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Towards a Framework for Better Decision Making Under Subsurface Uncertainty

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Abstract

The Smart Fields collaboration between Shell and Schlumberger is developing an Uncertainty Management Framework aimed at reducing both Hydrocarbon Development Planning cycle time and improving the quality of decisions made under uncertainty. The objective is to better manage the impact of the full range of project uncertainties on key development decisions.

Schlumberger, working closely with Shell, have developed an Uncertainty Management Tool (UMT) for the purpose of capturing uncertainties, their ranges, additional qualitative and contextual information, and associated risks and action plans. Uncertainty assessments are typically made during the course of discipline and application specific technical work. Whilst not performing uncertainty analysis itself, the UMT aims to maintain an internally consitent view of uncertainties throughout the multi-disciplinary reservoir modeling workflow, which is input to the field development decision making process. Teams would continue to use existing techniques and applications for uncertainty analyis (monte carlo simulation, experimental design etc) but use the UMT for tracking the reduction of uncertainty and risk over time. The UMT tool provides a central repository where this information can be collected, monitored and managed throughout the life of the asset, and archived for future analysis.

Another challenge faced by the asset team is in managing the large numbers of realizations that may be required in order to address the full range of uncertainty. This can be a laborious and time-consuming process, if it is attempted at all. The prototype has the ability to interactively create and edit a realization tree using captured uncertainty information.

The realization tree serves as a guide to the team as they construct their reservoir models. It also allows the team to conveniently track their progress, capture decisions made along the way, and work toward a final concept selection.

In addition to the prototype tool, a model-building workflow using Petrel was developed to assist in ranking and screening static model realizations prior to full dynamic simulation.

Introduction

Risk plays a part in all field development decisions. Much of this is related to the uncertainty in the static reservoir characterisation, which also affects the dynamic response. The inability to properly manage subsurface uncertainty is often a key reason for projects failing to meet their objectives. In general, geoscientists and engineers use reservoir modeling applications like Petrel or Eclipse to help them visualize and quantitatively assess the impact of uncertainties. None of these tools, however, allows the users to structure and store contextual uncertainty information and link these to risks (or opportunities). Information such as rationale, assumptions, and confidence levels behind uncertainties are lost during the modeling process and therefore impair the decision-making process. It is also common practice for asset teams to produce a realization tree to track the static model realizations required to adequately address the full range of uncertainty. This exercise is often a very time-consuming and laborious process.

As part of the Smart Fields project, SLB developed a software tool that captures and manages both quantitative and qualitative information regarding uncertainties.

3D Modelling

Most geologists who have been in the petroleum industry over the past 10-15 years would agree that computer software applications, particularly those with 3D visualisation capability, have revolutionised their day-to-day work. From well planning, borehole image analysis, reservoir correlation, mapping and reservoir modelling; 3D visualisation has become not only *de rigueur* but is now an expected part of the workflow. As such, geologists have adapted from a world of paper, coloured pencils, rulers and planimeters and have had to become experts in computing, databases and numerous software packages.

One of the disciplines at the forefront of this technology is geological reservoir modelling, or static modelling, where many aspects of geology are integrated in order to build static reservoir descriptions. Fundamental to this process is not only the use of 3D visualisation but the fact that true 3D reservoir geometries and characteristics are now interpreted and captured as "virtual" 3D entities through the use of cellular grids (or sgrids). Three market leaders for geological modelling software have emerged: GoCcad (Earth Decision Sciences), Irap RMS (Roxar) and Petrel (Schlumberger). Unlike dynamic reservoir modelling (simulation) which is a mature technology that is a required part of the reservoir engineering workflow, static modelling is an evolving technology both in terms of software and workflow.

Uncertainty Analysis and 3D Modelling

The authors believe that in in order to appropriately manage uncertainty linked to various aspects of reservoir management requires a method and a tool that satisfies these 3 requirements: 1) to be able to evaluate the complete range of uncertainties by being able to capture them; 2) to be able to identify the relevant elements of uncertainty and filter out those that don't matter, and once key uncertainty elements have been identified, 3) to be able to rapidly know what actions are required to reduce their uncertainty to an acceptable level for decision making.

