The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

#3 - Is Shale Oil Production from Bakken Headed for a Run with "The Red Queen"?

Posted by Rune Likvern on January 1, 2013 - 3:12am

The Oil Drum staff wishes a Happy New Year to all in our readership community. We are on a brief hiatus during this period, and will be back with our regular publications early in the new year. In the meantime, we present the top ten of best read Oil Drum posts in 2012. The eight in this series is a post by Rune Likvern on shale oil production in the US Bakken basin.

In this post I present the results from an in-depth time series analysis from wells producing crude oil (and small volumes of natural gas) from the Bakken - Bakken, Sanish, Three Forks and Bakken/Three Forks Pools - formation in North Dakota. The analysis uses actual production data from the North Dakota Industrial Commission as of July 2012 from what was found to be a representative selection of wells from operating companies and areas.

The reference in the title to the Red Queen from "Through the Looking-Glass" by the English author Charles Lutwidge Dodgson (perhaps better known as his pseudonym Lewis Carroll) who was also a mathematician and logician, is deliberate to create associations with the Red Queen's statement **"It takes all the running you can do, to keep in the same place"**.

After presenting, discussing and concluding the results from the study presented in this post, the reference to the Red Queen was found to be an apt analogy to describe why technology and/or price cannot overcome the inevitable fact that field size and well productivity declines in most plays, whether in shale or any other plays. Put in a different way: shale plays do not get a pass on the laws of physics or the history of play and basin developments.The potential and technology for extraction (production) of shale/tight oil has been around for several decades.

There is every reason to embrace the recent additions of shale oil (from Bakken, Eagle Ford and other plays). These additions will help ease the present tight global oil supply situation and thus slow down the growth in oil prices.

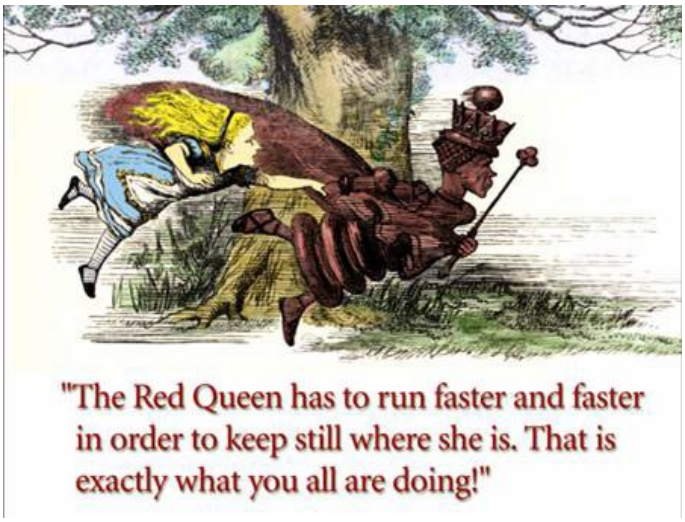

Figure 01: *The illustration above is from "Through the Looking-Glass". At the top of the hill, the Red Queen begins to run, faster and faster. Alice runs after the Red Queen, but is further perplexed to find that neither one seems to be moving. When they stop running, they are in exactly the same place. Alice remarks on this, to which the Red Queen responds:* ***"Now, here, you see, it takes all the running you can do to keep in the same place"****.*

Continued below the fold.

MAJOR FINDINGS FROM THE STUDY

All charts in this post are clickable for a larger version.

Findings from this in-depth study of time series for production from some individual wells:

- Presently the estimated breakeven price for the "average" well in the Bakken formation in North Dakota is **$80 - $90/Bbl** *In plain language this means that presently the commercial profitability for new wells is barely positive.*
- The "average" well now yields around 85 000 Bbls during the first 12 months of production and then experiences a year over year decline of 40% (+/-) 2%
- The recent trend for newer "average" wells is one of a perceptible decline in well productivity (lower yields)
- As of 2007 and also as of recent months, the total production of shale oil from Bakken, has shown exceptional growth and the (relatively high) specific average productivity (expressed as Bbls/day/well) has been sustained by starting up flow from an accelerating number of new wells
- Now and based upon present observed trends for principally well productivity and crude oil futures (WTI), it is challenging to find support for the idea that total production of shale oil from the Bakken formation will move much above present levels of **0.6 - 0.7 Mb/d** on an annual basis.

Authoritative research companies (like Bernstein Research) and widely acknowledged specialists/institutions like USGS and SPE have recently and in general arrived at identical conclusions by applying different sets of methodologies and from studying other areas.I am of course in no position to rule out that the required breakeven price in the future could be lowered driven by technological innovations and improvements in well design and operations. However recently there have been a flow of reports that casts a reasonable doubt that this will become a given.

The content for this post was first posted in two parts (with data as of June 2012) on my Norwegian blog; "Fractional Flow" Part 1 and Part 2.

