RESERVOIR SOLUTIONS

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A&D fundamentals strong in Canada, says Haugen

"Available investment capital can selectively acquire great assets in Canada now," said **Dave Haugen**, manager of Ryder Scott Canada and senior vice president. "Early, proactive analysis will pay off." He made his remarks at the latest Ryder Scott reserves conference in Houston.

Among the factors that are creating a buyer's market for U.S. companies and others are an attractive currency profile — for instance, a stronger U.S. dollar vs. the Canadian dollar — and financial pressures that are forcing Canadian companies to move quality assets now.

"Sellers are coming to the table more often because of pressure on leveraged balance sheets," said Haugen. "Sellers are becoming more realistic. Asking prices for crown jewels are going to come down as financial pressure continues and hedges fall off."

He also remarked that service, land and employee costs have fallen significantly. "High-quality personnel are available to drive innovation and reduce capital and operating costs," said Haugen. "A few years ago in Canada, it was almost impossible to get the quality of people that are available now to support your operations."

Please see Fundamentals on Page 2

TABLE OF CONTENTS:

Fundamentals – Cont. from Page 1

Supply and service costs are dropping in Canada as they are across all of North America. "Producers are leading an industrywide, focused effort to drive costs down further. When you see cost decreases from focused effort, and the service industry is working alongside producers, it creates a more competitive investment jurisdiction," said Haugen.

He also cited what he called "world-class public information" on oil and gas activities available from provincial oil and gas regulators. "In Canada, we have some of the best data access in the world," said Haugen.

The country boasts what is recognized as one of the most advanced regulatory systems worldwide for oil and gas disclosures under National Instrument 51-101. Its companion reference, the Canadian Oil & Gas Evaluation Handbook, provides guidance on recommended procedures for estimating oil and gas resources and reserves.

"If you want to look at a company or an asset, you have drilling, geological, fracing and completions data, production histories and much more information to analyze. You can take something completely apart and rebuild it for your own purposes," said Haugen.

Regulators are moving to play-based development approvals and shortening the cycle time for licensing. Dozens of licenses for wells, water, etc. can be issued under one approval, which speeds up cycle time and gives more confidence to the investor, said Haugen.

Also, a large portion of the provincial revenue base for the three western provinces — Alberta, Saskatchewan and British Columbia — is resource based, so they are competing with each other with favorable terms to attract further investment.

Ryder Scott Canada conducted a study of Alberta's new Modernized Royalty Framework equations introduced last April and found that they improve the competitiveness of investing in the province's oil and gas. Please see, "Investment in Alberta O&G more attractive than in competing provinces thanks to new royalty framework," in *Reservoir Solutions* newsletter, July – Sept. 2016, Page 9.

Some market obstacles remain. Resources require pipeline access to receive full value, and pipeline regulatory approvals are moving slowly.

"It is in the national interest of the country to get this done," said Haugen. TransCanada Corp. said it hopes to persuade a new Donald Trump administration in the U.S. to revive the controversial Keystone XL crude oil pipeline that President Obama rejected more than a year ago.

Other industry trends to watch are increasing environmental opposition to energy development projects, and recent elections of governments that are moving forward with increased corporate taxes and carbon tax regulations that will affect all sectors of the industry.

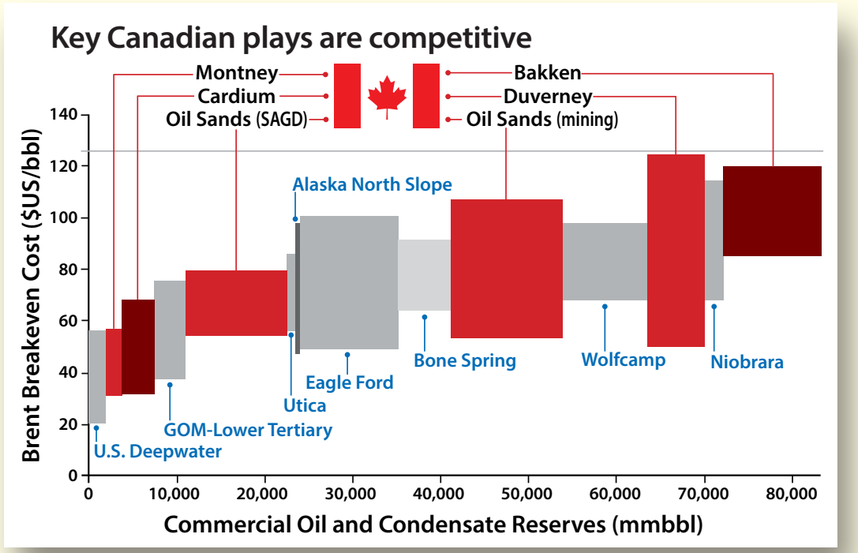
Haugen said that the Montney, Duvernay and Cardium are good plays to investigate for potential acquisitions. "What is interesting to me is that there are some key available acquisition positions right in the heart of plays, such as the Montney," said Haugen. "The Montney is not the Permian but you do have some attractive options."

