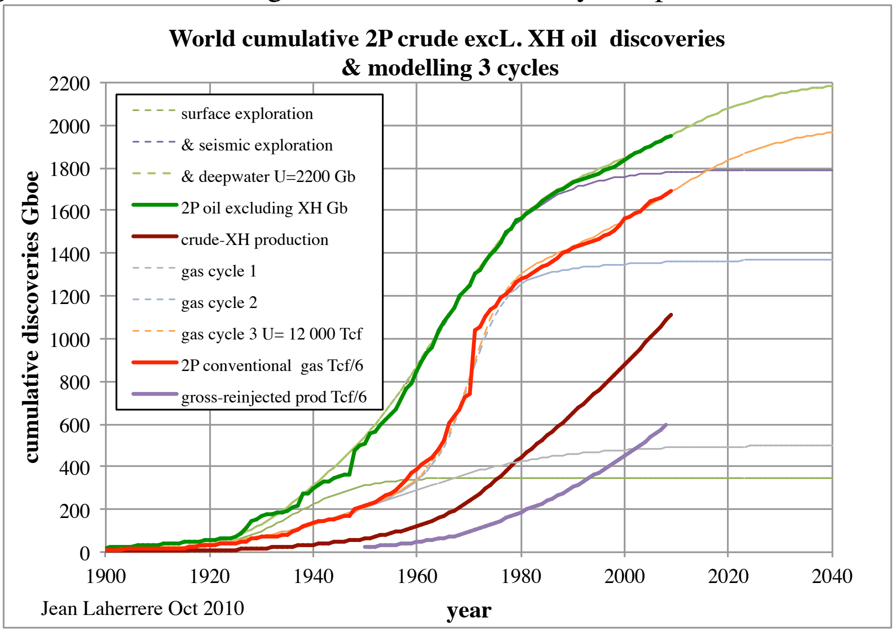
Jean Laherrere 30 August 2011

Deepwater GOM: reserves versus production
Part 1: Thunder Horse & Mars-Ursa

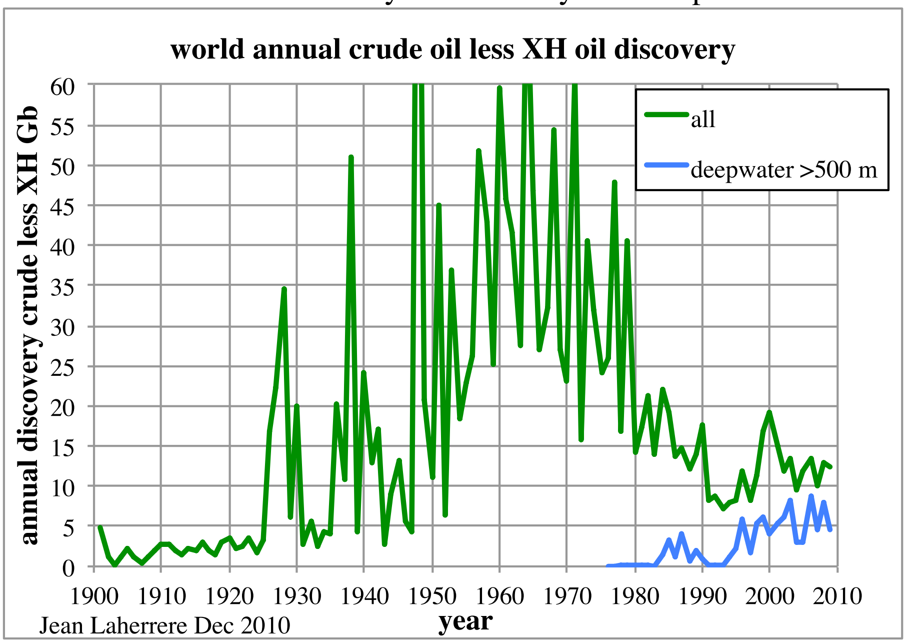
The world oil and gas 2P cumulative discoveries are modelled with 3 cycles. For crude excluding extra-heavy oil, the first cycle corresponds to surface exploration (1900-1950), the second cycle to seismic exploration starting in 1930 and the third cycle to deepwater (>500 m) starting in 1990, with the model trending towards an ultimate of 2200 Gb (crude less extra-heavy oil) against a cumulative production over 1100 Gb.

Figure 1: world oil and gas cumulative discovery and production with modelling

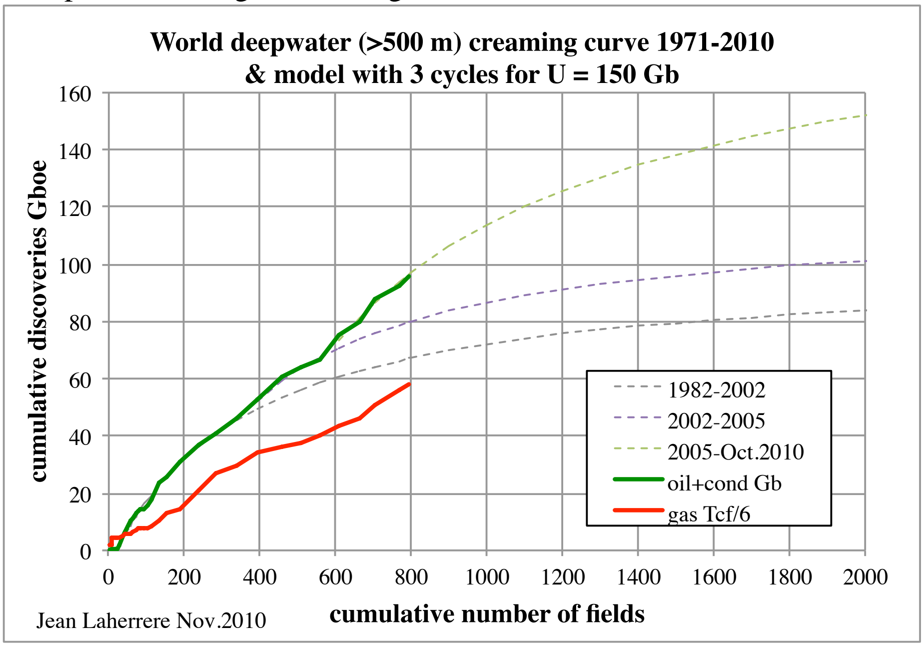


Deepwater discoveries are now making a large part of the world crude excluding extra-heavy oil discoveries

Figure 2: world annual crude less extra-heavy oil discovery with deepwater



The ultimate for deepwater oil can be estimated at around 150 Gb from the creaming curve versus cumulative number of field. Deepwater oil is mainly found in the Gulf of Mexico, Brazil, Nigeria, Angola and Congo. The model is made with three cycles, the last one since 2005 is associated with subsalt. A fourth cycle could occur if a new oil deepwater play is found like it occurred for natural gas in Israel waters.
Figure 3: world deepwater oil & gas creaming curve modelled with an ultimate of 150 Gb



MMS 2004-021 report "Deepwater Gulf of Mexico: America's expanding frontier" displays a similar creaming curve for the GOM comparing shallow and deepwater (>1000 ft)
The shallow curve is really hyperbolic close to the asymptote, and the deepwater curve seems to follow but lower.
Figure 4: GOM oil & gas creaming curve from MMS 2004 for shallow and deepwater

