The SL Ross Oil Spill Fate and Behavior Model : SLROSM

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1. Model Background and Development History

Oil spill model development at SL Ross was initiated to provide professional staff with the best possible quantitative information on oil spills for contingency planning and spill response purposes. The model's strengths are in the areas of oil behavior at source and oil property change estimation. The spill trajectory component relies on the entry of best available wind and water current data. Early command line versions of the model were developed in the mid 1980s and these evolved into the current MS Windows compatible version known as SLROSM. All software development was completed and funded in-house at SL Ross Environmental Research Ltd.

2. Model Formulation

The major processes that determine the behavior of oil spilled on water are evaporation, spreading, natural dispersion into the water column and the formation of water-in-oil emulsions. These processes are interrelated and must be considered together to arrive at an accurate estimate of an oil's likely behavior. We have drawn upon the work of a number of researchers in developing our models for these processes and have added our own enhancements to deal with pour point, viscosity changes and waxy oil behavior.

Our spreading models rely on the work of Fay (1971) and Mackay et al. (1980) but include our own modifications to account for oil viscosity changes and the development of a yield stress in the oil (i.e., pour point). Longer term spreading takes into account oceanic diffusion processes according to relationships developed by Okubo (1971). Our evaporation models use the work of Stiver and Mackay (1983) with modifications developed by S.L. Ross and Mackay (1988). Natural dispersion is modelled using either Audunson's (1980) natural dispersion model modified to account for oil density, viscosity, interfacial tension and pour point or Delvigne's (1987, 1988) oil entrainment model. For emulsification we use the relationship developed by Zagorski and Mackay (1982) with modifications by Bobra (1989) and S.L. Ross and Mackay (1988).

We strongly believe that a major component of a spill model's precision lies in accurately predicting the properties of the oil over time. We perform a number of laboratory analyses on crude oil and oil products to generate the parameters necessary for our model to confidently calculate oil spill behavior. A modified ASTM distillation is completed on the fresh oil and an oil sample is weathered for a prolonged period in a wind tunnel. The distillation data and wind tunnel weathering provide the information necessary to predict the fraction of oil that will evaporate in a given time and under a specific wind history or evaporative exposure. The wind tunnel weathering also provides aged oil samples for property analysis. Oil density, viscosity, pour point, interfacial tension, flash point, and emulsification factors are determined at two temperatures for both the fresh and weathered oil samples. These analyses provide the coefficients needed to estimate oil properties and behavior at different temperatures and weathered states. The expressions used to estimate property changes with time and temperature are those given by Mackay et al. 1983.

Spills can originate from subsea pipelines or drilling operations with or without the presence of gas; from slow, long term leaks or virtually instantaneous releases of oil at the water's surface from tankers or platform operations; or, from above-sea discharges of oil and gas from a platform blowout. The characteristics of a spill source can greatly affect subsequent spill behavior. Our model can simulate all of these possible release scenarios.

Subsea blowouts with the presence of gas are modeled using Fannelop and Sjoen's (1980) algorithms. Above sea blowouts are modeled using a jet rise and droplet breakup algorithm coupled with a Gaussian dispersion and droplet fallout model patterned after Turner (1970). The initial slick areas, thicknesses and properties are determined for these various release scenarios and then the same basic oil fate models are used to predict the long term behavior of the surface oil.

Long-term, continuous oil spills are modeled using multiple slick releases. The user specifies the number of "slicklets" to use and they are discharged at equal intervals over the period of the oil release with equal volumes of oil. The behavior of each slicklet is modeled separately because the slicklets may be subjected to different wind histories depending on the their time of release, and oil property information is reported for each slick discharged.

The movement of slicks discharged in our model is determined through the vector addition of the local surface water current and 3% of the prevailing wind speed. Wind forecasts are entered by the user for each spill scenario of interest based on the best available data. Surface water currents are provided, in map form, that identify the spatial variation in the water velocities. If surface water currents vary with time, such as in a tidal situation, a number of map sets can be used to represent the variation. The model is given a "schedule" of the time histories for the use of the appropriate map at a given time in the life of the spill.