He also said that the potential for an improved gas market is strong and market demand should increase with the prospect of future LNG projects planned for the west coast. Haugen's presentation is posted at ryderscott.com/presentations.

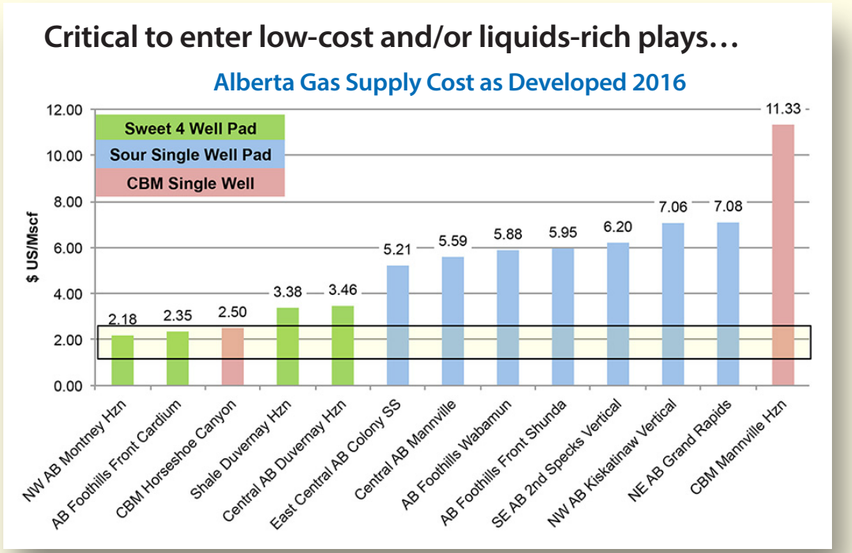
He can be reached on email at dave_haugen@ryderscott.com or at his phone number, +1-403-262-2799, ext. 1025.

Dave Haugen

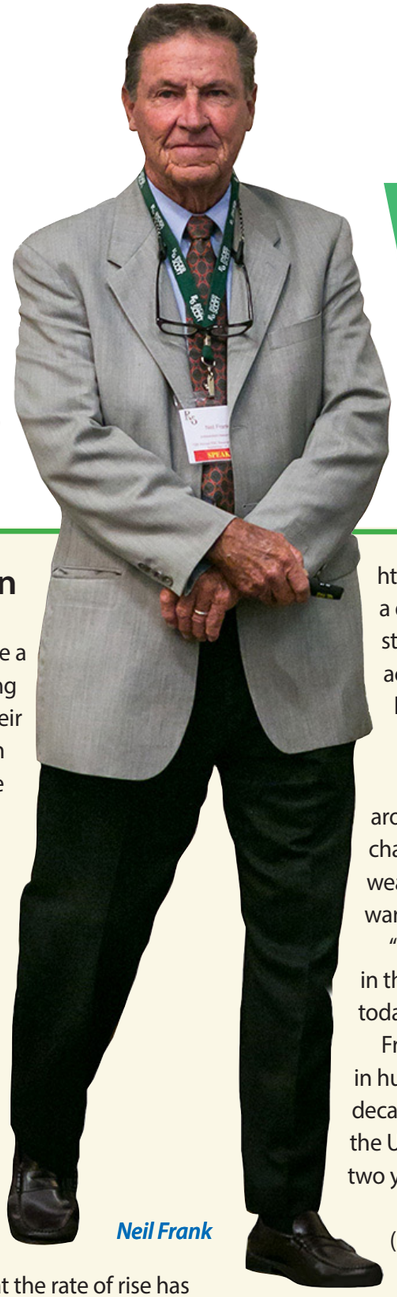
Liquid reserves shown on the horizontal axis are cumulative recovery, and on the vertical axis is the range of costs to develop those resources to deliver a 10-percent return. U.S. deepwater is the least expensive play to develop and the most expensive is mining the Canadian oil sands. The wider the column, the more reserves potential indicated.



Source: Wood Mackenzie



"GLOBAL WARMING ...is not man-made."



