Why and How MMS Uses the Physical Sciences to Fulfill Its Environmental Goals

U.S. Department of the Interior
MMS Minerals Management Service
Branch of Environmental Sciences

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Introduction

This document explains why and how the Minerals Management Service (MMS) of the U.S. Department of the Interior uses physical sciences to fulfill its environmental goals, and provides background information on the role of physical sciences in decisionmaking for Outer Continental Shelf oil, gas, and other minerals development.

By linking research endeavors to MMS's decisionmaking processes and by using sample MMS studies, this document also communicates the general direction of MMS physical sciences research to interested constituents including industry, State and local governments, and environmental groups.

This document is not intended to give a comprehensive review on physical sciences research in MMS. Instead, sample MMS studies are presented to illustrate why and how MMS uses the physical sciences to fulfill its environmental goals.

Support for MMS Mission

The Minerals Mangement Services (MMS) is a bureau of the U.S. Department of the Interior. The mission of MMS is to manage the mineral resources on the Nation's Outer Continental Shelf (OCS) in an environmentally sound and safe manner, and to collect, verify, and distribute, in a timely fashion, mineral revenues generated from Federal (onshore and offshore) and Indian lands.

The term "Outer Continental Shelf" is a legal term created by Federal statute and is distinct from the geographic term "continental shelf." There is no scientific definition for the OCS. Legally, the OCS comprises that part of the submerged lands, subsoil, and seabed lying between the seaward extents of State[1] and of Federal jurisdictions[2], which is generally 3 nautical miles seaward from the State's coastline to about 200-300 nautical miles offshore.

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[1] **State jurisdiction** is defined as follows:

- Texas and the Gulf coast of Florida are extended 3 marine leagues (1 marine league = 18,228.3 feet) seaward from the baseline from which the breadth of the territorial sea is measured.
- Louisiana is extended 3 imperial nautical miles (1 imperial nautical mile = 6,080 feet) seaward of the baseline from which the breadth of the territorial sea is measured.
- All other States' seaward limits are extended 3 nautical miles (1 nautical miles = 6,076 feet) seaward of the baseline from which the breadth of the territorial sea is measured.

[2] **Federal jurisdiction** is defined under accepted principles of international law. The seaward limit is defined as the farthest of 200 nautical miles seaward of the baseline from which the breadth of the territorial sea is measured or, if the continental shelf can be shown to exceed 200 nautical miles, a distance not greater than a line 100 nautical miles from the 2,500-meter isobath or a line 350 nautical miles from the baseline.

Offshore drilling for oil and gas has been conducted since the early 1900’s. Oil and gas under the seabed continue to be an important part of the energy resources of the United States. The OCS provides approximately 30 percent of domestically produced crude oil and 25 percent of domestic natural gas. Approximately $4-6 billion per year in minerals revenue is collected from offshore and onshore leases. The need to balance the value of these resources against the potential for environmental damage is an important concern, and has become increasingly recognized in Federal laws and national debates over energy.

The majority of OCS activity occurs in the U.S. Gulf of Mexico, off the coast of southern California, and off the coast of Alaska (see Figure 1). The western and central portions of the northern Gulf of Mexico are one of the world’s major oil and gas production areas, and have been a steady and reliable source of crude oil and natural gas for more than 50 years.

Until 1969, potential environmental damage from OCS oil and gas activities was mostly a local concern in the affected States. However, environmental concerns were brought to national attention by oil-spill damage from a blowout in the Santa Barbara Channel in January 1969. The spilled oil covered 660 square miles, including 150 miles of coastline (Cicin-Sain, 1986).

Established in the 1970's, the MMS’ Environmental Studies Program (ESP) is a highly focused marine research program designed to provide the environmental information necessary for OCS energy and nonenergy minerals planning and development activities. The program supports studies in marine biology, physical oceanography, endangered species, marine chemistry, socioeconomics, and air quality. Figure 2 illustrates types of environmental studies used in decisionmaking.

The MMS prepares environmental assessments (EA’s) and environmental impact statements (EIS’s) to determine any possible environmental consequences of OCS marine minerals development. An EA is a concise document that (1) briefly provides sufficient evidence and analysis for determining whether to prepare an EIS, and (2) determines whether the proposed action poses a significant environmental risk. An EIS is a detailed document that thoroughly analyzes the proposed action, alternatives, and cumulative impacts. An EIS is prepared when MMS has determined that a major Federal action is being considered and is environmentally significant in scope and magnitude such that the potential impacts must be examined in greater detail. The MMS’s physical sciences research provides important information for both EA and EIS documents.

Environmental assessments, compliance regulations, and study activities also help MMS meet obligations required by numerous legislative authorities, such as the Outer Continental Shelf Lands Act, the National Environmental Policy Act (NEPA), the Endangered Species Act, the Clean Air Act, and the Oil Pollution Act of 1990. Other examples of applicable laws include the Marine Mammal Protection Act, the Coastal Zone Management Act, the Clean Water Act, and the Alaska National Interest Lands Conservation Act. These legal mandates direct MMS to (1) establish the information needed for assessment and management of environmental impacts on the human, marine, and coastal environments of the OCS and potentially affected coastal areas, and (2) provide the information needed for balanced decisionmaking.

Physical Sciences Research Components

Physical sciences are an important part of the ESP and provide information for EA and EIS documents. The physical sciences research supported in MMS includes physical oceanography, oil-spill risk analysis (OSRA), atmospheric sciences, and sand and gravel studies.

Physical Oceanography

Physical oceanography is the scientific study of ocean movements. Physical oceanographic research supported by MMS includes field data collection, analysis, and modeling studies. This research is important for estimating the transport and fate of any spilled oil and other OCS discharges. The general strategy is to use field observation and model results to calculate the circulation for a given area. These calculations, in turn, provide the basis for OSRA's (see below) and other assessments.

Although physical oceanographic information is used primarily in the OSRA model and associated EIS document preparations, it is also used to support biological and ecological studies and to predict the transport of drilling muds and water discharges containing petroleum compounds and other byproducts of oil and gas exploration and production. Variability in physical oceanographic conditions, for example, may be a cause of variation in biological communities and may be useful in interpreting long-term monitoring and cumulative impact studies.

