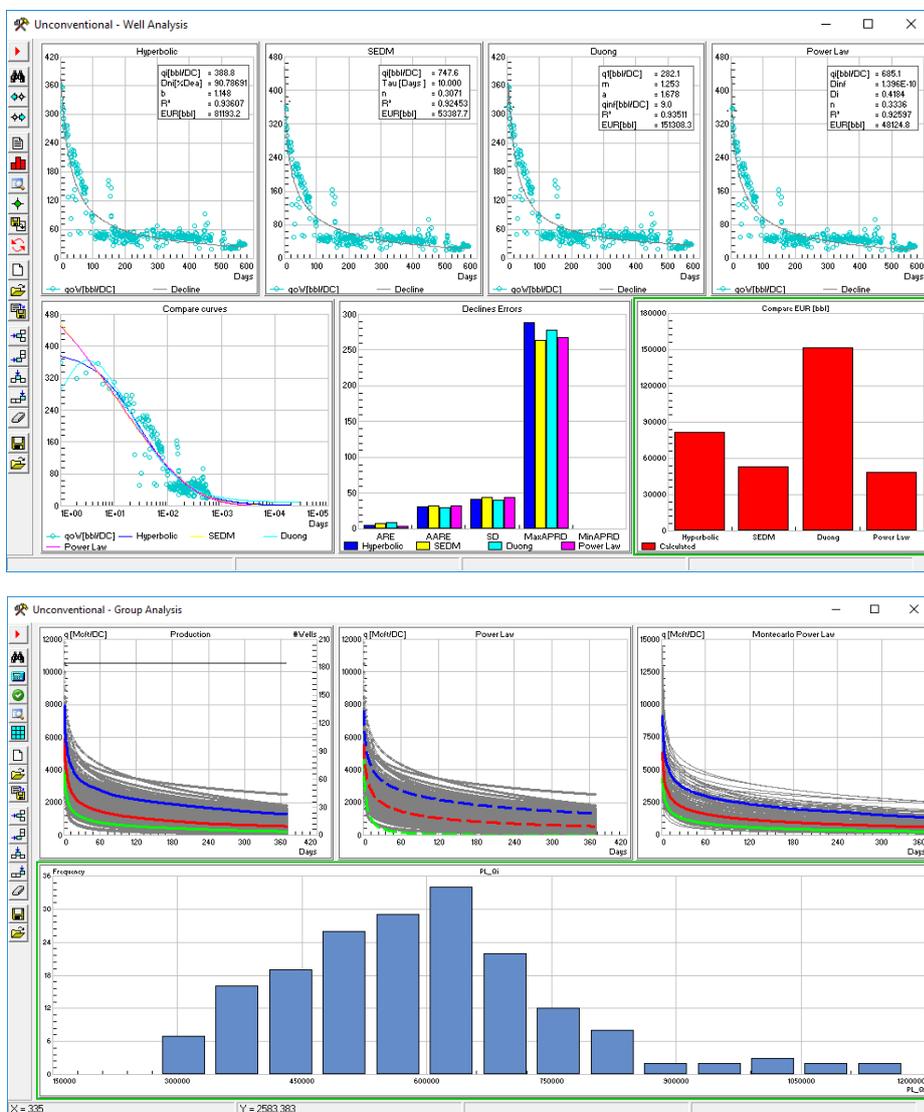


COMPARISON OF EMPIRICAL DECLINE CURVE METHODS FOR UNCONVENTIONAL WELLS

Sahara Unconventional is a complete suite of tools and methodologies specifically designed to analyze unconventional resources data. It allows to make a thorough well by well analysis enabling to define different workflows to standardize the job. In order to do this, there are different production data visualization and diagnostic plots, specialized Rate Transient Analysis and Decline Curve Analysis available for unconventional wells.

This brochure explains how to compare results from different DCA methodologies developed for unconventional wells in order to study which one better suits your wells.



This workflow facilitates comparing results obtained from different DCA methodologies, obtain statistical forecasts and define type wells.

Sahara

Decline Curve Analysis provides a quick way for forecasting production and estimate ultimate recovery (EUR) that can be applied to individual wells or a group of them. It is still the most common approach to analyze declining production. The most commonly and extensively used decline model are Arps models published in 1945 for conventional wells. Conventional wells typically reach boundary dominated flow (BDF) in a period of hours or days. Arps equations are used to fit and extrapolate production in time during BDF providing reasonable estimations to the forecast and EUR. Unconventional wells often exhibit long transient flow regimes and BDF may occur after several years on production. This long transient flow is due to the low permeability of the matrix.