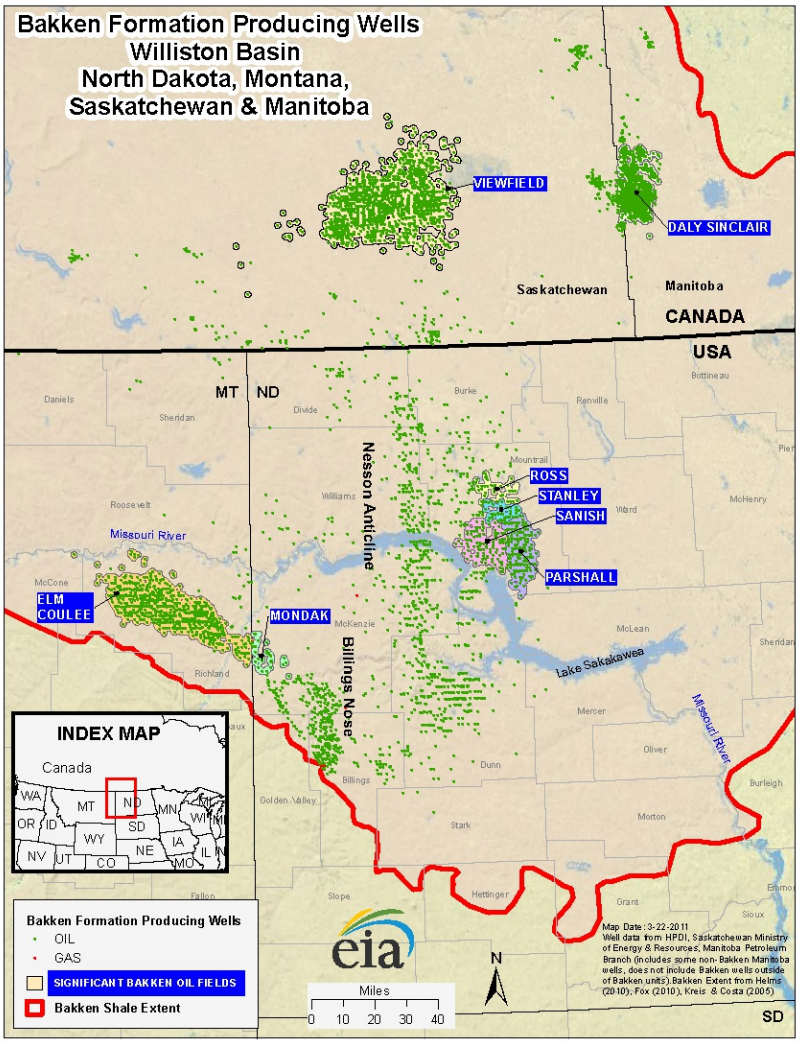

Figure 02: *The map above from EIA (Energy Information Administration) shows the extent of the Bakken formation, areas with considerable activity and oil and natural gas wells. The most active areas are also the most productive ones (sweetest spots) and data now shows that these are well developed (saturated).*

As of July 2012, data from the North Dakota Industrial Commission documented extraction (production) from 4 319 wells in the Bakken formation (which includes Bakken, Sanish, Three Forks and Bakken/Three Forks basins). Total reported production in July 2012 was around 610 000 Bbls/day with a specific average of 141 Bbls/day/well.

The production of shale oil/tight oil (which is not to be confused with oil shale; kerogen) is proclaimed by many to constitute a “revolution” and/or “game changer” for the global supplies of crude oil. Shale oil has unquestionably added valuable supplies during a period of tight global crude oil supplies.

SCOPE OF THE STUDY

The scope of the study incorporated companies/areas that had a specific average production (Bbls/day/well) above the average for the Bakken formation, see also figure 06. Further the study concentrated on newer wells where there were reported starts of production as from January 2010 and later. This was also to make sure that effects from those newer wells with “state of the art” technologies (technological innovations/improvements like horizontal wells also with laterals, multistaged hydraulic fracking, to name a few) were incorporated. This was done to

document recent trends. Normally it takes somewhere between 5 to 6 months from start of drilling of a well until it starts flowing. Then add time for planning and approvals.

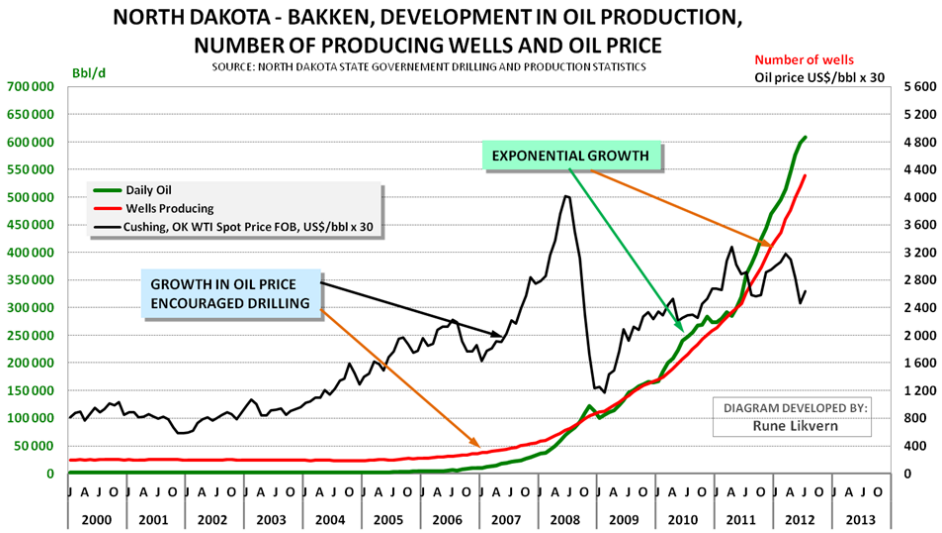

Figure 03: *The chart above shows the development in the number of reported producing wells, oil production and the crude oil price (NOTE; to enable the inclusion of the oil price in the chart the actual price has been multiplied by 30. In other words actual prices are found by dividing the value in the chart by 30.). The chart shows that the growth in oil prices has been the dominant driver for acceleration of drilling and the resulting growth in oil production from the Bakken formation in North Dakota.*

Figure 03 could also create the illusion that growth in shale oil production from the Bakken is still continuing at a rapid pace.However if the time series of actual production data are studied in further detail and are presented in an appropriate manner it becomes easier to document and spot the true underlying trend. From figure 03 it may also be seen that the collapse of the oil price during the fall of 2008 led to a slowdown of activities and lower total production. As illustrated in figure 03 it was primarily the growth in the oil price together with technological innovations in recent years that caused production of shale oil to make economic sense.