Oil-Spill Risk Analysis

The OSRA model is used by MMS to estimate the probability of oils spills occurring in a specific lease area, to calculate hypothetical oil-spill trajectories from selected spill launch points (i.e., places that a spill is assumed to occur), and to determine the probability that an environmental resource or coastline segment might be affected by oil released from the selected launch points. To date, the results from OSRA modeling are used in different types of documents: (1) EA and EIS reports completed by the MMS for OCS oil exploration, development, and production; (2) oil-spill response plans submitted by industry; (3) environmental reports submitted by industry, (4) biological opinions for endangered/threatened species, and (5) other Federal and State agencies' special reports. Figure 3 shows the uses of OSRA results.

Atmospheric Sciences and Air Quality Modeling

Oil and gas production may alter the composition of the marine atmosphere and may affect air quality over populated and other protected areas. Atmospheric sciences studies are used by MMS to develop air quality impact analyses. Atmospheric sciences research focuses on air quality modeling and field data collection. Initially, field studies in the MMS Pacific Region were important in developing air quality models. Currently, the studies emphasize Gulf of Mexico issues. This is due to the continued rapid growth in the oil/gas-related activities in the Gulf as well as new regulatory standards that are being implemented by the Environmental Protection Agency (EPA).

Sand and Gravel Program

In addition to offshore oil and gas, the MMS has legal and jurisdictional authority over other mineral resources on the OCS. This includes sand and gravel deposits, many of which are suitable as beach nourishment or wetlands restoration material, or as a source of coarse material for construction aggregate. In recent years, there has been increasing interest in the sand and gravel resources of the OCS, and the MMS has responsibilities with respect to the potential environmental impacts of these resources and must fulfill its NEPA responsibilities by addressing biological and physical environmental questions concerning sand extraction from the Federal OCS.

Physical Oceanography

The U.S. continental margins are divided into four regions: the Alaska Coast, the Pacific Coast, the Gulf of Mexico, and the Atlantic Coast. These four regions have fundamental differences in geology, topography, and bathymetry and in the processes that control the circulation of shelf waters. Although some characteristics, such as the response of currents to wind forcing, are common to many continental shelves, the relative importance of various physical processes in influencing the shelf flows varies from region to region. All of these features could influence the transport and dispersion of any spilled oil or OCS discharges. The following studies illustrate how physical oceanography research is used in EA and EIS documents.

Studies of Deepwater Processes in the Gulf of Mexico

With the passage of the Deepwater Royalty Relief Act and the development of technologies that allow for more cost-effective development beyond the continental shelf, oil and gas activities in deep water (areas deeper than 1,000 feet) have proceeded at an unprecedented rate. If predictions of even larger reservoirs in deepwater areas are proven true, then the Gulf of Mexico will experience a profound change in the pattern of development during the next 8-10 years.

Development in deepwater has led to concerns about oil released by accidents near the seafloor. Figure 4 is a sketch of some physical features in a subsurface plume. Oil spill experts have realized that oil and natural gas releases in deep water behave much differently than in shallow water. This is primarily because of the density stratification, high pressures, and low temperatures in deep water. Preliminary calculations suggest that a plume of gas and/or oil could travel beneath the surface for many kilometers and surface many hours after release. Some physical and chemical changes that occur in this deepwater environment, such as the formation of frozen gas hydrates from gas bubbles, could significantly reduce the buoyancy of the plume and keep large amounts of the oil submerged for an extended time. This has significant implications for environmental impact assessment, oil-spill cleanup, contingency planning, and source tracing.

Recently, it has been shown that there are strong currents at water depths between 1,000 and 2,000 meters. These strong flows affect oil and gas operations and MMS assessments of subsurface spills.

The interactions between eddies and the continental slope are also being modeled to study the dynamics of three-dimensional, physical and oceanographic processes. The MMS also participated in studies to evaluate observations made during controlled subsea oil-spill experiments. Ultimately, this information will be used to build a model to assist in the development of deepwater oil-spill response plans.

Studies on Sea Ice and Ocean Circulation in the Alaska Region

Ice conditions are highly influential in determining the movement and final disposition of spilled oil. Under calm conditions, the primary processes affecting the oil are spreading, advection, and evaporation. Under rough water conditions, dispersion and emulsification also become important to oil movement. Even at 0 °C, evaporation occurs, with estimates of up to 30-percent evaporation in 48 hours and up to 40-percent evaporation over a 2-week period. Such weathering results in greater density of the remaining oil, which in turn causes increased thickness of the oil by increasing its viscosity. The low temperatures in the Arctic further increase the viscosity and the oil's equilibrium film thickness. The oiled ice can be transported for a considerable distance before melting occurs and the oil is released.

Understanding under-ice currents is also necessary for estimating the potential effects on environmental resources from oil spills. A study of under-ice currents by MMS indicated that under-ice oil spills could move and pose risk to offsite and, in particular, shoreward resources. The MMS continues to develop and improve a model of sea-ice formation and ocean circulation. Results of this study will include details of ice motion and ocean currents that will be used in oil spill risk analysis.

These studies are helpful for simulating arctic circulation, improving oil-spill trajectory modeling applied to Alaskan waters, and enhancing MMS's environmental impact evaluations.

Santa Barbara Channel-Santa Maria Basin Circulation Study in California

The MMS, through a cooperative agreement with the Scripps Institution of Oceanography, is conducting the Santa Barbara Channel-Santa Maria Basin (SBC-SMB) Circulation Study. This decade-long study is providing information and understanding of circulations needed to support postlease decisions, such as reviews of oil-spill response plans

The MMS continues to develop a numerical model of currents in the Santa Barbara Channel and Santa Maria Basin area. Once completed, the model will aid in the primary form of risk assessment, which is the assessment of probable paths and fates of any spilled oil. The model is useful for determining the frequency and short-term variability of the major circulation processes important to postlease activities. All of these time and spatially varying flow processes also affect variations of the biological characteristics in the area, such as the transport of nutrients, fish larvae, plankton, and other biota.

