Strategies for Oil Spill Planning Modeling

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Executive Summary

Oil spill modeling for contingency planning is a common means of assessing the potential risks from oil spills related to new projects and facilities. Stochastic oil spill modeling is a powerful tool to provide these risk insights. Stochastic modeling typically utilizes hydrodynamic data for the location in combination with historic wind data. The models will run 100-250 iterations utilizing the data that are most relevant to the season or timing of the project. The scenarios that are evaluated should represent a cross section of the potential releases associated with the project. These should range from the higher probability low-volume operational releases to low probability worst case discharges, e.g. blowouts. The stochastic data are typically processed to produce a water-surface probability footprint, a water-surface timing footprint, and a shoreline oiling probability footprint. These probability footprints are used to provide two primary pieces of information for the project:

- In the event of a spill, where is oil expected to go
- In the event of a spill, what is the timing of the oil's travel

These two pieces of information help oil spill responders understand what resources require protection and how much time is available to respond prior to impact of the oil.

In performing stochastic analyses, it is important to understand the significance of the stochastic footprints relative to the footprint of one individual spill. Regulators who do not have an understanding of the modeling tools may easily misinterpret this information, e.g. size of the footprint. In order to prevent misinterpretation, the stochastic results are often paired with a single deterministic trajectory. These single trajectories can be selected based on a number of variables, e.g. least time to shoreline impact, or maximum water surface oiling. Interpretation issues may be further complicated by the set-up of the models. Many modeling tools provide the ability to adjust a slick trajectory for its' predicted thickness. The thickness limits can be established based upon a wide range. This can be from barely visible sheens to oil that is sufficiently thick to be the focus of cleanup.

These modeling variables are the focus of this paper. The individuals that are responsible for oil spill contingency planning must be aware of modeling setup alternatives and how they can dramatically change the evaluation of results. In order for the analytical modeling process to produce the most value for oil spill preparedness and response, a complete understanding of the modeling outputs is required.

Stochastic Modeling

Stochastic oil spill modeling is generally utilized in facility or project oil spill response planning. The first goal of response modeling is to determine where oil is expected to travel either by season or during the period of exploration drilling or production development. The second goal of the response modeling is to determine how long it will take for the oil to reach various locations or resources under typical ambient conditions. The spill scenarios that are modeled in this phase of oil spill planning should represent a cross section of the project's risk assessment. The scenarios should range from higher probability, low volume operational events to low probability, high volume and worst case drilling releases such as blow-outs. The ultimate goal of this modeling is to provide responders with an idea of what resources are potentially at risk and the amount of time available to protect those resources or perform on-water response to protect those resources.

Stochastic modeling utilizes the anticipated volumes of oil released under a variety of risk scenarios and then models those releases utilizing hydrodynamic data for the location in combination with historic winds for the area. The model will run a specified number of spill iterations that often ranges from 100-250. The model will select a random start time from within the period or season of interest, for each iteration, and select the wind and hydrodynamic records beginning with that start time. The end result is an overlay of 100-250 oil spill trajectories each with the randomly selected start time.

The model will then post-process these data by identifying the model grid blocks that contain oil at some time in the spill iterations that were examined. These grid blocks form the basis of the probabilistic analysis. Each grid block is examined to determine how many times that block has been oiled during the 100-250 iterations and contours are drawn according to the number of times that oil appears/the total number of model runs. The proportions are then lumped and contours are drawn according to the legend. The result is a series of probability contours around the spill source. An example predicting the probability of oil on the water surface is presented in Figure 1.