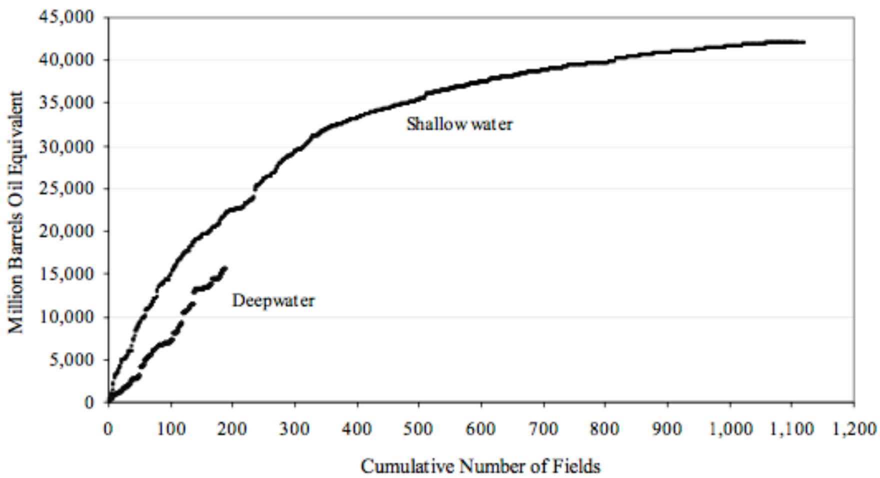
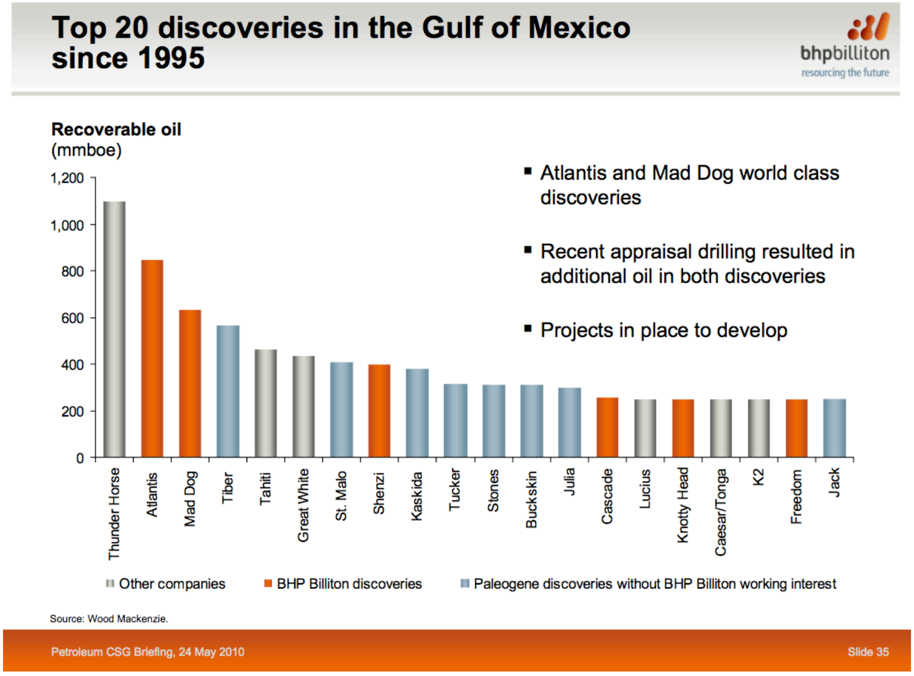


Figure 57. Modified creaming curve for shallow- and deepwater areas of the GOM (includes reserves, resources, and industry-announced discoveries).

But deepwater reserves estimates are questionable because they have not been yet confronted to long-term production (it is the same for shale gas).
International oil companies are the main operators in deepwater and they are reluctant to revise their reserves estimate.

The GOM is the best place to study field data because there are numerous big fields and because the monthly production (oil, gas & water) is available on BOEMRE (formerly MMS) site.
BHP Billiton (2010) has published the top 20 discoveries in the GOM since 1995 but the largest field (for MMS) is Mars-Ursa found in 1989
Figure 5: top discoveries in the GOM since 1995 from BHP



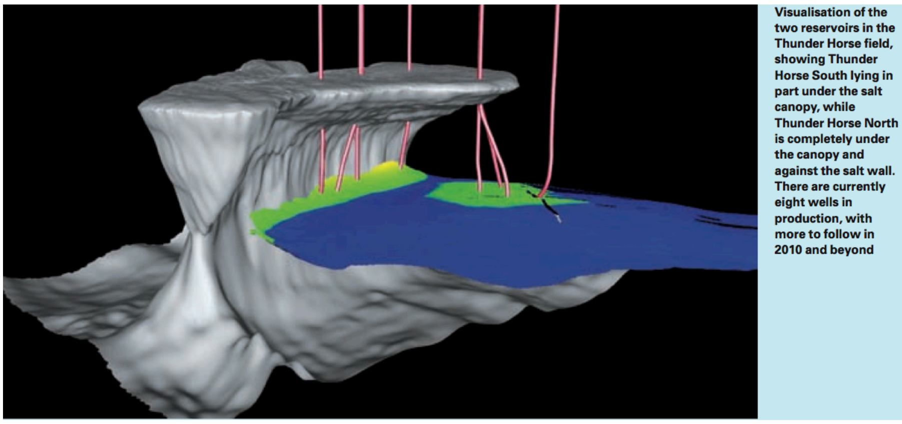
The goal is to compare the evolution of reserves estimate with the oil decline.
Let's start with Thunder Horse operated by BP, followed by Mars-Ursa operated by Shell

Thunder Horse complex

Thunder Horse field was found in 1999 in deepwater (near 2000 m) in subsalt deep sediments (over 7000 m) with high pressure (1200 bar), 125 miles southeast of New Orleans.
The field is operated by BP (75%) with partner Exxon-Mobil (25%).
The discovery was first called Crazy Horse, but the name was changed quickly at the request of the descendants of the Native American warrior of the same name.
For BP (Frontiers Aug 2009) the field consists of two reservoirs Thunder Horse South and Thunder Horse North produced by only one semi-sub platform
Figure 6: map of BP discoveries in the GOM

Thunder Horse South (called main or Thunder Horse) is a four-way structure in part below salt canopy when North Horse North is a trap against the salt wall as shown in the following graph

Figure 7: Visualisation by BP of the South & North Thunder Horse reservoirs and salt wall & canopy



From this graph, it is obvious that there are two fields located in blocks MC 775, 776, 777, 778, 821 and 822, but for some it is reported as one field, because produced by the same platform in MC 778. For MMS there are two fields MC 778 (main) and MC 776 (north)
http://www.gomr.boemre.gov/homepg/offshore/gulfocs/subsalt/subsalt.html
The largest of the subsalt discoveries was made by BP and ExxonMobil at Mississippi Canyon 778, the "Thunder Horse" prospect, (OCS-G-09868 #1) in 6,050 ft of water in 1999. Thunder Horse is one of the largest deepwater Gulf of Mexico discoveries to date, with estimated reserves of 1 billion BOE. A second discovery, "North Thunder Horse" at Mississippi Canyon 776 (OCS-G-09866 #1), was made in 2000 in 5,636 ft of water. Industry press releases report that the entire Thunder Horse and North Thunder Horse field complex may have reserves of 1.5 billion BOE. Thunder Horse is scheduled to commence production in late 2005.

The following seismic line shows both the Thunder Horse plain structure in the middle with the log in green and on the left the north trap against the wall of the allochthonous salt (from Abu Chowdhury and Laura Borton, 2007, Salt Geology and New Plays in Deep-Water Gulf of Mexico: Search and Discovery article #10132)
Figure 8: Seismic profile across Thunder Horse and Thunder Horse North (left)

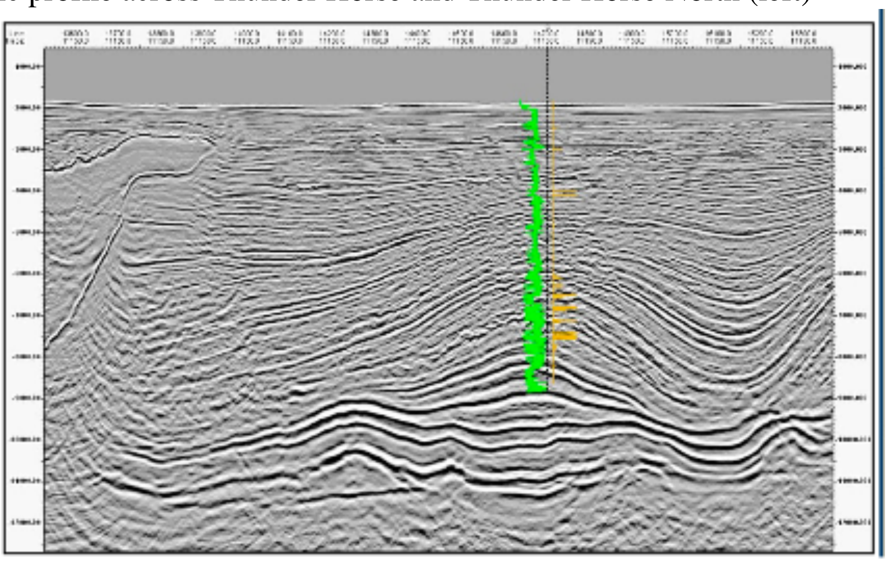


Figure 4. Thunder Horse in Mississippi Canyon, and Vicksburg

Figure 9: Thunder Horse semi-sub platform from Korea to GOM
Thunder Horse complex was produced with the largest semi-submersible platform (130 000 t) built in South Korea and transported to the GOM on September 2004.

