Calculating Oil & Gas Reserves: An Art Form Or A Science?

Standing Group on the Oil Market
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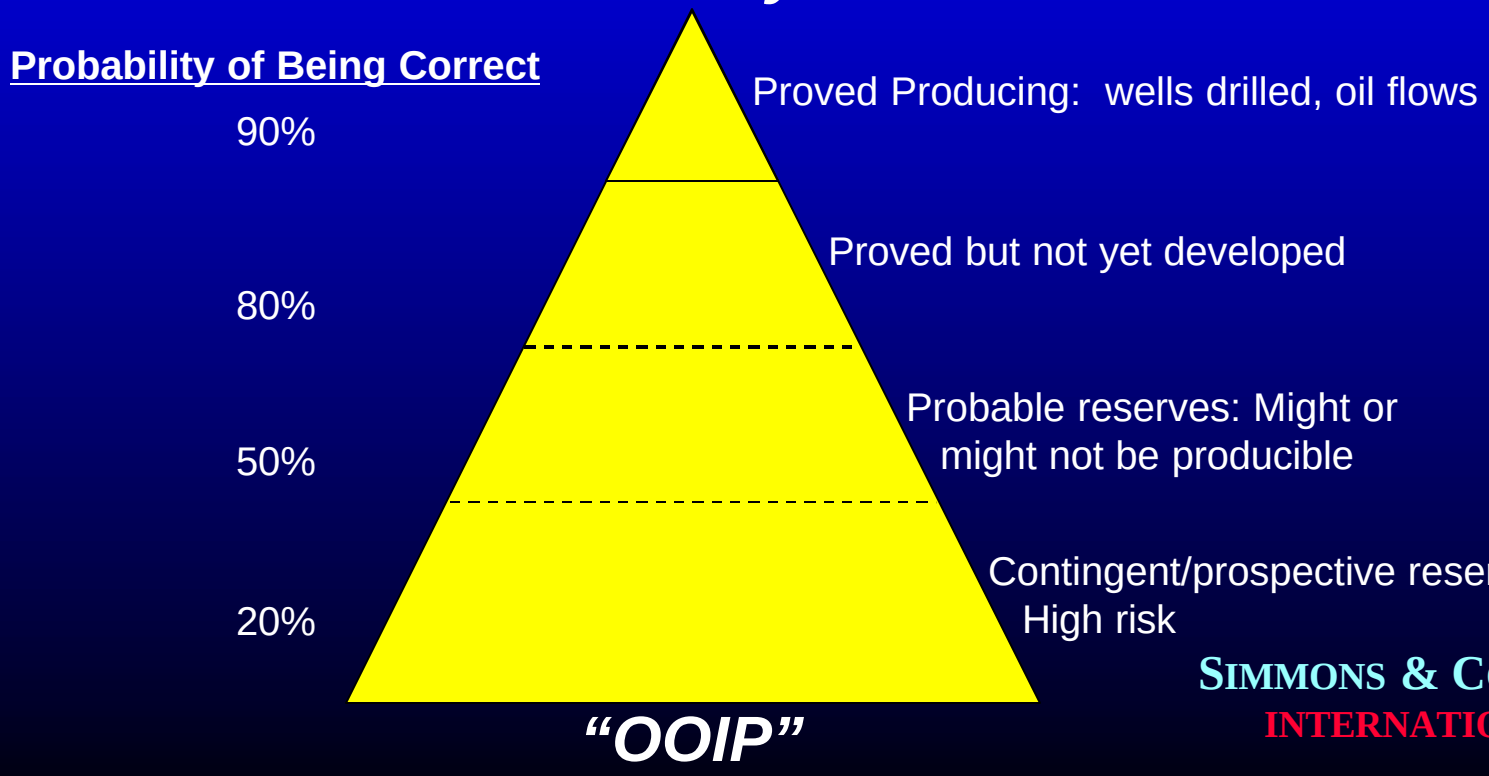
Proved Reserves Anchor Oil And Gas Resource Adequacy

- "Proved" oil (and gas) reserves are the basis for oil company valuations and future oil production forecasts.
- The science of estimating reserves has been known for 70 years.
  - Original oil in place ("OOIP") must be estimated.
  - Amount of OOIP that is technically and economically recoverable is then estimated.
- Before oil flows, estimates are volumetric approximations.
- After oil flows for some time, estimates are easier to do.
- When fields approach maturity, estimating remaining recovery gets hard once more.