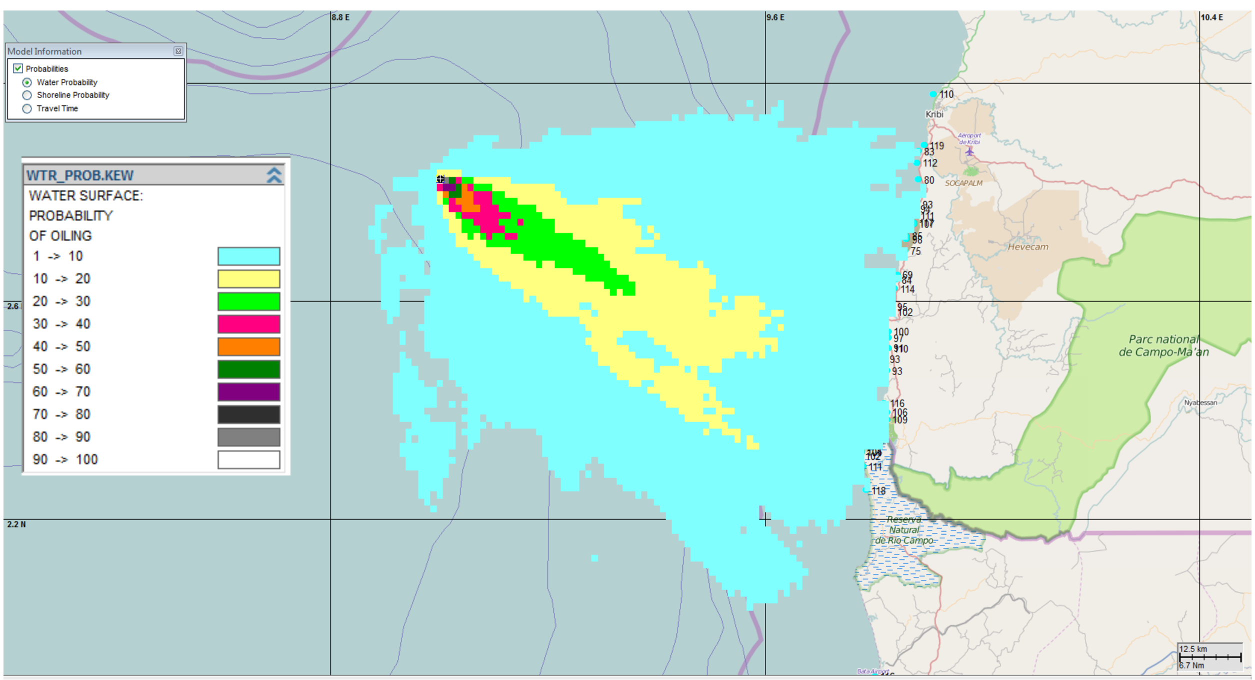


Figure 1 - Example of stochastic analysis showing probability of oil on water surface

This figure presents information that the most probable direction of travel from the spill source is to the Southeast. The figure also presents the areas of shoreline that are most likely to be impacted given the prevailing hydrodynamic and wind data utilized in the modeling. The numeric values on the shoreline represent the time in hours to stranding. This shoreline information is valuable in identifying those coastal areas that have the highest vulnerability to spilled oil stranding. This can be utilized to prioritize shoreline protection strategies.

The model utilizes the same data from the trajectory iterations and post-processes it to present the timing of oil travel. In this instance the grid blocks are identified and contours presented by day. Figure 2 presents the timing of oil trajectory movement for the scenario presented in Figure 1. This particular model run was analyzed for five days so that is the time limit for oil movement.

