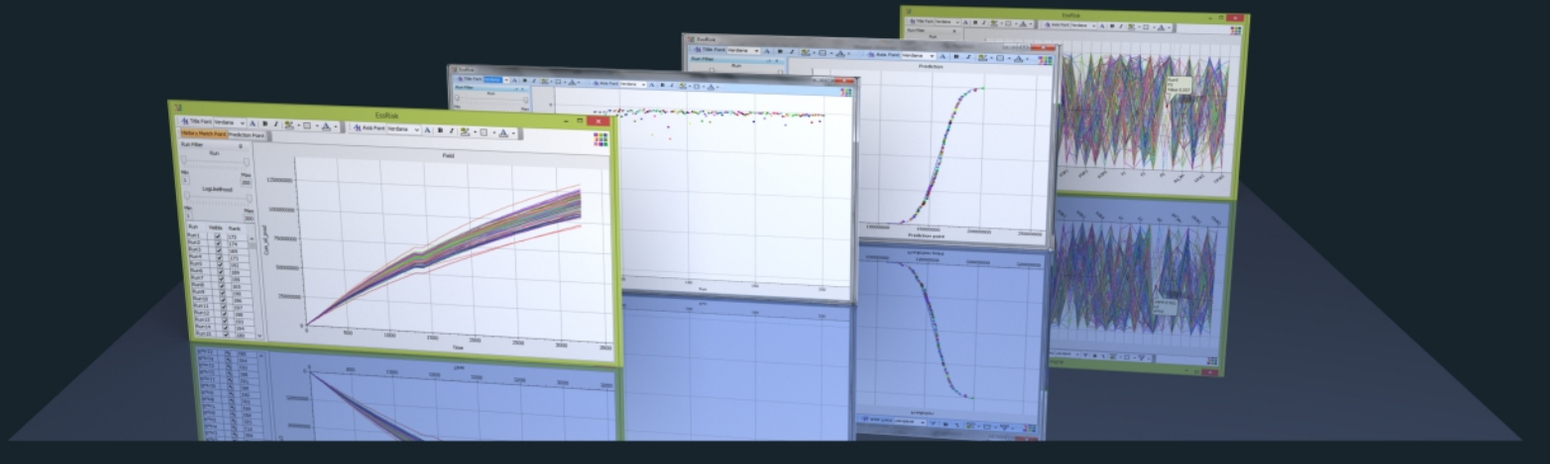
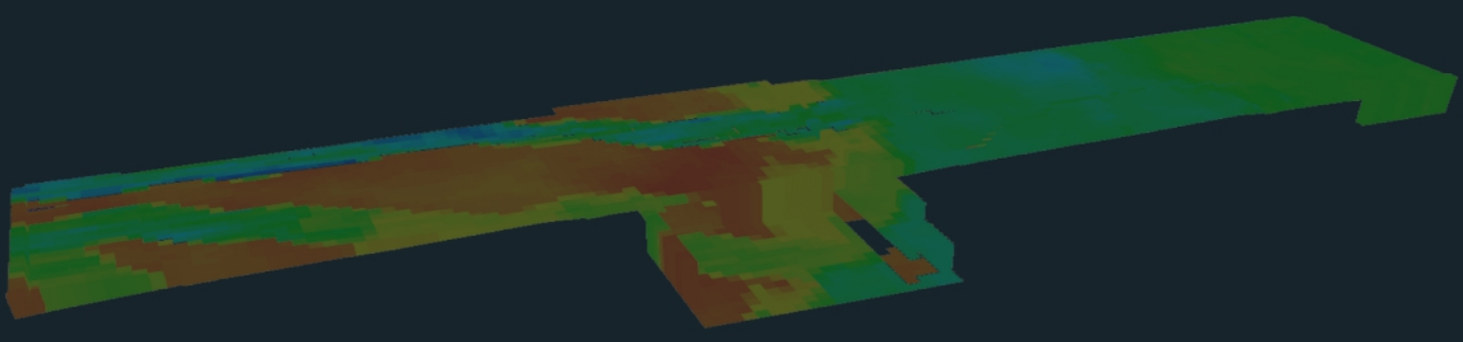
essence

Managing Uncertainty





EssRisk

What is EssRisk?

EssRisk is a software tool used by reservoir engineers to streamline their work and help them optimize field development and increase daily production. It's an ideal cost reduction, field development, optimization and production enhancement solution.

Why do engineers do reservoir simulation?

The purpose of reservoir simulation history matching is not to find a history match. Rather, simulation studies should be aimed at:

- Understanding the reservoir asset value
- Quantifies the uncertainty in those assets
- Making optimal investment or divestment decisions
- Making operational decisions (day to day operations, well designs and placement, workover strategies, EOR strategies)

How does EssRisk help?

EssRisk is a complete decision making tool for reservoir simulation. It maximises the productivity of the engineer, guides them to a robust set of solutions, and provides a valid, realistic uncertainty profile. It does this using a minimal set of simulation runs, without needing large computer clusters or many simulation licenses. It performs the following tasks:

- Appraisal (or greenfield) uncertainty analysis
- History matching and prediction uncertainty
- Optimisation of a given geological model
- Optimisation under uncertainty

Productivity

Studies have shown that history match studies with proxy-based tools can be completed in less than a third of the time compared with traditional manual approaches or less sophisticated tools. Moreover, rather than produce a single history match, a valid probabilistic ensemble of history matches is generated.