Proved Producing Reserves Are Easiest To Estimate

- A field producing and in steady decline is easiest to estimate.
- There are no clear lines between each reserve status.

The Value Pyramid



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Many Energy Observers Have Assumed Proven Meant Absolutely "Proven"

- The vast distinction between "proven, probable and possible hydrocarbon reserves" faded into silence until Shell's recent "bombshell".
- A rash of other reserve write-downs now highlights the art form that still goes into creating hydrocarbon reserve estimates and classifications.
- Despite oilfield technology revolution, estimating reserves is still akin to actuarial estimates of remaining years in a human life - a scientific guess.

"A Reserve Is A Reserve Is A Reserve"……Is *Not* True

- "A rose is a rose is a rose" (Gertrude Stein, 1913) does not apply to oil and gas reserves.
- Every reservoir is unique.
- "Analogies" can work if truly analogous.
- One's ultimate age is only known after death.
- Long life reservoirs are hard to produce fast.
  - Sunset Midway was found in 1888. It is still a giant oilfield.
  - 80% of many deepwater GOM oilfields are produced in 5 years.
- Rate of recovery and ultimate recovery differs by reservoir.

Does Industry Now Have Better Set Of "Reserve Eyes"?

- Has the industry's ability to assess reserves increased by quantum leaps?
- Do current estimation techniques require even "fuzzier logic" to divine the truth?

- Old system:
  - Volumetric calculations are guesses.
  - Flow testing appraisal wells sharpens the picture.
  - Long history of production heightens the proof.

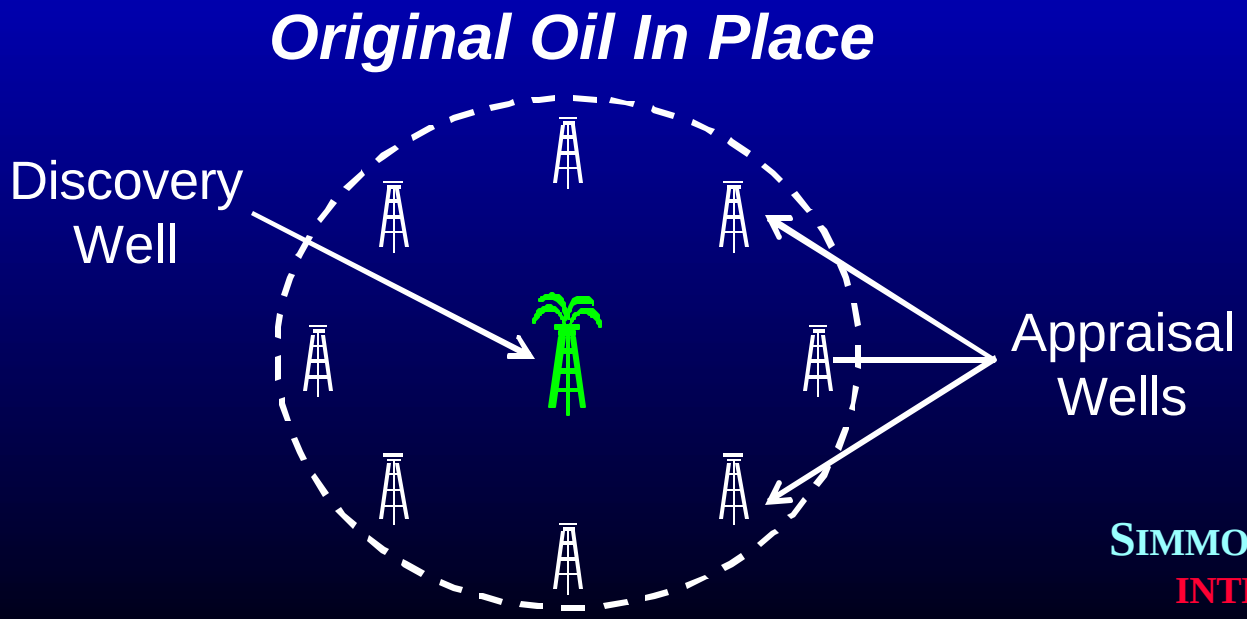
Can New Technologies See The Reservoir Better?