A typical 3D uncertainty analysis workflow for an integrated, reservoir modeling project is as follows:

(i) capture and evaluate the uncertainties;
(ii) integrate and quantify the uncertainties through the construction Shared Earth Model
(iii) analyze the impact of constructing multiple models on the metrics used to make a decision; and
(iv) iterate to reduce the uncertainties until the risks are minimized sufficiently to allow decision making.

The Current Situation

One of the key objectives in the Shell-Schlumberger program is improving the handling of uncertainties in the Hydrocarbon Development and Integrated Reservoir Modeling processes. In the current IRM process, Shell geoscientists and engineers use various applications that help them model uncertainties in a quantitative way. However, none of those tools allow the users to capture and manage uncertainty in a qualitative way.

At present the evaluation of a large number of development scenarios is limited by the computational power and time required to build and run dynamic reservoir models. There is also currently no industry consensus on best practices to keep the number of realizations manageable, so typically a most likely scenario is chosen, followed by a sensitivity analysis (i.e. P10, P90, etc.).

By adopting Shell's Hydrocarbon Development Planning (HDP) and Integrated Reservoir Modeling (IRM) global processes, asset teams are being challenged to produce and analyze more numerous and complex scenarios in order to more fully account for the impact of uncertainties on development planning. At the same time they are also being asked to accelerate the progression of development opportunities through Shell's technical review process, while adopting and maintaining these global standards.

The Solution

To address these challenges, Shell has chosen to optimize the workflows through the static and dynamic modeling loops. Bottlenecks and barriers impacting work progress must be reduced or eliminated. In some instances this may mean bringing new tools into play within the IRM workflows. In other cases there is a desire to enhance the current tool set to provide more streamlined modeling methods, processes or automation.

Schlumberger, working closely with Shell, have developed an Uncertainty Management Tool (UMT) for the purpose of capturing uncertainties, their ranges, additional qualitative and contextual information, and associated risks and action plans. This information is typically gathered or generated during the project framing stage for an asset, but until now had limited visibility and continuity during the asset development and decision making process. The focus of asset team review and review boards is tracking and reduction of uncertainty and risk over time, not simply risk quantification at any particular time. The UMT tool provides a central repository where this information can be collected, monitored and managed throughout the life of the asset, and archived for future analysis.

The tool has the ability to interactively create and edit a realization tree using captured uncertainty information.
The realization tree serves as a guide to the team as they construct their reservoir models. It also allows the team to conveniently track their progress, capture decisions made along the way, and work toward a final concept selection, ranking multiple realizations, then pruning options to a reasonable number of realizations. In addition to the tool, a Petrel workflow was developed to assist in ranking and screening static model realizations prior to full dynamic simulation.

The Uncertainty Management Tool

In the current IRM process, Shell geoscientists and engineers use modeling applications (e.g. Petrel, MoReS, Experimental Design) that help them examine uncertainties in a quantitative way. However, none of those tools allow the users to capture and manage uncertainty in a qualitative way. Information such as rationale, assumptions, and confidence levels behind uncertainties are lost during the modeling process and therefore impair the decision-making process.

We therefore have developed an Uncertainty Management Tool (UMT) that captures and manages contextual information on uncertainties, and is integrated with other applications capturing the quantitative details. The UMT has the following capabilities:

- It eliminates and replaces an ad hoc process with a centralized knowledge and information capture solution.
- It provides a catalog of uncertainties for given subsurface environments which draws on knowledge from domain experts and other assets.
- It enables a collaborative team to rapidly identify uncertainties, documents decisions, risks and comments as well as elaborates action plans and task.
- It promotes the decision-making process through consolidating information through screening and ranking multiple realizations, then pruning options to a reasonable number of realizations.
- It facilitates next step processes including 3-D modeling, technical reviews, etc.
- It builds consistency to approach, process and methods through a well-defined set of standards
- It provides an auditable process for determining decisions, rationale, etc.