Why do you claim EssRisk is the first valid uncertainty tool?

EssRisk is the result of many decades of research, in both the oil industry and outside. The founders of EssencePS have a long history within this area. EssRisk is the first tool which uses valid Markov Chain Monte Carlo techniques which have recently emerged from Bayesian probability research institutes, used in areas from social analysis to medical biostatistics. Previous tools used throughout the oil industry use techniques which generally underestimate uncertainty, and introduce bias in the forecasts.

Implementation

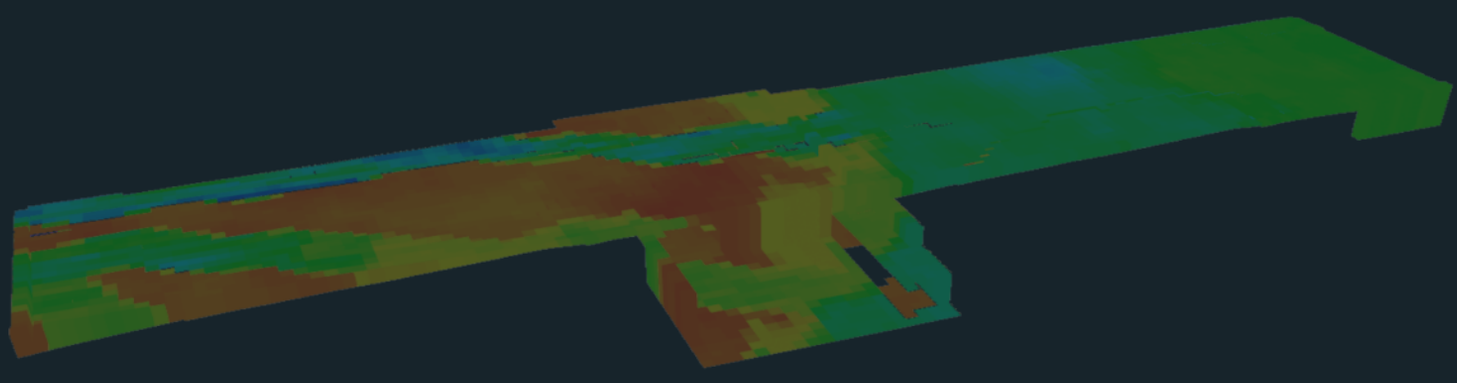
EssRisk takes advantage of emerging application product trends. It is high value/low cost, deployment is easy (it is 100% pure Java), and the user interface uses the latest approaches (for example JavaFX) designed for multiple platforms from desktops to mobile phones

Open philosophy

EssRisk is designed to work with other third party tools, and has its own growing internal library of functions or scripts that is open to all users.

It has proprietary internal pre and post processing languages. These are used to help manipulate the simulation deck and produce derived results (such as NPV). These are implemented and executed entirely within EssRisk, without recourse to external complex languages, facilitating ease of use.

In addition, EssRisk can interface to geomodelling tools, such as Petrel or RMS, to manipulate the geomodel directly and provide a fully integrated 'big loop' workflow. The founders of EssencePS were the first to implement this workflow for reservoir engineers.



Evergreen Reservoirs

Costs, productivity and reservoir studies

This service, a collaboration between EssencePS and Dinova Petroleum, provides a major improvement in business workflows and management of reservoirs, resulting in optimised performance, reduced costs and mitigated risks.

Subscription service

Instead of one-off reservoir studies, which are irregular and can take months to negotiate and complete, the Evergreen service is subscription based, and for an annual fee the history match and production uncertainty is regularly updated and available, so that decisions can be made in a timely manner based on up to date information.

Evergreen fields

Traditional reservoir studies are carried out as discrete studies, with limited continuity of engineers, data or knowledge. With modern tools, engineers can now perform history matching or uncertainty studies in days. This allows the reservoir studies to be performed as a continuous process, with the models and uncertainties updated each time new information is obtained.

We propose a service which facilitates this continual process, with a commitment over a period of time and continual updating of models and conclusions.

Timely intervention

With a continuous process, rapid revisions of forecasts are possible, and timely intervention becomes a reality. This keeps the decision makers, geomodellers and reservoir engineers in step, and the decision makers always have available up to date reservoir analysis.

Investment decisions

An evergreen model allows rapid decisions on investments or divestments, taking into account changes in economic conditions or approaches from competitors.

Unexpected events

Whenever there is an unexpected event in the field:

- water breakthrough
- GOR increase
- Well Shut down or lost
- compressor shut down
- pump failure (producer or injector)

The production engineer is left to make his own decisions on how to react, without much knowledge of the consequences. With an evergreen model, the reservoir engineer can provide optimized recommendations on the best way forward, or until the breakdown is repaired.

Value of information

In many companies there is no standard protocol for managing information from reservoir studies. Where an individual engineer moves job or project, the knowledge and data can become lost.

We propose to manage the necessary information so that access to the official models is always available.

Reduced costs

The Evergreen service can provide an ensemble of uncertainty cases at any time, and is particularly useful for auditors and stake holders, avoiding the need for expensive studies.