- Fewer appraisal wells now drilled.
- 3-D seismic, core analysis, logging data is now integrated into complex state-of-the-art simulation models.
- Technology can simulate being able to “see into a reservoir”.

- Have these new “eyes” created better data and more accurate assumptions?
- Or are we missing the old tried and true tools?

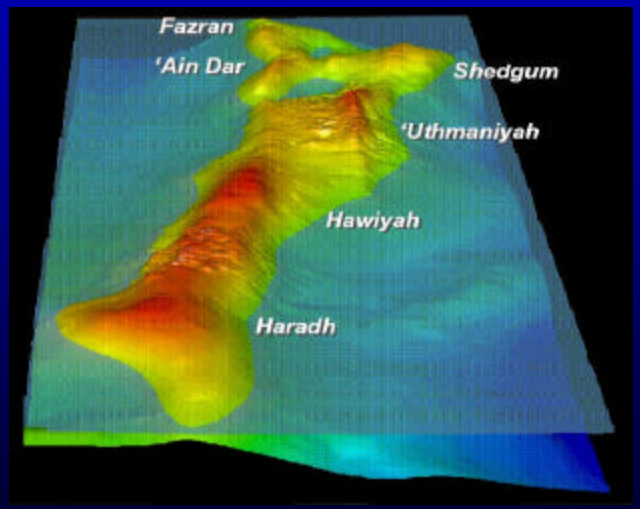
Historic Placement Of Appraisal Wells Created A "Reserve Safety Net"

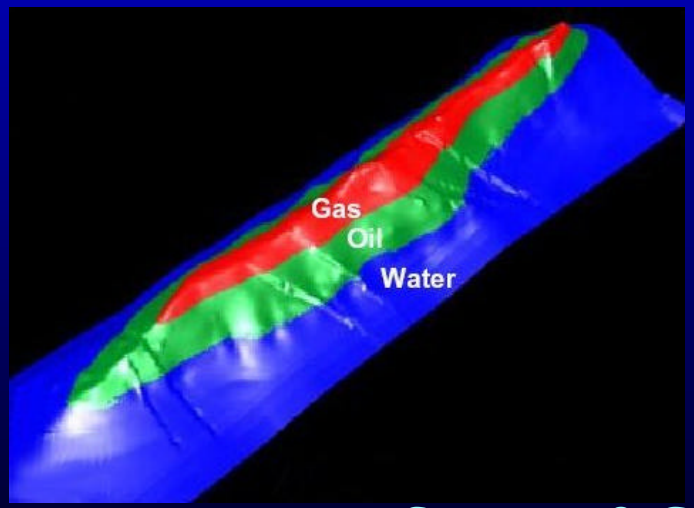
- Appraisal wells delineate the edges of oilfields.
- Well placement never tries to hit the edge: too risky.
- This tends to leave "the edges" as reserve appreciation.



Have Appraisal Wells Started To Become Obsolete?

- As industry embraced “geophysical work station analysis”, fewer appraisal wells were drilled.
- Use of third-party independent engineering also waned.
- 3-D reservoir visualization modeling was deemed to finally see into an oilfield.





Low Oil Price Era Pushed Analysis To "Envelope's Edge"

- In high price era, only the sweet spot had to be proved.
- The extra recoverable oil was "the pleasant extra surprise".
- 1983 - 2000: $15 to $18 oil made it hard to justify solid new projects. Every barrel to be produced was needed.
- Appraisal wells often became too risky and expensive to drill.
- Group geophysical data cost $0.05 of $1.00 of real costs.
- Computing costs plummeted.
- This led to widespread belief "oil prices will steadily fall". (Moore's Law)

Oilfield Technology Did Not Find Lots More Oil

- Despite widespread booking of 120% to 150% more reserves than production, little came from drill bits.
- Acquisitions and work stations found most of this oil.
- Basics were still basics:
  - Reservoir rocks details how reservoirs drain.
  - Reservoir recovery plans dictate efficiency of reservoir recovery.
- Oilfield technology had complex fields possible to exploit.
- Oilfield technology accelerated the speed of draining the reservoir.

