Chemical/Oil Spill Modeling

Fate, Transport, and Effects Modeling for Contingency Planning, Emergency Response, and Natural Resource Damage Estimates

INTRODUCTION

Though there are several publicly available models to simulate an oil or chemical spill, most do not provide the necessary flexibility and detail needed for an accurate hindcast or forecast of a release to enable proper understanding of the fate of the various components of the oil. ERM has addressed this need through COSIM, the Chemical/ Oil Spill Impact Module. This tool is a plug-in component to ERM's Generalized Environmental Modeling System for Surfacewaters (GEMSS), a numerical waterbody modeling package, capable of one-, two-, or three-dimensional hydrodynamic analyses. GEMSS can be applied to any type of waterbody and can compute the circulation and transport of water and any constituents, including water quality parameters and the chemical or oil constituents of concern. The GEMSS-COSIM modeling system can produce time-varying mass balances to examine the fate of the released chemical constituents into the various phases and forms including the surface slick, shoreline, atmosphere, water column (dissolved or entrained), sediments, or removed via cleanup activities. The fate calculation includes the following processes: advection, spreading, evaporation, dispersion, dissolution, emulsification, photo-oxidation, sinking/ sedimentation, biodegradation and encapsulation (when ice is present).

Several features set COSIM apart from more traditional two-dimensional surface-only spill models like the General NOAA Oil Modeling Environment (GNOME) or the Automated Data Inquiry for Oil Spills (ADIOS2). COSIM has the flexibility to examine any location, whether coastal or inland, without being restricted to the shorelines built into the model. One of the strongest distinctions is its capability to examine in three-dimensions water column and sediment concentrations of specific released contaminants. Unlike any other spill model, COSIM can perform simultaneous mass balances for a full suite of specific chemicals. This feature enables greater precision by applying chemical specific rates for solubility, evaporation, solids partitioning, and toxicological response estimates.

Other advanced features of COSIM include:

- shoreline classification designations for different degrees of reflection or absorption of shoreline oiling
- sub-surface release
- booming
- skimming
- multiple wind data locations
- multiple current data locations
- incident specific release rate
- multiple release locations including a moving source release option.

Within GEMSS, the results of COSIM can be combined with conventional GIS shape files to produce graphical representations of surface and cross-sectional mass via concentration contours, automated Cartesian plots, animations, or exported to three-dimensional renderings.

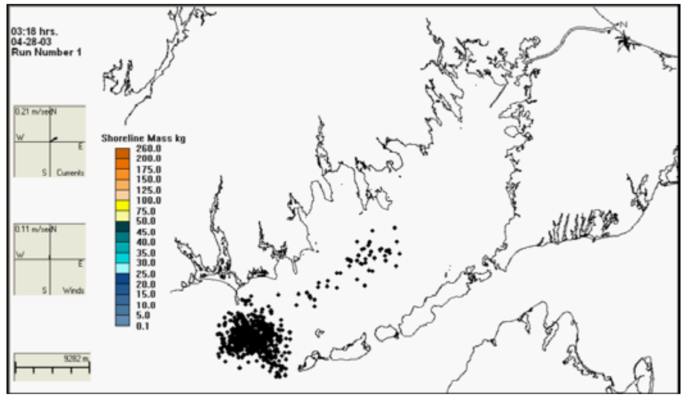
COSIM's MODULES

COSIM has several sub-modules which can each be run independently or in concert. These include trajectory/ fate modeling, cleanup/ response modeling, receptor modeling, stochastic modeling, and toxicological modeling.

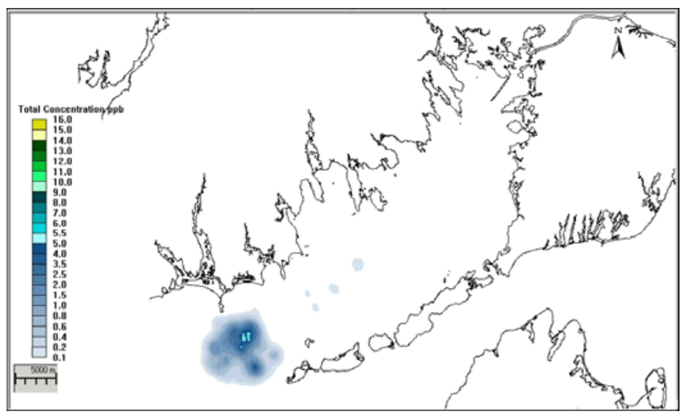
HINDCASTING – Damage Assessments

COSIM has been used on several major oil spills to provide assistance with trustee negotiations to formulate an estimate of natural resource damages resulting from the spill. Since spill response activities typically do not allow time for a thorough sampling effort while the focus is upon spill containment, cleanup, and recovery, modeling provides the necessary insights otherwise unavailable to perform detailed impact assessments. Our clients have identified COSIM as the best available technology to perform such modeling, and trustee agencies including CA OSPR, USFWS, and NOAA, have agreed with the results and implications of COSIM modeling.