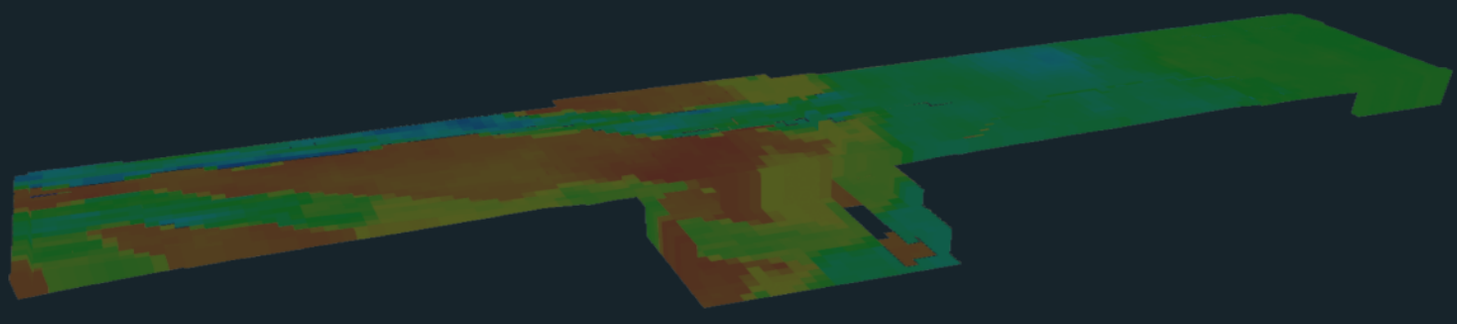
It also reduces time spent preparing budgets, and helps decision makers to balance risks and rewards in a more comprehensive way.

Increased production

Rapid decision can be made on:

- reallocation of gas-lift
- changes of pump rates (VSD)
- shutting down high GOR or water producers.

The production engineer can be proactive and propose actions that can increase production. As an example, it can help finding production bottlenecks, and more particularly see the impact on long term production.



EssBuilder

Overview

EssBuilder is a new interactive development environment for reservoir simulation decks.

It helps the editing of decks, and helps visualise the elements of the deck. Moreover, it provides a scripting facility allowing the engineer to generate various aspects of the deck automatically.

Intelligent editor

The intelligent deck editor does a full syntax check. It shows any syntax errors graphically, and does 'folding' so that sections of the deck can be contracted or expanded.

Visualisation of tables

Simple charts of tables can be shown, by clicking on an icon next to the relevant table in the editor

3D display

A full 3D display of the deck can be shown, using 3D graphics. This includes rotation, zooming, well and fault display, interactive selection of layers or X/Y sections, and display of dynamic data from a binary results file.

Python editor

It includes a full syntax check on Python files. Python files are sometimes used by engineers to manipulate or generate decks.

Pre and post processing languages

EssBuilder includes a full implementation of a proprietary pre and post processing language. The pre processor is designed to manipulate or generate sections of a deck, and the post processing language is designed to manipulate simulation results so that derived results (such as NPV) can be created.

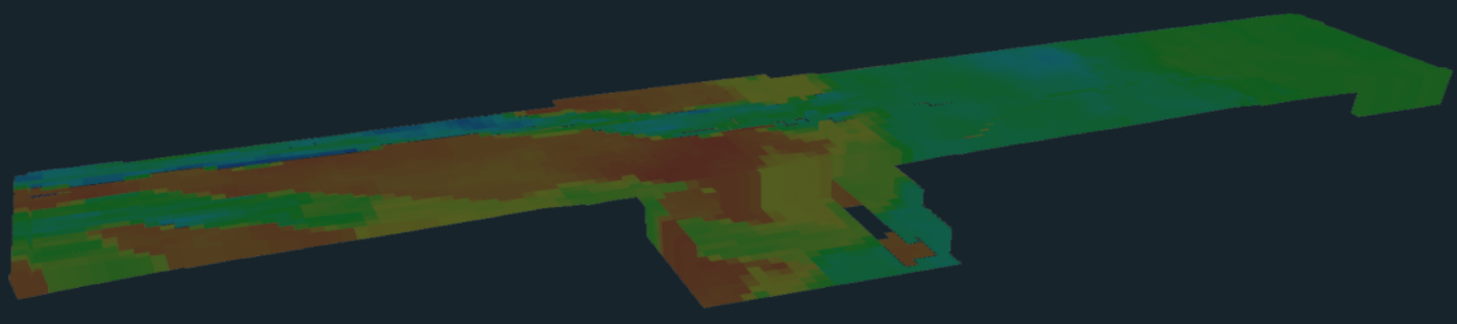
These languages are specially designed to be easy to use for engineers, and the language includes special features. For example, the language includes the ability to implement logic based on well names.

These languages have an interactive editor, full syntax analysis, and error checking. Moreover, the languages are executed within the same Java environment, using a Java-based implementation.

This close integration avoids many of the frustrations arising from the use of external languages and implementations, where tracing errors can be difficult.

Integration of EssRisk and EssBuilder

EssBuilder is available as a standalone free-to-use product, but its full power comes into play when integrated into EssRisk. The preprocessing language can be used to manipulate the deck in a history matching or optimisation project, and the post processing can be used to derive new results.