Recovery Efficiencies Vary Primarily By Recovery Mechanism And Reservoir Type

- Oilfield technology accelerated the recovery of hydrocarbons.
- Occasionally, it increased the ultimate recovery of a field.
- Primary recovery efficiency still depends on the “rocks” and recovery mechanism.

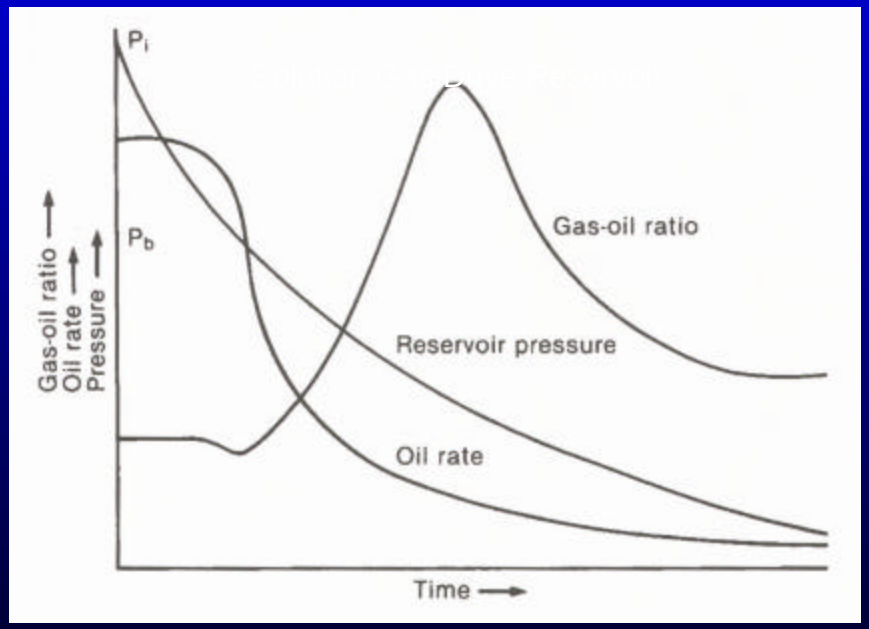
	Recovery[1] (Percent OOIP)	
	Range	Median
Solution Gas Drive	12% - 37%	20%
Gas Cap Drive	15 - 60	33
Water Drive	18 - 84	51

[1] Courtesy of IHRDC.

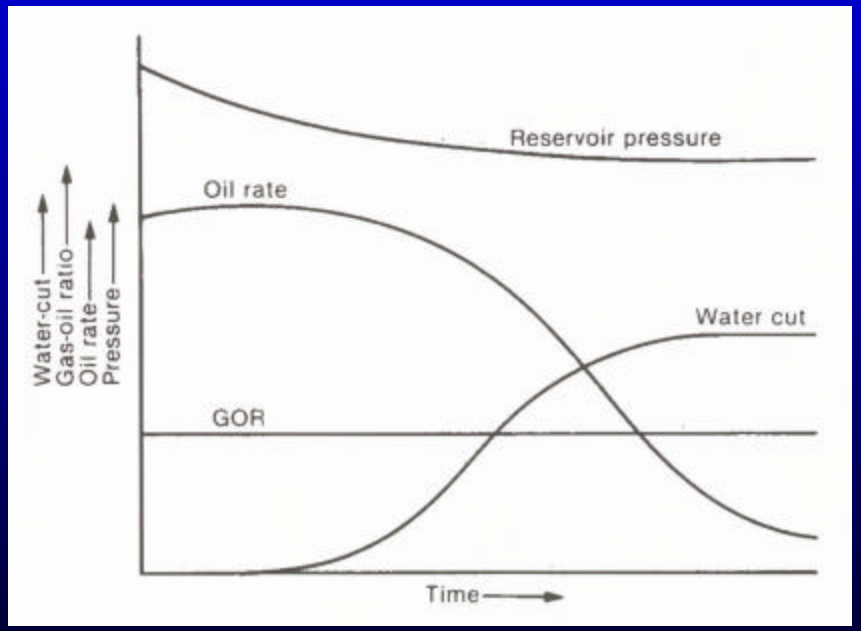
All Recovery Mechanisms Ultimately Create Production Declines

