RESERVOIR SOLUTIONS

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CONFERENCE PREVIEW

11th Annual Ryder Scott Reserves Conference

Sept. 2

Houston Conference Agenda

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Analytical equations introduced to calculate RFs for waterflood fields with radial flow

— He Zhang, petroleum engineer, and Herman Acuna, managing senior vice president

Although we are progressing on renewable energy, no known technologies can move us off petroleum for the next 20, or even 30 years. Meanwhile, the days of so-called "easy oil" are over. We have to face the challenges involved in using secondary-recovery techniques to improve oil and gas recovery from reservoirs with flagging primary production.

In the waterflooding technique, fluids—typically water—are injected into the reservoir to increase/maintain reservoir pressure and to enhance hydrocarbon flow. Waterflooding can increase the recovery factor (RF), which usually results in more bookable oil and gas reserves.

When combined with the Buckley-Leverett waterflood frontal advance equation (1942) used to calculate RFs, the volumetric method is one of the most important reserves estimation techniques.[1]

To supplement Buckley-Leverett, Welge (1952) proposed a tangent construction method to calculate water fraction at the water front, and consequently estimate oil RFs.[2]

Because both algorithms are derived from the linear-displacement theory, they have inherent weaknesses. Undoubtedly, Buckley-Leverett is well recognized and has been successfully verified by experiments on linear displacement systems. Unfortunately, that method has also shown major limitations in predicting the performance of multiple water injectors drilled to enhance oil recovery around the producers, especially in mature fields.

Meanwhile, radial waterflooding displacement patterns in fields are becoming more common now. In those cases, the calculated RFs from the Buckley-Leverett and Welge algorithms can be quite unreliable.

In addition to volumetric calculations, standard reserves evaluation methods include material balance, decline-curve analysis (DCA), analogy and numerical-simulation. A reserves evaluation process typically involves a combination of two or more methods. In most cases, the evaluation methods will yield comparable reserves quantities.

However, volumetric techniques in combination with the Buckley-Leverett method may yield reserves quantities that differ significantly when compared to those generated with other methods. In some cases, total estimated ultimate recoveries (EURs) can be lower than cumulative production over time using Buckley-Leverett.

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Considering that, the evaluator must make some adjustments based on fluid-displacement mechanisms to reach a reasonable confidence level in the results of a given reserves study. In SPE paper, "New Analytical Equations of Recovery Factor for Radial Flow Systems" (164766), we have presented a new set of equations to calculate waterflood frontal advance for peripheral water-flooding systems.[3] The model incorporates derivation techniques parallel to the Buckley-Leverett method.

Kegang Ling, who previously worked at Ryder Scott and is at the University of North Dakota, is a co-author.

The new radial-displacement model generally provides higher recovery factors and supplements conventional methods used to determine reservoir performance. This article summarizes the related case study and conclusions as follows.

The analytical fractional advance equation for radial-flowing systems has been developed as Eq. (1).

$$\text{1.}\quad f_w = \frac{1 - \dfrac{2\pi hkk_{ro}}{q_t\mu_o}\left(\dfrac{r\partial P_c}{\partial r} + P_c + \dfrac{(\rho_o - \rho_w)Z\sin\theta}{144}\right)}{1 + \dfrac{k_{ro}\mu_w}{k_{rw}\mu_o}}$$

where:

- f_w = fractional flow of water at reservoir, dimensionless
- h = payzone thickness, ft
- k = reservoir permeability, md
- k_{ro} = relative permeability to oil, dimensionless
- k_{rw} = relative permeability to water, dimensionless
- P_c = capillary pressure, psia
- q_t = total liquid rate, STB/D
- r = radius from wellbore, ft
- ρ_o = oil density, lbm/cu-ft
- ρ_w = water density, lbm/cu-ft
- μ_o = oil viscosity, cp
- μ_w = water viscosity, cp
- θ = dip angle, degrees

Comparing the fractional flow of linear displacement in Eq. (2), the way to handle capillary pressure is quite different. Applying linear-displacement, fractional-flow equations to radial-displacement systems yields results that cannot be fully trusted.

$$\text{2.}\quad f_w = \frac{1 - \dfrac{A'kk_{ro}}{q_t\mu_o}\left(\dfrac{\partial p_c}{\partial x} + \dfrac{(\rho_o - \rho_w)Z\sin\theta}{144}\right)}{1 + \dfrac{k_{ro}\mu_w}{k\ \ \mu}}$$

where: A' = flow area in linear flow system, ft², and x = one dimension in linear flow system, ft

Neglecting the capillary pressure (SPE Paper 164766, Appendix A), Eq. (1) and (2) collapse into the same form in Eq. (3).

$$\text{3.}\quad f_w = \frac{1 - \dfrac{A_x kk_{ro}}{q_t\mu_o}\dfrac{(\rho_o - \rho_w)Z\sin\theta}{144}}{1 + \dfrac{k_{ro}\mu_w}{k\ \ \mu}}$$

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where: A_x = flow area, ft^2 (different definition in two systems)

For any water saturation at time t, S_w, the position in radial displacement system can be located

4. $$r_{Sw} = r_e - \sqrt{r_e^2 - \frac{5.615 t q_t}{\pi h \phi}\left(\frac{df_w}{dS_w}\right)_t}$$

where: r_{Sw} = position of any water saturation in radial system, ft.