These studies directly support MMS management decisions for southern California. The study is useful for oil-spill trajectory analyses, mud discharge estimates, and produced water dispersion estimates for review of development and production plans, and oil-spill contingency plans. An accurate understanding of the time and spatial variability of the flow processes is important to support: (1) the development of flow fields appropriate for the MMS's oil spill risk analysis; (2) MMS biological research; and (3) oil-spill response efforts conducted by local, State, and Federal Agencies, and industry.

Support for Biological and Ecological Studies

Although physical oceanographic information has been used primarily as input to the OSRA model and to prepare associated EA and EIS documents, it is also used to support biological and ecological studies. The GulfCet Program (Davis et al., 2000) is one example.

There has been much concern about how various aspects of oil and gas exploration and development might affect whales and dolphins (cetaceans). The purposes of GulfCet were to determine the distribution and abundance of cetaceans along the continental slope in the northern Gulf of Mexico and to help MMS assess the potential effects of deepwater oil and gas exploration and production on these marine mammals.

Whales and dolphins do not occur randomly in the Gulf. The GulfCet Program has shown that sperm whales and other cetaceans are found in conjunction with areas of upwelling and nutrient enrichment that enhance productivity and prey abundance. Cetaceans in the northern Gulf of Mexico concentrate along the continental slope in or near cyclones (upwelling waters) and the confluence of cyclone-anticyclone eddy pairs. Cyclones also show the greatest diversity of seabird species. High numbers of zooplankton, lanternfish, and squid were found inside cyclone and confluence areas. As the physical oceanographic features move and change, prey distribution changes and moves, and so will the presence and movements of whales and dolphins.

Oil-Spill Risk Analyses

The MMS assesses oil-spill risks associated with offshore oil and gas activities. Analyzing the risk of oil spills contacting coastal and marine resources is part of the EIS process. This analysis addresses the likelihood of spill occurrence, the transport and fate of spilled oil, and the environmental impacts that might occur as a result of the spill. The MMS produces OSRA reports for proposed OCS oil and gas lease sales and developmental activities. These analyses estimate the potential oil spill risks that may be associated with offshore activities that occur once leases are awarded. The OSRA results are also used by other Federal Agencies (such as by the Fish and Wildlife Service for endangered species analysis), State agencies (such as for coastal zone consistency determination), and the oil industry (such as for oil-spill response plans and for environmental reports).

One focus of MMS's Environmental Studies Program is to develop supporting environmental data sets for the OSRA model. The OSRA model's supporting environmental data are among the most comprehensive for all oil-spill trajectory models and include the best available current and wind fields from national and international sources. In addition to the driving wind and ocean current fields, the model uses data on the geographical extents of biological and commercial resources, such as seagrass beds, native subsistence areas, coastal habitats, and recreational beaches.

OSRA Model

The OSRA model was developed in 1975 by the Department of the Interior, U.S. Geological Survey, for the analysis of possible oil-spill impacts from offshore oil and gas operations (Smith et al., 1982). The OSRA model produces probabilistic estimates of oil-spill occurrence and contact to biological and economic resources using historical records of oil spills, winds, and ocean currents. The model initiates thousands of oil-spill simulations at hundreds to thousands of hypothetical spill locations to generate an ensemble of oil-spill trajectories, which can statistically characterize oil-spill risk over a large area. The spill locations are in areas of prospective drilling and production, and along projected pipeline and tanker routes.

The OSRA depends on the meteorological and geographical conditions of the study area, the environmental resources that are at risk, and the estimated volumes of oil resources that are assumed to be discovered, produced, and transported. The MMS works closely with State and other Federal Agencies to obtain the best available geographic information on natural resources and the shoreline, represented by one or more equal-distant partitions called land segments.

The analysis is usually conducted in three parts corresponding to different aspects of the overall problem:

- The first part addresses the probability of oil-spill occurrence (Anderson and LaBelle, 1994, 2001).
- The second part addresses the trajectories of oil spills from hypothetical spill locations to various environmental resources (LaBelle and Anderson, 1985).
- The third part combines results of the first two to estimate the overall oil-spill risk if there is oil development.

Projection of potential oil-spill impacts is based on results generated by the OSRA model. The OSRA results provide information for imposing stipulations or deleting certain tracts from leasing where there is a high probability that any oil spilled would affect particularly sensitive areas and valuable resources. Because potential risks are principally evaluated through OSRA modeling, the MMS has used physical oceanographic information primarily to support the OSRA model and to prepare associated EIS's.

The OSRA model has been used successfully to hindcast several documented oil-spill incidents including the Argo Merchant incident (off Nantucket Island, 1976), the Santa Barbara Channel blowout (1969), and the IXTOC-I spill (1979-1980). The spill trajectories generated by the OSRA model closely matched the observed movement of the spilled oil during these incidents. To provide information for EA and EIS documents, the OSRA model has been applied also to the U.S. continental coasts and off Alaska. A recent OSRA application for the Gulf of Mexico is presented in the following section.

Oil-Spill Risk Analysis in the Gulf of Mexico

The Federal Government proposed multiple OCS lease sales in the Western and Central Gulf of Mexico Planning Areas during the 5-year time period, 1998 through 2002. Because oil spills may occur from activities associated with offshore oil development, MMS conducted formal risk assessments prior to the proposed lease sales (Ji et al., 2002a, 2002b).

When applied to the Gulf of Mexico, the OSRA model uses 3-hourly ocean currents over a 9-year period (1986-1994), which are generated by the Princeton Dynalysis Ocean Model (PDOM) (Herring et al., 1999). The PDOM is driven by wind, heat flux, and river flows. The wind data are from the European Center for Medium Range Weather Forecasting Center and are enhanced by observations from meteorological buoys (Berger et al. 1996). Figure 5 shows the stretched, curvilinear computational grid of the PDOM, which illustrates that the PDOM has high spatial resolution of a few kilometers off the Texas-Louisiana coast and is able to resolve the dynamic processes in the entire Gulf. Figure 6 presents the surface currents and wind stresses on August 25, 1992, which are used in the OSRA model.