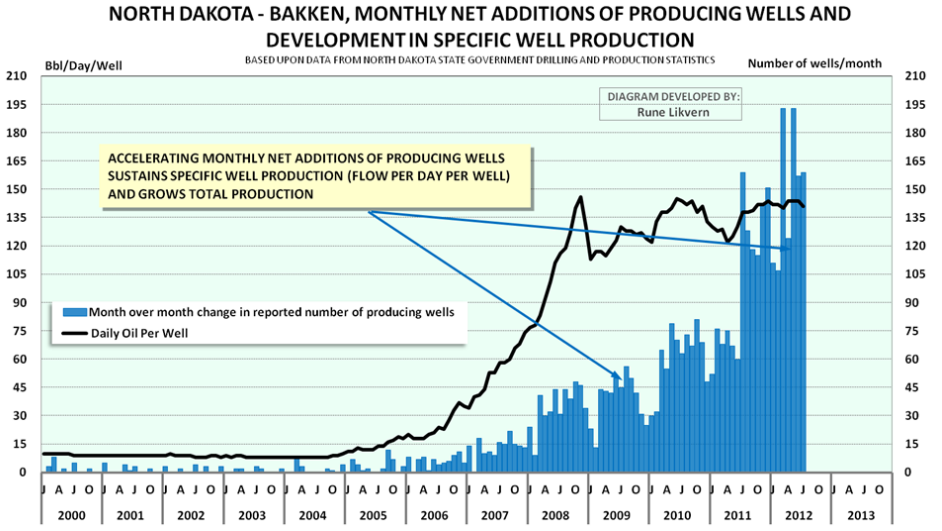

Figure 04: *The chart above shows the development in the reported net total monthly start up of wells (blue columns) and the development in the specific productivity (Bbls/day/well; black line) for the Bakken formation from January 2001 and as of July 2012.*

Figure 04 shows that the specific average production (Bbls/day/well) had strong growth as from 2006 to 2008 and has since been sustained at around 140 Bbls/day/well. Start up of new wells shows an accelerating trend as from 2006. It is this accelerating start up of new wells that have resulted in growth in total production. Extraction/production of oil and gas from shale formations has its own distinct physics governed by geology and comprised of steep decline rates and challenging dynamics that define the rules to create overall growth, sustain a plateau and/or declines.

There are also considerable variations in the productivity between plays within the same play and normally the areas with the best production potential (sweetest spots) become developed first (harvesting the lowest hanging fruit first etc.). The development of shale plays thus follows exactly the same pattern as developments of other petroleum basins.

THE WELLS, AREAS AND COMPANIES COVERED BY THE STUDY

What follows is a presentation of some selected wells from the study and the wells from the areas/companies covered by the study.

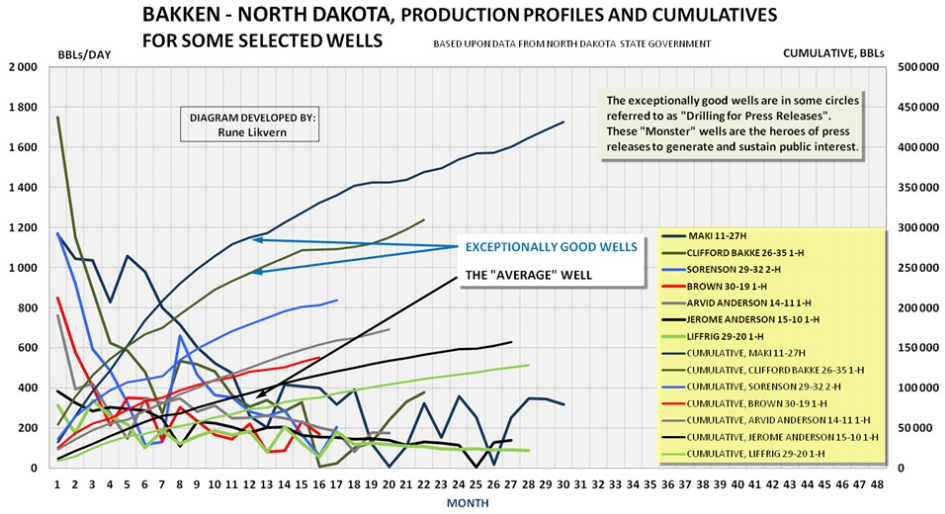

Figure 05: *The chart above show the development in reported average daily production versus number of months in production for some selected wells (well identifications in the legend box) (left y-axis). Incorporated in the chart is the development of total production versus number of months in production (right y-axis).*

The chart above illustrates that there is a huge spread in well productivity, cumulative and decline rates amongst individual wells. The well Sorenson 29-32 2-H (blue line) got attention from, amongst others, the Oil&Gas Financial Journal back in April 2011. Normally it is the exceptionally good wells that get the attention of media and its readers.

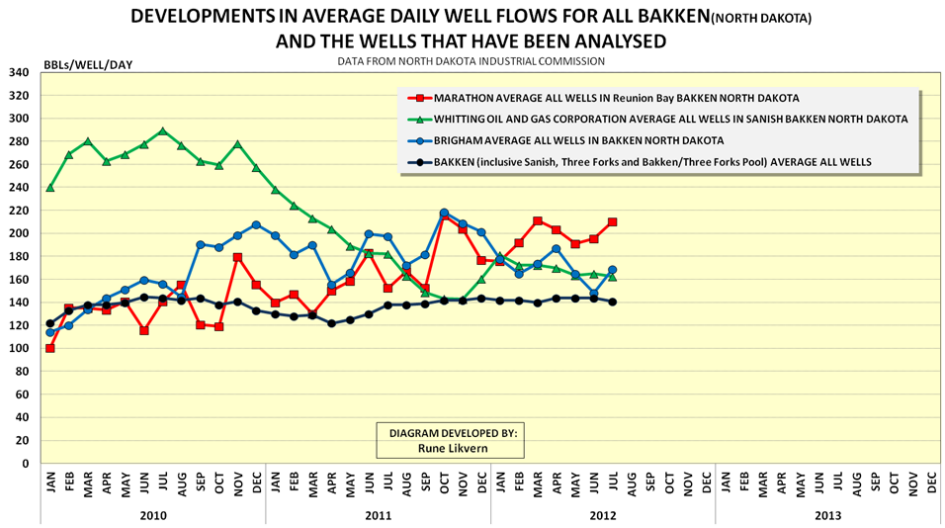

Figure 06: *The chart above shows the development in specific average productivity (Bbls/day/well) for all Bakken in North Dakota (black circles connected by black line), Whitting Oil and Gas Corporation's wells in Sanish (green triangles connected by green line), all of Brigham's wells (blue circles connected by blue line) and Marathon's wells in Reunion Bay (red squares connected by red line) from January 2010 and as of July 2012.*

Figure 06 documents that the wells from the areas/companies that were subject to the in depth time series studies had productivity that was above the average for all reported wells in the Bakken play in North Dakota. Notice also the pronounced decline of more than 40% over 2 years in the average well productivity for the wells in Sanish.