- At some point in time, a field's oil output begins to decline.
- The rate of decline is determined by many factors.

Solution Gas Drive Reservoir

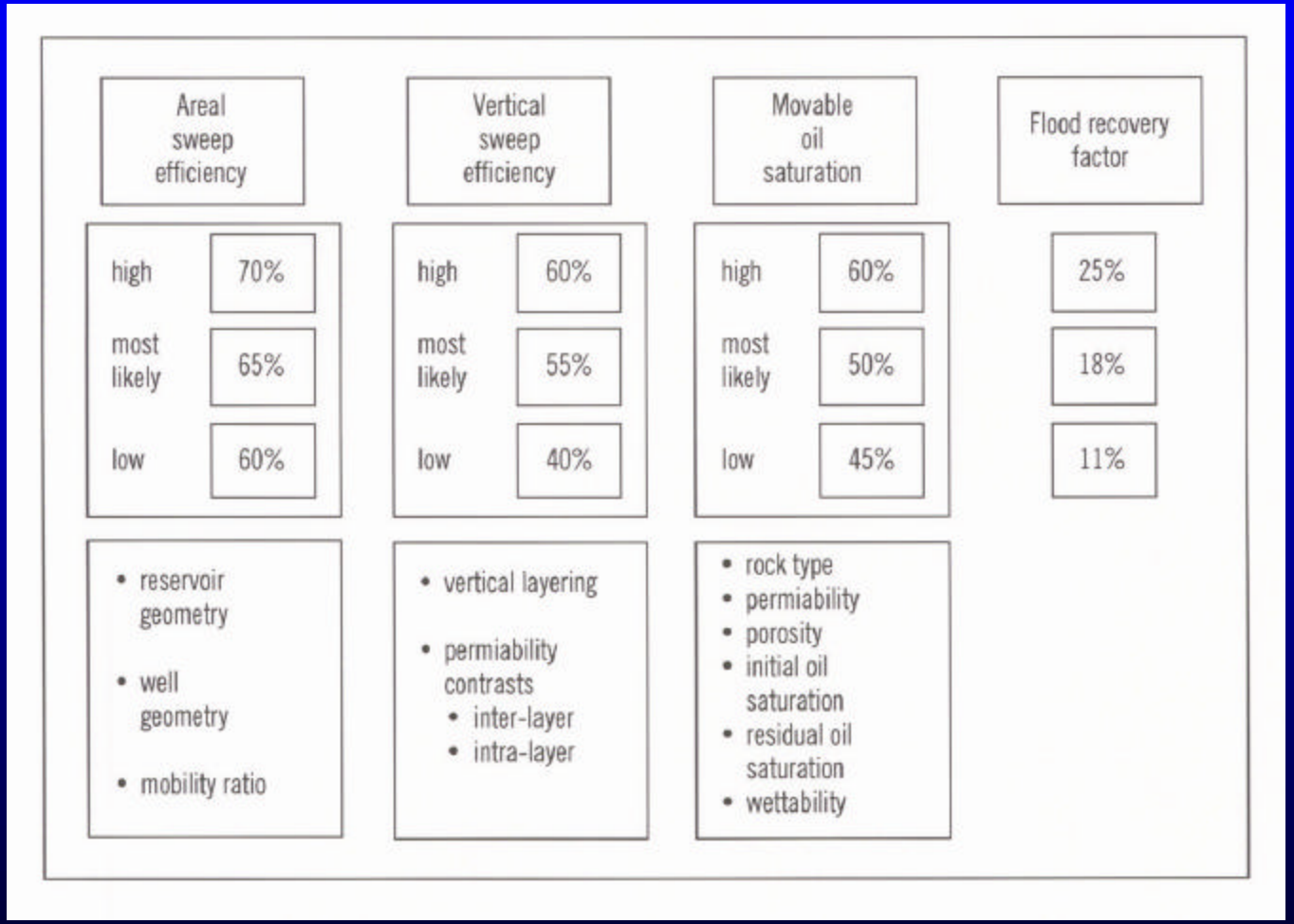


Water Drive Reservoir



Source: IHRDC.