Among the observations used for model verification is a set of current measurements from over 800 satellite-tracked surface drifters deployed in the Gulf. The drifter deployments constitute one of the most extensive synoptic surveys of mesoscale and larger-scale surface circulation and, together with other observations, facilitated a thorough verification of the model-derived surface currents. The model current field produced very realistic mesoscale eddies and Loop Current variations and was, therefore, accepted as a realistic representation of the surface currents in the Gulf.

Atmospheric Sciences

Oil and gas production may alter the composition of the marine atmosphere and may affect air quality over populated and other protected areas. To address how OCS oil and gas activities are affecting air quality, it is necessary to have information regarding air emissions (i.e., types and amounts) as well as an understanding of the transport and dispersion of these emissions.

The MMS has air quality jurisdiction in the Gulf of Mexico in all OCS waters west of 87.5^{o} W. longitude, in which most of the oil/gas development activity takes place. The EPA has jurisdiction in all other areas (the Eastern Gulf, Atlantic, Pacific, and Alaska). Under the authority of the Clean Air Act, EPA carries out a rigorous program designed to improve the Nation’s air quality. The MMS works with EPA and the States to assure that air emissions on the OCS do not hinder this effort. Through the ESP, the MMS provides much of the scientific data needed in support of these coordination efforts. The results of atmospheric sciences studies are ultimately used in EA and EIS documents.

Air Quality Models

Based on an EPA regulatory model, MMS developed the Offshore and Coastal Dispersion (OCD) model in the 1980's. The OCD Model is used to evaluate air quality impacts from emission sources located on the OCS. The MMS applies the OCD model to air quality analyses for lease sale EIS documents.

There is a continuing need for air quality modeling, particularly in the Gulf of Mexico, to assist analysts in developing air quality impact analyses for NEPA documents. The EPA has developed what is called third-generation air quality models for regulatory applications. These models incorporate more realistic atmospheric processes. The MMS is developing a new-generation air quality model based on the EPA model. The model will incorporate the most current knowledge of dispersion modeling and will be versatile enough to be used spatially in short-range as well as long-range applications. The complete model package will consist of (1) preprocessors for generating land use and terrain data, (2) meteorological data preprocessor, (3) a meteorological model, (4) an air quality model, and (5) postprocessors for model result analysis and presentation.

Recently, EPA promulgated revised standards for ozone, particulate matter, and regional haze. These required the collection of additional data, further studies, and increased cooperation with other Federal and State agencies. To evaluate possible degradation of air quality in sensitive areas, MMS pursued cooperative efforts to conduct field sampling and data collections. The information generated was used to determine if any actions were needed to minimize the degradation. Emissions, air quality, and meteorological data were collected from both onshore and offshore areas.

Predictive models are incorporated with measured data to quantify the pollution levels over the area and their changes over time. Results are used to determine if there has been degradation that exceeds the limits allowed under the Clean Air Act. Appropriate action may then be taken to remedy any significant degradation.

Haze and Ozone Modeling Studies

The EPA has promulgated new regulatory programs to address regional haze and ozone. Emissions of air pollutants over the OCS, including carbon monoxide, sulfur dioxide, nitrogen oxides, particulate matter, and hydrocarbon compounds, influence the ambient concentrations of ozone and haze material. State agencies, therefore, must assess how air emissions in the Gulf of Mexico contribute to ozone and haze material over coastal regions. The MMS supports the States by providing emissions data regarding OCS oil and gas activities, so these agencies can interpret and control regional concentrations of ozone and haze material. For completeness, MMS may also collect and provide emissions data for other activities such as recreational boating and commercial shipping.

These studies also support EA and EIS documents. The information obtained supports cumulative impact analyses for NEPA documents. These studies develop a framework for making decisions about where and which emissions should be targeted for controls to reduce current or foreseeable significant impacts.

There is a continuing need to improve the science and gather additional data, especially as conditions change and new issues arise. The MMS is augmenting its existing meteorological monitoring programs to get a better understanding of the atmospheric conditions that affect the movement and spread of air pollutants. This knowledge is important for improving the predictive models that are used to estimate what the pollutant levels will be and which areas will be affected.

Sand and Gravel Program

In addition to offshore oil and gas, MMS has legal and jurisdictional authority over other mineral resources on the OCS. These include sand and gravel deposits, which maybe suitable as beach nourishment or wetlands restoration material, or as a source of coarse material for construction aggregate.

Dredging significant volumes of sand from OCS sites could potentially alter the bottom topography. An important physical impact issue is whether the dredging will have any measurable influence on the nearshore wave regime and local littoral sediment budget. Prior to any dredging activity at identified borrow sites, the potential for adverse changes in the local wave and current patterns must be assessed. The MMS conducts site-specific studies to evaluate the possible physical effects associated with extraction of sand and gravel material from OCS. These studies:

- compile and analyze existing oceanographic literature and data sets to develop an understanding of existing environmental conditions and the ramifications of dredging operations at selected sand borrow sites;
- use physical processes field data sets and wave climate simulations to predict wave transformation under natural conditions and in the presence of proposed dredging activities;
- determine existing coastal and nearshore sediment transport patterns using historical data sets, and predict future changes resulting from proposed sand dredging operations;
- evaluate the potential cumulative environmental effects of multiple dredging scenarios.

Increased wave action after dredging offshore shoal areas has been noted in certain coastal areas. A proper and thorough assessment should take into account the local current regime and the historical wind and wave climate. Knowledge of the general circulation and bottom-boundary flow conditions provides a basis for estimating the transport of suspended materials.

Computer modeling is the primary tool used to evaluate the physical effects of offshore dredging. A primary advantage of wave modeling is its ability to simulate multiple scenarios. The model domain can be modified (e.g., comparison of existing and postdredging scenarios, different structural configurations, evaluation of varying beach nourishment templates, etc.) to determine the effects that various seafloor changes have on the wave climate. Wave input also can be modified to simulate a wide range of wave conditions (e.g., storm events, seasonal variations) to determine the impacts on shoreline response.

Summary and Conclusions

This document describes why MMS conducts research in physical sciences and how MMS uses this information to fulfill its environmental goals. Instead of giving a comprehensive review on physical sciences research in MMS, sample MMS studies are presented.