Given an economic limit, for example, a specific surface water-cut, $f_{ws\_abandon}$, the ultimate RF is calculated in the following steps:

1. Perform laboratory core analysis to obtain relative permeability and capillary pressure data.
2. Use Welge's displacement efficiency equation (1952) to calculate watercut at reservoir conditions.

5. $$f_{ws} = \frac{B_o}{B_w\left(\frac{1}{f_w}-1\right)+B_o}$$

Construct the f_w, df_w/dS_w, f_{ws} and df_{ws}/dS_w vs. S_w tables along with Eq. (1).

3. According to the given economic limit (abandonment watercut), look up the f_w and df_w/dS_w, S_w and S_o at sand face from the above tables.
4. Calculate the average water saturation at the producer to the reservoir in Eq. (6) (SPE Paper No. 164766, Appendix B, Eq. B9).

6. $$\overline{S_w} = S_{w2} + \frac{1-f_{w2}}{\left(\frac{\partial f_w}{\partial S_w}\right)_t}$$

5. Apply Eq. (7) to calculate the maximum recovery factor.

7. $$RF_{max} = \frac{\overline{S_w} - S_{wirr}}{1 - S_{wirr}} \times 100\%$$

6. Calculate the ultimate recovery factor by Eq. (8).

8. $$RF_{Final} = RF_{max} \cdot E_{Sweep} \times 100\%$$

This method has been tested in an oil field in north Africa. **Fig. 1** shows the location of the producer of interest and three surrounding water injectors.

We first estimated the EUR and remaining reserves using Buckley-Leverett algorithms shown as the red dash line in **Fig. 2.** The results were not considered consistent with the historical production data, so we obtained an improved projection, shown as the solid black line, using the new radial waterflooding equations. Radial algorithms tend to generate slightly higher RFs than linear-system approaches.

Furthermore, characteristics of fractional flow are different between radial and linear flow systems as shown in **Fig. 3.** The water-breakthrough process (water saturation increases) is relatively quick for radial systems in the near-wellbore region.

Ultimately, linear and radial algorithms are not completely reliable because no reservoir has an ideal linear or radial water-displacement pattern. While the Buckley-Leverett and Welge methods should be used with caution, the new equations provide a better solution to the estimation of ultimate recovery in radial systems.

In the reserves-estimation process, evaluators should consider all available techniques and use the right set of tools and equations to produce results based on valid, reliable interpretive field data and sound engineering judgement.

References

1. Buckley, S.E. and Leverett, M.C.1942. Mechanism of Fluid Displacement in Sands, *Trans.*, AIME **146**, 107.
2. Welge, H.J.1952. A Simplified Method for Computing Oil Recovery by Gas or Water Drive, *Trans.*, AIME **195**, 91–98.
3. Zhang, H., Ling, K., and Acuna, H., 2013. New Analytical Equations of Recovery Factor for Radial Flow System. SPE Paper 164766 presented at 2013 SPE North Africa Technical Conference and Exhibition at Cairo, Egypt, April 15-17, 2013.

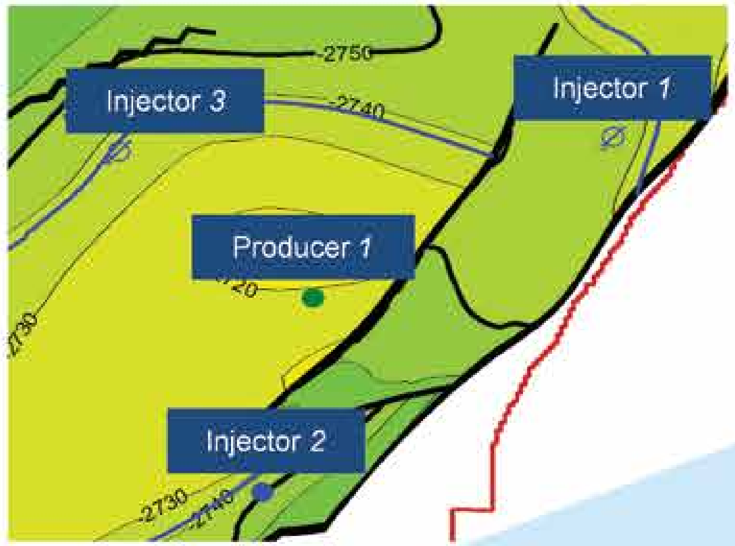


Fig. 1 – Location of the producer in relation to three water injectors.