Plots

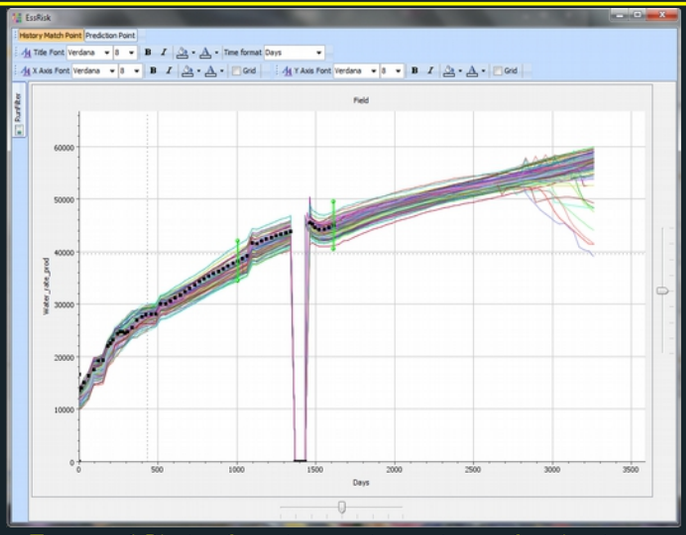


Figure 1 Plot of water rate v. time for history matched runs

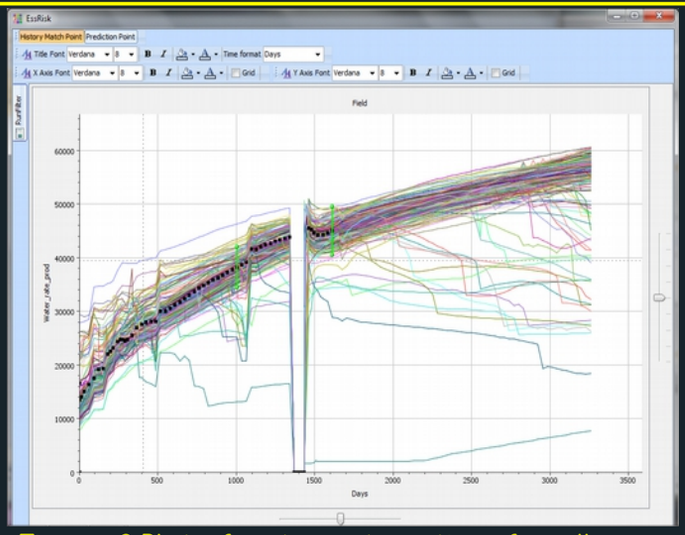


Figure 2 Plot of water rate v. time for all runs

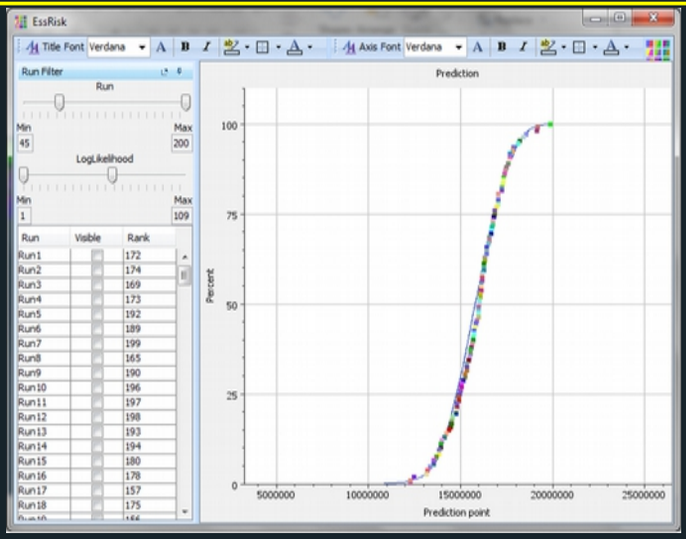


Figure 3 S curve from runs and from proxy model. The runs validate the smooth proxy curve

