1. Introduction

Energiring Oil and Gas upstream is a Data and Consultancy Services firm sweeping a wide range of Geoscience and Engineering Services including Borehole Seismic (VSP) processing/interpretation, Surface Seismic processing/interpretation, Geological Studies (Image log processing/interpretations, Fracture Modeling, Geomechanical analysis, etc.), Petrophysical Evaluations, Reservoir Engineering Services and Master Development Plan (MDP) preparation.

What makes us different from the others is the vast knowledge and experience in each discipline and also possessing the leading-edge software of the moment in the O&G industry, providing the best chance to extract the maximum value from any acquired data set.

Energiring will provide CLIENTS with unbiased quality check on the acquired data and highlight any subsequent data quality impact on the interpretation. The interpretation will be conducted on reliable data, and poor-quality data will be discussed with CLIENT team and recommendations for future acquisition improvement will be provided.

Our mission is to deliver high quality competitive answer products, exceeding client’s expectation in both Turn Around Time of the product delivery and high standards of the processing.

Our vision is to be the recognized leader in providing Data and Consultancy Services to O&G companies all over the world.

2. Capabilities and Answer products

Energiring is fully prepared and equipped to professionally conduct different types of Geoscience and Engineering Services. Below is a short list of what we offer and capable to perform:

2.1. Petrophysics Study and Modelling

Introduction

The Petrophysics field study, which is one of the main parts of a comprehensive full field study, should rigorously be conducted for each reservoir. During the steps of the full field study, all members who are involved in the project must be kept fully informed of the progress of the Petrophysical analysis. The main objective of the Petrophysical study is to provide basic reservoir parameters which are useful for all departments such as geology and reservoir.

based on the data availability such as conventional and unconventional data (Image log, Shear Sonic log, …) we can prepare a comprehensive petrophysical proposal in two parts. First part includes usual or basic study which is used for reservoir characterization. The second part is dedicated to advanced Petrophysical study to reduce uncertainty. Suggested Outline for an Integrated Petrophysical Filed study can be summarized as is depicted in the following workflow (Figure-1).
Figure 1: Integrated Petrophysical Evaluation workflow

- Part one: Conventional Petrophysical Study
Data base management

Data gathering and management shall be done on client database in petrophysics department. Main input data and information of Fields is as below:

- Digital and prints log data (Cased and Open Hole Logs)
- Identification of missing well logs
- Digitizing logs data (Raw and Process)
- Drilling information (such as final drilling report, well deviation data survey and gyro, cutting data, mud types, BHT, etc)
- Geological information (such as final geological reports, graphic well logs, geological core description, cutting data, thin section and sedimentary facies, well markers, etc).
- Conventional and Special core analysis data
- Results of Drill Stem Tests and Production Tests for clarifies uncertainties
- Check shot and VSP data
- Formation water analysis
- Hydrocarbon fluid properties
- 2D seismic interpretation results
- Hydrocarbon Shows
- H2S data
- Related reports
- Comprehend Inventory and data base preparation for available data and defying lack of data
- The report shall be prepared and data/information should be delivered.

Petrophysics Modelling

Schlumberger Techlog software, based on combination of Deterministic and probabilistic method approach could be used in the study.

The petrophysical modelling proposed workflow are as bellow:

- Loading all digital data (drilling, reservoir, geology, Petrophysics, and the like)
- Loading deviation data and calculating TVD depths. The raw and processed logs should be personated on both depth scales.
- Data quality control and Checking logs quality.
- Digitizing missing well logs
Log editing, environmental correction of logs and depth shifting based on specific tool Types

Estimating missing logs by any kind of correlation or single/multi regression and other method

Archie parameters (m, n, a, RW, etc.) should be determined based on core and log data. It is necessary to apply variable m in carbonate reservoir. It is recommended to use core data of nearby wells.

Defining fluid types and parameters

Mineralogy types and parameters

Clay rock types based on logs and XRD analysis, etc.

Designing model solver and defining related parameters

Conductivity models selection

Calculating residual/moved hydrocarbons, connate water saturation, permeability and etc in addition to calibrating with core data.

QC of the results and investigating model consistency

Calibrating results with core, well test, geological data, etc.

Sensitivity analysis based on petrophysical parameters and input logs

Multi wells interpretation on rest of the wells using key well models

QC Results and determination of uncertainties

Using Image logs (FMI, DSI, Sonic scanner) to define all properties specially in fracture zones (using the Image log will be explained in individual chapter)

**Multi Well Interpretations**

- Calculating average petrophysical properties such as volume of shale, porosity, water saturation and compare with core and test data.

- Defining net reservoir and net pay sections with applying accurate cut-offs.

- The cut-off values shall be defined using proper methodology reference to the field data and any regional data. Sensitivity analysis of cut-off value will be done through volumetric calculation through static/dynamic modelling.

- Evaluating secondary, primary and fracture porosities.

- Porosity types consist of isolated, parallel, moldic, inter-granular shall be defined and compare with sediment logical results and core data.

- Defining initial fluid contacts using logs and pressure data and DST measurements
• Image analysis (FMI and OBMI, UBI, DSI, Sonic Scanner, ...) and determination of all geological features.

• Geomechanic rock parameters and properties should be evaluated by core and open/cased hole logs and so on.

**Rock Typing based on electrofacies studies**

In order to distributed dynamic properties in the matrix cells of static model, rock types will be defined. Rock-typing shall be defined based on geological studies, petrophysical results, and CCAL/SCAL core analyses through correlation between dynamic properties and permeability-porosity.

**Flow unit determination and layering**

The flow units will be defined based on the stratigraphical framework, full set log analysis and rock typing. The flow units will be used as a base of layering in the 3D Geo model.

**Permeability Estimation**

In the part emphasis is on separate steps because of their predominant effects on the modelling. Intrinsic, relative and effective permeability shall be determined using all data, reference correlations and other sources.

• Defining all parameters including pores types/size/distributions, clay types/distributions, fractures and so on which effect on permeability as well as driving a proper relationship using any core and log data

• Deriving a relationship between permeability and other properties such as core data based on key well in defined rock types.

• Utilizing permeability estimator by statistical means for all zones

**Saturation Height Function**

Saturation-height functions based on core capillary pressure data and regression to well logs in defined rock types shall be prepared. Many functional techniques have already been developed to fit on core or log data. Proper method for curve fitting/smoothing shall be selected and discussed. Suitable technique shall be used for fitting the wireline log measurements with height above the FWL, and be substituted for Pc, Swe and Swt. Final water saturation shall be constructed in all wells and will be compare to log interpretation water saturation (free and connate) and oil (residual and moved) saturation. Any inconsistency and discrepancy shall be discussed and investigated.

The report will be prepared and delivered to the Client upon performing Petrophysical study. All data also will be handed over digitally in standard format.
Initial fluid contacts and pressure data

All available data (Logs, pressure data, fluid gradients, tests results, geochemical analysis) will be cross checked to define fluid contacts and possible compartmentalization for reservoirs.