In this context, new empirical methods have been developed to model the special production trend in unconventional wells. In this workflow, different specialized unconventional decline methods are compared along with the traditional Arps methods.

The specialized methods used in this brochure are Hyperbolic with b greater than one, Duong, Power Law and Stretched Exponential.

The different equations described in Figure 1 will result in different estimations of EUR, so it is very important to make a comparative study between methodologies. Sahara Unconventional enables to perform a complete comparative study between available methodologies allowing to measure the quality fit in the history matching and comparing EUR for different methodologies as showed in Figure 3. Sahara Unconventional allows to set economic limits in terms of a date or a minimum rate. For each methodology a forecast can be saved in order to be visualized in the Production Window as can be seen in Figure 2.

Sahara Unconventional fits daily or monthly productions minimizing the least square function using a Levenberg Marquardt Algorithm.

| Methodology | Equation | Notes | References |
|-------------|---|---|---|
| SEDM | $q = q_i \exp[-(t/\tau)^n]$ | q_i : initial rate τ : characteristic time n : exponent | Valkó, P.P. and Lee, W.J. 2010. SPE 134231 |
| Duong | $q = q_1 t(a,m) + q_\infty$ $t(a,m) = t - m \exp(a(1-m)(t-1))$ | q_1 : rate at day 1 a, m : dimensionless parameters q_∞ : infinite time rate | Duong A.N. 2011, SPE-137748 |
| Power Law | $q = \hat{q}_i \exp(-D \omega t - D i t^n)$ | \hat{q}_i : interception rate $D \omega, D i$: decline constants n : dimensionless time exponent | Dilhan Ilk, Rushing J.A., Perego A.D., Blasingame T.A. 2008, SPE 116731 |

Figure 1. Most popular DCA methodologies developed for unconventional wells.

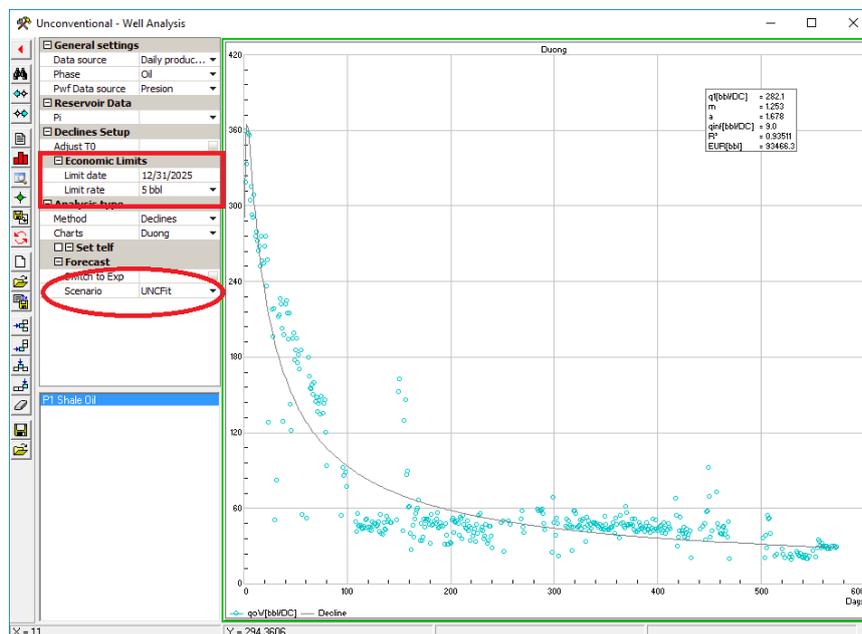


Figure 2. Setting Economic Limits and Forecast Scenario for Duong model in an unconventional oil Well.