Neil Frank

Meteorologist argues that man-made climate change is fiction

Arguments that burning fossil fuels leads to climate change were challenged by a former director of the National Hurricane Center at the latest Ryder Scott reserves conference. In somewhat of a twist, weeks before the U.S. presidential election, meteorologist **Neil Frank** supported claims that man-made global warming was a hoax. President-elect Donald Trump's campaign articulated the same view.

"Do you believe the earth is warming? Do you believe CO_2 is a pollutant? Do you believe the earth's warming is being caused by man through the burning of fossil fuels? Why do you believe what you believe," Frank asked.

He claims media bias is partly responsible for what the public believes. Frank quoted figures from the Media Research Center in Reston, VA. (The sole mission of the research and education organization is "to expose and neutralize the propaganda arm of the left — the national news media," as stated on its website.)

"The research center reported that mainstream news media interviewed those with sympathies to global warming on an eight-to-one ratio," said Frank. He added that none of 92 articles over the first six months of 2013 took issue with the notion of man-made global warming.

News from mainstream media competes with blog posts, tweets and other social media, some of which perpetuate "fake news" and conspiracy theories.

Which begs the question: Is the notion of man-made climate change a hoax? Or is the hoax a hoax? As long as the political right and left spin their messages and divide public opinion along ideological lines, pure science and the public are the real losers.

Polar opposites

Frank not only questioned whether global temperature increases have melted sea ice. He questioned whether polar ice was thawing out at all.

"Ice in the Antarctic has been increasing and Arctic ice has been stable for years since 2007. I'm happy to report that the polar bears are doing very well," he said.

Sea levels have been rising since the last ice age but the "important fact," said Frank, was that the rate of rise has slowed.

Others disagree. Global sea level rose about 6.7 inches in the last century but the rate in the last decade is nearly double that of the last century, according to geophysical research cited by the National Aeronautics and Space Administration at http://climate.nasa.gov/evidence/. NASA has more than a dozen earth science spacecraft/instruments in orbit studying sea level rise, changes in sea and land ice, solar activity, atmospheric and oceanic temperatures, ozone layer and air pollution.

How's the weather?

Frank took aim at the notion that extreme weather around the world is shaped by human-induced climate change. The former long-time KHOU-TV weatherman said weather patterns don't point to a dangerous global warming threat.

"The number of droughts has been very normal. Some in the past have been much more severe than those of today," he remarked.

Frank pointed to what he called a "significant decrease" in hurricanes, typhoons and cyclones during the past three decades. "It has been 10 years since a major hurricane hit the U.S. Before that, we expected one, on average, every two years," he said.

The Intergovernmental Panel on Climate Change (IPCC) also agrees that CO_2 emissions most likely have not caused a greater number or more severe tropical cyclones. However, that is where consensus ends.

The IPCC is a major player in the climate-change debate. The panel is a worldwide organization devoted to publishing scientific research on climate change to advise, not govern, its 195 member countries seeking to develop their respective national policies. The United Nations, long a favorite scapegoat for the alternative right, established the panel almost 30 years ago. With a limited annual budget of $6 million, the IPCC has enlisted hundreds of volunteer scientists and thousands of reviewers to write and edit some 9,200 peer-reviewed papers.

The IPCC has released five major assessments which, among other findings, have concluded that some weather patterns, including extreme global warming and precipitation, are most likely caused by CO_2 emissions.

Rebuttals to the IPCC assessments are published by the privately funded Nongovernmental International Panel on Climate Change (NIPCC). It concludes weather events of the past few decades are not unusual, unnatural or unprecedented and that the rising CO_2 concentration in the atmosphere is having no measurable influence on weather phenomena.

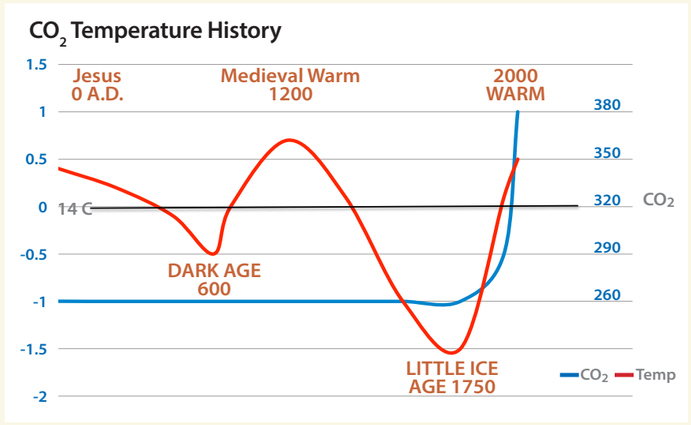
The NIPCC said it was created by a group of scientists concerned about "flaws" in the IPCC, and found it necessary and appropriate to present those flaws. The NIPCC has three lead authors.