The hull and drilling rig of the PDQ loaded onboard the 63m-wide *Blue Marlin* heavy lift ship

But in July 2005 before production, the hurricane Dennis obliged the developing crew to leave and when they returned the semi-sub was listing by 20-30°.

Figure 10: Thunder Horse platform tilted after Hurricane Dennis in 2005

Due to a faulty ballast valve, water has entered the ballasts and expensive work were carried out to remedy all the faulted parts.

BP (Frontiers August 2009) was planning 28 production wells and 5 water injection wells (expecting life 20-25 years Dan Replogle). The facility is designed to process 250 000 b/d of oil and 200 Mcf/d. Production started in 2008.

BOEMRE (former MMS) provides GOM field report in their "Estimated oil and gas reserves" but the last report is dated 2009 (MMS 2009-064) and only up to end 2006: the report is very complete, which can be loaded freely in pdf or excel tables
BOEMRE provides an annual report (updated for 2011 every month, in August updated at end May) giving the monthly well oil, gas & water production as the number of days per well, sorted by field, lease and API number, but there are several sources (annual report up to over 7000 pages), all in pdf:

-by unit http://www.gomr.boemre.gov/homepg/pubinfo/repcat/product/Units.html,

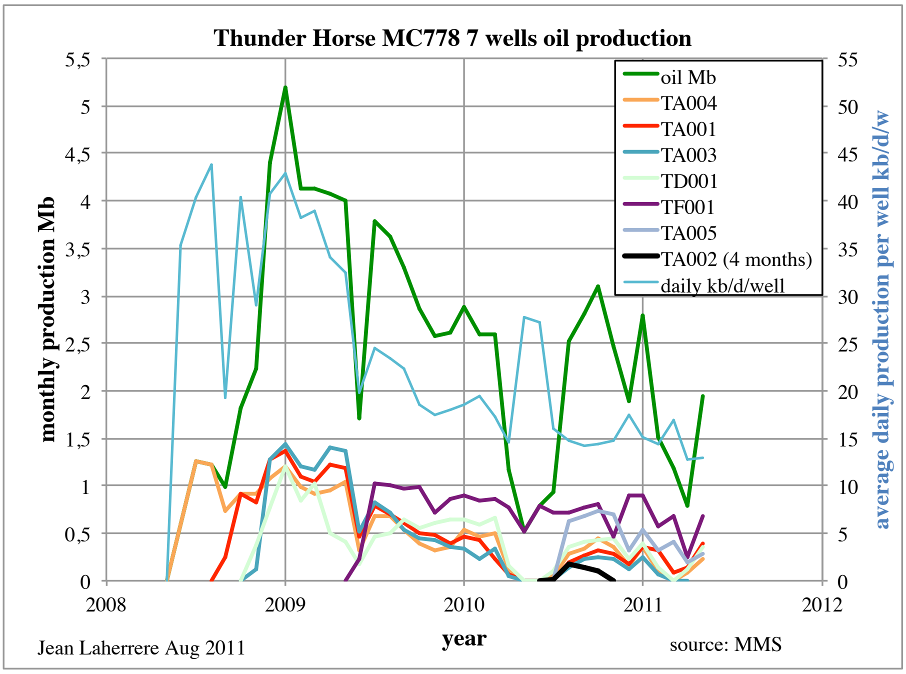
-production by lease =PBP9152A: OGOR/9152, reporting separately crude and condensate, gas-well gas and casing gas and water
http://www.gomr.boemre.gov/homepg/pubinfo/repcat/product/Production%20by%20lease.html

-production A sorted by lease = PBOGORAL : OGOR-A report 4081
http://www.gomr.boemre.gov/homepg/pubinfo/repcat/product/Production-A.html

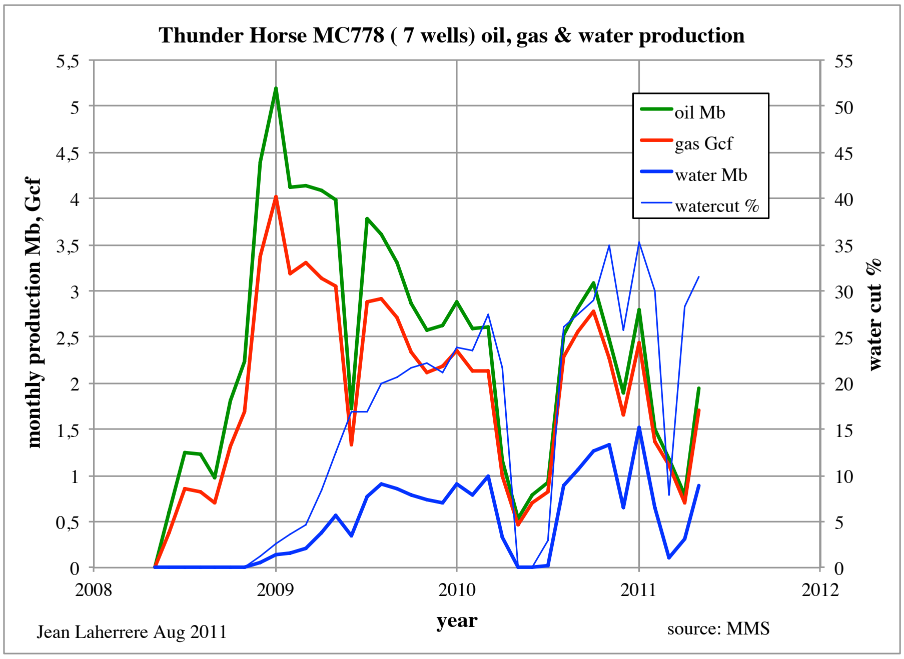
The smallest source is per unit (I found later see part 2 that it is incomplete). The best source is production A per lease (OGOR A-well production data) but it is heavy and the conversion from pdf into excel is necessary and long.
It is a nuisance to have several reports on the same data with sometime different values!
Furthermore these reports should be available in excel like the
The best report to deal with field without bothering with wells is the "Estimated oil & gas reserves" but the last report is only up to end 2006

Thunder Horse (main or south) MC 778

BOEMRE reports 7 producing wells, but TA002 only produced during 4 months in 2010 despite no water.
The monthly oil production peaked in January 2009 at 5.2 Mb (168 000 b/d) with 4 wells, the average daily production per well peaked in 2008 over 40 000 b/d.
The individual well oil production varies. The wells are sorted by decreasing cumulative production at end May 2011.
Figure 11: Thunder Horse MC778 oil monthly production; all and 7 wells & average well daily production

