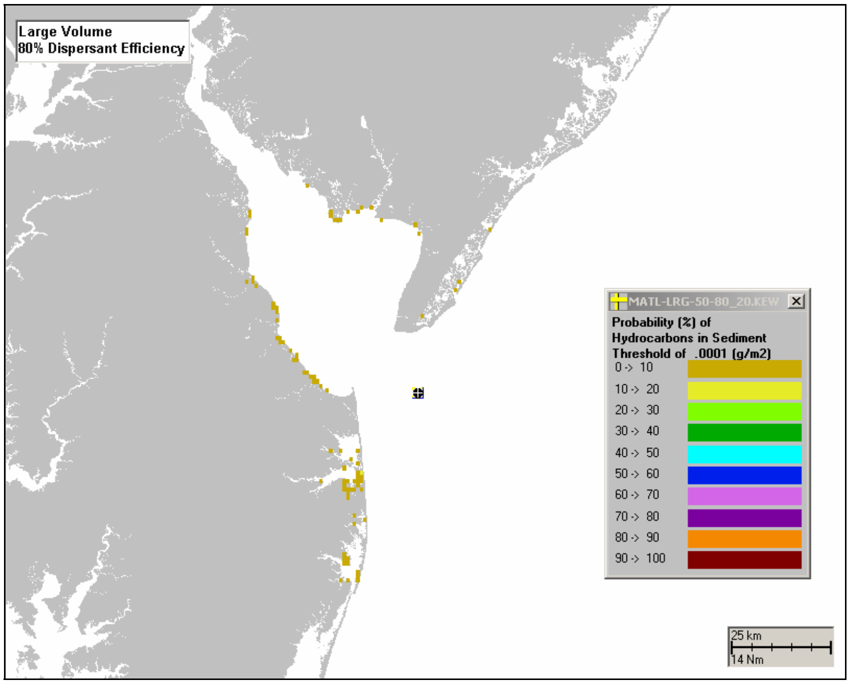

Figure B-II.1.6.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

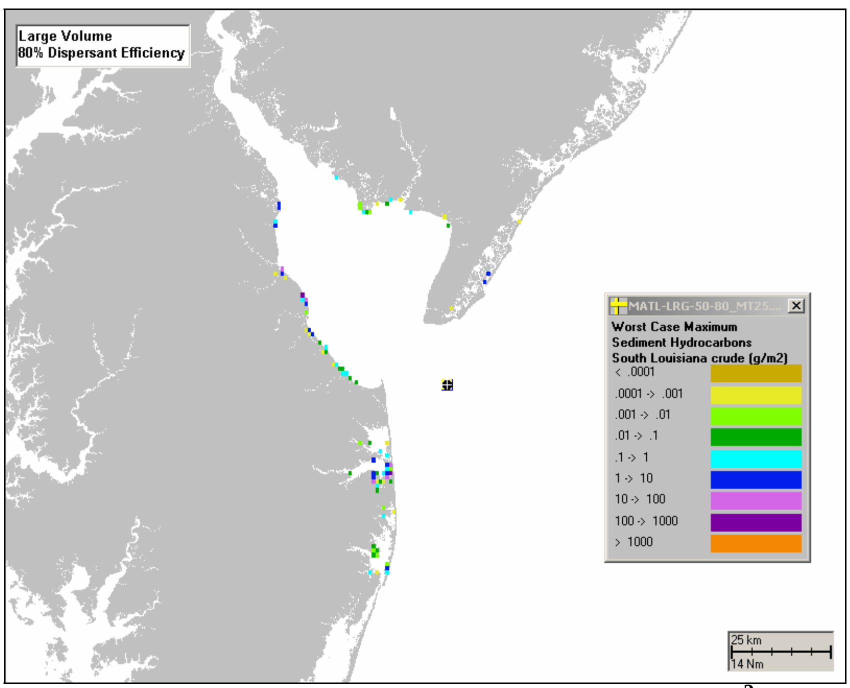

Figure B-II.1.6.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

B-II.1.6.6 Sediment pore water dissolved aromatic concentrations. Scenario: Large Volume, 80% Dispersant Efficiency

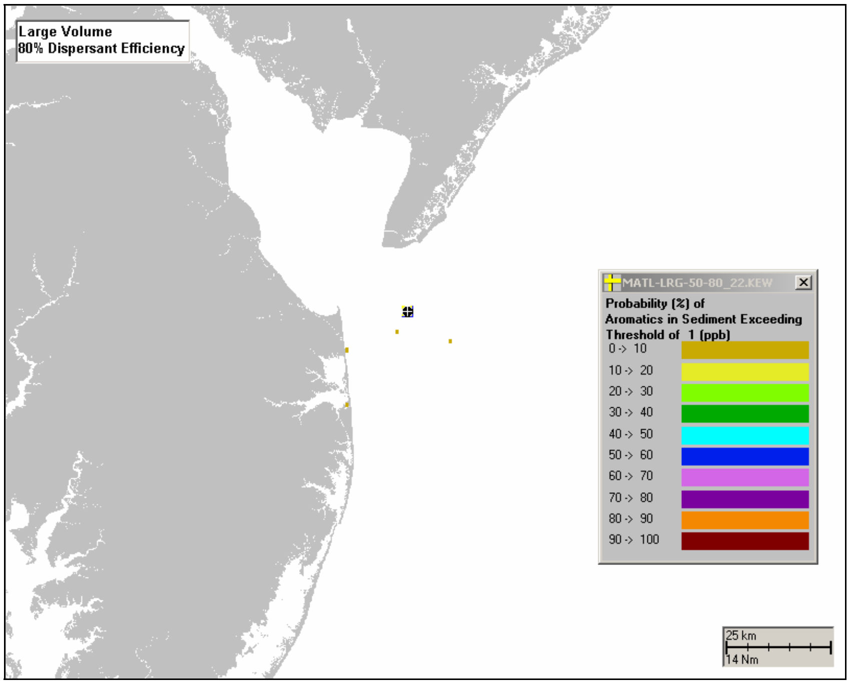

Figure B-II.1.6.6-1 Probability (%) of sediment pore water dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

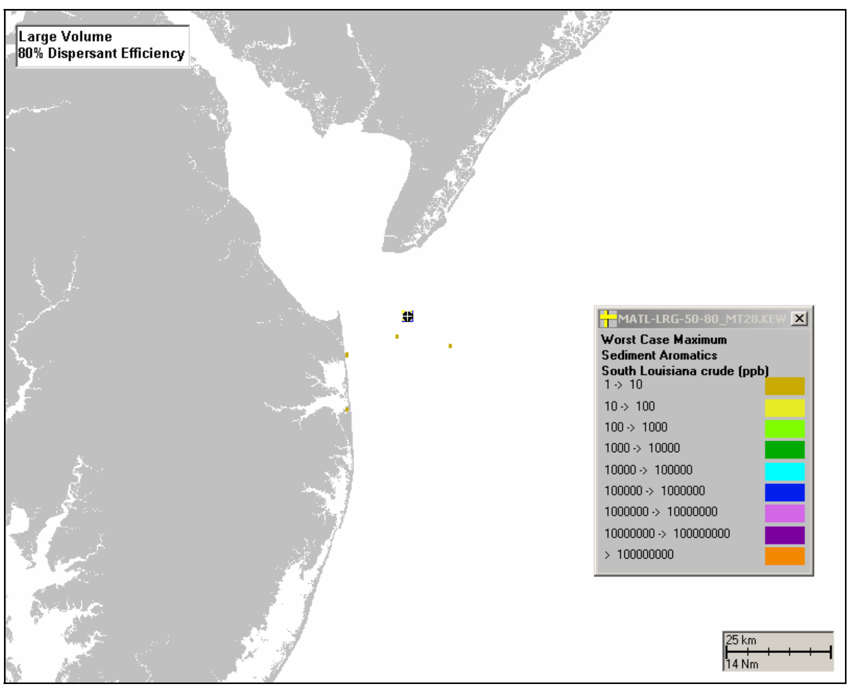

Figure B-II.1.6.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part B: Delaware Bay and Mid-Atlantic Shelf

Section B-II.2

by

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ASA 00-246

August 2004

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B-II.2 Results of the Stochastic Modeling: Tables Summarizing Exposure Indices

Tables B-II.2-1 to B-II.2-6 summarize the exposure indices for all model runs in the stochastic oil spill modeling analysis for the spill site off Delaware Bay. Average and the maximum of the 100 simulations performed for each scenario are presented. The 95th percentile conditions used in the risk analysis were calculated as the mean plus two times the standard deviation. The following are the exposure indices used in the analysis.

- Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr) – integrated area swept by oil sheen or thicker oil times duration that oil is present [Note that this index is the oil mass passing through the cell averaged over the grid cell area, and so dilutes smaller patches of contamination. For this reason, evaluation of potential effects on wildlife is made using area swept by individual oil spillets; see explanation in Part A.4]
- Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) –area swept by oil sheen or thicker oil times, for landward (estuarine), seaward (marine), and all waters
- Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2) – shoreline oiled with a thickness exceeding this amount, averaged over the grid cell area (segment length of 1,004.48 m times width for the shore type, which is 2 m for rock/artificial, 5m for gravel beaches, 10 m for sand beaches and 140 m for wetlands and mud flats)
- Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2) – shoreline oiled with a thickness exceeding this amount, averaged over the grid cell area (segment length times typical width for the shore type, as above)
- Length of Shoreline Oiling Exceeding 10 g/m^2 (m) – shoreline of various shore types oiled with a thickness exceeding this amount:
    - Total shoreline
    - Wetlands and mudflats
    - Other shoreline (rocky shore, gravel beach, sand beach, artificial shore)
    - Seaward (marine) sand beach
- Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – water volume contaminated at any time after the spill by > 1ppb dissolved aromatic concentration (in all subtidal habitats) [Note that this index is averaged over the grid cell and upper mixed layer, and so dilutes smaller patches of contamination. For this reason, evaluation of potential effects on biota is made using higher resolution small scale grids around the plume in the water; see explanation in Part A.4]
- Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs) – integrated exposure to dissolved aromatics, as ppb-hrs averaged over the water volume contaminated at any time after the spill by > 1ppb dissolved aromatic concentration
- Percent of Spilled Hydrocarbon Mass Coming Ashore (%) – percent of the spilled oil coming ashore by 14 days after the spill, assuming no shoreline cleanup
- Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)

- Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%) – maximum percent of the oil dispersed by natural forces (waves) and chemical dispersant. (Some naturally dispersed oil may resurface and be re-entrained into the water column, so this is the maximum percent in the water at any time after the spill.)
- Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%) – calculated by difference between no-dispersant and dispersant use scenario
- Percent of Spilled Hydrocarbon Mass Mechanically Removed (%) – The percentage decreases as chemical dispersion increases because less oil remains on the surface and is available to be skimmed.

Table B-II.2-1. Summary of exposure indices for all model runs (Medium Volume, No Dispersant).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2-hr)	$11,872 \times 10^6$	$11,327 \times 10^6$	0	$62,534 \times 10^6$
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for landward (estuarine) cells only	77×10^6	201×10^6	54	$1,027 \times 10^6$
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for seaward (marine) area only	$1,818 \times 10^6$	$2,099 \times 10^6$	0	$9,446 \times 10^6$
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for all waters	$1,894 \times 10^6$	$2,068 \times 10^6$	0	$9,446 \times 10^6$
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) - excluding waters > 3 nautical miles offshore of Delaware and Maryland	810×10^6	$1,164 \times 10^6$	2	$6,167 \times 10^6$
Surface Oil Exposure Exceeding $10 g/m^2$ (m^2) - excluding waters > 3 nautical miles offshore of Delaware and Maryland	57×10^6	60×10^6	13	303×10^6
Area of Shoreline Oiling Exceeding $0.01 g/m^2$ (m^2)	1,020,746	1,721,368	17	11,220,000
Area of Shoreline Oiling Exceeding $10 g/m^2$ (m^2)	99,935	111,229	22	614,740
Length of Shoreline Oiling Exceeding $10 g/m^2$ - Total Shoreline (m)	11,652	10,239	22	41,184

Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	100	505	95	4,018
Length of Shoreline Oiling Exceeding 10 g/m^2 - Other Shoreline (m)	11,551	10,153	22	41,184
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	7,122	8,348	30	38,170
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	130×10^6	96×10^6	0	507×10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	500	277	0	1,389
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	11.78	9.63	17	28.59
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.1543	0.9585	10	7.6080
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	26.01	14.63	0	64.33
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	0	0	100	0
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	13.63	7.22	3	25.64

Table B-II.2-2. Summary of exposure indices for all model runs (Medium Volume, 45% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	3,215 x 10^6	3,979 x 10^6	0	20,769 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) cells only	11 x 10^6	46 x 10^6	78	362 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	275 x 10^6	389 x 10^6	0	2,884 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	286 x 10^6	399 x 10^6	0	2,944 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) - excluding waters > 3 nautical miles offshore of Delaware and Maryland	87 x 10^6	165 x 10^6	21	994 x 10^6
Surface Oil Exposure Exceeding 10g/m^2 (m^2) - excluding waters > 3 nautical miles offshore of Delaware and Maryland	3.6 x 10^6	8 x 10^6	68	40 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	318,148	649,975	35	4,163,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	13,641	33,418	65	182,815
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	1,999	4,287	64	21,094
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	0	0	100	0
Length of Shoreline Oiling Exceeding 10 g/m^{2-} Other Shoreline (m)	1,999	4,287	64	21,094
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	1,346	3,346	74	17,076
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	230 x 10^6	90 x 10^6	0	551 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-	3,070	1,435	0	8,601

hrs)				
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	1.07	4.14	41	24.25
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0993	0.5357	0	4.7356
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	81.19	10.55	0	91.32
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	55.19	18.07	0	80.01
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	0.25	0.60	57	3.29

Table B-II.2-3. Summary of exposure indices for all model runs (Medium Volume, 80% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2-hr)	3,207 x 10^6	3,686 x 10^6	0	19,212 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for landward (estuarine) cells only	7.7 x 10^6	29 x 10^6	80	260 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for seaward (marine) area only	267 x 10^6	332 x 10^6	0	2,199 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for all waters	275 x 10^6	339 x 10^6	0	2,251 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) - excluding waters > 3 nautical miles offshore of Delaware and Maryland	73 x 10^6	114 x 10^6	21	512 x 10^6
Surface Oil Exposure Exceeding $10 g/m^2$ (m^2) - excluding waters > 3 nautical miles offshore of Delaware and Maryland	3.4 x 10^6	8 x 10^6	70	32 x 10^6
Area of Shoreline Oiling Exceeding $0.01 g/m^2$ (m^2)	273,725	564,791	34	3,612,000
Area of Shoreline Oiling Exceeding $10 g/m^2$ (m^2)	11,773	27,275	68	150,671
Length of Shoreline Oiling Exceeding $10 g/m^2$ - Total Shoreline (m)	1,788	3,814	66	20,090
Length of Shoreline Oiling Exceeding $10 g/m^2$ - Wetland and Mudflats (m)	0	0	100	0
Length of Shoreline Oiling Exceeding $10 g/m^{2-}$ Other Shoreline (m)	1,788	3,814	66	20,090
Length of Shoreline Oiling Exceeding $10 g/m^2$ (m) for seaward (marine) sand beach only	1,205	2,812	75	17,076
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	230 x 10^6	86 x 10^6	0	551 x 10^6

Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	3,008	1,343	0	7,186
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	0.93	4.06	39	24.25
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0721	0.4034	0	3.7150
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	81.22	10.54	0	91.24
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	55.22	18.10	0	80.10
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	0.24	0.60	58	3.33

Table B-II.2-4. Summary of exposure indices for all model runs (Large Volume, No Dispersant).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2-hr)	187,803 x 10^6	166,038 x 10^6	0	744,782 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for landward (estuarine) cells only	140 x 10^6	300 x 10^6	43	1,338 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for seaward (marine) area only	2,553 x 10^6	1,936 x 10^6	0	7,617 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for all waters	2,693 x 10^6	1,823 x 10^6	0	7,617 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) - excluding waters > 3 nautical miles offshore of Delaware and Maryland	1,155 x 10^6	1,114 x 10^6	1	4,361 x 10^6
Surface Oil Exposure Exceeding $10 g/m^2$ (m^2) - excluding waters > 3 nautical miles offshore of Delaware and Maryland	469 x 10^6	464 x 10^6	2	1,910 x 10^6
Area of Shoreline Oiling Exceeding $0.01 g/m^2$ (m^2)	1,747,460	2,265,496	19	11,260,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	426,260	651,536	19	4,429,739
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	29,240	20,864	19	81,363
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	1,446	4,357	81	29,130
Length of Shoreline Oiling Exceeding 10 g/m^{2} - Other Shoreline (m)	27,794	19,510	19	81,363
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	17,458	15,325	21	51,228
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	698 x 10^6	465 x 10^6	0	2,505 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-	1,869	1,057	0	5,152

hrs)				
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	11.95	8.81	19	31.52
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0472	0.2865	11	2.4349
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	14.10	6.39	0	32.55
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	0	0	100	0
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	20.33	6.87	0	29.66

Table B-II.2-5. Summary of exposure indices for all model runs (Large Volume, 45% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	33,047 x 10^6	34,182 x 10^6	0	184,593 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) cells only	38 x 10^6	128 x 10^6	63	1,063 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	705 x 10^6	522 x 10^6	0	3,001 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	744 x 10^6	523 x 10^6	0	3,001 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) - excluding waters > 3 nautical miles offshore of Delaware and Maryland	268 x 10^6	349 x 10^6	8	1,912 x 10^6
Surface Oil Exposure Exceeding 10g/m^2 (m^2) - excluding waters > 3 nautical miles offshore of Delaware and Maryland	46 x 10^6	79 x 10^6	37	448 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	663,864	1,213,348	32	6,212,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	73,267	135,721	48	867,868
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	7,815	10,516	48	40,179
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	80	565	98	4,018
Length of Shoreline Oiling Exceeding 10 g/m^{2} - Other Shoreline (m)	7,734	10,334	48	36,161
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	5,253	7,949	53	31,139
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	1,797 x 10^6	756 x 10^6	0	3,848 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-	8,297	4,996	0	32,350

hrs)				
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	3.15	6.47	38	26.74
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0816	0.5226	0	4.6186
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	73.17	17.62	0	86.78
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	59.08	19.92	0	80.99
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	3.07	1.56	0	10.28

Table B-II.2-6. Summary of exposure indices for all model runs (Large Volume, 80% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	31,884 x 10^6	34,206 x 10^6	0	178,179 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) cells only	32 x 10^6	114 x 10^6	65	1,047 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	659 x 10^6	506 x 10^6	0	2,596 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	691 x 10^6	510 x 10^6	0	2,596 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) - excluding waters > 3 nautical miles offshore of Delaware and Maryland	219 x 10^6	287 x 10^6	11	1,543 x 10^6
Surface Oil Exposure Exceeding 10g/m^2 (m^2) - excluding waters > 3 nautical miles offshore of Delaware and Maryland	40 x 10^6	71 x 10^6	45	308 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	568,171	1,054,883	35	5,910,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	153,042	617,513	47	5,560,779
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	8,578	13,578	48	79,354
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	653	4,131	95	38,170
Length of Shoreline Oiling Exceeding 10 g/m^{2-} Other Shoreline (m)	7,925	11,955	48	64,286
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	5,022	8,119	54	37,166
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	1,781 x 10^6	782 x 10^6	0	4,072 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-	9,643	5,675	0	31,980

hrs)				
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	2.56	5.54	38	22.79
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.1059	0.7071	0	6.2300
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	77.65	15.86	0	89.92
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	63.56	18.32	0	84.12
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	1.84	1.45	0	8.37

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part B: Delaware Bay and Mid-Atlantic Shelf

Section B-II.3

by

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ASA 00-246

August 2004

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B-II.3 Rank Order Distributions for All Model Runs

In this section, the following impact indices are plotted as rank order distributions:

- Water surface exposed to floating hydrocarbons, as the sum of area covered by more than $0.01 g/m^2$ (which is sheen) times duration of exposure (in m^2-hrs)
- Shoreline area (m^2) exposed to hydrocarbons of various threshold thicknesses (>1, 10, 100, and 1000 g/m^2)
- Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill
- Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill
- Percent of spilled hydrocarbon mass eventually going ashore
- Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats)
- Maximum percent of spilled hydrocarbon mass in the water column at any time after the spill, and
- Percent of spilled hydrocarbon mass mechanically removed.

B-II.3.1 Scenario: Medium Volume, No Dispersant.

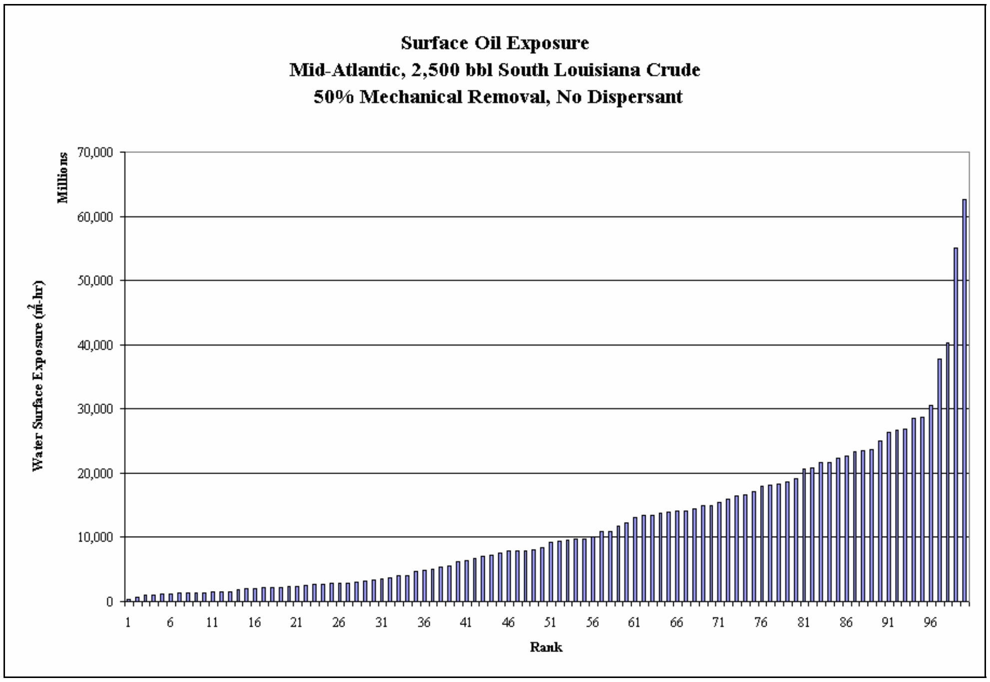

Figure B-II.3.1-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Medium Volume, No Dispersant.

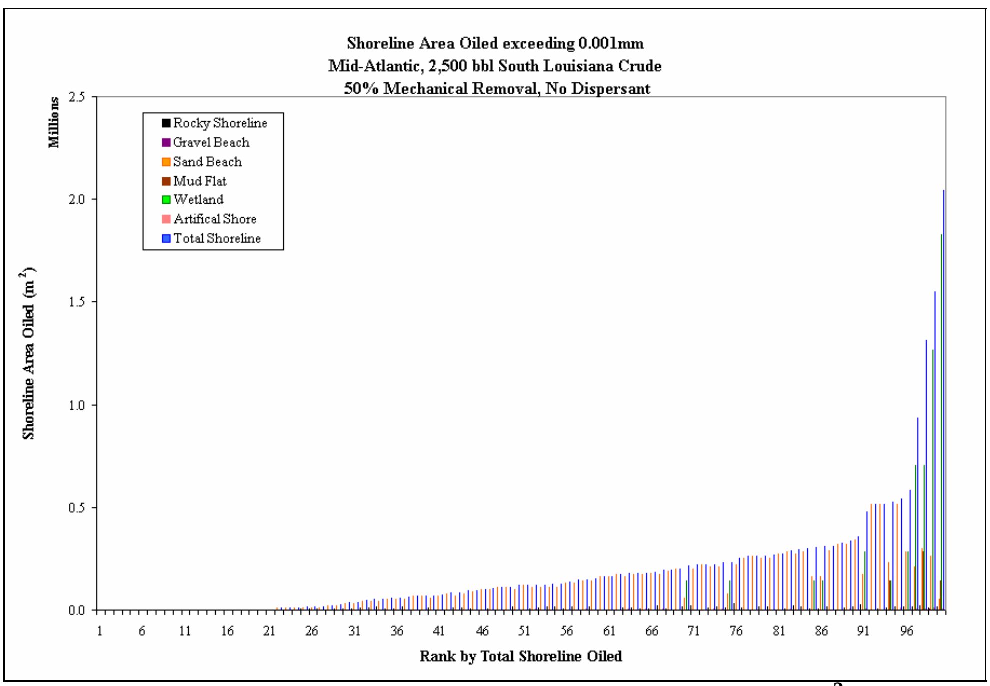

Figure B-II.3.1-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Medium Volume, No Dispersant.

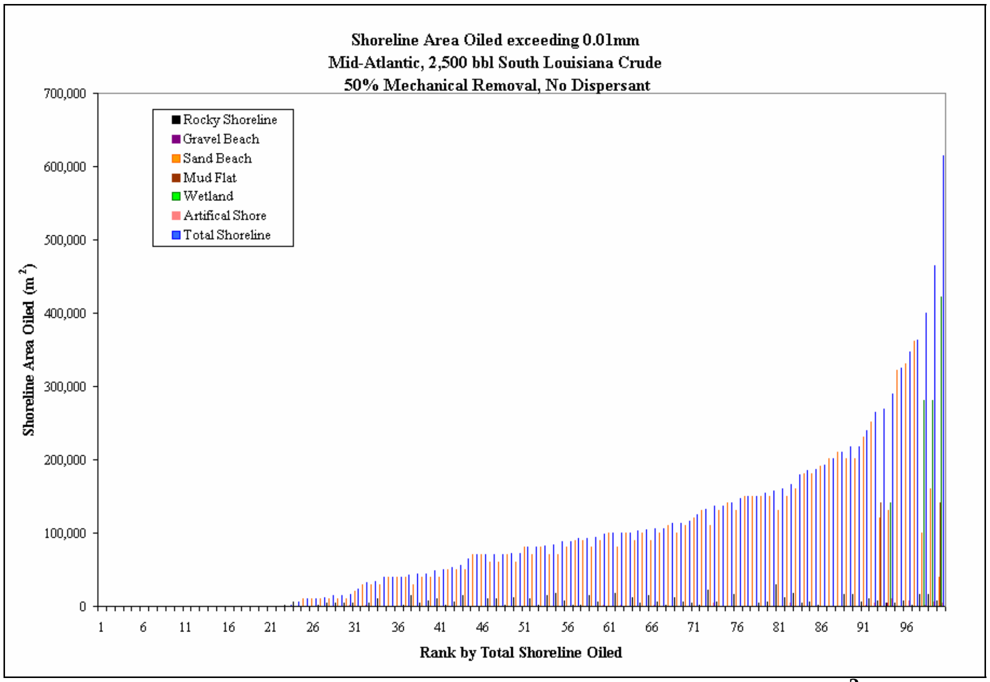

Figure B-II.3.1-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Medium Volume, No Dispersant.

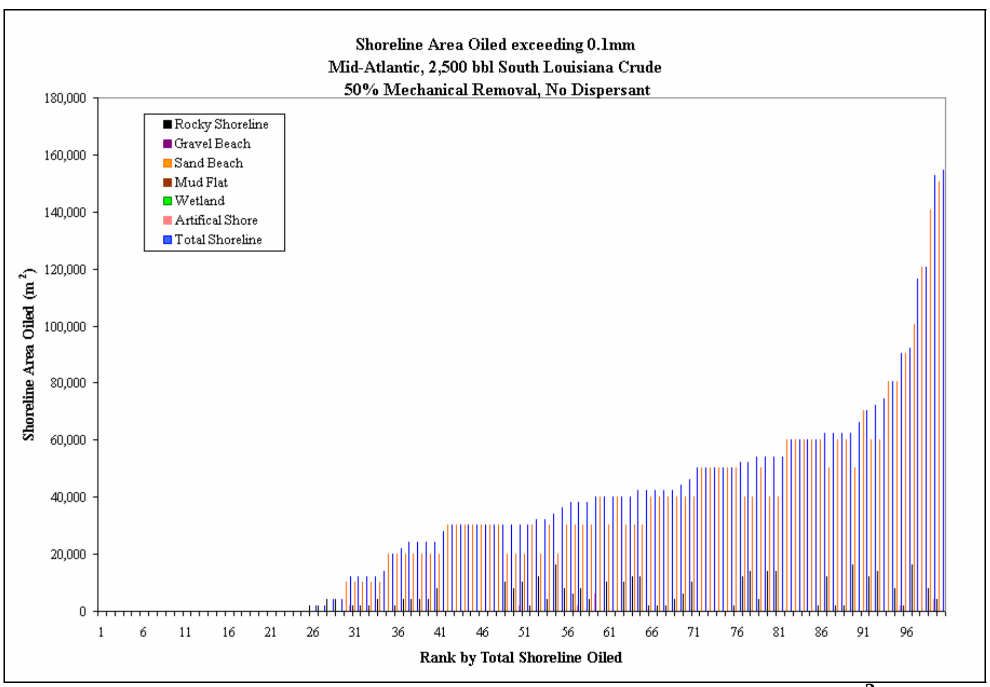

Figure B-II.3.1-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Medium Volume, No Dispersant.

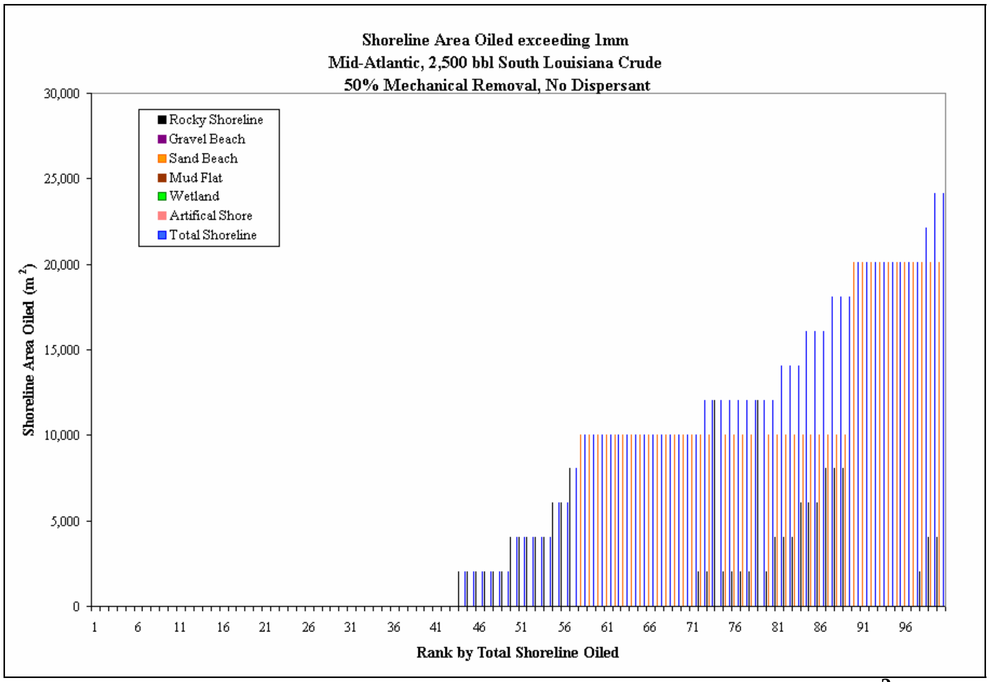

Figure B-II.3.1-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Medium Volume, No Dispersant.

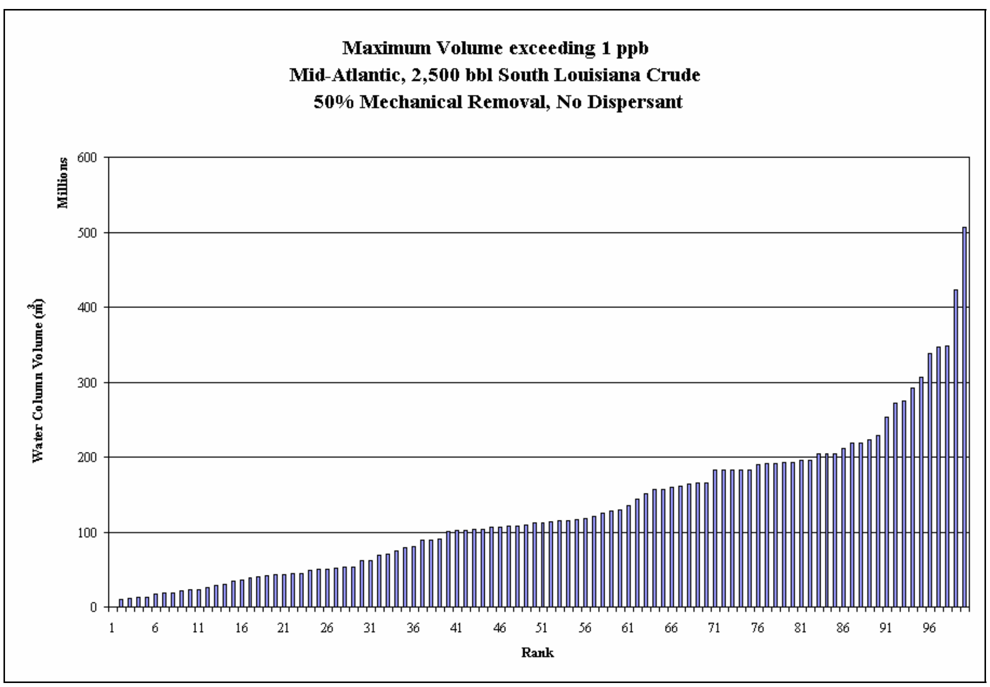

Figure B-II.3.1-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, No Dispersant.

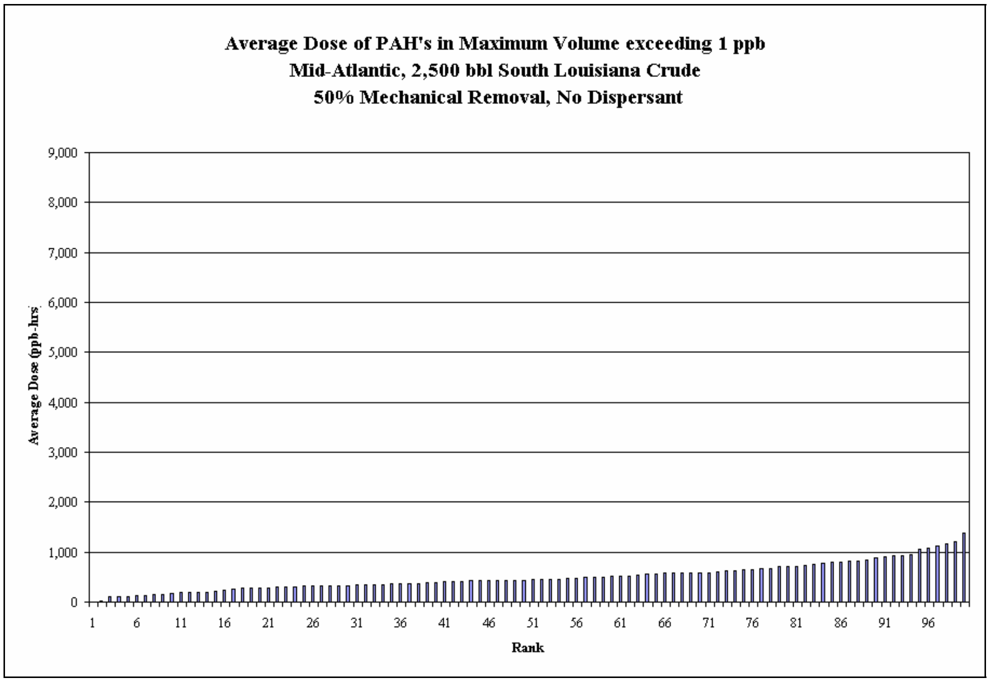

Figure B-II.3.1-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, No Dispersant.

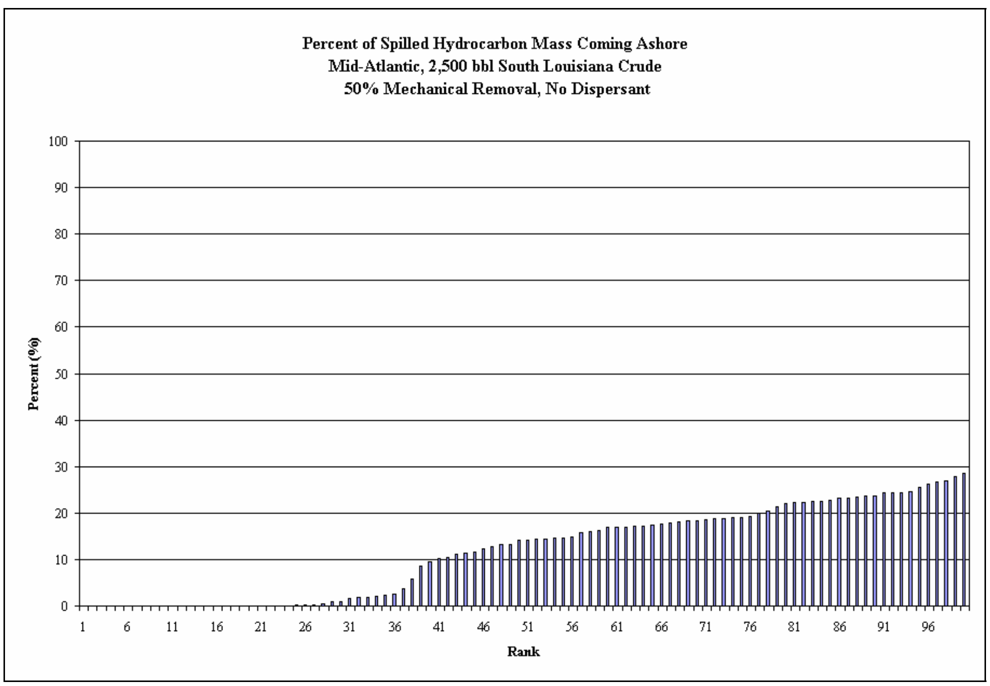

Figure B-II.3.1-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Medium Volume, No Dispersant.

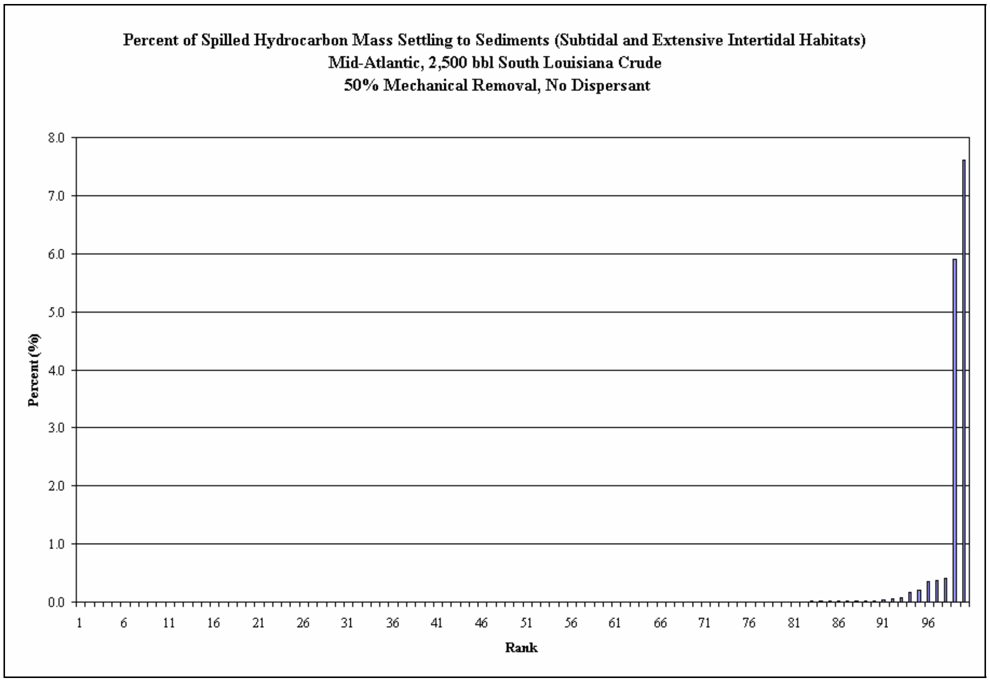

Figure B-II.3.1-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Medium Volume, No Dispersant.

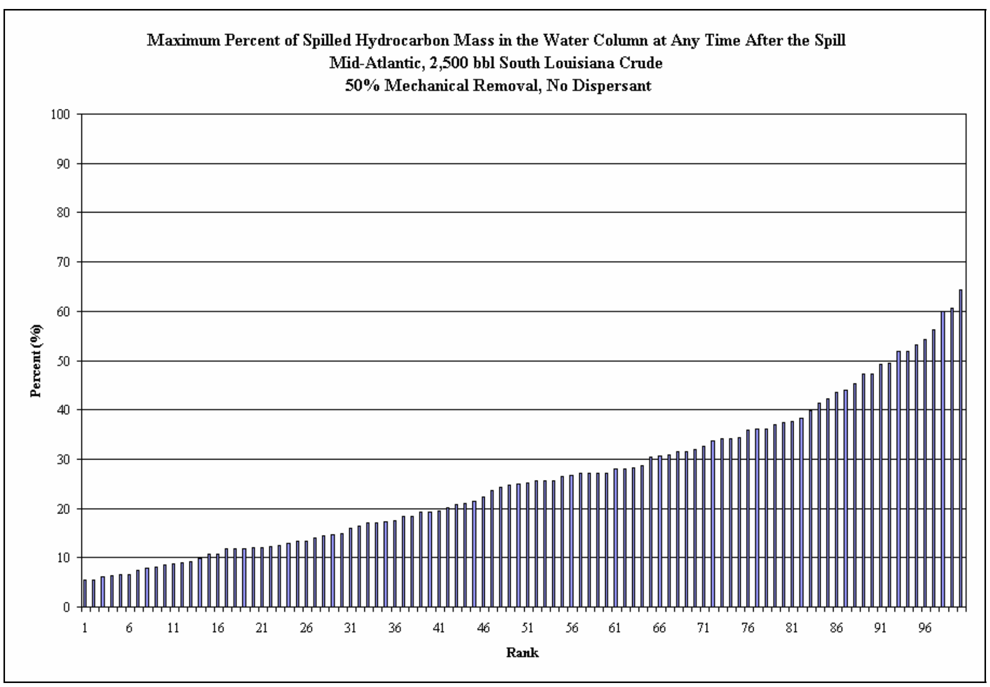

Figure B-II.3.1-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Medium Volume, No Dispersant.

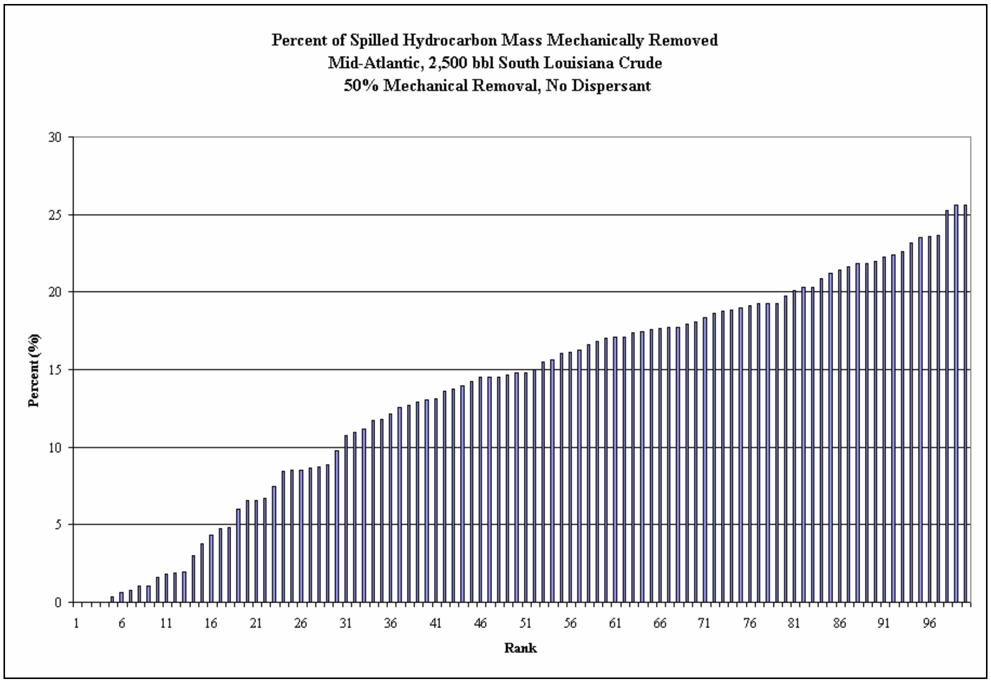

Figure B-II.3.1-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Medium Volume, No Dispersant.

B-II.3.2 Scenario: Medium Volume, 45% Dispersant Efficiency.

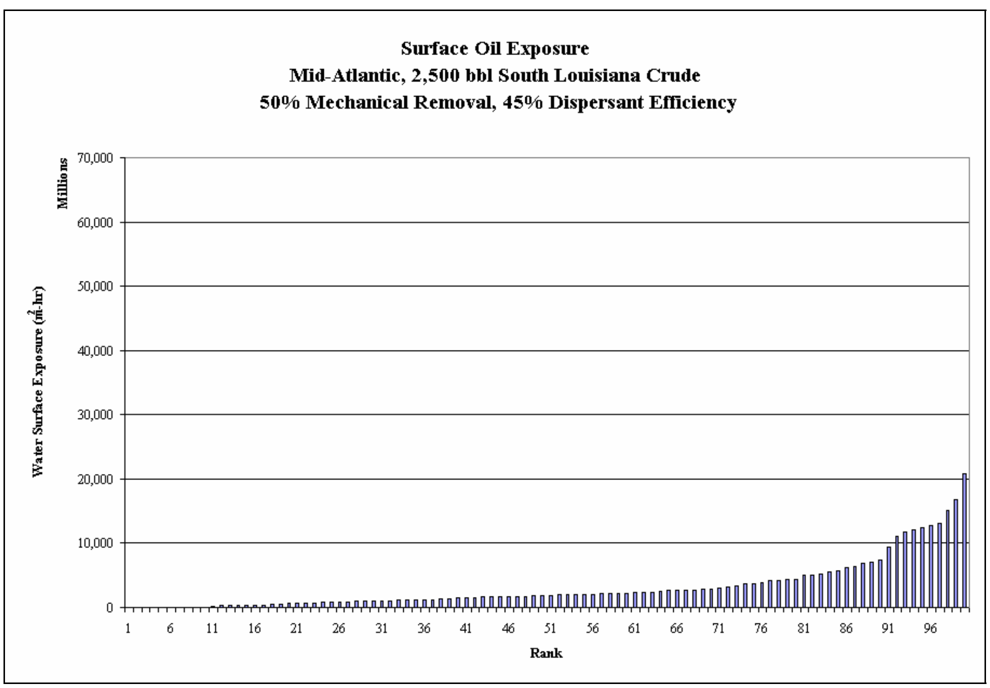

Figure B-II.3.2-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

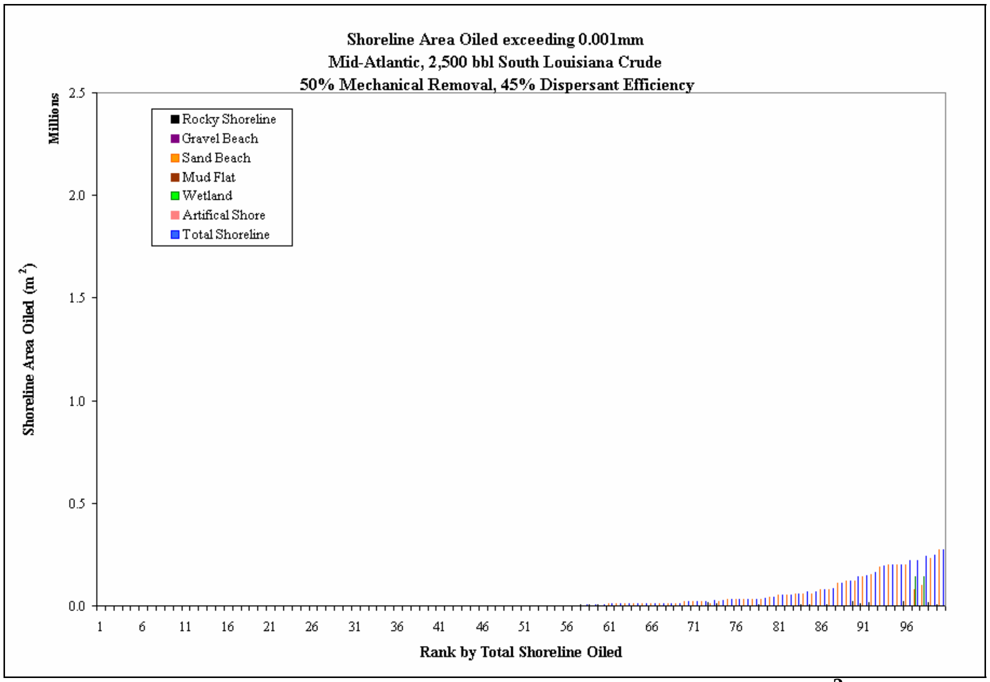

Figure B-II.3.2-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

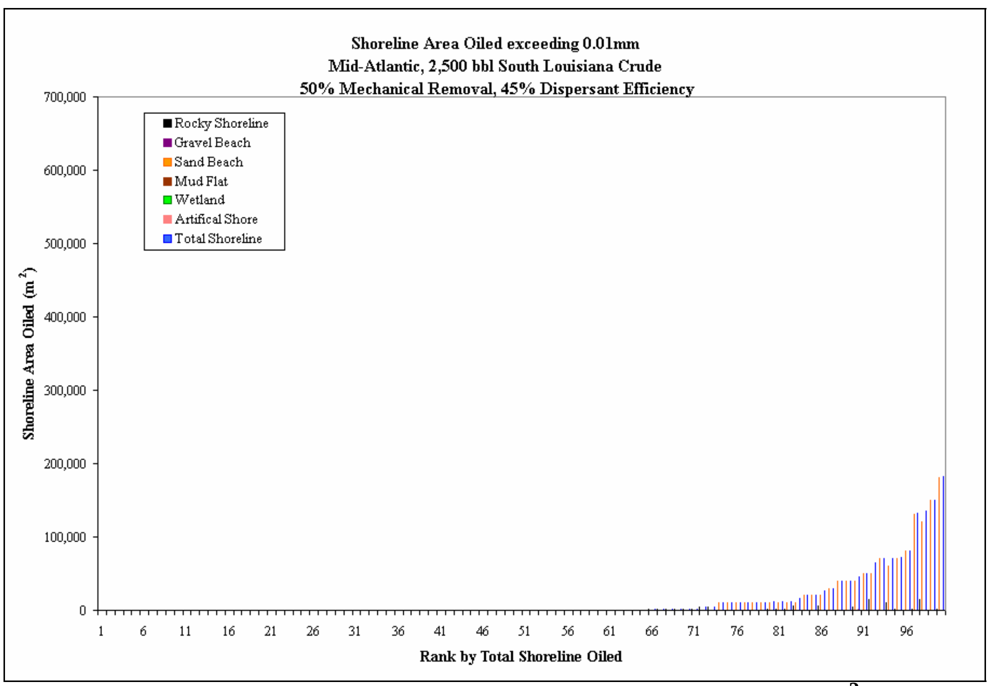

Figure B-II.3.2-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

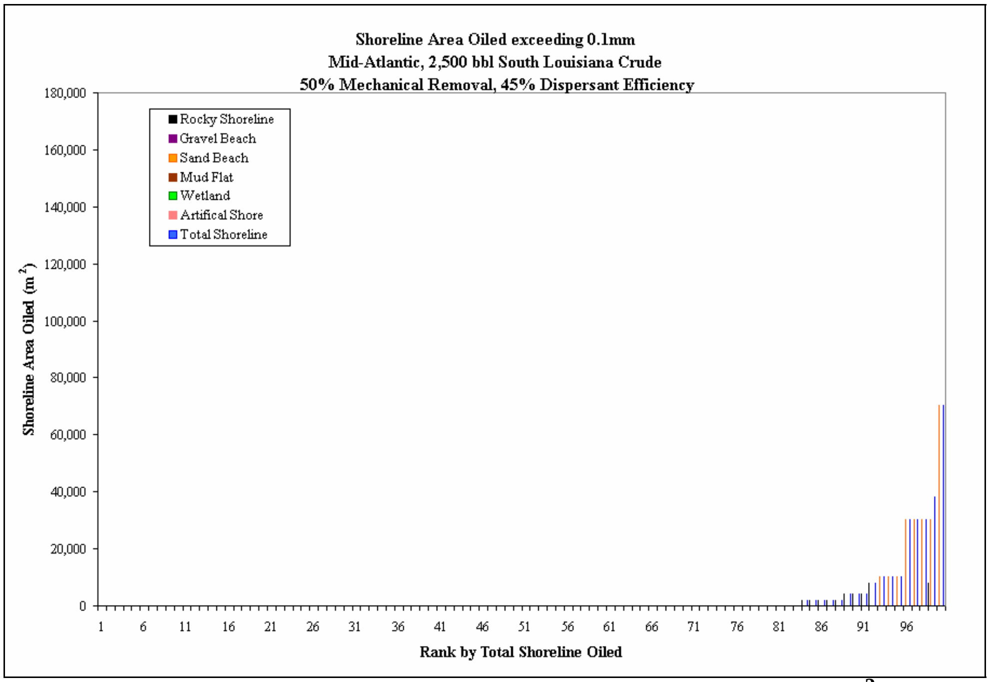

Figure B-II.3.2-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

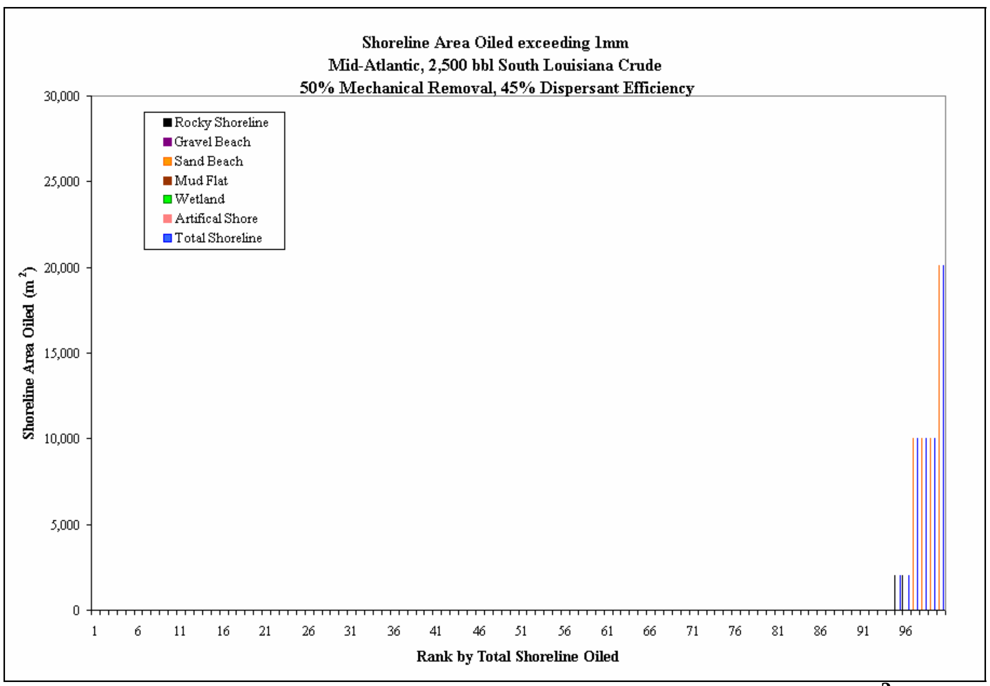

Figure B-II.3.2-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

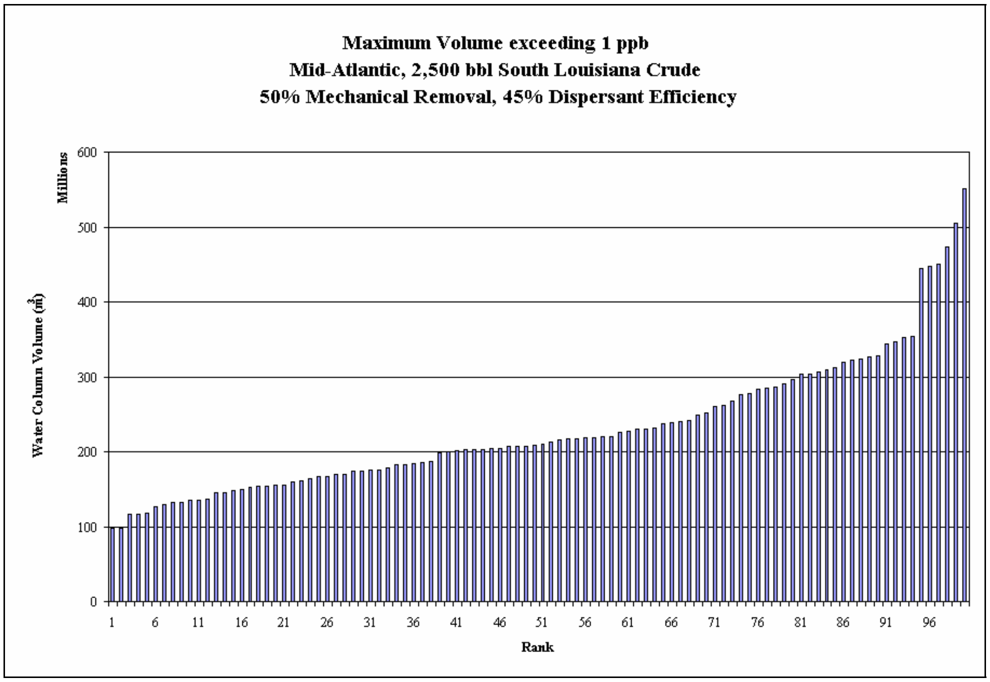

Figure B-II.3.2-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 45% Dispersant Efficiency.

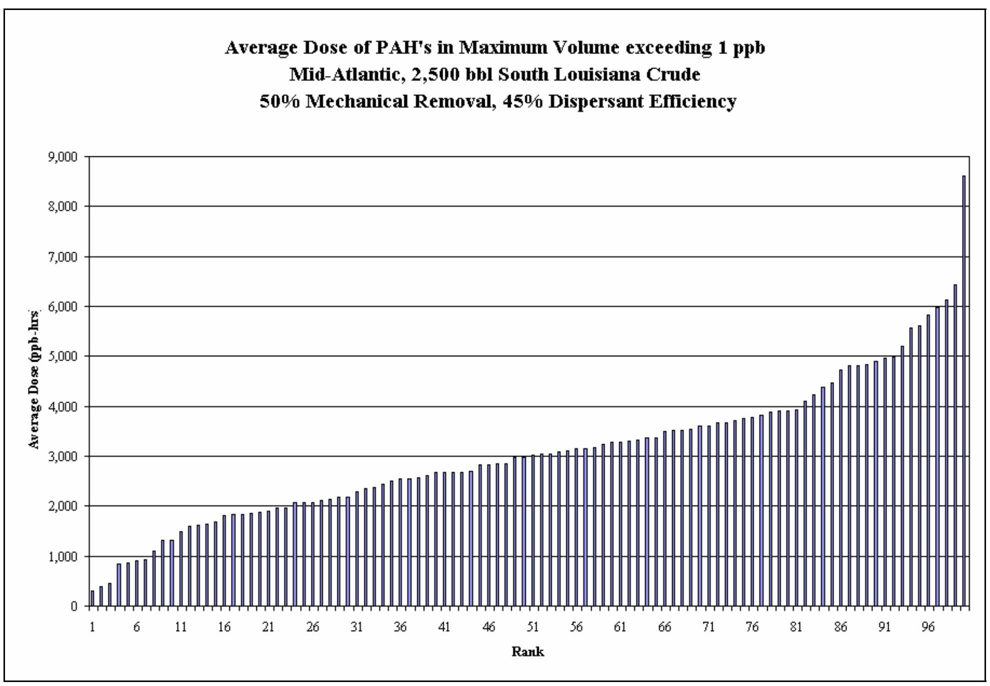

Figure B-II.3.2-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 45% Dispersant Efficiency.

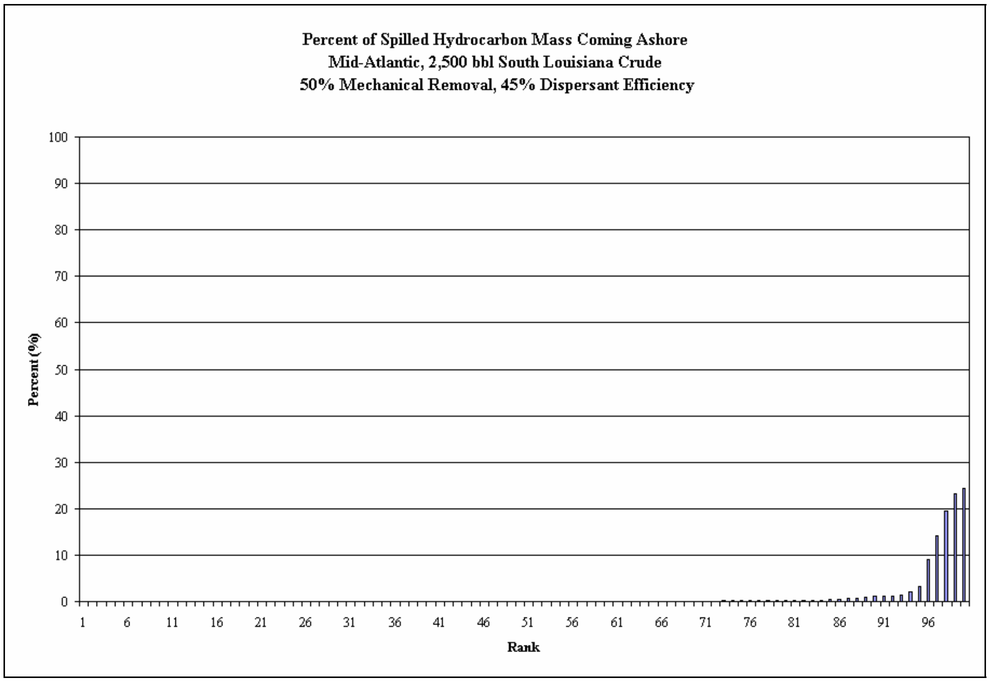

Figure B-II.3.2-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Medium Volume, 45% Dispersant Efficiency.

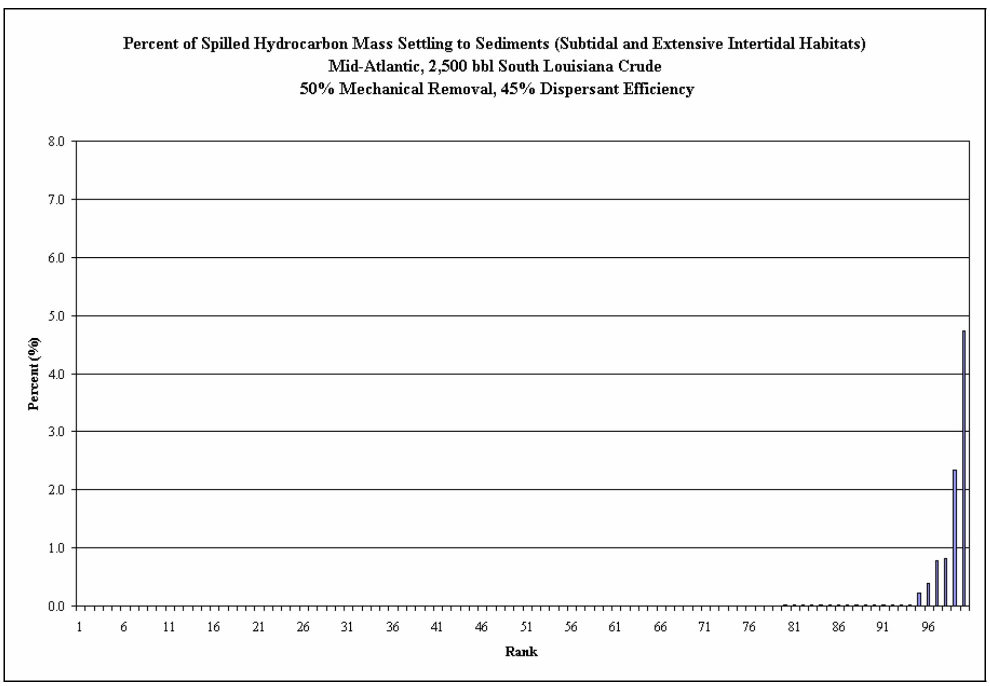

Figure B-II.3.2-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Medium Volume, 45% Dispersant Efficiency.

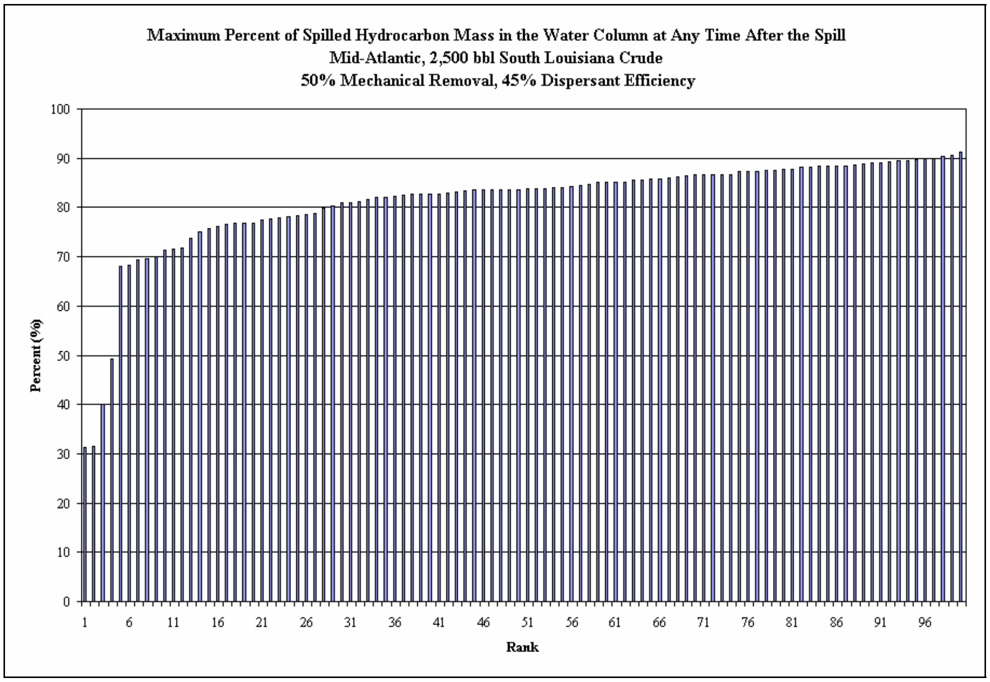

Figure B-II.3.2-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Medium Volume, 45% Dispersant Efficiency.

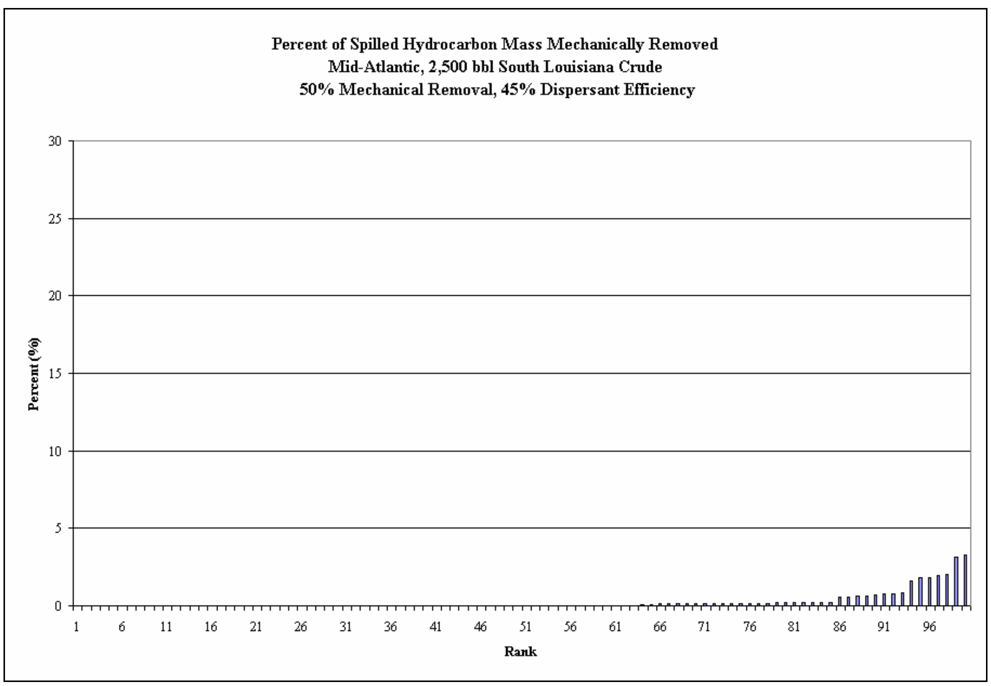

Figure B-II.3.2-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Medium Volume, 45% Dispersant Efficiency.

B-II.3.3 Scenario: Medium Volume, 80% Dispersant Efficiency.

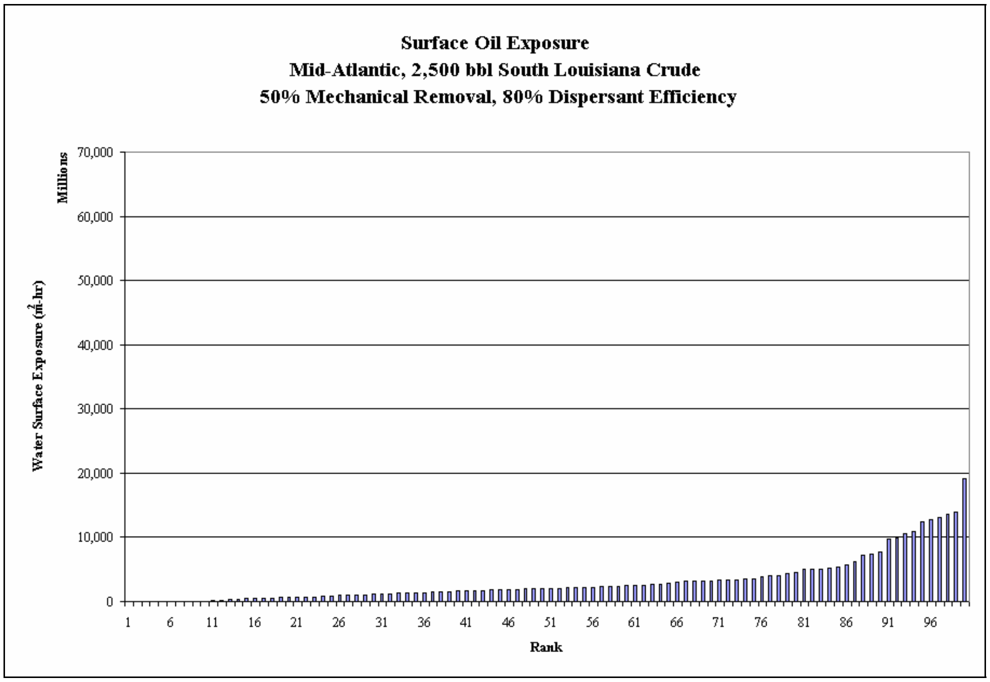

Figure B-II.3.3-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

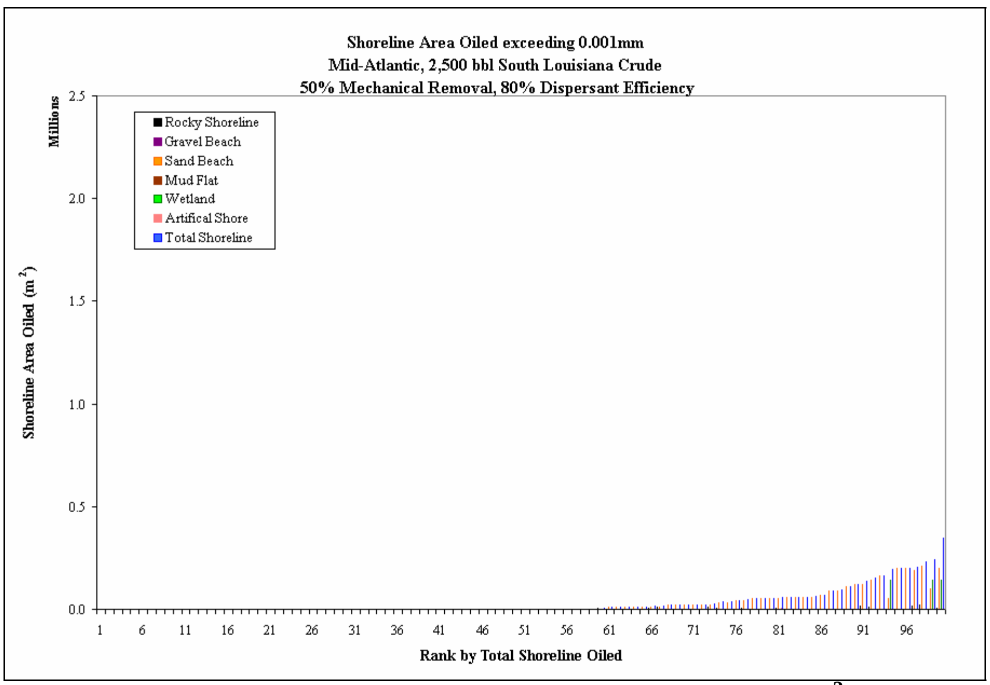

Figure B-II.3.3-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

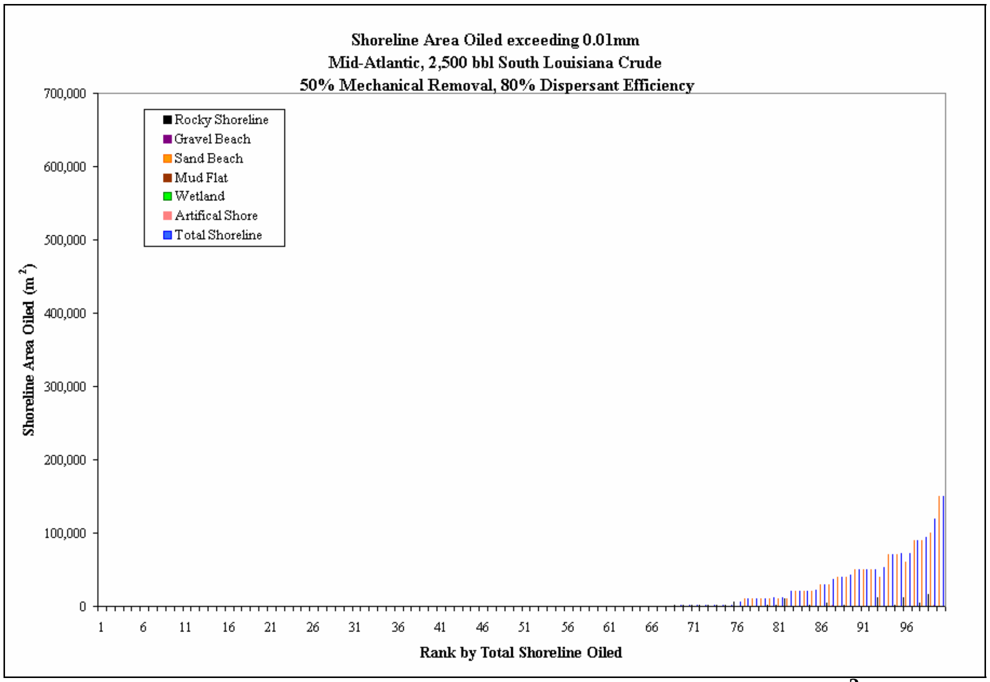

Figure B-II.3.3-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

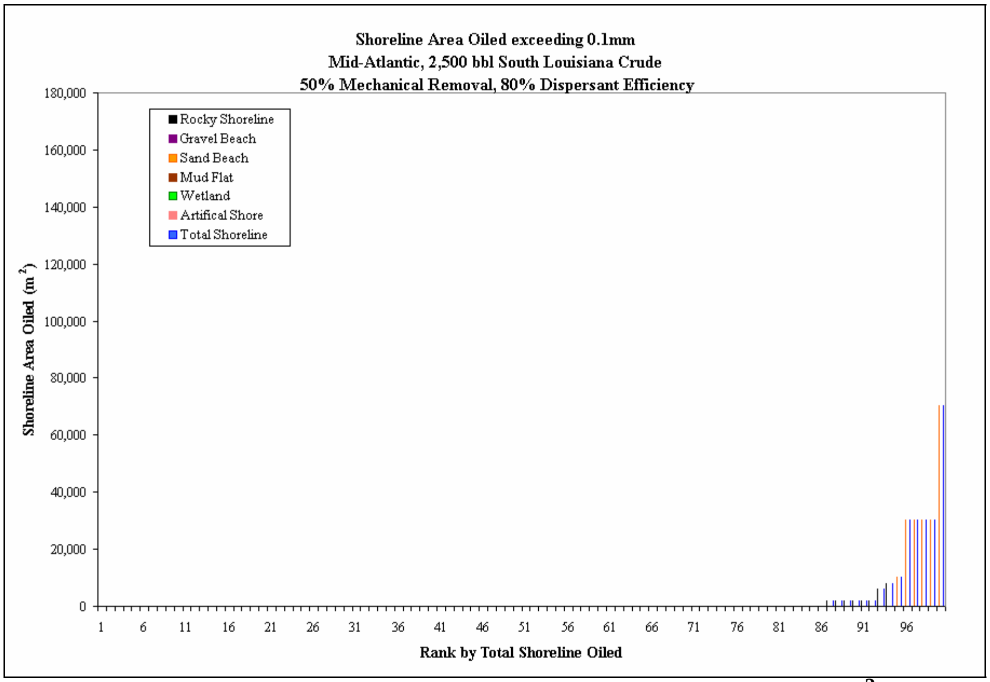

Figure B-II.3.3-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

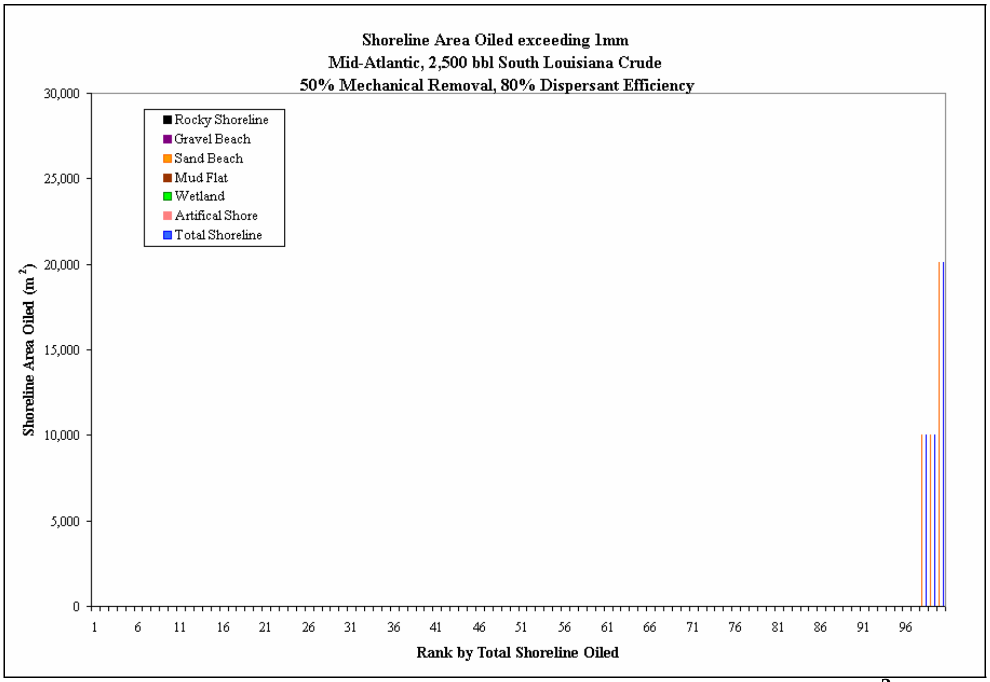

Figure B-II.3.3-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

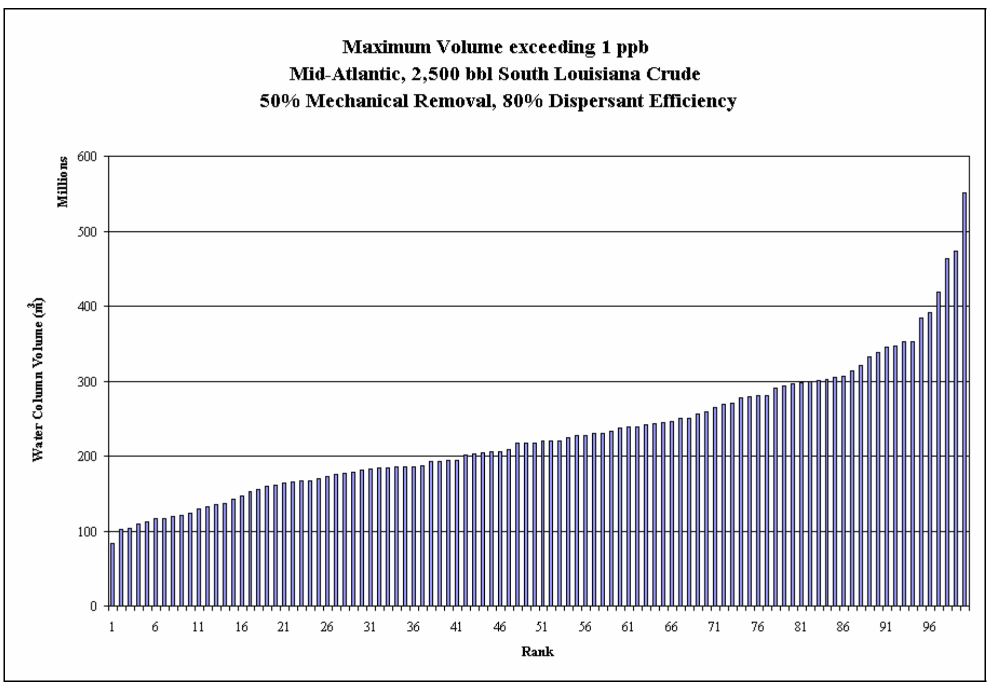

Figure B-II.3.3-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 80% Dispersant Efficiency.

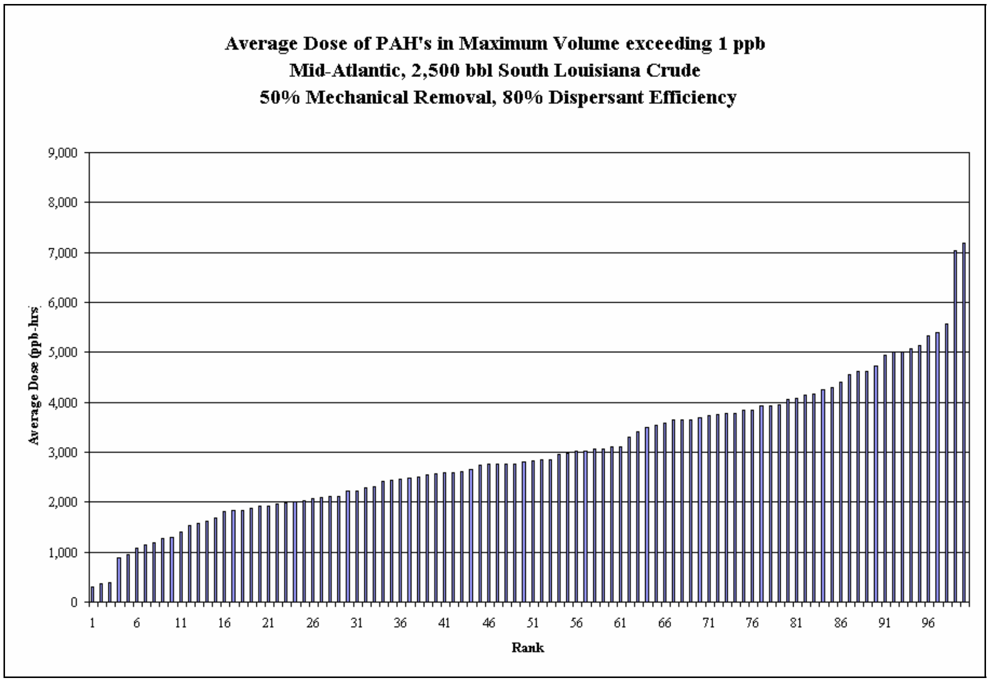

Figure B-II.3.3-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 80% Dispersant Efficiency.

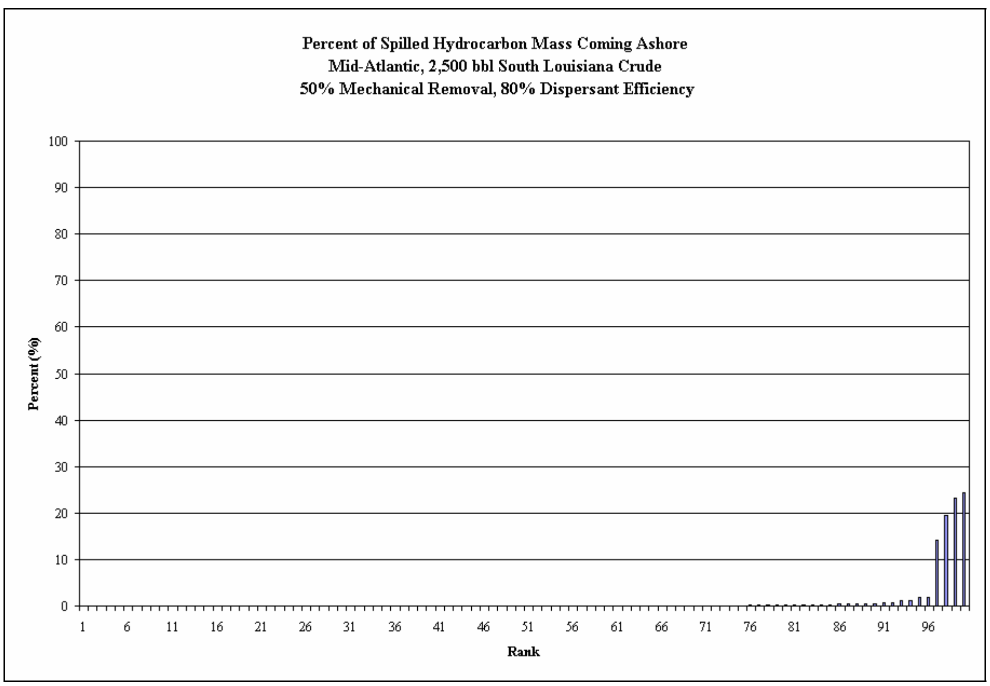

Figure B-II.3.3-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Medium Volume, 80% Dispersant Efficiency.

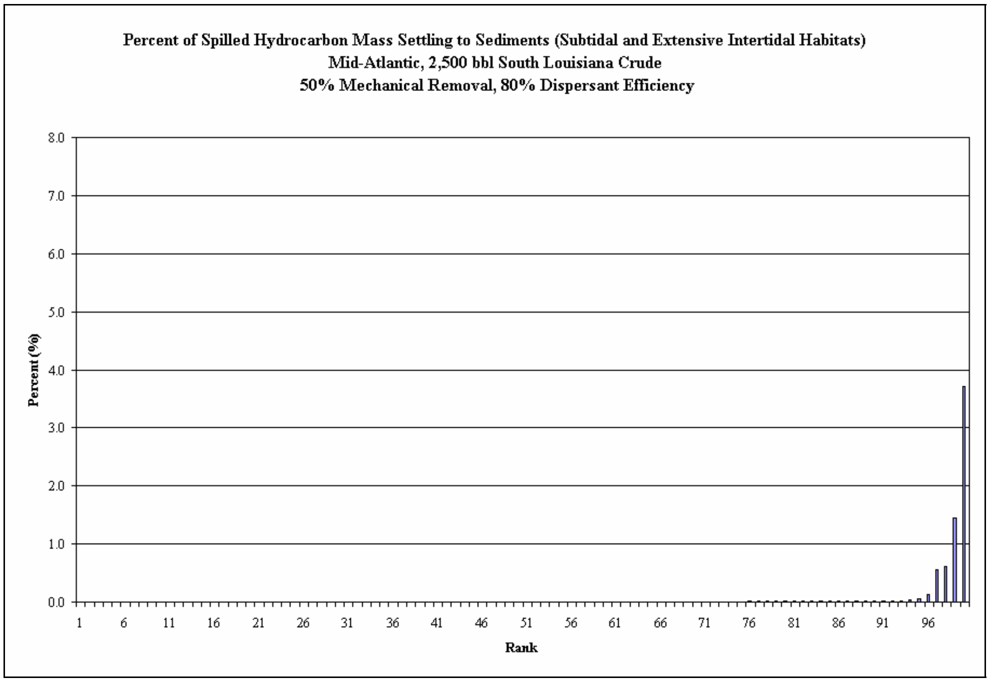

Figure B-II.3.3-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Medium Volume, 80% Dispersant Efficiency.

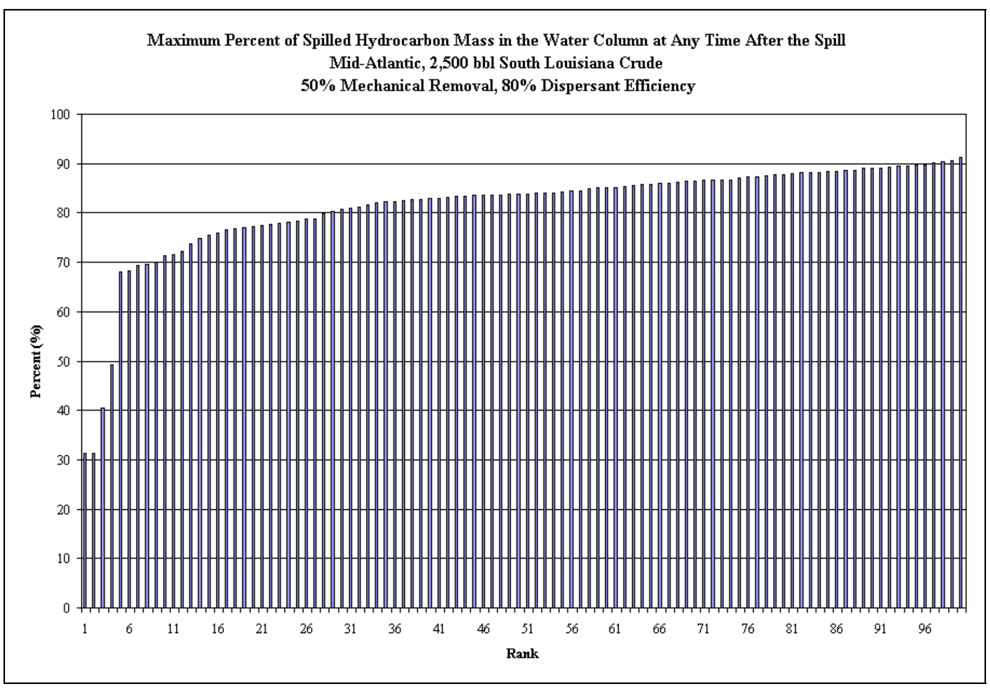

Figure B-II.3.3-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Medium Volume, 80% Dispersant Efficiency.

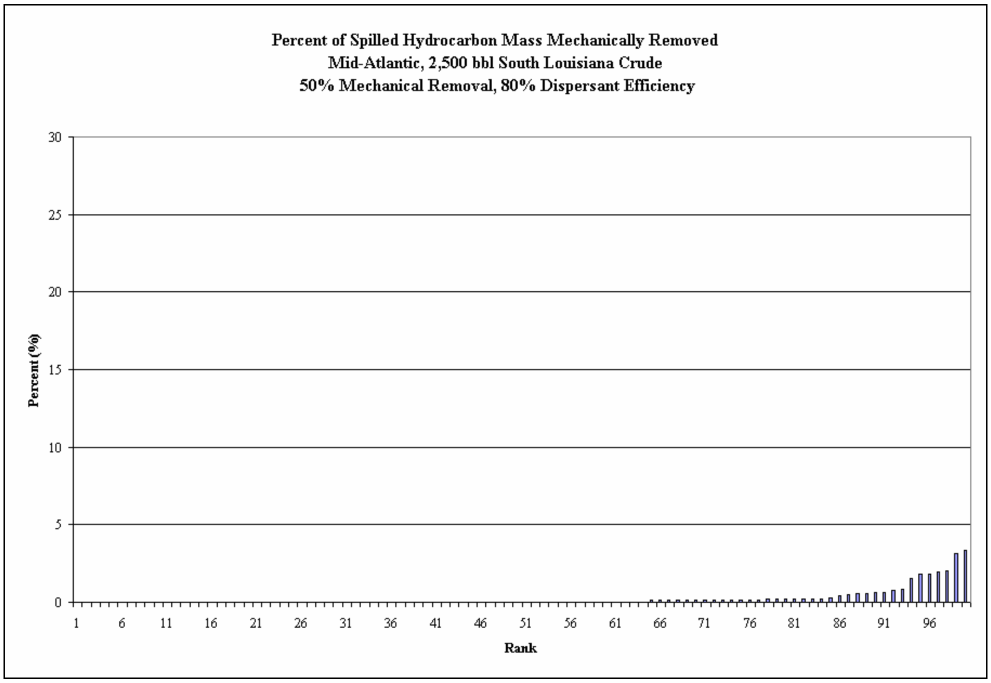

Figure B-II.3.3-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Medium Volume, 80% Dispersant Efficiency.

B-II.3.4 Scenario: Large Volume, No Dispersant.

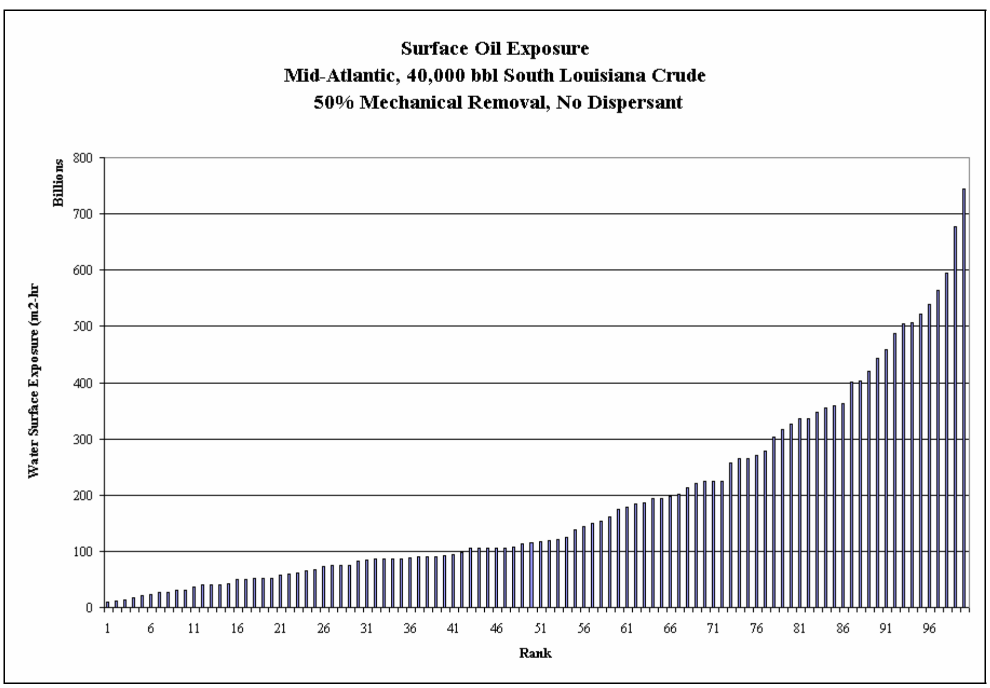

Figure B-II.3.4-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Large Volume, No Dispersant.

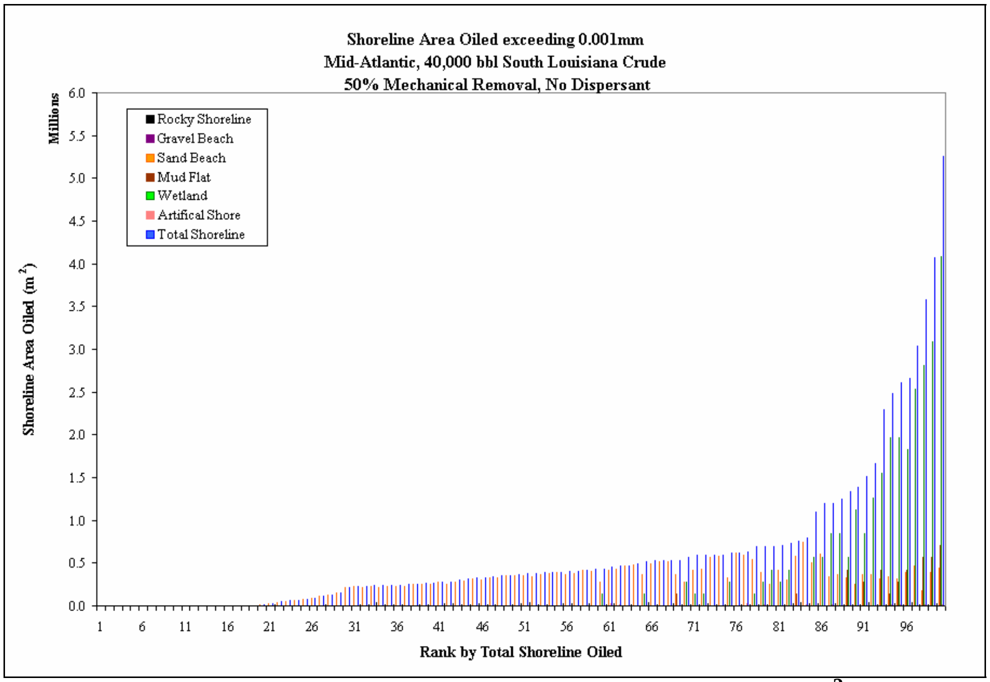

Figure B-II.3.4-2 Shoreline area exposed to hydrocarbons of >1g/m² (about 0.001mm thick). Scenario: Large Volume, No Dispersant.

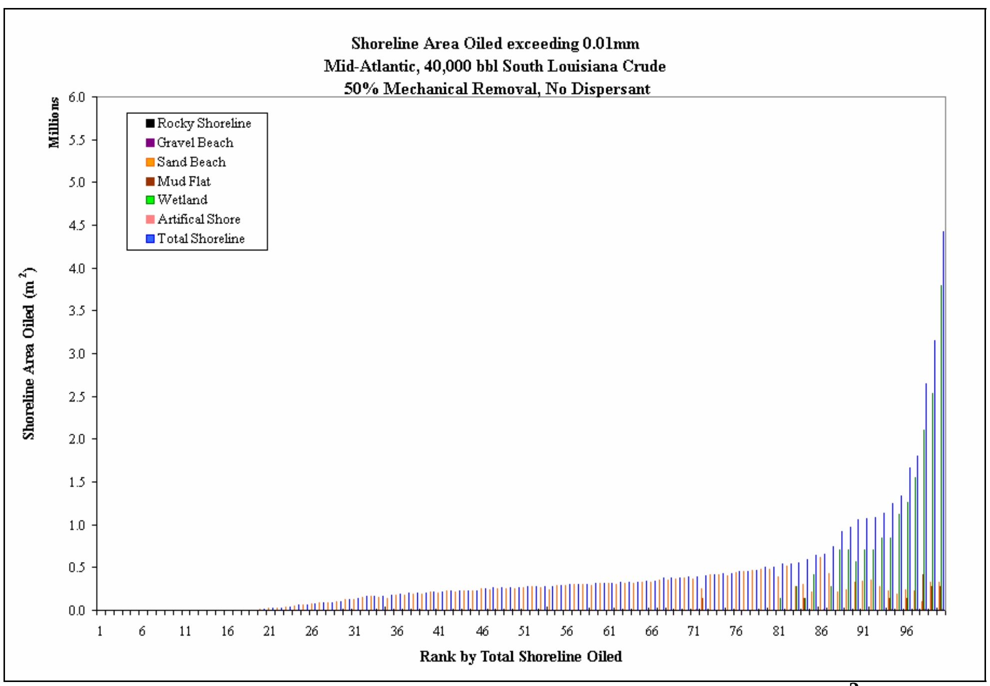

Figure B-II.3.4-3 Shoreline area exposed to hydrocarbons of >10g/m² (about 0.01mm thick). Scenario: Large Volume, No Dispersant.

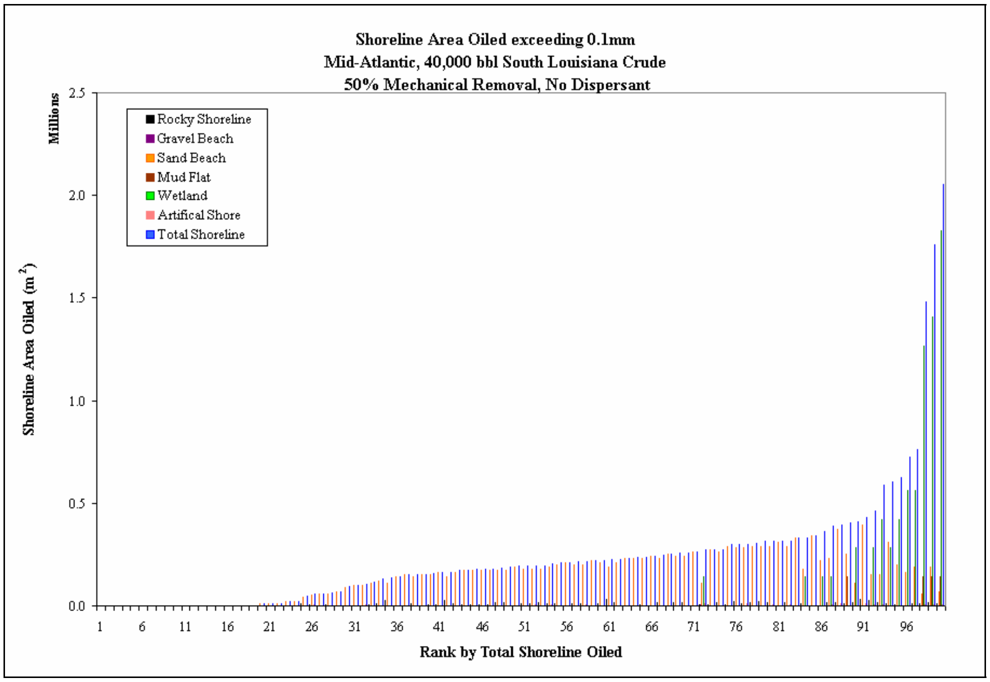

Figure B-II.3.4-4 Shoreline area exposed to hydrocarbons of >100g/m² (about 0.1mm thick). Scenario: Large Volume, No Dispersant.

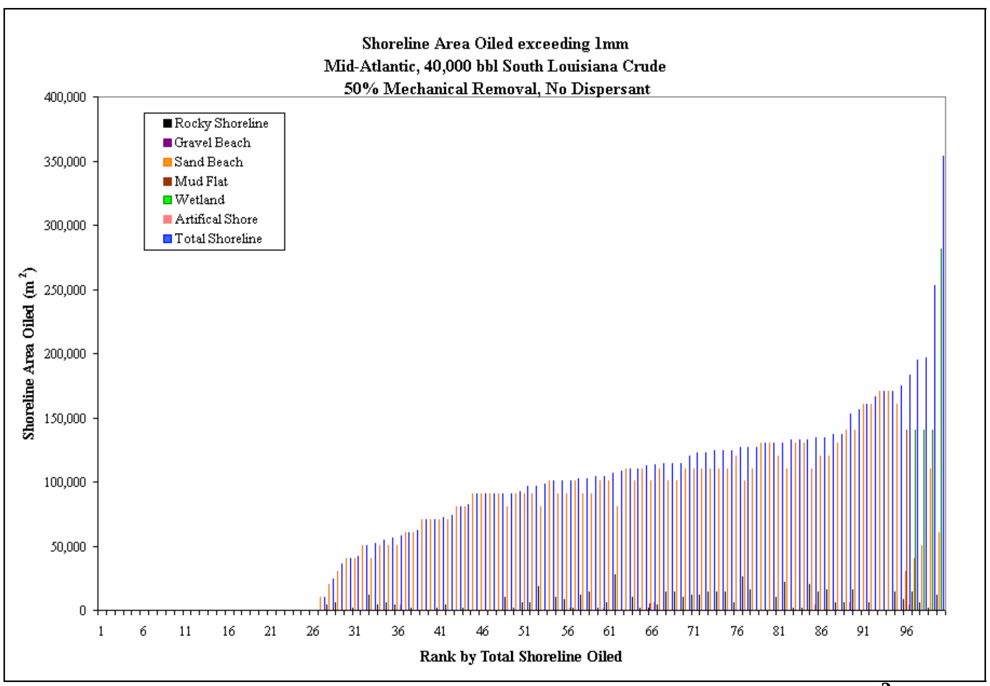

Figure B-II.3.4-5 Shoreline area exposed to hydrocarbons of >1000g/m² (about 1mm thick). Scenario: Large Volume, No Dispersant.

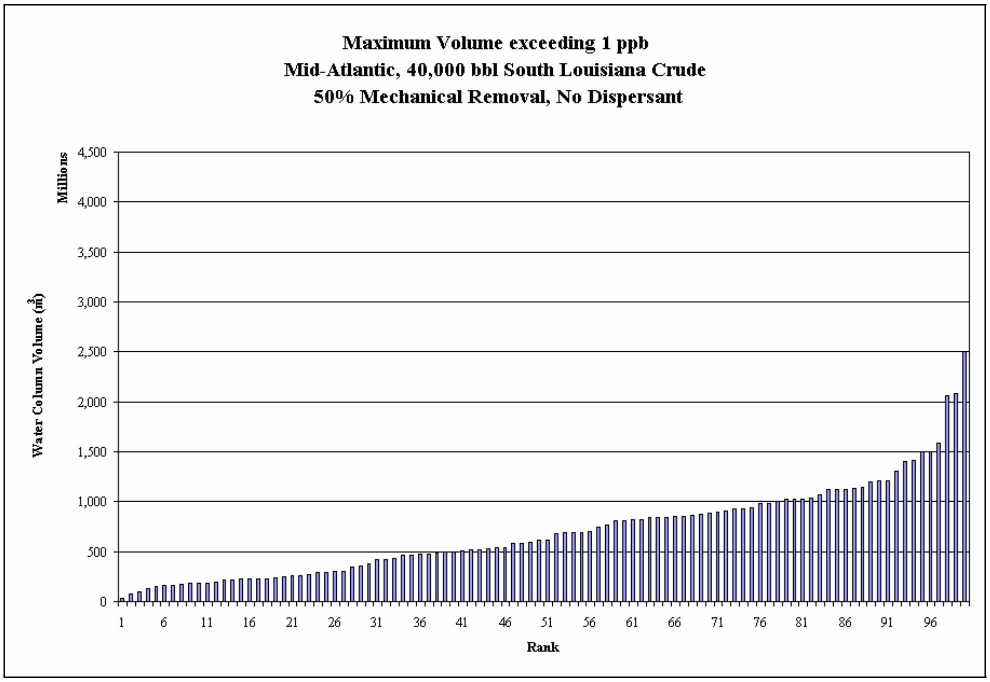

Figure B-II.3.4-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, No Dispersant.

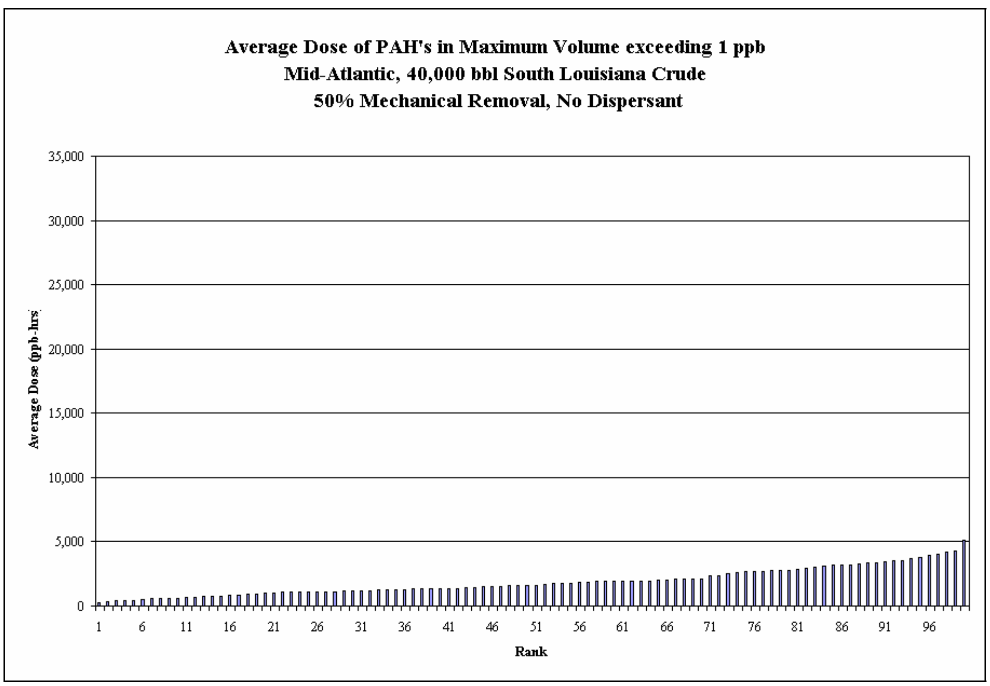

Figure B-II.3.4-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, No Dispersant.

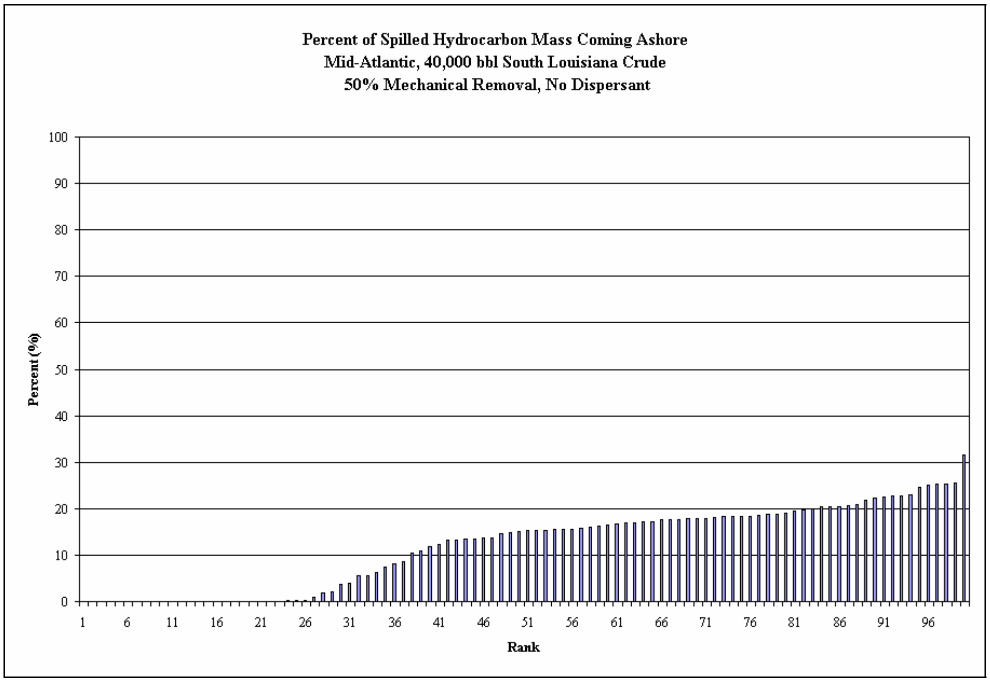

Figure B-II.3.4-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Large Volume, No Dispersant.

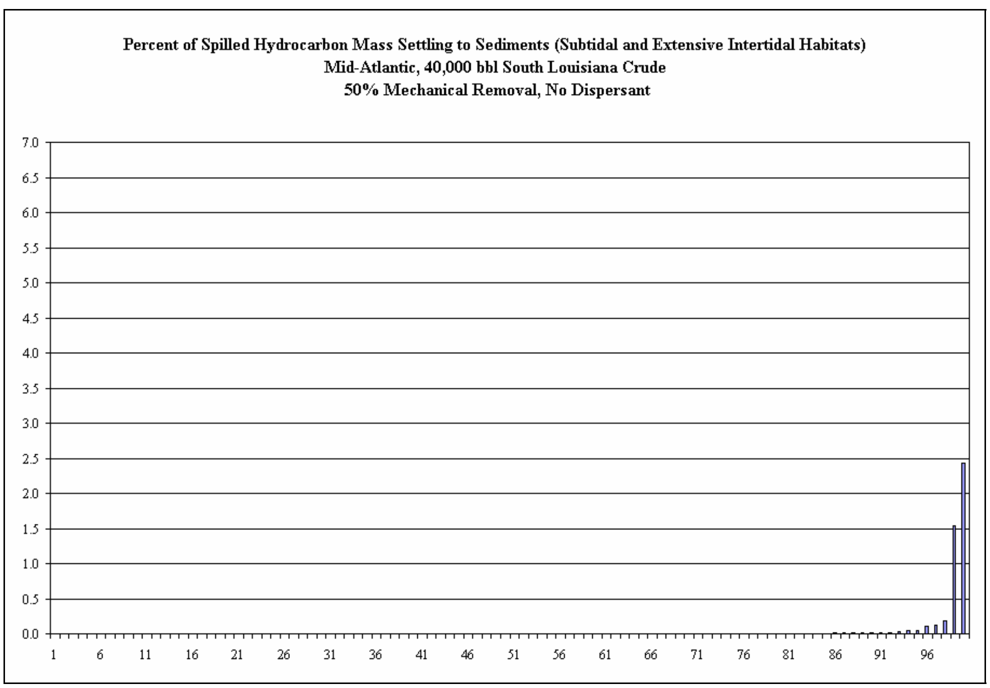

Figure B-II.3.4-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Large Volume, No Dispersant.

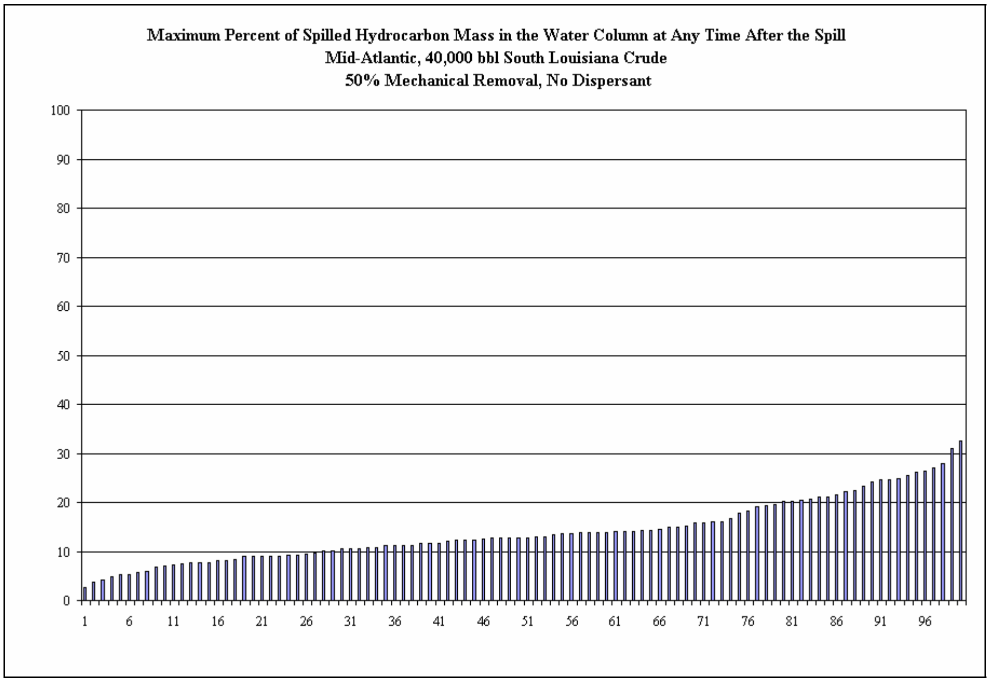

Figure B-II.3.4-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Large Volume, No Dispersant.

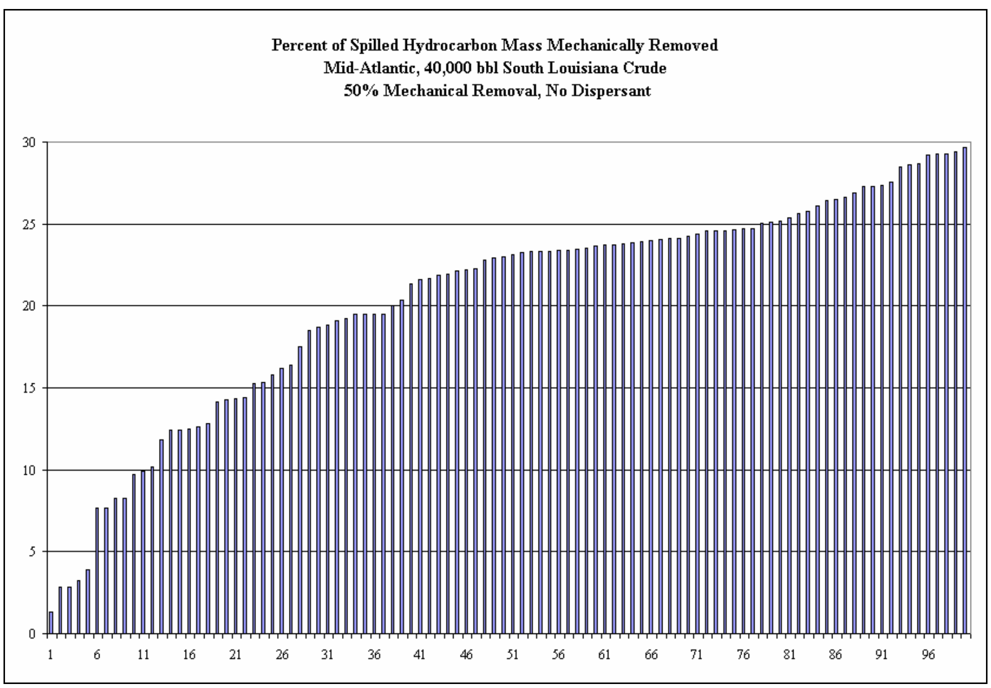

Figure B-II.3.4-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Large Volume, No Dispersant.

B-II.3.5 Scenario: Large Volume, 45% Dispersant Efficiency.

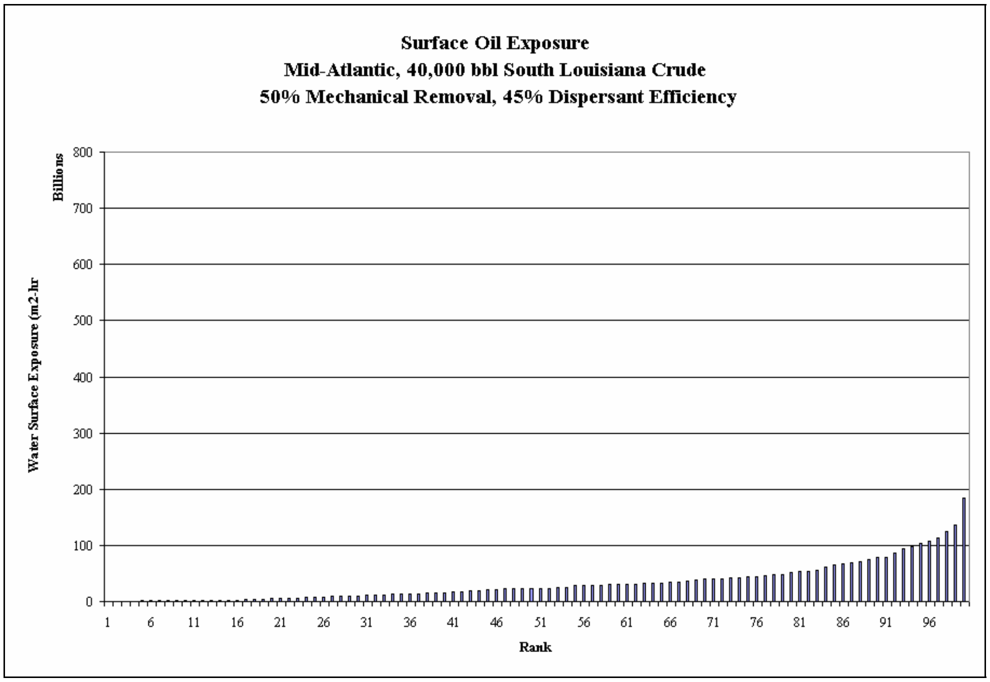

Figure B-II.3.5-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

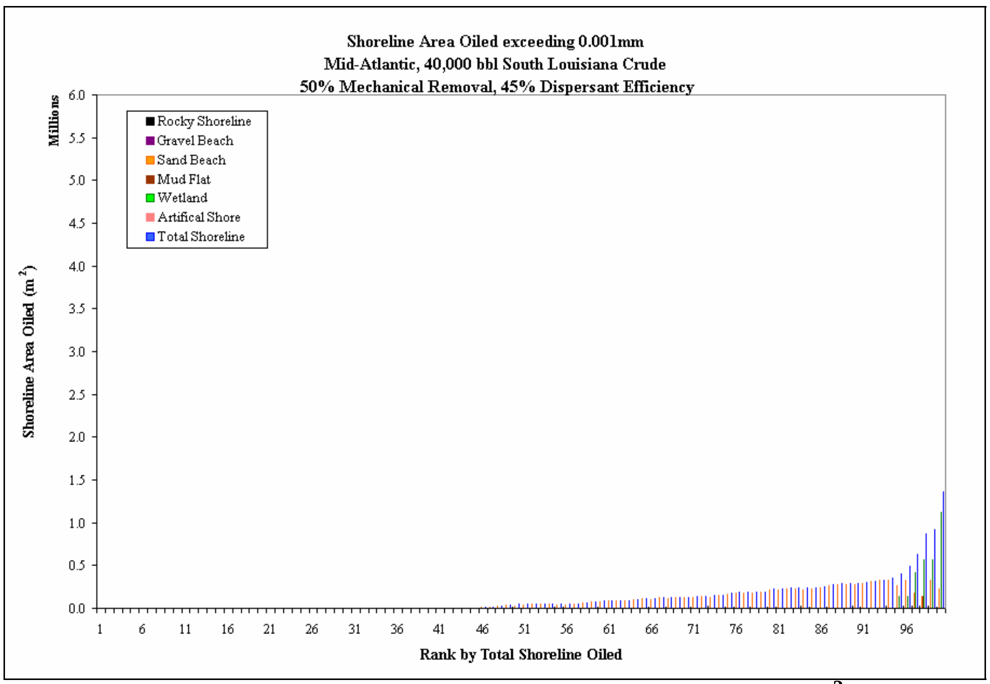

Figure B-II.3.5-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

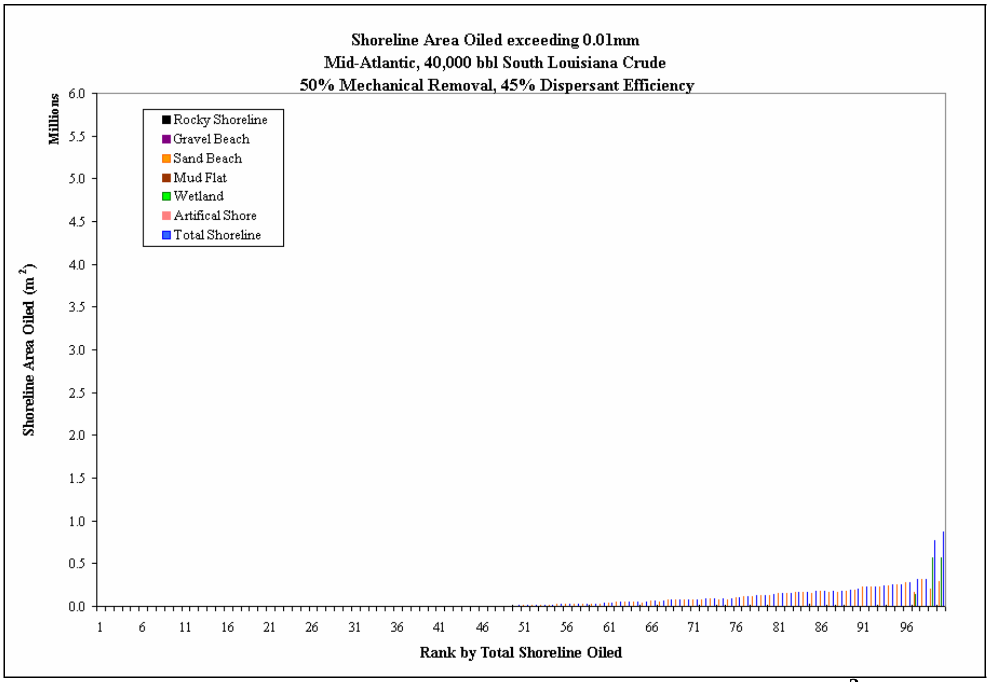

Figure B-II.3.5-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

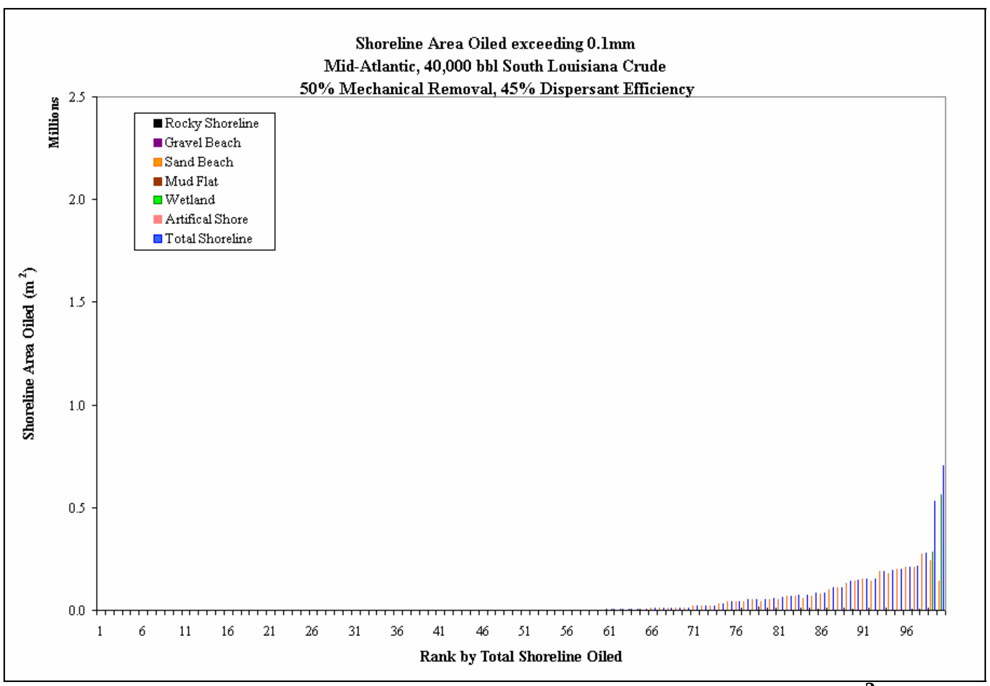

Figure B-II.3.5-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

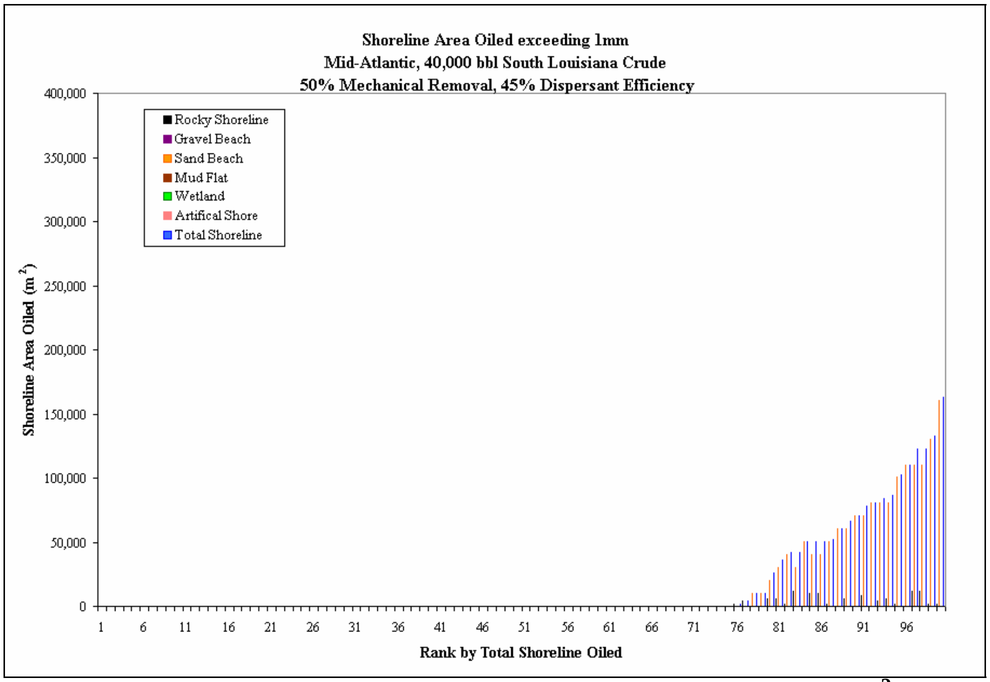

Figure B-II.3.5-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

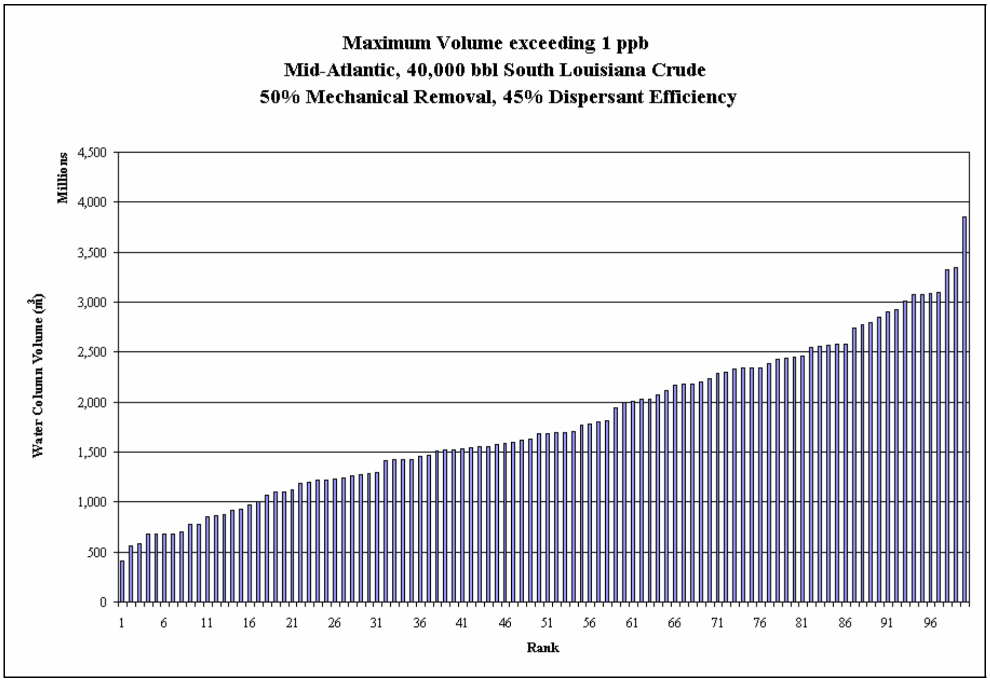

Figure B-II.3.5-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 45% Dispersant Efficiency.

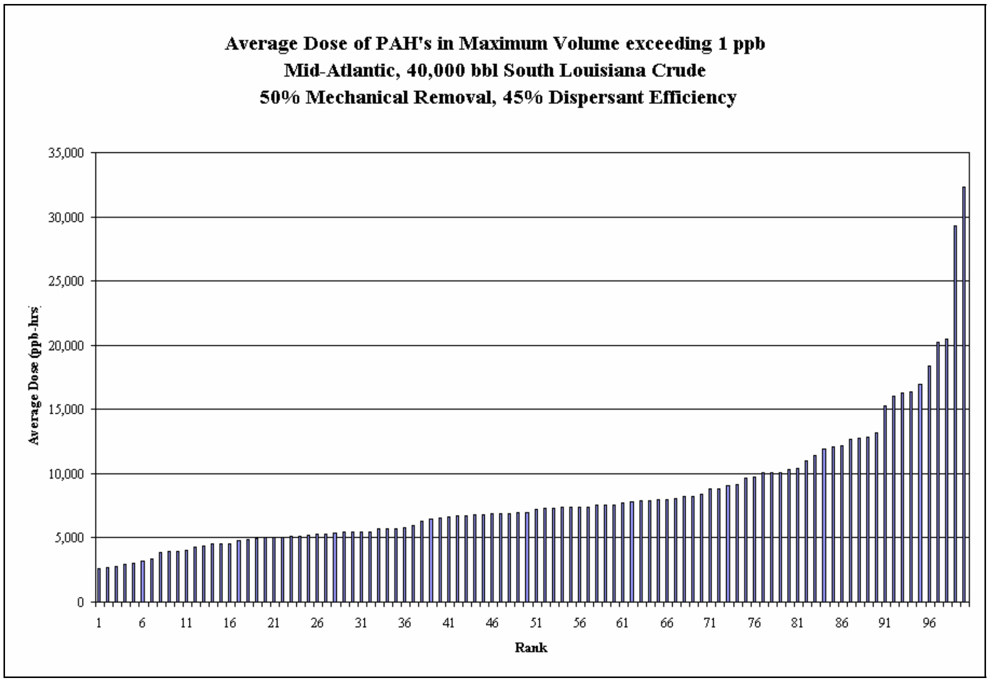

Figure B-II.3.5-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 45% Dispersant Efficiency.

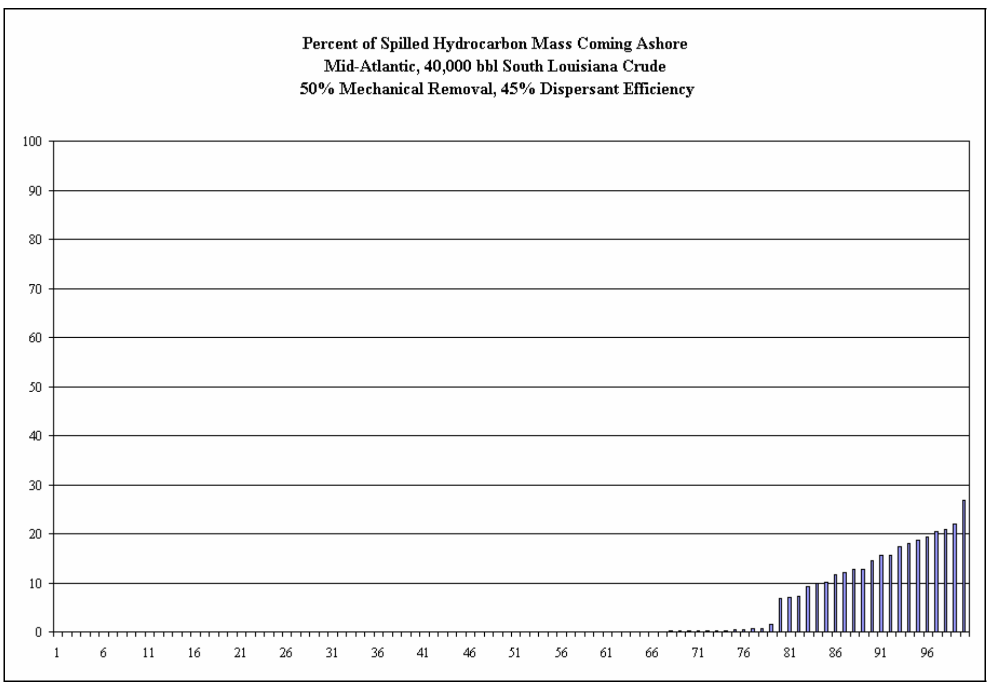

Figure B-II.3.5-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Large Volume, 45% Dispersant Efficiency.

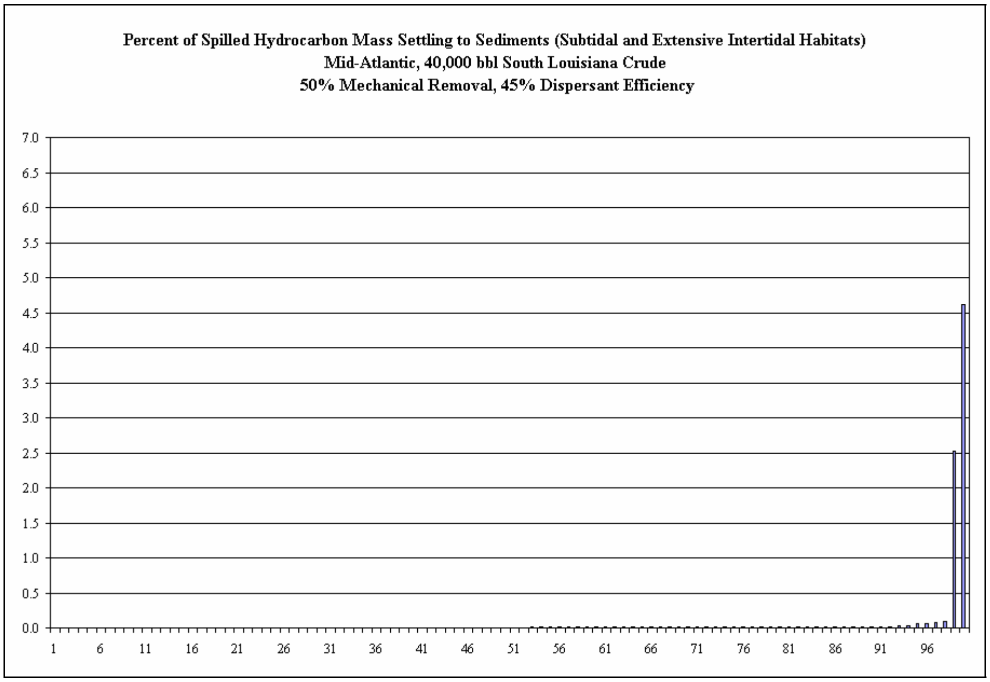

Figure B-II.3.5-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Large Volume, 45% Dispersant Efficiency.

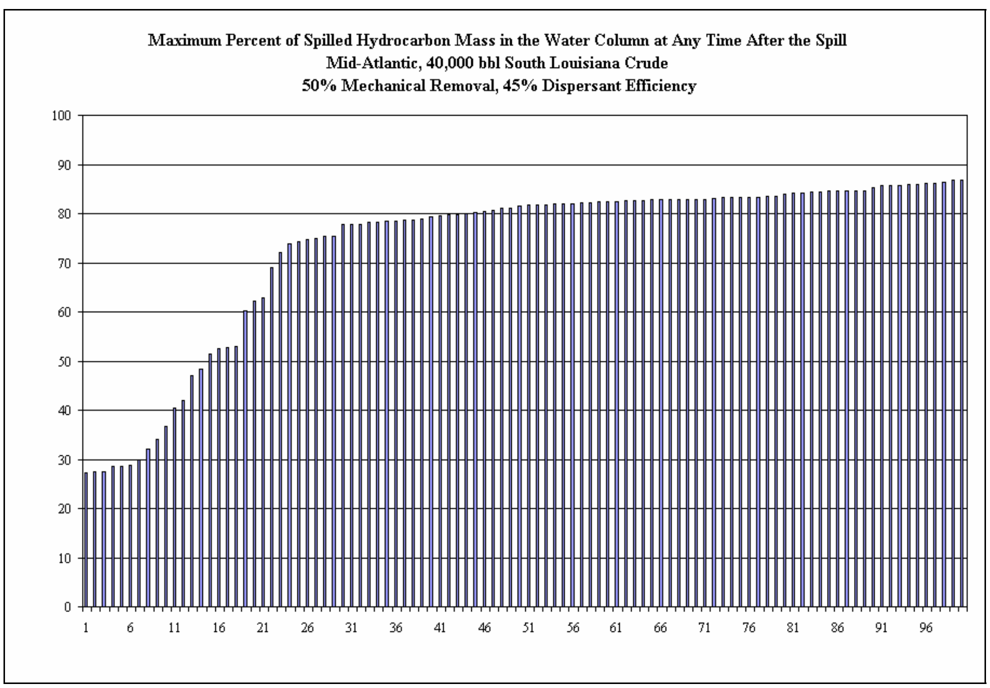

Figure B-II.3.5-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Large Volume, 45% Dispersant Efficiency.

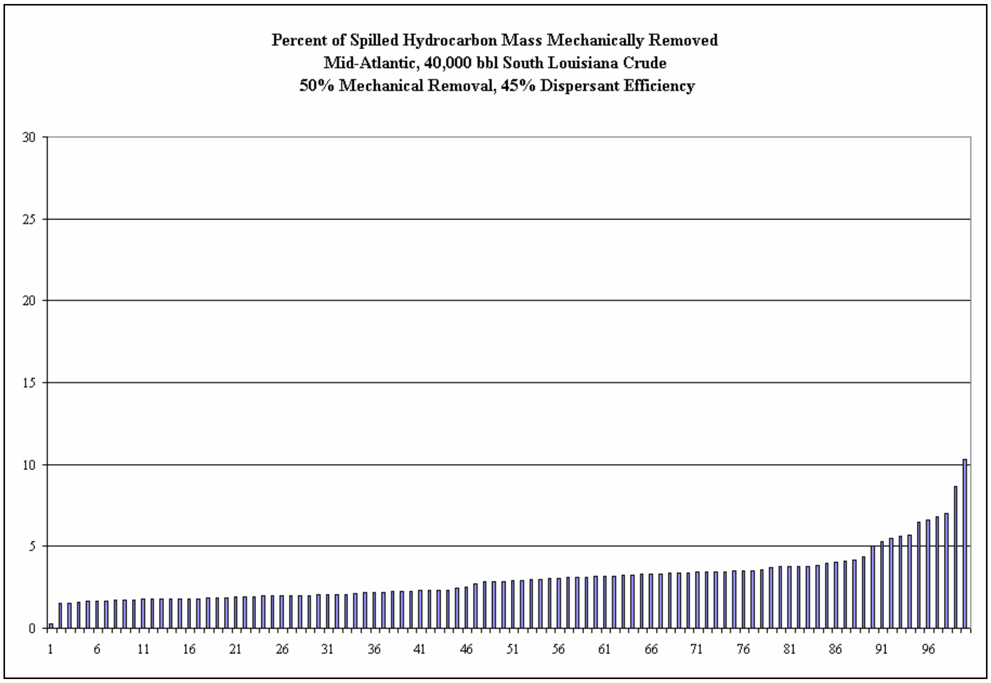

Figure B-II.3.5-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Large Volume, 45% Dispersant Efficiency.

B-II.3.6 Scenario: Large Volume, 80% Dispersant Efficiency.

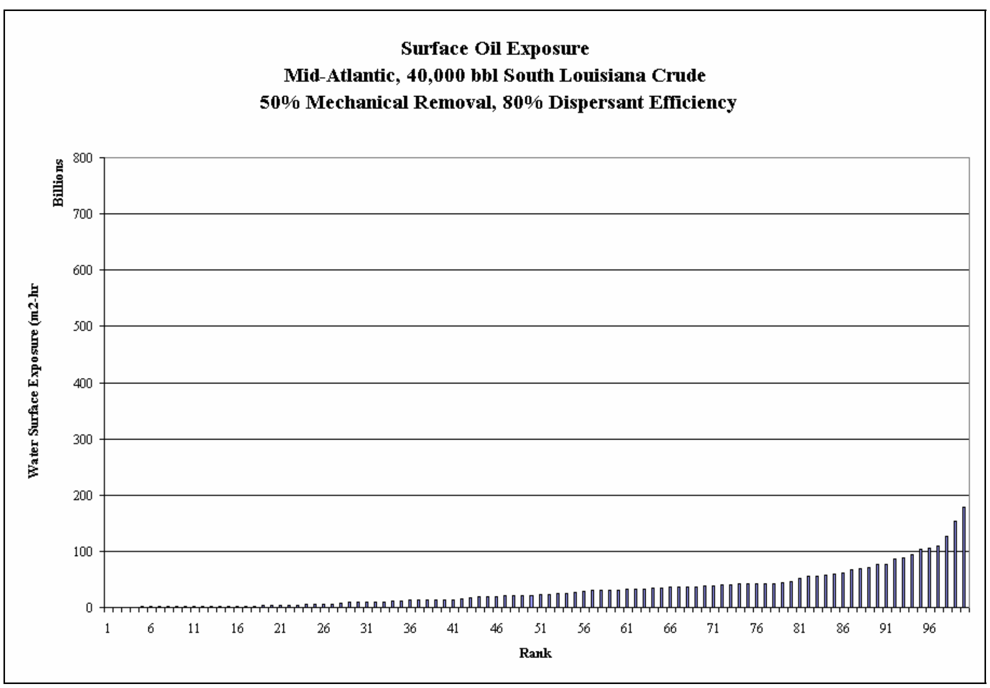

Figure B-II.3.6-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

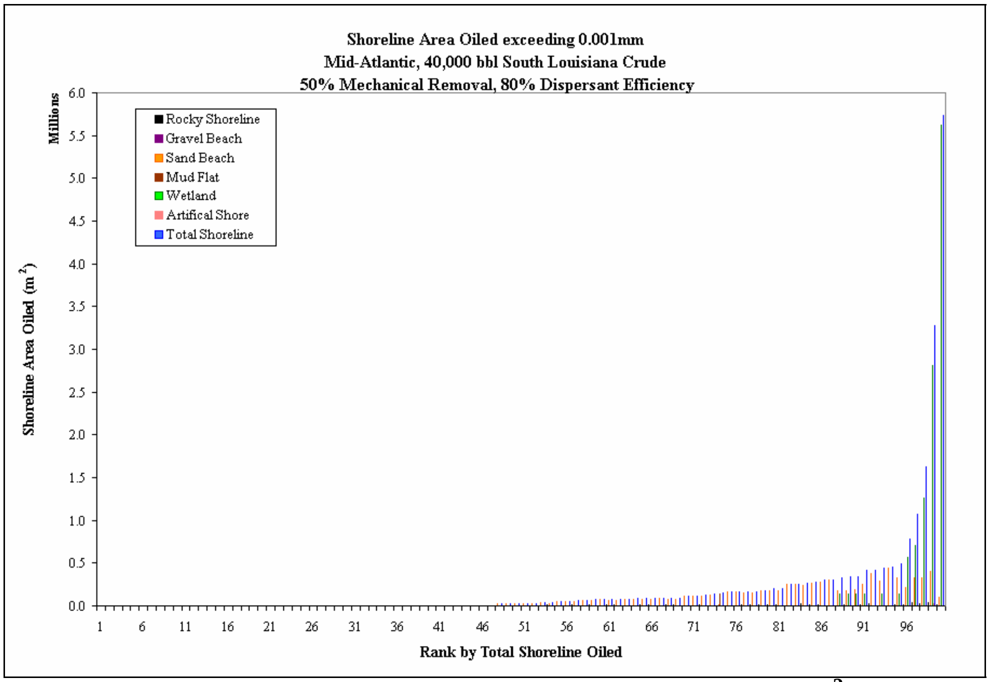

Figure B-II.3.6-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

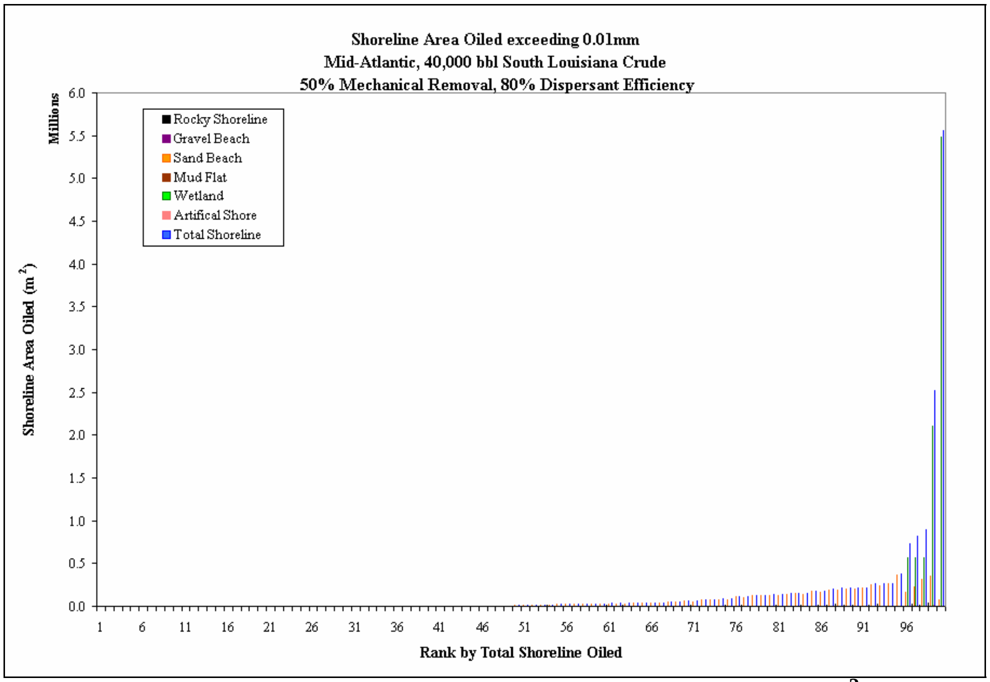

Figure B-II.3.6-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

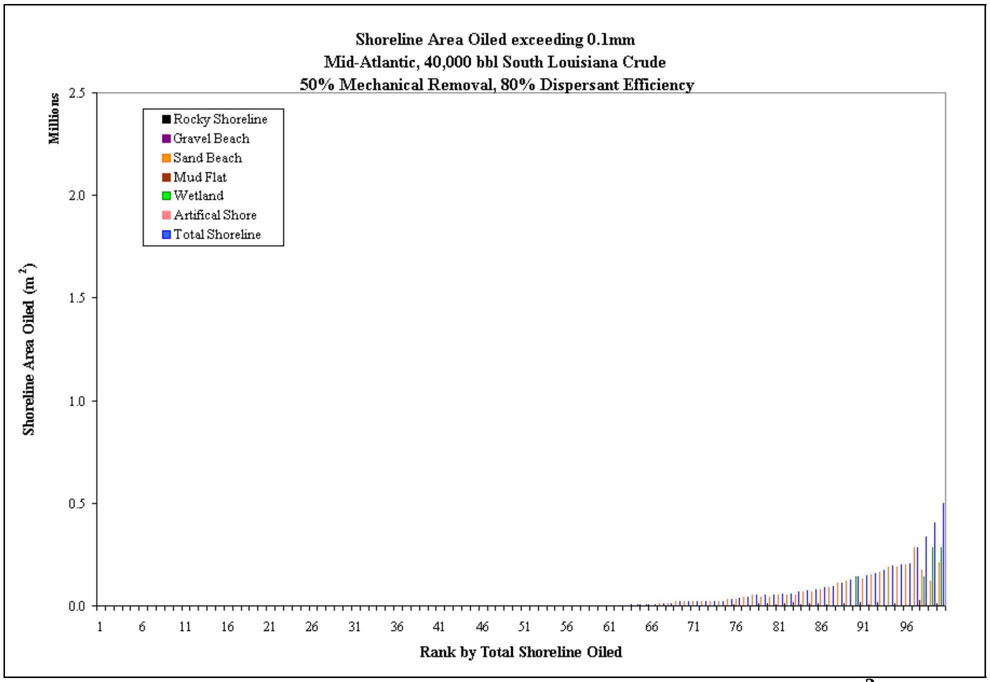

Figure B-II.3.6-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

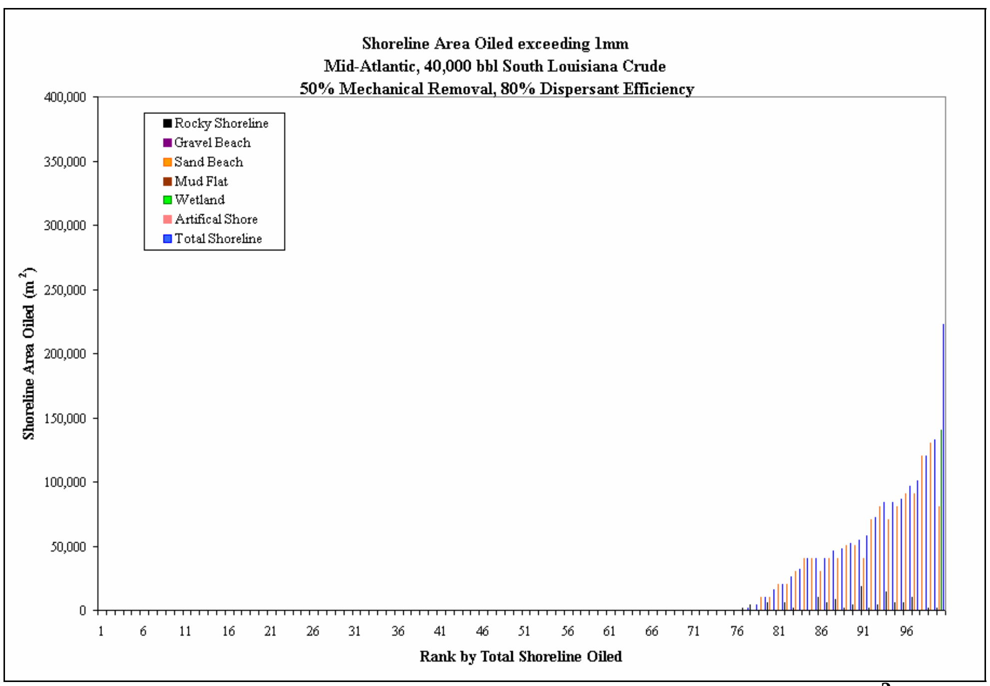

Figure B-II.3.6-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

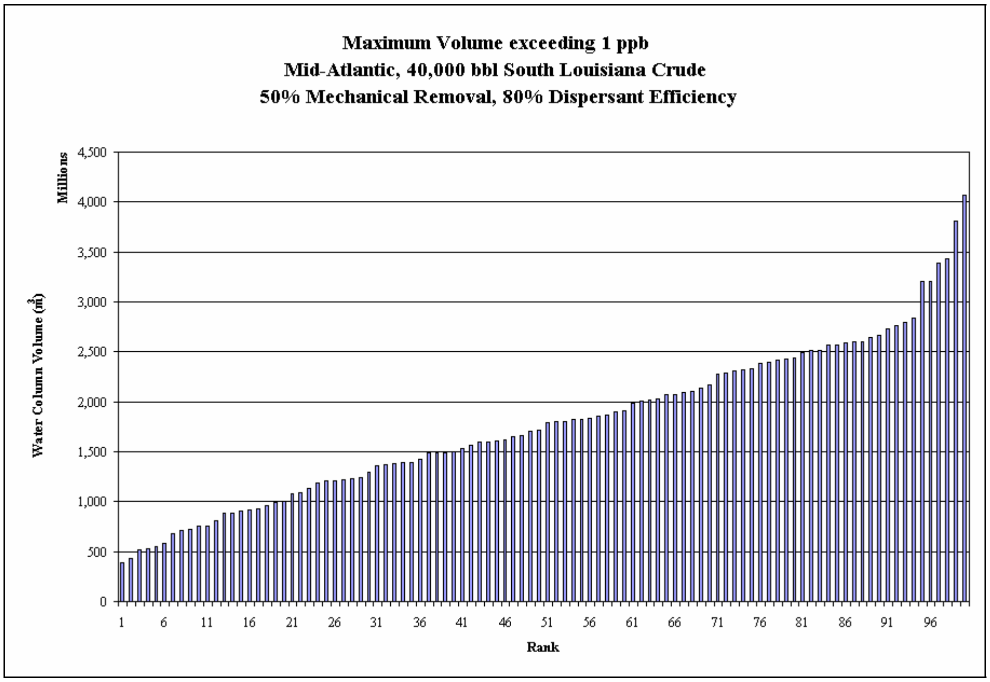

Figure B-II.3.6-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 80% Dispersant Efficiency.

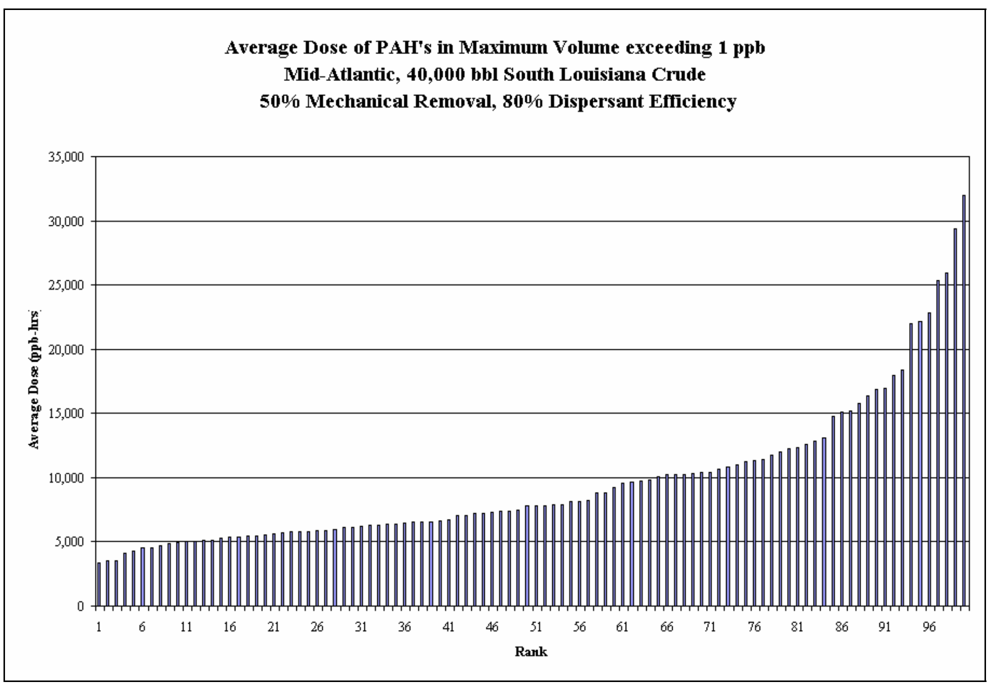

Figure B-II.3.6-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 80% Dispersant Efficiency.

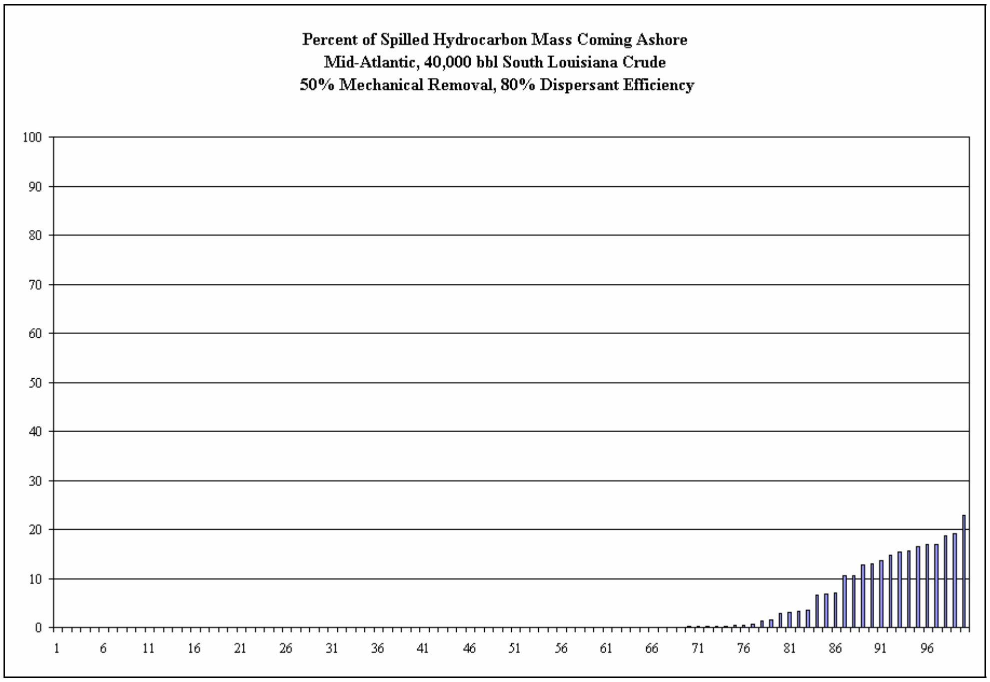

Figure B-II.3.6-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Large Volume, 80% Dispersant Efficiency.

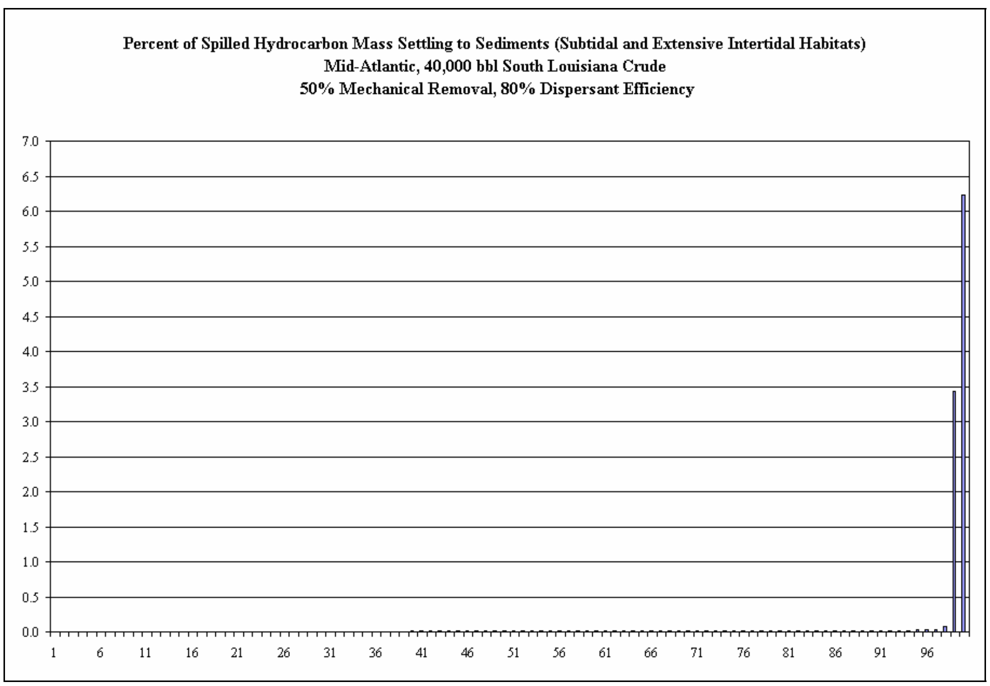

Figure B-II.3.6-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Large Volume, 80% Dispersant Efficiency.

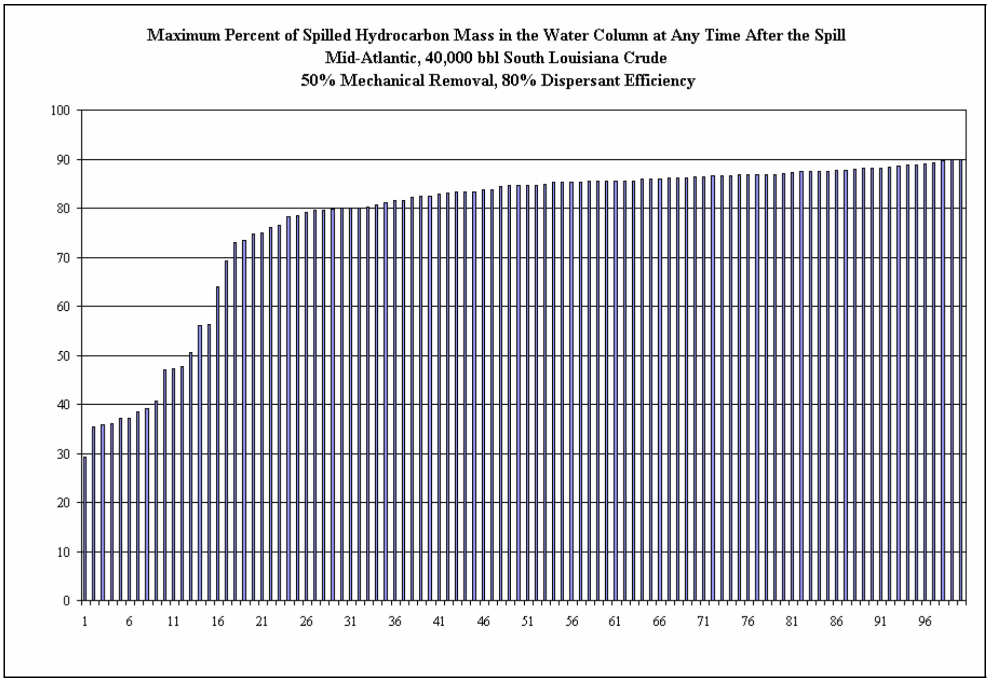

Figure B-II.3.6-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Large Volume, 80% Dispersant Efficiency.

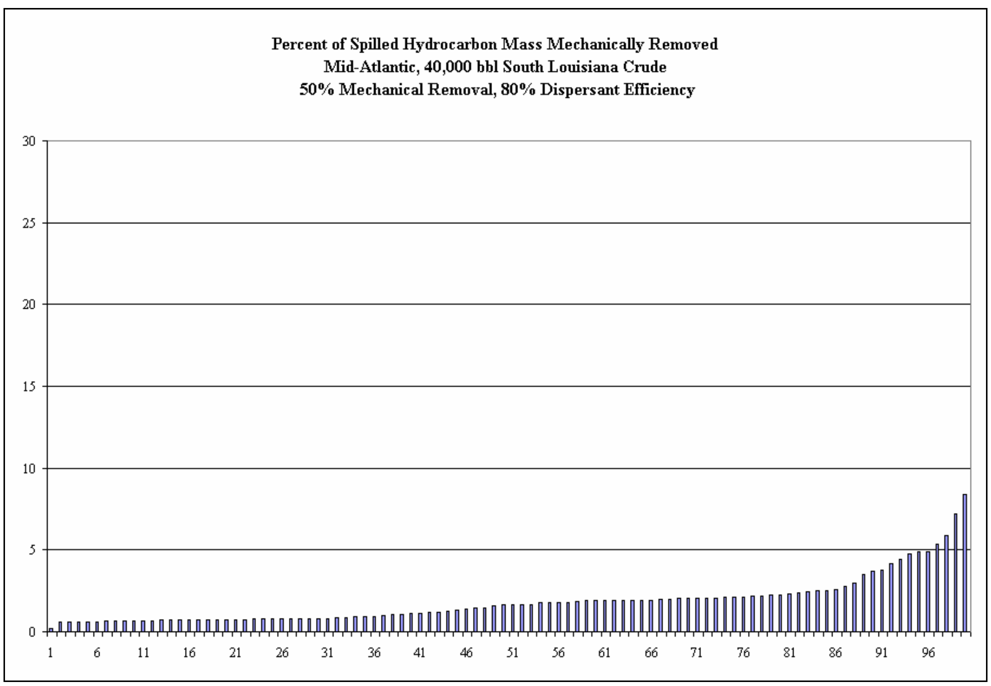

Figure B-II.3.6-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Large Volume, 80% Dispersant Efficiency.

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part B: Delaware Bay and Mid-Atlantic Shelf

Section B-II.4

by

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ASA 00-246

August 2004

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B-II.4 Exposure for Representative Individual Model Runs.

In this appendix, the results for the 50th percentile cases for surface oiling, shoreline oiling, water column effects, and sediment contamination are shown, as plots of the following measures of exposure:

- Water surface exposure to floating hydrocarbons (g/m^2)
- Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile surface oil exposure run
- Shoreline exposure to hydrocarbons (g/m^2)
- Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill
- Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill
- Water column exposure dose of dissolved aromatic concentration (ppb-hours)
- Sediment pore water exposure of dissolved aromatic concentration (ppb)
- Sediment exposure to total hydrocarbons (g/m^2)

The percentile runs plotted are those runs which apply to the exposure index being considered. Thus, different runs are plotted for each of surface oil, shoreline oil, water column effect measures, and sediment contamination. Tables B-II.4-1 to B-II.4-3 summarize the run number and date and time of the runs resulting in the 50th and 95th percentile exposures. The 95th percentile exposure indicates the maximum likely effect.

The Crosshair mark ( ) in figures below represents oil spill site.

Table B-II.4-1 Run number and date and time of the runs resulting in the 50th and 95th percentile exposures for surface oil exposure.

Surface Oil Exposure (exceeding 0.01 g/m^2)							
Scenario	**Percentile**	**Run Number**	**Year**	**Month**	**Day**	**Hour**	**Area-hrs (m^2-hrs)**
MATL-Med-50-0	50th	100	1996	5	11	13	9,285 x 10^6
	95th	11	1997	5	11	12	30,506 x 10^6
MATL-Med-50-45	50th	58	1992	1	30	10	1,853 x 10^6
	95th	83	1996	5	29	23	12,700 x 10^6
MATL-Med-50-80	50th	42	1998	3	13	4	2,020 x 10^6
	95th	11	1997	5	11	12	12,748 x 10^6
MATL-Lrg-50-0	50th	60	1993	5	9	0	117,748 x 10^6
	95th	26	1997	12	29	11	539,077 x 10^6
MATL-Lrg-50-45	50th	11	1997	5	11	12	23,244 x 10^6
	95th	27	1999	6	28	3	106,609 x 10^6
MATL-Lrg-50-80	50th	99	1997	8	5	10	23,013 x 10^6
	95th	63	2000	2	1	4	106,219 x 10^6

Table B-II.4-2 Run number and date and time of the runs resulting in the 50th and 95th percentile exposures for dissolved aromatic exposure.

Maximum Dissolved Aromatic Plume Volume exceeding 1 ppb							
Scenario	**Percentile**	**Run Number**	**Year**	**Month**	**Day**	**Hour**	**Volume (m^3)**
MATL-Med-50-0	50th	50	1995	11	18	6	112×10^6
	95th	62	1990	12	18	20	339×10^6
MATL-Med-50-45	50th	96	1994	2	7	5	210×10^6
	95th	58	1992	1	30	10	448×10^6
MATL-Med-50-80	50th	31	2000	10	4	11	220×10^6
	95th	5	1999	5	4	19	392×10^6
MATL-Lrg-50-0	50th	97	2000	8	28	7	620×10^6
	95th	15	2001	9	30	4	$1{,}504 \times 10^6$
MATL-Lrg-50-45	50th	27	1999	6	28	3	$1{,}684 \times 10^6$
	95th	11	1997	5	11	12	$3{,}085 \times 10^6$
MATL-Lrg-50-80	50th	36	1991	1	5	10	$1{,}793 \times 10^6$
	95th	49	1991	1	31	8	$3{,}204 \times 10^6$

Table B-II.4-3 Run number and date and time of the runs resulting in the 50th and 95th percentile exposures for sediment exposure.

Percent of Spilled Mass Reaching Sediment							
Scenario	**Percentile**	**Run Number**	**Year**	**Month**	**Day**	**Hour**	**%**
MATL-Med-50-0	50th	20	1994	11	18	21	0.002
	95th	96	1994	2	7	5	0.352
MATL-Med-50-45	50th	10	1992	10	12	2	0.006
	95th	55	1992	8	27	16	0.382
MATL-Med-50-80	50th	50	1995	11	18	6	0.007
	95th	55	1992	8	27	16	0.135
MATL-Lrg-50-0	50th	4	1999	2	5	8	23.123
	95th	7	2000	2	7	23	29.234
MATL-Lrg-50-45	50th	59	1999	7	19	17	2.906
	95th	25	1994	11	17	20	6.613
MATL-Lrg-50-80	50th	59	1999	7	19	17	1.657
	95th	26	1997	12	29	11	4.922

B-II.4.1 Scenario: Medium Volume, No Dispersant.

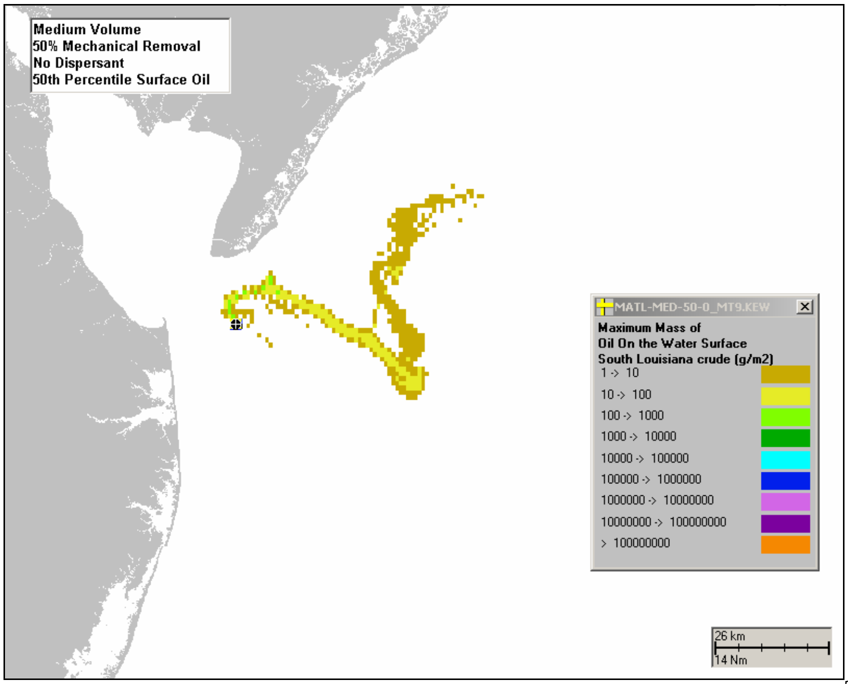

Figure B-II.4.1-1. Water surface exposure to floating hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, No Dispersant.

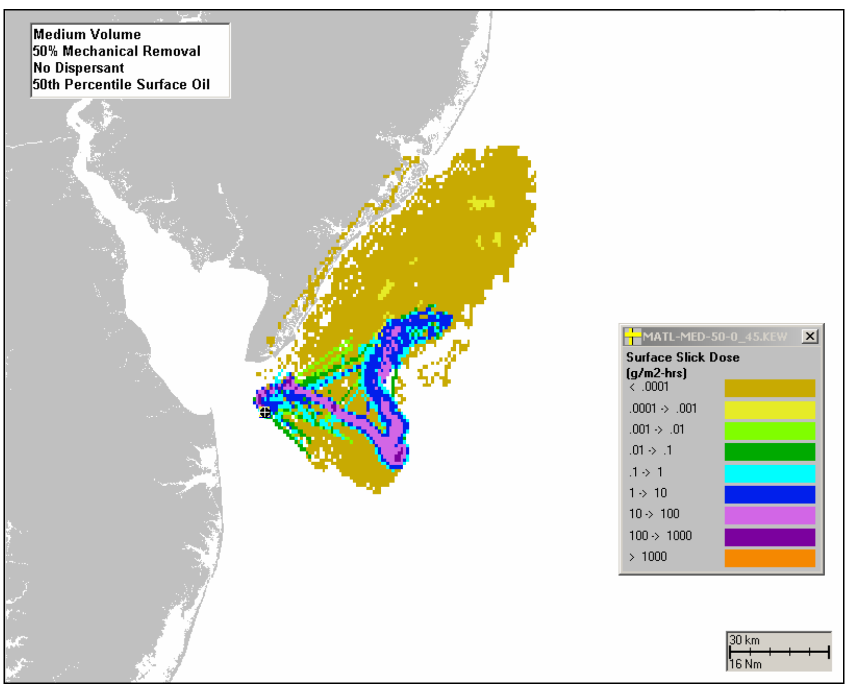

Figure B-II.4.1-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, No Dispersant.

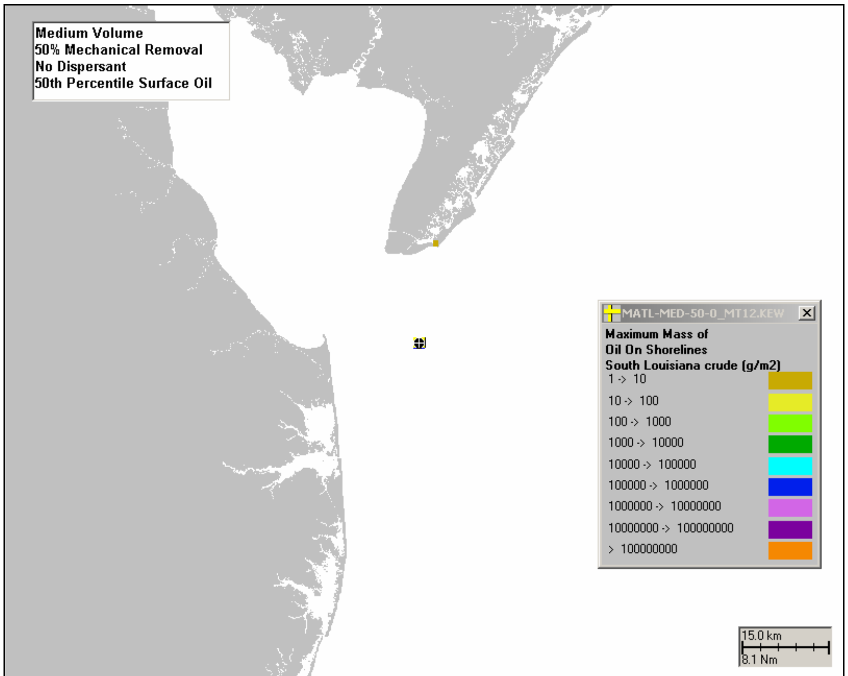

Figure B-II.4.1-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, No Dispersant.

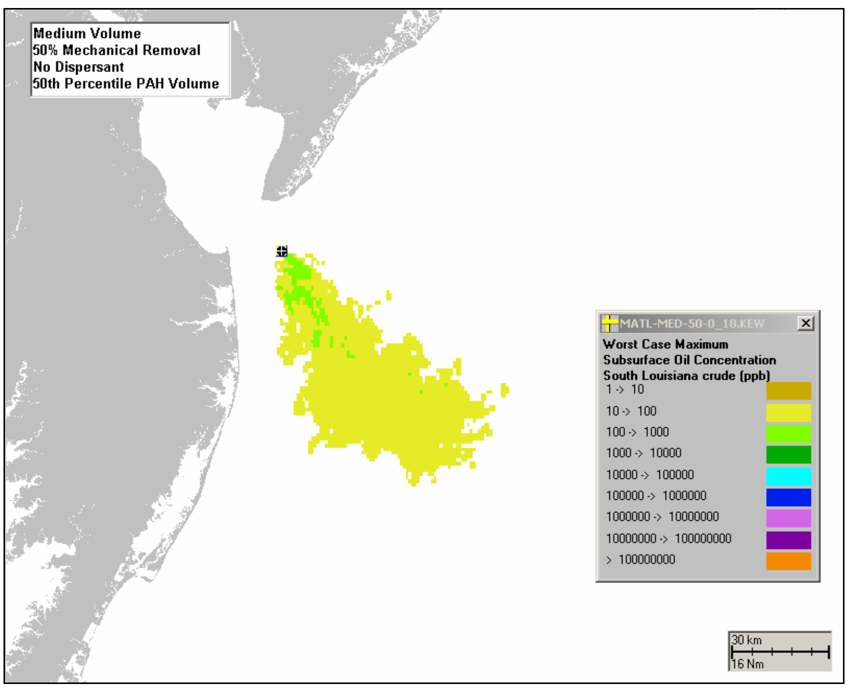

Figure B-II.4.1-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, No Dispersant.

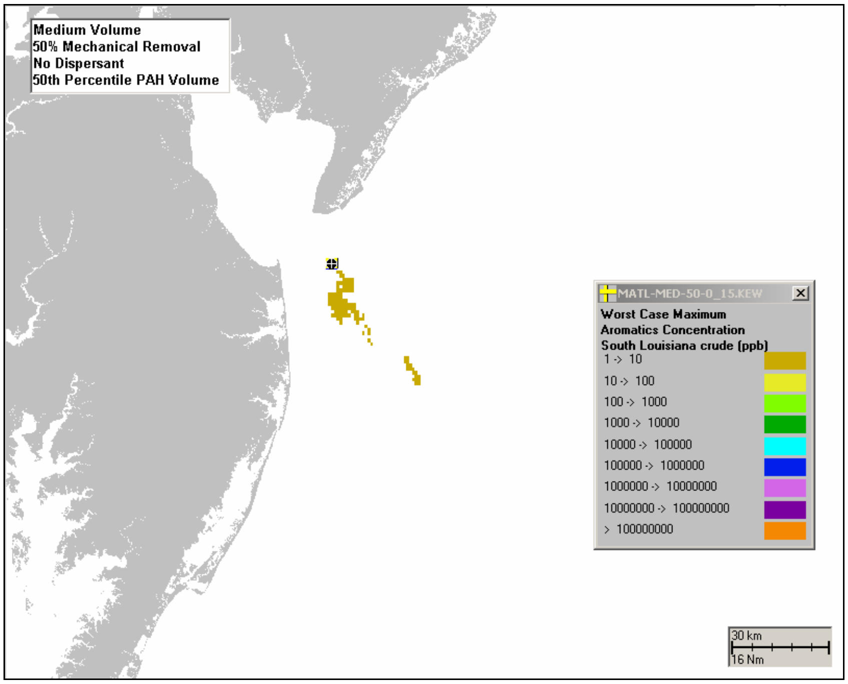

Figure B-II.4.1-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, No Dispersant.

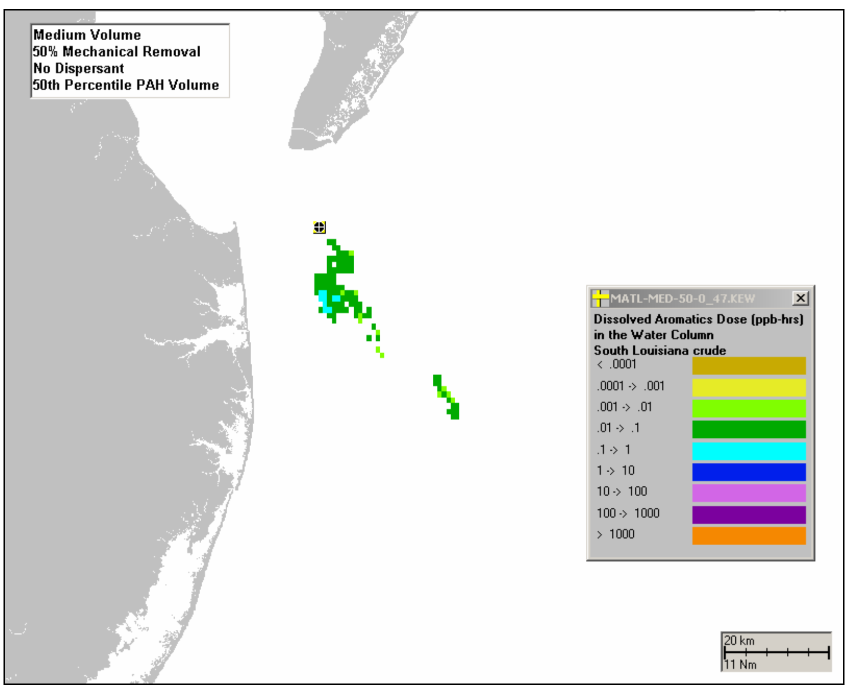

Figure B-II.4.1-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, No Dispersant.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Medium Volume, No Dispersant.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Medium Volume, No Dispersant.

B-II.4.2 Scenario: Medium Volume, 45% Dispersant Efficiency.

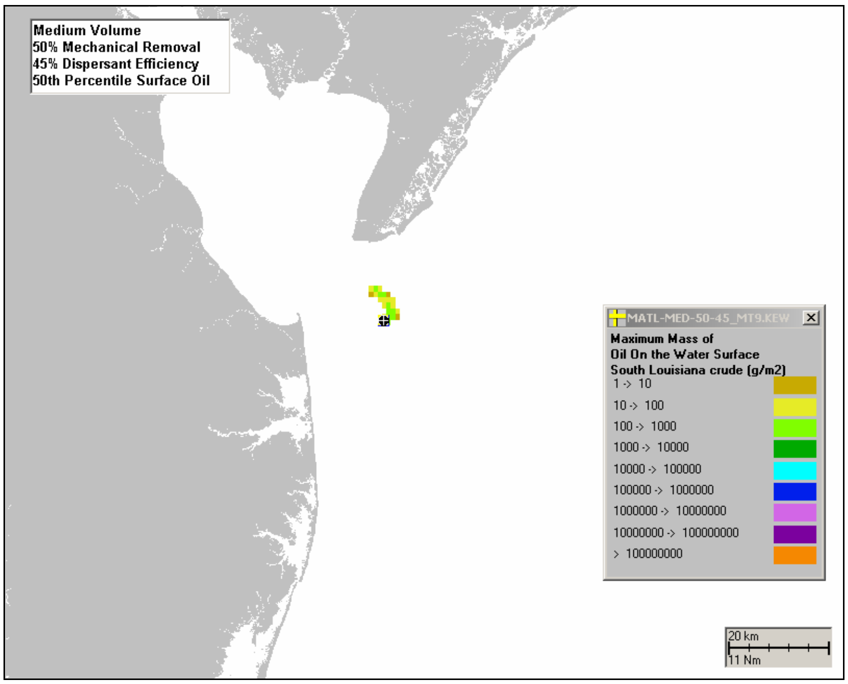

Figure B-II.4.2-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

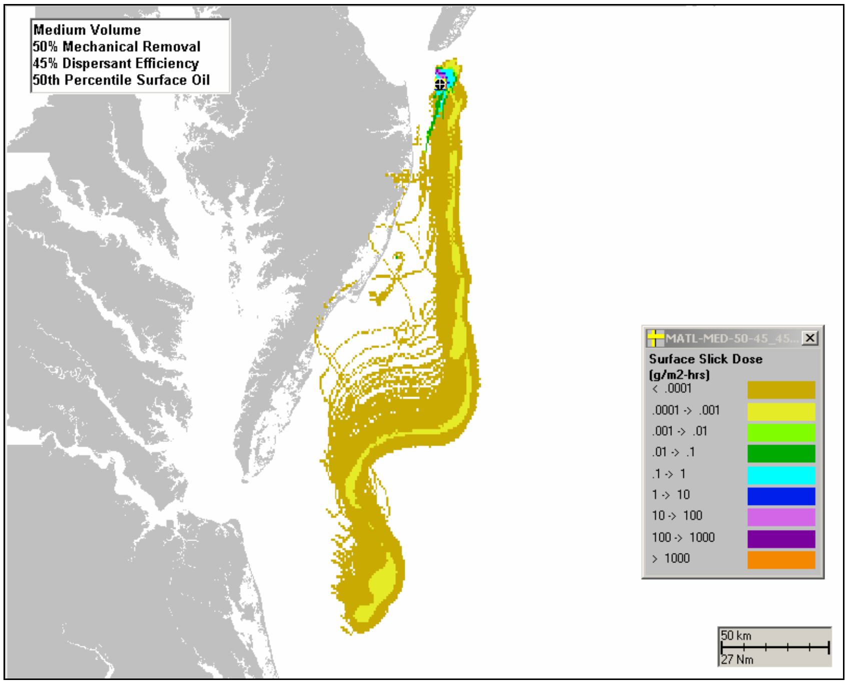

Figure B-II.4.2-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

Shoreline exposure to hydrocarbons, for 50th percentile run based on surface oil exposure does not exceed threshold of 0.01 g/m^2. Scenario: Medium Volume, 45% Dispersant Efficiency.

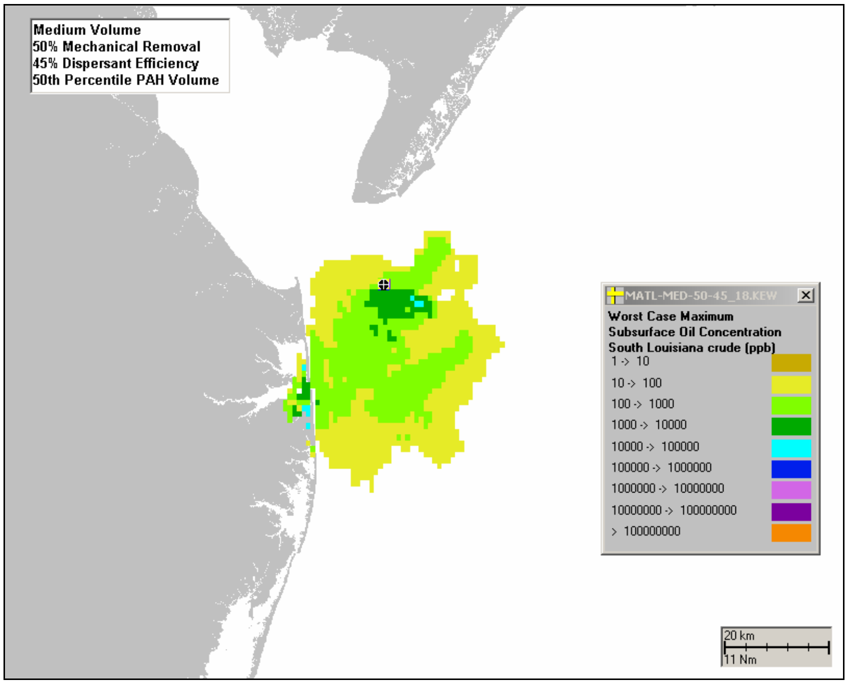

Figure B-II.4.2-3. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 45% Dispersant Efficiency.

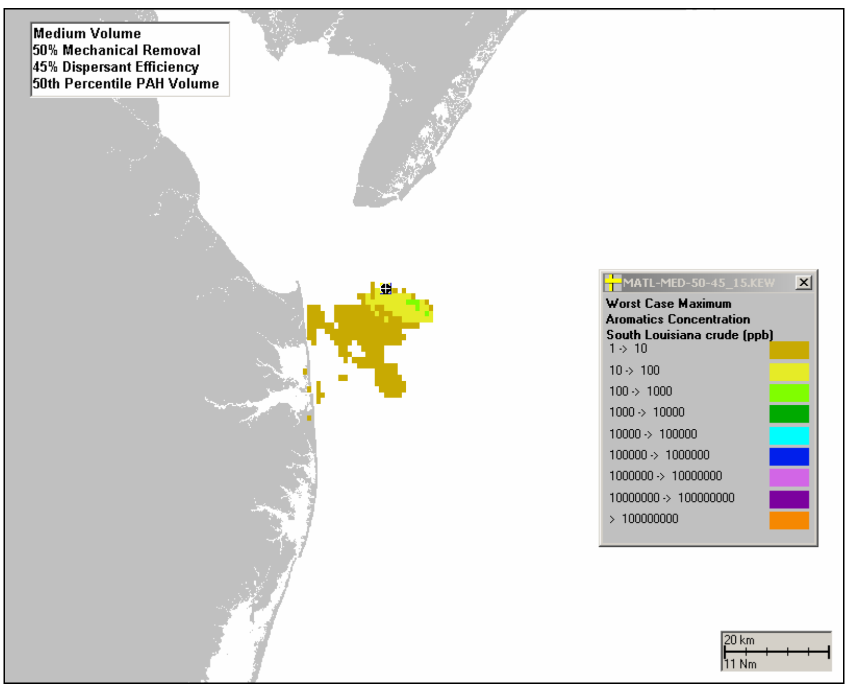

Figure B-II.4.2-4. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 45% Dispersant Efficiency.

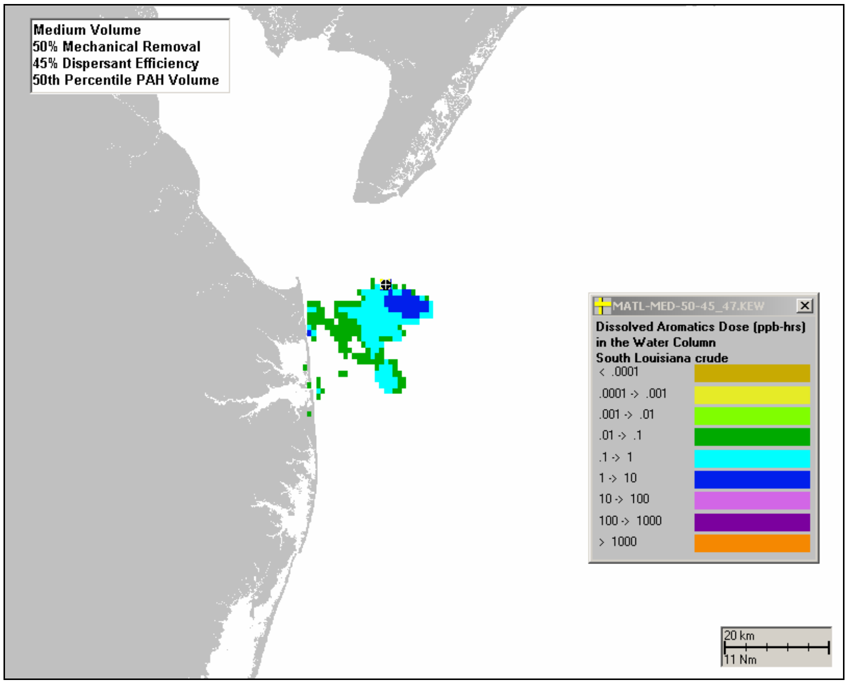

Figure B-II.4.2-5. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 45% Dispersant Efficiency.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Medium Volume, 45% Dispersant Efficiency..

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

B-II.4.3 Scenario: Medium Volume, 80% Dispersant Efficiency.

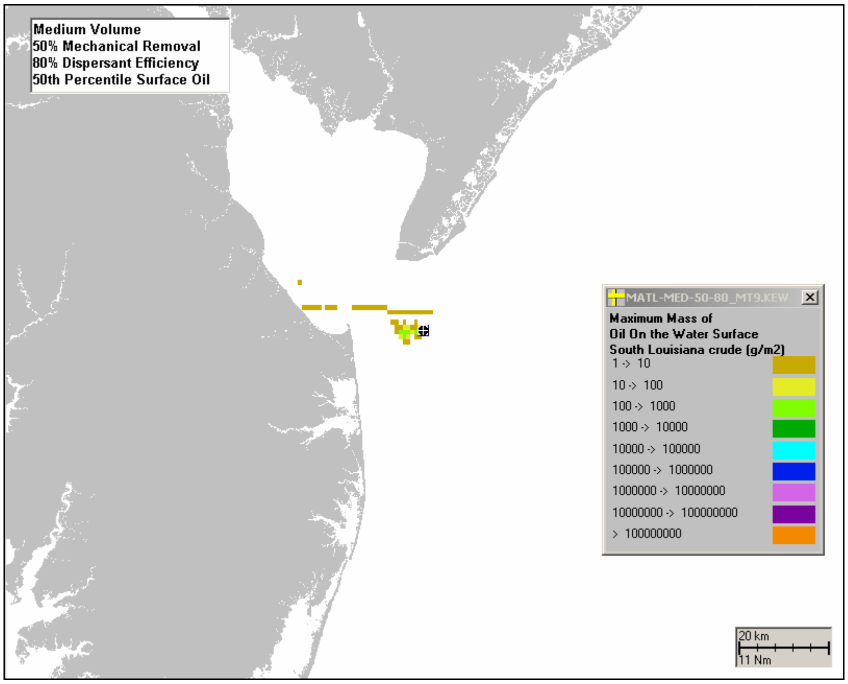

Figure B-II.4.3-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

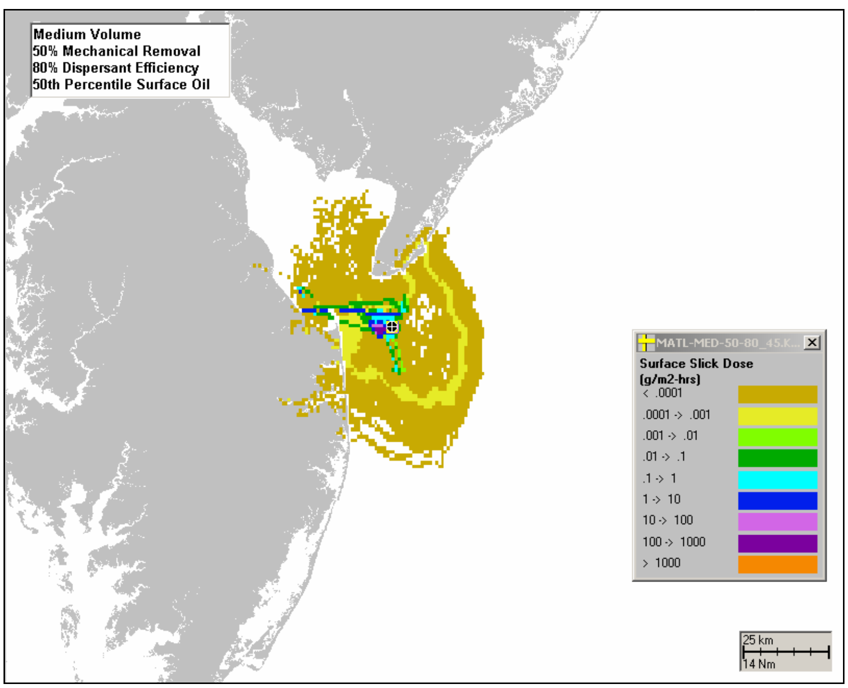

Figure B-II.4.3-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

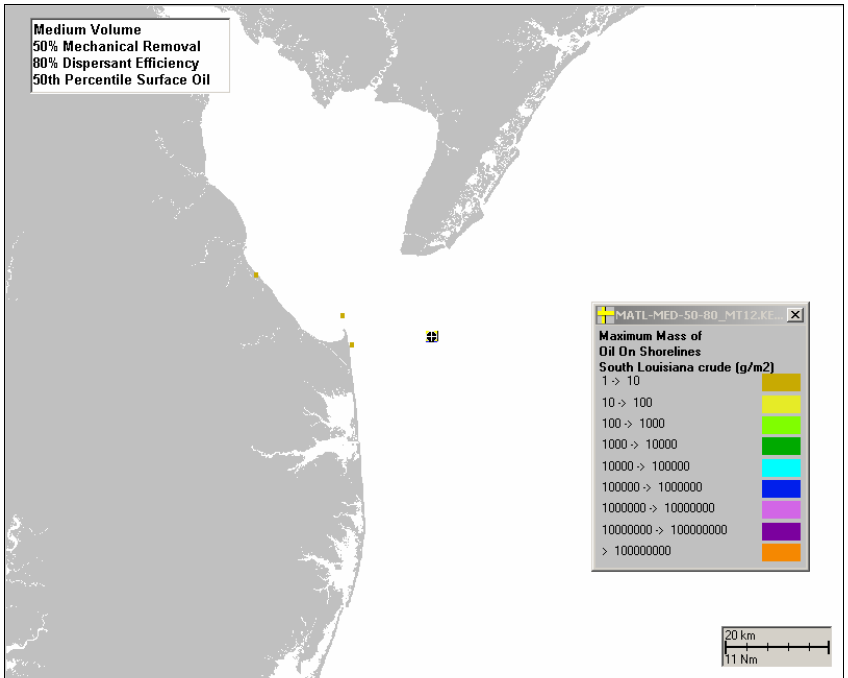

Figure B-II.4.3-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

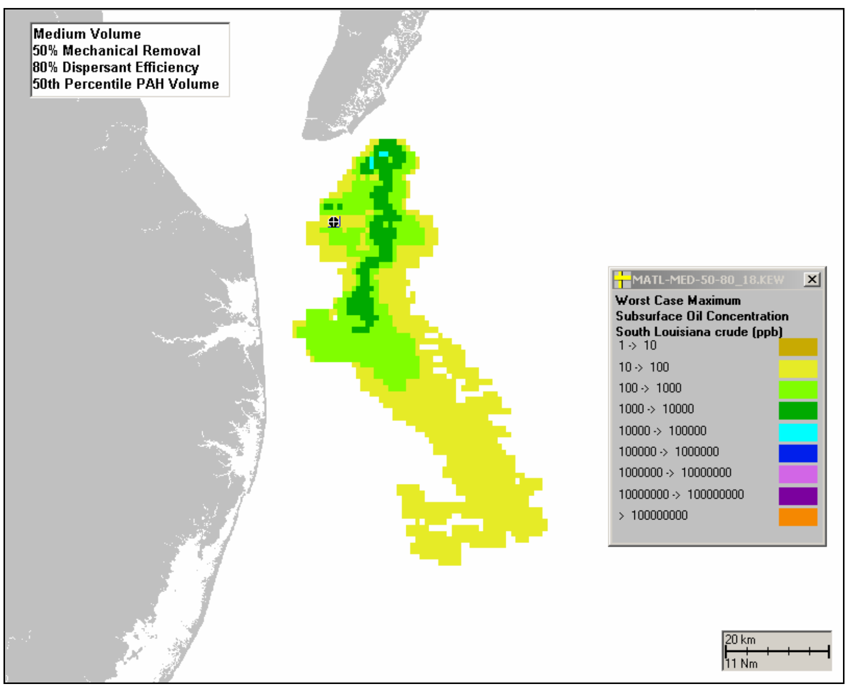

Figure B-II.4.3-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 80% Dispersant Efficiency.

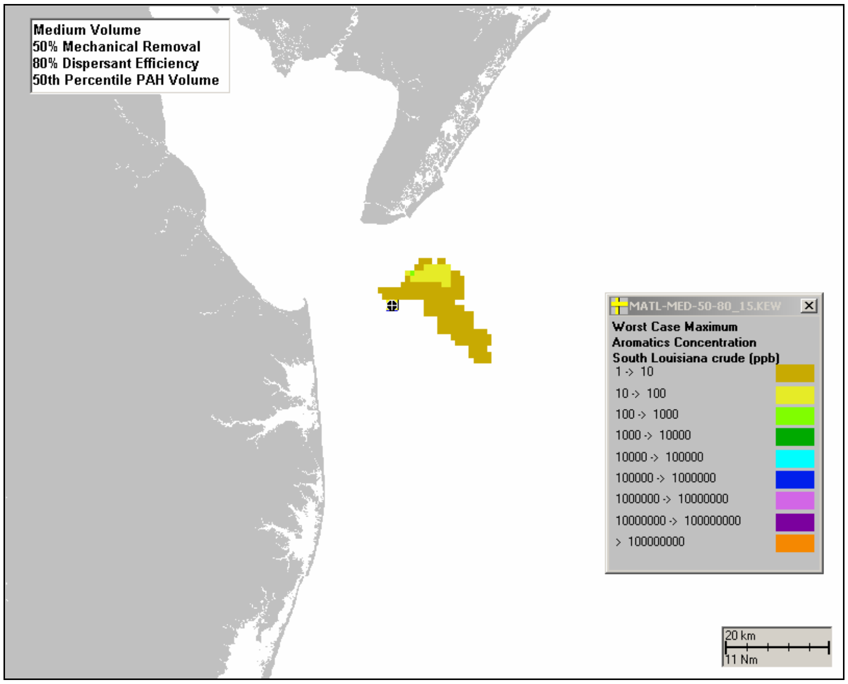

Figure B-II.4.3-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 80% Dispersant Efficiency.

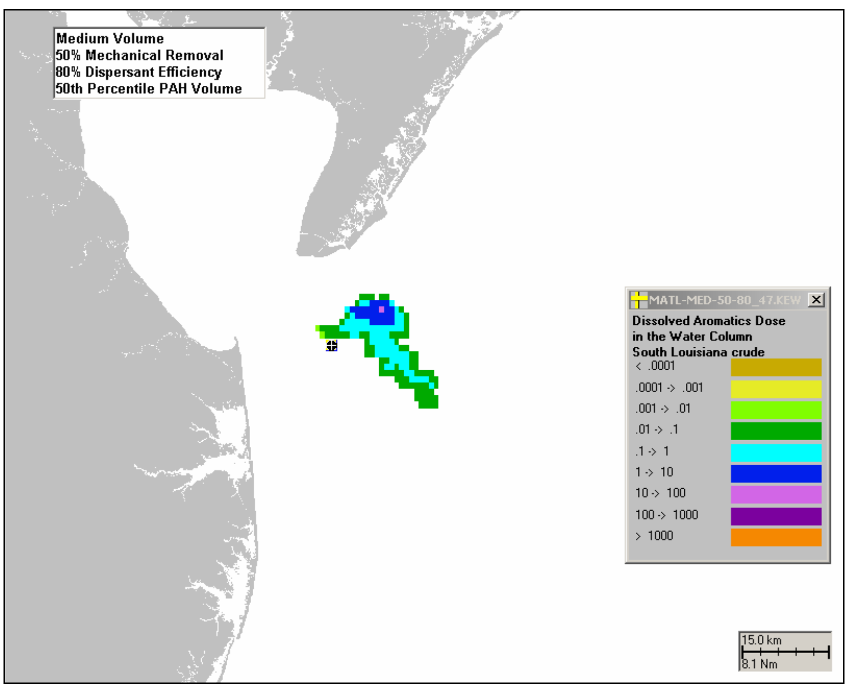

Figure B-II.4.3-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 80% Dispersant Efficiency.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Medium Volume, 80% Dispersant Efficiency..

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

B-II.4.4 Scenario: Large Volume, No Dispersant.

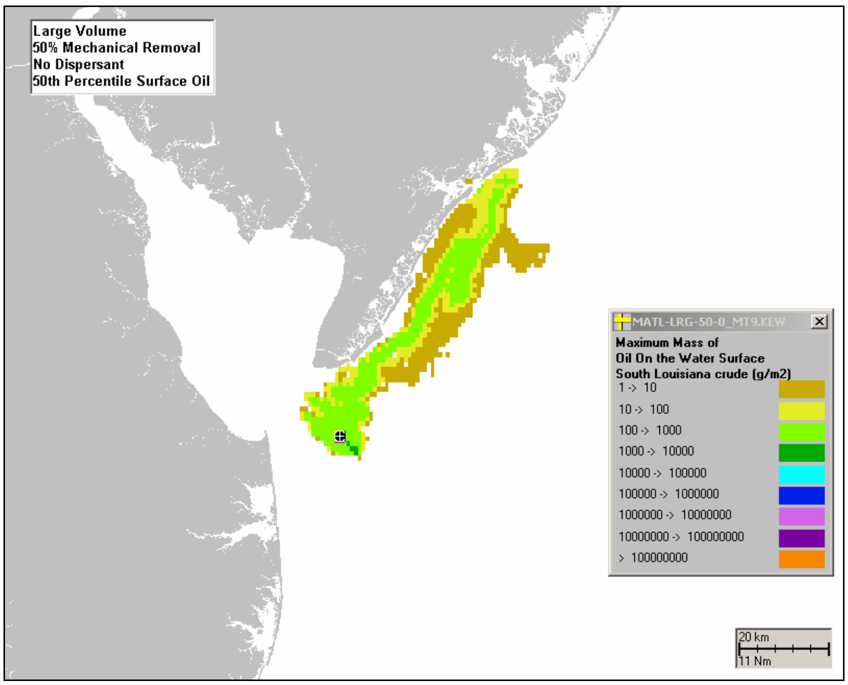

Figure B-II.4.4-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, No Dispersant.

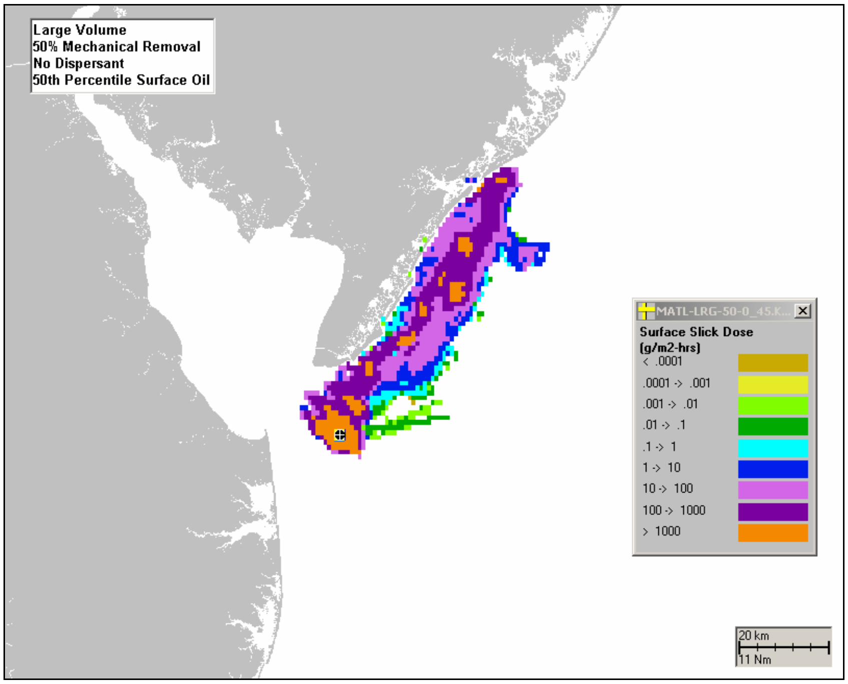

Figure B-II.4.4-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Large Volume, No Dispersant.

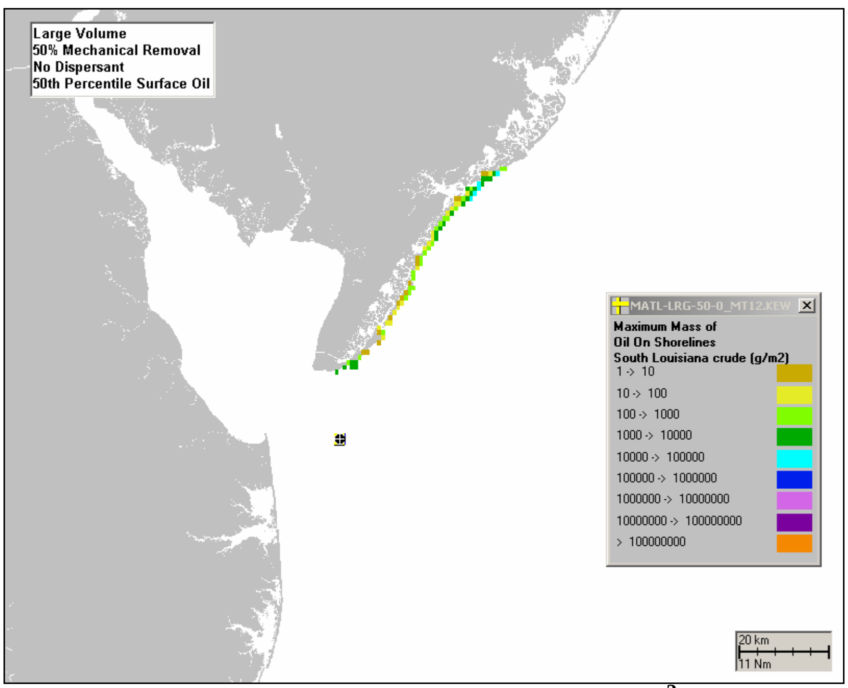

Figure B-II.4.4-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, No Dispersant.

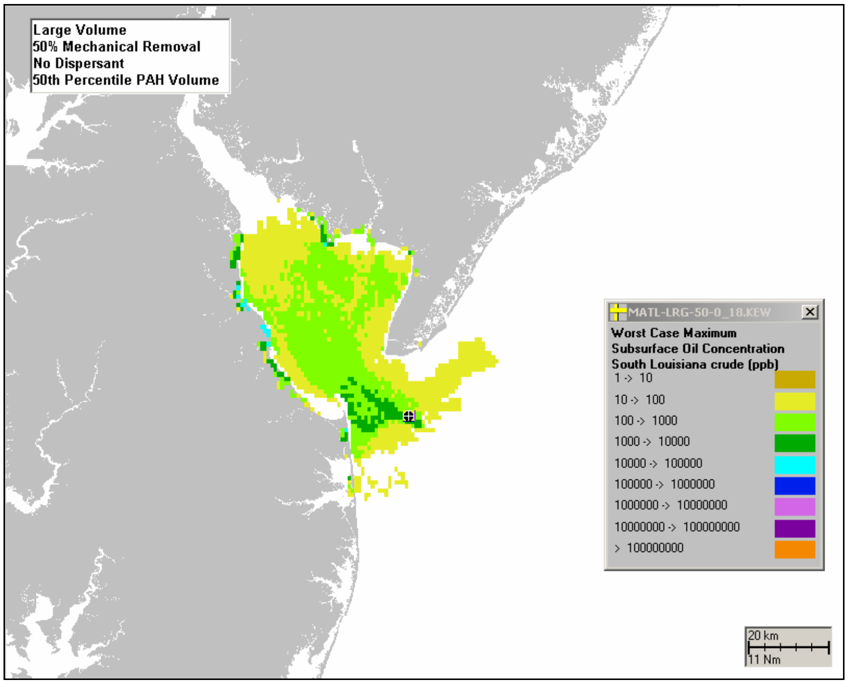

Figure B-II.4.4-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, No Dispersant.

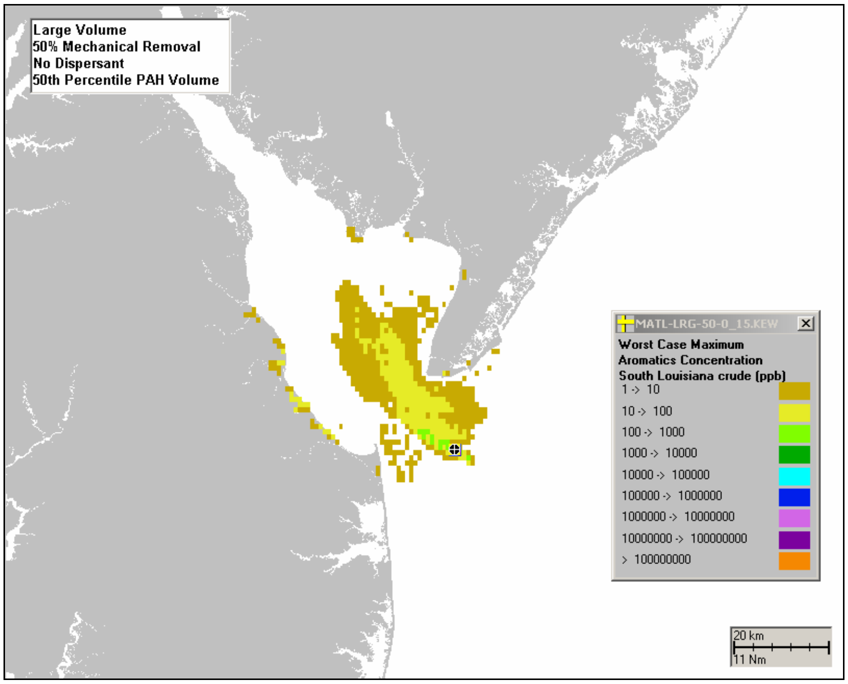

Figure B-II.4.4-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, No Dispersant.

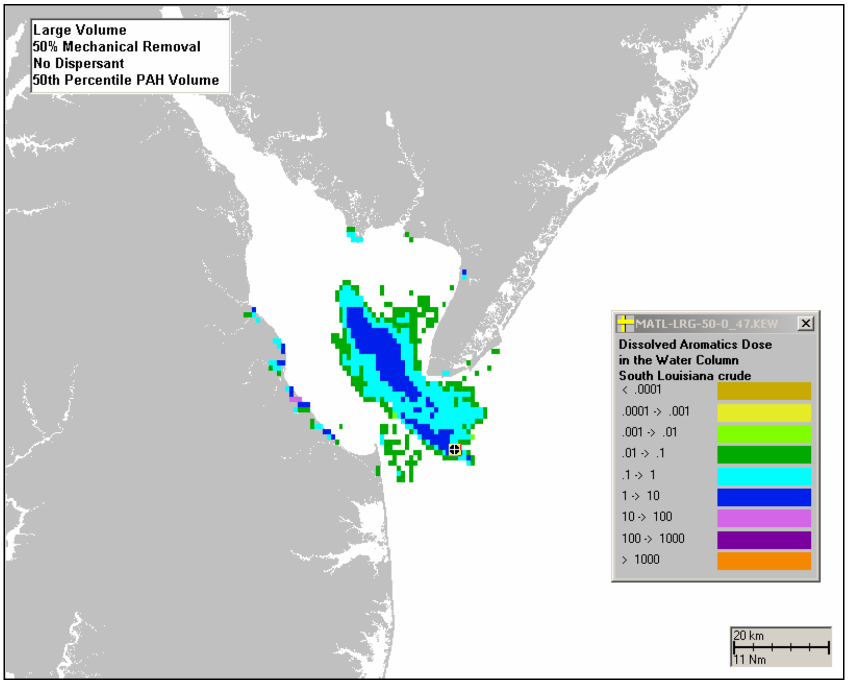

Figure B-II.4.4-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, No Dispersant.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Large Volume, No Dispersant.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Large Volume, No Dispersant.

B-II.4.5 Scenario: Large Volume, 45% Dispersant Efficiency.

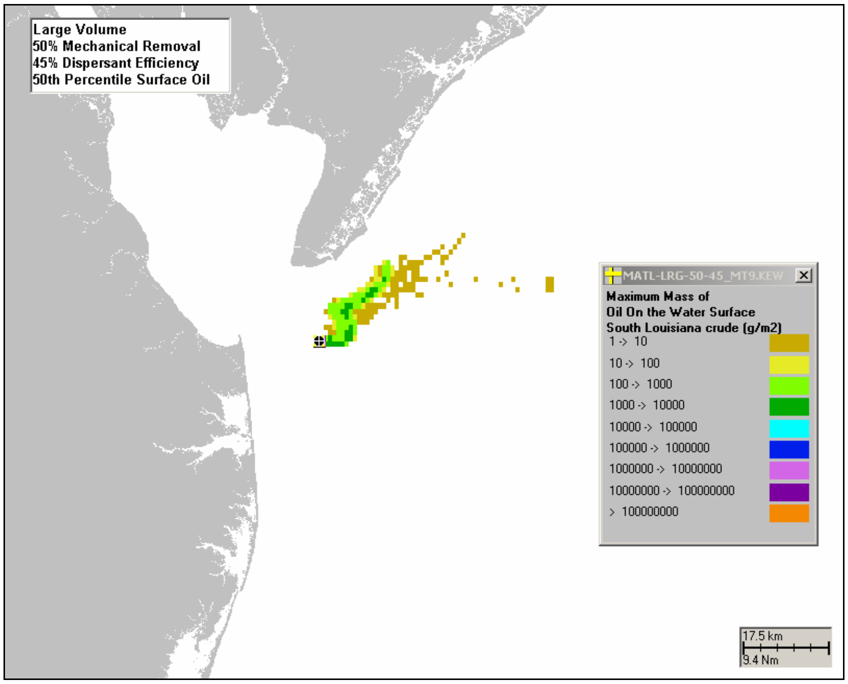

Figure B-II.4.5-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

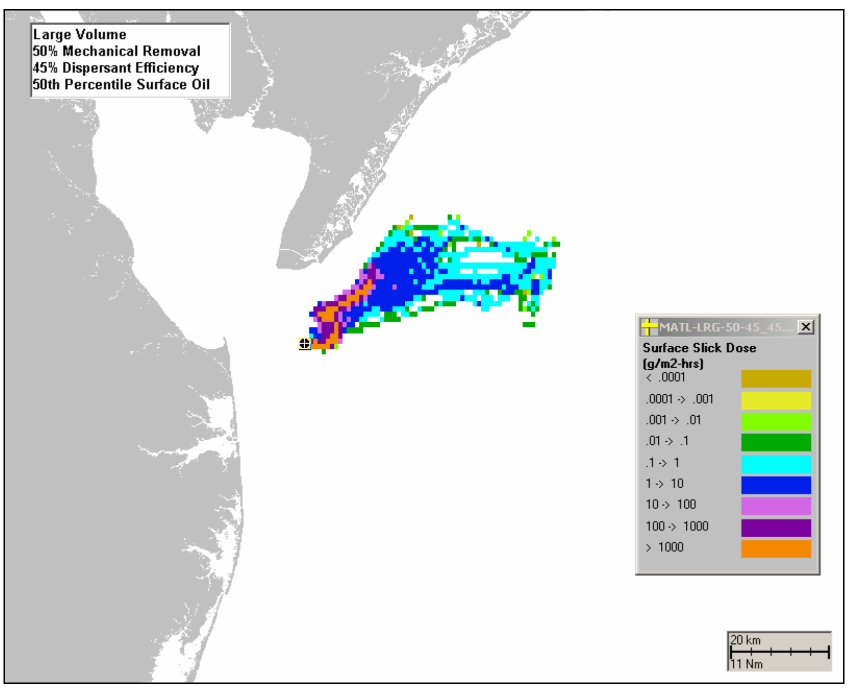

Figure B-II.4.5-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

Shoreline exposure to hydrocarbons, for 50th percentile run based on surface oil exposure does not exceed threshold of 0.01 g/m^2. Scenario: Large Volume, 45% Dispersant Efficiency.

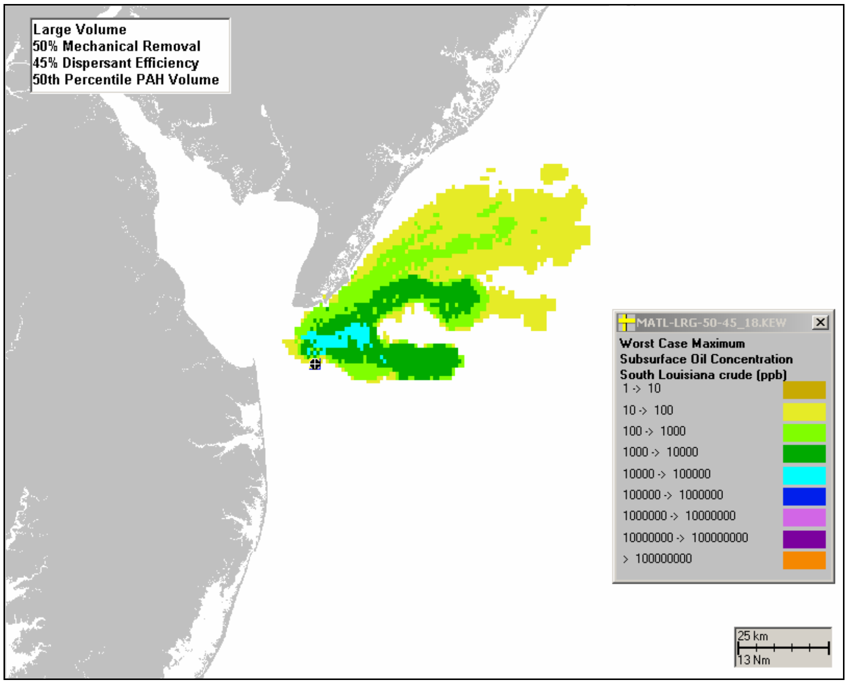

Figure B-II.4.5-3. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 45% Dispersant Efficiency.

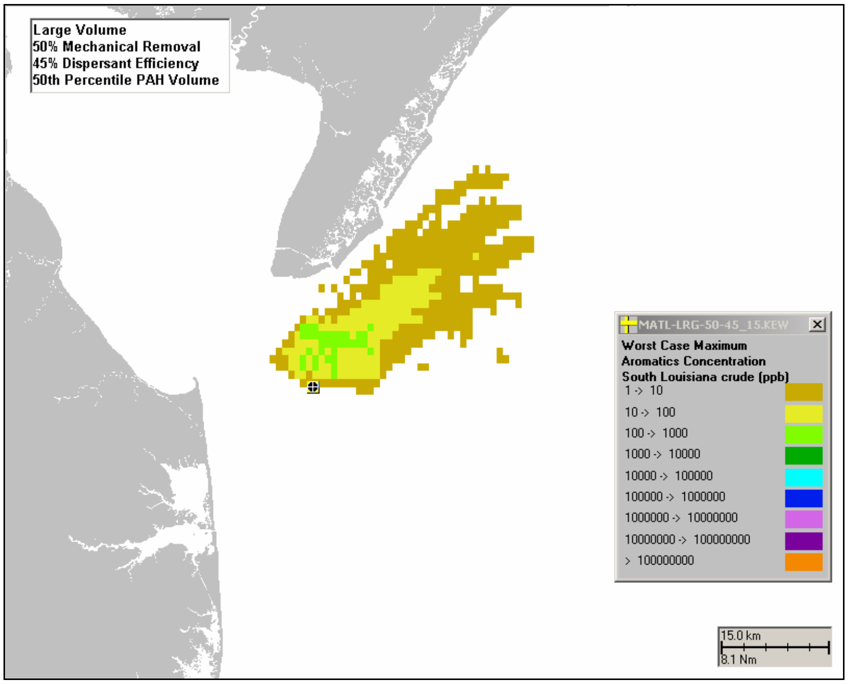

Figure B-II.4.5-4. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 45% Dispersant Efficiency.

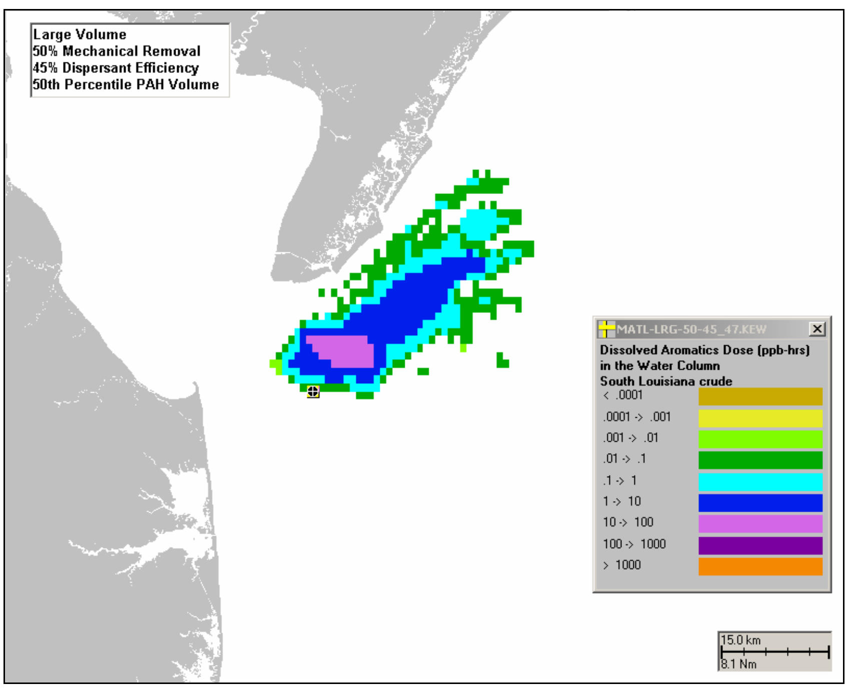

Figure B-II.4.5-5. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 45% Dispersant Efficiency.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

B-II.4.6 Scenario: Large Volume, 80% Dispersant Efficiency.

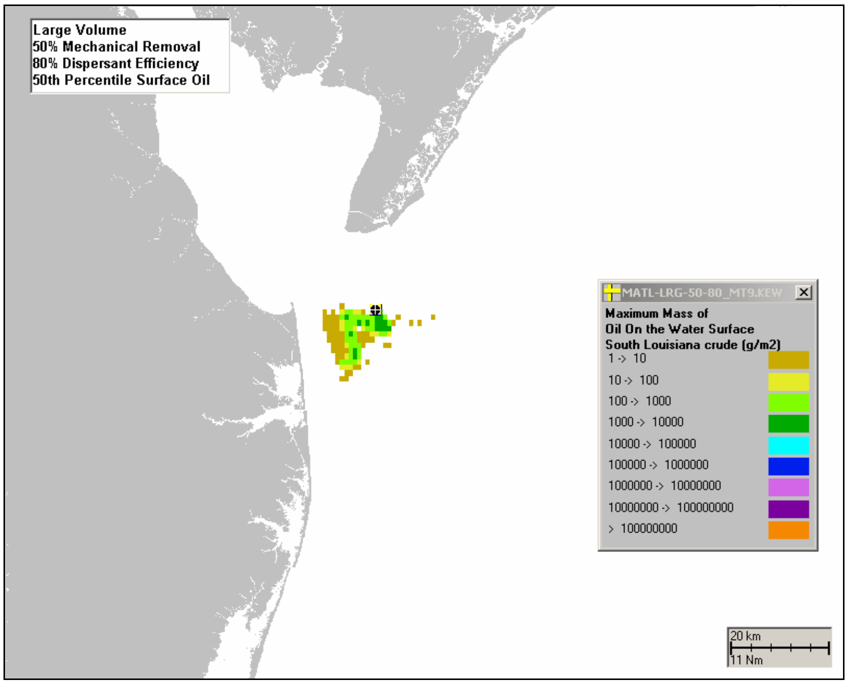

Figure B-II.4.6-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure.   Scenario: Large Volume, 80% Dispersant Efficiency.

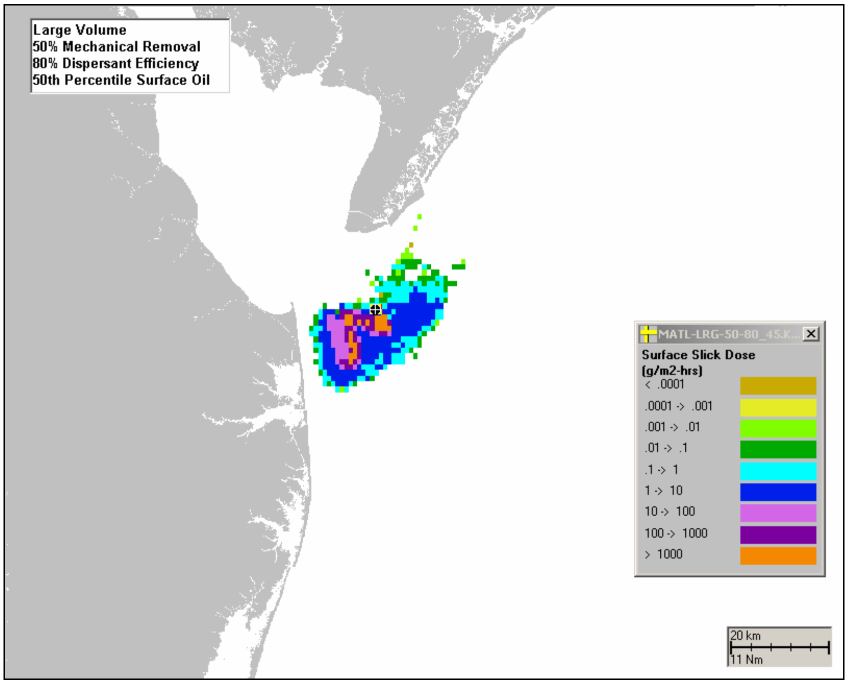

Figure B-II.4.6-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

Shoreline exposure to hydrocarbons, for 50th percentile run based on surface oil exposure does not exceed threshold of 0.01 g/m^2. Scenario: Large Volume, 80% Dispersant Efficiency.

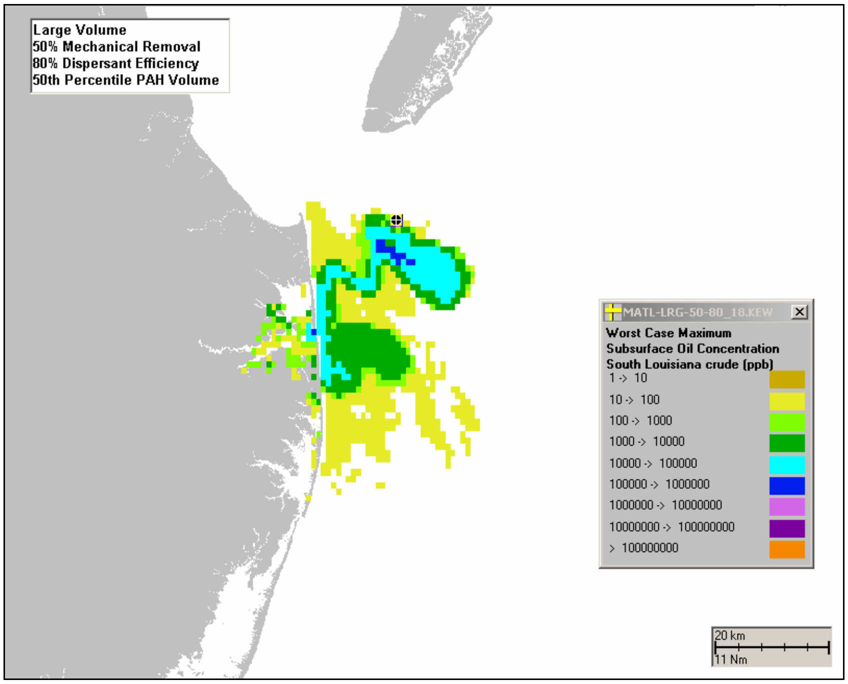

Figure B-II.4.6-3. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 80% Dispersant Efficiency.

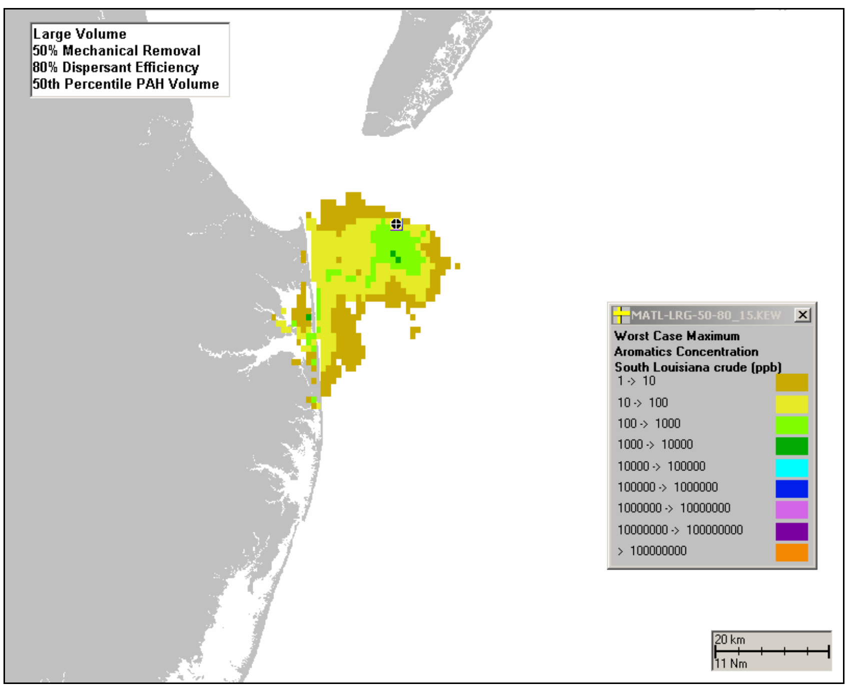

Figure B-II.4.6-4. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 80% Dispersant Efficiency.

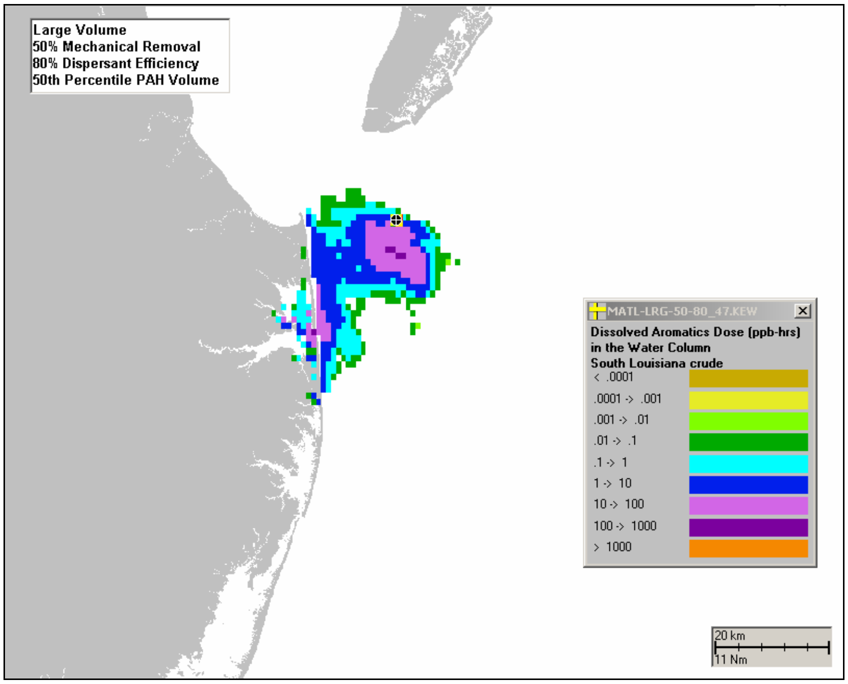

Figure B-II.4.6-5. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 80% Dispersant Efficiency.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part B: Delaware Bay and Mid-Atlantic Shelf

Section B-II.5

by

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B-II.5 Area swept by surface oil greater than the threshold affecting wildlife.

This appendix contains estimates of area swept by surface oil multiplied by probability of wildlife being oiled, for each behavior category. This is summarized as an equivalent area of 100% mortality by behavior group. The equivalent area for 100% mortality is the integrated sum of area swept times probability of mortality.

The mean equivalent area killed for all possible environmental conditions is calculated using the index of surface oil exposure exceeding $0.01 g/m^2$, which is the integrated area swept by oil sheen or thicker oil times the duration that oil is present, in m^2-hours. The biological exposure model was run for the 50^{th} percentile run (with respect to m^2-hours) of each of the six scenarios (two volumes times three dispersant conditions). The resulting equivalent areas of 100% mortality (in km^2) were regressed against m^2-hours to obtain an equation for each behavior group that may be used to scale from m^2-hours to area killed. Table B-II.5-1 contains the regression slope, intercept, standard error, and correlation coefficient for each behavior group. Figures B-II.5-1 and B-II.5-2 plot equivalent area killed (of 100% mortality) against m^2-hours for wildlife behavior groups. Tables B-II.5-2 and B-II.5-3 contain estimated equivalent areas killed for mean environmental conditions, based on the mean (i.e., numerical average) surface oil exposure in m^2-hours from Appendix B-II.2.

Table B-II.5-1 Regression slope, intercept, standard error, and correlation coefficient for equivalent area killed (km^2) against m^2-hours based on the 50th percentile runs of each scenario.

Behavior Group	Probability of Mortality	Slope	Intercept	Std Error	Correlation
Dabbling waterfowl	0.99	2.6430E-10	-2.9121	2.8952	0.976
Nearshore aerial divers	0.35	9.3574E-11	-1.0310	1.0250	0.976
Surface seabirds	0.99	7.1390E-09	8.1707	102.9474	0.960
Aerial seabirds	0.05	3.6401E-10	0.3798	5.2290	0.960
Wetland wildlife (Waders and shorebirds)	0.35	8.7580E-11	-0.9650	0.9594	0.976
Terrestrial wildlife	0.001	2.5241E-13	-0.0028	0.0028	0.976
Cetaceans	0.001	7.0147E-12	0.0105	0.1030	0.959
Furbearing marine mammals	0.75	5.4215E-09	6.0645	78.1033	0.960
Pinnipeds, manatee, sea turtles	0.01	7.2832E-11	0.0757	1.0460	0.960
Surface birds, seaward	0.99	7.1158E-09	8.4158	102.7922	0.960
Diving birds, seaward	0.35	2.5336E-09	2.8046	36.4942	0.960
Aerial and subsurface, seaward	0.05	3.6316E-10	0.3892	5.2238	0.960
Surface birds, landward	0.99	1.4999E-11	-0.1653	0.1643	0.976
Diving birds, landward	0.35	5.3028E-12	-0.0584	0.0581	0.976
Aerial and subsurface, landward	0.05	7.5755E-13	-0.0083	0.0083	0.976
Diving birds, water only	0.35	2.5233E-09	2.9201	36.4350	0.960
Aerial and subsurface, water only	0.05	3.6156E-10	0.4067	5.2144	0.960
All water surface	1	7.2093E-09	8.3431	104.0999	0.960
All seaward water surface	1	7.2389E-09	8.0132	104.2692	0.960
All landward water surface	1	1.5151E-11	-0.1669	0.1660	0.976

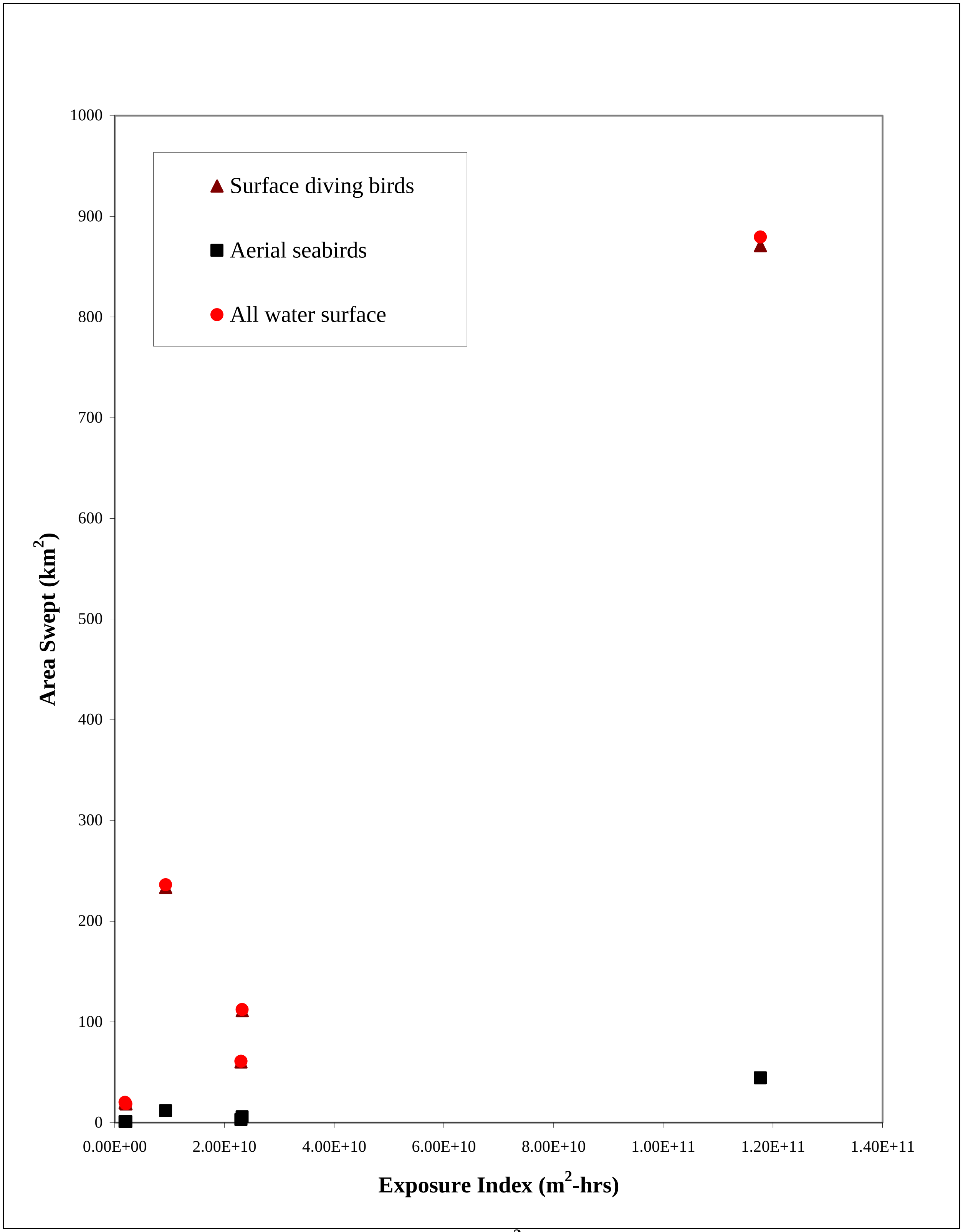

Figure B-II.5-1. Equivalent area killed against m^2-hours for wildlife behavior groups (groups in offshore waters).

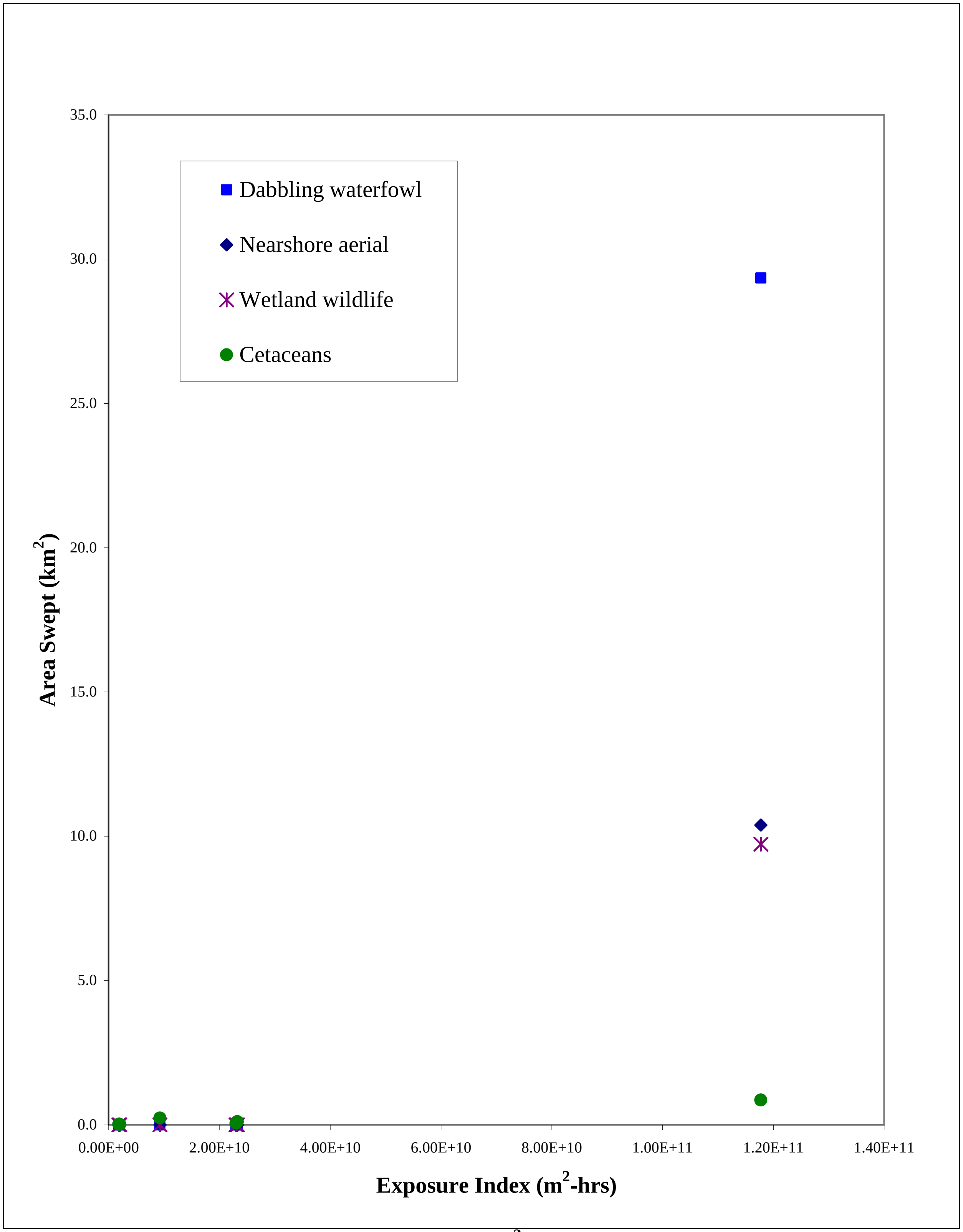

Figure B-II.5-2. Equivalent area killed against m^2-hours for wildlife behavior groups (coastal species and cetaceans)).

Table B-II.5-2. Equivalent area (km^2) of 100% mortality by wildlife behavior group, based on mean surface oil exposure, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	Probability of Mortality	0%	45%	80%
Dabbling waterfowl	0.99	0.23	0	0
Nearshore aerial divers	0.35	0.08	0.00	0.00
Surface seabirds	0.99	92.93	31.12	31.06
Aerial seabirds	0.05	4.70	1.55	1.55
Wetland wildlife (Waders and shorebirds)	0.35	0.07	0.00	0.00
Terrestrial wildlife	0.001	0.00	0.00	0.00
Cetaceans	0.001	0.09	0.03	0.03
Furbearing marine mammals	0.75	70.43	23.50	23.45
Pinnipeds, manatee, sea turtles	0.01	0.94	0.31	0.31
Surface birds, seaward	0.99	92.90	31.29	31.23
Diving birds, seaward	0.35	32.88	10.95	10.93
Aerial and subsurface, seaward	0.05	4.70	1.56	1.55
Surface birds, landward	0.99	0.01	0.00	0.00
Diving birds, landward	0.35	0.00	0.00	0.00
Aerial and subsurface, landward	0.05	0.00	0.00	0.00
Diving birds, water only	0.35	32.88	11.03	11.01
Aerial and subsurface, water only	0.05	4.70	1.57	1.57
All water surface	1.00	93.93	31.52	31.46
All seaward water surface plus intertidal	1.00	93.96	31.29	31.23
All landward water surface plus intertidal	1.00	0.01	0.00	0.00
All water surface plus intertidal	1.00	93.97	31.17	31.11

Table B-II.5-3. Equivalent area (km^2) of 100% mortality by wildlife behavior group, based on mean surface oil exposure, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	Probability of Mortality	0%	45%	80%
Dabbling waterfowl	0.99	46.72	5.82	5.51
Nearshore aerial divers	0.35	16.54	2.06	1.95
Surface seabirds	0.99	1348.89	244.09	235.79
Aerial seabirds	0.05	68.74	12.41	11.99
Wetland wildlife (Waders and shorebirds)	0.35	15.48	1.93	1.83
Terrestrial wildlife	0.001	0.04	0.01	0.01
Cetaceans	0.001	1.33	0.24	0.23
Furbearing marine mammals	0.75	1024.24	185.23	178.92
Pinnipeds, manatee, sea turtles	0.01	13.75	2.48	2.40
Surface birds, seaward	0.99	1344.78	243.57	235.30
Diving birds, seaward	0.35	478.63	86.53	83.59
Aerial and subsurface, seaward	0.05	68.59	12.39	11.97
Surface birds, landward	0.99	2.65	0.33	0.31
Diving birds, landward	0.35	0.94	0.12	0.11
Aerial and subsurface, landward	0.05	0.13	0.02	0.02
Diving birds, water only	0.35	476.80	86.31	83.37
Aerial and subsurface, water only	0.05	68.31	12.36	11.93
All water surface	1.00	1362.27	246.59	238.21
All seaward water surface plus intertidal	1.00	1367.51	247.23	238.82
All landward water surface plus intertidal	1.00	2.68	0.33	0.32
All water surface plus intertidal	1.00	1370.19	247.57	239.14

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part B: Delaware Bay and Mid-Atlantic Shelf

Section B-II.6

by

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B-II.6 Exposures for fish and invertebrates to dissolved aromatic concentrations.

This appendix tabulates estimated mortality of water column, demersal (on the bottom) and benthic (in the bottom) organisms by behavior type for the Delaware Bay spill location. Effects are summarized as an equivalent area of 100% mortality by behavior group and habitat type. The equivalent area for 100% mortality is the integrated sum of equivalent area affected times percent mortality. For water column and demersal species, the equivalent area affected is calculated as water volume affected times the fraction of the water depth zone the behavior group occupies that the affected volume encompasses. For pelagic species, the depth zone occupied is the entire water column. For demersal species (on the bottom sediments, exposed to bottom water), the depth zone occupied is the bottom 1 meter of the water column. The methods and assumptions for these calculations are described in Part A.

For water column and demersal species, the mean equivalent area killed for all possible environmental conditions is calculated using the water volume (m^3) exposed to greater than 1 mg/m^3 (1 ppb) dissolved aromatic concentration at any time after the spill. The biological exposure model was run for the 50th percentile run (with respect to water volume exposed to >1ppb) of each of the six scenarios (two spill volumes times three dispersant conditions). The toxicity parameter (LC50) assumed in these calculations was that for sensitive species (the 2.5th percentile in rank order sensitivity), in order to provide conservatively high estimates of potential water column effects. The resulting equivalent areas of 100% mortality (in km^2) were regressed against water volume exposed (m^3) to obtain an equation for each behavior group that may be used to scale from volume exposed to area killed (for sensitive species). Figure B-II.6-1 plots equivalent water column area killed (area of 100% mortality) against volume exposed to >1ppb for each of the water column and demersal behavior groups. Table B-II.6-1 contains the regression slope, intercept, standard error, and correlation coefficient for each behavior group. Tables B-II.6-2 and B-II.6-3 contain estimated equivalent areas killed (for sensitive species) for mean environmental conditions, based on the mean volume exposed to >1ppb dissolved aromatic concentration (from Appendix B-II.2). Tables B-II.6-4 and B-II.6-5 contain estimated equivalent areas killed (for sensitive species) for 95th percentile environmental conditions, based on the mean plus two standard deviations of volume exposed to >1ppb dissolved aromatic concentration. Mean and standard deviation of volume exposed to >1ppb dissolved aromatic concentration are tabulated in Appendix B-II.2 and the full distribution of all 100 runs is plotted in Appendix B-II.3. The effects on water column communities are discussed in Sections B.3.2 and B.4.2.

Benthic effects are related to the bottom sediment area exposed to oil exceeding a threshold of concern. Table B-II.6-6 summarizes the loading of oil to the sediments. For most species, the dissolved aromatic concentration in the pore water of the sediments is what is bioavailable and causes toxicity (Table B-II.6-7). A threshold of 6 ppb dissolved aromatic concentration could cause effects on sensitive (2.5% of) species, whereas the threshold for average species is 50 ppb (see Part A, Section A.3.4). The effects on benthic organisms are discussed in Sections B.3.2 and B.4.2.

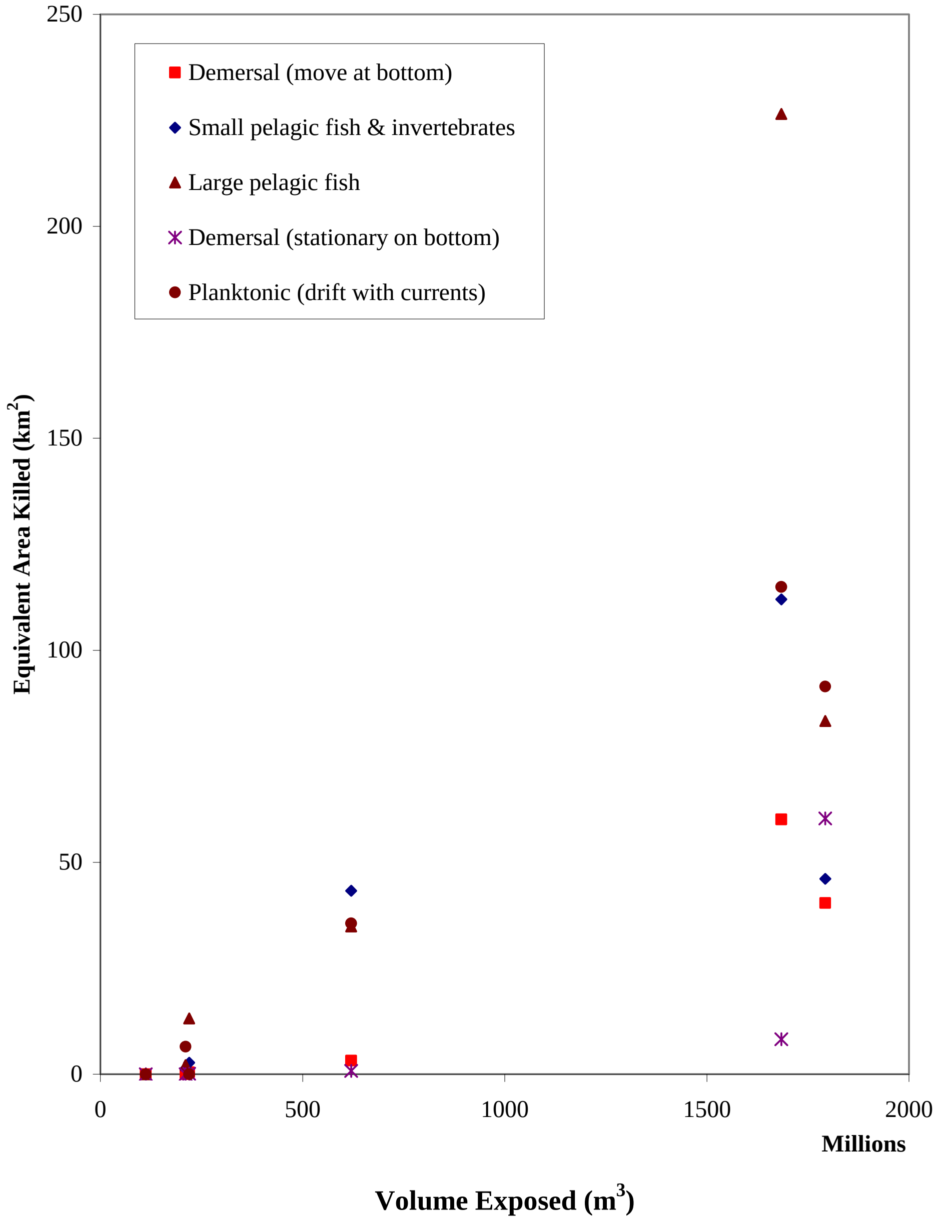

Figure B-II.6-1. Equivalent area killed (for sensitive species) against volume exposed to > 1ppb dissolved aromatic concentration for water column behavior groups.

Table B-II.6-1 Regression slope, intercept, standard error, and correlation coefficient for equivalent water column area killed (km^2) against water volume exposed to >1ppb (m^3), based on the 50^{th} percentile runs of each scenario.

Behavior Group	Slope	Intercept	Std Error	Correlation
Demersal (move at bottom)	3.2231E-08	-7.5530	9.7128	0.944
Small pelagic fish & invertebrates	4.7451E-08	-2.4482	26.7630	0.836
Large pelagic fish	9.3951E-08	-12.6514	54.7115	0.828
Demersal (stationary on bottom)	2.3325E-08	-6.4503	18.0078	0.744
Planktonic (drift with currents)	6.3952E-08	-8.0356	11.3695	0.979

Table B-II.6-2. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	**0%**	**45%**	**80%**
Demersal (move at bottom)	0.0	0.0	0.0
Small pelagic fish & invertebrates	3.7	8.5	8.4
Large pelagic fish	0.0	9.0	8.9
Demersal (stationary on bottom)	0.0	0.0	0.0
Planktonic (drift with currents)	0.2	6.7	6.6

Table B-II.6-3. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	**0%**	**45%**	**80%**
Demersal (move at bottom)	14.9	50.4	49.8
Small pelagic fish & invertebrates	30.7	82.8	82.0
Large pelagic fish	52.9	156.2	154.6
Demersal (stationary on bottom)	9.8	35.5	35.1
Planktonic (drift with currents)	36.6	106.9	105.8

Table B-II.6-4. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean plus two standard deviations (i.e., 95^{th} percentile) of water volume exposed to > 1ppb dissolved aromatic concentration, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	0%	45%	80%
Demersal (move at bottom)	2.8	13.2	12.9
Small pelagic fish & invertebrates	12.8	19.4	19.0
Large pelagic fish	17.5	38.5	37.7
Demersal (stationary on bottom)	1.0	9.6	9.4
Planktonic (drift with currents)	12.5	26.2	25.7

Table B-II.6-5. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean plus two standard deviations (i.e., 95^{th} percentile) of water volume exposed to > 1ppb dissolved aromatic concentration, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	0%	45%	80%
Demersal (move at bottom)	52.5	106.6	107.8
Small pelagic fish & invertebrates	77.2	157.0	158.7
Large pelagic fish	152.9	310.8	314.3
Demersal (stationary on bottom)	38.0	77.2	78.0
Planktonic (drift with currents)	104.1	211.6	213.9

Table B-II.6-6. Area (m^2) of sediment exceeding indicated thresholds of total hydrocarbon loading per unit area (g/m^2) under average environmental conditions, by spill volume and dispersant treatment.

Threshold (g/m^2)	Medium 0%	Medium 45%	Medium 80%	Large 0%	Large 45%	Large 80%
0	35,314,000	33,296,000	28,251,000	75,673,000	51,458,000	58,520,000
0.001	25,224,000	22,197,000	21,188,000	55,493,000	39,350,000	40,359,000
0.01	12,108,000	9,081,000	7,063,000	35,314,000	26,233,000	23,206,000
0.1	0.0	0.0	0.0	7,063,000	7,063,000	7,063,000
1	0.0	0.0	0.0	0.0	1,009,000	2,018,9000
10	0.0	0.0	0.0	0.0	0.0	0.0

Table B-II.6-7. Area (m^2) of sediment exceeding indicated thresholds of dissolved aromatic concentration in pore waters (mg/m^3 = ppb) under average environmental conditions, by spill volume and dispersant treatment.

Threshold (mg/m^3 = ppb)	Medium 0%	Medium 45%	Medium 80%	Large 0%	Large 45%	Large 80%
1	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part B: Delaware Bay and Mid-Atlantic Shelf

Section B-III.1

by

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B-III.1 Air Concentrations from Unburned Oil

This section contains model results for spills in the Atlantic Region used to evaluate volatile hydrocarbon emissions from unburned oil and resulting air quality effects. The amount of volatilized mass entering the atmosphere for each chemical (or chemical class) of concern was estimated using oil spill modeling (SIMAP). SIMAP also provided the time frame over which the emissions occur. The atmospheric concentrations of volatilized hydrocarbons were modeled using AIRMAP (as described in Part A, Section A.5.1). The estimated concentrations at the water surface were compared to air quality standards to evaluate the potential for human health effects and wildlife effects.

As a screening analysis, SIMAP runs were performed for both the medium (2500 bbl) and large (40,000 bbl) spill volumes of South Louisiana crude under various wind conditions to determine the possible hydrocarbon emissions from unburned oil to the atmosphere. Emissions were estimated using SIMAP for the warmest water temperature occurring in the region, 30^{o}C (French et al. 1996b) and for varying wind speeds from 3 to 25 kts. (Evaporation is very slow in conditions of no wind, so this case was not included.)

As a worst case, these model runs were performed assuming no dispersants are applied, since the use of dispersants would reduce emissions to the extent that volatile components are permanently mixed into the water. It is also assumed that any mechanically-removed oil still volatilizes, so no correction for removal was made to the volatilized mass. Likewise, no correction for amount burned was made to the rate of unburned oil emission. Thus, the screening model runs estimated the maximum rate and amount of emissions which would be expected under any environmental conditions and response scenario for the region.

In the next step of the analysis, the atmospheric concentrations of volatilized hydrocarbons released by unburned oil were modeled using AIRMAP, which accounts for transport and dilution of hydrocarbons in the local atmosphere around the spill site. Each hydrocarbon constituent was modeled separately, releasing the mass of the constituent emitted from the oil over time from the area covered by surface floating oil (as estimated by SIMAP). AIRMAP was run for each constituent and wind speed condition, from 3 to 25 kts. The constituent mass released in the AIRMAP simulation (over 10 hours) was the maximum amount emitted to the air (of that constituent) in any 10-hour period in the SIMAP spill simulation. The AIRMAP simulation was run assuming a stable atmosphere with minimal turbulence to disperse contaminants.

The atmospheric dispersion model provided estimates of air concentrations in the air layer within 2 m of the water surface (for each 55m X 55m cell of a 200 by 200 cell grid covering the horizontal extent of the plume) as a function of time after the spill. The estimated concentrations were then compared to air quality standards to evaluate the potential for human health effects. Two averaging periods were used in accordance with the standards: 0.5 hour for comparison to the Immediate Danger to Life and Health (IDLH) value and 8 hours for comparison to the 8-hour time weighted average (TWA).

The maximum 0.5-hour and 8-hour average air concentration for any time period in the AIRMAP simulation was compared to the appropriate standard (Table B-III.1-1). The IDLH (from Table A.5-5 in Part A) is not to be exceeded for a ½ hour exposure. The PEL-TWA is the minimum of the 8-hour time weighed averages in Table A.5-5. Heptane is used as representative of the volatile aliphatic VOCs. Its air quality standards are the lowest of those available for this group of chemicals (see Section A.5.3), so comparison to the standards for heptane is conservative. The area adversely affected was that where the standard was exceeded for the appropriate averaging period. The maximum distance from the release site that concentrations exceeded the air quality standard was also estimated for each constituent using the AIRMAP results.

These results are applicable to spills of crude oils with similar volatile content in any location where conditions are at the temperature, atmospheric stability, and wind speed assumed. Concentrations and areas affected would be lower than those reported below for less stable atmospheres and lower temperature conditions. The results are assuming no dispersant applied, such that all the volatiles are assumed released to the atmosphere. Dispersants could permanently disperse some of the volatiles in the water column, reducing the air concentrations and areas adversely affected. Also, volatiles would be burned and emissions reduced to the extent that ISB is used. Thus, these areas of potential adverse effect are the maximum possible in the region under any response scenario and environmental conditions.

Table B-III.1-1. IDLH and TWA thresholds for evaluating potential effects of air concentrations.

Chemical	IDLH (mg/m^3)	PEL-TWA (mg/m^3)
Benzene	1595	3.19
Toluene	1885	754
Ethylbenzene	3472	434
Xylene	3906	434
Naphthalene	1310	52.4
Biphenyl	631	1.262
Phenanthrene	80	(not available)
Aliphatic VOCs with boiling points <180^{o}C (based on heptane)	3075	2050

B-III.1.1 Medium Volume Spills

Emissions from Unburned Oil

Table B-III.1.1-1 contains the estimated maximum volatilized mass released to the atmosphere in any 10-hour period for each constituent of concern in the medium-volume spill under the worst-case (highest) temperature condition (30^{o}C) and with various wind speeds. The results show (Figure B-III.1.1-1) that the emission rates of the MAHs (benzene, toluene, ethylbenzene, xylenes) increase as wind speed increases to about 5 kts and then level off. Volatile aliphatics indicate a similar pattern with wind speed (Table B-III.1.1-1). The emission rates for PAHs are much lower than for the volatiles and increase with wind speed (Figure B-III.1.1-1).

Table B-III.1.1-1. Maximum mass (MT) of chemical volatilized from unburned South Louisiana crude oil in any 10-hour period after a spill of 2,500 bbl at the indicated wind speed.

Constituent	**3 kts**	**5 kts**	**7 kts**	**9 kts**	**10 kts**	**12 kts**	**15 kts**	**20 kts**	**25 kts**
Total MAHs	256	268	266	260	257	250	242	232	224
Benzene	0.20	0.21	0.21	0.21	0.21	0.20	0.19	0.19	0.18
Toluene	0.56	0.59	0.58	0.57	0.56	0.55	0.53	0.51	0.49
Ethylbenzene	0.18	0.19	0.19	0.18	0.18	0.18	0.17	0.16	0.16
Xylenes	1.37	1.43	1.42	1.39	1.38	1.34	1.30	1.24	1.20
Total volatile and semi-volatile PAHs	56.6	73.0	85.6	95.6	102.9	113.7	128.9	150.7	199.9
Naphthalene	0.02	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.07
Biphenyl	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Phenanthrene	0.03	0.04	0.05	0.06	0.06	0.07	0.08	0.09	0.12
Aliphatic VOCs with boiling points <180^{o}C	42.3	44.2	43.9	43.0	42.5	41.3	40.1	38.4	37.1

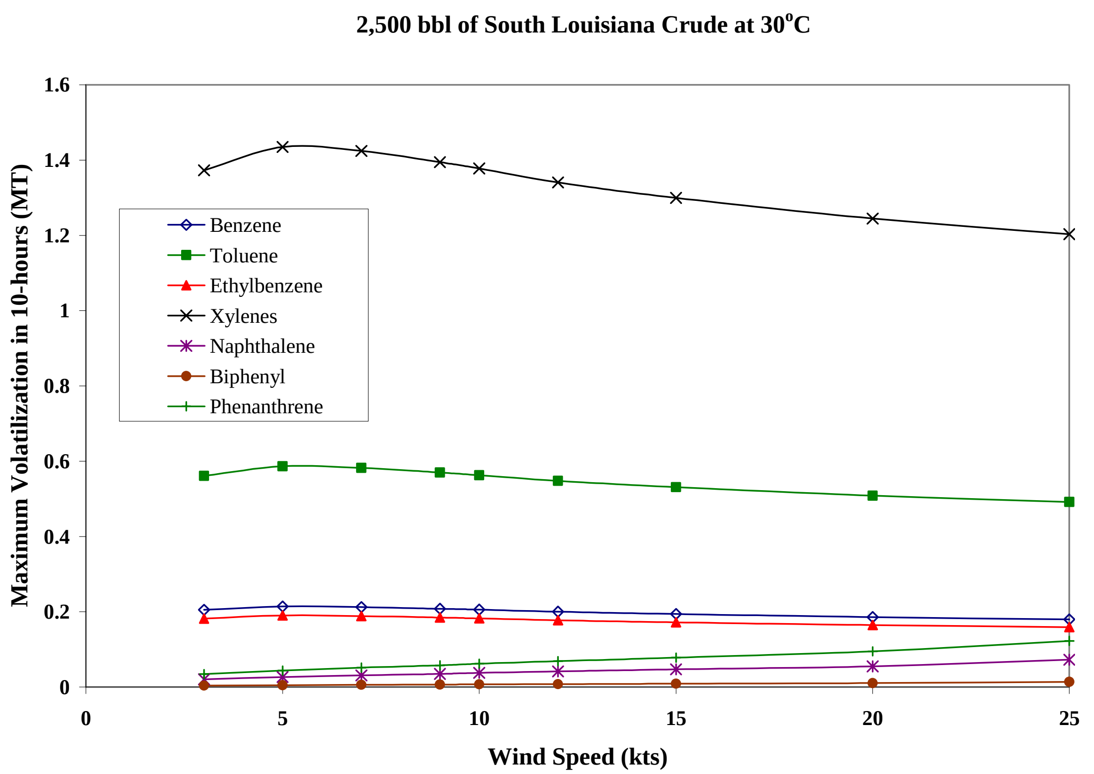

Figure B-III.1.1-1 Maximum mass (MT) of chemical volatilized from unburned South Louisiana crude oil in any 10-hour period after a spill of 2,500 bbl at the indicated wind speed.

Air Concentrations from Unburned Oil Emissions

Tables B-III.1.1-2 and B-III.1.1-3 list the areas where the air concentrations exceeded the comparable air quality standards. Tables B-III.1.1-4 and B-III.1.1-5 list the maximum distances (down wind) from the release site that concentrations exceeded the air quality standards. Since the emissions were more rapidly dispersed in the atmosphere the higher the wind speed, the conditions where concentrations of volatiles in air were at maximum were those where winds were assumed light (3 kts). This is demonstrated in the results. The IDLH is not exceeded for any of the chemical constituents under these worst-case conditions for medium volume spills of South Louisiana crude oil. The TWA would only be exceeded after spills of 2,500 bbl for benzene in the immediate spill area (≤0.7 km downwind of the spill site) and under light (≤3 kts) winds. Air concentrations of other constituents would not exceed the TWA standards at any time after a medium volume spill.

Table B-III.1.1-2. Maximum area (m^2) where the IDLH would be exceeded due to volatilization of unburned South Louisiana crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180°C	0	0	0	0	0	0	0	0	0

Table B-III.1.1-3. Maximum area (m^2) where the PEL-TWA would be exceeded due to volatilization of unburned South Louisiana crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	75,625	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180°C	0	0	0	0	0	0	0	0	0

Table B-III.1.1-4. Maximum distance down wind (km) where the IDLH would be exceeded due to volatilization of unburned South Louisiana crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0	0	0	0	0	0	0	0	0

Table B-III.1.1-5. Maximum distance down wind (km) where the PEL-TWA would be exceeded due to volatilization of unburned South Louisiana crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0.7	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0	0	0	0	0	0	0	0	0

B-III.1.2 Large Volume Spills

<u>Emissions from Unburned Oil</u>

Table B-III.1.2-1 contains the estimated maximum volatilized mass released to the atmosphere in any 10-hour period for each constituent of concern in the large-volume spill under the worst-case (highest) temperature condition and with various wind speeds. The results show (Figure B-III.1.2-1) that the emission rates of the MAHs (benzene, toluene, ethylbenzene, xylenes) increase as wind speed increases to about 15 kts and then level off. Volatile aliphatics indicate a similar pattern with wind speed (Table B-III.1.2-1). The emission rates for PAHs are much lower than for the volatiles and increase with wind speed (Figure B-III.1.2-1).

Table B-III.1.2-1. Maximum mass (MT) of chemical volatilized from unburned South Louisiana crude oil in any 10-hour period after a spill of 40,000 bbl at the indicated wind speed.

Constituent	**3 kts**	**5 kts**	**7 kts**	**9 kts**	**10 kts**	**12 kts**	**15 kts**	**20 kts**	**25 kts**
Total MAHs	2826	3257	3519	3749	3806	3869	4007	4026	3989
Benzene	2.26	2.61	2.82	3.00	3.05	3.10	3.21	3.22	3.19
Toluene	6.19	7.13	7.71	8.21	8.34	8.47	8.77	8.82	8.74
Ethylbenzene	2.01	2.31	2.50	2.66	2.70	2.75	2.84	2.86	2.83
Xylenes	15.15	17.46	18.86	20.09	20.40	20.74	21.48	21.58	21.38
Total volatile and semi-volatile PAHs	457.3	591.8	697.1	785.7	810.7	969.3	1345.4	1984.7	2592.1
Naphthalene	0.17	0.22	0.25	0.29	0.30	0.35	0.49	0.72	0.94
Biphenyl	0.03	0.04	0.05	0.05	0.06	0.07	0.09	0.14	0.18
Phenanthrene	0.28	0.36	0.42	0.48	0.49	0.61	0.89	1.43	1.87
Aliphatic VOCs with boiling points <180°C	467	538	581	619	629	639	662	665	659

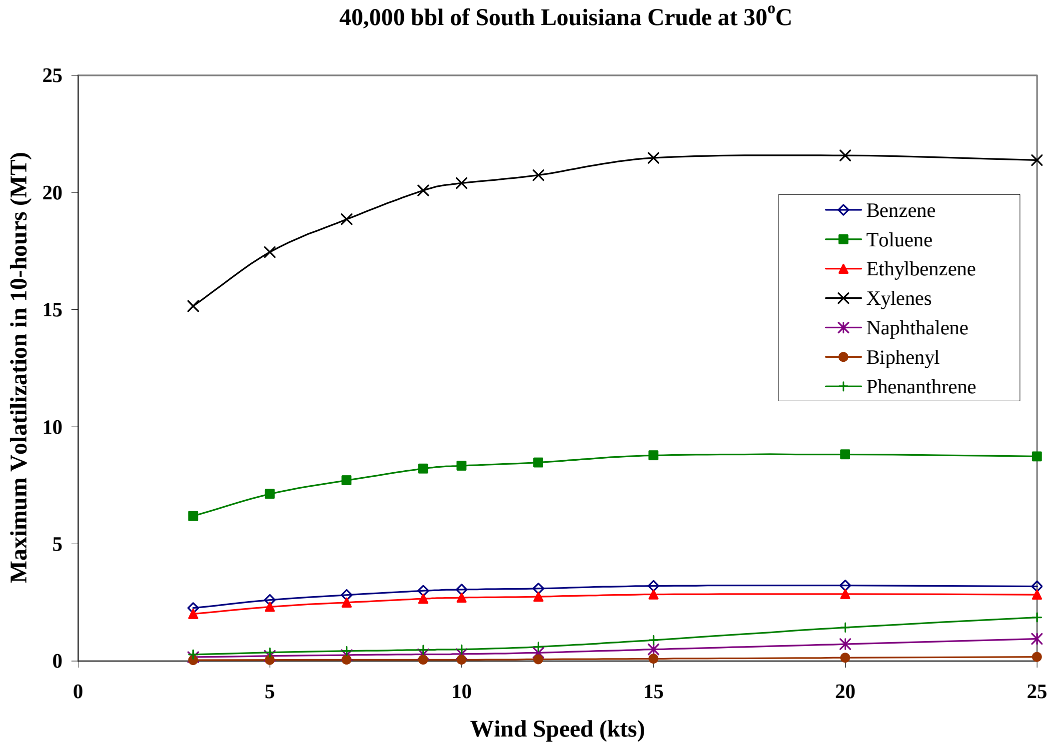

Figure B-III.1.2-1 Maximum mass (MT) of chemical volatilized from unburned South Louisiana crude oil in any 10-hour period after a spill of 40,000 bbl at the indicated wind speed.

Air Concentrations from Unburned Oil Emissions

Tables B-III.1.2-2 and B-III.1.2-3 list the areas where the air concentrations exceeded the comparable air quality standards for large volume spills. Tables B-III.1.2-4 and B-III.1.2-5 list the maximum distances (down wind) from the release site that concentrations exceeded the air quality standards. Since the emissions were more rapidly dispersed in the atmosphere the higher the wind speed, the conditions where concentrations of volatiles in air were at maximum were those where winds were assumed light (3 kts), as demonstrated by the results. The IDLH for heptane is exceeded at $\leq$1.3 km downwind of the spill site by the total volatile aliphatic VOC concentration under these worst-case temperature and air stability conditions for wind speeds up to 5 kts. The IDLH is not exceeded for any of the MAHs or PAHs, and would not be expected to under any environmental conditions for spills of this large volume. The TWA would be exceeded after spills of 40,000 bbl for benzene, xylenes, biphenyl and volatile aliphatic VOCs in the spill area and under light to moderate winds ($\leq$12 kts). For xylenes and biphenyl, the areas adversely affected would not exceed 0.1 km^2 in the worst case conditions of light winds and a stable atmosphere. The adversely affected areas are larger for benzene (up to 3.4 km^2) and volatile aliphatic VOCs (up to 0.9 km^2), assuming a worst case of a stable atmosphere. The areas would be less for less stable atmospheric conditions and lower temperatures than assumed.

Table B-III.1.2-2. Maximum area (m^2) where the IDLH would be exceeded due to volatilization of unburned South Louisiana crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	226,875	93,775	0	0	0	0	0	0	0

Table B-III.1.2-3. Maximum area (m^2) where the PEL-TWA would be exceeded due to volatilization of unburned South Louisiana crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	3,357,750	1,948,100	1,203,950	580,800	435,600	93,775	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	5,900	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	51,425	6,050	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	880,275	335,775	51,425	0	0	0	0	0	0

Table B-III.1.2-4. Maximum distance down wind (km) where the IDLH would be exceeded due to volatilization of unburned South Louisiana crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	1.3	0.7	0	0	0	0	0	0	0

Table B-III.1.2-5. Maximum distance down wind (km) where the PEL-TWA would be exceeded due to volatilization of unburned South Louisiana crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	7.4	5.0	3.4	1.9	1.5	0.8	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0.9	0.3	0.0	0.0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	3.5	1.6	0.5	0.0	0	0	0	0	0

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part B: Delaware Bay and Mid-Atlantic Shelf

Section B-III.2

by

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ASA 00-246

August 2004

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B-III.2 Air Concentrations from In-Situ Burning

Section A.5.2 of Part A describes the methods used to evaluate emissions from ISB and their potential effects on air quality. For scenarios involving ISB, the maximum potential amount of oil burned was assumed to be 25% by volume of the amount of oil mechanically removed (see Section A.3.7). The amount burned was calculated for each scenario since the percent of oil mechanically removed varies for each of the 100 stochastic runs. The 50th and 95th percentiles of the volumes mechanically cleaned up (for the 100 stochastic runs) were multiplied by 0.25 to calculate the 50th and 95th percentile volumes burned by ISB. The atmospheric concentrations of compounds and particulates released by an in-situ burn are dependent upon both the distance from and the area of the fire. All chemicals in the emissions that might be of concern are considered in the analysis.

B-III.2.1 Medium Volume Spills

The estimated distances from an in-situ burn to thresholds of concern are tabulated below. The maximum burn areas for each scenario were calculated by dividing the burn volume by the minimum oil thickness required for burning (3 mm). Burn areas were calculated for all 100 runs for each scenario. Table B-III.2.1-1 shows, for each of the three medium volume scenarios, the percentage of simulations whose calculated burn area (burn volume divided by 3 mm) is less than the maximum possible burn area of 500 m^2. For these three scenarios, some of the individual simulations have burn areas smaller than 500 m^2. The effect of the dispersant application on the area of oil requiring burning is apparent from the numbers in the table. When no dispersant is applied (0% dispersant efficiency), 9% of the simulations have burn areas smaller than 500 m^2. For 45% dispersant efficiency, 93% of the burn areas are smaller than 500 m^2, and the same is true for 80% dispersant efficiency. Therefore, the results show that the more efficient the dispersant, the smaller the area of oil is that needs to be burned. This is not a surprising result, as dispersant removes oil from the surface of the water, decreasing the amount of oil that remains on the surface, and thereby decreasing the area of oil that needs to be burned.

Table B-III.2.1-1. Percentile where burn volume, divided by 3 mm, is less than the maximum burn area of 500 m^2, for each medium volume scenario.

Scenario	Percentile
Medium Volume, 0% Dispersant Efficiency	9%
Medium Volume, 45% Dispersant Efficiency	93%
Medium Volume, 80% Dispersant Efficiency	93%

Table B-III.2.1-2 shows, for each medium volume scenario, the number of burns that would be necessary to burn the entire amount of oil that was designated for burning. A range of oil thicknesses are shown in Table B-III.2.1-2: between 3 mm and 10 cm (100 mm). Three mm is the minimum thickness of oil required for in-situ oil burning (Buist et al., 1994). However, 10 cm is a more preferable oil thickness for burning (Allen, 2002). If one burn can be accomplished at less than 10 cm thick and 500 m^2 of area (i.e., the burn volume is < 50 m^3), it is assumed that this occurs and the actual thickness is calculated from volume burned divided by 500 m^2. However, if the calculated thickness for one burn is <3mm, the minimum (i.e., the burn volume is < 1.5 m^3), the burn area is instead the burn volume divided by 3 mm.

Table B-III.2.1-2. Assumed burn thickness for medium volume spill scenarios and number of burns needed to burn the oil, assuming the maximum burn area is 500 m^2.

Scenario		Total Volume Burned (m^3)	Burn Area (m^2)	Oil thickness (mm)	Number of Burns
Medium Volume, 0% Dispersant Efficiency	50th Percentile	14.7	500	30	1
	95th Percentile	23.4	500	47	1
Medium Volume, 45% Dispersant Efficiency	50th Percentile	0	500	-	0
	95th Percentile	1.82	500	4	1
Medium Volume, 80% Dispersant Efficiency	50th Percentile	0	500	-	0
	95th Percentile	1.82	500	4	1

In all cases (Table B-III.2.1-2), the burn volumes are less than 50 m^3, the maximum volume for a single burn. For cases where there is a burn, none of the burn volumes are less than 1.5 m^3, so all the burn areas are 500 m^2. The distance-to-threshold calculations reported below assume an area per burn of 500 m^2.

Table B-III.2.1-3 reports calculations of distance to the air quality thresholds for the chemicals of concern that are released when oil is burned. There are three thresholds in these tables: IDLH, TWA, and EPA NAAQS (Primary and Secondary Standards). These thresholds were described and listed in Table A.5-5. The chemicals listed in Table B-III.2.1-3 were designated by Fingas, et al. (2001) as being of concern, and they are split

into five chemical classes: total particulates, fixed gases, carbonyls, PAHs, and VOCs. For those chemicals for which U.S. air quality standards were not available, we have assumed the lowest of the available thresholds within that chemical class. For example, we do not have an IDLH threshold value for butane, a member of the VOC chemical class, but we do have IDLH values for several other members of the VOC class. We selected the lowest of the available IDLH values for the VOCs and used that value as an IDLH threshold for butane and other chemicals in the VOC class for which we are missing threshold values. We used the same strategy for the PAH chemical class as well. This substitution method provides an estimate of the distance to the threshold for those chemicals for which threshold data are not available. However, because those threshold values are just assumed estimates, the distance values in the following tables that were derived using these threshold values are shaded gray.

It should also be noted that three different TWA threshold values were obtained for this study: ACGIH TLV, OSHA PEL, and NIOSH REL. We calculated the distance to the threshold for each of these, but we present only the maximum of the three distances in these tables. For example, in Table B-III.2.1-3, for formaldehyde, the distance to the ACGIH TLV threshold is 237 m, to the OSHA PEL threshold is 0 m, and to the NIOSH REL threshold is 89 m. The maximum of these three distances is 237 m, which is the TWA value reported in the table.

Table B-III.2.1-3 shows the distance-to-threshold calculations for an individual 500 m^2 burn. In the table, the calculated distances represent the distance (from the center of the fire) at which the concentration of each chemical has decreased to the threshold level. In the case of sulphur dioxide in Table B-III.2.1-3, the distance at which the concentration of sulphur dioxide in the air equals the IDLH threshold is essentially zero, meaning that the concentration of sulphur dioxide produced by the 500-m^2 fire never exceeds the IDLH threshold. However, for the other thresholds in the table (TWA and EPA NAAQS), the concentrations do exceed the thresholds and do not decrease to the threshold level until 331 m, 471 m, and 440 m from the center of the fire.

Table B-III.2.1-3 shows that, for a 500-m^2 burn area, the total particulates, fixed gases, and carbonyls are of the greatest concern (i.e., the distances from the fire to the threshold level are greatest). The majority of other chemicals have distances of zero meters to the threshold level, meaning that their concentrations never exceed the threshold. Acetone has the largest distance to the threshold, at 710 m, and acetaldehyde and the total particulates are the next largest.

In Table B-III.2.1-3, there are four additional chemicals with distances to the threshold that stand out: 2-methylbutane, 3-methylhexane, 3-methylpentane, and methylcyclopentane. However, as can be seen from the tables, these values are shaded gray because we did not have a regulatory threshold value for them. Instead, we used the lowest threshold value from within their group (VOCs). From this, we can conclude that their distance to threshold values *may* represent that they are chemicals whose concentrations will still be above threshold levels far from the fire, or it may be that the threshold estimates used for the distance-to-threshold calculation are unreasonably low and our estimate method is not suitable for these chemicals.

Table B-III.2.1-3. Estimated distances (m) from fire to the thresholds of concern for the 50th and 95th percentile volumes for ISB for burn area of 500 m^2. For those chemicals for which U.S. air quality standards were not available, the smallest of the available thresholds within that chemical class is assumed, and the results are shaded in gray.

	Distance to the Threshold (m)			
Substances	**IDLH**	**TWA**	**EPA NAAQS**	
			Primary Standard	**Secondary Standard**
Total Particulates				
10-um particle			514	514
2.5-um particle			523	523
Fixed gases				
Sulphur Dioxide	0	331	471	440
Carbon Dioxide	0	0		
Carbon Monoxide	0	0	0	
Carbonyls				
Acetaldehyde	0	525		
Acetone	0	710		
Formaldehyde	0	237		
PAHs				
1- Methylnaphthalene	0	0		
1-Methylphenanthrene	0	0		
2,3,5-Trimethylnaphthalene	0	0		
2,6-Dimethylnaphthalene	0	0		
2-Methylnaphthalene	0	0		
Acenaphthene	0	0		
Acenaphthylene	0	0		
Anthracene	0	0		
Benz(a)anthracene	0	0		
Benzo(a)pyrene	0	0		
Benzo(b) fluoranthene	0	0		
Benzo(e) pyrene	0	0		
Benzo(g,h,I) perylene	0	0		

Biphenyl	0	0		
Chrysene	0	0		
Dibenz(a,h)anthracene	0	0		
Dimethylnaphthalenes	0	0		
Fluoranthene	0	0		
Fluorene	0	0		
Indenol(1,2,3-cd)pyrene	0	0		
Methylphenanthrenes	0	0		
Naphthalene	0	0		
Perylene	0	0		
Phenanthrene	0	0		
Pyrene	0	0		
Trimethylnaphthalenes	0	0		
VOCs				
1,2,3-Trimethylbenzene	0	0		
1,2,4-Trimethylbenzene	0	0		
1,3,5-Trimethylbenzene	0	0		
1,4-Diethylbenzene	0	0		
2,2,3-Trimethylbutane	0	0		
2,2,4-Trimethylpentane	0	0		
2,2,5-Trimethylhexane	0	0		
2,2-Dimethylbutane	0	0		
2,2-Dimethylpropane	0	0		
2,3,4-Trimethylpentane	0	0		
2,3-Dimethylbutane	0	1		
2,3-Dimethylpentane	0	1		
2,4-Dimethylhexane	0	0		
2,4-Dimethylpentane	0	0		
2,5-Dimethylhexane	0	0		
2-Ethyltoluene	0	0		
2-Methylbutane	0	165		
2-Methylheptane	0	4		
3-Methylhexane	0	42		
3-Methylpentane	0	85		
4-Ethyltoluene	0	0		
4-Methylheptane	0	0		
Benzene	0	0		
Butane	0	1		
c-1,3-Dimethylcyclohexane	0	0		
c-1,4/t-1,3-Dimethylcyclohexane	0	0		
c-2-Butene	0	0		
Cyclohexane	0	0		
Cyclopentane	0	0		

Decane	0	0		
Dodecane	0	0		
Ethylbenzene	0	0		
Heptane	0	0		
Indan (2,3-Dihydroindene)	0	0		
Isobutane (2-Methylpropane)	0	0		
m,p-xylene	0	0		
Methylcyclohexane	0	0		
Methylcyclopentane	0	92		
Naphthalene	0	0		
n-Butylbenzene	0	0		
Nonane	0	0		
n-Propylbenzene	0	0		
Octane	0	0		
o-Xylene	0	0		
p-Cymene (1-Methyl-4-iso-propylbenzene)	0	0		
Pentane	0	0		
Propane	0	0		
Propene	0	0		
2,2-Dimethylpentane	0	0		
iso-Butylbenzene	0	0		
Isoprene (2-Methyl-1,3-Butadiene)	0	0		
iso-Propylbenzene	0	0		
Undecane	0	0		

The ISB effects are summarized in Table B-III.2.1-4. The affected area is calculated by assuming the circular area around each burn is affected to the maximum distance to any air quality threshold (i.e., this distance is the circle radius) and multiplying the circular area per burn by the number of burns. The percent of the region of interest is calculated using the province area in Table A.4-4.

Table B-III.2.1-4. Estimation of area affected by ISB, for medium volume spills by dispersant scenario and for 50th and 95th percentile burn volumes.

Dispersant % Efficiency		0	45	80
Burn Area (m^2)	50th	500	0	0
	95th	500	500	500
Maximum Distance (m) to Threshold (1 burn)	50th	710	0	0
	95th	710	710	710
# of Burns	50th	1	0	0
	95th	1	1	1
Area (km^2) Exposed (assuming circle with radius = maximum distance)	50th	1.584	0	0
	95th	1.584	1.584	1.584
Percent of Province Area	50th	0.002	0	0
	95th	0.002	0.002	0.002

B-III.2.2 Large Volume Spills

The estimated distances from an in-situ burn to thresholds of concern for the large volume scenarios are below. Burn areas were calculated for all 100 runs for each scenario. Table B-III.2.2-1 lists, for each of the three large volume scenarios, the percentage of simulations whose calculated burn area (burn volume divided by 3 mm) is less than the maximum burn area of 500 m^2. This table shows that the three scenarios in which the large volume of 40,000 bbl of crude oil was released do not have any burn areas smaller than 500 m^2, regardless of the use of dispersant and its efficiency.

Table B-III.2.2-1. Percentile where burn volume, divided by 3 mm, is less than the maximum burn area of 500 m^2, for each large volume scenario.

Scenario	Percentile
Large Volume, 0% Dispersant Efficiency	0%
Large Volume, 45% Dispersant Efficiency	0%
Large Volume, 80% Dispersant Efficiency	0%

Table B-III.2.2-2 shows, for each large volume scenario, the number of burns that would be necessary to burn the entire amount of oil that was designated for burning. The number of burns was calculated by dividing the burn volume (Table B-III.1.2-3) by the assumed oil thickness of 10 cm and then dividing this number into the maximum area allowed per burn (500 m^2).

With a thickness greater than 100 mm, all of the large volume cases will require multiple burns (1 – 10) to remove all the oil. The effectiveness of dispersant application in reducing the amount of oil needing to be burned can be seen in Table B-III.2.2-2. The table shows that the more efficient the dispersant is, the fewer the number of burns required to remove the oil.

Table B-III.2.2-2. Assumed burn thickness for large volume spill scenarios and number of burns needed to burn the oil, assuming the maximum burn area is 500 m^2.

Scenario		Total Volume Burned (m^3)	Burn Area (m^2)	Oil thickness (mm)	Number of Burns
Large Volume, 0% Dispersant Efficiency	50th Percentile	367.6	500	100	8
	95th Percentile	464.8	500	100	10
Large Volume, 45% Dispersant Efficiency	50th Percentile	46.2	500	93	1
	95th Percentile	105.1	500	100	3
Large Volume, 80% Dispersant Efficiency	50th Percentile	26.4	500	53	1
	95th Percentile	78.3	500	100	2

Table B-III.2.1-3 shows distance-to-threshold calculations, in meters, for an individual 500-m^2 burn. Descriptions of Table B-III.2.1-3 and its results can be found in the previous section.

The distances to the threshold would apply to each burn. Thus, the effect is proportional to the number of burns. Table B-III.2.2-2 indicates that on average (50th percentile) the air quality effect is reduced by 7/8 if dispersant is applied with either 45% or 80% efficiency.

The ISB effects are summarized in Table B-III.2.2-3. The affected area is calculated by assuming the circular area around each burn is affected to the maximum distance to any air quality threshold (i.e., this distance is the circle radius) and multiplying the circular area per burn by the number of burns. The percent of the region of interest is calculated using the province area in Table A.4-4.

Table B-III.2.2-3. Estimation of area affected by ISB, for large volume spills by dispersant scenario and for 50th and 95th percentile burn volumes.

Dispersant % Efficiency		**0**	**45**	**80**
Burn Area (m^2)	50th	500	500	500
	95th	500	500	500
Maximum Distance (m) to Threshold (1 burn)	50th	710	710	710
	95th	710	710	710
# of Burns	50th	8	1	1
	95th	10	3	2
Area (km^2) Exposed (assuming circle with radius = maximum distance)	50th	12.67	1.58	1.58
	95th	15.84	4.75	3.17
Percent of Province Area	50th	0.018	0.002	0.002
	95th	0.023	0.007	0.005

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part C: Galveston Bay and North Texas Shelf

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ASA 00-246

August 2004

Preface

This technical report is a supplement to the Programmatic Environmental Impact Statement (PEIS: US Coast Guard, 2004) in support of the US Coast Guard's (USCG) Notice of Proposed Rulemaking (NPRM, USCG, 2002) regarding Vessel and Facility Response Plan oil removal capacity (Caps) requirements for tank vessels and marine transportation-related facilities. The PEIS (USCG, 2004), in accordance with National Environmental Policy Act of 1969 (NEPA), examines a series of alternatives, including a no action alternative, which could influence the availability of oil spill response equipment around the United States.

This technical report is in six (6) parts:

1. Part A contains a description of models and underlying assumptions used in the analysis.
2. Parts B to F contain:
    a. Model results for 5 locations where model runs were performed
    b. Analysis of potential benefits and risks to resources of concern for each of these locations and various spill response alternatives.

Citation for entire report:

> French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Lord, C. Dalton, R. Levine, J. Rowe, S. Sankaranarayanan, H-S. Kim, R. Piovesan and M. Hitchings, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, March 2004, 6 volumes.

Citations for parts of the report:

Part A: Description of Models and Assumptions:

> French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Dalton, R. Levine, J. Rowe, S. Sankaranarayanan and H-S. Kim, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios, Part A: Description of Models and Assumptions. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, March 2004.

Parts B to F:

French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Lord, C. Dalton, J. Rowe, S. Sankaranarayanan, H-S. Kim, R. Piovesan and M. Hitchings 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios, Part C: Galveston Bay and North Texas Shelf. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, 2004.

Part A: Description of Models and Assumptions.
Part B: Delaware Bay and Mid-Atlantic Shelf.
Part C: Galveston Bay and North Texas Shelf
Part D: Florida Straits
Part E: San Francisco Bay and Central California Shelf
Part F: Prince William Sound

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C. GALVESTON BAY AND NORTH TEXAS SHELF

C.1 INTRODUCTION

This report deals with the modeling results for a location near the entrance to Galveston Bay, the selected by the U.S. Coast Guard (USCG) for analysis in the Gulf of Mexico region. It is one of five locations used to develop modeling data to analyze the regional and national implications of potential changes in oil spill response requirements. The results and a summary of the assumptions are discussed in a separate volume for each of these locations, while details on the methodology are presented in Part A of this Technical Report. The results of the site specific modeling analyses were used to develop the discussions about the impacts of the various alternatives under consideration in the Programmatic Environmental Impact Statement (PEIS).

All of the sites were selected because they are either located in the approaches to “higher volume ports” as defined in the Code of Federal Regulations (33 CFR 154.1020) or because they are in an area of high vessel traffic. In either case, they are considered to be areas where congestion could increase the risk of oil spills.

C.1.1 Selection of the Location

The location used in this scenario is 7.5 miles offshore, in the approach channel for Galveston Bay (Figure B.I. 1.1-1). This is the approximate mid-point of the near shore zone as defined in 33 CFR 155.1020 and represents a location where an open water oil spill could threaten shore resources and where on-water mechanical recovery, in-situ burning (ISB) or dispersant use could be considered. The specific coordinates are given in Table C.I.4-1

The Galveston Bay and Houston Ship Channel region is a designated higher volume port area by the USCG. The Galveston Bay region is one of the centers of the oil refining industry in the United States. In 2002, refineries in the Galveston Bay area accounted for nearly 20% of the refining capacity of the United States (Pennwell Corporation, 2002). More oil moves into the Houston area than any other port along the Texas coast. In 1997, the Houston-Baytown area imported more than 941,000 barrels (bbl) of persistent oils per day. In addition, an average of 430,137 barrels per day (bpd) of refined product were exported in 1997. In total, over 500,000,000 bbl of oil move through the Galveston Bay each year (Pond et al., 2000). In 2000, there were over 5600 total tanker transits (inbound and outbound) of the Houston Ship Channel. In addition, a total of over 46,000 non-self propelled tank vessels (usually barges) also used the channel (U.S. Army Corps of Engineers, 2000). All of the tankers and many of the barges entered or left Galveston Bay past the location selected for this scenario.

C.1.2 Description of the Local Study Area

The study area for this analysis consists of two biogeographical provinces, as defined in Table A.4-2 of Part A of this Technical Report. The two provinces are: the Galveston Bay (Province 39) and the Texas portion of the Louisiana-North Texas Shelf (Province 37). Collectively, these areas are referred to as the North Texas Shelf. On occasion, Galveston Bay (Province 39) provides a reference area for potential effects of spills into coastal areas. The boundaries of the provinces were delineated in French et al. (1996) and are based on the ecoregion (province) concept outlined in Cowardin et al. (1979) used by the Department of the Interior. The divisions into provinces are based on the distributions of, and natural boundaries between, marine populations. Biota within a province are exposed to similar environmental factors and the populations typically cover the entire province (as appropriate habitat is available). Thus, effects can be evaluated as percentages of the province(s) occupied by the populations of concern. A map of the two provinces used to analyze the offshore Galveston Bay scenario is presented as Figure A.4-3 in Part A of this Technical Report. The total areas of the provinces are presented in Table A.4-3. The areas of various habitats and shoreline types in the North Texas Shelf reference area are given in Tables A.4-4 and A.4-5, and shoreline lengths for various shoreline types are given in Table A.4-6.

C.1.3 Modeling Input Assumptions

Part A of this Technical Report provides details on the modeling approach used in the analysis of all of the five locations. In summary, for each of the locations the Spill Impact Model Application Package (SIMAP) oil spill model was run in a probabilistic mode (100 simulations) to evaluate both physical fate and biological effects. Running the model in probabilistic mode allows the estimation of the variance due to random circumstances, such as weather, time of day, and hydrographic conditions. The basic model scenario is described in Section A.1.4, while the specific model algorithms are presented in Section A.2, and details on model input parameters are presented in Section A.3. Air quality effects, which are not directly evaluated by SIMAP, were estimated using the Air Model Application Package (AIRMAP) and then estimated concentrations at the water surface were compared to air quality standards (see Section A.5).

The results of the model runs consist of a series of tables and figures which summarize areas or linear distances, by habitat type and/or location, which exceed thresholds of concern (see Section A.4). These results were compared to information on the distribution and abundance of various resources in appropriate geographic areas to estimate the percentage of habitats or biological resources that are potentially affected, and the results were then scored using a relative risk matrix which included proportion of the resource affected and time of recovery (see Section A.1.5). Socioeconomic effects could not be evaluated with the same risk matrix, since the concept of recovery time was not appropriate. The method used for those elements is described in Section A.6 and is based strictly on the magnitude of the effect on the resource of concern relative to the total resource that is available.

The input parameters which were specific to the offshore Galveston Bay study location are presented in Appendix C.I (this volume). Appendix C.I.1 presents a series of maps which define the basic geographic data input into the model; Appendix C.I.2 discusses the development of current (hydrodynamic) data used in the model runs; Appendix C.I.3 presents the properties for South Louisiana crude oil (the oil used in the analysis); and Appendix C.I.4 summarizes all of the input parameters and the sources of the information that were used to run the model.

C.2 MODELING RESULTS

Two spill volumes and three response scenarios were simulated using modeling and the results are provided in Appendices C-II and C-III. Section A.1.4 of Part A contains a description of the rationale for running these scenarios to provide the needed information for evaluating the alternatives being considered in the PEIS. The two spill volumes were for medium (2,500 bbl) and large spills (40,000 bbl). Oil properties used were for South Louisiana crude oil, as representative of oils shipped in the Gulf of Mexico region. The three response scenarios modeled for each of two spill volumes were:

- mechanical removal at present levels of capability, or with some of that removal accomplished by ISB;
- the same mechanical removal response as above, or with some of that removal accomplished by ISB, plus dispersant application at 45% efficiency (based on minimum dispersant effectiveness criteria established in the National Oil and Hazardous Substances Contingency Plan, NCP – 40 CFR Part 300); and
- the same mechanical removal response as above, or with some of that removal accomplished by ISB, plus dispersant application at 80% efficiency (based on theoretically successful dispersant operation).

Appendices C-II.1 to C-II.6 contain results of the SIMAP oil spill model simulations that estimate oil hydrocarbon exposure on/in the water surface, shorelines, water column, and sediments. Each of these appendices contains results for all six volume-response scenario combinations. Appendix C-II.1 contains maps of exposure probability, time of first exposure for each medium (water surface, shorelines, water column, and sediments) and location surrounding the spill site, and maximum possible mass or concentration at each location at any time after a spill. These maps are gridded, presenting the average amount of contamination over the entire grid cell (which for water cells is 0.086 km^2 in area) at any time after a spill. The grid average is calculated from the mass passing through the cell, divided by the area or volume of the cell. Note that if the mass is concentrated in patches much smaller than the area of the grid cell, as is often the case, the gridded data will average out the patches and not resolve small concentrations of oil. Thus, the gridded data are used as indices of exposure, rather than areas exposed at specific levels. (See Section A.4.2 in Part A and Sections C.II.5 and C.II.6 for the methods used to more accurately evaluate exposure of biota to surface floating oil and dissolved aromatic hydrocarbons.)

Tables summarizing areas and volumes potentially affected using gridded exposure indices specific to water surface, shorelines, water column, and sediments are in Appendix C-II.2. Average, standard deviation, and the maximum of the 100 simulations performed for each scenario are presented. The 95th percentile conditions used in the risk analysis were calculated as the mean plus two times the standard deviation. Appendix C-II.3 contains rank order distributions of results for all 100 model runs, from which 50th and 95th percentile of exposure areas and volumes were derived. Mass balance information, such as percent of the oil mechanically removed, dispersed in the water column, and eventually going ashore or to the sediments, is also included in Appendices C-II.2 and C-II.3. Appendix C-II.4 contains the results for the 50th percentile cases for surface oiling, shoreline oiling, water column effects, and sediment contamination, presented as plots of various measures of exposure.

In Appendix C-II.5, estimates of mean (for all 100 runs of varying environmental conditions) equivalent area of 100% mortality are listed for each of several wildlife behavior categories. The equivalent area for 100% mortality is the integrated sum of surface water area swept by oil multiplied by probability of mortality, which varies by foraging behavior and whether the animal has feathers or fur. Appendix C-II.6 contains estimated mean mortality of water column, demersal (on the bottom) and benthic (in the bottom) organisms, summarized as an equivalent area of 100% mortality by behavior group and habitat type. The equivalent area for 100% mortality is the integrated sum of equivalent area affected times percent mortality. For water column and demersal species, the equivalent area affected is calculated as water volume affected times the fraction of the water depth zone the behavior group occupies that the affected volume encompasses. For pelagic species, the depth zone occupied is the entire water column. For demersal species (on the bottom sediments, exposed to bottom water), the depth zone occupied is the bottom 1 meter (3.3 ft) of the water column. The methods and assumptions for these calculations are described in Part A and Sections C-II-5 and C-II-6.

Appendices C-III.1 and C-III.2 contains the model results of atmospheric exposure to volatilized oil hydrocarbons and soot from ISB, relevant to air quality evaluations. Appendix C-III.1 contains model results used to evaluate volatile hydrocarbon emissions from unburned oil and resulting air quality effects. The amount of volatilized mass entering the atmosphere, and the time frame for those emissions, was estimated for each chemical (or chemical class) of concern using oil spill modeling (SIMAP). The atmospheric concentrations of volatilized hydrocarbons were modeled using AIRMAP (as described in Part A, Section A.5.1). The estimated concentrations at the water surface were compared to air quality standards to evaluate the areas exceeding the standards. Section A.5.2 of Part A describes the methods used to evaluate emissions from ISB and their potential effects on air quality. The results for ISB are in Appendix C-III.2.

The model results in Appendices C-II and C-III are summarized in sections C.3 and C.4, and were used in the analysis of potential effects for the various alternatives being considered in the PEIS. All summary risk rankings are based on the average results. In some sections, the results of the 95th percentile calculation are also presented to illustrate the variability for that particular resource. Section C.3 contains the discussion of potential impacts for medium volume spills (2,500 bbl), and Section C.4 contains that for large volume spills (40,000 bbl). Sections C.3 and C.4 are organized by each of the physical, biological and socioeconomic resource categories evaluated in the PEIS. Section C.5 contains a summary of all the risk scores and conclusions. References are in Section C.6.

C.3 ENVIRONMENTAL CONSEQUENCES BASED ON THE MEDIUM VOLUME SPILL MODELING SCENARIOS

C.3.1 Effects on the Physical Environment

C.3.1.1 Air Quality

In the event of a spill, there are two possible sources of contamination to the atmosphere: volatilization of hydrocarbons from unburned oil and emissions produced by ISB. The hydrocarbon and ISB emissions are of concern for both human health and wildlife that may be exposed. Concentrations in the lowest 2 m (6.6 ft) of the atmosphere were estimated for both unburned and burned oil using modeling and observational data from test burns, as described in Part A, Section A.5. Distances from the spill or burn site to thresholds of concern and areas affected above these thresholds were calculated for each of a number of chemicals. The thresholds of concern are air quality standards for human health (IDLH (Immediate Danger to Life and health) for a ½ hour exposure and minimum TWA (time weighted average) for an 8-hour exposure, Table D.1-1 in Appendix D of the PEIS and Table A.5-5 in Part A).

Emissions from unburned oil were estimated using SIMAP, assuming the warmest (monthly mean) water temperature in the reference area and for varying wind speeds from 3 to 25 kts. As a worst case, these model runs were performed assuming no response, which would otherwise reduce emissions to some degree. Atmospheric concentrations of volatilized hydrocarbons were estimated using AIRMAP, which accounts for transport and dilution of hydrocarbons in the local atmosphere around the spill site. The worst case of a stable atmosphere was assumed for these calculations. Area and the down-wind distance affected above the thresholds were calculated from the model results, as described in Section A.5.1 of Part A.

For emissions from ISB, the maximum potential amount of oil burned was assumed to be 25% by volume of the amount of oil mechanically removed (see Section A.3.7, Part A). The 50th and 95th percentiles of the cleanup volumes (for the 100 stochastic runs) were multiplied by 0.25 to calculate the 50th and 95th percentile volumes burned by ISB. The atmospheric concentrations of compounds and particulates released by an in-situ burn of a particular volume of oil were estimated using the models developed by Fingas et al. (2001), as described in Section A.5.2 of Part A. The number of burns needed was estimated from the total volume burned and a maximum burn size. The burn model provides concentration as a function of distance down wind from the fire. Distances were translated to areas of potential effect, assuming the air plume could move in any direction depending on the wind direction, such that the area of a circle of this radius could be affected for each of the burns.

The area potentially contaminated was divided by the area of the North Texas Shelf (39,602 km^2 or 15,290 mi^2, Table A.4-4) to estimate the percentage affected by the scenario. Appendices C-III.1.1 and C-III.2.1 provide data for unburned and burned oil, respectively, from medium volume spills into the North Texas Shelf.

Results of On-Water Mechanical Recovery Only

Under the medium volume spill scenario with no dispersant response, volatilized hydrocarbons would not exceed air quality standards for human health at $\geq$0.7 km (0.4 mi) from the spill site, with a maximum of 0.08 km^2 (0.03 mi^2) adversely affected. While this would be of concern for personnel close to the spill site within the first few hours after emissions are released, it is a very small percentage of the area of the North Texas Shelf. Evaporation and dispersion in the air would be very rapid after a spill, and recovery time would be less than 1 day. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
For the medium volume spill scenario with 45% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
For the medium volume spill scenario with 80% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would also be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, the worst case for air quality would be a single large burn 500 m^2 in area at one location. Based on model results described in Appendix C-III.2.1 and areas affected as summarized in Table C-III.2.1-4, air quality would be affected up to 710 m (2,329 ft) downwind of the burn site, assuming a stable atmosphere and light wind at the time of the burning (environmental conditions that would inhibit dispersion of the plume and induce the highest adverse effects to air quality). The area potentially affected is a 1.6 km^2 (0.6 mi^2) circular area around the burn site. This represents 0.004% of the North Texas Shelf and Galveston Bay. Thus, the percent of the resource affected is <1%. The recovery time for the atmosphere after ISB would be on the order of hours, and a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Summary of the Consequences for Air Quality in the Medium Volume Scenarios
The consequences of the three response options for medium spills (1) on-water mechanical recovery only, (2) on-water mechanical recovery plus dispersants at 45% efficiency, and (3) on-water mechanical recovery plus dispersants at 80% efficiency are all essentially the same with respect to air quality. Evaporation off the water surface and volatilization from the water column creates a plume of volatile hydrocarbon gases that disperses quickly after a spill. The concentrations in the atmosphere at the water surface would exceed human health thresholds up to 0.7 km (0.4 mi) from the spill site. Dispersant use would reduce the evaporation rate, but dissolved hydrocarbons would still volatilize, although dispersed over a wider area. Thus, atmospheric concentrations would be slightly less under the dispersant use options. In all three options, the impact would be small, affecting much less than 1% of the reference area (i.e., the North Texas Shelf in Table A.4-4), and the recovery time for the atmosphere would be on the order of hours. The alternatives involving on-water mechanical recovery plus ISB (whether or not dispersants are used) could increase atmospheric pollutants by the amount injected via burning.

Table C.3.1.1-1 indicates risk scores for air quality for all response options for a medium volume spill. Both the area affected and the recovery times are assigned the lowest risk score for all the response options. These results would apply to any spill site at least 3 miles from shore.

Table C.3.1.1-1. Air quality risk scores for medium spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB, With or Without Dispersant Application	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

C.3.1.2 Water Quality

The lowest water quality thresholds of concern are those concentrations of dissolved aromatics that could have effects on sensitive species in the water (see Section 4.3.1.1 of the PEIS). These thresholds are much lower than human health thresholds. The threshold for effects on water column organisms would be 5 ppb for at least 4 days of exposure. As an exposure dose, the threshold would be 500 ppb-hours. (See Part A, Section A.3.4 for development of these thresholds.)

The volume affected by greater than 500 ppb-hours was estimated by the model. Table C.3.1.2-1 summarizes the mean and 95th percentile values of the water volume affected by >1 ppb for at least 1 hour and the average exposure dose in that volume of water. These data are the mean and the mean plus 2 standard deviations of the model results for all 100 runs performed for each scenario (Appendix C-II.2). The average exposure doses in the volumes are at or greater than the 500 ppb-hour threshold. Thus, the volume exposed to >1 ppb for at least 1 hour is an appropriate criterion for identifying water volumes exceeding the exposure dose threshold of 500 ppb-hours.

The percentages affected of total water volumes in coastal and marine reference areas were calculated using the biogeographical province areas in Tables A.4-3 and A.4-4 for Galveston Bay (coastal) and the North Texas Shelf (marine). The total coastal volume was the area of Galveston Bay times a mean depth of 2 m (6.6 ft). In this calculation it is assumed that the entire contaminated volume would be located in the coastal reference area (Galveston Bay) after a spill, a worst case assumption for a spill in that estuary. The total marine volume was the area of the province times the depth at the spill site, 10 m (33 ft). Thus, only the surface water volume was considered in the marine estimation. Risk scores for potential effects were assigned for each of coastal and marine areas.

Table C.3.1.2-1. Estimation of effects on water quality for medium volume spills by dispersant scenario, based on mean and 95th percentile water volumes exceeding 1 ppb dissolved aromatic concentration.

Dispersant % Efficiency		**0**	**45**	**80**
Volume (millions of m^3) Exposed to >1 ppb	mean	70.6	163.4	165.9
	95th	194.6	365.9	400.0
Average ppb-hrs in Volume	mean	451	2223	2523
	95th	987	5165	6211
Percent of Reference Area, coastal	mean	2.0	4.6	4.6
	95th	5.4	10.2	11.2
Percent of Reference Area, marine	mean	0.02	0.04	0.04
	95th	0.05	0.09	0.10

Results of On-Water Mechanical Recovery Only
For the medium volume spill in Galveston Bay and no dispersant response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 2% on average. For 5% of spills, the percentage affected would exceed 5.4% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days, the time for concentrations to disperse to background levels. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions. Coastal spills under average and extreme (95th percentile) conditions were assigned risk matrix rankings of **4D** and **4C**, respectively.

Results of the Addition of a Dispersant Response at Low Efficiency
For the medium volume spill scenario and 45% dispersant efficiency response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 4.6% on average. For 5% of spills, the percentage affected would slightly exceed 10% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions. Coastal spills under average and extreme (95th percentile) conditions, were assigned risk matrix rankings of **4D** and **4B**, respectively. Note that dispersants would not be applied in coastal waters under the alternatives considered in the PEIS that include dispersant use.

Results of the Addition of a Dispersant Response at High Efficiency
For the medium volume spill scenario and 80% dispersant efficiency response, the volumes affected are nearly the same as for 45% dispersant efficiency (because more than sufficient dispersant would be available to disperse the floating oil, see Section A.3.7 of Part A). Thus, the risk matrix rankings assigned to water quality for this scenario were the same as for the 45%

dispersant efficiency case.

Results of the Addition of an On-Water ISB Response

Under the medium volume spill scenario and the ISB response option, the water quality effects would be slightly less, by the amount removed by burning. Thus, the percent of the resource affected slightly less for on-water mechanical and both dispersant response scenarios when ISB is included. The recovery time for water quality would be on the order of days. Thus, the risk matrix rankings assigned to water quality for scenarios involving burning were the same as those assigned for scenarios without burning.

Summary of the Consequences for Water Quality in the Medium Volume Scenarios

Table C.3.1.2-2 summarizes risk scores for water quality for all response options for a medium volume spill in coastal waters under average and extreme (95^{th}) environmental conditions. Table C.3.1.2-3 summarizes risk scores for medium volume spills in marine waters. The coastal results would apply to similar volume coastal areas and the marine results would apply to any spill site at least 3 miles from shore.

Table C.3.1.2-2. Water quality risk scores for medium spills in coastal areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: D 95^{th}: C	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: D 95^{th}: B	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: D 95^{th}: B	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%

** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

Table C.3.1.2-3. Water quality risk scores for medium spills in marine areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%

** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

C.3.2 Effects on the Biological Environment

C.3.2.1 Intertidal Habitats

The sensitive intertidal habitats in the North Texas Shelf include sand beaches along the outer coast and extensive intertidal wetlands along the interior bays that are important habitats for birds and nursery areas for commercially valuable fisheries. Coastal wetlands in the area provide many valuable ecological functions. The threshold concentration of concern for intertidal habitats is 10 g/m^2 (10-micron) thickness of oil (see Section A.4 in Part A). Table C.3.2-1-1 shows the outputs of the different scenarios in terms of the area and length of shoreline habitat affected, by major shoreline habitat type (shoreline classifications are defined in NOAA, 2000b). "Gravel" habitats include shell beaches and riprap structures, and these habitats are included in the table to account for the dominant shoreline habitats in the study area, but the following discussion focuses on beaches and wetlands.

Table C.3.2-1-1. Mean area and length of shoreline habitats oiled above a threshold of 10 g/m^2 (10 micron) oil thickness for the medium volume scenarios. The numbers are summarized from Appendix C Tables C-II.2-1 through C-II.2-3.

Response Option	Total Oiled Shoreline Area (m^2)	Total Oiled Shoreline Length (km)	Outer Sand Beach Length (km)	Gravel Length (km)	Wetlands Length (km)
On-Water Mechanical Recovery (with or without ISB)	74,000	15.9	9.4	5.0	0.6
On-Water Mechanical Recovery and Dispersant Application (45% efficiency) (with or without ISB)	33,500	7.4	4.1	2.4	0.3
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	25,500	5.7	3.3	1.8	0.2

Results of On-Water Mechanical Recovery Only

Under the medium volume spill scenario and no dispersant response option, the mean area of shoreline oiling exceeding a threshold of 10 g/m^2 (~ 10 microns) for all model runs would be 74,000 m^2 (88,000 yd^2) and the mean length would be 16 km (10 mi), representing less than 1% of the total coastline area in the North Texas Shelf reference area which is 1,360 km^2 (525 mi^2) (Tables A.4-4 and A.4-5). Most of the intertidal habitats oiled above this threshold would be outer sand beaches (about 3.4% of the outer sand beaches in the reference area, Table a.4-6), and oil loadings on sand beaches would reach 10,000-100,000 g/m^2 on beaches north of Bolivar Roads. The areal extent and oil loadings in wetland habitats would be low (Figure C-II.1.1.2-3). With rapid and effective removal of oil from sand beaches and the relatively light oiling of wetlands, these habitats would be expected to recover within 1-3 years (NRC, 2003). A risk matrix ranking of **3D** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45% dispersant efficiency response option, the mean area of shoreline oiling exceeding a threshold of 10 g/m^2 (~ 10 microns) for all model runs would be 33,500 m^2 (40,000 yd^2) and the mean length would be 7.4 km (4.6 mi). The oiled shoreline area would be reduced by more than 50% compared to mechanical recovery alone. Furthermore, oil loadings on sand beaches and wetlands would be reduced (Figure C-II.1.2.2-3). With such low oil loading, wetlands would be expected to recover within 1-3 years (NRC, 2003). Thus a risk matrix ranking of **3E** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80% dispersant efficiency response option, the mean area of shoreline oiling exceeding a threshold of 10 g/m^2 (~ 10 microns) for all model runs would be 25,500 m^2 (30,500 yd^2) and the mean length would be 5.7 km (3.6 mi). Use of dispersants at 80% efficiency would reduce the shoreline impacts by over 65%, with very little oil reaching sensitive interior habitats (Figure C-II.1.3.2-3). With rapid and effective removal of oil from sand beaches and the relatively light oiling of wetlands, these habitats would be expected to recover within 1-3 years (NRC, 2003). A risk matrix ranking of **3E** was assigned to intertidal habitats for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects to intertidal habitats would be similar to the on-water mechanical recovery only response option, since the pattern of oil stranding would remain unchanged. A risk matrix ranking of **3D** was assigned to intertidal habitats for this scenario.

Summary of the Consequences for Intertidal Habitats in the Medium Volume Scenarios
Under the medium volume scenario, the application of dispersants would reduce the level of impacts to intertidal habitats by 55-65%, compared to mechanical only and ISB.

C.3.2.2 Marine and Coastal Birds

The Gulf of Mexico region, and particularly Galveston Bay in the North Texas Shelf reference area, provides important habitat for migrant and resident coastal birds, including shorebirds [e.g. piping plover, (*Charadrius melodus,* federally threatened), sandpipers, etc.] that utilize sand beaches and mud flats, wading birds (e.g. herons and egrets), and other nesting species (e.g. rails and moorhens), that utilize marsh habitats; and waterfowl, seabirds, and diving birds that use open water habitats (Section 3.4.2.2 of the PEIS)

Of particular importance in this region are two international WHSRN (Western Hemispheric Shorebird Reserve Network) sites, Bolivar Flats and Brazoria National Wildlife Refuge. Both sites are estimated to support approximately 140,000 shorebirds annually for feeding and roosting. Brazoria National Wildlife Refuge is also an important area for wintering ducks, snow geese (*Chen caerulescens*), and nesting colonial water birds.

It is important to note that the species groups being considered are not normally distributed equally throughout the North Texas Shelf, and that effects may not be proportional to the total amount of shoreline or water surface area oiled. Effects of seasonal concentrations of particular species in high-use areas need to be considered (NOAA, 1995). This is particularly true of shorebirds concentrating in staging areas on beaches and mudflats within the WHSRN sites.

In the North Texas Shelf reference area, waterfowl, diving birds, gulls, and terns are concentrated primarily in bays. Some species of wintering waterfowl (e.g. sea ducks), diving birds (e.g. pelicans), and gulls and terns utilize the nearshore area within approximately 5-20 km of shore, with a few species ranging to up to 30 km offshore (USFWS, 1982a, 1982b, and 1983). The offshore boundary of the biogeographical province ranges from approximately 20 to 200 km offshore, therefore considering the surface area of bays and inshore waters, we assume that water associated species are only utilizing approximately 10 percent of the North Texas Shelf area. Therefore, we used a multiplier of 10 when calculating risk to open-water associated species.

When calculating the risk scores to include shoreline associated species, we took into account the fact that shorebirds, wading birds, and waterfowl concentrate in wetlands and on sand beaches and tidal flats, but are not distributed evenly throughout these habitats spatially or seasonally (Texas General Land Office, 2002). The current body of data available for these species in the North Texas Shelf does not allow for quantifying the “level of concentration”, as was possible for open-water species. We used a multiplier of 5 to account for the importance of these key shoreline habitats, which when oiled, particularly in the case of marshes, are difficult to clean and oil exposure can persist for months to years.

Birds would likely be affected if a threshold of 10 g/m^2 (~10-micron) thickness of oil is exceeded on the shoreline or on the water surface (see Section A.4 in Part A).

Results of On-Water Mechanical Recovery Only

Under the medium volume spill scenario and no dispersant response option, outer sand beaches used as staging habitat by large numbers of shorebirds would be oiled above the 10-micron threshold. Oiled areas could include: Bolivar Flats, the outer coast, and the jetties (Figure C-II.1.1.2-3). The mean area of shoreline oiled above a threshold of 10 g/m^2 would be about 74,000 m^2 (796,500 ft^2), most of which would be outer sand beaches (Table C.3.2.1-1).

Surface water oiling above the 10-micron threshold in the modeled area would be primarily outside of the Galveston Bay entrance (Figure C-II.1.1.1-3). Some diving bird and seabird habitat may be affected, but adverse population impacts to these groups are likely to be less severe than for birds utilizing shoreline habitats since their populations are more widely distributed throughout the Gulf of Mexico than the highly concentrated migratory species.

When considering all species groups together (e.g. shorebirds, waterfowl, diving birds, etc.), it is possible that 5 to 10 percent of the North Texas Shelf marine and coastal bird population may be adversely affected under these spill conditions. Recovery would likely occur in 1 to 3 years for most species, as was the case following the Exxon Valdez oil spill (Kuletz, 1993; Boersma et al., 1995; Erikson, 1995; and Wiens, 1995). A risk matrix ranking of **3C** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency

Under the medium volume spill scenario and the low efficiency dispersant response option, the mean area of shoreline oiled above a threshold of 10 g/m^2 was reduced by over 50 percent (Table C.3.2.1-1). Areas oiled could include Bolivar Flats, the jetties, and some outer coast beaches, but adverse effects on birds utilizing the Brazoria National Wildlife Refuge and areas inside Galveston Bay should be reduced (Figure C-II.1.2.2-3).

Surface water oiling above the 10-micron threshold in the modeled area would be reduced and restricted to mostly outside of Galveston Bay (Figure C-II.1.2.1-3). Limited diving bird and seabird habitat may be adversely affected.

Due to the estimated decrease in shoreline and surface water oiling compared to when no dispersants were used, it is possible that adverse effects on birds would be reduced, and that 1 to 5 percent of the area marine and coastal bird population may be adversely affected under these spill conditions. Recovery would likely occur in 1 to 3 years for most species. A risk matrix ranking of **3D** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the medium volume spill scenario and the high efficiency dispersant response option, the mean area of shoreline oiled above a threshold of 10 g/m^2 was reduced by over 65 percent (Table C.3.2.1-1). Oiled areas could include the outer coast beaches, the jetties, and Bolivar Flats (Figure C-II.1.3.2-3).

Surface water oiling should be similar with dispersant use regardless of efficiency, and limited diving bird and seabird habitat may be adversely affected (C-II.1.3.1-3).

When considering all species groups together, it is possible that 1 to 5 percent of the North Texas Shelf bird population may be adversely affected under these spill conditions. Recovery would likely occur in 1 to 3 years for most species. A risk matrix ranking of **3D** was assigned to birds for this scenario.

Results of the Addition of an On-Water ISB Response

Under the medium volume spill scenario and the ISB response option, adverse impacts to birds would be similar to the on-water mechanical recovery only response option. When considering all species groups together, 5 to 10 percent of the North Texas Shelf population may be adversely affected under these spill conditions, and recovery would likely occur in 1 to 3 years for most species. A risk matrix ranking of **3C** was assigned to birds for this scenario.

Summary of the Consequences for marine and Coastal Birds in the Medium Volume Scenarios
Under the medium volume scenario and under the mechanical recovery only and use of ISB response option, adverse effects on birds are likely to be of moderate concern when no dispersants are used due to the high probability of important migratory staging and wetland concentration areas being oiled. The use of dispersants is projected to likely lessen the water surface and shoreline impacts enough to decrease the area and lower the percentage of birds affected, but this decrease is not enough to lower the overall risk ranking.

C.3.2.3 Marine Mammals

Twenty-eight species of cetaceans occur in the Gulf of Mexico, and many of these occur in the North Texas Shelf (Section 3.4.2.1 of the PEIS provides details on the marine mammals of the Gulf of Mexico region). There are five baleen [northern right (*Eubalaena glacialis*), blue (*Balaenoptera musculus*), fin (*Balaenoptera physalus*), sei (*Balaenoptera borealis*), and humpback (*Megaptera novaeangliae*)] and one toothed (sperm, *Physeter catodon*) whale species occurring in the Gulf of Mexico that are endangered. The sperm whale is common in deep water in the Gulf, while the baleen whales are considered uncommon. A number of dolphins and small whales are relatively abundant and are much more likely to be found in shallow near shore areas than are the larger whales. The only other marine mammal found in the Gulf is the West Indian manatee (*Trichechus manatus*). The manatees occasionally appearing in Texas waters are most likely from the Antillean rather than the Florida subspecies. There are no pinnipeds or furred marine mammals in the area. Terrestrial mammals, however, are common in the coastal marshes.

Marine mammals may be at risk from either floating oil, or from oil which strands in coastal shoreline areas that are used as haul out or breeding areas. The latter concern is not important in the North Texas Shelf, since there are no species which use such areas. There is, however, a risk to terrestrial species in marshes and along the shore, particularly in the estuaries and behind the barrier islands.

Marine mammals are assumed to be at risk when a threshold of 10 g/m^2 (~10-micron) of oil is exceeded on the shoreline or the water surface (see Section A.4 in Part A), however the level of risk varies by the behavior group. Potential adverse effects on marine mammals (i.e., terrestrial wildlife, cetaceans, furbearing marine mammals, pinnipeds, manatees, and sea turtles were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the medium volume North Texas Shelf spills are in Appendix C-II.5, Table C-II.5.2. The equivalent areas of 100% mortality for all response options are summarized in Table C.3.2.3-1 as percentages of the North Texas Shelf (defined in Tables A.4-4 and A.4-5 of Part A). In addition to this calculation, which is based on the mean result, the mean length of shoreline oiled and the surface oil exposure exceeding 0.01 g/m^2 (in m^2-hrs) based on all model runs was also compared between the treatment options (Tables C-II.2-1 through C-II.2-3).

Table C.3.2.3-1. Percentage of reference area adversely affected for medium spills, by dispersant option and behavior group (assuming North Texas Shelf area in Tables A.4-4 and A.4-5).

Behavior Group (Habitat Occupied)	0	45	80
Terrestrial wildlife (wetlands, sea grass beds and shoreline)	0	0	0
Cetaceans (seaward subtidal)	<0.001	<0. 001	<0. 001
Furbearing marine mammals (all intertidal and subtidal)	0. 15	0. 08	0. 08
Pinnipeds and manatees (all intertidal and subtidal)	0. 002	0. 001	0. 001

Results of On-Water Mechanical Recovery Only

In the North Texas Shelf, the only marine mammals at risk are cetaceans and terrestrial mammals along the shore. The resistance of cetaceans to oiling coupled with the very small percentage of area affected creates a very minimal risk to cetaceans under the on-water mechanical recovery only option for the medium volume spill scenario. The cetaceans that are oiled as a result of contact with floating oil would most likely recover in within a few days, if not hours, of the spill (**4E**) (RPI, 1987). Similarly, terrestrial mammals are at very low risk, based on the extent of shoreline oiling, but if an individual were killed or reproductively impaired by contact with oil on the shoreline, the recovery period could exceed one year (**3E**). The higher score is reported for marine mammals overall.

Results of the Addition of a Dispersant Response at Low Efficiency

Under the medium volume spill scenario and the 45% efficiency dispersant option the areas of equivalent mortality are slightly reduced in absolute area, and are still very small relative to the reference areas. Even though the use of dispersants would reduce the amount of surface oil entering sensitive shoreline habitats, the change would not affect the recovery time and so the risk score of **3E** remains the same. There is no evidence that cetaceans are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency

Under the medium volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality are essentially the same as those for the 45% option, as is the extent of shoreline oiled, thus the risk score remains unchanged.

Results of the Addition of an On-Water ISB Response

Oil removal by ISB in addition to on-water mechanical recovery should not change the effects on marine mammals (**3E**), since the amount of floating oil remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to marine mammals.

Summary of the Consequences for Marine Mammals in the Medium Volume Scenarios

The results indicate that on average for medium volume spills in the North Texas Shelf adverse effects on marine mammals would be negligible with or without the use of dispersants. Dispersant use would potentially reduce the possibility of terrestrial mammals being affected, but this risk would already be very low. The absence of furbearing marine mammals and pinnipeds in the area, and the low sensitivity of cetaceans are the major contributing factors to this conclusion. These results are consistent with experience with spills of this size in areas where marine mammals are uncommon.

C.3.2.4 Sea Turtles

The Gulf coast contains a variety of sea turtles: green sea turtle (*Chelonia mydas*); leatherback sea turtle (*Dermochelys coriacea*); hawksbill sea turtle (*Eretmochelys imbricate*); Kemp's ridley sea turtle (*Lepidochelys kempii*); and loggerhead sea turtle (*Caretta caretta*) (see Section 3.4.3 of the PEIS). The Kemp's ridley, hawksbill, and leatherback turtles are endangered species. The green turtle and the loggerhead turtle are listed as threatened. In order of abundance in U.S. waters the species are ranked as follows: loggerhead turtles, Kemp's ridley, green turtles, leatherback turtles, and hawksbills (MMS, 1996). There are nesting beaches along the Texas coast, and individuals are often seen in coastal areas and associated with offshore platforms. The primary risk to sea turtles is from exposure to shoreline oiling in areas where they breed, however adult turtles do have a low sensitivity to floating oil and they could ingest tar balls. Certain critical nesting sites on sand beaches exist for sea turtles and there is high site fidelity. If these beaches are oiled when the females are laying their eggs or while the young are emerging from the nest and making their way to the water, there is the potential for increased harmful effects. Similarly, it has been noted that oiled nests are less likely to produce viable young. However, direct contact between oil and the egg is often necessary to render the egg unviable (MMS, 1996).

Sea turtles are assumed to be at risk when a threshold of 10 g/m^2 (~10-micron) of oil is exceeded on the shoreline or the water surface (see Section A.4 in Part A). Potential adverse effects on sea turtles were estimated using the modeling (SIMAP) and summarized as the mean equivalent area of 100% mortality (i.e., under average environmental conditions). The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the medium volume North Texas Shelf spills are in Appendix C-II.5, Table C-II.5.2. The equivalent areas of 100% mortality for all response options are summarized in Table C.3.2.3-1 as percentages of the North Texas Shelf (defined in Tables A.4-4 and A.4-5 of Part A). The sensitivity of sea turtles is assumed to be the same as that for pinnipeds and manatees, and the area of equivalent mortality never exceeds 0.001% of the total reference area, regardless of the response option (see Table C.3.2.3-1). In addition, the total area of shoreline oiled greater than 10 g/m^2, as well as the area of seaward sand beaches oiled was compared to the respective total shoreline habitat. With on-water mechanical recovery, approximately 15 km (9.3 mi) of shoreline was oiled above the threshold, including approximately 9 km (5.6 mi) of sand beach. While this is less than 1% of the total shoreline length, the oiling of sand beaches does exceed one percent of the available resource, but is less than 5% (see Table A.4-6). If dispersants are used at 45% efficiency the lengths oiled reduce to approximately 7 and 4 km (4.3 and 2.5 mi), which means the seaward sand beach is only slightly more than 1%. Dispersant use at 80% efficiency reduces both values even more, to approximately 1%.

Results of On-Water Mechanical Recovery Only
Under the medium volume scenario with only on-water mechanical recovery, the area of equivalent mortality is 0.001% of the total reference area. If an individual were to be oiled at sea, however, the result would probably be only minor physiological effects but it is conceivable that it could interfere with reproductive capacity. The greater risk would be from oiling a nesting beach. The risk to specific nesting beaches depends on many factors, especially the time of year, and cannot be specifically identified by the model; however, the length of sand beaches oiled was between 1 and 5% of the reference area. If an adult turtle was affected physiologically at sea, or if a nesting beach were oiled when eggs or hatchlings were present, recovery of the population could require 1 to 3 years, thus a risk ranking of **3D** was assigned.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and the 45% efficiency dispersant option the area of equivalent mortality is slightly reduced in absolute area, and is still very small relative to the reference areas. However, the use of dispersants would reduce the risk of oiling to sand beaches, including nesting beaches. The model estimate of the average oiling is approximately equal to one percent of the length of seaward sand beaches, but the recovery time would remain unchanged and so the risk score is reduced to **3E**. There is no evidence that sea turtles are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality and the length of shoreline oiling are slightly less than those for the 45% option, thus the risk score remains unchanged.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in addition to mechanical recovery should not change the effects on sea turtles (**3D**), since the amount of floating oil and shoreline oiling remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to sea turtles.

Summary of the Consequences for Sea Turtles in the Medium Volume Scenarios
The results indicate that on average for medium volume spills in the North Texas Shelf there would be a moderate level of concern for sea turtles with on-water mechanical recovery only. The primary threat is the oiling of nesting beaches. Because of their protected status, special precautions would be taken to protect such areas, and the actual impacts would therefore be reduced. Dispersant use would potentially reduce the possibility of turtles coming into contact with floating oil, but the greater benefit is the reduction in shoreline oiling. This results in lowering the level of concern from moderate to low.

C.3.2.5 Plankton and Fish

Adverse effects on plankton and fish are of high concern, particularly when dispersants are potentially considered as a response alternative. As described in Part A (Section A.2), plankton and fish are adversely affected either directly or via the food web by the toxic effects of oil components that enter the water column: the soluble compounds (i.e., MAHs (mono aromatic hydrocarbons) and PAHs (polynuclear aromatic hydrocarbons)) and microscopic oil droplets mixed by waves into the water. Overall, adverse effects increase the larger the spill size. However, there is great variability related to the environmental conditions after the spill: plankton and fish suffer much more adverse effects under storm conditions where high waves mix unweathered oil into the water than in calm weather (French et al., 1999; French McCay et al., 2002; French McCay, 2003). Species and life stages vary considerably in sensitivity to the toxic components, with species from relatively unpolluted and environmentally stable locations more sensitive than those from polluted and environmentally variable areas (French McCay, 2002).

Potential adverse effects on water column organisms (i.e., plankton and fish, as well as pelagic invertebrates such as squid) were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. Estimated water volumes where adverse impacts could occur were converted to equivalent areas of 100% loss by integrating percentage losses over all affected volumes and multiplying by water depth at the spill site, allowing comparison to other resources that are distributed on a per area basis (e.g., mammals and shorelines). In the near shore areas modeled, effects were nearly evenly distributed throughout the water column because of water column mixing and vertical movements of animals. If these results are used to infer potential for adverse effects in deeper waters, the areas of effect would only apply to surface waters up to on the order of 30-50 m (98-164 ft) deep (during strong wind conditions). The modeling methods are described in Part A and Section C-II.6, and the results of the calculations for the medium volume North Texas Shelf spills are in C-II.6, Tables C-II.6-2 to C-II.6-5.

For these calculations, the toxicity parameter for sensitive species (i.e., two standard deviations more sensitive than the average of all species tested, which is the 2.5th percentile in rank order of sensitivity) was assumed. Thus, the volumes and areas potentially affected would only apply to 2.5% of species (based on a Gaussian distribution of species sensitivities, see also Part A, Section A.2.3), and adverse effect areas to 97.5% of species would be smaller than the volumes and areas of effect estimated by the model. Thus the model estimated areas should not be interpreted as experiencing 100% mortality of all plankton and fish. They are conservative estimates used for comparative purposes among response scenarios.

Table C-II.6-2 lists the average equivalent areas projected to be killed (for sensitive species) for medium volume spills. These areas are based on the mean of all 100 runs, and so represent an average of all environmental conditions that may occur after a spill (see explanation in Section C-II.6). Table C-II.6-4 lists the 95th percentile equivalent areas where sensitive species would be adversely affected. This maximum potential effect is calculated as the mean plus two standard deviations, using the statistics of all 100 model runs for the scenario, and assuming the toxicity values for sensitive species.

The mean areas adversely affected for all response options are summarized in Table C.3.2.5-1 as percentages of the North Texas Shelf (defined in Table A.4-4 of Part A). The maximum areas (95th percentile) for sensitive species are summarized in Table C.3.2.5-2 (also as percentages of the North Texas Shelf).

Table C.3.2.5-1. Average percentage of reference area adversely affected for medium spills, by dispersant option and behavior group (assuming North Texas Shelf area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.00	0.020	0.021
Small pelagic fish & invertebrates	0.00	0.034	0.035
Large pelagic fish	0.00	0.039	0.041
Demersal (stationary on bottom)	0.00	0.022	0.023
Planktonic (drift with currents)	0.00	0.033	0.035

Table C.3.2.5-2. Maximum (95th percentile) percentage of reference area adversely affected for medium spills, by dispersant option and behavior group (assuming North Texas Shelf area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.03	0.11	0.13
Small pelagic fish & invertebrates	0.05	0.22	0.24
Large pelagic fish	0.07	0.36	0.39
Demersal (stationary on bottom)	0.03	0.11	0.12
Planktonic (drift with currents)	0.05	0.22	0.24

Results of On-Water Mechanical Recovery Only
Under the medium volume spill scenario and no dispersant response option, the area adversely affected would be negligible (<0.001% of the North Texas Shelf) for spills under average environmental conditions. For 5% of spills, the area affected would be 0.03-0.07% of the North Texas Shelf, depending on the behavioral group of the organism. Because the adverse effects are very small, much less than the range of natural variability, the recovery time would be <1 year (given the short generation time of many species and annual reproduction of others). Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45% dispersant efficiency response option, the area adversely affected would be 0.02-0.04% of the North Texas Shelf for spills under average environmental conditions. For 5% of spills, the area affected would be 0.1-0.4% of the North Texas Shelf, depending on the behavioral group of the organism. Because the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80% dispersant efficiency response option, the area

adversely affected would be 0.02-0.04% of the North Texas Shelf for spills under average environmental conditions. For 5% of spills, the area affected would be 0.1-0.4% of the North Texas Shelf, depending on the behavioral group of the organism. These results are not very different from the low-efficiency dispersant response because approximately the same amount of oil is dispersed in either case (i.e., more than sufficient dispersant is available to disperse available oil for such activity in the low efficiency case). Since the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario, if ISB is effectively used in the response, the adverse effects on water column organisms would be slightly less than otherwise by the amount removed by burning. Thus, the percent of the resource affected is <1% for on-water mechanical and both dispersant response scenarios when ISB is included. Since the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Summary of the Consequences for Plankton and Fish in the Medium Volume Scenarios
The results indicate that on average for medium volume spills, adverse water column effects would be negligible without the use of dispersants. With dispersants, and on average, up to 16 km^2 (6.2 mi^2) of water could be toxic to the most sensitive species (Table C-II.6-2). Exposure for larger fish is higher because they are more mobile, and new animals move into the dissolved aromatic plume over time (assuming they do not avoid hydrocarbon contamination). Under worst case conditions for sensitive species, the potentially affected areas for no dispersants and dispersant use are on the order of 30 and 150 km^2 (12 and 58 mi^2), respectively (Table C-II.6-4). Thus, the extreme event assuming no dispersant use affects more area than the average area affected with dispersant use. In other words, use of dispersants would not turn an average spill into an extremely adverse event for water column organisms. The increase in water column effect is smaller than natural variability for spill effects.

It should be emphasized that the areas affected are those where there is a potential to affect the most sensitive species. Areas adversely affected would be much less for species of average sensitivity. These areas should not be interpreted as experiencing 100% mortality. They are used for comparative purposes among response scenarios.

The mean areas adversely affected for all response options are <0.05% of the North Texas Shelf (Table C.3.2.5-1). Thus, the risk scores for these effects are "**E**" (<1%, Table C.3.2.5-3). The maximum areas (95^{th} percentile) for sensitive species are also <1% of the North Texas Shelf (Table C.3.2.5-2). Because the effects are small, much less than the range of natural variability, the recovery time would be <1 year.

These results are consistent with experience for oil spills of about 2500 bbl generally (French McCay and Payne, 2001; French McCay et al., 2002; and as discussed in Part A). In the Gulf of Mexico in particular, the high temperatures facilitate rapid evaporation and volatilization of the toxic fraction, the soluble aromatics. Also, winds are typically light to moderate, except in infrequent storm events. Thus, natural dispersion into the water is typically low, while evaporation is rapid. Because of logistical constraints, in the scenarios examined the dispersion by chemical dispersants occurred beginning at 12 hours after the spill. By this time, most of the toxic components have volatilized (see Section C.3.1), such that dissolved aromatic concentrations resulting from dispersant use are only slightly elevated over the no-dispersant option. The adversely affected water column would be a small area around the spill site, and recovery of affected biota would be rapid (weeks to months).

Table C.3.2.5-3. Risk scores for plankton and fish for medium spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

C.3.2.6 Subtidal Benthic Habitat

In deeper water, subtidal habitats are relatively protected from exposure to oil by the overlying water column. It is possible for extreme storm events to mix oil with sediments which then settle to the bottom, but this is a rare event. The use of dispersants can also transport oil into the water column, but dilution usually reduces concentrations to levels that are not of a concern when the water column is more than 30 feet deep, and in any case dispersed oil is less adhesive than untreated oil. In shallow, near shore water, the risk of contamination of the sediments increases, and may either occur by mixing into the water column due to wave action, or to erosion of contaminated shoreline sediments (Section 4.3.2.5 of the PEIS).

Benthic habitat was assumed to be at risk when a threshold of 0.10 g/m^2 of total hydrocarbon loading was exceeded in the sediment or 0.0001 g/m^2 of dissolved aromatic hydrocarbons was exceeded in the pore water (see Section A.4 of Part A). These concentrations are approximately equivalent to 1 ppm of total hydrocarbons or 1 ppb of dissolved aromatic hydrocarbons, when a sediment mixing depth of 10 cm is assumed. The area was estimated using SIMAP and the modeling methods are described in Part A. The area estimates of sediment loading for the medium volume North Texas Shelf spills are presented in Table C-II.6.6. The area estimates for dissolved aromatic hydrocarbons in sediment pore water are in Table C-II.6.7. Regardless of the treatment option, the sediment thresholds were not exceeded under average conditions.

Benthic habitat was also assumed to be at risk if epiflora and epifauna (demersal) organisms were affected by dissolved aromatic concentrations in the bottom water just above the sediments. The percentage of benthic habitat where stationary demersal biota would be affected, assuming the toxicity parameter for sensitive species (i.e., two standard deviations more sensitive than the average of all species tested), was estimated using SIMAP and the modeling methods described in Part A and Section C.II.6.

Results of On-Water Mechanical Recovery Only
In the on-water mechanical recovery only option for the medium volume spill scenario, the model results indicate that the sediment threshold concentrations were never exceeded. As indicated in Table C.3.2.5-1, <0.001% of the reference area was affected by bottom water concentrations when no dispersants were assumed used. Thus there is no expected effect on the benthic habitat, and the risk ranking is **4E**.

Results of the Addition of a Dispersant Response at Low Efficiency
Use of a dispersant at 45% efficiency in the medium spill scenario still does not result in measurable hydrocarbon contamination in subtidal habitat sediments. As indicated in Table C.3.2.5-1, 0.022% of the reference area was affected by bottom water concentrations when dispersants were assumed used at low efficiency. Thus, the risk score remains at **4E**.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and the 80% efficiency dispersant option, sediments still do not accumulate hydrocarbons in excess of the threshold levels. As indicated in Table C.3.2.5-1, 0.023% of the reference area was affected by bottom water concentrations when dispersants were assumed used at high efficiency. Thus, the risk ranking remains at **4E**.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in the medium spill scenario should have no additional effect when combined with mechanical recovery on benthic habitats, since ISB takes place on the water's surface and results in the removal of an equivalent amount of oil (**4E**). The only concern associated with ISB is the chance of heavy burn residues sinking and mixing with sediments, but this risk is minimal based on both the toxicity of the material and on the amount that would be produced from the limited burning possible in the scenarios.

Summary of the Consequences for Subtidal Habitat in the Medium Spill Scenarios
Oil spills and oil-spill response activities could potentially affect benthic habitats. Floating oil does not pose a great level of concern unless sufficient wave energy exists to mix the surface oil into the water column, or sediments contaminated with oil are transported from the intertidal zone into subtidal habitats. Mechanically dispersed oil could reach bottom water and adhere to sediments, flora and fauna in benthic habitats, and could cause potentially adverse effects. However, in this simulation, essentially no hydrocarbon exposure is expected on or in the sediments, even near shore. Given the limited length of shoreline oiled, regardless of response option, the small spill volume, the distance of the spill offshore, and the relatively deep water in the area of dispersant operations dispersant use would not change the results. Regardless of the response option, the risk to benthic habitat is low.

C.3.2.7 Biological Areas of Special Concern

The North Texas Shelf has numerous areas of special concern (Section 3.4.2.6 of the PEIS). They include both coastal and subtidal areas, and a number are susceptible to the effects of an oil spill. The risk to such areas is clearly site specific and highly dependant upon the location and trajectory of the slick. In general, the greatest risk to the majority of the areas of concern is from floating oil, but areas such as marine sanctuaries (for example, the Flower Garden Banks) are at risk from dispersed oil. For the purposes of this evaluation, the average risk to such areas is assumed to be defined by the higher of the risks to intertidal (Section C.3.2.1) or subtidal (Section C.3.2.6) habitats, adjusted for the type, abundance and distribution of areas of special concern, if appropriate. Details on the development of those scores are provided in those sections. For the medium spill scenarios, the risk to subtidal habitat was always **4E** regardless of response option, and so the larger risk is always associated with the risk to shoreline habitats of special concern

Results of On-Water Mechanical Recovery Only

For the on-water mechanical response option under the medium spill scenario, floating oil poses a moderate risk (**3D**) to intertidal habitat, while subtidal habitat was at minimal risk (**4E**). The area affected was almost exactly 1% of the shoreline length available in the Galveston Bay, but was much less than one percent of the total shoreline length. Since areas of special concern occur along the entire shoreline, the percentage potentially affected is assumed to be less than one percent and so the intertidal score is conservative. There is no reason, however, to assume areas of special concern would recover more quickly, so the risk score of **3D** is used.

Results of the Addition of a Dispersant Response at Low Efficiency

The use of dispersants at 45% efficiency in the medium spill scenario reduced the risk to intertidal habitat by reducing the amount of surface oil which reaches shore. The fact that the oiling would be very light and mostly restricted to sand beaches means recovery should be fairly rapid, resulting in a risk score of **3E** (see Section C.3.2.1). The risk to subtidal habitats does not increase (**4E**), because of the limited extent of the dispersed oil plume and rapid dilution, and so the intertidal score of 3E is used.

Results of the Addition of a Dispersant Response at High Efficiency

The use of dispersants at an efficiency of 80% in the medium spill scenario does not change the scores from the application at 45% efficiency, based on the minimal additional reduction in shoreline oiling. The risk to subtidal habitats does not increase (**4E**), because of the limited extent of the dispersed oil plume and rapid dilution, and the higher efficiency was not more protective of the shoreline (3E), so the higher intertidal score is used.

Results of the Addition of an On-Water ISB Response

ISB should produce a black smoke plume that could pass over an area of special concern if the proper weather conditions exist. In this case, however, the burning can only occur three miles or more offshore, and the results for air quality (Section C.3.1.1) indicate that the plume should not travel that far. The use of ISB in addition to on-water mechanical recovery is not expected to change the risk to these resources (**3D**).

Summary of the Consequences for Areas of Special Concern in the Medium Volume Scenarios
The effects on areas of special concern in this scenario are focused on the potential risk to shoreline habitats. The use of dispersants can reduce the risk to such areas without increasing the minimal risk to subtidal areas. In this analysis the risk to such areas is probably slightly less than the risk to Intertidal habitat in general. While this accurately reflects the ecological consequences of the event, it does not account for the social values which may be attached to such areas. If the spill trajectory of an actual event did threaten such areas, special attention would be given to their protection.

C.3.2.8 Essential Fish Habitat

Areas of essential fish habitat are extensive in the North Texas Shelf (Section 3.4.4 of the PEIS). Included as EFH areas are all estuarine and marine waters and substrates from the shoreline to the seaward limit of the Exclusive Economic Zone (EEZ). In the entire Gulf of Mexico Region, approximately 28 species of finfish and shellfish are managed under the Magnuson-Stevens Fishery Conservation and Management Act.

For this evaluation, the effects on essential fish habitat are assumed to be reflected by the risk to plankton and fish (Section C.3.2.5) and subtidal habitat (Section C.3.2.6), since they define the risk to the majority of fish habitat. Intertidal habitats, such as marshes, are also important habitat for fisheries resources, but were considered separately. The average risk to essential fish habitat is assumed to be defined by the higher of the risk scores for plankton and fish (Section C.3.2.5) or subtidal habitat (Section C.3.2.6). Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
In the medium spill scenario, with the use of on-water mechanical recovery only, the risk to both plankton and fish and subtidal habitat was minimal, resulting in a risk score for both habitats of **4E**. This is a reflection of the relatively small volume of oil, the large volume of water for dilution, and the areal extent of the habitats.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency did not change the risk score for either plankton or fish or for subtidal habitat, and the scores remained **4E**. The dispersed oil plume produced was not large enough to have any effect on the exposure levels for these resources. However, dispersant use did reduce effects on intertidal habitat, which includes areas that are also important for fisheries resources and EFH.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at 80% efficiency in the medium spill scenario resulted in no change to the risk to plankton and fish or subtidal habitat, and the score remains **4E**. Again, dispersant use does benefit intertidal habitat, some of which is also important to EFH.

Results of the Addition of an On-Water ISB Response

The addition of ISB to mechanical recovery in the medium spill scenario did not change the evaluation for either plankton or fish or for subtidal habitat, and the score remains **4E**.

Summary of the Consequences for Essential Fish Habitats in the Medium Volume Scenario
Overall, the risk to essential fish habitat is low for the medium spill scenario, regardless of the response option employed. This is a reflection of the relatively small area of the spill, the volume and depth of water available for dilution, and the large area of habitat present in the area.

C.3.3 Effects on the Socio-Economic Environment

C.3.3.1 Human Health

Operation of the type of equipment associated with oil spill response can be dangerous. This is well recognized and is the basis for the worker certification and training requirements that are now in place. There are also protocols in place for the proper application and handling of dispersants. The safety risk is greater as the spill size, and thus the intensity and duration of operations increases, but is minimized if safety standards are followed. There is a health risk from inhalation of hydrocarbon fumes for first responders, which is recognized in current safety protocols. Exposure to hydrocarbon fumes is the only health risk that can be directly estimated in the SIMAP model, and the results are presented in Section C.3.1.1.

C.3.3.2 Subsistence

Information on subsistence use of fish and shellfish in the North Texas Shelf is limited. While some residents may supplement their diets with these resources, subsistence is not known to be a prominent activity in this area, as compared to Alaska, where Native communities may suffer substantial economic and cultural losses due to contamination of subsistence seafood during an oil spill.

Results of Mechanical Recovery Only
Under the medium volume spill scenario and no dispersant response option, water column exposure of dissolved aromatics between 1-100 pbb should be localized to directly outside Galveston Bay (Figure C-II.1.1.4-3). Tainting of fish and invertebrates becomes a concern when water concentrations exceed approximately 100 ppb in a brief (order of hours) exposure (See Section 4.3.5.6 of the PEIS). Sediment exposure is expected to be negligible (Figure C-II.1.1.5-2). A very small percentage (<1%) of shoreline habitats in the reference area would be oiled, therefore a proportionally small percentage of subsistence resources associated with these habitats are likely to be exposed (Section C.3.2.1. Intertidal Habitats). Therefore, at most a very small percentage of subsistence resources are likely to be adversely affected, and recovery should be rapid (<1 year). A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and low efficiency dispersant response option, water column exposure of dissolved aromatics between 1-100 pbb for one hour or more would cover a larger area outside and within Galveston Bay than when no dispersants were used, and dissolved

aromatic concentrations between 100-10,000 ppb would occur in localized areas (Figure C-II.1.2.4-3). Sediment exposure is expected to be negligible (Figure C-II.1.2.5-2), and oiling of shoreline and intertidal organisms would be reduced. Although a larger water column area may be affected under these spill conditions, it is still likely that only a small percentage of subsistence resources would be adversely affected, and recovery should be rapid. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and high efficiency dispersant response option, water column exposure of dissolved aromatics between 1-100 pbb would cover a larger area outside and within Galveston Bay than when no dispersants were used, and dissolved aromatic concentrations between 100-10,000 ppb would occur in localized areas (Figure C-II.1.3.4-3). Sediment exposure is expected to be negligible (Figure C-II.1.3.5-2), and oiling of shoreline and intertidal organisms would be reduced. These estimations are similar to when low efficiency dispersants were used, and therefore it is still likely that only a small percentage of subsistence resources would be adversely affected, and recovery should be rapid. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, adverse impacts to subsistence resources would be similar to the on-water mechanical recovery only response option. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Summary of the Consequences for Subsistence in the Medium Volume Scenarios
Because subsistence use of resources is not a predominant activity in this area, and because water column impacts should be localized and shoreline impacts are minor, a risk matrix ranking of **4E** was assigned to subsistence resources for all of the response options.

C.3.3.3 Cultural Resources

In the Gulf of Mexico Region, archaeological sites are potentially present along the shoreline and buried in the sediments, particularly along barrier islands and back barrier embayments, river channels, floodplains, and terraces (Section 3.4.5.6 of the PEIS). Results from several studies indicated that direct oiling caused negligible impacts to cultural resources following the Exxon Valdez oil spill (Reger et al., 1992; Dekin, 1993; Wooley and Haggarty, 1995; Bittner, 1996). Other prehistoric resources are located 3-9 miles offshore in deep water benthic habitats and submerged shipwrecks are located near the continental shelf. These resources are not at risk of oiling due to depth. Therefore, open water response options, such as the use of dispersants, ISB, and on-water mechanical recovery, may help reduce the amount of oil that strands on the shoreline, which would also reduce the amount of shoreline clean up and disturbance of sensitive cultural resources. For these reasons, a risk matrix ranking of **4E** was assigned to cultural resources for all response options under this scenario.

C.3.3.4 Coastal Communities

Oil spills affect the pleasure that coastal residents and visitors derive from coastal activities and the economic contribution that natural resources make to local income and employment. Spills are likely to have effects on water- and shore-based recreation, fisheries (recreational and commercial), marine transportation and tourism. The effects on these activities are described in more detail in subsequent sections.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to coastal communities in the North Texas Shelf under various spill response options. The model results are presented in Appendix C-II.2, Tables C-II.2-1 to C-II.2-3, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to coastal communities of response options other than on-water mechanical recovery.

Results of Mechanical Recovery Only

Given the use of on-water mechanical recovery only, the average medium size spill in the North Texas Shelf would be expected to adversely affect approximately 9.4 km (35.8 mi) of sandy shoreline and sweep approximately 338 km^2 (130.5 mi^2) of surface water above recognized effect thresholds (Table C-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency

Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by more than 55 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by almost 65 percent (Table C-II.2-2). This results in risk factor ratings of 0.44 and 0.36 (effected length or area with dispersants divided by that for mechanical only) for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 20 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by approximately 30 percent as compared to the low efficiency dispersant response option (Table C-II.2-3). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.35 and 0.25, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on coastal communities would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to coastal communities for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Coastal Communities in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 3.3 to 4.1 km (2.1 to 2.6 mi) of sandy shoreline and 85 to 120 km^2 (32.8 to 46.3 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 56 to 65 percent and 64 to 75 percent, respectively, the dispersant efficiency does not greatly affect the level of concern about coastal communities in this spill scenario.

C.3.3.5 Economic Status

The overall economic status of communities, industries and individuals that rely on coastal resources for sustenance, revenue and quality of life can be affected by an oil spill. As noted above, coastal communities can suffer direct and indirect economic effects due to an oil spill, as beach and fishery closures decrease revenues, eliminate jobs, and adversely affect subsistence users of the resources.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds in Galveston Bay is used to represent the risk of socioeconomic effects to economic status in the North Texas Shelf under various spill response options. The model results are presented in Appendix C-II.2, Tables C-II.2-1 to C-II.2-3, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to economic status of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the North Texas Shelf could be expected to adversely impact approximately 9.4 km (5.8 mi) of sandy shoreline and sweep approximately 338 km^2 (130.5 mi^2) of surface water above recognized effect thresholds (Table C-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by more than 55 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by almost 65 percent (Table C-II.2-2). This results in risk factor ratings of 0.44 and 0.36 for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 20 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by approximately 30 percent compared to the low dispersant efficiency option (Table C-II.2-3). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.35 and 0.25, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on economic status would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to economic status for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Economic Status in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 3.3 to 4.1 km (2.1 to2.6 mi) of sandy shoreline and 85 to 120 km^2 (32.8 to 46.3 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 56 to 65 percent and 64 to 75 percent, respectively, the level of dispersant efficiency does not greatly affect the level of concern about economic status in this spill scenario.

C.3.3.6 Vessel Transportation and Ports

Marine transportation is of paramount importance for many industries along the Gulf Coast. Any interruption in the standard use of vessels or increase in travel times over water can result in hardship for coastal communities and businesses as fewer goods are exchanged, transportation costs rise, and the revenue streaming through the local economy falls.

As described in Part A., the amount of total surface water oiled above selected thresholds in Galveston Bay is used to represent the risk of socioeconomic effects to marine transportation and ports in the North Texas Shelf under various response options. The model results are presented in Appendix C-II.2, Tables C-II.2-1 to C-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to the marine transportation industry of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the North Texas Shelf would be expected to adversely affect approximately 338 km^2 (130.5 $mi^{2)}$of surface

water used by the marine transportation industry above recognized effect thresholds (Table C-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by almost 65 percent as compared to on-water mechanical recovery alone (Table C-II.2-2). This results in a risk factor rating of 0.36 for the marine transportation industry under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 30 percent as compared to the low dispersant efficiency response option (Table C-II.2-3). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for the marine transportation industry decreases to 0.25 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on the marine transportation industry would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to the marine transportation industry for this scenario.

Summary of the Consequences for Vessel Transportation and Ports in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 85 to 120 km^2 (32.8 to46.3 mi^2) of surface water. While the use of dispersants is projected to likely lessen the area of surface water affect by approximately 64 to 75 percent, the level of dispersant efficiency does not greatly affect the level of concern about vessel transportation and ports in this spill scenario.

C.3.3.7 Fisheries (Commercial and Recreational)

Commercial and recreational fishing and related industries are vulnerable to oil spills, due to closures as well as market perceptions surrounding taint of the catch. In addition, recreational anglers, who fish for pleasure or sport, as opposed to monetary gain, may experience a reduced quality of experience. Large-scale spills also hold the potential to injure nursery grounds and impose other effects that could reduce fish harvests in the longer run.

As described in Part A., the amount of total surface water oiled above selected thresholds in Galveston Bay is used to represent the risk of socioeconomic effects to commercial and recreational fishing in the North Texas Shelf under various response options. The model results are presented in Appendix C-II.2, Tables C-II.2-1 to C-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to commercial and recreational fishing of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the North Texas Shelf would be expected to adversely affect approximately 338 km^2 (130.5 mi^2) of surface water used for commercial and recreational fishing above recognized effect thresholds (Table C-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by almost 65 percent as compared to on-water mechanical recovery alone (Table C-II.2-2). This results in a risk factor rating of 0.36 for commercial and recreational fishing under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 30 percent as compared to the low dispersant efficiency response option (Table C-II.2-3). Because the adverse effects on surface water resources is less with higher dispersant efficiency, the risk factor rating for commercial and recreational fishing decreases to 0.25 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on commercial and recreational fishing would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to commercial and recreational fishing for this scenario.

Summary of the Consequences for Commercial and Recreational Fishing in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 85 to 120 km^2 (32.8 to 46.3 mi^2) of surface water. While the use of dispersants is projected to likely lessen the area of surface water impacted by approximately 64 to 75 percent, the level of dispersant efficiency does not greatly affect the level of concern about commercial and recreational fishing in this spill scenario.

C.3.3.8 Recreation and Tourism

An oil spill would be expected to cause local decreases in tourism, recreation, associated business revenues and the quality of coastal living. Similar to recreational fishing effects, an oil spill would also be expected to affect recreationalists' overall social welfare.

As described in Part A, the amount of total sandy shoreline oiled above selected thresholds in Galveston Bay is used to represent the risk of socioeconomic effects to recreation and tourism in the North Texas Shelf under various spill response options. The model results are presented in Appendix C-II.2, Tables C-II.2-1 to C-II.2-3, and are based on an effects threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns). From the model results, risk is then expressed in terms of the length of shoreline affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to recreation and tourism of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the North Texas Shelf could be expected to adversely effect approximately 9.4 km (5.8 mi) of sandy shoreline used for recreation and tourism above recognized effect thresholds (Table C-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by more than 55 percent as compared to on-water mechanical recovery alone (Table C-II.2-2). This results in a risk factor rating of 0.44 for recreation and tourism under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 20 percent as compared to the low dispersant efficiency response option (Table C-II.2-3). Because the adverse effect on sandy shoreline resources is less with higher dispersant efficiency, the risk factor rating for recreation and tourism decreases to 0.35 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on recreation and tourism would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to recreation and tourism for this scenario.

Summary of the Consequences for Recreation and Tourism in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 3.3 to 4.1 km (2.1 to 2.6 mi) of sandy shoreline. While the use of dispersants is projected to likely lessen the length of sandy shoreline affected by approximately 56 to 65 percent, the level of dispersant efficiency does not greatly affect the level of concern about recreation and tourism in this spill scenario.

C.3.3.9 Environmental Justice

Low-income, indigenous, and minority sub populations in some coastal areas may rely on regional fisheries for subsistence or on tourism, recreation or other marine-resource related industry for employment. These groups may experience the effects of a spill more severely than the general population, which relies on a more diverse economic base for their livelihoods and on the availability of a widespread and commercially available selection of foods.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds in Galveston Bay is used to represent the risk of socioeconomic effects to environmental justice in the North Texas Shelf under various spill response options. The model results are presented in Appendix C-II.2, Tables C-II.2-1 to C-II.2-3, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to environmental justice of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the North Texas Shelf would be expected to adversely affect approximately 9.4 km (5.8 mi) of sandy shoreline and sweep approximately 338 km^2 (130.5 mi^2)of surface water above recognized effect thresholds (Table C-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by more than 55 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by almost 65 percent (Table C-II.2-2). This results in risk factor ratings of 0.44 and 0.36 for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 20 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by approximately 30 percent as compared to the low dispersant efficiency response option (Table C-II.2-3). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.35 and 0.25, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on environmental justice would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to environmental justice for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Environmental Justice in the Medium Volume Scenarios

Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 3.3 to 4.1 km (2.1 to 2.6 mi) of sandy shoreline and 85 to 120 km^2 (32.8 to 46.3 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 56 to 65 percent and 64 to 75 percent, respectively, the level of dispersant efficiency does not greatly affect the level of concern about environmental justice in this spill scenario.

C.4 ENVIRONMENTAL CONSEQUENCES BASED ON THE LARGE VOLUME SPILL MODELING SCENARIOS

C.4.1 Effects on the Physical Environment

C.4.1.1 Air Quality

There are two possible sources of contamination to the atmosphere: volatilization of hydrocarbons from unburned oil and emissions produced by ISB (ISB), both of which are of concern for both human health and wildlife that may be exposed. Concentrations in the lowest 2 m (6.6 ft) of the atmosphere, as well as distances to and areas above thresholds of concern, were estimated for both unburned and burned oil. The thresholds of concern are air quality standards for human health (IDLH for ½ hour exposure and minimum TWA for an 8-hour exposure, Table D.1-1 of Appendix D of the PEIS and Table A.5-5 in Part A). The area potentially contaminated was divided by the area of the North Texas Shelf (39,602 km^2 or 15,290 mi^2, Table A.4-4) to estimate a percentage of the region affected by the scenario. Appendices C-III.1.2 and C-III.2.2 provide data for unburned and burned oil, respectively, from large volume (40,000 bbl) spills into the North Texas Shelf.

