DCA & Type Wells

A Petroleum Engineering Reference Guide

whitson

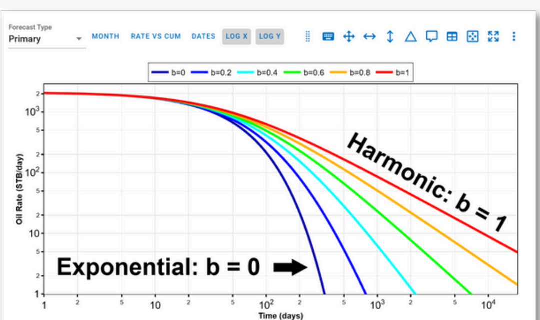
Decline Curve Analysis (DCA)

Arps Equation

$$q(t) = q_i(1 + ba_i t)^{-1/b}$$

q_i = initial flow rate
a_i = nominal decline rate at time zero
b = rate exponent
$q(t)$ = flow rate at time t

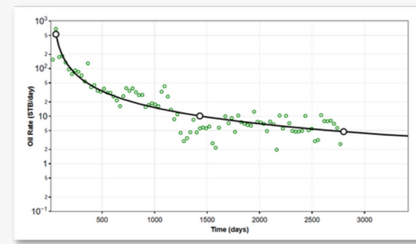
Type	Decline Rate	Producing Rate, q	Elapsed Time, t	Cum. Production, Q_t
Exponential b = 0	$a_t = ln(\frac{q_i}{q_t})/t$	$q_i e^{-a_i t}$	$ln(\frac{q_i}{q_t})/a_i$	$\frac{q_i - q_t}{a_i}$
Hyperbolic b > 1	$\frac{a_i}{a_t} = (\frac{q_i}{q_t})^b$	$q_i(1 + ba_i t)^{-1/b}$	$\frac{(q_i/q_t)^b - 1}{ba_i}$	$\frac{q_i}{a_i(1-b)}(1 - \frac{q_t}{q_i}^{1-b})$
Harmonic b = 1	$\frac{a_i}{a_t} = \frac{q_i}{q_t}$	$q_i(1 + a_i t)^{-1}$	$\frac{(q_i - q_t)}{a_i q_t}$	$\frac{q_i}{D_i} ln(\frac{q_i}{q_t})$



b-factor Rules of Thumb	
b = 0	single-phase oil, or gas at high pressure
b = 0.1-0.4	solution gas drive
b = 0.4-0.5	single-phase gas flow
b = 0.5-1	layered reservoirs
b >= 1	infinite acting, or transitional flow

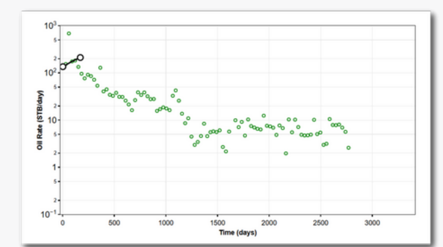
DCA Segment Types

Decline (Arps)



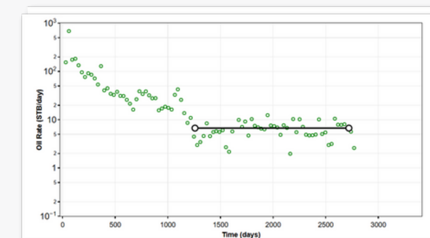
$$q(t) = q_i(1 + ba_i t)^{-1/b}$$

Linear



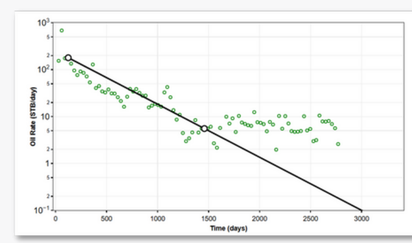
$$q(t) = q_i + m \cdot t$$

Constant



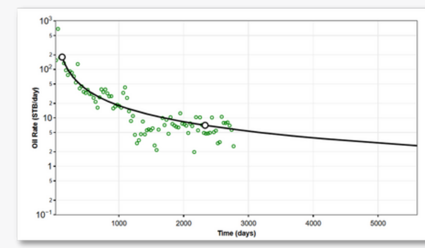
$$q(t) = q_i$$

Semi-Log



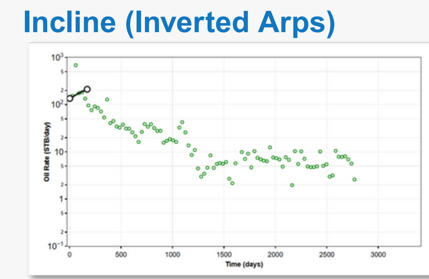
$$q(t) = q_i e^{-a_i t}$$

Power Law



$$q(t) = q_i \cdot t^{-n}$$

Incline (Inverted Arps)