Please see Climate Change on Page 6

Climate Change – Cont. from Page 5

Natural or man-made?

Frank showed a graph of reconstructed temperatures and CO_2 levels over the last 2,000 years estimated from geologic data, including ice cores from Law Dome in Antarctica.



The chart indicates that during the highpoint of a medieval warm period around 1200 AD, which was hotter than our current period, CO_2 levels were much lower than today.

Presented by meteorologist Neil Frank. Primary source uncredited.

"The science is indisputable. The data supports natural cycles. The case for CO_2 is very weak. The statistical analysis does not show spikes in the (CO_2) curve that reflect spikes in the (temperature) curve," said Frank. "Ice ages were followed by warm periods. Over the past 400,000 years, there have been numerous warm and cold cycles. Now we are in a 100-year warm period."

He showed a chart indicating that the earth's temperature has been rising over the past 150 years since the Little Ice Age, during which temperatures bottomed out in 1750 AD.

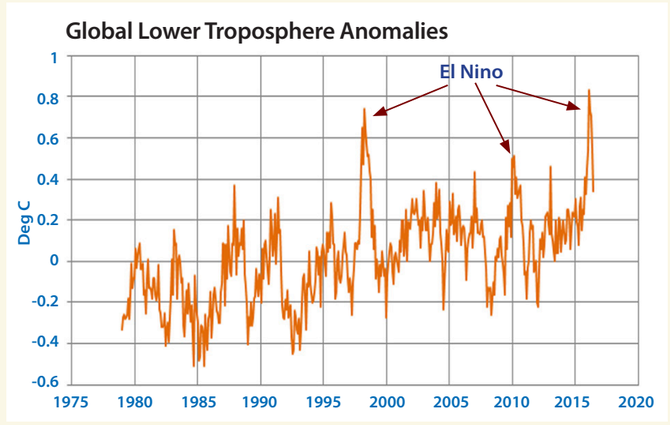
If earth has warmed and cooled throughout history, what makes scientists think that humans are causing global warming now? NASA points to an accelerated rate of warming of the atmosphere. "The warming of the past century—0.7 degrees C.—is roughly eight times faster than the ice-age-recovery warming on average."

Also scientists worldwide have stated that empirical observations have failed to show any long-term changes that fully account for the recent, rapid warming, NASA states. Those scientists considered changes in the sun's brightness, major volcanic eruptions and oceanic cycles.

Frank showed a slide, "The Right Climate Stuff," indicating that in 2013, 49 retired NASA scientists and astronauts challenged NASA's position on global warming.

World's oceans: Global heat engine

Frank said the oceans' cyclical surface-temperature swings cause global warming. El Nino is a naturally occurring warming event in the equatorial region of the Pacific Ocean off South America. In an El Nino cycle, warmer-than-normal sea surface temperatures heat up the lower atmosphere, as indicated by one of his graphs.



Credited to Bob Tisdale, author and climate-change skeptic.

It showed El Ninos occurring in 1997-98, 2009-10 and 2015-16 and the associated temperature spikes. Frank also cited the Atlantic multidecadal oscillation as another cyclical oceanic influencer of higher atmospheric temperatures.

He questioned forecasting models — which he called hypothesis expressed in mathematical terms — that have not taken into account solar influences and natural weather cycles. "Some of these models are not even good for a five-day forecast," Frank remarked.

CO_2: Plant food or biosphere pollutant?

Atmospheric CO_2 is 400 parts per million (ppm). Frank put that concentration into perspective. "That's equivalent to about 40 seats out of 110,000 seats in Cowboys (AT&T) Stadium," he said. Concentrations of 350 to 1,000 ppm are typical of occupied indoor spaces with good air exchange.

"CO_2 is vital for plant life. Several field experiments confirm that higher levels increase agricultural productivity," said Frank. "Nurseries bump their CO_2 levels up." They use generators to raise indoor CO_2 levels up to 1,500 ppm.

What do the experts think?

Frank acknowledged that some scientists, particularly modelers, believe that man-made CO_2 emissions cause climate change and global warming. He said they are joined by environmentalists, profiteers and advocates of a one-world government. (UN supporters are notoriously pigeon-holed as champions of world government.)