Results of On-Water Mechanical Recovery Only

Under the large volume spill scenario with no dispersant response, volatilized hydrocarbons would not exceed air quality standards for human health at $\geq$7.4 km (4.6 mi) from the spill site, with a maximum of 3.4 km^2 (1.3 mi^2) adversely affected. While this would be of concern for personnel close to the spill site within the first few hours after emissions are released, it is a very small percentage of the area of the North Texas Shelf. Evaporation and dispersion in the air would be very rapid after a spill, and recovery time would be less than 1 day. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency

For the large volume spill scenario with 45% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

For the large volume spill scenario with 80% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would also be similar or slightly less than for on-water

mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, the worst case for air quality would result from the 95th percentile of volume burned (estimated as 25% of the mechanically-removed oil) for the no-dispersant scenario. The volume to be burned in this case would require nine large burns, each 500 m^2 (5381 ft^2) in area. The 50th percentile burn volume would require six large burns, each 500 m^2 in area. If dispersant is used, the amount burned would be less, requiring fewer burns (See Appendix C-III.2.2).

Air quality would be affected up to 710 m (2,329 ft) downwind of *each* burn site, assuming a stable atmosphere and light wind at the time of the burning. Accounting for the worst case of 9 burns in different locations, the area potentially affected is a 14.25 km^2 (5.5 mi^2) area. This represents 0.036% of the North Texas Shelf. Thus, the percent of the resource affected is <1%. The recovery time for the atmosphere after ISB would be on the order of hours. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Summary of the Consequences for Air Quality in the Large Volume Scenarios
The consequences of the three response options for large spills (1) on-water mechanical recovery only, (2) on-water mechanical recovery plus dispersants at 45% efficiency, and (3) on-water mechanical recovery plus dispersants at 80% efficiency are the same with respect to air quality. Evaporation off the water surface and volatilization from the water column creates a plume of volatile hydrocarbon gases that disperses quickly after a spill. For the large volume spill, the concentrations in the atmosphere at the water surface would exceed human health thresholds of concern at a maximum of 7.4 km (4.6 mi) from the spill site. Dispersant use would reduce the evaporation rate, but dissolved hydrocarbons would still volatilize, although dispersed over a wider area. Thus, atmospheric concentrations would be somewhat less under the dispersant use options. In all three options for the large spill, the effect would be small, affecting much less than 1% of the region of interest (i.e., the North Texas Shelf in Table A.4-4), and the recovery time for the atmosphere would be on the order of hours.

The alternatives involving on-water mechanical recovery plus ISB (whether or not dispersants are used) should increase atmospheric pollutants by the amount injected via burning. The maximum area potentially affected is 14.25 km^2 (5.5 mi^2). However, this represents much less than 1% of the North Texas Shelf.

Table C.4.1.1-1 indicates risk scores for air quality for all response options for a large volume spill. Both the area impacted and the recovery times are assigned the lowest risk score for all the response options. These results would apply to any spill site at least 3 miles from shore.

Table C.4.1.1-1. Air quality risk scores for large spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)

On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB, With or Without Dispersant Application	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

C.4.1.2 Water Quality

The lowest water quality thresholds of concern are those concentrations of dissolved aromatics that could have effects on sensitive species in the water (see Section 4.3.1.1 of the PEIS). These thresholds are much lower than human health thresholds. The threshold for effects on water column organisms would be 5 ppb for at least 4 days of exposure. As an exposure dose, the threshold would be 500 ppb-hours. (See Part A, section A.3.4 for development of these thresholds.)

Table C.4.1.2-1 summarizes the mean and 95th percentile values of the water volume affected by >1 ppb for at least 1 hour and the average exposure dose in that volume of water. These data are the mean and the mean plus 2 standard deviations of the model results for all 100 runs performed for each scenario (Appendix C-II.2). The average exposure doses in the volumes are at or greater than the 500 ppb-hour threshold.

The percentages affected of total water volumes in coastal and marine area of interest were calculated using the biogeographical province areas in Table s A.4-3 and A.4-4 for Galveston Bay (coastal) and the North Texas Shelf (marine). The total coastal volume was the area of Galveston Bay times a mean depth of 2 m (6.6 ft). In this calculation it is assumed that the entire contaminated volume would be located in the coastal reference area (Galveston Bay) after a spill, a worst case assumption for a spill in that estuary. The total marine volume was the area of the entire reference area times the depth at the spill site, 10 m (33 ft). Thus, only the surface water volume was considered in the marine estimation. Risk scores for potential effects were assigned for each of coastal and marine areas.

Table C.4.1.2-1. Estimation of adverse effects on water quality for large volume spills by dispersant scenario, based on mean and 95th percentile water volumes exceeding 1 ppb dissolved aromatic concentration.

Dispersant % Efficiency	0	45	80

Volume (millions of m^3) Exposed to >1 ppb	mean	373.1	642.1	719.4
	95th	984.2	1472.	1637.
Average ppb-hrs in Volume	mean	1632	3734	4948
	95th	3652	7794	11190
Percent of Reference Area, coastal	mean	10.4	18.0	20.1
	95th	27.6	41.2	45.8
Percent of Reference Area, marine	mean	0.09	0.16	0.18
	95th	0.25	0.37	0.41

Results of On-Water Mechanical Recovery Only

For the large volume spill scenario in Galveston Bay and no dispersant response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 10.4% on average. For 5% of spills, the percentage affected would exceed 27% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days to weeks, the time for concentrations to disperse to background levels. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions. For coastal spills under average conditions, the risk score is **4B**. Extreme (95^{th} percentile) events, expected to occur for <5% of spills in coastal areas, were assigned a risk matrix ranking of **4A**.

Results of the Addition of a Dispersant Response at Low Efficiency

For the large volume spill scenario and 45% dispersant efficiency response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 18% on average. For 5% of spills, the percentage affected would exceed 41% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days to weeks, the time for concentrations to disperse to background levels. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions. For coastal spills under average conditions, the risk score is **4B**. Extreme (95^{th} percentile) events, expected to occur for <5% of spills in coastal areas, were assigned a risk matrix ranking of **4A**. Note that dispersants would not be applied in coastal waters under the alternatives considered in the PEIS that include dispersant use.

Results of the Addition of a Dispersant Response at High Efficiency

For the large volume spill scenario and 80% dispersant efficiency response, the volumes affected are slightly higher than those for 45% dispersant efficiency (because sufficient dispersant would be available to disperse the floating oil in both cases, see Section A.3.7 of Part A). Thus, the risk matrix rankings assigned to water quality for this scenario were the same as for the 45% dispersant efficiency case, with the exception that the risk ranking for coastal waters was **4A** for all conditions.

Results of the Addition of an On-Water ISB Response

Under the large volume spill scenario and the ISB response option, the water quality effects would be slightly less, by the amount removed by burning. Thus, the percent of the resource affected is also slightly less for the mechanical only response scenario when ISB is included.

The risk matrix rankings assigned to water quality for scenarios involving burning were the same as those assigned for scenarios without burning.

Summary of the Consequences for Water Quality in the Large Volume Scenarios
Table C.4.1.2-2 summarizes risk scores for water quality for all response options for a large volume spill in coastal waters under average and extreme (95th) environmental conditions. Table C.4.1.2-3 summarizes risk scores for large volume spills in marine waters. The coastal results would apply to similar volume coastal areas and the marine results would apply to any spill site at least 3 miles from shore.

Table C.4.1.2-2. Water quality risk scores for large spills in coastal areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: B 95th: A	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: B 95th: A	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: A 95th: A	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

Table C.4.1.2-3. Water quality risk scores for large spills in marine areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: E 95th: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: E 95th: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: E 95th: E	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

C.4.2 Impacts to the Biological Environment

C.4.2.1 Intertidal Habitats

The sensitive intertidal habitats in the North Texas Shelf include sand beaches along the outer coast and extensive intertidal wetlands along the interior bays that are important habitats for birds and nursery areas for commercially valuable fisheries. Coastal wetlands in the area provide many valuable ecological functions. The threshold concentration of concern for intertidal habitats is 10 g/m^2 (10-micron) thickness of oil (see Section A.4 in Part A). Table C.4.2.1-1 shows the outputs of the different scenarios in terms of the area and length of shoreline habitat affected, by major shoreline habitat type (shoreline classifications are defined in NOAA, 2000b). "Gravel" habitats include shell beaches and riprap structures, and these habitats are included in the table to account for the dominant shoreline habitats in the study area, but the following discussion focuses on beaches and wetlands.

Table C.4.2.1-1. Mean area and length of shoreline habitats oiled above a threshold of 10 g/m^2 (10 micron) oil thickness for the large volume scenarios. The numbers are summarized from Appendix C Tables C-II.2-4 through C-II.2-6.

Scenario	Total Oiled Shoreline Area (m^2)	Total Oiled Shoreline Length (km)	Outer Sand Beach Length (km)	Gravel Length (km)	Wetlands Length (km)
On-Water Mechanical Recovery (with or without ISB)	270,000	56.4	28.5	14.2	9.4
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	239,000	50.0	25.5	13.1	7.7
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	212,000	44.6	23.0	12.4	5.7

Results of On-Water Mechanical Recovery Only

Under the large volume spill scenario and on-water mechanical response option, the mean area of shoreline oiling exceeding a threshold of 10 g/m^2 (~ 10 microns) for all model runs would be 270,000 m^2 (323,000 yd^2) and the mean length would be 56.4 km (35.3 mi). This affected area represents less than 1% of the total coastline area in the North Texas Shelf (which is 1,360 km^2 (525 mi^2); Tables a.4-4 and A.4-5) but 10 percent of the length of outer sand beaches. For the highest shoreline impact model run, almost the entire Gulf shoreline from Cedar Lakes to Sabine Pass would be oiled above the 10-micron threshold, with extensive areas of heavy oil loading (Figure C-II.1.4.2-3). Wetland oiling would be most significant in the southern parts of the Galveston Bay area, with some areas reaching 1,000-10,000 g/m2. Therefore, a risk matrix ranking of **2D** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency

Under the large volume spill scenario and 45% dispersant efficiency response option, the mean area of shoreline oiling exceeding a threshold of 10 g/m^2 (~ 10 microns) for all model runs would be 239,000 m^2 (286,000 yd^2), and the mean length would be 50 km (31.2 mi). The extent and degree of oiling of intertidal habitats would be reduced, compared to on-water mechanical recovery alone, but the pattern would be similar (Figure C-II.1.5.2-3). Therefore a risk matrix ranking of **2D** was kept for intertidal habitats for this scenario to reflect the limited reduction in the extent and degree of oiling of intertidal habitats.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% dispersant efficiency response option, the mean area of shoreline oiling exceeding a threshold of 10 g/m^2 (~ 10 microns) for all model runs would be 212,000 m^2 (253,000 yd^2), and the mean length would be 45 km (28.1 mi). Use of dispersants at this high efficiency reduced the extent of wetland oiling to a greater degree than other shoreline types (reduction of 40 percent for wetlands versus 21 percent for all shoreline types) over on-water mechanical recovery alone (Figure C-II.1.5.3-3). A risk matrix ranking of **2D** was assigned to intertidal habitats for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on intertidal habitats would be similar to the on-water mechanical recovery only response option. A risk matrix ranking of **2D** was assigned to intertidal habitats for this scenario.

Summary of the Consequences for Intertidal Habitats in the Large Volume Scenarios
Under the large volume scenarios, effects on intertidal habitats would be to be similar regardless of ISB or dispersant use. The use of dispersants would reduce the extent of shoreline oiling by a maximum of only 20 percent, but the use of dispersants at the high efficiency rate would reduce effects on wetlands by up to 40 percent.

C.4.2.2 Marine and Coastal Birds

The Galveston Bay in the North Texas Shelf provides an important habitat for migrant and resident coastal birds. Refer to Section C.3.2 for additional information on important bird habitats in the Gulf of Mexico region and on factors considered in risk score calculations.

Results of On-Water Mechanical Recovery Only
Under the large volume spill scenario and on-water mechanical recovery option, outer sand beaches used as staging habitat by large numbers of shorebirds would be oiled above the 10-micron threshold. Oiled areas could include: Bolivar Flats, the outer coast from Cedar Lakes to Sabine Pass, the jetties, Brazoria National Wildlife Refuge, and areas inside Galveston Bay. Extensive areas of heavy oil loading are possible and could include interior marsh habitats that have long recovery periods (Figure C-II.1.4.2-3). The mean area of shoreline oiled above a threshold of 10 g/m^2 would be about 270,000 m^2 (2.9 million ft^2), and would include wetlands, flats, and beaches (Table C.4.2.1-1).

Surface water oiling above the 10-micron threshold in the modeled area would be primarily outside of the Galveston Bay entrance (Figure C-II.1.4.1-3). Some diving bird and seabird habitat may be affected, but adverse population effects to these groups are likely to be less severe than for birds utilizing shoreline habitats since their populations are more widely distributed throughout the Gulf of Mexico than the highly concentrated migratory species.

When considering all species groups together (e.g. shorebirds, waterfowl, diving birds, etc.), it is possible that over 20 percent of the North Texas Shelf marine and coastal bird population may be adversely affected under these spill conditions. Recovery would likely occur in 1 to 3 years for most species, as was the case following the Exxon Valdez oil spill (Kuletz, 1993; Boersma et al., 1995; Erikson, 1995, and Wiens, 1995). A risk matrix ranking of **3A** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and the low efficiency dispersant response option, the mean area of shoreline oiled above a threshold of 10 g/m^2 was only reduced by 11 percent (Table C.4.2.1-1). Areas oiled could include: outer coast sand beaches, Bolivar Flats, the jetties, and interior marsh habitat (Figure C-II.1.5.2-3).

Surface water oiling above the 10-micron threshold would be reduced and restricted to mostly outside of Galveston Bay (Figure C-II.1.5.1-3). Limited diving bird and seabird habitat may be adversely affected.

The decrease in the amount of shoreline oiling in sensitive bird habitats when low efficiency dispersants were used was not enough to justify changing the risk factors compared to the on-water mechanical recovery only option. Recovery would likely occur in 1 to 3 years for most species. A risk matrix ranking of **3A** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and the high efficiency dispersant response option, the mean area of shoreline oiled above a threshold of 10 g/m^2 was only reduced by 21 percent (Table C.4.2.1-1). Areas oiled could include those described when low efficiency dispersants were used (Figure C-II.1.6.2-3).

Surface water oiling should be similar with dispersant use regardless of efficiency, and limited diving bird and seabird habitat may be adversely affected (C-II.1.6.1-3).

The decrease in the amount of shoreline oiling in sensitive bird habitats when high efficiency dispersants were used was not enough to justify changing the risk factors compared to when no dispersants or low efficiency dispersants were used. Recovery would likely occur in 1 to 3 years for most species. A risk matrix ranking of **3A** was assigned to birds for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, adverse effects on birds would be similar to the on-water mechanical recovery only response option. When considering all species groups together, over 20 percent of the regional population may be adversely affected under these spill conditions, and recovery would likely occur in 1 to 3 years for most species. A risk matrix ranking of **3A** was assigned to birds for this scenario.

Summary of the Consequences for Marine and Coastal Birds in the Large Volume Scenarios
Under the large volume scenario and under the mechanical recovery only and use of ISB response option, adverse effects on birds are likely to be important when no dispersants are used due to the high probability of a large percentage of important migratory staging and wetland concentration areas being oiled. The use of dispersants would not lessen the water surface and shoreline effects enough to appreciably lower the percentage of birds affected in the mean spill,

therefore adverse population effects are probably important at this spill volume regardless of the response option used.

C.4.2.3 Marine Mammals

The North Texas Shelf has a limited population of marine mammals. Refer to Section C.3.2.3 for additional information on marine mammal populations. Marine mammals are assumed to be at risk when a threshold of 10 g/m^2 (~10-micron) of oil is exceeded on the shoreline or the water surface (see Section A.4 in Part A), however, the level of risk varies by the behavior group. Potential adverse effects on marine mammals (i.e., terrestrial wildlife, cetaceans, furbearing marine mammals, pinnipeds, manatees, and sea turtles were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the large volume North Texas Shelf spills are in Appendix C-II.5, Table C-II.5.3. The equivalent areas of 100% mortality for all response options are summarized in Table C.4.2.3-1 as percentages of the North Texas Shelf (defined in Tables A.4-4 and A.4-5 of Part A). In addition to this calculation, which is based on the mean result, the mean length of shoreline oiled and the surface oil exposure exceeding 0.01 g/m^2 (in m^2-hrs) based on all model runs was also compared between the treatment options (Tables C-II.2-4 through C-II.2-6).

Table C.4.2.3-1. Percentage of reference area adversely affected for large spills, by dispersant option and behavior group (assuming North Texas Shelf area in Tables A.4-4 and A.4-5).

Behavior Group (Habitat Occupied)	0	45	80
Terrestrial wildlife (wetlands, sea grass beds and shoreline)	0	0	0
Cetaceans (seaward subtidal)	0.002	0.002	0.001
Furbearing marine mammals (all intertidal and subtidal)	1.53	1.14	0.96
Pinnipeds and manatees (all intertidal and subtidal)	0.02	0.02	0.01

Results of On-Water Mechanical Recovery Only

In the North Texas Shelf, the only marine mammals at risk are cetaceans, occasional stray manatees, and terrestrial mammals along the shore. The resistance of cetaceans to oiling coupled with the very small percentage of habitat affected yields a minimal risk to cetaceans under the on-water mechanical recovery only option even for the large volume spill scenario. The cetaceans that are oiled as a result of contact with floating oil would most likely recover within days, if not a few hours, of the spill (**4E)**, (RPI, 1987). Potential effects on the occasional manatee also increase, but the proportion of the area remains well below 1% of the total habitat. Similarly, terrestrial mammals are at very low risk. The area of equivalent mortality is much less than one percent of the total habitat, and even though the length of shoreline oiled is considerably higher than in the medium spill scenario (56 km (35 mi) versus 16 km (10 mi), see Section C.4.2.1), it is still less than 1% of the total shoreline. Recovery times would remain unchanged. Given the limited area affected, and the fact that much of the oiling is on outer sand beaches where terrestrial mammals are uncommon the overall risk score remained the same as for the medium size spill scenario, **3E**.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and the 45% efficiency dispersant option the areas of equivalent mortality for the groups of concern are slightly reduced in absolute area, and are still very small relative to the reference areas. The use of dispersants would reduce the amount of the length of shoreline oiled, but would not reduce the recovery time, thus the score remains unchanged. There is no evidence that cetaceans are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality and shoreline oiling are essentially the same as those for the 45% option, thus the risk score remains unchanged.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in addition to on-water mechanical recovery should not change the effects on marine mammals (**3E**), since the amount of floating oil remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to marine mammals.

Summary of the Consequences for Marine Mammals in the Large Volume Scenario
The results indicate that on average for large volume spills in the North Texas Shelf, adverse effects on marine mammals would be low with only on-water mechanical recovery, and while that this risk could be reduced by the use of dispersants, the reduction is not enough to change the already low overall risk. The absence of furbearing marine mammals; the fact that manatees are only rare visitors in the area, and the low sensitivity of cetaceans is the major contributing factors to this conclusion. These results are consistent with experience with spills of this size in areas where marine mammals are uncommon.

C.4.2.4 Sea Turtles

Sea turtles are an important resource in the North Texas Shelf, and there are important nesting beaches in the area. Refer to Section C.3.2.4 for additional information on sea turtle populations in the Region. The primary risk to sea turtles is from exposure to shoreline oiling in areas where they breed, however, adult turtles do have a low sensitivity to floating oil and they could ingest tar balls.

Sea turtles are assumed to be at risk when a threshold of 10 g/m^2 (~10-micron) is exceeded on the shoreline or the water surface (see Section A.4 in Part A). Potential adverse effects on sea turtles were estimated using the modeling (SIMAP) and summarized as the equivalent area of 100% mortality. The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the medium volume North Texas Shelf spills are in Appendix C-II.5, Table C-II.5.3. The equivalent areas of 100% mortality for all response options are summarized in Table C.4.2.3-1 as percentages of the North Texas Shelf (defined in Tables A.4-4 and A.4-5 of Part A). The sensitivity of sea turtles is assumed to be the same as that for pinnipeds and manatees, and so the area of equivalent mortality never exceeds 0.002%, regardless of the response option (see Table C.4.2.3-1). The area of surface oil exposure in m^2-hrs (see Tables C-II.2-1 and C-II.2-4), however, is increased 11-fold over that in the medium spill scenario and the area in m^2 is roughly 2% of the total reference area (a 6-fold increase over the medium spill scenario). This increase in both area and duration greatly increases the potential for contact if a sea turtle were to be in the area, and therefore, increases the risk of sublethal effects. In addition, the total area of shoreline oiled greater than 10 g/m^2, as well as the area of seaward sand beaches oiled, was compared to the respective total shoreline habitat. With mechanical recovery, approximately 56 km (35 mi) of shoreline was oiled above the threshold, including approximately 28 km (17.4 mi) of sand beach. While the total shoreline value does not exceed one percent of the available resource (see Table A.4-6), the percentage of seaward sand beach affected is approximately 10%. If dispersants are used at 45% efficiency the lengths oiled reduce to approximately 50 and 25 km (31 and 15 mi), which is not a major reduction. Dispersant use at 80% efficiency provides an additional, but small reduction in both parameters.

Results of On-Water Mechanical Recovery Only

Under the large volume scenario with only on-water mechanical recovery, the area of equivalent mortality is less than 0.002% of the total reference area, but the surface slick is much larger. This increases the potential area where an individual could be oiled. The effect would probably result in minor physiological effects, but it is conceivable that it could interfere with reproductive capacity or lead to the loss of an individual. The much greater risk is from the oiling of sand beaches, which could involve turtle nesting beaches. Approximately 10% of this resource was affected, but even if turtle eggs or hatchlings were affected, the population would be likely to recover within 3 years, thus a risk ranking of **3C** was assigned.

Results of the Addition of a Dispersant Response at Low Efficiency

Under the large volume spill scenario and the 45% efficiency dispersant option, the area of equivalent mortality is slightly reduced in absolute area, and is still very small relative to the reference areas. Furthermore, the use of dispersants would greatly reduce the area of the surface slick. However, the oiling of sand beaches was not significantly reduced, and on this basis the risk ranking remained at **3C**. This appears to be due to the fact that, on average, oiling of outer sand beaches occurs very rapidly after the spill, and therefore, dispersant use does not have a significant benefit. In any specific situation, however, dispersant use might provide a much greater benefit. There is no evidence that sea turtles are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency

Under the large volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality and shoreline oiling are essentially the same as those for the 45% option, thus the risk score remains **3C**.

Results of the Addition of an On-Water ISB Response

Oil removal by ISB in addition to mechanical recovery should not change the effects on sea turtles (**3C**), since the amount of floating oil remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to sea turtles.

Summary of the Consequences for Sea Turtles in the Large Volume Scenario
The results indicate that on average for large volume spills in the North Texas Shelf concern for sea turtles could potentially be moderate with the use of only on-water mechanical recovery. While the use of dispersants would reduce the possibility of turtles coming into contact with floating oil and slightly reduce oiling of sand beaches, on average the change is not enough to reduce the risk. Oil on the shoreline is the major concern since sea turtles nest in the area, however, only specific beaches are used, thus the risk is not randomly distributed. If a specific nesting beach were threatened, there would be special efforts made to protect or clean it.

C.4.2.5 Plankton and Fish

Potential adverse effects on water column organisms (i.e., plankton and fish, as well as pelagic invertebrates such as squid) were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. Estimated water volumes where adverse effects could occur were converted to equivalent areas of 100% loss by integrating percentage losses over all affected volumes and multiplying by water depth at the spill site, allowing comparison to other resources that are distributed on a per area basis (e.g., mammals and shorelines). In the near shore areas modeled, effects were nearly evenly distributed throughout the water column because of water column mixing and vertical movements of animals. If these results are used to infer potential for adverse effects in deeper waters, the areas of effect would only apply to surface waters up to on the order of 30-50 m (98-164 ft) deep (during strong wind conditions). The modeling methods are described in Part A and Section C-II.6, and the results of the calculations for the large North Texas Shelf spills are in C-II.6. For these calculations, the toxicity parameter for sensitive species was assumed. Thus, the areas affected would only apply to 2.5% of species (based on a Gaussian distribution of species sensitivities), and areas of adverse effect for 97.5% of species would be smaller.

Table C-II.6-3 lists the average equivalent areas projected to be killed (for sensitive species) for large volume spills. These areas are based on the mean of all 100 runs, and so represent an average of all environmental conditions that may occur after a spill (see explanation in Section C-II.6). Table C-II.6-5 lists the 95th percentile equivalent areas where sensitive species would be adversely affected. This maximum potential effect is calculated as the mean plus two standard deviations, using the statistics of all 100 model runs for the scenario, and assuming the toxicity values for sensitive species.

The mean areas adversely affected for all response options are summarized in Table C.4.2.5-1 as percentages of the North Texas Shelf (defined in Table A.4-4 of Part A). The maximum areas (95th percentile) for sensitive species are summarized in Table C.4.2.5-2 (also as percentages of the North Texas Shelf reference area).

Table C.4.2.5-1. Average percentage of reference area adversely affected for large spills, by dispersant option and behavior group (assuming North Texas Shelf area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.086	0.170	0.194
Small pelagic fish & invertebrates	0.161	0.325	0.372
Large pelagic fish	0.243	0.505	0.580
Demersal (stationary on bottom)	0.087	0.170	0.194
Planktonic (drift with currents)	0.161	0.324	0.372

Table C.4.2.5-2. Maximum (95th percentile) percentage of reference area adversely affected for large spills, by dispersant option and behavior group (assuming North Texas Shelf area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.309	0.462	0.514
Small pelagic fish & invertebrates	0.598	0.895	0.995
Large pelagic fish	0.958	1.432	1.593
Demersal (stationary on bottom)	0.303	0.454	0.505
Planktonic (drift with currents)	0.599	0.896	0.997

Results of On-Water Mechanical Recovery Only

Under the large volume spill scenario and on-water mechanical recovery only option, the area adversely affected would be 0.1-0.2% of the North Texas Shelf for spills under average environmental conditions. For 5% of spills, the area affected would be 0.3-1.0% of the North Texas Shelf, depending on the behavioral group of the organism. As the percentage affected is <1%, it is less than the range of natural variability and would not be perceptible at the population level. Given this, the short generation time of many species, and annual reproduction of others, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency

Under the large volume spill scenario and 45% dispersant efficiency response option, the area adversely affected would be 0.2-0.5% of the North Texas Shelf for spills under average environmental conditions. For 5% of spills, the area affected would be 0.5-1.4% of the North Texas Shelf, depending on the behavioral group of the organism. The adverse effects are slightly higher than the on-water mechanical recovery only response but still relatively small, and, for the reasons stated above, the affected species would require less than a year to replace the missing individuals. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the large volume spill scenario and 80% dispersant efficiency response option, the area adversely affected would be 0.2-0.6% of the North Texas Shelf for spills under average environmental conditions. For 5% of spills, the area affected would be 0.5-1.6% of the North

Texas Shelf, depending on the behavioral group of the organism. These results are not very different from the low-efficiency dispersant response because approximately the same amount of oil is dispersed in either case (i.e., more than sufficient dispersant is available to disperse available oil for such activity in the low efficiency case). The effects are only slightly greater than the low efficiency response scenario, which is in turn slightly higher than the on-water mechanical recovery only response. The adverse effect is relatively small on the scale of the populations involved, and the affected species would require less than a year to replace the missing individuals. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of an On-Water ISB Response

Under the large volume spill scenario, if ISB is effectively used in the response, the adverse effects to water column organisms would be slightly less than otherwise by the amount removed by burning. Thus, the percent of the resource affected is <1% for on-water mechanical and both dispersant response scenarios when ISB is included. The adverse effects are relatively small on the scale of the populations involved, and the affected species would require less than a year to replace the missing individuals. Thus, a risk matrix ranking of **4E** was assigned to water column effects for this scenario.

Summary of the Consequences for Plankton and Fish in the Large Volume Scenarios

The results indicate that on average for large volume spills, adverse water column effects for sensitive species could affect 30-100 km^2 (12-39 mi^2) without the use of dispersants. With dispersants, and on average, up to 230 km^2 (89 mi^2) of water could be toxic to the most sensitive and mobile species (Table C-II.6-2). Exposure for larger fish is higher because they are more mobile, and new animals move into the dissolved aromatic plume over time (assuming they do not avoid hydrocarbon contamination). Under worst case conditions, the potentially affected areas for sensitive species and for no dispersants and dispersant use are on the order of 180 and 630 km^2 (69 and 243 mi^2), respectively (Table C-II.6-5).

The mean areas adversely affected for all response options are <1% of the North Texas Shelf (Table C.4.2.5-1). Thus, the risk scores for these effects are "**E**" (Table C.4.2.5-3). The maximum areas (95^{th} percentile) for sensitive species are also <1% of the area of concern, except for the large mobile fish, which just exceed 1% (Table C.4.2.5-2). The effects are relatively small on the scale of the populations involved, and the affected species would require less than a year to replace the missing individuals.

It should be noted that these results are assuming toxicity threshold for sensitive (2.5^{th} percentile) species. The average species would not be so sensitive, and these estimated adverse effects would not apply to most or average species. The effect estimates are used in a comparative manner, comparing potential areas of concern to the most sensitive species.

These results are consistent with experience for large oil spills of about 40,000 bbl (about 1 million gallons or more; French McCay and Payne, 2001; French McCay et al., 2002, and as discussed in Part A). In the Gulf of Mexico and other warm regions, high temperatures facilitate rapid evaporation and volatilization of the toxic fraction, the soluble aromatics. Also, winds are typically light to moderate, except in infrequent storm events. Thus, natural dispersion into the water is typically low, while evaporation is rapid. Because of logistical constraints, in the scenarios examined the dispersion by chemical dispersants occurred beginning at 12 hours after the spill. By this time, most of the toxic components have volatilized (Section C.4.1), such that dissolved aromatic concentrations resulting from dispersant use are only slightly elevated over the no-dispersant option.

Only in rare storm events where high waves entrain fresh un-weathered oil, such as in the *North Cape* oil spill (French, 1998a,b; French McCay, 2003), would the concentrations of toxic components be high enough to cause concern about effects on water column communities. The 95^{th} percentile case assuming no dispersant use would be the analogous case to the *North Cape* situation for sensitive species (analogous to the lobster affected in the *North Cape* spill). It should be noted that dispersants would not be likely to be used in such a situation. Thus, the 95^{th} percentile result for the dispersant option scenarios are unlikely to ever occur, based on probability of the event and likelihood that dispersants would actually be used in a storm situation.

Table C.4.2.5-3. Risk scores for plankton and fish for large spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

C.4.2.6 Subtidal Benthic Habitat

Subtidal benthic habitat in the North Texas Shelf, and its susceptibility to oil was discussed in Section C.3.2.6. Benthic habitat was assumed to be at risk when a threshold of 0.10 g/m^2 of total hydrocarbon loading was exceeded in the sediment or 0.0001 g/m^2 of dissolved aromatic hydrocarbons was exceeded in the pore water (see Section A.4 in Part A). These concentrations are approximately equivalent to 1 ppm of total hydrocarbons or 1 ppb of dissolved aromatic hydrocarbons, when a sediment mixing depth of 10 cm is assumed. The area was estimated using SIMAP and the modeling methods are described in Part A. The area estimates of sediment loading for the large volume North Texas Shelf spills are in Appendix C-II.6, Table C-II.6.6. The area estimates for dissolved aromatic hydrocarbons in sediment pore water are in Table C-II.6.7. Regardless of the treatment option, the 0.10 g/m^2 total hydrocarbon threshold was only exceeded in an area of less than 0.1 km^2 (0.03 mi^2), while the dissolved aromatic concentrations exceeded the sediment threshold for the dispersant use options only, 0.6 and 1.5 km^2 (.23 and .58 mi^2) respectively. All are much less than 1% of either the total area or the area just in Galveston Bay.

Benthic habitat was also assumed to be at risk if epiflora and epifauna (demersal) organisms were affected by dissolved aromatic concentrations in the bottom water just above the sediments. The percentage of benthic habitat where stationary demersal biota would be affected, assuming the toxicity parameter for sensitive species (i.e., two standard deviations more sensitive than the average of all species tested), was estimated using SIMAP and the modeling methods described in Part A and Section C.II.6.

Results of On-Water Mechanical Recovery Only

In the on-water mechanical recovery only option for the large volume spill scenario, the model results indicate that for sediments only the total hydrocarbon threshold was exceeded, and then only in a very small area. As indicated in Table C.4.2.5-1, 0.087% of the reference area was affected by bottom water concentrations when no dispersants were assumed used. Since recovery would be rapid, the risk ranking is **4E**.

Results of the Addition of a Dispersant Response at Low Efficiency

Use of a dispersant at 45% efficiency in the large spill scenario does not appreciably change the level of sediment contamination in subtidal habitat, although both criteria are exceeded in a very small area. As indicated in Table C.4.2.5-1, 0.170% of the reference area was affected by bottom water concentrations when dispersants were assumed used at low efficiency. Thus, the ranking remains at **4E**.

Results of the Addition of a Dispersant Response at High Efficiency

Under the large volume spill scenario and the 80% efficiency dispersant option, potential sediment contamination effects are essentially unchanged from the 45% efficiency dispersant option (actually predicted to be slightly less). As indicated in Table C.4.2.5-1, 0.194% of the reference area was affected by bottom water concentrations when dispersants were assumed used at high efficiency. Thus, the risk ranking remains at **4E**.

Results of the Addition of an On-Water ISB Response

Oil removal by ISB in the large spill scenario should have no additional effect when combined with on-water mechanical recovery on benthic habitats since ISB takes place on the water's surface, and results in the removal of an equivalent amount of oil (**4E**). The only concern associated with ISB is the chance of heavy burn residues sinking and mixing with sediments, but this risk is minimal based on both the toxicity of the material and on the amount that would be produced from the limited burning possible in the scenarios.

Summary of the Consequences for Subtidal Benthic Habitat in the Large Volume Scenarios

Oil spills and oil-spill response activities could potentially affect benthic habitats. Floating oil does not pose a great level of concern unless sufficient wave energy exists to mix the surface oil into the water column, or sediments contaminated with oil are transported from the intertidal zone into subtidal habitats. Mechanically dispersed oil could reach bottom water and adhere to sediments, flora and fauna in benthic habitats and could cause potentially adverse effects. However, in this simulation, only very low levels of hydrocarbon exposure are expected on or in the sediments, even near shore. Dispersant use does not change this risk in the simulation, even though it increased the amount of oil in the water column. The risk to benthic habitat is low regardless of response option.

C.4.2.7 Biological Areas of Special Concern

The North Texas Shelf has numerous areas of special concern which were described in Section C.3.2.7. As discussed in that section, the average risk to such areas is assumed to be defined by the risk to intertidal (Section C.4.2.1) or subtidal habitats (Section C.4.2.6), adjusted for the extent of areas of special concern which occur in the North Texas Shelf, if appropriate. The higher of the risk scores for these two resource groups is used as the starting point to define the risk to areas of special concern. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
For the on-water mechanical response option under the large volume spill scenario, floating oil poses a moderate risk (**2D**) to intertidal habitat, while subtidal habitat was at minimal risk (**4E**). Therefore, coastal areas of special concern are the only areas which require consideration. The concerns for intertidal habitat were discussed in Section C.4.2.1. Since areas of special concern occupy only selected locations, the probability of contact is less than for intertidal habitat as a whole, but probably not enough to reduce the areal estimate. If contact did occur, recovery times would be as estimated for intertidal habitat. Therefore the estimated score remains **2D.**

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency in the large spill scenario reduced the risk to intertidal habitat by reducing the amount of surface oil which reaches shore, decreasing the probability of contacting an area of concern. However, the likelihood of contact is only slightly reduced, and recovery time in any sensitive areas would probably remain unchanged, resulting in a risk score of **2D**. The risk to subtidal habitat remains low (**4E**) because of the limited extent of the dispersed oil plume and rapid dilution, so the score of **2D** is used.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at an efficiency of 80% in the large spill scenario did not change the amount of shoreline oiled or the volume of oil dispersed by a large amount over that for dispersant use at 45% efficiency, therefore, the risk score remained unchanged from that at 45% at **2D**.

Results of the Addition of an On-Water ISB Response
ISB should produce a smoke plume that could pass over an area of special concern if the proper weather conditions exist. In this case, however, the burning can only occur three miles or more offshore, and the results for air quality (Section C.3.1.1) indicate that the plume should not travel that far. The use of ISB in addition to on-water mechanical recovery is not expected to change the risk to these resources (**2D**).

Summary of the Consequences for Biological Areas of Special Concern in the Large Volume Scenarios
The effects to areas of special concern in this scenario are focused on the potential risk to shoreline habitats. The use of dispersants can reduce the risk to such areas without increasing the minimal risk to subtidal areas. In this analysis the risk to such areas is defined as equivalent to the risk to intertidal habitat, in general. While this accurately reflects the ecological consequences of the event, it does not account for the social values which may be attached to such areas. If the spill trajectory of an actual event did threaten such areas, special attention would be given to their protection.

C.4.2.8 Essential Fish Habitat

Areas of essential fish habitat are extensive in the Gulf of Mexico Region (Section 3.4.4 of the PEIS) and were discussed in Section C.3.2.8. Included are estuaries, especially the coastal bays of Texas, as well as coastal and offshore areas. The area functions as a valuable spawning and nursery ground for many species. Fish eggs and larvae can be found in the offshore waters of this area throughout the year.

For this evaluation, the effects on essential fish habitat are assumed to be reflected by the risk to plankton and fish (Section C.4.2.5) and subtidal habitat (Section C.4.2.6) since they define the risk to the majority of fish habitat. Intertidal habitats, such as marshes, are also important habitat for fisheries resources, but were considered separately. The average risk to essential fish habitat is assumed to be defined by the higher of the risk scores for plankton and fish or subtidal habitat. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
In the large spill scenario, with the use of on-water mechanical recovery only, the risk to plankton and fish and to subtidal habitat was **4E**, resulting in a risk score for EFH of **4E**. Even though the areal extent of effects on water column organisms was larger than for the medium size spill, it still remained far below 1%. Recovery time should be less than one year, based on natural variability and the fecundity of most species.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency increases the possibility of exposure for both plankton and fish and subtidal habitat. The dispersed oil plume produced was not large enough to change the risk scores for plankton and fish or for subtidal habitat, therefore, the risk score remains **4E** for EFH. Dispersant use did reduce effects on intertidal habitat, which includes areas that are important for fisheries resources and EFH.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at 80% efficiency in the large spill scenario resulted in no change to the risk to plankton and fish or subtidal habitat from the 45% efficiency scenario, and the score remains **4E**. Again, dispersant use does benefit intertidal habitat, some of which are also important to EFH.

Results of the Addition of an On-Water ISB Response
The addition of ISB to on-water mechanical recovery in the large spill scenario did not change the evaluation for either plankton or fish or for subtidal habitat, and the score remains **4E**.

Summary of the Consequences for Essential Fish Habitat in the Large Volume Scenarios
Overall, the risk to essential fish habitat is low for the large spill scenario regardless of what response option is used. The risk score is determined by the potential risk to plankton and fish, rather than subtidal habitat, but in this case both were a low concern.

C.4.3 Effects on the Socio-Economic Environment

C.4.3.1 Human Health

Operation of the type of equipment associated with oil spill response can be dangerous. This is well recognized and is the basis for the worker certification and training requirements that are now in place. There are also protocols in place for the proper application and handling of dispersants. The safety risk is greater as the spill size, and thus the intensity and duration of operations increases, but is minimized if safety standards are followed. There is a health risk from inhalation of hydrocarbon fumes for first responders, which is recognized in current safety protocols. Exposure to hydrocarbon fumes is the only health risk that can be directly estimated in the SIMAP model, and the results are presented in Section C.4.1.1.

C.4.3.2 Subsistence

Information on subsistence use of fish and shellfish in the North Texas Shelf is limited. While some residents may supplement their diets with these resources, subsistence is not known to be a prominent activity in this area, as compared to Alaska, where Native communities may suffer substantial economic and cultural losses due to contamination of subsistence seafood during an oil spill.

Results of On-Water Mechanical Recovery Only
Under the large volume spill scenario and no dispersant response option, water column exposure of dissolved aromatics between 1-100 pbb would occur within and outside Galveston Bay, and higher concentrations (between 100-10,000 ppb) would occur mostly in near shore areas (Figure C-II.1.4.4-3). Tainting of fish and invertebrates becomes a concern when water concentrations exceed approximately 100 ppb in a brief (order of hours) exposure (See Section 4.3.5.6 of the PEIS). Sediment exposure is expected to occur in very small areas within Galveston Bay (Figure C-II.1.4.5-2). A small percentage (<1%) of shoreline habitats in the reference area would be oiled, and a proportionally small percentage of subsistence resources associated with these habitats are likely to be exposed (Section C.4.2.. Intertidal Habitats). Therefore, a very small percentage of subsistence resources are likely to be adversely affected, and recovery should be rapid. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and low efficiency dispersant response option, water column exposure of dissolved aromatics between 1-100 ppb is expected to occur in a similar sized area as to when no dispersants were used, although higher concentrations (between 100-1000 ppb) would occur in a larger area (Figure C-II.1.5.4-3). Sediment exposure is expected to occur in small areas within Galveston Bay (Figure C-II.1.5.5-2), and oiling of shoreline and intertidal organisms would be slightly reduced (approximately 11%, Section C.4.2.1. Intertidal Habitats). Although a larger water column area may be affected under these spill conditions, it is still likely that only a small percentage of subsistence resources may be adversely affected, and recovery should be rapid. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and high efficiency dispersant response option, water column exposure of dissolved aromatics between 1-10,000 pbb is expected to cover a larger area outside and within Galveston Bay than when no dispersants or low efficiency dispersants are used (Figure C-II.1.6.4-3). Sediment exposure is expected to occur in small near shore areas (Figure C-II.1.6.5-2), and oiling of shoreline and intertidal organisms would be somewhat reduced (approximately 21%, Section C.4.2.1. Intertidal Habitats). It is possible that a slightly higher percentage of subsistence resources may be adversely affected compared to when low efficiency dispersants are used, but recovery should be rapid. A risk matrix ranking of **4D** was assigned to subsistence resources for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, adverse effects to subsistence resources are expected to be similar to the on-water mechanical recovery only response option. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Summary of the Consequences for Subsistence in the Large Volume Scenarios
Because water column effects are expected to be localized and shoreline effects are expected to occur in a small percentage of the reference area, a risk matrix ranking of **4E** was assigned to subsistence resources for all of the response options except for when high efficiency dispersants were used (ranking of **4D**), and a large near shore area may have high concentrations of dissolved aromatics. Impacts to subsistence resources are not likely to be an important concern in the North Texas Shelf.

C.4.3.3 Cultural Resources

In the Gulf of Mexico region, archaeological sites are potentially present along the shoreline and buried in the sediments, particularly along barrier islands and back barrier embayments, river channels, floodplains, and terraces (Section 3.4.5.6 of the PEIS). Results from several studies indicated that direct oiling caused negligible effects on cultural resources following the Exxon Valdez oil spill (Reger et al., 1992; Dekin, 1993; Wooley and Haggarty, 1995; Bittner, 1996). Other prehistoric resources are located 3-9 miles offshore in deep water benthic habitats and submerged shipwrecks are located near the continental shelf. These resources are not at risk of oiling due to depth. Therefore, open water response options, such as the use of dispersants, ISB, and on-water mechanical recovery, may help reduce the amount of oil that strands on the shoreline, which would also reduce the amount of shoreline clean up and disturbance of sensitive cultural resources. For these reasons, a risk matrix ranking of **4E** was assigned to cultural resources for all response options under this scenario.

C.4.3.4 Coastal Communities

Oil spills affect the pleasure that coastal residents and visitors derive from coastal activities and the economic contribution that resources make to local income and employment. Effects are likely to include effects on water- and shore-based recreation, fisheries (recreational and commercial), marine transportation and tourism. The effects on these activities are described in more detail in subsequent sections.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to coastal communities in the North Texas Shelf under various spill response options. The model results are presented in Appendix C-II.2, Tables C-II.2-4 to C-II.2-6, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to coastal communities of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Gulf of Mexico region would be expected to adversely affect approximately 28.5 km (17.7 mi) of sandy shoreline and sweep approximately 789 km^2 (304.6 mi^2)of surface water above recognized effect thresholds (Table C-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by more than 10 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was also reduced by more than 10 percent (Table C-II.2-5). This results in risk factor ratings of 0.89 and 0.90 for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by almost 10 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was also reduced by approximately 10 percent as compared to the low dispersant efficiency response option (Table C-II.2-6). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.81 and 0.80, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on coastal communities would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to coastal communities for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Coastal Communities in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 23.1 to 25.5 km (14.4 to 15.8 mi) of sandy shoreline and 650 to 700 km^2 (251.0 to 270.3 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 11 to 19 percent and 11 to 17 percent, respectively, the level of dispersant efficiency does not greatly affect the level of concern about coastal communities in this spill scenario.

C.4.3.5 Economic Status

The overall economic status of communities, industries and individuals that rely on coastal resources for sustenance, revenue and quality of life can be affected by an oil spill. As noted above, coastal communities can suffer direct and indirect economic effects due to an oil spill, as beach and fishery closures decrease revenues, eliminate jobs, and adversely affect subsistence users of the resources.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to economic status in the North Texas Shelf under various spill response options. The model results are presented in Appendix C-II.2, Tables C-II.2-4 to C-II.2-6, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to economic status of response options other than mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the North Texas Shelf would be expected to adversely effect approximately 28.5 km (17.7 mi) of sandy shoreline and sweep approximately 789 km^2 (304.6 mi^2) of surface water above recognized effect thresholds (Table C-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by more than 10 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was also reduced by more than 10 percent (Table C-II.2-5). This results in risk factor ratings of 0.89 and 0.90 for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by almost 10 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was also reduced by approximately 10 percent (Table C-II.2-6). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.81 and 0.80, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on economic status would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to economic status for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Economic Status in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 23.1 to 25.5 km (14.4 to 15.8 mi) of sandy shoreline and 650 to 700 km^2 (251.0 to 270.3 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 11 to 19 percent and 11 to 17 percent, respectively, the level of dispersant efficiency does not greatly affect the level of concern about economic status in this spill scenario.

C.4.3.6 Vessel Transportation and Ports

Marine transportation is of paramount importance for many industries along the Gulf Coast. Any interruption in the standard use of vessels or increase in travel times over water can result in hardship for coastal communities and businesses as fewer goods are exchanged, transportation costs rise, and the revenue streaming through the local economy falls.

As described in Part A., the amount of total surface water oiled above selected thresholds in Galveston Bay is used to represent the risk of socioeconomic effects to marine transportation and ports in the North Texas shelf under various response options. The model results are presented in Appendix C-II.2, Tables C-II.2-4 to C-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to the marine transportation industry of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the North Texas Shelf would be expected to adversely effect approximately 789 km^2 (304.6 mi^2) of surface water used by the marine transportation industry above recognized effect thresholds (Table C-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 10 percent as compared to on-water mechanical recovery alone (Table C-II.2-5). This results in a risk factor rating of 0.90 for the marine transportation industry under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 10 percent as compared to the low dispersant efficiency response option (Table C-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for the marine transportation industry decreases to 0.80 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on the marine transportation industry would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to the marine transportation industry for this scenario.

Summary of the Consequences for Vessel Transportation and Ports in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 650 to 700 km^2 (251.0 to 270.3 mi^2) of surface water. While the use of dispersants is projected to likely lessen the area of surface water affected by approximately 11 to 17 percent, the level of dispersant efficiency does not greatly affect the level of concern about vessel transportation and ports in this spill scenario.

C.4.3.7 Fisheries (Commercial and Recreational)

Commercial and recreational fishing and related industries are vulnerable to oil spills, due to closures as well as market perceptions surrounding taint of the catch. In addition, recreational anglers, who fish for pleasure or sport, as opposed to monetary gain, may experience a reduced quality of experience. Large-scale spills also hold the potential to injure nursery grounds and impose other effects that could reduce fish harvests in the longer run.

As described in Part A., the amount of total surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to commercial and recreational fishing in the North Texas Shelf under various response options. The model results are presented in Appendix C-II.2, Tables C-II.2-4 to C-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to commercial and recreational fishing of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the North Texas Shelf would be expected to adversely affect approximately 789 km^2 (304.6 mi^2) of surface water used for commercial and recreational fishing above recognized effect thresholds (Table C-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 10 percent as compared to on-water mechanical recovery alone (Table C-II.2-5). This results in a risk factor rating of 0.90 for commercial and recreational fishing under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 10 percent as compared to the low dispersant efficiency response option (Table C-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for commercial and recreational fishing decreases to 0.80 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on commercial and recreational fishing would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to commercial and recreational fishing for this scenario.

Summary of the Consequences for Commercial and Recreational Fishing in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 650 to 700 km^2 (251.0 to 270.3 mi^2) of surface water. While the use of dispersants is projected to likely lessen the area of surface water affected by approximately 11 to 17 percent, the level of dispersant efficiency does not greatly affect the level of concern about commercial and recreational fishing in this spill scenario.

C.4.3.8 Recreation and Tourism

An oil spill would be expected to cause local decreases in tourism, recreation, associated business revenues and the quality of coastal living. Similar to recreational fishing effects, an oil spill would also be expected to affect recreationalists' overall social welfare.

As described in Part A, the amount of total sandy shoreline oiled above selected thresholds is used to represent the risk of socioeconomic effects to recreation and tourism in the North Texas Shelf under various spill response options. The model results are presented in Appendix C-II.2, Tables C-II.2-4 to C-II.2-6, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns). From the model results, risk is then expressed in terms of the length of shoreline affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to recreation and tourism of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the North Texas Shelf would be expected to adversely affect approximately 28.5 km (17.7 mi) of sandy shoreline used for recreation and tourism above recognized effect thresholds (Table C-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by more than 10 percent as compared to on-water mechanical recovery alone (Table C-II.2-5). This results in a risk factor rating of 0.89 for recreation and tourism under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by almost 10 percent as compared to the low dispersant efficiency response option (Table C-II.2-6). Because the adverse effect to sandy shoreline resources is less with higher dispersant efficiency, the risk factor rating for recreation and tourism decreases to 0.81 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on recreation and tourism would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to recreation and tourism for this scenario.

Summary of the Consequences for Recreation and Tourism in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 23.1 to 25.5 km (14.4 to 15.8 mi) of sandy shoreline. While the use of dispersants is projected to likely lessen the length of sandy shoreline affected by approximately 11 to 19 percent, the level of dispersant efficiency does not greatly affect the level of concern about recreation and tourism in this spill scenario.

C.4.3.9 Environmental Justice

Low-income, indigenous, and minority sub populations in some coastal areas may rely on regional fisheries for subsistence or on tourism, recreation or other marine-resource related industry for employment. These groups may experience the effects of a spill more severely than the general population, which relies on a more diverse economic base for their livelihoods and on the availability of a widespread and commercially available selection of foods.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to environmental justice in the North Texas Shelf under various spill response options. The model results are presented in Appendix C-II.2, Tables C-II.2-4 to C-II.2-6, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to environmental justice of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only

Given the use of on-water mechanical recovery only, the average large size spill in the North Texas Shelf would be expected to adversely affect approximately 28.1 km (17.7mi) of sandy shoreline and sweep approximately 789 km^2 (304.6 mi^2) of surface waters above recognized effect thresholds (Table C-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency

Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by more than 10 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was also reduced by more than 10 percent (Table C-II.2-5). This results in risk factor ratings of 0.89 and 0.90 for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by almost 10 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was also reduced by approximately 10 percent as compared to the low dispersant efficiency response option (Table C-II.2-6). Because the adverse effects on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.81 and 0.80, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response

Under the large volume spill scenario and the ISB response option, effects on environmental justice would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to environmental justice for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Environmental Justice in the Large Volume Scenarios

Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 23.1 to 25.5 km (14.4 to 15.8 mi) of sandy shoreline and 650 to 700 km^2 (251.0 to 270.3 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 11 to 19 percent and 11 to 17 percent, respectively, the level of dispersant efficiency does not greatly influence the level of concern about environmental justice in this spill scenario.

C.5 SUMMARY CONCLUSIONS

For the moderate (2500 bbl) spill (Table C.5-1) the level of concern predicted for the average spill remains low for all environmental resources except for marine and coastal birds, intertidal habitat, sea turtles and biological areas of special concern, which were determined to be at moderate risk without dispersant use. When dispersants were used, regardless of the efficiency, the model suggests that the reduction in shoreline oiling will be sufficient enough to lower the overall level of concern to low for intertidal habitats, which also lowers the risk for sea turtles and biological areas of special concern. Reduction of floating oil is also a benefit for sea turtles, but the larger risk is from the potential for shoreline oiling of nesting beaches. Dispersant use (at either efficiency) does reduce the proportion of the population likely to be affected for marine and coastal birds, but this benefit was not sufficient to change the overall level of concern. The use of ISB does not change the predicted risk to the environment when compared to on-water mechanical recovery alone, because it results in the treatment of an equivalent volume of spilled oil.

When the spill size increases to 40,000 bbl (large spill scenario, Table C.5-2) the expected effects also increase. The average model results suggest that the same four resources are at risk, but now in addition there is also the possibility of a moderate level of concern for coastal water quality. Risk scores for the first four resource categories have increased, but are still in the moderate range. The use of dispersants does not reduce the risks likely to occur with the average large spill. This result can generally be explained by the fact that shoreline oiling and surface water oil are not greatly reduced by the use of dispersants. This is related to the relatively short trajectories which result in shoreline oiling. Dispersant use is predicted to reduce the risk to all resources, but not by enough to change the overall level of concern. In this case, the average effects for a high efficiency dispersant application were not greatly different than the low efficiency option. This reflects the fact that, under the assumed conditions, sufficient supplies of dispersant are available to achieve the maximum level of dispersion, regardless of which efficiency is assumed. Again, the use of ISB does not change the results from those predicted with only on-water mechanical recovery.

Examination of the entire suite of model runs indicates that the range of effects to resources of concern is highly variable, which reflects the dynamic nature of oil spills. For example, for the medium spill no oil reaches the shore at all with only on-water mechanical recovery only rarely (1 out of 100 runs), while this value increases to 15 out of 100 with dispersant use at low efficiency and to 23 out of 100 with dispersant use at high efficiency. Alternatively, also for the medium spill, the maximum shoreline oiling length predicted was slightly less than 32 km (19.9 mi), just over four times the average. Similar observations can be made for other exposure indices. The same pattern exists for the large spill results, and in many cases the relative relationships are quite similar. These model results are consistent with observed effects from spills that originate offshore and with the expected impacts described in Section 4.3 of the PEIS.

With respect to socioeconomic resources, the use of dispersants would limit the effects of the spill in all cases.

Table C.5-1. Risk Ranking for Medium (2,500 Barrel) Spills at the North Texas Shelf Location

	Physical Environment			Biological Environment								Socioeconomic Environment			
Response Option	Coastal Water Quality	Marine Water Quality	Air Quality	Intertidal Habitat	Marine and Coastal Birds	Marine Mammals	Sea Turtles	Plankton and Fish	Subtidal Benthic Habitat	Biological Areas of Special Concern	Essential Fish Habitat	Subsistence	Cultural Resources	Shoreline Oiling Index	Surface Water Oiling Index
On-Water Mechanical Recovery	4D	4E	4E	3D	3C	3E	3D	4E	4E	3D	4E	4E	4E	1.0	1.0
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	4D	4E	4E	3E	3D	3E	3E	4E	4E	3E	4E	4E	4E	0.44	0.36
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	4D	4E	4E	3E	3D	3E	3E	4E	4E	3E	4E	4E	4E	0.35	0.25
On-Water Mechanical Recovery and In-Situ Burning	4D	4E	4E	3D	3C	3E	3D	4E	4E	3D	4E	4E	4E	1.0	1.0

Legend: Black cells represent a "high" level of concern, medium gray cells represent a "moderate" level of concern, and light gray cells represent a "limited" level of concern.

Table C.5-2. Risk Ranking for Large (40,000 Barrel) Spills at the North Texas Shelf Location

	Physical Environment			Biological Environment								Socioeconomic Environment			
Response Option	Coastal Water Quality	Marine Water Quality	Air Quality	Intertidal Habitat	Marine and Coastal Birds	Marine Mammals	Sea Turtles	Plankton and Fish	Subtidal Benthic Habitat	Biological Areas of Special Concern	Essential Fish Habitat	Subsistence	Cultural Resources	Shoreline Oiling Index	Surface Water Oiling Index
On-Water Mechanical Recovery	4B	4E	4E	2D	3A	3E	3C	4E	4E	2D	4E	4E	4E	1.0	1.0
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	4B	4E	4E	2D	3A	3E	3C	4E	4E	2D	4E	4E	4E	0.89	0.90
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	4A	4E	4E	2D	3A	3E	3C	4E	4E	2D	4E	4D	4E	0.81	0.80
On-Water Mechanical Recovery and In-Situ Burning	4B	4E	4E	2D	3A	3E	3C	4E	4E	2D	4E	4E	4E	1.0	1.0

Legend: Black cells represent a "high" level of concern, medium gray cells represent a "moderate" level of concern, and light gray cells represent a "limited" level of concern.

C.6 REFERENCES

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Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part C: Galveston Bay and North Texas Shelf

Sections C-I.1 – C-I.4

by

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ASA 00-246

August 2004

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C-I. OIL SPILL MODEL INPUT DATA

This appendix contains model input data (in maps, figures and tables) for the modeled location in the Gulf of Mexico (near the entrance of Galveston Bay) and the sources for that information. The approach and sources applicable to all modeled locations are described in Part A, Section A.3 of this technical report. Specifics to this model location are below. Thus, the reader should refer to Part A, Section A.3 for background and the context within which these data are used.

C-I.1 Geographical Data Input to the Model

Geographic data for the modeled location are presented in this section. The sources for these data are described in Part A, Section A.3.1. A map is also presented below showing areas where dispersant application was assumed in model simulations. The assumptions for the dispersant application scenarios are in Part A, Section A.3.7. The crosshair mark (⊞) in the figures below represents the assumed oil spill site for the model simulations.

C-I.1.1 Maps of the Vicinity of the Spill Site

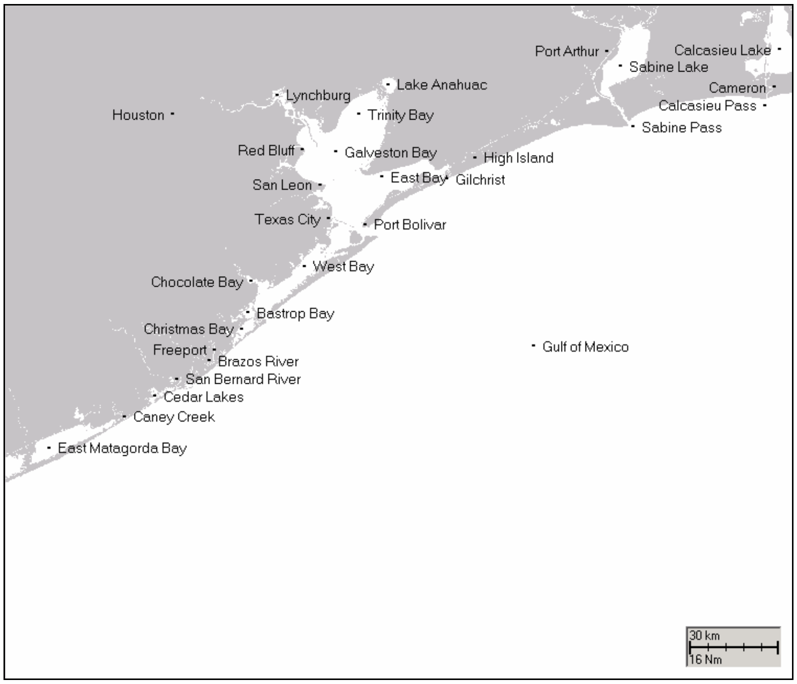

Figure C-I.1.1-1 Map of spill site and location names used in the text (entire grid).

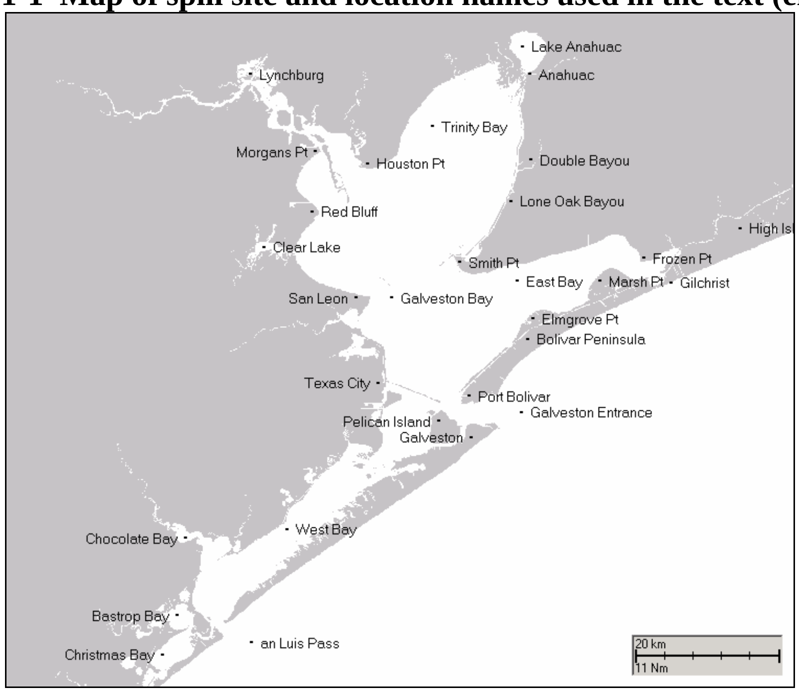

Figure C-I.1.1-2 Map of spill site and location names used in the text (Galveston Bay).

C-I.1.2 Gridded Depth Data

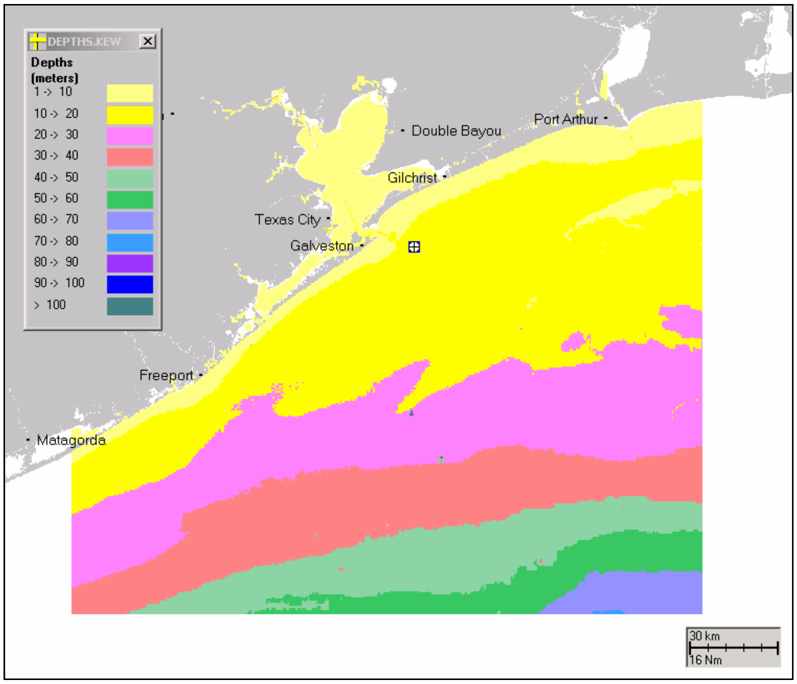

Figure C-I.1.2-1 Gridded depth data used in model runs (entire grid).

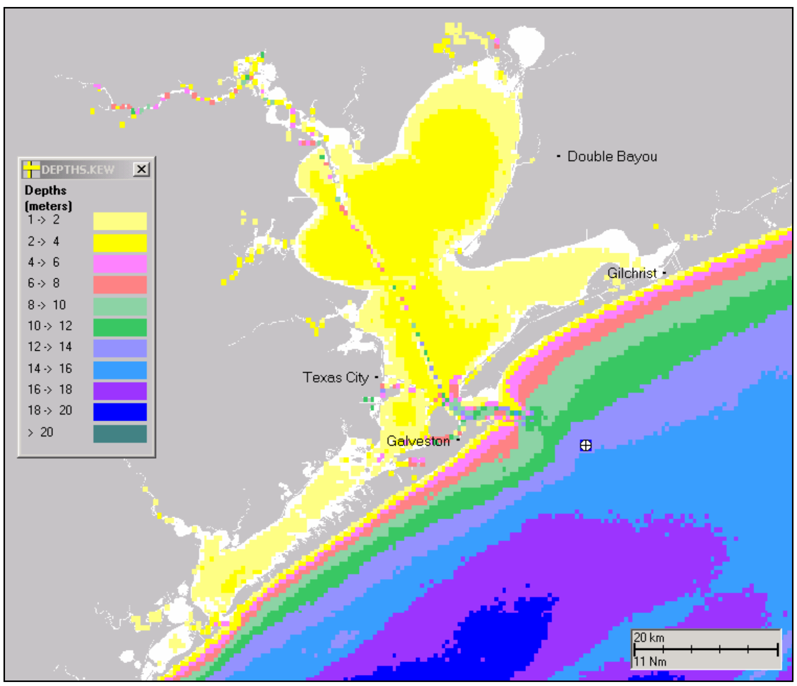

Figure C-I.1.2-2 Gridded depth data used in model runs (Galveston Bay).

C-I.1.3 Gridded Habitat Mapping

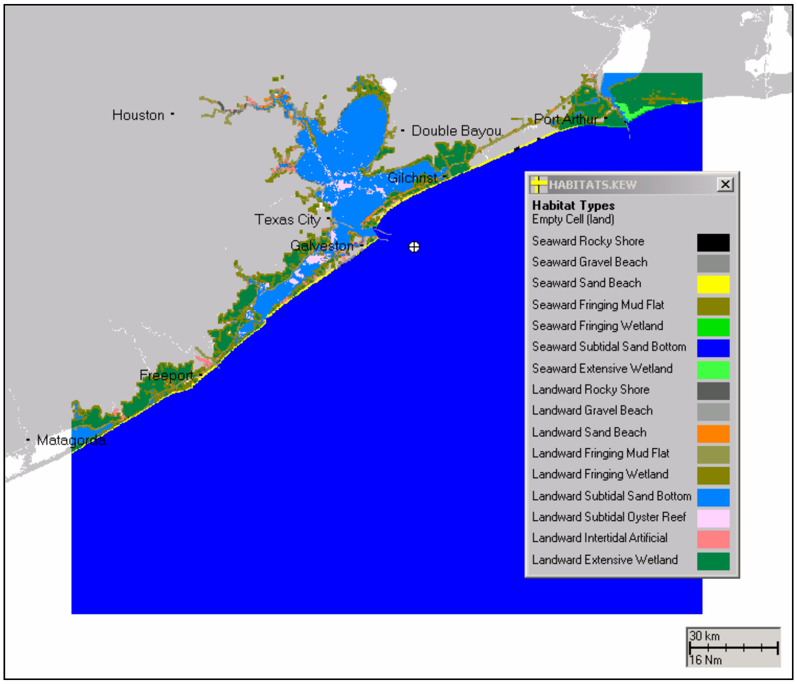

Figure C-I.1.3-1 Gridded habitat map used in model runs (entire grid).

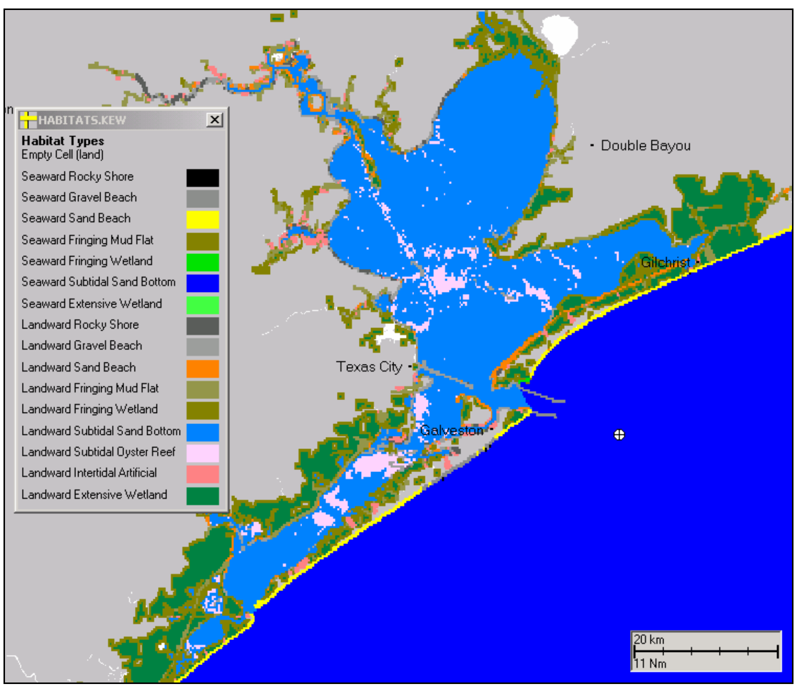

Figure C-I.1.3-2 Gridded habitat map used in model runs (Galveston Bay).

C-I.1.4 Dispersant Application Areas for Response

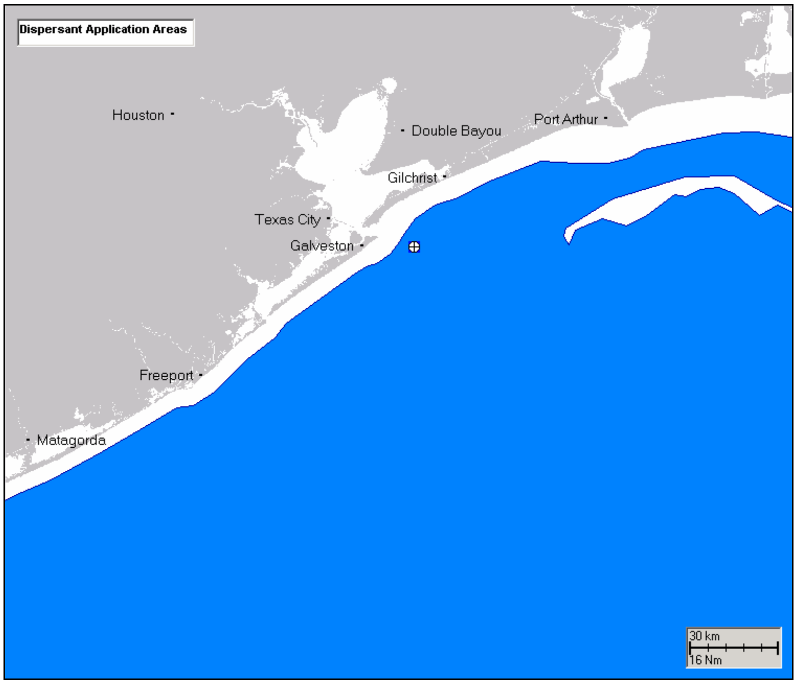

Figure C-I.1.4-1 Map of dispersant application areas (blue shaded area is where dispersants are assumed applied).

C-I.2 Current Data

C-I.2.1 Hydrodynamic Model for Prediction of Currents

The modeling domain included Galveston Bay and the coastal area of the Gulf of Mexico extending 235 km along shore to the east, 275 km along shore to the west and 195 km into the offshore Gulf of Mexico from the Galveston Bay entrance. For simulation of currents, tides were forced along the east and west boundaries. The forcing functions applied were major harmonic constituents (M_2, S_2, K_1 and O_1) derived from Tides and Currents time series (Tides & Currents Pro for Windows, Version 3.0. Nautical Software Inc.) generated for Atchafalaya Bay and Port Aransas, representing the east and west boundaries, respectively. Since minimal boundary forcing was expected from offshore due to the coastal currents flowing parallel to the coastline, no forcing was applied along the offshore boundary.

Another forcing function applied for the current simulations was river flow that discharges into Galveston Bay from primarily Harris County, Fort Bend County and Galveston County. The flow applied was 100 m^3/s, which is a climatological mean value derived from combined measurements from several USGS stream flow gauging stations in the counties (http://waterdata.usgs.gov/tx/nwis).

The circulation in Galveston Bay and adjacent waters of the coastal area is rather simple, except area around Pelican Island and Mud Island. A characteristic of the circulation is that the movement varies at the same frequency as semi-diurnal M_2 tide. Maximum currents occur approximately midway between the high and low tides, indicating standing waves. Maximum currents observed in the simulation were at Galveston Entrance and San Luis Pass, with magnitude of 60 cm/s and 100 cm/s, respectively. The currents at San Luis Pass, however, lags behind Galveston Entrance by about 1.5 hours. In general, near-shore currents are small, on the order of 20 cm/s, and vary at the semi-diurnal frequency as well.

The crosshair mark () in the figures below represents oil spill site.

C-I.2.2 Current Vector Plots at Selected Times

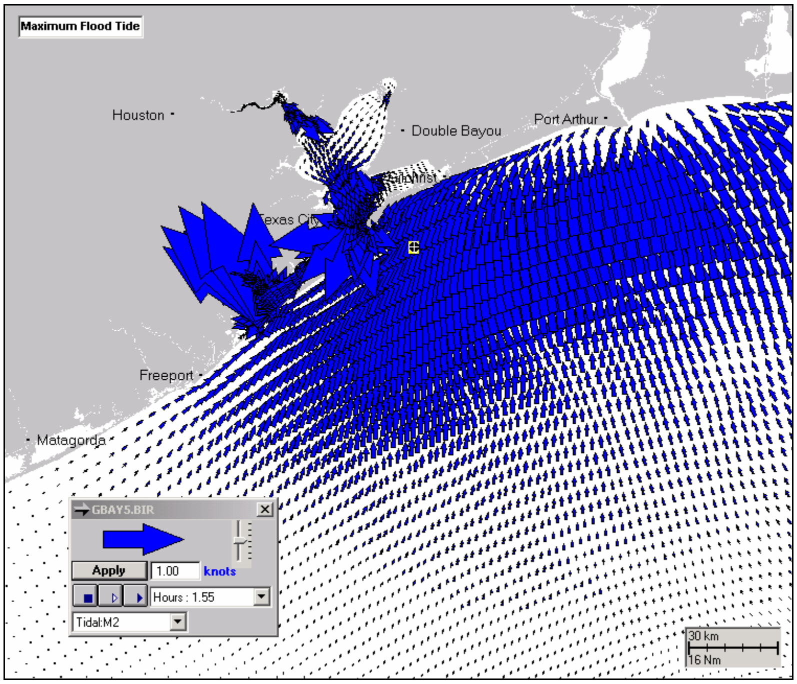

Figure C-I.2.2-1 Current vectors at maximum flood tide (entire grid).

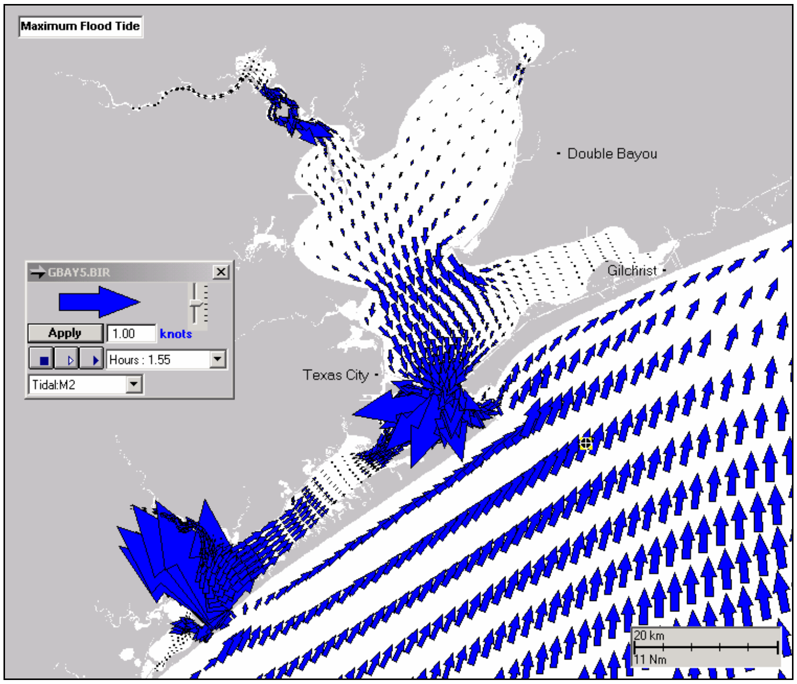

Figure C-I.2.2-2 Current vectors at maximum flood tide (Galveston Bay).

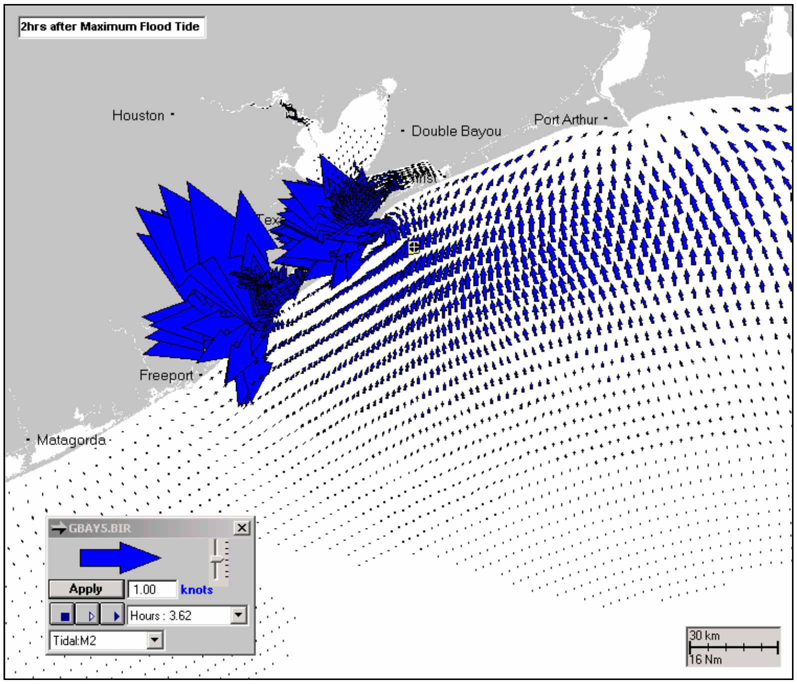

Figure C-I.2.2-3 Current vectors at 2 hours after maximum flood tide (entire grid).

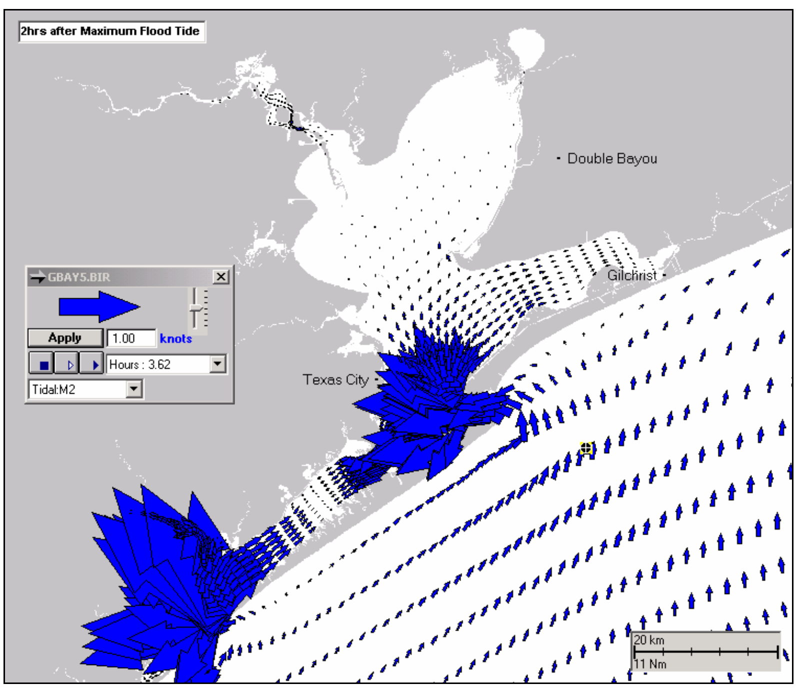

Figure C-I.2.2-4 Current vectors at 2 hours after maximum flood tide (Galveston Bay).

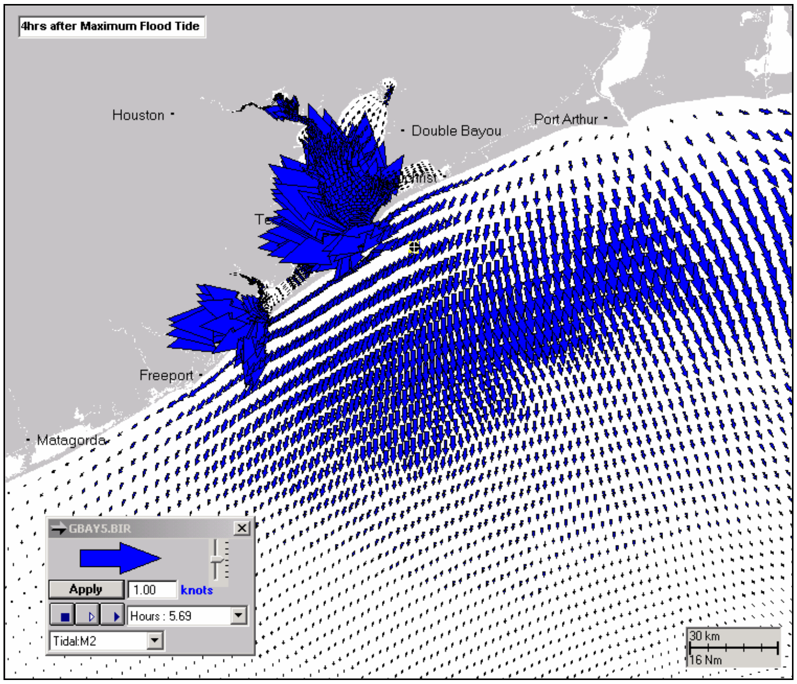

Figure C-I.2.2-5 Current vectors at 4 hours after maximum flood tide (entire grid).

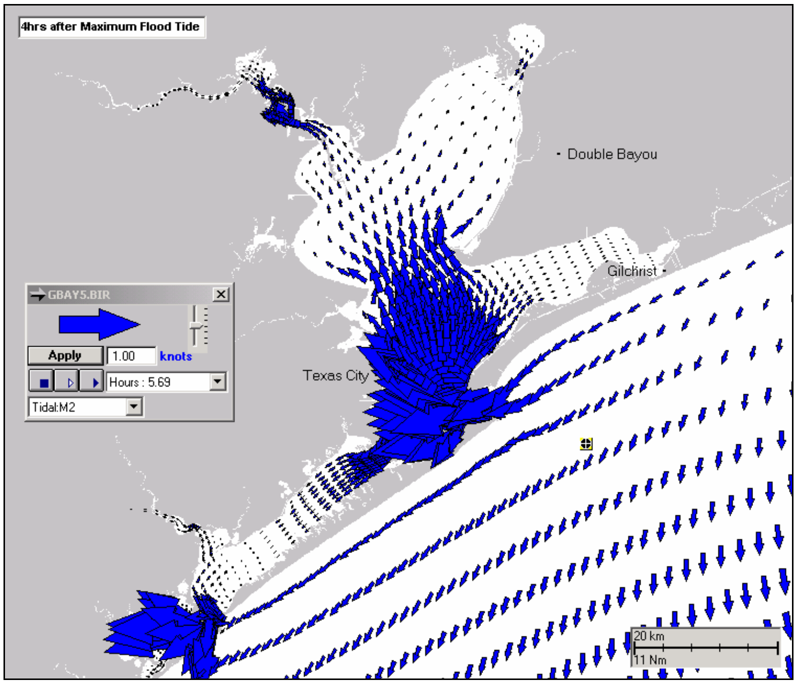

Figure C-I.2.2-6 Current vectors at 4 hours after maximum flood tide (Galveston Bay).

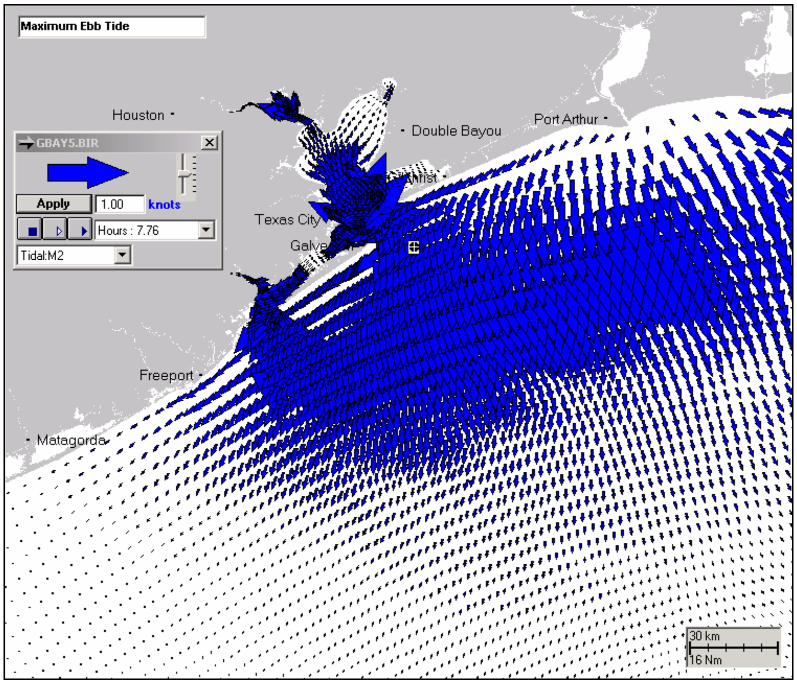

Figure C-I.2.2-7 Current vectors at maximum ebb tide (entire grid).

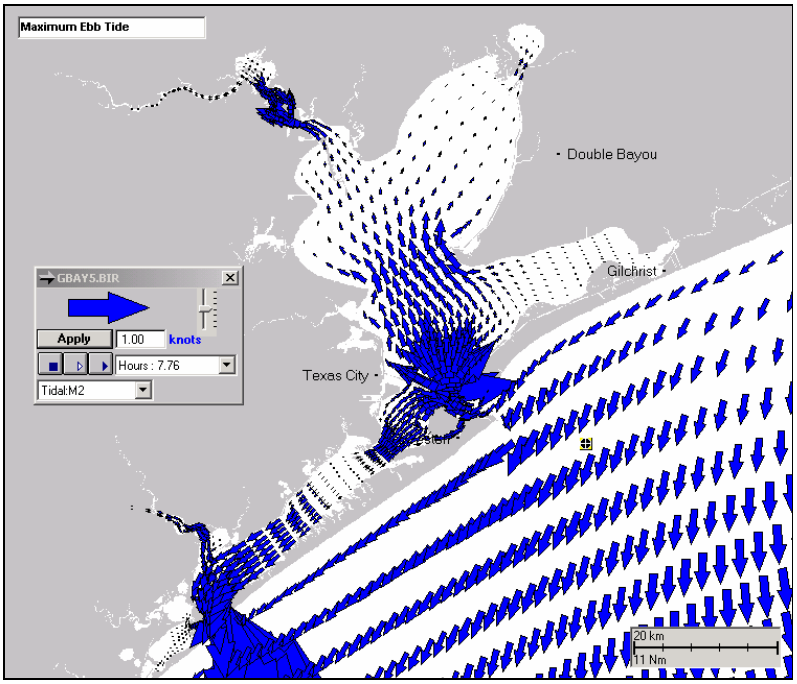

Figure C-I.2.2-8 Current vectors at maximum ebb tide (Galveston Bay).

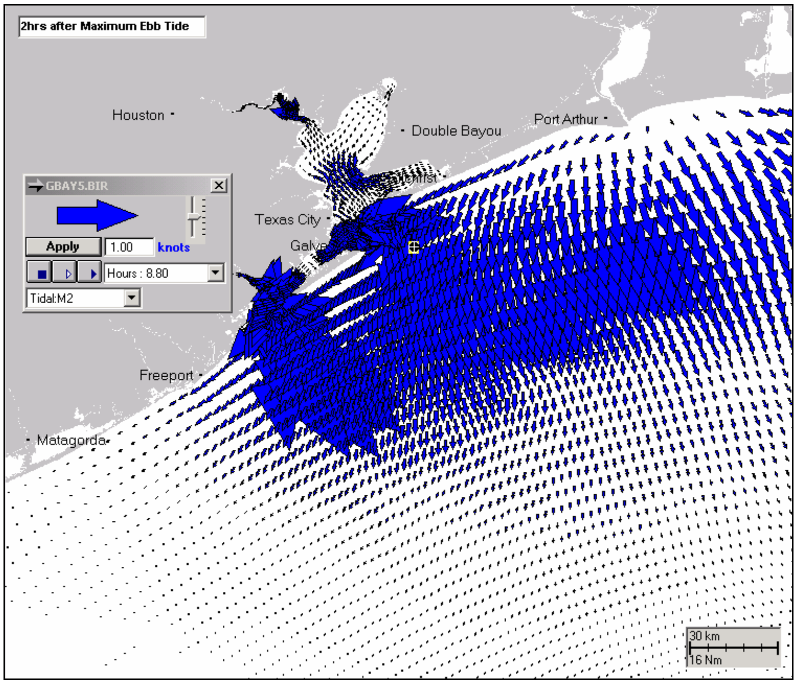

Figure C-I.2.2-9 Current vectors at 2 hours after maximum ebb tide (entire grid).

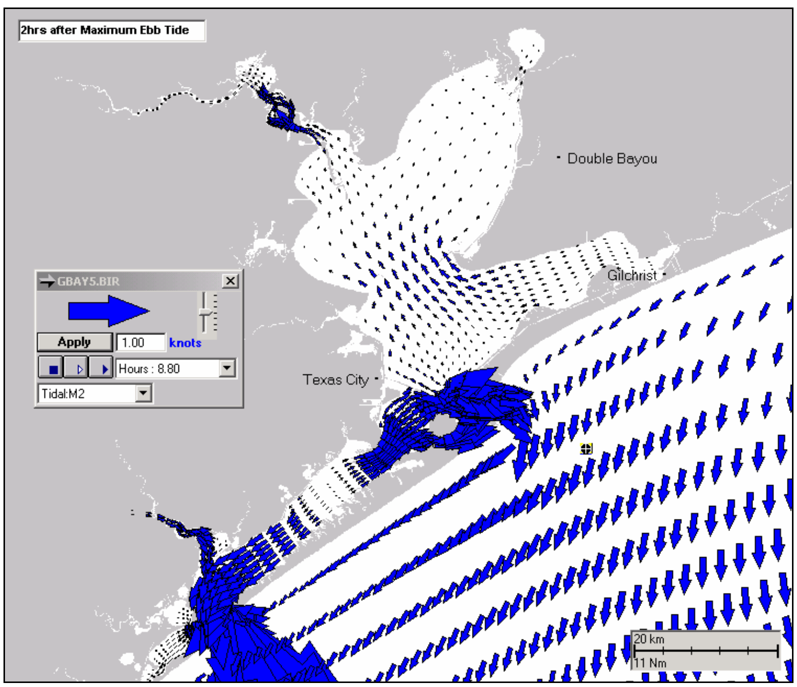

Figure C-I.2.2-10 Current vectors at 2 hours after maximum ebb tide (Galveston Bay).

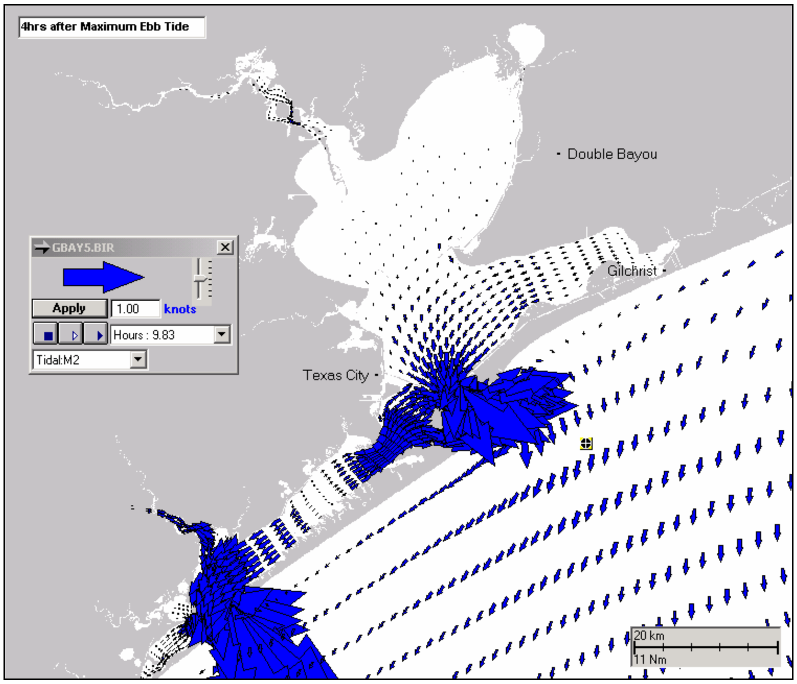

Figure C-I.2.2-11 Current vectors at 4 hours after maximum ebb tide (entire grid).

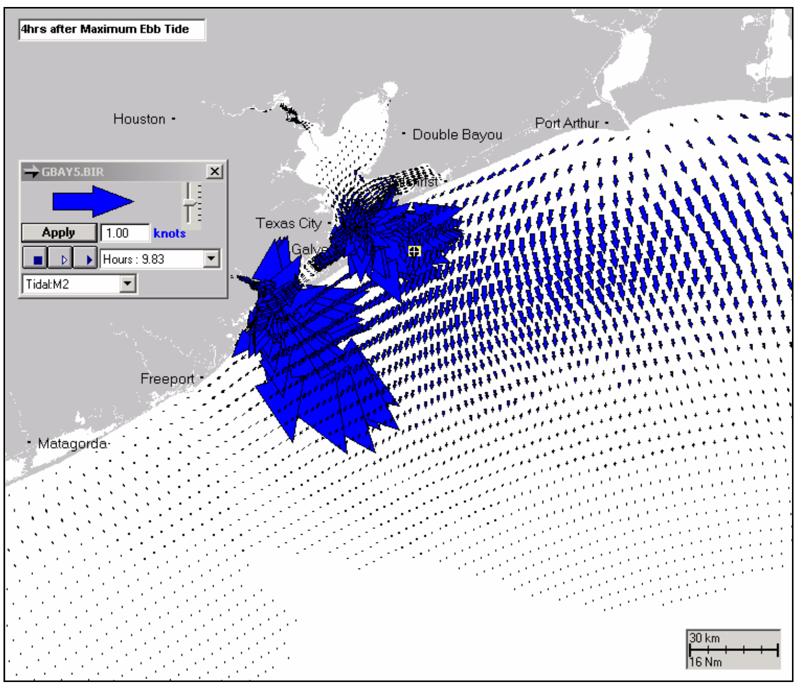

Figure C-I.2.2-12 Current vectors at 4 hours after maximum ebb tide (Galveston Bay).

C-I.3 Oil Properties

Table C-I.3-1. Oil properties for South Louisiana crude oil.

Property	Value	Reference
Density @ 25 deg. C (g/cm3)	0.8518	Jokuty et al. (1999)
Viscosity @ 25 deg. C (cp)	8.0	Jokuty et al. (1999)
Surface Tension (dyne/cm)	25.9	Jokuty et al. (1999)
Pour Point (deg. C)	-28	Jokuty et al. (1999)
Adsorption Rate to Suspended Sediment	0.01008	Kolpack et al. (1977)
Adsorption Salinity Coef.(/ppt)	0.023	Kolpack et al. (1977)
Fraction monoaromatic hydrocarbons (MAHs)	0.01478	Jokuty et al. (1999)
Fraction polynuclear aromatic hydrocarbons (PAHs)	0.008108	French (1998c)
Fraction 2-ring aromatics (included in PAHs above)	0.003104	French (1998c)
Fraction 3-ring aromatics (included in PAHs above)	0.005004	French (1998c)
Fraction Non-Aromatic Volatiles: boiling point < 180^oC	0.16522	Jokuty et al. (1999)
Fraction Non-Aromatic Volatiles: boiling point 180-264^oC	0.18590	Jokuty et al. (1999)
Fraction Non-Aromatic Volatiles: boiling point 264-380^oC	0.62711	Jokuty et al. (1999)
Minimum Oil Thickness (m)	0.00001	McAuliffe (1987)
Maximum Mousse Water Content (%)	75	NOAA (2000a)
Mousse Water Content as Spilled (%)	0	French et al. (1996b)
Water content of fuel (not in mousse, %)	0	French et al. (1996b)
Degradation Rate (/day), Surface & Shore	0.01	National Research Council (1985)
Degradation Rate (/day), Hydrocarbons in Water	0.01	National Research Council (1985)
Degradation Rate (/day), Oil in Sediment	0.001	Haines and Atlas (1982)
Degradation Rate (/day), Aromatics in Water	0.01	French et al. (1996b)
Degradation Rate (/day), Aromatics in Sediment	0.001	French et al. (1996b)

[1] – Jokuty et al. (1999) provided total hydrocarbon data. The aromatic hydrocarbon fraction was subtracted from the total hydrocarbon fraction to obtain the aliphatic fraction.

Table C-I.3-2. Aromatic concentrations (mg/kg) for South Louisiana crude oil.

Aromatic	$Log(K_{ow})$*	Concentration (mg/kg)
benzene	2.13	800
toluene	2.69	2190
ethylbenzene	3.13	710
o-xylene	3.15	0
p-xylene	3.18	0
m-xylene	3.2	0
xylenes	3.18	5360
1,2,3-trimethylbenzene	3.55	0
1,3,4-trimethylbenzene	3.6	0
1,3,5-trimethylbenzene	3.58	0
trimethylbenzenes	3.58	0
n-propylbenzene	3.69	0
iso-propylbenzene	3.63	0
ethyl-methylbenzenes	3.63	0
iso-propyl-4-methylbenzene	4.10	0
butylbenzenes	4.12	0
tetramethylbenzenes	4.01	0
styrene	3.05	0
methylstyrenes	3.35	0
tetralin	3.83	0
diphenylmethane	4.14	0
naphthalene	3.37	364.0
C1-naphthalenes	3.87	1400.0
C2-naphthalenes	4.37	1340.0
C3-naphthalenes	5.00	1200.0
C4-naphthalenes	5.55	637.0
acenaphthylene	4.07	11.4
acenaphthene	3.92	9.0
biphenyls	3.9	68.5
dibenzofuran	4.31	0.0
fluorene	4.18	34.4
C1-fluorenes	4.97	60.2
C2-fluorenes	5.20	223.0
C3-fluorenes	5.50	227.0

*Estimates of $log(K_{ow})$ are from Mackay et al. (1992a,b) and Neff and Burns (1996).

Table C-I.3-2. Aromatic concentrations (mg/kg) for South Louisiana crude oil (continued).

Aromatic	Log(Kow)*	Concentration (mg/kg)
anthracene	4.54	2.5
phenanthrene	4.57	90.2
C1-phenanthrenes/ anthracenes	4.49	278.0
C2-phenanthrenes/ anthracenes	5.14	327.0
C3-phenanthrenes/ anthracenes	5.25	254.0
C4-phenanthrenes/ anthracenes	6.00	104.0
dibenzothiophene	6.51	79.9
C1-dibenzothiophene	4.49	315.0
C2-dibenzothiophene	4.86	570.0
C3-dibenzothiophene	5.50	513.0
fluoranthene	5.73	0.0
pyrene	5.22	0.0
Total $\log(K_{ow}) \leq 5.6$	5.18	22037.1

*Estimates of log(Kow) are from Mackay et al. (1992a,b) and Neff and Burns (1996).

C-I.4 Inputs to the SIMAP Oil Spill Model

This section summarizes the model input data for the scenarios run and the sources for that information. The approach and sources applicable to all modeled locations are described in Part A, Section A.3 of this technical report. Specifics to this model location are below. Thus, the reader should refer to Part A, Section A.3 for background and the context within which these data are used.

The model grid and cell size (Table C-I.4-4) were set to provide the maximum resolution (minimum cell size) possible within the memory constraints of the model, while also providing sufficient geographic coverage to encompass the maximum extent of oiling possible for a large volume scenario. Test runs (randomizing weather conditions) were made with the largest spill volume simulated (40,000 bbl) and assuming no dispersant application. The maximum extent of surface oiling was determined and the grid size set to cover that area (Figure C-I.1.3-1).

Table C-I.4-1. Inputs to the Fates Model for Stochastic Scenarios.

Name	Description	Units	Source(s) of Information	Value(s)
Spill Site(s)	Location of the spill site	-	(Part A, Section A.3.6)	Spill site 7.5 nmiles from entrance to port
Spill Latitude	Latitude of the spill site	Degrees	Chart (Part A, Section A.3.6)	29^{o} 18.124' N
Spill Longitude	Longitude of the spill site	Degrees	Chart (Part A, Section A.3.6)	94^{o} 35.86' W
Depth of release	Depth below the water surface of the release or 0 for surface release	m	assumed (Part A, Section A.3.6)	0 m
Start time and date	Randomized over selected months of the year	Date, hr,min	randomized (Part A, Section A.2.4)	Jan-Dec
Spill duration	Hours over which the release occurs	Hours	(Part A, Section A.3.6)	Large – 4 Small – 1
Total spill amount	Total volume (or weight) released (maximum if range)	bbl	(Part A, Section A.3.6)	Large – 40,000 Small – 2,500
Randomize spill amount	Volume spilled is constant or maximum of range	-	-	Constant
Model time step	Time step used for model calculations	Hours	(Part A, Section A.2.1)	0.2
Model duration	Length of each model simulation	Days	(Part A, Section A.3.6)	14 days
Number of runs	Number of random start times to run in stochastic mode	#	(Part A, Section A.2.4)	100
Number of surface spillets	Number of Lagrangian elements used to simulate mass floating on the surface	#	(Part A, Section A.2)	500
Number of aromatic spillets	Number of Lagrangian elements used to simulate dissolved aromatics in the water	#	(Part A, Section A.2)	2000

Table C-I.4-1. Inputs to the Fates Model for Stochastic Scenarios (continued).

Fates Output Threshold: floating on water surface	Slick or surface mass thickness passing through a grid cell	g/m^2 (microns)	Minimum value for sheens (Part A, Section A.4.1)	0.01
Fates Output Threshold: shoreline	Total hydrocarbons deposited on shorelines, averaged over each habitat grid cell.	g/m^2 (microns)	Minimum value for sheens (Part A, Section A.4.1)	0.01
Fates Output Threshold: dissolved aromatics in water or sediment	Dissolved concentration of aromatics with $\log(K_{ow}) \leq 5.6$ (bioavailable fraction)	mg/m^3 = $\mu g/L$ = ppb	Below minimum for effects to sensitive species exposed for at least two weeks (Part A, Section A.4.1)	1
Fates Output Threshold: Subsurface (water) total hydrocarbons	Concentration of total hydrocarbons in droplets	mg/m^3 = $\mu g/L$ = ppb	Minimum value with no potential for impact (Part A, Section A.4.1)	10
Fates Output Threshold: Sediment total hydrocarbons	Total hydrocarbon loading to sediments, averaged over each habitat grid cell.	g/m^2	Minimum value with no potential for impact (Part A, Section A.4.1)	0.0001 g/m^2 (which is 1.0 mg/m^3 = 1ppb averaged over the top 10cm)
Salinity	Surface water salinity	ppt	French et al. (1996b) province 37	36

Table C-I.4-1. Inputs to the Fates Model for Stochastic Scenarios (continued).

Surface Water Temper-ature	Water temperature at the sea surface	Degrees C	French et al. (1996b) province 37	monthly means (see Table D-4)
Subsurface Water Temper-ature	Water temperature for subsurface	Degrees C	French et al. (1996b) province 37	monthly means (see Table D-4)
Air Temper-ature	Air water temperature at water surface	Degrees C	(assume = water temperature; Part A, Section A.4.1)	(= water temperature)
Fetch	Fetch = distance to land to N, S, E, W (if landfall not in model domain)	km	Chart	N & W: (calculated from model grid) E: 320 S: 1,000
Wind drift speed	Speed oil moves down wind relative to wind	% of wind speed	Youssef (1993); Youssef and Spaulding (1993)	(model calculated)
Wind drift angle	Angle to right of wind (in northern hemisphere) that oil drifts	Deg. to right of down wind	Youssef (1993); Youssef and Spaulding (1993, 1994)	(model calculated)
Horizontal turbulent diffusion coefficient	Randomized turbulent mixing parameter in x & y	m^2/sec	French et al. (1996a, 1999) based on Okubo (1971)	1 m^2/sec (estuaries and low energy coastal areas)
Vertical turbulent diffusion coefficient	Randomized turbulent mixing parameter in z	m^2/sec	French et al. (1996a, 1999) based on Okubo (1971)	0.0001 m^2/sec
Suspended sediment concentrati on	Average suspended sediment concentration during spill period	mg/l	French et al. (1996b)	10 mg/l
Suspended sediment settling rate	Net settling rate for suspended sediments	m/day	French et al. (1996b)	1 m/day
Density change	Rate of change of droplet density due to adsorption of sediment	g/cm^3/hr	(data not available – fuel oil algorithm used)	0

Table C-I.4-2. Description of scenario runs.

Scenario Name	Description
Gal-Lrg-50-0	Large Spill; Removal at 50%; No Dispersant;
Gal-Lrg-50-80	Large Spill; Removal at 50%; Dispersant at 80% efficiency;
Gal-Lrg-50-45	Large Spill; Removal at 50%; Dispersant at 45% efficiency;
Gal-Med-50-0	Medium Spill; Removal at 50%; No Dispersant;
Gal-Med-50-80	Medium Spill; Removal at 50%; Dispersant at 80% efficiency;
Gal-Med-50-45	Medium Spill; Removal at 50%; Dispersant at 45% efficiency;

Table C-I.4-3. Matrix of scenarios run.

Scenario Name	Fuel	Latitude, Longitude	Depth (m)	Dura-tion (hr)	Volume (bbl) Released	Mechanical Removal Efficiency	Dispersant Efficiency
Gal-Lrg-50-0	South Louisiana crude	29.30207 N 94.59766 W	0 m (surface)	4	40,000	50%	none
Gal-Lrg-50-80	South Louisiana crude	29.30207 N 94.59766 W	0 m (surface)	4	40,000	50%	80%
Gal-Lrg-50-45	South Louisiana crude	29.30207 N 94.59766 W	0 m (surface)	4	40,000	50%	45%
Gal-Med-50-0	South Louisiana crude	29.30207 N 94.59766 W	0 m (surface)	1	2,500	50%	none
Gal-Med-50-80	South Louisiana crude	29.30207 N 94.59766 W	0 m (surface)	1	2,500	50%	80%
Gal-Med-50-45	South Louisiana crude	29.30207 N 94.59766 W	0 m (surface)	1	2,500	50%	45%

Table C-I.4-4. Dimensions of the habitat grid cells used to compile statistics for multiple fates model runs.

Item	Value
Grid W edge	28.162°W
Grid S edge	95.814°N
Cell size (°longitude)	0.00281
Cell size (°latitude)	0.00281
Cell size (m) west-east	274.99
Cell size (m) south-north	311.91
# cells west-east	800
# cells south-north	600
Water cell area (m^2)	85,770.9
Shore cell length (m)	292.87
Shore cell width – Rocky shore (m)	1.0
Shore cell width – Artificial shore (m)	1.0
Shore cell width – Gravel beach (m)	5.0
Shore cell width – Sand beach (m)	5.0
Shore cell width – Mud flat (m)	5.0
Shore cell width – Wetlands (fringing, m)	5.0

Table C-I.4-5. Water temperature by month of the year (from French et al., 1996b).

Month	Surface Water Temperature (°C)	Bottom Water Temperature (°C)	Pycnocline Depth (m)
January	18	17	20
February	18	17	20
March	18	17	20
April	23	20	20
May	23	20	20
June	23	20	20
July	29	24	10
August	29	24	10
September	29	24	10
October	23	21	20
November	23	21	20
December	23	21	20

Table C-I.4-6. Wind data sources and records used.

File Name	Location	Latitude Longitude	Dates	Data Source
42035_1990-JAN2002.WNE	Buoy 42035 - Galveston 22NM East of Galveston, TX	29.25 N 94.41 W	1994 - 1996 and 1998 - Jan 2002	National Data Buoy Center
	Buoy 42019 - Freeport, TX. 60 NM South of Freeport, TX.	27.92 N 95.36 W	1990-1993	National Data Buoy Center
	Station SRST2 - Sabine, TX	29.67 N 94.05 W	1990-1993 and 1997	National Data Buoy Center

The 42035_1990-JAN2002.WNE wind data were downloaded from 3 buoys 42035, 42019 and SRST2. Figure C-I.4-1 displays where each buoy is located. Buoy 42035 supplied data from 1994 to 1996 and then 1998 to January 2002. 1997 data was supplied by buoy SRST2 and 1990 to 1993 was supplied by a compilation of buoy 42019 and SRST2. The wind data contains two gaps 24 October 1996 to 31 December 1996 and 1 August 1997 to 11 September 1997.

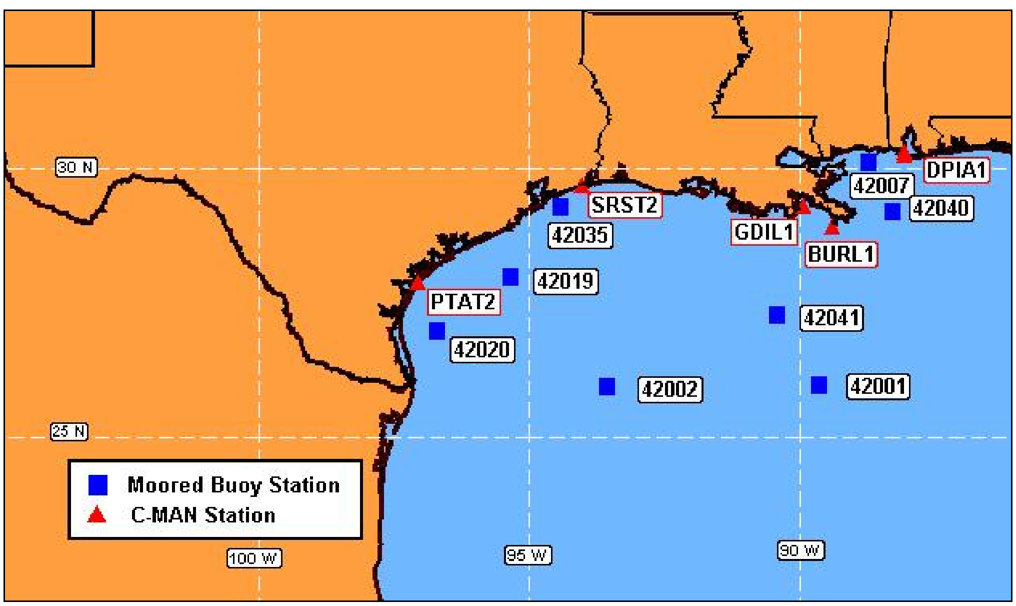

Figure C-I.4-1. Wind Station Locations

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part C: Galveston Bay and North Texas Shelf

Section C-II.1

by

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ASA 00-246

August 2004

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C-II.1 Results of the Stochastic Modeling: Maps of Exposure Probability, Time and Maximum Possible Mass and Concentration

The results of multiple model runs are evaluated to develop the following statistics, for each location (cell in the model grid) and for each exposure index. Maps of the results are contained in this section.

- Probability of exposure greater than the minimum threshold (probability that the minimum threshold thickness or concentration will be exceeded at each location at any time following the spill). For surface oil, the model records if any oil of greater than that thickness passes through the grid cell, regardless of the areal coverage of the oil.   For concentrations, the average concentration in the grid cell is used to determine if the threshold is exceeded.
- Time (hours) to first exceedance of the minimum threshold at each location
- Worst-case maximum exposure (thickness, volume or concentration) at any time after the spill, at a given location (peak exposure at each location delineated by the grid cells). The amounts are averaged over the area of the model grid cell. The worst-case maximum amount is for all possible releases (i.e., maximum peak exposure for all the model runs). This is calculated in two steps: (1) For each individual run (for each spill date run), the maximum amount over all time after the spill is saved for each location in the model grid. (2) The runs are evaluated to determine the highest amount possible at each location. Note that these *worst-case maximum* amounts are not additive over all locations. These represent maximum possible amounts of oil that could ever reach each site (grid cell), considered individually, and based on the model runs performed. Thus, "worst-case" represents the highest exposure of the most adverse of the runs performed.

Exposure indices and minimum thresholds (i.e., those less than values that might have an impact on any resource) used in the modeling were:

- Surface slick or floating oil: $\geq$ 0.01 g/m^2 (average thickness $\geq$ 0.01 micron)
- Shoreline: average mass loading over the shore segment (length of one grid cell, calculated as the cell diagonal length, times the typical width for the habitat type) $\geq$ 0.01 g/m^2
- Dissolved aromatics: average over the water cell $\geq$ 1 ppb (1 mg/m^3)
- Subsurface oil (entrained in water): average over the water cell $\geq$ 10 ppb (10 mg/m^3)
- Sediment total hydrocarbons: average over the cell $\geq$ 0.0001 g/ m^2
- Sediment dissolved aromatic concentrations: average over the cell $\geq$ 0.0001 g/ m^2 (which is 1.0 mg/m^3 = 1ppb averaged over the top 10 cm, the assumed bioturbation zone)

Discussion of exposure indices and minimum thresholds are described in Part A: Description of Models and Assumptions and Section 4.3 of the PEIS.

The Crosshair mark (⊞) in figures below represents oil spill site.

C-II.1.1. Scenario: Medium Volume, No Dispersant

C-II.1.1.1 Surface Floating Total Hydrocarbons. Scenario: Medium Volume, No Dispersant

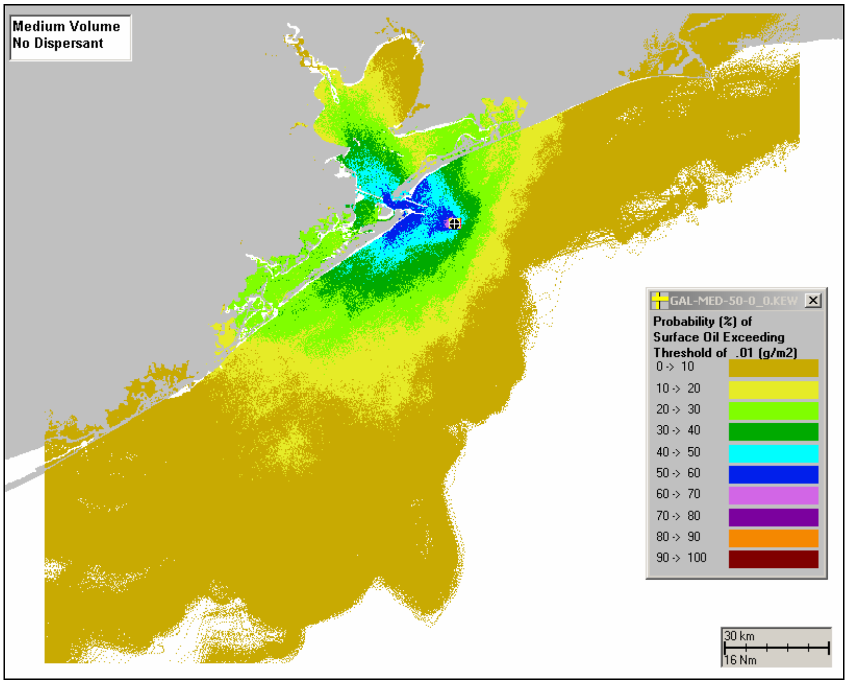

Figure C-II.1.1.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Medium Volume, No Dispersant.

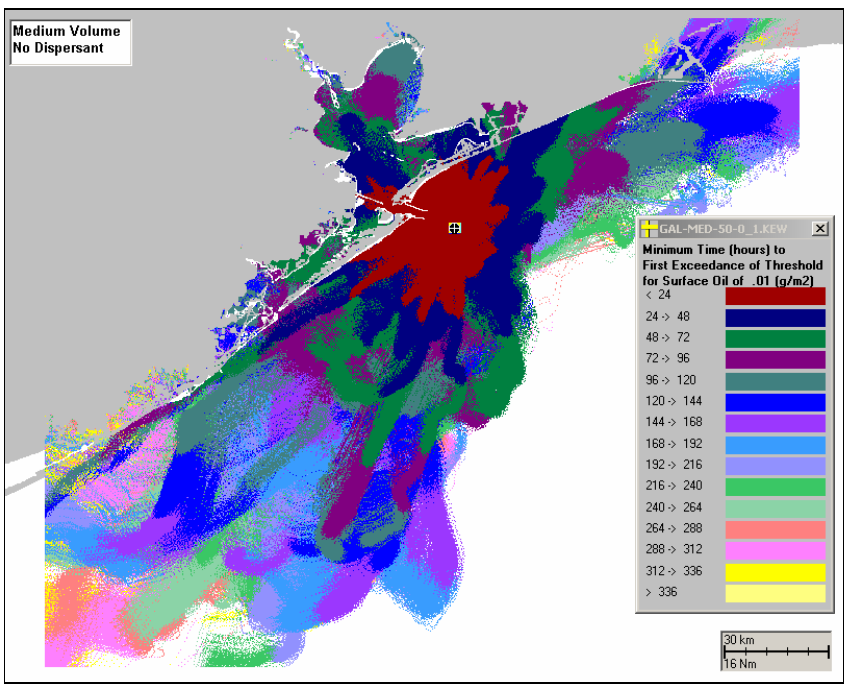

Figure C-II.1.1.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Medium Volume, No Dispersant.

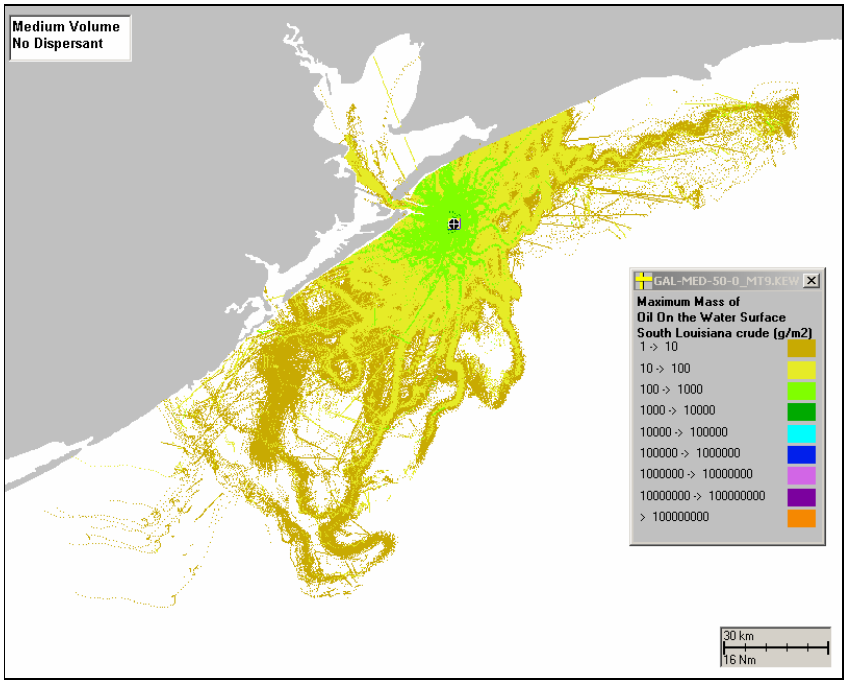

Figure C-II.1.1.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

C-II.1.1.2 Shoreline Oiled. Scenario: Medium Volume, No Dispersant

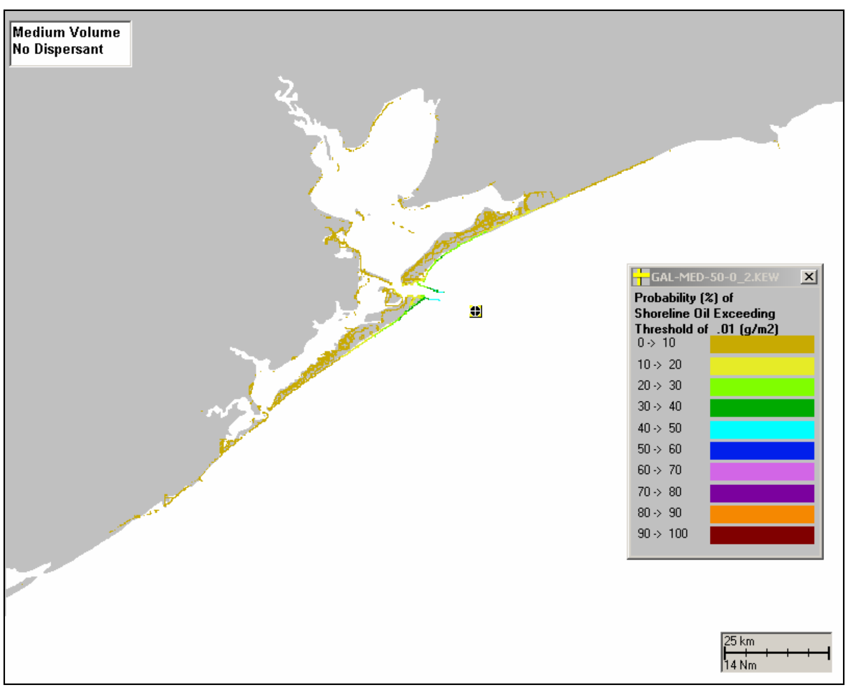

Figure C-II.1.1.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Medium Volume, No Dispersant.

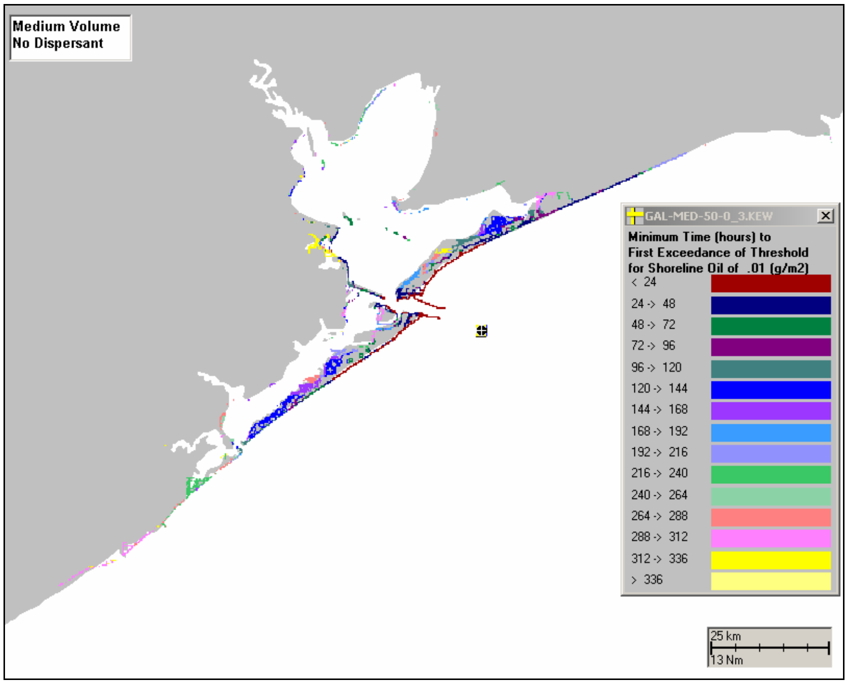

Figure C-II.1.1.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Medium Volume, No Dispersant.

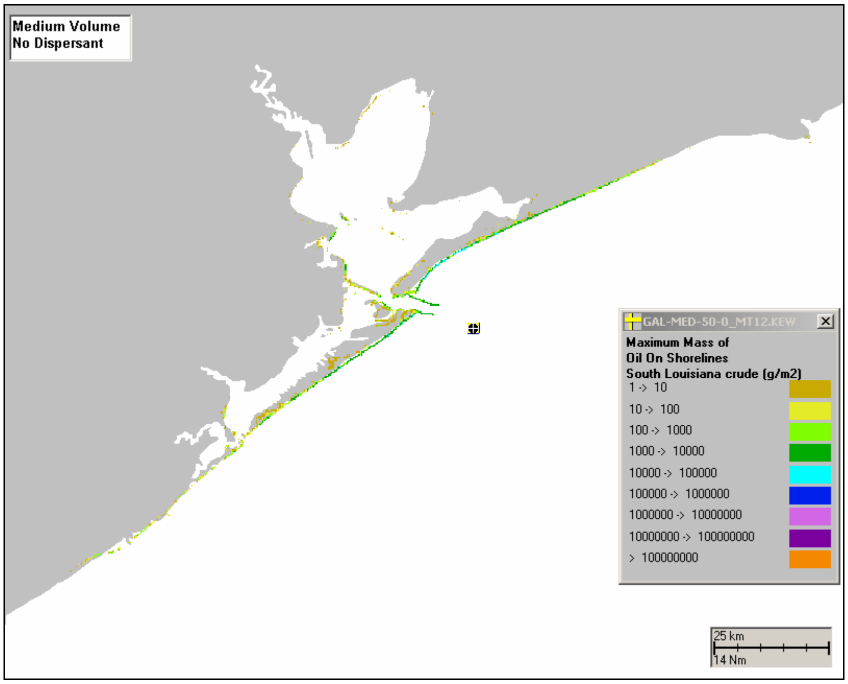

Figure C-II.1.1.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

C-II.1.1.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Medium Volume, No Dispersant

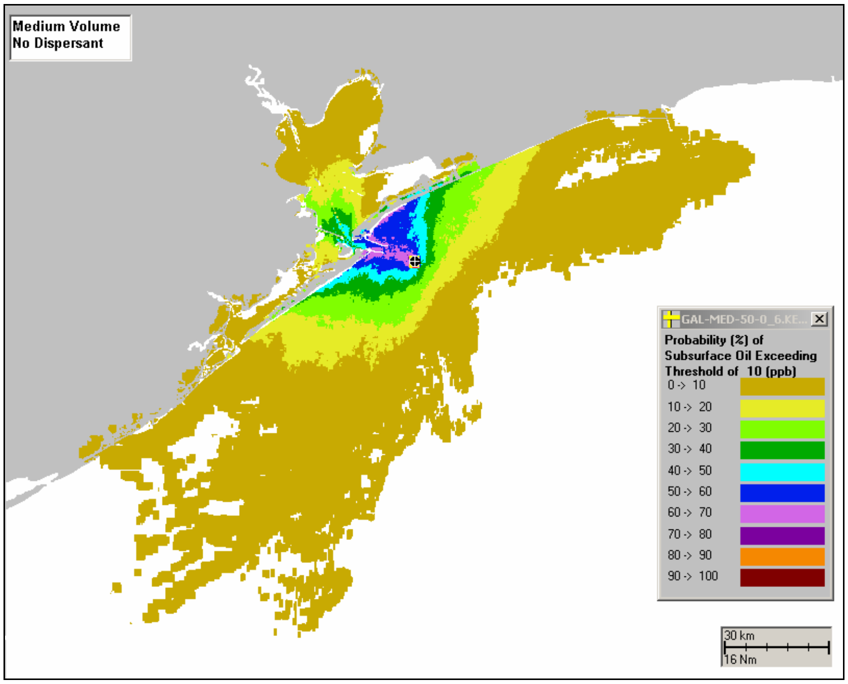

Figure C-II.1.1.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Medium Volume, No Dispersant.

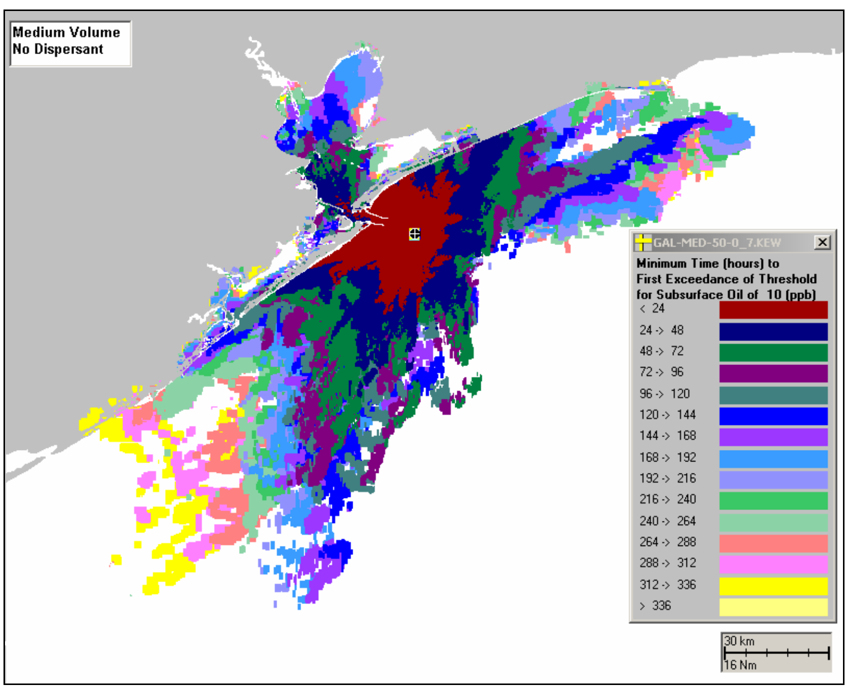

Figure C-II.1.1.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Medium Volume, No Dispersant.

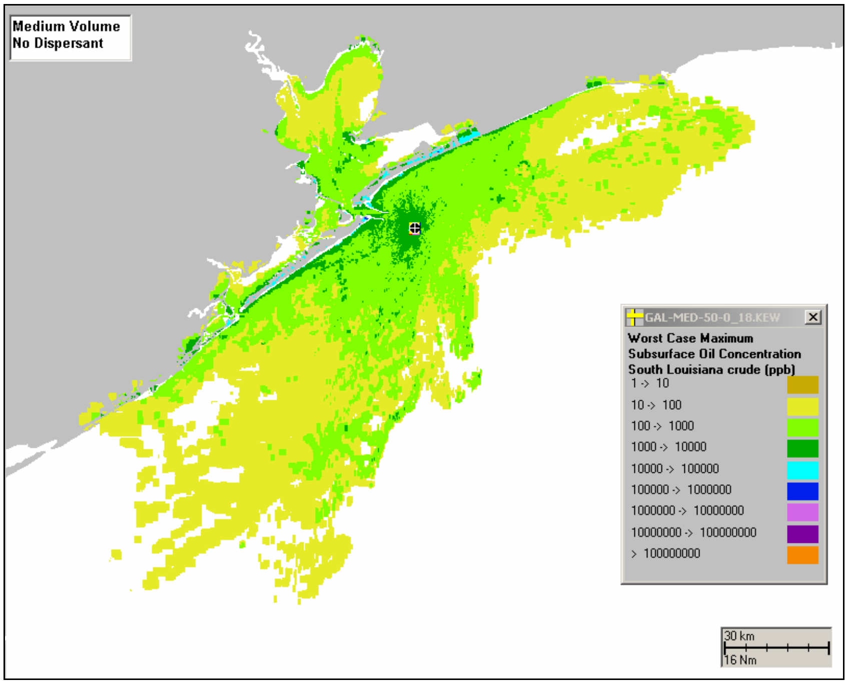

Figure C-II.1.1.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

C-II.1.1.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Medium Volume, No Dispersant

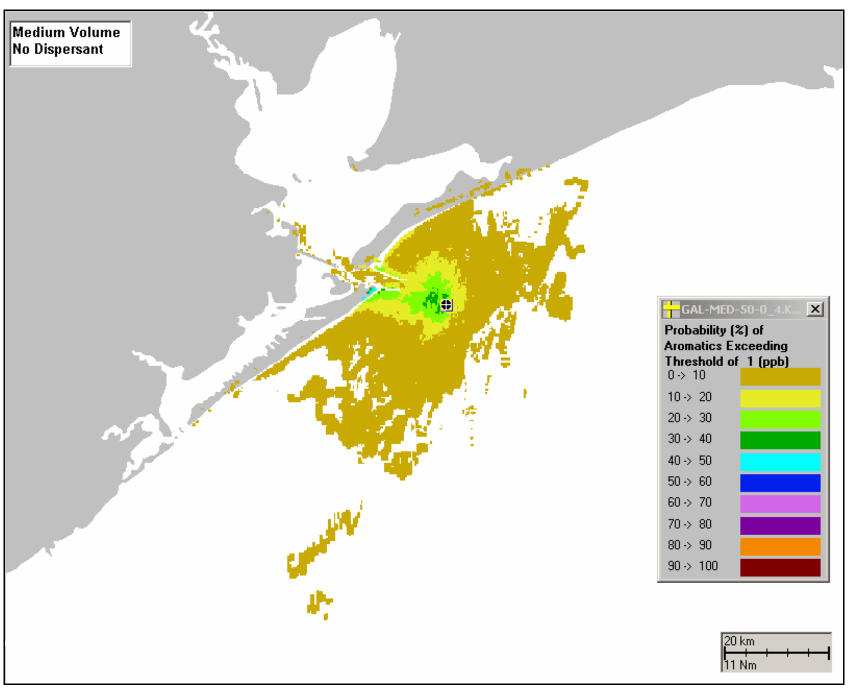

Figure C-II.1.1.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, No Dispersant.

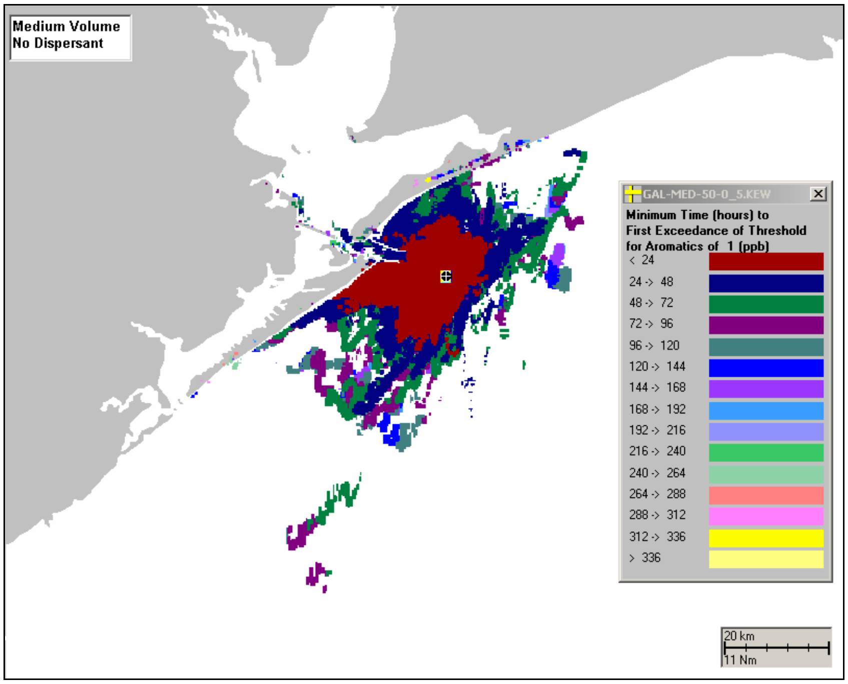

Figure C-II.1.1.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Medium Volume, No Dispersant.

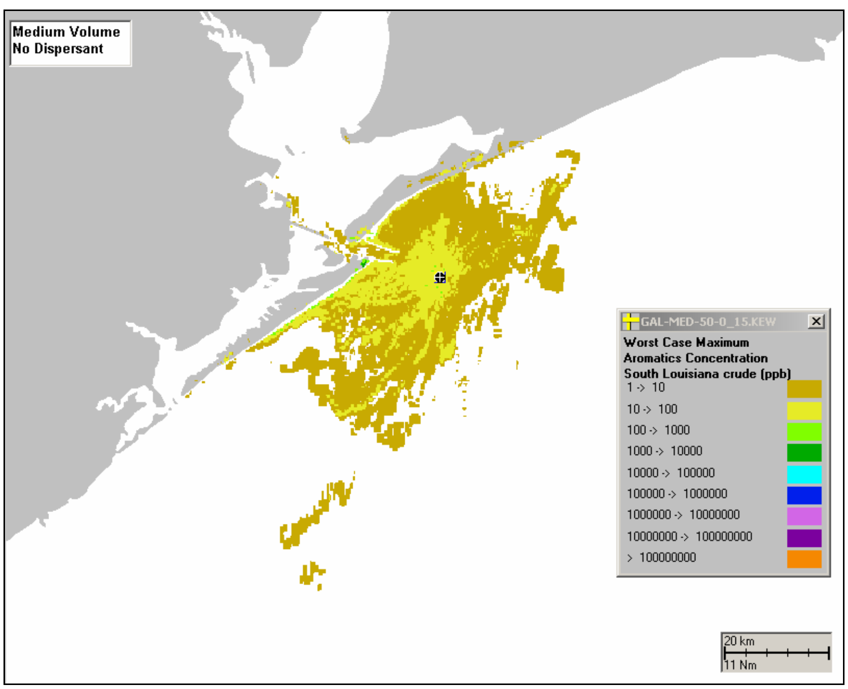

Figure C-II.1.1.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

C-II.1.1.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Medium Volume, No Dispersant

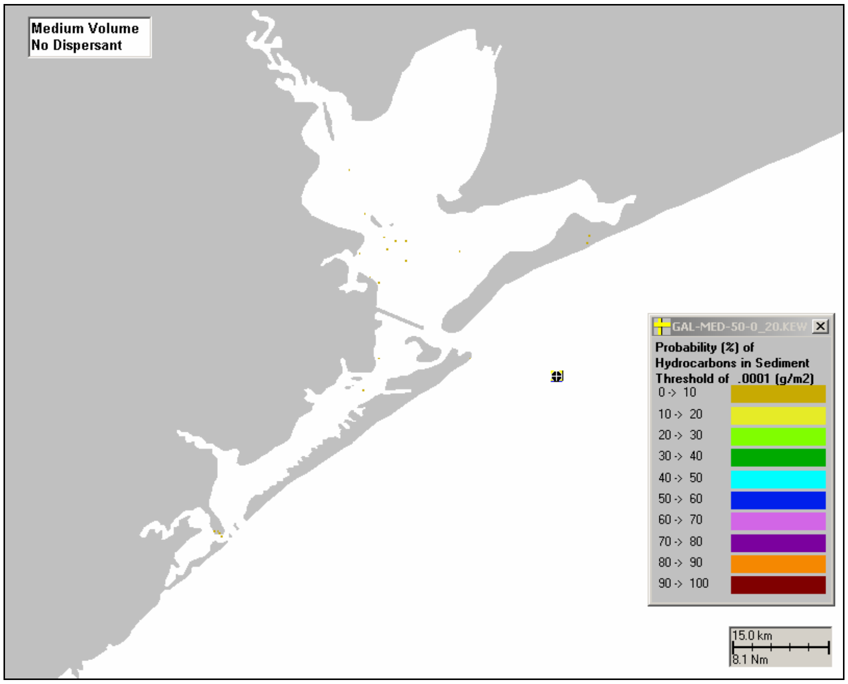

Figure C-II.1.1.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Medium Volume, No Dispersant.

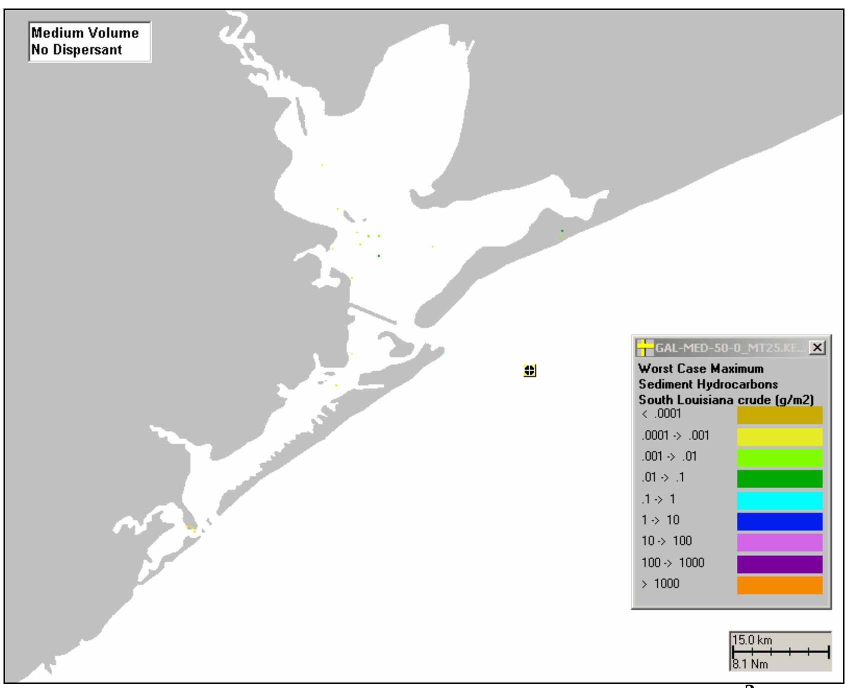

Figure C-II.1.1.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

C-II.1.1.6 Sediment pore water dissolved aromatic concentrations. Scenario: Medium Volume, No Dispersant

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time and for any of the 100 runs) does not exceed threshold of 1 ppb. Scenario: Medium Volume, No Dispersant.

C-II.1.2. Scenario: Medium Volume, 45% Dispersant Efficiency

C-II.1.2.1 Surface Floating Total Hydrocarbons. Scenario: Medium Volume, 45% Dispersant Efficiency

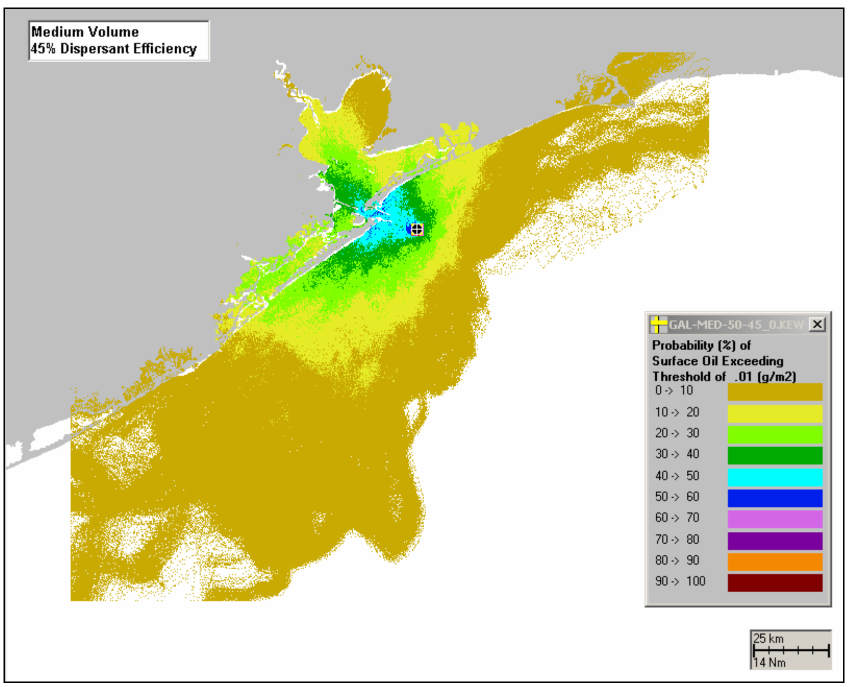

Figure C-II.1.2.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

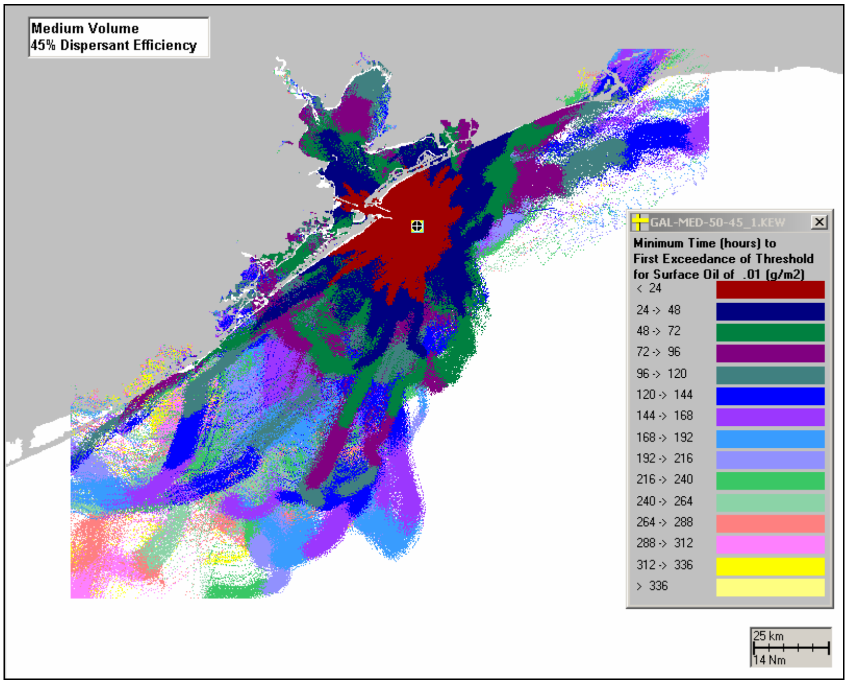

Figure C-II.1.2.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

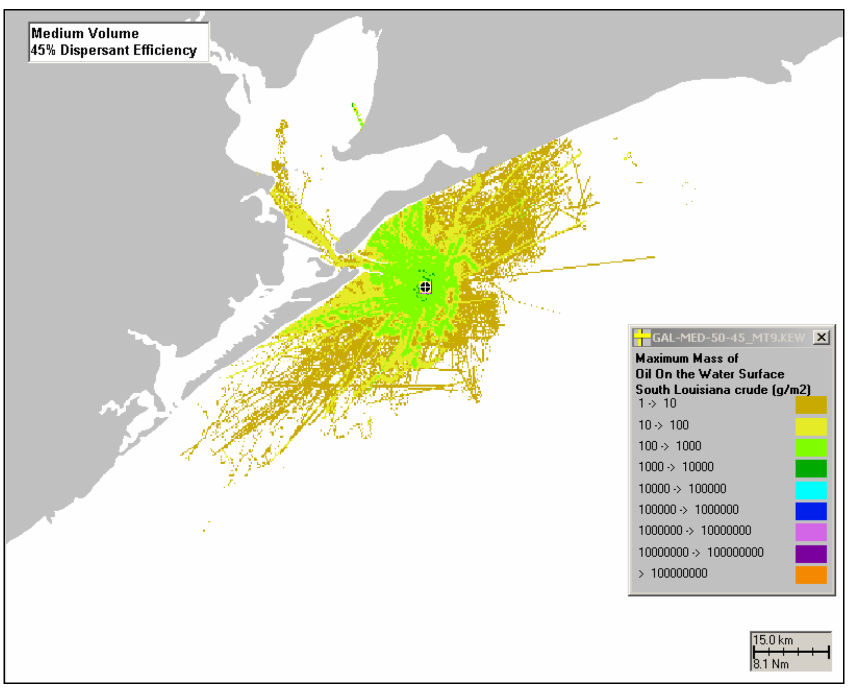

Figure C-II.1.2.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

C-II.1.2.2 Shoreline Oiled. Scenario: Medium Volume, 45% Dispersant Efficiency.

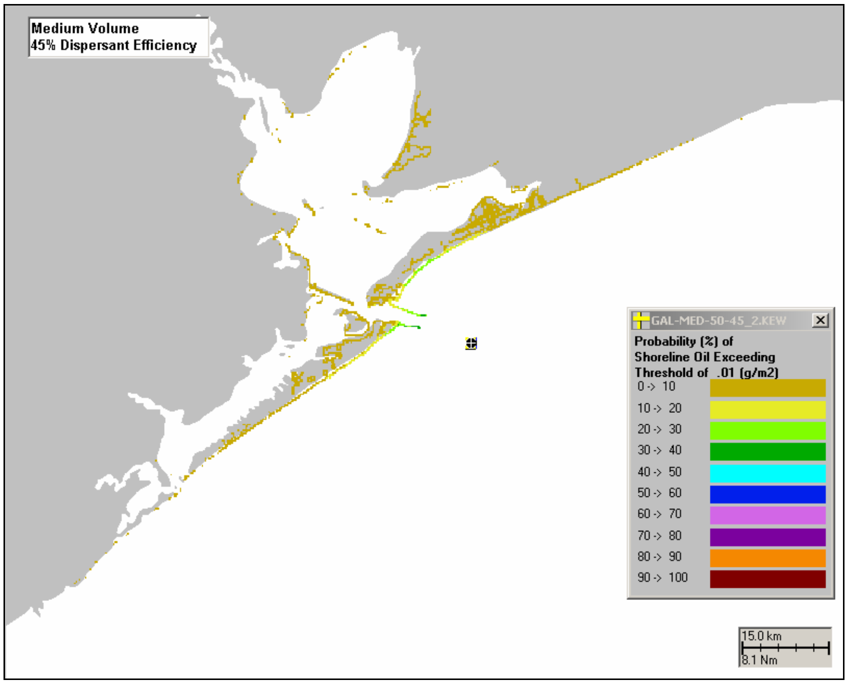

Figure C-II.1.2.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

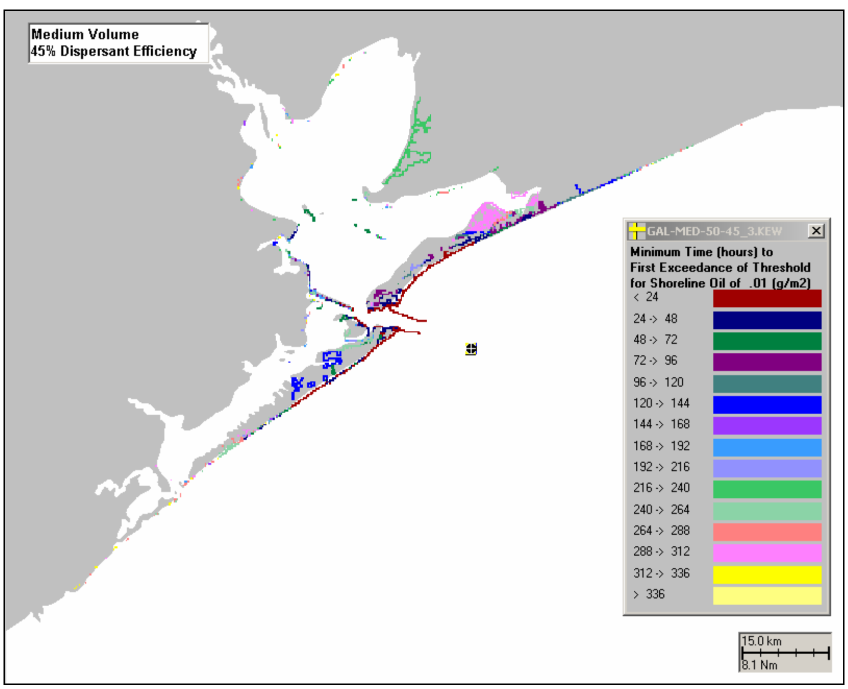

Figure C-II.1.2.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

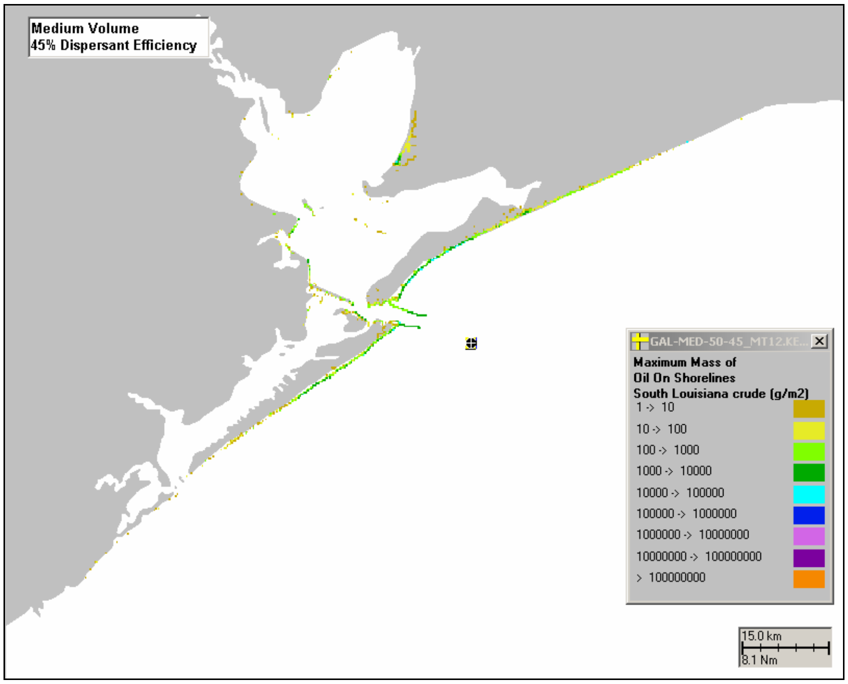

Figure C-II.1.2.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

C-II.1.2.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Medium Volume, 45% Dispersant Efficiency

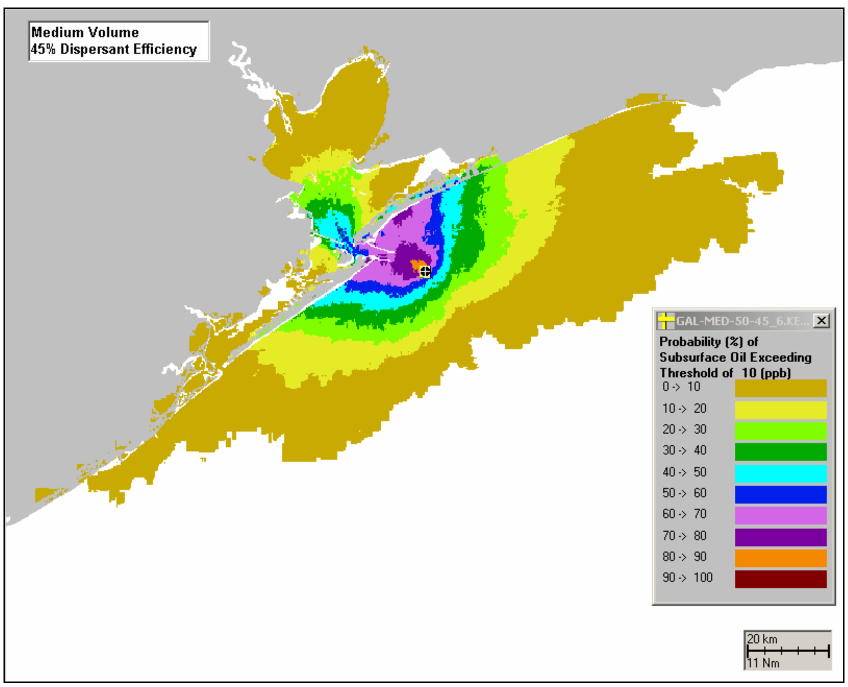

Figure C-II.1.2.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

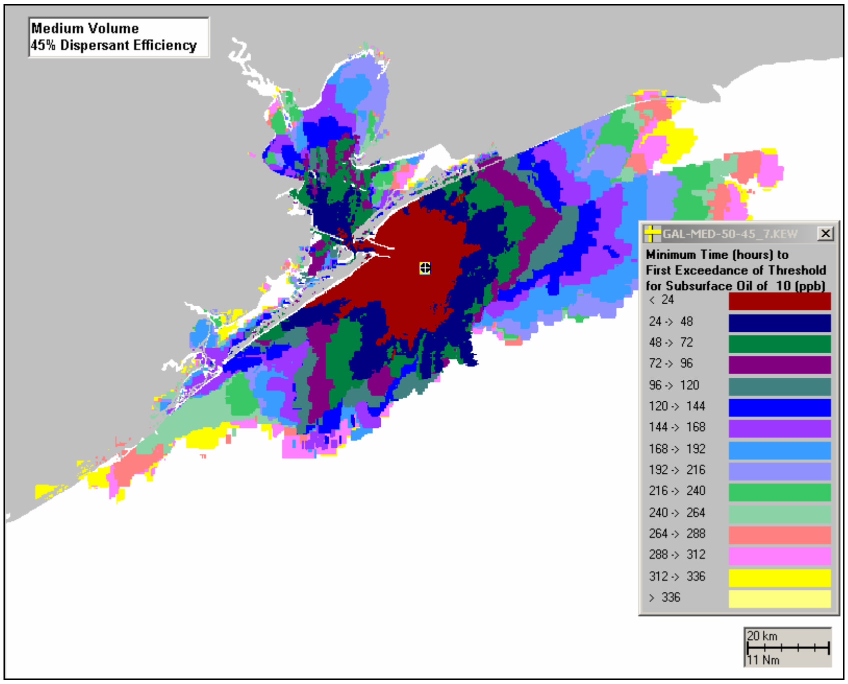

Figure C-II.1.2.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

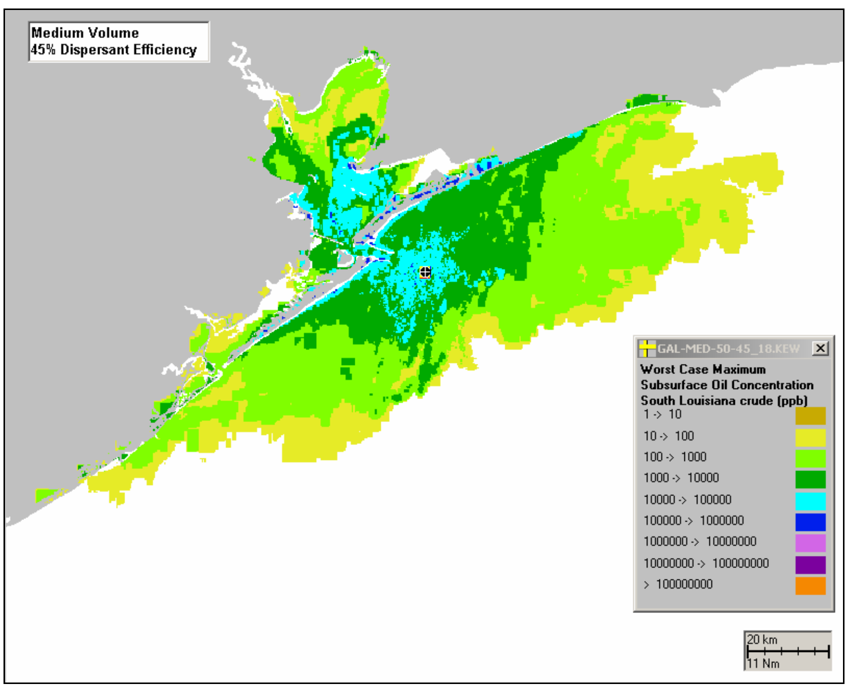

Figure C-II.1.2.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

C-II.1.2.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Medium Volume, 45% Dispersant Efficiency

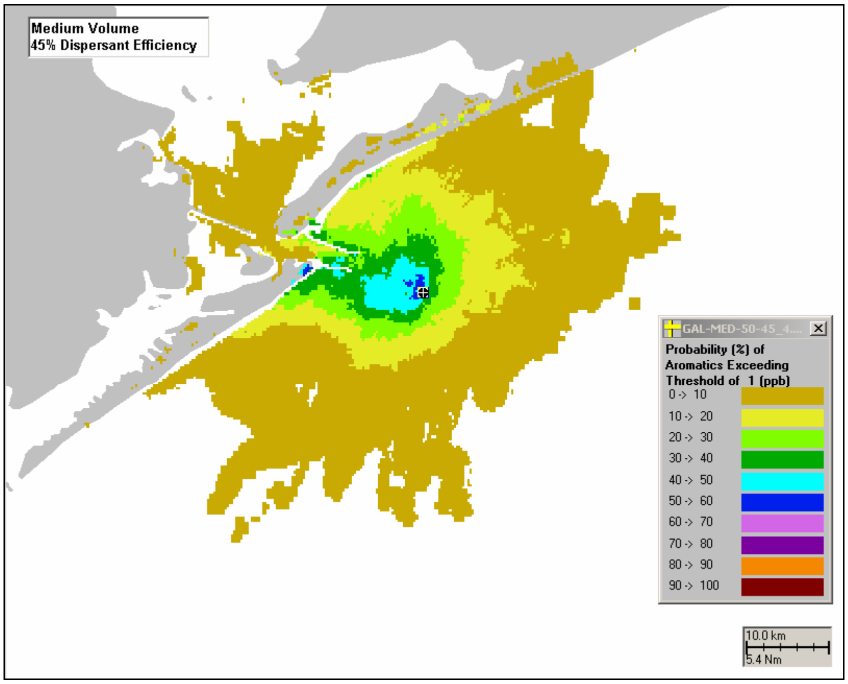

Figure C-II.1.2.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

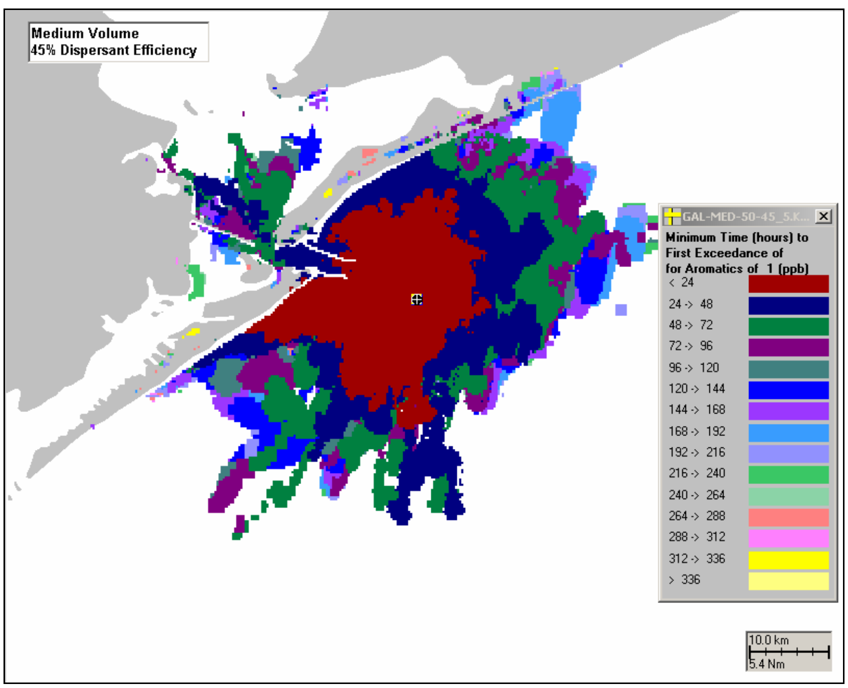

Figure C-II.1.2.4-2 Time (hrs) after spill when Dissolved Aromatic Concentrations could first exceed 1ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

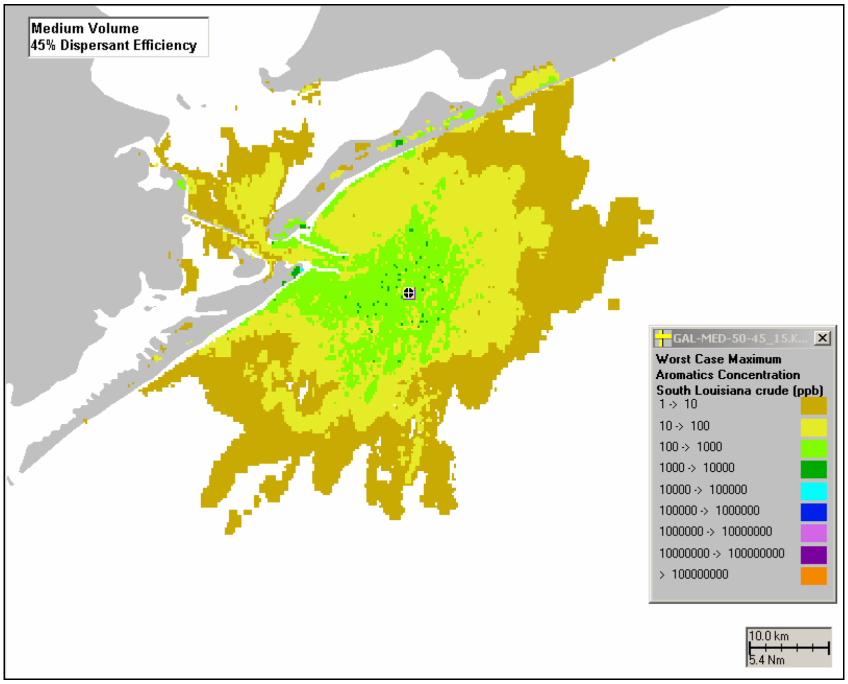

Figure C-II.1.2.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

C-II.1.2.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Medium Volume, 45% Dispersant Efficiency

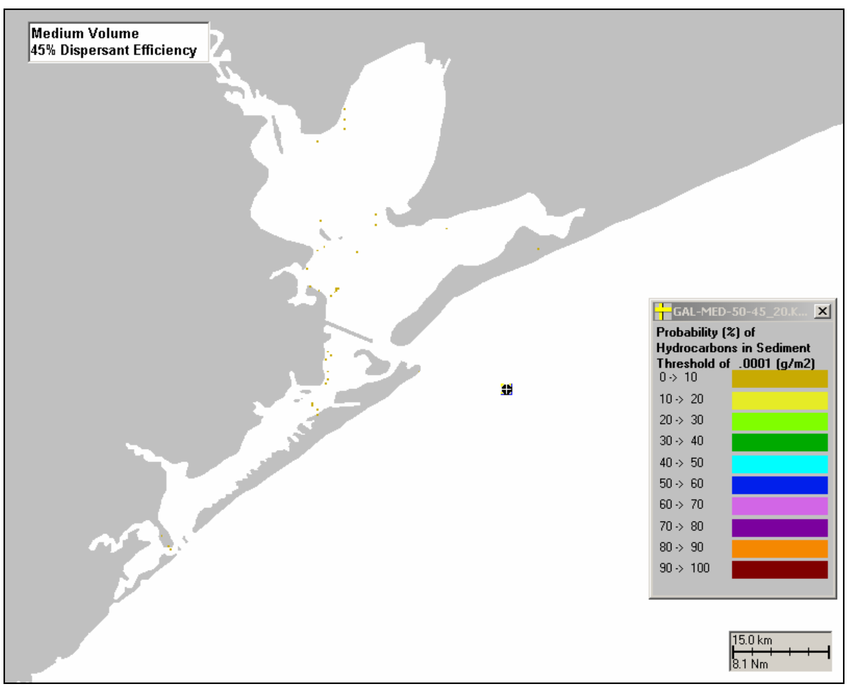

Figure C-II.1.2.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

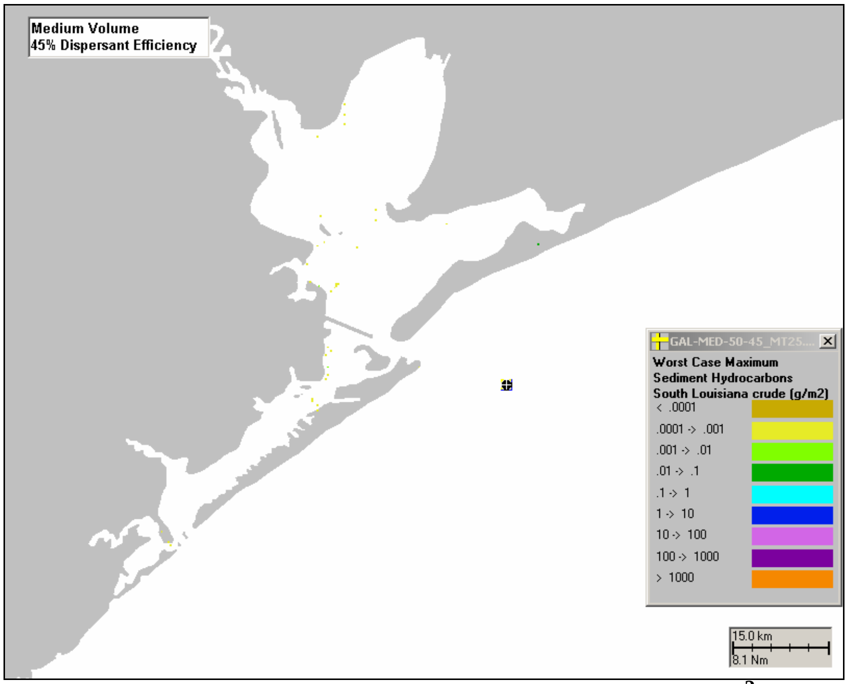

Figure C-II.1.2.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

C-II.1.2.6 Sediment pore water dissolved aromatic concentrations. Scenario: Medium Volume, 45% Dispersant Efficiency

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time and for any of the 100 runs) does not exceed threshold of 1 ppb. Scenario: Medium Volume, No Dispersant.

C-II.1.3. Scenario: Medium Volume, 80% Dispersant Efficiency

C-II.1.3.1 Surface Floating Total Hydrocarbons. Scenario: Medium Volume, 80% Dispersant Efficiency.

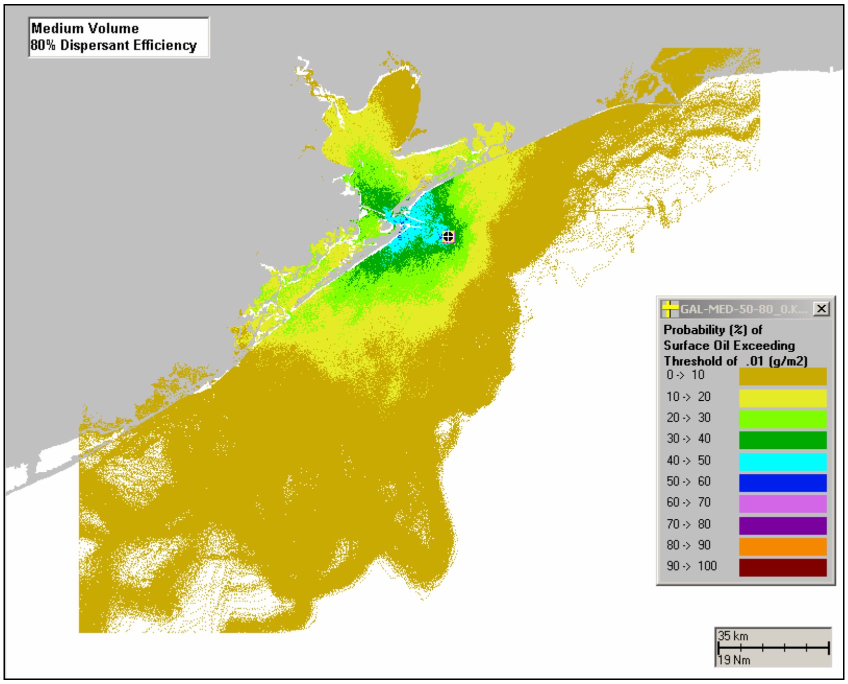

Figure C-II.1.3.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

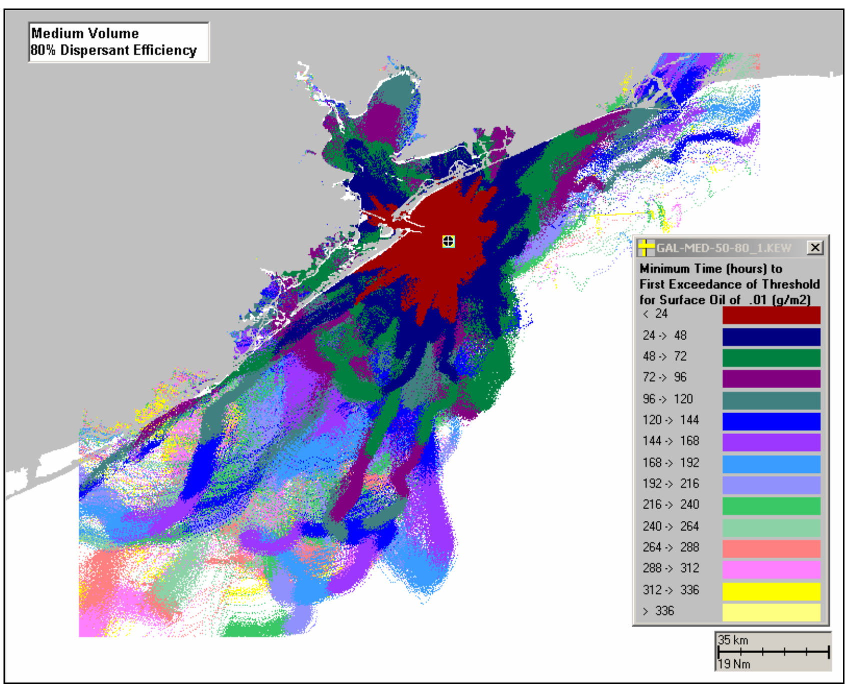

Figure C-II.1.3.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

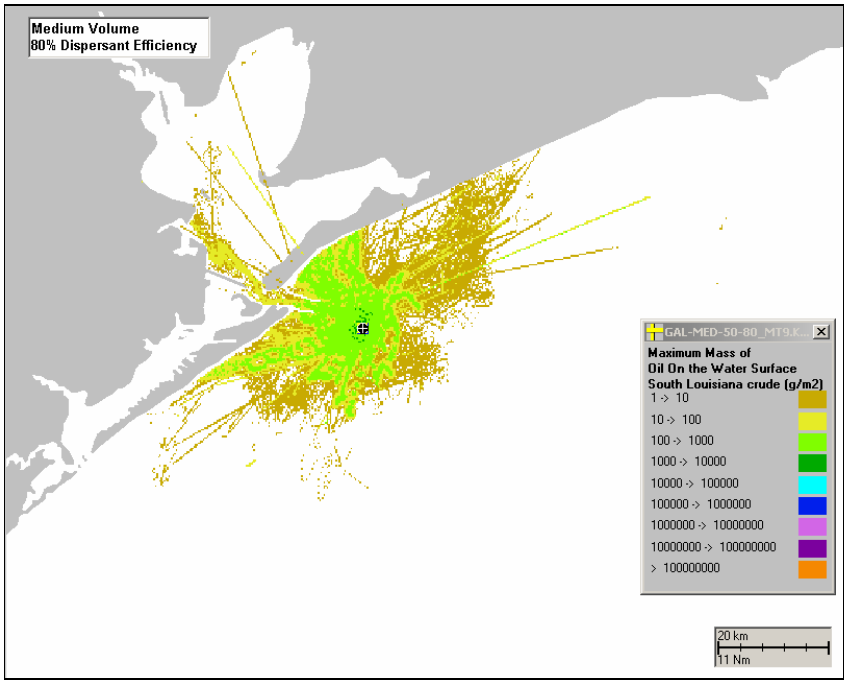

Figure C-II.1.3.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

C-II.1.3.2 Shoreline Oiled. Scenario: Medium Volume, 80% Dispersant Efficiency

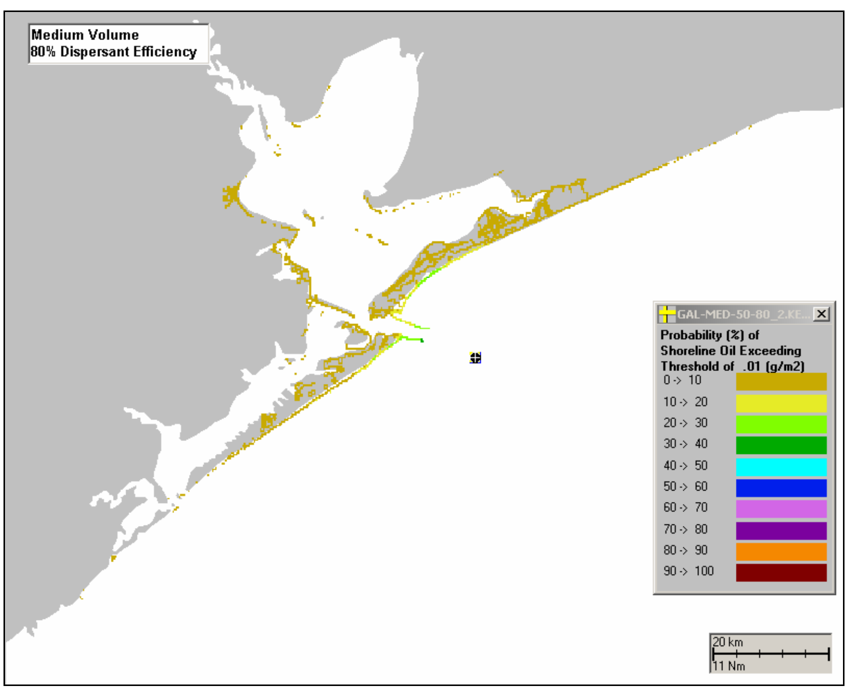

Figure C-II.1.3.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

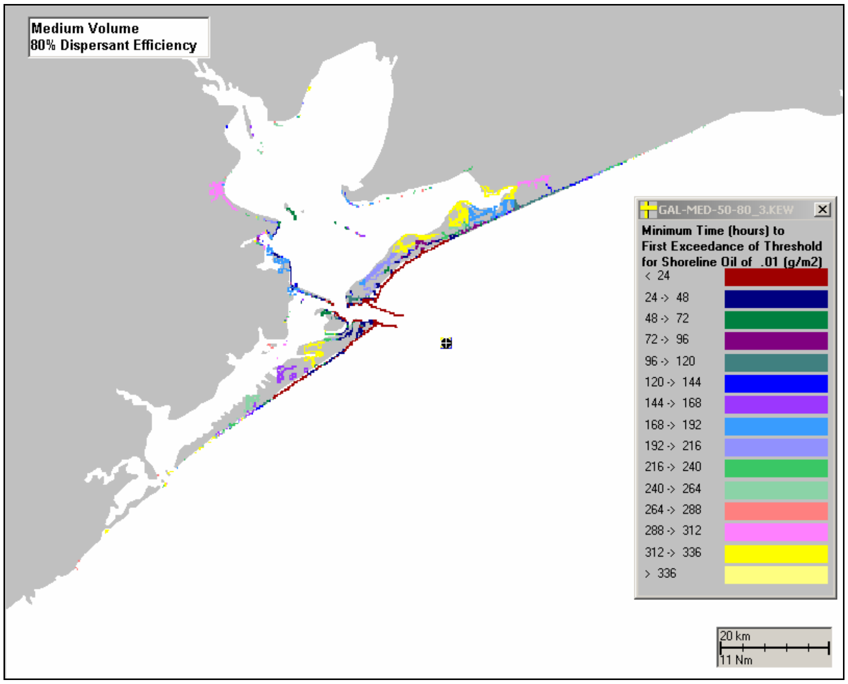

Figure C-II.1.3.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

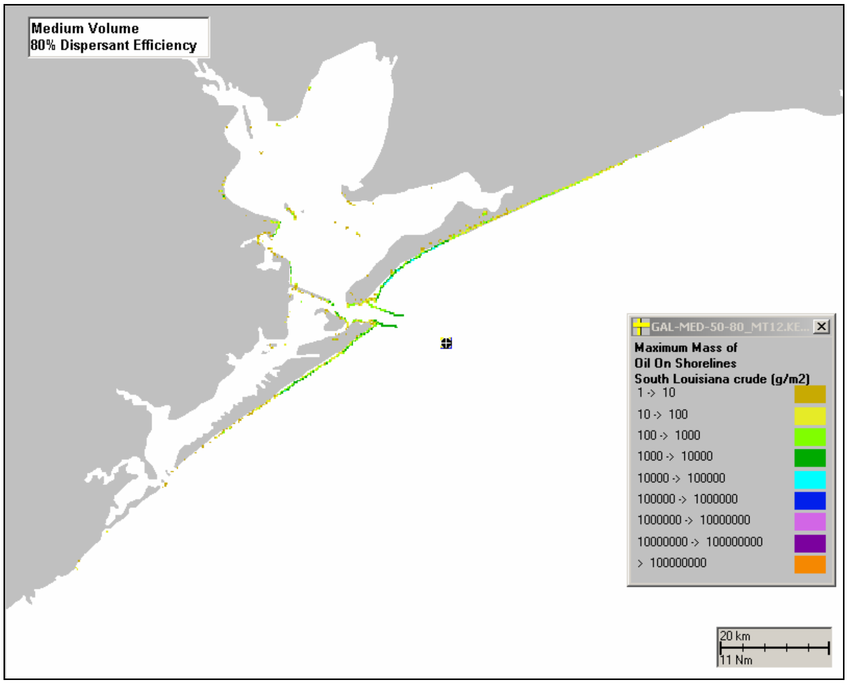

Figure C-II.1.3.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

C-II.1.3.3 Total Hydrocarbon Concentrations in the Water Column.
Scenario: Medium Volume, 80% Dispersant Efficiency

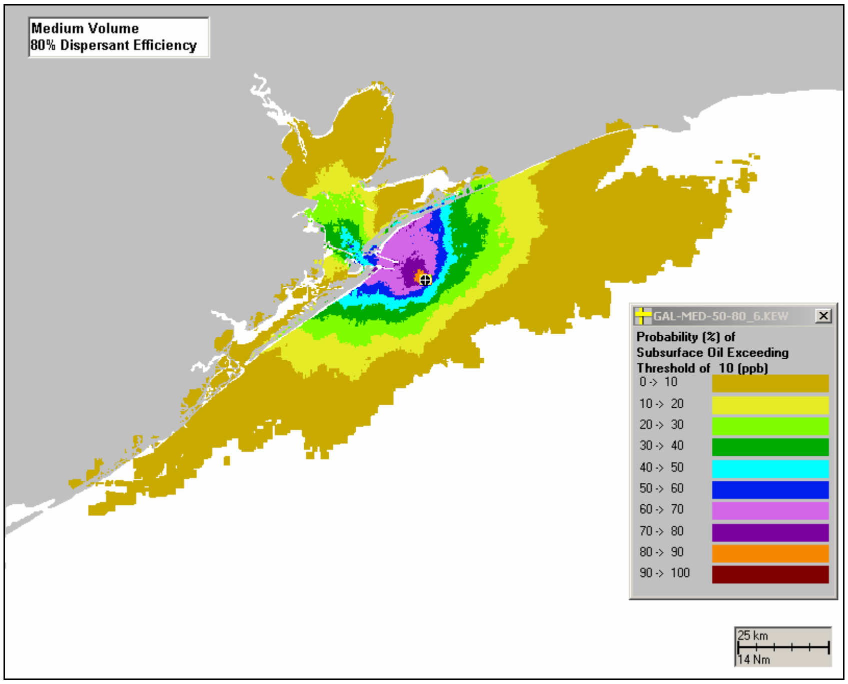

Figure C-II.1.3.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

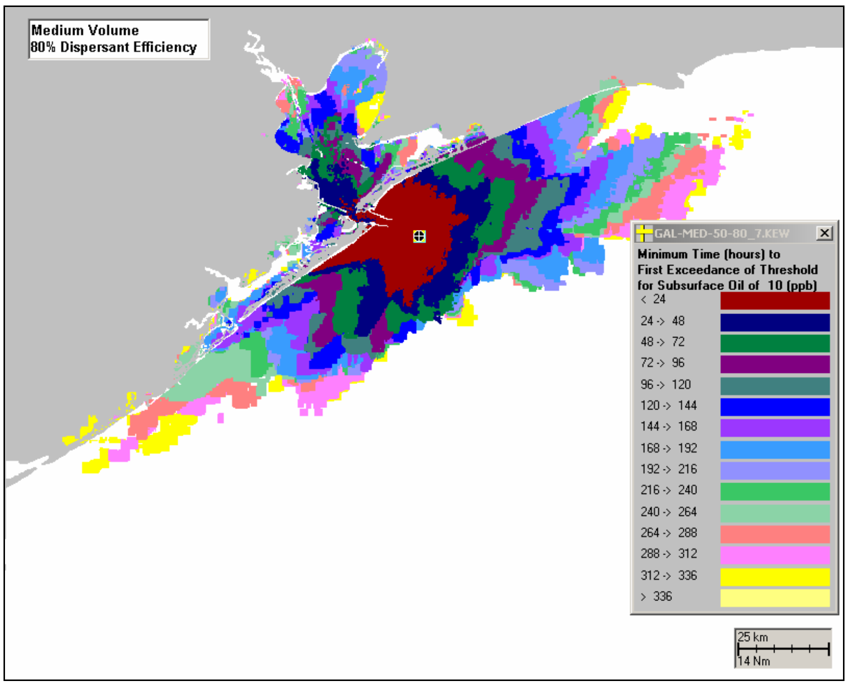

Figure C-II.1.3.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

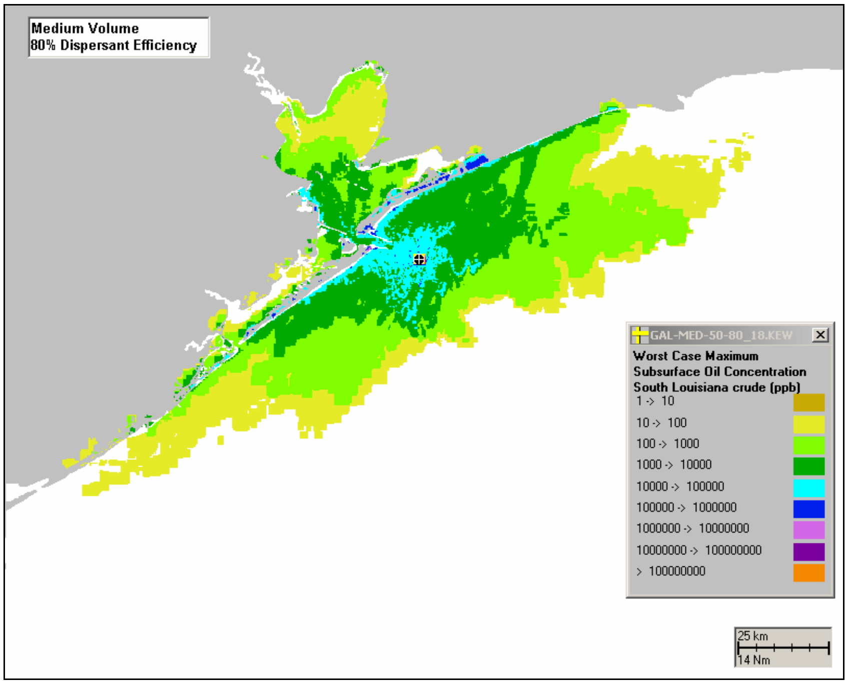

Figure C-II.1.3.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

C-II.1.3.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Medium Volume, 80% Dispersant Efficiency

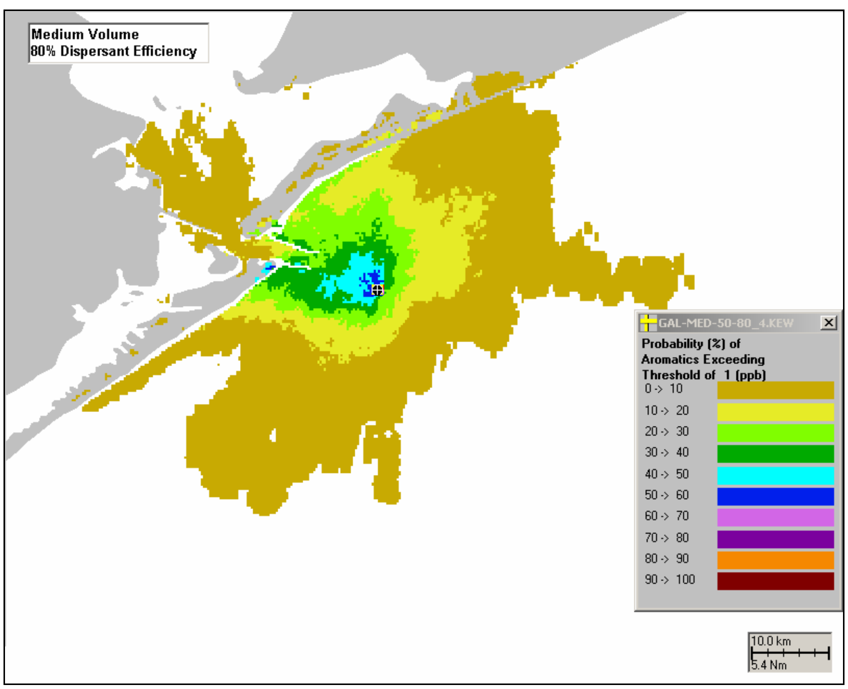

Figure C-II.1.3.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

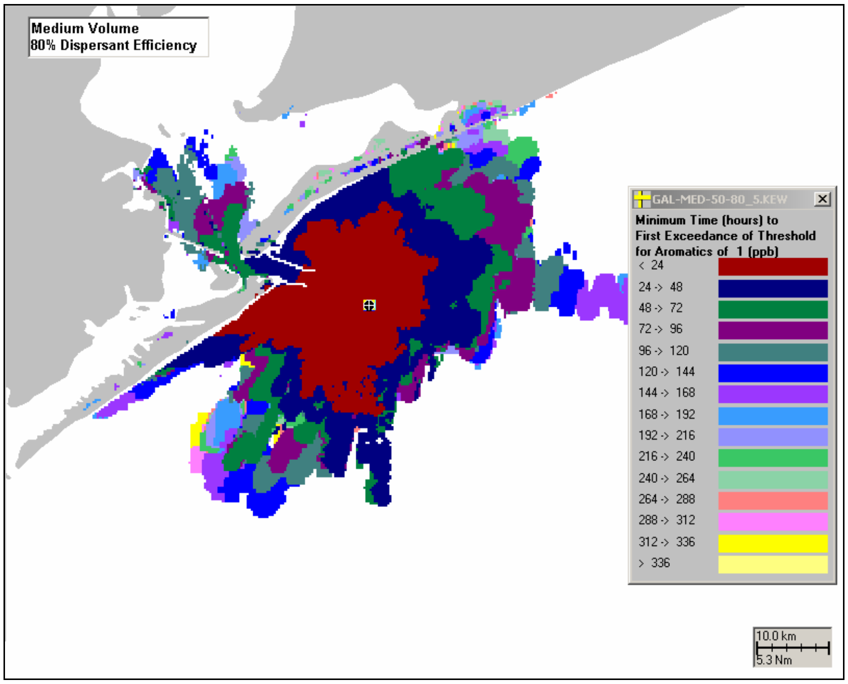

Figure C-II.1.3.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

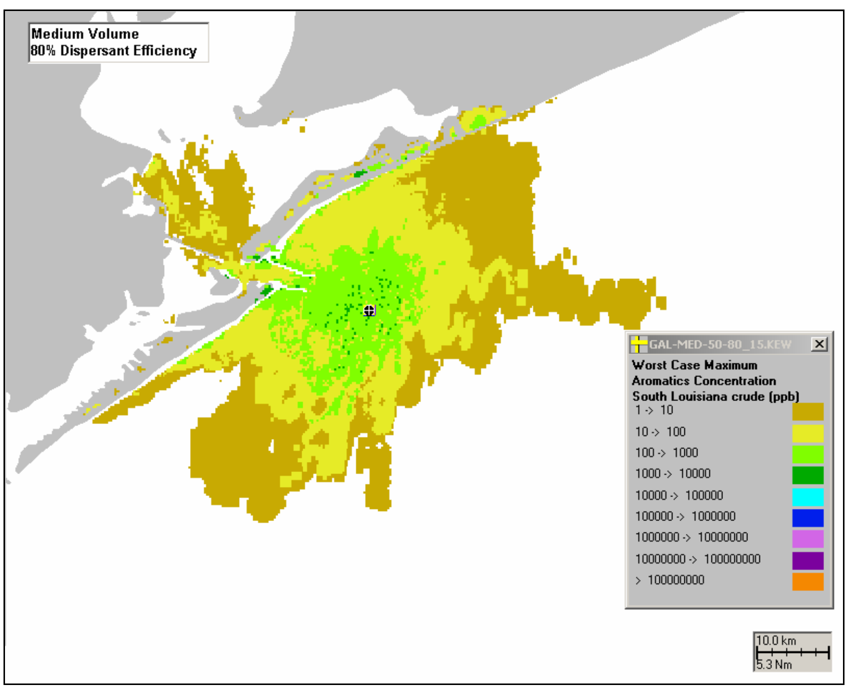

Figure C-II.1.3.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

C-II.1.3.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Medium Volume, 80% Dispersant Efficiency

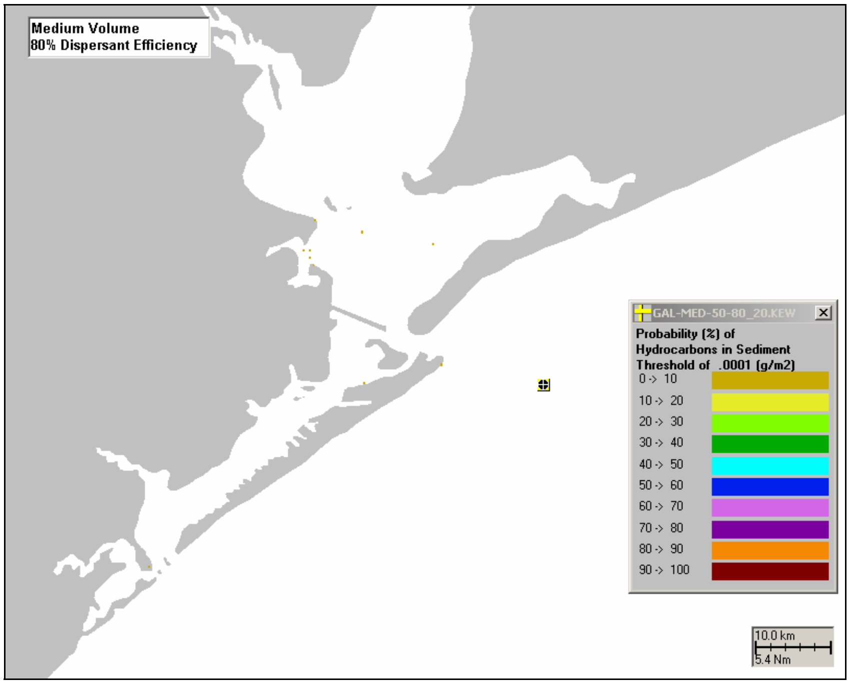

Figure C-II.1.3.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

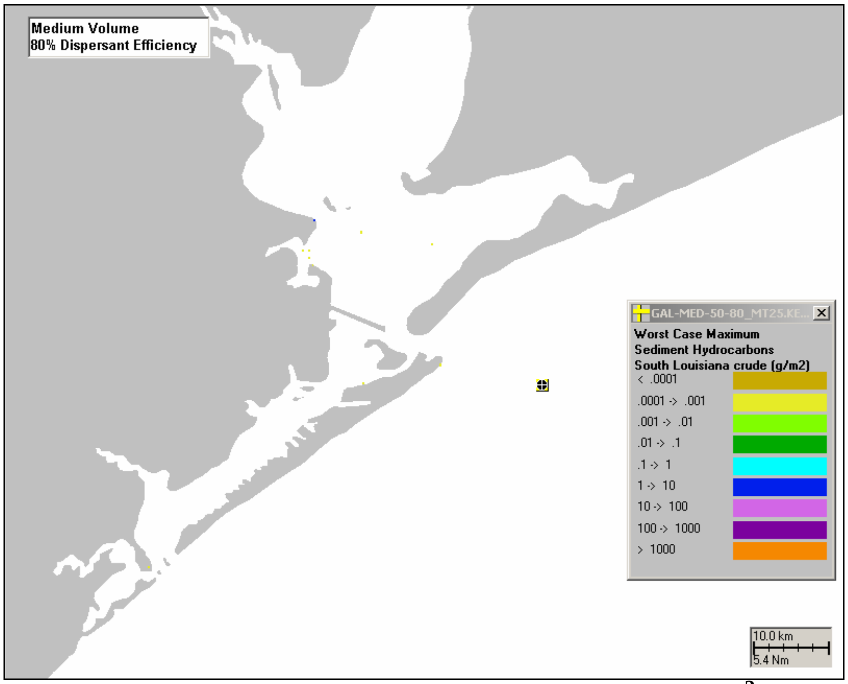

Figure C-II.1.3.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

C-II.1.3.6 Sediment pore water dissolved aromatic concentrations. Scenario: Medium Volume, 80% Dispersant Efficiency

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time and for any of the 100 runs) does not exceed threshold of 1 ppb. Scenario: Medium Volume, No Dispersant.

C-II.1.4. Scenario: Large Volume, No Dispersant

C-II.1.4.1 Surface Floating Total Hydrocarbons. Scenario: Large Volume, No Dispersant

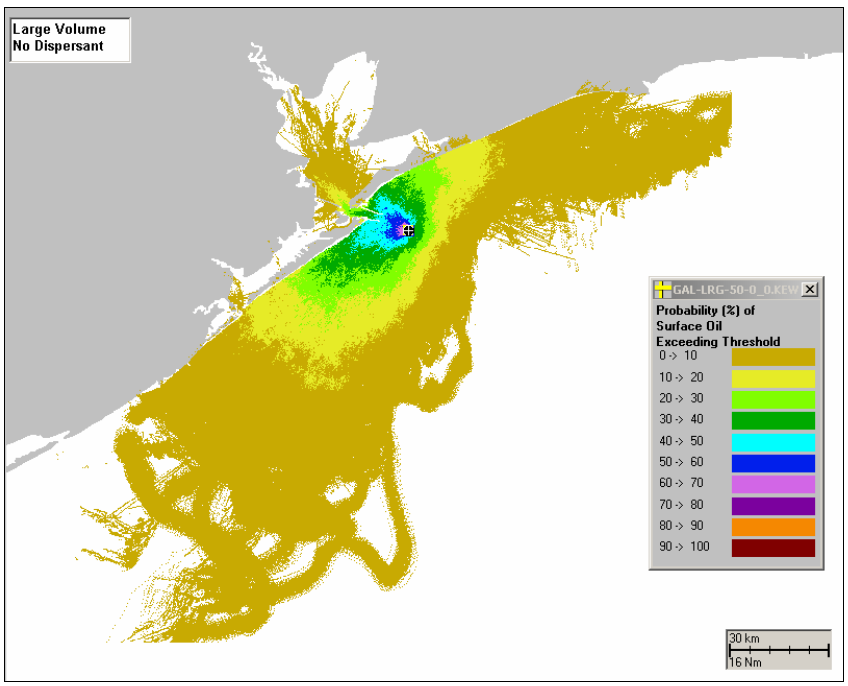

Figure C-II.1.4.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Large Volume, No Dispersant.

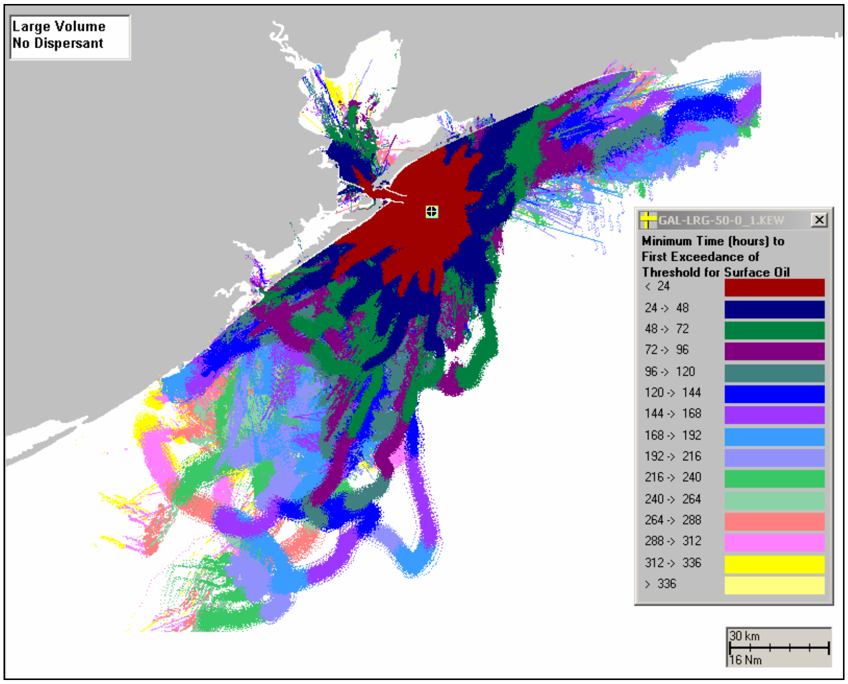

Figure C-II.1.4.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Large Volume, No Dispersant.

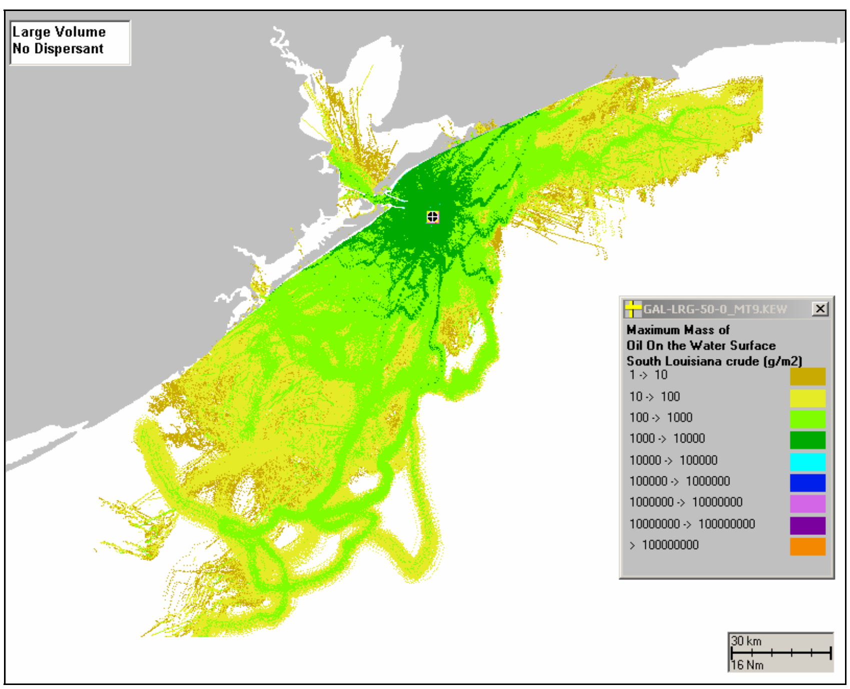

Figure C-II.1.4.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

C-II.1.4.2 Shoreline Oiled. Scenario: Large Volume, No Dispersant

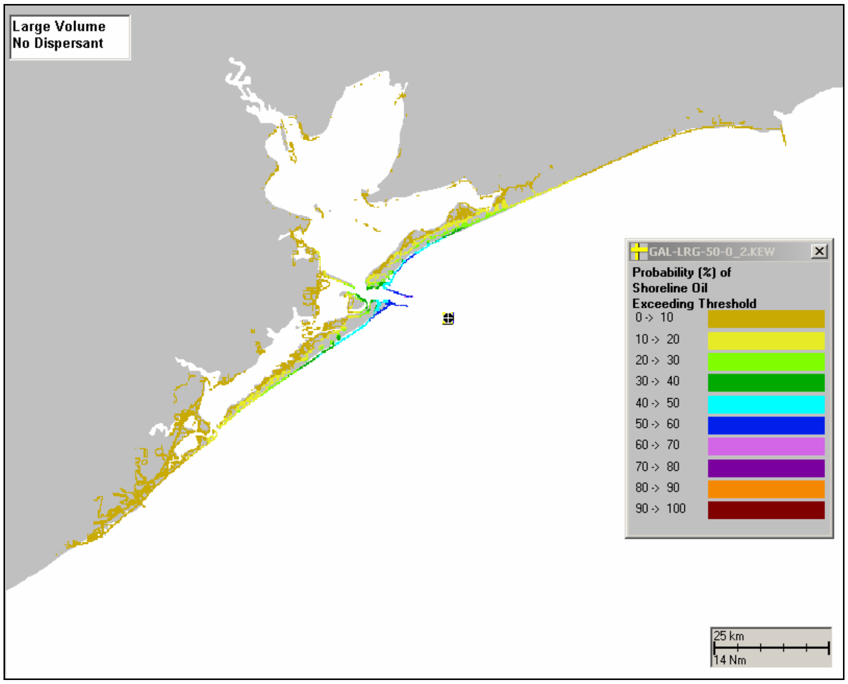

Figure C-II.1.4.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Large Volume, No Dispersant.

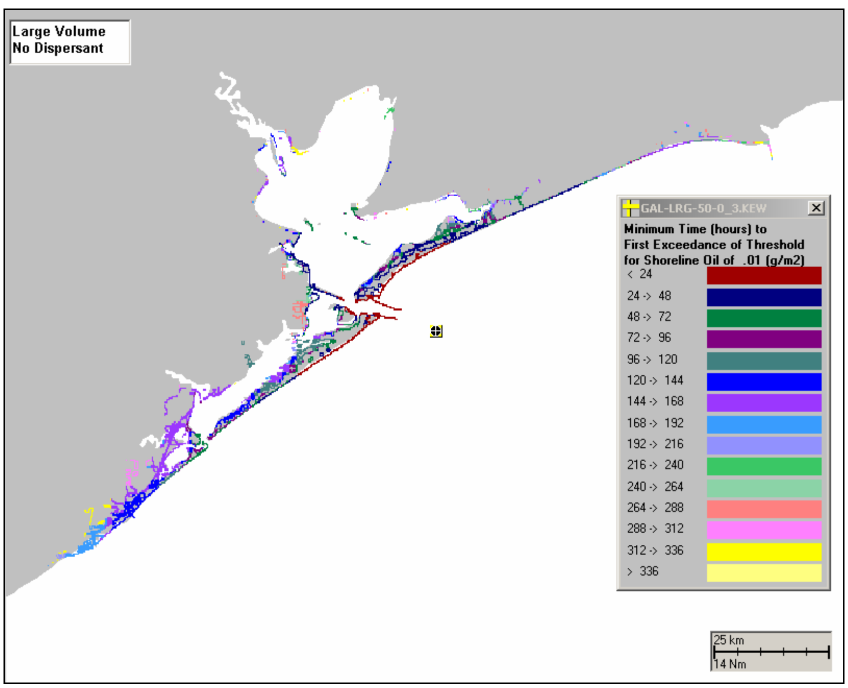

Figure C-II.1.4.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Large Volume, No Dispersant.

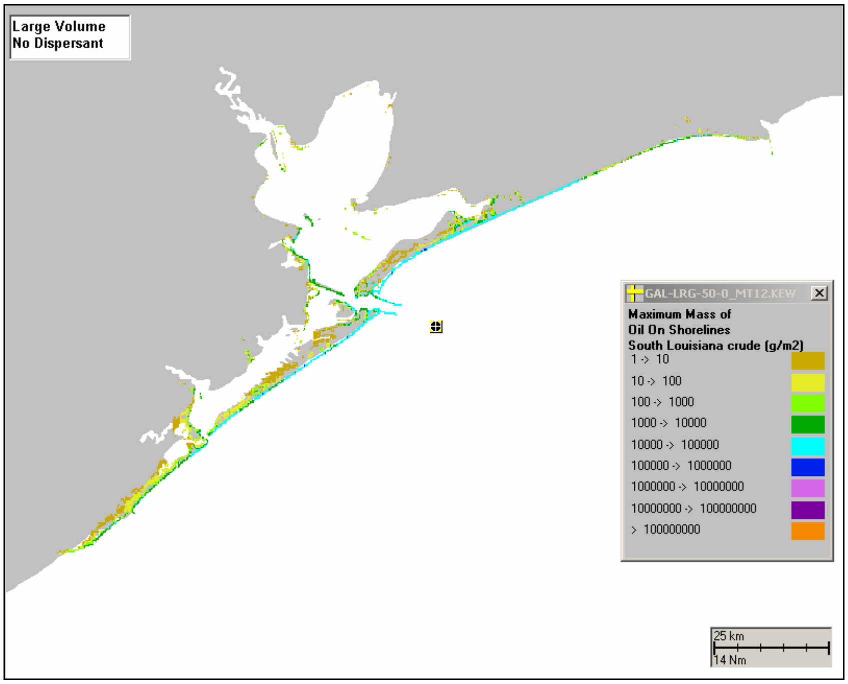

Figure C-II.1.4.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

C-II.1.4.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Large Volume, No Dispersant

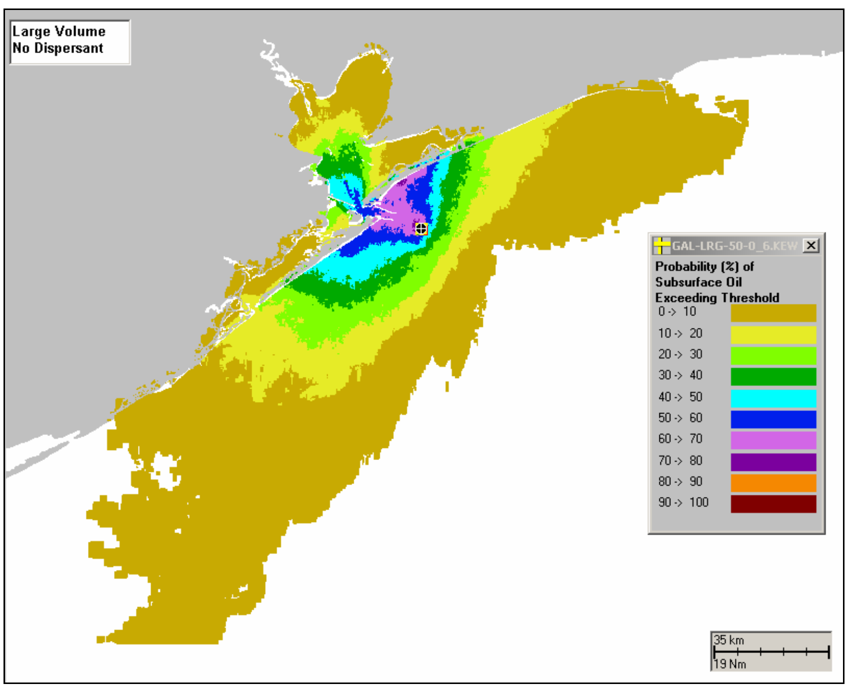

Figure C-II.1.4.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Large Volume, No Dispersant.

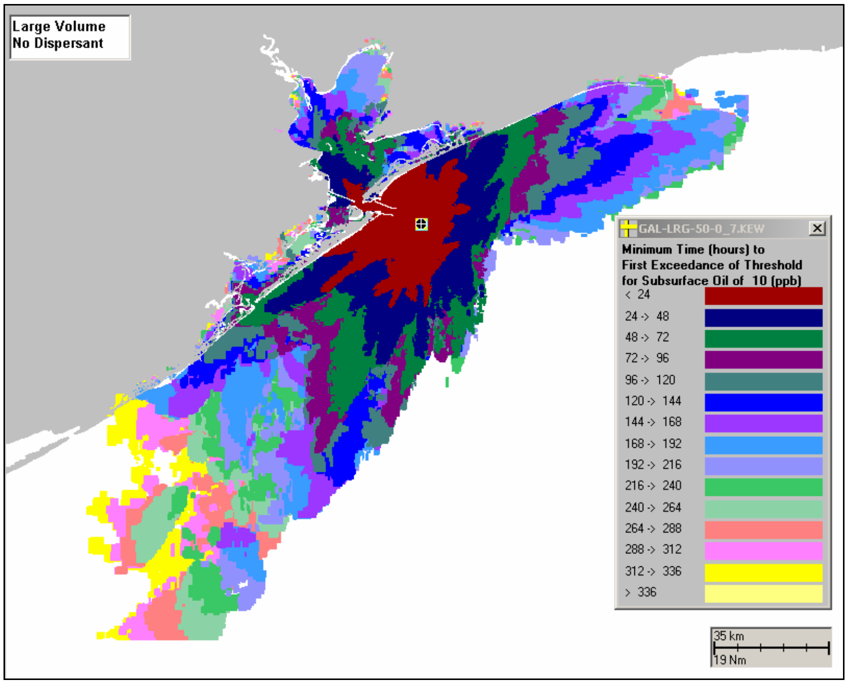

Figure C-II.1.4.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Large Volume, No Dispersant.

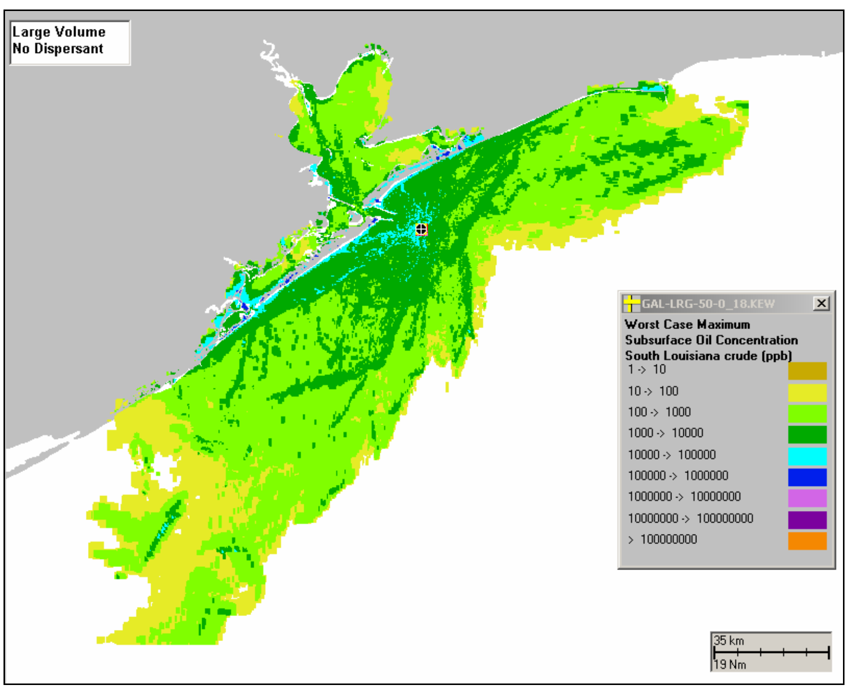

Figure C-II.1.4.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

C-II.1.4.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Large Volume, No Dispersant

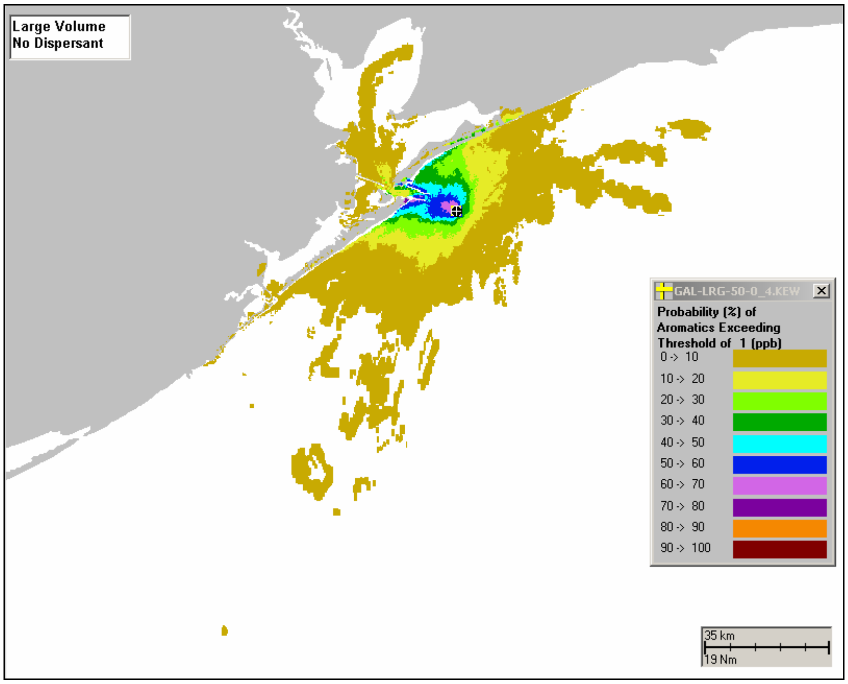

Figure C-II.1.4.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, No Dispersant.

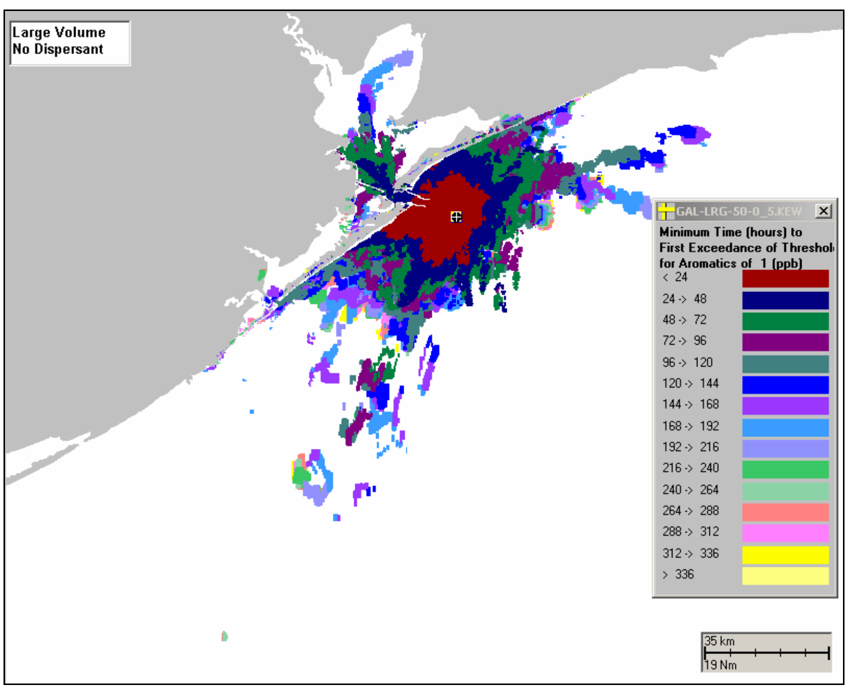

Figure C-II.1.4.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Large Volume, No Dispersant.

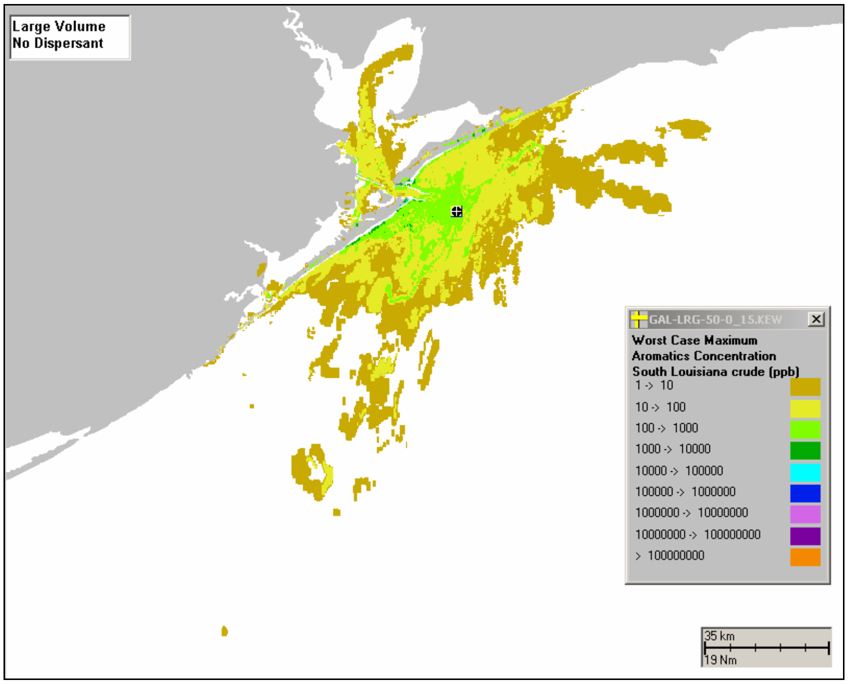

Figure C-II.1.4.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

C-II.1.4.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Large Volume, No Dispersant

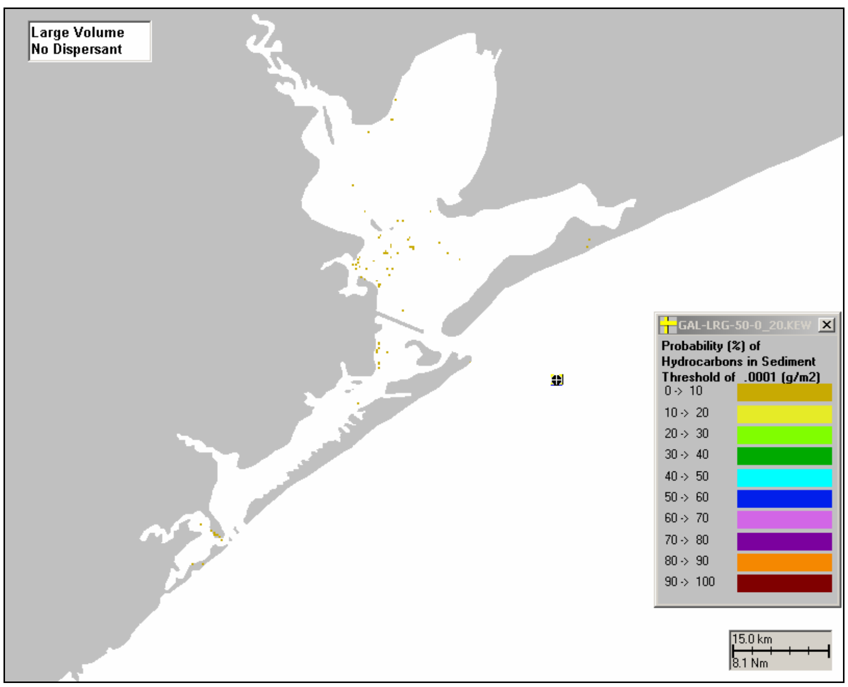

Figure C-II.1.4.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Large Volume, No Dispersant.

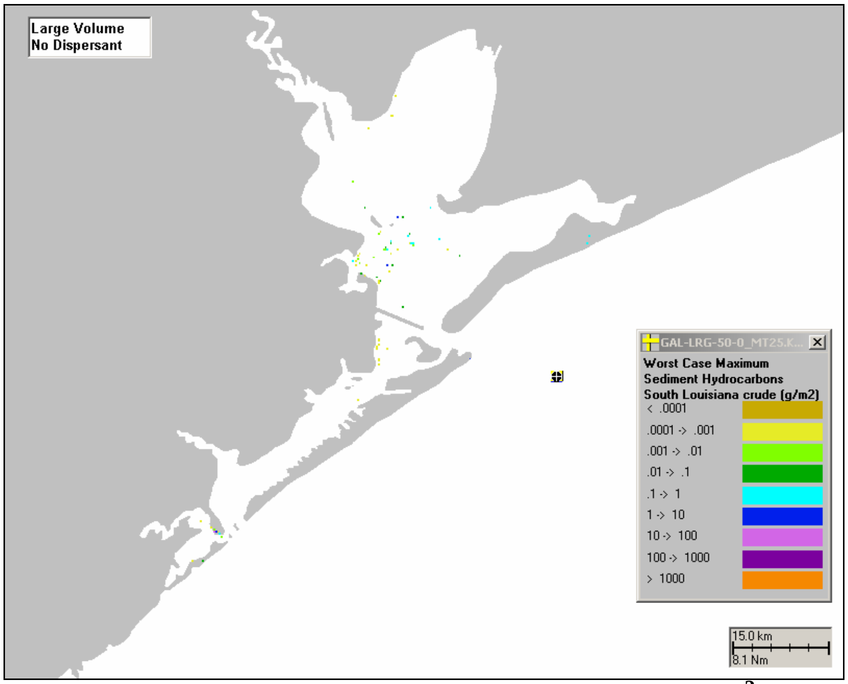

Figure C-II.1.4.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

C-II.1.4.6 Sediment pore water dissolved aromatic concentrations. Scenario: Large Volume, No Dispersant

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time and for any of the 100 runs) does not exceed threshold of 1 ppb. Scenario: Large Volume, No Dispersant.

C-II.1.5. Scenario: Large Volume, 45% Dispersant Efficiency

C-II.1.5.1 Surface Floating Total Hydrocarbons. Scenario: Large Volume, 45% Dispersant Efficiency

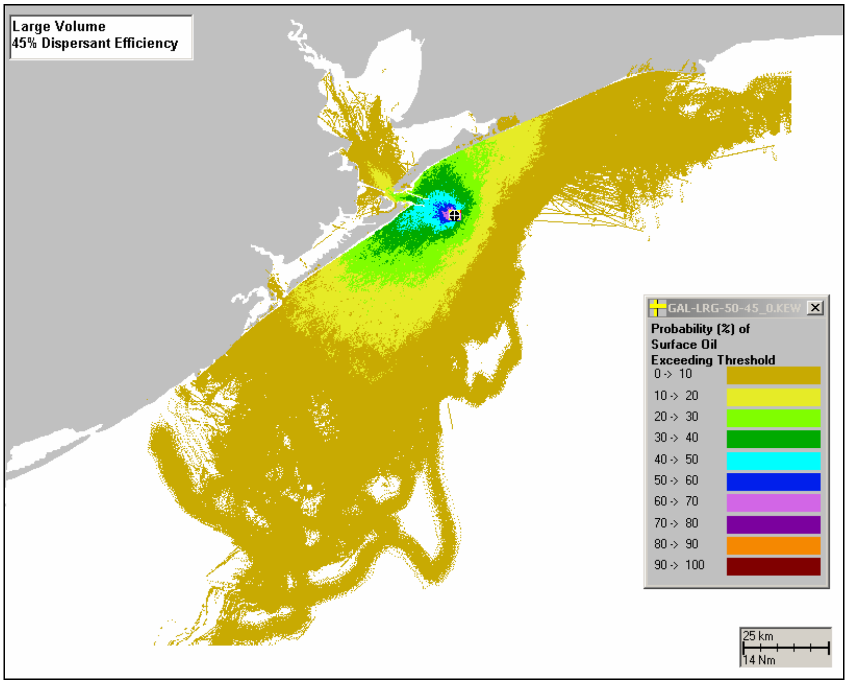

Figure C-II.1.5.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

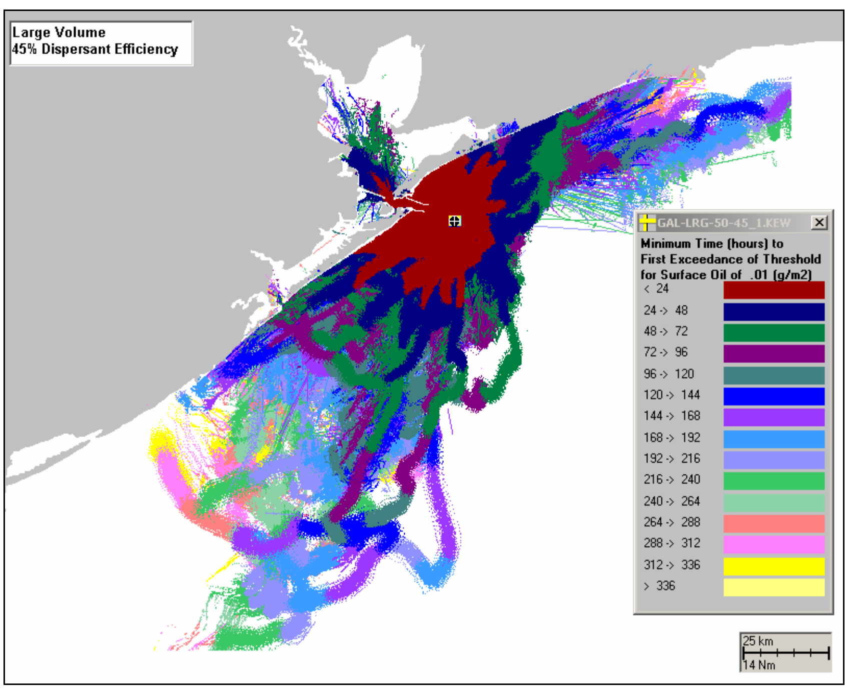

Figure C-II.1.5.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

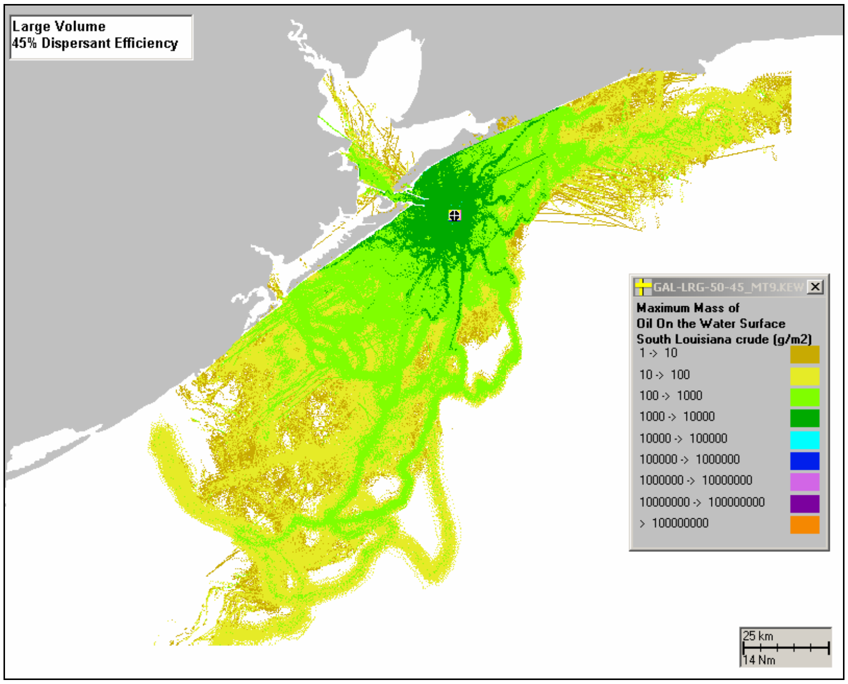

Figure C-II.1.5.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

C-II.1.5.2 Shoreline Oiled. Scenario: Large Volume, 45% Dispersant Efficiency

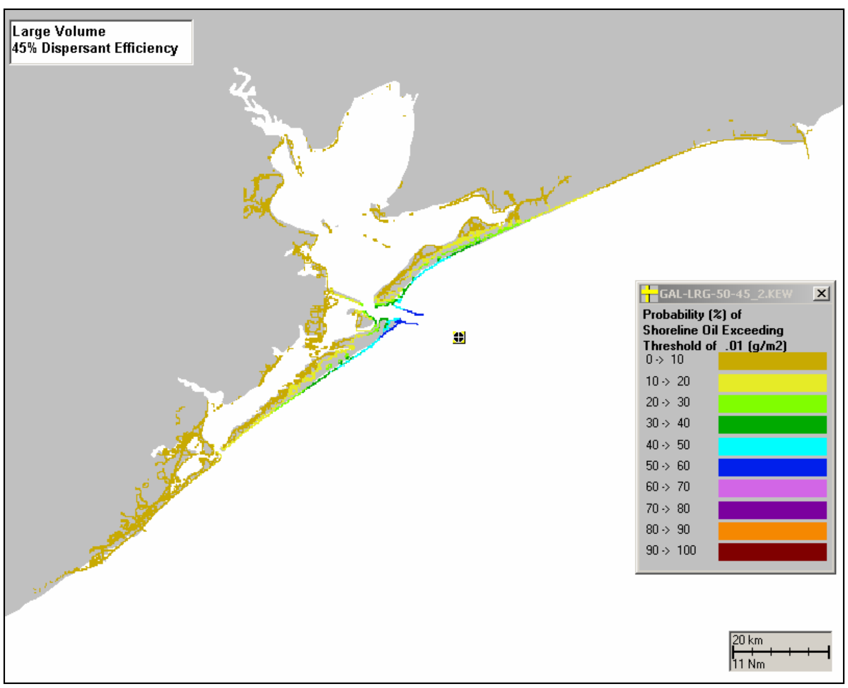

Figure C-II.1.5.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

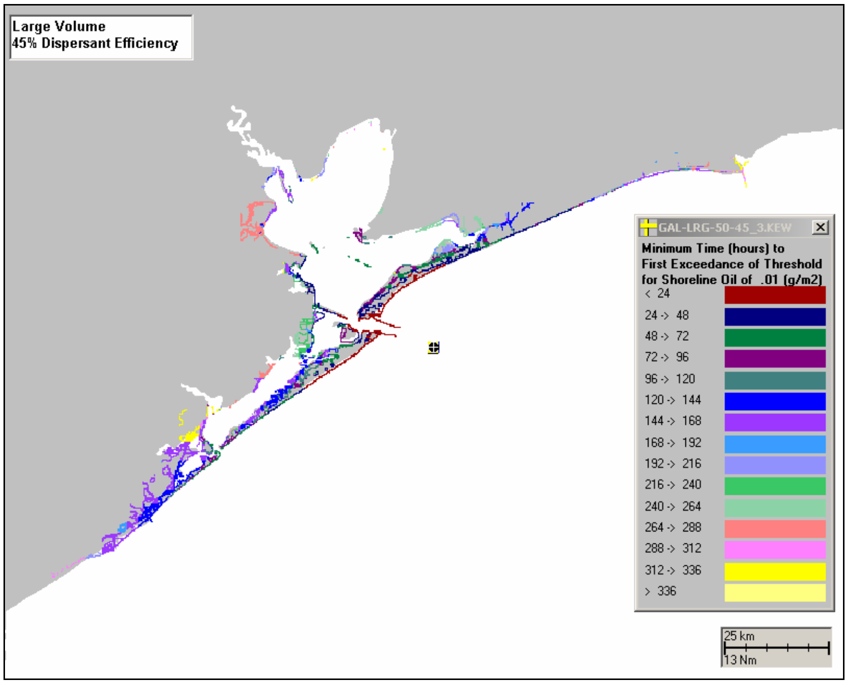

Figure C-II.1.5.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

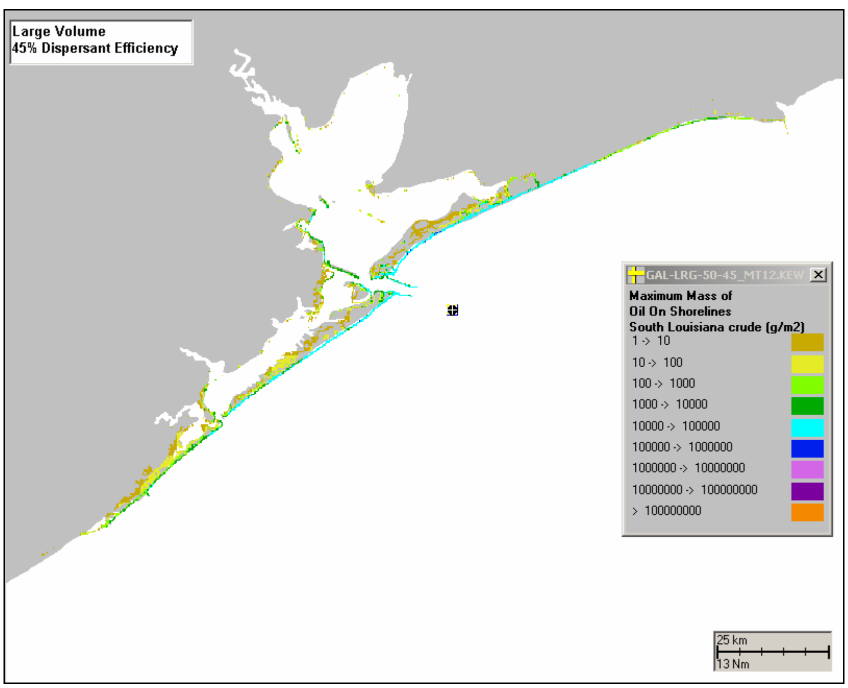

Figure C-II.1.5.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

C-II.1.5.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Large Volume, 45% Dispersant Efficiency

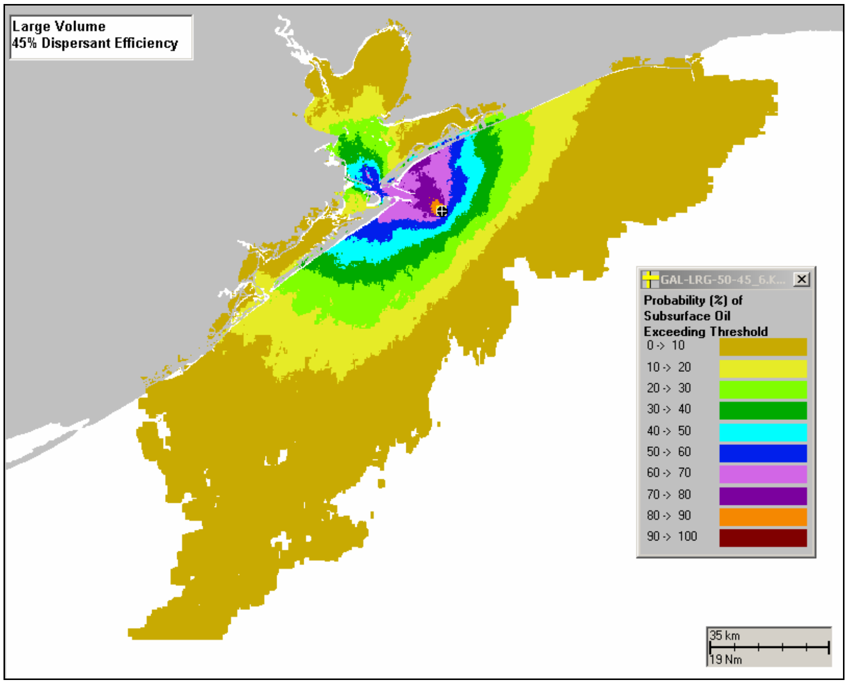

Figure C-II.1.5.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

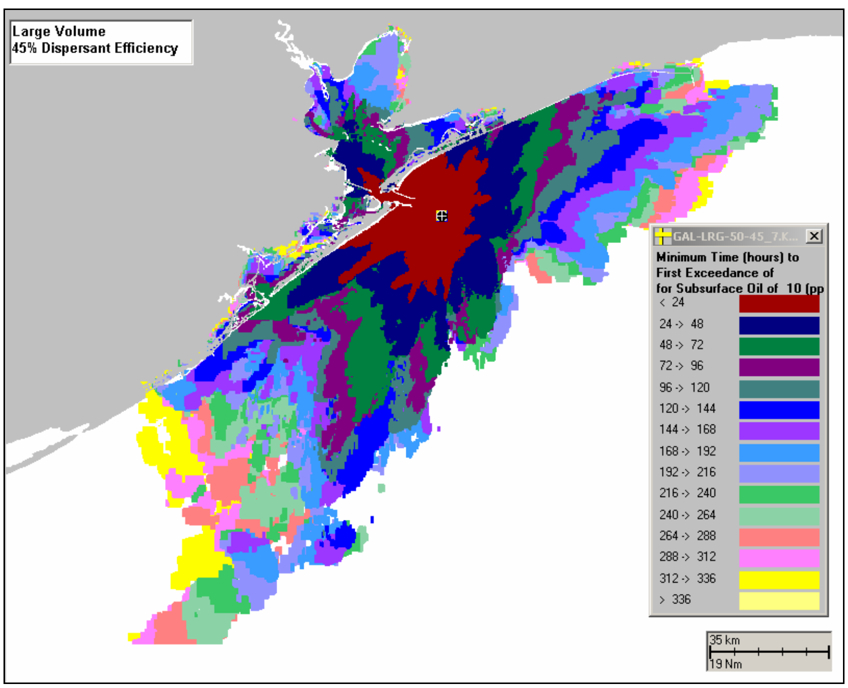

Figure C-II.1.5.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

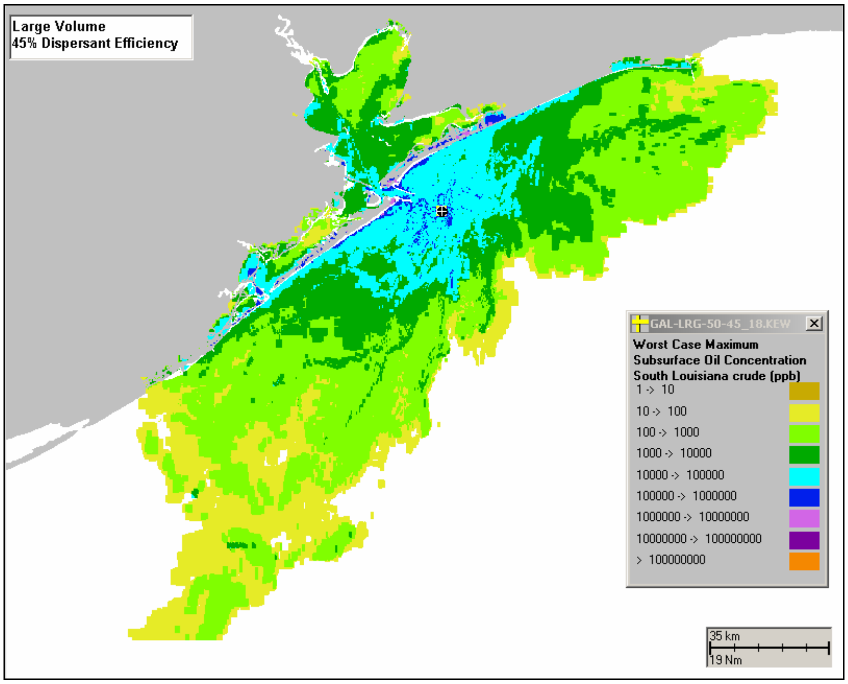

Figure C-II.1.5.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

C-II.1.5.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Large Volume, 45% Dispersant Efficiency

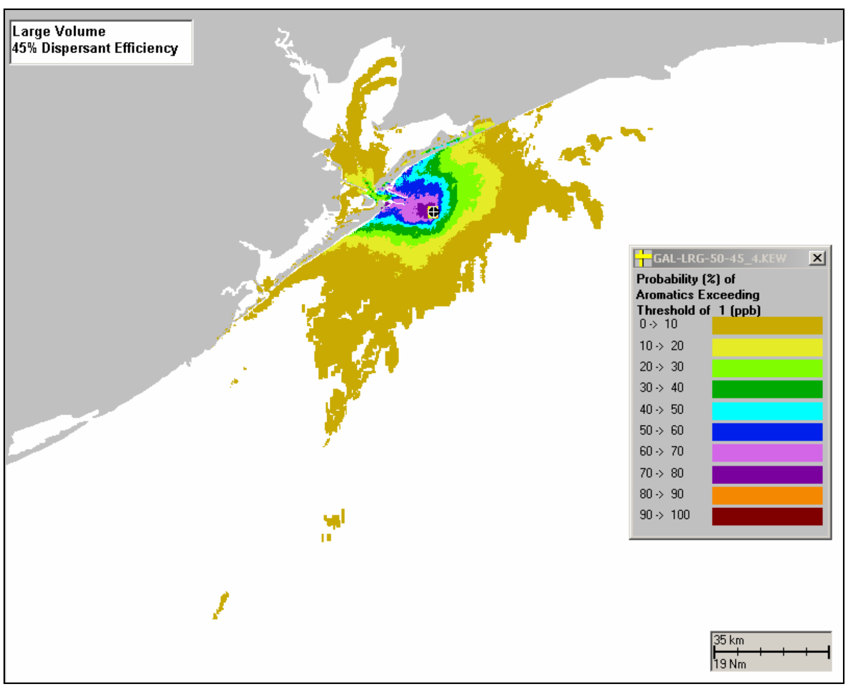

Figure C-II.1.5.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

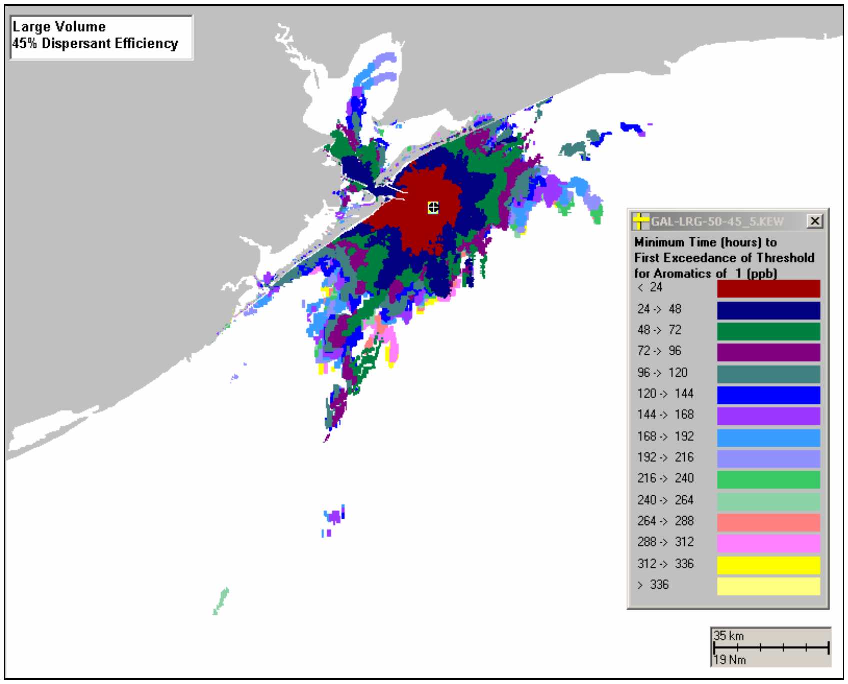

Figure C-II.1.5.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

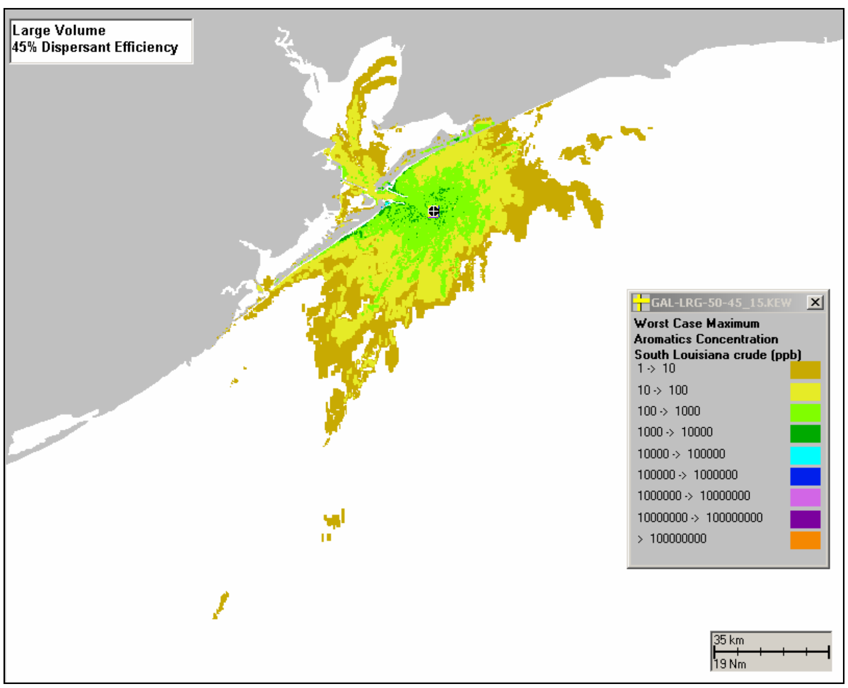

Figure C-II.1.5.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

C-II.1.5.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Large Volume, 45% Dispersant Efficiency

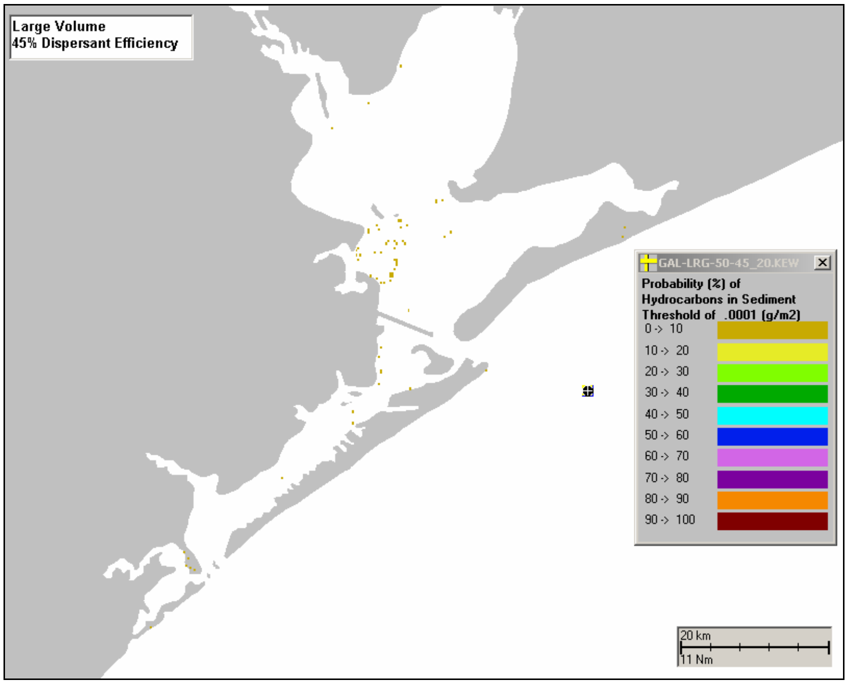

Figure C-II.1.5.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

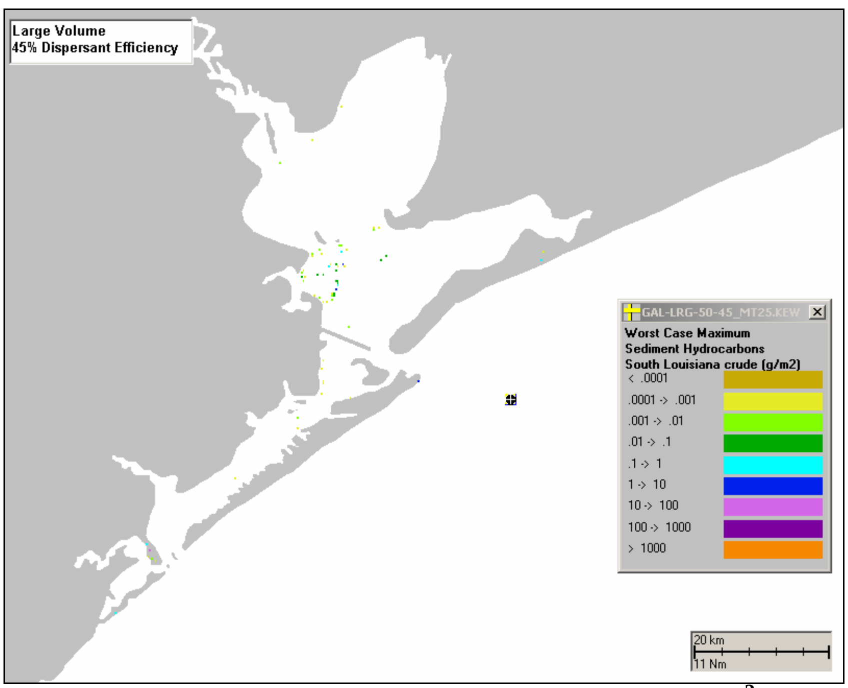

Figure C-II.1.5.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

C-II.1.5.6 Sediment pore water dissolved aromatic concentrations. Scenario: Large Volume, 45% Dispersant Efficiency

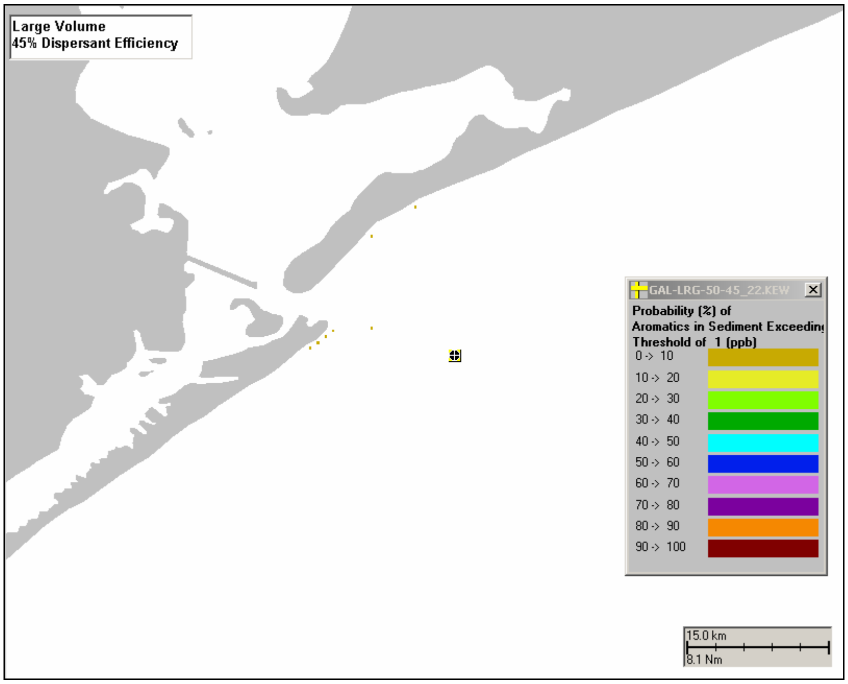

Figure C-II.1.5.6-1 Probability (%) of sediment pore water concentrations exceeding 1ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

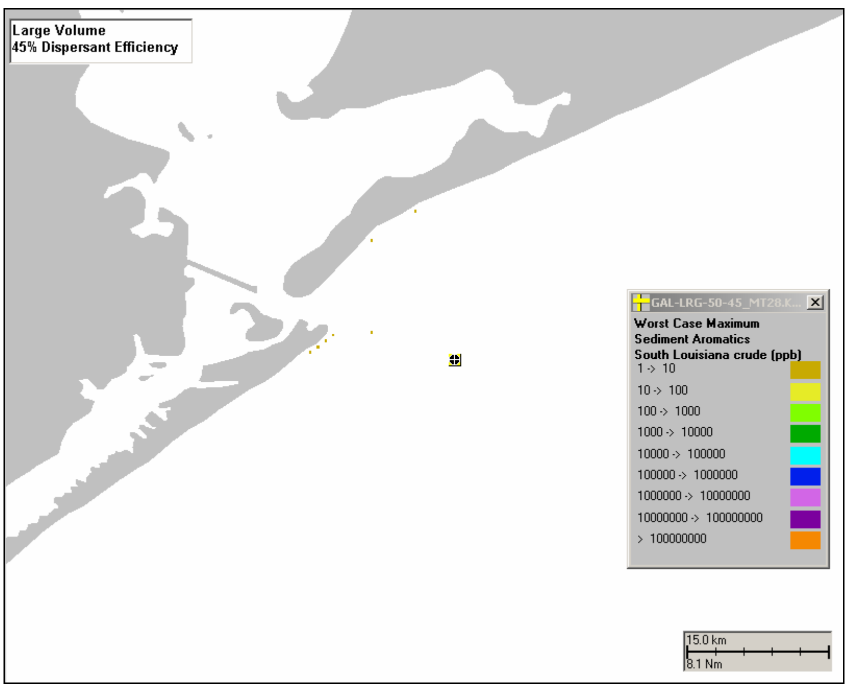

Figure C-II.1.5.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

C-II.1.6. Scenario: Large Volume, 80% Dispersant Efficiency

C-II.1.6.1 Surface Floating Total Hydrocarbons. Scenario: Large Volume, 80% Dispersant Efficiency.

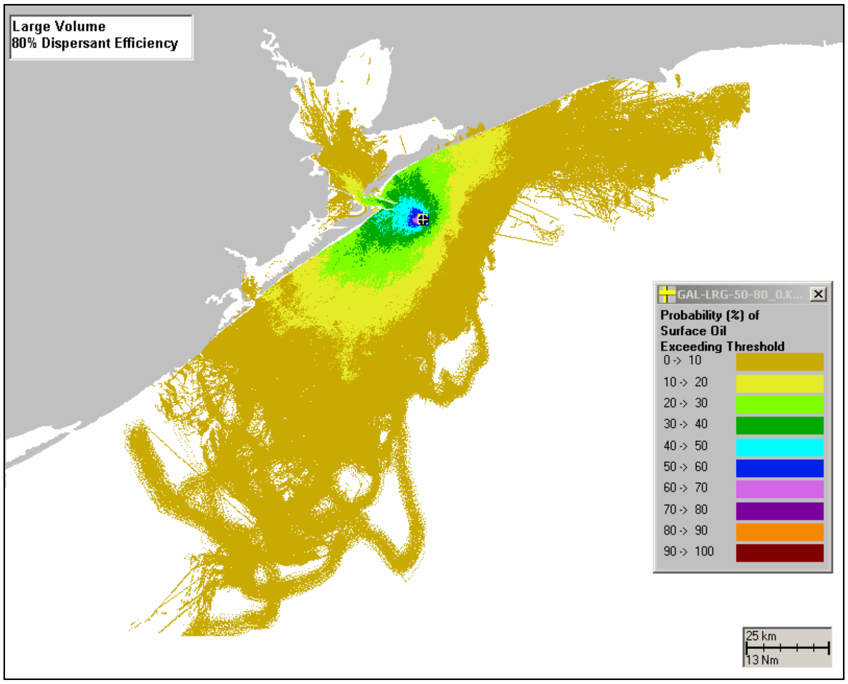

Figure C-II.1.6.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

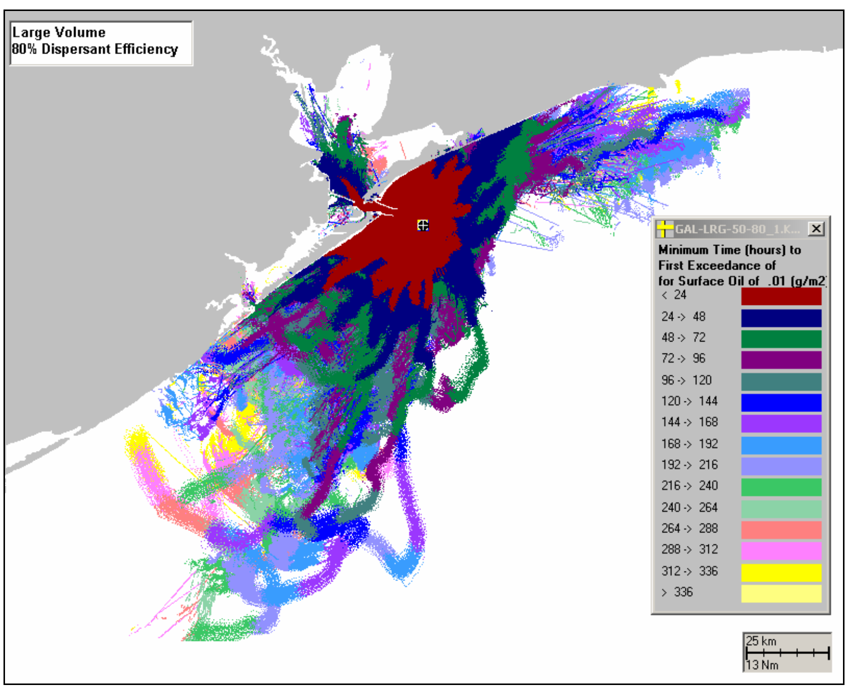

Figure C-II.1.6.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

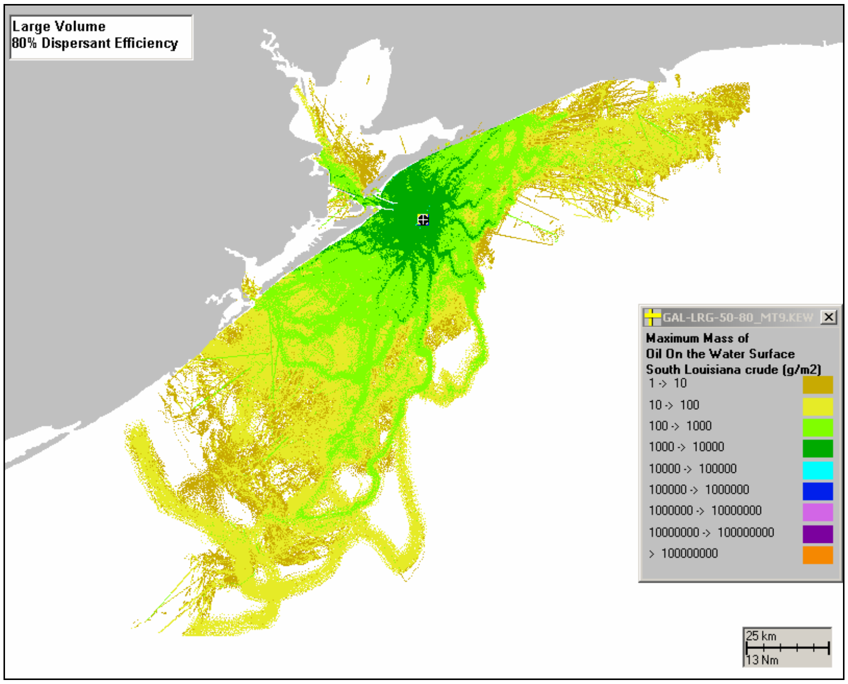

Figure C-II.1.6.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

C-II.1.6.2 Shoreline Oiled. Scenario: Large Volume, 80% Dispersant Efficiency

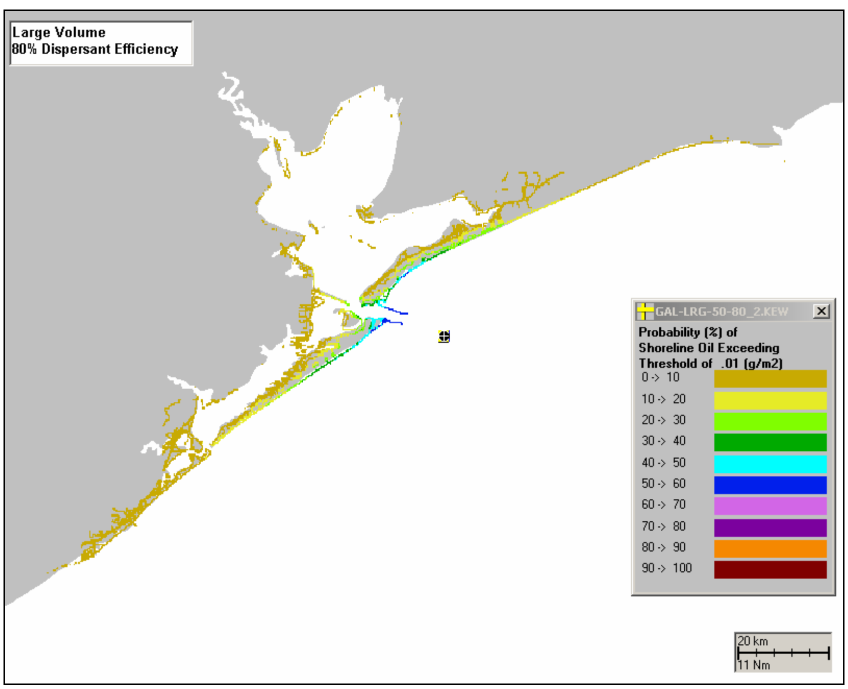

Figure C-II.1.6.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

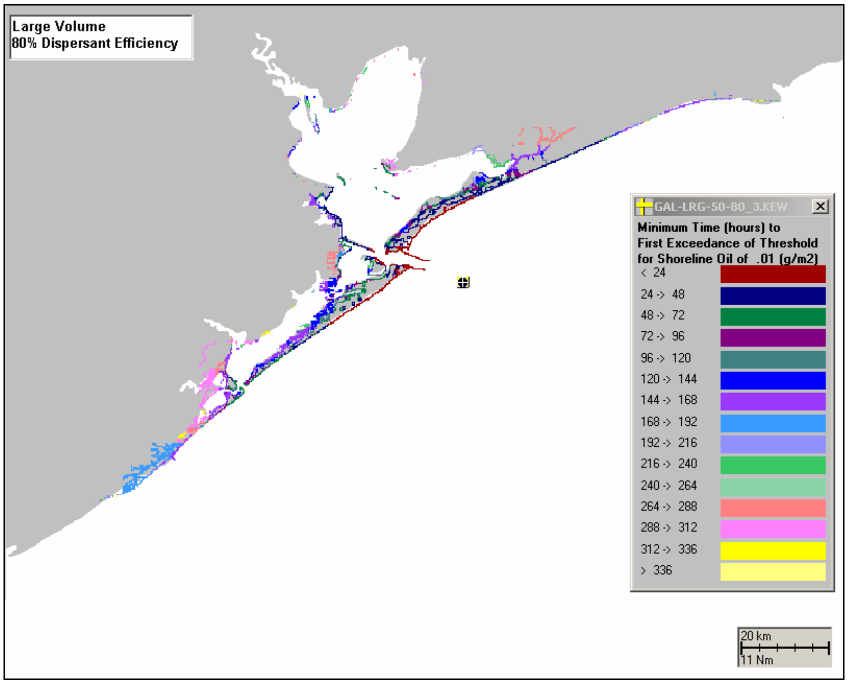

Figure C-II.1.6.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

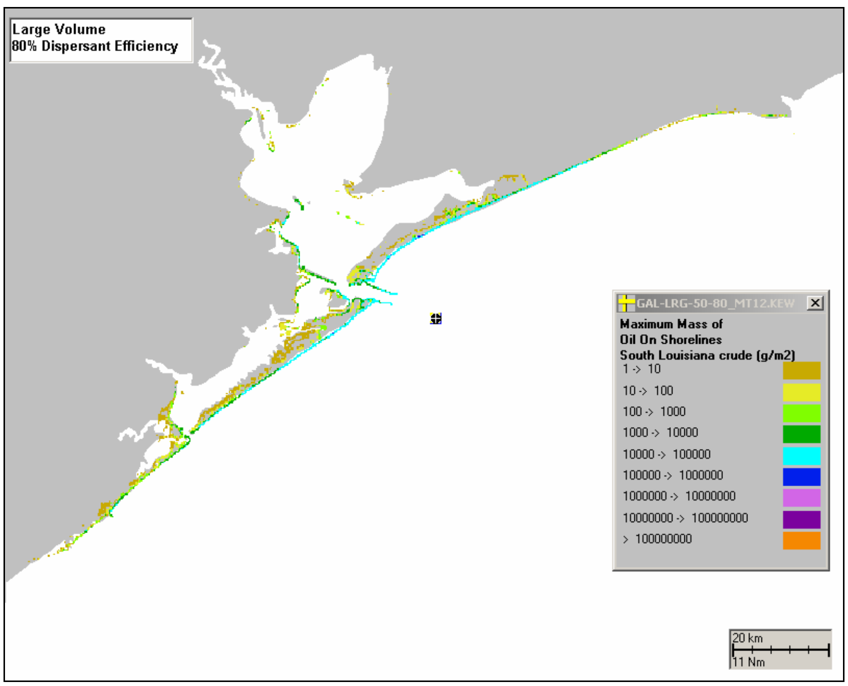

Figure C-II.1.6.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

C-II.1.6.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Large Volume, 80% Dispersant Efficiency

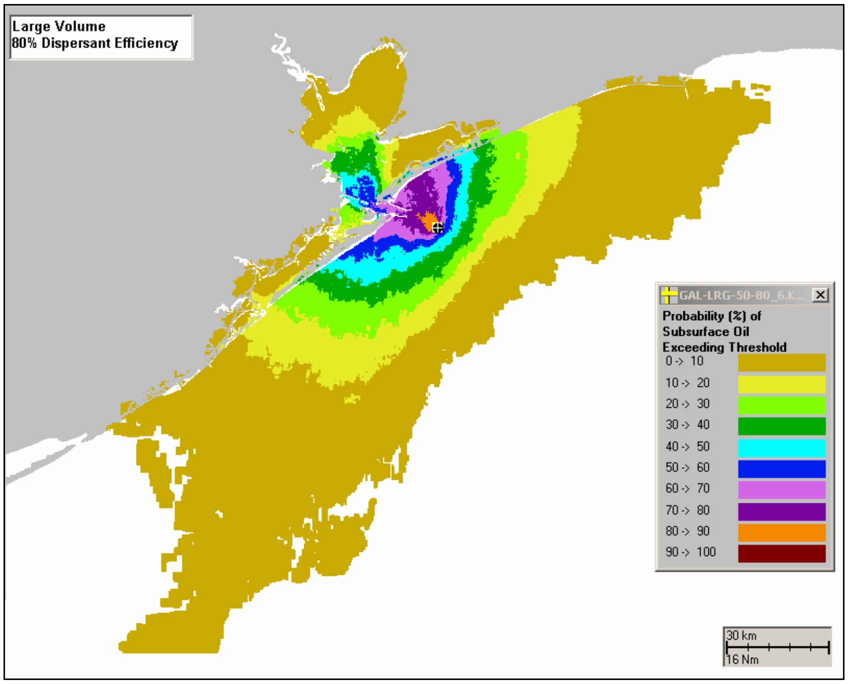

Figure C-II.1.6.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

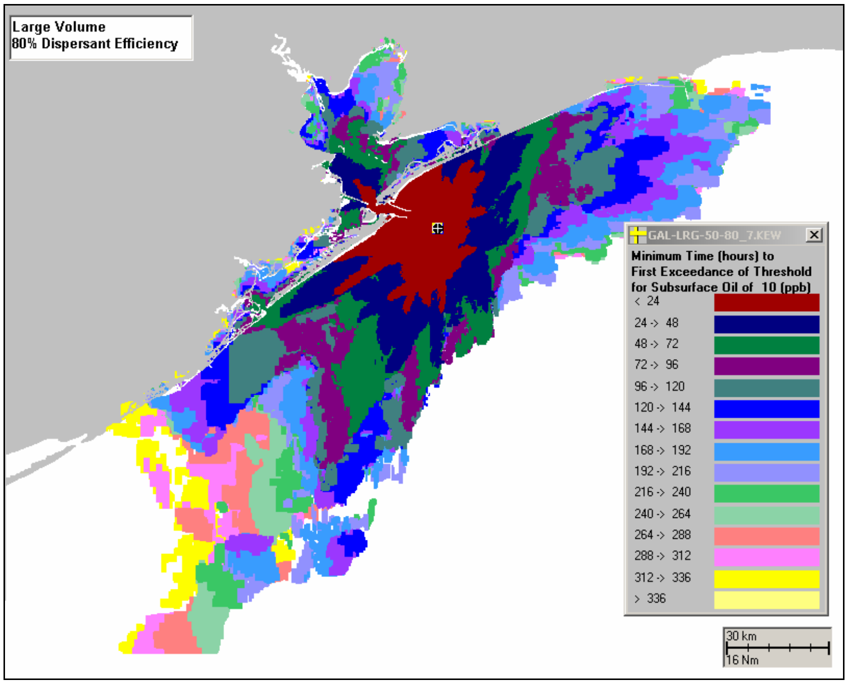

Figure C-II.1.6.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

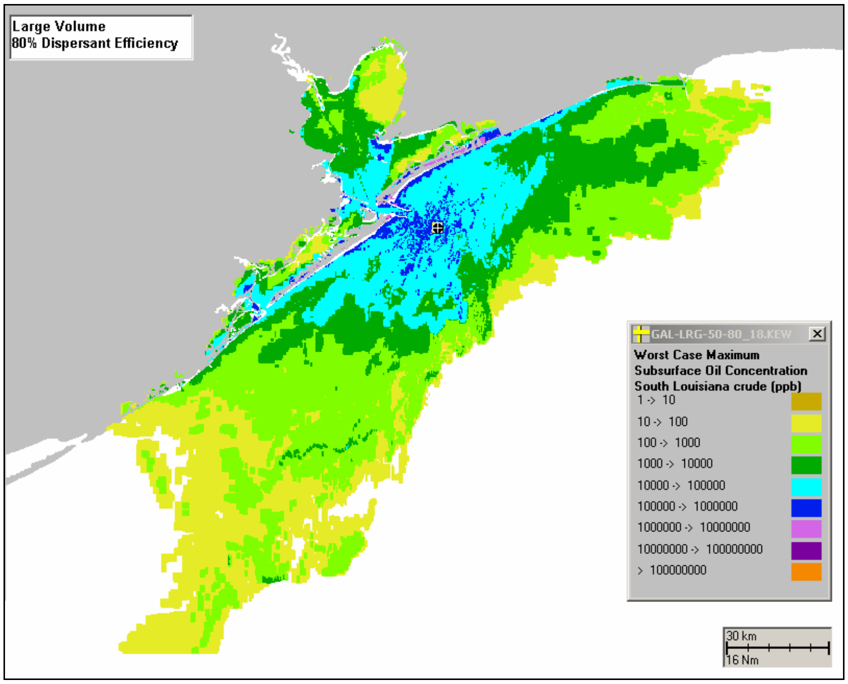

Figure C-II.1.6.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

C-II.1.6.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Large Volume, 80% Dispersant Efficiency

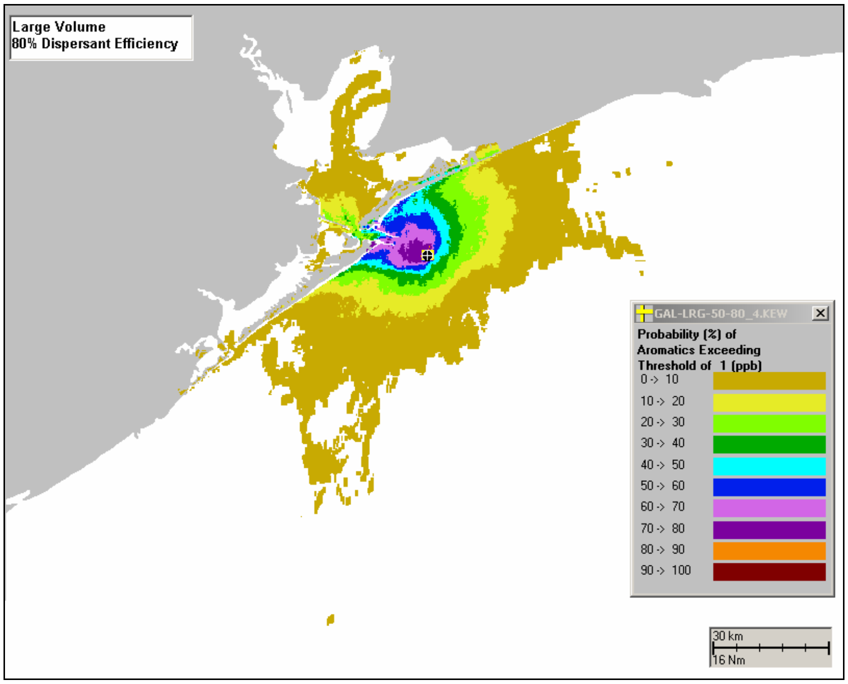

Figure C-II.1.6.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

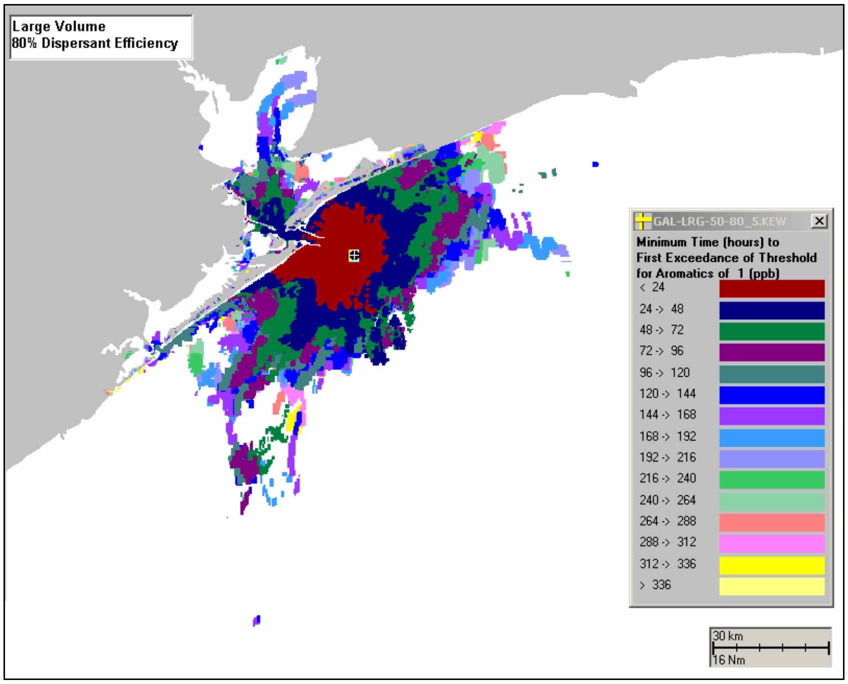

Figure C-II.1.6.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

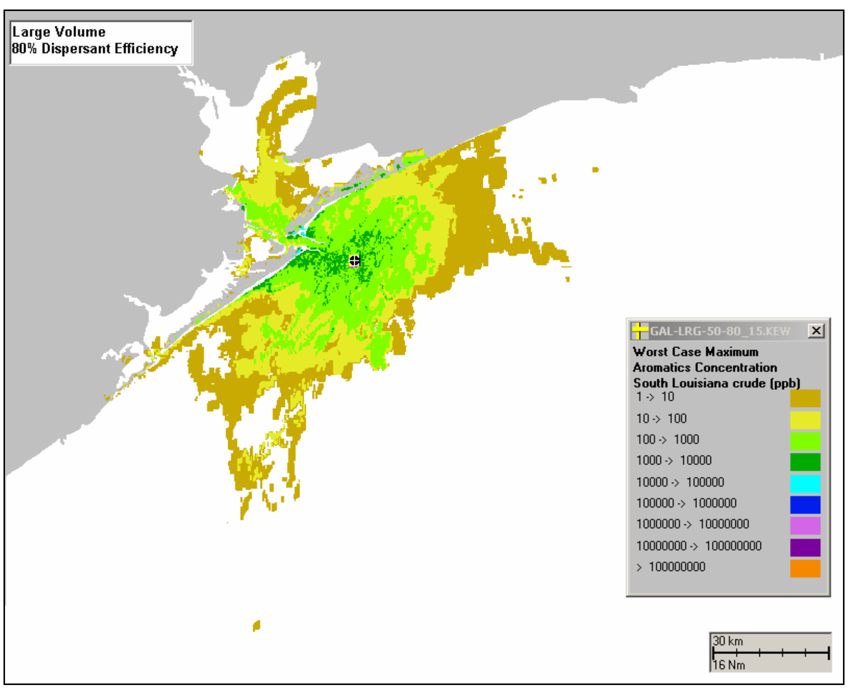

Figure C-II.1.6.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

C-II.1.6.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Large Volume, 80% Dispersant Efficiency

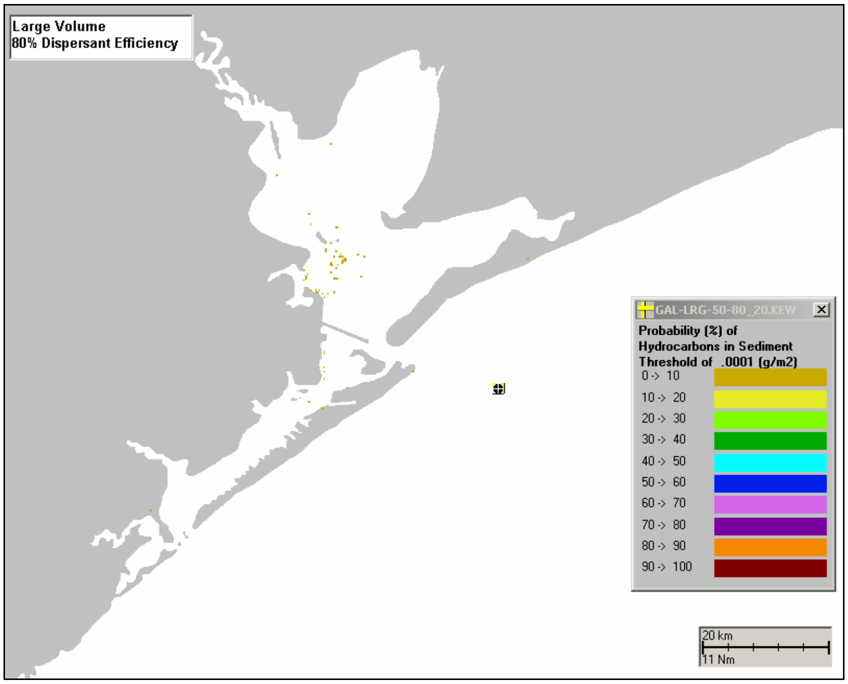

Figure C-II.1.6.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

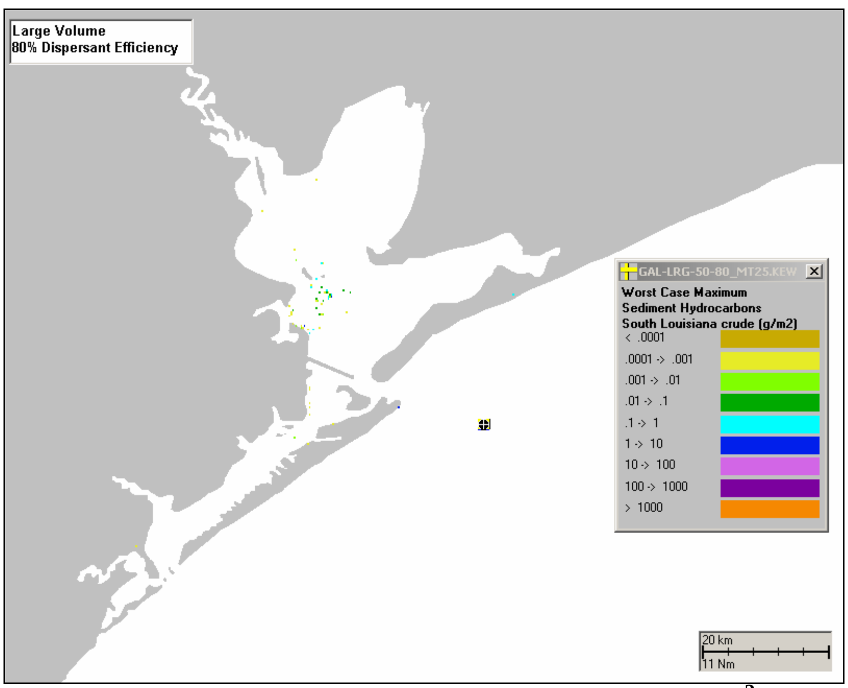

Figure C-II.1.6.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

C-II.1.6.6 Sediment pore water dissolved aromatic concentrations. Scenario: Large Volume, 80% Dispersant Efficiency

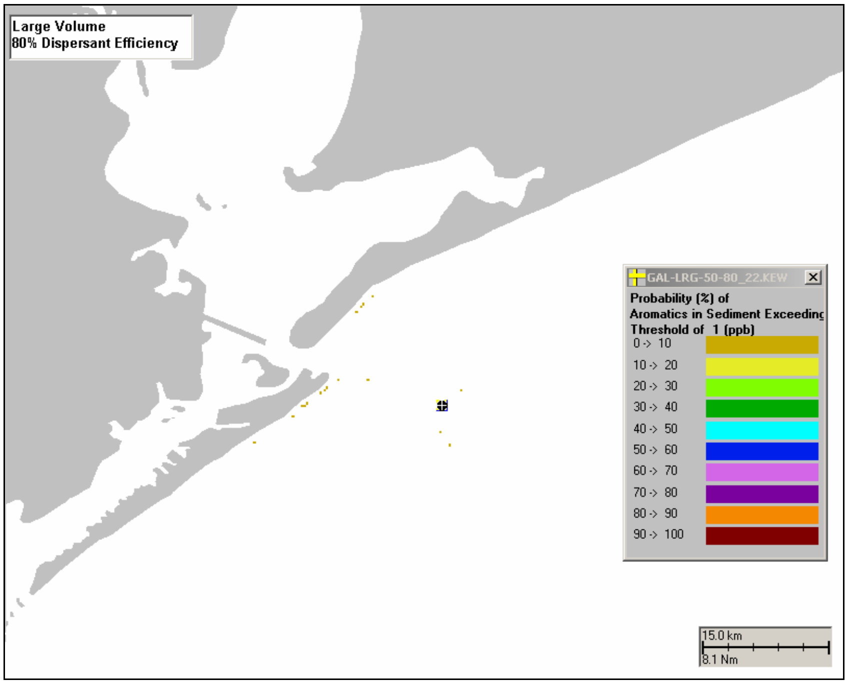

Figure C-II.1.6.6-1 Probability (%) of sediment pore water dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

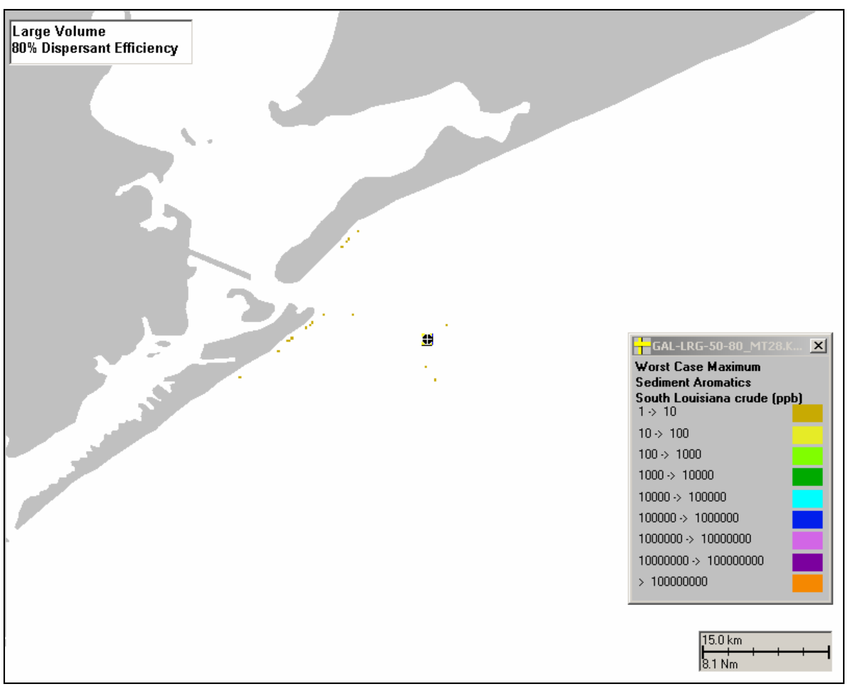

Figure C-II.1.6.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part C: Galveston Bay and North Texas Shelf

Section C-II.2

by

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ASA 00-246

August 2004

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C-II.2 Results of the Stochastic Modeling: Tables Summarizing Exposure Indices

Tables C-II.2-1 to C-II.2-6 summarize the exposure indices for all model runs in the stochastic oil spill modeling analysis for the spill site off Galveston Bay. Average and the maximum of the 100 simulations performed for each scenario are presented. The 95th percentile conditions used in the risk analysis were calculated as the mean plus two times the standard deviation. The following are the exposure indices used in the analysis.

- Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr) – integrated area swept by oil sheen or thicker oil times duration that oil is present [Note that this index is the oil mass passing through the cell averaged over the grid cell area, and so dilutes smaller patches of contamination. For this reason, evaluation of potential effects on wildlife is made using area swept by individual oil spillets; see explanation in Part A.4]
- Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) –area swept by oil sheen or thicker oil times, for landward (estuarine), seaward (marine), and all waters
- Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2) – shoreline oiled with a thickness exceeding this amount, averaged over the grid cell area (segment length of 293 m times typical width for the shore type, which is 1 m for rock/artificial and 5 m for other shore types)
- Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2) – shoreline oiled with a thickness exceeding this amount, averaged over the grid cell area (segment length times typical width for the shore type, as above)
- Length of Shoreline Oiling Exceeding 10 g/m^2 (m) – shoreline of various shore types oiled with a thickness exceeding this amount:
    - Total shoreline
    - Wetlands and mudflats
    - Other shoreline (rocky shore, gravel beach, sand beach, artificial shore)
    - Seaward (marine) sand beach
- Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – water volume contaminated at any time after the spill by > 1ppb dissolved aromatic concentration (in all subtidal habitats) [Note that this index is averaged over the grid cell and upper mixed layer, and so dilutes smaller patches of contamination. For this reason, evaluation of potential effects on biota is made using higher resolution small scale grids around the plume in the water; see explanation in Part A.4]
- Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs) – integrated exposure to dissolved aromatics, as ppb-hrs averaged over the water volume contaminated at any time after the spill by > 1ppb dissolved aromatic concentration
- Percent of Spilled Hydrocarbon Mass Coming Ashore (%) – percent of the spilled oil coming ashore by 14 days after the spill, assuming no shoreline cleanup
- Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)

- Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%) – maximum percent of the oil dispersed by natural forces (waves) and chemical dispersant. (Some naturally dispersed oil may resurface and be re-entrained into the water column, so this is the maximum percent in the water at any time after the spill.)
- Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%) – calculated by difference between no-dispersant and dispersant use scenario
- Percent of Spilled Hydrocarbon Mass Mechanically Removed (%) – The percentage decreases as chemical dispersion increases because less oil remains on the surface and is available to be skimmed.

Table C-II.2-1. Summary of exposure indices for all model runs (Medium Volume, No Dispersant).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	5,310 x 10^6	8,914 x 10^6	0	75,548 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) area only	7.352 x 10^6	26.06 x 10^6	52	169 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	331 x 10^6	470 x 10^6	0	2,620 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	338.2 x 10^6	471.6 x 10^6	0	2,640 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	281,098	192,072	1	980,200
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	74,078	48,131	1	250,694
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	15,888	10,229	1	51,545
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	609	953	50	4,100
Length of Shoreline Oiling Exceeding 10 g/m^{2} - Other Shoreline (m)	15,279	9,774	1	51,545

Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach	9,386	7,355	1	38,073
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	71×10^6	62×10^6	0	331×10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	451	268	0	1,371
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	20.51	7.81	1	33.01
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0104	0.0130	9	0.0442
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	19.84	11.83	0	70.58
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	0	0	100	0
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	9.25	6.96	3	23.49

Table C-II.2-2. Summary of exposure indices for all model runs (Medium Volume, 45% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2-hr)	2,726 x 10^6	6,354 x 10^6	0	59,995 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for landward (estuarine) area only	2.716 x 10^6	14.64 x 10^6	74	118.4 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for seaward (marine) area only	118.6 x 10^6	129.8 x 10^6	0	753.6 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for all waters	121.3 x 10^6	130.3 x 10^6	0	753.6 x 10^6
Area of Shoreline Oiling Exceeding $0.01 g/m^2$ (m^2)	168,670	150,746	5	760,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	33,489	31,767	15	145,556
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	7,369	6,983	15	31,922
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	334	1,276	71	11,422
Length of Shoreline Oiling Exceeding 10 g/m^{2} - Other Shoreline (m)	7,035	6,435	15	26,944
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach	4,109	4,380	18	21,379
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	163 x 10^6	101 x 10^6	0	536 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	2,223	1,471	0	6,433
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	8.58	10.58	7	30.04

Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0089	0.0096	4	0.0402
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	59.91	23.57	0	85.30
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	40.07	25.25	0	71.92
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	0.97	1.65	3	7.92

Table C-II.2-3. Summary of exposure indices for all model runs (Medium Volume, 80% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	2,136 x 10^6	4,060 x 10^6	0	32,186 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) area only	3.464 x 10^6	14 x 10^6	73	110.8 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	82.23 x 10^6	99.71 x 10^6	0	734.7 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	85.7 x 10^6	101.1 x 10^6	0	734.7 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	165,959	160,688	6	706,400
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	25,532	30,727	24	165,762
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	5,693	6,894	23	39,537
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	155	502	80	3,807
Length of Shoreline Oiling Exceeding 10 g/m^{2} - Other Shoreline (m)	5,538	6,553	23	35,730
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach	3,315	4,273	27	21,672
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	166 x 10^6	117 x 10^6	0	620 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	2,523	1,844	0	8,285
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	6.78	10.64	10	30.03
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal	0.0101	0.0112	4	0.0730

habitats) (%)				
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	64.49	25.39	0	88.63
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	44.65	27.19	0	78.82
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	0.76	1.68	38	7.90

Table C-II.2-4. Summary of exposure indices for all model runs (Large Volume, No Dispersant).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2-hr)	59,127 x 10^6	52,171 x 10^6	0	217,210 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for landward (estuarine) area only	24.66 x 10^6	47.25 x 10^6	13	214.9 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for seaward (marine) area only	764.7 x 10^6	738.6 x 10^6	0	3,904 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for all waters	789.3 x 10^6	730.8 x 10^6	0	3,910 x 10^6
Area of Shoreline Oiling Exceeding $0.01 g/m^2$ (m^2)	755,445	483,843	0	2,738,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	270,322	149,308	0	1,038,800
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	56,353	31,435	0	222,286
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	9,419	11,722	5	90,203
Length of Shoreline Oiling Exceeding 10 g/m^2 - Other Shoreline (m)	46,935	22,970	0	132,083
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach	28,531	16,586	0	96,060
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	373 x 10^6	306 x 10^6	0	1,353 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	1,632	1,010	0	5,426
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	17.40	5.72	0	27.96
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0025	0.0042	19	0.0271

Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	10.95	6.26	0	59.82
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	0	0	100	0
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	17.76	5.65	0	26.96

Table C-II.2-5. Summary of exposure indices for all model runs (Large Volume, 45% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	45,377 x 10^6	39,892 x 10^6	0	184,201 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) area only	20.38 x 10^6	39.86 x 10^6	19	217.6 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	685.1 x 10^6	674.2 x 10^6	0	3,825 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	705.5 x 10^6	668.2 x 10^6	0	3,832 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	727,073	474,970	0	2,421,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	239,246	130,570	1	812,704
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	49,963	27,394	1	170,448
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	7,749	9,685	6	66,481
Length of Shoreline Oiling Exceeding 10 g/m^{2-} Other Shoreline (m)	42,214	20,964	1	103,968
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach	25,468	14,508	1	72,045
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	642 x 10^6	415 x 10^6	0	2,140 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	3,734	2,030	0	10,050
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	14.90	6.33	1	27.35
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal	0.0034	0.0043	8	0.0237

habitats) (%)				
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	22.13	9.11	0	63.16
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	11.18	8.19	0	23.72
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	14.35	3.69	0	20.61

Table C-II.2-6. Summary of exposure indices for all model runs (Large Volume, 80% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	38,158 x 10^6	33,831 x 10^6	0	139,785 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) area only	22.74 x 10^6	46.74 x 10^6	19	255.1 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	629.6 x 10^6	603.8 x 10^6	0	3,468 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	652.4 x 10^6	598.4 x 10^6	0	3,476 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	676,665	465,523	0	2,703,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	211,681	120,193	1	672,423
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	44,607	25,596	1	146,140
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	5,655	6,047	8	30,458
Length of Shoreline Oiling Exceeding 10 g/m^{2} - Other Shoreline (m)	38,951	21,103	1	116,854
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach	23,049	13,889	1	68,531
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	719 x 10^6	459 x 10^6	0	1,903 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	4,948	3,121	0	13,960
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	12.81	7.37	1	26.62
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal	0.0040	0.0052	5	0.0355

habitats) (%)				
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	31.04	15.21	0	66.49
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	20.09	15.18	0	44.21
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	11.87	2.93	0	18.46

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part C: Galveston Bay and North Texas Shelf

Section C-II.3

by

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ASA 00-246

August 2004

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In this section, the following impact indices are plotted as rank order distributions:

- Water surface exposed to floating hydrocarbons, as the sum of area covered by more than $0.01 g/m^2$ (which is sheen) times duration of exposure (in m^2-hrs)
- Shoreline area (m^2) exposed to hydrocarbons of various threshold thicknesses (>1, 10, 100, and 1000 g/m^2)
- Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill
- Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill
- Percent of spilled hydrocarbon mass eventually going ashore
- Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats)
- Maximum percent of spilled hydrocarbon mass in the water column at any time after the spill, and
- Percent of spilled hydrocarbon mass mechanically removed.

C-II.3.1 Scenario: Medium Volume, No Dispersant.

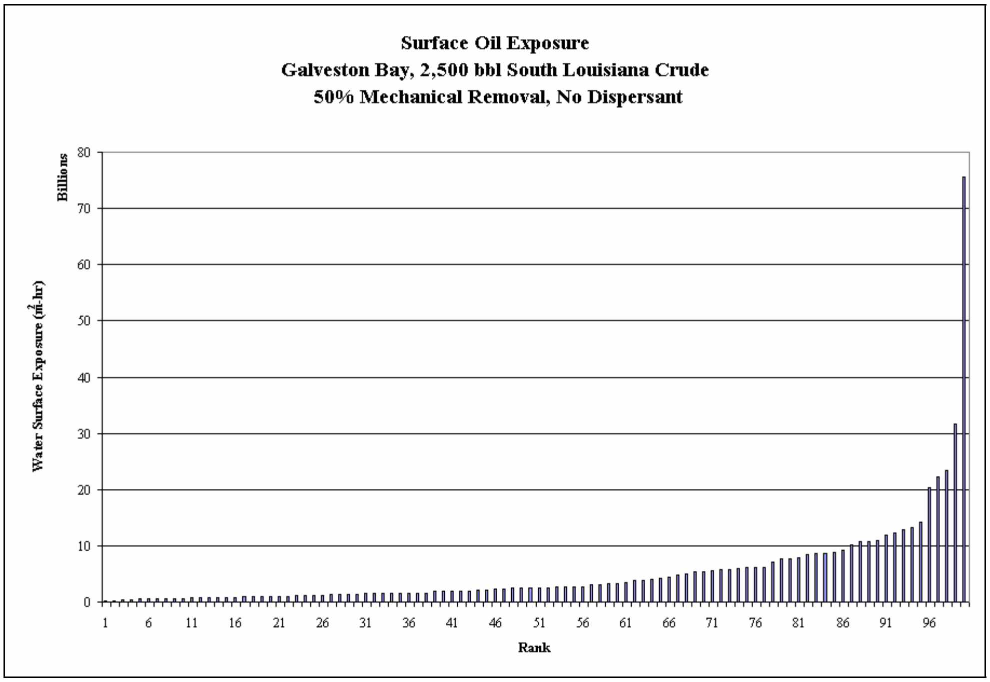

Figure C-II.3.1-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Medium Volume, No Dispersant.

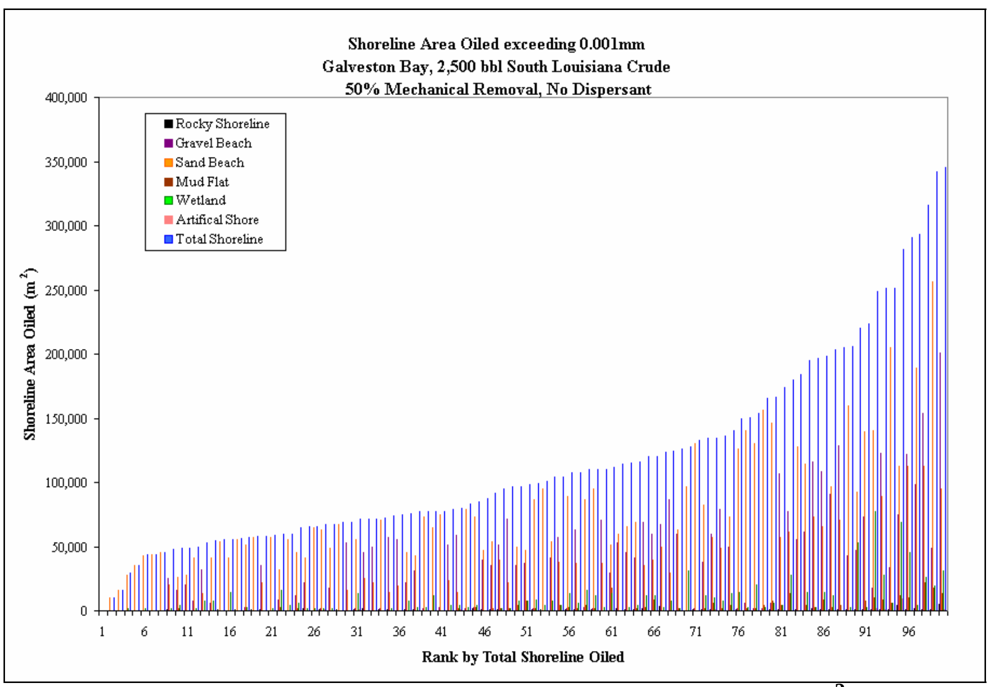

Figure C-II.3.1-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Medium Volume, No Dispersant.

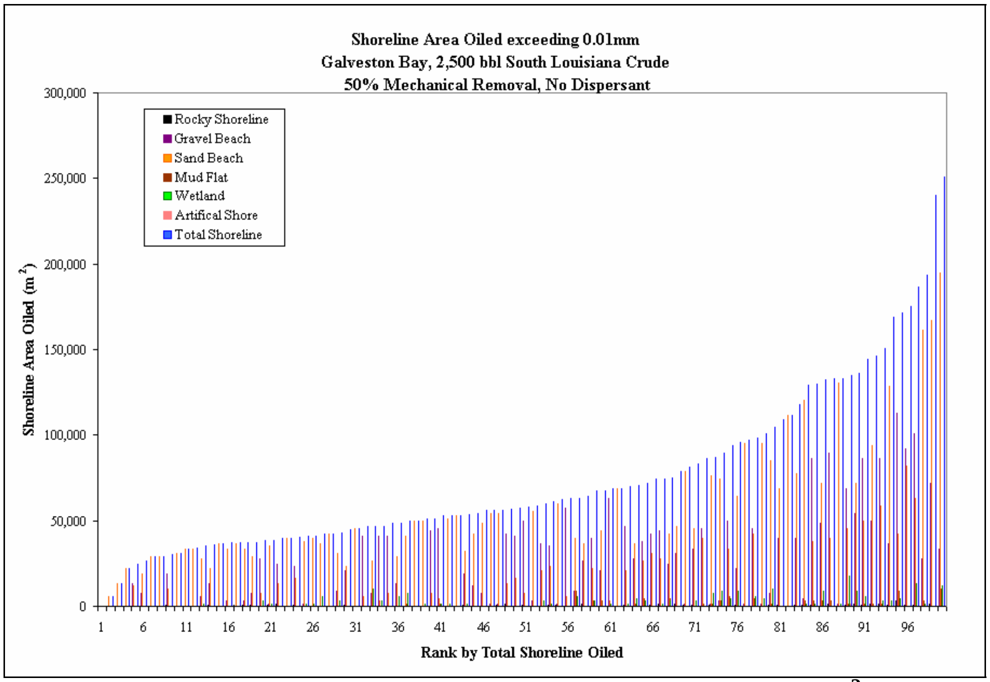

Figure C-II.3.1-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Medium Volume, No Dispersant.

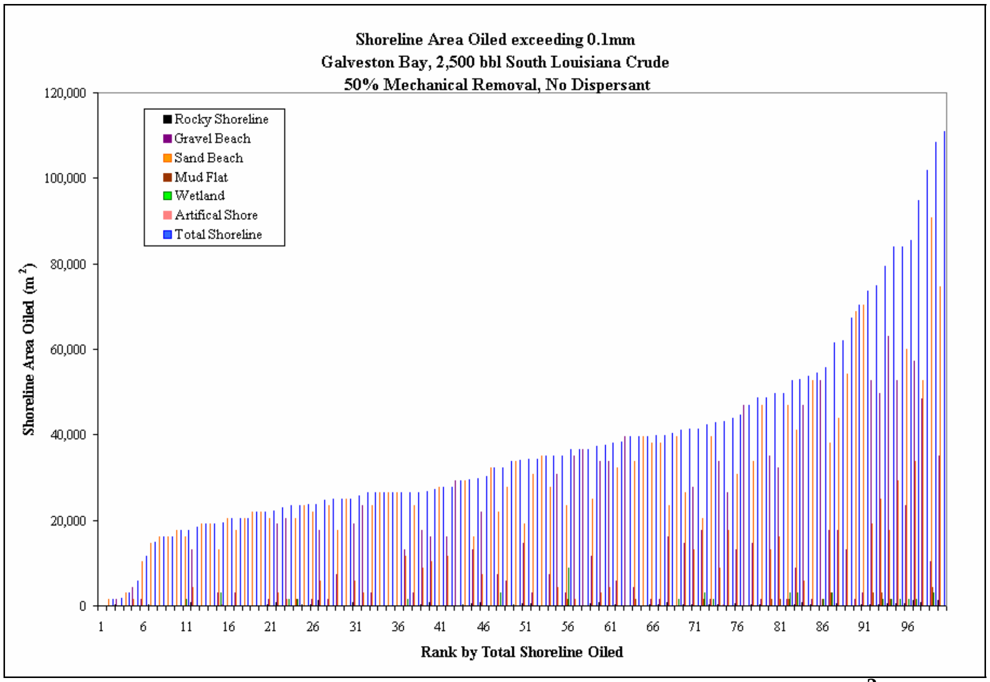

Figure C-II.3.1-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Medium Volume, No Dispersant.

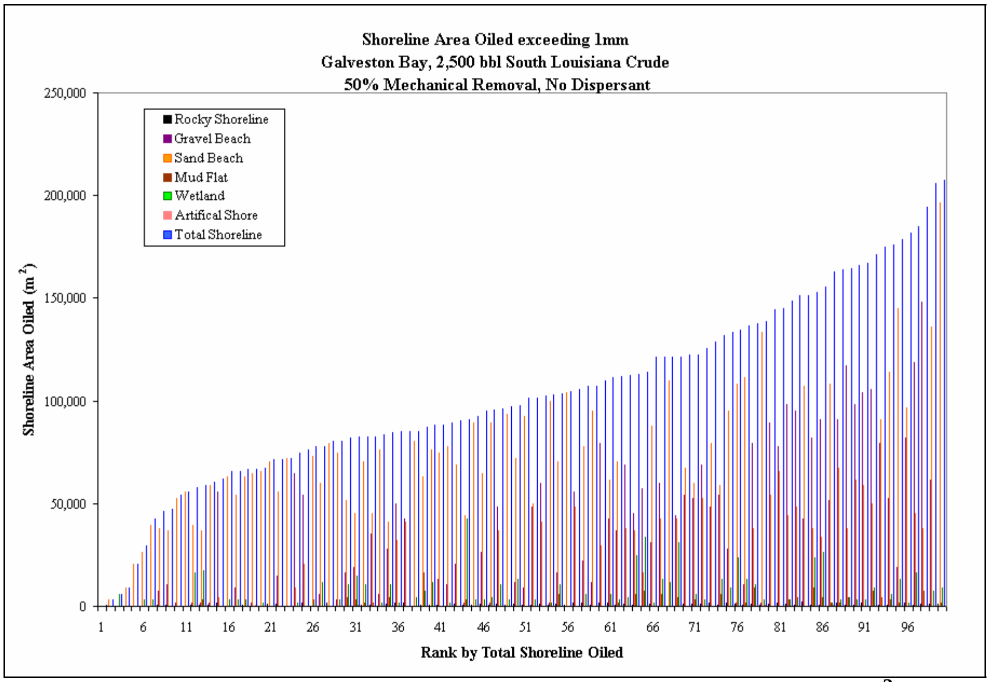

Figure C-II.3.1-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Medium Volume, No Dispersant.

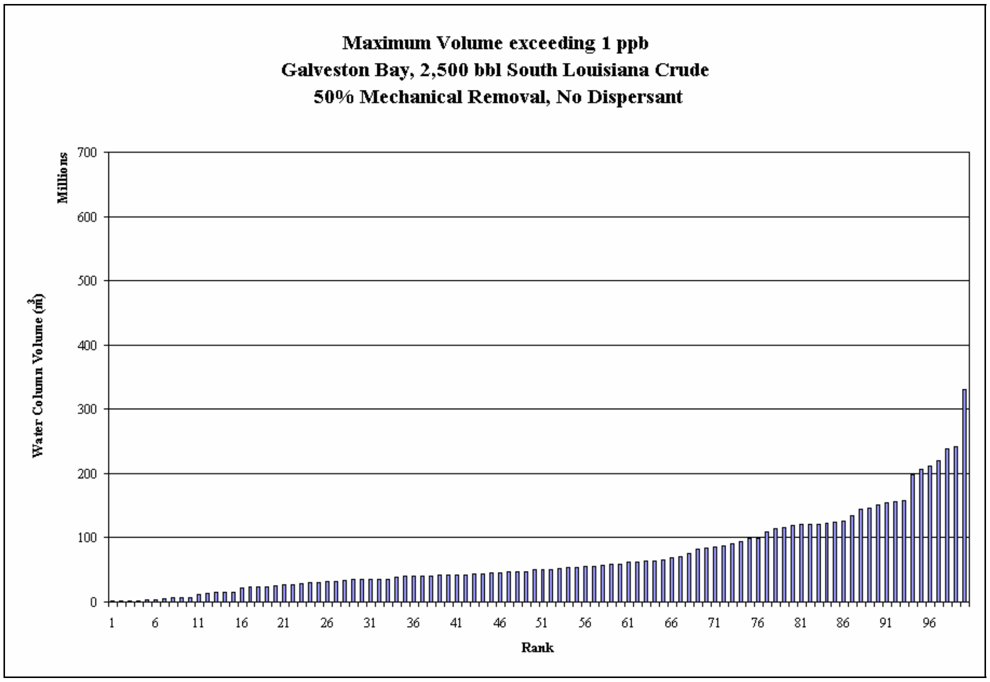

Figure C-II.3.1-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, No Dispersant.

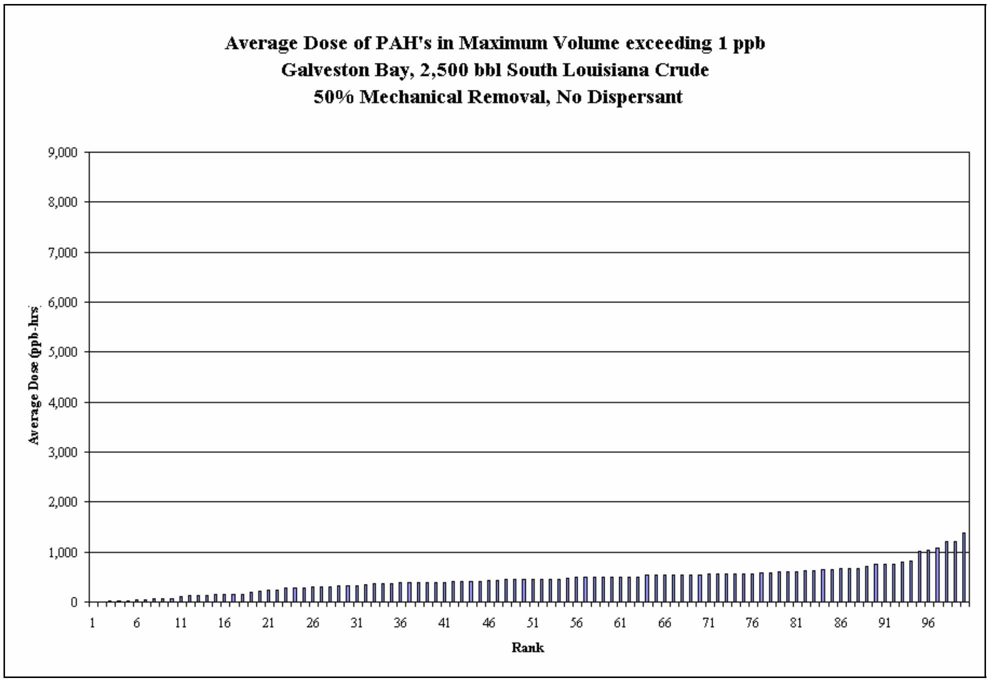

Figure C-II.3.1-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, No Dispersant.

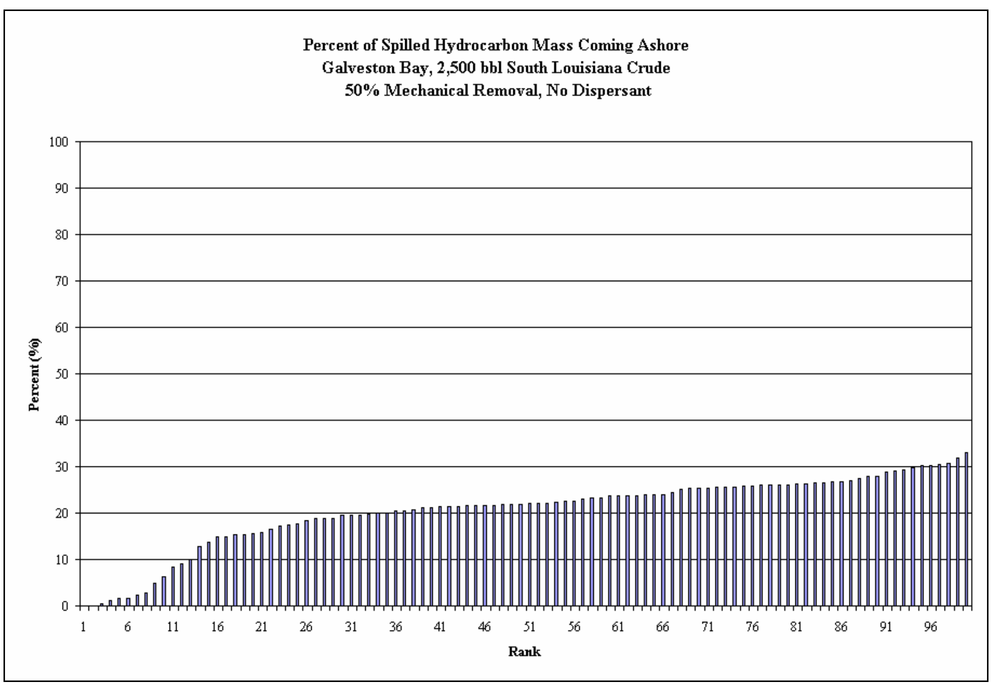

Figure C-II.3.1-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Medium Volume, No Dispersant.

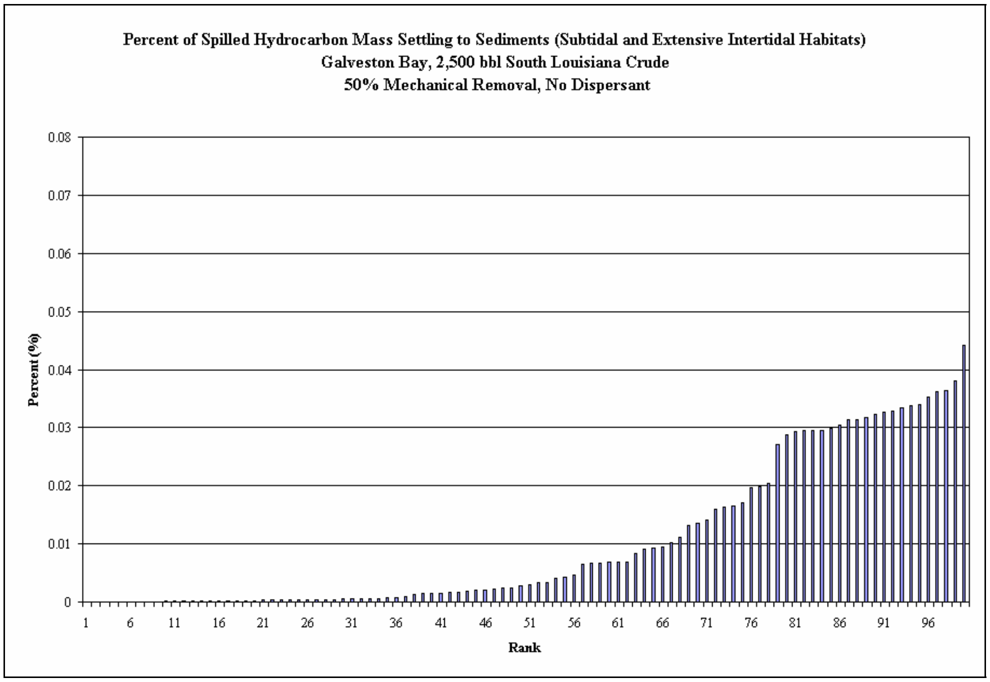

Figure C-II.3.1-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Medium Volume, No Dispersant.

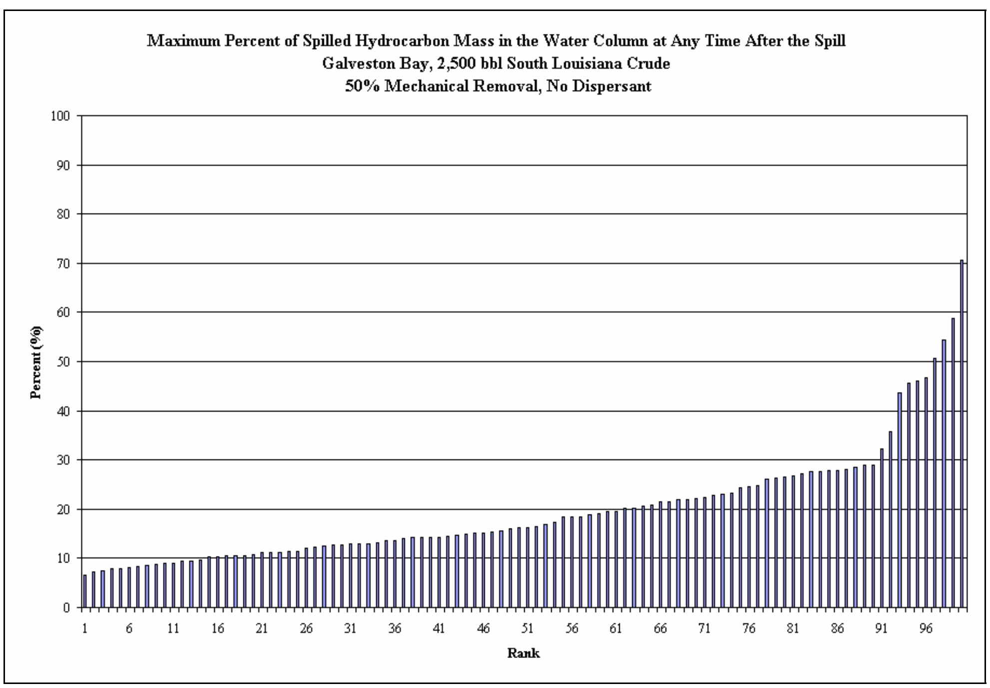

Figure C-II.3.1-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Medium Volume, No Dispersant.

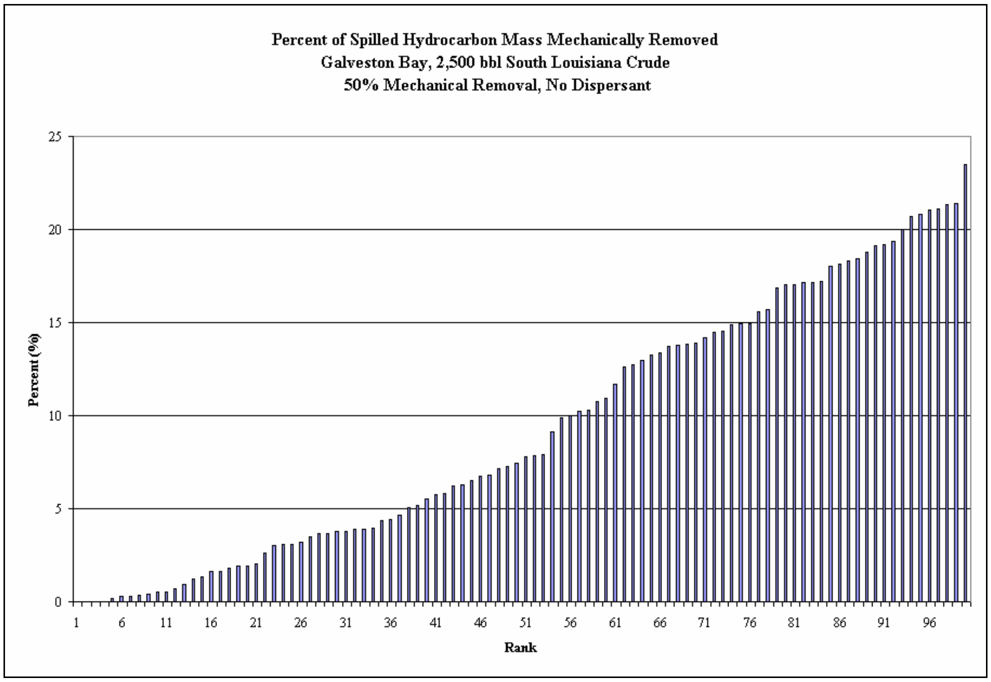

Figure C-II.3.1-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Medium Volume, No Dispersant.

C-II.3.2 Scenario: Medium Volume, 45% Dispersant Efficiency.

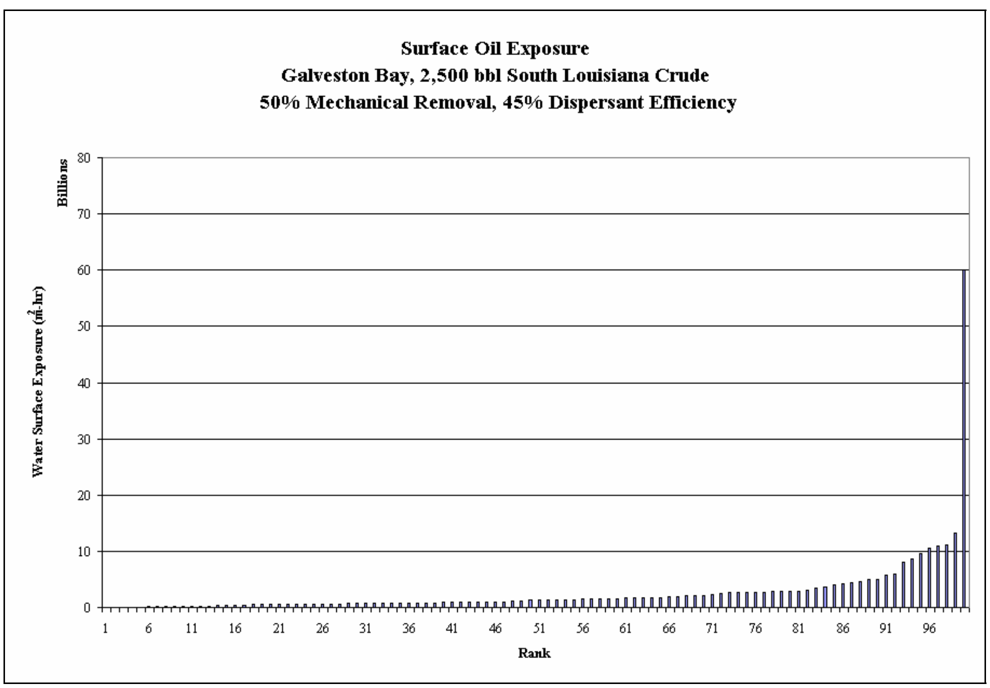

Figure C-II.3.2-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

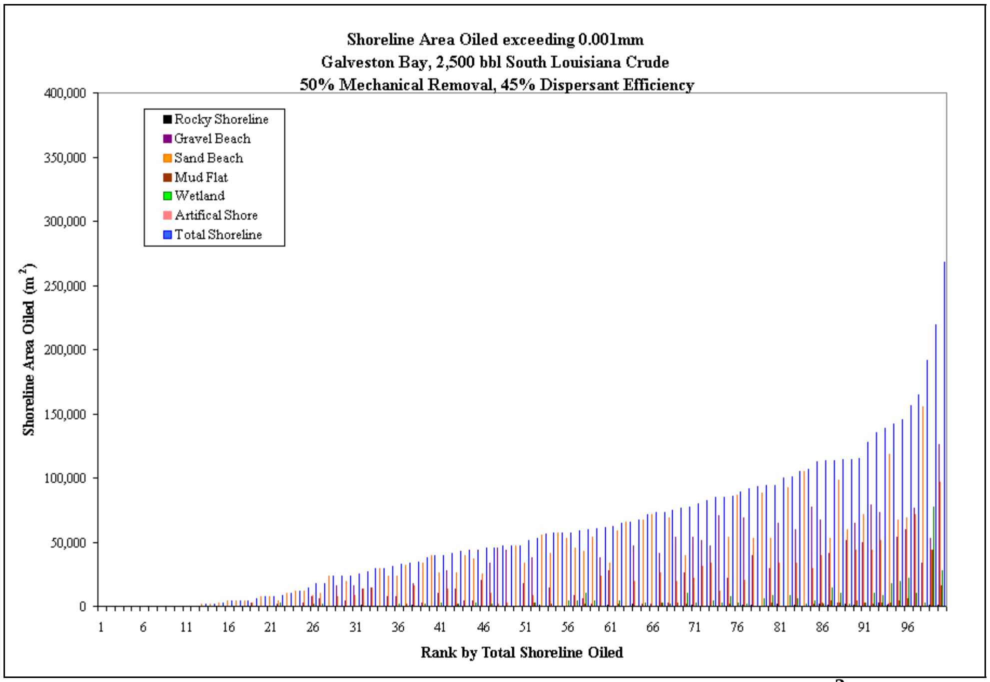

Figure C-II.3.2-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

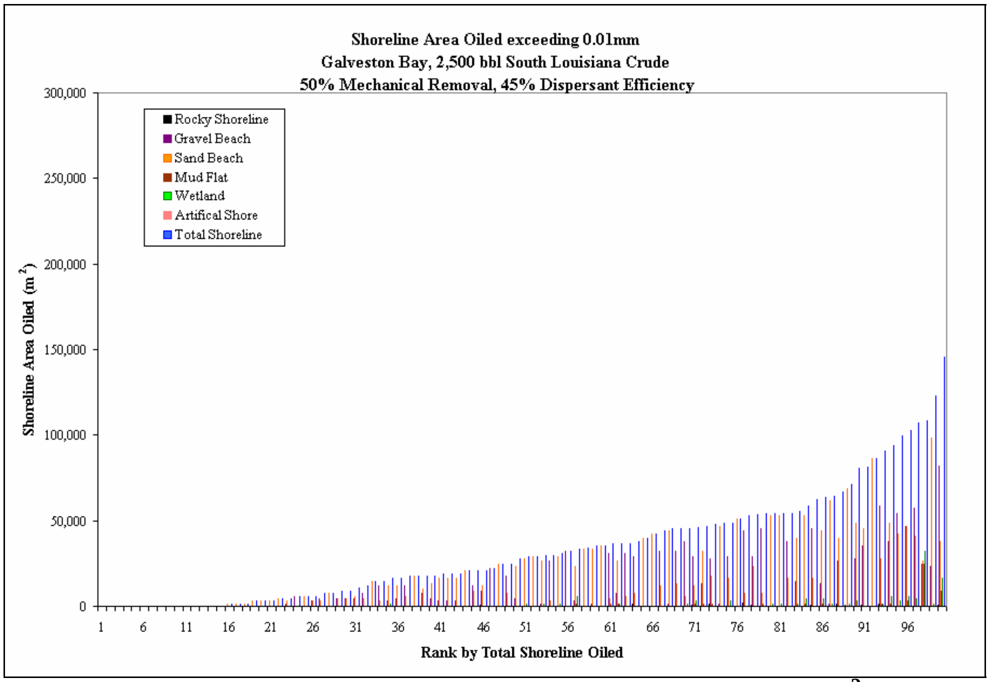

Figure C-II.3.2-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

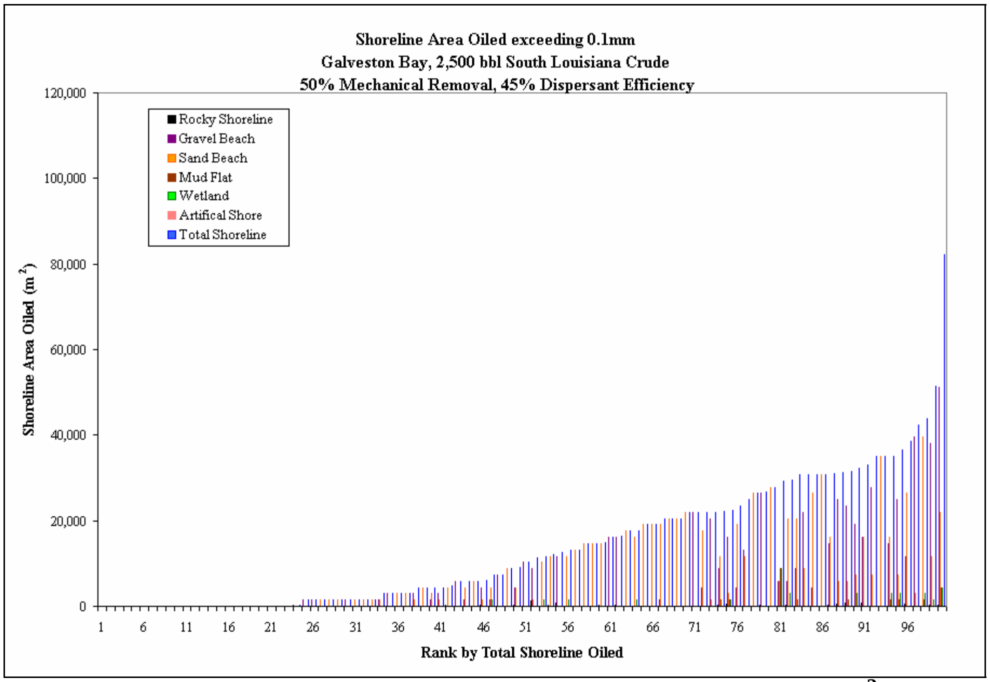

Figure C-II.3.2-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

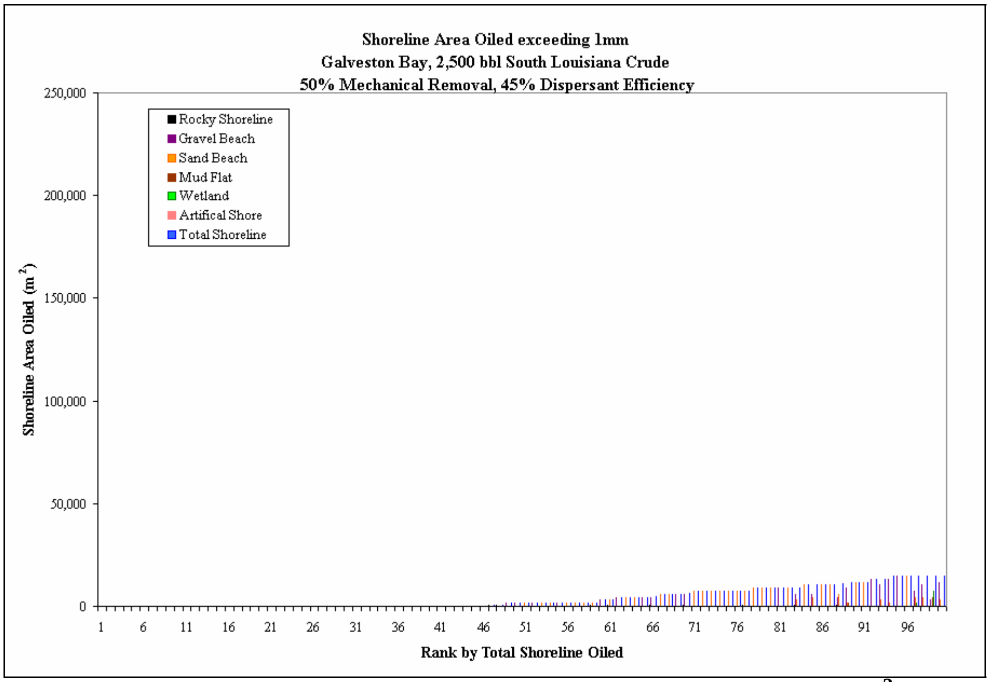

Figure C-II.3.2-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

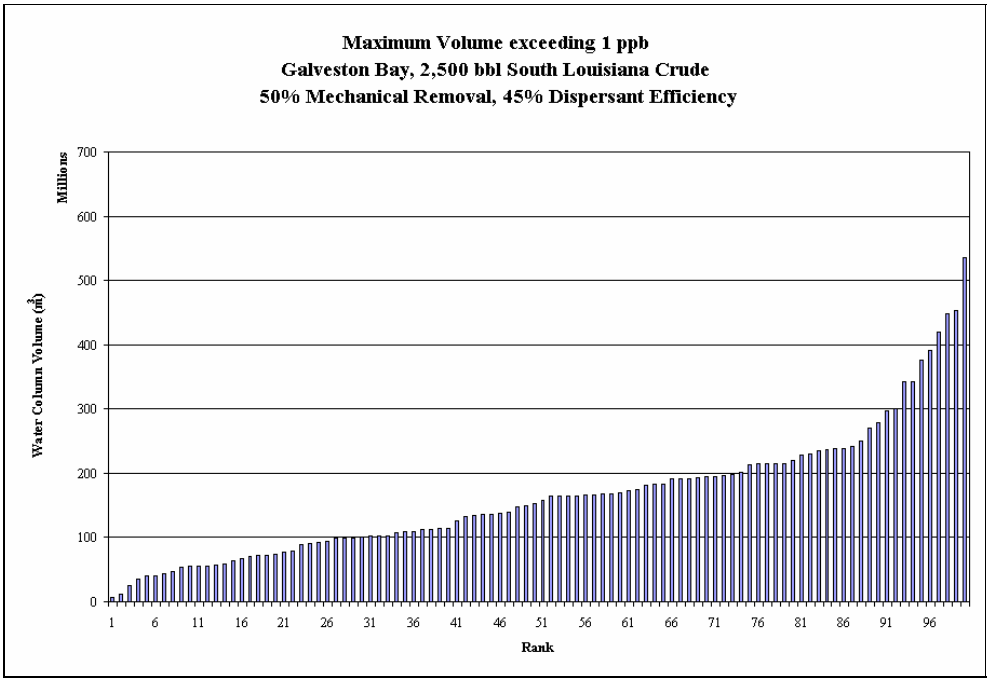

Figure C-II.3.2-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 45% Dispersant Efficiency.

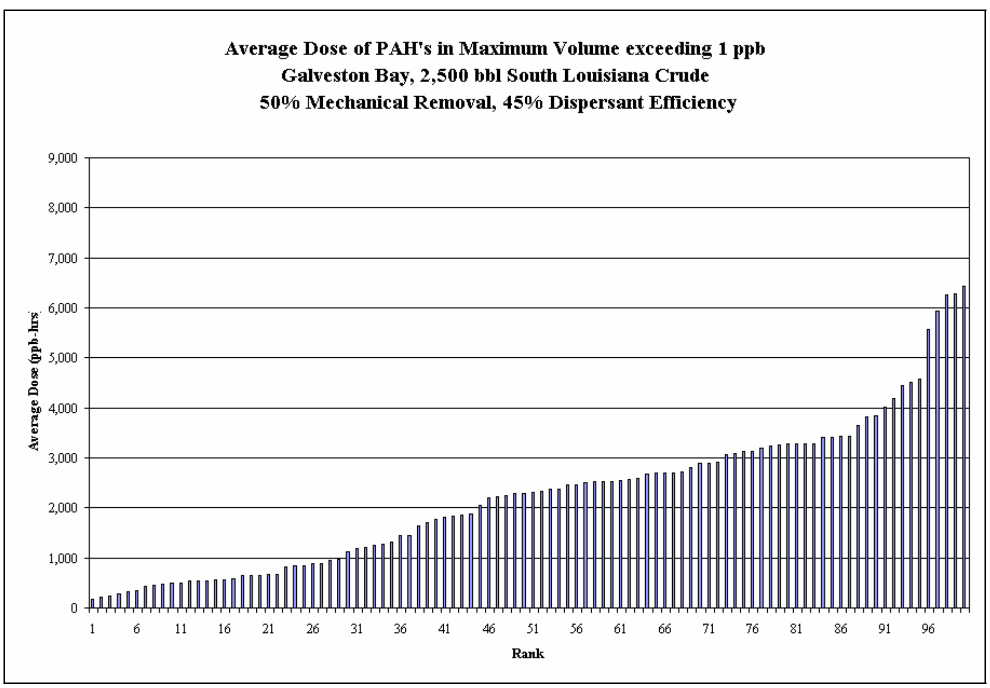

Figure C-II.3.2-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 45% Dispersant Efficiency.

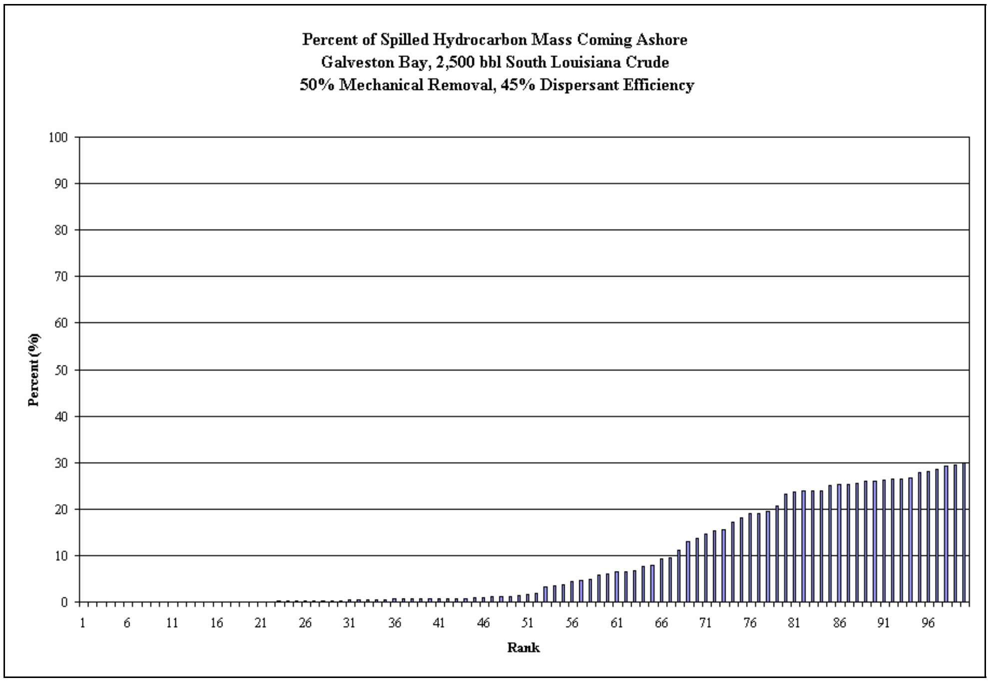

Figure C-II.3.2-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Medium Volume, 45% Dispersant Efficiency.

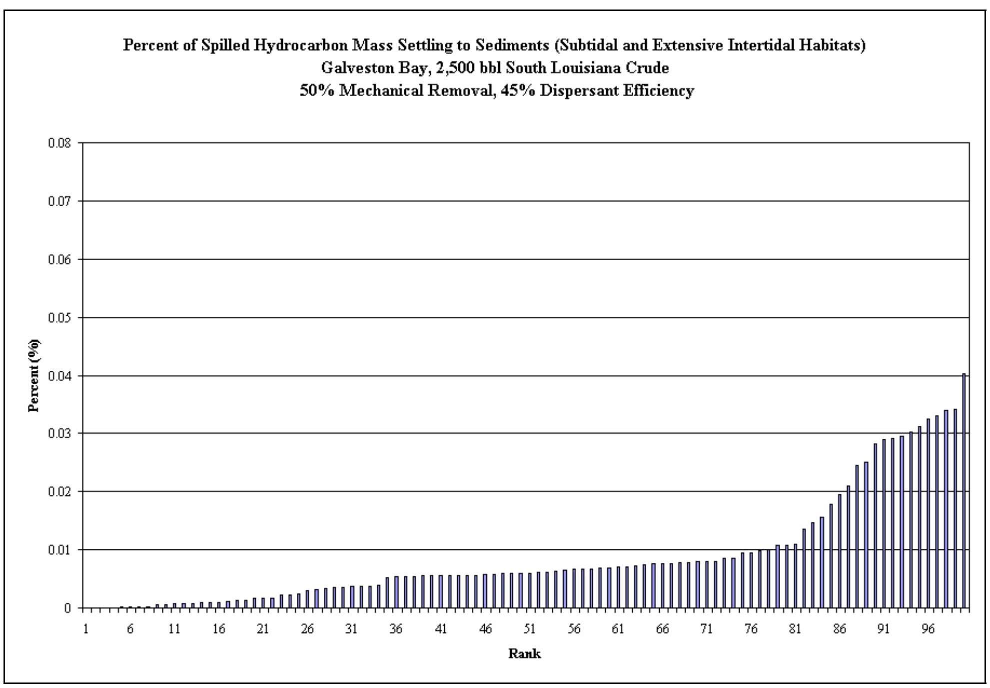

Figure C-II.3.2-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Medium Volume, 45% Dispersant Efficiency.

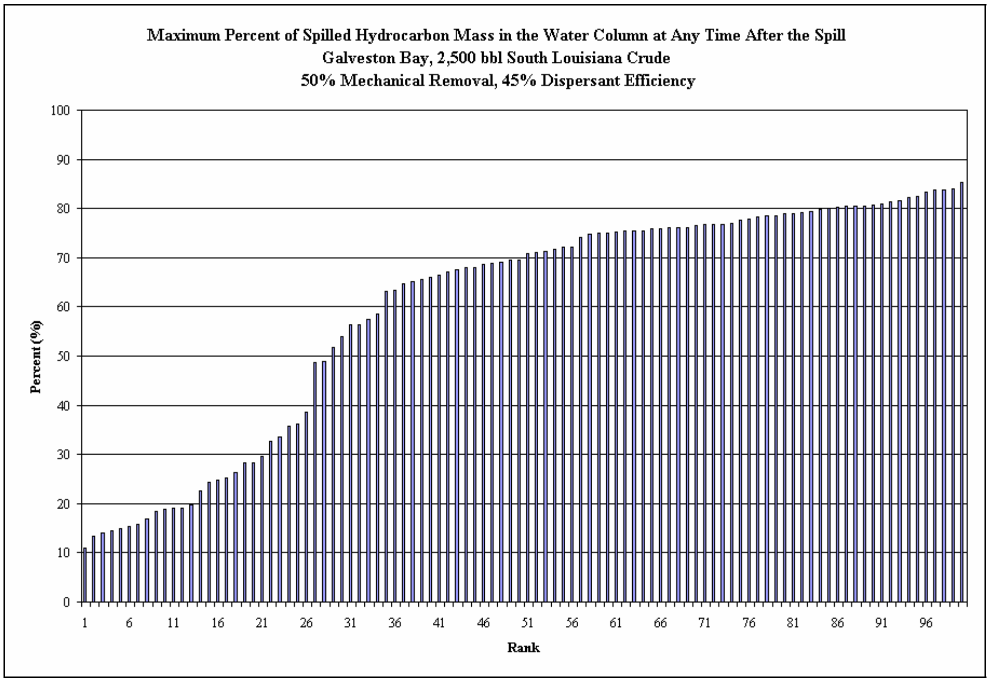

Figure C-II.3.2-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Medium Volume, 45% Dispersant Efficiency.

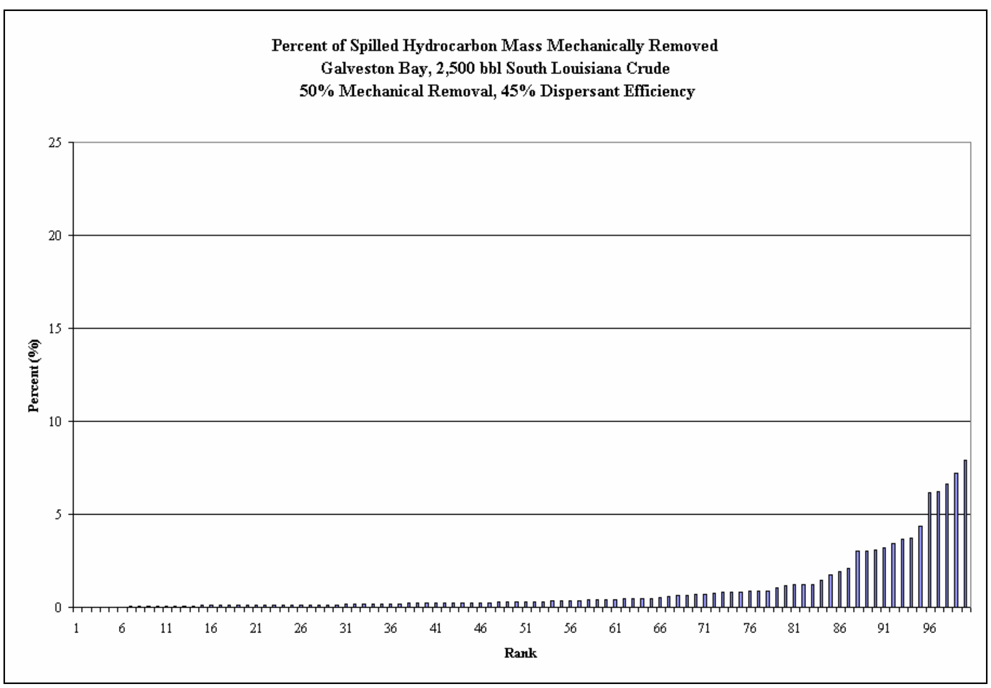

Figure C-II.3.2-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Medium Volume, 45% Dispersant Efficiency.

C-II.3.3 Scenario: Medium Volume, 80% Dispersant Efficiency.

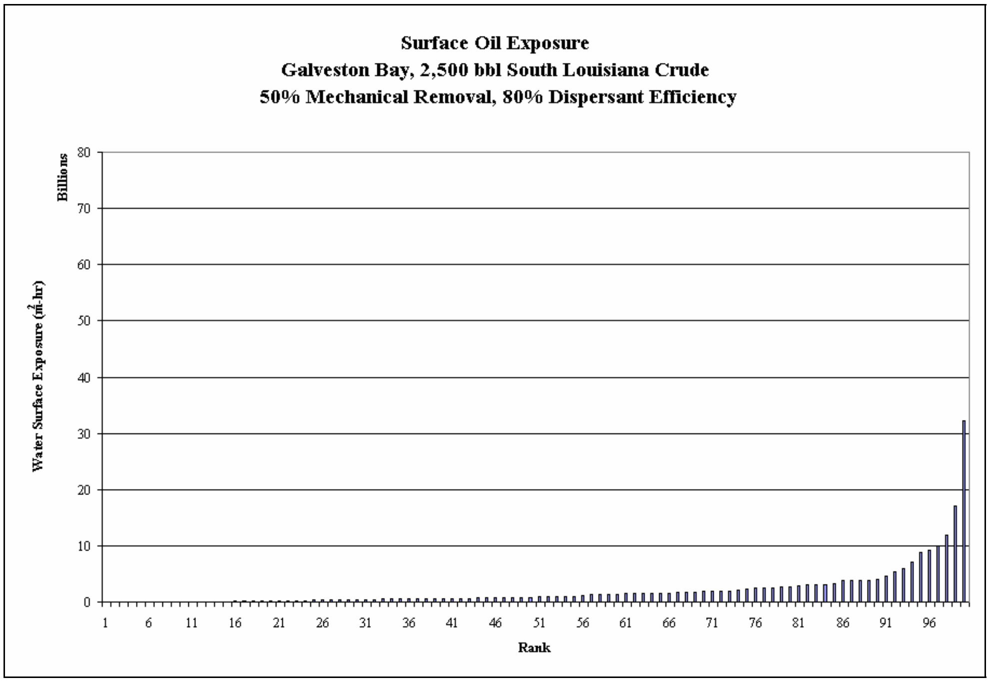

Figure C-II.3.3-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

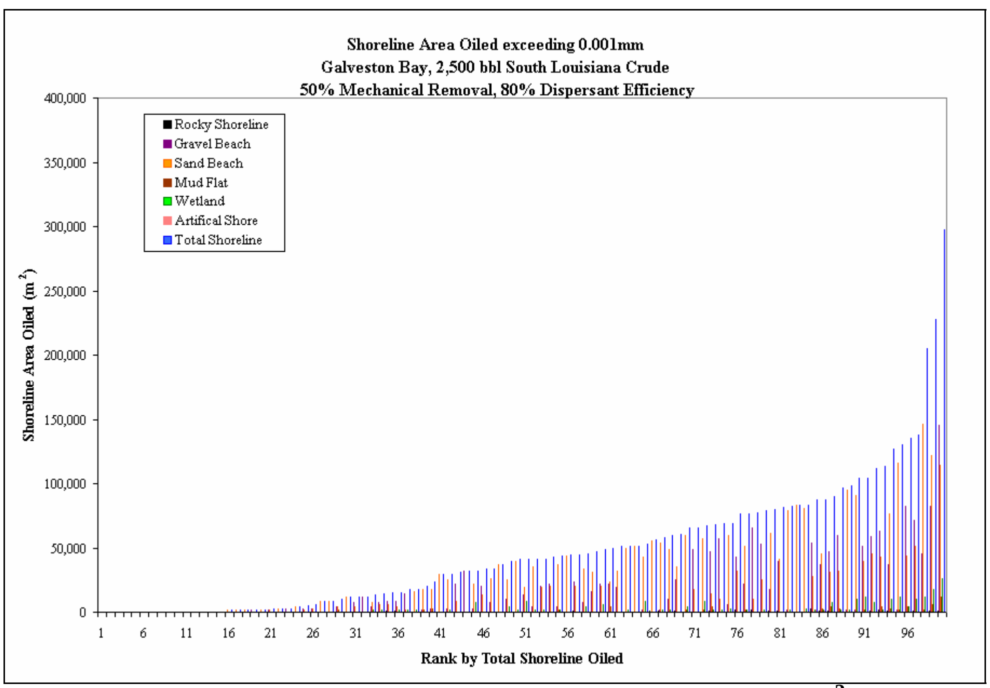

Figure C-II.3.3-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

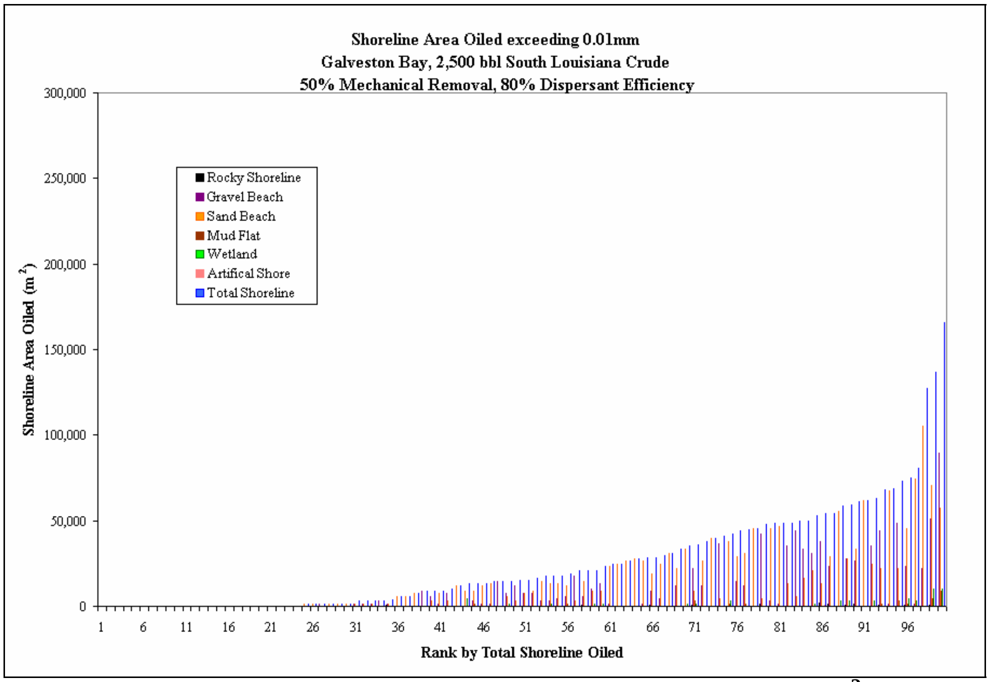

Figure C-II.3.3-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

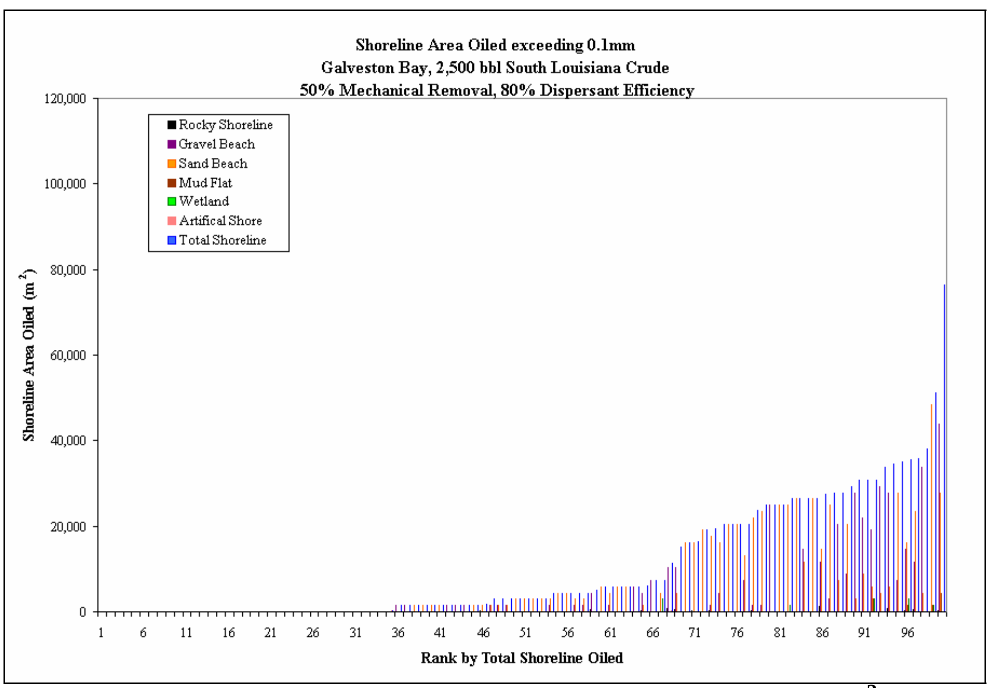

Figure C-II.3.3-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

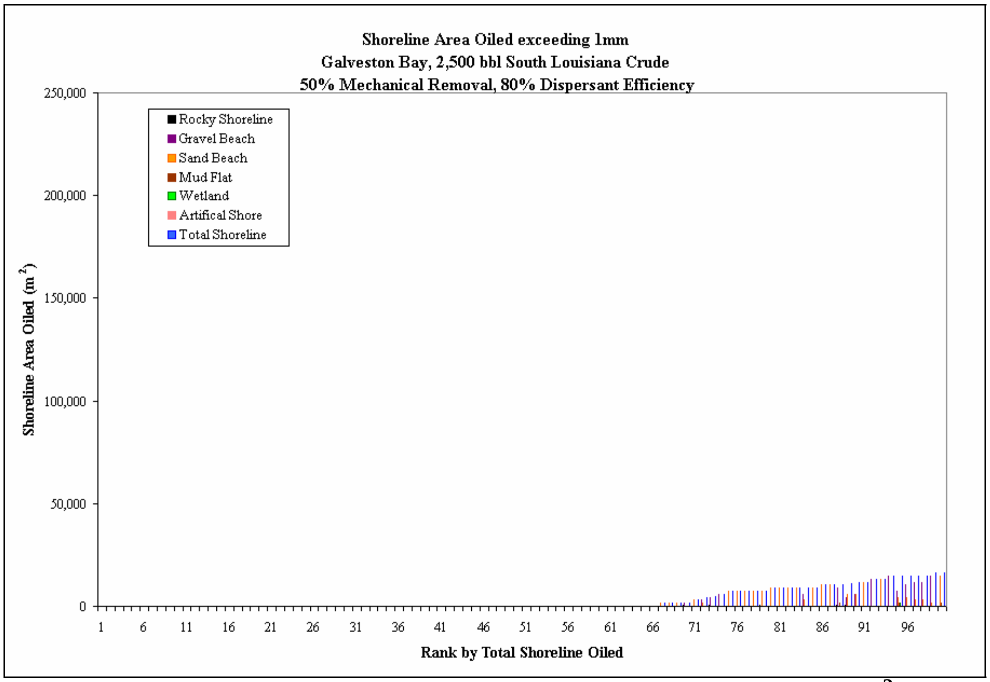

Figure C-II.3.3-5 Shoreline area exposed to hydrocarbons of >1000g/m² (about 1mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

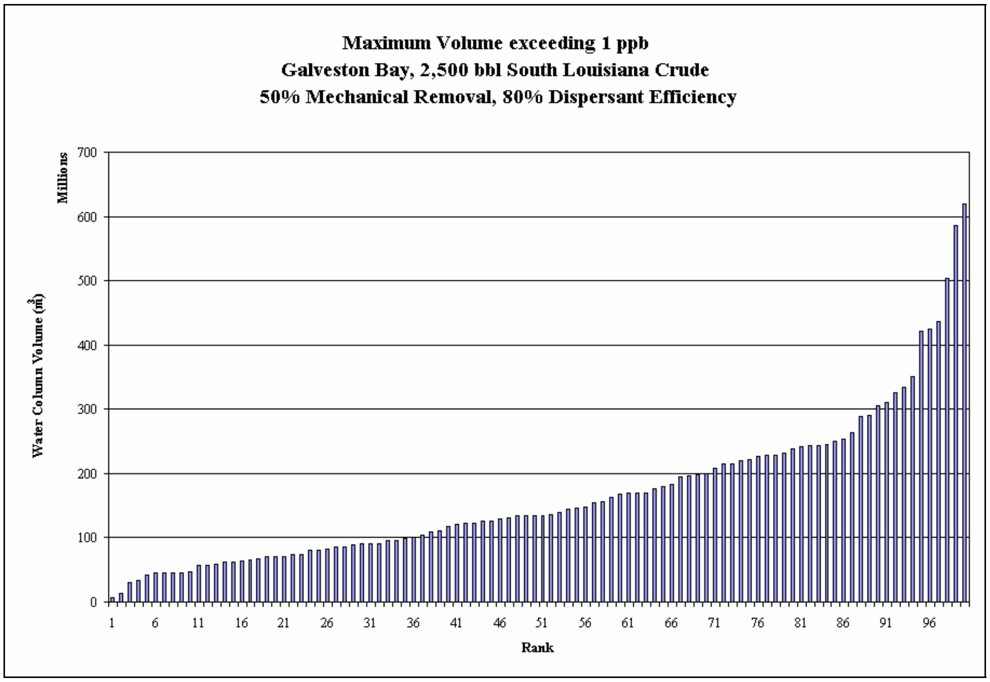

Figure C-II.3.3-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 80% Dispersant Efficiency.

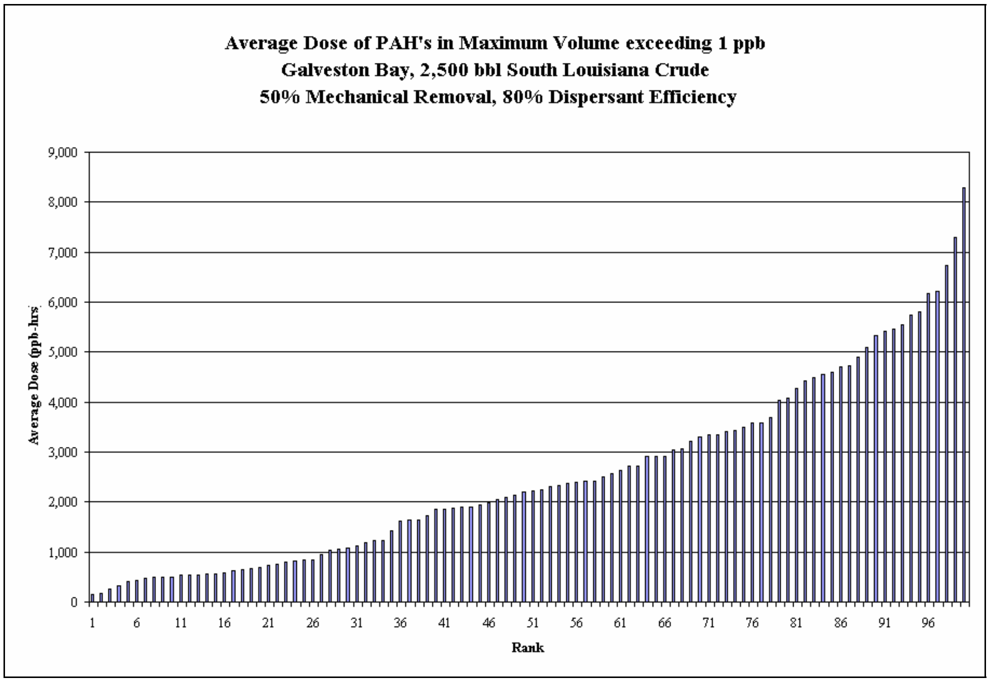

Figure C-II.3.3-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 80% Dispersant Efficiency.

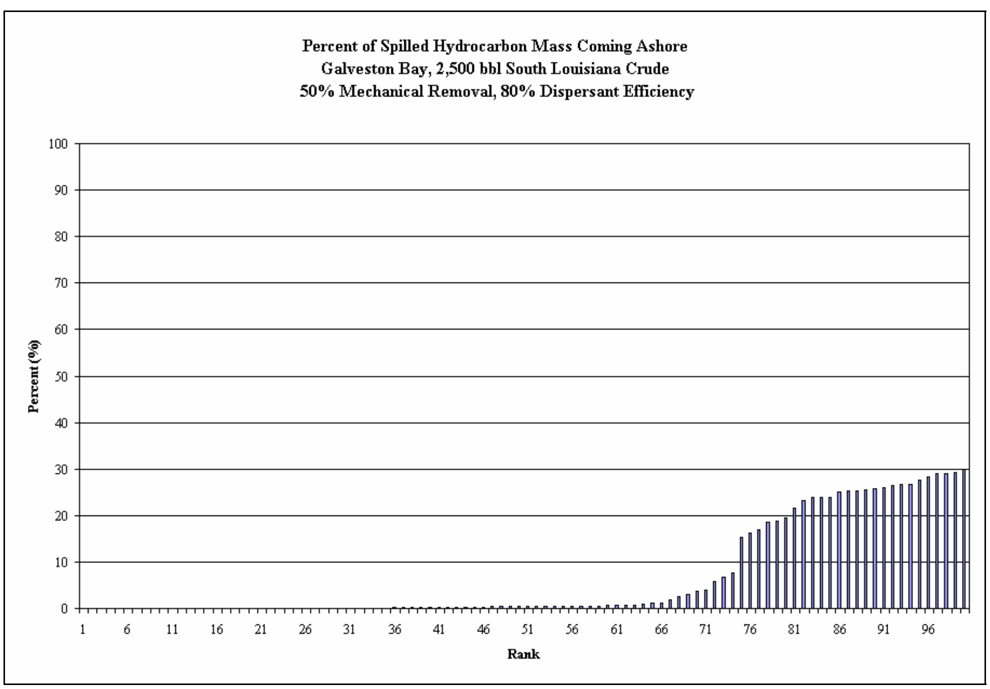

Figure C-II.3.3-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Medium Volume, 80% Dispersant Efficiency.

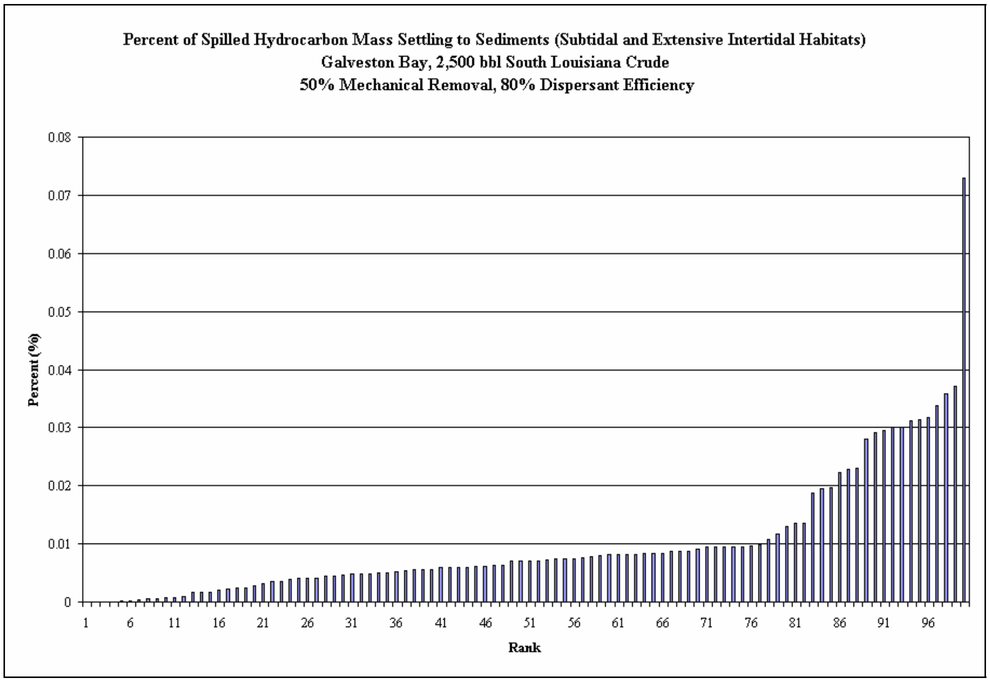

Figure C-II.3.3-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Medium Volume, 80% Dispersant Efficiency.

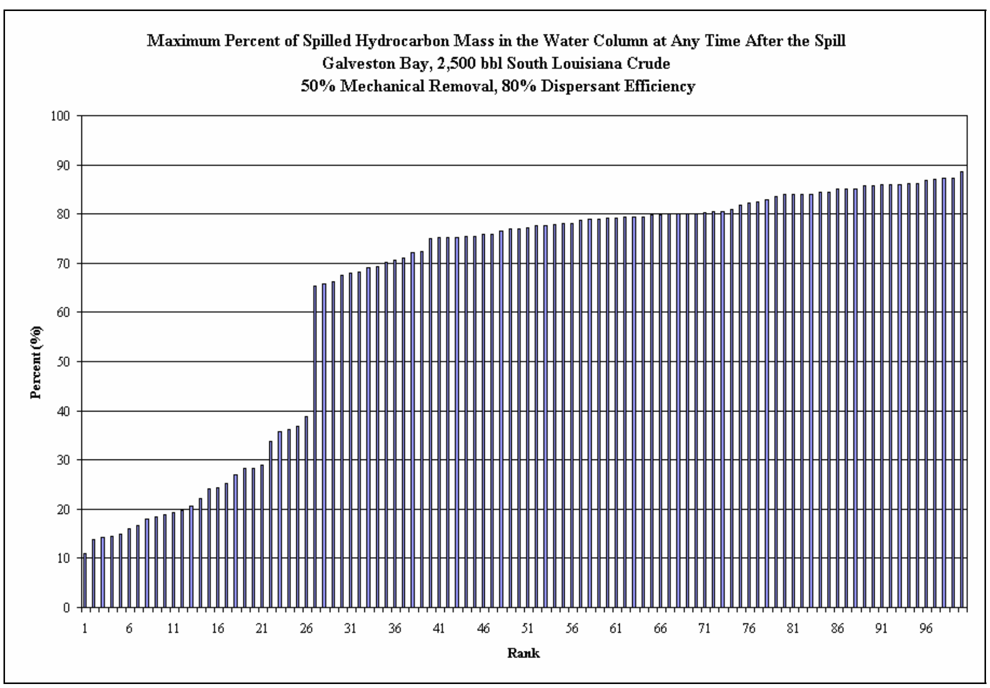

Figure C-II.3.3-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Medium Volume, 80% Dispersant Efficiency.