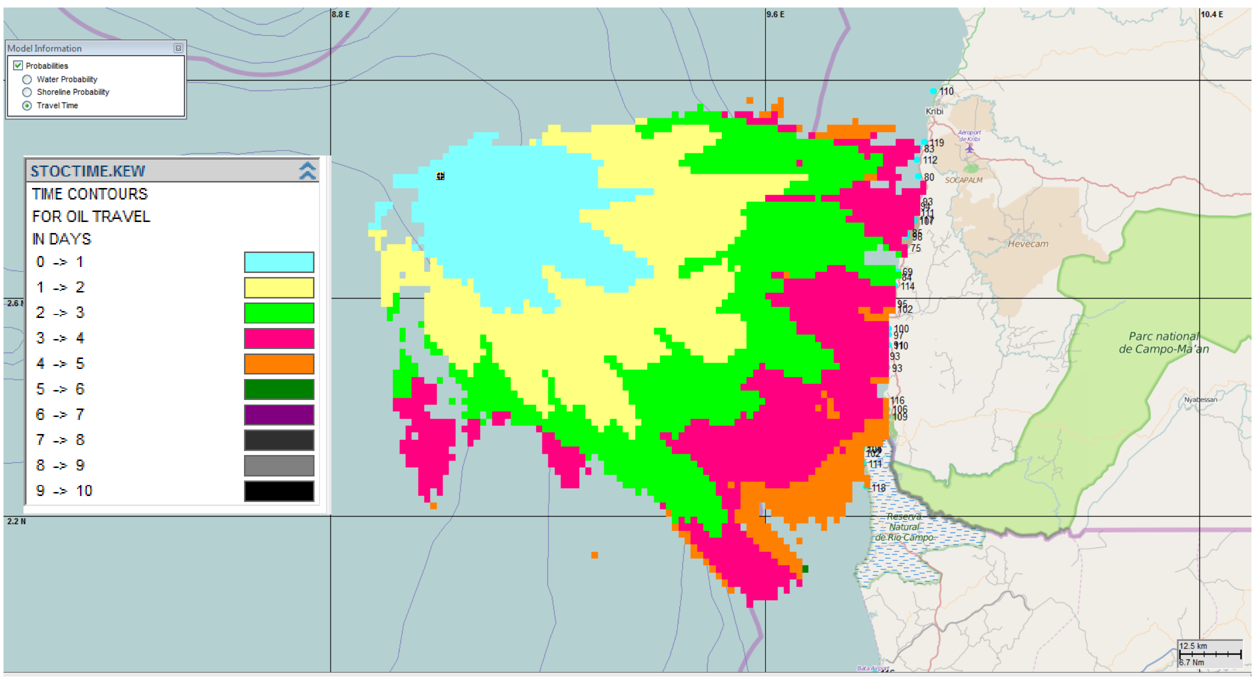


Figure 2 – Time contours for oil travel in days

The examples presented in Figure 1 and 2 represent very low oil thickness thresholds, e.g. 0.040um. Oil slicks >0.040um and <100um are sheens and would not be the primary focus of mechanical or chemical spill response. The volume of oil represented by these sheens is quite low. These slicks are short lived; they further thin with time, and present a low probability of producing environmental damage. The slick thickness that is typically the focus of a mechanical or chemical cleanup is dark color oil >200 um. The ideal thicknesses targeted for cleanup are far thicker, so if that threshold is the focus of the modeling effort, the footprint of the stochastic analysis will be far different. Thinner oil thickness thresholds produce larger slick footprints in stochastic analyses. Thicker oil thickness thresholds produce smaller slick footprints. Thickness thresholds along with the corresponding visual appearance were established internationally in the Bonn Convention. This information is presented in Figure 3. The appearance and thickness are supplemented with information regarding the volume that is represented by an area with a homogenous slick of that thickness.

Code	Description	Layer-Thickness Interval		Concentration	
		microns (μm)	inches (in.)	m^3 per Km^2	bbl/acre
S	Sheen (silver/gray)	0.04 – 0.30	1.6×10^{-6} – 1.2×10^{-5}	0.04 – 0.30	1×10^{-3} – 7.8×10^{-3}
R	Rainbow	0.30 – 5.0	1.2×10^{-5} – 2.0×10^{-4}	0.30 – 5.0	7.8×10^{-3} – 1.28×10^{-1}
M	Metallic	5.0 – 50	2.0×10^{-4} – 2.0×10^{-3}	5.0 – 50	1.28×10^{-1} – 1.28
T	Transitional Dark (or True) Color	50 – 200	2.0×10^{-3} – 8×10^{-3}	50 – 200	1.28 – 5.1
D	Dark (or True) Color	>200	$> 8 \times 10^{-3}$	>200	> 5.1
E	Emulsified	Thickness range is very similar to dark oil.			