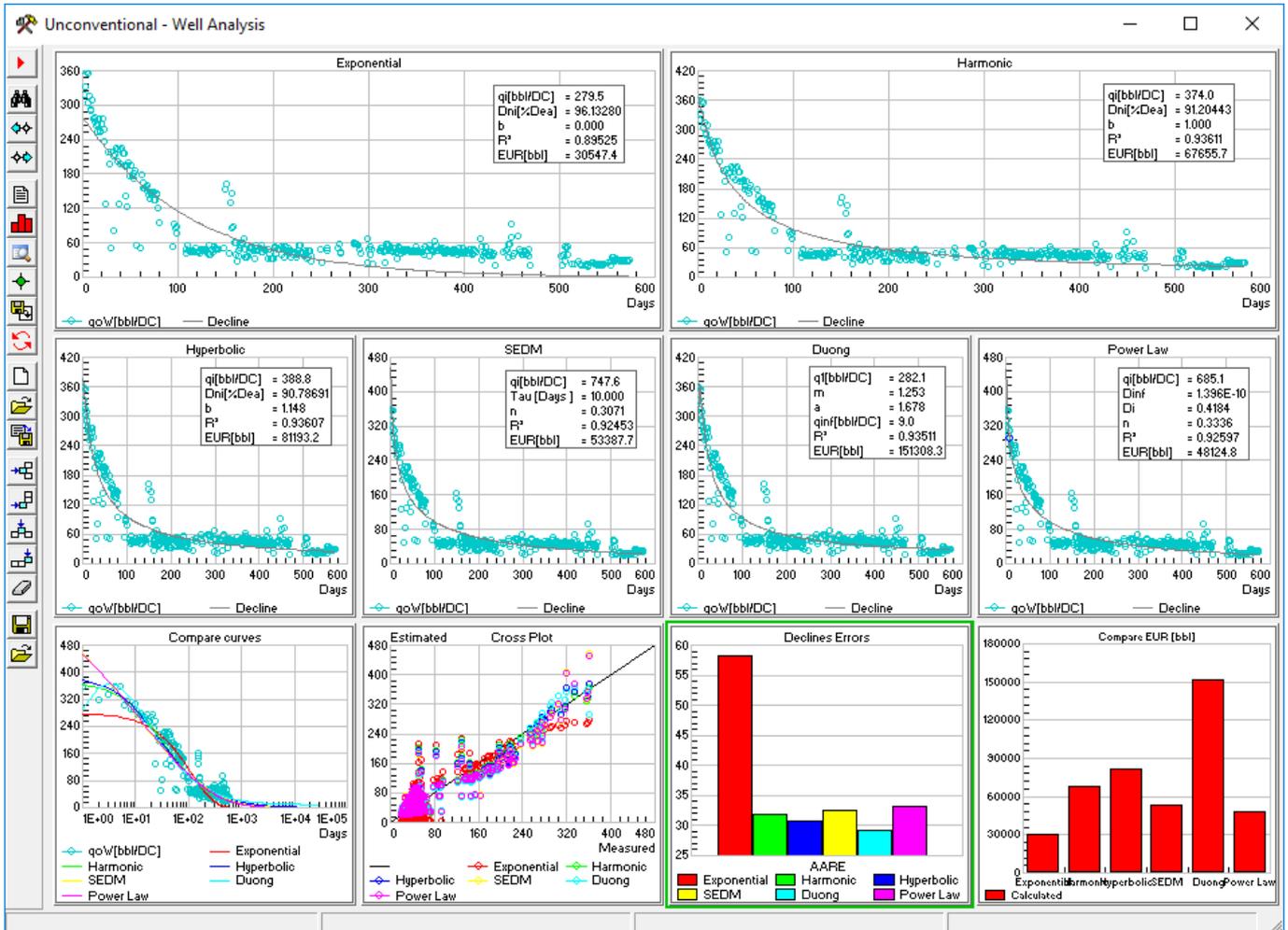


Figure 3. Comparison for the daily history matching of an unconventional oil well using different methodologies. The last three plots help quantify the quality of the fit and compare the different EUR obtained at the set economic limit.

The same kind of analysis can be performed in the Group Analysis Window comparing the final cumulative productions with the statistic average, P10, P50 and P90 wells.