COMPANY/AREA	TOTAL NUMBER OF WELLS FLOWING AS OF JULY 2012	TOTAL NUMBER OF WELLS WITH REPORTED FLOW FOR 12 MONTHS OR MORE WITH REPORTED START OF FLOW JANUARY 2010 OR LATER
BRIGHAM, ALL AREAS	183	72
MARATHON, Reunion Bay	53	21
WHITTING OIL AND GAS CORPORATION, Sanish	242	109
TOTAL	*478*	*202*

Table1: *The table above lists the number of wells that were subject to the in depth time series studies, and what companies/areas these were reported.*

The in-depth time series study was comprised of 478 wells (around 11%) of the 4 319 wells reporting production from the Bakken. These wells represent around 13% of the total production as of July 2012. The wells with reported start of production as of January 2010 and later and that had reported production for 12 months or more were subject to additional analysis which includes the wells with reported start of flow as of August 2011. In the period January 2010 and through August 2011 there was reported start of flow from a net addition of 1 417 wells of which 202 (or more than 14%) were subject to extensive statistical analysis. The statistical analysis formed the basis to define what is presently considered a pro forma well (or "average" well) for Bakken. The "average" (pro forma) well should not be expected to be static as it will continually change with time and presently the trend is one of declining productivity.

For this "average" (pro forma) well an economic analysis was performed which is presented further down.

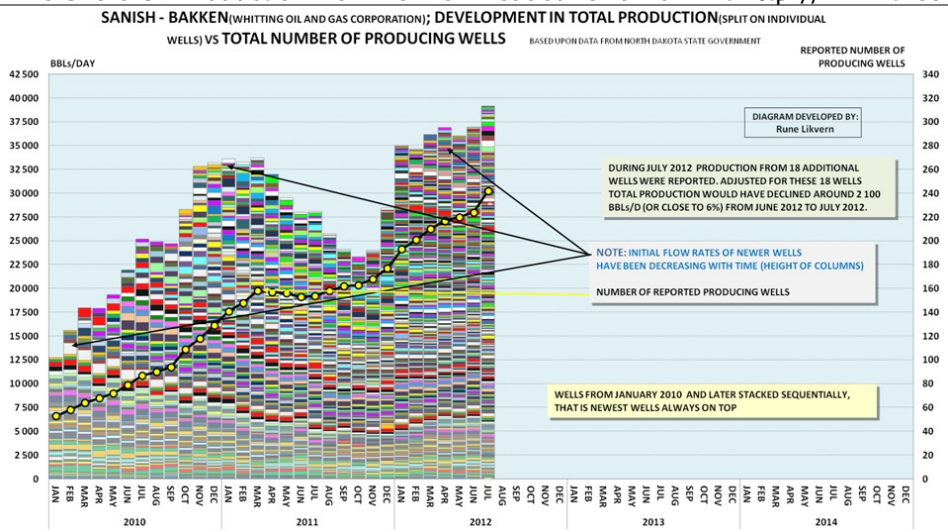

Figure 07: *The chart above shows the monthly total number of wells, month of start up of reported production from added wells, production from the individual wells and total production from the 242 wells reported for Whitting Oil and Gas Corporation in Sanish - Bakken as of July 2012. The chart spans the period January 2010 through July 2012. The wells in the chart are stacked sequentially according to reported start up of production that is newest wells always on top.*

Figure 07 is a suitable illustration of what is to be expected in developments of shale formations (or areas within shale formations) for both oil and natural gas. From the figure it should also be possible to perceive the development of well productivity with time.

- The wells normally have a high production at start up that rapidly enters into steep declines.
- To facilitate growth in total production an accelerating number of wells needs to be brought into production.
- To sustain a plateau requires a continual addition of a high number of producing wells.
- Note in figure 07 how total production declined between March 2011 and as of October 2011 while the reported number of total wells with production saw little change.
- Figure 07 also shows how well productivity (note the arrows and height of columns) has shown a general decline for newer wells.

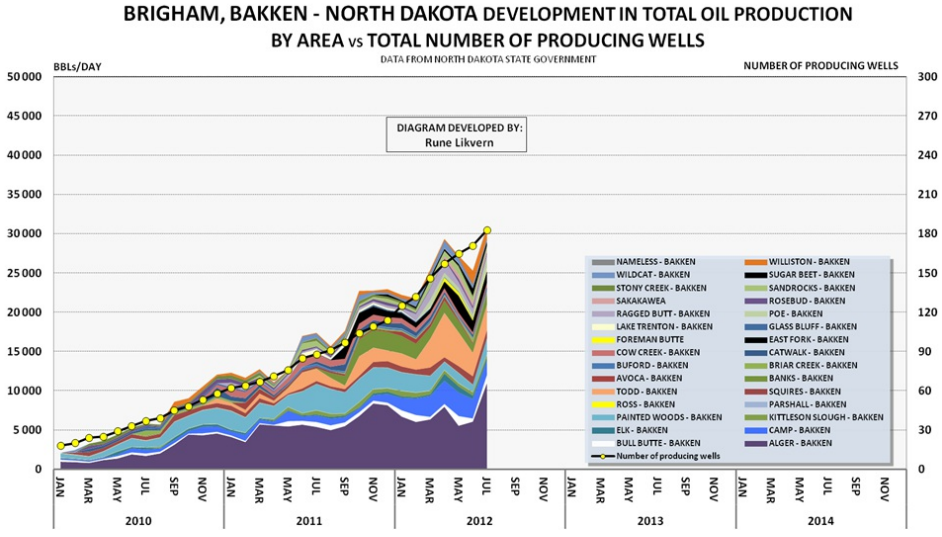

Figure 08: *The chart above shows the development in reported total production by area for*

all the wells for Statoil/Brigham in the Bakken formation, North Dakota. The chart also shows the development of total number of wells. The chart spans January 2010 through July 2012.