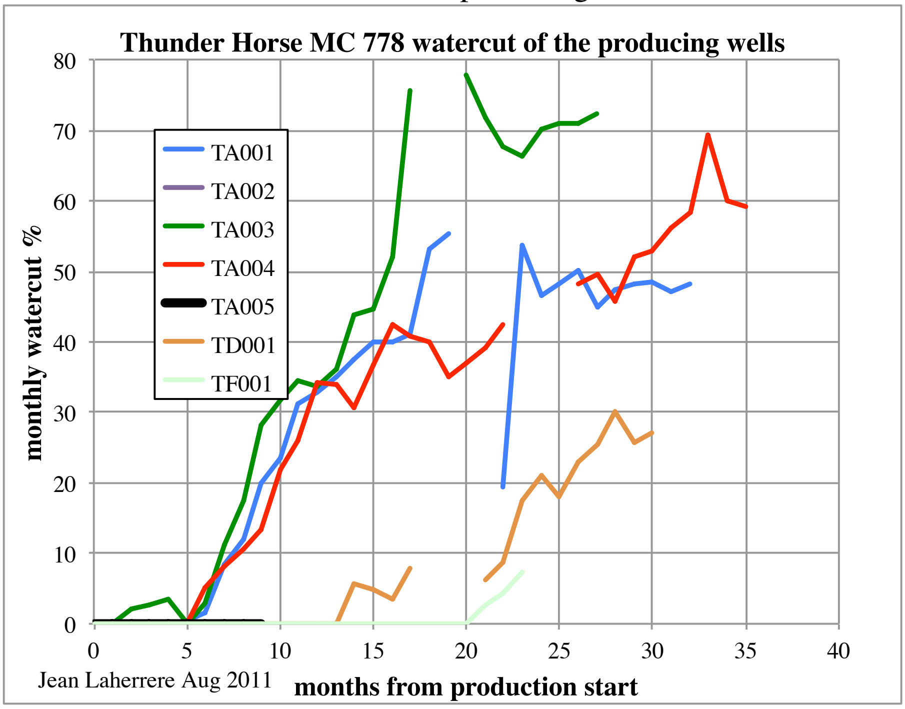


The production of oil, gas and water drops during periods of work over and also the Macondo oil spill of April 2010.
Figure 12: Thunder Horse MC778 oil, gas & water monthly production



The individual well watercut from production start varies widely: 20 months from start TF001 is still at zero when TA001 is over 70%.

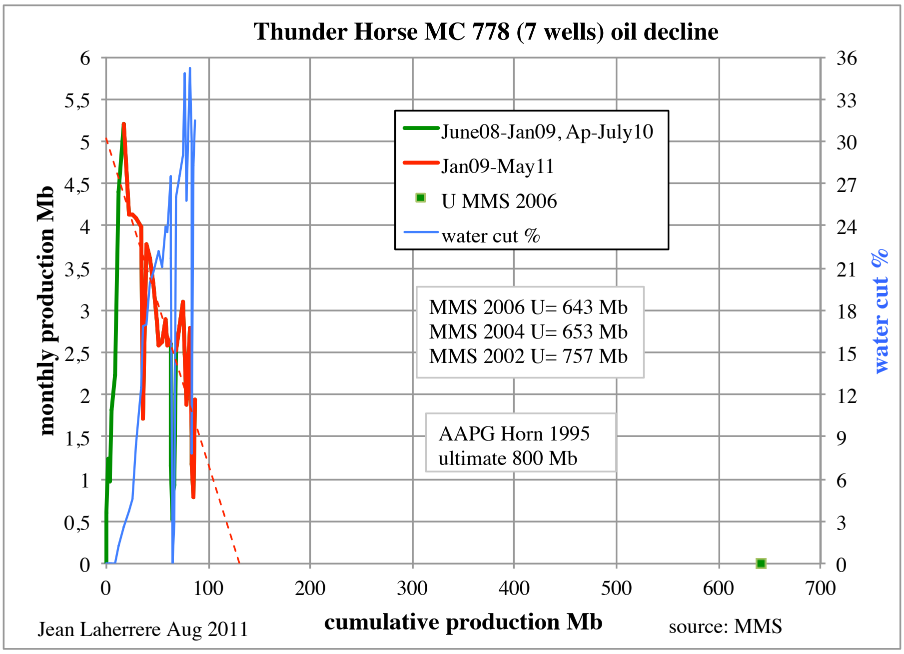
Figure 13: Thunder Horse MC778 watercut of the producing wells from start



Thunder Horse oil production decline plotted versus cumulative production trends towards less than 150 Mb, when original reserves were estimated by MMS at 757 Mb in 2002, 653 Mb in 2004 and 643 Mb in 2006 (last estimate)

It is obvious that old estimate were too high, but also the field needs more wells. But BP does not publish enough on the real potential of the field, no field reserves are reported by BP, neither Exxon-Mobil.

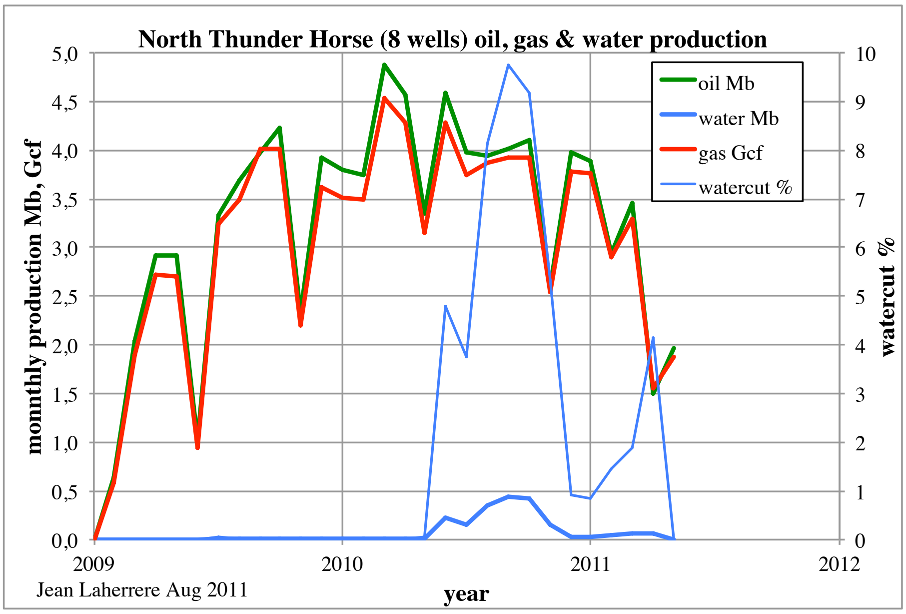
Figure 14: Thunder Horse MC778 oil decline, watercut and ultimate



North Thunder Horse (MC776)

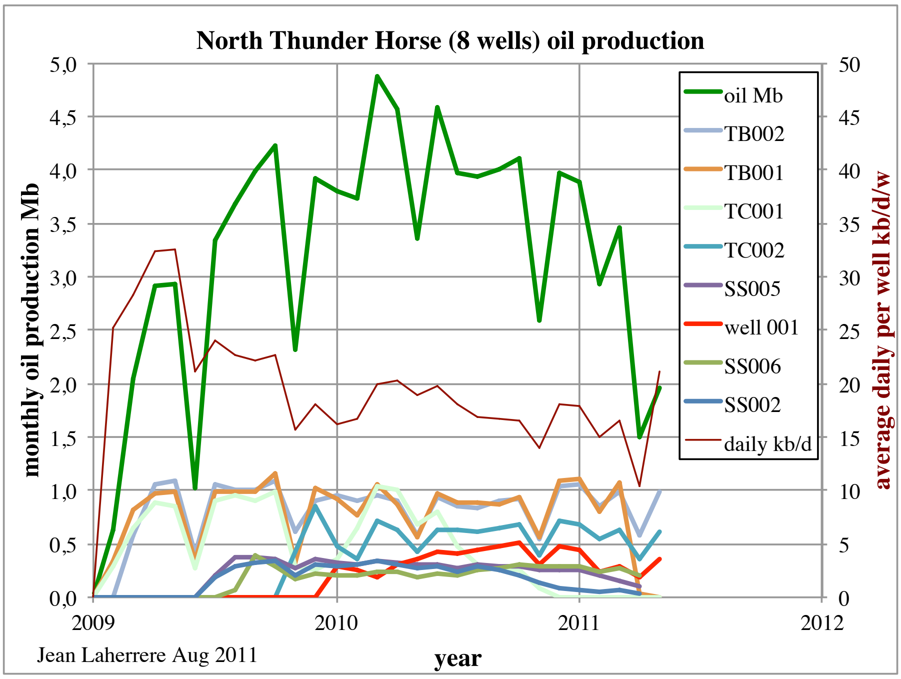
MMS reports 8 wells and oil production is declining in 2011 after a bumpy plateau, but surprising also the water cut.