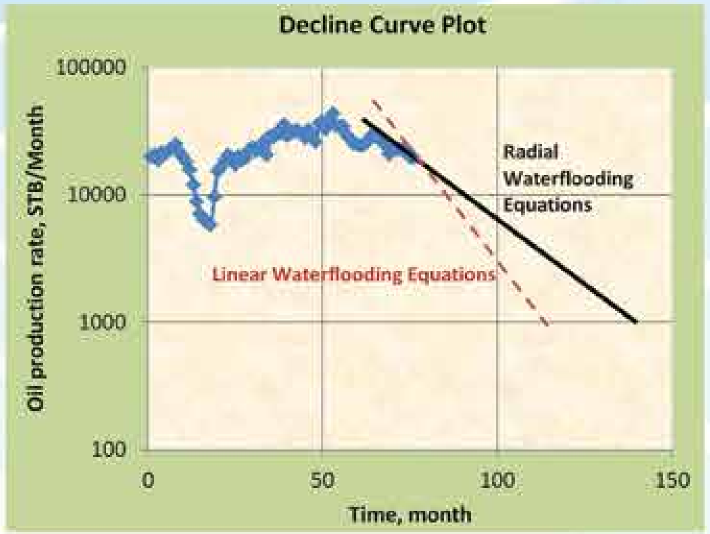


Fig. 2 – Decline curves based on remaining reserves calculated by radial- and linear-displacement equations.

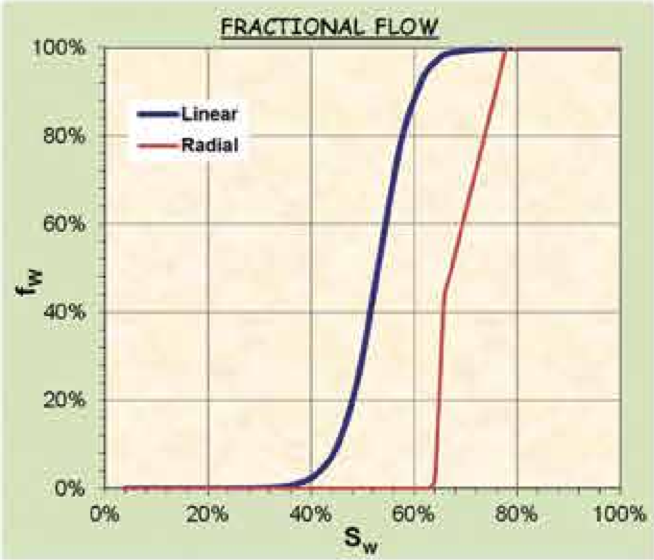
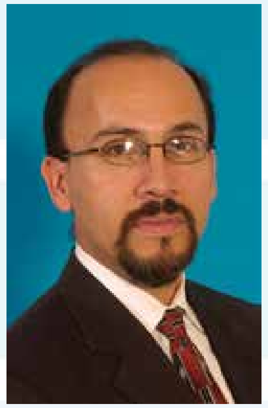


Fig. 3 – Fractional flow characterization by radial- and linear-displacement equations.

About the authors

He Zhang, petroleum engineer, evaluates oil and gas reserves. Previously, he worked for Schlumberger and has more than 10 years research and working experience. Zhang has published more than 30 technical papers and serves as an associate editor and reviewer for several journals. Zhang has BS degrees in chemistry and computer applications, respectively, from the University of Science and Technology of China, and a PhD degree in petroleum engineering from Texas A&M University. He is a registered professional engineer in Texas and is an SPE certified petroleum engineer.



Herman Acuna, managing senior vice president, has been a petroleum engineer since 1987. Before joining Ryder Scott, Acuña worked at Exxon Corp. for nine years as a petroleum engineer in reservoir simulation R&D and later in reservoir modeling for depletion strategies, field development and production optimization. He began his career in 1988 as a petroleum engineer at a Tulsa, OK, consulting firm. Acuna has BS and MS degrees in petroleum engineering from the University of Tulsa. He is a registered professional engineer in Texas and member of SPE and Association of International Petroleum Negotiators.

Latest "wrinkles" in industry, petroleum reserves sector on tap at conference

"Change or be left behind" could be the theme of the 11th Annual Ryder Scott Reserves Conference this year as oil and gas companies reshape their strategies in reservoir evaluation and related technical, financial and legal areas. Experts in petroleum geology and engineering, investment banking and law will share their respective insights with an expected full audience at the Hyatt Regency hotel in downtown Houston on Wednesday, Sept. 2.

The day-long event is essential for those wanting to keep in step with the latest issues in estimating and reporting oil and gas reserves. The conference attracts more than 300 oil and gas professionals, making it the single largest gathering of reserves evaluators in the world.