An option also exists to enter a pre-defined spill trajectory and bypass the internal trajectory calculations. This is useful if it is desirable to use another model's trajectory prediction with our oil behavior models. If the slick moves beyond the last pre-defined trajectory point, the model returns to the use of the winds and surface water currents to predict the remaining movement. This is useful in a spill situation where information on the actual movement of the slick is available and the user wants to force the model to follow the actual path of the oil during model updates.

3. Provision for Supporting Environmental Data

SLROSM uses an internal raster format to store the land, water current and shoreline type mapping. The base map files are generated from simple, uncompressed raster files that can be exported from most GIS packages. Spatial water current data are also converted to a raster format for use in the model. Water currents are entered into the system either through direct on-screen entry and built-in interpolation software or by importing the data from standard GIS raster file formats. Editing tools are provided in the model to generate shoreline corridors on the land mapping. These corridors can be classified according to oil retention capability for shoreline smearing estimates. Basic GIS functions such as map zooming, distance measurement, text labelling, scale bar placement and map recoloring are included.

Wind data are provided by the user in a series of magnitude, direction and duration entries or via historical wind records that can be both spatially and temporally varying.

A videotape management system is also built into the model. The user selects a location on the shoreline and the system automatically identifies the appropriate video clip for that portion of the shore, advances the media to that location and plays the video record either on-screen or on a television set.

The model does not presently support a detailed biological data base system but resource symbols and labels can be entered via the text entry system to identify important resource areas. The model does not support biological or economic impact assessments.

4. Model Inputs and Outputs

4.1 Model Inputs

The model operates on a spill scenario basis. The input parameters for each spill scenario are entered via a series of data input dialogs. Figure 1 shows the summary dialog for the scenario data entry. The spilled oil type, wind data, water current data, spill location, type of spill (batch or blowout, etc.), oil volume and leak rate parameters, time dependent inputs (such as spill duration and data output interval), environmental conditions (air and water temperature) and countermeasures operations descriptions can all be entered via this dialog. Within each of these data categories several options exist for the specification of the spill scenario's characteristics.

4.2 Model Output

Because model users are usually interested in different aspects of a spill prediction SLROSM offers complete freedom in selecting output data. The user selects the data of interest from over 30 available choices and the units that are to be used in their presentation. An output table is generated that contains the information requested and can be printed for direct inclusion into reports. This data can also be accessed on screen through a query function that permits the user to see oil property information for a slick at a specific time and position in its history. This is very useful for quickly determining whether or not the properties (e.g., viscosity) of a particular slick make it amenable to countermeasures.

SLROSM can provide as a function of time: areas, thicknesses and volumes, for both the thin and thick slick portions; viscosity, density, pour point and water content of any emulsions that may form; the volumes and percentages of the thick and thin slick portions that evaporate and disperse; and the maximum possible in-water oil concentration as a result of natural or chemically induced dispersion. Figure 2 shows a complete list of the information that the model can output. Figure 3 shows the model's main menu layout and an example spill trajectory.

5. Model Validation History

As previously mentioned, the strength of SLROSM lies in the prediction of oil property change as a function of environmental exposure and the use of these oil properties to estimate the longevity of an oil slick. Unfortunately, adequate information is seldom collected or published from actual oil spill events to properly validate this aspect of spill models. The few cases that we have used to validate the fate components of SLROSM are described below.

Data from the Ekofisk Bravo blowout, the Halifax dispersant application trials and the Manuk Island diesel spill have been used to validate Audunson's natural dispersion algorithm. Published data from the *Exxon* Valdez spill has been used to verify the evaporation and emulsification algorithms. Information from the Uniacke condensate blowout off Canada's east coast has been used to verify the above sea fallout and natural dispersion components of the model. The Ixtoc sub sea blowout data has been used to validate SLROSM's estimates of initial slick conditions from a sub sea gas and oil release.

Our confidence in the ability of the model to accurately estimate evaporation rate and oil property change is increased dramatically for those oils that have undergone a detailed oil weathering and property analysis in our own laboratory, or when an equivalent series of test results is available from other sources. By weathering an oil in our wind tunnel and measuring its physical properties and emulsification tendency and stability at various weathered states we can collect the oil specific parameters that the model needs to accurately predict oil property change under various environmental exposures. When educated guesses or estimates are made for some of the parameters oil property change prediction is much less certain.