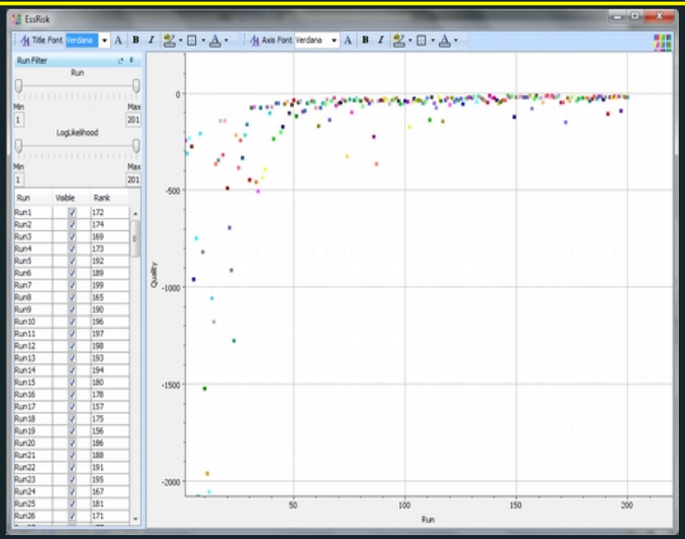


Figure 4 Plot showing evoluation of history match quality

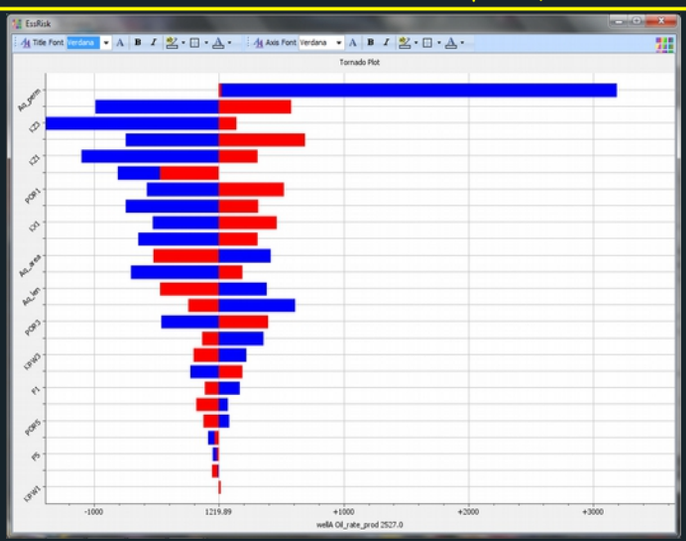


Figure 5 Tornado plot showing sensitivity to modifier values

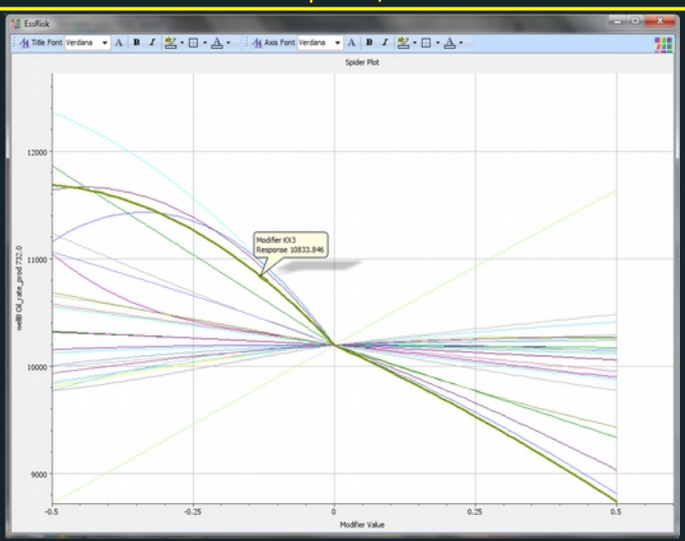


Figure 6 Spider sensitivity plot showing more detailed behaviour

Plots

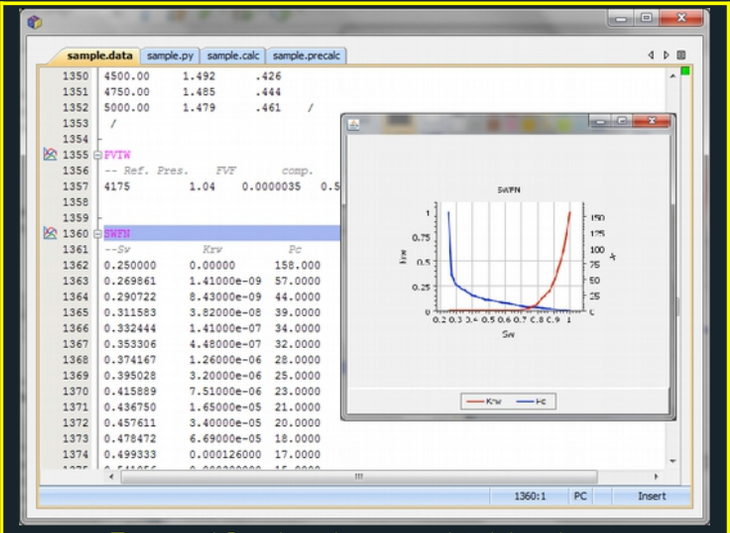


Figure 1 Deck editor and table chart

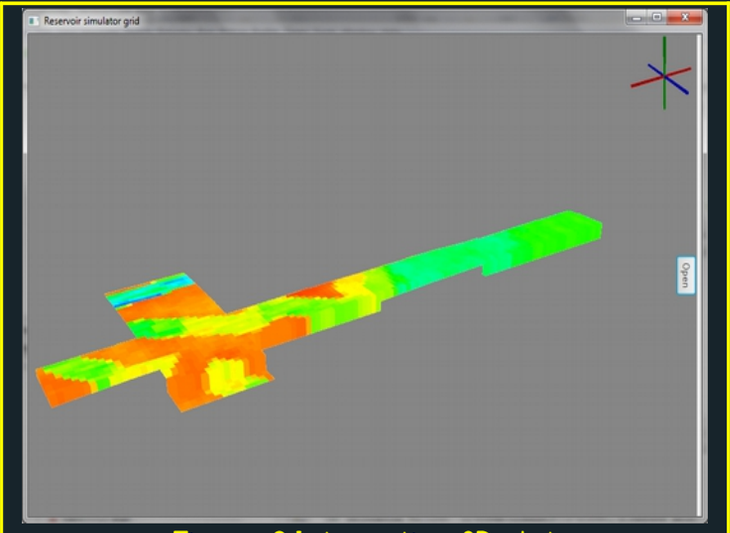


Figure 2 Interactive 3D plot

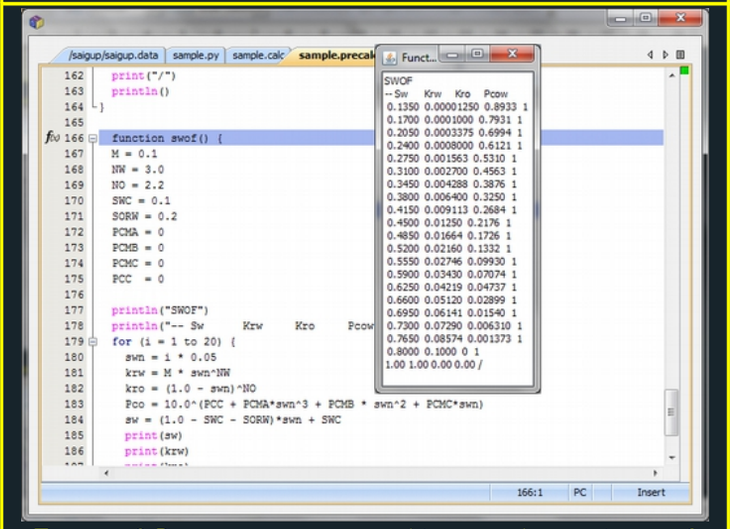


Figure 3 Pre processing editor and creation of table

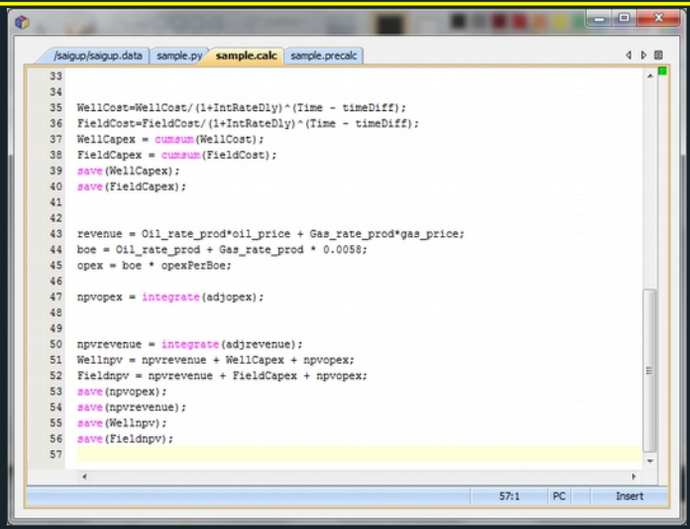


Figure 4 Post processing editor

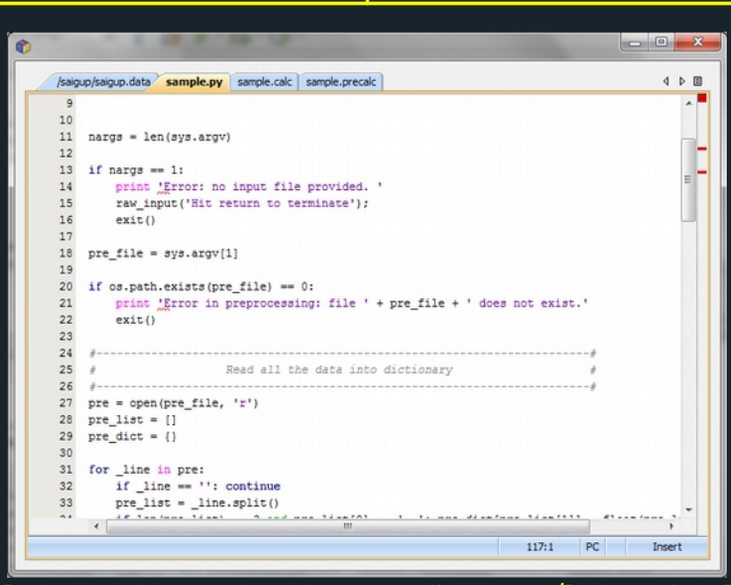


Figure 5 Python editor with indication of errors (Python 3 v. Python 4)

Implementation

Modern tools

EssRisk uses the latest Java 8 tools, including JavaFX, for a modern user interface which can take full advantage of the desk top, including OpenGL 3D graphics.

Multi processing

EssRisk has been designed from bottom up to use the full power of multi threading, taking advantage of the Java concurrency utilities and Java 8 functional programming.

Designing concurrency at the correct level is key. Fortunately the EssRisk algorithms are highly suited to parallelism, and separate threads handle:

- individual simulation runs
- initialising individual estimator points (proxy models)
- Calculating likelihood function for individual estimator points

Lightening graphics

2D well plots can be time consuming. For 100 wells, 200 simulation runs, 1000 time steps and 20 output variables, there are potentially 400,000,000 points to be plotted.

EssRisk implements various methods to make this lightening fast.

- Tabular display of plots, using the full detail and specially written rendering engines
- Cache plots as images
- Render images in background, using LIFO (last in first out) queue so that as the user scrolls around plots, the last one is rendered
- Multithreaded rendering. Each plot is rendered in a separate thread, so multiple plots can be rendered simultaneously.

Data management

A pure Java database management system H2 is used, which is ideally suited to performant desktop applications. It comes with all the caching, security and robustness expected in a modern DBMS. It supports SQL standards for array data, and is implemented with a Hibernate layer. Large projects are no longer a problem.

Plots

All plots can easily be customised to change titles, axes, fonts, colours, and background colours. Plot types include:

- well plots showing simulation results and history data, for standard data and RFT data
- quality plot showing evoluton of history match quality
- sensitivity plots, showing tornado and spider plots
- uncertainty plots, showing calculated S curves, for both proxy-based S curves and simulation run S curves
- modifier values, showing for each run the modifier values, and an indication of whether modifier values cluster for high quality history match runs.

Plot filters

Plots can be filtered, where appropriate, with simulation run filters. Also, wells and variables can be filtered and reordered.