- Part second: Unconventional Petrophysical Study

2.2. Image log processing and Interpretation

Image log evaluation is divided into Processing & Interpretation phases. Processing task is very important part of this study and the main objective is producing a high resolution with suitable contrast Image for feature and texture analysis. Processing workflow steps are as follows;

**Processing Section**

- **Inclinometry QC**: Use the well location and logging date to calculate the correct gravity and magnetic field parameters. Use these parameters to QC the accelerometer and magnetometer curves.
- **Speed Correction**: Calculate speed correction using accelerometer and frame time data and apply to the image data.
- **Pad Image creation**: Reorganize the button rows and pads (for example, apply button or pad offsets or flip the arrays) so that each pad or flap array presents the data in the correct clockwise order for the outward view of the borehole
- **Button Harmonization**: Harmonize the distribution of values in a column of an array to a global distribution of values by using a linear transformation so the mean and variance for each button of the output matches the mean and variance of the entire array or group of arrays.
- **Image based speed correction**: Correct the individual buttons and the pad/flap arrays for offsets due to residual speed correction errors.
- **Histogram Equalization**: To map the distribution of borehole image data values to a user specified range.
- **Pad Concatenation and Orientation**: To concatenate the individual pads of wireline electrical images into a single array representing the entire borehole circumference.
- **Image Calibration**: Calibrate any borehole image against an appropriate calibration curve. The method generates a best guess calibration that you can interactively edit with the results shown in real time.
**Interpretation Section**

- **Basic Interpretation:**
  
The main objective is functionality providing a means to pick dips, change dip display properties, and prepare imported dips for display in Layout. Techlog software can be used to pick dips simultaneously from multiple image logs. Major Dips are divided to several Picks. Breakout and Induced Fracture as an essential data are the main feature which must be detected as a Figure-2 and, Figure.

![Figure 2: Breakout image interval](image1.png)

![Figure 3: induced fracture image interval](image2.png)

In Basic Section we can make a report and finalize all of the features as below. All bedding can be classified as a High confidential Bedding, Low confidential Bedding and lamination. Also Fractures based on size and type can be categorized as a Major, Medium, Minor, Hairline and Possible. Conductive seam, dense streak, stylolite, Breakout, Induced Fracture are the other important outputs of basic interpretation. (Figure to Figure)
<table>
<thead>
<tr>
<th>Features Name</th>
<th>Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breakout</td>
<td>□</td>
</tr>
<tr>
<td>Closed Fracture</td>
<td>■</td>
</tr>
<tr>
<td>Conductive Seam</td>
<td>▲</td>
</tr>
<tr>
<td>Fault</td>
<td>●</td>
</tr>
<tr>
<td>Dense Streak</td>
<td>●</td>
</tr>
<tr>
<td>Hairline Fracture</td>
<td>●</td>
</tr>
<tr>
<td>H.C. Bedding</td>
<td>●</td>
</tr>
<tr>
<td>Induced fracture</td>
<td>●</td>
</tr>
<tr>
<td>Lamination</td>
<td>●</td>
</tr>
<tr>
<td>I.C. Bedding</td>
<td>●</td>
</tr>
<tr>
<td>Major Open Fracture</td>
<td>■</td>
</tr>
<tr>
<td>Medium Open Fracture</td>
<td>▲</td>
</tr>
<tr>
<td>Minor Open Fracture</td>
<td>▲</td>
</tr>
<tr>
<td>Possible Open Fracture</td>
<td>▲</td>
</tr>
<tr>
<td>Stylolite</td>
<td>●</td>
</tr>
</tbody>
</table>

Figure 4: Rose diagram of XRMI interpretation in carbonate reservoir in Middle

Figure 5: Image log interpretation Header East oil field
Figure 6: Different features in image log(XRMI) layout in carbonate reservoir in Middle East oil field

Fracture Analysis:

- Fracture Picking and classification

All fractures are classified in 2 groups: Open fractures (Major, Medium, Minor, Hairline and Possible) and Closed Fracture. figure-7 contains about 500 fractures in Asmari formation in one of carbonate field in Iran.
Dip Fracture Counting

The Dip Fracture Counting method counts specific dip Fractures. This method can generate a fracture density curve. Fracture porosity can also be computed using caliper data and fracture aperture values. Appropriate inputs data will be used to correct the density for borehole sampling bias by Terzaghi correction method. Any type of fractures in dip data sets can be counted as Figure 7. Dip Fractures spacing, Fracture Density, Fracture Length and Fracture porosity can be useful outputs for making DFN model and Geomechanical study.
Figure 8: All types of Fracture counting

Fracture Aperture Detection:

The aperture of fractures interpreted by using electrical imaging tools in WBM can be calculated using the equation proposed by Luthi S.M. and Souhaite P. (Figure)

\[ W = cAR_{m}^{p}N_{f}^{1-p} \]
Integrated Fracture Analysis (Techlog Plugin)

The natural fracture distribution and connectivity generally have a huge impact on fluid flow in hydrocarbon reservoirs. Characterizing the natural fractures properties (length, aperture, surface and volume) and layout (connectivity) is therefore essential in order to provide an accurate estimation of the oil reserves and of the reservoir productivity. Borehole images, acquired with wireline after drilling or logging-while-drilling tools, are a very convenient tool for that purpose. They give a high-resolution representation of the reservoir along the path of the well, along which fracture traces at the wellbore surface can easily be picked, sorted and counted. Historically, the fracture traces were picked manually by image interpreters.

This task is however time-consuming (picking fractures over thousand meters could take a few days) and the results can be interpreter-dependent. In order to overcome these issues, automatic extraction and characterization methods have been developed, enabling a much faster and more reliable analysis. In the early 2000s, Schlumberger GeoFrame* platform was equipped with a module to pick partial sinusoids manually over the fractures and to perform an automatic fracture counting and density calculation. The fracture aperture computation method for FMI*/XRMI*, also known as Luthi-Souhaité method (Luthi and Souhaité, 1990) was also available in the software at that time. The latest developments in the GeoFrame BorView* module (Kherroubi, 2008), integrated a semi-automatic method (i.e. supervised by the interpreter) to extract the fracture
traces. The statistics part was also enriched with more meaningful curve computations, such as the fracture surface per unit borehole volume (P32), and the fracture volume per unit rock volume (P33). The Fracture Analysis plug-in for Techlog inherits these developments. It is designed to enable fast and easy fracture characterization in a very similar way to the module in GeoFrame.

Figure 10 : Fracture analysis

Advanced Image Interpretation

Porosity spectrum Analysis:

The PoroSpect (Porosity spectrum analysis) method provides porosity distribution and vug fraction quantification from high-resolution electrical borehole images such as FMI or XRMI images. The technique is only valid for images acquired in conductive muds.