Chart from Bonn Agreement Oil Appearance Code (BAOAC) May 02, 2006, modified by A. Allen.

Figure 3 – Visual oil description and slick thickness

In order to examine the difference in stochastic footprint when different thickness thresholds are considered, models were run with thickness thresholds of 0.4um, representing very thin rainbow sheen (Figure 5), and 100 um, representing the transition to dark oil (Figure 6). A comparison of the two figures indicates that the thinner threshold produces a footprint that is significantly larger that the footprint of the thicker threshold. The two scenarios otherwise utilized identical data for historical hydrodynamics and winds. These scenarios examined the footprint of 10,000 BBL of fuel oil, released over 6 hours, during January through December. The point of this comparison is that the footprint can change dramatically depending upon the desired minimum thickness threshold. When preparing a statistical analysis for submission to a regulatory body in an oil spill contingency plan, it is important to understand this difference and select a threshold that meets the regulatory requirements and the needs to plan for an appropriate on-water oil spill response.

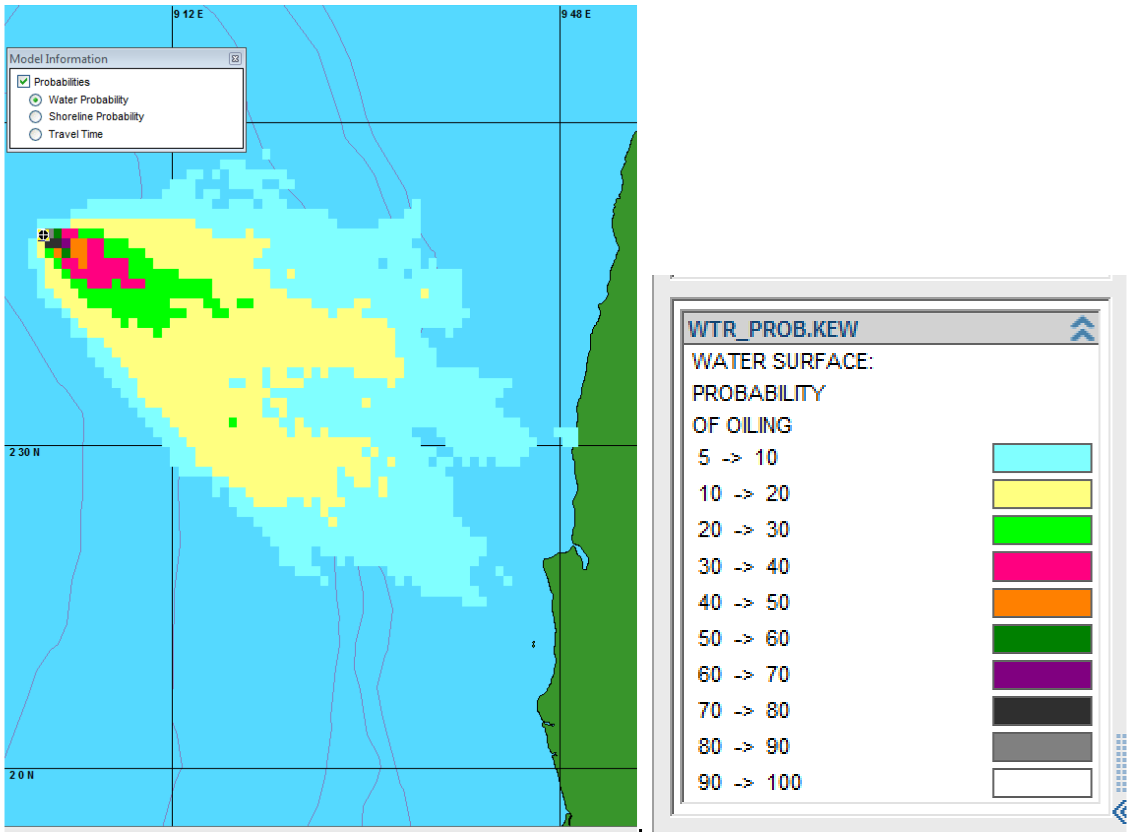


Figure 5 – Stochastic footprint with minimum thickness of 0.40 um