SLROSM relies on user entered wind and water current information. The model's trajectory predictions are therefore only as good as the input data used. Validation of the model's trajectory component can only be accomplished on a case-by-case basis where it is the quality of the input data that is validated more so than the model itself.

6. Current User Community

Our intent from the outset was to develop a model for internal use to develop and assess oil spill fate and behavior scenarios for use in contingency and spill response planning. The model's functionality and ease of use progressed to the point where it also became a useful tool for those clients interested in completing their own spill modeling. The U.S. firm, Ship Analytics, has incorporated SLROSM into their computerized ship handling and training system to provide an oil spill response training component to their clients.

SLROSM is currently in use by private oil companies, consulting engineering firms, research institutions and government agencies around the world.

7. Future Model Development Plans

Future development of the model will focus on the updating the oil spill behavior algorithms as new data and models become available. Areas of particular interest are improved emulsification and natural dispersion algorithms as these are currently the weakest components of all oil spill fate and behavior models. We will also continue to develop detailed fresh and weathered oil property information that is essential to the confident prediction of oil evaporation, property change, and, ultimately, the fate of an oil slick.

8. References

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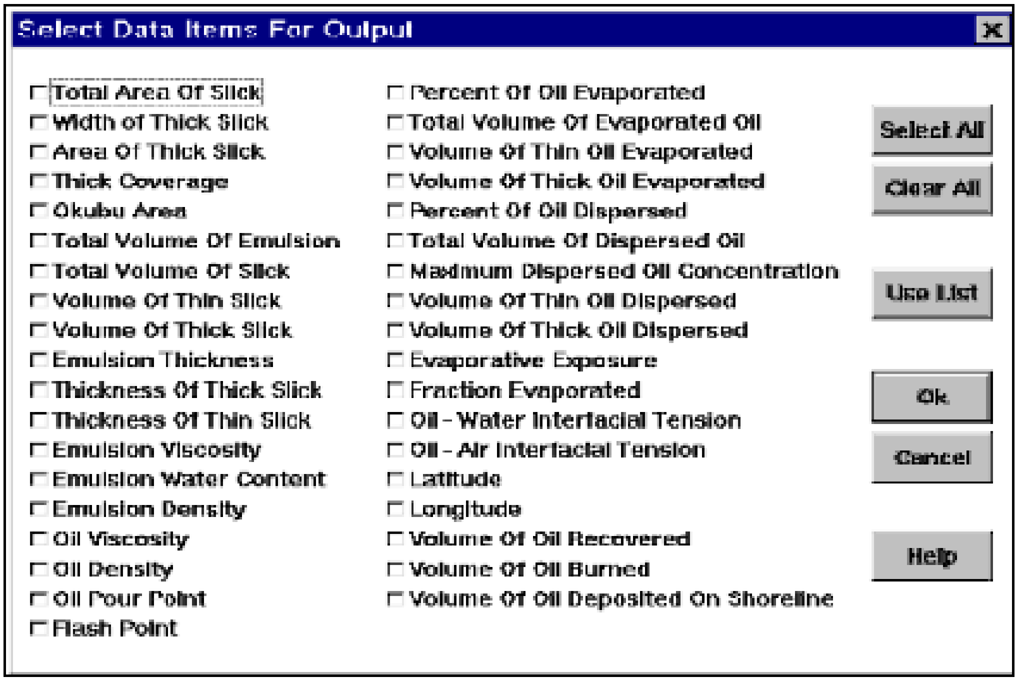