Modern user interface

The latest user interface tools and application desktop frameworks from JIDE software are used. This includes a docking framework and a clear concise user experience.

JavaFX

JavaFX, a new user interface toolkit provided as part of standard Java 8, is used for 3d graphics.

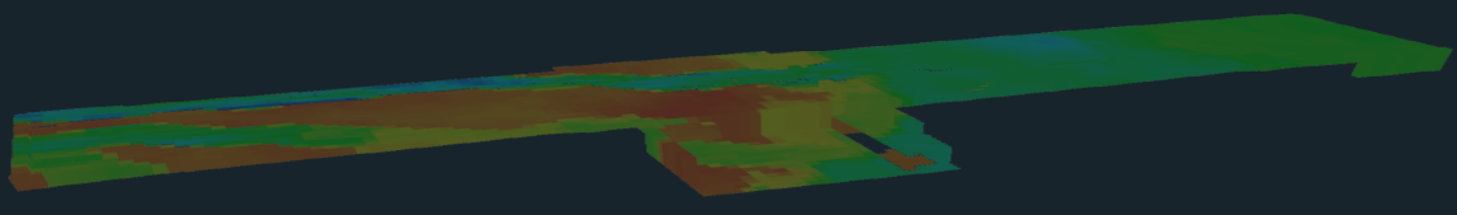
Matrix algebra

All matrix algebra has been written from scratch in Java, which is surprisingly close to the best Fortran or C performance. No third party libraries such as R or Python are used, as these have been shown to be very inefficient.

Utilities

Approximate methods are used to avoid the overhead for various complex functions. Special approximation techniques have been specially designed, and can handle a very wide range of input values. These are used for:

- Matern correlation functions
- Cumulative normal probability functions.



Decision Tools

Decisions and Risk

Engineers are fully immersed in risk. Subsurface uncertainty is a daily challenge, yet decision making under risk is a relatively immature area for the petroleum engineer.

Optimisation without Risk

Optimisation without addressing risk has emerged in the last decade. The founders of EssencePS have carried out complex optimisation studies in the North Sea and Gulf of Mexico, looking at well placement and drilling schedule optimisation.

Intelligent wells

Optimisation can be used for intelligent wells, using all the data available. Optimal completion designs, optimal operational controls, optimal injection plans, can all be investigated together with a full reservoir simulation model, so that both static and dynamic effects are included.

Optimisation under uncertainty

Whilst optimisation with a single geological model provides benefits, the full decision analysis requires investigation of the robustness of the decision against different possible subsurface scenarios. The 'Flaw of Averages' demonstrates that a decision based on a most likely scenario may be the wrong decision for the 'low case' model – such as water breakthrough – which will only be known too late.

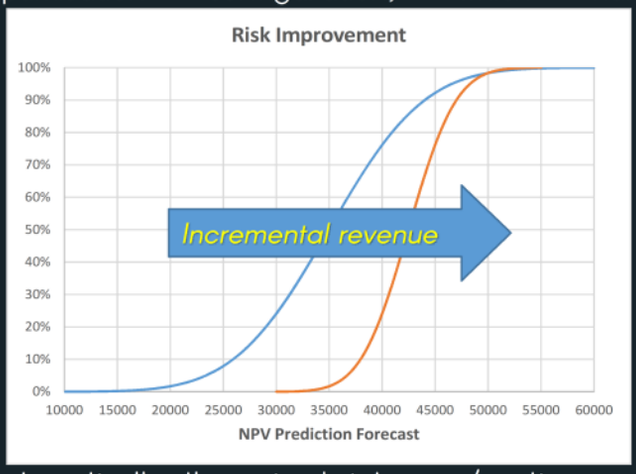
Optimisation under uncertainty examines the complete range of probabilistic geological models, and provides an optimum decision for the complete uncertainty range.

Decision tools and Risk

EssRisk is the first software in the industry which performs optimisation under uncertainty. Through the use of powerful and performant proxy models, it is now possible to examine the robustness of decisions against uncertainty and optimise those decisions.

Case study

A recent case study has looked at intelligent well design, in the context of controlling water within an uncertain geological structure. Different types of ICD/ICV's were examined and optimised in a single optimisation configuration, which handled automatically the mixed integer (continuous and discrete variables) nature of the problem.

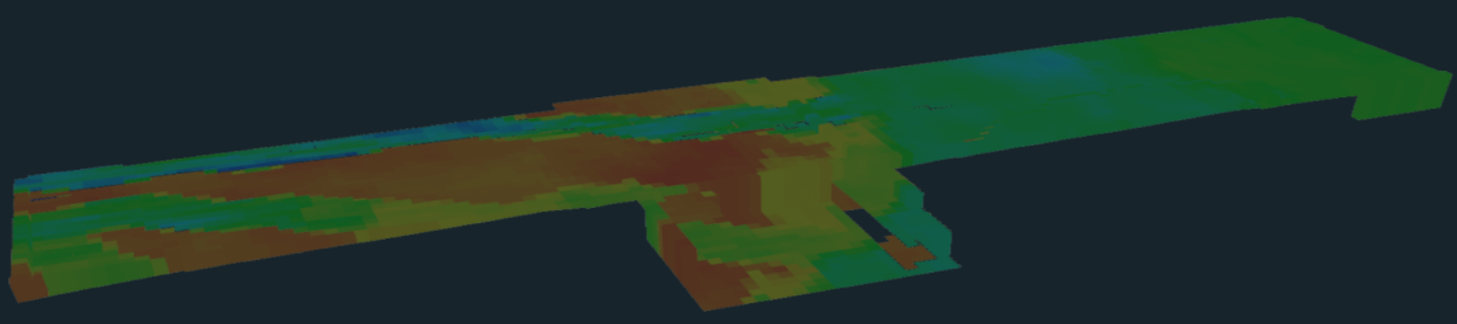


A single simulation model was constructed which embedded all the different options and variables to be optimised.