The chart in figure 08 also illustrates how an accelerating number of additional producing wells are needed to create growth in total production. Brigham was acquired by Statoil December 1st 2011 for a price of US$4.4 Billion.

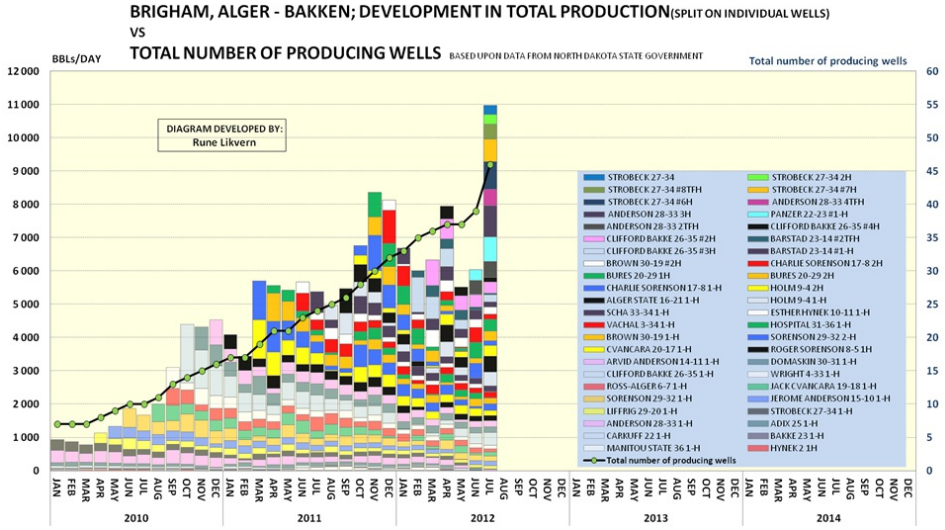

Figure 09: *The chart above shows development in total production by individual wells (ref the legend) and total number of reported wells with production for all Statoil/Brigham wells in the Alger area of Bakken.*
The wells in the chart are stacked sequentially according to reported start up of production, that is newest wells always on top.

The chart may also serve as an illustration to what in some circles presently is referred to as "the Red Queen" effect. It is not a given that total production will grow by adding new producing wells.

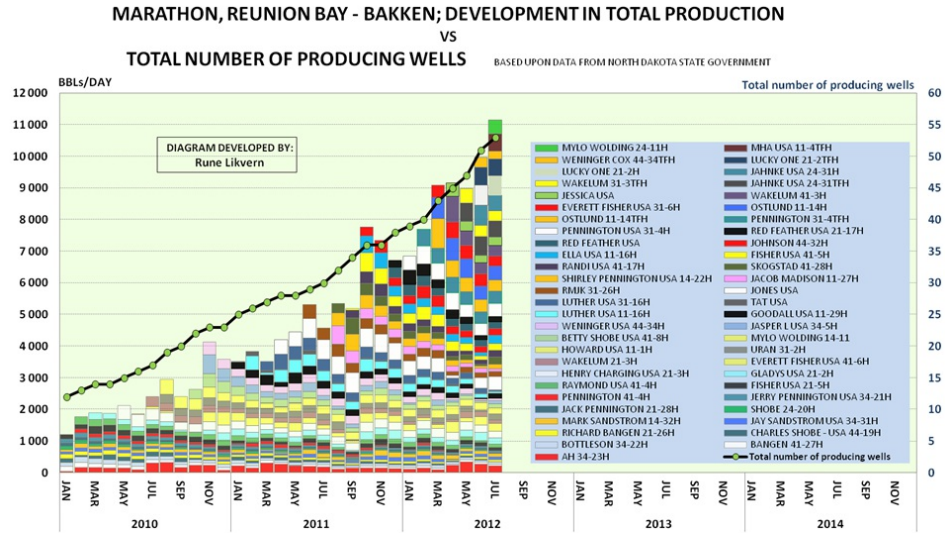

Figure 10: *The chart above shows development in total production by individual wells (ref the legend) and total number of reported wells with production for all Marathon wells in the Reunion Bay area of Bakken.*
The wells in the chart are stacked sequentially according to reported start up of production, that is newest wells always on top.

The chart above also illustrates that growth in total production requires accelerating additions of producing wells. The Marathon wells in the area above have recently seen some improvements in well productivity.

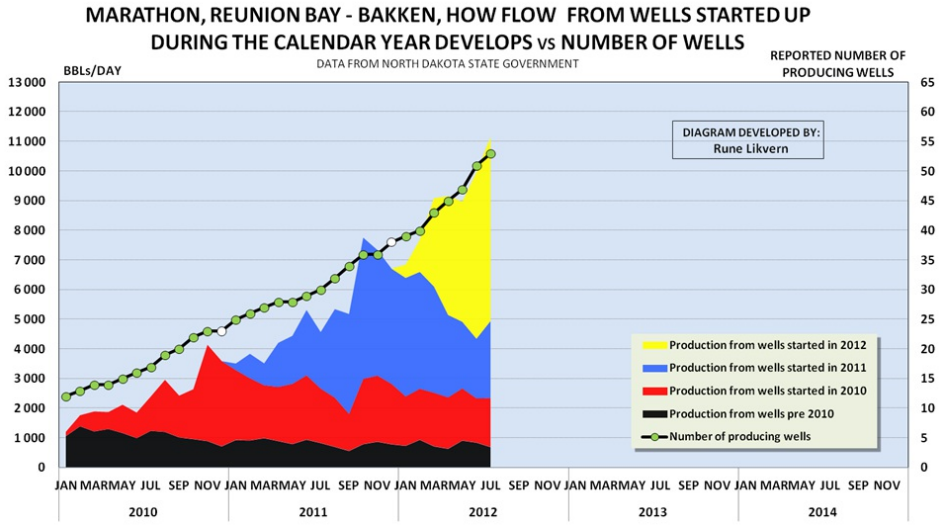

Figure 11: *The chart shows development in total production from wells started within specified calendar years for Marathon's wells in Reunion Bay - Bakken.*

The purpose of including the chart above was to give a better feel of annual production declines from wells within an area.