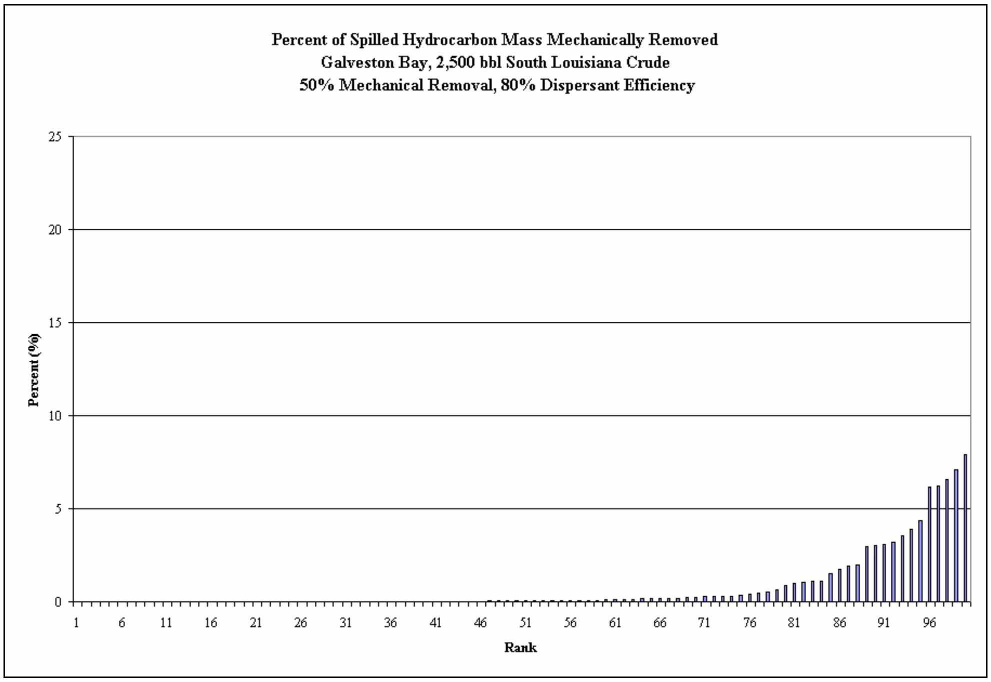

Figure C-II.3.3-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Medium Volume, 80% Dispersant Efficiency.

C-II.3.4 Scenario: Large Volume, No Dispersant.

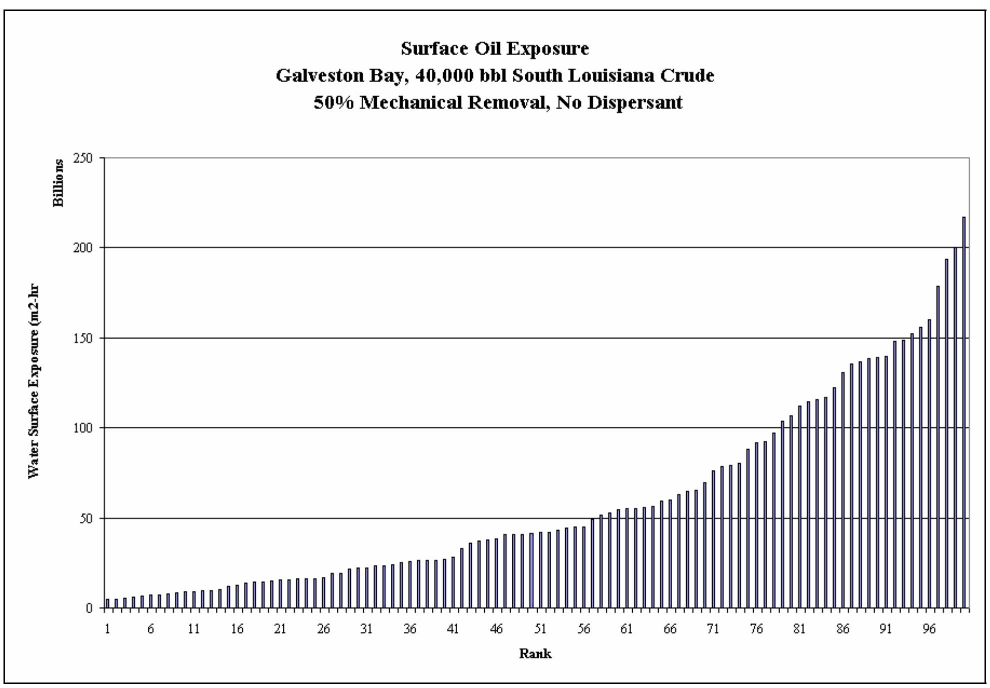

Figure C-II.3.4-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Large Volume, No Dispersant.

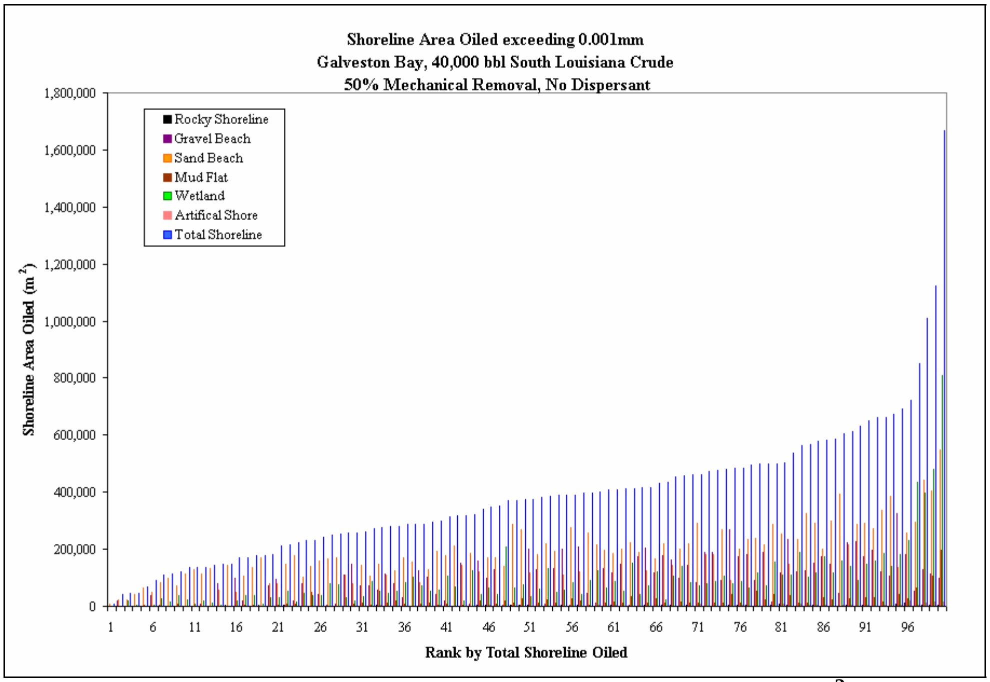

Figure C-II.3.4-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Large Volume, No Dispersant.

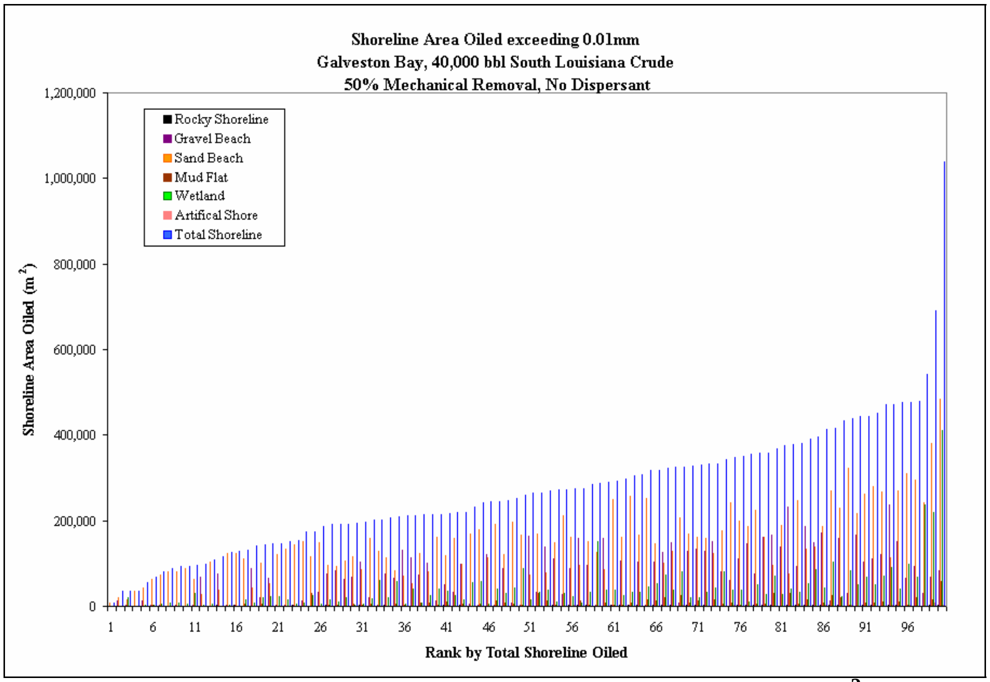

Figure C-II.3.4-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Large Volume, No Dispersant.

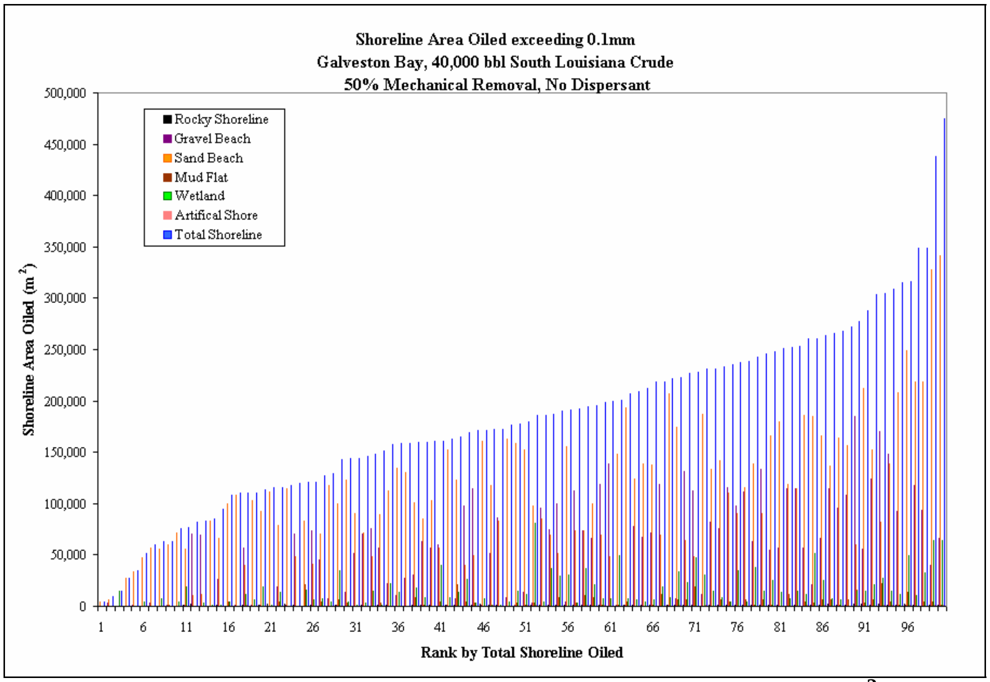

Figure C-II.3.4-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Large Volume, No Dispersant.

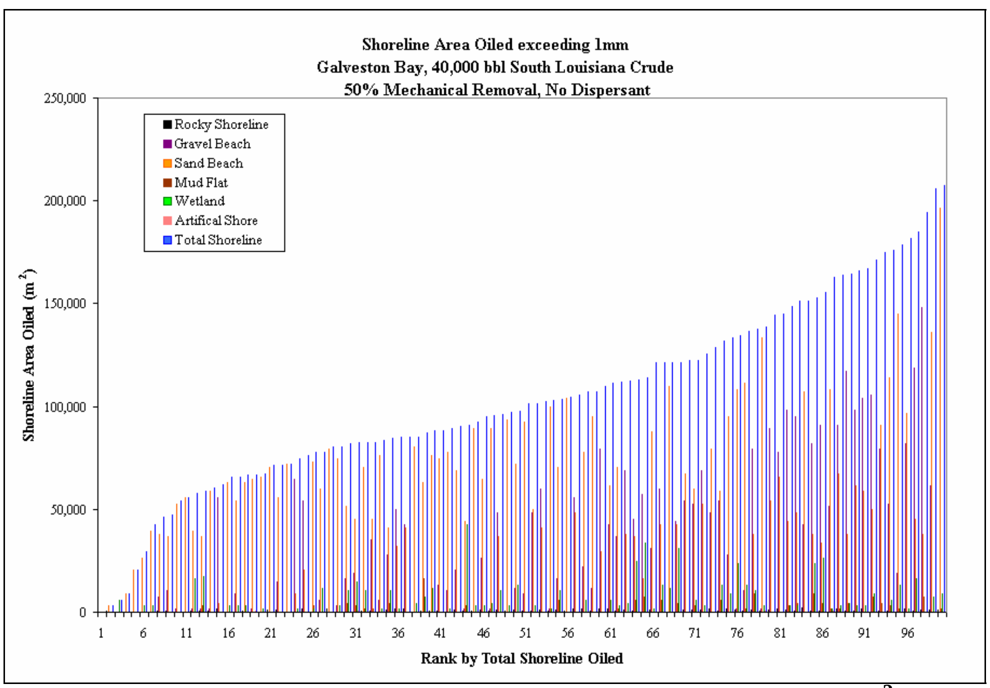

Figure C-II.3.4-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Large Volume, No Dispersant.

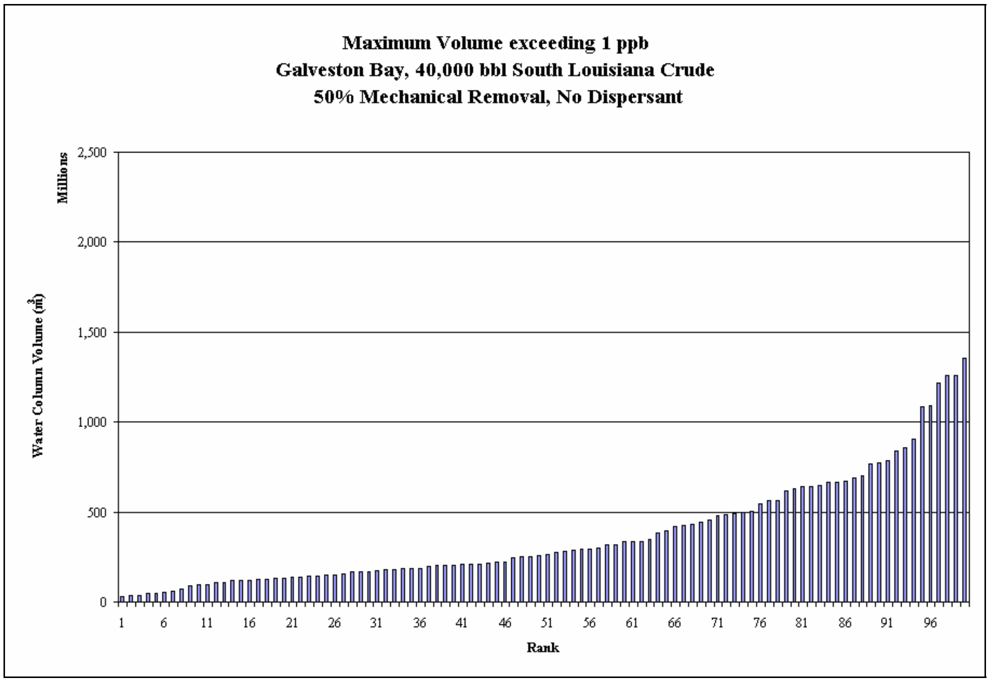

Figure C-II.3.4-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, No Dispersant.

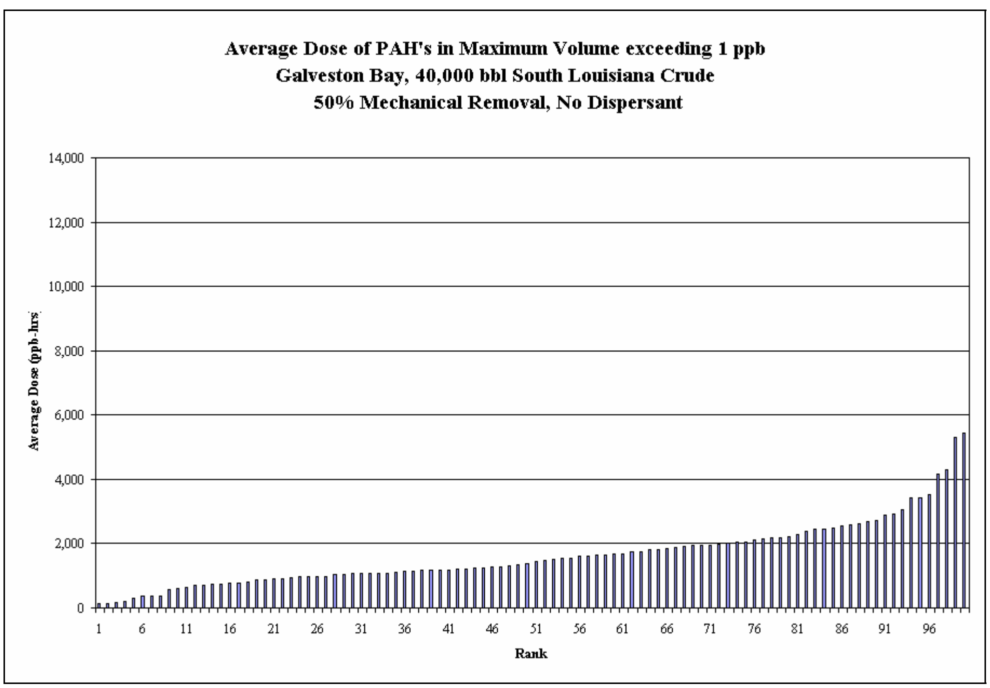

Figure C-II.3.4-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, No Dispersant.

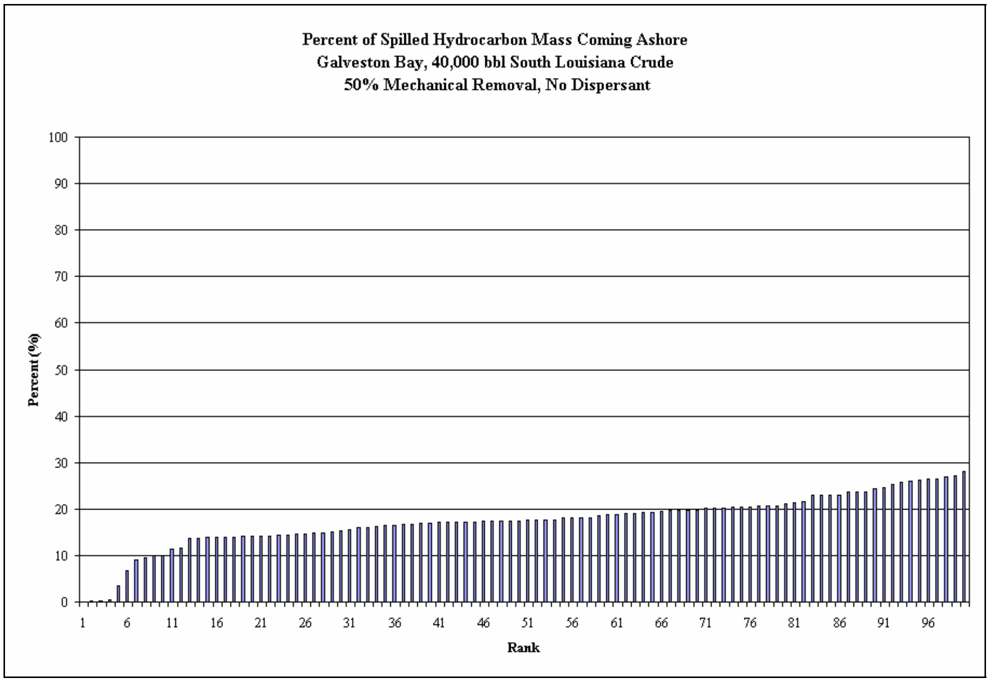

Figure C-II.3.4-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Large Volume, No Dispersant.

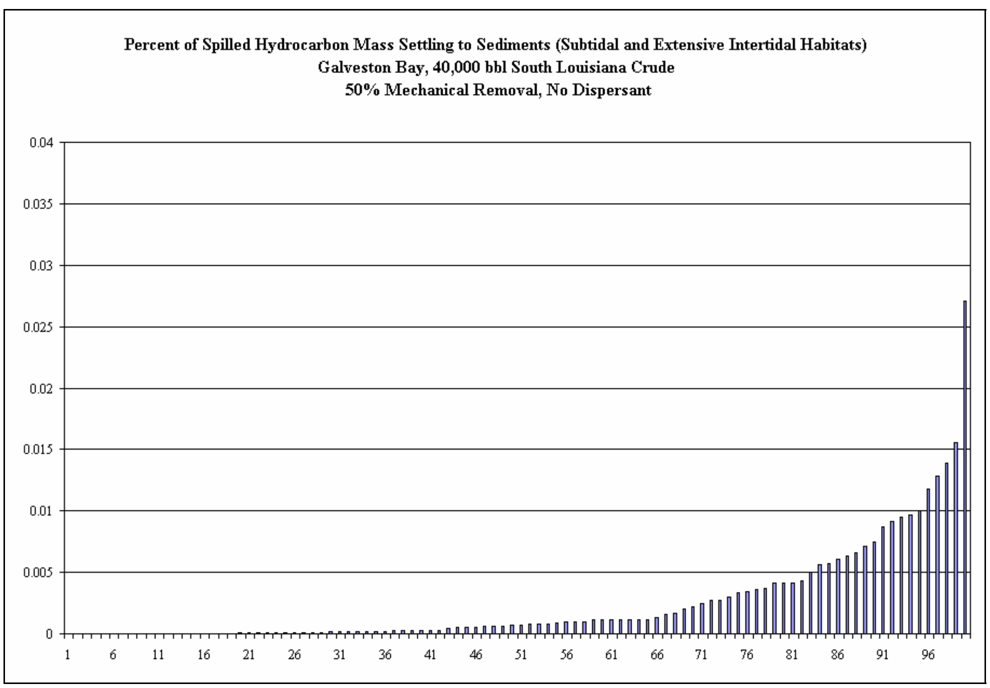

Figure C-II.3.4-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Large Volume, No Dispersant.

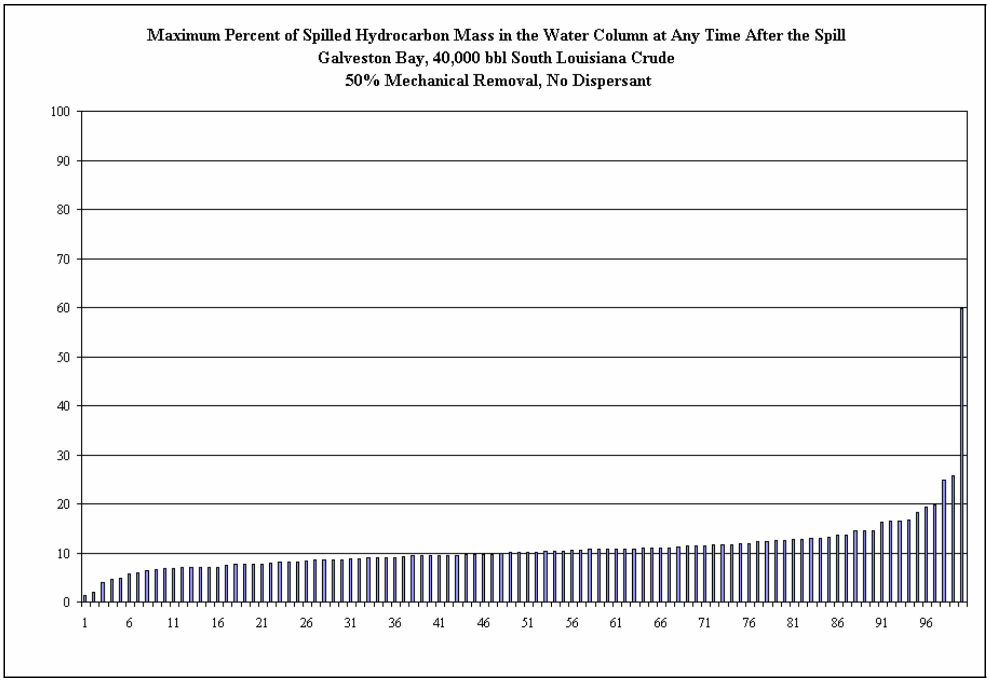

Figure C-II.3.4-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Large Volume, No Dispersant.

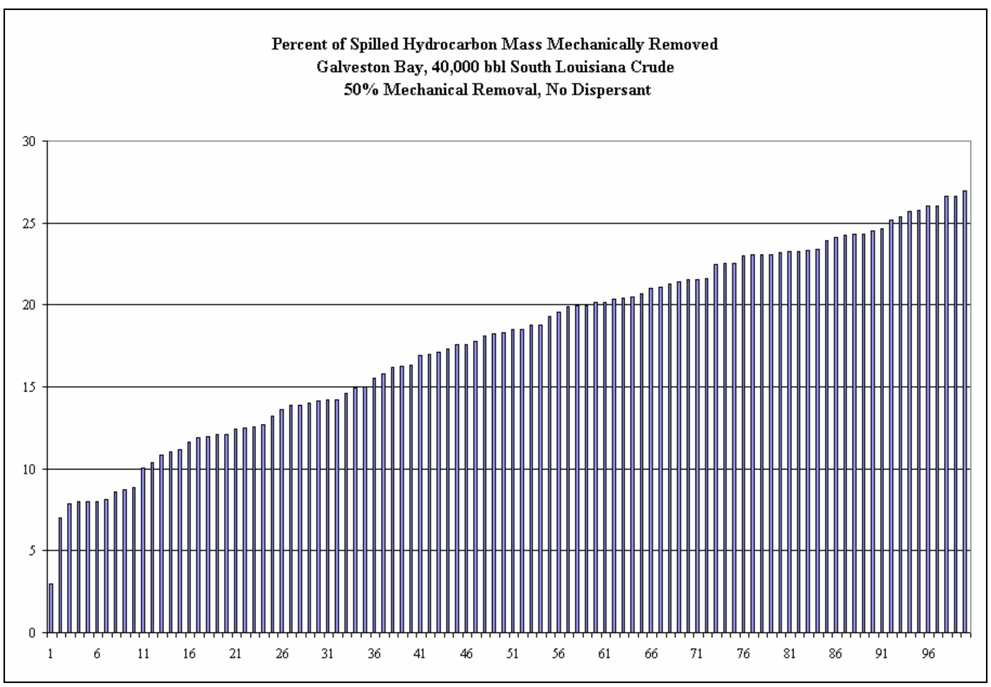

Figure C-II.3.4-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Large Volume, No Dispersant.

C-II.3.5 Scenario: Large Volume, 45% Dispersant Efficiency.

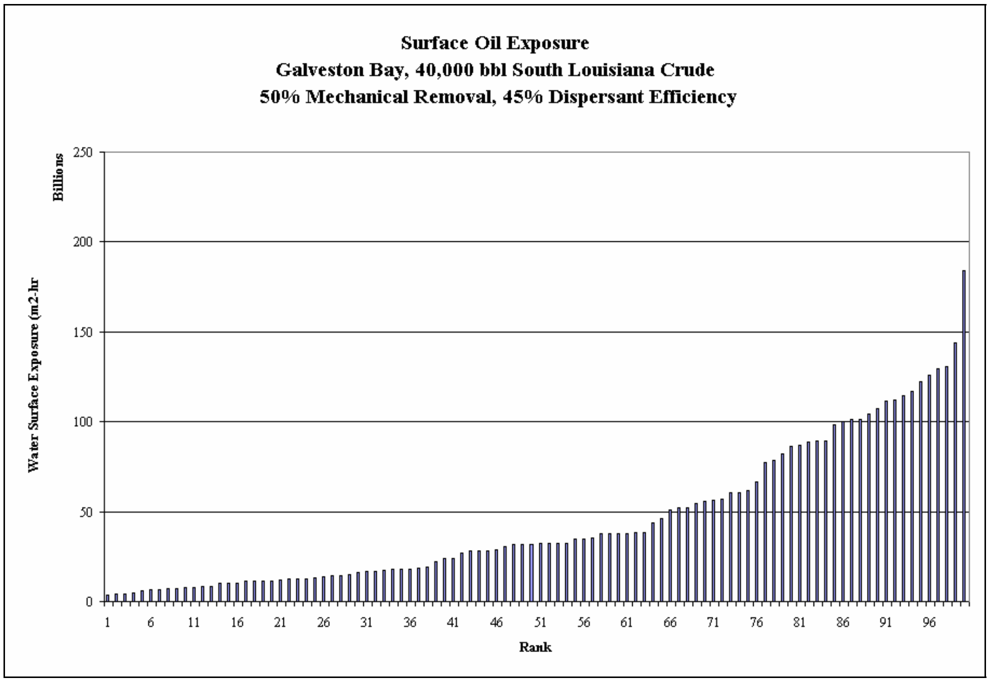

Figure C-II.3.5-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

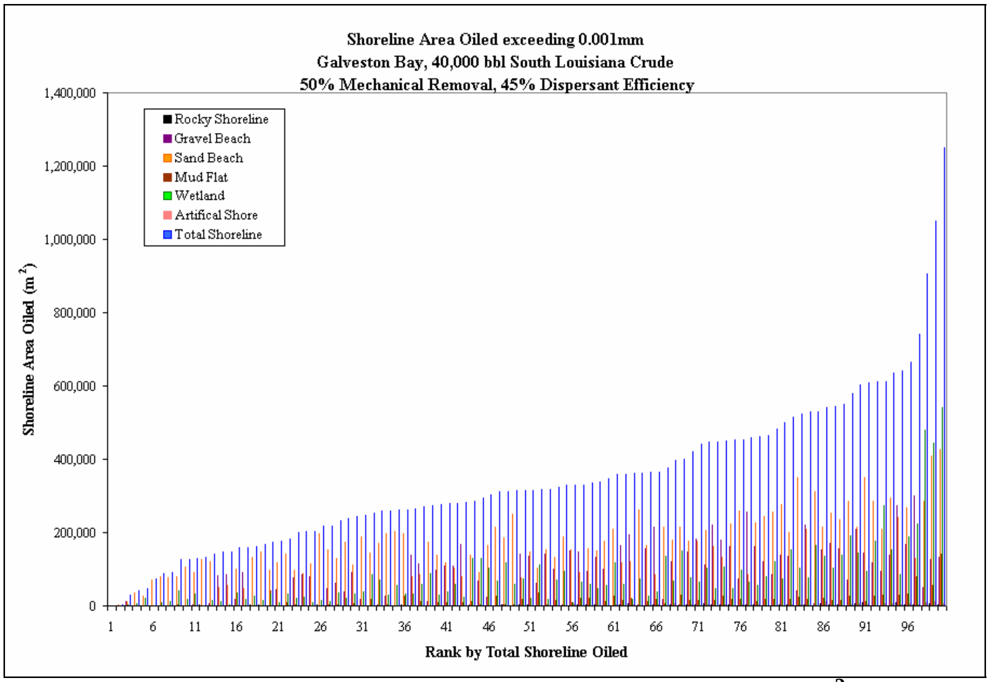

Figure C-II.3.5-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

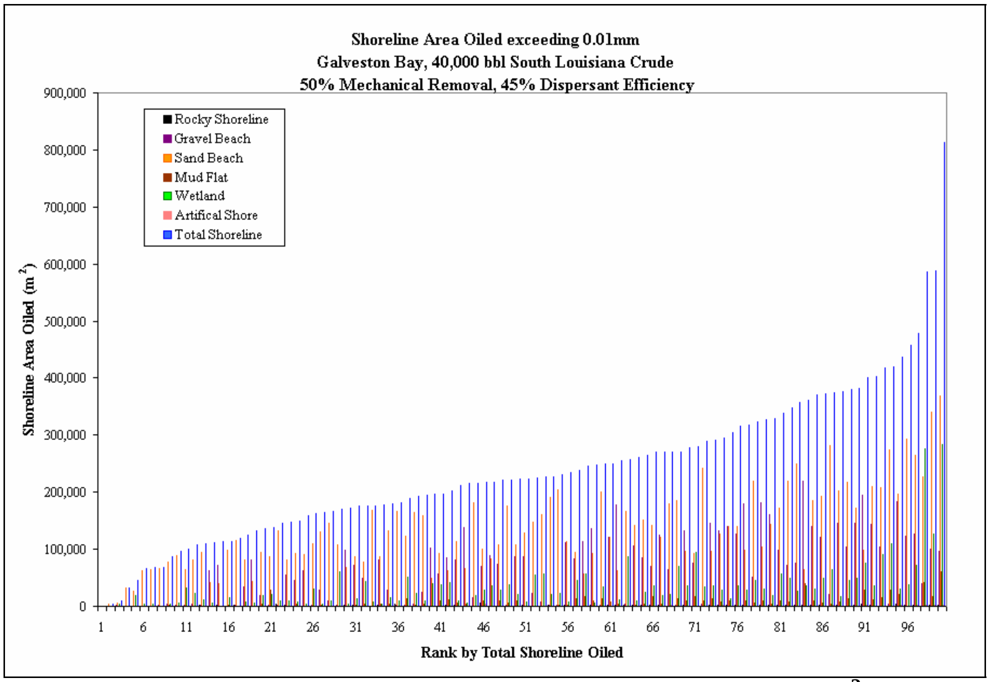

Figure C-II.3.5-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

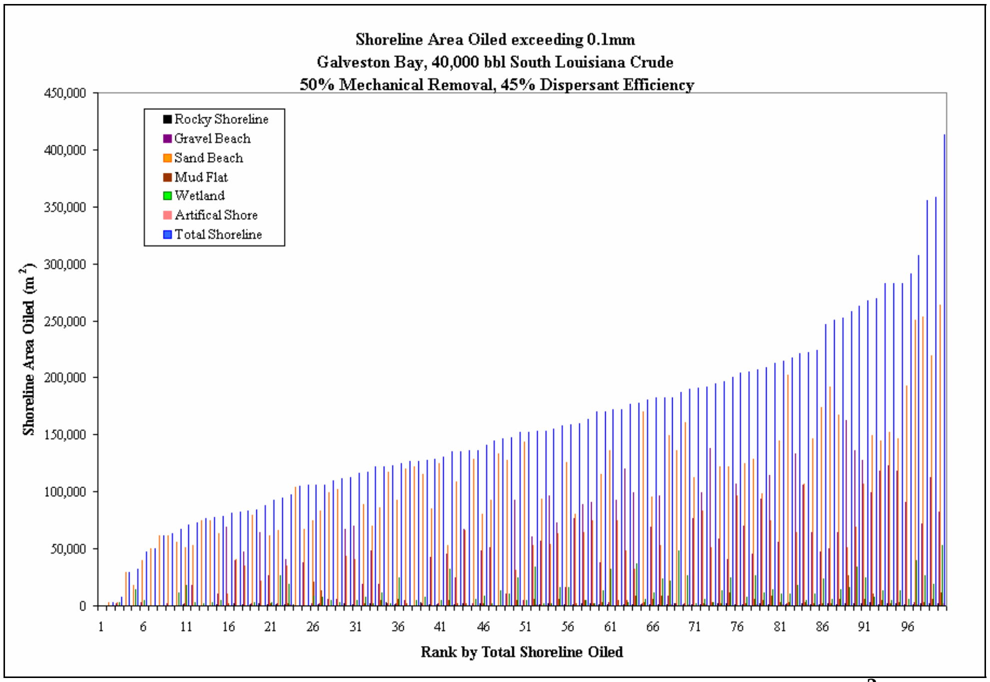

Figure C-II.3.5-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

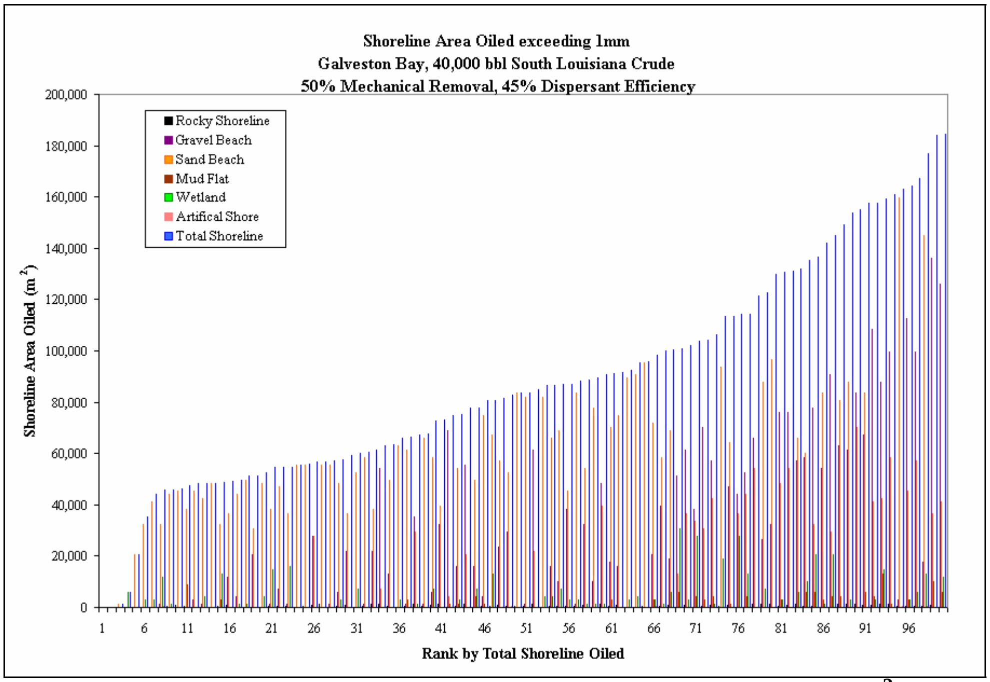

Figure C-II.3.5-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

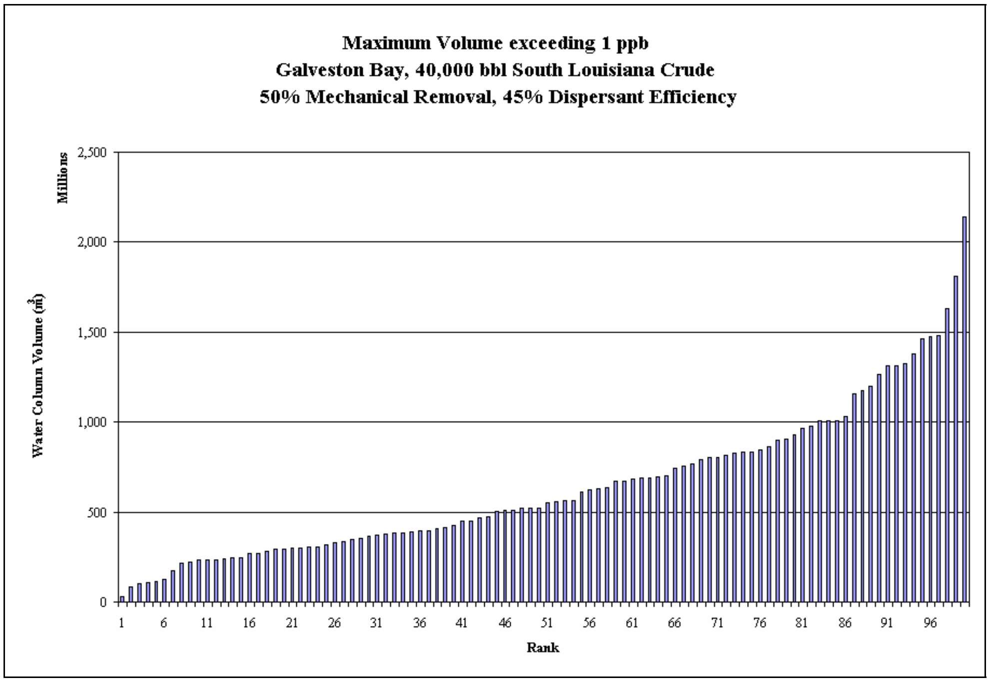

Figure C-II.3.5-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 45% Dispersant Efficiency.

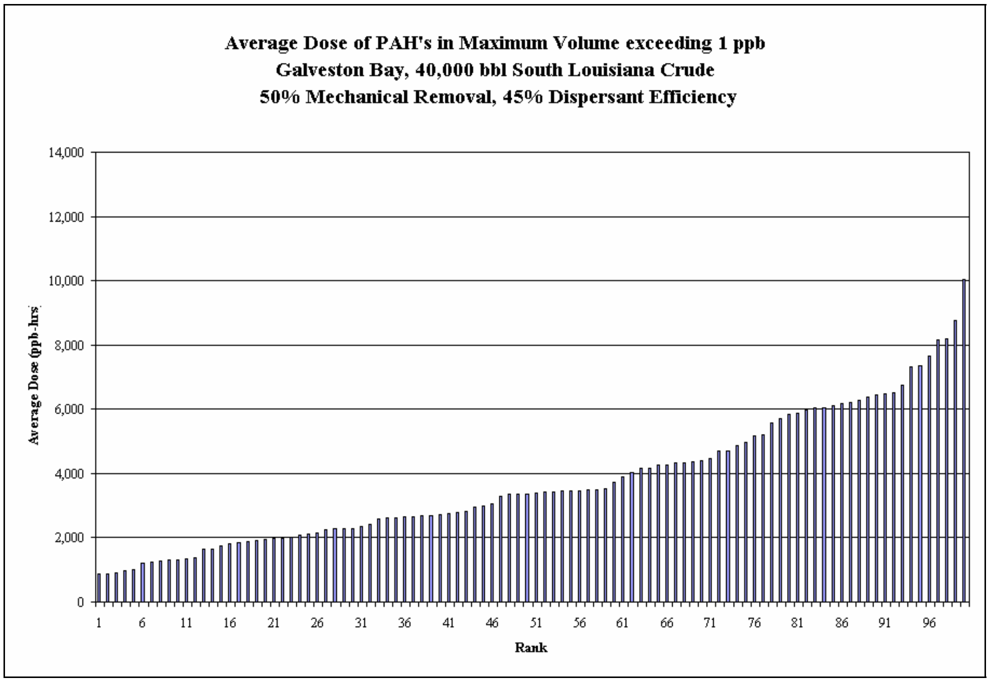

Figure C-II.3.5-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 45% Dispersant Efficiency.

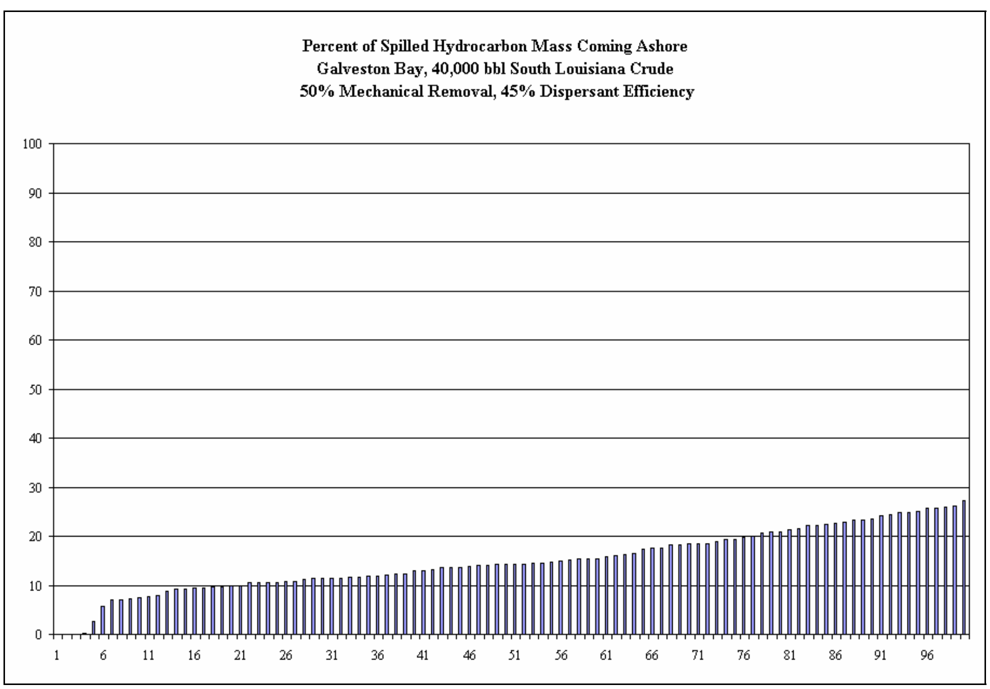

Figure C-II.3.5-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Large Volume, 45% Dispersant Efficiency.

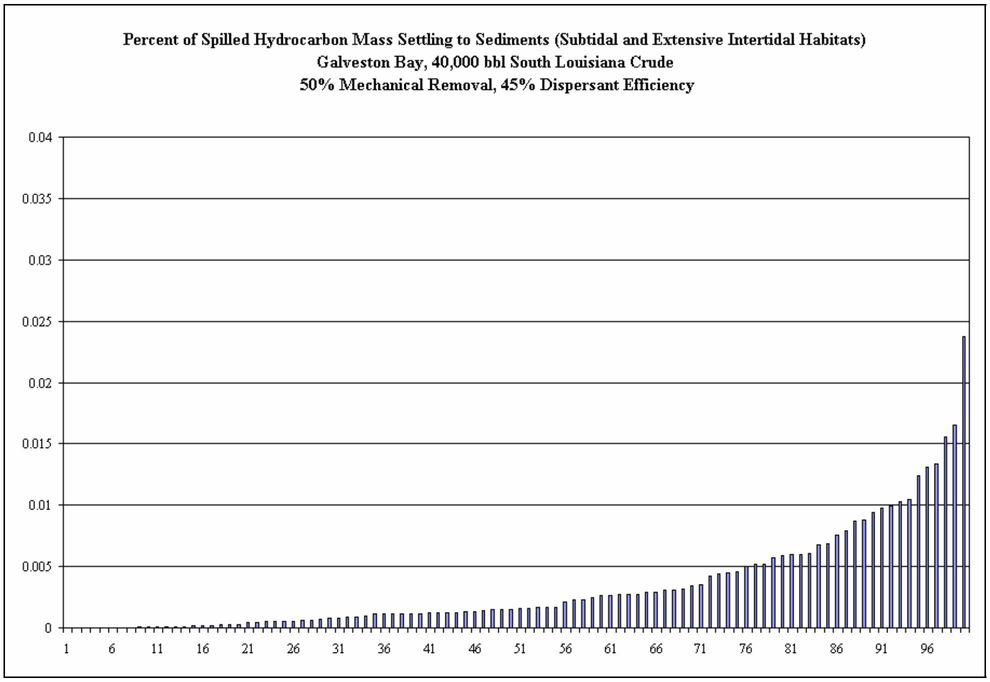

Figure C-II.3.5-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Large Volume, 45% Dispersant Efficiency.

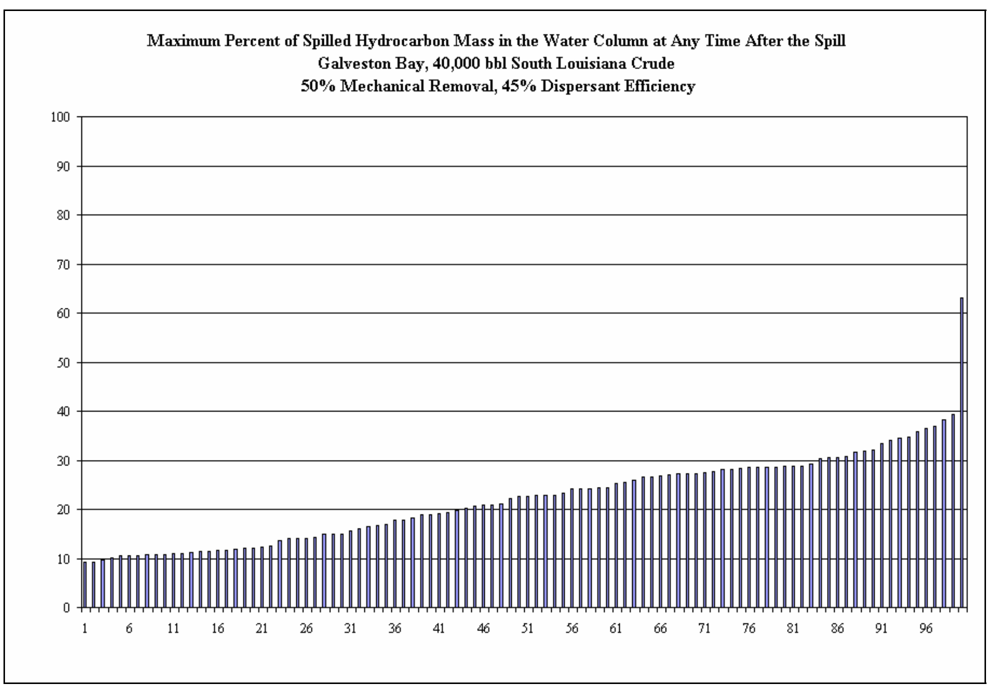

Figure C-II.3.5-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Large Volume, 45% Dispersant Efficiency.

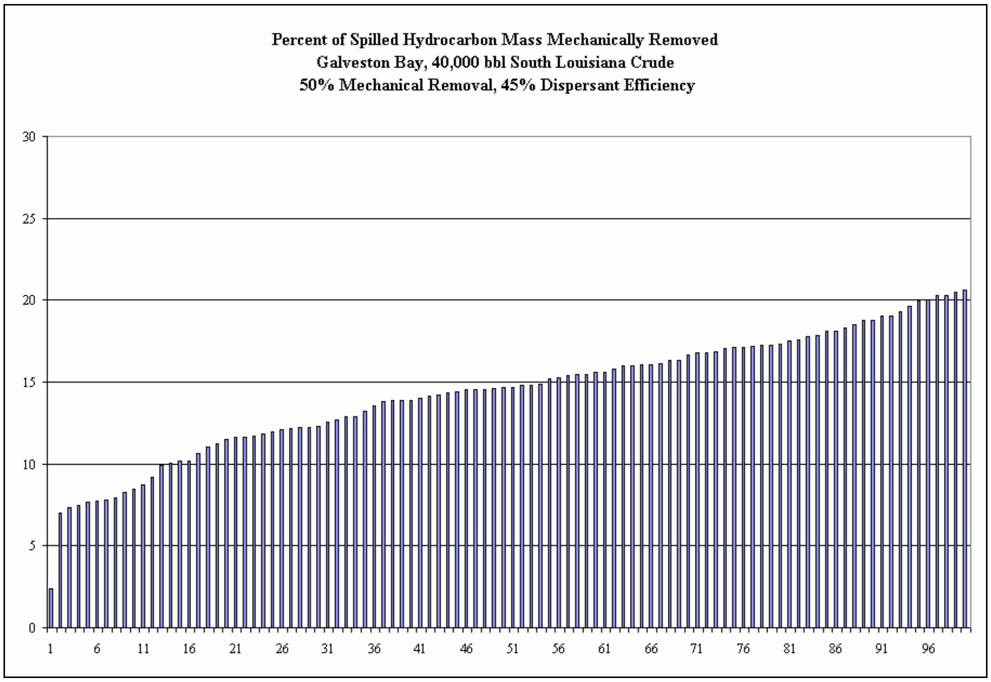

Figure C-II.3.5-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Large Volume, 45% Dispersant Efficiency.

C-II.3.6 Scenario: Large Volume, 80% Dispersant Efficiency.

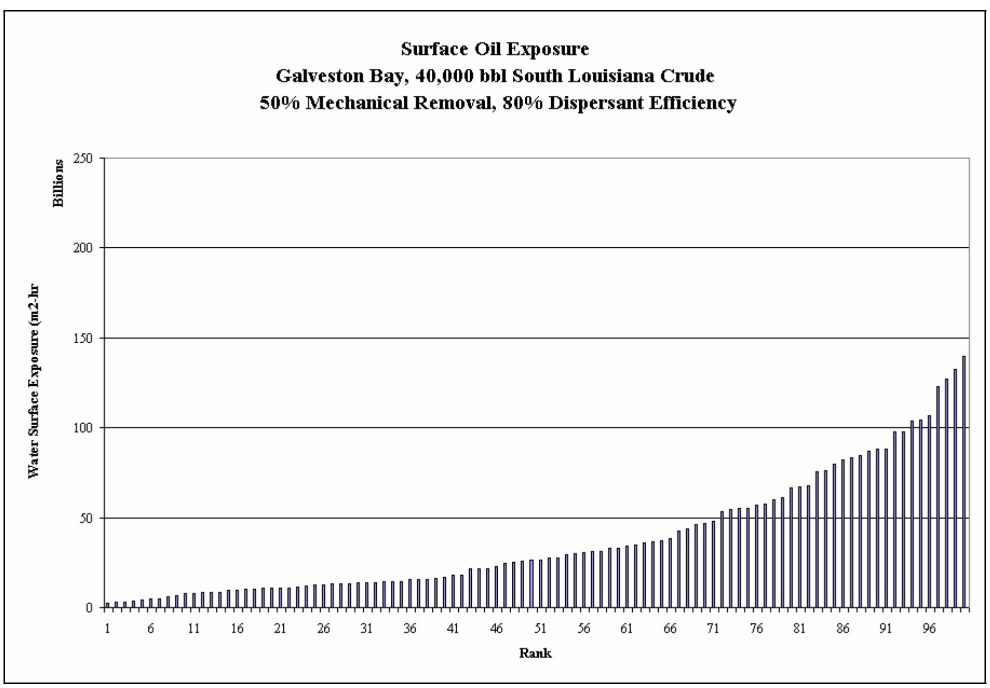

Figure C-II.3.6-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

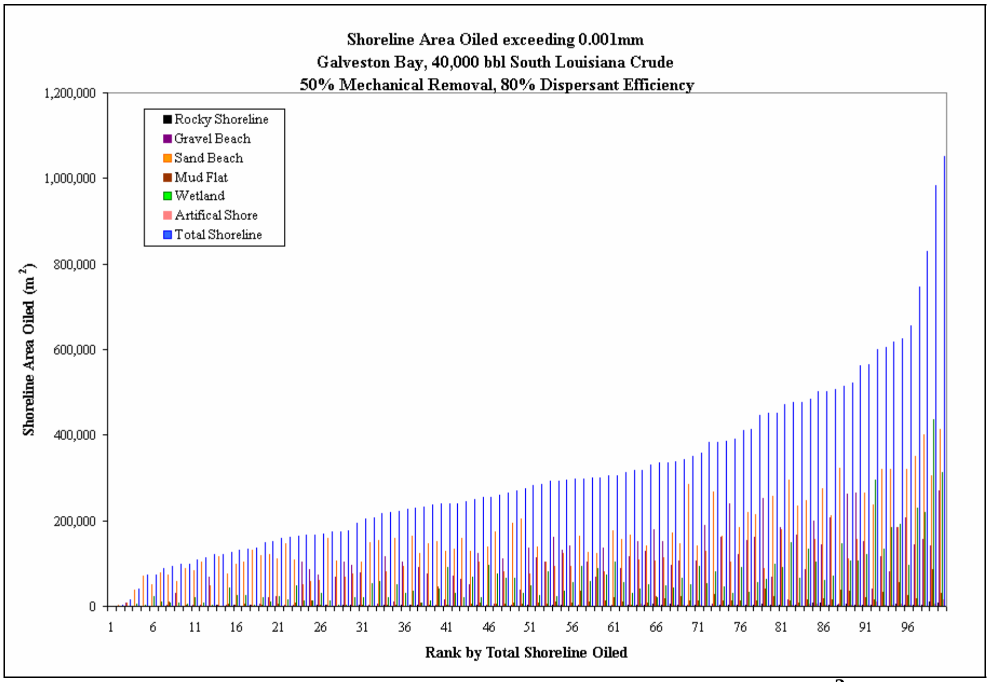

Figure C-II.3.6-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

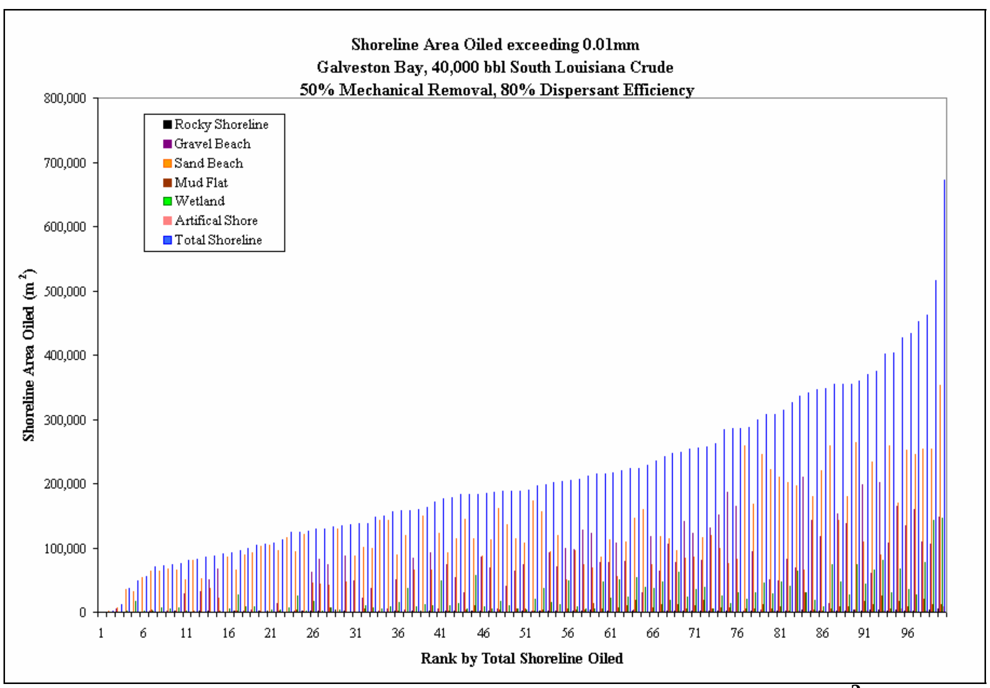

Figure C-II.3.6-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

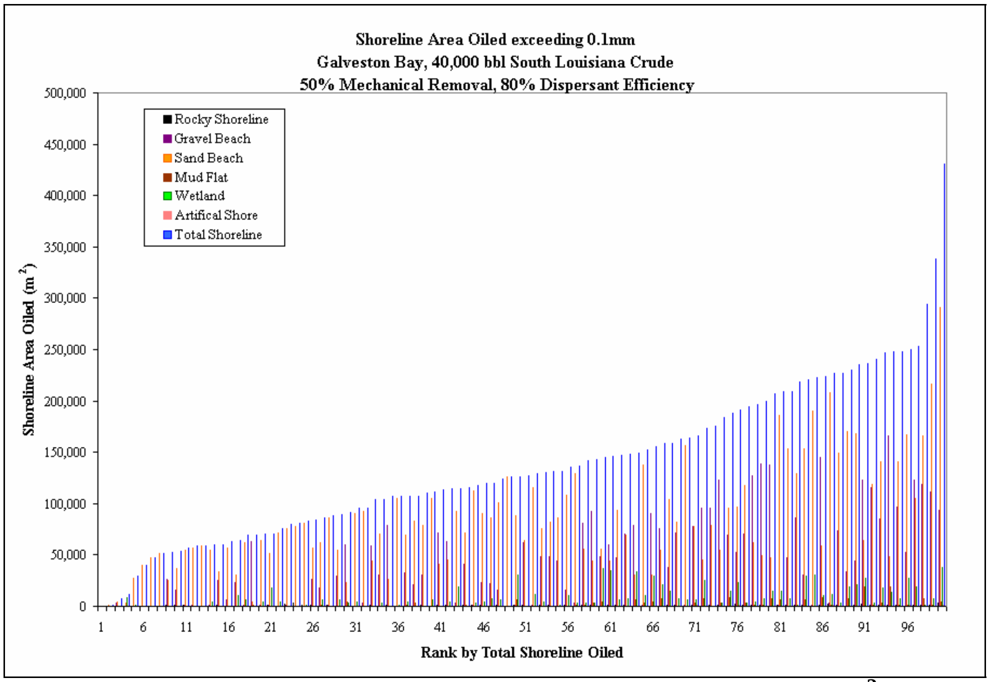

Figure C-II.3.6-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

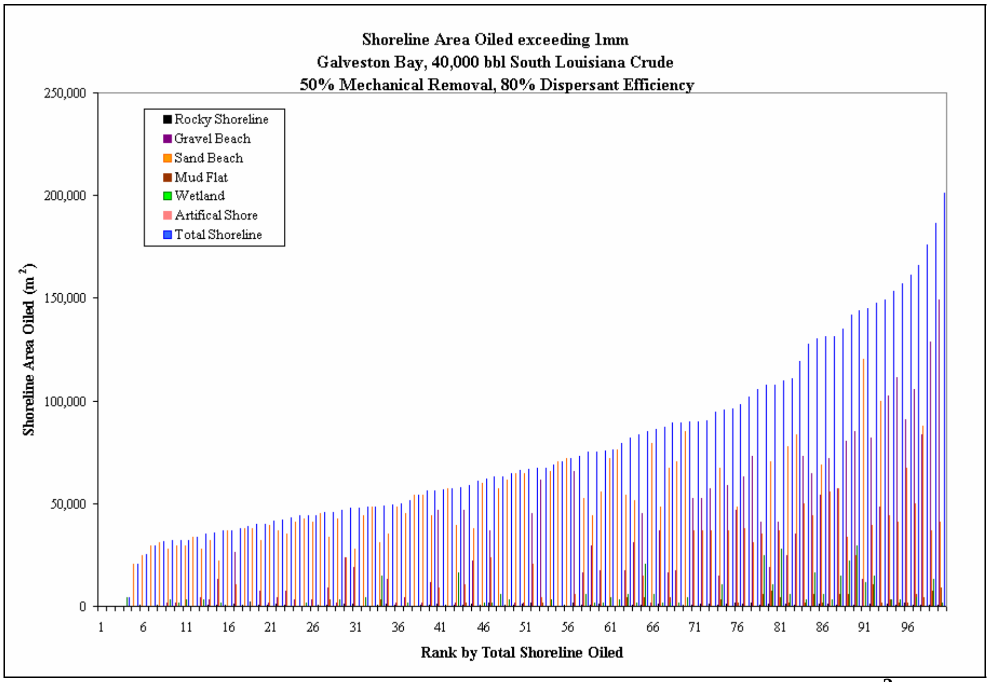

Figure C-II.3.6-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

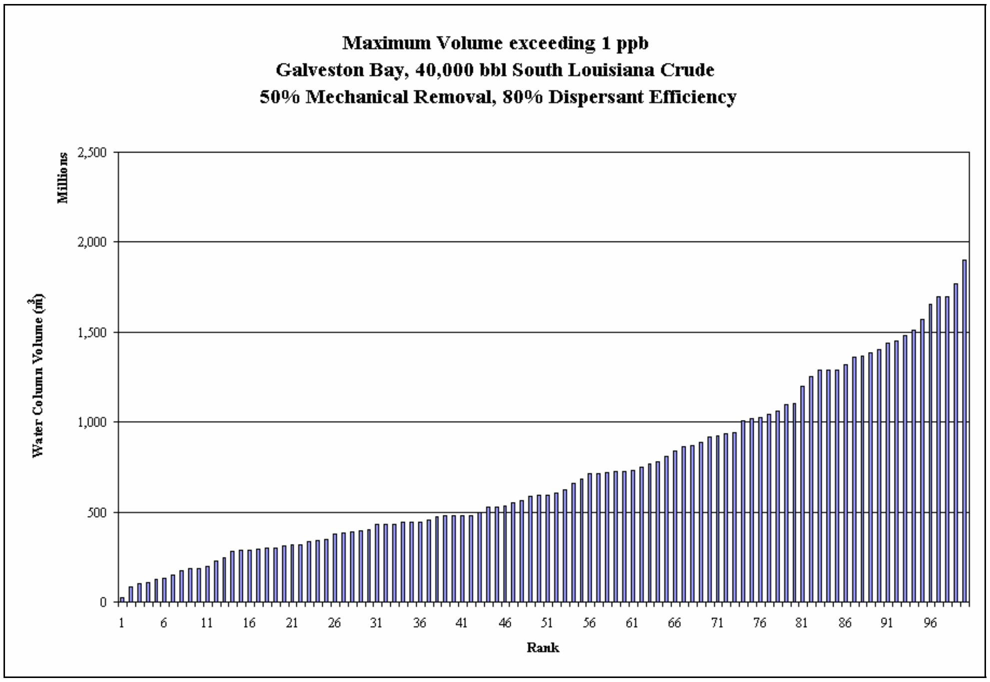

Figure C-II.3.6-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 80% Dispersant Efficiency.

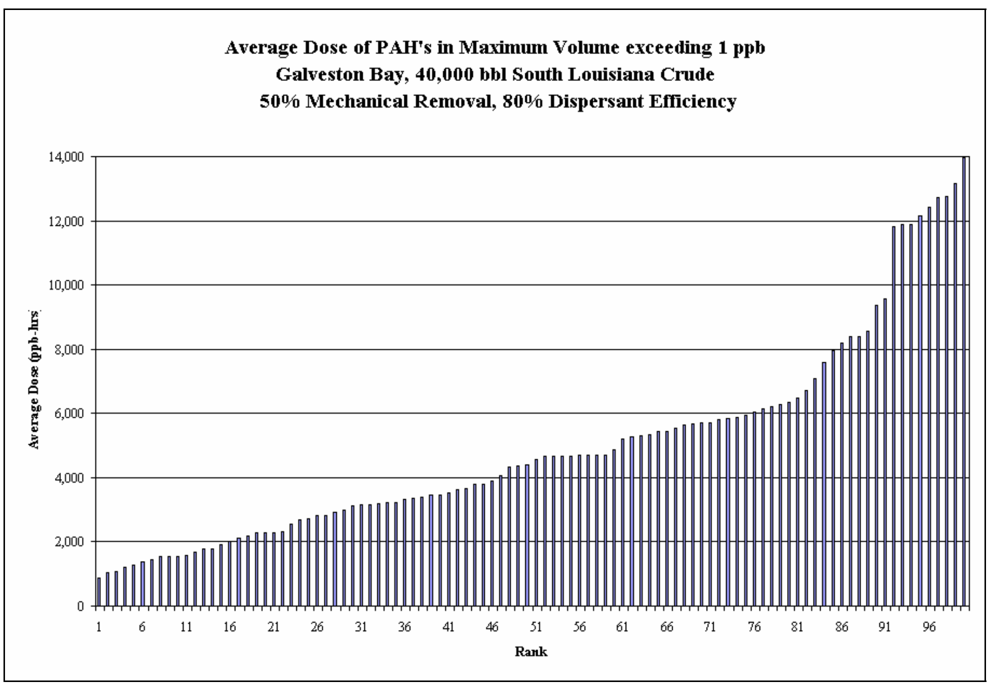

Figure C-II.3.6-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 80% Dispersant Efficiency.

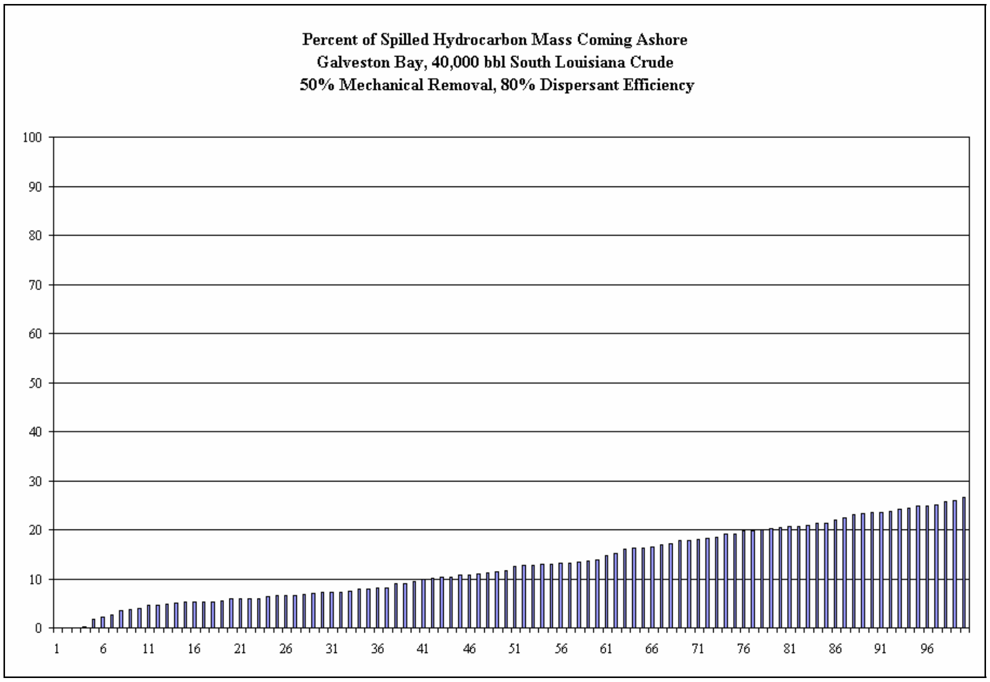

Figure C-II.3.6-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Large Volume, 80% Dispersant Efficiency.

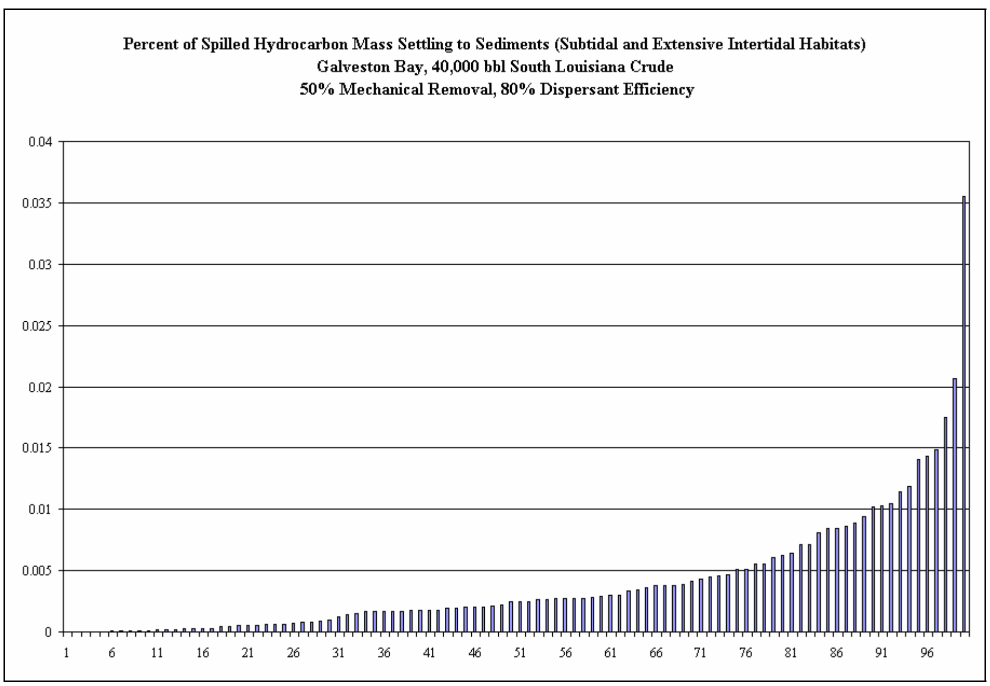

Figure C-II.3.6-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Large Volume, 80% Dispersant Efficiency.

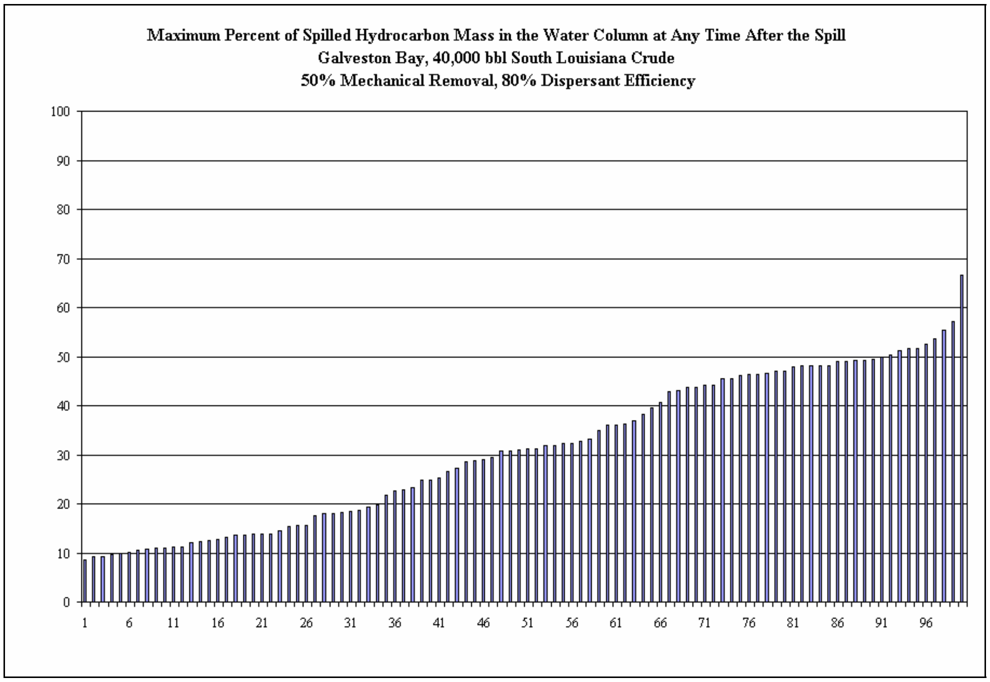

Figure C-II.3.6-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Large Volume, 80% Dispersant Efficiency.

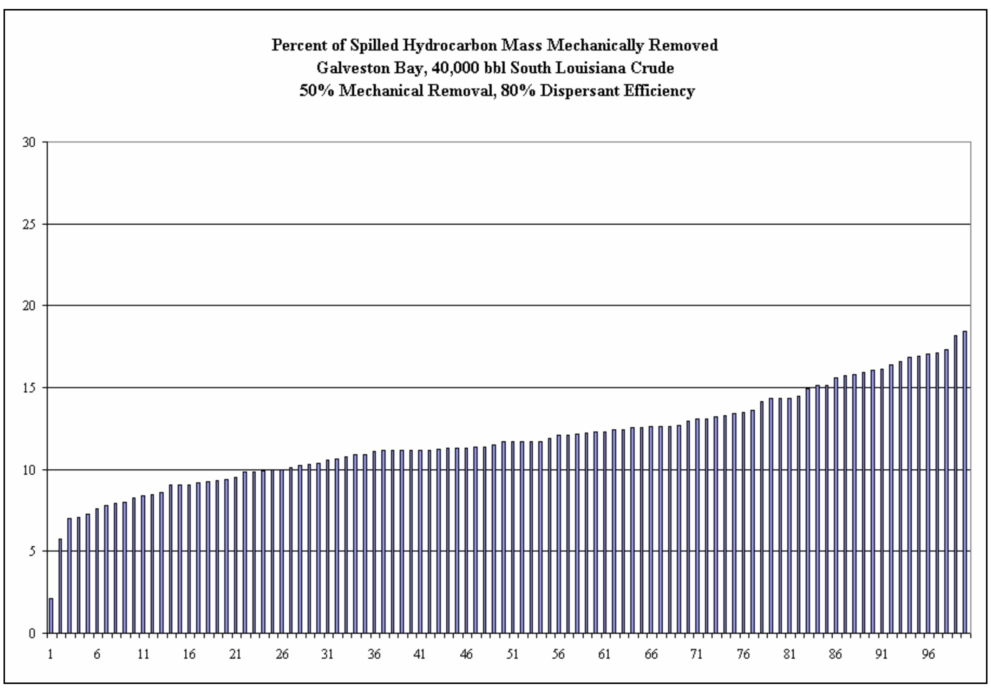

Figure C-II.3.6-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Large Volume, 80% Dispersant Efficiency.

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part C: Galveston Bay and North Texas Shelf

Section C-II.4

by

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ASA 00-246

August 2004

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C-II.4 Exposure for Representative Individual Model Runs.

In this appendix, the results for the 50th percentile cases for surface oiling, shoreline oiling, water column effects, and sediment contamination are shown, as plots of the following measures of exposure:

- Water surface exposure to floating hydrocarbons (g/m^2)
- Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile surface oil exposure run
- Shoreline exposure to hydrocarbons (g/m^2)
- Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill
- Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill
- Water column exposure dose of dissolved aromatic concentration (ppb-hours)
- Sediment pore water exposure of dissolved aromatic concentration (ppb)
- Sediment exposure to total hydrocarbons (g/m^2)

The percentile runs plotted are those runs which apply to the exposure index being considered. Thus, different runs are plotted for each of surface oil, shoreline oil, water column effect measures, and sediment contamination. Tables C-II.4-1 to C-II.4-3 summarize the run number and date and time of the runs resulting in the 50th and 95th percentile exposures. The 95th percentile exposure indicates the maximum likely effect.

The Crosshair mark () in figures below represents oil spill site.

Table C-II.4-1 Run number and date and time of the runs resulting in the 50th and 95th percentile exposures for surface oil exposure.

Scenario Name	Surface Oil Exposure exceeding 0.01 g/m^2						
	Percentile	Run Number	Year	Month	Day	Hour	Area-hrs (m^2-hrs)
Gal-Med-50-0	50th	76	1991	10	6	15	2,457 x 10^6
	95th	5	1992	3	8	21	14,187 x 10^6
Gal-Med-50-45	50th	70	1991	6	10	5	1,280 x 10^6
	95th	13	1993	1	30	14	9,555 x 10^6
Gal-Med-50-80	50th	10	1991	2	1	1	801 x 10^6
	95th	58	1996	4	6	16	8,774 x 10^6
Gal-Lrg-50-0	50th	30	1999	2	26	8	41,465 x 10^6
	95th	5	1992	3	8	21	155,734 x 10^6
Gal-Lrg-50-45	50th	63	1993	12	2	17	31,953 x 10^6
	95th	15	1997	7	13	9	122,293 x 10^6
Gal-Lrg-50-80	50th	60	2001	1	11	18	26,292 x 10^6
	95th	87	1997	11	2	4	104,246 x 10^6

Table C-II.4-2 Run number and date and time of the runs resulting in the 50th and 95th percentile exposures for dissolved aromatic exposure.

Scenario Name	Maximum Dissolved Aromatic Plume Volume exceeding 1 ppb						
	Percentile	Run Number	Year	Month	Day	Hour	Volume (m^3)
Gal-Med-50-0	50th	21	1994	6	1	12	50×10^6
	95th	83	1993	11	5	0	207×10^6
Gal-Med-50-45	50th	35	2000	11	7	13	153×10^6
	95th	69	1991	8	17	8	376×10^6
Gal-Med-50-80	50th	35	2000	11	7	13	135×10^6
	95th	69	1991	8	17	8	421×10^6
Gal-Lrg-50-0	50th	70	1991	6	10	5	255×10^6
	95th	100	1991	3	29	8	$1{,}083 \times 10^6$
Gal-Lrg-50-45	50th	48	1999	5	23	11	523×10^6
	95th	97	1991	12	3	6	$1{,}460 \times 10^6$
Gal-Lrg-50-80	50th	2	1999	8	11	19	594×10^6
	95th	95	2001	12	12	19	$1{,}570 \times 10^6$

Table C-II.4-3 Run number and date and time of the runs resulting in the 50th and 95th percentile exposures for sediment exposure.

Scenario Name	**Percent of Spilled Mass Reaching Sediment**						
	Percentile	Run Number	Year	Month	Day	Hour	%
Gal-Med-50-0	50th	58	1996	4	6	16	0.003
	95th	94	1999	9	26	15	0.035
Gal-Med-50-45	50th	90	1993	11	18	1	0.006
	95th	33	2000	10	4	16	0.032
Gal-Med-50-80	50th	18	1994	9	25	4	0.007
	95th	74	1993	6	9	15	0.032
Gal-Lrg-50-0	50th	55	1999	10	17	8	0.001
	95th	84	2000	8	26	23	0.012
Gal-Lrg-50-45	50th	20	1997	9	19	16	0.002
	95th	54	1998	5	24	21	0.013
Gal-Lrg-50-80	50th	34	1994	1	6	9	0.003
	95th	30	1999	2	26	8	0.014

C-II.4.1 Scenario: Medium Volume, No Dispersant.

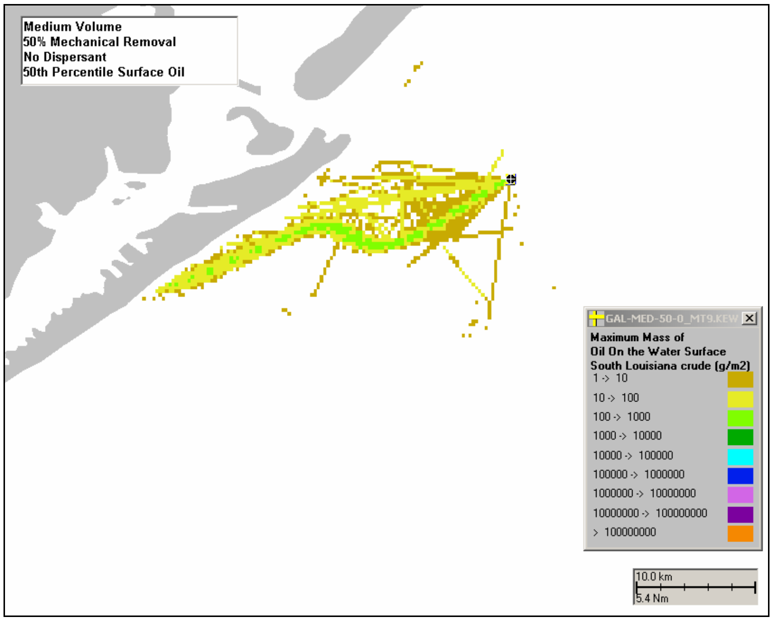

Figure C-II.4.1-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, No Dispersant.

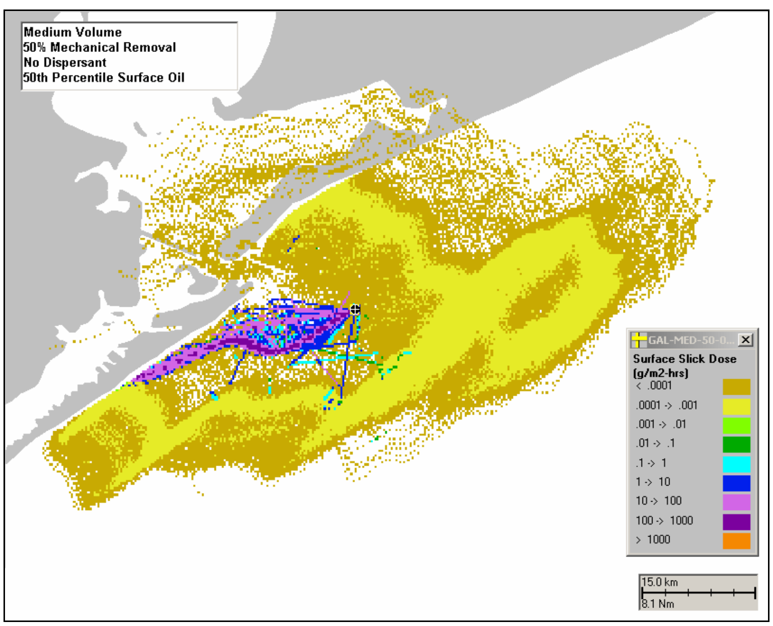

Figure C-II.4.1-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, No Dispersant.

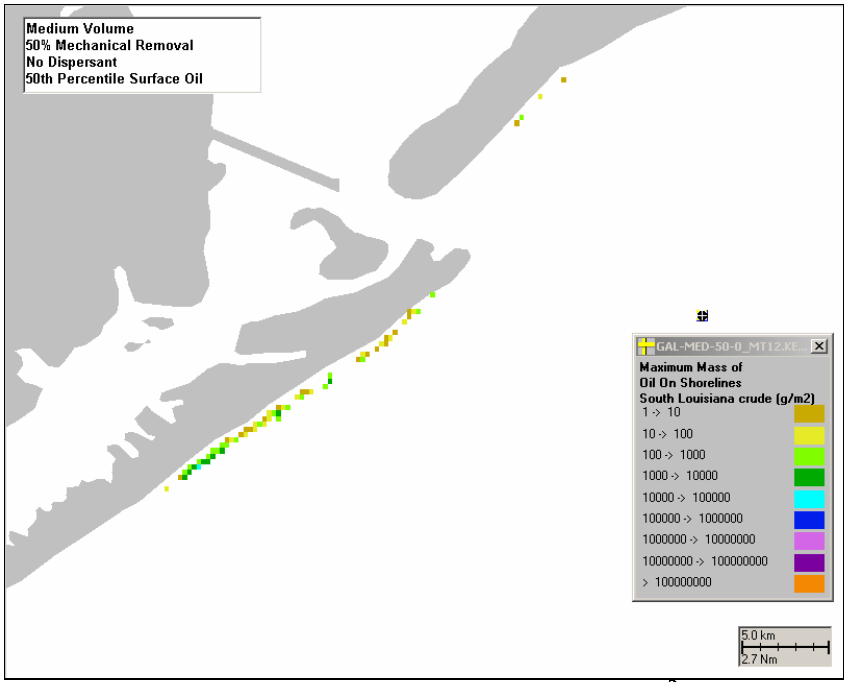

Figure C-II.4.1-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, No Dispersant.

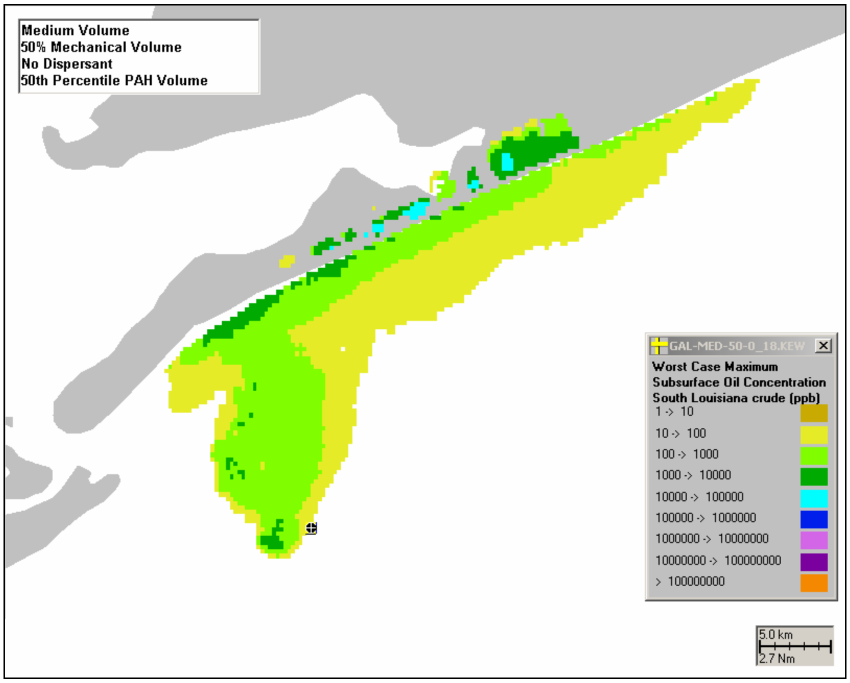

Figure C-II.4.1-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, No Dispersant.

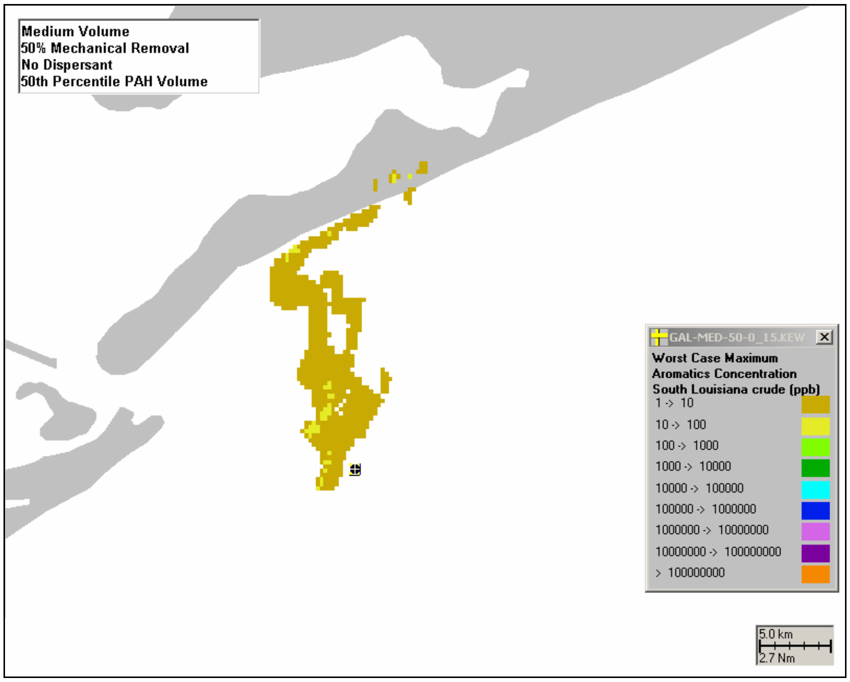

Figure C-II.4.1-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, No Dispersant.

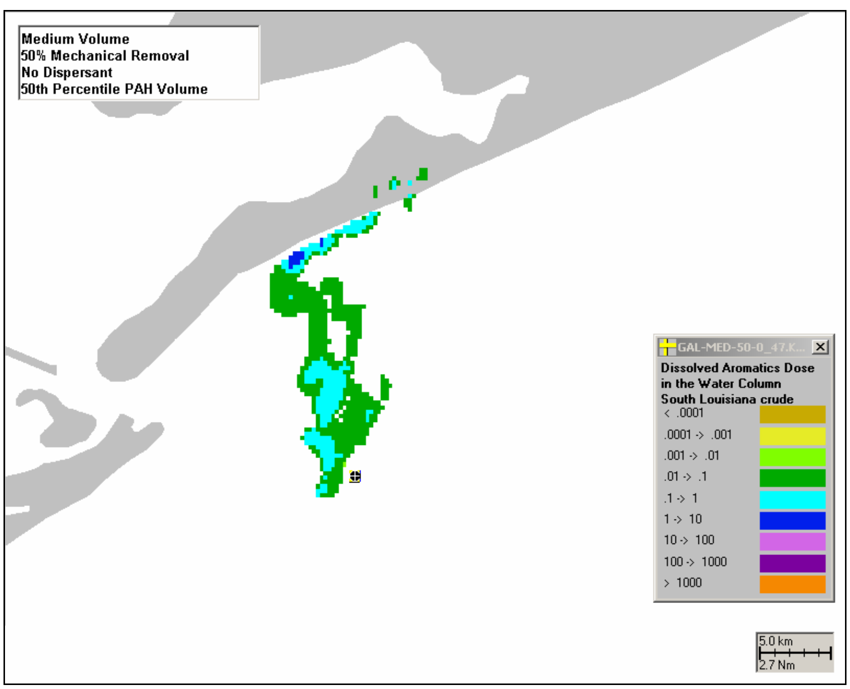

Figure C-II.4.1-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, No Dispersant.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Medium Volume, No Dispersant.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Medium Volume, No Dispersant.

C-II.4.2 Scenario: Medium Volume, 45% Dispersant Efficiency.

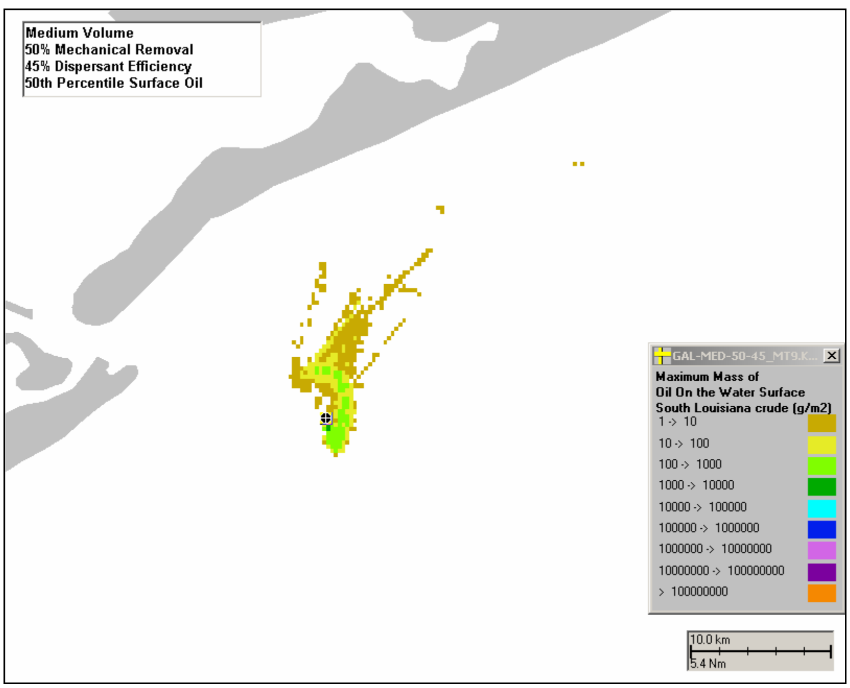

Figure C-II.4.2-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure.   Scenario: Medium Volume, 45% Dispersant Efficiency.

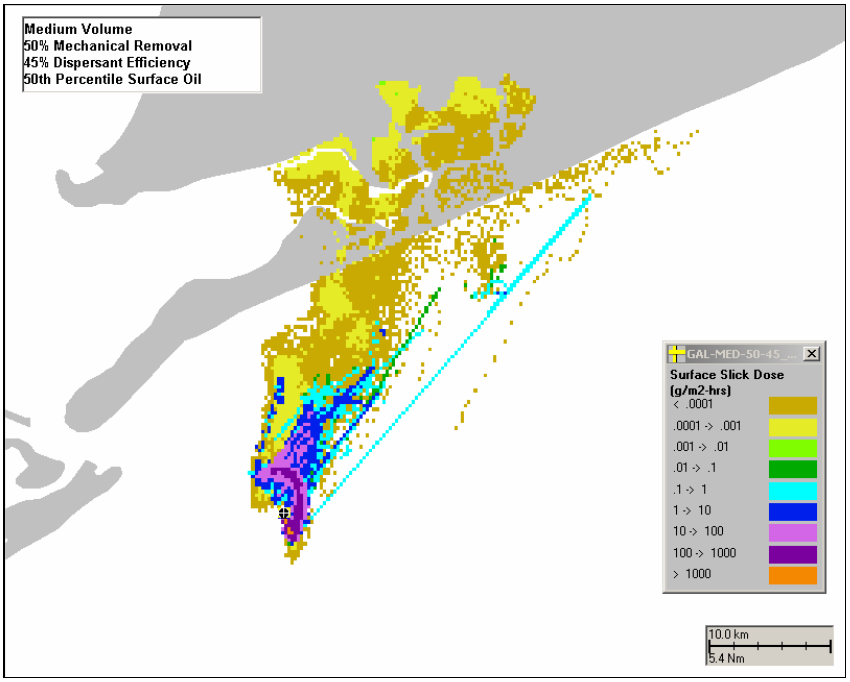

Figure C-II.4.2-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

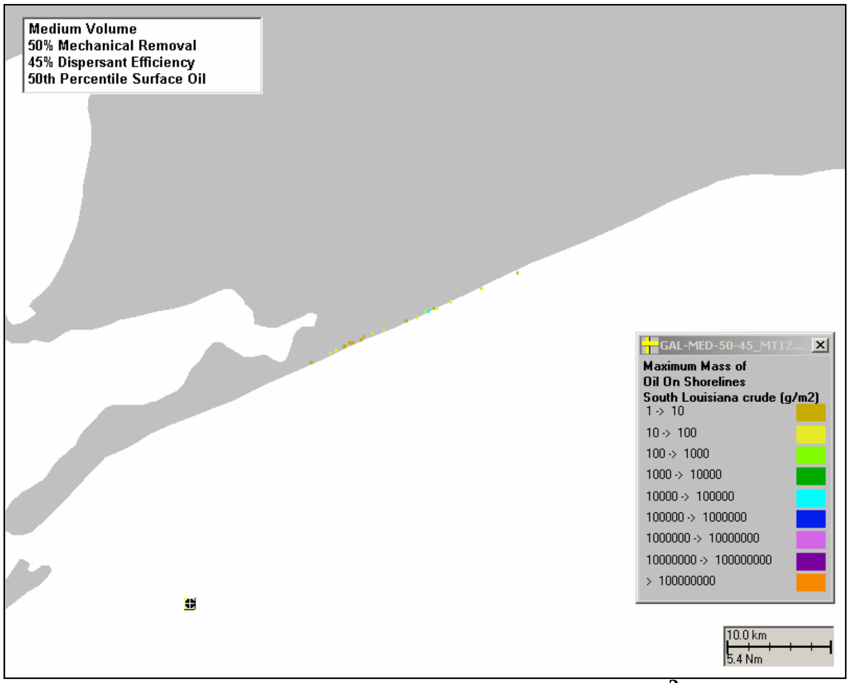

Figure C-II.4.2-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

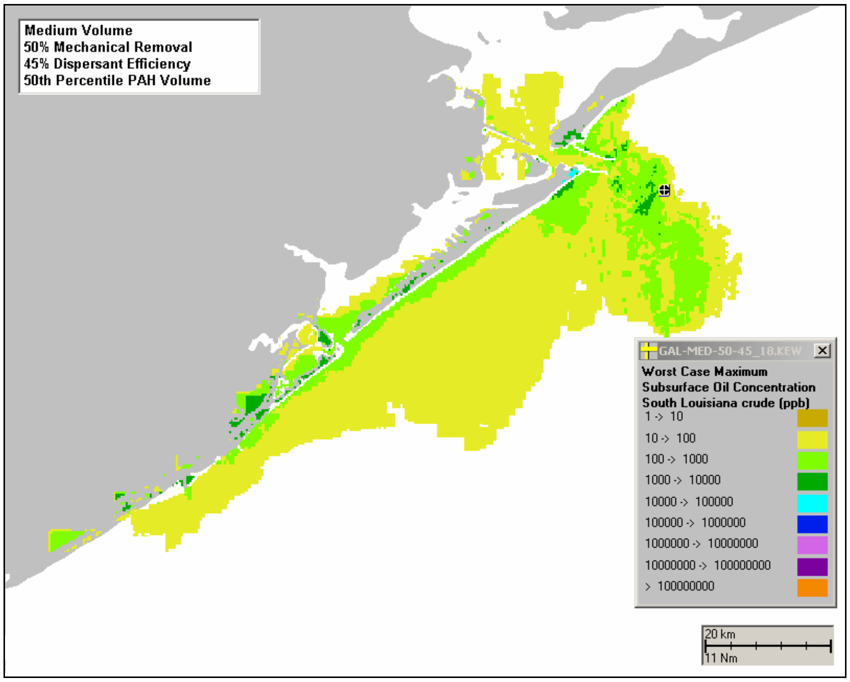

Figure C-II.4.2-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 45% Dispersant Efficiency.

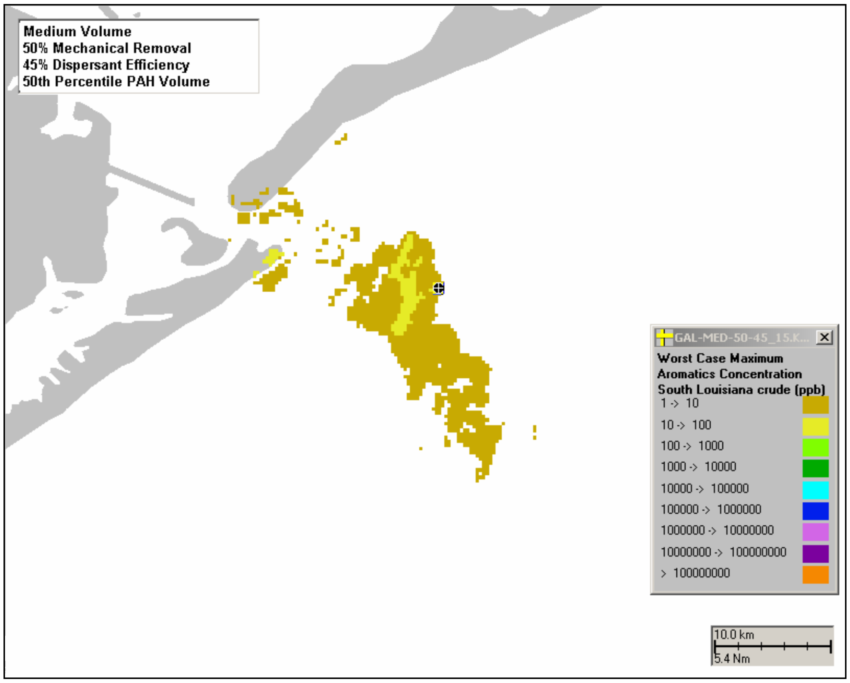

Figure C-II.4.2-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 45% Dispersant Efficiency.

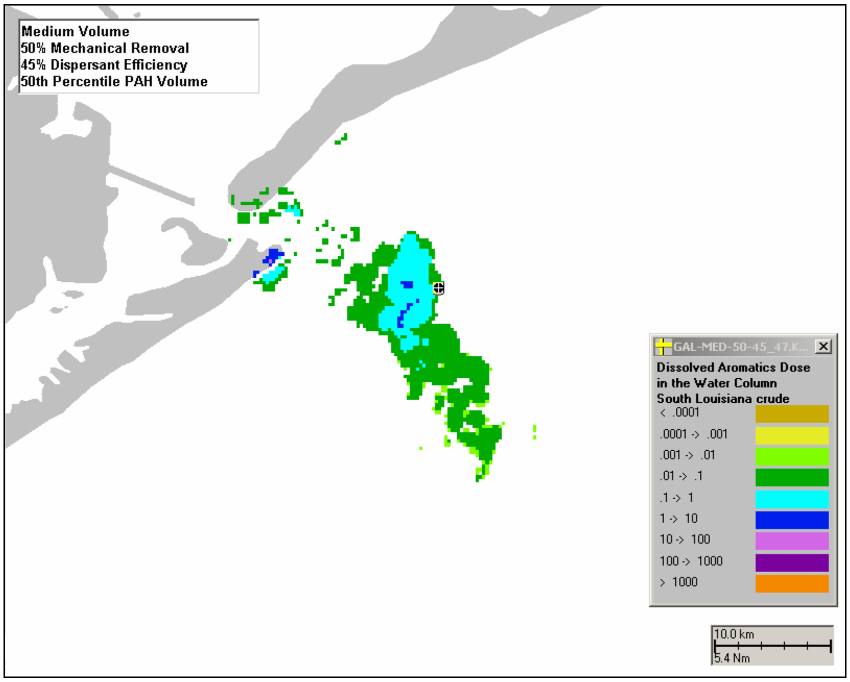

Figure C-II.4.2-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 45% Dispersant Efficiency.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Medium Volume, 45% Dispersant Efficiency..

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

C-II.4.3 Scenario: Medium Volume, 80% Dispersant Efficiency.

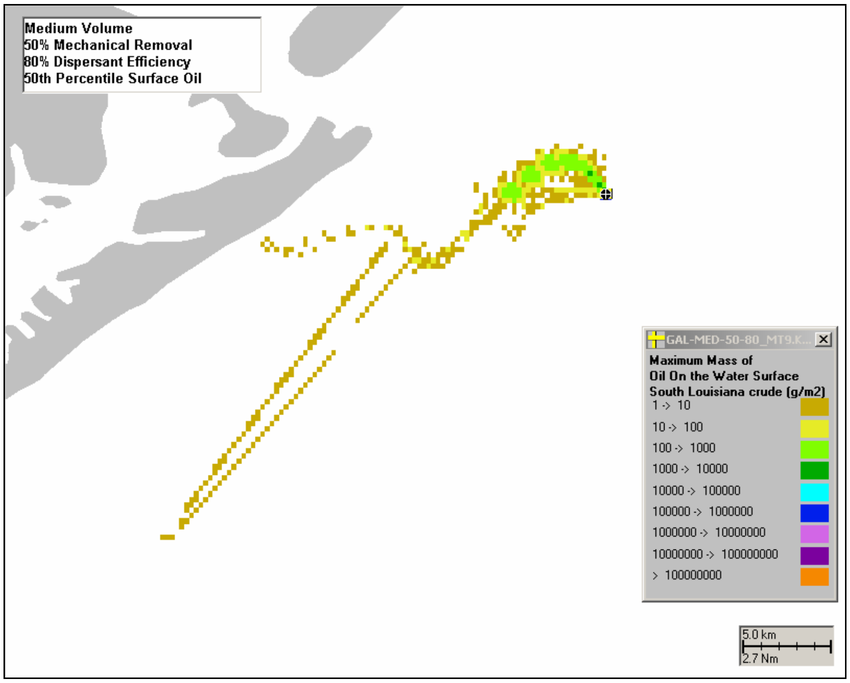

Figure C-II.4.3-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

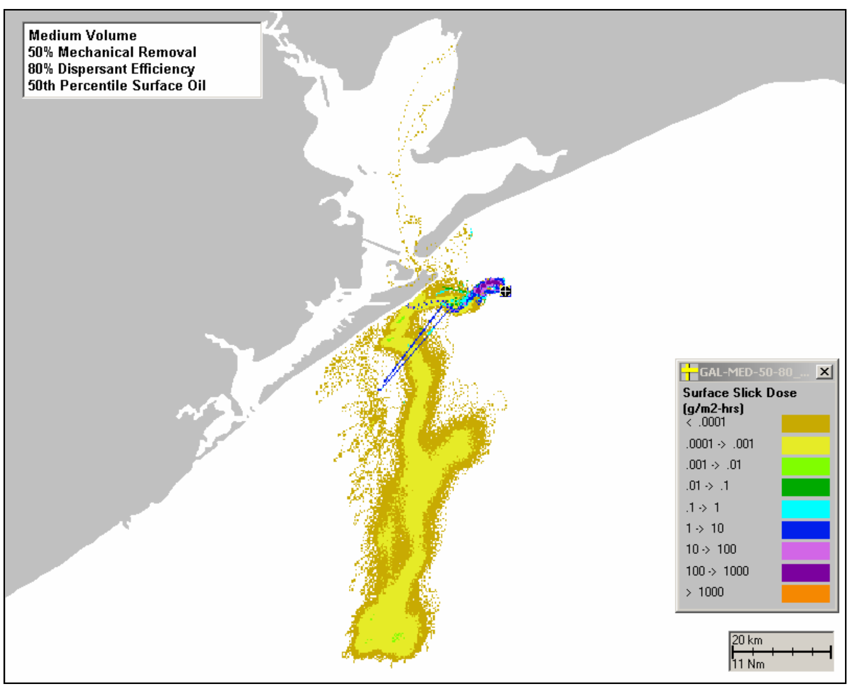

Figure C-II.4.3-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

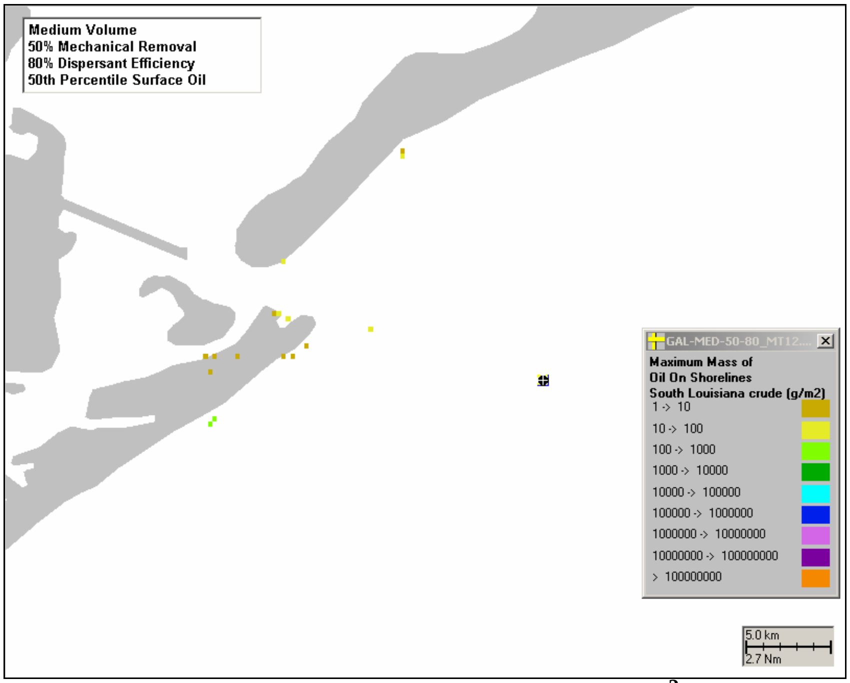

Figure C-II.4.3-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

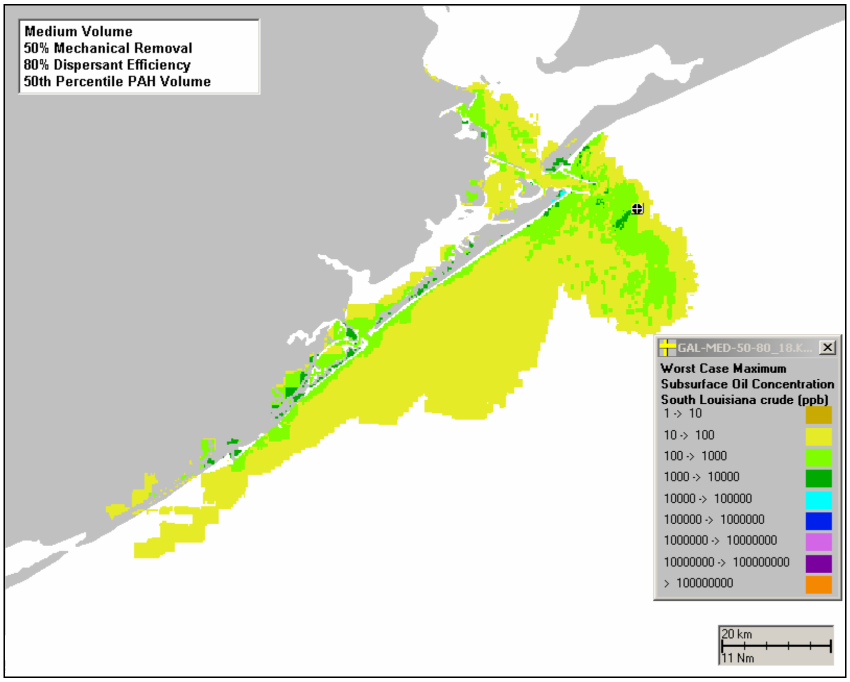

Figure C-II.4.3-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 80% Dispersant Efficiency.

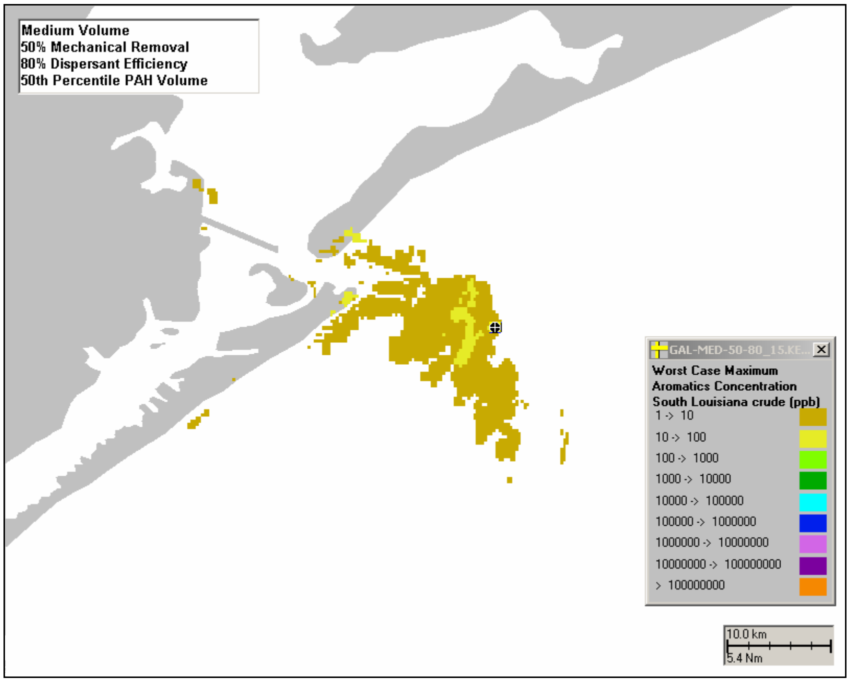

Figure C-II.4.3-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 80% Dispersant Efficiency.

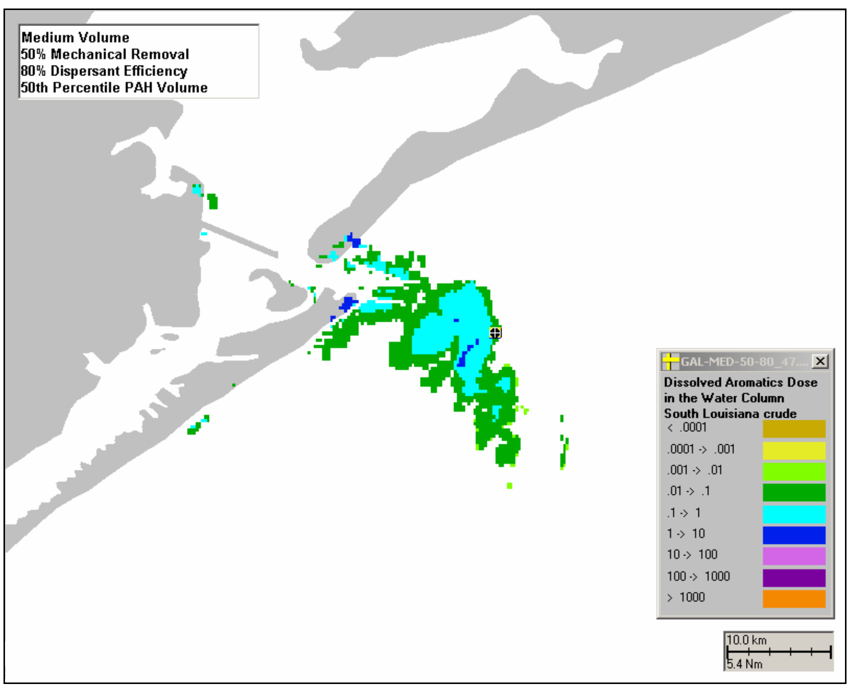

Figure C-II.4.3-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 80% Dispersant Efficiency.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Medium Volume, 80% Dispersant Efficiency..

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

C-II.4.4 Scenario: Large Volume, No Dispersant.

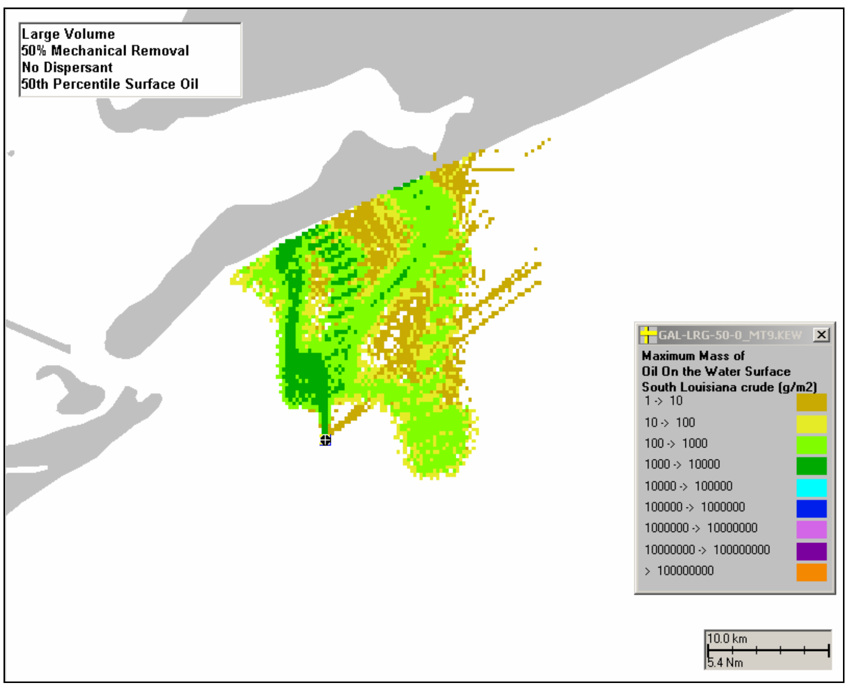

Figure C-II.4.4-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure.   Scenario: Large Volume, No Dispersant.

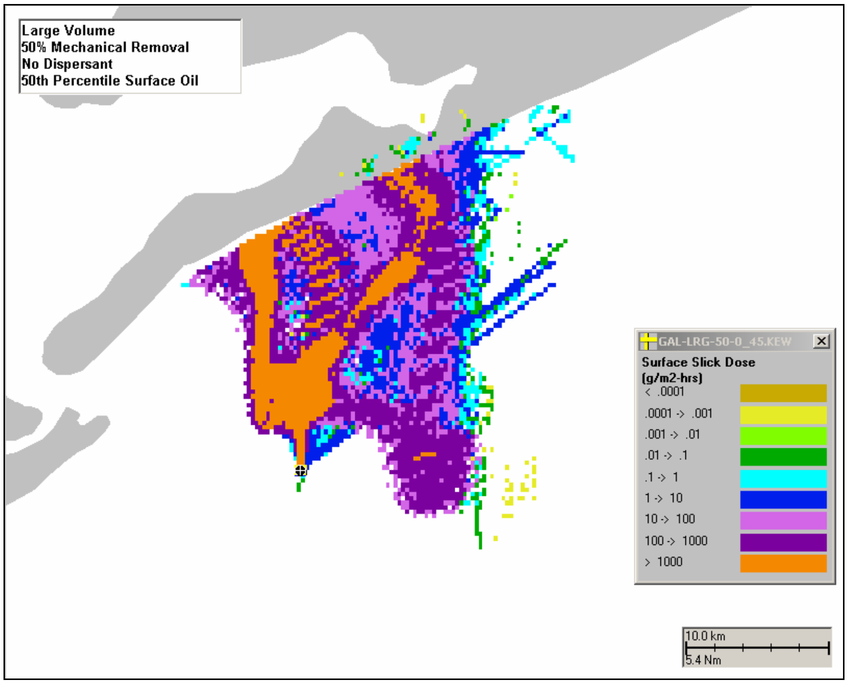

Figure C-II.4.4-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Large Volume, No Dispersant.

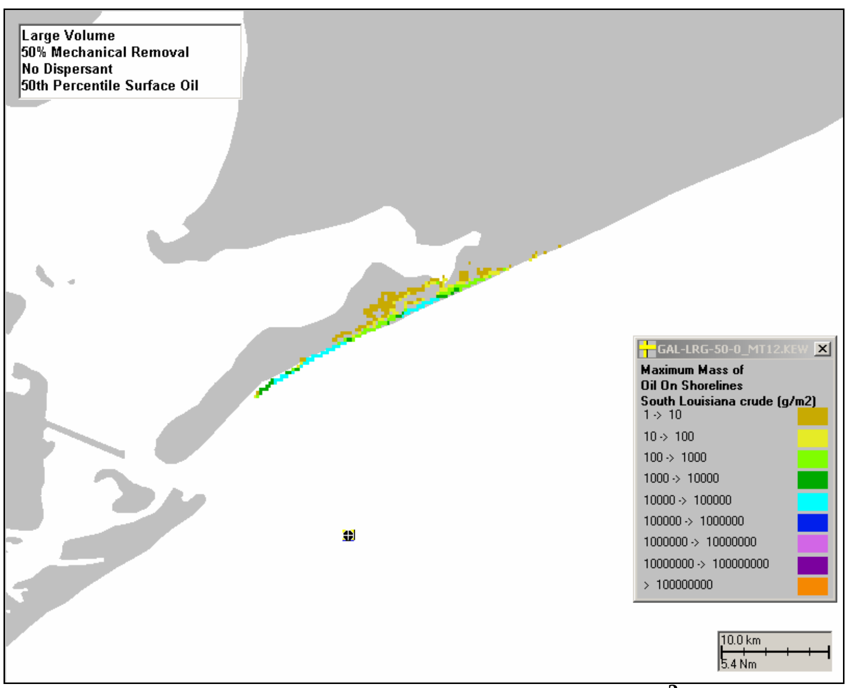

Figure C-II.4.4-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, No Dispersant.

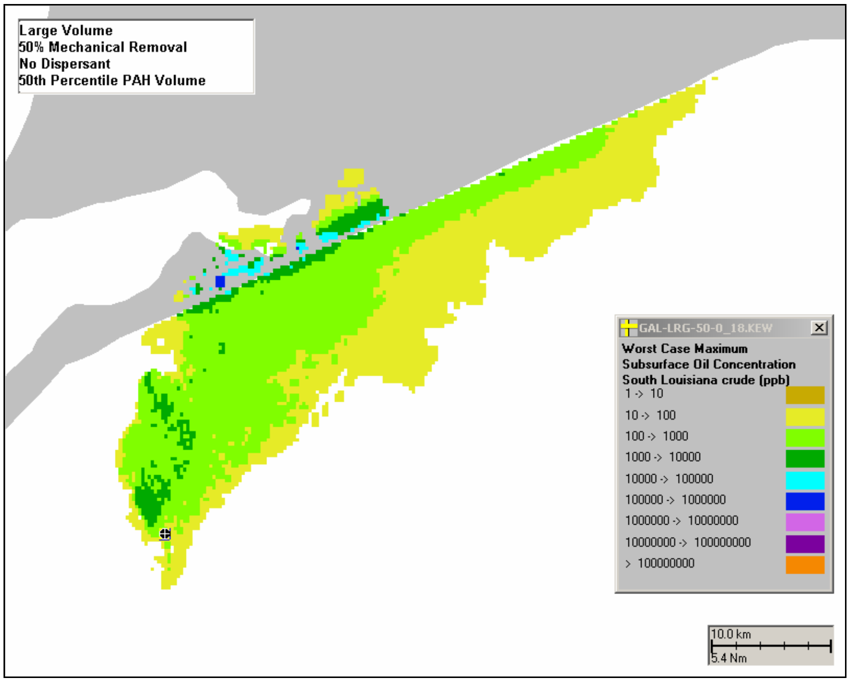

Figure C-II.4.4-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, No Dispersant.

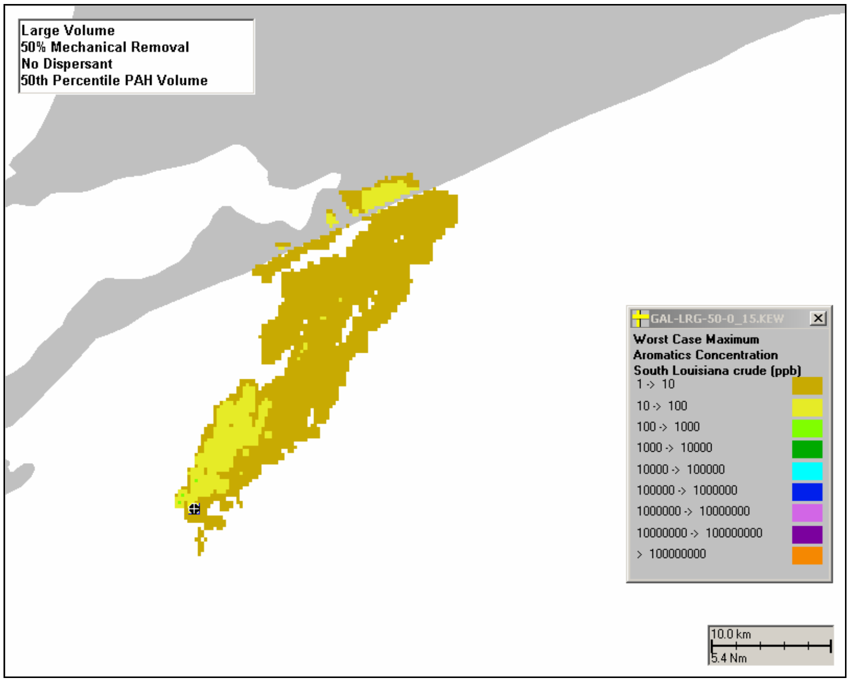

Figure C-II.4.4-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, No Dispersant.

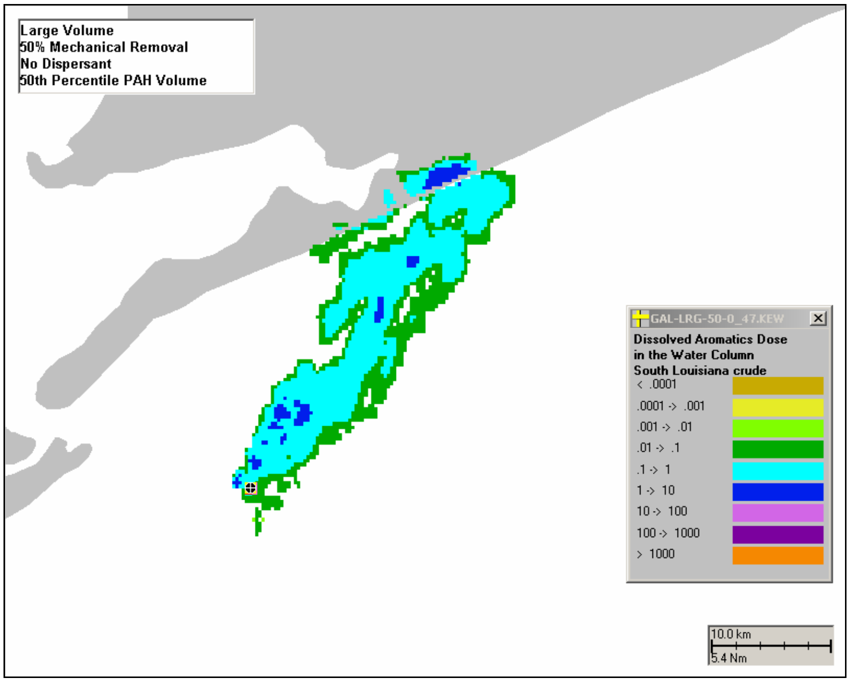

Figure C-II.4.4-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, No Dispersant.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Large Volume, No Dispersant.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Large Volume, No Dispersant.

C-II.4.5 Scenario: Large Volume, 45% Dispersant Efficiency.

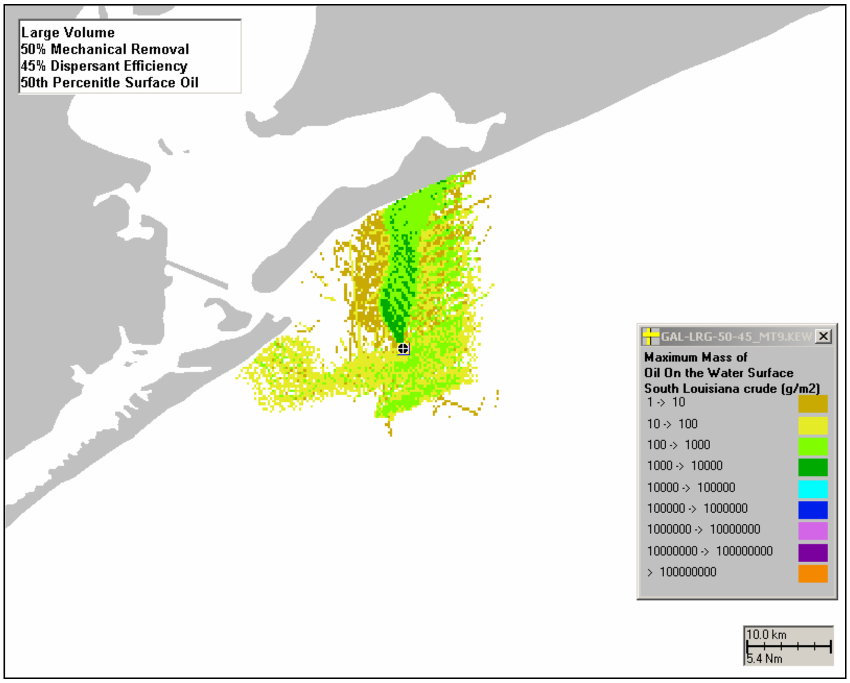

Figure C-II.4.5-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

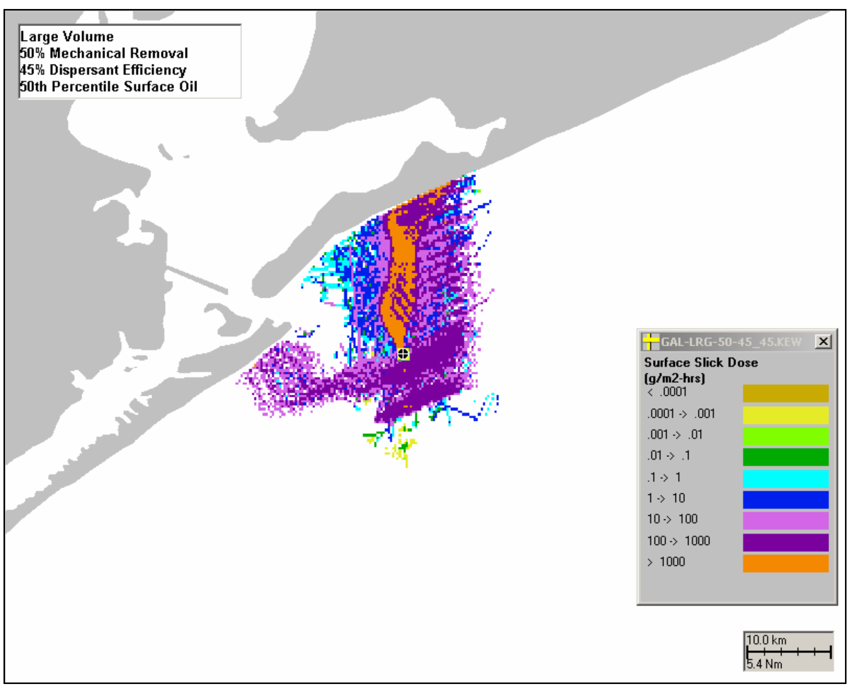

Figure C-II.4.5-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

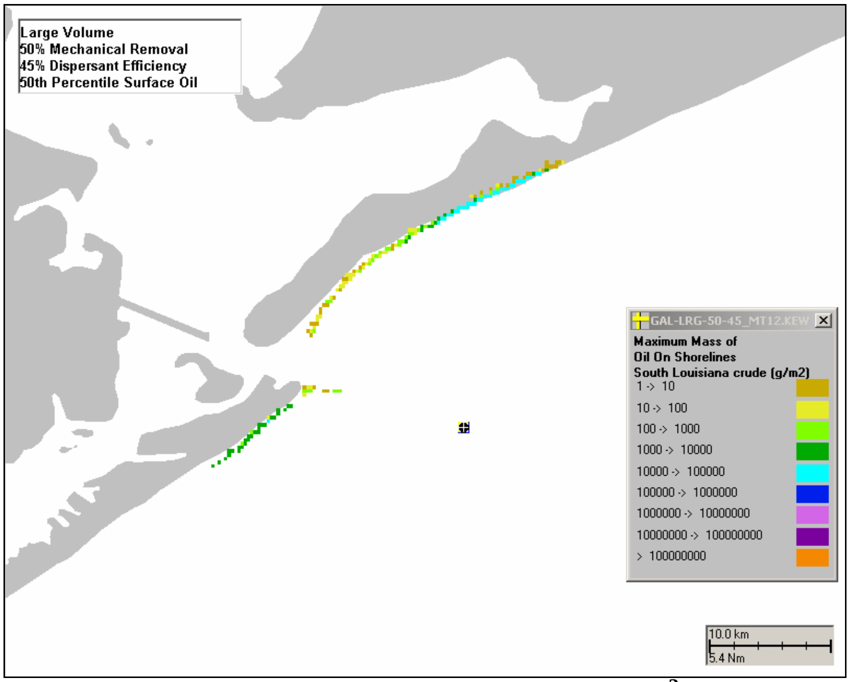

Figure C-II.4.5-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

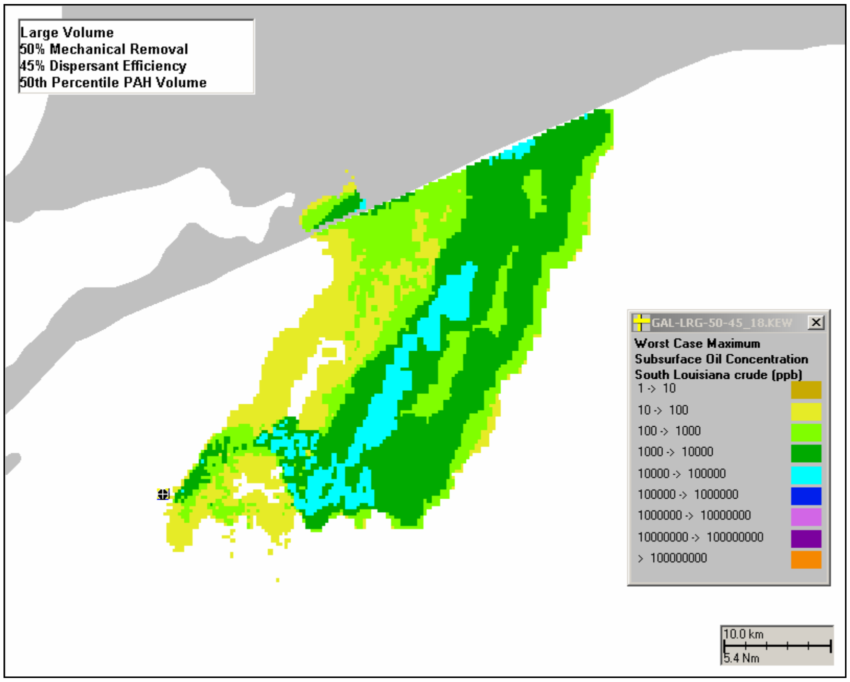

Figure C-II.4.5-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 45% Dispersant Efficiency.

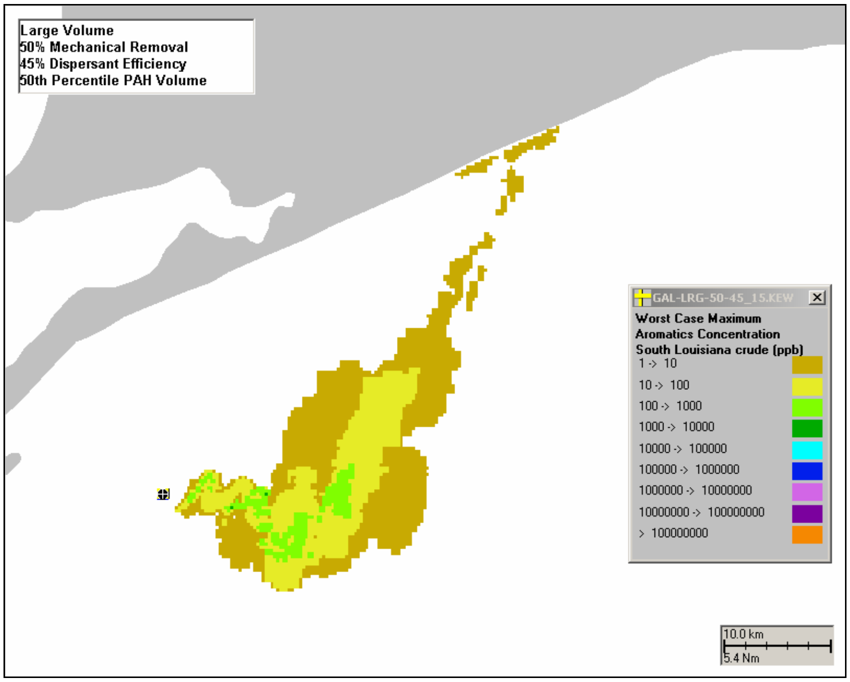

Figure C-II.4.5-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 45% Dispersant Efficiency.

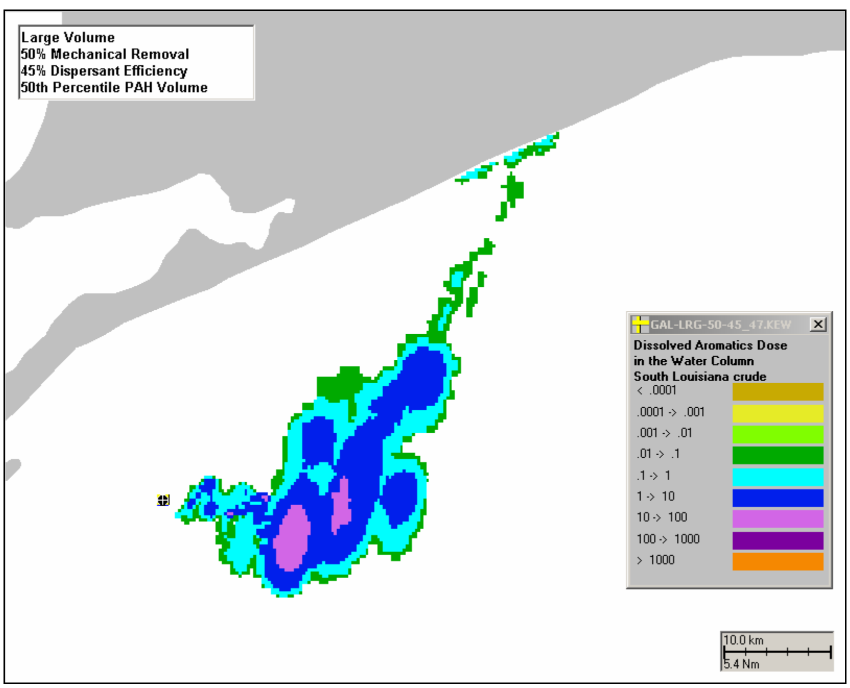

Figure C-II.4.5-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 45% Dispersant Efficiency.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

C-II.4.6 Scenario: Large Volume, 80% Dispersant Efficiency.

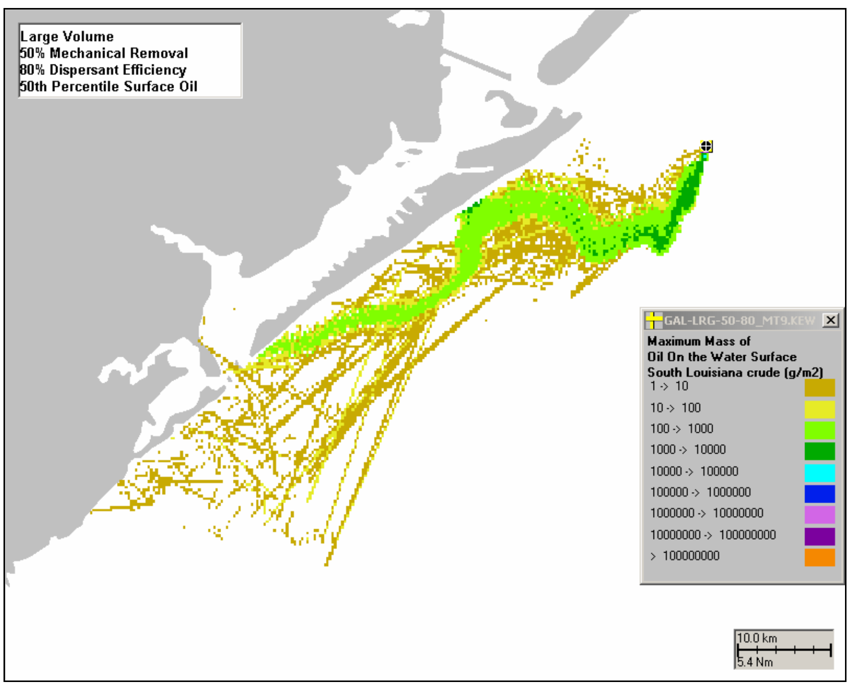

Figure C-II.4.6-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

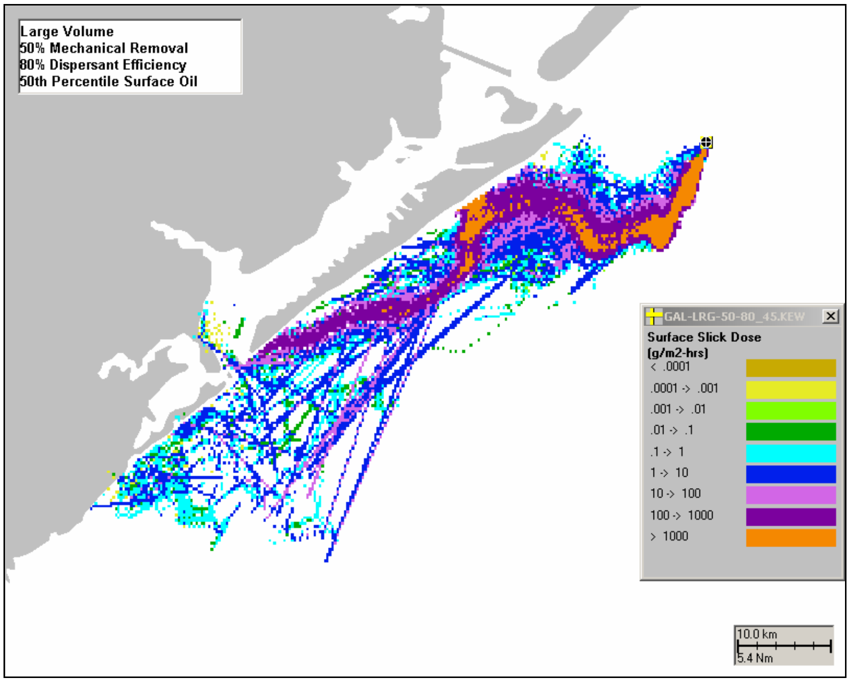

Figure C-II.4.6-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

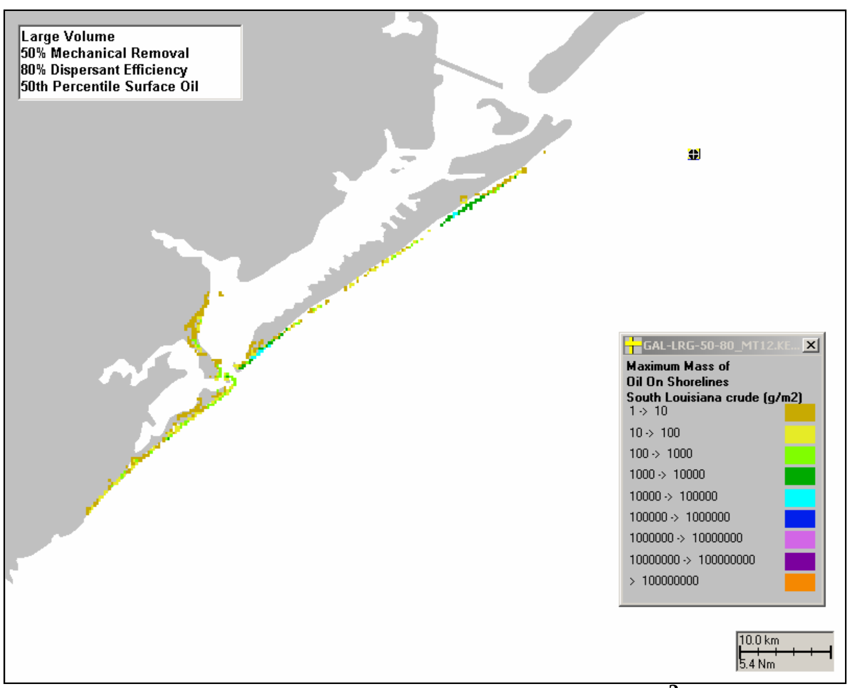

Figure C-II.4.6-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

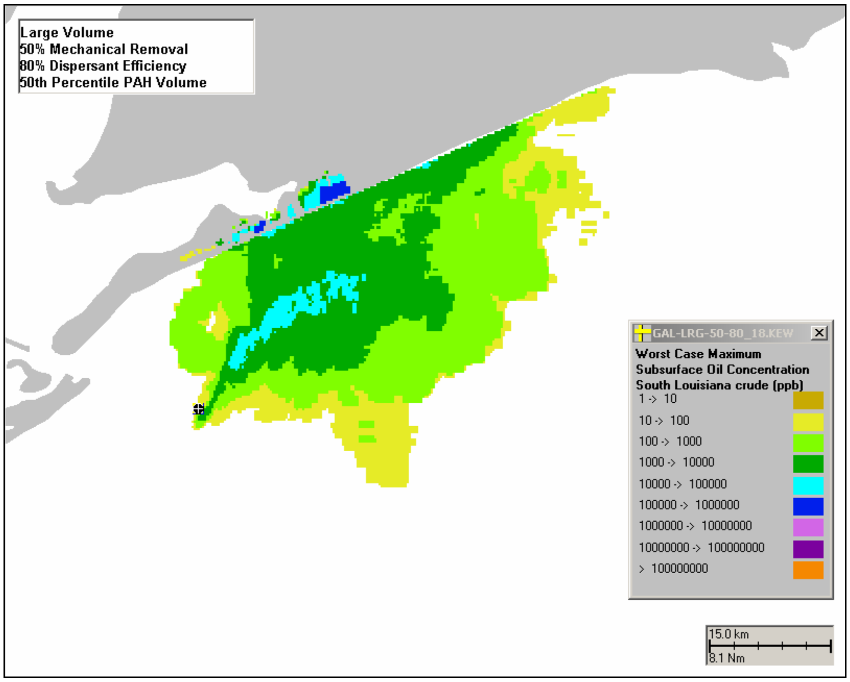

Figure C-II.4.6-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 80% Dispersant Efficiency.

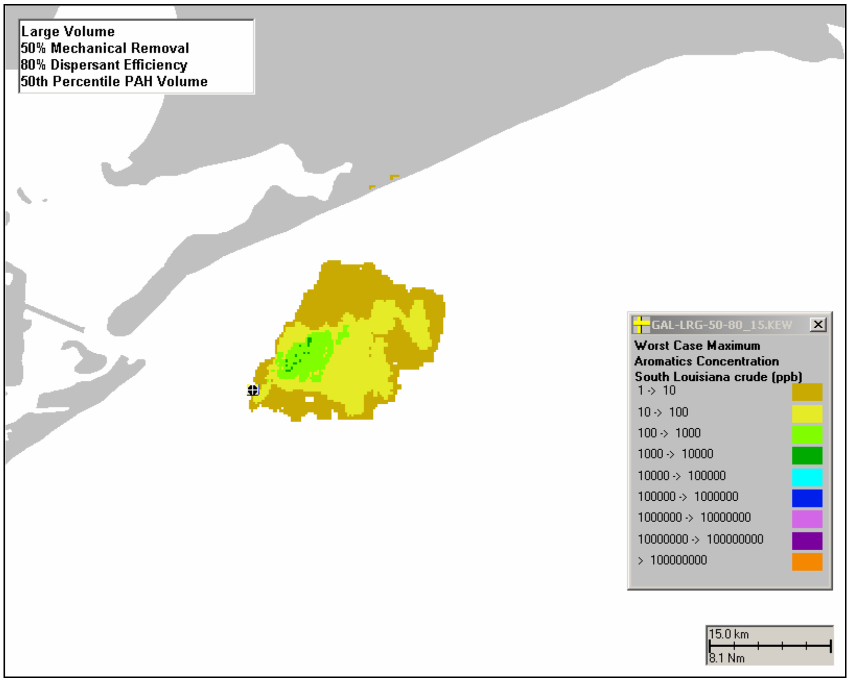

Figure C-II.4.6-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 80% Dispersant Efficiency.

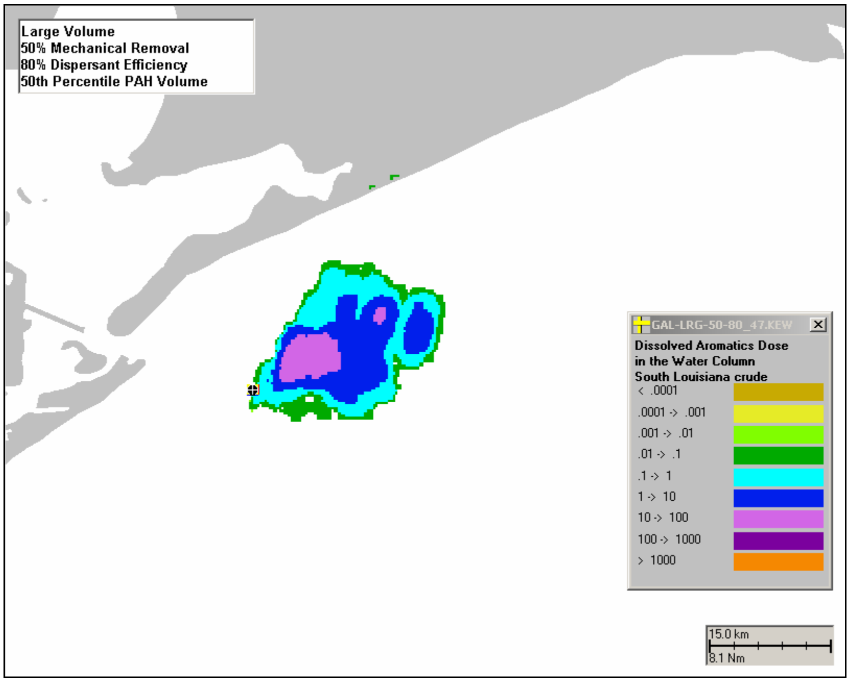

Figure C-II.4.6-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 80% Dispersant Efficiency.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part C: Galveston Bay and North Texas Shelf

Section C-II.5

by

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ASA 00-246

August 2004

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C-II.5 Area swept by surface oil greater than the threshold affecting wildlife.

This appendix contains estimates of area swept by surface oil multiplied by probability of wildlife being oiled, for each behavior category. This is summarized as an equivalent area of 100% mortality by behavior group. The equivalent area for 100% mortality is the integrated sum of area swept times probability of mortality.

The mean equivalent area killed for all possible environmental conditions is calculated using the index of surface oil exposure exceeding $0.01 g/m^2$, which is the integrated area swept by oil sheen or thicker oil times the duration that oil is present, in m^2-hours. The biological exposure model was run for the 50^{th} percentile run (with respect to m^2-hours) of each of the six scenarios (two volumes times three dispersant conditions). The resulting equivalent areas of 100% mortality (in km^2) were regressed against m^2-hours to obtain an equation for each behavior group that may be used to scale from m^2-hours to area killed. Table C-II.5-1 contains the regression slope, intercept, standard error, and correlation coefficient for each behavior group. Figures C-II.5-1 and C-II.5-2 plot equivalent area killed (of 100% mortality) against m^2-hours for wildlife behavior groups. Tables C-II.5-2 and C-II.5-3 contain estimated equivalent areas killed for mean environmental conditions, based on the mean (i.e., numerical average) surface oil exposure in m^2-hours from Appendix C-II.2.

Table C-II.5-1 Regression slope, intercept, standard error, and correlation coefficient for equivalent area killed (km^2) against m^2-hours based on the 50^{th} percentile runs of each scenario.

Behavior Group	Probability of Mortality	Slope	Intercept	Std Error	Correla-tion
Dabbling waterfowl	0.99	8.2984E-11	0.0595	0.4759	0.962
Nearshore aerial divers	0.35	2.9374E-11	0.0209	0.1686	0.962
Surface seabirds	0.99	1.2805E-08	9.0587	106.8935	0.924
Aerial seabirds	0.05	6.6373E-10	0.4153	5.5393	0.924
Wetland wildlife (Waders and shorebirds)	0.35	2.7778E-11	-0.0388	0.2698	0.901
Cetaceans	0.001	1.3208E-11	0.0082	0.1106	0.924
Furbearing marine mammals	0.75	9.7654E-09	6.7032	81.5129	0.924
Pinnipeds, manatee, sea turtles	0.01	1.3289E-10	0.0827	1.1091	0.924
Surface birds, seaward	0.99	1.2722E-08	8.9227	107.8959	0.922
Diving birds, seaward	0.35	4.5909E-09	3.0091	38.5753	0.923
Aerial and subsurface, seaward	0.05	6.6218E-10	0.4200	5.5397	0.924
Surface birds, landward	0.99	2.7652E-11	-0.1041	0.2884	0.888
Diving birds, landward	0.35	9.7792E-12	-0.0368	0.1020	0.888
Aerial and subsurface, landward	0.05	1.3972E-12	-0.0053	0.0146	0.888
Diving birds, water only	0.35	4.5870E-09	2.9516	38.3476	0.924
Aerial and subsurface, water only	0.05	6.6071E-10	0.4081	5.5234	0.924
All water surface	1	1.3106E-08	8.4330	109.5646	0.924
All seaward water surface	1	1.3117E-08	8.5975	110.2152	0.923
All landward water surface	1	2.7941E-11	-0.1052	0.2915	0.888

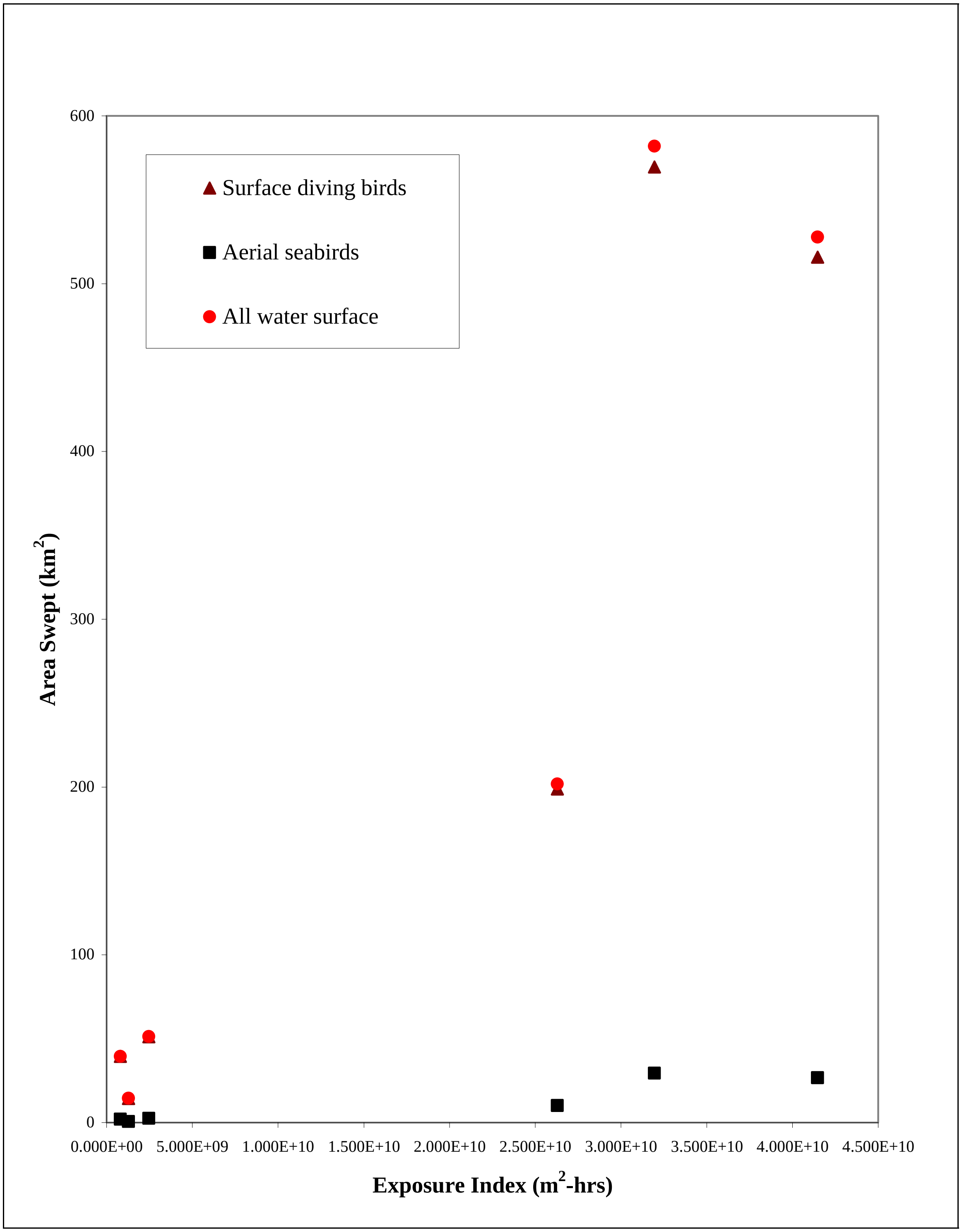

Figure C-II.5-1. Equivalent area killed against m^2-hours for wildlife behavior groups (groups in offshore waters).

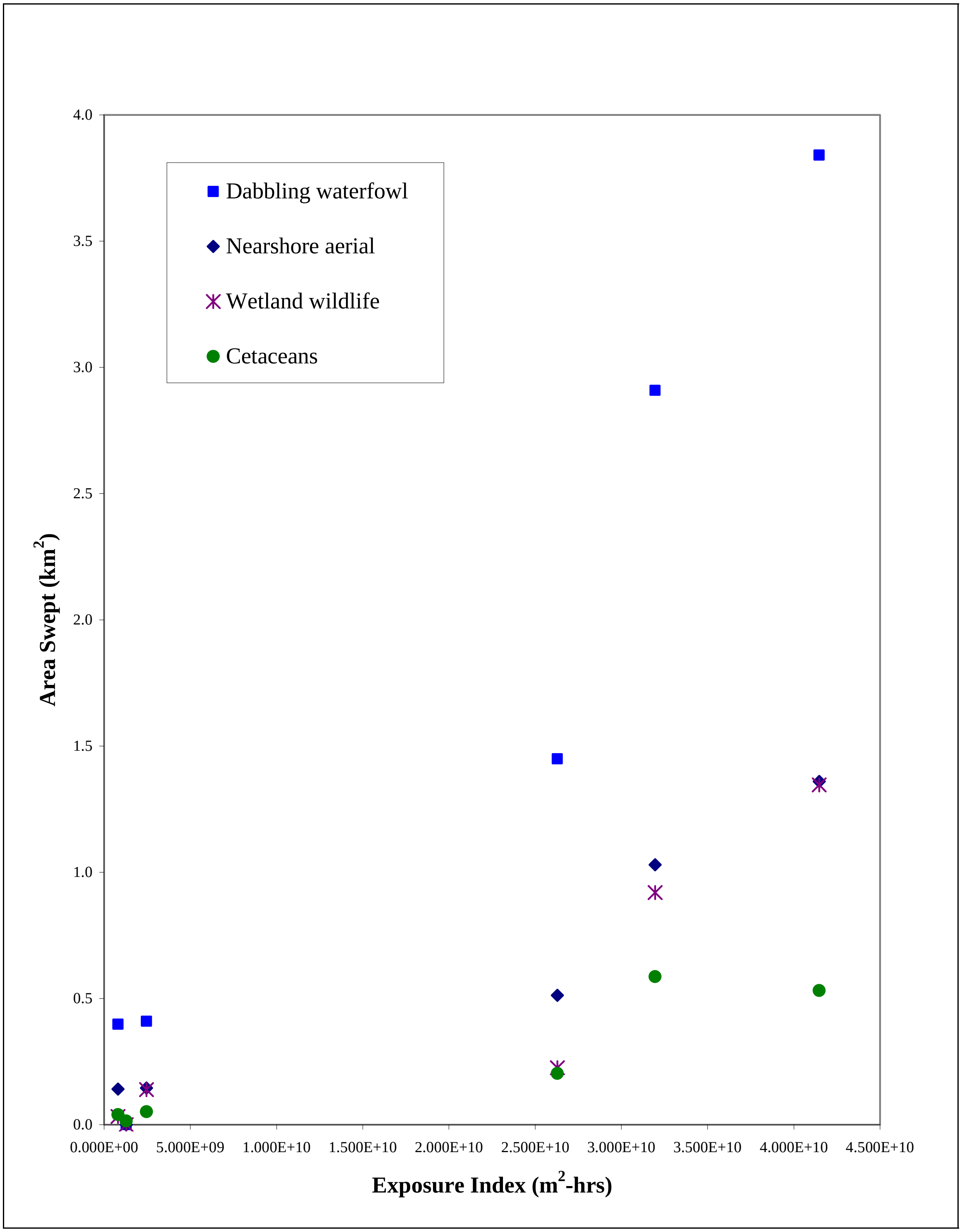

Figure C-II.5-2. Equivalent area killed against m^2-hours for wildlife behavior groups (coastal species and cetaceans)).

Table C-II.5-2. Equivalent area (km^2) of 100% mortality by wildlife behavior group, based on mean surface oil exposure, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	Probability of Mortality	0%	45%	80%
Dabbling waterfowl	0.99	0.50	0.29	0.24
Nearshore aerial divers	0.35	0.18	0.10	0.08
Surface seabirds	0.99	77.06	43.97	36.41
Aerial seabirds	0.05	3.94	2.22	1.83
Wetland wildlife (Waders and shorebirds)	0.35	0.11	0.04	0.02
Cetaceans	0.001	0.08	0.04	0.04
Furbearing marine mammals	0.75	58.56	33.33	27.56
Pinnipeds, manatee, sea turtles	0.01	0.79	0.44	0.37
Surface birds, seaward	0.99	76.48	43.60	36.10
Diving birds, seaward	0.35	27.39	15.52	12.82
Aerial and subsurface, seaward	0.05	3.94	2.23	1.83
Surface birds, landward	0.99	0.04	0.0	0.0
Diving birds, landward	0.35	0.02	0.0	0.0
Aerial and subsurface, landward	0.05	0.00	0.00	0.00
Diving birds, water only	0.35	27.31	15.46	12.75
Aerial and subsurface, water only	0.05	3.92	2.21	1.82
All water surface	1.00	78.02	44.16	36.43
All seaward water surface plus intertidal	1.00	78.25	44.36	36.62
All landward water surface plus intertidal	1.00	0.04	0.0	0.0
All water surface plus intertidal	1.00	78.29	44.33	36.57

Table C-II.5-3. Equivalent area (km^2) of 100% mortality by wildlife behavior group, based on mean surface oil exposure, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	Probability of Mortality	0%	45%	80%
Dabbling waterfowl	0.99	4.97	3.83	3.23
Nearshore aerial divers	0.35	1.76	1.35	1.14
Surface seabirds	0.99	766.20	590.13	497.68
Aerial seabirds	0.05	39.66	30.53	25.74
Wetland wildlife (Waders and shorebirds)	0.35	1.60	1.22	1.02
Cetaceans	0.001	0.79	0.61	0.51
Furbearing marine mammals	0.75	584.11	449.83	379.33
Pinnipeds, manatee, sea turtles	0.01	7.94	6.11	5.15
Surface birds, seaward	0.99	761.14	586.21	494.36
Diving birds, seaward	0.35	274.46	211.33	178.19
Aerial and subsurface, seaward	0.05	39.57	30.47	25.69
Surface birds, landward	0.99	1.53	1.15	0.95
Diving birds, landward	0.35	0.54	0.41	0.34
Aerial and subsurface, landward	0.05	0.08	0.06	0.05
Diving birds, water only	0.35	274.17	211.10	177.98
Aerial and subsurface, water only	0.05	39.47	30.39	25.62
All water surface	1.00	783.34	603.13	508.52
All seaward water surface plus intertidal	1.00	784.16	603.81	509.11
All landward water surface plus intertidal	1.00	1.55	1.16	0.96
All water surface plus intertidal	1.00	785.71	604.97	510.07

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part C: Galveston Bay and North Texas Shelf

Section C-II.6

by

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ASA 00-246

August 2004

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C-II.6 Exposures for fish and invertebrates to dissolved aromatic concentrations.

This appendix tabulates estimated mortality of water column, demersal (on the bottom) and benthic (in the bottom) organisms by behavior type for the Galveston spill location. Effects are summarized as an equivalent area of 100% mortality by behavior group and habitat type. The equivalent area for 100% mortality is the integrated sum of equivalent area affected times percent mortality. For water column and demersal species, the equivalent area affected is calculated as water volume affected times the fraction of the water depth zone the behavior group occupies that the affected volume encompasses. For pelagic species, the depth zone occupied is the entire water column. For demersal species (on the bottom sediments, exposed to bottom water), the depth zone occupied is the bottom 1 meter of the water column. The methods and assumptions for these calculations are described in Part A.

For water column and demersal species, the mean equivalent area killed for all possible environmental conditions is calculated using the water volume (m^3) exposed to greater than 1 mg/m^3 (1 ppb) dissolved aromatic concentration at any time after the spill. The biological exposure model was run for the 50th percentile run (with respect to water volume exposed to >1ppb) of each of the six scenarios (two spill volumes times three dispersant conditions). The toxicity parameter (LC50) assumed in these calculations was that for sensitive species (the 2.5th percentile in rank order sensitivity), in order to provide conservatively high estimates of potential water column effects. The resulting equivalent areas of 100% mortality (in km^2) were regressed against water volume exposed (m^3) to obtain an equation for each behavior group that may be used to scale from volume exposed to area killed (for sensitive species). Figure C-II.6-1 plots equivalent water column area killed (area of 100% mortality) against volume exposed to >1ppb for each of the water column and demersal behavior groups. Table C-II.6-1 contains the regression slope, intercept, standard error, and correlation coefficient for each behavior group. Tables C-II.6-2 and C-II.6-3 contain estimated equivalent areas killed (for sensitive species) for mean environmental conditions, based on the mean volume exposed to >1ppb dissolved aromatic concentration (from Appendix C-II.2). Tables C-II.6-4 and C-II.6-5 contain estimated equivalent areas killed (for sensitive species) for 95th percentile environmental conditions, based on the mean plus two standard deviations of volume exposed to >1ppb dissolved aromatic concentration. Mean and standard deviation of volume exposed to >1ppb dissolved aromatic concentration are tabulated in Appendix C-II.2 and the full distribution of all 100 runs is plotted in Appendix C-II.3. The effects on water column communities are discussed in Sections C.3.2 and C.4.2.

Benthic effects are related to the bottom sediment area exposed to oil exceeding a threshold of concern. Table C-II.6-6 summarizes the loading of oil to the sediments. For most species, the dissolved aromatic concentration in the pore water of the sediments is what is bioavailable and causes toxicity (Table C-II.6-7). A threshold of 6 ppb dissolved aromatic concentration could cause effects on sensitive (2.5% of) species, whereas the threshold for average species is 50 ppb (see Part A, Section A.3.4). The effects on benthic organisms are discussed in Sections C.3.2 and C.4.2.

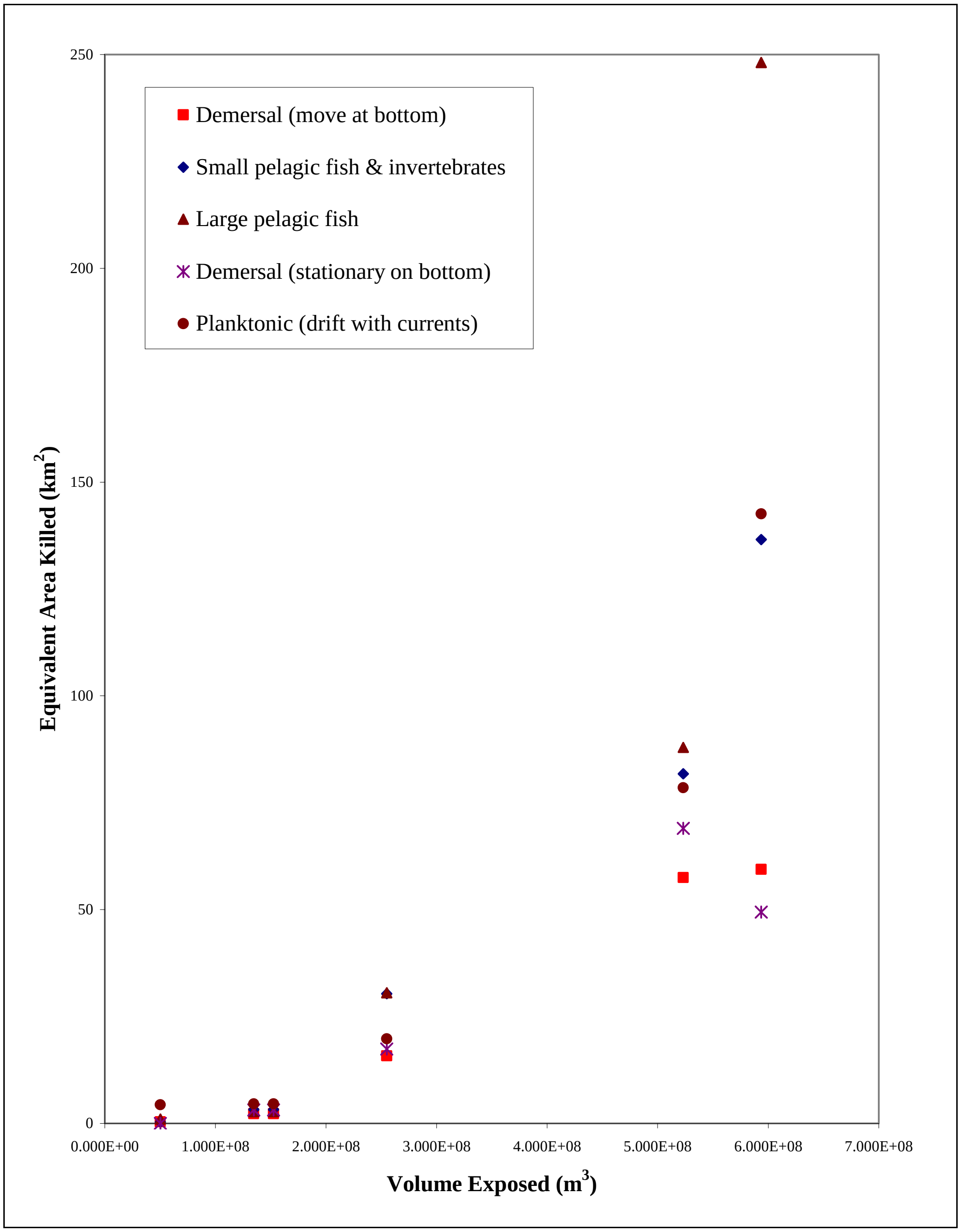

Figure C-II.6-1. Equivalent area killed (for sensitive species) against volume exposed to > 1ppb dissolved aromatic concentration for water column behavior groups.

Table C-II.6-1 Regression slope, intercept, standard error, and correlation coefficient for equivalent water column area killed (km^2) against water volume exposed to >1ppb (m^3), based on the 50th percentile runs of each scenario.

Behavior Group	Slope	Intercept	Std Error	Correlation
Demersal (move at bottom)	1.2427E-07	-12.4514	5.1135	0.987
Small pelagic fish & invertebrates	2.4080E-07	-26.0133	15.9196	0.967
Large pelagic fish	3.8534E-07	-47.5587	50.4559	0.885
Demersal (stationary on bottom)	1.2211E-07	-11.0905	10.7430	0.943
Planktonic (drift with currents)	2.4107E-07	-26.2755	20.8407	0.945

Table C-II.6-2. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	**0%**	**45%**	**80%**
Demersal (move at bottom)	0	7.9	8.2
Small pelagic fish & invertebrates	0	13.3	13.9
Large pelagic fish	0	15.4	16.4
Demersal (stationary on bottom)	0	8.9	9.2
Planktonic (drift with currents)	0	13.1	13.7

Table C-II.6-3. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	**0%**	**45%**	**80%**
Demersal (move at bottom)	33.9	67.3	77.0
Small pelagic fish & invertebrates	63.8	128.6	147.2
Large pelagic fish	96.2	199.9	229.7
Demersal (stationary on bottom)	34.5	67.3	76.8
Planktonic (drift with currents)	63.7	128.5	147.2

Table C-II.6-4. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean plus two standard deviations (i.e., 95th percentile) of water volume exposed to > 1ppb dissolved aromatic concentration, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	0%	45%	80%
Demersal (move at bottom)	11.7	45.5	49.7
Small pelagic fish & invertebrates	20.8	88.1	96.3
Large pelagic fish	27.4	141.0	154.1
Demersal (stationary on bottom)	12.7	44.7	48.8
Planktonic (drift with currents)	20.6	88.2	96.4

Table C-II.6-5. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean plus two standard deviations (i.e., 95th percentile) of water volume exposed to > 1ppb dissolved aromatic concentration, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	0%	45%	80%
Demersal (move at bottom)	122.3	182.9	203.5
Small pelagic fish & invertebrates	237.0	354.4	394.2
Large pelagic fish	379.2	567.2	630.9
Demersal (stationary on bottom)	120.2	179.7	199.9
Planktonic (drift with currents)	237.3	354.8	394.7

Table C-II.6-6. Area (m^2) of sediment exceeding indicated thresholds of total hydrocarbon loading per unit area (g/m^2) under average environmental conditions, by spill volume and dispersant treatment.

Threshold (g/m^2)	Medium 0%	Medium 45%	Medium 80%	Large 0%	Large 45%	Large 80%
0	257,313	85,771	85,771	2,401,585	1,886,959	2,058,501
0.001	85,771	-	85,771	1,372,334	857,709	1,115,022
0.01	-	-	85,771	428,854	343,084	257,313
0.1	-	-	-	85,771	85,771	-
1	-	-	-	-	-	-
10	-	-	-	-	-	-

Table C-II.6-7. Area (m^2) of sediment exceeding indicated thresholds of dissolved aromatic concentration in pore waters (mg/m^3 = ppb) under average environmental conditions, by spill volume and dispersant treatment.

Threshold (mg/m^3 = ppb)	Medium 0%	Medium 45%	Medium 80%	Large 0%	Large 45%	Large 80%
1	0	0	0	0	600,396	1,458,105
10	0	0	0	0	0	0

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part C: Galveston Bay and North Texas Shelf

Section C-III.1

by

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ASA 00-246

August 2004

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C-III.1 Air Concentrations from Unburned Oil

This section contains model results for spills in the Gulf of Mexico used to evaluate volatile hydrocarbon emissions from unburned oil and resulting air quality effects. The amount of volatilized mass entering the atmosphere for each chemical (or chemical class) of concern was estimated using oil spill modeling (SIMAP). SIMAP also provided the time frame over which the emissions occur. The atmospheric concentrations of volatilized hydrocarbons were modeled using AIRMAP (as described in Part A, Section A.5.1). The estimated concentrations at the water surface were compared to air quality standards to evaluate the potential for human health effects and wildlife effects.

As a screening analysis, SIMAP runs were performed for both the medium (2500 bbl) and large (40,000 bbl) spill volumes of South Louisiana crude under various wind conditions to determine the possible hydrocarbon emissions from unburned oil to the atmosphere. Emissions were estimated using SIMAP for the warmest water temperature occurring in the region, 30^{o}C (French et al. 1996b) and for varying wind speeds from 3 to 25 kts. (Evaporation is very slow in conditions of no wind, so this case was not included.)

As a worst case, these model runs were performed assuming no dispersants are applied, since the use of dispersants would reduce emissions to the extent that volatile components are permanently mixed into the water. It is also assumed that any mechanically-removed oil still volatilizes, so no correction for removal was made to the volatilized mass. Likewise, no correction for amount burned was made to the rate of unburned oil emission. Thus, the screening model runs estimated the maximum rate and amount of emissions which would be expected under any environmental conditions and response scenario for the region.

In the next step of the analysis, the atmospheric concentrations of volatilized hydrocarbons released by unburned oil were modeled using AIRMAP, which accounts for transport and dilution of hydrocarbons in the local atmosphere around the spill site. Each hydrocarbon constituent was modeled separately, releasing the mass of the constituent emitted from the oil over time from the area covered by surface floating oil (as estimated by SIMAP). AIRMAP was run for each constituent and wind speed condition, from 3 to 25 kts. The constituent mass released in the AIRMAP simulation (over 10 hours) was the maximum amount emitted to the air (of that constituent) in any 10-hour period in the SIMAP spill simulation. The AIRMAP simulation was run assuming a stable atmosphere with minimal turbulence to disperse contaminants.

The atmospheric dispersion model provided estimates of air concentrations in the air layer within 2 m of the water surface (for each 55m X 55m cell of a 200 by 200 cell grid covering the horizontal extent of the plume) as a function of time after the spill. The estimated concentrations were then compared to air quality standards to evaluate the potential for human health effects. Two averaging periods were used in accordance with the standards: 0.5 hour for comparison to the Immediate Danger to Life and Health (IDLH) value and 8 hours for comparison to the 8-hour time weighted average (TWA).

The maximum 0.5-hour and 8-hour average air concentration for any time period in the AIRMAP simulation was compared to the appropriate standard (Table C-III.1-1). The IDLH (from Table A.5-5 in Part A) is not to be exceeded for a ½ hour exposure. The PEL-TWA is the minimum of the 8-hour time weighed averages in Table A.5-5. Heptane is used as representative of the volatile aliphatic VOCs. Its air quality standards are the lowest of those available for this group of chemicals (see Section A.5.3), so comparison to the standards for heptane is conservative. The area adversely affected was that where the standard was exceeded for the appropriate averaging period. The maximum distance from the release site that concentrations exceeded the air quality standard was also estimated for each constituent using the AIRMAP results.

These results are applicable to spills of crude oils with similar volatile content in any location where conditions are at the temperature, atmospheric stability, and wind speed assumed. Concentrations and areas affected would be lower than those reported below for less stable atmospheres and lower temperature conditions. The results are assuming no dispersant applied, such that all the volatiles are assumed released to the atmosphere. Dispersants could permanently disperse some of the volatiles in the water column, reducing the air concentrations and areas adversely affected. Also, volatiles would be burned and emissions reduced to the extent that ISB is used. Thus, these areas of potential adverse effect are the maximum possible in the region under any response scenario and environmental conditions.

Table C-III.1-1. IDLH and TWA thresholds for evaluating potential effects of air concentrations.

Chemical	IDLH (mg/m^3)	PEL-TWA (mg/m^3)
Benzene	1595	3.19
Toluene	1885	754
Ethylbenzene	3472	434
Xylene	3906	434
Naphthalene	1310	52.4
Biphenyl	631	1.262
Phenanthrene	80	(not available)
Aliphatic VOCs with boiling points <180^{o}C (based on heptane)	3075	2050

C-III.1.1 Medium Volume Spills

Emissions from Unburned Oil

Table C-III.1.1-1 contains the estimated maximum volatilized mass released to the atmosphere in any 10-hour period for each constituent of concern in the medium-volume spill under the worst-case (highest) temperature condition (30^{o}C) and with various wind speeds. The results show (Figure C-III.1.1-1) that the emission rates of the MAHs (benzene, toluene, ethylbenzene, xylenes) increase as wind speed increases to about 5 kts and then level off. Volatile aliphatics indicate a similar pattern with wind speed (Table C-III.1.1-1). The emission rates for PAHs are much lower than for the volatiles and increase with wind speed (Figure C-III.1.1-1).

Table C-III.1.1-1. Maximum mass (MT) of chemical volatilized from unburned South Louisiana crude oil in any 10-hour period after a spill of 2,500 bbl at the indicated wind speed.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Total MAHs	256	268	266	260	257	250	242	232	224
Benzene	0.20	0.21	0.21	0.21	0.21	0.20	0.19	0.19	0.18
Toluene	0.56	0.59	0.58	0.57	0.56	0.55	0.53	0.51	0.49
Ethylbenzene	0.18	0.19	0.19	0.18	0.18	0.18	0.17	0.16	0.16
Xylenes	1.37	1.43	1.42	1.39	1.38	1.34	1.30	1.24	1.20
Total volatile and semi-volatile PAHs	56.6	73.0	85.6	95.6	102.9	113.7	128.9	150.7	199.9
Naphthalene	0.02	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.07
Biphenyl	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Phenanthrene	0.03	0.04	0.05	0.06	0.06	0.07	0.08	0.09	0.12
Aliphatic VOCs with boiling points <180^{o}C	42.3	44.2	43.9	43.0	42.5	41.3	40.1	38.4	37.1

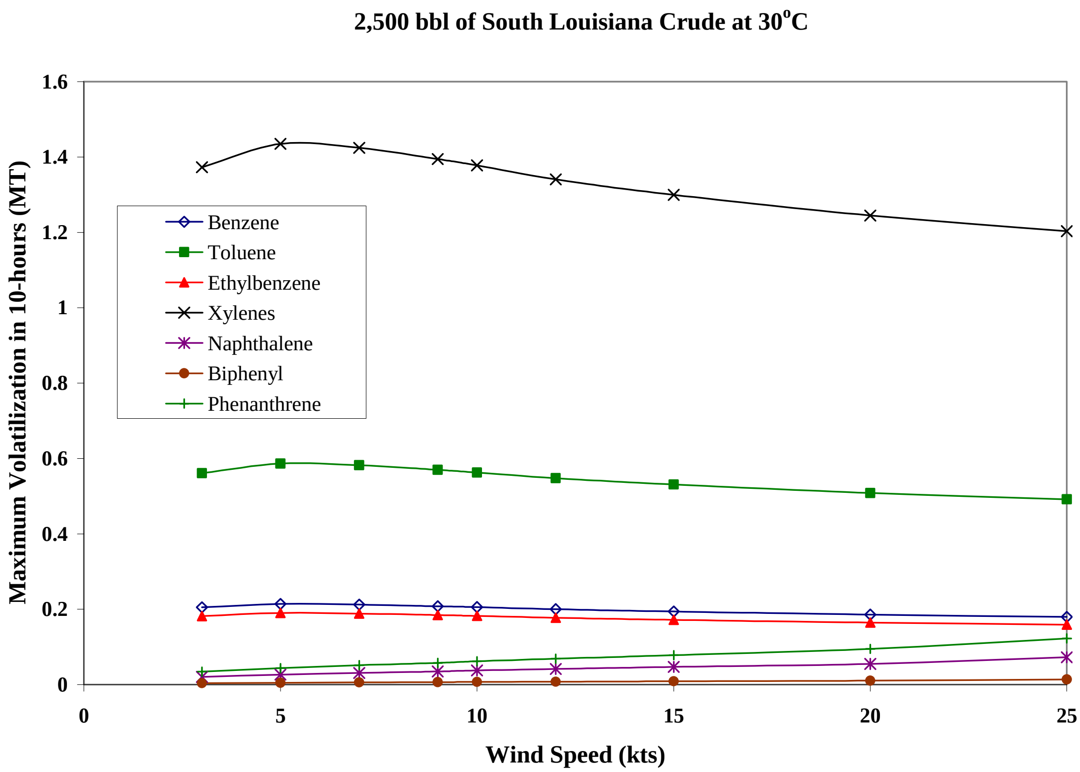

Figure C-III.1.1-1 Maximum mass (MT) of chemical volatilized from unburned South Louisiana crude oil in any 10-hour period after a spill of 2,500 bbl at the indicated wind speed.

Air Concentrations from Unburned Oil Emissions

Tables C-III.1.1-2 and C-III.1.1-3 list the areas where the air concentrations exceeded the comparable air quality standards. Tables C-III.1.1-4 and C-III.1.1-5 list the maximum distances (down wind) from the release site that concentrations exceeded the air quality standards. Since the emissions were more rapidly dispersed in the atmosphere the higher the wind speed, the conditions where concentrations of volatiles in air were at maximum were those where winds were assumed light (3 kts). This is demonstrated in the results. The IDLH is not exceeded for any of the chemical constituents under these worst-case conditions for medium volume spills of South Louisiana crude oil. The TWA would only be exceeded after spills of 2,500 bbl for benzene in the immediate spill area (≤0.7 km downwind of the spill site) and under light (≤3 kts) winds. Air concentrations of other constituents would not exceed the TWA standards at any time after a medium volume spill.

Table C-III.1.1-2. Maximum area (m^2) where the IDLH would be exceeded due to volatilization of unburned South Louisiana crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180°C	0	0	0	0	0	0	0	0	0

Table C-III.1.1-3. Maximum area (m^2) where the PEL-TWA would be exceeded due to volatilization of unburned South Louisiana crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	75,625	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180°C	0	0	0	0	0	0	0	0	0

Table C-III.1.1-4. Maximum distance down wind (km) where the IDLH would be exceeded due to volatilization of unburned South Louisiana crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0	0	0	0	0	0	0	0	0

Table C-III.1.1-5. Maximum distance down wind (km) where the PEL-TWA would be exceeded due to volatilization of unburned South Louisiana crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0.7	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0	0	0	0	0	0	0	0	0

C-III.1.2 Large Volume Spills

Emissions from Unburned Oil

Table C-III.1.2-1 contains the estimated maximum volatilized mass released to the atmosphere in any 10-hour period for each constituent of concern in the large-volume spill under the worst-case (highest) temperature condition and with various wind speeds. The results show (Figure C-III.1.2-1) that the emission rates of the MAHs (benzene, toluene, ethylbenzene, xylenes) increase as wind speed increases to about 15 kts and then level off. Volatile aliphatics indicate a similar pattern with wind speed (Table C-III.1.2-1). The emission rates for PAHs are much lower than for the volatiles and increase with wind speed (Figure C-III.1.2-1).

Table C-III.1.2-1. Maximum mass (MT) of chemical volatilized from unburned South Louisiana crude oil in any 10-hour period after a spill of 40,000 bbl at the indicated wind speed.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Total MAHs	2826	3257	3519	3749	3806	3869	4007	4026	3989
Benzene	2.26	2.61	2.82	3.00	3.05	3.10	3.21	3.22	3.19
Toluene	6.19	7.13	7.71	8.21	8.34	8.47	8.77	8.82	8.74
Ethylbenzene	2.01	2.31	2.50	2.66	2.70	2.75	2.84	2.86	2.83
Xylenes	15.15	17.46	18.86	20.09	20.40	20.74	21.48	21.58	21.38
Total volatile and semi-volatile PAHs	457.3	591.8	697.1	785.7	810.7	969.3	1345.4	1984.7	2592.1
Naphthalene	0.17	0.22	0.25	0.29	0.30	0.35	0.49	0.72	0.94
Biphenyl	0.03	0.04	0.05	0.05	0.06	0.07	0.09	0.14	0.18
Phenanthrene	0.28	0.36	0.42	0.48	0.49	0.61	0.89	1.43	1.87
Aliphatic VOCs with boiling points <180^{o}C	467	538	581	619	629	639	662	665	659

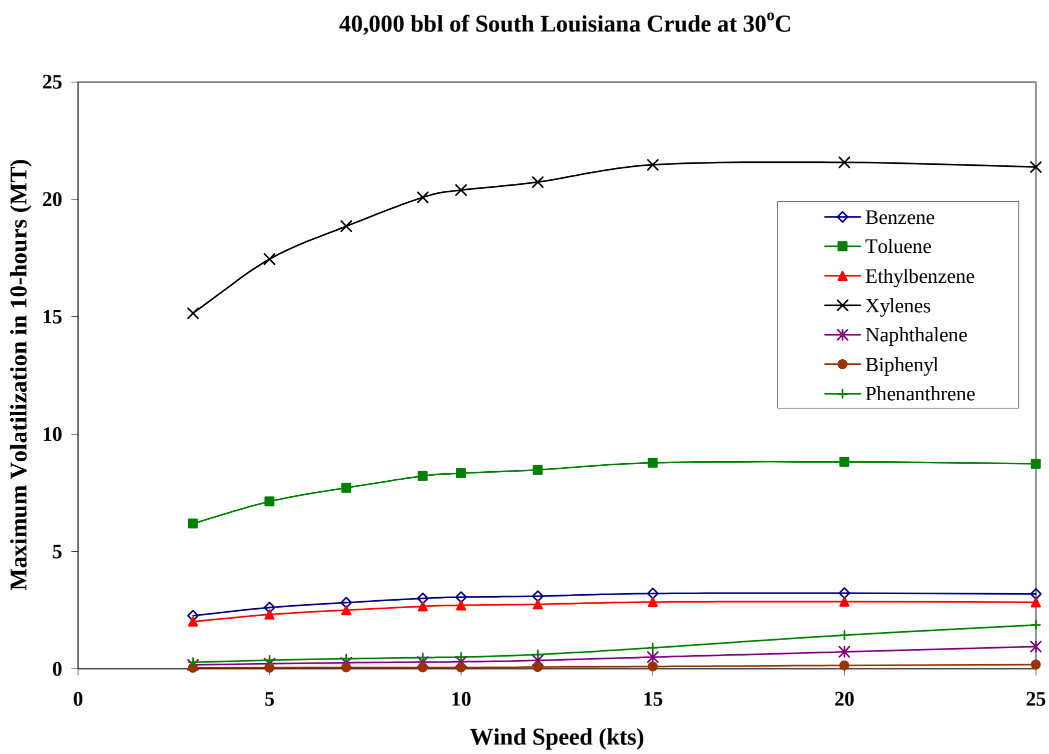

Figure C-III.1.2-1 Maximum mass (MT) of chemical volatilized from unburned South Louisiana crude oil in any 10-hour period after a spill of 40,000 bbl at the indicated wind speed.

Air Concentrations from Unburned Oil Emissions

Tables C-III.1.2-2 and C-III.1.2-3 list the areas where the air concentrations exceeded the comparable air quality standards for large volume spills. Tables C-III.1.2-4 and C-III.1.2-5 list the maximum distances (down wind) from the release site that concentrations exceeded the air quality standards. Since the emissions were more rapidly dispersed in the atmosphere the higher the wind speed, the conditions where concentrations of volatiles in air were at maximum were those where winds were assumed light (3 kts), as demonstrated by the results. The IDLH for heptane is exceeded at ≤1.3 km downwind of the spill site by the total volatile aliphatic VOC concentration under these worst-case temperature and air stability conditions for wind speeds up to 5 kts. The IDLH is not exceeded for any of the MAHs or PAHs, and would not be expected to under any environmental conditions for spills of this large volume. The TWA would be exceeded after spills of 40,000 bbl for benzene, xylenes, biphenyl and volatile aliphatic VOCs in the spill area and under light to moderate winds (≤12 kts). For xylenes and biphenyl, the areas adversely affected would not exceed 0.1 km^2 in the worst case conditions of light winds and a stable atmosphere. The adversely affected areas are larger for benzene (up to 3.4 km^2) and volatile aliphatic VOCs (up to 0.9 km^2), assuming a worst case of a stable atmosphere. The areas would be less for less stable atmospheric conditions and lower temperatures than assumed.

Table C-III.1.2-2. Maximum area (m^2) where the IDLH would be exceeded due to volatilization of unburned South Louisiana crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180°C	226,875	93,775	0	0	0	0	0	0	0

Table C-III.1.2-3. Maximum area (m^2) where the PEL-TWA would be exceeded due to volatilization of unburned South Louisiana crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	3,357,750	1,948,100	1,203,950	580,800	435,600	93,775	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	5,900	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	51,425	6,050	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180°C	880,275	335,775	51,425	0	0	0	0	0	0

Table C-III.1.2-4. Maximum distance down wind (km) where the IDLH would be exceeded due to volatilization of unburned South Louisiana crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	1.3	0.7	0	0	0	0	0	0	0

Table C-III.1.2-5. Maximum distance down wind (km) where the PEL-TWA would be exceeded due to volatilization of unburned South Louisiana crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	7.4	5.0	3.4	1.9	1.5	0.8	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0.9	0.3	0.0	0.0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	3.5	1.6	0.5	0.0	0	0	0	0	0

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part C: Galveston Bay and North Texas Shelf

Section C-III.2

by

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ASA 00-246

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C-III.2 Air Concentrations from In-Situ Burning

Section A.5.2 of Part A describes the methods used to evaluate emissions from ISB and their potential effects on air quality. For scenarios involving ISB, the maximum potential amount of oil burned was assumed to be 25% by volume of the amount of oil mechanically removed (see Section A.3.7). The amount burned was calculated for each scenario since the percent of oil mechanically removed varies for each of the 100 stochastic runs. The 50th and 95th percentiles of the volumes mechanically cleaned up (for the 100 stochastic runs) were multiplied by 0.25 to calculate the 50th and 95th percentile volumes burned by ISB. The atmospheric concentrations of compounds and particulates released by an in-situ burn are dependent upon both the distance from and the area of the fire. All chemicals in the emissions that might be of concern are considered in the analysis.

C-III.2.1 Medium Volume Spills

The estimated distances from an in-situ burn to thresholds of concern are tabulated below. The maximum burn areas for each scenario were calculated by dividing the burn volume by the minimum oil thickness required for burning (3 mm). Burn areas were calculated for all 100 runs for each scenario. Table C-III.2.1-1 shows, for each of the three medium volume scenarios, the percentage of simulations whose calculated burn area (burn volume divided by 3 mm) is less than the maximum possible burn area of 500 m^2. For these three scenarios, some of the individual simulations have burn areas smaller than 500 m^2. The effect of the dispersant application on the area of oil requiring burning is apparent from the numbers in the table. When no dispersant is applied (0% dispersant efficiency), 15% of the simulations have burn areas smaller than 500 m^2. For 45% dispersant efficiency, 84% of the burn areas are smaller than 500 m^2, and the same is true for 80% dispersant efficiency. Therefore, the results show that the more efficient the dispersant, the smaller the area of oil is that needs to be burned. This is not a surprising result, as dispersant removes oil from the surface of the water, decreasing the amount of oil that remains on the surface, and thereby decreasing the area of oil that needs to be burned.

Table C-III.2.1-1. Percentile where burn volume, divided by 3 mm, is less than the maximum burn area of 500 m^2, for each medium volume scenario.

Scenario	Percentile
Medium Volume, 0% Dispersant Efficiency	15%
Medium Volume, 45% Dispersant Efficiency	84%
Medium Volume, 80% Dispersant Efficiency	84%

Table C-III.2.1-2 shows, for each medium volume scenario, the number of burns that would be necessary to burn the entire amount of oil that was designated for burning. A range of oil thicknesses are shown in Table C-III.2.1-2: between 3 mm and 10 cm (100 mm). Three mm is the minimum thickness of oil required for in-situ oil burning (Buist et al., 1994). However, 10 cm is a more preferable oil thickness for burning (Allen, 2002). If one burn can be accomplished at less than 10 cm thick and 500 m^2 of area (i.e., the burn volume is < 50 m^3), it is assumed that this occurs and the actual thickness is calculated from volume burned divided by 500 m^2. However, if the calculated thickness for one burn is <3mm, the minimum (i.e., the burn volume is < 1.5 m^3), the burn area is instead the burn volume divided by 3 mm.

Table C-III.2.1-2. Assumed burn thickness for medium volume spill scenarios and number of burns needed to burn the oil, assuming the maximum burn area is 500 m^2.

Scenario		Total Volume Burned (m^3)	Burn Area (m^2)	Oil thickness (mm)	Number of Burns
Medium Volume, 0% Dispersant Efficiency	50th Percentile	7.75	500	16	1
	95th Percentile	20.9	500	42	1
Medium Volume, 45% Dispersant Efficiency	50th Percentile	0.29	96	3	1
	95th Percentile	6.11	500	13	1
Medium Volume, 80% Dispersant Efficiency	50th Percentile	0.04	14	3	1
	95th Percentile	6.10	500	13	1

With a 3-mm thickness, only two cases have a total burn volume <1.5 m^3 and thus a burn area smaller than 500 m^2. Those two cases are the 50th percentile volumes for the medium volume, 45% dispersant efficiency and the 80% dispersant efficiency. For example, the scenario with a medium oil volume and 45% dispersant efficiency would have a total burn area of 96 m^2 (with a 3-mm oil thickness) for the 50th percentile volume, but for the 95th percentile burn volume, the volume is large enough for 1 burn with 10 cm thick oil and an area of 500 m^2. For the distance calculations described below, in which burn area is an important consideration, the 3-mm thickness is used for the burns of < 1.5 m^3 volume as it yields a larger burn area than 10 cm and represents a conservative approach to calculating the distance to the threshold. For all other cases examined, the burn area exceeds 500 m^2, and the distance-to-threshold calculations reported below assume an area per burn of 500 m^2.

Tables C-III.2.1-3, C-III.2.1-4, and C-III.2.1-5 report calculations of distance to the air quality thresholds for the chemicals of concern that are released when oil is burned. There are three thresholds in these tables: IDLH, TWA, and EPA NAAQS (Primary and Secondary Standards). These thresholds were described and listed in Table A.5-5. The chemicals listed in Table C-III.2.1-3 were designated by Fingas, et al. (2001) as being of concern, and they are split into five chemical classes: total particulates, fixed gases, carbonyls, PAHs, and VOCs. For those chemicals for which U.S. air quality standards were not available, we have assumed the lowest of the available thresholds within that chemical class. For example, we do not have an IDLH threshold value for butane, a member of the VOC chemical class, but we do have IDLH values for several other members of the VOC class. We selected the lowest of the available IDLH values for the VOCs and used that value as an IDLH threshold for butane and other chemicals in the VOC class for which we are missing threshold values. We used the same strategy for the PAH chemical class as well. This substitution method provides an estimate of the distance to the threshold for those chemicals for which threshold data are not available. However, because those threshold values are just assumed estimates, the distance values in the following tables that were derived using these threshold values are shaded gray.

It should also be noted that three different TWA threshold values were obtained for this study: ACGIH TLV, OSHA PEL, and NIOSH REL. We calculated the distance to the threshold for each of these, but we present only the maximum of the three distances in these tables. For example, in Table C-III.2.1-3, for formaldehyde, the distance to the ACGIH TLV threshold is 237 m, to the OSHA PEL threshold is 0 m, and to the NIOSH REL threshold is 89 m. The maximum of these three distances is 237 m, which is the TWA value reported in the table.

Table C-III.2.1-3 shows the distance-to-threshold calculations for an individual 500 m^2 burn. In the table, the calculated distances represent the distance (from the center of the fire) at which the concentration of each chemical has decreased to the threshold level. In the case of sulphur dioxide in Table C-III.2.1-3, the distance at which the concentration of sulphur dioxide in the air equals the IDLH threshold is essentially zero, meaning that the concentration of sulphur dioxide produced by the 500-m^2 fire never exceeds the IDLH threshold. However, for the other thresholds in the table (TWA and EPA NAAQS), the concentrations do exceed the thresholds and do not decrease to the threshold level until 331 m, 471 m, and 440 m from the center of the fire.

Table C-III.2.1-3 shows that, for a 500-m^2 burn area, the total particulates, fixed gases, and carbonyls are of the greatest concern (i.e., the distances from the fire to the threshold level are greatest). The majority of other chemicals have distances of zero meters to the threshold level, meaning that their concentrations never exceed the threshold. Acetone has the largest distance to the threshold, at 710 m, and acetaldehyde and the total particulates are the next largest.

Table C-III.2.1-4 shows distance-to-threshold calculations for one of the two cases in which the 50th percentile volume was smaller than 500 m^2: the medium volume, 45% dispersant efficiency scenario. The total burn area for this case was 96 m^2 with an oil thickness of 3 mm. The distance (calculated as described in Section 4.3.1) varies with the size of the fire: the larger the fire size, the greater the distance to the threshold. Thus, Table C-III.2.-4 contains only those chemicals where distances were >0 m for the larger 500m^2 burn area. The results show similar patterns to the 500-m^2 burn results, with the total particulates, fixed gases, and carbonyls being of the most concern, but the distance-to-threshold values are much smaller than for the 500-m^2 burn. Sulphur dioxide is of the greatest concern, followed by formaldehyde, and then the total particulates.

Table C-III.2.1-5 shows distance-to-threshold calculations for the other case in which the 50th percentile volume was smaller than 500 m^2: the medium volume, 80% dispersant efficiency scenario (for only those chemicals where distances were >0 m for the larger 500m^2 burn area). The overall trends of the results are similar to the other two burn cases, with sulphur dioxide being of the greatest concern, followed by formaldehyde, and the total particulates.

In Tables C-III.2.1-3, C-III.2.1-4, and C-III.2.1-5, there are four additional chemicals with distances to the threshold that stand out: 2-methylbutane, 3-methylhexane, 3-methylpentane, and methylcyclopentane. However, as can be seen from the tables, these values are shaded gray because we did not have a regulatory threshold value for them. Instead, we used the lowest threshold value from within their group (VOCs). From this, we can conclude that their distance to threshold values *may* represent that they are chemicals whose concentrations will still be above threshold levels far from the fire, or it may be that the threshold estimates used for the distance-to-threshold calculation are unreasonably low and our estimate method is not suitable for these chemicals.

Table C-III.2.1-3. Estimated distances (m) from fire to the thresholds of concern for the 50th and 95th percentile volumes for ISB for burn area of 500 m^2. For those chemicals for which U.S. air quality standards were not available, the smallest of the available thresholds within that chemical class is assumed, and the results are shaded in gray.

	Distance to the Threshold (m)			
Substances	**IDLH**	**TWA**	**EPA NAAQS**	
			Primary Standard	**Secondary Standard**
Total Particulates				
10-um particle			514	514
2.5-um particle			523	523

Fixed gases				
Sulphur Dioxide	0	331	471	440
Carbon Dioxide	0	0		
Carbon Monoxide	0	0	0	
Carbonyls				
Acetaldehyde	0	525		
Acetone	0	710		
Formaldehyde	0	237		
PAHs				
1- Methylnaphthalene	0	0		
1-Methylphenanthrene	0	0		
2,3,5-Trimethylnaphthalene	0	0		
2,6-Dimethylnaphthalene	0	0		
2-Methylnaphthalene	0	0		
Acenaphthene	0	0		
Acenaphthylene	0	0		
Anthracene	0	0		
Benz(a)anthracene	0	0		
Benzo(a)pyrene	0	0		
Benzo(b) fluoranthene	0	0		
Benzo(e) pyrene	0	0		
Benzo(g,h,I) perylene	0	0		
Biphenyl	0	0		
Chrysene	0	0		
Dibenz(a,h)anthracene	0	0		
Dimethylnaphthalenes	0	0		
Fluoranthene	0	0		
Fluorene	0	0		
Indenol(1,2,3-cd)pyrene	0	0		
Methylphenanthrenes	0	0		
Naphthalene	0	0		
Perylene	0	0		
Phenanthrene	0	0		
Pyrene	0	0		
Trimethylnaphthalenes	0	0		
VOCs				
1,2,3-Trimethylbenzene	0	0		
1,2,4-Trimethylbenzene	0	0		
1,3,5-Trimethylbenzene	0	0		
1,4-Diethylbenzene	0	0		

2,2,3-Trimethylbutane	0	0		
2,2,4-Trimethylpentane	0	0		
2,2,5-Trimethylhexane	0	0		
2,2-Dimethylbutane	0	0		
2,2-Dimethylpropane	0	0		
2,3,4-Trimethylpentane	0	0		
2,3-Dimethylbutane	0	1		
2,3-Dimethylpentane	0	1		
2,4-Dimethylhexane	0	0		
2,4-Dimethylpentane	0	0		
2,5-Dimethylhexane	0	0		
2-Ethyltoluene	0	0		
2-Methylbutane	0	165		
2-Methylheptane	0	4		
3-Methylhexane	0	42		
3-Methylpentane	0	85		
4-Ethyltoluene	0	0		
4-Methylheptane	0	0		
Benzene	0	0		
Butane	0	1		
c-1,3-Dimethylcyclohexane	0	0		
c-1,4/t-1,3-Dimethylcyclohexane	0	0		
c-2-Butene	0	0		
Cyclohexane	0	0		
Cyclopentane	0	0		
Decane	0	0		
Dodecane	0	0		
Ethylbenzene	0	0		
Heptane	0	0		
Indan (2,3-Dihydroindene)	0	0		
Isobutane (2-Methylpropane)	0	0		
m,p-xylene	0	0		
Methylcyclohexane	0	0		
Methylcyclopentane	0	92		
Naphthalene	0	0		
n-Butylbenzene	0	0		
Nonane	0	0		
n-Propylbenzene	0	0		
Octane	0	0		
o-Xylene	0	0		
p-Cymene (1-Methyl-4-iso-propylbenzene)	0	0		
Pentane	0	0		
Propane	0	0		
Propene	0	0		

2,2-Dimethylpentane	0	0		
iso-Butylbenzene	0	0		
Isoprene (2-Methyl-1,3-Butadiene)	0	0		
iso-Propylbenzene	0	0		
Undecane	0	0		

Table C-III.2.1-4. Estimated distances (m) from fire to the thresholds of concern for the 50th percentile volume for ISB for burn area of 96 m^2. Scenario: Medium Volume, 45% Dispersant Efficiency. For those chemicals for which U.S. air quality standards were not available, the smallest of the available thresholds within that chemical class is assumed, and the results are shaded in gray.

	Distance to the Threshold (m)			
Substances	**IDLH**	**TWA**	**EPA NAAQS**	
			Primary Standard	**Secondary Standard**
Total Particulates				
10-um particle			28	28
2.5-um particle			28	28
Fixed gases				
Sulphur Dioxide	0	43	62	58
Carbonyls				
Acetaldehyde	0	14		
Acetone	0	21		
Formaldehyde	0	30		
PAHs (all, considered individually)	0	0		
VOCs				
2,3-Dimethylbutane	0	0		
2,3-Dimethylpentane	0	0		
2-Methylbutane	0	17		
2-Methylheptane	0	1		
3-Methylhexane	0	5		
3-Methylpentane	0	10		
Butane	0	0		
Methylcyclopentane	0	18		

Table C-III.2.1-5. Estimated distances (m) from fire to the thresholds of concern for the 50th percentile volume for ISB for burn area of 14 m^2. Scenario: Medium Volume, 80% Dispersant Efficiency. For those chemicals for which U.S. air quality standards were not available, the smallest of the available thresholds within that chemical class is assumed, and the results are shaded in gray.

Substances	Distance to the Threshold (m)			
	IDLH	TWA	EPA NAAQS	
			Primary Standard	Secondary Standard
Total Particulates				
10-um particle			15	15
2.5-um particle			15	15
Fixed gases				
Sulphur Dioxide	0	29	41	38
Carbonyls				
Acetaldehyde	0	7		
Acetone	0	10		
Formaldehyde	0	20		
PAHs (all, considered individually)	0	0		
VOCs				
2,3-Dimethylbutane	0	0		
2,3-Dimethylpentane	0	0		
2-Methylbutane	0	11		
2-Methylheptane	0	0		
3-Methylhexane	0	4		
3-Methylpentane	0	7		
Butane	0	0		
Methylcyclopentane	0	13		

The ISB effects are summarized in Table C-III.2.1-6. The affected area is calculated by assuming the circular area around each burn is affected to the maximum distance to any air quality threshold (i.e., this distance is the circle radius) and multiplying the circular area per burn by the number of burns. The percent of the region of interest is calculated using the province area in Table A.4-4.

Table C-III.2.1-6. Estimation of area affected by ISB, for medium volume spills by dispersant scenario and for 50th and 95th percentile burn volumes.

Dispersant % Efficiency		**0**	**45**	**80**
Burn Area (m^2)	50th	500	96	14
	95th	500	500	500
Maximum Distance (m) to Threshold (1 burn)	50th	710	43	29
	95th	710	710	710
# of Burns	50th	1	1	1
	95th	1	1	1
Area (km^2) Exposed (assuming circle with radius = maximum distance)	50th	1.584	0.006	0.003
	95th	1.584	1.584	1.584
Percent of Province Area	50th	0.004	0.000	0.000
	95th	0.004	0.004	0.004

C-III.2.2 Large Volume Spills

The estimated distances from an in-situ burn to thresholds of concern for the large volume scenarios are below. Burn areas were calculated for all 100 runs for each scenario. Table C-III.2.2-1 lists, for each of the three large volume scenarios, the percentage of simulations whose calculated burn area (burn volume divided by 3 mm) is less than the maximum burn area of 500 m^2. This table shows that the three scenarios in which the large volume of 40,000 bbl of crude oil was released do not have any burn areas smaller than 500 m^2, regardless of the dispersant efficiency.

Table C-III.2.2-1. Percentile where burn volume, divided by 3 mm, is less than the maximum burn area of 500 m^2, for each large volume scenario.

Scenario	**Percentile**
Large Volume, 0% Dispersant Efficiency	0%
Large Volume, 45% Dispersant Efficiency	0%
Large Volume, 80% Dispersant Efficiency	0%

Table C-III.2.2-2 shows, for each large volume scenario, the number of burns that would be necessary to burn the entire amount of oil that was designated for burning. The number of burns was calculated by dividing the burn volume (Table C- III.1.2-3) by the assumed oil thickness of 10 cm and then dividing this number into the maximum area allowed per burn (500 m^2).

With a thickness greater than 100 mm, all of the large volume cases will require multiple burns (4 – 9) to remove all the oil. The effectiveness of dispersant application in reducing the amount of oil needing to be burned can be seen in Table C-III.2.2-2. The table shows that the more efficient the dispersant is, the fewer the number of burns required to remove the oil.

Table C-III.2.2-2. Assumed burn thickness for large volume spill scenarios and number of burns needed to burn the oil, assuming the maximum burn area is 500 m^2.

Scenario		Total Volume Burned (m^3)	Burn Area (m^2)	Oil thickness (mm)	Number of Burns
Large Volume, 0% Dispersant Efficiency	50^{th} Percentile	294	500	100	6
	95^{th} Percentile	414	500	100	9
Large Volume, 45% Dispersant Efficiency	50^{th} Percentile	234	500	100	5
	95^{th} Percentile	318	500	100	7
Large Volume, 80% Dispersant Efficiency	50^{th} Percentile	186	500	100	4
	95^{th} Percentile	271	500	100	6

Table C-III.2.1-3 shows distance-to-threshold calculations, in meters, for an individual 500-m^2 burn. Descriptions of Table C-III.2.1-3 and its results can be found in the previous section.

The distances to the threshold would apply to each burn. Thus, the effect is proportional to the number of burns. Table C-III.2.2-2 indicates that on average (50^{th} percentile) the air quality effect is reduced by 1/6 if dispersant is applied with 45% efficiency, and the air quality effect is reduced by 1/3 if dispersant is applied with 80% efficiency.

The ISB effects are summarized in Table C-III.2.2-3. The affected area is calculated by assuming the circular area around each burn is affected to the maximum distance to any air quality threshold (i.e., this distance is the circle radius) and multiplying the circular area per burn by the number of burns. The percent of the region of interest is calculated using the province area in Table A.4-4.

Table C-III.2.2-3. Estimation of area affected by ISB, for large volume spills by dispersant scenario and for 50th and 95th percentile burn volumes.

Dispersant % Efficiency		**0**	**45**	**80**
Burn Area (m^2)	50th	500	500	500
	95th	500	500	500
Maximum Distance (m) to Threshold (1 burn)	50th	710	710	710
	95th	710	710	710
# of Burns	50th	6	5	4
	95th	9	7	6
Area (km^2) Exposed (assuming circle with radius = maximum distance)	50th	9.50	7.92	6.34
	95th	14.25	1.09	9.50
Percent of Province Area	50th	0.024	0.020	0.016
	95th	0.036	0.028	0.024

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part D: Florida Straits

by

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ASA 00-246

August 2004

Preface

This technical report is a supplement to the Programmatic Environmental Impact Statement (PEIS: US Coast Guard, 2004) in support of the US Coast Guard's (USCG) Notice of Proposed Rulemaking (NPRM, USCG, 2002) regarding Vessel and Facility Response Plan oil removal capacity (Caps) requirements for tank vessels and marine transportation-related facilities. The PEIS (USCG, 2004), in accordance with National Environmental Policy Act of 1969 (NEPA), examines a series of alternatives, including a no action alternative, which could influence the availability of oil spill response equipment around the United States.

This technical report is in six (6) parts:

1. Part A contains a description of models and underlying assumptions used in the analysis.
2. Parts B to F contain:
    a. Model results for 5 locations where model runs were performed
    b. Analysis of potential benefits and risks to resources of concern for each of these locations and various spill response alternatives.

Citation for entire report:

> French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Lord, C. Dalton, R. Levine, J. Rowe, S. Sankaranarayanan, H-S. Kim, R. Piovesan and M. Hitchings, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, March 2004, 6 volumes.

Citations for parts of the report:

Part A: Description of Models and Assumptions:

> French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Dalton, R. Levine, J. Rowe, S. Sankaranarayanan and H-S. Kim, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios, Part A: Description of Models and Assumptions. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, March 2004.

Parts B to F:

French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Lord, C. Dalton, J. Rowe, S. Sankaranarayanan, H-S. Kim, R. Piovesan and M. Hitchings, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios, Part D: Florida Straits. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, 2004.

Part A: Description of Models and Assumptions.
Part B: Delaware Bay and Mid-Atlantic Shelf.
Part C: Galveston Bay and North Texas Shelf
Part D: Florida Straits
Part E: San Francisco Bay and Central California Shelf
Part F: Prince William Sound

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D. Florida Straits

D.1 INTRODUCTION

This report deals with the modeling results for a location approximately 30 km (19 mi) southwest of Key West, almost directly south of the Marquesas Keys, one of the two sites selected by the U.S. Coast Guard (USCG) for analysis in the Atlantic region. While the site is in the Atlantic region, it is essentially located right on the boundary line between the Gulf of Mexico and Atlantic regions. It is also representative of tropical habitats, which are not present in the other modeled locations. Since the prevailing currents move to the east in this area, the primary resources at risk are in the Atlantic region. It is one of five locations used to develop modeling data to analyze the regional and national implications of potential changes in oil spill response requirements. The results and a summary of the assumptions are discussed in a separate volume for each of these locations, while details on the methodology are presented in Part A of this Technical Report. The results of the site specific modeling analyses were used to develop the discussions about the effects of the various alternatives under consideration in the Programmatic Environmental Impact Statement (PEIS).

All of the sites were selected because they are either located in the approaches to "higher volume ports" as defined in the Code of Federal Regulations (33 CFR 154.1020) or because they are in an area of high vessel traffic. In either case, they are considered to be areas where congestion could increase the risk of oil spills.

D.1.1 Selection of the Location

The location discussed in this volume is located approximately 30 km (19 mi) southwest of Key West, Florida, almost directly south of the Marquesas Keys (Figure D.I.1.1-1). The Florida Straits, unlike the other modeling locations, is not a port, but rather a transportation 'choke point' where vessel traffic is concentrated. Vessels traveling to and from Gulf Coast ports pass through the Florida Straits. This means that tankers carrying crude oil from the Middle East, West Africa, the North Sea, Mexico, Venezuela and other sources transit the Straits westbound, while tankers carrying refined products leave the Gulf heading to East Coast ports and overseas destinations. There is no requirement for any agency to keep records of the numbers of vessels transiting the area, but it is clearly very high. Phillips (1990) reported estimates of tanker transits (one round-trip) through the Straits in the late 1970s to early 1980s of between 1,000 and 5,500 transits per year, and a total volume of between 500 million barrels (bbl) and 1.2 billion bbl of oil per year.

Phillips (1990) identified four areas where a crossing or merging risk existed for vessel traffic, which presumably increases the threat of collision. One of these, 23 km (12 nm) south of the Dry Tortugas, is in the vicinity of the modeling location used here and represents a converging area for vessels coming from the west.

Because so much of the shipping entering and leaving the Gulf of Mexico moves through this area, the modeled spill site is among the most likely locations for spills in the Atlantic region. In addition, the location near the Florida Keys involves potential effects on habitats, such as coral reefs and mangroves, which exist in regions where no modeling locations were selected. Given these considerations and that the release site is near the midpoint of the nearshore zone where dispersant use and in-situ burning (ISB) might be used along with on-water mechanical recovery, it is a representative location with which to perform the analysis of potential effects for various response alternatives in tropical waters.

D.1.2 Description of the Local Study Area

The study area for this analysis consists of two biogeographical provinces, as defined in Table A.4-2 of Part A of this Technical Report. The two provinces are: the Florida Straits (Province 26), and Florida Bay (Province 28). Collectively, these areas are referred to in this report as the Florida Straits. On occasion, Florida Bay (Province 28) provides a reference area for potential effects of spills into coastal areas. The boundaries of the provinces were delineated in French et al. (1996) and are based on the ecoregion (province) concept outlined in Cowardin et al. (1979) used by the Department of the Interior. The divisions into provinces are based on the distributions of, and natural boundaries between, marine populations. Biota within a province are exposed to similar environmental factors and the populations typically cover the entire province (as appropriate habitat is available). Thus, effects can be evaluated as percentages of the province(s) occupied by the populations of concern. A map of the two provinces used to analyze the Florida Straits scenario is presented as Figure A.4-2 in Part A of this Technical Report. The total areas of the provinces are presented in Table A.4-3. The areas of various habitats and shoreline types in the Florida Straits reference area are given in Tables A.4-4 and A.4-5, and shoreline lengths for various shoreline types are given in Table A.4-6.

D.1.3 Modeling Input Assumptions

Part A of this Technical Report provides details on the modeling approach used in the analysis of all of the five locations. In summary, for each of the locations the Spill Impact Model Application Package (SIMAP) oil spill model was run in a probabilistic mode (100 simulations) to evaluate both physical fate and biological effects. Running the model in probabilistic mode allows the estimation of the variance due to random circumstances, such as weather, time of day, and hydrographic conditions. The basic model scenario is described in Section A.1.4, while the specific model algorithms are presented in Section A.2, and details on model input parameters are presented in Section A.3. Air quality effects, which are not directly evaluated by SIMAP were estimated using the Air Model Application Package (AIRMAP) and then estimated concentrations at the water surface were compared to air quality standards (see Section A.5).

The results of the model runs consist of a series of tables and figures which summarize areas or linear distances, by habitat type and/or location, which exceed thresholds of concern (see Section A.4). These results were compared to information on the distribution and abundance of various resources in appropriate geographic areas to estimate the percentage of habitats or biological resources that are potentially affected, and the results were then scored using a relative risk matrix which included proportion of the resource affected and time of recovery (see Section A.1.5). Socioeconomic effects could not be evaluated with the same risk matrix, since the concept of recovery time was not appropriate. The method used for those elements is described in Section A.6 and is based strictly on the magnitude of the effect on the resource of concern relative to the total resource that is available.

The input parameters which were specific to the Florida Straits study location are presented in Appendix D.I (this volume). Appendix D.I.1 presents a series of maps which define the basic geographic data input into the model; Appendix D.I.2 discusses the development of current (hydrodynamic) data used in the model runs; Appendix D.I.3 presents the properties for South Louisiana crude oil (the oil used in the analysis); and Appendix D.I.4 summarizes all of the input parameters and the sources of the information that were used to run the model.

D.2 MODELING RESULTS

Two spill volumes and three response scenarios were simulated using modeling and the results are provided in Appendices D-II and D-III. Section A.1.4 of Part A contains a description of the rationale for running these scenarios to provide the needed information for evaluating the alternatives being considered in the PEIS. The two spill volumes were for medium (2,500 bbl) and large spills (40,000 bbl). Oil properties used were for South Louisiana crude oil, as representative of oils shipped through the Florida Straits. The three response scenarios modeled for each of two spill volumes were:

- mechanical removal at present levels of capability, or with some of that removal accomplished by ISB;
- the same mechanical removal response as above, or with some of that removal accomplished by ISB, plus dispersant application at 45% efficiency (based on minimum dispersant effectiveness criteria established in the National Oil and Hazardous Substances Contingency Plan, NCP – 40 CFR Part 300); and
- the same mechanical removal response as above, or with some of that removal accomplished by ISB, plus dispersant application at 80% efficiency (based on theoretically successful dispersant operation).

Appendices D-II.1 to D-II.6 contain results of the SIMAP oil spill model simulations that estimate oil hydrocarbon exposure on/in the water surface, shorelines, water column, and sediments. Each of these appendices contains results for all six volume-response scenario combinations. Appendix D-II.1 contains maps of exposure probability, time of first exposure for each medium (water surface, shorelines, water column, and sediments) and location surrounding the spill site, and maximum possible mass or concentration at each location at any time after a spill. These maps are gridded, presenting the average amount of contamination over the entire grid cell (which for water cells is 0.082 km^2 in area) at any time after a spill. The grid average is calculated from the mass passing through the cell, divided by the area or volume of the cell. Note that if the mass is concentrated in patches much smaller than the area of the grid cell, as is often the case, the gridded data will average out the patches and not resolve small concentrations of oil. Thus, the gridded data are used as indices of exposure, rather than areas exposed at specific levels. (See Section A.4.2 in Part A and Sections D.II.5 and D.II.6 for the methods used to more accurately evaluate exposure of biota to surface floating oil and dissolved aromatic hydrocarbons.)

Tables summarizing areas and volumes potentially affected using gridded exposure indices specific to water surface, shorelines, water column, and sediments are in Appendix D-II.2.

Average, standard deviation, and the maximum of the 100 simulations performed for each scenario are presented. The 95th percentile conditions used in the risk analysis were calculated as the mean plus two times the standard deviation. Appendix D-II.3 contains rank order distributions of results for all 100 model runs, from which 50th and 95th percentile of exposure areas and volumes were derived. Mass balance information, such as percent of the oil mechanically removed, dispersed in the water column, and eventually going ashore or to the sediments, is also included in Appendices D-II.2 and D-II.3. Appendix D-II.4 contains the results for the 50th percentile cases for surface oiling, shoreline oiling, water column effects, and sediment contamination, presented as plots of various measures of exposure.

In Appendix D-II.5, estimates of mean (for all 100 runs of varying environmental conditions) equivalent area of 100% mortality are listed for each of several wildlife behavior categories. The equivalent area for 100% mortality is the integrated sum of surface water area swept by individual spillets representing surface floating oil multiplied by probability of mortality, which varies by foraging behavior and whether the animal has feathers or fur. Appendix D-II.6 contains estimated mean mortality of water column, demersal (on the bottom) and benthic (in the bottom) organisms, summarized as an equivalent area of 100% mortality by behavior group and habitat type. The equivalent area for 100% mortality is the integrated sum of equivalent area affected times percent mortality. For water column and demersal species, the equivalent area affected is calculated as water volume affected times the fraction of the water depth zone the behavior group occupies that the affected volume encompasses. For pelagic species, the depth zone occupied is the entire water column. For demersal species (on the bottom sediments, exposed to bottom water), the depth zone occupied is the bottom 1 meter (3.3 feet) of the water column. The methods and assumptions for these calculations are described in Part A and Sections D-II-5 and D-II-6.

Appendices D-III.1 and D-III.2 contains the model results of atmospheric exposure to volatilized oil hydrocarbons and soot from ISB, relevant to air quality evaluations. Appendix D-III.1 contains model results used to evaluate volatile hydrocarbon emissions from unburned oil and resulting air quality effects. The amount of volatilized mass entering the atmosphere, and the time frame for those emissions, was estimated for each chemical (or chemical class) of concern using oil spill modeling (SIMAP). The atmospheric concentrations of volatilized hydrocarbons were modeled using AIRMAP (as described in Part A, Section A.5.1). The estimated concentrations at the water surface were compared to air quality standards to evaluate the areas exceeding the standards. Section A.5.2 of Part A describes the methods used to evaluate emissions from ISB and their potential effects on air quality. The results for ISB are in Appendix D-III.2.

The model results in Appendices D-II and D-III are summarized in Sections D.3 and D.4 and were used in the analysis of potential impacts for the various alternatives being considered in the PEIS. All summary risk rankings are based on the average results. In some sections, the results of the 95th percentile calculation are also presented to illustrate the variability for that particular resource. Section D.3 contains the discussion of potential effects for medium volume spills (2,500 bbls), and Section D.4 contains that for large volume spills (40,000 bbls). Sections D.3 and D.4 are organized by each of the physical, biological and socioeconomic resource categories evaluated in the PEIS. Section D.5 contains a summary of all the risk scores and conclusions. References are in Section D.6.

D.3 ENVIRONMENTAL CONSEQUENCES BASED ON THE MEDIUM VOLUME SPILL MODELING SCENARIOS

D.3.1 Effects on the Physical Environment

D.3.1.1 Air Quality

In the event of a spill, there are two possible sources of contamination to the atmosphere: volatilization of hydrocarbons from unburned oil and emissions produced by ISB. The hydrocarbon and ISB emissions are of concern for both human health and wildlife that may be exposed. Concentrations in the lowest 2 m (6.6 ft) of the atmosphere were estimated for both unburned and burned oil using modeling and observational data from test burns, as described in Part A, Section A.5. Distances from the spill or burn site to thresholds of concern and areas affected above these thresholds were calculated for each of a number of chemicals. The thresholds of concern are air quality standards for human health (IDLH (Immediate Danger to Life and Health) for ½ hour exposure and minimum TWA (Time Weighted Average) for an 8-hour exposure, Table D.1-1 in Appendix D of the PEIS and Table A.5-5 in Part A).

Emissions from unburned oil were estimated using SIMAP, assuming the warmest (monthly mean) water temperature in the reference area and for varying wind speeds from 3 to 25 kts. As a worst case, these model runs were performed assuming no response, which would otherwise reduce emissions to some degree. Atmospheric concentrations of volatilized hydrocarbons were estimated using AIRMAP, which accounts for transport and dilution of hydrocarbons in the local atmosphere around the spill site. The worst case of a stable atmosphere was assumed for these calculations. Area and the down-wind distance affected above the thresholds were calculated from the model results, as described in Section A.5.1 of Part A.

For emissions from ISB, the maximum potential amount of oil burned was assumed to be 25% by volume of the amount of oil mechanically removed (see Section A.3.7, Part A). The 50th and 95th percentiles of the cleanup volumes (for the 100 stochastic runs) were multiplied by 0.25 to calculate the 50th and 95th percentile volumes burned by ISB. The atmospheric concentrations of compounds and particulates released by an in-situ burn of a particular volume of oil were estimated using the models developed by Fingas et al. (2001), as described in Section A.5.2 of Part A. The number of burns needed was estimated from the total volume burned and a maximum burn size. The burn model provides concentration as a function of distance down wind from the fire. Distances were translated to areas of potential effect, assuming the air plume could move in any direction depending on the wind direction, such that the area of a circle of this radius could be affected for each of the burns.

The area potentially contaminated was divided by the area of the Florida Straits (42,689 km^2 or 16,482 mi^2, Table A.4-4) to estimate the percentage affected by the scenario. Appendices D-III.1.1 and D-III.2.1 provide data for unburned and burned oil, respectively, from medium volume spills into the Florida Straits.

Results of On-Water Mechanical Recovery Only

Under the medium volume spill scenario with no dispersant response, volatilized hydrocarbons would not exceed air quality standards for human health at $\geq$0.7 km (0.4 mi) from the spill site, with a maximum of 0.08 km^2 (0.03 mi^2) adversely affected. While this would be of concern for personnel close to the spill site within the first few hours after emissions are released, it is a very small percentage of the area of the Florida Straits. Evaporation and dispersion in the air would be very rapid after a spill, and recovery time would be less than 1 day. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency

For the medium volume spill scenario with 45% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

For the medium volume spill scenario with 80% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would also be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of an On-Water ISB Response

Under the medium volume spill scenario and the ISB response option, the worst case for air quality would be a single large burn 500 m^2 in area at one location. Based on model results described in Appendix D-III.2.1 and areas affected as summarized in Table D-III.2.1-4, air quality would be affected up to 710 m (2,329 ft) downwind of the burn site, assuming a stable atmosphere and light wind at the time of the burning (environmental conditions that would inhibit dispersion of the plume and induce the highest adverse effects on air quality). The area potentially affected is a 1.6 km^2 (0.62 mi^2) circular area around the burn site. This represents 0.004% of the Florida Straits, and the percent of the resource affected is <1%. The recovery time for the atmosphere after ISB would be on the order of hours. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Summary of the Consequences for Air Quality in the Medium Volume Scenarios

The consequences of the three response options for medium spills (1) on-water mechanical recovery only, (2) on-water mechanical recovery plus dispersants at 45% efficiency, and (3) on-water mechanical recovery plus dispersants at 80% efficiency are all essentially the same with respect to air quality. Evaporation off the water surface and volatilization from the water column creates a plume of volatile hydrocarbon gases that disperses quickly after a spill. The concentrations in the atmosphere at the water surface would exceed human health thresholds up to 0.7 km (0.4 mi) from the spill site. Dispersant use would reduce the evaporation rate, but dissolved hydrocarbons would still volatilize, although dispersed over a wider area. Thus, atmospheric concentrations would be slightly less under the dispersant use options. In all three options, the effect would be small, affecting much less than 1% of the reference area (i.e., the Florida Straits in Table A.4-4), and the recovery time for the atmosphere would be on the order of hours. The alternatives involving on-water mechanical recovery plus ISB (whether or not dispersants are used) could increase atmospheric pollutants by the amount injected via burning.

Table D.3.1.1-1 indicates risk scores for air quality for all response options for a medium volume spill. Both the area affected and the recovery times are assigned the lowest risk score for all the response options. These results would apply to any spill site at least 3 miles from shore along the Florida Keys.

Table D.3.1.1-1. Air quality risk scores for medium spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB, With or Without Dispersant Application	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

D.3.1.2 Water Quality

The lowest water quality thresholds of concern are those concentrations of dissolved aromatics that could have effects on sensitive species in the water (see Section 4.3.1.1 of the PEIS). These thresholds are much lower than human health thresholds. The threshold for effects on water column organisms would be 5 ppb for at least 4 days of exposure. As an exposure dose, the threshold would be 500 ppb-hours. (See Part A, Section A.3.4 for development of these thresholds.)

The volume affected by greater than 500 ppb-hours was estimated by the model. Table D.3.1.2-1 summarizes the mean and 95th percentile values of the water volume affected by >1 ppb for at least 1 hour and the average exposure dose in that volume of water. These data are the mean and the mean plus 2 standard deviations of the model results for all 100 runs performed for each scenario (Appendix D-II.2). The average exposure doses in the volumes are at or greater than the 500 ppb-hour threshold. Thus, the volume exposed to >1 ppb for at least 1 hour is an appropriate criterion for identifying water volumes exceeding the exposure dose threshold of 500 ppb-hours.

The percentages affected of total water volumes in coastal and marine reference areas of interest were calculated using the biogeographical province areas in Tables A.4-3 and A.4-4 for Florida Bay (coastal) and Florida Straits (marine). The total coastal volume was the area of Florida Bay times a mean depth of 2 m (6.6 ft). In this calculation it is assumed that the entire contaminated volume would be located in the coastal reference area (Florida Bay) after a spill, a worst case assumption for a spill in that estuary. The total marine volume was the area of the province times the depth at the spill site, 20 m (66 ft). Thus, only the surface water volume was considered in the marine estimation. Risk scores for potential effects were assigned for each of coastal and marine areas.

Table D.3.1.2-1. Estimation of adverse effects on water quality for medium volume spills by dispersant scenario, based on mean and 95th percentile water volumes exceeding 1 ppb dissolved aromatic concentration.

Dispersant % Efficiency		0	45	80
Volume (millions of m^3) Exposed to >1 ppb	mean	83	166	167
	95th	237	351	355
Average ppb-hrs in Volume	mean	339	1558	1593
	95th	843	3188	3313
Percent of Reference Area, coastal	mean	1.7	3.5	3.5
	95th	4.9	7.3	7.4
Percent of Reference Area, marine	mean	0.01	0.02	0.02
	95th	0.03	0.04	0.04

Results of On-Water Mechanical Recovery Only
For the medium volume spill in Florida Bay and no dispersant response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 1.7% on average. For 5% of spills, the percentage affected would exceed 4.9% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days, the time for concentrations to disperse to background levels. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions. Coastal spills under average and extreme (95th percentile) conditions were assigned a risk matrix ranking of **4D**.

Results of the Addition of a Dispersant Response at Low Efficiency
For the medium volume spill scenario and 45% dispersant efficiency response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 3.5% on average. For 5% of spills, the percentage affected would exceed 7.3% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions. Coastal spills under average and extreme (95th percentile) conditions, were assigned risk matrix rankings of **4D** and **4C**, respectively. Note that dispersants would not be

applied in coastal waters under the alternatives considered in the PEIS that include dispersant use.

Results of the Addition of a Dispersant Response at High Efficiency
For the medium volume spill scenario and 80% dispersant efficiency response, the volumes affected are nearly the same as for 45% dispersant efficiency (because more than sufficient dispersant would be available to disperse the floating oil, see Section A.3.7 of Part A). Thus, the risk matrix rankings assigned to water quality for this scenario were the same as for the 45% dispersant efficiency case.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, the water quality effects would be slightly less, by the amount removed by burning. Thus, the percent of the resource affected is slightly less for on-water mechanical and both dispersant response scenarios when ISB is included. The recovery time for water quality would be on the order of days. Thus, the risk matrix rankings assigned to water quality for scenarios involving burning were the same as those assigned for scenarios without burning.

Summary of the Consequences for Water Quality in the Medium Volume Scenarios
Table D.3.1.2-2 summarizes risk scores for water quality for all response options for a medium volume spill in coastal waters under average and extreme (95^{th}) environmental conditions. Table D.3.1.2-3 summarizes risk scores for medium volume spills in marine waters. The coastal results would apply to similar volume coastal areas and the marine results would apply to any spill site at least 3 miles from shore.

Table D.3.1.2-2. Water quality risk scores for medium spills in coastal areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: D 95^{th}: D	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: D 95^{th}: C	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: D 95^{th}: C	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

Table D.3.1.2-3. Water quality risk scores for medium spills in marine areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

D.3.2 Effects on the Biological Environment

D.3.2.1 Intertidal Habitats

The intertidal habitats in the Florida Straits are dominated by sand beaches, rocky platforms, and mangroves (RPI, 1996). Beaches provide important habitat for shorebirds, wading birds, and turtle nesting. Mangrove forests provide many ecological and human services, including nesting and foraging habitat, protection from coastal erosion, primary production, etc. The threshold concentration of concern for intertidal habitats is 10 g/m^2 (~10 microns) oil thickness (see Section A.4 in Part A). Table D.3.2-1-1 shows the outputs of the different scenarios in terms of the area and/or length of shoreline habitat affected, for the major shoreline habitat types for the medium spill volume (shoreline classifications are defined in NOAA, 2000b). Oiled areas are reported in kilometers for linear features such as beaches and rocky shores and in square meters for wide habitats such as mangroves.

Table D.3.2-1-1. Area and length of shoreline habitats oiled above a threshold of ~10 micron oil thickness for the medium volume scenarios. The numbers are summarized from Appendix D Tables D-II.2-1 through D-II.2-3.

Response Options	Total Oiled Shoreline Area (m^2)	Total Oiled Shoreline Length (km)	Sand Beach Length (km)	Rocky Shore (km)	Wetlands Area (m^2)
On-Water Mechanical Recovery (with or without ISB)	235,400	9.9	1.7	3.9	223,000
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	54,000	2.8	0.5	1.3	50,300
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	50,000	2.7	0.5	1.3	46,600

Results of On-Water Mechanical Recovery Only

Under the medium volume spill scenario and no dispersant response option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs would be about 235 km^2 (2.5 million ft^2) or 9.9 km (6.2 mi) of shoreline. The oiled shoreline would represent less than 1 percent of the shoreline in the reference area (Table A.4-4), but nearly 2 percent of the mangrove-dominated wetlands under the highest shoreline effect conditions. Under these conditions, oil above the threshold would be scattered on the shoreline on both the ocean and bay sides of the entire Florida Keys (Figure D-II.1.1.2-3). Thus, oil effects would be scattered throughout the Florida Keys. Mangroves would account for 95 percent of the affected shoreline area and about 50 percent of the total length of shoreline oiled above the threshold. Because of their life history, areas where mangroves are killed can take 25-50 years to recover (NRC, 2003), depending on the age of the forest. Thus, a risk matrix ranking of **1D** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency

Under the medium volume spill scenario and 45% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs would be reduced by over 75 percent, compared to on-water mechanical recovery alone (Table D.3.2-1-1). Most of the shoreline oiling would be less than 1,000 g/m^2 and affect only the lower Keys (Figure D-II.1.2.2-3). Because of the lower oil loadings, few mangroves are likely to be killed, thus oiled mangroves are estimated to recover within 3-7 years (Getter and Lewis, 2003). Therefore, a risk matrix ranking of **2E** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron oil threshold for all model runs would be slightly reduced compared to the low dispersant efficiency option (Table D.3.2-1-1). The oil loading on oiled shorelines would be further reduced, although the distribution of shoreline oiling would be about the same as the low dispersant efficiency results (Figure D-II.1.3.2-3). With even lower oil loadings, mangroves are expected to recover within 3 years (Getter and Lewis, 2003), thus, a risk matrix ranking of **3E** was assigned to intertidal habitats for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects to intertidal habitats would be similar to the on-water mechanical recovery only response option. When considering the areas of the different shoreline habitats affected under these spill conditions, a risk matrix ranking of **1D** was assigned to intertidal habitats for this scenario.

Summary of the Consequences for Intertidal Habitats in the Medium Volume Scenarios
Under the medium volume scenario, effects on mangroves would be expected to take 25-50 years to recover in those areas of heaviest oiling on the shoreline (NRC, 2003), under the on-water mechanical recovery only and use of ISB response options. The use of dispersants would likely lessen both the area of shoreline affected by about 75-80 percent and the area of heaviest oil loading in the mangroves. This would also influence recovery time and moves the potential risk score from high to moderate. The level of dispersant efficiency would slightly reduce the level of concern for intertidal habitats in this spill scenario.

D.3.2.2 Marine and Coastal Birds

The Caribbean Region, and particularly the Florida Straits, provides important habitat for migrant and resident coastal birds, including: diving birds that nest on keys and islands and utilize open water habitats for feeding; wading birds that utilize mangroves, marshes, and tidal flats; raptors that feed in open water along the shoreline and roost in various habitats; wintering waterfowl, and gulls, terns, and shorebirds, including some listed species [e.g., least tern (*Sterna antillarum*) and piping plover (*Charadrius melodus*)], that nest on sand and gravel beaches, particularly on small islands and keys, and use tidal flats and beaches for staging (NOAA, 1996).

Of particular importance in this region is Everglades National Park, which is also a Ramsar site, indicating a wetland area of international importance (Ramsar Convention on Wetlands, 2002). High concentrations of wading birds, diving birds, raptors, gulls, and terns, (including several state and federally listed species), nest in mangroves, salt marshes, and on beaches and dunes, and utilize shallow grass beds, tidal flats, and open waters of the bay for feeding. Also of importance in the area are numerous wildlife refuges and sanctuaries. Many of the smaller keys and islands are important nesting areas for a variety of species.

In the Florida Straits reference area, waterfowl, diving birds, seabirds, gulls, and terns are concentrated primarily in bays, around keys, and in nearshore waters. Some species of wintering waterfowl (e.g. sea ducks), seabirds (e.g. frigatebirds), diving birds (e.g. pelicans), and gulls and terns utilize the nearshore area within approximately 20-30 km of shore, with a few species ranging to up to 50 km offshore (Clapp et al., 1982a, 1982b, and 1983). The offshore boundary of the biogeographical lies between approximately 50 and 500 km offshore, therefore considering the surface area of bays and inshore waters, we assume that water associated species are only utilizing approximately 10 percent of the reference area. Therefore, we used a multiplier of 10 when calculating risk to open-water associated species.

When calculating the risk scores to include shoreline associated species, we took into account the fact that shorebirds, wading birds, diving birds, and seabirds concentrate on keys and small islands in the region, particularly while breeding, in a variety of habitats (mangroves, sand beaches, tidal flats), as well as in similar habitats along the mainland shoreline. Birds are distributed more uniformly throughout these habitats spatially and seasonally than in the other modeled regions (NOAA, 1996). Also, oil contaminated a more significant percentage of shoreline habitats in this area as compared to the other modeled regions (See D.3.2.1: Intertidal Habitats), therefore we did not use a multiplier to calculate risk scores for shoreline associated birds, but rather factored in the percentage of shoreline oiled in the reference area.

Birds could likely be affected if a threshold of 10 g/m^2 (~10-micron) thickness of oil is exceeded on the shoreline or on the water surface (see Section A.4 in Part A).

Results of On-Water Mechanical Recovery Only

Under the medium volume spill scenario and no dispersant response option, important nesting and roosting habitat for terns, diving birds, wading birds, osprey, and seabirds could be oiled above the 10-micron threshold (Figure D-II.1.1.2-3). Oiled habitats could include the area from Sands Key on Biscayne Bay to Marquesas Key. The mean area of shoreline oiled above a threshold of 10 g/m^2 would be about 35,400 m^2 (2.5 million ft^2) (Table D-II.2-1). Mangroves, which are important bird habitat, could account for 95 percent of the affected shoreline area (Section D.3.2.1: Intertidal Habitats).

Surface water oiling above the 10-micron threshold in the modeled area could occur on both sides of the Keys, but may be more widespread on the Atlantic side. The mass of oil on the water surface would range from 100-1,000 g/m^2 near Marquesas Key and some of the lower Keys (Figure D-II.1.1.1-3). The total mean surface water area oiled above the threshold would be about 92 km^2 (35 mi^2) (Table D-II.5-2). Diving birds, seabirds, gulls, terns, and waders in shallow areas where the surface water was oiled could be affected around the lower Keys. Tropical seabirds (e.g. magnificent frigate bird, *Fregata magnificens*) tend to concentrate in the lower Keys, and are not present in other areas in Florida.

When considering all species groups together, it is possible that 10 to 20 percent of the Florida Straits bird population may be adversely affected under these spill conditions. Recovery could likely occur in 1 to 3 years for most species, as was the case following the Exxon Valdez oil spill (Kuletz, 1993; Boersma et al., 1995; Erikson, 1995, and Wiens, 1995), although reproductive recovery may be greater than three years for pelicans (Anderson et al., 1996). A risk matrix ranking of **3B** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and the low efficiency dispersant response option, the mean area of shoreline oiling was reduced by over 75 percent compared to when no dispersants were used (Figure D-II.1.2.2-3). Oiled areas could include the Fanny Keys and the Key West National Wildlife Refuge which may potentially affect important nesting and foraging habitat for diving birds, least terns, roseate terns (*Sterna dougalli*) wading birds, osprey (*Pandion haliaetus*), piping plovers, and seabirds.

Mean surface water oiling above the 10-micron threshold in the modeled area was reduced 54 percent to 42 km^2 (16 mi^2) compared to when no dispersants were used (Table D-II.5-2). Diving birds, seabirds, gulls and terns, and waders could be adversely affected around the lower Keys (Figure D-II.1.2.1-3).

Due to the decrease in shoreline and surface water oiling compared to when no dispersants were used, it is possible that adverse effects on birds would be reduced, and that 1 to 5 percent of the area bird population of would be affected under these spill conditions. Recovery could likely occur in 1 to 3 years for most species. A risk matrix ranking of **3D** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and the high efficiency dispersant response option, total shoreline oiling was similar to when low efficiency dispersants were used (Figure D-II.1.3.2-3). Important nesting areas in the lower Keys could be oiled.

The distribution and mean surface area oiled above the 10-micron threshold in the modeled area would be similar compared to when low efficiency dispersants were used (Figure D-II.1.3.1-3). Diving birds, seabirds, gulls and terns, and waders could be adversely affected.

When considering all species groups together, it is possible that 1 to 5 percent of the Florida Straits bird population may be adversely affected under these spill conditions. Recovery could likely occur in 1 to 3 years for most species. A risk matrix ranking of **3D** was assigned to birds for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, adverse effects on birds would be similar to the on-water mechanical recovery only response option. When considering all species groups together, 10 to 20 percent of the Florida Straits population may be adversely affected under these spill conditions, and recovery could likely occur in 1 to 3 years for most species. A risk matrix ranking of **3B** was assigned to birds for this scenario.

Summary of the Consequences for marine and Coastal Birds in the Medium Volume Scenarios

Under the medium volume scenario, adverse effects on birds are likely to be of concern when no dispersants are used, regardless of the use of ISB, due to the high probability of a large percentage of important nesting, roosting, feeding, and rafting areas being oiled, particularly in the lower Keys. The use of dispersants is projected to likely lessen the water surface and shoreline effects enough to decrease the area and lower the percentage of birds affected thus reducing the relative risk, but not enough to change the overall level of concern.

D.3.2.3 Marine Mammals

Twenty-eight species of cetaceans and one sirenian species have been confirmed to occur in the vicinity of the Florida Straits (see Sections 3.2.2.1 and 3.3.2.1 of the PEIS). Whales tend to be restricted to open, deeper water, while many of the dolphins are also found in nearshore, shallow water areas. The only member of the Order Sirenia found in the area is the West Indian manatee (*Trichechus manatus*). There are two subspecies of the West Indian manatee, the Florida manatee (*T. m. latirostris*) and the Antillean manatee (*T. m. manatus*). The Florida manatee subspecies is found from Louisiana (and possibly eastern Texas) east to Florida and north seasonally to the Carolinas and Chesapeake Bay, generally inhabiting the coastal and inland waters of the southeastern United States. There are no pinnipeds or furred marine mammals in the Florida Straits, but within the estuaries and marshes and mangrove forests, terrestrial mammals are occasionally present.

Marine mammals may be at risk from either floating oil, or from oil which strands in coastal shoreline areas that are used as haul out or breeding areas. The latter concern is not important in the Florida Straits, since there are no species which use such areas. The primary concerns are for manatees and potentially for terrestrial mammals in intertidal habitat.

For this analysis, marine mammals are assumed to be at risk if a threshold of 10 g/m^2 (~10-micron) thickness of oil is exceeded on the shoreline or on the water surface (see Section A.4 in Part A), however the level of risk varies by the behavior group. Potential adverse effects on marine mammals (i.e., terrestrial wildlife, cetaceans, furbearing marine mammals, and pinnipeds, manatees and sea turtles were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the medium volume Florida Straits spills are in Appendix D-II.5, Table D-II.5.2. The equivalent areas of 100% mortality for all response options are summarized in Table D.3.2.3-1 as percentages of the Florida Straits (defined in Tables A.4-4 and A.4-5 of Part A). In addition to this calculation, which is based on the mean result, the mean length of shoreline oiled and the surface oil exposure exceeding 0.01 g/m^2 (in m^2-hrs) based on all model runs was also compared between the treatment options (Tables D-II.2-1 through D-II.2-3).

Table B.3.2.3-1. Percentage of reference area adversely affected for medium spills, by dispersant option and behavior group (assuming areas in Tables A.4-4 and A.4-5).

Behavior Group (Habitat Occupied)	0	45	80
Terrestrial wildlife (wetlands, sea grass beds and shoreline)	0	0	0
Cetaceans (seaward subtidal)	<0.001	<0.001	<0.001
Furbearing marine mammals (all intertidal and subtidal)	0.16	0.07	0.07
Pinnipeds and manatees (all intertidal and subtidal)	0.002	<0.001	<0.001

Results of On-Water Mechanical Recovery Only
In the Florida Straits, the only marine mammals at risk are cetaceans, manatees, and terrestrial mammals along the shore. The resistance of cetaceans to oiling coupled with the very small percentage of area affected creates a very minimal risk to cetaceans under the on-water mechanical recovery only option for the medium volume spill scenario. The cetaceans that are oiled as a result of contact with floating oil would most likely recover in within days, if not a few hours, of the spill (**4E)**, (RPI, 1987). Similarly, manatees and, to a limited extent, terrestrial mammals are at very low risk, but if an individual were killed or reproductively impaired by contact with oil on the shoreline, the recovery period could exceed one year (**3E**). The higher score is reported for marine mammals overall.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and the 45% efficiency dispersant option the areas of equivalent mortality are slightly reduced in absolute area, and are still very small relative to the reference areas. Even though the use of dispersants would reduce the amount of surface oil entering Florida Bay, the change would not affect the recovery time and so the risk score of **3E** remains the same. There is no evidence that cetaceans or manatees are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality are essentially the same as those for the 45% option, as is the extent of shoreline oiled, thus the risk score remains unchanged.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in addition to on-water mechanical recovery should not change the effects on marine mammals (**3E**), since the amount of floating oil remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to marine mammals.

Summary of the Consequences for Marine Mammals in the Medium Volume Scenarios
The results indicate that on average for medium volume spills in the Florida Straits averse effects on marine mammals would be negligible with or without the use of dispersants. Dispersant use would potentially reduce the possibility of manatees or terrestrial mammals being affected, but this risk would already be very low. The absence of furbearing marine mammals and pinnipeds

in the area, and the low sensitivity of cetaceans are the major contributing factors to this conclusion. It is quite likely that the recovery time of more than one year is an over-estimate, given the low probability of a manatee (the species of most concern) coming into contact with enough oil to cause a major physiological response.

D.3.2.4 Sea Turtles

The Florida Straits contains a variety of sea turtles: green sea turtle (*Chelonia mydas*); leatherback sea turtle (*Dermochelys coriacea*); hawksbill sea turtle (*Eretmochelys imbricate*); Kemp's ridley sea turtle (*Lepidochelys kempii*); and loggerhead sea turtle (*Caretta caretta*) (see Sections 3.2.3 and 3.3.3. of the PEIS). The Kemp's ridley, hawksbill, and leatherback turtles are endangered species. The green turtle and the loggerhead turtle are listed as threatened. In order of abundance in U.S. waters the species are ranked as follows: loggerhead turtles, Kemp's ridley, green turtles, leatherback turtles, and hawksbills (MMS, 1996). There are nesting beaches along the Florida coast, and individuals are often seen in coastal areas and associated with coral reefs and sea grass beds. The primary risk to sea turtles is from exposure to shoreline oiling in areas where they breed, however adult turtles do have a low sensitivity to floating oil and they could ingest tar balls. Certain critical nesting sites on sand beaches exist for sea turtles and there is high site fidelity. If these beaches are oiled when the females are laying their eggs or while the young are emerging from the nest and making their way to the water, there is the potential for increased harmful effects. Similarly, it has been noted that oiled nests are less likely to produce viable young. However, direct contact between oil and the egg is often necessary to render the egg unviable (MMS, 1996).

Sea turtles are assumed to be at risk when a threshold of 10 g/m^2 (~10-micron) of oil is exceeded on the shoreline or the water surface (see Section A.4 in Part A). Potential adverse effects on sea turtles were estimated using the modeling (SIMAP) and summarized as the mean equivalent area of 100% mortality (i.e., under average environmental conditions). The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the medium volume Florida Straits spills are in Appendix D-II.5, Table D-II.5.2. The equivalent areas of 100% mortality for all response options are summarized in Table D.3.2.3-1 as percentages of the Florida Straits (defined in Tables A.4-4 and A.4-5 of Part A). The sensitivity of sea turtles is assumed to be the same as that for pinnipeds and manatees, and the area of equivalent mortality never exceeds 0.002% of the total reference area, regardless of the response option (see Table D.3.2.3-1). In addition, the total area of shoreline oiled greater than 10 g/m^2, as well as the area of seaward sand beaches oiled was compared to the respective total shoreline habitat. With on-water mechanical recovery, approximately 10 km (6.2 mi) of shoreline was oiled above the threshold, but this included less than 0.1 km (0.06 mi) of sand beach. While the shoreline total is more than 1% of the reference shoreline length, the oiling of sand beaches does not exceed one percent of the available resource (see Table A.4-6). If dispersants are used at 45% efficiency the total length oiled is reduced to approximately 3 km or 1.8 mi (less than 1% of the total) and sand beach is essentially unaffected. Dispersant use at 80% efficiency reduces both values only slightly more.

Results of On-Water Mechanical Recovery Only
Under the medium volume scenario with only on-water mechanical recovery, the area of equivalent mortality is 0.001% of the total reference area. If an individual were to be oiled, the result would probably be only minor physiological effects, but it is conceivable that it could interfere with reproductive capacity. In this scenario, the risk from oiling on a nesting beach is predicted to be very low, and so only open water contact is likely to be a concern. If an adult turtle was affected physiologically at sea, or if a nesting beach were oiled when eggs or hatchlings were present, recovery of the population could require 1 to 3 years and so a risk ranking of **3E** was assigned.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and the 45% efficiency dispersant option the area of equivalent mortality is slightly reduced in absolute area, and is still very small relative to the reference areas. Reducing floating oil would benefit turtles, but the difference would be small with the medium spill scenario and recovery time would remain unchanged, thus the risk score remains **3E**. There is no evidence that sea turtles are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality and the length of shoreline oiling are slightly less than those for the 45% option, thus the risk score remains unchanged.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in addition to on-water mechanical recovery should not change the effects on sea turtles (**3E**), since the amount of floating oil and shoreline oiling remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to sea turtles.

Summary of the Consequences for Sea Turtles in the Medium Volume Scenarios
The results indicate that on average for medium volume spills in the Florida Straits the level of concern for sea turtles would be low regardless of the response option. This risk is low primarily because of the low probability of oiling sand beaches, which would normally be the major risk.

D.3.2.5 Plankton and Fish

Adverse effects on plankton and fish are of high concern, particularly when dispersants are potentially considered as a response alternative. As described in Part A (Section A.2), plankton and fish are adversely affected either directly or via the food web by the toxic effects of oil components that enter the water column: the soluble compounds (i.e., MAHs (monoaromatic hydrocarbons) and PAHs (polynuclear aromatic hydrocarbons) and microscopic oil droplets mixed by waves into the water. Overall, adverse effects increase the larger the spill size. However, there is great variability related to the environmental conditions after the spill: plankton and fish suffer much more adverse effects under storm conditions where high waves mix unweathered oil into the water than in calm weather (French et al., 1999; French McCay et al., 2002; French McCay, 2003). Species and life stages vary considerably in sensitivity to the toxic components, with species from relatively unpolluted and environmentally stable locations more sensitive than those from polluted and environmentally variable areas (French McCay, 2002).

Potential adverse effects on water column organisms (i.e., plankton and fish, as well as pelagic invertebrates such as squid) were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. Estimated water volumes where adverse effects could occur were converted to equivalent areas of 100% loss by integrating percentage losses over all affected volumes and multiplying by water depth at the spill site, allowing comparison to other resources that are distributed on a per area basis (e.g., mammals, shorelines). In the near shore areas modeled, effects were nearly evenly distributed throughout the water column because of water column mixing and vertical movements of animals. If these results are used to infer potential for adverse effects in deeper waters, the areas of effect would only apply to surface waters up to on the order of 30-50 m (98-164 ft) deep (during strong wind conditions). The modeling methods are described in Part A and Section D-II.6, and the results of the calculations for the medium volume Florida Straits spills are in D-II.6, Tables D-II.6-2, D-II.6-4, D-II.6-6, D-II.6-8, and D-II.6-10.

For these calculations, the toxicity parameter for sensitive species (i.e., two standard deviations more sensitive than the average of all species tested, which is the 2.5th percentile in rank order of sensitivity) was assumed. Thus, the volumes and areas potentially affected would only apply to 2.5% of species (based on a Gaussian distribution of species sensitivities, see also Part A, Section A.2.3), and adverse effect areas to 97.5% of species would be smaller than the volumes and areas of effect estimated by the model. Thus the model estimated areas should not be interpreted as experiencing 100% mortality of all plankton and fish. They are conservative estimates used for comparative purposes among response scenarios.

Because of the presence of coral reefs and other sensitive habitats in the Florida Straits near the spill site, the calculations of areas adversely affected were made for four subtidal habitats:

1. all subtidal habitats
2. coral reef
3. seagrass bed
4. hard bottom (rocky reef, which has similar water column and demersal fish and invertebrate communities to coral reef)

Table D-II.6-2 lists the average equivalent areas projected to be killed (for sensitive species) for medium volume spills and for all subtidal habitats. These areas are based on the mean of all 100 runs, and so represent an average of all environmental conditions that may occur after a spill (see explanation in Section D-II.6). Table D-II.6-4 lists the 95th percentile equivalent areas for all subtidal habitats where sensitive species would be adversely affected. This maximum potential effect is calculated as the mean plus two standard deviations, using the statistics of all 100 model runs for the scenario, and assuming the toxicity values for sensitive species.

The mean areas of all subtidal habitats adversely affected are summarized for all response options in Table D.3.2.5-1 as percentages of the Florida Straits (defined in Table A.4-4 of Part

A). The maximum areas (95th percentile) for sensitive species are summarized in Table D.3.2.5-2 (also as percentages of the Florida Straits reference area). Tables D.3.2.5-3 to D.3.2.5-5 list the percentages for coral reef, seagrass bed, and hard bottom, respectively, based on average areas affected over all model runs from Tables D-II.6-6, D-II.6-8, and D-II.6-10. The total areas of each of these habitats in the Florida Straits reference area, which are the divisors for these calculations, are listed in Table A.4-4 of Part A.

Table D.3.2.5-1. Average percentage of all subtidal habitats adversely affected for medium spills, by dispersant option and behavior group (assuming Florida Straits area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.036	0.053	0.053
Small pelagic fish & invertebrates	0.073	0.092	0.092
Large pelagic fish	0.058	0.096	0.097
Demersal (stationary on bottom)	0.035	0.046	0.047
Planktonic (drift with currents)	0.074	0.089	0.090

Table D.3.2.5-2. Maximum (95th percentile) percentage of all subtidal habitats adversely affected for medium spills, by dispersant option and behavior group (assuming Florida Straits area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.07	0.07	0.07
Small pelagic fish & invertebrates	0.11	0.08	0.08
Large pelagic fish	0.13	0.16	0.16
Demersal (stationary on bottom)	0.06	0.05	0.05
Planktonic (drift with currents)	0.10	0.06	0.07

Table D.3.2.5-3. Average percentage of coral reef habitat adversely affected for medium spills, by dispersant option and behavior group (assuming area of coral reef in the Florida Straits reference area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	4.0	4.4	4.3
Small pelagic fish & invertebrates	10.9	11.3	11.2
Large pelagic fish	4.7	5.5	5.3
Demersal (stationary on bottom)	4.6	4.9	4.8
Planktonic (drift with currents)	11.6	11.9	11.9

Table D.3.2.5-4. Average percentage of seagrass bed habitat adversely affected for medium spills, by dispersant option and behavior group (assuming area of seagrass in the Florida Straits reference area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.34	0.43	0.43
Small pelagic fish & invertebrates	0.72	0.81	0.81
Large pelagic fish	0.54	0.74	0.74
Demersal (stationary on bottom)	0.33	0.39	0.39
Planktonic (drift with currents)	0.73	0.81	0.81

Table D.3.2.5-5. Average percentage of hard bottom habitat adversely affected for medium spills, by dispersant option and behavior group (assuming area of hard bottom in the Florida Straits reference area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.9	1.0	1.0
Small pelagic fish & invertebrates	2.5	2.6	2.6
Large pelagic fish	1.1	1.3	1.3
Demersal (stationary on bottom)	1.1	1.1	1.1
Planktonic (drift with currents)	2.6	2.7	2.7

Results of On-Water Mechanical Recovery Only

Under the medium volume spill scenario and no dispersant response option, the total subtidal area adversely affected would be very small (<0.07% of the Florida Straits) for spills under average environmental conditions. For 5% of spills, the total subtidal area affected would be 0.06-0.13% of the Florida Straits, depending on the behavioral group of the organism. Thus, for ubiquitous species distributed over all habitats, adverse effects are relatively small. Because the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year (given the short generation time of many species and annual reproduction of others). A risk matrix ranking of **4E** applies to plankton and fish with broad distribution over all subtidal habitats.

For small fish, invertebrates and plankton in the water column in coral reef habitats, the adversely affected area is 11-12% of the coral reef area in the Florida Keys. This is a relatively high effect. For larger more mobile fish and demersal organisms on the bottom, exposure is slightly lower but still significant – the percentage of habitat affected is 4-5%. As the effect would be felt by the structural demersal species (corals, etc.), recovery of the community would likely take 1 to 3 years, indicating a risk ranking of **3C** for the community as a whole.

For small fish, invertebrates and plankton in the water column over seagrass beds, the adversely affected area is 0.7% of the seagrass area in the Florida Keys. For larger more mobile fish and demersal organisms on the bottom, the percentage of habitat affected is 0.3-0.5%. This is a relatively small effect and recovery would likely take <1 year, indicating a risk ranking of **4E**. , For small fish, invertebrates and plankton in the water column over hard bottom, the adversely affected area is 2.5-2.6% of the habitat area in the Florida Keys. For larger more mobile fish and demersal organisms on the bottom, the percentage of habitat affected is 0.9-1.1%. Recovery would likely take 1-3 years, indicating a risk ranking of **3D**.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45% dispersant efficiency response option, the total subtidal area adversely affected would be 0.05-0.1% of the Florida Straits for spills under average environmental conditions. These percentages, as well as those to water column and demersal species in coral reefs, seagrass beds, and hard bottom habitats (see Tables D.3.5-3 to D.3.5-5), are not significantly different than the on-water mechanical recovery only scenario. This is because the water column effects occur only in the shallower waters in areas where dispersants may not be applied. The addition of dispersant in deep water, which in this area are 100s to 1000s of meters deep, does not have significant consequences to water column organisms. Also, water column effects are highest immediately after the spill near the spill site before dispersant application begins. The dispersant application occurred after most of the toxic components have evaporated and when the oil is over deep water in most runs. Thus, a risk ranking of **4E** applies to plankton and fish with broad distribution over all subtidal habitats, **3C** applies to coral reefs, **4E** applies to seagrass, and **3D** applies to hard bottom habitat organisms.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80% dispersant efficiency response option, the total subtidal area adversely affected would be 0.05-0.1% of the Florida Straits for spills under average environmental conditions. These percentages, as well as those to water column and demersal species in coral reefs, seagrass beds, and hard bottom habitats (see Tables D.3.5-3 to D.3.5-5), are not significantly different than the on-water mechanical recovery only scenario or the 45% dispersant efficiency response option. Again, this is because the water column effects occur only in the shallower waters in areas where dispersants may not be applied. The addition of dispersant in deep water, which in this area are 100s to 1000s of meters deep, does not have significant consequences to water column organisms. Also, water column effects are highest immediately after the spill near the spill site before dispersant application begins. The dispersant application occurred after most of the toxic components have evaporated and when the oil is over deep water in most runs. Thus, a risk ranking of **4E** applies to plankton and fish with broad distribution over all subtidal habitats, **3C** applies to coral reefs, **4E** applies to seagrass, and **3D** applies to hard bottom habitat organisms.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario, if ISB is effectively used in the response, the adverse effects on water column organisms would be slightly less than otherwise by the amount removed by burning. Thus, the same overall risk matrix ranking of **4E** was assigned to plankton and fish with broad distribution over all subtidal habitats for this scenario.

Summary of the Consequences for Plankton and Fish in the Medium Volume Scenarios
The results indicate that on average for medium volume spills and no dispersant use, 15-25 km^2 (9.6 mi^2) of water could be toxic to the most sensitive species. With dispersants, and on average,

up to 41 km^2 (16 mi^2) of water could be toxic to the most sensitive species (Table D-II.6-2). Under worst case conditions for sensitive species, the potentially adversely affected areas for no dispersants and dispersant use are on the order of 55 and 69 km^2 (21 and 27 mi^2), respectively (Table D-II.6-4).

It should be emphasized that the areas affected are those where there is a potential to affect the most sensitive species. Areas adversely affected would be much less for species of average sensitivity. These areas should not be interpreted as experiencing 100% mortality. They are used for comparative purposes among response scenarios.

If the adversely affected area is open water habitat and for water column organisms with broad distribution over all subtidal habitats, a risk ranking of **4E** applies (Table D.3.2.5-6). A risk of **3C** applies to coral reefs, **4E** applies to seagrass, and **3D** applies to hard bottom habitat organisms. The risk scores do not change with use of dispersants. Given that many species and life stages of plankton and fish on and over coral reefs are more broadly distributed rather than restricted to the coral reefs (for example they inhabit hard bottom habitats as well), and that these organisms reproduce on time scales less than one year, the overall risk score of 4D is assigned for plankton and fish for all response treatments. This overall risk score is carried forward to the final matrix.

These results are consistent with experience for oil spills of about 2500 bbl generally (French McCay and Payne, 2001; French McCay et al., 2002; and as discussed in Part A). In the Florida Straits in particular, the high temperatures facilitate rapid evaporation and volatilization of the toxic fraction, the soluble aromatics. Also, winds are typically light to moderate, except in infrequent storm events. Thus, natural dispersion into the water is typically low, while evaporation is rapid. Because of logistical constraints, in the scenarios examined the dispersion by chemical dispersants occurred beginning at 12 hours after the spill. By this time, most of the toxic components have volatilized (see Section D.3.1), such that dissolved aromatic concentrations resulting from dispersant use are only slightly elevated over the no-dispersant option.

Table D.3.2.5-6. Overall risk scores for plankton and fish for medium spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	D (1-5%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	D (1-5%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	D (1-5%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB, With or Without Dispersant Application	D (1-5%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

D.3.2.6 Subtidal Benthic Habitat

The greatest concern for subtidal benthic habitats in the Florida Straits is for the coral reefs that are found off the tip of Florida and for seagrass beds in shallow nearshore and estuarine areas (see Section 3.2.2.5 of the PEIS). The coral reefs found seaward of the Florida Keys and around the Dry Tortugas represent a unique resource along the North American coast (Snedaker et al., 1990). While water depths over parts of the reefs and sea grass beds can be quite shallow, none are truly intertidal, and so the risk to both resources is defined by oil in the water column, rather than floating on the surface. Both can be affected by sediment containing oil which may erode from coastline habitats, since they tend to be located close to the shore. In deeper water, subtidal habitats are relatively protected from exposure to oil by the overlying water column. It is possible for extreme storm events to mix oil with sediments which then settle to the bottom, but this is a rare event. The use of dispersants can also transport oil into the water column, but dilution usually reduces concentrations to levels that are not of a concern when the water column is more than 30 feet deep, and in any case dispersed oil is less adhesive than untreated oil. In shallow, nearshore water, the risk of contamination of the sediments increases, and may either occur by mixing into the water column due to wave action, or to erosion of contaminated shoreline sediments (Section 4.3.2.5 of the PEIS).

Benthic habitat was assumed to be at risk when a threshold of 0.10 g/m^2 of total hydrocarbon loading was exceeded in the sediment or 0.0001 g/m^2 of dissolved aromatic hydrocarbons was exceeded in the pore water (see Section A.4 in Part A). These concentrations are approximately equivalent to 1 ppm of total hydrocarbons or 1 ppb of dissolved aromatic hydrocarbons, when a sediment mixing depth of 10 cm is assumed. The area was estimated using SIMAP and the modeling methods are described in Part A. The area estimates of sediment loading for the medium volume Florida Straits spills are presented in Table D-II.6.6. The area estimates for dissolved aromatic hydrocarbons are in Table D-II.6.7. For the medium volume spill, the total hydrocarbon criteria was exceeded in an area of less than 0.2 km^2 (0.08 mi^2), and the dissolved aromatic hydrocarbon threshold was never exceeded.

Benthic habitat was also assumed to be at risk if epiflora and epifauna (demersal) organisms were affected by dissolved aromatic concentrations in the bottom water just above the sediments. As indicated in Table D.3.2.5-1, the percentage of benthic habitat where stationary demersal biota would be affected, assuming the toxicity parameter for sensitive species (i.e., two standard deviations more sensitive than the average of all species tested), was estimated by the model as <0.1% of the reference area, regardless of treatment option. In this location, however, there are three subhabitats which were analyzed separately because of their high value. They are coral reefs, seagrass beds, and hard bottom habitat. The average results for these three resources are presented in Tables D.3.2.5-3 through D.3.2.5-5. While these indices were calculated for plankton and fish, they reflect the risk to many of the animals which constitute important parts of the community in these three habitats. Of the three, coral reefs are at the greatest risk. The model estimated that 4.6% of the coral reef habitat could be affected with on-water mechanical recovery only. The use of dispersants (at either efficiency) increased the risk, but not substantially (the values were 4.9 and 4.8%, respectively). This appears to be caused by the relatively rapid contact of the oil slick with these areas, so that the application of dispersants to areas further offshore has little influence on the risk. This index represents a more short-term effect than would be the case with accumulation of hydrocarbons in the sediment. It is consistent with field observations (see Section 4.3.2.5 for the PEIS) which have indicated reduced coral growth for a period of several years, and the loss of some mobile invertebrates (such as sea urchins, with recovery in one or two years.

Results of On-Water Mechanical Recovery Only
In the on-water mechanical recovery only option for the medium volume spill scenario, the model results indicate that the sediment threshold concentration for dissolved aromatic hydrocarbons was never exceeded. There was water column exposure above threshold values to coral reefs, sea grass beds, and hard bottom habitat, with the highest values (coral reefs) approaching five percent of the reference area. Recovery of the coral reef community would probably require 1 to 3 years, and so, the risk ranking is **3D** (indicating a moderate level of concern). The risk to other types of subtidal habitats would be much less. .

Results of the Addition of a Dispersant Response at Low Efficiency
Use of a dispersant at 45% efficiency in the medium spill scenario still does not result in measurable dissolved aromatic hydrocarbon contamination in subtidal habitat sediments, nor did it appreciably change the area of possible water column exposures in excess of threshold values for coral reefs, sea grass beds or hard bottom communities. Using coral reefs as the indicator, the affected area remains just below 5% and the recovery time should not change, and so the overall level of concern remains moderate and the risk score remains **3D**.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and the 80% efficiency dispersant option, sediments still do not accumulate hydrocarbons in excess of the threshold levels, and the water column exposure for corals and sea grass beds does not change, so the risk ranking remains at **3D**.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in the medium spill scenario should have no additional effect when combined with on-water mechanical recovery on benthic habitats since ISB takes place on the water's surface and results in the removal of an equivalent amount of oil (**3D**). The only concern associated with ISB is the chance of heavy burn residues sinking and mixing with sediments, but this risk is minimal based on both the toxicity of the material and on the amount that would be produced from the limited burning possible in the scenarios.

Summary of the Consequences for Subtidal Habitat in the Medium Volume Scenarios
Oil spills and oil-spill response activities could potentially affect benthic habitats. Floating oil does not pose a great level of concern unless sufficient wave energy exists to mix the surface oil into the water column, or sediments contaminated with oil are transported from the intertidal zone into subtidal habitats. Mechanically dispersed oil could adhere to sediments, flora and fauna in benthic habitats and could cause potentially adverse effects. However, in this simulation, essentially no hydrocarbon accumulation is expected in the sediments, even near shore. However there are areas of hard bottom community, seagrass beds and coral reefs which would be exposed to hydrocarbons in the water column, at concentrations which could be a concern to sensitive species. With or without dispersant use this area is estimated to be approximately 5% of the available habitat for coral reefs, which had the highest percentage. The risk to subtidal habitat in general is much lower. The predicted exposures could lead to sublethal physiological effects or mortality for sensitive species, but are unlikely to require more than one to three years for recovery. Overall, the risk is considered to be moderate.

D.3.2.7 Biological Areas of Special Concern

The Florida Straits has numerous areas of special concern (Section 3.2.2.6 of the PEIS). They include both intertidal and subtidal areas, and a number are susceptible to the effects of an oil spill. The risk to such areas is clearly site specific and highly dependant upon the location and trajectory of the slick. In general, the greatest risk to the majority of the areas of concern is from floating oil, but areas such as marine sanctuaries are also at risk from dispersed oil. For the purposes of this evaluation, the average risk to such areas is assumed to be defined by the higher of the risks to intertidal (Section D.3.2.1) or subtidal (Section D.3.2.6) habitats, adjusted for the type, abundance and distribution of areas of special concern, if appropriate. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
For the on-water mechanical recovery option under the medium spill scenario, floating oil poses a high level of concern (**1D**) for intertidal habitat, while subtidal habitat was at moderate risk (3**D**). Even though subtidal habitat has a lower risk score, there is potential exposure of coral reefs (all of which are of special concern). However, intertidal areas of special concern are clearly the primary consideration because of the potential extended recovery period. Since areas of special concern occur throughout the coastal zone in this region, and there is no reason to assume areas of special concern would recover more quickly, the score of **1D** is used. The concerns for intertidal habitat were discussed in Section D.3.2.1.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency in the medium spill scenario greatly reduced the risk to intertidal habitat by reducing the amount of surface oil which reaches shore by over 75%. The fact that the remaining oiling would be very light means recovery should be more rapid, resulting in a risk score of **2E** (see Section D.3.2.1). The risk to subtidal habitats (based on coral reefs) did not change (**3D**), but now the overall level of concern is based on subtidal habitat.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at an efficiency of 80% in the medium spill scenario reduced the level of shoreline contamination even more, and consequently the time of recovery was reduced and the risk score becomes **3E**. The risk to subtidal habitats did not change from the low efficiency option (**3D**), and so that score now defines the risk to areas of special concern.

Results of the Addition of an On-Water ISB Response
ISB should produce a black smoke plume that could pass over an area of special concern if the proper weather conditions exist. In this case, however, the burning can only occur three miles or more offshore, and the results for air quality (Section D.3.1.1) indicate that the plume should not travel that far. The use of ISB in addition to on-water mechanical recovery is not expected to increase the risk to intertidal or subtidal resources, and so the higher intertidal score is used (**1D**).

Summary of the Consequences for Areas of Special Concern in the Medium Spill Scenarios
The effects on areas of special concern in this scenario are focused on the potential risk to shoreline habitats when dispersants are not used. The use of dispersants can reduce the risk to such areas without increasing the moderate risk to subtidal areas (the same score with or without dispersants). In this analysis the risk to such areas is defined as equivalent to the risk to intertidal habitat with on-water mechanical recovery only, and is equivalent to the subtidal risk when dispersants are used. The subtidal risk, however, did not change with dispersant use, while intertidal habitat was greatly benefited. While this accurately reflects the ecological consequences of the event, it does not account for the social values which may be attached to a wide range of areas in this region. If the spill trajectory of an actual event did threaten such areas, whether intertidal or subtidal, special attention would be given to their protection.

D.3.2.8 Essential Fish Habitat

Areas of essential fish habitat are extensive in the Florida Straits, which is a transitional area between the Caribbean, the Gulf of Mexico and the Atlantic regions (see Sections 3.2.4, 3.3.4 and 3.4.4 of the PEIS). The Florida Bay, areas of coral reef habitat, and mangrove forests, as well as coastal and offshore areas are important habitat areas.

For this evaluation, effects on essential fish habitat are assumed to be reflected by the risk to plankton and fish (Section D.3.2.5) and subtidal habitat (Section D.3.2.6), since they define the risk to the majority of fish habitat. Intertidal habitats, such as mangrove forests, are also important habitat for fisheries resources, but were considered separately. The average risk to essential fish habitat is assumed to be defined by the higher of the risk scores for plankton and fish or subtidal habitat. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
In the medium spill scenario, with the use of on-water mechanical recovery only, the risk to both plankton and fish was low, with a risk score of **4D**. This is a reflection of the relatively small volume of oil and the large volume of water for dilution. Subtidal habitat overall is probably also at low risk, but specific communities within that habitat are at greater risk. The highest scores were for coral reefs (**3D**) and so that score is used here.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency did not change the risk score for plankton or fish or for subtidal habitat affected (based on coral reefs), and so the score remains unchanged. Dispersant use also reduced effects on intertidal habitat, which includes areas that are also important for fisheries resources and EFH.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at 80% efficiency in the medium spill scenario resulted in no change to the risk scores for plankton and fish or for subtidal habitat, and so the EFH score remains **3D**. Again, dispersant use does greatly benefit intertidal habitats, some of which are also important to EFH.

Results of the Addition of an On-Water ISB Response
The addition of ISB to mechanical recovery in the medium spill scenario did not change the evaluation for either plankton or fish or for subtidal habitat, and the score remains **3D**.

Summary of the Consequences for Essential Fish Habitats in the Medium Volume Scenarios
Overall, the risk to essential fish habitat is moderate (based on the risk to a specific resource, coral reefs) for the medium spill scenario, regardless of the response option employed. The risk to other EFH areas would be lower.

D.3.3 Effects on the Socio-Economic Environment

D.3.3.1 Human Health

Operation of the type of equipment associated with oil spill response can be dangerous. This is well recognized and is the basis for the worker certification and training requirements that are now in place. There are also protocols in place for the proper application and handling of dispersants. The safety risk is greater as the spill size, and thus the intensity and duration of operations increases, but is minimized if safety standards are followed. There is a health risk from inhalation of hydrocarbon fumes for first responders, which is recognized in current safety protocols. Exposure to hydrocarbon fumes is the only health risk that can be directly estimated in the SIMAP model, and the results are presented in Section D.3.1.1.

D.3.3.2 Subsistence

Information on subsistence use of fish and shellfish in the Florida Straits is limited. While some residents may supplement their diets with these resources, subsistence is not known to be a prominent activity in this area, as compared to Alaska, where Native communities may suffer substantial economic and cultural losses due to contamination of subsistence seafood during an oil spill.

Results of On-Water Mechanical Recovery Only
Under the medium volume spill scenario and no dispersant response option, water column exposure of dissolved aromatics between 1-100 pbb is expected to occur mostly around the lower Keys, with some small areas of higher concentrations (100-10,000 ppb) (Figure D-II.1.1.4-3). Tainting of fish and invertebrates becomes a concern when water concentrations exceed approximately 100 ppb in a brief (order of hours) exposure (See Section 4.3.5.6 of the PEIS). Sediment exposure is expected to be negligible (Figure D-II.1.1.5-2). A small percentage (<1%) of shoreline habitats in the reference area would be oiled, and a proportionally small percentage of subsistence resources associated with these habitats are likely to be exposed (Section D.3.2.1. Intertidal Habitats). Therefore, at most a very small percentage of subsistence resources are likely to be affected, and recovery should be rapid (<1 year). A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and low efficiency dispersant response option, water column exposure of dissolved aromatics between 1-100 pbb for one hour or more is expected to occur west of Long Key, and concentrations of 100-10,000 ppb could occur along the lower Keys (Figure D-II.1.2.4-3). Sediment exposure is expected to be negligible (Figure D-II.1.2.5-2), and oiling of shoreline and intertidal organisms would be reduced (Section D.4.2.1. Intertidal Habitats). A larger water column area could be affected under these spill conditions, and therefore tainting of lobster is probable, yet it is still likely that only a small percentage of subsistence resources would be adversely affected, and recovery should be rapid. A risk matrix ranking of **4D** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and high efficiency dispersant response option, water column exposure of dissolved aromatics is expected to be similar compared to when low efficiency dispersants were used (Figure D-II.1.3.4-3). Sediment exposure s expected to be negligible (Figure D-II.1.3.5-2), and oiling of shoreline and intertidal organisms would be reduced (Section D.4.2.1: Intertidal Habitats). Similar to when low efficiency dispersants are used, it is likely that only a small percentage of subsistence resources would be adversely affected, and recovery should be rapid. A risk matrix ranking of **4D** was assigned to subsistence resources for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, adverse effects to subsistence resources would be similar to the on-water mechanical recovery only response option. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Summary of Consequences for Subsistence in the Medium Volume Scenarios
Because water column effects should be localized and shoreline effects are expected to occur in a small percentage of the Florida Straits, a risk matrix ranking of **4E** was assigned to subsistence resources for the no dispersant and ISB response options. A ranking of **4D** was assigned for both low and high dispersant efficiency response options because larger water column areas are expected to have higher concentrations of dissolved aromatics, which could increase the risk of tainting.

D.3.3.3 Cultural Resources

Most archaeological artifacts and some shipwrecks in the Florida Straits are buried under sediment and coral formations, and therefore are at low risk of oiling (Section 3.2.5.6 of the PEIS). Historic sites such as forts and walls are located on land and are protected from oiling by barriers and proximity to shore. Some submerged shipwrecks occur in nearshore waters, but results from several studies following the Exxon Valdez indicated that direct oiling caused negligible effects on historic artifacts (Reger et al., 1992; Dekin, 1993; Wooley and Haggarty, 1995; Bittner, 1996). Therefore, open water response options, such as the use of dispersants, ISB, and on-water mechanical recovery, may help reduce the amount of oil that strands onshore and in intertidal areas, which should also reduce the amount of shoreline clean up and disturbance of sensitive cultural resources. For these reasons, a risk matrix ranking of **4E** was assigned to cultural resources for all response options under this scenario.

D.3.3.4 Coastal Communities

Oil spills affect the pleasure that coastal residents and visitors derive from coastal activities and the economic contribution that natural resources make to local income and employment. Effects are likely to include effects on water- and shore-based recreation, fisheries (recreational and commercial), marine transportation and tourism. The effects on these activities are described in more detail in subsequent sections.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to coastal communities in the Florida Straits under various spill response options. At this modeling location, the length of shoreline oiling above the effects threshold is not considered relevant because the shoreline oiling results were highly sensitive to specific location, the ability to identify shoreline with characteristics amenable to use was limited, and areas of surface water oiled above the threshold was expected to provide a more accurate measure of expected risk, given the region’s geographic characteristics. The model results are presented in Appendix D-II.2, Tables D-II.2-1 to D-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to coastal communities of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the Florida Straits is expected to adversely effect approximately 312 km^2 (120.5 mi^2) of surface water above recognized effect thresholds (Table D-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by almost 70 percent as compared to on-water mechanical recovery alone (Table D-II.2-2). This results in a risk factor rating of 0.31 (effected length or area with dispersants divided by that for mechanical only) for surface water resources under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 2 percent as compared to the low dispersant efficiency response option (Table D-II.2-3). Because the adverse effect on surface water resources is only 2 percent less with higher dispersant efficiency, the risk factor rating remained unchanged at 0.31 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on coastal communities would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to coastal communities for surface water resources for this scenario.

Summary of the Consequences for Coastal Communities in the MediumVolume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 100 km^2 (38.6 mi^2)of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 68 percent, the level of dispersant efficiency does not greatly affect the level of concern about coastal communities in this spill scenario.

D.3.3.5 Economic Status

The overall economic status of communities, industries and individuals that rely on coastal resources for sustenance, revenue and quality of life can be affected by an oil spill. As noted above, coastal communities can suffer direct and indirect economic effects due to an oil spill, as beach and fishery closures decrease revenues, eliminate jobs, and adversely affect subsistence users of the resources.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to economic status in the Florida Straits under various spill response options. The model results are presented in Appendix D-II.2, Tables D-II.2-1 to D-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to economic status of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the Florida Keys National Marine Sanctuary is expected to adversely effect approximately 312 km^2 (120.5 mi^2) of surface water above recognized effect thresholds (Table D-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by almost 70 percent as compared to on-water mechanical recovery alone (Table D-II.2-2). This results in a risk factor rating of 0.31 for surface water resources under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 2 percent as compared to the low dispersant efficiency response option (Table D-II.2-3). Because the adverse effect on surface water resources is only 2 percent less with higher dispersant efficiency, the risk factor rating remained unchanged at 0.31 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on economic status would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to economic status for surface water resources for this scenario.

Summary of the Consequences for Economic Status in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 100 km^2 (38.6 mi^2)of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 68 percent, the level of dispersant efficiency does not greatly affect the level of concern about economic status in this spill scenario.

D.3.3.6 Vessel Transportation and Ports

Any interruption in the standard use of vessels or increase in travel times over water can result in hardship for coastal communities and businesses as fewer goods are exchanged, transportation costs rise, and the revenue streaming through the local economy falls.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to marine transportation in the Florida Straits under various spill response options. The model results are presented in Appendix D-II.2, Tables D-II.2-1 to D-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to the marine transportation industry of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the Florida Keys National Marine Sanctuary is expected to adversely effect approximately 312 km^2 (120.5 mi^2) of surface water used by the marine transportation industry above recognized effect thresholds (Table D-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by almost 70 percent as compared to on-water mechanical recovery alone (Table D-II.2-2). This results in a risk factor rating of 0.31 for the marine transportation industry under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 2 percent as compared to the low dispersant efficiency response option (Table D-II.2-3). Because the adverse effect on surface water resources is only 2 percent less with higher dispersant efficiency, the risk factor rating for the marine transportation industry remained unchanged at 0.31 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on the marine transportation industry would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to the marine transportation industry for this scenario.

Summary of the Consequences for Vessel Transportation and Ports in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 100 km^2 (38.6 mi^2)of surface water. While the use of dispersants is projected to likely lessen the surface water area affect by approximately 68 percent, the level of dispersant efficiency does not greatly affect the level of concern about the marine transportation industry in this spill scenario.

D.3.3.7 Fisheries (Commercial and Recreational)

Commercial and recreational fishing and related industries are vulnerable to oil spills, due to closures as well as market perceptions surrounding taint of the catch. In addition, recreational anglers, who fish for pleasure or sport, as opposed to monetary gain, may experience a reduced quality of experience. Large-scale spills also hold the potential to injure nursery grounds and impose other effects that could reduce fish harvests in the longer run.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to commercial and recreational fishing in the Florida Straits under various spill response options. The model results are presented in Appendix D-II.2, Tables D-II.2-1 to D-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to commercial and recreational fishing of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the Florida Keys National Marine Sanctuary is expected to adversely effect approximately 312 39 km^2 (120.5 mi^2) of surface water used for commercial and recreational fishing above recognized effect thresholds (Table D-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by almost 70 percent as compared to on-water mechanical recovery alone (Table D-II.2-2). This results in a risk factor rating of 0.31 for commercial and recreational fishing under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 2 percent as compared to the low dispersant efficiency response option (Table D-II.2-3). Because the adverse effect on surface water resources is only 2 percent less with higher dispersant efficiency, the risk factor rating for commercial and recreational fishing remained unchanged at 0.31 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on commercial and recreational fishing would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to commercial and recreational fishing for this scenario.

Summary of the Consequences for Commercial and Recreational Fishing in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 100 km^2 (38.6 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 68 percent, the level of dispersant efficiency does not greatly affect the level of concern about commercial and recreational fishing in this spill scenario.

D.3.3.8 Recreation and Tourism

An oil spill would be expected to cause local decreases in tourism, recreation, associated business revenues and the quality of coastal living. Similar to recreational fishing effects, an oil spill would also be expected to affect recreationalists' overall social welfare.

As described in Part A, the amount of surface water oiled above selected thresholds in the Florida Keys National Marine Sanctuary area is used to represent the risk of socioeconomic effects to recreation and tourism in the Florida Straits under various spill response options. The model results are presented in Appendix D-II.2, Tables D-II.2-1 to D-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to recreation and tourism of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only

Given the use of on-water mechanical recovery only, the average medium size spill in the Florida Keys National Marine Sanctuary is expected to adversely effect approximately 312 km^2 (120.5 mi^2) of surface water used for recreation and tourism above recognized effect thresholds (Table D-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency

Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by almost 70 percent as compared to on-water mechanical recovery alone (Table D-II.2-2). This results in a risk factor rating of 0.31 for recreation and tourism under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 2 percent as compared to the low dispersant efficiency response option (Table D-II.2-3). Because the adverse effects on surface water resources is only 2 percent less with higher dispersant efficiency, the risk factor rating for recreation and tourism remained unchanged at 0.31 for this scenario.

Results of the Addition of an On-Water ISB Response

Under the medium volume spill scenario and the ISB response option, effects on recreation and tourism would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to recreation and tourism for this scenario.

Summary of the Consequences for Recreation and Tourism in the Medium Volume Scenarios

Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 100 km^2 (38.6 $mi^{2)}$ of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 68 percent, the level of dispersant efficiency does not greatly affect the level of concern about recreation and tourism in this spill scenario.

D.3.3.9 Environmental Justice

Low-income, indigenous, and minority sub populations in some coastal areas may rely on regional fisheries for subsistence or on tourism, recreation or other marine-resource related industry for employment. These groups may experience the effects of a spill more severely than the general population, which relies on a more diverse economic base for their livelihoods and on the availability of a widespread and commercially available selection of foods.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to environmental justice in the Florida Straits under various spill response options. The model results are presented in Appendix D-II.2, Tables D-II.2-1 to D-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to environmental justice of recovery options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the Florida Keys National Marine Sanctuary is expected to adversely effect approximately 312 km^2 (120.5 mi^2) of surface water above recognized effect thresholds (Table D-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by almost 70 percent as compared to on-water mechanical recovery alone (Table D-II.2-2). This results in a risk factor rating of 0.31 for surface water resources under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 2 percent as compared to the low dispersant efficiency response option (Table D-II.2-3). Because the adverse effects on surface water resources is only 2 percent less with higher dispersant efficiency, the risk factor rating remained unchanged at 0.31 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on environmental justice would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to surface water resources for this scenario.

Summary of the Consequences for Environmental Justice in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 100 km^2 (38.6 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 68 percent, the level of dispersant efficiency does not greatly affect the level of concern about environmental justice in this spill scenario.

D.4 ENVIRONMENTAL CONSEQUENCES BASED ON THE LARGE VOLUME SPILL MODELING SCENARIOS

D.4.1 Effects on the Physical Environment

D.4.1.1 Air Quality

There are two possible sources of contamination to the atmosphere: volatilization of hydrocarbons from unburned oil and emissions produced by ISB, both of which are of concern for both human health and wildlife that may be exposed. Concentrations in the lowest 2 m (6.6 ft) of the atmosphere, as well as distances to and areas above thresholds of concern, were estimated for both unburned and burned oil. The thresholds of concern are air quality standards for human health (IDLH for ½ hour exposure and minimum TWA for an 8-hour exposure, Table D.1-1 in Appendix D of the PEIS and Table A.5-5 in Part A). The area potentially contaminated was divided by the area of the Florida Straits (42,689 km^2 or 16,482 mi^2, Table A.4-4) to estimate a percentage affected by the scenario. Appendices D-III.1.2 and D-III.2.2 provide data for unburned and burned oil, respectively, from large volume (40,000 bbl) spills into the Florida Straits.

Results of On-Water Mechanical Recovery Only
Under the large volume spill scenario with no dispersant response, volatilized hydrocarbons would not exceed air quality standards for human health at $\geq$7.4 km (4.6 mi) from the spill site, with a maximum of 3.4 km^2 (1.3 mi^2) adversely affected. While this would be of concern for personnel close to the spill site within the first few hours after emissions are released, it is a very small percentage of the area of the Florida Straits. Evaporation and dispersion in the air would be very rapid after a spill, and recovery time would be less than 1 day. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
For the large volume spill scenario with 45% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
For the large volume spill scenario with 80% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would also be similar or slightly less than for on-water

mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of an On-Water ISB Response

Under the large volume spill scenario and the ISB response option, the worst case for air quality would result from the 95^{th} percentile of volume burned (estimated as 25% of the mechanically-removed oil) for the no-dispersant scenario. The volume to be burned in this case would require 10 large burns, each 500 m^2 in area. The 50^{th} percentile burn volume would require 8 large burns, each 500 m^2 in area. If dispersant is used, the amount burned would be less, requiring fewer burns (See Appendix D-III.2.2).

Air quality would be affected up to 710 m (2,329 ft) downwind of *each* burn site, assuming a stable atmosphere and light wind at the time of the burning. Accounting for the worst case of 10 burns in different locations, the area potentially affected is a 15.84 km^2 (6.1 mi^2) area. This represents 0.04% of the Florida Straits. Thus, the percent of the resource affected is <1%. The recovery time for the atmosphere after ISB would be on the order of hours. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Summary of the Consequences for Air Quality in the Large Volume Scenarios

The consequences of the three response options for large spills (1) on-water mechanical recovery only, (2) on-water mechanical recovery plus dispersants at 45% efficiency, and (3) on-water mechanical recovery plus dispersants at 80% efficiency are the same with respect to air quality. Evaporation off the water surface and volatilization from the water column creates a plume of volatile hydrocarbon gases that disperses quickly after a spill. For the large volume spill, the concentrations in the atmosphere at the water surface would exceed human health thresholds of concern at a maximum of 7.4 km (4.6 mi) from the spill site. Dispersant use would reduce the evaporation rate, but dissolved hydrocarbons would still volatilize, although dispersed over a wider area. Thus, atmospheric concentrations would be somewhat less under the dispersant use options. In all three options for the large spill, the effect would be small, affecting much less than 1% of the area of interest (i.e., the Florida Straits in Table A.4-4), and the recovery time for the atmosphere would be on the order of hours.

The alternatives involving on-water mechanical recovery plus ISB (whether or not dispersants are used) could increase atmospheric pollutants by the amount injected via burning. The maximum area potentially affected is 15.84 km^2 (6.1 mi^2). However, this represents much less than 1% of the Florida Straits.

Table D.4.1.1-1 indicates risk scores for air quality for all response options for a large volume spill. Both the area affected and the recovery times are assigned the lowest risk score for all the response options. These results would apply to any spill site at least 3 miles from shore.

Table D.4.1.1-1. Air quality risk scores for large spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB, With or Without Dispersant Application	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

D.4.1.2 Water Quality

The lowest water quality thresholds of concern are those concentrations of dissolved aromatics that could have effects on sensitive species in the water (see Section 4.3.1.1 of the PEIS). These thresholds are much lower than human health thresholds. The threshold for effects on water column organisms would be 5 ppb for at least 4 days of exposure. As an exposure dose, the threshold would be 500 ppb-hours. (See Part A, section A.3.4 for development of these thresholds.)

Table D.4.1.2-1 summarizes the mean and 95th percentile values of the water volume affected by >1 ppb for at least 1 hour and the average exposure dose in that volume of water. These data are the mean and the mean plus 2 standard deviations of the model results for all 100 runs performed for each scenario (Appendix D-II.2). The average exposure doses in the volumes are at or greater than the 500 ppb-hour threshold.

The percentages affected of total water volumes in coastal and marine areas of interest were calculated using the biogeographical province areas in Tables A.4-3 and A.4-4 for Florida Bay (coastal) and Florida Straits (marine). The total coastal volume was the area of Florida Bay times a mean depth of 2 m (6.6 ft). In this calculation it is assumed that the entire contaminated volume would be located in the coastal reference area (Florida Bay) after a spill, a worst case assumption for a spill in that estuary. The total marine volume was the area of the entire reference area times the depth at the spill site, 20 m (66 ft). Thus, only the surface water volume was considered in the marine estimation. Risk scores for potential effects were assigned for each of coastal and marine areas.

Table D.4.1.2-1. Estimation of adverse effects on water quality for large volume spills by dispersant scenario, based on mean and 95th percentile water volumes exceeding 1 ppb dissolved aromatic concentration.

Dispersant % Efficiency		**0**	**45**	**80**
Volume (millions of m^3) Exposed to >1 ppb	mean	325.9	1153.	1095.
	95th	1057.	3154.	3071.
Average ppb-hrs in Volume	mean	968	5049	5935
	95th	2984	12047	13511
Percent of Reference Area, coastal	mean	6.8	24.0	22.8
	95th	22.0	65.7	63.9
Percent of Reference Area, marine	mean	0.04	0.14	0.13
	95th	0.12	0.37	0.36

Results of On-Water Mechanical Recovery Only
For the large volume spill scenario in Florida Bay and no dispersant response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 6.8% on average. For 5% of spills, the percentage affected would exceed 22% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days to weeks, the time for concentrations to disperse to background levels. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions. For coastal spills under average conditions, the risk score is **4C**. Extreme (95th percentile) events, expected to occur for <5% of spills in coastal areas, were assigned a risk matrix ranking of **4A**.

Results of the Addition of a Dispersant Response at Low Efficiency
For the large volume spill scenario and 45% dispersant efficiency response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 23% on average. For 5% of spills, the percentage affected would exceed 64% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days to weeks, the time for concentrations to disperse to background levels. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions. For coastal spills under average and extreme (95th percentile) conditions, the risk score is **4A**. Note that dispersants would not be applied in coastal waters under the alternatives considered in the PEIS that include dispersant use.

Results of the Addition of a Dispersant Response at High Efficiency
For the large volume spill scenario and 80% dispersant efficiency response, the volumes affected are nearly the same as for 45% dispersant efficiency (because more than sufficient dispersant would be available to disperse the floating oil, see Section A.3.7 of Part A). Thus, the risk matrix rankings assigned to water quality for this scenario were the same as for the 45% dispersant efficiency case.

Results of the Addition of an On-Water ISB Response

Under the large volume spill scenario and the ISB response option, the water quality effects would be slightly less, by the amount removed by burning. Thus, the percent of the resource affected is also slightly less for the on-water mechanical recovery only response scenario when ISB is included, and the risk matrix rankings assigned to water quality for scenarios involving burning were the same as those assigned for scenarios without burning.

Summary of the Consequences for Water Quality in the Large Volume Scenarios

Table D.4.1.2-2 summarizes risk scores for water quality for all response options for a large volume spill in coastal waters under average and extreme (95^{th}) environmental conditions. Table D.4.1.2-3 summarizes risk scores for large volume spills in marine waters. The coastal results would apply to similar volume coastal areas and the marine results would apply to any spill site at least 3 miles from shore.

Table D.4.1.2-2. Water quality risk scores for large spills in coastal areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: C 95^{th}: A	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: A 95^{th}: A	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: A 95^{th}: A	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

Table D.4.1.2-3. Water quality risk scores for large spills in marine areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

D.4.2 Effects on the Biological Environment

D.4.2.1 Intertidal Habitats

The intertidal habitats in the Florida Straits are dominated by sand beaches, rocky platforms, and mangroves (RPI, 1996). Beaches provide important habitat for shorebirds, wading birds, and turtle nesting. Mangrove forests provide many ecological and human services, including nesting and foraging habitat, protection from coastal erosion, primary production, etc. The threshold concentration of concern for intertidal habitats is 10 g/m^2 (~10 microns) oil thickness (see Section A.4 in Part A). Table D.4.2.1-1 shows the outputs of the different scenarios in terms of the area and/or length of shoreline habitat affected, for the major shoreline habitat types for the large spill volume (shoreline classifications are defined in NOAA, 2000b). Shoreline oiling is reported in kilometers for linear features such as sand beaches and in square meters for wide habitats such as mangroves.

Table D.4.2.1-1. Area and length of shoreline habitats oiled above a threshold of ~10 micron oil thickness for the large volume scenarios. The numbers are summarized from Appendix D Tables D-II.2-4 through D-II.2-6.

Response Option	Total Oiled Shoreline Area (m2)	Total Oiled Shoreline Length (km)	Sand Beach Length (km)	Rocky Shore (km)	Wetlands Area (m2)
On-Water Mechanical Recovery (with or without ISB)	757,000	27.1	4.0	9.0	728,000
On-Water mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	291,000	10.6	2.1	3.7	277,000
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	284,000	10.2	2.0	3.5	270,000

Results of On-Water Mechanical Recovery Only

Under the large volume spill scenario and on-water mechanical recovery only option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs would be 757,000 m^2 (8.1 million ft^2) and the mean oiled shoreline length would be about 27 km (17 mi). Shoreline oiling under the highest shoreline effect conditions would extend throughout the Florida Keys, on both the ocean and bay shorelines (Figure D-II.1.4.2-3). Mangroves would account for about

95 percent of the shoreline area and 54 percent of the shoreline length oiled above the threshold. The oiled shoreline represents less than 1 percent of the shoreline area in the reference area (Table A.4-4) but 5-10 percent of the mangrove-dominated wetlands area under the highest shoreline effect conditions. Stranded oil would scattered throughout the entire Florida Keys, and many areas would be exposed to oil loadings of 10,000-100,000 g/m^2. Effects on mangroves under these high oil loadings would include mortality, and recovery could take 25-50 years, depending on the forest age. Thus, a risk matrix ranking of **1C** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs would be reduced by about 60 percent, compared to on-water mechanical recovery alone (Table D.4.2.1-1). The extent of heavy shoreline oiling under the highest shoreline effect conditions would be greatly reduced (Figure D-II.1.5.2-3). However, about 2 percent of the wetlands would be oiled, and the oil loadings would still be high enough to cause significant mortality and a recovery period of 25-50 years. Thus, a risk matrix ranking of **1D** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron oil threshold for all model runs would be only slightly reduced from the low efficiency model results (Table D.4.2.1-1). The oiling would affect about the same area and length of shoreline habitats, but with slightly lower oil loadings on the affected habitats (Figure D-II.1.6.2-3). Thus, a risk matrix ranking of **1D** was assigned to intertidal habitats for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on intertidal habitats would be similar to the on-water mechanical recovery only response option. When considering the areas of the different shoreline habitats affected under these spill conditions, a risk matrix ranking of **1C** was assigned to intertidal habitats for this scenario.

Summary of the Consequences for Intertidal Habitats in the Large Volume Scenarios
Under the large volume scenarios, oil effects on intertidal habitats would be scattered throughout the entire length of the Florida Keys. The use of dispersants would likely lessen the area of shoreline effect by about 60 percent, and greatly reduce the oil loading in the affected areas. High efficiency dispersant use would slightly lower the overall oil loadings, but the overall effects are likely to be similar for both dispersant scenarios.

D.4.2.2 Marine and Coastal Birds

The Florida Straits provides important habitat for nesting, staging, and wintering coastal birds. Refer to Section D.3.2.2 for additional information on important bird habitats in the area and factors considered in risk score calculations.

It is important to note that the species groups being considered are not distributed equally throughout the region, and that effects should not be proportional to the amount of shoreline or water surface area oiled, but rather could depend on seasonal concentrations of particular species in high-use areas.

Results of On-Water Mechanical Recovery Only

Under large volume spill scenario and on-water mechanical recovery only option, important nesting and roosting habitat for terns, diving birds, wading birds, osprey, and seabirds throughout the entire Florida Keys could be oiled above the 10-micron threshold (Figure D-II.1.4.2-3). Many areas could be exposed to loadings 1,000 to 10,000 times greater than the 10-micron threshold level for bird effects. Most of the affected shoreline area would be mangrove habitat where birds could become oiled during feeding and nesting. Some small keys in Everglades National Park used for nesting could be oiled. The mean area of shoreline oiled above a threshold of 10 g/m^2 would be about 757,000 m^2 (8.1 million ft^2, Table D-II.2 -4).

Surface water oiling above the 10-micron threshold in the modeled area could occur on both sides of the Keys. The mass of oil on the water surface would range from 100-1,000 g/m^2 in a widespread area, and up to 10,000 g/m^2 near Marquesas Key and in the Key West and Great White Heron National Wildlife Refuges (Figure D-II.1.4.1-3). The mean surface water area oiled above the threshold would be about 1,100 km^2 (424 mi^2, Table D-II.5 -3). Diving birds, seabirds, gulls and terns, and waders in shallow areas where surface water is oiled would be adversely affected throughout the Keys. Tropical seabirds (e.g., magnificent frigate bird (*Fregata magnificens*) tend to concentrate in the lower Keys and are not present in other areas in Florida.

When considering all species groups together, it is possible that over 20 percent of the area bird population of may be adversely affected under these spill conditions. Recovery is projected to likely occur in 1 to 3 years for most species, as was the case following the Exxon Valdez oil spill (Kuletz, 1993; Boersma et al., 1995; Erikson, 1995, and Wiens, 1995), although reproductive recovery may be greater than three years for pelicans (Anderson et al., 1996). A risk matrix ranking of **3A** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency

Under the large volume spill scenario and the low efficiency dispersant response option, areas along most of the Florida Keys would be oiled (Figure D-II.1.5.2-3). The mean area of shoreline oiled above a threshold of 10 g/m^2 was reduced by 60 percent compared to when no dispersants were used (Table D-II.2 -5). Areas oiled could include important nesting habitat for diving birds, wading birds, osprey, least terns, piping plovers, and seabirds from Vaca Key west to Marquesas Key, and on some small keys in Everglades National Park. Oil loadings may range from 100-100,000 g/m^2 in Key West National Wildlife Refuge.

Mean surface water oiling above the 10-micron threshold in the modeled area was reduced approximately 70 percent compared to when no dispersants were used (Table D-II.5-3). Marquesas Key and the Key West National Wildlife Refuge occur within an area where surface water oiling may range from 100-10,000 g/m^2 (Figure D-II.1.5.1-3). Diving birds, seabirds, gulls and terns, and waders could be adversely affected around the lower Keys.

Due to a decrease in shoreline and surface water oiling compared to when no dispersants were used, it is possible that between 10 and 20 percent of the area bird population may be adversely affected under these spill conditions. Recovery is projected to likely occur in 1 to 3 years for most species. A risk matrix ranking of **3B** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and the high efficiency dispersant response option, total shoreline oiling would be similar to when low efficiency dispersants were used (Figure D-II.1.6.2-3). Important nesting areas throughout the Keys could be oiled.

The distribution of surface water oiling above the 10-micron threshold in the modeled area was similar to when low efficiency dispersants were used (Figure D-II.1.6.1-3). Diving birds, seabirds, gulls and terns, and waders could be adversely affected, particularly around the lower Keys.

When considering all species groups together, it is possible that between 10 and 20 percent of the area bird population of the may be adversely affected under these spill conditions. Recovery is projected to likely occur in 1 to 3 years for most species. A risk matrix ranking of **3B** was assigned to birds for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, adverse effects on birds would be similar to the on-water mechanical recovery only response option. When considering all species groups together, over 20 percent of the area population may be adversely affected under these spill conditions, and recovery is projected to likely occur in 1 to 3 years for most species. A risk matrix ranking of **3A** was assigned to birds for this scenario.

Summary of the Consequences for Marine and Coastal birds for the Large Volume Scenario
Under the large volume scenario, adverse effects on birds are likely to be of the highest level of moderate concern when no dispersants are used, regardless of the use of ISB, due to the high probability of a large percentage of important nesting, roosting, feeding, and rafting areas being oiled, particularly in the lower Keys. The use of dispersants is projected to likely lessen the water surface and shoreline effects enough to decrease the area and lower the percentage of birds affected, but the likely risk remains in the moderate range.

D.4.2.3 Marine Mammals

The Florida Straits has a limited population of marine mammals. Refer to Section D.3.2.3 for additional information on marine mammal populations. Marine mammals are assumed to be at risk when a threshold of 10 g/m^2 (~10-micron) of oil is exceeded on the shoreline or the water surface (see Section A.4 in Part A), however, the level of risk varies by the behavior group. Potential adverse effects on marine mammals (i.e., terrestrial wildlife, cetaceans, furbearing marine mammals, pinnipeds, manatees, and sea turtles were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the large volume Florida Straits spills are in Appendix D-II.5, Table D-II.5.3. The equivalent areas of 100% mortality for all response options are summarized in Table D.4.2.3-1 as percentages of the Florida Straits (defined in Tables A.4-4 and A.4-5 of Part A). In addition to this calculation, which is based on the 50 percentile runs, the mean length of shoreline oiled and the surface oil exposure exceeding 0.01 g/m^2 (in m^2-hrs) based on all model runs was also compared between the treatment options (Tables D-II.2-4 through D-II.2-6).

Table D.4.2.3-1. Percentage of reference area adversely affected for large spills, by dispersant option and behavior group (assuming Florida Straits area in Tables A.4-4 and A.4-5).

Behavior Group (Habitat Occupied)	0	45	80
Terrestrial wildlife (wetlands, sea grass beds and shoreline)	0.003	<0.001	<0.001
Cetaceans (seaward subtidal)	0.003	<0.001	<0.001
Furbearing marine mammals (all intertidal and subtidal)	2.0	0.57	0.49
Pinnipeds and manatees (all intertidal and subtidal)	0.03	0.008	0.007

Results of On-Water Mechanical Recovery Only
In the Florida Straits, the only marine mammals at risk are cetaceans, manatees and terrestrial mammals along the shore. The resistance of cetaceans to oiling coupled with the very small percentage of habitat affected yields a minimal risk to cetaceans under the on-water mechanical recovery only option even for the large volume spill scenario. The cetaceans that are oiled as a result of contact with floating oil would most likely recover in within a few days, if not hours, of the spill (**4E**, RPI, 1987). Potential effects on manatees also increase, but the proportion of the area remains well below 1% of the total habitat. Similarly, terrestrial mammals are at very low risk, but even though the area of equivalent mortality is still below 1%, the length of shoreline oiled is considerably higher than in the medium spill scenario (see Section D.4.2.1) and now is approximately 5% of the total shoreline. The surface slick exposure (in m^2-hr) also increased nearly 15-fold, which represents an increased risk of sublethal effects for manatees. On this basis the percentage at risk is increased. There is no reason to assume recovery time would be different than for the medium spill scenario, and the risk score becomes **3D**.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and the 45% efficiency dispersant option the areas of equivalent mortality for the groups of concern are slightly reduced in absolute area, and are still very small relative to the reference areas. The use of dispersants would reduce the extent and duration of the surface slick (by a factor of 3), as well as the length of shoreline oiled (2.8 versus 9.9 km, or 1.7 versus 6.1 mi), but would not reduce the risk ranking since the recovery time does not change. There is no evidence that cetaceans or manatees are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality and surface oil exposure and shoreline oiling are essentially the same as those for the 45% option, thus the risk score remains unchanged.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in addition to on-water mechanical recovery should not change the effects on marine mammals (**3D**), since the amount of floating oil remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to marine mammals.

Summary of the Consequences for Marine Mammals in the Large Volume Scenarios
The results indicate that on average for large volume spills in the Florida Straits adverse effects on marine mammals would be low with only on-water mechanical recovery, and that this risk could be reduced by the use of dispersants. Dispersant use would provide this benefit by potentially reducing the possibility of manatees, and to a lesser extent terrestrial mammals, being affected, which is the primary concern in the area. This would not, however, reduce the recovery time and so the risk ranking does not change. The absence of furbearing marine mammals; the fact that manatees are primarily an inshore species, and the low sensitivity of cetaceans are the major contributing factors to this conclusion.

D.4.2.4 Sea Turtles

The Florida Straits contain a variety of sea turtles and contains breeding beaches (see Section D.3.2.4). Sea turtles are assumed to be at risk when a threshold of 10 g/m^2 (~10-micron) of oil is exceeded on the shoreline or the water surface (see Section A.4 in Part A). Potential adverse effects on sea turtles were estimated using the modeling (SIMAP) and summarized as the equivalent area of 100% mortality. The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the medium volume Florida Straits spills are in Appendix D-II.5, Table D-II.5.2. The equivalent areas of 100% mortality for all response options are summarized in Table D.4.2.3-1 as percentages of the Florida Straits (defined in Tables A.4-4 and A.4-5 of Part A). The sensitivity of sea turtles is assumed to be the same as that for pinnipeds and manatees, and so the area of equivalent mortality never exceeds 0.03% of the total reference area, regardless of the response option (see Table D.4.2.3-1). In addition, the total area of shoreline oiled greater than 10 g/m^2, as well as the area of seaward sand beaches oiled was compared to the respective total shoreline habitat. With on-water mechanical recovery, approximately 27 km (17 mi) of shoreline was oiled above the threshold, but this included less than 0.4 km (0.25 mi) of sand beach. While the shoreline total is more than 1% of the reference shoreline length, the oiling of sand beaches does not exceed one percent of the available resource (see Table A.4-6). If dispersants are used at 45% efficiency the total length oiled is reduced to approximately 11 km or 7 mi (approximately 2% of the total) and sand beach is essentially unaffected (still much less than 1%). Dispersant use at 80% efficiency reduces both values only slightly more.

Results of On-Water Mechanical Recovery Only
Under the large volume scenario with only on-water mechanical recovery, the area of equivalent mortality is 0.03% of the total reference area. If an individual were to be oiled, however, the effect would probably result in minor physiological effects but it is conceivable that it could interfere with reproductive capacity. In this case, the risk from oiling on a nesting beach is still predicted to be very low, thus only open water contact is likely to be a concern. The surface slick exposure with on-water mechanical recovery (in m^2-hr) increased nearly 15-fold, which represents an increased risk of sublethal effects for turtles. On this basis the percentage at risk is increased. There is no reason to assume recovery time would be different than for the medium spill scenario, and the risk score becomes **3D**.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and the 45% efficiency dispersant option, the area of equivalent mortality is slightly reduced in absolute area, and is still very small relative to the reference areas. Reducing floating oil would benefit turtles, and use of dispersants would reduce the extent and duration of the surface slick (by a factor of 3), and on this basis the risk ranking was reduced to **3E**. There is no evidence that sea turtles are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality and the extent of surface oiling are slightly less than those for the 45% option, thus the risk score remains unchanged.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in addition to on-water mechanical recovery should not change the effects on sea turtles (**3D**), since the amount of floating oil and shoreline oiling remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to sea turtles.

Summary of the Consequences for Sea Turtles in the Large Volume Scenarios
The results indicate that on average for large volume spills in the Florida Straits area adverse effects on sea turtles could barely reach the moderate level, due to the risk of exposure to floating oil. Nesting beaches are not at risk, even in the large volume scenario. Dispersant use can reduce this risk.

D.4.2.5 Plankton and Fish

Potential adverse effects on water column organisms (i.e., plankton and fish, as well as pelagic invertebrates such as squid) were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. Estimated water volumes where adverse effects could occur were converted to equivalent areas of 100% loss by integrating percentage losses over all affected volumes and multiplying by water depth at the spill site, allowing comparison to other resources that are distributed on a per area basis (e.g., mammals and shorelines). In the near shore areas modeled, effects were nearly evenly distributed throughout the water column because of water column mixing and vertical movements of animals. If these results are used to infer potential for adverse effects in deeper waters, the area of effect would only apply to surface waters up to on the order of 30-50 m (98-164 ft) deep (during strong wind conditions). The modeling methods are described in Part A and Section D-II.6, and the results of the calculations for the large volume Florida Straits spills are in D-II.6, Tables D-II.6-3, D-II.6-5, D-II.6-7, D-II.6-9, and D-II.6-11. For these calculations, the toxicity parameter for sensitive species was assumed. Thus, the areas affected would only apply to 2.5% of species (based on a Gaussian distribution of species sensitivities), and areas of adverse effect for 97.5% of species would be smaller.

Because of the presence of coral reefs and other sensitive habitats along the Florida Straits near the spill site, the calculations of areas affected were made for four subtidal habitats:

1. all subtidal habitats
2. coral reef
3. seagrass bed
4. hard bottom (rocky reef)

Table D-II.6-3 lists the average equivalent areas projected to be killed (for sensitive species) for large volume spills and for all subtidal habitats. These areas are based on the mean of all 100 runs, and so represent an average of all environmental conditions that may occur after a spill (see explanation in Section D-II.6). Table D-II.6-5 lists the 95th percentile equivalent areas for all subtidal habitats where sensitive species would be adversely affected. This maximum potential effect is calculated as the mean plus two standard deviations, using the statistics of all 100 model runs for the scenario, and assuming the toxicity values for sensitive species.

The mean areas of all subtidal habitats adversely affected are summarized for all response options in Table D.4.2.5-1 as percentages of the Florida Straits (defined in Table A.4-4 of Part A). The maximum areas (95th percentile) for sensitive species are summarized in Table D.4.2.5-2 (also as percentages of the Florida Straits reference area). Tables D.4.2.5-3 to D.4.2.5-5 list the percentages of the reference area for coral reef, seagrass bed, and hard bottom, respectively, based on average areas affected over all model runs from Tables D-II.6-7, D-II.6-9, and D-II.6-11. The total areas of each of these habitats in the Florida Straits reference area, which are the divisors for these calculations, are listed in Table A.4-4 of Part A.

Table D.4.2.5-1. Average percentage of all subtidal habitats adversely affected for large spills, by dispersant option and behavior group (assuming Florida Straits reference area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.09	0.25	0.24
Small pelagic fish & invertebrates	0.13	0.31	0.30
Large pelagic fish	0.17	0.55	0.52
Demersal (stationary on bottom)	0.07	0.19	0.18
Planktonic (drift with currents)	0.12	0.27	0.26

Table D.4.2.5-2. Maximum (95th percentile) percentage of all subtidal habitats adversely affected for large spills, by dispersant option and behavior group (assuming Florida Straits reference area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.22	0.64	0.63
Small pelagic fish & invertebrates	0.24	0.70	0.69
Large pelagic fish	0.48	1.44	1.40
Demersal (stationary on bottom)	0.15	0.45	0.44
Planktonic (drift with currents)	0.19	0.58	0.56

Table D.4.2.5-3. Average percentage of coral reef habitat adversely affected for large spills, by dispersant option and behavior group (assuming area of coral reef in the Florida Straits reference area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	4.6	5.4	5.4
Small pelagic fish & invertebrates	11.6	12.5	12.5
Large pelagic fish	6.1	7.8	7.8
Demersal (stationary on bottom)	5.0	5.6	5.6
Planktonic (drift with currents)	12.2	12.9	12.9

Table D.4.2.5-4. Average percentage of seagrass bed habitat adversely affected for large spills, by dispersant option and behavior group (assuming area of seagrass in the Florida Straits reference area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.55	0.78	0.76
Small pelagic fish & invertebrates	0.94	1.20	1.17
Large pelagic fish	1.00	1.52	1.48
Demersal (stationary on bottom)	0.48	0.64	0.63
Planktonic (drift with currents)	0.91	1.12	1.10

Table D.4.2.5-5. Average percentage of hard bottom habitat adversely affected for large spills, by dispersant option and behavior group (assuming area of hard bottom in the Florida Straits reference area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	1.1	1.3	1.3
Small pelagic fish & invertebrates	2.7	2.9	2.9
Large pelagic fish	1.5	2.0	2.1
Demersal (stationary on bottom)	1.2	1.3	1.3
Planktonic (drift with currents)	2.8	3.0	3.0

Results of On-Water Mechanical Recovery Only
Under the large volume spill scenario and no dispersant response option, the total subtidal area adversely affected would be 0.07-0.17% of the Florida Straits for spills under average environmental conditions. For 5% of spills, the total subtidal area affected would be 0.15-0.5% of the Florida Straits, depending on the behavioral group of the organism. Thus, for ubiquitous species distributed over all habitats, effects are relatively small. As the percentage affected is <1%, it is less than the range of natural variability and would not be perceptible at the population level. Given this, the short generation time of many species, and annual reproduction of others, the recovery time would be <1 year. A risk matrix ranking of **4E** applies to plankton and fish with broad distribution over all subtidal habitats.

For small fish, invertebrates and plankton in the water column in coral reef habitats, the adversely affected area is 12-13% of the coral reef area in the Florida Straits. This is a relatively high effect. For larger more mobile fish and demersal organisms on the bottom, exposure is slightly lower but still significant – the percentage of habitat affected is 5-6%. As the recovery of structural demersal species (corals, etc.), would be slower than for small fish and invertebrates (1 to 3 years) the risk ranking of **3B** for the water column community as a whole is based on the longest recovery time and the highest percentage.

For fish, invertebrates and plankton in the water column over seagrass beds, the adversely affected area is 0.9-1.0% of the seagrass area in the Florida Straits. For demersal organisms on the bottom, the percentage of habitat adversely affected is 0.5-0.6%. This is a relatively small effect and recovery would likely take <1 year, indicating a risk ranking of **4E**.

For small fish, invertebrates and plankton in the water column over hard bottom, the adversely affected area is 2.8% of the habitat area in the Florida Straits. For larger more mobile fish and demersal organisms on the bottom, the percentage of habitat affected is 1.1-1.5%. Recovery would likely take 1-3 years, indicating a risk ranking of **3D**.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45% dispersant efficiency response option, the total subtidal area adversely affected would be 0.2-0.3% of the Florida Straits for spills under average environmental conditions. These percentages, as well as those to water column and demersal

species in coral reefs, seagrass beds, and hard bottom habitats (see Tables D.3.5-3 to D.3.5-5), are slightly higher than the on-water mechanical recovery only scenario. This is because the water column effects occur only in the shallower waters in areas where dispersants may not be applied. The addition of dispersant in deep water, which in this area are 100s to 1000s of meters deep, does not have significant consequences to water column organisms. Also, water column effects are highest immediately after the spill near the spill site before dispersant application begins. The dispersant application occurred after most of the toxic components have evaporated and when the oil is over deep water in most runs. A risk ranking of **4E** applies to plankton and fish with broad distribution over all subtidal habitats, **3B** applies to coral reefs, **3D** applies to seagrass, and **3D** applies to hard bottom habitat organisms.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% dispersant efficiency response option, the total subtidal area adversely affected would be 0.2-0.3% of the Florida Straits for spills under average environmental conditions. These percentages, as well as those to water column and demersal species in coral reefs, seagrass beds, and hard bottom habitats (see Tables D.3.5-3 to D.3.5-5), are not significantly different from the 45% dispersant efficiency response option. A risk ranking of **4E** applies to plankton and fish with broad distribution over all subtidal habitats, **3B** applies to coral reefs, 3**D** applies to seagrass, and **3D** applies to hard bottom habitat organisms.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario, if ISB is effectively used in the response, the adverse effects on water column organisms would be slightly less than otherwise by the amount removed by burning for on-water mechanical and both dispersant response scenarios. Thus, the same overall risk matrix ranking of **4E** was assigned to plankton and fish with broad distribution over all subtidal habitats for this scenario.

Summary of the Consequences for Plankton and Fish in the Large Volume Scenarios
The results indicate that on average for large volume spills, adverse water column effects for sensitive species could affect 30-72 km^2 (12-28 mi^2) without the use of dispersants. With dispersants, and on average, up to 233 km^2 (90 mi^2) of water could be toxic to the most sensitive species (Table D-II.6-2). Under worst case conditions, the potentially affected areas for sensitive species and for no dispersants and dispersant use are on the order of 206 and 614 km^2 (79 and 237 mi^2), respectively (Table D-II.6-5).

It should be noted that these results are assuming toxicity threshold for sensitive (2.5^{th} percentile) species. The average species would not be so sensitive, and these estimated adverse effects would not apply to most or average species. The effect estimates are used in a comparative manner, comparing potential areas of concern to the most sensitive species.

If dispersants are not used, and if the affected area is open water habitat and for water column organisms with broad distribution over all subtidal habitats, a risk ranking of **4E** applies (Table D.4.2.5-6). A risk of **3B** applies to coral reefs, **4E** applies to seagrass, and **3D** applies to hard bottom habitat organisms. If dispersants are used, and if the affected area is open water habitat and for water column organisms with broad distribution over all subtidal habitats, a risk ranking of **4E** applies (Table D.4.2.5-6). A risk of **3B** applies to coral reefs, **3D** applies to seagrass, and

3D applies to hard bottom habitat organisms. Given that many species and life stages of plankton and fish on and over coral reefs are more broadly distributed rather than restricted to the coral reefs (for example they inhabit hard bottom habitats as well), and that these organisms reproduce on time scales less than one year, the overall risk score of 4D is assigned for plankton and fish for all response treatments. This overall risk score is carried forward to the final matrix.

These results are consistent with experience for large oil spills of about 40,000 bbl (about 1 million gallons or more; French McCay and Payne, 2001; French McCay et al., 2002, and as discussed in Part A). In the Florida Straits in particular, high temperatures facilitate rapid evaporation and volatilization of the toxic fraction, the soluble aromatics. Also, winds are typically light to moderate, except in infrequent storm events. Thus, natural dispersion into the water is typically low, while evaporation is rapid. Because of logistical constraints, in the scenarios examined the dispersion by chemical dispersants occurred beginning at 12 hours after the spill. By this time, most of the toxic components have volatilized (Section D.4.1), such that dissolved aromatic concentrations resulting from dispersant use are only slightly elevated over the no-dispersant option.

Table D.4.2.5-6. Overall risk scores for plankton and fish for large spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	D (1-5%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	D (1-5%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	D (1-5%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB	D (1-5%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

D.4.2.6 Subtidal Benthic Habitat

The greatest concern for subtidal benthic habitats in the Florida Straits is for the coral reefs that are found off tip of Florida and for seagrass beds in shallow nearshore and estuarine areas (see Section D.3.2.6). Benthic habitat was assumed to be at risk when a threshold of 0.10 g/m^2 of total hydrocarbon loading was exceeded in the sediment or 0.0001 g/m^2 of dissolved aromatic hydrocarbons was exceeded in the pore water (see Section A.4 in Part A). These concentrations are approximately equivalent to 1 ppm of total hydrocarbons or 1 ppb of dissolved aromatic hydrocarbons, when a sediment mixing depth of 10 cm is assumed. The area was estimated using SIMAP and the modeling methods are described in Part A. The area estimates of sediment loading for the medium volume Florida Straits spills are presented in Table D-II.6.6. The area estimates for dissolved aromatic hydrocarbons are in Table D-II.6.7. For the large volume spill, the total hydrocarbon criteria was exceeded in an area of less than 0.8 km^2 (0.3 mi^2) without dispersants, and approximately 0.4 km^2 (0.15 mi^2) when dispersants were used. The dissolved aromatic hydrocarbon threshold was exceeded when dispersants were used, but the total area affected was less than 0.1% of the total reference area.

Benthic habitat was also assumed to be at risk if epiflora and epifauna (demersal) organisms were affected by dissolved aromatic concentrations in the bottom water just above the sediments. As indicated in Table D.4.2.5-1, the percentage of benthic habitat where stationary demersal biota would be affected, assuming the toxicity parameter for sensitive species (i.e., two standard deviations more sensitive than the average of all species tested), was estimated by the model as less than 1% of the reference area, regardless of treatment option. As discussed in Section D.3.2.6, there are three communities in the subtidal habitat which were analyzed separately because of their high value (coral reefs, seagrass beds, and hard bottom habitat). The average results for these three resources are presented in Tables D.4.2.5-3 through D.4.2.5-5. While these indices were calculated for the plankton and fish discussion, they reflect the risk to many of the animals which constitute important parts of the community in these three habitats. In this case, however, the discussion focuses only on demersal species. Of the three habitats, coral reefs are at the greatest risk. The model estimated that 5.0% of the coral reef habitat could be affected with on-water mechanical recovery only. The use of dispersants (at either efficiency) increased the risk, but not substantially (the values were both 5.6%). As was the case for the medium volume spill, this appears to be caused by the relatively rapid contact of the oil slick with these areas, so that the application of dispersants to areas further offshore has little influence on the risk, and the predicted exposures are not greatly different than in the medium volume spill. This index represents a more short-term effect than would be the case with accumulation of hydrocarbons in the sediment. It is consistent with field observations (see Section 4.3.2.5 for the PEIS) which have indicated reduced coral growth for a period of several years, and the loss of some mobile invertebrates (such as sea urchins) with recovery in one or two years.

Results of On-Water Mechanical Recovery Only
In the on-water mechanical recovery only option for the large volume spill scenario, the model results indicate that the sediment threshold concentrations were exceeded in only a limited area, however, since the potential area of water column exposure above effects thresholds to coral reefs was estimated as 5% of the resource, which should recover in 1 to 3 years, the risk score became **3C**, or a moderate level of concern.

Results of the Addition of a Dispersant Response at Low Efficiency
Use of a dispersant at 45% efficiency in the large spill scenario slightly reduced the level of total hydrocarbon contamination in subtidal habitat sediments, but slightly increased the contamination by dissolved aromatic hydrocarbons. All areas of exposure were estimated to be quite small relative to the overall habitat. Dispersant use did not have much effect on the area of water column exposures above effects thresholds for coral reefs so the score remains **3C**.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and the 80% efficiency dispersant option, sediments still do not accumulate hydrocarbons in excess of the threshold levels except in small areas, and the water column exposure for corals and sea grass beds does not change significantly, so the risk ranking remains at **3C**.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in the large spill scenario should have no additional effect when combined with on-water mechanical recovery on benthic habitats since ISB takes place on the water's surface and results in the removal of an equivalent amount of oil (**3C**). The only concern associated with ISB is the chance of heavy burn residues sinking and mixing with sediments, but this risk is minimal based on both the toxicity of the material and on the amount that would be produced from the limited burning possible in the scenarios.

Summary of the Consequences for Subtidal Habitat in the Large Volume Scenarios
Oil spills and oil-spill response activities could potentially affect benthic habitats. Floating oil does not pose a great level of concern unless sufficient wave energy exists to mix the surface oil into the water column, or sediments contaminated with oil are transported from the intertidal zone into subtidal habitats. Mechanically dispersed oil could adhere to sediments, flora and fauna in benthic habitats and could cause potentially adverse effects. However, in this simulation, essentially no hydrocarbon accumulation is expected in the sediments, even near shore. There are areas of specialized habitats, especially coral reefs, which would be exposed, for brief periods, to hydrocarbons above thresholds of concern in the water column, and for the larger spill volume these areas are between 5.0 and 5.6% of the total (for coral reefs). This exposure was not greatly affected by the use of dispersants. In either case, recovery is expected to within one to three years. Overall, the risk is considered to be moderate, with or without the use of dispersants.

D.4.2.7 Biological Areas of Special Concern

The Florida Straits has numerous areas of special concern (Section D.3.2.7). They include both coastal and subtidal areas, and for the purposes of this evaluation the average risk to such areas is assumed to be defined by the higher of the risks to intertidal (Section D.4.2.1) or subtidal (Section D.4.2.6) habitats, adjusted for the type, abundance and distribution of areas of special concern, if appropriate. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
For the mechanical response option under the large spill scenario, floating oil poses a high risk (**1C**) to intertidal habitat, while subtidal habitat was at moderate risk (**3C**). Even though subtidal habitat has a lower risk score, there is potential exposure of coral reefs (all of which are of special concern), however, intertidal areas of special concern are clearly the primary consideration since oil accumulates in such areas and represents a longer term effect. In this case, the oiling of sensitive areas of mangroves and marshes with heavy amounts of oil created a very large effect. Since areas of special concern occur throughout the coastal zone in this region, and there is no reason to assume areas of special concern would recover more quickly, the score for intertidal habitat of **1C** is used. The concerns for intertidal habitat were discussed in Section D.4.2.1.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency in the large spill scenario reduced the amount of surface oil which reaches shore by approximately 60%. The fact that the remaining oiling would still be

fairly heavy means recovery would remain slow, resulting in a risk score of **1D** (see section D.4.2.1). The risk to subtidal habitats does not change (**3C**), and recovery is much more rapid than for intertidal habitats, where the oil accumulates, and so the risk score for intertidal habitat is used.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at an efficiency of 80% in the large spill scenario did not appreciably change the risk to either intertidal or subtidal habitats from that observed for dispersant use at 45% efficiency, and the risk remains at **1D**. This score is used since the risk to subtidal habitats remains at **3C** because of the limited change in the extent of the dispersed oil plume.

Results of the Addition of an On-Water ISB Response
ISB should produce a black smoke plume that could pass over an area of special concern if the proper weather conditions exist. In this case, however, the burning can only occur three miles or more offshore, and the results for air quality (Section D.4.1.1) indicate that the plume should not travel that far. The use of ISB in addition to on-water mechanical recovery is not expected to increase the risk to these resources and the score remains the same as for on-water mechanical recovery only (**1C**).

Summary of the Consequences for Areas of Special Concern in the Large Volume Scenarios
The effects on areas of special concern in this scenario are focused on the potential risk to shoreline habitats. The use of dispersants can reduce the risk to such areas without substantially increasing the moderate risk to subtidal areas. In this analysis the estimated risk to areas of special concern is defined as equivalent to the risk to intertidal habitat, in general. While this accurately reflects the ecological consequences of the event, it does not account for the social values which may be attached to such areas. If the spill trajectory of an actual event did threaten such areas, whether intertidal or subtidal, special attention would be given to their protection.

D.4.2.8 Essential Fish Habitat

Areas of essential fish habitat are extensive in the Florida Straits (see Section D.3.2.8). For this evaluation, the effects on essential fish habitat are assumed to be reflected by the risk to plankton and fish (Section D.4.2.5) and subtidal habitat (Section D.4.2.6) since they define the risk to the majority of fish habitat. Intertidal habitats, such as mangrove forests, are also important habitat for fisheries resources, but were considered separately. The average risk to essential fish habitat is assumed to be defined by the higher of the risk scores for plankton and fish or subtidal habitat. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
In the large spill scenario, with the use of on-water mechanical recovery only, the risk to plankton and fish was **4D** while that to subtidal habitat was **3C**, which was used for EFH as a whole. This is a reflection of the extent of the area where water column effects thresholds may be exceeded (especially for corals), the relatively large volume of water for dilution, the areal extent of the habitats, and the rapid recovery of the resources from a short-term exposure. Based on the risk score for corals, there is a moderate level of concern for EFH.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency did not change the risk score for subtidal habitat or fish and plankton, and the risk score remains **3C**.The dispersed oil plume did not increase the area of sensitive subtidal habitat (based on coral reefs) potentially exposed to oil above effects thresholds in the water column by much. Dispersant use also reduced effects on intertidal habitat, which includes areas that are also important for fisheries resources and EFH.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at 80% efficiency in the large spill scenario resulted in no change to the risk to plankton and fish or subtidal habitat relative to that at 45% efficiency, and the score remains **3C**. Again, dispersant use does benefit intertidal habitat, some of which are also important to EFH.

Results of the Addition of an On-Water ISB Response
The addition of ISB to on-water mechanical recovery in the large spill scenario did not change the evaluation for either plankton and fish or for subtidal habitat, and the score remains **3C**.

Summary of the Consequences for Essential Fish Habitats in the Medium Spill Scenarios
Overall, the estimated risk to essential fish habitat is moderate for the large spill scenario, regardless of the response option employed, based on concern about exposure to hydrocarbons in the water column for sensitive subtidal habitat, especially coral reefs. This exposure is only at very low concentrations, of short duration and does not lead to accumulation of hydrocarbon in the habitat, so recovery is expected to occur within one to three years.

D.4.3 Effects on the Socio-Economic Environment

D.4.3.1 Human Health

Operation of the type of equipment associated with oil spill response can be dangerous. This is well recognized and is the basis for the worker certification and training requirements that are now in place. There are also protocols in place for the proper application and handling of dispersants. The safety risk is greater as the spill size, and thus the intensity and duration of operations increases, but is minimized if safety standards are followed. There is a health risk from inhalation of hydrocarbon fumes for first responders, which is recognized in current safety protocols. Exposure to hydrocarbon fumes is the only health risk that can be directly estimated in the SIMAP model, and the results are presented in Section D.4.1.1.

D.4.3.2 Subsistence

Information on subsistence use of fish and shellfish in the Florida Straits is limited. While some residents may supplement their diets with these resources, subsistence is not known to be a prominent activity in this area, as compared to Alaska, where Native communities may suffer substantial economic and cultural losses due to contamination of subsistence seafood during an oil spill.

Results of On-Water Mechanical Recovery Only
Under the large volume spill scenario and no dispersant response option, water column exposure of dissolved aromatics between 1-100 pbb is expected to occur mostly around the lower Keys, with some small areas of higher concentrations (100-10,000 ppb), especially near Marquesas Key (Figure D-II.1.4.4-3). Tainting of fish and invertebrates becomes a concern when water concentrations exceed approximately 100 ppb in a brief (order of hours) exposure (See Section 4.3.5.6 of the PEIS). Sediment exposure is expected to be negligible (Figure D-II.1.4.5-2). A very small percentage (<1%) of shoreline habitats in the reference area would be oiled, therefore a proportionally small percentage of subsistence resources associated with these habitats are likely to be exposed (Section D.4.2.1. Intertidal Habitats). A very small percentage of subsistence resources are likely to be adversely affected under these conditions, and recovery should be rapid (<1 year). A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and low efficiency dispersant response option, water column exposure of dissolved aromatics between 1-100 pbb is expected to occur west of Lower Matecumbie Key, and concentrations of 100-10,000 ppb are expected to occur along the lower Keys west of Little Big Pine Key (Figure D-II.1.5.4-3). Sediment exposure would be negligible (Figure D-II.1.5.5-2), and oiling of shoreline and intertidal organisms would be reduced (Section D.4.2.1. Intertidal Habitats). A larger water column area may be affected under these spill conditions, yet it is still likely that only a small percentage of subsistence resources, particularly spiny lobster, would be adversely affected, and recovery should be rapid. A risk matrix ranking of **4D** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and high efficiency dispersant response option, water column exposure of dissolved aromatics is expected to be similar compared to when low efficiency dispersants are used (Figure D-II.1.6.4-3). There may be minimal sediment exposure in the lower Keys (Figure D-II.1.6.5-2), and oiling of shoreline and intertidal organisms would be reduced (Section D.4.2.1. Intertidal Habitats). Therefore, it is likely that only a small percentage of subsistence resources would be adversely affected, and recovery should be rapid. A risk matrix ranking of **4D** was assigned to subsistence resources for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, adverse effects to subsistence resources would be similar to the on-water mechanical recovery only response option. A risk matrix ranking of **4D** was assigned to subsistence resources for this scenario.

Summary of the Consequences for Subsistence in the Large Volume Scenarios
Because water column effects should be localized and shoreline effects are expected to occur in a small percentage of the reference area, a risk matrix ranking of **4E** was assigned to subsistence resources for the no dispersant and ISB response options. A ranking of **4D** was assigned for both low and high dispersant efficiency response options because larger water column areas are expected to have higher concentrations of dissolved aromatics.

D.4.3.3 Cultural Resources

Most archaeological artifacts and some shipwrecks in the Florida Straits are buried under sediment and coral formations, and therefore are at low risk of oiling (Section 3.2.5.6 of the PEIS). Historic sites such as forts and walls are located on land and are protected from oiling by barriers and proximity to shore. Some submerged shipwrecks occur in nearshore waters, but results from several studies following the Exxon Valdez indicated that direct oiling caused negligible effects on historic artifacts (Reger et al., 1992; Dekin, 1993; Wooley and Haggarty, 1995; Bittner, 1996). Therefore, open water response options, such as the use of dispersants, ISB, and on-water mechanical recovery, may help reduce the amount of oil that strands onshore and in intertidal areas, which should also reduce the amount of shoreline clean up and disturbance of sensitive cultural resources. For these reasons, a risk matrix ranking of **4E** was assigned to cultural resources for all response options under this scenario.

D.4.3.4 Coastal Communities

Oil spills affect the pleasure that coastal residents and visitors derive from coastal activities and the economic contribution that resources make to local income and employment. Effects are likely to include effects on water- and shore-based recreation, fisheries (recreational and commercial), marine transportation and tourism. The effects on these activities are described in more detail in subsequent sections.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to coastal communities in the Florida Straits under various spill response options. At this modeling location, the length of shoreline oiling above the effects threshold is not considered relevant because the shoreline oiling results were highly sensitive to specific location, the ability to identify shoreline with characteristics amenable to use was limited, and areas of surface water oiled above the threshold was expected to provide a more accurate measure of expected risk, given the region's geographic characteristics. The model results are presented in Appendix D-II.2, Tables D-II.2-4 to D-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to coastal communities of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Florida Keys National Marine Sanctuary is expected to adversely affect approximately 659 km^2 (254.4 mi^2) of surface water above recognized effect thresholds (Table D-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 50 percent as compared to on-water mechanical recovery alone (Table D-II.2-5). This results in a risk factor rating of 0.50 for surface water resources under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 15 percent as compared to the low dispersant efficiency response option (Table D-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating decreased to 0.43 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on coastal communities would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to coastal communities for surface water resources for this scenario.

Summary of the Consequences for Coastal Communities in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 280 to 330 km^2 (108 to 126 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 50 to 57 percent, the level of dispersant efficiency does not greatly affect the level of concern about coastal communities in this spill scenario.

D.4.3.5 Economic Status

The overall economic status of communities, industries and individuals that rely on coastal resources for sustenance, revenue and quality of life can be affected by an oil spill. As noted above, coastal communities can suffer direct and indirect economic effects due to an oil spill, as beach and fishery closures decrease revenues, eliminate jobs, and adversely affect subsistence users of the resources.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to economic status in the Florida Straits under various spill response options. The model results are presented in Appendix D-II.2, Tables D-II.2-4 to D-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to economic status of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Florida Keys National Marine Sanctuary is expected to adversely effect approximately 659 km^2 (254.4 mi^2) of surface water above recognized effect thresholds (Table D-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was

reduced by approximately 50 percent as compared to on-water mechanical recovery alone (Table D-II.2-5). This results in a risk factor rating of 0.50 for surface water resources under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 15 percent as compared to the low dispersant efficiency response option (Table D-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating decreased to 0.43 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on economic status would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to economic status for surface water resources for this scenario.

Summary of the Consequences for Economic Status in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 280 to 330 km^2 (108 to 127.4 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 50 to 57 percent, the level of dispersant efficiency does not greatly affect the level of concern about economic status in this spill scenario.

D.4.3.6 Vessel Transportation and Ports

Any interruption in the standard use of vessels or increase in travel times over water can result in hardship for coastal communities and businesses as fewer goods are exchanged, transportation costs rise, and the revenue streaming through the local economy falls.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to marine transportation and ports in the Florida Straits under various spill response options. The model results are presented in Appendix D-II.2, Tables D-II.2-4 to D-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to the marine transportation industry of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Florida Straits is expected to adversely effect approximately 659 km^2 (254.4 mi^2) of surface water used by the marine transportation industry above recognized effect thresholds (Table D-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was

reduced by approximately 50 percent as compared to on-water mechanical recovery alone (Table D-II.2-5). This results in a risk factor rating of 0.50 for the marine transportation industry under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 15 percent as compared to the low dispersant efficiency response option (Table D-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for the marine transportation industry decreases to 0.43 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on the marine transportation industry would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to the marine transportation industry for surface water resources for this scenario.

Summary of the Consequences for Vessel Transportation and Ports in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 280 to 330 km^2 (108 to 127.4 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 50 to 57 percent, the level of dispersant efficiency does not greatly affect the level of concern about vessel transportation and ports in this spill scenario.

D.4.3.7 Fisheries (Commercial and Recreational)

Commercial and recreational fishing and related industries are vulnerable to oil spills, due to closures as well as market perceptions surrounding taint of the catch. In addition, recreational anglers, who fish for pleasure or sport, as opposed to monetary gain, may experience a reduced quality of experience. Large-scale spills also hold the potential to injure nursery grounds and impose other effects that could reduce fish harvests in the longer run.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to commercial and recreational fishing in the Florida Straits under various spill response options. The model results are presented in Appendix D-II.2, Tables D-II.2-4 to D-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to commercial and recreational fishing of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Florida Straits is expected to adversely affect approximately 659 km^2 (254.4 mi^2) of surface water used for commercial and recreational fishing above recognized effect thresholds (Table D-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 50 percent as compared to on-water mechanical recovery alone (Table D-II.2-5). This results in a risk factor rating of 0.50 for commercial and recreational fishing under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 15 percent as compared to the low dispersant efficiency response option (Table D-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for commercial and recreational fishing decreases to 0.43 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on commercial and recreational fishing would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to commercial and recreational fishing for surface water resources for this scenario.

Summary of the Consequences for Commercial and Recreational Fishing in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 280 to 330 km^2 (108 to 127.4 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 50 to 57 percent, the level of dispersant efficiency does not greatly affect the level of concern about commercial and recreational fishing in this spill scenario.

D.4.3.8 Recreation and Tourism

An oil spill would be expected to cause local decreases in tourism, recreation, associated business revenues and the quality of coastal living. Similar to recreational fishing effects, an oil spill would also be expected to affect recreationalists' overall social welfare.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to recreation and tourism in the Florida Straits under various spill response options. The model results are presented in Appendix D-II.2, Tables D-II.2-4 to D-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to recreation and tourism of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Florida Straits is expected to adversely affect approximately 659 km^2 (254.4 mi^2) of surface water used for recreation and tourism above recognized effect thresholds (Table D-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 50 percent as compared to on-water mechanical recovery alone (Table D-II.2-5). This results in a risk factor rating of 0.50 for recreation and tourism under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 15 percent as compared to the low dispersant efficiency response option (Table D-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for recreation and tourism decreases to 0.43 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on recreation and tourism would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to recreation and tourism for this scenario.

Summary of the Consequences for Recreation and Tourism in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 280 to 330 km^2 (108 to 127.4 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 50 to 57 percent, the level of dispersant efficiency does not greatly affect the level of concern about recreation and tourism in this spill scenario.

D.4.3.9 Environmental Justice

Low-income, indigenous, and minority sub populations in some coastal areas may rely on regional fisheries for subsistence or on tourism, recreation or other marine-resource related industry for employment. These groups may experience the effects of a spill more severely than the general population, which relies on a more diverse economic base for their livelihoods and on the availability of a widespread and commercially available selection of foods.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to environmental justice in the Florida Straits under various spill response options. The model results are presented in Appendix D-II.2, Tables D-

II.2-4 to D-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to environmental justice of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Florida Straits is expected to adversely affect approximately 659 km^2 (254.4 mi^2) of surface water above recognized effect thresholds (Table D-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 50 percent as compared to on-water mechanical recovery alone (Table D-II.2-5). This results in a risk factor rating of 0.50 for surface water resources under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 15 percent as compared to the low dispersant efficiency response option (Table D-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating decreased to 0.43 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on environmental justice would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to environmental justice for this scenario.

Summary of the Consequences for Environmental Justice in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 280 to 330 km^2 (108 to 127.4 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 50 to 57 percent, the level of dispersant efficiency does not greatly affect the level of concern about environmental justice in this spill scenario.

D.5 SUMMARY CONCLUSIONS

The results for the two spill volumes are more complex at this modeling location than at any of the others. This is a reflection of the complexity of the environment, as well as the sensitivity and unique nature of many of the habitats. In addition, the spill site for the Florida modeling location is relatively close to sensitive habitats, as compared to the other modeling locations.

For the moderate (2500 bbl) spill (Table D.5-1) the level of concern predicted for the average spill remains low for all environmental resources except for marine and coastal birds, intertidal habitat, subtidal habitat, EFH and biological areas of special concern. While subtidal habitat, EFH, and marine and coastal birds were determined to be at moderate risk without dispersant use, intertidal habitat and areas of special concern were at a high risk. This is a factor of the sensitivity of the mangrove forests which are found in this region, and which recover only slowly from oiling. When dispersants were used at low efficiency, the model suggests that the reduction in shoreline oiling will be sufficient to lower the overall level of concern to moderate for intertidal habitats. This risk is reduced even further if the dispersant treatment is 80% effective. Subtidal areas of special concern then become relatively more important, even though the level of risk did not change. Dispersant use (at either efficiency) does reduce the proportion of the population likely to be affected for marine and coastal birds, but this benefit was not sufficient to change the overall level of concern. Dispersant use had no effect on the risk to subtidal habitat, which was driven by the potential risk to coral reefs. Effects on these areas occurred early in the spill trajectory, and consequently were not greatly influenced by dispersant application. The use of ISB does not change the predicted risk to the environment when compared to on-water mechanical recovery alone, because it results in the treatment of an equivalent volume of spilled oil. When dispersants are used with the 2500 bbl spill volume, predicted water column concentrations of hydrocarbons do not increase the overall risk to planktonic communities, but could affect those resources associated with high value subtidal communities.

When the spill size increases to 40,000 bbls (large spill scenario, Table D.5-2) the expected effects also increase. The average model results suggest that now the risk to marine mammals and sea turtles is also likely to be moderate with on-water mechanical recovery only. The level of concern with only on-water mechanical recovery for other resources remained unchanged, however some risk scores did increase. While coastal water quality was not directly estimated by the modeled results, dispersant use would cause moderate levels of concern if the entire plume were to enter coastal water prior to dilution (not the case in the scenario). Intertidal habitat remains the primary concern, with a high risk ranking, which carries over to areas of special concern. At this volume, the use of dispersants did not prevent the impacts to intertidal habitat from being a high concern. The use of dispersants did reduce the risks likely to occur to other categories resources, but again, usually not enough to change the overall risk score (except for sea turtles). While the use of dispersants does not eliminate the risk, it does improve the situation somewhat without an increase in the risk to plankton and fish in open water areas or to specific subtidal habitats. In this case, the average changes in effects for a high efficiency dispersant application were only slightly different than the low efficiency option. This reflects the fact that, under the assumed conditions, sufficient supplies of dispersant are available to achieve the maximum level of dispersion, regardless of which efficiency is assumed. Again, the use of ISB does not change the results from those predicted with only on-water mechanical recovery.

Examination of the entire suite of model runs indicates that the range of effects on resources of concern is highly variable, which reflects the dynamic nature of oil spills. For example, for the medium spill no oil reaches the shore at all with only on-water mechanical recovery 13 out of 100 model runs, while this value increases to 27 out of 100 with dispersant use at low efficiency and to 28 out of 100 with dispersant use at high efficiency. Alternatively, also for the medium spill, the maximum shoreline oiling length predicted for on-water recovery only was 36.7 km

(22.8 mi), just over four times the average. Similar observations can be made for other exposure indices. The same pattern exists for the large spill results, and in many cases the relative relationships are quite similar. These model results are consistent with observed effects from spills that originate offshore and with the expected impacts described in Section 4.3 of the PEIS.

With respect to socioeconomic resources, the use of dispersants would limit the effects of the spill in all cases.

Table D.5-1. Risk Ranking for Medium (2,500 bbl) Spills at the Florida Straits Modeling Location

	Physical Environment			Biological Environment								Socioeconomic Environment			
Response Option	Coastal Water Quality	Marine Water Quality	Air Quality	Intertidal Habitat	Marine and Coastal Birds	Marine Mammals	Sea Turtles	Plankton and Fish	Subtidal Benthic Habitat	Biological Areas of Special Concern	Essential Fish Habitat	Subsistence	Cultural Resources	Shoreline Oiling Index	Surface Water Oiling Index
On-Water Mechanical Recovery	4D	4E	4E	1D	3B	3E	3E	4D	3D	1D	3D	4E	4E		1.0
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	4D	4E	4E	2E	3D	3E	3E	4D	3D	3D	3D	4D	4E		0.31
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	4D	4E	4E	3E	3D	3E	3E	4D	3D	3D	3D	4D	4E		0.31
On-Water Mechanical Recovery and In-Situ Burning	4D	4E	4E	1D	3B	3E	3E	4D	3D	1D	3D	4E	4E		1.0

Legend: Black cells represent a “high” level of concern, medium gray cells represent a “moderate” level of concern, and light gray cells represent a “limited” level of concern.

Table D.5-2. Risk Ranking for Large (40,000 bbl) Spills at the Straits of Florida Modeling Location

	Physical Environment			Biological Environment								Socioeconomic Environment			
Response Option	Coastal Water Quality	Marine Water Quality	Air Quality	Intertidal Habitat	Marine and Coastal Birds	Marine Mammals	Sea Turtles	Plankton and Fish	Subtidal Benthic Habitat	Biological Areas of Special Concern	Essential Fish Habitat	Subsistence	Cultural Resources	Shoreline Oiling Index	Surface Water Oiling Index
On-Water Mechanical Recovery	4C	4E	4E	1C	3A	3D	3D	4D	3C	1C	3C	4E	4E		1.0
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	4A	4E	4E	1D	3B	3D	3E	4D	3C	1D	3C	4D	4E		0.50
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	4A	4E	4E	1D	3B	3D	3E	4D	3C	1D	3C	4D	4E		0.43
On-Water Mechanical Recovery and In-Situ Burning	4C	4E	4E	1C	3A	3D	3D	4D	3C	1C	3C	4E	4E		1.0

Legend: Black cells represent a "high" level of concern, medium gray cells represent a "moderate" level of concern, and light gray cells represent a "limited" level of concern.

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Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part D: Florida Straits

Sections D-I.1 – D-I.4

by

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ASA 00-246

August 2004

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D-I. OIL SPILL MODEL INPUT DATA

This appendix contains model input data (in maps, figures and tables) for the modeled location in the Straits of Florida (off of the Florida Keys) and the sources for that information. The approach and sources applicable to all modeled locations are described in Part A, Section A.3 of this technical report. Specifics to this model location are below. Thus, the reader should refer to Part A, Section A.3 for background and the context within which these data are used.

D-I.1 Geographical Data Input to the Model

Geographic data for the modeled location are presented in this section. The sources for these data are described in Part A, Section A.3.1. A map is also presented below showing areas where dispersant application was assumed in model simulations. The assumptions for the dispersant application scenarios are in Part A, Section A.3.7. The crosshair mark ( ) in the figures below represents the assumed oil spill site for the model simulations.

D-I.1.1 Maps of the Vicinity of the Spill Site

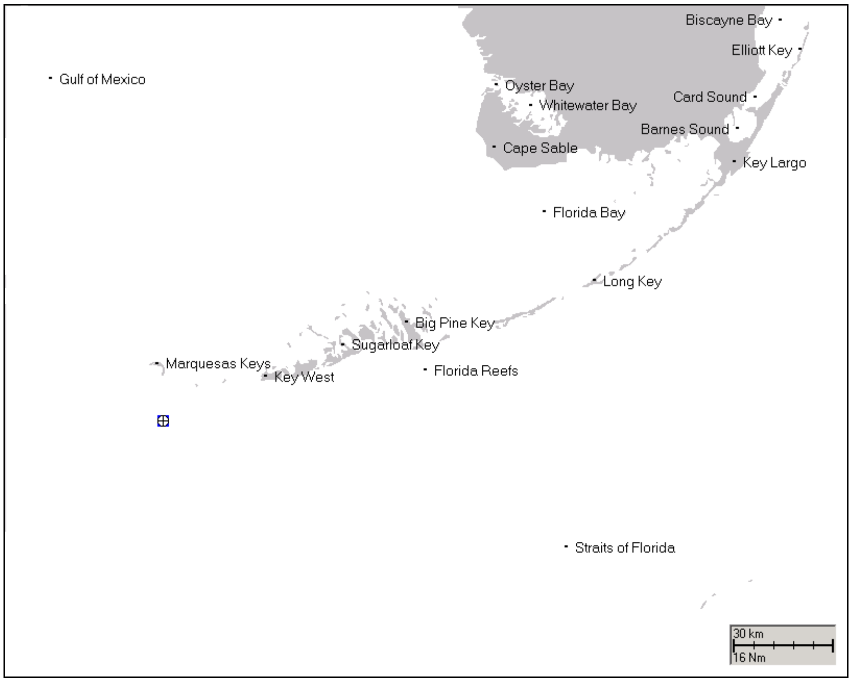

Figure D-I.1.1-1 Map of spill site and location names used in the text (entire grid).

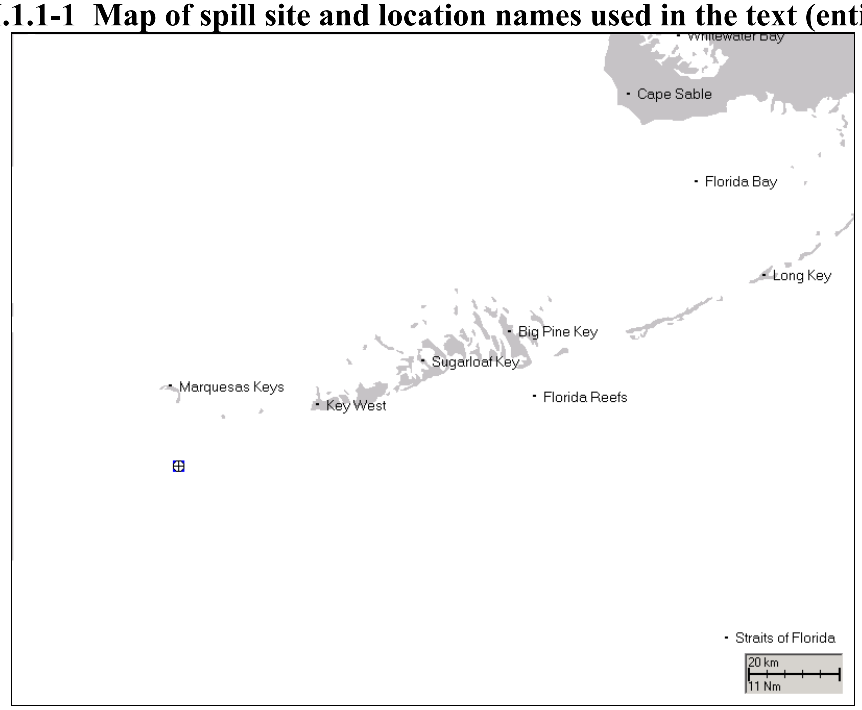

Figure D-I.1.1-2 Map of spill site and location names used in the text (Florida Keys).

D-I.1.2 Gridded Depth Data

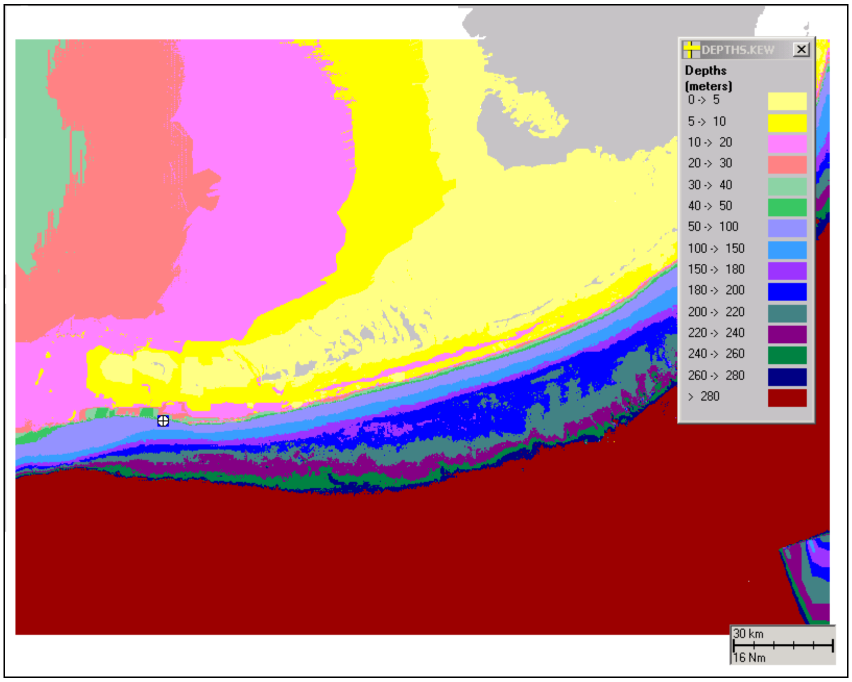

Figure D-I.1.2-1 Gridded depth data used in model runs (entire grid).

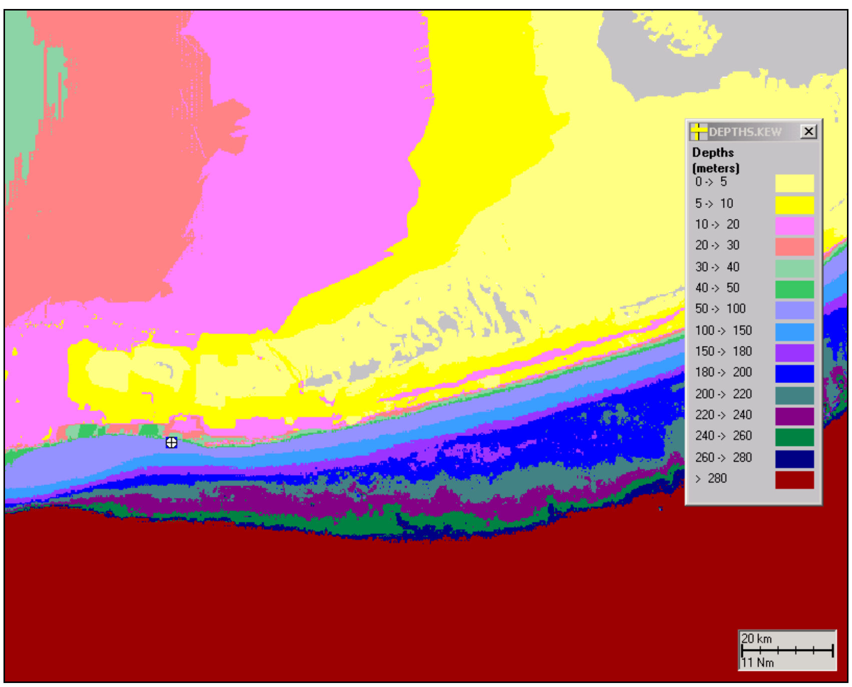

Figure D-I.1.2-2 Gridded depth data used in model runs (Florida Keys).

D-I.1.3 Gridded Habitat Mapping

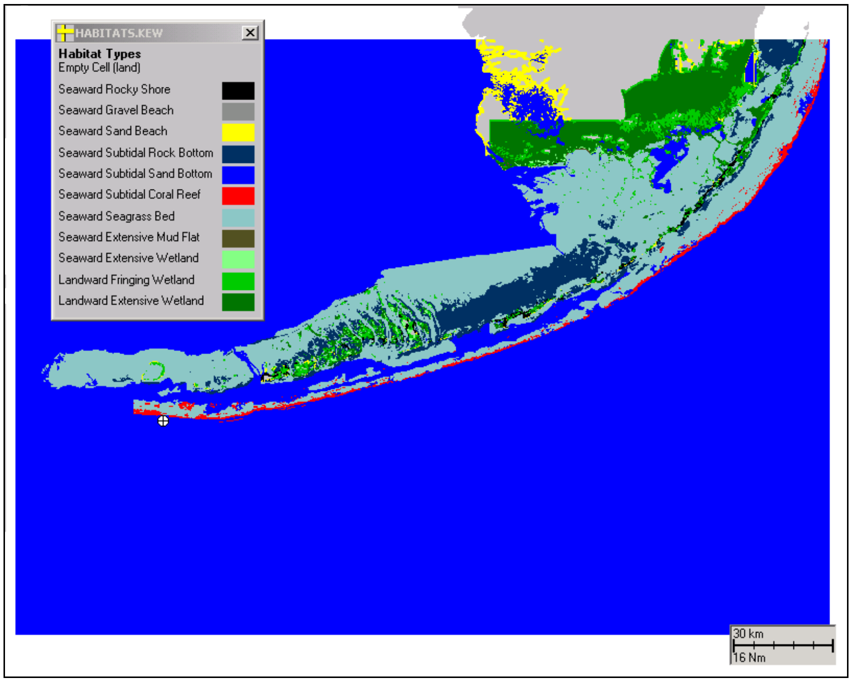

Figure D-I.1.3-1 Gridded habitat map used in model runs (entire grid).

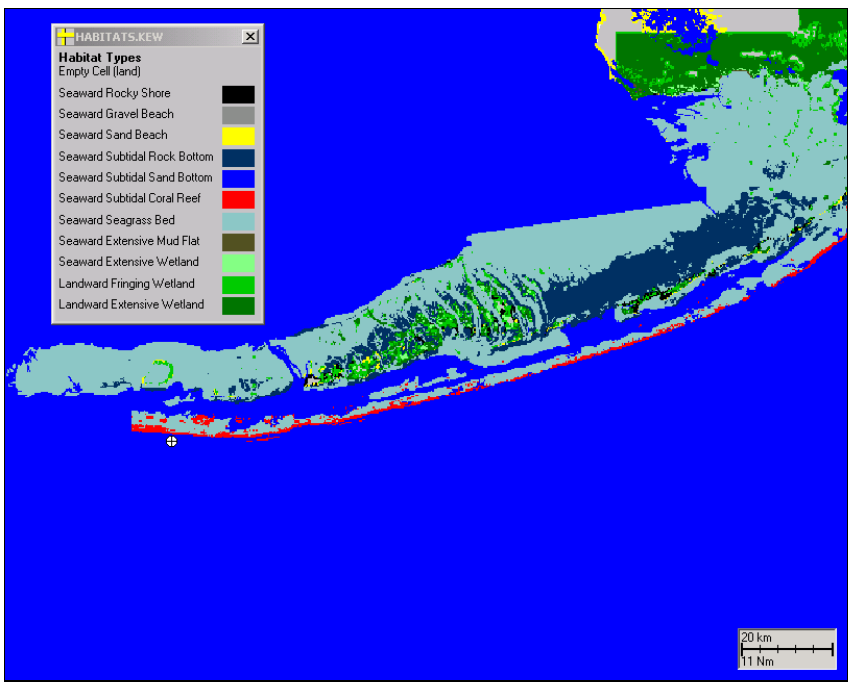

Figure D-I.1.3-2 Gridded habitat map used in model runs (Florida Keys).

D-I.1.4 Dispersant Application Areas for Response

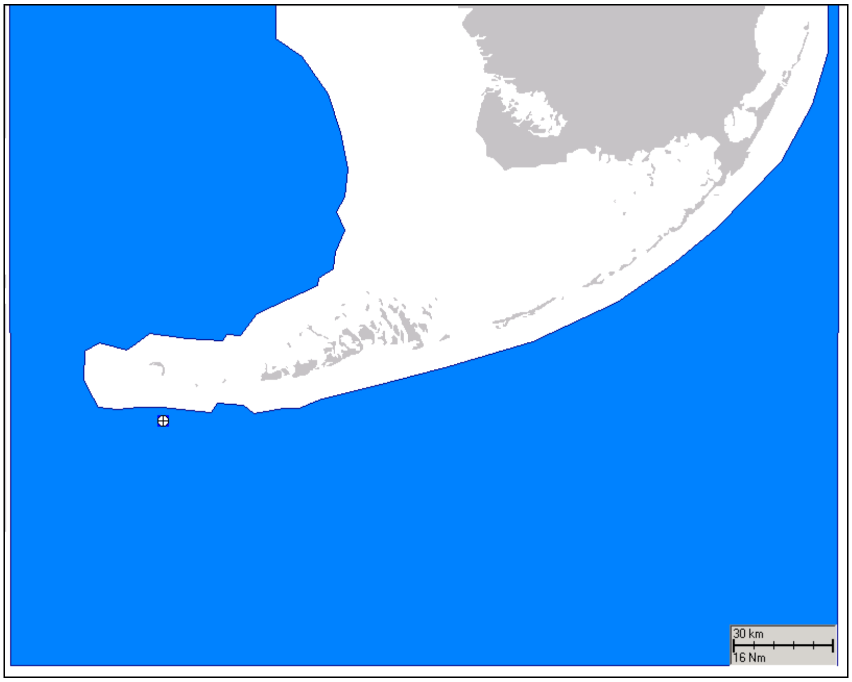

Figure D-I.1-4-1 Map of dispersant application areas (blue shaded area is where dispersants are assumed applied).

D-I.2 Current Data

The currents used in the oil model simulations were estimated using a hydrodynamic model forced with climatology data so as to represent long-term mean flow in the Florida Straits and surroundings. The current vectors were generated at 1/6° (latitude and longitude) resolution from the 1/6° POP (Parallel Ocean Program) model, developed at Los Alamos National Laboratory (Dukowicz and Smith, 1994). The data were provided by Chao et al. (1996) at four different depths (5m, 1000m, 2000m and 3000m) on a 60×30 mesh-grid. The spatial coverage was an area spanning between 20°N to 26°N and from 73°W to 84°W, including the Straits of Florida.

Figure 1 shows the current fields at four different depths. The Florida Straits currents are conspicuous, with a maximum speed is on the order of 100 cm/s (about 2 knots). With depth, the magnitude of current speed decreases. Oil released at the surface would not be present at 1000m 2000m or 3000m. Therefore, for the simulations the 5m mean current data were used.

The crosshair mark ( ) in figures below represents oil spill site.