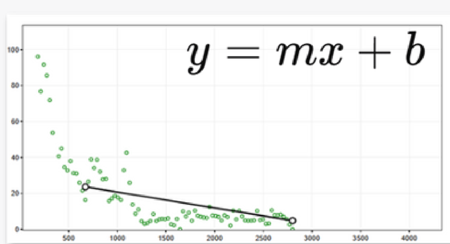


$$q(t) = q_i(1 + ba_i t)^{-1/b}$$

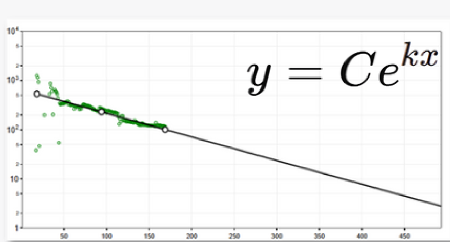
* Negative b and negative decline rate

DCA Segment Types & Straight Lines

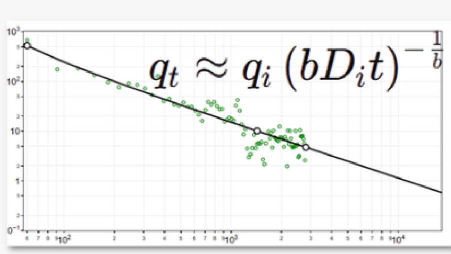
Linear?
Straight line on a Cartesian plot. Useful for identifying constant rate declines or trends in linear relationships.



Exponential?
Straight line on a semi-log plot. Exponential declines, often typical in fluid-flow-dominated regimes, become linear in this format.

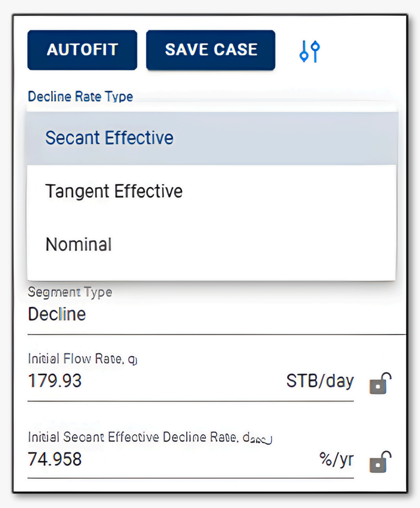


Power-law? Arps?
Straight line on a log-log plot. Power-law declines, as observed in fractured reservoirs, are best visualized in this plot.



DCA Decline Rate Type

Nominal annual decline rate is denoted "a". The effective annual decline rate is denoted "d", with units %/yr. There are two common ways the industry converts annual decline into effective decline,



Secant Effective: Default in whitson*

$$d_{sec} = 100(1 - (a_i b + 1)^{-1/b})$$

Tangent Effective

$$d_{tan} = 100(1 - e^{-a_i})$$

Nominal

$$a_i = \frac{1}{b}[(1 - d_{sec}/100)^{-b} - 1]$$

$$a_i = -ln(1 - d_{tan}/100)$$

DCA Limiting Decline Rate

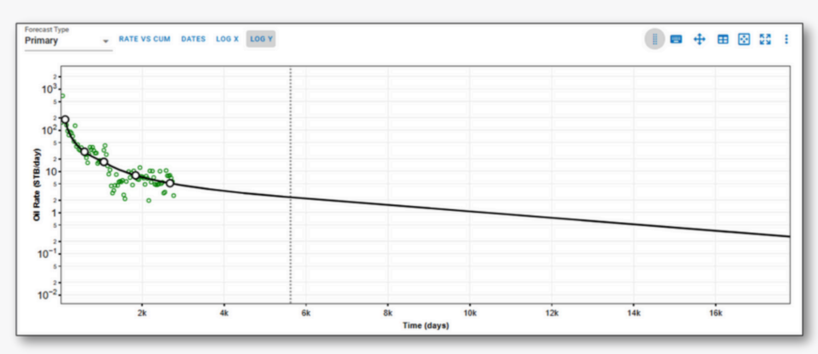
The limited decline rate begins when the hyperbolic decline curve transitions into an exponential decline curve at a specified limiting effective decline rate d_{lim}. The limiting effective decline rate is converted to a limiting nominal decline rate a_{lim} and the following equations are applied.