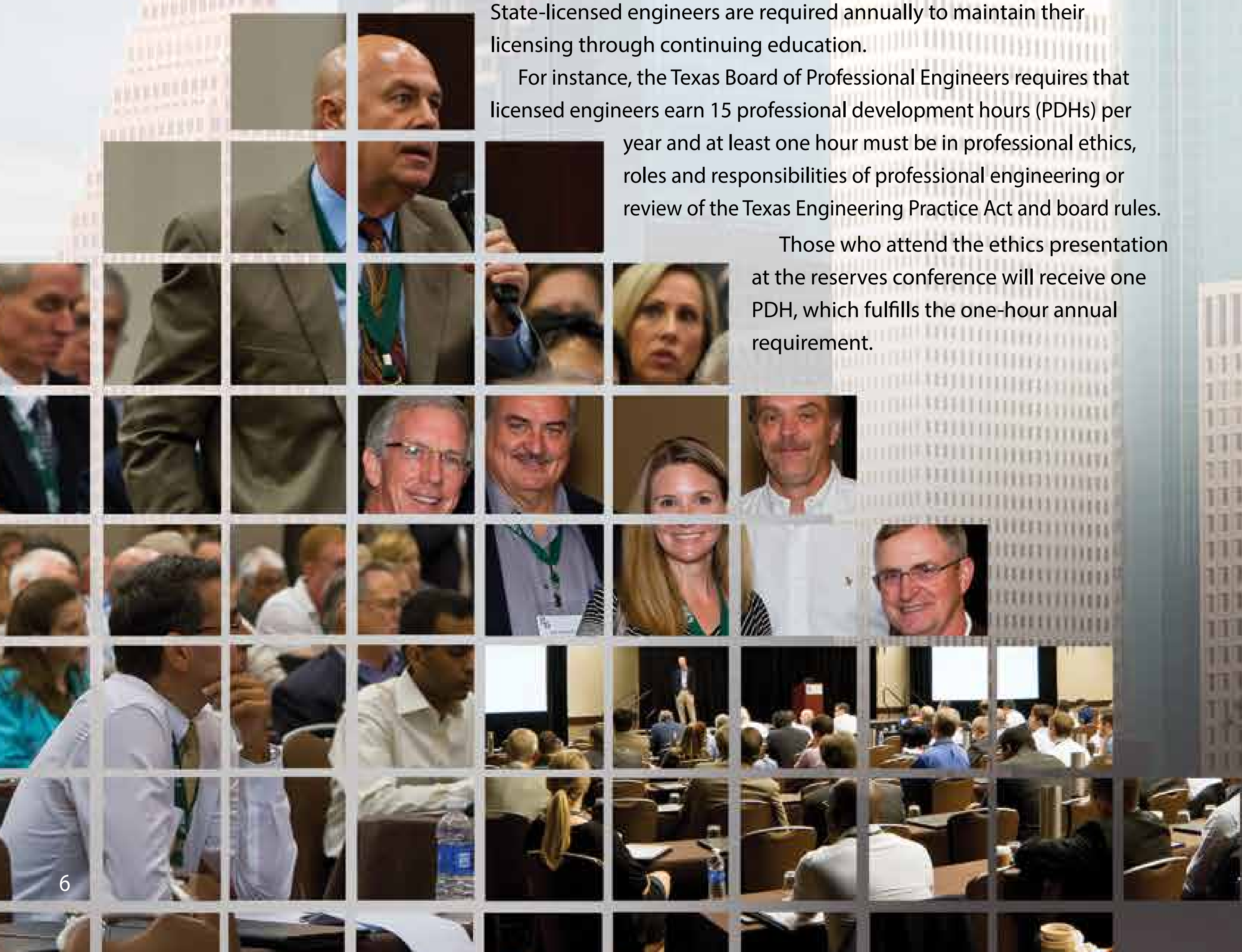
Attendees will receive digital versions (PDF files) of the presentations on USB drives. All presentations, except any withheld by a given speaker, will be posted on the Ryder Scott website at www.ryderscott.com.

Larry Connor, managing senior vice president, manages the event. Email requests, questions or comments to RSCConfHouston@ryderscott.com.

Attending licensed petroleum engineers will receive six to eight hours of CEUs (Continuing Education Units). State-licensed engineers are required annually to maintain their licensing through continuing education.

For instance, the Texas Board of Professional Engineers requires that licensed engineers earn 15 professional development hours (PDHs) per year and at least one hour must be in professional ethics, roles and responsibilities of professional engineering or review of the Texas Engineering Practice Act and board rules.

Those who attend the ethics presentation at the reserves conference will receive one PDH, which fulfills the one-hour annual requirement.



When: Wednesday, Sept. 2, 7 a.m. to 4 p.m.
Ethics Hour: 4 p.m. to 5 p.m.
Cocktail Reception: 5 p.m. to 7 p.m.
Where: Hyatt Regency Hotel, Imperial Ballroom, 1200 Louisiana St., Houston, Texas 77002

Schedule of Events

"Evaluation Challenges in a Changing World"