The MMS utilizes physical sciences data and analyses throughout the various phases of 5-year planning, prelease and leasing activities, exploration, development, production, and decommissioning of offshore platforms. The MMS designs studies to address the data and analytical needs arising from these specific phases in the decisionmaking process.

Physical oceanographic studies focus on understanding and verifying physical processes and features on the OCS. The mechanisms of these processes and features in the ocean and atmosphere control the transport of materials and cause the mixing and redistribution of pollutants. The information obtained through studies in physical oceanography and meteorology are used in assessing: (1) the transport of spilled oil, (2) the dispersion of discharge fluids and produced water, (3) the movement and spread of air pollutants, (4) sand and gravel dredging impacts, and (5) the effects on the migration of marine mammals, the distribution of fishes, and other biological resources.

Physical oceanography and meteorological data are required to calculate the probable trajectories of any spilled oil and, more generally, to provide background information for environmental impact assessment. Circulation and trajectory model results are ultimately integrated into the EIS's used for lease sales. The information is also used by other investigators (biologists, chemists, and geologists, for example) to assist them in interpreting and analyzing their data.

Improving the modeling and observations of ocean currents and winds and modeling their action on spilled oil with time-varying physical properties are difficult tasks. However, the MMS is committed to continued improvement of the OSRA estimations and EIS analyses, and it will use the most recent results of field and modeling studies to fulfill this commitment. As offshore activity expands into deeper waters and new geographic areas, MMS modeling results will be applied to risk assessments and be validated with environmental observations.

This document (Volume 1) summaries why and how MMS uses physical sciences to fulfill its environmental goals. A companion document (Volume 2) presents the strategic plan for physical sciences in MMS.

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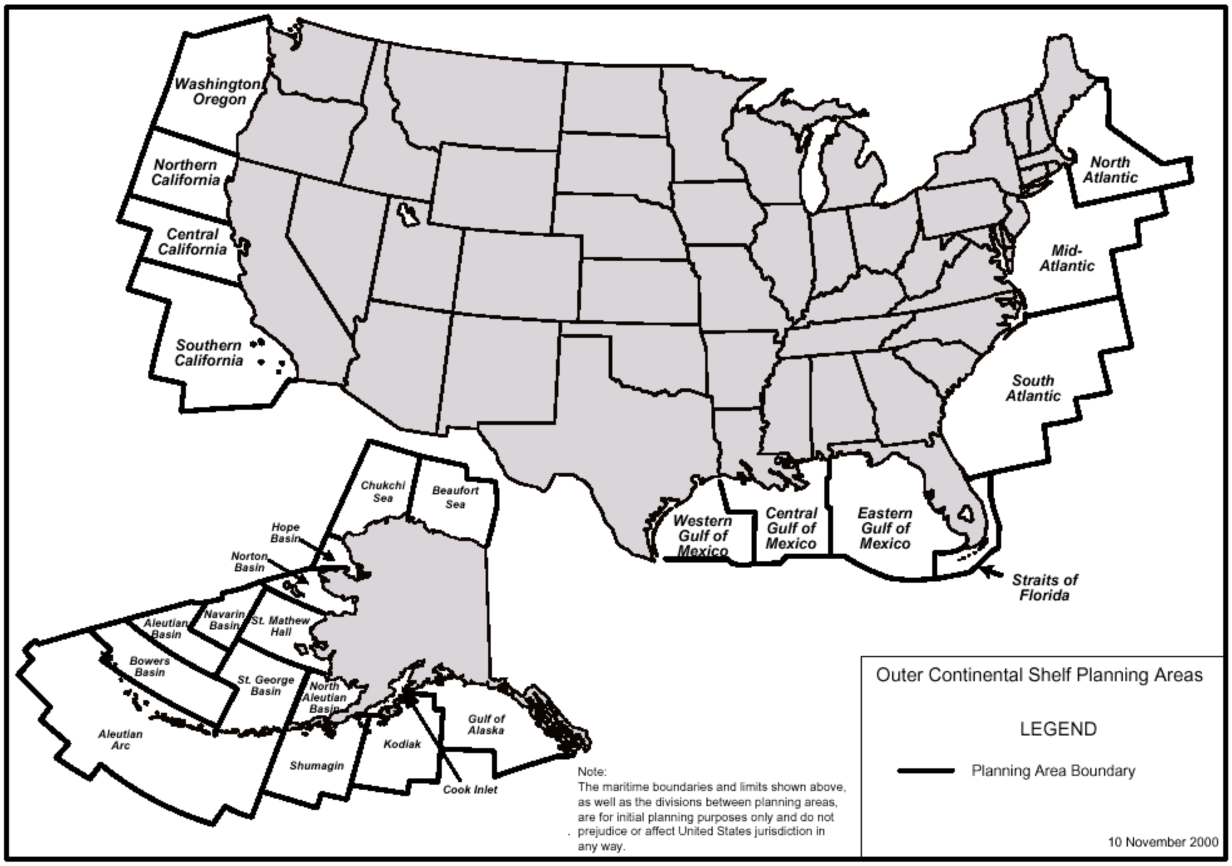

Figure 1. Outer Continental Shelf (OCS) planning areas.