Spill related injury assessments using COSIM have been made for aquatic biota, shoreline wildlife, and avians. Assessments begin with the GEMSS fate and transport model, using the best available historical data (including winds, tides, currents, meteorology, oil or chemical type, and release information) to recreate the conditions surrounding the spill. The model is calibrated using available surface slick data, shoreline oiling reports, and water column concentrations.



Surface slick represented by surface particles

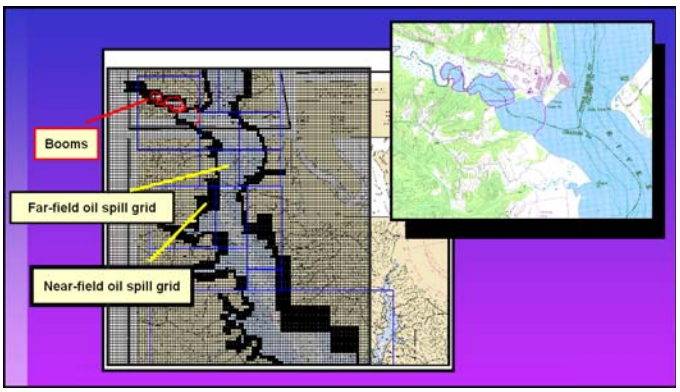


Subsurface dissolved aromatic hydrocarbon concentrations represented by colored contours

To make the hindcasting as realistic as possible and to improve calibration results, the cleanup and response model may be used. This may include simulating the placement of booms and barriers, sorbent material, skimmers, and other methods of product removal from the site such as vacuuming or in-situ burning.

If available, neat oil chemistry is used to describe the initial composition of the oil in terms of the constituents of concern (typically mono or polyaromatic hydrocarbons for oil spills) and heavy residuals. For simplicity, these constituents may be bundled into user defined groups with chemical similarity. The mass of each chemical constituent or group is then tracked over space and time, allowing each component to weather at its own rate. Populations and locations of the site's aquatic and benthic species of interest are estimated. To simulate variable fish movement and speed, a particle tracking locomotion model is run. The resulting magnitudes and durations of the combined bioavailable (dissolved) aromatic hydrocarbons exposed to the organisms are then processed using COSIM's toxicological model, producing estimates of mortality.

Uncertainty in bird injury assessments may be addressed via modeling as well. Collection efforts typically cannot account for every oiled bird that washed ashore considering the length of shoreline and scavenging of carcasses. Even when sufficient data enables a bird injury assessment via beached bird modeling or exposure/ mortality approaches, it is difficult to determine what proportion of birds may have been oiled, died, and sunk before coming to shore. GEMSS hydrodynamic and particle modeling can be used to track the fate of floating birds to estimate the quantity or proportion of birds that were oiled, sunk, hit shoreline, or left the study area.



Spill modeling grids with booms, Patuxent River, MD

SOURCE DETERMINATION – Receptor Modeling

When the presence of oil of unknown origin warrants a source identification investigation, receptor modeling can be performed using COSIM. In these hindcast modeling exercises, known locations of oil can be traced backwards in time using the oil's chemical/physical properties and available winds, tides, and currents to estimate probable locations where the oil release originated.

LIVE SIMULATIONS – Emergency Response

During spill emergencies, real time deployment of COSIM can be used to aid responders with predictions of a slick's trajectory and ultimate destination for strategic decision making. Though two-dimensional surface models have been traditionally used in such events, they typically are unable to simulate complex conditions such as sub-surface releases, sinking oil, or moving sources of the release. With its 3-D engine, and flexibility to be customized, COSIM can supply a more thorough and realistic estimate for responders.

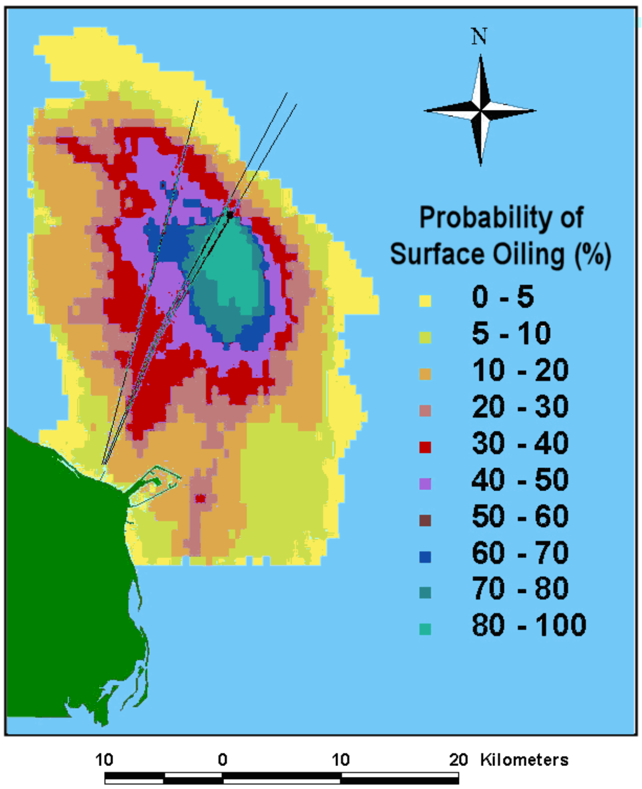
Photo: ENTRIX, Inc.