Time	Speaker	Affiliation	Topic
7 a.m. – 8 a.m.			Conference Check In and Light Breakfast
8 a.m. – 8:30 a.m.	Dean Rietz	Ryder Scott	Welcome and Introduction
8:30 a.m. – 9:15 a.m.	John Lee	University of Houston	*SPE Summit on Estimating Reserves in Unconventional Reservoirs*
9:15 a.m. – 10 a.m.	Tom Blasingame	Texas A&M University	*Reservoir Engineering Aspects of Unconventional Reservoirs*
10 a.m. – 10:30 a.m.			Break
10:30 a.m. – 11:15 a.m.	David Pursell	Tudor, Pickering, Holt & Co.	*Oil Prices in 2015 and Beyond*
11:15 a.m. – 12:15 p.m.			Buffet Luncheon
12:15 p.m. – 1 p.m.	Steve Phillips	Ryder Scott	*Geomodeling and Computer Mapping*
	Stuart Filler	Ryder Scott	*Update on Type Curve Analysis*
1 p.m. – 1:45 p.m.	He Zhang	Ryder Scott	*A New Empirical Analysis Technique for Unconventional Reservoirs*
1:45 p.m. – 2:15 p.m.			Break
2:15 p.m. – 3 p.m.	John Ritter	Occidental Petroleum Corp.	*SPE-PRMS Future Challenges and Updates*
3 p.m. – 3:45 p.m.	Jeff Elkin	Porter Hedges LLP	*Legal Issues Caused by the Low Price Environment*
3:45 p.m. – 4 p.m.			Break
4 p.m. – 5 p.m.			Ethics Hour
	Steve Corso	Haynes and Boone LLP	*Reserves Disclosures, FCPA and Professional Conduct and Ethics Regulations*
	Don Jackson	Haynes and Boone LLP	*Texas Board of Professional Engineers Professional Conduct and Ethics Regulations and Disciplinary Actions*
5 p.m. – 7 p.m.			*Cocktail Reception*

New Russian reserves classification system introduces economic limits

— Dmitry Zabrodin, vice president at FDP Engineering LLP, Moscow

The new Russian Federation classification system for petroleum reserves (RF-2013) has introduced the concept of economic limits. The system, which was approved in November 2013 by the Ministry of Natural Resources, will go into effect Jan. 1, 2016.

RF-2013 differs radically from the previous system by stipulating that the producer calculate two recovery factors (RFs)—an RF with economic limits and a technologically achievable RF, which takes into account hydrocarbon production after the point when net operating cash flows are negative. The old Soviet system required that the producer conduct a recovery efficiency feasibility study (TEO KIN in Russian) to determine a single RF as part of the reserves filing.

The feasibility study, RF and booked reserves were submitted to FGU State Commission on Mineral Reserves (GKZ) for approval before filing a field development plan (FDP), which in turn, had to be approved by the State Commission on Oil Field Development (TcKR). To achieve booked RF values, producers had to regularly revise development scenarios in concert with the GKZ, the regulatory agency that sets and oversees requirements for reserves reporting in Russia.

New bureaucratic streamlining will change that scenario. The government plans to merge the GKZ and TcKR to head off any potential for the two agencies' decisions to conflict. After RF-2013 is implemented, the producer will not have to conduct and file a TEO KIN (feasibility study).

The reserves filing will comprise two parts—a report on in-place volumes and a submitted FDP with several development scenarios. RF-2013 stipulates that once the producer chooses the best-case development scenario and it is approved by regulators, then the two RF values are booked. The best scenario is a blended one that provides "an optimal balance between the technical and economic matrices" of development.

The intent of having two RFs is to clearly indicate those fields, reservoirs and areas that require government intervention to make production economic. Russia's options for relief include changes in tax concessions, tax abatements and product prices. Without government-imposed economic conditions, wider spreads between technical and economic RFs are likely to cause producers to cap production before Russia's version of the "end of field life."