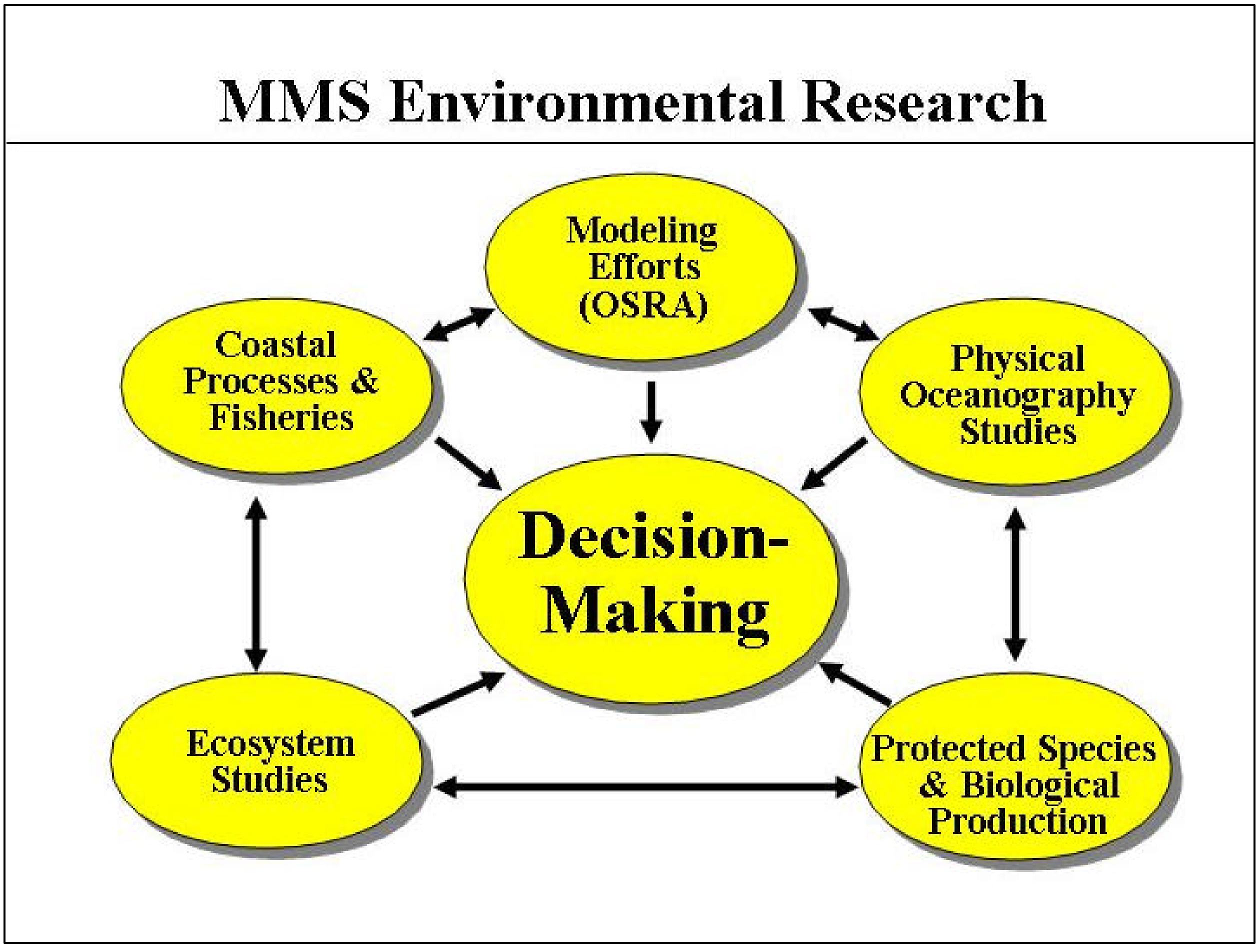

Figure 2. Environmental studies used in decisionmaking.

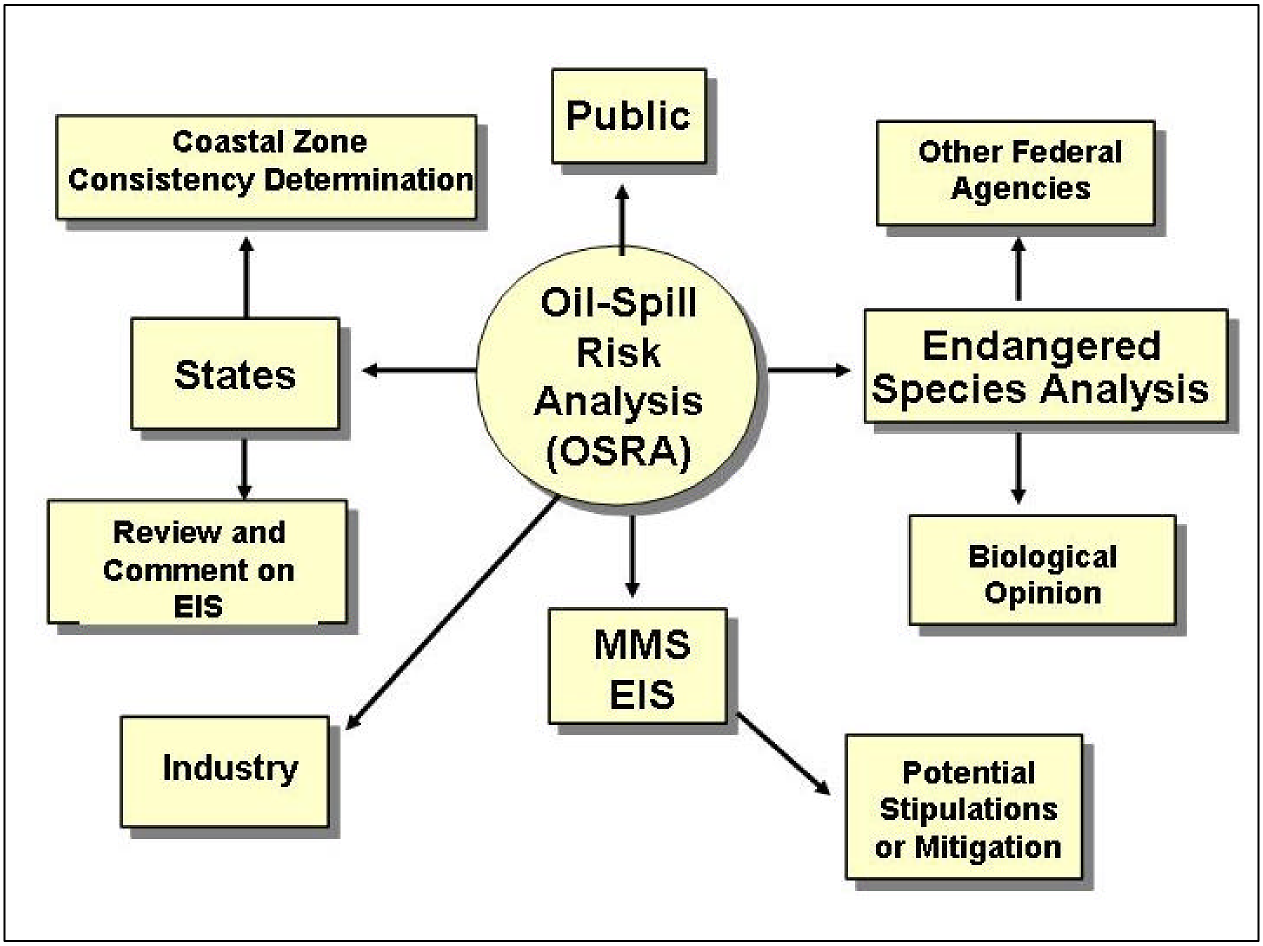

Figure 3. The uses of Oil-Spill Risk Analysis (OSRA) results.