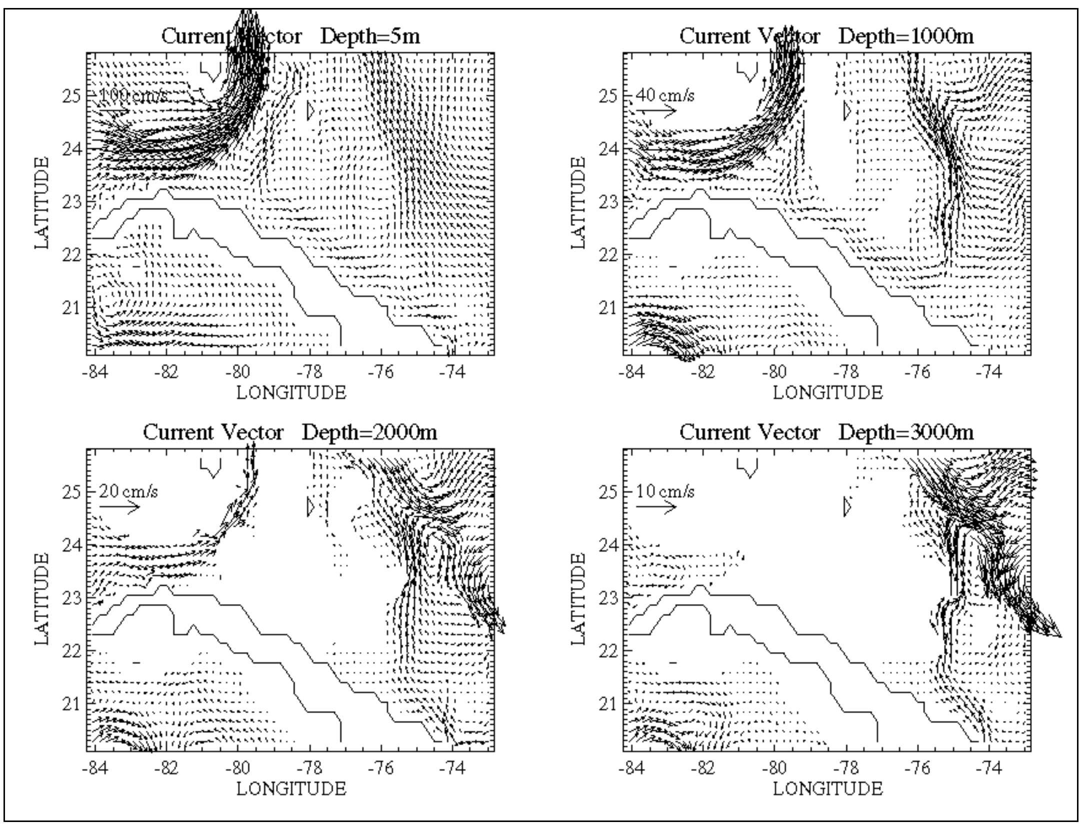

Figure D-I.2-1. Climatology current fields from the 1/6° POP model (Chao et al., 1996).

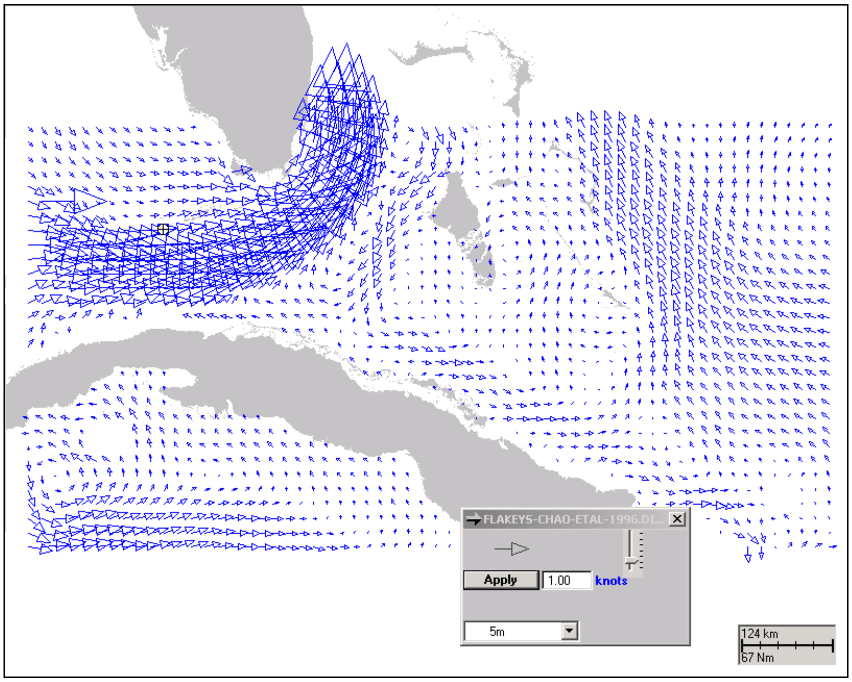

Figure D-I.2-2. Climatology current fields from the 1/6° POP model (Chao et al., 1996) used in model runs.

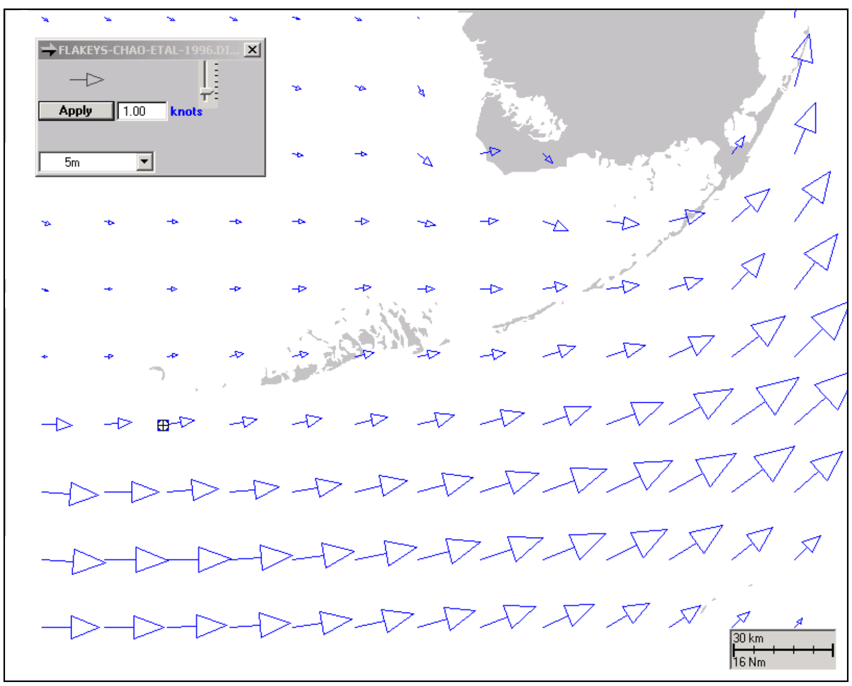

Figure D-I.2-3 Mean current data obtained from Chao et al. (1996) at 5m (entire grid).

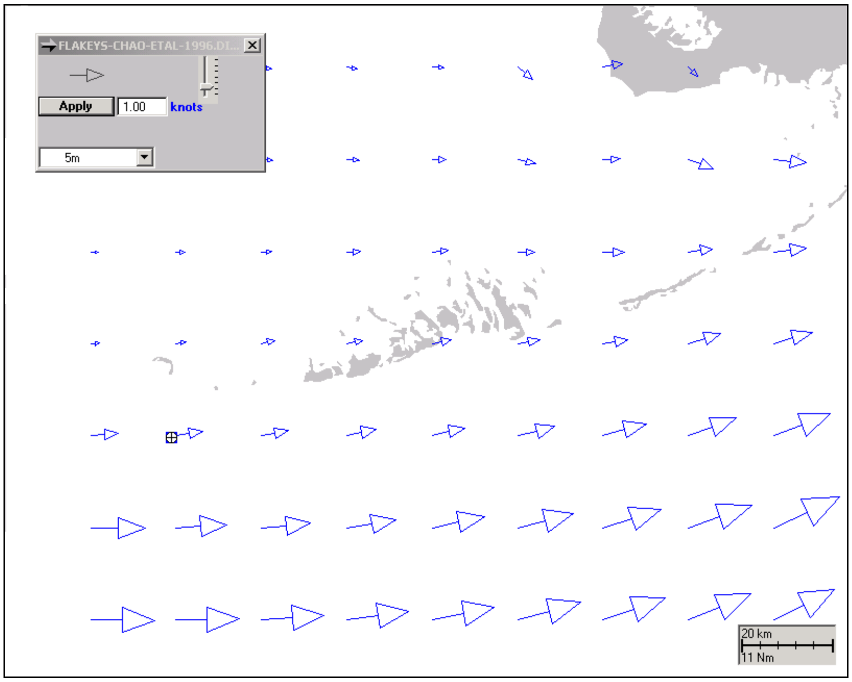

Figure D-I.2-4 Mean current data obtained from Chao et al. (1996) at 5m (Florida Keys).

D-I.3 Oil Properties

Table D-I.3-1. Oil properties for South Louisiana crude oil.

Property	Value	Reference
Density @ 25 deg. C (g/cm3)	0.8518	Jokuty et al. (1999)
Viscosity @ 25 deg. C (cp)	8.0	Jokuty et al. (1999)
Surface Tension (dyne/cm)	25.9	Jokuty et al. (1999)
Pour Point (deg. C)	-28	Jokuty et al. (1999)
Adsorption Rate to Suspended Sediment	0.01008	Kolpack et al. (1977)
Adsorption Salinity Coef.(/ppt)	0.023	Kolpack et al. (1977)
Fraction monoaromatic hydrocarbons (MAHs)	0.01478	Jokuty et al. (1999)
Fraction polynuclear aromatic hydrocarbons (PAHs)	0.008108	French (1998c)
Fraction 2-ring aromatics (included in PAHs above)	0.003104	French (1998c)
Fraction 3-ring aromatics (included in PAHs above)	0.005004	French (1998c)
Fraction Non-Aromatic Volatiles: boiling point < 180^{o}C	0.16522	Jokuty et al. (1999)
Fraction Non-Aromatic Volatiles: boiling point 180-264^{o}C	0.18590	Jokuty et al. (1999)
Fraction Non-Aromatic Volatiles: boiling point 264-380^{o}C	0.62711	Jokuty et al. (1999)
Minimum Oil Thickness (m)	0.00001	McAuliffe (1987)
Maximum Mousse Water Content (%)	75	NOAA (2000a)
Mousse Water Content as Spilled (%)	0	French et al. (1996b)
Water content of fuel (not in mousse, %)	0	French et al. (1996b)
Degradation Rate (/day), Surface & Shore	0.01	National Research Council (1985)
Degradation Rate (/day), Hydrocarbons in Water	0.01	National Research Council (1985)
Degradation Rate (/day), Oil in Sediment	0.001	Haines and Atlas (1982)
Degradation Rate (/day), Aromatics in Water	0.01	French et al. (1996b)
Degradation Rate (/day), Aromatics in Sediment	0.001	French et al. (1996b)

[1] – Jokuty et al. (1999) provided total hydrocarbon data. The aromatic hydrocarbon fraction was subtracted from the total hydrocarbon fraction to obtain the aliphatic fraction.

Table D-I.3-2. Aromatic concentrations (mg/kg) for South Louisiana crude oil.

Aromatic	Log(K_{ow})*	Concentration (mg/kg)
benzene	2.13	800
toluene	2.69	2190
ethylbenzene	3.13	710
o-xylene	3.15	0
p-xylene	3.18	0
m-xylene	3.2	0
xylenes	3.18	5360
1,2,3-trimethylbenzene	3.55	0
1,3,4-trimethylbenzene	3.6	0
1,3,5-trimethylbenzene	3.58	0
trimethylbenzenes	3.58	0
n-propylbenzene	3.69	0
iso-propylbenzene	3.63	0
ethyl-methylbenzenes	3.63	0
iso-propyl-4-methylbenzene	4.10	0
butylbenzenes	4.12	0
tetramethylbenzenes	4.01	0
styrene	3.05	0
methylstyrenes	3.35	0
tetralin	3.83	0
diphenylmethane	4.14	0
naphthalene	3.37	364.0
C1-naphthalenes	3.87	1400.0
C2-naphthalenes	4.37	1340.0
C3-naphthalenes	5.00	1200.0
C4-naphthalenes	5.55	637.0
acenaphthylene	4.07	11.4
acenaphthene	3.92	9.0
biphenyls	3.9	68.5
dibenzofuran	4.31	0.0
fluorene	4.18	34.4
C1-fluorenes	4.97	60.2
C2-fluorenes	5.20	223.0
C3-fluorenes	5.50	227.0

*Estimates of log(K_{ow}) are from Mackay et al. (1992a,b) and Neff and Burns (1996).

Table D-I.3-2. Aromatic concentrations (mg/kg) for South Louisiana crude oil (continued).

Aromatic	Log(Kow)*	Concentration (mg/kg)
anthracene	4.54	2.5
phenanthrene	4.57	90.2
C1-phenanthrenes/ anthracenes	4.49	278.0
C2-phenanthrenes/ anthracenes	5.14	327.0
C3-phenanthrenes/ anthracenes	5.25	254.0
C4-phenanthrenes/ anthracenes	6.00	104.0
dibenzothiophene	6.51	79.9
C1-dibenzothiophene	4.49	315.0
C2-dibenzothiophene	4.86	570.0
C3-dibenzothiophene	5.50	513.0
fluoranthene	5.73	0.0
pyrene	5.22	0.0
Total $\log(K_{ow}) \leq 5.6$	5.18	22037.1

*Estimates of $\log(K_{ow})$ are from Mackay et al. (1992a,b) and Neff and Burns (1996).

D-I.4 Inputs to the SIMAP Oil Spill Model

This section summarizes the model input data for the scenarios run and the sources for that information. The approach and sources applicable to all modeled locations are described in Part A, Section A.3 of this technical report. Specifics to this model location are below. Thus, the reader should refer to Part A, Section A.3 for background and the context within which these data are used.

The model grid and cell size (Table D-I.4-4) were set to provide the maximum resolution (minimum cell size) possible within the memory constraints of the model, while also providing sufficient geographic coverage to encompass the maximum extent of oiling possible for a large volume scenario. Test runs (randomizing weather conditions) were made with the largest spill volume simulated (40,000 bbl) and assuming no dispersant application. The maximum extent of surface oiling was determined and the grid size set to cover that area (Figure D-I.1.3-1).

Table D-I.4-1. Inputs to the Fates Model for Stochastic Scenarios.

Name	Description	Units	Source(s) of Information	Value(s)
Spill Site(s)	Location of the spill site	-	(Part A, Section A.3.6)	Spill site 7.5 nmiles off shore
Spill Latitude	Latitude of the spill site	Degrees	Chart (Part A, Section A.3.6)	24° 26.001' N
Spill Longitude	Longitude of the spill site	Degrees	Chart (Part A, Section A.3.6)	82° 6.187' W
Depth of release	Depth below the water surface of the release or 0 for surface release	m	assumed (Part A, Section A.3.6)	0 m
Start time and date	Randomized over selected months of the year	Date, hr,min	randomized (Part A, Section A.2.4)	Jan-Dec
Spill duration	Hours over which the release occurs	Hours	(Part A, Section A.3.6)	Large – 4 Small – 1
Total spill amount	Total volume (or weight) released (maximum if range)	bbl	(Part A, Section A.3.6)	Large – 40,000 Small – 2,500
Randomize spill amount	Volume spilled is constant or maximum of range	-	-	Constant
Model time step	Time step used for model calculations	Hours	(Part A, Section A.2.1)	0.1
Model duration	Length of each model simulation	Days	(Part A, Section A.3.6)	7 days
Number of runs	Number of random start times to run in stochastic mode	#	(Part A, Section A.2.4)	100
Number of surface spillets	Number of Lagrangian elements used to simulate mass floating on the surface	#	(Part A, Section A.2)	500
Number of aromatic spillets	Number of Lagrangian elements used to simulate dissolved aromatics in the water	#	(Part A, Section A.2)	2000

Table D-I.4-1. Inputs to the Fates Model for Stochastic Scenarios (continued).

Fates Output Threshold: floating on water surface	Slick or surface mass thickness passing through a grid cell	g/m^2 (microns)	Minimum value for sheens (Part A, Section A.4.1)	0.01
Fates Output Threshold: shoreline	Total hydrocarbons deposited on shorelines, averaged over each habitat grid cell.	g/m^2 (microns)	Minimum value for sheens (Part A, Section A.4.1)	0.01
Fates Output Threshold: dissolved aromatics in water or sediment	Dissolved concentration of aromatics with $\log(K_{ow}) \leq 5.6$ (bioavailable fraction)	mg/m^3 = µg/L = ppb	Below minimum for effects to sensitive species exposed for at least two weeks (Part A, Section A.4.1)	1
Fates Output Threshold: Subsurface (water) total hydrocarbons	Concentration of total hydrocarbons in droplets	mg/m^3 = µg/L = ppb	Minimum value with no potential for impact (Part A, Section A.4.1)	10
Fates Output Threshold: Sediment total hydrocarbons	Total hydrocarbon loading to sediments, averaged over each habitat grid cell.	g/m^2	Minimum value with no potential for impact (Part A, Section A.4.1)	0.0001 g/m^2 (which is 1.0 mg/m^3 = 1ppb averaged over the top 10cm)
Salinity	Surface water salinity	ppt	French et al. (1996b) province 28	36

Table D-I.4-1. Inputs to the Fates Model for Stochastic Scenarios (continued).

Surface Water Temper-ature	Water temperature at the sea surface	Degrees C	French et al. (1996b) province 28	monthly means (see Table D-I.4-5)
Subsurface Water Temper-ature	Water temperature for subsurface	Degrees C	French et al. (1996b) province 28	monthly means (see Table D-I.4-5)
Air Temper-ature	Air water temperature at water surface	Degrees C	(assume = water temperature; Part A, Section A.4.1)	(= water temperature)
Fetch	Fetch = distance to land to N, S, E, W (if landfall not in model domain)	km	Chart	N: 162 E: 350 S: 139 W: 1,620
Wind drift speed	Speed oil moves down wind relative to wind	% of wind speed	Youssef (1993); Youssef and Spaulding (1993)	(model calculated)
Wind drift angle	Angle to right of wind (in northern hemisphere) that oil drifts	Deg. to right of down wind	Youssef (1993); Youssef and Spaulding (1993, 1994)	(model calculated)
Horizontal turbulent diffusion coefficient	Randomized turbulent mixing parameter in x & y	m^2/sec	French et al. (1996a, 1999) based on Okubo (1971)	1 m^2/sec (estuaries and low energy coastal areas)
Vertical turbulent diffusion coefficient	Randomized turbulent mixing parameter in z	m^2/sec	French et al. (1996a, 1999) based on Okubo (1971)	0.0001 m^2/sec
Suspended sediment concentrati on	Average suspended sediment concentration during spill period	mg/l	French et al. (1996b)	10 mg/l
Suspended sediment settling rate	Net settling rate for suspended sediments	m/day	French et al. (1996b)	1 m/day
Density change	Rate of change of droplet density due to adsorption of sediment	g/cm^3/hr	(data not available – fuel oil algorithm used)	0

Table D-I.4-2. Description of scenario runs.

Scenario Name	Description
FLC-Lrg-50-0	Large Spill; Removal at 50%; No Dispersant;
FLC-Lrg-50-80	Large Spill; Removal at 50%; Dispersant at 80% efficiency;
FLC-Lrg-50-45	Large Spill; Removal at 50%; Dispersant at 45% efficiency;
FLC-Med-50-0	Medium Spill; Removal at 50%; No Dispersant;
FLC-Med-50-80	Medium Spill; Removal at 50%; Dispersant at 80% efficiency;
FLC-Med-50-45	Medium Spill; Removal at 50%; Dispersant at 45% efficiency;

Table D-I.4-3. Matrix of scenarios run.

Scenario Name	Fuel	Latitude, Longitude	Depth (m)	Dura-tion (hr)	Volume (bbl) Released	Mechanical Removal Efficiency	Dispersant Efficiency
FLC-Lrg-50-0	South Louisiana crude	24.43335 N 82.10312 W	0 m (surface)	4	40,000	50%	none
FLC-Lrg-50-80	South Louisiana crude	24.43335 N 82.10312 W	0 m (surface)	4	40,000	50%	80%
FLC-Lrg-50-45	South Louisiana crude	24.43335 N 82.10312 W	0 m (surface)	4	40,000	50%	45%
FLC-Med-50-0	South Louisiana crude	24.43335 N 82.10312 W	0 m (surface)	1	2,500	50%	none
FLC-Med-50-80	South Louisiana crude	24.43335 N 82.10312 W	0 m (surface)	1	2,500	50%	80%
FLC-Med-50-45	South Louisiana crude	24.43335 N 82.10312 W	0 m (surface)	1	2,500	50%	45%

Table D-I.4-4. Dimensions of the habitat grid cells used to compile statistics for multiple fates model runs.

Item	Value
Grid W edge	82.545°W
Grid S edge	23.85°N
Cell size (°longitude)	0.0027
Cell size (°latitude)	0.0027
Cell size (m) west-east	274.11
Cell size (m) south-north	299.70
# cells west-east	900
# cells south-north	600
Water cell area (m^2)	82,149.81
Shore cell length (m)	286.62
Shore cell width – Rocky shore (m)	1.0
Shore cell width – Artificial shore (m)	1.0
Shore cell width – Gravel beach (m)	5.0
Shore cell width – Sand beach (m)	5.0
Shore cell width – Mud flat (m)	20.0
Shore cell width – Wetlands (fringing, m)	50.0

Table D-I.4-5. Water temperature by month of the year (from French et al., 1996b).

Month	Surface Water Temperature (°C)	Bottom Water Temperature (°C)	Pycnocline Depth (m)
January	24	17	10
February	25	17	10
March	25	17	10
April	26	20	10
May	27	20	10
June	28	20	10
July	29	23	5
August	30	23	5
September	29	23	5
October	28	21	10
November	27	21	10
December	25	21	10

Table D-I.4-6. Wind data sources and records used.

File Name	Location	Latitude Longitude	Dates	Data Source
SMKF1_1988-2002.WNE	Station SMKF1 - Sombrero Key, FL	24.63 N 81.11 W	1988 - 2002	National Data Buoy Center
	Station LONF1 - Long Key, FL	24.84 N 80.86 W	1995-1998	National Data Buoy Center
	Station MLRF1 - Molasses Reef, FL	25.01 N 80.38 W	1989- 1991	National Data Buoy Center

The SMKF1_1988-2002.WNE wind data were downloaded from 3 buoys SMKFI, LONF1 and MLRF1. Figure D-I.4-1 displays where each buoy is located. The majority of the wind data is from Buoy SMKF1. Missing or bad data in buoy SMKF1 was filled from buoy LONF1 and MLRF1. Buoy MLRF1 filled: 24 June 1990 to 19 July 1990; 18 October 1990 to 30 October 1990; and 21 December 1990 to 26 February 1991. Buoy LONF1 filled: 3 September 1997 to 26 September 1997; 31 January 1998; 31 March 1998; 30 April 1998 and 27 October 1998.

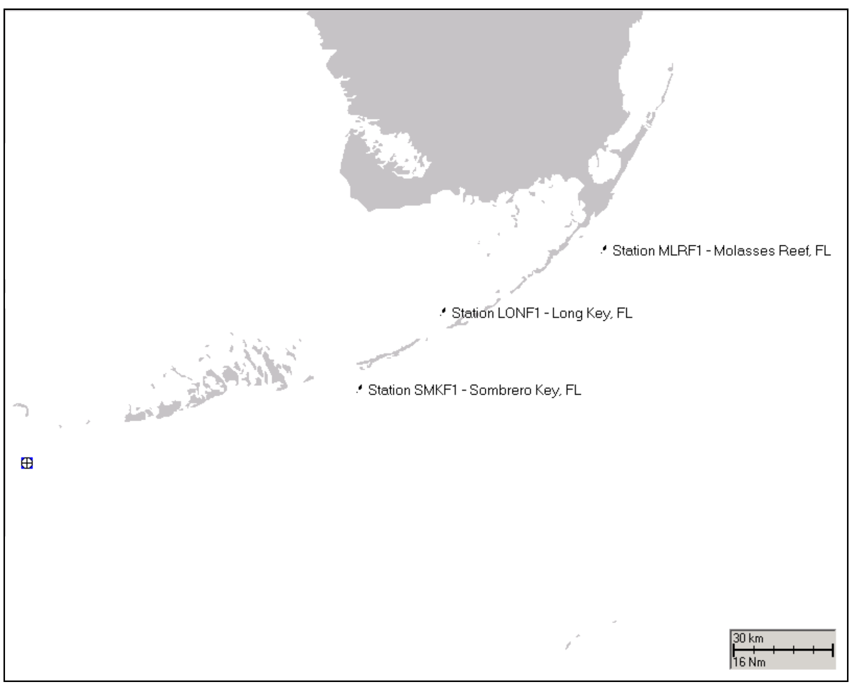

Figure D-I.4-1. Wind Station Locations. (The crosshair mark ( ) represents the oil spill site.)

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part D: Florida Straits

Section D-II.1

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ASA 00-246

August 2004

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D-II.1 Results of the Stochastic Modeling: Maps of Exposure Probability, Time and Maximum Possible Mass and Concentration

The results of multiple model runs are evaluated to develop the following statistics, for each location (cell in the model grid) and for each exposure index. Maps of the results are contained in this section.

- Probability of exposure greater than the minimum threshold (probability that the minimum threshold thickness or concentration will be exceeded at each location at any time following the spill). For surface oil, the model records if any oil of greater than that thickness passes through the grid cell, regardless of the areal coverage of the oil. For concentrations, the average concentration in the grid cell is used to determine if the threshold is exceeded.
- Time (hours) to first exceedance of the minimum threshold at each location
- Worst-case maximum exposure (thickness, volume or concentration) at any time after the spill, at a given location (peak exposure at each location delineated by the grid cells). The amounts are averaged over the area of the model grid cell. The worst-case maximum amount is for all possible releases (i.e., maximum peak exposure for all the model runs). This is calculated in two steps: (1) For each individual run (for each spill date run), the maximum amount over all time after the spill is saved for each location in the model grid. (2) The runs are evaluated to determine the highest amount possible at each location. Note that these *worst-case maximum* amounts are not additive over all locations. These represent maximum possible amounts of oil that could ever reach each site (grid cell), considered individually, and based on the model runs performed. Thus, "worst-case" represents the highest exposure of the most adverse of the runs performed.

Exposure indices and minimum thresholds (i.e., those less than values that might have an impact on any resource) used in the modeling were:

- Surface slick or floating oil: $\geq$ 0.01 g/m^2 (average thickness $\geq$ 0.01 micron)
- Shoreline: average mass loading over the shore segment (length of one grid cell, calculated as the cell diagonal length, times the typical width for the habitat type) $\geq$ 0.01 g/m^2
- Dissolved aromatics: average over the water cell $\geq$ 1 ppb (1 mg/m^3)
- Subsurface oil (entrained in water): average over the water cell $\geq$ 10 ppb (10 mg/m^3)
- Sediment total hydrocarbons: average over the cell $\geq$ 0.0001 g/ m^2
- Sediment dissolved aromatic concentrations: average over the cell $\geq$ 0.0001 g/ m^2 (which is 1.0 mg/m^3 = 1ppb averaged over the top 10 cm, the assumed bioturbation zone)

Discussion of exposure indices and minimum thresholds are described in Part A: Description of Models and Assumptions and Section 4.3 of the PEIS.

The Crosshair mark (⊞) in figures below represents oil spill site.

D-II.1.1 Scenario: Medium Volume, No Dispersant

D-II.1.1.1 Surface Floating Total Hydrocarbons. Scenario: Medium Volume, No Dispersant

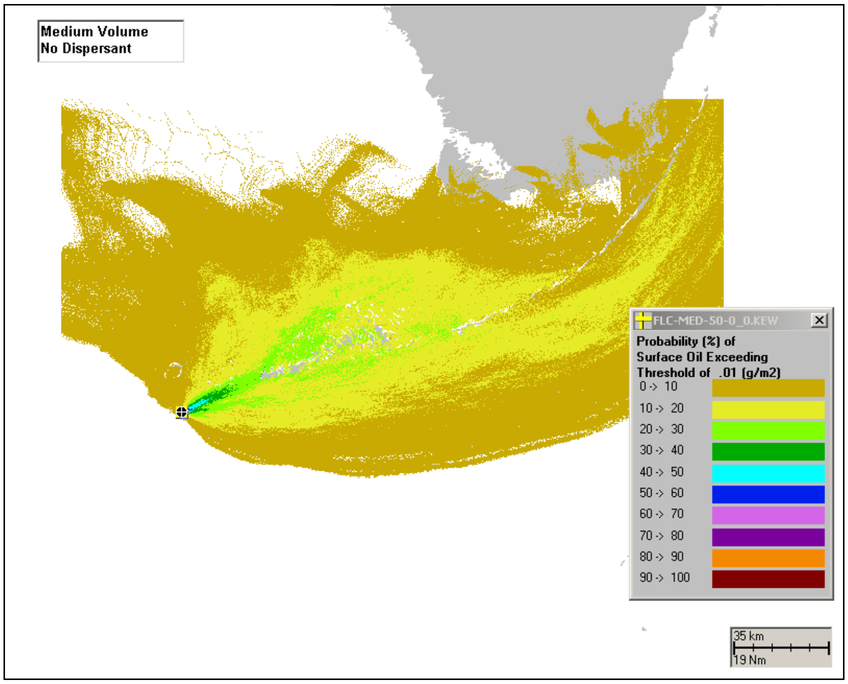

Figure D-II.1.1.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Medium Volume, No Dispersant.

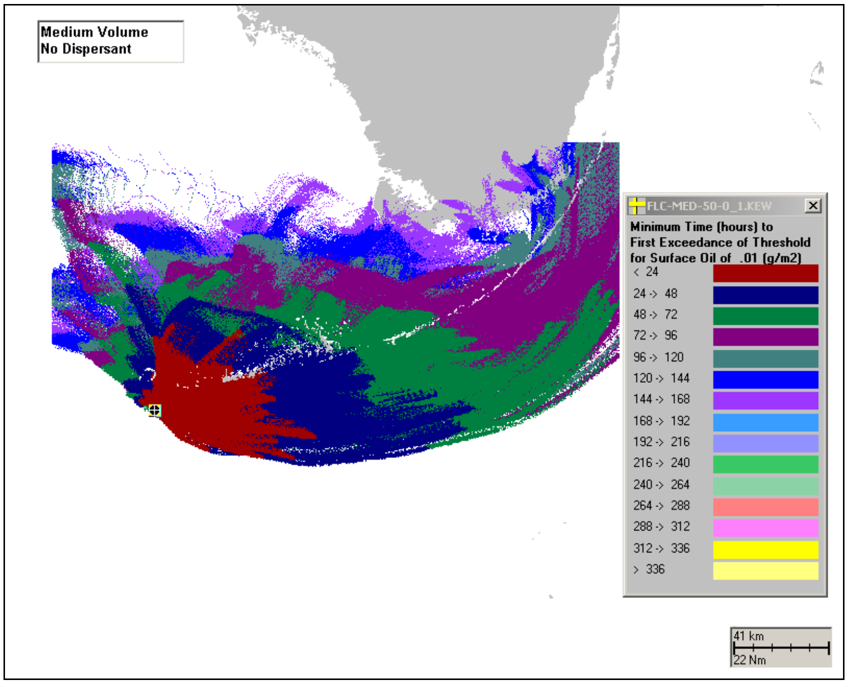

Figure D-II.1.1.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Medium Volume, No Dispersant.

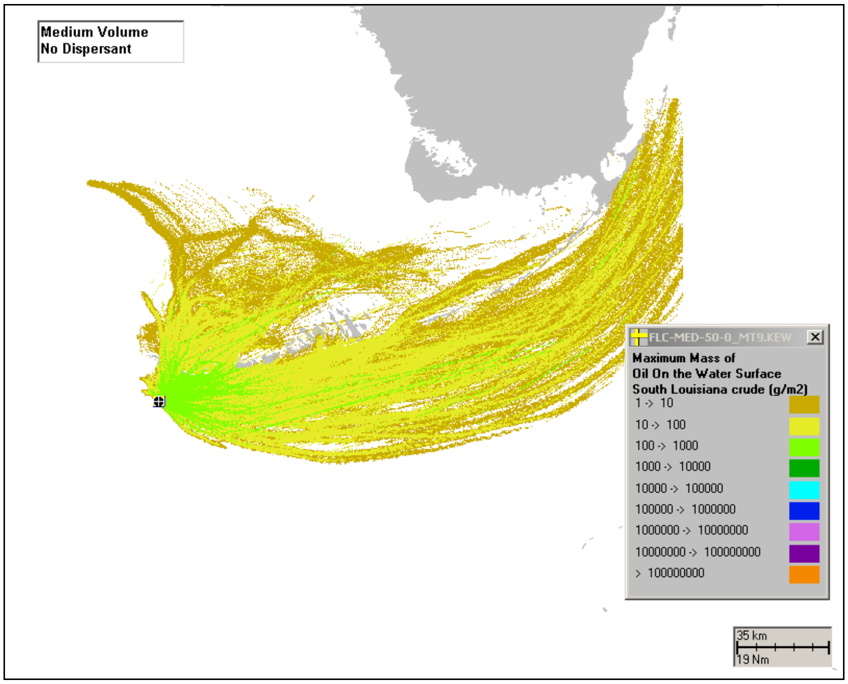

Figure D-II.1.1.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

D-II.1.1.2 Shoreline Oiled. Scenario: Medium Volume, No Dispersant

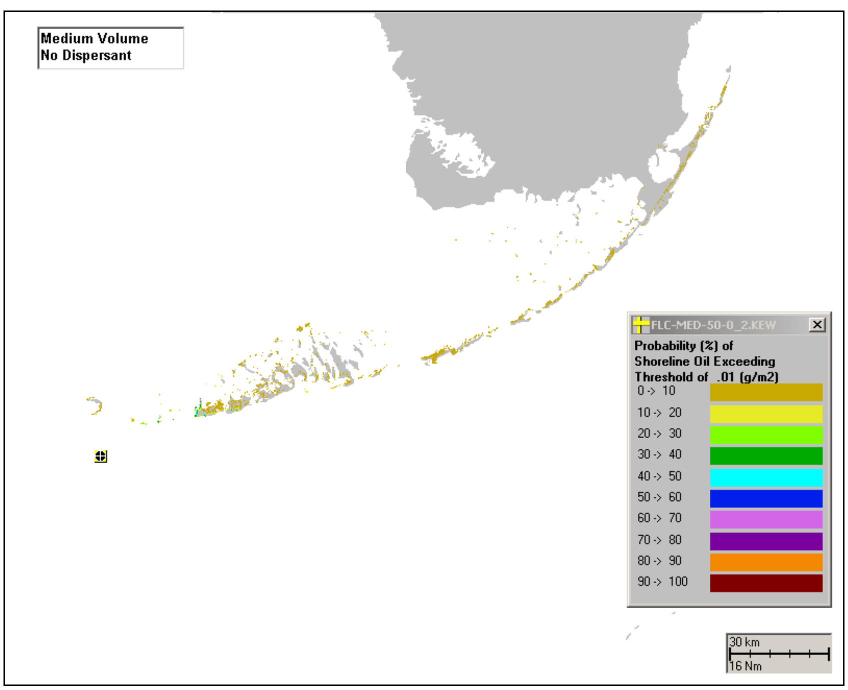

Figure D-II.1.1.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Medium Volume, No Dispersant.

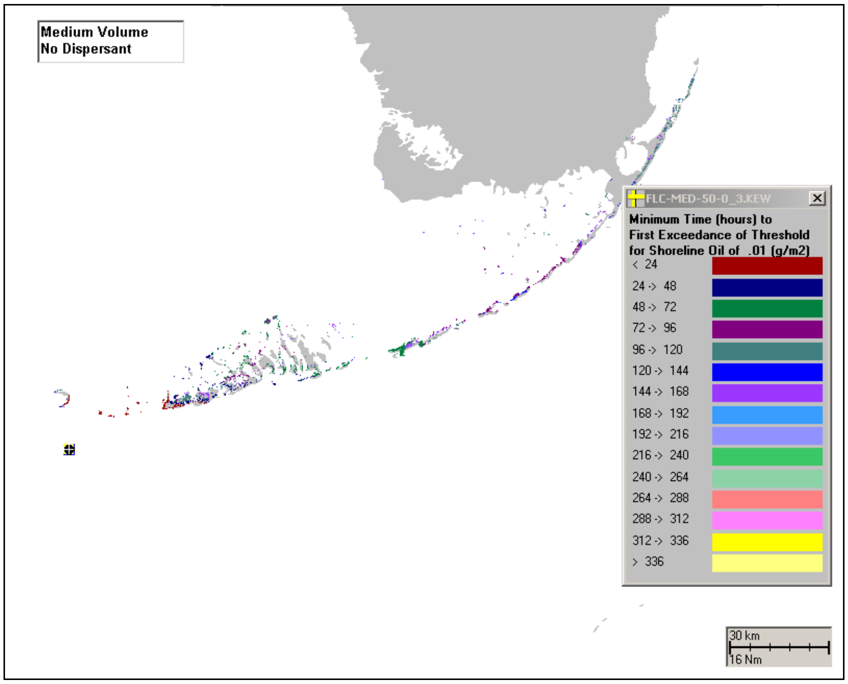

Figure D-II.1.1.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Medium Volume, No Dispersant.

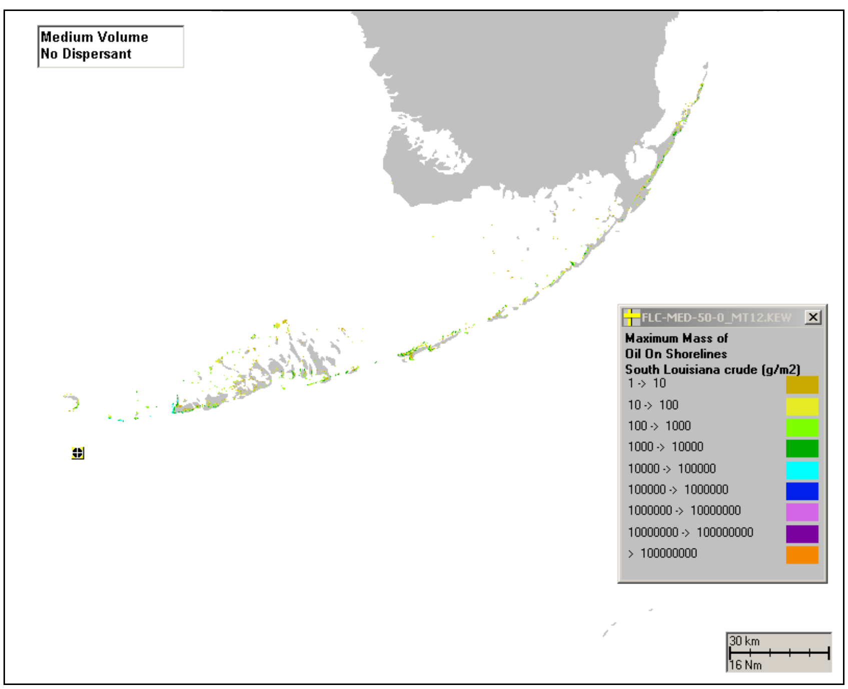

Figure D-II.1.1.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

D-II.1.1.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Medium Volume, No Dispersant

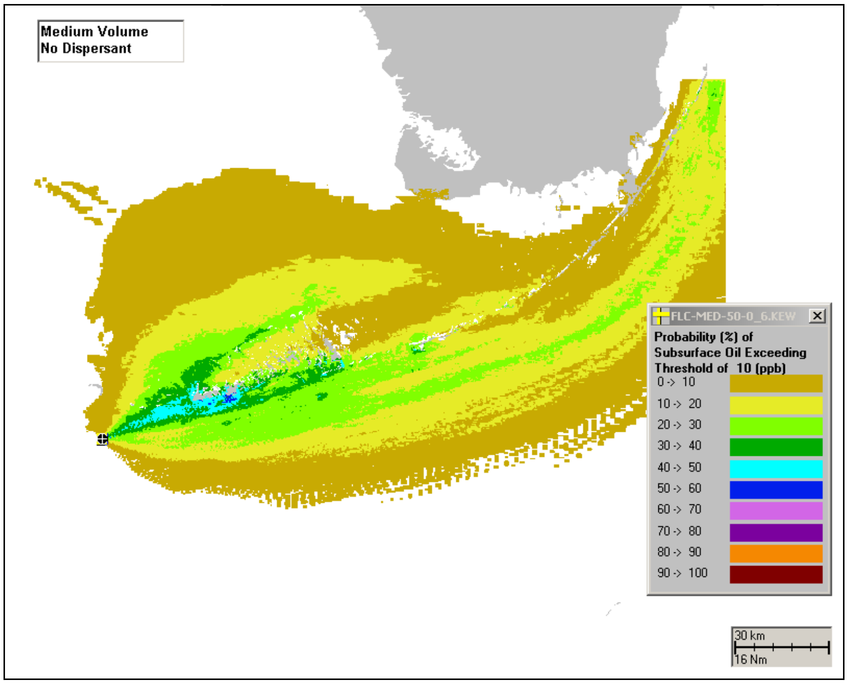

Figure D-II.1.1.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Medium Volume, No Dispersant.

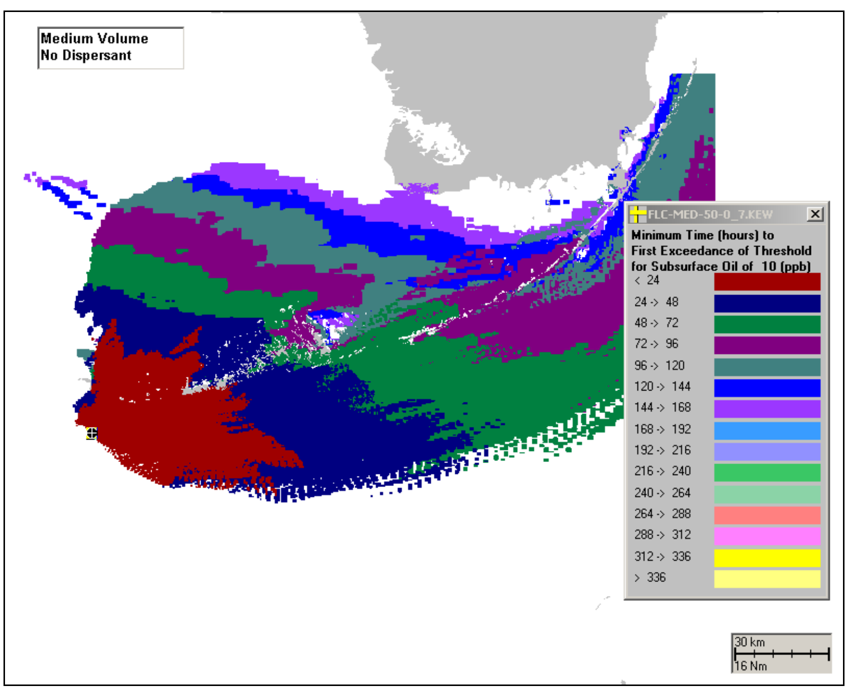

Figure D-II.1.1.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Medium Volume, No Dispersant.

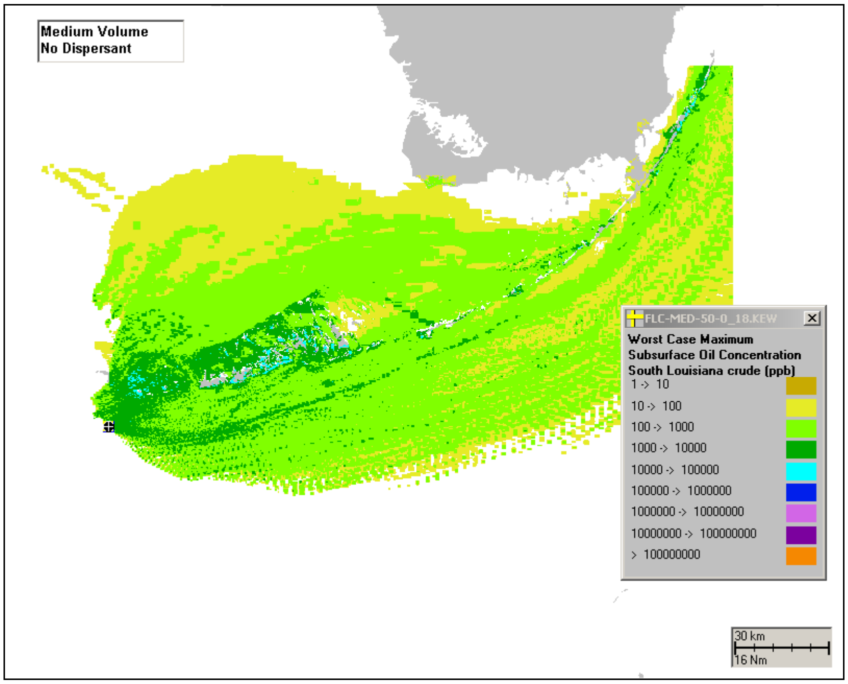

Figure D-II.1.1.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

D-II.1.1.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Medium Volume, No Dispersant

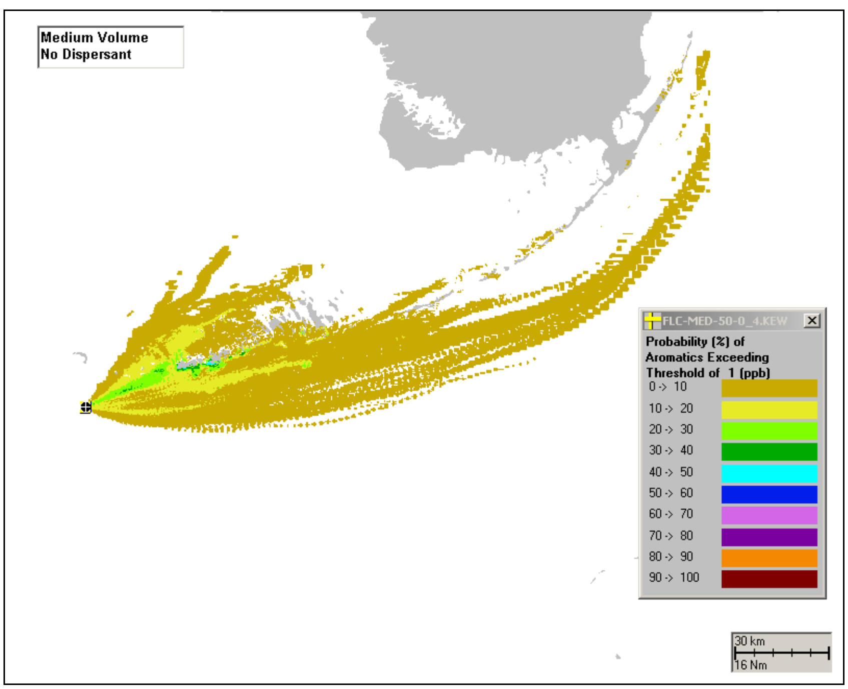

Figure D-II.1.1.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, No Dispersant.

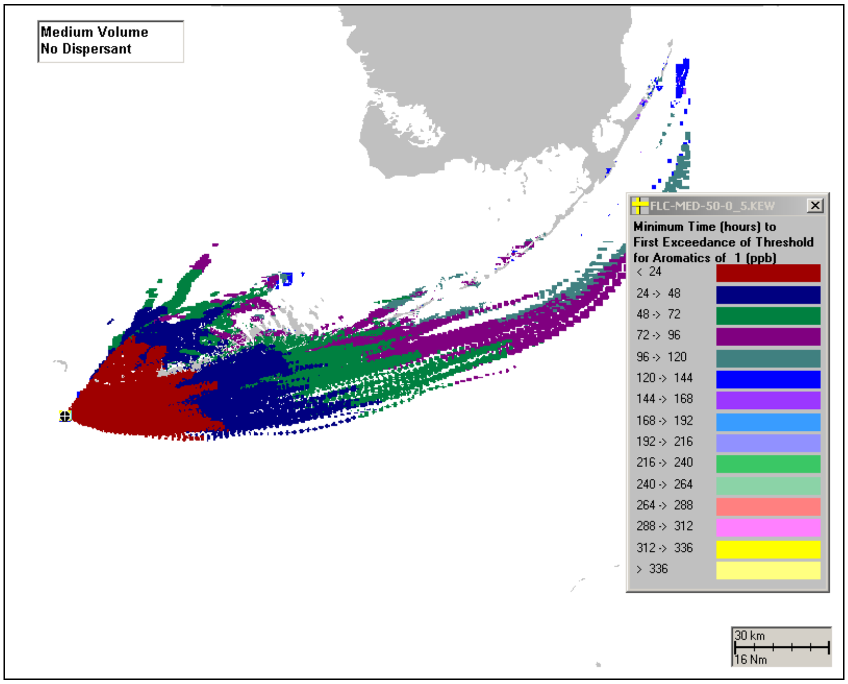

Figure D-II.1.1.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Medium Volume, No Dispersant.

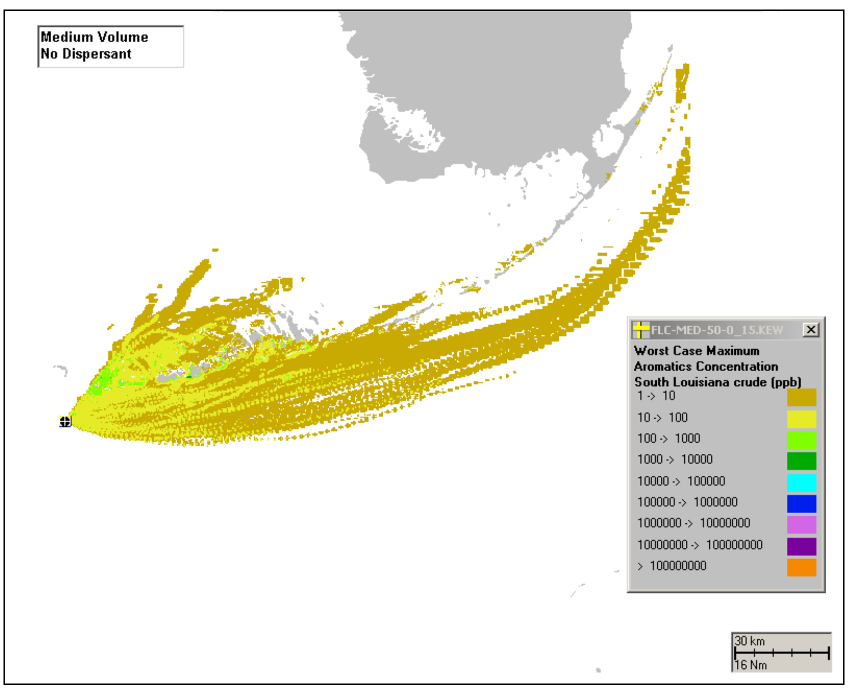

Figure D-II.1.1.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

D-II.1.1.5 Sediment exposure to total hydrocarbons (g/m²). Scenario: Medium Volume, No Dispersant

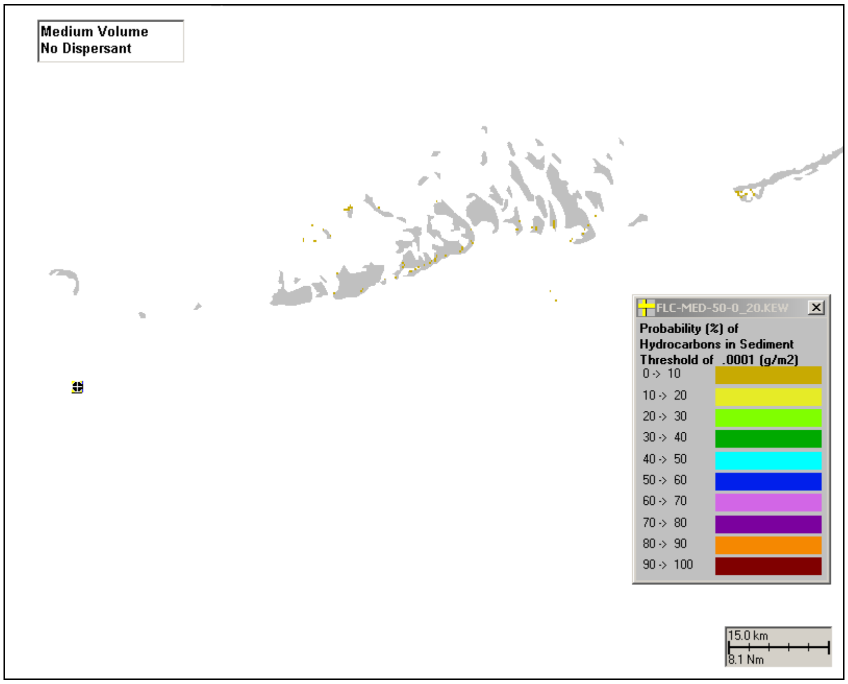

Figure D-II.1.1.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Medium Volume, No Dispersant.

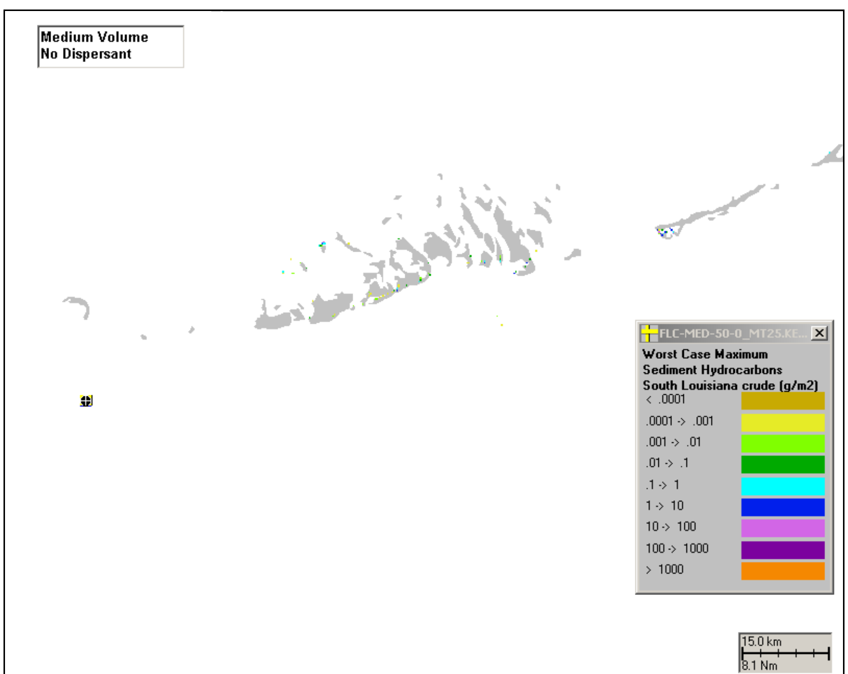

Figure D-II.1.1.5-2 Sediment exposure to total hydrocarbons (g/m²) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

D-II.1.1.6 Sediment pore water dissolved aromatic concentrations. Scenario: Medium Volume, No Dispersant

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time and for any of the 100 runs) does not exceed threshold of 1 ppb. Scenario: Medium Volume, No Dispersant.

D-II.1.2 Scenario: Medium Volume, 45% Dispersant Efficiency

D-II.1.2.1 Surface Floating Total Hydrocarbons. Scenario: Medium Volume, 45% Dispersant Efficiency

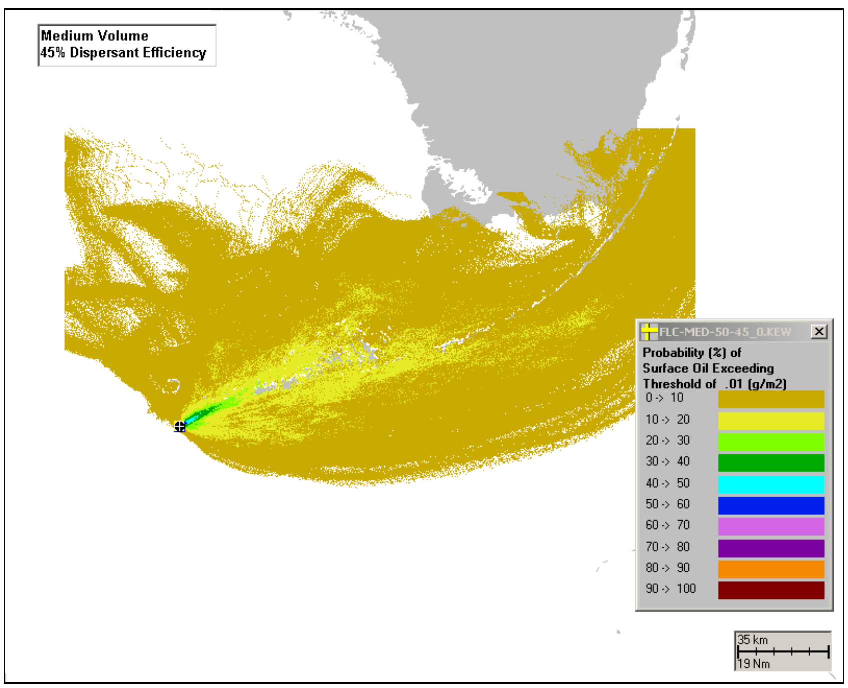

Figure D-II.1.2.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

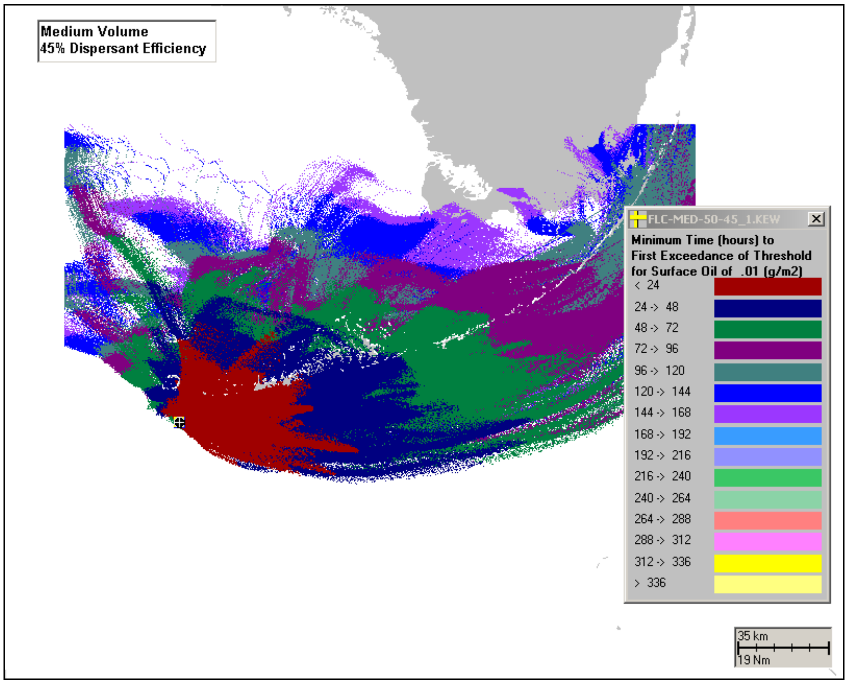

Figure D-II.1.2.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

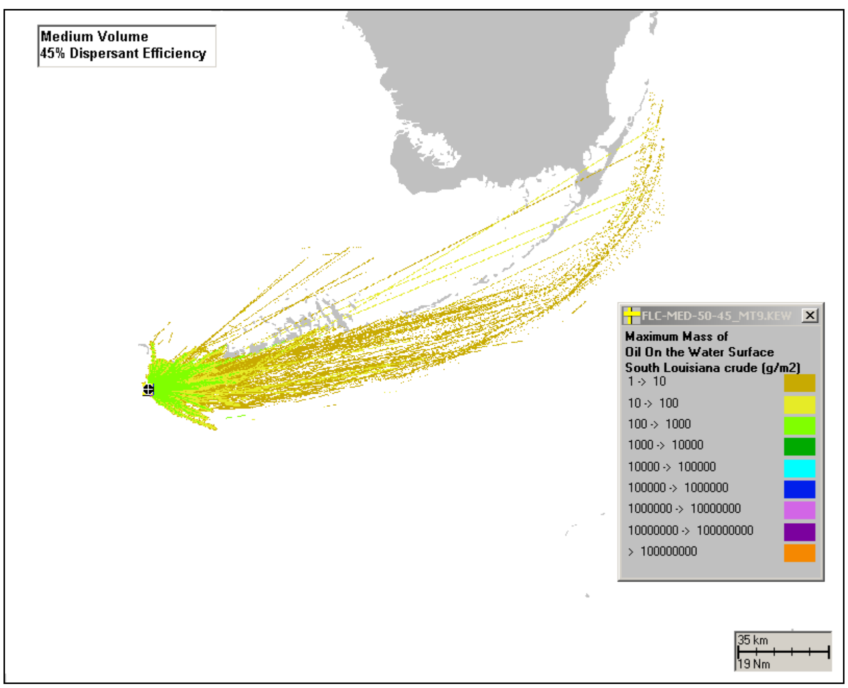

Figure D-II.1.2.1-.3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

D-II.1.2.2 Shoreline Oiled. Scenario: Medium Volume, 45% Dispersant Efficiency.

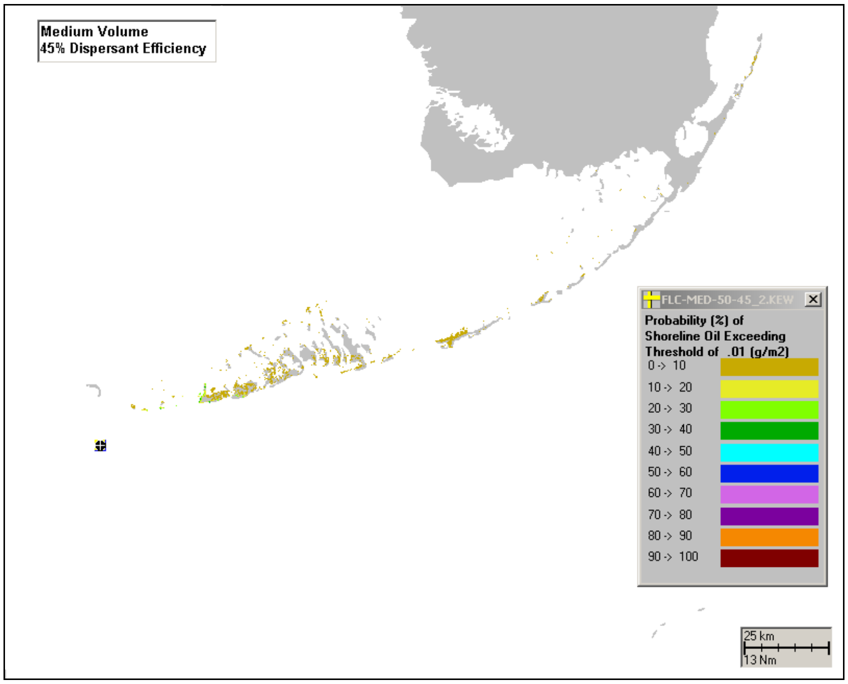

Figure D-II.1.2.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

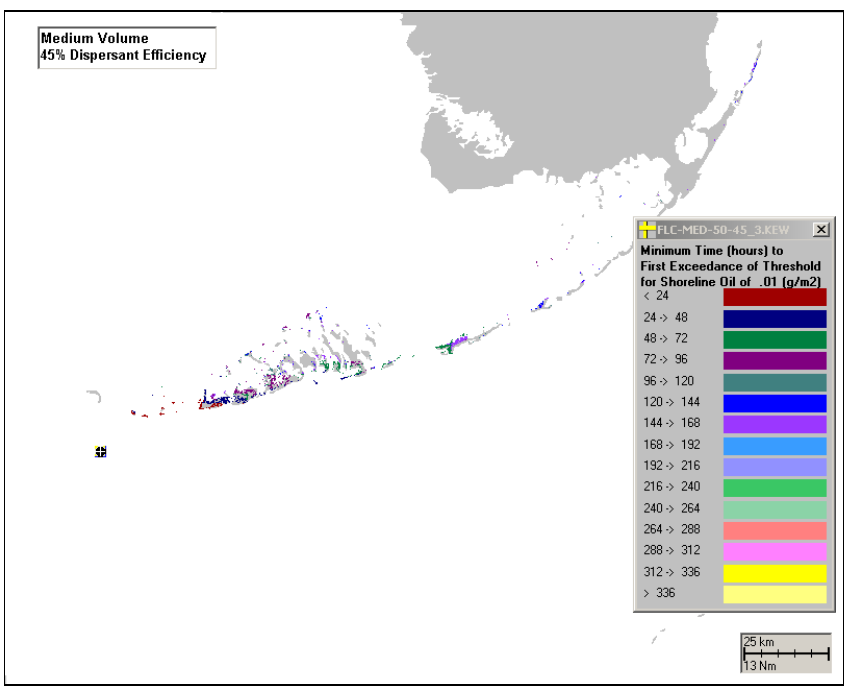

Figure D-II.1.2.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

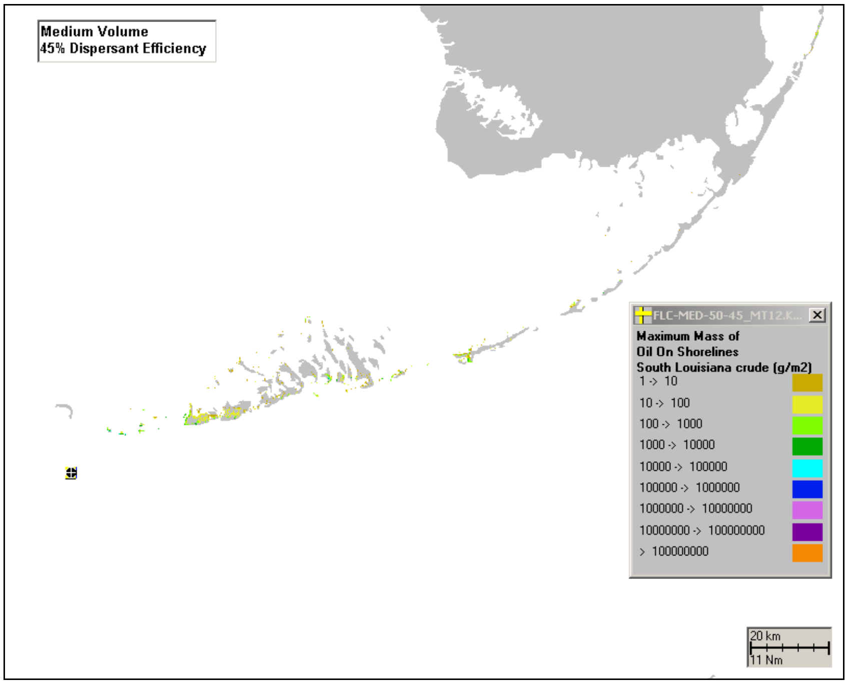

Figure D-II.1.2.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

D-II.1.2.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Medium Volume, 45% Dispersant Efficiency

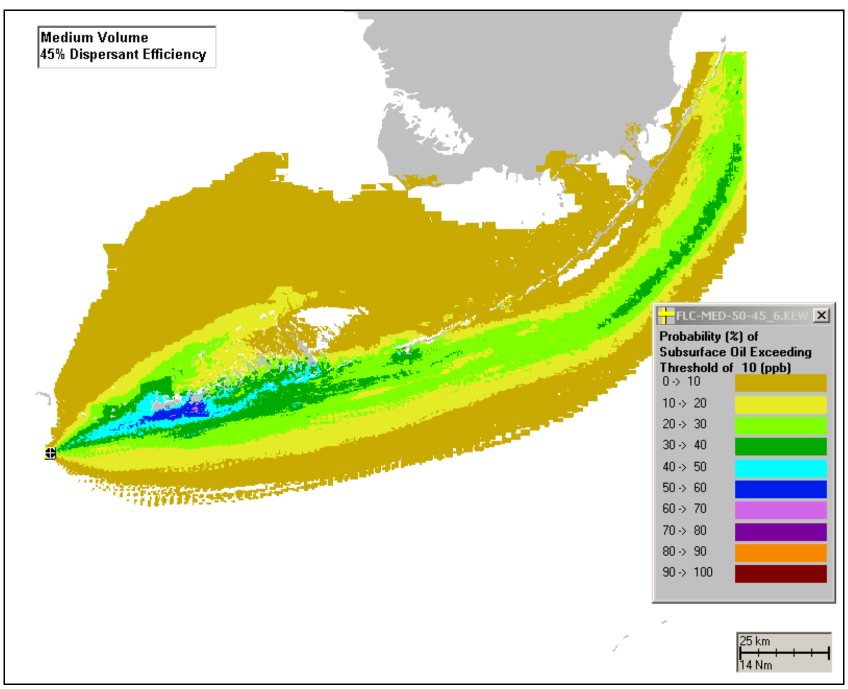

Figure D-II.1.2.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

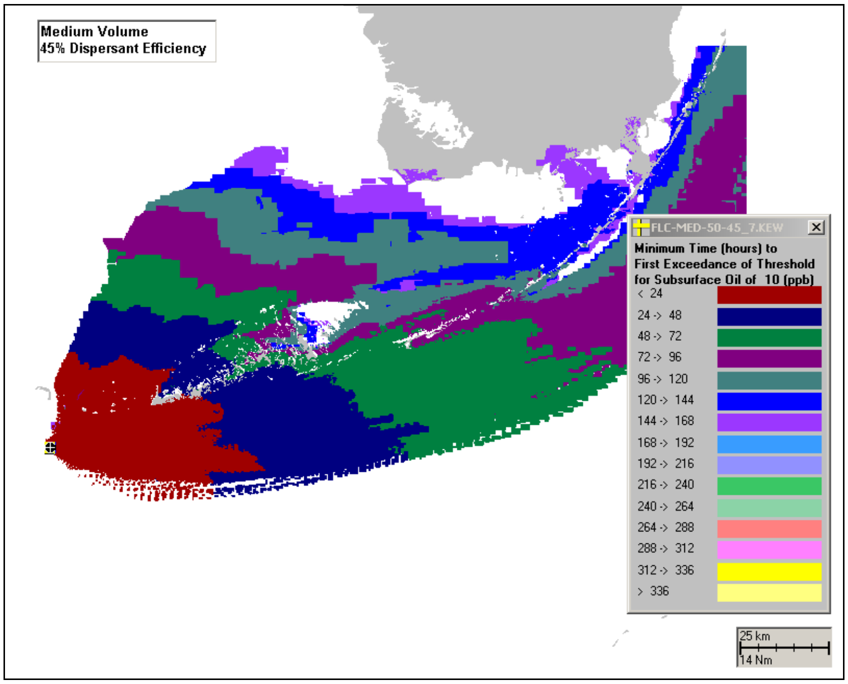

Figure D-II.1.2.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

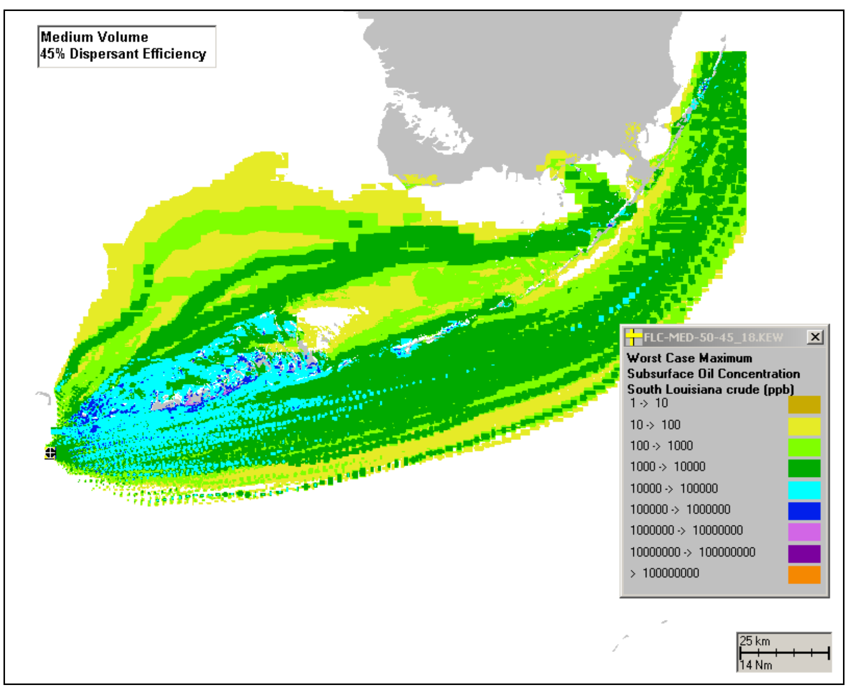

Figure D-II.1.2.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

D-II.1.2.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Medium Volume, 45% Dispersant Efficiency

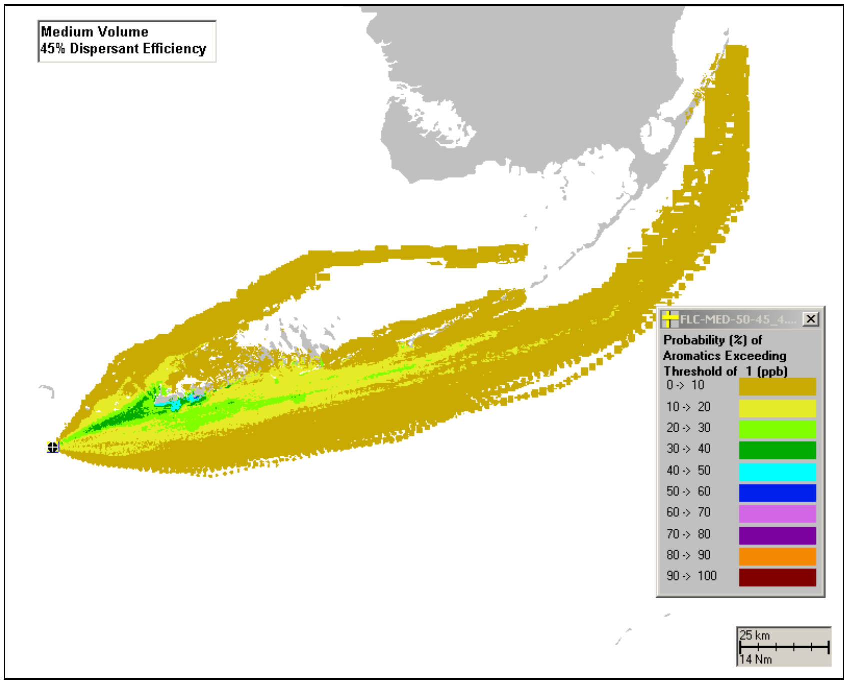

Figure D-II.1.2.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

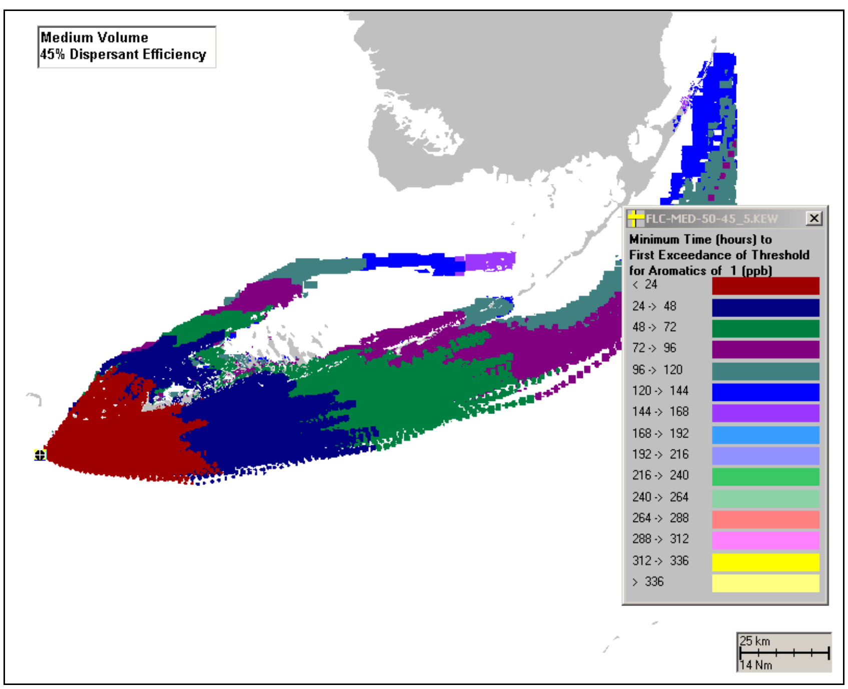

Figure D-II.1.2.4-2 Time (hrs) after spill when Dissolved Aromatic Concentrations could first exceed 1ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

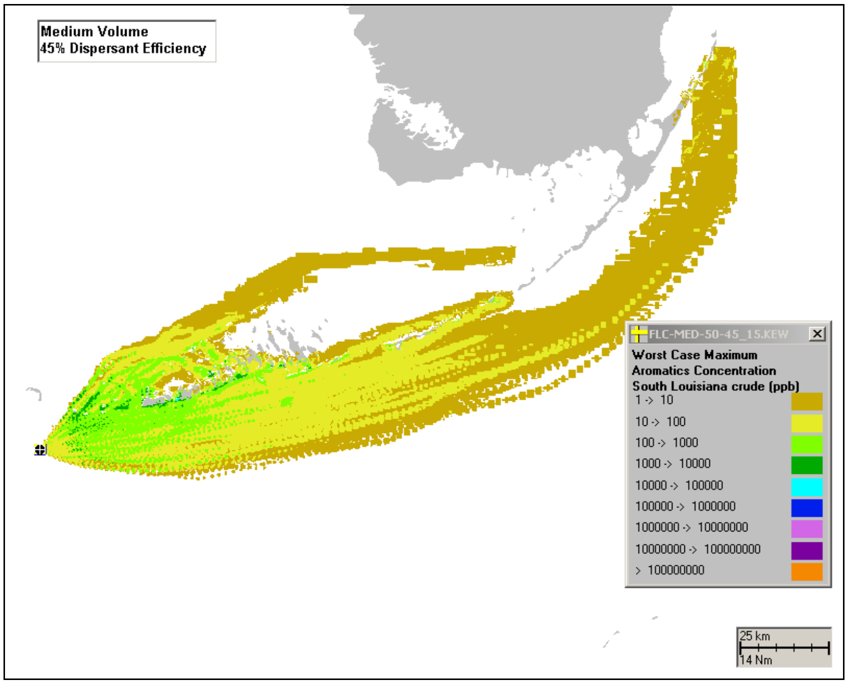

Figure D-II.1.2.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

D-II.1.2.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Medium Volume, 45% Dispersant Efficiency

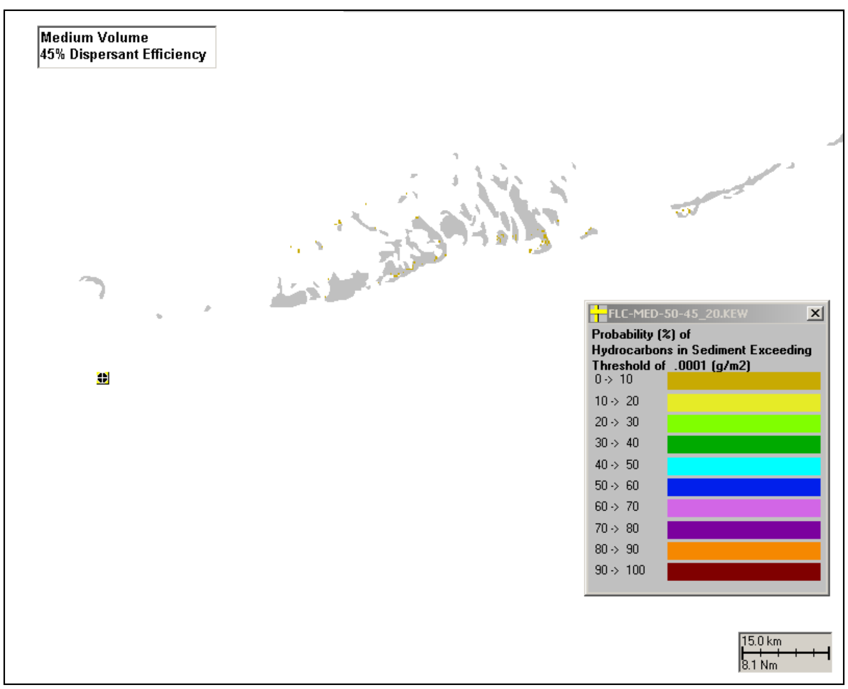

Figure D-II.1.2.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

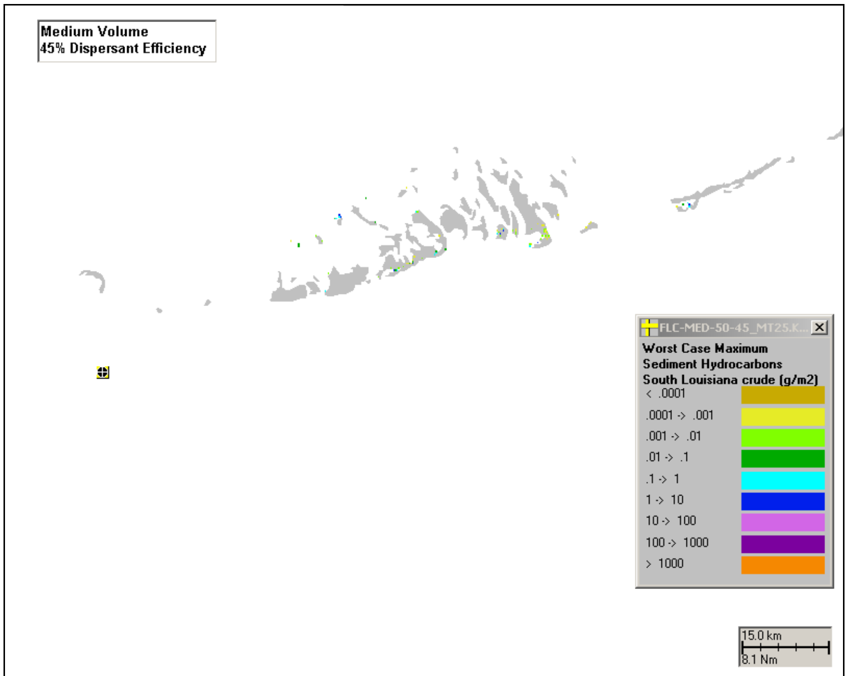

Figure D-II.1.2.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

D-II.1.2.6 Sediment pore water dissolved aromatic concentrations. Scenario: Medium Volume, 45% Dispersant Efficiency

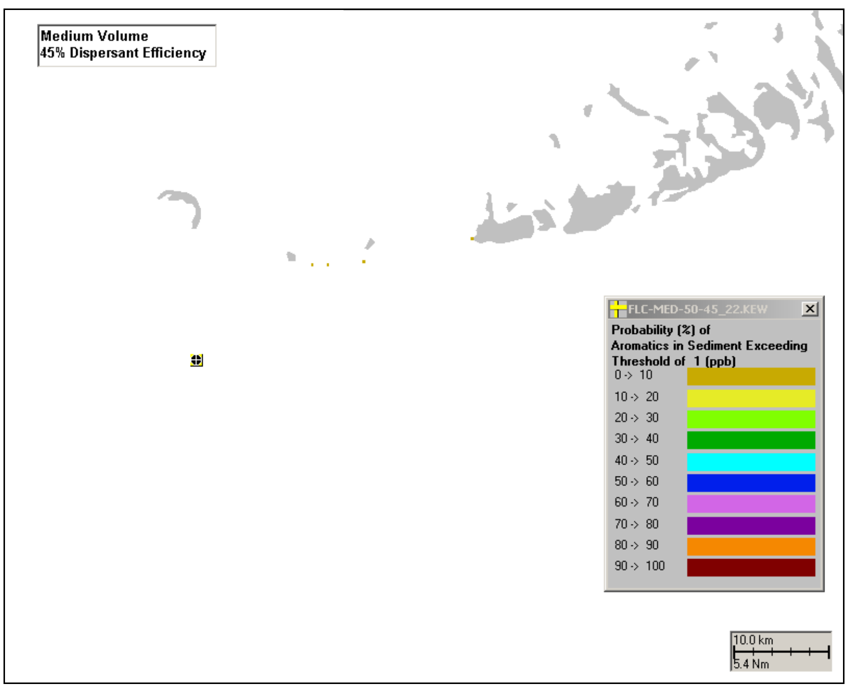

Figure D-II.1.2.6-1 Probability (%) of sediment pore water dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

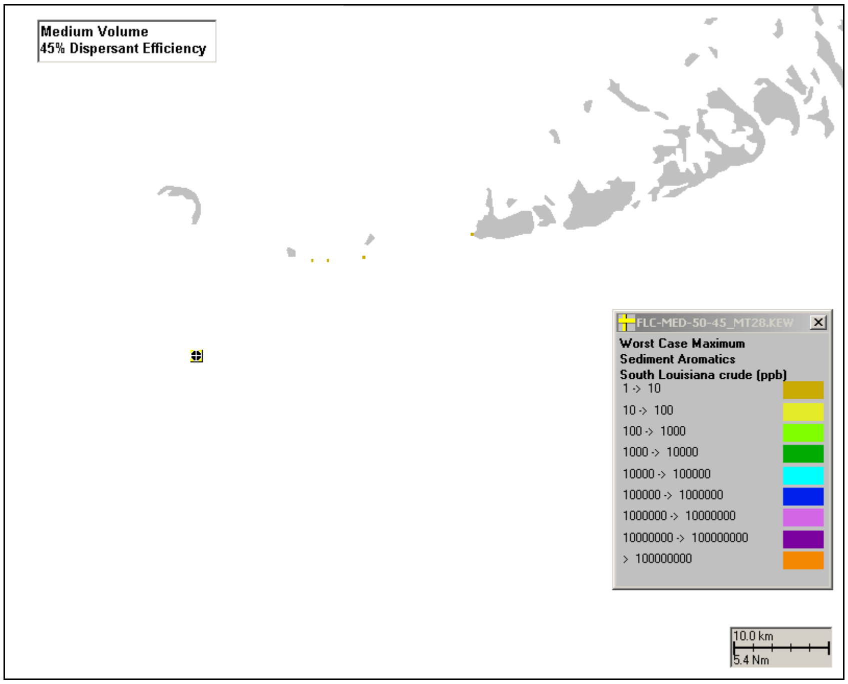

Figure D-II.1.2.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

D-II.1.3 Scenario: Medium Volume, 80% Dispersant Efficiency

D-II.1.3.1 Surface Floating Total Hydrocarbons. Scenario: Medium Volume, 80% Dispersant Efficiency.

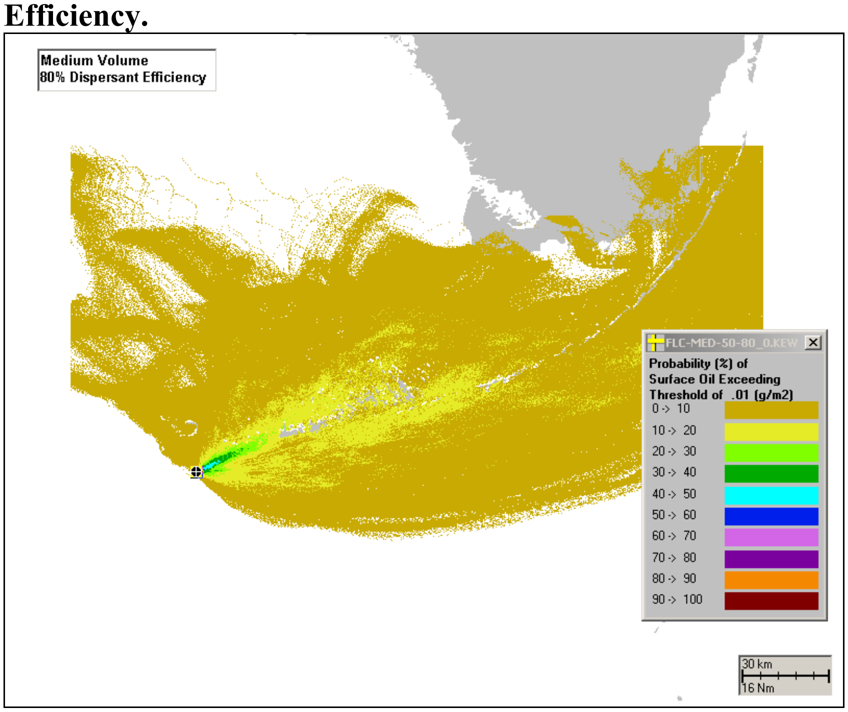

Figure D-II.1.3.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

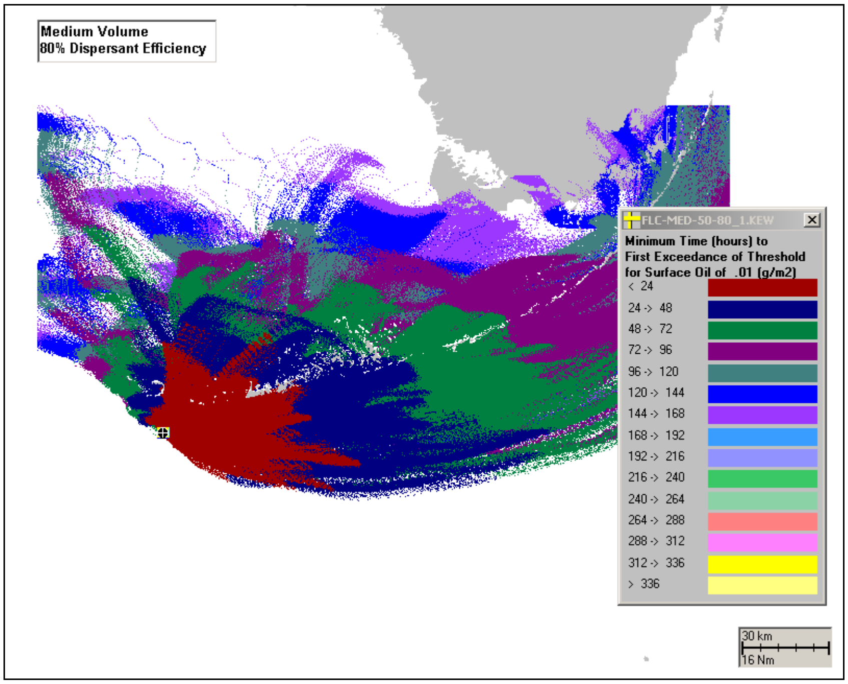

Figure D-II.1.3.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

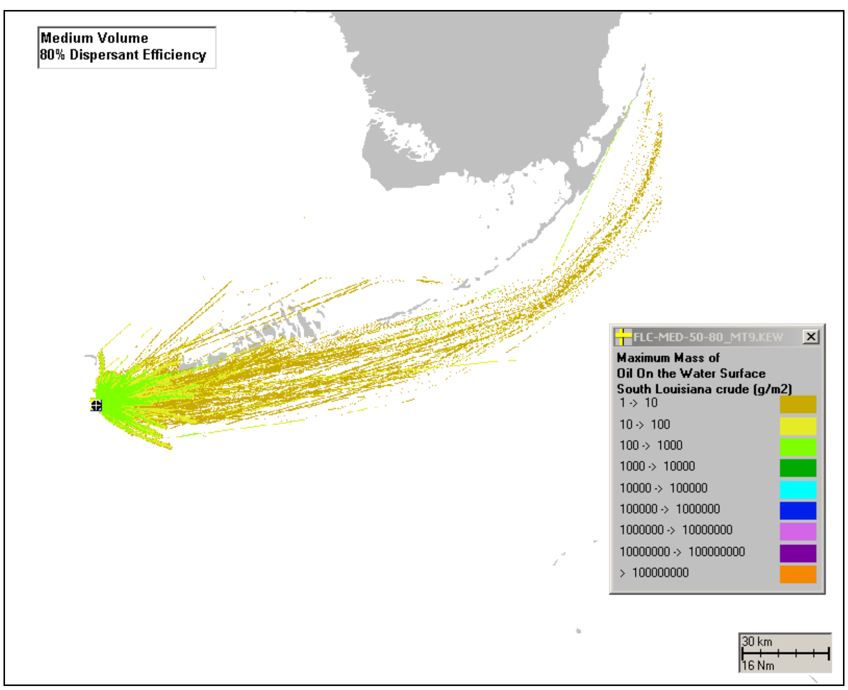

Figure D-II.1.3.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

D-II.1.3.2 Shoreline Oiled. Scenario: Medium Volume, 80% Dispersant Efficiency

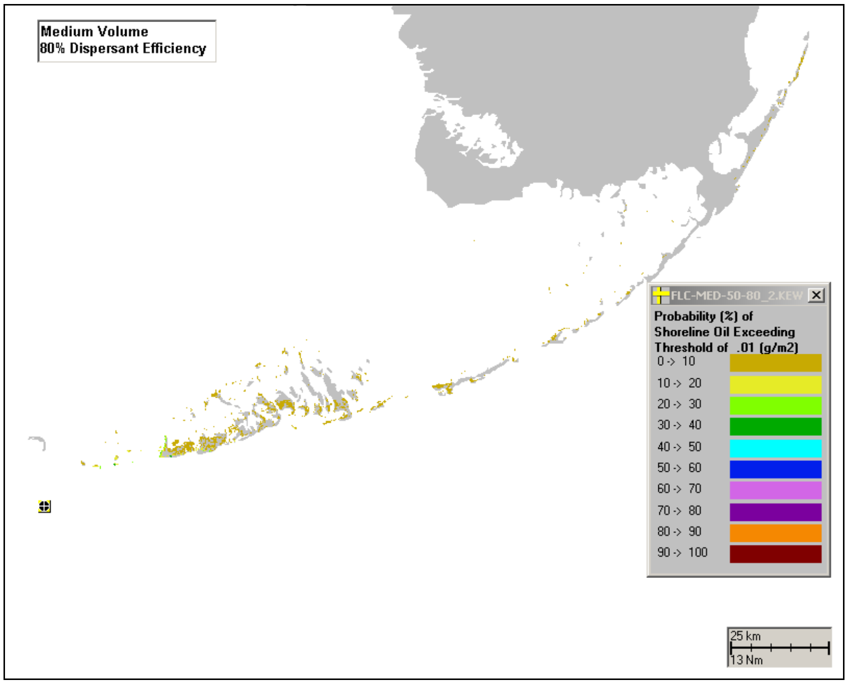

Figure D-II.1.3.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

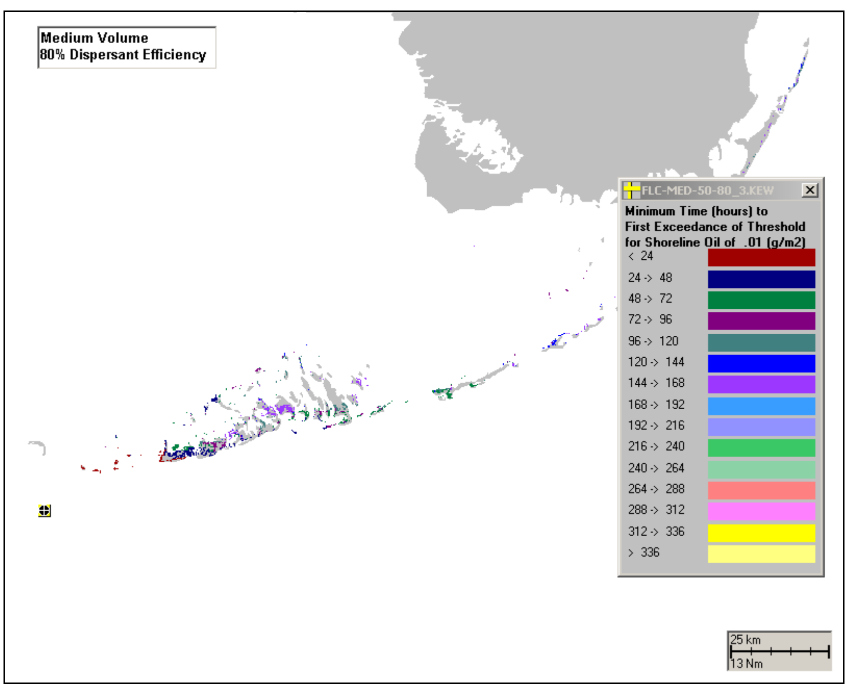

Figure D-II.1.3.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

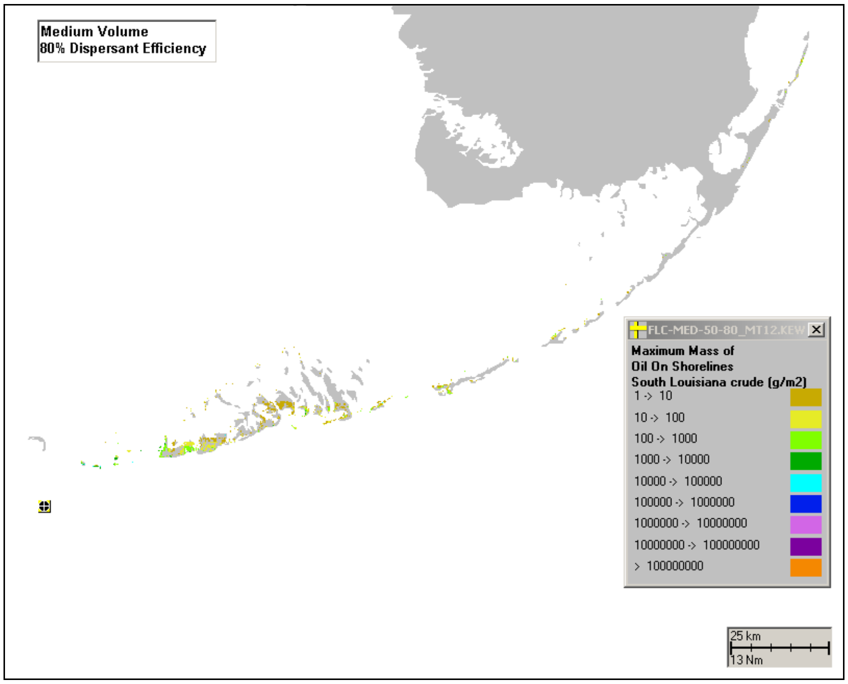

Figure D-II.1.3.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

D-II.1.3.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Medium Volume, 80% Dispersant Efficiency

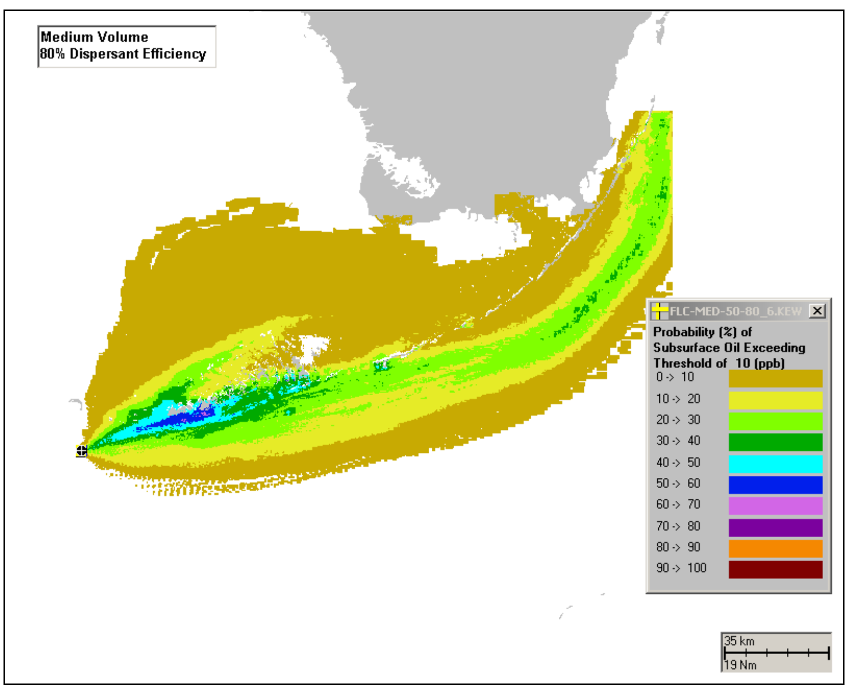

Figure D-II.1.3.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

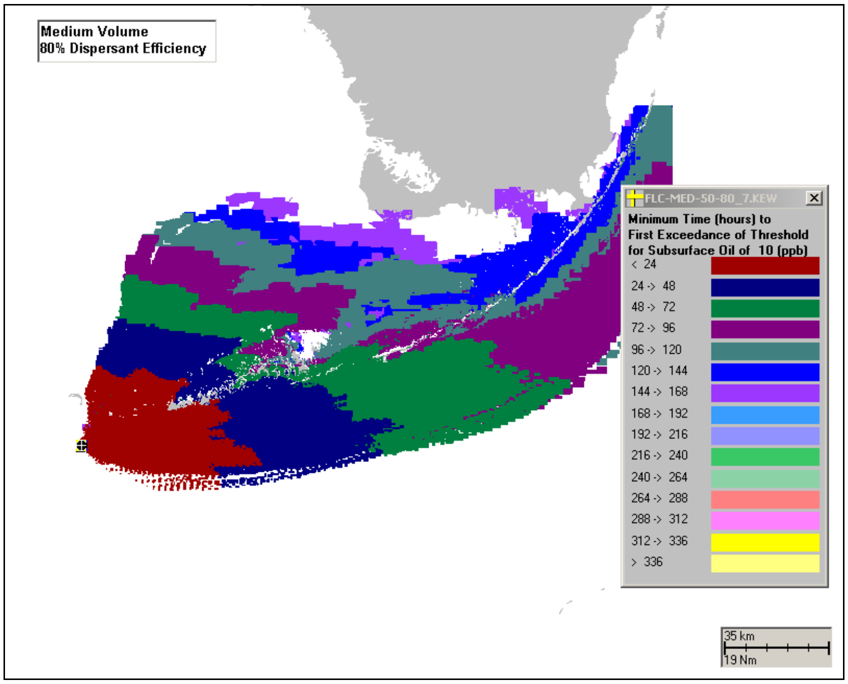

Figure D-II.1.3.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

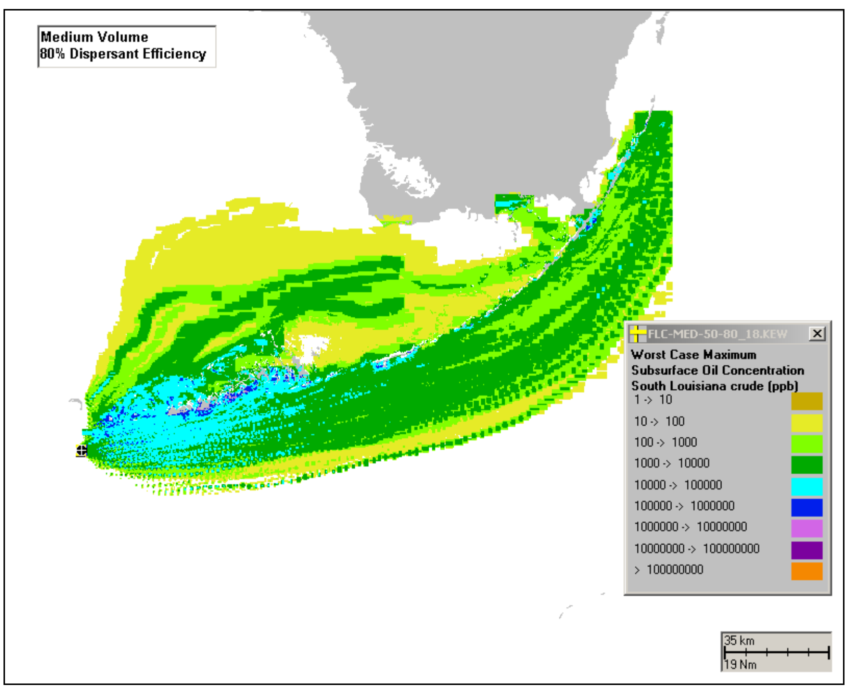

Figure D-II.1.3.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

D-II.1.3.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Medium Volume, 80% Dispersant Efficiency

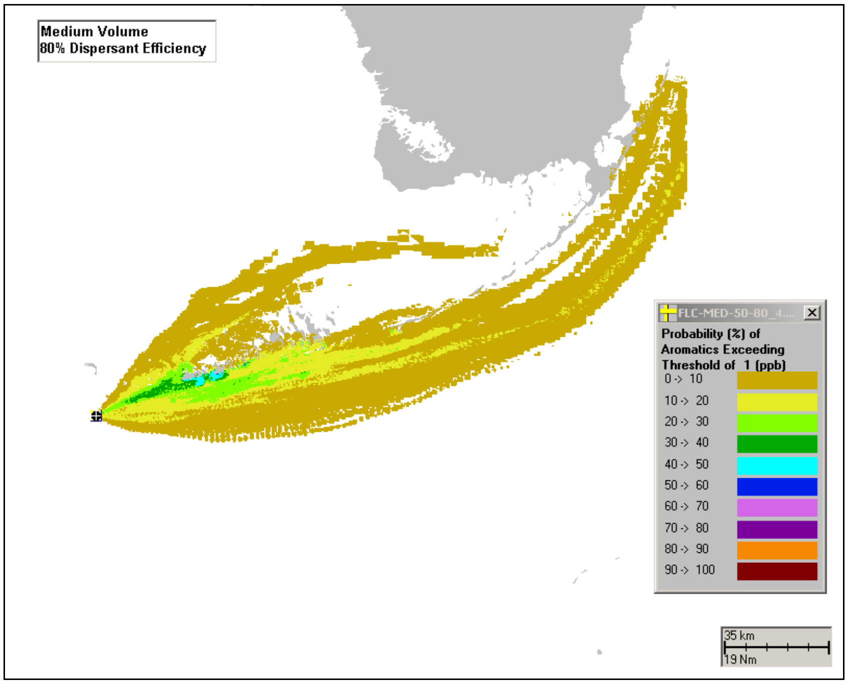

Figure D-II.1.3.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

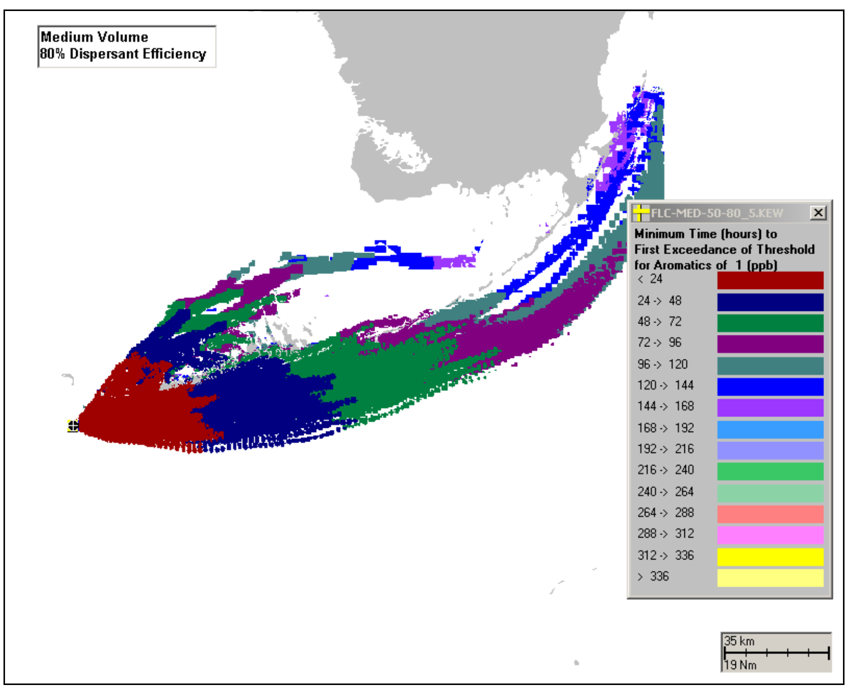

Figure D-II.1.3.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

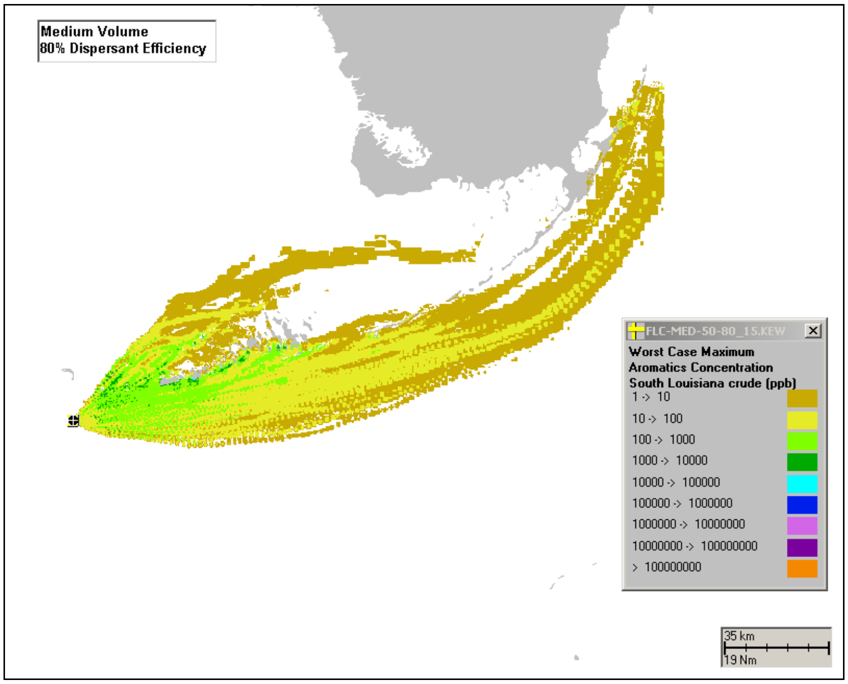

Figure D-II.1.3.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

D-II.1.3.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Medium Volume, 80% Dispersant Efficiency

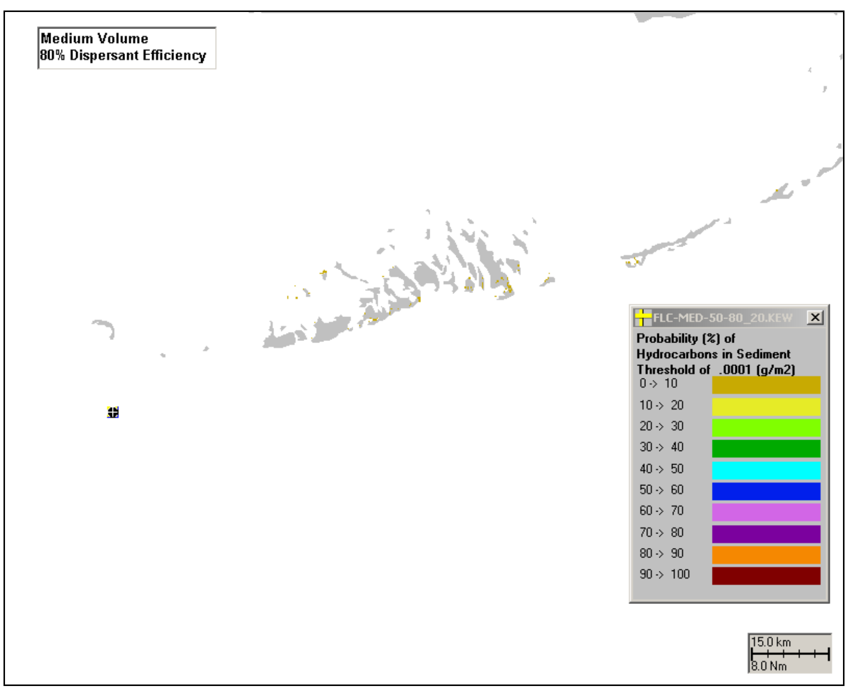

Figure D-II.1.3.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

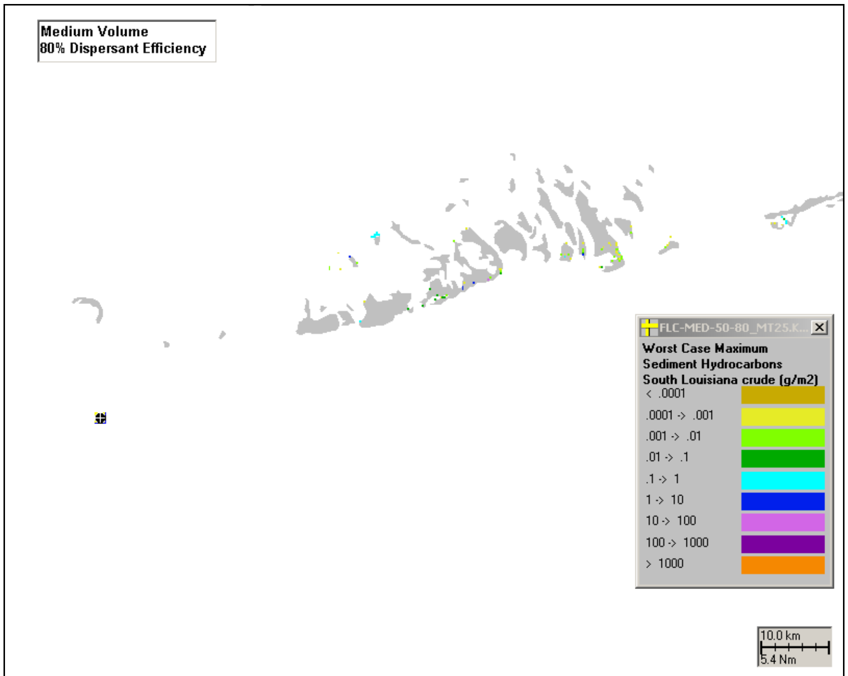

Figure D-II.1.3.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

D-II.1.3.6 Sediment pore water dissolved aromatic concentrations. Scenario: Medium Volume, 80% Dispersant Efficiency

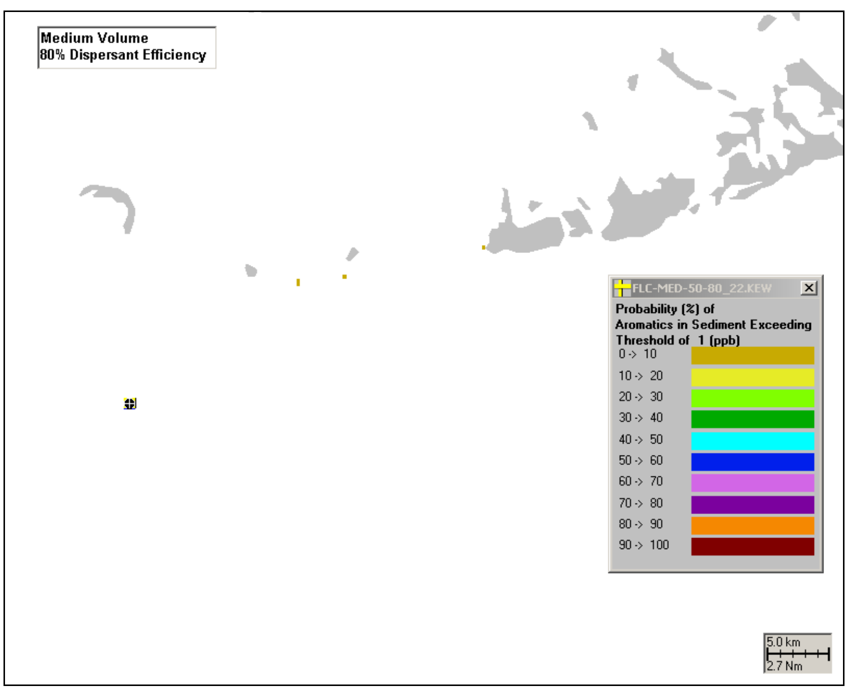

Figure D-II.1.3.6-1 Probability (%) of sediment pore water dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

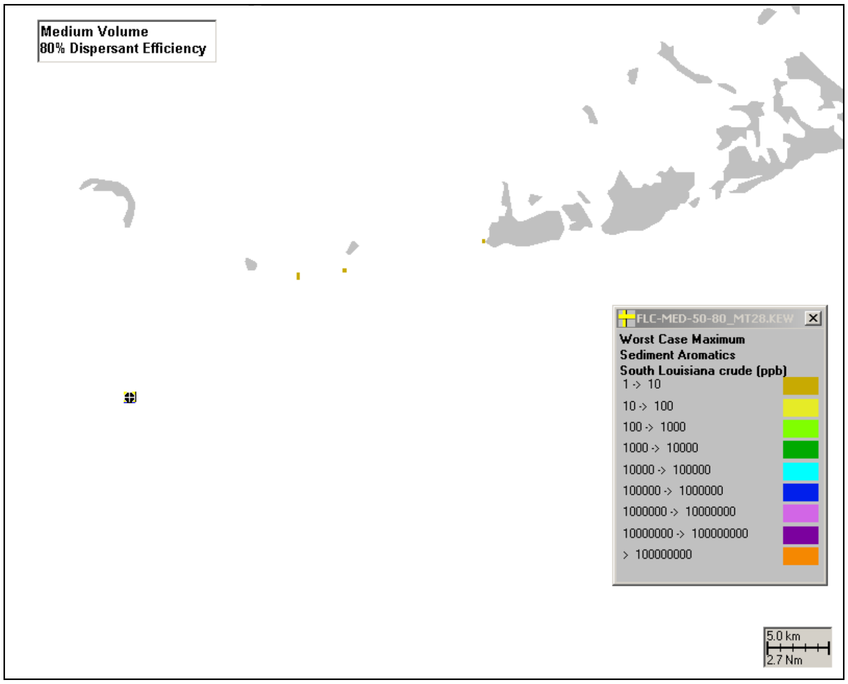

Figure D-II.1.3.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

D-II.1.4 Scenario: Large Volume, No Dispersant

D-II.1.4.1 Surface Floating Total Hydrocarbons. Scenario: Large Volume, No Dispersant

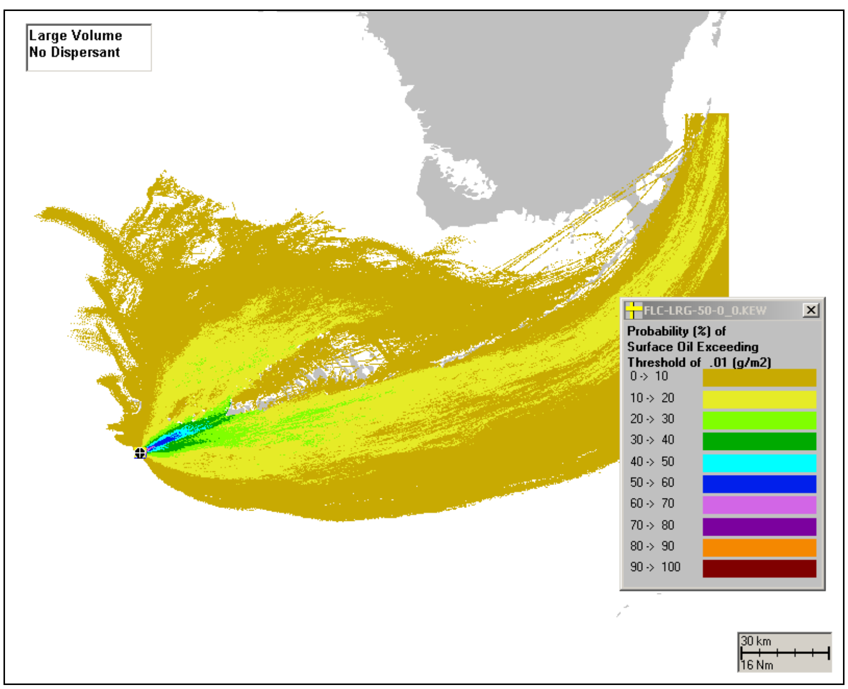

Figure D-II.1.4.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Large Volume, No Dispersant.

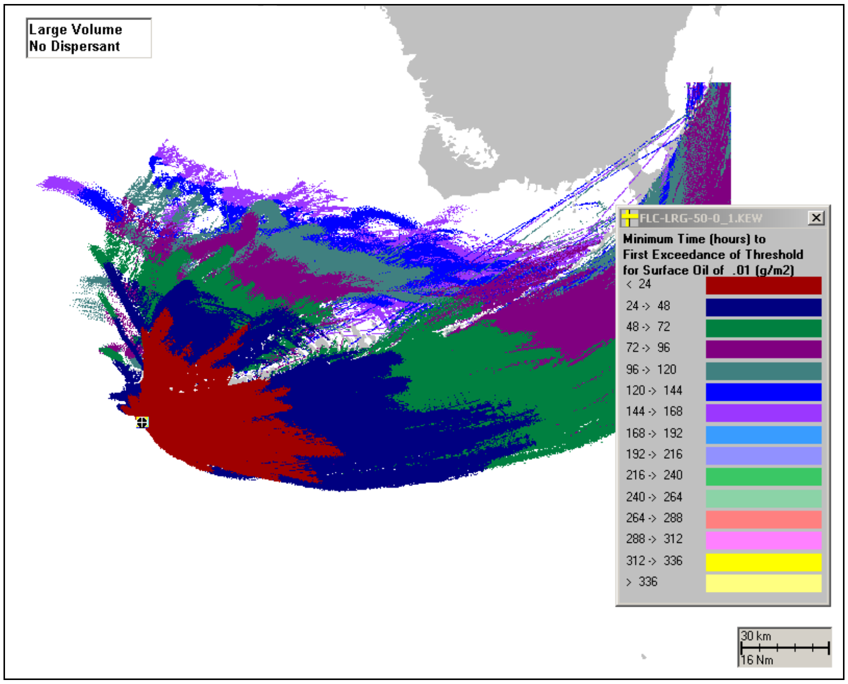

Figure D-II.1.4.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Large Volume, No Dispersant.

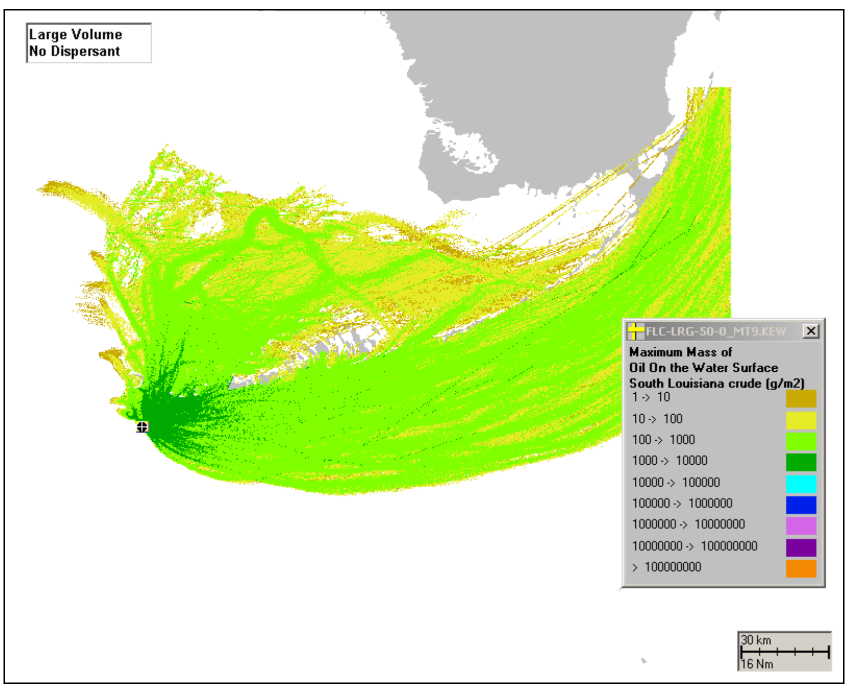

Figure D-II.1.4.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

D-II.1.4.2 Shoreline Oiled. Scenario: Large Volume, No Dispersant

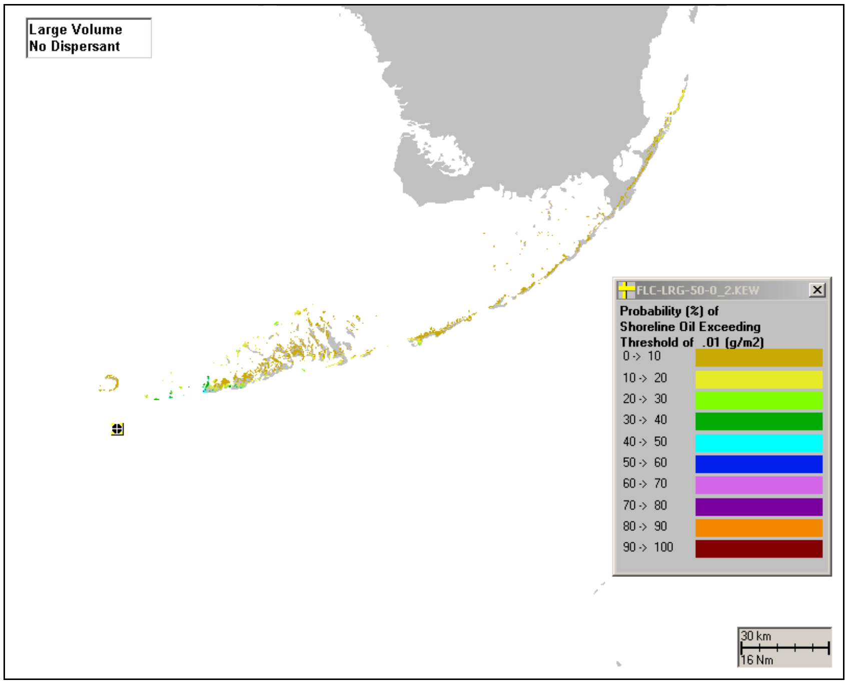

Figure D-II.1.4.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Large Volume, No Dispersant.

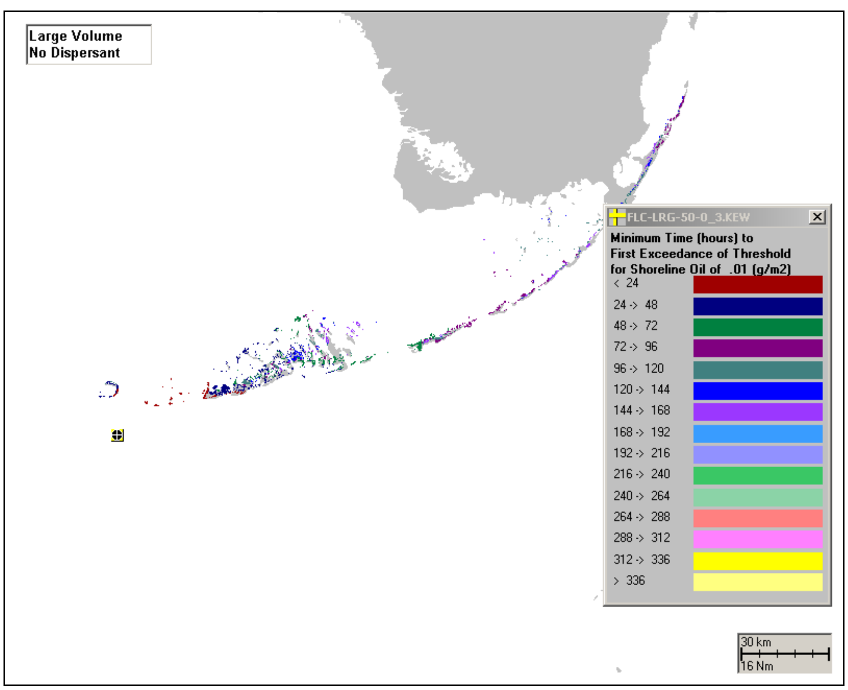

Figure D-II.1.4.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Large Volume, No Dispersant.

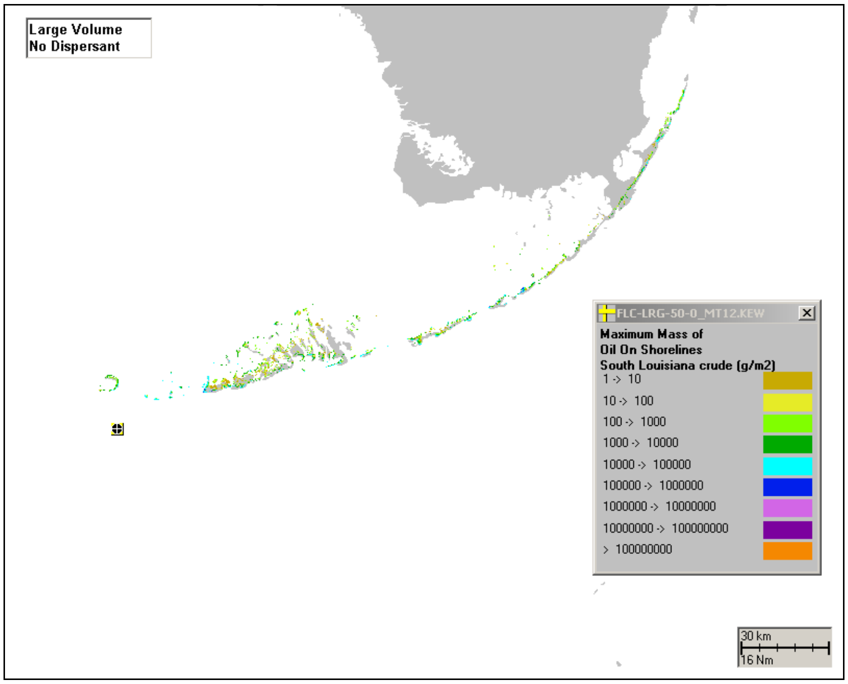

Figure D-II.1.4.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

D-II.1.4.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Large Volume, No Dispersant

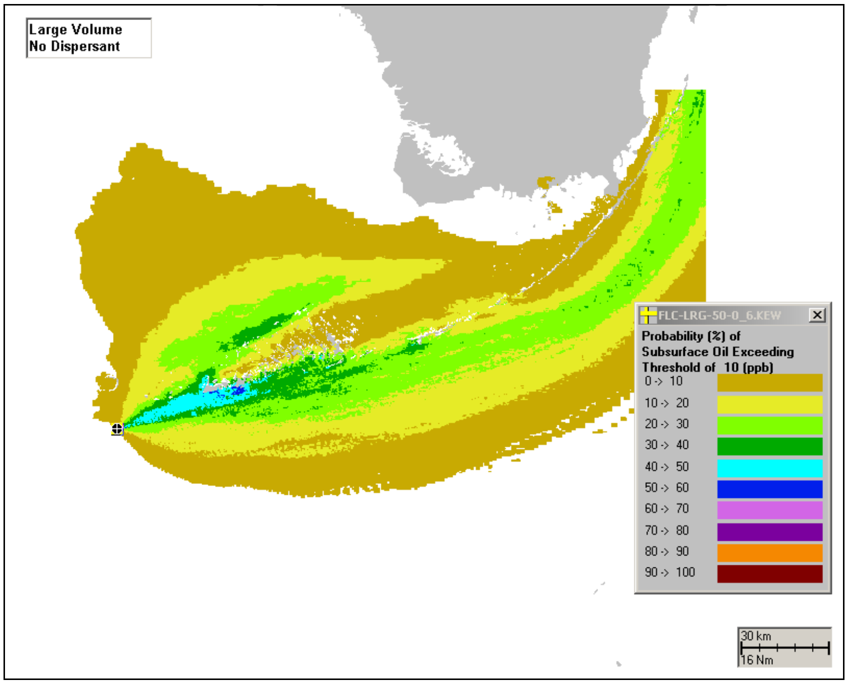

Figure D-II.1.4.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Large Volume, No Dispersant.

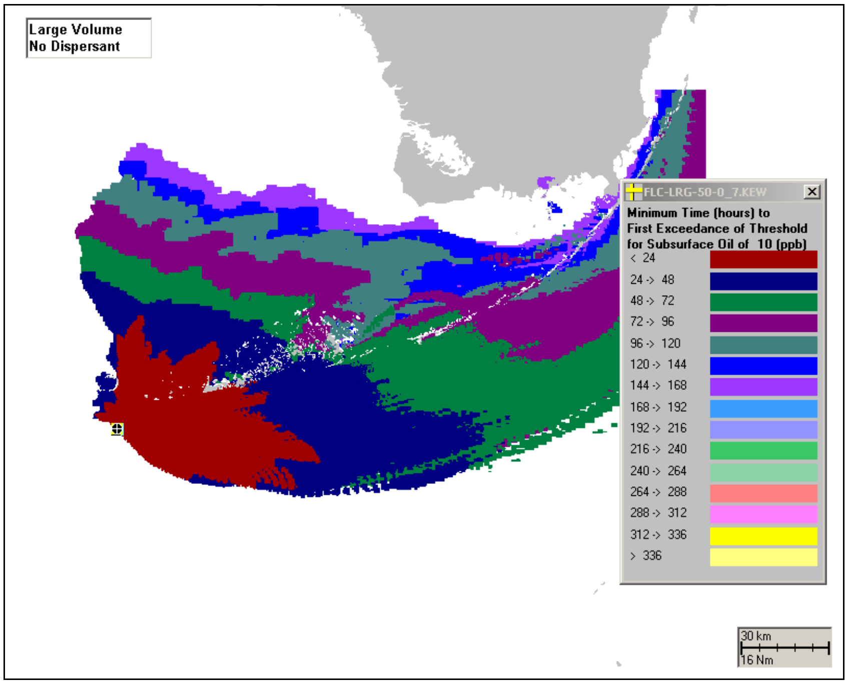

Figure D-II.1.4.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Large Volume, No Dispersant.

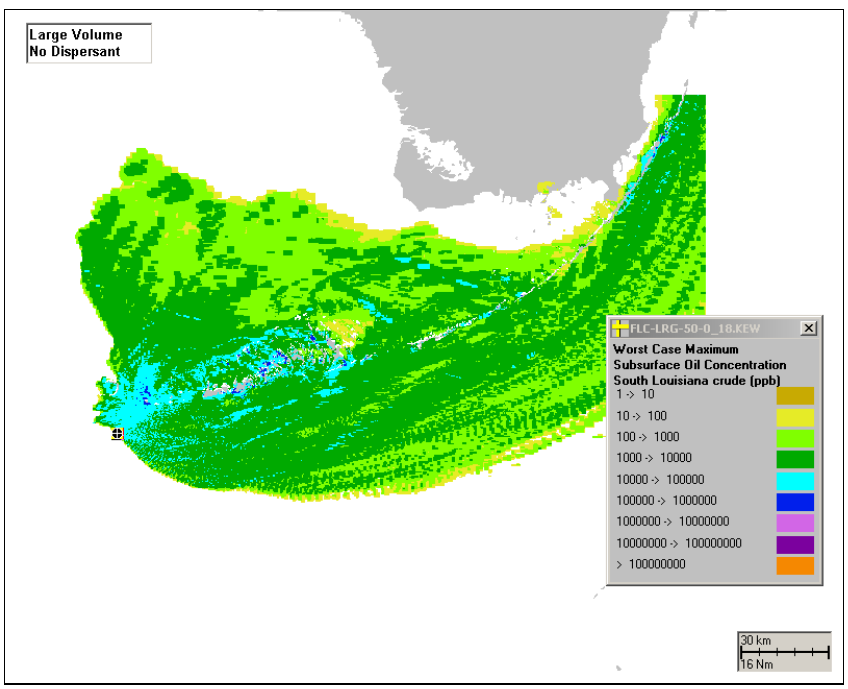

Figure D-II.1.4.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

D-II.1.4.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Large Volume, No Dispersant

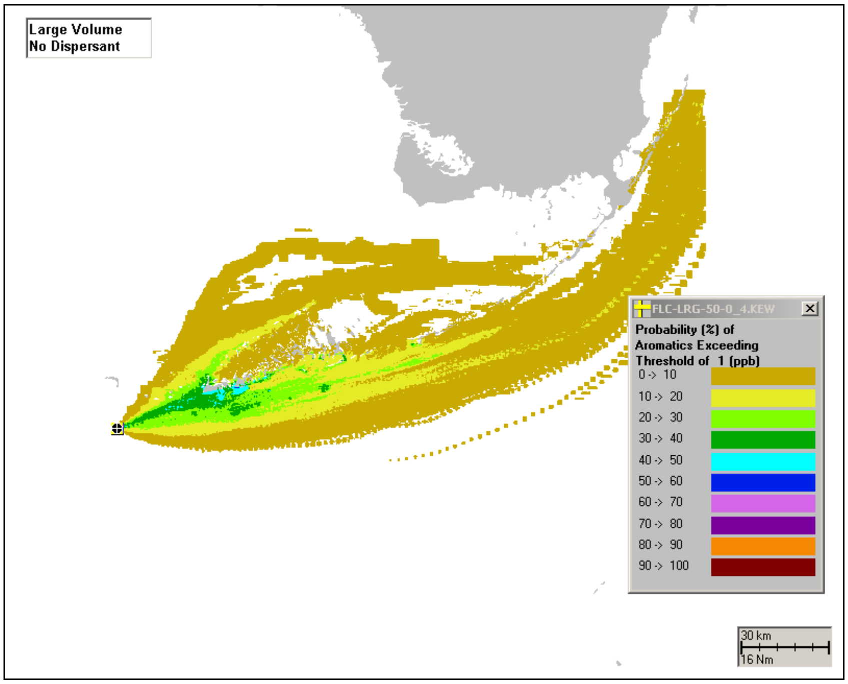

Figure D-II.1.4.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, No Dispersant.

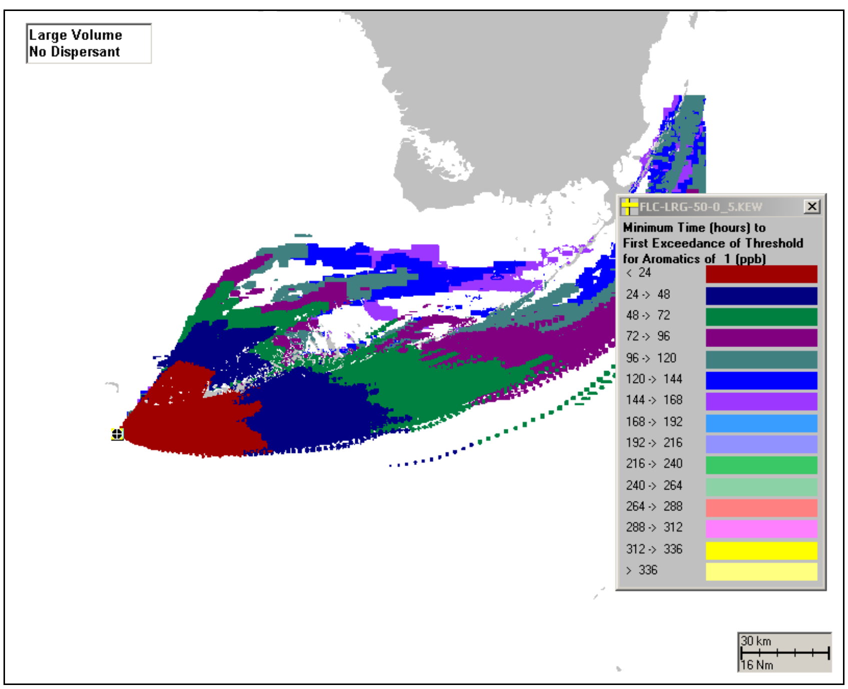

Figure D-II.1.4.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Large Volume, No Dispersant.

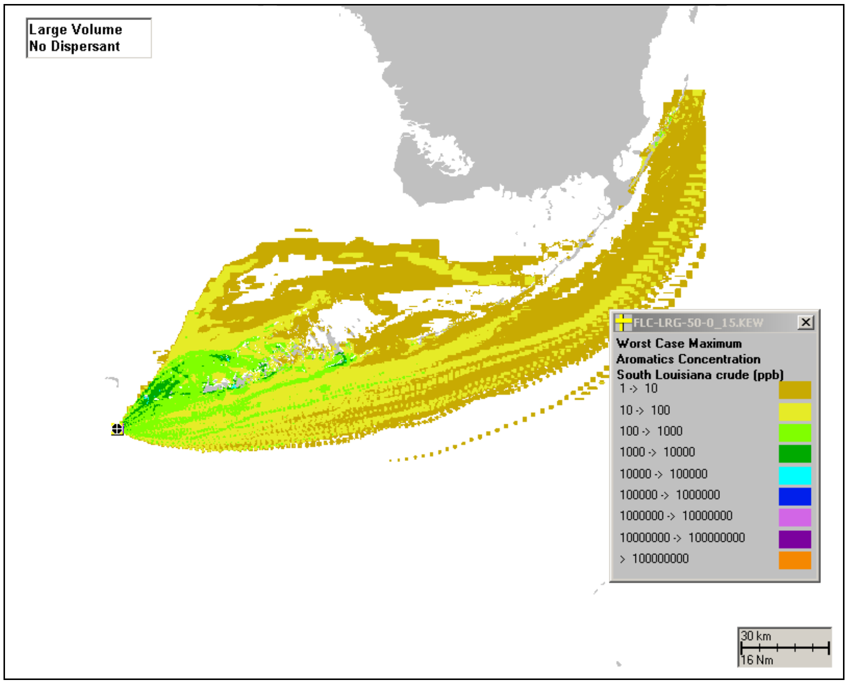

Figure D-II.1.4.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

D-II.1.4.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Large Volume, No Dispersant

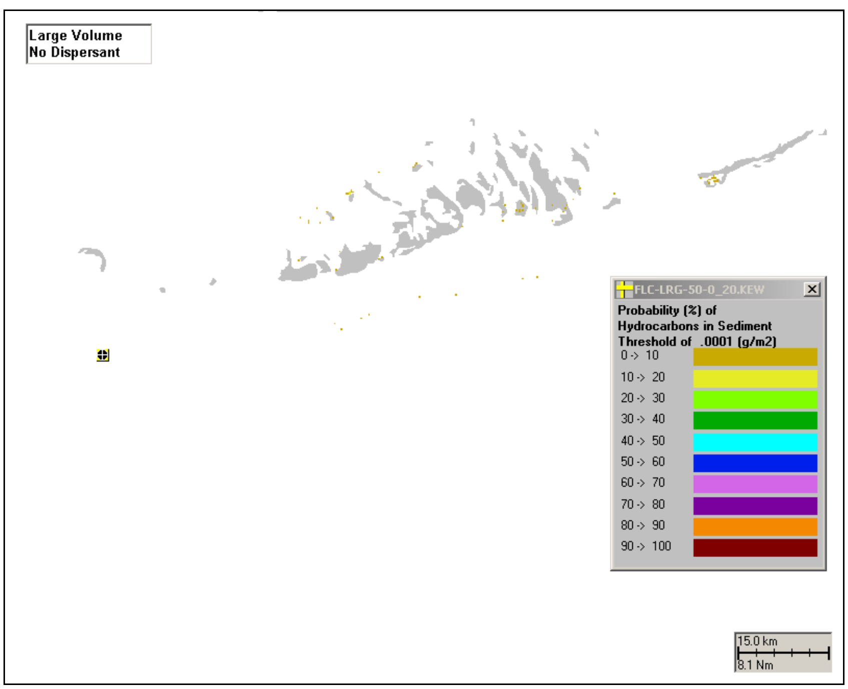

Figure D-II.1.4.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Large Volume, No Dispersant.

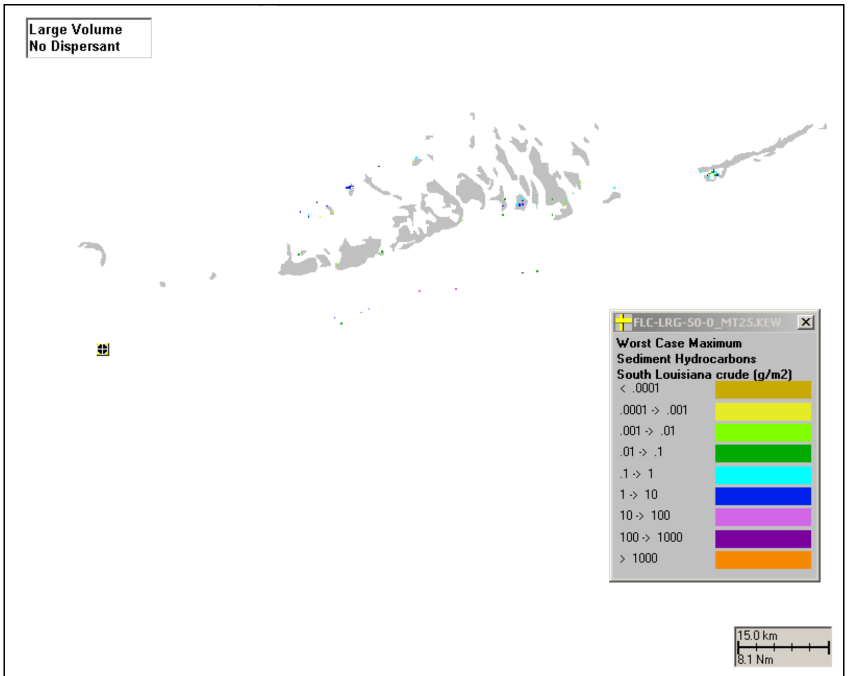

Figure D-II.1.4.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

D-II.1.4.6 Sediment pore water dissolved aromatic concentrations. Scenario: Large Volume, No Dispersant

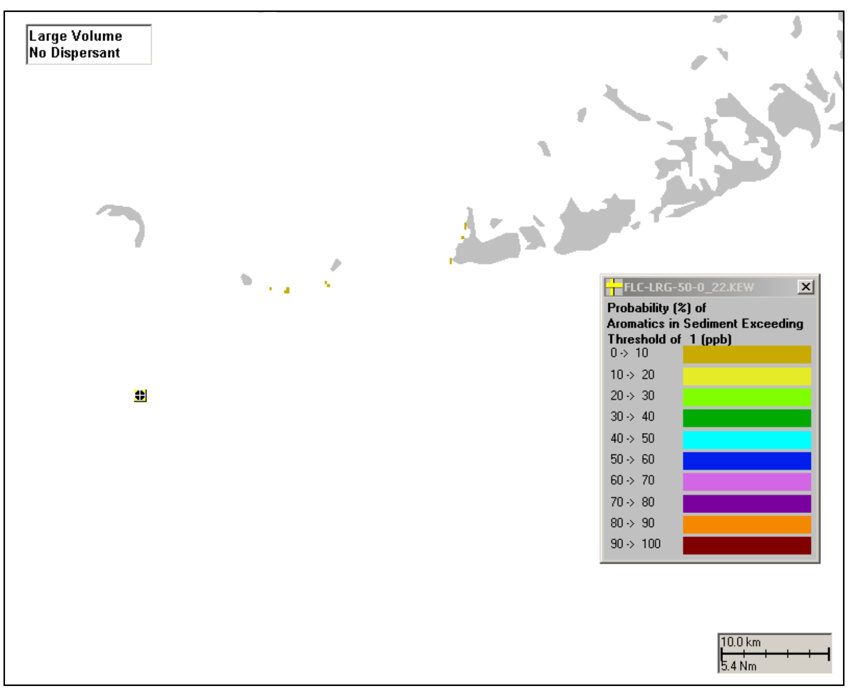

Figure D-II.1.6.6-1 Probability (%) of sediment pore water dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, No Dispersant.

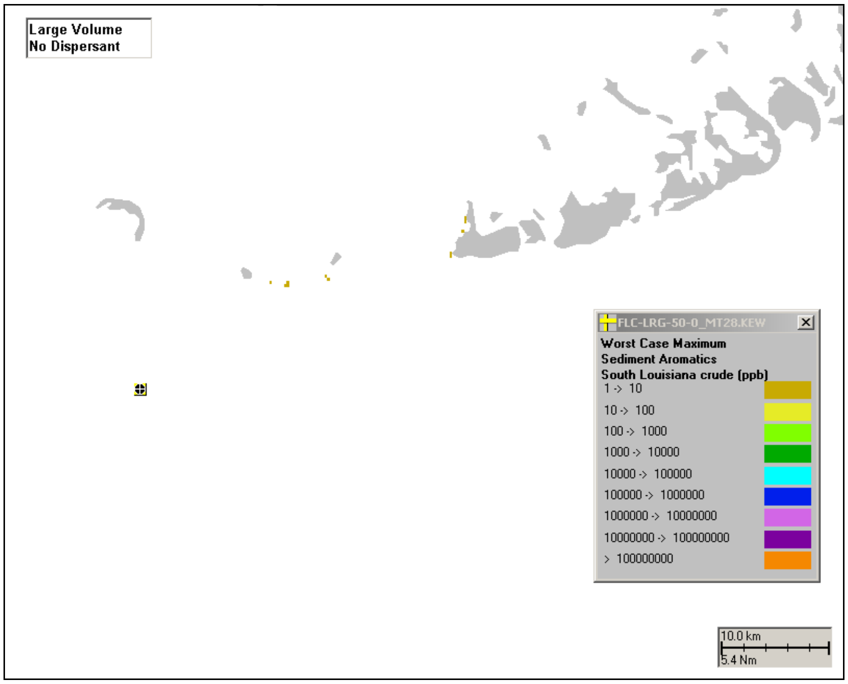

Figure D-II.1.6.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

D-II.1.5 Scenario: Large Volume, 45% Dispersant Efficiency

D-II.1.5.1 Surface Floating Total Hydrocarbons. Scenario: Large Volume, 45% Dispersant Efficiency

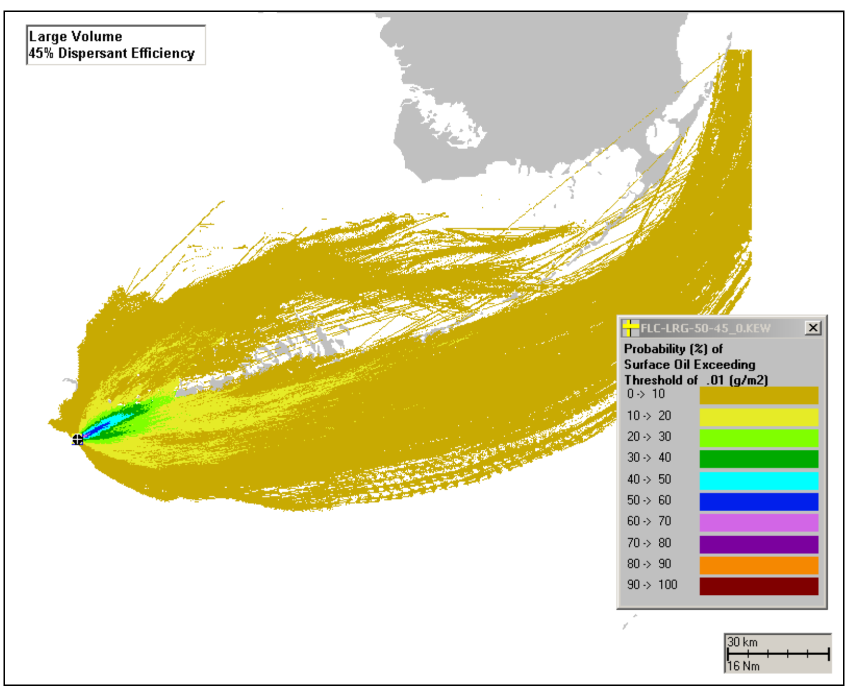

Figure D-II.1.5.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

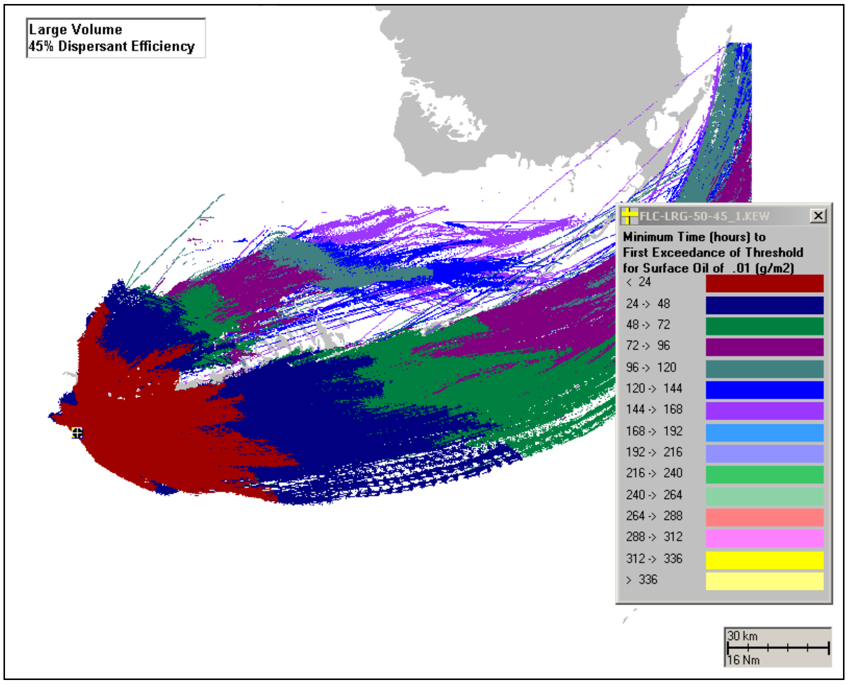

Figure D-II.1.5.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

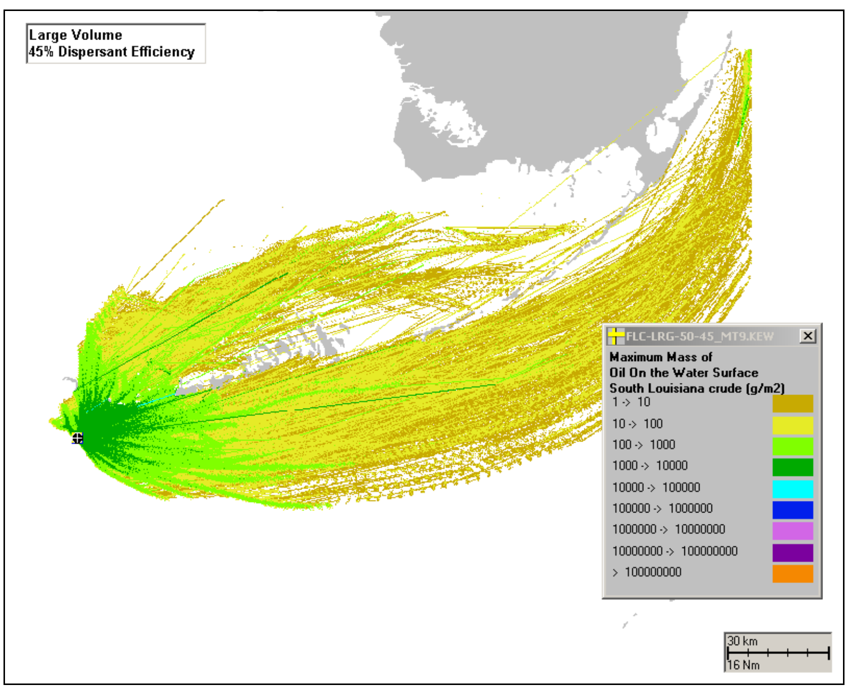

Figure D-II.1.5.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

D-II.1.5.2 Shoreline Oiled. Scenario: Large Volume, 45% Dispersant Efficiency

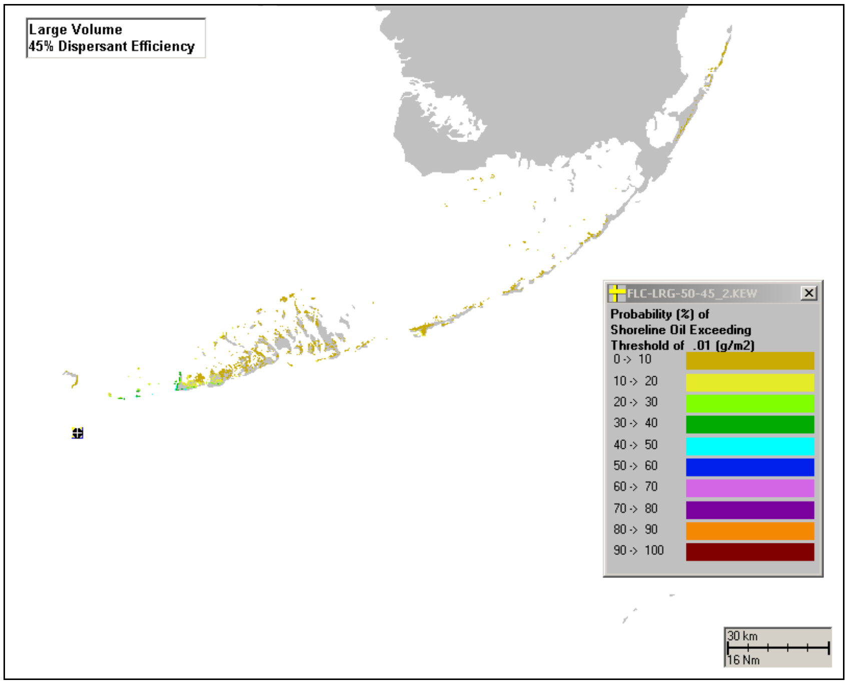

Figure D-II.1.5.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

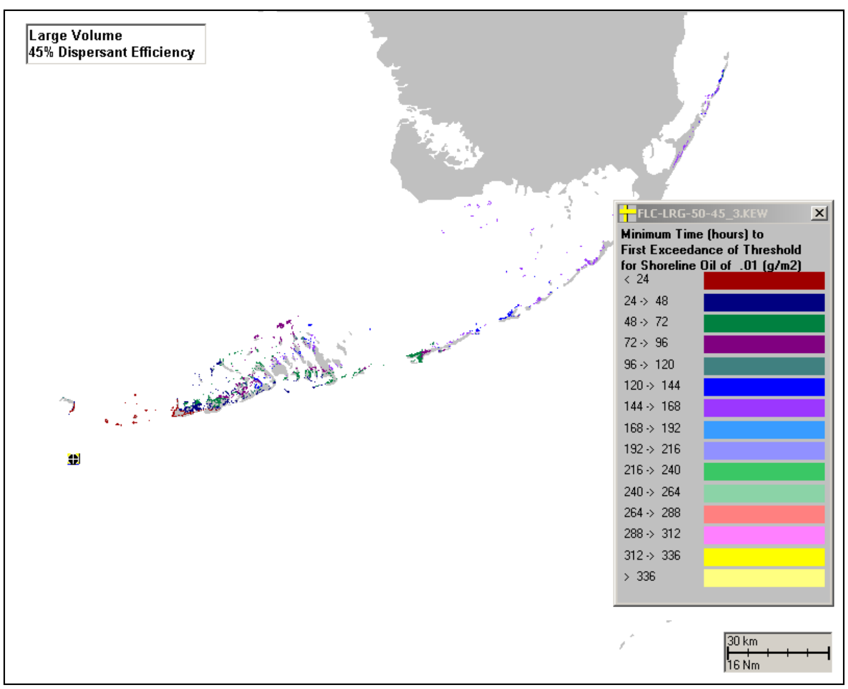

Figure D-II.1.5.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

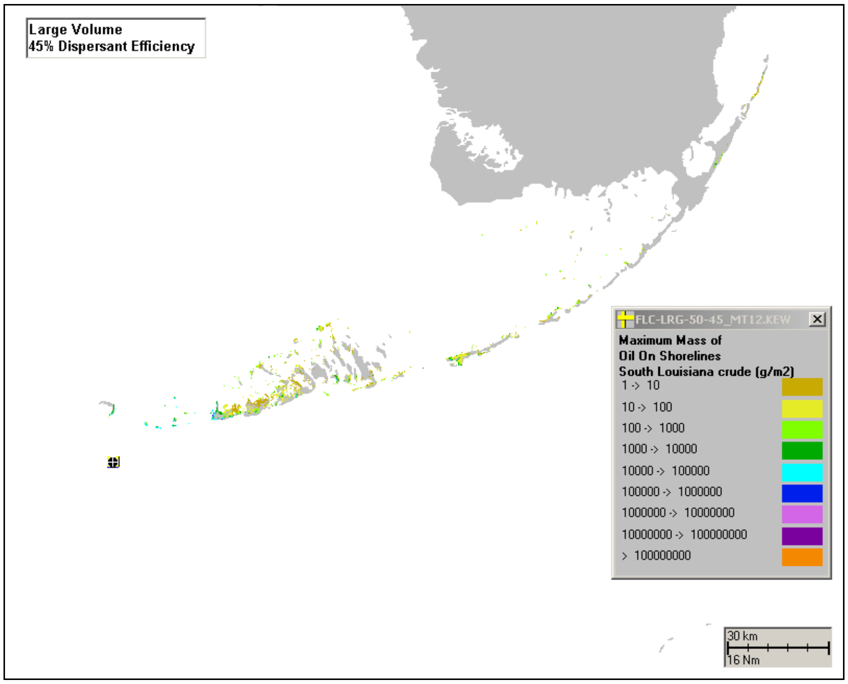

Figure D-II.1.5.2-.3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

D-II.1.5.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Large Volume, 45% Dispersant Efficiency

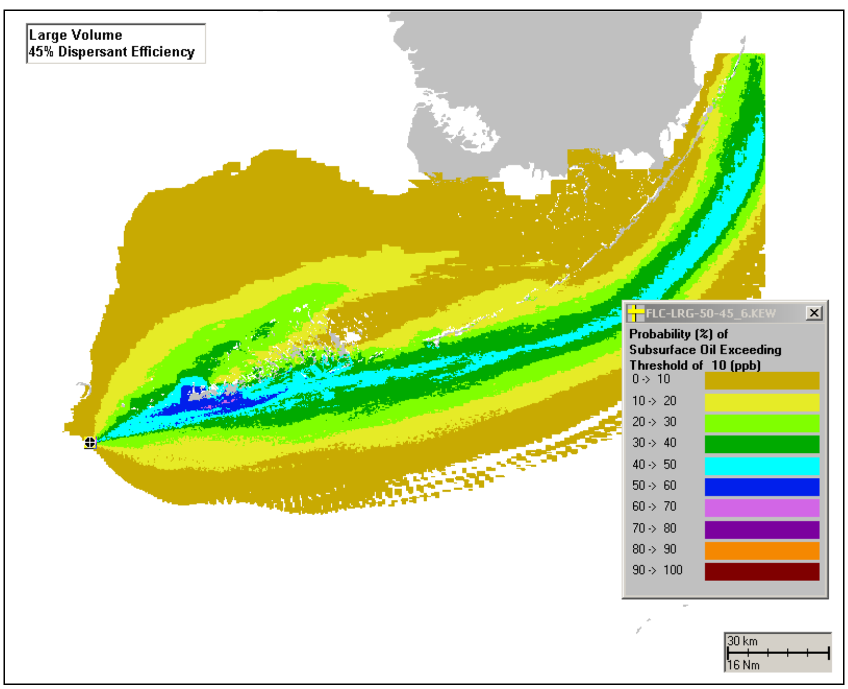

Figure D-II.1.5.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

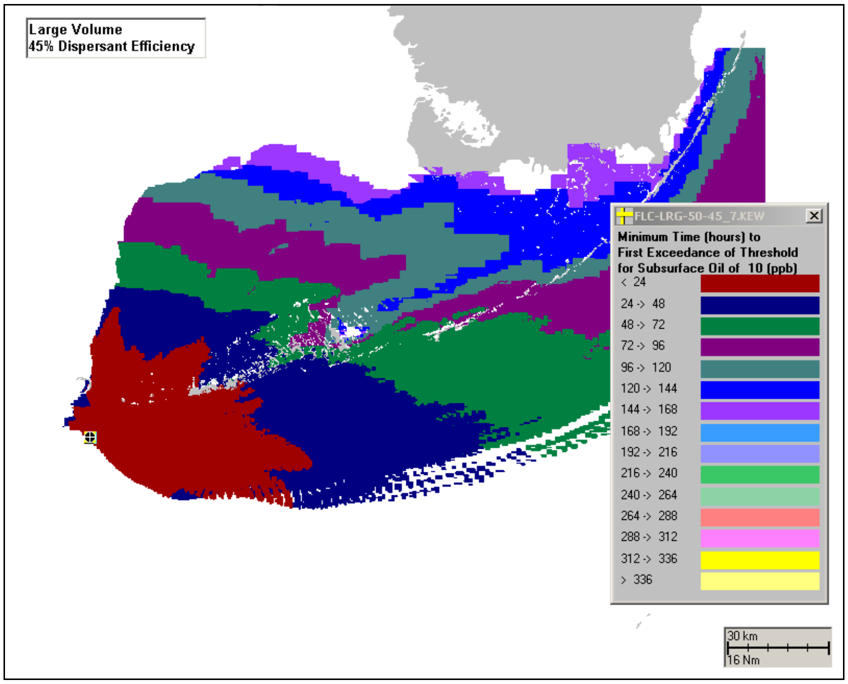

Figure D-II.1.5.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

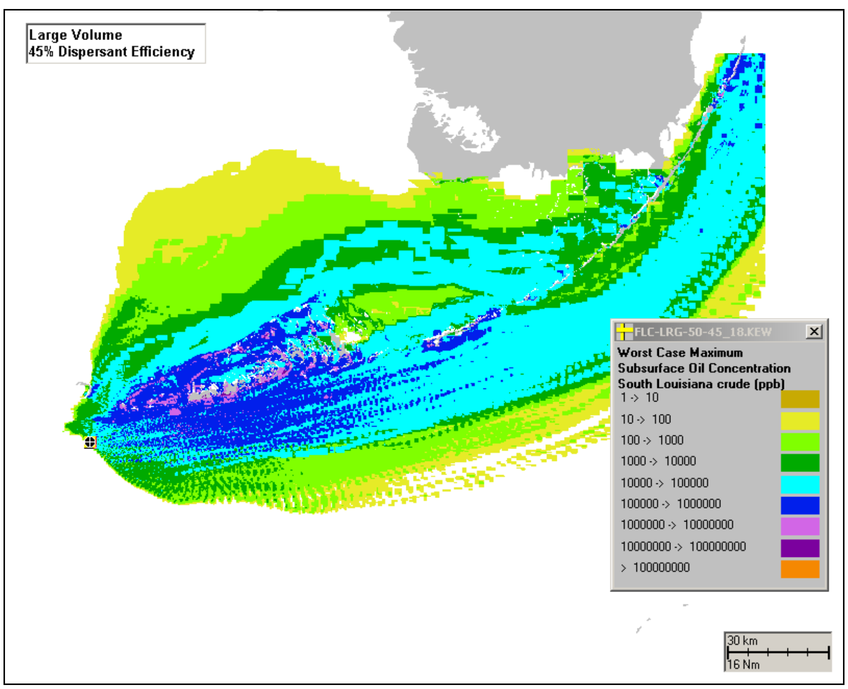

Figure D-II.1.5.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

D-II.1.5.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Large Volume, 45% Dispersant Efficiency

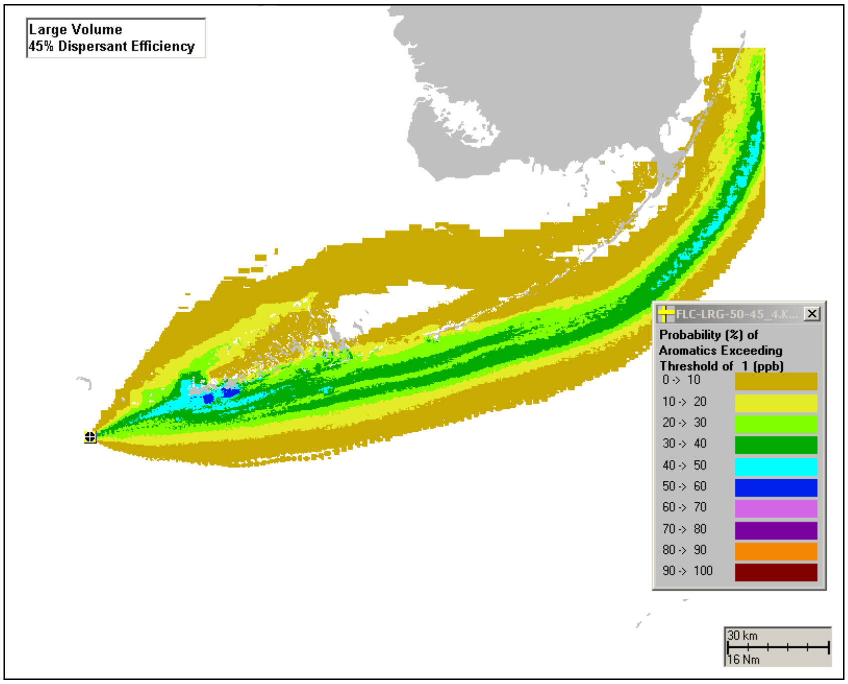

Figure D-II.1.5.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

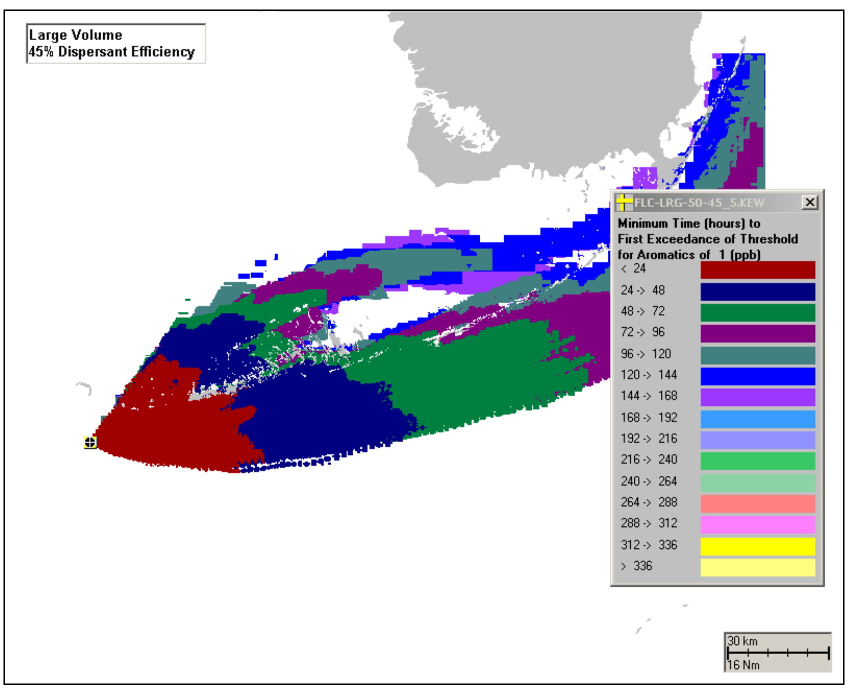

Figure D-II.1.5.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

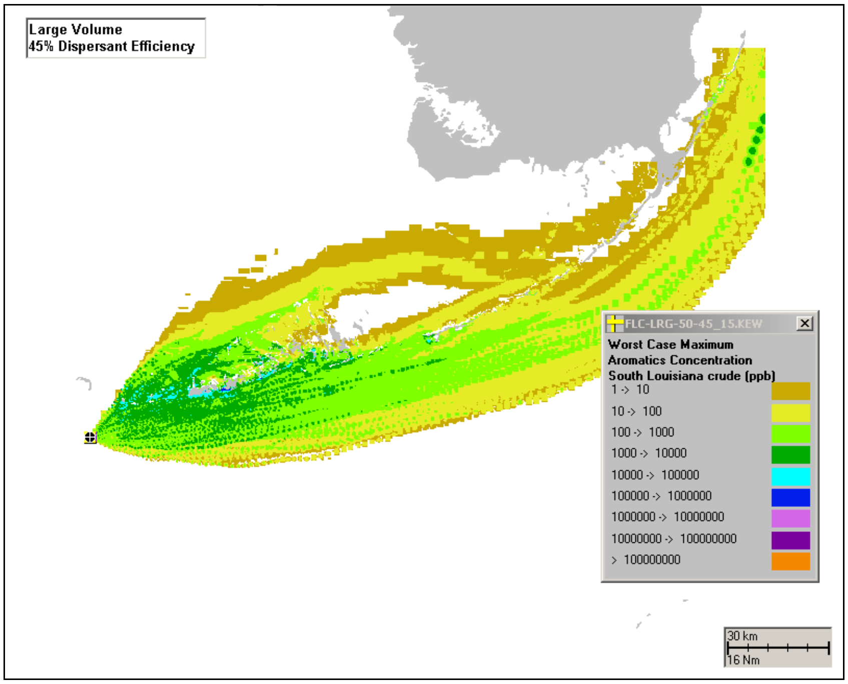

Figure D-II.1.5.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

D-II.1.5.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Large Volume, 45% Dispersant Efficiency

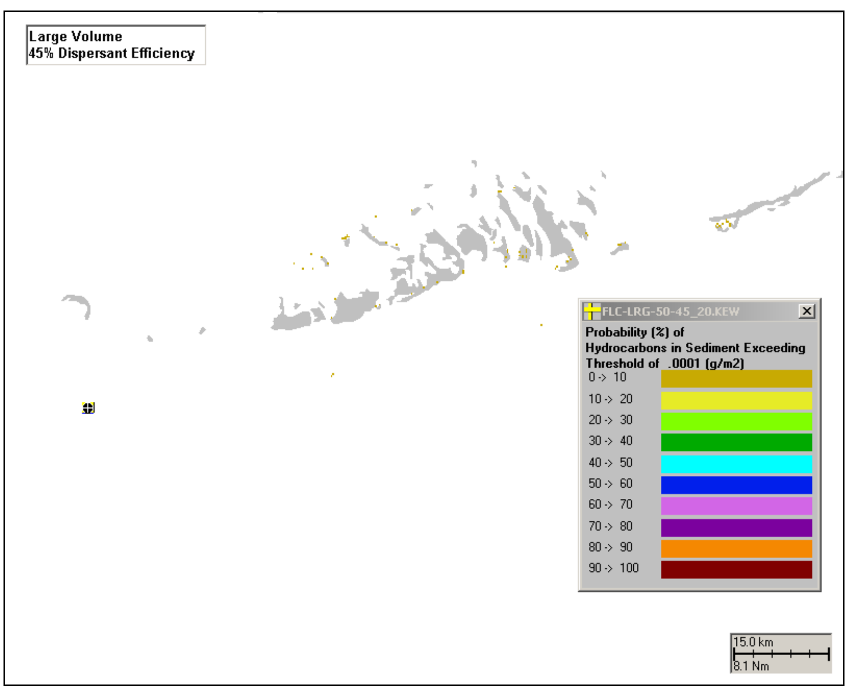

Figure D-II.1.5.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

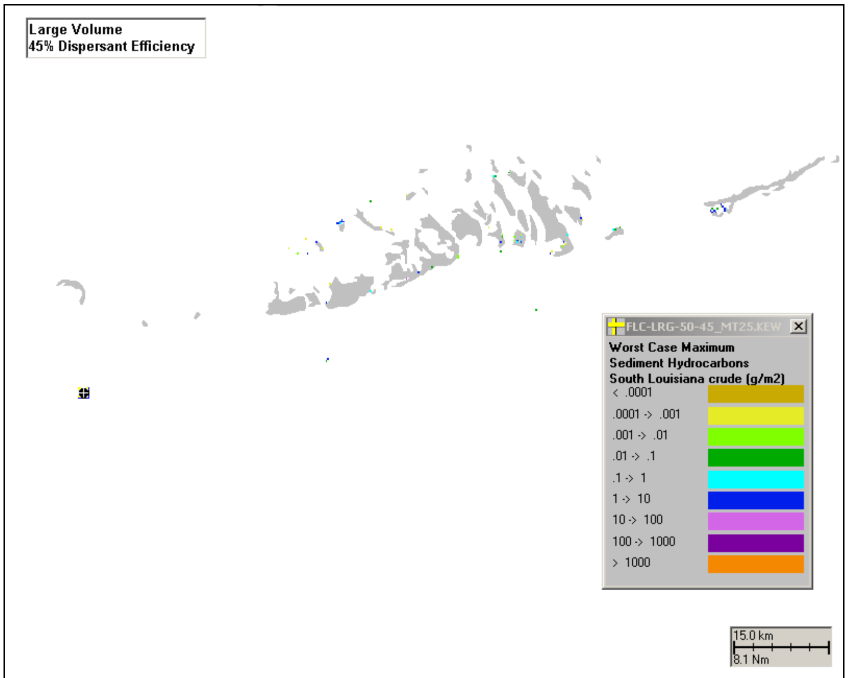

Figure D-II.1.5.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

D-II.1.5.6 Sediment pore water dissolved aromatic concentrations. Scenario: Large Volume, 45% Dispersant Efficiency

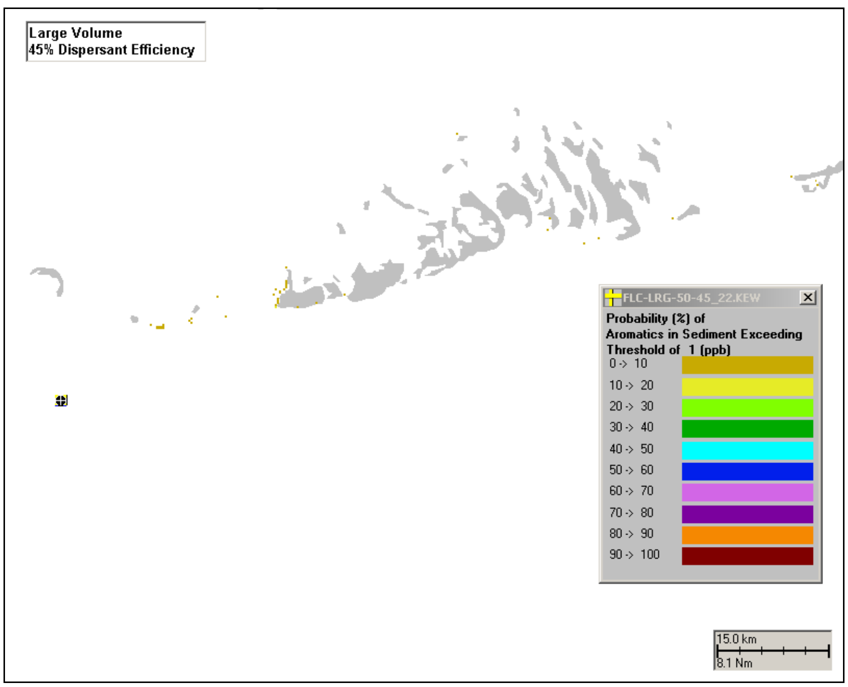

Figure D-II.1.5.6-1 Probability (%) of sediment pore water concentrations exceeding 1ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

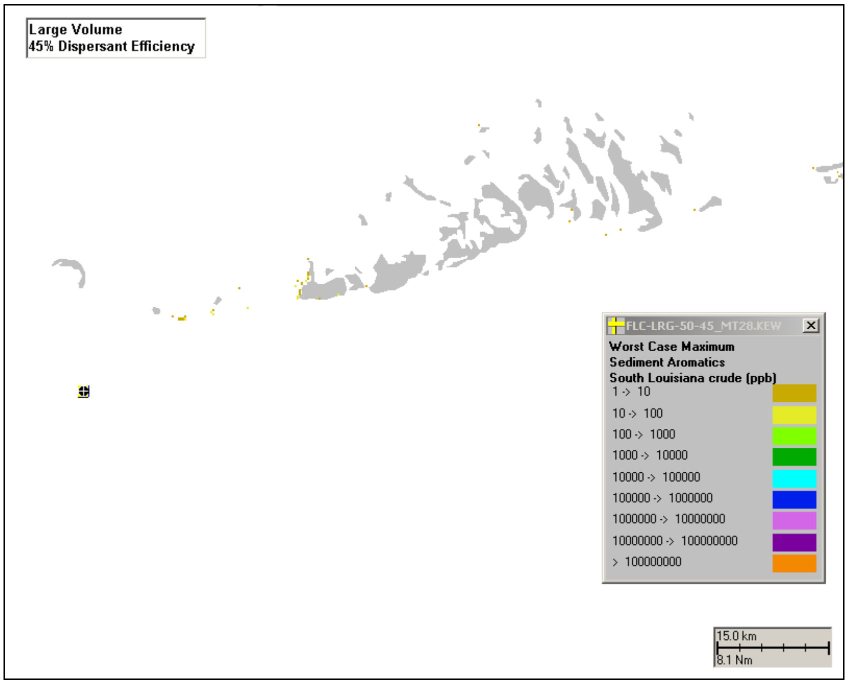

Figure D-II.1.5.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

D-II.1.6 Scenario: Large Volume, 80% Dispersant Efficiency

D-II.1.6.1 Surface Floating Total Hydrocarbons. Scenario: Large Volume, 80% Dispersant Efficiency.

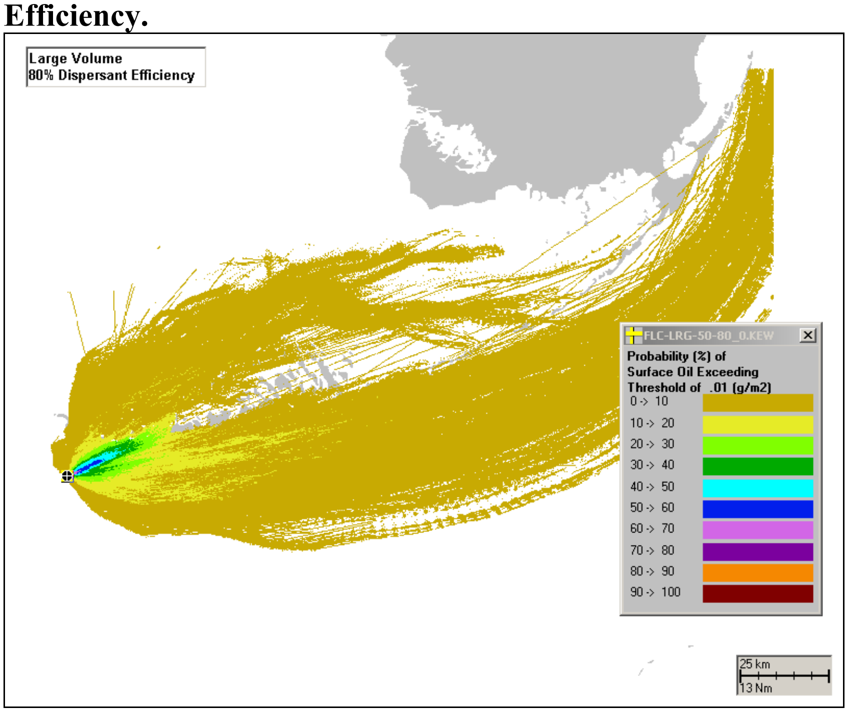

Figure D-II.1.6.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

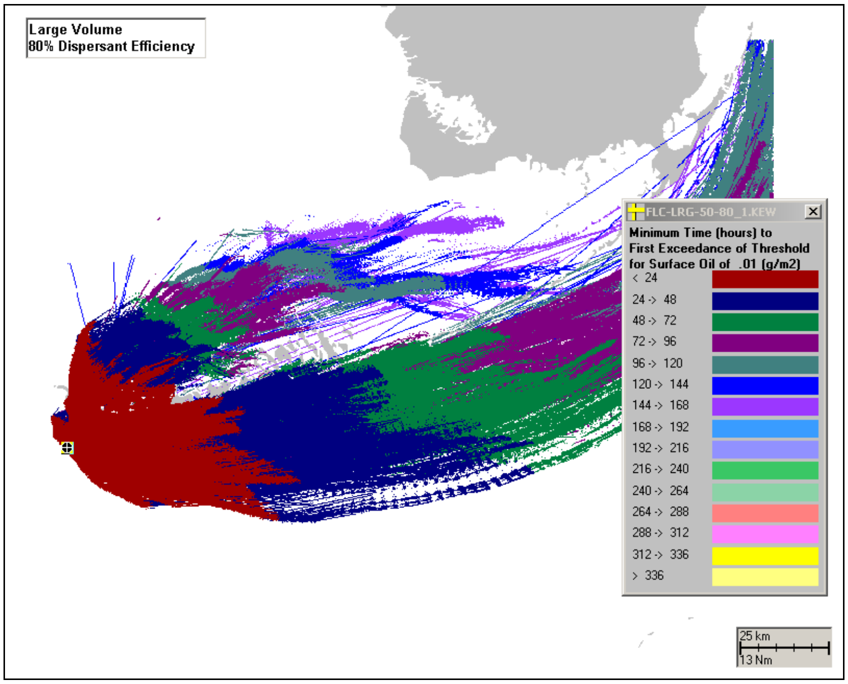

Figure D-II.1.6.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

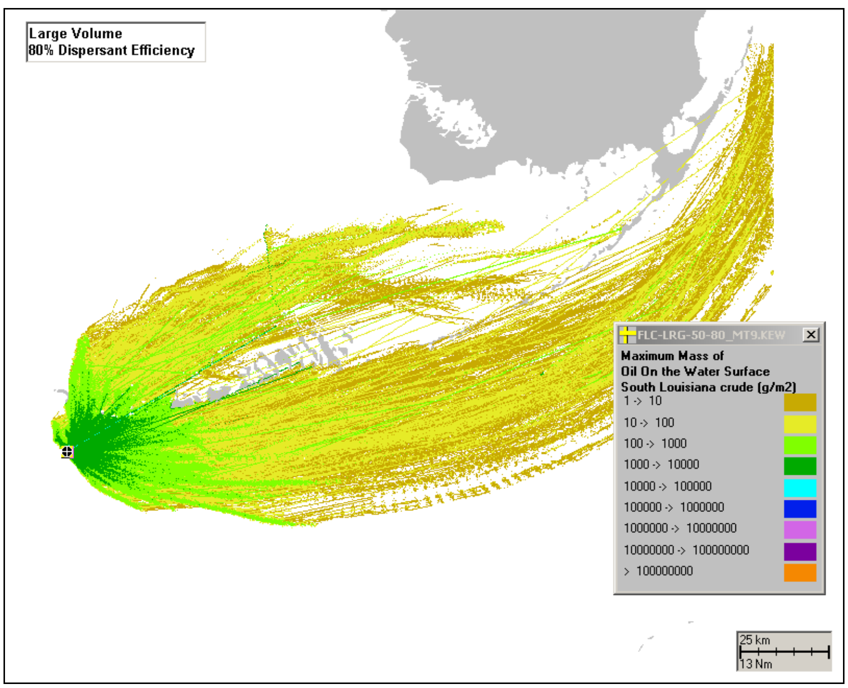

Figure D-II.1.6.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

D-II.1.6.2 Shoreline Oiled. Scenario: Large Volume, 80% Dispersant Efficiency

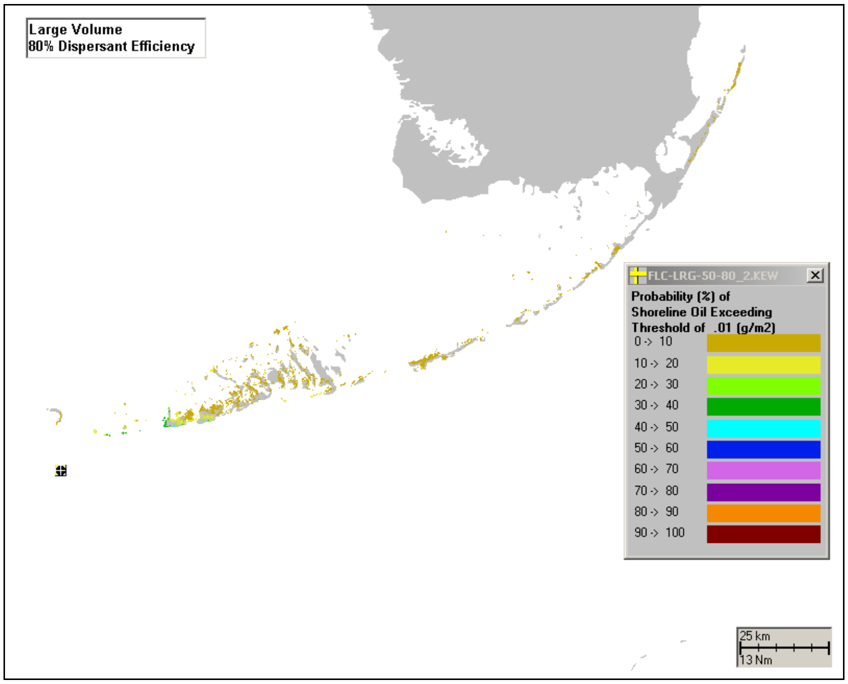

Figure D-II.1.6.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

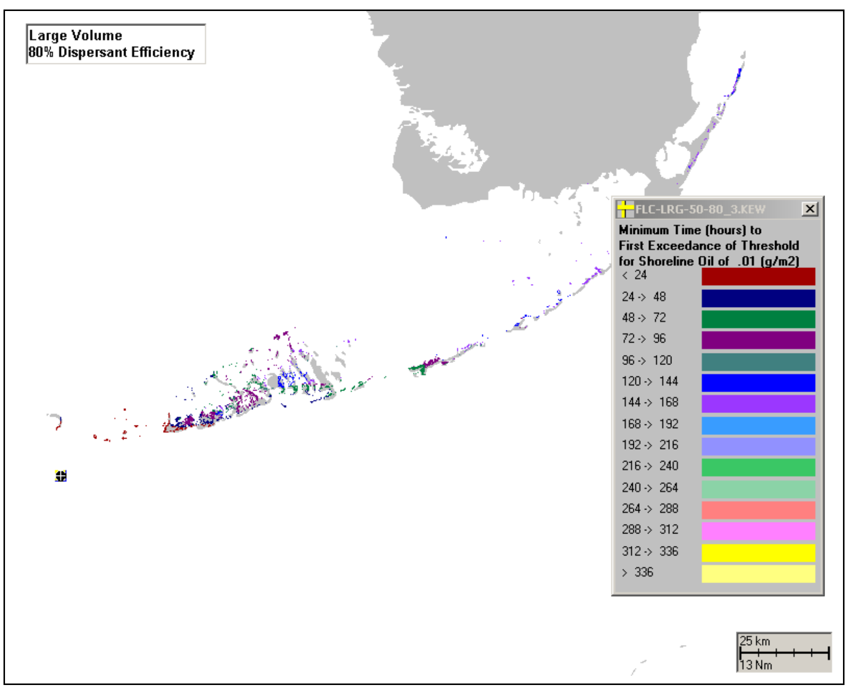

Figure D-II.1.6.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

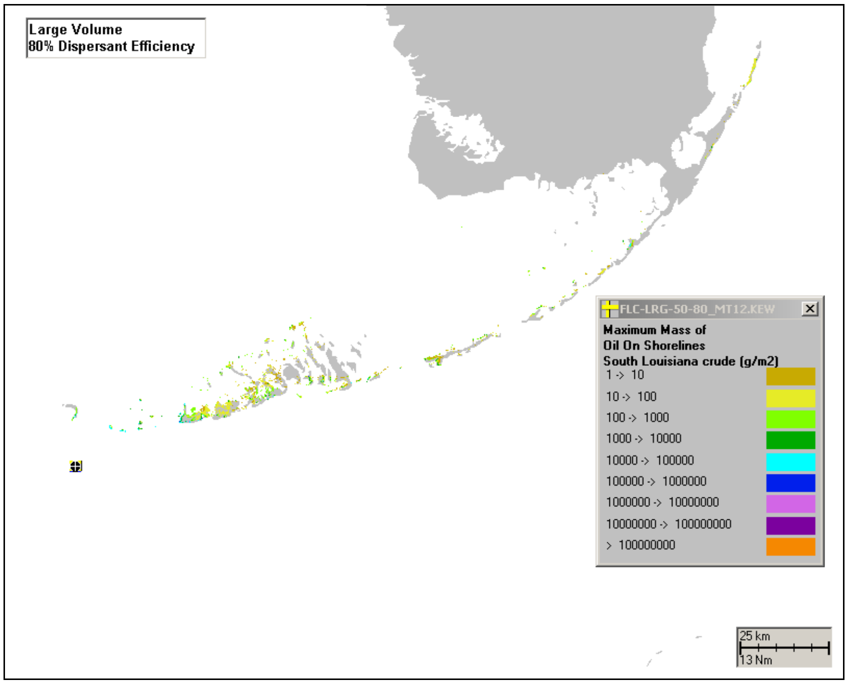

Figure D-II.1.6.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

D-II.1.6.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Large Volume, 80% Dispersant Efficiency

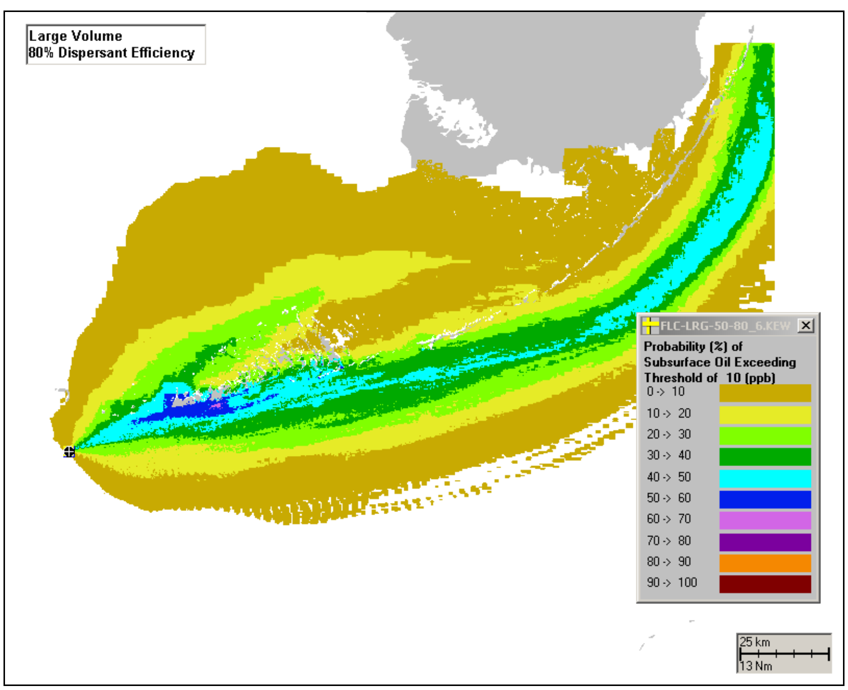

Figure D-II.1.6.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

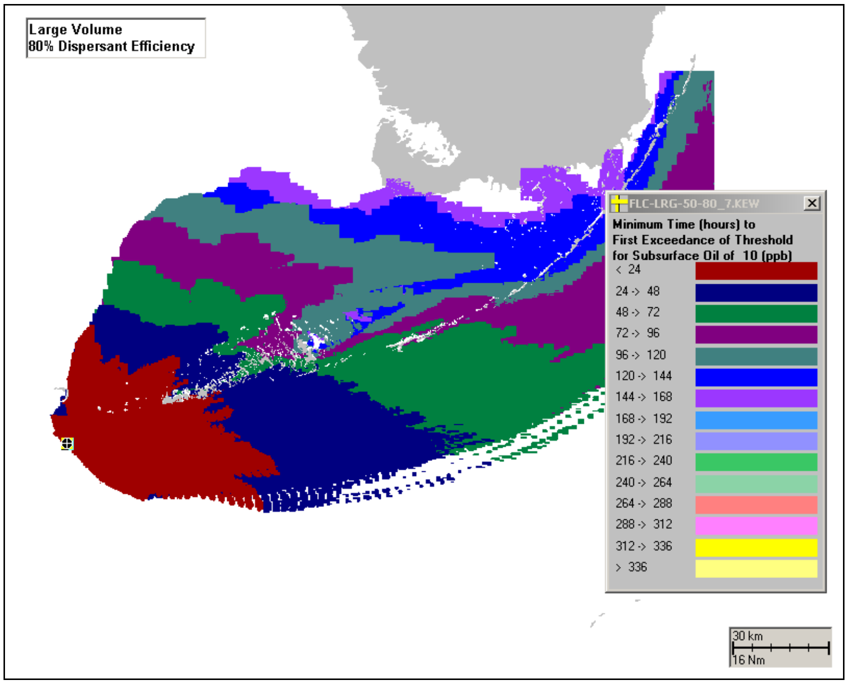

Figure D-II.1.6.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

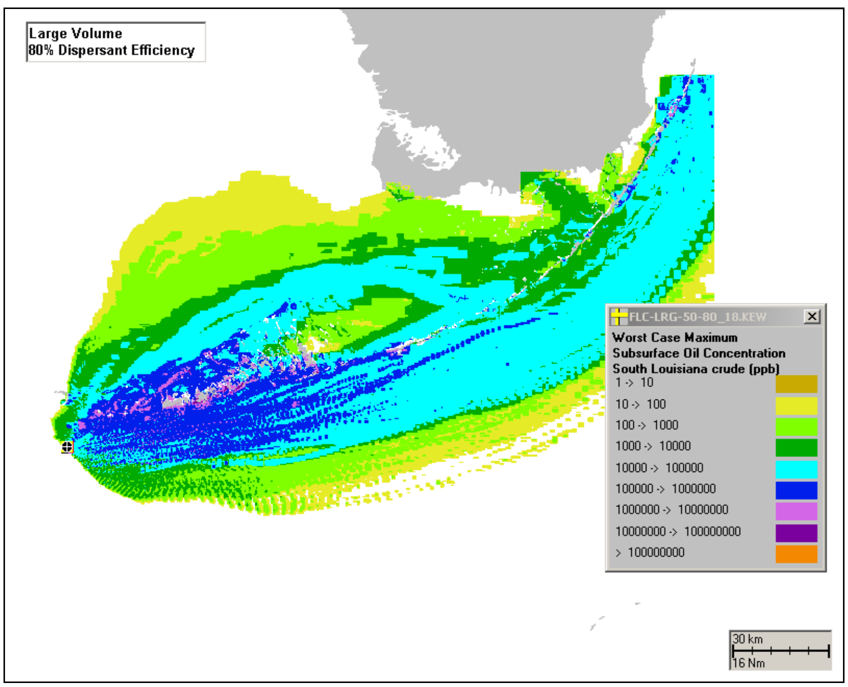

Figure D-II.1.6.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

D-II.1.6.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Large Volume, 80% Dispersant Efficiency

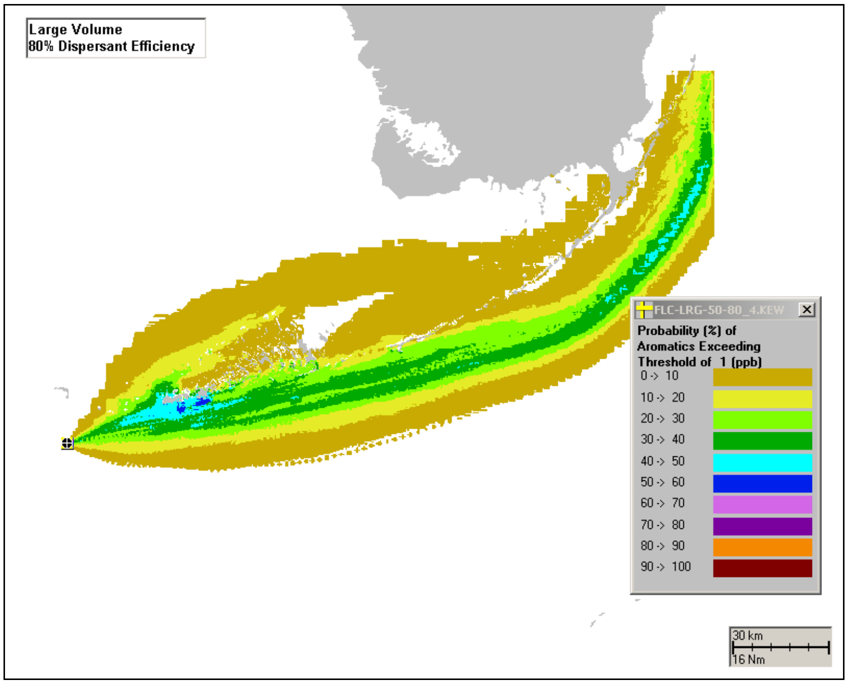

Figure D-II.1.6.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

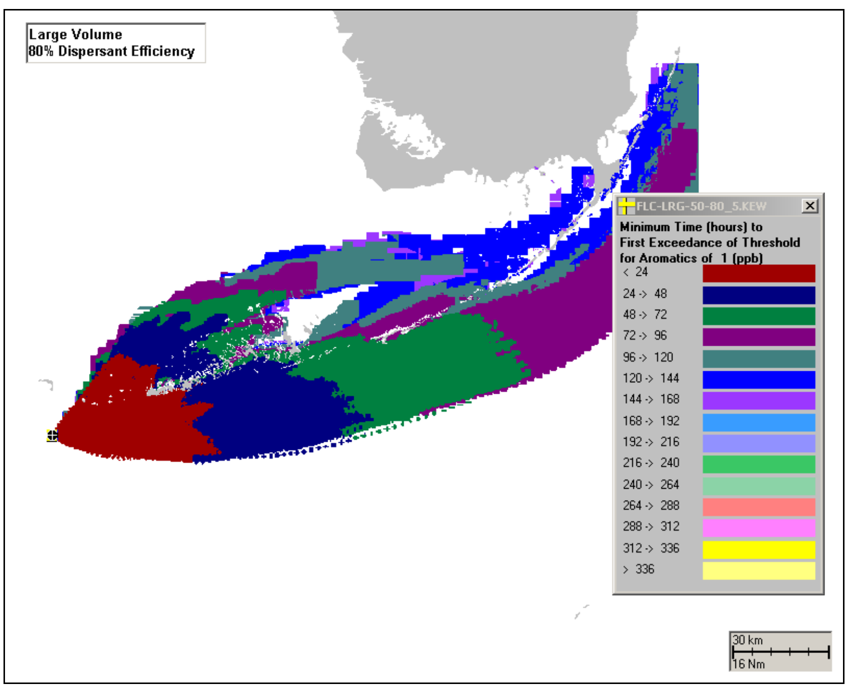

Figure D-II.1.6.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

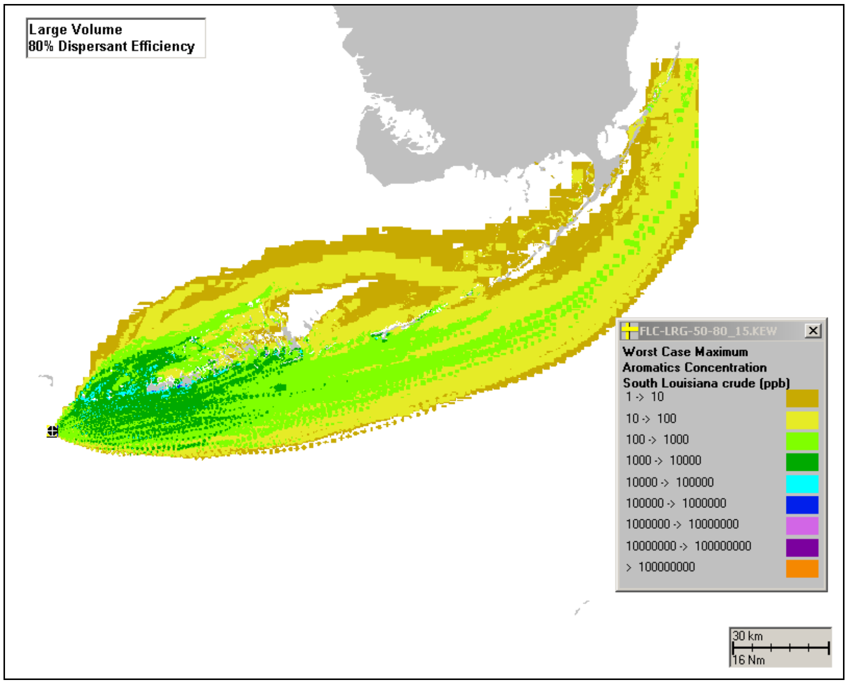

Figure D-II.1.6.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

D-II.1.6.5 Sediment exposure to total hydrocarbons (g/m²). Scenario: Large Volume, 80% Dispersant Efficiency

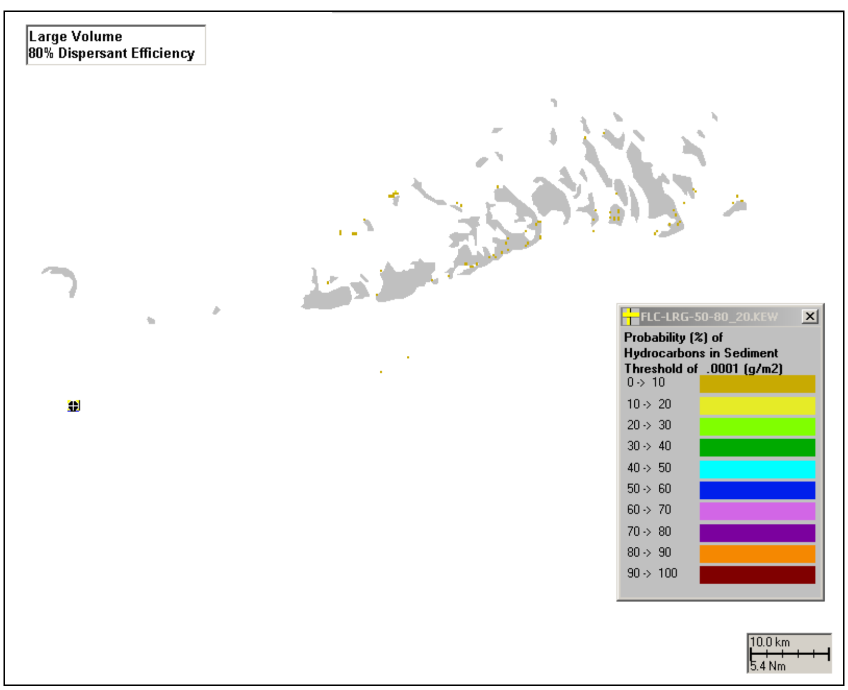

Figure D-II.1.6.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

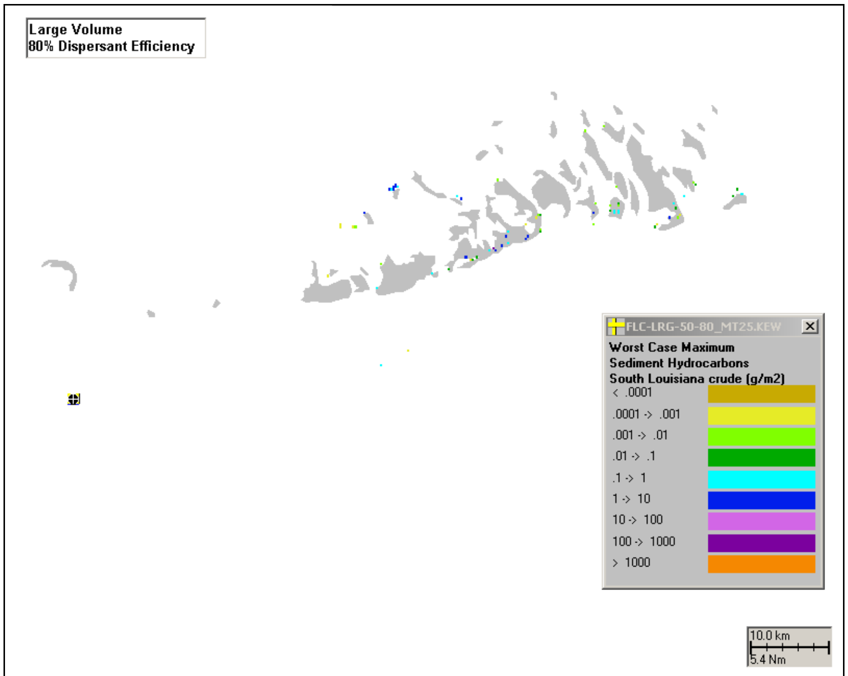

Figure D-II.1.6.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

D-II.1.6.6 Sediment pore water dissolved aromatic concentrations. Scenario: Large Volume, 80% Dispersant Efficiency

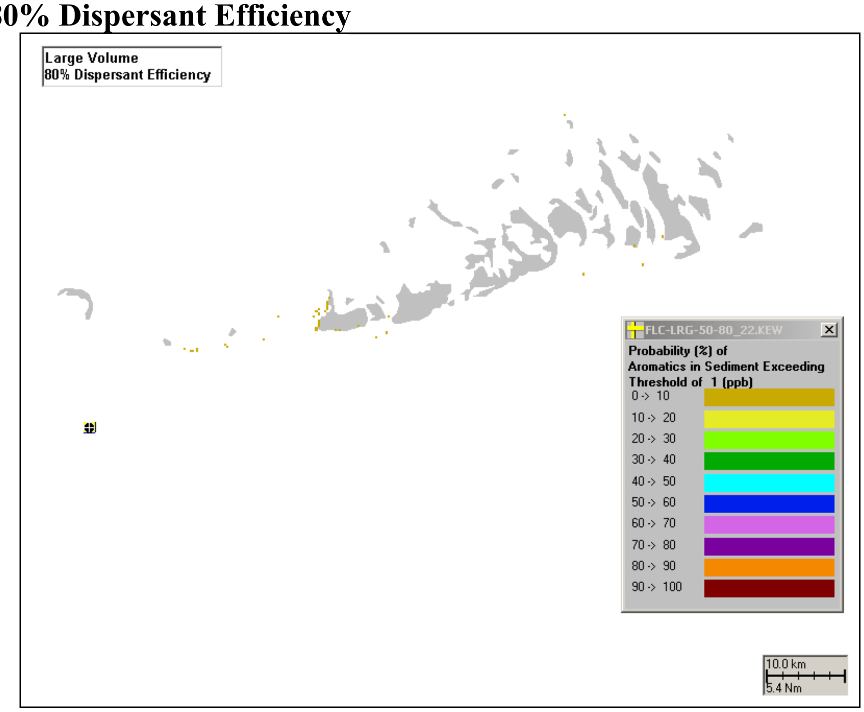

Figure D-II.1.6.6-1 Probability (%) of sediment pore water dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

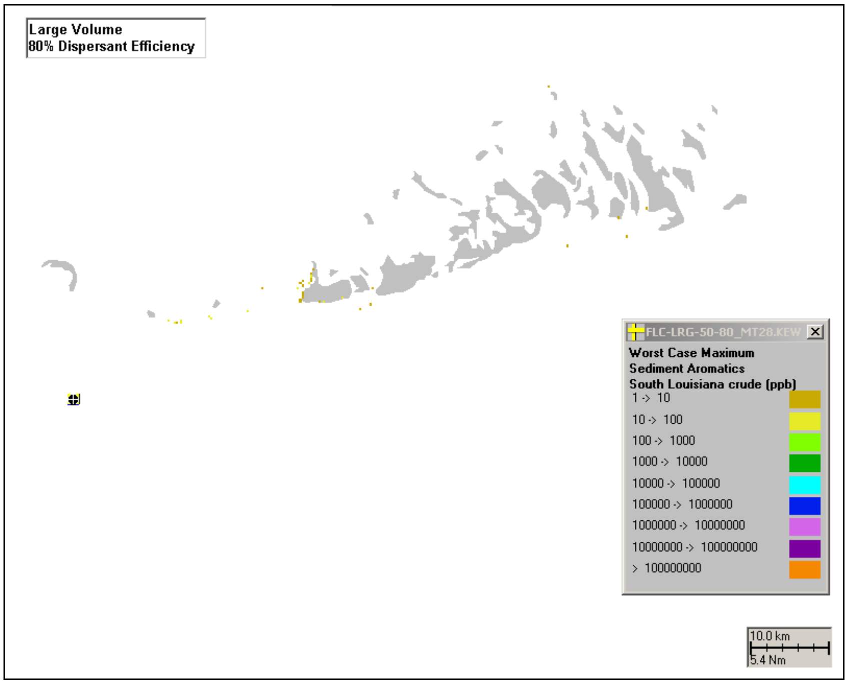

Figure D-II.1.6.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part D: Florida Straits

Section D-II.2

by

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ASA 00-246

August 2004

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D-II.2 Results of the Stochastic Modeling: Tables Summarizing Exposure Indices

Tables D-II.2-1 to D-II.2-6 summarize the exposure indices for all model runs in the stochastic oil spill modeling analysis for the Florida Straits spill site. Average and the maximum of the 100 simulations performed for each scenario are presented. The 95th percentile conditions used in the risk analysis were calculated as the mean plus two times the standard deviation. The following are the exposure indices used in the analysis.

- Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr) – integrated area swept by oil sheen or thicker oil times duration that oil is present [Note that this index is the oil mass passing through the cell averaged over the grid cell area, and so dilutes smaller patches of contamination. For this reason, evaluation of potential effects on wildlife is made using area swept by individual oil spillets; see explanation in Part A.4]
- Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) –area swept by oil sheen or thicker oil times, for landward (estuarine), seaward (marine), and all waters
- Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2) – shoreline oiled with a thickness exceeding this amount, averaged over the grid cell area (segment length of 286.62 m times typical width for the shore type, which is 1 m for rock/artificial, 5m for gravel and sand beaches, 50 m for wetlands and 20 m for mud flats)
- Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2) – shoreline oiled with a thickness exceeding this amount, averaged over the grid cell area (segment length times typical width for the shore type, as above)
- Length of Shoreline Oiling Exceeding 10 g/m^2 (m) – shoreline of various shore types oiled with a thickness exceeding this amount:
    - Total shoreline
    - Wetlands and mudflats
    - Other shoreline (rocky shore, gravel beach, sand beach, artificial shore)
    - Seaward (marine) sand beach
- Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – water volume contaminated at any time after the spill by > 1ppb dissolved aromatic concentration [Note that this index is averaged over the grid cell and upper mixed layer, and so dilutes smaller patches of contamination. For this reason, evaluation of potential effects on biota is made using higher resolution small scale grids around the plume in the water; see explanation in Part A.4]
    - Coral reef
    - Seagrass bed
    - Rock bottom (hard bottom reef)
    - All subtidal habitats
- Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs) – integrated exposure to dissolved aromatics, as ppb-hrs averaged over the water volume contaminated at any time after the spill by > 1ppb dissolved aromatic concentration (all subtidal habitats)

- Percent of Spilled Hydrocarbon Mass Coming Ashore (%) – percent of the spilled oil coming ashore by 14 days after the spill, assuming no shoreline cleanup
- Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)
- Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%) – maximum percent of the oil dispersed by natural forces (waves) and chemical dispersant. (Some naturally dispersed oil may resurface and be re-entrained into the water column, so this is the maximum percent in the water at any time after the spill.)
- Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%) – calculated by difference between no-dispersant and dispersant use scenario
- Percent of Spilled Hydrocarbon Mass Mechanically Removed (%) – The percentage decreases as chemical dispersion increases because less oil remains on the surface and is available to be skimmed.

Table D-II.2-1. Summary of exposure indices for all model runs (Medium Volume, No Dispersant).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2-hr)	1,784 x 10^6	1,886 x 10^6	0	8,351 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for landward (estuarine) cells only	1.6 x 10^6	2 x 10^6	31	11 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for seaward (marine) area only	611 x 10^6	576 x 10^6	0	2,547 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for all waters	612 x 10^6	576 x 10^6	0	2,547 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for the Florida Keys National Marine Sanctuary area	312 x 10^6	248 x 10^6	0	1,142 x 10^6
Surface Oil Exposure Exceeding $10 g/m^2$ (m^2) for the Florida Keys National Marine Sanctuary area	99 x 10^6	74 x 10^6	0	379 x 10^6
Area of Shoreline Oiling Exceeding $0.01 g/m^2$ (m^2)	987,261	932,307	10	4,798,000
Area of Shoreline Oiling Exceeding $10 g/m^2$ (m^2)	235,388	207,343	13	850,682

Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	9,863	8,344	13	36,687
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	4,291	3,898	18	16,337
Length of Shoreline Oiling Exceeding 10 g/m^2 - Other Shoreline (m)	5,572	5,374	13	28,375
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	1,725	1,459	24	5,446
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Coral Reef (m^3)	8.6×10^6	12×10^6	20	51×10^6
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Seagrass Bed (m^3)	74×10^6	92×10^6	12	343×10^6
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Rock Bottom (m^3)	14×10^6	20×10^6	31	96×10^6
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	83×10^6	77×10^6	0	292×10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	339	252	0	916
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	14.70	11.50	11	33.06
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0219	0.1052	33	0.9399
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	23.37	20.62	0	69.45
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	0	0	100	0
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	8.45	5.51	0	21.54

Table D-II.2-2. Summary of exposure indices for all model runs (Medium Volume, 45% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	596 x 10^6	1,291 x 10^6	0	7,348 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) cells only	0.39 x 10^6	1 x 10^6	68	5.6 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	142 x 10^6	259 x 10^6	0	1,757 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	142 x 10^6	260 x 10^6	0	1,759 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for the Florida Keys National Marine Sanctuary area	101 x 10^6	155 x 10^6	0	967 x 10^6
Surface Oil Exposure Exceeding 10g/m^2 (m^2) for the Florida Keys National Marine Sanctuary area	22 x 10^6	22 x 10^6	0	157 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	566,768	718,663	19	3,738,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	54,145	141,293	27	884,788
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	2,766	4,657	27	30,381
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	946	2,615	53	15,191
Length of Shoreline Oiling Exceeding 10 g/m^{2} - Other Shoreline (m)	1,820	2,605	32	18,630
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	513	821	53	4,873
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Coral Reef (m^3)	18 x 10^6	20 x 10^6	6	77 x 10^6
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Seagrass Bed (m^3)	116 x 10^6	95 x 10^6	4	345 x 10^6
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Rock	21 x 10^6	25 x 10^6	25	159 x 10^6

Bottom (m^3)				
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	166 x 10^6	93 x 10^6	0	500 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	1,558	815	0	4,629
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	1.98	5.05	19	32.15
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0092	0.0350	4	0.3205
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	75.70	12.46	0	86.46
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	52.33	20.08	0	83.34
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	0.15	0.49	43	3.69

Table D-II.2-3. Summary of exposure indices for all model runs (Medium Volume, 80% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2-hr)	613 x 10^6	1,307 x 10^6	0	7,262 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for landward (estuarine) cells only	0.35 x 10^6	0.89 x 10^6	66	5.3 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for seaward (marine) area only	138 x 10^6	260 x 10^6	0	1,604 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for all waters	138 x 10^6	260 x 10^6	0	1,604 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for the Florida Keys National Marine Sanctuary area	99 x 10^6	164 x 10^6	0	1,013 x 10^6
Surface Oil Exposure Exceeding $10 g/m^2$ (m^2) for the Florida Keys National Marine Sanctuary area	20 x 10^6	16 x 10^6	0	111 x 10^6
Area of Shoreline Oiling Exceeding $0.01 g/m^2$ (m^2)	553,171	677,374	19	3,151,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	50,453	131,831	28	854,122
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	2,697	4,437	28	30,668
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	866	2,490	54	16,624
Length of Shoreline Oiling Exceeding 10 g/m^2 - Other Shoreline (m)	1,831	2,588	32	14,044
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	545	881	52	4,586
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Coral Reef (m^3)	16 x 10^6	20 x 10^6	7	76 x 10^6
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Seagrass Bed (m^3)	116 x 10^6	102 x 10^6	7	473 x 10^6

Dissolved Aromatic Plume Volume Exceeding 1 ppb - Rock Bottom (m^3)	21×10^6	22×10^6	26	111×10^6
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	167×10^6	94×10^6	0	432×10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	1,593	860	0	5,033
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	1.96	5.08	19	31.84
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0101	0.0617	4	0.5985
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	75.88	12.18	0	86.56
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	52.51	20.01	0	83.45
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	0.15	0.49	47	3.69

Table D-II.2-4. Summary of exposure indices for all model runs (Large Volume, No Dispersant).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2-hr)	26,529 x 10^6	24,531 x 10^6	0	103,801 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for landward (estuarine) cells only	4.5 x 10^6	4.9 x 10^6	17	27 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for seaward (marine) area only	1,357 x 10^6	917 x 10^6	0	3,433 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for all waters	1,361 x 10^6	917 x 10^6	0	3,451 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for the Florida Keys National Marine Sanctuary area	659 x 10^6	397 x 10^6	0	2,006 x 10^6
Surface Oil Exposure Exceeding $10 g/m^2$ (m^2) for the Florida Keys National Marine Sanctuary area	422 x 10^6	307 x 10^6	0	1,556 x 10^6
Area of Shoreline Oiling Exceeding $0.01 g/m^2$ (m^2)	1,840,872	1,707,057	12	9,882,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	757,290	606,852	12	2,640,039
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	27,117	19,182	12	97,163
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	14,242	11,556	15	49,872
Length of Shoreline Oiling Exceeding 10 g/m^{2-} Other Shoreline (m)	12,875	9,769	12	49,298
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	4,013	2,902	16	10,318
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Coral Reef (m^3)	25 x 10^6	30 x 10^6	8	141 x 10^6
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Seagrass Bed (m^3)	173 x 10^6	167 x 10^6	2	673 x 10^6
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Rock	32 x 10^6	41 x 10^6	17	229 x 10^6

Bottom (m^3)				
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	326 x 10^6	366 x 10^6	0	2,249 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	968	1,008	0	5,231
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	16.14	10.08	12	32.08
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0029	0.0156	46	0.1516
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	9.22	10.58	0	42.99
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	0	0	100	0
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	14.39	5.98	0	25.01

Table D-II.2-5. Summary of exposure indices for all model runs (Large Volume, 45% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	7,272 x 10^6	7,809 x 10^6	0	44,838 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) cells only	1.4 x 10^6	2 x 10^6	34	10.4 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	576 x 10^6	522 x 10^6	0	2,378 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	578 x 10^6	523 x 10^6	0	2,378 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for the Florida Keys National Marine Sanctuary area	332 x 10^6	235 x 10^6	0	1,309 x 10^6
Surface Oil Exposure Exceeding 10g/m^2 (m^2) for the Florida Keys National Marine Sanctuary area	131 x 10^6	116 x 10^6	0	622 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	1,235,606	1,437,223	18	6,576,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	291,358	362,859	23	2,196,064
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	10,645	10,332	23	47,865
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	4,961	6,263	28	40,127
Length of Shoreline Oiling Exceeding 10 g/m$^{2\,-}$ Other Shoreline (m)	5,684	5,454	24	24,363
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	2,118	2,077	28	8,312
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Coral Reef (m^3)	45 x 10^6	45 x 10^6	3	166 x 10^6
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Seagrass Bed (m^3)	288 x 10^6	217 x 10^6	1	866 x 10^6
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Rock	55 x 10^6	63 x 10^6	17	352 x 10^6

Bottom (m^3)				
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	$1,153 \times 10^6$	$1,001 \times 10^6$	0	$5,020 \times 10^6$
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	5,049	3,499	0	21,140
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	3.44	4.89	21	22.51
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0104	0.0635	7	0.6275
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	67.79	10.44	0	78.69
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	58.57	14.02	0	76.28
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	2.09	0.92	0	4.43

Table D-II.2-6. Summary of exposure indices for all model runs (Large Volume, 80% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	6,147 x 10^6	8,411 x 10^6	0	54,937 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) cells only	1.2 x 10^6	2 x 10^6	42	8 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	487 x 10^6	504 x 10^6	0	2,355 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	488 x 10^6	504 x 10^6	0	2,355 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for the Florida Keys National Marine Sanctuary area	282 x 10^6	219 x 10^6	0	1,131 x 10^6
Surface Oil Exposure Exceeding 10g/m^2 (m^2) for the Florida Keys National Marine Sanctuary area	106 x 10^6	100 x 10^6	0	598 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	1,122,606	1,300,604	18	5,931,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	283,795	446,087	19	2,637,173
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	10,204	11,861	20	56,464
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	4,938	7,300	29	38,980
Length of Shoreline Oiling Exceeding 10 g/m^{2-} Other Shoreline (m)	5,265	5,279	22	23,789
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	1,981	2,012	30	6,592
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Coral Reef (m^3)	45 x 10^6	47 x 10^6	3	158 x 10^6
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Seagrass Bed (m^3)	278 x 10^6	234 x 10^6	1	1,004 x 10^6
Dissolved Aromatic Plume Volume Exceeding 1 ppb - Rock	60 x 10^6	81 x 10^6	18	473 x 10^6

Bottom (m^3)				
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	1,095 x 10^6	988 x 10^6	0	4,646 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	5,935	3,788	0	19,940
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	2.70	4.40	18	20.07
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0051	0.0278	7	0.2776
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	72.73	9.27	0	81.57
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	63.51	13.58	0	79.85
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	1.12	0.72	0	4.28

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part D: Florida Straits

Section D-II.3

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ASA 00-246

August 2004

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D-II.3 Rank Order Distributions for All Model Runs

In this section, the following impact indices are plotted as rank order distributions:

- Water surface exposed to floating hydrocarbons, as the sum of area covered by more than $0.01 g/m^2$ (which is sheen) times duration of exposure (in m^2-hrs)
- Shoreline area (m^2) exposed to hydrocarbons of various threshold thicknesses (>1, 10, 100, and 1000 g/m^2)
- Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill
- Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill
- Percent of spilled hydrocarbon mass eventually going ashore
- Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats)
- Maximum percent of spilled hydrocarbon mass in the water column at any time after the spill, and
- Percent of spilled hydrocarbon mass mechanically removed.

D-II.3.1 Scenario: Medium Volume, No Dispersant.

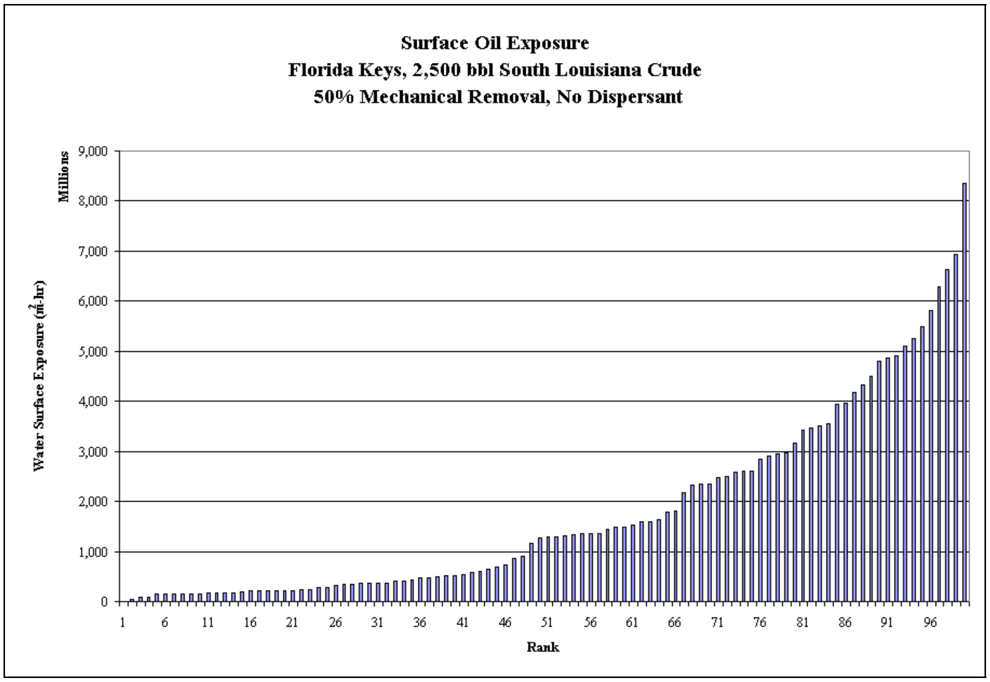

Figure D-II.3.1-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Medium Volume, No Dispersant.

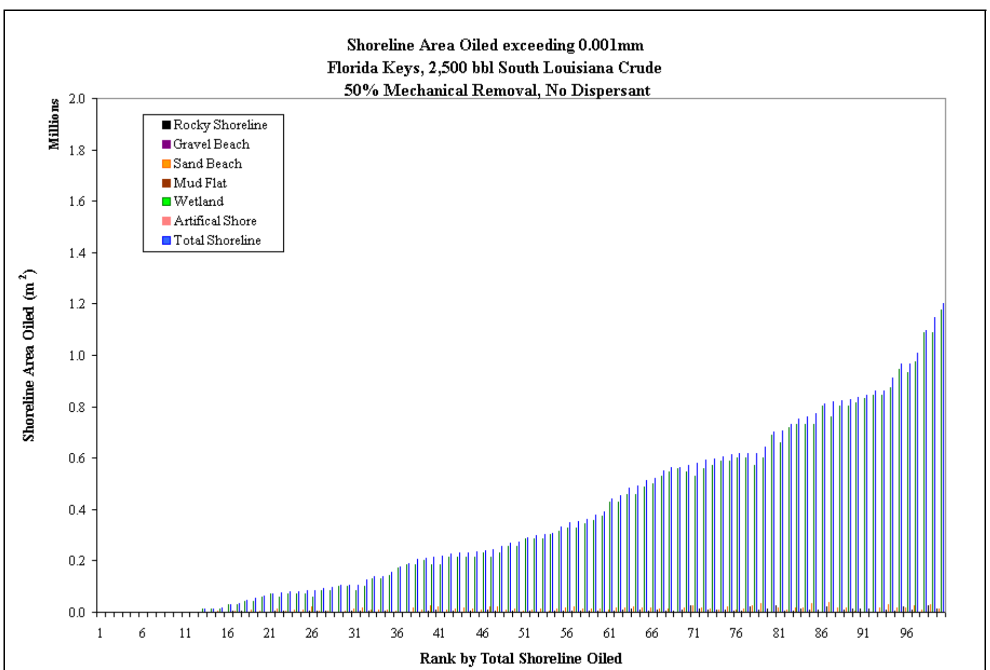

Figure D-II.3.1-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Medium Volume, No Dispersant.

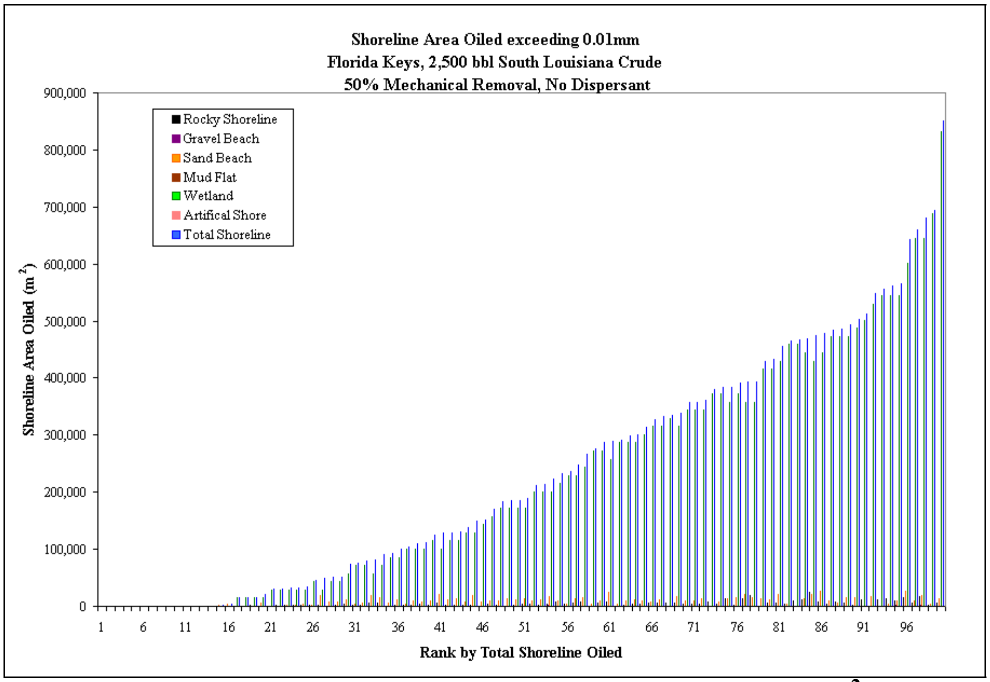

Figure D-II.3.1-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Medium Volume, No Dispersant.

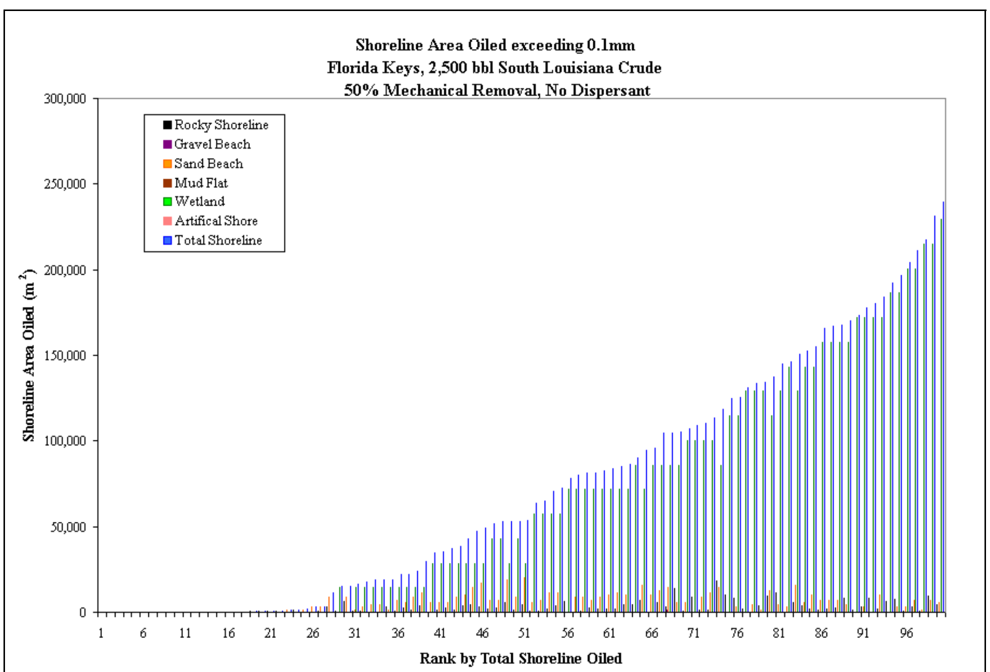

Figure D-II.3.1-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Medium Volume, No Dispersant.

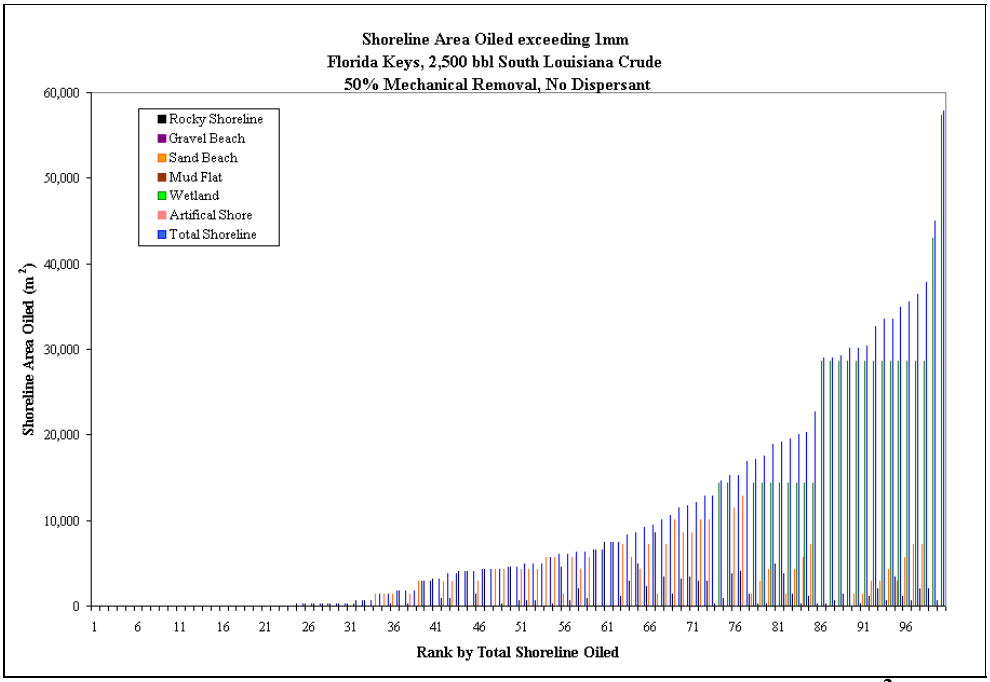

Figure D-II.3.1-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Medium Volume, No Dispersant.

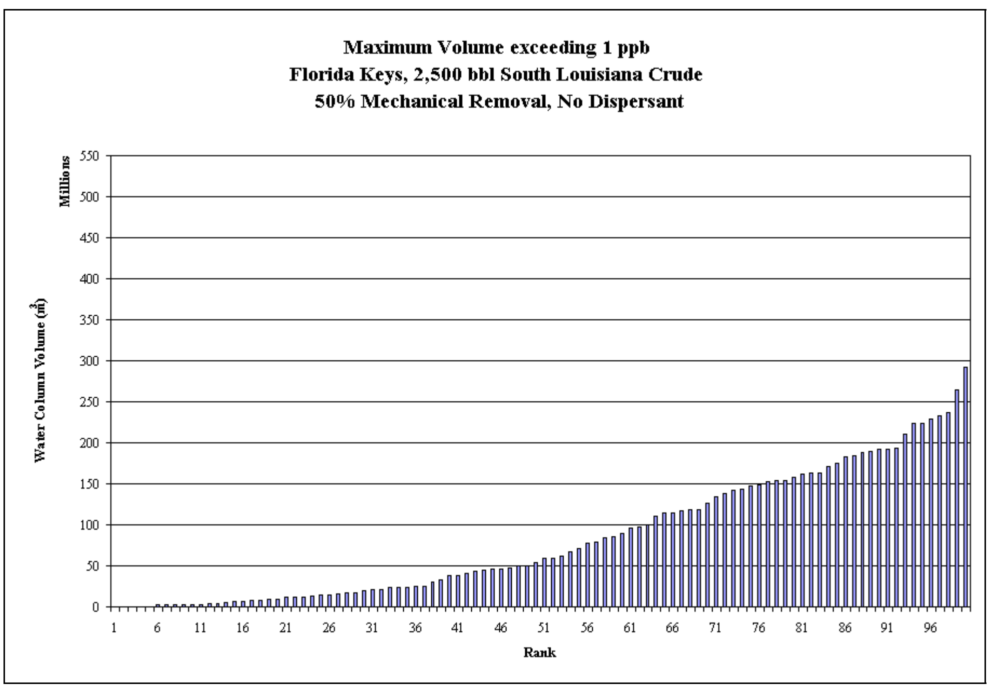

Figure D-II.3.1-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, No Dispersant.

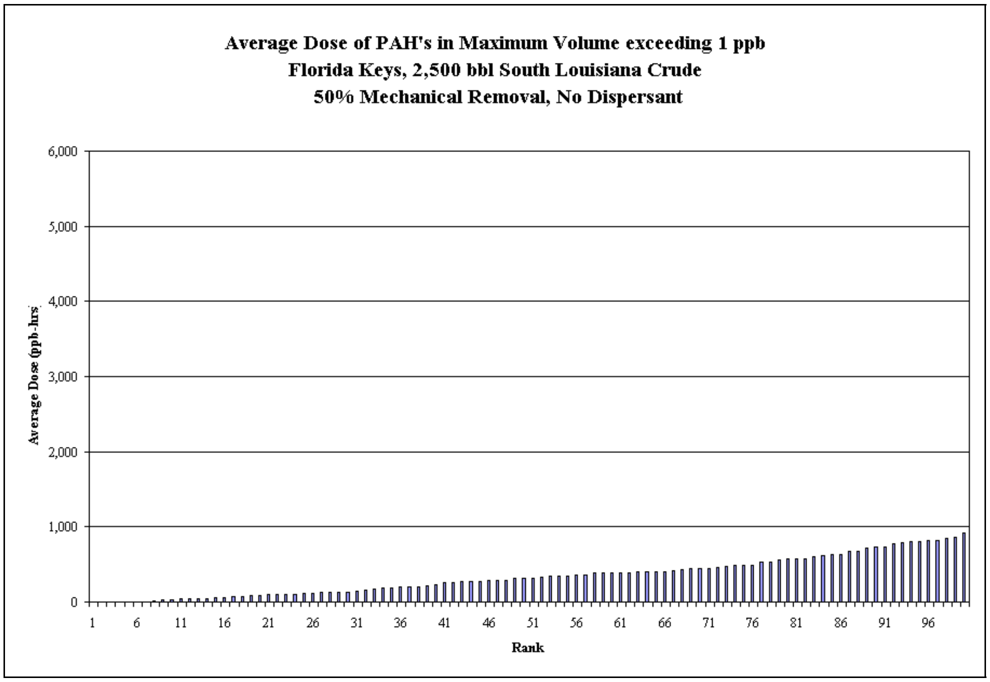

Figure D-II.3.1-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, No Dispersant.

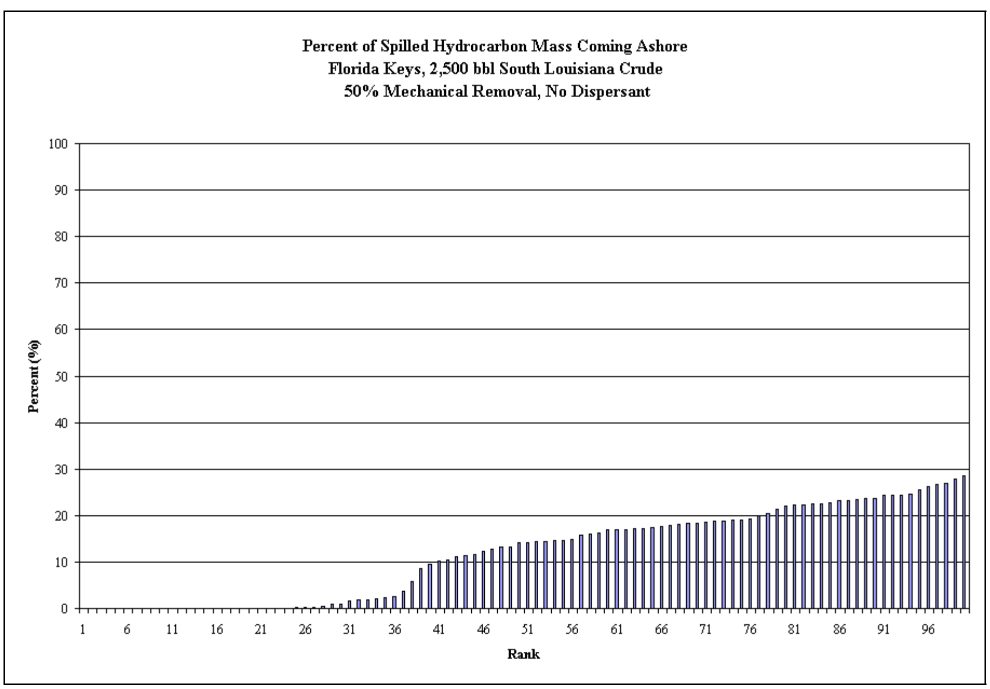

Figure D-II.3.1-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Medium Volume, No Dispersant.

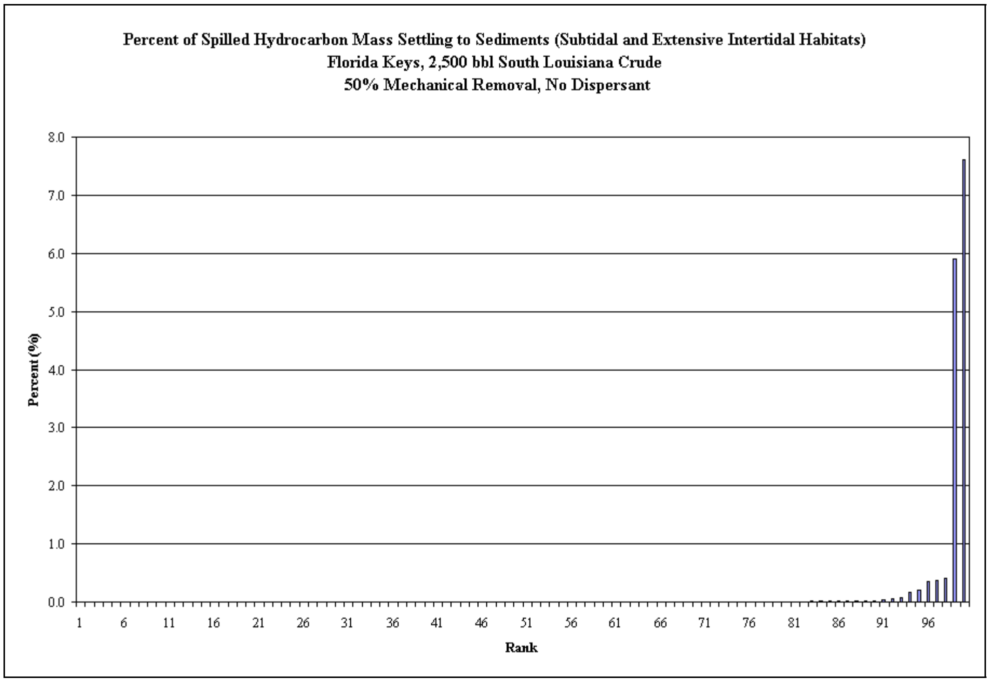

Figure D-II.3.1-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Medium Volume, No Dispersant.

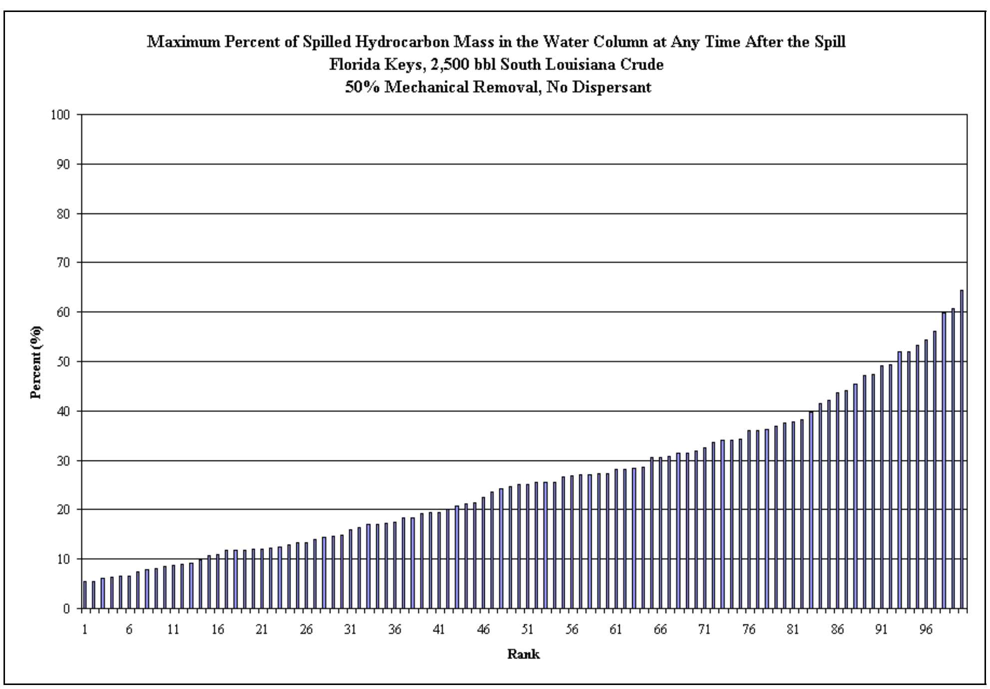

Figure D-II.3.1-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Medium Volume, No Dispersant.

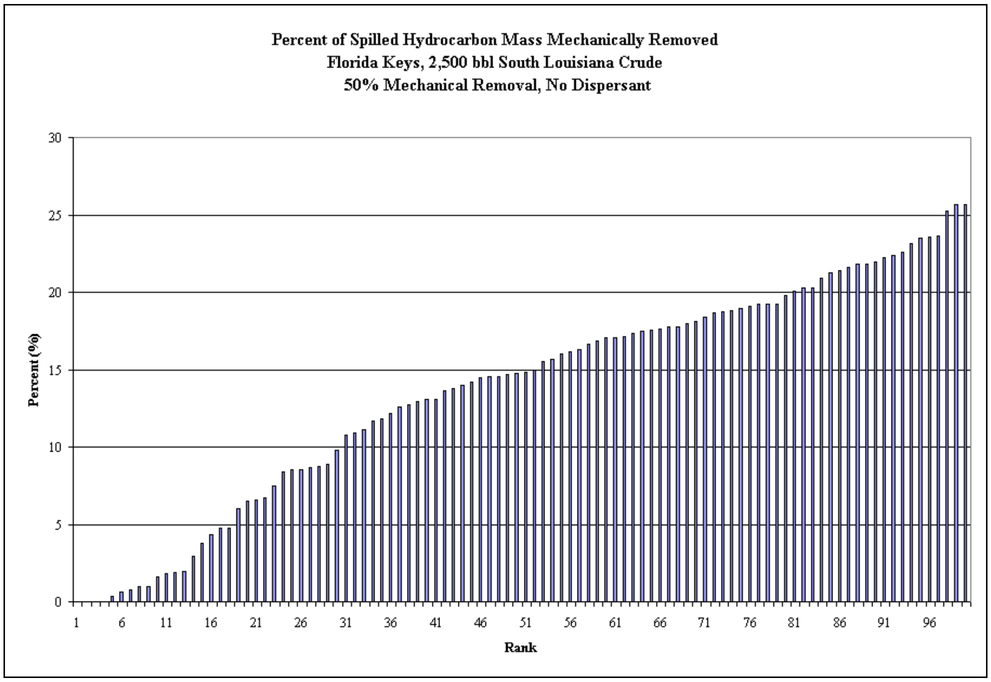

Figure D-II.3.1-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Medium Volume, No Dispersant.

D-II.3.2 Scenario: Medium Volume, 45% Dispersant Efficiency.

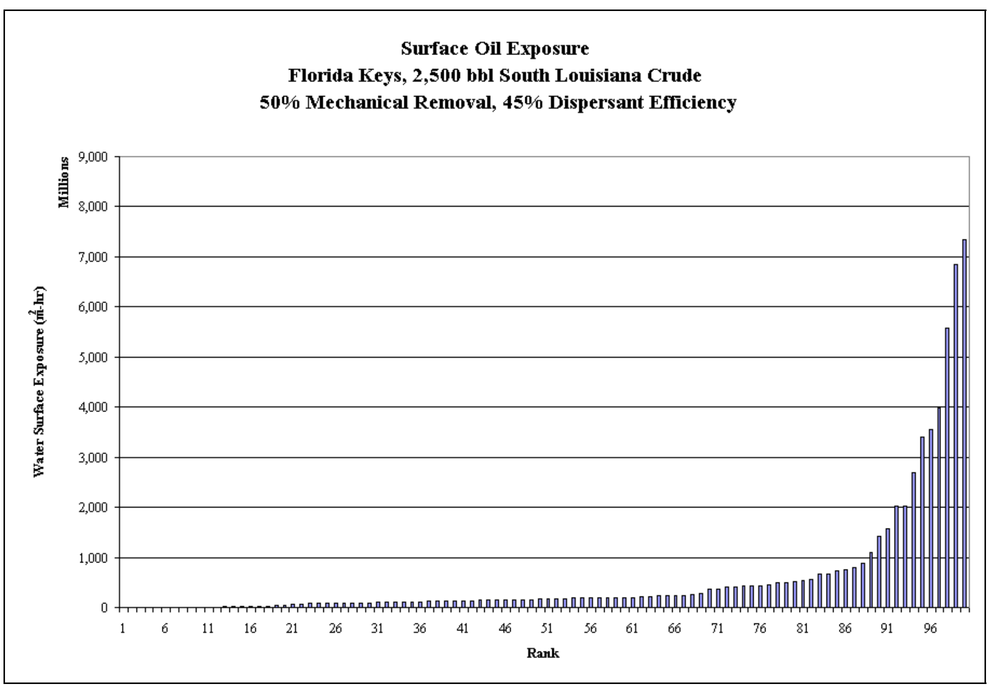

Figure D-II.3.2-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

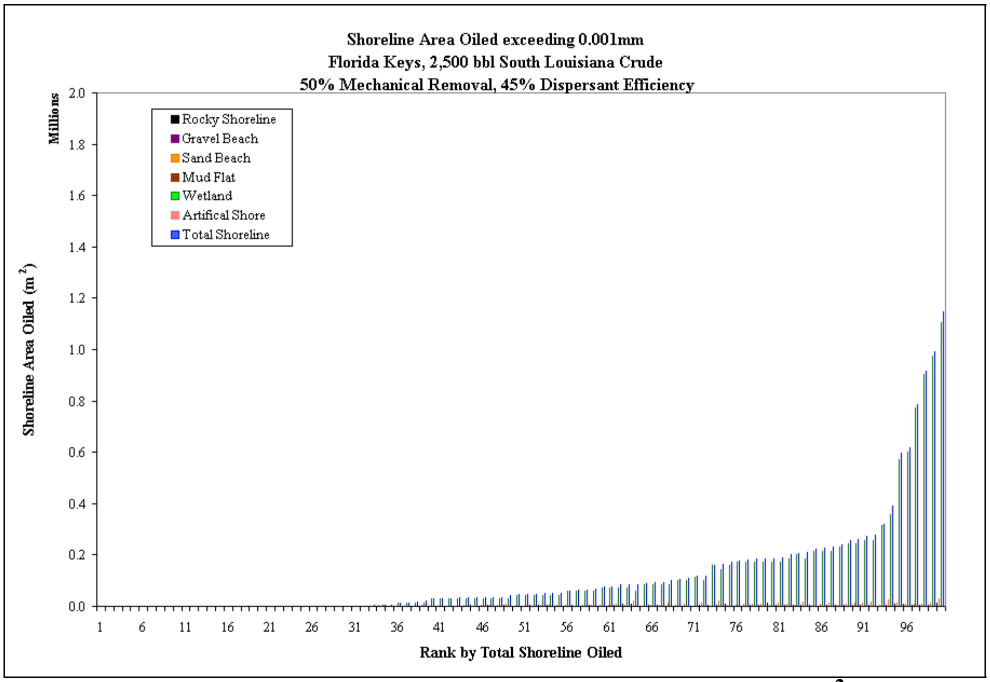

Figure D-II.3.2-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

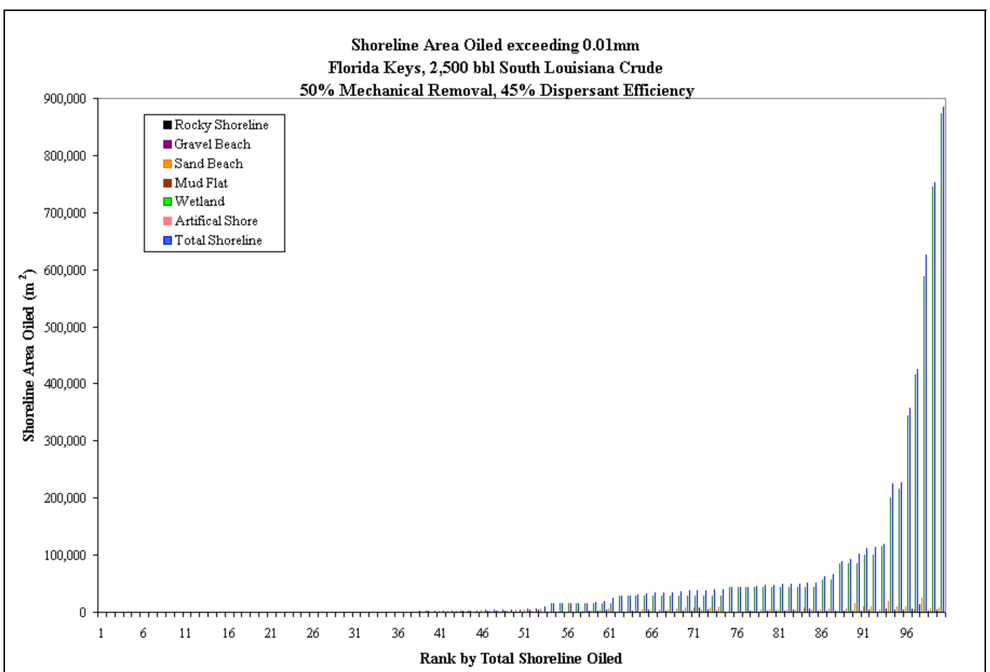

Figure D-II.3.2-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

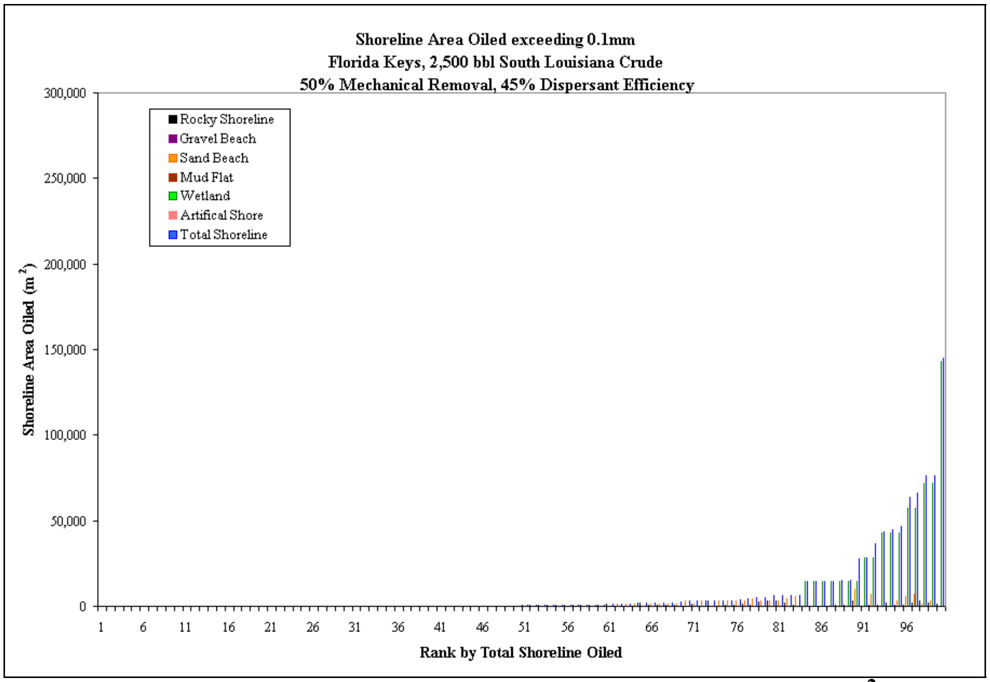

Figure D-II.3.2-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

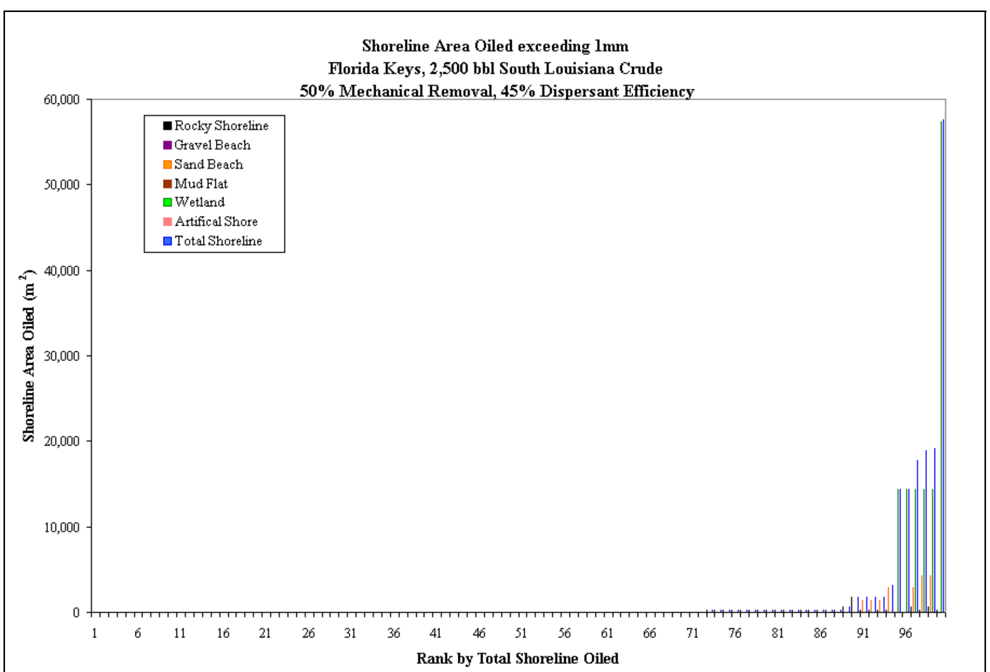

Figure D-II.3.2-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

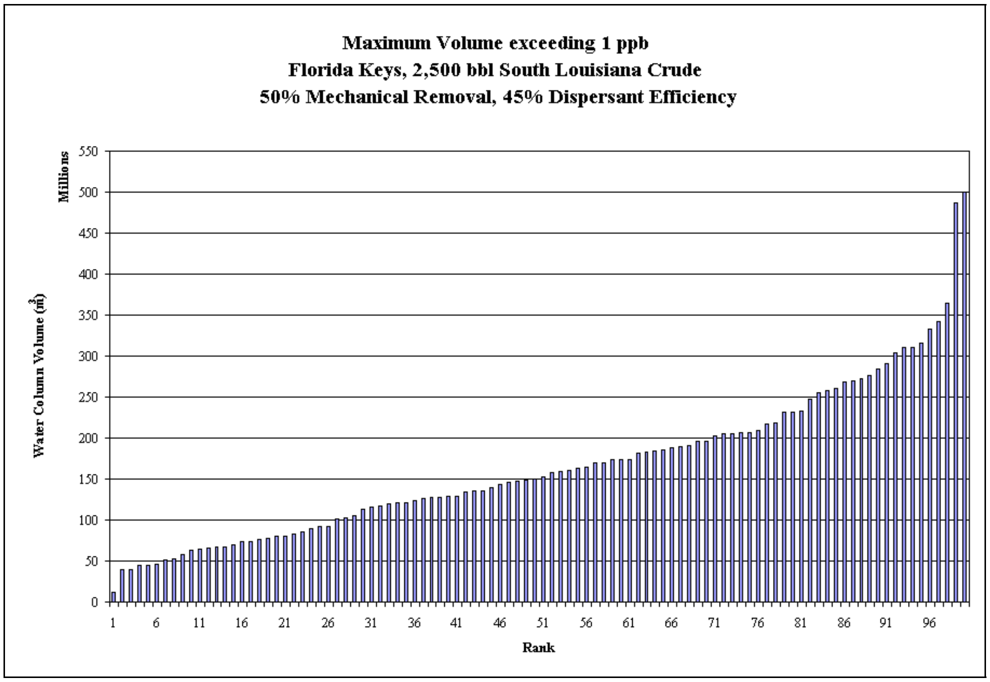

Figure D-II.3.2-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 45% Dispersant Efficiency.

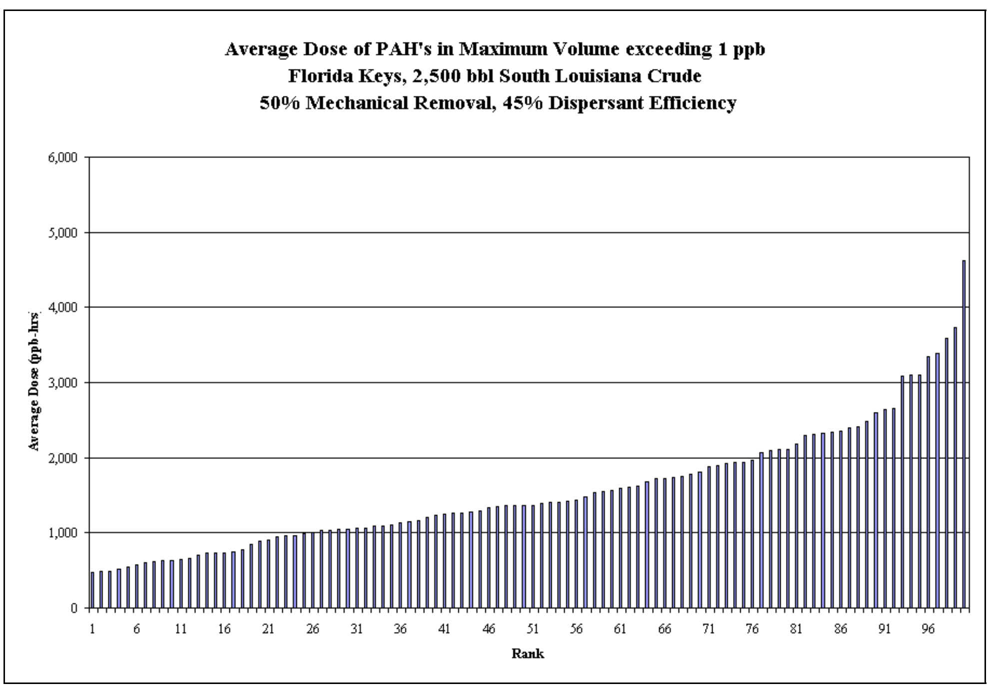

Figure D-II.3.2-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 45% Dispersant Efficiency.

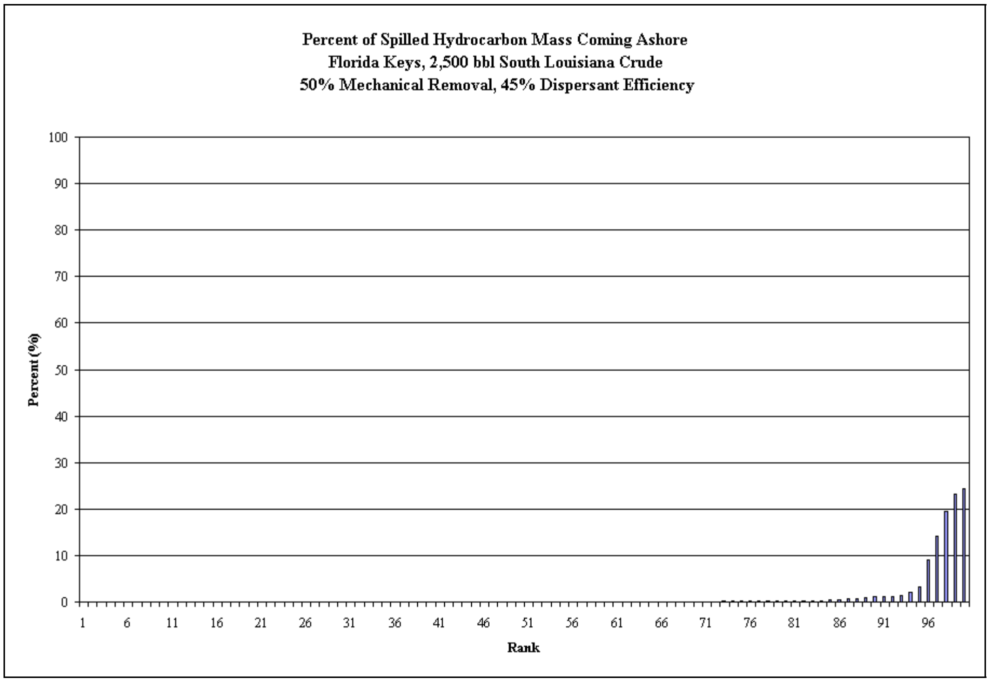

Figure D-II.3.2-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Medium Volume, 45% Dispersant Efficiency.

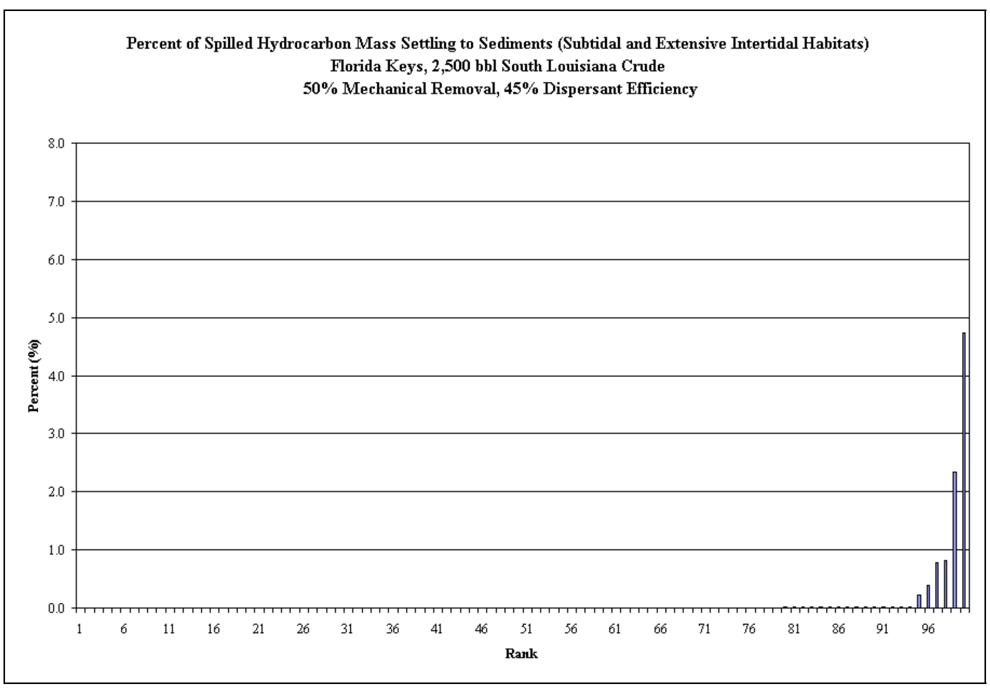

Figure D-II.3.2-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Medium Volume, 45% Dispersant Efficiency.

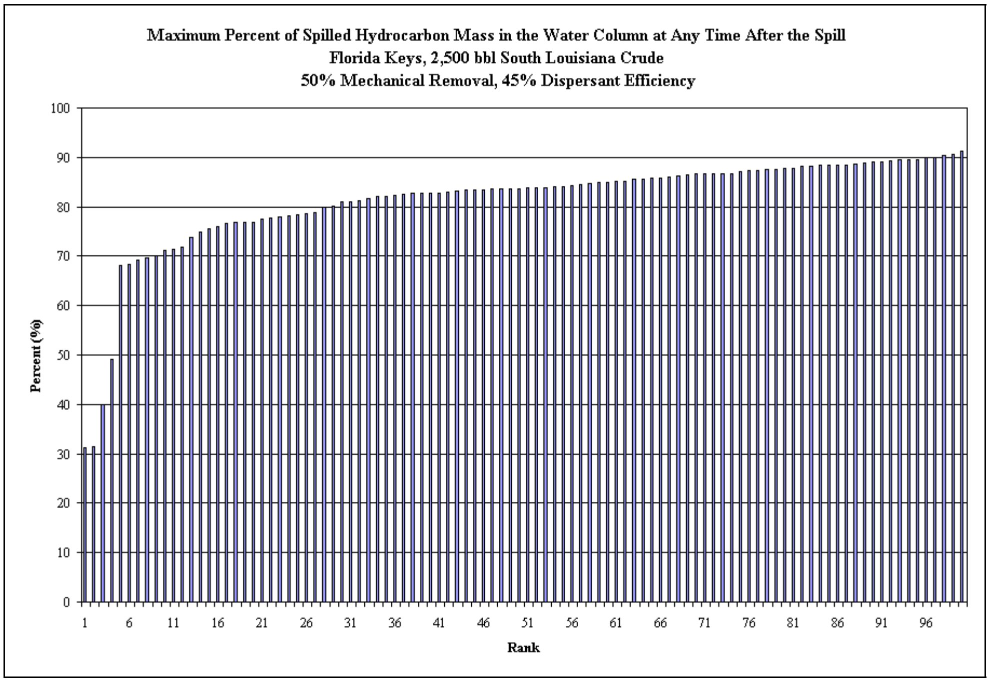

Figure D-II.3.2-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Medium Volume, 45% Dispersant Efficiency.

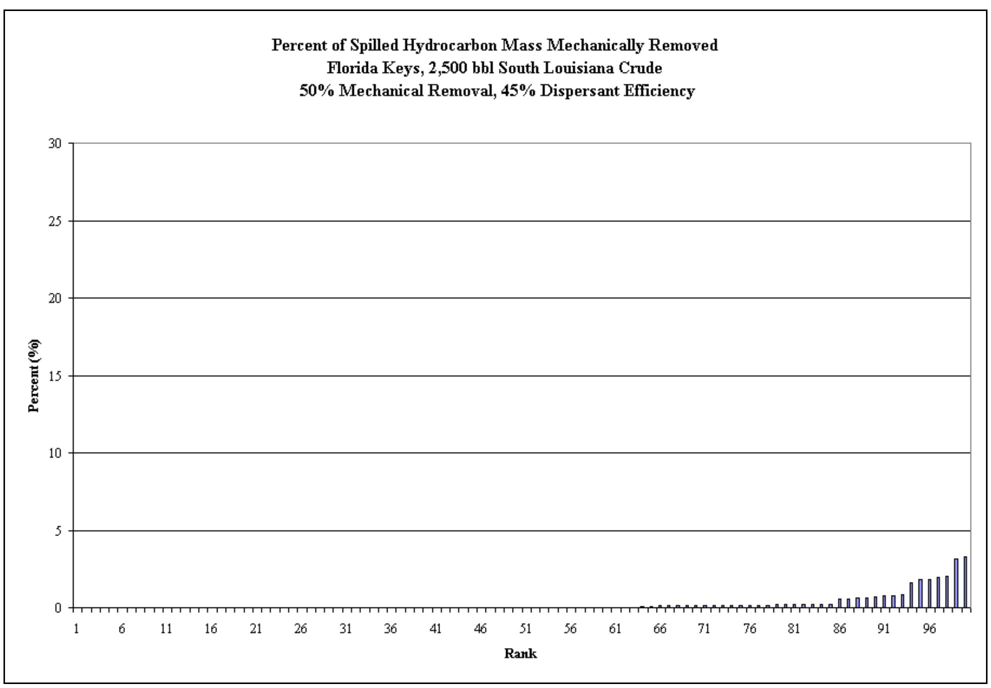

Figure D-II.3.2-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Medium Volume, 45% Dispersant Efficiency.

D-II.3.3 Scenario: Medium Volume, 80% Dispersant Efficiency.

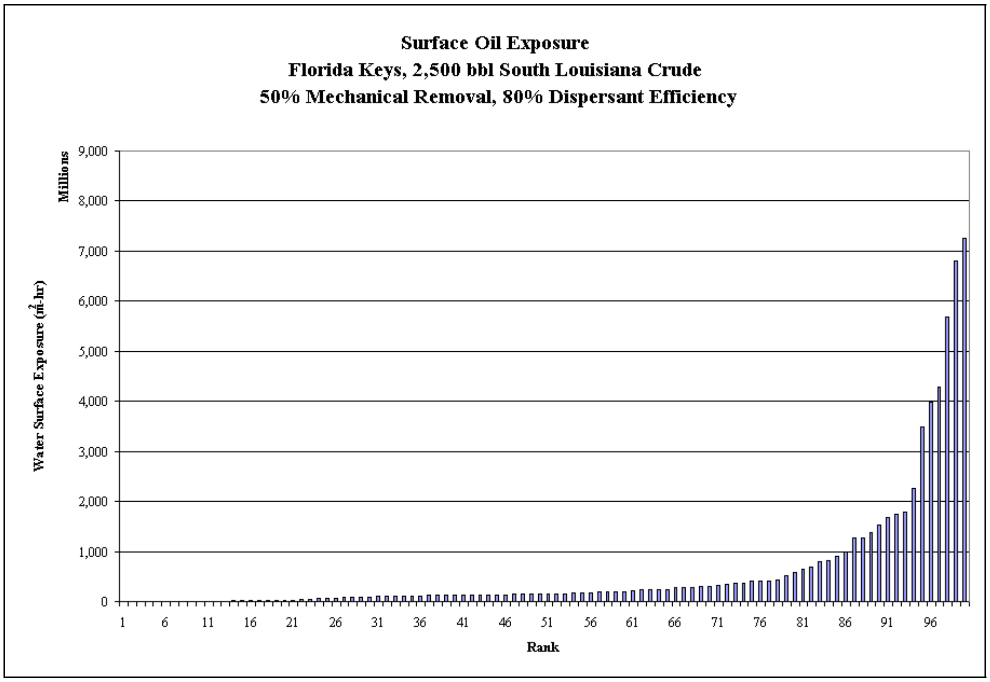

Figure D-II.3.3-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

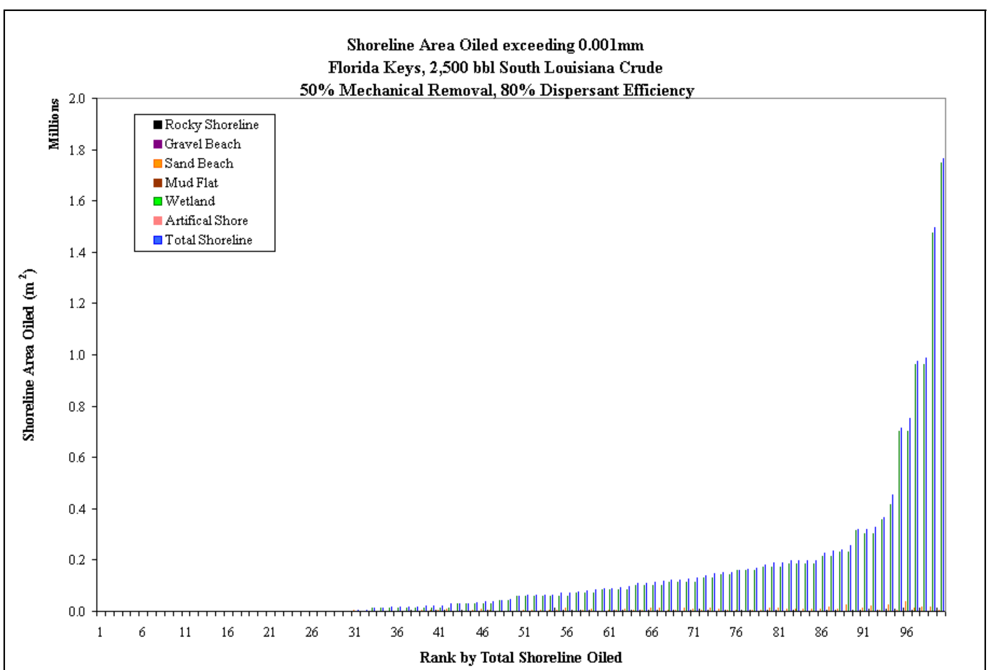

Figure D-II.3.3-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

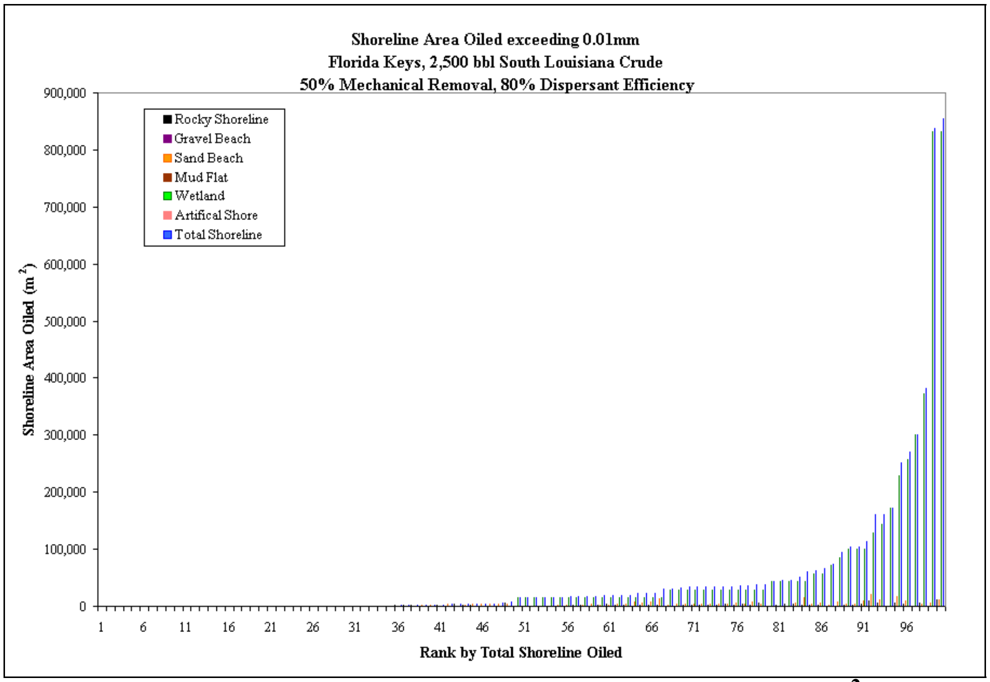

Figure D-II.3.3-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

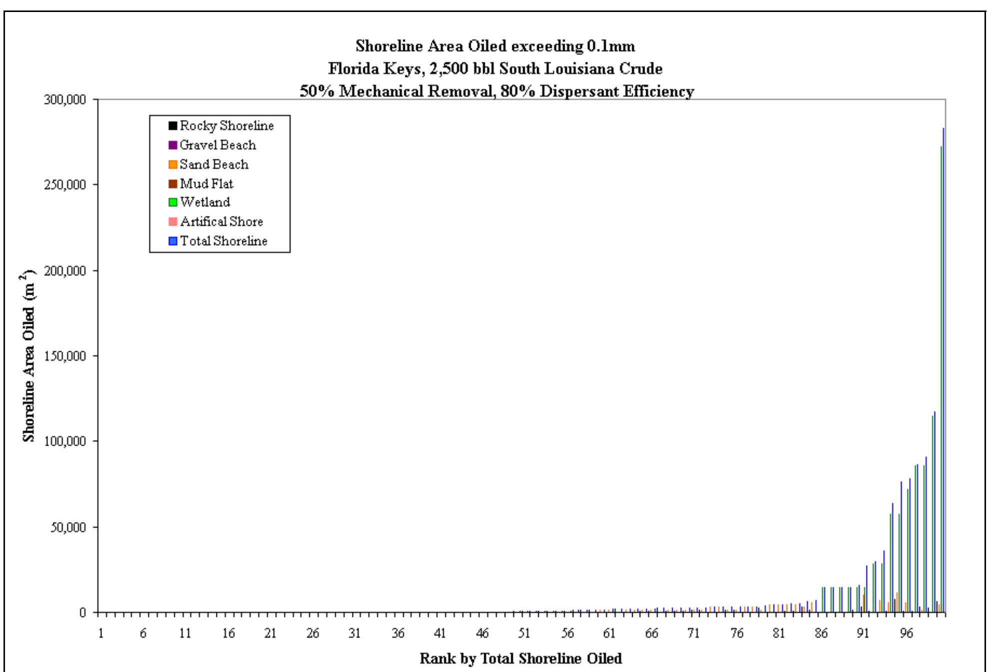

Figure D-II.3.3-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

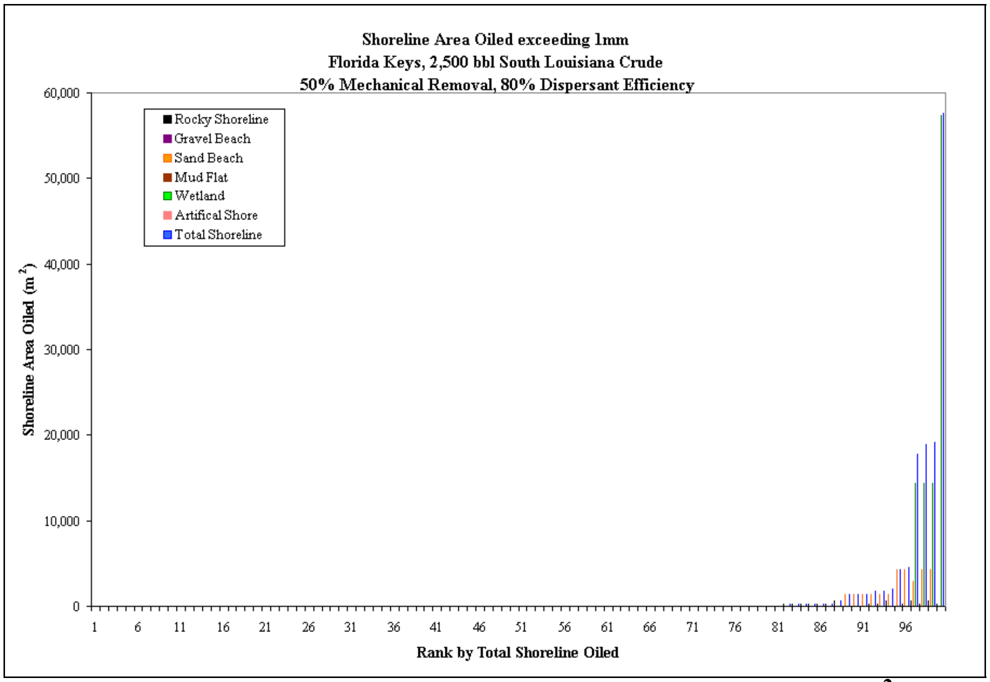

Figure D-II.3.3-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

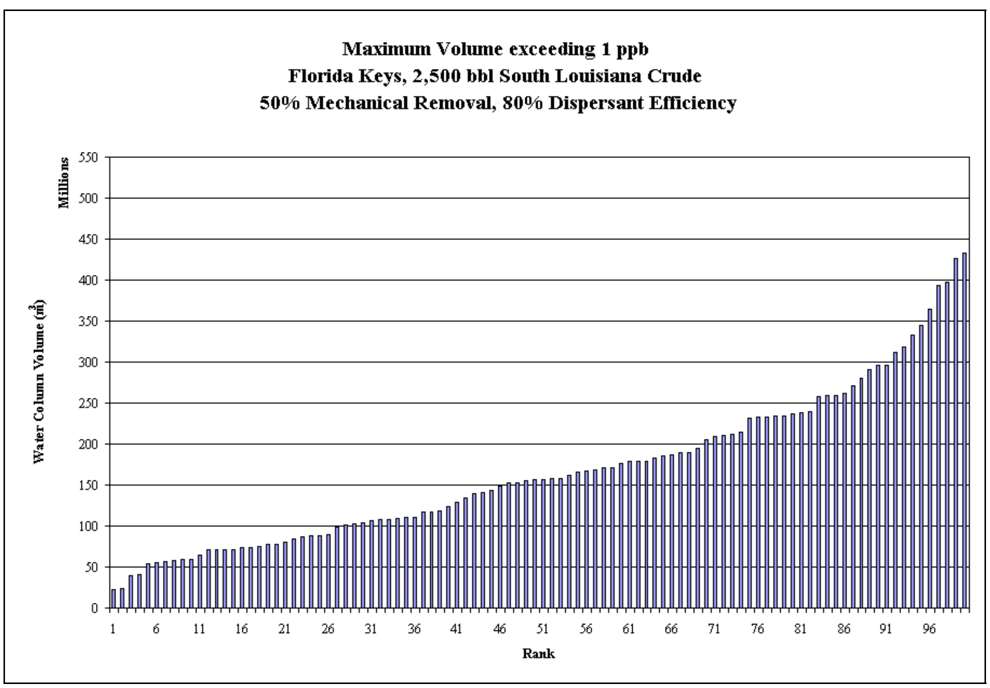

Figure D-II.3.3-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 80% Dispersant Efficiency.

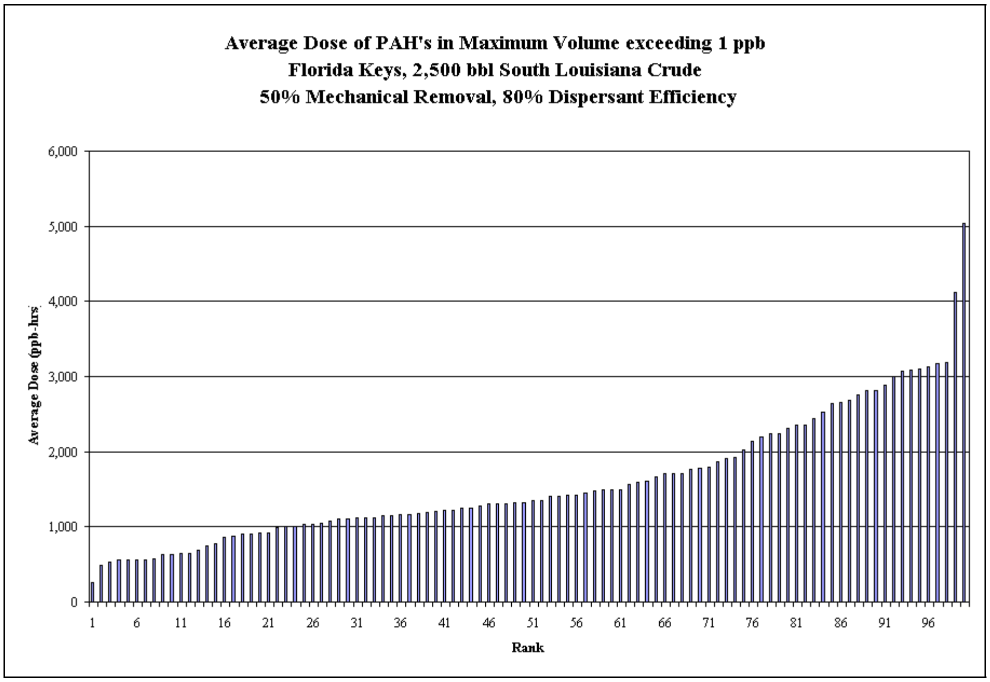

Figure D-II.3.3-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 80% Dispersant Efficiency.

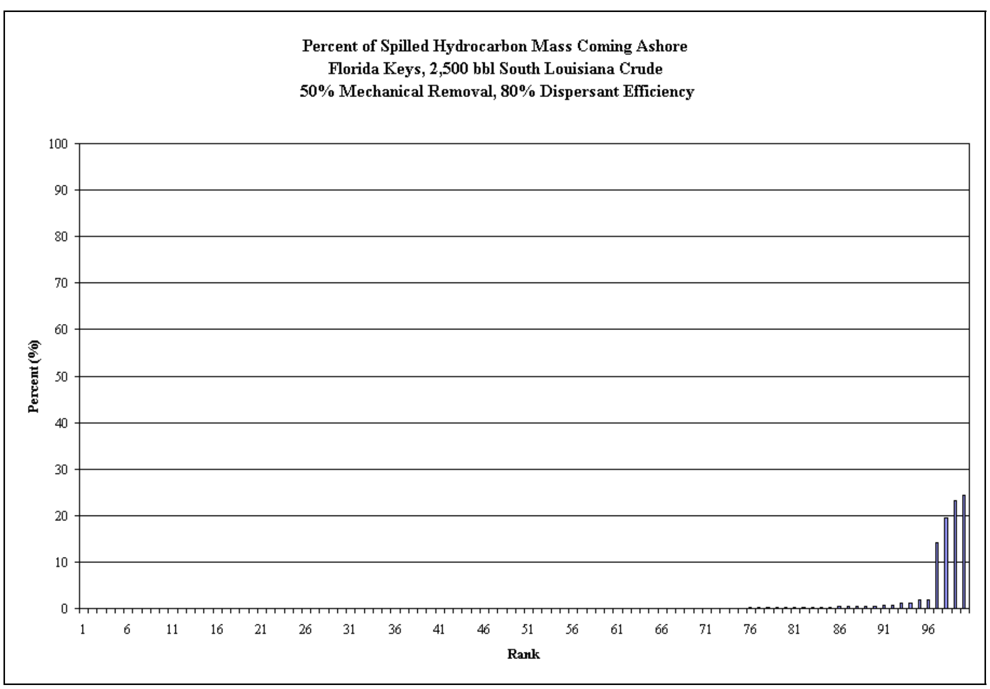

Figure D-II.3.3-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Medium Volume, 80% Dispersant Efficiency.

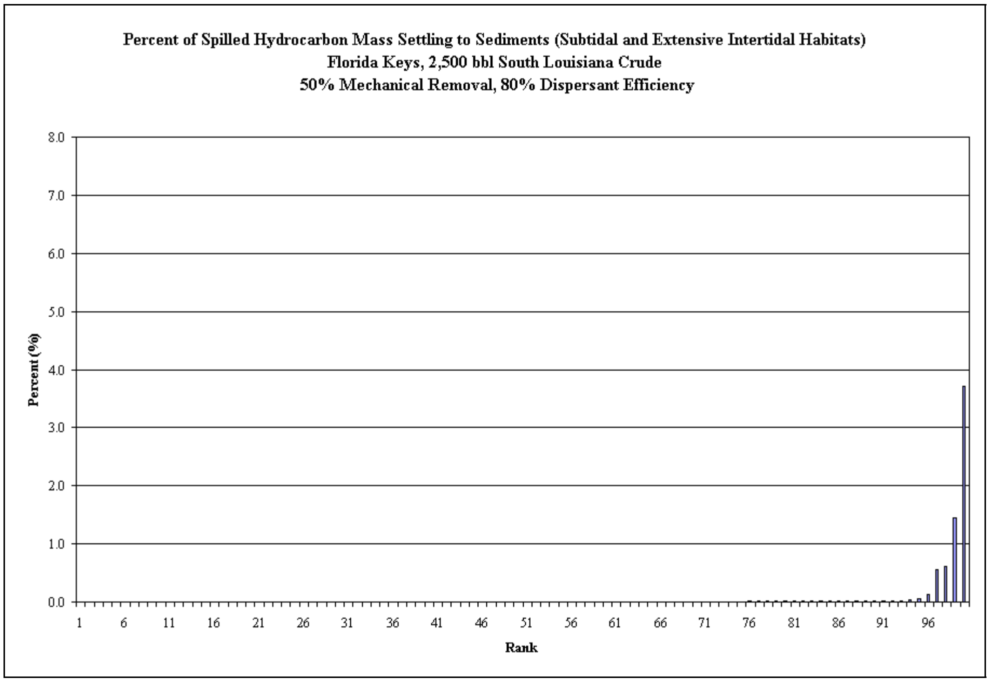

Figure D-II.3.3-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Medium Volume, 80% Dispersant Efficiency.

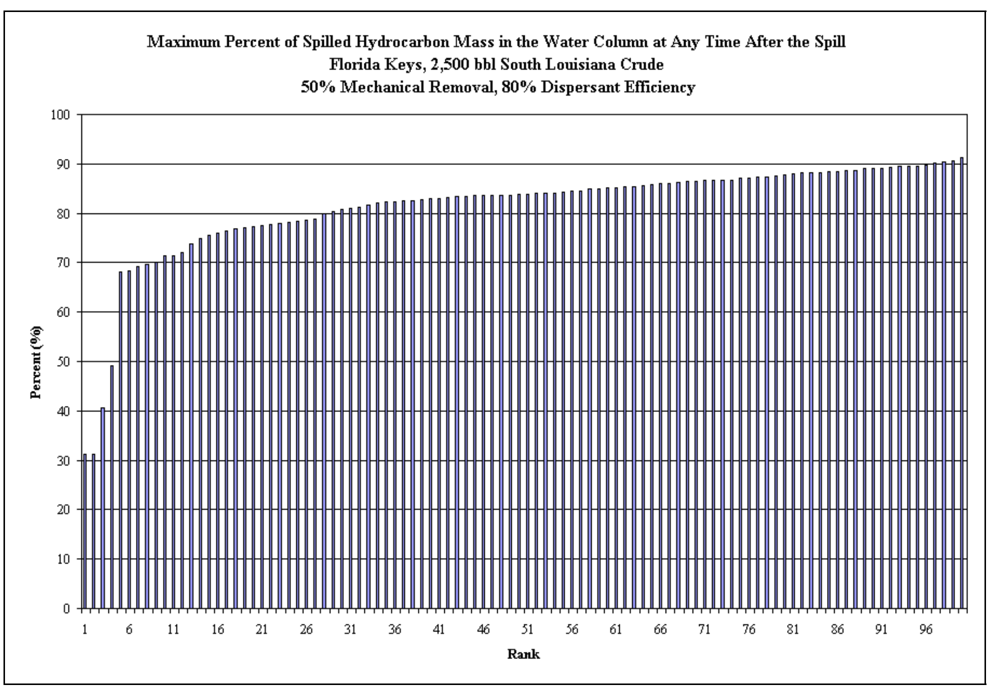

Figure D-II.3.3-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Medium Volume, 80% Dispersant Efficiency.

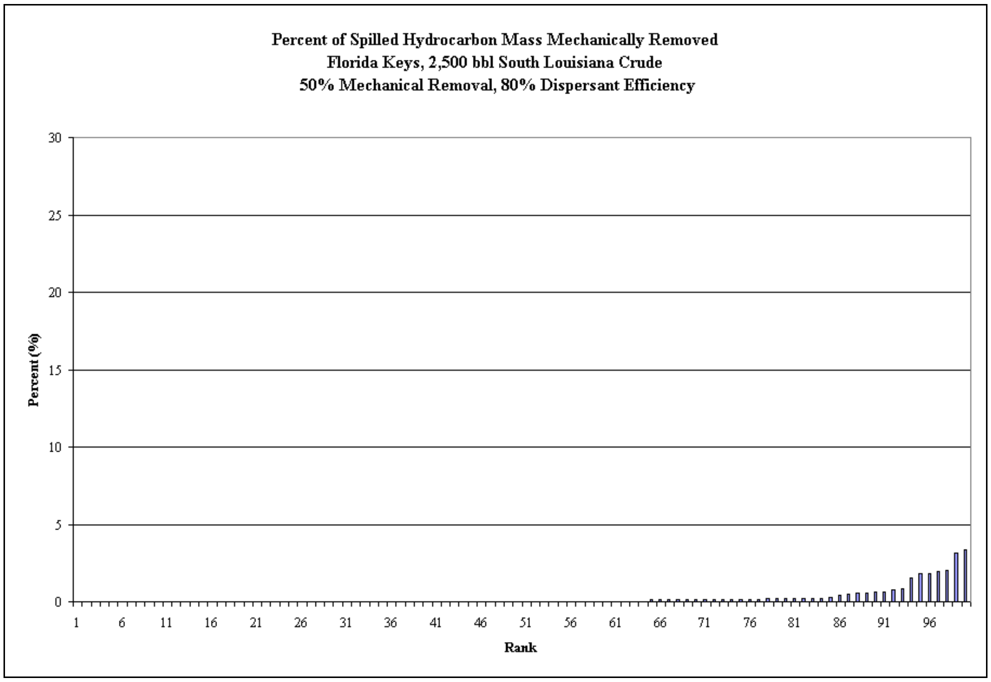

Figure D-II.3.3-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Medium Volume, 80% Dispersant Efficiency.

D-II.3.4 Scenario: Large Volume, No Dispersant.

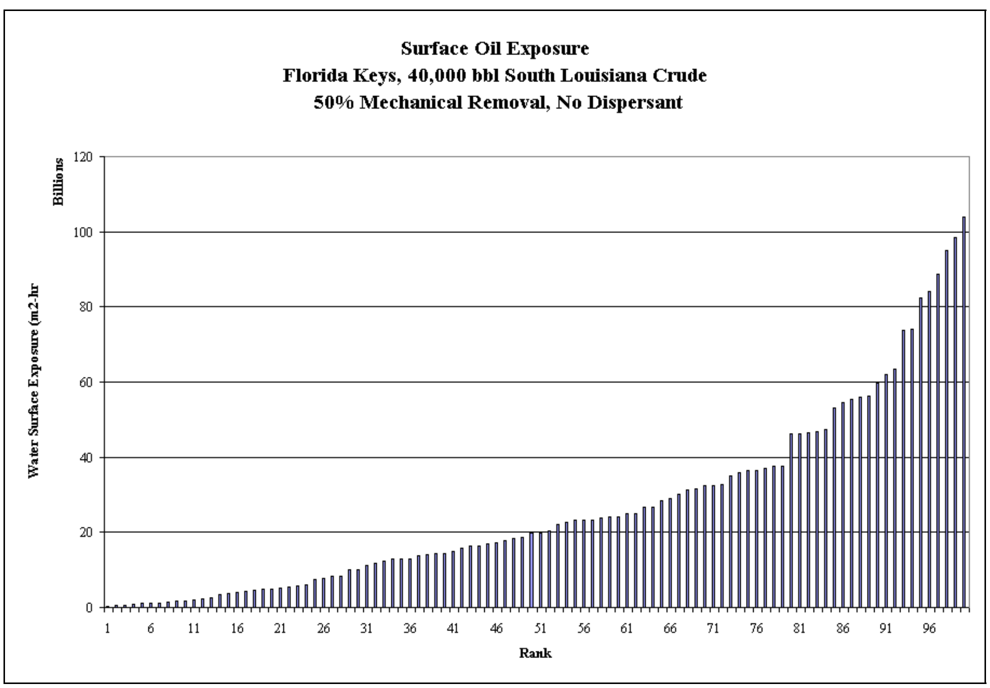

Figure D-II.3.4-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Large Volume, No Dispersant.

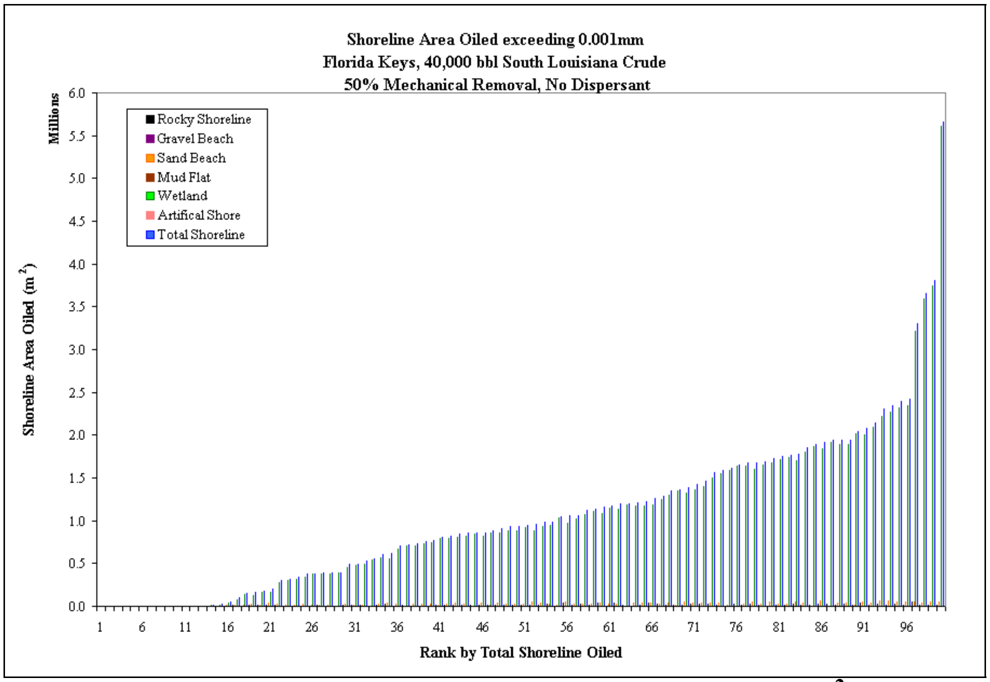

Figure D-II.3.4-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Large Volume, No Dispersant.

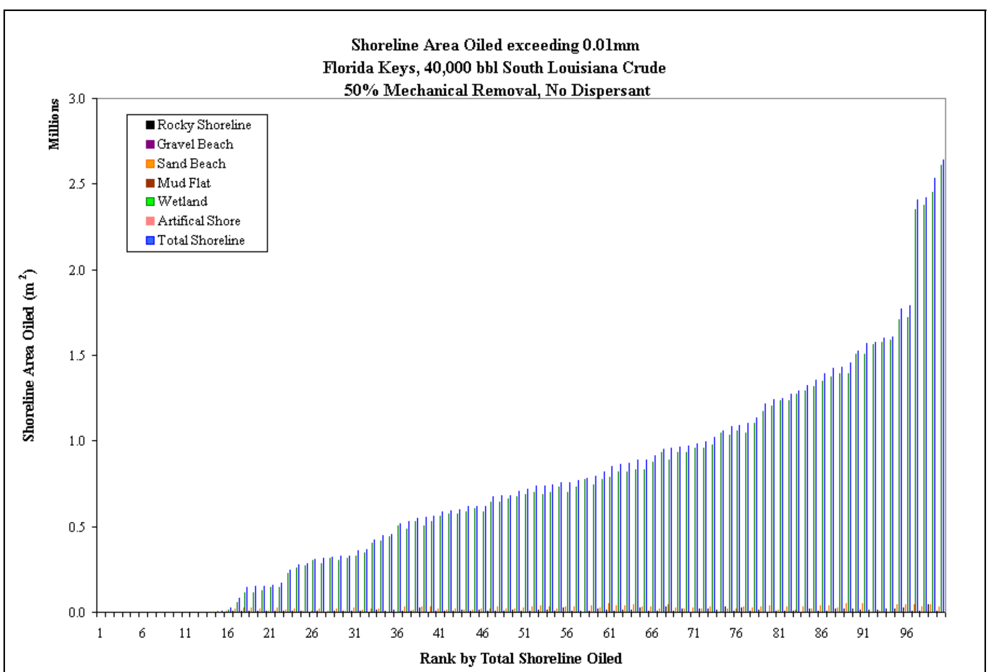

Figure D-II.3.4-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Large Volume, No Dispersant.

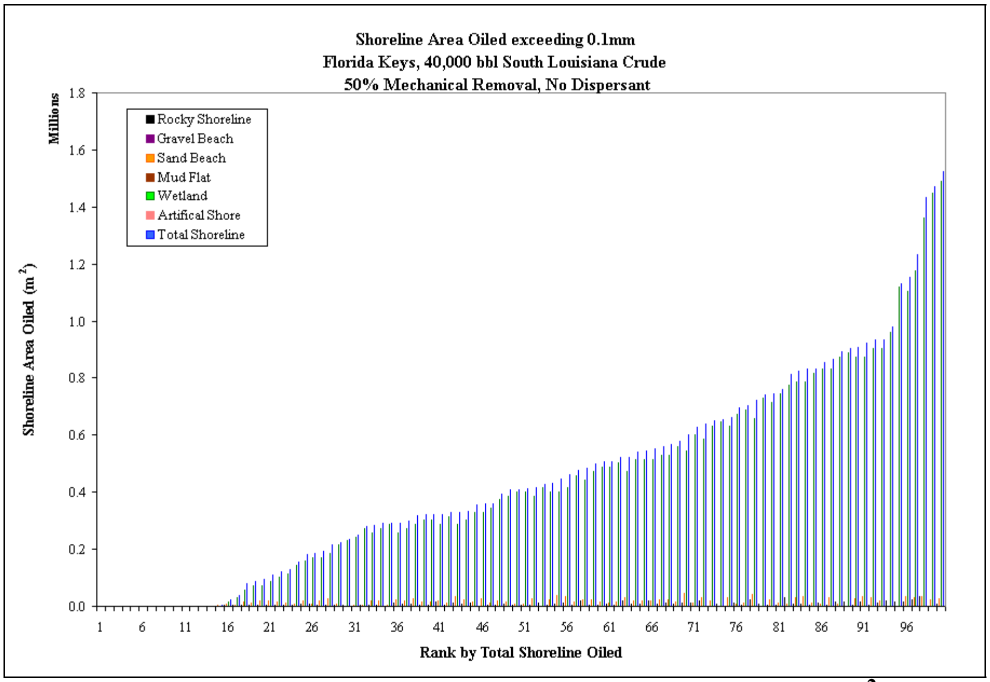

Figure D-II.3.4-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Large Volume, No Dispersant.

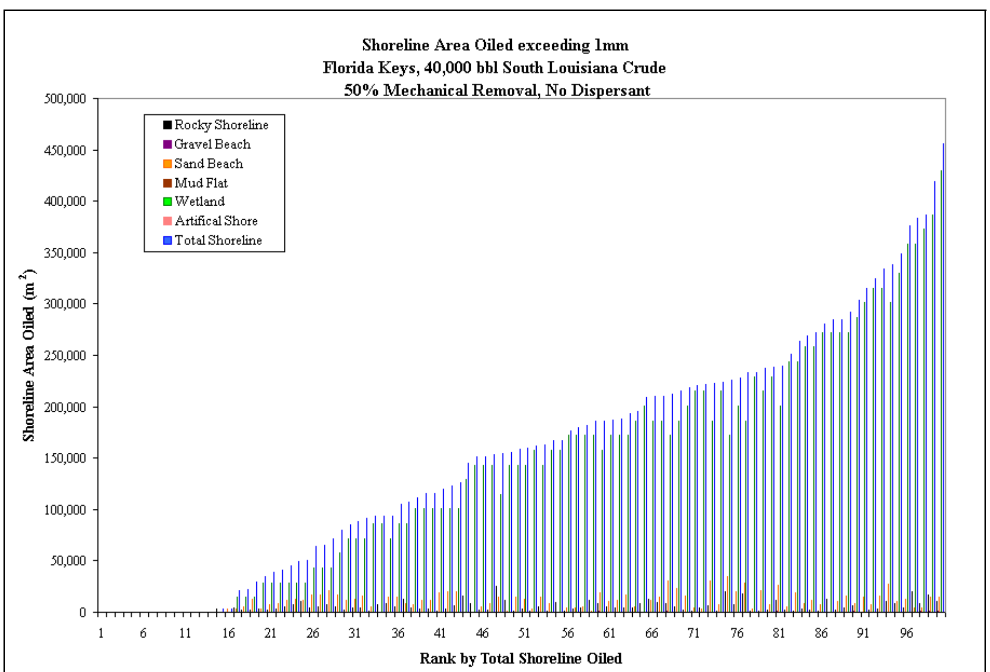

Figure D-II.3.4-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Large Volume, No Dispersant.

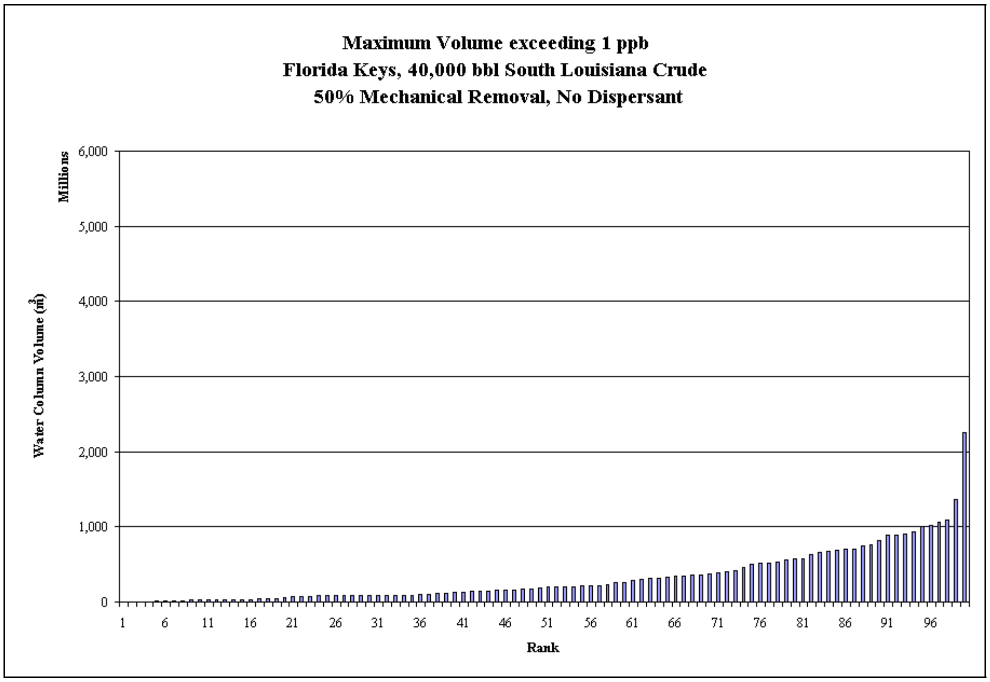

Figure D-II.3.4-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, No Dispersant.

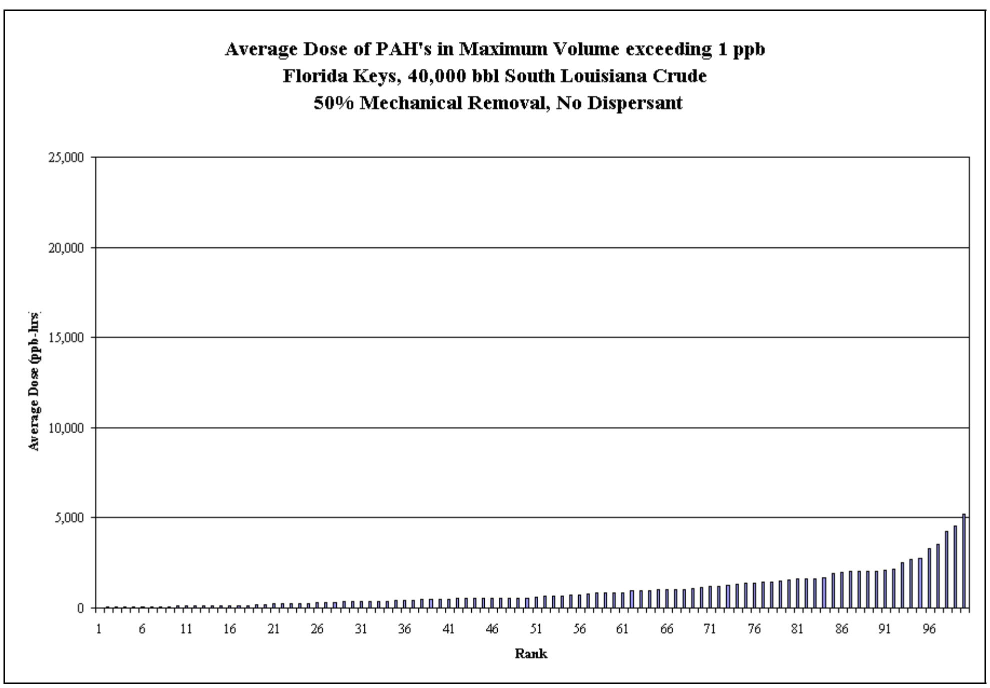

Figure D-II.3.4-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, No Dispersant.

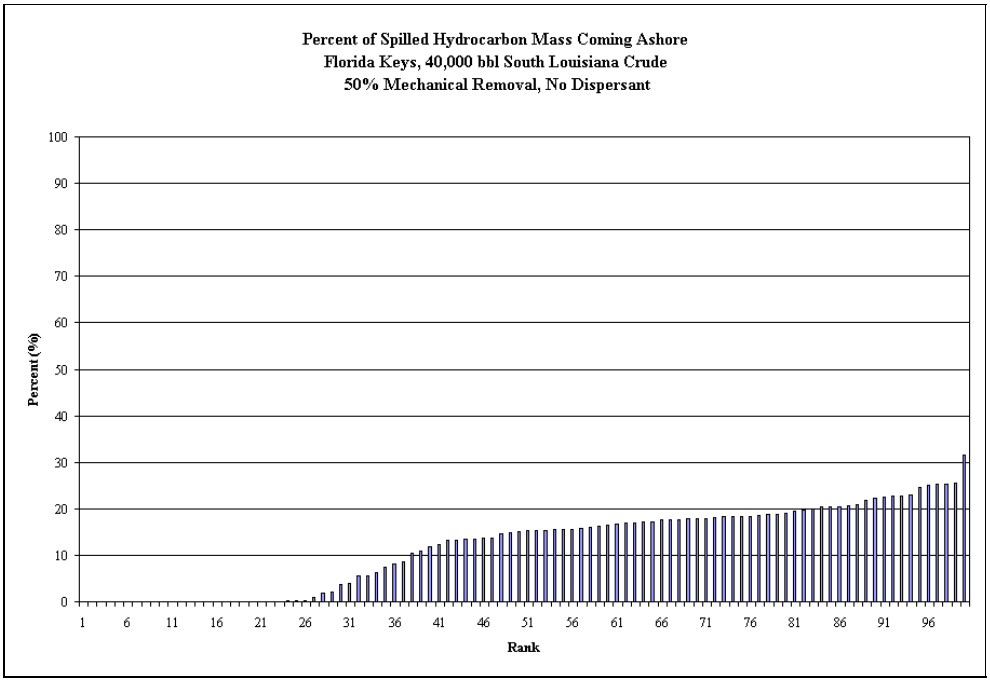

Figure D-II.3.4-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Large Volume, No Dispersant.

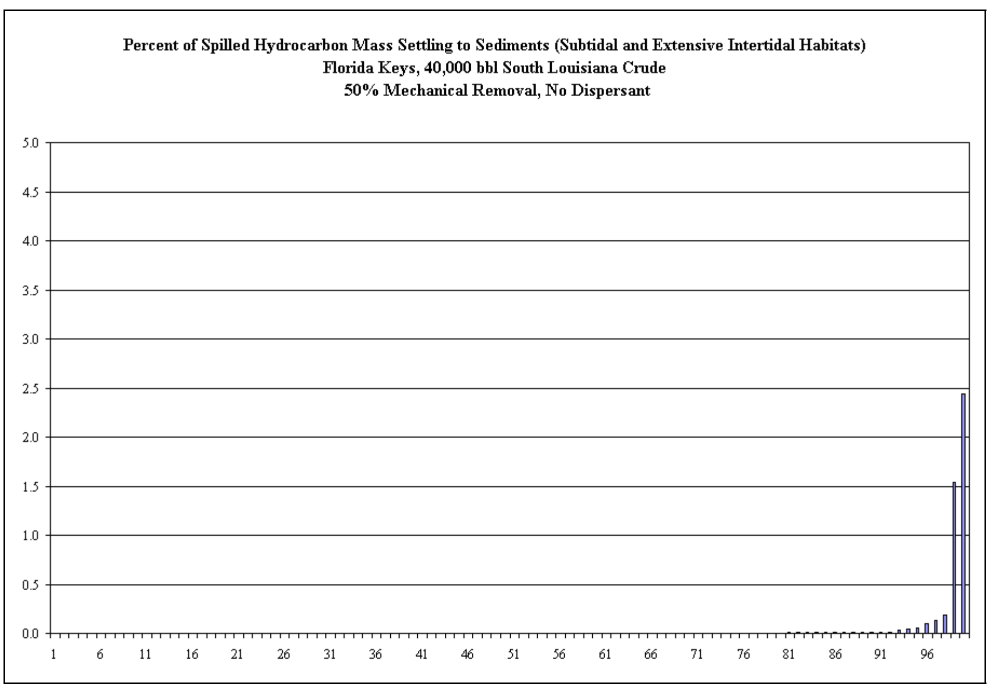

Figure D-II.3.4-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Large Volume, No Dispersant.

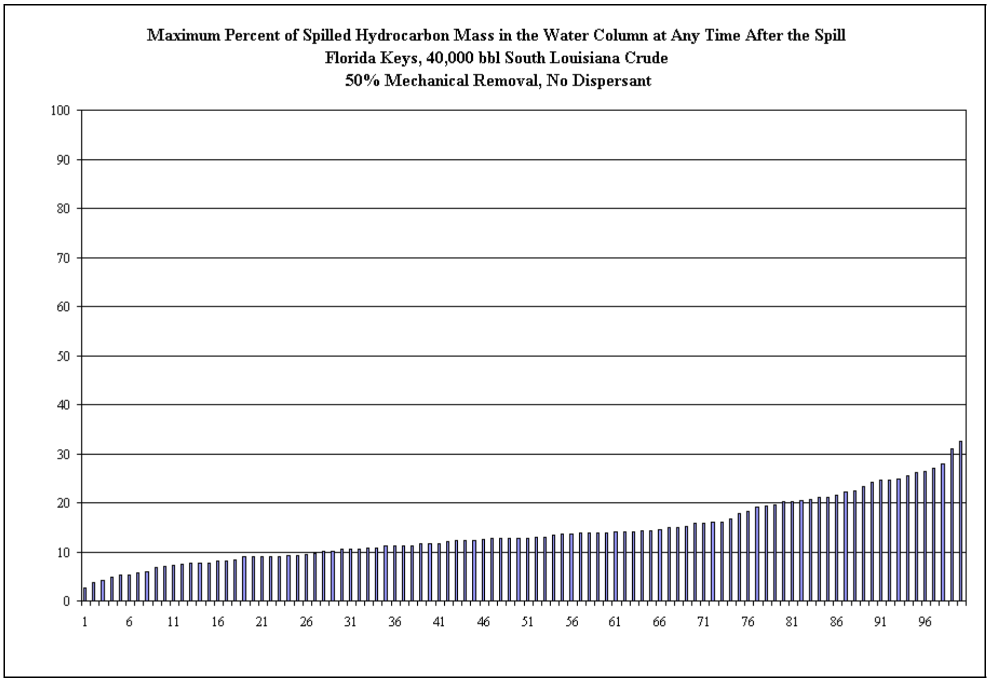

Figure D-II.3.4-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Large Volume, No Dispersant.

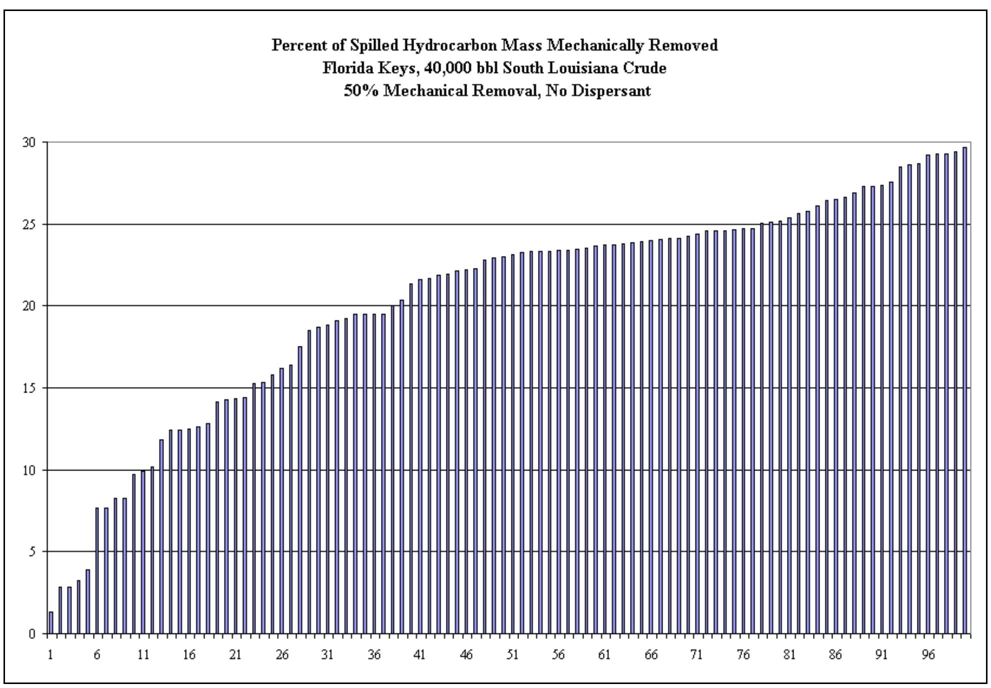

Figure D-II.3.4-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Large Volume, No Dispersant.

D-II.3.5 Scenario: Large Volume, 45% Dispersant Efficiency.

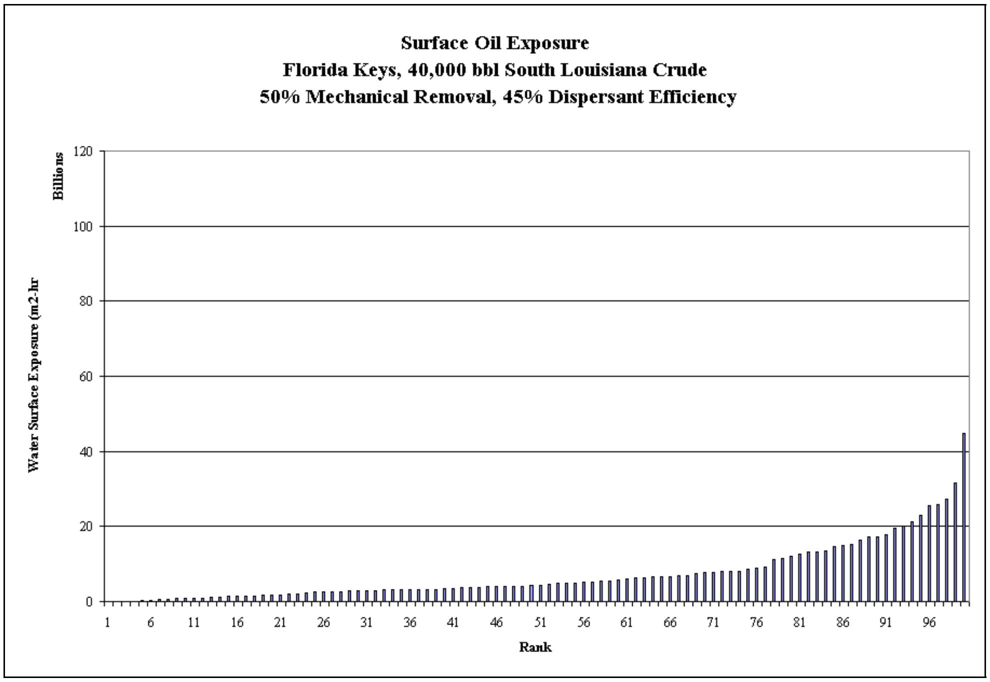

Figure D-II.3.5-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

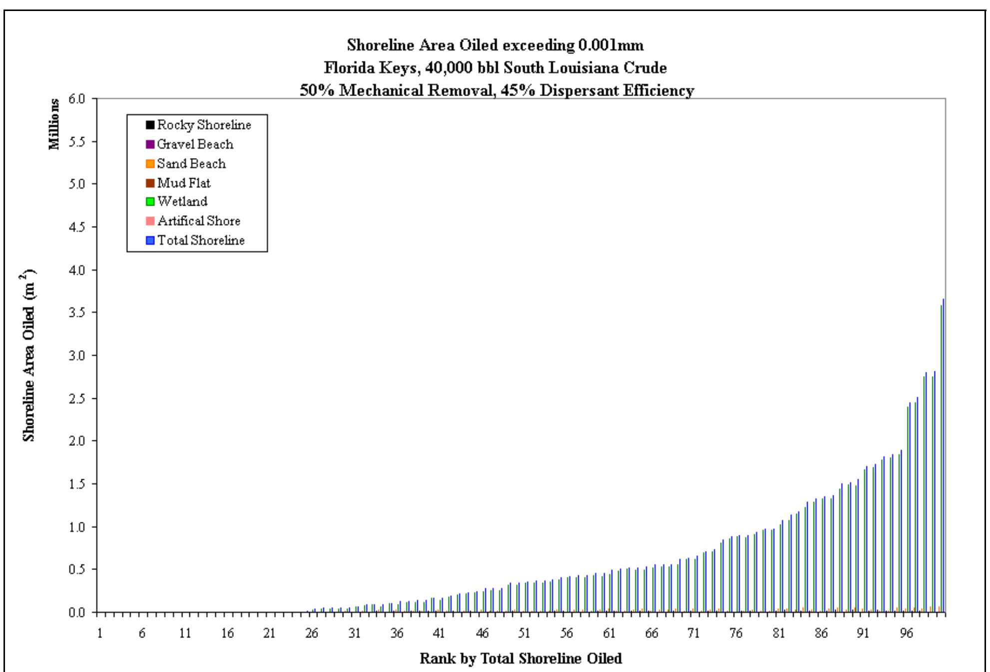

Figure D-II.3.5-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

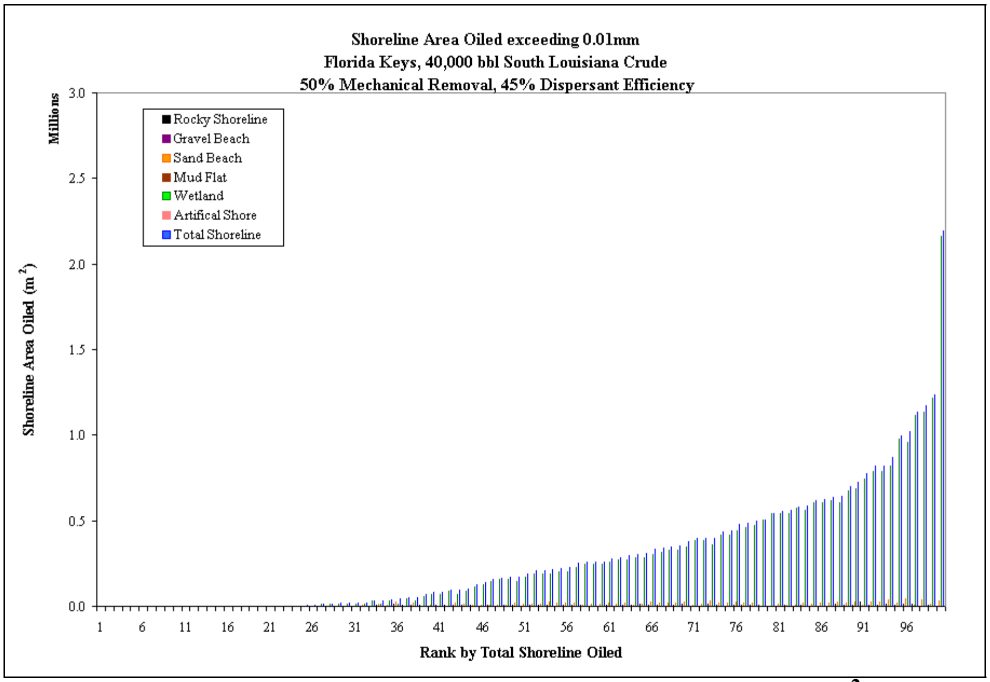

Figure D-II.3.5-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

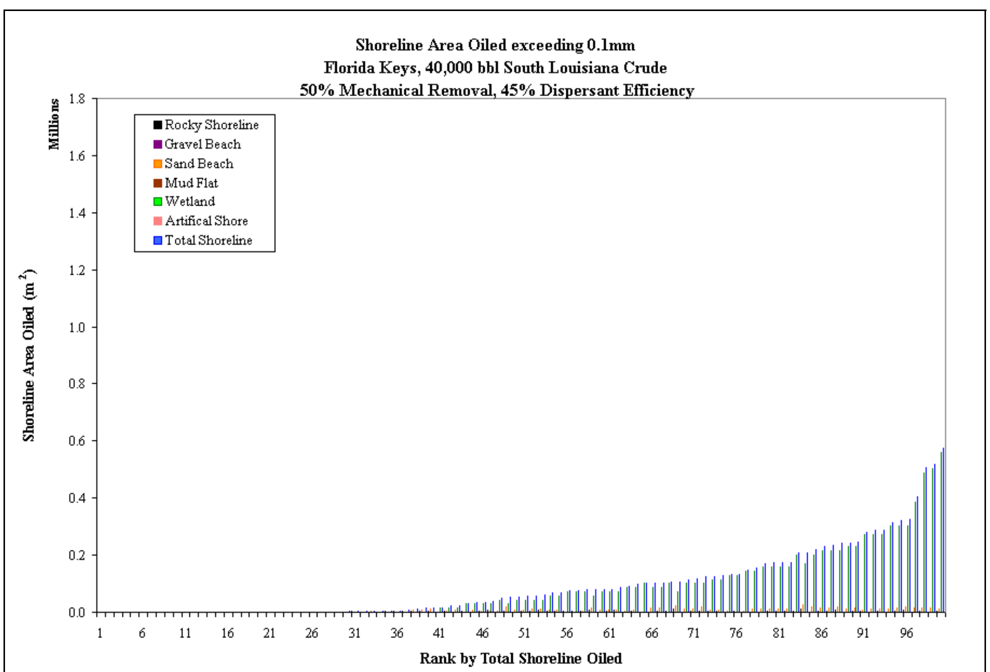

Figure D-II.3.5-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

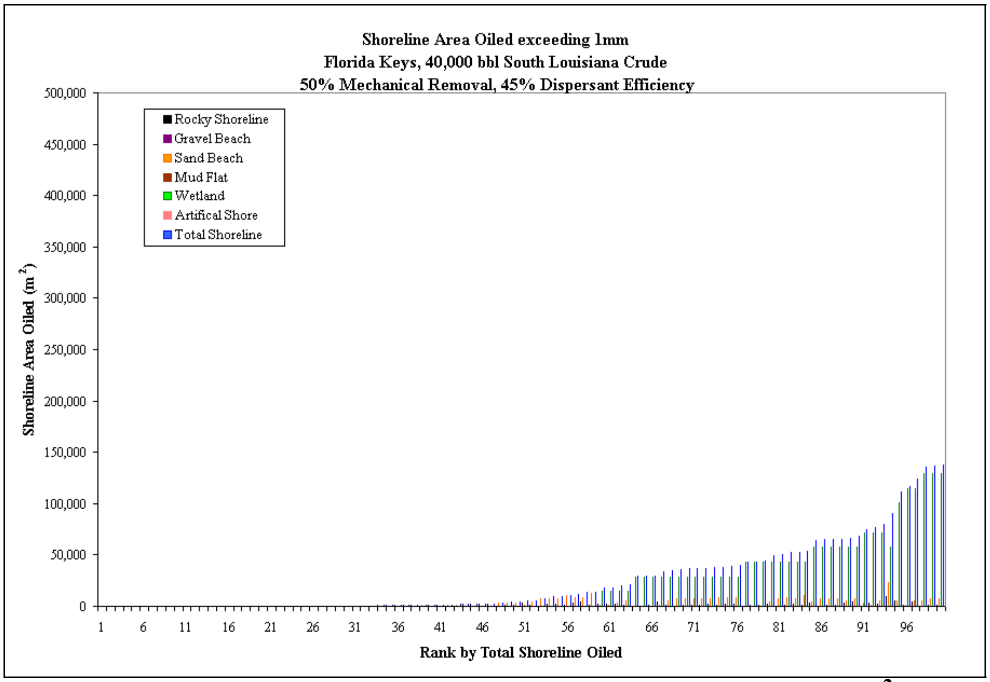

Figure D-II.3.5-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

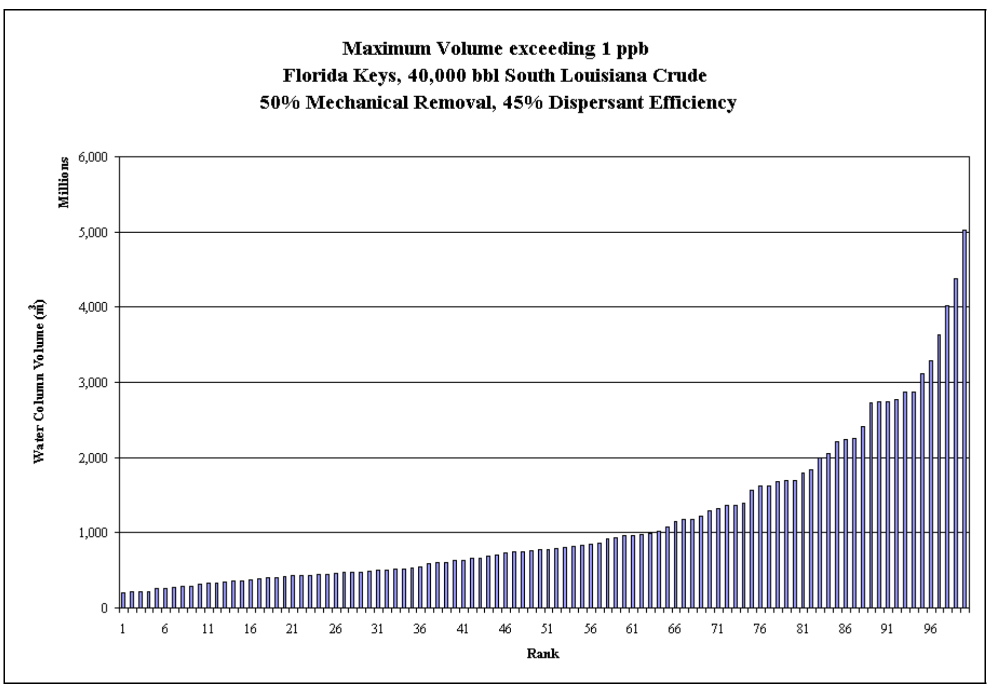

Figure D-II.3.5-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 45% Dispersant Efficiency.

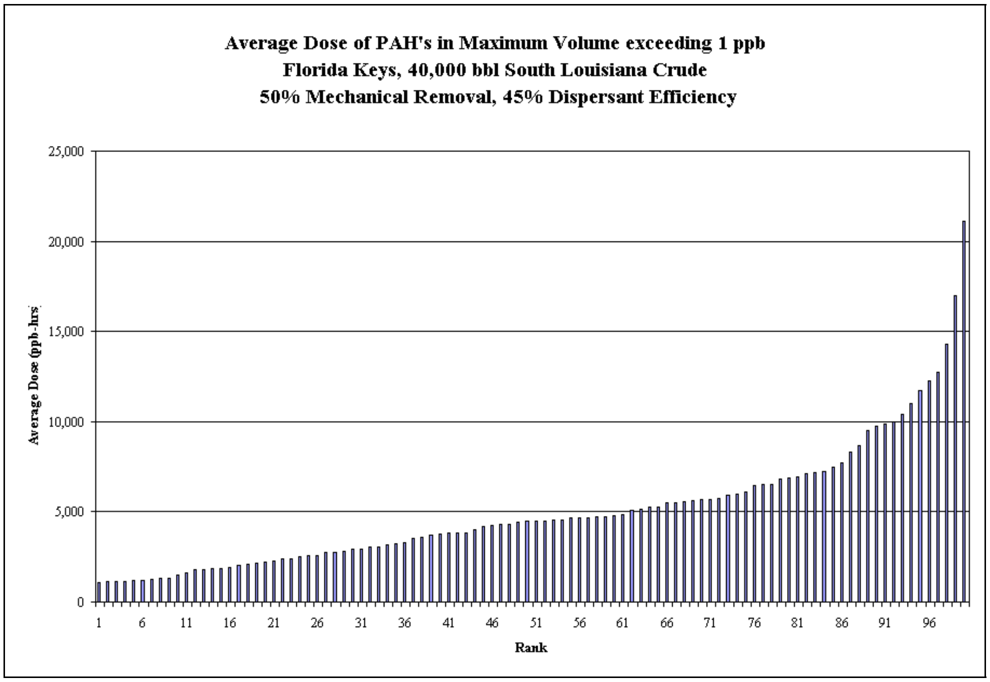

Figure D-II.3.5-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 45% Dispersant Efficiency.

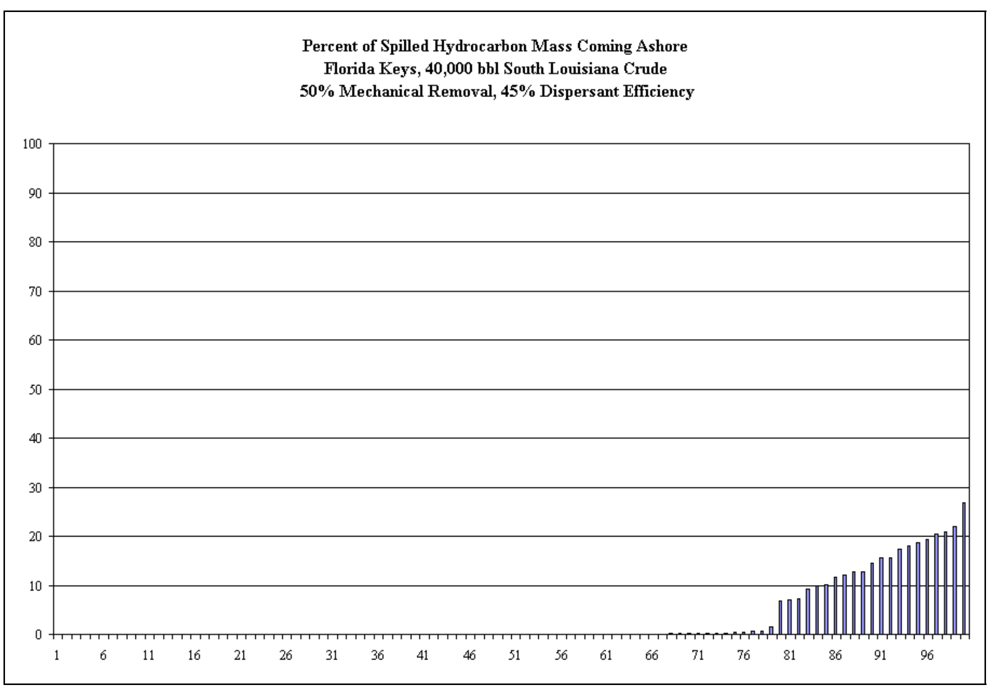

Figure D-II.3.5-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Large Volume, 45% Dispersant Efficiency.

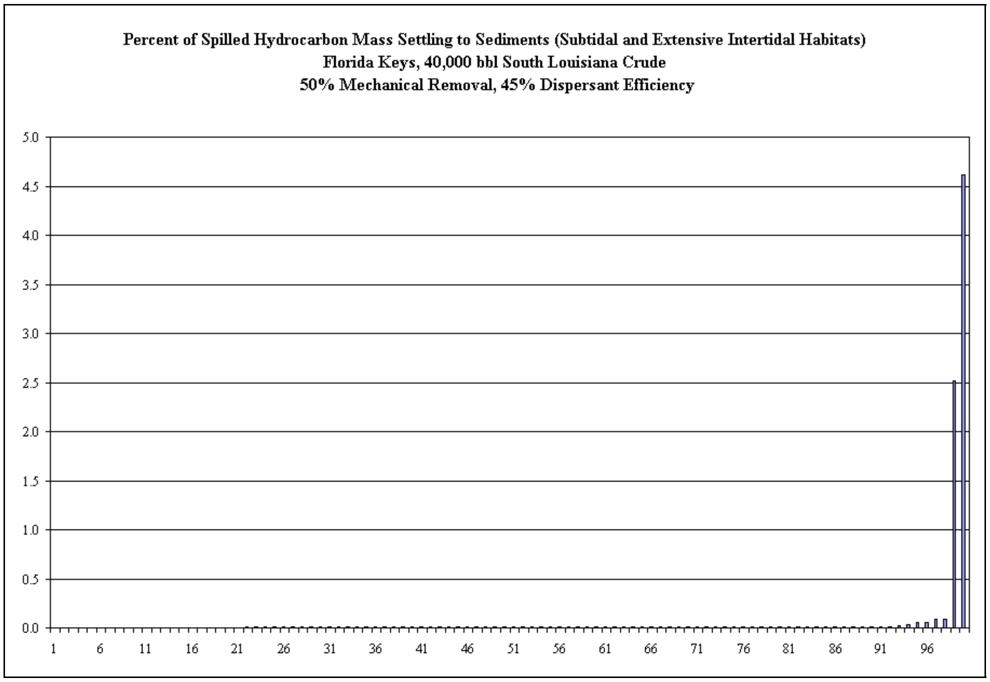

Figure D-II.3.5-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Large Volume, 45% Dispersant Efficiency.

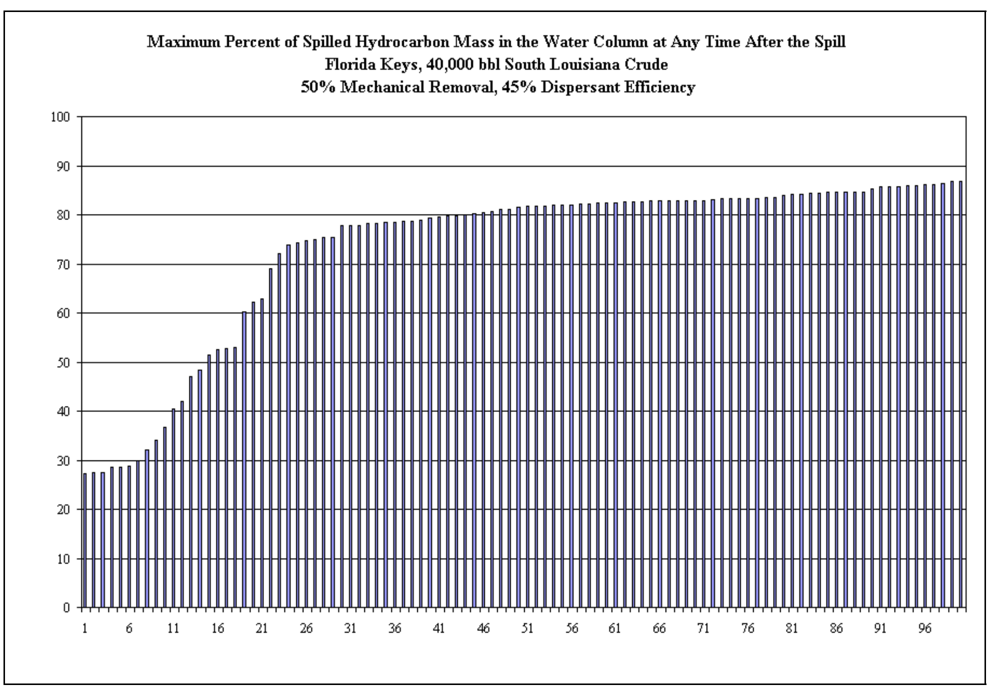

Figure D-II.3.5-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Large Volume, 45% Dispersant Efficiency.

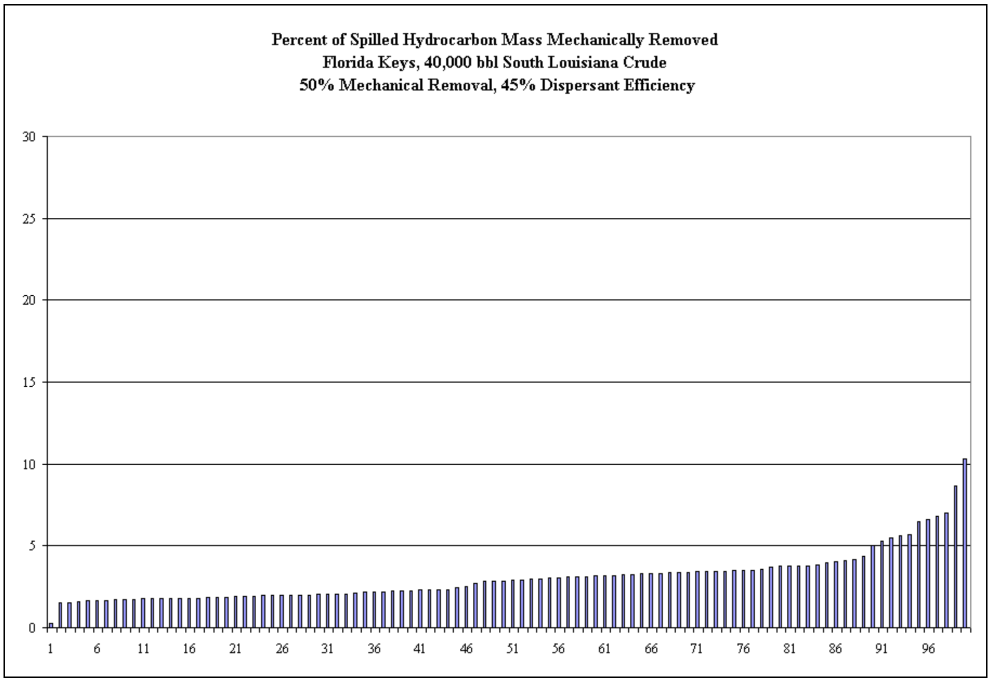

Figure D-II.3.5-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Large Volume, 45% Dispersant Efficiency.

D-II.3.6 Scenario: Large Volume, 80% Dispersant Efficiency.

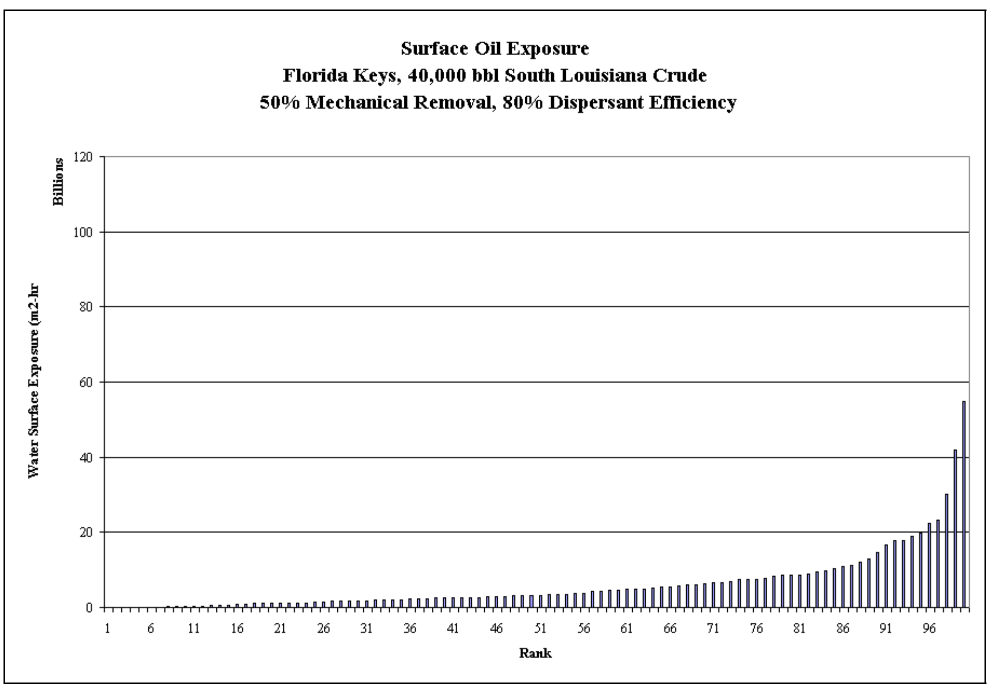

Figure D-II.3.6-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

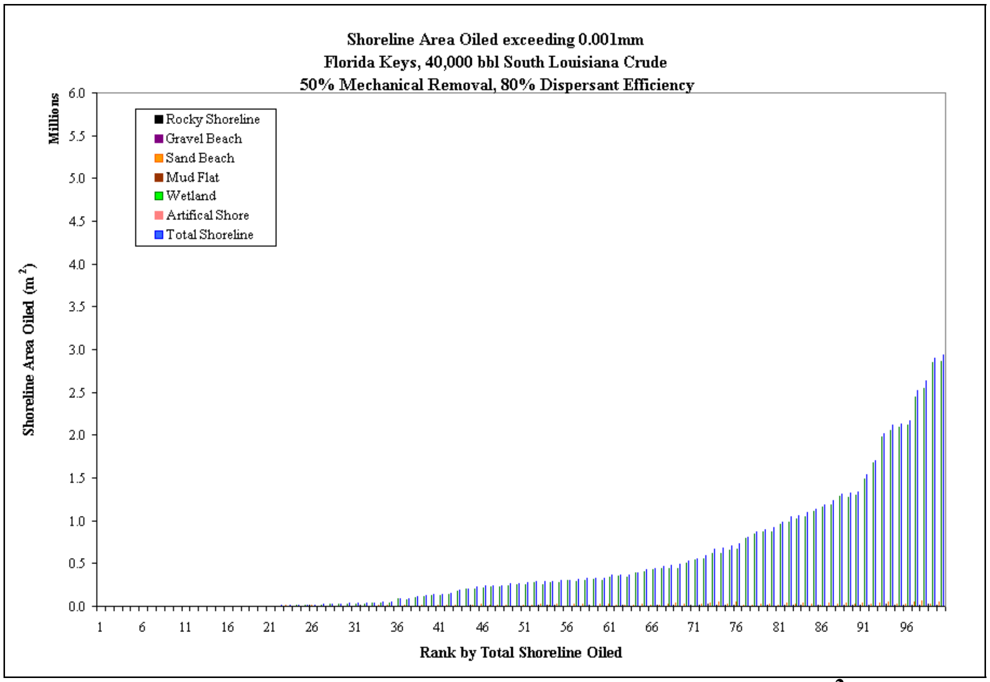

Figure D-II.3.6-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

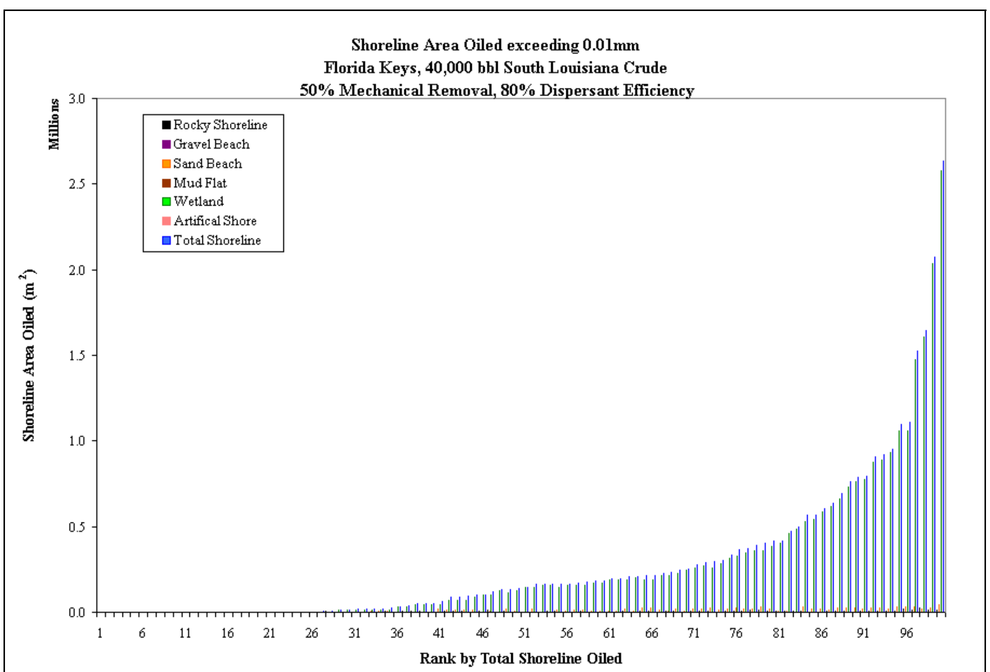

Figure D-II.3.6-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

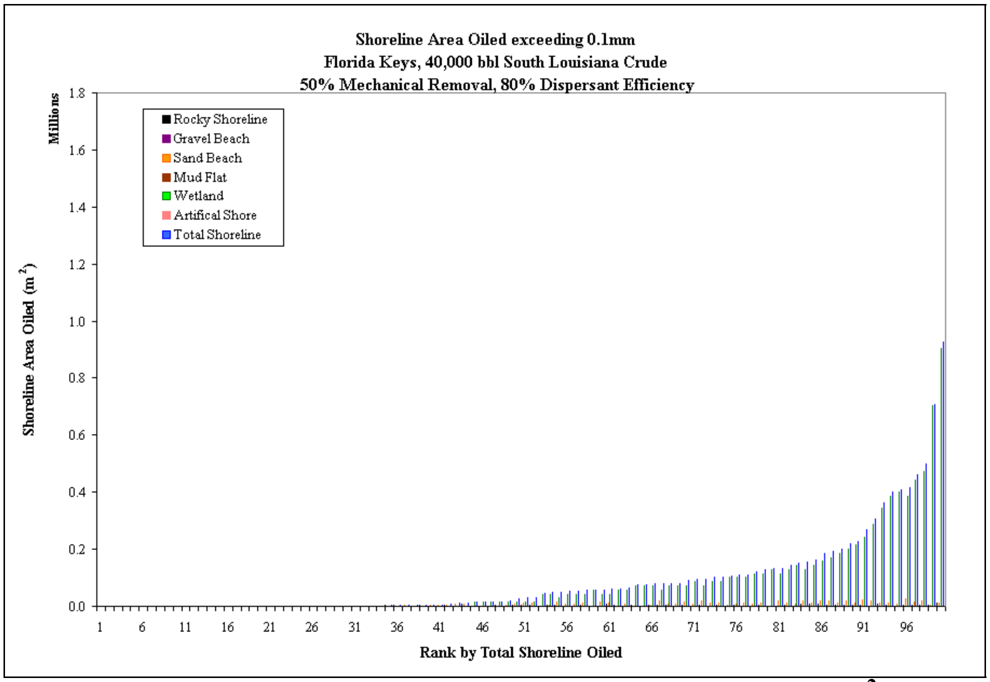

Figure D-II.3.6-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

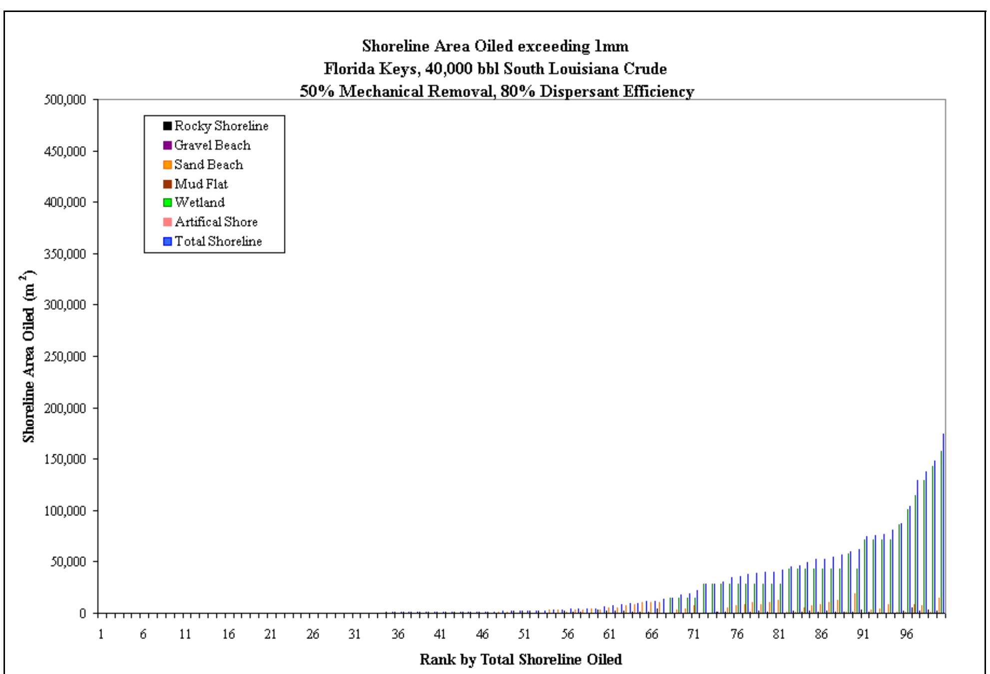

Figure D-II.3.6-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

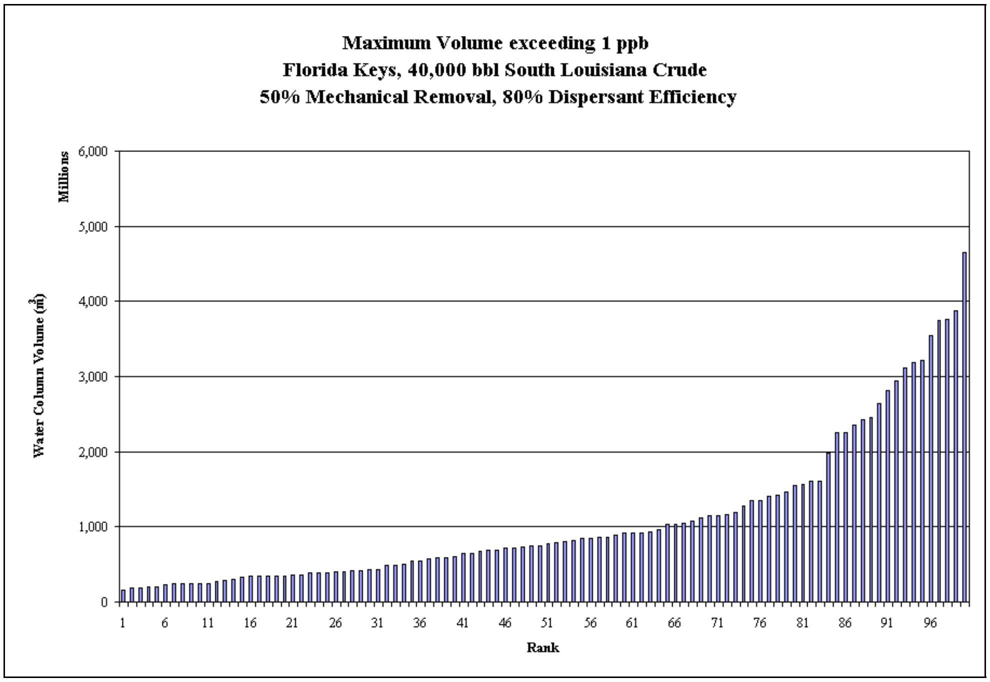

Figure D-II.3.6-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 80% Dispersant Efficiency.

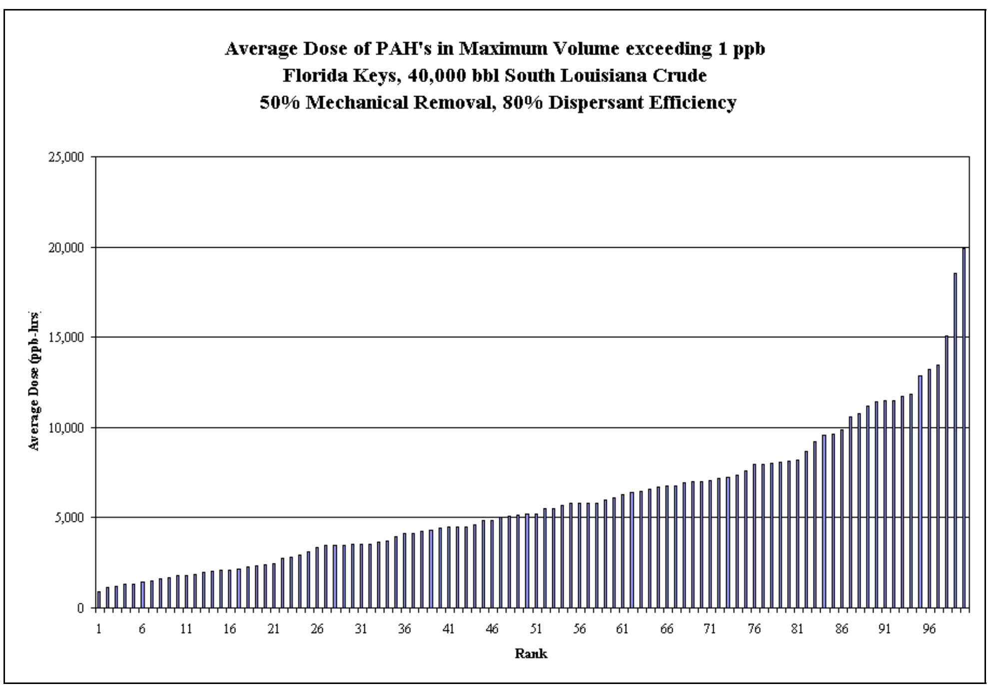

Figure D-II.3.6-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 80% Dispersant Efficiency.

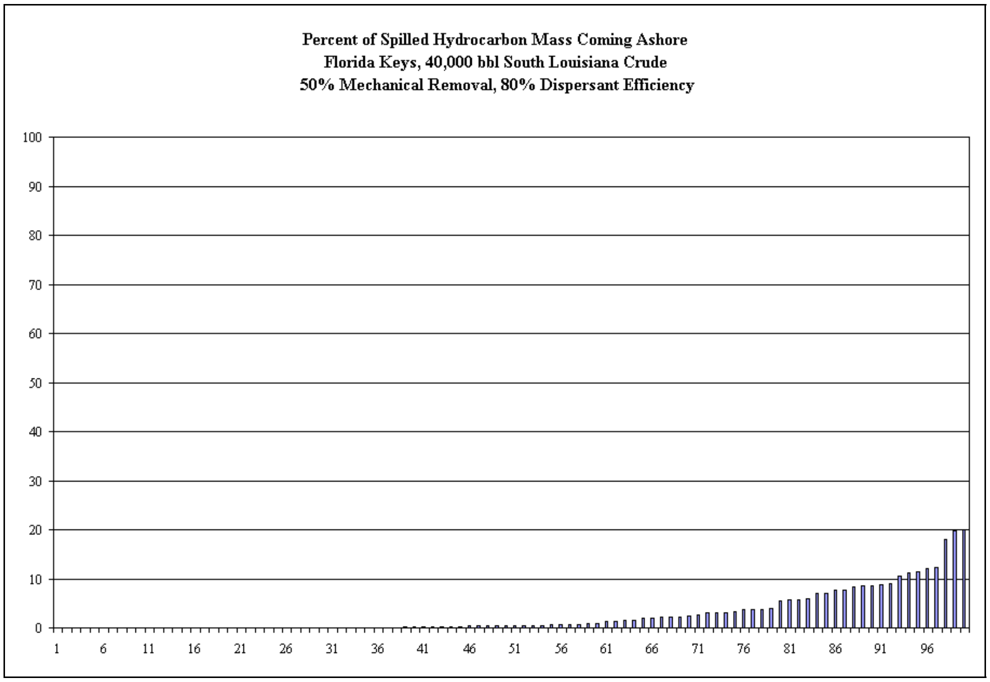

Figure D-II.3.6-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Large Volume, 80% Dispersant Efficiency.

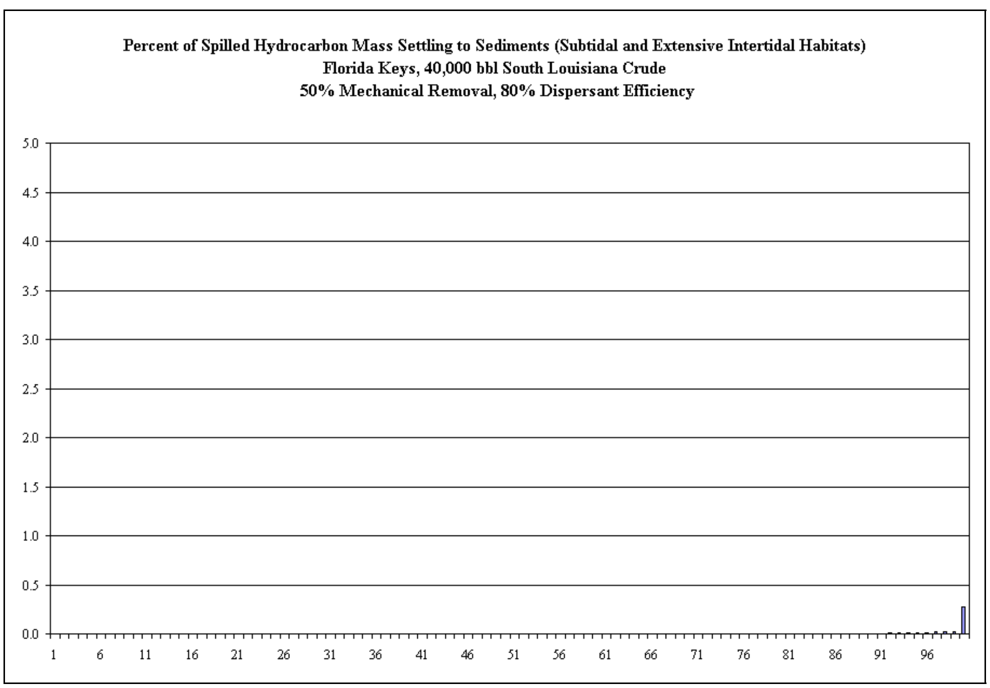

Figure D-II.3.6-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Large Volume, 80% Dispersant Efficiency.