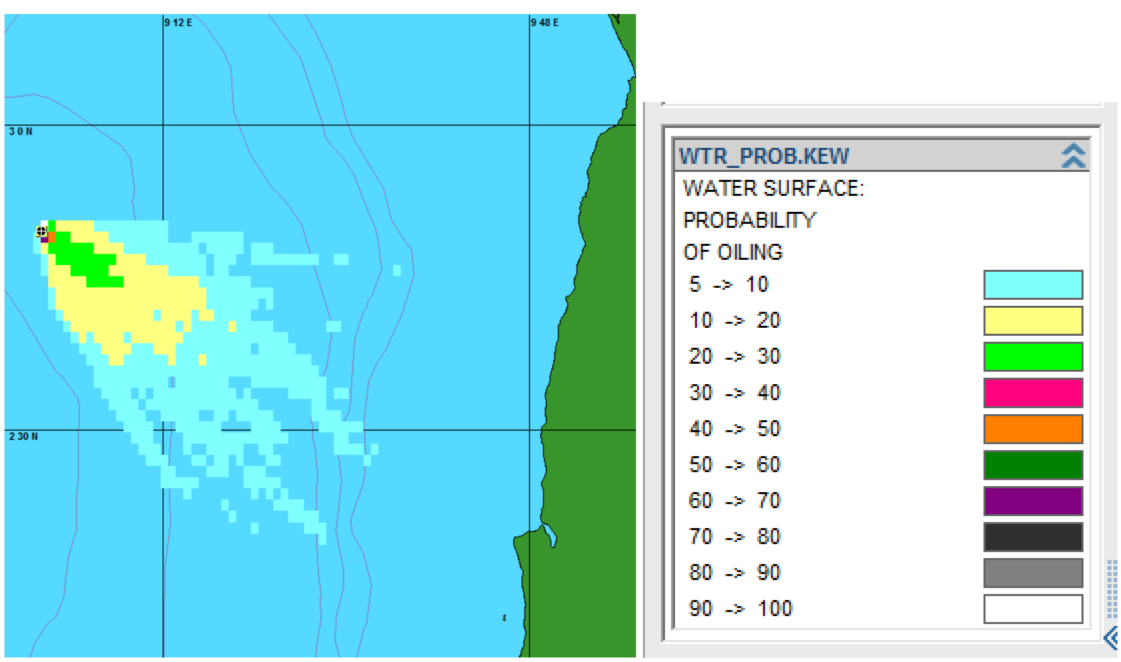


Figure 6 – Stochastic footprint with minimum thickness of 100 um

Deterministic Modeling

Deterministic modeling is the predictive modeling of a single incident. As noted earlier, stochastic models are generally paired with a single deterministic model in order to put the large stochastic footprint into perspective. This deterministic analysis is generally a single run selected from the stochastic analysis and serves as the basis for developing the plans and equipment needs for a realistic spill response. The deterministic scenario may be selected from the stochastic iterations based upon a variety of parameters. Several that might typically be considered are:

- Minimum time to shoreline stranding
- Maximum water surface oiling
- Maximum shoreline contamination

While the modeling in support of a contingency plan is designed to be conservative, the selection of the minimum time to shoreline stranding scenario might preclude any response prior to shoreline impact based upon timing or other aspects of the scenario. Again, it is important in the design of the modeling process to utilize the information that would best benefit the regulatory understanding of the modeling of oil spill risk in conjunction with the information that is most valuable in the development of the Oil Spill Response Contingency Plan.