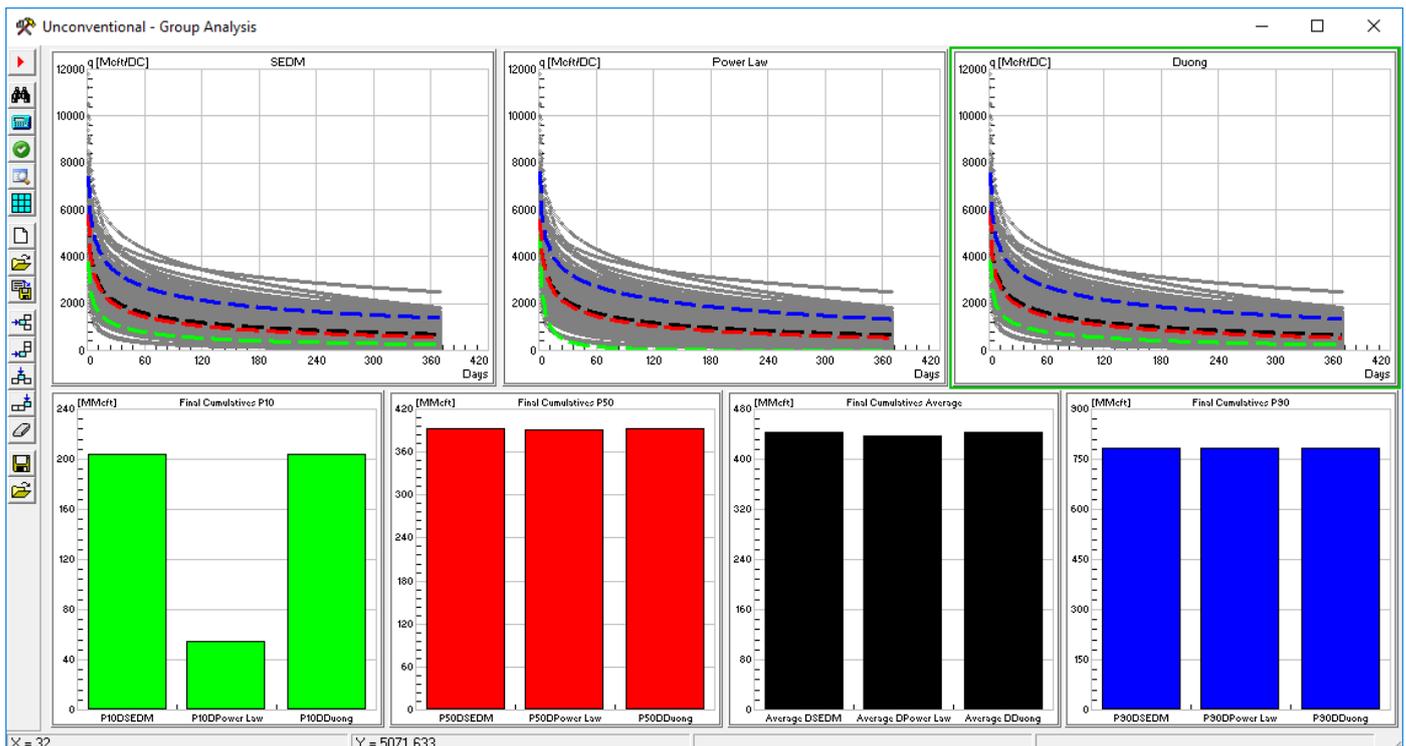


Figure 4. Group Analysis Window comparing the different statistic wells for Duong, SEDM and Power Law decline models.

A complete comparative study of the different available DCA methodologies for unconventional resources can be performed combining the Well Analysis Window and the Group Analysis Window. For example, if a good amount of wells have been analyzed with one or different DCA methodologies the fitted parameters and EUR results can be saved and visualized in the Statistical Analysis Tool or the Unconventional Group Analysis Window. The Group Analysis Window allows different ways to perform DCA analysis for a group of wells. As showed in **Figure 4** it is possible to calculate and decline the statistical wells (average, P10, P50, P90) and compare the results obtained from different methodologies. If a considerable group of wells have been fitted with any of the available models the Statistical Analysis Tool allows fitting a theoretical distribution using the Anderson Darling and Kolmogorov Smirnov goodness of fit tests.

Once a probability distribution is assigned to each DCA parameter, a Montecarlo Simulation can be run for any of the available DCA methods. The idea is to analyze different ways to calculate type wells. The window allows saving type wells in order to be used in the Forecast Exercises Window.

Selecting a well within the group under study or from the Map Window allows studying the behavior of an individual well within the group.