Items Affecting Recovery Factors



Source: IHRDC.

Recovery Of Oil Remains Embedded In "The Rocks"

- Recovery factor as function of API gravity.

	Range
Heavy Oil	5% - 20%
Medium To Light Oil	20 - 55
Condensate	50 - 80

- Ultimate recovery from Type II fractured carbonate oil reservoirs.

Frequency	Number Of Fields	Frequency	Number Of Fields
10%	1	40%	3
15	1	45	2
20	7	50	4
25	4	55	0
30	4	60	1
35	8		

Mean = 31%

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[1] Source: C&C Reservoirs (SPE 84459).

How Solid Are Global Proved Reserves

- Most of large gains seem to be merely “paper barrel” changes.
- Drill bit additions are small portion of global gains.
- Some countries clearly lost reserves.
- The quality of proved reserve data is hazy.

Countries Adding Significant Reserves

	Billion Barrels Proved Reserves			
	1982	1992	2002	Change 1982-2002
Drill Bit Success				
Brazil	1.8	3.0	8.3	6.5
Norway	6.8	8.8	10.3	3.5
Angola	1.6	1.5	5.4	3.8
Nigeria	16.8	17.9	24.0	7.2
Australia	1.6	1.8	3.5	1.9
Total	28.6	33.0	51.5	22.9
Paper Barrel Success				
Middle East	369.0	661.8	685.6	316.6
FSU	66.9	60.7	80.6	13.7
Libya	21.5	22.8	29.6	8.0
Venezuela	21.5	62.7	77.8	56.3
Total	478.9	808.0	873.5	394.6

[1] Source: BP Statistical Review of Energy 2003.

Countries Losing Proved Reserves

	Billion Barrels Proved Reserves			
	1982	1992	2002	Change 1982-2002
U.S.	35.1	32.1	30.4	(4.7)
Canada	8.3	5.5	6.9	(1.4)
Mexico	48.3	51.3	26.9	(21.4)
U.K.	13.9	4.1	4.7	(9.2)
Egypt	3.3	6.2	3.7	0.4
Indonesia	9.6	5.8	5.0	(4.6)
China	19.5	24.0	18.3	(1.2)
Total	138.0	129.0	95.9	(42.1)

[1] Source: BP Statistical Review of Energy 2003.

Summing Up Global Proved Reserves

	Billion Barrels Proved Reserves			
	1982	1992	2002	Change 1982-2002
Drill Bit Success	28.6	33.0	55.5	22.9
Paper Barrel Success	478.9	808.0	873.5	394.6
Country Losses	138.0	129.0	95.9	(42.1)
Remainder	31.2	36.7	22.8	(8.4)
Total	676.7	1,006.7	1,047.7	367.0

Bottom Line: Approximately 6% of proved reserve gains came from exploring new fields. Was part of the balance imagination?

[1] Source: BP Statistical Review of Energy 2003.

How Fuzzy Are Public Company Proved Reserves?

- BOE Production:

	BOE/d (Millions)
1998	42.6
1999	42.5
2000	43.5
2001	44.9
2002	46.2

Growth of 2.1% per year.

- Costs Incurred:

	$US (Billions)
1998	$120
1999	115
2000	143
2001	158
2002	151

Negative net cash flow even after “$30 oil”.

- Most companies grew proved reserves by 15% to 40% more than they produced.

Source: J.S. Herold Data Bank.