The UMT within an Overall Uncertainty Analysis Workflow

A key goal for improving uncertainty management within Shell is to bring transparency to the hydrocarbon development planning process. It should be clear to external reviewers which uncertainties the asset team is focusing their attention on and why, and the overall status of capturing and modeling the uncertainty. It is important for project Team Leads, Reviewers and Senior Management to see the changes (in most cases, reductions) in uncertainties and risks over the span of a project as it moves through the various technical review stages. The UMT as an uncertainty and risk dashboard view can provide graphical depictions such as a TreeMap as an effective means for providing transparency. When combined with system snapshots and animation, it is possible to see how uncertainty and risk has evolved during the course of a project.

Another challenge faced by the asset team is in understanding the potentially large numbers of realizations required in order to address the full range of uncertainty. This can be a laborious and time-consuming process,. As such, it was important that the tool have the ability to populate and manage realization trees representing the full range of realizations. The UMT interactively creates and edits a realization tree using the uncertainty information collected in the tool (i.e. the ranges). It also has the ability to generate the realization matrix from the realization tree. This matrix represents individual realizations and their parameters that must be generated to capture the range of uncertainty. The most likely, or reference case, is defined within the matrix to which other realizations are compared in order to determine sensitivities within the reservoir. The "final" realization matrix consisting of P10/P90 or similar cases is then paired with development scenarios encompassing topside facilities and other development factors

Uncertainty information will change during the evolution of a project as more data becomes available and uncertainties become better understood (reduced). As users make changes inside the UMT, the tool will keep an audit trail of the changes and provide the ability to generate reports representing the audit trail content.

The UMT and Decision-Making

Throughout the life of a hydrocarbon reservoir from discovery to abandonment, a great number of decisions (e.g. which development option with which recovery mechanism? pipeline capacity? number of wells?) depend on incomplete and uncertain information. These uncertainties are also case dependant and, for a given field, they depend on its stage of development (initial appraisal, initial development, complementary development). Therefore uncertainties affect the decisions.

One of the biggest challenges facing asset teams is understanding the relationships between uncertainties and decisions. In an effort to reduce cycle time, this tool attempts to promote a change in the way asset teams view uncertainties and the effort spent in analysing them. Due to of the lack of clarity around what constitutes a key uncertainty in the context of the decision that is needs to be made, often there is too much time spent in analyzing uncertainties that ultimately prove to have no or little impact on viable field development options.

The UMT will improve integrated decision making by providing the foundational base that will help enable better understanding of the relationship between economic decisions and uncertainties by clarifying the links between these two key elements in field development planning.

IRM Workflow Automation and Integration Example

Shell's IRM is an iterative process in which reservoir models are built and successively refined, beginning with a first pass model and ending with a fit-for-purpose detailed model or models. The goal of the first pass model is to gain a better understanding of data completeness and consistency, while also helping to validate existing interpretations and geologic concepts. The first-pass models are subsequently refined to produce detailed models in order to provide more detailed forecasts, and to quantify the impact of the major uncertainties on key development decisions identified in the first pass review.

In static reservoir modelling, there are various approaches for facies modeling and each approach could result in any number of realizations. Typically, the high, most-likely and low cases are selected for further study to take into account the range of uncertainty. Automated screening of these different facies model realizations prior to dynamic flow simulation