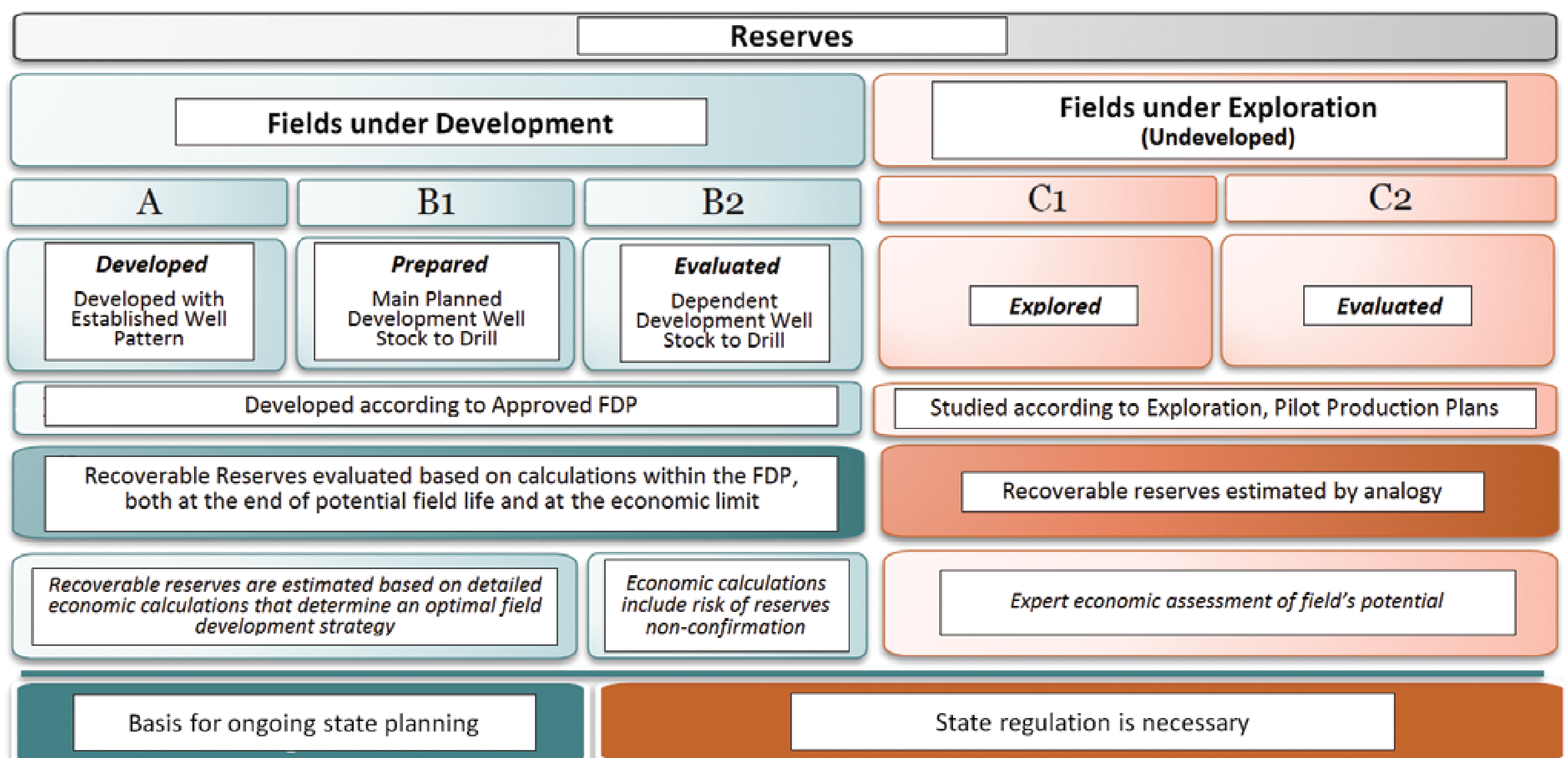
In Russia, the producing life of a well often goes past its economic limit. That is at odds with the Society of Petroleum Engineers Petroleum Resources Management System (SPE-PRMS) where the life of a well lasts until its economic limit is reached and the well is shut down. The SPE-PRMS is considered to be the best set of technical guidelines for reserves reporting.

Russian authorities say that because negative cash flow to keep marginal wells active beyond their economic lives is offset by cash-positive wells, all wells in a field should be produced until the field as a whole reaches its economic limit. The wholistic Russian philosophy is based on a belief that oil and gas accumulations are limited resources that should not be wasted in the form of bypassed, unswept oil left behind from selective depletion of "sweet spots."

To test RF-2013, several major Russian oil and gas companies conducted system-compliant pilot reserves calculations in almost 40 oil fields. The GKZ initiated those efforts and summarized the results. The writedowns of technically recoverable volumes after factoring in economics varied from relatively small percentages to as high as 96 percent.

RF-2013 charted

The following figure is a graphical representation of RF-2013:



In the new system, discovered fields are classified into two major groups—Fields under Exploration and Fields under Development according to maturity level. This classification is new to the industry and not found in previous Russian systems or in SPE-PRMS. In general, recoverable volumes associated with the two classes coincide with contingent resources and reserves categories in SPE-PRMS.

The category Fields under Exploration includes economically recoverable volumes corresponding with SPE-PRMS reserves and non-economic recoverable volumes corresponding with SPE-PRMS contingent resources. The categories C1 and C2 in RF-2013 directly correspond to those in the old Russian system, although they are confined only to the Fields under Exploration, not to post-evaluation commercial development.

C1 is the volume in the area around wells that demonstrates commercial productivity and C2 is the volume in the remaining estimated productive area, Fig.1. The RF and corresponding recoverable volumes are estimated using analogies or by other expert methods. The estimated recoverable volumes are not booked and serve as information only.

Test production is foreseen from individual wells or at C1 category pilot areas to refine the geologic model and to study formation fluid PVT data and productive characteristics of the reservoir to prepare for

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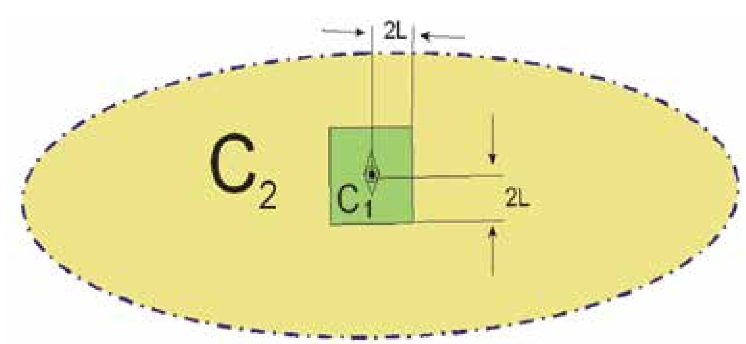