Many productive carbonate formations have complex dual porosity system consisting of matrix primary porosity and secondary porosity. The secondary porosity might contain vugs, molds and fractures. Borehole electrical conductivity and resistivity images provide both small scale resolution and azimuthal coverage to quantify the heterogeneous nature of the carbonate porosity component. The implementation of PoroSpect in Techlog supports any calibrated borehole image scaled in conductivity or resistivity. The conductivity or resistivity data from the electrical images is measured in the flushed zone of the borehole.
The Methods includes:

- WN (William Newberry) Method
- SDR or Fixed-Percentage Method
- TSR (T.S. Ramakrishnan) Discriminant Method
- Gaussian Extraction Optimization-based Method

This optimization-based method is designated as JCG (Jaideva C. Goswami. The approach is the multi-modal decomposition of a composite distribution, applied in this case to the porosity distribution which one may consider as a superposition of several distributions, each corresponding to some type of pore configuration. The JCG method identifies one of the Gaussian distributions as secondary porosity and computes the secondary porosity by integrating the individual distribution. (Figure )
Permeability Image log analysis

As result of the high resolution porosity computation, the permeability index is calculated using a derivation of the Timur porosity to permeability transform that takes into account the secondary porosity.

\[ k_{\text{IMG}} = KA \cdot PHIE - IMG \cdot 10^{\frac{(KB \cdot PHIS - IMG)}{PHIP - IMG}}} \]
Other advanced image interpretation

- Full Image Computation
- The geological characterization of hydrocarbon reservoirs has been considerably improved by the use of borehole imaging tools. The tools developed today are able to provide a high resolution map of the borehole, which can be used as a virtual outcrop on which lithology, bedding planes, texture (vugs, etc.) and fractures can be clearly identified. The borehole images are conventionally displayed as 2D unrolled maps of the borehole (Figure 0-1).

![Figure 13: 2D unrolled maps of the borehole](image)

- Lamination Analysis

This document describes the processing theory and the processing steps of the Lamination Analysis plug-in for Techlog. Lamination Analysis plug-in allows to perform very fast dip picking on any borehole image. It also characterizes laminated formation from borehole image for a better understanding of the stratigraphic environment and provides quantitative information that can be used as input for well completion or reservoir software.

The workflow:

The characterization is a workflow composed of 4 successive steps. Given the orientation information provided by the dips, a dynamic and a calibrated conductivity curves are extracted from respectively the dynamic and the calibrated row image log.
Figure 14: Laminated detection Plugin in Techlog

**PoroTex (Heterogeneity) Analysis**

This document describes the processing theory and processing steps of the methods provided by the PoroTexAnalysis plugin for Techlog. The PoroTexAnalysis plugin provides a workflow (PoroTex workflow) to obtain quantitative measures of important reservoir parameters from electrical borehole images. With the PoroTex workflow, it is possible to classify the different types of pore space: connected to vugs (vug to vug), isolated, connected to fractures, aligned at bed boundaries, or within the rock matrix. The contribution of these different pore types to the total porosity of the formation is quantified in addition to the geometric information of delineated pore space. In addition, the connectedness of the different types of porosity is quantified. The methods available in the PoroTexAnalysis plugin are used to evaluate any types of heterogeneous formation. However, the methods are typically useful in carbonates as the porosity distribution is often very complex.
Heterogeneity Analysis

Heterogeneity analysis is the examination step to delineate heterogeneity. This step does not provide any petrophysical or geological outputs. To correctly and efficiently characterize the image property, the entire image is segmented by the watershed transform. The watershed transform is a well-known image segmentation method which can be visually explained by a topographic notion (Meyer and Beucher, 1990). First, we bore a hole at every local minimum on the surface (i.e., image) and immerse the surface in a lake with a uniform vertical speed. The water entering through each hole fills up the various catchment basins. We build a dam along the lines where the floods would merge.

Figure 15: Outputs of Heterogeneity layout

Heterogeneity Classification

In this step, heterogeneities on the computed heterogeneity image in Heterogeneity cutoff can be further classified using connectivity and logic of association with dips and fractures. Conductive heterogeneity spots are sub-classified using the crest lines (computed in Heterogeneity analysis) into connected and isolated types, respectively. Spots connected by crest lines to another spot are classified as connected spots and the rest are classified as isolated conductive spots. The connectedness curve is defined by the average of the differences in conductivity between matrix and crest line (zero if there is no line) at each depth level.
Vug Integrity Analysis

High-resolution porosity estimation from high-resolution images can complement conventional porosity logs (neutron, density, etc...), providing detailed information on the distribution and proportion of secondary porosity. For oil-based mud systems, and especially in carbonate formations, amplitude acoustic borehole images show high values representing the average acoustic amplitudes of the matrix of the volume investigated, while low amplitudes correspond to low acoustic material such as volcanic debris, clays or fluid filled vugs. The density of vugs can therefore be inferred in clean formations from the analysis of the amplitude values, and used for further Petrophysical analysis. The Vug Density Analysis plugin provides the workflow to determine the vug density of a formation from acoustic borehole images.
2.3. Geomechanical Study and Modelling

Objective

Our goal is to support our clients with various ranges of Geomechanical Data Services from exploration phase to drilling, completion, and production. Providing 1D to 3D geomechanical models can have a noticeable impact on time and cost saving especially during drilling. The main objectives of Geomechanical Data Services are giving solutions associated with well planning and wellbore stability problems, casing design, sand production issues, reservoir compaction, pore pressure prediction, hydraulic fracturing design, and any other subject related to present day stresses in an oil/ gas field and mechanical properties of formations.

Scope of work

A geomechanical model development and borehole stability analysis will be generated for technical and technological decisions for the construction of the planned well in phase of exploration/ development. This is the most basic phase of a geomechanical study and can be followed by variable well-path sensitivity analysis to recommend the best mud weight for the planned well-path to have safe and clean borehole. In phase of completion and production, many other advanced products can be provided depending on the current issues in well to field scale.

The key objectives of a geomechanical study are to:

- Optimize drilling process of a planned well;
- Reduction of possible risks and complications (while drilling, completion and production);
- Borehole stability analysis of problematic formations;
- Variable well-path sensitivity analysis to recommend the best inclination/azimuth and prediction of possible hazards/challenges for pre-planned trajectories and recommendation of the proper remedy.
- Sand management program to provide critical draw down pressure in case the reservoir is a sandy formation.
- Hydraulic fracturing feasibility study of prospect formation to determine rough fracture pressure, fracture geometry, and fracture control possibility.
- Study of casing collapse/ shear in plastic/ creeping formations especially salts to recommend the best casing design to overcome the applied stresses coming from the creeping formations

The proposed study will be accomplished through the following work program:

- Conduct Data Audit for offset wells
Data Collection, Auditing, and Preparation (PART-I)

The data collection and audit is the first step of geomechanical study. It will involve the review and qualitative assessment of the available data that is relevant to the well construction process and to the construction of the well based Mechanical Model. Data audit will be conducted to identify completeness, correctness and availability of the input data.