THE STATISTICAL ANALYSIS

What follows are the results from the statistical analysis of the wells that were subject to the in depth time series analysis. If the trend described by the statistical analysis persists and the wells analyzed are representative for Bakken it should be expected that total production from the Bakken formation is about to experience what in some circles is referred to as "the Red Queen" effect.
In plain language this means that a high number of new wells needs to be brought to production to sustain total production.

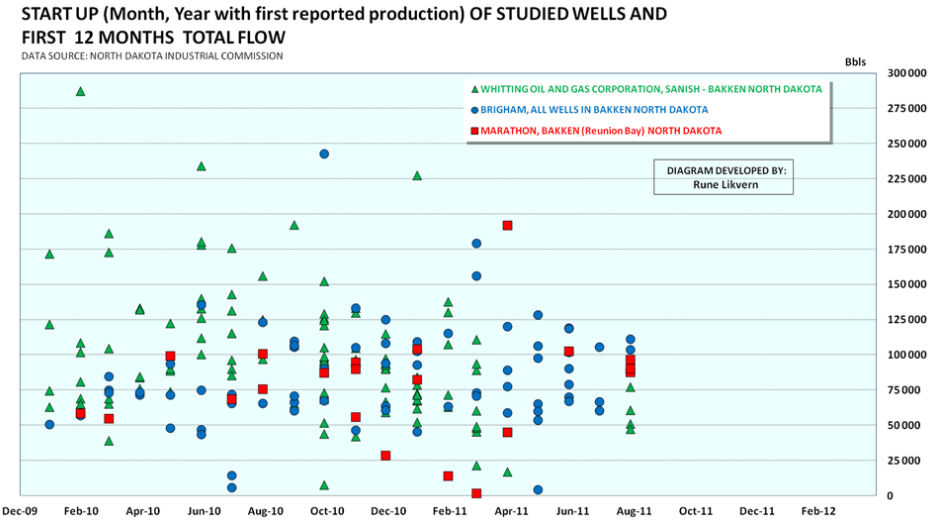

Figure 12: *The scatter chart above may appear complex for those who are not familiar with this kind of chart. Based upon data from the North Dakota Industrial Commission it shows*

total reported produced crude oil for the 12 first months (y-axis) versus reported start of first production (x-axis). Wells that were started as of August 2011 or later had as of July 2012 not attained 12 months with reported production. This is the reason why there presently are no data points in the chart after August 2011.

The figure shows that there is a huge spread in the total production for the first 12 months amongst the wells. It may be challenging to perceive any trends for well productivity with time from the scatter chart, but as of now it appears as the spread in productivity has narrowed with time.

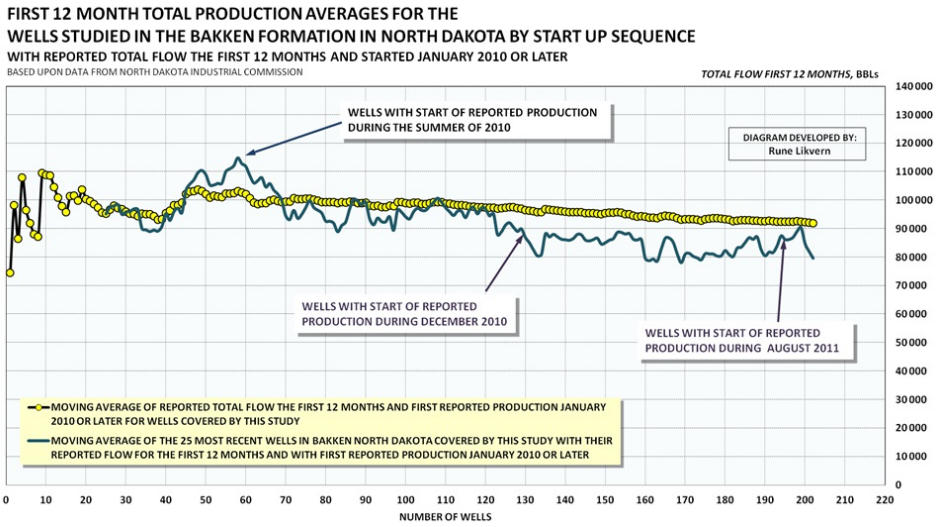

Figure 13: *If the data on total reported production for the first 12 months on all the wells that were subject to in depth time series studies are organized sequentially according to when production were started and a moving average is used, the picture above emerges. The moving average is the total first 12 months production divided by total number of wells (yellow circles connected by black line). Described another way the first data points are for wells with reported production from January 2010 and the last data points in the chart are for wells with first reported production as of August 2011. This function is slow. To both speed up the function and improve visualizations a 25 moving average was added. The 25 moving average shows the average of the 25 most recent wells (aquamarine line, 25 moving average was chosen as a compromise to smooth out wild swings and achieve an acceptable speed).*

Figure 13 shows a worrying development for newer wells in the Bakken formation. Productivity as expressed by total first 12 month production has shown steep declines for newer wells. The productivity was growing until the summer of 2010 where it reached a high. Since the summer of 2010 to the summer of 2011 average first year productivity for newer wells in Bakken declined around 25%!