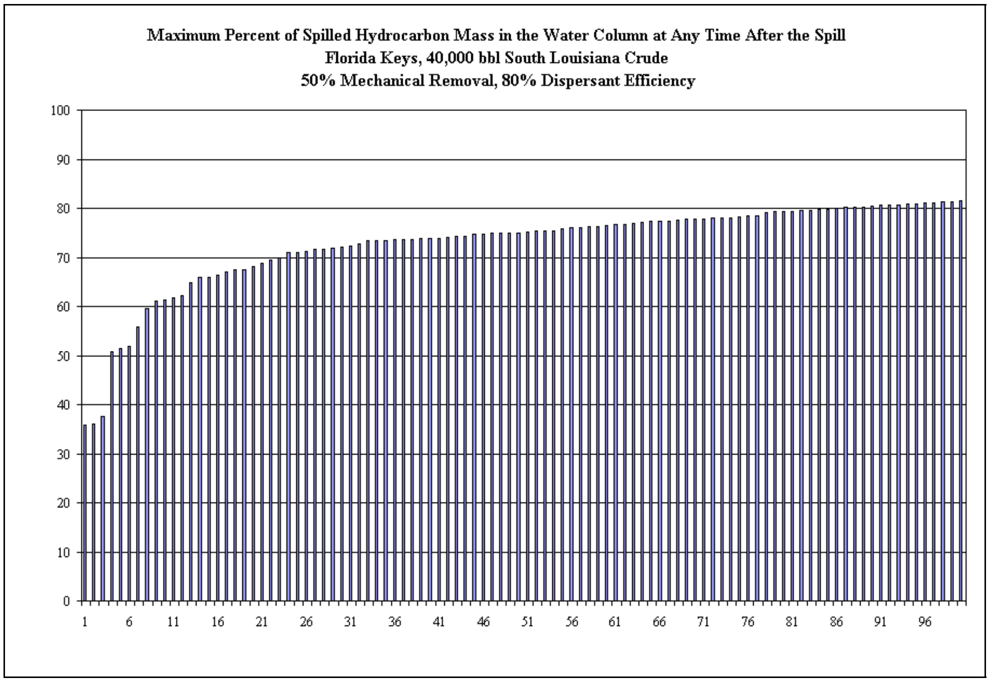

Figure D-II.3.6-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Large Volume, 80% Dispersant Efficiency.

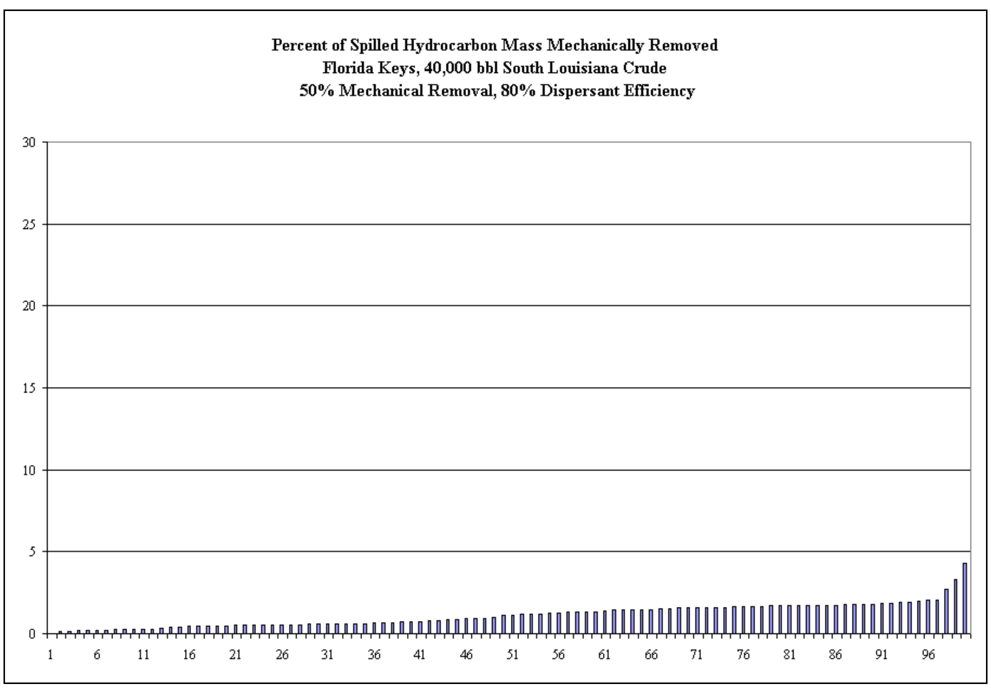

Figure D-II.3.6-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Large Volume, 80% Dispersant Efficiency.

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part D: Florida Straits

Section D-II.4

by

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ASA 00-246

August 2004

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D-II.4 Exposure for Representative Individual Model Runs.

In this appendix, the results for the 50th percentile cases for surface oiling, shoreline oiling, water column effects, and sediment contamination are shown, as plots of the following measures of exposure:

- Water surface exposure to floating hydrocarbons (g/m^2)
- Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile surface oil exposure run
- Shoreline exposure to hydrocarbons (g/m^2)
- Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill
- Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill
- Water column exposure dose of dissolved aromatic concentration (ppb-hours)
- Sediment pore water exposure of dissolved aromatic concentration (ppb)
- Sediment exposure to total hydrocarbons (g/m^2)

The percentile runs plotted are those runs which apply to the exposure index being considered. Thus, different runs are plotted for each of surface oil, shoreline oil, water column effect measures, and sediment contamination. Tables D-II.4-1 to D-II.4-3 summarize the run number and date and time of the runs resulting in the 50th and 95th percentile exposures. The 95th percentile exposure indicates the maximum likely effect.

The Crosshair mark (⊞) in figures below represents oil spill site.

Table D-II.4-1 Run number and date and time of the runs resulting in the 50th and 95th percentile exposures for surface oil exposure.

Surface Oil Exposure (exceeding 0.01 g/m^2)							
Scenario	**Percentile**	**Run Number**	**Year**	**Month**	**Day**	**Hour**	**Area-hrs (m^2-hrs)**
FLC-Med-50-0	50th	16	1988	8	13	10	1,286 x 10^6
	95th	12	1988	4	12	18	5,813 x 10^6
FLC-Med-50-45	50th	93	2000	2	9	4	176 x 10^6
	95th	95	1996	6	24	19	3,545 x 10^6
FLC-Med-50-80	50th	19	1999	7	24	11	153 x 10^6
	95th	42	1991	6	1	8	3,981 x 10^6
FLC-Lrg-50-0	50th	79	1989	8	17	23	19,938 x 10^6
	95th	56	1991	12	2	3	84,086 x 10^6
FLC-Lrg-50-45	50th	31	2000	11	9	20	4,413 x 10^6
	95th	62	2002	3	30	6	25,546 x 10^6
FLC-Lrg-50-80	50th	45	1990	9	20	7	3,149 x 10^6
	95th	6	1990	3	30	8	22,379 x 10^6

Table D-II.4-2 Run number and date and time of the runs resulting in the 50th and 95th percentile exposures for dissolved aromatic exposure.

Maximum Dissolved Aromatic Plume Volume exceeding 1 ppb							
Scenario	**Percentile**	**Run Number**	**Year**	**Month**	**Day**	**Hour**	**Volume (m^3)**
FLC-Med-50-0	50th	66	1995	5	16	10	59×10^6
	95th	23	1995	12	24	15	228×10^6
FLC-Med-50-45	50th	89	1990	1	16	14	152×10^6
	95th	47	1999	11	7	7	333×10^6
FLC-Med-50-80	50th	26	1998	8	14	22	156×10^6
	95th	46	1998	8	30	17	364×10^6
FLC-Lrg-50-0	50th	62	2002	3	30	6	197×10^6
	95th	23	1995	12	24	15	$1,020 \times 10^6$
FLC-Lrg-50-45	50th	9	1998	1	9	14	772×10^6
	95th	12	1988	4	12	18	$3,285 \times 10^6$
FLC-Lrg-50-80	50th	86	1992	3	5	21	781×10^6
	95th	82	1998	5	31	0	$3,547 \times 10^6$

Table D-II.4-3 Run number and date and time of the runs resulting in the 50th and 95th percentile exposures for sediment exposure.

Percent of Spilled Mass Reaching Sediment							
Scenario	**Percentile**	**Run Number**	**Year**	**Month**	**Day**	**Hour**	**%**
FLC-Med-50-0	50th	20	1996	4	14	18	0.002
	95th	96	1993	10	29	23	0.352
FLC-Med-50-45	50th	10	2002	2	7	7	0.006
	95th	55	1995	5	1	3	0.382
FLC-Med-50-80	50th	50	1994	3	1	9	0.007
	95th	55	1995	5	1	3	0.135
FLC-Lrg-50-0	50th	46	1998	8	30	17	0.001
	95th	57	1997	3	22	4	0.102
FLC-Lrg-50-45	50th	66	1995	5	16	10	0.008
	95th	95	1996	6	24	19	0.058
FLC-Lrg-50-80	50th	28	1988	12	31	2	0.001
	95th	20	1996	4	14	18	0.016

D-II.4.1 Scenario: Medium Volume, No Dispersant.

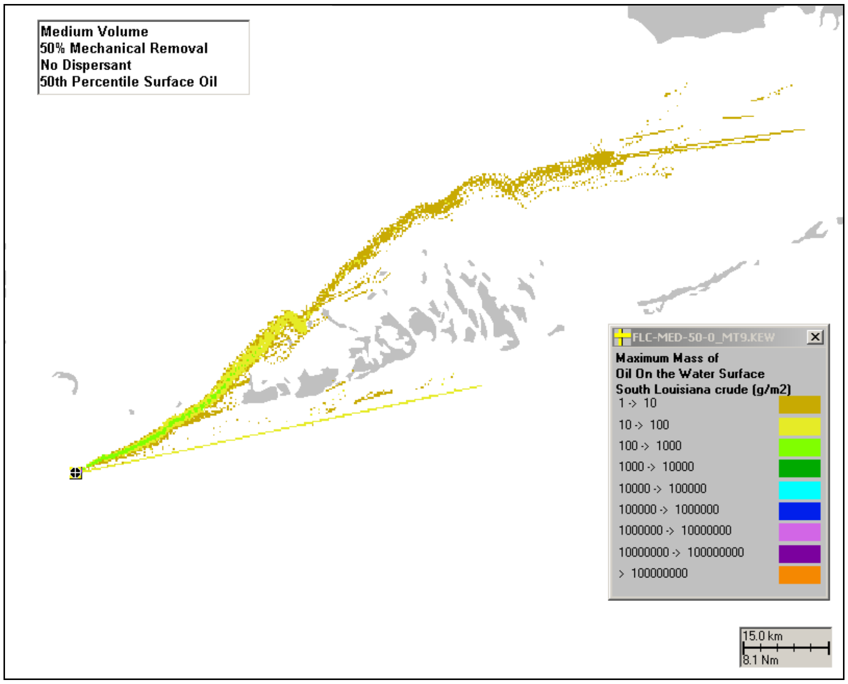

Figure D-II.4.1-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, No Dispersant.

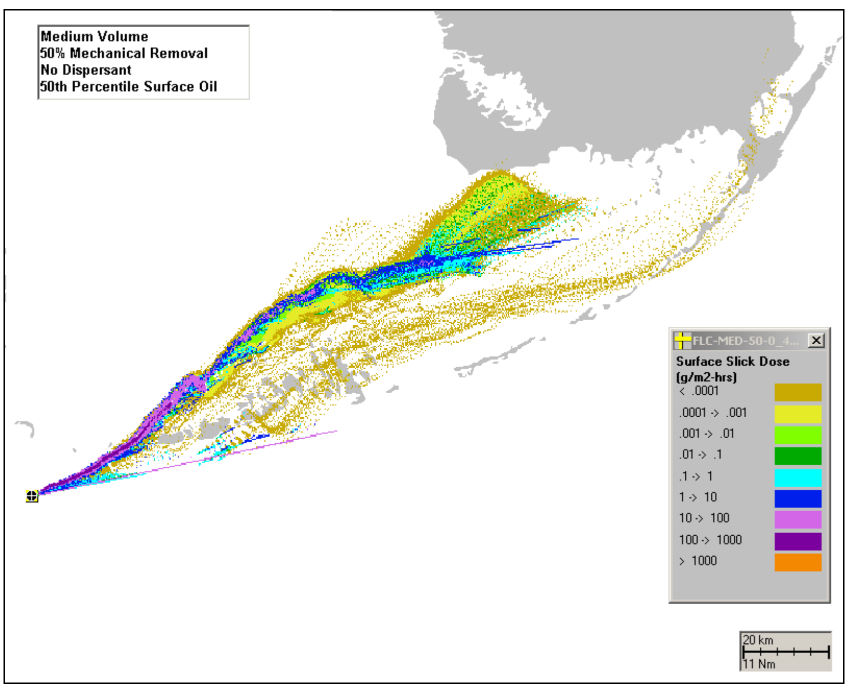

Figure D-II.4.1-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, No Dispersant.

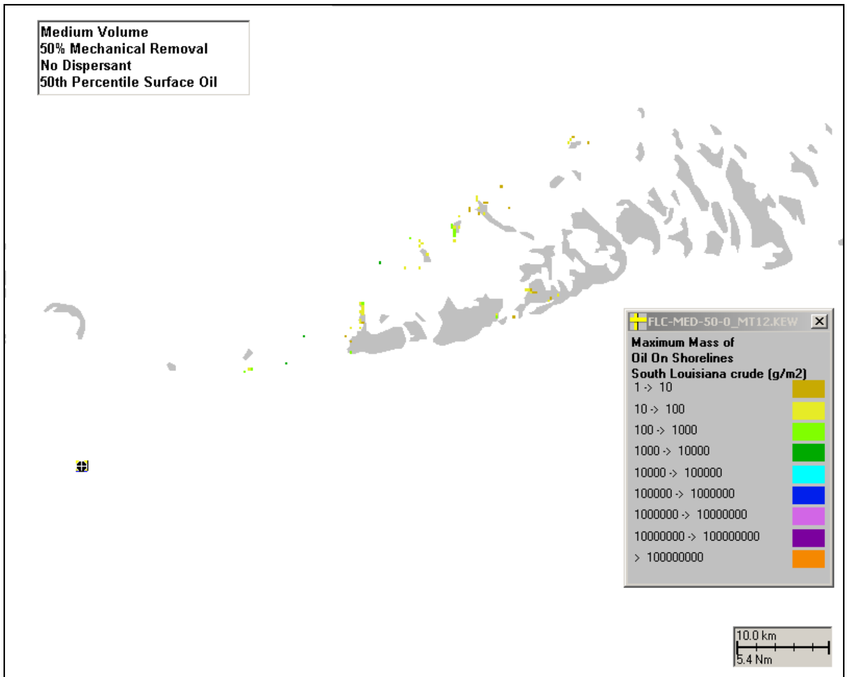

Figure D-II.4.1-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, No Dispersant.

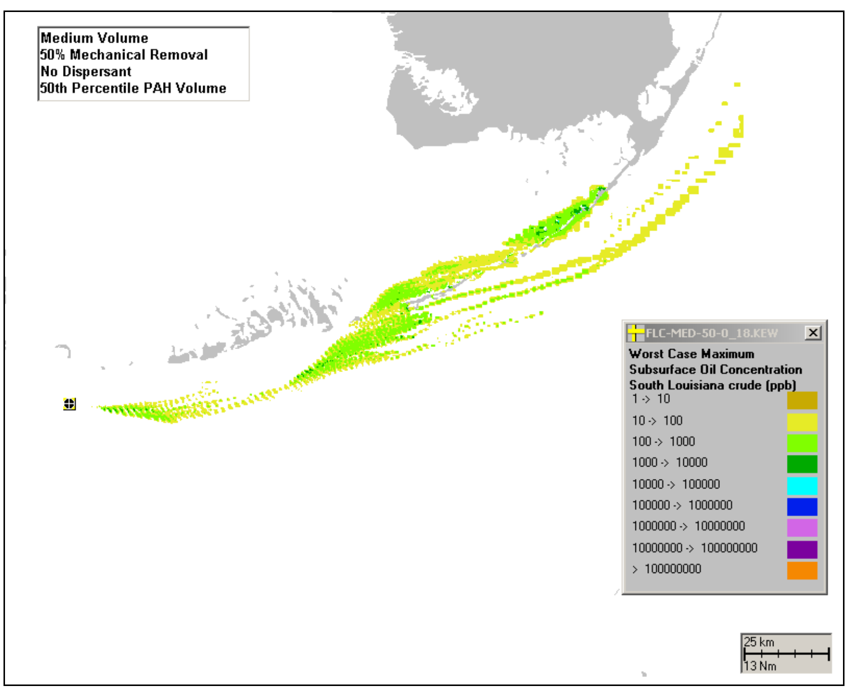

Figure D-II.4.1-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, No Dispersant.

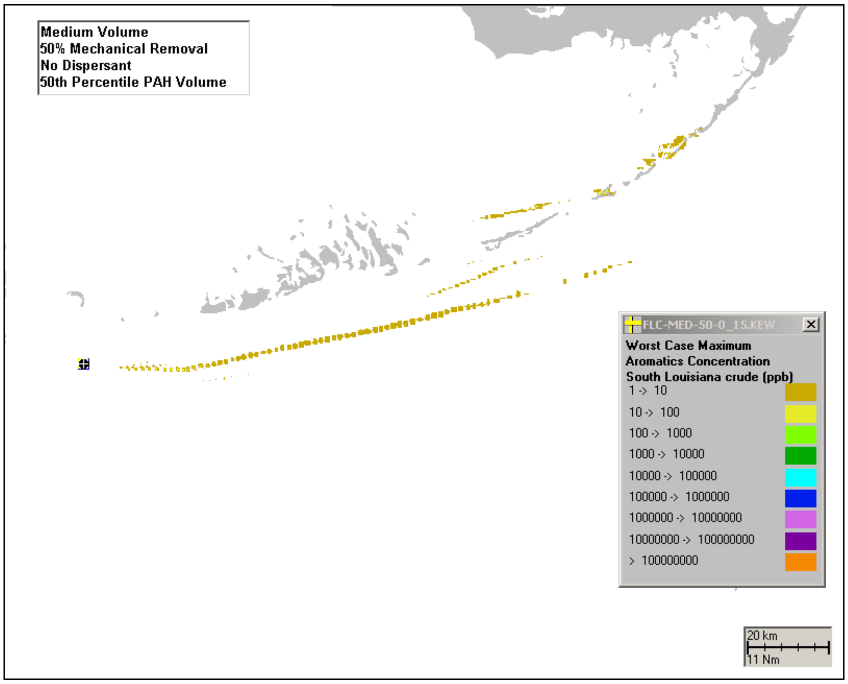

Figure D-II.4.1-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, No Dispersant.

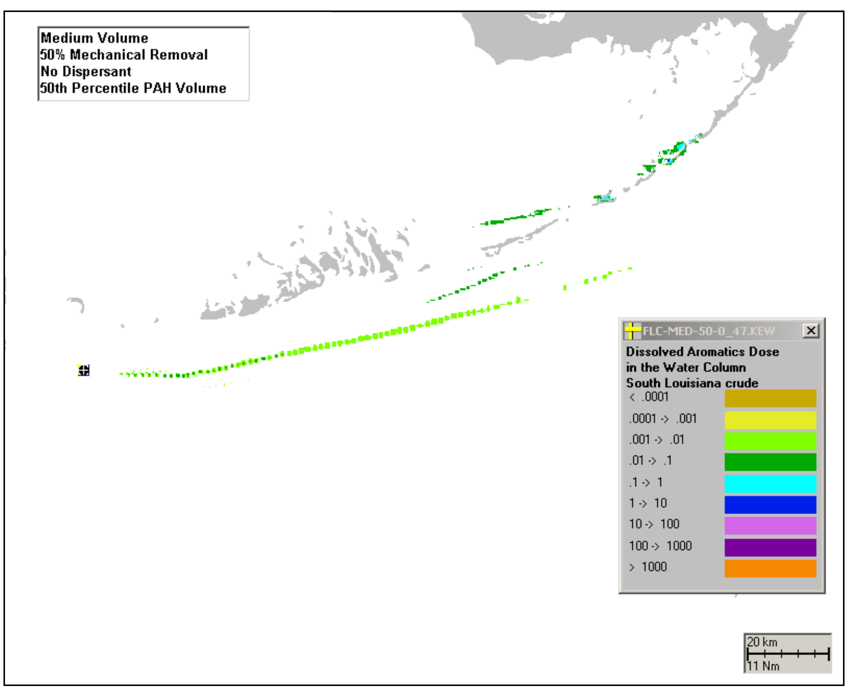

Figure D-II.4.1-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, No Dispersant.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Medium Volume, No Dispersant.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Medium Volume, No Dispersant.

D-II.4.2 Scenario: Medium Volume, 45% Dispersant Efficiency.

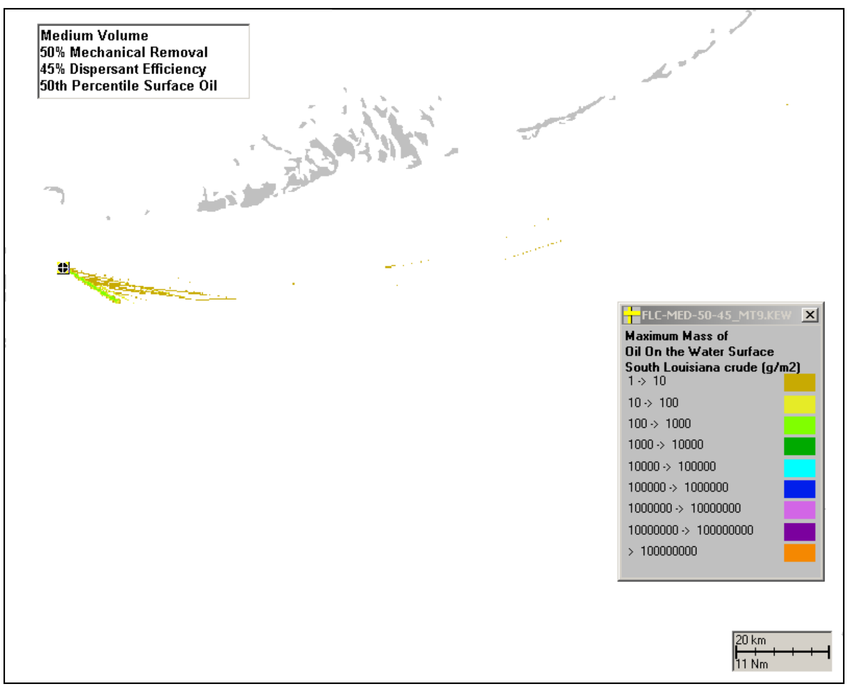

Figure D-II.4.2-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure.   Scenario: Medium Volume, 45% Dispersant Efficiency.

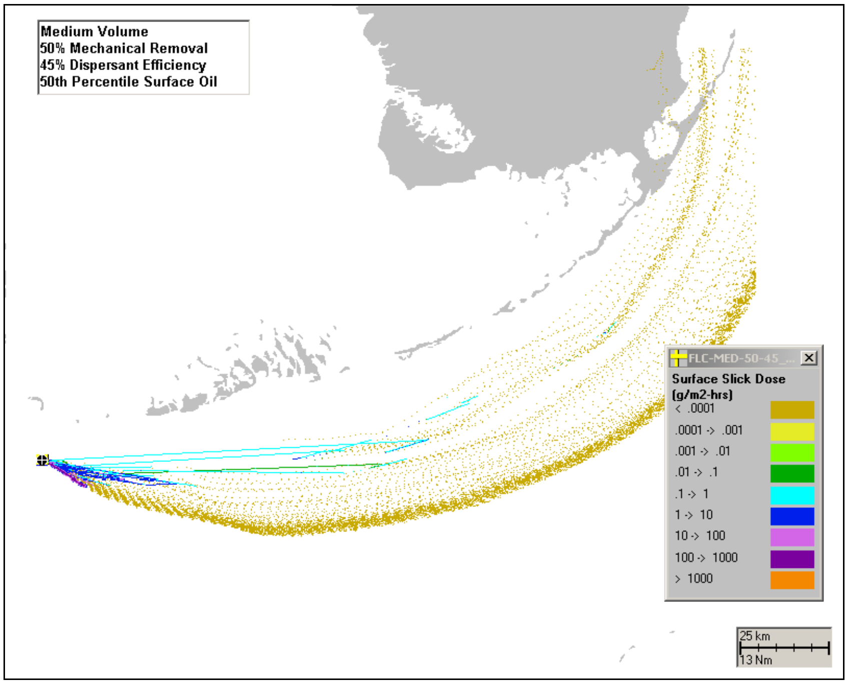

Figure D-II.4.2-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure does not exceed threshold of 0.01 g/m^2. Scenario: Medium Volume, 45% Dispersant Efficiency.

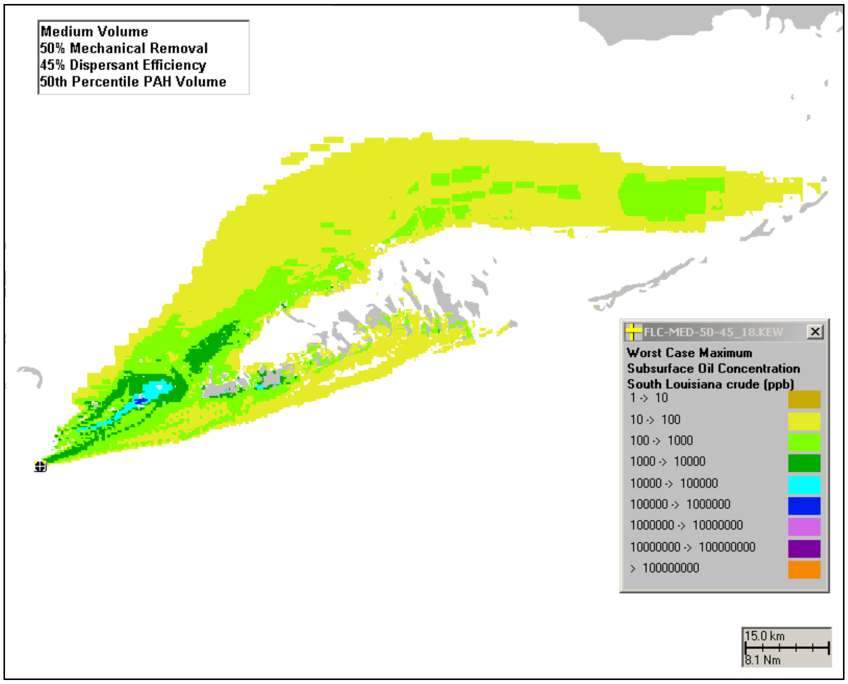

Figure D-II.4.2-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 45% Dispersant Efficiency.

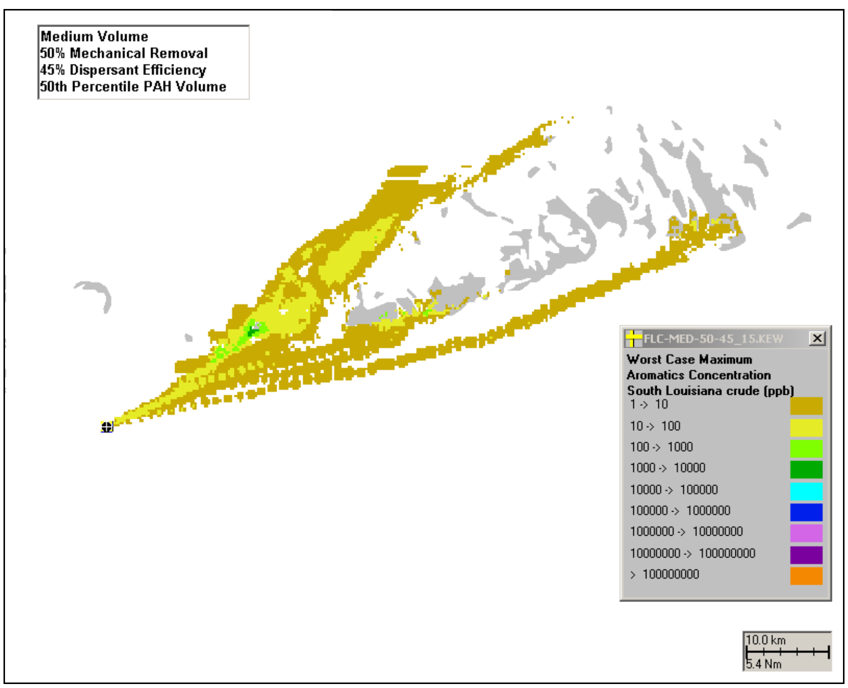

Figure D-II.4.2-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 45% Dispersant Efficiency.

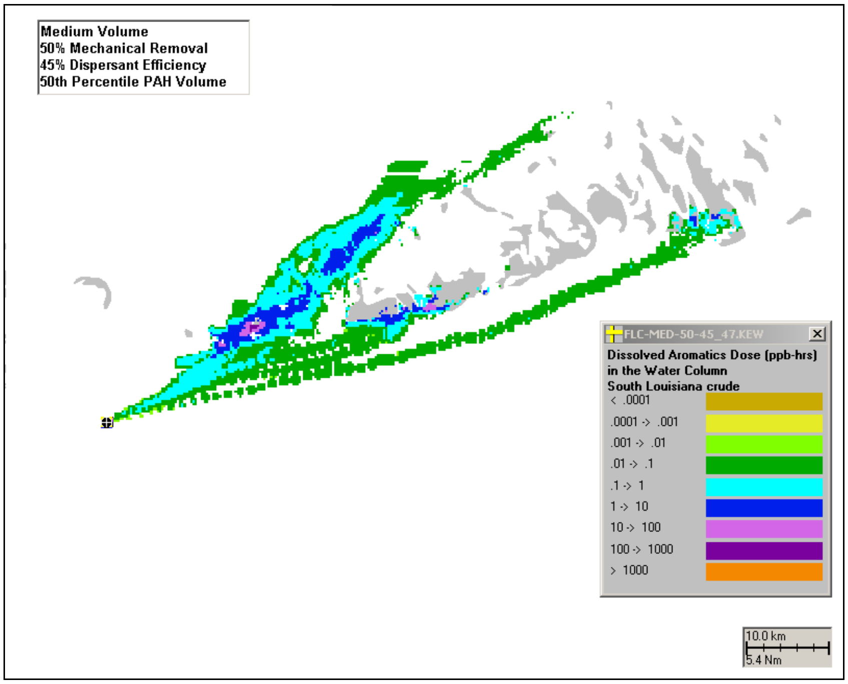

Figure D-II.4.2-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 45% Dispersant Efficiency.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

D-II.4.3 Scenario: Medium Volume, 80% Dispersant Efficiency.

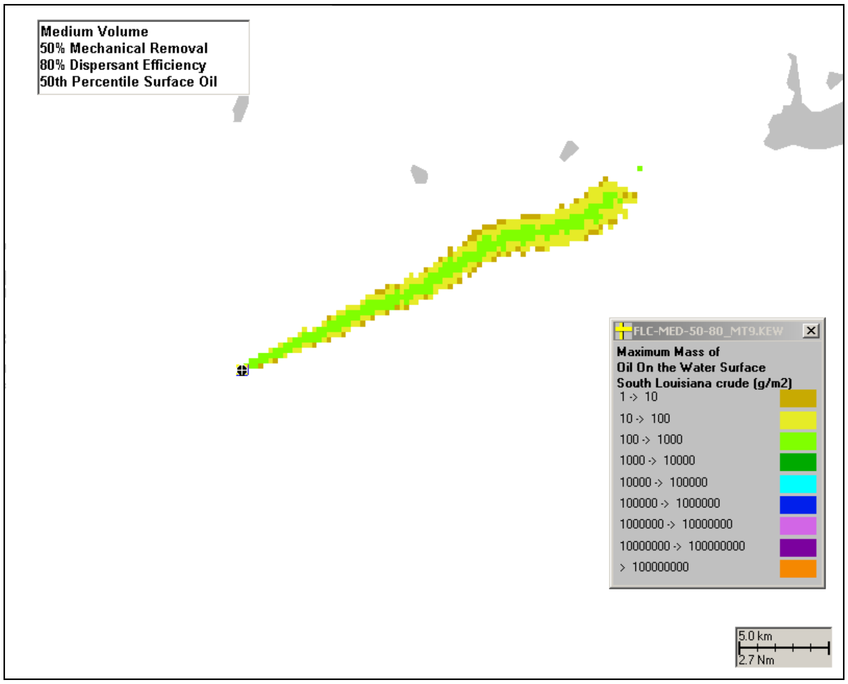

Figure D-II.4.3-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure.   Scenario: Medium Volume, 80% Dispersant Efficiency.

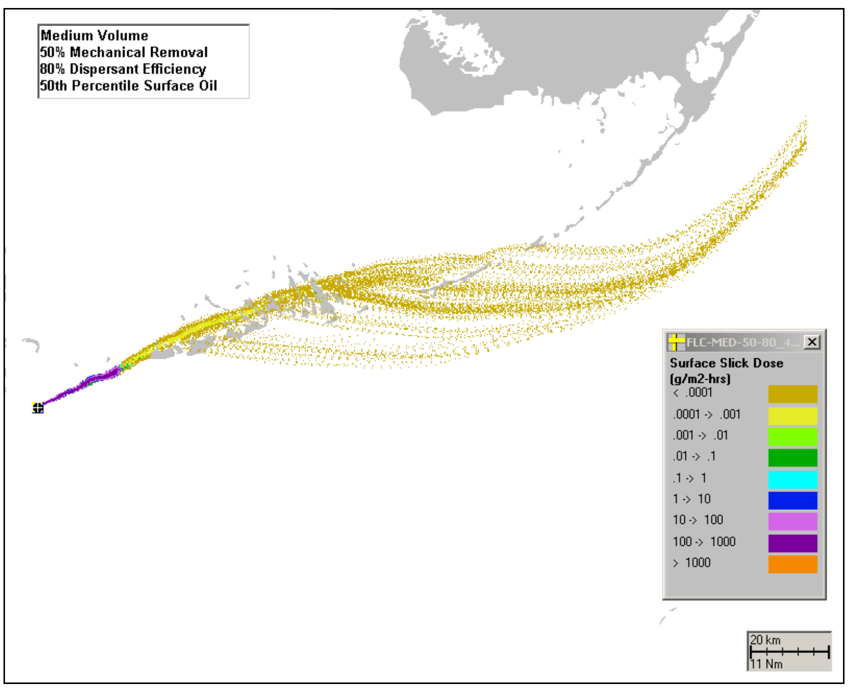

Figure D-II.4.3-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

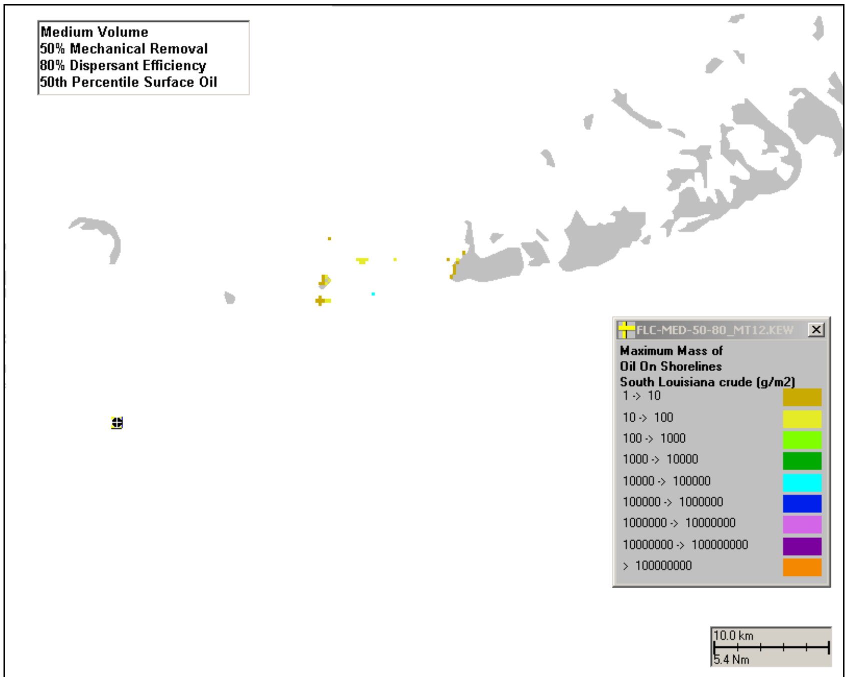

Figure D-II.4.3-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

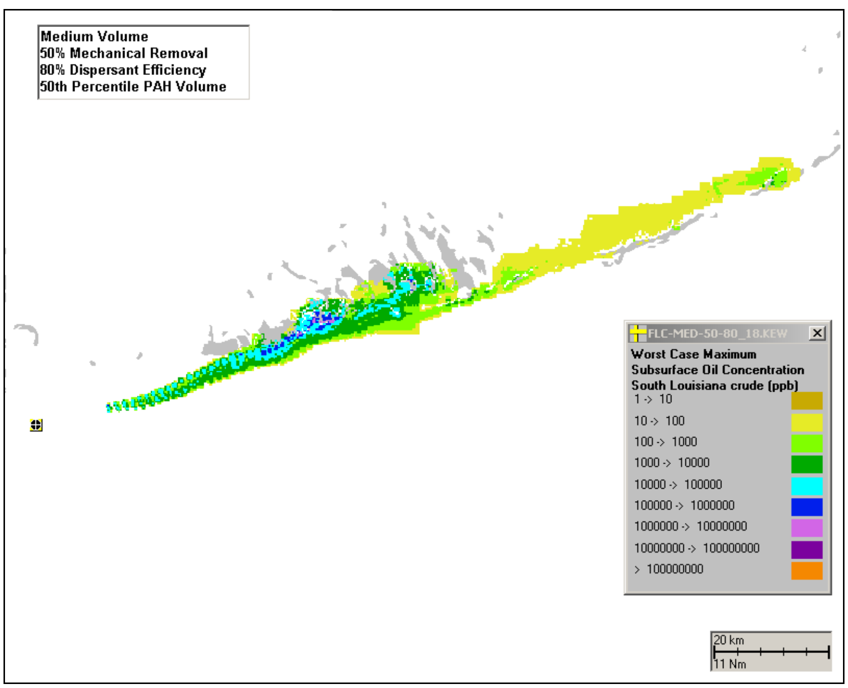

Figure D-II.4.3-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 80% Dispersant Efficiency.

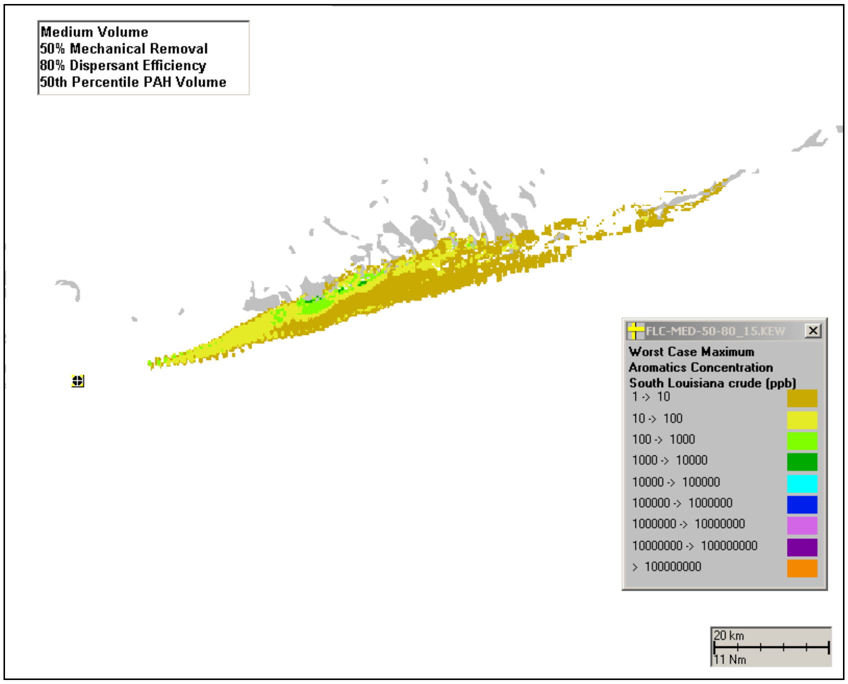

Figure D-II.4.3-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 80% Dispersant Efficiency.

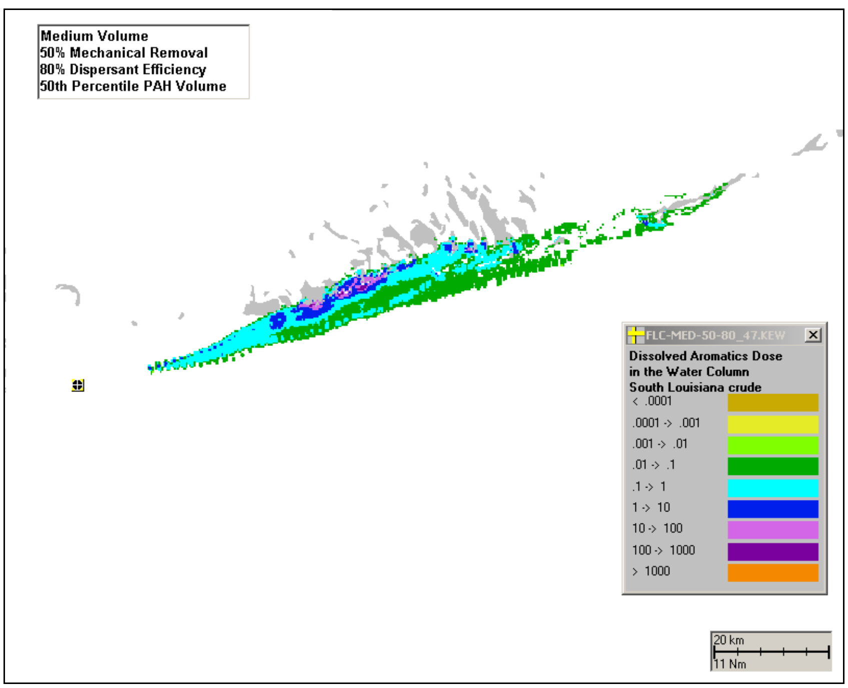

Figure D-II.4.3-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 80% Dispersant Efficiency.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Medium Volume, 80% Dispersant Efficiency..

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

D-II.4.4 Scenario: Large Volume, No Dispersant.

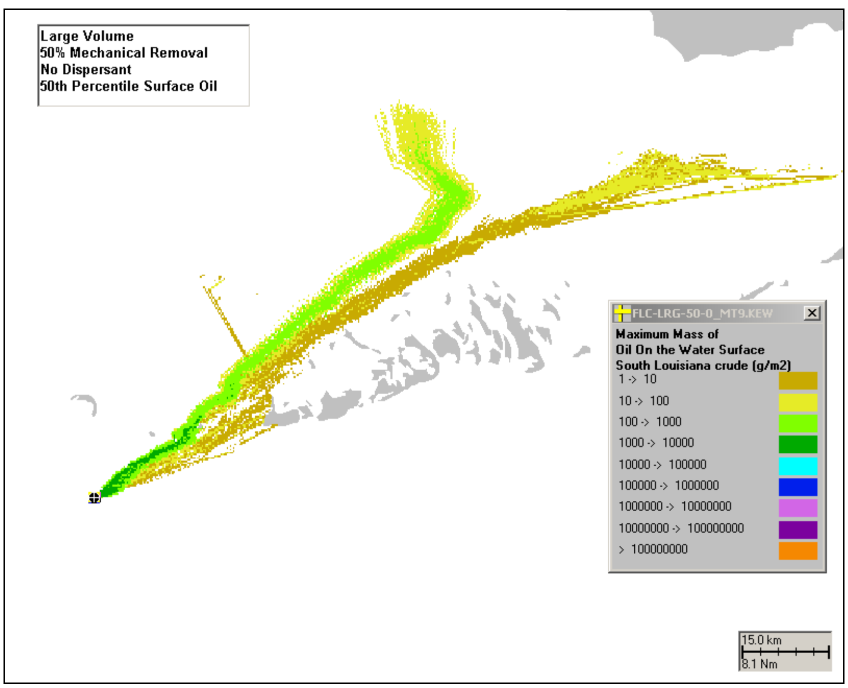

Figure D-II.4.4-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure.   Scenario: Large Volume, No Dispersant.

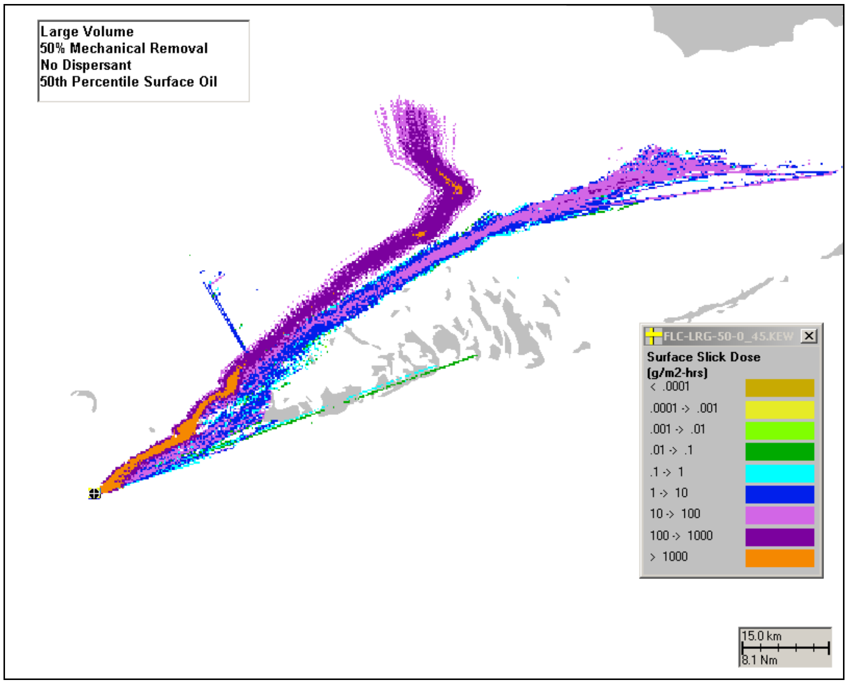

Figure D-II.4.4-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Large Volume, No Dispersant.

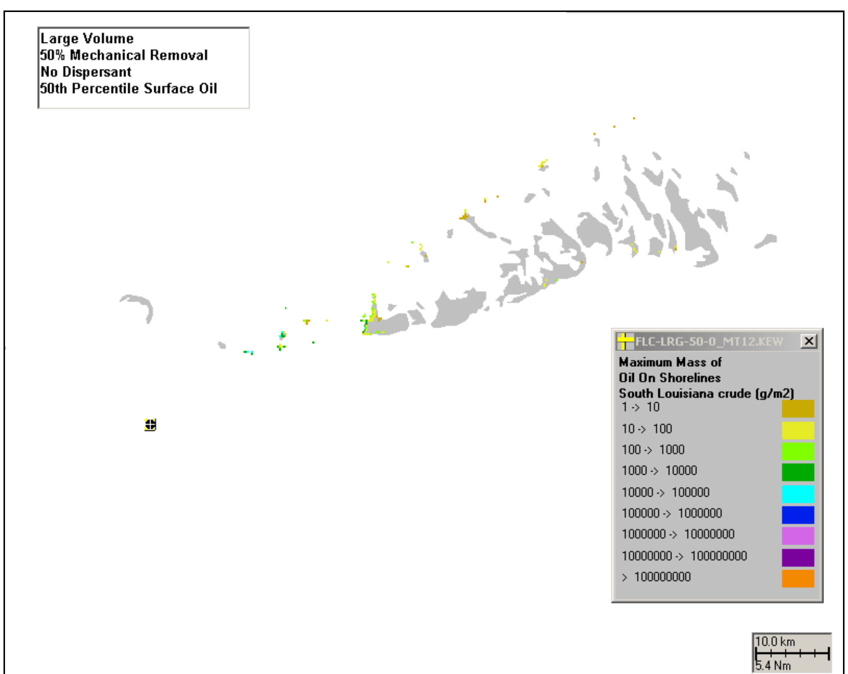

Figure D-II.4.4-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, No Dispersant.

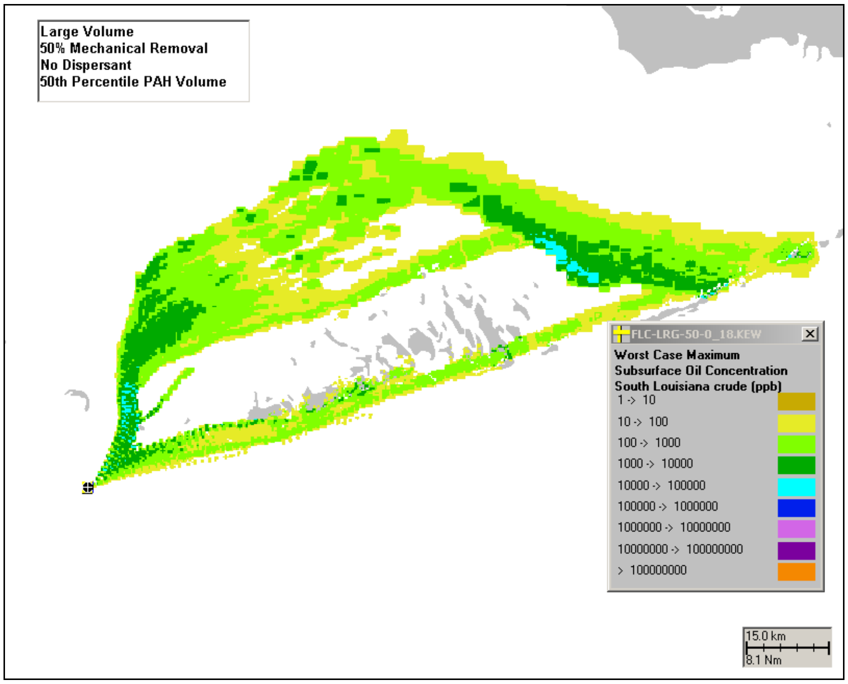

Figure D-II.4.4-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, No Dispersant.

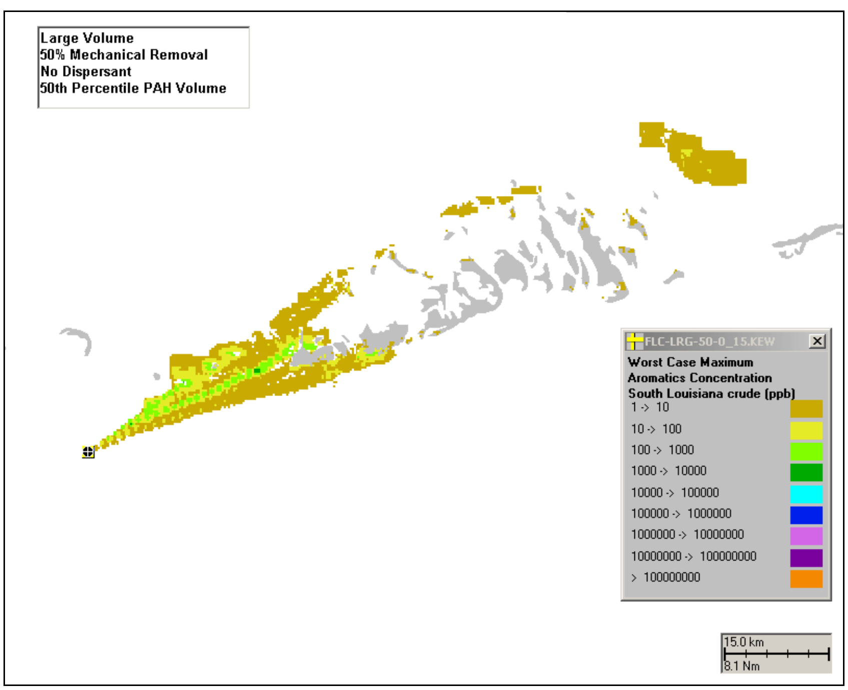

Figure D-II.4.4-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, No Dispersant.

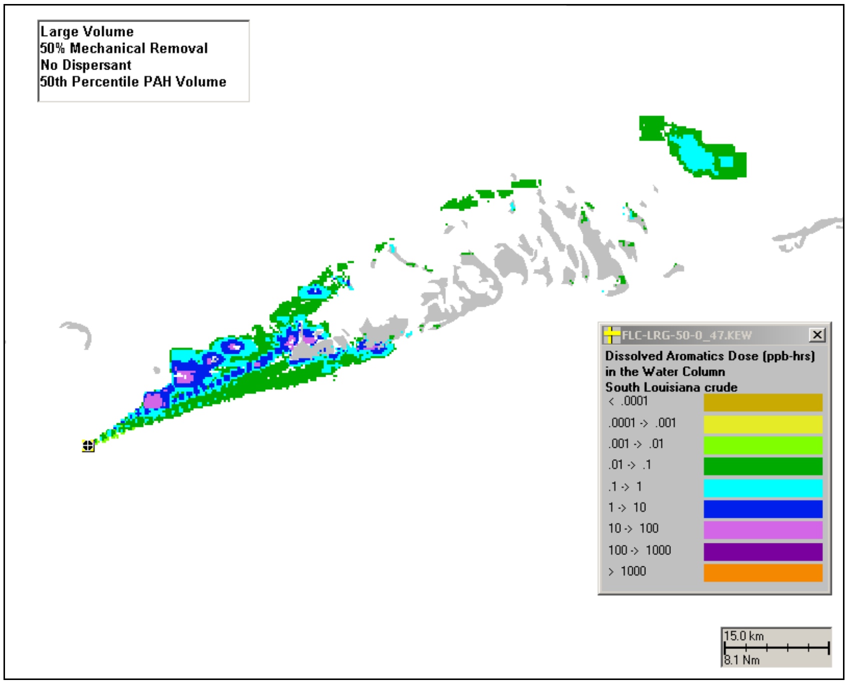

Figure D-II.4.4-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, No Dispersant.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Large Volume, No Dispersant.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Large Volume, No Dispersant.

D-II.4.5 Scenario: Large Volume, 45% Dispersant Efficiency.

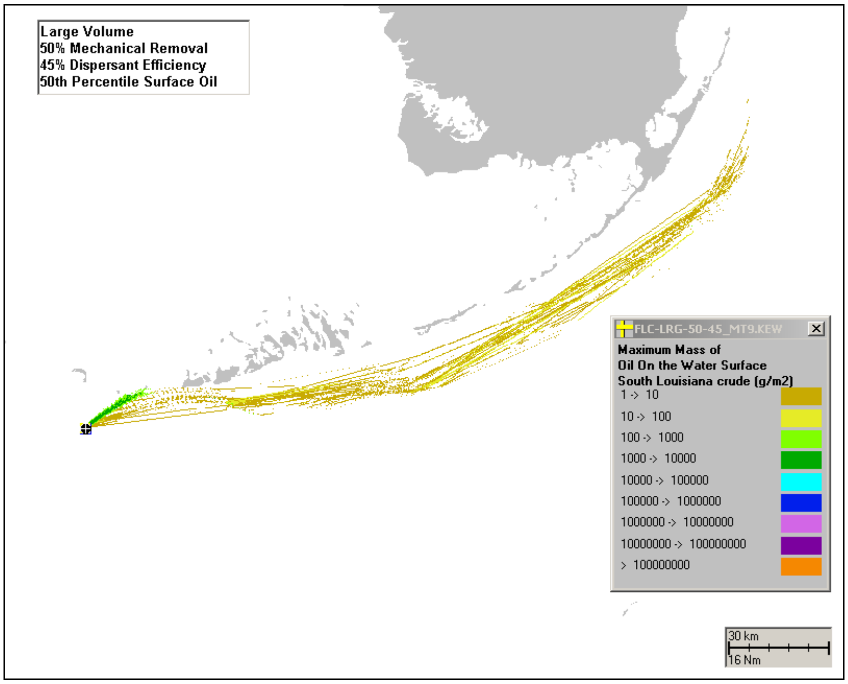

Figure D-II.4.5-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

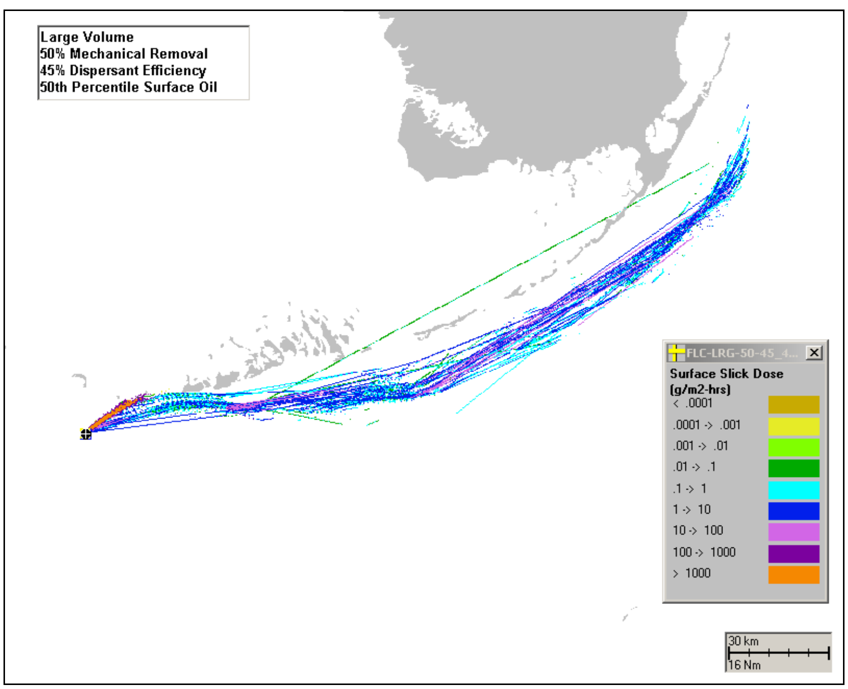

Figure D-II.4.5-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

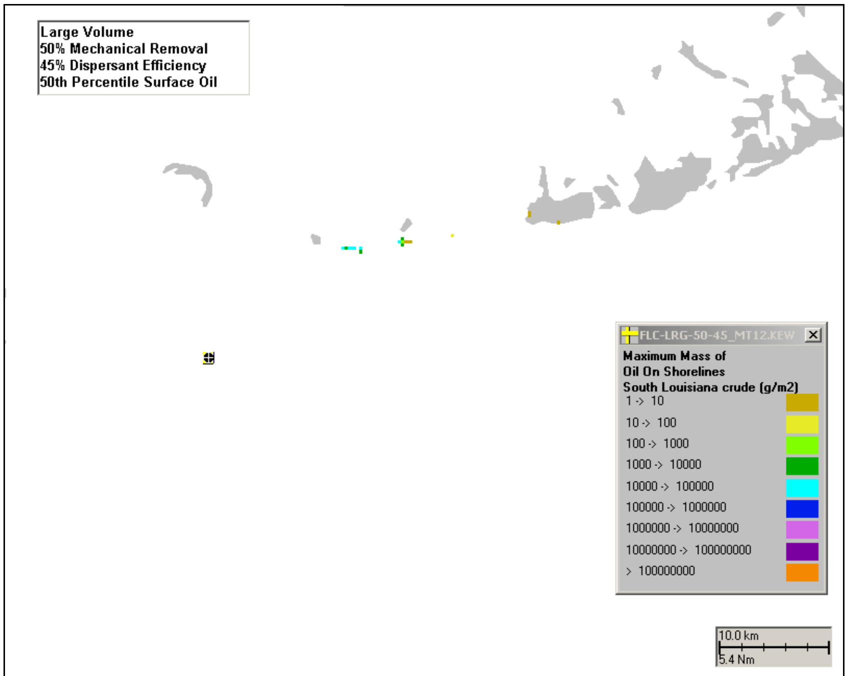

Figure D-II.4.5-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

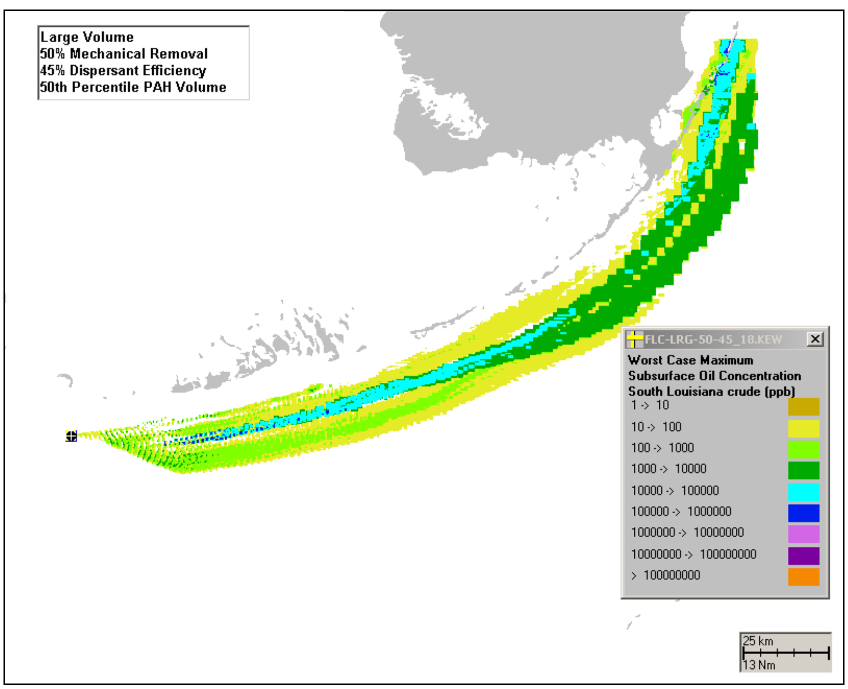

Figure D-II.4.5-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 45% Dispersant Efficiency.

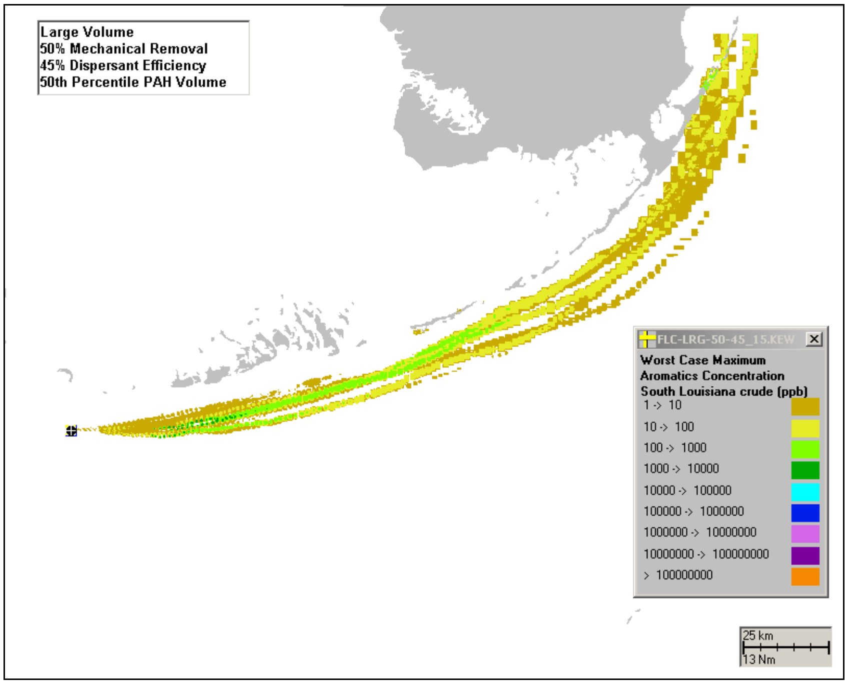

Figure D-II.4.5-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 45% Dispersant Efficiency.

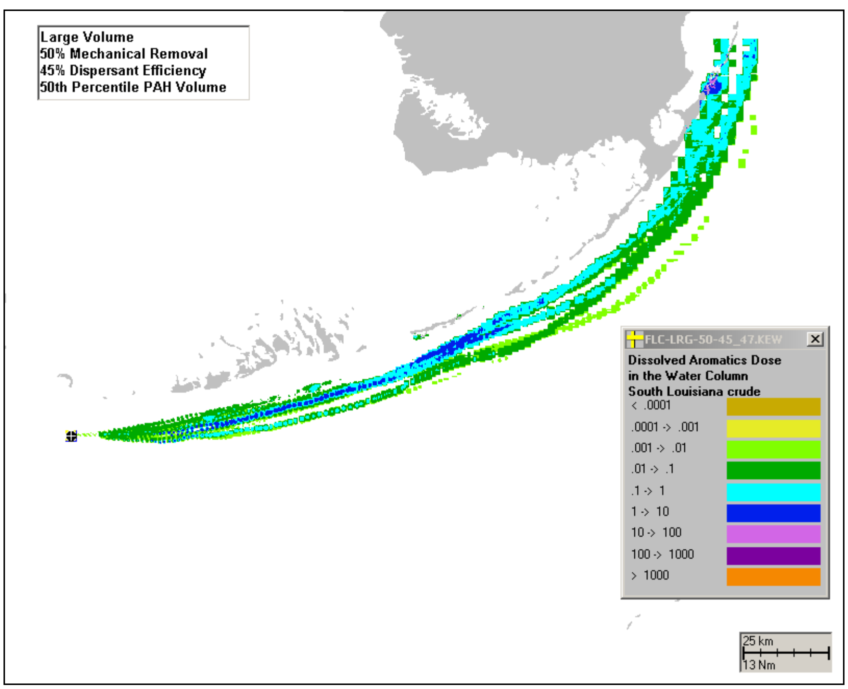

Figure D-II.4.5-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 45% Dispersant Efficiency.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

D-II.4.6 Scenario: Large Volume, 80% Dispersant Efficiency.

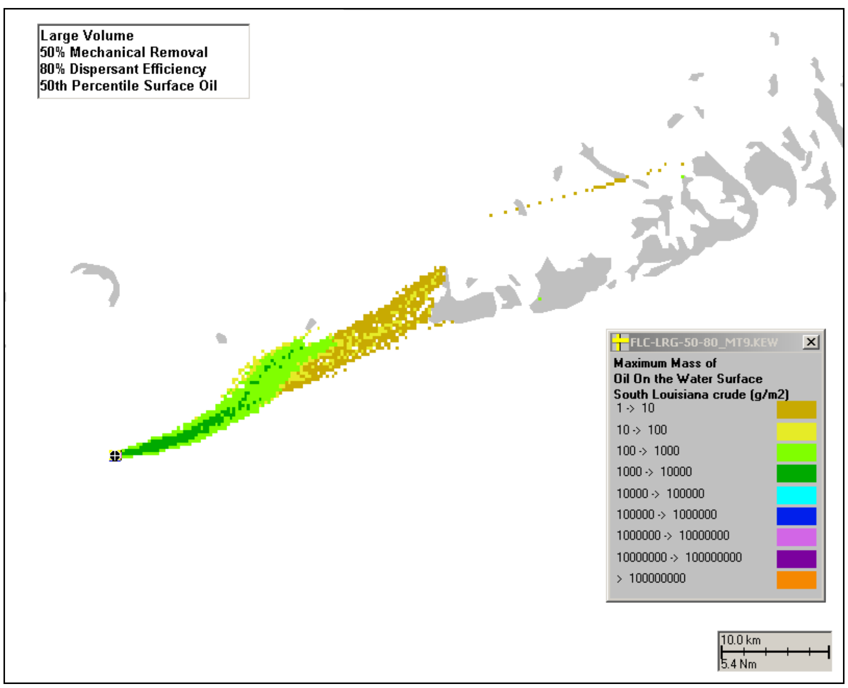

Figure D-II.4.6-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

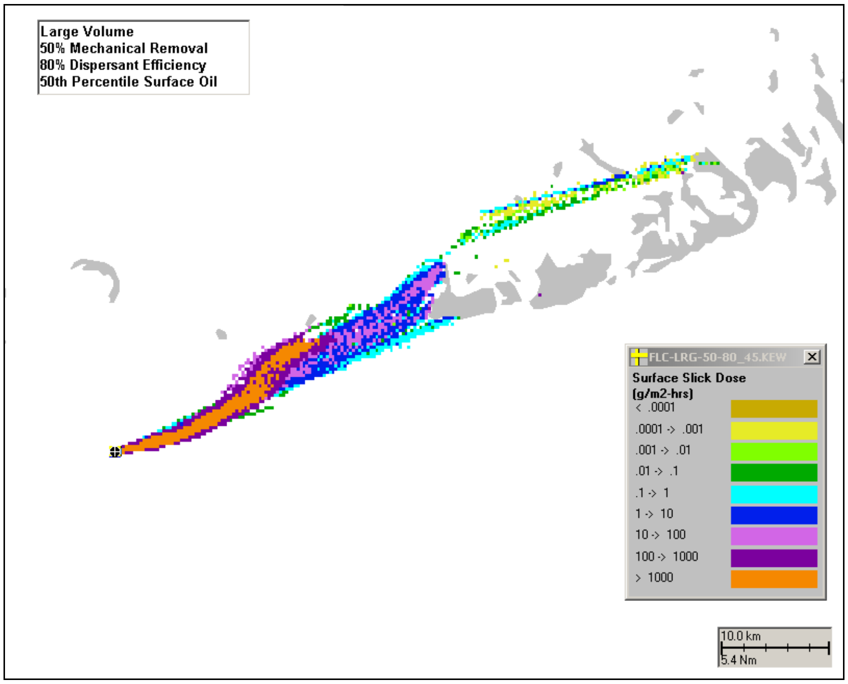

Figure D-II.4.6-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

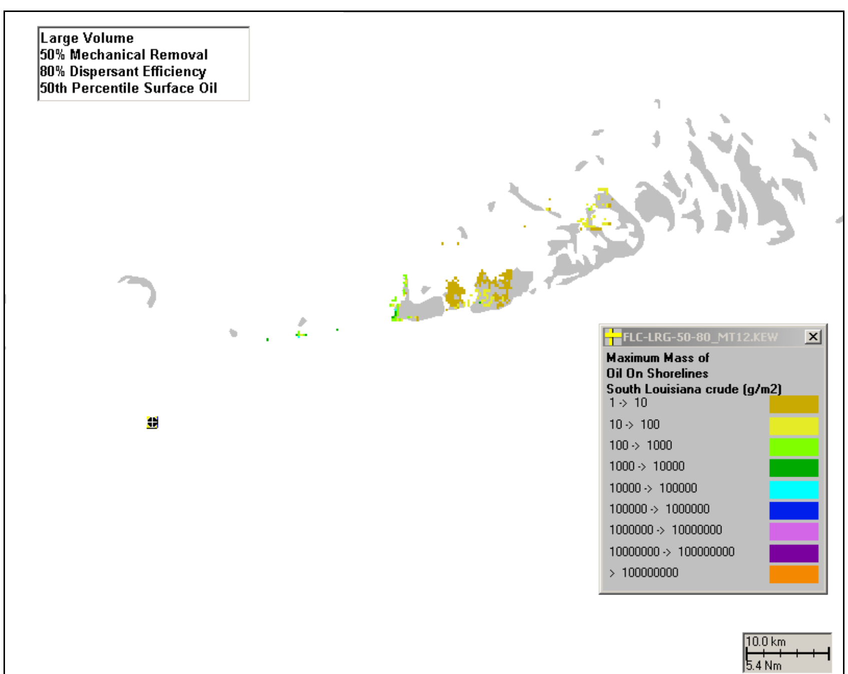

Figure D-II.4.6-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

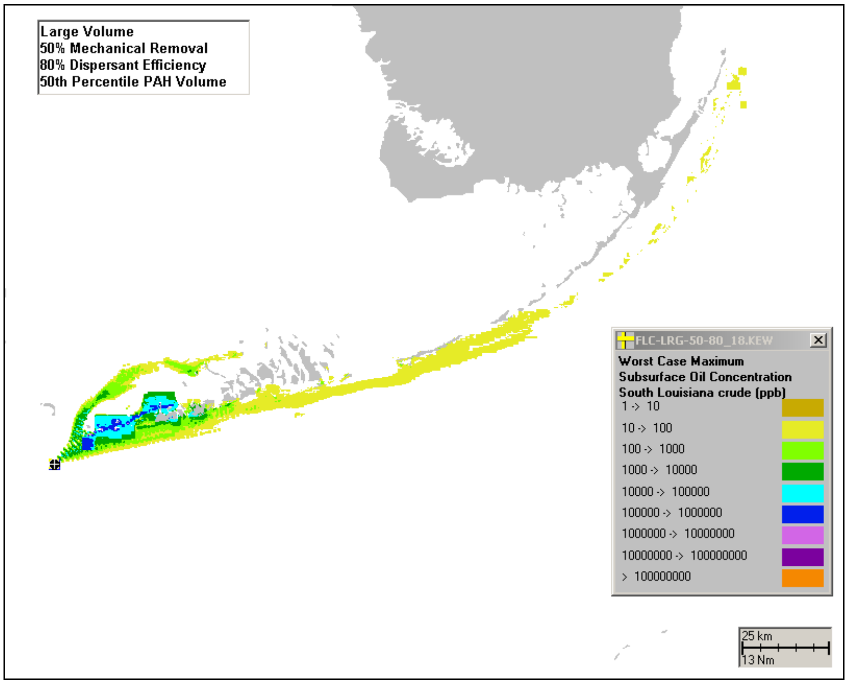

Figure D-II.4.6-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 80% Dispersant Efficiency.

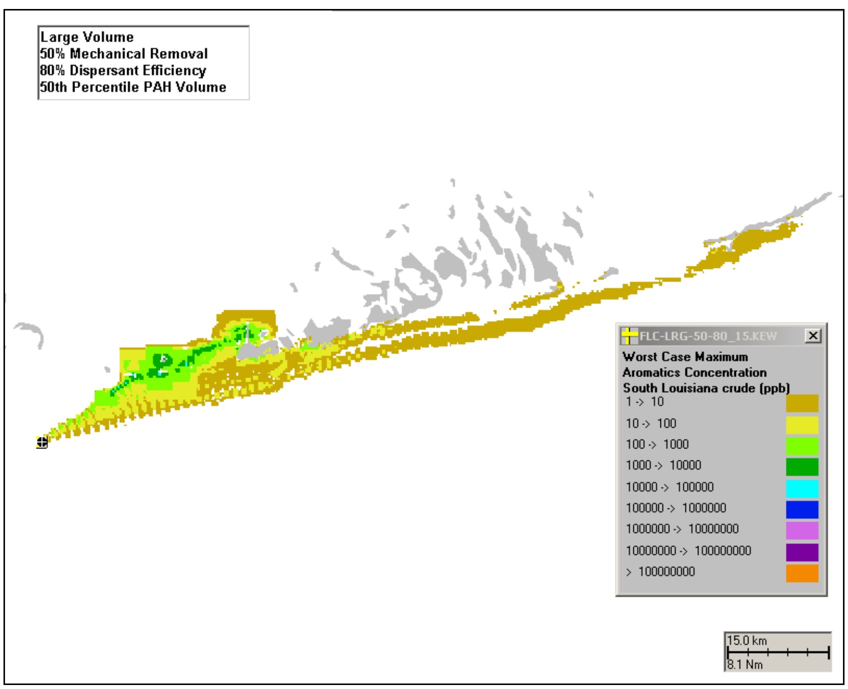

Figure D-II.4.6-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 80% Dispersant Efficiency.

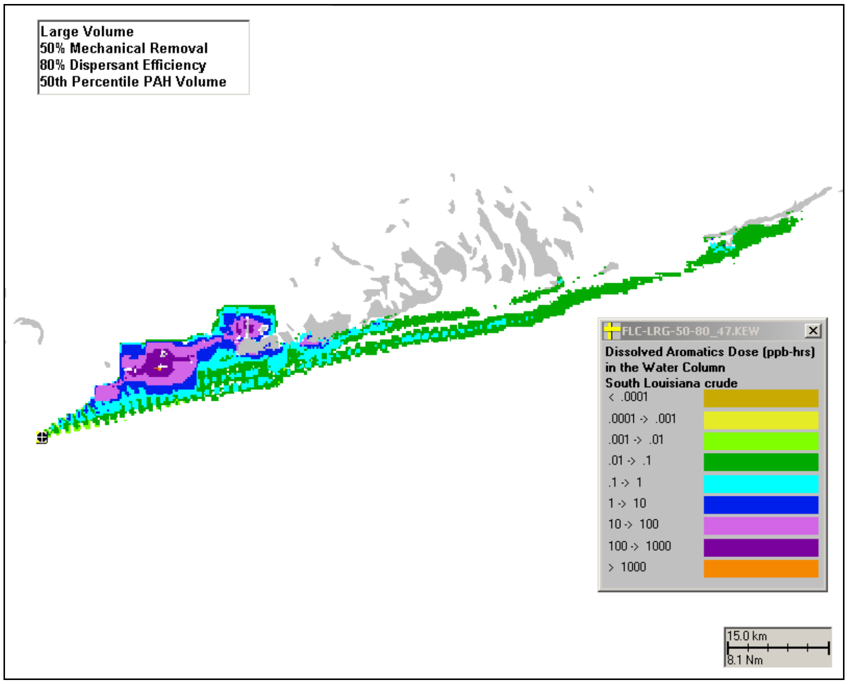

Figure D-II.4.6-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 80% Dispersant Efficiency.

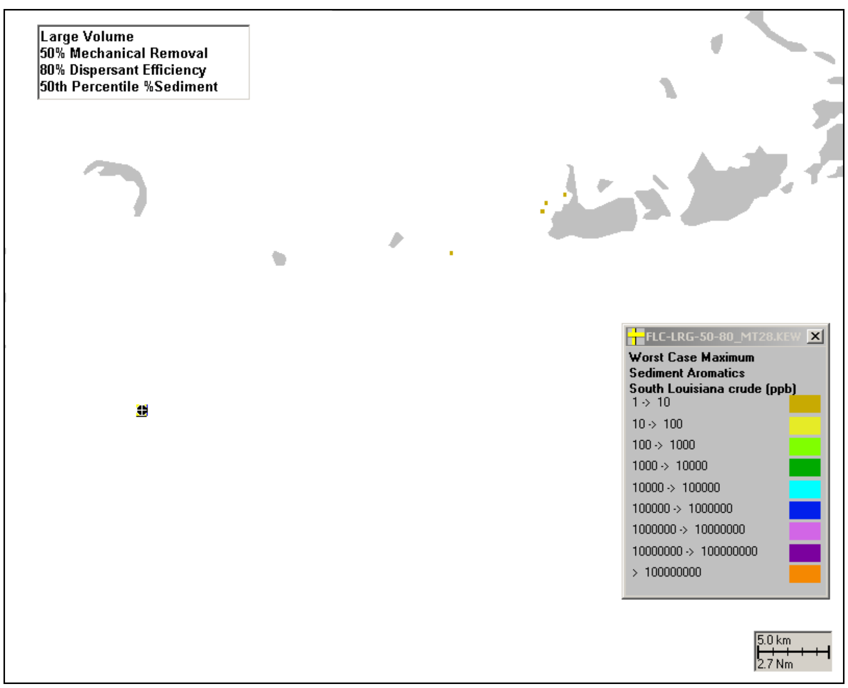

Figure D-II.4.6-7. Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment. Scenario: Large Volume, 80% Dispersant Efficiency.

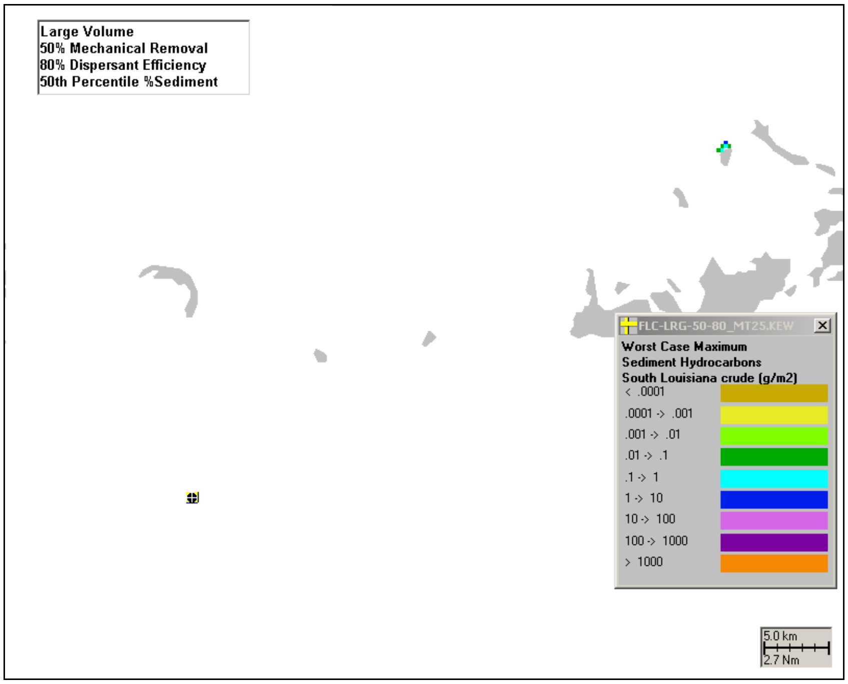

Figure D-II.4.6-8. Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment. Scenario: Large Volume, 80% Dispersant Efficiency.

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part D: Florida Straits

Section D-II.5

by

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D-II.5 Area swept by surface oil greater than the threshold affecting wildlife.

This appendix contains estimates of area swept by surface oil multiplied by probability of wildlife being oiled, for each behavior category. This is summarized as an equivalent area of 100% mortality by behavior group. The equivalent area for 100% mortality is the integrated sum of area swept times probability of mortality.

The mean equivalent area killed for all possible environmental conditions is calculated using the index of surface oil exposure exceeding 0.01g/m^2, which is the integrated area swept by oil sheen or thicker oil times the duration that oil is present, in m^2-hours. The biological exposure model was run for the 50^{th} percentile run (with respect to m^2-hours) of each of the six scenarios (two volumes times three dispersant conditions). The resulting equivalent areas of 100% mortality (in km^2) were regressed against m^2-hours to obtain an equation for each behavior group that may be used to scale from m^2-hours to area killed. Table D-II.5-1 contains the regression slope, intercept, standard error, and correlation coefficient for each behavior group. Figures D-II.5-1 and D-II.5-2 plot equivalent area killed (of 100% mortality) against m^2-hours for wildlife behavior groups. Tables D-II.5-2 and D-II.5-3 contain estimated equivalent areas killed for mean environmental conditions, based on the mean (i.e., numerical average) surface oil exposure in m^2-hours from Appendix D-II.2.

Table D-II.5-1 Regression slope, intercept, standard error, and correlation coefficient for equivalent area killed (km^2) against m^2-hours based on the 50th percentile runs of each scenario.

Behavior Group	Probability of Mortality	Slope	Intercept	Std Error	Correla-tion
Dabbling waterfowl	0.99	1.54×10^{-9}	-2.5852	2.9835	0.975
Nearshore aerial divers	0.35	0.546×10^{-9}	-0.9153	1.0563	0.975
Surface seabirds	0.99	41.7×10^{-9}	16.8037	103.6019	0.960
Aerial seabirds	0.05	2.12×10^{-9}	0.8201	5.2632	0.960
Wetland wildlife (Waders and shorebirds)	0.35	0.511×10^{-9}	-0.8567	0.9887	0.975
Terrestrial wildlife	0.001	0.001×10^{-9}	-0.0025	0.0028	0.975
Cetaceans	0.001	0.041×10^{-9}	0.0190	0.1036	0.958
Furbearing marine mammals	0.75	31.6×10^{-9}	12.6210	78.6035	0.960
Pinnipeds, manatee, sea turtles	0.01	0.425×10^{-9}	0.1638	1.0529	0.960
Surface birds, seaward	0.99	41.5×10^{-9}	17.0201	103.4394	0.959
Diving birds, seaward	0.35	14.8×10^{-9}	5.8688	36.7289	0.960
Aerial and subsurface, seaward	0.05	2.12×10^{-9}	0.8284	5.2577	0.960
Surface birds, landward	0.99	0.087×10^{-9}	-0.1467	0.1693	0.975
Diving birds, landward	0.35	0.031×10^{-9}	-0.0519	0.0599	0.975
Aerial and subsurface, landward	0.05	0.004×10^{-9}	-0.0074	0.0086	0.975
Diving birds, water only	0.35	14.7×10^{-9}	5.9715	36.6665	0.959
Aerial and subsurface, water only	0.05	2.11×10^{-9}	0.8440	5.2478	0.960
All water surface	1	42.1×10^{-9}	17.0614	104.7614	0.959
All seaward water surface	1	42.2×10^{-9}	16.7681	104.9398	0.960
All landward water surface	1	0.088×10^{-9}	-0.1482	0.1710	0.975

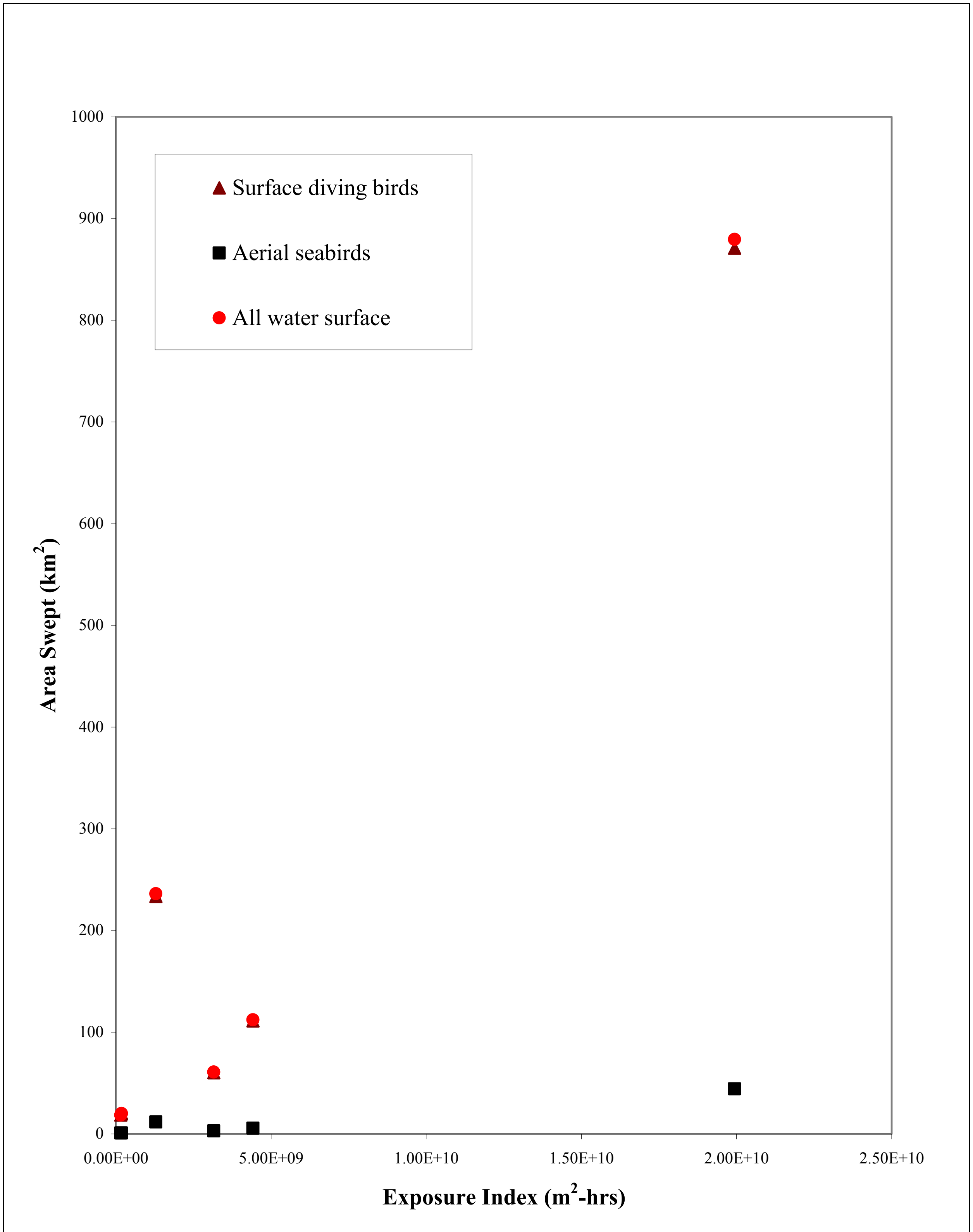

Figure D-II.5-1. Equivalent area killed against m^2-hours for wildlife behavior groups (groups in offshore waters).

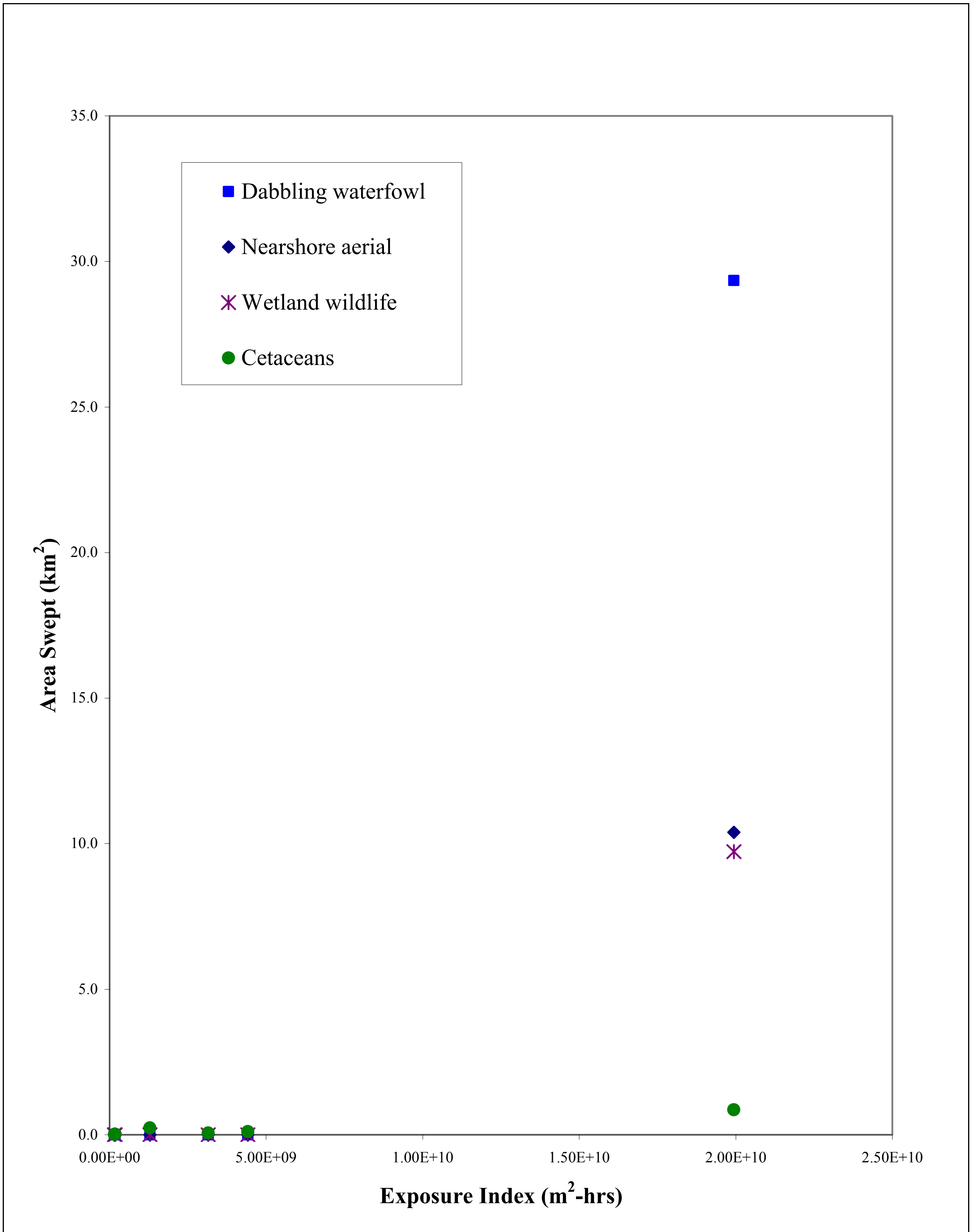

Figure D-II.5-2. Equivalent area killed against m^2-hours for wildlife behavior groups (coastal species and cetaceans)).

Table D-II.5-2. Equivalent area (km^2) of 100% mortality by wildlife behavior group, based on mean surface oil exposure, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	Probability of Mortality	0%	45%	80%
Dabbling waterfowl	0.99	0.16	0.00	0.00
Nearshore aerial divers	0.35	0.06	0.00	0.00
Surface seabirds	0.99	91.12	41.64	42.32
Aerial seabirds	0.05	4.61	2.09	2.12
Wetland wildlife (Waders and shorebirds)	0.35	0.05	0.00	0.00
Terrestrial wildlife	0.001	0.00	0.00	0.00
Cetaceans	0.001	0.09	0.04	0.04
Furbearing marine mammals	0.75	69.06	31.48	32.00
Pinnipeds, manatee, sea turtles	0.01	0.92	0.42	0.42
Surface birds, seaward	0.99	91.09	41.77	42.46
Diving birds, seaward	0.35	32.24	14.68	14.93
Aerial and subsurface, seaward	0.05	4.61	2.09	2.13
Surface birds, landward	0.99	0.01	0.00	0.00
Diving birds, landward	0.35	0.00	0.00	0.00
Aerial and subsurface, landward	0.05	0.00	0.00	0.00
Diving birds, water only	0.35	32.24	14.75	14.99
Aerial and subsurface, water only	0.05	4.61	2.10	2.14
All water surface	1.00	92.11	42.14	42.83
All seaward water surface plus intertidal	1.00	92.12	41.95	42.65
All landward water surface plus intertidal	1.00	0.01	0.00	0.00
All water surface plus intertidal	1.00	92.13	41.86	42.55

Table D-II.5-3. Equivalent area (km^2) of 100% mortality by wildlife behavior group, based on mean surface oil exposure, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	Probability of Mortality	0%	45%	80%
Dabbling waterfowl	0.99	38.29	8.62	6.89
Nearshore aerial divers	0.35	13.56	3.05	2.44
Surface seabirds	0.99	1,122.03	319.75	272.88
Aerial seabirds	0.05	57.17	16.27	13.88
Wetland wildlife (Waders and shorebirds)	0.35	12.69	2.86	2.28
Terrestrial wildlife	0.001	0.04	0.01	0.01
Cetaceans	0.001	1.11	0.32	0.27
Furbearing marine mammals	0.75	851.96	242.69	207.09
Pinnipeds, manatee, sea turtles	0.01	11.44	3.25	2.78
Surface birds, seaward	0.99	1,118.66	318.98	272.27
Diving birds, seaward	0.35	398.11	113.38	96.75
Aerial and subsurface, seaward	0.05	57.05	16.24	13.85
Surface birds, landward	0.99	2.17	0.49	0.39
Diving birds, landward	0.35	0.77	0.17	0.14
Aerial and subsurface, landward	0.05	0.11	0.02	0.02
Diving birds, water only	0.35	396.61	113.05	96.48
Aerial and subsurface, water only	0.05	56.82	16.19	13.81
All water surface	1.00	1,133.18	322.99	275.66
All seaward water surface plus intertidal	1.00	1,137.47	323.96	276.43
All landward water surface plus intertidal	1.00	2.20	0.49	0.39
All water surface plus intertidal	1.00	1,139.67	324.45	276.83

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part D: Florida Straits

Section D-II.6

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D-II.6 Exposures for fish and invertebrates to dissolved aromatic concentrations.

This appendix tabulates estimated mortality of water column, demersal (on the bottom) and benthic (in the bottom) organisms by behavior type for the Florida Keys spill location. Effects are summarized as an equivalent area of 100% mortality by behavior group and habitat type. The equivalent area for 100% mortality is the integrated sum of equivalent area affected times percent mortality. For water column and demersal species, the equivalent area affected is calculated as water volume affected times the fraction of the water depth zone the behavior group occupies that the affected volume encompasses. For pelagic species, the depth zone occupied is the entire water column. For demersal species (on the bottom sediments, exposed to bottom water), the depth zone occupied is the bottom 1 meter of the water column. The methods and assumptions for these calculations are described in Part A.

For water column and demersal species, the mean equivalent area killed for all possible environmental conditions is calculated using the water volume (m^3) exposed to greater than 1 mg/m^3 (1 ppb) dissolved aromatic concentration at any time after the spill. The biological exposure model was run for the 50th percentile run (with respect to water volume exposed to >1ppb) of each of the six scenarios (two spill volumes times three dispersant conditions). The toxicity parameter (LC50) assumed in these calculations was that for sensitive species (the 2.5th percentile in rank order sensitivity), in order to provide conservatively high estimates of potential water column effects. The resulting equivalent areas of 100% mortality (in km^2) were regressed against water volume exposed (m^3) to obtain an equation for each behavior group that may be used to scale from volume exposed to area killed (for sensitive species). Figure D-II.6-1 plots equivalent water column area killed (area of 100% mortality) against volume exposed to >1ppb for each of the water column and demersal behavior groups. Table D-II.6-1 contains the regression slope, intercept, standard error, and correlation coefficient for each behavior group. Tables D-II.6-2 and D-II.6-3 contain estimated equivalent areas killed (for sensitive species) for mean environmental conditions, based on the mean volume exposed to >1ppb dissolved aromatic concentration (from Appendix D-II.2). Tables D-II.6-4 and D-II.6-5 contain estimated equivalent areas killed (for sensitive species) for 95th percentile environmental conditions, based on the mean plus two standard deviations of volume exposed to >1ppb dissolved aromatic concentration. Mean and standard deviation of volume exposed to >1ppb dissolved aromatic concentration are tabulated in Appendix D-II.2 and the full distribution of all 100 runs is plotted in Appendix D-II.3. The effects on water column communities are discussed in Sections D.3.2 and D.4.2.

The effect areas in Tables D-II.6-2 to D-II.6-5 are for all subtidal habitats. Calculations were also made for three sensitive habitats present in the Florida Keys area: coral reefs, seagrass beds, and hard bottom (i.e., rocky reef, mapped as rocky subtidal habitat in the model grid). Tables D-II.6-6 to D-II.6-11 list the areas effected by behavior type for organisms in these habitats.

Benthic effects are related to the bottom sediment area exposed to oil exceeding a threshold of concern. Table D-II.6-12 summarizes the loading of oil to the sediments. For most species, the dissolved aromatic concentration in the pore water of the sediments is what is bioavailable and causes toxicity (Table D-II.6-13). A threshold of 6 ppb dissolved aromatic concentration could cause effects on sensitive (2.5% of) species, whereas the threshold for average species is 50 ppb (see Part A, Section A.3.4). The effects on benthic organisms are discussed in Sections D.3.2 and D.4.2.

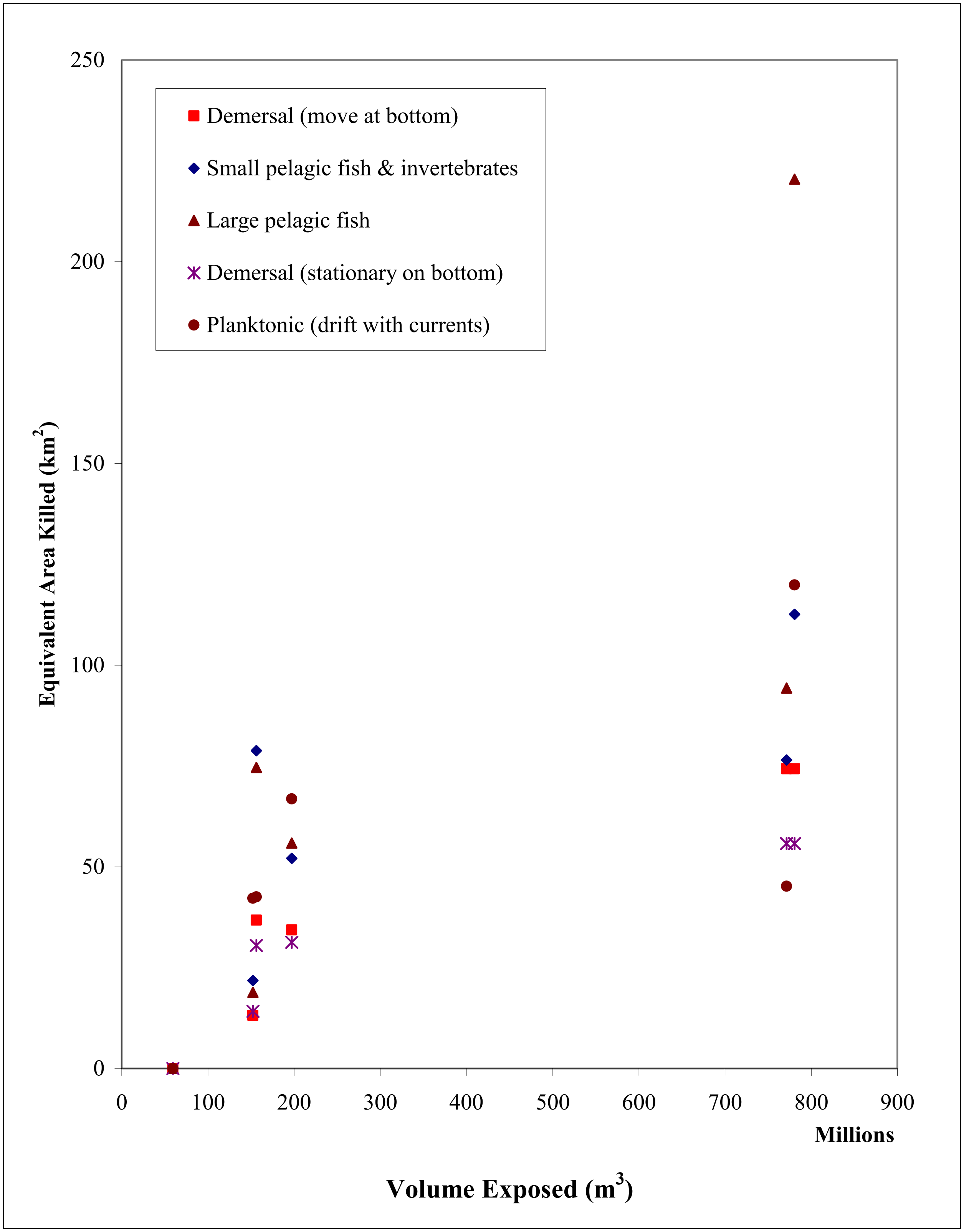

Figure D-II.6-1. Equivalent area killed (for sensitive species) against volume exposed to > 1ppb dissolved aromatic concentration for water column behavior groups.

Table D-II.6-1 Regression slope, intercept, standard error, and correlation coefficient for equivalent water column area killed (km^2) against water volume exposed to >1ppb (m^3), based on the 50th percentile runs of each scenario.

Behavior Group	Slope	Intercept	Std Error	Correlation
Demersal (move at bottom)	87×10^{-9}	8.1198	11.7959	0.939
Small pelagic fish & invertebrates	95×10^{-9}	23.3722	29.4799	0.767
Large pelagic fish	195×10^{-9}	8.6621	49.6719	0.823
Demersal (stationary on bottom)	61×10^{-9}	9.6792	10.2812	0.910
Planktonic (drift with currents)	78×10^{-9}	25.0896	33.1383	0.659

Table D-II.6-2. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	**0%**	**45%**	**80%**
Demersal (move at bottom)	15.4	22.5	22.7
Small pelagic fish & invertebrates	31.3	39.2	39.3
Large pelagic fish	24.9	40.9	41.3
Demersal (stationary on bottom)	14.8	19.8	19.9
Planktonic (drift with currents)	31.6	38.1	38.2

Table D-II.6-3. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	**0%**	**45%**	**80%**
Demersal (move at bottom)	36.5	108.5	103.4
Small pelagic fish & invertebrates	54.4	133.2	127.7
Large pelagic fish	72.1	233.2	221.8
Demersal (stationary on bottom)	29.6	80.2	76.6
Planktonic (drift with currents)	50.7	115.6	111.0

Table D-II.6-4. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean plus two standard deviations (i.e., 95^{th} percentile) of water volume exposed to > 1ppb dissolved aromatic concentration, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	0%	45%	80%
Demersal (move at bottom)	28.7	30.6	30.9
Small pelagic fish & invertebrates	46.0	33.5	33.8
Large pelagic fish	54.8	68.4	69.1
Demersal (stationary on bottom)	24.2	21.5	21.7
Planktonic (drift with currents)	43.7	27.6	27.8

Table D-II.6-5. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean plus two standard deviations (i.e., 95^{th} percentile) of water volume exposed to > 1ppb dissolved aromatic concentration, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	0%	45%	80%
Demersal (move at bottom)	92.0	274.4	267.2
Small pelagic fish & invertebrates	100.7	300.5	292.5
Large pelagic fish	205.9	614.2	597.9
Demersal (stationary on bottom)	64.6	192.8	187.7
Planktonic (drift with currents)	83.0	247.6	241.0

Table D-II.6-6. Equivalent area (km^2) of 100% mortality (for sensitive species) in coral reefs by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	0%	45%	80%
Demersal (move at bottom)	8.9	9.7	9.5
Small pelagic fish & invertebrates	24.2	25.1	24.9
Large pelagic fish	10.3	12.2	11.8
Demersal (stationary on bottom)	10.2	10.8	10.7
Planktonic (drift with currents)	25.8	26.5	26.3

Table D-II.6-7. Equivalent area (km^2) of 100% mortality (for sensitive species) in coral reefs by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	0%	45%	80%
Demersal (move at bottom)	10.3	12.0	12.0
Small pelagic fish & invertebrates	25.8	27.7	27.7
Large pelagic fish	13.5	17.4	17.4
Demersal (stationary on bottom)	11.2	12.4	12.4
Planktonic (drift with currents)	27.1	28.6	28.6

Table D-II.6-8. Equivalent area (km^2) of 100% mortality (for sensitive species) in seagrass beds by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	0%	45%	80%
Demersal (move at bottom)	14.6	18.2	18.2
Small pelagic fish & invertebrates	30.4	34.4	34.4
Large pelagic fish	23.1	31.2	31.2
Demersal (stationary on bottom)	14.2	16.8	16.8
Planktonic (drift with currents)	30.9	34.2	34.2

Table D-II.6-9. Equivalent area (km^2) of 100% mortality (for sensitive species) in seagrass beds by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	0%	45%	80%
Demersal (move at bottom)	23.2	33.2	32.3
Small pelagic fish & invertebrates	39.9	50.8	49.9
Large pelagic fish	42.3	64.7	62.8
Demersal (stationary on bottom)	20.3	27.3	26.7
Planktonic (drift with currents)	38.7	47.7	46.9

Table D-II.6-10. Equivalent area (km^2) of 100% mortality (for sensitive species) in hard bottom (rocky reef) habitats by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	0%	45%	80%
Demersal (move at bottom)	9.3	9.9	9.9
Small pelagic fish & invertebrates	24.7	25.4	25.4
Large pelagic fish	11.4	12.8	12.8
Demersal (stationary on bottom)	10.5	11.0	11.0
Planktonic (drift with currents)	26.2	26.7	26.7

Table D-II.6-11. Equivalent area (km^2) of 100% mortality (for sensitive species) in hard bottom (rocky reef) habitats by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	0%	45%	80%
Demersal (move at bottom)	10.9	12.9	13.3
Small pelagic fish & invertebrates	26.4	28.6	29.1
Large pelagic fish	14.9	19.4	20.3
Demersal (stationary on bottom)	11.6	13.0	13.3
Planktonic (drift with currents)	27.6	29.4	29.8

Table D-II.6-12. Area (m^2) of sediment exceeding indicated thresholds of total hydrocarbon loading per unit area (g/m^2) under average environmental conditions, by spill volume and dispersant treatment.

Threshold (g/m^2)	Medium 0%	Medium 45%	Medium 80%	Large 0%	Large 45%	Large 80%
0	3,778,889	3,039,541	2,957,392	4,846,838	4,025,338	4,764,688
0.001	2,218,044	1,807,295	1,889,445	3,532,440	2,957,392	3,696,739
0.01	1,232,247	821,498	739,348	2,464,493	2,218,044	2,053,744
0.1	246,449	0.0	82,150	821,498	410,749	328,599
1	0.0	0.0	0.0	0.0	0.0	82,150
10	0.0	0.0	0.0	0.0	0.0	0.0

Table D-II.6-13. Area (m^2) of sediment exceeding indicated thresholds of dissolved aromatic concentration in pore waters (mg/m^3 = ppb) under average environmental conditions, by spill volume and dispersant treatment.

Threshold (mg/m^3 = ppb)	Medium 0%	Medium 45%	Medium 80%	Large 0%	Large 45%	Large 80%
1	0.0	0.0	0.0	0.0	82,150	82,150
10	0.0	0.0	0.0	0.0	0.0	0.0

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part D: Florida Straits

Section D-III.1

by

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ASA 00-246

August 2004

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D-III.1 Air Concentrations from Unburned Oil

This section contains model results for spills in South Florida (or similar subtropical-tropical areas) used to evaluate volatile hydrocarbon emissions from unburned oil and resulting air quality effects. The amount of volatilized mass entering the atmosphere for each chemical (or chemical class) of concern was estimated using oil spill modeling (SIMAP). SIMAP also provided the time frame over which the emissions occur. The atmospheric concentrations of volatilized hydrocarbons were modeled using AIRMAP (as described in Part A, Section A.5.1). The estimated concentrations at the water surface were compared to air quality standards to evaluate the potential for human health effects and wildlife effects.

As a screening analysis, SIMAP runs were performed for both the medium (2500 bbl) and large (40,000 bbl) spill volumes of South Louisiana crude under various wind conditions to determine the possible hydrocarbon emissions from unburned oil to the atmosphere. Emissions were estimated using SIMAP for the warmest water temperature occurring in the region, 30°C (French et al. 1996b) and for varying wind speeds from 3 to 25 kts. (Evaporation is very slow in conditions of no wind, so this case was not included.)

As a worst case, these model runs were performed assuming no dispersants are applied, since the use of dispersants would reduce emissions to the extent that volatile components are permanently mixed into the water. It is also assumed that any mechanically-removed oil still volatilizes, so no correction for removal was made to the volatilized mass. Likewise, no correction for amount burned was made to the rate of unburned oil emission. Thus, the screening model runs estimated the maximum rate and amount of emissions which would be expected under any environmental conditions and response scenario for the region.

In the next step of the analysis, the atmospheric concentrations of volatilized hydrocarbons released by unburned oil were modeled using AIRMAP, which accounts for transport and dilution of hydrocarbons in the local atmosphere around the spill site. Each hydrocarbon constituent was modeled separately, releasing the mass of the constituent emitted from the oil over time from the area covered by surface floating oil (as estimated by SIMAP). AIRMAP was run for each constituent and wind speed condition, from 3 to 25 kts. The constituent mass released in the AIRMAP simulation (over 10 hours) was the maximum amount emitted to the air (of that constituent) in any 10-hour period in the SIMAP spill simulation. The AIRMAP simulation was run assuming a stable atmosphere with minimal turbulence to disperse contaminants.

The atmospheric dispersion model provided estimates of air concentrations in the air layer within 2 m of the water surface (for each 55m X 55m cell of a 200 by 200 cell grid covering the horizontal extent of the plume) as a function of time after the spill. The estimated concentrations were then compared to air quality standards to evaluate the potential for human health effects. Two averaging periods were used in accordance with the standards: 0.5 hour for comparison to the Immediate Danger to Life and Health

(IDLH) value and 8 hours for comparison to the 8-hour time weighted average (TWA). The maximum 0.5-hour and 8-hour average air concentration for any time period in the AIRMAP simulation was compared to the appropriate standard (Table D-III.1-1). The IDLH (from Table A.5-5 in Part A) is not to be exceeded for a ½ hour exposure. The PEL-TWA is the minimum of the 8-hour time weighed averages in Table A.5-5. Heptane is used as representative of the volatile aliphatic VOCs. Its air quality standards are the lowest of those available for this group of chemicals (see Section A.5.3), so comparison to the standards for heptane is conservative. The area adversely affected was that where the standard was exceeded for the appropriate averaging period. The maximum distance from the release site that concentrations exceeded the air quality standard was also estimated for each constituent using the AIRMAP results.

These results are applicable to spills of crude oils with similar volatile content in any location where conditions are at the temperature, atmospheric stability, and wind speed assumed. Concentrations and areas affected would be lower than those reported below for less stable atmospheres and lower temperature conditions. The results are assuming no dispersant applied, such that all the volatiles are assumed released to the atmosphere. Dispersants could permanently disperse some of the volatiles in the water column, reducing the air concentrations and areas adversely affected. Also, volatiles would be burned and emissions reduced to the extent that ISB is used. Thus, these areas of potential adverse effect are the maximum possible in the region under any response scenario and environmental conditions.

Table D-III.1-1. IDLH and TWA thresholds for evaluating potential effects of air concentrations.

Chemical	IDLH (mg/m^3)	PEL-TWA (mg/m^3)
Benzene	1595	3.19
Toluene	1885	754
Ethylbenzene	3472	434
Xylene	3906	434
Naphthalene	1310	52.4
Biphenyl	631	1.262
Phenanthrene	80	(not available)
Aliphatic VOCs with boiling points <180°C (based on heptane)	3075	2050

D-III.1.1 Medium Volume Spills

<u>Emissions from Unburned Oil</u>

Table D-III.1.1-1 contains the estimated maximum volatilized mass released to the atmosphere in any 10-hour period for each constituent of concern in the medium-volume spill under the worst-case (highest) temperature condition (30°C) and with various wind speeds. The results show (Figure D-III.1.1-1) that the emission rates of the MAHs (benzene, toluene, ethylbenzene, xylenes) increase as wind speed increases to about 5 kts and then level off. Volatile aliphatics indicate a similar pattern with wind speed (Table D-III.1.1-1). The emission rates for PAHs are much lower than for the volatiles and increase with wind speed (Figure D-III.1.1-1).

Table D-III.1.1-1. Maximum mass (MT) of chemical volatilized from unburned South Louisiana crude oil in any 10-hour period after a spill of 2,500 bbl at the indicated wind speed.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Total MAHs	256	268	266	260	257	250	242	232	224
Benzene	0.20	0.21	0.21	0.21	0.21	0.20	0.19	0.19	0.18
Toluene	0.56	0.59	0.58	0.57	0.56	0.55	0.53	0.51	0.49
Ethylbenzene	0.18	0.19	0.19	0.18	0.18	0.18	0.17	0.16	0.16
Xylenes	1.37	1.43	1.42	1.39	1.38	1.34	1.30	1.24	1.20
Total volatile and semi-volatile PAHs	56.6	73.0	85.6	95.6	102.9	113.7	128.9	150.7	199.9
Naphthalene	0.02	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.07
Biphenyl	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Phenanthrene	0.03	0.04	0.05	0.06	0.06	0.07	0.08	0.09	0.12
Aliphatic VOCs with boiling points <180°C	42.3	44.2	43.9	43.0	42.5	41.3	40.1	38.4	37.1

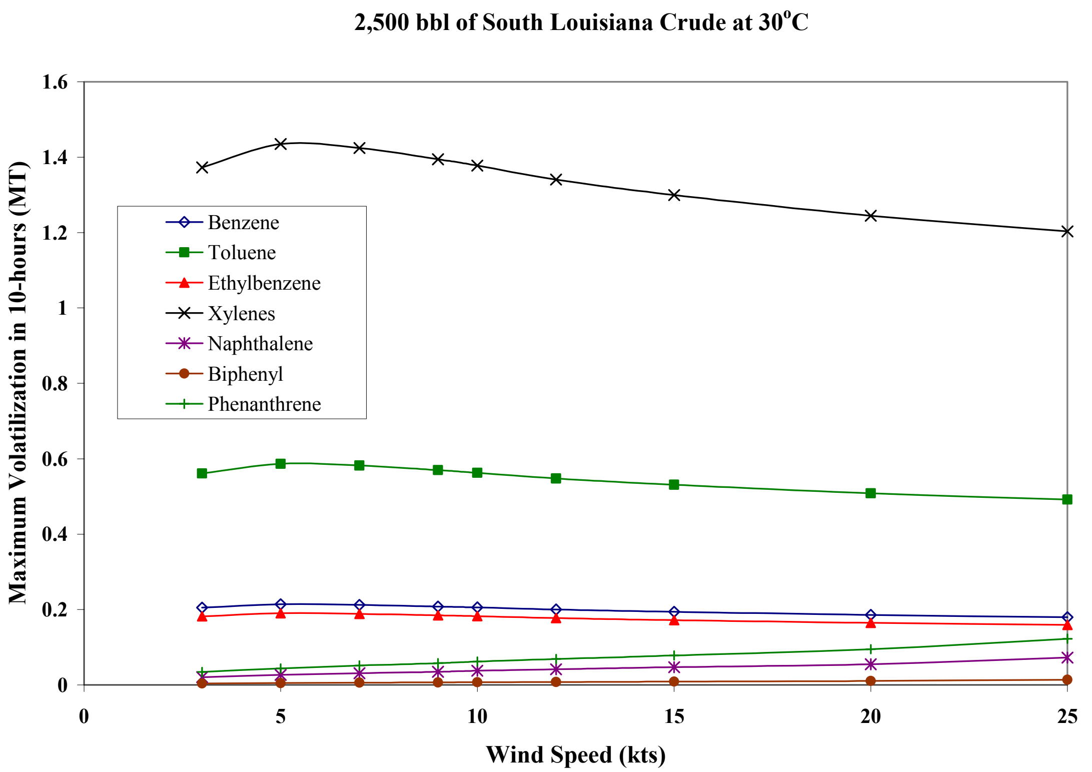

Figure D-III.1.1-1 Maximum mass (MT) of chemical volatilized from unburned South Louisiana crude oil in any 10-hour period after a spill of 2,500 bbl at the indicated wind speed.

<u>Air Concentrations from Unburned Oil Emissions</u>

Tables D-III.1.1-2 and D-III.1.1-3 list the areas where the air concentrations exceeded the comparable air quality standards. Tables D-III.1.1-4 and D-III.1.1-5 list the maximum distances (down wind) from the release site that concentrations exceeded the air quality standards. Since the emissions were more rapidly dispersed in the atmosphere the higher the wind speed, the conditions where concentrations of volatiles in air were at maximum were those where winds were assumed light (3 kts). This is demonstrated in the results. The IDLH is not exceeded for any of the chemical constituents under these worst-case conditions for medium volume spills of South Louisiana crude oil. The TWA would only be exceeded after spills of 2,500 bbl for benzene in the immediate spill area (≤0.7 km downwind of the spill site) and under light (≤3 kts) winds. Air concentrations of other constituents would not exceed the TWA standards at any time after a medium volume spill.

Table D-III.1.1-2. Maximum area (m^2) where the IDLH would be exceeded due to volatilization of unburned South Louisiana crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180°C	0	0	0	0	0	0	0	0	0

Table D-III.1.1-3. Maximum area (m^2) where the PEL-TWA would be exceeded due to volatilization of unburned South Louisiana crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	75,625	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180°C	0	0	0	0	0	0	0	0	0

Table D-III.1.1-4. Maximum distance down wind (km) where the IDLH would be exceeded due to volatilization of unburned South Louisiana crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0	0	0	0	0	0	0	0	0

Table D-III.1.1-5. Maximum distance down wind (km) where the PEL-TWA would be exceeded due to volatilization of unburned South Louisiana crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0.7	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0	0	0	0	0	0	0	0	0

D-III.1.2 Large Volume Spills

Emissions from Unburned Oil

Table D-III.1.2-1 contains the estimated maximum volatilized mass released to the atmosphere in any 10-hour period for each constituent of concern in the large-volume spill under the worst-case (highest) temperature condition and with various wind speeds. The results show (Figure D-III.1.2-1) that the emission rates of the MAHs (benzene, toluene, ethylbenzene, xylenes) increase as wind speed increases to about 15 kts and then level off. Volatile aliphatics indicate a similar pattern with wind speed (Table D-III.1.2-1). The emission rates for PAHs are much lower than for the volatiles and increase with wind speed (Figure D-III.1.2-1).

Table D-III.1.2-1. Maximum mass (MT) of chemical volatilized from unburned South Louisiana crude oil in any 10-hour period after a spill of 40,000 bbl at the indicated wind speed.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Total MAHs	2826	3257	3519	3749	3806	3869	4007	4026	3989
Benzene	2.26	2.61	2.82	3.00	3.05	3.10	3.21	3.22	3.19
Toluene	6.19	7.13	7.71	8.21	8.34	8.47	8.77	8.82	8.74
Ethylbenzene	2.01	2.31	2.50	2.66	2.70	2.75	2.84	2.86	2.83
Xylenes	15.15	17.46	18.86	20.09	20.40	20.74	21.48	21.58	21.38
Total volatile and semi-volatile PAHs	457.3	591.8	697.1	785.7	810.7	969.3	1345.4	1984.7	2592.1
Naphthalene	0.17	0.22	0.25	0.29	0.30	0.35	0.49	0.72	0.94
Biphenyl	0.03	0.04	0.05	0.05	0.06	0.07	0.09	0.14	0.18
Phenanthrene	0.28	0.36	0.42	0.48	0.49	0.61	0.89	1.43	1.87
Aliphatic VOCs with boiling points <180°C	467	538	581	619	629	639	662	665	659

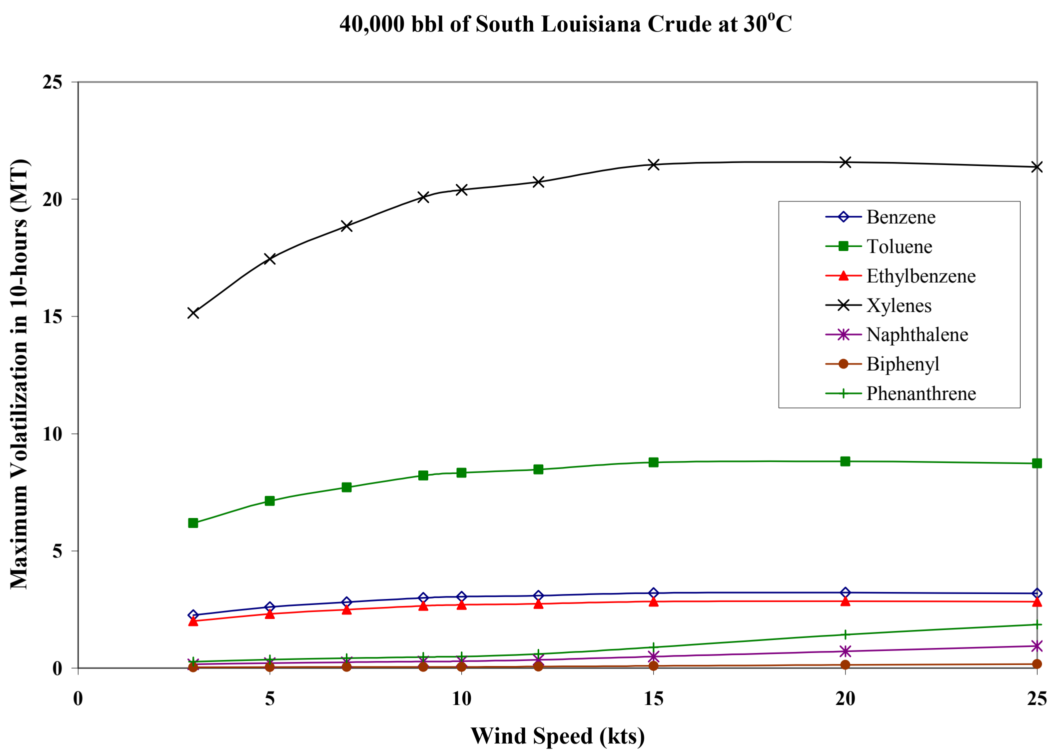

Figure D-III.1.2-1 Maximum mass (MT) of chemical volatilized from unburned South Louisiana crude oil in any 10-hour period after a spill of 40,000 bbl at the indicated wind speed.

<u>Air Concentrations from Unburned Oil Emissions</u>

Tables D-III.1.2-2 and D-III.1.2-3 list the areas where the air concentrations exceeded the comparable air quality standards for large volume spills. Tables D-III.1.2-4 and D-III.1.2-5 list the maximum distances (down wind) from the release site that concentrations exceeded the air quality standards. Since the emissions were more rapidly dispersed in the atmosphere the higher the wind speed, the conditions where concentrations of volatiles in air were at maximum were those where winds were assumed light (3 kts), as demonstrated by the results. The IDLH for heptane is exceeded at ≤1.3 km downwind of the spill site by the total volatile aliphatic VOC concentration under these worst-case temperature and air stability conditions for wind speeds up to 5 kts. The IDLH is not exceeded for any of the MAHs or PAHs, and would not be expected to under any environmental conditions for spills of this large volume. The TWA would be exceeded after spills of 40,000 bbl for benzene, xylenes, biphenyl and volatile aliphatic VOCs in the spill area and under light to moderate winds (≤12 kts). For xylenes and biphenyl, the areas adversely affected would not exceed 0.1 km^2 in the worst case conditions of light winds and a stable atmosphere. The adversely affected areas are larger for benzene (up to 3.4 km^2) and volatile aliphatic VOCs (up to 0.9 km^2), assuming a worst case of a stable atmosphere. The areas would be less for less stable atmospheric conditions and lower temperatures than assumed.

Table D-III.1.2-2. Maximum area (m^2) where the IDLH would be exceeded due to volatilization of unburned South Louisiana crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180°C	226,875	93,775	0	0	0	0	0	0	0

Table D-III.1.2-3. Maximum area (m^2) where the PEL-TWA would be exceeded due to volatilization of unburned South Louisiana crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	3,357,750	1,948,100	1,203,950	580,800	435,600	93,775	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	5,900	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	51,425	6,050	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180°C	880,275	335,775	51,425	0	0	0	0	0	0

Table D-III.1.2-4. Maximum distance down wind (km) where the IDLH would be exceeded due to volatilization of unburned South Louisiana crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	1.3	0.7	0	0	0	0	0	0	0

Table D-III.1.2-5. Maximum distance down wind (km) where the PEL-TWA would be exceeded due to volatilization of unburned South Louisiana crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	7.4	5.0	3.4	1.9	1.5	0.8	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0.9	0.3	0.0	0.0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	3.5	1.6	0.5	0.0	0	0	0	0	0

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part D: Florida Straits

Section D-III.2

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ASA 00-246

August 2004

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D-III.2 Air Concentrations from In-Situ Burning

Section A.5.2 of Part A describes the methods used to evaluate emissions from ISB and their potential effects on air quality. For scenarios involving ISB, the maximum potential amount of oil burned was assumed to be 25% by volume of the amount of oil mechanically removed (see Section A.3.7). The amount burned was calculated for each scenario since the percent of oil mechanically removed varies for each of the 100 stochastic runs. The 50th and 95th percentiles of the volumes mechanically cleaned up (for the 100 stochastic runs) were multiplied by 0.25 to calculate the 50th and 95th percentile volumes burned by ISB. The atmospheric concentrations of compounds and particulates released by an in-situ burn are dependent upon both the distance from and the area of the fire. All chemicals in the emissions that might be of concern are considered in the analysis.

D-III.2.1 Medium Volume Spills

The estimated distances from an in-situ burn to thresholds of concern are tabulated below. The maximum burn areas for each scenario were calculated by dividing the burn volume by the minimum oil thickness required for burning (3 mm). Burn areas were calculated for all 100 runs for each scenario. Table D-III.2-1 shows, for each of the three medium volume scenarios, the percentage of simulations whose calculated burn area (burn volume divided by 3 mm) is less than the maximum possible burn area of 500 m^2. For these three scenarios, some of the individual simulations have burn areas smaller than 500 m^2. The effect of the dispersant application on the area of oil requiring burning is apparent from the numbers in the table. When no dispersant is applied (0% dispersant efficiency), 9% of the simulations have burn areas smaller than 500 m^2. For 45% dispersant efficiency, 93% of the burn areas are smaller than 500 m^2, and the same is true for 80% dispersant efficiency. Therefore, the results show that the more efficient the dispersant, the smaller the area of oil is that needs to be burned. This is not a surprising result, as dispersant removes oil from the surface of the water, decreasing the amount of oil that remains on the surface, and thereby decreasing the area of oil that needs to be burned.

Table D-III.2-1. Percentile where burn volume, divided by 3 mm, is less than the maximum burn area of 500 m^2, for each medium volume scenario.

Scenario	Percentile
Medium Volume, 0% Dispersant Efficiency	9%
Medium Volume, 45% Dispersant Efficiency	93%
Medium Volume, 80% Dispersant Efficiency	93%

Table D-III.2-2 shows, for each medium volume scenario, the number of burns that would be necessary to burn the entire amount of oil that was designated for burning. A range of oil thicknesses are shown in Table D-III.2-2: between 3 mm and 10 cm (100 mm). Three mm is the minimum thickness of oil required for in-situ oil burning (Buist et al., 1994). However, 10 cm is a more preferable oil thickness for burning (Allen, 2002). If one burn can be accomplished at less than 10 cm thick and 500 m^2 of area (i.e., the burn volume is < 50 m^3), it is assumed that this occurs and the actual thickness is calculated from volume burned divided by 500 m^2. However, if the calculated thickness for one burn is <3mm, the minimum (i.e., the burn volume is < 1.5 m^3), the burn area is instead the burn volume divided by 3 mm.

Table D-III.2-2. Assumed burn thickness for medium volume spill scenarios and number of burns needed to burn the oil, assuming the maximum burn area is 500 m^2.

Scenario		Total Volume Burned (m^3)	Burn Area (m^2)	Oil thickness (mm)	Number of Burns
Medium Volume, 0% Dispersant Efficiency	50th Percentile	14.7	500	30	1
	95th Percentile	23.4	500	47	1
Medium Volume, 45% Dispersant Efficiency	50th Percentile	0	500	-	0
	95th Percentile	1.82	500	4	1
Medium Volume, 80% Dispersant Efficiency	50th Percentile	0	500	-	0
	95th Percentile	1.82	500	4	1

In all cases (Table E.5.12-2), the burn volumes are less than 50 m^3, the maximum volume for a single burn. For cases where there is a burn, none of the burn volumes are less than 1.5 m^3, so all the burn areas are 500 m^2. The distance-to-threshold calculations reported below assume an area per burn of 500 m^2.

Table D-III.2-3 reports calculations of distance to the air quality thresholds for the chemicals of concern that are released when oil is burned. There are three thresholds in these tables: IDLH, TWA, and EPA NAAQS (Primary and Secondary Standards). These thresholds were described and listed in Table A.5-5. The chemicals listed in Table D-III.2-3 were designated by Fingas, et al. (2001) as being of concern, and they are split

into five chemical classes: total particulates, fixed gases, carbonyls, PAHs, and VOCs. For those chemicals for which U.S. air quality standards were not available, we have assumed the lowest of the available thresholds within that chemical class. For example, we do not have an IDLH threshold value for butane, a member of the VOC chemical class, but we do have IDLH values for several other members of the VOC class. We selected the lowest of the available IDLH values for the VOCs and used that value as an IDLH threshold for butane and other chemicals in the VOC class for which we are missing threshold values. We used the same strategy for the PAH chemical class as well. This substitution method provides an estimate of the distance to the threshold for those chemicals for which threshold data are not available. However, because those threshold values are just assumed estimates, the distance values in the following tables that were derived using these threshold values are shaded gray.

It should also be noted that three different TWA threshold values were obtained for this study: ACGIH TLV, OSHA PEL, and NIOSH REL. We calculated the distance to the threshold for each of these, but we present only the maximum of the three distances in these tables. For example, in Table D-III.2-3, for formaldehyde, the distance to the ACGIH TLV threshold is 237 m, to the OSHA PEL threshold is 0 m, and to the NIOSH REL threshold is 89 m. The maximum of these three distances is 237 m, which is the TWA value reported in the table.

Table D-III.2-3 shows the distance-to-threshold calculations for an individual 500 m^2 burn. In the table, the calculated distances represent the distance (from the center of the fire) at which the concentration of each chemical has decreased to the threshold level. In the case of sulphur dioxide in Table D-III.2-3, the distance at which the concentration of sulphur dioxide in the air equals the IDLH threshold is essentially zero, meaning that the concentration of sulphur dioxide produced by the 500-m^2 fire never exceeds the IDLH threshold. However, for the other thresholds in the table (TWA and EPA NAAQS), the concentrations do exceed the thresholds and do not decrease to the threshold level until 331 m, 471 m, and 440 m from the center of the fire.

Table D-III.2-3 shows that, for a 500-m^2 burn area, the total particulates, fixed gases, and carbonyls are of the greatest concern (i.e., the distances from the fire to the threshold level are greatest). The majority of other chemicals have distances of zero meters to the threshold level, meaning that their concentrations never exceed the threshold. Acetone has the largest distance to the threshold, at 710 m, and acetaldehyde and the total particulates are the next largest.

In Table D-III.2-3 there are four additional chemicals with distances to the threshold that stand out: 2-methylbutane, 3-methylhexane, 3-methylpentane, and methylcyclopentane. However, as can be seen from the tables, these values are shaded gray because we did not have a regulatory threshold value for them. Instead, we used the lowest threshold value from within their group (VOCs). From this, we can conclude that their distance to threshold values *may* represent that they are chemicals whose concentrations will still be above threshold levels far from the fire, or it may be that the threshold estimates used for the distance-to-threshold calculation are unreasonably low and our estimate method is not suitable for these chemicals.

Table D-III.2-3. Estimated distances (m) from fire to the thresholds of concern for the 50th and 95th percentile volumes for ISB for burn area of 500 m^2. For those chemicals for which U.S. air quality standards were not available, the smallest of the available thresholds within that chemical class is assumed, and the results are shaded in gray.

	Distance to the Threshold (m)			
Substances	**IDLH**	**TWA**	**EPA NAAQS**	
			Primary Standard	**Secondary Standard**
Total Particulates				
10-um particle			514	514
2.5-um particle			523	523
Fixed gases				
Sulphur Dioxide	0	331	471	440
Carbon Dioxide	0	0		
Carbon Monoxide	0	0	0	
Carbonyls				
Acetaldehyde	0	525		
Acetone	0	710		
Formaldehyde	0	237		
PAHs				
1- Methylnaphthalene	0	0		
1-Methylphenanthrene	0	0		
2,3,5-Trimethylnaphthalene	0	0		
2,6-Dimethylnaphthalene	0	0		
2-Methylnaphthalene	0	0		
Acenaphthene	0	0		
Acenaphthylene	0	0		
Anthracene	0	0		
Benz(a)anthracene	0	0		
Benzo(a)pyrene	0	0		
Benzo(b) fluoranthene	0	0		
Benzo(e) pyrene	0	0		
Benzo(g,h,I) perylene	0	0		

Biphenyl	0	0		
Chrysene	0	0		
Dibenz(a,h)anthracene	0	0		
Dimethylnaphthalenes	0	0		
Fluoranthene	0	0		
Fluorene	0	0		
Indenol(1,2,3-cd)pyrene	0	0		
Methylphenanthrenes	0	0		
Naphthalene	0	0		
Perylene	0	0		
Phenanthrene	0	0		
Pyrene	0	0		
Trimethylnaphthalenes	0	0		
VOCs				
1,2,3-Trimethylbenzene	0	0		
1,2,4-Trimethylbenzene	0	0		
1,3,5-Trimethylbenzene	0	0		
1,4-Diethylbenzene	0	0		
2,2,3-Trimethylbutane	0	0		
2,2,4-Trimethylpentane	0	0		
2,2,5-Trimethylhexane	0	0		
2,2-Dimethylbutane	0	0		
2,2-Dimethylpropane	0	0		
2,3,4-Trimethylpentane	0	0		
2,3-Dimethylbutane	0	1		
2,3-Dimethylpentane	0	1		
2,4-Dimethylhexane	0	0		
2,4-Dimethylpentane	0	0		
2,5-Dimethylhexane	0	0		
2-Ethyltoluene	0	0		
2-Methylbutane	0	165		
2-Methylheptane	0	4		
3-Methylhexane	0	42		
3-Methylpentane	0	85		
4-Ethyltoluene	0	0		
4-Methylheptane	0	0		
Benzene	0	0		
Butane	0	1		
c-1,3-Dimethylcyclohexane	0	0		
c-1,4/t-1,3-Dimethylcyclohexane	0	0		
c-2-Butene	0	0		
Cyclohexane	0	0		
Cyclopentane	0	0		

Decane	0	0		
Dodecane	0	0		
Ethylbenzene	0	0		
Heptane	0	0		
Indan (2,3-Dihydroindene)	0	0		
Isobutane (2-Methylpropane)	0	0		
m,p-xylene	0	0		
Methylcyclohexane	0	0		
Methylcyclopentane	0	92		
Naphthalene	0	0		
n-Butylbenzene	0	0		
Nonane	0	0		
n-Propylbenzene	0	0		
Octane	0	0		
o-Xylene	0	0		
p-Cymene (1-Methyl-4-iso-propylbenzene)	0	0		
Pentane	0	0		
Propane	0	0		
Propene	0	0		
2,2-Dimethylpentane	0	0		
iso-Butylbenzene	0	0		
Isoprene (2-Methyl-1,3-Butadiene)	0	0		
iso-Propylbenzene	0	0		
Undecane	0	0		

The ISB effects are summarized in Table D-III.2-4. The affected area is calculated by assuming the circular area around each burn is affected to the maximum distance to any air quality threshold (i.e., this distance is the circle radius) and multiplying the circular area per burn by the number of burns. The percent of the region of interest is calculated using the province area in Table A.4-4.

Table D-III.2-4. Estimation of area affected by ISB, for medium volume spills by dispersant scenario and for 50th and 95th percentile burn volumes.

Dispersant % Efficiency		**0**	**45**	**80**
Burn Area (m^2)	50th	500	0	0
	95th	500	500	500
Maximum Distance (m) to Threshold (1 burn)	50th	710	0	0
	95th	710	710	710
# of Burns	50th	1	0	0
	95th	1	1	1
Area (km^2) Exposed (assuming circle with radius = maximum distance)	50th	1.584	0	0
	95th	1.584	1.584	1.584
Percent of Province Area	50th	0.004	0.000	0.000
	95th	0.004	0.004	0.004

D-III.2.2 Large Volume Spills

The estimated distances from an in-situ burn to thresholds of concern for the large volume scenarios are below. Burn areas were calculated for all 100 runs for each scenario. Table D-III.2-5 lists, for each of the three large volume scenarios, the percentage of simulations whose calculated burn area (burn volume divided by 3 mm) is less than the maximum burn area of 500 m^2. This table shows that for the three scenarios in which the large volume of 40,000 bbl of crude oil was released, burn areas are larger than 500 m^2, regardless of the dispersant efficiency, with the exception of 1% of cases for the 80% dispersant efficiency.

Table D-III.2-5. Percentile where burn volume, divided by 3 mm, is less than the maximum burn area of 500 m^2, for each large volume scenario.

Scenario	Percentile
Large Volume, 0% Dispersant Efficiency	0%
Large Volume, 45% Dispersant Efficiency	0%
Large Volume, 80% Dispersant Efficiency	1%

Table D-III.2-6 shows, for each large volume scenario, the number of burns that would be necessary to burn the entire amount of oil that was designated for burning. The number of burns was calculated by dividing the burn volume (Table D-III.1.7) by the assumed oil thickness of 10 cm and then dividing this number into the maximum area allowed per burn (500 m^2).

The large volume cases with a thickness greater than 100 mm (Table D-III.2-6) will require multiple burns (1 – 10) to remove all the oil. The effectiveness of dispersant application in reducing the amount of oil needing to be burned can be seen in Table D-III.2-6. The table shows that the more efficient the dispersant is, the fewer the number of burns required to remove the oil.

Table D-III.2-6. Assumed burn thickness for large volume spill scenarios and number of burns needed to burn the oil, assuming the maximum burn area is 500 m^2.

Scenario		Total Volume Burned (m^3)	Burn Area (m^2)	Oil thickness (mm)	Number of Burns
Large Volume, 0% Dispersant Efficiency	50th Percentile	367.6	500	100	8
	95th Percentile	464.8	500	100	10
Large Volume, 45% Dispersant Efficiency	50th Percentile	46.2	500	93	1
	95th Percentile	105.1	500	100	3
Large Volume, 80% Dispersant Efficiency	50th Percentile	18.1	500	37	1
	95th Percentile	32.3	500	65	1

Table D-III.2-3 shows distance-to-threshold calculations, in meters, for an individual 500-m^2 burn. Descriptions of Table D-III.2-3 and its results can be found in the previous section.

The distances to the threshold would apply to each burn. Thus, the effect is proportional to the number of burns. Table D-III.2-6 indicates that on average (50th percentile) the air quality effect is reduced by 7/8 if dispersant is applied with either 45% or 80% efficiency.

The ISB effects are summarized in Table D-III.2-7. The affected area is calculated by assuming the circular area around each burn is affected to the maximum distance to any air quality threshold (i.e., this distance is the circle radius) and multiplying the circular area per burn by the number of burns. The percent of the region of interest is calculated using the province area in Table A.4-4.

Table D-III.2-7. Estimation of area affected by ISB, for large volume spills by dispersant scenario and for 50th and 95th percentile burn volumes.

Dispersant % Efficiency		0	45	80
Burn Area (m^2)	50th	500	500	500
	95th	500	500	500
Maximum Distance (m) to Threshold (1 burn)	50th	710	710	710
	95th	710	710	710
# of Burns	50th	8	1	1
	95th	10	3	2
Area (km^2) Exposed (assuming circle with radius = maximum distance)	50th	12.67	1.58	1.58
	95th	15.84	4.75	3.17
Percent of Province Area	50th	0.03	0.00	0.00
	95th	0.04	0.01	0.01

Oil Spills and Effects Modeling for Alternative Response Scenarios

Part E: San Francisco Bay and Central California Shelf

by

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ASA 00-246

August 2004

Preface

This technical report is a supplement to the Programmatic Environmental Impact Statement (PEIS: US Coast Guard, 2004) in support of the US Coast Guard's (USCG) Notice of Proposed Rulemaking (NPRM, USCG, 2002) regarding Vessel and Facility Response Plan oil removal capacity (Caps) requirements for tank vessels and marine transportation-related facilities. The PEIS (USCG, 2004), in accordance with the National Environmental Policy Act of 1969 (NEPA), examines a series of alternatives, including a no action alternative, which could influence the availability of oil spill response equipment around the United States.

This technical report is in six (6) parts:

1. Part A contains a description of models and underlying assumptions used in the analysis.
2. Parts B to F contain:
    a. Model results for 5 locations where model runs were performed
    b. Analysis of potential benefits and risks to resources of concern for each of these locations and various spill response alternatives.

Citation for entire report:

> French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Lord, C. Dalton, R. Levine, J. Rowe, S. Sankaranarayanan, H-S. Kim, R. Piovesan and M. Hitchings, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, March 2004, 6 volumes.

Citations for parts of the report:

Part A: Description of Models and Assumptions:

> French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Dalton, R. Levine, J. Rowe, S. Sankaranarayanan and H-S. Kim, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios, Part A: Description of Models and Assumptions. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, March 2004.

Parts B to F:

French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Lord, C. Dalton, J. Rowe, S. Sankaranarayanan, H-S. Kim, R. Piovesan and M. Hitchings, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios, Part E: San Francisco Bay and Central California Shelf. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, 2004.

Part A: Description of Models and Assumptions.
Part B: Delaware Bay and Mid-Atlantic Shelf.
Part C: Galveston Bay and North Texas Shelf
Part D: Florida Straits
Part E: San Francisco Bay and Central California Shelf
Part F: Prince William Sound

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E. San Francisco Bay and Central California Shelf

E.1 INTRODUCTION

This report deals with the modeling results for a location 7.5 miles offshore in the approach channel for San Francisco Bay, the site selected by the U.S. Coast Guard (USCG) for analysis in the Pacific region. It is one of five locations used to develop modeling data to analyze the regional and national implications of potential changes in oil spill response requirements. The results and a summary of the assumptions are discussed in a separate volume for each of these locations, while details on the methodology are presented in Part A of this Technical Report. The results of the site specific modeling analyses were used to develop the discussions about the impacts of the various alternatives under consideration in the Programmatic Environmental Impact Statement (PEIS).

All of the sites were selected because they are either located in the approaches to "higher volume ports" as defined in the Code of Federal Regulations (33 CFR 154.1020) or because they are in an area of high vessel traffic. In either case, they are considered to be areas where congestion could increase the risk of oil spills.

E.1.1 Selection of the Location

The location used in this scenario is 7.5 miles offshore, in the approach channel for San Francisco Bay (Figure E.I.1.1-1). The San Francisco Bay is a designated higher volume port area by the USCG. A series of refineries operate in the San Francisco area, with a capacity of approximately 7 million barrels per day (bpd). In 2000, over 194 million barrels (bbl) of oil (both crude and refined products) moved through San Francisco Bay. This is equivalent to over 500,000 bpd. Of the total amount, approximately 63% was crude oil. The crude oil imports were split relatively equally between foreign imports and transport of domestic oil (primarily Alaska North Slope crude oil). There is a significant movement of refined product out of the Bay as well (U.S. Army Corps of Engineers, 2000).

There are numerous navigational hazards both inside San Francisco Bay and along the coast. The San Francisco Vessel Traffic Service (VTS) coordinates more than 93,000 vessel movements per year. This includes approximately 2,800 oil tank ships, 5,000 other commercial ships (Pond et al. 2000; based on statistics from San Francisco Vessel Traffic Service). Based on local spill statistics, there are approximately 400 spills per year in the Bay area, but approximately 99% of these are less than 100 gallons. While most spills are small, there have been several major incidents in or near the Bay. These include the collision of the tankers Oregon Standard and Arizona Standard near the Golden Gate Bridge in 1971, and the sinking of the motor vessel Puerto Rican near the Farallon Islands in 1984 (Pond et al. 2000).

Because so much oil enters San Francisco Bay, the modeled spill site is among the most likely locations for spills in the Pacific region. Given this and that the release site is near the midpoint of the nearshore zone as defined in 33 CFR 155.1020 where dispersant use and in-situ burning (ISB) might be used along with on-water mechanical recovery, it is a representative location with which to perform the analysis of potential impacts for various response alternatives. The specific coordinates of the location are given in Table E.I.4-1.

E.1.2 Description of the Local Study Area

The study area for this analysis consists of two biogeographical provinces, as defined in Table A.4-2 of Part A of this Technical Report. The two provinces are: the Central California Coast (Province 44) and the San Francisco Bay (Province 46). Collectively, these areas are referred to in this report as the Central California Shelf. On occasion, San Francisco Bay (Province 46) provides a reference area for potential effects of spills into coastal areas. The boundaries of the provinces were delineated in French et al. (1996a) and are based on the ecoregion (province) concept outlined in Cowardin et al. (1979) used by the Department of the Interior. The divisions into provinces are based on the distributions of, and natural boundaries between, marine populations. Biota within a province are exposed to similar environmental factors and the populations typically cover the entire province (as appropriate habitat is available). Thus, effects can be evaluated as percentages of the province(s) occupied by the populations of concern. A map of the two provinces used to analyze the Central California Shelf scenario is presented as Figure A.4-4 in Part A of this Technical Report. The total areas of the provinces are presented in Table A.4-3. The areas of various habitats and shoreline types in the Central California Shelf reference area are given in Tables A.4-4 and A.4-5, and shoreline lengths for various shoreline types are given in Table A.4-6.

E.1.3 Modeling Input Assumptions

Part A of this Technical Report provides details on the modeling approach used in the analysis of all of the five locations. In summary, for each of the locations the Spill Impact Model Application Package (SIMAP) oil spill model was run in a probabilistic mode (100 simulations) to evaluate both physical fate and biological effects. Running the model in probabilistic mode allows the estimation of the variance due to random circumstances, such as weather, time of day, and hydrographic conditions. The basic model scenario is described in Section A.1.4, while the specific model algorithms are presented in Section A.2, and details on model input parameters are presented in Section A.3. Air quality effects, which are not directly evaluated by SIMAP were estimated using the Air Model Application Package (AIRMAP) and then estimated concentrations at the water surface were compared to air quality standards (see Section A.5).

The results of the model runs consist of a series of tables and figures which summarize areas or linear distances, by habitat type and/or location, which exceed thresholds of concern (see Section A.4). These results were compared to information on the distribution and abundance of various resources in appropriate geographic areas to estimate the percentage of habitats or biological resources that are potentially affected, and the results were then scored using a relative risk matrix which included proportion of the resource affected and time of recovery (see Section A.1.5). Socioeconomic effects could not be evaluated with the same risk matrix, since the concept of recovery time was not appropriate. The method used for those elements is described in Section A.6 and is based strictly on the magnitude of the effect on the resource of concern relative to the total resource that is available.

The input parameters which were specific to the Central California Shelf study location are presented in Appendix E.I (this volume). Appendix E.I.1 presents a series of maps which define the basic geographic data input into the model; Appendix E.I.2 discusses the development of current (hydrodynamic) data used in the model runs; Appendix E.I.3 presents the properties for Alaskan North Slope crude oil (the oil used in the analysis); and Appendix E.I.4 summarizes all of the input parameters and the sources of the information that were used to run the model.

E.2 MODELING RESULTS

Two spill volumes and three response scenarios were simulated using modeling and the results are provided in Appendices E-II and E-III. Section A.1.4 of Part A contains a description of the rationale for running these scenarios to provide the needed information for evaluating the alternatives being considered in the PEIS. The two spill volumes were for medium (2,500 bbl) and large spills (40,000 bbl). Oil properties used were for Alaskan North Slope crude oil, as representative of oils shipped in the Pacific region. The three response scenarios modeled for each of two spill volumes were:

- mechanical removal at present levels of capability, or with some of that removal accomplished by ISB;
- the same mechanical removal response as above, or with some of that removal accomplished by ISB, plus dispersant application at 45% efficiency (based on minimum dispersant effectiveness criteria established in the National Oil and Hazardous Substances Contingency Plan, NCP – 40 CFR Part 300); and
- the same mechanical removal response as above, or with some of that removal accomplished by ISB, plus dispersant application at 80% efficiency (based on theoretically successful dispersant operation).

Appendices E-II.1 to E-II.6 contain results of the SIMAP oil spill model simulations that estimate oil hydrocarbon exposure on/in the water surface, shorelines, water column, and sediments. Each of these appendices contains results for all six volume-response scenario combinations. Appendix E-II.1 contains maps of exposure probability, time of first exposure for each medium (water surface, shorelines, water column, and sediments) and location surrounding the spill site, and maximum possible mass or concentration at each location at any time after a spill. These maps are gridded, presenting the average amount of contamination over the entire grid cell (which for water cells is 0.039 km^2 in area) at any time after a spill. The grid average is calculated from the mass passing through the cell, divided by the area or volume of the cell. Note that if the mass is concentrated in patches much smaller than the area of the grid cell, as is often the case, the gridded data will average out the patches and not resolve small concentrations of oil. Thus, the gridded data are used as indices of exposure, rather than areas exposed at specific levels. (See Section A.4.2 in Part A and Sections E.II.5 and E.II.6 for the methods used to more accurately evaluate exposure of biota to surface floating oil and dissolved aromatic hydrocarbons.)

Tables summarizing areas and volumes potentially affected using gridded exposure indices specific to water surface, shorelines, water column, and sediments are in Appendix E-II.2. Average, standard deviation, and the maximum of the 100 simulations performed for each scenario are presented. The 95th percentile conditions used in the risk analysis were calculated as the mean plus two times the standard deviation. Appendix E-II.3 contains rank order distributions of results for all 100 model runs, from which 50th and 95th percentile of exposure areas and volumes were derived. Mass balance information, such as percent of the oil mechanically removed, dispersed in the water column, and eventually going ashore or to the sediments, is also included in Appendices E-II.2 and E-II.3. Appendix E-II.4 contains the results for the 50th percentile cases for surface oiling, shoreline oiling, water column effects, and sediment contamination, presented as plots of various measures of exposure.

In Appendix E-II.5, estimates of mean (for all 100 runs of varying environmental conditions) equivalent area of 100% mortality are listed for each of several wildlife behavior categories. The equivalent area for 100% mortality is the integrated sum of surface water area swept by oil multiplied by probability of mortality, which varies by foraging behavior and whether the animal has feathers or fur. Appendix E-II.6 contains estimated mean mortality of water column, demersal (on the bottom) and benthic (in the bottom) organisms, summarized as an equivalent area of 100% mortality by behavior group and habitat type. The equivalent area for 100% mortality is the integrated sum of equivalent area affected times percent mortality. For water column and demersal species, the equivalent area affected is calculated as water volume affected times the fraction of the water depth zone the behavior group occupies that the affected volume encompasses. For pelagic species, the depth zone occupied is the entire water column. For demersal species (on the bottom sediments, exposed to bottom water), the depth zone occupied is the bottom 1 meter (3.3 feet) of the water column. The methods and assumptions for these calculations are described in Part A and Sections E-II-5 and E-II-6.

Appendices E-III.1 and E-III.2 contains the model results of atmospheric exposure to volatilized oil hydrocarbons and soot from ISB, relevant to air quality evaluations. Appendix E-III.1 contains model results used to evaluate volatile hydrocarbon emissions from unburned oil and resulting air quality effects. The amount of volatilized mass entering the atmosphere, and the time frame for those emissions, was estimated for each chemical (or chemical class) of concern using oil spill modeling (SIMAP). The atmospheric concentrations of volatilized hydrocarbons were modeled using AIRMAP (as described in Part A, Section A.5.1). The estimated concentrations at the water surface were compared to air quality standards to evaluate the areas exceeding the standards. Section A.5.2 of Part A describes the methods used to evaluate emissions from ISB and their potential effects on air quality. The results for ISB are in Appendix E-III.2.

The model results in Appendices E-II and E-III are summarized in Sections E.3 and E.4, and were used in the analysis of potential impacts for the various alternatives being considered in the PEIS. All summary risk rankings are based on the average results. In some sections, the results of the 95th percentile calculation are also presented to illustrate the variability for that particular resource. Section E.3 contains the discussion of potential effects for medium volume spills (2,500 bbl), and Section E.4 contains that for large volume spills (40,000 bbl). Sections E.3 and E.4 are organized by each of the physical, biological and socioeconomic resource categories evaluated in the PEIS. Section E.5 contains a summary of all the risk scores and conclusions. References are in Section E.6.

E.3 ENVIRONMENTAL CONSEQUENCES BASED ON THE MEDIUM VOLUME SPILL MODELING SCENARIOS

E.3.1 Effects on the Physical Environment

E.3.1.1 Air Quality

In the event of a spill, there are two possible sources of contamination to the atmosphere: volatilization of hydrocarbons from unburned oil and emissions produced by ISB. The hydrocarbon and ISB emissions are of concern for both human health and wildlife that may be exposed. Concentrations in the lowest 2 m (6.6 ft) of the atmosphere were estimated for both unburned and burned oil using modeling and observational data from test burns, as described in Part A, Section A.5. Distances from the spill or burn site to thresholds of concern and areas affected above these thresholds were calculated for each of a number of chemicals. The thresholds of concern are air quality standards for human health (IDLH (Immediate Danger to Life and Health) for ½ hour exposure and minimum TWA (Time Weighted Average) for an 8-hour exposure, Table D.1-1 in Appencix D of the PEIS and Table A.5-5 in Part A).

Emissions from unburned oil were estimated using SIMAP, assuming the warmest (monthly mean) water temperature in the reference area and for varying wind speeds from 3 to 25 kts. As a worst case, these model runs were performed assuming no response, which would otherwise reduce emissions to some degree. Atmospheric concentrations of volatilized hydrocarbons were estimated using AIRMAP, which accounts for transport and dilution of hydrocarbons in the local atmosphere around the spill site. The worst case of a stable atmosphere was assumed for these calculations. Area and the down-wind distance affected above the thresholds were calculated from the model results, as described in Section A.5.1 of Part A.

For emissions from ISB, the maximum potential amount of oil burned was assumed to be 25% by volume of the amount of oil mechanically removed (see Section A.3.7, Part A). The 50^{th} and 95^{th} percentiles of the cleanup volumes (for the 100 stochastic runs) were multiplied by 0.25 to calculate the 50^{th} and 95^{th} percentile volumes burned by ISB. The atmospheric concentrations of compounds and particulates released by an in-situ burn of a particular volume of oil were estimated using the models developed by Fingas et al. (2001), as described in Section A.5.2 of Part A. The number of burns needed was estimated from the total volume burned and a maximum burn size. The burn model provides concentration as a function of distance down wind from the fire. Distances were translated to areas of potential effect, assuming the air plume could move in any direction depending on the wind direction, such that the area of a circle of this radius could be affected for each of the burns.

The area potentially contaminated was divided by the area of the Central California Shelf (16,639 km^2 or 6,424 mi^2, Table A.4-4) to estimate the percentage affected by the scenario. Appendices E-III.1.1 and E-III.2.1 provide data for unburned and burned oil, respectively, from medium volume spills into the Central California Shelf.

Results of On-Water Mechanical Recovery Only
Under the medium volume spill scenario with no dispersant response, volatilized hydrocarbons would not exceed air quality standards for human health at $\geq$3.6 km (2.2 mi) from the spill site, with a maximum of 0.9 km^2 (0.3 mi^2) adversely affected. While this would be of concern for personnel close to the spill site within the first few hours after emissions are released, it is a very small percentage of the area of the Central California Shelf. Evaporation and dispersion in the air would be very rapid after a spill, and recovery time would be less than 1 day. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
For the medium volume spill scenario with 45% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
For the medium volume spill scenario with 80% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would also be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, the worst case for air quality would be a single large burn 500 m^2 in area at one location. Based on model results described in Appendix E-III.2.1 and areas affected as summarized in Table E-III.2.1-4, air quality would be affected up to 710 m (2,329 ft) downwind of the burn site, assuming a stable atmosphere and light wind at the time of the burning (environmental conditions that would inhibit dispersion of the plume and induce the highest adverse effects to air quality). Thus, the area potentially affected is a 1.6 km^2 (0.62 mi^2) circular area around the burn site. This represents 0.01% of the Central California Shelf. Thus, the percent of the resource affected is <1%. The recovery time for the atmosphere after ISB would be on the order of hours. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Summary of the Consequences for Air Quality in the Medium Volume Scenarios
The consequences of the three response options for medium spills (1) on-water mechanical recovery only, (2) on-water mechanical recovery plus dispersants at 45% efficiency, and (3) on-water mechanical recovery plus dispersants at 80% efficiency are all essentially the same with respect to air quality. Evaporation off the water surface and volatilization from the water column creates a plume of volatile hydrocarbon gases that disperses quickly after a spill. The

concentrations in the atmosphere at the water surface would exceed human health thresholds up to 3.6 km (2.2 mi) from the spill site. Dispersant use would reduce the evaporation rate, but dissolved hydrocarbons would still volatilize, although dispersed over a wider area. Thus, atmospheric concentrations would be slightly less under the dispersant use options. In all three options, the effect would be small, affecting much less than 1% of the reference area (i.e., the Central California Shelf in Table A.4-4), and the recovery time for the atmosphere would be on the order of hours. The alternatives involving on-water mechanical recovery plus ISB (whether or not dispersants are used) should increase atmospheric pollutants by the amount injected via burning.

Table E.3.1.1-1 indicates risk scores for air quality for all response options for a medium volume spill. Both the area affected and the recovery times are assigned the lowest risk score for all the response options. These results would apply to any spill site at least 3 miles from shore.

Table E.3.1.1-1. Air quality risk scores for medium spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB, With or Without Dispersant Application	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

E.3.1.2 Water Quality

The lowest water quality thresholds of concern are those concentrations of dissolved aromatics that could have effects on sensitive species in the water (see Section 4.3.1.1 of the PEIS). These thresholds are much lower than human health thresholds. The threshold for effects on water column organisms would be 5 ppb for at least 4 days of exposure. As an exposure dose, the threshold would be 500 ppb-hours. (See Part A, Section A.3.4 for development of these thresholds.)

The volume affected by greater than 500 ppb-hours was estimated by the model. Table E.3.1.2-1 summarizes the mean and 95th percentile values of the water volume affected by >1 ppb for at least 1 hour and the average exposure dose in that volume of water. These data are the mean and the mean plus 2 standard deviations of the model results for all 100 runs performed for each scenario (Appendix E-II.2). The average exposure doses in the volumes are near or greater than the 500 ppb-hour threshold. Thus, the volume exposed to >1 ppb for at least 1 hour is an appropriate criterion for identifying water volumes exceeding the exposure dose threshold of 500 ppb-hours.

The percentages affected of total water volumes in coastal and marine reference areas were calculated using the biogeographical province areas in Tables A.4-3 and A.4-4 for San Francisco Bay (coastal) and the Central California Shelf (marine). The total coastal volume was the area of San Francisco Bay times a mean depth of 5 m (16 ft). In this calculation it is assumed that the entire contaminated volume would be located in the coastal reference area (San Francisco Bay) after a spill, a worst case assumption for a spill in that estuary. The total marine volume was the area of the province times the depth at the spill site, 30 m (98 ft). Thus, only the surface water volume was considered in the marine estimation. Risk scores for potential effects were assigned for each of coastal and marine areas.

Table E.3.1.2-1. Estimation of adverse effects on water quality for medium volume spills by dispersant scenario, based on mean and 95th percentile water volumes exceeding 1 ppb dissolved aromatic concentration.

Dispersant % Efficiency		0	45	80
Volume (millions of m^3) Exposed to >1 ppb	mean	65.9	396.9	372.6
	95th	220.3	785.5	725.8
Average ppb-hrs in Volume	mean	131	2445	2868
	95 h	285	5579	7146
Percent of Reference Area, coastal	mean	0.8	4.6	4.3
	95th	2.5	9.1	8.4
Percent of Reference Area, marine	mean	0.01	0.08	0.07
	95th	0.04	0.16	0.15

Results of On-Water Mechanical Recovery Only
For the medium volume spill in San Francisco Bay and no dispersant response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be <1% on average. For 5% of spills, the percentage affected would exceed 2.5% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days, the time for concentrations to disperse to background levels. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions and coastal spills under average conditions. Extreme (95th percentile) events, expected to occur for <5% of spills in coastal areas, were assigned a risk matrix ranking of **4D**.

Results of the Addition of a Dispersant Response at Low Efficiency
For the medium volume spill scenario and 45% dispersant efficiency response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 4.6% on average. For 5% of spills, the percentage affected would exceed 9.1% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions. Coastal spills under average and extreme (95th percentile) conditions, were assigned risk matrix rankings of **4D** and **4C**, respectively. Note that dispersants would not be applied in coastal waters under the alternatives considered in the PEIS that include dispersant use.

Results of the Addition of a Dispersant Response at High Efficiency
For the medium volume spill scenario and 80% dispersant efficiency response, the volumes affected are nearly the same as for 45% dispersant efficiency (because more than sufficient dispersant would be available to disperse the floating oil, see Section A.3.7 of Part A). Thus, the

risk matrix rankings assigned to water quality for this scenario were the same as for the 45% dispersant efficiency case.

Results of the Addition of an On-Water ISB Response

Under the medium volume spill scenario and the ISB response option, the water quality effects would be slightly less, by the amount removed by burning. Thus, the percent of the resource affected is slightly less for on-water mechanical and both dispersant response scenarios when ISB is included. The recovery time for water quality would be on the order of days. Thus, the risk matrix rankings assigned to water quality for scenarios involving burning were the same as those assigned for scenarios without burning.

Summary of the Consequences for Water Quality in the Medium Volume Scenarios

Table E.3.1.2-2 summarizes risk scores for water quality for all response options for a medium volume spill under in coastal waters under average and extreme (95^{th}) environmental conditions. Table E.3.1.2-3 summarizes risk scores for medium volume spills in marine waters. The coastal results would apply to similar volume coastal areas and the marine results would apply to any spill site at least 3 miles from shore.

Table E.3.1.2-2. Water quality risk scores for medium spills in coastal areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: E 95^{th}: D	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: D 95^{th}: C	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: D 95^{th}: C	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

Table E.3.1.2-3. Water quality risk scores for medium spills in marine areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

E.3.2 Effects on the Biological Environment

E.3.2.1 Intertidal Habitats

The intertidal habitats in the Central California Shelf and San Francisco Bay include beaches and rocky shores along the outer coast and extensive tidal flats and wetlands in the bays (NOAA, 1998). These shorelines are highly utilized by birds for feeding and nesting, and they have very high recreational use. The threshold concentration of concern for intertidal habitats is 10 g/m^2 (~10 microns) oil thickness (see Section A.4 in Part A). Table E.3.2-1-1 shows the outputs of the different scenarios in terms of the area and/or length of shoreline habitat affected, for the major shoreline habitat types for the medium spill volume (shoreline classifications are defined in NOAA, 2000b). Shoreline oiling is reported in kilometers for linear features such as beaches and rocky shores and in square meters for wide habitats such as tidal flats and wetlands. Table E.3.2-1-1. Area and length of shoreline habitats oiled above a threshold of ~10 micron oil thickness for the medium volume scenarios. The numbers are summarized from Appendix E Tables E-II.2-1 through E-II.2-3.

Table E.3.2.1-1. Area and length of shoreline habitats oiled above a threshold of ~10 micron oil thickness for the medium volume scenarios. The numbers are summarized from Appendix E Tables E.II.2-1 through E.II.2-3.

Response Options	Total Oiled Shoreline Area (m^2)	Rocky Shore Length (km)	Sand/Gravel Beach Length (km)	Tidal Flats Area (m^2)	Wetlands Area (m^2)
On-Water Mechanical Recovery (with or without ISB)	138,000	8.2	8.5	46,500	7,150
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	50,800	3.5	3.6	16,700	1,430
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	51,900	3.9	3.8	16,400	950

Results of On-Water Mechanical Recovery Only

Under the medium volume spill scenario and no dispersant response option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs would be 138,000 m^2 (1.5

million ft^2) or about 17.6 km (11 mi) of shoreline (Table E.3.2-1-1). Most of the affected habitats would be located along the outer shore, from Point Reyes to El Jarro Point (just north of Santa Cruz) and just inside the Golden Gate (Figure E-II.1.1.2-3). The oiled shoreline would represent less than 1 percent of the shoreline in the reference area, but 1.1 percent of the length of rocky shores (Table A.4-6). The more sensitive oiled wetlands and tidal flats would take 3-7 years to recover (NRC, 2003), but a very small percentage of these habitats in the reference area would be affected (7,150 m^2 (76,934 ft^2) oiled whereas there are 568 km^2 (219.3 mi^2) present, as shown in Table A.4-4). Beaches and rocky shores would account for 95 percent of the affected shoreline length. Exposed rocky shores and beaches should recover within 1-3 years (Sell et al., 1995). Thus, a risk matrix ranking of **3D** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs would be reduced by over 60 percent, compared to mechanical alone (Table E.3.2-1-1). No oil would reach the Point Reyes area and less oil would enter Bolinas Lagoon, whereas heavy oiling would still occur on either side of the Golden Gate (Figure E-II.1.2.2-3). Rocky shores and beaches would recover within 1-3 years (Sell et al., 1995). Thus, a risk matrix ranking of **3E** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron oil threshold for all model runs would be very similar to the low dispersant efficiency (Table E.3.2-1-1). Thus, a risk matrix ranking of **3E** was assigned to intertidal habitats for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on intertidal habitats would be similar to the on-water mechanical recovery only response option, since the pattern of oil stranding would remain unchanged. When considering the areas of the different shoreline habitats affected under these spill conditions, a risk matrix ranking of **3D** was assigned to intertidal habitats for this scenario.

Summary of the Consequences for Intertidal Habitats in the Medium Volume Scenarios
Under the medium volume scenario, effects on intertidal habitats would occur primarily to exposed shorelines where recovery is expected to take 1-3 years, with use of on-water mechanical recovery only with or without use of ISB. The use of dispersants would likely lessen the area of shoreline effect by about 60 percent. The level of dispersant efficiency does not affect the level of concern about intertidal habitats in this spill scenario because sufficient dispersant is assumed applied to disperse available floating oil assuming 45% efficiency.

E.3.2.2 Marine and Coastal Birds

The Pacific region, and particularly the Central California Shelf, provides important habitat for migrant and resident marine and coastal birds, including species utilizing open water habitats, (e.g. seabirds, gulls, terns, diving birds); migratory shorebirds that utilize tidal flats, salt ponds, and marshes; wetland nesting and resident species (e.g. herons, egrets, rails), and wintering waterfowl. Several threatened and endangered bird species occur in the Central California Shelf (Section 3.5.2.2 of the PEIS).

Of particular importance along the Central California Shelf is the abundance of nesting and feeding seabirds near and offshore. During 1980-1983, extrapolated total monthly populations at sea were 1.4 to 6.4 million birds for northern and central California, with the highest concentrations seen over the continental shelf (Dohl et al., 1983). Over 100 species of seabirds occur in the area, and important nesting colonies occur at Point Reyes and the Farallon National Wildlife Refuge. Total numbers of nesting birds in the area ranged from 0.70-0.85 million birds in the late 70's and early 80's (Dohl et al., 1983). The Farallones support the world's largest colonies of ashy storm-petrels (*Oceanodroma homochroa*), Brandt's cormorants (*Phalacrocorax penicillatus*), and western gulls (*Larus occidentalis*). The key feeding areas in the Central California Shelf are from Monterey to Bodega Head, and south of Pt. Buchon. An important feeding area for breeders is from Point Ano Nuevo to Cordell Bank (Dohl et al., 1983).

Also occurring in the area is the San Francisco Bay hemispheric WHSRN site (Western Hemispheric Shorebird Reserve Network), and the Bolinas Lagoon Ramsar site (indicating wetlands of international importance). The San Francisco Bay WHSRN site supports at least 34 species of shorebirds regularly, and counts of nearly 1 million or more birds have been recorded (San Francisco Estuary Project, 1992). The Bolinas Lagoon (located approximately 20 km or 12 mi north of the Golden Gate Bridge) is a tidal embayment of open water, mudflat, and marsh, and provides migratory and wintering habitat for waterfowl and shorebirds. A second WHSRN site is the Elkhorn Slough, a regional reserve that drains into Monterey Bay.

In the Central California Coast Shelf, waterfowl and diving birds are concentrated primarily in San Francisco Bay, other sheltered bays, and in nearshore waters approximately 1-2 km from shore (NOAA, 1994a, 1994b, and 1998). Seabirds utilize the nearshore area, particularly directly offshore of San Francisco Bay, in Monterey Bay, and along the shoreline south of Monterey Bay. Higher densities of seabirds (>20 birds/km2) typically occur within 15-20 km of shore than beyond this range (Dohl et. al, 1983). The offshore boundary of the Central California Shelf lies between approximately 15 and 40 km offshore, therefore considering the surface area of bays and inshore waters, we assume that water associated species are only utilizing approximately 50 percent of the reference area area. Therefore, we used a multiplier of 2 when calculating risk to open-water associated species.

When calculating the risk scores to include shoreline associated species, we took into account the fact that shorebirds, wading birds, and waterfowl concentrate in wetlands and on sand beaches and tidal flats, but are not distributed evenly throughout these habitats spatially or seasonally (NOAA, 1994a, 1994b, and 1998). The current body of data available for these species does not allow for quantifying the "level of concentration", as was possible for open-water species. We used a multiplier of 5 to account for the importance of these key shoreline habitats, which when oiled, particularly in the case of marshes, are difficult to clean and oil exposure can persist for months to years.

Birds would likely be adversely affected if a threshold of 10 g/m^2 (~10-micron) thickness of oil is exceeded on the shoreline or on the water surface (see Section A.4 in Part A).

Results of On-Water Mechanical Recovery Only

Under the medium volume spill scenario and no dispersant response option, some areas of important habitat for multiple species groups would be oiled above the 10-micron threshold. Oiled areas could include: the flats along Oakland and Alameda; the eastern flats north of San Mateo Bridge; the western flats south of San Mateo Bridge; the Farallon Islands, and the entrance to Bolinas Lagoon which may affect multiple species groups (Figure E-II.1.1.2-3). The mean area of shoreline oiled above a threshold of 10 g/m^2 would be about 138,000 m^2 (1.5 million ft^2, Table E.3.2-1-1).

The mean water area swept by oil above a threshold of 10-microns under this scenario would be about 121.5 km^2 (47 mi^2, Table E-II.5-2). An area of potential surface water oiling directly outside of San Francisco Bay and around the Farallon Islands (Figure E -II.1.1.1-3) corresponds to an area of high seabird biomass year-round, typically higher than in other areas in the Central California Shelf (Dohl et al., 1983). Surface water oiling inside San Francisco Bay may also adversely affect diving birds and waterfowl.

When considering all species groups together, it is possible that 5 to 10 percent of the Central California Shelf bird population may be adversely affected under these spill conditions. Recovery could likely occur in 1 to 3 years for most species, as was the case following the Exxon Valdez spill (Kuletz, 1993; Boersma et al., 1995; Erikson, 1995; and Wiens, 1995), although reproductive recovery may be greater than three years for pelicans (Anderson et al., 1996). A risk matrix ranking of **3C** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency

Under the medium volume spill scenario and the low efficiency dispersant response option, the mean area of shoreline oiled above a threshold of 10 g/m^2 was reduced by over 60 percent (Table E.3.2-1-1). Oiled areas could include the western flats south of San Mateo Bridge and the entrance to Bolinas Lagoon, which may potentially affect important habitat for multiple species groups (Figure E-II.1.2.2-3).

Surface water oiling above the 10-micron threshold in the modeled area was reduced by approximately 37 percent to about 77 km^2 (30 mi^2) when low efficiency dispersants were used (Table E-II.5-2). Oiled areas would be similar to when no dispersants were used, potentially affecting seabird, diving bird, and waterfowl habitat (Figure E-II.1.2.1-3).

When considering all species groups together, because of the decrease in shoreline length and surface water area swept by oil compared to the on-water mechanical recovery only option, it is estimated that 1 to 5 percent of the area population may be adversely affected under these spill conditions, and recovery could likely occur in 1 to 3 years for most species. A risk matrix ranking of **3D** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and high efficiency dispersant response option, the mean area of shoreline oiled would be similar to when low efficiency dispersants were used (Table E.3.2-1-1). Oiled areas could include: the entrance to Richardson Bay; the western flats south of the San Mateo Bridge; the entrance to Bolinas Lagoon, and the Farallon Islands (Figure E-II.1.3.2-3). Important habitat for multiple species groups may be adversely affected.

Surface water oiling above the 10-micron threshold in the modeled area should be similar with high efficiency dispersant use as compared to low efficiency dispersant use (Table E-II.5-2). Seabird, diving bird, and waterfowl habitat may be adversely affected inside and outside of San Francisco Bay (E-II.1.3.1-3).

When considering all species groups together, because of the decrease in shoreline length and water surface area swept by oil compared to the on-water mechanical recovery only option, it is estimated that 1 to 5 percent of the Central California Shelf population may be adversely affected under these spill conditions, and recovery could likely occur in 1 to 3 years for most species. A risk matrix ranking of **3D** was assigned to birds for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, adverse effects on birds would be similar to the on-water mechanical recovery only response option. When considering all species groups together, it is estimated that 5 to 10 percent of the population may be adversely affected under these spill conditions, and recovery could likely occur in 1 to 3 years for most species. A risk matrix ranking of **3C** was assigned to birds for this scenario.

Summary of Consequences for Marine and Coastal Birds in the Medium Volume Scenarios
Under the medium volume scenario, the estimated adverse effects on birds are moderate when no dispersants are used, regardless of the use of ISB, due to the high probability that a moderate percentage of the Bolinas Lagoon Ramsar site; the San Francisco Bay hemispheric WHSRN site; the Farallon Island National Wildlife Refuge, and on-water seabird feeding areas would be oiled. The use of dispersants is projected to likely lessen the water surface and shoreline effects enough to decrease the area and lower the percentage of birds affected, but this change was not enough to reduce the overall moderate risk.

E.3.2.3 Marine Mammals

The marine and coastal waters of the Central California Shelf support a relatively large and diverse population of marine mammals, with 30 or more species occurring there during at least part of the year. These 30 species include 6 pinnipeds (seals and sea lions), at least 23 species of cetaceans (whales, porpoises, and dolphins), and the sea otter (Section 3.4.2.1 of the PEIS). Threatened or endangered species found within the region are: blue (*Balaenoptera musculus*), right (*Eubalaena glacialis*), sei (*Balaenoptera borealis*), humpback (*Megaptera novaeangliae*), fin (*Balaenoptera physalus*), sperm (*Physeter catodon*) whales, the Stellar sea lion (*Eumetopias jubatus*), the Guadalupe fur seal (*Arctocephalus townsendi*), and the California sea otter (*Enhydra lutris*). The non-endangered pinnipeds found within the region are: the harbor seal (*Phoca vitulina*), California sea lion (*Zalophus califonianus*), northern fur seal (*Callorhinus* *ursinus*), and northern elephant seal (*Mirounga angustirostris*). These species breed at various locations along the coast, and thousands more (mainly northern fur seals) move into the area during migration. The islands off southern California are especially important to pinnipeds. All six species found within the region have bred there historically. Among these islands are found extensive California sea lion rookeries, the largest northern elephant seal rookery in the region, the only northern fur seal rookery south of the Pribilof Islands, as well as several important harbor seal pupping areas. Other important pinnipeds areas within the region include Ano Nuevo Island and the Farallon Islands off central California; Cape Mendocino and Pt. St. George off northern California; Cape Arago off southern Oregon, and the Columbia River and Willapa Bay and Grays Harbor along the Washington coast (MMS, 1996).

Common non-endangered cetaceans found within the waters of the Pacific region include the common dolphin (*Delphinus delphis*), northern right whale dolphin (*Lissodelphis borealis*), Risso's dolphin (*Grampus griseus*), Pacific white-sided dolphin (*Lagenorhynchus obliquidens*) , killer whale (*Orcinus orca*), Dall's porpoise (*Phocoenoides dalli*), harbor porpoise (*Phocoena phocoena*), short-finned pilot whale (*Globicephala macrorhynchus*), gray whale (*Eschrichtius robustus),* and minke whale (*Balaenoptera acutorostrata*). Although the gray whale and harbor porpoise generally prefer shallow water close to shore, most cetaceans occur in greater numbers in waters overlying the continental slope (200 to 2,000 m or 656 to 6,561 ft).

Marine mammals may be at risk from either floating oil, or from oil which strands in coastal shoreline areas that are used as haul out or breeding areas. The latter concern is important in the Central California Shelf, since there are many such areas, primarily along rocky shorelines.

For this analysis, marine mammals are assumed to be at risk if a threshold of 10 g/m^2 (~10-micron) thickness of oil is exceeded on the shoreline or on the water surface (see Section A.4 in Part A), however the level of risk varies by the behavior group. Potential adverse effects on marine mammals (i.e., terrestrial wildlife, cetaceans, furbearing marine mammals and pinnipeds and manatees) were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the medium volume Central California Shelf spills are in Appendix E-II.5, Table E-II.5.2. The equivalent areas of 100% mortality for all response options are summarized in Table E.3.2.3-1 as percentages of the Central California Shelf (defined in Tables A.4-4 and A.4-5 of Part A). In addition to this calculation, which is based on the mean result, the mean length of shoreline oiled and the surface oil exposure exceeding 0.01 g/m^2 (in m^2-hrs) based on all model runs was also compared between the treatment options (Tables E-II.2-1 through E-II.2-3).

Table E.3.2.3-1. Percentage of reference area adversely affected for medium spills, by dispersant option and behavior group (assuming Central California Shelf area in Tables A.4-4 and A.4-5).

Behavior Group (Habitat Occupied)	0	45	80
Terrestrial wildlife (wetlands, sea grass beds and shoreline)	0	0	0
Cetaceans (seaward subtidal)	<0.001	<0.001	<0.001
Furbearing marine mammals (all intertidal and subtidal)	0.54	0.34	0.36
Pinnipeds and manatees (all intertidal and subtidal)	0.007	0.005	0.005

Results of On-Water Mechanical Recovery Only

In the Central California Shelf, marine mammals at risk include cetaceans, several pinniped species, sea otters, and terrestrial mammals along the shore. The resistance of cetaceans to oiling coupled with the very small percentage of affected area creates a very minimal risk to cetaceans under the on-water mechanical recovery only option for the medium volume spill scenario. The cetaceans that are oiled as a result of contact with floating oil would most likely recover in within a few days, if not hours, of the spill (**4E)**, (RPI, 1987). Similarly, terrestrial mammals are at very low risk, but if an individual were killed or reproductively impaired by contact with oil on the shoreline, the recovery period could exceed one year (**3E**). Pinnipeds also have a low estimate for the area of equivalent mortality. The area for sea otters is approximately 0.5%, the highest calculated. As an alternative measure, the length of shoreline oiling was compared to the total shoreline length (17.6 versus 1,620 km or 10.9 versus 1,006 mi), which is slightly over 1%. This is presumed to be a measure of the possibility of contacting a haul out area. The primary concerns in the region are for sea otters and pinnipeds. While the area of potential effect for both is still low with the medium spill scenario, the loss of a reproductive adult or sublethal effects to reproductive adults could affect the population for a number of years. On this basis the risk score of **2D** was assigned.

Results of the Addition of a Dispersant Response at Low Efficiency

Under the medium volume spill scenario and the 45% efficiency dispersant option the areas of equivalent mortality are slightly reduced in absolute area, and are still very small relative to the reference areas. The use of dispersants would reduce the amount of shoreline oiling somewhat, enough to be below 1 percent, but would not affect the recovery time, so the risk score becomes **2E**. There is no evidence that cetaceans, sea otters or pinnipeds are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency

Under the medium volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality are essentially the same as those for the 45% option, as is the extent of shoreline oiled, and so the risk score remains the same as for 45% efficiency.

Results of the Addition of an On-Water ISB Response

Oil removal by ISB in addition to on-water mechanical recovery should not change the effects on marine mammals (**2D**), since the amount of floating oil and shoreline oiling remains unchanged.

The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to marine mammals.

Summary of the Consequences for Marine Mammals in the Medium Volume Scenarios
The results indicate that on average for medium volume spills in the Central California Shelf adverse effects on marine mammals would be moderate with or without the use of dispersants. Dispersant use would decrease the area of concern, but would not effect recovery time, which is the factor of most concern.

E.3.2.4 Sea Turtles

Sea turtles typically inhabit tropical and subtropical seas and are uncommon in eastern North Pacific waters north of Mexico. Historically, four species of sea turtles have been recorded in the eastern North Pacific: the leatherback sea turtle (*Dermochelys coriacea*), the green sea turtle (*Chelonia mydas*), and Pacific (or olive) ridley sea turtle (*Lepidochelys olivacea*), and the loggerhead sea turtle (*Caretta caretta*) (see Section 3.5.3 of the PEIS). Sea turtle populations have been greatly reduced by over-harvesting and, to a lesser extent, coastal development of nesting beaches in developed countries. Three of these species (leatherback, green, and Pacific ridley) are listed as endangered, and the fourth (loggerhead) as threatened under the U.S. Endangered Species Act. There are no breeding beaches on the Pacific Coast north of Mexico, and sea turtles are uncommon along the U.S. coast, but are sometimes present. The primary risk to sea turtles is from exposure to shoreline oiling in areas where they breed (not an issue in this area), however, adult turtles do have a low sensitivity to floating oil and they could ingest tar balls.

Sea turtles are assumed to be at risk when a threshold of 10 g/m^2 (~10-micron) of oil is exceeded on the shoreline or the water surface (see Section A.4 in Part A). Potential adverse effects on sea turtles were estimated using the modeling (SIMAP) and summarized as the mean equivalent area of 100% mortality (i.e., under average environmental conditions). The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the medium volume Central California Shelf spills are in Appendix E-II.5, Table E-II.5.2. The equivalent areas of 100% mortality for all response options are summarized in Table E.3.2.3-1 as percentages of the Central California Shelf (defined in Tables A.4-4 and A.4-5 of Part A). The sensitivity of sea turtles is assumed to be the same as that for pinnipeds and manatees, and the area of equivalent mortality never exceeds 0.007% of the total reference area, regardless of the response option (see Table E.3.2.3-1).

Results of On-Water Mechanical Recovery Only
Under the medium volume scenario with only on-water mechanical recovery, the area of equivalent mortality is 0.007% of the total reference area. If an individual were to be oiled, the result would probably be only minor physiological effects, but it is conceivable that it could interfere with reproductive capacity, thus a risk ranking of **3E** was assigned. There are no nesting beaches in the area, so that is not a consideration.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and the 45% efficiency dispersant option the area of equivalent mortality is slightly reduced in absolute area, and is still very small relative to the reference areas. Even though the use of dispersants would reduce the amount and duration that surface oil was present, it does not change the potential recovery time, thus the score remains **3E**. There is no evidence that sea turtles are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality are essentially the same as those for the 45% option, and so the risk score remains unchanged.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in addition to on-water mechanical recovery should not change the effects on sea turtles (**3E**), since the amount of floating oil remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to sea turtles.

Summary of the Consequences for Sea Turtles in the Medium Volume Scenarios
The results indicate that on average for medium volume spills in the Central California Shelf adverse effects on sea turtles would be minor with or without the use of dispersants. Dispersant use would potentially reduce the possibility of turtles coming into contact with floating oil, but this risk would already be very low. These results are consistent with experience with spills of this size in areas where sea turtles are uncommon.

E.3.2.5 Plankton and Fish

Adverse effects on plankton and fish are of high concern, particularly when dispersants are potentially considered as a response alternative. As described in Part A (Section A.2), plankton and fish are adversely affected either directly or via the food web by the toxic effects of oil components that enter the water column: the soluble compounds (i.e., MAHs (monoaromatic hydrocarbons) and PAHs (polynuclear aromatic hydrocarbons)) and microscopic oil droplets mixed by waves into the water. Overall, adverse effects increase the larger the spill size. However, there is great variability related to the environmental conditions after the spill: plankton and fish suffer much more adverse effect under storm conditions where high waves mix unweathered oil into the water than in calm weather (French et al., 1999; French McCay et al., 2002; French McCay, 2003). Species and life stages vary considerably in sensitivity to the toxic components, with species from relatively unpolluted and environmentally stable locations more sensitive than those from polluted and environmentally variable areas (French McCay, 2002).

Potential adverse effects on water column organisms (i.e., plankton and fish, as well as pelagic invertebrates such as squid) were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. Estimated water volumes where adverse effects could occur were converted to equivalent areas of 100% loss by integrating percentage losses over all affected volumes and multiplying by water depth at the spill site, allowing comparison to other resources that are distributed on a per area basis (e.g., mammals and shorelines). In the near shore areas modeled, effects were nearly evenly distributed throughout the water column because of water column mixing and vertical movements of animals. If these results are used to infer potential for adverse effects in deeper waters, the areas of effect would only apply to surface waters up to on the order of 30-50 m (98-164 ft) deep (during strong wind conditions). The modeling methods are described in Part A and Section E-II.6, and the results of the calculations for the medium volume Central California Shelf spills are in E-II.6, Tables E-II.6-2 to E-II.6-5.

For these calculations, the toxicity parameter for sensitive species (i.e., two standard deviations more sensitive than the average of all species tested, which is the 2.5th percentile in rank order of sensitivity) was assumed. Thus, the volumes and areas potentially affected would only apply to 2.5% of species (based on a Gaussian distribution of species sensitivities, see also Part A, Section A.2.3), and adverse effect areas to 97.5% of species would be smaller than the volumes and areas of effect estimated by the model. Thus the model estimated areas should not be interpreted as experiencing 100% mortality of all plankton and fish. They are conservative estimates used for comparative purposes among response scenarios.

Table E-II.6-2 lists the average equivalent areas projected to be killed (for sensitive species) for medium volume spills. These areas are based on the mean of all 100 runs, and so represent an average of all environmental conditions that may occur after a spill (see explanation in Section E-II.6). Table E-II.6-4 lists the 95th percentile equivalent areas where sensitive species would be adversely affected. This maximum potential effect is calculated as the mean plus two standard deviations, using the statistics of all 100 model runs for the scenario, and assuming the toxicity values for sensitive species.

The mean areas adversely affected for all response options are summarized in Table E.3.2.5-1 as percentages of the Central California Shelf (defined in Table A.4-4 of Part A). The maximum areas (95th percentile) for sensitive species are summarized in Table E.3.2.5-2 (also as percentages of the Central California Shelf).

Table E.3.2.5-1. Average percentage of reference area adversely affected for medium spills, by dispersant option and behavior group (assuming Central California Shelf area in Table A.4-4).

Behavior Group	**0**	**45**	**80**
Demersal (move at bottom)	0.00	0.03	0.02
Small pelagic fish & invertebrates	0.00	0.12	0.10
Large pelagic fish	0.00	0.15	0.13
Demersal (stationary on bottom)	0.00	0.01	0.01
Planktonic (drift with currents)	0.13	0.17	0.17

Table E.3.2.5-2. Maximum (95th percentile) percentage of reference area adversely affected for medium spills, by dispersant option and behavior group (assuming Central California Shelf area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.00	0.10	0.09
Small pelagic fish & invertebrates	0.02	0.41	0.38
Large pelagic fish	0.02	0.56	0.51
Demersal (stationary on bottom)	0.00	0.05	0.05
Planktonic (drift with currents)	0.15	0.11	0.10

Results of On-Water Mechanical Recovery Only

Under the medium volume spill scenario and no dispersant response option, the area adversely affected would be negligible (<0.001% of the Central California Shelf) for spills under average environmental conditions and for all but planktonic organisms (which move with the water column plume and are exposed longer). For 5% of spills, the area affected would be similarly low. Because the adverse effects are very small, much less than the range of natural variability, the recovery time would be <1 year (given the short generation time of many species and annual reproduction of others). Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency

Under the medium volume spill scenario and 45% dispersant efficiency response option, the area adversely affected would be <0.2% of the Central California Shelf for spills under average environmental conditions. For 5% of spills, the area affected would be 0.1-0.6% of the Central California Shelf, depending on the behavioral group of the organism. Because the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the medium volume spill scenario and 80% dispersant efficiency response option, the area adversely affected would be <0.2% of the Central California Shelf for spills under average environmental conditions. For 5% of spills, the area affected would be 0.1-0.5% of the Central California Shelf, depending on the behavioral group of the organism. These results are not very different from the low-efficiency dispersant response because approximately the same amount of oil is dispersed in either case (i.e., more than sufficient dispersant is available to disperse available oil for such activity in the low efficiency case). Since the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of an On-Water ISB Response

Under the medium volume spill scenario, if ISB is effectively used in the response, the adverse effects on water column organisms would be slightly less than otherwise by the amount removed by burning. Thus, the percent of the resource affected is <1% for on-water mechanical and both dispersant response scenarios when ISB is included. Since the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Summary of the Consequences for Plankton and Fish in the Medium Volume Scenarios
The results indicate that on average for medium volume spills, adverse water column effects would be negligible without the use of dispersants. With dispersants, and on average, up to 29 km^2 (11 mi^2) of water could be toxic to the most sensitive species (Table E-II.6-2). Exposure for planktonic organisms is highest because they drift with the plume of dissolved aromatic concentrations. Exposure for larger fish is relatively high because they are more mobile, and new animals move into the dissolved aromatic plume over time (assuming they do not avoid hydrocarbon contamination). Under worst case conditions for sensitive species, the potentially affected areas for no dispersants and dispersant use are on the order of 25 and 90 km^2 (10 and 35 mi^2), respectively (Table E-II.6-4).

It should be emphasized that the areas affected are those where there is a potential to affect the most sensitive species. Areas adversely affected would be much less for species of average sensitivity. These areas should not be interpreted as experiencing 100% mortality. They are used for comparative purposes among response scenarios.

The mean areas adversely affected for all response options are <0.2% of the Central California Shelf (Table E.3.2.5-1). Thus, the risk scores for these effects are "**E**" (<1%, Table E.3.2.5-3). The maximum areas (95th percentile) for sensitive species are also <1% of the Central California Shelf (Table E.3.2.5-2). Because the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year.

These results are consistent with experience for oil spills of about 2500 bbl generally (French McCay and Payne, 2001; French McCay et al., 2002; and as discussed in Part A). Winds are typically light to moderate, except in infrequent storm events. Thus, natural dispersion into the water is typically low, while evaporation is rapid. Because of logistical constraints, in the scenarios examined the dispersion by chemical dispersants began 12 hours after the spill. By this time, most of the toxic components have volatilized (see Section E.3.1), such that dissolved aromatic concentrations resulting from dispersant use are only slightly elevated over the no-dispersant option. The adverse affected water column would be a small area around the spill site, and recovery of affected biota would be rapid (weeks to months).

Table E.3.2.5-3. Risk scores for plankton and fish for medium spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

E.3.2.6 Subtidal Benthic Habitat

In deeper water subtidal habitats are relatively protected from exposure to oil by the overlying water column. It is possible for extreme storm events to mix oil with sediments which then settle to the bottom, but this is a rare event. The use of dispersants can also transport oil into the water column, but dilution usually reduces concentrations to levels that are not of a concern when the water column is more than 30 feet deep, and in any case dispersed oil is less adhesive than untreated oil. Along most of the Pacific coast, including this location, deep water occurs very close to shore and except for the San Francisco Bay proper, dilution is very rapid. In the shallow waters of the Bay, the risk of contamination of the sediments increases, and may either occur by mixing into the water column due to wave action, or to erosion of contaminated shoreline sediments (Section 4.3.2.5 of the PEIS).

Benthic habitat was assumed to be at risk when a threshold of 0.10 g/m^2 of total hydrocarbon loading was exceeded in the sediment or 0.0001 g/m^2 of dissolved aromatic hydrocarbons was exceeded in the pore water (see Section A.4 in Part A). These concentrations are approximately equivalent to 1 ppm of total hydrocarbons or 1 ppb of dissolved aromatic hydrocarbons, when a sediment mixing depth of 10 cm is assumed. The area was estimated using SIMAP and the modeling methods are described in Part A. The area estimates of sediment loading for the medium volume Central California Shelf spills are presented in Table E-II.6.6. The area estimates for dissolved aromatic hydrocarbons in sediment pore water are in Table E-II.6.7. The only scenarios the sediment threshold was exceeded in were for scenarios with dispersant use, when the area for total hydrocarbons was exceeded in an area totaling approximately 0.04 km^2 (0.02 mi^2). The sediment dissolved aromatic threshold was never exceeded.

Benthic habitat was also assumed to be at risk if epiflora and epifauna (demersal) organisms were affected by dissolved aromatic concentrations in the bottom water just above the sediments. The percentage of benthic habitat where stationary demersal biota would be affected, assuming the toxicity parameter for sensitive species (i.e., two standard deviations more sensitive than the average of all species tested), was estimated using SIMAP and the modeling methods described in Part A and Section E.II.6.

Results of On-Water Mechanical Recovery Only
In the on-water mechanical recovery only option for the medium volume spill scenario, the model results indicate that the sediment thresholds of concern are not exceeded with only on-water mechanical recovery. As indicated in Table E.3.2.5-1, <0.01% of the reference area was affected by bottom water concentrations when no dispersants were assumed used. Thus, there is essentially no effect on the benthic habitat, and the risk ranking is **4E**.

Results of the Addition of a Dispersant Response at Low Efficiency
Use of a dispersant at 45% efficiency in the medium spill scenario results in a very small area of total hydrocarbon contamination in subtidal habitat sediments. As indicated in Table E.3.2.5-1, 0.01% of the reference area was affected by bottom water concentrations when dispersants were assumed used at low efficiency. Thus, the area is much less than 1% of the reference habitat, so the risk score remains at **4E**.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and the 80% efficiency dispersant option, sediments still do not accumulate hydrocarbons in excess that for the 45% efficiency option. As indicated in Table E.3.2.5-1, 0.01% of the reference area was affected by bottom water concentrations when dispersants were assumed used at high efficiency. Thus, the risk ranking remains at **4E**.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in the medium spill scenario should have no additional effect when combined with on-water mechanical recovery on benthic habitats since ISB takes place on the water's surface and results in the removal of an equivalent amount of oil (**4E**). The only concern associated with ISB is the chance of heavy burn residues sinking and mixing with sediments, but this risk is minimal based on both the toxicity of the material and on the amount that would be produced from the limited burning possible in the scenarios.

Summary of the Consequences for Subtidal Habitat in the Medium Volume Scenarios
Oil spills and oil-spill response activities could potentially affect benthic habitats. Floating oil does not pose a great level of concern unless sufficient wave energy exists to mix the surface oil into the water column, or sediments contaminated with oil are transported from the intertidal zone into subtidal habitats. Mechanically dispersed oil could reach bottom water and adhere to sediments, flora and fauna in benthic habitats, and could cause potentially adverse effects. However, in this simulation, essentially no hydrocarbon exposure is expected on or in the sediments, even near shore. Given the limited length of shoreline oiled, regardless of response option, the small spill volume, the distance of the spill offshore, and the deep water in the area of dispersant operations dispersant use would not change the results. Regardless of the response option, the risk to benthic habitat is low.

E.3.2.7 Biological Areas of Special Concern

The Central California Shelf has numerous areas of special concern (Section 3.5.2.6 of the PEIS). They include both intertidal and subtidal areas, and a number are susceptible to the effects of an oil spill. The risk to such areas is clearly site specific and highly dependant upon the location and trajectory of the slick. In general, the greatest risk to the majority of the areas of concern is from floating oil, but areas such as marine sanctuaries are also at risk from dispersed oil. For the purposes of this evaluation, the average risk to such areas is assumed to be defined by the higher of the risks to intertidal (Section E.3.2.1) or subtidal (Section E.3.2.6) habitats, adjusted for the type, abundance and distribution of areas of special concern, if appropriate. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
For the on-water mechanical recovery response option under the medium spill scenario, floating oil poses a moderate risk (**3D**) to intertidal habitat, while subtidal habitat was at minimal risk (**4E**). Therefore, intertidal areas of special concern are the only areas at risk. Since the area affected is already low, and there is no reason to assume areas of special concern would recover more quickly, the score of **3D** is used. The concerns for intertidal habitat were discussed in Section E.3.2.1.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency in the medium spill scenario reduced the risk to intertidal habitat by reducing the amount of surface oil which reaches shore by approximately 60% and preventing oiling in several areas. The fact that the oiling would be primarily to outer, higher energy habitats means recovery should be fairly rapid, resulting in a risk score of **3E** (see Section E.3.2.1). The risk to subtidal habitats does not increase (**4E**), because of the limited extent of the dispersed oil plume and rapid dilution, and so the intertidal score of **3E** is used.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at an efficiency of 80% in the medium spill scenario does not change the scores from the application at 45% efficiency, based on the results for intertidal and subtidal habitat.

Results of the Addition of an On-Water ISB Response
ISB should produce a black smoke plume that could pass over an area of special concern if the proper weather conditions exist. In this case, however, the burning can only occur three miles or more offshore, and the results for air quality (Section E.3.1.1) indicate that the plume should not travel that far. The use of ISB in addition to on-water mechanical recovery is not expected to increase the risk to these resources (**3D**), based on intertidal habitats.

Summary of the Consequences for Areas of Special Concern in the Medium Volume Scenarios
The effects on areas of special concern in this scenario are focused on the potential risk to shoreline habitats. The use of dispersants can reduce the risk to such areas without increasing the minimal risk to subtidal areas. In this analysis the risk to such areas is defined as equivalent to the risk to intertidal habitat in general. While this accurately reflects the ecological consequences

of the event, it does not account for the social values which may be attached to such areas. If the spill trajectory of an actual event did threaten such areas, special attention would be given to their protection.

E.3.2.8 Essential Fish Habitat

Areas of essential fish habitat are extensive in the Central California Shelf (Section 3.5.4 of the PEIS). Included are numerous estuaries, especially the San Francisco Bay, as well as coastal and offshore areas. In the entire Central California Shelf, approximately 90 species of finfish and shellfish are managed under the Magnuson-Stevens Fishery Conservation and Management Act. Due to the wide variation in habitat requirements for this many species, EFH for the Central California Shelf includes all estuarine and marine waters and substrates from the shoreline to the seaward limit of the Exclusive Economic Zone (EEZ).

For this evaluation, the effects on essential fish habitat are assumed to be reflected by the risk to plankton and fish (Section E.3.2.5) and subtidal habitat (Section E.3.2.6), since they define the risk to the majority of fish habitat. Intertidal habitats, such as marshes, are also important habitat for fisheries resources, but were considered separately. The average risk to essential fish habitat is assumed to be defined by the higher of the risk scores for plankton and fish or subtidal habitat. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
In the medium spill scenario, with the use of on-water mechanical recovery only, the risk to both plankton and fish and subtidal habitat was minimal, resulting in a risk score for both habitats of **4E**. This is a reflection of the relatively small volume of oil, the large volume of water for dilution, and the areal extent of the habitats.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency did not change the risk score for either plankton or fish or for subtidal habitat, and the scores remained **4E**. The dispersed oil plume produced was not large enough to have any effect on the exposure levels for these resources. However, dispersant use did reduce effects on intertidal habitats, which includes areas that are also important for fisheries resources and EFH.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at 80% efficiency in the medium spill scenario resulted in no change to the risk to plankton and fish or subtidal habitat, and the score remains **4E**. Again, dispersant use does benefit intertidal habitat, some of which is also important to EFH.

Results of the Addition of an On-Water ISB Response
The addition of ISB to on-water mechanical recovery in the medium spill scenario did not change the evaluation for either plankton or fish or for subtidal habitat, and the score remains **4E**.

Summary of the Consequences for Essential Fish Habitats in the Medium Volume Scenarios

Overall, the risk to essential fish habitat is low for the medium spill scenario, regardless of the response option employed. This is a reflection of the relatively small area of the spill, the volume and depth of water available for dilution, and the large area of habitat present in the area.

E.3.3 Effects on the Socio-Economic Environment

E.3.3.1 Human Health

Operation of the type of equipment associated with oil spill response can be dangerous. This is well recognized and is the basis for the worker certification and training requirements that are now in place. There are also protocols in place for the proper application and handling of dispersants. The safety risk is greater as the spill size, and thus the intensity and duration of operations increases, but is minimized if safety standards are followed. There is a health risk from inhalation of hydrocarbon fumes for first responders, which is recognized in current safety protocols. Exposure to hydrocarbon fumes is the only health risk that can be directly estimated in the SIMAP model, and the results are presented in Section E.3.1.1.

E.3.3.2 Subsistence

Information on subsistence use of fish and shellfish in the Central California Shelf is limited. Along the Pacific Coast of the mainland U.S., Native American subsistence gathering is more common in Washington and Oregon than in California, but some Native American groups do exist in California, and members of various ethnic groups may supplement their diets with shellfish harvested from the intertidal zone and some salmon and other finfish species (Section 3.5.5.6 of the PEIS).

Results of On-Water Mechanical Recovery Only
Under the medium volume spill scenario and no dispersant response option, water column exposure of dissolved aromatics between 1-10 ppb would be localized to directly outside and in the mouth of San Francisco Bay, with some higher concentrations farther offshore (Figure E-II.1.1.4-3). Tainting of fish and invertebrates becomes a concern when water concentrations exceed approximately 100 ppb in a brief (order of hours) exposure (See Section 4.3.5.6 of the PEIS). Sediment exposure is expected to occur only in small areas (Figure E-II.1.1.5-2). A small percentage (<1%) of shoreline habitats in the reference area would be oiled, therefore a proportionally small percentage of subsistence resources associated with these habitats are likely to be exposed (Section E.3.2.1 Intertidal Habitats). Therefore, at most a very small percentage of subsistence resources are likely to be affected, and recovery should be within 1 year. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and low efficiency dispersant response option, water column exposure of dissolved aromatics between 1-100 ppb for one hour or more is expected to cover a larger area outside and within San Francisco Bay than when no dispersants were used, and dissolved aromatic concentrations between 100-10,000 ppb are expected to occur in localized areas directly outside the bay (Figure E-II.1.2.4-3). Sediment exposure would only occur in small areas (Figure E-II.1.2.5-2), and oiling of shoreline and intertidal organisms would

be reduced (Section E.3.2.1. Intertidal Habitats). Although a larger water column area may be affected under these spill conditions, it is still likely that only a small percentage of subsistence resources would be adversely affected, and recovery should be a within 1 year. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and high efficiency dispersant response option, water column exposure of dissolved aromatics between 1-100 pbb is expected to cover a larger area outside and within San Francisco Bay than when low efficiency dispersants were used, and dissolved aromatic concentrations between 100-10,000 ppb are expected to occur in localized areas outside and in the bay (Figure E-II.1.3.4-3). Sediment exposure would only occur in small areas (Figure E-II.1.3.5-2), and oiling of shoreline and intertidal organisms would be reduced (Section E.4.2.1. Intertidal Habitats). A larger water column area may be affected under these spill conditions than when low efficiency dispersants were used, but it is still likely that only 1-5 percent of subsistence resources would be affected, and recovery should be within 1 year. A risk matrix ranking of **4D** was assigned to subsistence resources for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, adverse effects on subsistence resources would be similar to the on-water mechanical recovery only response option. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Summary of the Consequences for Subsistence in the Medium Volume Scenarios
Because water column effects should be fairly localized and shoreline effects are expected to occur only in a small percentage of the reference area, a risk matrix ranking of **4E** was assigned to subsistence resources for the no dispersant and ISB response options, as well as for the low efficiency dispersant option. When high efficiency dispersants are used the affected area is expected to be slightly larger, and therefore a risk matrix ranking of **4D** was assigned.

E.3.3.3 Cultural Resources

In the Pacific region, some archaeological artifacts occur on land along the coast, while others are likely submerged offshore (Section 3.5.5.7 of the PEIS). Historic structures on land are numerous, and a large number of submerged shipwrecks occur in nearshore waters. Results from several studies indicated that direct oiling caused negligible effects to cultural resources following the *Exxon Valdez* oil spill (Reger et al., 1992; Dekin, 1993; Wooley and Haggarty, 1995; Bittner, 1996). Open water response options, including on-water mechanical recovery, the use of dispersants and ISB may help reduce the amount of oil that strands on the shoreline, which should also reduce the amount of shoreline clean up and potential disturbance to sensitive archaeological sites and historic structures. Offshore archaeological and historic resources would not become oiled regardless of the response option used. For these reasons, a risk matrix ranking of **4E** was assigned to cultural resources for all response options under this scenario.

E.3.3.4 Coastal Communities

Oil spills affect the pleasure that coastal residents and visitors derive from coastal activities and the economic contribution that natural resources make to local income and employment. Spills are likely to cause effects on water- and shore-based recreation, fisheries (recreational and commercial), marine transportation and tourism. The effects on these activities are described in more detail in subsequent sections.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to coastal communities in the Central California Shelf under various spill response options. The model results are presented in Appendix E-II.2, Tables E-II.2-1 to E-II.2-3, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to coastal communities of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only

Given the use of on-water mechanical recovery only, the average medium size spill in the Pacific region would be expected to adversely affect approximately 6 km (3.7 mi) of sandy shoreline and sweep approximately 421 km^2 (162.5 mi^2) of surface water above recognized effect thresholds (Table E-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency

Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 60 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by approximately 35 percent as compared to on-water mechanical recovery alone (Table E-II.2-2). This results in risk factor ratings of 0.40 and 0.64 (effected length or area with dispersants divided by that for mechanical only) for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 1 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by approximately 3 percent as compared to the low dispersant efficiency response option (Table E-II.2-3). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.39 and 0.63, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on coastal communities would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to coastal communities for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Coastal Communities in the Medium Volume Spill Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 2.4 km (1.5 mi) of sandy shoreline and 265 to 275 km^2 (102.3 to 106.2 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 60 and 36 percent, respectively, the level of dispersant efficiency does not greatly affect the level of concern about coastal communities in this spill scenario.

E.3.3.5 Economic Status

The overall economic status of communities, industries and individuals that rely on coastal resources for sustenance, revenue and quality of life can be affected by an oil spill. As noted above, coastal communities can suffer direct and indirect economic effects due to an oil spill, as beach and fishery closures decrease revenues, eliminate jobs, and adversely affect subsistence users of the resources.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to economic status in the Central California Shelf under various spill response options. The model results are presented in Appendix E-II.2, Tables E-II.2-1 to E-II.2-3, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to economic status of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the Central California Shelf could be expected to adversely effect approximately 6.0 km (3.7 mi) of sandy shoreline and sweep approximately 421 km^2 (162.5 mi^2) of surface water above recognized effect thresholds (Table E-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 60 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by approximately 35 percent as compared to on-water mechanical recovery alone (Table

E-II.2-2). This results in risk factor ratings of 0.40 and 0.64 for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 1 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by approximately 3 percent as compared to the low dispersant efficiency response option (Table E-II.2-3). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.39 and 0.63, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on economic status would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to economic status for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Economic Status in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 2.4 km (1.5 mi) of sandy shoreline and 265 to 275 km^2 (102.3 to 106.2 mi^2) of surface water . While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 60 and 36 percent, respectively, the level of dispersant efficiency does not greatly affect the level of concern about economic status in this spill scenario.

E.3.3.6 Vessel Transportation and Ports

Marine transportation is of paramount importance for many industries along the Pacific Coast. Any interruption in the standard use of vessels or increase in travel times over water can result in hardship for coastal communities and businesses as fewer goods are exchanged, transportation costs rise, and the revenue streaming through the local economy falls.

As described in Part A., the amount of total surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to marine transportation and ports in the Central California Shelf under various response options. The model results are presented in Appendix E-II.2, Tables E-II.2-1 to E-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to the marine transportation industry of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the Central California Shelf would be expected to adversely affect approximately 421 km^2 (162.5

mi^2) of surface water used by the marine transportation industry above recognized effect thresholds (Table E-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 35 percent as compared to on-water mechanical recovery alone (Table E-II.2-2). This results in a risk factor rating of 0.64 for the marine transportation industry under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 3 percent as compared to the low dispersant efficiency response option (Table E-II.2-3). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for the marine transportation industry decreases to 0.63 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on the marine transportation industry would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to the marine transportation industry for this scenario.

Summary of the Consequences for Vessel Transportation and Ports in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 265 to 275 km^2 (102.3 to 106.2 mi^2) of surface water. While the use of dispersants is projected to likely lessen the area of surface water affected by approximately 36 percent, the level of dispersant efficiency does not greatly affect the level of concern about vessel transportation and ports in this spill scenario.

E.3.3.7 Fisheries (Commercial and Recreational)

Commercial and recreational fishing and related industries are vulnerable to oil spills, due to closures as well as market perceptions surrounding taint of the catch. In addition, recreational anglers, who fish for pleasure or sport, as opposed to monetary gain, may experience a reduced quality of experience. Large-scale spills also hold the potential to injure nursery grounds and impose other effects that could reduce fish harvests in the longer run.

As described in Part A., the amount of total surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to commercial and recreational fishing in the Central California Shelf under various response options. The model results are presented in Appendix E-II.2, Tables E-II.2-1 to E-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to commercial and recreational fishing of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the Central California Shelf would be expected to adversely effect approximately 421 km^2 (161 mi^2) of surface water used for commercial and recreational fishing above recognized effect thresholds (Table E-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 35 percent as compared to on-water mechanical recovery alone (Table E-II.2-2). This results in a risk factor rating of 0.64 for commercial and recreational fishing under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 3 percent as compared to the low dispersant efficiency response option (Table E-II.2-3). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for commercial and recreational fishing decreases to 0.63 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on commercial and recreational fishing would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to commercial and recreational fishing for this scenario.

Summary of the Consequences for Commercial and Recreational Fishing in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 265 to 275 km^2 (102.3 to 106.2 mi^2) of surface water. While the use of dispersants is projected to likely lessen the area of surface water affected by approximately 36 percent, the level of dispersant efficiency does not greatly affect the level of concern about commercial and recreational fishing in this spill scenario.

E.3.3.8 Recreation and Tourism

An oil spill would be expected to cause local decreases in tourism, recreation, associated business revenues and the quality of coastal living. Similar to recreational fishing effects, an oil spill would also be expected to affect recreationalists' overall social welfare.

As described in Part A, the amount of total sandy shoreline oiled above selected thresholds is used to represent the risk of socioeconomic effects to recreation and tourism in the Central California Shelf under various spill response options. The model results are presented in Appendix E-II.2, Tables E-II.2-1 to E-II.2-3, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns). From the model results, risk is then expressed in terms of the length of shoreline affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to recreation and tourism of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only

Given the use of on-water mechanical recovery only, the average medium size spill in the Central California Shelf could be expected to adversely affect approximately 6.0 km (3.7 mi) of sandy shoreline used for recreation and tourism above recognized effect thresholds (Table E-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency

Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 60 percent as compared to on-water mechanical recovery alone (Table E-II.2-2). This results in a risk factor rating of 0.40 for recreation and tourism under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 1 percent as compared to the low dispersant efficiency response option (Table E-II.2-3). Because the adverse effect on sandy shoreline resources is less with higher dispersant efficiency, the risk factor rating for recreation and tourism decreases to 0.39 for this scenario.

Results of the Addition of an On-Water ISB Response

Under the medium volume spill scenario and the ISB response option, effects on recreation and tourism would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to recreation and tourism for this scenario.

Summary of the Consequences for Recreation and Tourism in the Medium Volume Scenarios

Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 2.4 km (1.5 mi) of sandy shoreline. While the use of dispersants is projected to likely lessen the length of sandy shoreline affected by approximately 60 percent, the level of dispersant efficiency does not greatly affect the level of concern about recreation and tourism in this spill scenario.

E.3.3.9 Environmental Justice

Low-income, indigenous, and minority sub populations in some coastal areas may rely on regional fisheries for subsistence or on tourism, recreation or other marine-resource related industry for employment. These groups may experience the effects of a spill more severely than the general population, which relies on a more diverse economic base for their livelihoods and on the availability of a widespread and commercially available selection of foods.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to environmental justice in the Central California Shelf under various spill response options. The model results are presented in Appendix E-II.2, Tables E-II.2-1 to E-II.2-3, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to environmental justice of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in the Central California Shelf would be expected to adversely effect approximately 6.0 km (3.7 mi) of sandy shoreline and sweep approximately 421 km^2 (162.5 mi^2) of surface water above recognized effect thresholds (Table E-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 60 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by approximately 35 percent compared to on-water mechanical recovery alone (Table E-II.2-2). This results in risk factor ratings of 0.40 and 0.64 for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 1 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by approximately 3 percent compared to the low dispersant efficiency respose option (Table E-II.2-3). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.39 and 0.63, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on environmental justice would be similar to the on-water mechanical recovery only response option. Therefore, a

risk factor of 1.0 was assigned to environmental justice for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Environmental Justice in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 2.4 km (1.5 mi) of sandy shoreline and 265 to 275 km^2 (102.3 to 106.2 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 60 and 36 percent, respectively, the level of dispersant efficiency does not greatly affect the level of concern about environmental justice in this spill scenario.

E.4 ENVIRONMENTAL CONSEQUENCES BASED ON THE LARGE VOLUME SPILL MODELING SCENARIOS

E.4.1 Effects on the Physical Environment

E.4.1.1 Air Quality

There are two possible sources of contamination to the atmosphere: volatilization of hydrocarbons from unburned oil and emissions produced by ISB, both of which are of concern for both human health and wildlife that may be exposed. Concentrations in the lowest 2 m (6.6 ft) of the atmosphere, as well as distances to and areas above thresholds of concern, were estimated for both unburned and burned oil. The thresholds of concern are air quality standards for human health (IDLH for ½ hour exposure and minimum TWA for an 8-hour exposure, Table D.1-1 in Appendix D of the PEIS and Table A.5-5 in Part A). The area potentially contaminated was divided by the area of the Central California Shelf (16,639 km^2 or 6,424 mi^2, Table A.4-4) to estimate a percentage affected by the scenario. Appendices E-III.1.2 and E-III.2.2 provide data for unburned and burned oil, respectively, from large volume (40,000 bbl) spills in the Central California Shelf.

Results of On-Water Mechanical Recovery Only
Under the large volume spill scenario with no dispersant response, volatilized hydrocarbons would not exceed air quality standards for human health at $\geq$15 km (9.3 mi) from the spill site, with a maximum of 10 km^2 (3.9 mi^2) adversely affected. While this would be of concern for personnel close to the spill site within the first few hours after emissions are released, it is a very small percentage of the area of the Central California Shelf. Evaporation and dispersion in the air would be very rapid after a spill, and recovery time would be less than 1 day. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
For the large volume spill scenario with 45% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
For the large volume spill scenario with 80% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would also be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, the worst case for air quality would result from the 95th percentile of volume burned (estimated as 25% of the mechanically-removed oil) for the no-dispersant scenario. The volume to be burned in this case would require 9 large burns, each 500 m^2 in area. The 50th percentile burn volume would require 7 large burns, each 500 m^2 in area. If dispersant is used, the amount burned would be less, requiring fewer burns (See Appendix E-III.2.2).

Air quality would be affected up to 710 m (2329 ft) downwind of *each* burn site, assuming a stable atmosphere and light wind at the time of the burning. Accounting for the worst case of 9 burns in different locations, the area potentially affected is a 14.25 km^2 (5.5 mi^2) area. This represents 0.09% of the Central California Shelf. Thus, the percent of the resource affected is <1%. The recovery time for the atmosphere after ISB would be on the order of hours. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Summary of the Consequences for Air Quality in the Large Volume Scenarios
The consequences of the three response options for large spills (1) on-water mechanical recovery only, (2) on-water mechanical recovery plus dispersants at 45% efficiency, and (3) on-water mechanical recovery plus dispersants at 80% efficiency are the same with respect to air quality. Evaporation off the water surface and volatilization from the water column creates a plume of volatile hydrocarbon gases that disperses quickly after a spill. For the large volume spill, the concentrations in the atmosphere at the water surface would exceed human health thresholds of concern at a maximum of 15 km (9.3 mi) from the spill site. Dispersant use would reduce the evaporation rate, but dissolved hydrocarbons would still volatilize, although dispersed over a wider area. Thus, atmospheric concentrations would be somewhat less under the dispersant use options. In all three options for the large spill, the effect would be small, affecting much less than 1% of the area of interest (i.e., the Central California Shelf in Table A.4-4), and the recovery time for the atmosphere would be on the order of hours.

The alternatives involving on-water mechanical recovery plus ISB (whether or not dispersants are used) should increase atmospheric pollutants by the amount injected via burning. The maximum area potentially affected is 14.25 km^2 (5.5 mi^2). However, this represents much less than 1% of the Central California Shelf.

Table E.4.1.1-1 indicates risk scores for air quality for all response options for a large volume spill. Both the area affected and the recovery times are assigned the lowest risk score for all the response options. These results would apply to any spill site at least 3 miles from shore.

Table E.4.1.1-1. Air quality risk scores for large spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB, With or Without Dispersant Application	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

E.4.1.2 Water Quality

The lowest water quality thresholds of concern are those concentrations of dissolved aromatics that could have effects on sensitive species in the water (see Section 4.3.1.1 of the PEIS). These thresholds are much lower than human health thresholds. The threshold for effects on water column organisms would be 5 ppb for at least 4 days of exposure. As an exposure dose, the threshold would be 500 ppb-hours. (See Part A, section A.3.4 for development of these thresholds.)

Table E.4.1.2-1 summarizes the mean and 95th percentile values of the water volume affected by >1 ppb for at least 1 hour and the average exposure dose in that volume of water. These data are the mean and the mean plus 2 standard deviations of the model results for all 100 runs performed for each scenario (Appendix E-II.2). The average exposure doses in the volumes are at or greater than the 500 ppb-hour threshold.

The percentages affected of total water volumes in coastal and marine areas of interest were calculated using the biogeographical province areas in Tables A.4-3 and A.4-4 for San Francisco Bay (coastal) and the central California shelf (marine). The total coastal volume was the area of San Francisco Bay times a mean depth of 5 m (16 ft). In this calculation it is assumed that the entire contaminated volume would be located in the coastal reference area (San Francisco Bay) after a spill, a worst case assumption for a spill in that estuary. The total marine volume was the area of the entire reference area times the depth at the spill site, 30 m (98 ft). Thus, only the surface water volume was considered in the marine estimation. Risk scores for potential effects were assigned for each of coastal and marine areas.

Table E.4.1.2-1. Estimation of adverse effects on water quality for large volume spills by dispersant scenario, based on mean and 95th percentile water volumes exceeding 1 ppb dissolved aromatic concentration.

Dispersant % Efficiency	0	45	80

Volume (millions of m^3) Exposed to >1 ppb	mean	384.9	2495.	2554.
	95th	1201.	5439.	5411.
Average ppb-hrs in Volume	mean	484	6492	8701
	95th	1116	16344	23695
Percent of Reference Area, coastal	mean	4.4	28.8	29.5
	95th	13.9	62.8	64.4
Percent of Reference Area, marine	mean	0.08	0.50	0.51
	95th	0.24	1.09	1.08

Results of On-Water Mechanical Recovery Only

For the large volume spill scenario in San Francisco Bay and no dispersant response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 4.4% on average. For 5% of spills, the percentage affected would exceed 13.9% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days to weeks, the time for concentrations to disperse to background levels. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions. For coastal spills under average conditions, the risk score is **4D**. Extreme (95th percentile) events, expected to occur for <5% of spills in coastal areas, were assigned a risk matrix ranking of **4B**.

Results of the Addition of a Dispersant Response at Low Efficiency

For the large volume spill scenario and 45% dispersant efficiency response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 29% on average. For 5% of spills, the percentage affected would exceed 63% of the area of concern. For nearly 95% spills in marine areas, the percentage of surface waters adversely affected is <1%, but in the rare event (≤5% of the time), >1% would be affected. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days to weeks, the time for concentrations to disperse to background levels. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under average (and most) conditions, while **4D** was assigned for extreme events in marine waters. For coastal spills under average and extreme (95th percentile) conditions, the risk score is **4A**. Note that dispersants would not be applied in coastal waters under the alternatives considered in the PEIS that include dispersant use.

Results of the Addition of a Dispersant Response at High Efficiency

For the large volume spill scenario and 80% dispersant efficiency response, the volumes affected are nearly the same as for 45% dispersant efficiency (because more than sufficient dispersant would be available to disperse the floating oil, see Section A.3.7 of Part A). Thus, the risk matrix rankings assigned to water quality for this scenario were the same as for the 45% dispersant efficiency case.

Results of the Addition of an On-Water ISB Response

Under the large volume spill scenario and the ISB response option, the water quality effects would be slightly less, by the amount removed by burning. Thus, the percent of the resource affected is also slightly less for the on-water mechanical only response scenario when ISB is included, and the risk matrix rankings assigned to water quality for scenarios involving burning were the same as those assigned for scenarios without burning.

Summary of the Consequences for Water Quality in the Large Volume Scenarios
Table E.4.1.2-2 summarizes risk scores for water quality for all response options for a medium volume spill in coastal waters under average and extreme (95th) environmental conditions. Table E.4.1.2-3 summarizes risk scores for large volume spills in marine waters. The coastal results would apply to similar volume coastal areas and the marine results would apply to any spill site at least 3 miles from shore.

Table E.4.1.2-2. Water quality risk scores for large spills in coastal waters by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: D 95th: B	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: A 95th: A	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: A 95th: A	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

Table E.4.1.2-3. Water quality risk scores for large spills in marine areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: E 95th: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: E 95th: D	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: E 95th: D	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

E.4.2 Effects on the Biological Environment

E.4.2.1 Intertidal Habitats

The intertidal habitats in the Central California Shelf include beaches and rocky shores along the outer coast and extensive tidal flats and wetlands in the bays. These shorelines are highly utilized by birds for feeding and nesting, and they have very high recreational use. The threshold concentration of concern for intertidal habitats is 10 g/m^2 (~10 microns) oil thickness (see Section A.4 in Part A). Table E.4.2.1-1 shows the outputs of the different scenarios in terms of the area and/or length of shoreline habitat affected, for the major shoreline habitat types for the large spill volume (shoreline classifications are defined in NOAA, 2000). Shoreline oiling is reported in kilometers for linear features such as beaches and rocky shores and in square meters for wide habitats such as tidal flats and wetlands.

Table E.4.2.1-1. Area and length of shoreline habitats oiled above a threshold of ~10 micron oil thickness for the large volume scenarios. The numbers are summarized from Appendix E Tables E-II.2-4 through E-II.2-6.

Scenario	Total Oiled Shoreline Area (m2)	Rocky Shore Length (km)	Sand/Gravel Beach Length (km)	Tidal Flats Area (m2)	Wetlands Area (m2)
On-Water Mechanical Recovery (with or without ISB)	498,000	19.7	19.1	243,000	40,500
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	265,000	12.5	11.4	120,000	16,400
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	219,000	10.8	9.9	92,900	15,000

Results of On-Water Mechanical Recovery Only

Under the large volume spill scenario and on-water mechanical response only option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs would be nearly 500 km^2 (194 mi^2) and the mean oiled shoreline length would be 45.1 km (28.2 mi). Affected habitats would extend along the outer shore from Point Reyes to El Jarro Point (just north of Santa Cruz) and inside San Francisco Bay north to Suisan Bay and most of the southern bay (Figure E-II.1.4.2-3). The oiled shoreline would represent less than 1 percent of the total shoreline (1620 km or 1010 mi) in the Central California Shelf, but 2.7 percent of the outer rocky shore habitat (Table A.4-6). Rocky shores would account for about 44 percent of the affected shoreline length. Exposed rocky shores would recover within 1-3 years (Sell et al., 1995). Nearly half of the oiled intertidal habitats were sensitive tidal flats that could take 3-7 years to recover. Thus, a risk matrix ranking of **2D** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs would be reduced by nearly 50 percent, compared to on-water mechanical recovery alone (Table E.4.2.1-1). The degree of oiling of the more sensitive habitats inside San Francisco Bay under the worst-case environmental conditions would be reduced (Figure E-II.1.5.2-3). However, the areas affected would still represent large effects on about 2 percent of the shoreline and to sensitive habitats that would likely take 3-7 years to recover (Sell et al., 1995). Thus, a risk matrix ranking of **2D** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron oil threshold for all model runs would be very similar to the low dispersant efficiency (Table E.4.2.1-1). Thus, a risk matrix ranking of **2D** was assigned to intertidal habitats for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on intertidal habitats would be similar to the on-water mechanical recovery only response option. When considering the areas of the different shoreline habitats affected under these spill conditions, a risk matrix ranking of **2D** was assigned to intertidal habitats for this scenario.

Summary of the Consequences for Intertidal Habitats in the Large Volume Scenarios
Under the large volume scenario, effects on intertidal habitats would occur to sensitive tidal flats and marshes where recovery would be expected to be 3-7 years, under the on-water mechanical recovery only and use of ISB. The use of dispersants would likely lessen the area of shoreline effect by about 50 percent. The level of dispersant efficiency does not significantly affect the level of concern about intertidal habitats in this spill scenario.

E.4.2.2 Marine and Coastal Birds

The Central California Shelf provides important habitat for migrant and resident marine and coastal birds. Refer to Section E.3.2 for additional information on important bird habitats in the region and factors considered in risk score calculations

It is important to note that the species groups being considered are not distributed equally throughout the region, and that effects should not be proportional to the amount of shoreline or water surface area oiled, but rather could depend on seasonal concentrations of particular species in high-use areas.

Results of On-Water Mechanical Recovery Only
Under the large volume spill scenario and no dispersant response option, large areas of important shorebird habitat in the San Francisco Bay WHSRN site would be oiled above the 10-micron threshold. Oiled areas could include: Point Pinole, Richardson Bay; the flats along Oakland and Alameda; the eastern flats north of San Mateo Bridge; the western flats north and south of Dumbarton Bridge; the Farallon Islands, and some areas of Bolinas Lagoon (Figure E-II.1.4.2-3).

The mean area of shoreline oiled above a threshold of 10 g/m^2 was estimated to be 498,000 m^2 (5.4 million ft^2) and included important habitat for multiple species groups (Table E.4.2.1-1).

The mean water area swept by oil above a threshold of 10 microns under this scenario was 659 km^2 (254 mi^2) representing approximately 4 percent of the total Central California Shelf (Table E-II.5-3). The large area of potential heavy surface water oiling outside of San Francisco Bay and around the Farallon Islands corresponds to an area of high seabird biomass year-round, typically higher than in other areas in the reference area (Figure E-II.1.4.1-3, Dohl et al., 1983). Oiling inside of San Francisco Bay may adversely affect diving birds and waterfowl.

When considering all species groups together it is estimated that over 20 percent of the area bird population may be adversely affected under these spill conditions. Recovery could likely occur in 1 to 3 years for most species, as was the case following the Exxon Valdez spill (Kuletz, 1993; Boersma et al., 1995; Erikson, 1995; and Wiens, 1995), although reproductive recovery may be greater than three years for pelicans (Anderson et al., 1996). A risk matrix ranking of **3A** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency

Under the large volume spill scenario and low efficiency dispersant response option, the mean area of shoreline oiled above a threshold of 10 g/m^2 was reduced by over 50 percent (Table E.4.2.1-1). Oiled areas could include important shorebird habitat in the San Francisco Bay WHSRN site, the Farallon Islands, and the entrance to Bolinas Lagoon (Figure E-II.1.5.2-3).

Surface water oiling above the 10-micron threshold was reduced by approximately 48 percent to about 342 km^2 (132 mi^2), representing approximately 2 percent of the total Central California Shelf (Table E-II.5-2). Areas oiled would be similar to when no dispersants were used, potentially affecting seabird, diving bird, and waterfowl habitat (Figure E-II.1.2.2-3).

When considering all species groups together, because of the decrease in shoreline length and surface water area swept by oil compared to the on-water mechanical recovery only option, it is estimated that 10-20 percent of the area bird population may be adversely affected under these spill conditions, and recovery could likely occur in 1 to 3 years for most species. A risk matrix ranking of **3B** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the large volume spill scenario and high efficiency dispersant response option, the mean area of shoreline oiling would be similar to when low efficiency dispersants were used (Table E.4.2.1-1). Oiled areas could include important shorebird habitat in the San Francisco Bay WHSRN site, the Farallon Islands, and the entrance to Bolinas Lagoon (Figure E-II.1.6.2-3).

Surface water oiling above the 10-micron threshold in the modeled area should be similar with high efficiency dispersant use as compared to low efficiency dispersant use (Table E-II.5-2). Seabird, diving bird, and waterfowl habitat may be adversely affected inside and outside of San Francisco Bay.

When considering all species groups together, because of the decrease in shoreline length and water surface area swept by oil compared to the on-water mechanical recovery only option, it is estimated that 10-20 percent of the area bird population may be adversely affected under these spill conditions, and recovery could likely occur in 1 to 3 years for most species. A risk matrix ranking of **3B** was assigned to birds for this scenario.

Results of the Addition of an On-Water ISB Response

Under the large volume spill scenario and the ISB response option, adverse effects on birds would be similar to the on-water mechanical recovery only response option. When considering all species groups together, over 20 percent of the population may be adversely affected under these spill conditions, and recovery could likely occur in 1 to 3 years for most species. A risk matrix ranking of **3A** was assigned to birds for this scenario.

Summary of the Consequences for Marine and Coastal Birds in the Large Volume Scenarios

Under the large volume scenario, adverse effects on birds are estimated to be moderate when no dispersants are used, regardless of the use of ISB, due to the high probability that a large percentage of the Bolinas Lagoon Ramsar site, the San Francisco Bay hemispheric WHSRN site, the Farallon National Wildlife Refuge, and on-water seabird feeding areas would be oiled. The use of dispersants is projected to likely lessen the water surface and shoreline effects enough to decrease the area and lower the percentage of birds affected, although adverse population effects would still be moderate.

E.4.2.3 Marine Mammals

The marine and coastal waters of the Central California Shelf support a large and diverse population of marine mammals, with 30 or more species occurring there during at least part of the year (see Section E.3.2.3). Marine mammals may be at risk from either floating oil, or from oil which strands in coastal shoreline areas that are used as haul out or breeding areas. The latter concern is important in the Central California Shelf, since there are many such areas primarily along rocky shorelines.

For this analysis, marine mammals are assumed to be at risk if a threshold of 10 g/m^2 (~10-micron) thickness of oil is exceeded on the shoreline or on the water surface (see Section A.4 in Part A), however the level of risk varies by the behavior group. Potential adverse effects on marine mammals (i.e., terrestrial wildlife, cetaceans, furbearing marine mammals and pinnipeds and manatees) were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the large volume San Francisco Bay area spills are in Appendix E-II.5, Table E-II.5.3. The equivalent areas of 100% mortality for all response options are summarized in Table E.4.2.3-1 as percentages of the Central California Shelf (defined in Tables A.4-4 and A.4-5 of Part A). In addition to this calculation, which is based on the mean percentile runs, the mean length of shoreline oiled and the surface oil exposure exceeding 0.01 g/m^2 (in m^2-hrs) based on all model runs was also compared between the treatment options (Tables E-II.2-4 through E-II.2-6).

Table E.4.2.3-1. Percentage of reference area adversely affected for medium spills, by dispersant option and behavior group (assuming Central California Shelf area in Tables A.4-4 and A.4-5).

Behavior Group (Habitat Occupied)	0	45	80
Terrestrial wildlife (wetlands, sea grass beds and shoreline)	0.002	0.002	0.002
Cetaceans (seaward subtidal)	0.003	0.002	0.002
Furbearing marine mammals (all intertidal and subtidal)	2.90	1.51	1.47
Pinnipeds and manatees (all intertidal and subtidal)	0.04	0.02	0.02

Results of On-Water Mechanical Recovery Only
In the Central California Shelf, marine mammals at risk include cetaceans, several pinniped species, sea otters, and terrestrial mammals along the shore. The resistance of cetaceans to oiling coupled with the very small percentage of affected area creates a very minimal risk to cetaceans under the on-water mechanical recovery only option for the large volume spill scenario. The cetaceans that are oiled as a result of contact with floating oil would most likely recover in within a few days, if not hours, of the spill (**4E**, RPI, 1987). Similarly, terrestrial mammals are at very low risk, but if an individual were killed or reproductively impaired by contact with oil on the shoreline, the recovery period could exceed one year (**3E**). Pinnipeds also have a low estimate for the extent of the area of equivalent mortality. The area for sea otters is approximately 2.9%, the highest calculated. As an alternative measure, the length of shoreline oiling was compared to the total shoreline length (45 versus 1620 km or 28 versus 1,007 mi), which is nearly 3%. This is presumed to be a measure of the possibility of contacting a haul out area. The primary concerns in the region are for sea otters and pinnipeds. While the area of effect for pinnipeds is still low with the large spill scenario (based on the estimate of equivalent area), the percentage of the total habitat area for sea otters falls in the 1 to 5% range. The shoreline oiling also falls in this range, which could reflect increased risk of sublethal effects to pinnipeds using haul out areas. In either case, the death of or sublethal effects to reproductive adults could affect the population for a number of years. On this basis the risk score of **2D** was assigned.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and the 45% efficiency dispersant option the areas of equivalent mortality for terrestrial mammals, cetaceans, and pinnipeds are slightly reduced in absolute area, and are still very small relative to the reference areas. The calculated percentage for sea otters is reduced from 2.9% to approximately 1.5%. The length of shoreline oiled is also reduced, from 45 to 27 km or 28 to 17 mi (approximately 1.7% of the total). The use of dispersants would be a benefit in terms of the area, but is not enough to change the risk category and would not affect the recovery time, thus the risk score remains **2D**. There is no evidence that cetaceans, sea otters or pinnipeds are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality are essentially the same as those for the 45% option, however, the extent of

shoreline oiled is reduced to 23.7 km or 14.7 mi (1.5%). The decrease is not enough to affect the risk score, which remains the same as for 45% efficiency.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in addition to on-water mechanical recovery should not change the effects on marine mammals (**2D**), since the amount of floating oil remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to marine mammals.

Summary of the Consequences for Marine Mammals in the Large Volume Scenarios
The results indicate that on average for large volume spills in the Central California Shelf, adverse effects on marine mammals would be moderate with or without the use of dispersants. Dispersant use would decrease the area affected, but would not change the recovery time, which is the factor of most concern.

E.4.2.4 Sea Turtles

Sea turtles typically inhabit tropical and subtropical seas and are uncommon in eastern North Pacific waters north of Mexico (see Section E.3.2.4). The primary sensitivity to sea turtles is from exposure to shoreline oiling in areas where they breed (not an issue in this area), however, adult turtles do have a low sensitivity to floating oil and they could ingest tar balls.

Sea turtles are assumed to be at risk when a threshold of 10 g/m^2 (~10-micron) of oil is exceeded on the shoreline or the water surface (see Section A.4 in Part A). Potential adverse effects on sea turtles were estimated using the modeling (SIMAP) and summarized as the equivalent area of 100% mortality. The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the large volume Central California Shelf spills are in Appendix E-II.5, Table E-II.5.3. The equivalent areas of 100% mortality for all response options are summarized in Table E.4.2.3-1 as percentages of the Central California Shelf (defined in Tables A.4-4 and A.4-5 of Part A). The sensitivity of sea turtles is assumed to be the same as that for pinnipeds and manatees, and so the area of equivalent mortality never exceeds 0.02% of the total reference area, regardless of the response option (see Table E.4.2.3-1).

Results of On-Water Mechanical Recovery Only
Under the large volume scenario with only on-water mechanical recovery, the area of equivalent mortality is 0.02% of the total reference area. If an individual were to be oiled, the result would probably only be minor physiological effects but it is conceivable that it could interfere with reproductive capacity, thus a risk ranking of **3E** was assigned. There are no nesting beaches in the area, so that is not a consideration.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and the 45% efficiency dispersant option the area of equivalent mortality is slightly reduced in absolute area, and is still very small relative to the reference areas. Even though the use of dispersants would reduce the amount and duration that surface oil was present, the change does not affect the potential recovery time, therefore, the

score remains **3E**. There is no evidence that sea turtles are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality are essentially the same as those for the 45% option, thus the risk score remains unchanged.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in addition to on-water mechanical recovery should not change the effects on sea turtles (**3E**), since the amount of floating oil remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to sea turtles.

Summary of the Consequences for Sea Turtles in the Large Volume Scenarios
The results indicate that on average for large volume spills in the Central California Shelf, adverse effects on sea turtles would be minor with or without the use of dispersants. Dispersant use would potentially reduce the possibility of turtles coming into contact with floating oil, but this risk would already be very low. These results are consistent with experience with spills of this size in areas where sea turtles are uncommon.

E.4.2.5 Plankton and Fish

Potential adverse effects on water column organisms (i.e., plankton and fish, as well as pelagic invertebrates such as squid) were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. Estimated water volumes where adverse effects could occur were converted to equivalent areas of 100% loss by integrating percentage losses over all affected volumes and multiplying by water depth at the spill site, allowing comparison to other resources that are distributed on a per area basis (e.g., mammals and shorelines). In the near shore areas modeled, effects were nearly evenly distributed throughout the water column because of water column mixing and vertical movements of animals. If these results are used to infer potential for adverse effects in deeper waters, the areas of effect would only apply to surface waters up to on the order of 30-50 m (98-164 ft) deep (during strong wind conditions). The modeling methods are described in Part A and Section E-II.6, and the results of the calculations for the large San Francisco spills are in E-II.6. For these calculations, the toxicity parameter for sensitive species was assumed. Thus, the areas affected would only apply to 2.5% of species (based on a Gaussian distribution of species sensitivities), and areas of adverse effect for 97.5% of species would be smaller.

Table E-II.6-3 lists the average equivalent areas projected to be killed (for sensitive species) for large volume spills. These areas are based on the mean of all 100 runs, and so represent an average of all environmental conditions that may occur after a spill (see explanation in Section E-II.6). Table E-II.6-5 lists the 95th percentile equivalent areas where sensitive species would be adversely affected. This maximum potential effect is calculated as the mean plus two standard deviations, using the statistics of all 100 model runs for the scenario, and assuming the toxicity values for sensitive species.

The mean areas adversely affected for all response options are summarized in Table E.4.2.5-1 as percentages of the Central California Shelf (defined in Table A.4-4 of Part A). The maximum areas (95th percentile) for sensitive species are summarized in Table E.4.2.5-2 (also as percentages of the Central California Shelf reference area).

Table E.4.2.5-1. Average percentage of reference area adversely affected for large spills, by dispersant option and behavior group (assuming Central California Shelf area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.02	0.29	0.29
Small pelagic fish & invertebrates	0.11	1.22	1.25
Large pelagic fish	0.14	1.63	1.68
Demersal (stationary on bottom)	0.01	0.15	0.15
Planktonic (drift with currents)	0.17	0.48	0.48

Table E.4.2.5-2. Maximum (95th percentile) percentage of reference area adversely affected for large spills, by dispersant option and behavior group (assuming Central California Shelf area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.15	0.68	0.67
Small pelagic fish & invertebrates	0.63	2.86	2.85
Large pelagic fish	0.85	3.85	3.83
Demersal (stationary on bottom)	0.08	0.36	0.36
Planktonic (drift with currents)	0.17	0.79	0.78

Results of On-Water Mechanical Recovery Only
Under the large volume spill scenario and no dispersant response option, the area adversely affected would be 0.01-0.2% of the Central California Shelf for spills under average environmental conditions. For 5% of spills, the area affected would be 0.1-0.9% of the Central California Shelf, depending on the behavioral group of the organism. As the percentage affected is <1%, it is less than the range of natural variability and would not be perceptible at the population level. Given this, the short generation time of many species, and annual reproduction of others, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45% dispersant efficiency response option, the area adversely affected would be 0.2-1.6% of the Central California Shelf for spills under average environmental conditions. For 5% of spills, the area affected would be 0.4-3.9% of the Central

California Shelf, depending on the behavioral group of the organism. The adverse effects are higher than the on-water mechanical-only response but still relatively small. The affected species would require a generation to replace the missing individuals. Thus, the recovery time would be 1-3 years. A risk matrix ranking of **3D** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% dispersant efficiency response option, the area adversely affected would be 0.2-1.7% of the Central California Shelf for spills under average environmental conditions. For 5% of spills, the area affected would be 0.4-3.9% of the Central California Shelf, depending on the behavioral group of the organism. These results are not significantly different from the low-efficiency dispersant response because approximately the same amount of oil is dispersed in either case (i.e., more than sufficient dispersant is available to disperse available oil for such activity in the low efficiency case). The adverse effect is relatively small on the scale of the populations involved, and the affected species would require a generation to replace the missing individuals. Thus, the recovery time would be 1-3 years. A risk matrix ranking of **3D** was assigned to plankton and fish for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario, if ISB is effectively used in the response, the adverse effects on water column organisms would be slightly less than otherwise by the amount removed by burning. Thus, the percent of the resource affected is <1% for on-water mechanical and both dispersant response scenarios when ISB is included. Because the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to water column communities for this scenario.

Summary of the Consequences for Plankton and Fish in the Large Volume Scenarios
The results indicate that on average for large volume spills, adverse water column effects for sensitive species could affect 2-29 km^2 (0.8-11.2 mi^2) without the use of dispersants. With dispersants, and on average, up to 280 km^2 (108 mi^2) of water could be toxic to the most sensitive and mobile species (Table E-II.6-2). Exposure for larger fish is higher because they are more mobile, and new animals move into the dissolved aromatic plume over time (assuming they do not avoid hydrocarbon contamination, as was assumed in this analysis). Under worst case conditions, the potentially affected areas for sensitive species and for no dispersants and dispersant use are on the order of 140 and 640 km^2 (54 and 62 mi^2), respectively (Table E-II.6-5).

The mean areas adversely affected for all response options are <1% of the Central California Shelf (Table E.4.2.5-1). Thus, the risk scores for these effects are "**E**" and the recovery time is less than 1 year for these scenarios (Table E.4.2.5-3). The mean areas for response involving dispersants for sensitive species are 0.2-1.7% of the reference area (Table E.4.2.5-2), placing these scenarios in the "**D**" risk category. The effects are relatively small on the scale of the populations involved, but the affected species would require a generation to replace the missing individuals. Thus, the recovery time would be 1-3 years.

It should be noted that these results are assuming toxicity threshold for sensitive (2.5th percentile) species. The average species would not be so sensitive, and these estimated adverse effects would not apply to most or average species. The effect estimates are used in a comparative manner, comparing potential areas of concern to the most sensitive species.

These results are consistent with experience for large oil spills of about 40,000 bbl (about 1 million gallons or more; French McCay and Payne, 2001; French McCay et al., 2002, and as discussed in Part A). Winds are typically light to moderate, except in infrequent storm events. Thus, natural dispersion into the water is typically low, while evaporation is rapid. Because of logistical constraints, in the scenarios examined the dispersion by chemical dispersants began 12 hours after the spill. By this time, most of the toxic components have volatilized (Section E.4.1), such that dissolved aromatic concentrations resulting from dispersant use are only slightly elevated over the no-dispersant option.

Only in rare storm events where high waves entrain fresh un-weathered oil, such as in the *North Cape* oil spill (French, 1998a, b; French McCay, 2003), would the concentrations of toxic components be high enough to cause serious concern about potential effects to water column communities. The 95th percentile case assuming no dispersant use would be the analogous case to the *North Cape* situation for sensitive species (analogous to the lobster affected in the *North Cape* spill). It should be noted that dispersants would not be likely to be used in such a situation. Thus, the 95th percentile result for the dispersant option scenarios are unlikely to ever occur, based on probability of the event and likelihood that dispersants would actually be used in a storm situation.

Table E.4.2.5-3. Risk scores for plankton and fish for large spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	D (<1%)	3 (1-3 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	D (<1%)	3 (1-3 yr)
On-Water Mechanical Recovery and ISB	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

E.4.2.6 Subtidal Benthic Habitat

Subtidal benthic habitat in the Central California Shelf, and its susceptibility to oil was discussed in Section E.3.2.6. Benthic habitat was assumed to be at risk when a threshold of 0.10 g/m^2 of total hydrocarbon loading was exceeded in the sediment or 0.0001 g/m^2 of dissolved aromatic hydrocarbons was exceeded in the pore water (see Section A.4 in Part A). These concentrations are approximately equivalent to 1 ppm of total hydrocarbons or 1 ppb of dissolved aromatic hydrocarbons, when a sediment mixing depth of 10 cm is assumed. The area was estimated using SIMAP and the modeling methods are described in Part A. The area estimates of sediment loading for the large volume Central California Shelf spills are in Appendix E-II.6, Table E-II.6.6. The area estimates for dissolved aromatic hydrocarbons in sediment pore water are in Table E-II.6.7. Uncharacteristically, the 0.10 g/m^2 total hydrocarbon threshold was exceeded in an area totaling approximately 6.5 km^2 (2.5 mi^2) with on-water mechanical recovery only, while the area decreased when dispersants were used (2.2 km^2 or 0.8 mi^2 at 45% efficiency and 1.9 km^2 or 0.7 mi^2 at 80% efficiency). This appears to be a function of reduced amount of oil which enters the Bay when dispersants are used. This is much less than 1% of either Central California Shelf or the area just in San Francisco Bay. The dissolved aromatic concentrations never exceeded the sediment threshold.

Benthic habitat was also assumed to be at risk if epiflora and epifauna (demersal) organisms were affected by dissolved aromatic concentrations in the bottom water just above the sediments. The percentage of benthic habitat where stationary demersal biota would be affected, assuming the toxicity parameter for sensitive species (i.e., two standard deviations more sensitive than the average of all species tested), was estimated using SIMAP and the modeling methods described in Part A and Section E.II.6.

Results of On-Water Mechanical Recovery Only
In the on-water mechanical recovery only option for the large volume spill scenario, the model results indicate that for sediments only the total hydrocarbon threshold was exceeded, and then only in a very small area. As indicated in Table E.4.2.5-1, 0.01% of the reference area was affected by bottom water concentrations when no dispersants were assumed used. Since the overall area of effect on the benthic habitat is low and recovery would be rapid, the risk ranking is **4E**.

Results of the Addition of a Dispersant Response at Low Efficiency
Use of a dispersant at 45% efficiency in the large spill scenario reduces the level of sediment contamination in subtidal habitat. As indicated in Table E.4.2.5-1, 0.15% of the reference area was affected by bottom water concentrations when dispersants were assumed used at low efficiency. Thus, the risk score does not change the already low ranking of **4E**.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and the 80% efficiency dispersant option potential effects are essentially unchanged from the 45% efficiency dispersant option although the area of sediment effect is reduced still further. Therefore, the risk ranking remains at **4E**.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in the large spill scenario should have no additional effect when combined with on-water mechanical recovery on benthic habitats since ISB takes place on the water’s surface and results in the removal of an equivalent amount of oil (**4E**). The only concern associated with ISB is the chance of heavy burn residues sinking and mixing with sediments, but this risk is minimal based on both the toxicity of the material and on the amount that would be produced from the limited burning possible in the scenarios.

Summary of the Consequences for Subtidal Benthic Habitat in the Large Volume Scenarios
Oil spills and oil-spill response activities could potentially affect benthic habitats. Floating oil does not pose a great level of concern unless sufficient wave energy exists to mix the surface oil into the water column, or sediments contaminated with oil are transported from the intertidal zone into subtidal habitats. Mechanically dispersed oil could reach bottom water and adhere to sediments, flora and fauna in benthic habitats and could cause potentially adverse effects. However, in this simulation, only very low levels of hydrocarbon exposure are expected on or in the sediments, even near shore. Dispersant use reduces this risk slightly, by preventing oil from entering San Francisco Bay. With on-water mechanical recovery only, the risk to benthic habitat is low, and dispersant use makes it slightly lower.

E.4.2.7 Biological Areas of Special Concern

The Central California Shelf area has numerous areas of special concern which were described in Section E.3.2.7. As discussed in that section, the average risk to such areas is assumed to be defined by the risk to intertidal (Section E.4.2.1) or subtidal habitats (Section E.4.2.6), adjusted for the extent of areas of special concern which occur in the Central California Shelf, if appropriate. The higher of the risk scores for these two resource groups is used as the starting point to define the risk to areas of special concern. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
For the mechanical response option under the large volume spill scenario, floating oil poses a moderate risk (**2D**) to intertidal habitat, while subtidal habitat was at minimal risk (**4E**). Therefore, intertidal areas of special concern are the only areas which require consideration. The concerns for intertidal habitat were discussed in Section E.4.2.1. Since areas of special concern occupy only selected locations, the probability of contact is less than for intertidal habitat as a whole, but probably not enough to reduce the areal estimate. If contact did occur, recovery times would be as estimated for intertidal habitat. Therefore the estimated score remains **2D.**

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency in the large spill scenario reduced the risk to intertidal habitat by reducing the amount of surface oil which reaches shore, decreasing the probability of contacting an area of concern. While the likelihood of contact is reduced, the decrease was not enough to change the risk ranking. The risk to subtidal habitat remains low (**4E**) because of the limited extent of the dispersed oil plume and rapid dilution, so the score of **2D** is used.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at an efficiency of 80% in the large spill scenario slightly reduces the amount of shoreline oiled over that for dispersant use at 45% efficiency, but the reduction was not sufficient to change the risk score.

Results of the Addition of an On-Water ISB Response
ISB should produce a smoke plume that could pass over an area of special concern if the proper weather conditions exist. In this case, however, the burning can only occur three miles or more offshore, and the results for air quality (Section E.4.1.1) indicate that the plume should not travel

that far. The use of ISB in addition to on-water mechanical recovery is not expected to change the risk to these resources (**2D**).

Summary of the Consequences for Biological Areas of Special Concern in the Large Volume Scenarios
The effects on areas of special concern in this scenario are focused on the potential risk to shoreline habitats. The use of dispersants can reduce the risk to such areas without increasing the minimal risk to subtidal areas. In this analysis the risk to areas of special concern is defined as equivalent to the risk to intertidal habitat, in general. While this accurately reflects the ecological consequences of the event, it does not account for the social values which may be attached to such areas. If the spill trajectory of an actual event did threaten such areas, special attention would be given to their protection.

E.4.2.8 Essential Fish Habitat

Areas of essential fish habitat are extensive in the Central California Shelf (Section E.3.2.8). For this evaluation, the effects on essential fish habitat are assumed to be reflected by the risk to plankton and fish (Section E.4.2.5) and subtidal habitat (Section E.4.2.6) since they define the risk to the majority of fish habitat. Intertidal habitats, such as marshes, are also important habitat for fisheries resources, but were considered separately. The average risk to essential fish habitat is assumed to be defined by the higher of the risk scores for plankton and fish or subtidal habitat. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
In the large spill scenario, with the use of on-water mechanical recovery only, the risk to plankton and fish and to subtidal habitat was **4E**, resulting in a risk score for EFH of **4E**. The areal extent of effects on fish increased beyond that for the medium volume spill, but remained well below 1%. Recovery time should be less than one year, based on natural variability and the fecundity of most groups.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency increases the possibility of exposure for both plankton and fish and subtidal habitat. The dispersed oil plume produced was large enough to change the risk scores for plankton and fish but did not change the score for subtidal habitat. Recovery time also increased and so the risk score becomes **3D** for EFH. Dispersant use did reduce effects on intertidal habitat, which includes areas that are important for fisheries resources and EFH.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at 80% efficiency in the large spill scenario resulted in no change to the risk to plankton and fish or subtidal habitat from the 45% efficiency scenario, and the score remains **3D**. Again, dispersant use does benefit intertidal habitat, some of which are also important to EFH.

Results of the Addition of an On-Water ISB Response
The addition of ISB to on-water mechanical recovery in the large spill scenario did not change the evaluation for either plankton or fish or for subtidal habitat, and the score remains **4E**.

Summary of the Consequences for Essential Fish Habitat in the Large Volume Scenarios
Overall, the predicted risk to essential fish habitat is low for the large spill scenario when on-water mechanical recovery with or without ISB is used, but increases to moderate when dispersants are used. The risk score is determined by the potential risk to plankton and fish, rather than subtidal habitat.

E.4.3 Effects on the Socio-Economic Environment

E.4.3.1 Human Health

Operation of the type of equipment associated with oil spill response can be dangerous. This is well recognized and is the basis for the worker certification and training requirements that are now in place. There are also protocols in place for the proper application and handling of dispersants. The safety risk is greater as the spill size, and thus the intensity and duration of operations increases, but is minimized if safety standards are followed. There is a health risk from inhalation of hydrocarbon fumes for first responders, which is recognized in current safety protocols. Exposure to hydrocarbon fumes is the only health risk that can be directly estimated in the SIMAP model, and the results are presented in Section E.4.1.1.

E.4.3.2 Subsistence

Information on subsistence use of fish and shellfish in the Central California Shelf, is limited. Along the Pacific Coast of the mainland U.S., Native American subsistence gathering is more common in Washington and Oregon than in California, but some Native American groups do exist in California, and members of various ethnic groups may supplement their diets with shellfish harvested from the intertidal zone, and some salmon and other finfish species (Section 3.5.5.6 of the PEIS).

Results of On-Water Mechanical Recovery Only
Under the large volume spill scenario and no dispersant response option, water column exposure of dissolved aromatics between 1-100 ppb is expected to occur within and outside San Francisco Bay, and higher concentrations (between 100-1,000 ppb) are expected to occur in localized areas (Figure E-II.1.4.4-3). Tainting of fish and invertebrates becomes a concern when water concentrations exceed approximately 100 ppb in a brief (order of hours) exposure (See Section 4.3.5.6 of the PEIS). Sediment exposure would occur in several areas within the Bay (Figure E-II.1.4.5-2). A small percentage (<1%) of shoreline habitats in the reference area would be oiled, therefore a proportionally small percentage of subsistence resources associated with these habitats are likely to be exposed (Section E.4.2.1. Intertidal Habitats). A small percentage of subsistence resources are likely to be adversely affected, and recovery should be within 1 year. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the high volume spill scenario and low efficiency dispersant response option, water column exposure of dissolved aromatics between 1-10,000 ppb is expected to occur in a larger area outside and within San Francisco Bay compared to on-water mechanical recovery only

(Figure E-II.1.5.4-3). Sediment exposure is expected to occur in similar areas within San Francisco Bay as when no dispersants were used (Figure E-II.1.5.5-2), and oiling of shoreline and intertidal organisms would be reduced (Section E.4.2.1. Intertidal Habitats). A larger percentage of subsistence resources may be adversely affected under this scenario than when no dispersants were used, and recovery should be rapid (<1 year). A risk matrix ranking of **4D** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and high efficiency dispersant response option, water column exposure of dissolved aromatics between 1-10,000 ppb is expected to occur in similar areas as to when low efficiency dispersants were used (Figure E-II.1.6.4-3). Sediment exposure would occur in similar areas compared to the other response options (Figure E-II.1.6.5-2), and oiling of shoreline and intertidal organisms would be reduced (Section E.4.2.1. Intertidal Habitats). A larger percentage of subsistence resources may be affected under this scenario than when no dispersants were used, and recovery should be within 1 year. A risk matrix ranking of **4D** was assigned to subsistence resources for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, adverse effects on subsistence resources would be similar to the on-water mechanical recovery only response option. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Summary of the Consequences for Subsistence in the Large Volume Scenarios
Because water column effects should be fairly localized, and shoreline effects are expected to occur only in a small percentage of the reference area, a risk matrix ranking of **4E** was assigned to subsistence resources for the no dispersant and ISB response options. When dispersants are used, the area affected is expected to be larger, and therefore a risk matrix ranking of **4D** was assigned.

E.4.3.3 Cultural Resources

In the Pacific region, some archaeological artifacts occur on land along the coast, while others are likely submerged offshore (Section 3.4.8). Historic structures on land are numerous, and a large number of submerged shipwrecks occur in nearshore waters. Results from several studies indicated that direct oiling caused negligible effects on cultural resources following the *Exxon Valdez* oil spill (Reger et al., 1992; Dekin, 1993; Wooley and Haggarty, 1995; Bittner, 1996). Open water response options, including on-water mechanical recovery, use of dispersants and ISB may help reduce the amount of oil that strands on the shoreline, which should also reduce the amount of shoreline clean up and potential disturbance to sensitive archaeological sites and historic structures. Offshore archaeological and historic resources would not become oiled regardless of the response option used. For these reasons, a risk matrix ranking of **4E** was assigned to cultural resources for all response options under this scenario.

E.4.3.4 Coastal Communities

Oil spills affect the pleasure that coastal residents and visitors derive from coastal activities and the economic contribution that resources make to local income and employment. Effects are likely to include effects on water- and shore-based recreation, fisheries (recreational and commercial), marine transportation and tourism. The effects on these activities are described in more detail in subsequent sections.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to coastal communities in the Central California Shelf under various spill response options. The model results are presented in Appendix E-II.2, Tables E-II.2-4 to E-II.2-6, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to coastal communities of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Central California Shelf would be expected to adversely affect approximately 14.3 km (8.9 mi) of sandy shoreline and sweep approximately 672 km^2 (259.5 mi^2) of surface water above recognized effect thresholds (Table E-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 40 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by almost 30 percent (Table E-II.2-5). This results in risk factor ratings of 0.58 and 0.70 for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 12 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by approximately 9 percent as compared to the low efficiency response option (Table E-II.2-6). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.50 and 0.64, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on coastal communities would be similar to the on-water mechanical recovery only response option.

Therefore, a risk factor of 1.0 was assigned to coastal communities for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Coastal Communities in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 7.5 to 8.6 km (4.7 to 5.3 mi) of sandy shoreline and 430 to 475 km^2 (166 to 183.4 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 39 to 47 percent and 29 to 36 percent, respectively, the level of dispersant efficiency does not greatly affect the level of concern about coastal communities in this spill scenario.

E.4.3.5 Economic Status

The overall economic status of communities, industries and individuals that rely on coastal resources for sustenance, revenue and quality of life can be affected by an oil spill. As noted above, coastal communities can suffer direct and indirect economic effects due to an oil spill, as beach and fishery closures decrease revenues, eliminate jobs, and adversely affect subsistence users of the resources.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to economic status in the Central California Shelf under various spill response options. The model results are presented in Appendix E-II.2, Tables E-II.2-4 to E-II.2-6, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to economic status of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Central California Shelf would be expected to adversely affect approximately 14.s km (8.9 mi) of sandy shoreline and sweep approximately 672 km^2 (259.5 mi^2) of surface water above recognized effect thresholds (Table E-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 40 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by almost 30 percent as compared to on-water mechanical recovery alone (Table E-II.2-5). This results in risk factor ratings of 0.58 and 0.70 for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 12 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by approximately 9 percent as compared to the low dispersant efficiency response option (Table E-II.2-6). Because the adverse effect on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.50 and 0.64, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on economic status would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to economic status for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Economic Status in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 7.5 to 8.6 km (4.7 to 5.3 mi) of sandy shoreline and 430 to 475 km^2 (166 to 183.4 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 39 to 47 percent and 29 to 36 percent, respectively, the level of dispersant efficiency does not greatly affect the level of concern about economic status in this spill scenario.

E.4.3.6 Vessel Transportation and Ports

Marine transportation is of paramount importance for many industries along the Pacific Coast. Any interruption in the standard use of vessels or increase in travel times over water can result in hardship for coastal communities and businesses as fewer goods are exchanged, transportation costs rise, and the revenue streaming through the local economy falls.

As described in Part A., the amount of total surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to marine transportation and ports in the Central California Shelf under various response options. The model results are presented in Appendix E-II.2, Tables E-II.2-4 to E-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to the marine transportation industry of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Central California Shelf would be expected to adversely effect approximately 672 km^2 (259.5 mi^2) of surface water used by the marine transportation industry above recognized effect thresholds (Table E-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 30 percent as compared to on-water mechanical recovery alone (Table E-II.2-5). This results in a risk factor rating of 0.70 for the marine transportation industry under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 9 percent as compared to the low dispersant efficiency response option (Table E-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for the marine transportation industry decreases to 0.64 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on the marine transportation industry would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to the marine transportation industry for this scenario.

Summary of the Consequences for Vessel Transportation and Ports in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 430 to 475 km^2 (166 to 183.4 mi^2) of surface water. While the use of dispersants is projected to likely lessen the area of surface water affected by approximately 29 to 36 percent, the level of dispersant efficiency does not greatly affect the level of concern about vessel transportation and ports in this spill scenario.

E.4.3.7 Fisheries (Commercial and Recreational)

Commercial and recreational fishing and related industries are vulnerable to oil spills, due to closures as well as market perceptions surrounding taint of the catch. In addition, recreational anglers, who fish for pleasure or sport, as opposed to monetary gain, may experience a reduced quality of experience. Large-scale spills also hold the potential to injure nursery grounds and impose other effects that could reduce fish harvests in the longer run.

As described in Part A., the amount of total surface water oiled above selected is used to represent the risk of socioeconomic effects to commercial and recreational fishing in the Central California Shelf under various response options. The model results are presented in Appendix E-II.2, Tables E-II.2-4 to E-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to commercial and recreational fishing of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only

Given the use of on-water mechanical recovery only, the average large size spill in the Central California Shelf would be expected to adversely effect approximately 672 km^2 (259.5 mi^2) of surface water used for commercial and recreational fishing above recognized effect thresholds (Table E-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency

Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 30 percent as compared to on-water mechanical recovery alone (Table E-II.2-5). This results in a risk factor rating of 0.70 for commercial and recreational fishing under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 9 percent as compared to the low dispersant efficiency response option (Table E-II.2-6). Because the adverse effecs on surface water resources is less with higher dispersant efficiency, the risk factor rating for commercial and recreational fishing decreases to 0.64 for this scenario.

Results of the Addition of an On-Water ISB Response

Under the large volume spill scenario and the ISB response option, effects on commercial and recreational fishing would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to commercial and recreational fishing for this scenario.

Summary of the Consequences for Commercial and Recreational Fishing in the Large Volume Scenarios

Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 430 to 475 km^2 (166 to 183.4 mi^2) of surface water. While the use of dispersants is projected to likely lessen the area of surface water affected by approximately 29 to 36 percent, the level of dispersant efficiency does not greatly affect the level of concern about commercial and recreational fishing in this spill scenario.

E.4.3.8 Recreation and Tourism

An oil spill would be expected to cause local decreases in tourism, recreation, associated business revenues and the quality of coastal living. Similar to recreational fishing effects, an oil spill would also be expected to affect recreationalists' overall social welfare.

As described in Part A, the amount of total sandy shoreline oiled above selected thresholds is used to represent the risk of socioeconomic effects to recreation and tourism in the Central California Shelf under various spill response options. The model results are presented in Appendix E-II.2, Tables E-II.2-4 to E-II.2-6, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns). From the model results, risk is then expressed in terms of the length of shoreline affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to recreation and tourism of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in the Central California Shelf would be expected to adversely effect approximately 14.3 km (8.9 mi) of sandy shoreline used for recreation and tourism above recognized effect thresholds (Table E-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 40 percent as compared to on-water mechanical recovery alone (Table E-II.2-5). This results in a risk factor rating of 0.58 for recreation and tourism under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 12 percent as compared to the low dispersant efficiency response option (Table E-II.2-6). Because the adverse effect on sandy shoreline resources is less with higher dispersant efficiency, the risk factor rating for recreation and tourism decreases to 0.50 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on recreation and tourism would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to recreation and tourism for this scenario.

Summary of the Consequences for Recreation and Tourism in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 7.5 to 8.6 km (4.7 to 5.3 mi) of sandy shoreline. While the use of dispersants is projected to likely lessen the length of sandy shoreline affected by approximately 39 to 47 percent, the level of dispersant efficiency does not greatly affect the level of concern about recreation and tourism in this spill scenario.

E.4.3.9 Environmental Justice

Low-income, indigenous, and minority sub-populations in some coastal areas may rely on regional fisheries for subsistence or on tourism, recreation or other marine-resource related industry for employment. These groups may experience the effects of a spill more severely than the general population, which relies on a more diverse economic base for their livelihoods and on the availability of a widespread and commercially available selection of foods.

As described in Part A, the amount of total sandy shoreline and surface water oiled above selected thresholds are used to represent the risk of socioeconomic effects to environmental justice in the Central California Shelf under various spill response options. The model results are presented in Appendix E-II.2, Tables E-II.2-4 to E-II.2-6, and are based on an effect threshold for shoreline habitat of 10 g/m^2 (approximately 10-microns) and an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of the length of shoreline or surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to environmental justice of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only

Given the use of on-water mechanical recovery only, the average large size spill in the Central California Shelf would be expected to adversely effect approximately 14.3 km (8.9 mi) of sandy shoreline and sweep approximately 672 km^2 (259.5 mi^2) of surface water above recognized effect thresholds (Table E-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency

Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 40 percent as compared to on-water mechanical recovery alone. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by approximately 30 percent as compared to on-water mechanical recovery alone (Table E-II.2-5). This results in risk factor ratings of 0.58 and 0.70 for shoreline and surface water resources, respectively, under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average length of sandy shoreline exceeding the 10-micron effect threshold for all model runs was reduced by approximately 12 percent as compared to the low dispersant efficiency response option. Under this same response option, surface water exceeding the 0.01 g/m^2 effect threshold was reduced by approximately 9 percent as compared to the low dispersant efficiency response (Table E-II.2-6). Because the adverse effects on shoreline and surface water resources is less with higher dispersant efficiency, risk factor ratings decreased to 0.50 and 0.64, respectively, for this scenario.

Results of the Addition of an On-Water ISB Response

Under the large volume spill scenario and the ISB response option, effects on environmental justice would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to environmental justice for shoreline and surface water resources, respectively, for this scenario.

Summary of the Consequences for Environmental Justice in the Large Volume Scenarios

Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 7.5 to 8.6 km (4.7 to 5.3 mi) of sandy shoreline and 430 to 475 km^2 (166 to 183.4 mi^2) of surface water. While the use of dispersants is projected to likely lessen the length of sandy shoreline and surface water area affected by approximately 39 to 47 percent and 29 to 36 percent, respectively, the level of dispersant efficiency does not greatly influence the level of concern about environmental justice in this spill scenario.

E.5 SUMMARY CONCLUSIONS

For the moderate (2500 bbl) spill (Table E.5-1) the level of concern predicted for the average spill with on-water mechanical recovery only remains low for all environmental resources except for intertidal habitats, marine and coastal birds, marine mammals and areas of special concern which are predicted to be at moderate risk. The use of dispersants, at either efficiency, is sufficient to reduce the effects on all of these resources, but changes the overall risk score only for intertidal habitats, and, therefore, for areas of special concern. The use of ISB did not change the results relative to on-water mechanical recovery.

When the spill size increases to 40,000 bbl (large spill scenario, Table E.5-2) the expected effects also increase. The average model results do not, however, indicate that any additional categories are likely to move from the low level of concern category, and the moderate risk rankings did not increase to a high level of concern. The use of dispersants was less effective in reducing the level of concern in the large scenario than in the medium scenario, although there were clear reductions in the extent of the areas affected along the shoreline. The potential risk to plankton and fish and to coastal water quality from the average spill did increase enough to be ranked as a moderate concern. Of the five sites modeled, this is the only one where this occurred for plankton and fish (because of slower natural dispersion rates than for the other four sites). Again, the use of ISB does not change the results from those predicted with only on-water mechanical recovery.

Examination of the entire suite of model runs indicates that the range of effects on resources of concern is highly variable, which reflects the dynamic nature of oil spills. For example, for the medium spill no oil reaches the shore at all with only on-water mechanical recovery 3 out of 100 model runs, while this value increases to 35 out of 100 with dispersant use at low efficiency and is 28 out of 100 with dispersant use at high efficiency. Alternatively, also for the medium spill, the maximum shoreline oiling length predicted for on-water recovery only was 96.1 km (59.7 mi), just over four times the average. Similar observations can be made for other exposure indices. The same pattern exists for the large spill results, and in many cases the relative relationships are quite similar. These model results are consistent with observed effects from spills that originate offshore and with the expected impacts described in Section 4.3 of the PEIS.

With respect to socioeconomic resources, the use of dispersants would limit the effects of the spill in all cases.

Table E.5-1 Risk Ranking for Medium (2,500 bbl) Spills at the Central California Shelf Location

	Physical Environment			Biological Environment								Socioeconomic Environment			
Response Option	Coastal Water Quality	Marine Water Quality	Air Quality	Intertidal Habitat	Marine and Coastal Birds	Marine Mammals	Sea Turtles	Plankton and Fish	Subtidal Benthic Habitat	Biological Areas of Special Concern	Essential Fish Habitat	Subsistence	Cultural Resources	Shoreline Oiling Index	Surface Water Oiling Index
On-Water Mechanical Recovery	4E	4E	4E	3D	3C	2D	3E	4E	4E	3D	4E	4E	4E	1.0	1.0
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	4D	4E	4E	3E	3D	2E	3E	4E	4E	3E	4E	4E	4E	0.40	0.64
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	4D	4E	4E	3E	3D	2E	3E	4E	4E	3E	4E	4D	4E	0.39	0.63
On-Water Mechanical Recovery and In-Situ Burning	4E	4E	4E	3D	3C	2D	3E	4E	4E	3D	4E	4E	4E	1.0	1.0

Legend: Black cells represent a "high" level of concern, medium gray cells represent a "moderate" level of concern, and light gray cells represent a "limited" level of concern.

Table E.5-2 Risk Ranking for Large (40,000 bbl) Spills at the Central California Shelf Location

	Physical Environment			Biological Environment								Socioeconomic Environment			
Response Option	Coastal Water Quality	Marine Water Quality	Air Quality	Intertidal Habitat	Marine and Coastal Birds	Marine Mammals	Sea Turtles	Plankton and Fish	Subtidal Benthic Habitat	Biological Areas of Special Concern	Essential Fish Habitat	Subsistence	Cultural Resources	Shoreline Oiling Index	Surface Water Oiling Index
On-Water Mechanical Recovery	4D	4E	4E	2D	3A	2D	3E	4E	4E	2D	4E	4E	4E	1.0	1.0
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	4A	4E	4E	2D	3B	2D	3E	3D	4E	2D	3D	4D	4E	0.58	0.70
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	4A	4E	4E	2D	3B	2D	3E	3D	4E	2D	3D	4D	4E	0.50	0.64
On-Water Mechanical Recovery and In-Situ Burning	4D	4E	4E	2D	3A	2D	3E	4E	4E	2D	4E	4E	4E	1.0	1.0

Legend: Black cells represent a "high" level of concern, medium gray cells represent a "moderate" level of concern, and light gray cells represent a "limited" level of concern.

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Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part E: San Francisco Bay and Central California Shelf

Sections E-I.1 – E-I.4

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ASA 00-246

August 2004

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E-I. Oil Spill Model Input Data

This appendix contains model input data (in maps, figures and tables) for the modeled location in the Pacific (near the entrance of San Francisco Bay) and the sources for that information. The approach and sources applicable to all modeled locations are described in Part A, Section A.3 of this technical report. Specifics to this model location are below. Thus, the reader should refer to Part A, Section A.3 for background and the context within which these data are used.

E-I.1 Geographical Data Input to the Model

Geographic data for the modeled location are presented in this section. The sources for these data are described in Part A, Section A.3.1. A map is also presented below showing areas where dispersant application was assumed in model simulations. The assumptions for the dispersant application scenarios are in Part A, Section A.3.7. The crosshair mark (⊞) in the figures below represents the assumed oil spill site for the model simulations.

E-I.1.1 Maps of the Vicinity of the Spill Site

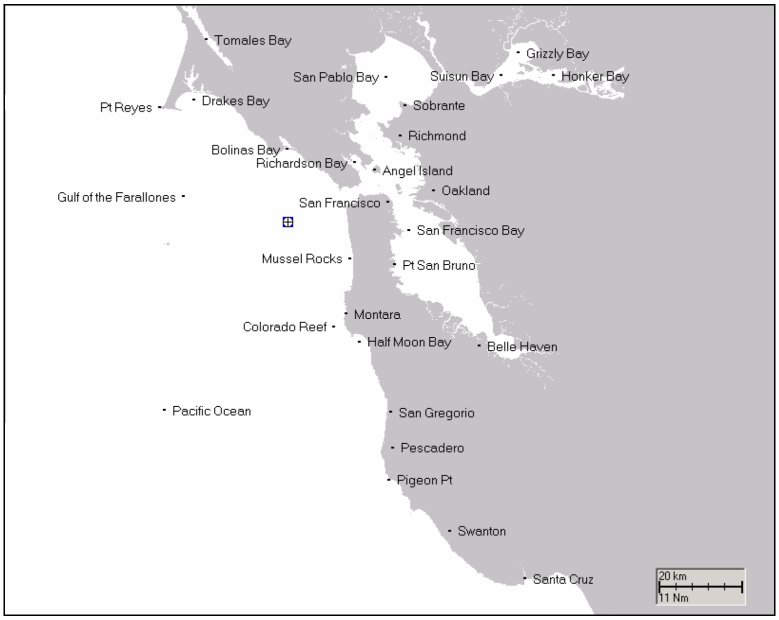

Figure E-I.1.1-1 Map of spill site and location names used in the text (entire grid).

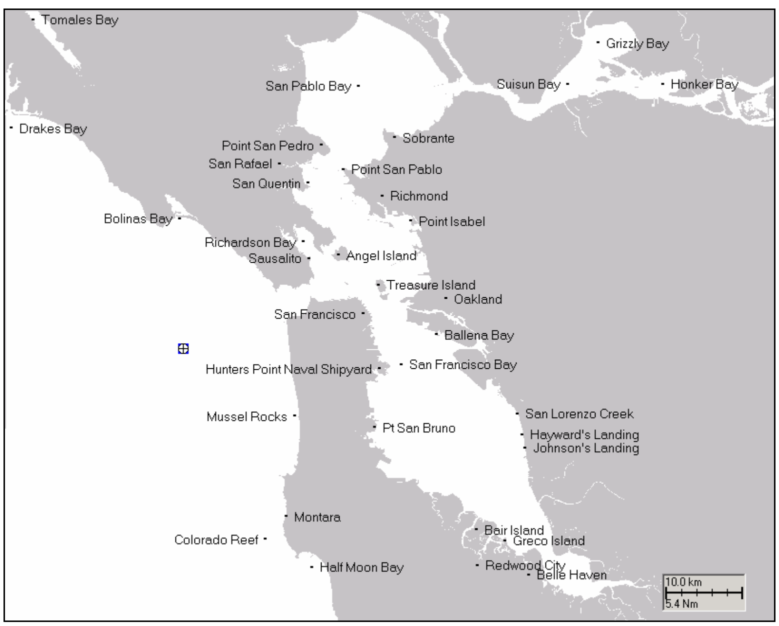

Figure E-I.1.1-2 Map of spill site and location names used in the text (San Francisco Bay).

E-I.1.2 Gridded Depth Data

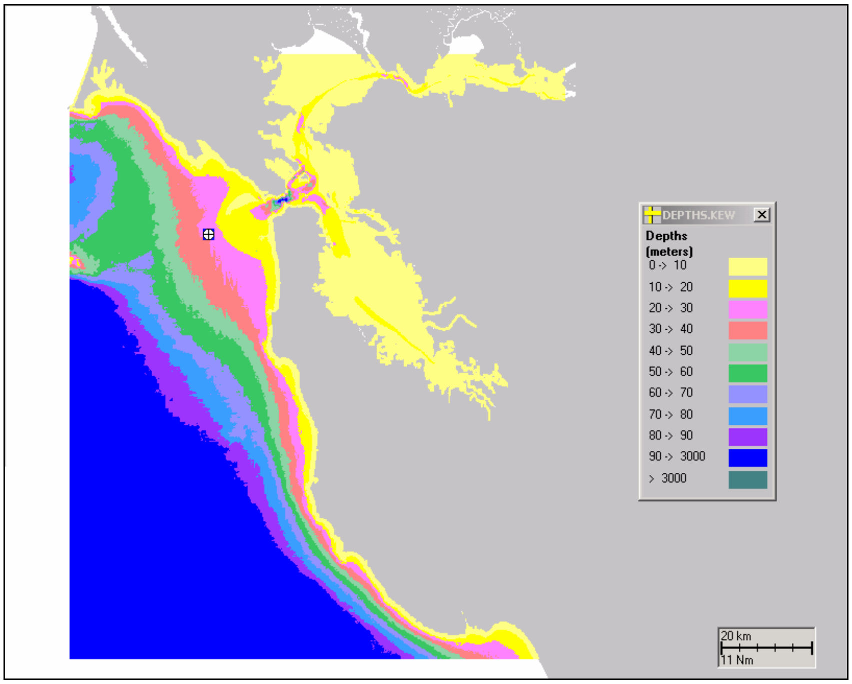

Figure E-I.1.2-1 Gridded depth data used in model runs (entire grid).

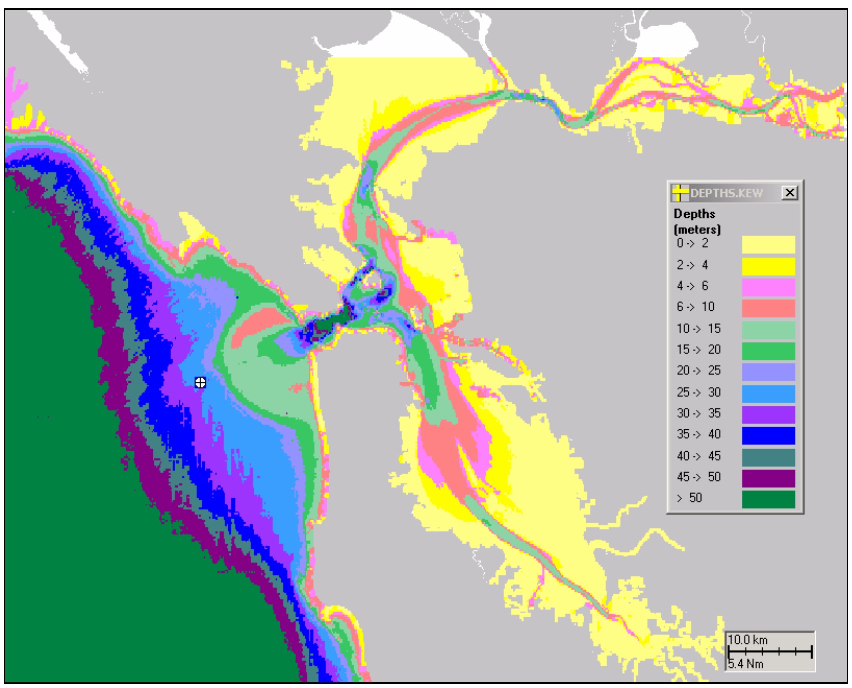

Figure E-I.1.2-2 Gridded depth data used in model runs (San Francisco Bay).

E-I.1.3 Gridded Habitat Mapping

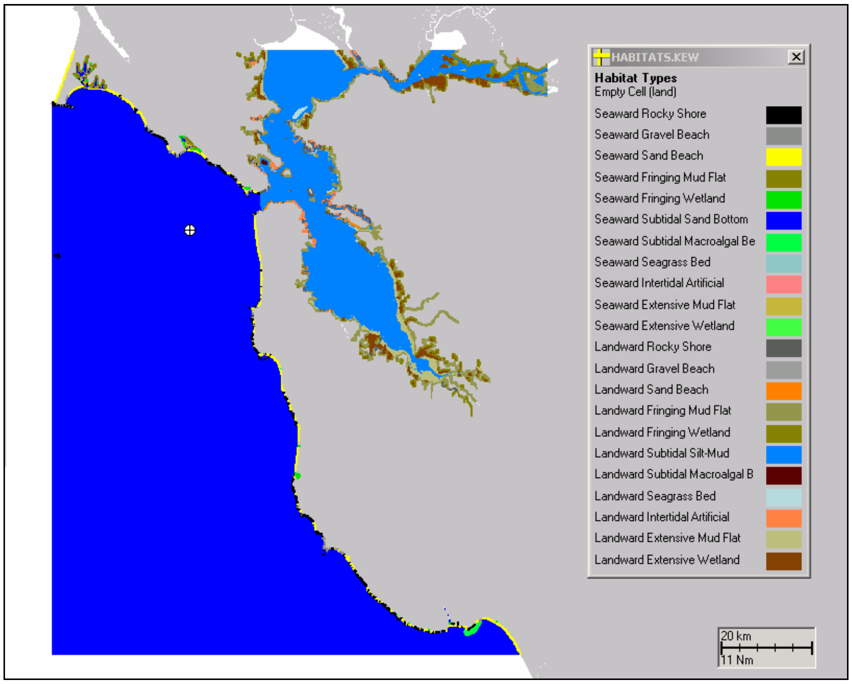

Figure E-I.1.3-1 Gridded habitat map used in model runs (entire grid).

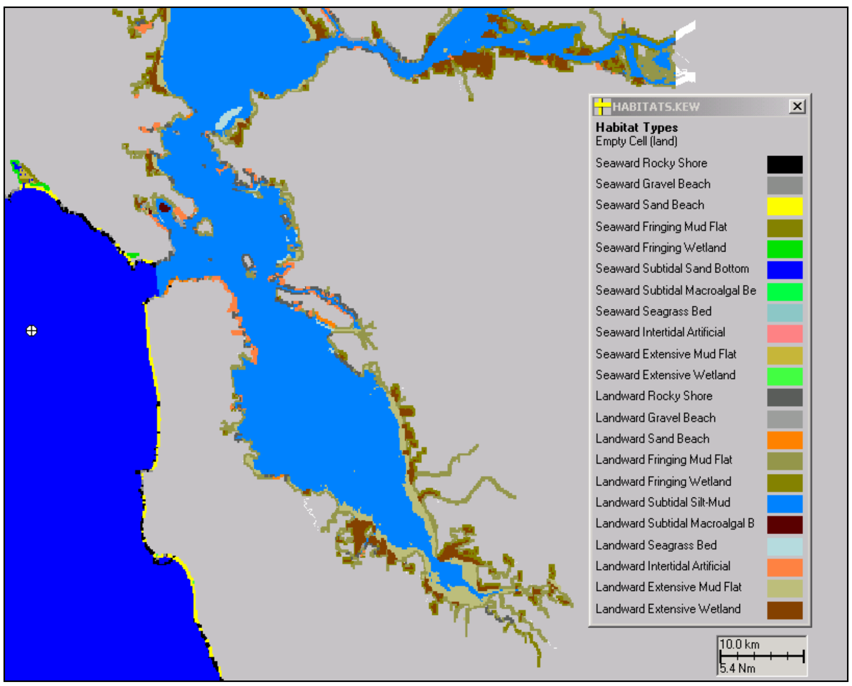

Figure E-I.1.3-2 Gridded habitat map used in model runs (San Francisco Bay).

E-I.1.4 Dispersant Application Areas for Response

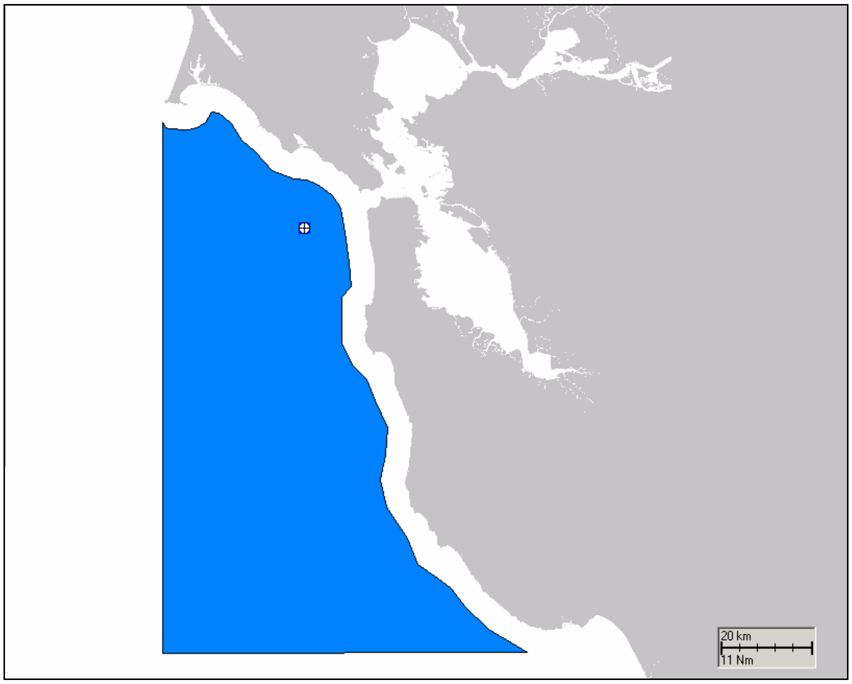

Figure E-I.1-4.1 Map of dispersant application areas (blue shaded area is where dispersants are assumed applied).

E-I.2 Current Data

The hydrodynamic model BFHYDRO (described in Section A.3.3.1 of Part A) was used to generate tidal and river-induced current data for San Francisco Bay. This model application was validated with observed current and tidal height data. Complete descriptions of the hydrodynamic model application and validation of the model results are available in French McCay et al. (2003). A summary is in French McCay et al. (2002). The validation is described in Sankaranarayanan and McCay (2003). Selected “snapshots” of the current data are shown in the figures in the next section.

The modeling domain included San Francisco Bay and the coastal area of California extending 182 km along the California shore, from Point Ryes in the north to Monterey in the South. The 17 major tidal constituents for the tidal stations at Monterey and Point Ryes were obtained from NOAA data sets. It was observed that the amplitudes and phases lags at both ends of the open boundary for the M_2 constituent vary by 6 cm and 10°, respectively. Hence, the tidal harmonics for the cells along the open boundary were obtained from a linear interpolation of the tidal harmonics at Point Ryes and Monterey and were used as the forcing functions.

The Delta outflows given by the California State Water Resources Department, and made available at http://cdec.water.ca.gov, were taken as the fresh water flow into the bay. A peak flow of 5000 m^3/s was observed during the spring of 2000.

Time series of observed tidal elevations and currents obtained from NOAA were used to compare the model-predicted currents and tidal elevations. The asymmetric diurnal and semi-diurnal tidal ranges and spring and neap tidal cycles for surface elevations and currents were very well reproduced in the model at all stations. Mean error in the model predicted surface elevations and currents for were less than 7% and 9%, respectively. Correlation coefficients for surface elevations and currents were higher than 0.94 and 0.95, respectively. Very strong currents of the order of 1.0 m/s were seen to occur near the Golden Gate.

E-I.2.1 Current Vector Plots at Selected Times

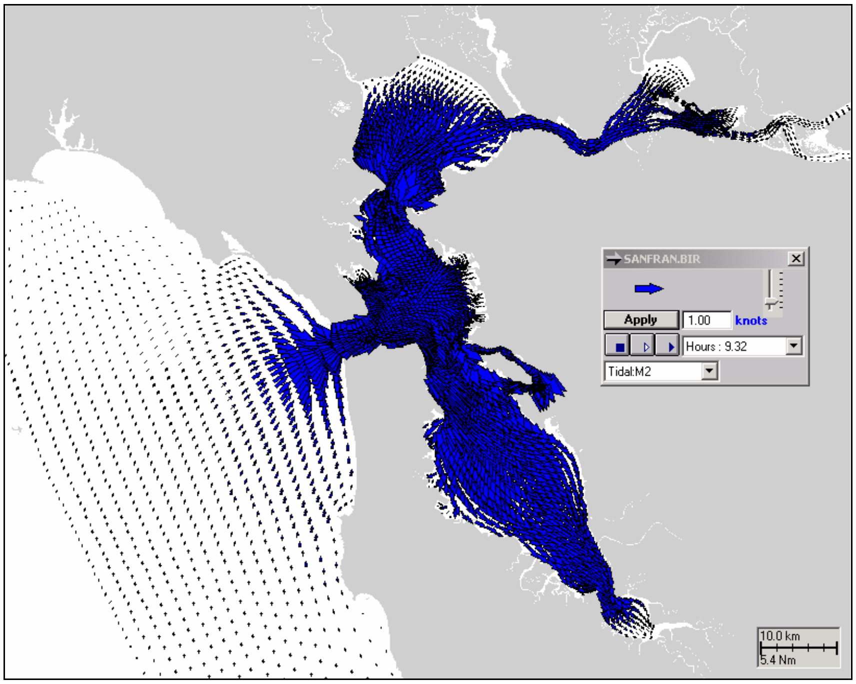

Figure E-I.2.1-1 Current vectors at maximum flood tide (entire grid).

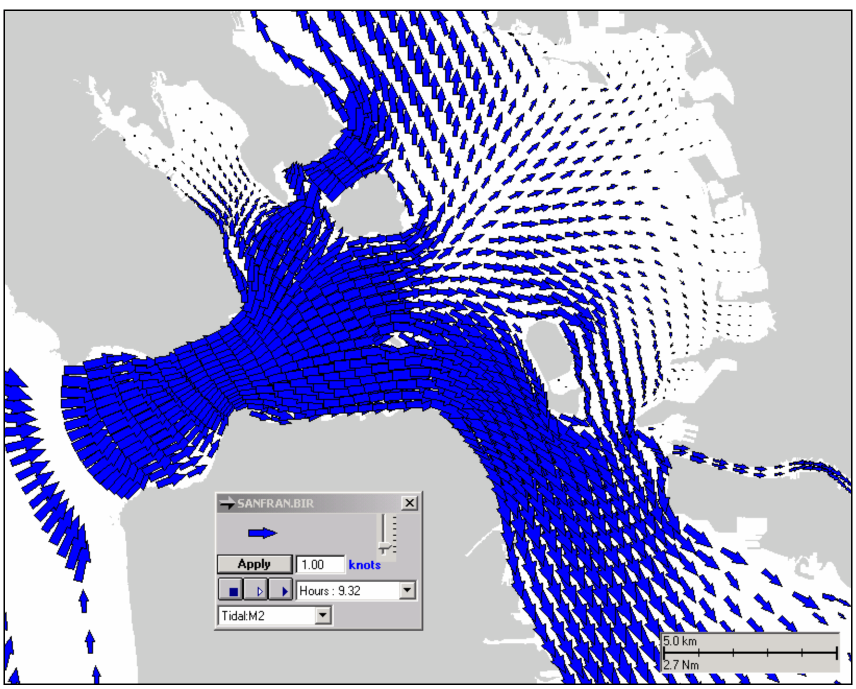

Figure E-I.2.1-2 Current vectors at maximum flood tide (San Francisco Bay).

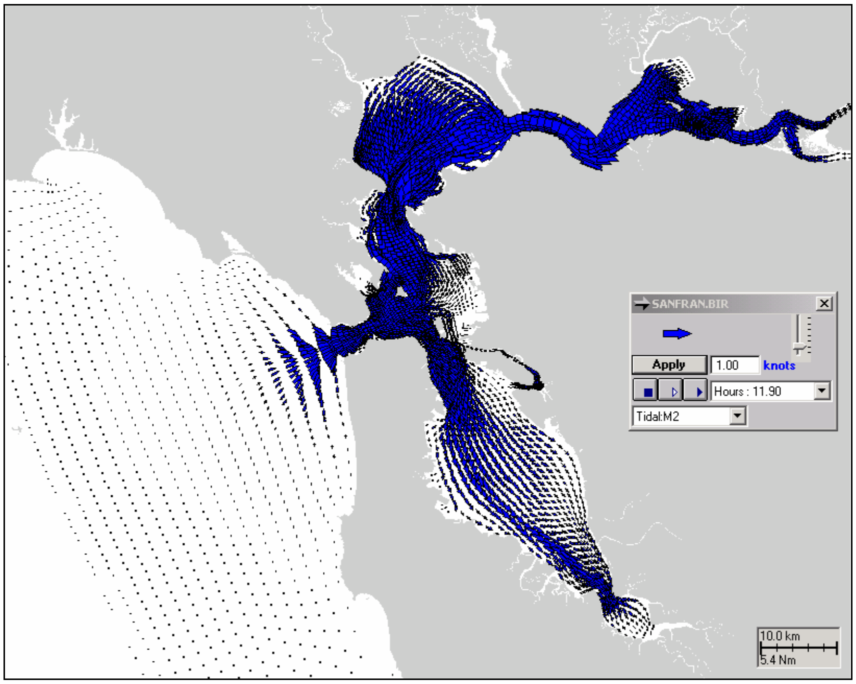

Figure E-I.2.1-3 Current vectors at 3 hours after maximum flood tide (entire grid).

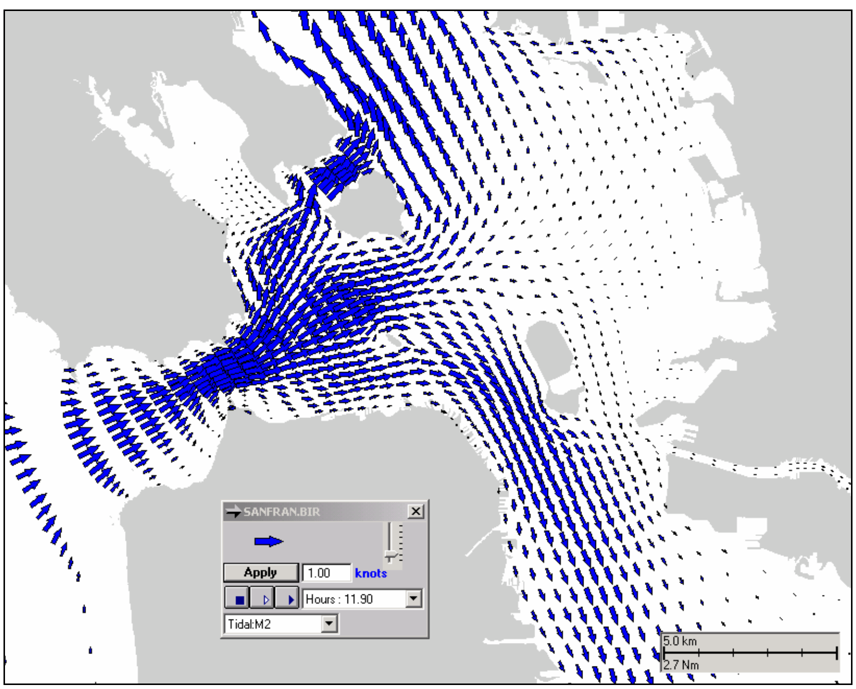

Figure E-I.2.1-4 Current vectors at 3 hours after maximum flood tide (San Francisco Bay).

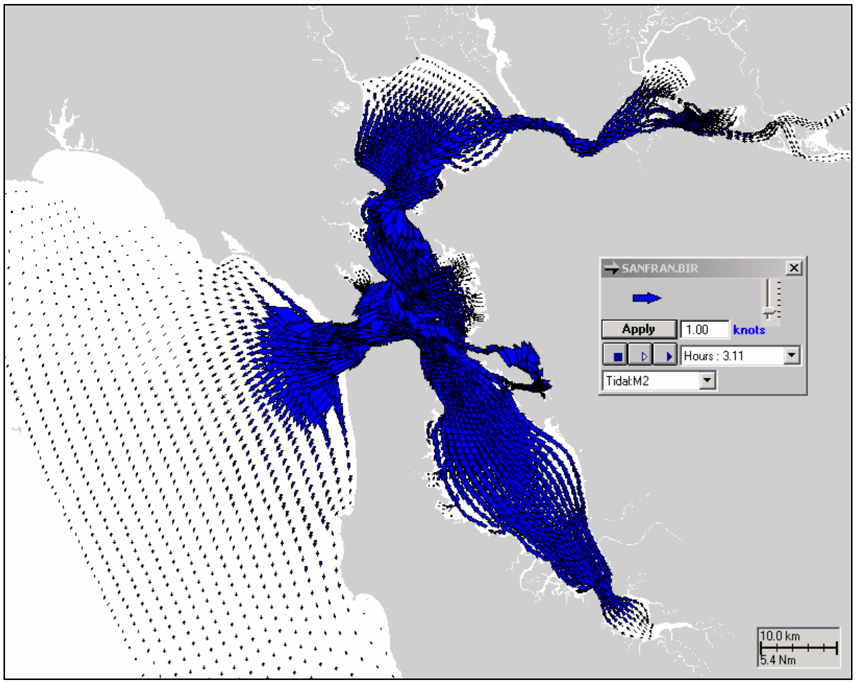

Figure E-I.2.1-5 Current vectors at maximum ebb tide (entire grid).

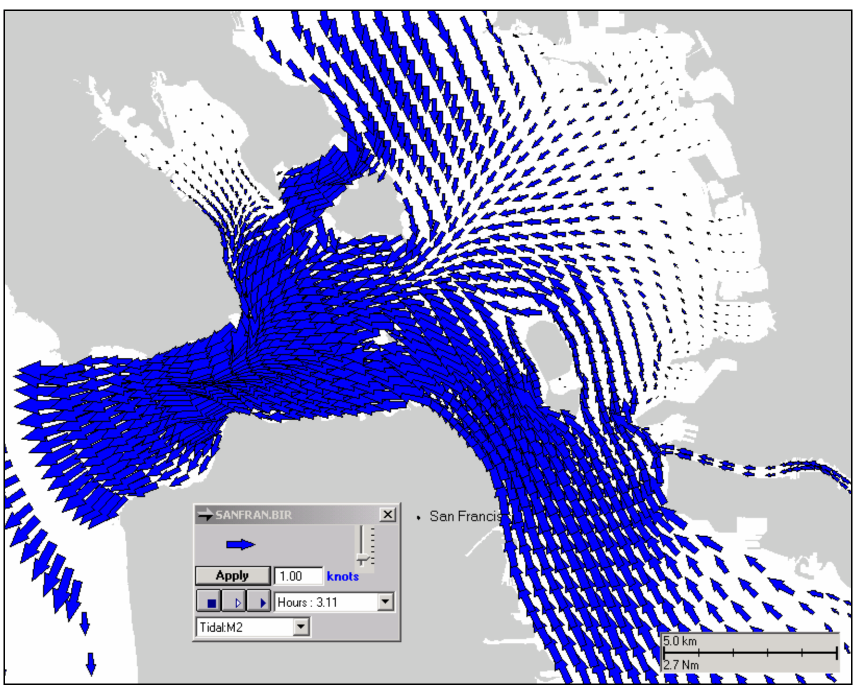

Figure E-I.2.1-6 Current vectors at maximum ebb tide (San Francisco Bay).

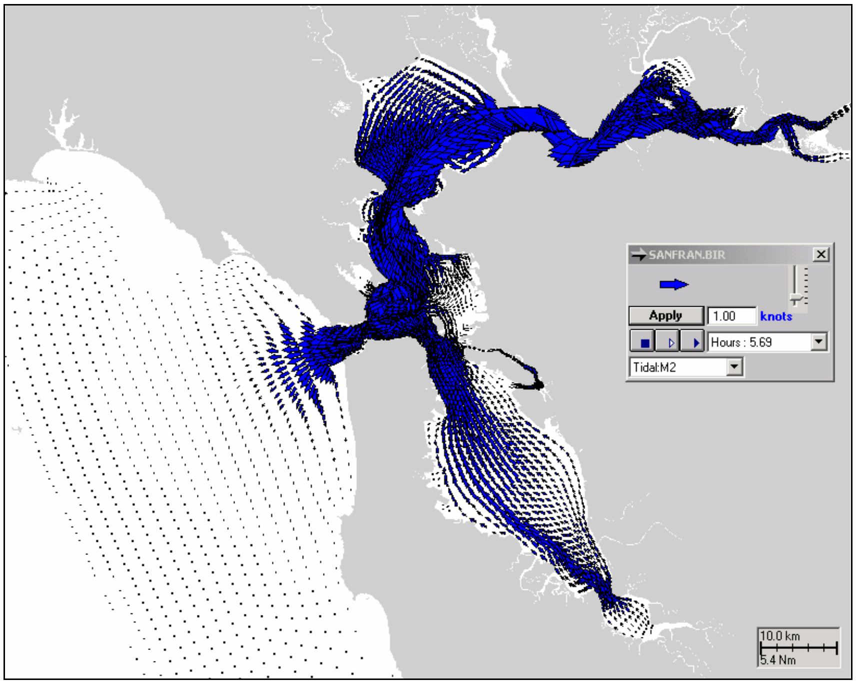

Figure E-I.2.1-7 Current vectors at 3 ½ hours after maximum ebb tide (entire grid).

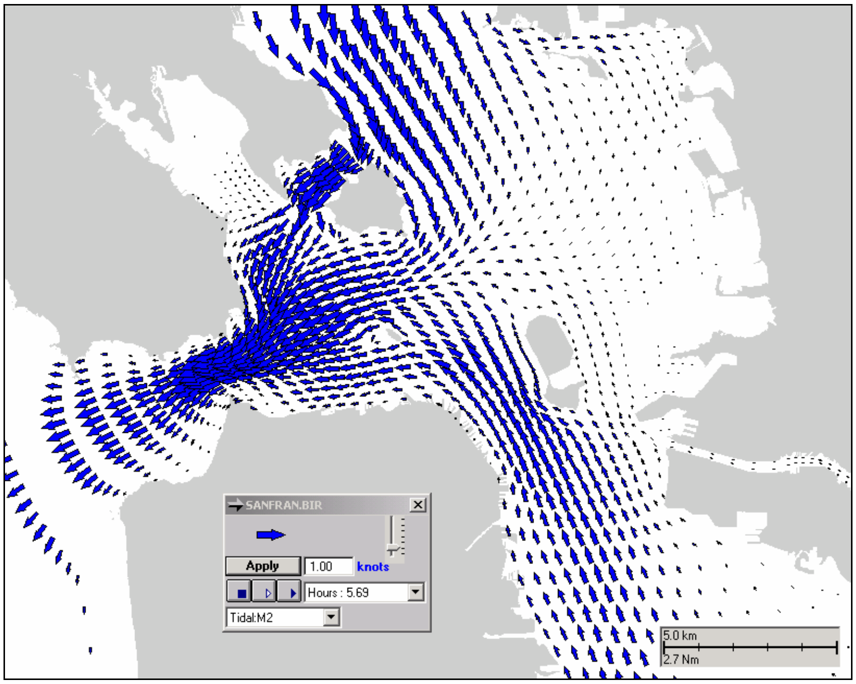

Figure E-I.2.1-8 Current vectors at 3 ½ hours after maximum ebb tide (San Francisco Bay).

E-I.3 Oil Properties

Table E-I.3-1. Oil properties for Alaskan North Slope crude oil.

Property	Value	Reference
Density @ 25 deg. C (g/cm3)	0.8761	Jokuty et al. (1999)
Viscosity @ 25 deg. C (cp)	16	Jokuty et al. (1999)
Surface Tension (dyne/cm)	27	Jokuty et al. (1999)
Pour Point (deg. C)	-54	Jokuty et al. (1999)
Adsorption Rate to Suspended Sediment	0.01008	Kolpack et al. (1977)
Adsorption Salinity Coef.(/ppt)	0.023	Kolpack et al. (1977)
Fraction monoaromatic hydrocarbons (MAHs)	0.030662	Jokuty et al. (1999)
Fraction polynuclear aromatic hydrocarbons (PAHs)	0.010372	A.D. Little (1996)
Fraction 2-ring aromatics (included in PAHs above)	0.00375	A.D. Little (1996)
Fraction 3-ring aromatics (included in PAHs above)	0.006622	A.D. Little (1996)
Fraction Non-Aromatic Volatiles: boiling point < 180°C	0.189338	Jokuty et al. (1999)[1]
Fraction Non-Aromatic Volatiles: boiling point 180-264°C	0.13325	Jokuty et al. (1999)[1]
Fraction Non-Aromatic Volatiles: boiling point 264-380°C	0.200378	Jokuty et al. (1999)[1]
Minimum Oil Thickness (m)	0.00005	McAuliffe (1987)
Maximum Mousse Water Content (%)	70	Jokuty et al. (1999)[2]; NOAA (2000a)[2]
Mousse Water Content as Spilled (%)	0	French et al. (1996b)
Water content of fuel (not in mousse, %)	0	French et al. (1996b)
Degradation Rate (/day), Surface & Shore	0.01	National Research Council (1985)
Degradation Rate (/day), Hydrocarbons in Water	0.01	National Research Council (1985)
Degradation Rate (/day), Oil in Sediment	0.001	Haines and Atlas (1982)
Degradation Rate (/day), Aromatics in Water	0.01	French et al. (1996b)
Degradation Rate (/day), Aromatics in Sediment	0.001	French et al. (1996b)

1 – Jokuty et al. (1999) provided total hydrocarbon data. The aromatic hydrocarbon fraction was subtracted from the total hydrocarbon fraction to obtain the aliphatic fraction.

2 – Mid-value used.

Table E-I.3-2. Aromatic concentrations (mg/kg) for Alaskan North Slope crude oil.

Aromatic	**Log(K_{ow})***	**Concentration (mg/kg)**
benzene	2.13	3,698
toluene	2.69	9,040
ethylbenzene	3.13	1,689
o-xylene	3.15	0
p-xylene	3.18	0
m-xylene	3.2	0
xylenes	3.18	8,197
1,2,3-trimethylbenzene	3.55	1,004.75
1,2,4-trimethylbenzene	3.6	1,004.75
1,3,4-trimethylbenzene	3.6	1,004.75
1,3,5-trimethylbenzene	3.58	1,004.75
trimethylbenzenes	3.58	1,004.75
n-propylbenzene	3.69	1,004.75
iso-propylbenzene	3.63	1,004.75
ethyl-methylbenzenes	3.63	1,004.75
iso-propyl-4-methylbenzene	4.10	0
butylbenzenes	4.12	0
tetramethylbenzenes	4.01	0
styrene	3.05	0
methylstyrenes	3.35	0
tetralin	3.83	0
diphenylmethane	4.14	0
naphthalene	3.37	650
C1-naphthalenes	3.87	1,300
C2-naphthalenes	4.37	1,800
C3-naphthalenes	5.00	1,400
C4-naphthalenes	5.55	850
acenaphthylene	4.07	0
acenaphthene	3.92	0
biphenyls	3.9	180
dibenzofuran	4.31	0
fluorene	4.18	82
C1-fluorenes	4.97	220
C2-fluorenes	5.20	260
C3-fluorenes	5.50	280

*Estimates of log(K_{ow}) are from Mackay et al. (1992a,b) and Neff and Burns (1996).

Table E-I.3-2. Aromatic concentrations (mg/kg) for Alaskan North Slope crude oil (continued).

Aromatic	Log(Kow)*	Concentration (mg/kg)
anthracene	4.54	0
phenanthrene	4.57	230
C1-phenanthrenes/ anthracenes	4.49	430
C2-phenanthrenes/ anthracenes	5.14	490
C3-phenanthrenes/ anthracenes	5.25	380
C4-phenanthrenes/ anthracenes	6.00	260
dibenzothiophene	6.51	200
C1-dibenzothiophene	4.49	360
C2-dibenzothiophene	4.86	540
C3-dibenzothiophene	5.50	460
fluoranthene	5.73	0
pyrene	5.22	0
Total $\log(K_{ow}) \leq 5.6$	5.18	9,272

*Estimates of log(Kow) are from Mackay et al. (1992a,b) and Neff and Burns (1996).

E-I.4 Inputs to the SIMAP Oil Spill Model

This section summarizes the model input data for the scenarios run and the sources for that information. The approach and sources applicable to all modeled locations are described in Part A, Section A.3 of this technical report. Specifics to this model location are below. Thus, the reader should refer to Part A, Section A.3 for background and the context within which these data are used.

The model grid and cell size (Table E-I.4-4) were set to provide the maximum resolution (minimum cell size) possible within the memory constraints of the model, while also providing sufficient geographic coverage to encompass the maximum extent of oiling possible for a large volume scenario. Test runs (randomizing weather conditions) were made with the largest spill volume simulated (40,000 bbl) and assuming no dispersant application. The maximum extent of surface oiling was determined and the grid size set to cover that area (Figure E-I.1.3-1).

Table E-I.4-1. Inputs to the Fates Model for Stochastic Scenarios.

Name	Description	Units	Source(s) of Information	Value(s)
Spill Site(s)	Location of the spill site	-	(Part A, Section A.3.6)	Spill site 7.5 nmiles from entrance to port
Spill Latitude	Latitude of the spill site	Degrees	Chart (Part A, Section A.3.6)	37^{o} 44.9579' N
Spill Longitude	Longitude of the spill site	Degrees	Chart (Part A, Section A.3.6)	122^{o} 40.2159' W
Depth of release	Depth below the water surface of the release or 0 for surface release	m	assumed (Part A, Section A.3.6)	0 m
Start time and date	Randomized over selected months of the year	Date, hr,min	randomized (Part A, Section A.2.4)	Jan-Dec
Spill duration	Hours over which the release occurs	Hours	(Part A, Section A.3.6)	Large – 4 Small – 1
Total spill amount	Total volume (or weight) released (maximum if range)	bbl	(Part A, Section A.3.6)	Large – 40,000 Small – 2,500
Randomize spill amount	Volume spilled is constant or maximum of range	-	-	Constant
Model time step	Time step used for model calculations	Hours	(Part A, Section A.2.1)	0.2
Model duration	Length of each model simulation	Days	(Part A, Section A.3.6)	14 days
Number of runs	Number of random start times to run in stochastic mode	#	(Part A, Section A.2.4)	100
Number of surface spillets	Number of Lagrangian elements used to simulate mass floating on the surface	#	(Part A, Section A.2)	500
Number of aromatic spillets	Number of Lagrangian elements used to simulate dissolved aromatics in the water	#	(Part A, Section A.2)	2000

Table E-I.4-1. Inputs to the Fates Model for Stochastic Scenarios (continued).

Fates Output Threshold: floating on water surface	Slick or surface mass thickness passing through a grid cell	g/m^2 (microns)	Minimum value for sheens (Part A, Section A.4.1)	0.01
Fates Output Threshold: shoreline	Total hydrocarbons deposited on shorelines, averaged over each habitat grid cell.	g/m^2 (microns)	Minimum value for sheens (Part A, Section A.4.1)	0.01
Fates Output Threshold: dissolved aromatics in water or sediment	Dissolved concentration of aromatics with $\log(K_{ow}) \leq 5.6$ (bioavailable fraction)	mg/m^3 = $\mu g/L$ = ppb	Below minimum for effects to sensitive species exposed for at least two weeks (Part A, Section A.4.1)	1
Fates Output Threshold: Subsurface (water) total hydrocarbons	Concentration of total hydrocarbons in droplets	mg/m^3 = $\mu g/L$ = ppb	Minimum value with no potential for impact (Part A, Section A.4.1)	10
Fates Output Threshold: Sediment total hydrocarbons	Total hydrocarbon loading to sediments, averaged over each habitat grid cell.	g/m^2	Minimum value with no potential for impact (Part A, Section A.4.1)	0.0001 g/m^2 (which is 1.0 mg/m^3 = 1ppb averaged over the top 10cm)
Salinity	Surface water salinity	ppt	French et al. (1996b) province 44	33

Table E-I.4-1. Inputs to the Fates Model for Stochastic Scenarios (continued).

Surface Water Temper-ature	Water temperature at the sea surface	Degrees C	French et al. (1996b) province 44	monthly means (see Table E-I.4-5)
Subsurface Water Temper-ature	Water temperature for subsurface	Degrees C	French et al. (1996b) province 44	monthly means (see Table E-I.4-5)
Air Temper-ature	Air water temperature at water surface	Degrees C	(assume = water temperature; Part A, Section A.4.1)	(= water temperature)
Fetch	Fetch = distance to land to N, S, E, W (if landfall not in model domain)	km	Chart	N & E: (calculated from model grid) W: 1,000 S: 1,000
Wind drift speed	Speed oil moves down wind relative to wind	% of wind speed	Youssef (1993); Youssef and Spaulding (1993)	(model calculated)
Wind drift angle	Angle to right of wind (in northern hemisphere) that oil drifts	Deg. to right of down wind	Youssef (1993); Youssef and Spaulding (1993, 1994)	(model calculated)
Horizontal turbulent diffusion coefficient	Randomized turbulent mixing parameter in x & y	m^2/sec	French et al. (1996a, 1999) based on Okubo (1971)	1 m^2/sec (estuaries and low energy coastal areas)
Vertical turbulent diffusion coefficient	Randomized turbulent mixing parameter in z	m^2/sec	French et al. (1996a, 1999) based on Okubo (1971)	0.0001 m^2/sec
Suspended sediment concentrati on	Average suspended sediment concentration during spill period	mg/l	French et al. (1996b)	10 mg/l
Suspended sediment settling rate	Net settling rate for suspended sediments	m/day	French et al. (1996b)	1 m/day
Density change	Rate of change of droplet density due to adsorption of sediment	g/cm^3/hr	(data not available – fuel oil algorithm used)	0

Table E-I.4-2. Description of scenario runs.

Scenario Name	Description
SF-Lrg-50-0	Large Spill; Removal at 50%; No Dispersant;
SF-Lrg-50-80	Large Spill; Removal at 50%; Dispersant at 80% efficiency;
SF-Lrg-50-45	Large Spill; Removal at 50%; Dispersant at 45% efficiency;
SF-Med-50-0	Medium Spill; Removal at 50%; No Dispersant;
SF-Med-50-80	Medium Spill; Removal at 50%; Dispersant at 80% efficiency;
SF-Med-50-45	Medium Spill; Removal at 50%; Dispersant at 45% efficiency;

Table E-I.4-3. Matrix of scenarios run.

Scenario Name	Fuel	Latitude, Longitude	Depth (m)	Duration (hr)	Volume (bbl) Released	Mechanical Removal Efficiency	Dispersant Efficiency
SF-Lrg-50-0	Alaskan North Slope crude	37.74930 N 122.67027 W	0 m (surface)	4	40,000	50%	none
SF-Lrg-50-80	Alaskan North Slope crude	37.74930 N 122.67027 W	0 m (surface)	4	40,000	50%	80%
SF-Lrg-50-45	Alaskan North Slope crude	37.74930 N 122.67027 W	0 m (surface)	4	40,000	50%	45%
SF-Med-50-0	Alaskan North Slope crude	37.74930 N 122.67027 W	0 m (surface)	1	2,500	50%	none
SF-Med-50-80	Alaskan North Slope crude	37.74930 N 122.67027 W	0 m (surface)	1	2,500	50%	80%
SF-Med-50-45	Alaskan North Slope crude	37.74930 N 122.67027 W	0 m (surface)	1	2,500	50%	45%

Table E-I.4-4. Dimensions of the habitat grid cells used to compile statistics for multiple fates model runs.

Item	Value
Grid W edge	123.017°W
Grid S edge	36.905°N
Cell size (°longitude)	0.002
Cell size (°latitude)	0.002
Cell size (m) west-east	177.52
Cell size (m) south-north	222
# cells west-east	619
# cells south-north	599
Water cell area (m^2)	39,409.07
Shore cell length (m)	198.52
Shore cell width – Rocky shore (m)	2.0
Shore cell width – Artificial shore (m)	2.0
Shore cell width – Gravel beach (m)	5.0
Shore cell width – Sand beach (m)	10.0
Shore cell width – Mud flat (m)	120.0
Shore cell width – Wetlands (fringing, m)	120.0

Table E-I.4-5. Water temperature by month of the year (from French et al., 1996b).

Month	Surface Water Temperature (°C)	Bottom Water Temperature (°C)	Pycnocline Depth (m)
January	13	12	20
February	13	12	20
March	13	12	20
April	12	12	20
May	12	12	20
June	13	12	20
July	14	13	10
August	15	13	10
September	15	13	10
October	14	13	20
November	14	13	20
December	13	13	20

Table E-I.4-6. Wind data sources and records used.

File Name	Location	Latitude Longitude	Dates	Data Source
96 TO 01 46026.WNE	Buoy 46026 - San Francisco	37.75 N 122.82 W	1988 to 2001	National Data Buoy Center

All acquired buoy data contained large amounts of missing data. To obtain a wind record sufficient for the model to use, the gaps data were filled for buoy 46026 – San Francisco. Data was filled using the other three buoys 46012 - Half Moon Bay, 46013 – Bodega, 46042 – Monterey in that order. Hourly mean wind speed and direction for 6 January 1988 to 31 May 2001 from the filled 46026 buoy data were compiled in the SIMAP model input file format.

Figure E-I.4-1. Wind Station Locations. (The crosshair mark (⊞) represents the oil spill site.)

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part E: San Francisco Bay and Central California Shelf

Section E-II.1

by

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ASA 00-246

August 2004

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E-II.1 Results of the Stochastic Modeling: Maps of Exposure Probability, Time and Maximum Possible Mass and Concentration

The results of multiple model runs are evaluated to develop the following statistics, for each location (cell in the model grid) and for each exposure index. Maps of the results are contained in this section.

- Probability of exposure greater than the minimum threshold (probability that the minimum threshold thickness or concentration will be exceeded at each location at any time following the spill). For surface oil, the model records if any oil of greater than that thickness passes through the grid cell, regardless of the areal coverage of the oil. For concentrations, the average concentration in the grid cell is used to determine if the threshold is exceeded.
- Time (hours) to first exceedance of the minimum threshold at each location
- Worst-case maximum exposure (thickness, volume or concentration) at any time after the spill, at a given location (peak exposure at each location delineated by the grid cells). The amounts are averaged over the area of the model grid cell. The worst-case maximum amount is for all possible releases (i.e., maximum peak exposure for all the model runs). This is calculated in two steps: (1) For each individual run (for each spill date run), the maximum amount over all time after the spill is saved for each location in the model grid. (2) The runs are evaluated to determine the highest amount possible at each location. Note that these *worst-case maximum* amounts are not additive over all locations. These represent maximum possible amounts of oil that could ever reach each site (grid cell), considered individually, and based on the model runs performed. Thus, "worst-case" represents the highest exposure of the most adverse of the runs performed.

Exposure indices and minimum thresholds (i.e., those less than values that might have an impact on any resource) used in the modeling were:

- Surface slick or floating oil: $\geq$ 0.01 g/m^2 (average thickness $\geq$ 0.01 micron)
- Shoreline: average mass loading over the shore segment (length of one grid cell, calculated as the cell diagonal length, times the typical width for the habitat type) $\geq$ 0.01 g/m^2
- Dissolved aromatics: average over the water cell $\geq$ 1 ppb (1 mg/m^3)
- Subsurface oil (entrained in water): average over the water cell $\geq$ 10 ppb (10 mg/m^3)
- Sediment total hydrocarbons: average over the cell $\geq$ 0.0001 g/ m^2

Sediment dissolved aromatic concentrations: average over the cell $\geq$ 0.0001 g/ m^2 (which is 1.0 mg/m^3 = 1ppb averaged over the top 10 cm, the assumed bioturbation zone)

Discussion of exposure indices and minimum thresholds are described in Part A: Description of Models and Assumptions and Section 4.3 of the PEIS.

The Crosshair mark (⊞) in figures below represents oil spill site.

E-II.1.1. Scenario: Medium Volume, No Dispersant

E-II.1.1.1 Surface Floating Total Hydrocarbons. Scenario: Medium Volume, No Dispersant

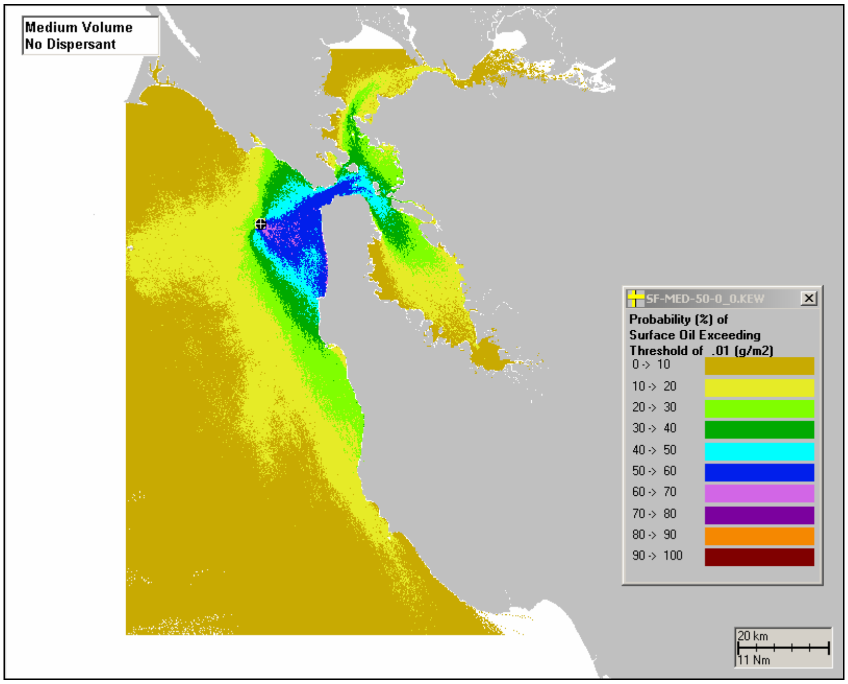

Figure E-II.1.1.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Medium Volume, No Dispersant.

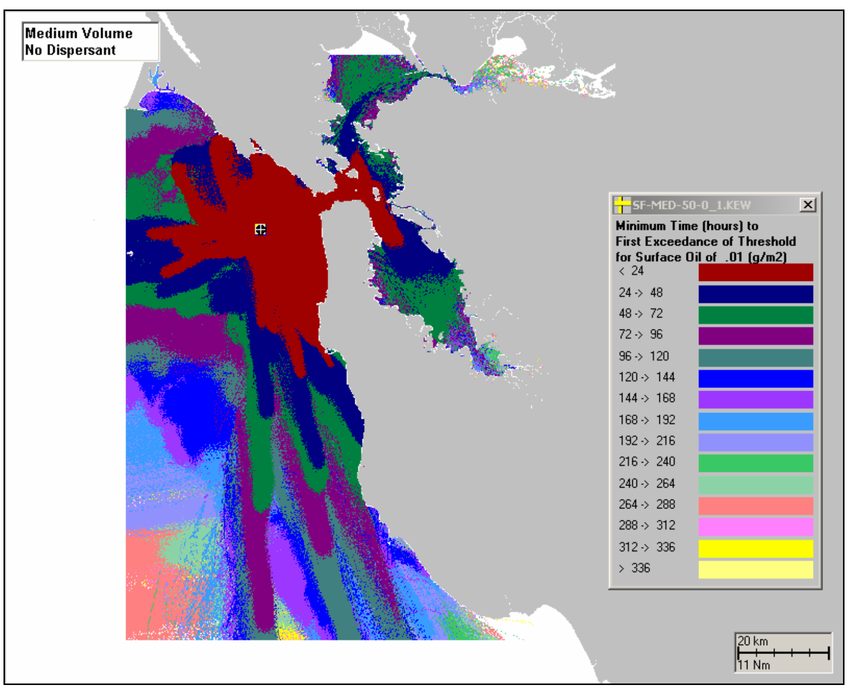

Figure E-II.1.1.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Medium Volume, No Dispersant.

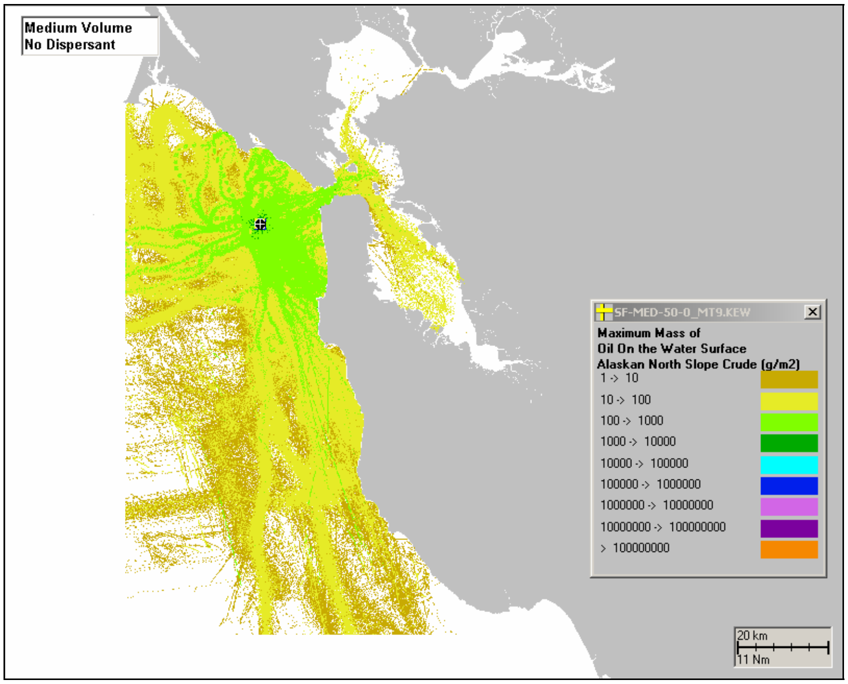

Figure E-II.1.1.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

E-II.1.1.2 Shoreline Oiled. Scenario: Medium Volume, No Dispersant

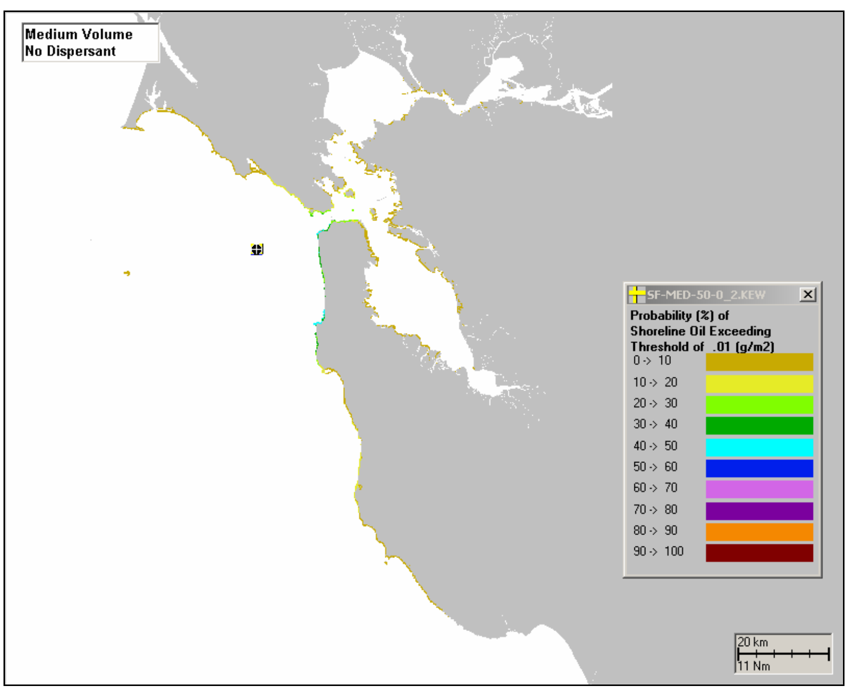

Figure E-II.1.1.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Medium Volume, No Dispersant.

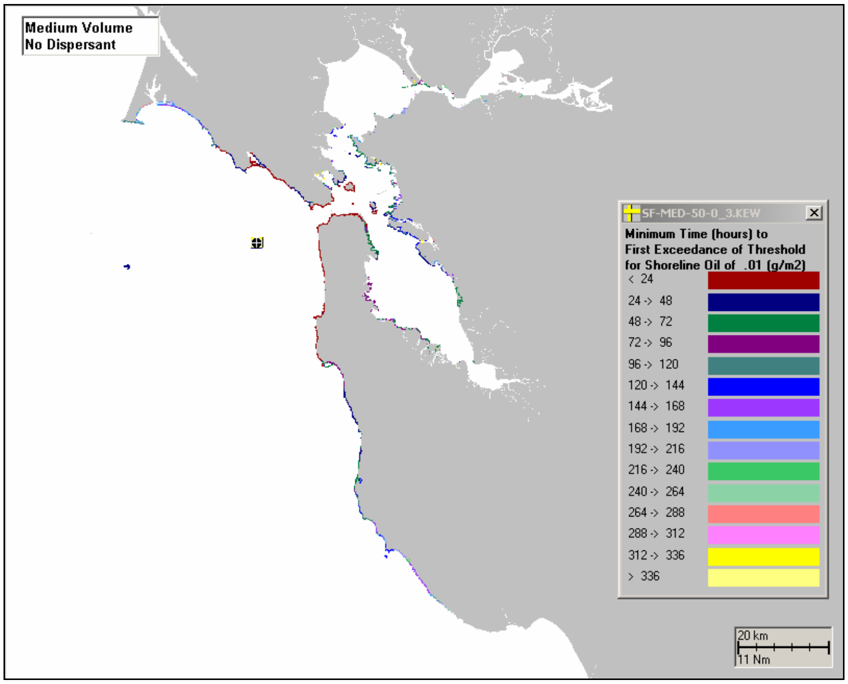

Figure E-II.1.1.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Medium Volume, No Dispersant.

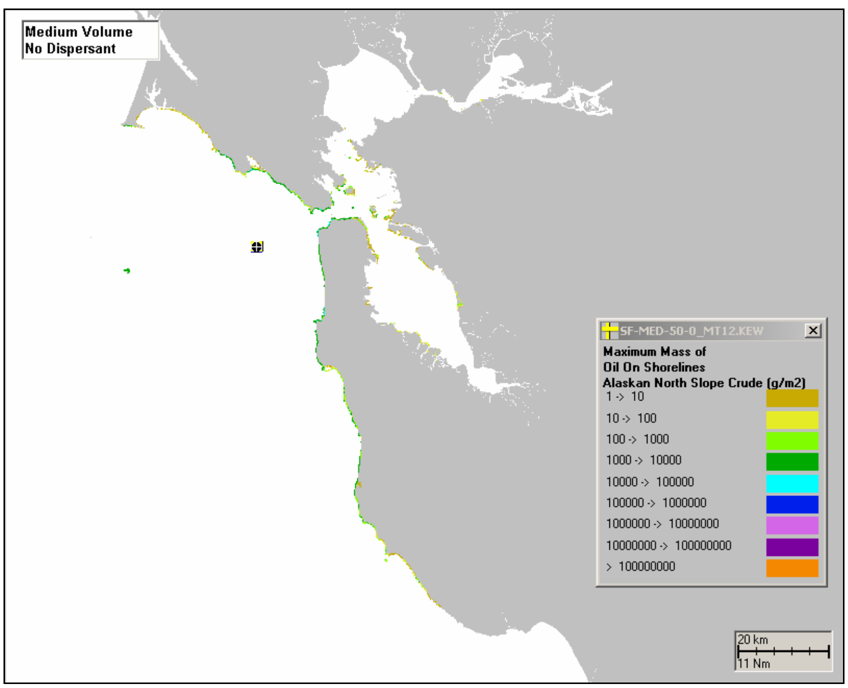

Figure E-II.1.1.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

E-II.1.1.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Medium Volume, No Dispersant

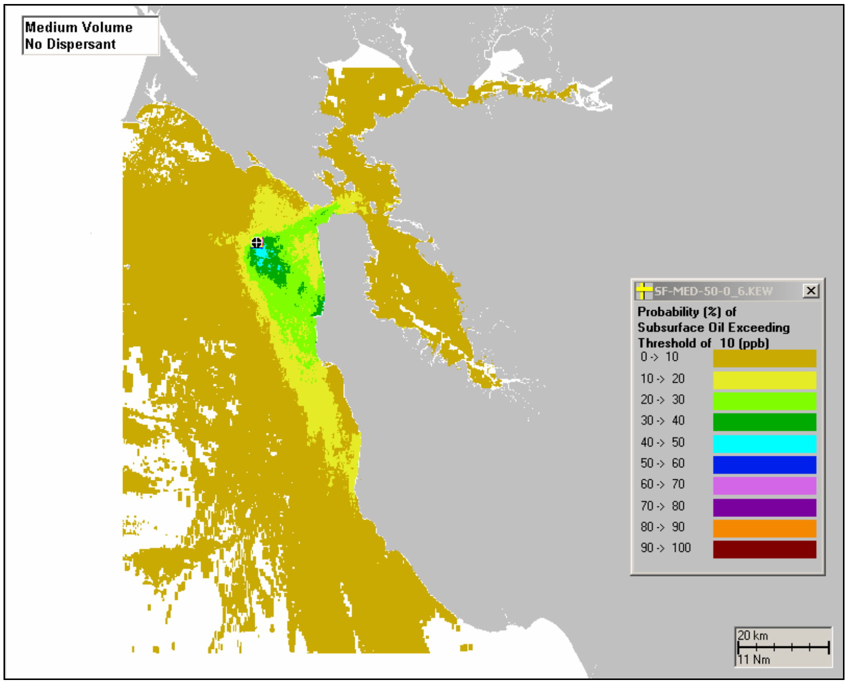

Figure E-II.1.1.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Medium Volume, No Dispersant.

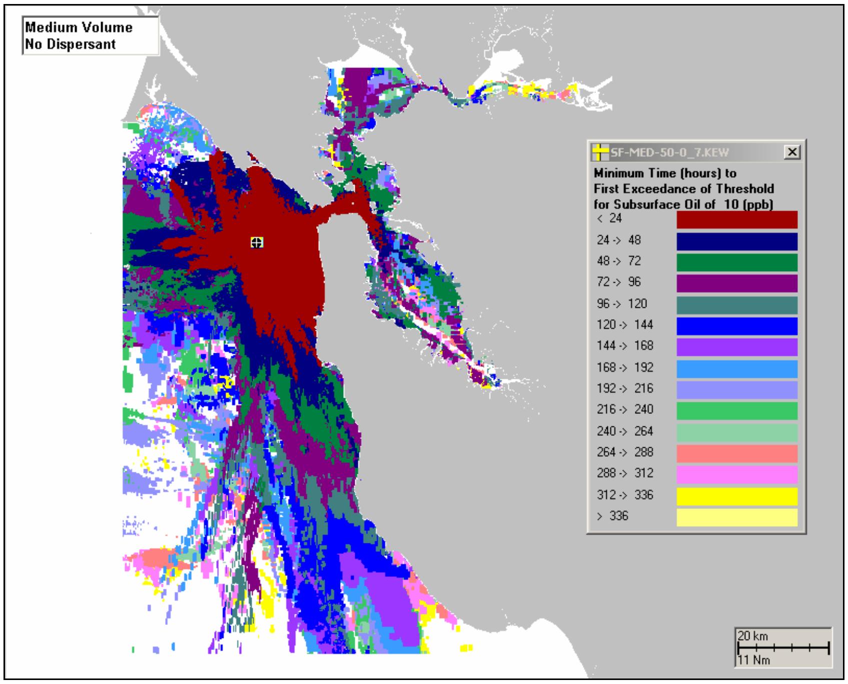

Figure E-II.1.1.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Medium Volume, No Dispersant.

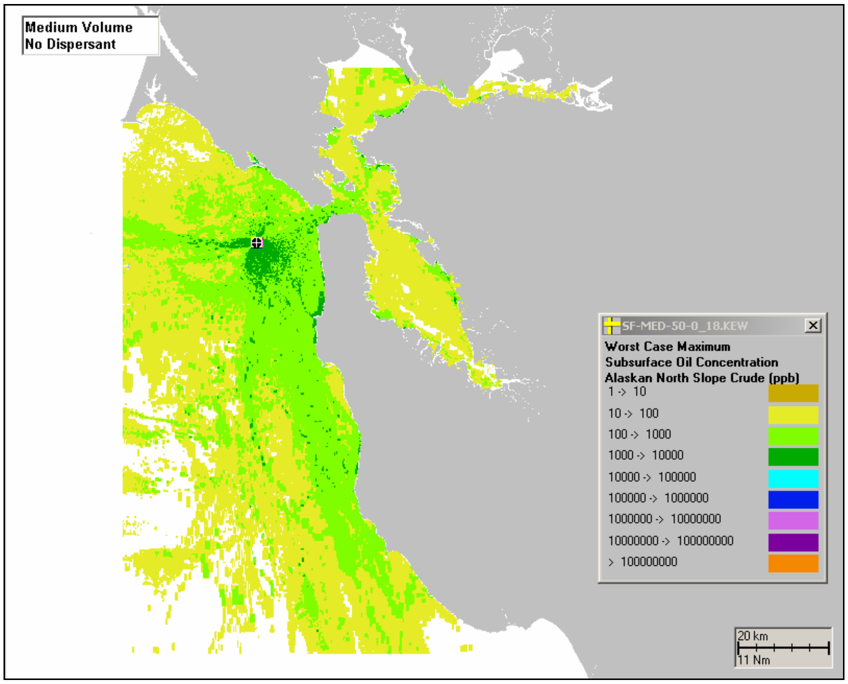

Figure E-II.1.1.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

E-II.1.1.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Medium Volume, No Dispersant

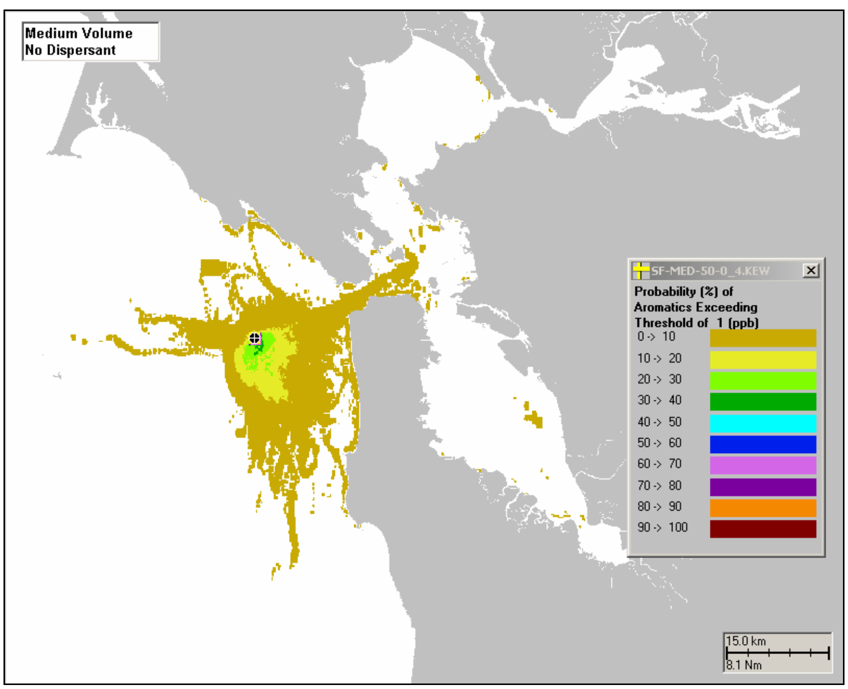

Figure E-II.1.1.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, No Dispersant.

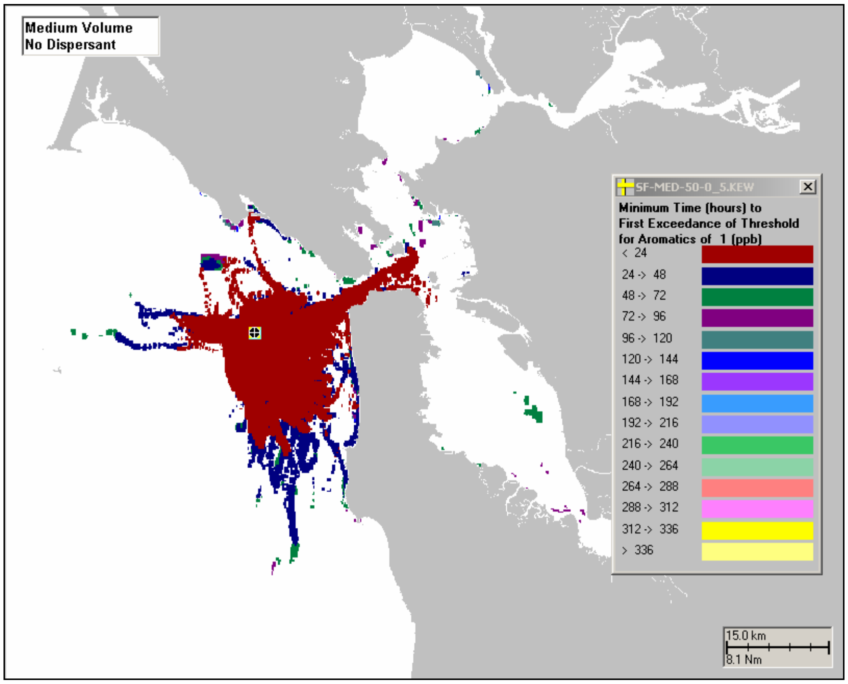

Figure E-II.1.1.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Medium Volume, No Dispersant.

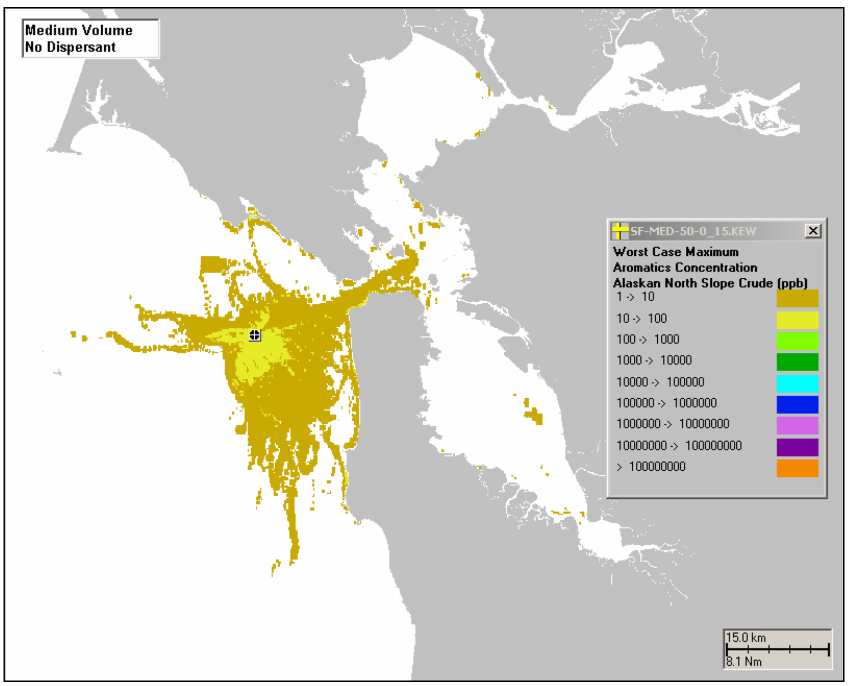

Figure E-II.1.1.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

E-II.1.1.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Medium Volume, No Dispersant

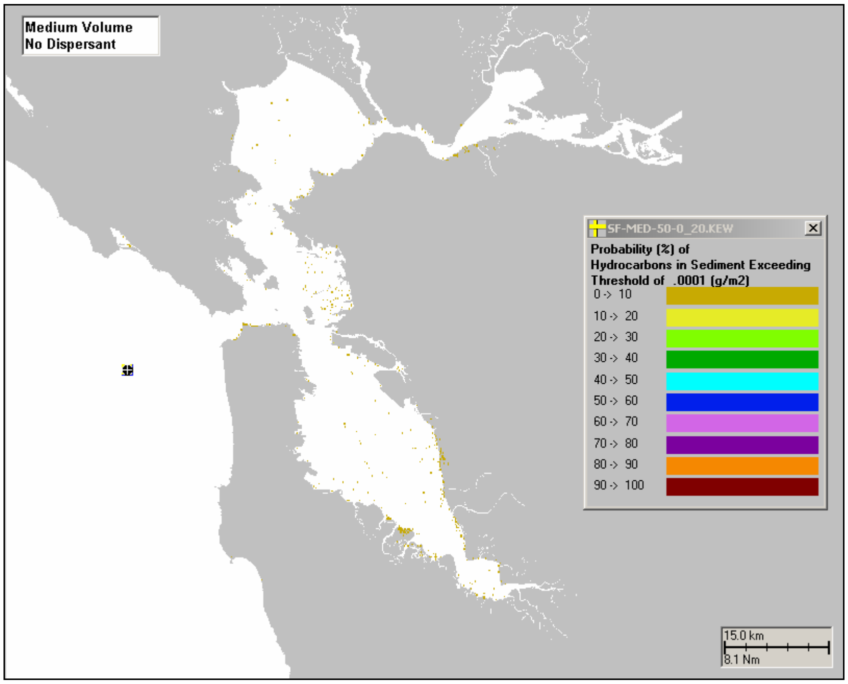

Figure E-II.1.1.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Medium Volume, No Dispersant.

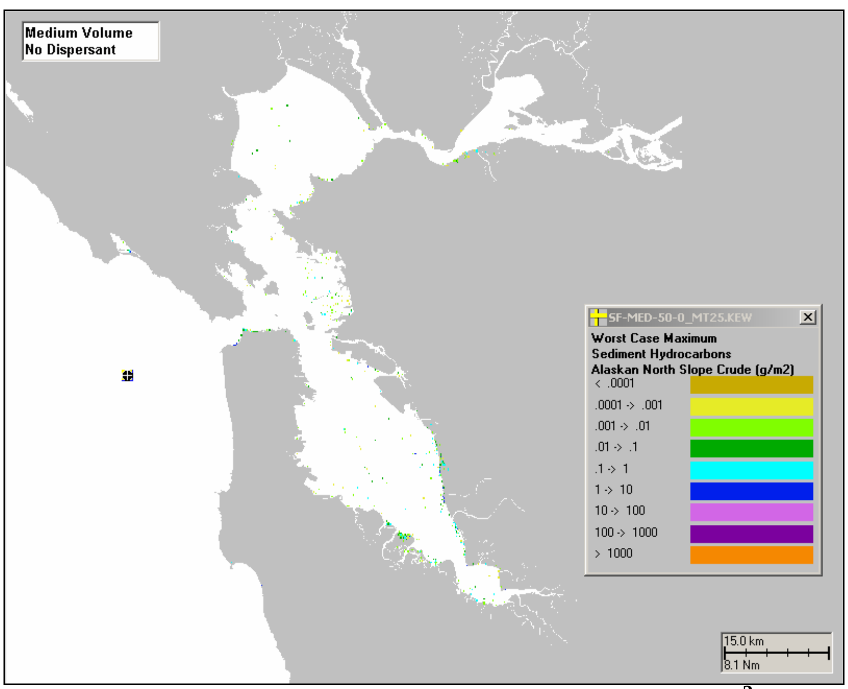

Figure E-II.1.1.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

E-II.1.1.6 Sediment pore water dissolved aromatic concentrations. Scenario: Medium Volume, No Dispersant

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time and for any of the 100 runs) does not exceed threshold of 1 ppb. Scenario: Medium Volume, No Dispersant.

E-II.1.2. Scenario: Medium Volume, 45% Dispersant Efficiency

E-II.1.2.1 Surface Floating Total Hydrocarbons. Scenario: Medium Volume, 45% Dispersant Efficiency

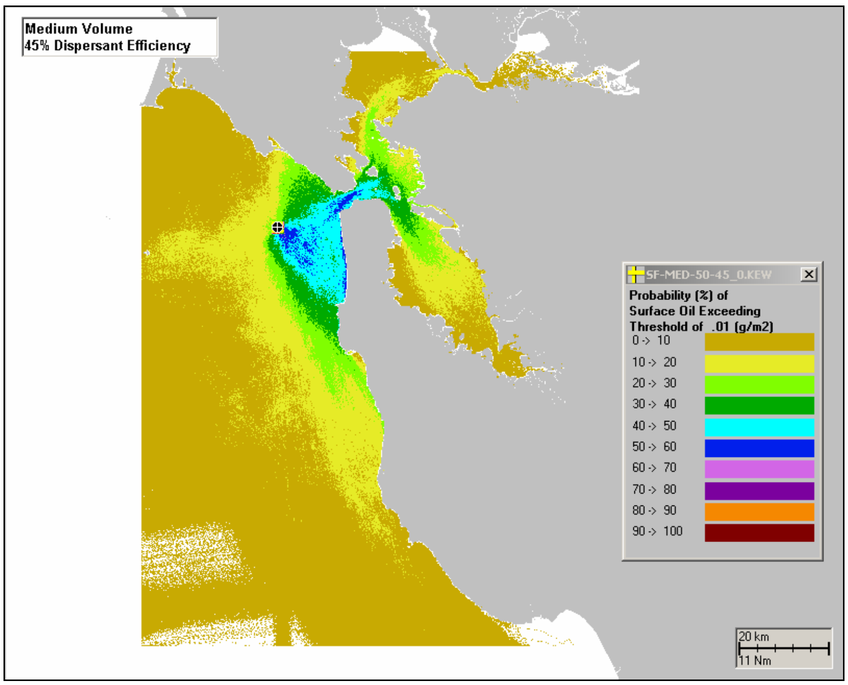

Figure E-II.1.2.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

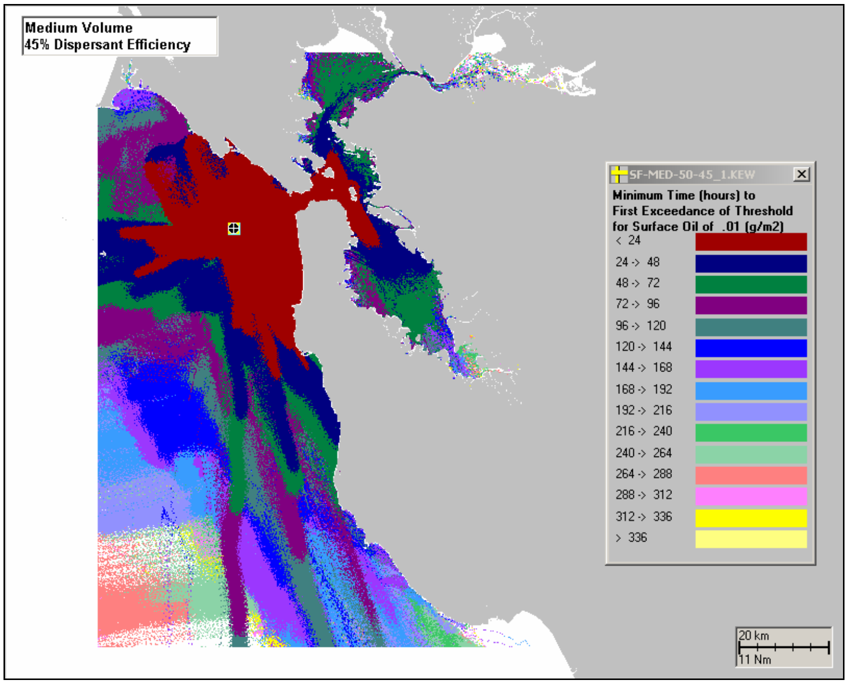

Figure E-II.1.2.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

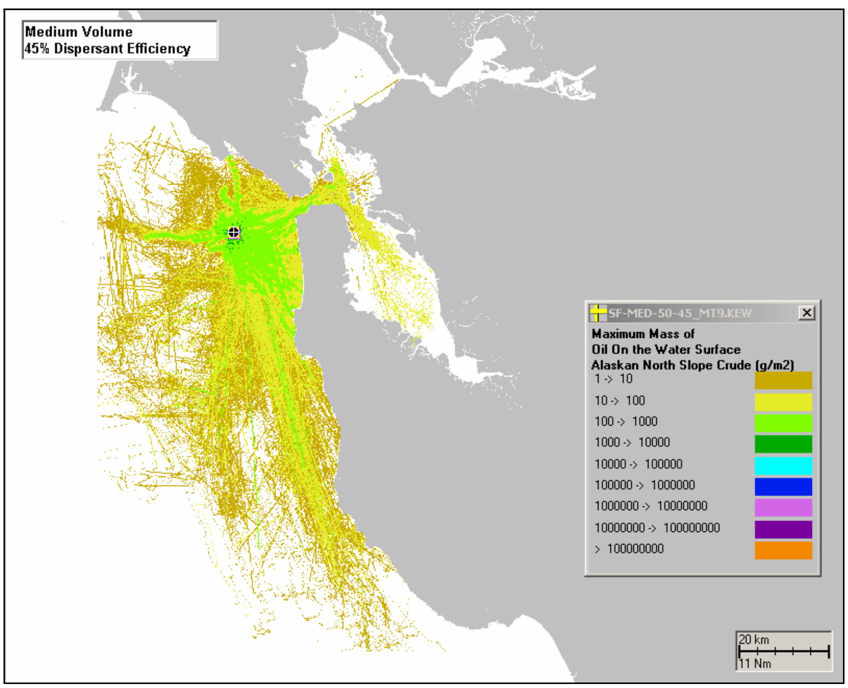

Figure E-II.1.2.1-.3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

E-II.1.2.2 Shoreline Oiled. Scenario: Medium Volume, 45% Dispersant Efficiency.

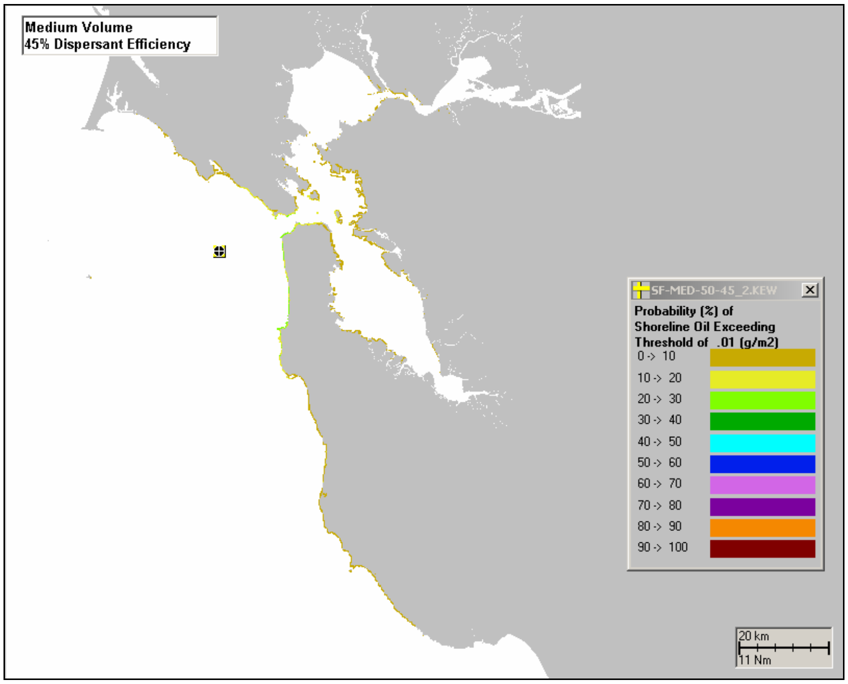

Figure E-II.1.2.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

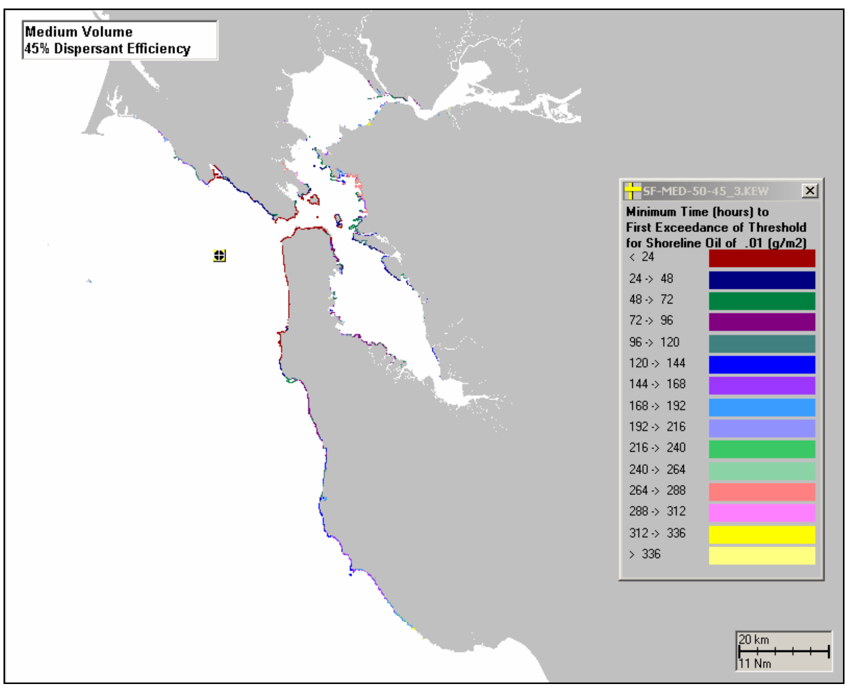

Figure E-II.1.2.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

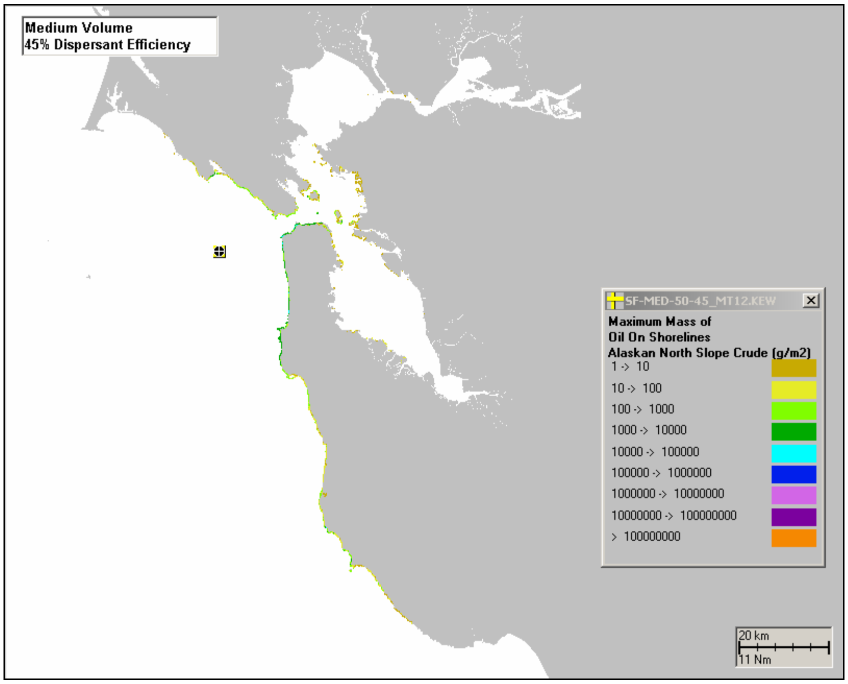

Figure E-II.1.2.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

E-II.1.2.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Medium Volume, 45% Dispersant Efficiency

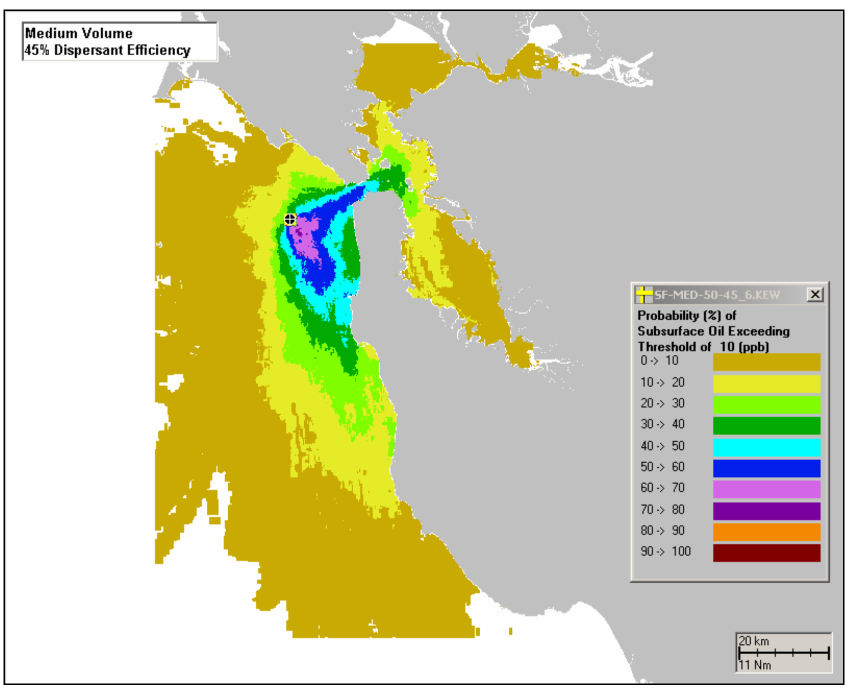

Figure E-II.1.2.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

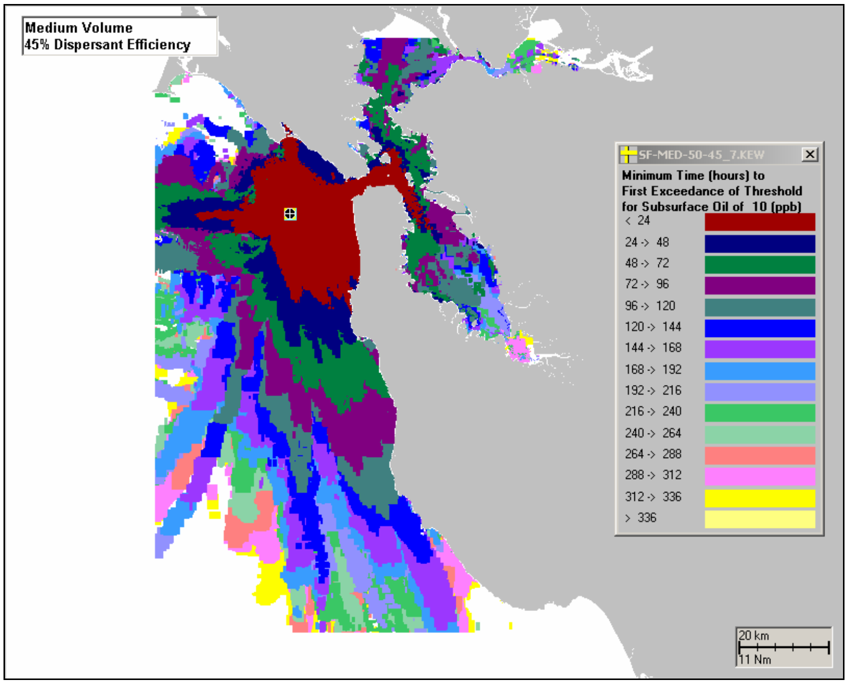

Figure E-II.1.2.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

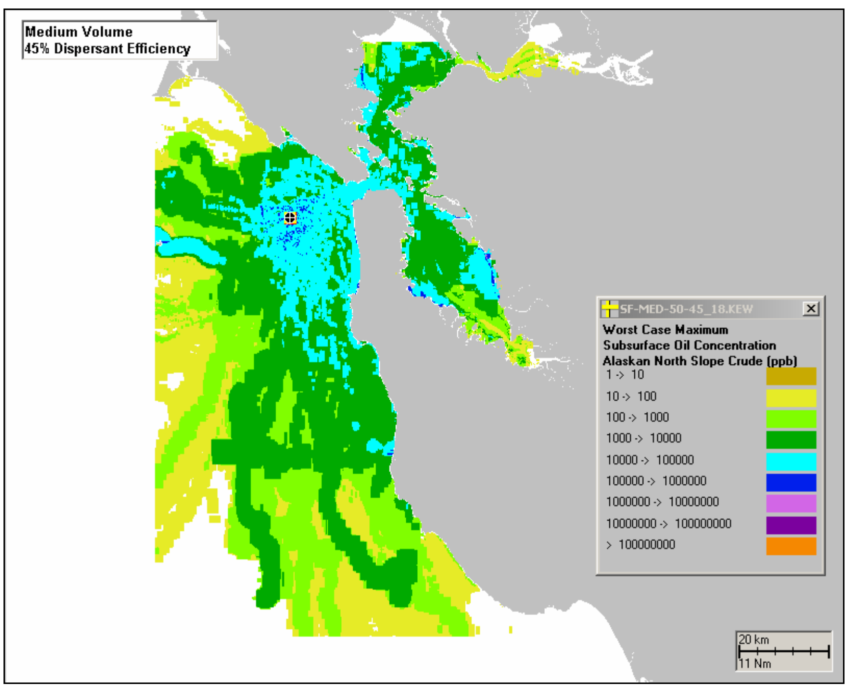

Figure E-II.1.2.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

E-II.1.2.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Medium Volume, 45% Dispersant Efficiency

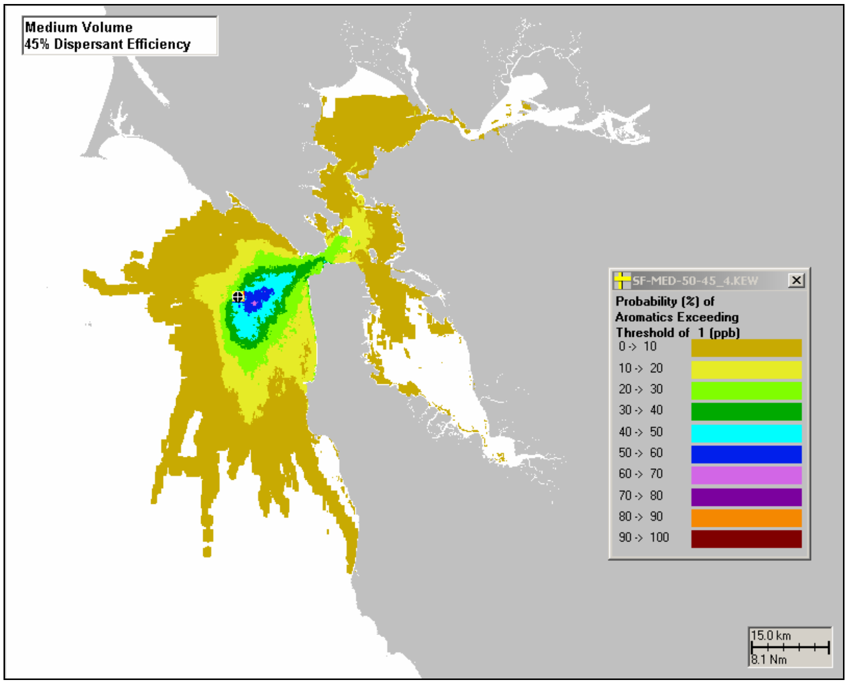

Figure E-II.1.2.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

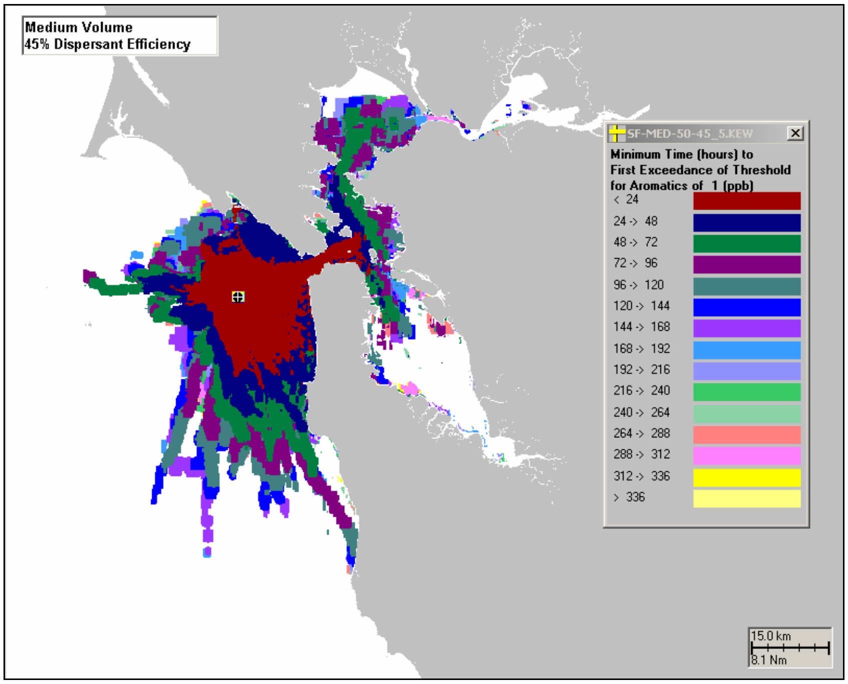

Figure E-II.1.2.4-2 Time (hrs) after spill when Dissolved Aromatic Concentrations could first exceed 1ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

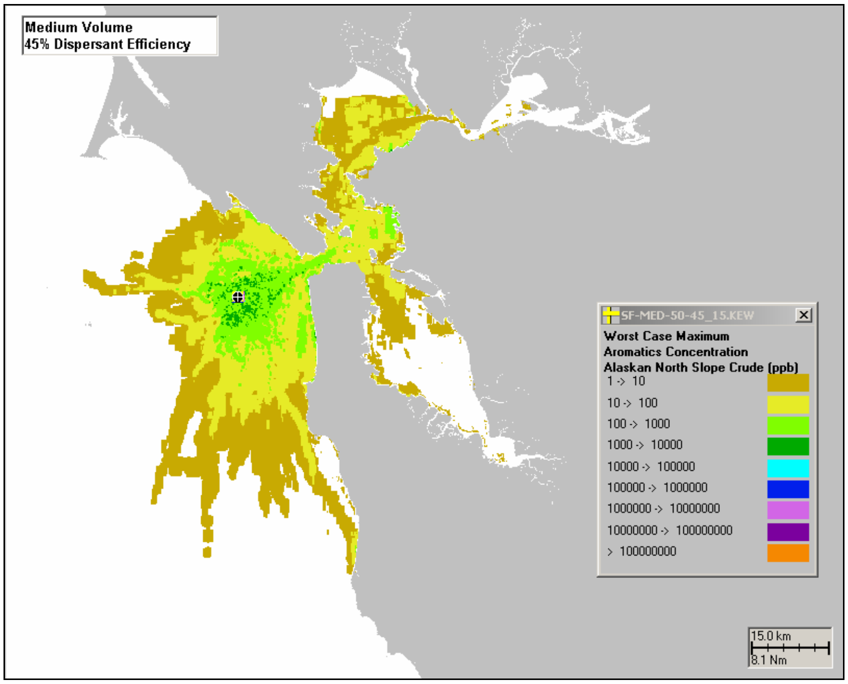

Figure E-II.1.2.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

E-II.1.2.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Medium Volume, 45% Dispersant Efficiency

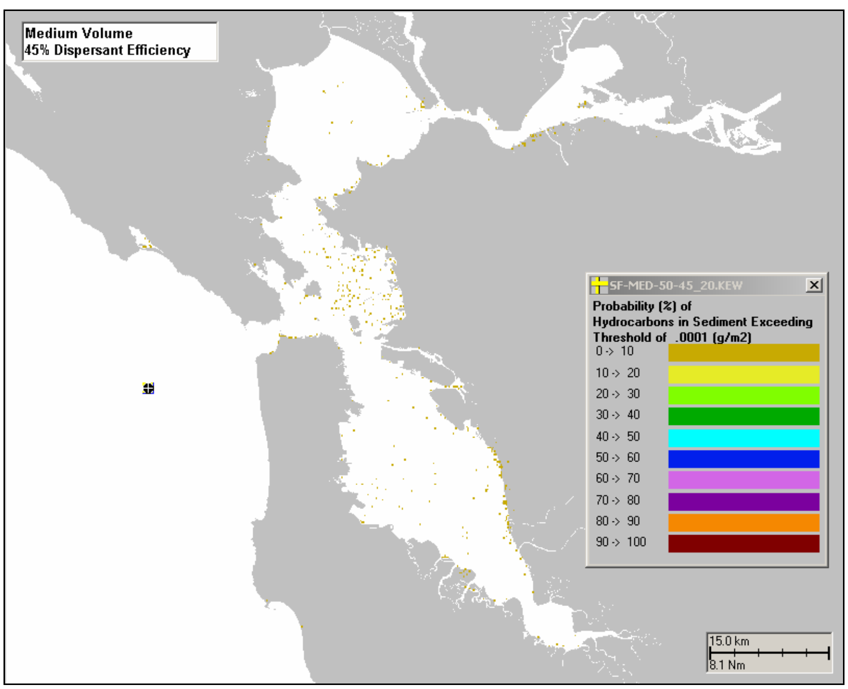

Figure E-II.1.2.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

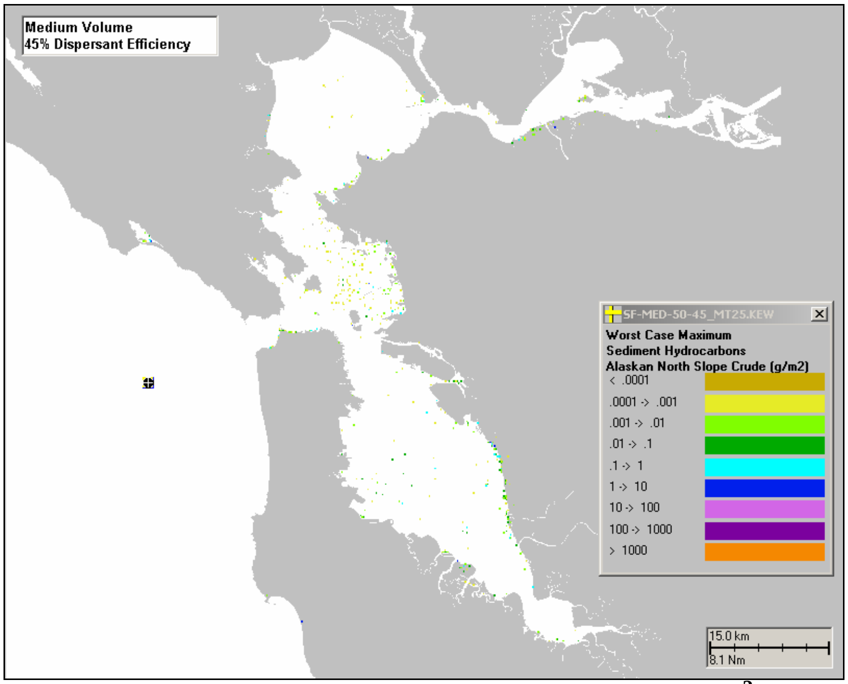

Figure E-II.1.2.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

E-II.1.2.6 Sediment pore water dissolved aromatic concentrations. Scenario: Medium Volume, 45% Dispersant Efficiency

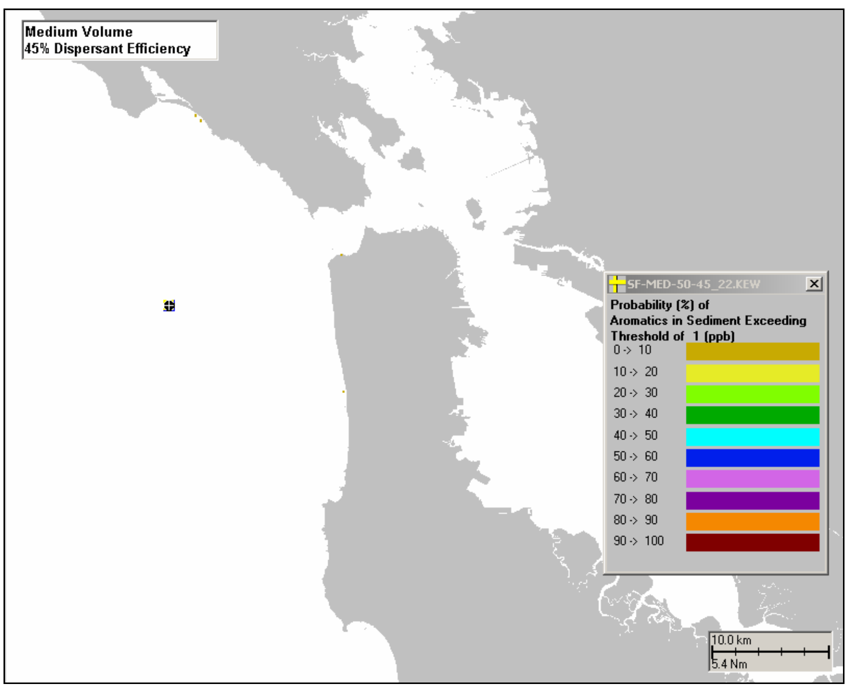

Figure E-II.1.2.6-1 Probability (%) of sediment pore water dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

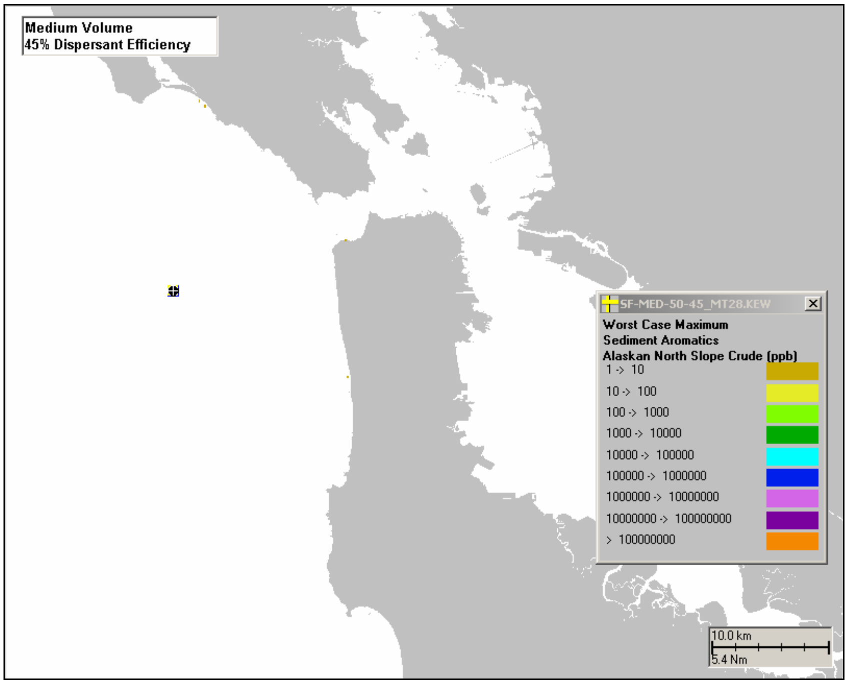

Figure E-II.1.2.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

E-II.1.3. Scenario: Medium Volume, 80% Dispersant Efficiency

E-II.1.3.1 Surface Floating Total Hydrocarbons. Scenario: Medium Volume, 80% Dispersant Efficiency.