Fig.1. *C1 and C2 areas on a reservoir under exploration. Symbol represents well with commercial productivity. L is typical interwell spacing.*

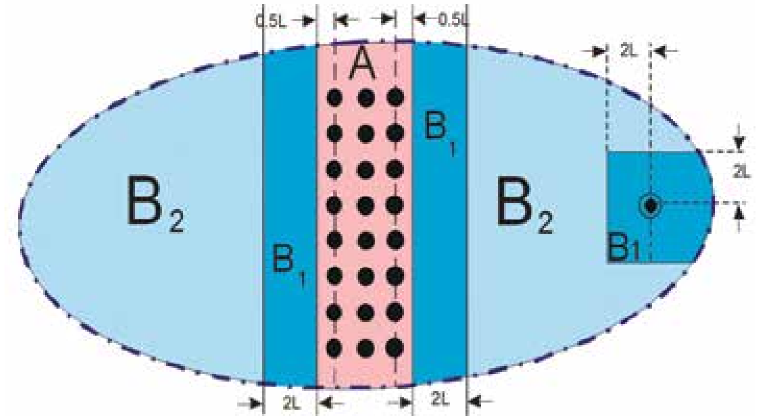

Fig.2. *A, B1 and B2 areas on a partially drilled-out reservoir with established development well pattern. L is established interwell spacing.*

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commercial development of the field.

The transition from the exploration to the commercial-development stage occurs after the C1 volume exceeds 50 percent of the total estimated C1+C2 volumes. Once the field reaches the commercial development stage (class Fields under Development), the previously estimated categories C1 and C2 immediately become categories B1 and B2, respectively.

In the course of further field development, the A category applies to the drilled-out area with an established development well pattern, Fig.2. The respective recoverable volumes correspond to the SPE-PRMS proved developed classification, which has the highest technical certainty. The undeveloped areas are assigned categories B1 and B2. The wells to be drilled on the B1 acreage are comparatively less risky than B2 where uncertainty is higher.

The categories A and B1 serve as the basis for both mid- and short-term drilling/production planning and appropriate state control. Unlike A and B1, development of the B2 areas is dependent on results of additional exploration and observations made during development and exploitation of A and B1 areas.

An FDP must be prepared, submitted and officially approved before proceeding with commercial development. FDPs include a technological scheme of development at the initial stage and technological project of development (TPD) at the mature stage. The TPD is prepared after drilling 80 percent of the planned well stock for a field with more than 75 percent of the reserves classified in the A category.

The RF and corresponding recoverable volumes for the Fields under Development category should be estimated based on multi-variant calculations presented in the FDP. Those calculations must be performed using 3D dynamic models. This approach is somewhat similar to the definition of a project in the SPE-PRMS.

RF-2013 mapping

The United Nations Economic Commission for Europe (UNECE) is updating mapping between its own UNFC-2009 classification system and RF-2013. UNECE is working with the GKZ to develop a draft bridging document that will be reviewed at the UNECE seventh session next year. The GKZ delivered a first-draft mapping document to UNECE last March.

GKZ position

In an article in national magazine Oil and Gas Vertical, No. 16, 2014, Igor Shpurov, director general of the GKZ, discussed the main goals and principles of the RF-2013. He said the purpose of the system is to split total resources volumes into those under development and economically viable and those being reviewed for commercial development, some of which may be uneconomic to produce.

RF-2013 is a guide to estimate difficult-to-recover resources volumes and to determine the location and conditions for developing those resources. Shpurov answered critics who question why Russia would invent a new classification system rather than use SPE-PRMS.

He states that the SPE classification system is focused on investor protection and maximum profits for subsoil users.

SPE-PRMS is a project-based system and a project may be considered as an investment opportunity. Under SPE-PRMS, the project is defined by the basis on which the investment decision is made. Reserves remain undeveloped until a final decision to invest in a project is made.

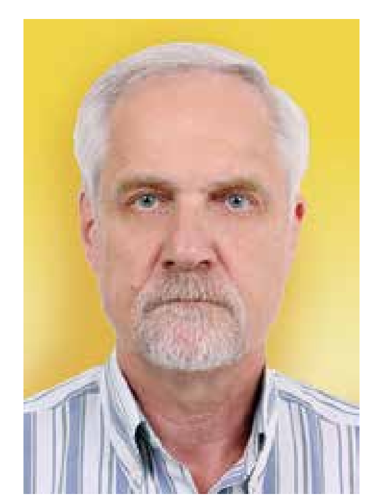
Shpurov said that under the SPE-PRMS, the interests of the state, which is a subsoil owner, are brushed aside.

On the other hand, the state, as the owner of the subsoil, needs its own reserves estimate that presents strategic potential and provides possibilities to manage subsoil use through regulation and subsoil-user relationships. In other words, while leasing the state-owned subsoil to a user, the state seeks to establish rules and controls that provide maximum subsoil-usage efficiency for the government and leaseholder. In this context, indicates Shpurov, SPE-PRMS is an assessment of value and conditions from the leaseholder's side while RF-2013 is an evaluation from the side of the Russian state.