Identification of geomechanics issues that would potentially affect specific operational risks and develop and mitigation measures for those risks is the goal of this part. Typically, information will be extracted from drilling-related data (well completion and drilling reports), geological information (field structure maps, data, lithology etc.), formation evaluation data/logs, pressure test and production data, LOT/XLOT/mini-frac data, seismic, geomechanical laboratory test data etc. This information will be used to finalize the data for the construction of the model. The comprehensive list of the data, covering geophysics, geology, petro-physics, drilling, production and reservoir engineering, useful for geomechanics studies is provided in the Appendix.

Building 1-D Well Based Mechanical Model for Offset Wells (PART-II)

The key requirement for any geomechanics analyses is construction of Well Based Mechanical Models. This is a numerical representation of the state of in-situ stress and rock mechanical properties for a specific stratigraphic section in a field or basin. It includes rock elastic and strength properties, in-situ earth stresses and pore pressure. Once rigorously validated, the model can be used to identify geomechanical problems during drilling and to devise contingency plans for the planned well by conducting a borehole stability analysis along the well-path. The purpose of performing borehole stability analysis is to determine the safe mud weight window and develop optimum mud weight program, casing setting depths, geomechanical predictions and engineering designs.

Construction of post-drill 1-D mechanical model of offset well will involve the following:

- Collate, review and validate input data of offset wells
- Load and QC available log data.
- In view of non-availability of shear slowness data in the offset wells, synthetic shear slowness logs would be generated from compressional slowness together with established correlation derived from regional geomechanics knowledge database/open literature for
similar rocks.

- Reviewing available data of the offset wells to identify and characterize stress-induced borehole instability events to depth, borehole inclination and azimuth, if applicable, mud density, drilling activity (such as tripping, back-reaming, differential sticking, etc.), identify the dominant failure mechanisms and operational problems associated with borehole instability. A sample of drilling events review is presented in Figure 18.

- Construct elastic and strength models for the overburden and reservoir sections using available log, core and drilling data. The models will be developed utilizing robust rock property correlations that have been verified on a local basis.

- Determine pore pressure profiles in the offset wells. The data utilized will include density, sonic and resistivity logs, local correlations, well test data, etc., and a review of available pore pressure data.

- Determine orientation and magnitude profiles of the principal in-situ stresses for overburden and reservoir sections. The minimum and maximum horizontal stress magnitudes will be rigorously validated against back-analysis of orientation and size of borehole breakout and drilling-induced fractures observed on borehole image logs, breakout analysis on caliper logs and drilling experiences. The data utilized will include density, LOT/ELOT data, image logs, caliper logs, daily drilling reports, mud reports, end of well reports, structural geology and local correlations.

![Figure 18: A sample of drilling events analysis](image)

- Validate the well based mechanical model through rigorous history matching with image logs, drilling experience, field observation, and field measurement and test data from the offset wells. A typical well based mechanical model is shown in Figure 19.
Provide recommendations on data to be obtained in the next well, if required, for increasing the reliability of the model and improve the accuracy of future predictions.

Figure 19: A typical Well Based Mechanical Model.

Borehole Stability Assessment of the planned deviated/horizontal well (Part-III)

Based on the borehole stability forecast and analysis of offset well data, depth-based forecast of safe mud weight window, casing points, optimal borehole pressure range and locations of potential drilling hazards, as well as risk mitigation options and operational parameters can be optimized to achieve improved borehole stability of the planned well. Generation of pre-drill 1-D mechanical model of planned well will involve:

- Propagation of the validated Well Based Mechanical Model to the location of the planned well, based on the well-path and formation tops.
- Conduct borehole stability analysis to evaluate the mud weight at which shear and tensile failures will occur at the borehole wall.
- Define the mud weight window required to maintain mechanical stability of the overburden and reservoir sections for the planned well.
- Recommend mud weight programme and casing point setting to circumvent risk associated with the planned well.
- Develop breakout and breakdown mud weight contour plots by conducting sensitivity runs for different well deviations and orientations within the in-situ stress field (see Figure 20). This output will be very helpful to plan horizontal/multi-lateral legs from a vertical root with the least possible drilling challenges.
The resulting pre-drill mud weight window of the planned well provides a starting point to aid in the development of the drilling plan, and borehole stability is examined to identify zones of potential drilling risks and hazards for the planned well. The analysis output will be put into a Geomechanical forecast including the predicted mud weight windows, recommended mud weight program, and identified drilling risks and contingencies.

**Notes on Geomechanical forecast:**

A Geomechanical forecast is a pragmatic and effective presentation of the mud weight window, recommended mud weight program, identified borehole stability issues and key drilling hazards for the planned well, suggested mitigation measure(s) for each drilling hazard, and supplementary information for drilling the planned well.

**Geomechanical Advanced Products According to Client Needs (Part-IV)**

As already mentioned in previous sections, the most fundamental phase of any geomechanical study is to prepare well based Mechanical Model and calibrate it against the available drilling/ testing/ log data. This point forward, according to the problem in which client faces in the field, various advanced products in form of modelling or study can be carried out. The most common advanced products are listed in the coming lines, however based on client requirements there is a vast range of Geomechanical data services to be offered:
Hydraulic Fracturing Feasibility Study of an existing/Planned Well

Having the predicted borehole stability model of the planned well, or Post-Drill mechanical model of an existing well, a fracture gradient model can be generated to predict the amount of required pressure to initiate and propagate hydraulic fracture in the zone of interest. This model can be also used for an accurate judgement about the stress barriers within the zone of interest or adjacent formations. This will let the operations team to decide whether the formation of interest is feasible for hydraulic fracturing or not. Figure 21 represents an example of how a well based Mechanical Model helps to decide on feasibility of HF operations in a given formation.

Figure 21: An example of Hydraulic Fracturing feasibility study
Sand Management/ Sand Control Program

To get sand from well or perforation:

- The sand must be separated from the rock (failure), which is controlled with mechanical properties, stress/drawdown, grain size and perforation.
- The sand must be transported, which is controlled with drawdown/flow rate.

If the rock doesn’t fail, no sand production at any flow rate will happen. If the sand isn’t transported, no sand production at any stress will happen but well fills with sand.

Main data requirements for sanding assessment can be summarized as In-situ stress state, mechanical properties, grain size, drawdown pressure and perforation size, which control sanding and critical drawdown pressure.

Having the amount of Critical Draw Down Pressure (CDDP) is the main key to plan a sand free program in any given problematic sand body. Figure 22 shows an example of a typical sand management chart highlighting the role of reservoir pressure and bottom hole pressure in sand production.