FORECASTING – EIA and Spill Response Planning

Public awareness and concern for the potential short and long term impacts of oil and chemical spills on the marine environment have generally been high, particularly for regions of special ecological importance or where significant numbers of marine mammals and birds are present. Recent increased maritime transport of chemicals, some more persistent to the marine biota than oil, has heightened the concerns for the marine environment. These factors necessitate chemical and oil spill preparedness via response and contingency planning.

An accurate prediction of oil trajectory and fate is essential for the efficient use of cleanup equipment and development of cleanup strategies. Modeling for an environmental impact assessment (EIA) or spill prevention plan involves constructing a database of the physical/ chemical properties of the chemicals or oil products present at a facility that could potentially be released, designing possible release scenarios, and running COSIM's stochastic model for probabilistic spill impact analyses.

The input modules are normally subdivided into two components: oil data and environmental data. The oil data defines the spill scenario and includes oil type and physical/chemical properties, release schedule, location and start/end times. Specification of the winds, currents, temperatures and ice (if present) over space and time constitutes the typical environmental data required. These values can be derived from other models or historical field observations. The output of the stochastic model is typically a presentation of the predicted spill's spatial extent (e.g., surface/subsurface oil) for each scenario, the mass balance segregated into the various environmental compartments (dissolved, evaporated, water surface, shoreline, etc.) as a function of time, and the probability contours. These contour plots summarize the stochastic analysis of all the release scenarios to show spatially a ranking of the likelihood of the presence of a slick or shoreline impact. Outputs are generally tailored in content and format to meet the user's need for information.



Slick location probability contours, RasGas, Qatar

CASE EXAMPLES

A list of selected relevant projects is given below.

RasGas, Qatar

At the Ras Laffan Industrial City, located in the north eastern coast of the State of Qatar, three 38" wet gas production pipelines were proposed from the North Field to the RasGas onshore processing facilities. Predictive spill modeling was performed to quantify the extent of four hypothetical accidental releases of hydrocarbons. The COSIM stochastic model was used to simulate the release of a gas bubble plume, the resulting fate between the gas and liquid phases, and the areas affected.

B-120 Oil Spill, Buzzards Bay, MA, 2003

During a Natural Resource Damage Assessment (NRDA) to assess potential impacts resulting from a release of No. 6 Fuel Oil from a fuel barge into Buzzards Bay, Massachusetts, COSIM was run on behalf of the responsible party (RP) in a cooperative assessment with NOAA. The use of COSIM for the aquatic injury assessment was performed concurrently with trustee-appointed modelers to form a consensus model, facilitating the cooperative process. The potential aquatic injuries associated with the oil's dissolved aromatic hydrocarbons in the water column and nearshore were assessed. The trustees and the responsible party were able to quickly arrive at an agreement regarding aquatic injury through the use of this consensus modeling process. COSIM was also used to aid in the evaluation of bird injury due to oiling, through comparisons of field observations with simulations of birds floating, sinking, or landing on a shoreline. This analysis was used to derive an appropriate scaling factor to estimate the number of bird injuries based on the subset of those carcasses discovered.

Photo: US Fish and Wildlife Service

M/V Stuyvesant Oil Spill, Humboldt Bay, CA

In September 1999, the Dredge *M/V Stuyvesant* released at least 2,100 gallons of Intermediate Fuel Oil 180 (IFO-180) off the coast of California near the entrance to Humboldt Bay. In the absence of field measurements of water column concentrations of oil constituents, COSIM was used to model the physical fate of the oil in the water column, in a cooperative assessment via the Trustee-RP technical working group. The best available data to calibrate the model was in the form of aerial overflights describing the locations of the surface slicks over time. These photographs were used as boundaries to confine the modeled surface slick locations to these known observations. The resulting modeled polyaromatic hydrocarbon concentrations yielded injury estimates of shrimp, anchovies, and general epipelagic fish which were used by the Trustees to request compensation via out-of-kind restoration in the form of salt marsh wetlands in Humboldt Bay.

PEPCO Oil Spill, Chalk Point, MD, 2000

In April 2000, a leak in an underground pipeline at the Potomac Electric Power Company (PEPCO) Chalk Point generating station in Aquasco, Maryland released

Photo: NOAA/ Dept. of Commerce

approximately 140,000 gallons of a mixture of No. 2 and No. 6 fuel oil. For a natural resource damage assessment, COSIM was run to estimate the dissolved concentrations of aromatic hydrocarbons that may have caused an injury to fish and shellfish in the Patuxent River. Boom deployment and failure after adverse weather conditions were recreated in COSIM. Model results were used by the RP for comparison to the Trustee's modeling efforts in quantifying the aquatic injury.

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