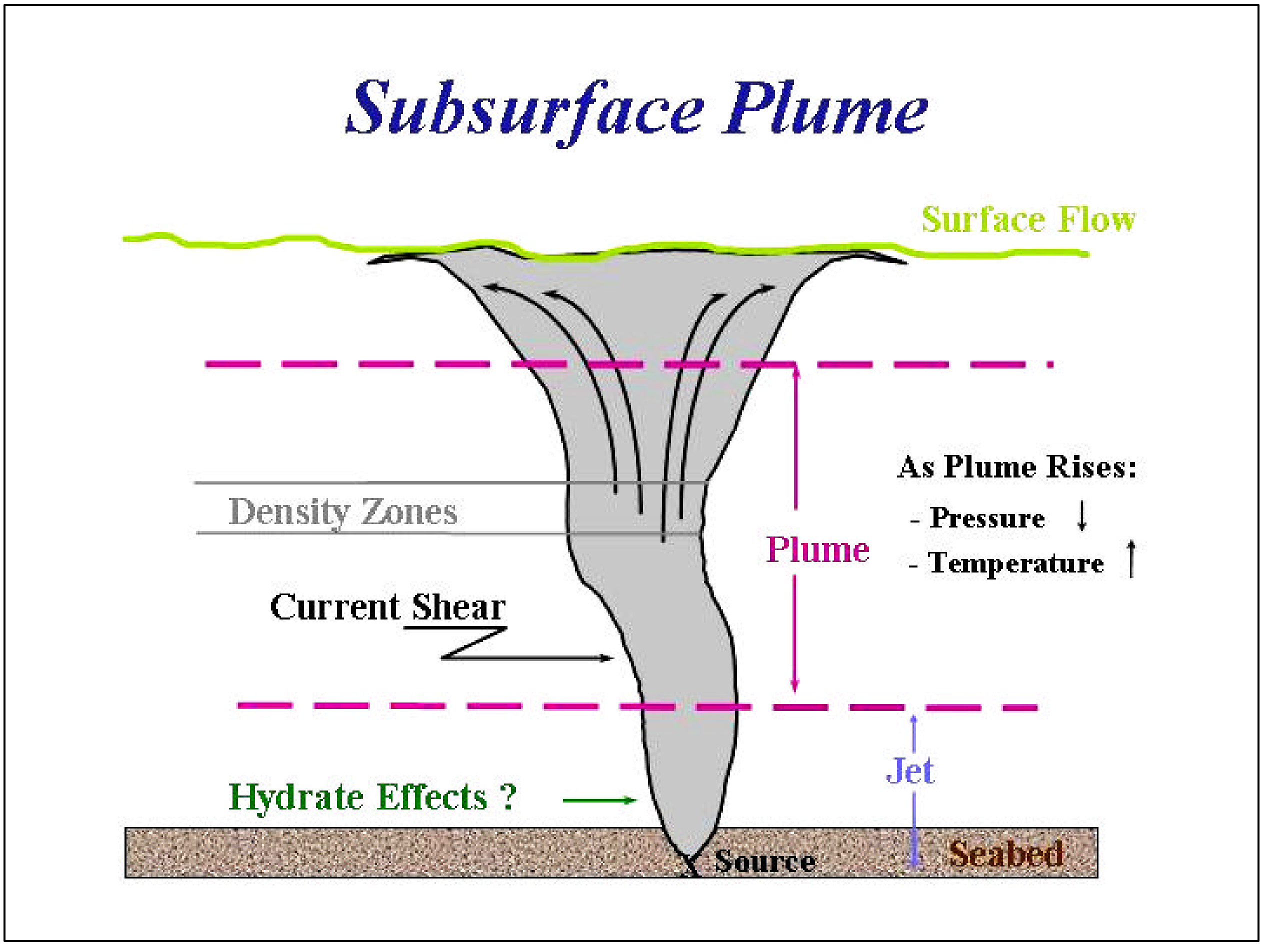

Figure 4. A sketch of some features in a subsurface plume in deepwater.