NASA cited a survey published in April 2016 that tracked "multiple studies published in peer-reviewed scientific journals" and it indicated "that 97 percent or more of actively publishing, climate scientists agree: Climate-warming trends over the past century are extremely likely due to human activities." In addition, most of the leading scientific organizations worldwide have issued public statements endorsing this position, said NASA, which cites numerous studies on the causes of climate change at http://climate.nasa.gov/scientific-consensus/

Alex Epstein, author of "The Moral Case for Fossil Fuels," challenges the 97-percent figure, saying that it is a "deliberate misrepresentation designed to intimidate the public." He said that one of the main surveys of the scientific papers was ill designed with questionable categories, including "explicit endorsement without quantification" and "implied man-made global warming."

Frank's presentation features climate change experts questioning man-made global warming. His slides, with charts, references and additional content, are posted at ryderscott.com/presentations.

Editor's Note: In 2014, "The Moral Case for Fossil Fuels," was the New York Times 17th best-selling science book. Wall Street Journal book reviewer Philip Delves Broughton critiqued it and wrote that Epstein's view is that "renouncing oil and its byproducts would plunge civilization into a pre-industrial hell. …The country goes dark. Transportation stops. Schools, hospitals and businesses close down. We are left to grow our own scrawny vegetables and slaughter our own animals for meat. We cannot even text." The book has a substantial pass-around circulation rate in the petroleum industry.

Controlling methane releases from gas wells is upstream challenge

The burning of fossil fuels and CO_2 emissions is less relevant to the upstream industry than the release of raw methane gas, which contributes to the greenhouse effect and global warming, some claim. The U.S. Interior Department finalized Bureau of Land Management rules in November to help curb methane leaks from oil and gas production on federal and tribal lands.

The agency said the move will avoid wasting 41 Bcf of gas per year. Some scientists say that in the first 20 years, atmospheric methane traps 84 times as much heat as an equivalent amount of CO_2.

Please see related article on political risks on Page 12

SEC comment letters focus on borrowing bases, reserves

The latest surveys on SEC comment letters show several E&P companies responding to U.S. Securities and Exchange Commission inquiries on credit facilities, capital resources and petroleum reserves. Besides a recent Ryder Scott survey, Haynes and Boone LLP has done a review on its own, which was presented by **Marc H. Folladori**, senior counsel, at the latest Ryder Scott reserves conference in Houston.

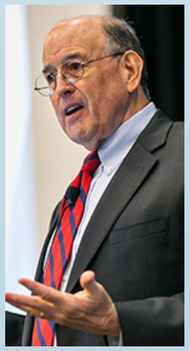
The following comment letter excerpts indicate a growing concern by the SEC about the financial wherewithal of the industry relative to reserves disclosures:

- **Energy XXI Ltd.** on 4/3/15 — If a reduction in your borrowing base is a possibility, address the extent to which it could decrease based on expected oil and gas reserves values and other relevant factors.
- **Clayton Williams Energy Inc.** on 9/16/15 — Are you in compliance with your revised debt covenant? Quantify your current total debt to EBITDAX.
- **Goodrich Petroleum Corp.** on 9/21/15 — Given the reduction in your borrowing base and negative cash flows from operations for six months ended 6/30/15, how did you conclude that you had adequate financing to support the recordation of proved reserves as of 12/31/14? What steps are you taking to avoid or address a covenant breach?
- **Lilis Energy Inc.** on 9/25/15 — What were the terms of the waiver from your lender?
- **Black Hills Corp.** on 9/15/15 — If your credit ratings are downgraded, it appears that you will be required to post additional collateral. Describe the additional collateral posting requirements for you that would likely result.
- **Lonestar Resources U.S. Inc.** on 1/29/16— Do you expect that the drilling of your PUD inventory and expansions and extensions in the next five years will be funded from cash on hand, cash from operations and borrowings under your credit facility?
  - What are the product prices and development/production costs you are assuming for your expectations? What are minimum prices you require to continue your current programs?
  - What is the current level of compliance with your debt covenants? It appears that the current ratio is down from 1.28 at 12/31/14 to 1.09 at 9/30/15.

Noteworthy 2014-2016 Comments by the U.S. SEC

- Development and conversion of PUDs
- Recurring changes in development plans
- Trends and uncertainties resulting from continuing low commodity prices, and the quantification of the impact thereof
- Effects of E&P companies' weaker financial conditions and decreased revenues on their reserves reporting
- Effects of lease expiration on PUD reporting
- Development costs

Folladori's presentation is posted at ryderscott.com/presentations.