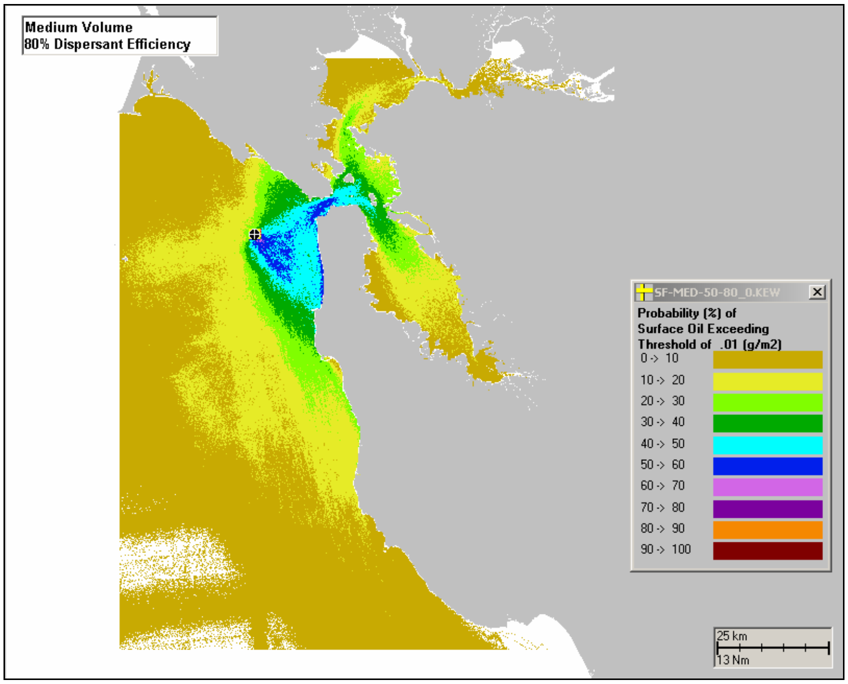

Figure E-II.1.3.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

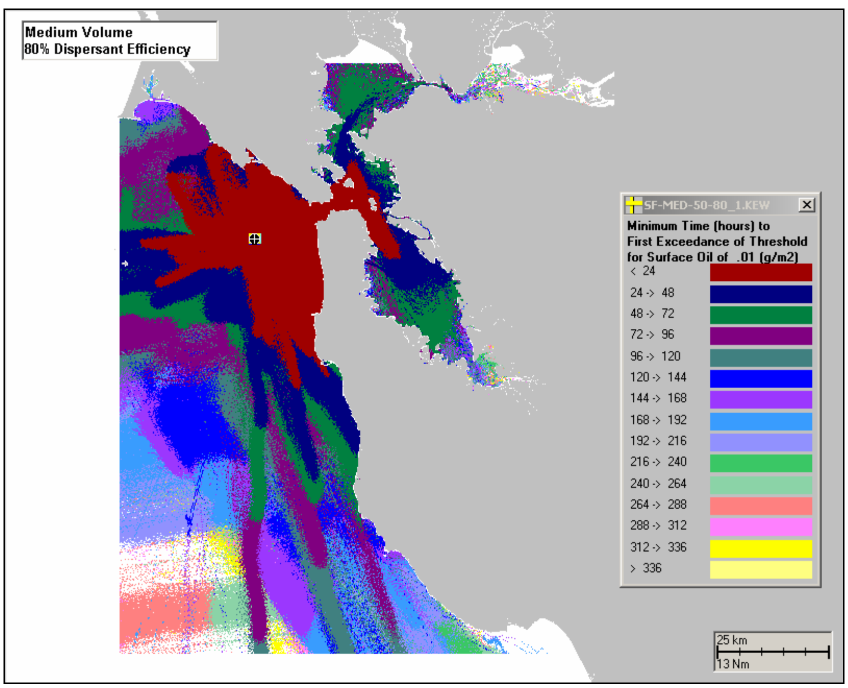

Figure E-II.1.3.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

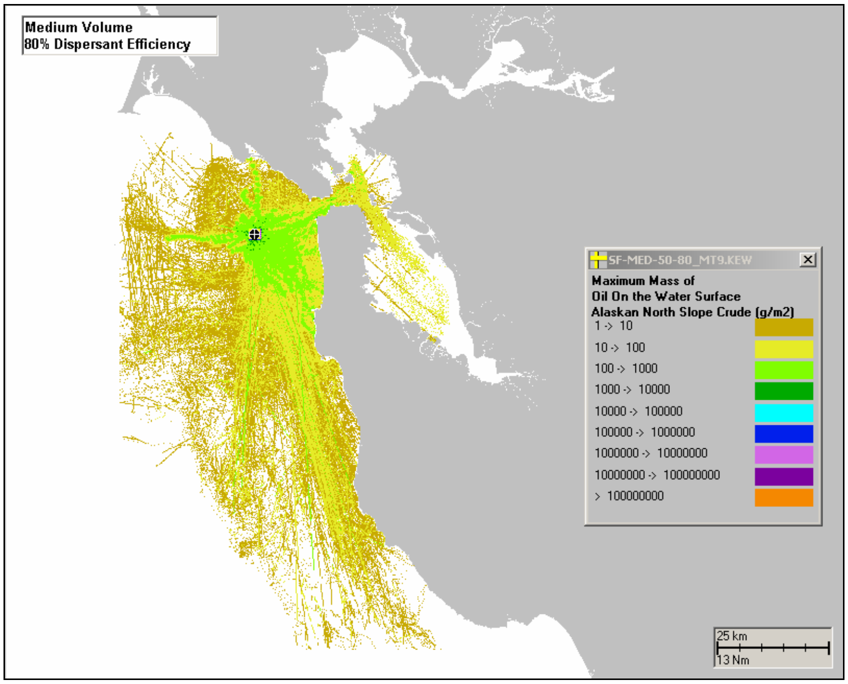

Figure E-II.1.3.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

E-II.1.3.2 Shoreline Oiled. Scenario: Medium Volume, 80% Dispersant Efficiency

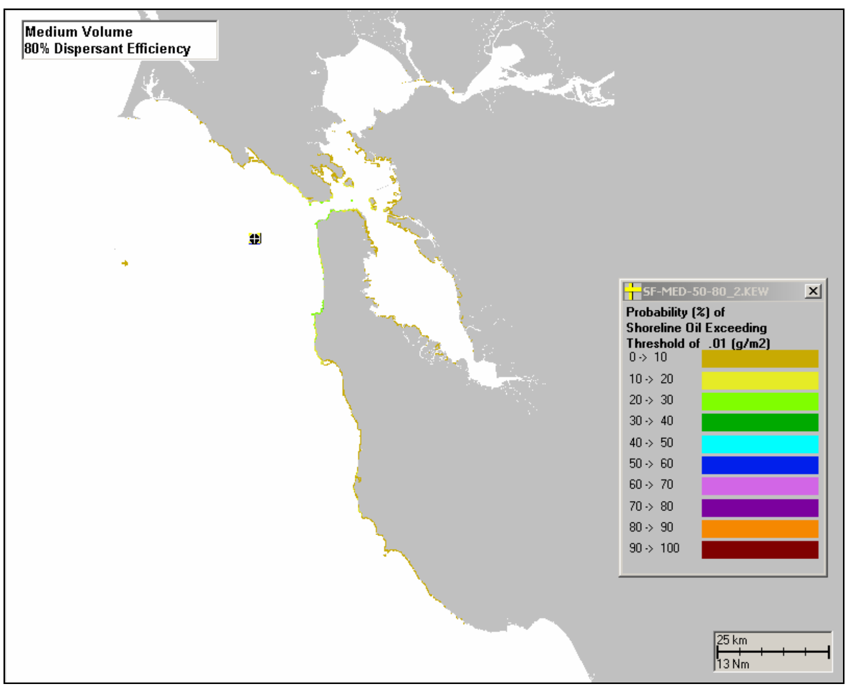

Figure E-II.1.3.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

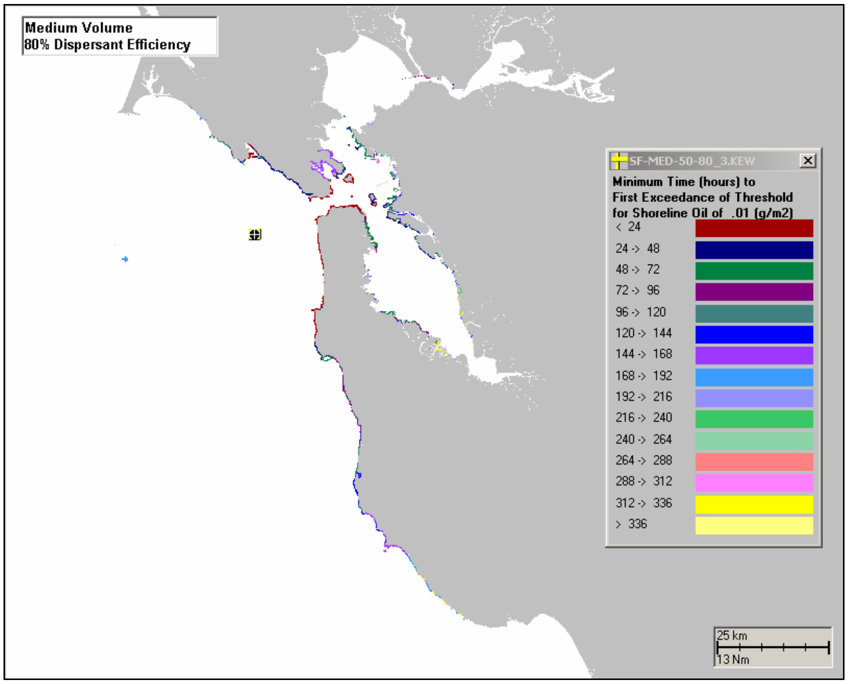

Figure E-II.1.3.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

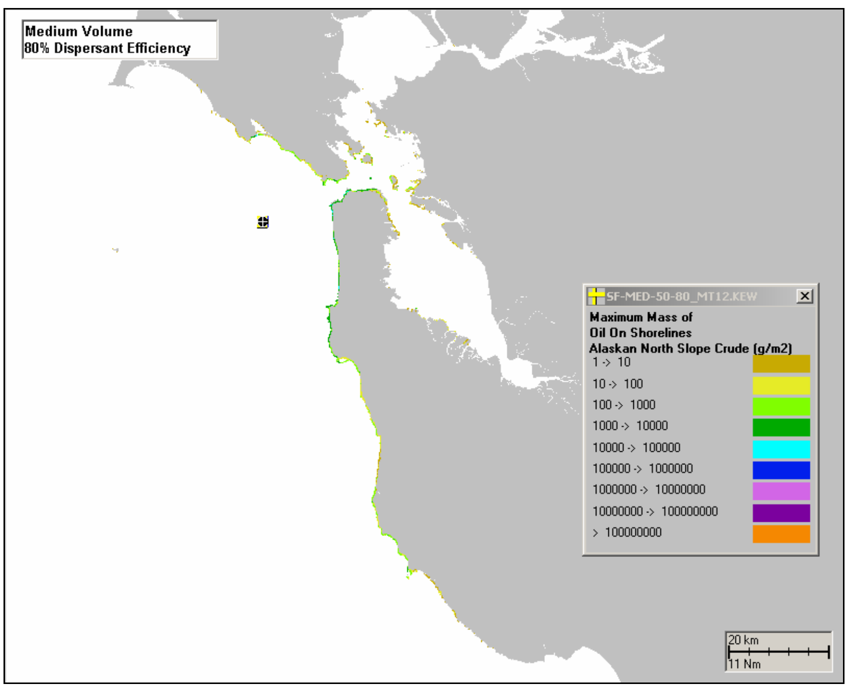

Figure E-II.1.3.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

E-II.1.3.3 Total Hydrocarbon Concentrations in the Water Column.
Scenario: Medium Volume, 80% Dispersant Efficiency

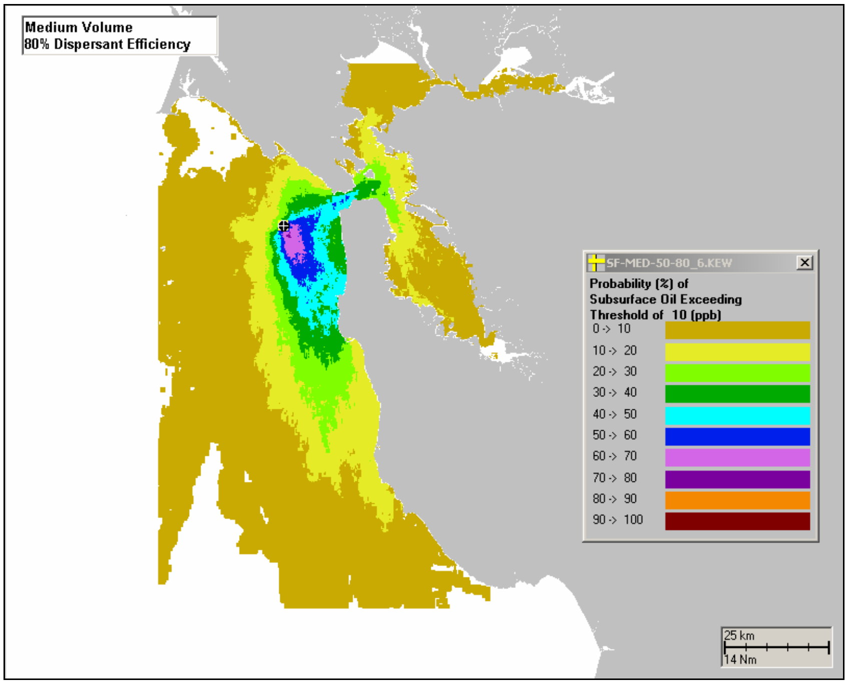

Figure E-II.1.3.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

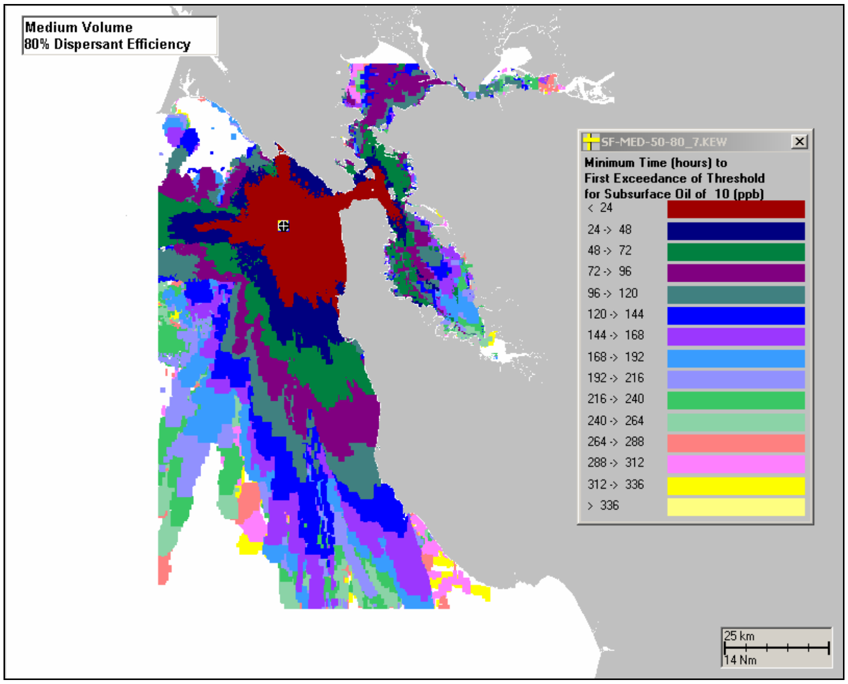

Figure E-II.1.3.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

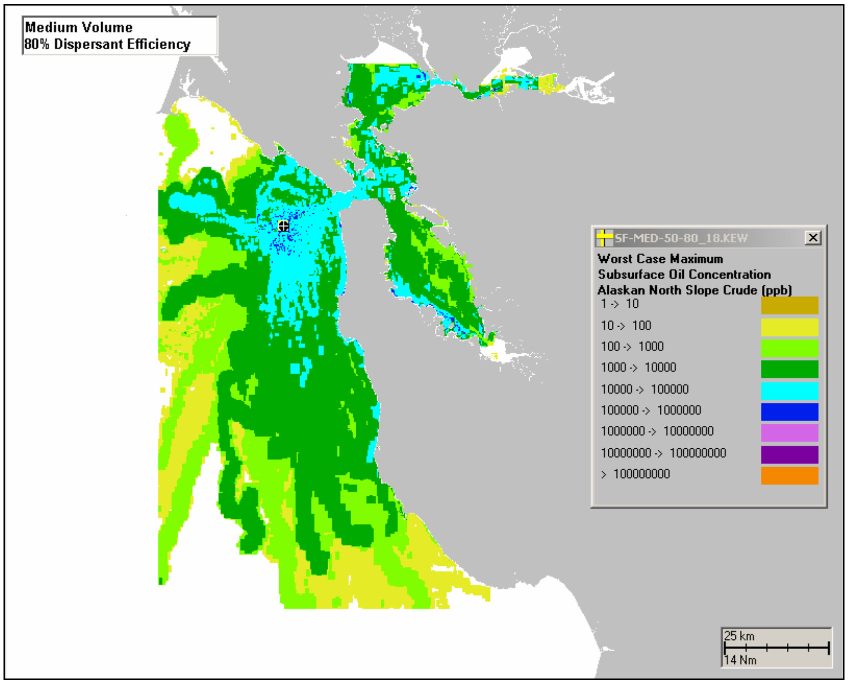

Figure E-II.1.3.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

E-II.1.3.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Medium Volume, 80% Dispersant Efficiency

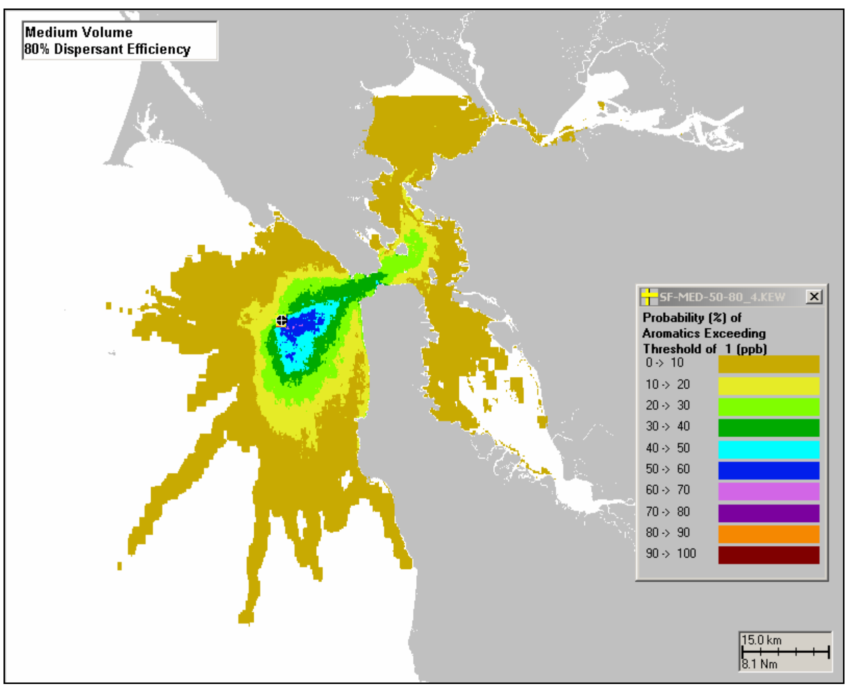

Figure E-II.1.3.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

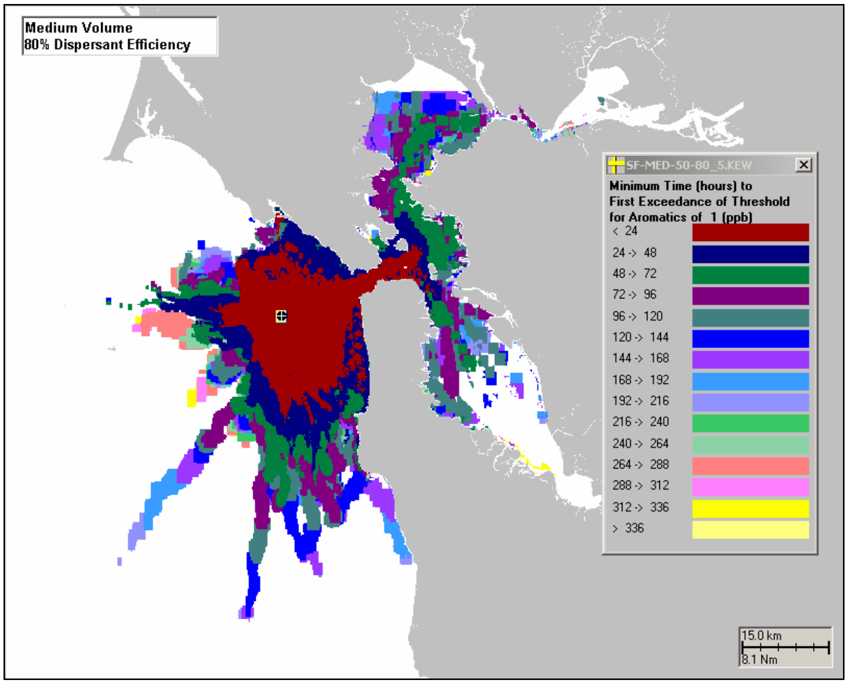

Figure E-II.1.3.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

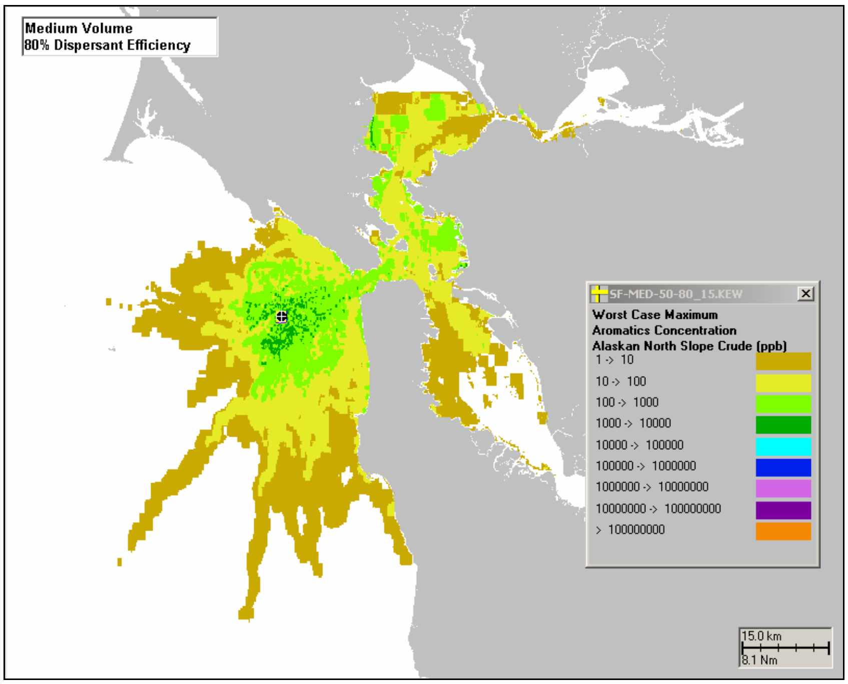

Figure E-II.1.3.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

E-II.1.3.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Medium Volume, 80% Dispersant Efficiency

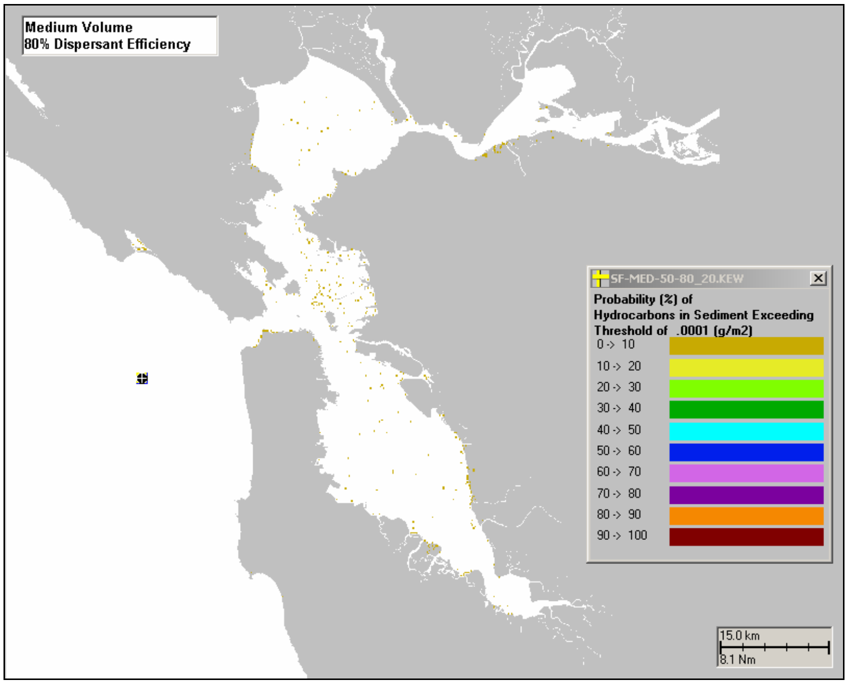

Figure E-II.1.3.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

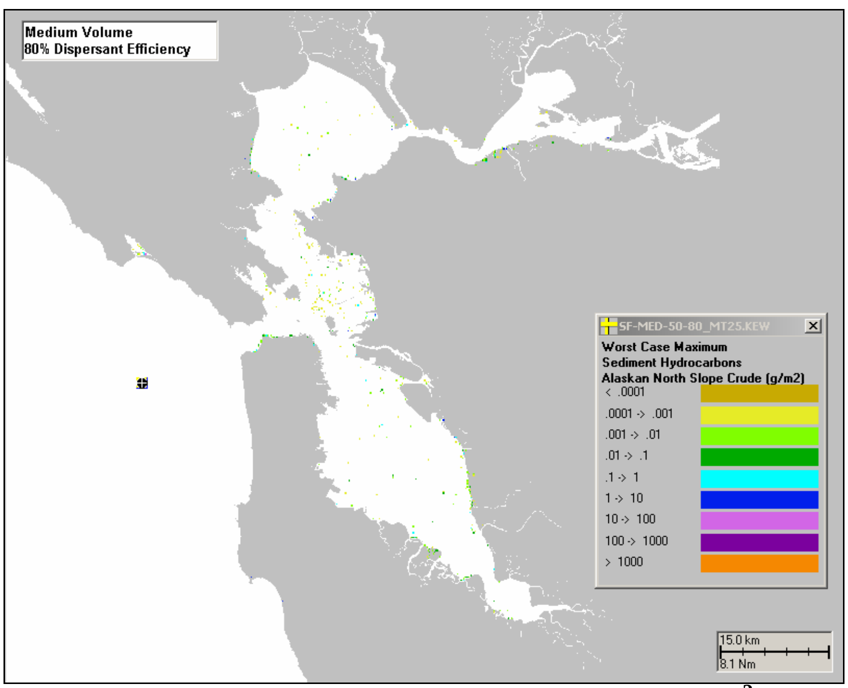

Figure E-II.1.3.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

E-II.1.3.6 Sediment pore water dissolved aromatic concentrations. Scenario: Medium Volume, 80% Dispersant Efficiency

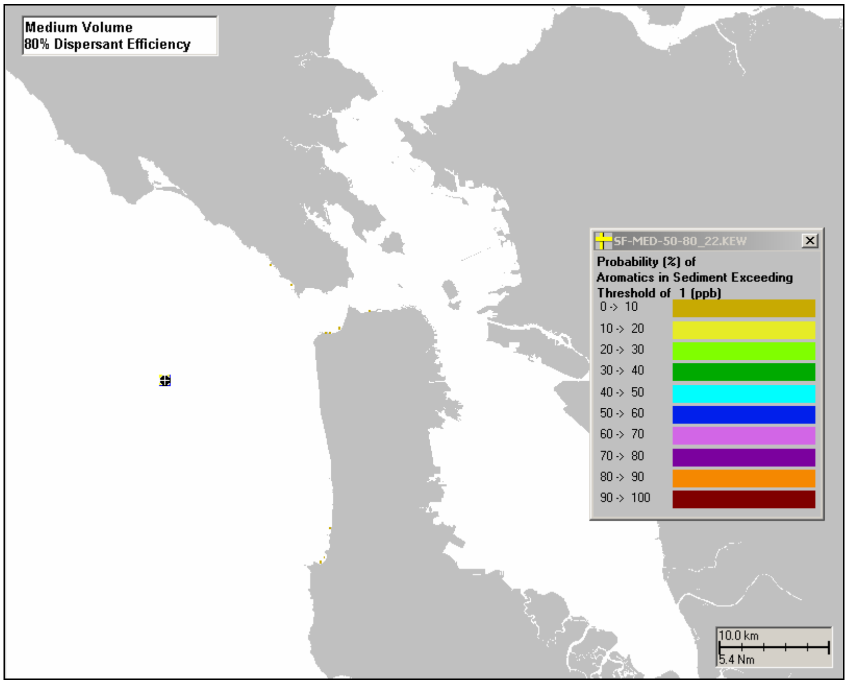

Figure E-II.1.3.6-1 Probability (%) of sediment pore water dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

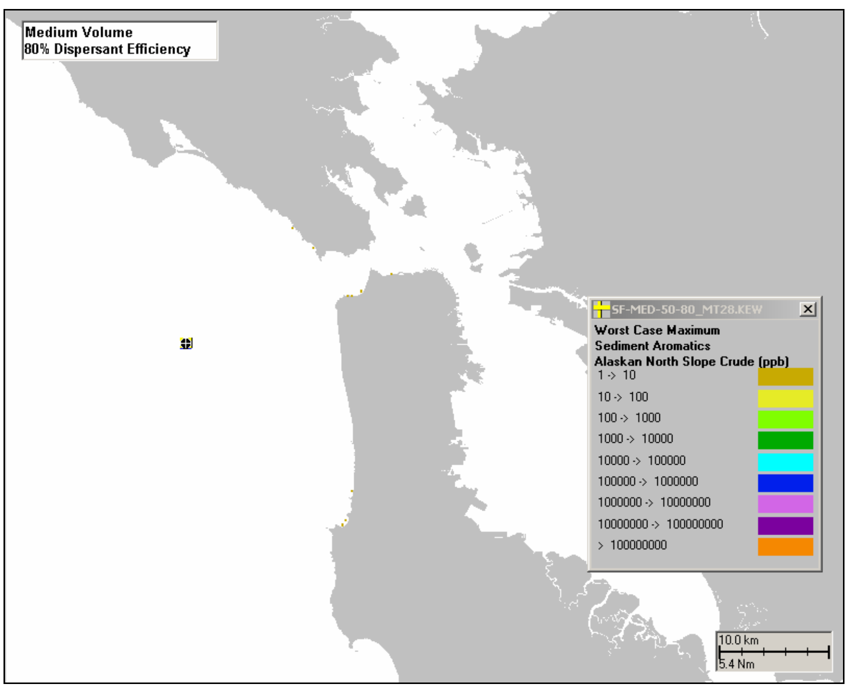

Figure E-II.1.3.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

E-II.1.4. Scenario: Large Volume, No Dispersant

E-II.1.4.1 Surface Floating Total Hydrocarbons. Scenario: Large Volume, No Dispersant

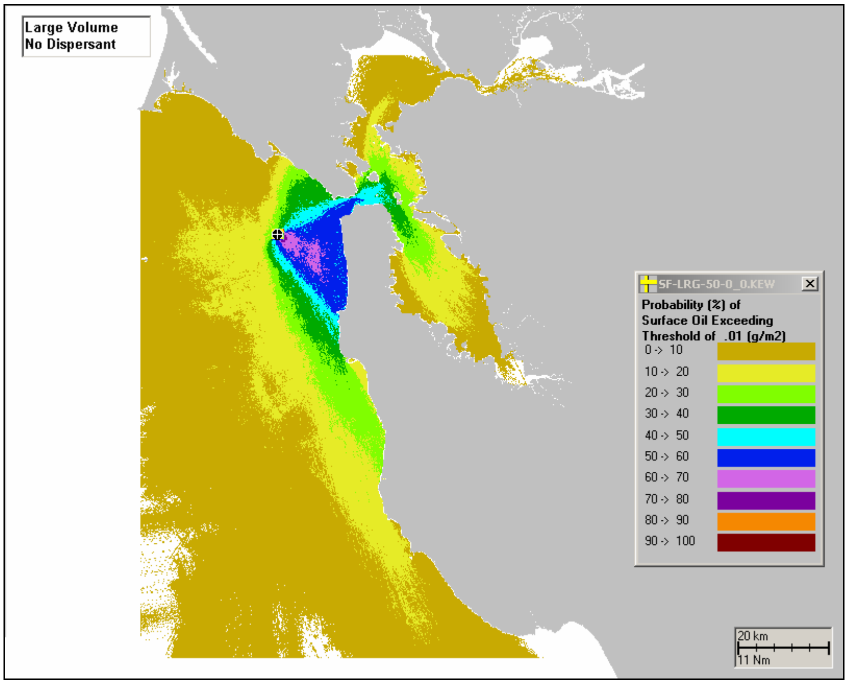

Figure E-II.1.4.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Large Volume, No Dispersant.

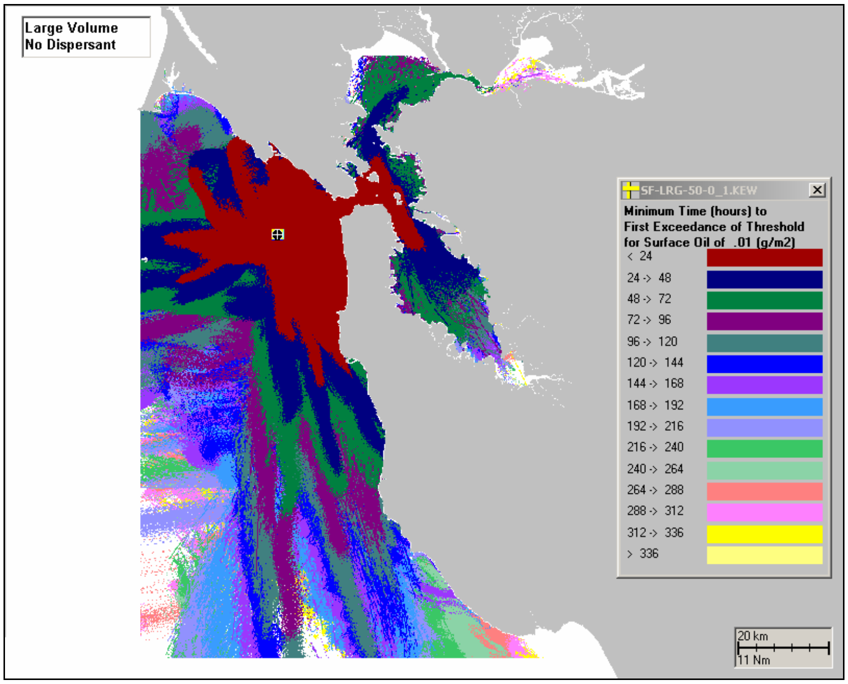

Figure E-II.1.4.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Large Volume, No Dispersant.

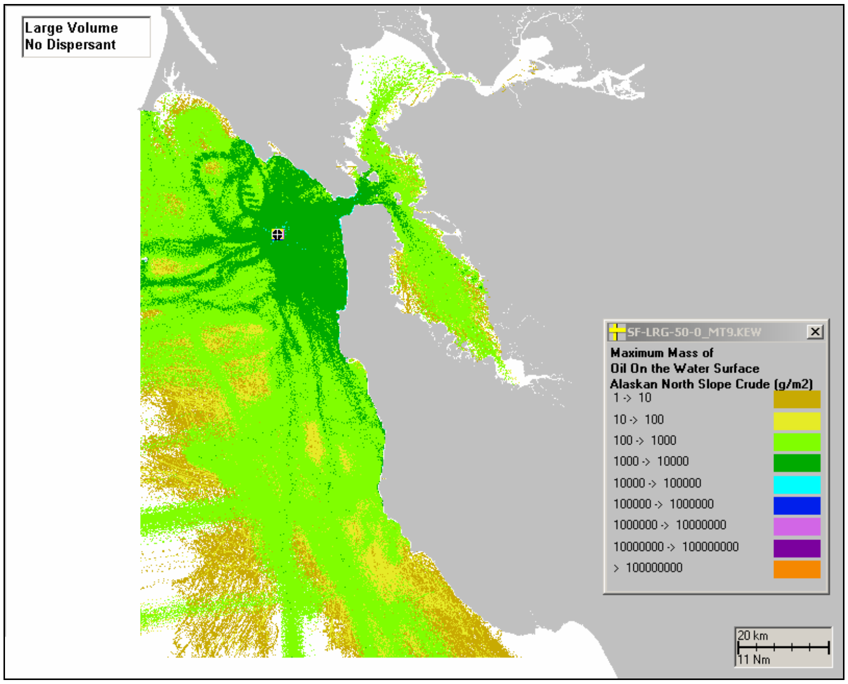

Figure E-II.1.4.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

E-II.1.4.2 Shoreline Oiled. Scenario: Large Volume, No Dispersant

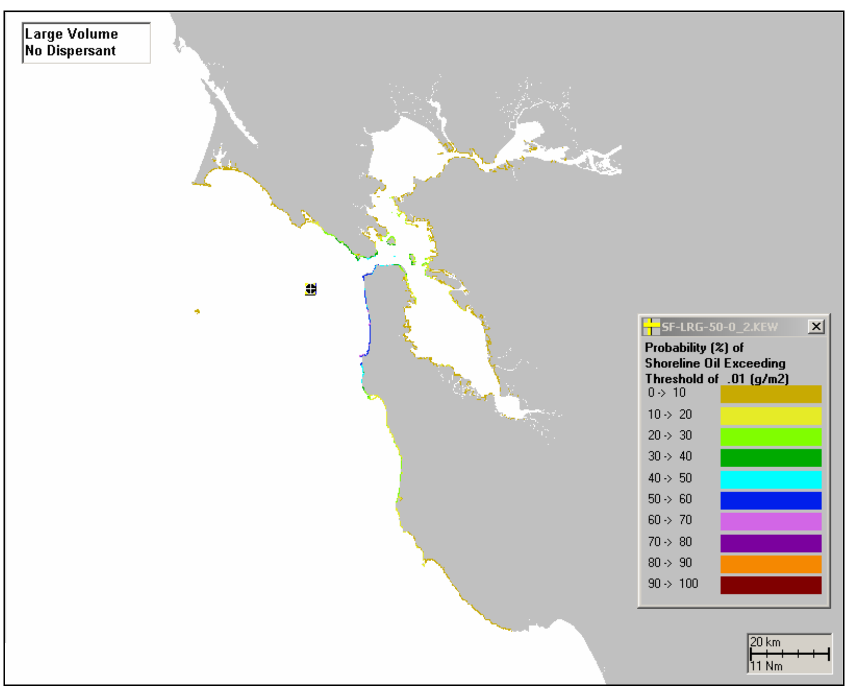

Figure E-II.1.4.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Large Volume, No Dispersant.

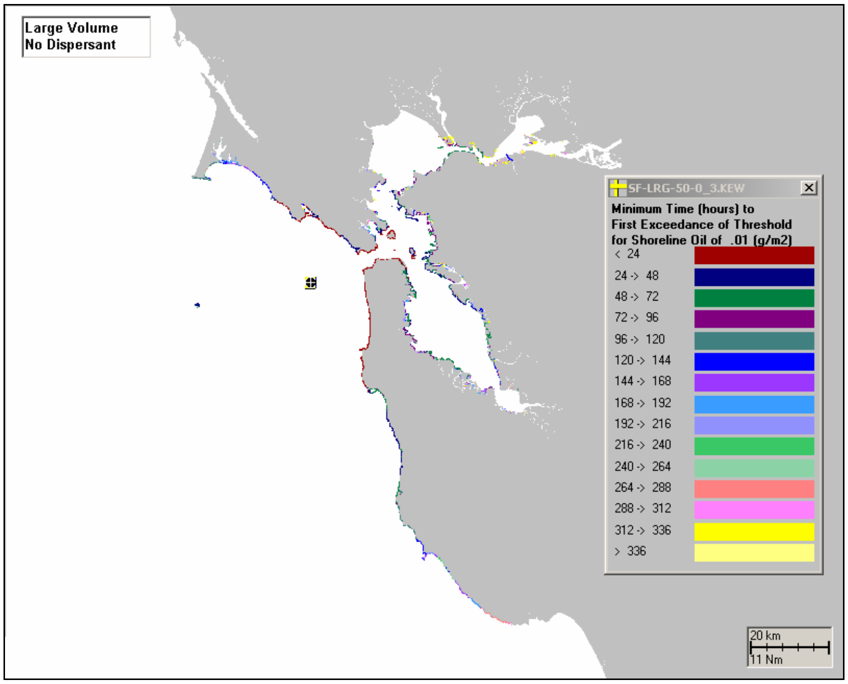

Figure E-II.1.4.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Large Volume, No Dispersant.

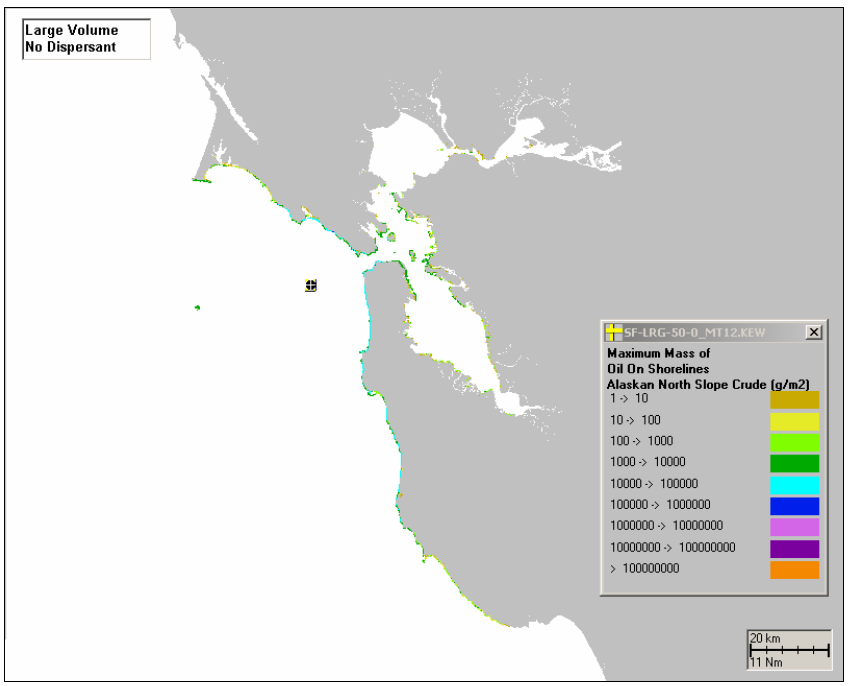

Figure E-II.1.4.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

E-II.1.4.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Large Volume, No Dispersant

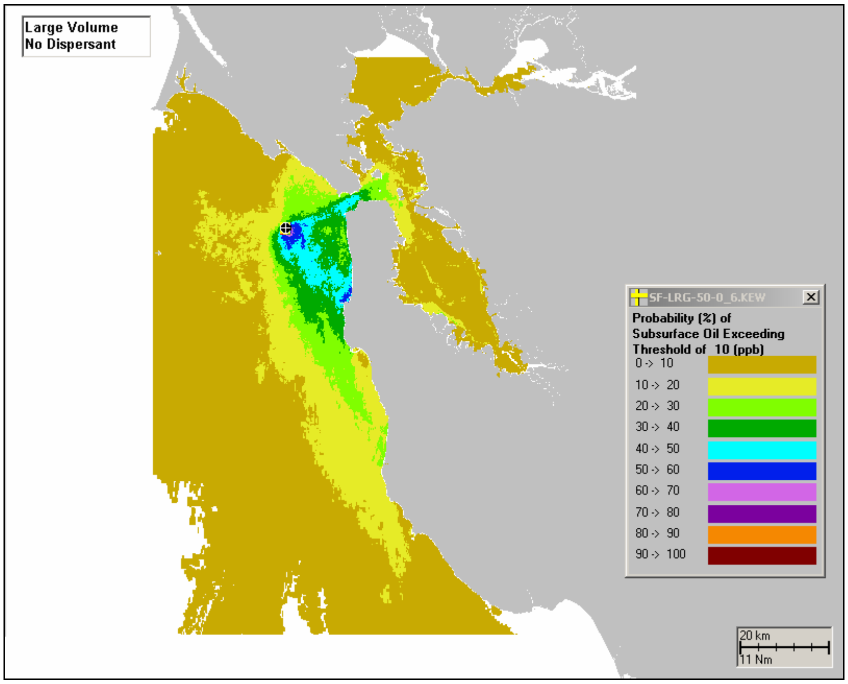

Figure E-II.1.4.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Large Volume, No Dispersant.

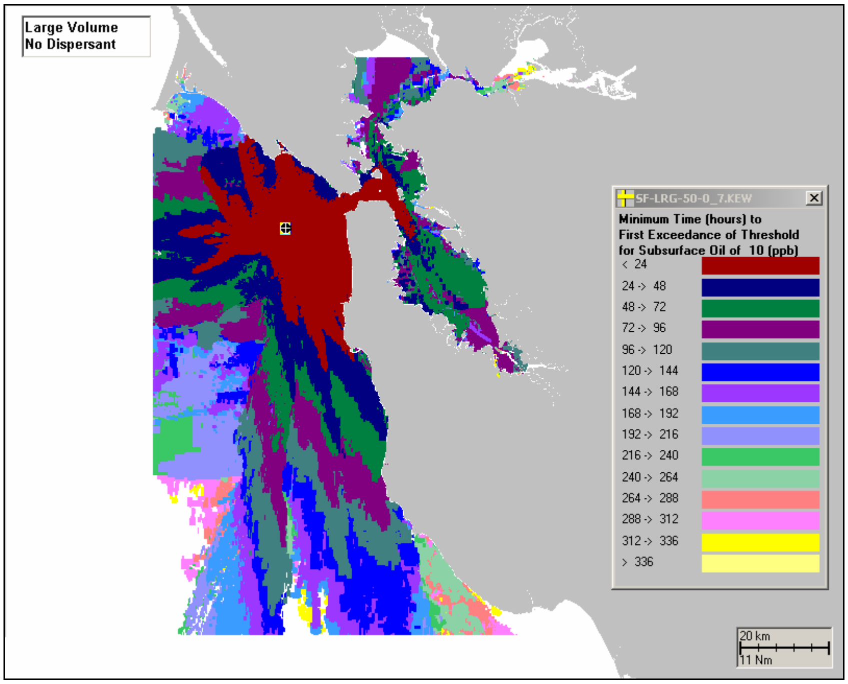

Figure E-II.1.4.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Large Volume, No Dispersant.

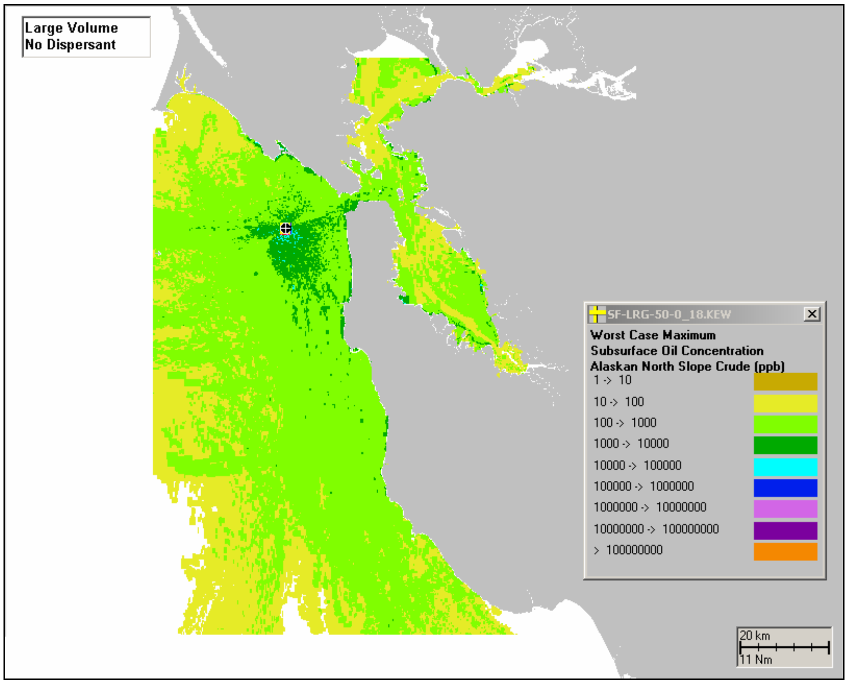

Figure E-II.1.4.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

E-II.1.4.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Large Volume, No Dispersant

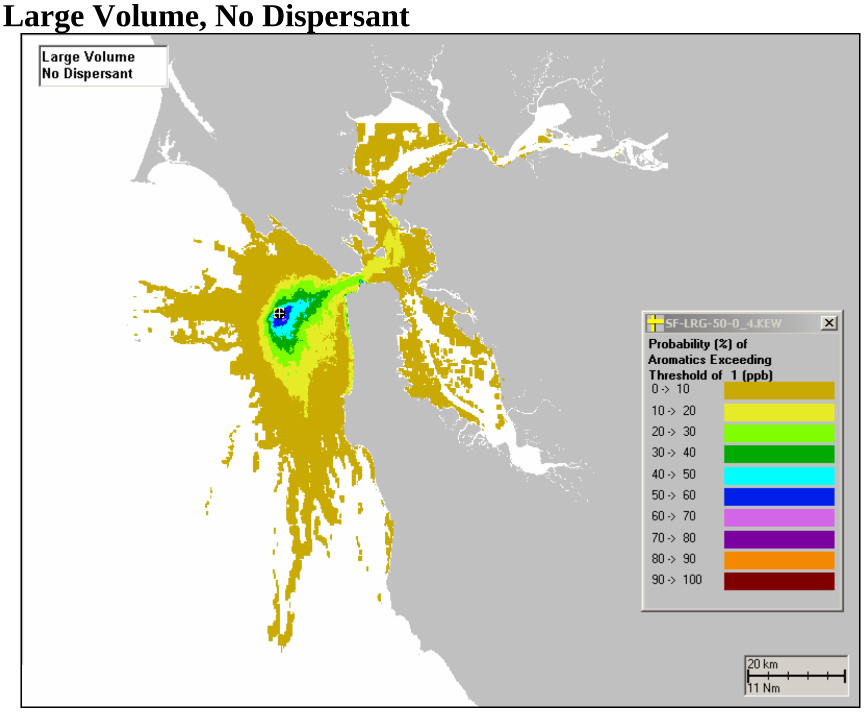

Figure E-II.1.4.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, No Dispersant.

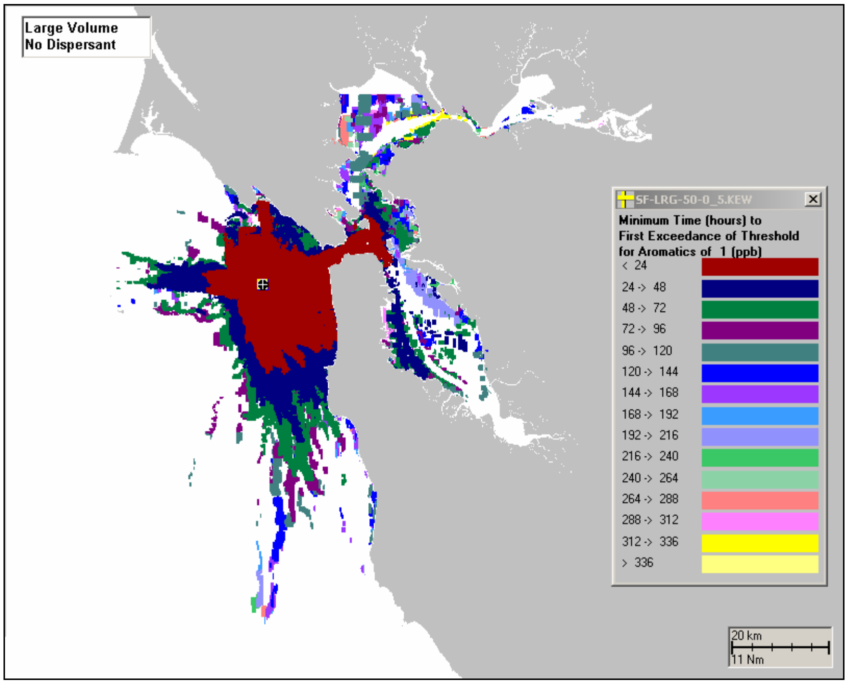

Figure E-II.1.4.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Large Volume, No Dispersant.

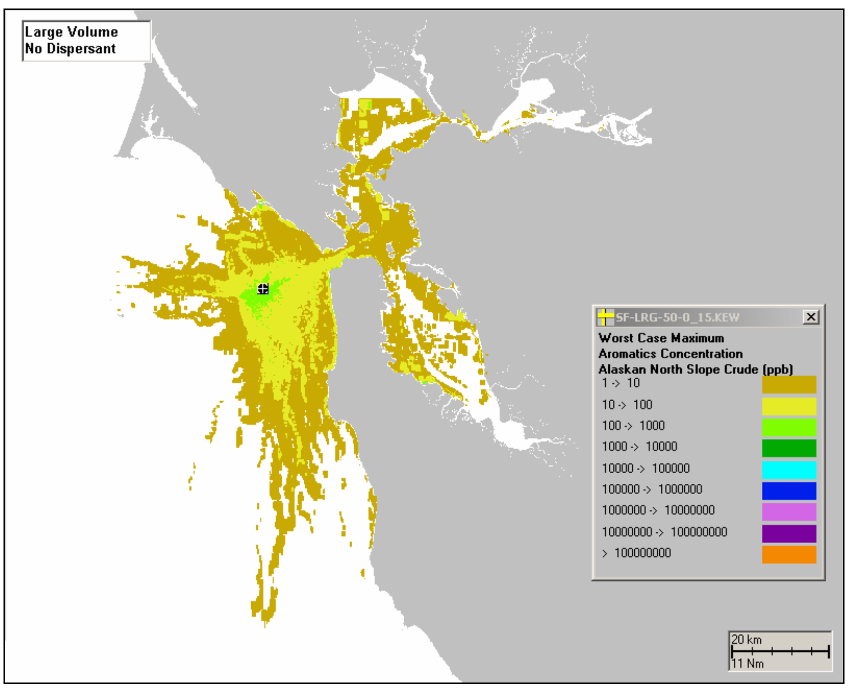

Figure E-II.1.4.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

E-II.1.4.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Large Volume, No Dispersant

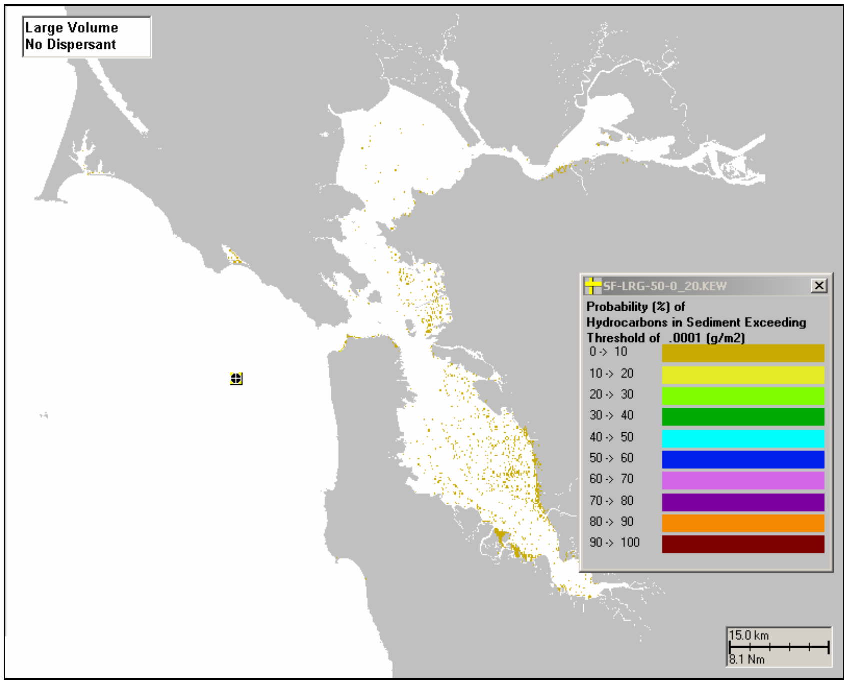

Figure E-II.1.4.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Large Volume, No Dispersant.

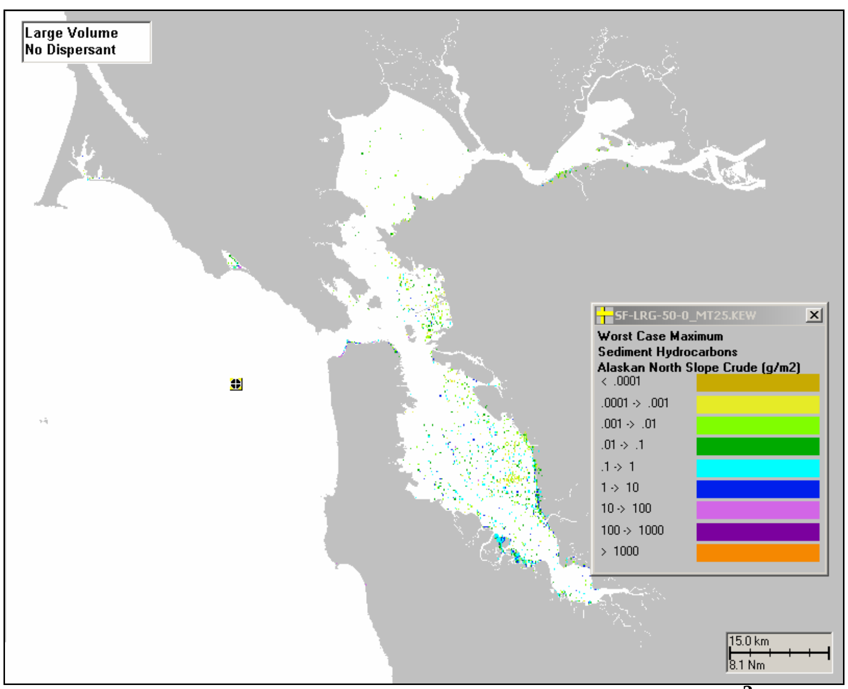

Figure E-II.1.4.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

E-II.1.4.6 Sediment pore water dissolved aromatic concentrations. Scenario: Large Volume, No Dispersant

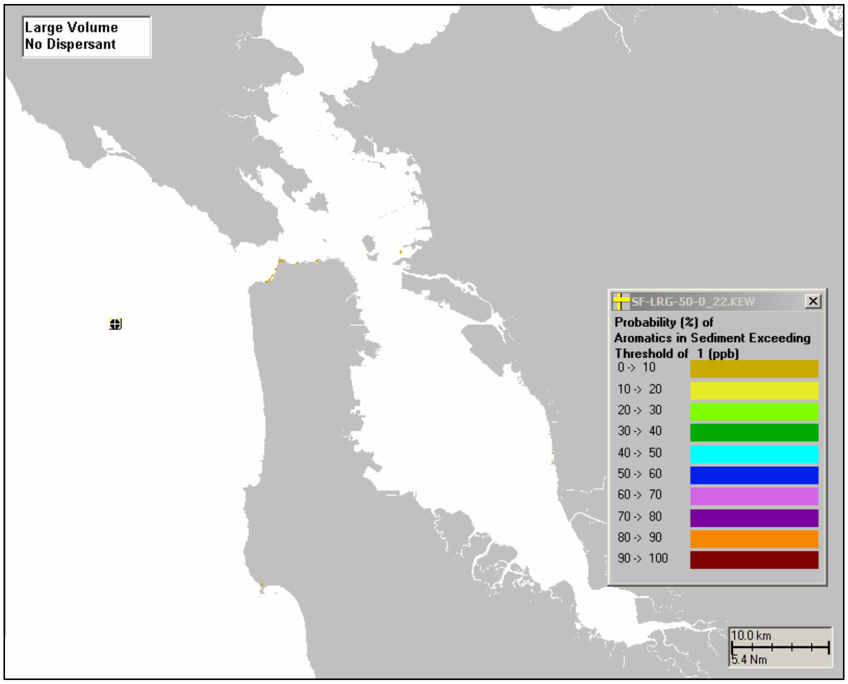

Figure E-II.1.6.4-1 Probability (%) of sediment pore water dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, No Dispersant.

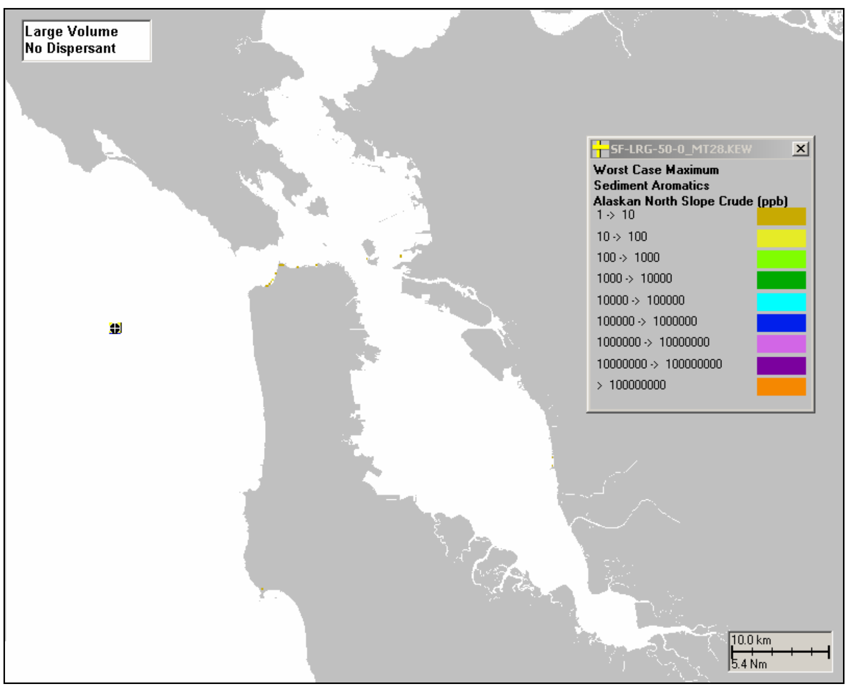

Figure E-II.1.4.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

E-II.1.5. Scenario: Large Volume, 45% Dispersant Efficiency

E-II.1.5.1 Surface Floating Total Hydrocarbons. Scenario: Large Volume, 45% Dispersant Efficiency

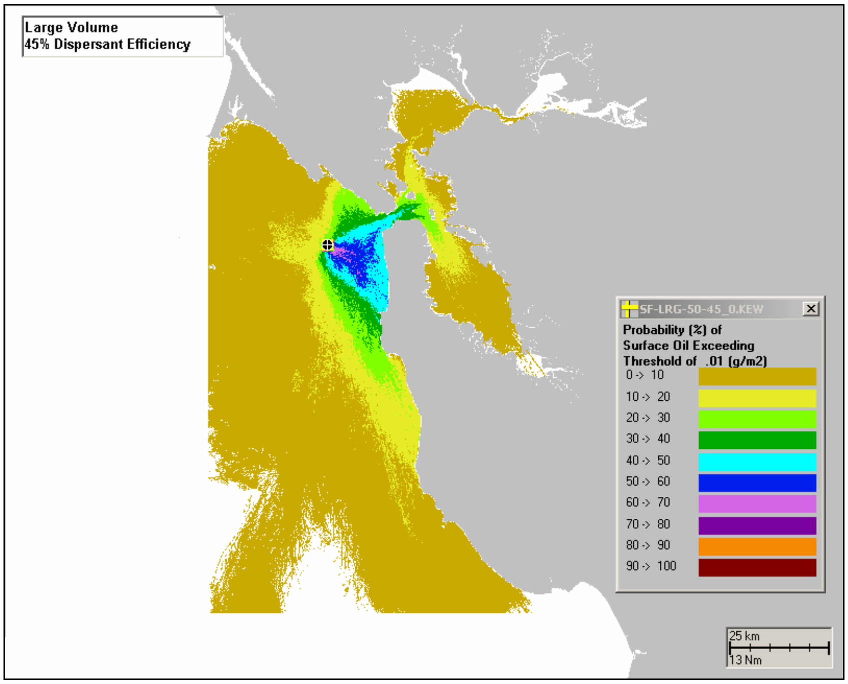

Figure E-II.1.5.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

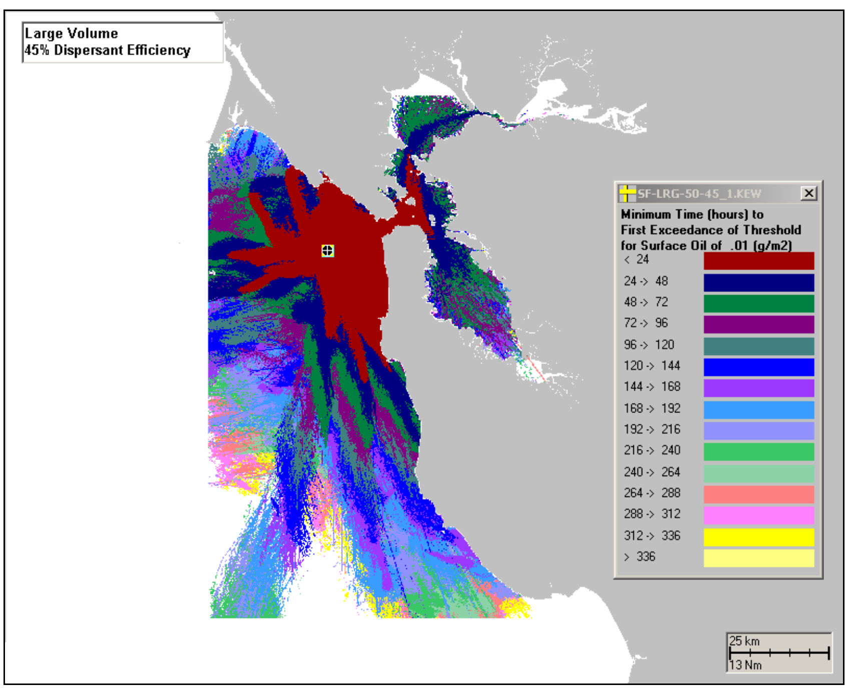

Figure E-II.1.5.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

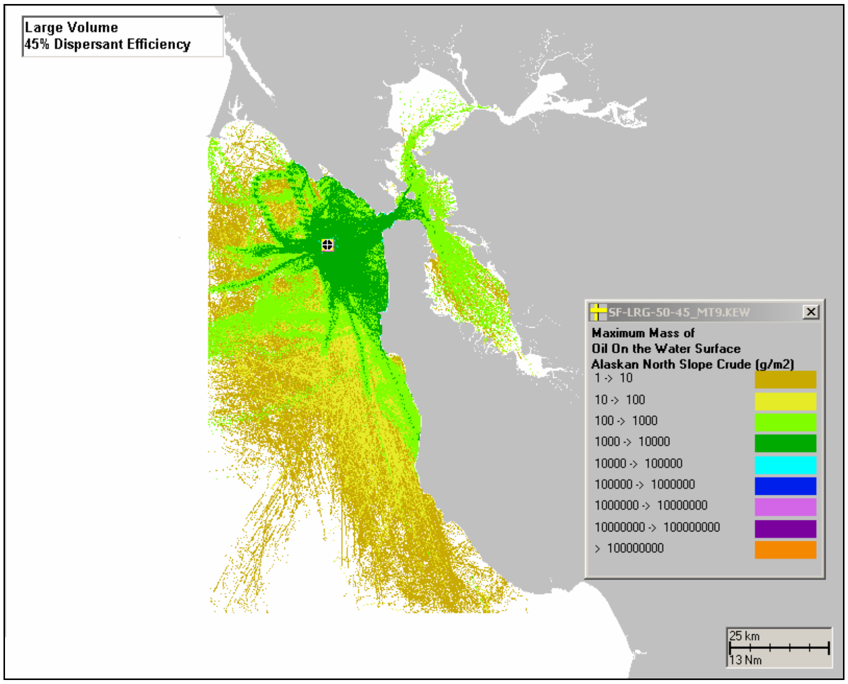

Figure E-II.1.5.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

E-II.1.5.2 Shoreline Oiled. Scenario: Large Volume, 45% Dispersant Efficiency

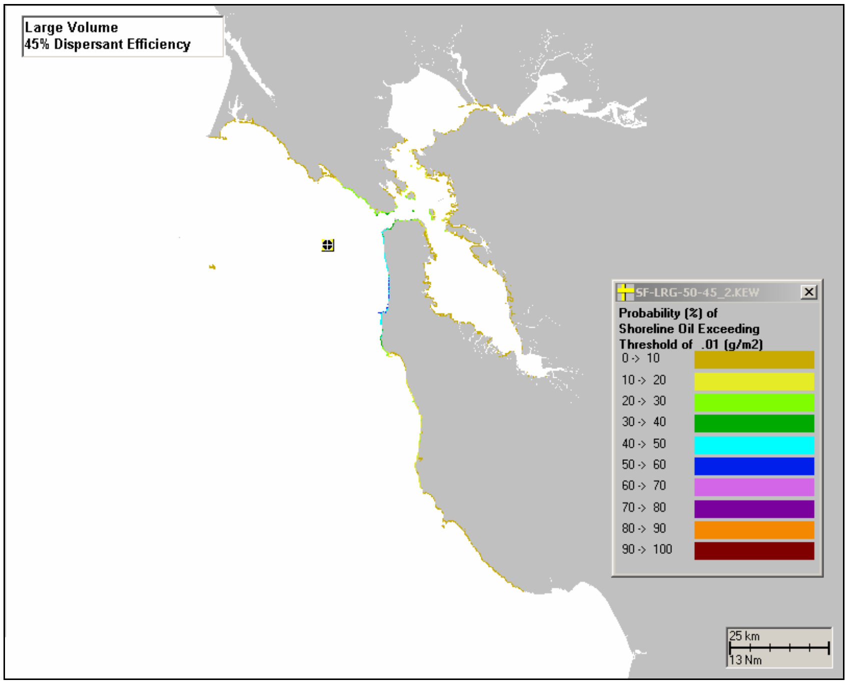

Figure E-II.1.5.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

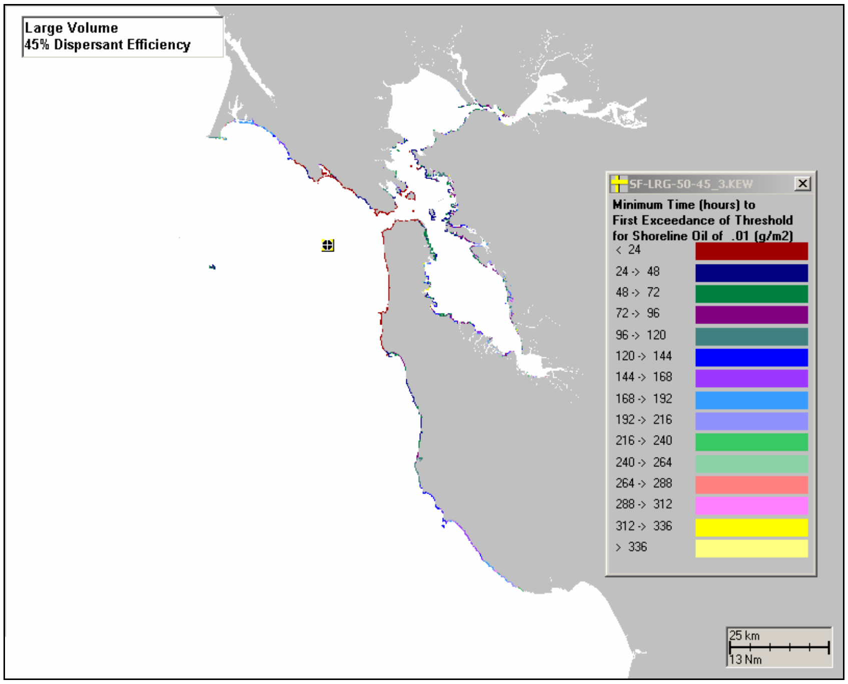

Figure E-II.1.5.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

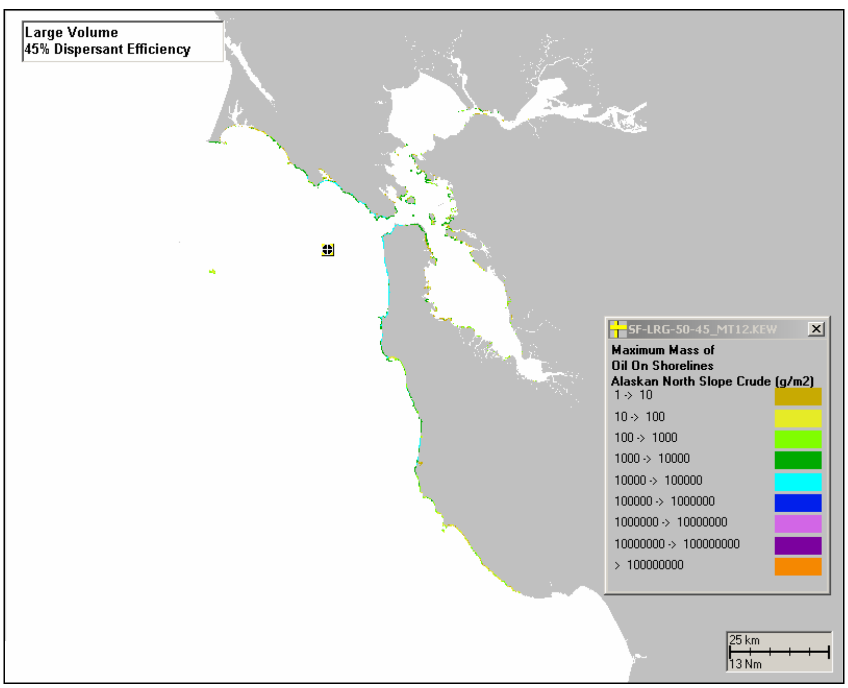

Figure E-II.1.5.2-.3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

E-II.1.5.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Large Volume, 45% Dispersant Efficiency

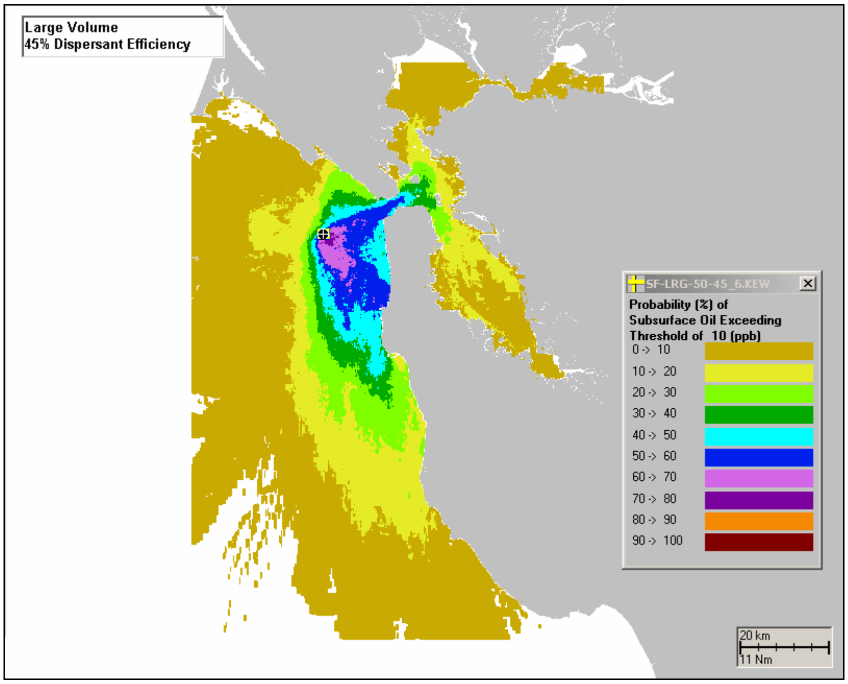

Figure E-II.1.5.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

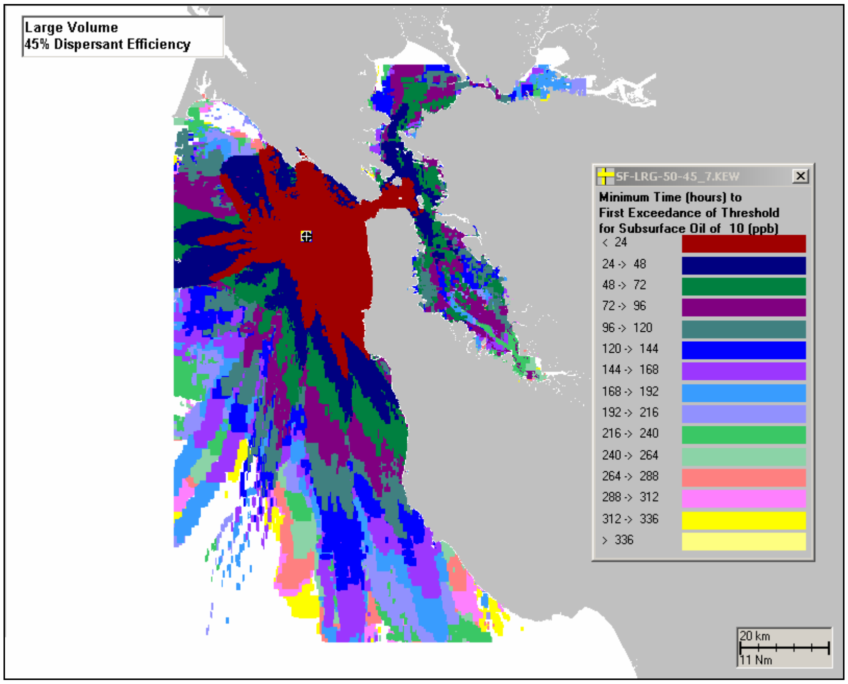

Figure E-II.1.5.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

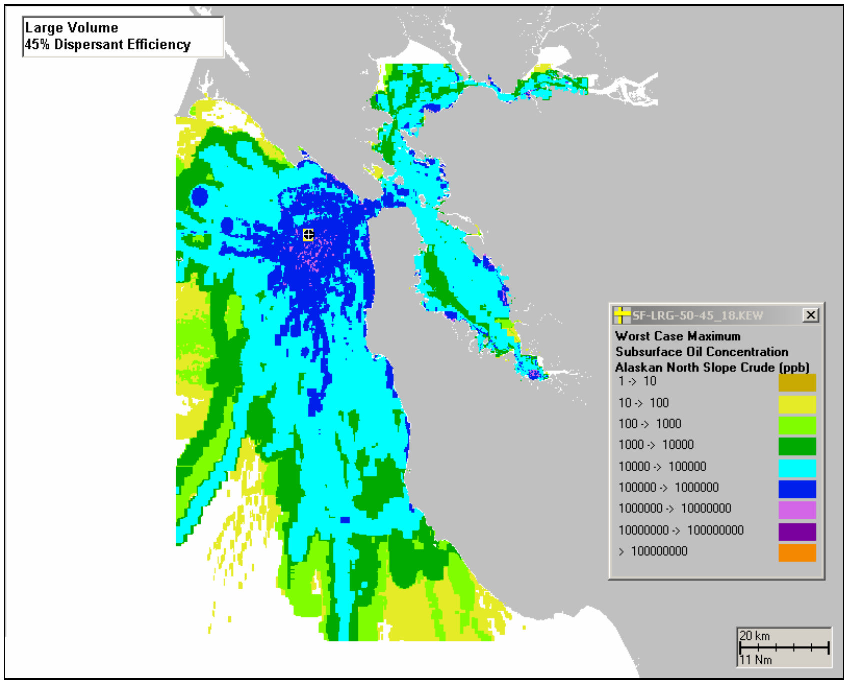

Figure E-II.1.5.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

E-II.1.5.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Large Volume, 45% Dispersant Efficiency

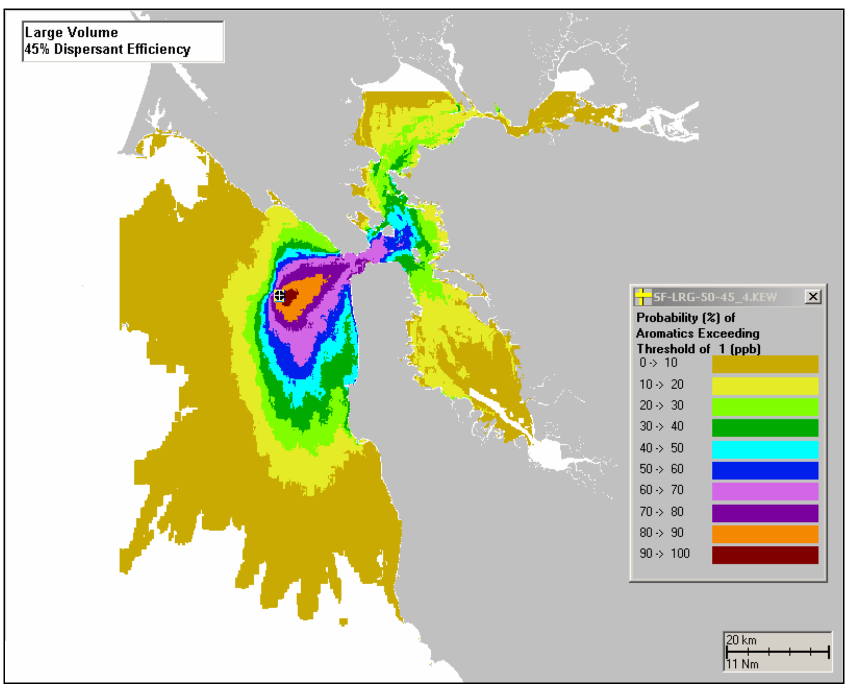

Figure E-II.1.5.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

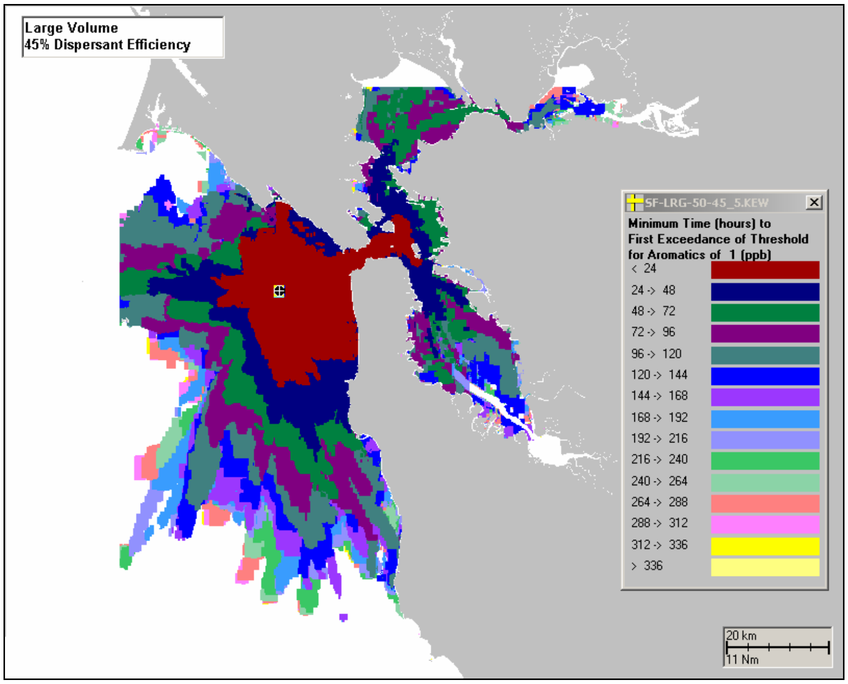

Figure E-II.1.5.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

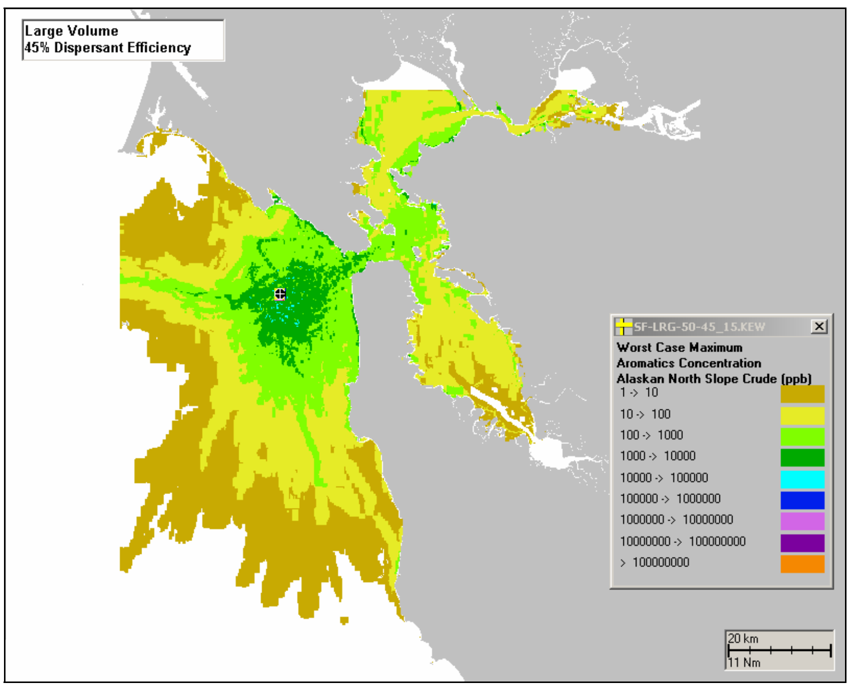

Figure E-II.1.5.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

E-II.1.5.5 Sediment exposure to total hydrocarbons (g/m²). Scenario: Large Volume, 45% Dispersant Efficiency

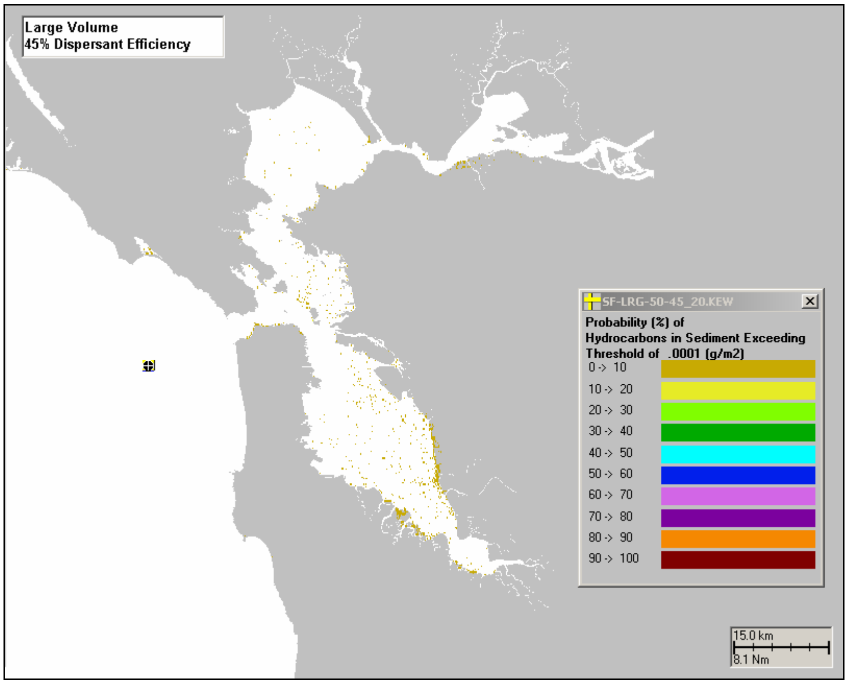

Figure E-II.1.5.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

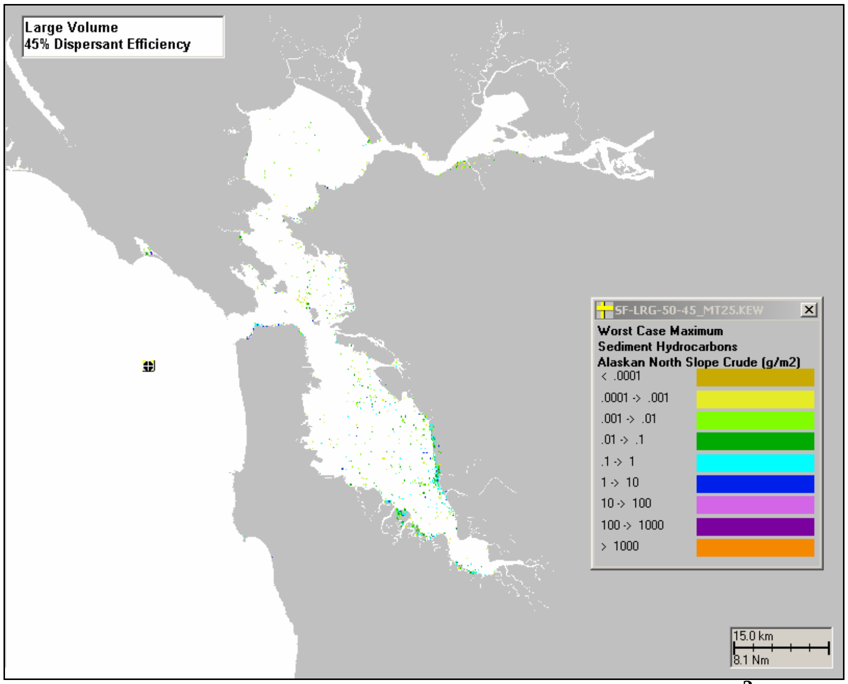

Figure E-II.1.5.5-2 Sediment exposure to total hydrocarbons (g/m²) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

E-II.1.5.6 Sediment pore water dissolved aromatic concentrations. Scenario: Large Volume, 45% Dispersant Efficiency

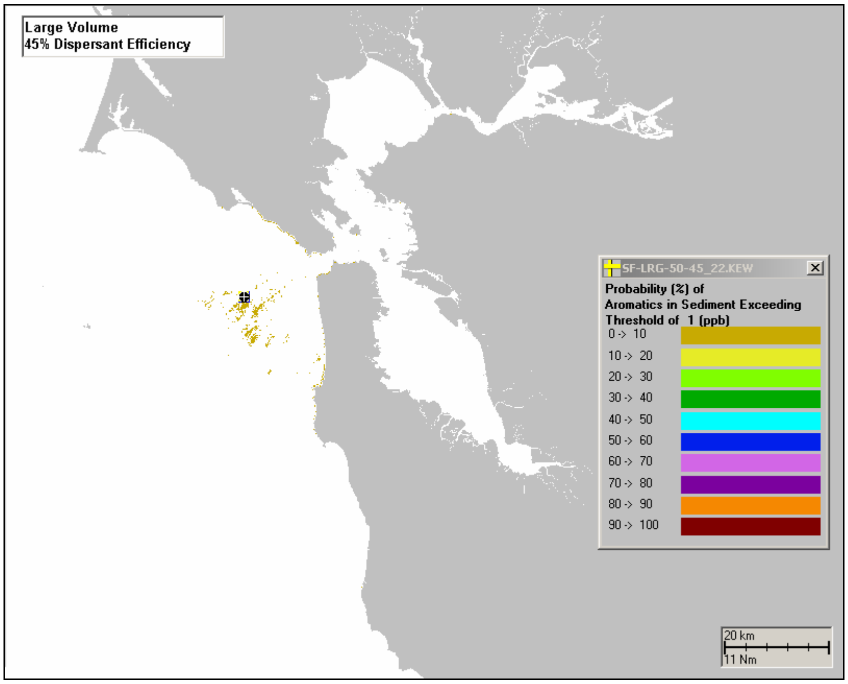

Figure E-II.1.5.6-1 Probability (%) of sediment pore water concentrations exceeding 1ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

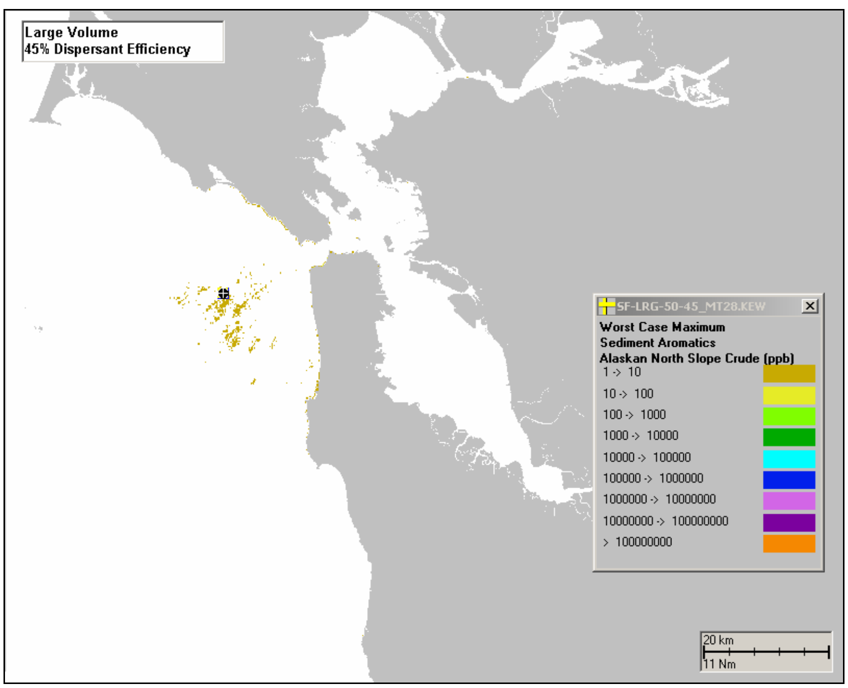

Figure E-II.1.5.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

E-II.1.6. Scenario: Large Volume, 80% Dispersant Efficiency

E-II.1.6.1 Surface Floating Total Hydrocarbons. Scenario: Large Volume, 80% Dispersant Efficiency.

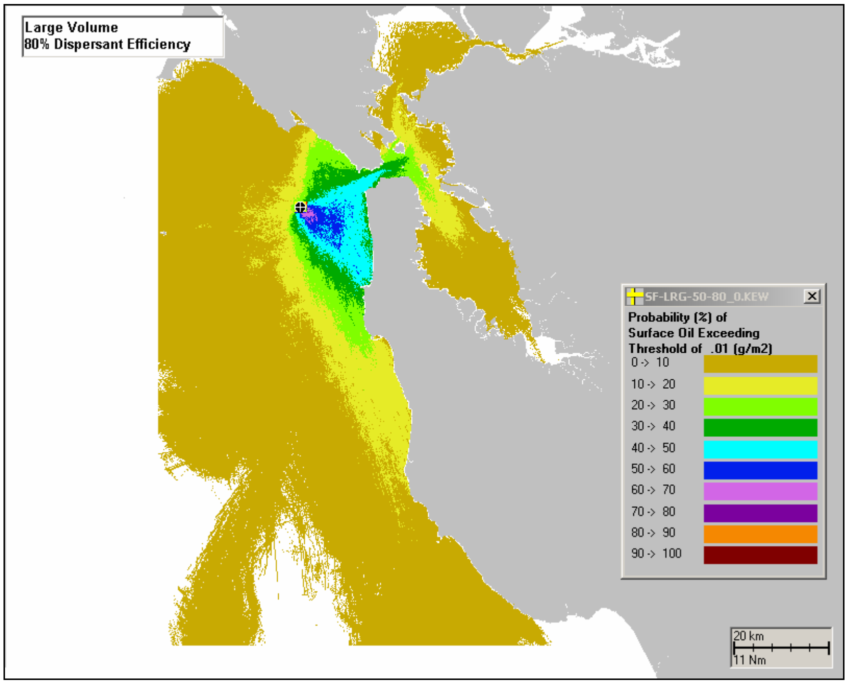

Figure E-II.1.6.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

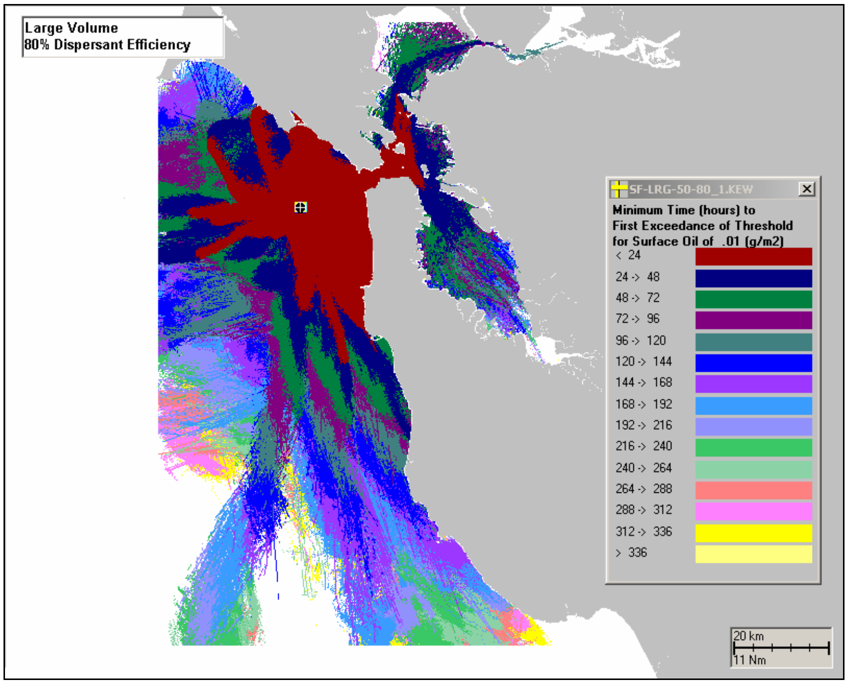

Figure E-II.1.6.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

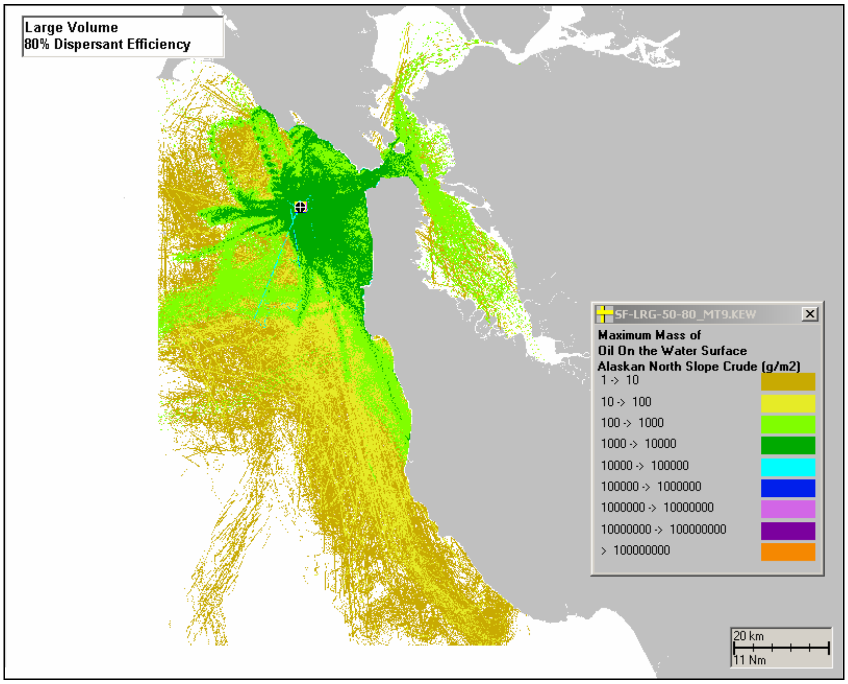

Figure E-II.1.6.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

E-II.1.6.2 Shoreline Oiled. Scenario: Large Volume, 80% Dispersant Efficiency

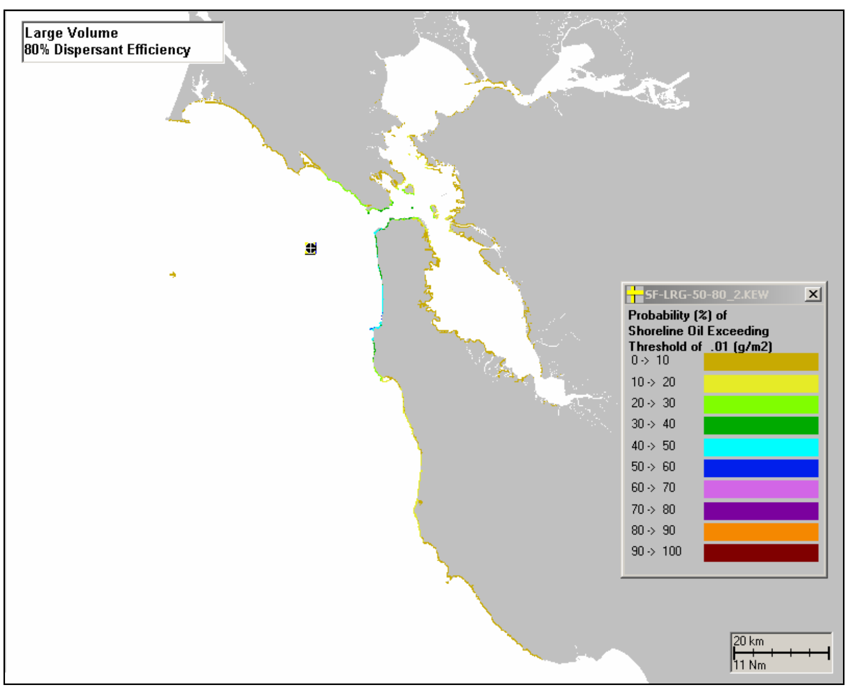

Figure E-II.1.6.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

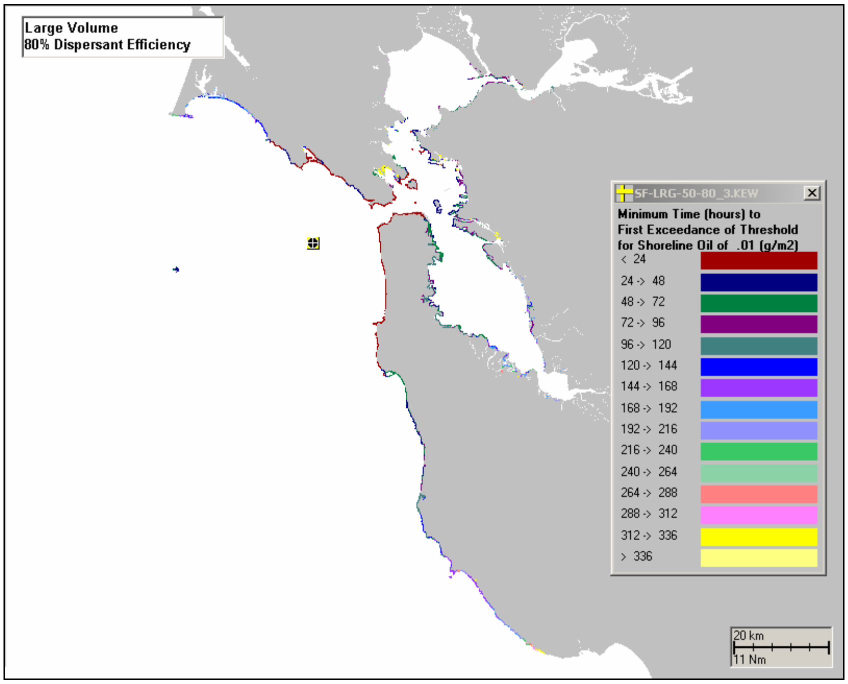

Figure E-II.1.6.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

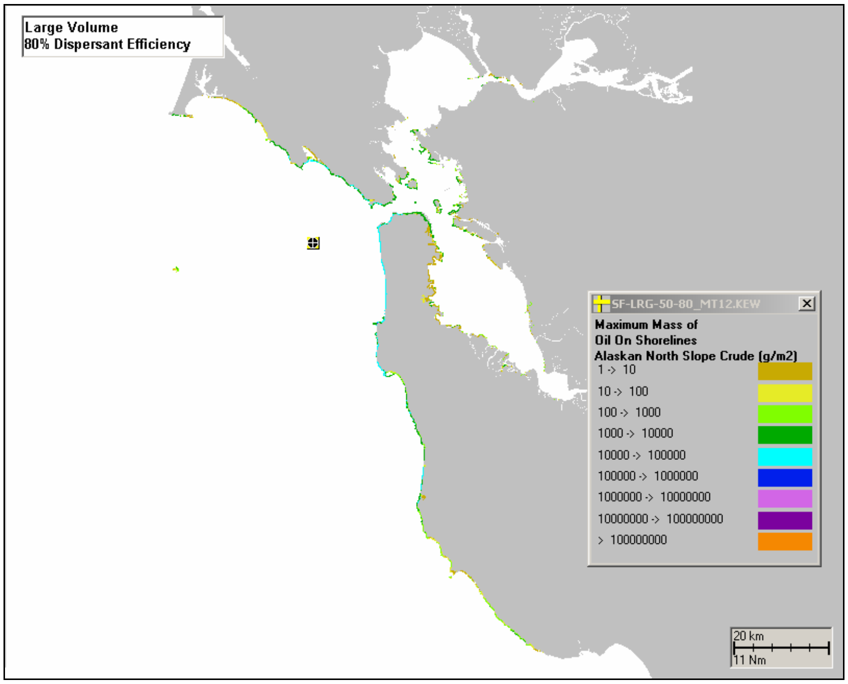

Figure E-II.1.6.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

E-II.1.6.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Large Volume, 80% Dispersant Efficiency

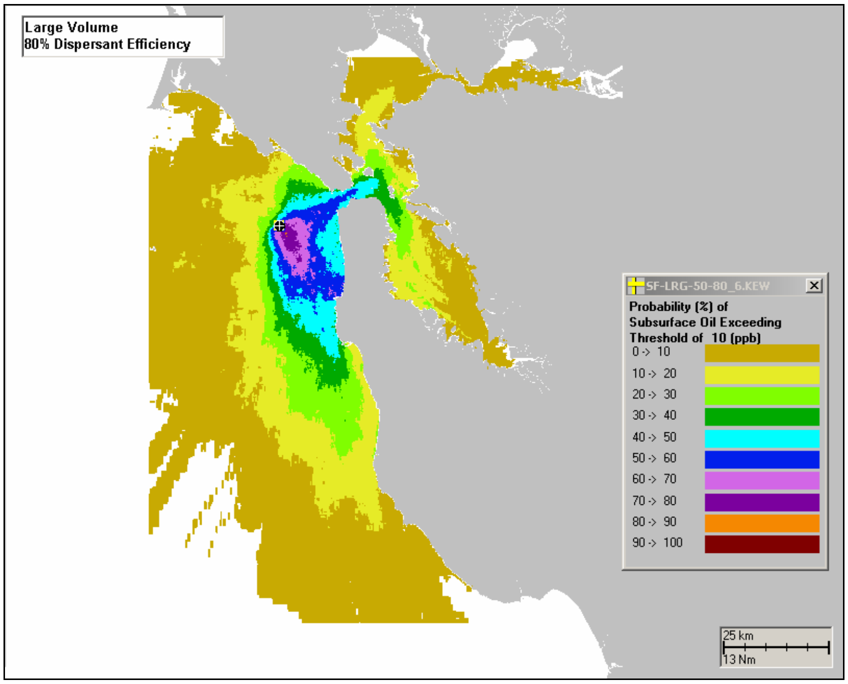

Figure E-II.1.6.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

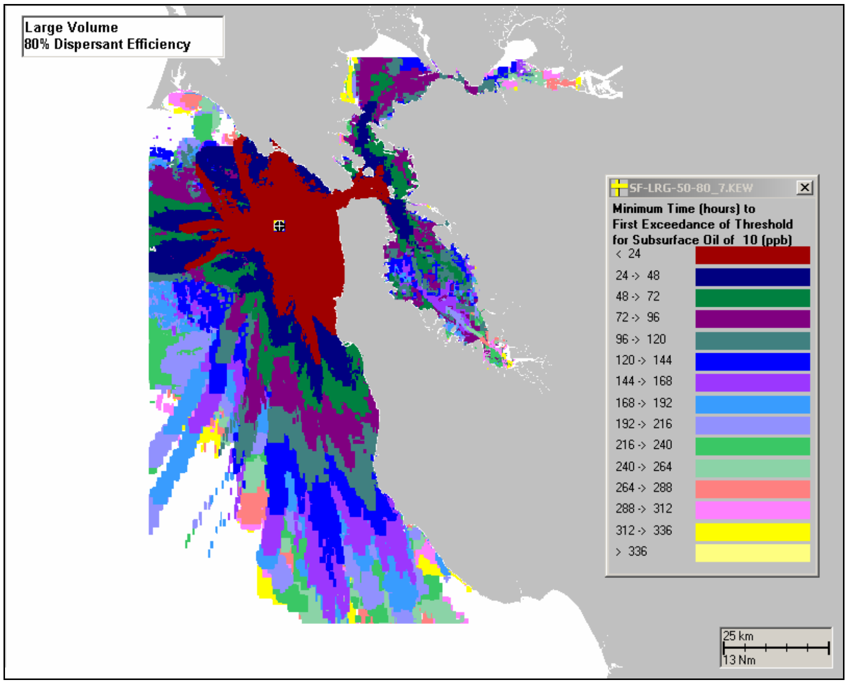

Figure E-II.1.6.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

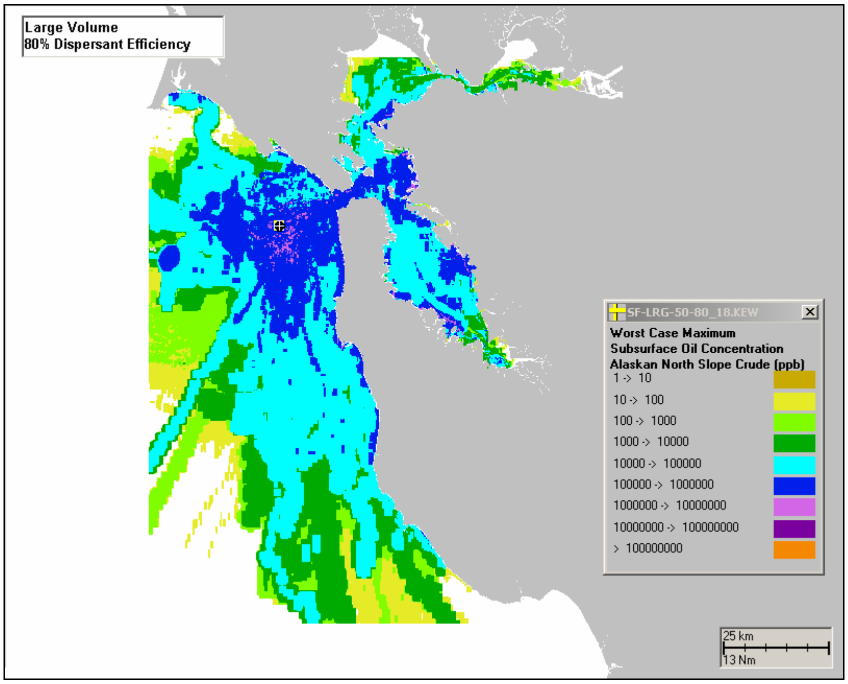

Figure E-II.1.6.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

E-II.1.6.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Large Volume, 80% Dispersant Efficiency

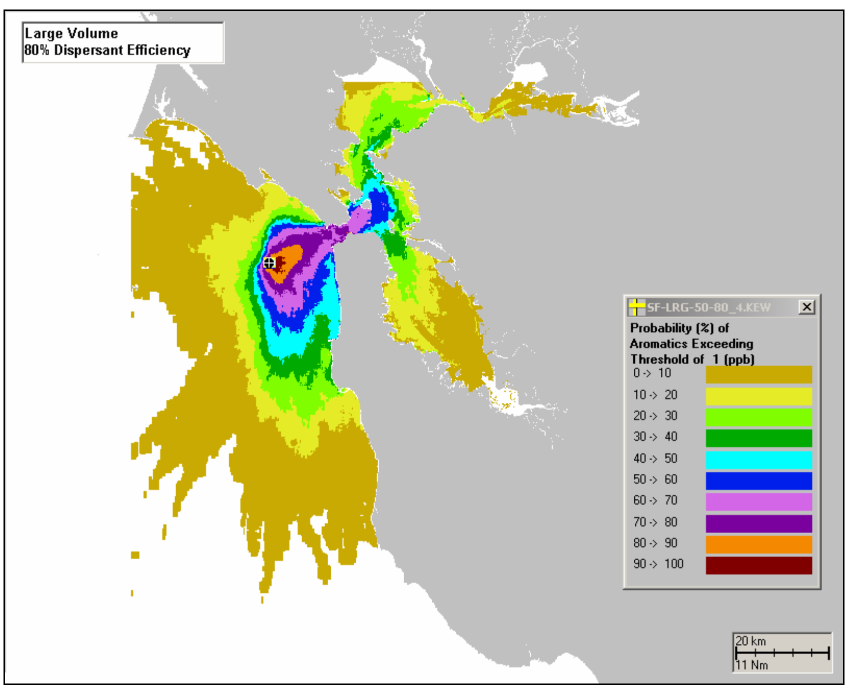

Figure E-II.1.6.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

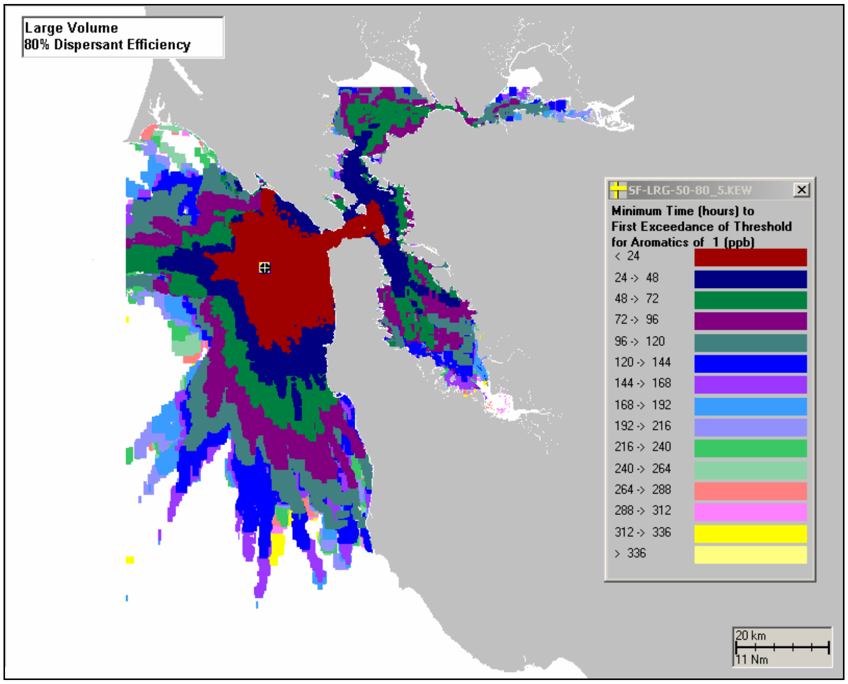

Figure E-II.1.6.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

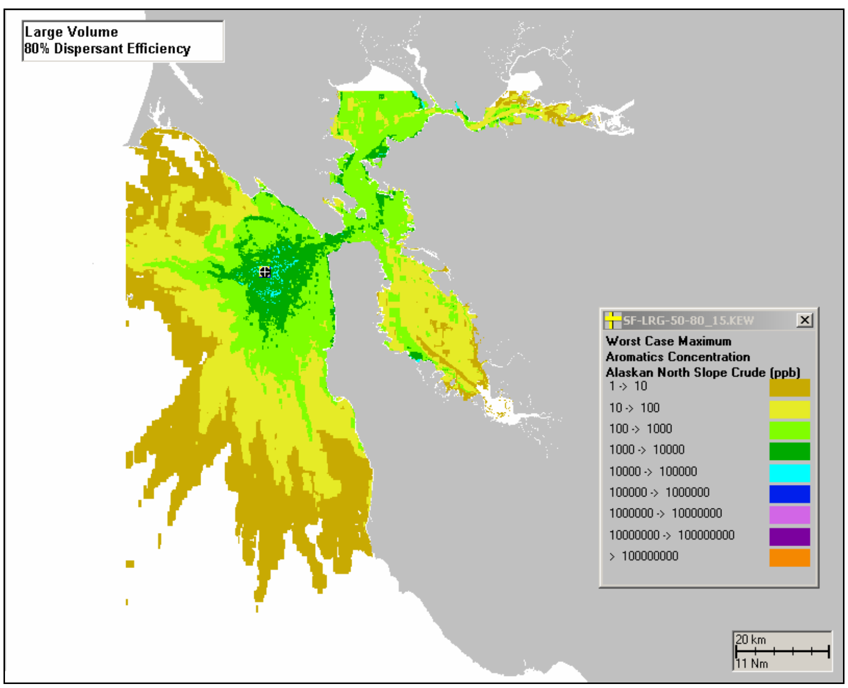

Figure E-II.1.6.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

E-II.1.6.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Large Volume, 80% Dispersant Efficiency

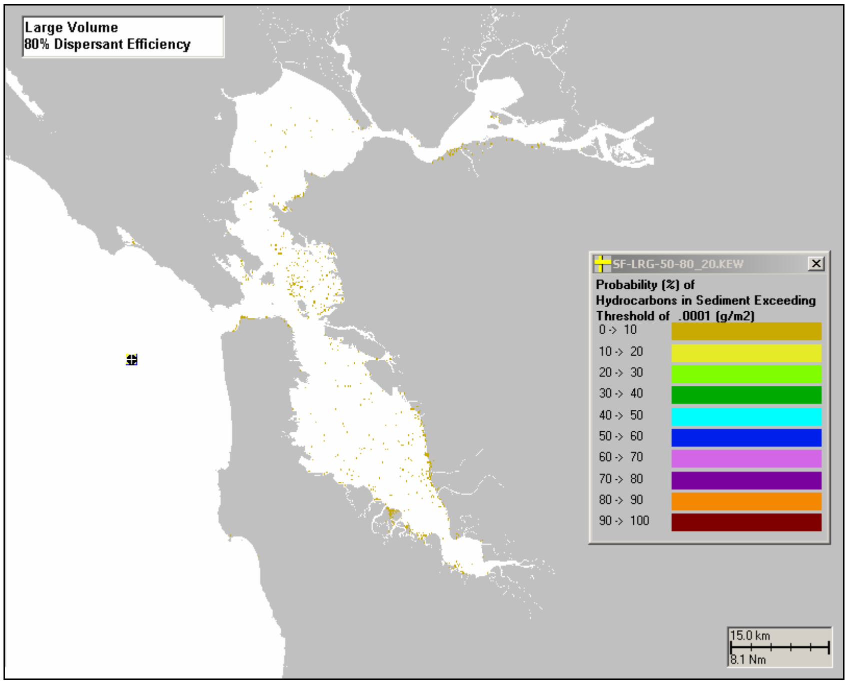

Figure E-II.1.6.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

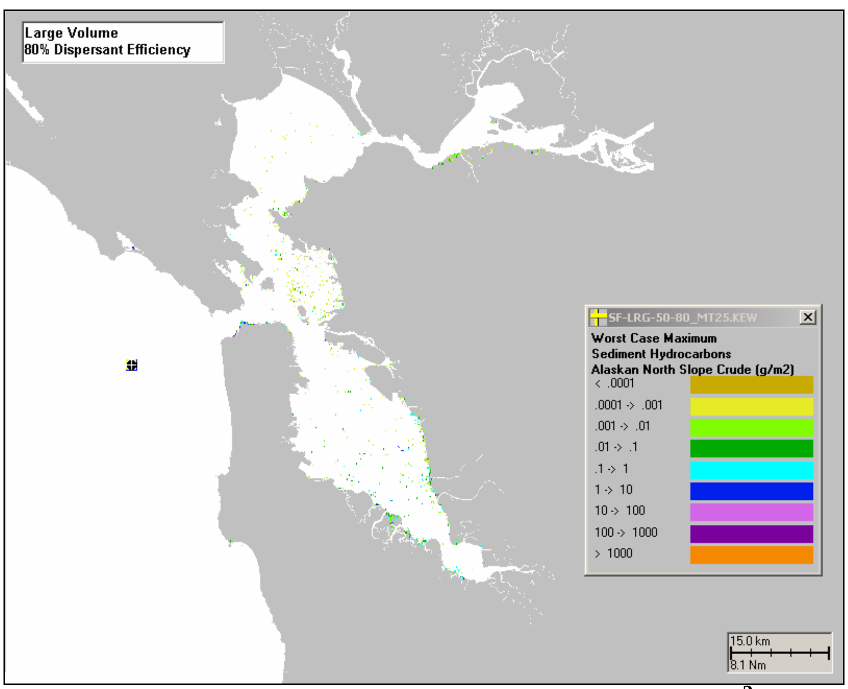

Figure E-II.1.6.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

E-II.1.6.6 Sediment pore water dissolved aromatic concentrations. Scenario: Large Volume, 80% Dispersant Efficiency

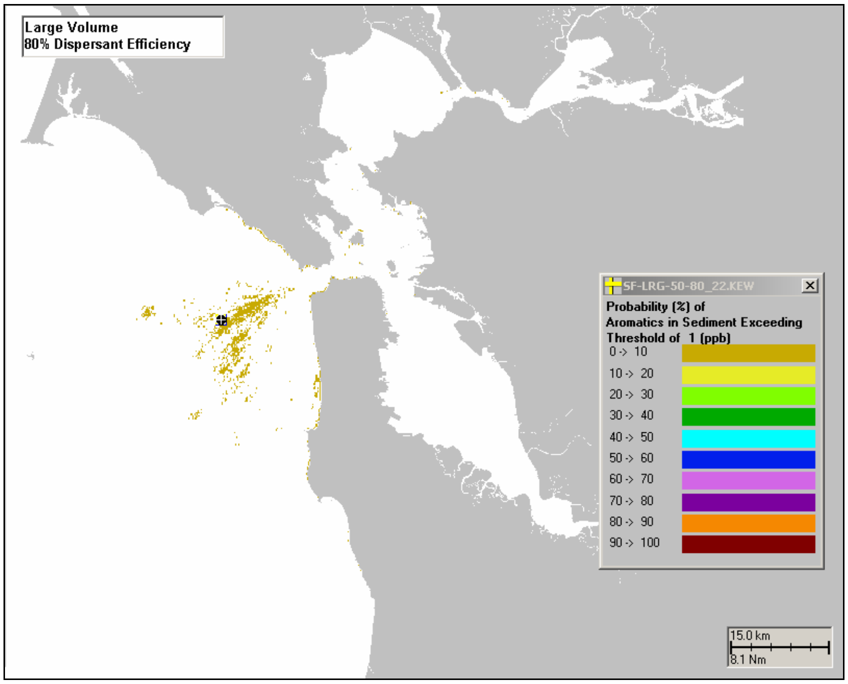

Figure E-II.1.6.6-1 Probability (%) of sediment pore water dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

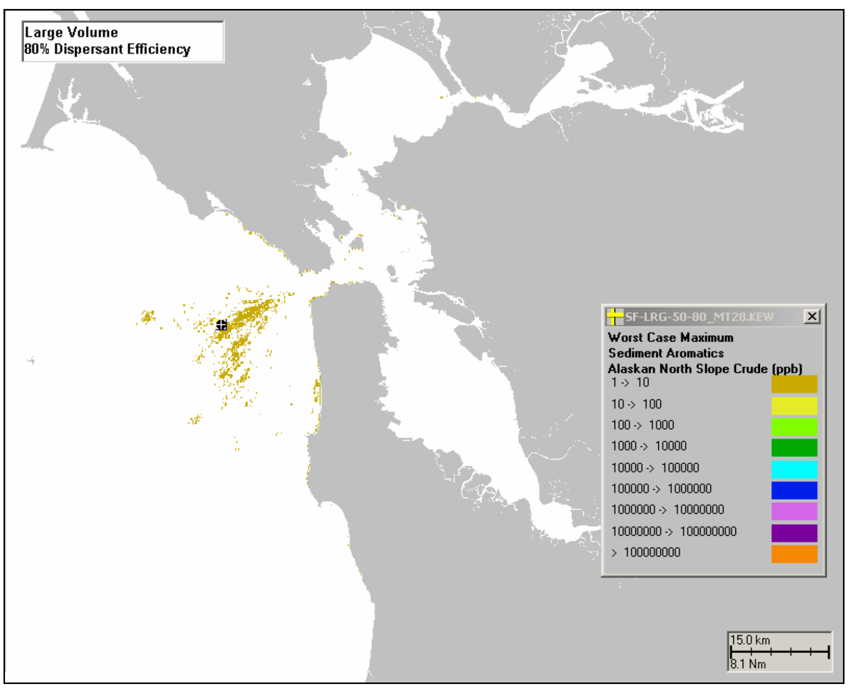

Figure E-II.1.6.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part E: San Francisco Bay and Central California Shelf

Section E-II.2

by

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ASA 00-246

August 2004

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E-II.2 Results of the Stochastic Modeling: Tables Summarizing Exposure Indices

Tables E-II.2-1 to E-II.2-6 summarize the exposure indices for all model runs in the stochastic oil spill modeling analysis for the spill site off San Francisco Bay. Average and the maximum of the 100 simulations performed for each scenario are presented. The 95^{th} percentile conditions used in the risk analysis were calculated as the mean plus two times the standard deviation. The following are the exposure indices used in the analysis.

- Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr) – integrated area swept by oil sheen or thicker oil times duration that oil is present [Note that this index is the oil mass passing through the cell averaged over the grid cell area, and so dilutes smaller patches of contamination. For this reason, evaluation of potential effects on wildlife is made using area swept by individual oil spillets; see explanation in Part A.4]
- Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) –area swept by oil sheen or thicker oil times, for landward (estuarine), seaward (marine), and all waters
- Area of Shoreline Oiling Exceeding 0.01 g/m^2 (m^2) – shoreline oiled with a thickness exceeding this amount, averaged over the grid cell area (segment length of 198.5 m times width for the shore type, which is 2 m for rock/artificial, 5m for gravel beaches, 10 m for sand beaches and 120 m for wetlands and mud flats)
- Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2) – shoreline oiled with a thickness exceeding this amount, averaged over the grid cell area (segment length times typical width for the shore type, as above)
- Length of Shoreline Oiling Exceeding 10 g/m^2 (m) – shoreline of various shore types oiled with a thickness exceeding this amount:
    - Total shoreline
    - Wetlands and mudflats
    - Other shoreline (rocky shore, gravel beach, sand beach, artificial shore)
    - Seaward (marine) sand beach
- Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – water volume contaminated at any time after the spill by > 1ppb dissolved aromatic concentration (in all subtidal habitats) [Note that this index is averaged over the grid cell and upper mixed layer, and so dilutes smaller patches of contamination. For this reason, evaluation of potential effects on biota is made using higher resolution small scale grids around the plume in the water; see explanation in Part A.4]
- Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs) – integrated exposure to dissolved aromatics, as ppb-hrs averaged over the water volume contaminated at any time after the spill by > 1ppb dissolved aromatic concentration
- Percent of Spilled Hydrocarbon Mass Coming Ashore (%) – percent of the spilled oil coming ashore by 14 days after the spill, assuming no shoreline cleanup

- Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)
- Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%) – maximum percent of the oil dispersed by natural forces (waves) and chemical dispersant. (Some naturally dispersed oil may resurface and be re-entrained into the water column, so this is the maximum percent in the water at any time after the spill.)
- Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%) – calculated by difference between no-dispersant and dispersant use scenario
- Percent of Spilled Hydrocarbon Mass Mechanically Removed (%) – The percentage decreases as chemical dispersion increases because less oil remains on the surface and is available to be skimmed.

Table E-II.2-1. Summary of exposure indices for all model runs (Medium Volume, No Dispersant).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	3,722 x 10^6	4,077 x 10^6	0	16,088 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) cells only	27.4 x 10^6	58 x 10^6	46	351 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	410 x 10^6	418 x 10^6	0	2,148 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	437 x 10^6	414 x 10^6	0	2,150 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) 0-20 nautical miles offshore (including all bays)	421 x 10^6	380 x 10^6	0	2,130 x 10^6
Surface Oil Exposure Exceeding 10g/m^2 (m^2) 0-20 nautical miles offshore (including all bays)	112 x 10^6	94 x 10^6	0	596 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	1,164,995	1,719,032	1	11,430,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	137,795	222,327	3	1,771,566
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	17,583	12,077	3	54,394

Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	441	1,836	80	14,492
Length of Shoreline Oiling Exceeding 10 g/m^{2} - Other Shoreline (m)	17,142	11,871	3	52,409
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	5,993	4,675	10	23,425
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	66×10^6	77×10^6	0	340×10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	131	77	0	276
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	28.36	11.09	2	41.61
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0034	0.0176	52	0.1661
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	12.23	5.29	0	23.49
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	0	0	100	0
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	10.11	6.63	3	26.17

Table E-II.2-2. Summary of exposure indices for all model runs (Medium Volume, 45% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2-hr)	2,591 x 10^6	3,751 x 10^6	0	18,184 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for landward (estuarine) cells only	21.4 x 10^6	56 x 10^6	58	339 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for seaward (marine) area only	249 x 10^6	288 x 10^6	0	1,745 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for all waters	270 x 10^6	293 x 10^6	0	1,750 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) 0-20 nautical miles offshore (including all bays)	265 x 10^6	285 x 10^6	0	1,744 x 10^6
Surface Oil Exposure Exceeding $10 g/m^2$ (m^2) 0-20 nautical miles offshore (including all bays)	34 x 10^6	43 x 10^6	0	203 x 10^6
Area of Shoreline Oiling Exceeding $0.01 g/m^2$ (m^2)	808,494	1,578,697	13	9,018,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	50,799	127,068	35	1,140,283
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	7,351	10,445	35	42,086
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	151	955	89	9,330
Length of Shoreline Oiling Exceeding 10 g/m^{2-} Other Shoreline (m)	7,200	10,330	36	41,887
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	2,376	4,177	52	19,256
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	397 x 10^6	194 x 10^6	0	997 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-	2,445	1,567	0	7,697

hrs)				
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	6.56	12.53	16	39.06
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0090	0.0208	5	0.1455
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	71.99	24.30	0	89.58
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	59.76	26.46	0	85.52
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	0.74	2.13	60	11.05

Table E-II.2-3. Summary of exposure indices for all model runs (Medium Volume, 80% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2-hr)	2,710 x 10^6	3,894 x 10^6	0	19,102 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for landward (estuarine) cells only	22.6 x 10^6	54 x 10^6	54	287 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for seaward (marine) area only	255 x 10^6	272 x 10^6	0	1,910 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for all waters	277 x 10^6	279 x 10^6	0	1,922 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) 0-20 nautical miles offshore (including all bays)	273 x 10^6	273 x 10^6	0	1,921 x 10^6
Surface Oil Exposure Exceeding $10 g/m^2$ (m^2) 0-20 nautical miles offshore (including all bays)	34 x 10^6	41 x 10^6	0	186 x 10^6
Area of Shoreline Oiling Exceeding $0.01 g/m^2$ (m^2)	837,850	1,500,141	12	8,437,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	51,912	115,533	28	993,578
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	7,861	10,409	28	42,284
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	145	859	90	8,139
Length of Shoreline Oiling Exceeding 10 g/m^{2-} Other Shoreline (m)	7,716	10,319	28	42,086
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	2,410	4,020	44	17,271
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	373 x 10^6	177 x 10^6	0	995 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-	2,868	2,139	0	12,980

hrs)				
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	6.38	12.36	14	39.37
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0141	0.0557	5	0.5373
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	72.10	24.23	0	89.69
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	59.87	26.39	0	85.56
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	0.74	2.15	59	11.04

Table E-II.2-4. Summary of exposure indices for all model runs (Large Volume, No Dispersant).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2-hr)	17,280 x 10^6	18,841 x 10^6	0	91,805 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for landward (estuarine) cells only	89.15 x 10^6	126 x 10^6	36	458 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for seaward (marine) area only	608 x 10^6	538 x 10^6	0	2,544 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) for all waters	697 x 10^6	513 x 10^6	0	2,565 x 10^6
Surface Oil Exposure Exceeding $0.01 g/m^2$ (m^2) 0-20 nautical miles offshore (including all bays)	672 x 10^6	469 x 10^6	0	2,440 x 10^6
Surface Oil Exposure Exceeding $10 g/m^2$ (m^2) 0-20 nautical miles offshore (including all bays)	263 x 10^6	210 x 10^6	0	1,280 x 10^6
Area of Shoreline Oiling Exceeding $0.01 g/m^2$ (m^2)	2,853,018	3,361,711	1	14,710,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	498,066	524,601	1	2,074,505
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	45,095	28,844	1	124,470
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	2,327	3,922	40	14,889
Length of Shoreline Oiling Exceeding 10 g/m^{2-} Other Shoreline (m)	42,769	26,720	1	121,493
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	14,232	9,150	7	40,696
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	385 x10^6	408 x 10^6	0	1,450 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	484	316	0	1,635

Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	19.58	9.38	1	35.49
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0039	0.0196	71	0.1844
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	8.58	4.22	0	17.82
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	0	0	100	0
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	18.10	5.19	0	28.92

Table E-II.2-5. Summary of exposure indices for all model runs (Large Volume, 45% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	9.275E+09	1.161E+10	0	5.6225E+10
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) cells only	52 x 10^6	94 x 10^6	47	394 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	437 x 10^6	358 x 10^6	0	1,652 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	489 x 10^6	350 x 10^6	0	1,653 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) 0-20 nautical miles offshore (including all bays)	476 x 10^6	330 x 10^6	0	1,632 x 10^6
Surface Oil Exposure Exceeding 10g/m^2 (m^2) 0-20 nautical miles offshore (including all bays)	115 x 10^6	84 x 10^6	0	581 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	1,577,370	2,326,861	5	11,440,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	264,856	355,900	9	1,695,733
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	27,250	23,093	9	90,524
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	1,124	2,580	65	12,904
Length of Shoreline Oiling Exceeding 10 g/m$^{2\text{ -}}$ Other Shoreline (m)	26,127	21,778	9	81,194
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	8,612	7,957	13	33,748
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	2,495 x 10^6	1,472 x 10^6	0	6,513 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-	6,492	4,926	0	40,810

hrs)				
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	9.76	9.52	6	35.08
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0042	0.0129	8	0.1117
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	53.32	24.35	0	85.45
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	44.74	26.61	0	83.51
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	6.88	4.22	0	16.82

Table E-II.2-6. Summary of exposure indices for all model runs (Large Volume, 80% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	9,081 x 10^6	1,176 x 10^6	0	55,565 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) cells only	46 x 10^6	85 x 10^6	50	411 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	398 x 10^6	325 x 10^6	0	1,623 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	444 x 10^6	323 x 10^6	0	1,625 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) 0-20 nautical miles offshore (including all bays)	432 x 10^6	307 x 10^6	0	1,578 x 10^6
Surface Oil Exposure Exceeding 10g/m^2 (m^2) 0-20 nautical miles offshore (including all bays)	99 x 10^6	82 x 10^6	0	569 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	1,452,721	2,134,329	4	11,780,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	218,790	295,761	9	1,460,293
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	23,653	20,709	9	96,082
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	897	2,085	68	10,918
Length of Shoreline Oiling Exceeding 10 g/m^{2} - Other Shoreline (m)	22,756	19,649	9	88,539
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	7,538	7,663	18	31,763
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	2,554 x 10^6	1,428 x 10^6	0	6,123 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-	8,701	7,497	0	49,470

hrs)				
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	7.65	9.18	7	34.84
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0054	0.0131	7	0.1046
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	62.17	25.03	0	88.42
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	53.59	27.11	0	86.05
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	4.92	4.39	0	16.77

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part E: San Francisco Bay and Central California Shelf

Section E-II.3

by

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ASA 00-246

August 2004

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E-II.3 Rank Order Distributions for All Model Runs

In this section, the following impact indices are plotted as rank order distributions:

- Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 (which is sheen) times duration of exposure (in m^2-hrs)
- Shoreline area (m^2) exposed to hydrocarbons of various threshold thicknesses (>1, 10, 100, and 1000 g/m^2)
- Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill
- Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill
- Percent of spilled hydrocarbon mass eventually going ashore
- Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats)
- Maximum percent of spilled hydrocarbon mass in the water column at any time after the spill, and
- Percent of spilled hydrocarbon mass mechanically removed.

E-II.3.1 Scenario: Medium Volume, No Dispersant.

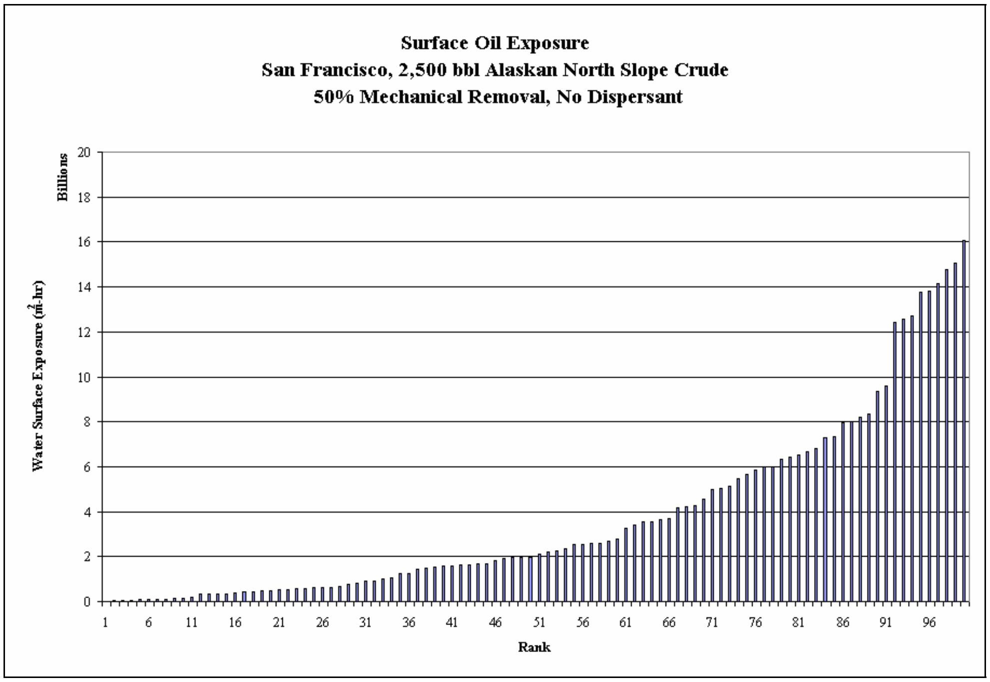

Figure E-II.3.1-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than $0.01 g/m^2$ times duration of exposure. Scenario: Medium Volume, No Dispersant.

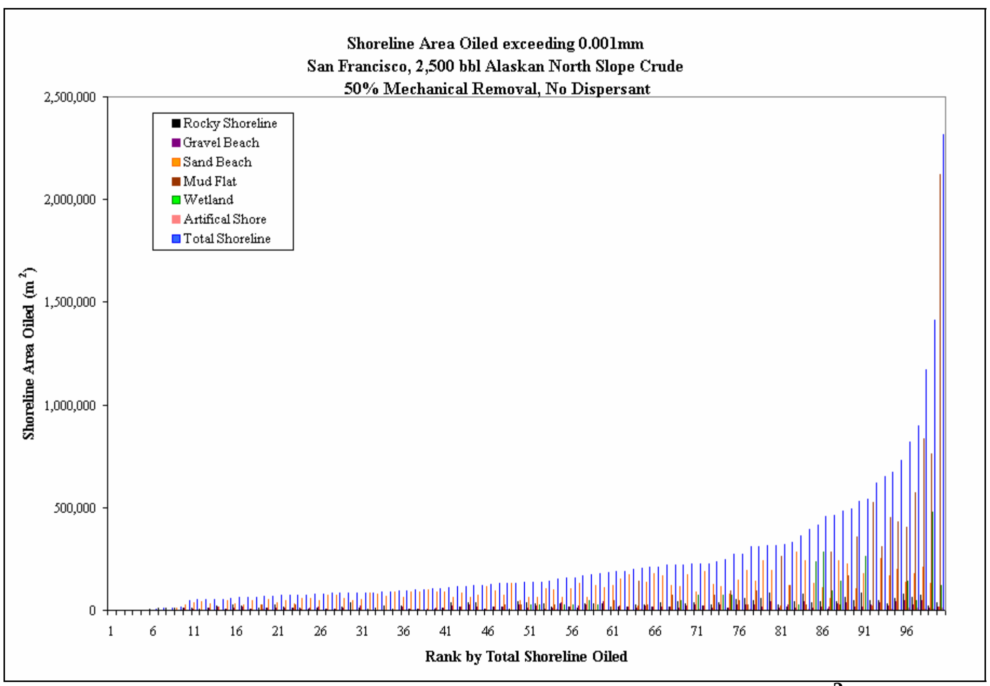

Figure E-II.3.1-2 Shoreline area exposed to hydrocarbons of $>1 g/m^2$ (about 0.001mm thick). Scenario: Medium Volume, No Dispersant.

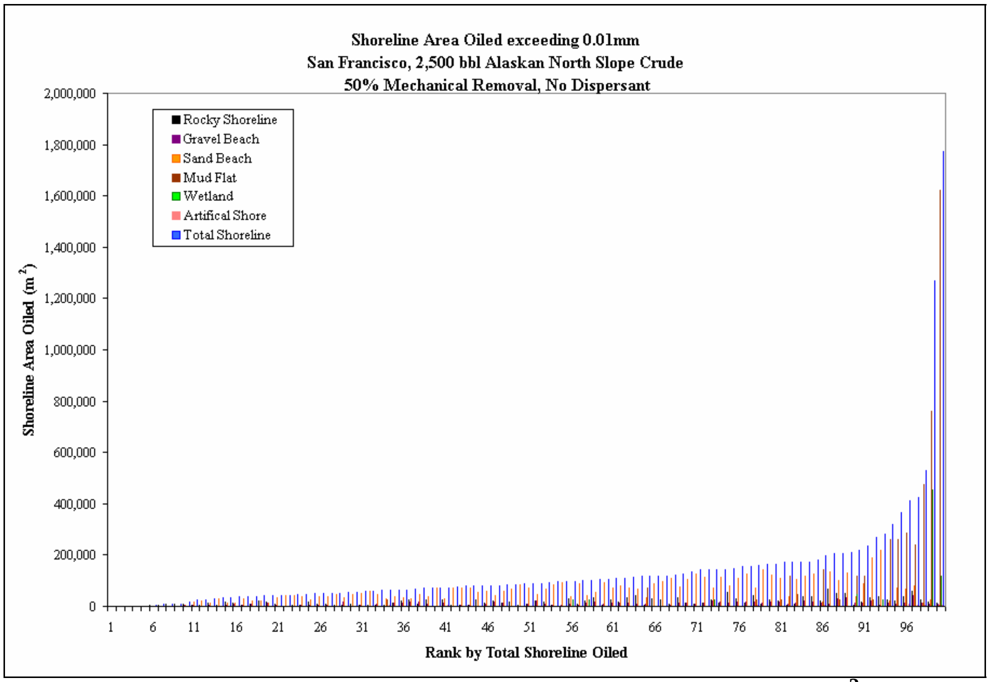

Figure E-II.3.1-3 Shoreline area exposed to hydrocarbons of >10g/m² (about 0.01mm thick). Scenario: Medium Volume, No Dispersant.

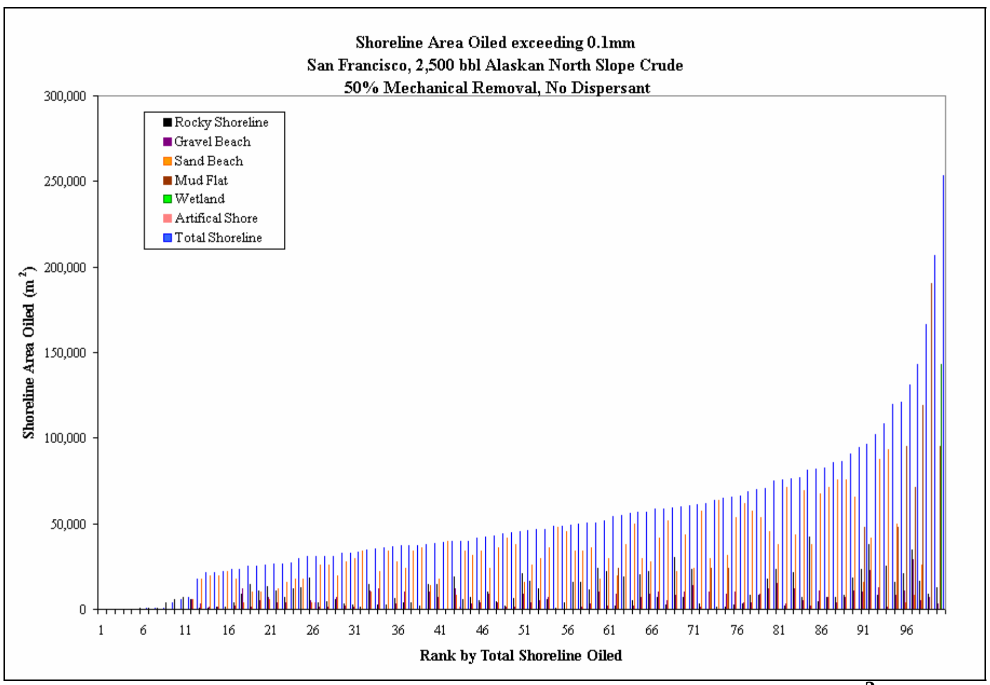

Figure E-II.3.1-4 Shoreline area exposed to hydrocarbons of >100g/m² (about 0.1mm thick). Scenario: Medium Volume, No Dispersant.

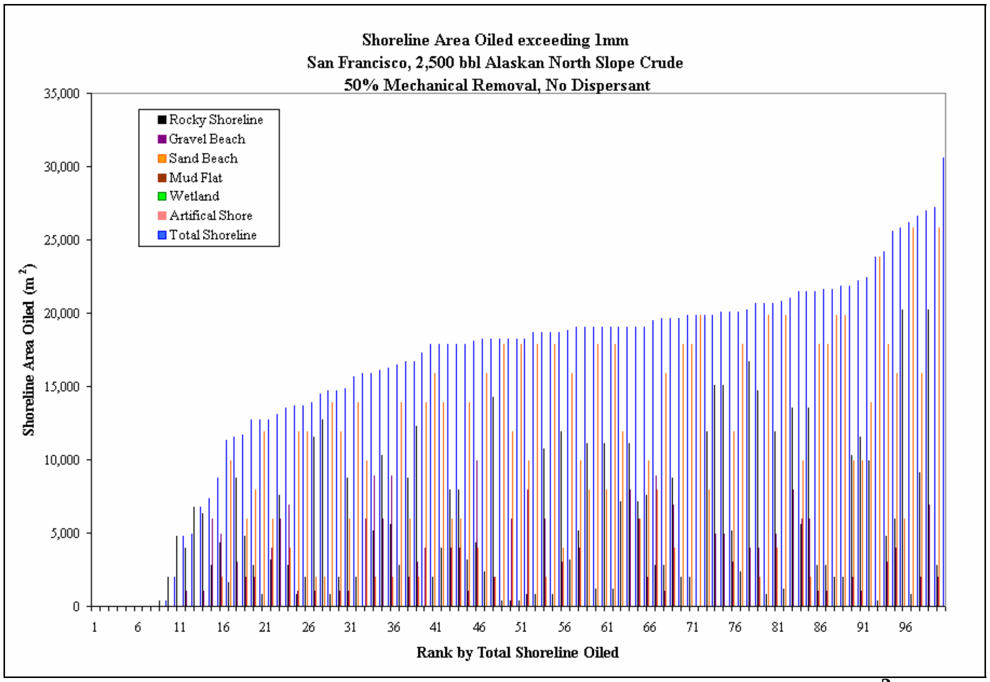

Figure E-II.3.1-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Medium Volume, No Dispersant.

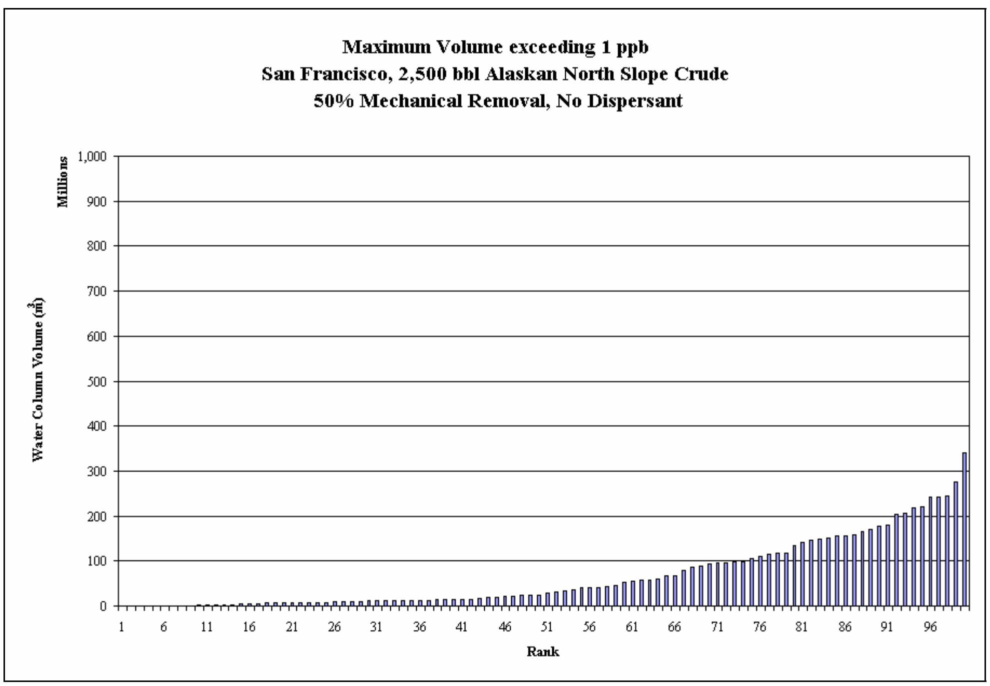

Figure E-II.3.1-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, No Dispersant.

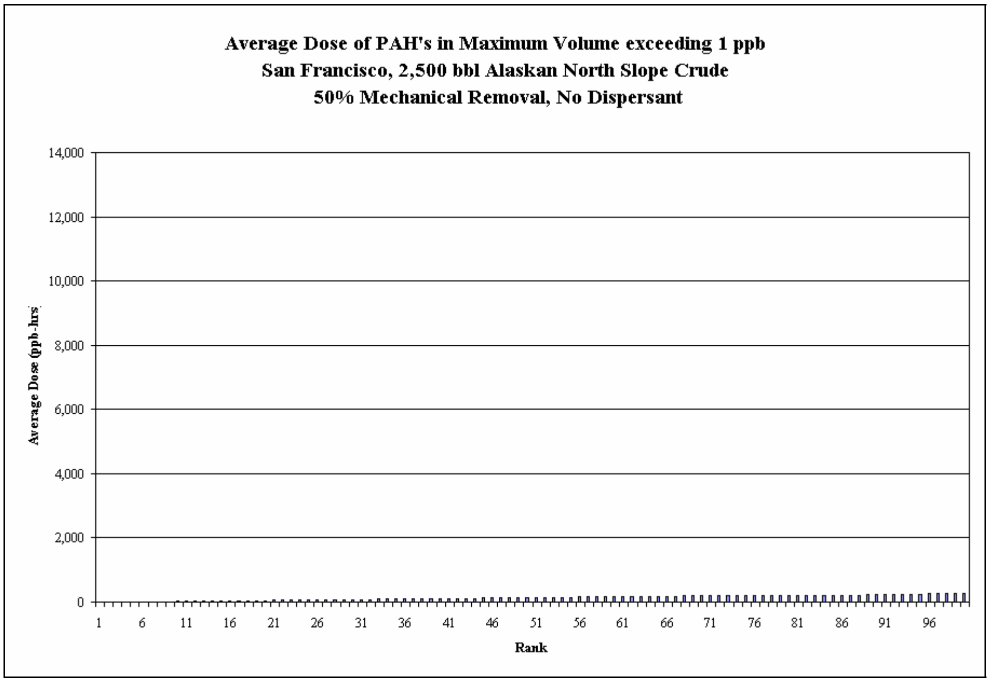

Figure E-II.3.1-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, No Dispersant.

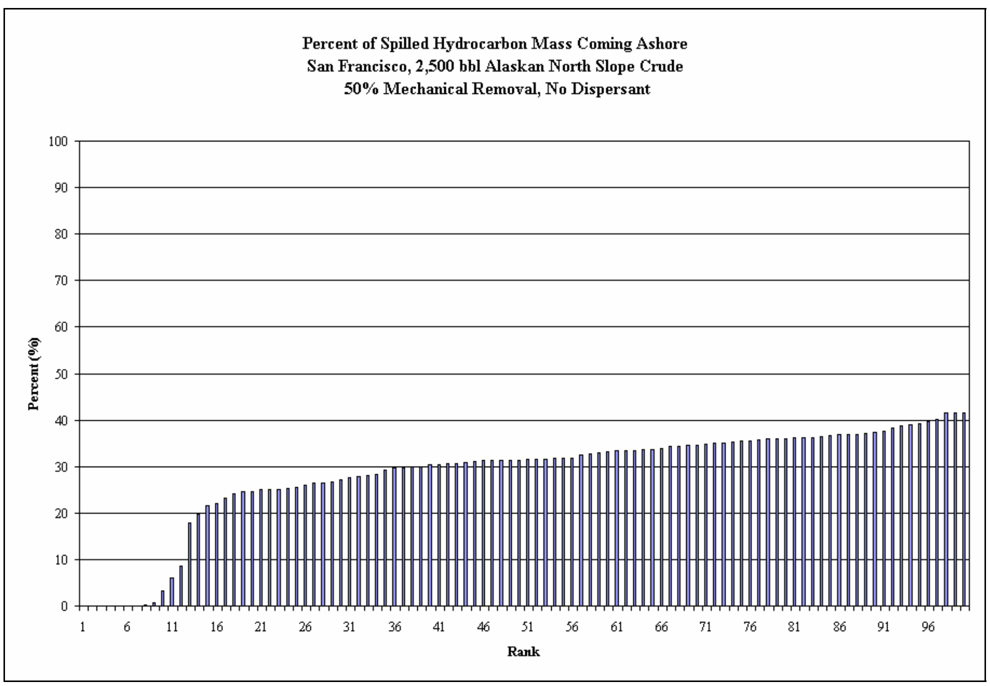

Figure E-II.3.1-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Medium Volume, No Dispersant.

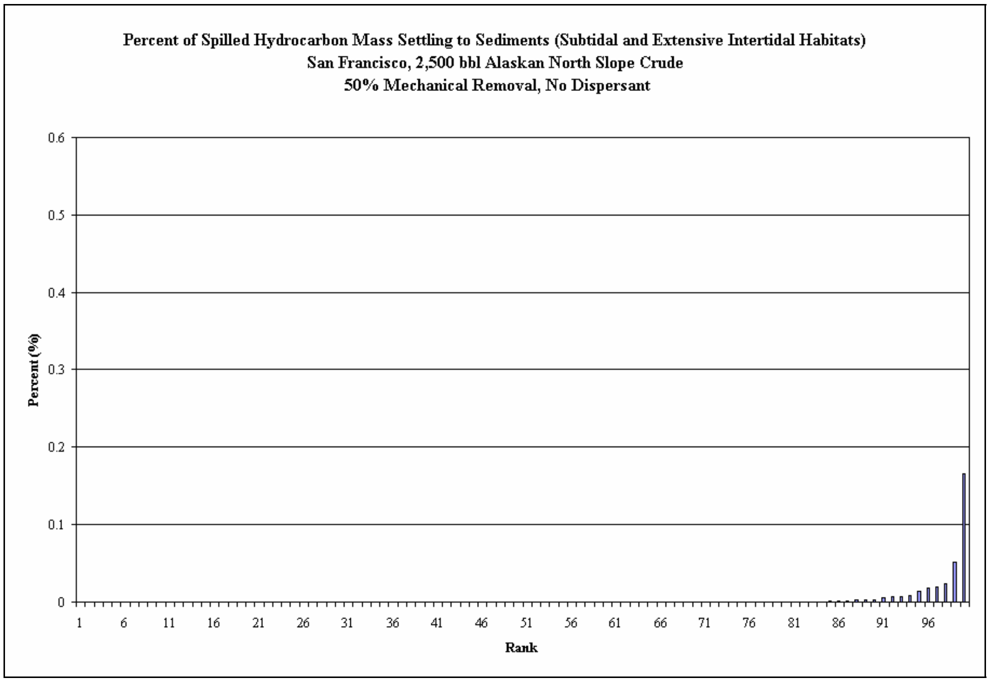

Figure E-II.3.1-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Medium Volume, No Dispersant.

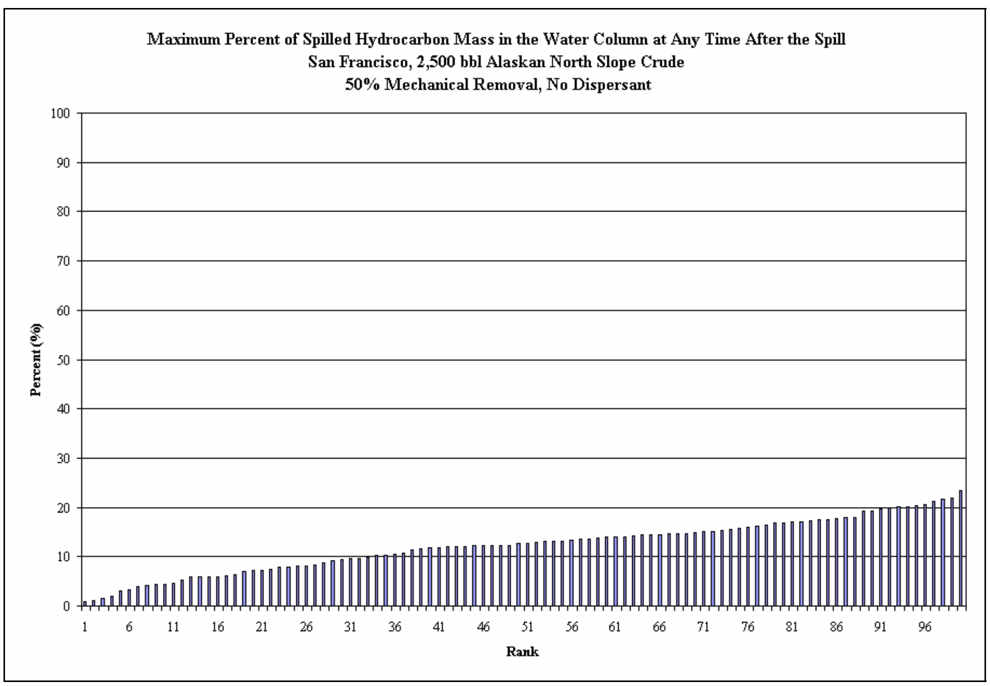

Figure E-II.3.1-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Medium Volume, No Dispersant.

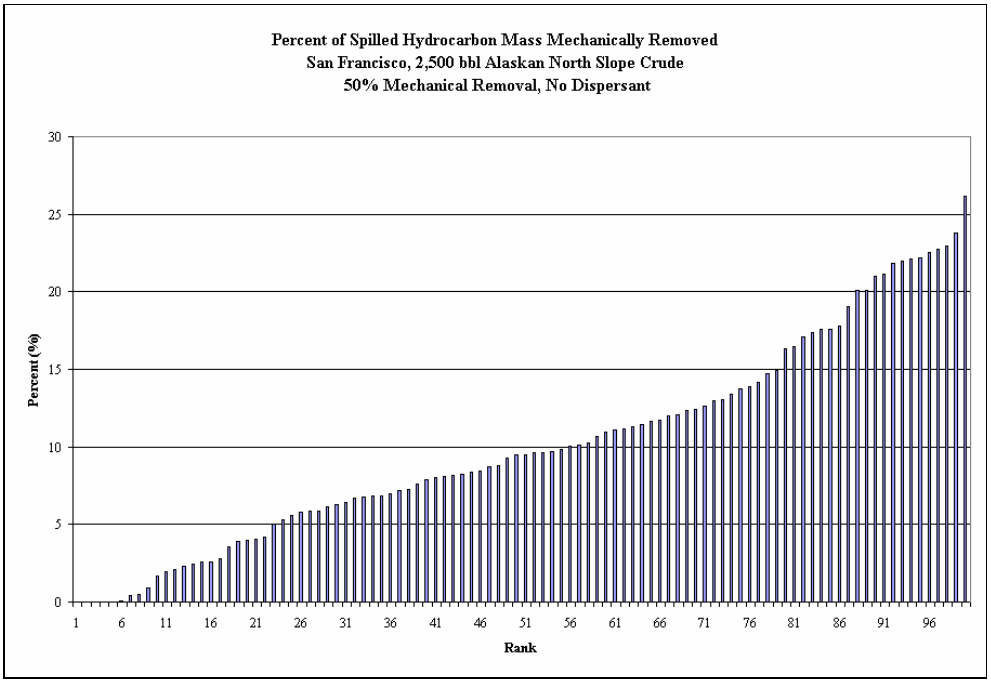

Figure E-II.3.1-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Medium Volume, No Dispersant.

E-II.3.2 Scenario: Medium Volume, 45% Dispersant Efficiency.

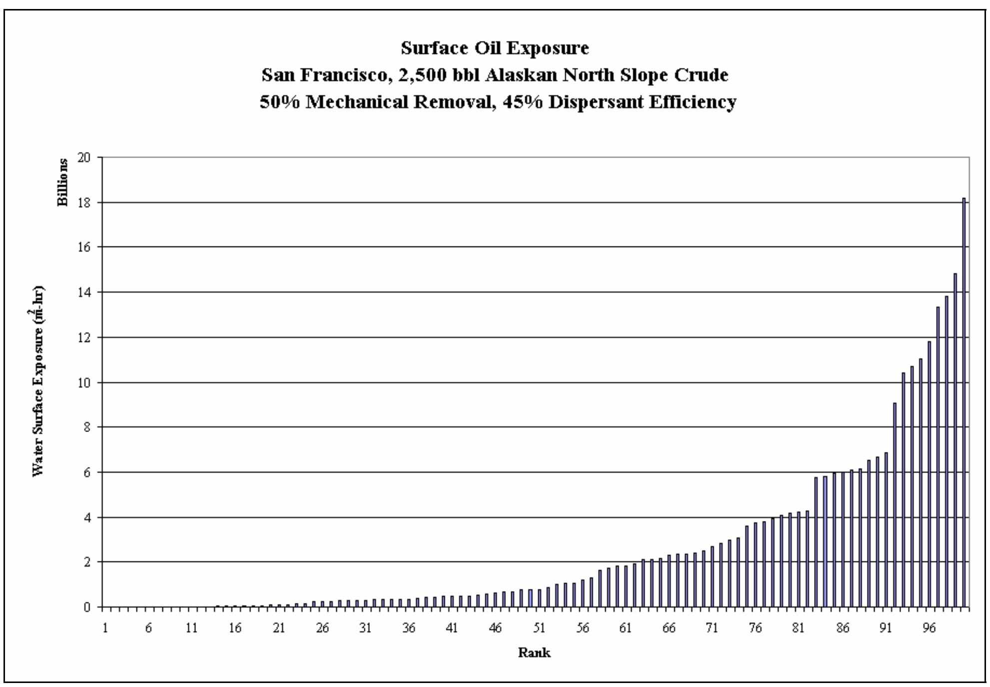

Figure E-II.3.2-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

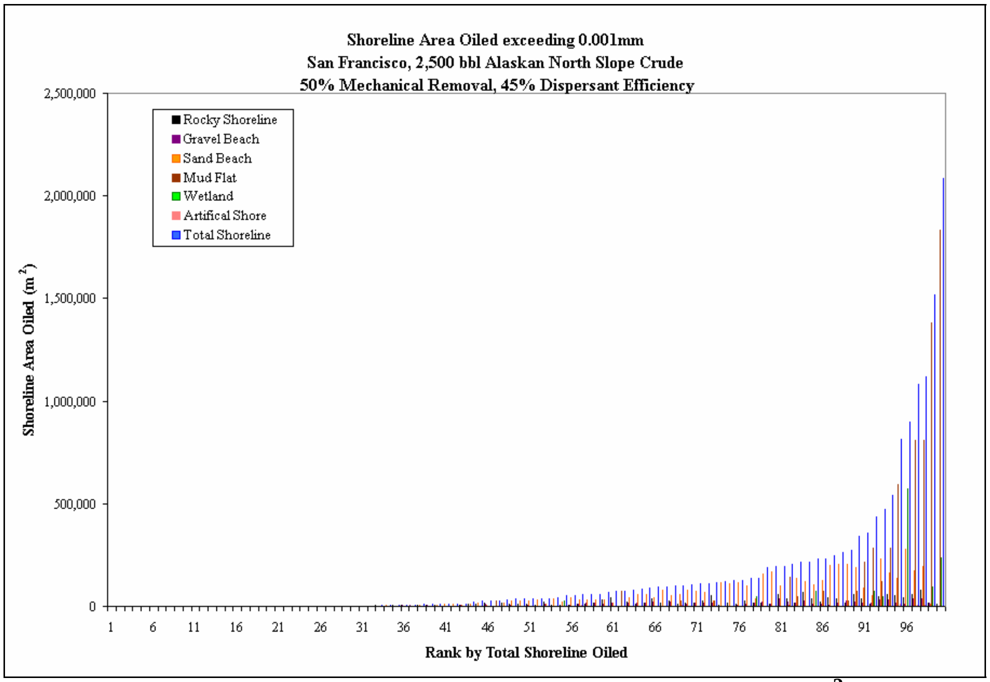

Figure E-II.3.2-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

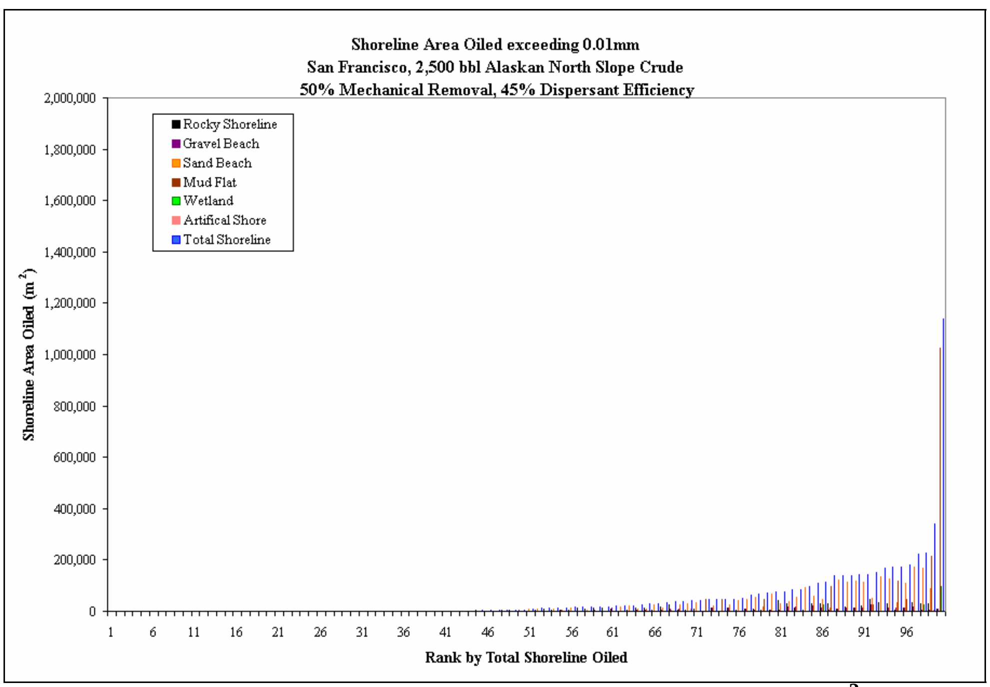

Figure E-II.3.2-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

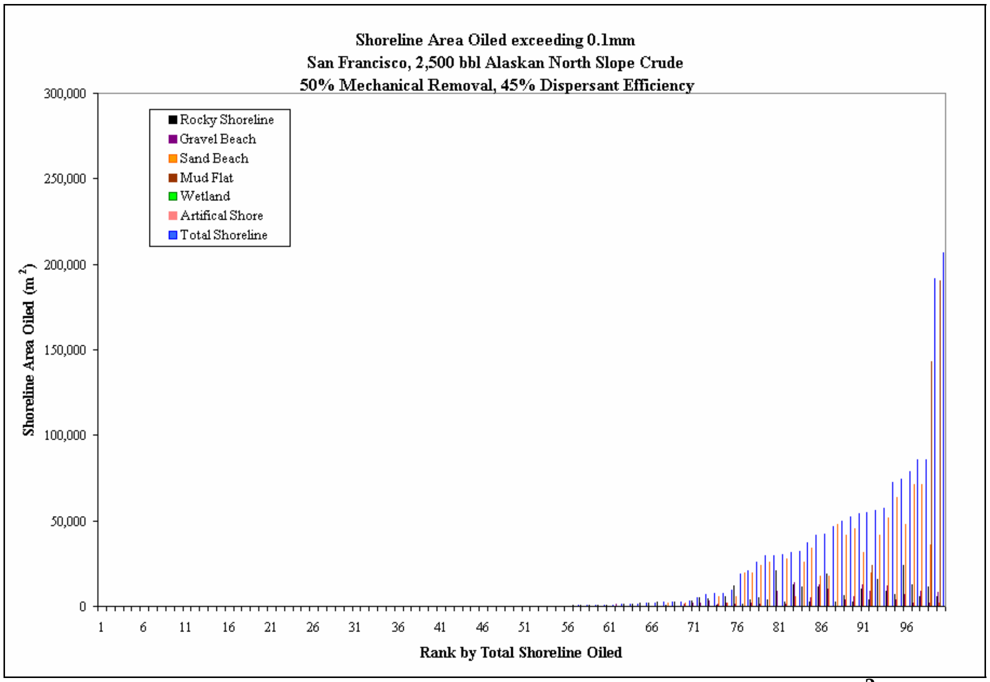

Figure E-II.3.2-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

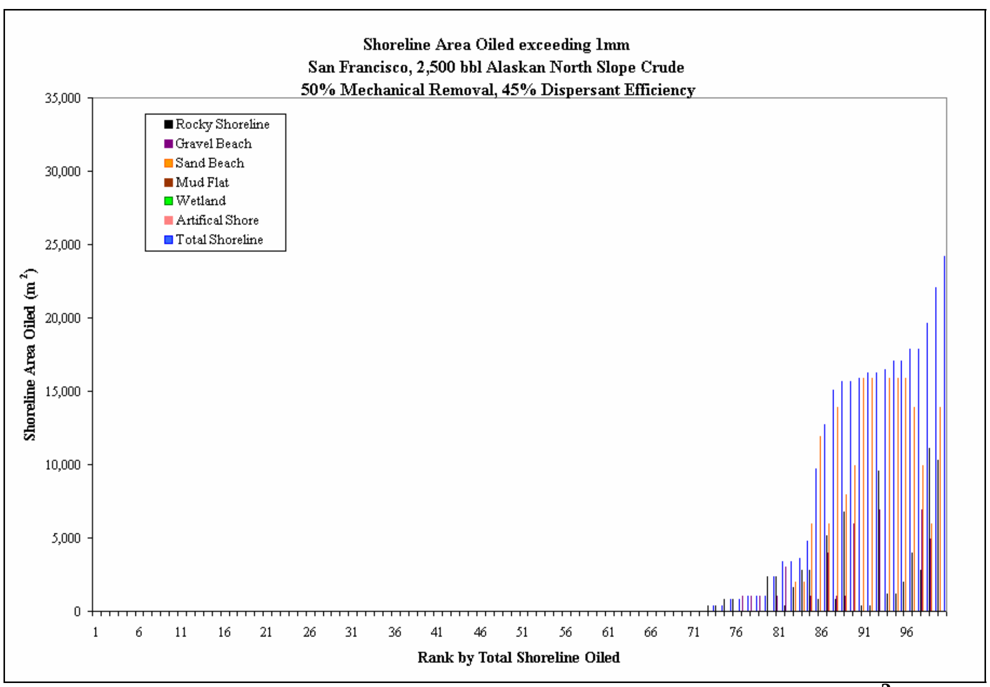

Figure E-II.3.2-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

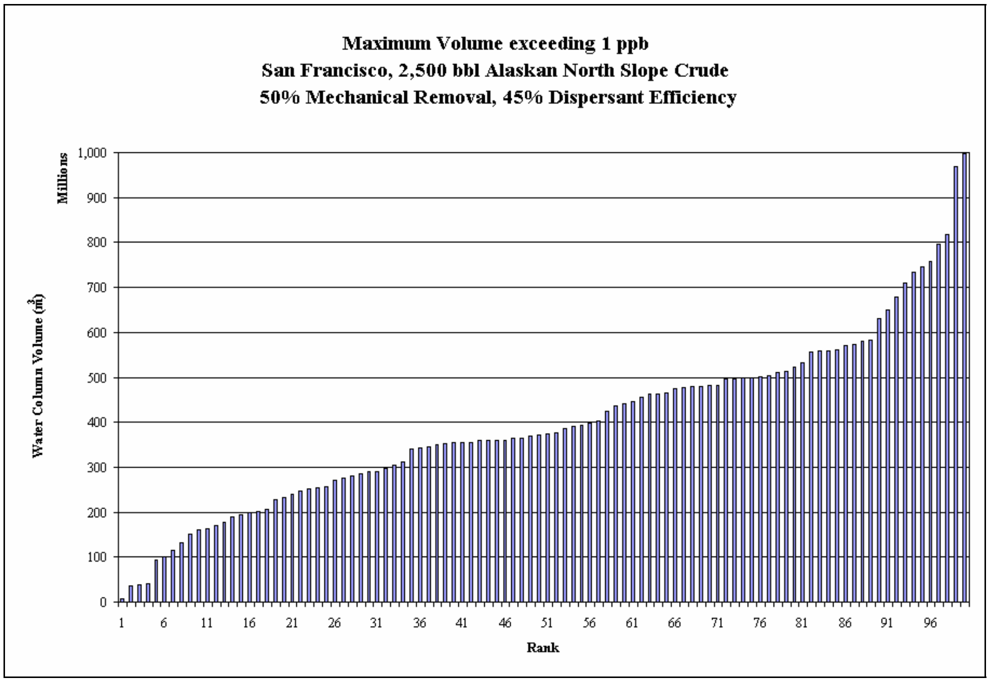

Figure E-II.3.2-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 45% Dispersant Efficiency.

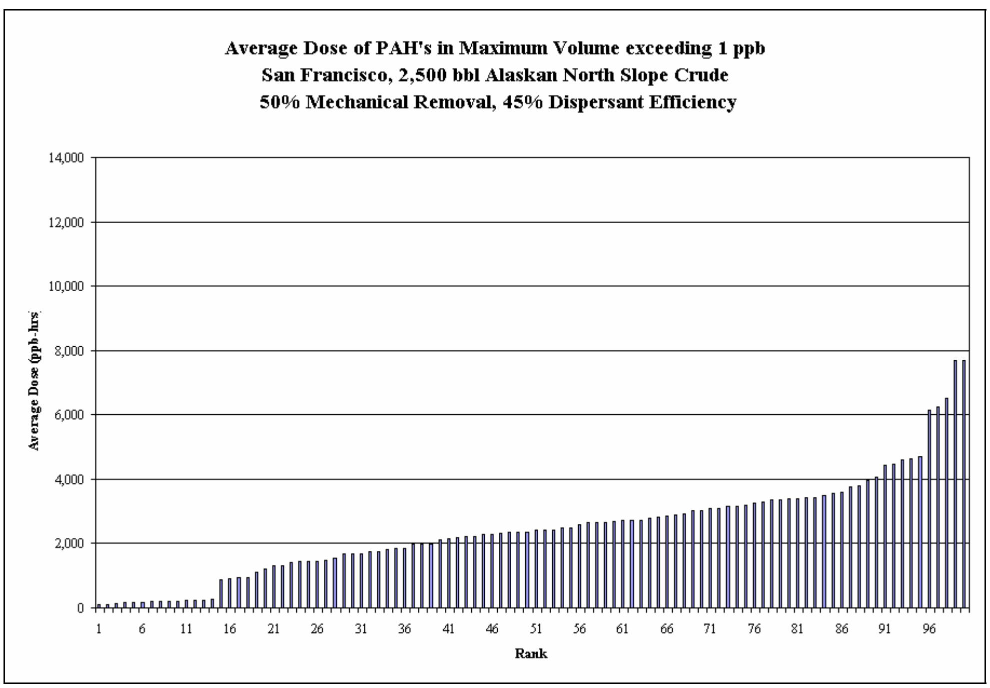

Figure E-II.3.2-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 45% Dispersant Efficiency.

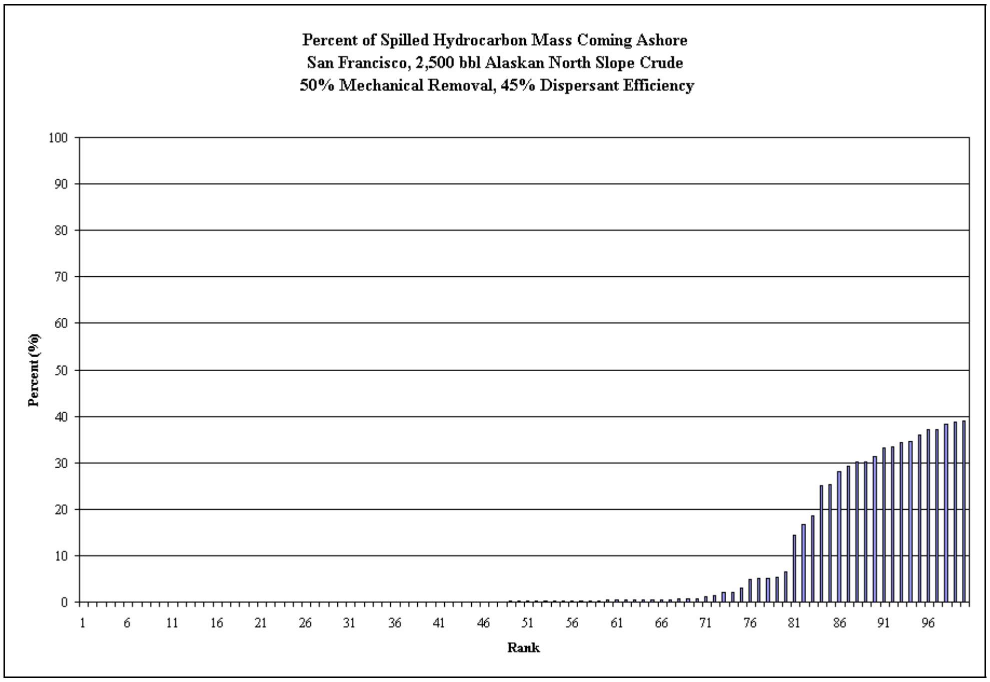

Figure E-II.3.2-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Medium Volume, 45% Dispersant Efficiency.

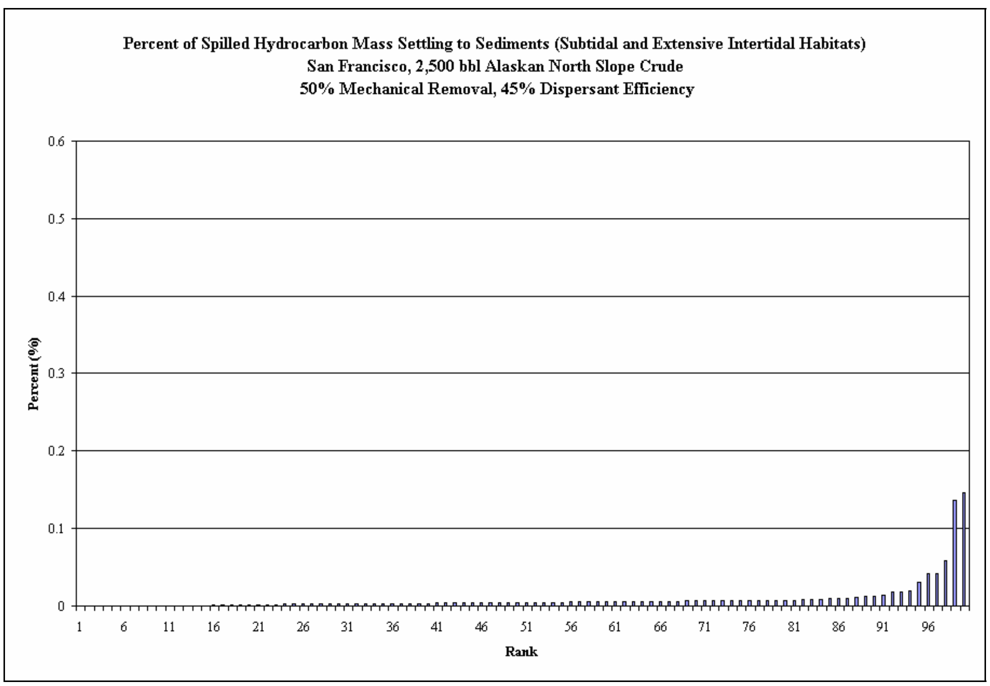

Figure E-II.3.2-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Medium Volume, 45% Dispersant Efficiency.

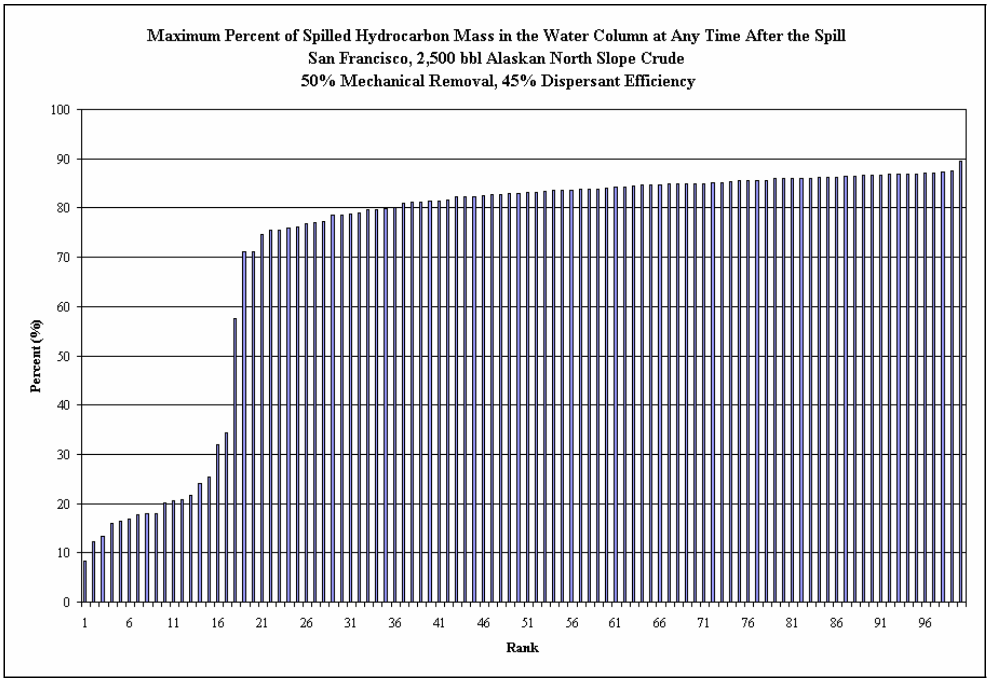

Figure E-II.3.2-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Medium Volume, 45% Dispersant Efficiency.

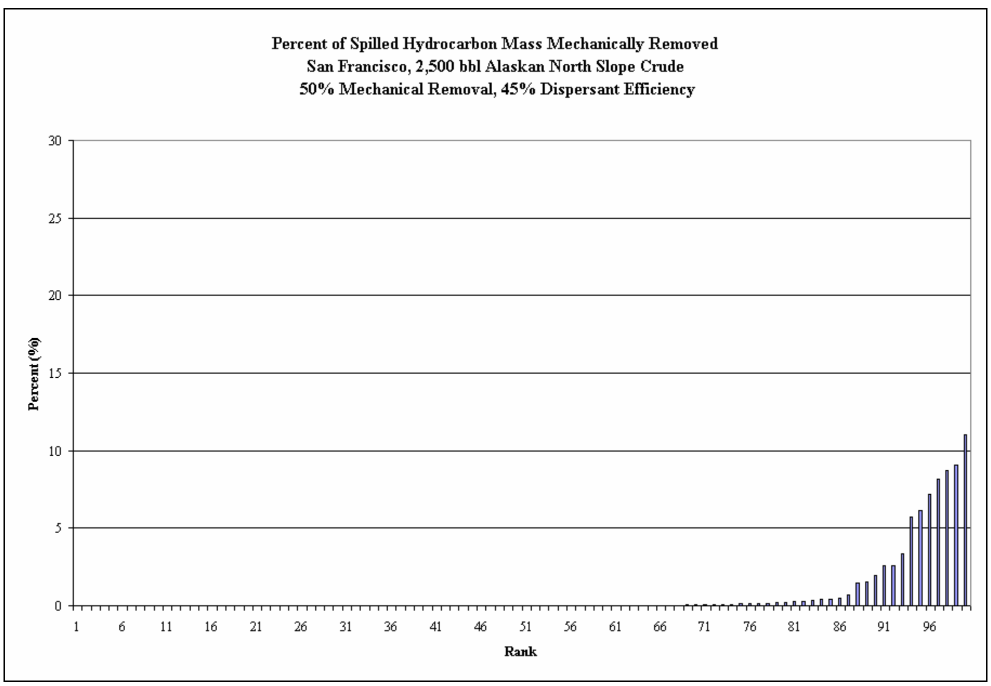

Figure E-II.3.2-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Medium Volume, 45% Dispersant Efficiency.

E-II.3.3 Scenario: Medium Volume, 80% Dispersant Efficiency.

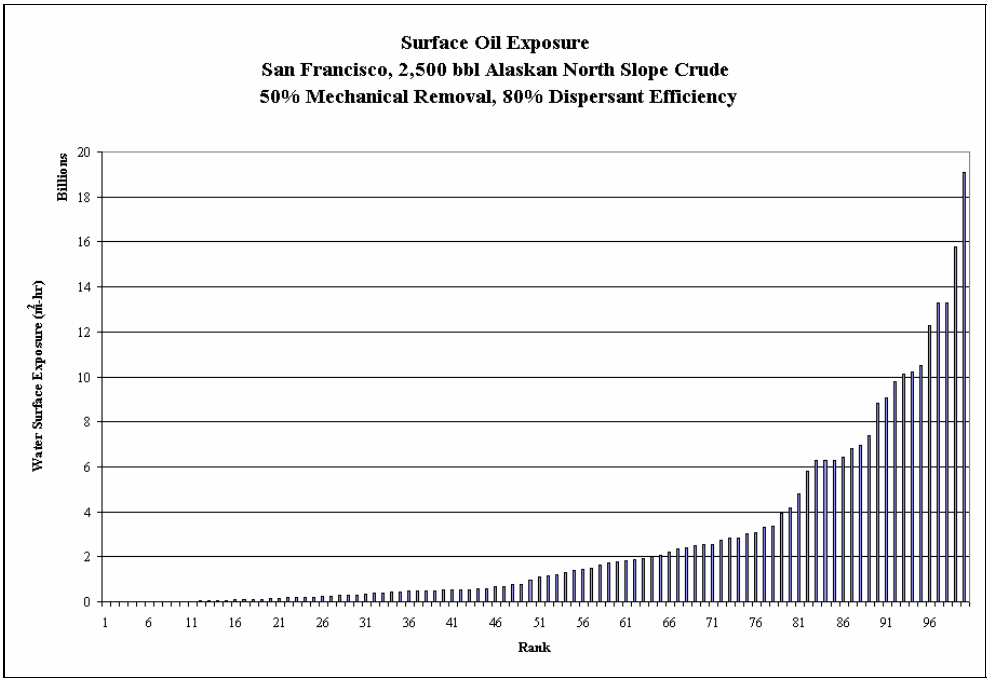

Figure E-II.3.3-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m² times duration of exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

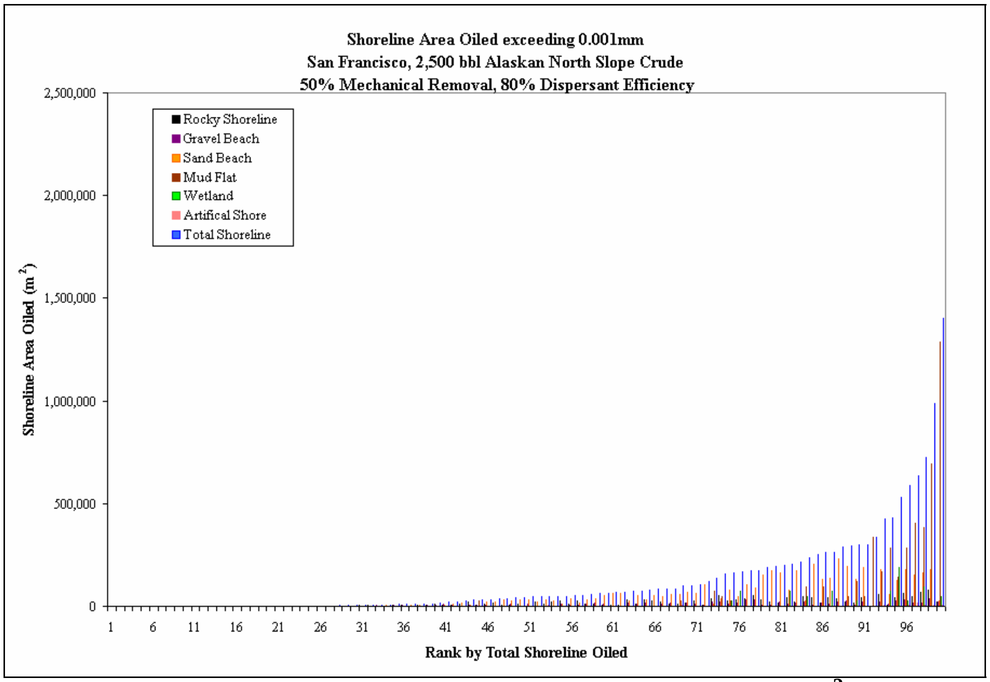

Figure E-II.3.3-2 Shoreline area exposed to hydrocarbons of >1g/m² (about 0.001mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

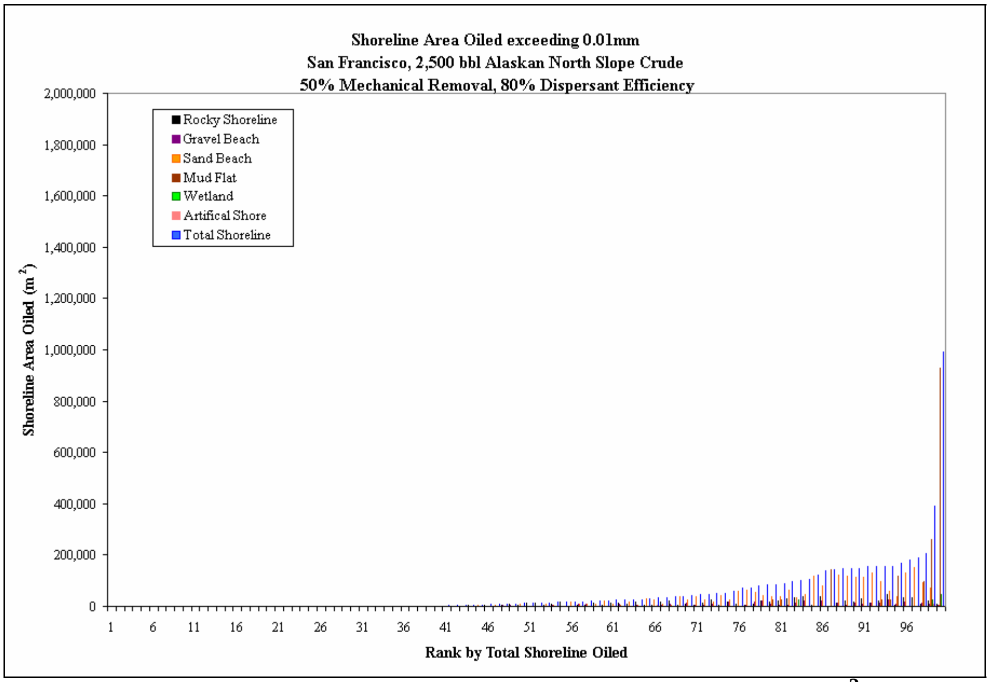

Figure E-II.3.3-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

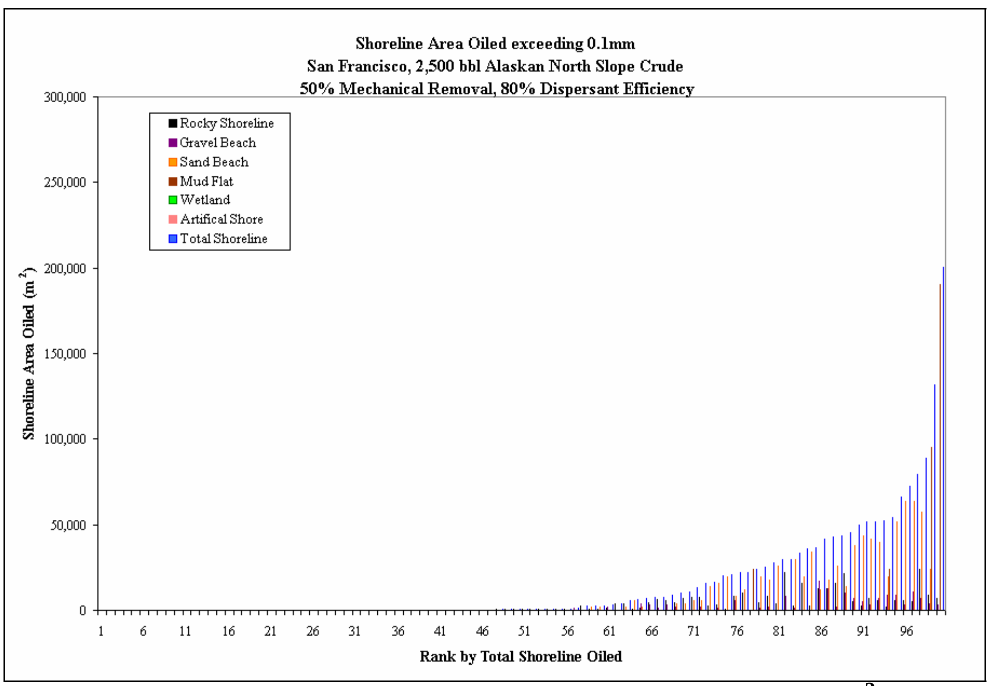

Figure E-II.3.3-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

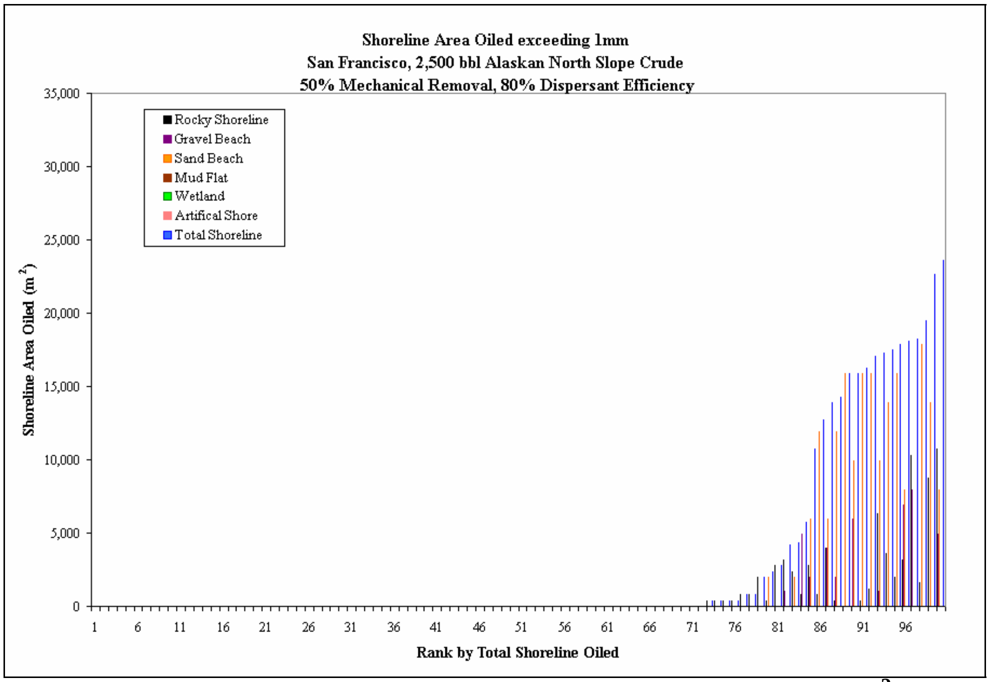

Figure E-II.3.3-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

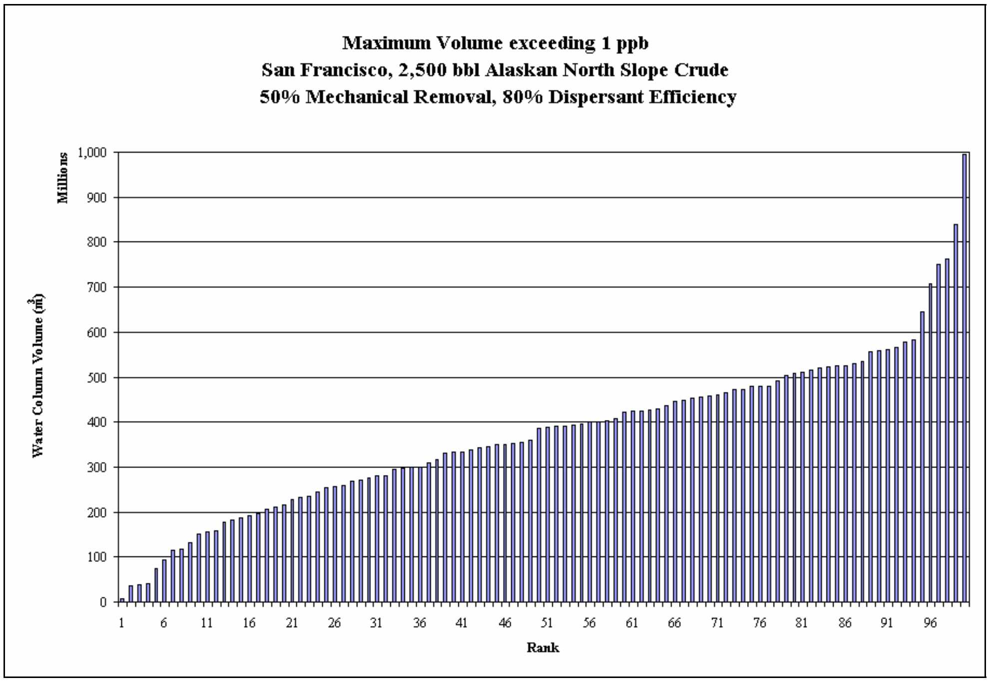

Figure E-II.3.3-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 80% Dispersant Efficiency.

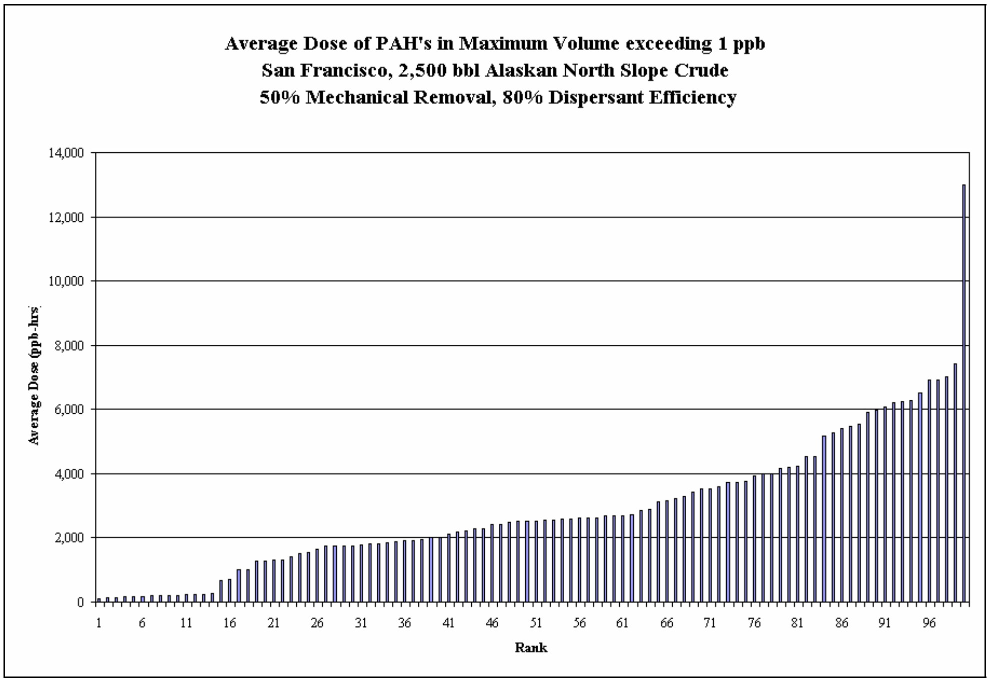

Figure E-II.3.3-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 80% Dispersant Efficiency.

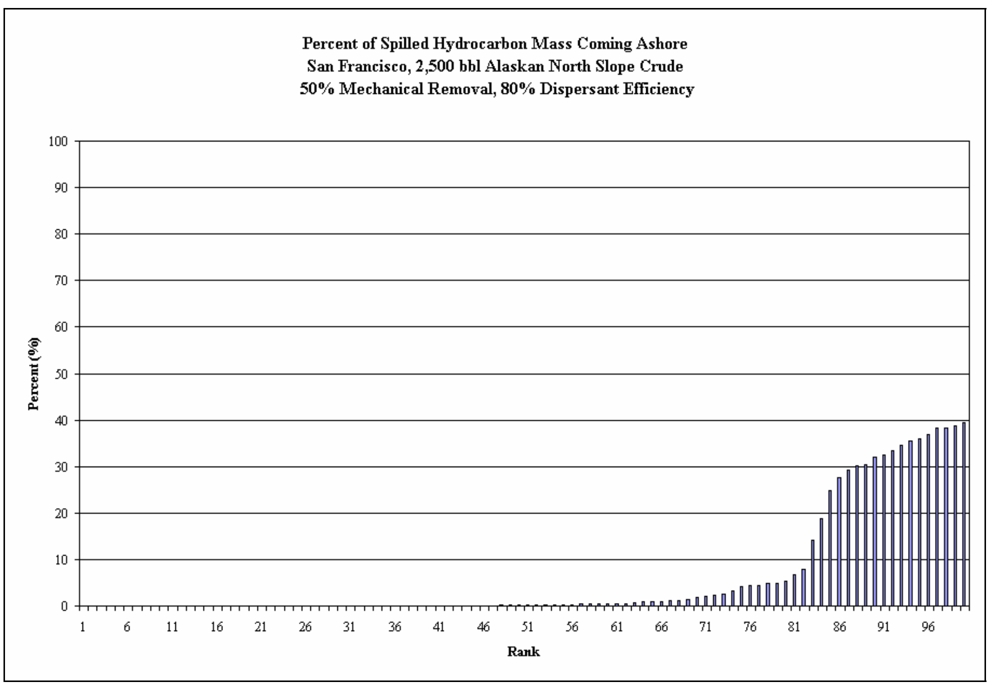

Figure E-II.3.3-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Medium Volume, 80% Dispersant Efficiency.

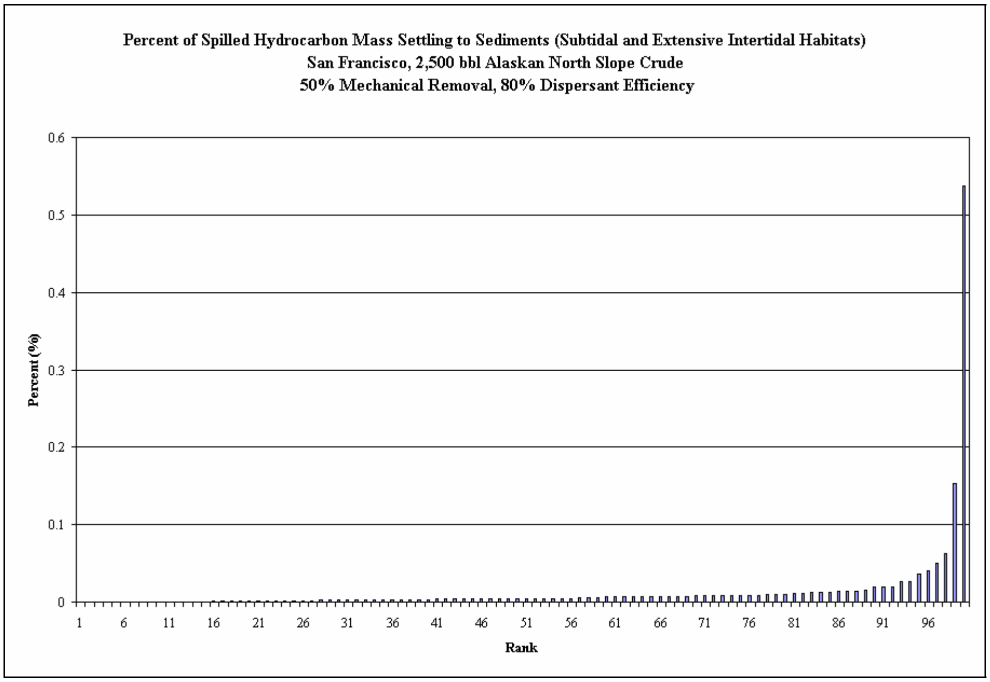

Figure E-II.3.3-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Medium Volume, 80% Dispersant Efficiency.

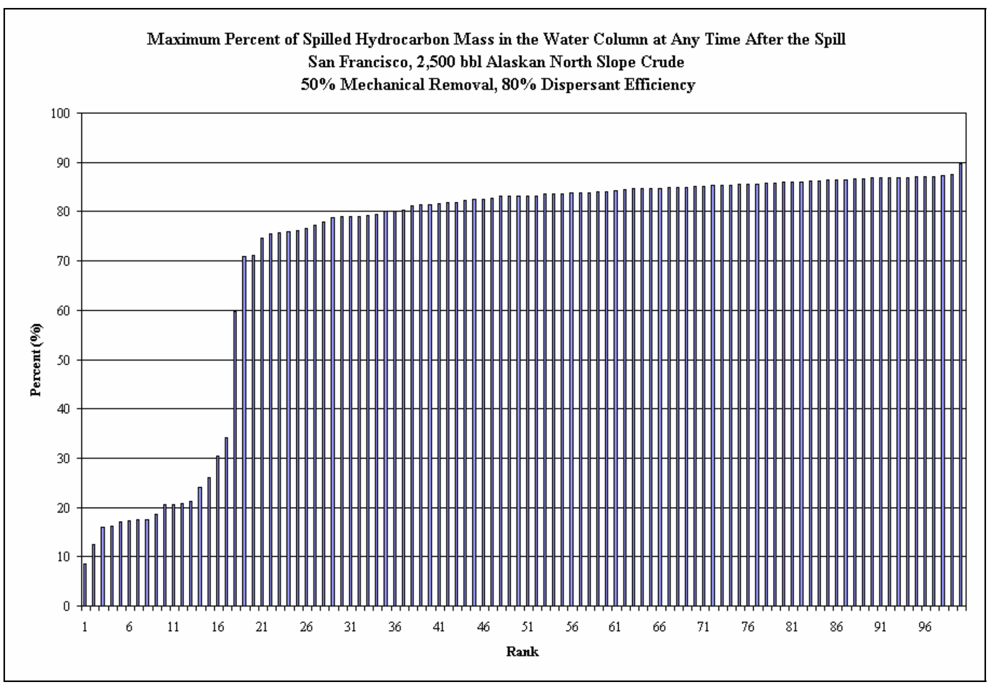

Figure E-II.3.3-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Medium Volume, 80% Dispersant Efficiency.

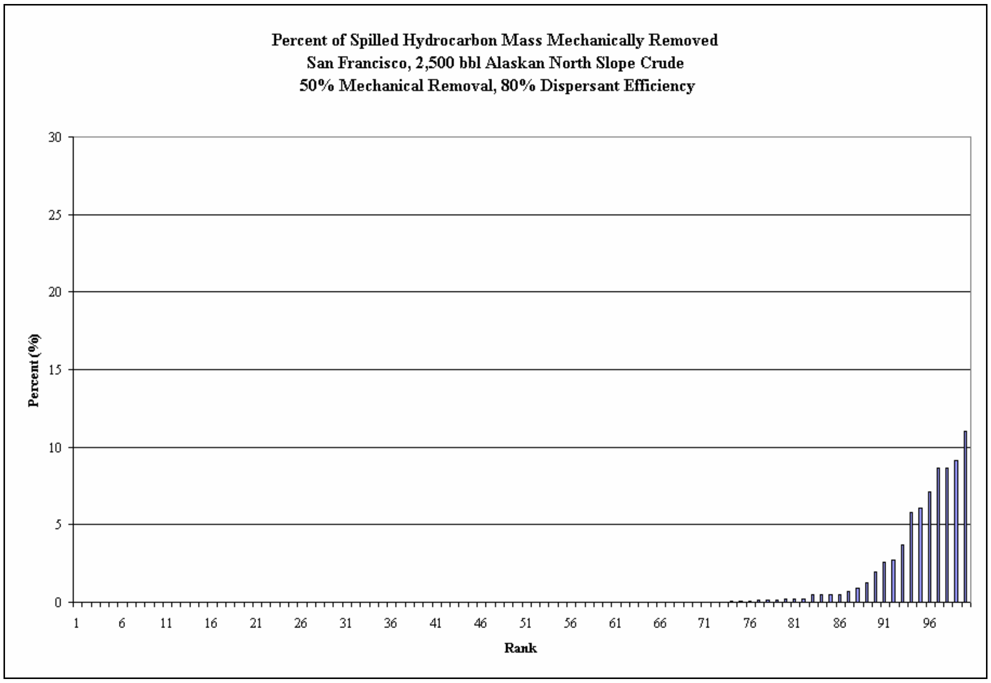

Figure E-II.3.3-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Medium Volume, 80% Dispersant Efficiency.

E-II.3.4 Scenario: Large Volume, No Dispersant.

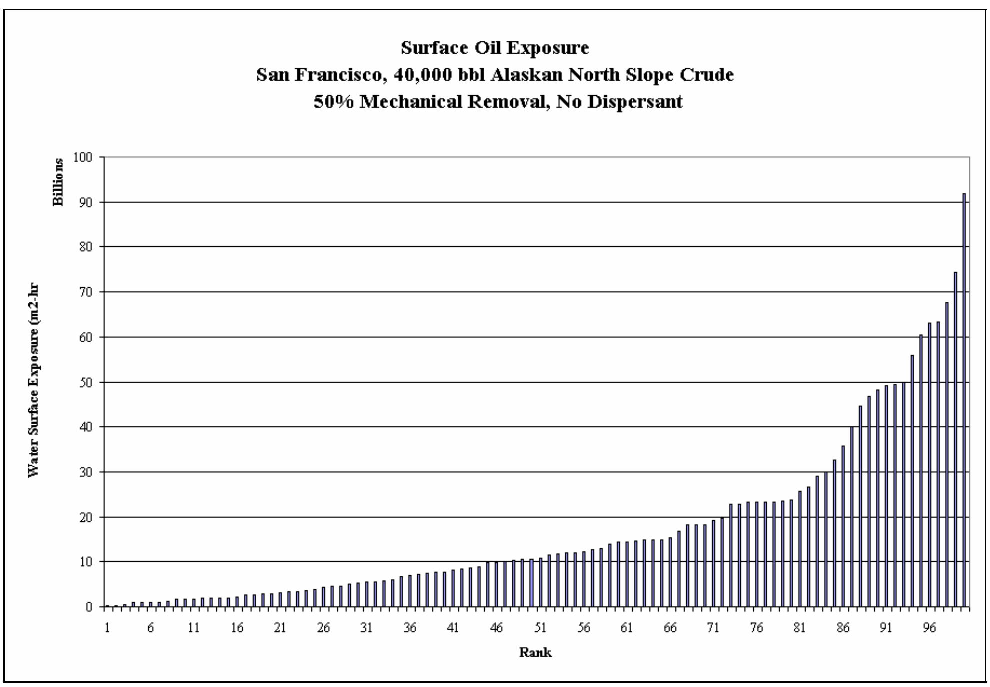

Figure E-II.3.4-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Large Volume, No Dispersant.

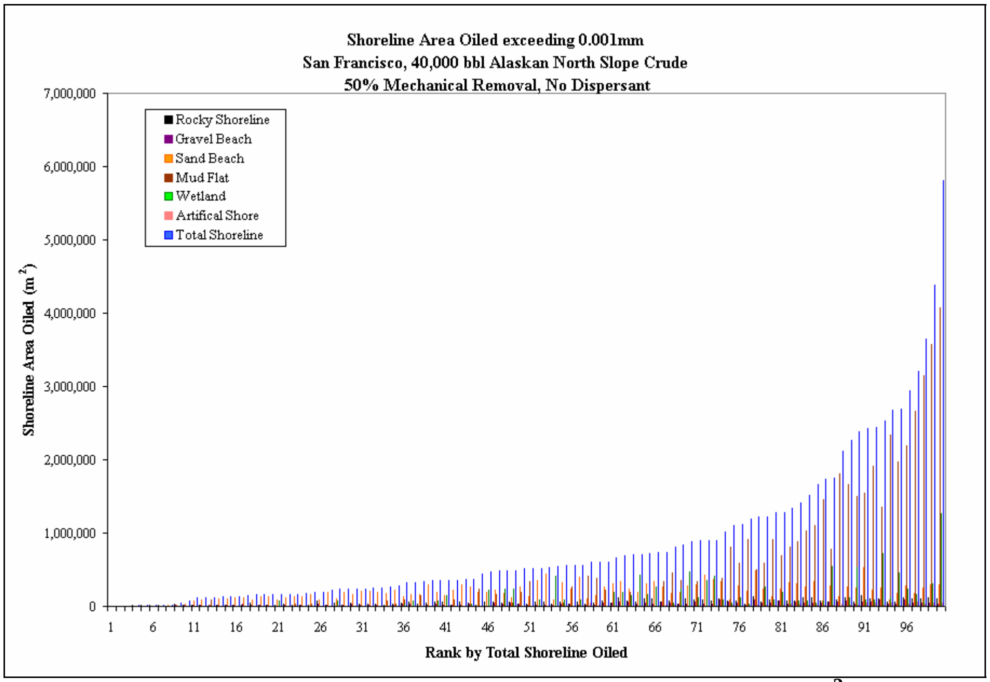

Figure E-II.3.4-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Large Volume, No Dispersant.

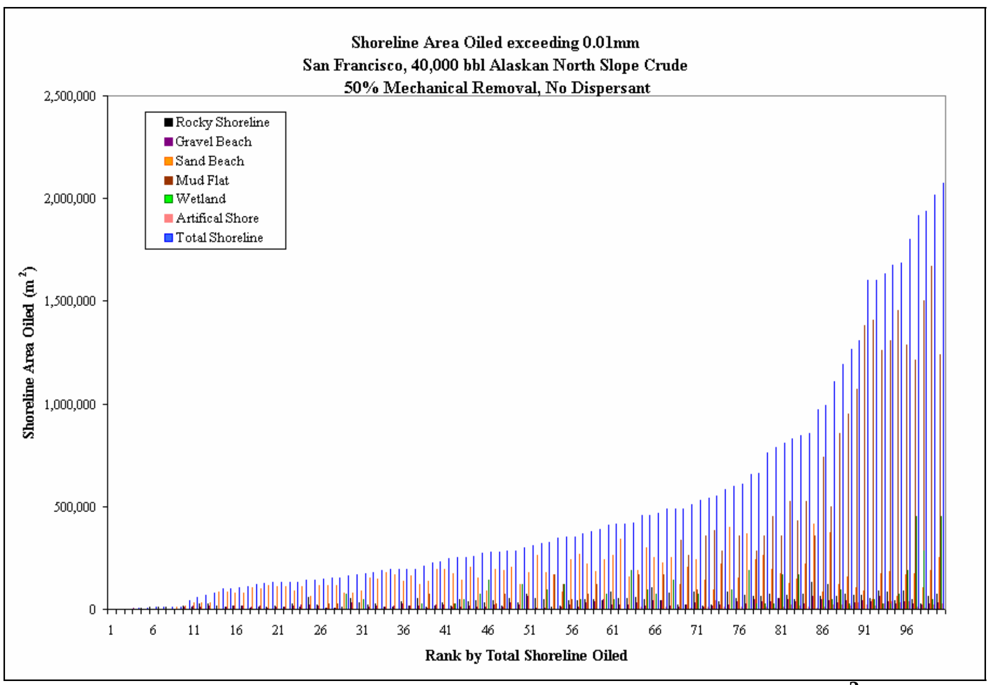

Figure E-II.3.4-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Large Volume, No Dispersant.

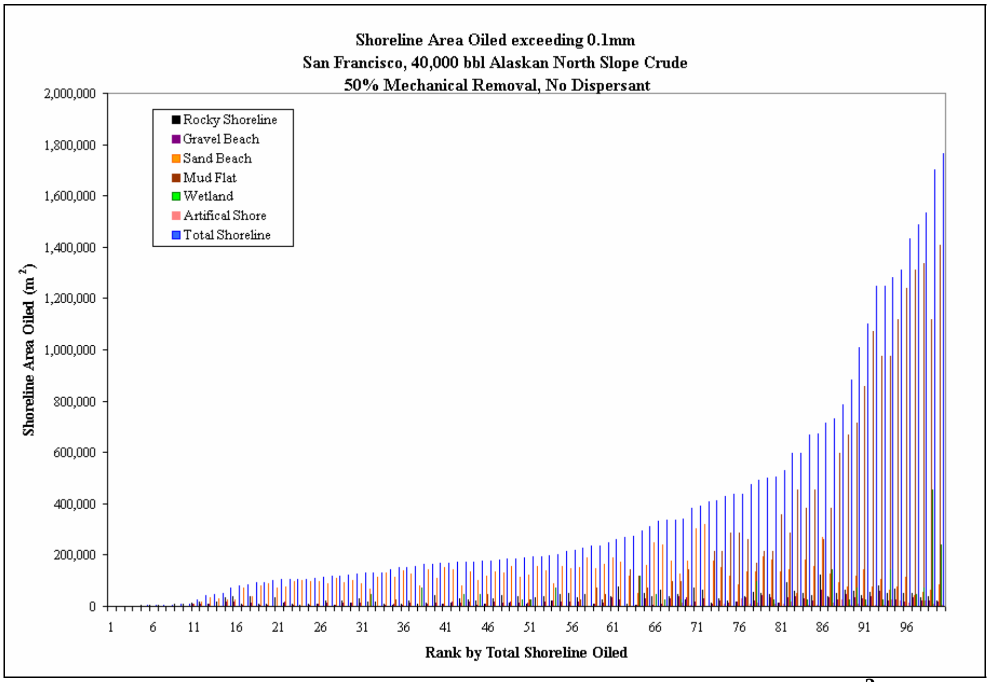

Figure E-II.3.4-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Large Volume, No Dispersant.

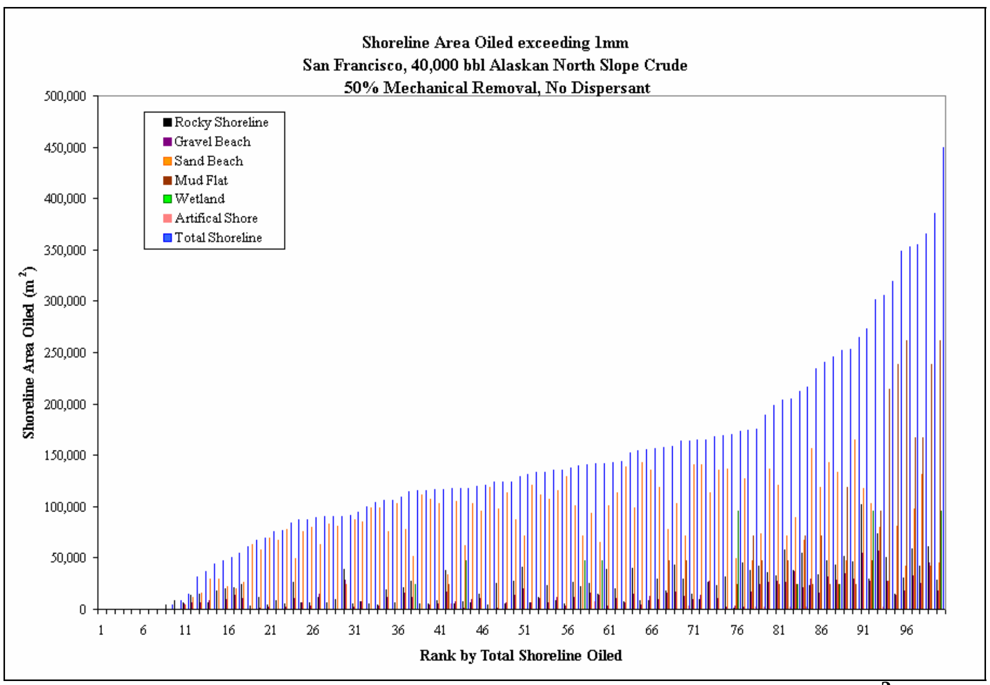

Figure E-II.3.4-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Large Volume, No Dispersant.

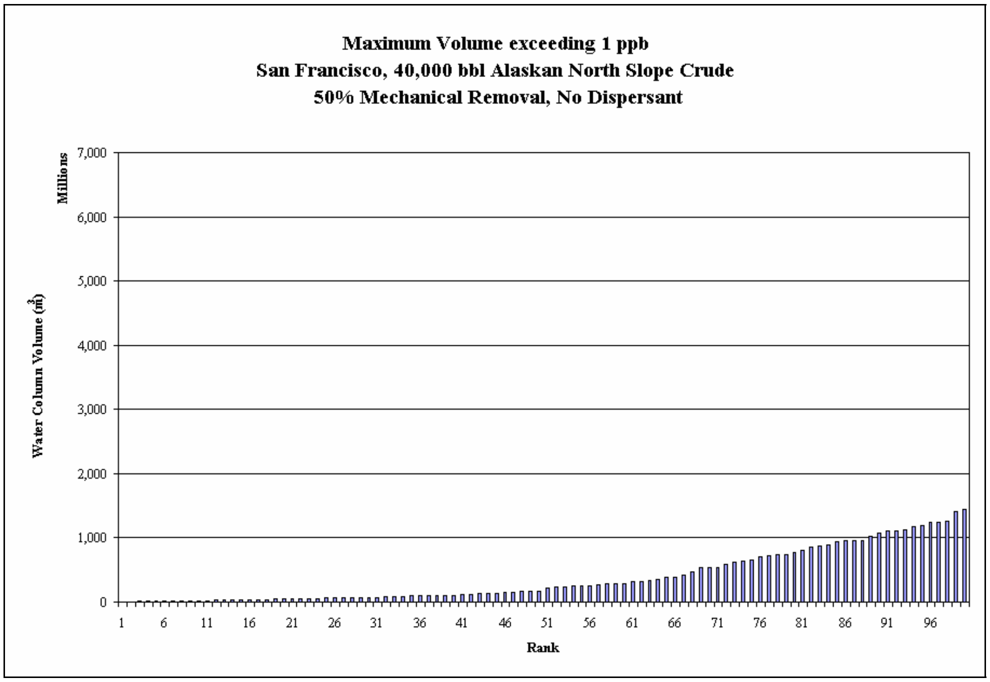

Figure E-II.3.4-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, No Dispersant.

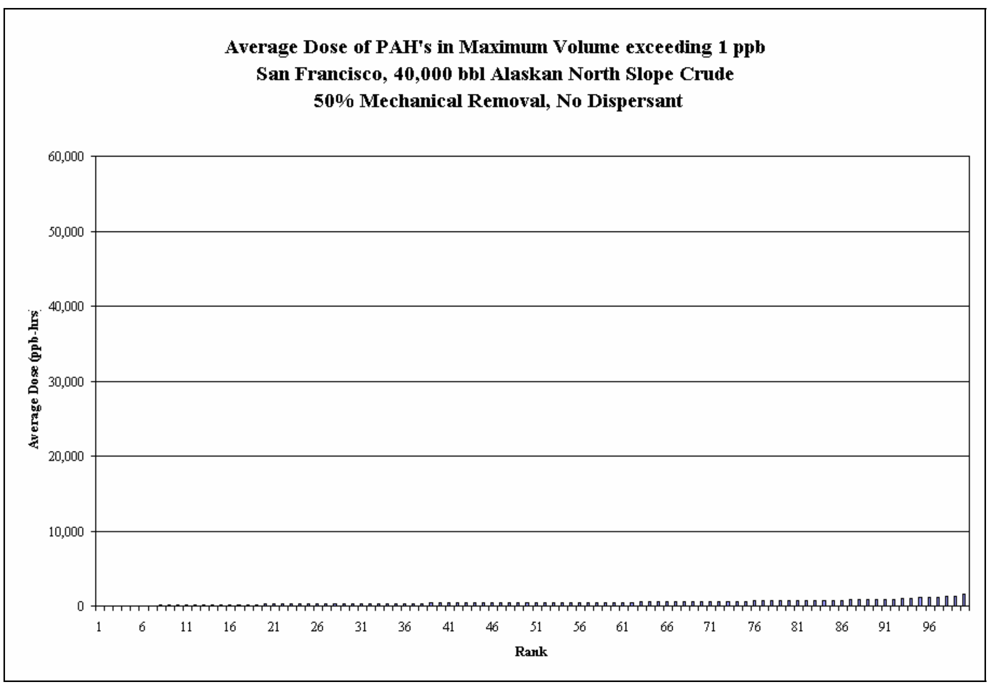

Figure E-II.3.4-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, No Dispersant.

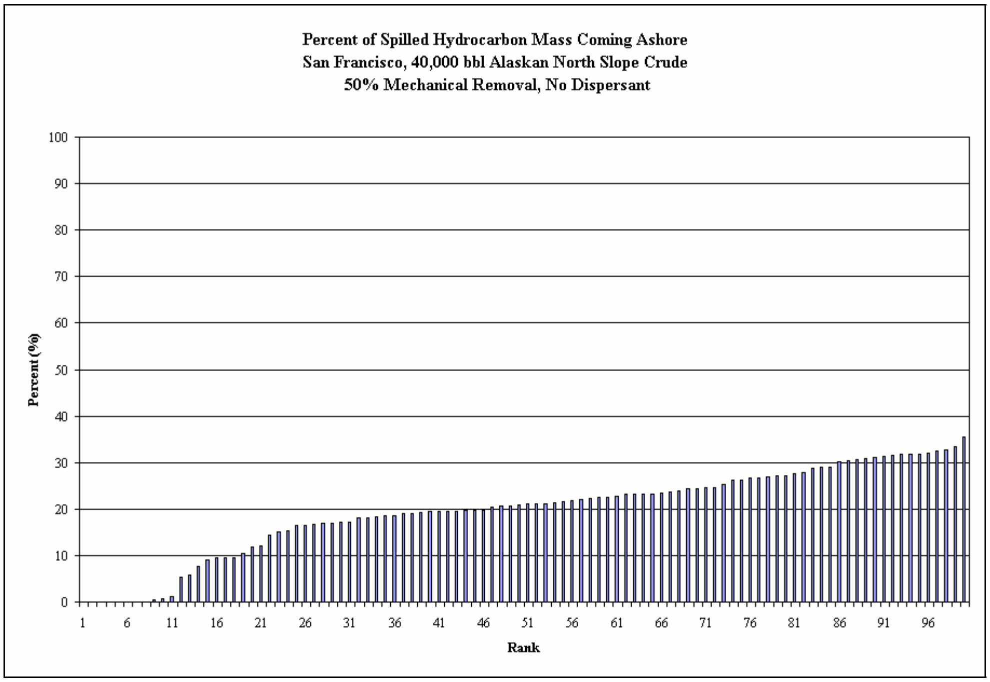

Figure E-II.3.4-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Large Volume, No Dispersant.

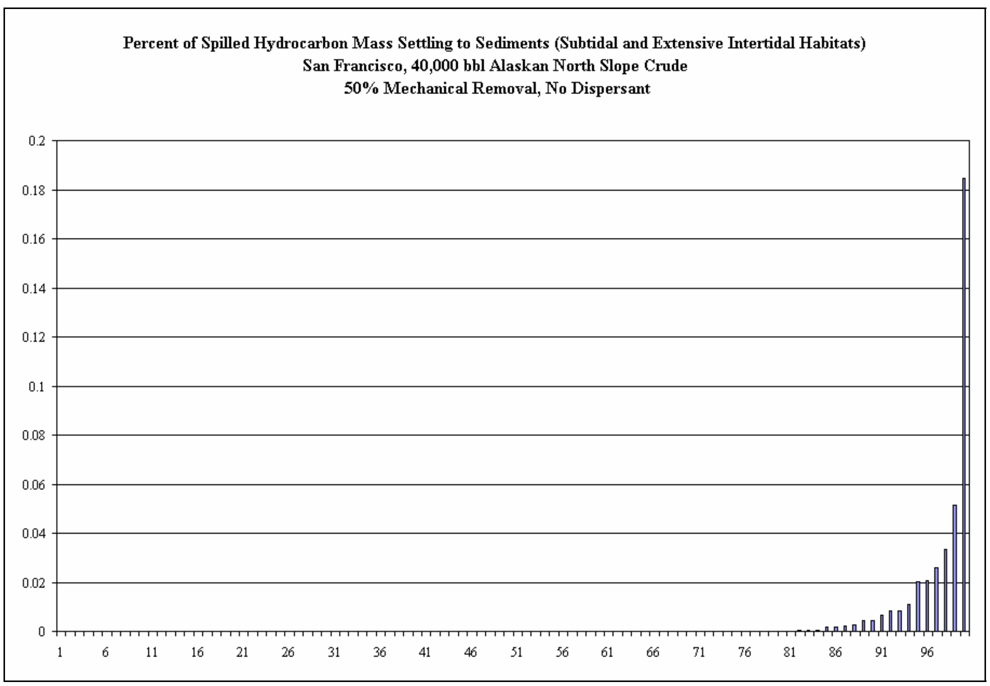

Figure E-II.3.4-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Large Volume, No Dispersant.

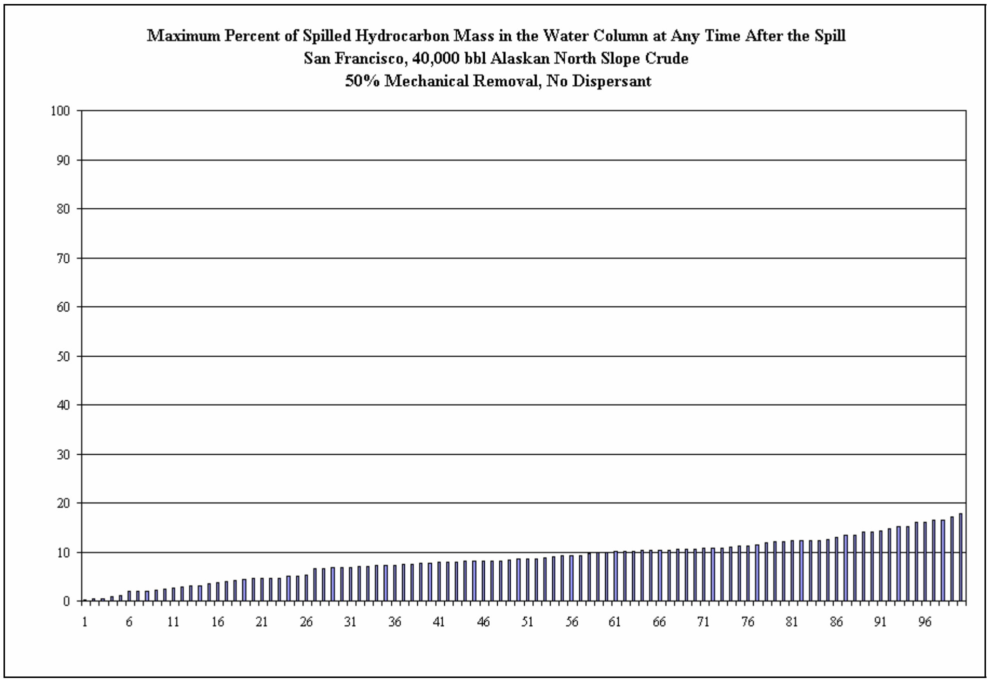

Figure E-II.3.4-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Large Volume, No Dispersant.

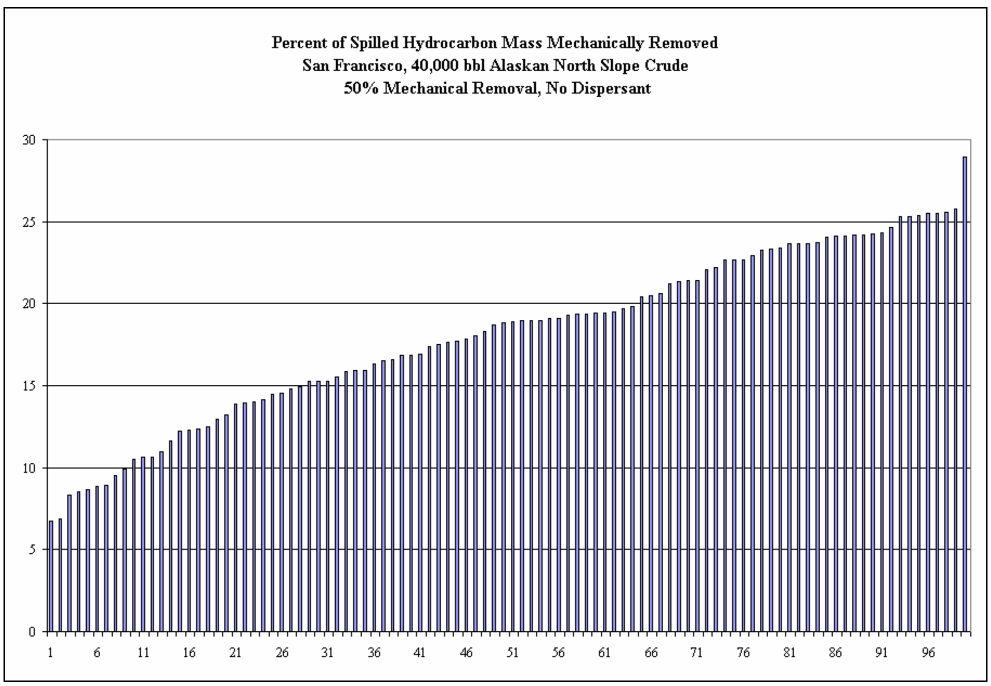

Figure E-II.3.4-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Large Volume, No Dispersant.

E-II.3.5 Scenario: Large Volume, 45% Dispersant Efficiency.

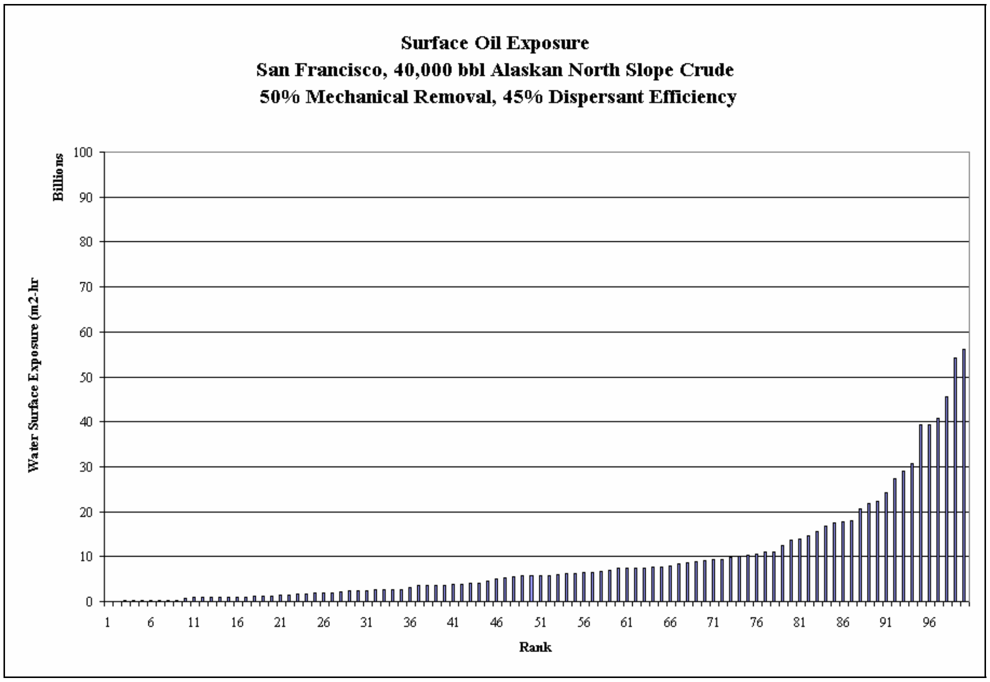

Figure E-II.3.5-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

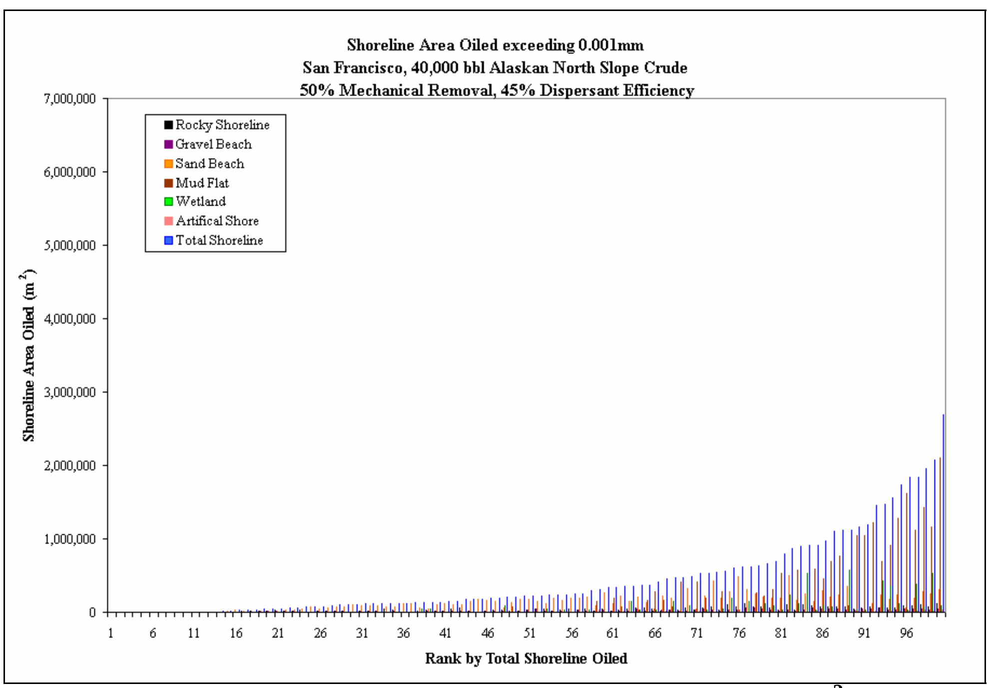

Figure E-II.3.5-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

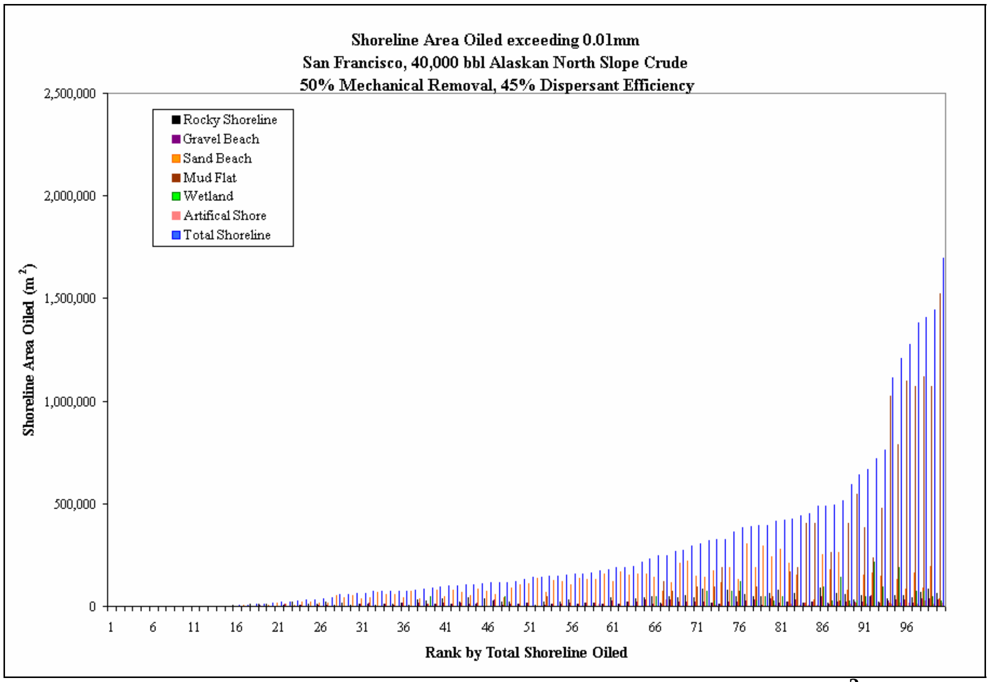

Figure E-II.3.5-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

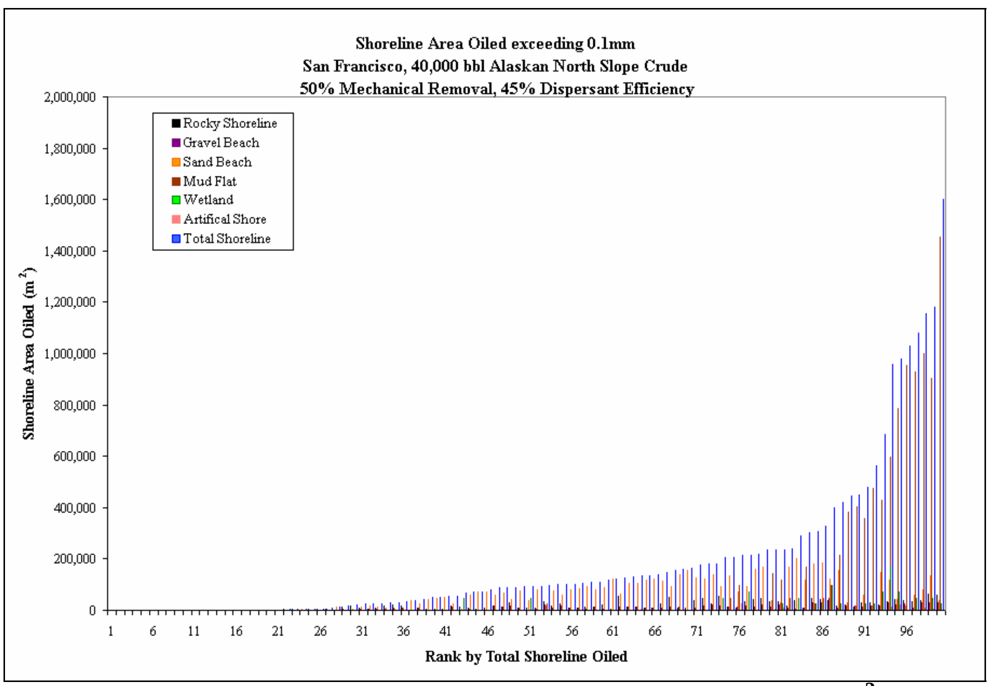

Figure E-II.3.5-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

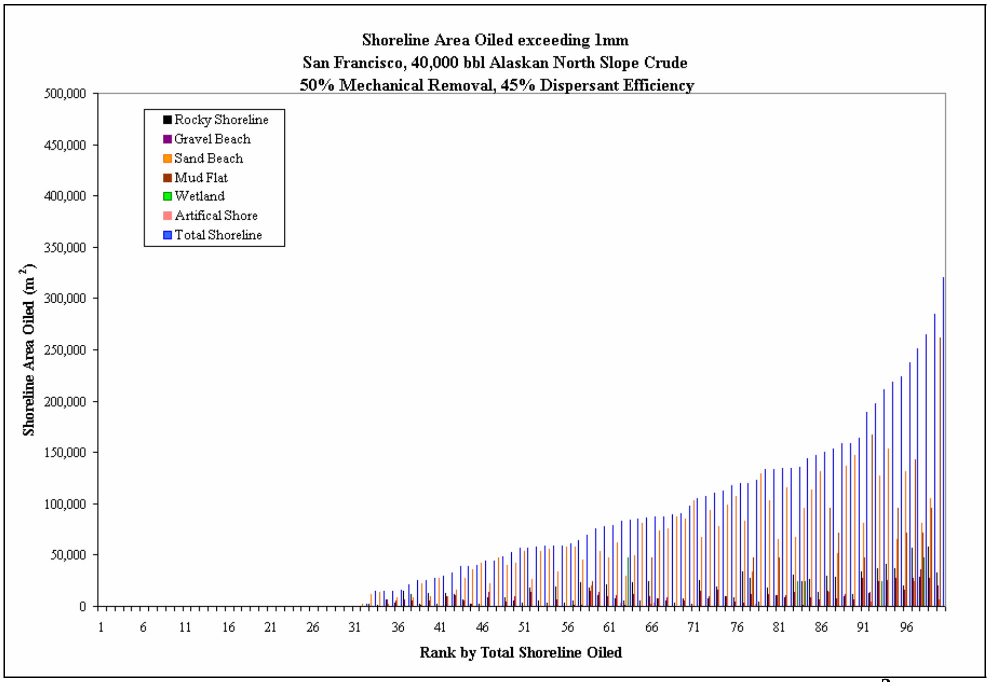

Figure E-II.3.5-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

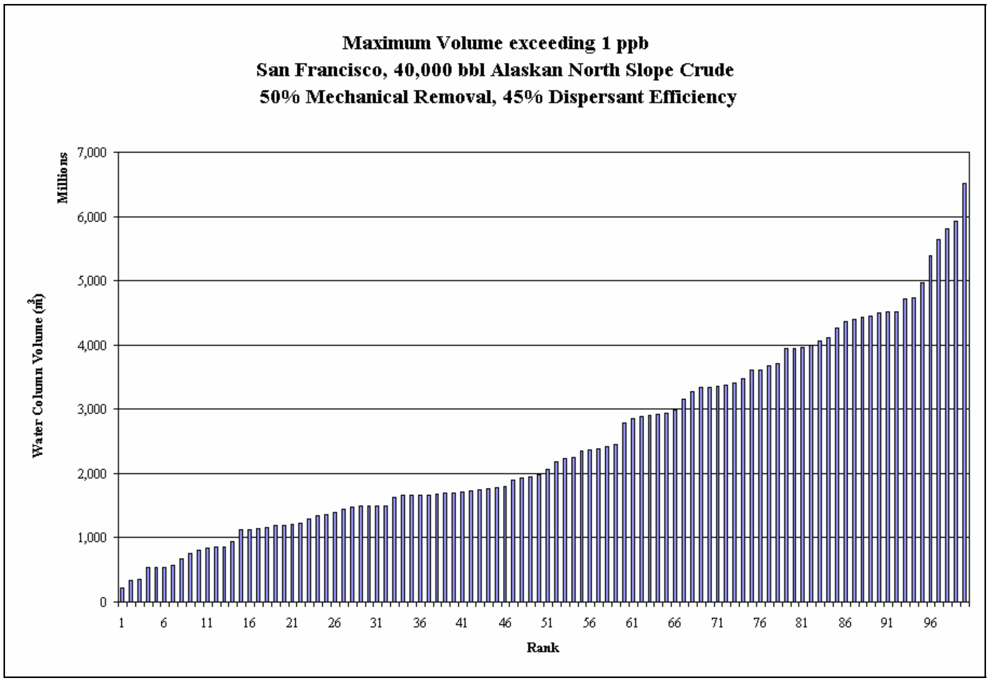

Figure E-II.3.5-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 45% Dispersant Efficiency.

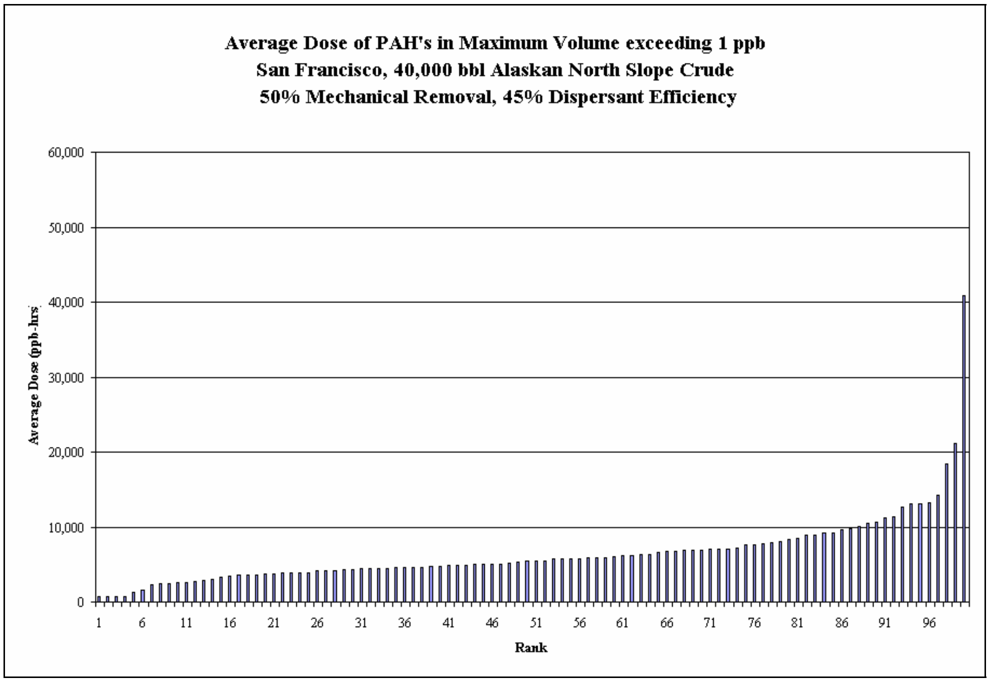

Figure E-II.3.5-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 45% Dispersant Efficiency.

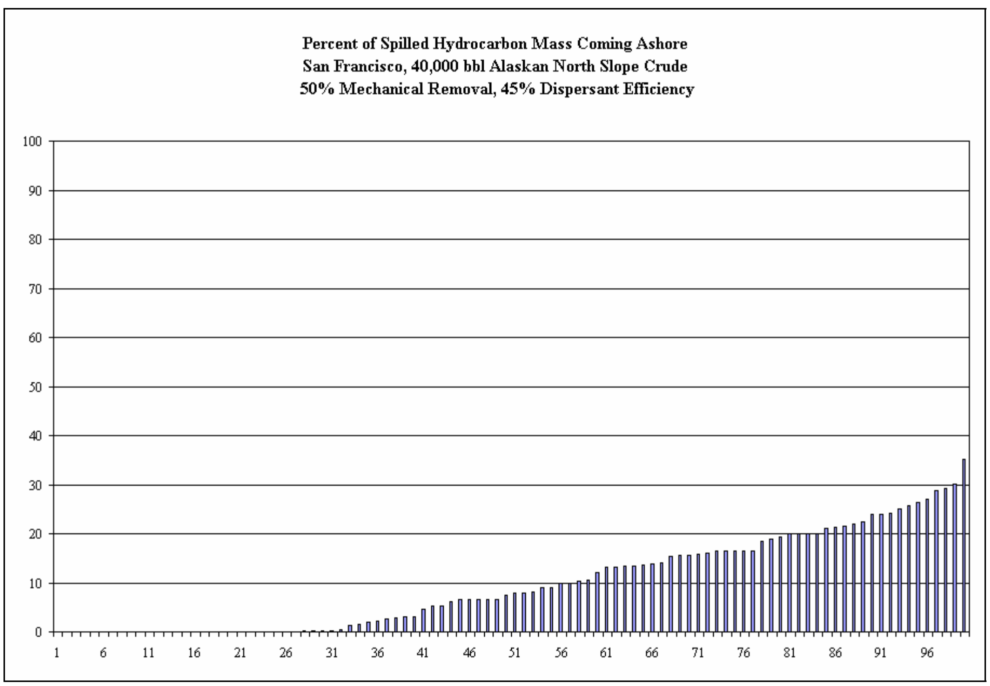

Figure E-II.3.5-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Large Volume, 45% Dispersant Efficiency.

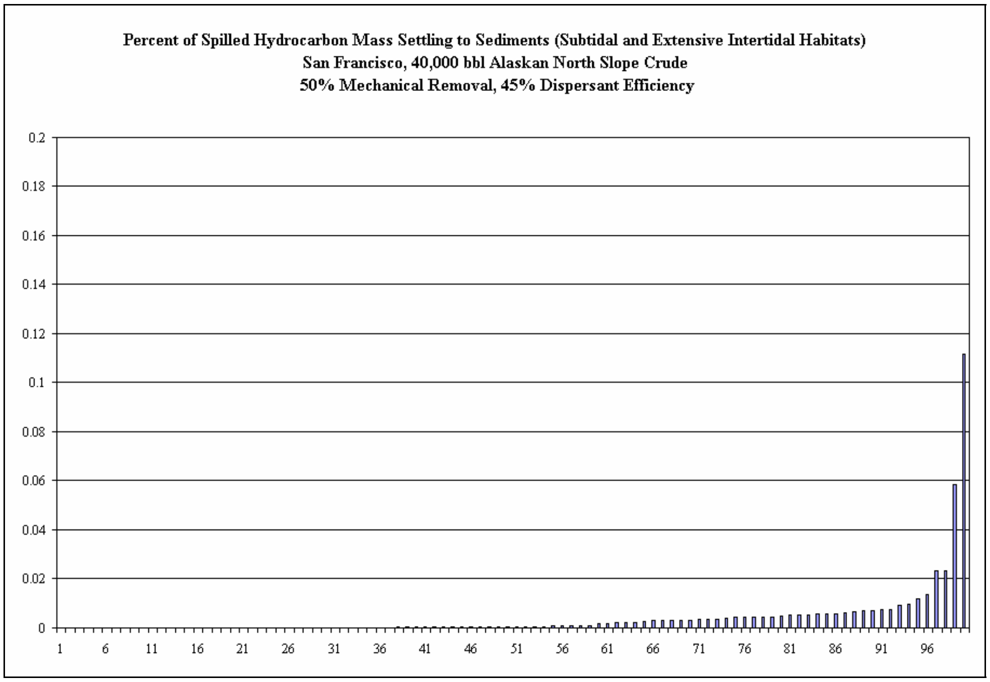

Figure E-II.3.5-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Large Volume, 45% Dispersant Efficiency.

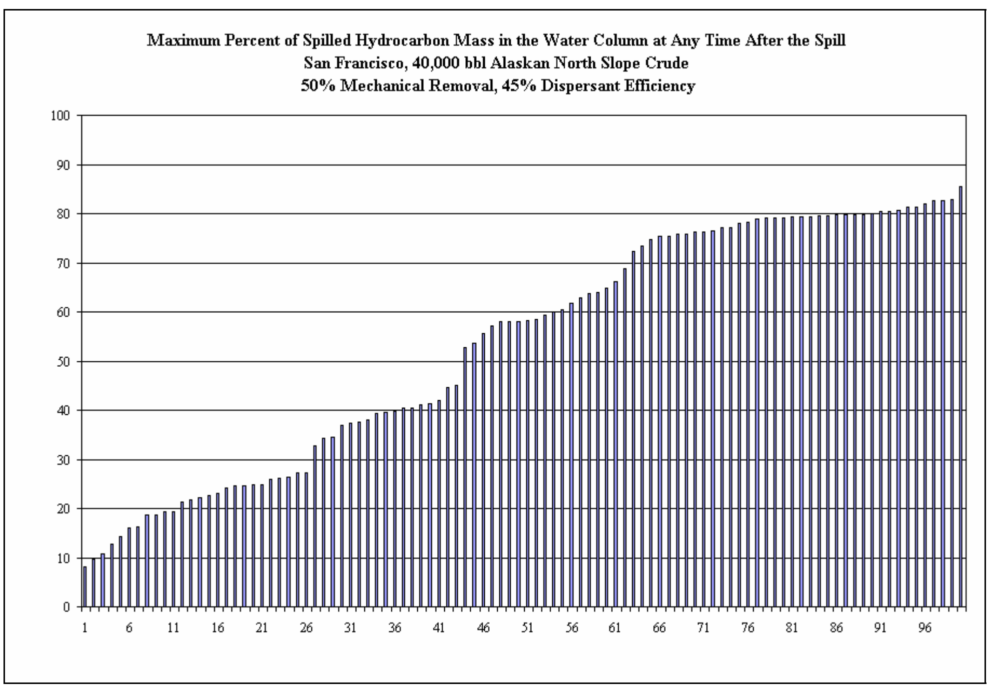

Figure E-II.3.5-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Large Volume, 45% Dispersant Efficiency.

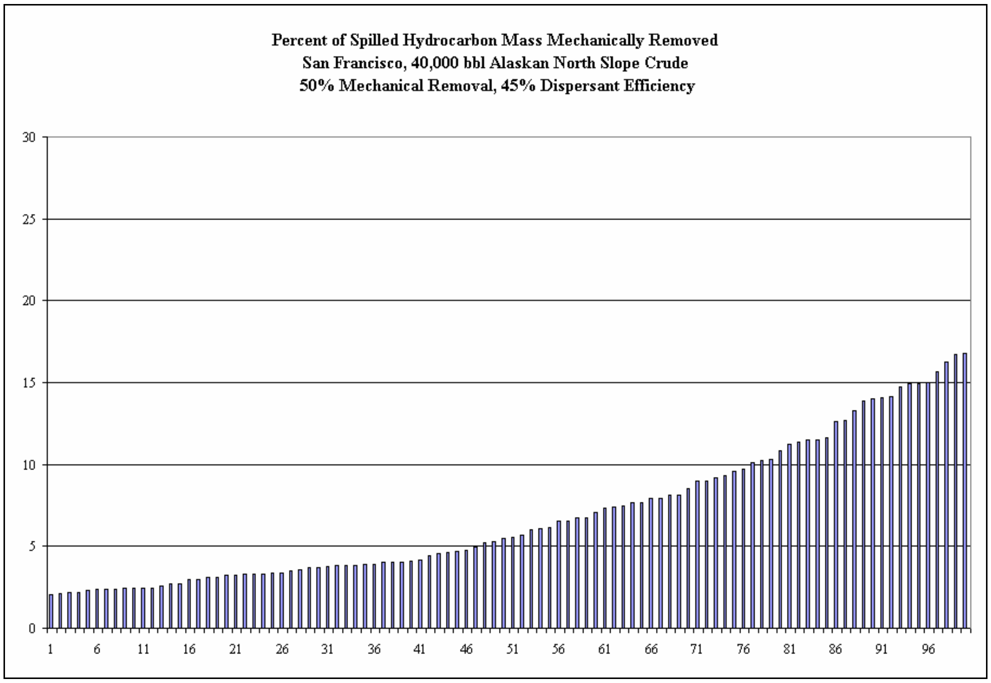

Figure E-II.3.5-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Large Volume, 45% Dispersant Efficiency.

E-II.3.6 Scenario: Large Volume, 80% Dispersant Efficiency.

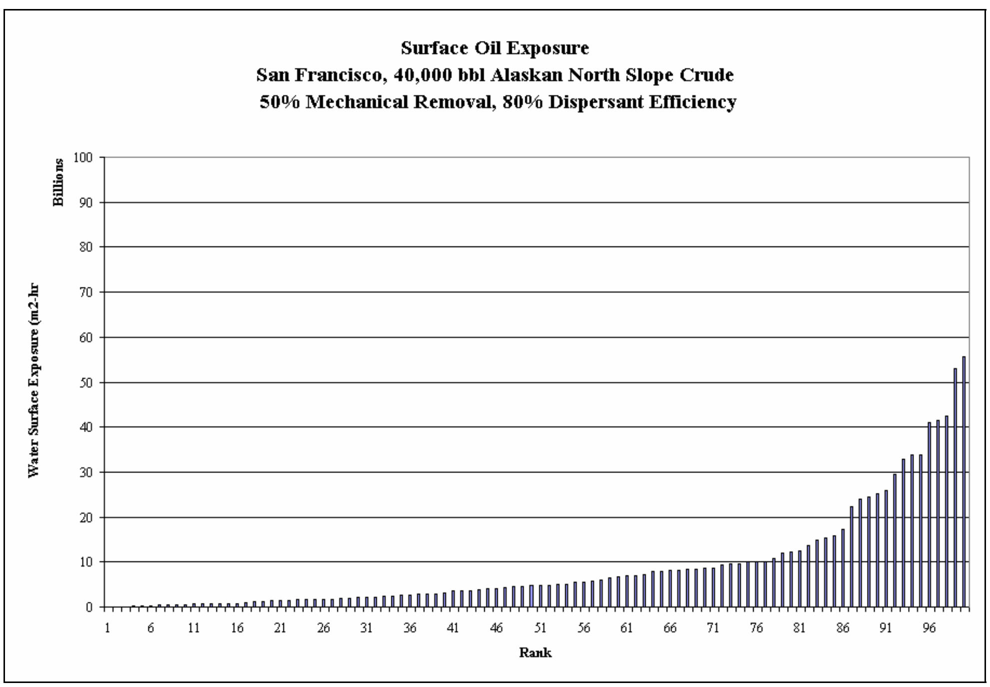

Figure E-II.3.6-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

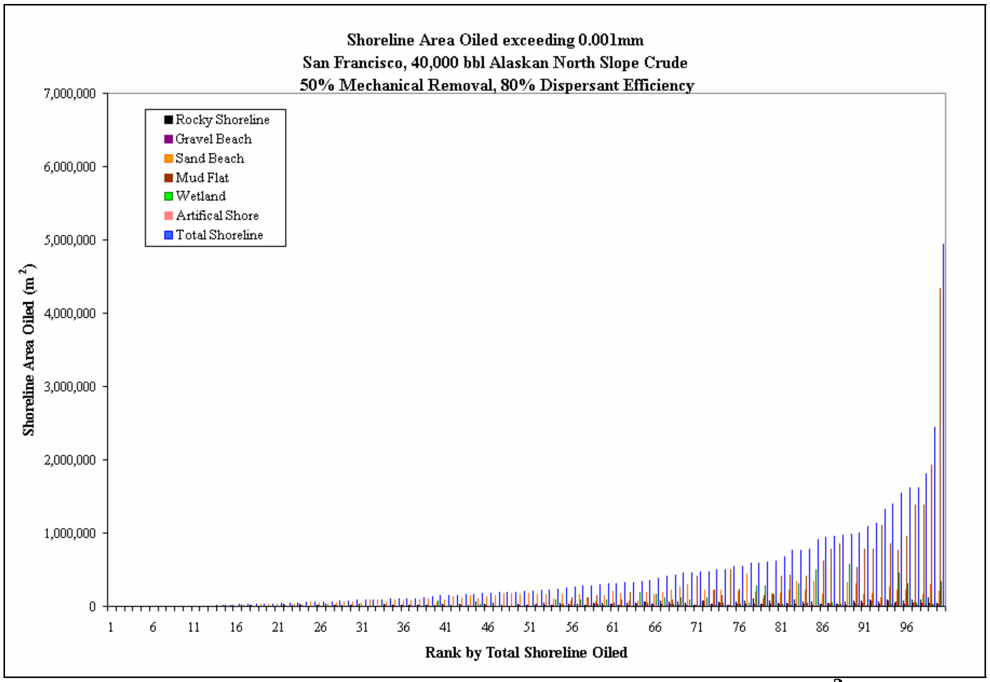

Figure E-II.3.6-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

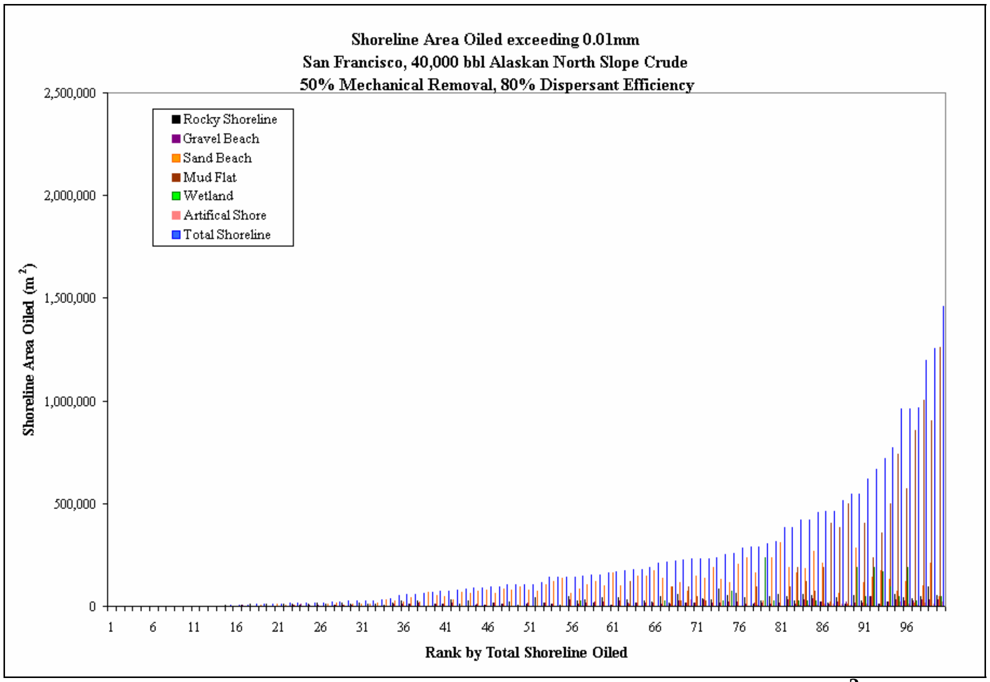

Figure E-II.3.6-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

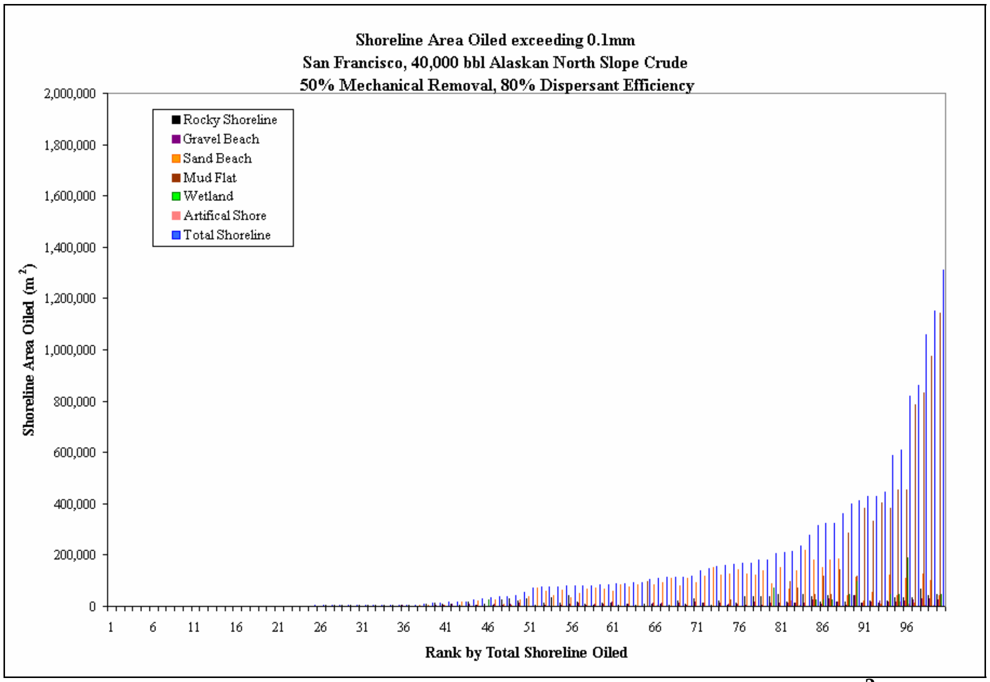

Figure E-II.3.6-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

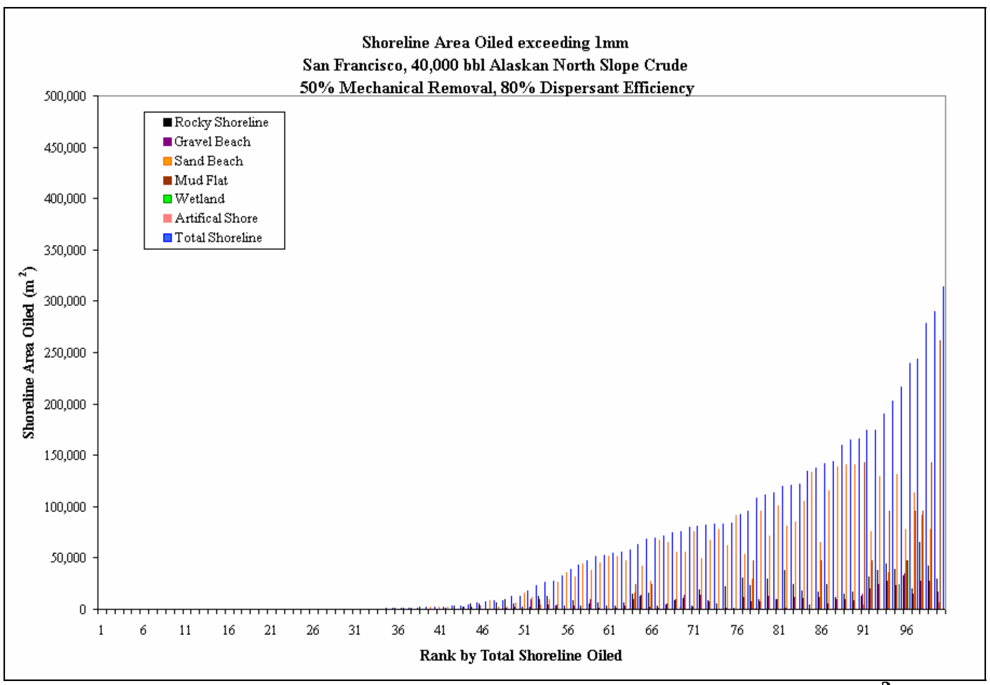

Figure E-II.3.6-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

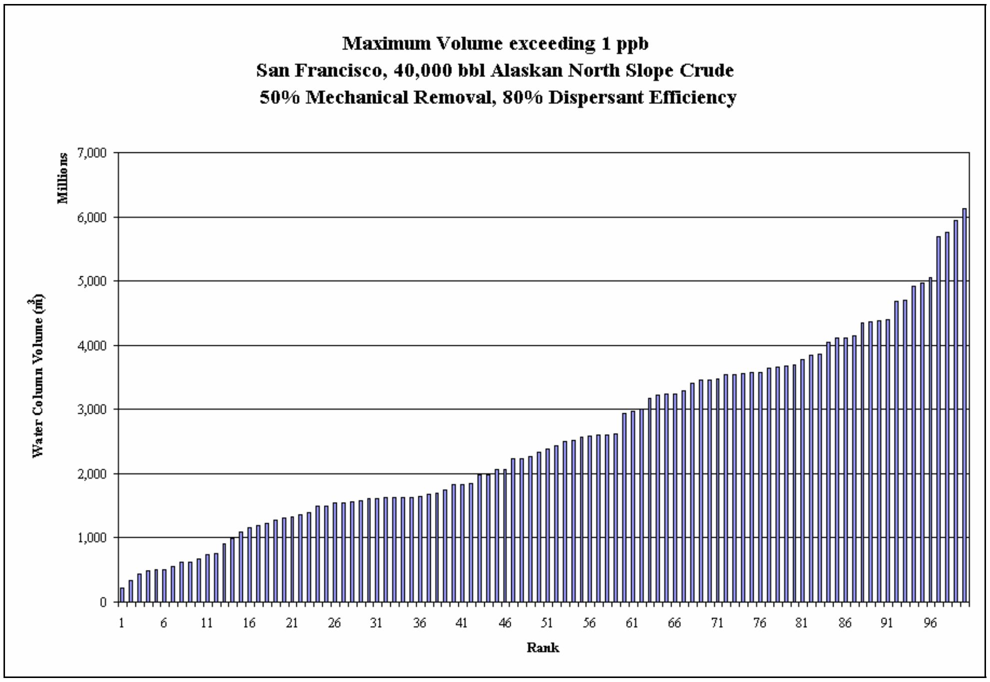

Figure E-II.3.6-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 80% Dispersant Efficiency.

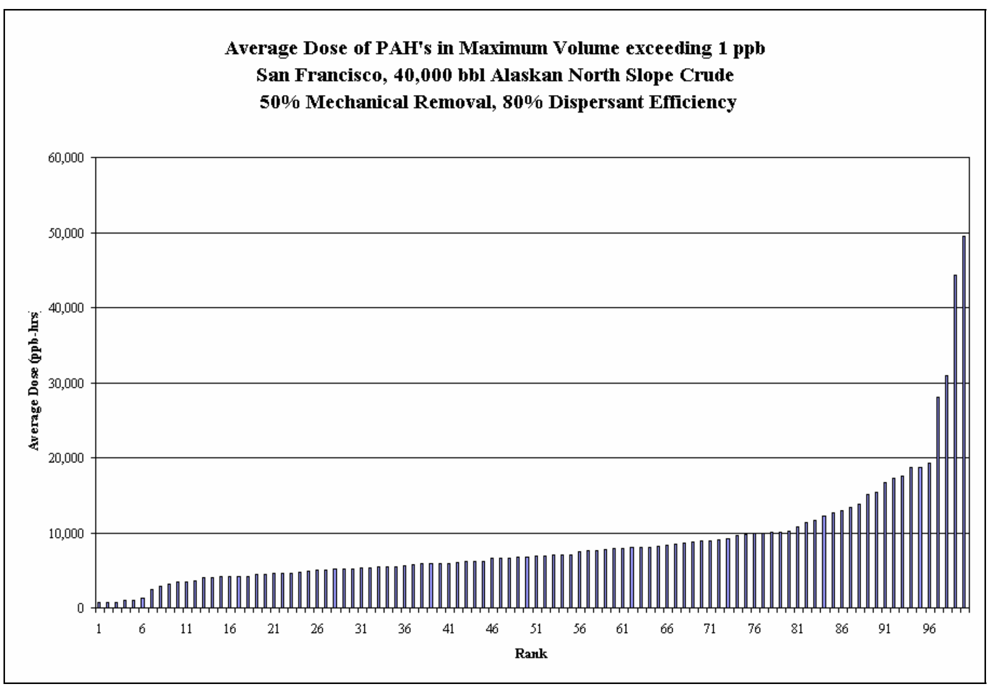

Figure E-II.3.6-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 80% Dispersant Efficiency.

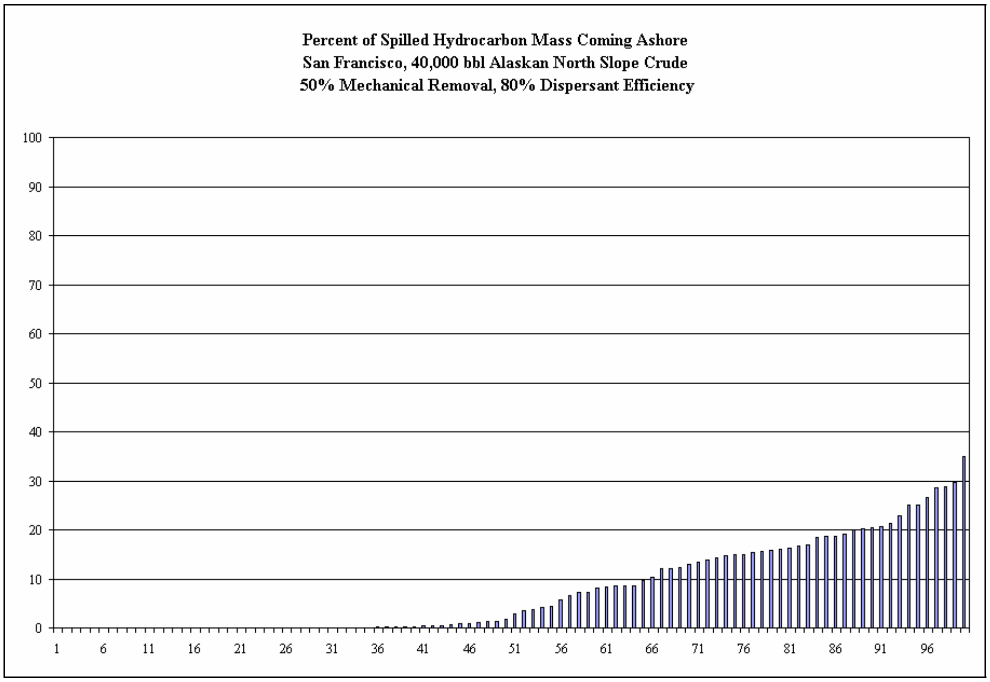

Figure E-II.3.6-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Large Volume, 80% Dispersant Efficiency.

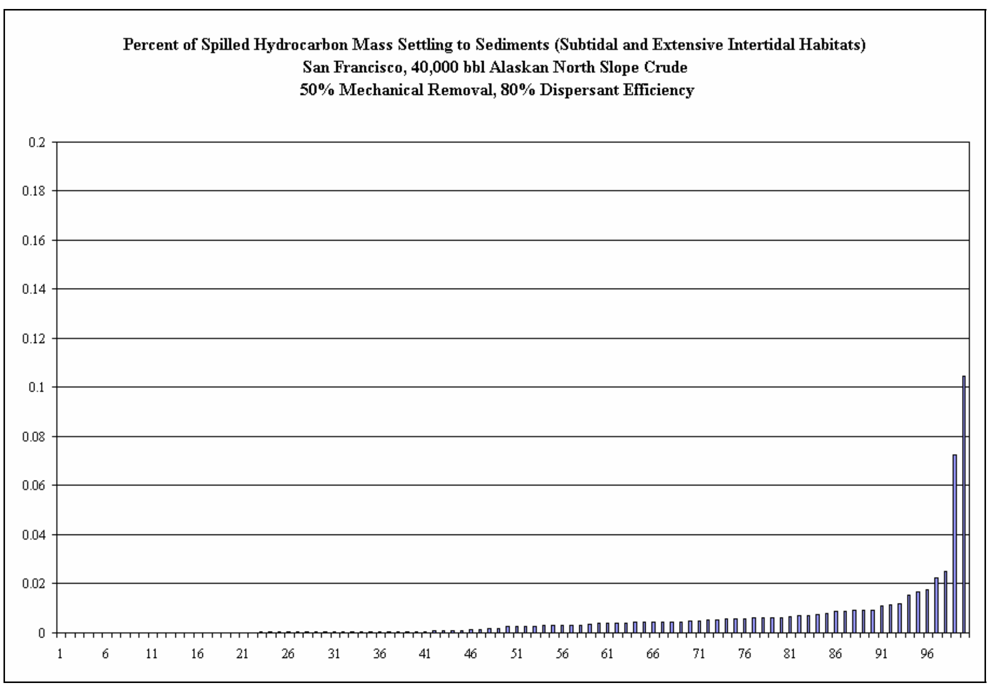

Figure E-II.3.6-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Large Volume, 80% Dispersant Efficiency.

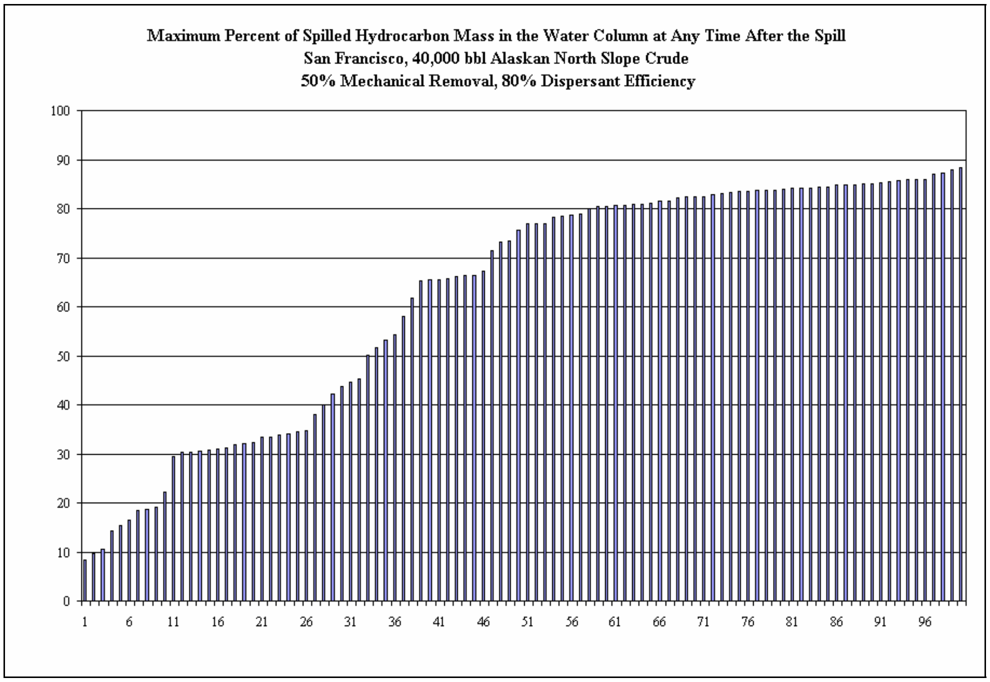

Figure E-II.3.6-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Large Volume, 80% Dispersant Efficiency.

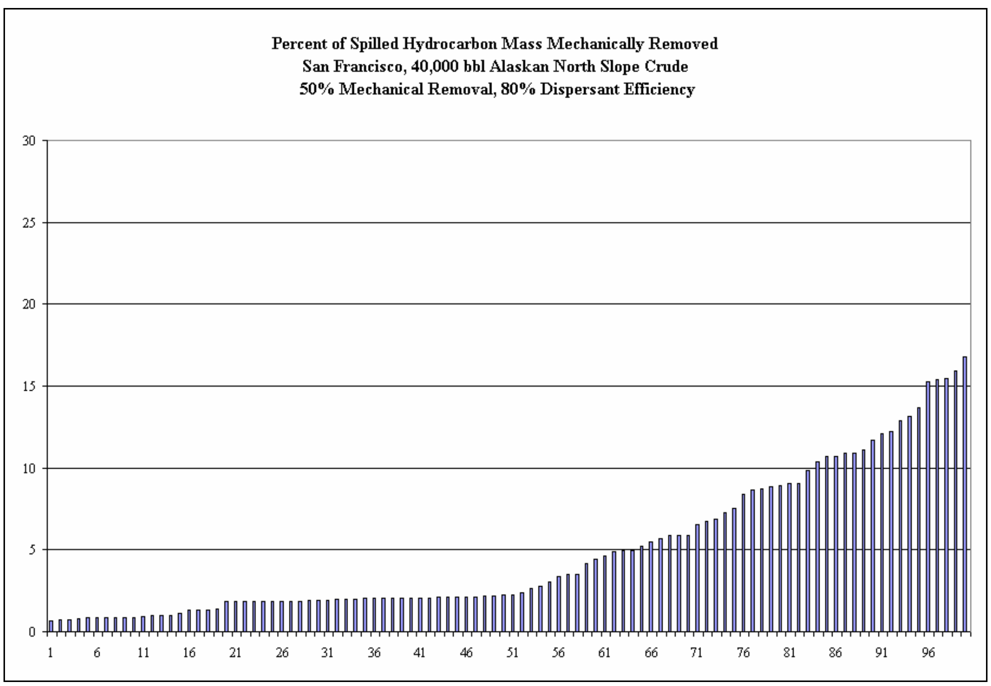

Figure E-II.3.6-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Large Volume, 80% Dispersant Efficiency.

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part E: San Francisco Bay and Central California Shelf

Section E-II.4

by

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ASA 00-246

August 2004

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E-II.4 Exposure for Representative Individual Model Runs.

In this appendix, the results for the 50th percentile cases for surface oiling, shoreline oiling, water column effects, and sediment contamination are shown, as plots of the following measures of exposure:

- Water surface exposure to floating hydrocarbons (g/m^2)
- Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile surface oil exposure run
- Shoreline exposure to hydrocarbons (g/m^2)
- Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill
- Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill
- Water column exposure dose of dissolved aromatic concentration (ppb-hours)
- Sediment pore water exposure of dissolved aromatic concentration (ppb)
- Sediment exposure to total hydrocarbons (g/m^2)

The percentile runs plotted are those runs which apply to the exposure index being considered. Thus, different runs are plotted for each of surface oil, shoreline oil, water column effect measures, and sediment contamination. Tables E-II.4-1 to E-II.4-3 summarize the run number and date and time of the runs resulting in the 50th and 95th percentile exposures. The 95th percentile exposure indicates the maximum likely effect.

The Crosshair mark () in figures below represents oil spill site.

Table E-II.4-1 Run number and date and time of the runs resulting in the 50th and 95th percentile exposures for surface oil exposure.

Surface Oil Exposure (exceeding 0.01 g/m2)							
Scenario	**Percentile**	**Run Number**	**Year**	**Month**	**Day**	**Hour**	**Area-hrs (m2-hrs)**
SF-Med-50-0	50th	59	1997	5	24	9	2,122 x 10^6
	95th	62	1992	11	8	17	13,803 x 10^6
SF-Med-50-45	50th	71	1996	6	15	2	772 x 10^6
	95th	72	1996	7	18	11	11,821 x 10^6
SF-Med-50-80	50th	86	1988	7	13	15	1,110 x 10^6
	95th	72	1996	7	18	11	12,295 x 10^6
SF-Lrg-50-0	50th	16	2001	3	18	10	10,742 x 10^6
	95th	62	1992	11	8	17	63,107 x 10^6
SF-Lrg-50-45	50th	39	1988	4	16	13	5,821 x 10^6
	95th	1	1988	5	16	21	39,390 x 10^6
SF-Lrg-50-80	50th	86	1988	7	13	15	4,756 x 10^6
	95th	18	1997	1	5	19	41,014 x 10^6

Table E-II.4-2 Run number and date and time of the runs resulting in the 50th and 95th percentile exposures for dissolved aromatic exposure.

Maximum Dissolved Aromatic Plume Volume exceeding 1 ppb							
Scenarario	**Percentile**	**Run Number**	**Year**	**Month**	**Day**	**Hour**	**Volume (m3)**
SF-Med-50-0	50th	40	1993	6	25	21	30 x 10^6
	95th	41	1993	5	7	11	241 x 10^6
SF-Med-50-45	50th	42	1988	8	30	22	374 x 10^6
	95th	37	1998	5	20	0	758 x 10^6
SF-Med-50-80	50th	76	1997	11	18	3	389 x 10^6
	95th	22	1997	9	27	22	706 x 10^6
SF-Lrg-50-0	50th	61	1995	3	7	17	223 x 10^6
	95th	94	1988	12	24	12	1,235 x 10^6
SF-Lrg-50-45	50th	99	1990	4	30	16	2,060 x 10^6
	95th	98	1988	10	15	4	5,391 x 10^6
SF-Lrg-50-80	50th	21	1990	9	19	9	2,392 x 10^6
	95th	92	2001	3	23	8	5,053 x 10^6

Table E-II.4-3 Run number and date and time of the runs resulting in the 50th and 95th percentile exposures for sediment exposure.

Percent of Spilled Mass Reaching Sediment							
Scenario	**Percentile**	**Run Number**	**Year**	**Month**	**Day**	**Hour**	**%**
SF-Med-50-0	50th	96	1993	6	7	3	0.000
	95th	61	1995	3	7	17	0.018
SF-Med-50-45	50th	88	1995	4	25	3	0.004
	95th	90	1999	2	21	10	0.041
SF-Med-50-80	50th	30	1988	5	24	7	0.004
	95th	89	1989	6	21	12	0.041
SF-Lrg-50-0	50th	72	1996	7	18	11	0.000
	95th	38	1991	3	18	15	0.021
SF-Lrg-50-45	50th	92	2001	3	23	8	0.000
	95th	11	2000	10	28	3	0.014
SF-Lrg-50-80	50th	92	2001	3	23	8	0.003
	95th	56	1996	11	1	22	0.018

E-II.4.1 Scenario: Medium Volume, No Dispersant.

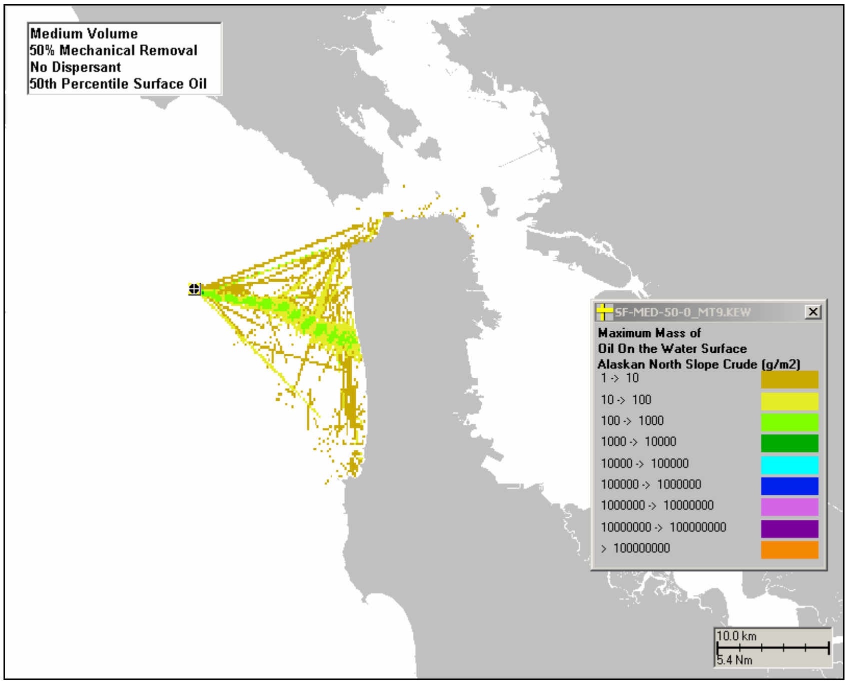

Figure E-II.4.1-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, No Dispersant.

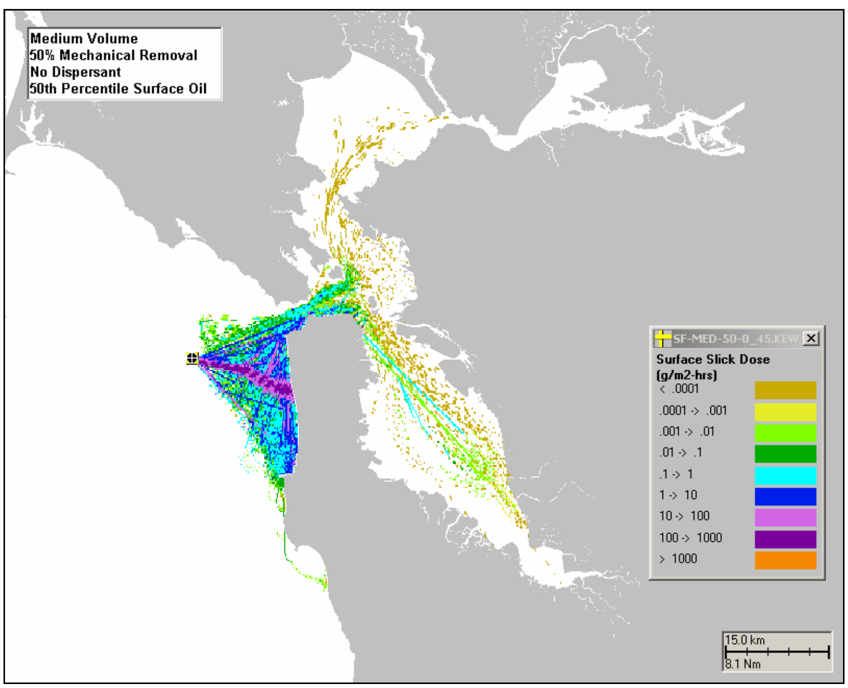

Figure E-II.4.1-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, No Dispersant.

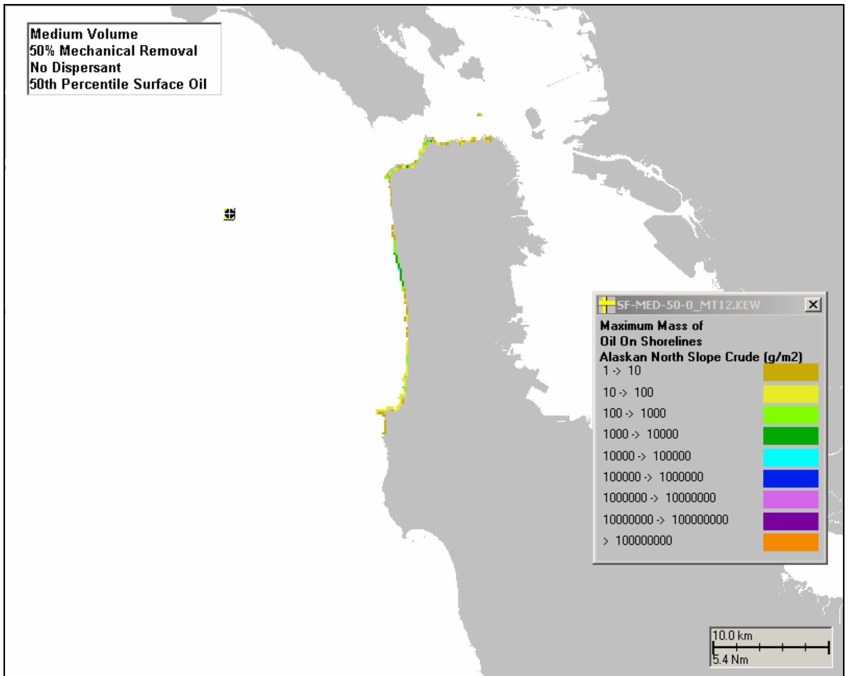

Figure E-II.4.1-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, No Dispersant.

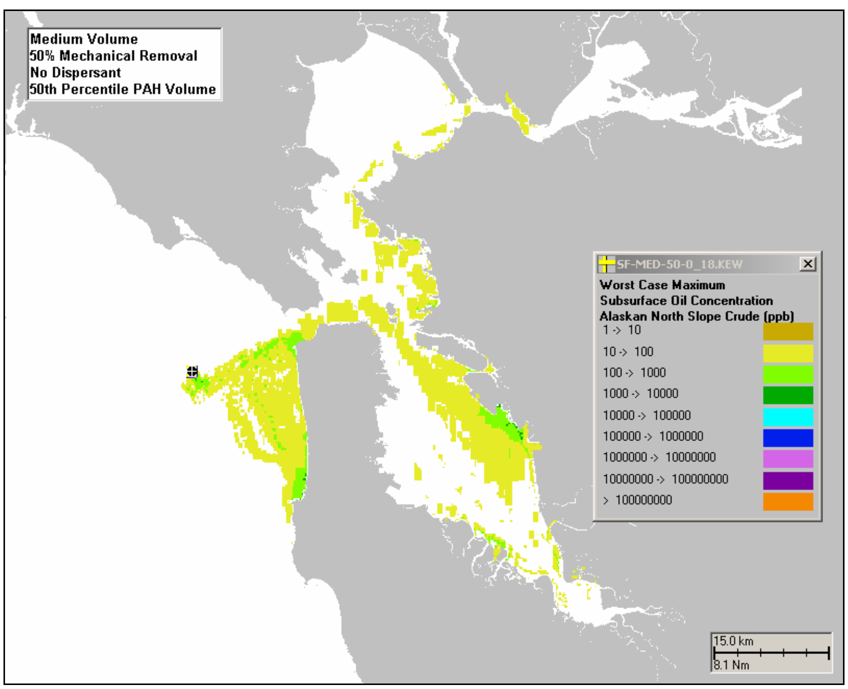

Figure E-II.4.1-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, No Dispersant.

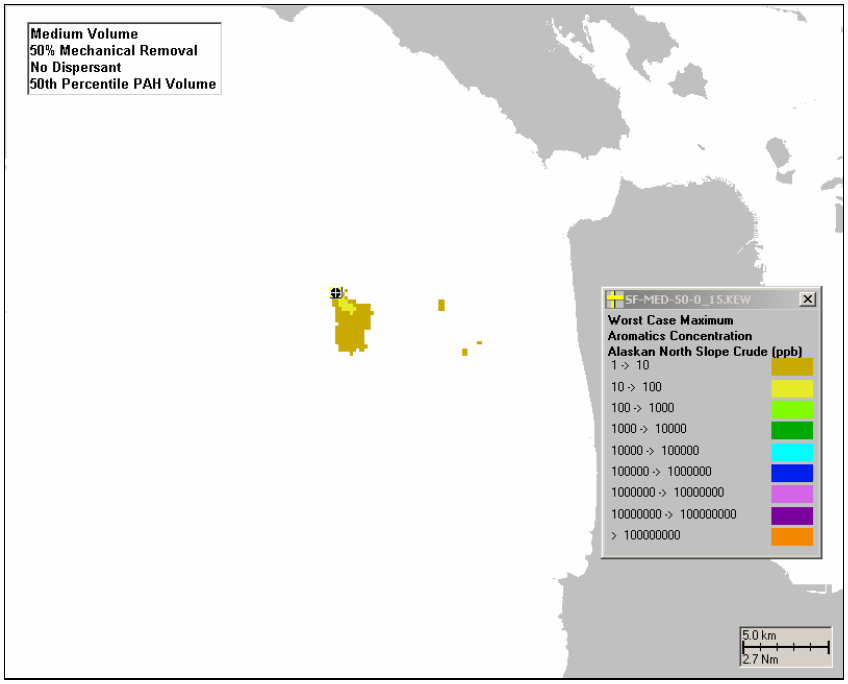

Figure E-II.4.1-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, No Dispersant.

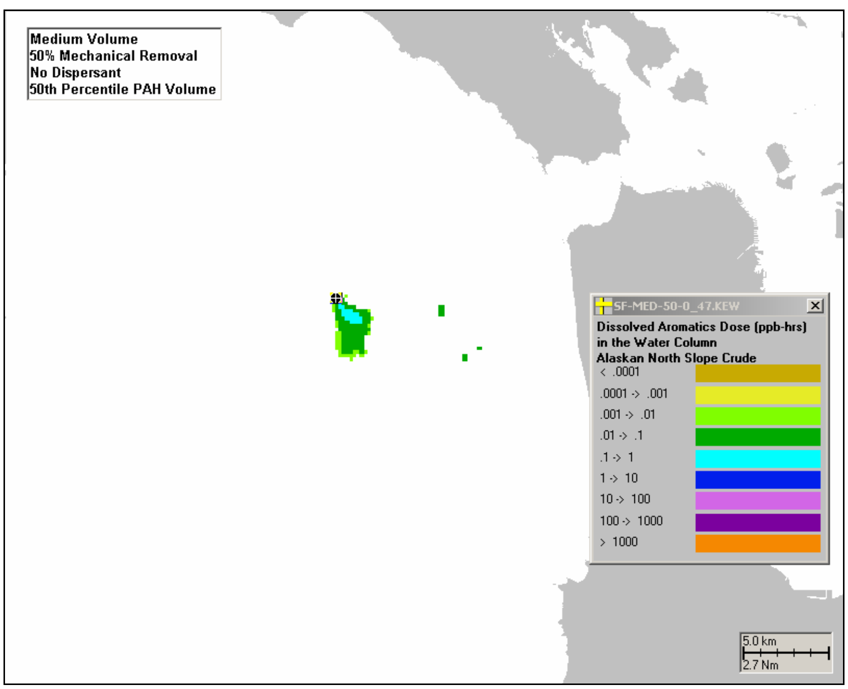

Figure E-II.4.1-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, No Dispersant.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Medium Volume, No Dispersant.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Medium Volume, No Dispersant.

E-II.4.2 Scenario: Medium Volume, 45% Dispersant Efficiency.

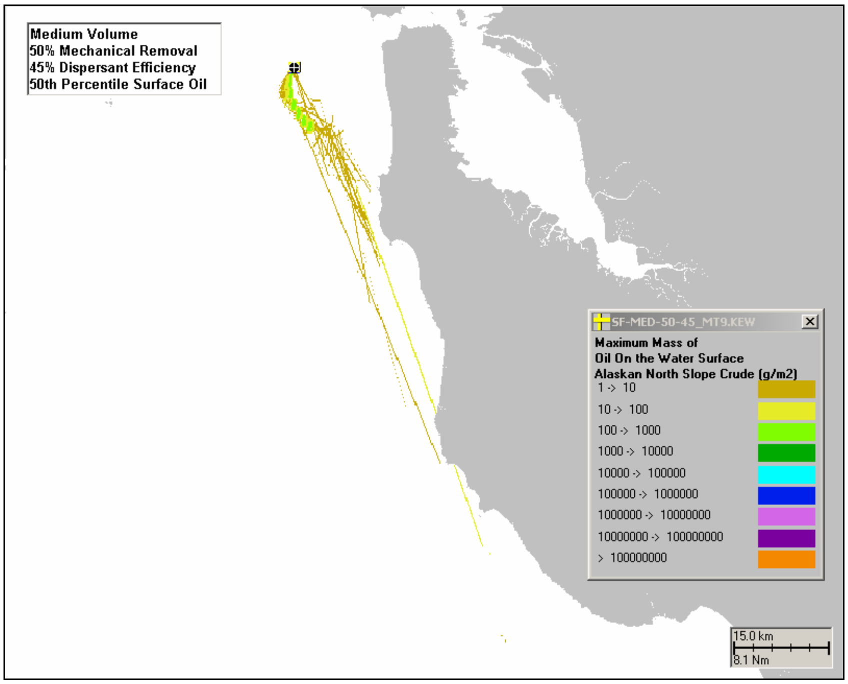

Figure E-II.4.2-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

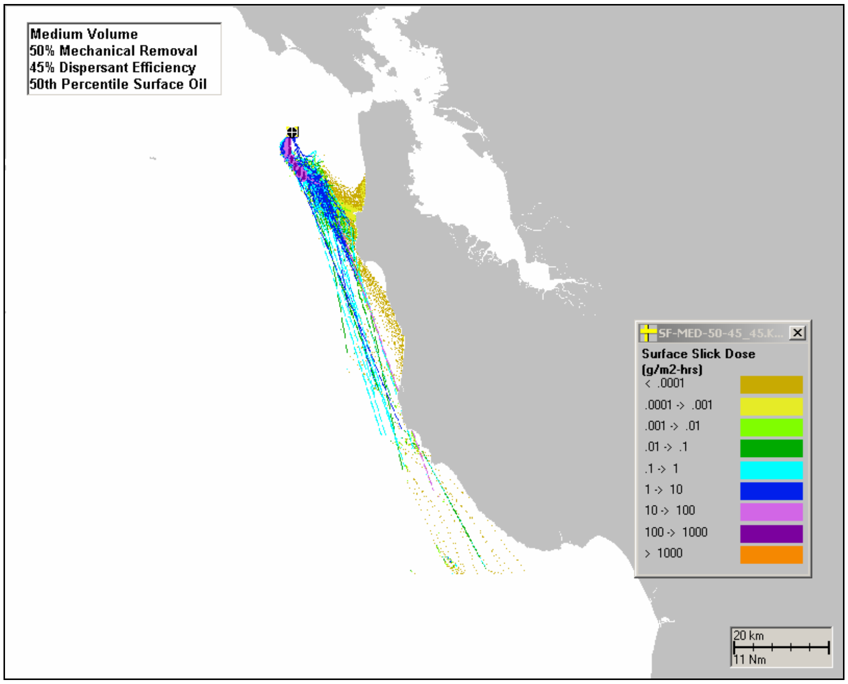

Figure E-II.4.2-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

Figure E-II.4.2-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

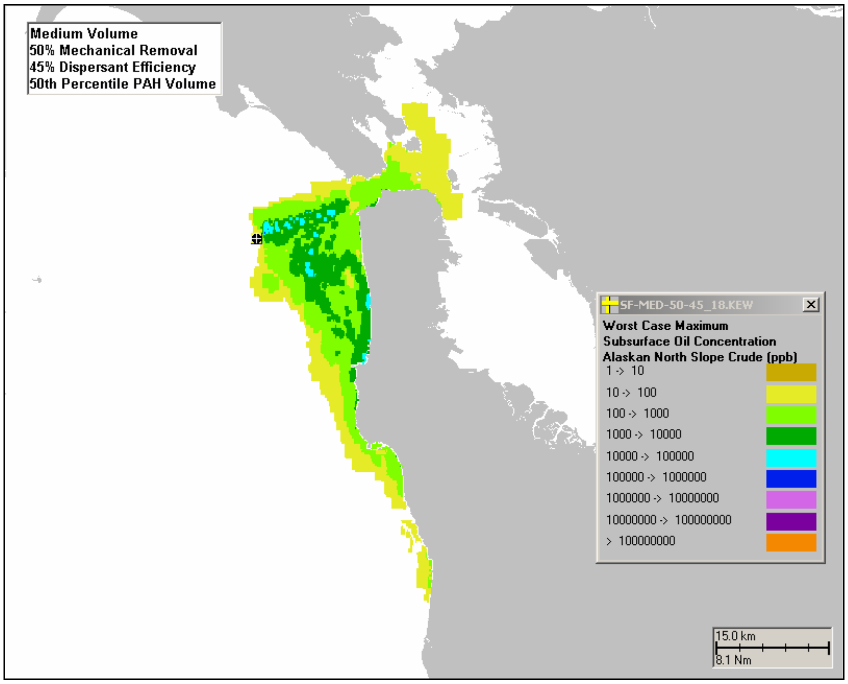

Figure E-II.4.2-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 45% Dispersant Efficiency.

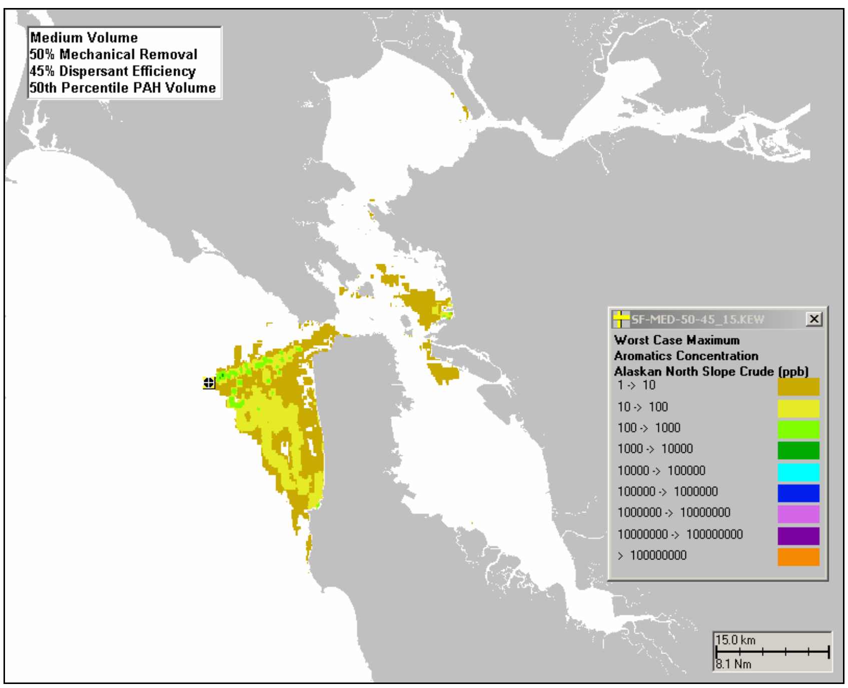

Figure E-II.4.2-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 45% Dispersant Efficiency.

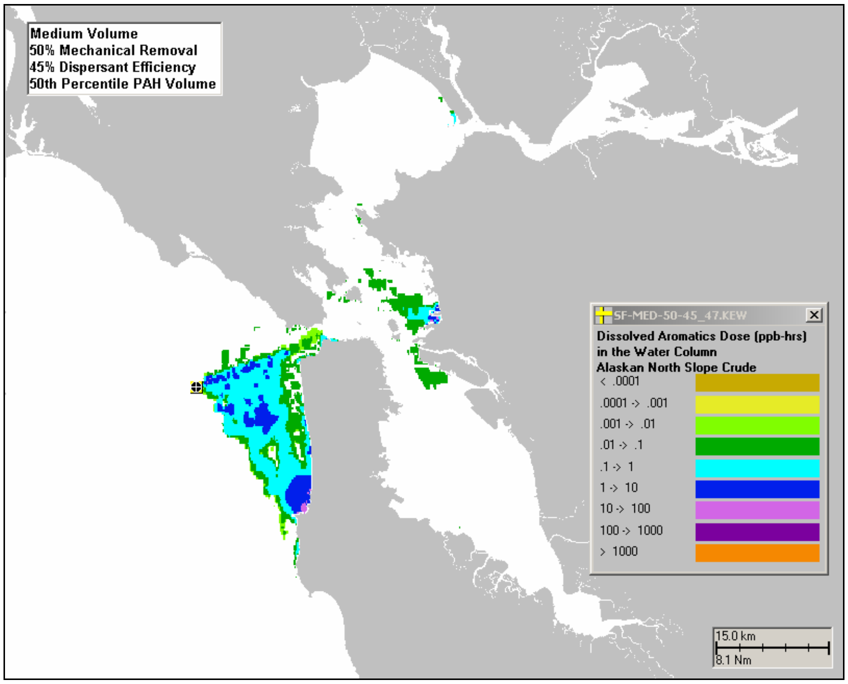

Figure E-II.4.2-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 45% Dispersant Efficiency.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Medium Volume, 45% Dispersant Efficiency..

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

E-II.4.3 Scenario: Medium Volume, 80% Dispersant Efficiency.

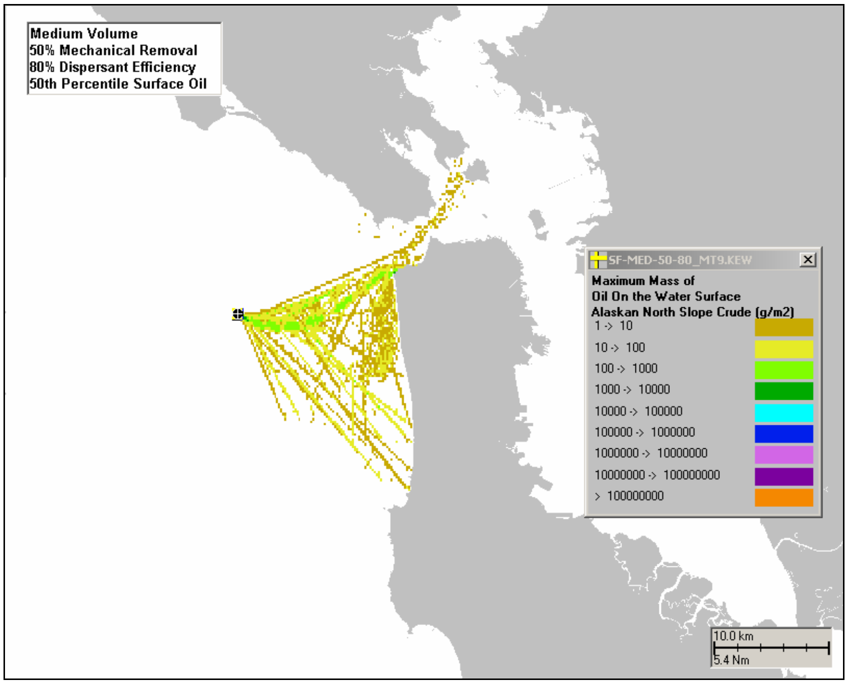

Figure E-II.4.3-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

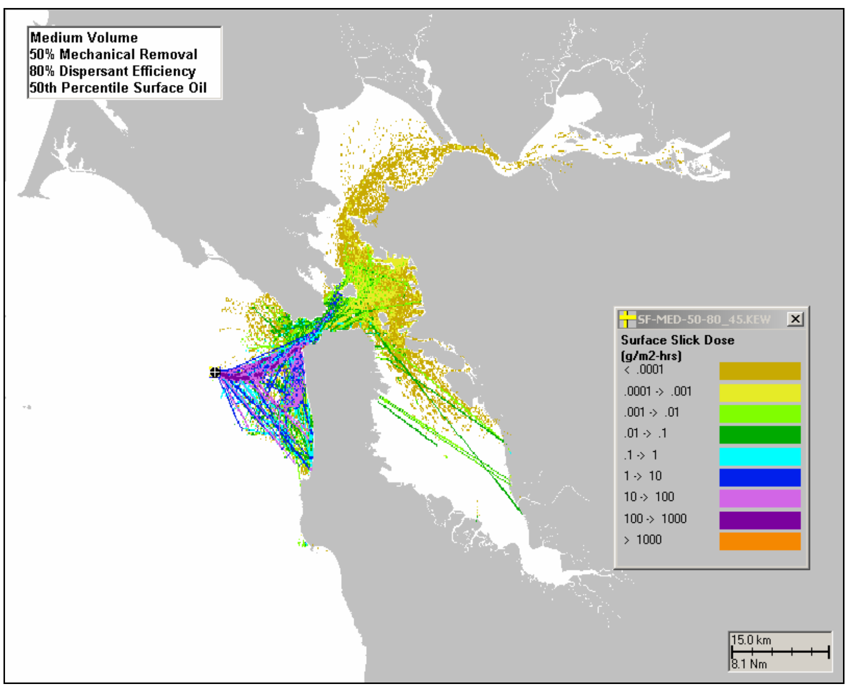

Figure E-II.4.3-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

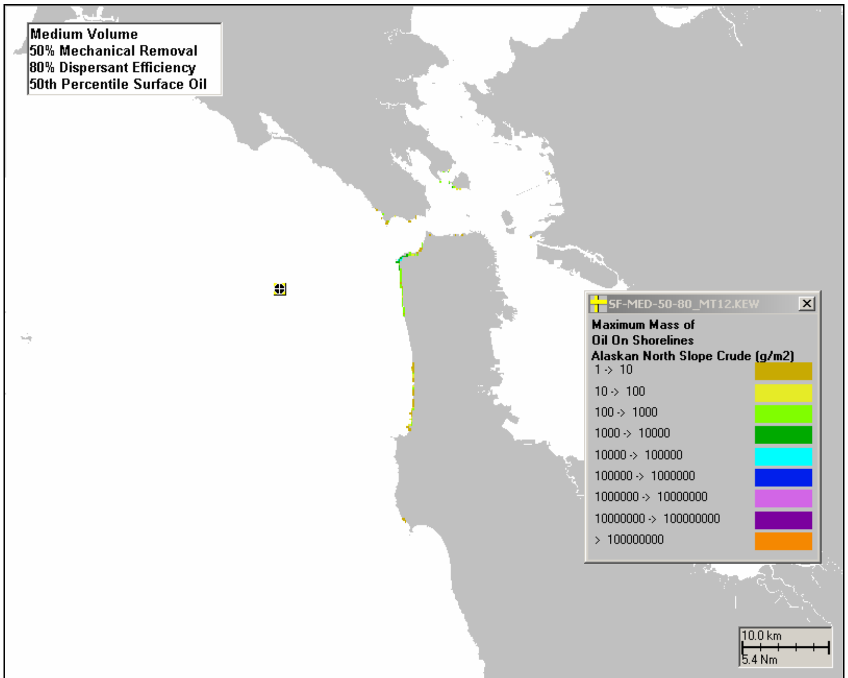

Figure E-II.4.3-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

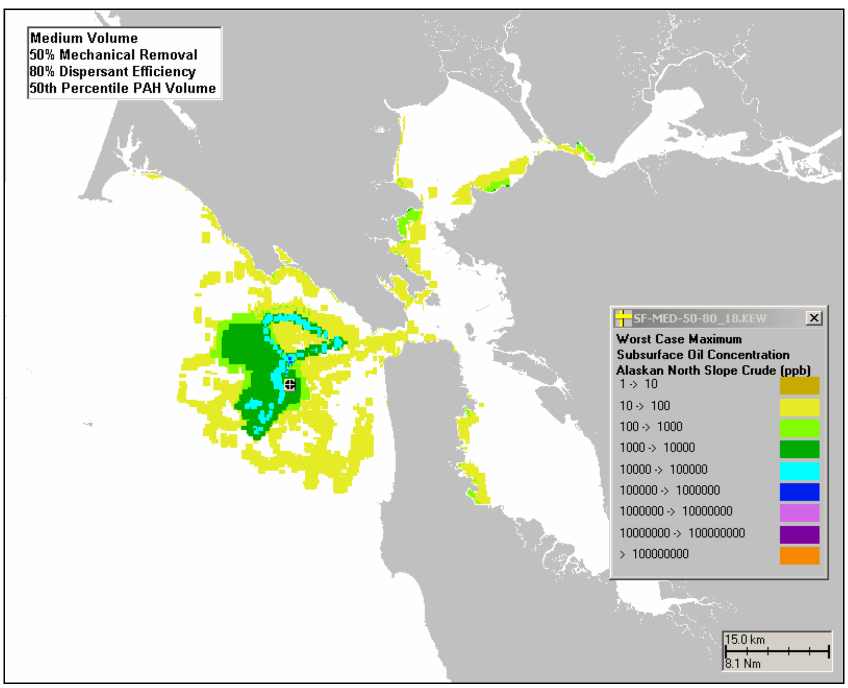

Figure E-II.4.3-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 80% Dispersant Efficiency.

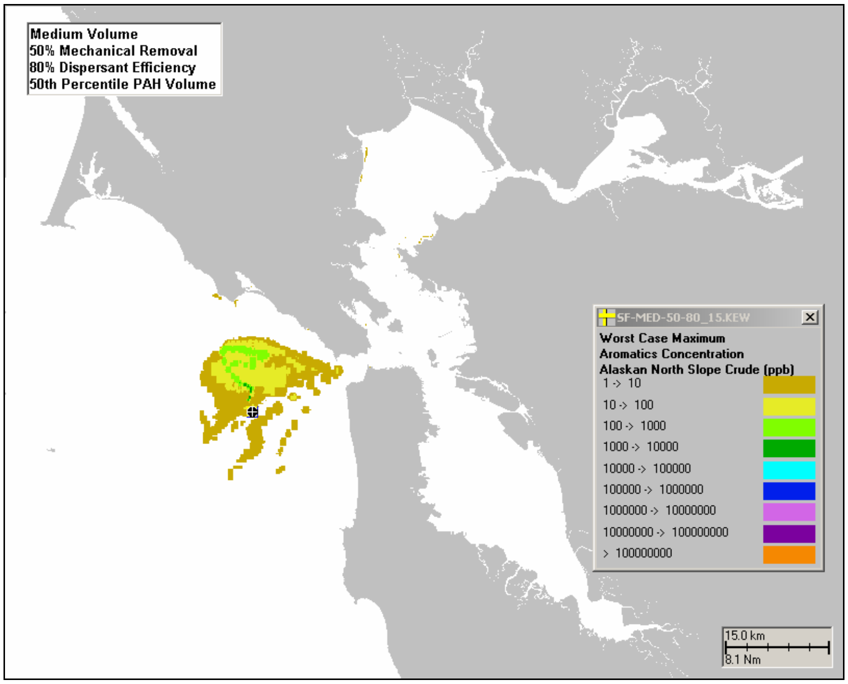

Figure E-II.4.3-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 80% Dispersant Efficiency.

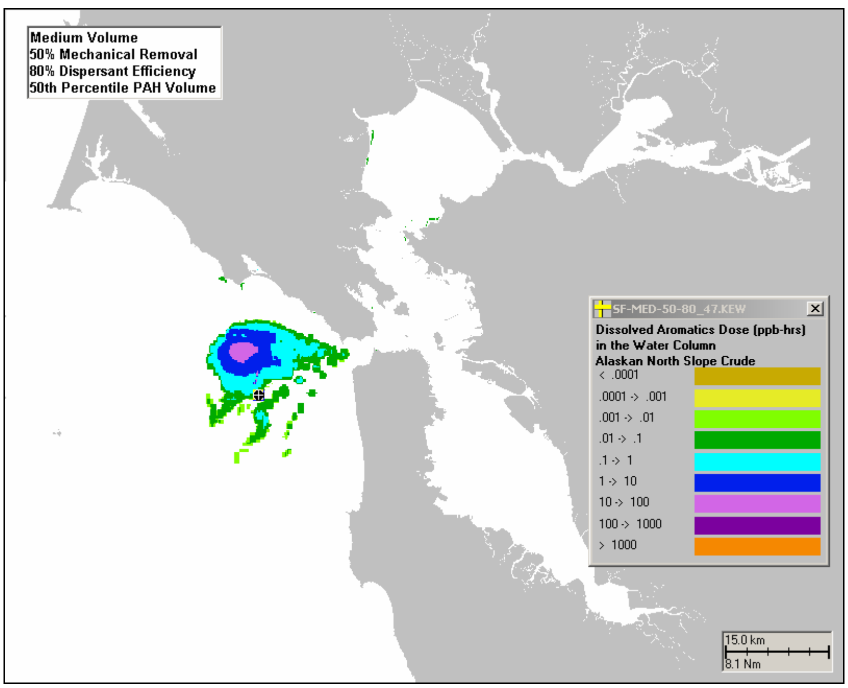

Figure E-II.4.3-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 80% Dispersant Efficiency.

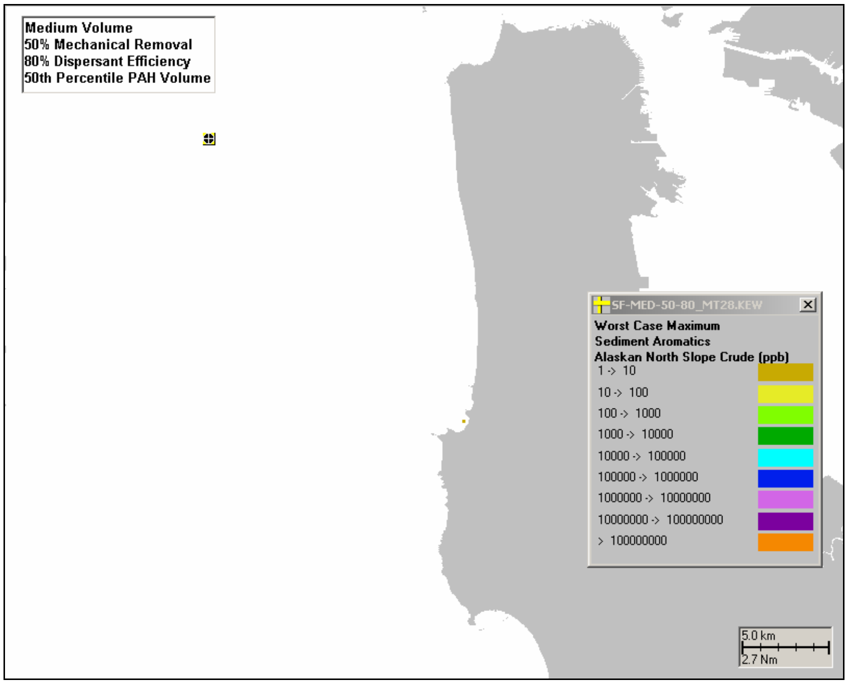

Figure E-II.4.3-7. Exposure of sediment pore water to dissolved aromatic concentration (ppb) (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does. Scenario: Medium Volume, 80% Dispersant Efficiency.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

E-II.4.4 Scenario: Large Volume, No Dispersant.

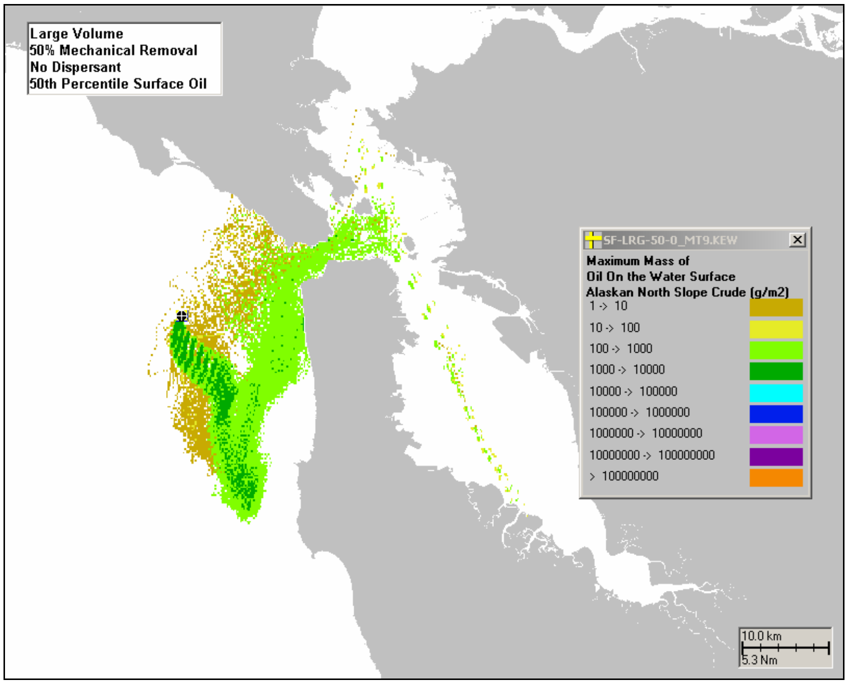

Figure E-II.4.4-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, No Dispersant.

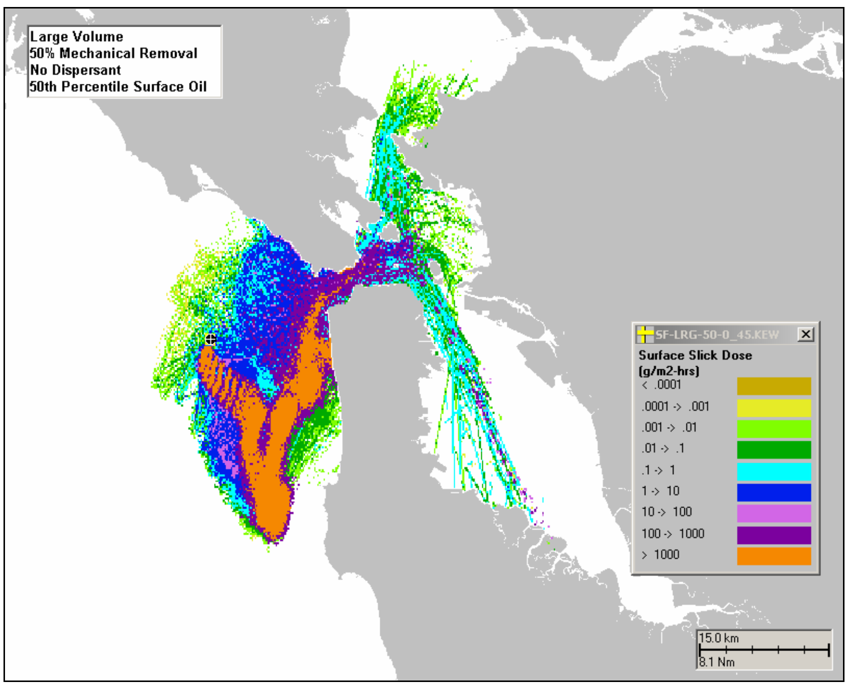

Figure E-II.4.4-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Large Volume, No Dispersant.

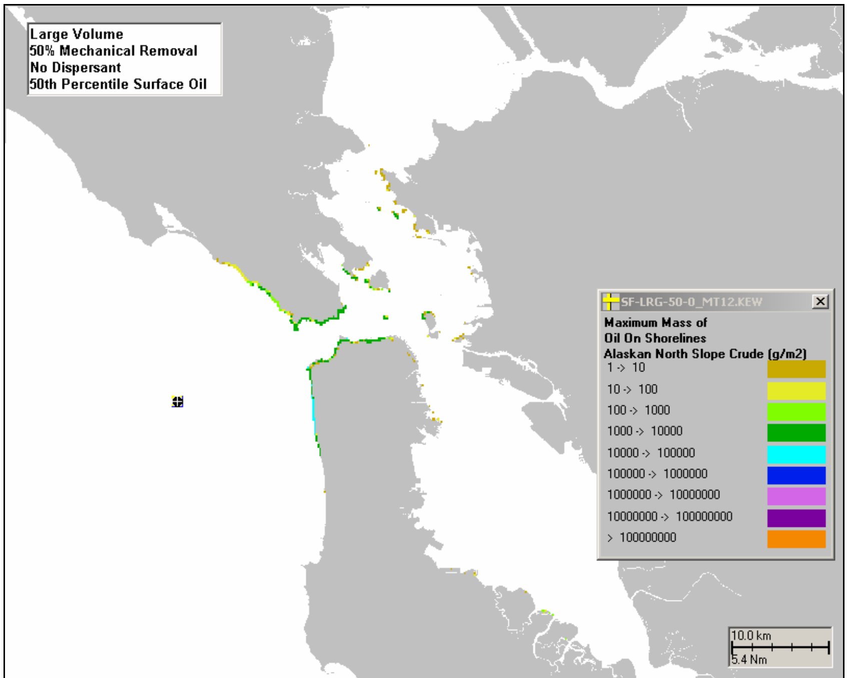

Figure E-II.4.4-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, No Dispersant.

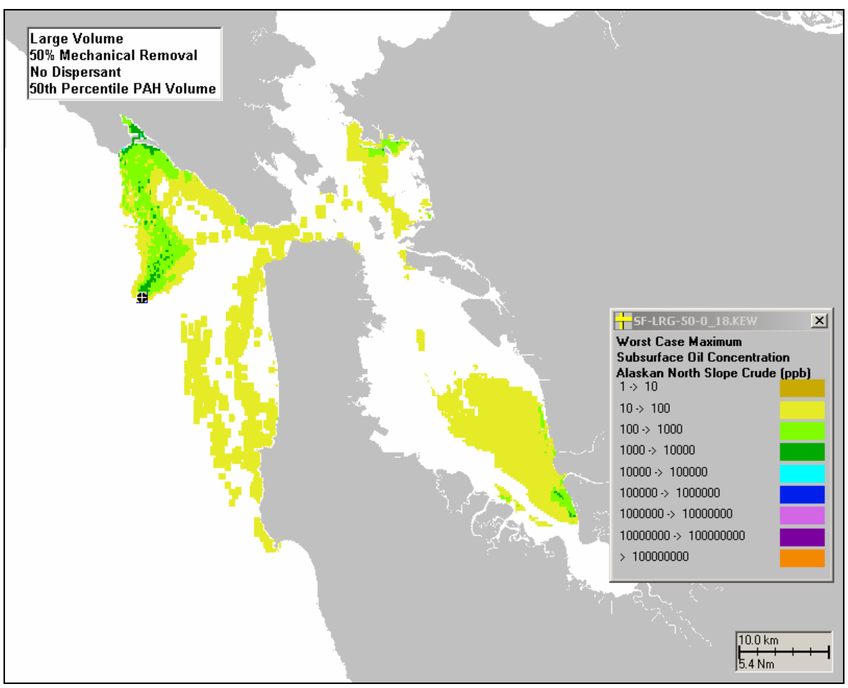

Figure E-II.4.4-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, No Dispersant.

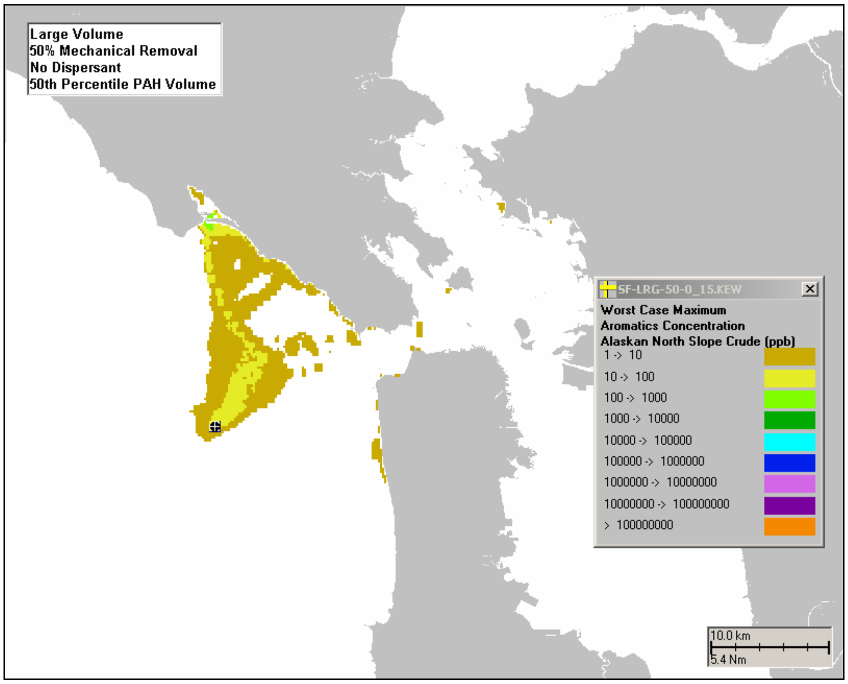

Figure E-II.4.4-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, No Dispersant.

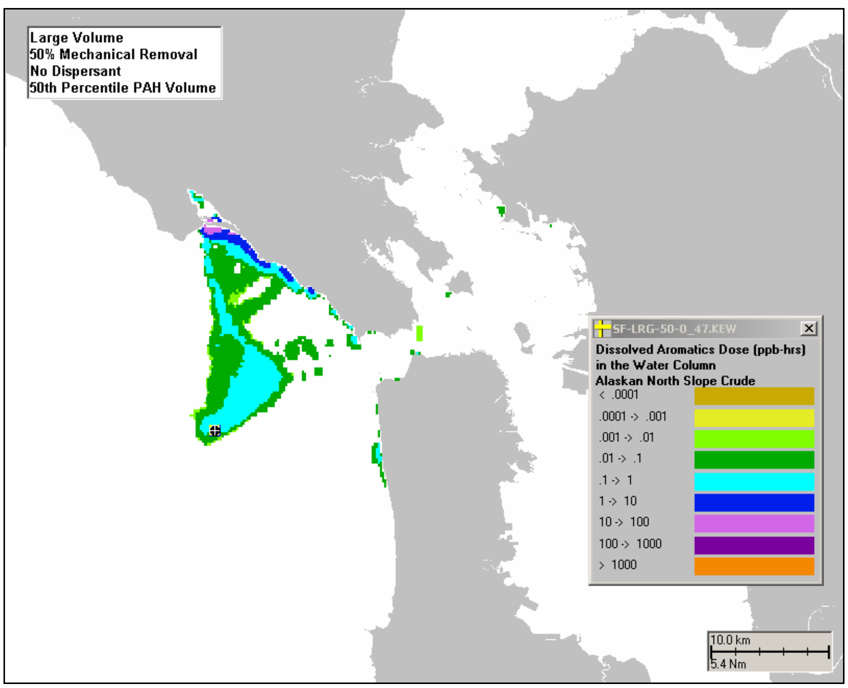

Figure E-II.4.4-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, No Dispersant.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Large Volume, No Dispersant.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Large Volume, No Dispersant.

E-II.4.5 Scenario: Large Volume, 45% Dispersant Efficiency.

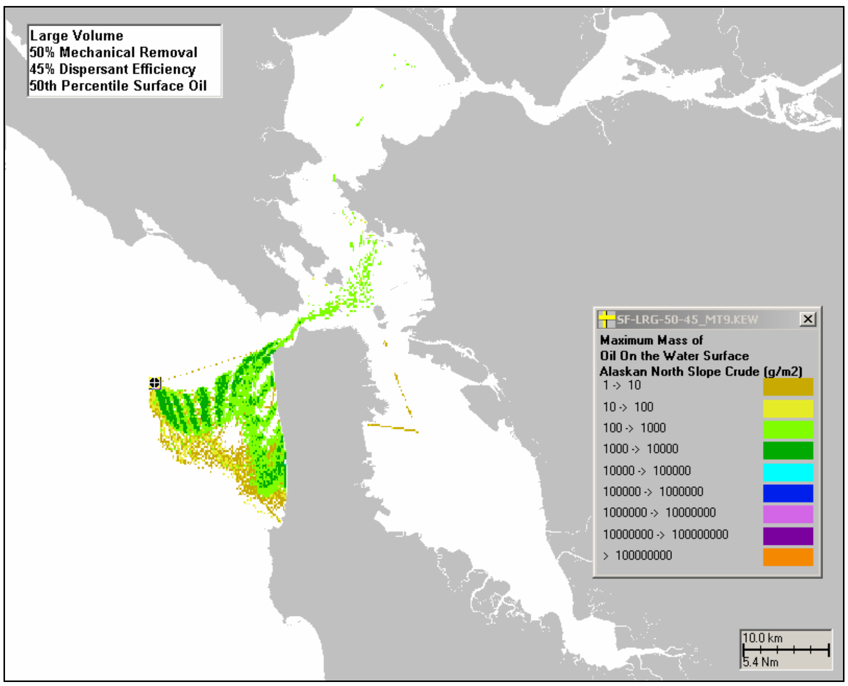

Figure E-II.4.5-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

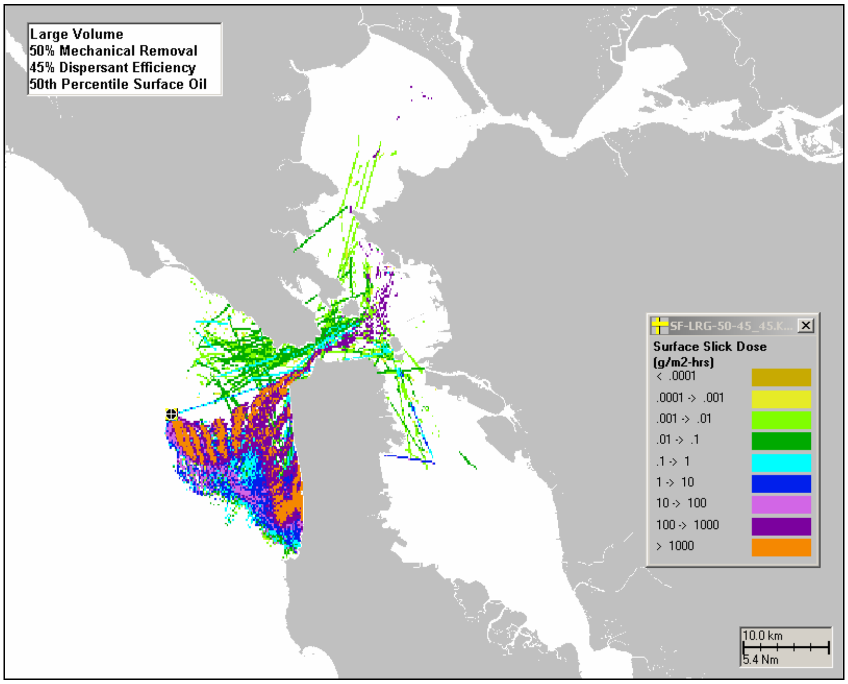

Figure E-II.4.5-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

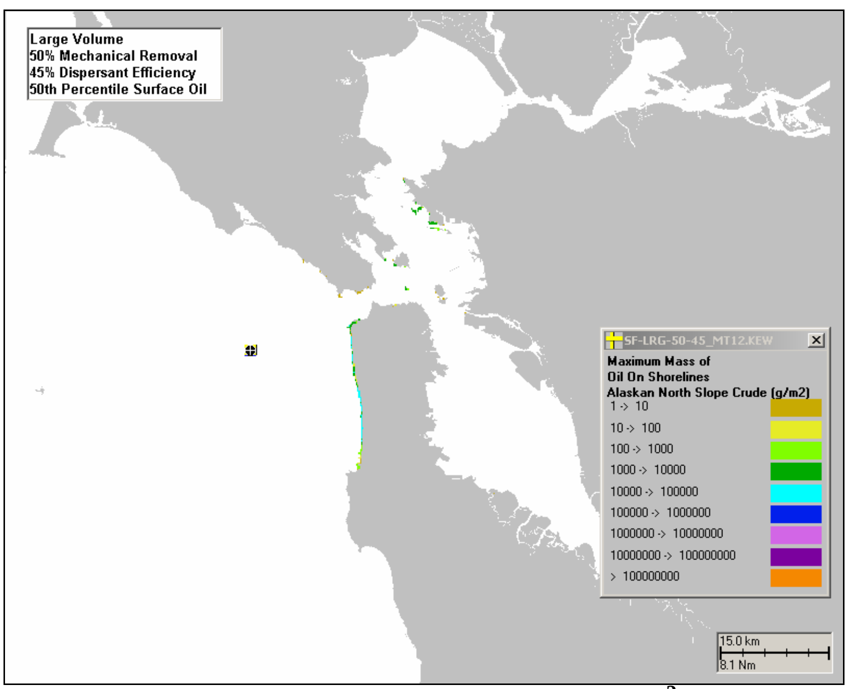

Figure E-II.4.5-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

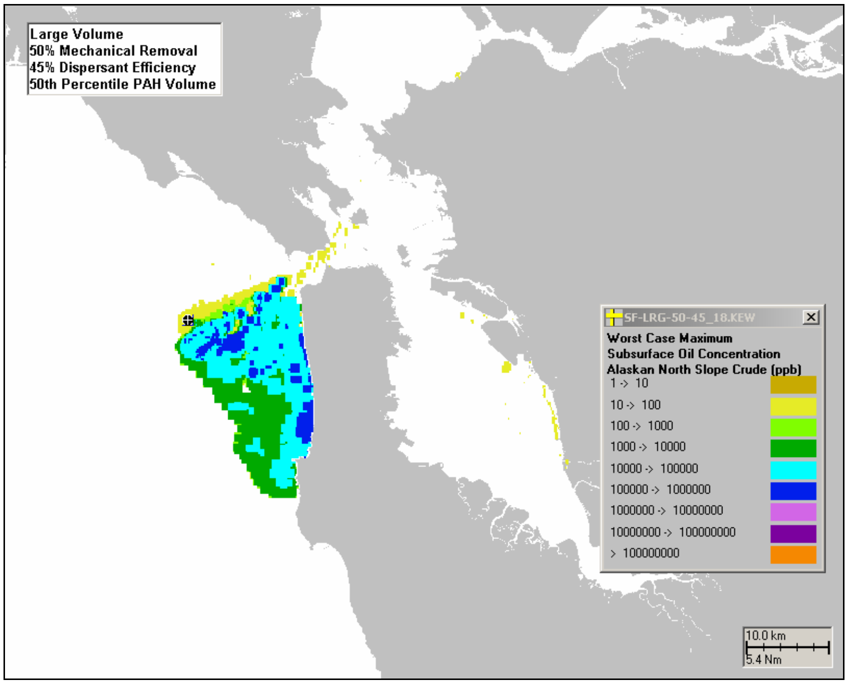

Figure E-II.4.5-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 45% Dispersant Efficiency.

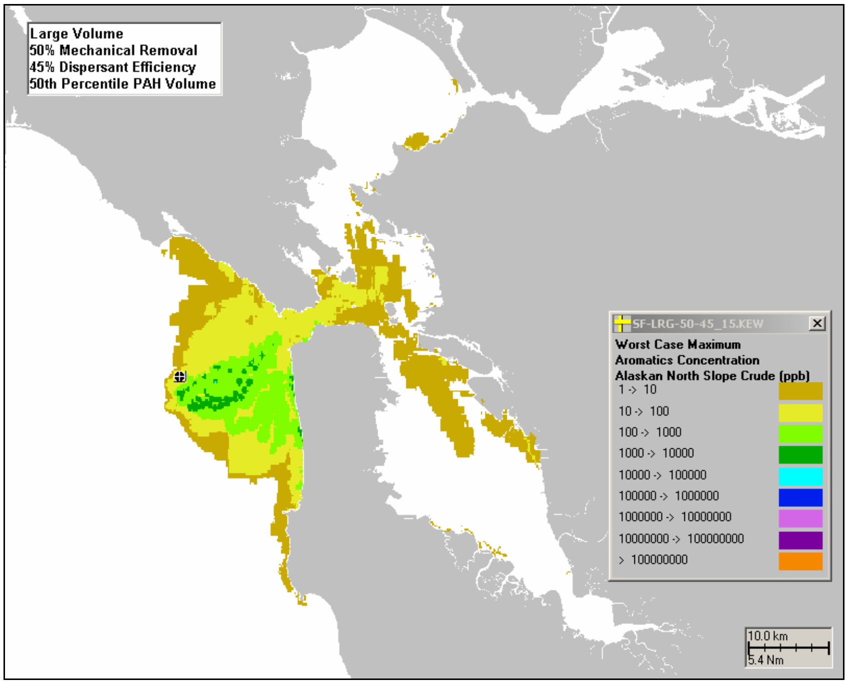

Figure E-II.4.5-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 45% Dispersant Efficiency.

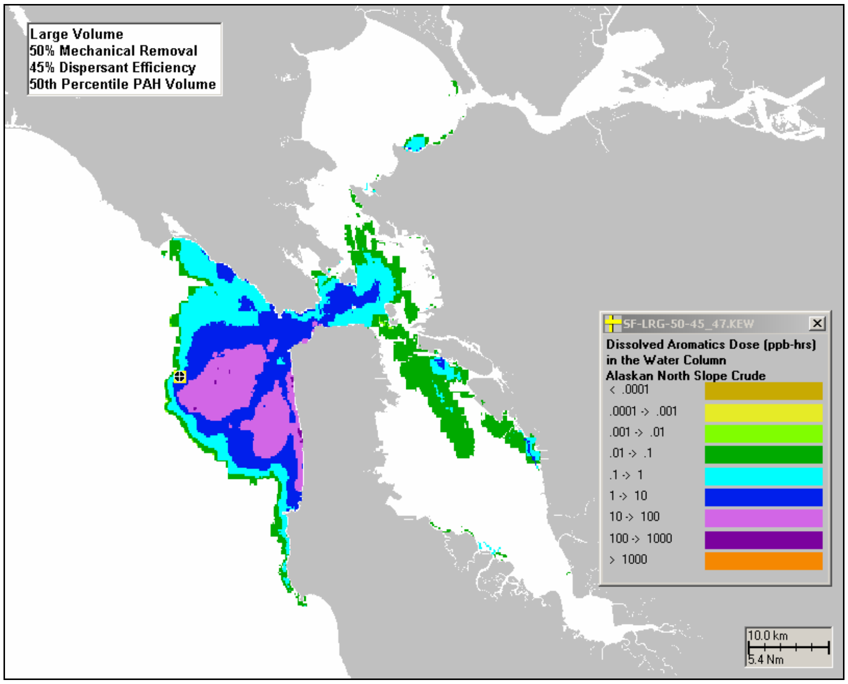

Figure E-II.4.5-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 45% Dispersant Efficiency.

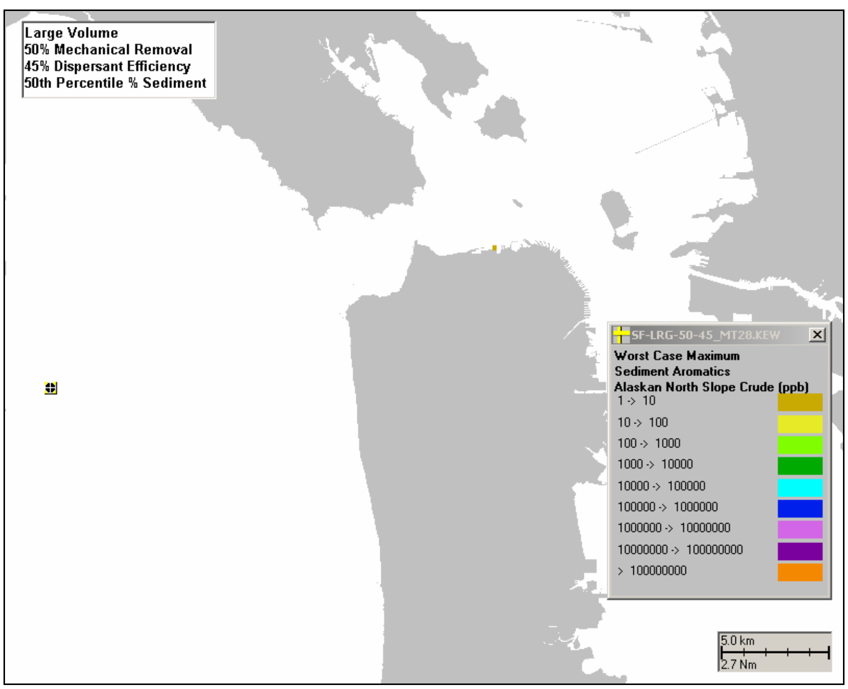

Figure E-II.4.5-7. Exposure of sediment pore water to dissolved aromatic concentration (ppb) (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does. Scenario: Large Volume, 45% Dispersant Efficiency.

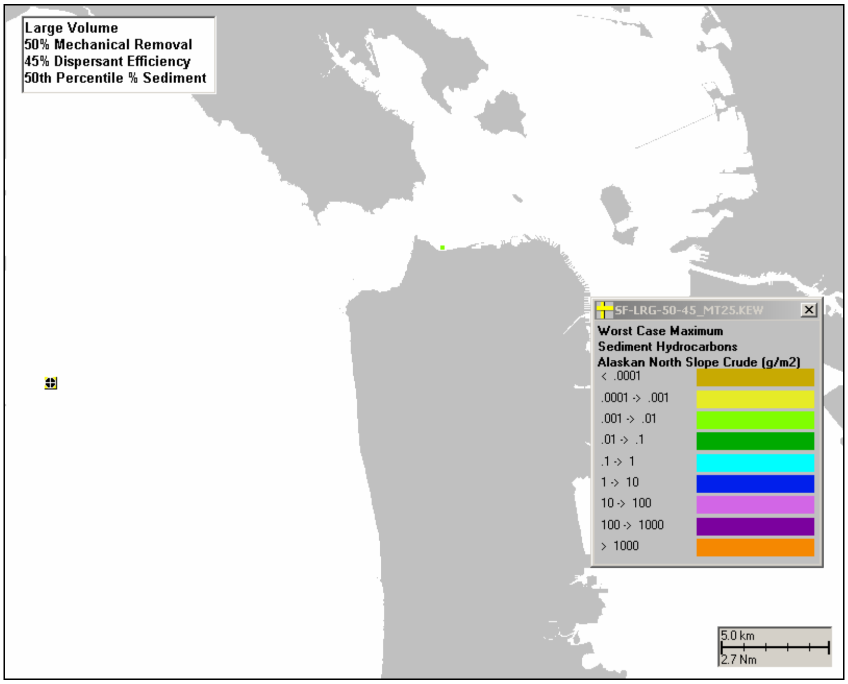

Figure E-II.4.5-8. Exposure of sediment to total hydrocarbons (ppb) (maximum exposure at any time) for 50th percentile run based on percent in/on sediment. Scenario: Large Volume, 45% Dispersant Efficiency.

E-II.4.6 Scenario: Large Volume, 80% Dispersant Efficiency.

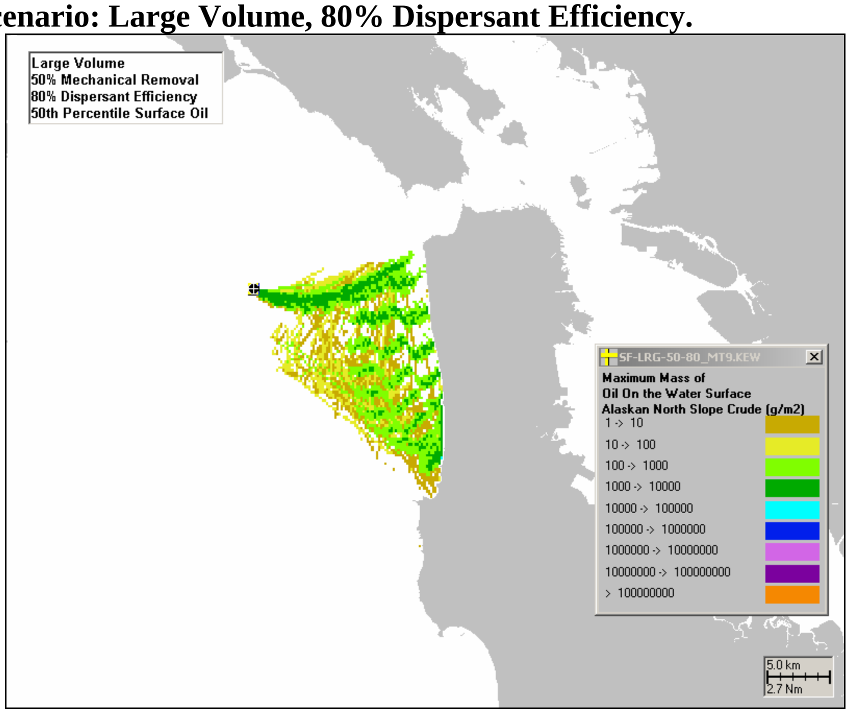

Figure E-II.4.6-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

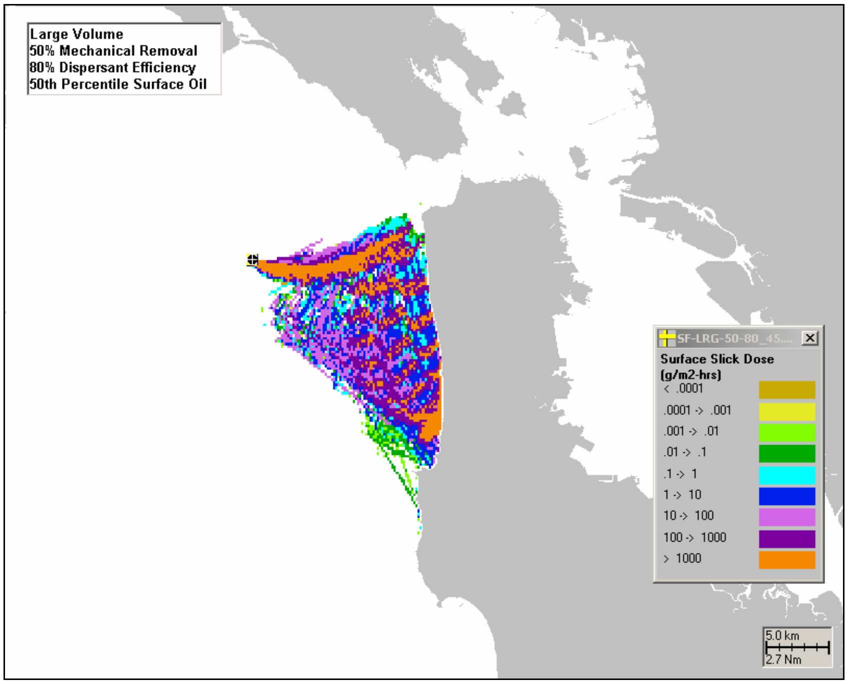

Figure E-II.4.6-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

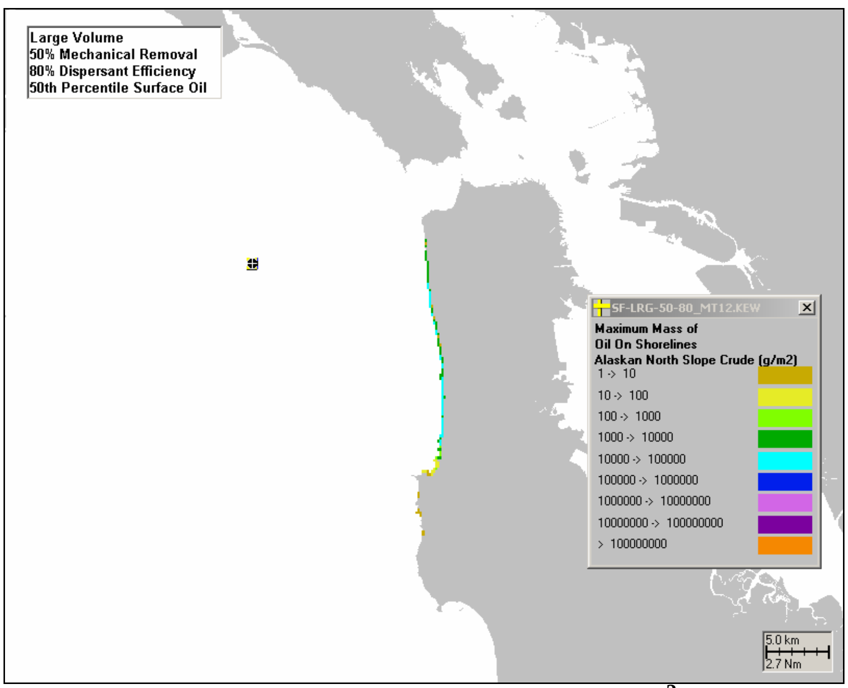

Figure E-II.4.6-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

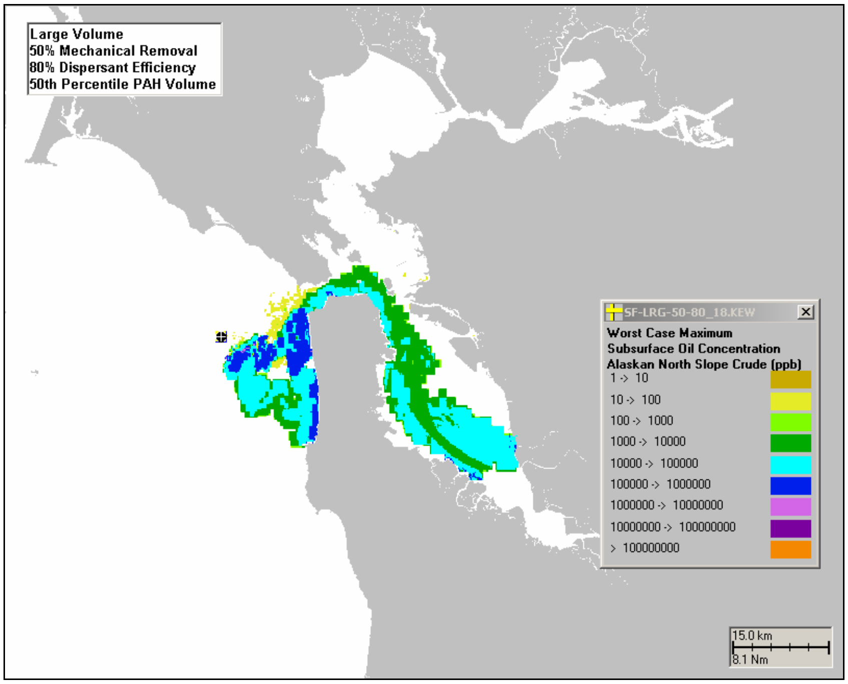

Figure E-II.4.6-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 80% Dispersant Efficiency.