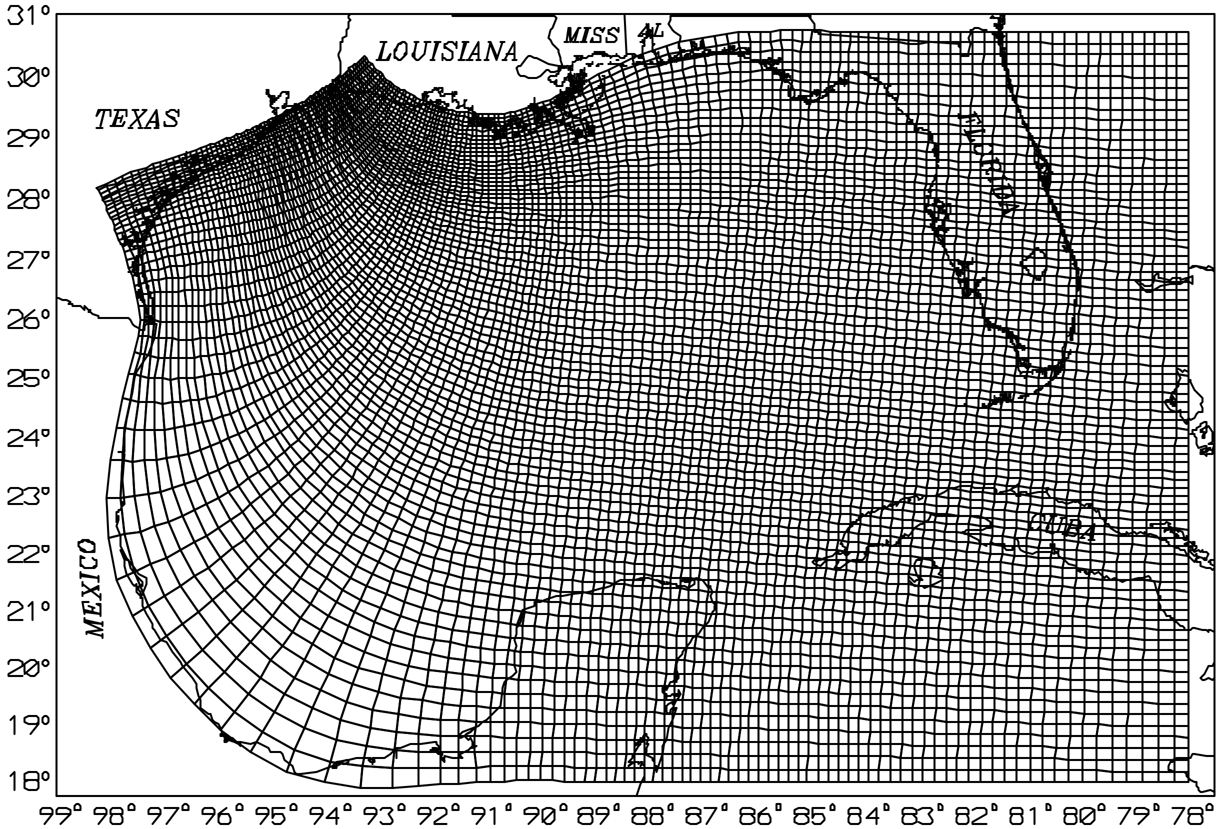

Figure 5. The surface current output grid of the PDOM applied to the Gulf of Mexico. This grid is also the OSRA model input grid for both ocean currents and winds.

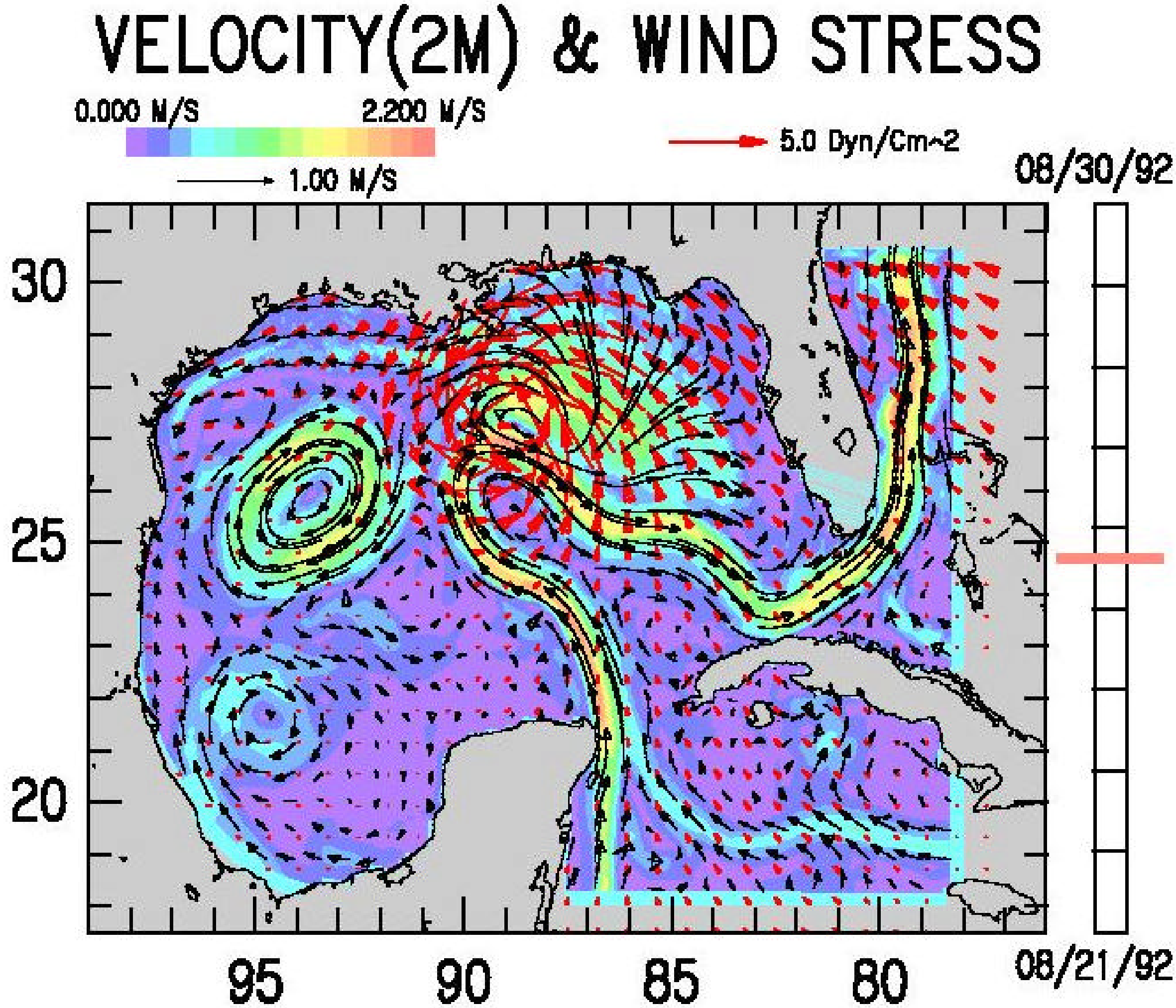

Figure 6. Surface currents and wind stresses (August 25, 1992) used in OSRA model.