When $d_{tan} > d_{lim}$: $q(t) = q_i(1 + ba_i t)^{-1/b}$

when $d_{tan} <= d_{lim}$: $q(t) = q_{lim} e^{-a_{lim}(t - t_{lim})}$

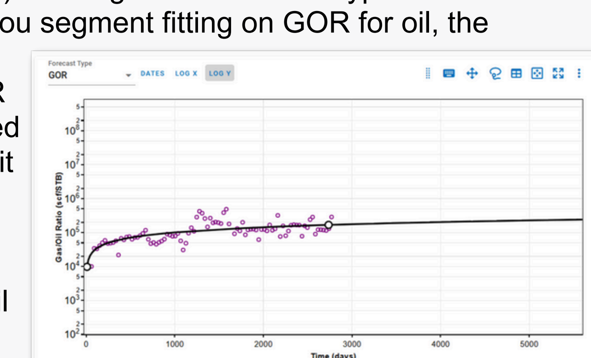
where

$$q_{lim} = q_i\left(\frac{a_{lim}}{a_i}\right)^{1/b} \quad t_{lim} = \frac{\left(\frac{q_i}{q_{lim}}\right)^b - 1}{ba_i}$$



DCA Ratio Forecasting: Power Law

You can switch from considering the primary phase (oil, gas, or water) to using a ratio forecast type. For example, if you segment fitting on GOR for oil, the forecast will use the GOR profile created and multiply it with the gas profile to obtain the forecasted oil rate profile.



Given Arps Hyperbolic functions for oil and gas rate, we take the late-time asymptotic form where *$D_i bt$ >> 1* and simplify to a Power-Law function

$$q_o = q_{i,0}(1 + D_{i,o}b_{i,o}t)^{-\frac{1}{b_{i,o}}} = \frac{q_{i,o}(D_{i,o}b_{i,o})^{-\frac{1}{b_{i,o}}}}{t^{\frac{1}{b_{i,o}}}} = \frac{\alpha_o}{t^{\frac{1}{b_{i,o}}}}$$

$$q_g = q_{i,g}(1 + D_{i,g}b_{i,g}t)^{-\frac{1}{b_{i,g}}} = \frac{\alpha_g}{t^{\frac{1}{b_{i,g}}}}$$

We can then compute GOR as the ratio of the two simplified functions

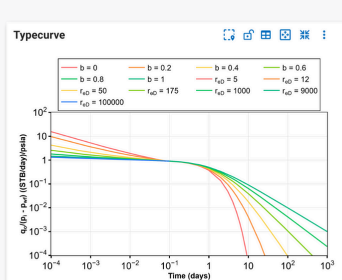
$$GOR = \frac{q_g}{q_o} = \frac{\alpha_g}{\alpha_o}\frac{t^{\frac{1}{b_{i,o}}}}{t^{\frac{1}{b_{i,g}}}} = \frac{\alpha_g}{\alpha_o} t^{\frac{1}{b_{i,o}} - \frac{1}{b_{i,g}}}$$

Source: David Fulford

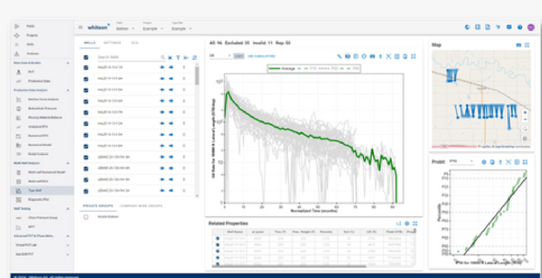
Type Wells

Type Wells help teams forecast production and evaluate economics, scope out plays, understand key production drivers, reduce uncertainty, and confidently support multi-million-dollar decisions.