Figure 22: An example of sand management chart for single depth analysis
Casing failure (collapse/shear) study and modelling

Casings may fail after some time of production or even immediately after completion of the well in plastic formations specially salts. Based on nature of stresses on casing body, casing may fail along an interval (collapse) or in a particular point (shear). Using well based Mechanical Models, both failure modes of casing (collapse and shear) can be studied. The result will be generation of 1D collapse evaluation curves. The optimized casing grades and depths will be the executive outcome of such study. Figure 23 shows an example of a 1D casing failure evaluation model.

Figure 23: An example of sand management chart for single depth analysis
2.4. Drilling and Completion Capabilities

**Feasibility studies**

In O&G drilling, the proposed problems are mainly based on the economic analysis of a real oil exploration and production project, more specifically, on the feasibility analysis of the development of an oil field. Energiring’s expert team can recommend the clients about feasibility of any drilling operations in various range of reservoirs and geological settings.

**Technology review**

When it comes to designing horizontal/ high deviated wells, oil and gas companies’ experience in challenging reservoir plays has made it clear that formations can vary considerably from one play to the next and from well to well within the same play, making planning and knowledge critical tools. Energiring helps clients to select the best technology according to the budget and timeline of any drilling project.

**Drilling/Completion program preparation**

Well planning is perhaps the most demanding aspect of drilling engineering. We integrate engineering principles, corporate or personal philosophies, and experience factors. Although well planning methods and practices may vary within the drilling industry, our result will be a safely drilled, minimum-cost hole that satisfies the reservoir engineer’s requirements for oil/gas production.

Preparation of drilling program and performing all aspects of drilling engineering works for the successful, cost effective and safe implementation of drilling activities is our goal in Energiring.

**Workover Planning and Execution**

In Energiring, we plan workovers in order to: 1. Increase hydrocarbon production! 2. Decrease unwanted by product! 3. Extend the life of the field!

Our workover planning, is to identify workover candidates and outline procedures for accomplishing well objectives. Evaluate well performance and identify workover or abandonment candidates, plan safe workovers using the tools and methods appropriate to individual wells, and apply procedures and standards in accordance with recognized safe practices and regulatory requirements are the main basis of workover planning.

**Drilling Optimization**

In today’s environment of increased well complexity, higher drilling costs, and tremendous growth in data, Energiring provides operators with a proven and cost-effective way to optimize drilling.

Our drilling optimization process begins with data collected in real-time at the rig site. We
then monitor drilling parameters, verify the thresholds and alert operators regarding unexpected trend changes from surface or downhole parameters. This allows us to help optimize drilling and prevent any potential problems.

Optimized drilling techniques, first applied in 1967, have significantly reduced drilling costs, but have not yet reached full potential. Detailed treatment is given to the interactions of the most important drilling variables. As a main factor, we know that better data, more experience, and confidence will result in greater savings in the future.

There is no such thing as a "true" optimum drilling program; invariably compromises must be made program; invariably compromises must be made because of limitations beyond our control that result in something less than optimum. Perhaps it can be explained this way: for years it has been known that rate of penetration could be increased by drilling with water, by rotating the bit faster, and by increasing flow velocity through jets in the bit. Lack of sufficient mechanical and hydraulic horsepower, however, often prevents the proper balancing of variables to obtain prevents the proper balancing of variables to obtain maximum drilling efficiency.

Project Tendering/Evaluation

When we help our clients plan drilling programs one of the first things we do is assist the client with preparing a tender document that we typically send to at least three drilling companies. Prices vary greatly and the cheapest offer is not always the best deal for our client. We evaluate the proposals we receive from the drillers to ensure our clients get what they need.

FDP/MDP preparations

With international drilling experts, Energiring has vast experience in Master Development Plan in drilling and completion. Teams of specialists which are used to work together can spell address the largest range of challenges:

- Definition of different development scheme of increasing complexity based on production profiles;
- Continuous application of improved recovery technologies;
  - Identification of new drilling techniques;
  - Identification of new completion techniques;
- Estimation of related Cost and planning.
- Economic analysis
Project Variety:

- Onshore and Offshore Drilling
- Gas Storage / Gas Injection Drilling
- Water Injection Drilling
- Under Balanced Drilling (UBD)
- Managed Pressure Drilling (MPD)
- High Pressure-High Temperature (HPHT)
- Highly Deviated / Horizontal Drilling
- Extended Reach Drilling (ERD)
- Well Integrity
- Harsh/Remote Area Drilling
- Source Environment (H2S/CO2)
- Fracing Well Design
- Shale gas well design
- Unconventional Well Design
- Workover Planning
2.5. Borehole Seismic Services

- Pre-job ray trace modeling and planning for ZVSP, OVSP, Walkabove VSP and Walkaway VSP
- (complex structures and/or highly deviated/Horizontal wells)
- Model-based / 3C VSP processing using ray trace modeling and migration for complex structures and highly deviated wells, ZVSP processing (P&S), Sonic calibration and Synthetic Seismogram generation
- Offset, Walkabove and Walkaway VSP processing for imaging
- Walkaway VSP for anisotropy (VTI/TTI)
- Walkaround VSP for HTI anisotropy
- Rush and Ultra Rush VSP Processing (full VSP processing, Sonic Calibration and Synthetic Seismogram generation, Surface Seismic Calibration, marker prediction ahead of the bit, documentation of the results and generating deliverables in less than 24 hrs. for rush and less than 12 hrs. for ultra-rush)
- Marker depth prediction ahead of the bit using different methods (Tangent method, Average Velocity Method and AI inversion method)
- Layer thickness estimation ahead of the bit using different methods (Cross Correlation with convolutional model method, Notch Filter method, AI inversion method, etc.)
- Deep water pre-salt VSP processing experience
- Real Time Seismic While Drilling Processing and Imaging (seismicVISION*)
- Q Attenuation estimation using VSP data
- VSP interferometry and imaging using multiples
- VSP PZ processing
- 3D pre-survey modeling using Petrel
- 3D finite difference modeling using Omega
2.6. Surface Seismic Interpretation and Integrated G&G Services

- Provide a comprehensive geological conceptual model of the Field in terms of depositional environment, structural setting, fracture intensity, fluid contacts etc.
- Provide seismic interpretation of all the area of interest to identify any possible prospects with providing the geological setting
- Fracture intensity distribution using the continuous fracture modelling approach conditioned by geostatistical variograms and seismic drivers
- Generate new static and dynamic models
- Identify the optimum recovery mechanism that will yield the highest Recovery Factor (RF)
- Determine the best and optimum approach for the development, including but not limited to well type, trajectory direction, well spacing, lateral length and well completion design
- Review/asses type of all methods and recommended for future
- Define production and reservoir management practices for such reservoir considering full lifecycles of field development
- Seismic AVO Inversion
- Seismic AVOAZ Inversion
- Seismic Stochastic Inversion
- Identify any additional data gathering needed (such as laboratory studies, experiments, appraisal drilling pilots, logging etc.) and propose the plan which shall include but not be limited to targeted risks or uncertainties (if any) time-frame to execute the plan, dependency as well as informational value added.
2.7. Static Modelling

Following data loading and QC there are a number of aspects to the Production Geology/Static Modelling workflow. First the Target formation will be placed within its regional stratigraphic framework to understand where such things as major unconformities (if any) should exist. Once done the stratigraphic tops will be correlated across the project AOI.

