# HALLIBURTON | Landmark

# Permedia™ Software Risking

## Evaluating risk in upstream exploration

Running a successful upstream operation requires evaluating risk. When modeling migration trajectories or petroleum emplacement in basin and reservoir scale models, you have to account for the uncertainties inherent in the petroleum system models in terms of both rock and fluid properties. The best way to do this is to vary your input parameters using probability distributions and run multiple realizations, sampling and evaluating the impact of your uncertainties. The more realizations the better.

This is often a brute force endeavor – you simply need to run enough realizations for an adequate sample size, and then somehow collate the results into something meaningful. To do it effectively, you need a simulator that is fast enough to run multiple realizations in a reasonable time frame and some means to qualify the results against observed data. Ideally, the mechanism for varying the input parameters, as well as evaluating the results is straightforward and easy to use. Permedia™ software qualifies on all counts.

Because the Permedia simulators run so fast, decisions can be based on multiple realizations from multiple scenarios. Permedia software includes built-in risking capabilities to generate and rank hundreds of realizations and combine them into probability maps and volumes to reveal commonalities and evaluate risk. And you can compare the results with observed data to rank model results.

## Applying uncertainty

Permedia software is designed from the ground up to consider the uncertainties that exist in any modeling regime. When building your model, you can enter petrophysical data as probability curves rather than discrete values. This allows you to base simulation results on a range of user-defined scenarios, better reflecting the reality of geological data collection.

Using Permedia Risk Editor, you can apply distributions to virtually any input value in a modeling scenario. For example, you can apply a triangular distribution to a source volume multiplier in a Migration scenario. The initial input value is used as the mean value for the new distribution.
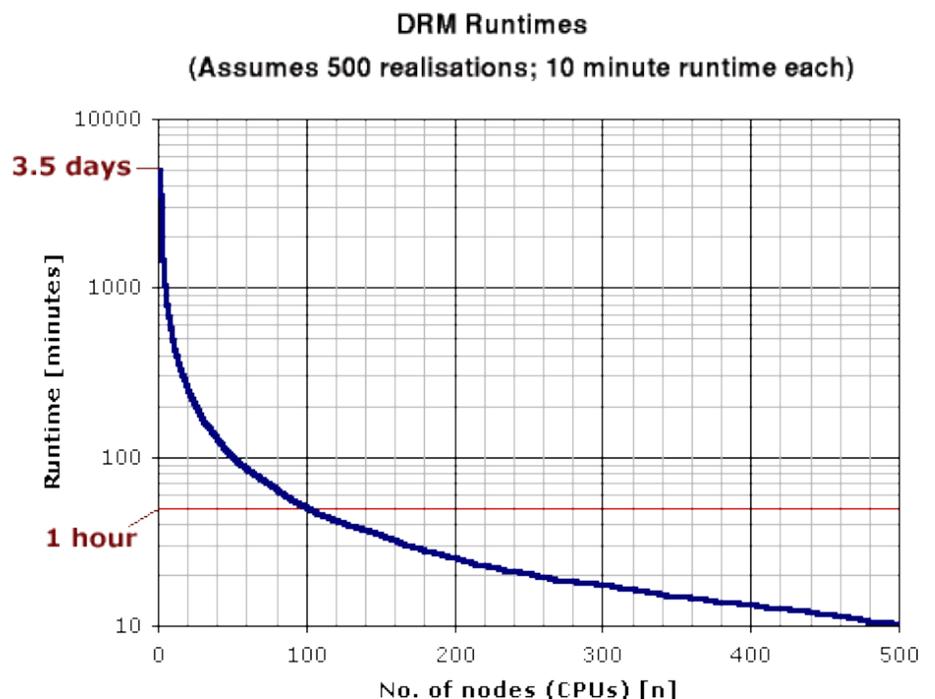
## Generating realizations

Generating the multiple realizations is easy using Permedia Batch Manager, a batch manager for running simulations. Since Permedia migration simulations run so quickly (e.g., 300,000 gridcells in under 15 seconds), Batch Manager can generate hundreds of separate realizations for analysis.