Type Wells are *not* Type Curves
It's important to remember that Type Wells are *not* Type Curves. Type Curves are idealized, model-based profiles, while Type Wells are built from actual production data to represent the typical performance of a group of wells.



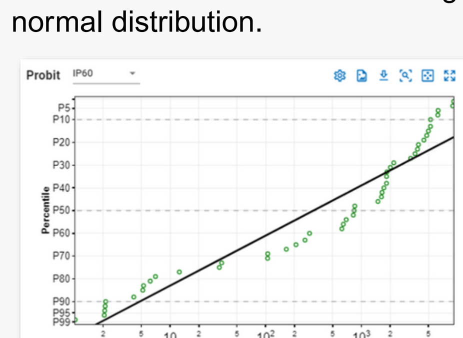
Type Curve



Type Well

Type Well Probit

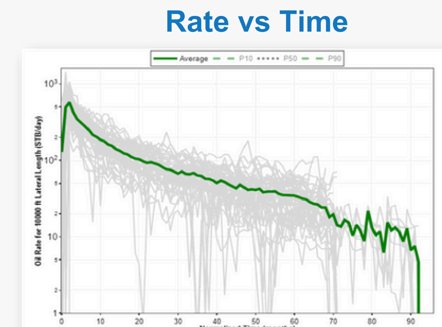
Represents the statistical distribution of a variable (e.g., EUR, IP60, or another physical parameter) at a point in time, with its shape indicating whether results trend toward a log-normal distribution.



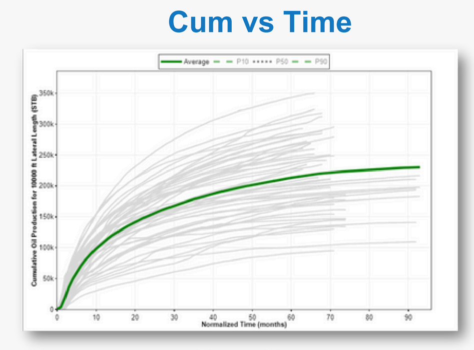
A "**probit best fit**" regression can yield statistical insights including uncertainty measures (e.g. P10/P90)

Type Well Charts

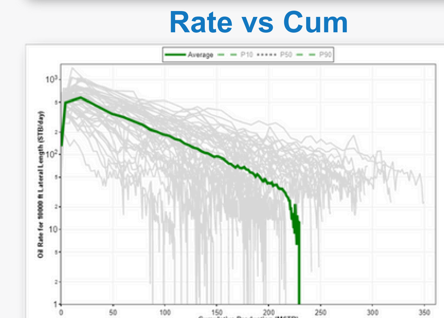
Rate vs Time



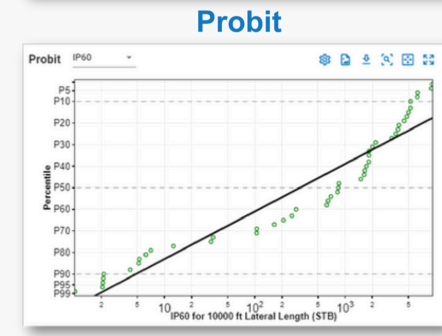
Cum vs Time



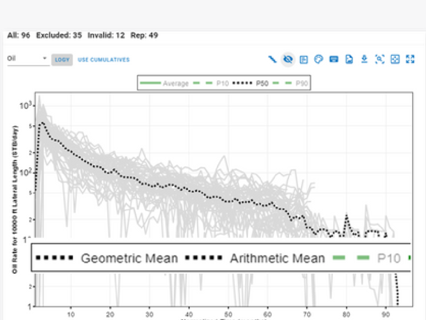
Rate vs Cum



Probit



Type Well Averaging



Source: David Fulford

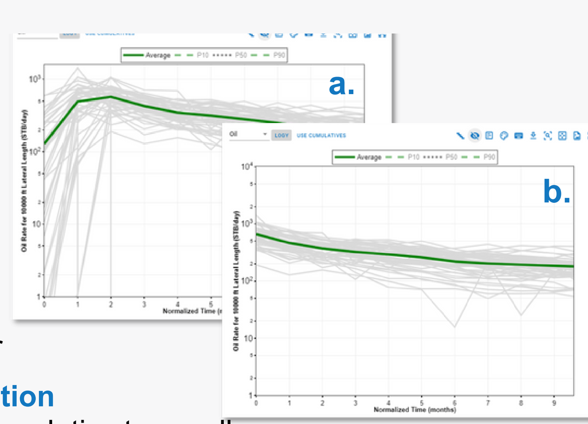
The **arithmetic mean** is highly biased by outliers and is not reliable to use as a basis for a type well profile nor (by itself) as a diagnostic.