The second segment focuses on defining rock property distributions that reflect the model cell-scale.

To achieve this objective, a successful process called “pore-scale modelling” will be used. The results from this process include rock property distributions and spatial parameters tuned to the selected model cell-scale.

The final segment begins with the construction of a Common Area Model (CAM) across the AOI. The CAM will be dynamically pre-conditioned to incorporate such data as pressure and inter-well connectivity and will serve as the initialization source for the dynamic model. Constructing these field models is the final portion of this segment of the workflow.

Sensitivity and uncertainty analysis will be carried out as follows:

➢ Sensitivity Analysis:
  ▶ Structure
  ▶ Contact
  ▶ Connectivity (Variography and seed number)
  ▶ Fracture intensity

➢ Uncertainty Analysis
  ▶ Combinations of the above

Depth Maps

Depth maps of key horizons, which should honor all well formation tops, will be provided by client. The depth maps will be used to create a 3D structural geocellular grid.

Structural Framework Building

The structural framework will be built using the depth maps created based on the formation tops and the major regional fault polygons to be provided by client (if available). Figure 24 shows an example of 3D Structural Framework Building.
Make Zones

The heights of initial cells that are created in make horizons are equal to horizons thickness. But this height is too much to capture varieties of log data inside model cells. So, the cell size should be reduced in vertical direction. Make zones means model the sub geological layers that are detectable on logs and well markers but they are not interpretable on seismic data. So the sub layers of each main horizons will be created by using well markers during the make zone process. All of these layers have geological meaning. Based on the geology of the reservoir these layers can be modeled in different forms. The preferred method to create these geological zones is using the isochore maps based on the well tops information. The result of the make zones process should be checked to ensure that all geological sub layer models correctly and according to the real geology.

At the end of the make zone process the number of cells in model will be increased and the cell height will be based on the thickness of the geological sub layers.

Make Layering

Even after sub dividing the main horizons by make zones process, the height of cells is still too much for capturing the variation of log data in cells of the model. Layering means to sub divide each zone to thin layers for capturing the log variations. The sub-layers height is defined based on the variation of log data and also the computation power. Sub layers can be defined in different forms (follow base, follow top (onlap), etc.) based on the geology of the zone boundaries. The
main parameter for defining the layer thickness is capturing the important interval log values in model. Also, the limitation in computation power should be considered for layering and the number of maximum of cells should be selected properly.

The layering is the end stage of the structural modeling and the structural model should be checked to find any problem regarding the crossing pillars, negative cells, etc. By defining the fine layers in model the number of cells will reach to the final value.

**3D Geocellular Building**

The structural framework will be used to create a 3D Geocellular grid in the depth domain (Figure 25).

![Figure 25: 3D Geocellular Grid Building](image)

**Facies & Property Modeling**

Most geologic modeling software provides conventional geostatistical algorithms such as collocatedco kriging, which constrains the geologic models with a single attribute. However, our workflow allows for modeling the reservoirs through the simultaneous use of multiple 3D attributes. For this purpose, a Neural Network or SIS is used to find relationships between the reservoir properties and multiple 3D attributes, by using the ranking tool available in the software.
This tool allows the identification of the attributes that are directly correlated with fractures or any other rock property.

Geological modeling involves assignment of petrophysical and facies properties to each empty cell, which is created during structural modeling by using measurements at wells (logs) and statistical procedures. Property modeling involves two steps: facies modeling and petrophysical modeling. The aim of property modeling is assigning the petrophysical and facies properties to each cell for volume calculation and reservoir fluid flow simulation. The most important criteria for correct property modeling are following geological structure and facies distributions. Therefore, it is necessary to do facies modeling before property modeling to ensure that properties are assigned based on facies distribution. It is likewise necessary to preserve the statistical distribution of input parameters.

**Facies Modeling - Facies log upscaling**

For proper petrophysical modeling, an accurate facies model is essential, as petrophysical properties vary between facies. Therefore, it is necessary to know the dominant facies in each cell for proper assignment of properties to each cell. By using the facies data, it is possible to condition petrophysical modeling to facies distribution. The first step of facies modeling is upscaling the facies logs into model cells (Figure 26), and then assigning dominant facies to each cell based on facies log data.
Figure 26: Concept of scaling up the facies logs. The most used method for averaging of log value is the “most of” method. This method means that the facies that dominantly covers the cell will be assigned to the cell.

Data Analysis on Upscaled Facies Logs

In this step, geostatistical variogram parameters such as sill and range will be extracted for each facies, and the input data will be statistically transformed to a normal distribution. In addition, lateral variation investigations and trend extractions will be completed in this stage (Figure 27).

Figure 27: Various statistical procedures completed in data analysis before facies modeling

Facies Modeling

Facies modeling propagates the upscaled facies data into model cells using various geostatistical algorithms such as Sequential Indicator Simulation or Multi Point Facies Modeling. The second algorithm is based on a conceptual model and is applicable if the required information is available. At the end of this stage, all cells in the model will have an assigned facies type. Furthermore, a probability distribution map (Sand, Shale, etc.) or a training image for the distribution of each facies will be used as a guide during the geostatistical population, in order to have better facies modeling. These maps and images may be extracted from probability maps. Various methods and algorithms may be used in the facies modeling process, based on the data availability and the field. Various models for facies modeling will be considered, including geostatistical/neural network and the best method will be selected based on available data and validation process in the field (Figure 28).
Figure 28: Facies Model Created Using a Sequential Gaussian Simulation

**Model QC and Validation**

All models will be reviewed and validated using various methods, such as blind well validation, lateral distribution maps, and vertical stacking pattern comparison (Figures 29 and 30).
Figure 29: QC and Validation of models using blind wells by comparing the predicted properties with the original logs

Figure 30: Histogram of Porosity (Left) & Histogram of Facies (Right)
**Volume Calculation**

The hydrocarbon in-place will be estimated using the 3D geological model. The hydrocarbon in-place calculated by static 3D geological model will be considered as the maximum deterministic value particularly if the porosity and water saturation is used without cut-off. Different values such as bulk volume, pore volume, STOIIP, GIIP, will be calculated in this process. These values would be calculated in each cell and the total volume will be calculated by summing all the cells. It is possible to have these values as properties in 3D model and also produce distribution maps for these values showing the distribution of hydrocarbon column height, pore volume distribution and etc.

In addition, an uncertainty analysis will be carried out on the Base Case of model using a Petrel based workflow covering all uncertain parameters used in building the model. A histogram of GIIP will be prepared and the P10/P50/P90 case will be identified.