Figure 15: North Thunder Horse MC776 oil, gas & water monthly production



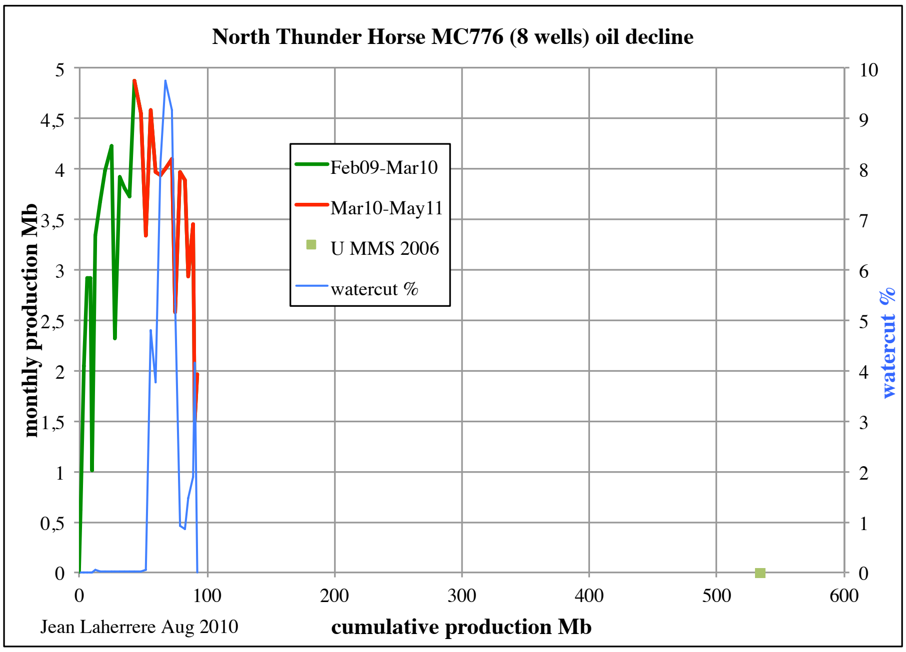
The oil productions per well are bumpy and the average production per well peaked at 32 000 b/d (less that the main field which was over 40 000 b/d)

Figure 16: North Thunder Horse: all & per well monthly oil production and average daily production



The monthly oil production versus the cumulative production displays a decline hard to extrapolate towards the ultimate value, which is estimated at 534 Mb MMS 2006 (440 Mb in 2005 data, 365 Mb in 2004 data and 347 Mb in 2003 data). The watercut is erratic.

Figure 17: North Thunder Horse MC776 oil decline, watercut and ultimate

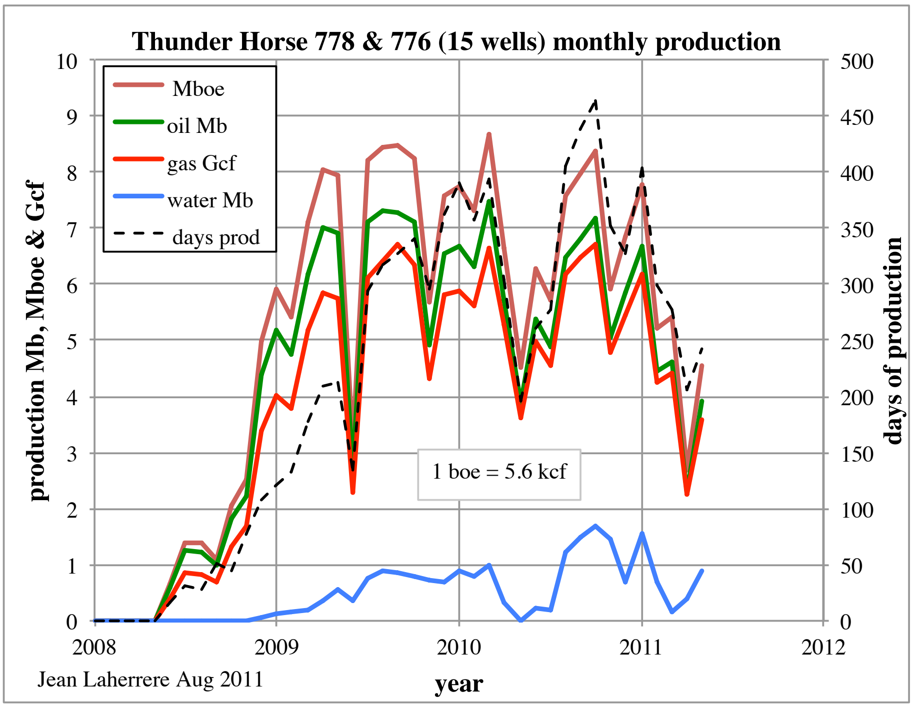


Thunder Horse main & north

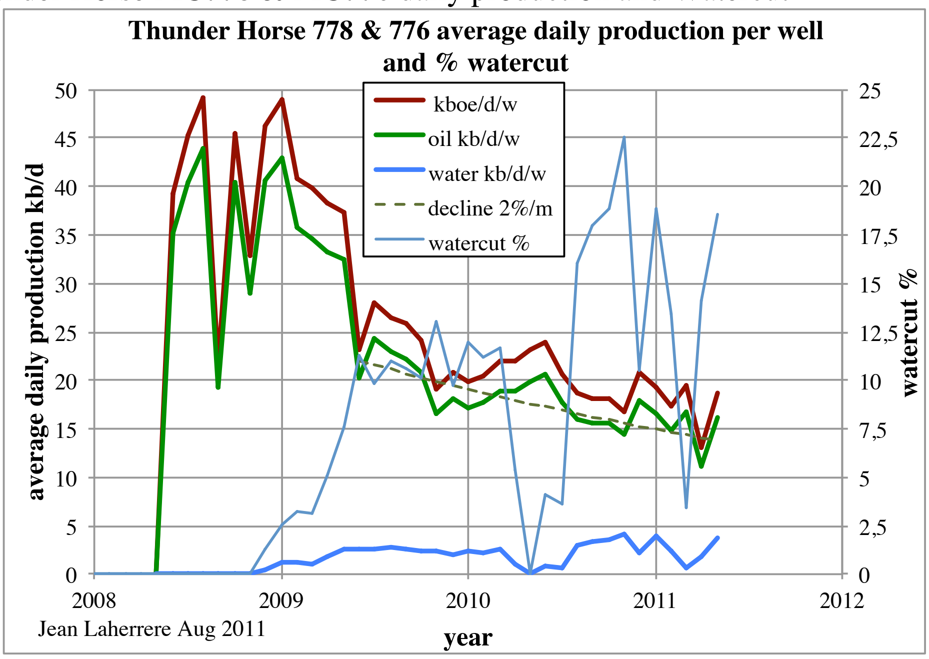
For the sum the two fields produced by the same platform (semi-sub), the oil production displays a bumpy plateau with a peak above 7 Mb per month (about 240 000 b/d).

Macondo blow out (April-July 2010) has disturbed the production, which resumes in the fall of 2010, but there is a strong decline in 2011 due to the natural decline of the wells but also the lack of new wells because the drilling moratorium due to Macondo blow.