The **geometric mean** is less biased by outliers, but susceptible to skewness in low values.

The **P50** *(recommended)* presents the least biased representation as it is wholly unaffected by values, only ordering.

Type Well Normalization

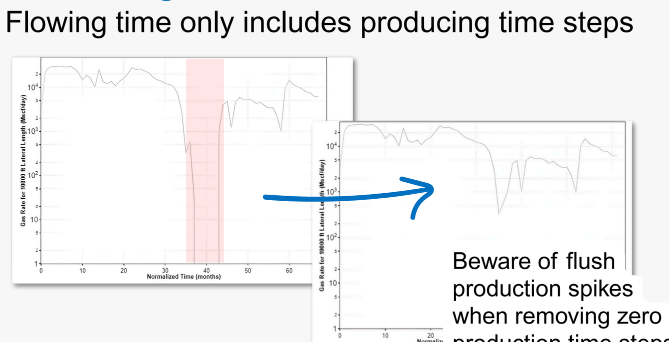
Time Normalization
Alignment to a common date or event
a. *First Production* - on large well sets portrays prod. profile considering time to peak
b. *Peak Rate* - more accurate prod. behaviour



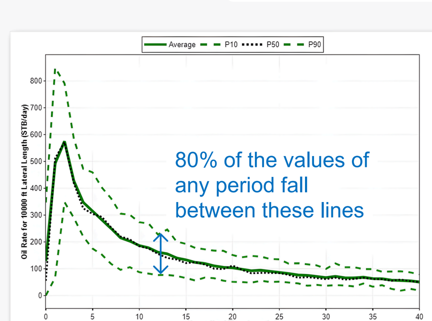
Dimensional Normalization
Scaling production values relative to a well design parameter, eg. production/lateral length

Advanced Normalization
Non-linear scaling of laterals, eg. a 10,000 ft lateral is 1.8x better than a 5,000 ft

Condensing Time
Flowing time only includes producing time steps

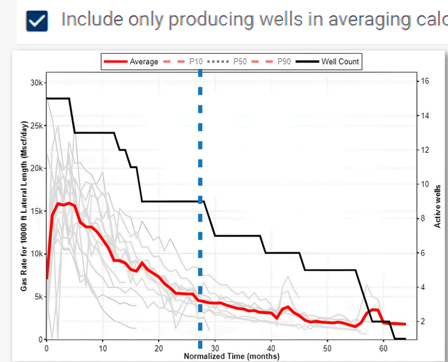


Percentile Trendlines
Communicate the range of values used to calculate the average of each month.



Type Well Survivor Bias

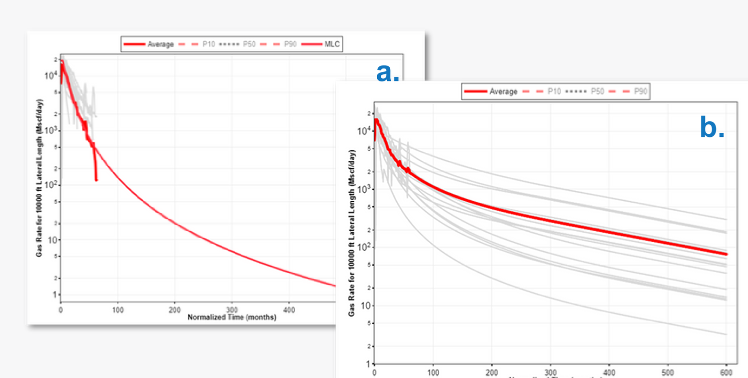
Include only producing wells in averaging calculation