Fortunately, the stochastic model runs can be analyzed to provide information that can help select the deterministic run that best serves the needs of the modeling analysis. Figures 7 through 10 demonstrate the examination of stochastic analyses that were run for a worst case spill on a seasonal basis. It should be noted that this analysis is not the same as presented previously. 100 Spills were simulated using a stochastic model and the values for the time required for oil from each trajectory to reach the shoreline were plotted in rank order. The plots can be utilized to identify the single spill that represents the worst case (1st Percentile), median (50th percentile, or maximum (say 95th percentile) spill event.

Figure 7 - Winter Season Stochastic Analysis

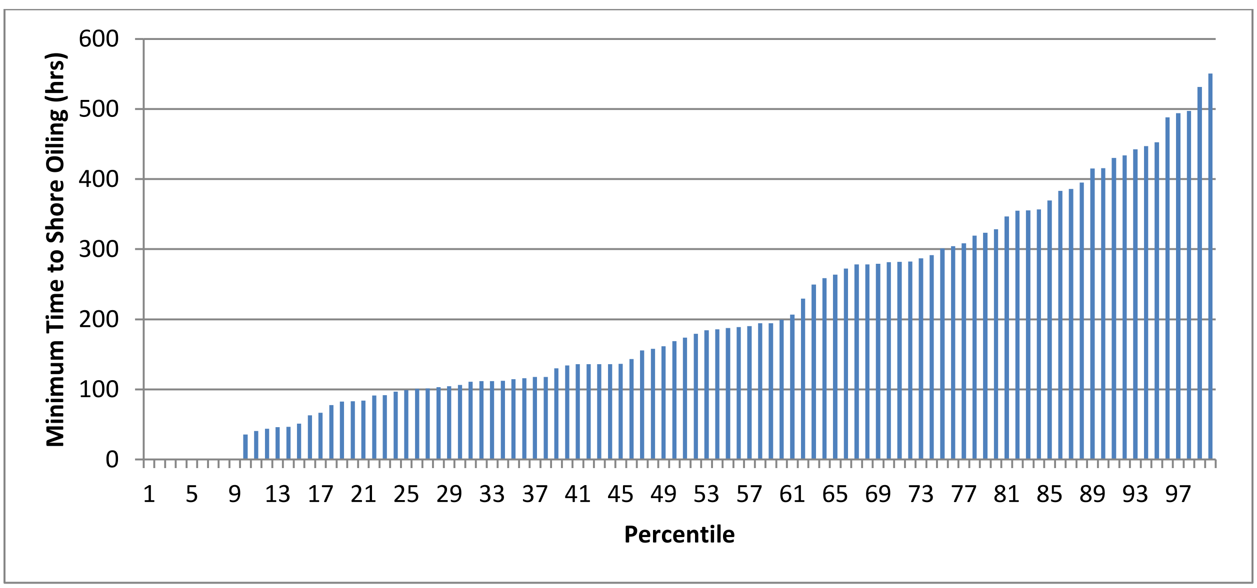


Figure 8 - Spring Season Stochastic Analysis

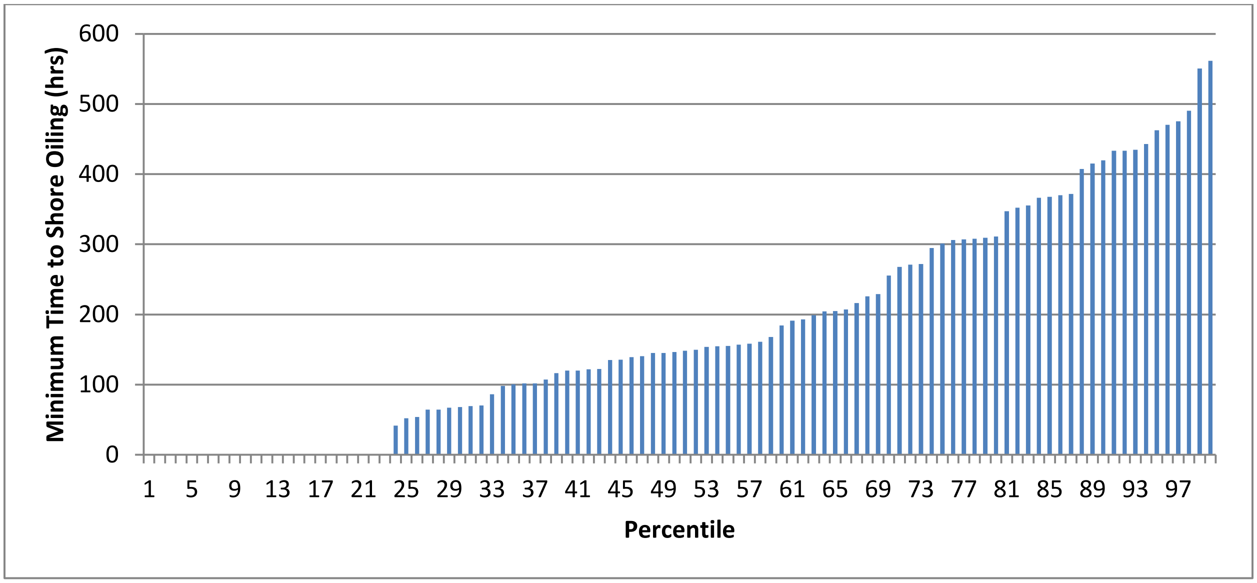


Figure 9 - Summer Season Stochastic Analysis

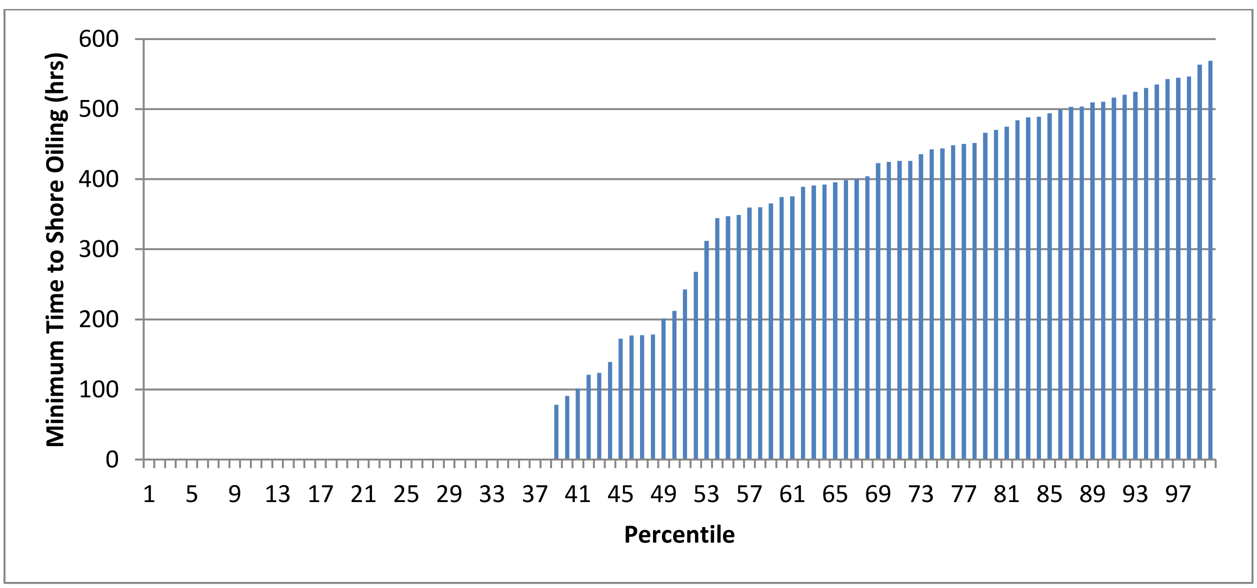
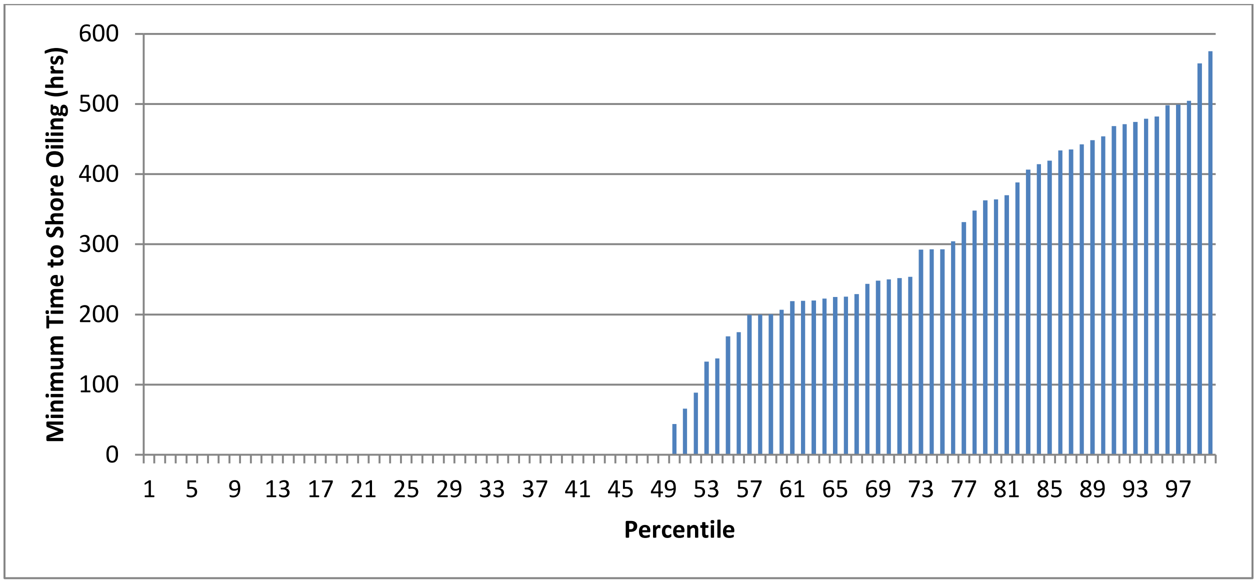