Figure 18: Thunder Horse MC778 & MC776 monthly production and production days

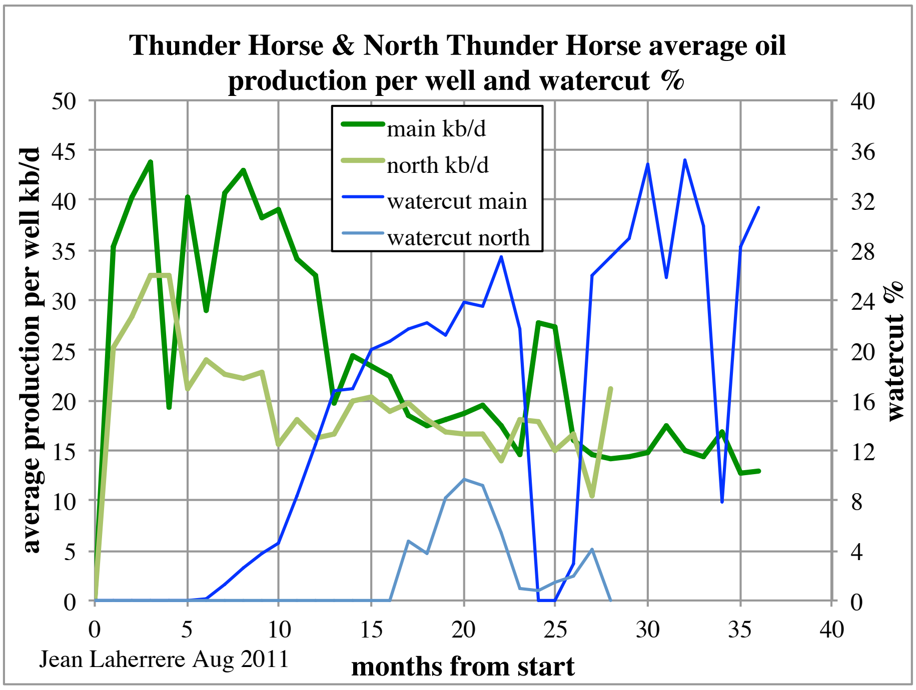


The total number of producing wells in May 2011 is 15, when the development was designed to consist of 25 wet-tree subsea tied into the floating platform (http://www.offshore-technology.com/projects/crazy_horse/). More wells could be drilled, but BP is very short in explanation for this decline and future planning.
The average oil production per well shows a peak in 2008 about 40 000 b/d/w, with a decline of about 2% per month (over 20 % per year).
Figure 19: Thunder Horse MC778 & MC776 daily production and Watercut



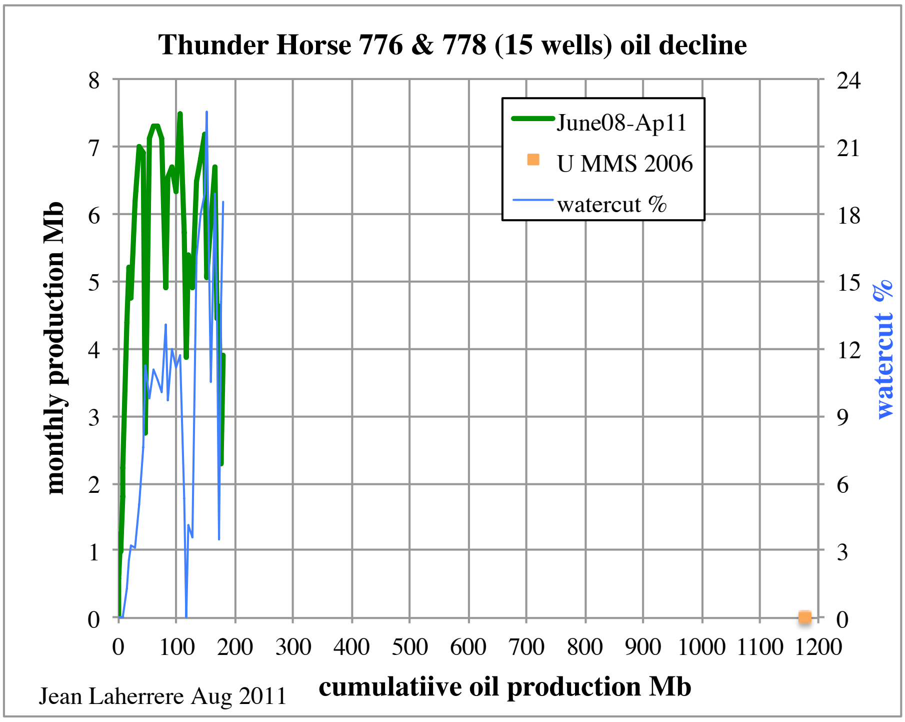
Water production varies with the opening of new wells and the closure of some.

The comparison of the two fields (MC778 = main and MC776 = north) average production per well and global watercut starting from first production shows difference, in particular for watercut likely due to the difference in trapping, but less for oil after the first year.
Figure 20: Thunder Horse: average daily production & watercut for MC778 and for MC776



The plot of monthly production versus cumulative production together with the watercut in % is difficult to extrapolate towards the ultimate value, which was estimated at 1177 Mb in 2006 data, when 1000 Mb in 2003 data.

Figure 21: Thunder Horse MC778 & MC776 oil decline and ultimate



The lack of data from the operator on the future development of Thunder Horse platform outside the actual number of producing wells compared to the initial project, prevents to make reliable forecast. It is obvious that present producers are in steep decline, but the watercut varies widely. The future production depends mainly on the drilling of new wells.

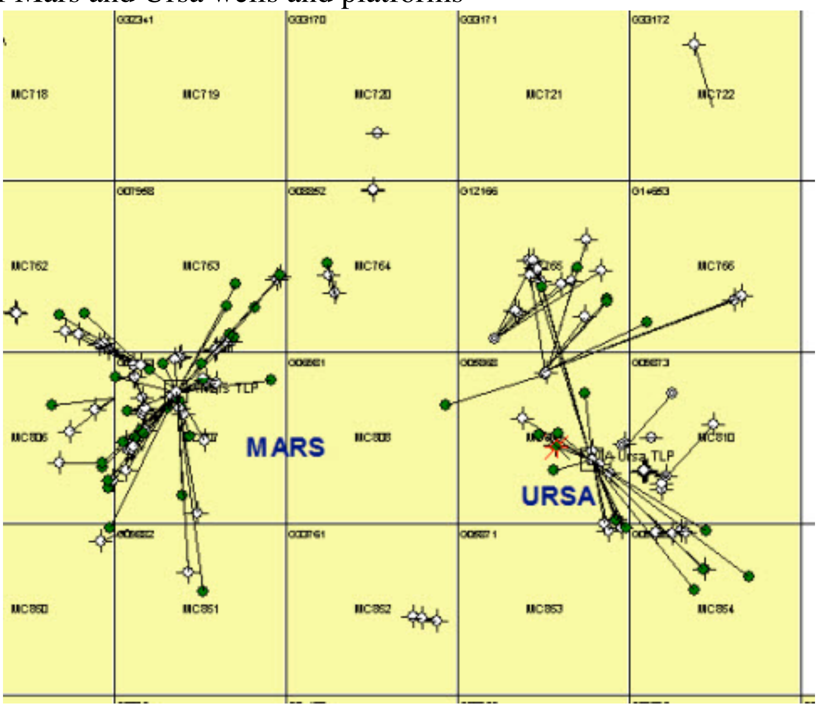
A report by GlobalData (2010) http://www.pr-inside.com/new-report-thunder-horse-gulf-of-r2076361.htm

« Thunder Horse, Gulf of Mexico, Commercial Asset Valuation and Forecast to 2035 or 2038" s(old for 2800 $) said in the description:
The field life of Thunder Horse is expected to be around 25-30 years with abandonment to start during 2036 without EOR or 2033 with EOR. The field is expected to generate $111.38 billion without EOR or $111.57 billion with EOR in revenues (undiscounted) during its remaining life (starting 1/1/2010) and is expected to yield an IRR of around 18.43% without EOR or 18.46% with EOR.
Like I always say: when more than 3 significant digits are given, it means that the author has a very poor knowledge of the accuracy of the reported value and the second digit surely must be wrong, and likely the first digit.
These 5 significant digits for the present net value of a field for a life of 25 years comes of a Monte Carlo simulation with many assumptions (in particular oil price) and the inaccuracy of such estimate should be at the most not less than 20% and the only conclusion is that EOR (which one?) does not change the result.