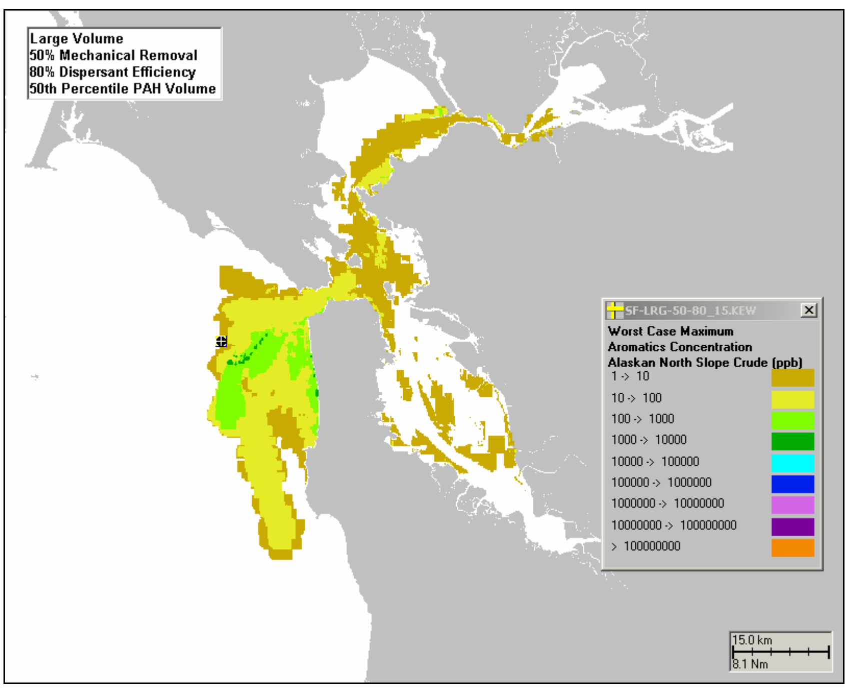

Figure E-II.4.6-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 80% Dispersant Efficiency.

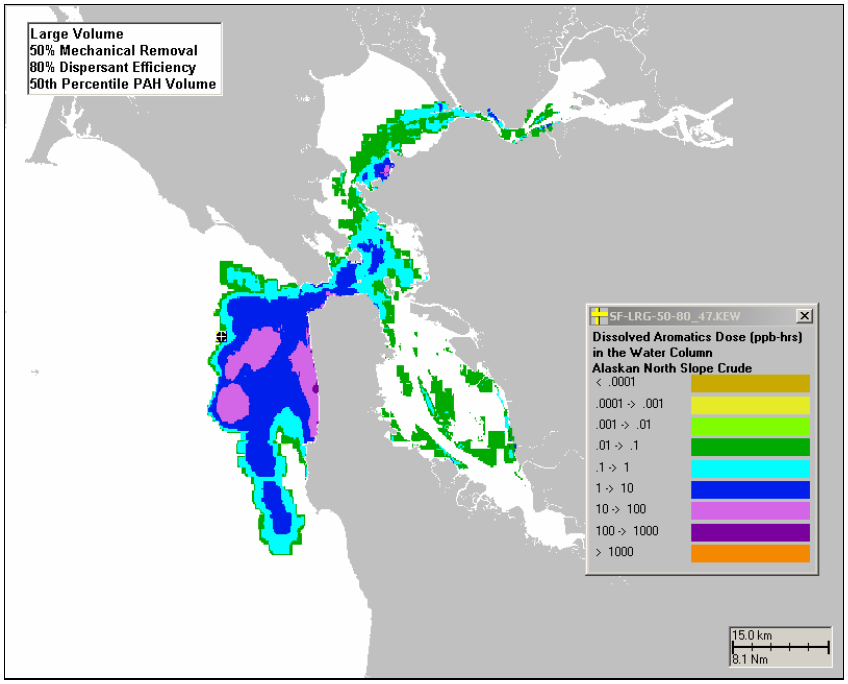

Figure E-II.4.6-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 80% Dispersant Efficiency.

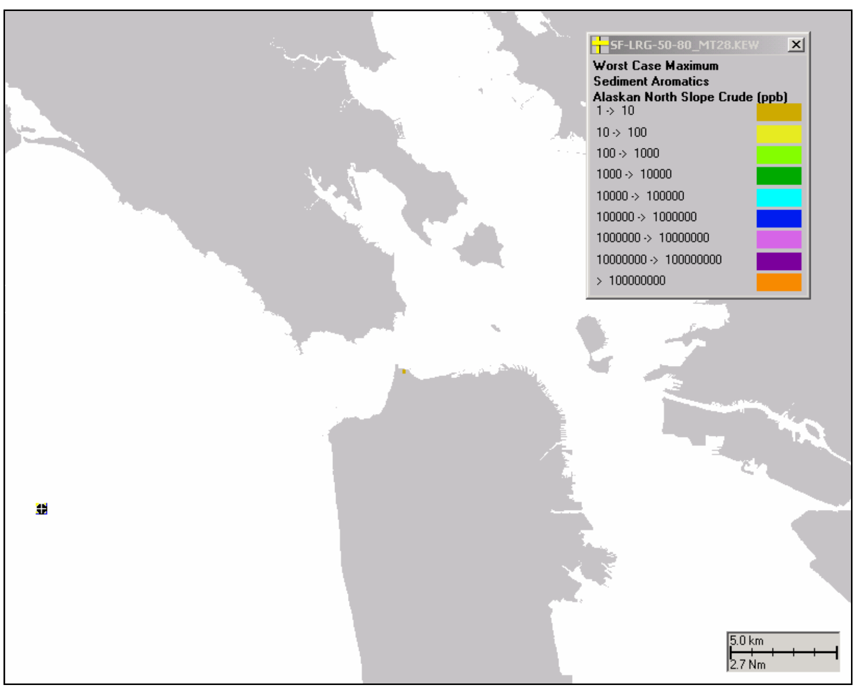

Figure E-II.4.6-7. Exposure of sediment pore water to dissolved aromatic concentration (ppb) (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does. Scenario: Large Volume, 80% Dispersant Efficiency.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part E: San Francisco Bay and Central California Shelf

Section E-II.5

by

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ASA 00-246

August 2004

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E-II.5 Area swept by surface oil greater than the threshold affecting wildlife.

This appendix contains estimates of area swept by surface oil multiplied by probability of wildlife being oiled, for each behavior category. This is summarized as an equivalent area of 100% mortality by behavior group. The equivalent area for 100% mortality is the integrated sum of area swept times probability of mortality.

The mean equivalent area killed for all possible environmental conditions is calculated using the index of surface oil exposure exceeding $0.01 g/m^2$, which is the integrated area swept by oil sheen or thicker oil times the duration that oil is present, in m^2-hours. The biological exposure model was run for the 50^{th} percentile run (with respect to m^2-hours) of each of the six scenarios (two volumes times three dispersant conditions). The resulting equivalent areas of 100% mortality (in km^2) were regressed against m^2-hours to obtain an equation for each behavior group that may be used to scale from m^2-hours to area killed. Table E-II.5-1 contains the regression slope, intercept, standard error, and correlation coefficient for each behavior group. Figures E-II.5-1 and E-II.5-2 plot equivalent area killed (of 100% mortality) against m^2-hours for wildlife behavior groups. Tables E-II.5-2 and E-II.5-3 contain estimated equivalent areas killed for mean environmental conditions, based on the mean (i.e., numerical average) surface oil exposure in m^2-hours from Appendix E-II.2.

Table E-II.5-1 Regression slope, intercept, standard error, and correlation coefficient for equivalent area killed (km^2) against m^2-hours based on the 50^{th} percentile runs of each scenario.

Behavior Group	Probability of Mortality	Slope	Intercept	Std Error	Correlation
Dabbling waterfowl	0.99	8.1012E-09	-15.0118	17.4317	0.891
Nearshore aerial divers	0.35	2.9798E-09	-5.5771	6.4461	0.890
Surface seabirds	0.99	3.7690E-08	-22.4423	35.9570	0.975
Aerial seabirds	0.05	2.0218E-09	-1.3927	2.0314	0.973
Wetland wildlife (Waders and shorebirds)	0.35	2.3922E-10	-0.0007	0.5387	0.882
Terrestrial wildlife	0.001	7.8153E-13	-0.0001	0.0016	0.897
Cetaceans	0.001	3.1853E-11	-0.0118	0.0286	0.978
Furbearing marine mammals	0.75	2.8995E-08	-17.9671	28.0180	0.975
Pinnipeds, manatee, sea turtles	0.01	4.0540E-10	-0.2808	0.4083	0.973
Surface birds, seaward	0.99	2.9834E-08	-6.7575	26.1729	0.979
Diving birds, seaward	0.35	1.0981E-08	-3.3257	9.6672	0.979
Aerial and subsurface, seaward	0.05	1.5988E-09	-0.5400	1.4141	0.979
Surface birds, landward	0.99	7.9001E-09	-15.7641	18.3697	0.876
Diving birds, landward	0.35	2.9047E-09	-5.8382	6.7752	0.875
Aerial and subsurface, landward	0.05	4.2267E-10	-0.8523	0.9873	0.875
Diving birds, water only	0.35	1.3624E-08	-9.1613	14.0203	0.972
Aerial and subsurface, water only	0.05	1.9838E-09	-1.3921	2.0756	0.971
All water surface	1	3.8925E-08	-26.1753	40.0581	0.972
All seaward water surface	1	3.1376E-08	-9.5021	27.6206	0.979
All landward water surface	1	8.2990E-09	-16.6804	19.3577	0.875

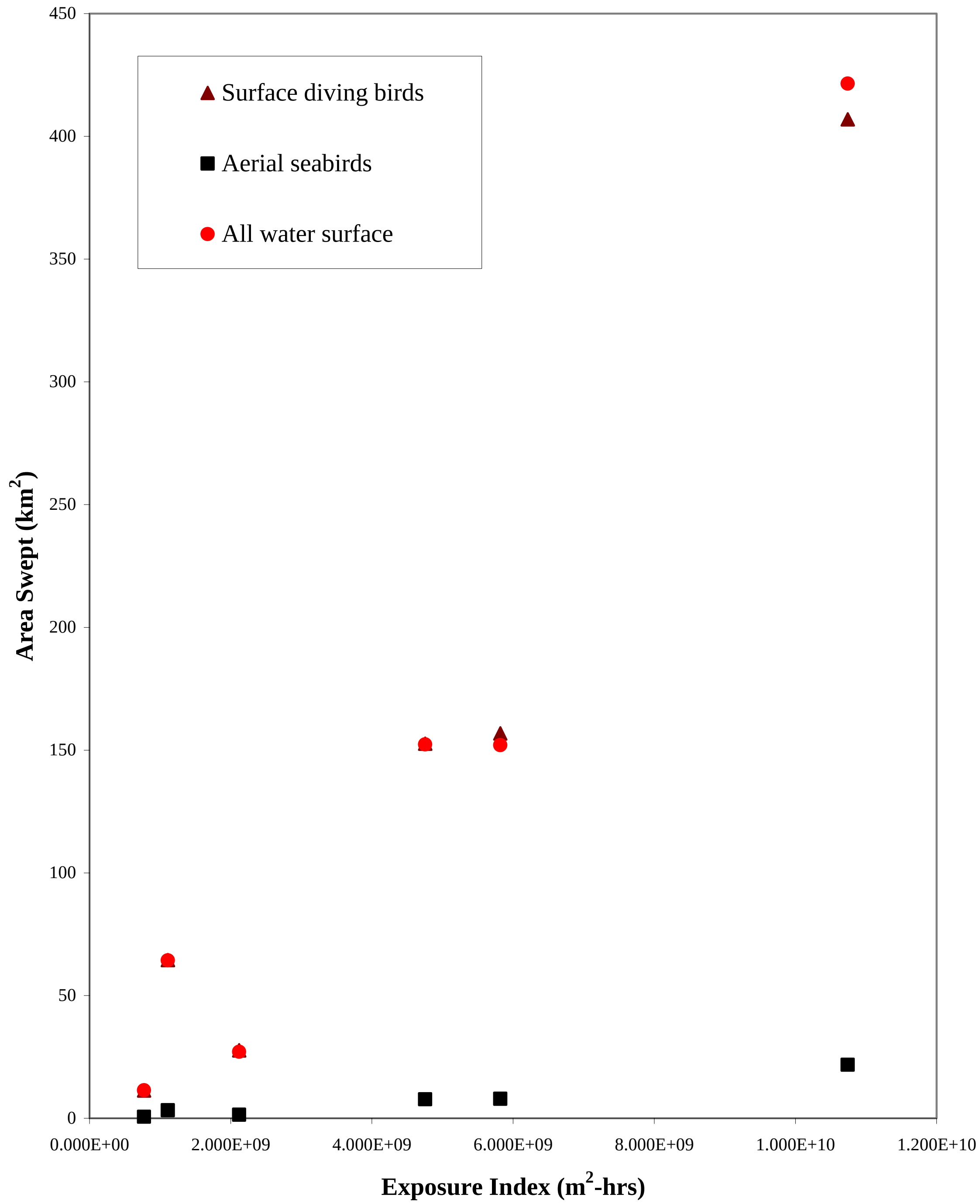

Figure E-II.5-1. Equivalent area killed against m^2-hours for wildlife behavior groups (groups in offshore waters).

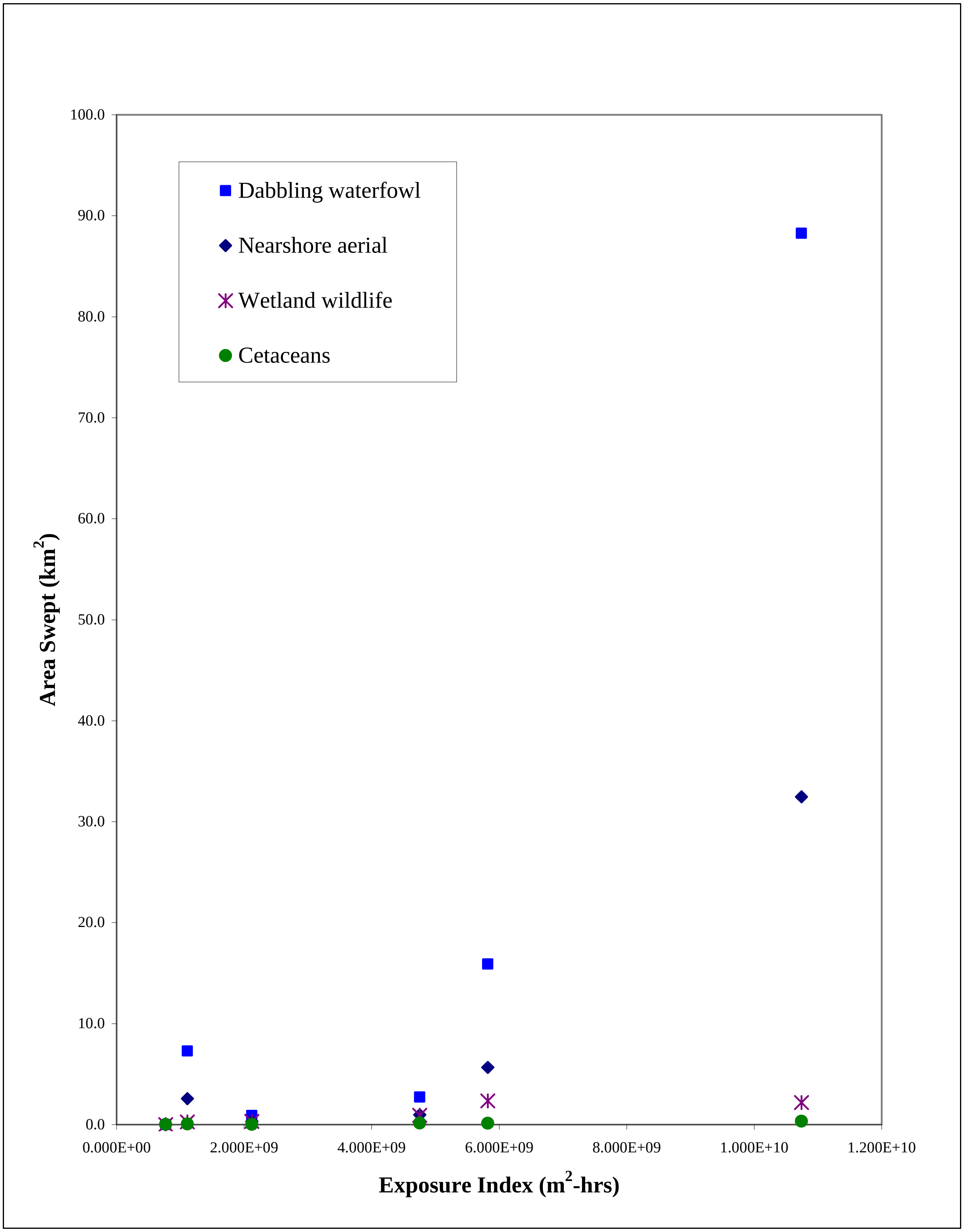

Figure E-II.5-2. Equivalent area killed against m^2-hours for wildlife behavior groups (coastal species and cetaceans)).

Table E-II.5-2. Equivalent area (km^2) of 100% mortality by wildlife behavior group, based on mean surface oil exposure, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	Probability of Mortality	0%	45%	80%
Dabbling waterfowl	0.99	15.14	5.98	6.94
Nearshore aerial divers	0.35	5.51	2.14	2.50
Surface seabirds	0.99	117.83	75.20	79.69
Aerial seabirds	0.05	6.13	3.85	4.09
Wetland wildlife (Waders and shorebirds)	0.35	0.89	0.62	0.65
Terrestrial wildlife	0.001	0.00	0.00	0.00
Cetaceans	0.001	0.11	0.07	0.07
Furbearing marine mammals	0.75	89.95	57.15	60.60
Pinnipeds, manatee, sea turtles	0.01	1.23	0.77	0.82
Surface birds, seaward	0.99	104.28	70.53	74.09
Diving birds, seaward	0.35	37.55	25.12	26.43
Aerial and subsurface, seaward	0.05	5.41	3.60	3.79
Surface birds, landward	0.99	13.64	4.7	5.6
Diving birds, landward	0.35	4.97	1.7	2.0
Aerial and subsurface, landward	0.05	0.72	0.24	0.29
Diving birds, water only	0.35	41.54	26.13	27.76
Aerial and subsurface, water only	0.05	5.99	3.75	3.98
All water surface	1.00	118.70	74.67	79.31
All seaward water surface plus intertidal	1.00	107.27	71.78	75.52
All landward water surface plus intertidal	1.00	14.21	4.8	5.8
All water surface plus intertidal	1.00	121.48	76.60	81.33

Table E-II.5-3. Equivalent area (km^2) of 100% mortality by wildlife behavior group, based on mean surface oil exposure, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	Probability of Mortality	0%	45%	80%
Dabbling waterfowl	0.99	124.98	60.13	58.56
Nearshore aerial divers	0.35	45.91	22.06	21.48
Surface seabirds	0.99	628.85	327.14	319.83
Aerial seabirds	0.05	33.54	17.36	16.97
Wetland wildlife (Waders and shorebirds)	0.35	4.13	2.22	2.17
Terrestrial wildlife	0.001	0.01	0.01	0.01
Cetaceans	0.001	0.54	0.28	0.28
Furbearing marine mammals	0.75	483.06	250.96	245.34
Pinnipeds, manatee, sea turtles	0.01	6.72	3.48	3.40
Surface birds, seaward	0.99	508.77	269.95	264.17
Diving birds, seaward	0.35	186.43	98.53	96.40
Aerial and subsurface, seaward	0.05	27.09	14.29	13.98
Surface birds, landward	0.99	120.75	57.51	55.98
Diving birds, landward	0.35	44.35	21.10	20.54
Aerial and subsurface, landward	0.05	6.45	3.07	2.99
Diving birds, water only	0.35	226.26	117.20	114.56
Aerial and subsurface, water only	0.05	32.89	17.01	16.62
All water surface	1.00	646.45	334.86	327.31
All seaward water surface plus intertidal	1.00	532.67	281.51	275.42
All landward water surface plus intertidal	1.00	126.73	60.29	58.68
All water surface plus intertidal	1.00	659.40	341.81	334.11

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part E: San Francisco Bay and Central California Shelf

Section E-II.6

by

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ASA 00-246

August 2004

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E-II.6 Exposures for fish and invertebrates to dissolved aromatic concentrations.

This appendix tabulates estimated mortality of water column, demersal (on the bottom) and benthic (in the bottom) organisms by behavior type for the Pacific spill location. Effects are summarized as an equivalent area of 100% mortality by behavior group and habitat type. The equivalent area for 100% mortality is the integrated sum of equivalent area affected times percent mortality. For water column and demersal species, the equivalent area affected is calculated as water volume affected times the fraction of the water depth zone the behavior group occupies that the affected volume encompasses. For pelagic species, the depth zone occupied is the entire water column. For demersal species (on the bottom sediments, exposed to bottom water), the depth zone occupied is the bottom 1 meter of the water column. The methods and assumptions for these calculations are described in Part A.

For water column and demersal species, the mean equivalent area killed for all possible environmental conditions is calculated using the water volume (m^3) exposed to greater than 1 mg/m^3 (1 ppb) dissolved aromatic concentration at any time after the spill. The biological exposure model was run for the 50th percentile run (with respect to water volume exposed to >1ppb) of each of the six scenarios (two spill volumes times three dispersant conditions). The toxicity parameter (LC50) assumed in these calculations was that for sensitive species (the 2.5th percentile in rank order sensitivity), in order to provide conservatively high estimates of potential water column effects. The resulting equivalent areas of 100% mortality (in km^2) were regressed against water volume exposed (m^3) to obtain an equation for each behavior group that may be used to scale from volume exposed to area killed (for sensitive species). Figure E-II.6-1 plots equivalent water column area killed (area of 100% mortality) against volume exposed to >1ppb for each of the water column and demersal behavior groups. Table E-II.6-1 contains the regression slope, intercept, standard error, and correlation coefficient for each behavior group. Tables E-II.6-2 and E-II.6-3 contain estimated equivalent areas killed (for sensitive species) for mean environmental conditions, based on the mean volume exposed to >1ppb dissolved aromatic concentration (from Appendix E-II.2). Tables E-II.6-4 and E-II.6-5 contain estimated equivalent areas killed (for sensitive species) for 95th percentile environmental conditions, based on the mean plus two standard deviations of volume exposed to >1ppb dissolved aromatic concentration. Mean and standard deviation of volume exposed to >1ppb dissolved aromatic concentration are tabulated in Appendix E-II.2 and the full distribution of all 100 runs is plotted in Appendix E-II.3. The effects on water column communities are discussed in Sections C.3.2 and C.4.2.

Benthic effects are related to the bottom sediment area exposed to oil exceeding a threshold of concern. Table E-II.6-6 summarizes the loading of oil to the sediments. For most species, the dissolved aromatic concentration in the pore water of the sediments is what is bioavailable and causes toxicity (Table E-II.6-7). A threshold of 6 ppb dissolved aromatic concentration could cause effects on sensitive (2.5% of) species, whereas the threshold for average species is 50 ppb (see Part A, Section A.3.4). The effects on benthic organisms are discussed in Sections C.3.2 and C.4.2.

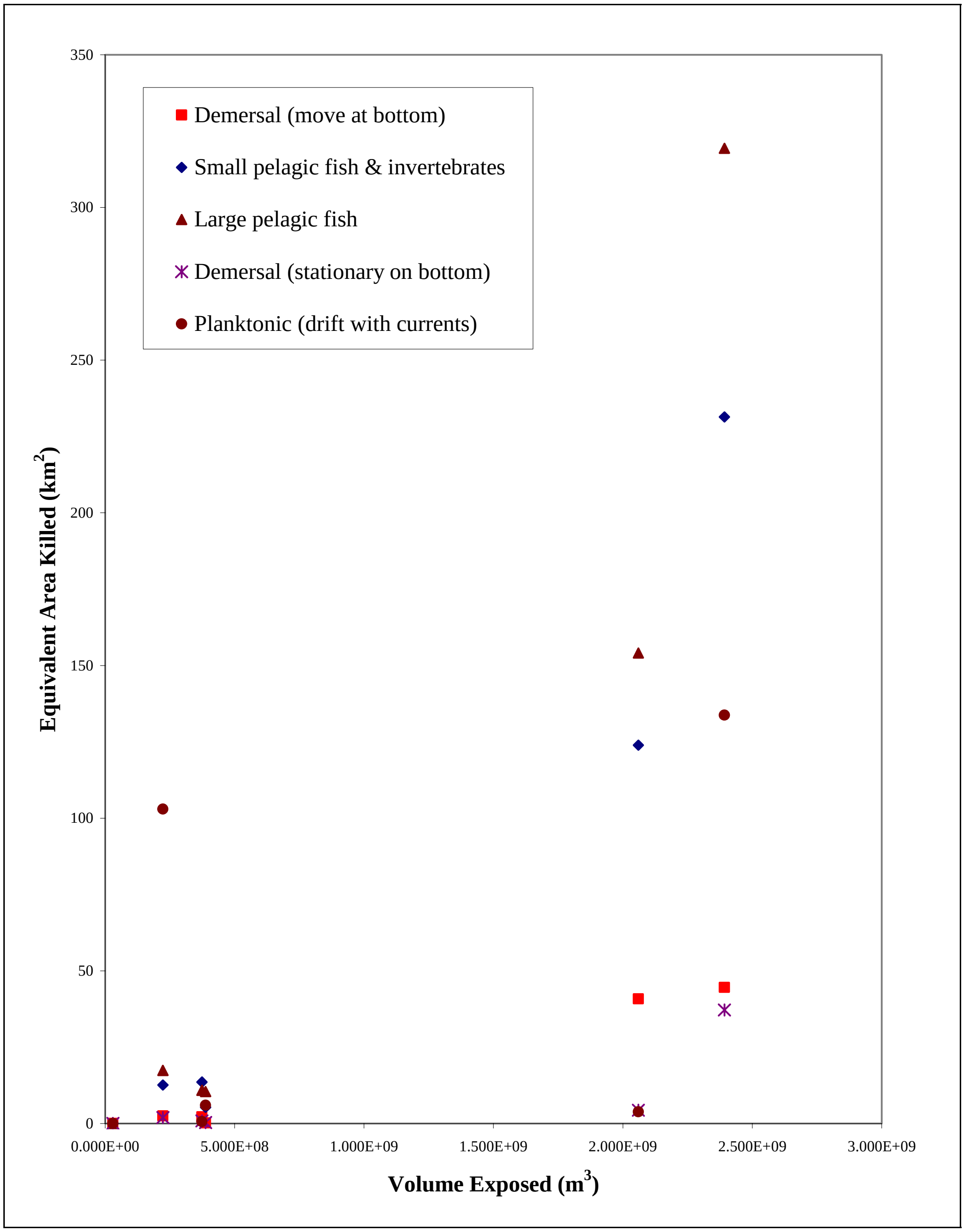

Figure E-II.6-1. Equivalent area killed (for sensitive species) against volume exposed to > 1ppb dissolved aromatic concentration for water column behavior groups.

Table E-II.6-1 Regression slope, intercept, standard error, and correlation coefficient for equivalent water column area killed (km^2) against water volume exposed to >1ppb (m^3), based on the 50^{th} percentile runs of each scenario.

Behavior Group	Slope	Intercept	Std Error	Correlation
Demersal (move at bottom)	2.0666E-08	-3.8066	3.0827	0.992
Small pelagic fish & invertebrates	8.7558E-08	-15.3198	29.6289	0.960
Large pelagic fish	1.1771E-07	-21.9005	46.9089	0.945
Demersal (stationary on bottom)	1.0919E-08	-2.5288	10.4915	0.768
Planktonic (drift with currents)	2.4047E-08	19.2447	61.8003	0.410

Table E-II.6-2. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	**0%**	**45%**	**80%**
Demersal (move at bottom)	0	4.4	3.9
Small pelagic fish & invertebrates	0	19.4	17.3
Large pelagic fish	0	24.8	22.0
Demersal (stationary on bottom)	0	1.8	1.5
Planktonic (drift with currents)	20.8	28.8	28.2

Table E-II.6-3. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	**0%**	**45%**	**80%**
Demersal (move at bottom)	4.1	47.8	49.0
Small pelagic fish & invertebrates	18.4	203.1	208.3
Large pelagic fish	23.4	271.8	278.8
Demersal (stationary on bottom)	1.7	24.7	25.4
Planktonic (drift with currents)	28.5	79.2	80.7

Table E-II.6-4. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean plus two standard deviations (i.e., 95th percentile) of water volume exposed to > 1ppb dissolved aromatic concentration, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	**0%**	**45%**	**80%**
Demersal (move at bottom)	0.7	16.2	15.0
Small pelagic fish & invertebrates	4.0	68.8	63.5
Large pelagic fish	4.0	92.5	85.4
Demersal (stationary on bottom)	0	8.6	7.9
Planktonic (drift with currents)	24.5	18.9	17.5

Table E-II.6-5. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean plus two standard deviations (i.e., 95th percentile) of water volume exposed to > 1ppb dissolved aromatic concentration, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	**0%**	**45%**	**80%**
Demersal (move at bottom)	24.8	112.4	111.8
Small pelagic fish & invertebrates	105.1	476.3	473.8
Large pelagic fish	141.3	640.3	636.9
Demersal (stationary on bottom)	13.1	59.4	59.1
Planktonic (drift with currents)	28.9	130.8	130.1

Table E-II.6-6. Area (m^2) of sediment exceeding indicated thresholds of total hydrocarbon loading per unit area (g/m^2) under average environmental conditions, by spill volume and dispersant treatment.

Threshold (g/m^2)	Medium 0%	Medium 45%	Medium 80%	Large 0%	Large 45%	Large 80%
0	7,448,306	4,729,085	4,689,676	31,842,860	16,788,240	10,246,345
0.001	4,059,132	1,970,455	1,970,455	19,152,840	8,945,848	5,280,811
0.01	788,181	394,091	591,136	6,581,308	2,246,318	1,852,227
0.1	-	39,409	39,409	906,408	354,682	472,909
1	-	-	-	78,818	78,818	78,818
10	-	-	-	-	-	

Table E-II.6-7. Area (m^2) of sediment exceeding indicated thresholds of dissolved aromatic concentration in pore waters (mg/m^3 = ppb) under average environmental conditions, by spill volume and dispersant treatment.

Threshold (mg/m^3 = ppb)	Medium 0%	Medium 45%	Medium 80%	Large 0%	Large 45%	Large 80%
1	0	0	0	0	0	0
10	0	0	0	0	0	0

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part E: San Francisco Bay and Central California Shelf

Section E-III.1

by

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ASA 00-246

August 2004

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E-III.1 Air Concentrations from Unburned Oil

This section contains model results for spills in the Pacific Region used to evaluate volatile hydrocarbon emissions from unburned oil and resulting air quality effects. The amount of volatilized mass entering the atmosphere for each chemical (or chemical class) of concern was estimated using oil spill modeling (SIMAP). SIMAP also provided the time frame over which the emissions occur. The atmospheric concentrations of volatilized hydrocarbons were modeled using AIRMAP (as described in Part A, Section A.5.1). The estimated concentrations at the water surface were compared to air quality standards to evaluate the potential for human health effects and wildlife effects.

As a screening analysis, SIMAP runs were performed for both the medium (2500 bbl) and large (40,000 bbl) spill volumes of Alaska North Slope crude under various wind conditions to determine the possible hydrocarbon emissions from unburned oil to the atmosphere. Emissions were estimated using SIMAP for the warmest water temperature occurring in the region, 15^{o}C (French et al. 1996b) and for varying wind speeds from 3 to 25 kts. (Evaporation is very slow in conditions of no wind, so this case was not included.)

As a worst case, these model runs were performed assuming no dispersants are applied, since the use of dispersants would reduce emissions to the extent that volatile components are permanently mixed into the water. It is also assumed that any mechanically-removed oil still volatilizes, so no correction for removal was made to the volatilized mass. Likewise, no correction for amount burned was made to the rate of unburned oil emission. Thus, the screening model runs estimated the maximum rate and amount of emissions which would be expected under any environmental conditions and response scenario for the region.

In the next step of the analysis, the atmospheric concentrations of volatilized hydrocarbons released by unburned oil were modeled using AIRMAP, which accounts for transport and dilution of hydrocarbons in the local atmosphere around the spill site. Each hydrocarbon constituent was modeled separately, releasing the mass of the constituent emitted from the oil over time from the area covered by surface floating oil (as estimated by SIMAP). AIRMAP was run for each constituent and wind speed condition, from 3 to 25 kts. The constituent mass released in the AIRMAP simulation (over 10 hours) was the maximum amount emitted to the air (of that constituent) in any 10-hour period in the SIMAP spill simulation. The AIRMAP simulation was run assuming a stable atmosphere with minimal turbulence to disperse contaminants.

The atmospheric dispersion model provided estimates of air concentrations in the air layer within 2 m of the water surface (for each 55m X 55m cell of a 200 by 200 cell grid covering the horizontal extent of the plume) as a function of time after the spill. The estimated concentrations were then compared to air quality standards to evaluate the potential for human health effects. Two averaging periods were used in accordance with the standards: 0.5 hour for comparison to the Immediate Danger to Life and Health (IDLH) value and 8 hours for comparison to the 8-hour time weighted average (TWA).

The maximum 0.5-hour and 8-hour average air concentration for any time period in the AIRMAP simulation was compared to the appropriate standard (Table E-III.1-1). The IDLH (from Table A.5-5 in Part A) is not to be exceeded for a ½ hour exposure. The PEL-TWA is the minimum of the 8-hour time weighed averages in Table A.5-5. Heptane is used as representative of the volatile aliphatic VOCs. Its air quality standards are the lowest of those available for this group of chemicals (see Section A.5.3), so comparison to the standards for heptane is conservative. The area adversely affected was that where the standard was exceeded for the appropriate averaging period. The maximum distance from the release site that concentrations exceeded the air quality standard was also estimated for each constituent using the AIRMAP results.

These results are applicable to spills of crude oils with similar volatile content in any location where conditions are at the temperature, atmospheric stability, and wind speed assumed. Concentrations and areas affected would be lower than those reported below for less stable atmospheres and lower temperature conditions. The results are assuming no dispersant applied, such that all the volatiles are assumed released to the atmosphere. Dispersants could permanently disperse some of the volatiles in the water column, reducing the air concentrations and areas adversely affected. Also, volatiles would be burned and emissions reduced to the extent that ISB is used. Thus, these areas of potential adverse effect are the maximum possible in the region under any response scenario and environmental conditions.

Table E-III.1-1. IDLH and TWA thresholds for evaluating potential effects of air concentrations.

Chemical	IDLH (mg/m^3)	PEL-TWA (mg/m^3)
Benzene	1595	3.19
Toluene	1885	754
Ethylbenzene	3472	434
Xylene	3906	434
Naphthalene	1310	52.4
Biphenyl	631	1.262
Phenanthrene	80	(not available)
Aliphatic VOCs with boiling points <180^{o}C (based on heptane)	3075	2050

E-III.1.1 Medium Volume Spills

Emissions from Unburned Oil

Table E-III.1.1-1 contains the estimated maximum volatilized mass released to the atmosphere in any 10-hour period for each constituent of concern in the medium-volume spill under the worst-case (highest) temperature condition (15^{o}C) and with various wind speeds. The results show (Figure E-III.1.1-1) that the emission rates of the MAHs (benzene, toluene, ethylbenzene, xylenes) increase as wind speed increases to about 10 kts and then level off. Volatile aliphatics indicate a similar pattern with wind speed (Table E-III.1.1-1). The emission rates for PAHs are much lower than for the volatiles and increase with wind speed (Figure E-III.1.1-1).

Table E-III.1.1-1. Maximum mass (MT) of chemical volatilized from unburned Alaskan North Slope crude oil in any 10-hour period after a spill of 2,500 bbl at the indicated wind speed.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Total MAHs	201	237	256	266	268	266	266	259	256
Benzene	0.75	0.88	0.95	0.98	0.99	0.98	0.98	0.96	0.95
Toluene	1.82	2.14	2.31	2.41	2.43	2.41	2.40	2.34	2.31
Ethylbenzene	0.34	0.40	0.43	0.45	0.45	0.45	0.45	0.44	0.43
Xylenes	1.65	1.94	2.10	2.18	2.20	2.18	2.18	2.12	2.10
Total volatile and semi-volatile PAHs	30.5	39.6	46.9	53.2	55.4	58.0	69.4	85.2	97.6
Naphthalene	0.020	0.026	0.030	0.035	0.036	0.038	0.045	0.055	0.063
Biphenyl	0.005	0.007	0.008	0.010	0.010	0.010	0.012	0.015	0.018
Phenanthrene	0.028	0.036	0.042	0.048	0.050	0.052	0.062	0.158	0.127
Aliphatic VOCs with boiling points <180^{o}C	33.3	39.2	42.3	44.0	44.3	44.0	43.9	42.8	42.3

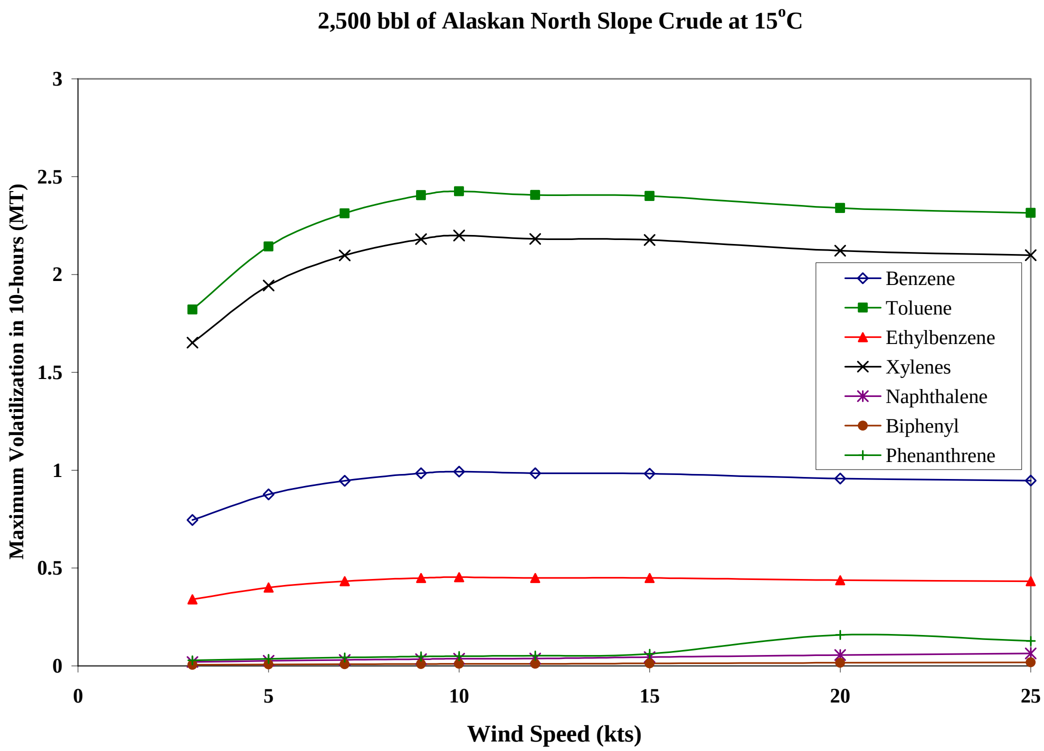

Figure E-III.1.1-1 Maximum mass (MT) of chemical volatilized from unburned Alaskan North Slope crude oil in any 10-hour period after a spill of 2,500 bbl at the indicated wind speed.

Air Concentrations from Unburned Oil Emissions

Tables E-III.1.1-2 and E-III.1.1-3 list the areas where the air concentrations exceeded the comparable air quality standards. Tables E-III.1.1-4 and E-III.1.1-5 list the maximum distances (down wind) from the release site that concentrations exceeded the air quality standards. Since the emissions were more rapidly dispersed in the atmosphere the higher the wind speed, the conditions where concentrations of volatiles in air were at maximum were those where winds were assumed light (3 kts). This is demonstrated in the results. The IDLH is not exceeded for any of the chemical constituents under these worst-case conditions for medium volume (2,500 bbl) spills of Alaskan North Slope crude oil. The TWA would be exceeded for benzene under light ($\leq$7 kts) winds in the immediate spill area (adversely effecting $\leq$3.6 km downwind of the spill site with an area <1 km^2). Air concentrations of other constituents would not exceed the TWA standards at any time after a medium volume spill.

Table E-III.1.1-2. Maximum area (m^2) where the IDLH would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0	0	0	0	0	0	0	0	0

Table E-III.1.1-3. Maximum area (m^2) where the PEL-TWA would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	904,475	375,100	60,500	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0	0	0	0	0	0	0	0	0

Table E-III.1.1-4. Maximum distance down wind (km) where the IDLH would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0	0	0	0	0	0	0	0	0

Table E-III.1.1-5. Maximum distance down wind (km) where the PEL-TWA would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	3.6	1.7	0.6	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0	0	0	0	0	0	0	0	0

E-III.1.2 Large Volume Spills

Emissions from Unburned Oil

Table E-III.1.2-1 contains the estimated maximum volatilized mass released to the atmosphere in any 10-hour period for each constituent of concern in the large-volume spill under the worst-case (highest) temperature condition and with various wind speeds. The results show (Figure E-III.1.2-1) that the emission rates of the MAHs (benzene, toluene, ethylbenzene, xylenes) increase as wind speed increases. At wind speeds above 15 kts, entrainment dominates and volatilization from the water column increases faster with wind speed than does evaporation within the range of wind speeds from 3-15 kts. Volatile aliphatics indicate a similar pattern with wind speed (Table E-III.1.2-1). The emission rates for PAHs are much lower than for the volatiles and also increase with wind speed (Figure E-III.1.2-1).

Table E-III.1.2-1. Maximum mass (MT) of chemical volatilized from unburned Alaskan North Slope crude oil in any 10-hour period after a spill of 40,000 bbl at the indicated wind speed.

Constituent	**3 kts**	**5 kts**	**7 kts**	**9 kts**	**10 kts**	**12 kts**	**15 kts**	**20 kts**	**25 kts**
Total MAHs	1827	2366	2738	2998	3087	3186	3249	3512	3743
Benzene	6.76	8.75	10.13	11.09	11.41	11.78	12.01	12.99	13.84
Toluene	16.5	21.4	24.8	27.1	27.9	28.8	29.4	31.7	33.8
Ethylbenzene	3.09	4.00	4.63	5.06	5.21	5.38	5.49	5.93	6.32
Xylenes	15.0	19.4	22.4	24.6	25.3	26.1	26.6	28.8	30.7
Total volatile and semi-volatile PAHs	248	321	381	434	452	475	522	651	880
Naphthalene	0.161	0.209	0.248	0.282	0.294	0.309	0.339	0.423	0.572
Biphenyl	0.045	0.058	0.069	0.078	0.081	0.086	0.094	0.117	0.158
Phenanthrene	0.23	0.30	0.35	0.40	0.41	0.43	0.47	2.50	2.57
Aliphatic VOCs with boiling points <180^{o}C	302	391	452	495	510	526	537	580	618

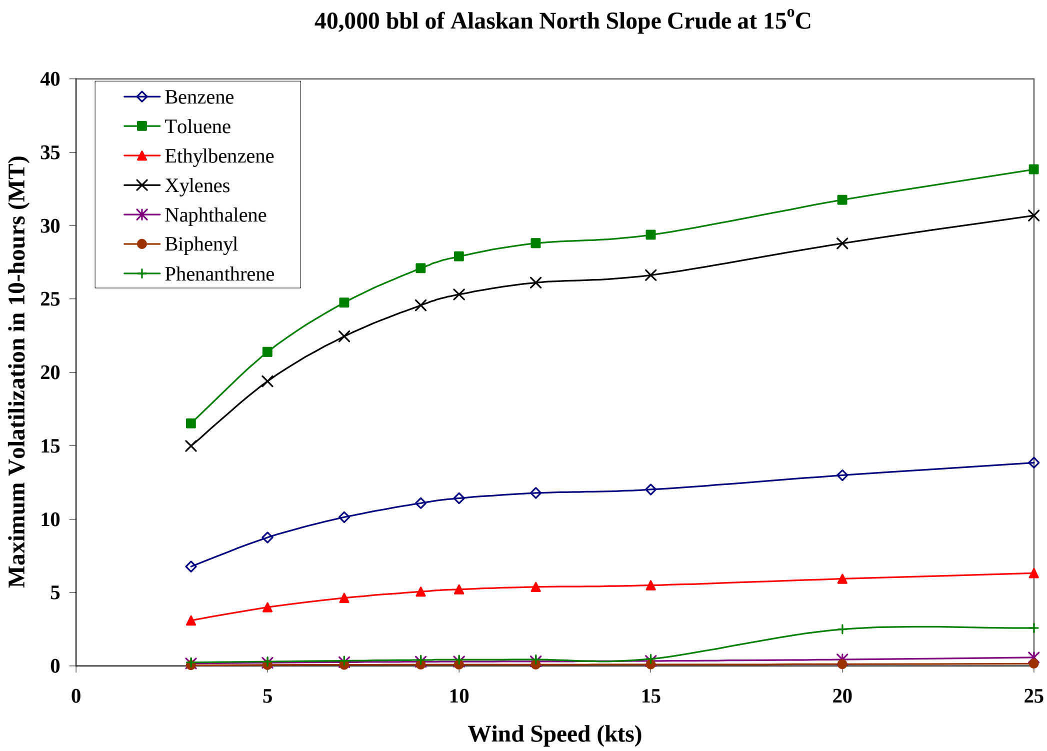

Figure E-III.1.2-1 Maximum mass (MT) of chemical volatilized from unburned Alaskan North Slope crude oil in any 10-hour period after a spill of 40,000 bbl at the indicated wind speed.

Air Concentrations from Unburned Oil Emissions

Tables E-III.1.2-2 and E-III.1.2-3 list the areas where the air concentrations exceeded the comparable air quality standards for large volume spills. Tables E-III.1.2-4 and E-III.1.2-5 list the maximum distances (down wind) from the release site that concentrations exceeded the air quality standards. Since the emissions were more rapidly dispersed in the atmosphere the higher the wind speed, the conditions where concentrations of volatiles in air were at maximum were those where winds were assumed light (3 kts), as demonstrated by the results. The IDLH for heptane is exceeded up to 0.9 km downwind of the spill site by the total volatile aliphatic VOC concentration under these worst-case temperature and air stability conditions for wind speeds up to 5 kts. The IDLH is not exceeded for any of the MAHs or PAHs, and would not be expected to under any environmental conditions for spills of this large volume. The TWA would be exceeded in the spill area after spills of 40,000 bbl for xylenes, biphenyl and volatile aliphatic VOCs under light winds ($\leq$5 kts) and for benzene under all wind conditions up to 20 kts. For xylenes and biphenyl, the areas adversely affected would not exceed 0.1 km^2 in the worst case conditions of light winds and a stable atmosphere. The adversely affected areas are larger for benzene (up to 9.7 km^2) and volatile aliphatic VOCs (up to 0.5 km^2), assuming a worst case of a stable atmosphere. The areas would be less for less stable atmospheric conditions and lower temperatures than assumed.

Table E-III.1.2-2. Maximum area (m^2) where the IDLH would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180°C	154,275	21,175	0	0	0	0	0	0	0

Table E-III.1.2-3. Maximum area (m^2) where the PEL-TWA would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	9,653,000	7,236,000	5,763,000	4,698,000	3,948,000	3,167,000	1,972,000	626,000	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	5,500	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	99,825	6,050	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180°C	447,700	145,200	0	0	0	0	0	0	0

Table E-III.1.2-4. Maximum distance down wind (km) where the IDLH would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0.9	0.3	0	0	0	0	0	0	0

Table E-III.1.2-5. Maximum distance down wind (km) where the PEL-TWA would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	15.1	15.1	8.5	7.3	6.2	5.1	3.6	1.7	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0.2	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	1.0	0.3	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	2.4	0.9	0	0	0	0	0	0	0

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part E: San Francisco Bay and Central California Shelf

Section E-III.2

by

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ASA 00-246

August 2004

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E-III.2 Air Concentrations from In-Situ Burning

Section A.5.2 of Part A describes the methods used to evaluate emissions from ISB and their potential effects on air quality. For scenarios involving ISB, the maximum potential amount of oil burned was assumed to be 25% by volume of the amount of oil mechanically removed (see Section A.3.7). The amount burned was calculated for each scenario since the percent of oil mechanically removed varies for each of the 100 stochastic runs. The 50^{th} and 95^{th} percentiles of the volumes mechanically cleaned up (for the 100 stochastic runs) were multiplied by 0.25 to calculate the 50^{th} and 95^{th} percentile volumes burned by ISB. The atmospheric concentrations of compounds and particulates released by an in-situ burn are dependent upon both the distance from and the area of the fire. All chemicals in the emissions that might be of concern are considered in the analysis.

E-III.2.1 Medium Volume Spills

The estimated distances from an in-situ burn to thresholds of concern are tabulated below. The maximum burn areas for each scenario were calculated by dividing the burn volume by the minimum oil thickness required for burning (3 mm). Burn areas were calculated for all 100 runs for each scenario. Table E-III.2-1 shows, for each of the three medium volume scenarios, the percentage of simulations whose calculated burn area (burn volume divided by 3 mm) is less than the maximum possible burn area of 500 m^2. For these three scenarios, some of the individual simulations have burn areas smaller than 500 m^2. The effect of the dispersant application on the area of oil requiring burning is apparent from the numbers in the table. When no dispersant is applied (0% dispersant efficiency), 9% of the simulations have burn areas smaller than 500 m^2. For 45% dispersant efficiency, 88% of the burn areas are smaller than 500 m^2, and for 80% dispersant efficiency, 89% of the burn areas are smaller than 500 m^2. Therefore, the results show that the more efficient the dispersant, the smaller the area of oil is that needs to be burned. This is not a surprising result, as dispersant removes oil from the surface of the water, decreasing the amount of oil that remains on the surface, and thereby decreasing the area of oil that needs to be burned.

Table E-III.2-1. Percentile where burn volume, divided by 3 mm, is less than the maximum burn area of 500 m^2, for each medium volume scenario.

Scenario	Percentile
Medium Volume, 0% Dispersant Efficiency	9%
Medium Volume, 45% Dispersant Efficiency	88%
Medium Volume, 80% Dispersant Efficiency	89%

Table E-III.2-2 shows, for each medium volume scenario, the number of burns that would be necessary to burn the entire amount of oil that was designated for burning. A range of oil thicknesses are shown in Table E-III.2-2: between 3 mm and 10 cm (100 mm). Three mm is the minimum thickness of oil required for in-situ oil burning (Buist et al., 1994). However, 10 cm is a more preferable oil thickness for burning (Allen, 2002). If one burn can be accomplished at less than 10 cm thick and 500 m^2 of area (i.e., the burn volume is < 50 m^3), it is assumed that this occurs and the actual thickness is calculated from volume burned divided by 500 m^2. However, if the calculated thickness for one burn is <3mm, the minimum (i.e., the burn volume is < 1.5 m^3), the burn area is instead the burn volume divided by 3 mm.

Table E-III.2-2. Assumed burn thickness for medium volume spill scenarios and number of burns needed to burn the oil, assuming the maximum burn area is 500 m^2.

Scenario		Total Volume Burned (m^3)	Burn Area (m^2)	Oil thickness (mm)	Number of Burns
Medium Volume, 0% Dispersant Efficiency	50th Percentile	9.46	500	19	1
	95th Percentile	22.4	500	45	1
Medium Volume, 45% Dispersant Efficiency	50th Percentile	0	0	-	0
	95th Percentile	7.15	500	15	1
Medium Volume, 80% Dispersant Efficiency	50th Percentile	0	0	-	0
	95th Percentile	7.07	500	15	1

In all cases (Table E-III.2-2), the burn volumes are less than 50 m^3, the maximum volume for a single burn. For cases where there is a burn, none of the burn volumes are less than 1.5 m^3, so all the burn areas are 500 m^2. The distance-to-threshold calculations reported below assume an area per burn of 500 m^2.

Table E-III.2-3 reports calculations of distance to the air quality thresholds for the chemicals of concern that are released when oil is burned. There are three thresholds in these tables: IDLH, TWA, and EPA NAAQS (Primary and Secondary Standards). These thresholds were described and listed in Table A.5-5. The chemicals listed in Table E-III.2-3 were designated by Fingas, et al. (2001) as being of concern, and they are split

into five chemical classes: total particulates, fixed gases, carbonyls, PAHs, and VOCs. For those chemicals for which U.S. air quality standards were not available, we have assumed the lowest of the available thresholds within that chemical class. For example, we do not have an IDLH threshold value for butane, a member of the VOC chemical class, but we do have IDLH values for several other members of the VOC class. We selected the lowest of the available IDLH values for the VOCs and used that value as an IDLH threshold for butane and other chemicals in the VOC class for which we are missing threshold values. We used the same strategy for the PAH chemical class as well. This substitution method provides an estimate of the distance to the threshold for those chemicals for which threshold data are not available. However, because those threshold values are just assumed estimates, the distance values in the following tables that were derived using these threshold values are shaded gray.

It should also be noted that three different TWA threshold values were obtained for this study: ACGIH TLV, OSHA PEL, and NIOSH REL. We calculated the distance to the threshold for each of these, but we present only the maximum of the three distances in these tables. For example, in Table E-III.2-3, for formaldehyde, the distance to the ACGIH TLV threshold is 237 m, to the OSHA PEL threshold is 0 m, and to the NIOSH REL threshold is 89 m. The maximum of these three distances is 237 m, which is the TWA value reported in the table.

Table E-III.2-3 shows the distance-to-threshold calculations for an individual 500 m^2 burn. In the table, the calculated distances represent the distance (from the center of the fire) at which the concentration of each chemical has decreased to the threshold level. In the case of sulphur dioxide in Table E-III.2-3, the distance at which the concentration of sulphur dioxide in the air equals the IDLH threshold is essentially zero, meaning that the concentration of sulphur dioxide produced by the 500-m^2 fire never exceeds the IDLH threshold. However, for the other thresholds in the table (TWA and EPA NAAQS), the concentrations do exceed the thresholds and do not decrease to the threshold level until 331 m, 471 m, and 440 m from the center of the fire.

Table E-III.2-3 shows that, for a 500-m^2 burn area, the total particulates, fixed gases, and carbonyls are of the greatest concern (i.e., the distances from the fire to the threshold level are greatest). The majority of other chemicals have distances of zero meters to the threshold level, meaning that their concentrations never exceed the threshold. Acetone has the largest distance to the threshold, at 710 m, and acetaldehyde and the total particulates are the next largest.

In Table E-III.2-3, there are four chemicals with distances to the threshold that stand out: 2-methylbutane, 3-methylhexane, 3-methylpentane, and methylcyclopentane. However, as can be seen from the table, these values are shaded gray because we did not have a regulatory threshold value for them. Instead, we used the lowest threshold value from within their group (VOCs). From this, we can conclude that their distance to threshold values *may* represent that they are chemicals whose concentrations will still be above threshold levels far from the fire, or it may be that the threshold estimates used for the distance-to-threshold calculation are unreasonably low and our estimate method is not suitable for these chemicals.

Table E-III.2-3. Estimated distances (m) from fire to the thresholds of concern for the 50th and 95th percentile volumes for ISB for burn area of 500 m^2. For those chemicals for which U.S. air quality standards were not available, the smallest of the available thresholds within that chemical class is assumed, and the results are shaded in gray.

Substances	Distance to the Threshold (m)			
	IDLH	TWA	EPA NAAQS	
			Primary Standard	Secondary Standard
Total Particulates				
10-um particle			514	514
2.5-um particle			523	523
Fixed gases				
Sulphur Dioxide	0	331	471	440
Carbon Dioxide	0	0		
Carbon Monoxide	0	0	0	
Carbonyls				
Acetaldehyde	0	525		
Acetone	0	710		
Formaldehyde	0	237		
PAHs				
1- Methylnaphthalene	0	0		
1-Methylphenanthrene	0	0		
2,3,5-Trimethylnaphthalene	0	0		
2,6-Dimethylnaphthalene	0	0		
2-Methylnaphthalene	0	0		
Acenaphthene	0	0		
Acenaphthylene	0	0		
Anthracene	0	0		
Benz(a)anthracene	0	0		
Benzo(a)pyrene	0	0		
Benzo(b) fluoranthene	0	0		
Benzo(e) pyrene	0	0		
Benzo(g,h,I) perylene	0	0		

Biphenyl	0	0		
Chrysene	0	0		
Dibenz(a,h)anthracene	0	0		
Dimethylnaphthalenes	0	0		
Fluoranthene	0	0		
Fluorene	0	0		
Indenol(1,2,3-cd)pyrene	0	0		
Methylphenanthrenes	0	0		
Naphthalene	0	0		
Perylene	0	0		
Phenanthrene	0	0		
Pyrene	0	0		
Trimethylnaphthalenes	0	0		
VOCs				
1,2,3-Trimethylbenzene	0	0		
1,2,4-Trimethylbenzene	0	0		
1,3,5-Trimethylbenzene	0	0		
1,4-Diethylbenzene	0	0		
2,2,3-Trimethylbutane	0	0		
2,2,4-Trimethylpentane	0	0		
2,2,5-Trimethylhexane	0	0		
2,2-Dimethylbutane	0	0		
2,2-Dimethylpropane	0	0		
2,3,4-Trimethylpentane	0	0		
2,3-Dimethylbutane	0	1		
2,3-Dimethylpentane	0	1		
2,4-Dimethylhexane	0	0		
2,4-Dimethylpentane	0	0		
2,5-Dimethylhexane	0	0		
2-Ethyltoluene	0	0		
2-Methylbutane	0	165		
2-Methylheptane	0	4		
3-Methylhexane	0	42		
3-Methylpentane	0	85		
4-Ethyltoluene	0	0		
4-Methylheptane	0	0		
Benzene	0	0		
Butane	0	1		
c-1,3-Dimethylcyclohexane	0	0		
c-1,4/t-1,3-Dimethylcyclohexane	0	0		
c-2-Butene	0	0		
Cyclohexane	0	0		
Cyclopentane	0	0		

Decane	0	0		
Dodecane	0	0		
Ethylbenzene	0	0		
Heptane	0	0		
Indan (2,3-Dihydroindene)	0	0		
Isobutane (2-Methylpropane)	0	0		
m,p-xylene	0	0		
Methylcyclohexane	0	0		
Methylcyclopentane	0	92		
Naphthalene	0	0		
n-Butylbenzene	0	0		
Nonane	0	0		
n-Propylbenzene	0	0		
Octane	0	0		
o-Xylene	0	0		
p-Cymene (1-Methyl-4-iso-propylbenzene)	0	0		
Pentane	0	0		
Propane	0	0		
Propene	0	0		
2,2-Dimethylpentane	0	0		
iso-Butylbenzene	0	0		
Isoprene (2-Methyl-1,3-Butadiene)	0	0		
iso-Propylbenzene	0	0		
Undecane	0	0		

The ISB effects are summarized in Table E-III.2-4. The affected area is calculated by assuming the circular area around each burn is affected to the maximum distance to any air quality threshold (i.e., this distance is the circle radius) and multiplying the circular area per burn by the number of burns. The percent of the region of interest is calculated using the province area in Table A.4-4.

Table E-III.2-4. Estimation of area affected by ISB, for medium volume spills by dispersant scenario and for 50th and 95th percentile burn volumes.

Dispersant % Efficiency		**0**	**45**	**80**
Burn Area (m^2)	50th	500	0	0
	95th	500	500	500
Maximum Distance (m) to Threshold (1 burn)	50th	710	0	0
	95th	710	710	710
# of Burns	50th	1	0	0
	95th	1	1	1
Area (km^2) Exposed (assuming circle with radius = maximum distance)	50th	1.584	0	0
	95th	1.584	1.584	1.584
Percent of Province Area	50th	0.010	0.000	0.000
	95th	0.010	0.010	0.010

E-III.2.2 Large Volume Spills

The estimated distances from an in-situ burn to thresholds of concern for the large volume scenarios are below. Burn areas were calculated for all 100 runs for each scenario. Table E-III.2-5 lists, for each of the three large volume scenarios, the percentage of simulations whose calculated burn area (burn volume divided by 3 mm) is less than the maximum burn area of 500 m^2. This table shows that the three scenarios in which the large volume of 40,000 bbl of crude oil was released do not have any burn areas smaller than 500 m^2, regardless of the dispersant efficiency.

Table E-III.2-5. Percentile where burn volume, divided by 3 mm, is less than the maximum burn area of 500 m^2, for each large volume scenario.

Scenario	**Percentile**
Large Volume, 0% Dispersant Efficiency	0%
Large Volume, 45% Dispersant Efficiency	0%
Large Volume, 80% Dispersant Efficiency	0%

Table E-III.2-6 shows, for each large volume scenario, the number of burns that would be necessary to burn the entire amount of oil that was designated for burning. The number of burns was calculated by dividing the burn volume (Table E-III.1.7) by the assumed oil thickness of 10 cm and then dividing this number into the maximum area allowed per burn (500 m^2).

The large volume cases with a thickness greater than 100 mm (Table E-III.2-6) will require multiple burns (2 – 9) to remove all the oil. The effectiveness of dispersant application in reducing the amount of oil needing to be burned can be seen in Table E-III.2-6. The table shows that the more efficient the dispersant is, the fewer the number of burns required to remove the oil.

Table E-III.2-6 Assumed burn thickness for large volume spill scenarios and number of burns needed to burn the oil, assuming the maximum burn area is 500 m^2.

Scenario		Total Volume Burned (m^3)	Burn Area (m^2)	Oil thickness (mm)	Number of Burns
Large Volume, 0% Dispersant Efficiency	50^{th} Percentile	300.6	500	100	7
	95^{th} Percentile	405.3	500	100	9
Large Volume, 45% Dispersant Efficiency	50^{th} Percentile	87.8	500	100	2
	95^{th} Percentile	238.6	500	100	5
Large Volume, 80% Dispersant Efficiency	50^{th} Percentile	36.0	500	72	1
	95^{th} Percentile	242.6	500	100	5

Table E-III.2-3 shows distance-to-threshold calculations, in meters, for an individual 500-m^2 burn. Descriptions of Table E-III.2-3 and its results can be found in the previous section.

The distances to the threshold would apply to each burn. Thus, the effect is proportional to the number of burns. Table E-III.2-6 indicates that on average (50^{th} percentile) the air quality effect is reduced by 5/7 if dispersant is applied with 45% efficiency, and the air quality effect is reduced by 6/7 if dispersant is applied with 80% efficiency.

The ISB effects are summarized in Table E-III.2-7. The affected area is calculated by assuming the circular area around each burn is affected to the maximum distance to any air quality threshold (i.e., this distance is the circle radius) and multiplying the circular area per burn by the number of burns. The percent of the region of interest is calculated using the province area in Table A.4-4.

Table E-III.2-7. Estimation of area affected by ISB, for large volume spills by dispersant scenario and for 50th and 95th percentile burn volumes.

Dispersant % Efficiency		**0**	**45**	**80**
Burn Area (m^2)	50th	500	500	500
	95th	500	500	500
Maximum Distance (m) to Threshold (1 burn)	50th	710	710	710
	95th	710	710	710
# of Burns	50th	7	2	1
	95th	9	5	5
Area (km^2) Exposed (assuming circle with radius = maximum distance)	50th	11.09	3.17	1.58
	95th	14.25	7.92	7.92
Percent of Province Area	50th	0.067	0.019	0.010
	95th	0.086	0.048	0.048

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part F: Prince William Sound

by

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ASA 00-246

August 2004

Preface

This technical report is a supplement to the Programmatic Environmental Impact Statement (PEIS: US Coast Guard, 2004) in support of the US Coast Guard's (USCG) Notice of Proposed Rulemaking (NPRM, USCG, 2002) regarding Vessel and Facility Response Plan oil removal capacity (Caps) requirements for tank vessels and marine transportation-related facilities. The PEIS (USCG, 2004), in accordance with the National Environmental Policy Act of 1969 (NEPA), examines a series of alternatives, including a no action alternative, which could influence the availability of oil spill response equipment around the United States.

This technical report is in six (6) parts:

1. Part A contains a description of models and underlying assumptions used in the analysis.
2. Parts B to F contain:
    a. Model results for 5 locations where model runs were performed
    b. Analysis of potential benefits and risks to resources of concern for each of these locations and various spill response alternatives.

Citation for entire report:

> French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Lord, C. Dalton, R. Levine, J. Rowe, S. Sankaranarayanan, H-S. Kim, R. Piovesan and M. Hitchings, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, March 2004, 6 volumes.

Citations for parts of the report:

Part A: Description of Models and Assumptions:

> French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Dalton, R. Levine, J. Rowe, S. Sankaranarayanan and H-S. Kim, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios, Part A: Description of Models and Assumptions. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, March 2004.

Parts B to F:

French McCay, D., D. Aurand, J. Michel, R. Unsworth, N. Whittier, C. Lord, C. Dalton, J. Rowe, S. Sankaranarayanan, H-S. Kim, R. Piovesan and M. Hitchings, 2004. Oil Spills Fate and Effects Modeling for Alternative Response Scenarios, Part F: Prince William Sound. Final Report to US Department of Transportation, Cambridge, MA and US Coast Guard, Washington, DC, submitted by Applied Science Associates, Narragansett, RI, USA, 2004.

Part A: Description of Models and Assumptions.
Part B: Delaware Bay and Mid-Atlantic Shelf.
Part C: Galveston Bay and North Texas Shelf
Part D: Florida Straits
Part E: San Francisco Bay and Central California Shelf
Part F: Prince William Sound

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F. Prince William Sound

F.1 INTRODUCTION

This report deals with the modeling results for a location in Prince William Sound Alaska, the site selected by the U.S. Coast Guard (USCG) for analysis in the Alaska region. It is one of five locations used to develop modeling data to analyze the regional and national implications of potential changes in oil spill response requirements. The results and a summary of the assumptions are discussed in a separate volume for each of these locations, while details on the methodology are presented in Part A of this Technical Report. The results of the site specific modeling analyses were used to develop the discussions about the impacts of the various alternatives under consideration in the Programmatic Environmental Impact Statement (PEIS).

All of the sites were selected because they are either located in the approaches to “higher volume ports” as defined in the Code of Federal Regulations (33 CFR 154.1020) or because they are in an area of high vessel traffic. In either case, they are considered to be areas where congestion could increase the risk of oil spills.

F.1.1 Selection of the Location

The location discussed in this volume is located at the approximate midpoint of Prince William Sound, in the vessel traffic lane leading to Port Valdez, Alaska, designated a high volume port by the USCG (Figure F.I.1.1-1). This is the approximate mid-point of the near shore zone as defined in 33 CFR 155.1020 and represents a location where an open water oil spill could threaten shore resources, and where on-water mechanical recovery, in-situ burning (ISB), or dispersant use could be considered.   The specific coordinates are given in Table F.I.4-1.

All of the oil shipped out of Port Valdez from production areas on the Alaskan North Slope moves through this area (US Army Corps of Engineers, 2000). In 2000, almost 47 million tons (more than 7.3 million barrels (bbl)) of crude oil left the port, mostly for refineries on the West Coast. The area is also the location of the worst spill in US history, which involved an export tanker leaving Port Valdez. Because of the large volume of crude oil moving through the area, the modeled spill site is in the most likely general area for a large spill in the Alaska region. Given this and that the release site is in an area where dispersant use and ISB might be used along with on-water mechanical recovery, it is a representative location with which to perform the analysis of potential impacts for various response alternatives.

F.1.2 Description of the Local Study Area

The study area for this analysis consists of one biogeographical province, Prince William Sound (Province 55) as defined in Table A.4-2 of Part A of this Technical Report. On occasion, Valdez Arm provides a reference area for potential effects of spills into coastal areas. The boundaries of the provinces were delineated in French et al. (1996) and are based on the ecoregion (province) concept outlined in Cowardin et al. (1979) used by the Department of the Interior. The divisions into provinces are based on the distributions of, and natural boundaries between, marine populations. Biota within a province are exposed to similar environmental factors and the populations typically cover the entire province (as appropriate habitat is available). Thus, effects can be evaluated as percentages of the province occupied by the populations of concern. A map of Prince William Sound area is presented as Figure A.4-5 in Part A of this Technical Report. The total areas of the provinces, including Prince William Sound, are presented in Table A.4-3. The areas of various habitats and shoreline types in the Prince William Sound reference area are given in Tables A.4-4 and A.4-5, and shoreline lengths for various shoreline types are given in Table A.4-6.

F.1.3 Modeling Input Assumptions

Part A of this Technical Report provides details on the modeling approach used in the analysis of all of the five locations. In summary, for each of the locations the Spill Impact Model Application Package (SIMAP) oil spill model was run in a probabilistic mode (100 simulations) to evaluate both physical fate and biological effects. Running the model in probabilistic mode allows the estimation of the variance due to random circumstances, such as weather, time of day, and hydrographic conditions. The basic model scenario is described in Section A.1.4, while the specific model algorithms are presented in Section A.2, and details on model input parameters are presented in Section A.3. Air quality effects, which are not directly evaluated by SIMAP were estimated using the Air Model Application Package (AIRMAP) and then estimated concentrations at the water surface were compared to air quality standards (see Section A.5).

The results of the model runs consist of a series of tables and figures which summarize areas or linear distances, by habitat type and/or location, which exceed thresholds of concern (see Section A.4). These results were compared to information on the distribution and abundance of various resources in appropriate geographic areas to estimate the percentage of habitats or biological resources that are potentially affected, and the results were then scored using a relative risk matrix which included proportion of the resource affected and time of recovery (see Section A.1.5). Socioeconomic effects could not be evaluated with the same risk matrix, since the concept of recovery time was not appropriate. The method used for those elements is described in Section A.6 and is based strictly on the magnitude of the effect on the resource of concern relative to the total resource that is available.

The input parameters which were specific to the Prince William Sound study location are presented in Appendix F.I (this volume). Appendix F.I.1 presents a series of maps which define the basic geographic data input into the model; Appendix F.I.2 discusses the development of current (hydrodynamic) data used in the model runs; Appendix F.I.3 presents the properties for Alaskan North Slope crude oil (the oil used in the analysis); and Appendix F.I.4 summarizes all of the input parameters and the sources of the information that were used to run the model.

F.2 MODELING RESULTS

Two spill volumes and three response scenarios were simulated using modeling and the results are provided in Appendices F-II and F-III. Section A.1.4 of Part A contains a description of the rationale for running these scenarios to provide the needed information for evaluating the alternatives being considered in the PEIS. The two spill volumes were for medium (2,500 bbl) and large spills (40,000 bbl). Oil properties used were for Alaskan North Slope crude oil, as representative of oils shipped in the Alaska region. The three response scenarios modeled for each of two spill volumes were:

- mechanical removal at present levels of capability, or with some of that removal accomplished by ISB;
- the same mechanical removal response as above, or with some of that removal accomplished by ISB, plus dispersant application at 45% efficiency (based on minimum dispersant effectiveness criteria established in the National Oil and Hazardous Substances Contingency Plan, NCP – 40 CFR Part 300); and
- the same mechanical removal response as above, or with some of that removal accomplished by ISB, plus dispersant application at 80% efficiency (based on theoretically successful dispersant operation).

Appendices F-II.1 to F-II.6 contain results of the SIMAP oil spill model simulations that estimate oil hydrocarbon exposure on/in the water surface, shorelines, water column, and sediments. Each of these appendices contains results for all six volume-response scenario combinations. Appendix F-II.1 contains maps of exposure probability, time of first exposure for each medium (water surface, shorelines, water column, and sediments) and location surrounding the spill site, and maximum possible mass or concentration at each location at any time after a spill. These maps are gridded, presenting the average amount of contamination over the entire grid cell (which for water cells is 0.076 km^2 in area) at any time after a spill. The grid average is calculated from the mass passing through the cell, divided by the area or volume of the cell. Note that if the mass is concentrated in patches much smaller than the area of the grid cell, as is often the case, the gridded data will average out the patches and not resolve small concentrations of oil. Thus, the gridded data are used as indices of exposure, rather than areas exposed at specific levels. (See Section A.4.2 in Part A and Sections F.II.5 and F.II.6 for the methods used to more accurately evaluate exposure of biota to surface floating oil and dissolved aromatic hydrocarbons.)

Tables summarizing areas and volumes potentially affected using gridded exposure indices specific to water surface, shorelines, water column, and sediments are in Appendix F-II.2. Average, standard deviation, and the maximum of the 100 simulations performed for each scenario are presented. The 95th percentile conditions used in the risk analysis were calculated as the mean plus two times the standard deviation. Appendix F-II.3 contains rank order distributions of results for all 100 model runs, from which 50th and 95th percentile of exposure areas and volumes were derived. Mass balance information, such as percent of the oil mechanically removed, dispersed in the water column, and eventually going ashore or to the sediments, is also included in Appendices F-II.2 and F-II.3. Appendix F-II.4 contains the results for the 50th percentile cases for surface oiling, shoreline oiling, water column effects, and sediment contamination, presented as plots of various measures of exposure.

In Appendix F-II.5, estimates of mean (for all 100 runs of varying environmental conditions) equivalent area of 100% mortality are listed for each of several wildlife behavior categories. The equivalent area for 100% mortality is the integrated sum of surface water area swept by oil multiplied by probability of mortality, which varies by foraging behavior and whether the animal has feathers or fur. Appendix F-II.6 contains estimated mean mortality of water column, demersal (on the bottom) and benthic (in the bottom) organisms, summarized as an equivalent area of 100% mortality by behavior group and habitat type. The equivalent area for 100% mortality is the integrated sum of equivalent area affected times percent mortality. For water column and demersal species, the equivalent area affected is calculated as water volume affected times the fraction of the water depth zone the behavior group occupies that the affected volume encompasses. For pelagic species, the depth zone occupied is the entire water column. For demersal species (on the bottom sediments, exposed to bottom water), the depth zone occupied is the bottom 1 meter (3.3 feet) of the water column. The methods and assumptions for these calculations are described in Part A and Sections F-II-5 and F-II-6.

Appendices F-III.1 and F-III.2 contain the model results of atmospheric exposure to volatilized oil hydrocarbons and soot from ISB, relevant to air quality evaluations. Appendix F-III.1 contains model results used to evaluate volatile hydrocarbon emissions from unburned oil and resulting air quality effects. The amount of volatilized mass entering the atmosphere, and the time frame for those emissions, was estimated for each chemical (or chemical class) of concern using oil spill modeling (SIMAP). The atmospheric concentrations of volatilized hydrocarbons were modeled using AIRMAP (as described in Part A, Section A.5.1). The estimated concentrations at the water surface were compared to air quality standards to evaluate the areas exceeding the standards. Section A.5.2 of Part A describes the methods used to evaluate emissions from ISB and their potential effects on air quality. The results for ISB are in Appendix F-III.2.

The model results in Appendices F-II and F-III are summarized in Sections F.3 and F.4 and were used in the analysis of potential impacts for the various alternatives being considered in the PEIS. All summary risk rankings are based on the average results. In some sections, the results of the 95th percentile calculation are also presented to illustrate the variability for that particular resource.. Section F.3 contains the discussion of potential effects for medium volume spills (2,500 bbl), and Section F.4 contains that for large volume spills (40,000 bbl). Sections F.3 and F.4 are organized by each of the physical, biological and socioeconomic resource categories evaluated in the PEIS. Section F.5 contains a summary of all the risk scores and conclusions. References are in Section F.6.

F.3 ENVIRONMENTAL CONSEQUENCES BASED ON THE MEDIUM VOLUME SPILL MODELING SCENARIOS

F.3.1 Effects on the Physical Environment

F.3.1.1 Air Quality

In the event of a spill, there are two possible sources of contamination to the atmosphere: volatilization of hydrocarbons from unburned oil and emissions produced by ISB. The hydrocarbons and ISB emissions are of concern for both human health and wildlife that may be exposed. Concentrations in the lowest 2 m (6.6 ft) of the atmosphere were estimated for both unburned and burned oil using modeling and observational data from test burns, as described in Part A, Section A.5. Distances from the spill or burn site to thresholds of concern and areas affected above these thresholds were calculated for each of a number of chemicals. The thresholds of concern are air quality standards for human health (IDLH (Immediate Danger to Life and Health) for a ½ hour exposure and minimum TWA (Time Weighted Average) for an 8-hour exposure, Table D.1-1 in Appendix D of the PEIS and Table A.5-5 in Part A).

Emissions from unburned oil were estimated using SIMAP, assuming the warmest (monthly mean) water temperature in the reference area and for varying wind speeds from 3 to 25 kts. As a worst case, these model runs were performed assuming no response, which would otherwise reduce emissions to some degree. Atmospheric concentrations of volatilized hydrocarbons were estimated using AIRMAP, which accounts for transport and dilution of hydrocarbons in the local atmosphere around the spill site. The worst case of a stable atmosphere was assumed for these calculations. Area and the down-wind distance affected above the thresholds were calculated from the model results, as described in Section A.5.1 of Part A.

For emissions from ISB, the maximum potential amount of oil burned was assumed to be 25% by volume of the amount of oil mechanically removed (see Section A.3.7, Part A). The 50^{th} and 95^{th} percentiles of the cleanup volumes (for the 100 stochastic runs) were multiplied by 0.25 to calculate the 50^{th} and 95^{th} percentile volumes burned by ISB. The atmospheric concentrations of compounds and particulates released by an in-situ burn of a particular volume of oil were estimated using the models developed by Fingas et al. (2001), as described in Section A.5.2 of Part A. The number of burns needed was estimated from the total volume burned and a maximum burn size. The burn model provides concentration as a function of distance down wind from the fire. Distances were translated to areas of potential effect, assuming the air plume could move in any direction depending on the wind direction, such that the area of a circle of this radius could be affected for each of the burns.

The area potentially contaminated was divided by the area of Prince William Sound (10,080 km^2 or 3,892 mi^2, Table A.4-4, Part A) to estimate the percentage affected by the scenario. Appendices F-III.1.1 and F-III.2.1 provide data for unburned and burned oil, respectively, from medium volume spills into Prince William Sound.

Results of On-Water Mechanical Recovery Only

Under the medium volume spill scenario with no dispersant response, volatilized hydrocarbons would not exceed air quality standards for human health at $\geq$3.6 km (2.2 mi) from the spill site, with a maximum of 0.9 km^2 (0.03 mi^2) adversely affected. While this would be of concern for personnel close to the spill site within the first few hours after emissions are released, it is a very small percentage of the area of Prince William Sound. Evaporation and dispersion in the air would be very rapid after a spill, and recovery time would be less than 1 day. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency

For the medium volume spill scenario with 45% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
For the medium volume spill scenario with 80% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would also be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, the worst case for air quality would be a single large burn 500 m^2 in area at one location. Based on model results described in Appendix F-III.2.1 and areas affected as summarized in Table F-III.2.1-4, air quality would be affected up to 710 m (2,329 ft) downwind of the burn site, assuming a stable atmosphere and light wind at the time of the burning (environmental conditions that would inhibit dispersion of the plume and induce the highest adverse effects on air quality). Thus, the area potentially affected is a 1.6 km^2 (0.6 mi^2) circular area around the burn site. This represents 0.02% of Prince William Sound. Thus, the percent of the resource affected is <1%. The recovery time for the atmosphere after ISB would be on the order of hours. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Summary of the Consequences for Air Quality in the Medium Volume Scenarios
The consequences of the three response options for medium spills (1) on-water mechanical recovery only, (2) on-water mechanical recovery plus dispersants at 45% efficiency, and (3) on-water mechanical recovery plus dispersants at 80% efficiency are all essentially the same with respect to air quality. Evaporation off the water surface and volatilization from the water column creates a plume of volatile hydrocarbon gases that disperses quickly after a spill. The concentrations in the atmosphere at the water surface would exceed human health thresholds up to 3.6 km (1.4 mi) from the spill site. Dispersant use would reduce the evaporation rate, but dissolved hydrocarbons would still volatilize, although dispersed over a wider area. Thus, atmospheric concentrations would be slightly less under the dispersant use options. In all three options, the effect would be small, affecting much less than 1% of the reference area (i.e., the area of Prince William Sound in Table A.4-4, Part A), and the recovery time for the atmosphere would be on the order of hours. The alternatives involving on-water mechanical recovery plus ISB (whether or not dispersants are used) should increase atmospheric pollutants by the amount injected via burning.

Table F.3.1.1-1 indicates risk scores for air quality for all response options for a medium volume spill. Both the area affected and the recovery times are assigned the lowest risk score for all the response options. These results would apply to any spill site at least 3 miles from shore.

Table F.3.1.1-1. Air quality risk scores for medium spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)

and Dispersant Application (80% Efficiency)		
On-Water Mechanical Recovery and ISB, With or Without Dispersant Application	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

F.3.1.2 Water Quality

The lowest water quality thresholds of concern are those concentrations of dissolved aromatics that could have effects on sensitive species in the water (see Section 4.3.1.1 of the PEIS). These thresholds are much lower than human health thresholds. The threshold for effects on water column organisms would be 5 ppb for at least 4 days of exposure. As an exposure dose, the threshold would be 500 ppb-hours. (See Part A, Section A.3.4 for development of these thresholds.)

The volume affected by greater than 500 ppb-hours was estimated by the model. Table F.3.1.2-1 summarizes the mean and 95th percentile values of the water volume affected by >1 ppb for at least 1 hour and the average exposure dose in that volume of water. These data are the mean and the mean plus 2 standard deviations of the model results for all 100 runs performed for each scenario (Appendix F-II.2). The average exposure doses in the volumes are near or greater than the 500 ppb-hour threshold. Thus, the volume exposed to >1 ppb for at least 1 hour is an appropriate criterion for identifying water volumes exceeding the exposure dose threshold of 500 ppb-hours.

The percentages affected of total water volumes in coastal and marine reference areas were calculated using the area of Valdez Arm (coastal) and the biogeographical province area in Table A.4-4 for Prince William Sound (marine). The total coastal volume was the area of Valdez Arm (108.9 km^2 = 42 mi^2) times a mean depth of 200 m (656 ft). In this calculation it is assumed that the entire contaminated volume would be located in the coastal reference area (Valdez Arm) after a spill, a worst case assumption for a spill in that water body. The total marine volume was the area of the province times the depth at the spill site, 312 m (1,024 ft). The affected volume would be much shallower than these depths. The contaminated volume calculated by the model was to the depth of the surface mixed layer and much broader horizontally than these calculated percentages times the total surface area of the water body would indicate. Risk scores for potential effects were assigned for each of coastal and marine areas.

Table F.3.1.2-1. Estimation of adverse effects on water quality for medium volume spills by dispersant scenario, based on mean and 95th percentile water volumes exceeding 1 ppb dissolved aromatic concentration.

Dispersant % Efficiency		**0**	**45**	**80**
Volume (millions of m^3) Exposed to >1 ppb	mean	43.2	492.3	477.8
	95th	171.8	926.0	895.7

Average ppb-hrs in Volume	mean	105	2117	2156
	95th	309	4757	4632
Percent of Reference Area, coastal	mean	0.2	2.3	2.2
	95th	0.8	4.3	4.1
Percent of Reference Area, marine	mean	0.00	0.02	0.02
	95th	0.01	0.03	0.03

Results of On-Water Mechanical Recovery Only
For the medium volume spill in Valdez Arm and no dispersant response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be <1% on average and for 95% of spills in water bodies the size of Valdez Arm. In smaller coastal bays, the percentages adversely affected would be higher. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days the time for concentrations to disperse to background levels. Thus, a risk matrix ranking of **4E** was assigned to water quality for both coastal and marine spills under all conditions. (In small coastal bays and the case where all the contamination is contained in the bay, the risk rankings would be higher.)

Results of the Addition of a Dispersant Response at Low Efficiency
For the medium volume spill scenario and 45% dispersant efficiency response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 2.3% on average. For 5% of spills, the percentage affected would exceed 4.3% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions. Coastal spills under average and extreme (95^{th} percentile) conditions, were assigned a risk matrix ranking of **4D**. Note that dispersants would not be applied in coastal waters under the alternatives considered in the PEIS that include dispersant use.

Results of the Addition of a Dispersant Response at High Efficiency
For the medium volume spill scenario and 80% dispersant efficiency response, the volumes affected are nearly the same as for 45% dispersant efficiency (because more than sufficient dispersant would be available to disperse the floating oil, see Section A.3.7 of Part A). Thus, the risk matrix rankings assigned to water quality for this scenario were the same as for the 45% dispersant efficiency case.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, the water quality effects would be slightly less, by the amount removed by burning. Thus, the percent of the resource affected is slightly less for on-water mechanical and both dispersant response scenarios when ISB is included. The recovery time for water quality would be on the order of days. Thus, the risk matrix rankings assigned to water quality for scenarios involving burning were the same as those assigned for scenarios without burning.

Summary of the Consequences for Water Quality in the Medium Volume Scenarios

Table F.3.1.2-2 summarizes risk scores for water quality for all response options for a medium volume spill in coastal waters under average and extreme (95^{th}) environmental conditions. Table F.3.1.2-3 summarizes risk scores for medium volume spills in marine waters. The coastal results would apply to similar volume coastal areas and the marine results would apply to any spill site at least 3 miles from shore.

Table F.3.1.2-2. Water quality risk scores for medium spills in coastal areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: E 95th: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: D 95th: D	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: D 95th: D	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

Table F.3.1.2-3. Water quality risk scores for medium spills in marine areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: E 95th: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: E 95th: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: E 95th: E	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

F.3.2 Effects on the Biological Environment

F.3.2.1 Intertidal Habitats

The intertidal habitats in Prince William Sound are dominated by exposed rocky shores and wave-cut platforms (23 percent of the shoreline), gravel beaches (21 percent), exposed tidal flats (21 percent), and rocky shores (31 percent), whereas sheltered tidal flats and marshes comprise less than 5 percent of the shoreline (Michel and Hayes, 1991). These shorelines are highly utilized by birds as feeding and nesting sites, by seals and sea lions for haulouts, by sea otters for feeding, by herring for spawning, by juvenile salmon as rearing areas, and they have very high recreational use (NOAA, 2000b). The threshold concentration of concern for intertidal habitats is 10 g/m^2 (~10 microns) oil thickness (see Section A.4 in Part A). Table F.3.2.1-1 shows the outputs of the different scenarios in terms of the area and/or length of shoreline habitat affected, for the major shoreline habitat types for the medium spill volume (shoreline classifications are defined in NOAA, 2000b). Shoreline oiling is reported in kilometers for linear features such as gravel beaches and rocky shores and in square meters for wide habitats such as tidal flats and wetlands.

Table F.3.2.1-1. Mean area and length of shoreline habitats oiled above a threshold of ~10 micron oil thickness for the medium volume scenarios. The numbers are summarized from Appendix F Tables F-II.2-1 through F-II.2-3.

Response Option	Total Oiled Shoreline Area (m^2)	Rocky Shore Length (km)	Gravel Beach Length (km)	Tidal Flats Area (m^2)	Wetlands Area (m^2)
On-Water Mechanical Recovery (with or without ISB)	117,000	18.1	5.7	5,000	0
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	56,000	8.5	2.7	7,500	0
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	49,000	7.9	2.5	0	0

Results of On-Water Mechanical Recovery Only
Under the medium volume spill scenario and no dispersant response option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs would be 117,000 m^2 (1.3 million ft) or about 24 km (15 mi) of shoreline. Most of the habitats oiled under the highest shoreline effect conditions would be scattered around northwestern Prince William Sound with few habitats receiving heavy oiling (>10,000 g/m^2, Figure F-II.1.1.2-3). The oiled shoreline area would represent less than 1 percent of the shoreline area in Prince William Sound, which covers 10,000 km^2 (3861 mi^2) (Table A.4-3) and about 5,000 km (3,100 mi, Neff et al., 1995). Rocky shores would account for over 75 percent of the affected shoreline area. No wetlands and only a minor amount of tidal flat habitat would be oiled. Lightly to moderately oiled rocky shores and beaches should recover within 1-3 years (Sell et al., 1195). Thus, a risk matrix ranking of **3E** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs would be reduced by over 50 percent, compared to mechanical alone. Most of the shoreline oiling would be very light (Figure F-II.1.2.2-3) and below the threshold of concern except for widely scattered of mostly exposed rocky shores and some gravel beaches. Most shoreline habitats are expected

to recover within 1 year under such light oiling. Thus, a risk matrix ranking of **4E** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron oil threshold for all model runs would be reduced by about 60 percent, compared to on-water mechanical recovery alone, and only 10% more than the low dispersant efficiency scenario (Table F.3.2.1-1). The distribution of shoreline oiling occurred mostly along relatively exposed shoreline sections (Figure F-II.1.3.2-3) that would be expected to recover within 1 year. Thus, a risk matrix ranking of **4E** was assigned to intertidal habitats for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on intertidal habitats would be similar to the on-water mechanical recovery only response option, since the pattern of oil stranding would remain unchanged. When considering the areas of the different shoreline habitats affected under these spill conditions, a risk matrix ranking of **3E** was assigned to intertidal habitats for this scenario.

Summary of the Consequences for Intertidal Habitats in the Medium Volume Scenarios
Under the medium volume scenario, effects on intertidal habitats would occur primarily as light to moderate oiling or oiling of mostly exposed shorelines where recovery would be expected to occur in 1-3 years, using on-water mechanical recovery only with or without the use of ISB. The use of dispersants would likely lessen the area of shoreline effect by about 50-60 percent and reduce the oil loading on the intertidal zone, leading to faster habitat recovery. The level of dispersant efficiency does not affect the level of concern about intertidal habitats in this spill scenario because sufficient dispersant is assumed applied to disperse available floating oil assuming 45% efficiency.

F.3.2.2 Marine and Coastal Birds

The Alaska region, and particularly Prince William Sound, provides very important habitat for migrant and resident marine and coastal birds, including species utilizing open water habitats (e.g. seabirds, gulls, terns, migratory waterfowl); migratory shorebirds that utilize tidal flats, gravel beaches, and small islands, and seabird nesting colonies that occur on rocky shorelines and small islands (Section 3.5.2.2 of the PEIS).

Of particular importance in Prince William Sound is the abundance of nesting and feeding seabirds. Over 20 species of seabirds nest in over 225 colonies (this number varies annually) in Prince William Sound, with the largest colony (>13,000 birds) occurring at Shoup Bay. Total numbers of nesting birds in the area range from tens to hundreds of thousands annually (NOAA, 2001).

This area is also very important for migrating shorebirds, particularly in the northern embayments of Montague Island, which host tens of thousands of shorebirds per year (Gill et. al, 2001). Other islands and embayments host large numbers of shorebirds as well. High concentrations of nesting and migratory waterfowl also occur in the area, especially around wetlands and embayments (NOAA, 2001).

It is important to note that the species groups being considered are not normally distributed equally throughout Prince William Sound, and that effects should not be proportional to the amount of shoreline or water surface area oiled. Effects of seasonal concentrations of particular species in high-use areas need to be considered (NOAA, 2001). In Prince Williams Sound, waterfowl and seabirds are concentrated primarily within 1-2 km from shore, particularly in sheltered bays, passages, inlets, arms, and ports. Some species of seabirds raft farther offshore, but still typically within approximately 5-10 km of land (NOAA, 2001). Considering that some portions of the open Sound are approximately 25 km from land, and the large surface area of water associated with the numerous bays, arms, etc., we assume that water associated species are only utilizing approximately 10 percent of the reference area area. Therefore, we used a multiplier of 10 when calculating risk to open-water associated species.

When calculating the risk scores to include shoreline associated species, we took into account the fact that shorebirds and nesting seabirds and raptors concentrate along gravel beaches, rocky shores, and tidal flats, but are not distributed evenly throughout these habitats spatially or seasonally (NOAA, 2001). The current body of data available for these species in Prince William Sound does not allow for quantifying the "level of concentration", as was possible for open-water species. We used a multiplier of 5 to account for the importance of these key shoreline habitats.

Birds would likely be adversely affected if a threshold of 10 g/m^2 (~10-micron) thickness of oil is exceeded on the shoreline or on the water surface (see Section A.4 in Part A).

Results of On-Water Mechanical Recovery Only
Under the medium volume spill scenario and no dispersant response option, some areas of important shorebird habitat would be oiled above the 10-micron threshold. Oiled areas could include: Eagle Bay and Inakwik Inlet; Naked Island; Montague Island, and Bligh Island (Figure F-II.1.1.2-3). The mean area of shoreline oiled above a threshold of 10 g/m^2 would be about 117,000 m^2 (1.3 million ft^2) (Table F-II.2 -1).

Potential surface water oiling above the 10-micron threshold in the modeled area around Bligh, Montague, Perry, Culross, and Glacier Islands, and around Eagle Bay and Inakwik Inlet would correspond with seabird and waterfowl concentration areas (NOAA, 2001, Figure F-II.1.1.1-3). The mean surface water area oiled above the threshold would be about 68 km^2 (26 mi^2, Table F-II.5-2).
When considering all species groups together, it is possible that between 5 to 10 percent of the area bird population may be adversely affected under these spill conditions. Recovery could likely occur in 1 to 3 years for most species, as was the case following the Exxon Valdez oil spill (Kuletz, 1993; Boersma et al., 1995; Erikson, 1995, and Wiens, 1995). Recovery times for other species, such as black oystercatchers and harlequin ducks, were longer after Exxon Valdez, and ranged from 3-9 years (Klosiewski and Laing 1994; Day et al., 1995, 1997, and Irons et al. 2000). Because black oystercatchers (*Haematopus bachmani*), harlequin ducks (*Histrionicus histrionicus*), and other species with longer recovery times are present, sometimes in high

concentrations, in many of the potentially oiled areas (Bligh Island, Montague Island, Green Island, etc.), recovery time should be considered to be from 1-7 years for birds in Prince William Sound (NOAA, 2000b). A risk matrix ranking of **2C** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency

Under the medium volume spill scenario and the low efficiency dispersant response option, the mean area of shoreline oiled above a threshold of 10 g/m^2 was reduced by over 50 percent (Table F.3.2.1-1). Similar important shorebird habitats could be oiled compared to when no dispersants were used, although less so (Figure F-II.1.2.2-3). More tidal flats, which are important shorebird staging habitats, were oiled under this scenario (7,500 m^2/81,000 ft^2 oiled), as compared to mechanical recovery alone (5,000 m^2/ 54,000 ft^2 oiled).

Potential surface water oiling above the 10-micron threshold in the modeled area around Bligh and Naked Islands, and around Eagle Bay and Inakwik Inlet would correspond with seabird and waterfowl concentration areas (NOAA, 2001, Figure F-II.1.2.1-3). The mean surface water area oiled above the threshold would be reduced approximately 23 percent to about 52 km^2 (20 mi^2,Table F-II.5-2).

Although there was an estimated decrease in shoreline and surface water oiling compared to when no dispersants were used, it is possible that adverse effects on birds would not be reduced enough to lower the risk score, do to that fact that more tidal flats were oiled., Therefore, we estimated that 5-10 percent of the area marine and coastal bird population may be adversely affected under these spill conditions. Recovery would likely occur in 1 to 7 years. A risk matrix ranking of **2C** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the medium volume spill scenario and the high efficiency dispersant response option, the mean area of shoreline oiling would be reduced by 10 percent compared to when low efficiency dispersants were used (Table F.3.2.1-1). Oiled areas could include some migratory shorebird staging areas (Figure F-II.1.3.2-3). No tidal flats, which are important shorebird staging habitats, were oiled under this scenario as compared to on-water mechanical recovery alone (5,000 m^2/ 54,000 ft^2 oiled) and when low efficiency dispersants were used (7,500 m^2/81,000 ft^2 oiled).

The mean surface water area oiled above the threshold in the modeled area would be reduced approximately 10 percent to 47 km^2 (18 mi^2) compared to when low efficiency dispersants were used (Table F-II.5-2). Potential surface water oiling above the 10-micron threshold around Naked Island and Perry Islands, and around Perry Passage could correspond with seabird and waterfowl concentration areas, but to a lesser extent than when low efficiency dispersants were used (NOAA, 2001) (Figure F-II.1.3.1-3).

Although the mean area of shoreline oiling and mean area of surface water oiling were only reduced by 10 percent each compared to the low efficiency dispersant option, less important shorebird, seabird and waterfowl concentration areas would be oiled under this scenario. Therefore, when considering all species groups together, it is possible that between 1-5 percent of the Prince William Sound bird population may be adversely affected under these spill conditions. Recovery would likely occur in 1 to 7 years (NOAA, 2000b). A risk matrix ranking of **2D** was assigned to birds for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, adverse effects on birds would be similar to the on-water mechanical recovery only response option. When considering all species groups together, between 5 and 10 percent of the area bird population may be adversely affected under these spill conditions, and recovery could likely occur in 1 to 7 years for most species. A risk matrix ranking of **2C** was assigned to birds for this scenario.

Summary of Consequences for marine and Coastal Birds in the Medium Volume Scenarios
Under the medium volume scenario, the estimated adverse effects on birds are likely to be of moderate concern when no dispersants are used, regardless of the use of ISB, due to the probability of a large percentage of important concentration areas being oiled. The use of high (but not low) efficiency dispersants would likely lessen the water surface and shoreline effects enough to decrease the area and lower the percentage of birds affected, thus reducing the risk, but not enough to lower the moderate risk score.

F.3.2.3 Marine Mammals

The marine and coastal waters of Prince William Sound support a large and diverse population of marine mammals. The threatened or endangered species include the bowhead (*Balaena mysticetus*), fin (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*), right (*Eubalaena glacialis*), sperm (*Physeter catodon*), blue (*Balaenoptera musculus*), and sei whales (*Balaenoptera borealis*), and the Stellar sea lion (*Eumetopias jubatus*). The nonendangered species include beluga (*Delphinapterus leucas*), minke (*Balaenoptera acutorostrata*), and killer whales (*Orcinus orca*); the harbor porpoise (*Phocoena phocoena*); the northern fur (*Callorhinus ursinus*), ringed (*Phoca hispida*), bearded (*Erignathus barbatus*), spotted (*Phoca largha*), ribbon (*Phoca fasciata*), and harbor (*Phoca vitulina*) seals; the Pacific walrus (*Odobenus rosmarus*); sea otters (*Enhydra lut*ris); and polar bears (*Ursus maritimus*) (Section 3.5.2.1 of the PEIS).

Marine mammals may be at risk from either floating oil, or from oil which strands in shoreline areas that are used as haul out or breeding areas. The latter concern is important in Prince William Sound, since there are many such areas primarily along rocky shorelines.

For this analysis, marine mammals are assumed to be at risk if a threshold of 10 g/m^2 (~10-micron) thickness of oil is exceeded on the shoreline or on the water surface (see Section A.4 in Part A), however the level of risk varies by the behavior group. Potential adverse effects on marine mammals (i.e., terrestrial wildlife, cetaceans, furbearing marine mammals, and pinnipeds and manatees were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the medium volume Prince William Sound spills are in Appendix F-II.5, Table F-II.5.2. The equivalent areas of 100% mortality for all response options are summarized in Table F.3.2.3-1 as percentages of Prince William Sound (defined in Tables A.4-4 and A.4-5 of Part A). In addition to this calculation, which is based on the mean result, the mean length of shoreline oiled and the surface oil exposure exceeding 0.01 g/m^2 (in m^2-hrs) based on all model runs was also compared between the treatment options (Tables F-II.2-1 through F-II.2-3).

Table F.3.2.3-1. Percentage of reference area adversely affected for medium spills, by dispersant option and behavior group (assuming the Prince William Sound area in Tables A.4-4 and A.4-5).

Behavior Group (Habitat Occupied)	0	45	80
Terrestrial wildlife (wetlands, sea grass beds and shoreline)	0	0	0
Cetaceans (seaward subtidal)	<0.001	<0.001	<0.001
Furbearing marine mammals (all intertidal and subtidal)	0.50	0.38	0.35
Pinnipeds and manatees (all intertidal and subtidal)	0.007	0.005	0.005

Results of On-Water Mechanical Recovery Only
In Prince William Sound, marine mammals at risk include cetaceans, several pinniped species, sea otters, and terrestrial mammals along the shore. The resistance of cetaceans to oiling coupled with the very small percentage of affected area creates a very minimal risk to cetaceans under the on-water mechanical recovery only option for the medium volume spill scenario. The cetaceans that are oiled as a result of contact with floating oil would most likely recover in within a few days, if not hours, of the spill (**4E)**, (RPI, 1987). Similarly, terrestrial mammals (which are more abundant along the Alaskan shoreline than in other areas that were modeled) are at very low risk, but if an individual were killed or reproductively impaired by contact with oil on the shoreline, the recovery period could exceed one year (**3E**). Pinnipeds also have a low estimate for the area of equivalent mortality. The area for sea otters is approximately 0.5%, the highest calculated. As an alternative measure, the length of shoreline oiling was compared to the total shoreline length (24.2 versus 5,047 km or 15 versus 3,136 mi), which is approximately 0.5%. This is presumed to be a measure of the possibility of contacting a haul out area. The primary concerns in Prince William Sound are for sea otters and pinnipeds. While the area of effect for both is low with the medium spill scenario, the loss of a reproductive adult or sublethal effects to reproductive adults could affect the population for a number of years. On this basis the risk score of **3E** was assigned.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and the 45% efficiency dispersant option the areas of equivalent mortality are slightly reduced in absolute area, and are still very small relative to the reference areas. The use of dispersants would reduce the length of shoreline oiling from 24.2 to 10.9 km (15 to 7 mi), but would not affect the recovery time, thus the risk score remains **3E**. There is no evidence that cetaceans, sea otters or pinnipeds are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency

Under the medium volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality are essentially the same as those for the 45% option, as is the extent of shoreline oiled, and so the risk score remains the same as for 45% efficiency.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in addition to on-water mechanical recovery should not change the effects on marine mammals (**3E**), since the amount of floating oil and shoreline oiling remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to marine mammals.

Summary of the Consequences for Marine Mammals in the Medium Volume Scenarios
The results indicate that on average for medium volume spills in Prince William Sound adverse effects on marine mammals would be moderate with or without the use of dispersants. Dispersant use would decrease the area of concern, but would not effect recovery time, which is the factor of most concern.

F.3.2.4 Sea Turtles

Sea turtles are not components of the Prince William Sound ecosystem.

F.3.2.5 Plankton and Fish

Adverse effects on plankton and fish are of high concern, particularly when dispersants are potentially considered as a response alternative. As described in Part A (Section A.2), plankton and fish are adversely affected either directly or via the food web by the toxic effects of oil components that enter the water column: the soluble compounds (i.e., MAHs (monoaromatic hydrocarbons) and PAHs (polynuclear aromatic hydrocarbons)) and microscopic oil droplets mixed by waves into the water. Overall, adverse effects increase the larger the spill size. However, there is great variability related to the environmental conditions after the spill: plankton and fish suffer much more adverse effect under storm conditions where high waves mix unweathered oil into the water than in calm weather (French et al., 1999; French McCay et al., 2002; French McCay, 2003). Species and life stages vary considerably in sensitivity to the toxic components, with species from relatively unpolluted and environmentally stable locations more sensitive than those from polluted and environmentally variable areas (French McCay, 2002).

Potential adverse effects on water column organisms (i.e., plankton and fish, as well as pelagic invertebrates such as squid) were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. Estimated water volumes where adverse effects could occur were converted to equivalent areas of 100% loss by integrating percentage losses over all affected volumes and multiplying by water depth at the spill site, allowing comparison to other resources that are distributed on a per area basis (e.g., mammals, shorelines). In the area modeled, effects were nearly evenly distributed throughout the water column because of water column mixing and vertical movements of animals. If these results are used to infer potential for adverse effects in deeper waters, the areas of effect would only apply to waters up to on the order of 200-300 m (656-984 ft) deep (during strong wind conditions). The modeling methods are described in Part A and Section F-II.6, and the results of the calculations for the medium volume Prince William Sound spills are in F-II.6, Tables F-II.6-2 to F-II.6-5.

For these calculations, the toxicity parameter for sensitive species (i.e., two standard deviations more sensitive than the average of all species tested, which is the 2.5th percentile in rank order of sensitivity) was assumed. Thus, the volumes and areas potentially affected would only apply to 2.5% of species (based on a Gaussian distribution of species sensitivities, see also Part A, Section A.2.3), and adverse effect areas to 97.5% of species would be smaller than the volumes and areas of effect estimated by the model. Thus the model estimated areas should not be interpreted as experiencing 100% mortality of all plankton and fish. They are conservative estimates used for comparative purposes among response scenarios.

Table F-II.6-2 lists the average equivalent areas projected to be killed (for sensitive species) for medium volume spills. These areas are based on the mean of all 100 runs, and so represent an average of all environmental conditions that may occur after a spill (see explanation in Section F-II.6). Table F-II.6-4 lists the 95th percentile equivalent areas where sensitive species would be adversely affected. This maximum potential effect is calculated as the mean plus two standard deviations, using the statistics of all 100 model runs for the scenario, and assuming the toxicity values for sensitive species.

The mean areas adversely affected for all response options are summarized in Table F.3.2.5-1 as percentages of Prince William Sound (defined in Table A.4-4 of Part A). The maximum areas (95th percentile) for sensitive species are summarized in Table F.3.2.5-2 (also as percentages of Prince William Sound).

Table F.3.2.5-1. Average percentage of reference area adversely affected for medium spills, by dispersant option and behavior group (assuming Prince William Sound area in Table A.4-4).

Behavior Group	**0**	**45**	**80**
Demersal (move at bottom)	0.0004	0.001	0.001
Small pelagic fish & invertebrates	0.0000	0.012	0.011
Large pelagic fish	0.0000	0.026	0.024
Demersal (stationary on bottom)	0.0006	0.001	0.001
Planktonic (drift with currents)	0.0000	0.010	0.009

Table F.3.2.5-2. Maximum (95th percentile) percentage of reference area adversely affected for medium spills, by dispersant option and behavior group (assuming Prince William Sound area in Table A.4-4).

Behavior Group	**0**	**45**	**80**
Demersal (move at bottom)	0.000	0.000	0.000
Small pelagic fish & invertebrates	0.000	0.044	0.043
Large pelagic fish	0.000	0.078	0.075

Demersal (stationary on bottom)	0.001	0.000	0.000
Planktonic (drift with currents)	0.000	0.035	0.034

Results of On-Water Mechanical Recovery Only
Under the medium volume spill scenario and no dispersant response option, the area adversely affected would be negligible (<0.001% of Prince William Sound) for spills under average environmental conditions. For 5% of spills, the area affected would be 0.001% or less of Prince William Sound. Because the adverse effects are extremely small, much less than the range of natural variability, the recovery time would be <1 year (given the annual reproduction of most species). Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45% dispersant efficiency response option, the area adversely affected would be 0.01-0.03% of Prince William Sound for spills under average environmental conditions. For 5% of spills, the area affected would be 0.4-0.8% of Prince William Sound, depending on the behavioral group of the organism. Because the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80% dispersant efficiency response option, the area adversely affected would be 0.01-0.03% of Prince William Sound for spills under average environmental conditions. For 5% of spills, the area affected would be 0.4-0.8% of Prince William Sound, depending on the behavioral group of the organism. These results are not very different from the low-efficiency dispersant response because approximately the same amount of oil is dispersed in either case (i.e., more than sufficient dispersant is available to disperse available oil for such activity in the low efficiency case). Since the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario, if ISB is effectively used in the response, the adverse effects on water column organisms would be slightly less than otherwise by the amount removed by burning. Thus, the percent of the resource affected is <1% for on-water mechanical and both dispersant response scenarios when ISB is included. Since the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Summary of the Consequences for Plankton and Fish in the Medium Volume Scenarios
The results indicate that on average for medium volume spills, adverse water column effects would be negligible without the use of dispersants. With dispersants, and on average, up to 3 km^2 (1 mi^2) of water could be toxic to the most sensitive species (Table F-II.6-2). Exposure for larger fish is higher because they are more mobile, and new animals move into the dissolved aromatic plume over time (assuming they do not avoid hydrocarbon contamination, as was assumed in this analysis). Under worst case conditions for sensitive species, the potentially

affected areas for no dispersants and dispersant use are on the order of 0.1 and 8 km^2 (0.04 to 3 mi^2), respectively (Table F-II.6-4).

It should be emphasized that the areas affected are those where there is a potential to affect the most sensitive species. Areas adversely affected would be much less for species of average sensitivity. These areas should not be interpreted as experiencing 100% mortality. They are used for comparative purposes among response scenarios.

The mean areas adversely affected for all response options are <0.03% of Prince William Sound (Table F.3.2.5-1). Thus, the risk scores for these effects are "**E**" (<1%, Table F.3.2.5-3). The maximum areas (95^{th} percentile) for sensitive species are also <1% of Prince William Sound (Table F.3.2.5-2). Because the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year.

These results are consistent with experience for oil spills of about 2500 bbl generally (French McCay and Payne, 2001; French McCay et al., 2002; and as discussed in Part A). Winds are typically light to moderate, except in infrequent storm events. Thus, natural dispersion into the water is typically low, while evaporation is rapid. Because of logistical constraints, in the scenarios examined the dispersion by chemical dispersants begins 12 hours after the spill. By this time, most of the toxic components have volatilized (see Section F.3.1), such that dissolved aromatic concentrations resulting from dispersant use are only slightly elevated over the no-dispersant option. The adversely affected water column would be a small area around the spill site, and recovery of affected biota would be rapid (weeks to months).

Table F.3.2.5-3. Risk scores for plankton and fish for medium spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

F.3.2.6 Subtidal Benthic Habitat

In deeper water subtidal habitats are relatively protected from exposure to oil by the overlying water column. It is possible for extreme storm events to mix oil with sediments which then settle to the bottom, but this is a rare event. The use of dispersants can also transport oil into the water column, but dilution usually reduces concentrations to levels that are not of a concern when the water column is more than 30 feet deep, and in any case dispersed oil is less adhesive than untreated oil. In most of Prince William Sound, deep water occurs very close to shore and dilution is very rapid (Section 4.3.2.5 of the PEIS).

Benthic habitat was assumed to be at risk when a threshold of 0.10 g/m^2 of total hydrocarbon loading was exceeded in the sediment or 0.0001 g/m^2 of dissolved aromatic hydrocarbons was exceeded in the pore water (see Section A.4 in Part A). These concentrations are approximately equivalent to 1 ppm of total hydrocarbons or 1 ppb of dissolved aromatic hydrocarbons, when a sediment mixing depth of 10 cm is assumed. The area was estimated using SIMAP and the modeling methods are described in Part A. The area estimates of sediment loading for the medium volume Prince William Sound spills are presented in Table F-II.6.6. The area estimates for dissolved aromatic hydrocarbons in sediment pore water are in Table F-II.6.7. Neither sediment threshold was ever exceeded, regardless of response option.

Benthic habitat was also assumed to be at risk if epiflora and epifauna (demersal) organisms were affected by dissolved aromatic concentrations in the bottom water just above the sediments. The percentage of benthic habitat where stationary demersal biota would be affected, assuming the toxicity parameter for sensitive species (i.e., two standard deviations more sensitive than the average of all species tested), was estimated using SIMAP and the modeling methods described in Part A and Section F.II.6.

Results of On-Water Mechanical Recovery Only

In the on-water mechanical recovery only option for the medium volume spill scenario, the model results indicate that the sediment thresholds of concern are not exceeded with only on-water mechanical recovery. As indicated in Table F.3.2.5-1, 0.0006% of the reference area was affected by bottom water concentrations when no dispersants were assumed used. Thus, there is essentially no effect on the benthic habitat, and the risk ranking is **4E**.

Results of the Addition of a Dispersant Response at Low Efficiency

Use of a dispersant at 45% efficiency in the medium spill scenario results there were still no exceedences of the sediment thresholds. As indicated in Table F.3.2.5-1, 0.001% of the reference area was affected by bottom water concentrations when dispersants were assumed used at low efficiency. Thus, the risk score remains at **4E**.

Results of the Addition of a Dispersant Response at High Efficiency

Under the medium volume spill scenario and the 80% efficiency dispersant option, sediments still do not accumulate hydrocarbons in excess of the thresholds. As indicated in Table F.3.2.5-1, 0.001% of the reference area was affected by bottom water concentrations when dispersants were assumed used at high efficiency. Thus, the risk ranking remains at **4E**.

Results of the Addition of an On-Water ISB Response

Oil removal by ISB in the medium spill scenario should have no additional effect when combined with on-water mechanical recovery on benthic habitats since ISB takes place on the water's surface and results in the removal of an equivalent amount of oil (**4E**). The only concern associated with ISB is the chance of heavy burn residues sinking and mixing with sediments, but this risk is minimal based on both the toxicity of the material and on the amount that would be produced from the limited burning possible in the scenarios.

Summary of the Consequences for Subtidal Habitat in the Medium Volume Scenarios
Oil spills and oil-spill response activities could potentially affect benthic habitats. Floating oil does not pose a great level of concern unless sufficient wave energy exists to mix the surface oil into the water column, or sediments contaminated with oil are transported from the intertidal zone into subtidal habitats. Mechanically dispersed oil could reach bottom water and adhere to sediments, flora and fauna in benthic habitats, and could cause potentially adverse effects. However, in this simulation, essentially no hydrocarbon exposure is expected on or in the sediments. Regardless of the response option, the risk to benthic habitat is low.

F.3.2.7 Biological Areas of Special Concern

Prince William Sound has numerous areas of special concern (Section 3.5.2.6 of the PEIS). These include National Wildlife Refuges, National Parks and National Forests, several of which are located on the coast, so that their shoreline could be affected by an oil spill. There is one Estuarine Research Reserve in Alaska, which is the only area of special concern which includes subtidal habitat. It is located near the mouth of Cook Inlet. The risk to such areas is clearly site specific and highly dependant upon the location and trajectory of the slick. Given the areas involved, the greatest risk is from floating oil. For the purposes of this evaluation, to be consistent with other areas, the average risk to such areas is assumed to be defined by the higher of the risks to intertidal (Section F.3.2.1) or subtidal (Section F.3.2.6) habitats, adjusted for the type, abundance and distribution of areas of special concern, if appropriate. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
For the on-water mechanical recovery option under the medium spill scenario, floating oil poses a low risk (**3E**) to intertidal habitat, while subtidal habitat was at even lower risk (**4E**). Therefore, intertidal areas of special concern are the areas most at risk. Since the area affected is already low, and there is no reason to assume areas of special concern would recover more quickly, the score of **3E** is used. The concerns for intertidal habitat were discussed in Section F.3.2.1.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency in the medium spill scenario reduced the risk to intertidal habitat by reducing the amount of surface oil which reaches shore by approximately 50%. The fact that the oiling is now reduced to a very low level and would be primarily to outer, higher energy habitats means recovery should be less than one year, resulting in a risk score of **4E** (see Section F.3.2.1). The risk to subtidal habitats does not increase (**4E**), because of the limited extent of the dispersed oil plume and rapid dilution.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at an efficiency of 80% in the medium spill scenario results in a further, small reduction in shoreline oiling, but does not change the scores from the application at 45% efficiency, based on the results for intertidal and subtidal habitat.

Results of the Addition of an On-Water ISB Response
ISB should produce a black smoke plume that could pass over an area of special concern if the proper weather conditions exist. In this case, however, the burning can only occur three miles or more offshore, and the results for air quality (Section F.3.1.1) indicate that the plume should not travel that far. The use of ISB in addition to on-water mechanical recovery is not expected to increase the risk to these resources (**3E**).

Summary of the Consequences for Areas of Special Concern in the Medium Volume Scenarios
The effects on areas of special concern in this scenario are focused on the potential risk to shoreline habitats. The use of dispersants can reduce the risk to such areas without increasing the minimal risk to subtidal areas. In this analysis the risk to such areas is defined as equivalent to the risk to intertidal habitat in general. While this accurately reflects the ecological consequences of the event, it does not account for the social values which may be attached to such areas. If the spill trajectory of an actual event did threaten such areas, special attention would be given to their protection.

F.3.2.8 Essential Fish Habitat

Fisheries are an important resource in Prince William Sound, and essentially the entire area is essential fish habitat (EFH) (Section 3.5.4 of the PEIS). In the entire Alaska region, approximately 18 species of finfish and shellfish are managed under the Magnuson-Stevens Fishery Conservation and Management Act.

For this evaluation, the effects on essential fish habitat are assumed to be reflected by the risk to plankton and fish (Section F.3.2.5) and subtidal habitat (Section F.3.2.6), since they define the risk to the majority of fish habitat. Intertidal habitats, which may also contain important habitat for fisheries resources, were considered separately. The average risk to essential fish habitat is assumed to be defined by the higher of the risk scores for plankton and fish or subtidal habitat. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
In the medium spill scenario, with the use of on-water mechanical recovery only, the risk to both plankton and fish and subtidal habitat was minimal, resulting in a risk score for both habitats of **4E**. This is a reflection of the relatively small volume of oil, the large volume of water for dilution, and the areal extent of the habitats.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency did not change the risk score for either plankton or fish or for subtidal habitat and the scores remained **4E**. The dispersed oil plume produced was not large enough to have any effect on the exposure levels for these resources.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at 80% efficiency in the medium spill scenario resulted in no change to the risk to plankton and fish or subtidal habitat, and the score remains **4E**.

Results of the Addition of an On-Water ISB Response
The addition of ISB to on-water mechanical recovery in the medium spill scenario did not change the evaluation for either plankton or fish or for subtidal habitat, and the score remains **4E**.

Summary of the Consequences for Essential Fish Habitats in the Medium Volume Scenarios
Overall, the risk to essential fish habitat is low for the medium spill scenario, regardless of the response option employed. This is a reflection of the relatively small area of the spill, the volume and depth of water available for dilution, and the large area of habitat present in the area.

F.3.3 Effects on the Socio-Economic Environment

F.3.3.1 Human Health

Operation of the type of equipment associated with oil spill response can be dangerous. This is well recognized and is the basis for the worker certification and training requirements that are now in place. There are also protocols in place for the proper application and handling of dispersants. The safety risk is greater as the spill size, and thus the intensity and duration of operations increases, but is minimized if safety standards are followed. There is a health risk from inhalation of hydrocarbon fumes for first responders, which is recognized in current safety protocols. Exposure to hydrocarbon fumes is the only health risk that can be directly estimated in the SIMAP model, and the results are presented in Section F.3.1.1.

F.3.3.2 Subsistence

Subsistence use of coastal resources is an important activity in the Alaska region, and includes participation from Prince William Sound communities (Section 3.5.5.6 of the PEIS). Gulf of Alaska residents harvest fresh and saltwater finfish and shellfish species and hunt for pinnipeds.

Results of On-Water Mechanical Recovery Only
Under the medium volume spill scenario and no dispersant response option, water column exposure of dissolved aromatics between 1-100 ppb would be localized to the southeast of Naked Island (Figure F-II.1.1.4-3). Tainting of fish and invertebrates becomes a concern when water concentrations exceed approximately 100 ppb in a brief (order of hours) exposure (See Section 4.3.5.6 of the PEIS). Sediment exposure is expected to be negligible (Figure F-II.1.1.5-2). A very small percentage of shoreline habitats would be oiled, and a proportionally small percentage of subsistence resources associated with these habitats are likely to be exposed (Section F.3.2.1 Intertidal Habitats). Therefore, a very small percentage of subsistence resources are likely to be adversely affected, and recovery should be within 1 year. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and low efficiency dispersant response option, water column exposure of dissolved aromatics between 1-100 ppb for one hour or more are expected to cover a much larger area of the western Sound compared to when no dispersants were used, and dissolved aromatic concentrations between 100-10,000 ppb would occur in localized areas

southeast of Naked Island (Figure F-II.1.2.4-3). Oiled areas should be over 7 miles from the closest village (Chenega). Sediment exposure is expected to be negligible (Figure F-II.1.2.5-2). The length of shoreline oiled was reduced by nearly 60 percent, decreasing the potential exposure for intertidal and shoreline resources (Section F.3.2.1 Intertidal Habitats). Although compared to on-water mechanical recovery only, a larger percentage of water column organisms may be adversely affected under these spill conditions, a smaller percentage of shoreline organisms would be adversely affected, and recovery should be a within 1 year. Therefore, the same risk matrix ranking of **4E** was assigned to subsistence resources for both scenarios.

Results of the Addition of a Dispersant Response at High Efficiency
Under medium volume spill scenario and high efficiency dispersant response option, water column, sediment exposure, and shoreline/intertidal exposure to dissolved aromatics is expected to be very similar to when low efficiency dispersants are used (Figures F-II.1.3.4-3 and F-II.1.3.5-2; Section F.3.2.1 Intertidal Habitats). A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, adverse effects on subsistence resources would be similar to the on-water mechanical recovery only response option. A risk matrix ranking of **4E** was assigned to subsistence resources for this scenario.

Summary of the Consequences for Subsistence in the Medium Volume Scenarios
Because water column effects should be fairly localized, a risk matrix ranking of **4E** was assigned to subsistence resources for the on-water mechanical recovery and ISB response options. A larger water column area may be affected when dispersants are used, but a smaller shoreline/intertidal area should be affected and therefore a risk matrix ranking of **4E** was assigned for both the low and high efficiency dispersant response options also.

F.3.3.3 Cultural Resources

Prehistoric resources in the Alaska region occur on and offshore and submerged shipwrecks occur offshore (Section 3.5.5.7 of the PEIS). Results from several studies following the Exxon Valdez oil spill indicated that direct oiling caused negligible effects on prehistoric and historic artifacts (Reger et al., 1992; Dekin, 1993; Wooley and Haggarty, 1995; Bittner, 1996). Open water response options, including on-water mechanical recovery, ISB, and the use of dispersants may help reduce the amount of oil that strands on the shoreline, which should also reduce the amount of shoreline clean up and potential disturbance to sensitive cultural resources. Offshore archaeological and historic resources would not become oiled regardless of the response option used. For these reasons, a risk matrix ranking of **4E** was assigned to cultural resources for all response options under this scenario.

F.3.3.4 Coastal Communities

Oil spills affect the pleasure that coastal residents and visitors derive from coastal activities and the economic contribution that natural resources make to local income and employment. Spills are likely to have effects on water- and shore-based recreation, fisheries (recreational and commercial), marine transportation and tourism. The effects on these activities are described in more detail in subsequent sections.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to coastal communities in Prince William Sound under various spill response options. At this modeling location, the length of shoreline oiling above the effects threshold is not considered relevant because the shoreline oiling results were highly sensitive to specific location, the ability to identify shoreline with characteristics amenable to use was limited, and areas of surface water oiled above the threshold was expected to provide a more accurate measure of expected risk, given the region's geographic characteristics. The model results are presented in Appendix F-II.2, Tables F-II.2-1 to F-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to coastal communities of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in Prince William Sound is expected to adversely affect approximately 419 km^2 (161.8 mi^2) of surface water above recognized effect thresholds (Table F-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by more than 40 percent as compared to on-water mechanical recovery alone (Table F-II.2-2). This results in a risk factor rating of 0.57 (effected length or area with dispersants divided by that for mechanical only) for surface water resources under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 2 percent as compared to the low dispersant efficiency response option (Table F-II.2-3). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating decreases to 0.55 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on coastal communities would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to coastal communities for surface water resources for this scenario.

Summary of the Consequences for Coastal Communities in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 235 km^2 (90.7 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 44

percent, the level of dispersant efficiency does not greatly affect the level of concern about coastal communities in this spill scenario.

F.3.3.5 Economic Status

The overall economic status of communities, industries and individuals that rely on coastal resources for sustenance, revenue and quality of life can be affected by an oil spill. As noted above, coastal communities can suffer direct and indirect economic effects due to an oil spill, as beach and fishery closures decrease revenues, eliminate jobs, and adversely affect subsistence users of the resources.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to economic status in Prince William Sound under various spill response options. The model results are presented in Appendix F-II.2, Tables F-II.2-1 to F-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to economic status of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average medium size spill in Prince William Sound is expected to adversely affect approximately 419 km^2 (161.8 mi^2) of surface water above recognized effect thresholds (Table F-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by more than 40 percent as compared to on-water mechanical recovery alone (Table F-II.2-2). This results in a risk factor rating of 0.57 for surface water resources under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 2 percent as compared to the low dispersant efficiency response option (Table F-II.2-3). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating decreases to 0.55 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on economic status would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to economic status for surface water resources for this scenario.

Summary of the Consequences for Economic Status in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 235 km^2 (90.7 mi^2) of surface water. While the use of

dispersants is projected to likely lessen the surface water area affected by approximately 44 percent, the level of dispersant efficiency does not greatly affect the level of concern about economic status in this spill scenario.

F.3.3.6 Vessel Transportation and Ports

Any interruption in the standard use of vessels or increase in travel times over water can result in hardship for coastal communities and businesses as fewer goods are exchanged, transportation costs rise, and the revenue streaming through the local economy falls.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to marine transportation in Prince William Sound under various spill response options. The model results are presented in Appendix F-II.2, Tables F-II.2-1 to F-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to the marine transportation industry of response options other than on-water mechanical recovery.

Results of Mechanical Recovery Only
Given the use of mechanical recovery only, the average medium size spill in Prince William Sound is expected to adversely effect approximately 419 km^2 (161.8 mi^2) of surface water used by the marine transportation industry above recognized effect thresholds (Table F-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by more than 40 percent as compared to on-water mechanical recovery alone (Table F-II.2-2). This results in a risk factor rating of 0.57 for the marine transportation industry under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 2 percent as compared to the low dispersant efficiency response option (Table F-II.2-3). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for the marine transportation industry decreases to 0.55 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on the marine transportation industry would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to the marine transportation industry for this scenario.

Summary of the Consequences for Vessel Transportation and Ports in the Medium Volume Scenarios

Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 235 km^2 (90.7 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 44 percent, the level of dispersant efficiency does not greatly affect the level of concern about the marine transportation industry in this spill scenario.

F.3.3.7 Fisheries (Commercial and Recreational)

Commercial and recreational fishing and related industries are vulnerable to oil spills, due to closures as well as market perceptions surrounding taint of the catch. In addition, recreational anglers, who fish for pleasure or sport, as opposed to monetary gain, may experience a reduced quality of experience. Large-scale spills also hold the potential to injure nursery grounds and impose other effects that could reduce fish harvests in the longer run.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to commercial and recreational fishing in Prince William Sound under various spill response options. The model results are presented in Appendix F-II.2, Tables F-II.2-1 to F-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2 (the threshold for visible sheen). From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to commercial and recreational fishing of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only

Given the use of on-water mechanical recovery only, the average medium size spill in Prince William Sound is expected to adversely effect approximately 419 km^2 (161.8 mi^2) of surface water used for commercial and recreational fishing above recognized effect thresholds (Table F-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency

Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by more than 40 percent as compared to on-water mechanical recovery alone (Table F-II.2-2). This results in a risk factor rating of 0.57 for commercial and recreational fishing under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 2 percent as compared to the low dispersant efficiency response option (Table F-II.2-3). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for commercial and recreational fishing decreases to 0.55 for this scenario.

Results of the Addition of an On-Water ISB Response

Under the medium volume spill scenario and the ISB response option, effects on commercial and recreational fishing would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to commercial and recreational fishing for this scenario.

Summary of the Consequences for Commercial and Recreational Fishing in the Medium Volume Scenarios

Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 235 km^2 (90.7 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 44 percent, the level of dispersant efficiency does not greatly affect the level of concern about commercial and recreational fishing in this spill scenario.

F.3.3.8 Recreation and Tourism

An oil spill would be expected to cause local decreases in tourism, recreation, associated business revenues and the quality of coastal living. Similar to recreational fishing effects, an oil spill would also be expected to affect recreationalists' overall social welfare.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to recreation and tourism in Prince William Sound under various spill response options. The model results are presented in Appendix F-II.2, Tables F-II.2-1 to F-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to recreation and tourism of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only

Given the use of on-water mechanical recovery only, the average medium size spill in Prince William Sound is expected to adversely effect approximately 419 km^2 (161.8 mi^2) of surface water used for recreation and tourism above recognized effect thresholds (Table F-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency

Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by more than 40 percent as compared to on-water mechanical recovery alone (Table F-II.2-2). This results in a risk factor rating of 0.57 for recreation and tourism under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 2 percent as compared to the low dispersant efficiency response option (Table F-II.2-3). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for recreation and tourism decreases to 0.55 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on recreation and tourism would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to recreation and tourism for this scenario.

Summary of the Consequences for Recreation and Tourism in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 235 km^2 (90.7 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 44 percent, the level of dispersant efficiency does not greatly affect the level of concern about recreation and tourism in this spill scenario.

F.3.3.9 Environmental Justice

Low-income, indigenous, and minority sub populations in some coastal areas may rely on regional fisheries for subsistence or on tourism, recreation or other marine-resource related industry for employment. These groups may experience the effects of a spill more severely than the general population, which relies on a more diverse economic base for their livelihoods and on the availability of a widespread and commercially available selection of foods.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to environmental justice in Prince William Sound under various spill response options. The model results are presented in Appendix F-II.2, Tables F-II.2-1 to F-II.2-3, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to environmental justice of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of 0n-water mechanical recovery only, the average medium size spill in Prince William Sound is expected to adversely effect approximately 419 km^2 (161.8 mi^2) of surface water above recognized effect thresholds (Table F-II.2-1).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by more than 40 percent as compared to on-water mechanical recovery alone (Table F-II.2-2). This results in a risk factor rating of 0.57 for surface water resources under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 2 percent as compared to the low dispersant efficiency response option (Table F-II.2-3). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating decreases to 0.55 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the medium volume spill scenario and the ISB response option, effects on environmental justice would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to surface water resources for this scenario.

Summary of the Consequences for Environmental Justice in the Medium Volume Scenarios
Under the medium volume spill scenario, dispersant use limits the effects from an average medium size spill to approximately 235 km^2 (90.7 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 44 percent, the level of dispersant efficiency does not greatly affect the level of concern about environmental justice in this spill scenario.

F.4 ENVIRONMENTAL CONSEQUENCES BASED ON THE LARGE VOLUME SPILL MODELING SCENARIOS

F.4.1 Effects on the Physical Environment

F.4.1.1 Air Quality

There are two possible sources of contamination to the atmosphere: volatilization of hydrocarbons from unburned oil and emissions produced by ISB (ISB), both of which are of concern for both human health and wildlife that may be exposed. Concentrations in the lowest 2 m (6.6 ft) of the atmosphere, as well as distances to and areas above thresholds of concern, were estimated for both unburned and burned oil. The thresholds of concern are air quality standards for human health (IDLH for ½ hour exposure and minimum TWA for an 8-hour exposure, Table D.1-1 of Appendix D of the PEIS and Table A.5-5 in Part A). The area potentially contaminated was divided by the area of Prince William Sound (10,080 km^2 or 3,892 mi^2, Table A.4-4) to estimate a percentage of the region affected by the scenario. Appendices F-III.1.2 and F-III.2.2 provide data for unburned and burned oil, respectively, from large volume (40,000 bbl) spills in Prince William Sound.

Results of On-Water Mechanical Recovery Only
Under the large volume spill scenario with no dispersant response, volatilized hydrocarbons would not exceed air quality standards for human health at $\geq$15 km (9 mi) from the spill site, with a maximum of 10 km^2 (4 mi^2) adversely affected. While this would be of concern for personnel close to the spill site within the first few hours after emissions are released, it is a very small percentage of the area of Prince William Sound. Evaporation and dispersion in the air

would be very rapid after a spill, and recovery time would be less than 1 day. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
For the large volume spill scenario with 45% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
For the large volume spill scenario with 80% dispersant efficiency response, the area adversely affected by volatilized hydrocarbons would also be similar or slightly less than for on-water mechanical recovery only. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, the worst case for air quality would result from the 95th percentile of volume burned (estimated as 25% of the mechanically-removed oil) for the no-dispersant scenario. The volume to be burned in this case would require 10 large burns, each 500 m^2 in area. The 50th percentile burn volume would require 8 large burns, each 500 m^2 in area. If dispersant is used, the amount burned would be less, requiring fewer burns (See Appendix F-III.2.2).

Air quality would be affected up to 710 m (2,329 ft) downwind of *each* burn site, assuming a stable atmosphere and light wind at the time of the burning. Accounting for the worst case of 10 burns in different locations, the area potentially affected is a 15.8 km^2 (6.1 mi^2) area. This represents 0.16% of Prince William Sound. Thus, the percent of the resource affected is <1%. The recovery time for the atmosphere after ISB would be on the order of hours. Thus, a risk matrix ranking of **4E** was assigned to air quality for this scenario.

Summary of the Consequences for Air Quality in the Large Volume Scenarios
The consequences of the three response options for large spills (1) on-water mechanical recovery only, (2) on-water mechanical recovery plus dispersants at 45% efficiency, and (3) on-water mechanical recovery plus dispersants at 80% efficiency are the same with respect to air quality. Evaporation off the water surface and volatilization from the water column creates a plume of volatile hydrocarbon gases that disperses quickly after a spill. For the large volume spill, the concentrations in the atmosphere at the water surface would exceed human health thresholds of concern at a maximum of 15 km (9.3 mi) from the spill site. Dispersant use would reduce the evaporation rate, but dissolved hydrocarbons would still volatilize, although dispersed over a wider area. Thus, atmospheric concentrations would be somewhat less under the dispersant use options. In all three options for the large spill, the effect would be small, affecting much less than 1% of the area of interest (i.e., Prince William Sound in Table A.4-4), and the recovery time for the atmosphere would be on the order of hours.

The alternatives involving on-water mechanical recovery plus ISB (whether or not dispersants are used) should increase atmospheric pollutants by the amount injected via burning. The maximum area potentially affected is 15.8 km^2 (6.1 mi^2). However, this represents much less than 1% of Prince William Sound.

Table F.4.1.1-1 indicates risk scores for air quality for all response options for a large volume spill. Both the area affected and the recovery times are assigned the lowest risk score for all the response options. These results would apply to any spill site at least 3 miles from shore.

Table F.4.1.1-1. Air quality risk scores for large spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB, With or Without Dispersant Application	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

F.4.1.2 Water Quality

The lowest water quality thresholds of concern are those concentrations of dissolved aromatics that could have effects on sensitive species in the water (see Section 4.3.1.1 of the PEIS). These thresholds are much lower than human health thresholds. The threshold for effects on water column organisms would be 5 ppb for at least 4 days of exposure. As an exposure dose, the threshold would be 500 ppb-hours. (See Part A, Section A.3.4 for development of these thresholds.)

Table F.4.1.2-1 summarizes the mean and 95th percentile values of the water volume affected by >1 ppb for at least 1 hour and the average exposure dose in that volume of water. These data are the mean and the mean plus 2 standard deviations of the model results for all 100 runs performed for each scenario (Appendix F-II.2). The average exposure doses in the volumes are at or greater than the 500 ppb-hour threshold.

The percentages affected of total water volumes in coastal and marine areas of interest were calculated using the area of Valdez Arm (coastal) and the biogeographical province area in Table A.4-4 for Prince William Sound (marine). The total coastal volume was the area of Valdez Arm (108.9 km^2 = 42 mi^2) times a mean depth of 200 m (656 ft). In this calculation it is assumed that the entire contaminated volume would be located in the coastal reference area (Valdez Arm) after a spill, a worst case assumption for a spill in that water body. The total marine volume was the area of the Prince William Sound province times the depth at the spill site, 312 m (1,024 ft). The affected volume would be much shallower than these depths. The contaminated volume calculated by the model was to the depth of the surface mixed layer and much broader horizontally than these calculated percentages times the total surface area of the water body would indicate. Risk scores for potential effects were assigned for each of coastal and marine areas.

Table F.4.1.2-1. Estimation of adverse effects on water quality for large volume spills by dispersant scenario, based on mean and 95th percentile water volumes exceeding 1 ppb dissolved aromatic concentration.

Dispersant % Efficiency		0	45	80
Volume (millions of m^3) Exposed to >1 ppb	mean	242.6	3635.	3687.
	95th	878.9	7569.	7734.
Average ppb-hrs in Volume	mean	368	4648	6321
	95th	952	10288	17617
Percent of Reference Area, coastal	mean	1.1	16.7	16.9
	95th	4.0	34.7	35.5
Percent of Reference Area, marine	mean	0.01	0.12	0.12
	95th	0.03	0.24	0.25

Results of On-Water Mechanical Recovery Only

For the large volume spill scenario in Valdez Arm and no dispersant response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 1.1% on average. For 5% of spills, the percentage affected would exceed 4.0% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days to weeks, the time for concentrations to disperse to background levels. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions. For coastal spills under average and extreme (95th percentile) conditions, the risk score is **4D**.

Results of the Addition of a Dispersant Response at Low Efficiency

For the large volume spill scenario and 45% dispersant efficiency response, the percentage of the coastal volume affected by >1ppb dissolved aromatic concentration would be 17% on average. For 5% of spills, the percentage affected would exceed 35% of the area of concern. For >95% spills in marine areas, the percentage of surface waters adversely affected is <1%. Dispersion in the water would be very rapid after a spill, and recovery time would be on the order of days to weeks, the time for concentrations to disperse to background levels. Thus, a risk matrix ranking of **4E** was assigned to water quality for marine spills under all conditions. For coastal spills under average conditions, the risk score is **4B**. Extreme (95th percentile) events, expected to occur for <5% of spills in coastal areas, were assigned a risk matrix ranking of **4A**. Note that dispersants would not be applied in coastal waters under the alternatives considered in the PEIS that include dispersant use.

Results of the Addition of a Dispersant Response at High Efficiency

For the large volume spill scenario and 80% dispersant efficiency response, the volumes affected are nearly the same as for 45% dispersant efficiency (because more than sufficient dispersant would be available to disperse the floating oil, see Section A.3.7 of Part A). Thus, the risk matrix rankings assigned to water quality for this scenario were the same as for the 45% dispersant efficiency case.

Results of the Addition of an On-Water ISB Response

Under the large volume spill scenario and the ISB response option, the water quality effects would be slightly less, by the amount removed by burning. Thus, the percent of the resource affected is also slightly less for the on-water mechanical only response scenario when ISB is included, and the risk matrix rankings assigned to water quality for scenarios involving burning were the same as those assigned for scenarios without burning.

Summary of the Consequences for Water Quality in the Large Volume Scenarios

Table F.4.1.2-2 summarizes risk scores for water quality for all response options for a medium volume spill in coastal waters under average and extreme (95^{th}) environmental conditions. Table F.4.1.2-3 summarizes risk scores for large volume spills in marine waters. The coastal results would apply to similar volume coastal areas and the marine results would apply to any spill site at least 3 miles from shore.

Table F.4.1.2-2. Water quality risk scores for large spills in coastal waters by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: D 95^{th}: D	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: B 95^{th}: A	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: B 95^{th}: A	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

Table F.4.1.2-3. Water quality risk scores for large spills in marine areas by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	mean: E 95^{th}: E	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

F.4.2 Effects on the Biological Environment

F.4.2.1 Intertidal Habitats

The intertidal habitats in Prince William Sound are dominated by exposed rocky shores and wave-cut platforms (23 percent of the shoreline), gravel beaches (21 percent), exposed tidal flats (21 percent), and sheltered rocky shores (31 percent), whereas sheltered tidal flats and marshes comprise less than 5 percent of the shoreline (Michel and Hayes, 1991). These shorelines are highly utilized by birds as feeding and nesting sites, by seals and sea lions for haulouts, by sea otters for feeding, by herring for spawning, by juvenile salmon as rearing areas, and they have very high recreational use (NOAA, 2000b). The threshold concentration of concern for intertidal habitats is 10 g/m^2 (~10 microns) oil thickness (see Section A.4 in Part A). Table F.4.2.1-1 shows the outputs of the different scenarios in terms of the area and/or length of shoreline habitat affected, for the major shoreline habitat types for the large spill volume (shoreline classifications are defined in NOAA, 2000b). Shoreline oiling is reported in kilometers for linear features such as gravel beaches and rocky shores and in square meters for wide habitats such as marshes and tidal flats.

Table F.4.2.1-1. Mean area and length of shoreline habitats oiled above a threshold of ~10 micron oil thickness for the large volume scenarios. The numbers are summarized from Appendix F Tables F-II.2-4 through F-II.2-6.

Response Option	Total Oiled Shoreline Area (m2)	Rocky Shore Length (km)	Gravel Beach Length (km)	Tidal Flats Area (m2)	Wetlands Area (m2)
On-Water Mechanical Recovery (with or without ISB)	512,000	62.5	26.2	58,000	800
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency) (with or without ISB)	255,000	31.8	12.4	34,000	0
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency) (with or without ISB)	178,000	25.1	9.1	11,000	0

Results of On-Water Mechanical Recovery Only

Under the large volume spill scenario and no dispersant response option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs would be 512,000 m^2 (5.5 million ft^2), and the mean oiled shoreline length would be about 89 km (55.6 mi). Affected habitats for the highest shoreline effect conditions would extend along northern Prince William Sound from Valdez Arm west to Wells Passage; Perry Island; Naked Island; the entrance to Port Nellie Juan; most of Knight Island; the northern shorelines of Green Island and Montague Island, and the shorelines bordering Knight Island Passage (Figure F-II.1.4.2-3). The oiled shoreline would represent 1.8 percent of the 5,000 km (3,100 mi) of shoreline in the reference area, and it is low compared to the 780 km (490 mi) of shoreline oiled during the *Exxon Valdez* spill, of which an estimated 235 km (147 mi) were moderately to heavily oiled (Neff et al., 1995). Gravel beaches would account for 51 percent of the shoreline oiled under the highest shoreline effect conditions, and many areas would be exposed to oil loadings of 10,000-100,000 g/m^2. Based on long-term monitoring of the *Exxon Valdez* oil spill, oil can persist in heavily oiled gravel beaches for more than 7 years, even after intensive cleanup efforts (Hayes and Michel, 1999). Exposed rocky shores would account for 37 percent of the oiled intertidal habitats, and they would be expected to recover within 3-7 years (Peterson, 2000). Overall, a risk matrix ranking of **1D** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency

Under the large volume spill scenario and 45% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron threshold for all model runs would be reduced by 50 percent, compared to on-water mechanical recovery alone (Table F.4.2.1-1). Less than 1 percent of the shoreline habitats in the reference area would be oiled above the threshold. The extent of heavy shoreline oiling under the highest shoreline effect conditions would be greatly reduced (Figure F-II.1.5.2-3). However, the there would be still 12.4 km (7.8 mi) of heavily oiled gravel beaches that would be expected to take more than 7 years to recover (Michel and Hayes, 1999). Thus a risk matrix ranking of **1E** was assigned to intertidal habitats for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the large volume spill scenario and 80% dispersant efficiency response option, the mean area of shoreline oiling exceeding the 10-micron oil threshold for all model runs would be reduced by 65 percent compared to on-water mechanical recovery only (Table F.4.2.1-1). The extent of heavily oiled shorelines would also be greatly reduced, although gravel beaches on Naked Island, Smith Island, and the northern part of Knight Island would be moderately oiled (Figure F-II.1.6.2-3). Thus, a risk matrix ranking of **2E** was assigned to intertidal habitats for this scenario.

Results of the Addition of an On-Water ISB Response

Under the large volume spill scenario and the ISB response option, effects on intertidal habitats would be similar to the on-water mechanical recovery only response option. When considering the areas of the different shoreline habitats affected under these spill conditions, a risk matrix ranking of **1D** was assigned to intertidal habitats for this scenario.

Summary of the Consequences for Intertidal Habitats in the Large Volume Scenarios
Under the large volume scenarios, gravel beaches would be heavily oiled and recovery would be expected to be greater than 7 years, for all response options. The use of dispersants would likely lessen the area of shoreline effect by about 50-65 percent, greatly reducing the extent of heavily oiled habitats thus improving the overall recovery of intertidal habitats. The level of dispersant efficiency does not have a large affect the level of concern about intertidal habitats in this spill scenario.

F.4.2.2 Marine and Coastal Birds

The Alaska region, and particularly Prince William Sound, provides important habitat for migrant and resident marine and coastal birds. Refer to Section F.3.2.2 for additional information on important bird habitats in Prince William Sound and factors considered in risk score calculation.

It is important to note that the species groups being considered are not distributed equally throughout Prince William Sound, and that adverse effects should not be proportional to the amount of shoreline or water surface area oiled, but rather could depend on seasonal concentrations of particular species in high-use areas.

Results of On-Water Mechanical Recovery Only
Under the large volume spill scenario and no dispersant response option, many areas of important shorebird habitat would be oiled above the 10-micron threshold. Oiled areas could include: Eagle Bay; Inakwik Inlet; Long Bay; Columbia Bay; Naked, Perry, Montague, Green, and Bligh Islands; Port Fidalgo, and Port Nellie Jean (Figure F-II.1.4.2-3). The mean area of shoreline oiled above a threshold of 10 g/m^2 was 512,000 m^2 (5.5 million ft^2, Table F-II.2-4).

Potential surface water oiling above the 10-micron threshold in the modeled area would correspond with seabird and waterfowl concentration areas (e.g. in the bays and inlets in the northern Sound, around Bligh, Montague, Green, Knight, Perry, and other islands, and in the bays and ports in the western Sound) (NOAA, 2001, Figure F-II.1.4.1-3). The mean surface water area oiled above a 10-micron threshold would be about 468 km^2 (181 mi^2, Table F-II.5-3).

Because of the potential for shoreline and water surface oiling in sensitive habitats, when considering all species groups together, it is possible that over 20 percent of the area bird population of may be adversely affected under these spill conditions. Recovery could likely occur in 1 to 3 years for most species, as was the case following the Exxon Valdez spill (Kuletz, 1993; Boersma et al., 1995; Erikson, 1995, and Wiens, 1995). Recovery times for other species, such as black oystercatchers and harlequin ducks, were longer after the Exxon Valdez, and ranged from 3-9 years (Klosiewski and Laing 1994; Day et al., 1995, 1997, Irons et al. 2000). Because black oystercatchers, harlequin ducks, and other species with longer recovery times are present, sometimes in high concentrations, in many of the potentially oiled areas (Bligh Island, Montague Island, Green Island, etc.), recovery time could be considered to be from 1-7 years for birds in Prince William Sound (NOAA, 2000b). A risk matrix ranking of **2A** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the medium volume spill scenario and the low efficiency dispersant response option, the mean area of shoreline oiling would be reduced by 50 percent compared to on-water mechanical recovery alone (Table F.4.2.1-1). Similar important shorebird habitats could be oiled compared to when no dispersants were used, although to a lesser extent (Figure F-II.1.5.2-3).

The total mean surface water area oiled above the threshold in the modeled area would be reduced approximately 50 percent to 235 km^2 (91 mi^2) compared to when low efficiency dispersants were used (Table F-II.5-2). Potential surface water oiling above the 10-micron threshold could occur in similar seabird and waterfowl concentrations compared to when no dispersants were used, but to a lesser extent (NOAA, 2001, Figure F-II.1.5.1-3).

When considering all species groups together, because of the decrease in shoreline length and surface water area swept by oil compared to the on-water mechanical recovery only option, it is estimated that 10-20 percent of the area bird population may be adversely affected under these spill conditions, and recovery could likely occur in 1 to 7 years. A risk matrix ranking of **2B** was assigned to birds for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the medium volume spill scenario and the high efficiency dispersant response option, the mean area of shoreline oiling would be reduced by 65 percent compared to mechanical recovery alone (Table F.4.2.1-1). Similar important shorebird areas could be oiled as compared to the low efficiency response option (Figure F-II.1.6.2-3).

Surface water oiling above the 10-micron threshold in the modeled area would occur to a similar extent and in similar areas compared to when low efficiency dispersants were used (NOAA, 2001, Figure F-II.1.6.1-3). Seabirds and waterfowl concentration areas may be adversely affected.

When considering all species groups together, because of the decrease in shoreline length and surface water area swept by oil compared to the on-water mechanical recovery only option, it is estimated that 10-20 percent of the area bird population may be adversely affected under these spill conditions, and recovery could likely occur in 1 to 7 years. A risk matrix ranking of **2B** was assigned to birds for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, adverse effects on birds would be similar to the on-water mechanical recovery only response option. Over 20 percent of the area bird population is estimated to be adversely affected under these spill conditions, and recovery could likely occur in 1 to 7 years for most species. A risk matrix ranking of **2A** was assigned to birds for this scenario.

Summary of the Consequences for Marine and Coastal Birds in the Large Volume Scenarios
Under the large volume scenario, adverse effects on birds are likely to be high when no dispersants are used, regardless of the use of ISB, due to the probability that a large percentage

of sensitive habitats used by shorebirds, waterfowl, and seabirds may be oiled. The use of dispersants is projected to likely lessen the water surface and shoreline effects enough to decrease the area and lower the percentage of birds affected, although concern about adverse population effects would still probably be high because of the recovery time required.

F.4.2.3 Marine Mammals

The marine and coastal waters of Prince William Sound support a large and diverse population of marine mammals (see Section F.3.2.3). Marine mammals may be at risk from either floating oil, or from oil which strands in shoreline areas that are used as haul out or breeding areas. The latter concern is important in Prince William Sound, since there are many such areas primarily along rocky shorelines.

For this analysis, marine mammals are assumed to be at risk if a threshold of 10 g/m^2 (~10-micron) thickness of oil is exceeded on the shoreline or on the water surface (see Section A.4 in Part A), however the level of risk varies by the behavior group. Potential adverse effects on marine mammals (i.e., terrestrial wildlife, cetaceans, furbearing marine mammals, and pinnipeds and manatees were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. The equivalent area for 100% mortality is the integrated sum of the area swept times the probability of mortality. The modeling methods are described in Part A, and the results of the calculations for the large volume Prince William Sound spills are in Appendix F-II.5, Table F-II.5.3. The equivalent areas of 100% mortality for all response options are summarized in Table F.4.2.3-1 as percentages of Prince William Sound (defined in Tables A.4-4 and A.4-5 of Part A). In addition to this calculation, which is based on the mean result, the mean length of shoreline oiled and the surface oil exposure exceeding 0.01 g/m^2 (in m^2-hrs) based on all model runs was also compared between the treatment options (Tables F-II.2-4 through F-II.2-6).

Table F.4.2.3-1. Percentage of reference area adversely affected for medium spills, by dispersant option and behavior group (assuming Prince William Sound area in Tables A.4-4 and A.4-5).

Behavior Group (Habitat Occupied)	0	45	80
Terrestrial wildlife (wetlands, sea grass beds and shoreline)	0.001	0.001	0.001
Cetaceans (seaward subtidal)	0.005	0.003	0.002
Furbearing marine mammals (all intertidal and subtidal)	3.42	1.72	1.43
Pinnipeds and manatees (all intertidal and subtidal)	0.05	0.02	0.02

Results of On-Water Mechanical Recovery Only
In Prince William Sound, marine mammals at risk include cetaceans, several pinniped species, sea otters, and terrestrial mammals along the shore. The resistance of cetaceans to oiling coupled with the very small percentage of affected area creates a very minimal risk to cetaceans under the on-water mechanical recovery only option for the large volume spill scenario. The cetaceans that are oiled as a result of contact with floating oil would most likely recover in within a few days, if not hours, of the spill **(4E)**, (RPI, 1987). Similarly, terrestrial mammals are at very low risk, but

if an individual were killed or reproductively impaired by contact with oil on the shoreline, the recovery period could exceed one year (**3E**). Pinnipeds also have a low estimate for the area of equivalent mortality. The area for sea otters is approximately 3.4%, the highest calculated. As an alternative measure, the length of shoreline oiling was compared to the total shoreline length (89 versus 5,047 km or 55 versus 3,136 mi), which is slightly less than 2%. This is presumed to be a measure of the possibility of contacting a haul out area. The primary concerns in Prince William Sound are for sea otters and pinnipeds. While the area of effect for pinnipeds is still low with the large spill scenario (based on the estimate of equivalent area), the percentage of the total habitat area for sea otters falls in the 1 to 5% range. The shoreline oiling also falls in this range, which could reflect increased risk of sublethal effects to pinnipeds using haul out areas. In either case, the death of or sublethal effects to reproductive adults could affect the population for a number of years. On this basis the risk score of **2D** was assigned.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and the 45% efficiency dispersant option the areas of equivalent mortality for terrestrial mammals, cetaceans, and pinnipeds are slightly reduced in absolute area, and are very small relative to the reference areas. The calculated percentage for sea otters is reduced from 3.4% to approximately 1.7%. The length of shoreline oiled is also reduced, from 89 to 45 km (55 to 28 mi) (approximately 0.9% of the total). The use of dispersants would be a benefit in terms of the estimated area, but does not fall below 1% and would not affect the recovery time, thus the risk score remains **2D**. There is no evidence that cetaceans, sea otters or pinnipeds are sensitive to dispersed oil in the concentrations expected to occur.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% efficiency dispersant option, the areas of equivalent mortality are essentially the same as those for the 45% option, however, the extent of shoreline oiled is reduced to 34 km (21 mi, 0.7%). The decrease is enough to lower the risk score (**2E**), but the overall level of concern remains moderate.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in addition to on-water mechanical recovery should not change the effects on marine mammals (**2D**), since the amount of floating oil remains unchanged. The concentrations of aromatic and post-combustion chemicals are not expected to exceed threshold levels that would pose a threat to marine mammals.

Summary of the Consequences for Marine Mammals in the Large Volume Scenarios
The results indicate that on average for large volume spills in Prince William Sound adverse effects on marine mammals would be moderate with or without the use of dispersants. Dispersant use would decrease the area of concern, but would not effect recovery time, which is the factor of most concern.

F.4.2.4 Sea Turtles

Sea turtles are not components of the Prince William Sound ecosystem.

F.4.2.5 Plankton and Fish

Potential adverse effects on water column organisms (i.e., plankton and fish, as well as pelagic invertebrates such as squid) were estimated using the modeling (SIMAP) and summarized as equivalent areas of 100% mortality. Estimated water volumes where adverse effects could occur were converted to equivalent areas of 100% loss by integrating percentage losses over all affected volumes and multiplying by water depth at the spill site, allowing comparison to other resources that are distributed on a per area basis (e.g., mammals and shorelines). In the area modeled, effects were nearly evenly distributed throughout the water column because of water column mixing and vertical movements of animals. If these results are used to infer potential for adverse effects in deeper waters, the areas of effect would only apply to waters up to on the order of 200-300 m (656-984 ft) deep (during strong wind conditions). The modeling methods are described in Part A and Section F-II.6, and the results of the calculations for the large Prince William Sound spills are in F-II.6. For these calculations, the toxicity parameter for sensitive species was assumed. Thus, the areas affected would only apply to 2.5% of species (based on a Gaussian distribution of species sensitivities), and areas of adverse effect for 97.5% of species would be smaller.

Table F-II.6-3 lists the average equivalent areas projected to be killed (for sensitive species) for large volume spills. These areas are based on the mean of all 100 runs, and so represent an average of all environmental conditions that may occur after a spill (see explanation in Section F-II.6). Table F-II.6-5 lists the 95th percentile equivalent areas where sensitive species would be adversely affected. This maximum potential effect is calculated as the mean plus two standard deviations, using the statistics of all 100 model runs for the scenario, and assuming the toxicity values for sensitive species.

The mean areas adversely affected for all response options are summarized in Table F.4.2.5-1 as percentages of Prince William Sound (defined in Table A.4-4 of Part A). The maximum areas (95th percentile) for sensitive species are summarized in Table F.4.2.5-2 (also as percentages of Prince William Sound).

Table F.4.2.5-1. Average percentage of reference area adversely affected for large spills, by dispersant option and behavior group (assuming Prince William Sound area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.000	0.002	0.002
Small pelagic fish & invertebrates	0.000	0.162	0.164
Large pelagic fish	0.005	0.291	0.295
Demersal (stationary on bottom)	0.001	0.001	0.001
Planktonic (drift with currents)	0.000	0.128	0.130

Table F.4.2.5-2. Maximum (95th percentile) percentage of reference area adversely affected for large spills, by dispersant option and behavior group (assuming Prince William Sound area in Table A.4-4).

Behavior Group	0	45	80
Demersal (move at bottom)	0.000	0.003	0.004
Small pelagic fish & invertebrates	0.042	0.362	0.370
Large pelagic fish	0.074	0.638	0.652
Demersal (stationary on bottom)	0.000	0.000	0.000
Planktonic (drift with currents)	0.033	0.284	0.290

Results of On-Water Mechanical Recovery Only
Under the large volume spill scenario and no dispersant response option, the area adversely affected would be <0.005% of Prince William Sound for spills under average environmental conditions. For 5% of spills, the area affected would be up to 0.07% of Prince William Sound, depending on the behavioral group of the organism. As the percentage affected is <1%, it is less than the range of natural variability and would not be perceptible at the population level. Given this, the short generation time of many species, and annual reproduction of others, the recovery time would be <1 year. Therefore, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45% dispersant efficiency response option, the area adversely affected would be 0.001-0.3% of Prince William Sound for spills under average environmental conditions. For 5% of spills, the area affected would be up to 0.6% of Prince William Sound, depending on the behavioral group of the organism. The adverse effects are slightly higher than the on-water mechanical recovery only response but still relatively small on the scale of the populations involved, and the affected species would require less than a year to replace the missing individuals. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80% dispersant efficiency response option, the area adversely affected would be 0.001-0.3% of Prince William Sound for spills under average environmental conditions. For 5% of spills, the area affected would be up to 0.7% of Prince William Sound, depending on the behavioral group of the organism. These results are not greatly different from the low-efficiency dispersant response because approximately the same amount of oil is dispersed in either case (i.e., more than sufficient dispersant is available to disperse available oil for such activity in the low efficiency case). The effects are only slightly more than the low efficiency response scenario, which is in turn slightly higher than the on-water mechanical recovery only response. The adverse effect is relatively small on the scale of the populations involved, and the affected species would require less than a year to replace the missing individuals. Thus, a risk matrix ranking of **4E** was assigned to plankton and fish for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario, if ISB is effectively used in the response, the adverse effects on water column organisms would be slightly less than otherwise by the amount removed

by burning. Thus, the percent of the resource affected is <1% for on-water mechanical and both dispersant response scenarios when ISB is included. Because the adverse effects are small, much less than the range of natural variability, the recovery time would be <1 year. Therefore, a risk matrix ranking of **4E** was assigned to water column communities for this scenario.

Summary of the Consequences for Plankton and Fish in the Large Volume Scenarios
The results indicate that on average for large volume spills, adverse water column effects for sensitive species would affect <0.5 km^2 (0.2 mi^2) without the use of dispersants. With dispersants, and on average, up to 30 km^2 (12 mi^2) of water could be toxic to the most sensitive and mobile species (Table F-II.6-2). Exposure for larger fish is higher because they are more mobile, and new animals move into the dissolved aromatic plume over time (assuming they do not avoid hydrocarbon contamination, as was assumed in this analysis). Under worst case conditions, the potentially affected areas for sensitive species and for no dispersants and dispersant use are on the order of 8 to 66 km^2 (3 to 25 mi^2), respectively (Table F-II.6-5).

The mean areas adversely affected for all response options are <1% of Prince William Sound (Table F.4.2.5-1). Thus, the risk scores for these effects are "**E**" (Table F.4.2.5-3). The maximum areas (95th percentile) for sensitive species are also <1% of the area of concern (Table F.4.2.5-2). The effects are relatively small on the scale of the populations involved.

It should be noted that these results are assuming toxicity threshold for sensitive (2.5th percentile) species. The average species would not be so sensitive, and these estimated adverse effects would not apply to most or average species. The effect estimates are used in a comparative manner, comparing potential areas of concern to the most sensitive species.

These results are consistent with experience for large oil spills of about 40,000 bbl (about 1 million gallons or more; French McCay and Payne, 2001; French McCay et al., 2002, and as discussed in Part A). Winds are typically light to moderate, except in infrequent storm events. Thus, natural dispersion into the water is typically low, while evaporation is rapid. Because of logistical constraints, in the scenarios examined the dispersion by chemical dispersants occurred beginning at 12 hours after the spill. By this time, most of the toxic components have volatilized (Section F.4.1), such that dissolved aromatic concentrations resulting from dispersant use are only slightly elevated over the no-dispersant option.

Only in rare storm events where high waves entrain fresh un-weathered oil into shallow water, such as in the *North Cape* oil spill (French, 1998a, b; French McCay, 2003), would the concentrations of toxic components be high enough to cause serious concern about effects on water column communities. This scenario is extremely unlikely in Prince William Sound because it is predominantly deep water. Similarly, dispersants would also not cause more than limited water column effects in Prince William Sound because of the depth and large water volume for dilution.

Table F.4.2.5-3. Risk scores for plankton and fish for large spills by response alternative.

Response Option	% of Resource Affected*	Time to Recovery**
On-Water Mechanical Recovery	E (<1%)	4 (<1 yr)

On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	E (<1%)	4 (<1 yr)
On-Water Mechanical Recovery and ISB	E (<1%)	4 (<1 yr)

* A: >20%; B: 10-20%; C: 5-10%; D: 1-5%; E: <1%
** 1: >7 years; 2: 3-7 years; 3: 1-3 years; 4: <1 year

F.4.2.6 Subtidal Benthic Habitat

Subtidal benthic habitat in Prince William Sound, and its susceptibility to oil was discussed in Section F.3.2.6. Benthic habitat was assumed to be at risk when a threshold of 0.10 g/m^2 of total hydrocarbon loading was exceeded in the sediment or 0.0001 g/m^2 of dissolved aromatic hydrocarbons was exceeded in the pore water (see Section A.4 in Part A). These concentrations are approximately equivalent to 1 ppm of total hydrocarbons or 1 ppb of dissolved aromatic hydrocarbons, when a sediment mixing depth of 10 cm is assumed. The area was estimated using SIMAP and the modeling methods are described in Part A. The area estimates of sediment loading for the large volume Prince William Sound spills are in Appendix F-II.6, Table F-II.6.6. The area estimates for dissolved aromatic hydrocarbons in sediment pore water are in Table F-II.6.7. Uncharacteristically, the 0.10 g/m^2 total hydrocarbon threshold was exceeded in an area totaling approximately 0.2 km^2 (0.08 mi^2) with on-water mechanical recovery only, while the threshold was not exceeded when dispersants were used. This area is so small that all values are essentially zero. The dissolved aromatic concentrations never exceeded the sediment threshold.

Benthic habitat was also assumed to be at risk if epiflora and epifauna (demersal) organisms were affected by dissolved aromatic concentrations in the bottom water just above the sediments. The percentage of benthic habitat where stationary demersal biota would be affected, assuming the toxicity parameter for sensitive species (i.e., two standard deviations more sensitive than the average of all species tested), was estimated using SIMAP and the modeling methods described in Part A and Section F.II.6.

Results of On-Water Mechanical Recovery Only
In the on-water mechanical recovery only option for the large volume spill scenario, the model results indicate that for sediments only the total hydrocarbon threshold was exceeded, and then only in a very small area. As indicated in Table F.4.2.5-1, 0.001% of the reference area was affected by bottom water concentrations when no dispersants were assumed used. Since the overall area of effect on the benthic habitat is low and recovery would be rapid, the risk ranking is **4E**.

Results of the Addition of a Dispersant Response at Low Efficiency
No sediment thresholds are exceeded when a dispersant at 45% efficiency is used in the large spill scenario. As indicated in Table F.4.2.5-1, 0.001% of the reference area was affected by

bottom water concentrations when dispersants were assumed used at low efficiency. Thus, the risk ranking remains **4E**.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and the 80% efficiency dispersant option potential effects are unchanged from the 45% efficiency dispersant option, therefore, the risk ranking remains at **4E**.

Results of the Addition of an On-Water ISB Response
Oil removal by ISB in the large spill scenario should have no additional effect when combined with on-water mechanical recovery on benthic habitats since ISB takes place on the water's surface and results in the removal of an equivalent amount of oil (**4E**). The only concern associated with ISB is the chance of heavy burn residues sinking and mixing with sediments, but this risk is minimal based on both the toxicity of the material and on the amount that would be produced from the limited burning possible in the scenarios.

Summary of the Consequences for Subtidal Benthic Habitat in the Large Volume Scenarios
Oil spills and oil-spill response activities could potentially affect benthic habitats. Floating oil does not pose a great level of concern unless sufficient wave energy exists to mix the surface oil into the water column, or sediments contaminated with oil are transported from the intertidal zone into subtidal habitats. Mechanically dispersed oil could reach bottom water and adhere to sediments, flora and fauna in benthic habitats and could cause potentially adverse effects. However, in this simulation, only very low levels of hydrocarbon exposure are expected on or in the sediments. Dispersant use appears to reduce this risk slightly, but that change is probably not important, given the low levels. With on-water mechanical recovery only, the risk to benthic habitat is low, and dispersant use makes it slightly lower.

F.4.2.7 Biological Areas of Special Concern

Prince William Sound has numerous areas of special concern which were described in Section F.3.2.7. As discussed in that section, the average risk to such areas is assumed to be defined by the risk to intertidal (Section F.4.2.1) or subtidal habitats (Section F.4.2.6), adjusted for the extent of areas of special concern which occur in Prince William Sound, if appropriate. The higher of the risk scores for these two resource groups is used as the starting point to define the risk to areas of special concern. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
For the mechanical response option under the large volume spill scenario, floating oil poses a high risk (**1D**) to intertidal habitat, while subtidal habitat was at minimal risk (**4E**). Therefore, intertidal areas of special concern are the only areas which require consideration. The concerns for intertidal habitat were discussed in Section F.4.2.1. Since areas of special concern occupy only selected locations, the probability of contact is less than for intertidal habitat overall. In addition, the long recovery time reflects the oiling of gravel beaches, and while these could occur in association with intertidal areas of special concern, they are only a small part of the resource in areas such as National Parks, National Forests, or National Wildlife Refuges and the presence

of deeply buried oil would not represent a major risk. On this basis, the recovery time is reduced from more than 7 to 3 to 7 years, and the risk score becomes **2D**.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency in the large spill scenario reduced the risk to intertidal habitat by reducing the amount of surface oil which reaches shore, decreasing the probability of contacting an area of concern. While the likelihood of contact is reduced, the decrease was not enough to change the risk ranking. The risk to subtidal habitat remains low (**4E**) because of the limited extent of the dispersed oil plume and rapid dilution. Based on the logic discussed for on-water mechanical recovery alone, a risk score of **2E** is used.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at an efficiency of 80% in the large spill scenario slightly reduces the amount of shoreline oiled over that for dispersant use at 45% efficiency, but the reduction was not sufficient to change the risk score.

Results of the Addition of an On-Water ISB Response
ISB should produce a smoke plume that could pass over an area of special concern if the proper weather conditions exist. In this case, however, the burning can only occur three miles or more offshore, and the results for air quality (Section E.4.1.1) indicate that the plume should not travel that far. The use of ISB in addition to on-water mechanical recovery is not expected to change the risk to these resources (**2D**).

Summary of the Consequences for Biological Areas of Special Concern in the Large Volume Scenarios
The effects on areas of special concern in this scenario are focused on the potential risk to shoreline habitats. The use of dispersants can reduce the risk to areas of special concern without increasing the minimal risk to subtidal areas. In this analysis the risk to such areas is defined as slightly less than the risk to intertidal habitat, in general, based on the nature of the area. While this accurately reflects the ecological consequences of the event, it does not account for the social values which may be attached to such areas. If the spill trajectory of an actual event did threaten such areas, special attention would be given to their protection.

F.4.2.8 Essential Fish Habitat

Areas of essential fish habitat are extensive in Prince William Sound (Section F.3.2.8). For this evaluation, the effects on essential fish habitat are assumed to be reflected by the risk to plankton and fish (Section F.4.2.5) and subtidal habitat (Section F.4.2.6), since they define the risk to the majority of fish habitat. The average risk to essential fish habitat is assumed to be defined by the higher of the risk scores for plankton and fish or subtidal habitat. Details on the development of those scores are provided in those sections.

Results of On-Water Mechanical Recovery Only
In the large spill scenario, with the use of on-water mechanical recovery only, the risk to plankton and fish and to subtidal habitat was **4E**, resulting in a risk score for EFH of **4E**. The areal extent of the area of potential effects on fish increased beyond that for the medium spill, but

remained well below 1%. Recovery time should be less than one year, based on natural variability and the fecundity of most groups.

Results of the Addition of a Dispersant Response at Low Efficiency
The use of dispersants at 45% efficiency increases the possibility of exposure for both plankton and fish and subtidal habitat. The dispersed oil plume produced was not sufficient to change the risk scores for plankton and fish or for subtidal habitat. Recovery time would not be affected and so the risk score remains **4E** for EFH. Dispersant use did reduce effects on intertidal habitat, which includes areas that are important for fisheries resources and EFH.

Results of the Addition of a Dispersant Response at High Efficiency
The use of dispersants at 80% efficiency in the large spill scenario resulted in no change to the risk to plankton and fish or subtidal habitat from the 45% efficiency scenario, and the score remains **4E**. Again, dispersant use does benefit intertidal habitat, some of which are also important to EFH.

Results of the Addition of an On-Water ISB Response
The addition of ISB to on-water mechanical recovery in the large spill scenario did not change the evaluation for either plankton or fish or for subtidal habitat, and the score remains **4E**.

Summary of the Consequences for Essential Fish Habitat in the Large Volume Scenarios
Overall, the risk to essential fish habitat is low for the large spill scenario regardless of what response option is used. The risk score is primarily determined by the potential risk to plankton and fish, rather than subtidal habitat. However, even though there was a slight increase in the area of concern for fish and plankton with dispersant use, it was not enough to affect the general low level of concern for EFH.

F.4.3 Effects on the Socio-Economic Environment

F.4.3.1 Human Health

Operation of the type of equipment associated with oil spill response can be dangerous. This is well recognized and is the basis for the worker certification and training requirements that are now in place. There are also protocols in place for the proper application and handling of dispersants. The safety risk is greater as the spill size, and thus the intensity and duration of operations increases, but is minimized if safety standards are followed. There is a health risk from inhalation of hydrocarbon fumes for first responders, which is recognized in current safety protocols. Exposure to hydrocarbon fumes is the only health risk that can be directly estimated in the SIMAP model, and the results are presented in Section F.4.1.1.

F.4.3.2 Subsistence

Subsistence use of coastal resources is an important activity in the Alaska region, and includes participation from Prince William Sound communities (Section 3.5.5.6 of the PEIS). Gulf of Alaska residents harvest fresh and saltwater finfish and shellfish species and hunt for pinnipeds.

Results of On-Water Mechanical Recovery Only

Under the large volume spill scenario and no dispersant response option, water column exposure of dissolved aromatics between 1-100 ppb would be localized to an area surrounding Naked and Knight Island (Figure F-II.1.4.4-3). Tainting of fish and invertebrates becomes a concern when water concentrations exceed approximately 100 ppb in a brief (order of hours) exposure (See Section 4.3.5.6 of the PEIS). Sediment exposure is expected to be negligible (Figure F-II.1.4.5-2). The length of oiled shoreline would represent about 2 percent of the shoreline in the reference area (Section F.4.2.1 Intertidal Habitats). Therefore, an estimated small percentage of subsistence resources, mostly shoreline associated, are likely to be adversely affected, and recovery should be within 1 year. A risk matrix ranking of **4D** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at Low Efficiency

Under the large volume spill scenario and low efficiency dispersant response option, water column exposure of dissolved aromatics between 1-100 ppb is expected to cover a much larger area of the Sound compared to on-water mechanical recovery only, and dissolved aromatic concentrations between 100-10,000 ppb would occur in fairly large areas south and east of Naked Island (Figure F-II.1.2.4-3). Potentially oiled areas could be within 5 miles of Chenega and 7 miles of Tatitlek. Sediment exposure is expected to be negligible (Figure F-II.1.2.5-2). Shoreline oiling at 45 percent dispersant efficiency would be reduced by approximately 50 percent (Section F.4.2.1 Intertidal Habitats). Although a much larger water column area may be affected under these spill conditions, a smaller percentage of shoreline associated organisms is expected to be adversely affected, and recovery should be a within 1 year. A risk matrix ranking of **4D** was assigned to subsistence resources for this scenario.

Results of the Addition of a Dispersant Response at High Efficiency

Under the large volume spill scenario and high efficiency dispersant response option, water column and sediment exposure to dissolved aromatics and the degree of shoreline oiling are expected to be similar to when low efficiency dispersants were used (Figures F-II.1.3.4-3 and F-II.1.3.5-2, Section F.4.2.1 Intertidal Habitats). A risk matrix ranking of **4D** was assigned to subsistence resources for this scenario.

Results of the Addition of an On-Water ISB Response

Under the large volume spill scenario and the ISB response option, adverse effects on subsistence resources would be similar to the on-water mechanical recovery only response option. A risk matrix ranking of **4D** was assigned to subsistence resources for this scenario.

Summary of the Consequences for Subsistence in the Large Volume Scenarios

While water column effects should be fairly localized, shoreline oiling would affect about 2 percent of the total shoreline length in the reference area and associated shoreline/intertidal organisms, so a risk matrix ranking of **4D** was assigned to subsistence resources for on-water mechanical recovery, with or without ISB. A much larger water column area would be affected when dispersants are used, but adverse effects on shoreline organisms would be reduced by 50 percent or more, therefore a risk matrix ranking of **4D** was assigned for both the low and high efficiency dispersant response options.

F.4.3.3 Cultural Resources

Prehistoric resources in the Alaska region occur on and offshore and submerged shipwrecks occur offshore (Section 3.5.5.7 of the PEIS). Results from several studies following the Exxon Valdez oil spill indicated that direct oiling caused negligible effects on prehistoric and historic artifacts (Reger et al., 1992; Dekin, 1993; Wooley and Haggarty, 1995; Bittner, 1996). Open water response options, including on-water mechanical recovery, ISB, and the use of dispersants may help reduce the amount of oil that strands on the shoreline, which should also reduce the amount of shoreline clean up and potential disturbance to sensitive cultural resources. Offshore archaeological and historic resources would not become oiled regardless of the response option used. For these reasons, a risk matrix ranking of **4E** was assigned to cultural resources for all response options under this scenario.

F.4.3.4 Coastal Communities

Oil spills affect the pleasure that coastal residents and visitors derive from coastal activities and the economic contribution that resources make to local income and employment. Effects are likely to include effects on water- and shore-based recreation, fisheries (recreational and commercial), marine transportation and tourism. The effects on these activities are described in more detail in subsequent sections.

As described in Part A, the proportion of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to coastal communities in Prince William Sound under various spill response options. At this modeling location, the length of shoreline oiling above the effects threshold is not considered relevant because the shoreline oiling results were highly sensitive to specific location, the ability to identify shoreline with characteristics amenable to use was limited, and areas of surface water oiled above the threshold was expected to provide a more accurate measure of expected risk, given the region's geographic characteristics. The model results are presented in Appendix F-II.2, Tables F-II.2-4 to F-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to coastal communities of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in Prince William Sound is expected to adversely effect approximately 770 km^2 (297.3 mi^2) of surface water above recognized effect thresholds (Table F-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 35 percent as compared to on-water mechanical recovery alone (Table

F-II.2-5). This results in a risk factor rating of 0.66 for surface water resources under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 15 percent as compared to the low dispersant efficiency response option (Table F-II.2-6). Because the adverse effects on surface water resources is less with higher dispersant efficiency, the risk factor rating decreased to 0.58 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on coastal communities would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to coastal communities for surface water resources for this scenario.

Summary of the Consequences for Coastal Communities in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 435 to 500 km^2 (165.7 to 193 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 35 to 43 percent, the level of dispersant efficiency does not greatly affect the level of concern about coastal communities in this spill scenario.

F.4.3.5 Economic Status

The overall economic status of communities, industries and individuals that rely on coastal resources for sustenance, revenue and quality of life can be affected by an oil spill. As noted above, coastal communities can suffer direct and indirect economic effects due to an oil spill, as beach and fishery closures decrease revenues, eliminate jobs, and adversely affect subsistence users of the resources.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to economic status in Prince William Sound under various spill response options. The model results are presented in Appendix F-II.2, Tables F-II.2-4 to F-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to economic status of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in Prince William Sound is expected to adversely effect approximately 770 km^2 (297.3 mi^2) of surface water above recognized effect thresholds (Table F-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 35 percent as compared to on-water mechanical recovery alone (Table F-II.2-5). This results in a risk factor rating of 0.66 for surface water resources under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 15 percent as compared to the low dispersant efficiency response option (Table F-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating decreased to 0.58 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on economic status would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to economic status for surface water resources for this scenario.

Summary of the Consequences for Economic Status in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 435 to 500 km^2 (165.7 to 193 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 35 to 43 percent, the level of dispersant efficiency does not greatly affect the level of concern about economic status in this spill scenario.

F.4.3.6 Vessel Transportation and Ports

Any interruption in the standard use of vessels or increase in travel times over water can result in hardship for coastal communities and businesses as fewer goods are exchanged, transportation costs rise, and the revenue streaming through the local economy falls.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to marine transportation and ports in Prince William Sound under various spill response options. The model results are presented in Appendix F-II.2, Tables F-II.2-4 to F-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to the marine transportation industry of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in Prince William Sound is expected to adversely effect approximately 770 km^2 (297.3 mi^2) of surface water used by the marine transportation industry above recognized effect thresholds (Table F-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 35 percent as compared to on-water mechanical recovery alone (Table F-II.2-5). This results in a risk factor rating of 0.66 for the marine transportation industry under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 15 percent as compared to the low dispersant efficiency response option (Table F-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for the marine transportation industry decreases to 0.58 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on the marine transportation industry would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to the marine transportation industry for surface water resources for this scenario.

Summary of the Consequences for Vessel Transportation and Ports in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 435 to 500 km^2 (165.7 to 193 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 35 to 43 percent, the level of dispersant efficiency does not greatly affect the level of concern about vessel transportation and ports in this spill scenario.

F.4.3.7 Fisheries (Commercial and Recreational)

Commercial and recreational fishing and related industries are vulnerable to oil spills, due to closures as well as market perceptions surrounding taint of the catch. In addition, recreational anglers, who fish for pleasure or sport, as opposed to monetary gain, may experience a reduced quality of experience. Large-scale spills also hold the potential to injure nursery grounds and impose other effects that could reduce fish harvests in the longer run.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to commercial and recreational fishing in Prince William Sound under various spill response options. The model results are presented in

Appendix F-II.2, Tables F-II.2-4 to F-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to commercial and recreational fishing of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in Prince William Sound is expected to adversely effect approximately 770 km^2 (297.3 mi^2) of surface water used for commercial and recreational fishing above recognized effect thresholds (Table F-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 35 percent as compared to on-water mechanical recovery alone (Table F-II.2-5). This results in a risk factor rating of 0.66 for commercial and recreational fishing under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 15 percent as compared to the low dispersant efficiency response option (Table F-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for commercial and recreational fishing decreases to 0.58 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on commercial and recreational fishing would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to commercial and recreational fishing for surface water resources for this scenario.

Summary of the Consequences for Commercial and Recreational Fishing in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 435 to 500 km^2 (165.7 to 193 mi^2)of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 35 to 43 percent, the level of dispersant efficiency does not greatly affect the level of concern about commercial and recreational fishing in this spill scenario.

F.4.3.8 Recreation and Tourism

An oil spill would be expected to cause local decreases in tourism, recreation, associated business revenues and the quality of coastal living. Similar to recreational fishing effects, an oil spill would also be expected to affect recreationalists' overall social welfare.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to recreation and tourism in Prince William Sound under various spill response options. The model results are presented in Appendix F-II.2, Tables F-II.2-4 to F-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to recreation and tourism of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in Prince William Sound is expected to adversely effect approximately 770 km^2 (297.3 mi^2) of surface water used for recreation and tourism above recognized effect thresholds (Table F-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 35 percent as compared to on-water mechanical recovery alone (Table F-II.2-5). This results in a risk factor rating of 0.66 for recreation and tourism under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 15 percent as compared to the low dispersant efficiency response option (Table F-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating for recreation and tourism decreases to 0.58 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on recreation and tourism would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to recreation and tourism for this scenario.

Summary of the Consequences for Recreation and Tourism in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 435 to 500 km^2 (165.7 to 193 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 35 to 43 percent, the level of dispersant efficiency does not greatly affect the level of concern about recreation and tourism in this spill scenario.

F.4.3.9 Environmental Justice

Low-income, indigenous, and minority sub populations in some coastal areas may rely on regional fisheries for subsistence or on tourism, recreation or other marine-resource related industry for employment. These groups may experience the effects of a spill more severely than the general population, which relies on a more diverse economic base for their livelihoods and on the availability of a widespread and commercially available selection of foods.

As described in Part A, the amount of surface water oiled above selected thresholds is used to represent the risk of socioeconomic effects to environmental justice in Prince William Sound under various spill response options. The model results are presented in Appendix F-II.2, Tables F-II.2-4 to F-II.2-6, and are based on an effect threshold for surface water of 0.01 g/m^2. From the model results, risk is then expressed in terms of surface water area affected under the recovery scenarios relative to that affected under on-water mechanical recovery only. In this manner, the metric indicates the potential benefit to environmental justice of response options other than on-water mechanical recovery.

Results of On-Water Mechanical Recovery Only
Given the use of on-water mechanical recovery only, the average large size spill in Prince William Sound is expected to adversely effect approximately 770 km^2 (297.3 mi^2) of surface water above recognized effect thresholds (Table F-II.2-4).

Results of the Addition of a Dispersant Response at Low Efficiency
Under the large volume spill scenario and 45 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 35 percent as compared to on-water mechanical recovery alone (Table F-II.2-5). This results in a risk factor rating of 0.66 for surface water resources under this scenario.

Results of the Addition of a Dispersant Response at High Efficiency
Under the large volume spill scenario and 80 percent dispersant efficiency response option, the average area of surface water exceeding the 0.01 g/m^2 effect threshold for all model runs was reduced by approximately 15 percent as compared to the low dispersant efficiency response option (Table F-II.2-6). Because the adverse effect on surface water resources is less with higher dispersant efficiency, the risk factor rating decreased to 0.58 for this scenario.

Results of the Addition of an On-Water ISB Response
Under the large volume spill scenario and the ISB response option, effects on environmental justice would be similar to the on-water mechanical recovery only response option. Therefore, a risk factor of 1.0 was assigned to environmental justice for this scenario.

Summary of the Consequences for Environmental Justice in the Large Volume Scenarios
Under the large volume spill scenario, dispersant use limits the effects from an average large size spill to approximately 435 to 500 km^2 (165.7 to 193 mi^2) of surface water. While the use of dispersants is projected to likely lessen the surface water area affected by approximately 35 to 43 percent, the level of dispersant efficiency does not greatly affect the level of concern about environmental justice in this spill scenario.

F.5 SUMMARY CONCLUSIONS

For the moderate (2500 bbl) spill (Table F.5-1) the level of concern predicted for the average spill remains low in all cases for all environmental resources except for marine and coastal birds, which are predicted to be at moderate risk. Dispersant use at high efficiency (but not low) reduced the proportion of the population likely to be affected for marine and coastal birds, but this benefit was not sufficient to change the overall level of concern. Using dispersants did not increase the risk to water quality or water column resources (plankton and fish or subtidal habitat), and it did benefit intertidal habitats, but the risk was already low. The use of ISB does not change the predicted risk to the environment when compared to on-water mechanical recovery alone, because it results in the treatment of an equivalent volume of spilled oil. These results reflect the limited spill volume, local conditions, and the large volume available for dilution.

When the spill size increases to 40,000 bbl (large spill scenario, Table F.5-2) the expected effects also increase. The average model results suggest that now, with only on-water mechanical recovery, intertidal habitat and marine and coastal birds are likely to be at high risk, while marine mammals are at moderate risk. The use of dispersants reduces the risks likely to occur to these resources, but marine and coastal birds remain at high risk. While this benefit does not eliminate the risk, it does improve the situation without an increase in the risk to plankton and fish in open water areas. In this case, the average changes in effects for a high efficiency dispersant application were not greatly different than the low efficiency option. This reflects the fact that, under the assumed conditions, sufficient supplies of dispersant are available to achieve the maximum level of dispersion, regardless of which efficiency is assumed. Coastal water quality could be affected by dispersant use and become a moderate concern, but only if most of the dispersed oil plume was to enter shallow water, a situation highly unlikely to occur in Prince William Sound. Again, the use of ISB does not change the results from those predicted with only on-water mechanical recovery.

Examination of the entire suite of model runs indicates that the range of effects to resources of concern is highly variable, which reflects the dynamic nature of oil spills. For example, for the medium spill oil reached the shore in all 100 simulations with only on-water mechanical recovery, while no oil reached the shore 32 out of 100 times with dispersant use at low efficiency and to 39 out of 100 times with dispersant use at high efficiency. Alternatively, also for the medium spill, the maximum shoreline oiling length predicted for on-water recovery only was 62.1 km (38.6 mi), just over 2.5 times the average. Similar observations can be made for other exposure indices. The same pattern exists for the large spill results, and in many cases the relative relationships are quite similar. These model results are consistent with observed effects from spills that originate offshore and with the expected impacts described in Section 4.3 of the PEIS.

With respect to socioeconomic resources, the use of dispersants would limit the effects of the spill in all cases.

Table F.5-1 Risk Ranking for Medium (2,500 bbl) Spills at the Prince William Sound Location

	Physical Environment			Biological Environment								Socioeconomic Environment			
Response Option	Coastal Water Quality	Marine Water Quality	Air Quality	Intertidal Habitat	Marine and Coastal Birds	Marine Mammals	Sea Turtles	Plankton and Fish	Subtidal Benthic Habitat	Biological Areas of Special Concern	Essential Fish Habitat	Subsistence	Cultural Resources	Shoreline Oiling Index	Surface Water Oiling Index
On-Water Mechanical Recovery	4E	4E	4E	3E	2C	3E		4E	4E	3E	4E	4E	4E		1.0
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	4D	4E	4E	4E	2C	3E		4E	4E	4E	4E	4E	4E		0.57
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	4D	4E	4E	4E	2D	3E		4E	4E	4E	4E	4E	4E		0.55
On-Water Mechanical Recovery and In-Situ Burning	4E	4E	4E	3E	2C	3E		4E	4E	3E	4E	4E	4E		1.0

Legend: Black cells represent a “high” level of concern, medium gray cells represent a “moderate” level of concern, and light gray cells represent a “limited” level of concern.

Table F.5-2 Risk Ranking for Large (40,000 bbl) Spills at the Prince William Sound Location

	Physical Environment			Biological Environment								Socioeconomic Environment			
Response Option	Coastal Water Quality	Marine Water Quality	Air Quality	Intertidal Habitat	Marine and Coastal Birds	Marine Mammals	Sea Turtles	Plankton and Fish	Subtidal Benthic Habitat	Biological Areas of Special Concern	Essential Fish Habitat	Subsistence	Cultural Resources	Shoreline Oiling Index	Surface Water Oiling Index
On-Water Mechanical Recovery	4D	4E	4E	1D	2A	2D		4E	4E	2D	4E	4D	4E		1.0
On-Water Mechanical Recovery and Dispersant Application (45% Efficiency)	4B	4E	4E	1E	2B	2D		4E	4E	2E	4E	4D	4E		0.66
On-Water Mechanical Recovery and Dispersant Application (80% Efficiency)	4B	4E	4E	2E	2B	2E		4E	4E	2E	4E	4D	4E		0.58
On-Water Mechanical Recovery and In-Situ Burning	4D	4E	4E	1D	2A	2D		4E	4E	2D	4E	4D	4E		1.0

Legend: Black cells represent a "high" level of concern, medium gray cells represent a "moderate" level of concern, and light gray cells represent a "limited" level of concern.

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Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part F: Prince William Sound

Sections F-I.1 – F-I.4

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ASA 00-246

August 2004

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F-I. Oil Spill Model Input Data

This appendix contains model input data (in maps, figures and tables) for the modeled location in Prince William Sound (Alaska) and the sources for that information. The approach and sources applicable to all modeled locations are described in Part A, Section A.3 of this technical report. Specifics to this model location are below. Thus, the reader should refer to Part A, Section A.3 for background and the context within which these data are used.

F-I.1 Geographical Data Input to the Model

Geographic data for the modeled location are presented in this section. The sources for these data are described in Part A, Section A.3.1. A map is also presented below showing areas where dispersant application was assumed in model simulations. The assumptions for the dispersant application scenarios are in Part A, Section A.3.7. The crosshair mark (⊞) in the figures below represents the assumed oil spill site for the model simulations.

F-I.1.1 Maps of the Vicinity of the Spill Site

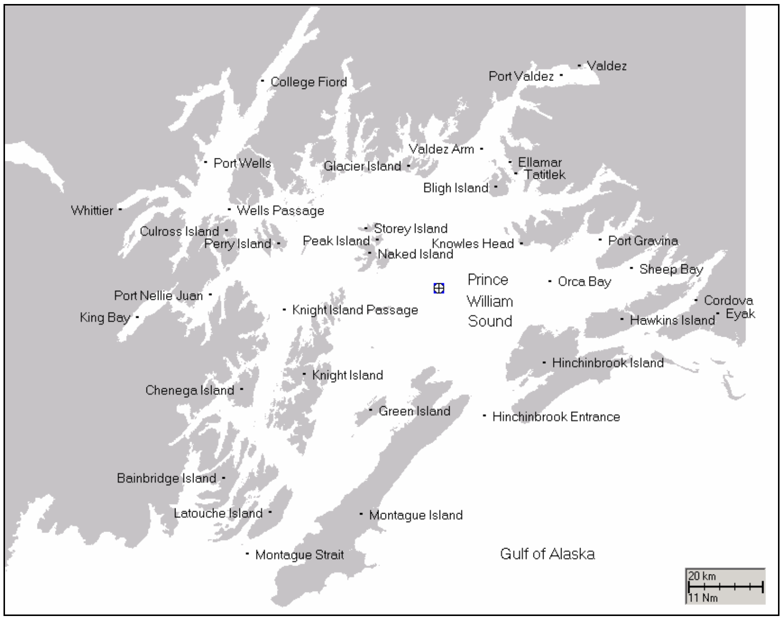

Figure F-I.1.1-1 Map of spill site and location names used in the text (entire grid).

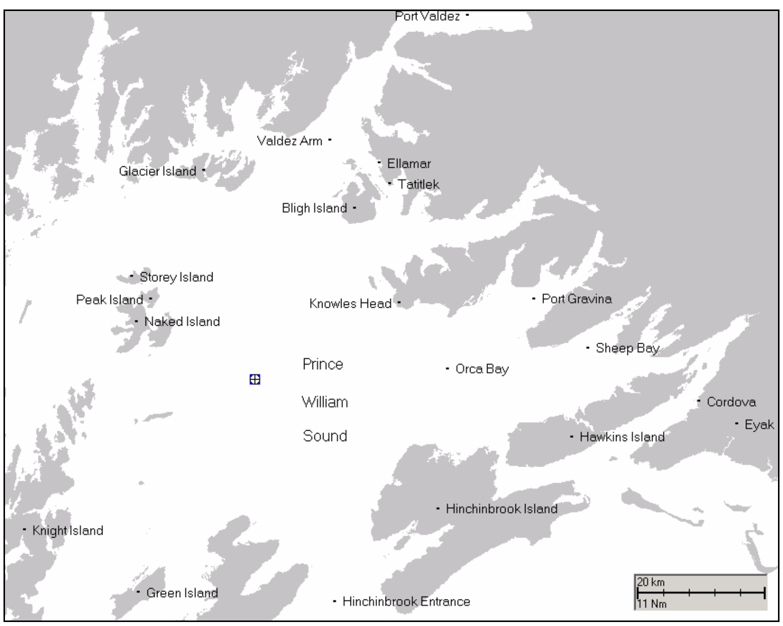

Figure F-I.1.1-2 Map of spill site and location names used in the text (central Prince William Sound).

F-I.1.2 Gridded Depth Data

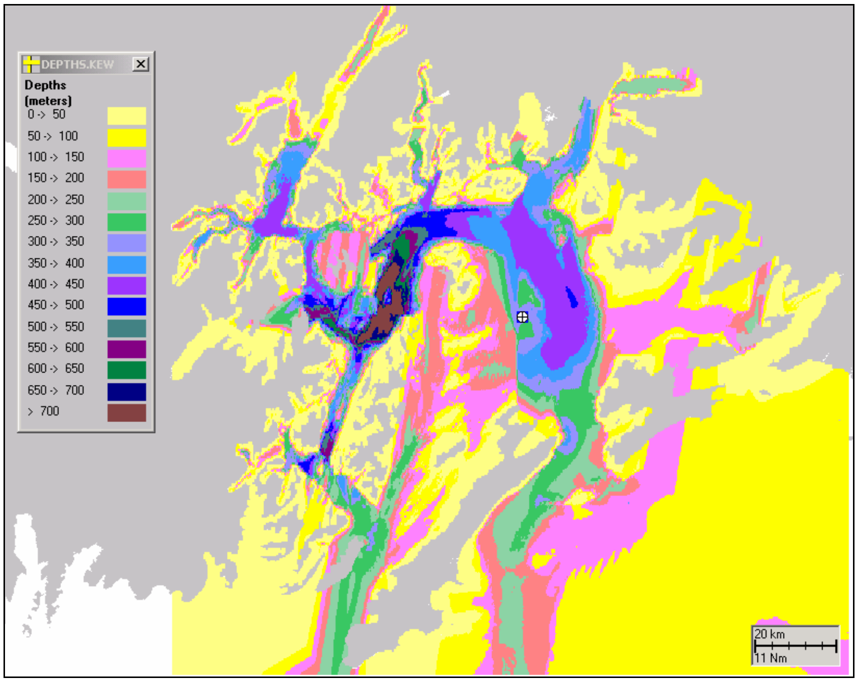

Figure F-I.1.2-1 Gridded depth data used in model runs (entire grid).

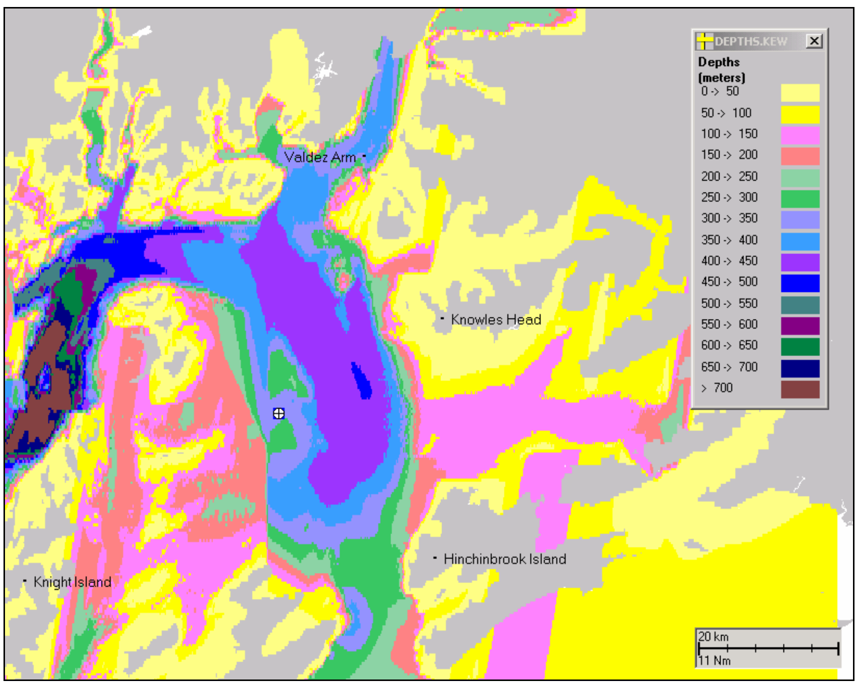

Figure F-I.1.2-2 Gridded depth data used in model runs (central Prince William Sound).

F-I.1.3 Gridded Habitat Mapping

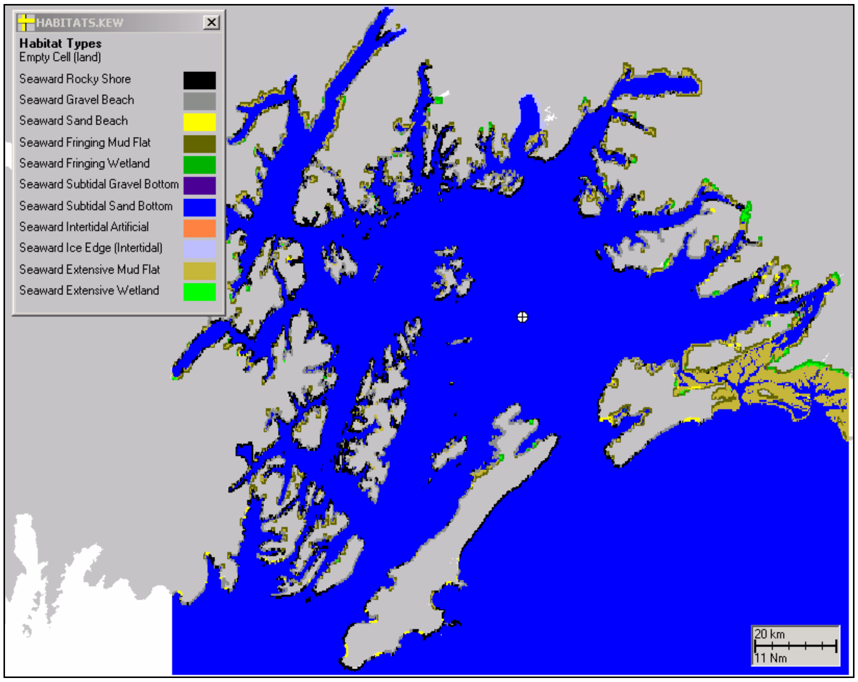

Figure F-I.1.3-1 Gridded habitat map used in model runs (entire grid).

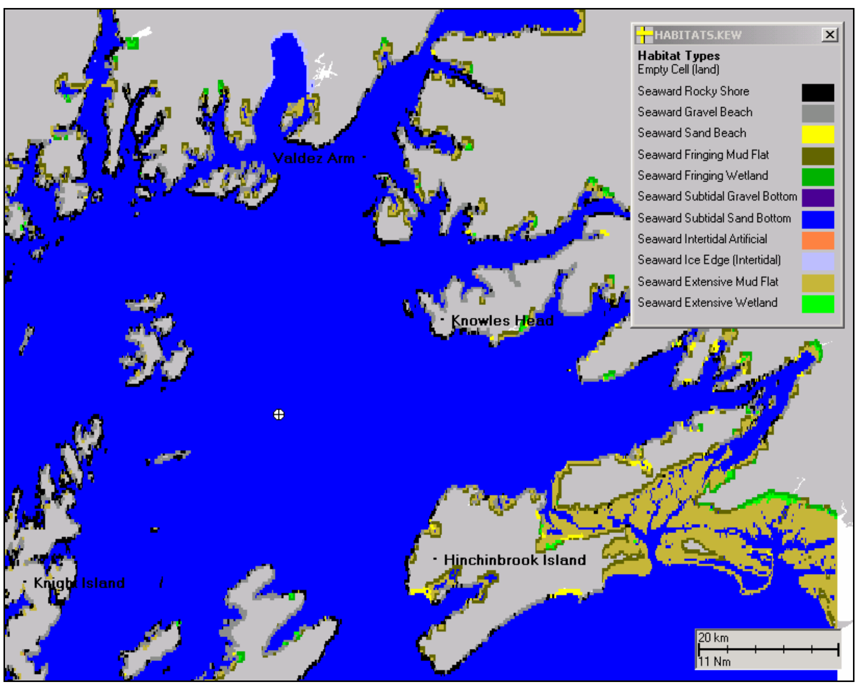

Figure F-I.1.3-2 Gridded habitat map used in model runs (central Prince William Sound).

F-I.1.4 Dispersant Application Areas for Response

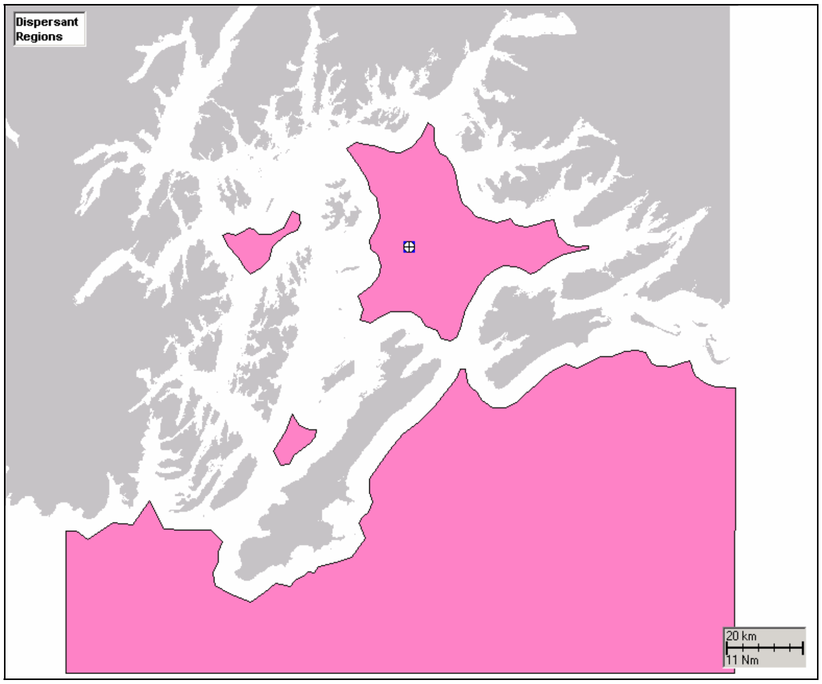

Figure F-I.1-4.1 Map of dispersant application areas (blue shaded area is where dispersants are assumed applied).

F-I.2 Current Data

Current data used in the simulations were developed previously for inclusion in the version of SIMAP used by Alyeska Pipeline Company, called the Alyeska Tactical Oil spill Model (ATOM), as described in Anderson et al. (1990). The modeling domain included all of Prince William Sound (PWS), with the boundary defined at the two entrances to PWS, Hinchinbrook Entrance and Montague Strait (Figure F-I.1.1-1).

For simulation of currents, tides were forced at these two entrances to PWS. The forcing functions applied were for the major harmonic constituent (M_2) derived from the larger-domain hydrodynamic model application for the Gulf of Alaska by Isaji and Spaulding (1987). Section F-I.2.2 contains plots of the tidal current vectors for a tidal cycle. The times of high and low tide, and of maximum flood and ebb tide, were based on tidal data for Knowles Head (Figures F-I.1.1-1, F-I.1.1-2, and Figures F-I.2.2-1 to -12).

A mean non-tidal current for each season was also simulated (Figure F-I.2.1-1), using seasonal mean water levels based on observations for forcing. Of the four seasonal non-tidal current patterns, the spring pattern was intermediate in current speeds. Thus, the spring pattern was used in the simulations performed here.

The crosshair mark ( ) in the figures below represents the oil spill site.

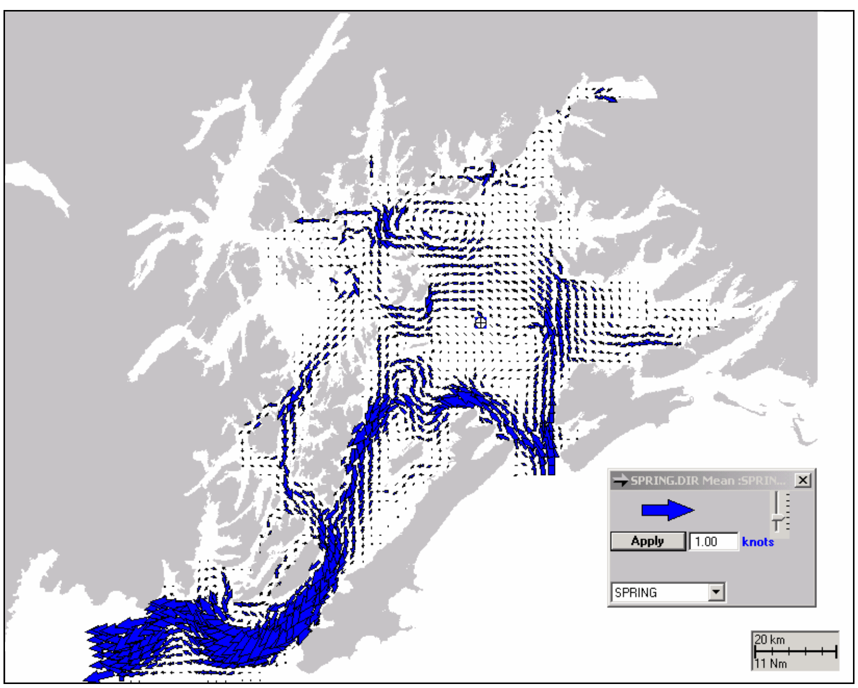

Figure F-I.2-1. Non-tidal current components used in oil model runs (mean for spring season in PWS).

F-I.2.1 Current Vector Plots at Selected Times

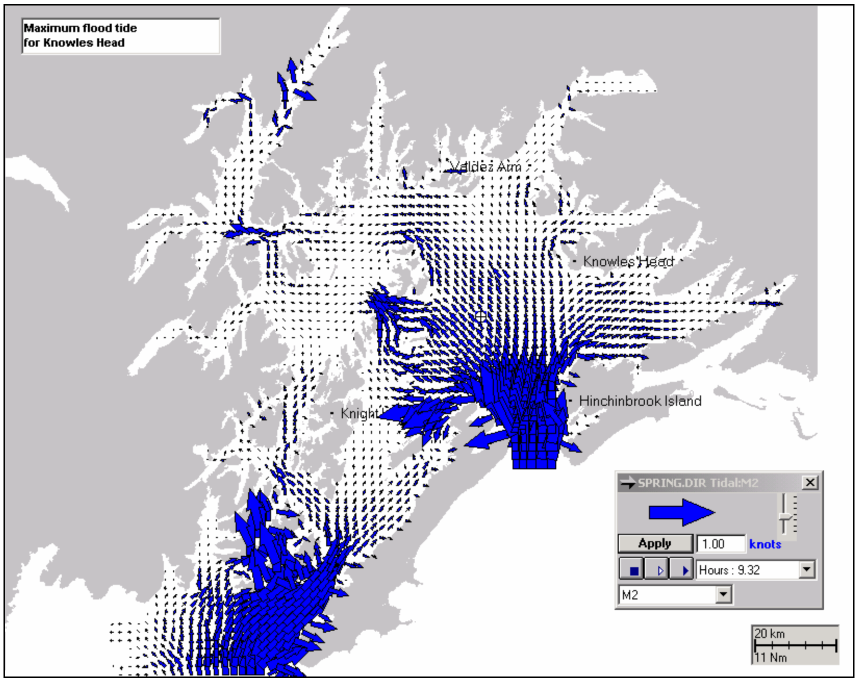

Figure F-I.2.1-1 Current vectors at maximum flood tide (entire grid).

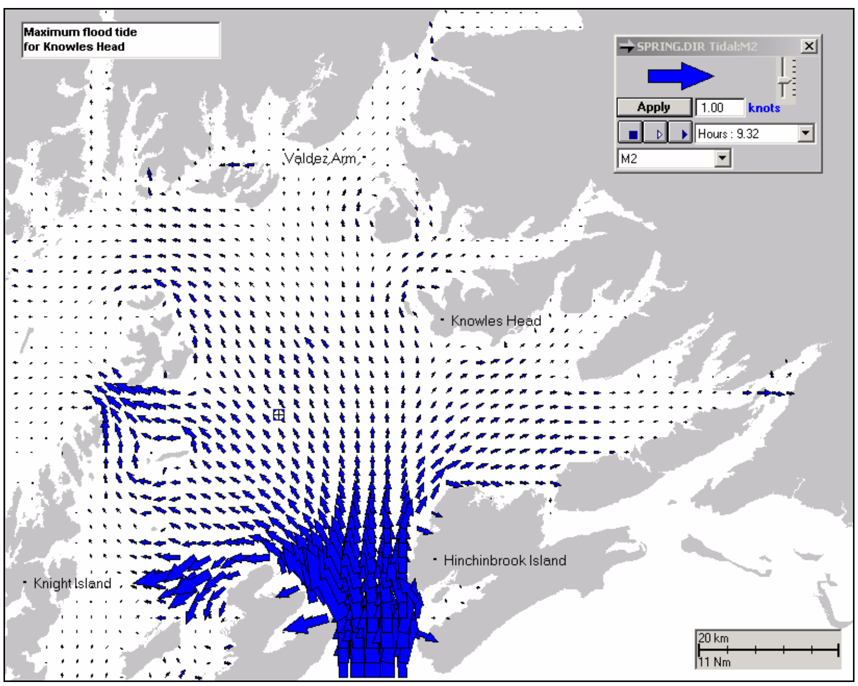

Figure F-I.2.1-2 Current vectors at maximum flood tide (central Prince William Sound).

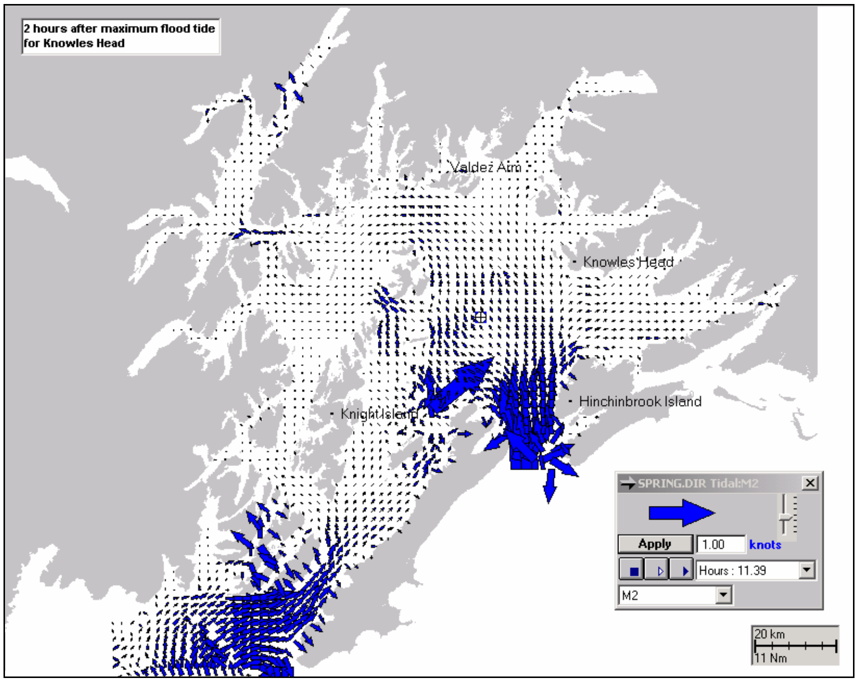

Figure F-I.2.1-3 Current vectors at 2 hours after maximum flood tide (entire grid).

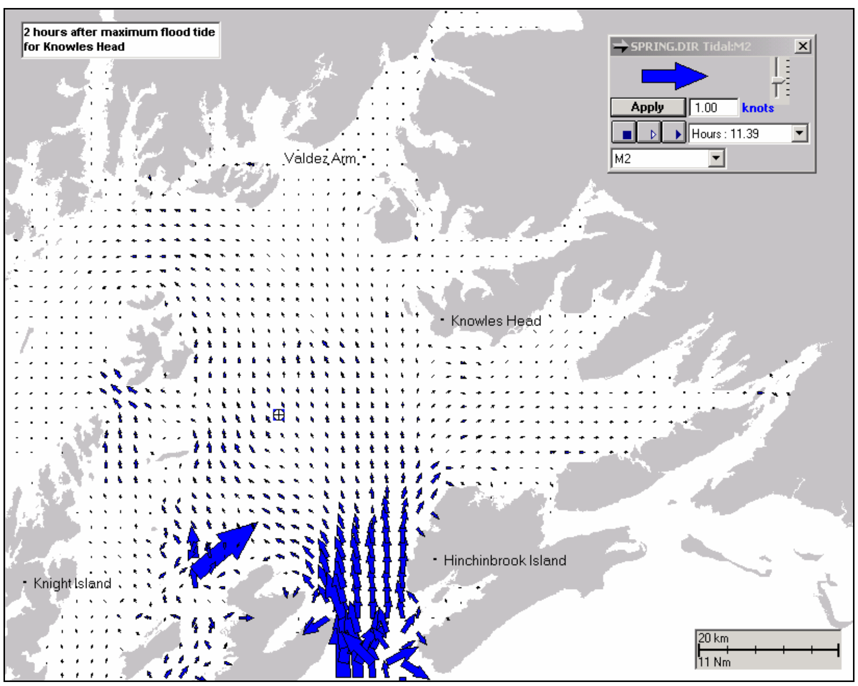

Figure F-I.2.1-4 Current vectors at 2 hours after maximum flood tide (central Prince William Sound).

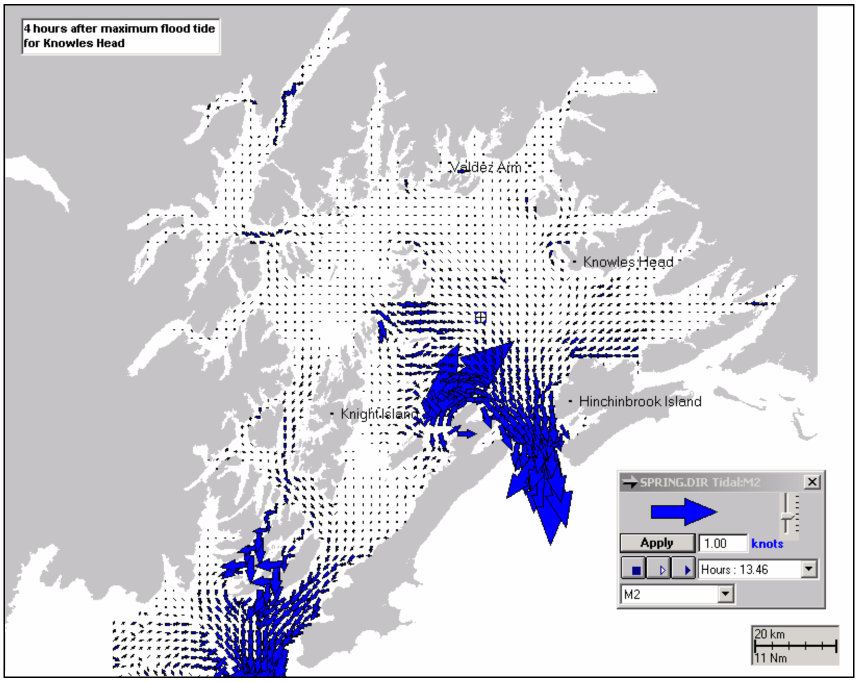

Figure F-I.2.1-5 Current vectors at 4 hours after maximum flood tide (entire grid).

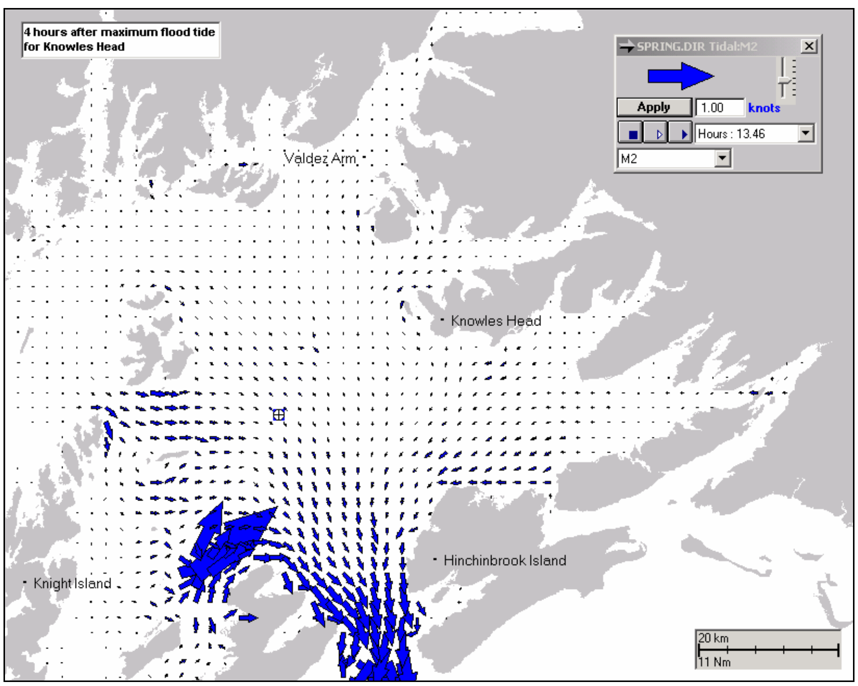

Figure F-I.2.1-6 Current vectors at 4 hours after maximum flood tide (central Prince William Sound).

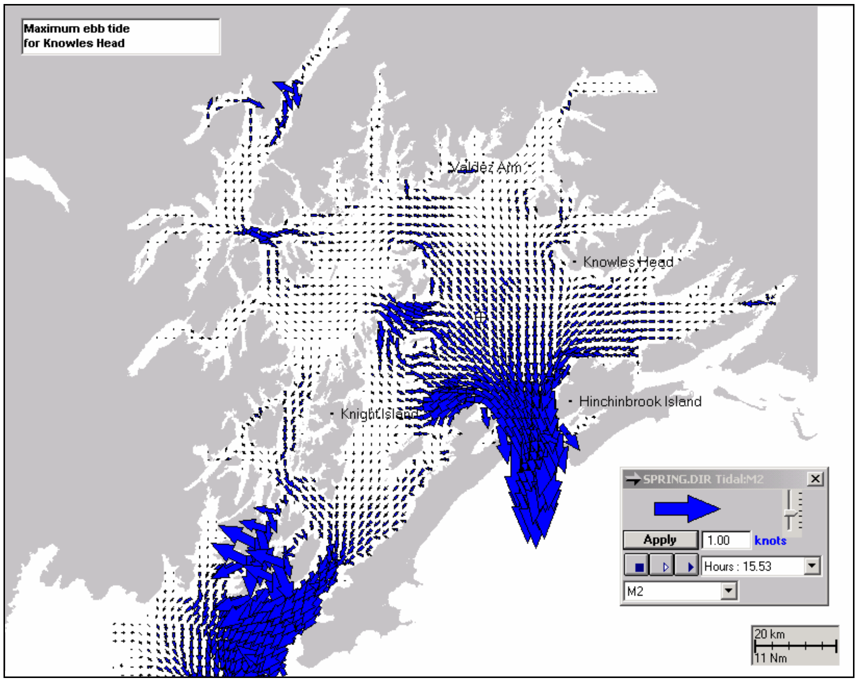

Figure F-I.2.1-7 Current vectors at maximum ebb tide (entire grid).

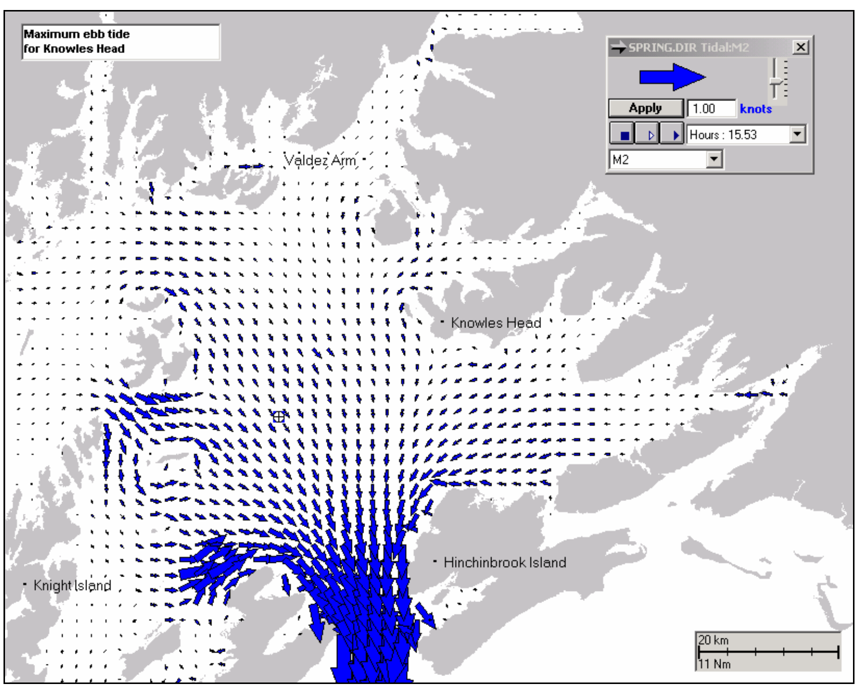

Figure F-I.2.1-8 Current vectors at maximum ebb tide (central Prince William Sound).

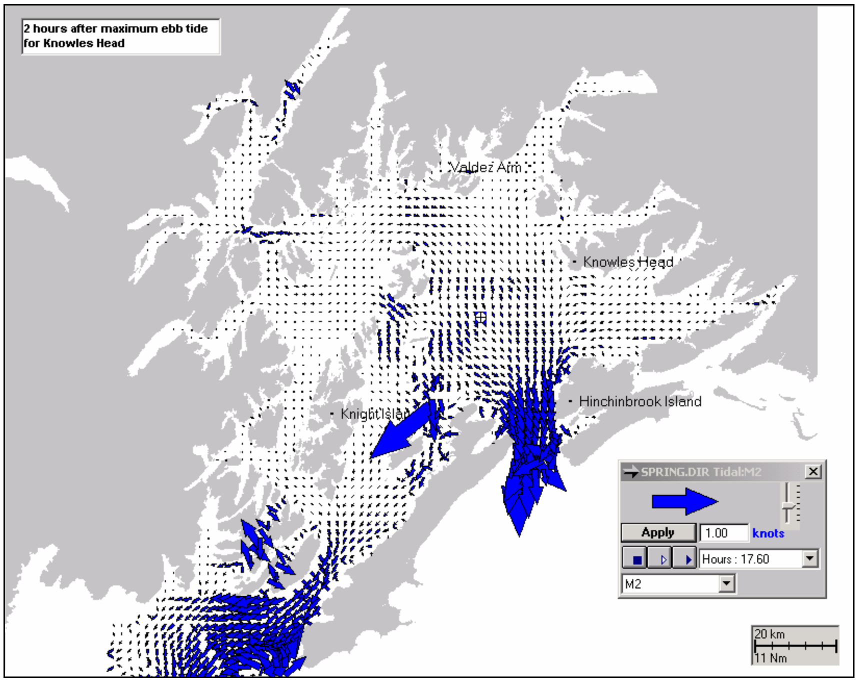

Figure F-I.2.1-9 Current vectors at 2 hours after maximum ebb tide (entire grid).

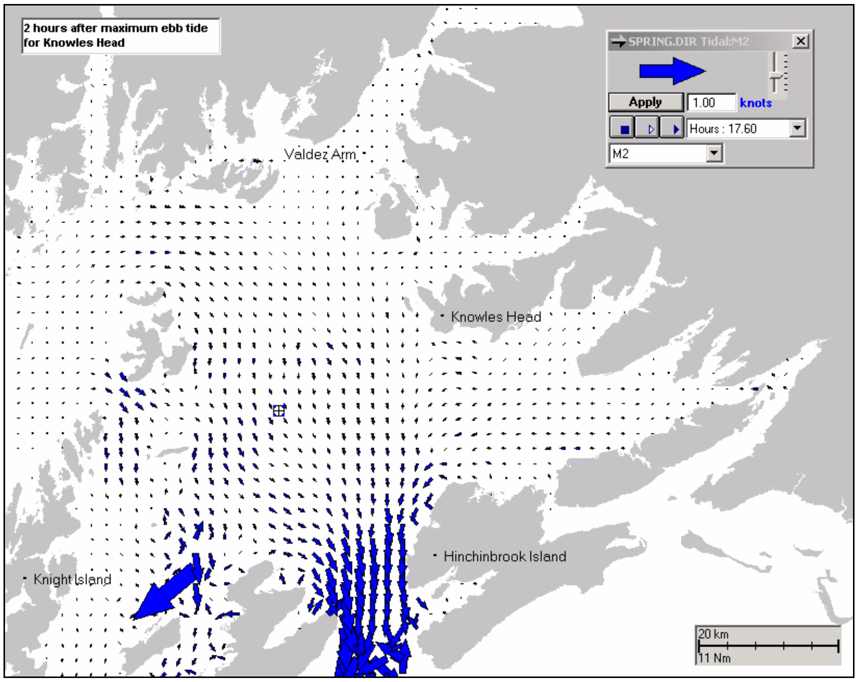

Figure F-I.2.1-10 Current vectors at 2 hours after maximum ebb tide (central Prince William Sound).

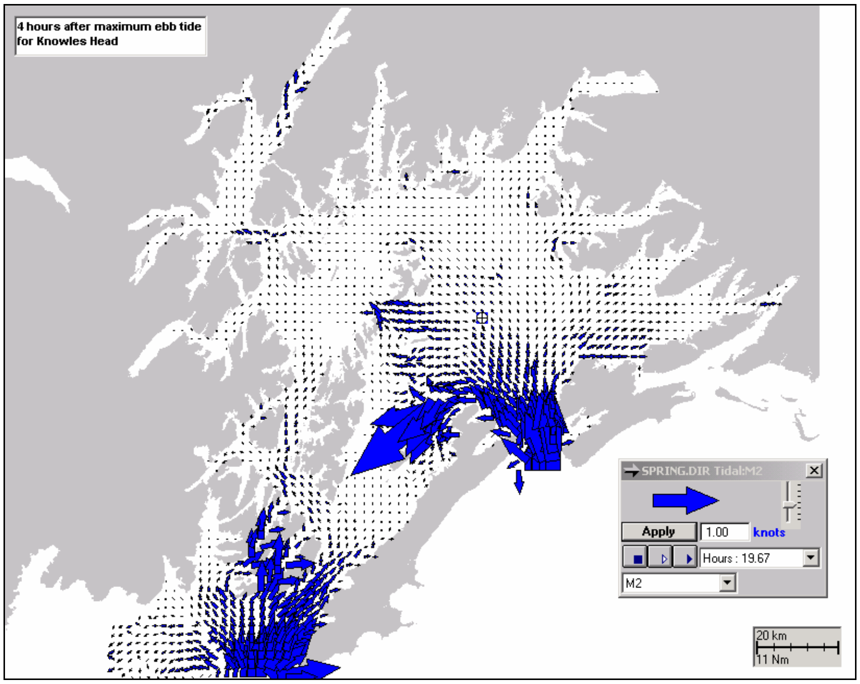

Figure F-I.2.1-11 Current vectors at 4 hours after maximum ebb tide (entire grid).

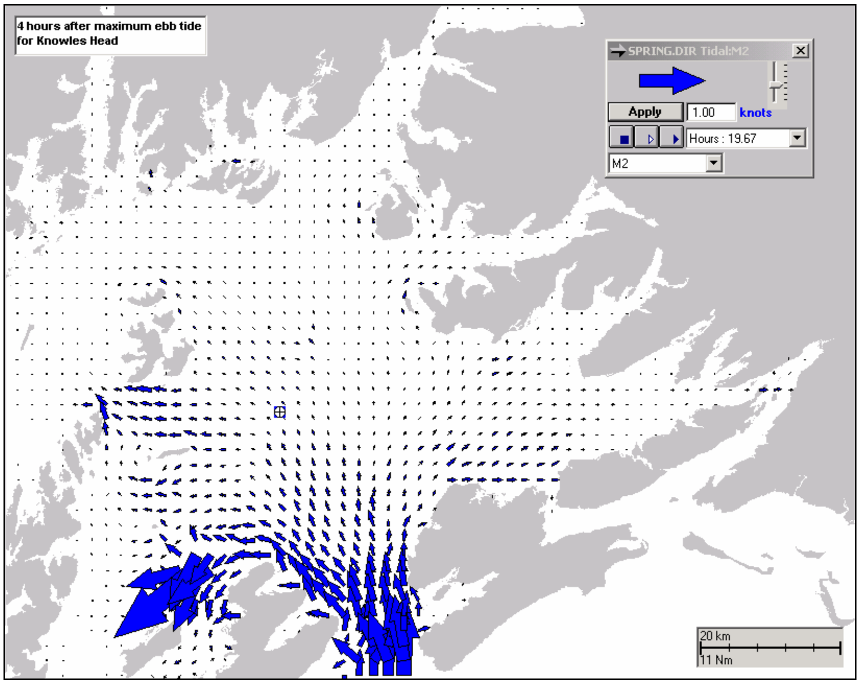

Figure F-I.2.1-12 Current vectors at 4 hours after maximum ebb tide (central Prince William Sound).

F-I.3 Oil Properties

Table F-I.3-1. Oil properties for Alaskan North Slope crude oil assumed in the modeling.

Property	Value	Reference
Density @ 25 deg. C (g/cm3)	0.8761	Jokuty et al. (1999)
Viscosity @ 25 deg. C (cp)	16	Jokuty et al. (1999)
Surface Tension (dyne/cm)	27	Jokuty et al. (1999)
Pour Point (deg. C)	-54	Jokuty et al. (1999)
Adsorption Rate to Suspended Sediment	0.01008	Kolpack et al. (1977)
Adsorption Salinity Coef.(/ppt)	0.023	Kolpack et al. (1977)
Fraction monoaromatic hydrocarbons (MAHs)	0.030662	Jokuty et al. (1999)
Fraction polynuclear aromatic hydrocarbons (PAHs)	0.010372	A.D. Little (1996)
Fraction 2-ring aromatics (included in PAHs above)	0.00375	A.D. Little (1996)
Fraction 3-ring aromatics (included in PAHs above)	0.006622	A.D. Little (1996)
Fraction Non-Aromatic Volatiles: boiling point < $180^{o}C$	0.189338	Jokuty et al. (1999)[1]
Fraction Non-Aromatic Volatiles: boiling point $180\text{-}264^{o}C$	0.13325	Jokuty et al. (1999)[1]
Fraction Non-Aromatic Volatiles: boiling point $264\text{-}380^{o}C$	0.200378	Jokuty et al. (1999)[1]
Minimum Oil Thickness (m)	0.00005	McAuliffe (1987)
Maximum Mousse Water Content (%)	70	Jokuty et al. (1999)[2]; NOAA (2000a)[2]
Mousse Water Content as Spilled (%)	0	French et al. (1996b)
Water content of fuel (not in mousse, %)	0	French et al. (1996b)
Degradation Rate (/day), Surface & Shore	0.01	National Research Council (1985)
Degradation Rate (/day), Hydrocarbons in Water	0.01	National Research Council (1985)
Degradation Rate (/day), Oil in Sediment	0.001	Haines and Atlas (1982)
Degradation Rate (/day), Aromatics in Water	0.01	French et al. (1996b)
Degradation Rate (/day), Aromatics in Sediment	0.001	French et al. (1996b)

[1] – Jokuty et al. (1999) provided total hydrocarbon data. The aromatic hydrocarbon fraction was subtracted from the total hydrocarbon fraction to obtain the aliphatic fraction.
[2] – Mid-value used.

Table F-I.3-2. Aromatic concentrations (mg/kg) for Alaskan North Slope crude oil.

Aromatic	Log(K_{ow})*	Concentration (mg/kg)
benzene	2.13	3,698
toluene	2.69	9,040
ethylbenzene	3.13	1,689
o-xylene	3.15	0
p-xylene	3.18	0
m-xylene	3.2	0
xylenes	3.18	8,197
1,2,3-trimethylbenzene	3.55	1,004.75
1,2,4-trimethylbenzene	3.6	1,004.75
1,3,4-trimethylbenzene	3.6	1,004.75
1,3,5-trimethylbenzene	3.58	1,004.75
trimethylbenzenes	3.58	1,004.75
n-propylbenzene	3.69	1,004.75
iso-propylbenzene	3.63	1,004.75
ethyl-methylbenzenes	3.63	1,004.75
iso-propyl-4-methylbenzene	4.10	0
butylbenzenes	4.12	0
tetramethylbenzenes	4.01	0
styrene	3.05	0
methylstyrenes	3.35	0
tetralin	3.83	0
diphenylmethane	4.14	0
naphthalene	3.37	650
C1-naphthalenes	3.87	1,300
C2-naphthalenes	4.37	1,800
C3-naphthalenes	5.00	1,400
C4-naphthalenes	5.55	850
acenaphthylene	4.07	0
acenaphthene	3.92	0
biphenyls	3.9	180
dibenzofuran	4.31	0
fluorene	4.18	82
C1-fluorenes	4.97	220
C2-fluorenes	5.20	260
C3-fluorenes	5.50	280

*Estimates of log(K_{ow}) are from Mackay et al. (1992a,b) and Neff and Burns (1996).

Table F-I.3-2. Aromatic concentrations (mg/kg) for Alaskan North Slope crude oil (continued).

Aromatic	Log(Kow)*	Concentration (mg/kg)
anthracene	4.54	0
phenanthrene	4.57	230
C1-phenanthrenes/ anthracenes	4.49	430
C2-phenanthrenes/ anthracenes	5.14	490
C3-phenanthrenes/ anthracenes	5.25	380
C4-phenanthrenes/ anthracenes	6.00	260
dibenzothiophene	6.51	200
C1-dibenzothiophene	4.49	360
C2-dibenzothiophene	4.86	540
C3-dibenzothiophene	5.50	460
fluoranthene	5.73	0
pyrene	5.22	0
Total $\log(K_{ow}) \leq 5.6$	5.18	9,272

*Estimates of $\log(K_{ow})$ are from Mackay et al. (1992a,b) and Neff and Burns (1996).

F-I.4 Inputs to the SIMAP Oil Spill Model

This section summarizes the model input data for the scenarios run and the sources for that information. The approach and sources applicable to all modeled locations are described in Part A, Section A.3 of this technical report. Specifics to this model location are below. Thus, the reader should refer to Part A, Section A.3 for background and the context within which these data are used.

The model grid and cell size (Table F-I.4-4) were set to provide the maximum resolution (minimum cell size) possible within the memory constraints of the model, while also providing sufficient geographic coverage to encompass the maximum extent of oiling possible for a large volume scenario. Test runs (randomizing weather conditions) were made with the largest spill volume simulated (40,000 bbl) and assuming no dispersant application. The maximum extent of surface oiling was determined and the grid size set to cover that area (Figure F-I.1.3-1). While it is possible that oil would exit Prince William Sound, as it did in the *Exxon Valdez* oil spill, the likelihood of this happening for the 40,000 bbl spill was very low. A larger grid could have been used, but at the expense of loosing resolution of the potential impacts in Prince William Sound. Thus, the choice was made to use high resolution in Prince William Sound to be able to quantify the potential impacts more accurately than would have been possible otherwise.

Table F-I.4-1. Inputs to the Fates Model for Stochastic Scenarios.

Name	Description	Units	Source(s) of Information	Value(s)
Spill Site(s)	Location of the spill site	-	(Part A, Section A.3.6)	At Midpoint in PWS, in traffic lane.
Spill Latitude	Latitude of the spill site	Degrees	Chart (Part A, Section A.3.6)	60^o 34.728' N
Spill Longitude	Longitude of the spill site	Degrees	Chart (Part A, Section A.3.6)	146^o 4.41' W
Depth of release	Depth below the water surface of the release or 0 for surface release	m	assumed (Part A, Section A.3.6)	0 m
Start time and date	Randomized over selected months of the year	Date, hr,min	randomized (Part A, Section A.2.4)	Jan-Dec
Spill duration	Hours over which the release occurs	Hours	(Part A, Section A.3.6)	Large – 4 Small – 1
Total spill amount	Total volume (or weight) released (maximum if range)	bbl	(Part A, Section A.3.6)	Large – 40,000 Small – 2,500
Randomize spill amount	Volume spilled is constant or maximum of range	-	-	Constant
Model time step	Time step used for model calculations	Hours	(Part A, Section A.2.1)	0.2
Model duration	Length of each model simulation	Days	(Part A, Section A.3.6)	14 days
Number of runs	Number of random start times to run in stochastic mode	#	(Part A, Section A.2.4)	100
Number of surface spillets	Number of Lagrangian elements used to simulate mass floating on the surface	#	(Part A, Section A.2)	500
Number of aromatic spillets	Number of Lagrangian elements used to simulate dissolved aromatics in the water	#	(Part A, Section A.2)	2000

Table F-I.4-1. Inputs to the Fates Model for Stochastic Scenarios (continued).

Fates Output Threshold: floating on water surface	Slick or surface mass thickness passing through a grid cell	g/m^2 (microns)	Minimum value for sheens (Part A, Section A.4.1)	0.01
Fates Output Threshold: shoreline	Total hydrocarbons deposited on shorelines, averaged over each habitat grid cell.	g/m^2 (microns)	Minimum value for sheens (Part A, Section A.4.1)	0.01
Fates Output Threshold: dissolved aromatics in water or sediment	Dissolved concentration of aromatics with $\log(K_{ow}) \leq 5.6$ (bioavailable fraction)	mg/m^3 = µg/L = ppb	Below minimum for effects to sensitive species exposed for at least two weeks (Part A, Section A.4.1)	1
Fates Output Threshold: Subsurface (water) total hydrocarbons	Concentration of total hydrocarbons in droplets	mg/m^3 = µg/L = ppb	Minimum value with no potential for impact (Part A, Section A.4.1)	10
Fates Output Threshold: Sediment total hydrocarbons	Total hydrocarbon loading to sediments, averaged over each habitat grid cell.	g/m^2	Minimum value with no potential for impact (Part A, Section A.4.1)	0.0001 g/m^2 (which is 1.0 mg/m^3 = 1ppb averaged over the top 10cm)
Salinity	Surface water salinity	ppt	French et al. (1996b) province 55	36

Table F-I.4-1. Inputs to the Fates Model for Stochastic Scenarios (continued).

Surface Water Temper-ature	Water temperature at the sea surface	Degrees C	French et al. (1996b) province 55	monthly means (see Table F-I.4-5)
Subsurface Water Temper-ature	Water temperature for subsurface	Degrees C	French et al. (1996b) province 55	monthly means (see Table F-I.4-5)
Air Temper-ature	Air water temperature at water surface	Degrees C	(assume = water temperature; Part A, Section A.4.1)	(= water temperature)
Fetch	Fetch = distance to land to N, S, E, W (if landfall not in model domain)	km	Chart	(calculated from model grid)
Wind drift speed	Speed oil moves down wind relative to wind	% of wind speed	Youssef (1993); Youssef and Spaulding (1993)	(model calculated)
Wind drift angle	Angle to right of wind (in northern hemisphere) that oil drifts	Deg. to right of down wind	Youssef (1993); Youssef and Spaulding (1993, 1994)	(model calculated)
Horizontal turbulent diffusion coefficient	Randomized turbulent mixing parameter in x & y	m^2/sec	French et al. (1996, 1999) based on Okubo (1971)	1 m^2/sec (estuaries and low energy coastal areas)
Vertical turbulent diffusion coefficient	Randomized turbulent mixing parameter in z	m^2/sec	French et al. (1996, 1999) based on Okubo (1971)	0.0001 m^2/sec
Suspended sediment concentrati on	Average suspended sediment concentration during spill period	mg/l	French et al. (1996b)	10 mg/l
Suspended sediment settling rate	Net settling rate for suspended sediments	m/day	French et al. (1996b)	1 m/day
Density change	Rate of change of droplet density due to adsorption of sediment	g/cm^3/hr	(data not available – fuel oil algorithm used)	0

Table F-I.4-2. Description of scenario runs.

Scenario Name	Description
PWS-Lrg-50-0	Large Spill; Removal at 50%; No Dispersant;
PWS-Lrg-50-80	Large Spill; Removal at 50%; Dispersant at 80% efficiency;
PWS-Lrg-50-45	Large Spill; Removal at 50%; Dispersant at 45% efficiency;
PWS-Med-50-0	Medium Spill; Removal at 50%; No Dispersant;
PWS-Med-50-80	Medium Spill; Removal at 50%; Dispersant at 80% efficiency;
PWS-Med-50-45	Medium Spill; Removal at 50%; Dispersant at 45% efficiency;

Table F-I.4-3. Matrix of scenarios run.

Scenario Name	Oil	Latitude, Longitude	Depth (m)	Duration (hr)	Volume (bbl) Released	Mechanical Removal Efficiency	Dispersant Efficiency
PWS-Lrg-50-0	Alaskan North Slope crude	60.57880 N 147.0735 W	0 m (surface)	4	40,000	50%	none
PWS-Lrg-50-80	Alaskan North Slope crude	60.57880 N 147.0735 W	0 m (surface)	4	40,000	50%	80%
PWS-Lrg-50-45	Alaskan North Slope crude	60.57880 N 147.0735 W	0 m (surface)	4	40,000	50%	45%
PWS-Med-50-0	Alaskan North Slope crude	60.57880 N 147.0735 W	0 m (surface)	1	2,500	50%	none
PWS-Med-50-80	Alaskan North Slope crude	60.57880 N 147.0735 W	0 m (surface)	1	2,500	50%	80%
PWS-Med-50-45	Alaskan North Slope crude	60.57880 N 147.0735 W	0 m (surface)	1	2,500	50%	45%

Table F-I.4-4. Dimensions of the habitat grid cells used to compile statistics for multiple fates model runs.

Item	Value
Grid W edge	148.709°W
Grid S edge	59.751 °N
Cell size (°longitude)	0.003505
Cell size (°latitude)	0.003505
Cell size (m) west-east	195.99
Cell size (m) south-north	389.05
# cells west-east	897
# cells south-north	439
Water cell area (m^2)	76,249.86
Shore cell length (m)	276.13
Shore cell width – Rocky shore (m)	3.0
Shore cell width – Artificial shore (m)	3.0
Shore cell width – Gravel beach (m)	10.0
Shore cell width – Sand beach (m)	20.0
Shore cell width – Mud flat (m)	300.0
Shore cell width – Wetlands (fringing, m)	300.0

Table F-I.4-5. Water temperature by month of the year (from French et al., 1996b).

Month	Surface Water Temperature (°C)	Bottom Water Temperature (°C)	Pycnocline Depth (m)
January	7	4	20
February	7	4	20
March	7	4	20
April	7	5	20
May	8	5	20
June	10	5	20
July	12	6	10
August	14	6	10
September	14	6	10
October	12	5	20
November	10	5	20
December	8	5	20

Table F-I.4-6. Wind data sources and records used.

File Name	Location	Latitude Longitude	Dates	Data Source
46060-1995-2002.WNE	Station 46060 - North Prince William Sound	60.58 N 146.83 W	1995-2002	National Data Buoy Center

The 46060-1995-2002.WNE wind data was downloaded from one buoy Station 46060, North Prince William Sound. Figure F-I.4-1 displays where the buoy is located along with surrounding buoys. 46060-1995-2002.WNE data starts on 21 June 1995 and end on 30 April 2002. The wind data contains one gap larger than a day, 16 May 1995 to 21 June 1995.

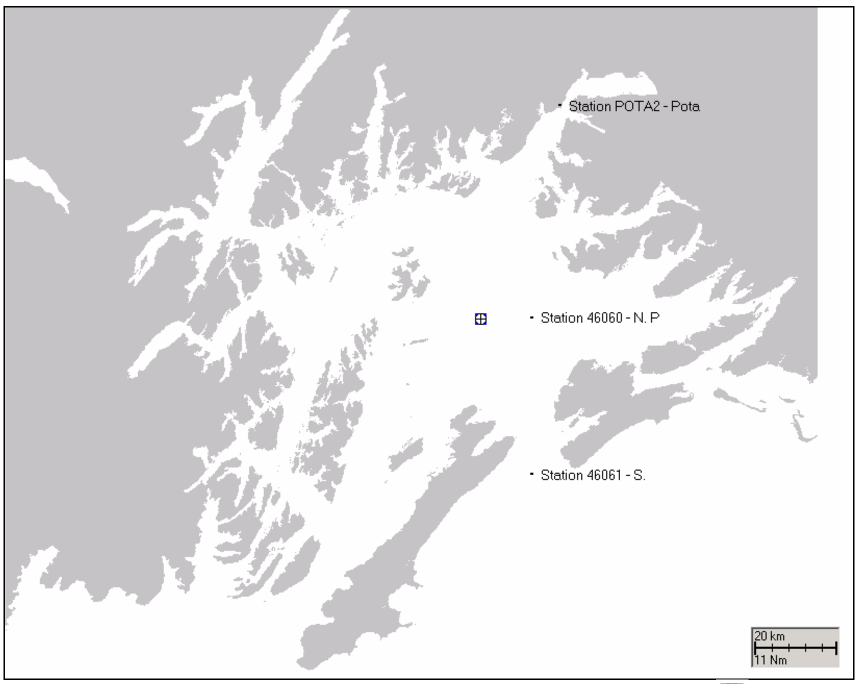

Figure F-I.4-1. Wind Station Locations. (The crosshair mark (⊞) represents the oil spill site.)

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part F: Prince William Sound

Section F-II.1

by

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ASA 00-246

August 2004

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F-II.1 Results of the Stochastic Modeling: Maps of Exposure Probability, Time and Maximum Possible Mass and Concentration

The results of multiple model runs are evaluated to develop the following statistics, for each location (cell in the model grid) and for each exposure index. Maps of the results are contained in this section.

- Probability of exposure greater than the minimum threshold (probability that the minimum threshold thickness or concentration will be exceeded at each location at any time following the spill). For surface oil, the model records if any oil of greater than that thickness passes through the grid cell, regardless of the areal coverage of the oil. For concentrations, the average concentration in the grid cell is used to determine if the threshold is exceeded.
- Time (hours) to first exceedance of the minimum threshold at each location
- Worst-case maximum exposure (thickness, volume or concentration) at any time after the spill, at a given location (peak exposure at each location delineated by the grid cells). The amounts are averaged over the area of the model grid cell. The worst-case maximum amount is for all possible releases (i.e., maximum peak exposure for all the model runs). This is calculated in two steps: (1) For each individual run (for each spill date run), the maximum amount over all time after the spill is saved for each location in the model grid. (2) The runs are evaluated to determine the highest amount possible at each location. Note that these *worst-case maximum* amounts are not additive over all locations. These represent maximum possible amounts of oil that could ever reach each site (grid cell), considered individually, and based on the model runs performed. Thus, "worst-case" represents the highest exposure of the most adverse of the runs performed.

Exposure indices and minimum thresholds (i.e., those less than values that might have an impact on any resource) used in the modeling were:

- Surface slick or floating oil: $\geq$ 0.01 g/m^2 (average thickness $\geq$ 0.01 micron)
- Shoreline: average mass loading over the shore segment (length of one grid cell, calculated as the cell diagonal length, times the typical width for the habitat type) $\geq$ 0.01 g/m^2
- Dissolved aromatics: average over the water cell $\geq$ 1 ppb (1 mg/m^3)
- Subsurface oil (entrained in water): average over the water cell $\geq$ 10 ppb (10 mg/m^3)
- Sediment total hydrocarbons: average over the cell $\geq$ 0.0001 g/ m^2
- Sediment dissolved aromatic concentrations: average over the cell $\geq$ 0.0001 g/ m^2 (which is 1.0 mg/m^3 = 1ppb averaged over the top 10 cm, the assumed bioturbation zone)

Discussion of exposure indices and minimum thresholds are described in Part A: Description of Models and Assumptions and Section 4.3 of the PEIS.
The Crosshair mark () in figures below represents oil spill site.

F-II.1.1. Scenario: Medium Volume, No Dispersant

F-II.1.1.1 Surface Floating Total Hydrocarbons. Scenario: Medium Volume, No Dispersant

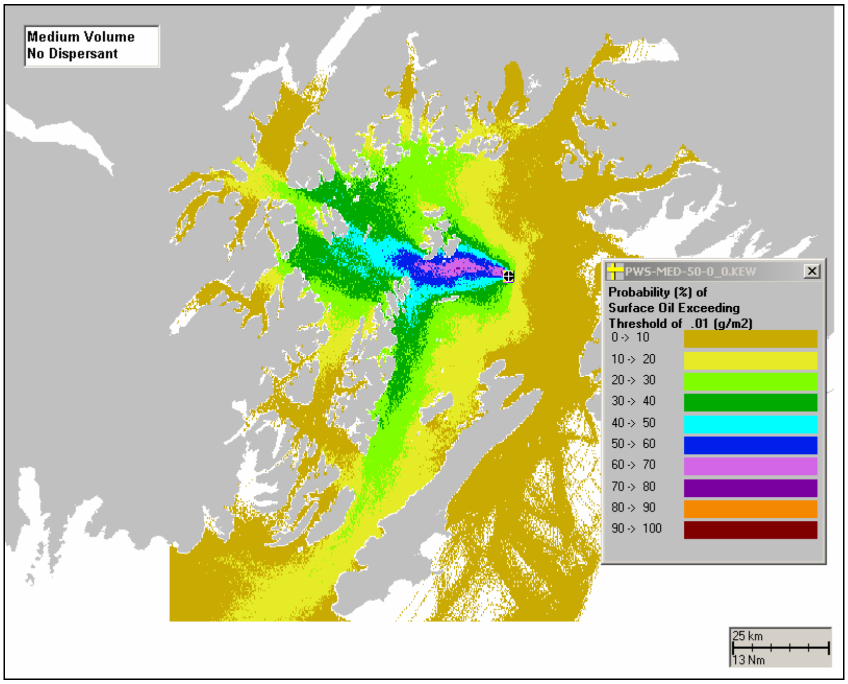

Figure F-II.1.1.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Medium Volume, No Dispersant.

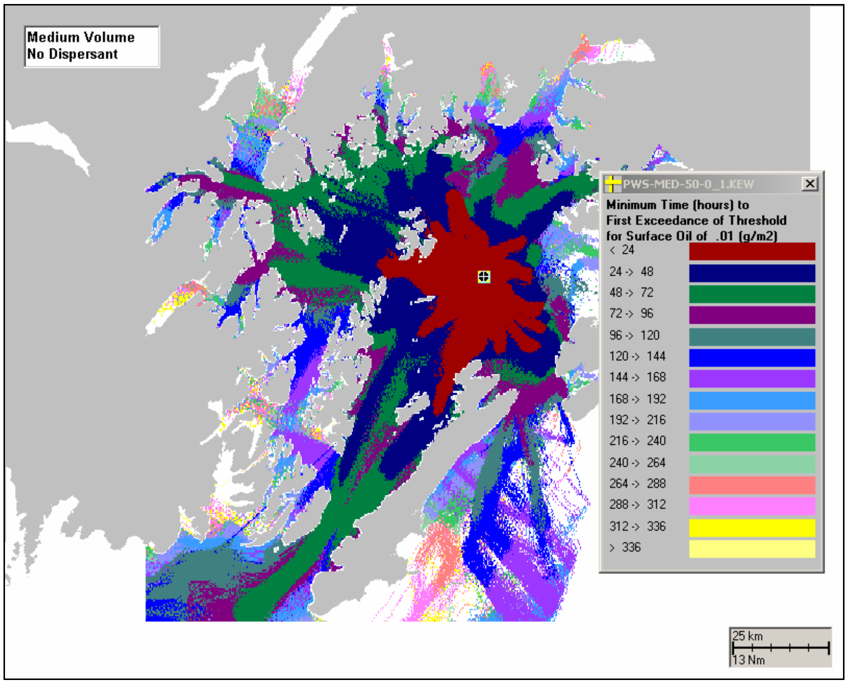

Figure F-II.1.1.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Medium Volume, No Dispersant.

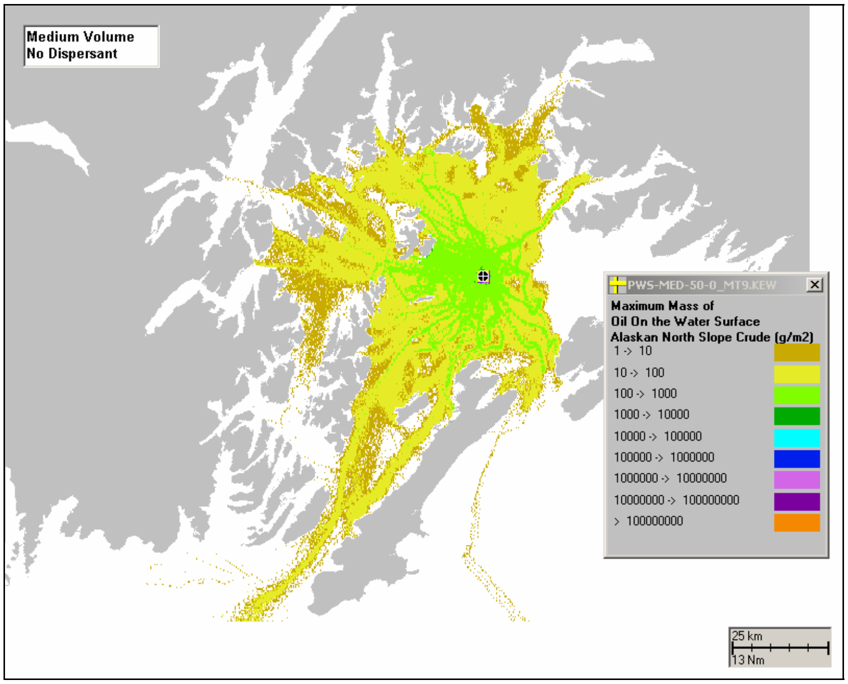

Figure F-II.1.1.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

F-II.1.1.2 Shoreline Oiled. Scenario: Medium Volume, No Dispersant

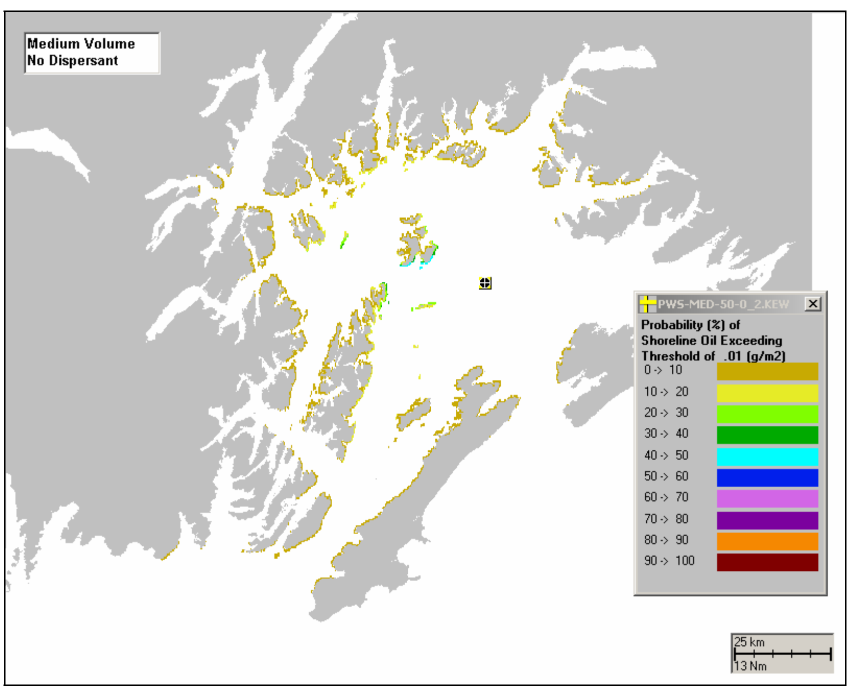

Figure F-II.1.1.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Medium Volume, No Dispersant.

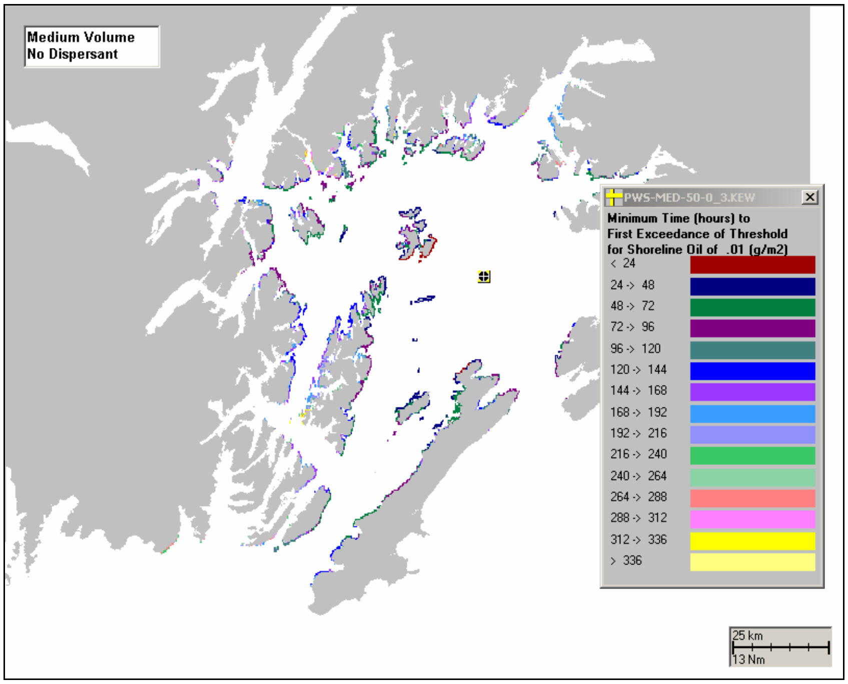

Figure F-II.1.1.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Medium Volume, No Dispersant.

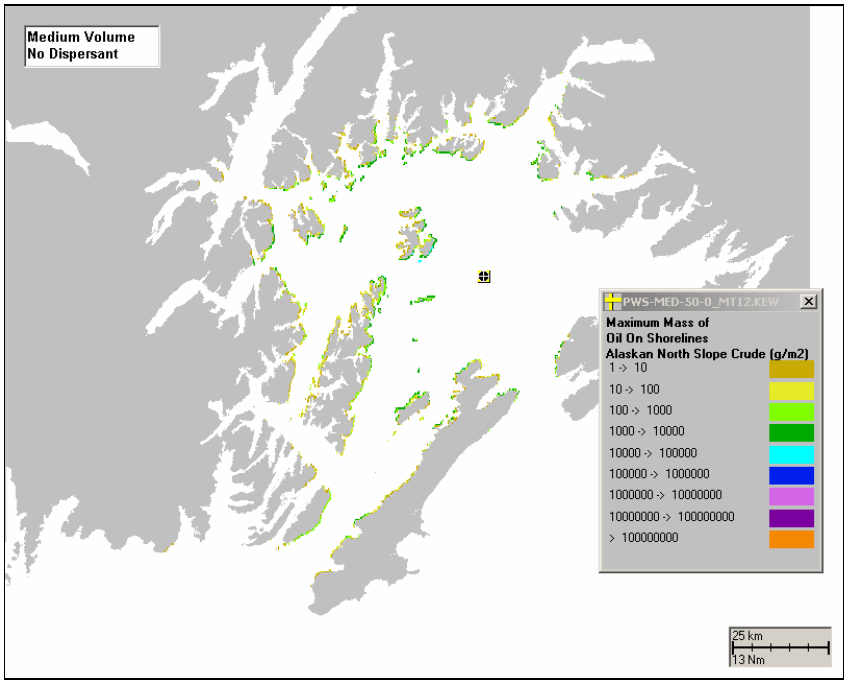

Figure F-II.1.1.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

F-II.1.1.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Medium Volume, No Dispersant

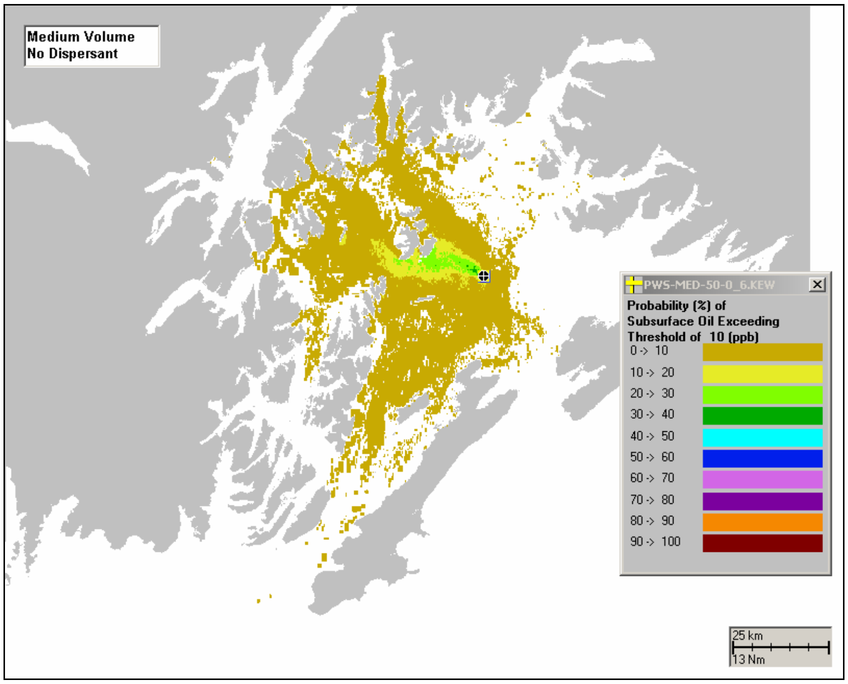

Figure F-II.1.1.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Medium Volume, No Dispersant.

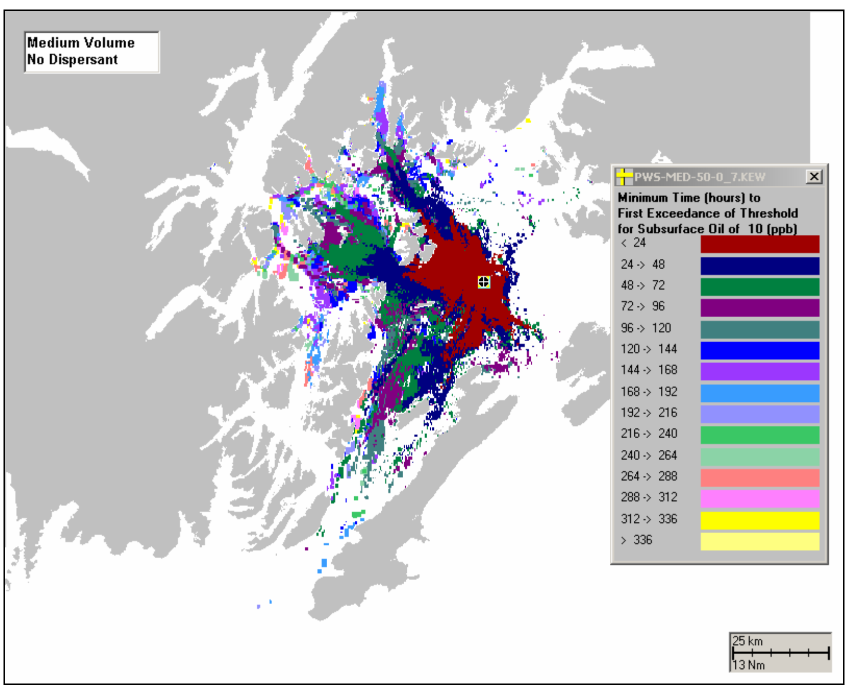

Figure F-II.1.1.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Medium Volume, No Dispersant.

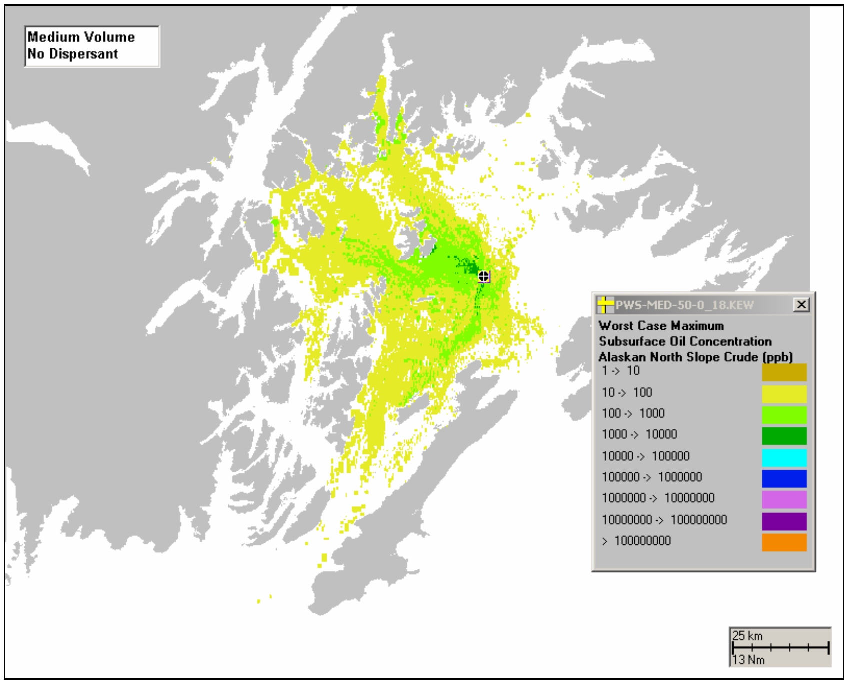

Figure F-II.1.1.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

F-II.1.1.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Medium Volume, No Dispersant

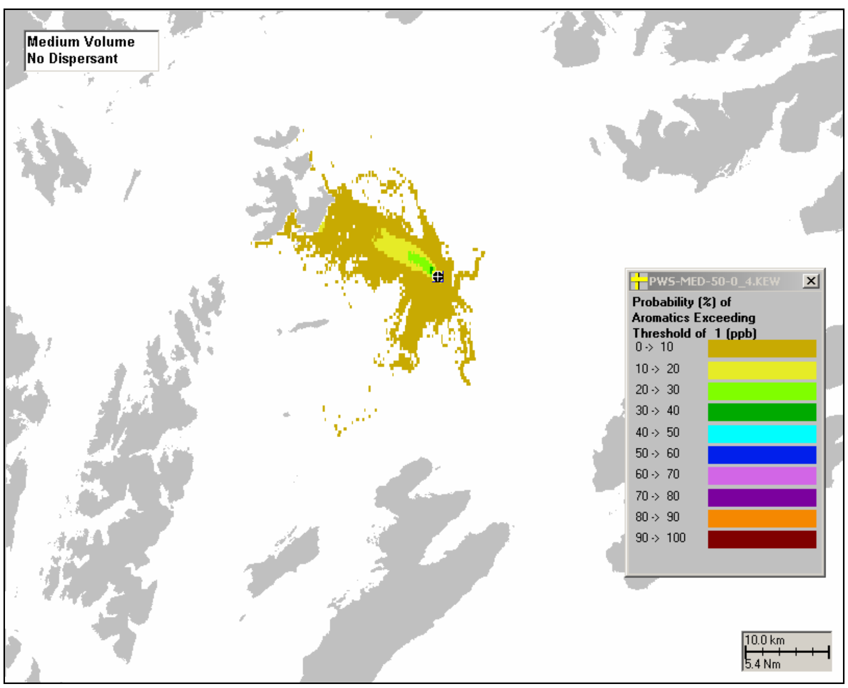

Figure F-II.1.1.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, No Dispersant.

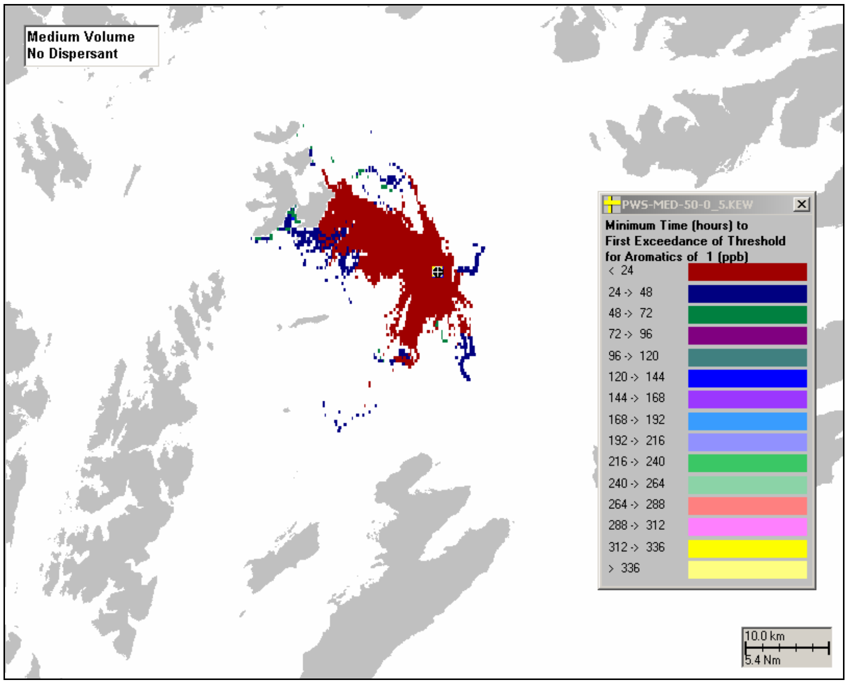

Figure F-II.1.1.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Medium Volume, No Dispersant.

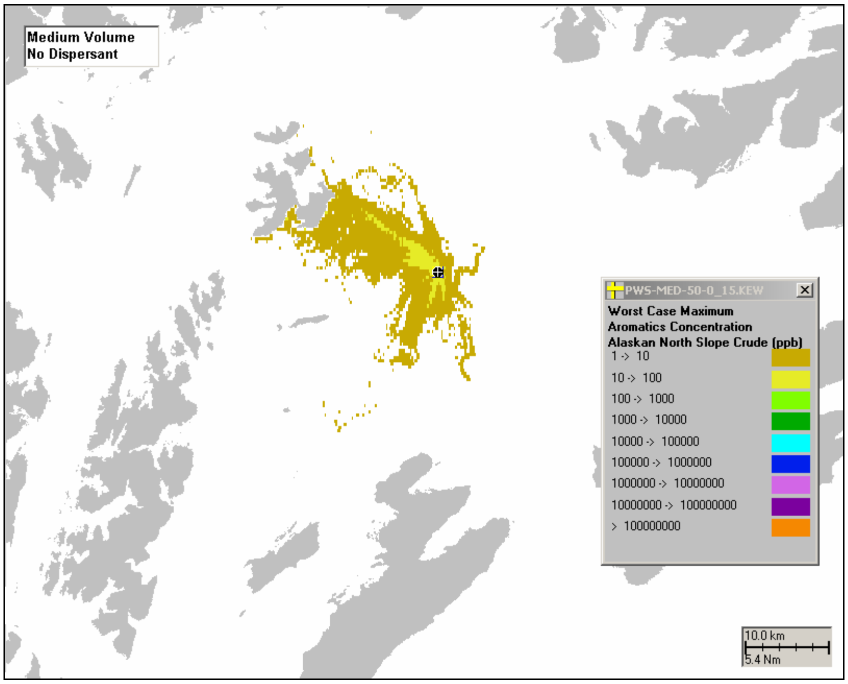

Figure F-II.1.1.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

F-II.1.1.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Medium Volume, No Dispersant

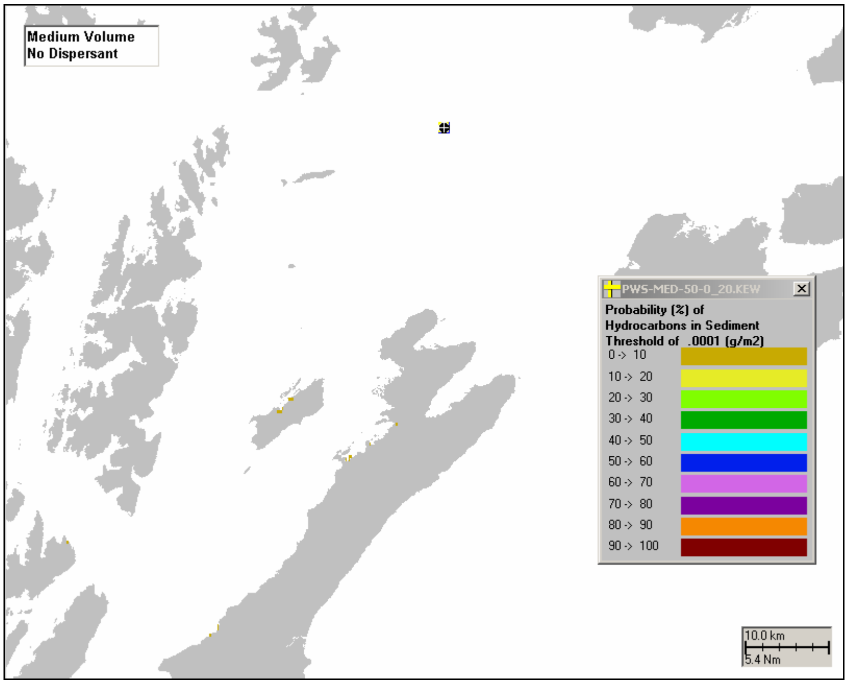

Figure F-II.1.1.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Medium Volume, No Dispersant.

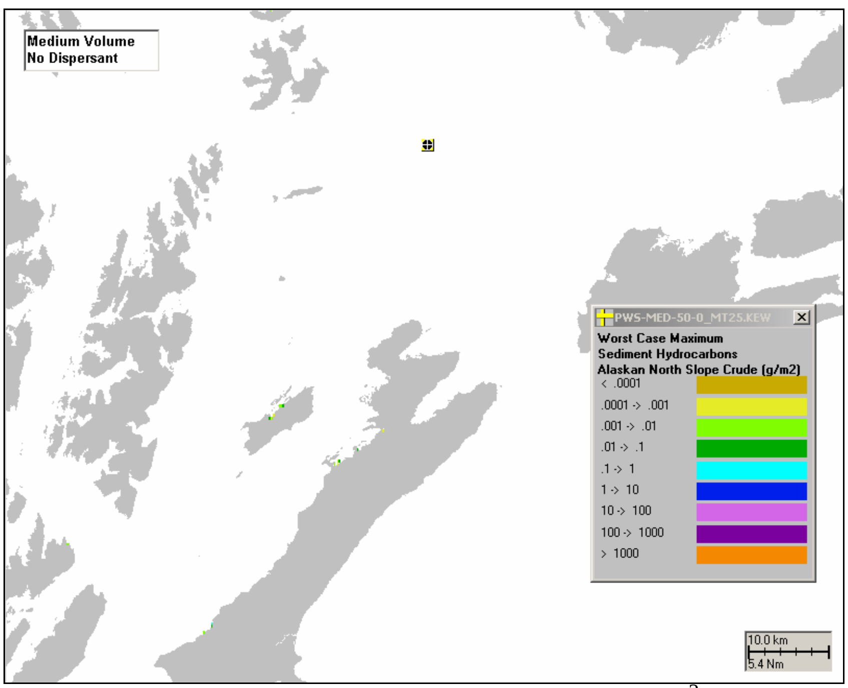

Figure F-II.1.1.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, No Dispersant.

F-II.1.1.6 Sediment pore water dissolved aromatic concentrations. Scenario: Medium Volume, No Dispersant

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time and for any of the 100 runs) does not exceed threshold of 1 ppb. Scenario: Medium Volume, No Dispersant.

F-II.1.2. Scenario: Medium Volume, 45% Dispersant Efficiency

F-II.1.2.1 Surface Floating Total Hydrocarbons. Scenario: Medium Volume, 45% Dispersant Efficiency

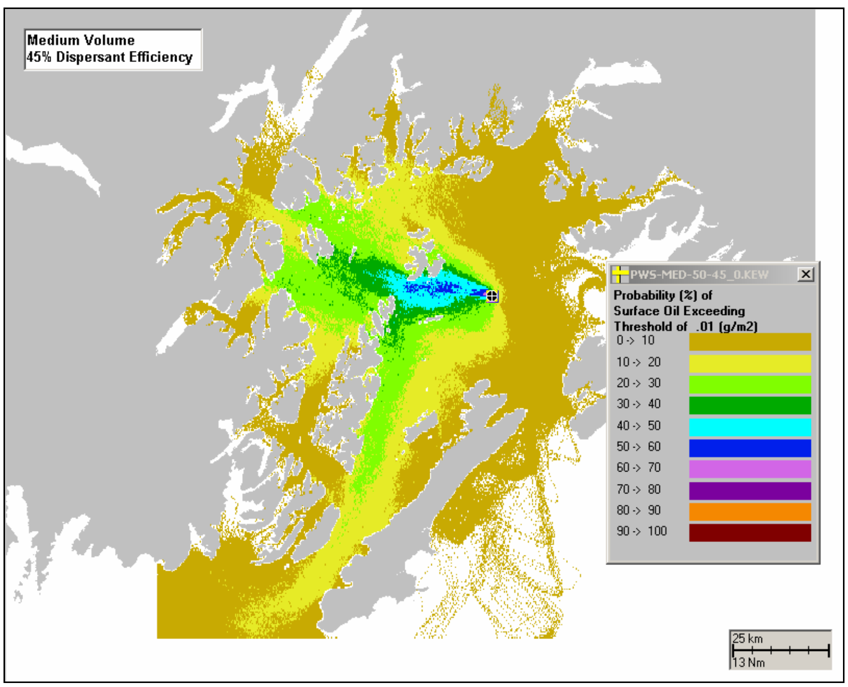

Figure F-II.1.2.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

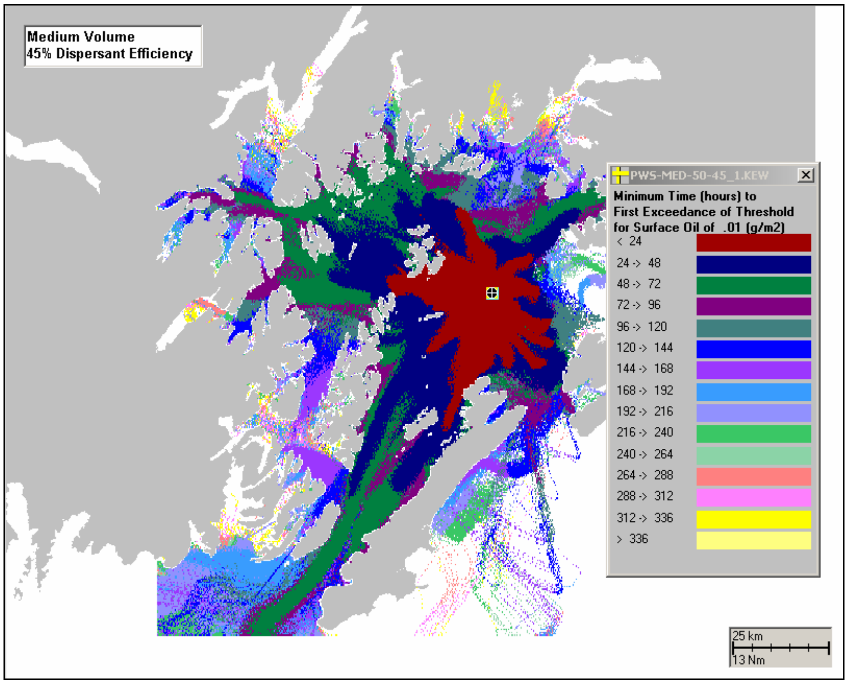

Figure F-II.1.2.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

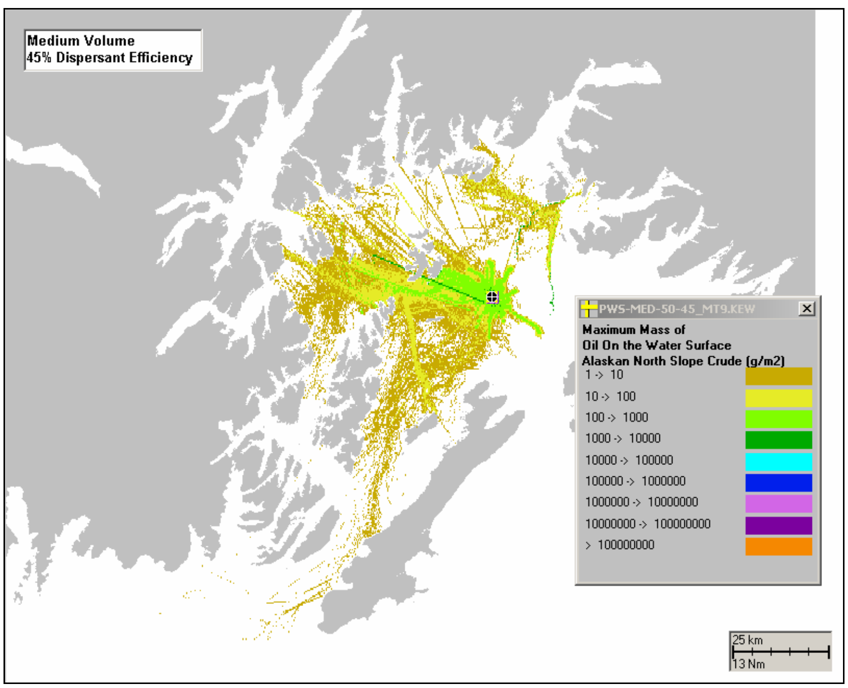

Figure F-II.1.2.1-.3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

F-II.1.2.2 Shoreline Oiled. Scenario: Medium Volume, 45% Dispersant Efficiency.

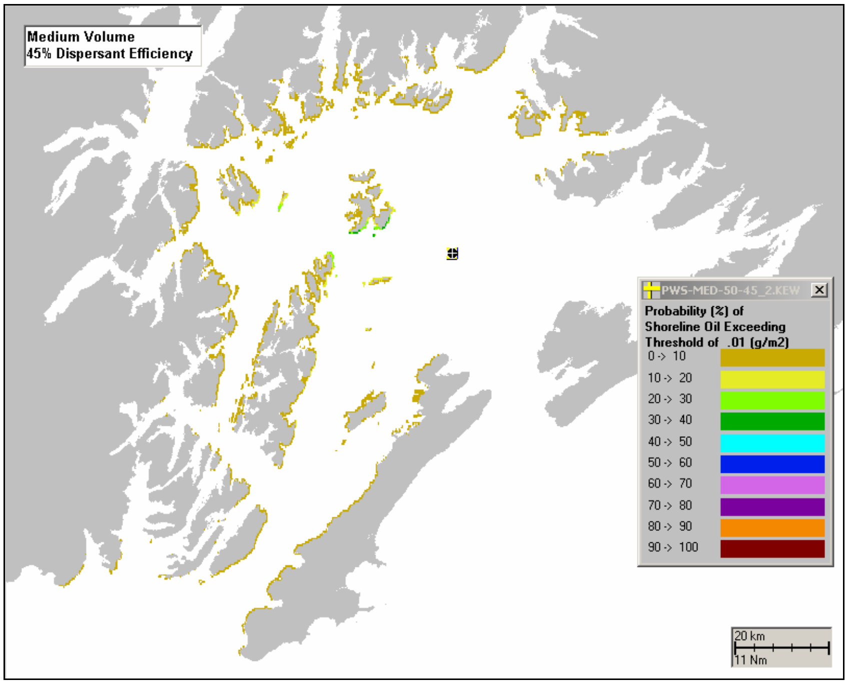

Figure F-II.1.2.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

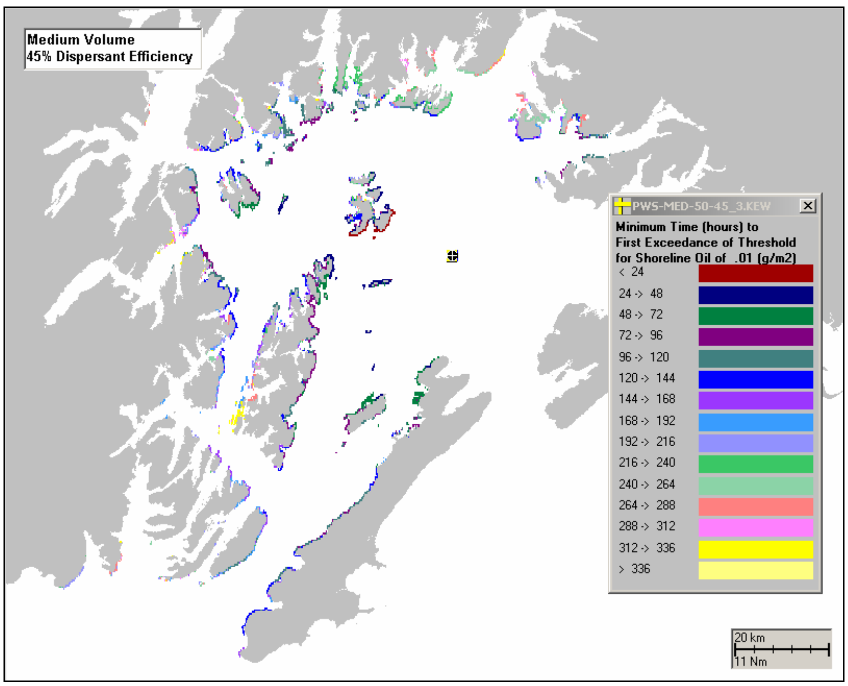

Figure F-II.1.2.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

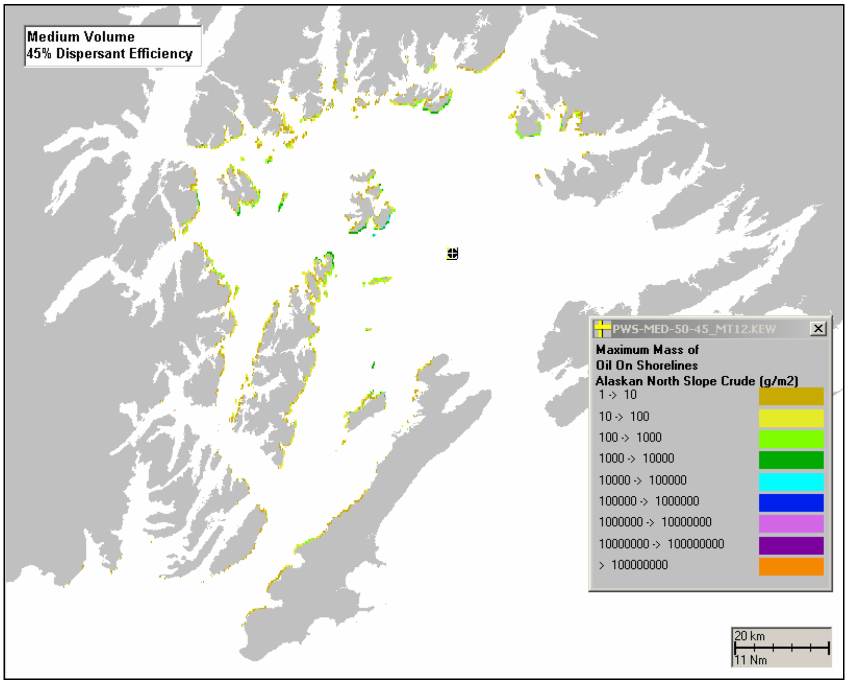

Figure F-II.1.2.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

F-II.1.2.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Medium Volume, 45% Dispersant Efficiency

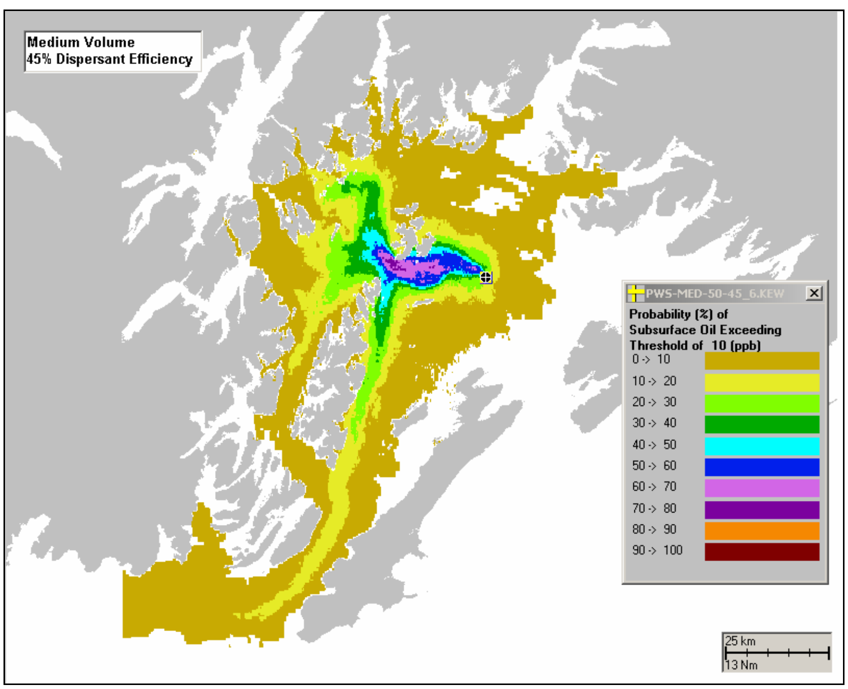

Figure F-II.1.2.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

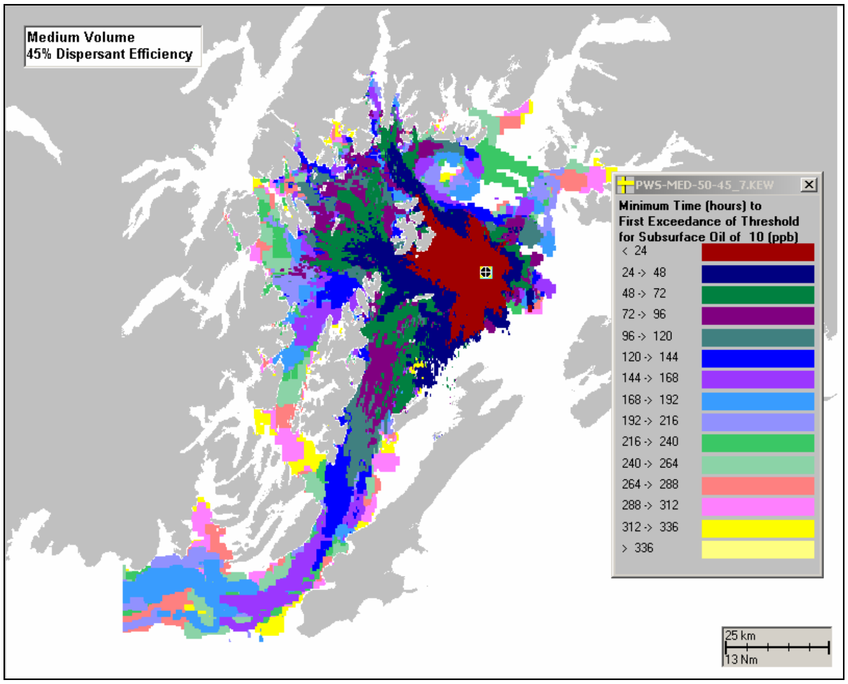

Figure F-II.1.2.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

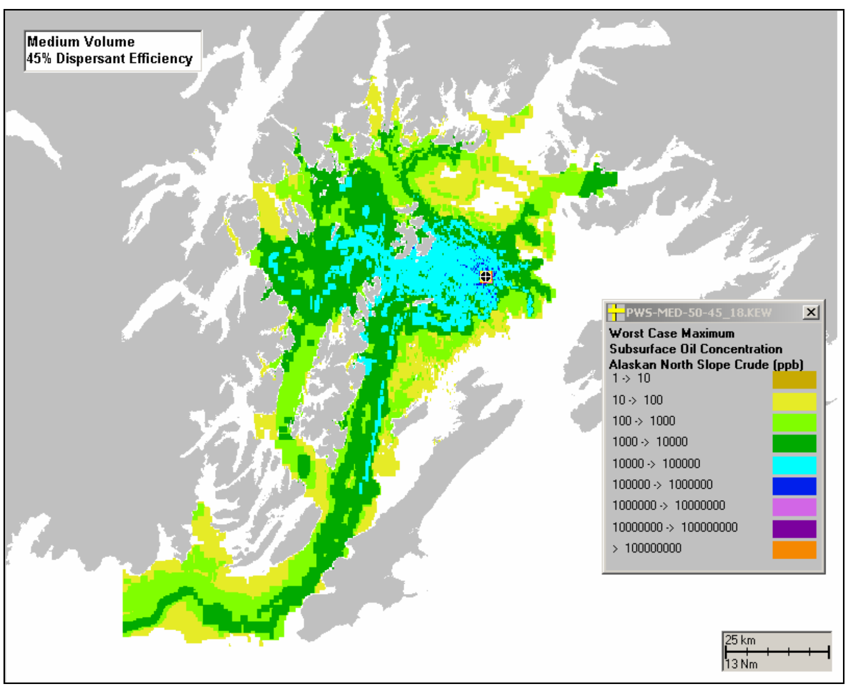

Figure F-II.1.2.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

F-II.1.2.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Medium Volume, 45% Dispersant Efficiency

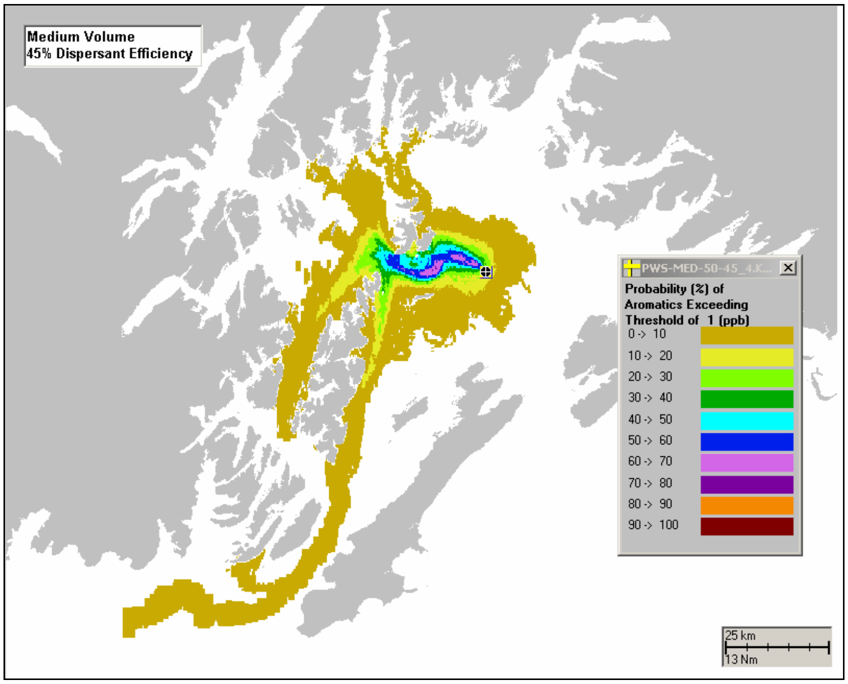

Figure F-II.1.2.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

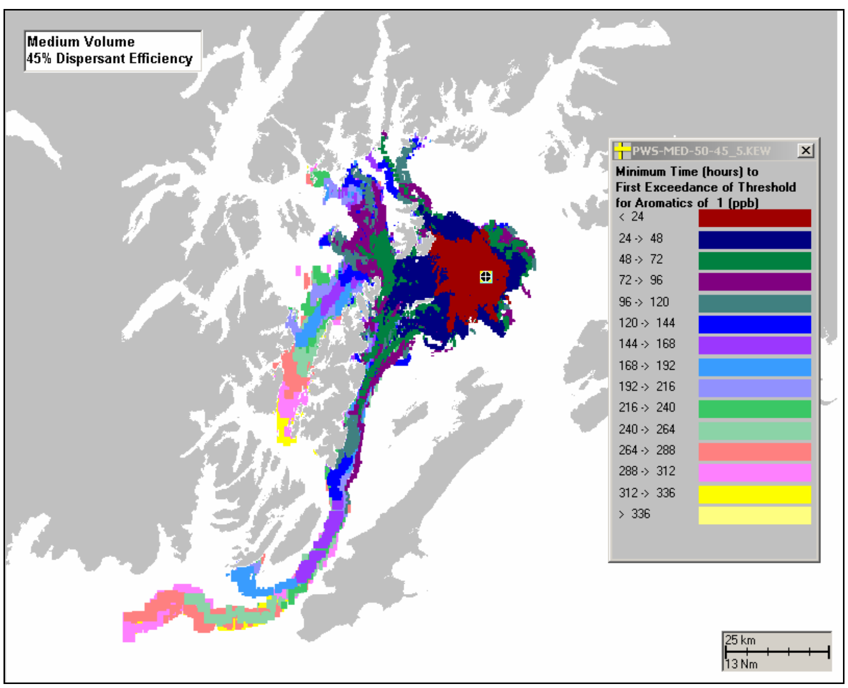

Figure F-II.1.2.4-2 Time (hrs) after spill when Dissolved Aromatic Concentrations could first exceed 1ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

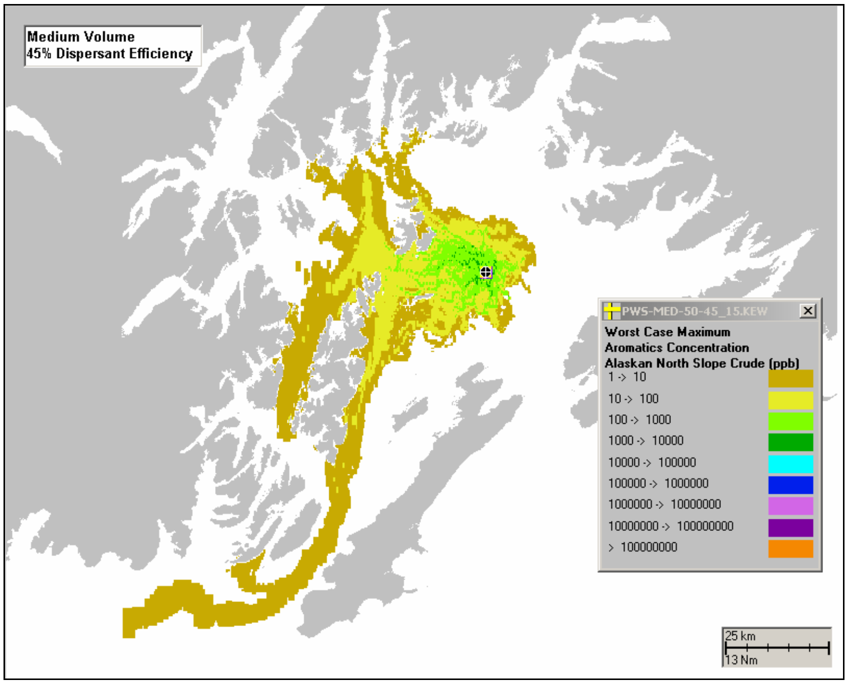

Figure F-II.1.2.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

F-II.1.2.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Medium Volume, 45% Dispersant Efficiency

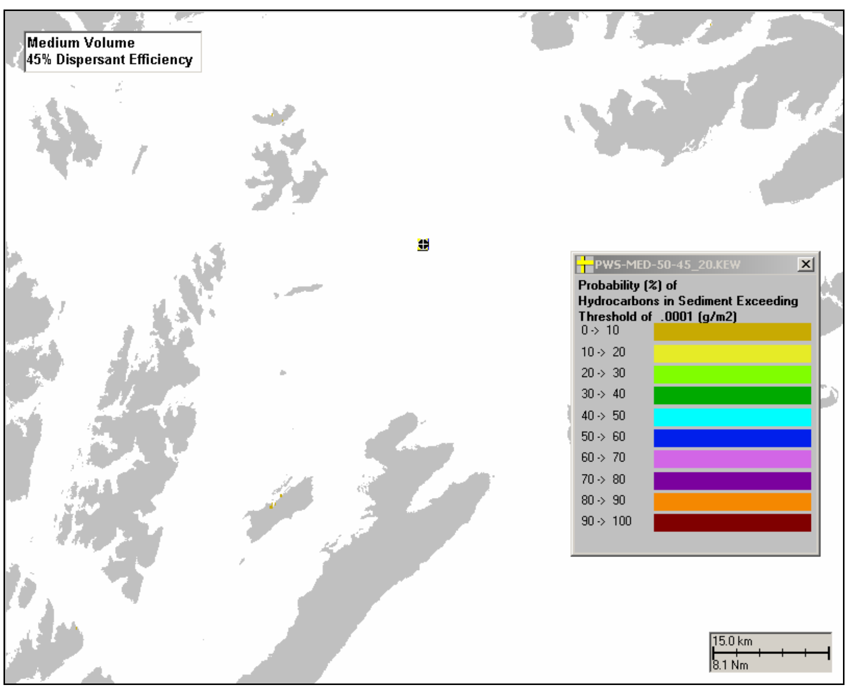

Figure F-II.1.2.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Medium Volume, 45% Dispersant Efficiency.

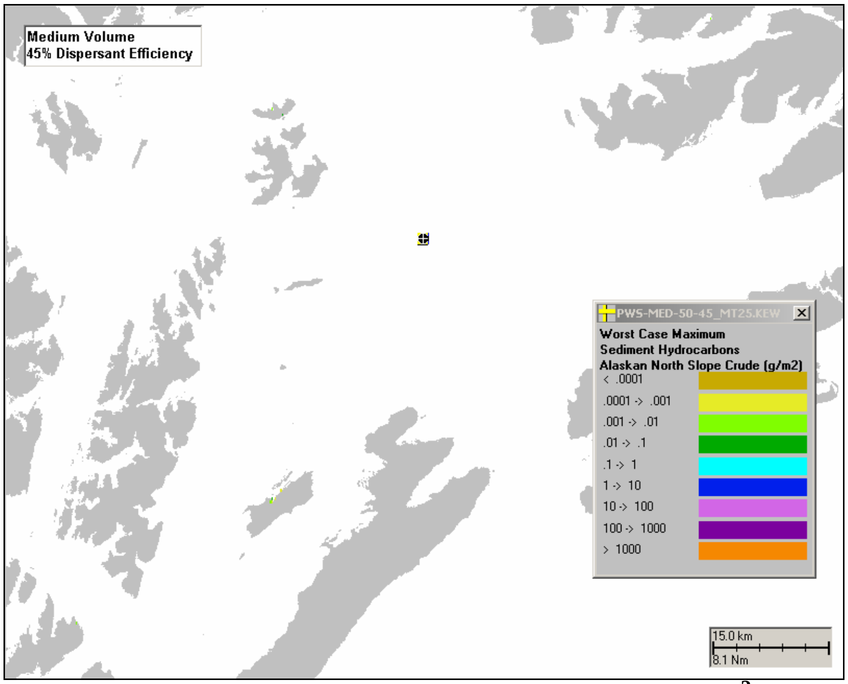

Figure F-II.1.2.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

F-II.1.2.6 Sediment pore water dissolved aromatic concentrations. Scenario: Medium Volume, 45% Dispersant Efficiency

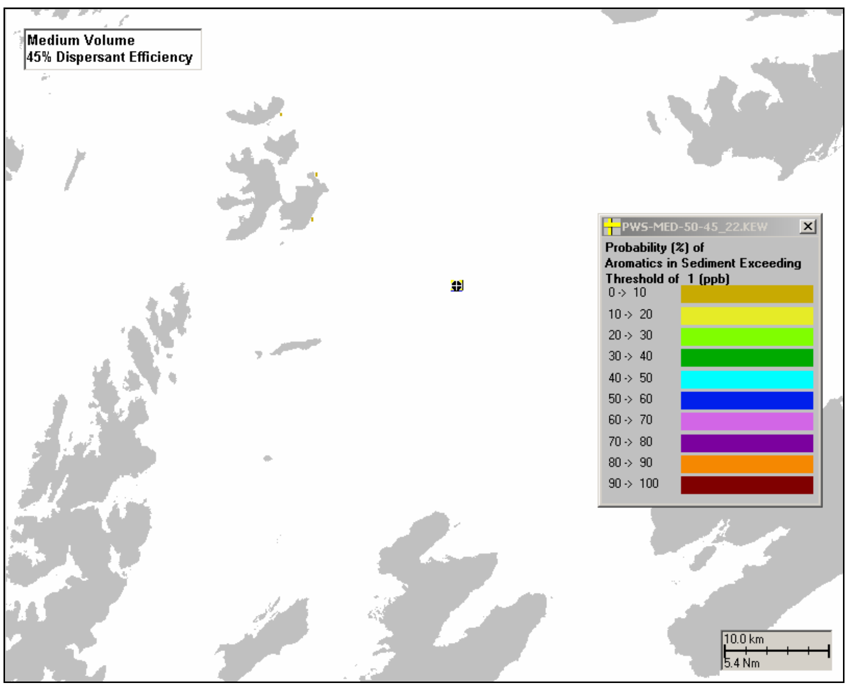

Figure F-II.1.2.6-1 Probability (%) of sediment pore water dissolved aromatic concentrations exceeding 1ppb. Scenario: MediumVolume, 45% Dispersant Efficiency.

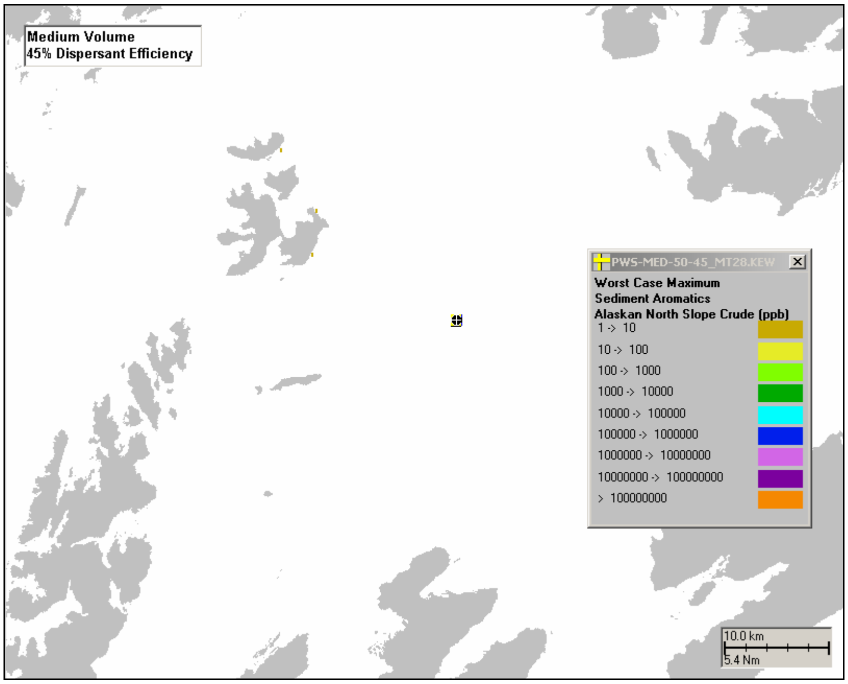

Figure F-II.1.6.2-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 45% Dispersant Efficiency.

F-II.1.3. Scenario: Medium Volume, 80% Dispersant Efficiency

F-II.1.3.1 Surface Floating Total Hydrocarbons. Scenario: Medium Volume, 80% Dispersant Efficiency.

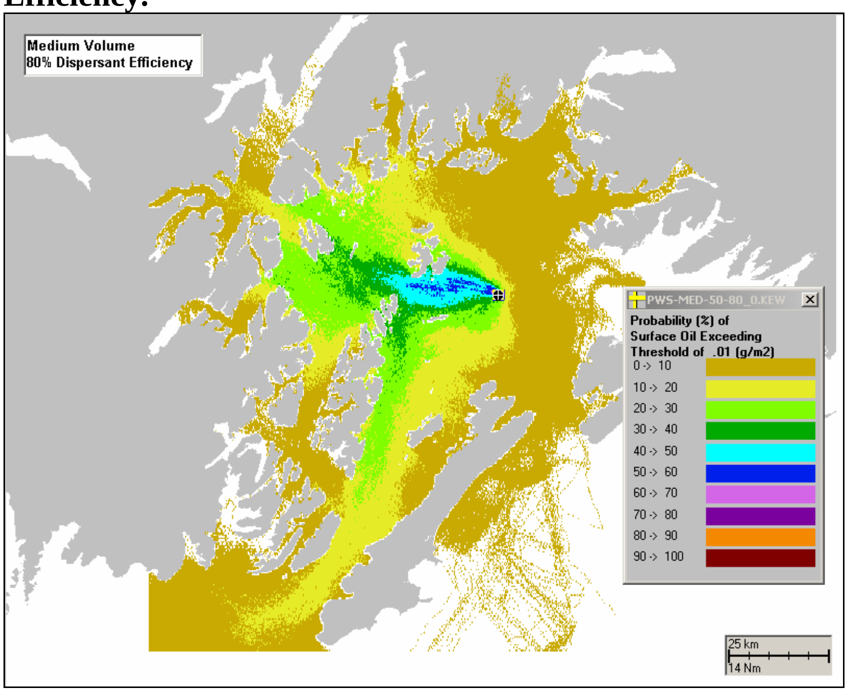

Figure F-II.1.3.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

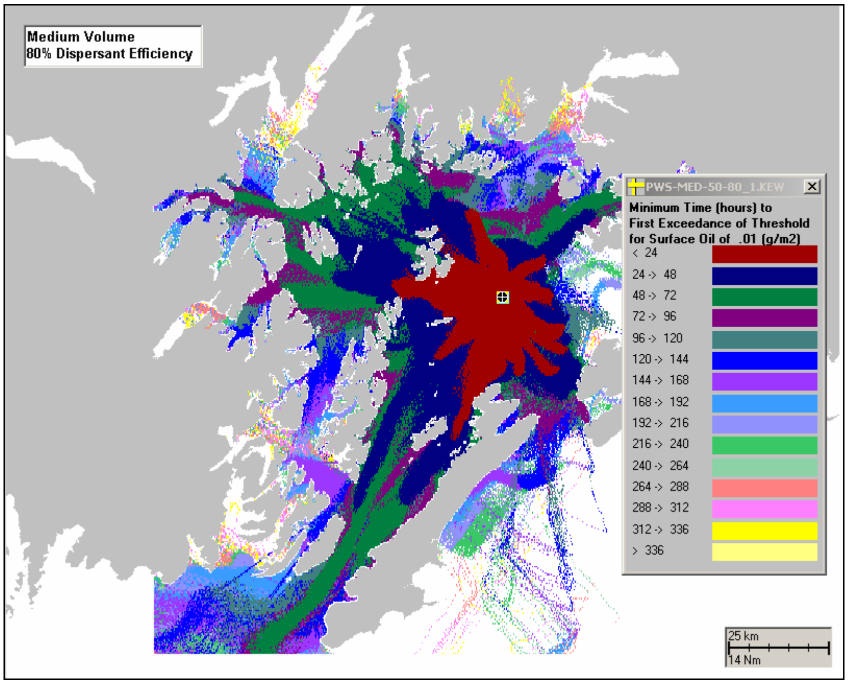

Figure F-II.1.3.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

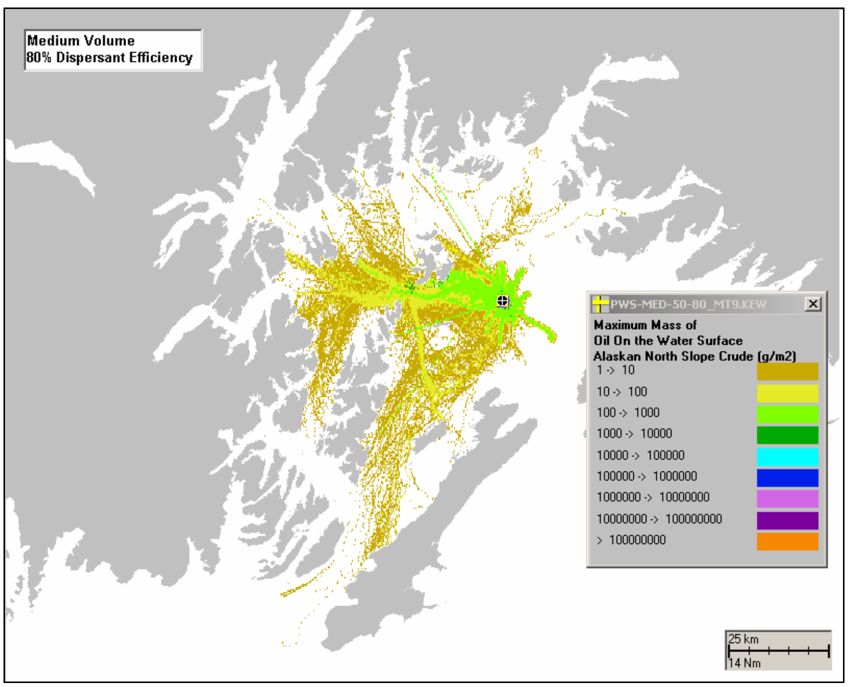

Figure F-II.1.3.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

F-II.1.3.2 Shoreline Oiled. Scenario: Medium Volume, 80% Dispersant Efficiency

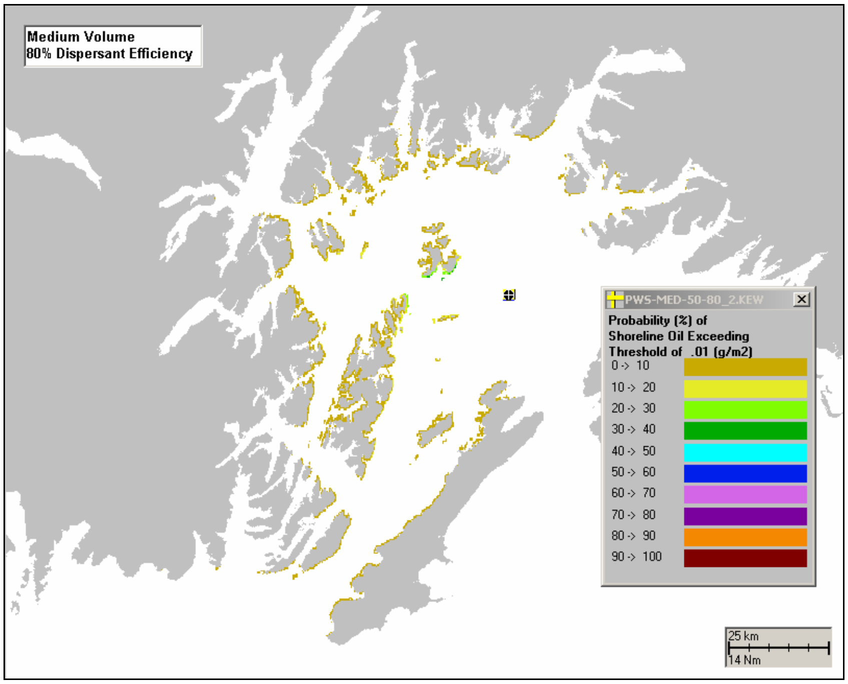

Figure F-II.1.3.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

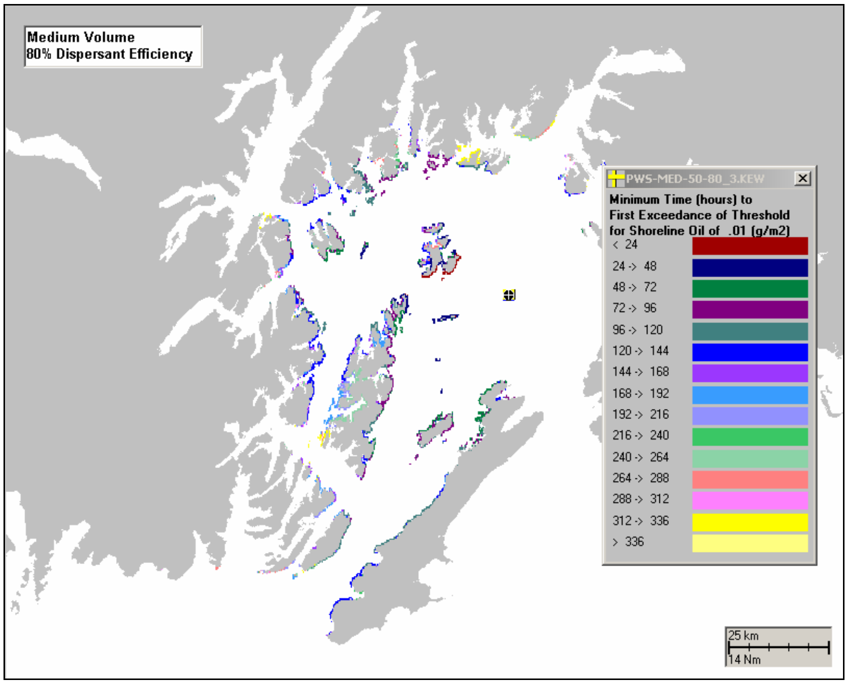

Figure F-II.1.3.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

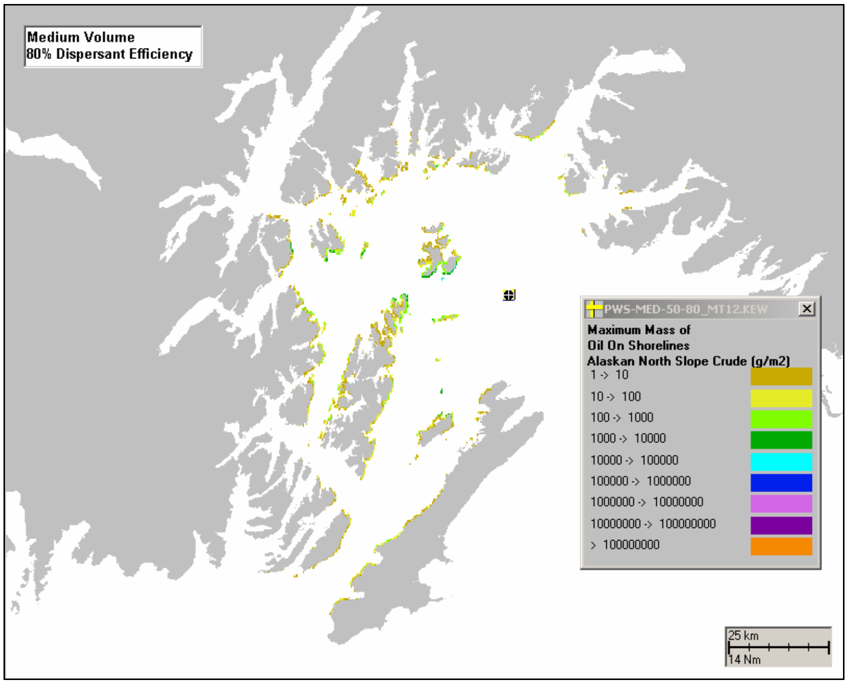

Figure F-II.1.3.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

F-II.1.3.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Medium Volume, 80% Dispersant Efficiency

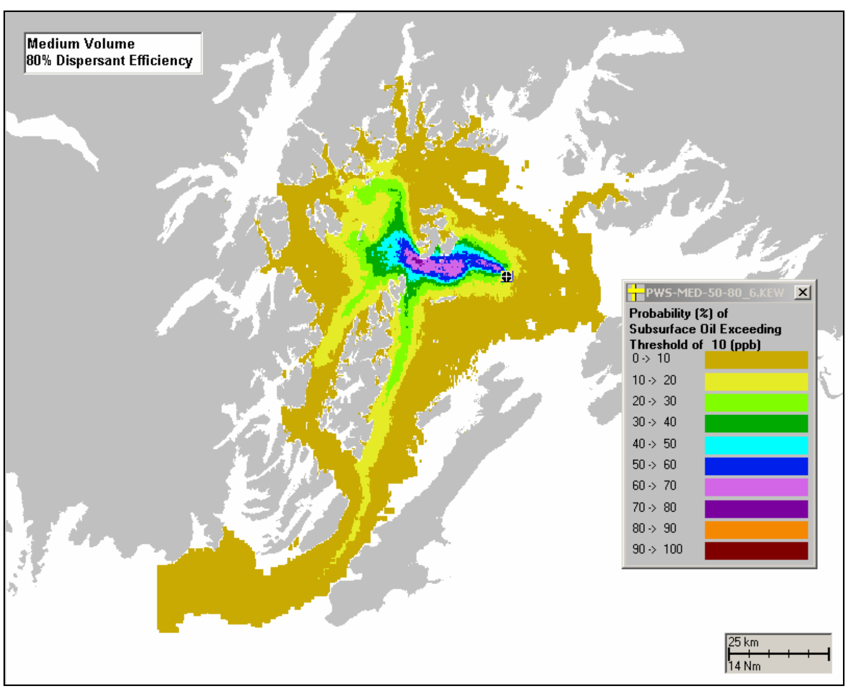

Figure F-II.1.3.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

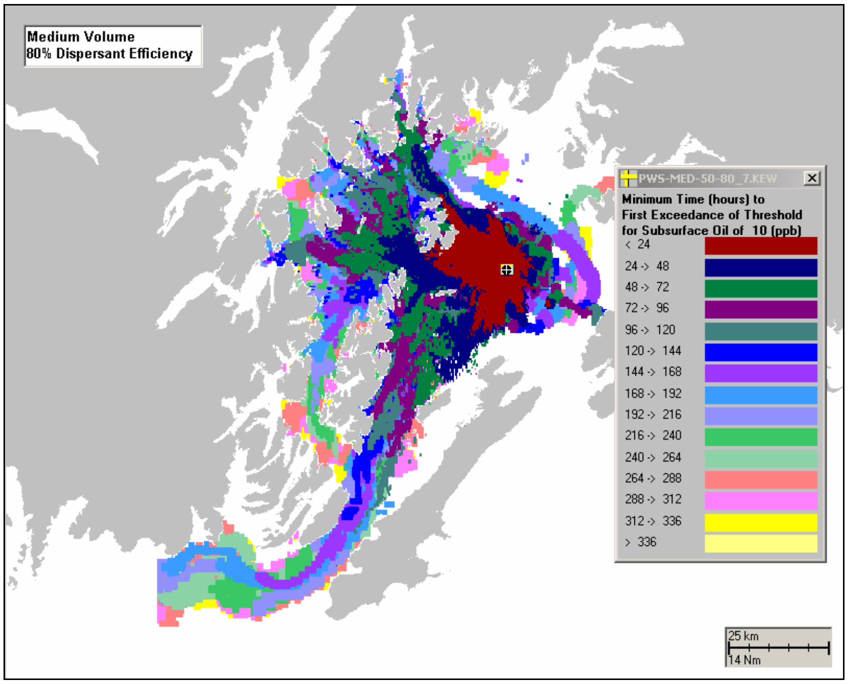

Figure F-II.1.3.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

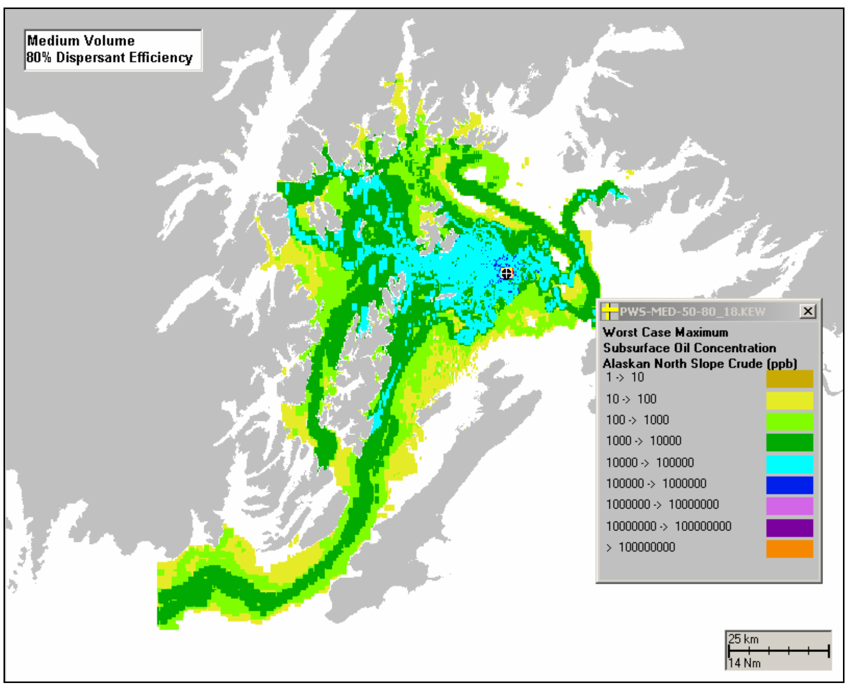

Figure F-II.1.3.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

F-II.1.3.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Medium Volume, 80% Dispersant Efficiency

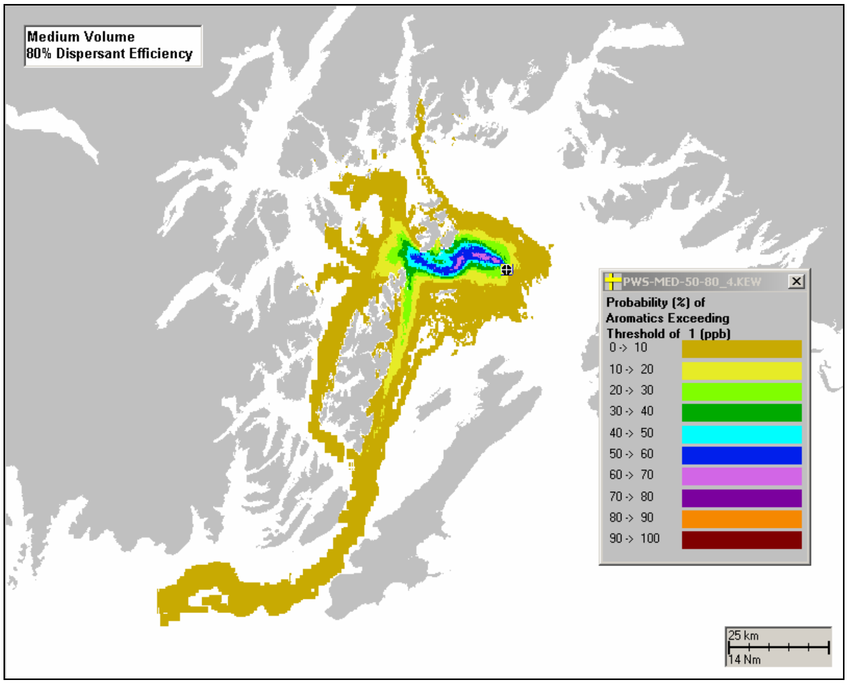

Figure F-II.1.3.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

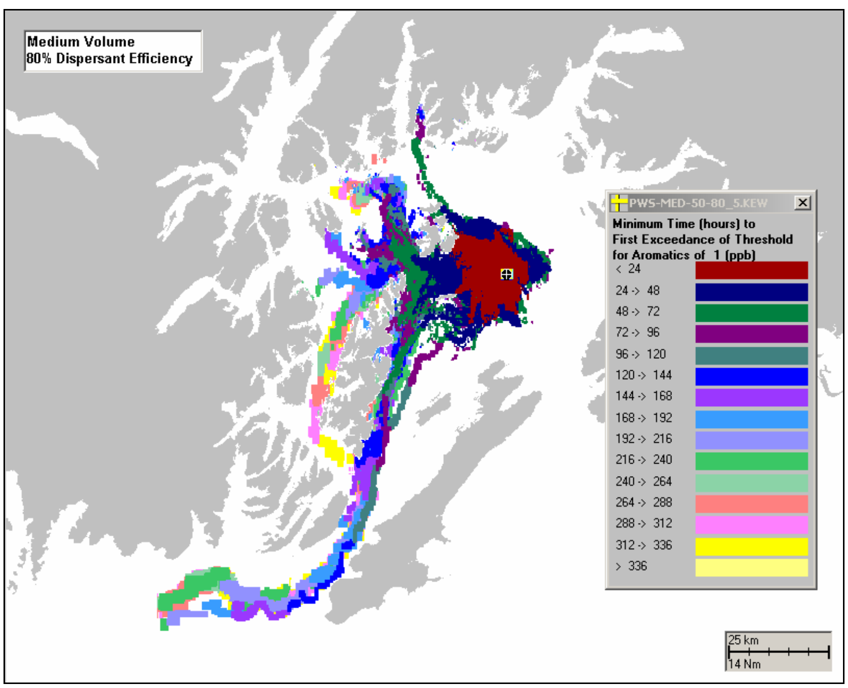

Figure F-II.1.3.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

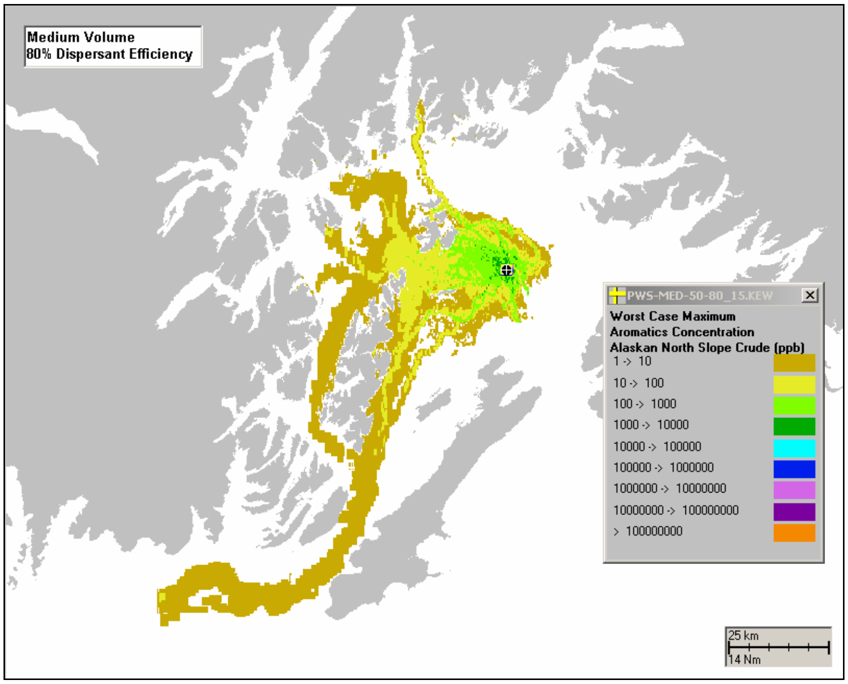

Figure F-II.1.3.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

F-II.1.3.5 Sediment exposure to total hydrocarbons (g/m²). Scenario: Medium Volume, 80% Dispersant Efficiency

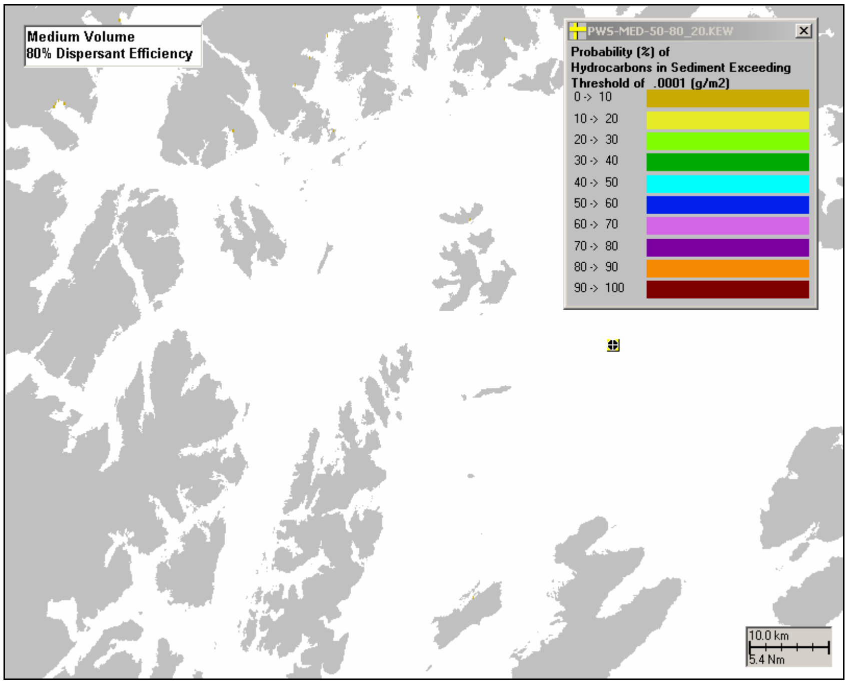

Figure F-II.1.3.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Medium Volume, 80% Dispersant Efficiency.

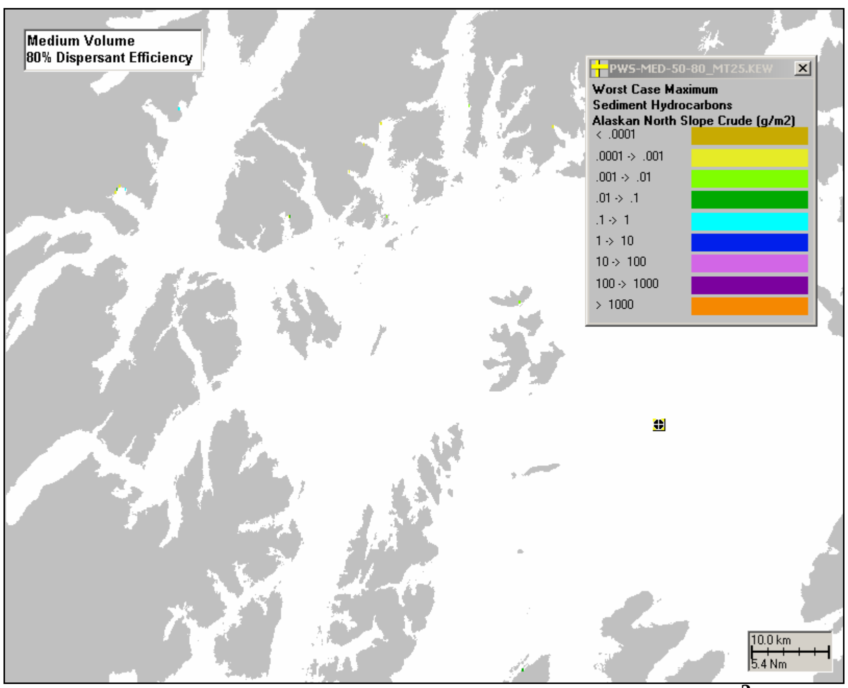

Figure F-II.1.3.5-2 Sediment exposure to total hydrocarbons (g/m²) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

F-II.1.3.6 Sediment pore water dissolved aromatic concentrations. Scenario: Medium Volume, 80% Dispersant Efficiency

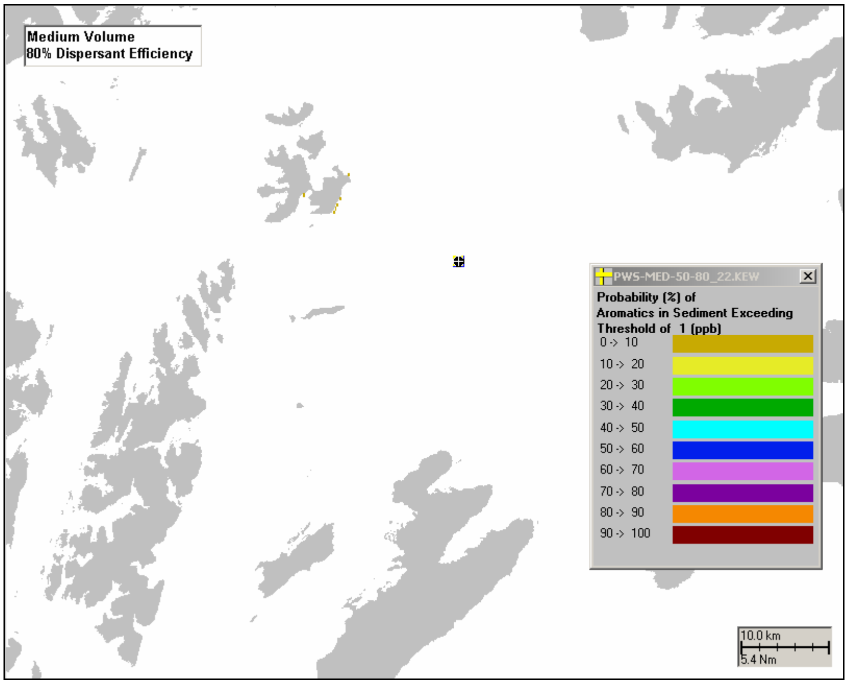

Figure F-II.1.3.6-1 Probability (%) of sediment pore water dissolved aromatic concentrations exceeding 1ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

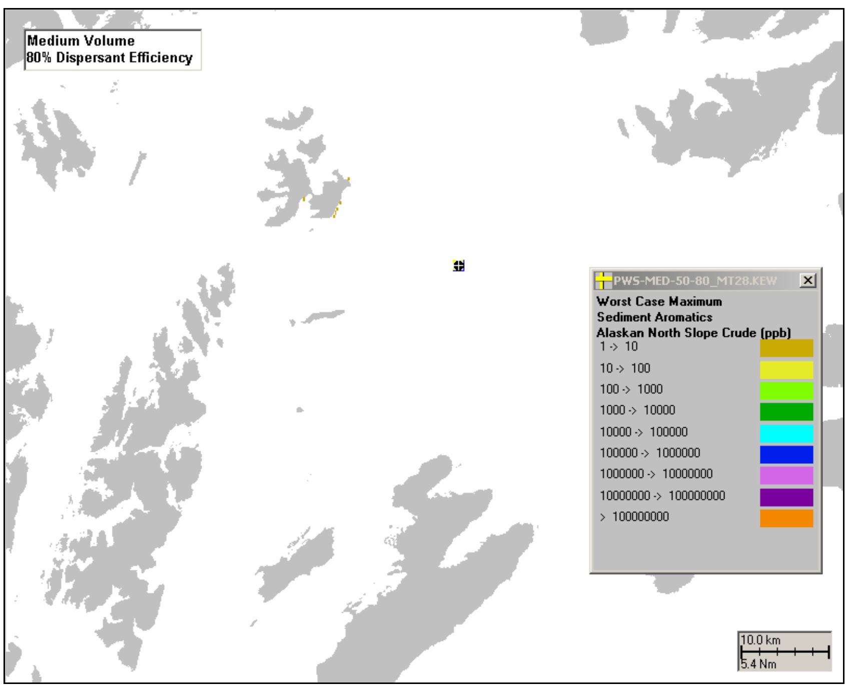

Figure F-II.1.3.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Medium Volume, 80% Dispersant Efficiency.

F-II.1.4. Scenario: Large Volume, No Dispersant

F-II.1.4.1 Surface Floating Total Hydrocarbons. Scenario: Large Volume, No Dispersant

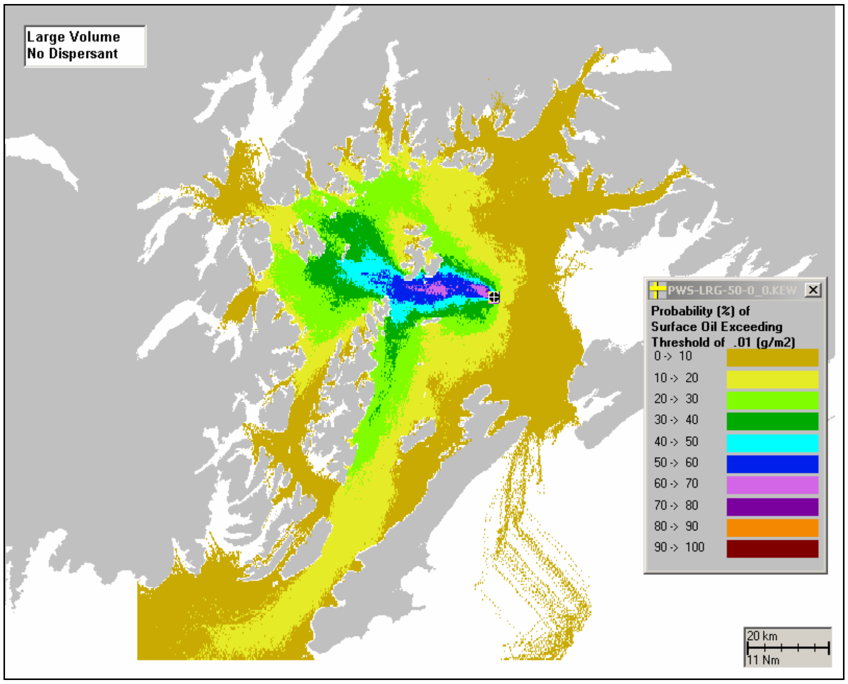

Figure F-II.1.4.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Large Volume, No Dispersant.

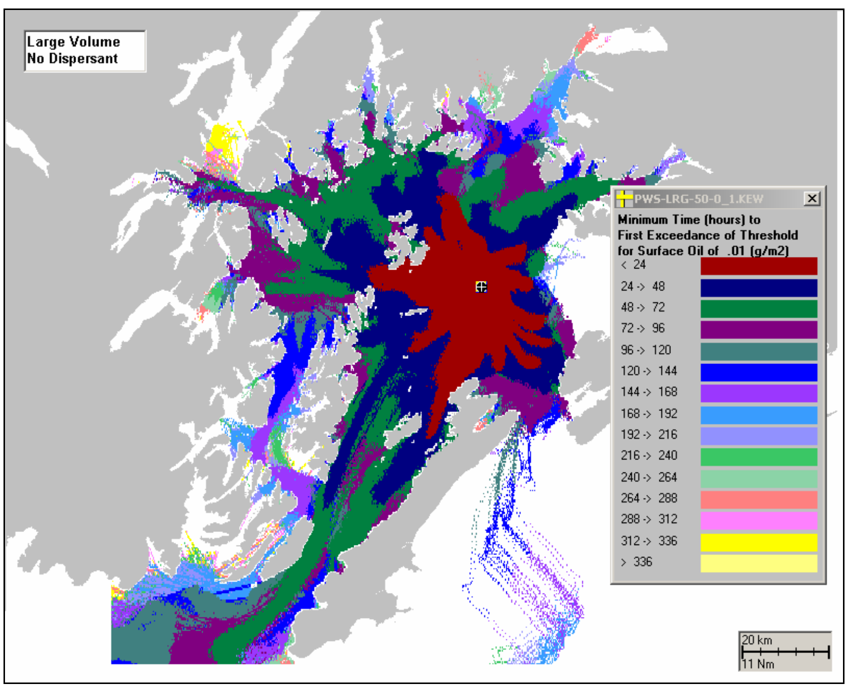

Figure F-II.1.4.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Large Volume, No Dispersant.

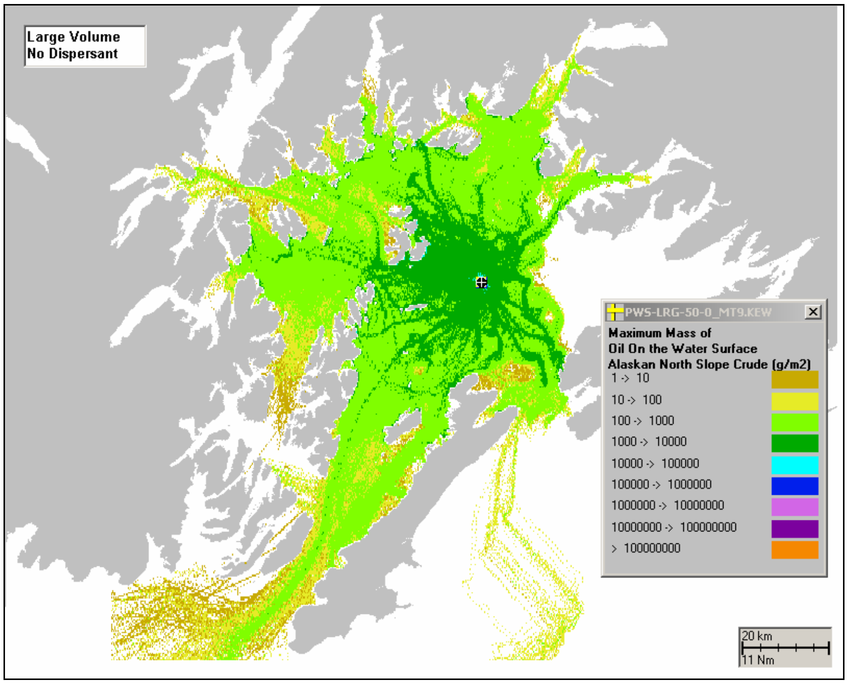

Figure F-II.1.4.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

F-II.1.4.2 Shoreline Oiled. Scenario: Large Volume, No Dispersant

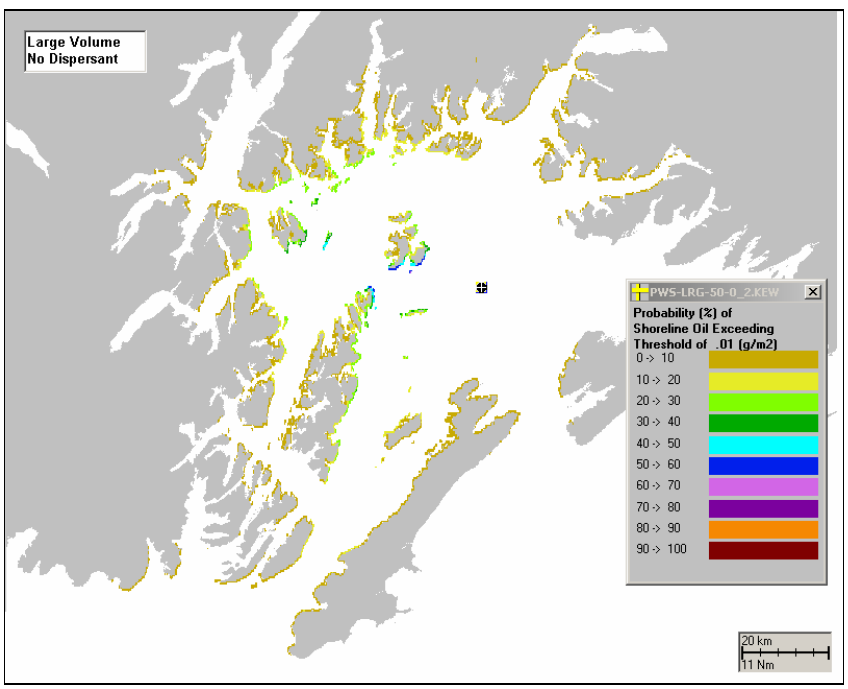

Figure F-II.1.4.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Large Volume, No Dispersant.

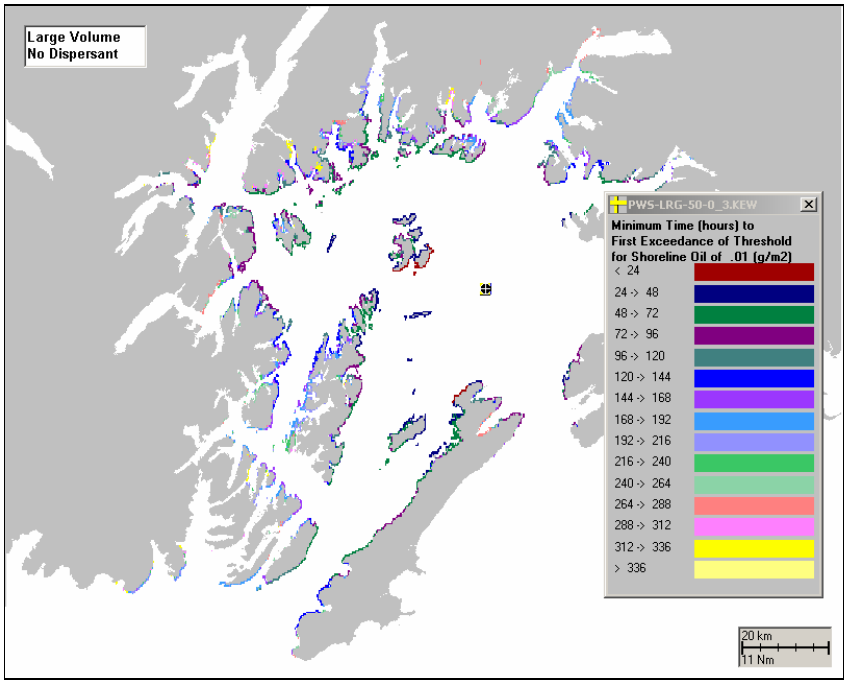

Figure F-II.1.4.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Large Volume, No Dispersant.

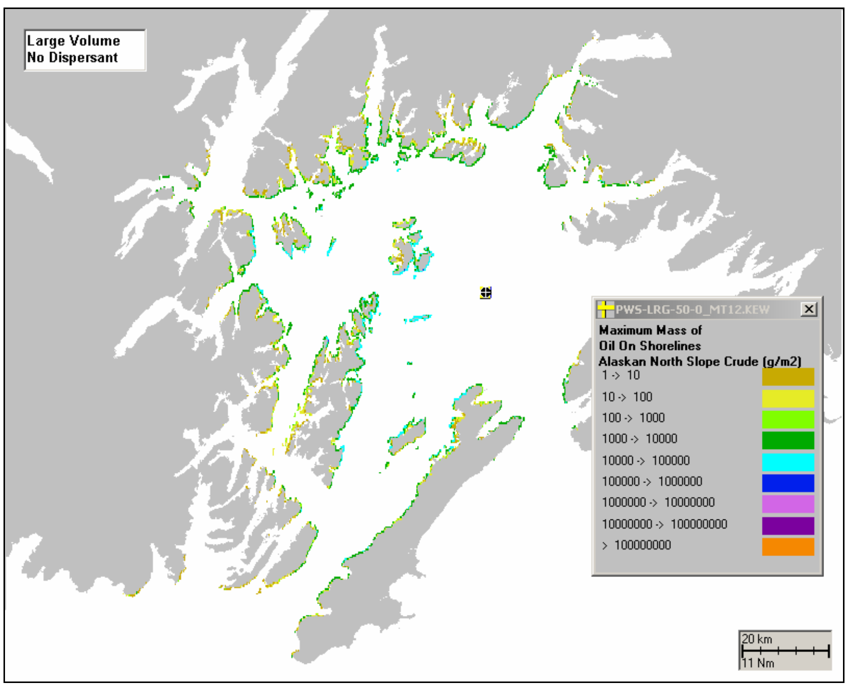

Figure F-II.1.4.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

F-II.1.4.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Large Volume, No Dispersant

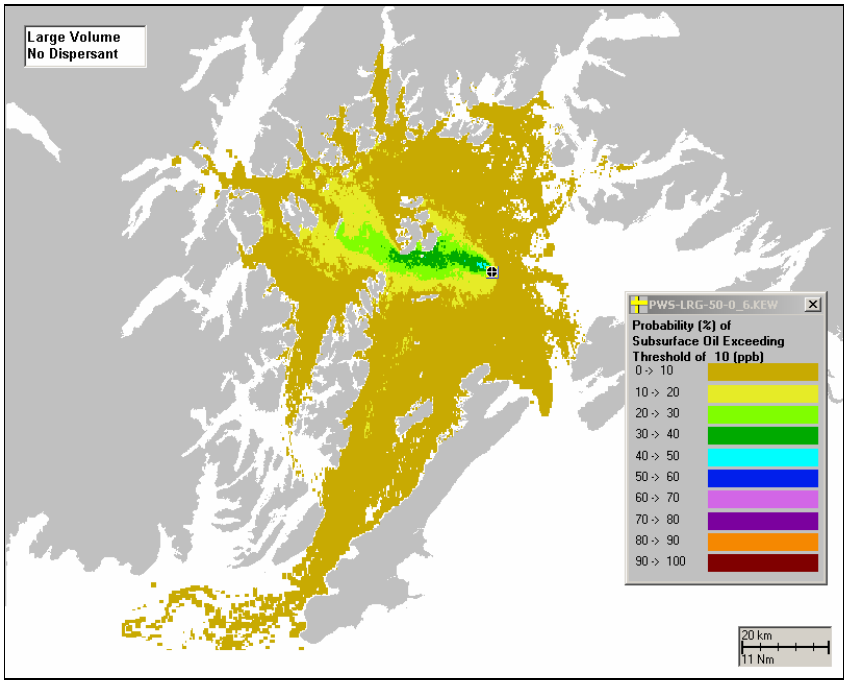

Figure F-II.1.4.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Large Volume, No Dispersant.

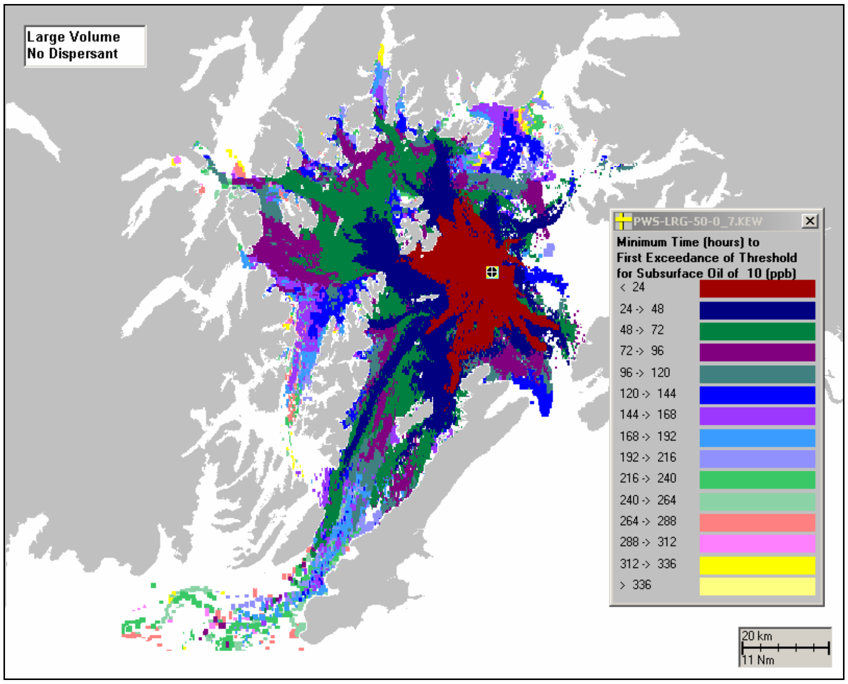

Figure F-II.1.4.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Large Volume, No Dispersant.

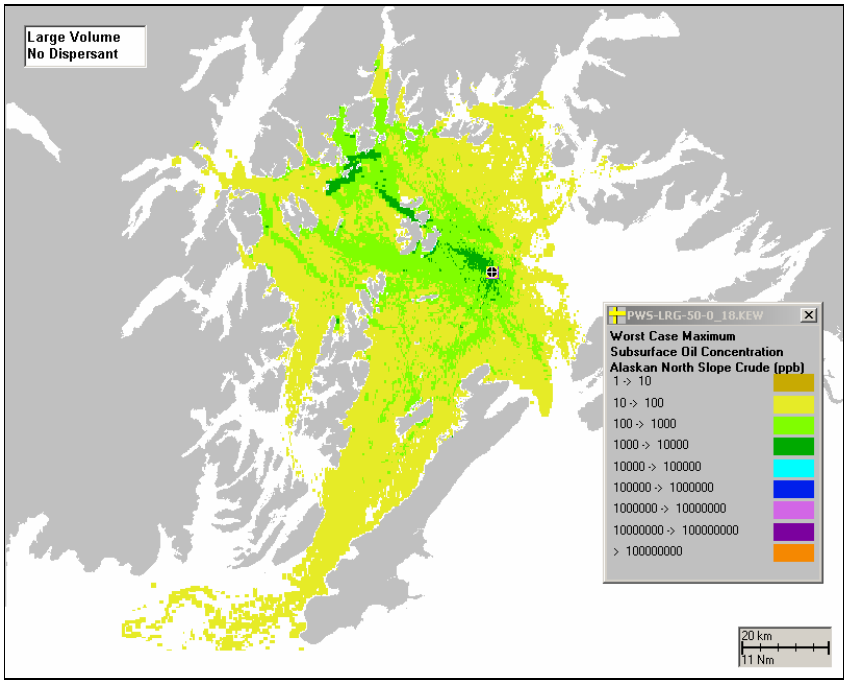

Figure F-II.1.4.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

F-II.1.4.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Large Volume, No Dispersant

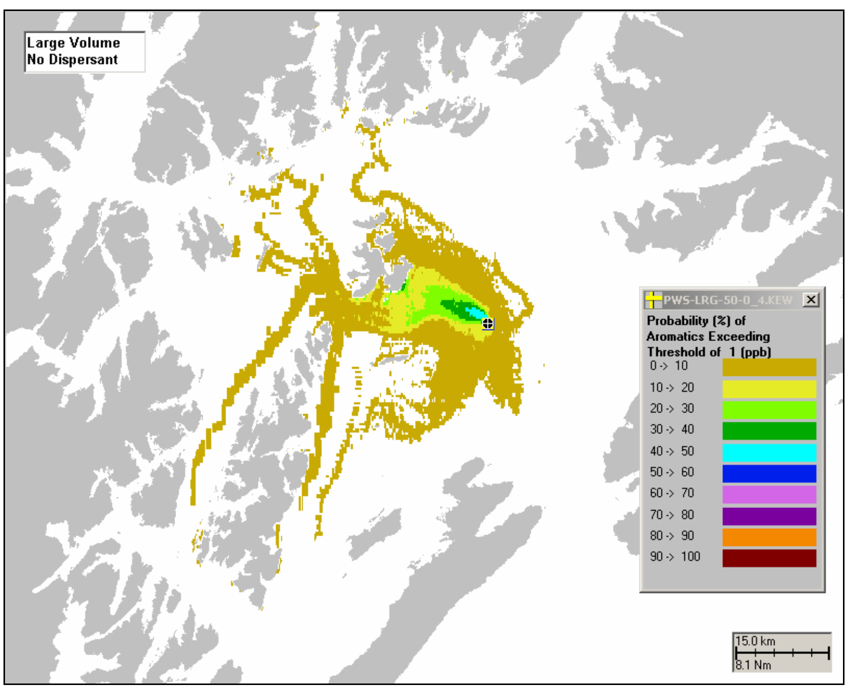

Figure F-II.1.4.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, No Dispersant.

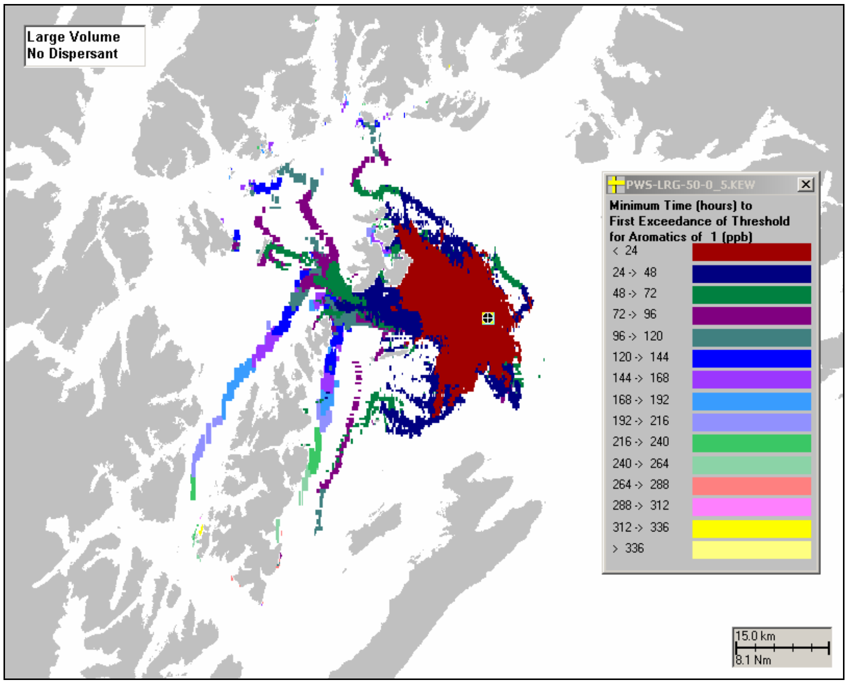

Figure F-II.1.4.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Large Volume, No Dispersant.

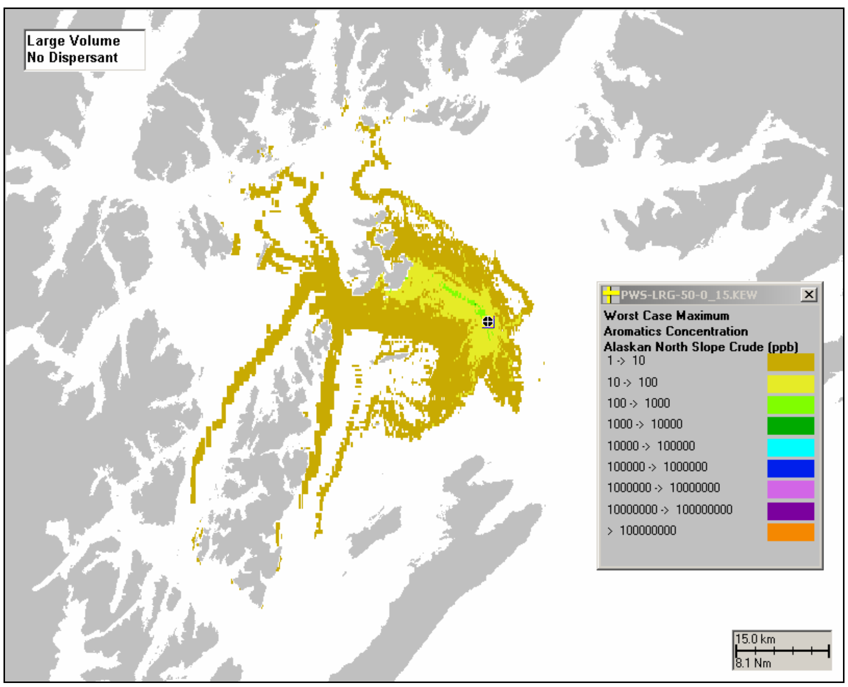

Figure F-II.1.4.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

F-II.1.4.5 Sediment exposure to total hydrocarbons (g/m^2). Scenario: Large Volume, No Dispersant

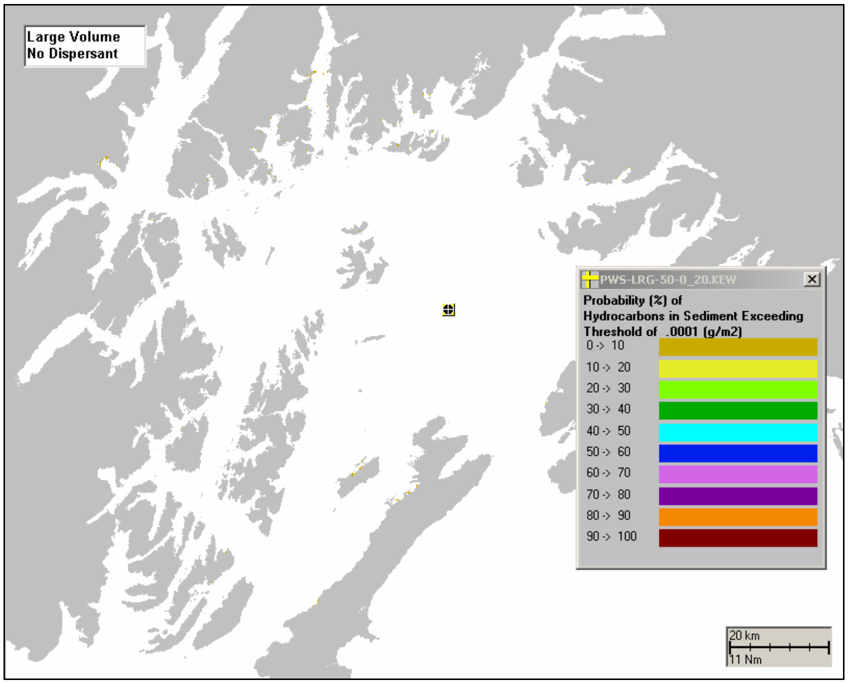

Figure F-II.1.4.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Large Volume, No Dispersant.