Figure 1 Spill Scenario Data Input Summary Dialog

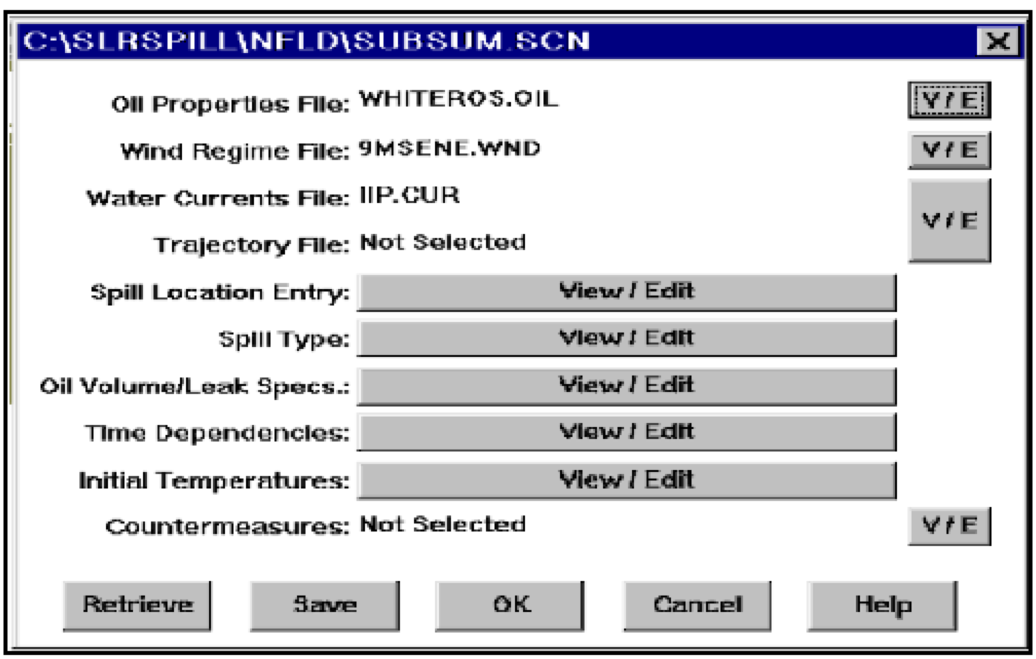

Figure 2 SLROSM Data Output Options

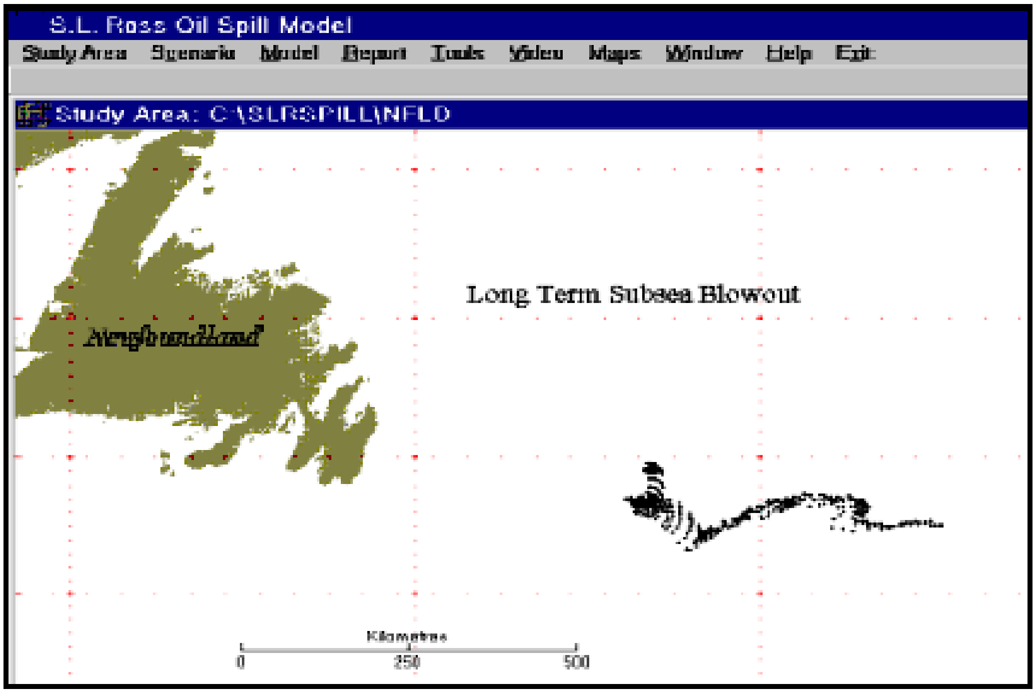

Figure 3 Main Dialog of SLROSM