Marc Folladori

Uneconomic proved reserves dropped from 2017 SPE-PRMS draft

Reservoir Solutions reported in June that the Society of Petroleum Engineers was considering that uneconomic proved reserves would be allowed to be booked under the 2017 SPE-PRMS if the project's 2P case was economic. That concept met resistance from sister societies involved in drafting of the guidelines, in part, because regulatory agencies, including the U.S. Securities and Exchange Commission, require all reserves to be economic — a hurdle that has become a widely adopted industry standard.

Considering that, the SPE Oil & Gas Reserves Committee dropped its concept of uneconomic and economic proved reserves and redrafted its proposed guidelines so that all reserves categories are required to be economic.

"The OGRC subcommittee had assumed that if the new guidelines revisions were approved, regulators or other parties would have simply added their own requirements that proved reserves be economic," said **Jeffrey Wilson** at the latest Ryder Scott reserves conference in Houston. "However, SPE and its sister societies decided that the concept of uneconomic proves reserves was too big of a change to current industry practices."

The OGRC has been working on a broader definition to accommodate the full range of uncertainty associated with reserves assessments. The committee intended to create a definition set that works in all areas of reserves, not just regulatory requirements.

"Once a project meets commercial criteria based on a best estimate (2P), then all associated resources estimates become classified as reserves, including proved reserves not commercial on their own," said Wilson.

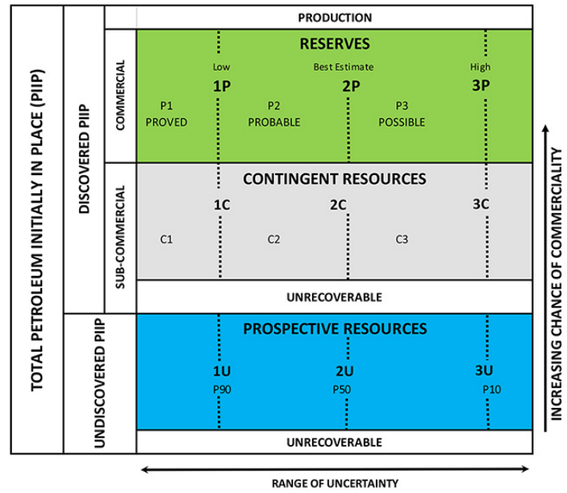
A commercial project has to meet minimum evaluation-decision criterion, such as rate of return, investment payout time, etc. If a project is certain to proceed, the low-side case, in a stochastic study for instance, still has to be represented even if it doesn't overcome initial capital expenditures.

In that situation, resources in the proved or 1P category still have to be "economically producible" as defined by the OGRC when the resource generates revenue that exceeds, or is reasonably expected to exceed, operating costs. Even though the resource may not meet an IRR, if net operating cash flow is positive, then the resource is economic.

Wilson also discussed other SPE-PRMS issues including the following:

- Resource classification framework
- Project maturity sub-classes
- Project definition
- Incremental and cumulative methods
- Clarify risk vs. uncertainty
- Contingent resources movement to reserves and split conditions

Classification Framework



Proposed updates

- Added P1, P2 and P3
- Added C1, C2 and C3
- Prospective Resource with 1U, 2U and 3U ("U" for undiscovered)
- Production box redrawn

Jeff Wilson

Promotions at Ryder Scott in Houston and Canada

Tim Smith in Houston has been promoted to senior vice president and group coordinator. **Vitaliy Charkovskyy** and **Anton Siyatskiy**, both in Calgary, have been promoted to senior petroleum engineers.

Oil price for year-end reserves filings with SEC drops 15%

Annual average prices for reporting year-end petroleum reserves to the U.S. Securities and Exchange Commission dropped 15 percent for oil and more than 3 percent for gas, using WTI crude and Henry Hub benchmarks, respectively.