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Precision/Quality Of Proved Reserve Estimate Varies

- There are great disparities between reserve estimates.
  - Company practices vary.
  - Company know-how varies.
  - Some reservoirs are easy to estimate. Others are not.
  - Reserve estimates change with price.
    - "Economically viable" at $15 different than $30.
    - Costs of oilfield services also varies.
- Void of data on specific oilfields makes it impossible to assess the quality of total reported proven reserves.

Source: SPE 81463, April 2003.

Ultimate Recoverable Reserves Tell Little About Future Oil Production

- Fields with extremely high recovery efficiencies still decline.
  - East Texas oilfield: Ultimate recovery will exceed 80%
    - 13,500 bbls of oil each day.
    - 1 million bbls of processed brine each day.

    } 2003
  - Prudhoe Bay recovery grew by 30%.
    - Peak production came in year 11 (approximately 1.6 million b/d).
    - 14 years later (and triple the wells in place) production is down 80%.
- Heterogeneity can wreak havoc on well planned recovery programs.
  - Leadon Field (U.K.)
  - Sable Island (Nova Scotia)
  - Brutus (Deepwater GOM)

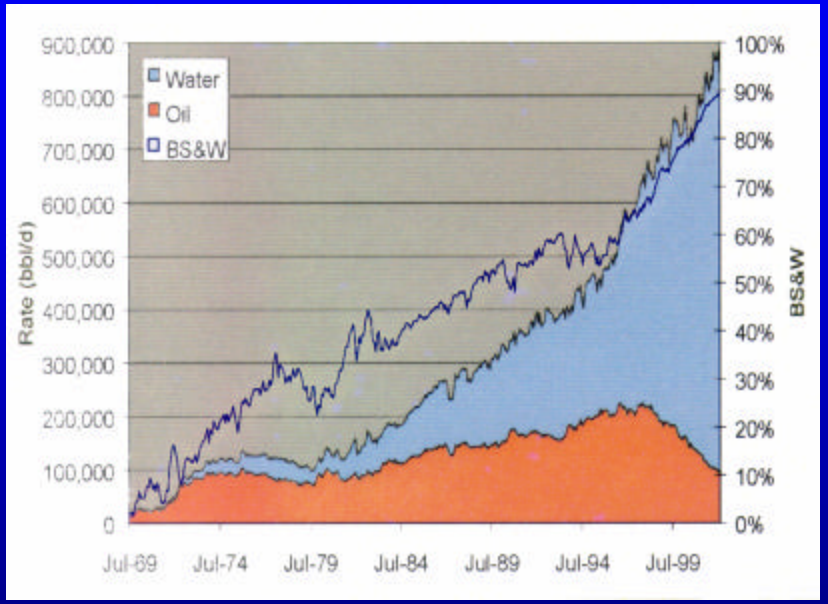
  } All were perfectly planned. None worked.

Oman's Ominous Omen: Giant Fields Can Collapse

- Yibal: A giant oilfield discovered in 1963.
  - Production began in 1969.
  - Water injection began in 1972.
  - Vertical wells became obsolete in 1990.
  - Horizontal wells recreated fabulous oil flows per well.
  - Field production peaked in 1997: 250,000 bopd.
  - By 2001, oil production was > 90,000 bopd.
  - 2004: Yibal is producing > 40,000 bopd.
- Moral of this case: The decline came "out of the blue".
- Yibal now expected to recover approximately 44% to 50% of OOIP (after EOR).

How Oman's Yibal Field Declined

- 2003 Status:
  - 460 wells:
    - 850 reservoir penetrations (multiple sidetracking)
    - 300 oil producers
    - 120 water injectors
    - 50 wells "closed"
  - Still approximately 855 million barrels to be produced.
  - 300 million of developed reserves.
  - 555 million undeveloped.



Yibal's Historical Liquid Rates - 1969 - 2002

- "Developed reserves will not all be recovered if better reservoir practices are not established as field's water cut continues to increase."