**Uncertainty and Sensitivity Analysis**

In a green field, there has to be an extensive uncertainty analysis on the estimated in-place hydrocarbon volume by making multiple realizations of the developed 3D geological model. If possible one or two alternate geological models should be made on the key geological uncertainty and uncertainty realization on that should also be carried out. A combination of all these results should give a P90, P50 and P10 values of in-place hydrocarbon estimation. These models need to be physically generated for use by the reservoir engineers for the dynamic uncertainty evaluation.

A sensitivity analysis on the key uncertainty parameters needs to be run and the result should be a tornado chart clearly showing the order and sensitivity of the key uncertainty elements helping the client to focus the future study and data acquisition plans. The uncertainty of velocity model will be considered during volumetric analysis and uncertainty. Uncertainty analysis will be done by considering the best realization of seismic inversion and considering the properties modeling as variable.
2.7. Dynamic Reservoir Simulation

Introduction

The main objective of the activity is to build and initialize 3D simulation model for different reservoirs of a field. These 3D models will be built based on the up-scaled version of the geological model (prepared and quality controlled during reservoir characterization phase) and will be validated through history matching process.

The simulation will be performed using appropriate reservoir simulation packages such as Petrel RE and Eclipse (Eclipse 100 or 300 which are three-phase, three-dimensional simulators capable of handling single porosity or dual porosity/dual permeability reservoirs). The exact definition of the simulator will be dependent on the prevalent condition of the reservoirs as well as the types of the prediction scenarios. The areal grid size and layering of the reservoirs will be dictated from the areal and vertical variation of petrophysical properties, facies studies, and structure of the reservoir.
Model Construction

The 3D geological model will be up-scaled using appropriate techniques and then imported to the Eclipse simulator to constitute a geological basis of the reservoir simulation model. In addition, all the necessary engineering information that has been independently processed in the reservoir engineering analysis will be formatted properly to be imported into Eclipse Simulator. All data which will be imported in the model include:

- Reservoir structural description
- PVT data
- Reservoir rock properties (porosity, water saturation, horizontal and vertical permeability, rock compaction data, SCAL data, and etc.)
- Equilibrium data (initial pressures and contacts)
- Well completion and workover data
- Aquifer size and its estimated properties
- Well production and injection data

The grid will be built by importing the geological model from reservoir characterization studies. The grid structure will be designed to retain the main reservoir heterogeneities, such as high permeability and also very low permeability layers as separate entities in the model by use of appropriate facilities such as Petrel "Upgridding Utility". The grid will then be verified against geological well picks and modified if necessary. Detailed checks will be made to ensure that any faults, unconformities, other geological or structural characteristics, and dynamic behavior are retained and properly modeled.

The final step of the model construction will be incorporating the dynamic information such as individual well production data (including oil, gas and water productions), well completion and workover data, and observed pressure data. After importing all necessary data, the model will be ready for initialization.
Model Initialization and Validation

To initialize dynamic reservoirs model, saturation functions need to be entered so that the model can calculate the initial hydrocarbon and water in place in each grid block. This will include entering all or some of the following:

- Permeability, fluid saturation, and etc.
- Capillary pressure and relative permeability curves for identified rock types
- Saturation function end points for different rock types

By importing required data, the model will be initialized and run for a sufficient period of time, without any production to ensure that equilibrium between phases is achieved and a "no-flow" condition is observed. This validity check will be performed to approve the initialization.

Results of the model initialization will be carefully examined and verified against well logs and volumetric OOIP. If necessary, appropriate changes, within realistic and acceptable tolerance limits, will be made to ensure overall correspondence of the model initial saturation and hydrocarbon in place to the initial fluid distribution obtained from petrophysical evaluation and 3D geological model.
Single Well and Cross Sectional Modeling

In order to have an idea about the performance of the wells during the production history and affecting parameters such as drainage area, rock permeability, water or gas encroachments, conning, fault patterns, and etc. on well performance, number of candidate wells will be selected for such purposes. The well models of such wells will be cut from the full-field model and studied. Any conclusion on the mentioned well models will be real and usable in the full field model when interactions among the wells are added to. The candidate wells could cover both normal and exceptional wells. Very problematic wells will be taken into account in phenomenological well studies.

Single well modeling can also be used for simulating and history matching of transient pressure tests. In addition, vertical grid resolution in the dynamic model and impact of key parameters such as relative permeability curves on well performance will be investigated.

Following to single well modeling, such models may be extended to reservoir compartments. Considering identified compartments of the reservoir, different cross-sectional models may be constructed and analyzed. The objectives of cross-sectional modeling can be:

- Understanding dominant drive mechanisms in the reservoir
- Design and study of non-conventional wells (deviated, horizontal, or multi-lateral)
- Investigating horizontal grid resolution
- Quantifying the impact of key parameters on reservoir performance
- Checking the validity of SCAL and PVT data to be used in full field model
Full Field Model History Matching

Before conduction of history matching, an appropriate strategy for history matching process must be planned. Normally lessons learned from single well and cross sectional modeling must be gathered and concluded for planning the history matching strategy. As a normal procedure, the history matching process is performed in 3 scales as follows:

- Field Scale
- Sector Scale
- Well Scale

Field Scale History Matching

In field scale history matching, the intention is to estimate the external energy to the reservoir and matching field average pressure and production/injection rates. In addition, main barriers inside the reservoir and contribution of the external energy (such as aquifer) affecting the reservoir compartments are validated.

Sector Scale History Matching

During the field production history, poorly communicating reservoir sectors depart from the field average pressure trend. Therefore, after matching the external energy of the total field and preliminary efforts on matching the sector performance, history matching process concentrates on the division of the external energy among the sectors and tuning the communication among them. This leads to match average sector performance such as pressure and reservoir voidage volume in acceptable degree of accuracy.

Well Scale History Matching

The two abovementioned steps facilitate the well scale history matching which is the final stage of history matching. At this stage full well-by-well history matching is performed.

The main data to be matched will be:

- The production/injection rate per well
- The pressure measurements per well (bottom hole and wellhead static and flowing, build up, and RFT/MDT pressure data)
- PLT data per well
- The water breakthrough time, water production rate per well or water-cut per well
- The gas breakthrough time, gas production rate per well or gas-oil ratio per well
- The fluid contacts, i.e. water-oil contact and/or gas-oil contact
- Additional data, particularly estimated production during blow-outs

For each type of data, the history matching process will be performed based on the uncertainty range of the measurement. The quality of the history match will be judged
based on a careful review of the existing field data:

- The accuracy of direct measurements (such as depth, pressure, and flow rate). It is expected that the technology used at the time of the measurement is an important factor to determine this accuracy, especially for a field having a long production history. A model will not be able to provide a better accuracy than that provided by the measurements.