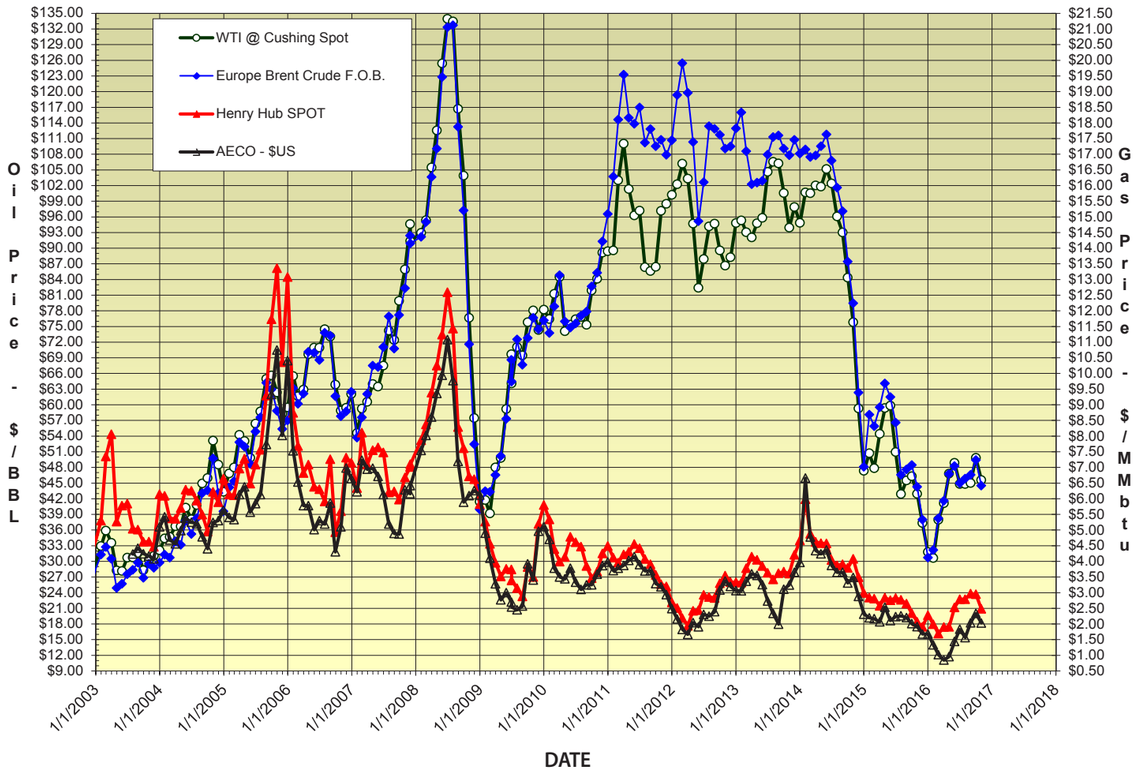
For 2016, WTI crude is $42.75 a barrel and Henry Hub gas is $2.49 per MMBTU. Other benchmarks and information on using differentials are posted at www.ryderscott.com. The prices are based on the unweighted, arithmetic average of the first-day-of-the-month price for each month in the calendar year. E-mail inquiries to fred_ziehe@ryderscott.com.

RS conference dates set for 2017

Ryder Scott has set the dates for its 2017 Houston and Calgary reserves conferences. The Calgary conference will be held at the Marriott Downtown Hotel on Tuesday, May 16. Organizers anticipate that up to 150 oil and gas executives, managers and technical professionals will attend the full-day event. For more information as it becomes available, please email ConferencesCalgary@ryderscott.com.

The Houston conference is set for Thursday, Sept. 21 at the Hyatt Regency Hotel in downtown, and a full house of almost 400 is anticipated. Attending licensed petroleum engineers will receive six to eight hours of CEUs (Continuing Education Units). Email requests, questions or comments to RSCConfHouston@ryderscott.com.

Price history of benchmark oil and gas in U.S. dollars



Published, monthly-average, cash market prices for WTI crude at Cushing (NYMEX), Brent crude and Henry Hub and AECO gas.

Machine learning better than manual production forecasting, says developer

David Fulford

With its speed and accuracy, probabilistic machine learning can replace manual production forecasting for most unconventional wells with consistent production trends, said **David Fulford**, a staff reservoir engineer at Apache Corp., who developed this new decline-curve analysis (DCA) technique.

Fulford uses a Markov-chain Monte Carlo (MCMC) simulation algorithm based on work published by Gong et al in 2011. The Markov decision process is based on reinforcement learning in which the machine trains itself through iterative trial and error. From an evaluator's initial guess, the algorithm handles the "mathematical drudgery" of fitting curves to data, remarked Fulford.

"At Apache, this has freed reservoir engineers to fit thousands of wells in a fraction of the time it has historically required with the traditional, manual process," he said.

Machine learning, if used properly, can be a "reliable technology" as defined by the SEC, added Fulford. The SEC defines the term "reliable technology," expressed in probabilistic terms or as a P90, as technology proven empirically to lead to correct conclusions in 90 percent or more of its applications. However, the agency has stopped short of adopting a 90-percent threshold as part of the definition.