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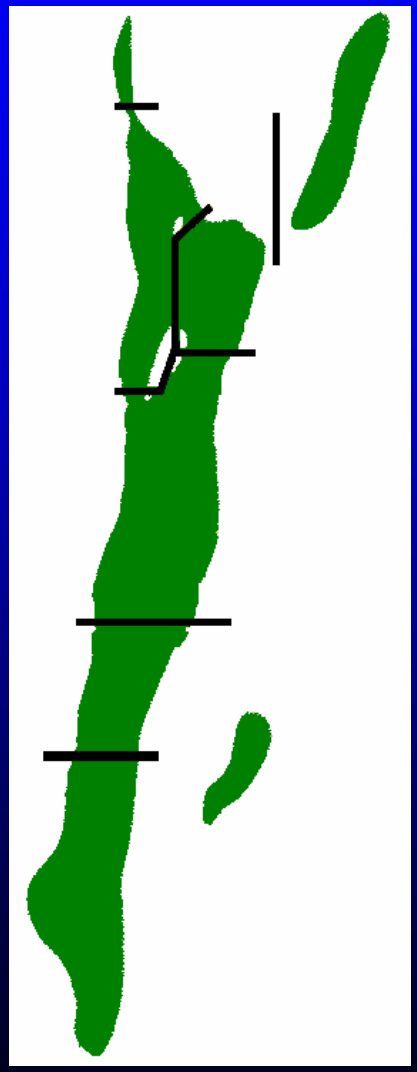
Source: SPE 81463, April 2003.

Ghawar's Fabulous Oil Output Could Be At Risk



- Ghawar is world's largest oilfield (approximately 5 million b/d).
- This great field is almost 60 years old.
- Its water cut was approximately 36.5% before vertical wells were stopped. Now approximately 30%.
- Horizontal/maximum reservoir contact wells postpones next leap of water cut. (But leap will arrive!)
- 1975 ultimate recoverable reserve estimate: 60 billion barrels.
- Cumulative production through 2003: 55 billion barrels.
- Saudi ARAMCO now states that Ghawar has 125 billion barrels left to recover.
- How wrong could 1975 Exxon, Mobil, Chevron and Texaco estimates have been?

“Trust Me” Era Is Over

- Shell’s stunning proven reserve write-down was a wake-up call.
- Most of world’s “proven reserves” are simply “statements”.
- Some of the “statements” have to be wrong.
- The majority of the public E&P companies might have overbooked reserves.
- Finding and development costs have doubled.
- Daily BOE production is flattening out.
- “Trust Me” was fine when world’s oil supply was young.
- The world’s oil supply is now extremely mature.

The World Needs An Energy Audited Annual Report

- With oil demand growing so fast, world has run out of spare production capacity.
  - 1.5 to 2.0 million b/d is not a safe cushion.
  - Not clear this is genuine sustainable spare capacity.
- An era of genuine "transparency" is badly needed.
  - Transparent reported production:
    - Field-by-field production history.
    - Reported wells-by-field.
  - Transparent reserve data:
    - Original oil in place.
    - Ultimate recoverable reserves.
    - Cumulative production.

    } By Key Fields
  - Independent audit of these numbers.
- If a producer will not comply, world needs to assume they must be in trouble.

Highlight Of What New Transparency Era Needs

Company: Simmons Oil	Historical Production 2000	2001	2002	2003
Key Producing Fields				
Giant Field A	120	100	85	80
Giant Field B	110	100	95	90
Giant Field C	80	70	60	40
Giant Field "New"	--	--	70	80
	310	270	310	290
Other (Percent)	90	65	50	40
Total Production	400	335	360	330
Number Of Producing Wells	220	270	330	375

	Reserve Data (Million Barrels) OOIP	Cumulative Production	Remaining Ultimate Recovery	Percent
Giant Field A	1,800	500	220	40%
Giant Field B	1,200	300	84	32
Giant Field C	900	250	74	36
Giant Field "New"	1,400	55	175	25
Other (Percent)	N/A	N/A		

“If Oil Producers Balk At Transparency”

- The world needs to be extremely alarmed.
- Can you imagine the integrity of reported GAAP accounting numbers absent an annual report and auditors certificate?
- No field-by-field data was fine when world had massive cushions.
  - Young giant oilfields.
  - 90 to 100 days oil stocks.
  - Massive shut-in capacity.
- All this luxury evaporated.
- *The time for data reform is now!*

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