Figure 10 - Fall Season Stochastic Analysis



The analysis of this particular release scenario indicates that the minimum time for an oil slick from any season to reach the shoreline is approximately 50 hours during the winter season. This analysis also indicates that in about 50% of the scenarios during the Fall Season, the slick never produces shoreline impact. In the spring and Summer Seasons approximately 25-40% of the scenarios never produce shoreline impact. In those scenarios that do produce shoreline impact, the minimum time to shoreline impact often exceeds 100 hours. This type of information is quite valuable for both regulators and oil spill responders. It provides and understanding of the risk of shoreline impact and allows the design of an offshore response that can minimize those risks.

Summary

Oil spill modeling is an invaluable tool for the analysis of spills that represent the risk from a project. Insights into the probability of shoreline oiling and timing of shoreline impacts are particularly valuable for both regulators and responders. While modeling analyses are generally conservative in nature, it is important to understand the extent the conservative aspects utilized in the modeling. Consideration must be given to whether the use of barely visible oil thicknesses or other available parameters benefit either the regulatory review of the oil spill response plan or the development of response tactics and equipment presented in those plans. Model analyses can be utilized to further understand the difference in shoreline stranding risk during different seasons of the year. This allows the selection of a variety of different endpoints in the selection of deterministic modeling analyses that will represent individual spill events and furthermore provide the basis for the development of response tactics and equipment. Large oil spill events are rare events (10^{-5}) and present a very low probability of happening. Given that low probability, decisions must be made regarding whether the presentation of extremely rare events identified by modeling, e.g. shortest time to shoreline stranding, are appropriate.