- The accuracy of indirect field values, which are obtained not through a direct measurement, but through interpretation and processing of other measured data (for example fluid saturations). These processes induce some additional sampling error in addition to the measurement errors.

- The time accuracy, which can be considered for the events to match. The time between measurements (e.g. time between two production tests with flow rate measurement in a two phase or three phase separator) is usually much larger than simulation time steps.

Another point which should be considered is the limitation in accuracy due to the use of numerical simulation, which attempts to simulate a continuous behavior by a discretized model in time and space domains. Space and time increments will be linked by the velocity of the mechanism in the reservoir and should be selected fine enough to capture the reservoir behavior and large enough to make the calculation economical.

Finally, the inherent uncertainty due to the meager knowledge of the reservoir has to be accounted for. The reservoir properties are only known at the wells locations. Reservoir characterization method allow only estimation (and not an exact determination) of reservoir properties between the wells. Thus, some discrepancies between model and actual reservoir behavior cannot be reduced by the rational approach used in history matching process. These discrepancies may be resulted from the uncertainty in reservoir knowledge. Usually, few wells present such discrepancies. Because of the abovementioned points, it is a common practice to accept a history match when an acceptable match for about 90% of wells is achieved.

Computed and measured data will be plotted against time for each well in order to demonstrate the quality of the match. Besides attempting to obtain reasonable match, emphasis will also be put on the variation trends.

**Reservoir Simulation and History Matching Report**

The outcome of the reservoir simulation process will be well documented to reflect the input and output of the model. All data inherited from the geological model will be highlighted and subsequent quality check and quality controls will be presented. The following documents will be provided to illustrate the history matching process.

- A complete data set for the run

- Model field performance plots (oil production rate, cumulative oil production, water cut, cumulative water production, gas oil ratio, cumulative gas production, and pressure) with comparison to measured performance
- Model well performance plots (oil production rate, cumulative oil production, water cut, cumulative water production, gas oil ratio, cumulative gas production, and pressure) with comparison to measured performance
- Comparison tables for pressure measurements and model results with gross and percentage difference
- Model fluid level plots (water-oil contact and/or gas oil contact) for the field, sectors and wells with comparison to measured fluid levels
- Maps of gas/oil saturation at the end of history per layer
- Maps of gas/oil saturation difference (final-initial) per layer
- Maps of pressure at the end of history per layer
- Maps of pressure difference (final-initial) per layer
Prediction Scenarios

The objective of this activity is to run the dynamic model (which was calibrated and tuned in the history matching phase) for a series of prediction cases to estimate the expected future performance of the field under alternative development plans and operational constraints.

Definition of Constraints

After determining the forecast period, decisions will be made for the following constraints.

- Minimum field/well gas/oil production rate before shut-in
- Minimum flowing bottom-hole/wellhead pressure
- Maximum field/well water cut and gas oil ratio before re-completion or shut in
- Maximum injection pressures and rates
- Field gas/oil and water storage/disposal and treatment capacities

Base Case Forecast

The present production policy at the current production rate or any other rate, which is expected to be achieved easily, will be the base case development scenario. This will be a case without major capital expenditures but will include normal wells workover/re-completions. This case will serve as a basis for comparison of all other forecasts.

The base case and its constraints will be defined and it will be consistent with the current production policy and surface facilities, unless other decisions are made.

Sensitivity Analyses of the Base Case Scenario

History matching will be performed on the basis of best estimates and engineering judgments. The inaccuracies in the model are related to meager data of any kind. In order to optimize the project costs, the impact of different uncertainties should be investigated on the production potential of the field. Therefore, series of comparative runs will be planned to investigate the relative impact of data uncertainties on the well/field production potential.

The Base Case scenario will be used to make such comparative runs over different uncertain parameters.

Well Planning and Screening of Different Scenarios

The well planning should be performed based on previous experiences and innovative methodologies to keep the existing production or increase existing production level. The history matching results which shows the remaining hydrocarbon saturation is only one of the parameters to be used in planning of future wells. In fact, well planning has different independent sources which intersection of all of them may present free areas for drilling new and/or infill wells. Such sources may be briefly listed as follows:
Wells must be away from water conducting faults to avoid pre-mature water production.

Wells must preferentially be seeking main target reservoir to have longer life with higher production. Completing wells in poor reservoir sections may not results good wells even if there is very good gas/oil saturation in place.

Wells must be drilled and completed in the area where the pay thickness is greater than a minimum value. Drilling wells in very thin parts of the target reservoir may not give productive wells.

Wells must be spaced according to the expected production role. Putting the wells too close to each other will result in well interference and higher drilling costs. On the other hand, putting wells too far away will leave un-swept reservoir behind. The appropriate well spacing may be determined by single well modeling.

If the region is relatively poor, the well must be longer to compensate poor rock quality. In other words, each selected well must be optimized for the length and direction.

The wells must be put in high remaining mobile oil saturation.

The last element on the above list is obtained using history matched model to select well locations. The wells will be put in high remaining oil saturation regions or sweet spots. At this stage, for future drilling, the history matched model helps to select the final position of the new wells in the area already filtered by previous stages. The inappropriate region is filtered out by other elements and the remaining region may be addressed as sweet spots. Using the history matched model, such region may be used for infill drilling or infill well positioning.

**Alternative Development Cases**

The detailed examination of the base case results will reveal a number of potential opportunities to improve reservoir performance. Various development scenarios will be simulated looking at the benefits gained by utilizing horizontal wells, gas or water injection or any other IOR/EOR method. The selected scenarios will evaluate the field performance at the oil plateau rates used in preliminary studies.

Different development scenarios will be evaluated as follows:

- Optimization of the number, location, completion interval, and type of new wells (vertical, deviated, horizontal, and multilateral)
- Work-over of the problematic wells
- Natural depletion scenario
- Application of ESP artificial lifting with determination of horsepower requirements
- Application of the gas lifts artificial lifting instead of ESP with determination of surface facilities requirements
- Application of acid fracturing to improve well production
Gas injection scenarios for both pressure maintenance and IOR/EOR application

Water injection scenarios for pressure maintenance, water disposal, and IOR/EOR application

Other IOR/EOR methods

**Economic Analyses and Selection of Executive Scenario**

In order to conclude the optimum development plan, economic analyses will be made on different development alternatives in regard to the wells and facilities considered and scenario studies. CAPEX and OPEX of evaluated alternatives, with speculated gas/oil prices over a reasonable time span will be discounted appropriately to calculate the corresponding NPVs and conclude an optimum MDP. Uncertainty analysis will also be performed on different factors affecting the NPVs of different scenarios.

For the economically optimal development scenario, the following studies will be conducted in more details using appropriate software packages:

- Development of the design basis
- Conceptual process simulation study
- Simplified process flow diagram (PFD) for surface facilities
- Pipeline sizing study (infield and transmission)
- Cost estimation of the selected development plan

www.energiring.com/oil-and-gas

info@energiring.com