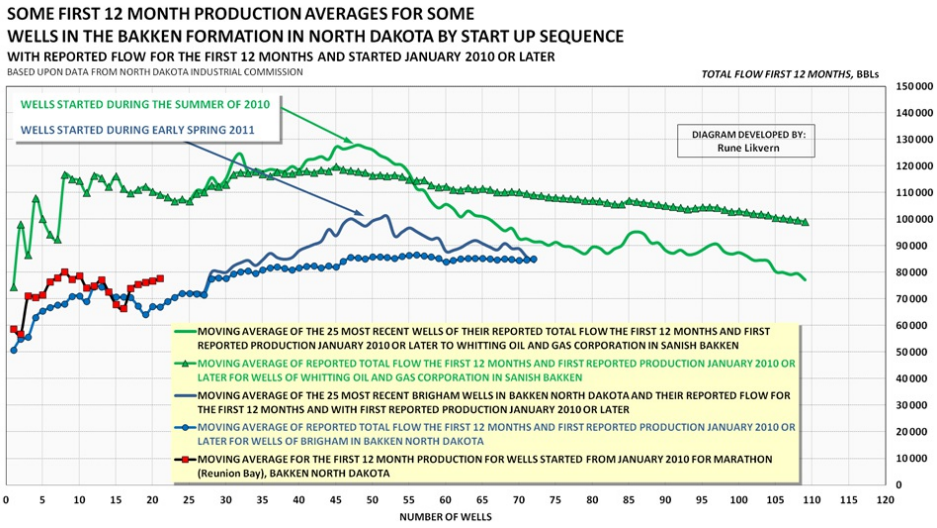

Figure 14: *In the chart above the same methodology as used for figure 13 is shown for the companies/areas covered by this study. The green triangles connected by green line are the moving average for Whitting Oil and Gas Corporation's wells in Sanish. The green line shows the 25 moving average. The blue circles connected with a blue line are for the wells of Statoil/Brigham. The dark blue line is the 25 moving average. The red squares connected by a black line are for Marathon's wells in Reunion Bay.*

On a long enough timeline, the highs in well productivities for the Sanish area and Statoil/Brigham will melt into a point. To repeat, the wells for the companies/areas subject to these in-depth studies had all a specific well productivity (as expressed by Bbls/day/well) that was above the average for the Bakken formation, see also figure 06. The Sanish area in the Bakken formation is/was considered being one of the best and during a year (from the summer of 2010 to the summer of 2011) the well productivity (as described by total reported production during the 12 first months) declined about 40%. For Statoil/Brigham the well productivity declined about 10% in one year.

Do the above create associations to ***the law of diminishing returns?***

THE ECONOMICS FOR THE PRESENT PRO FORMA ("AVERAGE") WELL IN BAKKEN

What follows is a little about the economics for what the analyzed data presently describes as the pro forma ("average") well in the Bakken formation.

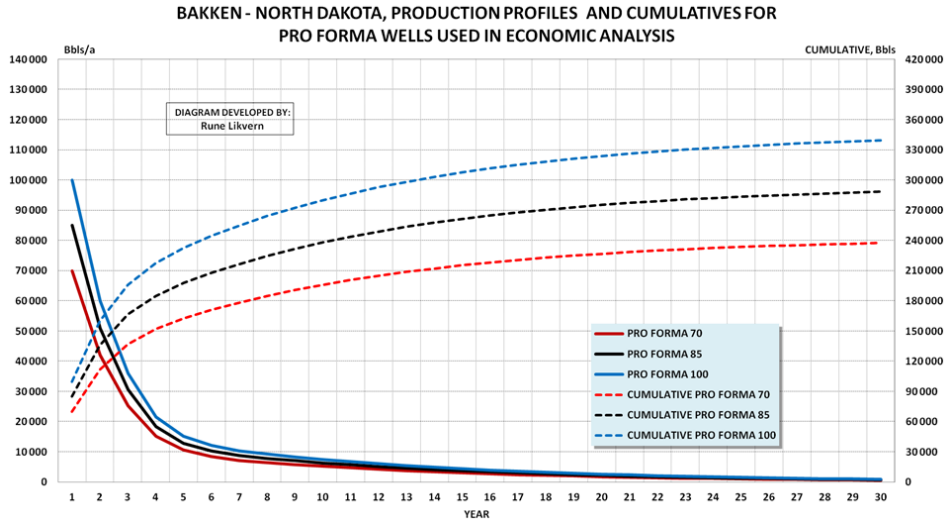

Figure 15: *Based upon the data from the wells that were subject to in depth time series studies a pro forma well (an "average" well) was established. The future development for this was forecast by using data from the North Dakota state government and what is presently available of forecasts from several reputable sources with regard to declines, total recovery or EUR (EUR, Estimated Ultimate Recovery) for wells producing oil from shale. From this study it was found that the pro forma ("average") well yielded around 85 000 barrels with crude oil during the first 12 months of production.*

The chart shows production profiles for pro forma ("average") wells with respectively 70 000 (red lines), 85 000 (black lines) and 100 000 Bbls (blue lines) for the first operational year, and how these are forecast to develop with time.
Presently the data documents that the production trend for the "average" well is in slight decline.

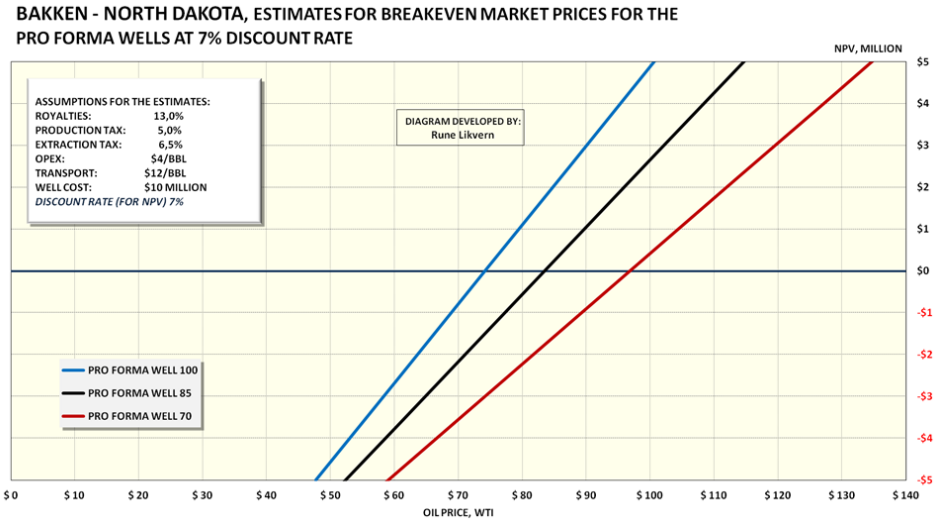

Figure 16: *The pro forma ("average") wells shown in figure 15 were subject to economic analysis. The assumptions used for the economic evaluations are shown in the box within the chart. (PRO FORMA WELL 100 = well with a total of 100 000 Bbls produced during the first year, etc.). The well costs include preparations of the well site (inclusive access), horizontal drilling, completion, multistage hydraulic fracking and hook up for processing, storage and transport. The well cost does NOT include full life cycle costs, financial costs, costs for mineral rights (acreage costs) and effects from potential changes to statutory regulations.*

NOTE: The "average" well also produces 0.5 - 1.0 Mcf/Bbl with associated natural gas. The

natural gas may be flared or sold if there is available infrastructure. Presently the natural gas price in USA (Henry Hub) is around $3/Mcf. In other words the potential contribution from natural gas is marginal and well within the uncertainties for the estimates.