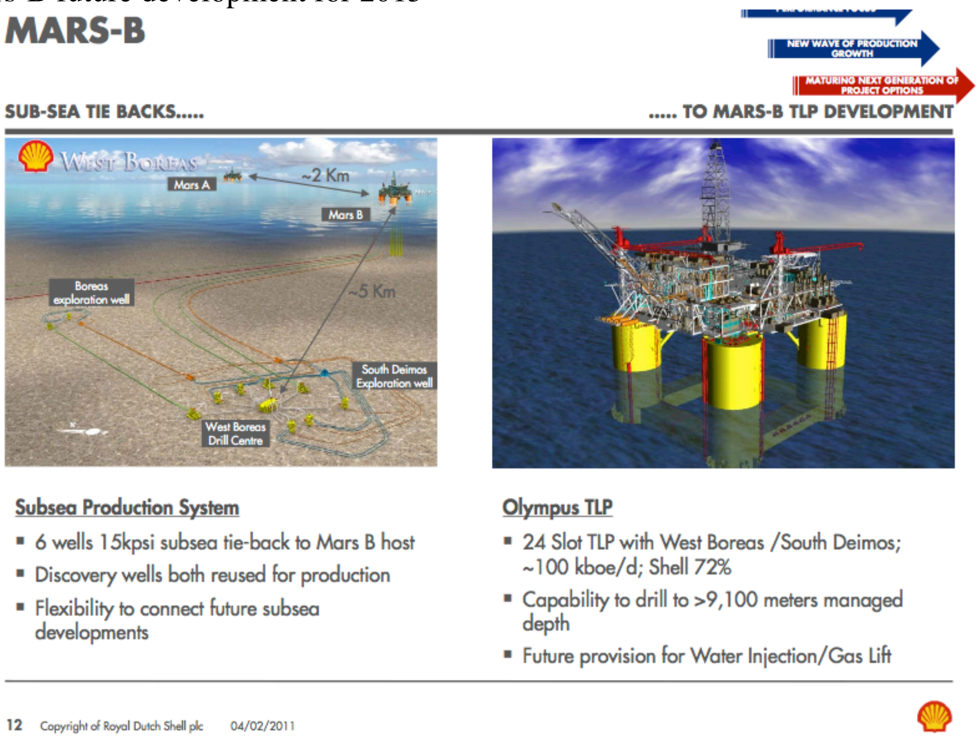
To conclude on Thunder Horse, there is not enough public data from the operator on future drilling to get reliable extrapolation of the past production. But it is likely that the MMS last estimates (MMS 2009-064 for 2006 reserves) are optimistic. It will be interesting to see the new estimate by BOEMRE lacking for the last two years!

Mars-Ursa

Shell publishes more and better than BP on their GOM production.
The two fields Mars (found in 1989 on MC 763 at 966 m water depth) and Ursa (found in 1990 on MC 854 at 1225 m water depth) are grouped by the BOEMRE under the name Mars/Ursa or MC807 as being the largest oil field in the GOM.
The two fields are clearly separated. They are both produced by Shell, but from two Tension Leg Platforms, being Mars on MC 807 since 1996 and Ursa on MC 809 since 1999.
The Mars unit encompasses 6 OCS leases in the Mississippi Canyon Area - Blocks 762, 763, 806, 807, 850 and 851 operated by Shell 71.5% with partner BP 28.5%)
The Ursa unit encompasses Blocks 808, 809, 810, 852, 853 and 854, operated by Shell 45% with partners BP 23%, Conoco 16%, Exxon-Mobil 16%.
Figure 22: map of Mars and Ursa wells and platforms

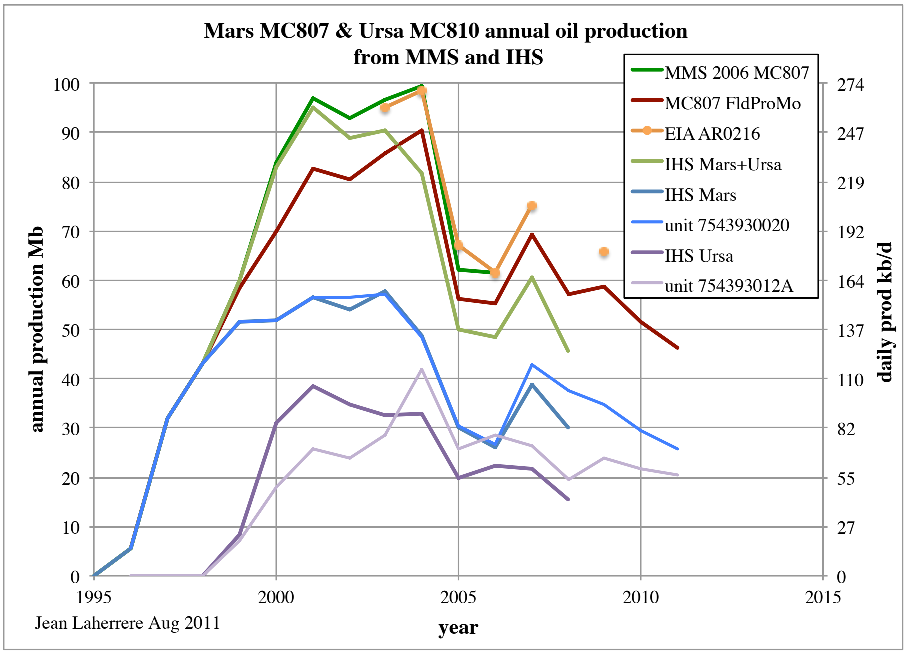


In 2008 Shell has achieved the Ursa/Princess waterflood project.
In 2010 Shell announced that the present Mars A platform will be added with a new one Mars B (called Olympus TLP) for production in 2015, because of new close by discoveries: West Boreas & South Deimos.
The Mars B development will draw production from eight Mississippi Canyon blocks 762, 763, 764, 805, 806, 807, 850 and 851.
Figure 23: Mars-B future development for 2015



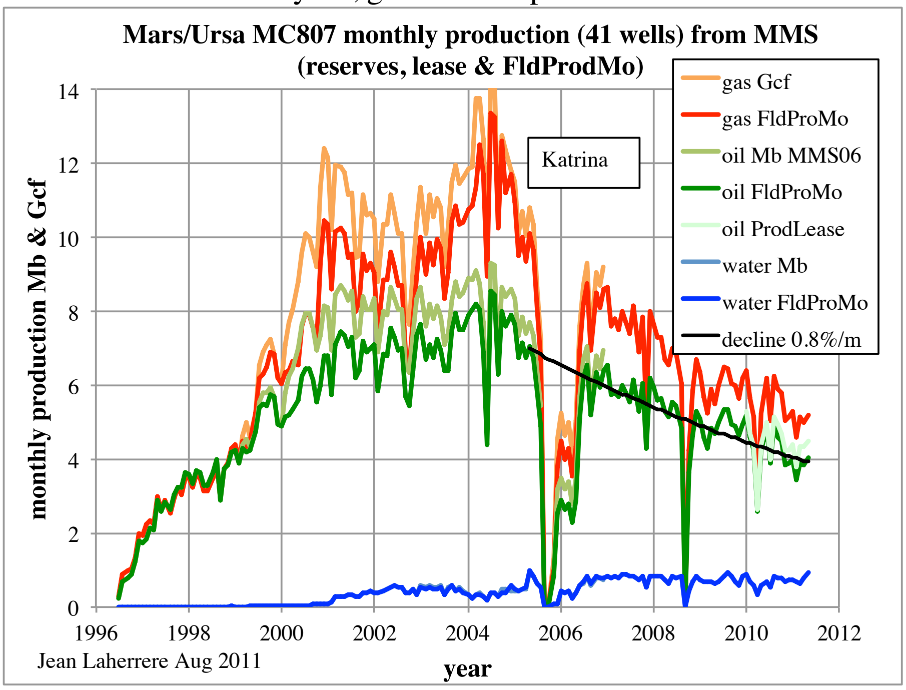
Harris et al (AAPG 2011 "Mars life cycle field development= maximizing recovery from a deepwater giant") wrote:
The Mars Field is comprised of a thick sequence of stacked Plio-Miocene turbidite deposits trapped within a salt-flanked basin, with charge access to a prolific source rock. This geologic sweet-spot generated a field comprised of more than 70 individual reservoirs stacked in a 10,000 foot sequence. In-place volume estimates exceed more than 4 billion BOE.
The recent Near Field Exploration discoveries of West Boreas & South Deimos, along with the redevelopment study, yielded a 2010 decision to deploy a second 24 well Tension Leg Platform, "Olympus TLP" at the Mars Field. Addition of new infrastructure, complementing the existing facilities, provides a combined 48 well slots and over 350K BOEPD processing facilities to optimize recovery from the Mars Field beyond 2050