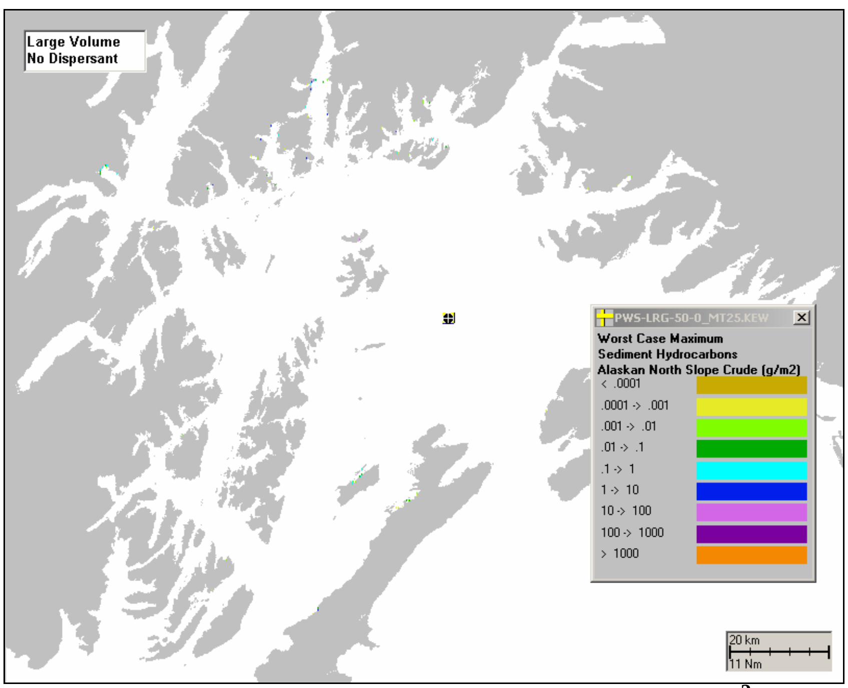

Figure F-II.1.4.5-2 Sediment exposure to total hydrocarbons (g/m^2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

F-II.1.4.6 Sediment pore water dissolved aromatic concentrations. Scenario: Large Volume, No Dispersant

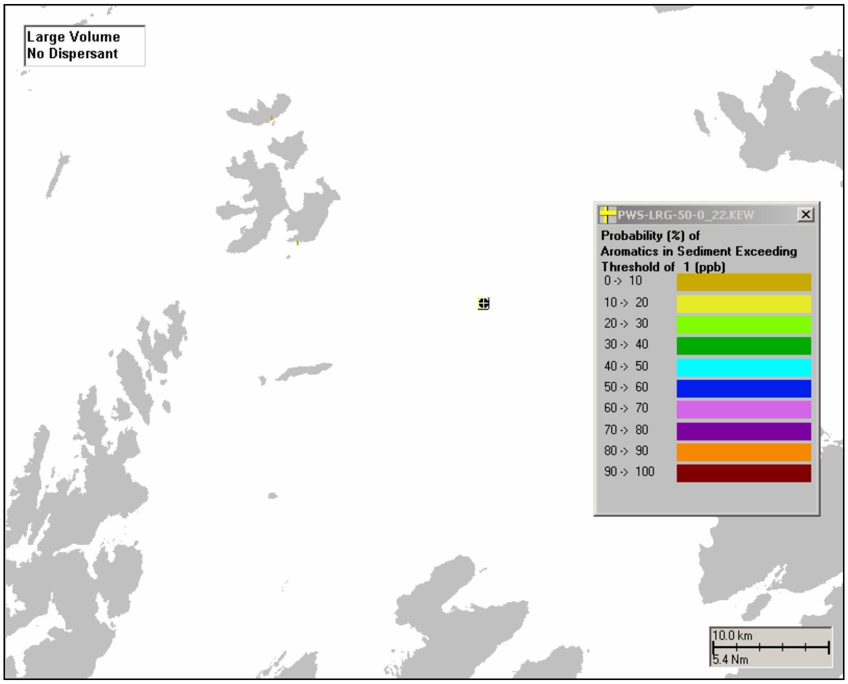

Figure F-II.1.4.6-1 Probability (%) of sediment pore water dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, No Dispersant.

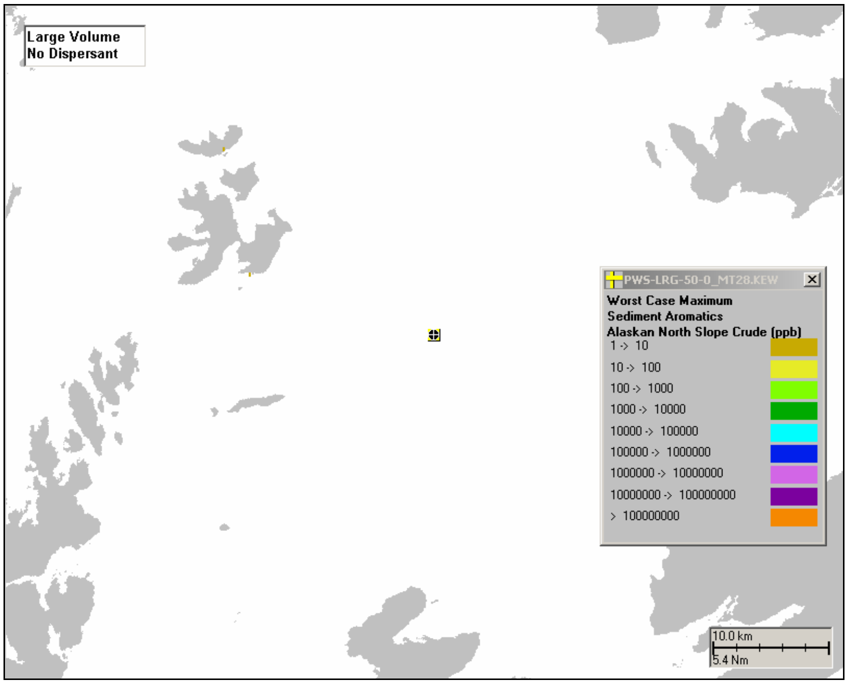

Figure F-II.1.4.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, No Dispersant.

F-II.1.5. Scenario: Large Volume, 45% Dispersant Efficiency

F-II.1.5.1 Surface Floating Total Hydrocarbons. Scenario: Large Volume, 45% Dispersant Efficiency

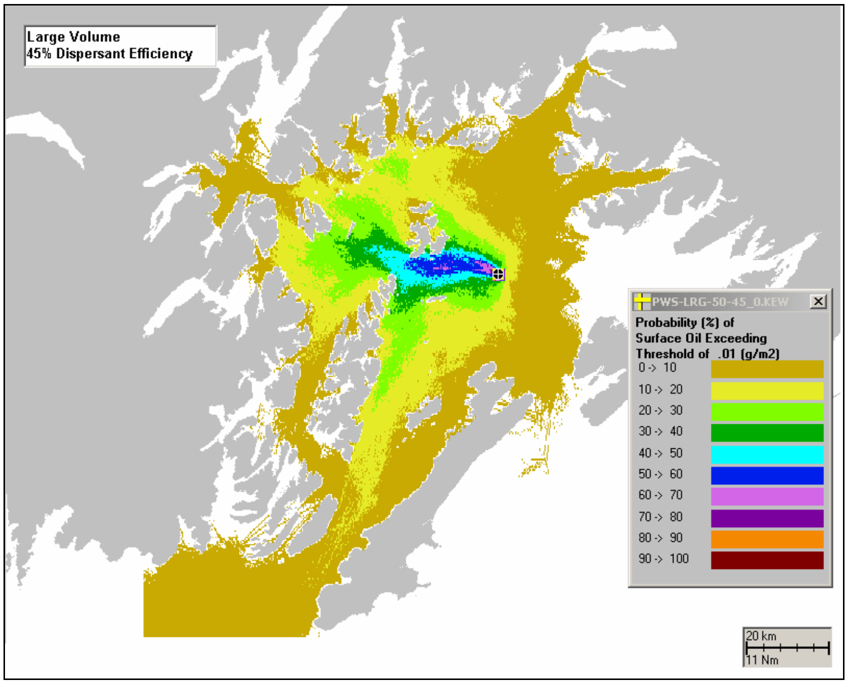

Figure F-II.1.5.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

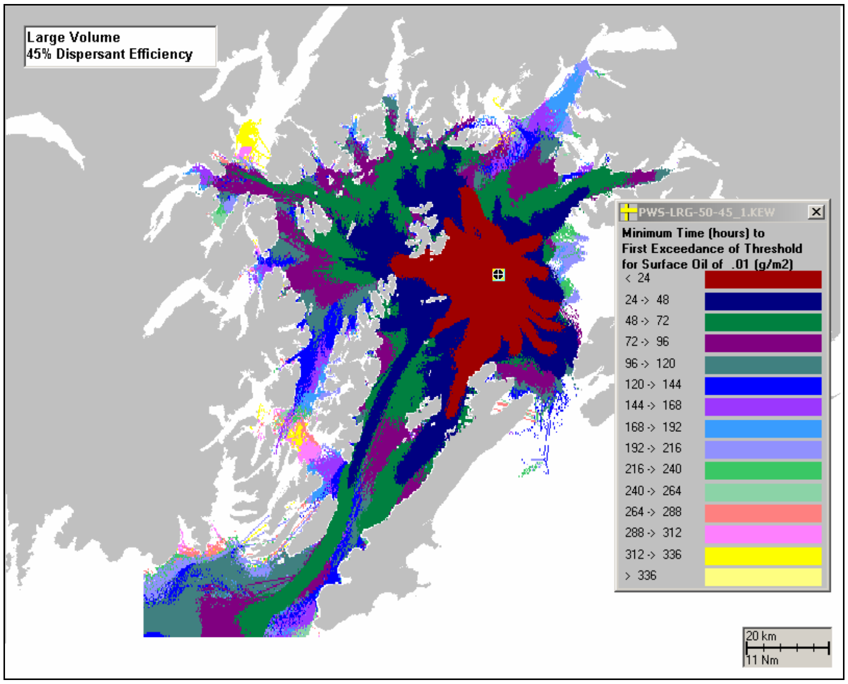

Figure F-II.1.5.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

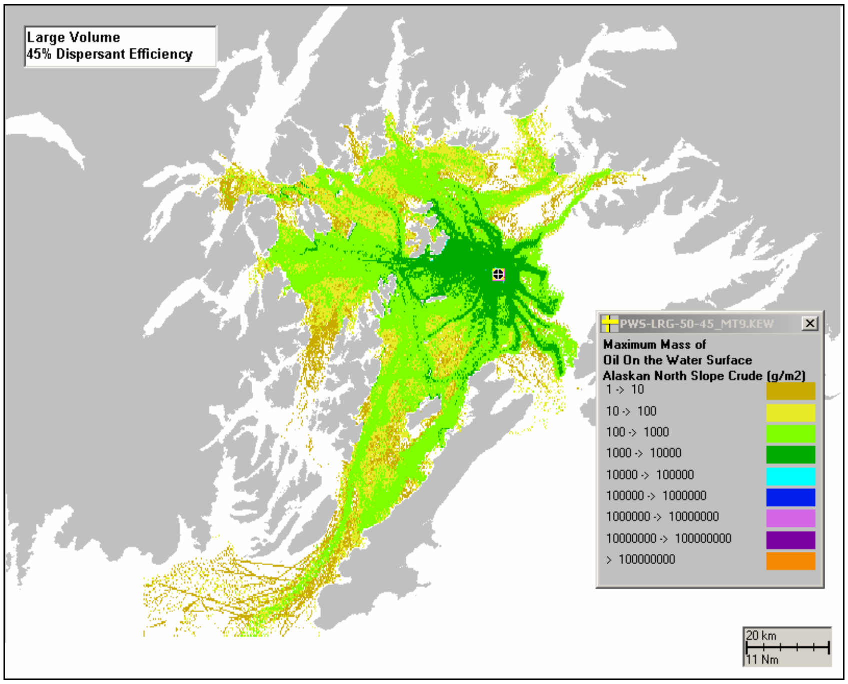

Figure F-II.1.5.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

F-II.1.5.2 Shoreline Oiled. Scenario: Large Volume, 45% Dispersant Efficiency

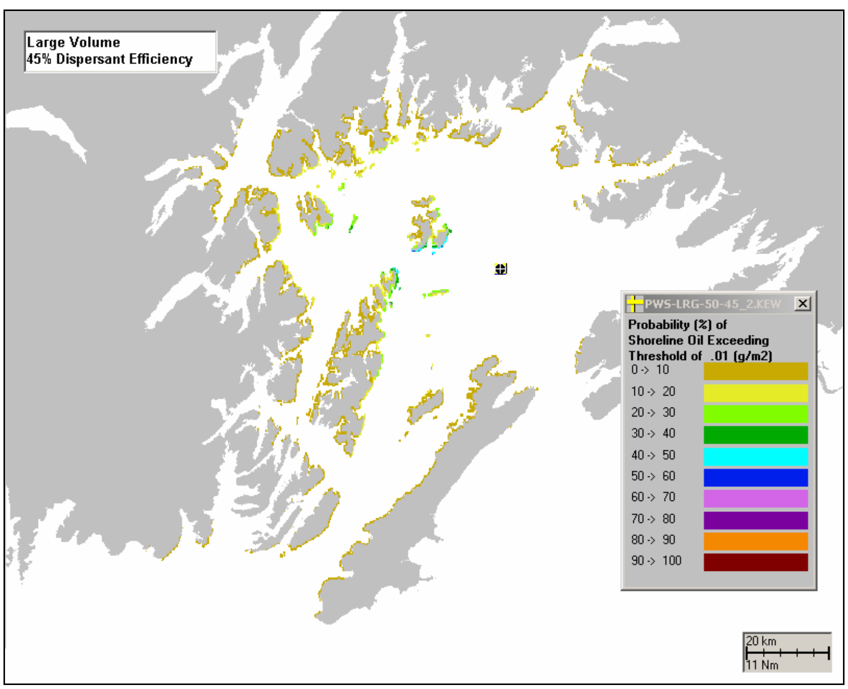

Figure F-II.1.5.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

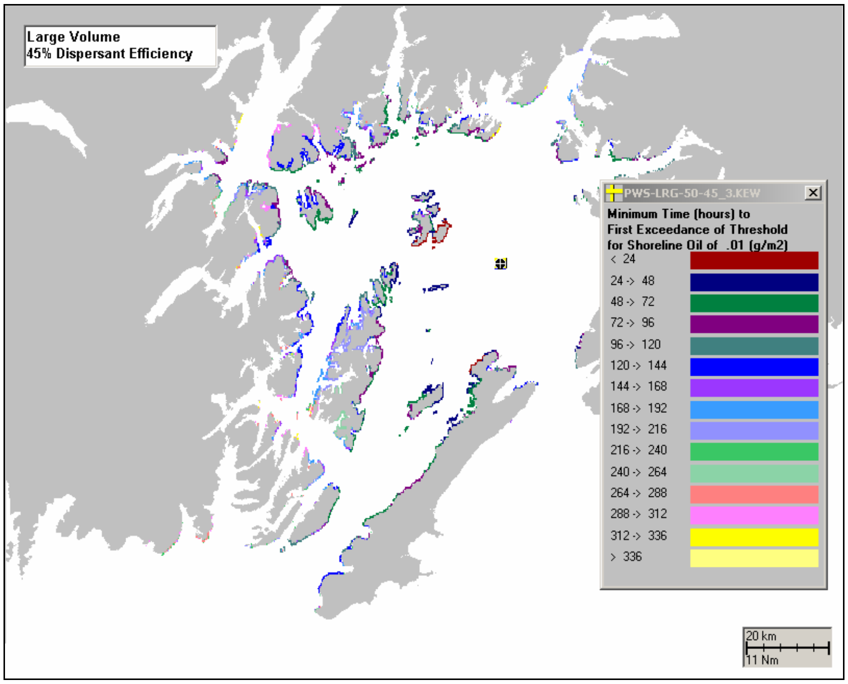

Figure F-II.1.5.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

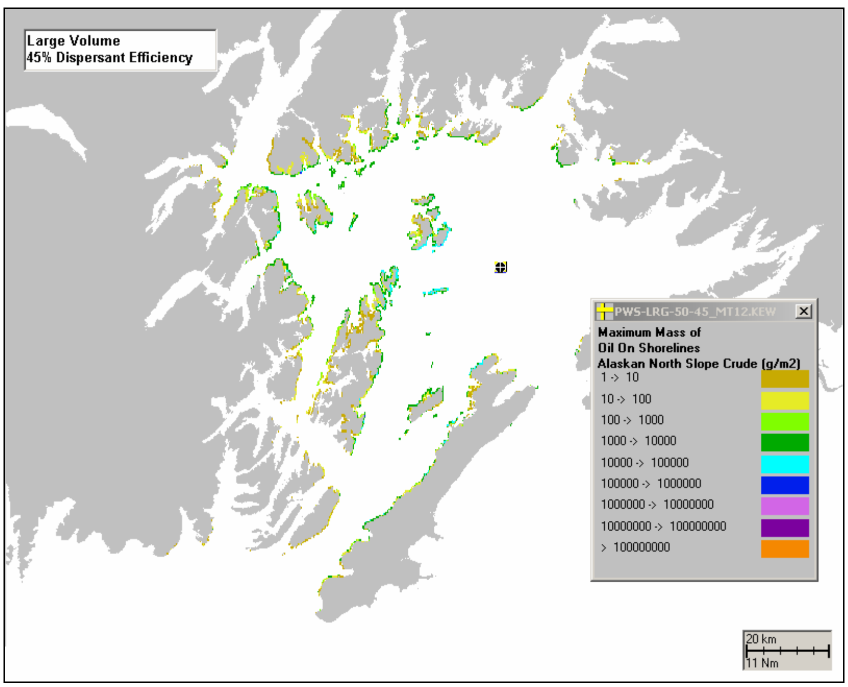

Figure F-II.1.5.2-.3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

F-II.1.5.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Large Volume, 45% Dispersant Efficiency

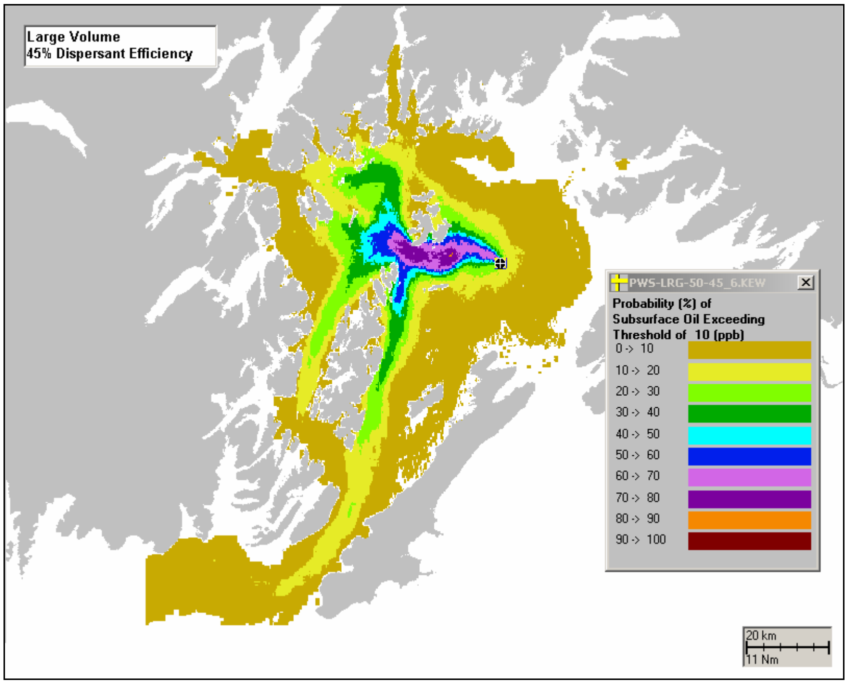

Figure F-II.1.5.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

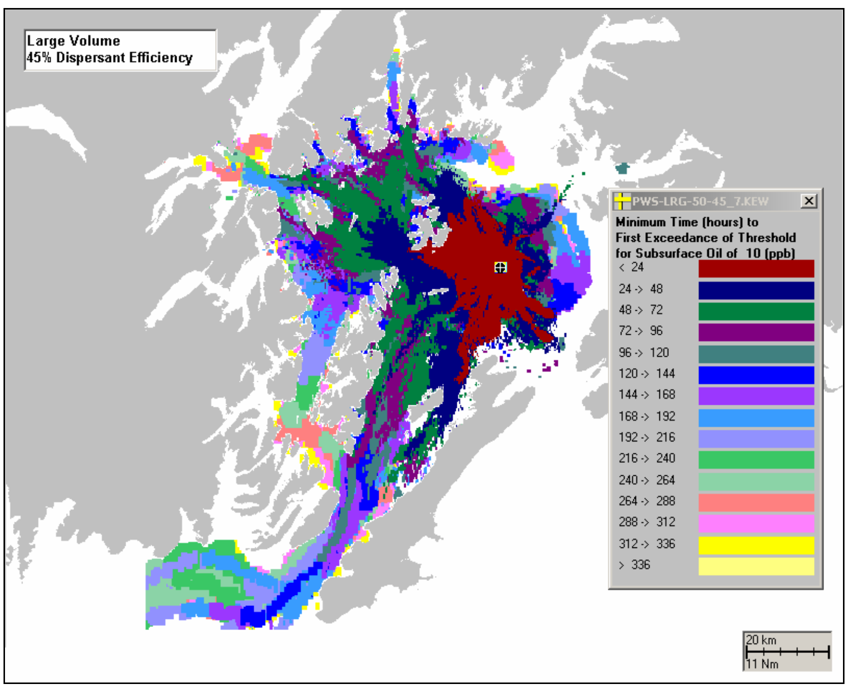

Figure F-II.1.5.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

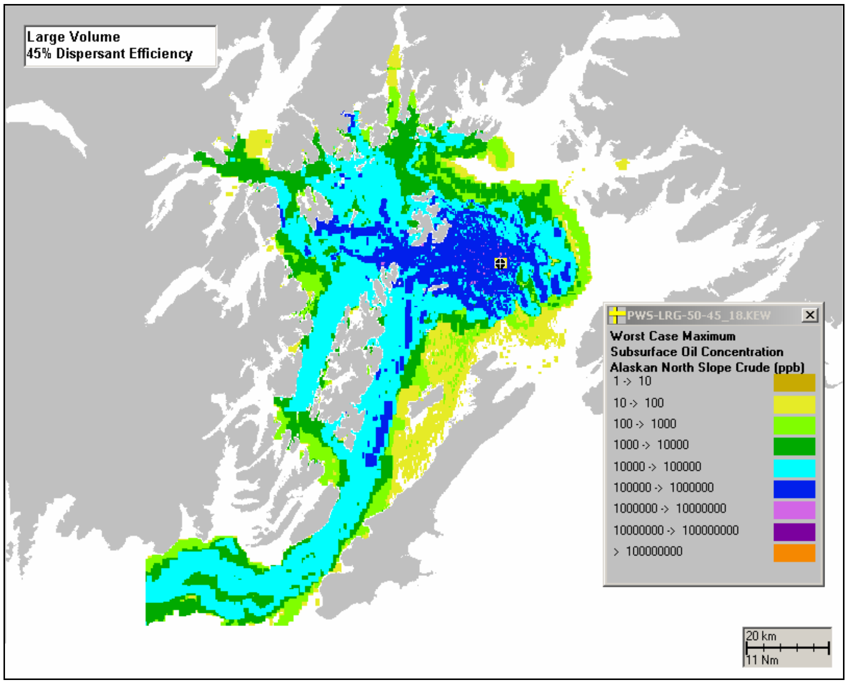

Figure F-II.1.5.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

F-II.1.5.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Large Volume, 45% Dispersant Efficiency

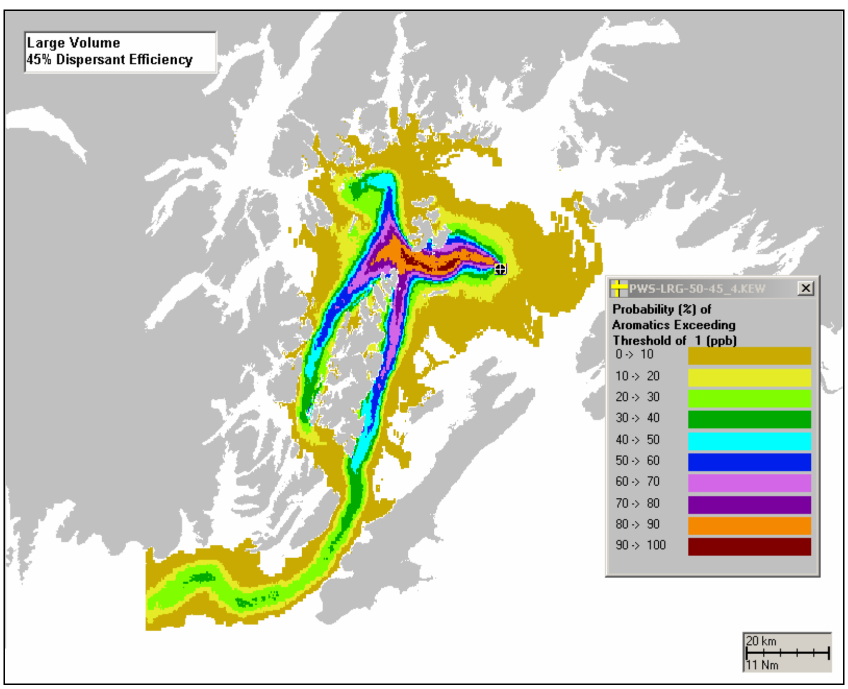

Figure F-II.1.5.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

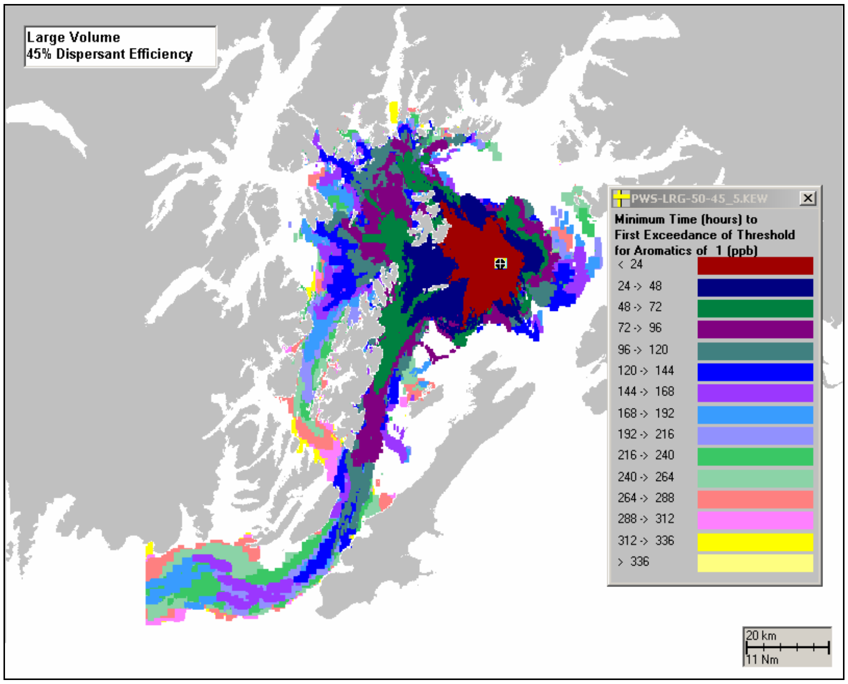

Figure F-II.1.5.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

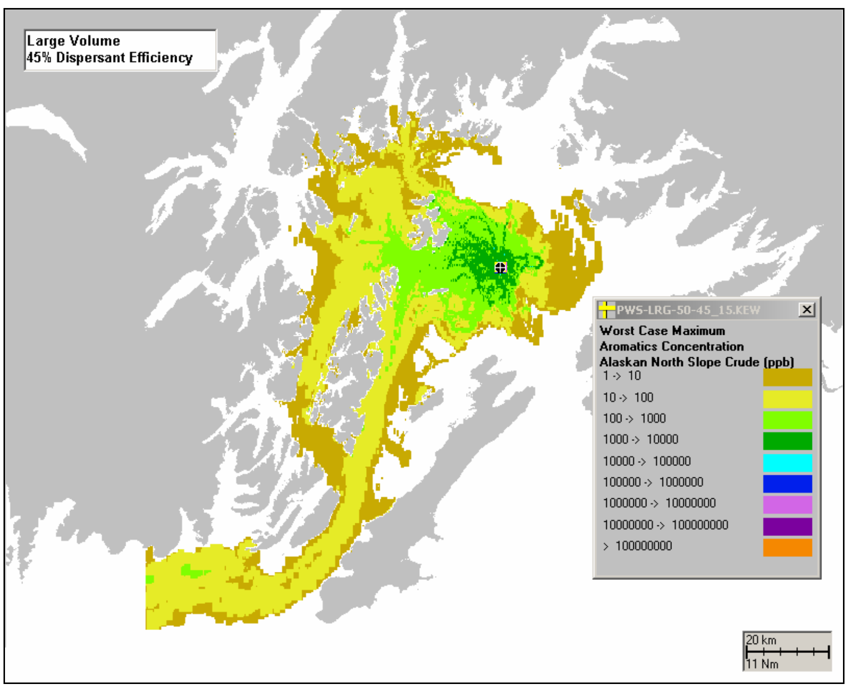

Figure F-II.1.5.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

F-II.1.5.5 Sediment exposure to total hydrocarbons (g/m²). Scenario: Large Volume, 45% Dispersant Efficiency

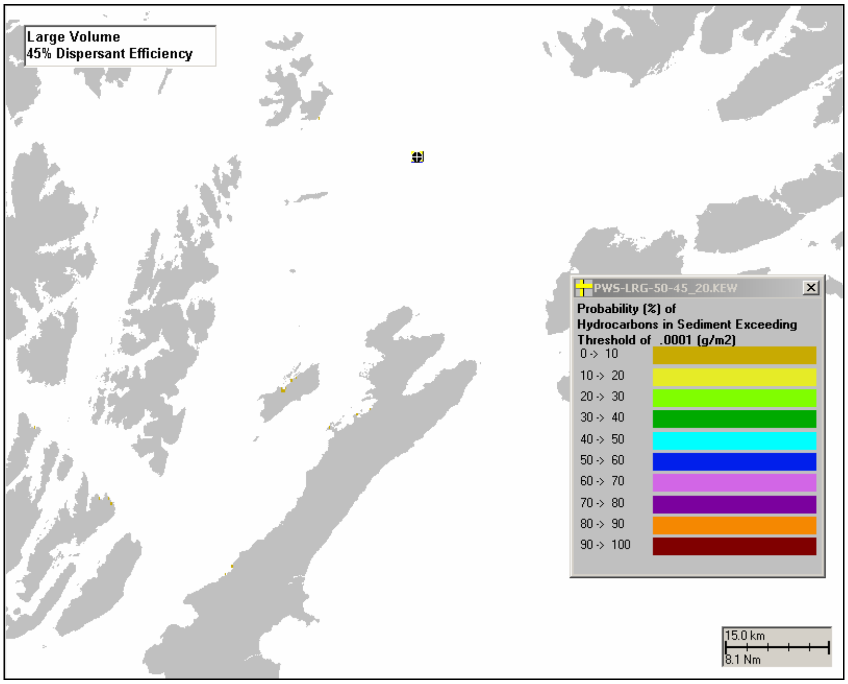

Figure F-II.1.5.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Large Volume, 45% Dispersant Efficiency.

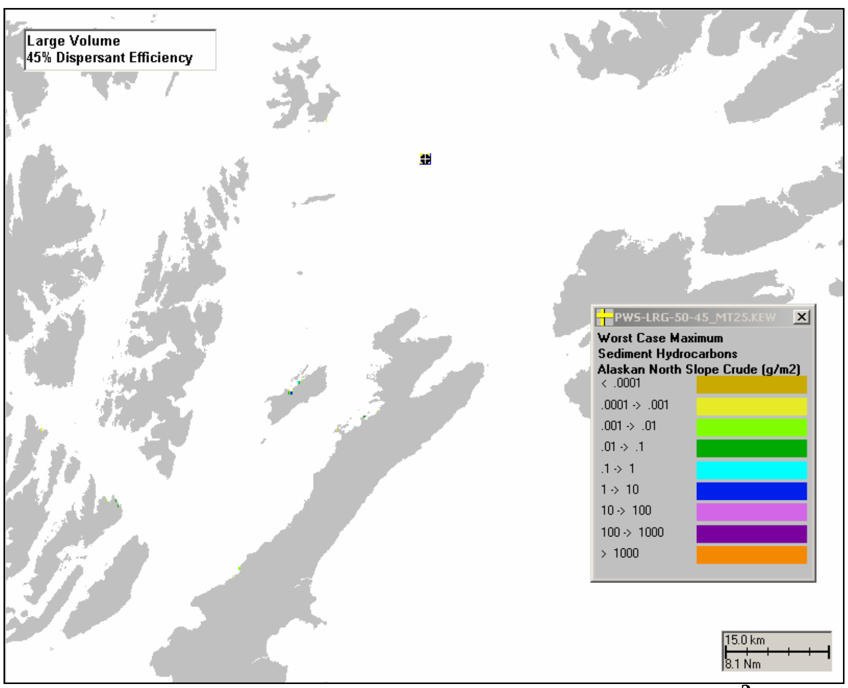

Figure F-II.1.5.5-2 Sediment exposure to total hydrocarbons (g/m²) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

F-II.1.5.6 Sediment pore water dissolved aromatic concentrations. Scenario: Large Volume, 45% Dispersant Efficiency

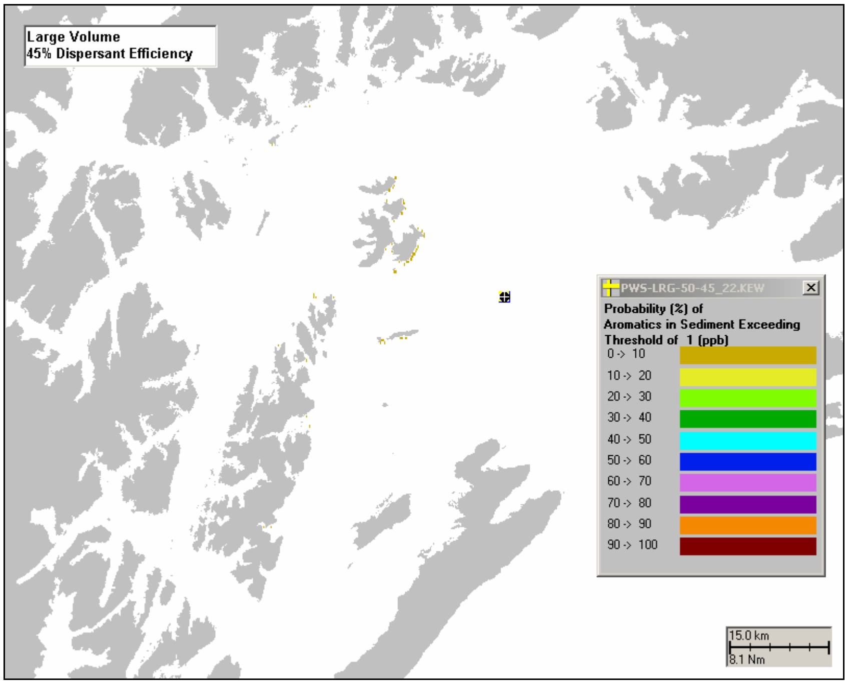

Figure F-II.1.5.6-1 Probability (%) of sediment pore water concentrations exceeding 1ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

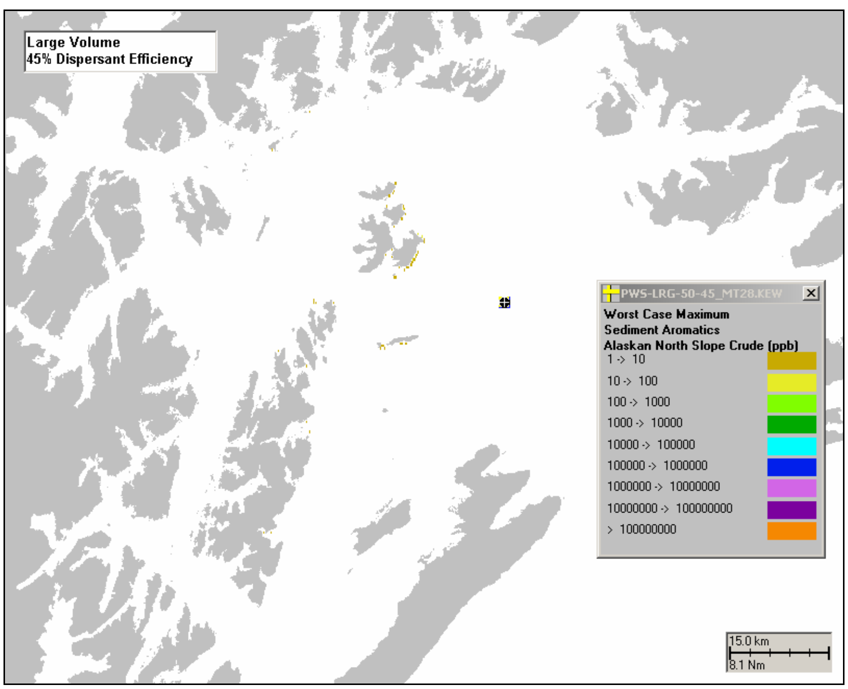

Figure F-II.1.5.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 45% Dispersant Efficiency.

F-II.1.6. Scenario: Large Volume, 80% Dispersant Efficiency

F-II.1.6.1 Surface Floating Total Hydrocarbons. Scenario: Large Volume, 80% Dispersant Efficiency.

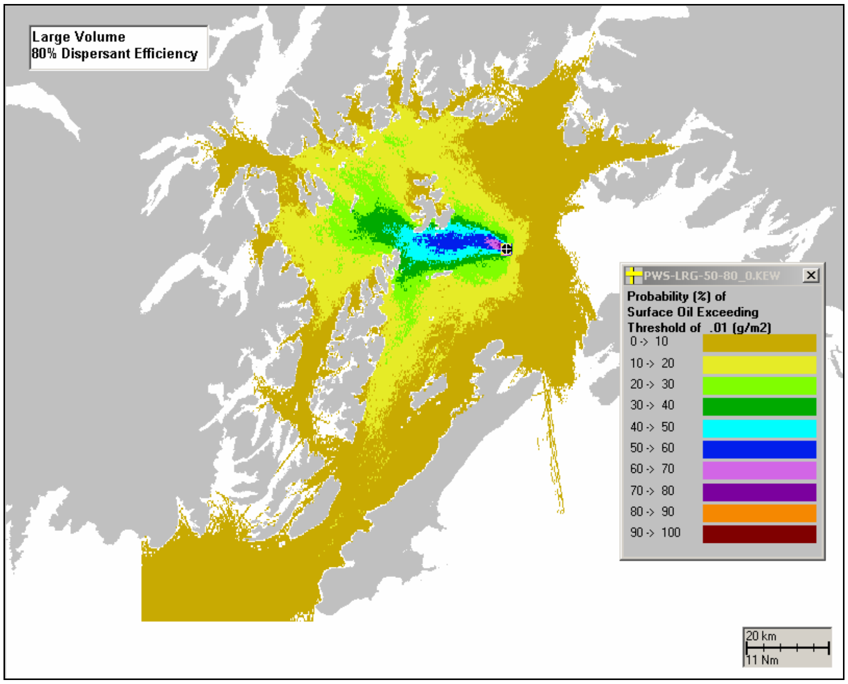

Figure F-II.1.6.1-1 Probability (%) of surface floating total hydrocarbons exceeding 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

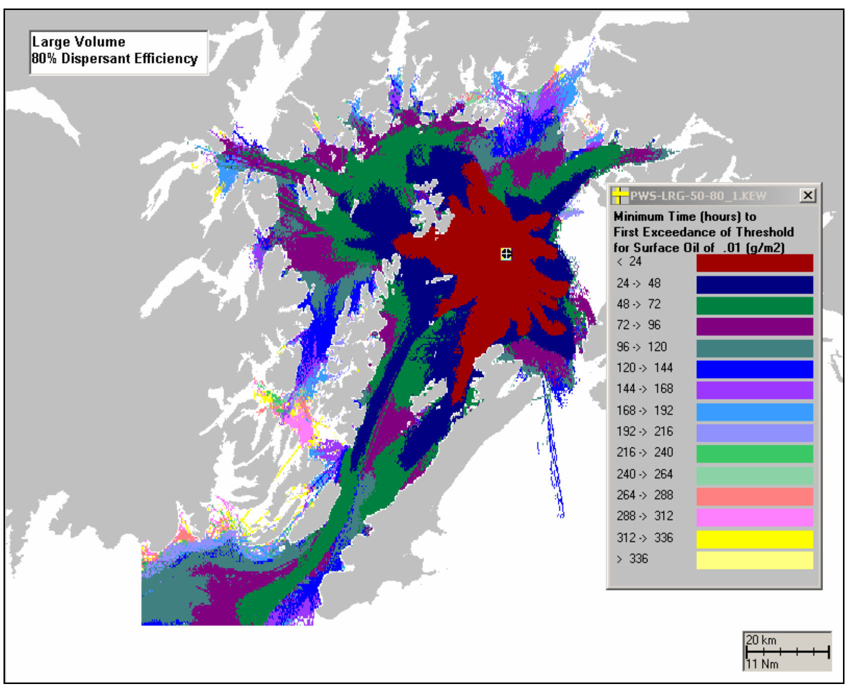

Figure F-II.1.6.1-2 Time (hrs) after spill when surface floating total hydrocarbons could first exceed 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

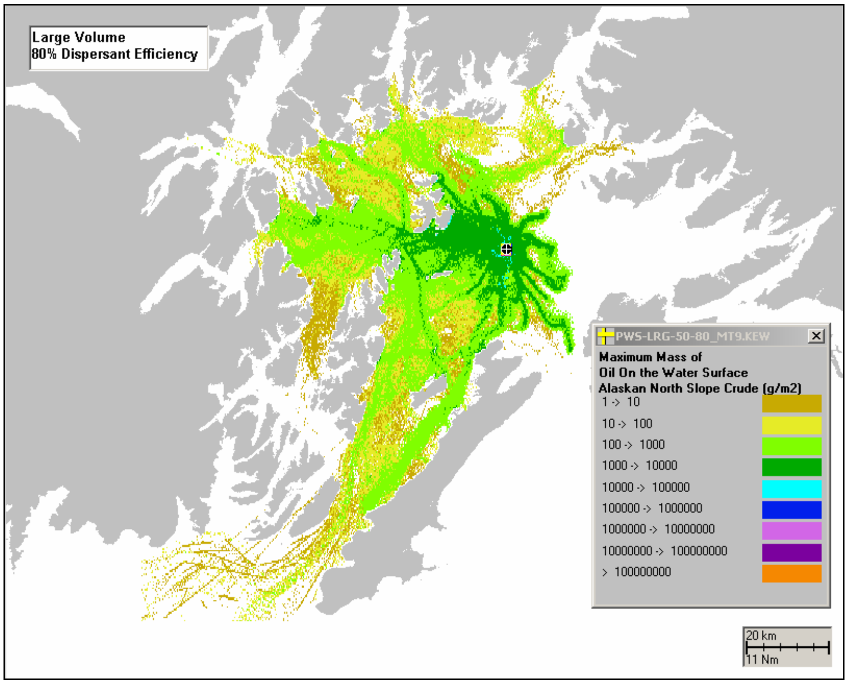

Figure F-II.1.6.1-3 Water surface exposure to floating hydrocarbons (g/m2) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

F-II.1.6.2 Shoreline Oiled. Scenario: Large Volume, 80% Dispersant Efficiency

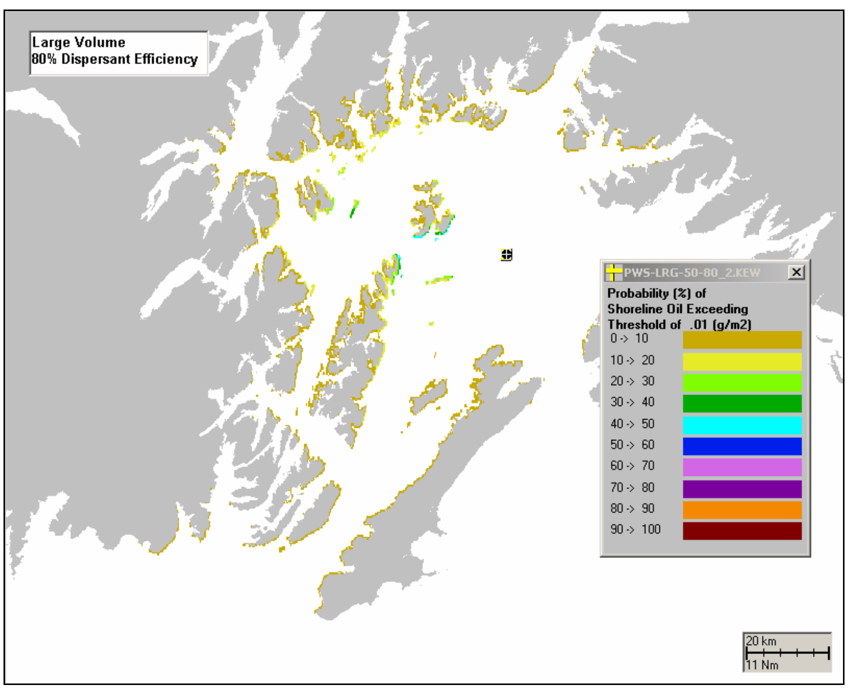

Figure F-II.1.6.2-1 Probability (%) of shoreline oiled exceeding 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

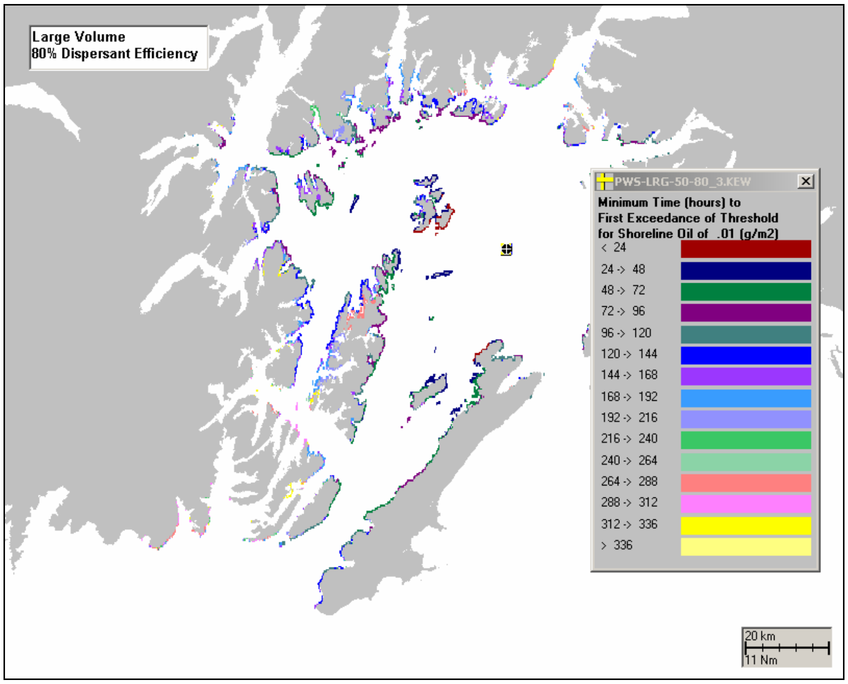

Figure F-II.1.6.2-2 Time (hrs) after spill when shoreline oiled could first exceed 0.01g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

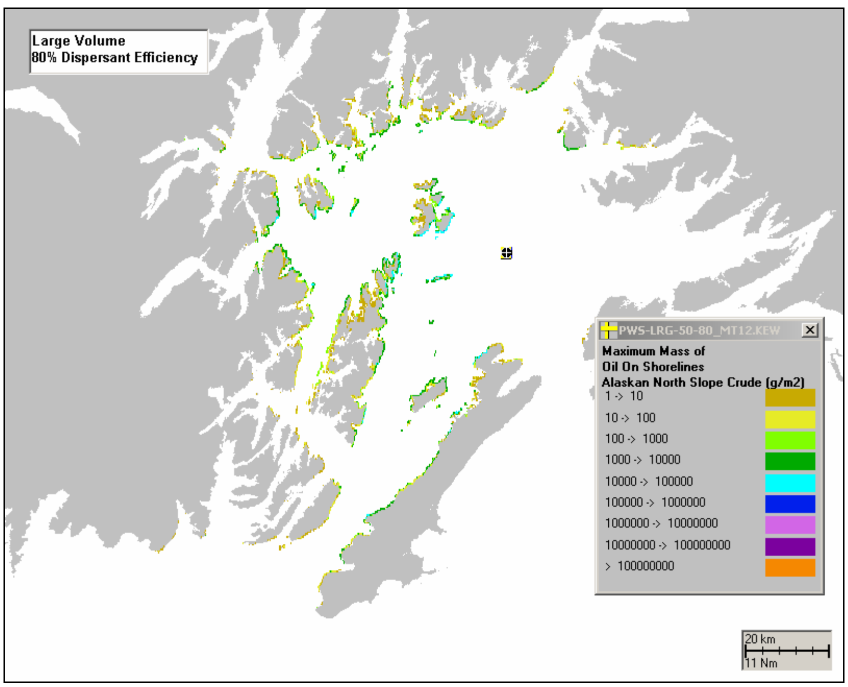

Figure F-II.1.6.2-3 Shoreline exposure to hydrocarbons (g/m2) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

F-II.1.6.3 Total Hydrocarbon Concentrations in the Water Column. Scenario: Large Volume, 80% Dispersant Efficiency

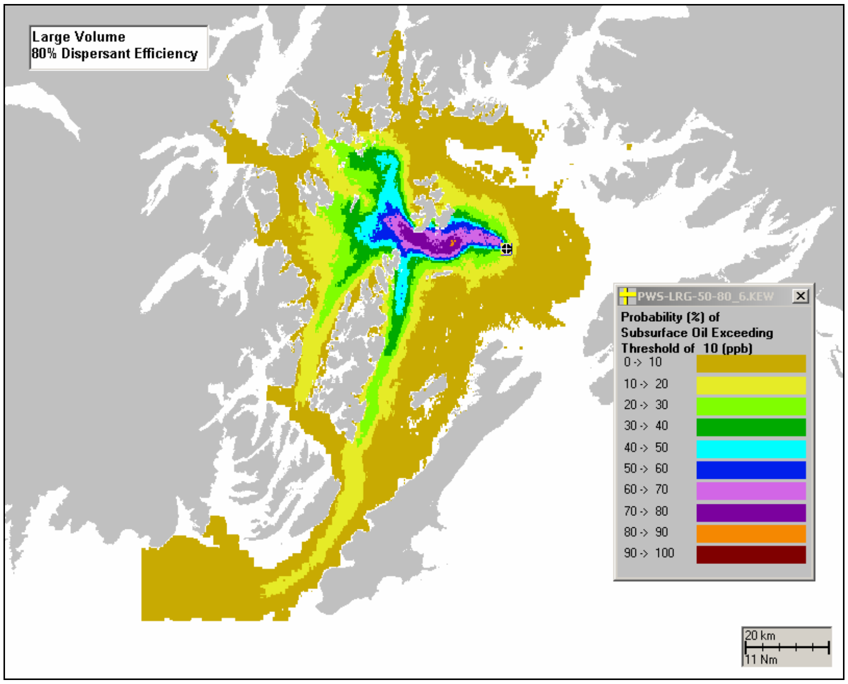

Figure F-II.1.6.3-1 Probability (%) of total hydrocarbon concentrations exceeding 10ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

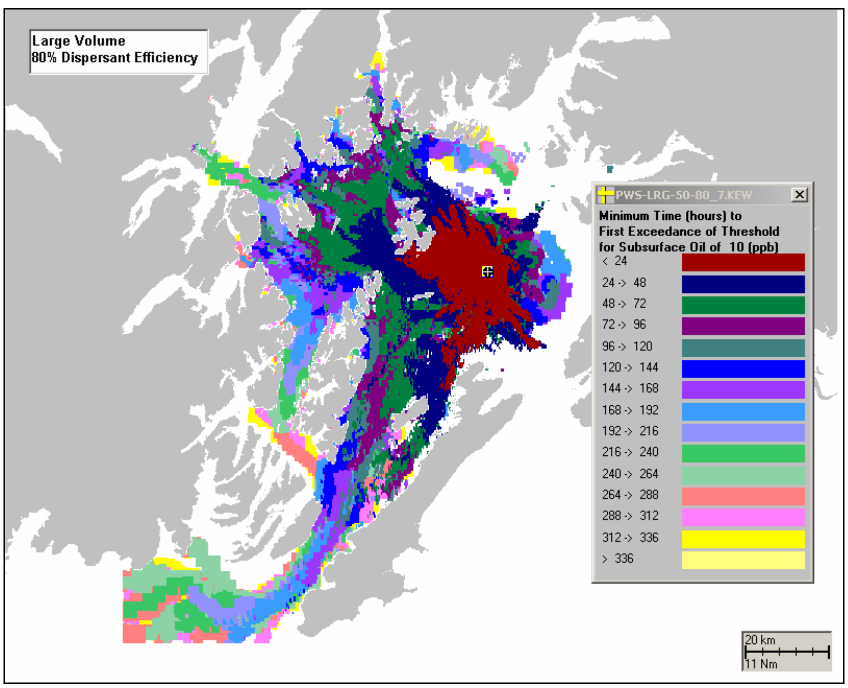

Figure F-II.1.6.3-2 Time (hrs) after spill when total hydrocarbon concentrations could first exceed 10ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

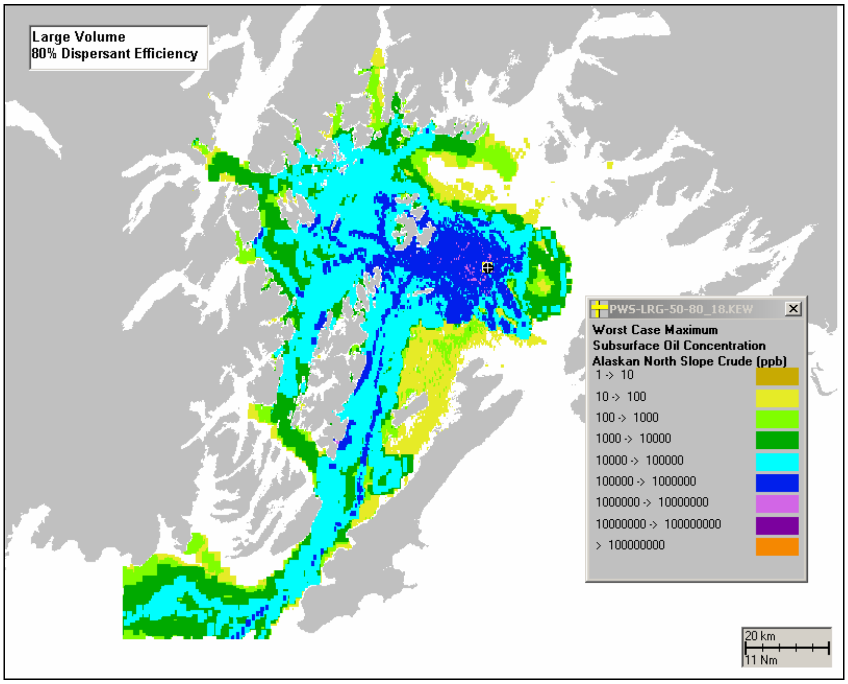

Figure F-II.1.6.3-3 Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

F-II.1.6.4 Dissolved Aromatic Concentrations in the Water Column. Scenario: Large Volume, 80% Dispersant Efficiency

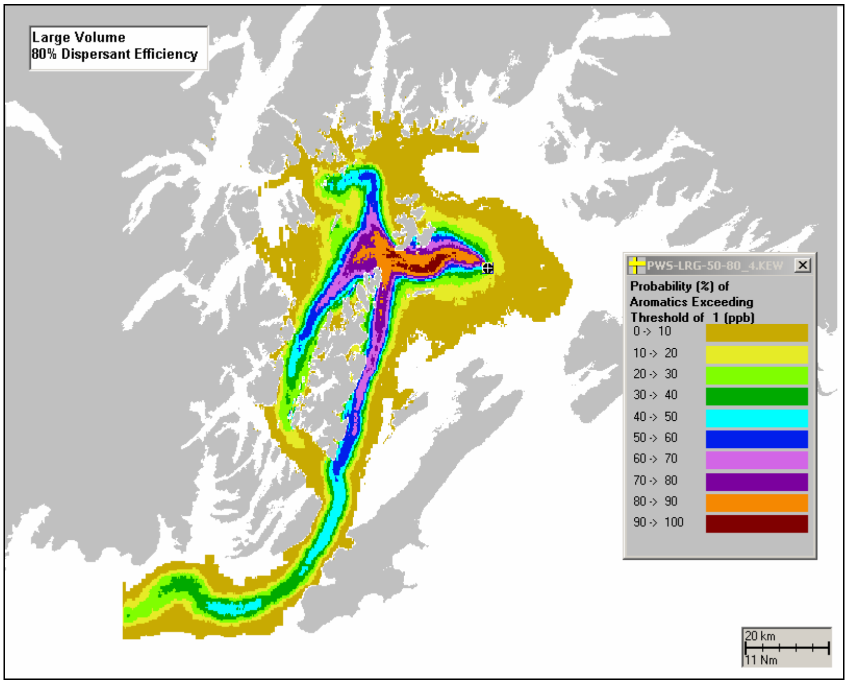

Figure F-II.1.6.4-1 Probability (%) of dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

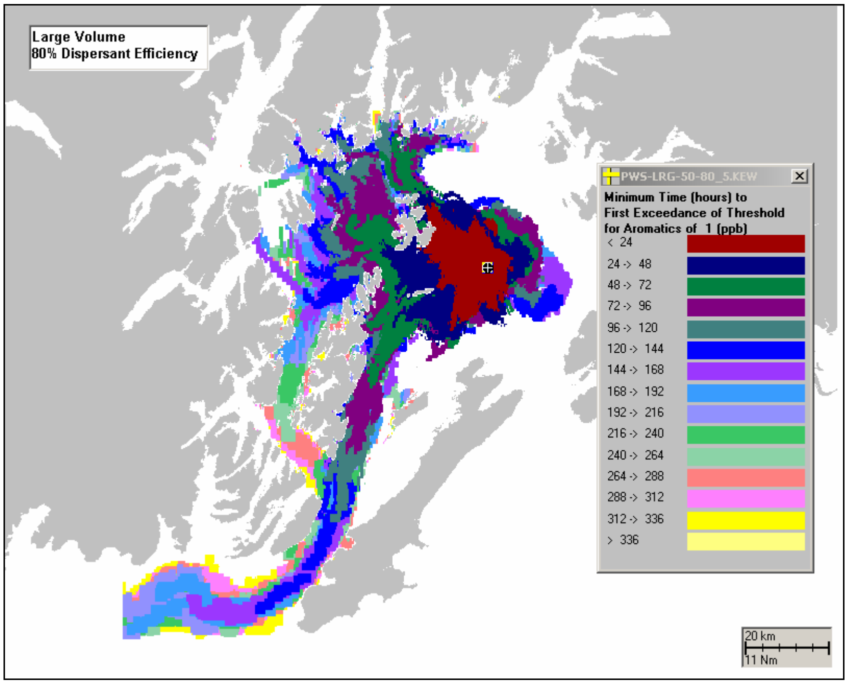

Figure F-II.1.6.4-2 Time (hrs) after spill when dissolved aromatic concentrations could first exceed 1ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

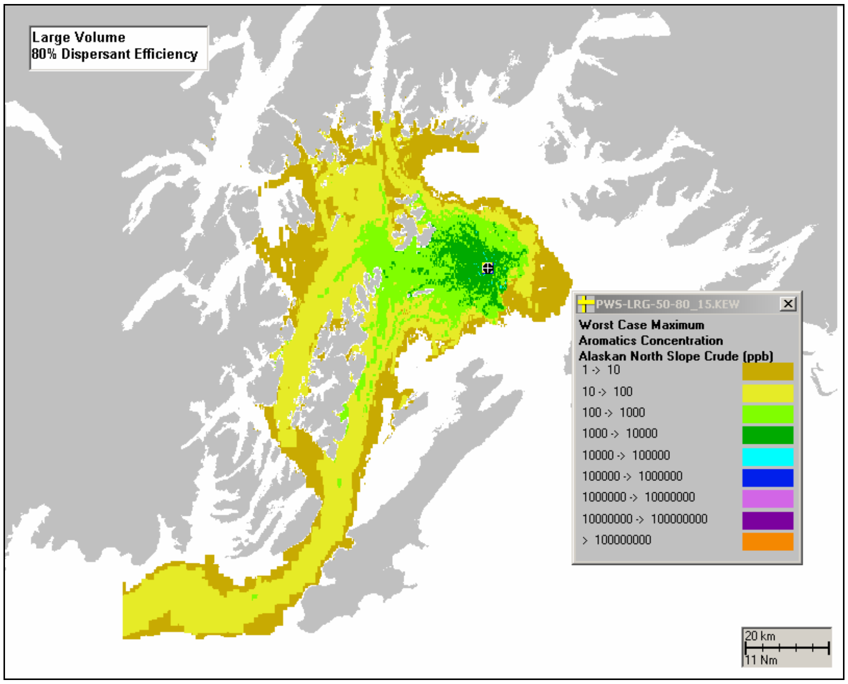

Figure F-II.1.6.4-3 Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

F-II.1.6.5 Sediment exposure to total hydrocarbons (g/m²). Scenario: Large Volume, 80% Dispersant Efficiency

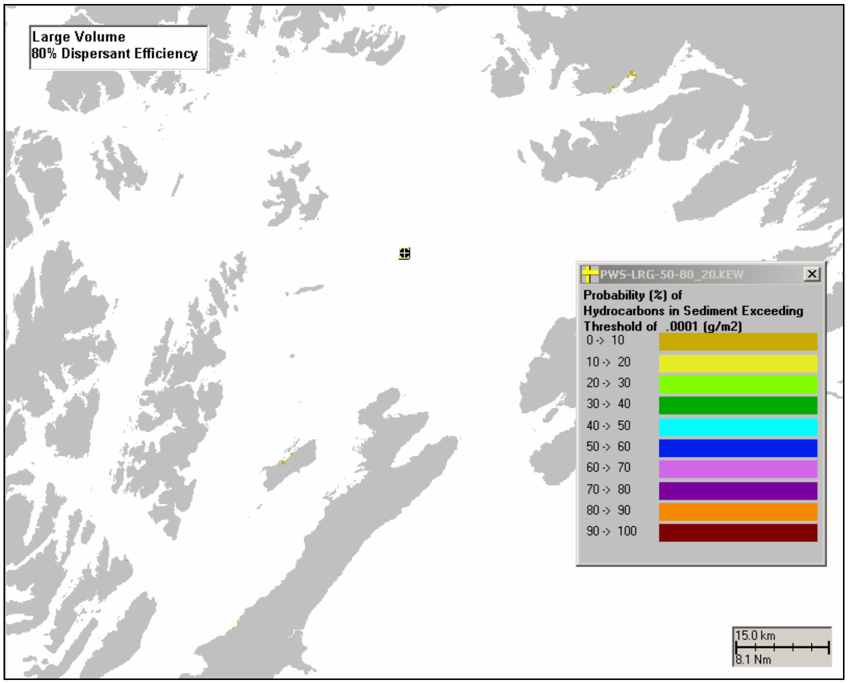

Figure F-II.1.6.5-1 Probability (%) of sediment exposure to total hydrocarbons exceeding 0.0001g/m2. Scenario: Large Volume, 80% Dispersant Efficiency.

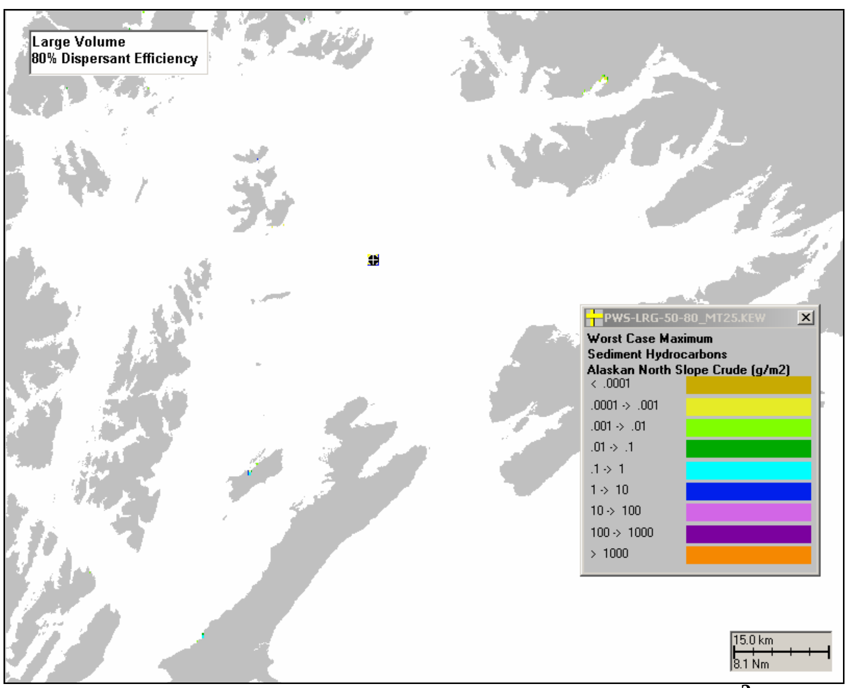

Figure F-II.1.6.5-2 Sediment exposure to total hydrocarbons (g/m²) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

F-II.1.6.6 Sediment pore water dissolved aromatic concentrations. Scenario: Large Volume, 80% Dispersant Efficiency

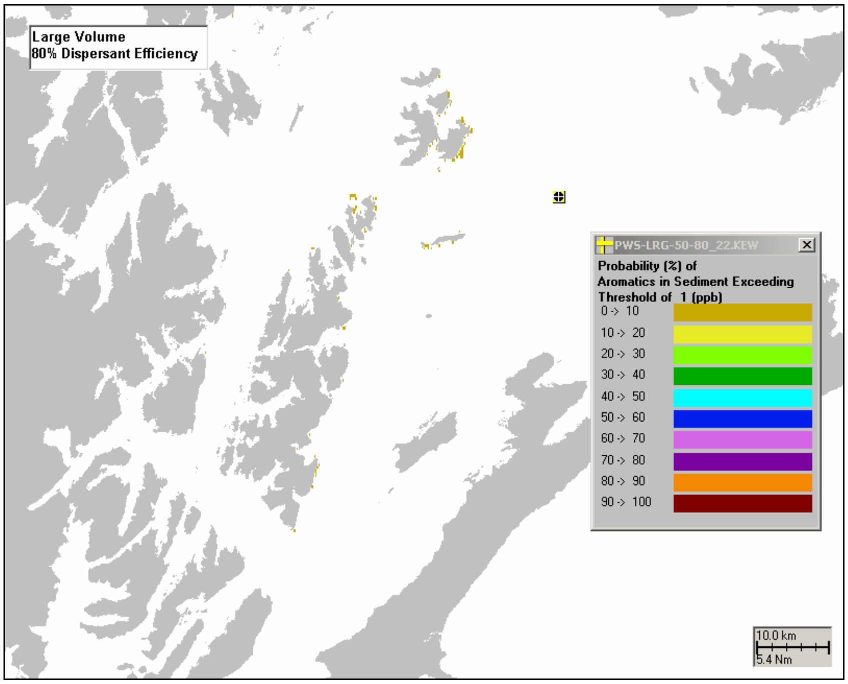

Figure F-II.1.6.6-1 Probability (%) of sediment pore water dissolved aromatic concentrations exceeding 1ppb. Scenario: Large Volume, 80% Dispersant Efficiency.

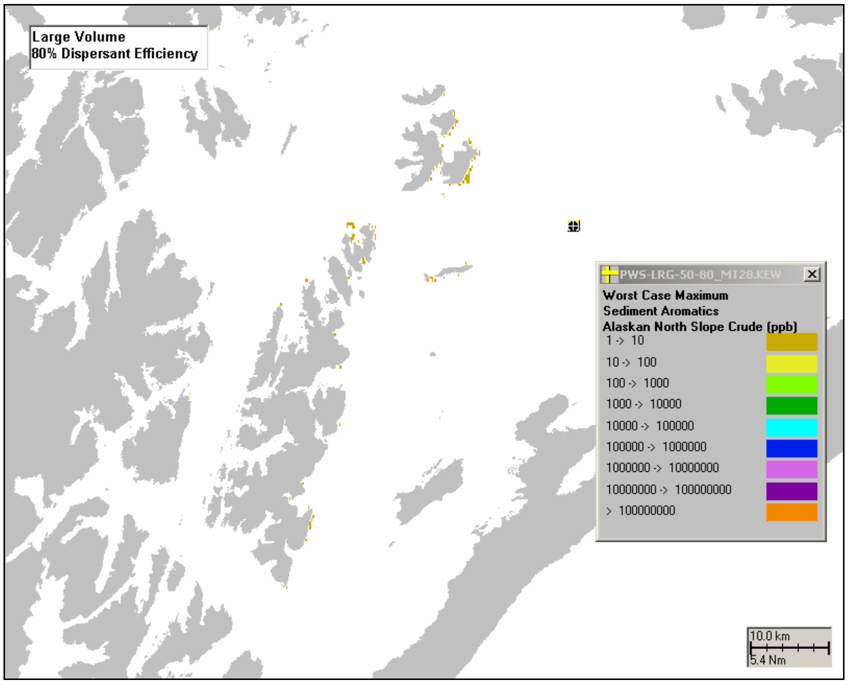

Figure F-II.1.6.6-2 Sediment pore water exposure of dissolved aromatic concentration (ppb) under worst-case environmental conditions for each location (i.e., maximum possible exposure). Scenario: Large Volume, 80% Dispersant Efficiency.

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part F: Prince William Sound

Section F-II.2

by

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ASA 00-246

August 2004

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F-II.2 Results of the Stochastic Modeling: Tables Summarizing Exposure Indices

Tables F-II.2-1 to F-II.2-6 summarize the exposure indices for all model runs in the stochastic oil spill modeling analysis for the spill site in Prince William Sound. Average and the maximum of the 100 simulations performed for each scenario are presented. The 95th percentile conditions used in the risk analysis were calculated as the mean plus two times the standard deviation. The following are the exposure indices used in the analysis.

- Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr) – integrated area swept by oil sheen or thicker oil times duration that oil is present [Note that this index is the oil mass passing through the cell averaged over the grid cell area, and so dilutes smaller patches of contamination. For this reason, evaluation of potential effects on wildlife is made using area swept by individual oil spillets; see explanation in Part A.4]
- Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) –area swept by oil sheen or thicker oil times, for landward (estuarine), seaward (marine), and all waters
- Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2) – shoreline oiled with a thickness exceeding this amount, averaged over the grid cell area (segment length of 276 m times width for the shore type, which is 3 m for rock/artificial, 10m for gravel beaches, 20 m for sand beaches and 300 m for wetlands and mud flats)
- Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2) – shoreline oiled with a thickness exceeding this amount, averaged over the grid cell area (segment length times typical width for the shore type, as above)
- Length of Shoreline Oiling Exceeding 10 g/m^2 (m) – shoreline of various shore types oiled with a thickness exceeding this amount:
    - Total shoreline
    - Wetlands and mudflats
    - Other shoreline (rocky shore, gravel beach, sand beach, artificial shore)
    - Seaward (marine) sand beach
- Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – water volume contaminated at any time after the spill by > 1ppb dissolved aromatic concentration (in all subtidal habitats) [Note that this index is averaged over the grid cell and upper mixed layer, and so dilutes smaller patches of contamination. For this reason, evaluation of potential effects on biota is made using higher resolution small scale grids around the plume in the water; see explanation in Part A.4]
- Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs) – integrated exposure to dissolved aromatics, as ppb-hrs averaged over the water volume contaminated at any time after the spill by > 1ppb dissolved aromatic concentration
- Percent of Spilled Hydrocarbon Mass Coming Ashore (%) – percent of the spilled oil coming ashore by 14 days after the spill, assuming no shoreline cleanup

- Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)
- Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%) – maximum percent of the oil dispersed by natural forces (waves) and chemical dispersant. (Some naturally dispersed oil may resurface and be re-entrained into the water column, so this is the maximum percent in the water at any time after the spill.)
- Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%) – calculated by difference between no-dispersant and dispersant use scenario
- Percent of Spilled Hydrocarbon Mass Mechanically Removed (%) – The percentage decreases as chemical dispersion increases because less oil remains on the surface and is available to be skimmed.

Table F-II.2-1. Summary of exposure indices for all model runs (Medium Volume, No Dispersant).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	2,515 x 10^6	2,821 x 10^6	0	16,485 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) cells only	0	0	100	0
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	430 x 10^6	230 x 10^6	0	1,036 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	430 x 10^6	230 x 10^6	0	1,036 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) 0-3 nautical miles offshore (including all bays and Prince William Sound)	419 x 10^6	215 x 10^6	0	1,035 x 10^6
Surface Oil Exposure Exceeding 10g/m^2 (m^2) 0-3 nautical miles offshore (including all bays and Prince William Sound)	104 x 10^6	49 x 10^6	0	234 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	1,485,042	1,255,441	0	5,489,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	116,515	64,788	0	315,621

Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	24,162	12,001	0	62,130
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	17	95	97	552
Length of Shoreline Oiling Exceeding 10 $g/m^{2\,-}$ Other Shoreline (m)	24,145	12,013	0	62,130
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	22	109	95	829
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	43×10^6	64×10^6	0	326×10^6
Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	105	102	0	629
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	29.07	4.85	0	39.20
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0000	0.0004	98	0.0035
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	5.07	3.17	0	14.54
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	0	0	100	0
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	15.59	6.40	0	28.25

Table F-II.2-2. Summary of exposure indices for all model runs (Medium Volume, 45% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	2,108 x 10^6	3,379 x 10^6	0	18,621 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) cells only	0	0	100	0
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	244 x 10^6	239 x 10^6	0	1,116 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	244 x 10^6	239 x 10^6	0	1,116 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) 0-3 nautical miles offshore (including all bays and Prince William Sound)	238 x 10^6	227 x 10^6	0	858 x 10^6
Surface Oil Exposure Exceeding 10g/m^2 (m^2) 0-3 nautical miles offshore (including all bays and Prince William Sound)	19 x 10^6	25 x 10^6	0	129 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	694,298	901,360	13	5,464,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	55,514	101,666	32	818,460
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	10,863	13,983	32	53,018
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	25	222	98	2,209
Length of Shoreline Oiling Exceeding 10 g/m^{2} - Other Shoreline (m)	10,838	13,944	32	53,018
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	14	99	98	829
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	492 x 10^6	217 x 10^6	0	1,197 x 10^6

Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	2,117	1,320	0	6,634
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	5.47	11.28	16	37.68
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0007	0.0006	15	0.0035
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	73.11	23.96	0	90.63
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	68.04	25.58	0	87.02
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	1.20	3.07	51	18.23

Table F-II.2-3. Summary of exposure indices for all model runs (Medium Volume, 80% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	1,991 x 10^6	3,151 x 10^6	0	15,674 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) cells only	0	0	100	0
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	238 x 10^6	243 x 10^6	0	1,134 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	238 x 10^6	243 x 10^6	0	1,134 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) 0-3 nautical miles offshore (including all bays and Prince William Sound)	234 x 10^6	232 x 10^6	0	880 x 10^6
Surface Oil Exposure Exceeding 10g/m^2 (m^2) 0-3 nautical miles offshore (including all bays and Prince William Sound)	17 x 10^6	23 x 10^6	0	136 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	633,207	714,872	9	2,973,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	48,635	77,501	41	426,627
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	10,568	15,653	39	76,213
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	0	0	100	0
Length of Shoreline Oiling Exceeding 10 g/m$^{2\ -}$ Other Shoreline (m)	10,568	15,653	39	76,213
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	11	87	98	828
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	478 x 10^6	209 x 10^6	0	1,160 x 10^6

Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	2,156	1,238	0	6,936
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	4.96	11.00	16	37.75
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0007	0.0007	15	0.0050
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	73.39	24.09	0	90.65
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	68.32	25.68	0	87.03
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	1.20	3.13	58	18.93

Table F-II.2-4. Summary of exposure indices for all model runs (Large Volume, No Dispersant).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	12,411 x 10^6	9,085 x 10^6	0	46,523 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) cells only	0	0	100	0
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	816 x 10^6	419 x 10^6	0	2,272 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	816 x 10^6	419 x 10^6	0	2,272 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) 0-3 nautical miles offshore (including all bays and Prince William Sound)	770 x 10^6	348 x 10^6	0	2,001 x 10^6
Surface Oil Exposure Exceeding 10g/m^2 (m^2) 0-3 nautical miles offshore (including all bays and Prince William Sound)	342 x 10^6	128 x 10^6	0	641 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	2,131,805	1,386,583	0	7,801,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	511,814	251,930	0	1,229,900
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	89,321	37,813	0	188,875
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	196	481	78	2,761
Length of Shoreline Oiling Exceeding 10 g/$m^{2\,-}$ Other Shoreline (m)	89,125	37,806	0	188,875
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	188	353	73	1,657
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	243 x 10^6	318 x 10^6	0	1,257 x 10^6
Average Dose of PAH's in Dissolved Aromatic Plume	368	292	0	1,262

Volume Exceeding 1 ppb (ppb-hrs)				
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	22.86	3.67	0	31.45
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0007	0.0036	92	0.0324
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	3.73	1.58	0	8.67
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	0	0	100	0
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	23.15	3.51	0	30.41

Table F-II.2-5. Summary of exposure indices for all model runs (Large Volume, 45% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	6,662 x 10^6	7,916 x 10^6	0	39,981 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) cells only	0	0	100	0
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	522 x 10^6	349 x 10^6	0	1,776 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	522 x 10^6	349 x 10^6	0	1,776 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) 0-3 nautical miles offshore (including all bays and Prince William Sound)	503 x 10^6	318 x 10^6	0	1,196 x 10^6
Surface Oil Exposure Exceeding 10g/m^2 (m^2) 0-3 nautical miles offshore (including all bays and Prince William Sound)	139 x 10^6	126 x 10^6	0	541 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	1,203,295	1,260,664	0	7,588,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	254,880	322,699	14	2,145,007
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	44,753	42,854	13	175,621
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	113	577	92	4,970
Length of Shoreline Oiling Exceeding 10 g/m^{2-} Other Shoreline (m)	44,640	42,644	13	173,136
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	72	235	88	1,657
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	3,635 x 10^6	1,967 x 10^6	0	8,435 x 10^6

Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	4,648	2,820	0	17,150
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	8.13	9.31	0	27.13
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0004	0.0009	37	0.0078
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	54.58	25.72	0	82.21
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	50.85	26.20	0	79.02
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	9.55	5.79	0	23.74

Table F-II.2-6. Summary of exposure indices for all model runs (Large Volume, 80% Dispersant Efficiency).

Exposure Index	Mean	Standard Deviation	Number of Zeros	Maximum
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2-hr)	5.684E+09	7.214E+09	0	4.1875E+10
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for landward (estuarine) cells only	0	0	100	0
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for seaward (marine) area only	456 x 10^6	337 x 10^6	0	1,854 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) for all waters	456 x 10^6	337 x 10^6	0	1,854 x 10^6
Surface Oil Exposure Exceeding 0.01g/m^2 (m^2) 0-3 nautical miles offshore (including all bays and Prince William Sound)	439 x 10^6	306 x 10^6	0	1,296 x 10^6
Surface Oil Exposure Exceeding 10g/m^2 (m^2) 0-3 nautical miles offshore (including all bays and Prince William Sound)	112 x 10^6	126 x 10^6	0	502 x 10^6
Area of Shoreline Oiling Exceeding 0.01g/m^2 (m^2)	967,816	886,191	0	4,912,000
Area of Shoreline Oiling Exceeding 10 g/m^2 (m^2)	178,396	209,602	16	1,333,174
Length of Shoreline Oiling Exceeding 10 g/m^2 - Total Shoreline (m)	34,691	35,159	16	133,925
Length of Shoreline Oiling Exceeding 10 g/m^2 - Wetland and Mudflats (m)	36	191	94	1,657
Length of Shoreline Oiling Exceeding 10 g/m^{2-} Other Shoreline (m)	34,655	35,089	16	132,268
Length of Shoreline Oiling Exceeding 10 g/m^2 (m) for seaward (marine) sand beach only	36	165	93	1,381
Dissolved Aromatic Plume Volume Exceeding 1 ppb (m^3) – All subtidal habitats	3,687 x 10^6	2,024 x 10^6	0	11,590 x 10^6

Average Dose of PAH's in Dissolved Aromatic Plume Volume Exceeding 1 ppb (ppb-hrs)	6,321	5,648	0	53,340
Percent of Spilled Hydrocarbon Mass Coming Ashore (%)	6.28	8.60	4	27.70
Percent of Spilled Hydrocarbon Mass Settling to Sediments (subtidal and extensive intertidal habitats) (%)	0.0006	0.0006	26	0.0030
Maximum Percent of Spilled Hydrocarbon Mass in the Water Column at Any Time after the Spill (%)	62.74	25.28	0	87.24
Spilled Hydrocarbon Mass Chemically Dispersed in the Water Column after the Spill (%)	59.02	25.71	0	85.15
Percent of Spilled Hydrocarbon Mass Mechanically Removed (%)	7.20	5.81	0	23.55

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part F: Prince William Sound

Section F-II.3

by

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ASA 00-246

August 2004

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F-II.3 Rank Order Distributions for All Model Runs

In this section, the following impact indices are plotted as rank order distributions:

- Water surface exposed to floating hydrocarbons, as the sum of area covered by more than $0.01 g/m^2$ (which is sheen) times duration of exposure (in m^2-hrs)
- Shoreline area (m^2) exposed to hydrocarbons of various threshold thicknesses (>1, 10, 100, and 1000 g/m^2)
- Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill
- Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill
- Percent of spilled hydrocarbon mass eventually going ashore
- Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats)
- Maximum percent of spilled hydrocarbon mass in the water column at any time after the spill, and
- Percent of spilled hydrocarbon mass mechanically removed.

F-II.3.1 Scenario: Medium Volume, No Dispersant.

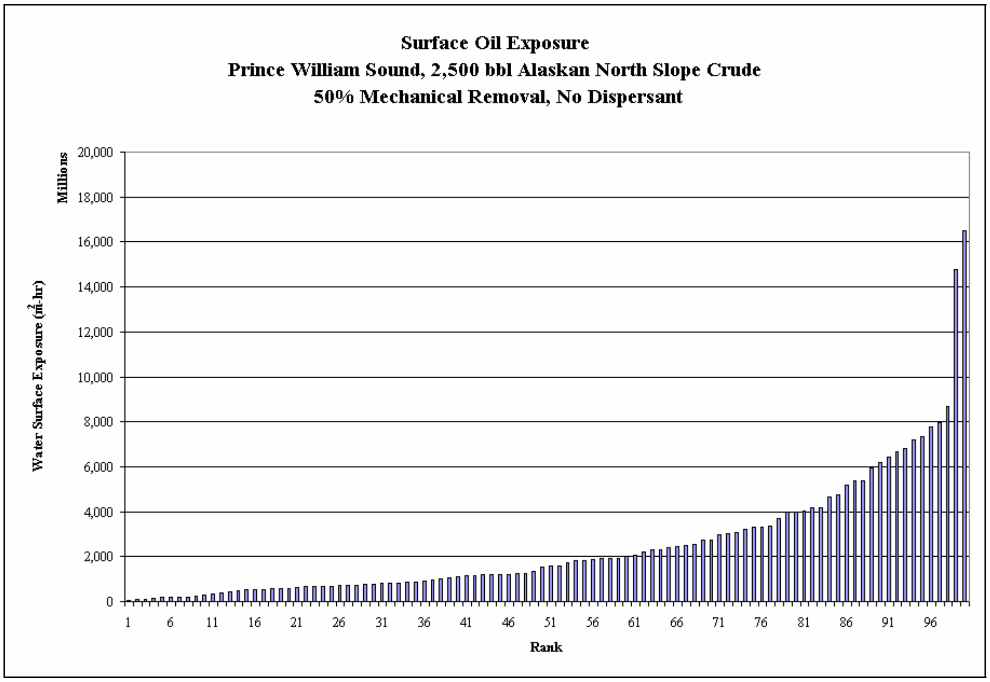

Figure F-II.3.1-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Medium Volume, No Dispersant.

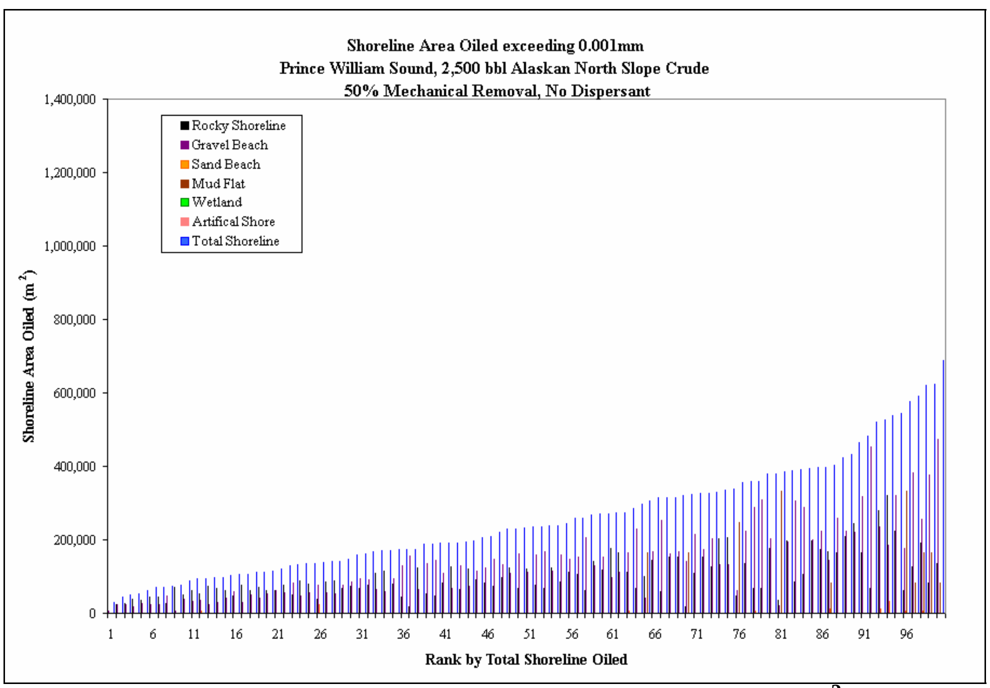

Figure F-II.3.1-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Medium Volume, No Dispersant.

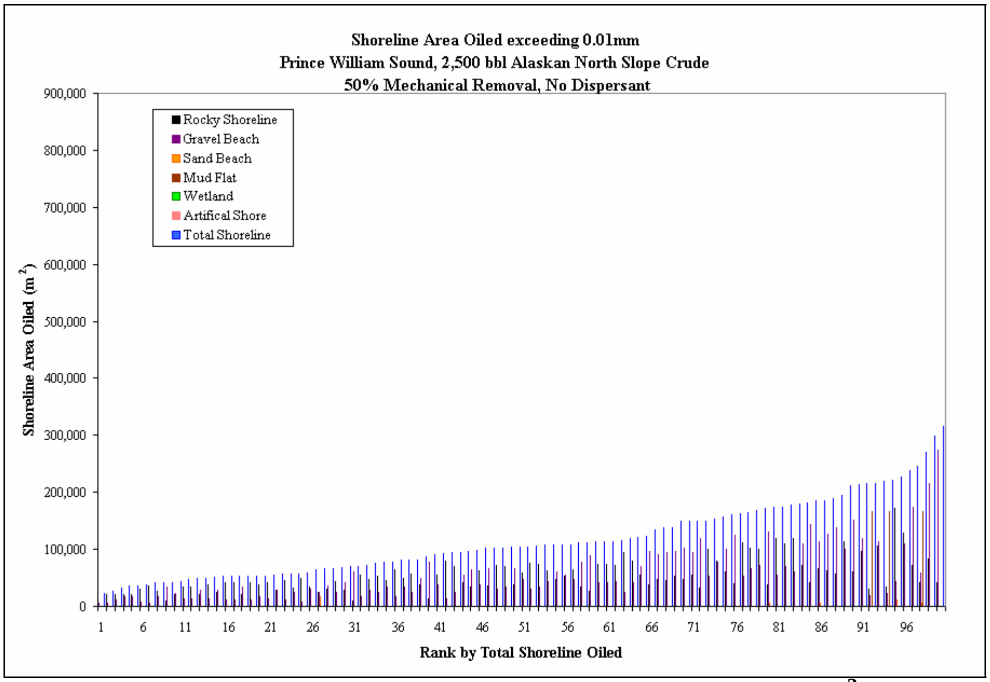

Figure F-II.3.1-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Medium Volume, No Dispersant.

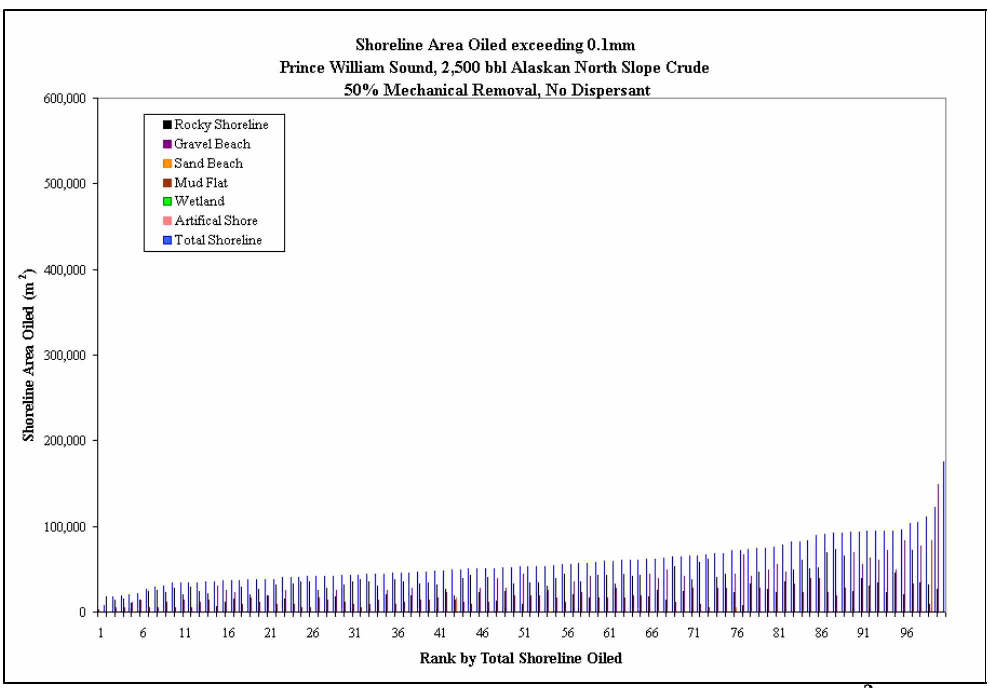

Figure F-II.3.1-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Medium Volume, No Dispersant.

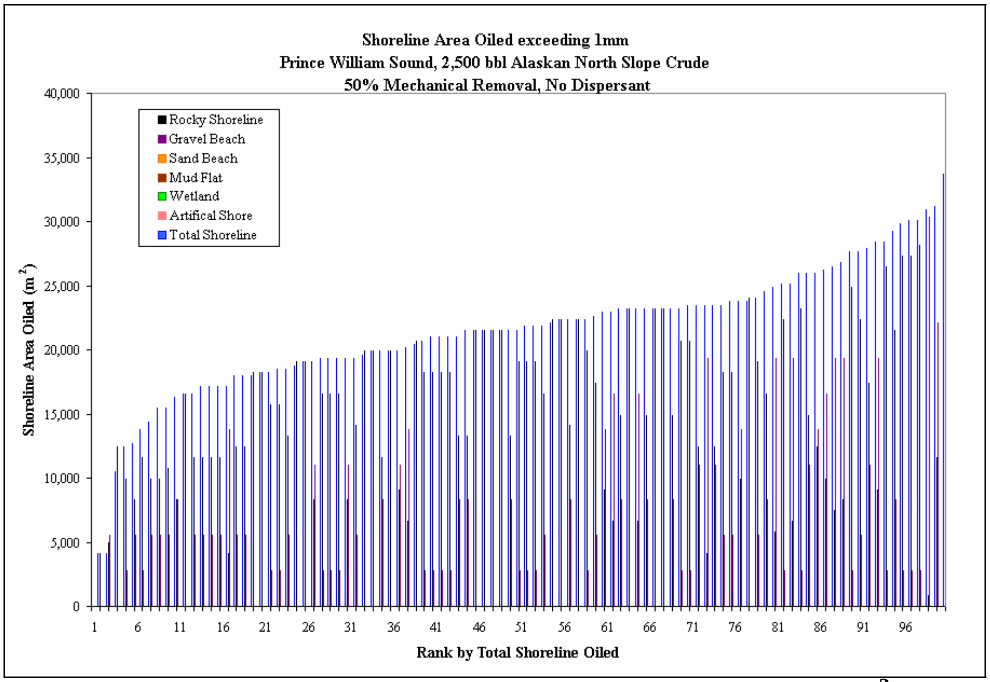

Figure F-II.3.1-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Medium Volume, No Dispersant.

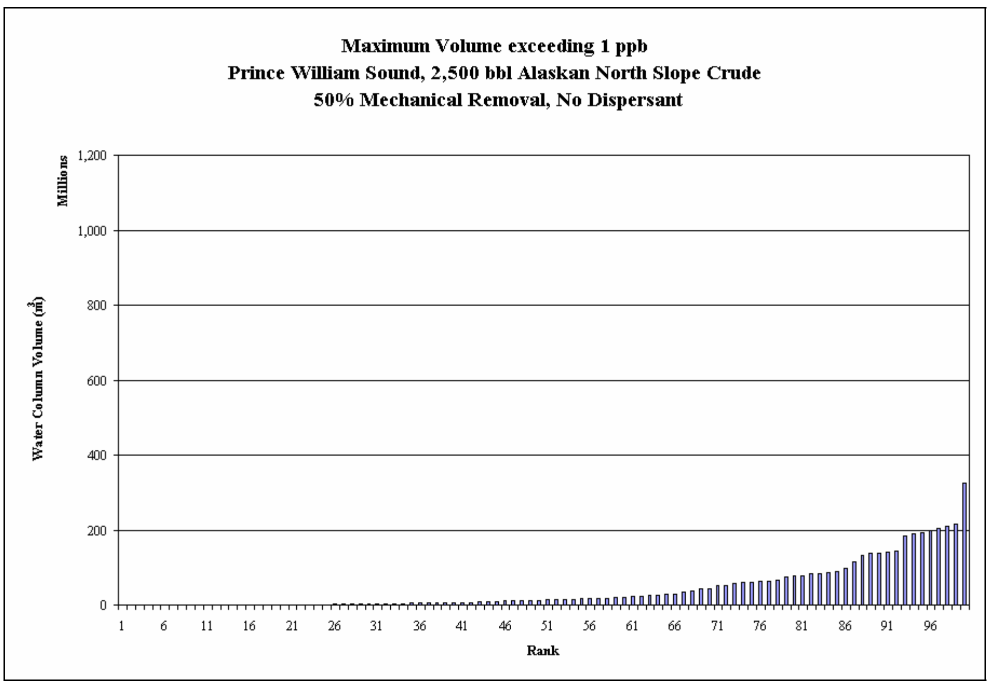

Figure F-II.3.1-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, No Dispersant.

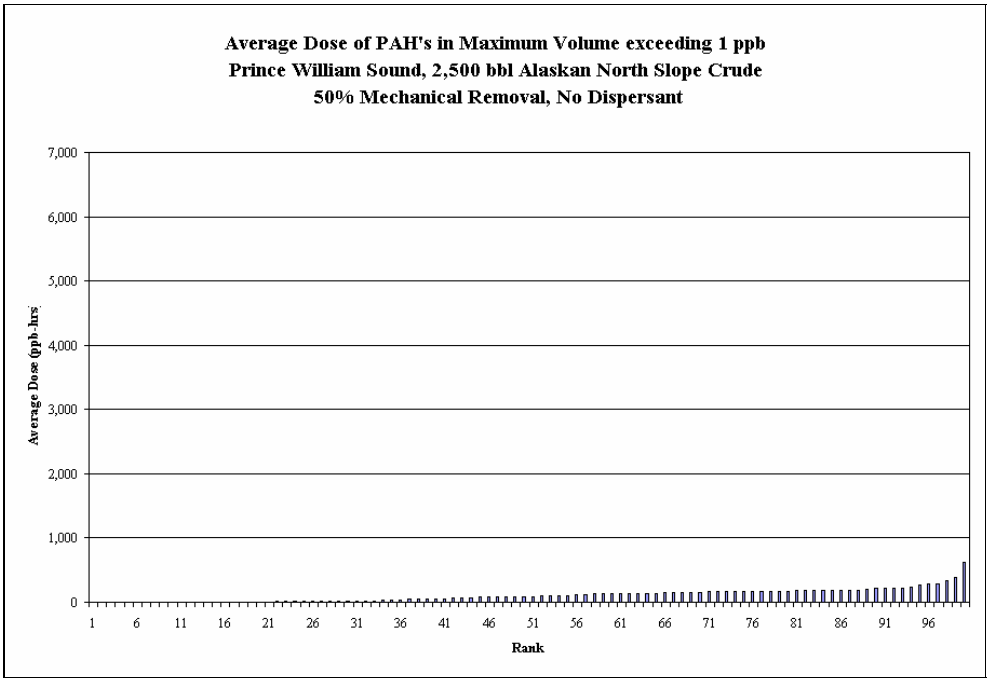

Figure F-II.3.1-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, No Dispersant.

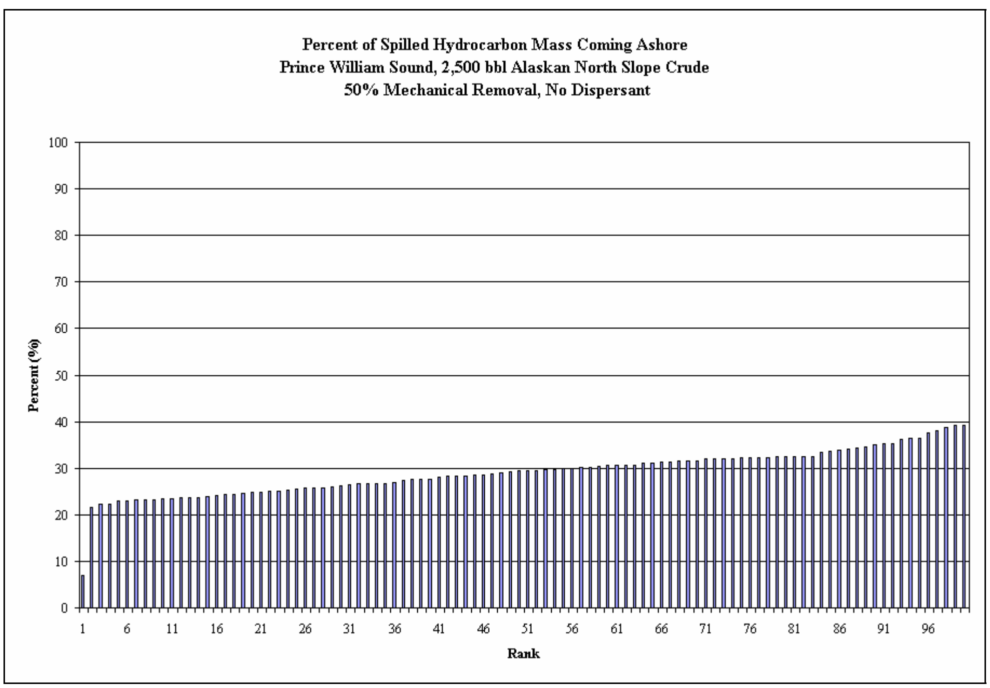

Figure F-II.3.1-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Medium Volume, No Dispersant.

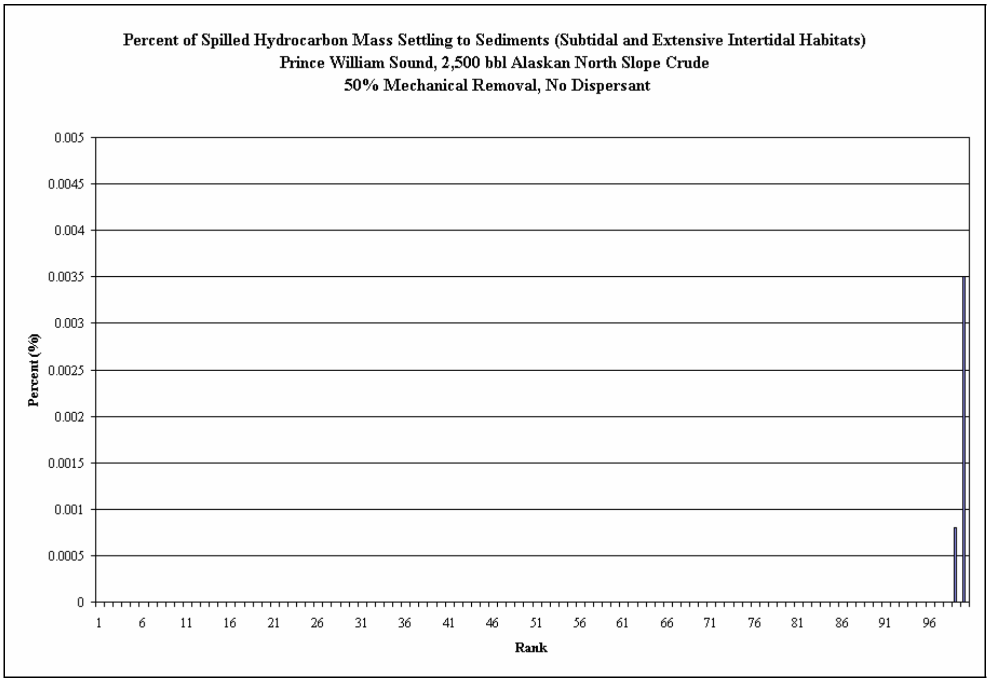

Figure F-II.3.1-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Medium Volume, No Dispersant.

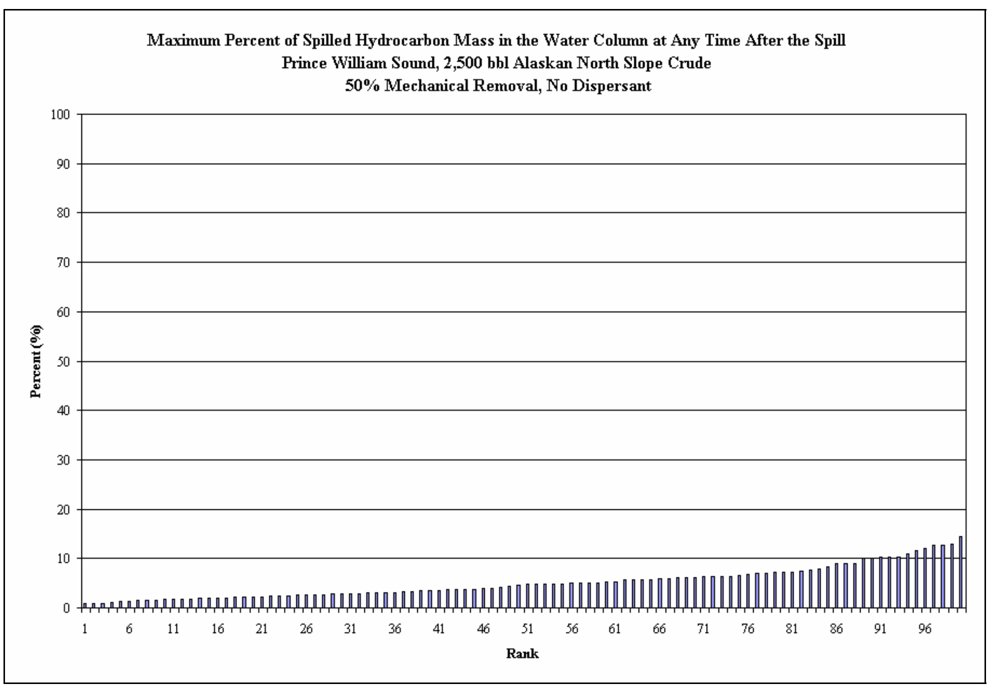

Figure F-II.3.1-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Medium Volume, No Dispersant.

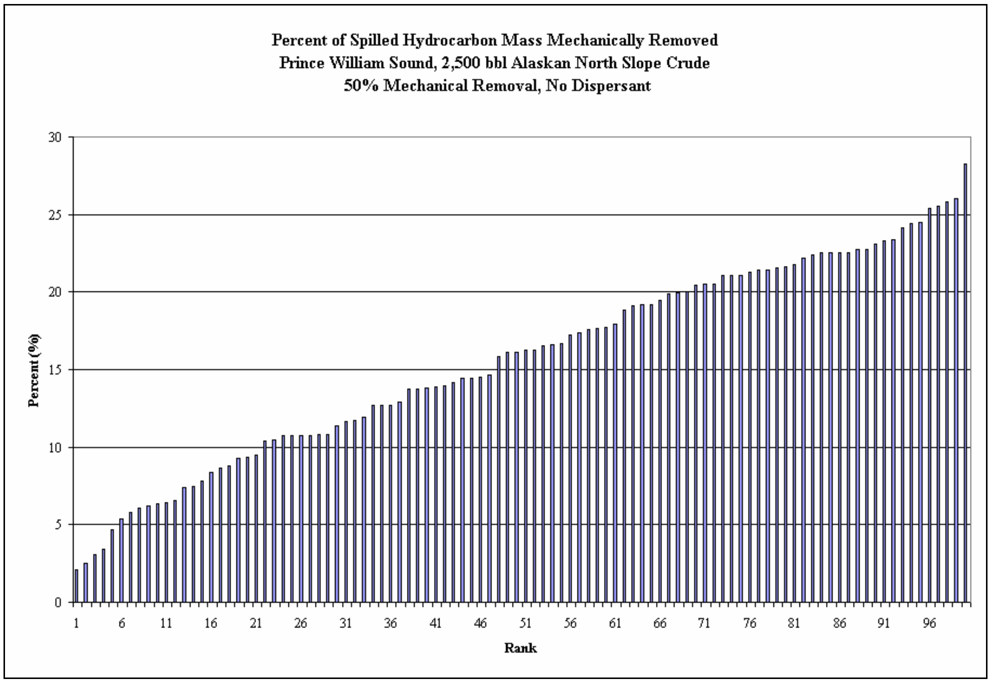

Figure F-II.3.1-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Medium Volume, No Dispersant.

F-II.3.2 Scenario: Medium Volume, 45% Dispersant Efficiency.

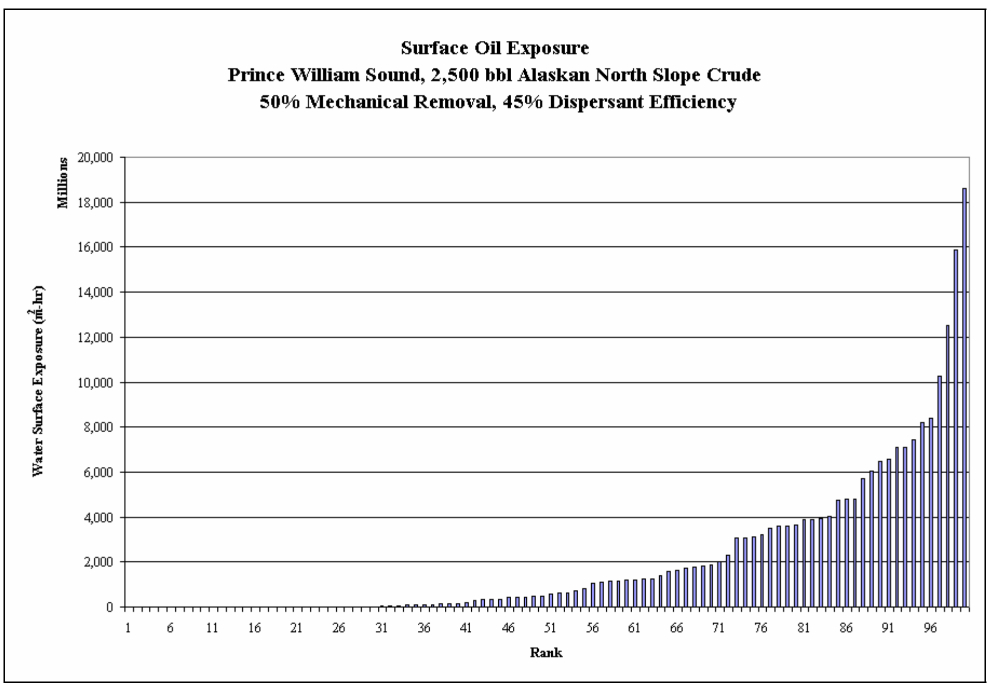

Figure F-II.3.2-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

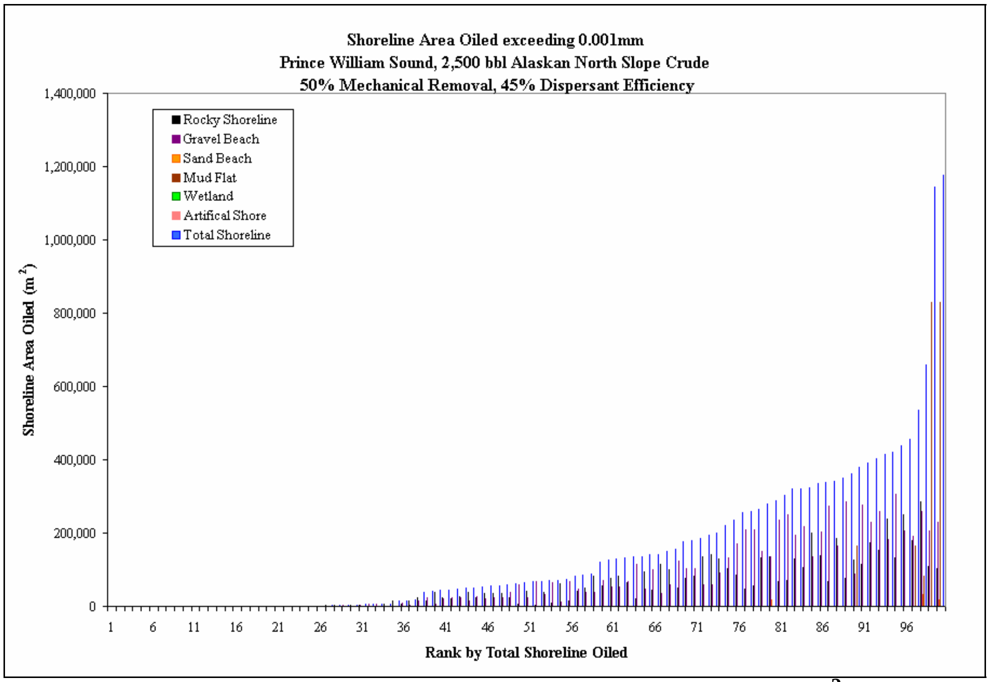

Figure F-II.3.2-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

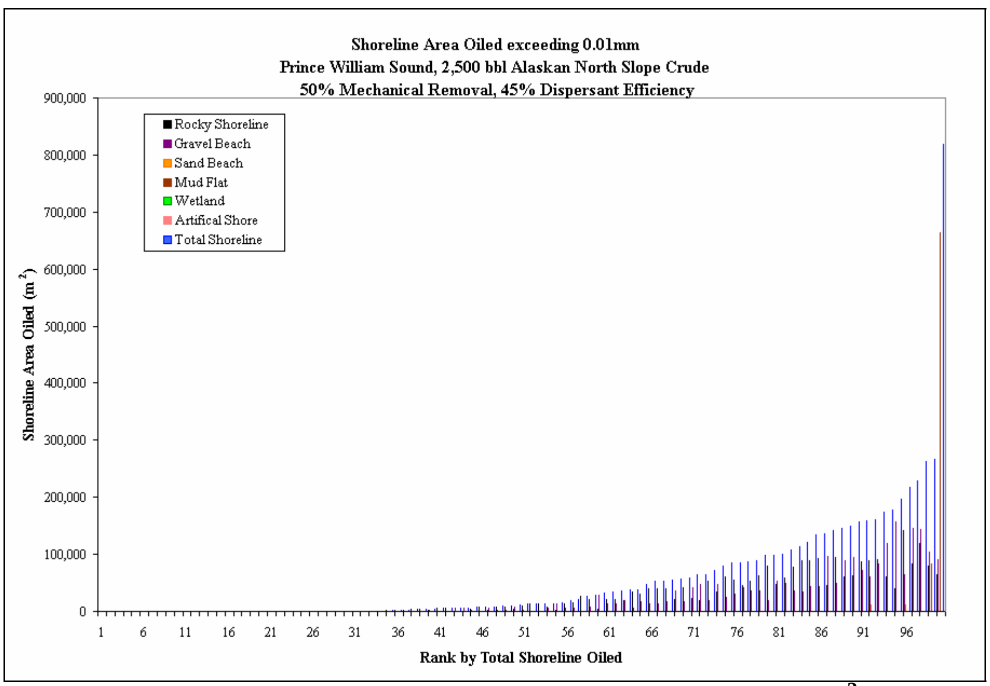

Figure F-II.3.2-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

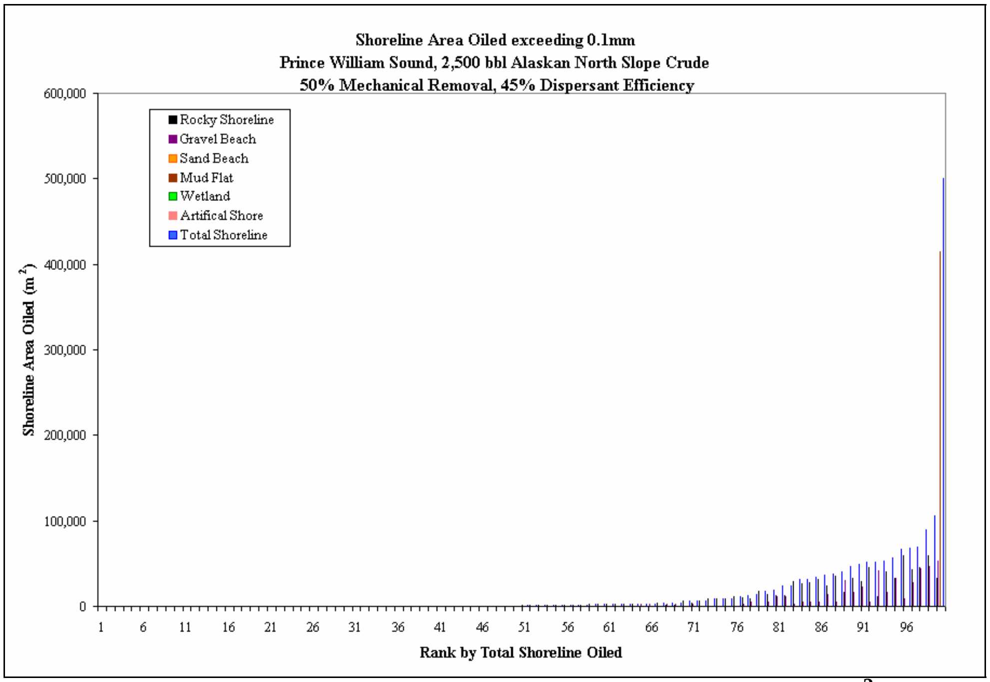

Figure F-II.3.2-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

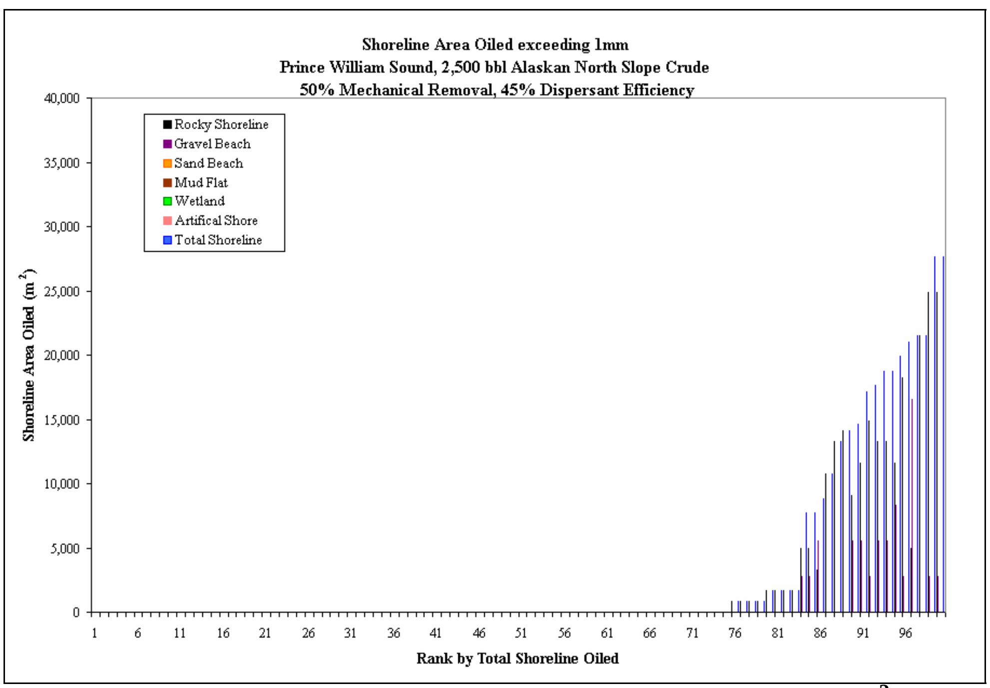

Figure F-II.3.2-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Medium Volume, 45% Dispersant Efficiency.

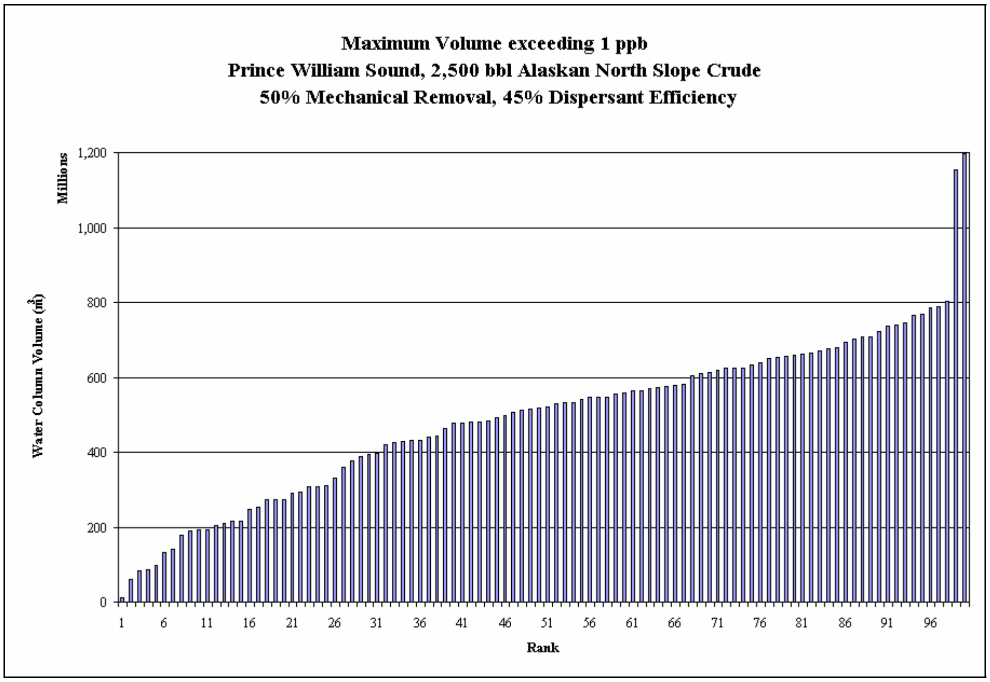

Figure F-II.3.2-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 45% Dispersant Efficiency.

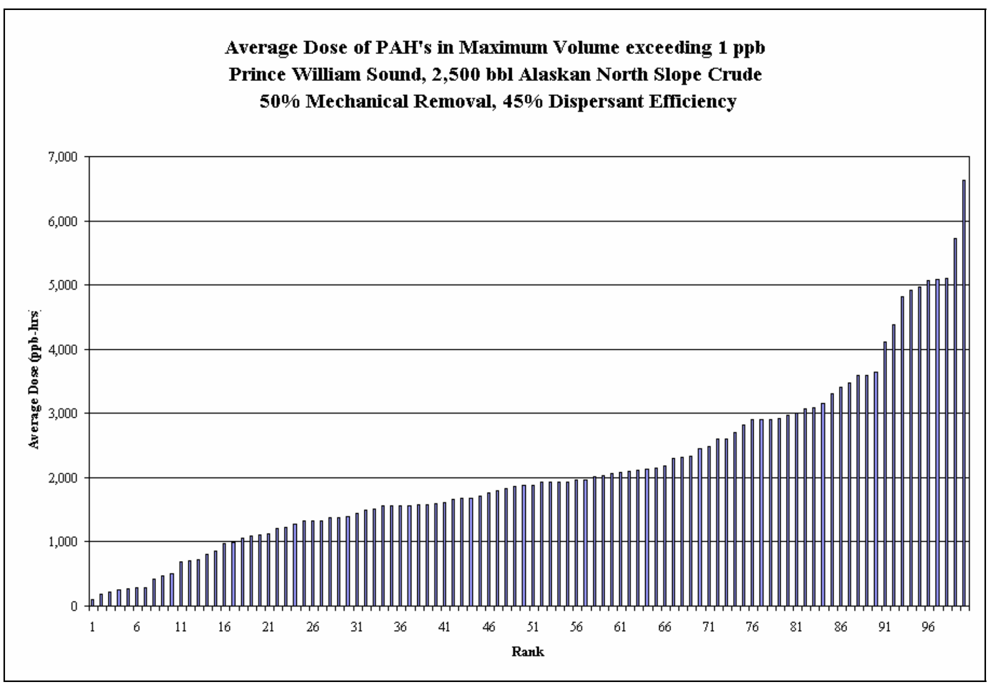

Figure F-II.3.2-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 45% Dispersant Efficiency.

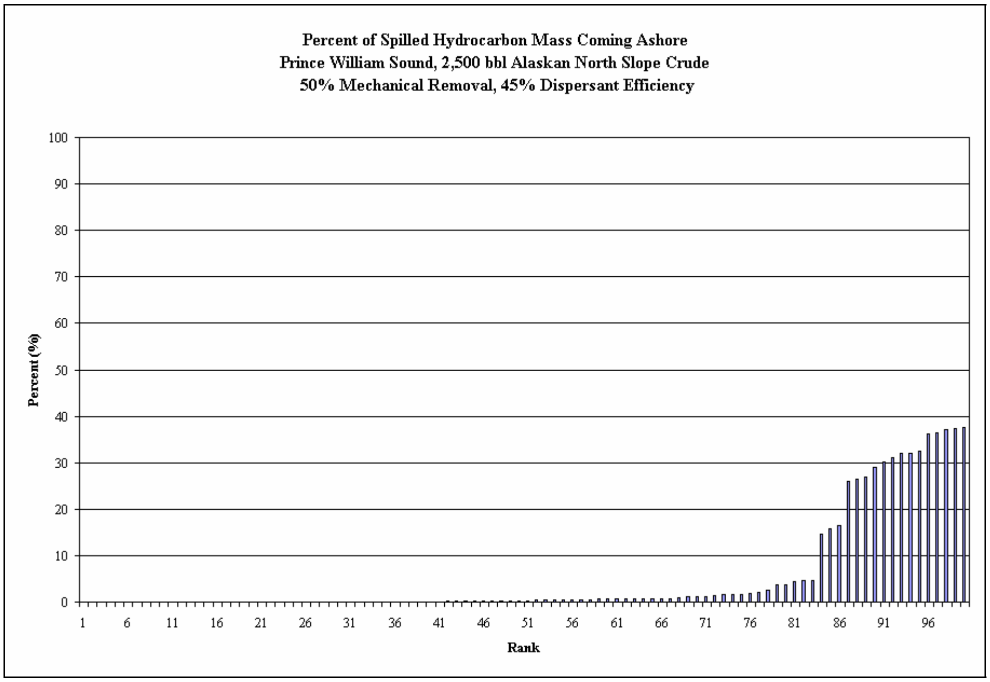

Figure F-II.3.2-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Medium Volume, 45% Dispersant Efficiency.

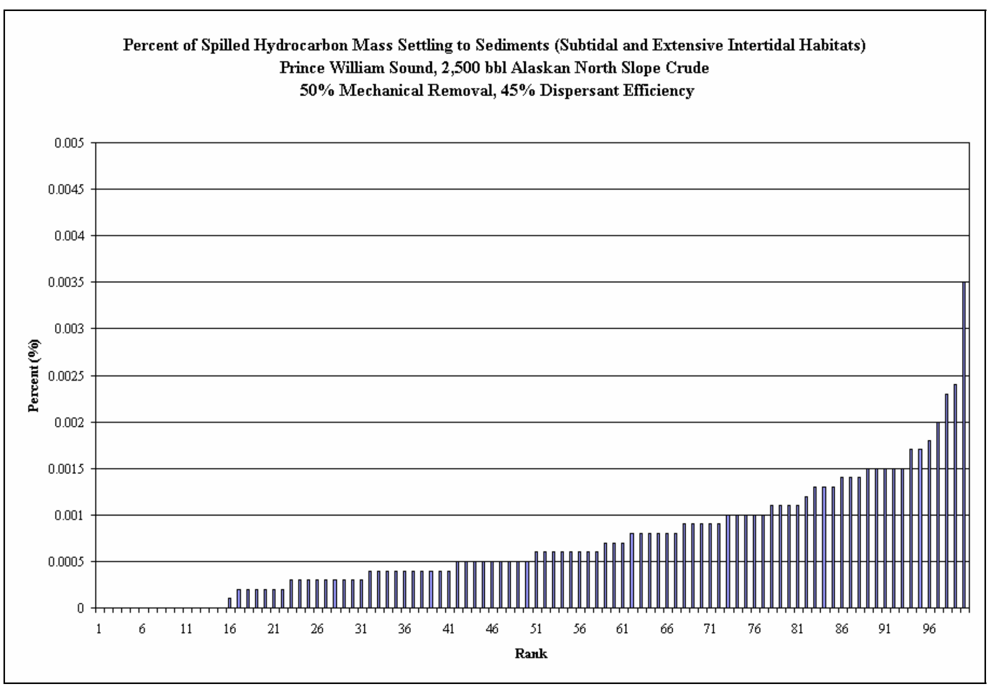

Figure F-II.3.2-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Medium Volume, 45% Dispersant Efficiency.

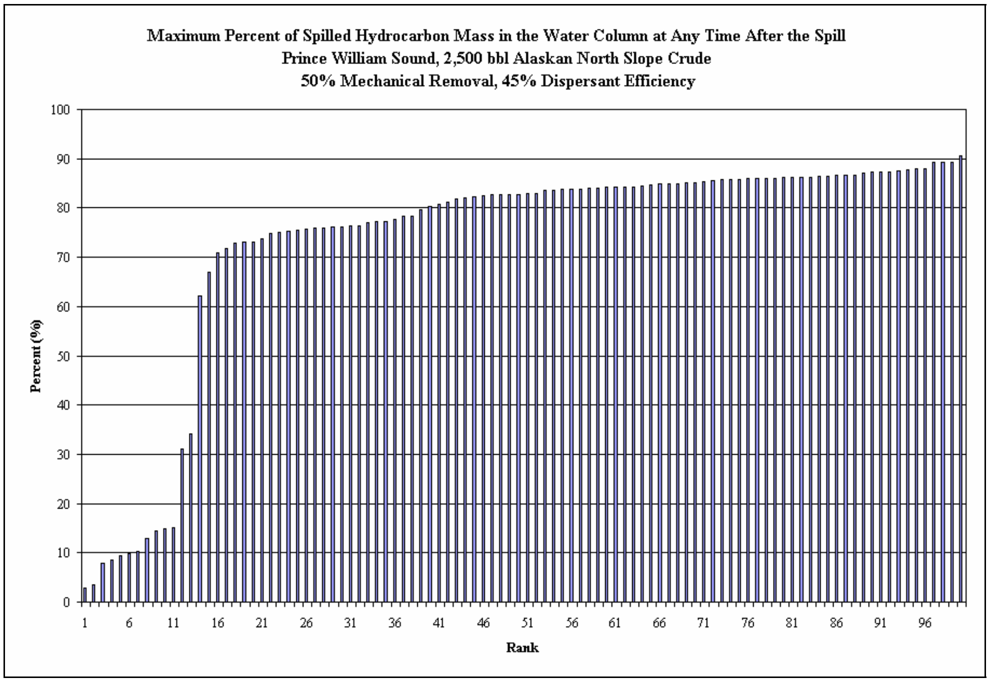

Figure F-II.3.2-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Medium Volume, 45% Dispersant Efficiency.

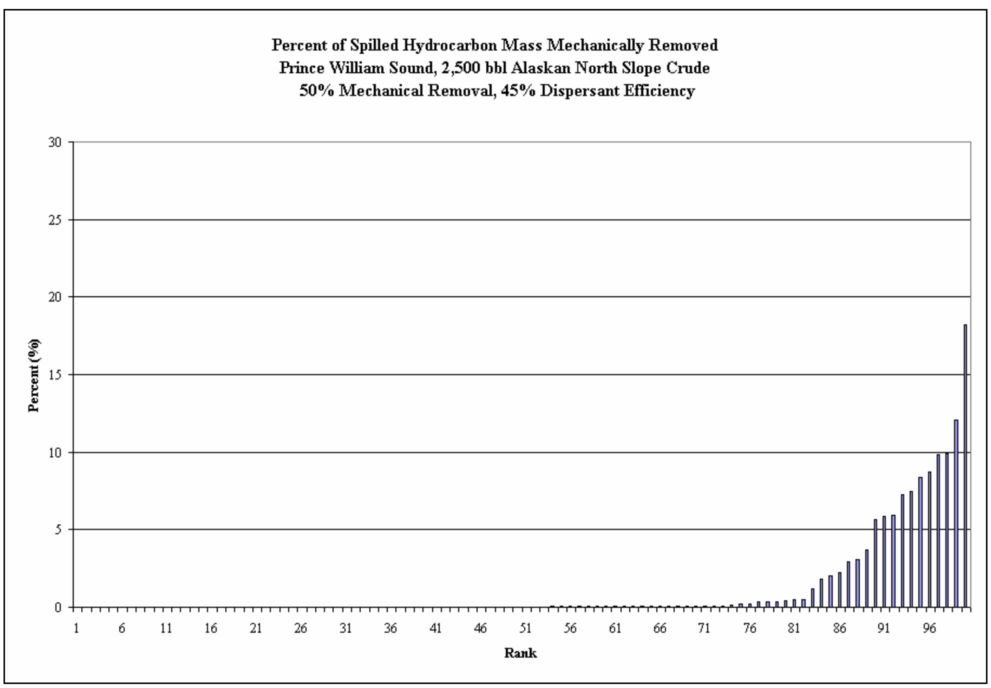

Figure F-II.3.2-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Medium Volume, 45% Dispersant Efficiency.

F-II.3.3 Scenario: Medium Volume, 80% Dispersant Efficiency.

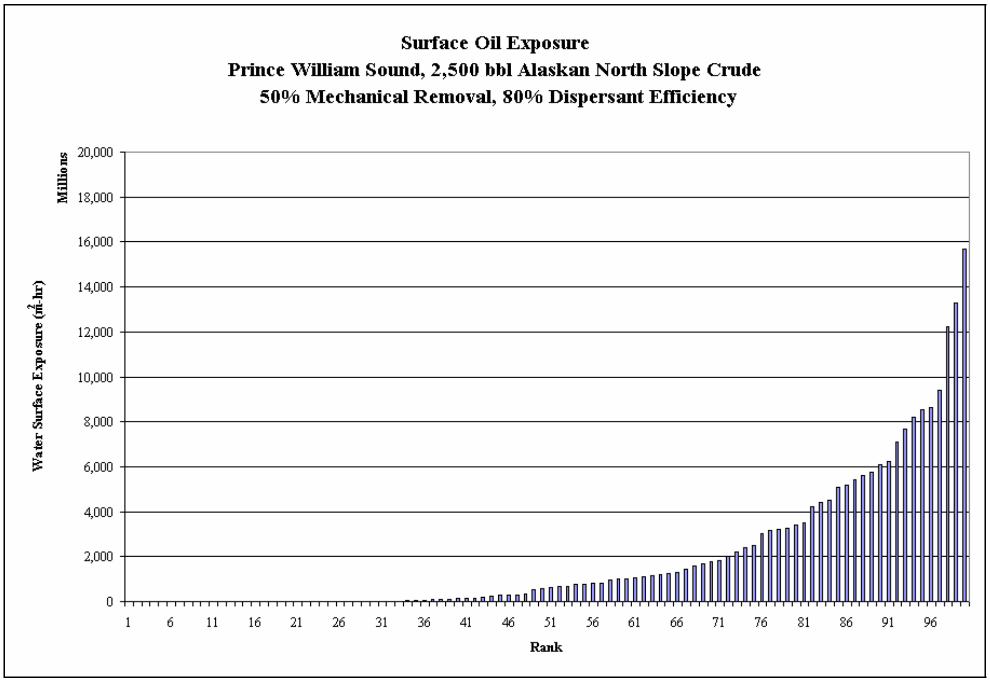

Figure F-II.3.3-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

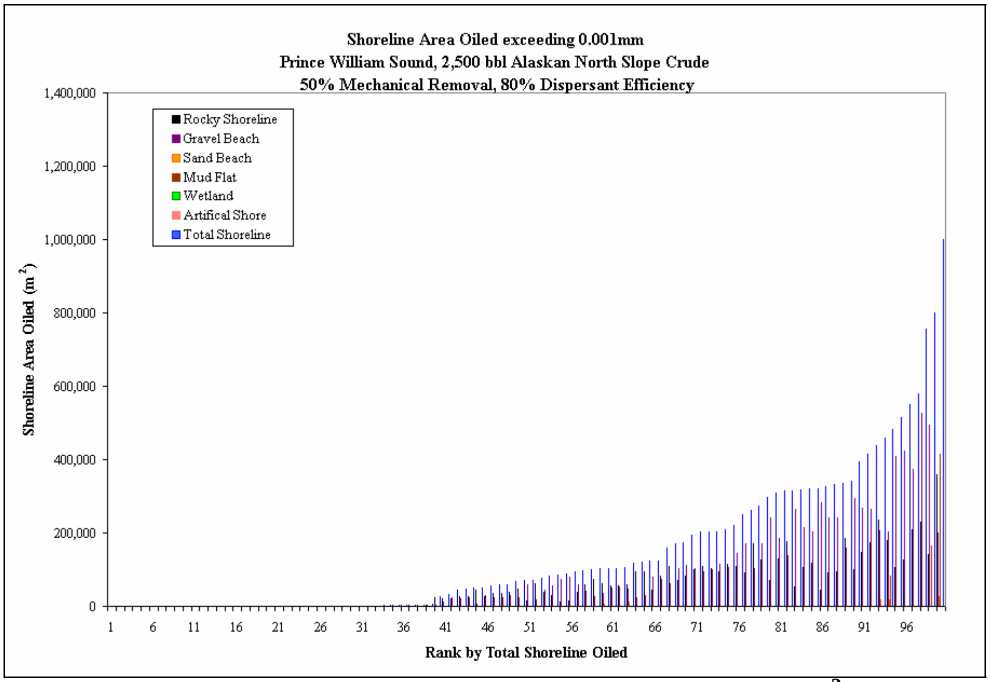

Figure F-II.3.3-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

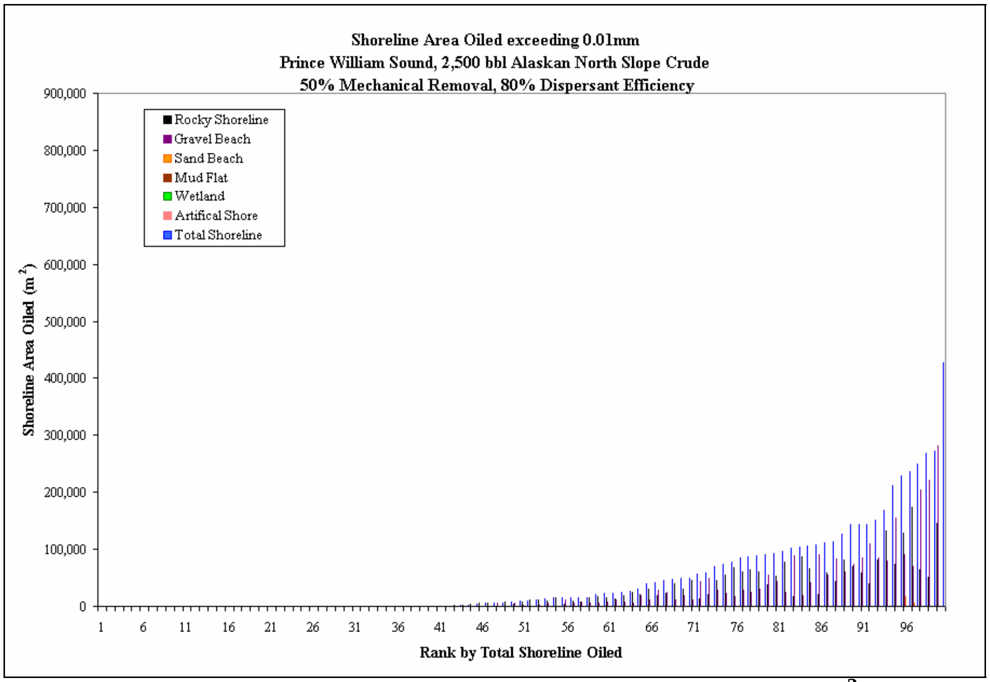

Figure F-II.3.3-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

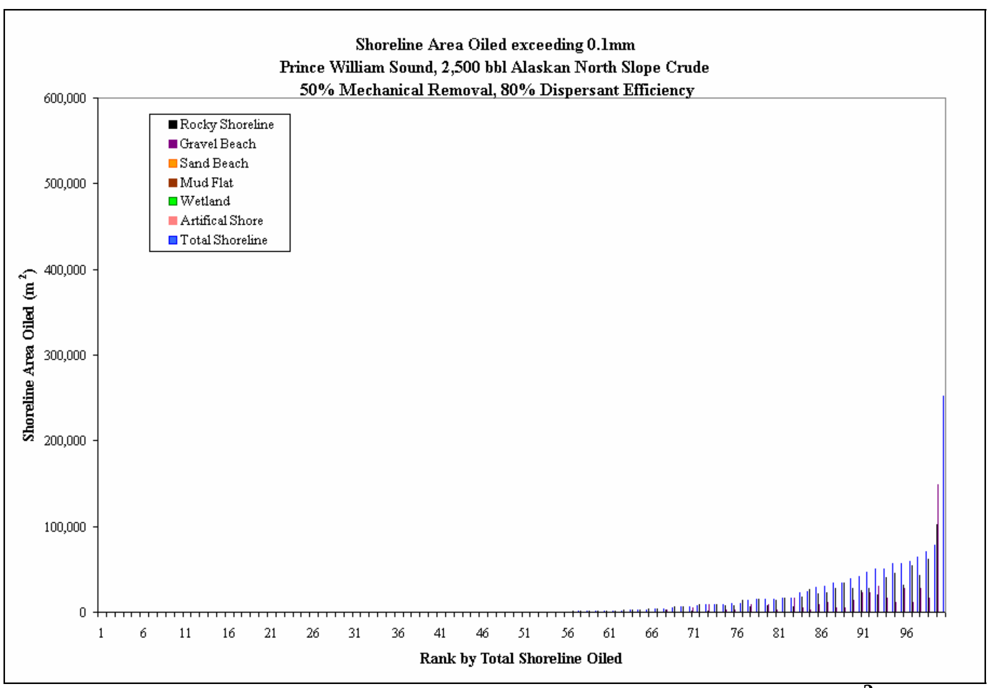

Figure F-II.3.3-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

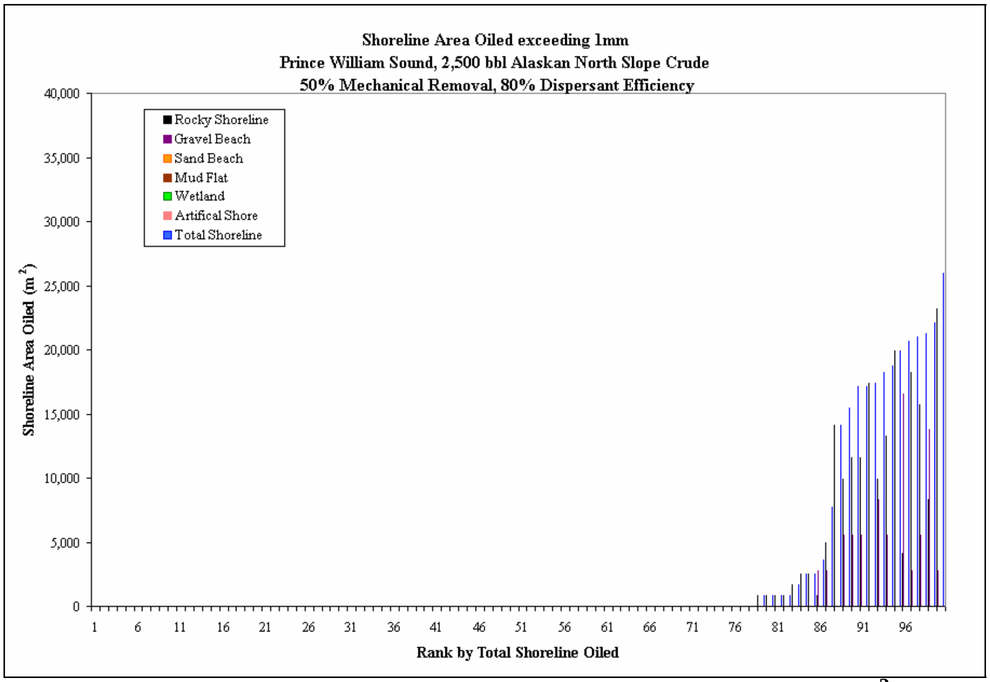

Figure F-II.3.3-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Medium Volume, 80% Dispersant Efficiency.

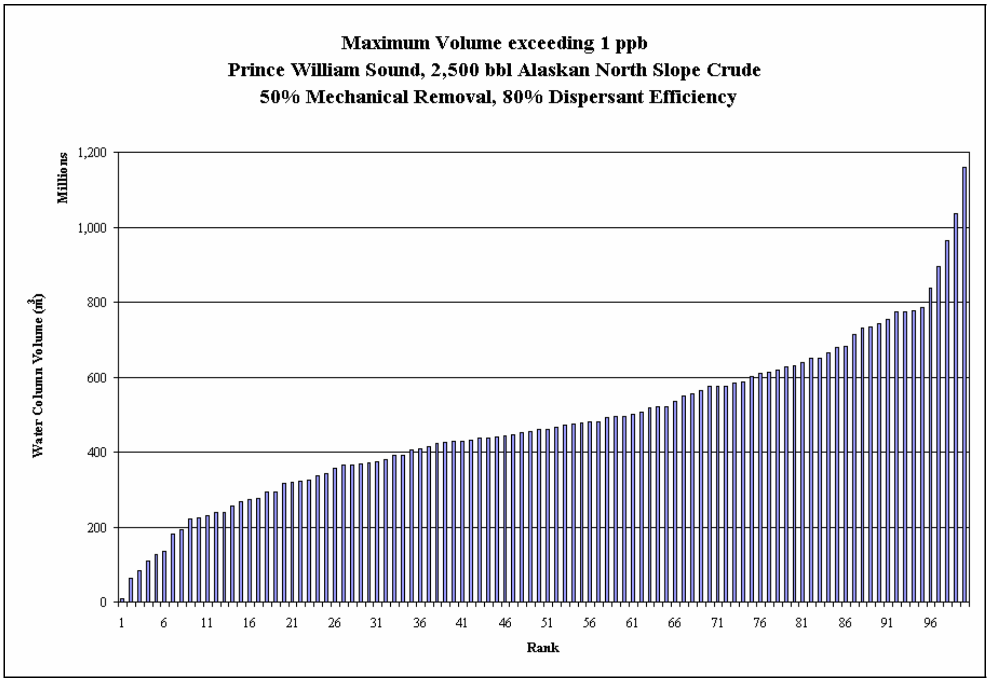

Figure F-II.3.3-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 80% Dispersant Efficiency.

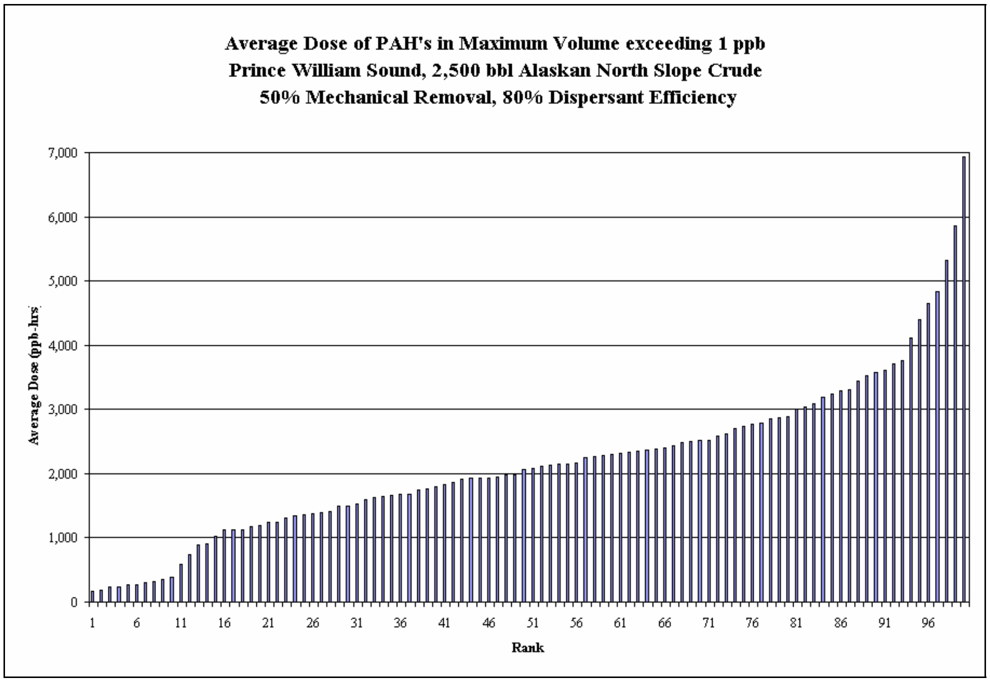

Figure F-II.3.3-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Medium Volume, 80% Dispersant Efficiency.

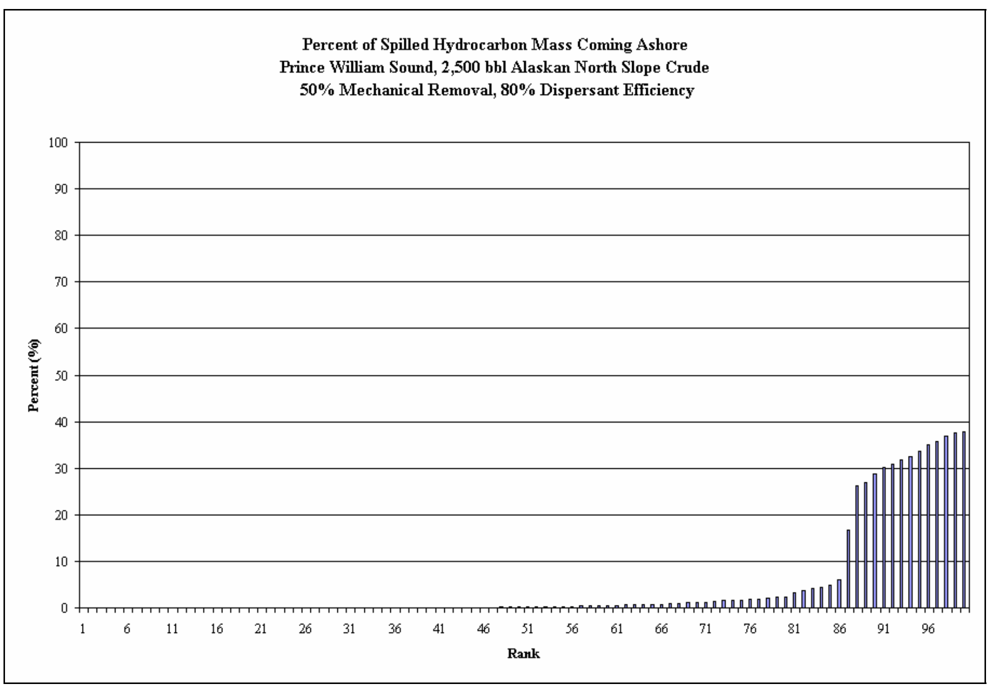

Figure F-II.3.3-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Medium Volume, 80% Dispersant Efficiency.

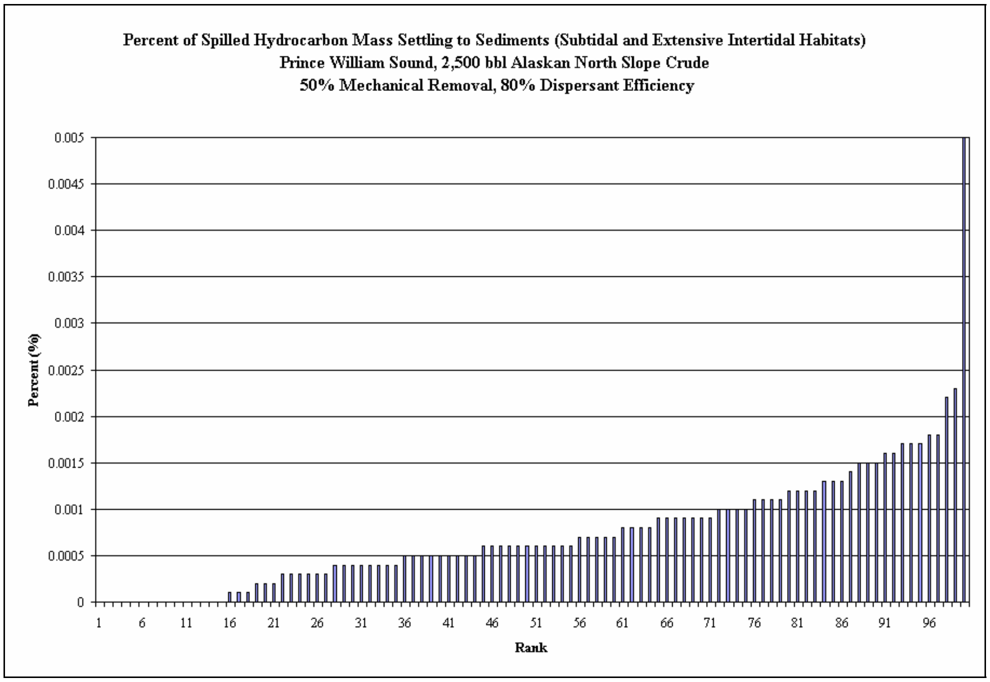

Figure F-II.3.3-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Medium Volume, 80% Dispersant Efficiency.

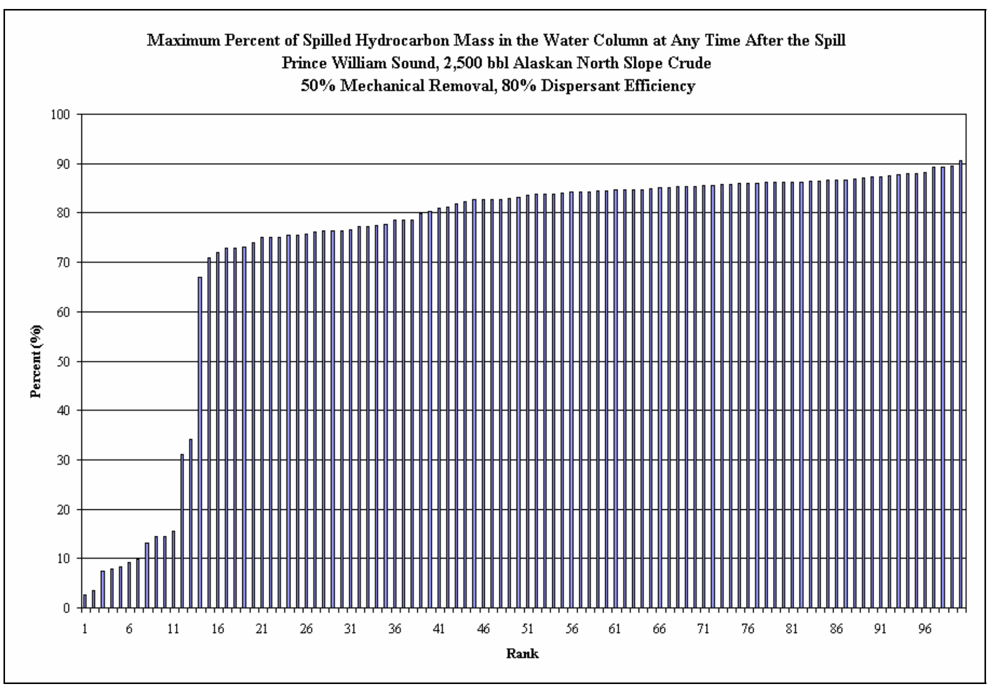

Figure F-II.3.3-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Medium Volume, 80% Dispersant Efficiency.

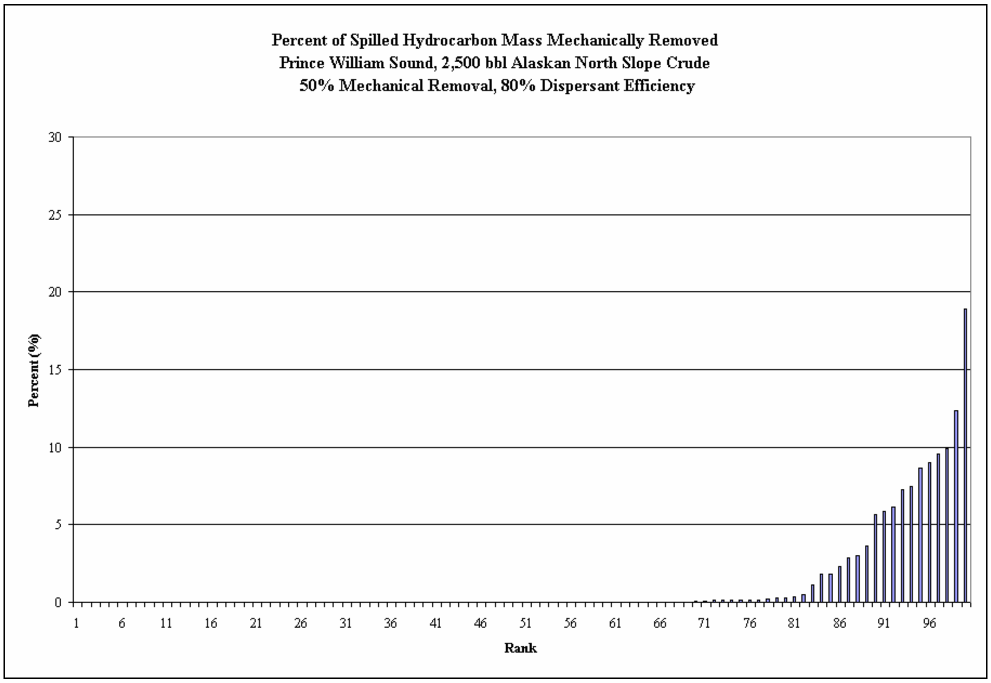

Figure F-II.3.3-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Medium Volume, 80% Dispersant Efficiency.

F-II.3.4 Scenario: Large Volume, No Dispersant.

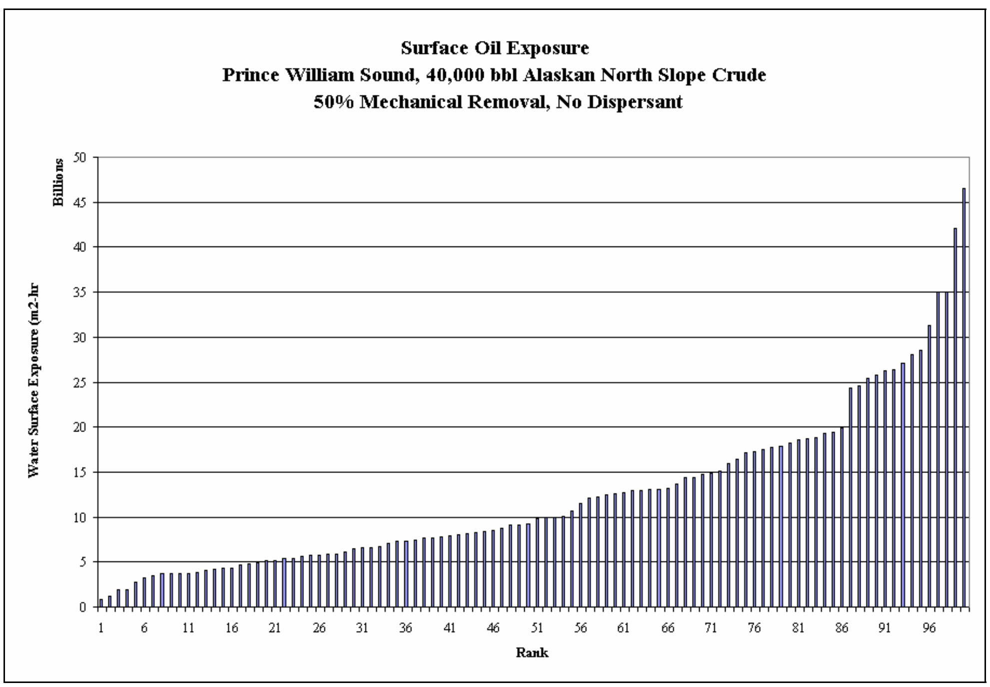

Figure F-II.3.4-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Large Volume, No Dispersant.

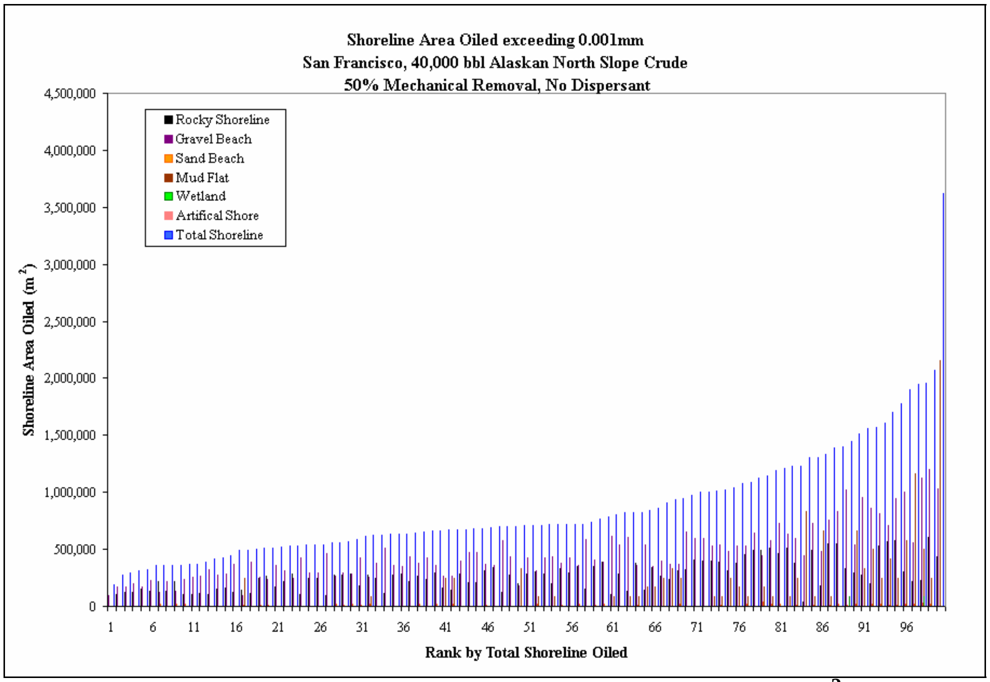

Figure F-II.3.4-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Large Volume, No Dispersant.

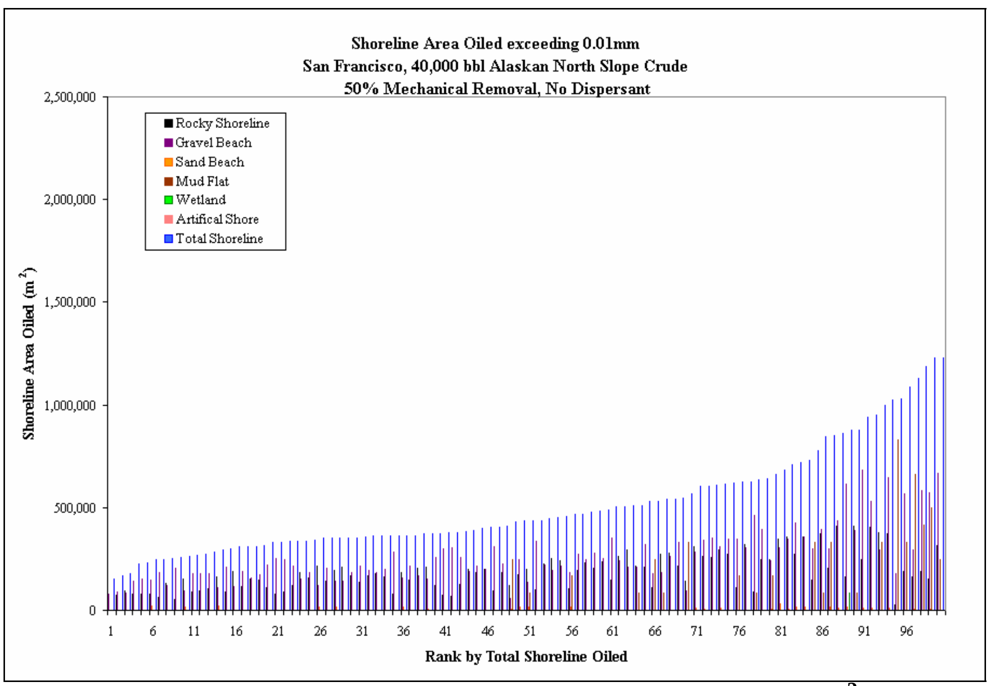

Figure F-II.3.4-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Large Volume, No Dispersant.

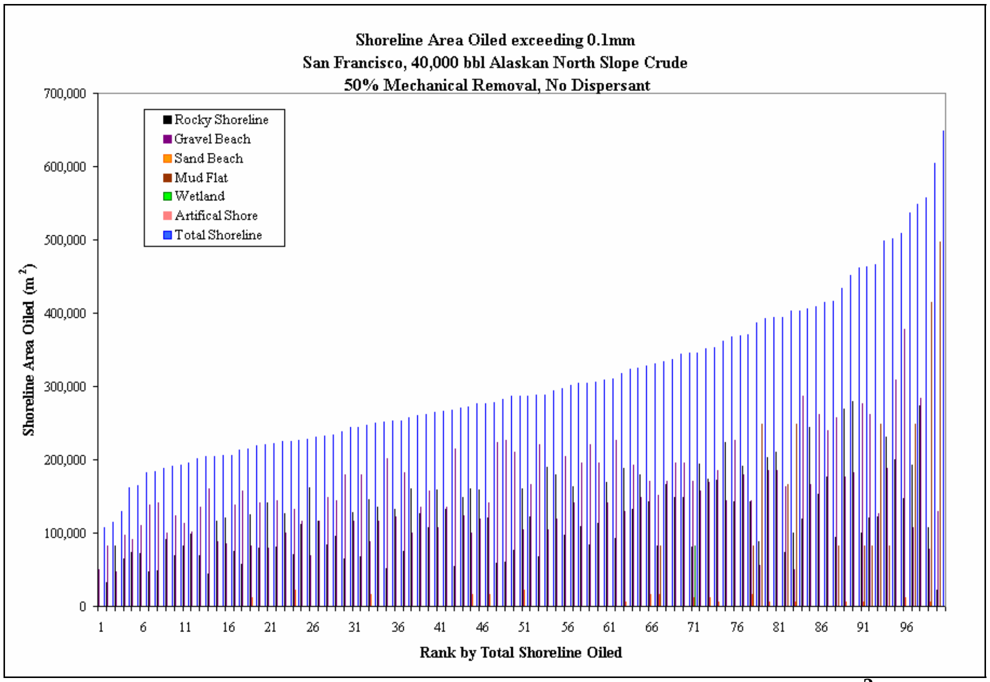

Figure F-II.3.4-4 Shoreline area exposed to hydrocarbons of >100g/m² (about 0.1mm thick). Scenario: Large Volume, No Dispersant.

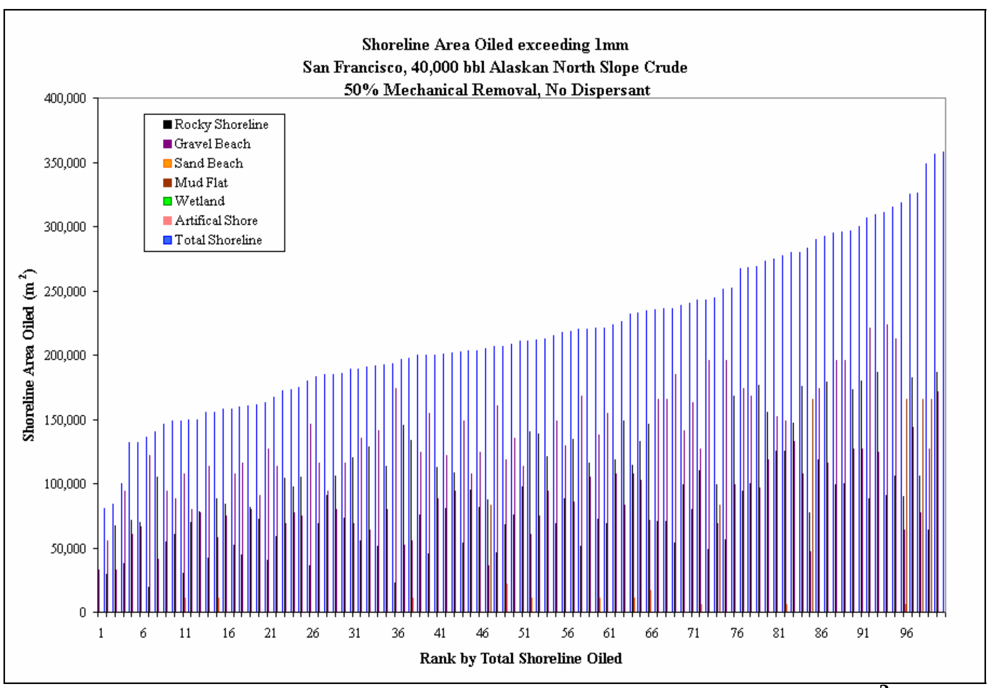

Figure F-II.3.4-5 Shoreline area exposed to hydrocarbons of >1000g/m² (about 1mm thick). Scenario: Large Volume, No Dispersant.

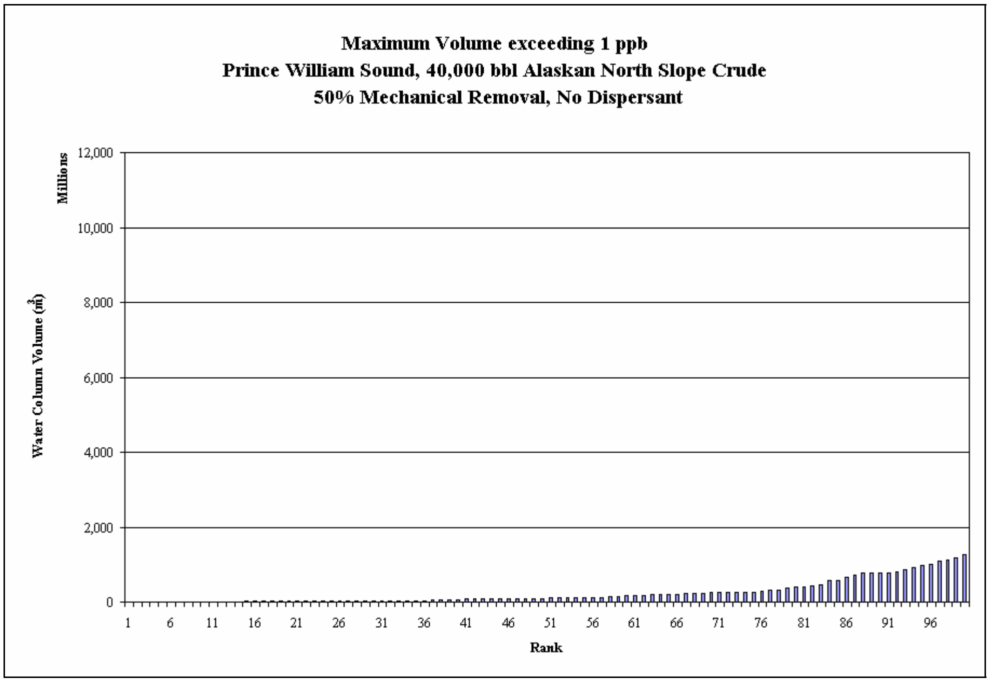

Figure F-II.3.4-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, No Dispersant.

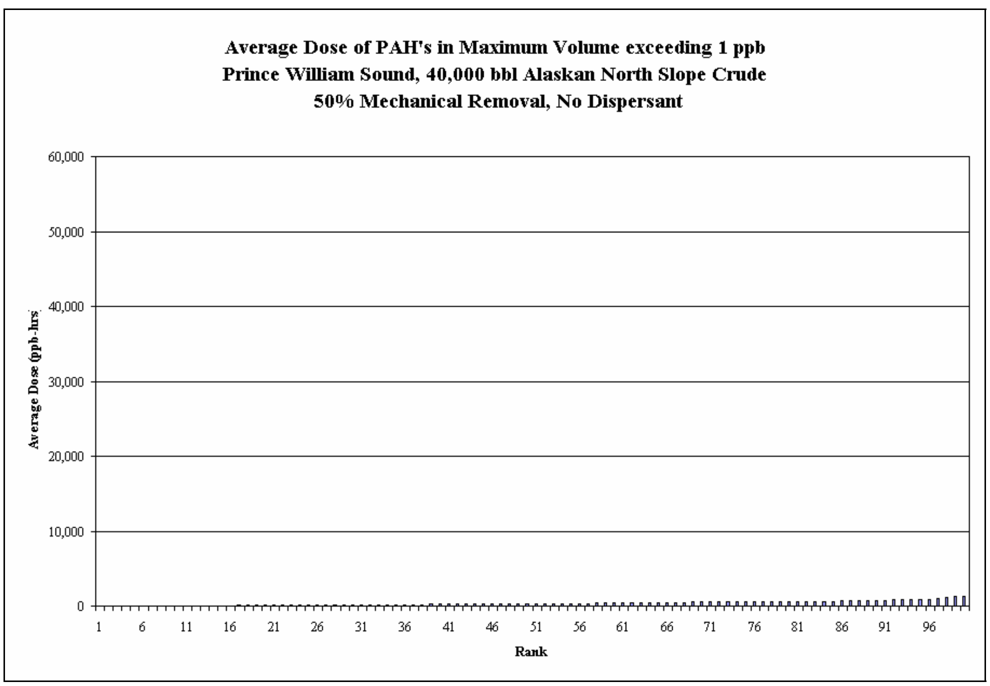

Figure F-II.3.4-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, No Dispersant.

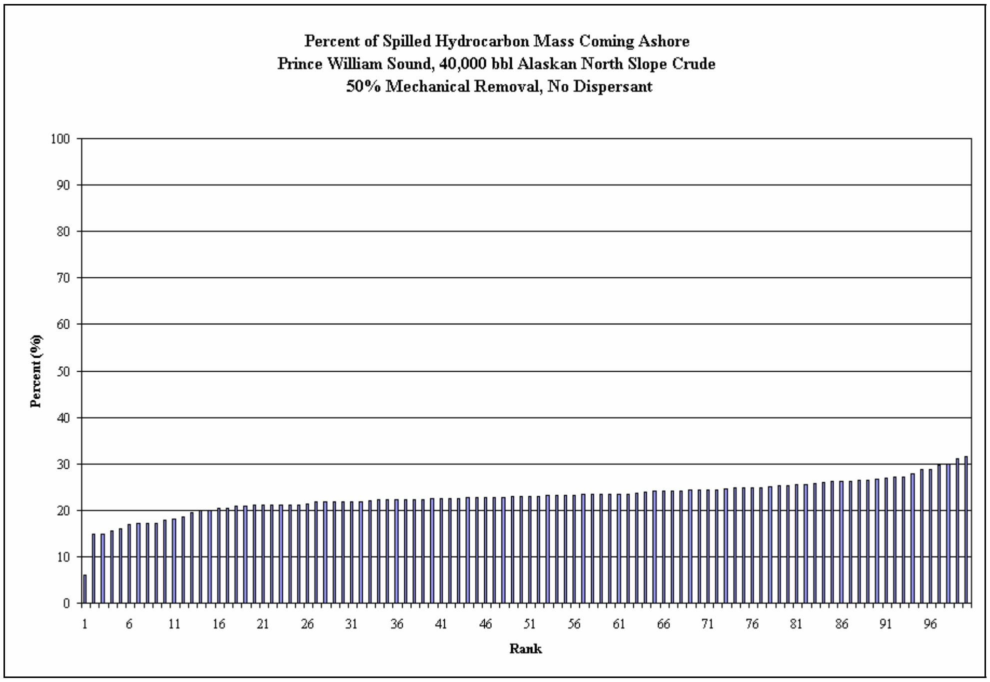

Figure F-II.3.4-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Large Volume, No Dispersant.

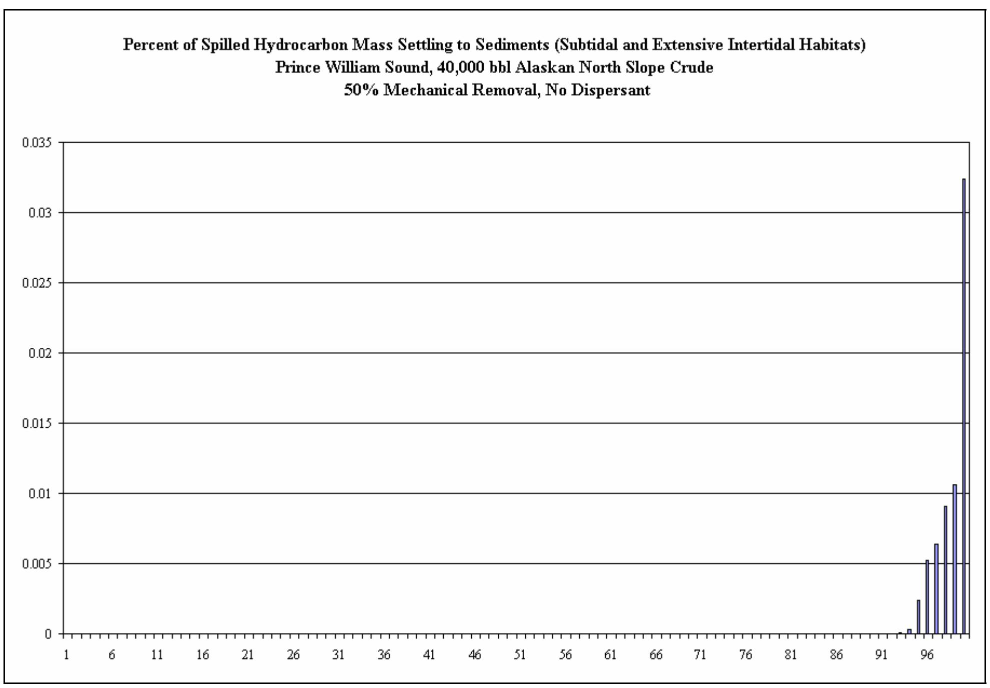

Figure F-II.3.4-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Large Volume, No Dispersant.

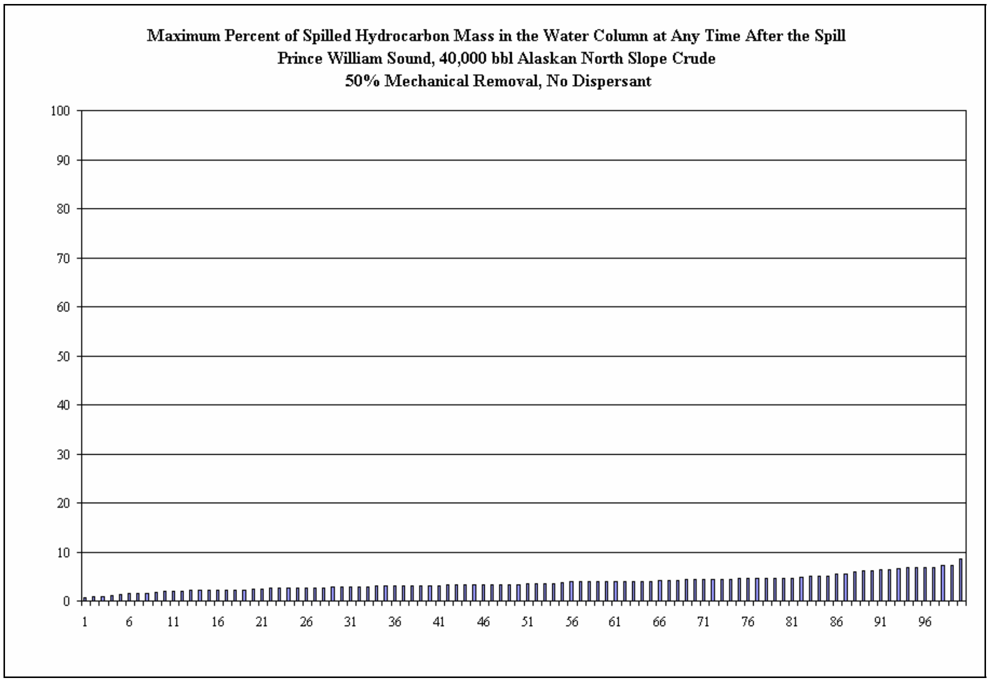

Figure F-II.3.4-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Large Volume, No Dispersant.

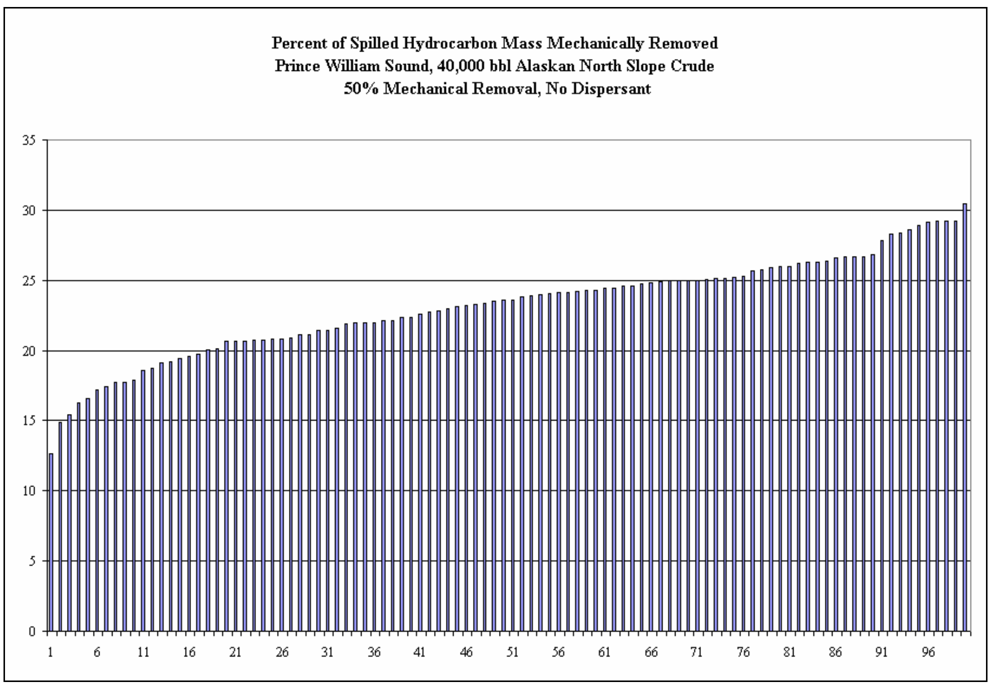

Figure F-II.3.4-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Large Volume, No Dispersant.

F-II.3.5 Scenario: Large Volume, 45% Dispersant Efficiency.

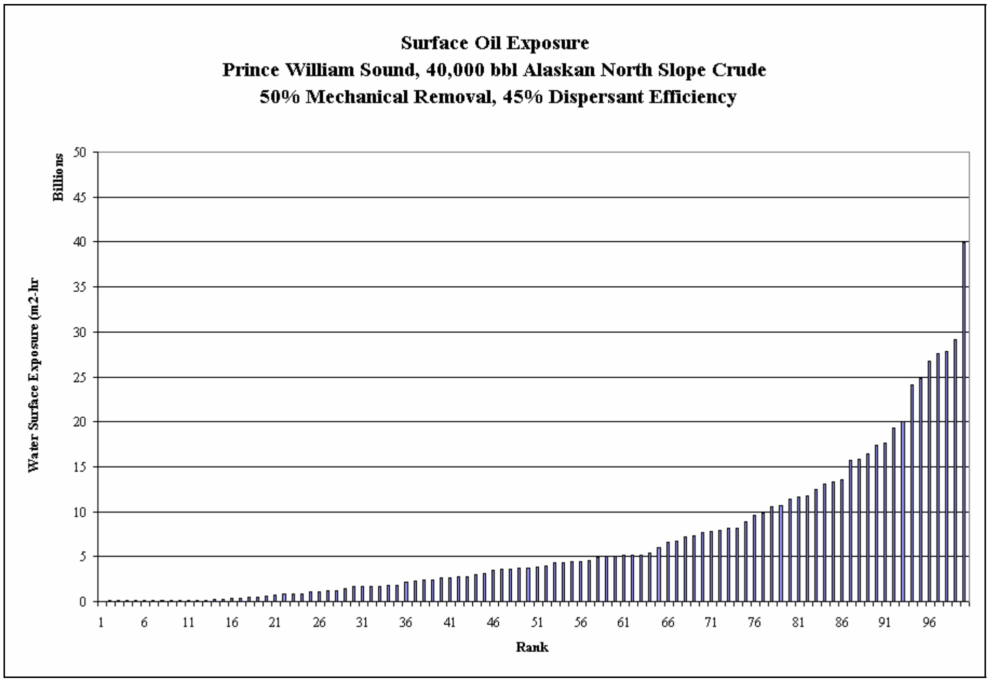

Figure F-II.3.5-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

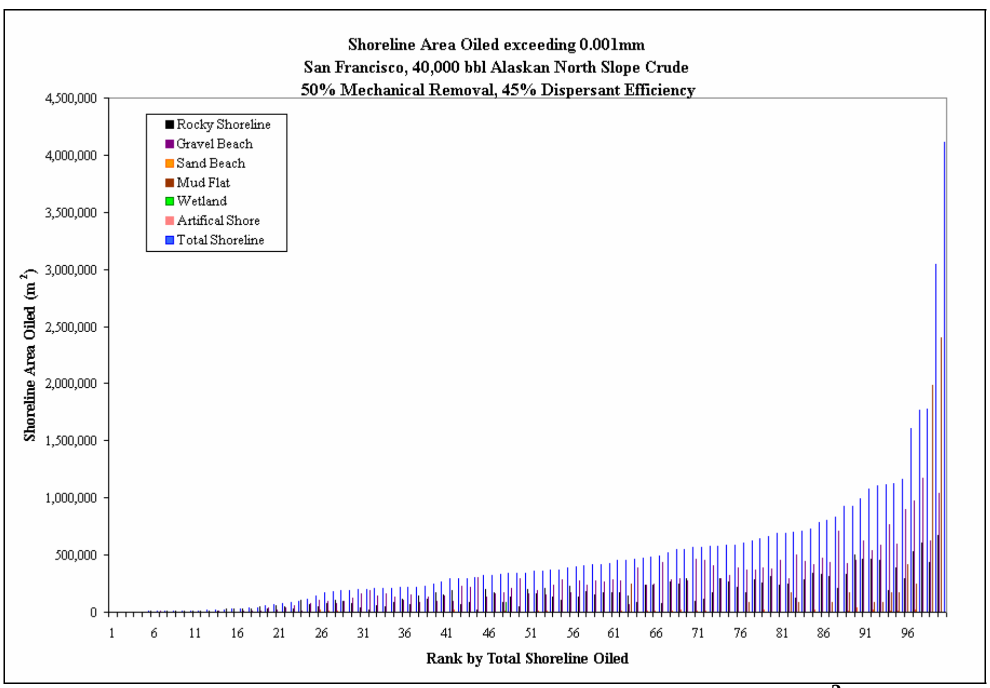

Figure F-II.3.5-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

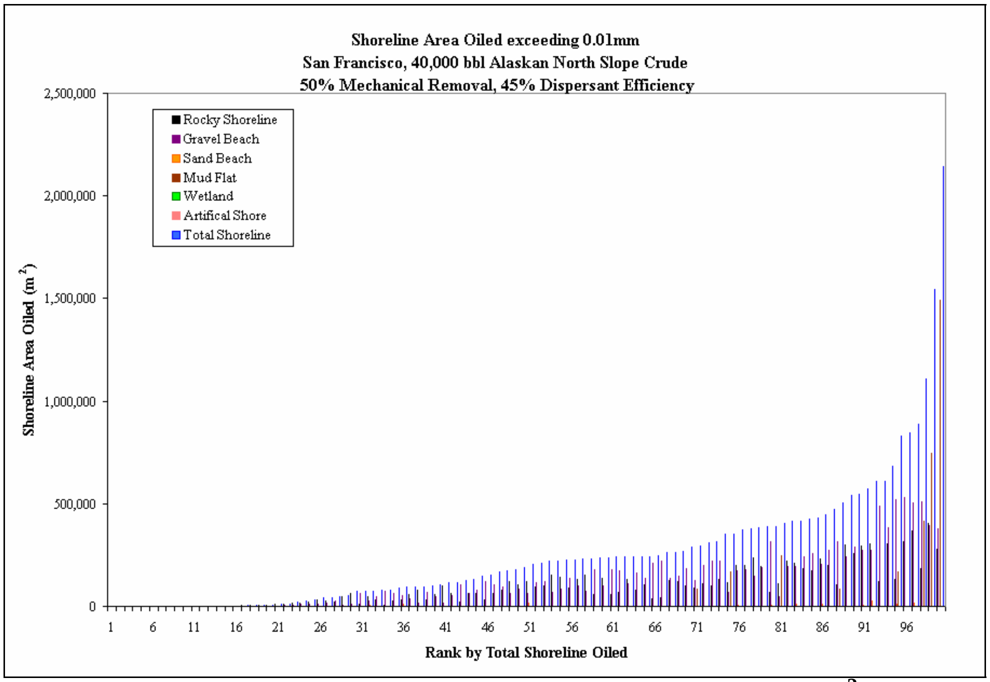

Figure F-II.3.5-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

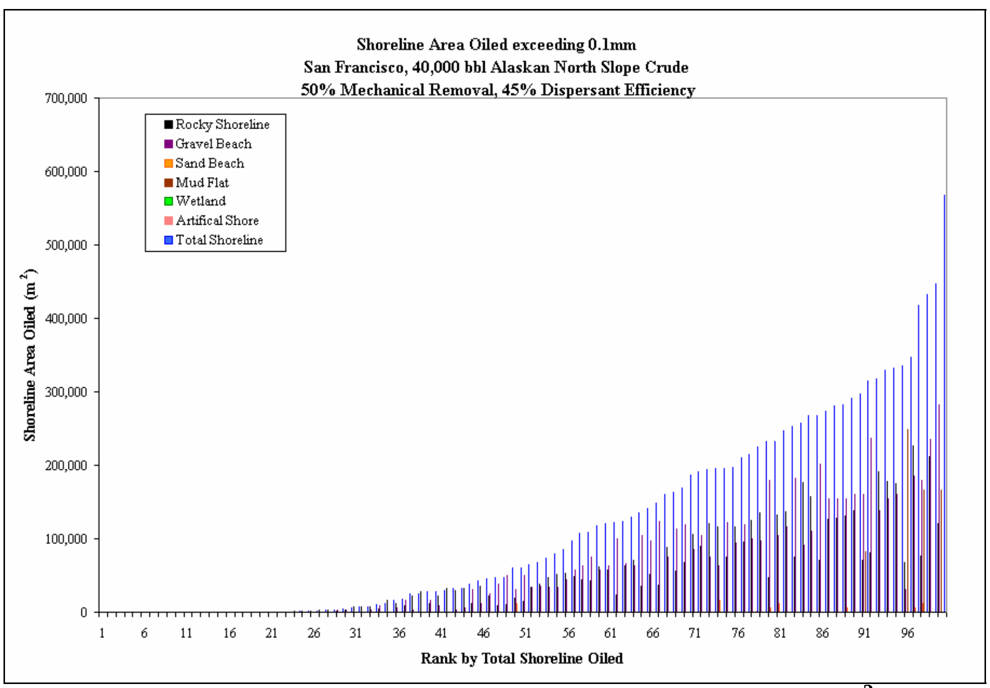

Figure F-II.3.5-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

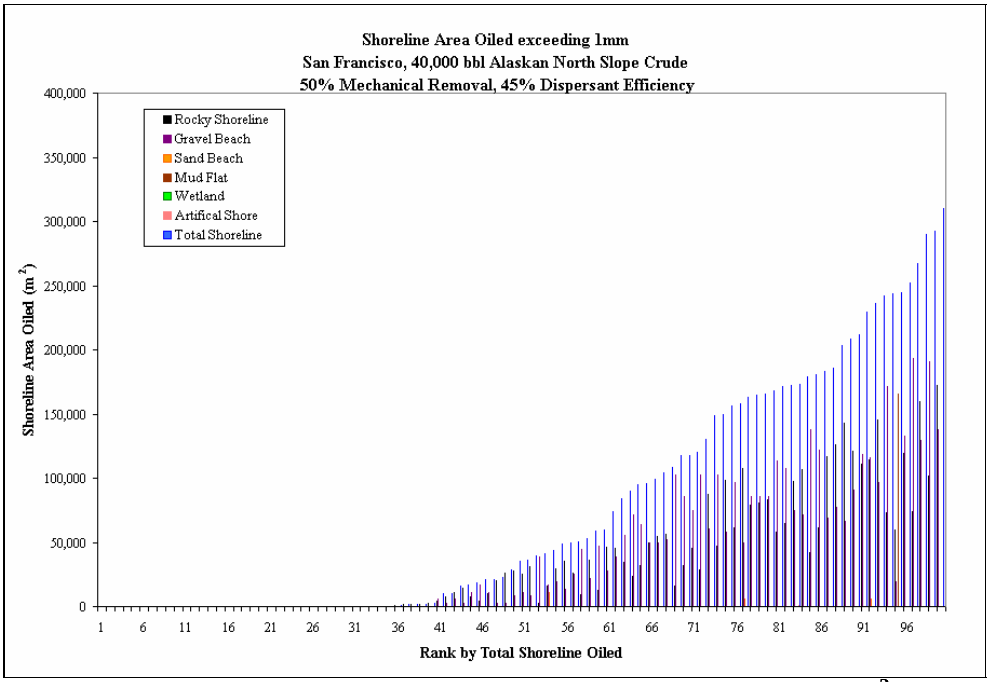

Figure F-II.3.5-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Large Volume, 45% Dispersant Efficiency.

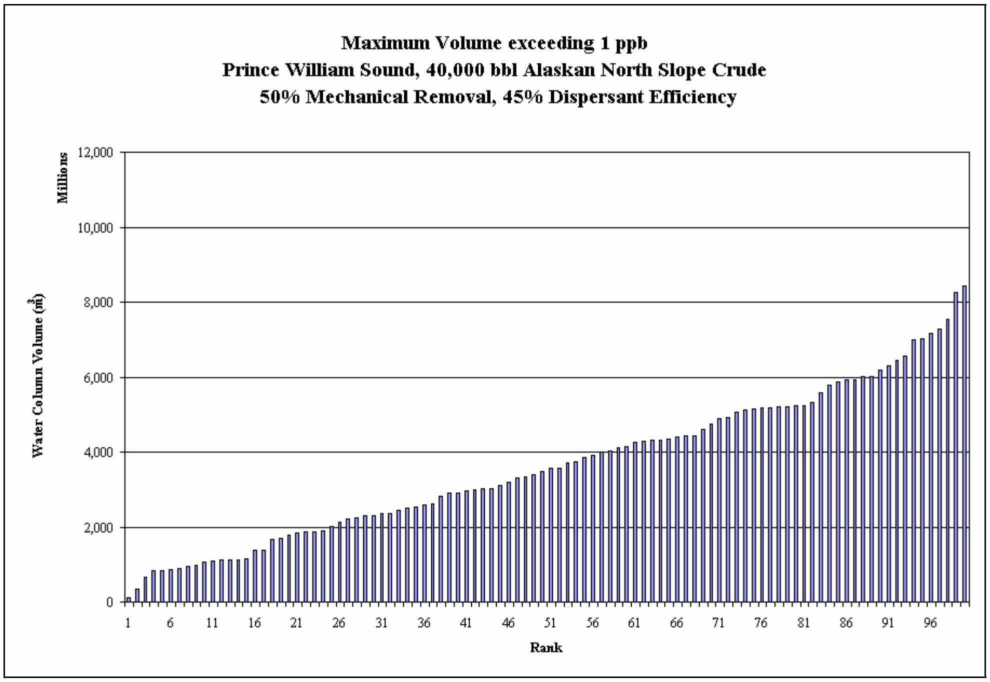

Figure F-II.3.5-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 45% Dispersant Efficiency.

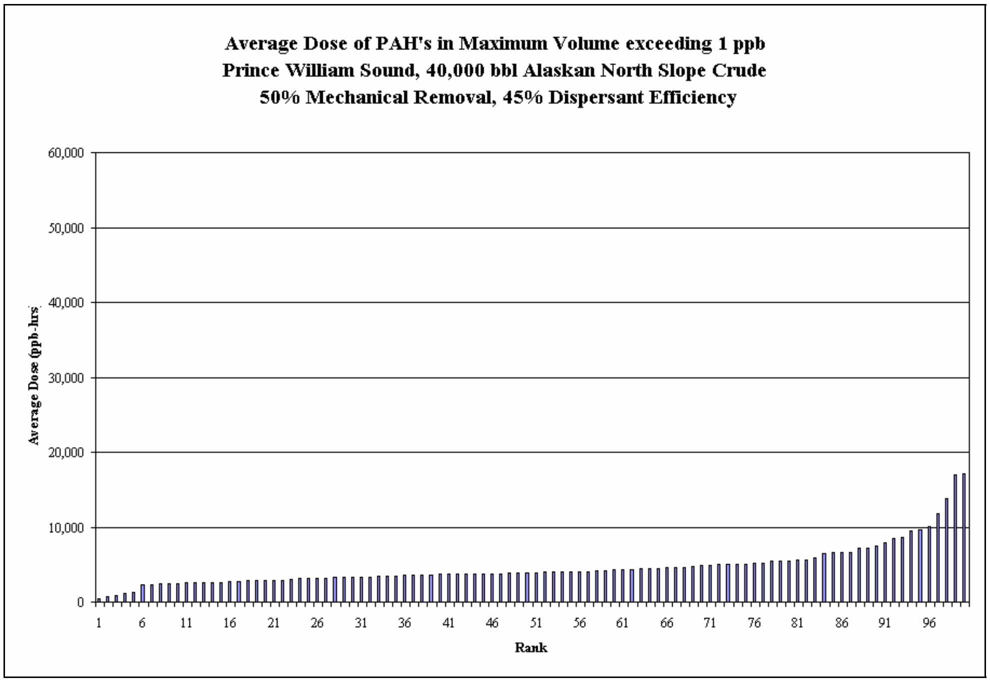

Figure F-II.3.5-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 45% Dispersant Efficiency.

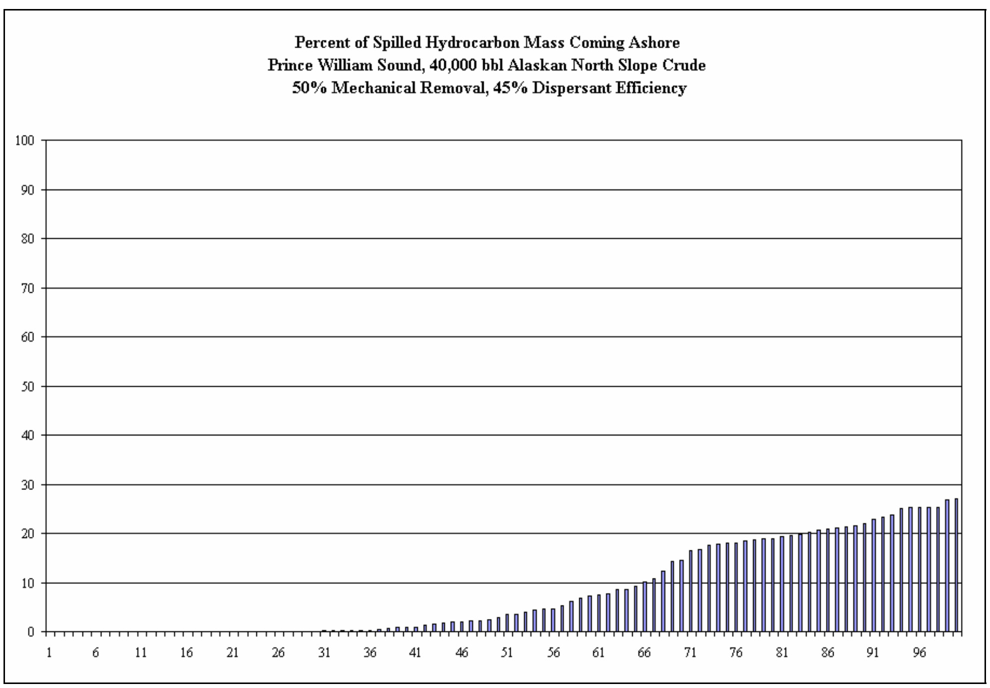

Figure F-II.3.5-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Large Volume, 45% Dispersant Efficiency.

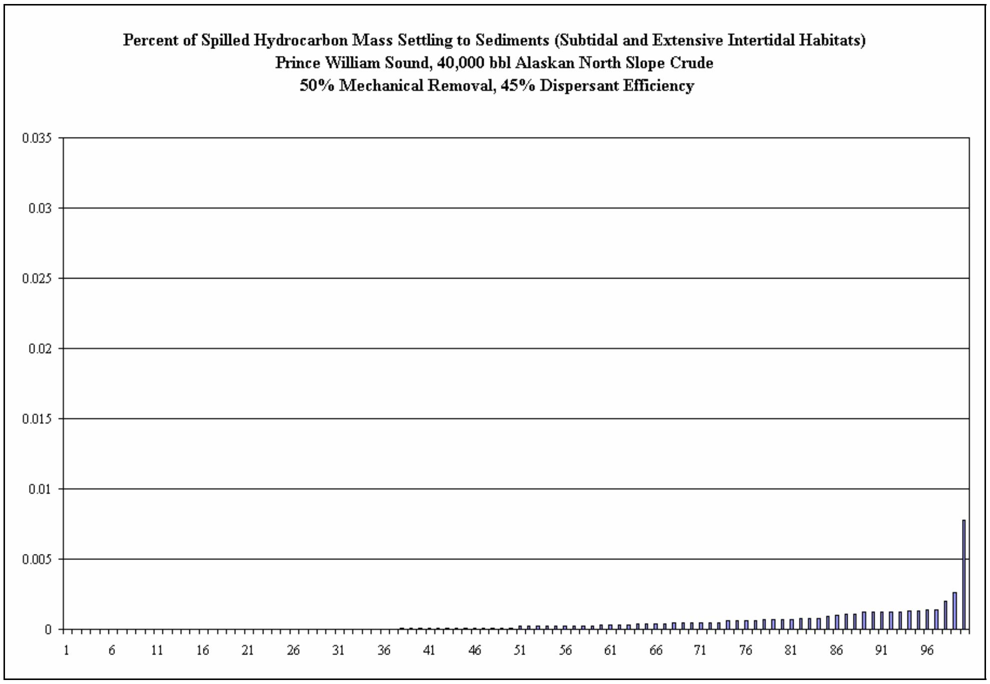

Figure F-II.3.5-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Large Volume, 45% Dispersant Efficiency.

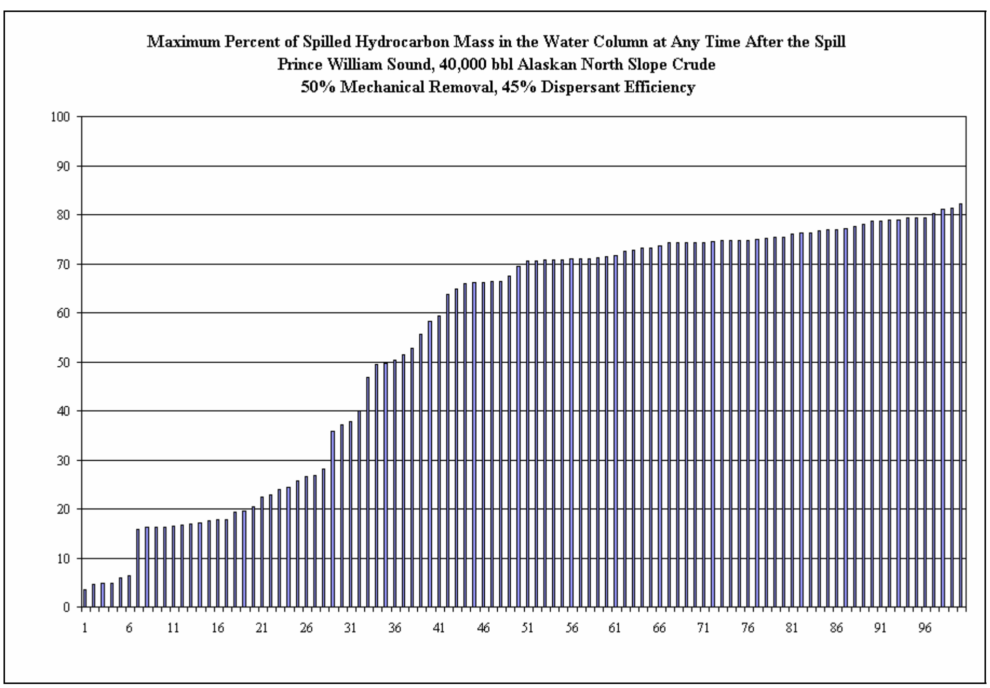

Figure F-II.3.5-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Large Volume, 45% Dispersant Efficiency.

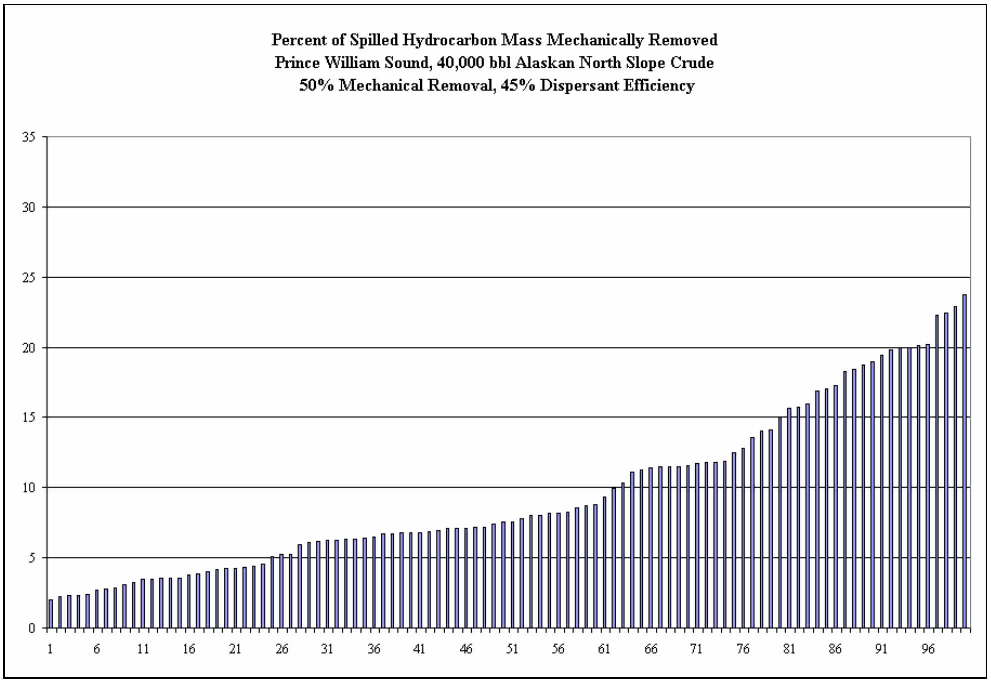

Figure F-II.3.5-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Large Volume, 45% Dispersant Efficiency.

F-II.3.6 Scenario: Large Volume, 80% Dispersant Efficiency.

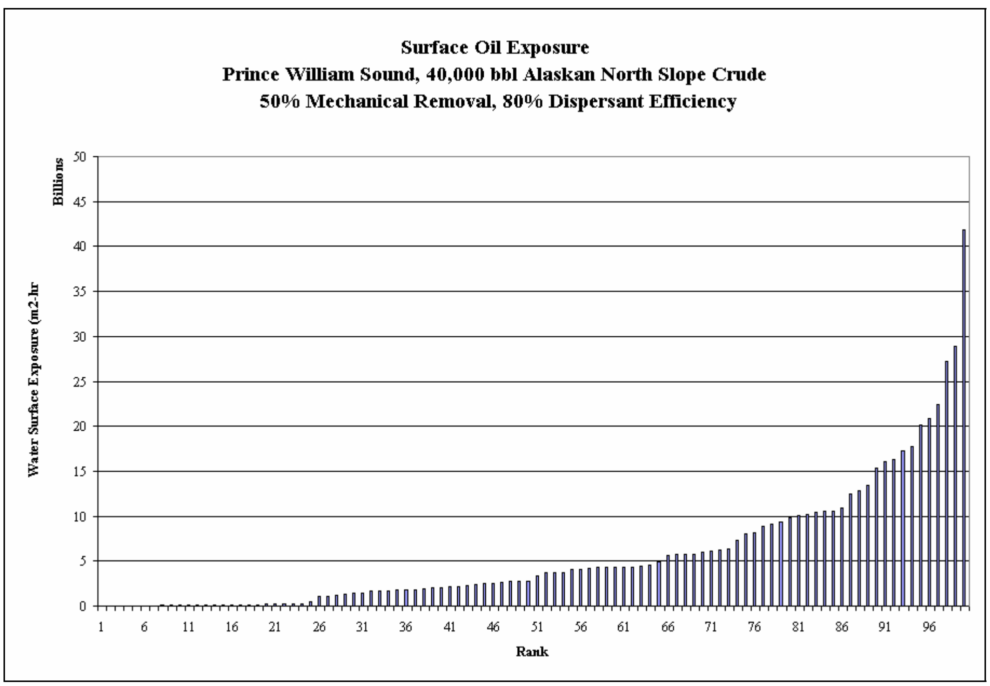

Figure F-II.3.6-1 Water surface exposed to floating hydrocarbons, as the sum of area covered by more than 0.01g/m^2 times duration of exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

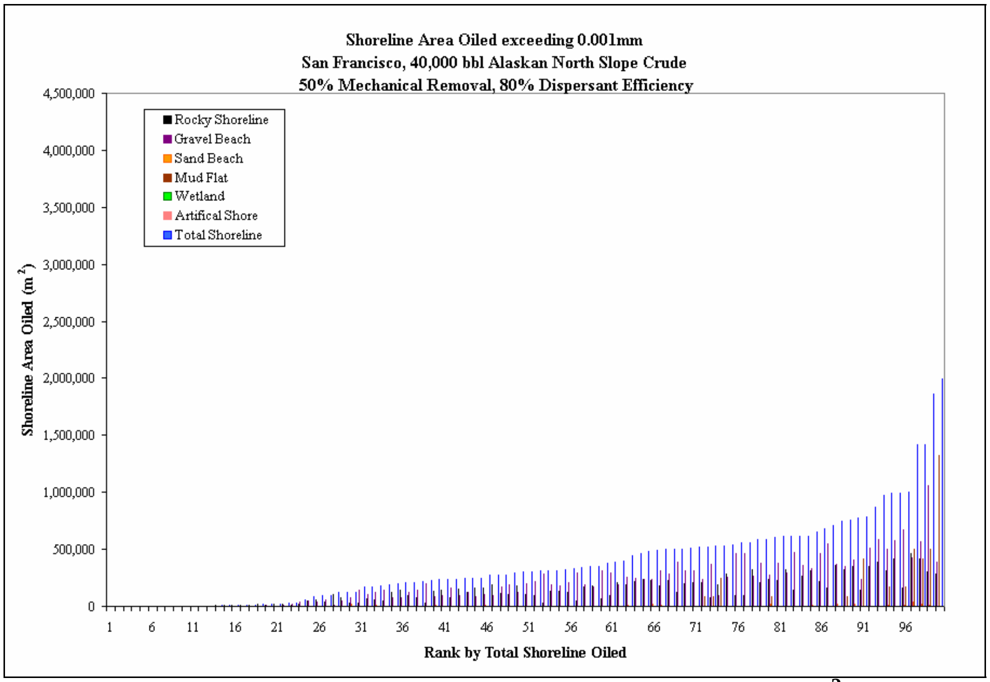

Figure F-II.3.6-2 Shoreline area exposed to hydrocarbons of >1g/m^2 (about 0.001mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

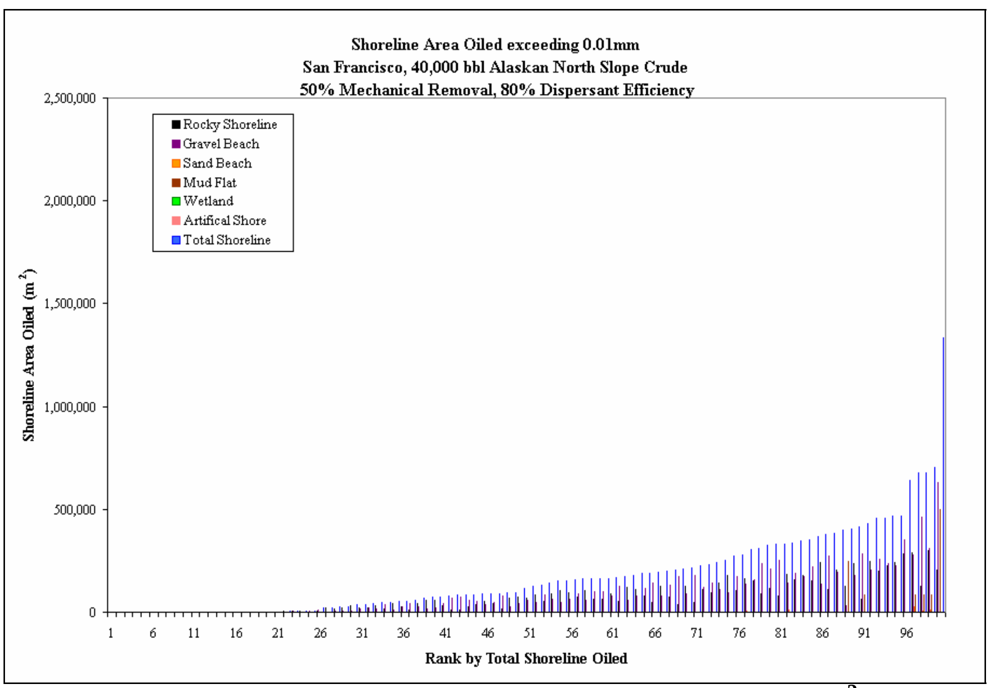

Figure F-II.3.6-3 Shoreline area exposed to hydrocarbons of >10g/m^2 (about 0.01mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

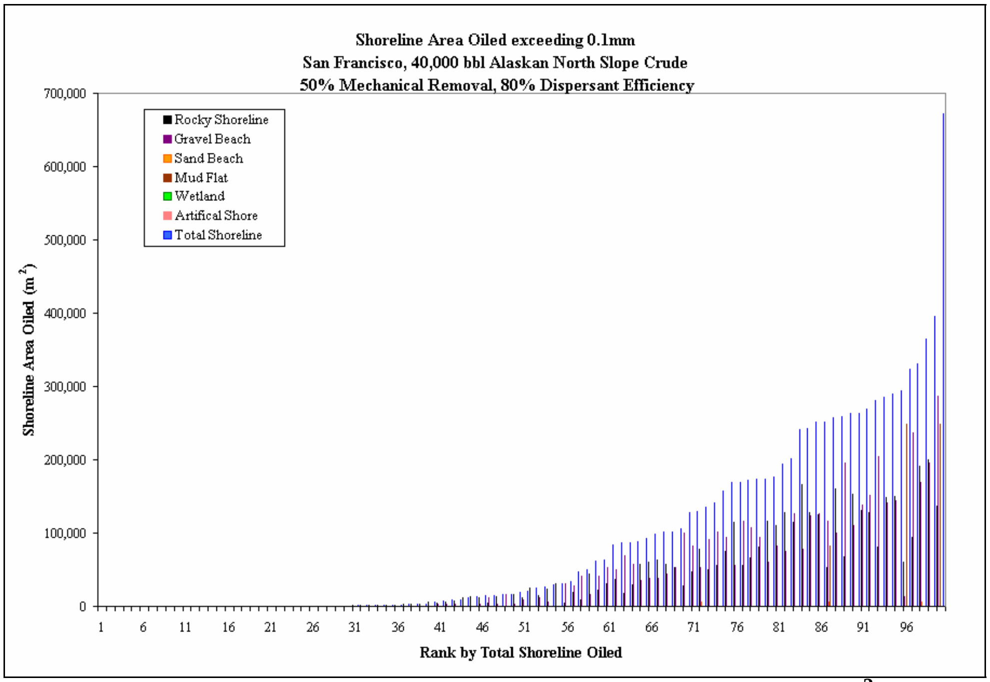

Figure F-II.3.6-4 Shoreline area exposed to hydrocarbons of >100g/m^2 (about 0.1mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

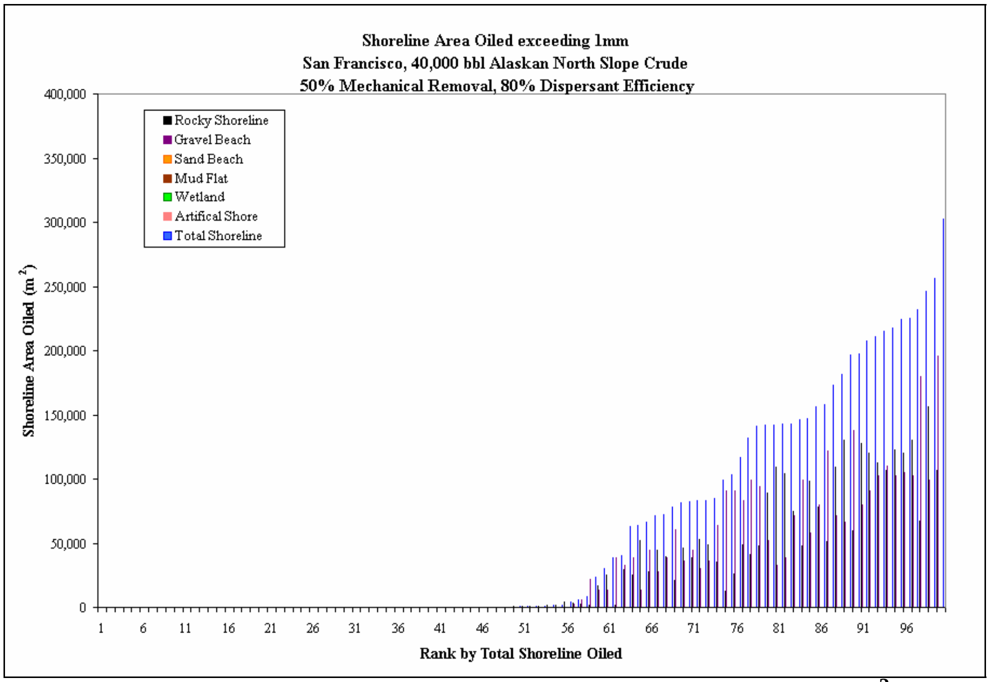

Figure F-II.3.6-5 Shoreline area exposed to hydrocarbons of >1000g/m^2 (about 1mm thick). Scenario: Large Volume, 80% Dispersant Efficiency.

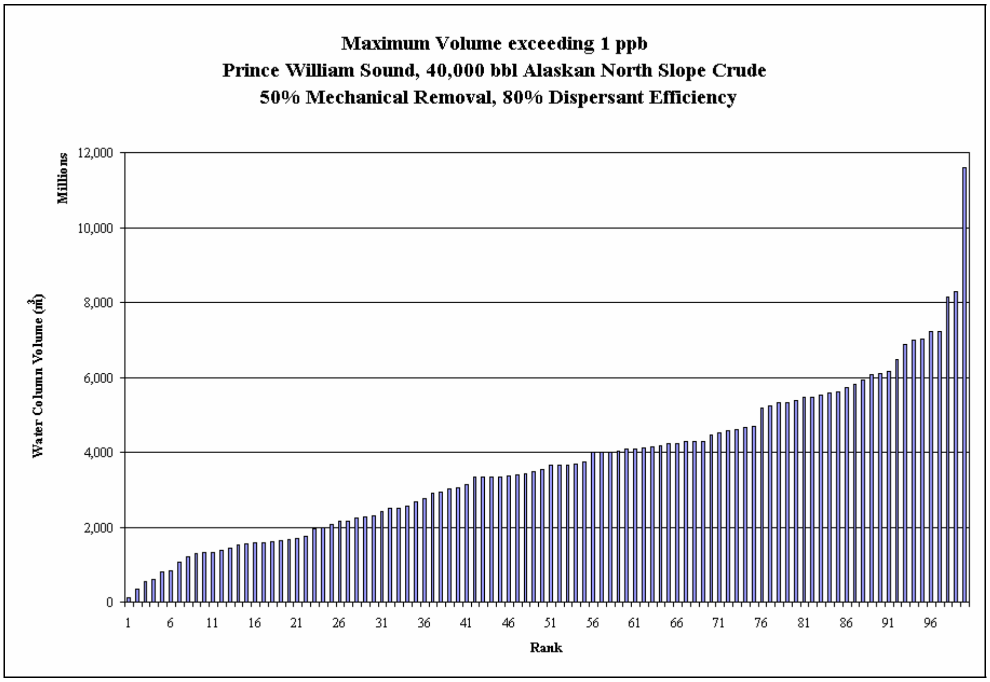

Figure F-II.3.6-6 Water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 80% Dispersant Efficiency.

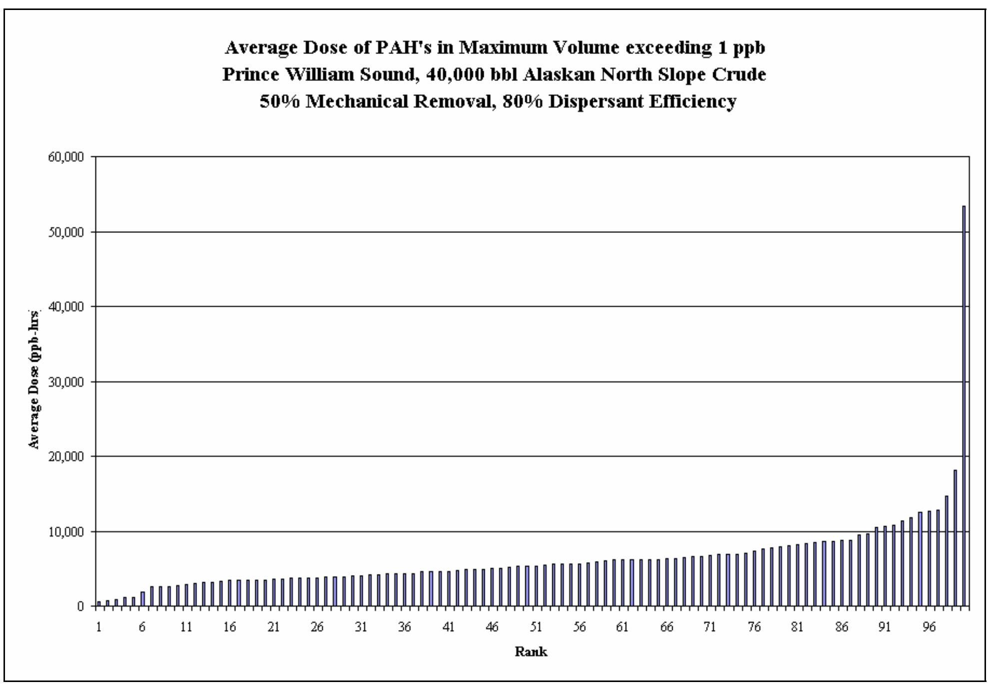

Figure F-II.3.6-7 Exposure dose of dissolved aromatics (ppb-hours) in the water volume exposed to > 1 ppb of dissolved aromatic concentration at some time after the spill. Scenario: Large Volume, 80% Dispersant Efficiency.

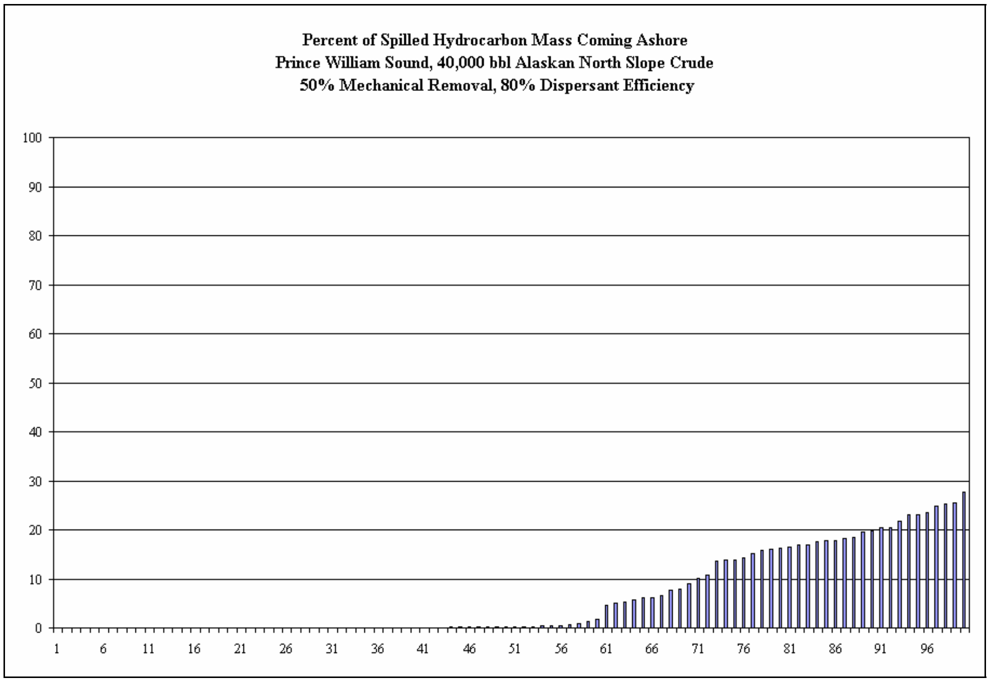

Figure F-II.3.6-8 Percent of spilled hydrocarbon mass eventually going ashore. Scenario: Large Volume, 80% Dispersant Efficiency.

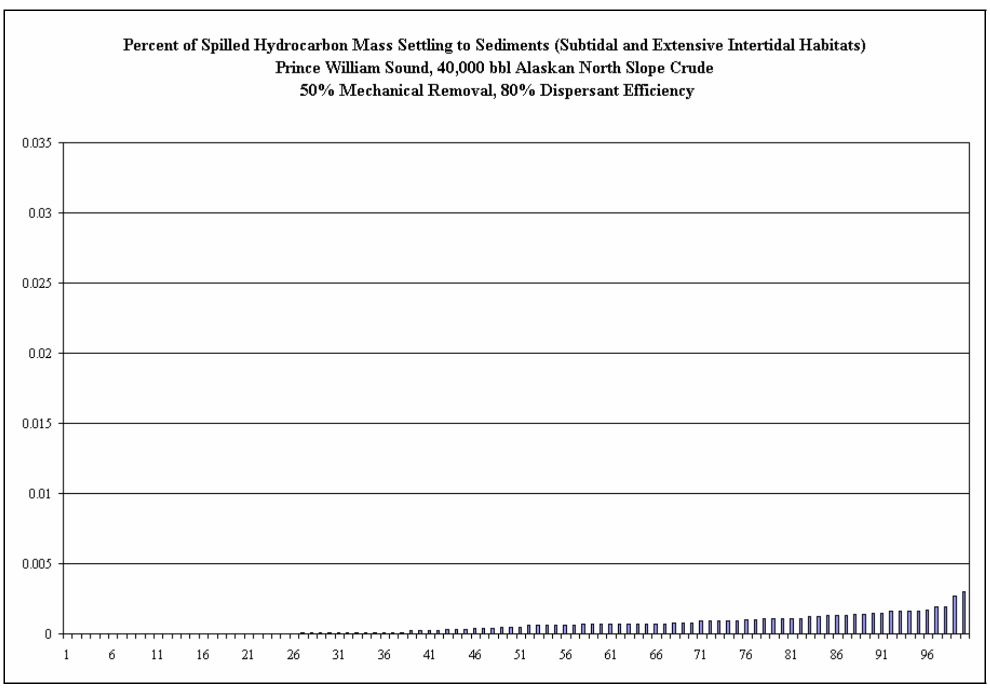

Figure F-II.3.6-9 Percent of spilled hydrocarbon mass settling to sediments (subtidal and extensive intertidal habitats). Scenario: Large Volume, 80% Dispersant Efficiency.

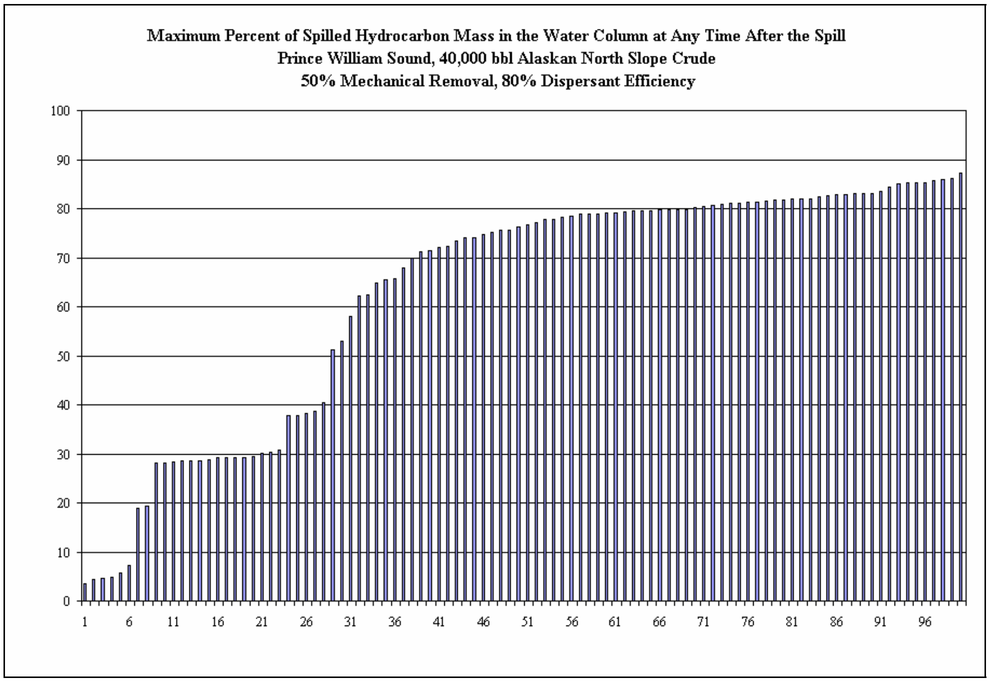

Figure F-II.3.6-10. Percent of spilled hydrocarbon mass in the water column at any time after the spill (%). Scenario: Large Volume, 80% Dispersant Efficiency.

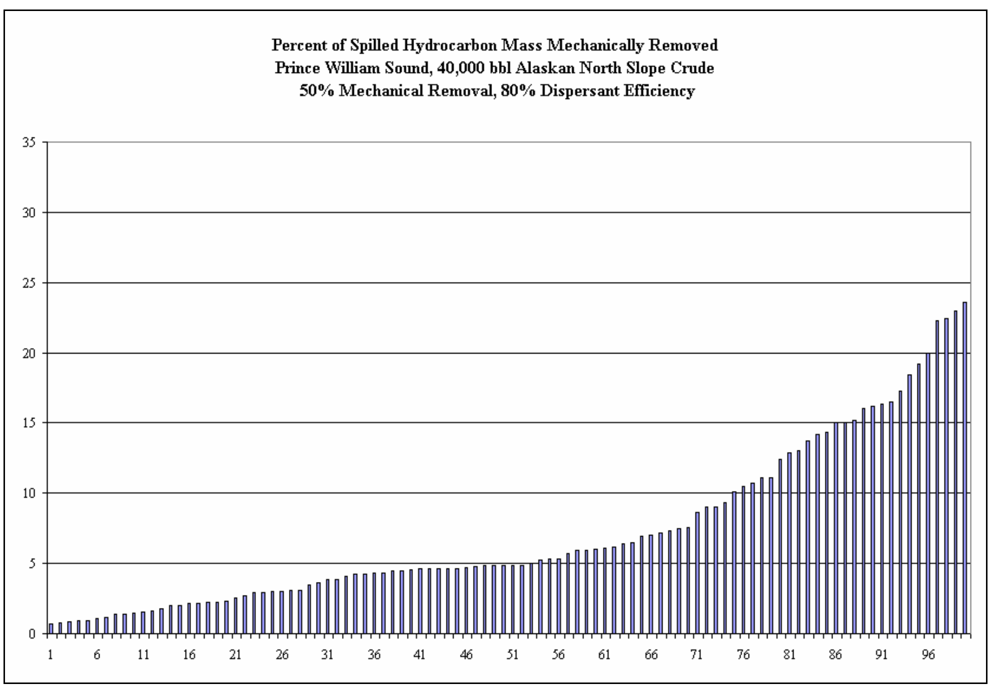

Figure F-II.3.6-11. Percent of spilled hydrocarbon mass mechanically removed (%). Scenario: Large Volume, 80% Dispersant Efficiency.

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part F: Prince William Sound

Section F-II.4

by

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ASA 00-246

August 2004

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F-II.4 Exposure for Representative Individual Model Runs.

In this appendix, the results for the 50th percentile cases for surface oiling, shoreline oiling, water column effects, and sediment contamination are shown, as plots of the following measures of exposure:

- Water surface exposure to floating hydrocarbons (g/m^2)
- Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile surface oil exposure run
- Shoreline exposure to hydrocarbons (g/m^2)
- Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill
- Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill
- Water column exposure dose of dissolved aromatic concentration (ppb-hours)
- Sediment pore water exposure of dissolved aromatic concentration (ppb)
- Sediment exposure to total hydrocarbons (g/m^2)

The percentile runs plotted are those runs which apply to the exposure index being considered. Thus, different runs are plotted for each of surface oil, shoreline oil, water column effect measures, and sediment contamination. Tables F-II.4-1 to F-II.4-3 summarize the run number and date and time of the runs resulting in the 50th and 95th percentile exposures. The 95th percentile exposure indicates the maximum likely effect.

The Crosshair mark () in figures below represents oil spill site.

Table F-II.4-1 Run number and date and time of the runs resulting in the 50th and 95th percentile exposures for surface oil exposure.

Surface Oil Exposure (exceeding 0.01 g/m2)							
Scenario	**Percentile**	**Run Number**	**Year**	**Month**	**Day**	**Hour**	**Area-hrs (m2-hrs)**
PWS-Med-50-0	50th	21	2002	1	30	2	$1,596 \times 10^6$
	95th	80	1999	7	26	1	$7,759 \times 10^6$
PWS-Med-50-45	50th	43	1995	11	6	4	552×10^6
	95th	38	1998	11	19	16	$8,392 \times 10^6$
PWS-Med-50-80	50th	96	1997	6	22	15	632×10^6
	95th	58	1998	5	16	3	$8,638 \times 10^6$
PWS-Lrg-50-0	50th	29	1997	7	4	10	$9,811 \times 10^6$
	95th	88	2000	7	9	15	$31,245 \times 10^6$
PWS-Lrg-50-45	50th	69	1998	3	26	13	$3,861 \times 10^6$
	95th	68	1996	8	28	18	$26,720 \times 10^6$
PWS-Lrg-50-80	50th	31	1998	6	1	8	$3,374 \times 10^6$
	95th	100	1999	9	17	4	$20,910 \times 10^6$

Table F-II.4-2 Run number and date and time of the runs resulting in the 50th and 95th percentile exposures for dissolved aromatic exposure.

Maximum Dissolved Aromatic Plume Volume exceeding 1 ppb							
Scenario	**Percentile**	**Run Number**	**Year**	**Month**	**Day**	**Hour**	**Volume (m3)**
PWS-Med-50-0	50th	98	2001	9	11	2	13×10^6
	95th	3	1998	10	17	20	198×10^6
PWS-Med-50-45	50th	51	2000	10	19	2	522×10^6
	95th	42	2001	3	27	12	784×10^6
PWS-Med-50-80	50th	40	2000	11	30	20	461×10^6
	95th	71	1995	7	27	20	838×10^6
PWS-Lrg-50-0	50th	98	2001	9	11	2	13×10^6
	95th	3	1998	10	17	20	198×10^6
PWS-Lrg-50-45	50th	51	2000	10	19	2	$520\ 10^6$
	95th	42	2001	3	27	12	784×10^6
PWS-Lrg-50-80	50th	5	2001	9	21	5	$3,642 \times 10^6$
	95th	15	1996	5	6	19	$7,213 \times 10^6$

Table F-II.4-3 Run number and date and time of the runs resulting in the 50th and 95th percentile exposures for sediment exposure.

Percent of Spilled Mass Reaching Sediment							
Scenario	**Percentile**	**Run Number**	**Year**	**Month**	**Day**	**Hour**	**%**
PWS-Med-50-0	50th	52	1996	6	15	17	0.000
	95th	98	2001	9	11	2	0.000
PWS-Med-50-45	50th	6	2001	2	22	18	0.001
	95th	55	2001	6	2	7	0.002
PWS-Med-50-80	50th	73	2000	2	23	17	0.001
	95th	71	1995	7	27	20	0.002
PWS-Lrg-50-0	50th	55	2001	6	2	7	0.000
	95th	33	1999	8	16	16	0.005
PWS-Lrg-50-45	50th	3	1998	10	17	20	0.000
	95th	26	2001	4	22	18	0.001
PWS-Lrg-50-80	50th	76	2000	9	11	10	0.001
	95th	56	1996	11	1	9	0.002

F-II.4.1 Scenario: Medium Volume, No Dispersant.

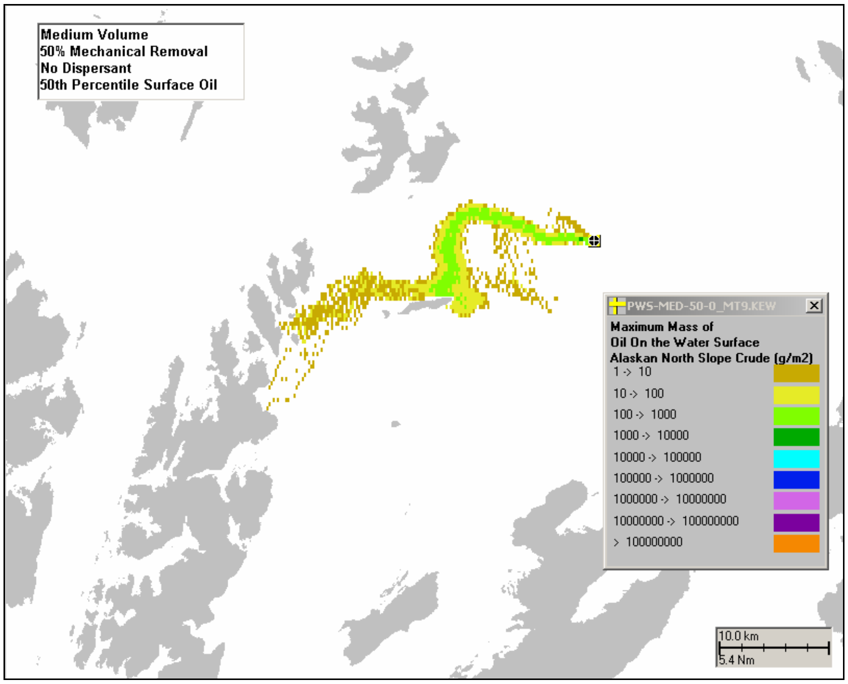

Figure F-II.4.1-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, No Dispersant.

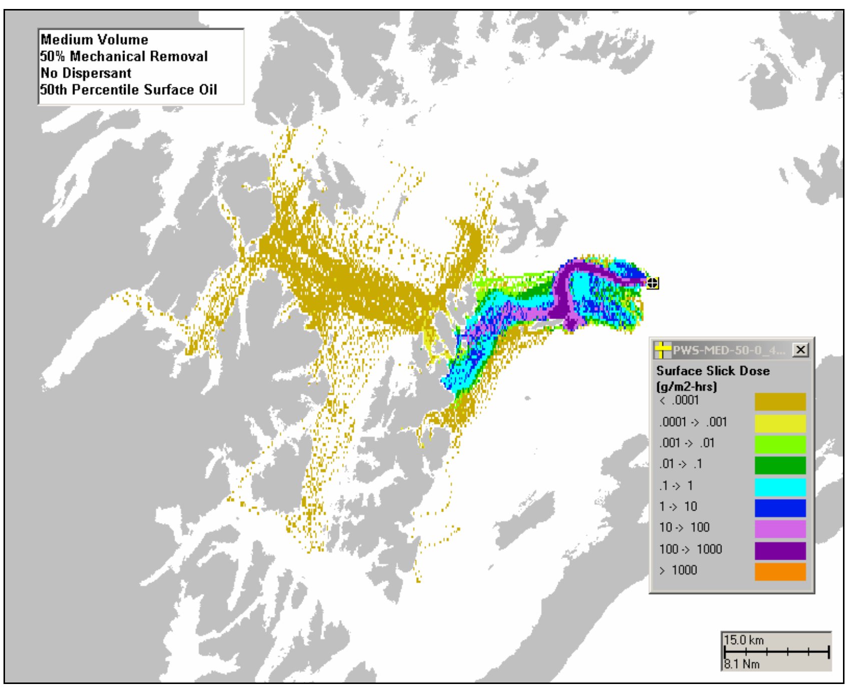

Figure F-II.4.1-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, No Dispersant.

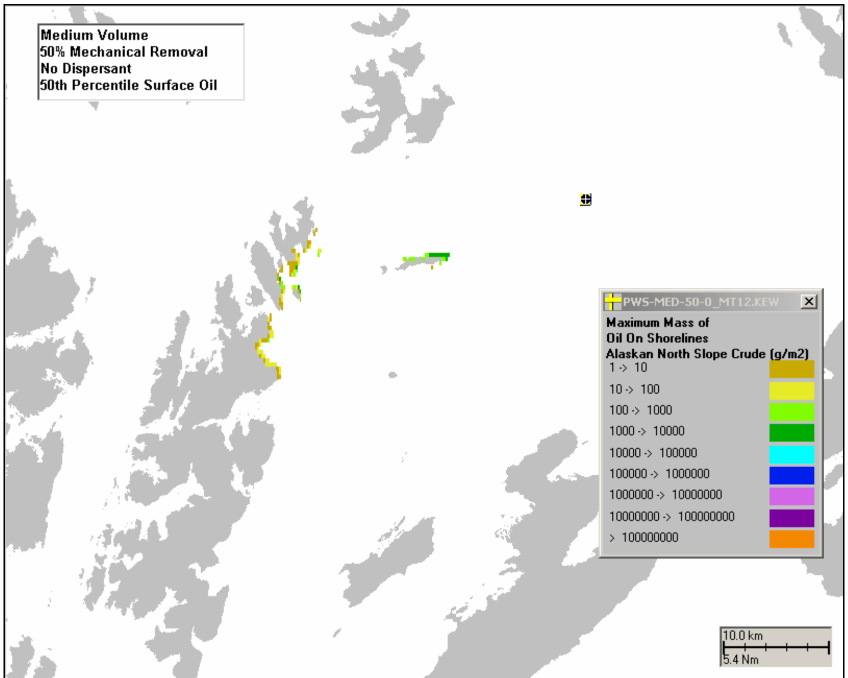

Figure F-II.4.1-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, No Dispersant.

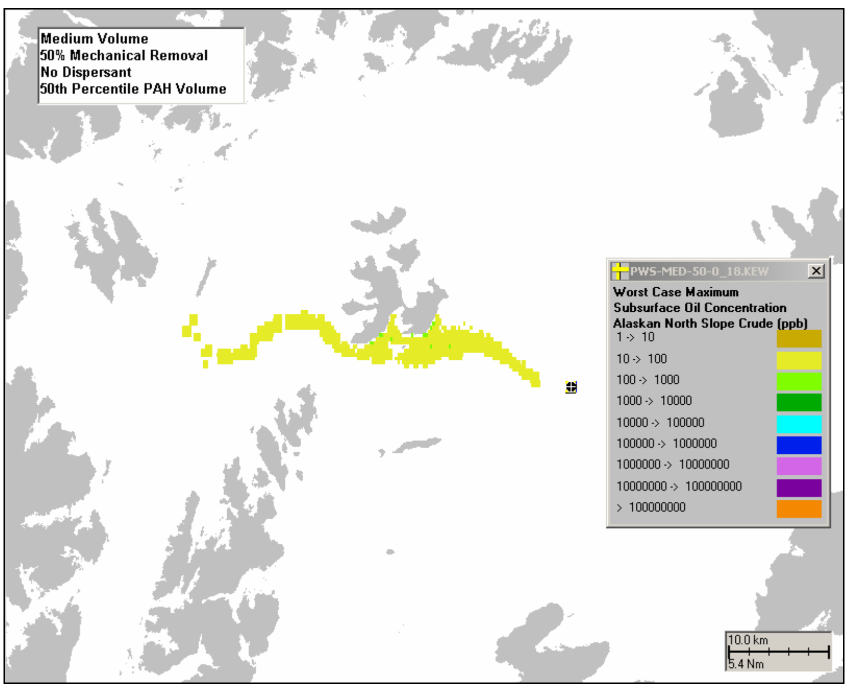

Figure F-II.4.1-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, No Dispersant.

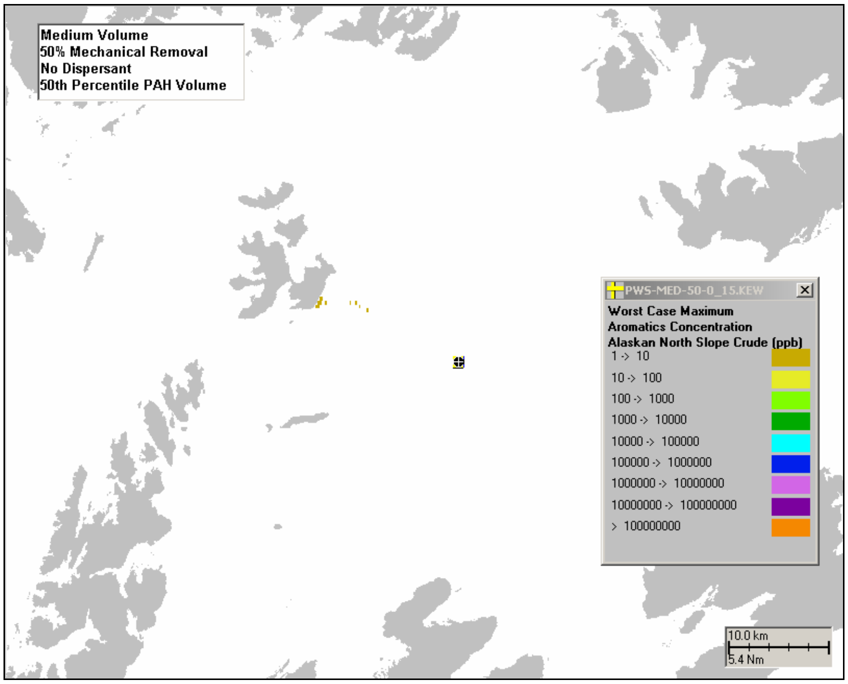

Figure F-II.4.1-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, No Dispersant.

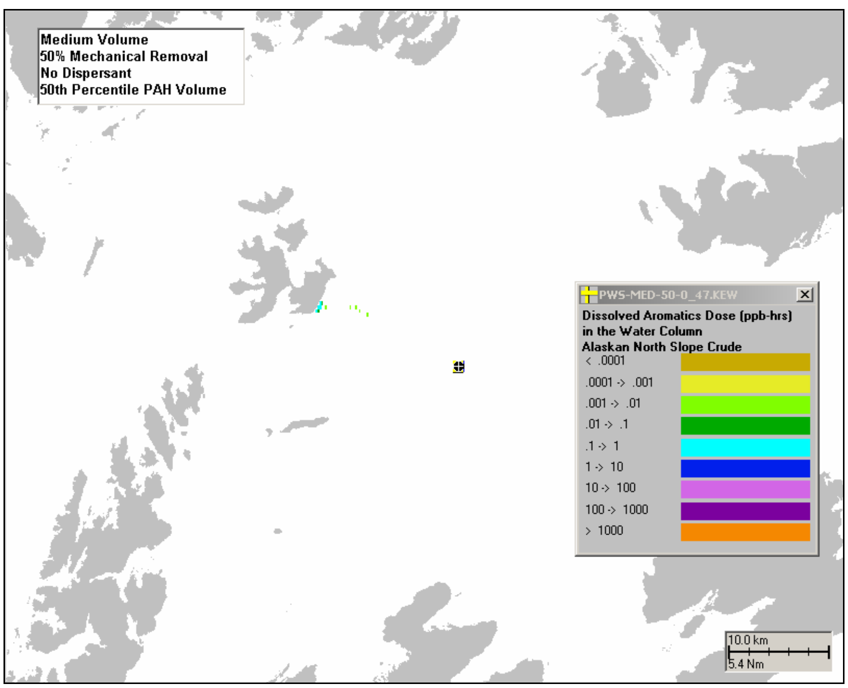

Figure F-II.4.1-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, No Dispersant.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Medium Volume, No Dispersant.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Medium Volume, No Dispersant.

F-II.4.2 Scenario: Medium Volume, 45% Dispersant Efficiency.

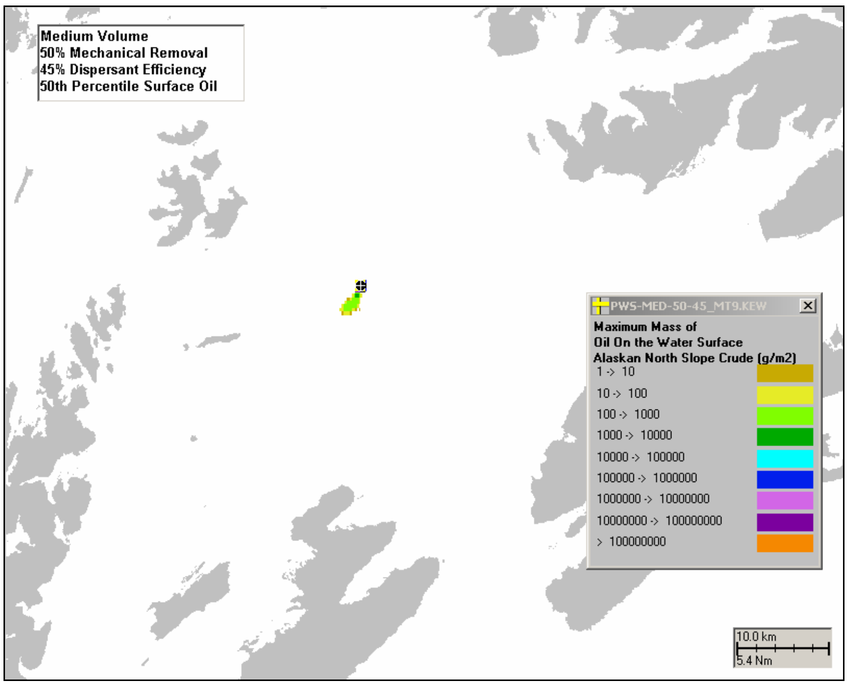

Figure F-II.4.2-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

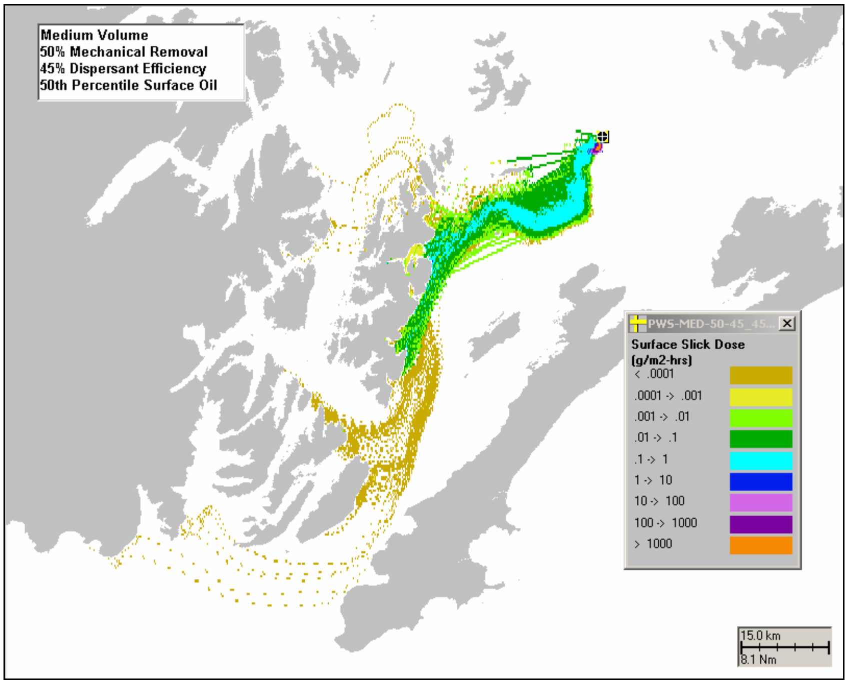

Figure F-II.4.2-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

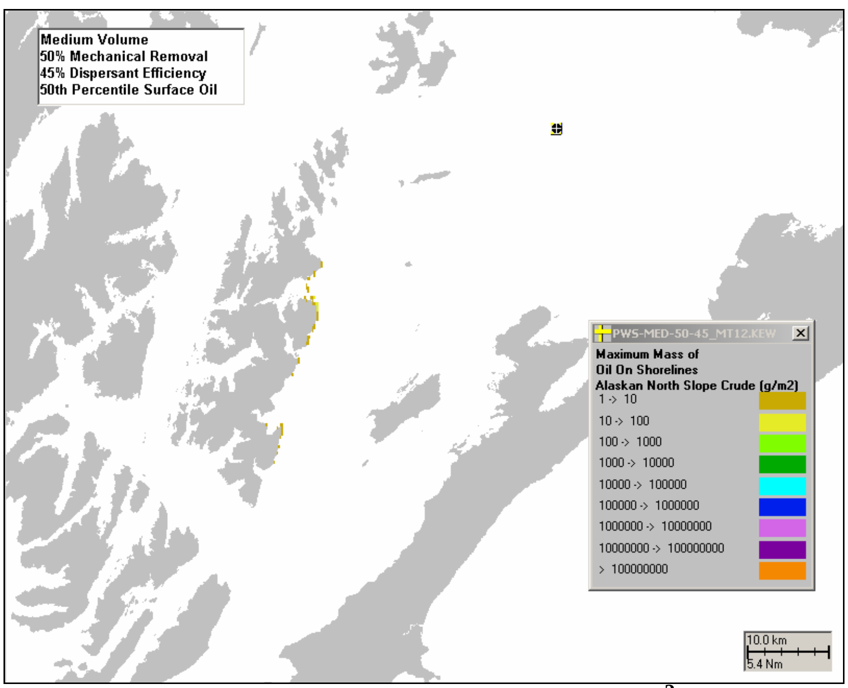

Figure F-II.4.2-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 45% Dispersant Efficiency.

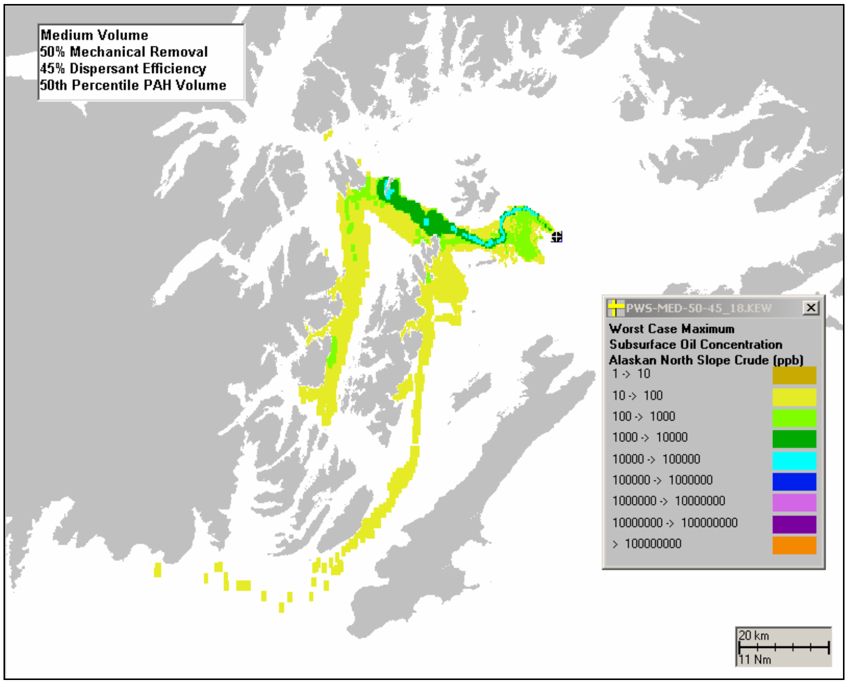

Figure F-II.4.2-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 45% Dispersant Efficiency.

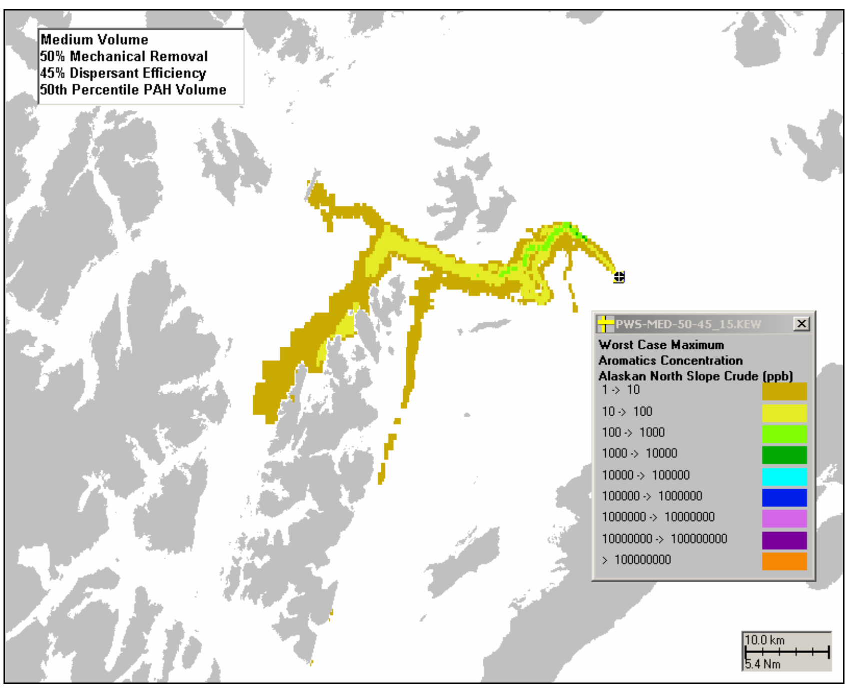

Figure F-II.4.2-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 45% Dispersant Efficiency.

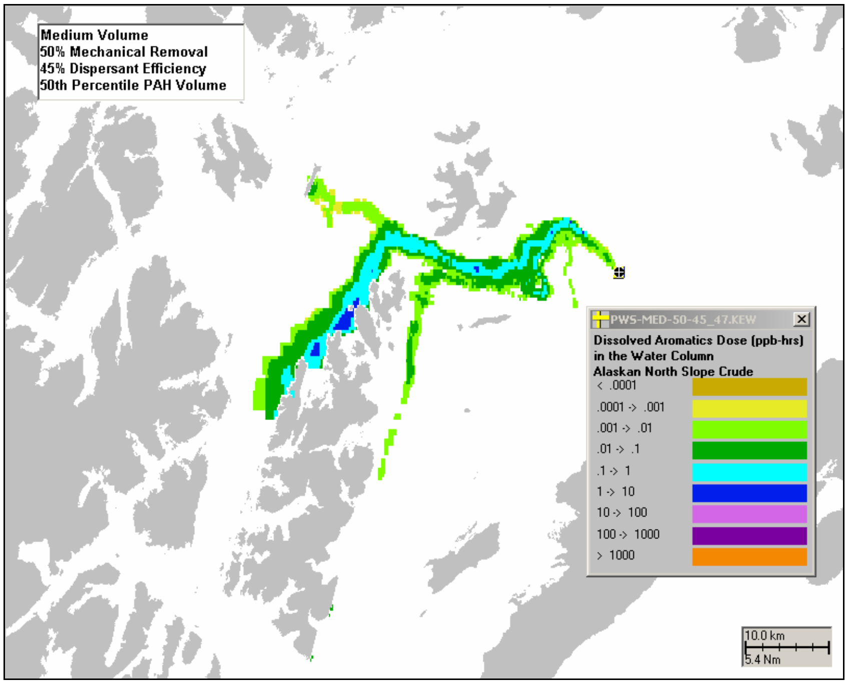

Figure F-II.4.2-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 45% Dispersant Efficiency.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Medium Volume, 45% Dispersant Efficiency..

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Medium Volume, 45% Dispersant Efficiency.

F-II.4.3 Scenario: Medium Volume, 80% Dispersant Efficiency.

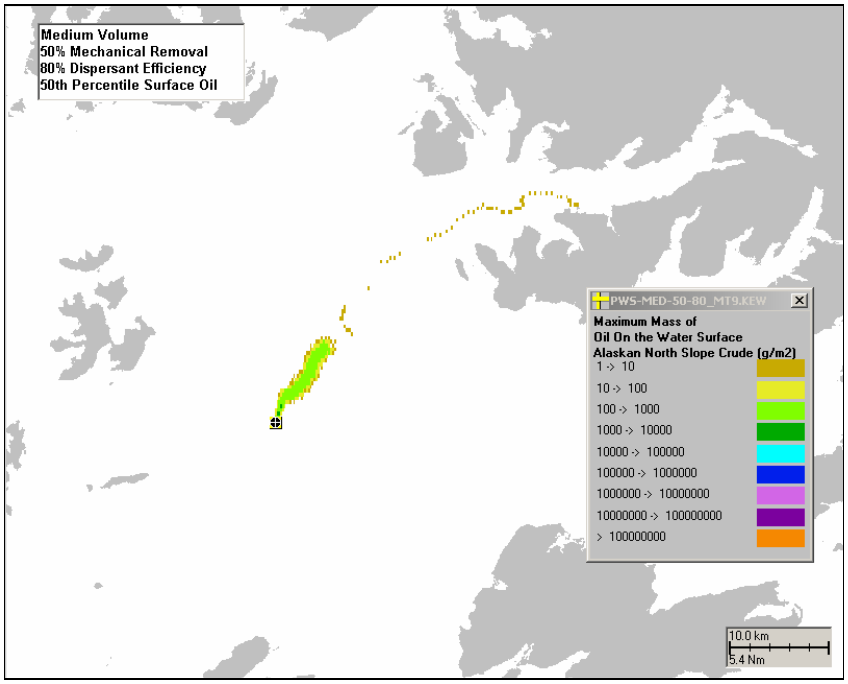

Figure F-II.4.3-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

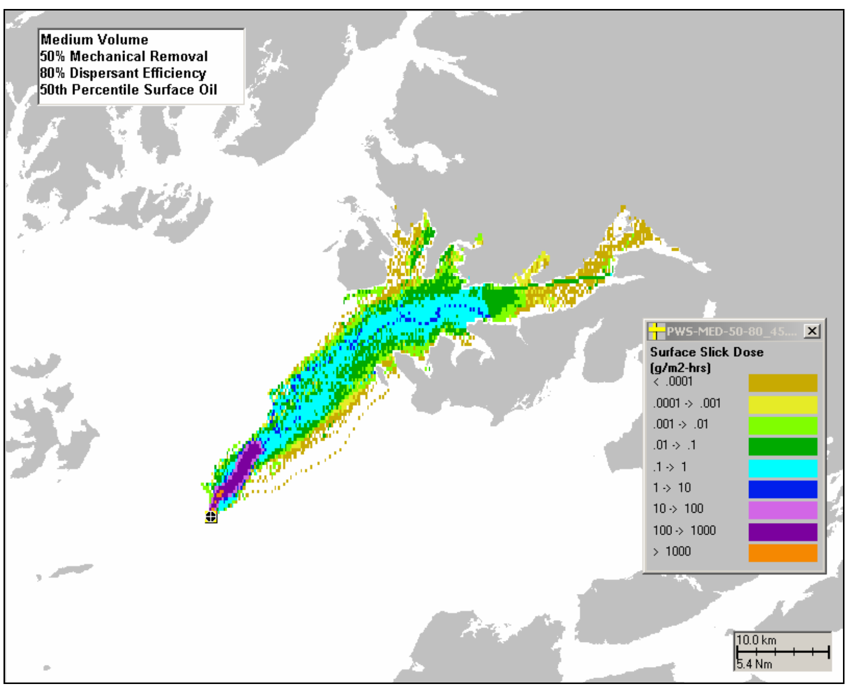

Figure F-II.4.3-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

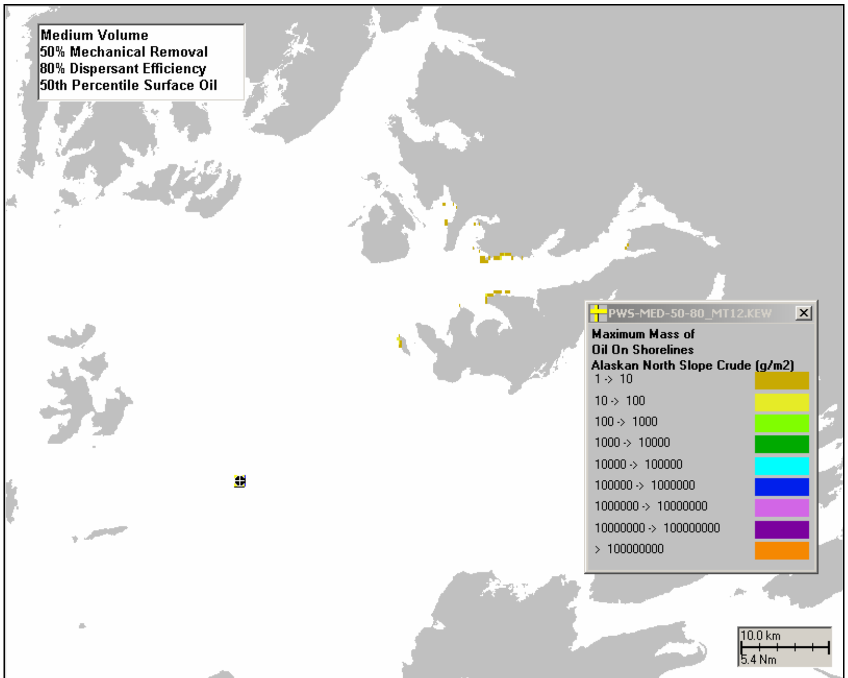

Figure F-II.4.3-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Medium Volume, 80% Dispersant Efficiency.

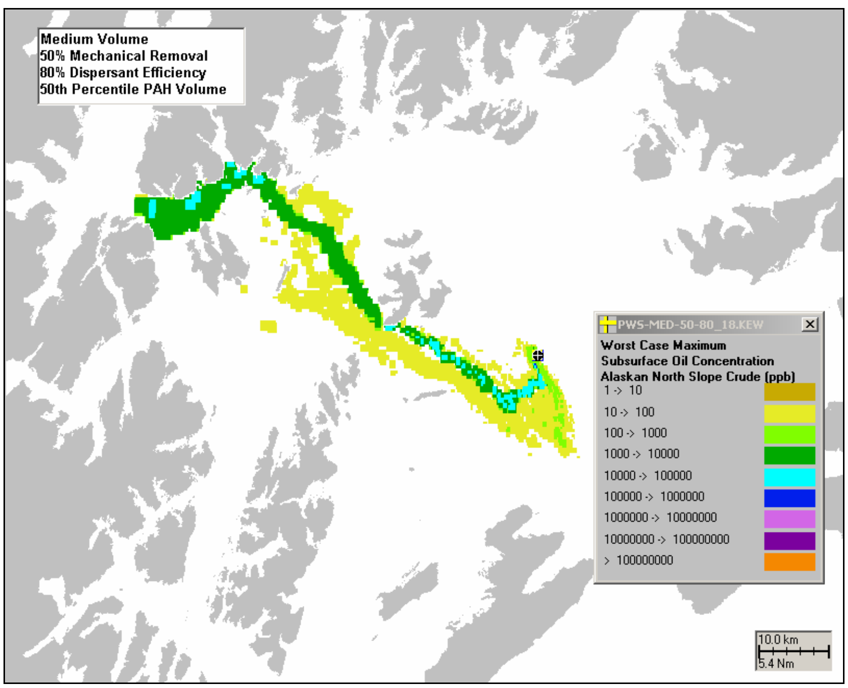

Figure F-II.4.3-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 80% Dispersant Efficiency.

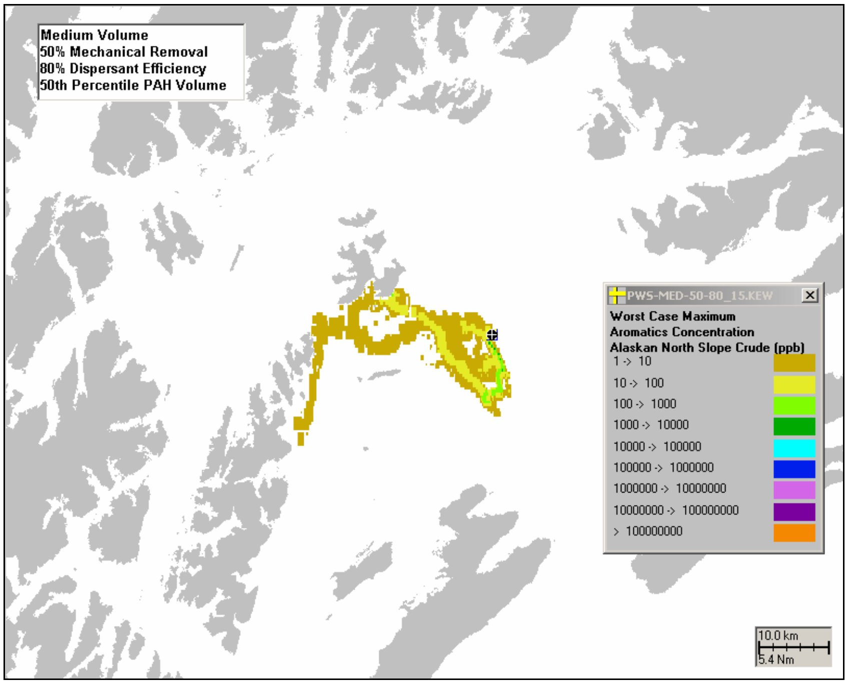

Figure F-II.4.3-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 80% Dispersant Efficiency.

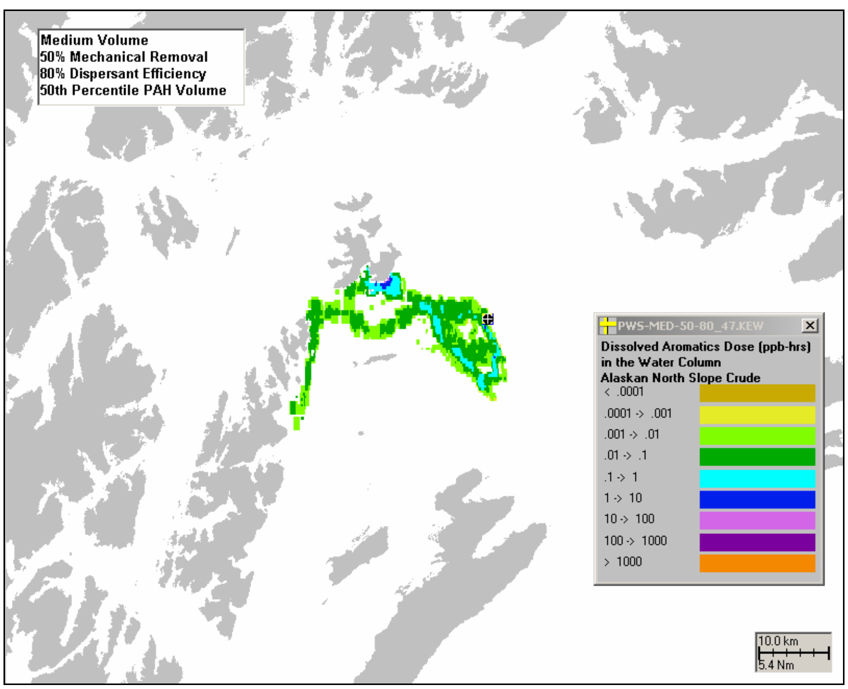

Figure F-II.4.3-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Medium Volume, 80% Dispersant Efficiency.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Medium Volume, 80% Dispersant Efficiency..

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Medium Volume, 80% Dispersant Efficiency.

F-II.4.4 Scenario: Large Volume, No Dispersant.

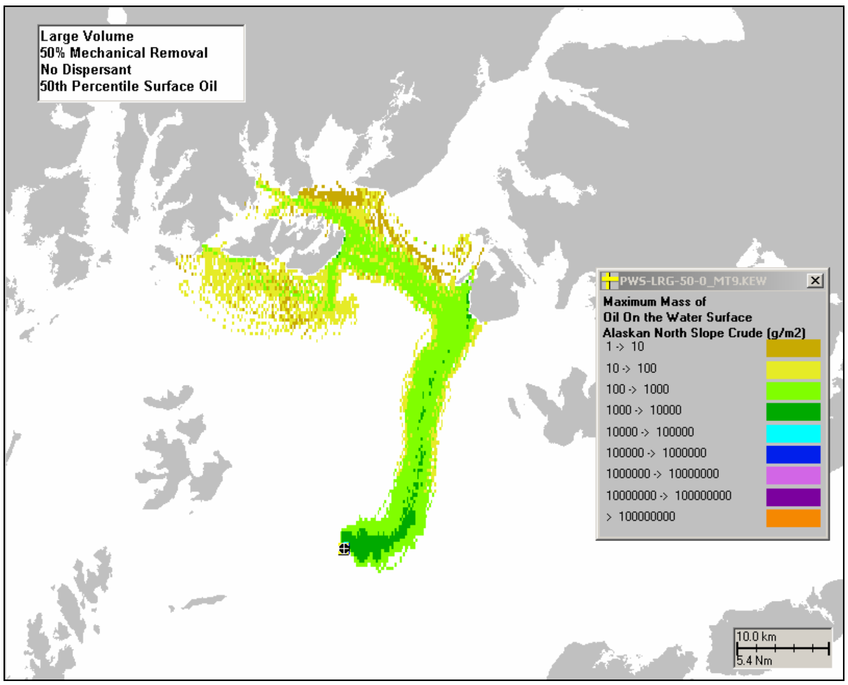

Figure F-II.4.4-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure.   Scenario: Large Volume, No Dispersant.

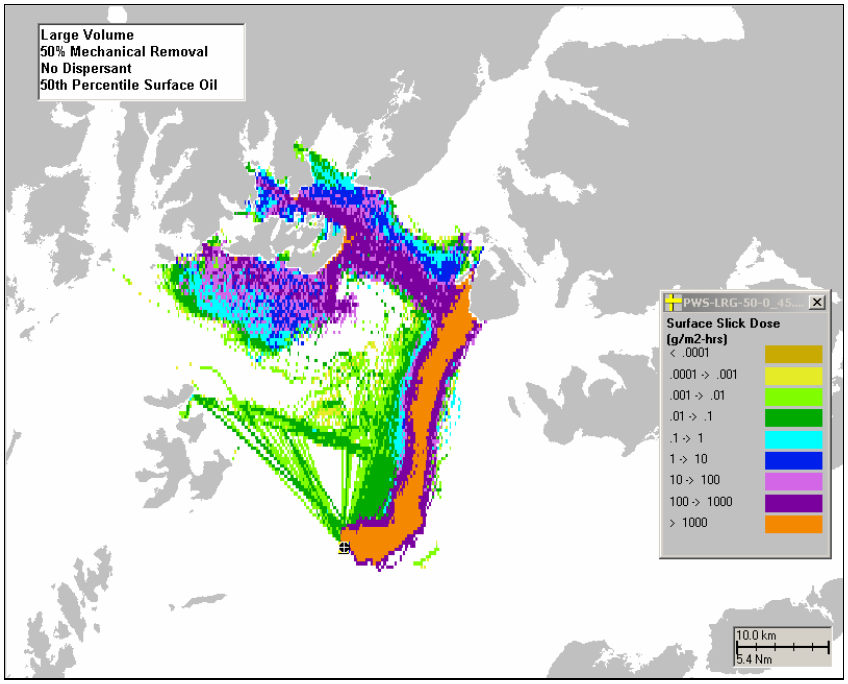

Figure F-II.4.4-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Large Volume, No Dispersant.

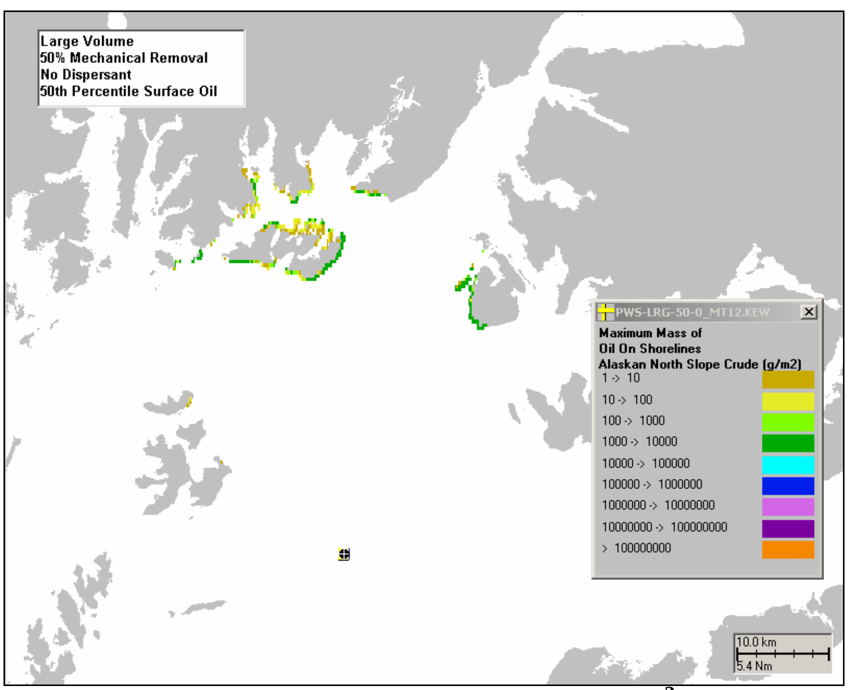

Figure F-II.4.4-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, No Dispersant.

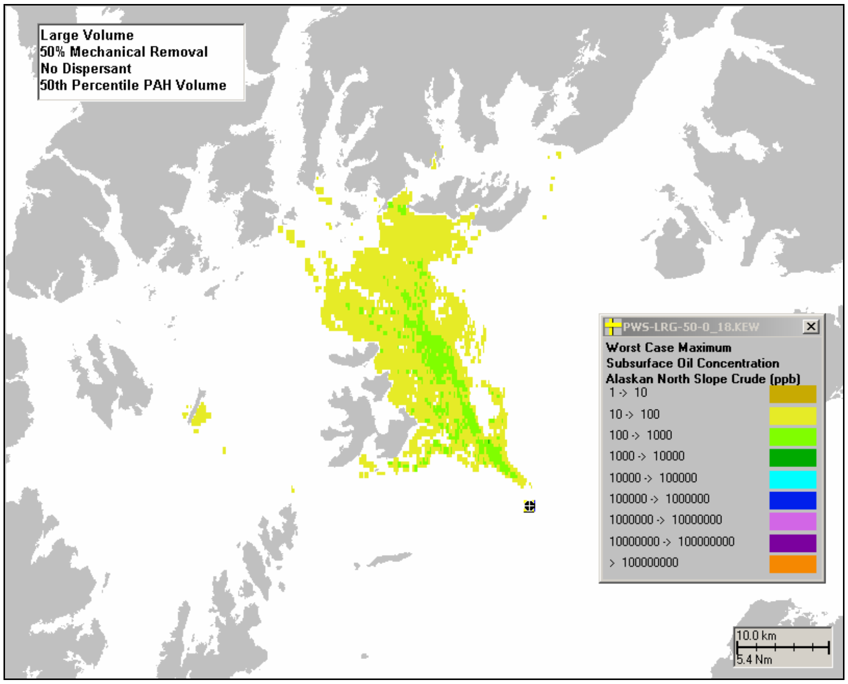

Figure F-II.4.4-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, No Dispersant.

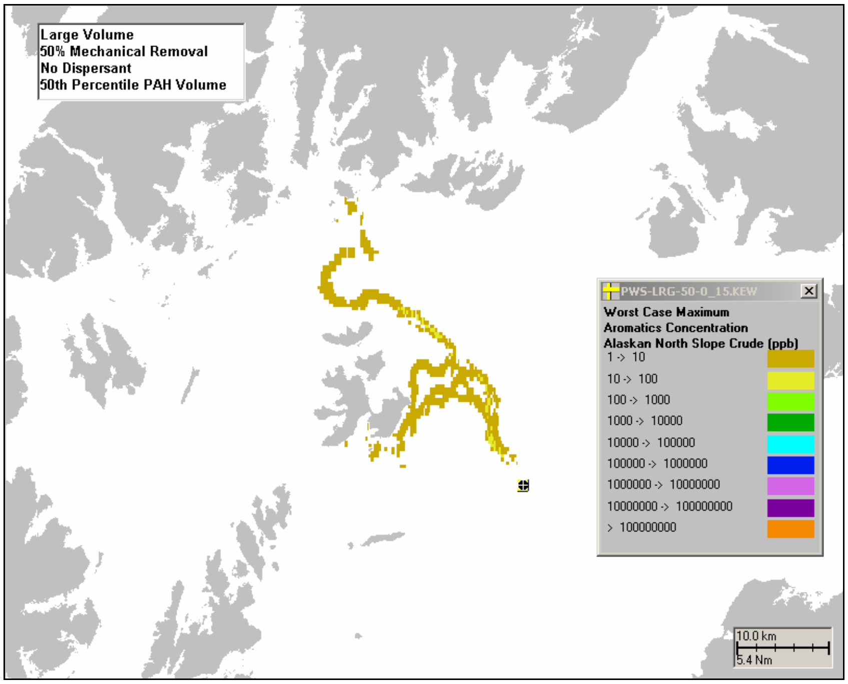

Figure F-II.4.4-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, No Dispersant.

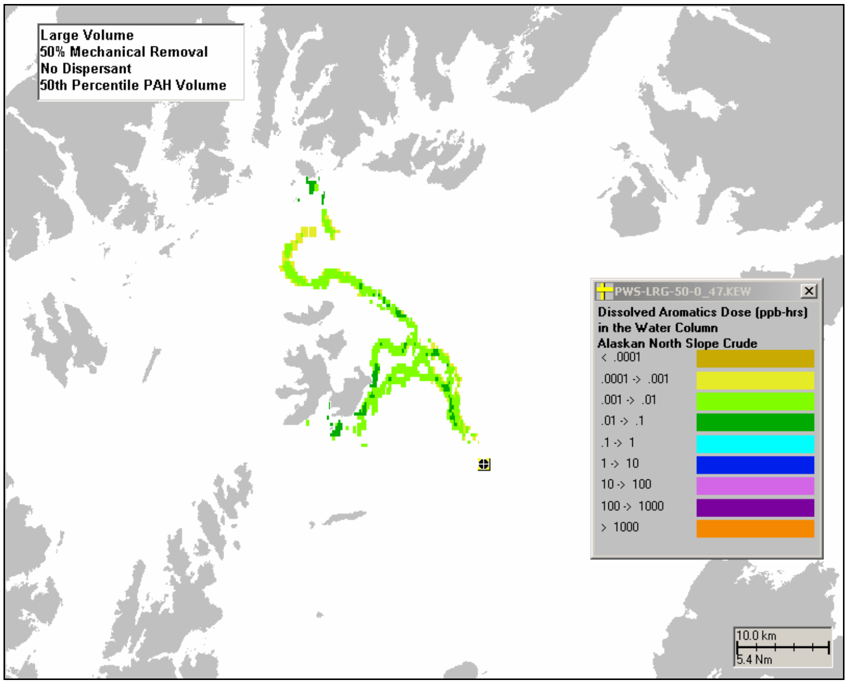

Figure F-II.4.4-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, No Dispersant.

Exposure of sediment pore water to dissolved aromatic concentration (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 1 ppb. Scenario: Large Volume, No Dispersant.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Large Volume, No Dispersant.

F-II.4.5 Scenario: Large Volume, 45% Dispersant Efficiency.

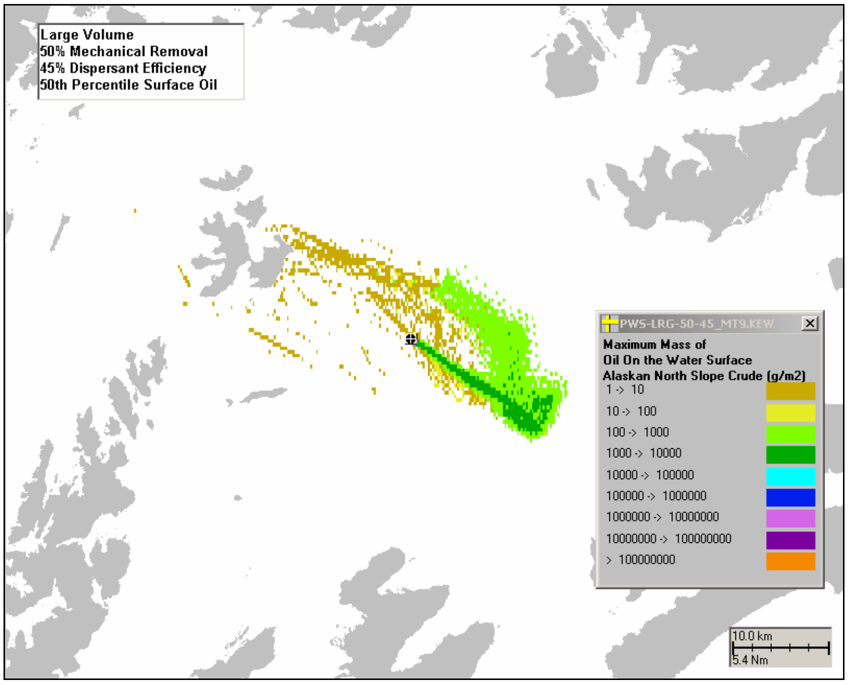

Figure F-II.4.5-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

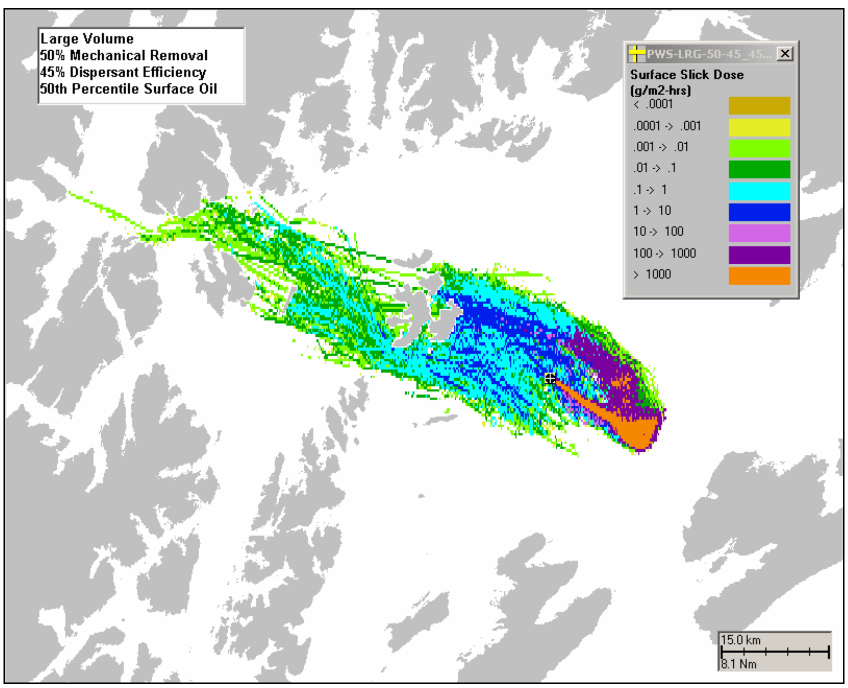

Figure F-II.4.5-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

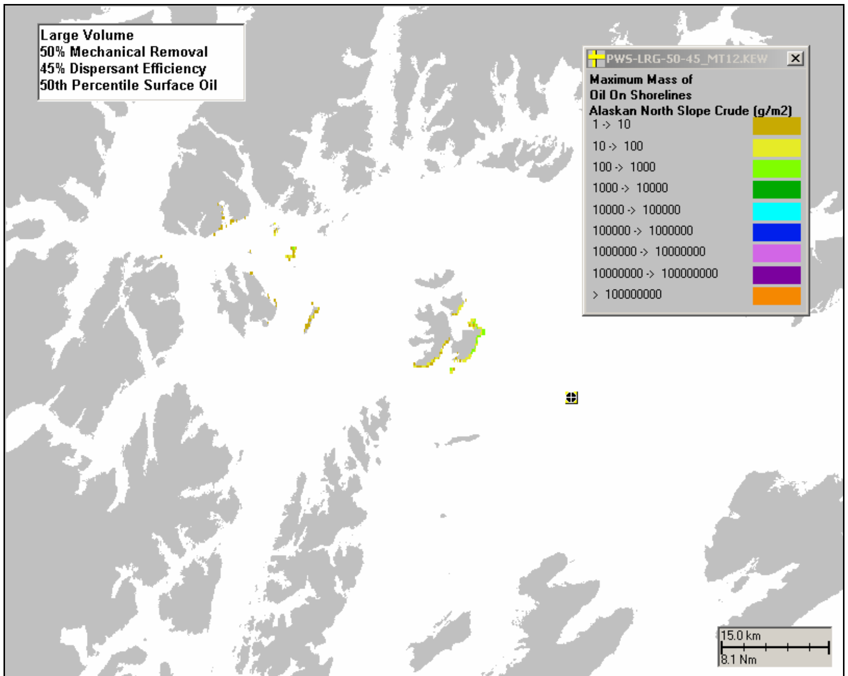

Figure F-II.4.5-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 45% Dispersant Efficiency.

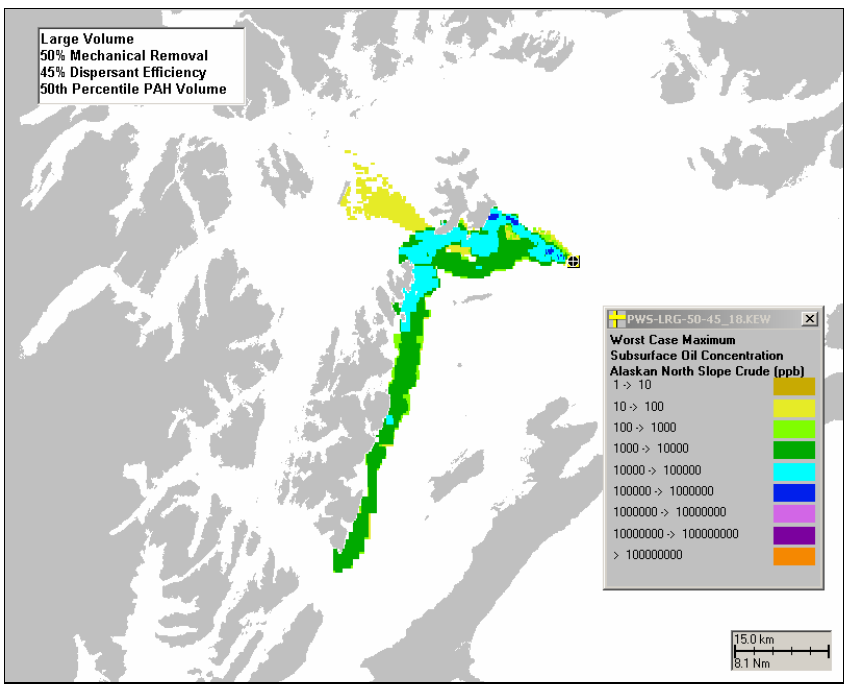

Figure F-II.4.5-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 45% Dispersant Efficiency.

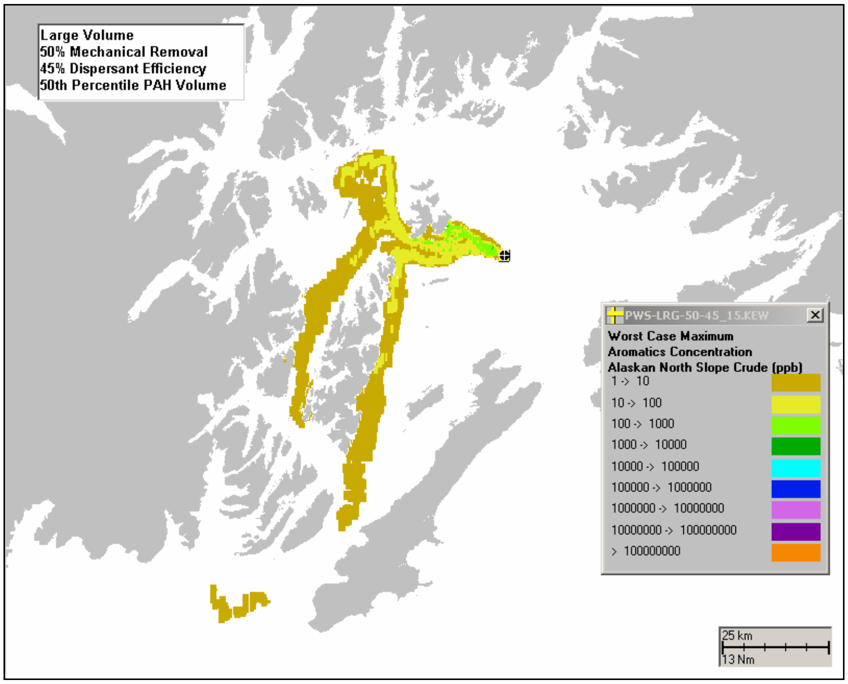

Figure F-II.4.5-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 45% Dispersant Efficiency.

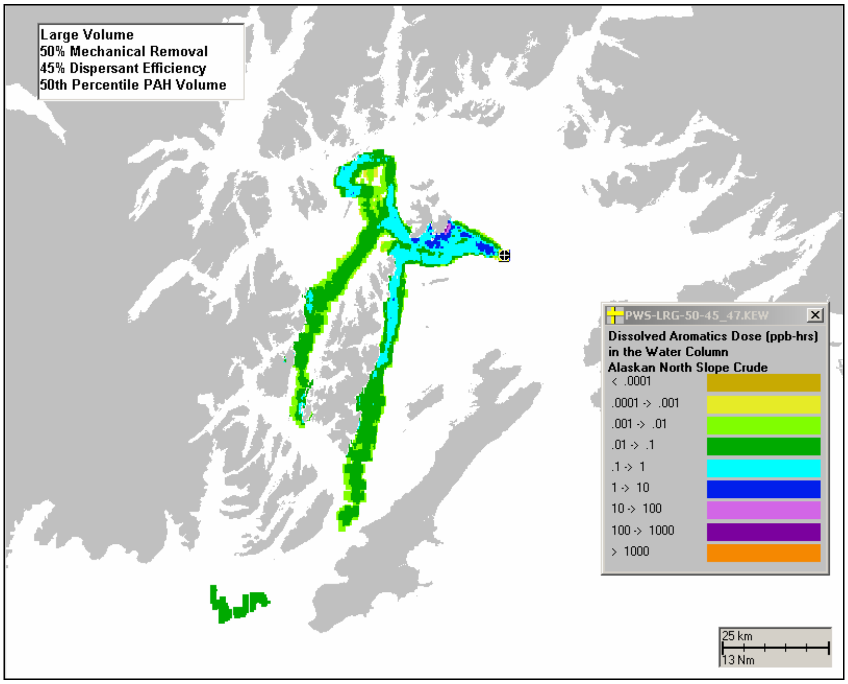

Figure F-II.4.5-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 45% Dispersant Efficiency.

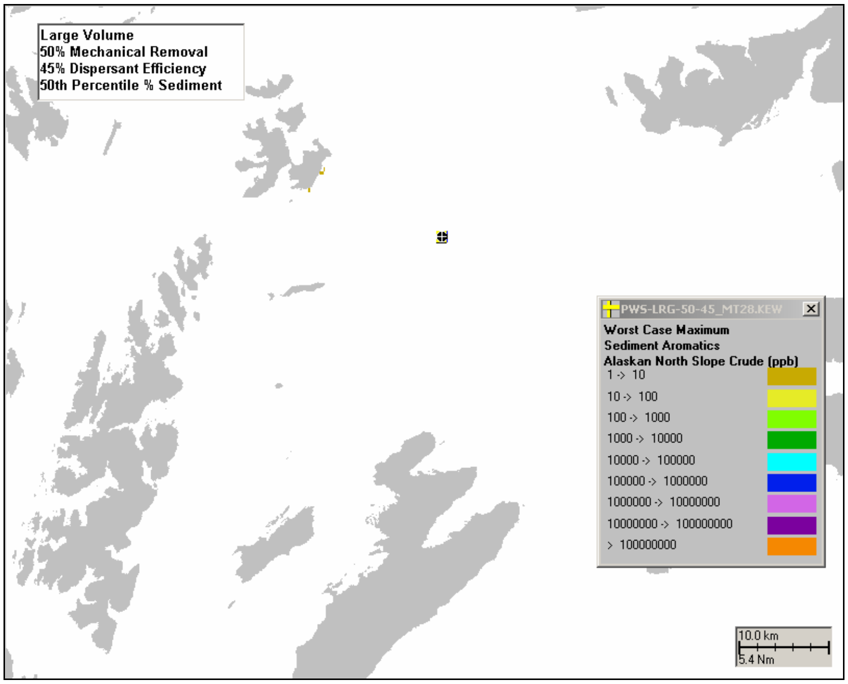

Figure F-II.4.5-7. Exposure of sediment pore water to dissolved aromatic concentration (ppb) (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does. Scenario: Large Volume, 45% Dispersant Efficiency.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does not exceed threshold of 0.0001ppb. Scenario: Large Volume, 45% Dispersant Efficiency.

F-II.4.6 Scenario: Large Volume, 80% Dispersant Efficiency.

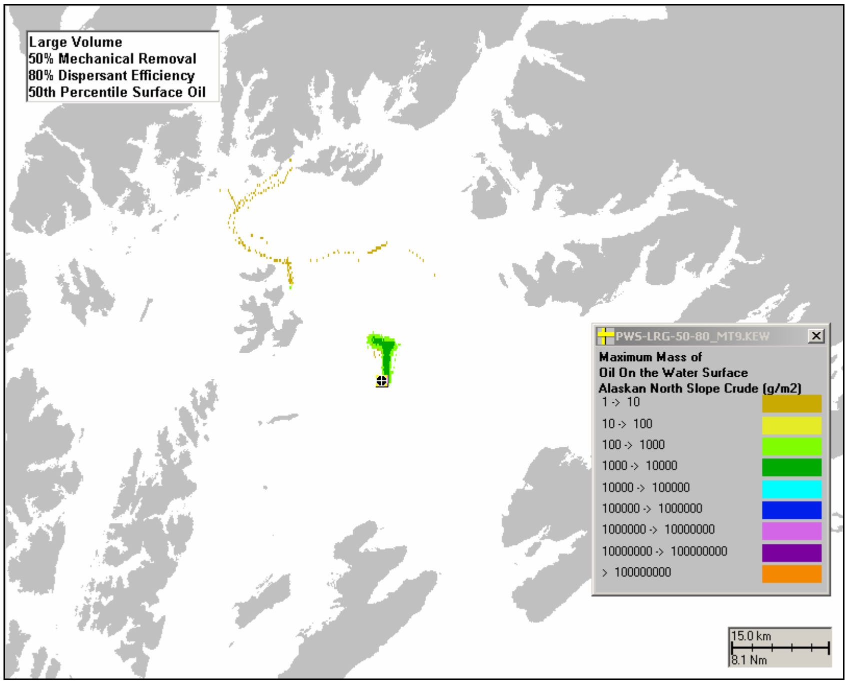

Figure F-II.4.6-1. Water surface exposure to floating hydrocarbons (g/m2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

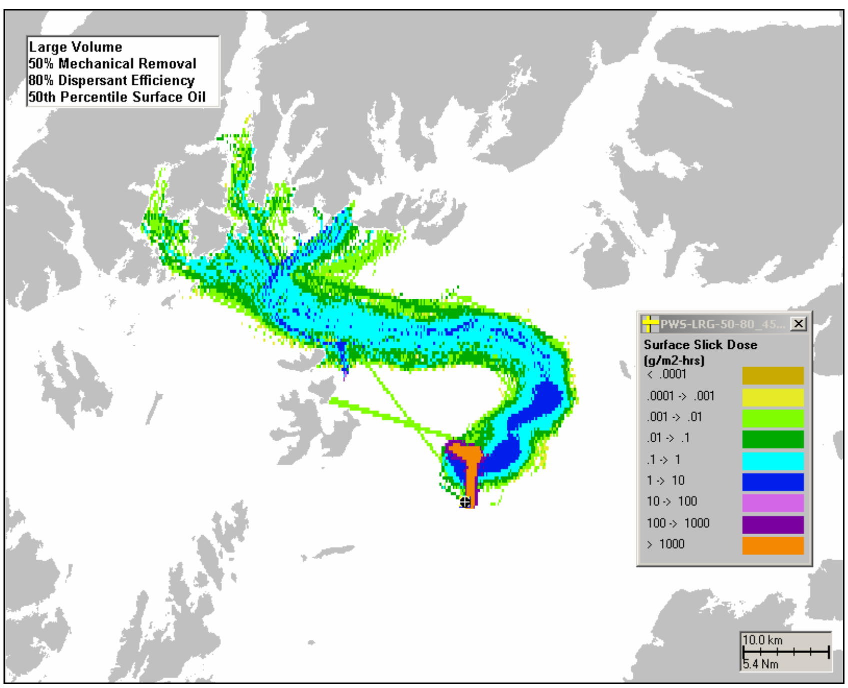

Figure F-II.4.6-2. Water surface exposed to floating hydrocarbons, as the sum of area (within the cell) covered by more than 1 g/m^2 times duration of exposure, for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

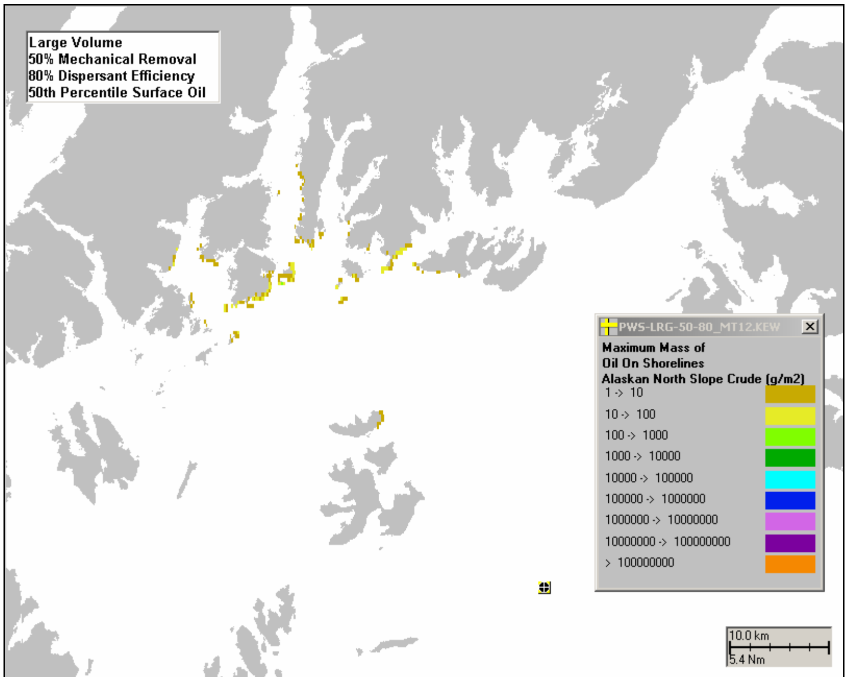

Figure F-II.4.6-3. Shoreline exposure to hydrocarbons (g/m^2), for 50th percentile run based on surface oil exposure. Scenario: Large Volume, 80% Dispersant Efficiency.

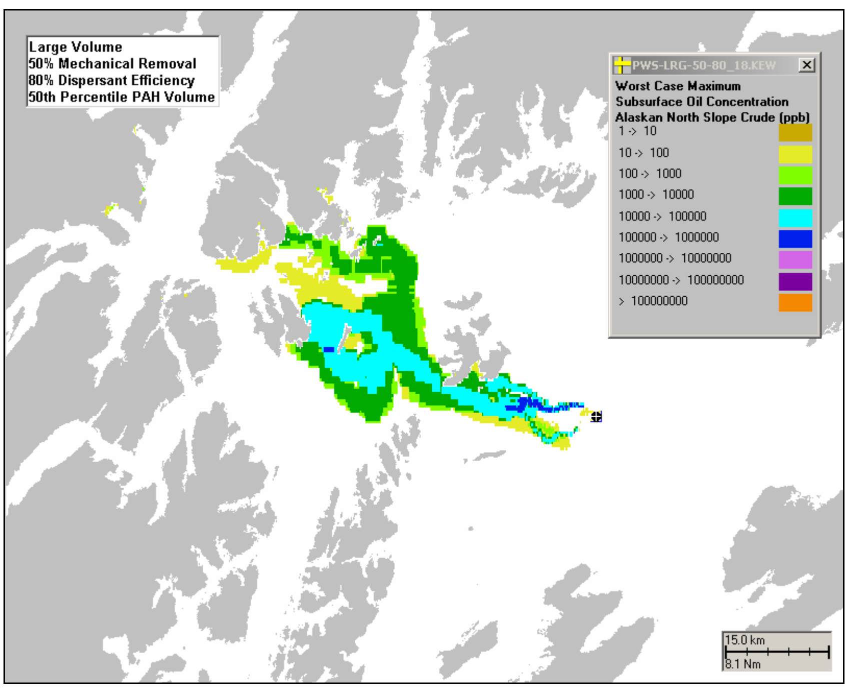

Figure F-II.4.6-4. Maximum water column exposure of total hydrocarbon concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 80% Dispersant Efficiency.

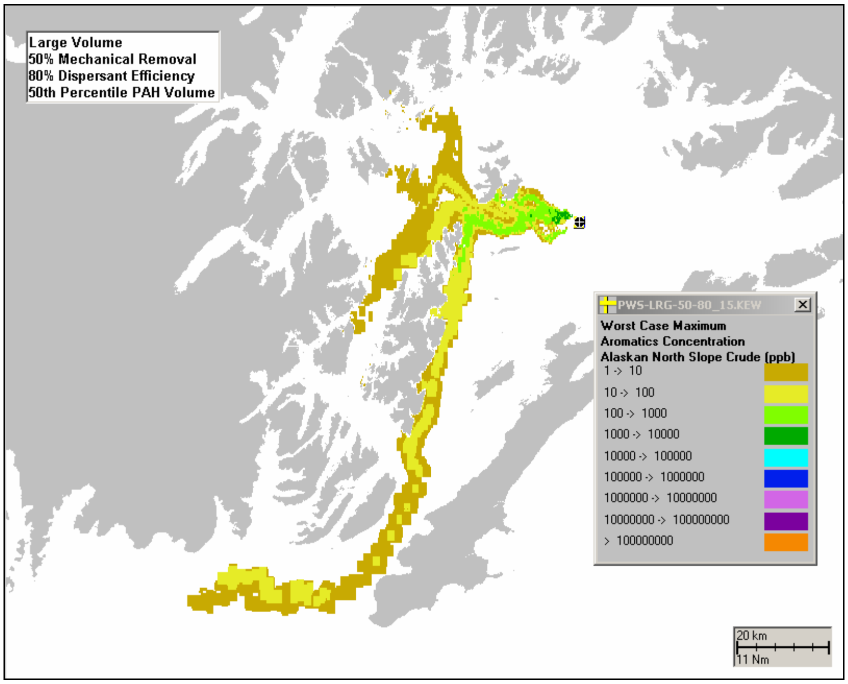

Figure F-II.4.6-5. Maximum water column exposure of dissolved aromatic concentration (ppb) at some time after the spill, for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 80% Dispersant Efficiency.

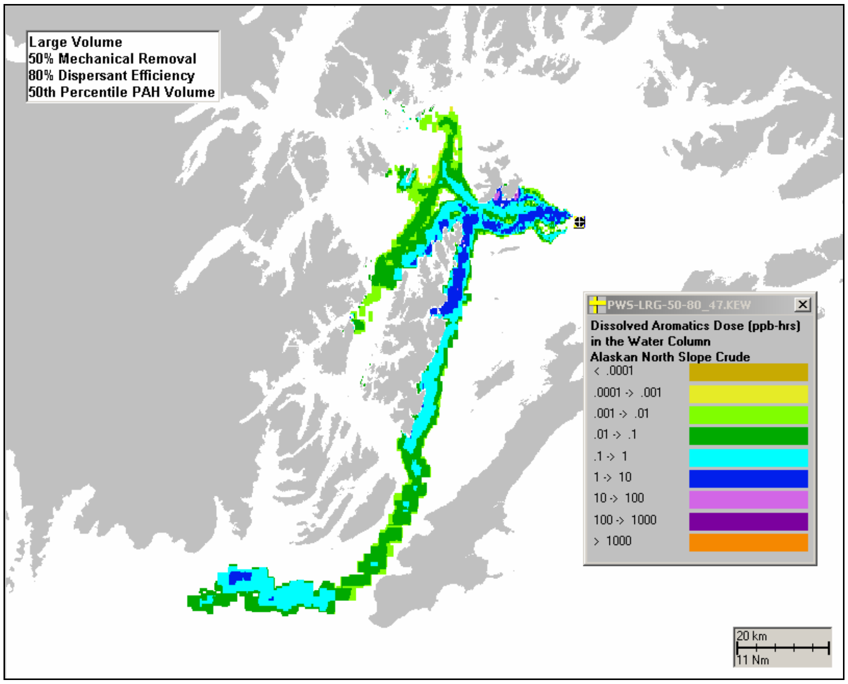

Figure F-II.4.6-6. Water column exposure dose of dissolved aromatic concentration (ppb-hours), for 50th percentile run based on dissolved aromatic plume volume. Scenario: Large Volume, 80% Dispersant Efficiency.

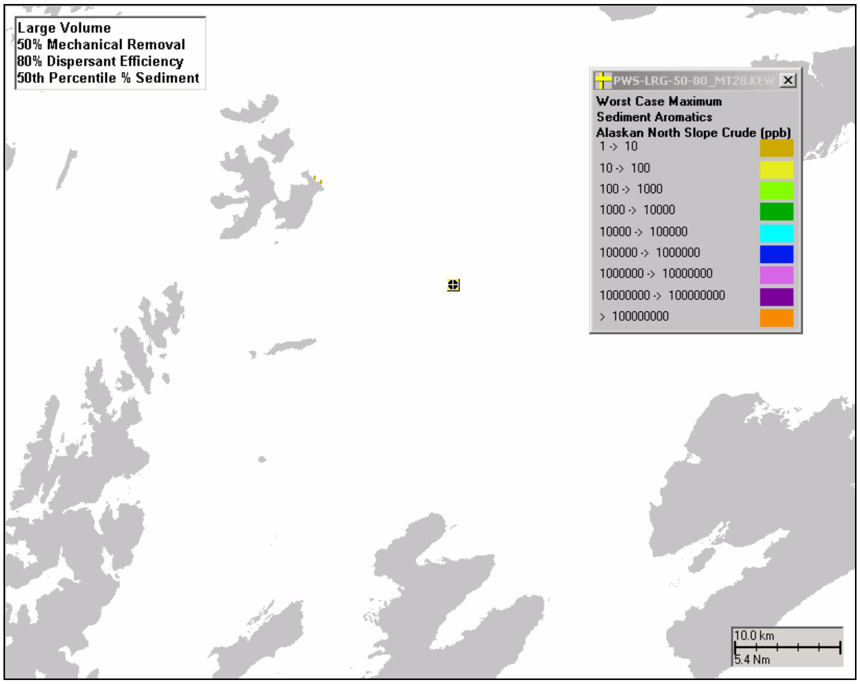

Figure F-II.4.6-7. Exposure of sediment pore water to dissolved aromatic concentration (ppb) (maximum exposure at any time) for 50th percentile run based on percent in/on sediment does. Scenario: Large Volume, 80% Dispersant Efficiency.

Exposure of sediment to total hydrocarbons (maximum exposure at any time) for 50th percentile run based on percent in/on sediment based on percent in/on sediment does. Scenario: Large Volume, 80% Dispersant Efficiency.

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part F: Prince William Sound

Section F-II.5

by

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ASA 00-246

August 2004

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F-II.5 Area swept by surface oil greater than the threshold affecting wildlife.

This appendix contains estimates of area swept by surface oil multiplied by probability of wildlife being oiled, for each behavior category. This is summarized as an equivalent area of 100% mortality by behavior group. The equivalent area for 100% mortality is the integrated sum of area swept times probability of mortality.

The mean equivalent area killed for all possible environmental conditions is calculated using the index of surface oil exposure exceeding $0.01 g/m^2$, which is the integrated area swept by oil sheen or thicker oil times the duration that oil is present, in m^2-hours. The biological exposure model was run for the 50^{th} percentile run (with respect to m^2-hours) of each of the six scenarios (two volumes times three dispersant conditions). The resulting equivalent areas of 100% mortality (in km^2) were regressed against m^2-hours to obtain an equation for each behavior group that may be used to scale from m^2-hours to area killed. Table F-II.5-1 contains the regression slope, intercept, standard error, and correlation coefficient for each behavior group. Figures F-II.5-1 and F-II.5-2 plot equivalent area killed (of 100% mortality) against m^2-hours for wildlife behavior groups. Tables F-II.5-2 and F-II.5-3 contain estimated equivalent areas killed for mean environmental conditions, based on the mean (i.e., numerical average) surface oil exposure in m^2-hours from Appendix F-II.2.

Table F-II.5-1 Regression slope, intercept, standard error, and correlation coefficient for equivalent area killed (km^2) against m^2-hours based on the 50th percentile runs of each scenario.

Behavior Group	Probability of Mortality	Slope	Intercept	Std Error	Correlation
Dabbling waterfowl	0.99	1.1819E-09	-1.7803	2.1778	0.903
Nearshore aerial divers	0.35	4.2337E-10	-0.6390	0.7790	0.904
Surface seabirds	0.99	3.8753E-08	-31.1676	45.9056	0.956
Aerial seabirds	0.05	2.0485E-09	-1.7276	2.4250	0.957
Wetland wildlife (Waders and shorebirds)	0.35	3.0697E-10	-0.5403	0.5148	0.918
Terrestrial wildlife	0.001	1.2184E-12	-0.0018	0.0022	0.904
Cetaceans	0.001	3.9850E-11	-0.0329	0.0469	0.957
Furbearing marine mammals	0.75	2.9700E-08	-24.1866	35.1707	0.956
Pinnipeds, manatee, sea turtles	0.01	4.1050E-10	-0.3469	0.4859	0.957
Surface birds, seaward	0.99	3.8752E-08	-31.1675	45.9055	0.956
Diving birds, seaward	0.35	1.4132E-08	-11.7434	16.7293	0.957
Aerial and subsurface, seaward	0.05	2.0485E-09	-1.7276	2.4250	0.957
Surface birds, landward	0.99	-	-	-	-
Diving birds, landward	0.35	-	-	-	-
Aerial and subsurface, landward	0.05	-	-	-	-
Diving birds, water only	0.35	1.3774E-08	-11.2206	16.2278	0.957
Aerial and subsurface, water only	0.05	1.9970E-09	-1.6521	2.3521	0.957
All water surface	1	3.9354E-08	-32.0590	46.3650	0.957
All seaward water surface	1	4.0376E-08	-33.5525	47.7979	0.957
All landward water surface	1	-	-	-	-

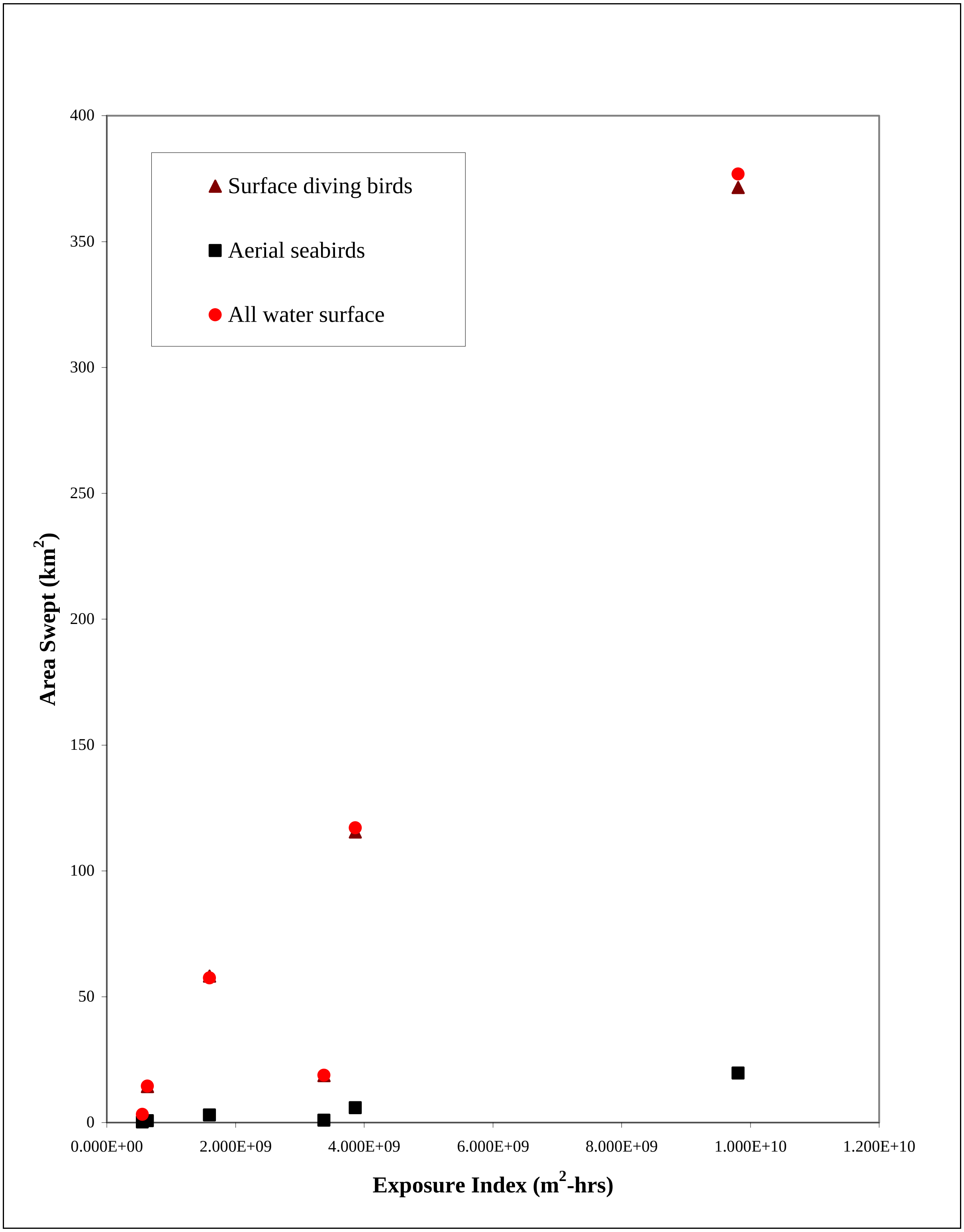

Figure F-II.5-1. Equivalent area killed against m^2-hours for wildlife behavior groups (groups in offshore waters).

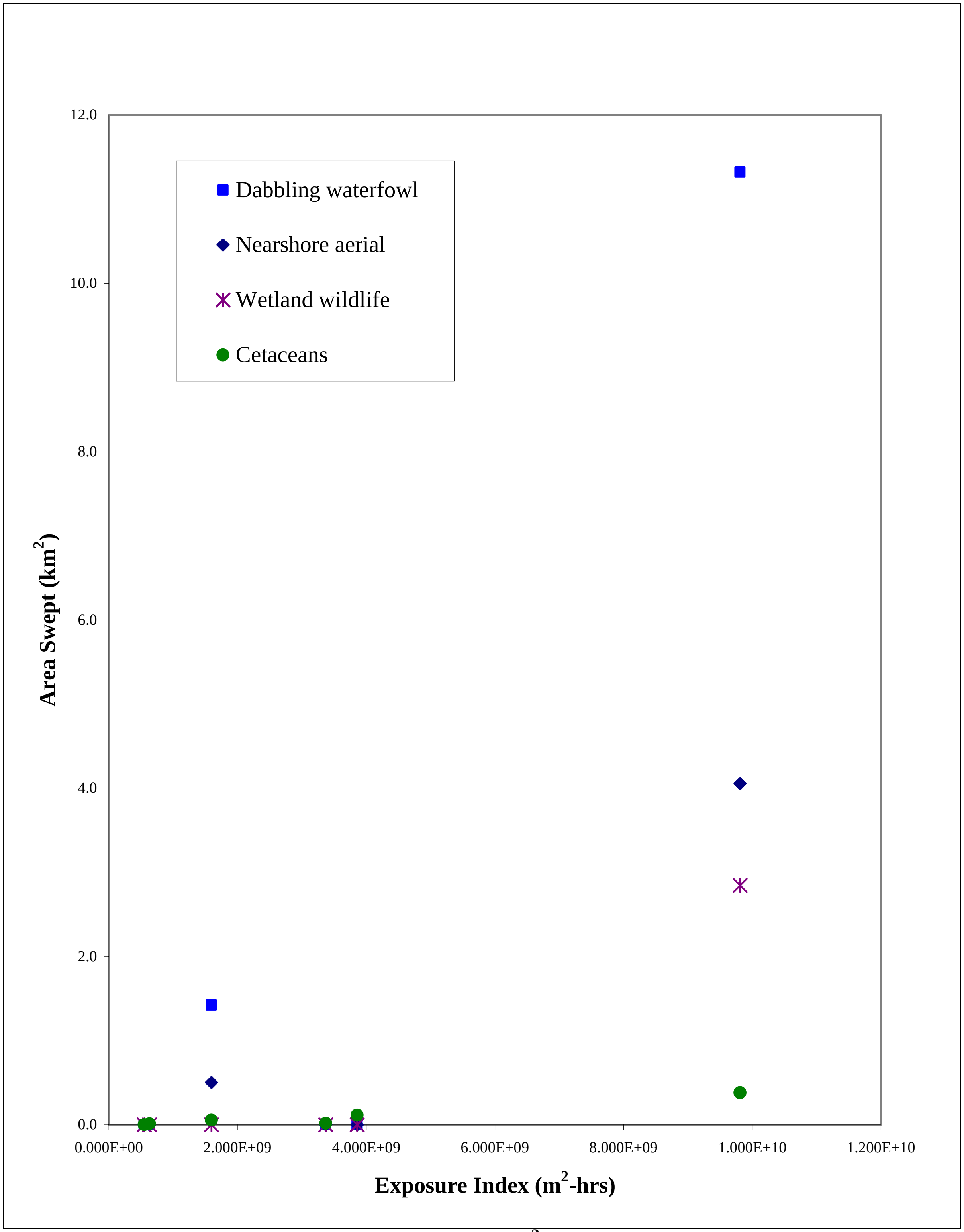

Figure F-II.5-2. Equivalent area killed against m^2-hours for wildlife behavior groups (coastal species and cetaceans)).

Table F-II.5-2. Equivalent area (km^2) of 100% mortality by wildlife behavior group, based on mean surface oil exposure, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	Probability of Mortality	0%	45%	80%
Dabbling waterfowl	0.99	1.19	0.71	0.57
Nearshore aerial divers	0.35	0.43	0.25	0.20
Surface seabirds	0.99	66.30	50.52	45.98
Aerial seabirds	0.05	3.42	2.59	2.35
Wetland wildlife (Waders and shorebirds)	0.35	0.23	0.11	0.07
Terrestrial wildlife	0.001	0.00	0.00	0.00
Cetaceans	0.001	0.07	0.05	0.05
Furbearing marine mammals	0.75	50.51	38.42	34.94
Pinnipeds, manatee, sea turtles	0.01	0.69	0.52	0.47
Surface birds, seaward	0.99	66.30	50.52	45.98
Diving birds, seaward	0.35	23.80	18.04	16.39
Aerial and subsurface, seaward	0.05	3.42	2.59	2.35
Surface birds, landward	0.99	0.00	0.0	0.0
Diving birds, landward	0.35	0.00	0.0	0.0
Aerial and subsurface, landward	0.05	0.00	0.00	0.00
Diving birds, water only	0.35	23.42	17.81	16.20
Aerial and subsurface, water only	0.05	3.37	2.56	2.32
All water surface	1.00	66.92	50.89	46.29
All seaward water surface plus intertidal	1.00	68.00	51.55	46.83
All landward water surface plus intertidal	1.00	0.00	0.0	0.0
All water surface plus intertidal	1.00	68.00	51.55	46.83

Table F-II.5-3. Equivalent area (km^2) of 100% mortality by wildlife behavior group, based on mean surface oil exposure, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	Probability of Mortality	0%	45%	80%
Dabbling waterfowl	0.99	12.89	6.09	4.94
Nearshore aerial divers	0.35	4.62	2.18	1.77
Surface seabirds	0.99	449.78	226.98	189.11
Aerial seabirds	0.05	23.70	11.92	9.92
Wetland wildlife (Waders and shorebirds)	0.35	3.27	1.50	1.20
Terrestrial wildlife	0.001	0.01	0.01	0.01
Cetaceans	0.001	0.46	0.23	0.19
Furbearing marine mammals	0.75	344.42	173.66	144.64
Pinnipeds, manatee, sea turtles	0.01	4.75	2.39	1.99
Surface birds, seaward	0.99	449.78	226.98	189.11
Diving birds, seaward	0.35	163.64	82.39	68.58
Aerial and subsurface, seaward	0.05	23.70	11.92	9.92
Surface birds, landward	0.99	0.00	0.00	0.00
Diving birds, landward	0.35	0.00	0.00	0.00
Aerial and subsurface, landward	0.05	0.00	0.00	0.00
Diving birds, water only	0.35	159.73	80.54	67.07
Aerial and subsurface, water only	0.05	23.13	11.65	9.70
All water surface	1.00	456.36	230.10	191.64
All seaward water surface plus intertidal	1.00	467.54	235.41	195.95
All landward water surface plus intertidal	1.00	0.00	0.00	0.00
All water surface plus intertidal	1.00	467.54	235.41	195.95

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part F: Prince William Sound

Section F-II.4

by

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ASA 00-246

August 2004

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F-II.6 Exposures for fish and invertebrates to dissolved aromatic concentrations.

This appendix tabulates estimated mortality of water column, demersal (on the bottom) and benthic (in the bottom) organisms by behavior type for the Prince William Sound spill location. Effects are summarized as an equivalent area of 100% mortality by behavior group and habitat type. The equivalent area for 100% mortality is the integrated sum of equivalent area affected times percent mortality. For water column and demersal species, the equivalent area affected is calculated as water volume affected times the fraction of the water depth zone the behavior group occupies that the affected volume encompasses. For pelagic species, the depth zone occupied is the entire water column. For demersal species (on the bottom sediments, exposed to bottom water), the depth zone occupied is the bottom 1 meter of the water column. The methods and assumptions for these calculations are described in Part A.

For water column and demersal species, the mean equivalent area killed for all possible environmental conditions is calculated using the water volume (m^3) exposed to greater than 1 mg/m^3 (1 ppb) dissolved aromatic concentration at any time after the spill. The biological exposure model was run for the 50^{th} percentile run (with respect to water volume exposed to >1ppb) of each of the six scenarios (two spill volumes times three dispersant conditions). The toxicity parameter (LC50) assumed in these calculations was that for sensitive species (the 2.5^{th} percentile in rank order sensitivity), in order to provide conservatively high estimates of potential water column effects. The resulting equivalent areas of 100% mortality (in km^2) were regressed against water volume exposed (m^3) to obtain an equation for each behavior group that may be used to scale from volume exposed to area killed (for sensitive species). Figure F-II.6-1 plots equivalent water column area killed (area of 100% mortality) against volume exposed to >1ppb for each of the water column and demersal behavior groups. Table F-II.6-1 contains the regression slope, intercept, standard error, and correlation coefficient for each behavior group. Tables F-II.6-2 and F-II.6-3 contain estimated equivalent areas killed (for sensitive species) for mean environmental conditions, based on the mean volume exposed to >1ppb dissolved aromatic concentration (from Appendix F-II.2). Tables F-II.6-4 and F-II.6-5 contain estimated equivalent areas killed (for sensitive species) for 95^{th} percentile environmental conditions, based on the mean plus two standard deviations of volume exposed to >1ppb dissolved aromatic concentration. Mean and standard deviation of volume exposed to >1ppb dissolved aromatic concentration are tabulated in Appendix F-II.2 and the full distribution of all 100 runs is plotted in Appendix F-II.3. The effects on water column communities are discussed in Sections C.3.2 and C.4.2.

Benthic effects are related to the bottom sediment area exposed to oil exceeding a threshold of concern. Table F-II.6-6 summarizes the loading of oil to the sediments. For most species, the dissolved aromatic concentration in the pore water of the sediments is what is bioavailable and causes toxicity (Table F-II.6-7). A threshold of 6 ppb dissolved aromatic concentration could cause effects on sensitive (2.5% of) species, whereas the threshold for average species is 50 ppb (see Part A, Section A.3.4). The effects on benthic organisms are discussed in Sections C.3.2 and C.4.2.

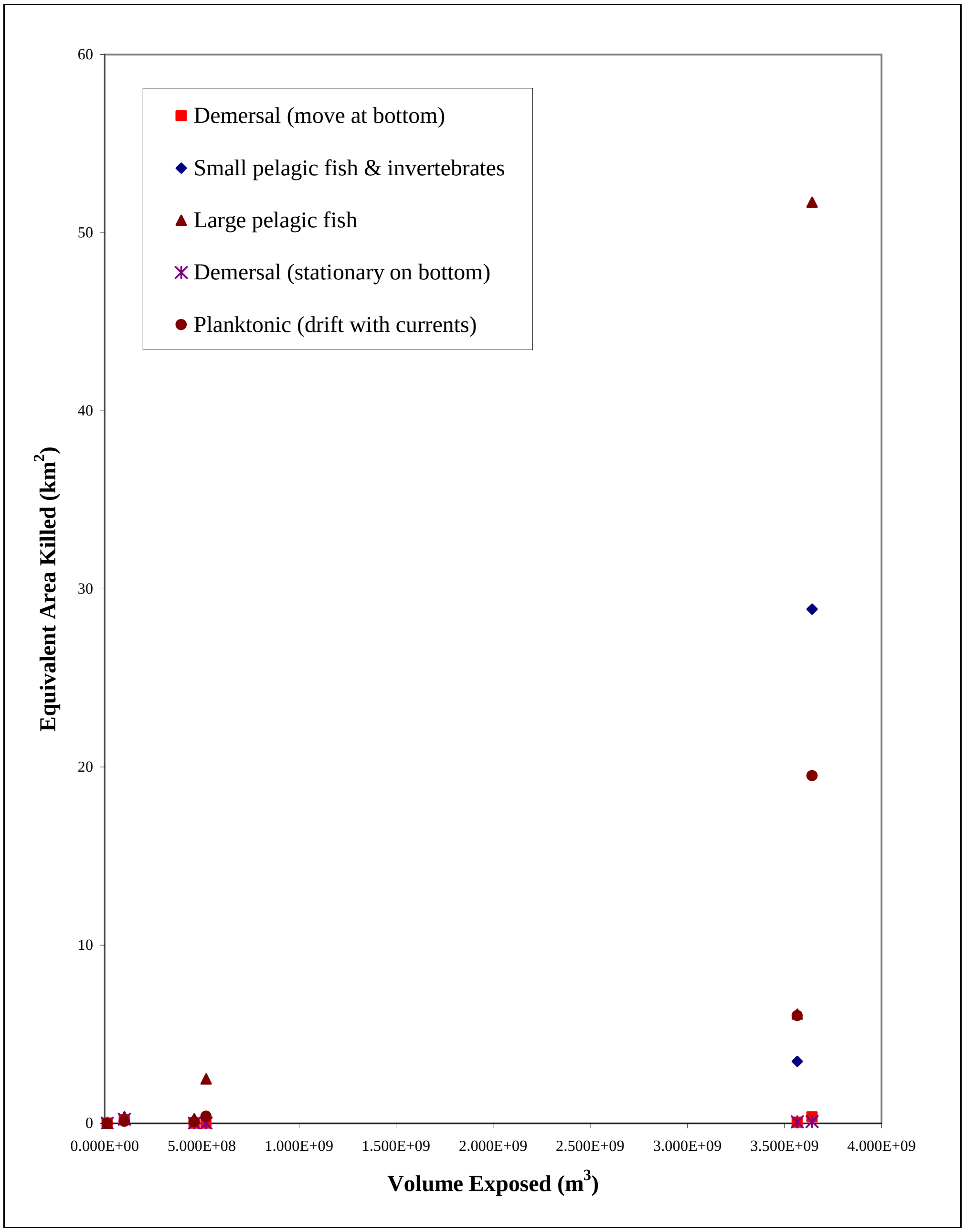

Figure F-II.6-1. Equivalent area killed (for sensitive species) against volume exposed to > 1ppb dissolved aromatic concentration for water column behavior groups.

Table F-II.6-1 Regression slope, intercept, standard error, and correlation coefficient for equivalent water column area killed (km^2) against water volume exposed to >1ppb (m^3), based on the 50^{th} percentile runs of each scenario.

Behavior Group	Slope	Intercept	Std Error	Correlation
Demersal (move at bottom)	4.5771E-11	0.0371	0.1375	0.542
Small pelagic fish & invertebrates	4.8205E-09	-1.1913	8.9020	0.723
Large pelagic fish	8.4961E-09	-1.5971	15.9466	0.718
Demersal (stationary on bottom)	3.4013E-12	0.0596	0.1002	0.066
Planktonic (drift with currents)	3.7859E-09	-0.8812	4.7190	0.841

Table F-II.6-2. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	**0%**	**45%**	**80%**
Demersal (move at bottom)	0.0	0.1	0.1
Small pelagic fish & invertebrates	0.0	1.2	1.1
Large pelagic fish	0.0	2.6	2.5
Demersal (stationary on bottom)	0.1	0.1	0.1
Planktonic (drift with currents)	0.0	1.0	0.9

Table F-II.6-3. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean water volume exposed to > 1ppb dissolved aromatic concentration, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	**0%**	**45%**	**80%**
Demersal (move at bottom)	0.0	0.2	0.2
Small pelagic fish & invertebrates	0.0	16.3	16.6
Large pelagic fish	0.5	29.3	29.7
Demersal (stationary on bottom)	0.1	0.1	0.1
Planktonic (drift with currents)	0.0	12.9	13.1

Table F-II.6-4. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean plus two standard deviations (i.e., 95th percentile) of water volume exposed to > 1ppb dissolved aromatic concentration, for medium volume scenarios with indicated dispersant efficiencies.

Behavior Group	0%	45%	80%
Demersal (move at bottom)	0.0	0.0	0.0
Small pelagic fish & invertebrates	0.0	4.5	4.3
Large pelagic fish	0.0	7.9	7.6
Demersal (stationary on bottom)	0.1	0.0	0.0
Planktonic (drift with currents)	0.0	3.5	3.4

Table F-II.6-5. Equivalent area (km^2) of 100% mortality (for sensitive species) by water column behavior group, based on mean plus two standard deviations (i.e., 95th percentile) of water volume exposed to > 1ppb dissolved aromatic concentration, for large volume scenarios with indicated dispersant efficiencies.

Behavior Group	0%	45%	80%
Demersal (move at bottom)	0.0	0.3	0.4
Small pelagic fish & invertebrates	4.2	36.5	37.3
Large pelagic fish	7.5	64.3	65.7
Demersal (stationary on bottom)	0.0	0.0	0.0
Planktonic (drift with currents)	3.3	28.7	29.3

Table F-II.6-6. Area (m^2) of sediment exceeding indicated thresholds of total hydrocarbon loading per unit area (g/m^2) under average environmental conditions, by spill volume and dispersant treatment.

Threshold (g/m^2)	Medium 0%	Medium 45%	Medium 80%	Large 0%	Large 45%	Large 80%
0	1,906,247	304,999	457,499	3,583,741	1,677,497	1,601,247
0.001	762,499	76,250	152,500	2,363,745	609,999	838,749
0.01	0.0	0.0	0.0	914,998	228,750	304,999
0.1	0.0	0.0	0.0	228,750	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0

Table F-II.6-7. Area (m^2) of sediment exceeding indicated thresholds of dissolved aromatic concentration in pore waters (mg/m^3 = ppb) under average environmental conditions, by spill volume and dispersant treatment.

Threshold (mg/m^3 = ppb)	Medium 0%	Medium 45%	Medium 80%	Large 0%	Large 45%	Large 80%
1	0.0	0.0	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.00	0.0

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part F: Prince William Sound

Section F-III.1

by

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ASA 00-246

August 2004

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F-III.1 Air Concentrations from Unburned Oil

This section contains model results for spills in the Alaska Region used to evaluate volatile hydrocarbon emissions from unburned oil and resulting air quality effects. The amount of volatilized mass entering the atmosphere for each chemical (or chemical class) of concern was estimated using oil spill modeling (SIMAP). SIMAP also provided the time frame over which the emissions occur. The atmospheric concentrations of volatilized hydrocarbons were modeled using AIRMAP (as described in Part A, Section A.5.1). The estimated concentrations at the water surface were compared to air quality standards to evaluate the potential for human health effects and wildlife effects.

As a screening analysis, SIMAP runs were performed for both the medium (2500 bbl) and large (40,000 bbl) spill volumes of Alaska North Slope crude under various wind conditions to determine the possible hydrocarbon emissions from unburned oil to the atmosphere. Emissions were estimated using SIMAP for the warmest water temperature occurring in the region, 15^{o}C (French et al. 1996b) and for varying wind speeds from 3 to 25 kts. (Evaporation is very slow in conditions of no wind, so this case was not included.)

As a worst case, these model runs were performed assuming no dispersants are applied, since the use of dispersants would reduce emissions to the extent that volatile components are permanently mixed into the water. It is also assumed that any mechanically-removed oil still volatilizes, so no correction for removal was made to the volatilized mass. Likewise, no correction for amount burned was made to the rate of unburned oil emission. Thus, the screening model runs estimated the maximum rate and amount of emissions which would be expected under any environmental conditions and response scenario for the region.

In the next step of the analysis, the atmospheric concentrations of volatilized hydrocarbons released by unburned oil were modeled using AIRMAP, which accounts for transport and dilution of hydrocarbons in the local atmosphere around the spill site. Each hydrocarbon constituent was modeled separately, releasing the mass of the constituent emitted from the oil over time from the area covered by surface floating oil (as estimated by SIMAP). AIRMAP was run for each constituent and wind speed condition, from 3 to 25 kts. The constituent mass released in the AIRMAP simulation (over 10 hours) was the maximum amount emitted to the air (of that constituent) in any 10-hour period in the SIMAP spill simulation. The AIRMAP simulation was run assuming a stable atmosphere with minimal turbulence to disperse contaminants.

The atmospheric dispersion model provided estimates of air concentrations in the air layer within 2 m of the water surface (for each 55m X 55m cell of a 200 by 200 cell grid covering the horizontal extent of the plume) as a function of time after the spill. The estimated concentrations were then compared to air quality standards to evaluate the potential for human health effects. Two averaging periods were used in accordance with the standards: 0.5 hour for comparison to the Immediate Danger to Life and Health (IDLH) value and 8 hours for comparison to the 8-hour time weighted average (TWA).

The maximum 0.5-hour and 8-hour average air concentration for any time period in the AIRMAP simulation was compared to the appropriate standard (Table F-III.1-1). The IDLH (from Table A.5-5 in Part A) is not to be exceeded for a ½ hour exposure. The PEL-TWA is the minimum of the 8-hour time weighed averages in Table A.5-5. Heptane is used as representative of the volatile aliphatic VOCs. Its air quality standards are the lowest of those available for this group of chemicals (see Section A.5.3), so comparison to the standards for heptane is conservative. The area adversely affected was that where the standard was exceeded for the appropriate averaging period. The maximum distance from the release site that concentrations exceeded the air quality standard was also estimated for each constituent using the AIRMAP results.

These results are applicable to spills of crude oils with similar volatile content in any location where conditions are at the temperature, atmospheric stability, and wind speed assumed. Concentrations and areas affected would be lower than those reported below for less stable atmospheres and lower temperature conditions. The results are assuming no dispersant applied, such that all the volatiles are assumed released to the atmosphere. Dispersants could permanently disperse some of the volatiles in the water column, reducing the air concentrations and areas adversely affected. Also, volatiles would be burned and emissions reduced to the extent that ISB is used. Thus, these areas of potential adverse effect are the maximum possible in the region under any response scenario and environmental conditions.

Table F-III.1-1. IDLH and TWA thresholds for evaluating potential effects of air concentrations.

Chemical	IDLH (mg/m^3)	PEL-TWA (mg/m^3)
Benzene	1595	3.19
Toluene	1885	754
Ethylbenzene	3472	434
Xylene	3906	434
Naphthalene	1310	52.4
Biphenyl	631	1.262
Phenanthrene	80	(not available)
Aliphatic VOCs with boiling points <180^{o}C (based on heptane)	3075	2050

F-III.1.1 Medium Volume Spills

Emissions from Unburned Oil

Table F-III.1.1-1 contains the estimated maximum volatilized mass released to the atmosphere in any 10-hour period for each constituent of concern in the medium-volume spill under the worst-case (highest) temperature condition (15^{o}C) and with various wind speeds. The results show (Figure F-III.1.1-1) that the emission rates of the MAHs (benzene, toluene, ethylbenzene, xylenes) increase as wind speed increases to about 10 kts and then level off. Volatile aliphatics indicate a similar pattern with wind speed (Table F-III.1.1-1). The emission rates for PAHs are much lower than for the volatiles and increase with wind speed (Figure F-III.1.1-1).

Table F-III.1.1-1. Maximum mass (MT) of chemical volatilized from unburned Alaskan North Slope crude oil in any 10-hour period after a spill of 2,500 bbl at the indicated wind speed.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Total MAHs	201	237	256	266	268	266	266	259	256
Benzene	0.75	0.88	0.95	0.98	0.99	0.98	0.98	0.96	0.95
Toluene	1.82	2.14	2.31	2.41	2.43	2.41	2.40	2.34	2.31
Ethylbenzene	0.34	0.40	0.43	0.45	0.45	0.45	0.45	0.44	0.43
Xylenes	1.65	1.94	2.10	2.18	2.20	2.18	2.18	2.12	2.10
Total volatile and semi-volatile PAHs	30.5	39.6	46.9	53.2	55.4	58.0	69.4	85.2	97.6
Naphthalene	0.020	0.026	0.030	0.035	0.036	0.038	0.045	0.055	0.063
Biphenyl	0.005	0.007	0.008	0.010	0.010	0.010	0.012	0.015	0.018
Phenanthrene	0.028	0.036	0.042	0.048	0.050	0.052	0.062	0.158	0.127
Aliphatic VOCs with boiling points <180^{o}C	33.3	39.2	42.3	44.0	44.3	44.0	43.9	42.8	42.3

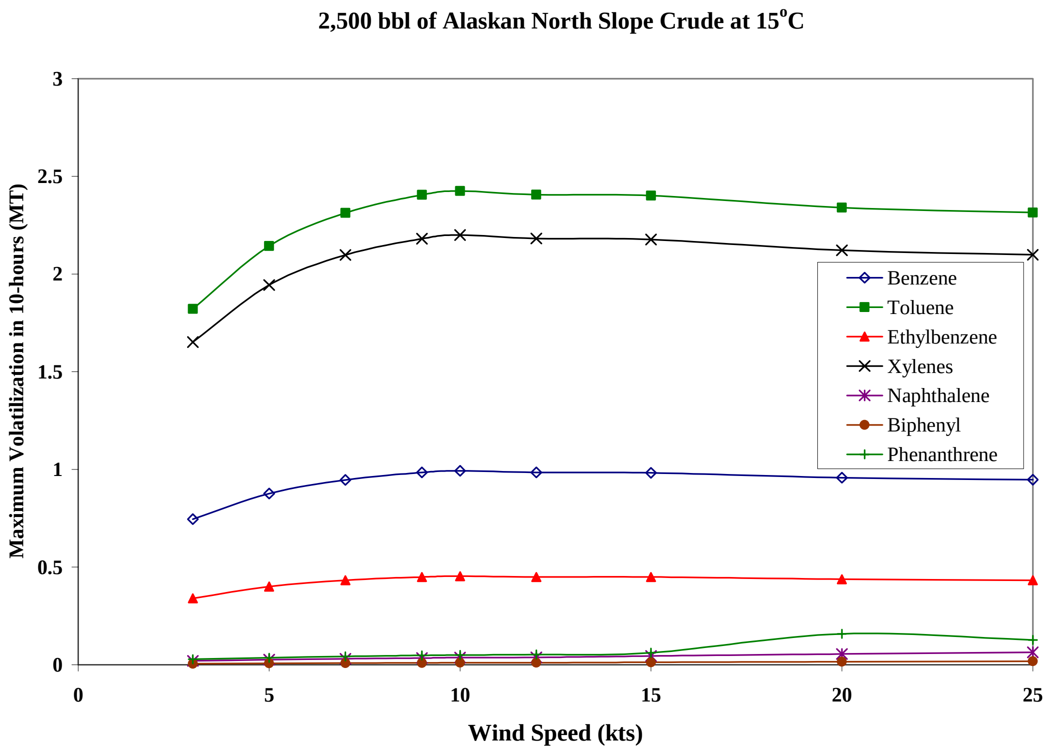

Figure F-III.1.1-1 Maximum mass (MT) of chemical volatilized from unburned Alaskan North Slope crude oil in any 10-hour period after a spill of 2,500 bbl at the indicated wind speed.

Air Concentrations from Unburned Oil Emissions

Tables F-III.1.1-2 and F-III.1.1-3 list the areas where the air concentrations exceeded the comparable air quality standards. Tables F-III.1.1-4 and F-III.1.1-5 list the maximum distances (down wind) from the release site that concentrations exceeded the air quality standards. Since the emissions were more rapidly dispersed in the atmosphere the higher the wind speed, the conditions where concentrations of volatiles in air were at maximum were those where winds were assumed light (3 kts). This is demonstrated in the results. The IDLH is not exceeded for any of the chemical constituents under these worst-case conditions for medium volume (2,500 bbl) spills of Alaskan North Slope crude oil. The TWA would be exceeded for benzene under light ($\leq$7 kts) winds in the immediate spill area (adversely effecting $\leq$3.6 km downwind of the spill site with an area <1 km^2). Air concentrations of other constituents would not exceed the TWA standards at any time after a medium volume spill.

Table F-III.1.1-2. Maximum area (m^2) where the IDLH would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0	0	0	0	0	0	0	0	0

Table F-III.1.1-3. Maximum area (m^2) where the PEL-TWA would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	904,475	375,100	60,500	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0	0	0	0	0	0	0	0	0

Table F-III.1.1-4. Maximum distance down wind (km) where the IDLH would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0	0	0	0	0	0	0	0	0

Table F-III.1.1-5. Maximum distance down wind (km) where the PEL-TWA would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from medium volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	3.6	1.7	0.6	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0	0	0	0	0	0	0	0	0

F-III.1.2 Large Volume Spills

Emissions from Unburned Oil

Table F-III.1.2-1 contains the estimated maximum volatilized mass released to the atmosphere in any 10-hour period for each constituent of concern in the large-volume spill under the worst-case (highest) temperature condition and with various wind speeds. The results show (Figure F-III.1.2-1) that the emission rates of the MAHs (benzene, toluene, ethylbenzene, xylenes) increase as wind speed increases. At wind speeds above 15 kts, entrainment dominates and volatilization from the water column increases faster with wind speed than does evaporation within the range of wind speeds from 3-15 kts. Volatile aliphatics indicate a similar pattern with wind speed (Table F-III.1.2-1). The emission rates for PAHs are much lower than for the volatiles and also increase with wind speed (Figure F-III.1.2-1).

Table F-III.1.2-1. Maximum mass (MT) of chemical volatilized from unburned Alaskan North Slope crude oil in any 10-hour period after a spill of 40,000 bbl at the indicated wind speed.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Total MAHs	1827	2366	2738	2998	3087	3186	3249	3512	3743
Benzene	6.76	8.75	10.13	11.09	11.41	11.78	12.01	12.99	13.84
Toluene	16.5	21.4	24.8	27.1	27.9	28.8	29.4	31.7	33.8
Ethylbenzene	3.09	4.00	4.63	5.06	5.21	5.38	5.49	5.93	6.32
Xylenes	15.0	19.4	22.4	24.6	25.3	26.1	26.6	28.8	30.7
Total volatile and semi-volatile PAHs	248	321	381	434	452	475	522	651	880
Naphthalene	0.161	0.209	0.248	0.282	0.294	0.309	0.339	0.423	0.572
Biphenyl	0.045	0.058	0.069	0.078	0.081	0.086	0.094	0.117	0.158
Phenanthrene	0.23	0.30	0.35	0.40	0.41	0.43	0.47	2.50	2.57
Aliphatic VOCs with boiling points <180^{o}C	302	391	452	495	510	526	537	580	618

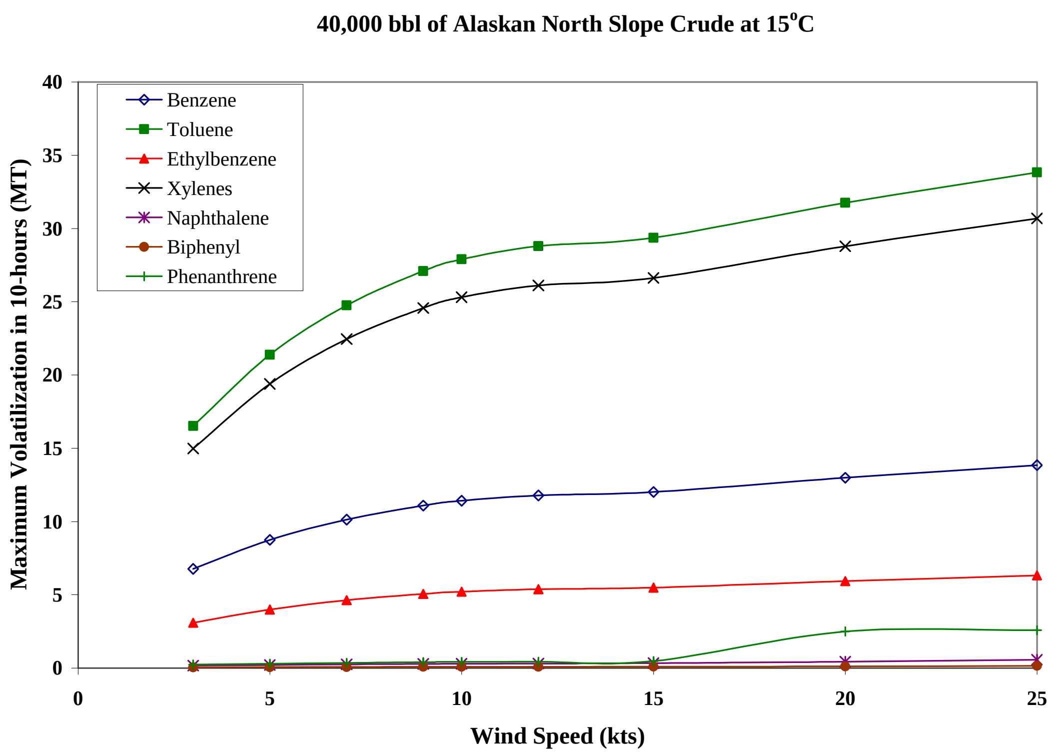

Figure F-III.1.2-1 Maximum mass (MT) of chemical volatilized from unburned Alaskan North Slope crude oil in any 10-hour period after a spill of 40,000 bbl at the indicated wind speed.

Air Concentrations from Unburned Oil Emissions

Tables F-III.1.2-2 and F-III.1.2-3 list the areas where the air concentrations exceeded the comparable air quality standards for large volume spills. Tables F-III.1.2-4 and F-III.1.2-5 list the maximum distances (down wind) from the release site that concentrations exceeded the air quality standards. Since the emissions were more rapidly dispersed in the atmosphere the higher the wind speed, the conditions where concentrations of volatiles in air were at maximum were those where winds were assumed light (3 kts), as demonstrated by the results. The IDLH for heptane is exceeded up to 0.9 km downwind of the spill site by the total volatile aliphatic VOC concentration under these worst-case temperature and air stability conditions for wind speeds up to 5 kts. The IDLH is not exceeded for any of the MAHs or PAHs, and would not be expected to under any environmental conditions for spills of this large volume. The TWA would be exceeded in the spill area after spills of 40,000 bbl for xylenes, biphenyl and volatile aliphatic VOCs under light winds ($\leq$5 kts) and for benzene under all wind conditions up to 20 kts.

For xylenes and biphenyl, the areas adversely affected would not exceed 0.1 km^2 in the worst case conditions of light winds and a stable atmosphere. The adversely affected areas are larger for benzene (up to 9.7 km^2) and volatile aliphatic VOCs (up to 0.5 km^2), assuming a worst case of a stable atmosphere. The areas would be less for less stable atmospheric conditions and lower temperatures than assumed.

Table F-III.1.2-2. Maximum area (m^2) where the IDLH would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	154,275	21,175	0	0	0	0	0	0	0

Table F-III.1.2-3. Maximum area (m^2) where the PEL-TWA would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	9,653,000	7,236,000	5,763,000	4,698,000	3,948,000	3,167,000	1,972,000	626,000	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	5,500	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	99,825	6,050	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	447,700	145,200	0	0	0	0	0	0	0

Table F-III.1.2-4. Maximum distance down wind (km) where the IDLH would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	0	0	0	0	0	0	0	0	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	0	0	0	0	0	0	0	0	0
Phenanthrene	0	0	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	0.9	0.3	0	0	0	0	0	0	0

Table F-III.1.2-5. Maximum distance down wind (km) where the PEL-TWA would be exceeded due to volatilization of unburned Alaskan North Slope crude oil from large volume spills.

Constituent	3 kts	5 kts	7 kts	9 kts	10 kts	12 kts	15 kts	20 kts	25 kts
Benzene	15.1	15.1	8.5	7.3	6.2	5.1	3.6	1.7	0
Toluene	0	0	0	0	0	0	0	0	0
Ethylbenzene	0	0	0	0	0	0	0	0	0
Xylenes	0.2	0	0	0	0	0	0	0	0
Naphthalene	0	0	0	0	0	0	0	0	0
Biphenyl	1.0	0.3	0	0	0	0	0	0	0
Aliphatic VOCs with boiling points <180^{o}C	2.4	0.9	0	0	0	0	0	0	0

Oil Spills Fate and Effects Modeling for Alternative Response Scenarios

Part F: Prince William Sound

Section F-III.2

by

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ASA 00-246

August 2004

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F-III.2 Air Concentrations from In-Situ Burning

Section A.5.2 of Part A describes the methods used to evaluate emissions from ISB and their potential effects on air quality. For scenarios involving ISB, the maximum potential amount of oil burned was assumed to be 25% by volume of the amount of oil mechanically removed (see Section A.3.7). The amount burned was calculated for each scenario since the percent of oil mechanically removed varies for each of the 100 stochastic runs. The 50^{th} and 95^{th} percentiles of the volumes mechanically cleaned up (for the 100 stochastic runs) were multiplied by 0.25 to calculate the 50^{th} and 95^{th} percentile volumes burned by ISB. The atmospheric concentrations of compounds and particulates released by an in-situ burn are dependent upon both the distance from and the area of the fire. All chemicals in the emissions that might be of concern are considered in the analysis.

F-III.2.1 Medium Volume Spills

The estimated distances from an in-situ burn to thresholds of concern are tabulated below. The maximum burn areas for each scenario were calculated by dividing the burn volume by the minimum oil thickness required for burning (3 mm). Burn areas were calculated for all 100 runs for each scenario. Table F-III.2-1 shows, for each of the three medium volume scenarios, the percentage of simulations whose calculated burn area (burn volume divided by 3 mm) is less than the maximum possible burn area of 500 m^2. For these three scenarios, some of the individual simulations have burn areas smaller than 500 m^2. The effect of the dispersant application on the area of oil requiring burning is apparent from the numbers in the table. When no dispersant is applied (0% dispersant efficiency), 0% of the simulations have burn areas smaller than 500 m^2. For 45% dispersant efficiency, 83% of the burn areas are smaller than 500 m^2, and the same is true for 80% dispersant efficiency. Therefore, the results show that the more efficient the dispersant, the smaller the area of oil is that needs to be burned. This is not a surprising result, as dispersant removes oil from the surface of the water, decreasing the amount of oil that remains on the surface, and thereby decreasing the area of oil that needs to be burned.

Table F-III.2-1. Percentile where burn volume, divided by 3 mm, is less than the maximum burn area of 500 m^2, for each medium volume scenario.

Scenario	Percentile
Medium Volume, 0% Dispersant Efficiency	0%
Medium Volume, 45% Dispersant Efficiency	83%
Medium Volume, 80% Dispersant Efficiency	83%

Table F-III.2-2 shows, for each medium volume scenario, the number of burns that would be necessary to burn the entire amount of oil that was designated for burning. A range of oil thicknesses are shown in Table F-III.2-2: between 3 mm and 10 cm (100 mm). Three mm is the minimum thickness of oil required for in-situ oil burning (Buist et al., 1994). However, 10 cm is a more preferable oil thickness for burning (Allen, 2002). If one burn can be accomplished at less than 10 cm thick and 500 m^2 of area (i.e., the burn volume is < 50 m^3), it is assumed that this occurs and the actual thickness is calculated from volume burned divided by 500 m^2. However, if the calculated thickness for one burn is <3mm, the minimum (i.e., the burn volume is < 1.5 m^3), the burn area is instead the burn volume divided by 3 mm.

Table F-III.2-2. Assumed burn thickness for medium volume spill scenarios and number of burns needed to burn the oil, assuming the maximum burn area is 500 m^2.

Scenario		Total Volume Burned (m^3)	Burn Area (m^2)	Oil thickness (mm)	Number of Burns
Medium Volume, 0% Dispersant Efficiency	50th Percentile	16.17	500	33	1
	95th Percentile	25.22	500	51	1
Medium Volume, 45% Dispersant Efficiency	50th Percentile	0	500	-	0
	95th Percentile	8.66	500	18	1
Medium Volume, 80% Dispersant Efficiency	50th Percentile	0	500	-	0
	95th Percentile	8.96	500	18	1

In all cases (Table F-III.2-2), the burn volumes are less than 50 m^3, the maximum volume for a single burn. For cases where there is a burn, none of the burn volumes are less than 1.5 m^3, so all the burn areas are 500 m^2. The distance-to-threshold calculations reported below assume an area per burn of 500 m^2.

Table F-III.2-3 reports calculations of distance to the air quality thresholds for the chemicals of concern that are released when oil is burned. There are three thresholds in these tables: IDLH, TWA, and EPA NAAQS (Primary and Secondary Standards). These thresholds were described and listed in Table A.5-5. The chemicals listed in Table F-III.2-3 were designated by Fingas, et al. (2001) as being of concern, and they are split

into five chemical classes: total particulates, fixed gases, carbonyls, PAHs, and VOCs. For those chemicals for which U.S. air quality standards were not available, we have assumed the lowest of the available thresholds within that chemical class. For example, we do not have an IDLH threshold value for butane, a member of the VOC chemical class, but we do have IDLH values for several other members of the VOC class. We selected the lowest of the available IDLH values for the VOCs and used that value as an IDLH threshold for butane and other chemicals in the VOC class for which we are missing threshold values. We used the same strategy for the PAH chemical class as well. This substitution method provides an estimate of the distance to the threshold for those chemicals for which threshold data are not available. However, because those threshold values are just assumed estimates, the distance values in the following tables that were derived using these threshold values are shaded gray.

It should also be noted that three different TWA threshold values were obtained for this study: ACGIH TLV, OSHA PEL, and NIOSH REL. We calculated the distance to the threshold for each of these, but we present only the maximum of the three distances in these tables. For example, in Table F-III.2-3, for formaldehyde, the distance to the ACGIH TLV threshold is 237 m, to the OSHA PEL threshold is 0 m, and to the NIOSH REL threshold is 89 m. The maximum of these three distances is 237 m, which is the TWA value reported in the table.

Table F-III.2-3 shows the distance-to-threshold calculations for an individual 500 m^2 burn. In the table, the calculated distances represent the distance (from the center of the fire) at which the concentration of each chemical has decreased to the threshold level. In the case of sulphur dioxide in Table F-III.2-3, the distance at which the concentration of sulphur dioxide in the air equals the IDLH threshold is essentially zero, meaning that the concentration of sulphur dioxide produced by the 500-m^2 fire never exceeds the IDLH threshold. However, for the other thresholds in the table (TWA and EPA NAAQS), the concentrations do exceed the thresholds and do not decrease to the threshold level until 331 m, 471 m, and 440 m from the center of the fire.

Table F-III.2-3 shows that, for a 500-m^2 burn area, the total particulates, fixed gases, and carbonyls are of the greatest concern (i.e., the distances from the fire to the threshold level are greatest). The majority of other chemicals have distances of zero meters to the threshold level, meaning that their concentrations never exceed the threshold. Acetone has the largest distance to the threshold, at 710 m, and acetaldehyde and the total particulates are the next largest.

In Table F-III.2-3, there are four additional chemicals with distances to the threshold that stand out: 2-methylbutane, 3-methylhexane, 3-methylpentane, and methylcyclopentane. However, as can be seen from the tables, these values are shaded gray because we did not have a regulatory threshold value for them. Instead, we used the lowest threshold value from within their group (VOCs). From this, we can conclude that their distance to threshold values *may* represent that they are chemicals whose concentrations will still be above threshold levels far from the fire, or it may be that the threshold estimates used for the distance-to-threshold calculation are unreasonably low and our estimate method is not suitable for these chemicals.

Table F-III.2-3. Estimated distances (m) from fire to the thresholds of concern for the 50th and 95th percentile volumes for ISB for burn area of 500 m^2. For those chemicals for which U.S. air quality standards were not available, the smallest of the available thresholds within that chemical class is assumed, and the results are shaded in gray.

Substances	Distance to the Threshold (m)			
	IDLH	TWA	EPA NAAQS	
			Primary Standard	Secondary Standard
Total Particulates				
10-um particle			514	514
2.5-um particle			523	523
Fixed gases				
Sulphur Dioxide	0	331	471	440
Carbon Dioxide	0	0		
Carbon Monoxide	0	0	0	
Carbonyls				
Acetaldehyde	0	525		
Acetone	0	710		
Formaldehyde	0	237		
PAHs				
1- Methylnaphthalene	0	0		
1-Methylphenanthrene	0	0		
2,3,5-Trimethylnaphthalene	0	0		
2,6-Dimethylnaphthalene	0	0		
2-Methylnaphthalene	0	0		
Acenaphthene	0	0		
Acenaphthylene	0	0		
Anthracene	0	0		
Benz(a)anthracene	0	0		
Benzo(a)pyrene	0	0		
Benzo(b) fluoranthene	0	0		
Benzo(e) pyrene	0	0		
Benzo(g,h,I) perylene	0	0		
Biphenyl	0	0		
Chrysene	0	0		
Dibenz(a,h)anthracene	0	0		

Dimethylnaphthalenes	0	0		
Fluoranthene	0	0		
Fluorene	0	0		
Indenol(1,2,3-cd)pyrene	0	0		
Methylphenanthrenes	0	0		
Naphthalene	0	0		
Perylene	0	0		
Phenanthrene	0	0		
Pyrene	0	0		
Trimethylnaphthalenes	0	0		
VOCs				
1,2,3-Trimethylbenzene	0	0		
1,2,4-Trimethylbenzene	0	0		
1,3,5-Trimethylbenzene	0	0		
1,4-Diethylbenzene	0	0		
2,2,3-Trimethylbutane	0	0		
2,2,4-Trimethylpentane	0	0		
2,2,5-Trimethylhexane	0	0		
2,2-Dimethylbutane	0	0		
2,2-Dimethylpropane	0	0		
2,3,4-Trimethylpentane	0	0		
2,3-Dimethylbutane	0	1		
2,3-Dimethylpentane	0	1		
2,4-Dimethylhexane	0	0		
2,4-Dimethylpentane	0	0		
2,5-Dimethylhexane	0	0		
2-Ethyltoluene	0	0		
2-Methylbutane	0	165		
2-Methylheptane	0	4		
3-Methylhexane	0	42		
3-Methylpentane	0	85		
4-Ethyltoluene	0	0		
4-Methylheptane	0	0		
Benzene	0	0		
Butane	0	1		
c-1,3-Dimethylcyclohexane	0	0		
c-1,4/t-1,3-Dimethylcyclohexane	0	0		
c-2-Butene	0	0		
Cyclohexane	0	0		
Cyclopentane	0	0		
Decane	0	0		
Dodecane	0	0		
Ethylbenzene	0	0		

Heptane	0	0		
Indan (2,3-Dihydroindene)	0	0		
Isobutane (2-Methylpropane)	0	0		
m,p-xylene	0	0		
Methylcyclohexane	0	0		
Methylcyclopentane	0	92		
Naphthalene	0	0		
n-Butylbenzene	0	0		
Nonane	0	0		
n-Propylbenzene	0	0		
Octane	0	0		
o-Xylene	0	0		
p-Cymene (1-Methyl-4-iso-propylbenzene)	0	0		
Pentane	0	0		
Propane	0	0		
Propene	0	0		
2,2-Dimethylpentane	0	0		
iso-Butylbenzene	0	0		
Isoprene (2-Methyl-1,3-Butadiene)	0	0		
iso-Propylbenzene	0	0		
Undecane	0	0		

The ISB effects are summarized in Table F-III.2-4. The affected area is calculated by assuming the circular area around each burn is affected to the maximum distance to any air quality threshold (i.e., this distance is the circle radius) and multiplying the circular area per burn by the number of burns. The percent of the region of interest is calculated using the province area in Table A.4-4.

Table F-III.2-4. Estimation of area affected by ISB, for medium volume spills by dispersant scenario and for 50th and 95th percentile burn volumes.

Dispersant % Efficiency		0	45	80
Burn Area (m^2)	50th	500	0	0
	95th	500	500	500
Maximum Distance (m) to Threshold (1 burn)	50th	710	0	0
	95th	710	710	710
# of Burns	50th	1	0	0
	95th	1	1	1
Area (km^2) Exposed (assuming circle with radius = maximum distance)	50th	1.584	0	0
	95th	1.584	1.584	1.584
Percent of Province Area	50th	0.016	0.000	0.000
	95th	0.016	0.016	0.016

F-III.2.2 Large Volume Spills

The estimated distances from an in-situ burn to thresholds of concern for the large volume scenarios are below. Burn areas were calculated for all 100 runs for each scenario. Table F-III.2-5 lists, for each of the three large volume scenarios, the percentage of simulations whose calculated burn area (burn volume divided by 3 mm) is less than the maximum burn area of 500 m^2. This table shows that the three scenarios in which the large volume of 40,000 bbl of crude oil was released do not have any burn areas smaller than 500 m^2, regardless of the dispersant efficiency.

Table F-III.2-5. Percentile where burn volume, divided by 3 mm, is less than the maximum burn area of 500 m^2, for each large volume scenario.

Scenario	Percentile
Large Volume, 0% Dispersant Efficiency	0%
Large Volume, 45% Dispersant Efficiency	0%
Large Volume, 80% Dispersant Efficiency	0%

Table F-III.2-6 shows, for each large volume scenario, the number of burns that would be necessary to burn the entire amount of oil that was designated for burning. The number of burns was calculated by dividing the burn volume (Table F-III.1.7) by the assumed oil thickness of 10 cm and then dividing this number into the maximum area allowed per burn (500 m^2).

With a thickness greater than 100 mm, all of the large volume cases will require multiple burns (2 – 10) to remove all the oil. The effectiveness of dispersant application in reducing the amount of oil needing to be burned can be seen in Table F-III.2-6. The table shows that the more efficient the dispersant is, the fewer the number of burns required to remove the oil.

Table F-III.2-6. Assumed burn thickness for large volume spill scenarios and number of burns needed to burn the oil, assuming the maximum burn area is 500 m^2.

Scenario		Total Volume Burned (m^3)	Burn Area (m^2)	Oil thickness (mm)	Number of Burns
Large Volume, 0% Dispersant Efficiency	50th Percentile	375.6	500	100	8
	95th Percentile	462.7	500	100	10
Large Volume, 45% Dispersant Efficiency	50th Percentile	120.7	500	100	3
	95th Percentile	320.9	500	100	7
Large Volume, 80% Dispersant Efficiency	50th Percentile	77.4	500	100	2
	95th Percentile	317.4	500	100	7

Table F-III.2-3 shows distance-to-threshold calculations, in meters, for an individual 500-m^2 burn. Descriptions of Table F-III.2-3 and its results can be found in the previous section.

The distances to the threshold would apply to each burn. Thus, the effect is proportional to the number of burns. Table F-III.2-6 indicates that on average (50th percentile) the air quality effect is reduced by 5/8 if dispersant is applied with 45% efficiency, and the air quality effect is reduced by 3/4 if dispersant is applied with 80% efficiency.

The ISB effects are summarized in Table F-III.2-7. The affected area is calculated by assuming the circular area around each burn is affected to the maximum distance to any air quality threshold (i.e., this distance is the circle radius) and multiplying the circular area per burn by the number of burns. The percent of the region of interest is calculated using the province area in Table A.4-4.

Table F-III.2-7. Estimation of area affected by ISB, for large volume spills by dispersant scenario and for 50th and 95th percentile burn volumes.

Dispersant % Efficiency		**0**	**45**	**80**
Burn Area (m^2)	50th	500	500	500
	95th	500	500	500
Maximum Distance (m) to Threshold (1 burn)	50th	710	710	710
	95th	710	710	710
# of Burns	50th	8	3	2
	95th	10	7	7
Area (km^2) Exposed (assuming circle with radius = maximum distance)	50th	12.67	4.75	3.17
	95th	15.84	11.09	11.09
Percent of Province Area	50th	0.126	0.047	0.031
	95th	0.157	0.110	0.110