This case study optimised NPV, including capex and opex for the different well designs.

Understanding decisions under uncertainty

Instead of a single incremental NPV value, optimisation under uncertainty allows the decision maker to look at the full effect on the forecast NPV, as represented by a cumulative distribution or S curve.



Technical Description

Probabilistic Uncertainty Quantification

An encapsulation of the team's beliefs about models, parameters and their ranges, quality of measurement data, and quality of simulation model, within a probabilistic or Bayesian framework which can generate accurate and validated probabilistic cumulative distribution curves (S curves) for quantities of interest at times of interest, which can then be represented by a suitable set of simulation runs.

Statistical Benefits of proxy models

In the oil and gas industry, proxy models are crucial for probabilistic uncertainty quantification of reservoirs with calibration against history. Markov Chain Monte Carlo (MCMC) methods cannot realistically be applied directly with lengthy reservoir simulations, and even fast proxy models with MCMC can fail dramatically to represent the full range of uncertainty.

Application of the latest Hamiltonian MCMC techniques, together with an efficient implementation of proxy models, can lead to a more reliable and validated probabilistic uncertainty quantification. These methods have been validated against high dimensional problems with known anaytical solutions.

Markov Chain Monte Carlo

Combination of:

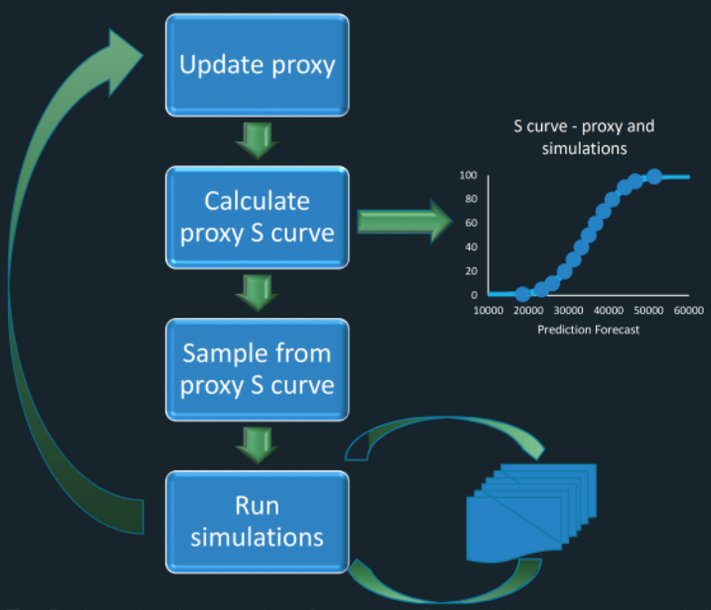
- Hamiltonian methods (NUTS)
- Differential methods (DREAM)
- Random walk

Proxy models

Uses multiple proxy models with the latest Gaussian Process techniques, including:

- Polynomial averaging
- Matern correlation functions
- Optimisation of Restricted Maximum Likelihood (REML)

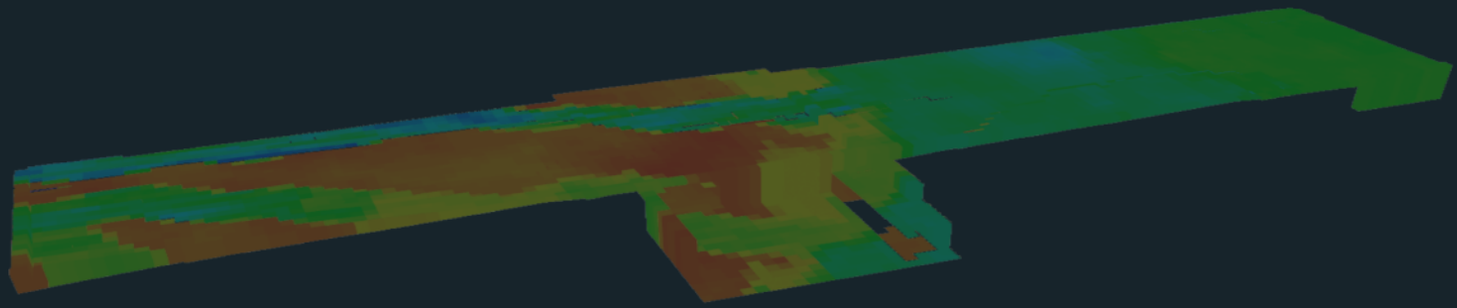
Workflow



EssRisk calculates the S curve from the proxy model, and then samples it to generate new simulation runs. In this way the proxy S curve and the simulation S curve converge, and the engineer can easily choose P10, P50 and P90 models to represent the uncertainty.

Features

- Pre and post processing
  - Links to geomodelling
  - Creating of tables
  - Rock properties
  - Rel perm tables
  - Derive complex NPV calculations
  - Interface to third party software
- Simulator interfaces
  - Eclipse
  - CMG
  - Echelon
  - Sensor
  - PSim
  - tNavigator



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