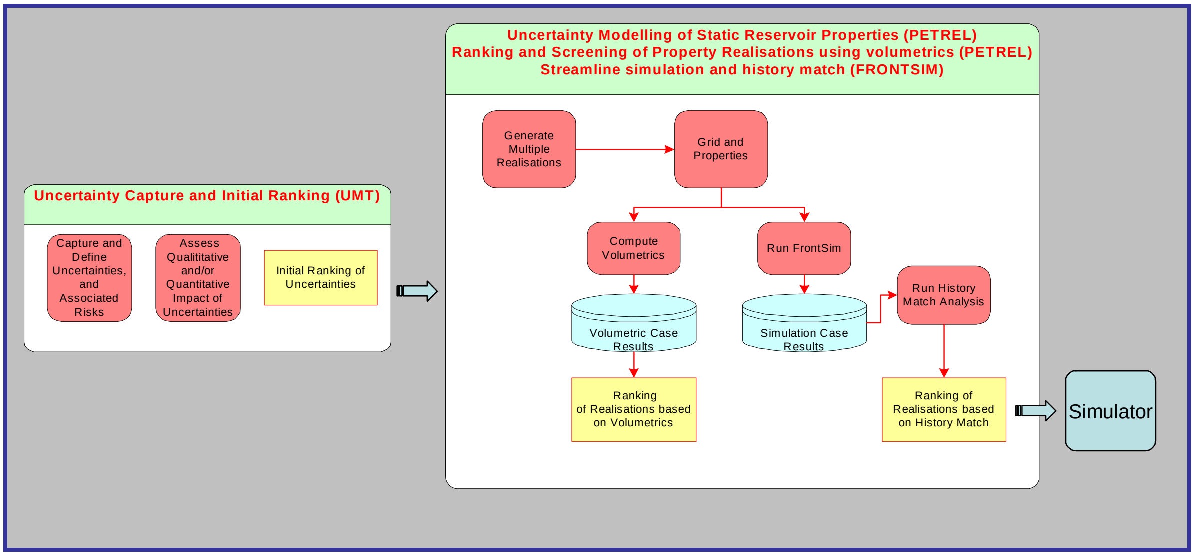

Figure: Screening and Ranking Workflow

improves efficiency of the modeling process and adds objectivity and repeatability to the static model selection.

In this example workflow, the user selects a number of facies models within Petrel and runs an algorithm to automatically determine the ranking of different realizations. One such ranking algorithm could be based on connected volume analysis based on transmissibility.

During the course of the workflow a streamline simulator (FrontSim) is utilized via the model-building (Petrel) Workflow Manager to rank multiple realizations in a waterflood project. This methodology allows rapid calibration of the static model. Users can define cases and rank and screen realizations prior to full-scale dynamic simulation, thus shortening the analysis cycle time. Streamline simulation is used as a method of ranking, visualising the dynamic effects of the static properties, fine- tuning and quality controlling the static models before upscaling and final history matching. Utilisation of this technology aids the subsurface team to not only work in a more integrated fashion but also to build more dynamically realistic geological models

Recent Case History: Impact of Smart Solutions

In a recent framing workshop for an offshore asset it was recommended that streamlined data management workflows and data access tools be applied to speed up the project set-up. The asset team also decided to use existing reservoir models in order to accelerate the project.

Sometime after project had commenced, technical leaders asked that additional detail be added to the existing geologic models. Use of the UMT would have helped the team initially agree upon the right level of detal, and prevented rework. Had the UMT been used, it would have improved decision planning process by adding clarity to the link between decisions and uncertainties and also by providing a foundational element upon which to plan tasks to mitigate the resulting risks. It would have allowed faster identification of key uncertainties and the right level of work required to address the unknown factors.

However, without the UMT, eight months of work were required to agree upon the right level of geologic detail. A systematic approach to uncertainty capture and propogation could potentially reduce this time by 50% (4 months).

Additionally, undocumented changes to a sand/shale log interpretation resulted in a surprising 50% increase in reservoir volume estimates. Two months of team analysis were required to determine the root cause of this change, which would have been documented and propogated to team members in real time via the UMT.

This anecdote touches on just several of the cycle time impact UMT will have in future Development projects.

Conclusion

A systematic, team-based approach to a common view of project uncertainties through a tool such as the UMT can improve development cycle time and improve the quality of decisions through systematic agreement, capture, and mitigation of the qualitative and quantitiative aspects of reservoir risk management.