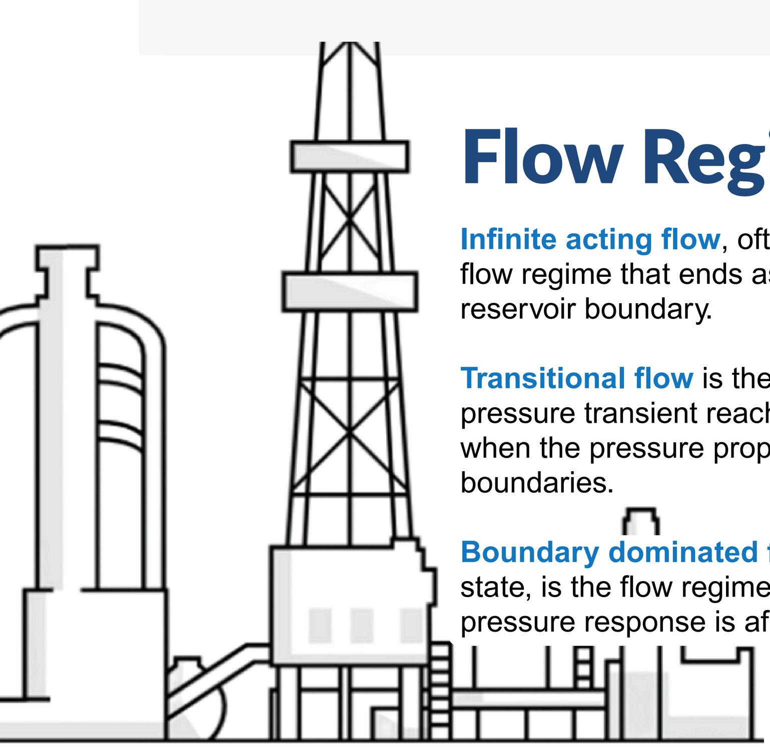
As depleted wells are excluded from the avg, the type well values are biased by the surviving wells. Applying survivor bias controls will include zeros in the average for wells after they are identified as depleted

Truncation Using Cut-offs *(see - - - - line above)*
Sample sets with a range of production history may have a late time portion biased by the older wells, so a "sample size cut-off" (commonly 50% or more) is often used, selecting wells by vintage to ensure contributing wells have a similar amount of production history.

Forecast Averaging



a. Forecast the Average Apply a decline to the truncated type well to obtain a full life profile of EUR. Time effective, but does not provide distribution of EURs
b. Average the Forecasts Time consuming without auto forecast option. Useful for statistical evaluation and P10/P90 quantification of EUR



Flow Regimes

Infinite acting flow, often referred to as transient flow, is the flow regime that ends as the pressure transient reaches *one* reservoir boundary.

Transitional flow is the flow regime that starts as the pressure transient reaches *one* reservoir boundary and ends when the pressure propagation reaches *all* reservoir boundaries.

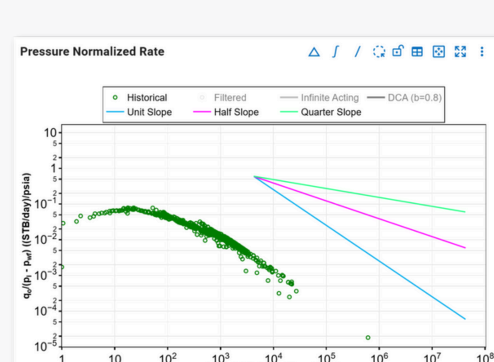
Boundary dominated flow, also called pseudo-steady state, is the flow regime that starts when the wellbore pressure response is affected by *all* reservoir boundaries.

Pressure Normalized Rate (PNR)

$$PNR = \frac{q}{\Delta p} = \frac{q}{p_i - p_{wf}}$$

Pressure normalized rate is very useful for production analysis where flowing pressures and rates change through time. It is defined as the rate divided by flowing pressure drop.

PNR is the inverse of RNP.



PNR DCA

$$q_{PNR} = \frac{q}{p_i - p_{wf}} \times (p_i - p_{wf,min})$$

Xie (2023) identified that DCA in unconventional wells can overestimate EUR due to extended early-time flat production. Using the PNR flowrate—calculated by multiplying PNR with a constant pressure drawdown—offers a more consistent alternative.

Where q_{PNR}, represents the PNR flowrate at a constant pressure drawdown and $p_{wf,min}$ is the estimated abandonment BHP.