MMS annual reports only the combined production, when IHS reports both fields separately
The oil production was disturbed in 2005 by the Katrina hurricane and the damaged platform was repaired when production was stopped..
The BOEMRE monthly reports (there are several like per unit or per lease) are slightly different.
Mars = MC807 corresponds to unit 7543930020 and Ursa = MC810 to unit 75439012A.
The annual oil production from MMS and IHS differs, but shows a decline disturbed by Katrina in 2005.
Mars decline seems larger than Ursa decline due to the Princess water flood.
Figure 24: Mars and Ursa annual oil production from different sources



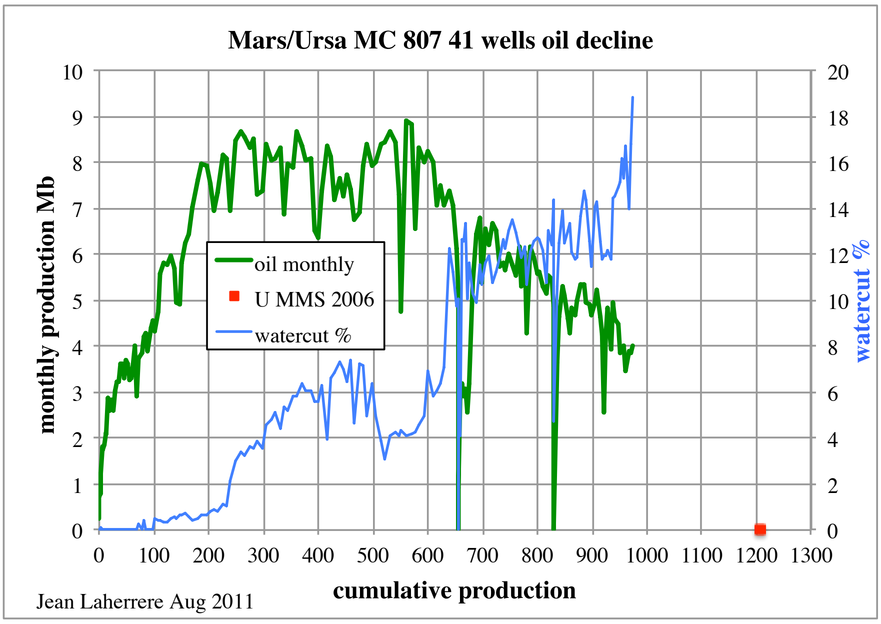
The monthly oil, gas and water production differs also slightly from the different MMS sources. The decline since 2007 is about 0.8 % per month or about 9 % per year, which is less than half Thunder Horse decline

Figure 25: Mars/Ursa MC807 monthly oil, gas & water production from different MMS



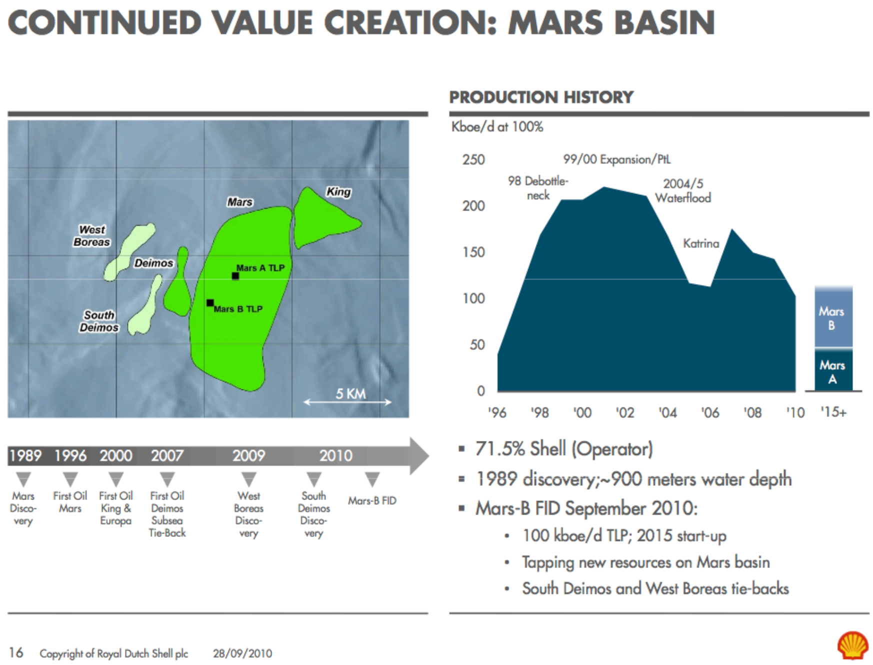
The monthly oil production versus cumulative production with watercut shows a decline in line with the reserves of 1208 Mb estimated by MMS 2006. Shell indicates that the new Mars B will bring secondary recovery (waterflood as Ursa) and new fields.

Figure 26: Mars/Ursa MC807 oil decline, watercut and ultimate



Shell (M.Odum2010) display Mars development planning

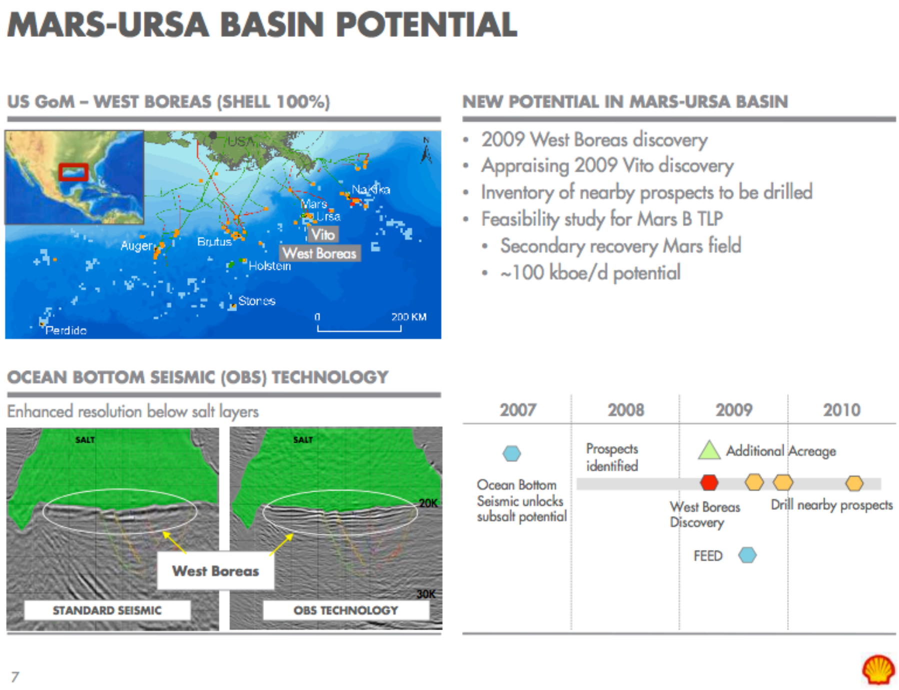
Figure 27: Mars map and planning



The planned Mars B Olympus platform starting in 2015 will slow the decline but some production will come from new discoveries being West Boreas (2009 on MC 809) & South Deimos (2007 on MC 806)

West Boreas field is trapped below the salt and the seismic profile is not easy to interpret, even with the new technology of ocean bottom recorders (Shell M.Odum Credit Suisse Feb.2010).

Figure 28: West Boreas seismic profile from Shell



Part 2 will present the graphs on Atlantis and Mad Dog and other fields, together with a synthesis and conclusion.