## Distributing the load

Batch Manager can run realizations across multiple processors and cores, to execute multiple realizations concurrently. This is a very powerful tool to help constrain cases where large uncertainties exist in the input parameters, typical for any exploration scenario.

Although a single realization of a single scenario will usually execute in under ten minutes, multiple realizations executed across multiple scenarios can quickly escalate execution times if each realization is run sequentially. For example, 500 realizations at 10 minutes apiece would take 3 days and 11 hours to complete.

But running Batch Manager on a single workstation with multiple 4- or 8-core processors can reduce that three day processing time dramatically: short enough for an overnight run. Imagine basing decisions on the results of 500 realizations rather than one or two.
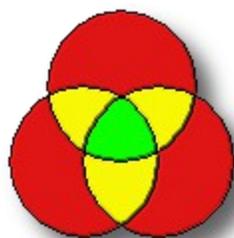


**DRM Runtimes**
(Assumes 500 realisations; 10 minute runtime each)
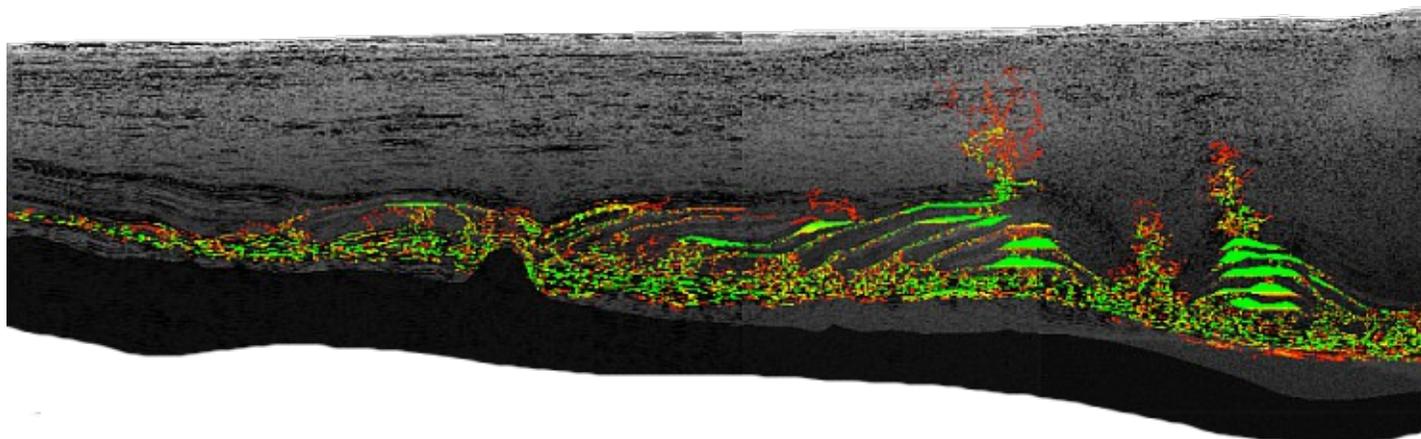
**Basin scale analysis: basin model from PetroMod; colors represent charge frequency – green cells saw petroleum in all realizations, red in only one**
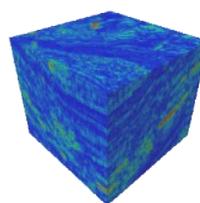
## Evaluating results

Permedia software includes reporting and analysis tools that make it easy to quantify and display low and high probability charge risks. Permedia Risk Analysis combines the results of a series of migration simulation realizations into an overall probability map or volume. For instance, to examine the effect on petroleum migration of the detailed structure of a particular model, a series of realizations can be performed in which the parameter varied is the random number seed value used to convert the user-specified probability distributions into cell attributes. These are then combined by Risk Analysis into a probability set (2D/3D) that reveals the commonalities between the realizations.



- Reservoir fluid emplacement
- Where would the petroleum be in the rock volume assuming petroleum migration occurred?