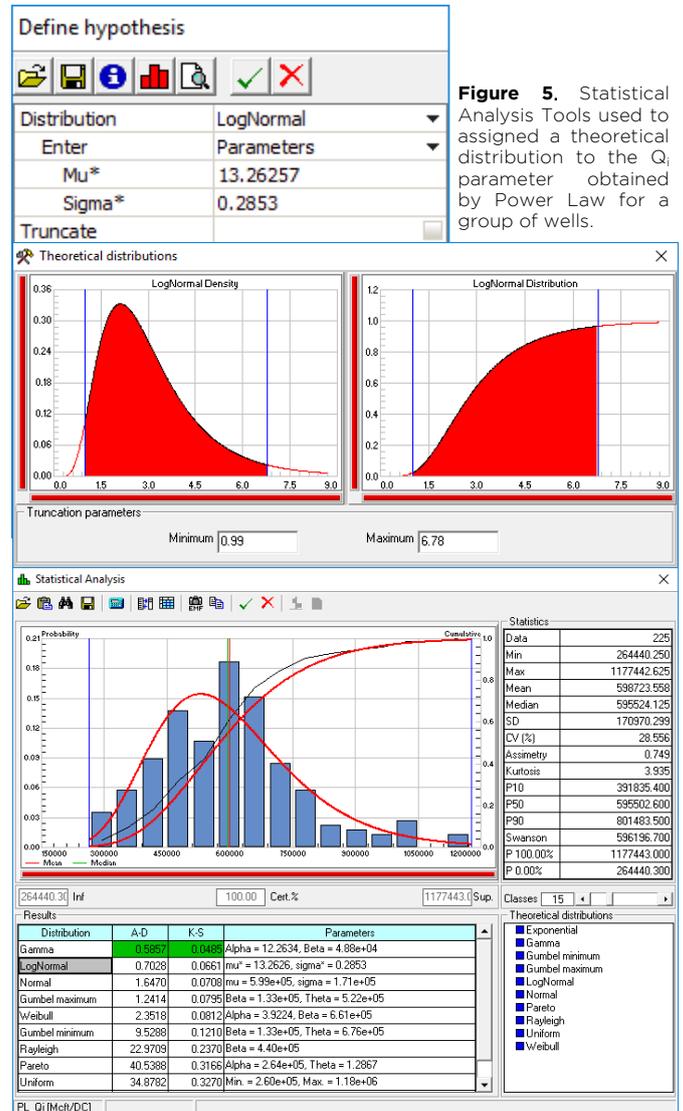


Figure 5. Statistical Analysis Tools used to assigned a theoretical distribution to the Q_i parameter obtained by Power Law for a group of wells.

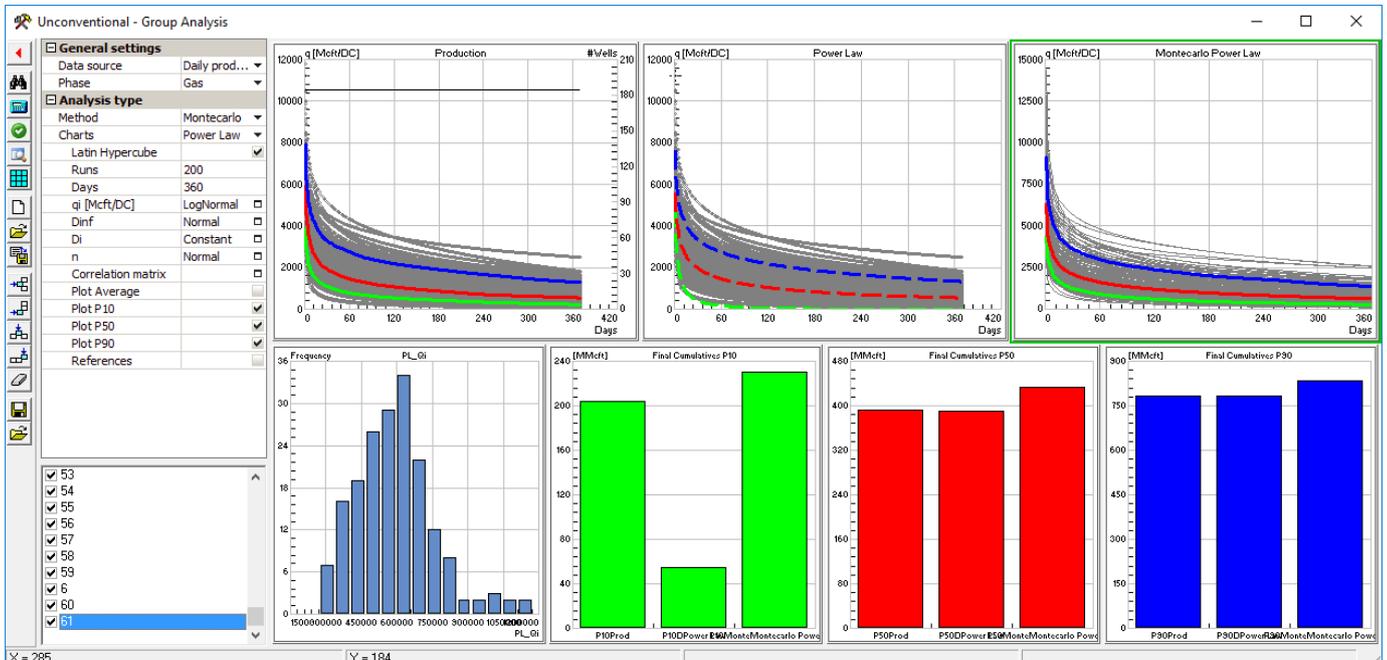


Figure 6. Calculation of statistics wells and results comparison for the final cumulative using different methodologies: from the productions, declining the statistic wells using Power Law and running a Montecarlo simulation.



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