The profitability analysis shows that the "average" well for Bakken now requires **$80 - $90/Bbl** to make commercial sense. A requirement for a higher rate of return (than the 7% used here, which is moderate) will raise the commercial threshold. If the trend with declining well productivity persists (all other things remaining equal) the threshold for profitability will move higher. During the planning of drilling campaigns several assumptions are made with regard to well productivity (performance), oil price, financing and an associated package of risk assessments. If these evaluations show high uncertainties (as in high risk) and a potential for no or at best uncertain profitability, the wells under consideration are most likely to not be drilled. The exception will be wells that the licensee is contractually obligated to drill within a specified deadline to maintain the rights for mineral extraction, so-called "drill it or lose it!"

Normally before wells within shale areas are put into production, it is close to impossible to issue any guarantees that it will make commercial sense. After six months or more of production, data will be available that may support the profitability expectations. For a well in a conventional reservoir information about whether it is worth completing will be available at the end of drilling. For wells in shale plays (both oil and natural gas) the companies (operators) commit themselves to produce these long before they know if the wells make commercial sense. If production from a completed well after some time shows that it will underperform (that is yield less than expected) then the oil company/operator will continue production from it as long it generates a positive cash flow. As with regard to total well costs given by oil companies/operators there are presently some spread in these. These spreads should be considered to be real and rooted in geological particulars like depth to and thickness of the organic zones, applied technologies, laterals, number of hydraulic fracking stages, topography, costs for hook up for processing, storage and transport to name a few.

Production of crude oil and natural gas from shale is also a lot about growing shareholder value. As long as shareholders do not suffer any losses it does not matter if production from shales makes little or no commercial sense. These dynamics led to the boom in drilling for shale gas. The recent collapse of natural gas prices in North America has resulted in huge balance sheet impairments for several oil and gas companies.

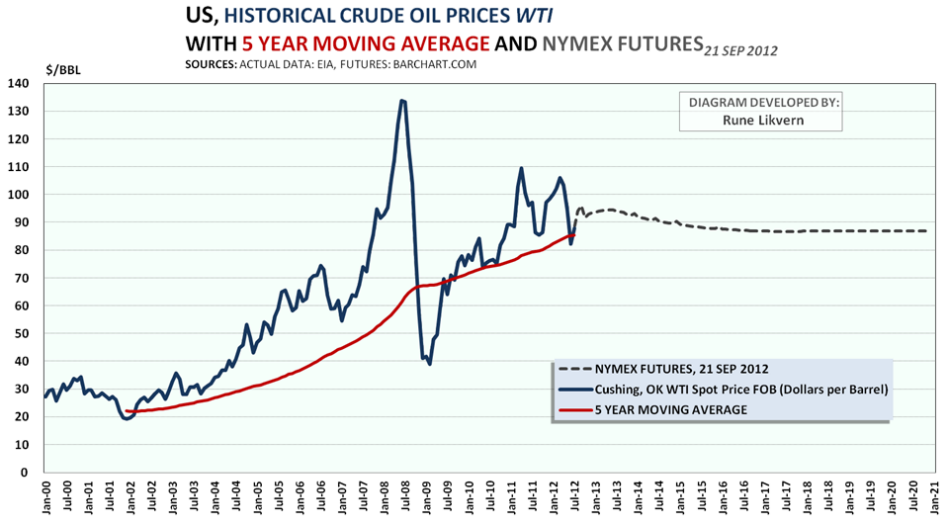

Figure 17: *The chart above shows the development in the oil price, WTI, as from January 2000 and now. Further the NYMEX futures (WTI) as of 21 September 2012 through December 2020 have been added. FWIIW the 5 year moving average of the actual WTI has been added*

(red line).

In reality, it was the growth in the oil price to an apparent structurally higher level that secured commercial support for crude oil production from shales. In that respect it was the oil price that was the true game changer and unleashed the "shale/tight oil revolution". There is a saying that goes like; "Do not listen to what they say. Look at what they are doing!". This may as well go for the Bakken formation.

The oil service giant Baker Hughes recently expressed concerns about slowing activity levels in shale plays if oil prices moved below **$80/Bbl**. Further the oil companies Marathon and Occidental recently cut back on their activities in the Bakken formation. Oil and gas companies still care about the colors of the numbers at the bottom line for their projects.

Indicators to follow that may be a harbinger of emerging developments in activity levels in shale plays:

- Number of drilling rigs, uncertain as there has been improvements to drilling.
- Net added number of wells with reported start of production.
- Changes to total reported production.

SOME RECENT REPORTS

U.S. Geological Survey (USGS) recently published (recently as in a few days ago) the report: *"Variability of Distributions of Well-Scale Estimated Ultimate Recovery for Continuous (Unconventional) Oil and Gas Resources in the United States"*. USGS has revised their estimates for many U.S. shale plays (oil and natural gas) and their recent estimates ought to have a sobering effect.

For production (extraction) of shale oil in the Eagle Ford formation in Texas the study:"Eagle Ford Shale - An Early Look at Ultimate Recovery" (**SPE 158207**; SPE, Society for Petroleum Engineers) documented a trend of declining well productivity.

ROCKMAN is an experienced geologist and as close you get to an inexorable fountainhead for oil and gas field experiences on The Oil Drum.
ROCKMAN applied the same methodology as I did for Bakken on data from Texas Rail Road Commission (TRCC) for shale/tight oil in Eagle Ford and documented the same trend.

Does it appear as if shale oil production from Bakken is headed for a run with "the Red Queen"?