P0          P25          P90

**Charge frequencies; green cells saw petroleum in all 20 realizations**
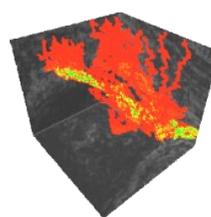


To demonstrate how this works, consider three realizations, each represented by a circle. If we run a single realization, then the probability of charging a given gridcell in the model is 100% for all charged gridcells (represented in green). If we run two realizations, some cells will be charged uniquely in a single realization, but a subset will be common to both. If we run three, then some will be unique to one (red), shared between two (yellow), and possibly shared between all three (green).

The following figure shows P0, P25, and P90 cases for a reservoir-scale analysis: a seismic property-based model was "filled" with petroleum by injection on one of the lateral boundaries and run 20 times.
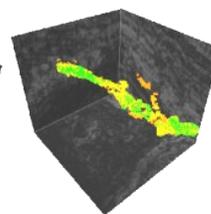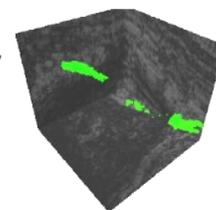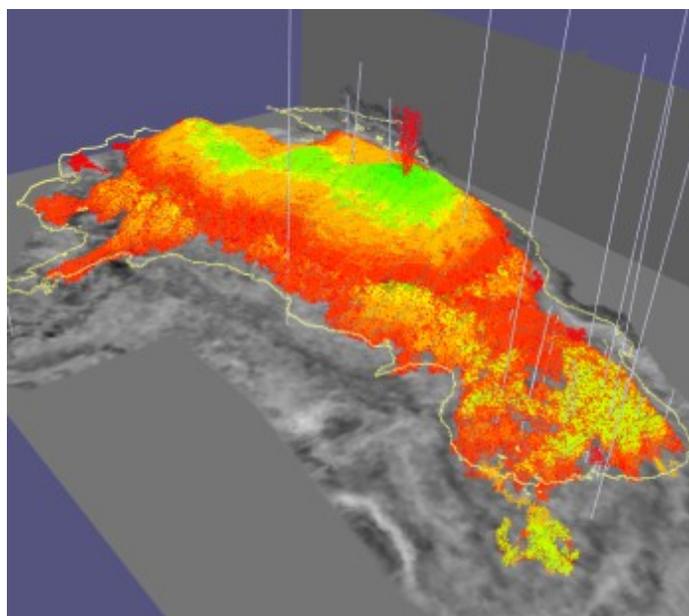


**Composite results from several reservoir filling scenarios. Assumptions on input petrophysics and charge points were varied between runs. Colors represent frequency of petroleum presence across scenarios**

# Correlating results with real world data

Permedia Correlation is used to compare migration simulation results with a set of objective data, such as well data and volumes. By comparing the results of each realization with the distribution of known petroleum accumulations or hydrocarbon indicators, you can discard models that fail to match, and focus on realizations that are most likely to correctly predict the location of new accumulations.

Correlation identifies degrees of spatial correlation and covariance between modeled and observed data, and ranks the results using various measures of "goodness-of-fit." To compare two datasets, simply select a set of objectives and modeled data, then specify the data variable from each set to use as the basis for comparison.

The variables being compared don't have to be exactly the same: Correlation determines whether they are spatially coincident within a specified distance tolerance. As the odds of an exact match between the point set in the simulation results and the point set in a well file are essentially zero, you can enter the spatial tolerance, called the Search radius. Points falling outside of this radius are disqualified. For optimal results, the Search radius should be at least 1.5-2.5 times the cell size of your model in the largest dimension. For example, if your model has cell sizes of dx = 2, dy = 3, and dz = 5 (in meters), the Search radius should be at least 10m.

Correlation results are colored using a "traffic" color scale (green = good, red = bad) to provide a quick visual assessment of rank.



**Correlation results: simulation results ranked according to goodness-of-fit with three wells**

As the results can potentially be presented and summarized in many different ways, the results table can be opened in Permedia Table Editor, where you can format and present the data in whatever way you feel appropriate, or export it to an external package.