Fulford has taken MCMC one step further and developed a probabilistic DCA technique that generates discrete P10, P50 and P90 forecasts that honor production data variances. Similar to various developers of recent alternative DCA applications, Fulford condemns the use of the modified Arps hyperbolic model when used for wells during long-duration transient flow.

The original Arps equations were developed when most wells exhibited boundary-dominated, stabilized flow regimes.

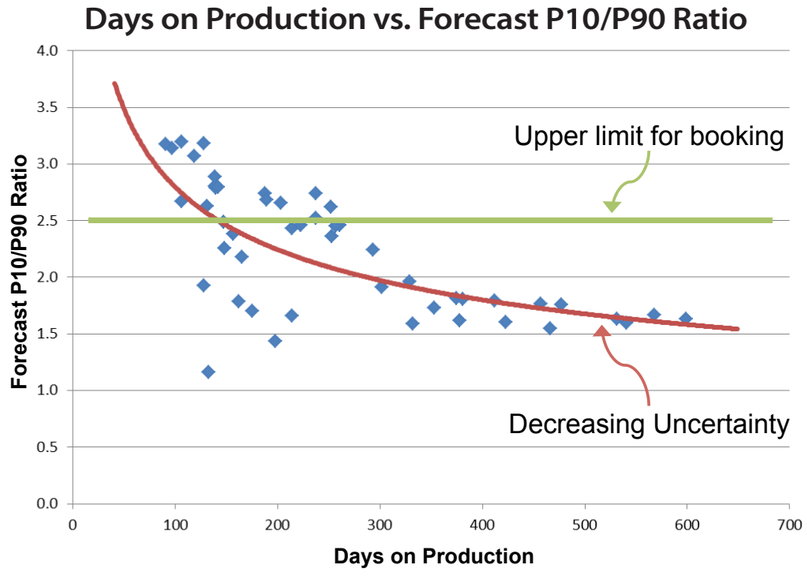
"There seems to be an urban legend and a collective group decision around which b parameter to use," Fulford said. "Potential bias will result if historical data is ignored and changing flow regimes are not recognized with a decreasing b parameter over time."

In Fulford's model, the b factor is transient and calculated on a theoretical basis vs. empirical. It is a function of bottom-hole pressure and fluid properties over time, specifically viscosity-compressibility characteristics of the fluid, viscosity-compressibility changes and well and fracture spacing.

At the latest Ryder Scott reserves conference in Houston, he presented a demonstration of the reliability of the method through an analysis of more than 130 wells in the Elm Coulee field in the Bakken shale play. Fulford also tested the DCA technique in the Permian Basin Wolfcamp play.

"We showed that the implementation of supervised machine learning, in combination with well-calibrated bias, improves the estimation of uncertainty of the distribution of forecasts," he said.

Fulford's presentation is posted on the Ryder Scott website at ryderscott.com/presentations.



Evaluators are often challenged with creating forecasts with limited production history, but how reliable are these forecasts? The forecast P10/P90 ratio shows increased scatter at early stages of production forecasting. David Fulford says machine learning may accurately quantify forecast uncertainty by mitigating human biases that tend toward overconfidence. Quantified uncertainty, he says, provides a diagnostic for confidence thresholds in reserves bookings and investment decisions.

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Political risks threaten field development and reserves bookings

In a federal securities class action court case filed Nov. 7, Exxon Corp. became the target of a claim that it failed to disclose the threats of its operations on the climate. Furthermore the suit alleges that this non-disclosure allowed the company to extract a material quantity of hydrocarbon reserves that should have been stranded.

Frivolous or not, that case and more serious ones that result in regulatory changes, such as New York's ban on fracing in the Delaware watershed, underscore the need for reserves evaluators to be conscious of those risks. Political outcries, legal actions and government interference can seriously impede or halt field development projects.

If field development is jeopardized, "technical" reserves are written down to contingent resources, a category that includes stranded oil and gas. The appropriate resources sub-category, according to the Society of Petroleum Engineers, is "development on hold." It applies if the project is "significant" in size, but awaits development of a market or removal of other constraints to development, which may be technical, environmental or political.

Publisher's Statement

Reservoir Solutions newsletter is published quarterly by Ryder Scott Co. LP. Established in 1937, the reservoir evaluation consulting firm performs hundreds of studies a year. Ryder Scott multidisciplinary studies incorporate geophysics, petrophysics, geology, petroleum engineering, reservoir simulation and economics. With 130 employees, including 90 engineers and geoscientists, Ryder Scott has the capability to complete the largest, most complex reservoir-evaluation projects in a timely manner.

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