In Soviet times under the previous reserves classification system, the state was both owner and user of the subsoil. Now, as an owner only, the government has had to develop laws for the leaseholder. Shpurov said that choosing a single classification for both owner and user would deprive one side of controlling and analytical instruments.

Producers will transition to RF-2013 with minimum disruption because the new classification scheme was designed with succession in mind, said Shpurov.

About author



Dmitri Zabrodin has been vice president at FDP Engineering LLP, an alliance partner of Ryder Scott, for more than 10 years. He manages reserves-certification projects and conducts engineering analysis and evaluations of hydrocarbon-producing assets in the FSU and internationally for various clients. His evaluations are done in accordance with both Russian and international standards. Zabrodin previously worked at United Consultants FDP for five years as deputy head of the E&P department. He conducted hydrocarbon reserves evaluations and field development analysis for various fields in all regions of Russia and several republics of the former USSR. He also worked at RPC Overseas Inc. from 1994 to 1999 as a manager of petroleum engineering.

Zabrodin served as an expert in the production division of Sonatrach in Algeria in two assignments, from 1986 to 1989, and from 1993 to 1994. In 1999 he worked as an expert in reservoir engineering for the WP-PPU consortium in Indonesia where he analyzed results of the implementation of vibro-seismic impact technology to improve oil production. He started his career as a lead research scientist at All-Union Oil and Gas Research Institute (VNIIneft) in Moscow in 1973.

Zabrodin has BS and MS degrees in petroleum engineering from the Gubkin Russian State University of Oil and Gas and a PhD degree in petroleum engineering from VNIIneft. He has written more than 60 research papers, conference proceedings and technical reports and penned a book on tertiary oil recovery that was published in 1989. He also served as a scientific editor for the monograph, "Reservoir Exploration and Appraisal," Luiz Amado, ELSEVIER, 2013, after it was translated into Russian.

Zabrodin can be contacted at his email, d_zabrodin@fdp.ru.

Ryder Scott evaluates reserves of Ukraine

Ryder Scott is performing a third-party certification of oil and gas reserves and resources in Ukraine, including in the Crimea, Black Sea and Azov Sea areas. Earlier this year, state-owned JSC Naftogaz Ukrainy selected Ryder Scott from 11 tender offers to conduct the study, which also includes an evaluation of properties in Egypt.

The firm has collected geophysical, geological, engineering and economic data from all oil and gas fields and acreage in the Ukraine for the ongoing evaluation. The independent report will include future production profiles and discounted net present values.

Geologists, engineers join RS Houston

Ryder Scott has added technical expertise to its Houston office with the addition of two geologists and two petroleum engineers.

Enzo Aconcha has joined as a senior petroleum geoscientist from Afren Resources USA. He integrates geological, geophysical and petrophysical interpretations with engineering analyses to quantify reservoir volumes and deliverability.

In his three years as a senior geoscientist at Afren, he interpreted seismic, planned well locations and managed G&G aspects of drilling operations. Aconcha explored and developed prospects in complex stratigraphic and structural clastic settings such as the Niger Delta in Nigeria. He also analyzed the carbonate stratigraphy and complex structures in Kurdistan.

Enzo Aconcha

Ariel Bennett

Victor Abu

Beau Utley

Aconcha was a geologist and geophysicist at Chevron Energy Technology Co. from 2008 to 2012. He built a stratigraphic framework for a dolomite reservoir in Saudi Arabia/ Kuwait and mapped potential gas-bearing structures in the Nile Delta and productive sands in the Campos basin in Brazil. Aconcha also updated mapped potential hydrate accumulations in the Green Canyon area in the Gulf of Mexico.

Aconcha has a BS degree in geophysical engineering from Universidad Simón Bolívar in Caracas, an MSc degree in petroleum geology from Ecole Nationale Superiéure du Petrole et des Moteurs in Paris and an MSc degree in geological sciences from the University of Texas at Austin. He is a member of AAPG and SEG.

Ariel Bennett also joined Ryder Scott as a geologist. She has performed structure and isopachous mapping, well-log correlation and interpretation and reservoir characterization. Bennett has also participated in integrated, multidisciplinary studies and conducted geochemical analysis.

Before joining Ryder Scott, she was a petroleum systems analyst at BP Plc where she most recently allocated production of commingled reservoirs in the Atlantis oil field in the Gulf of Mexico through geochemical analysis, using gas chromatography fingerprinting and PVT data. She also designed a major field study for the Atlantis development plan.

Before that, Bennett was an operations geologist for BP where she conducted an integrated reservoir characterization study for the Woodlawn field in east Texas. She mapped targeted intervals, planned wells, assessed risk, planned and submitted data-acquisition requirements and delivered post-well evaluations.

She was a geologist at BP in 2012 and evaluated GOM Cretaceous prospects and Anadarko basin Ordovician carbonates for conventional and unconventional potential. Bennett has a BS degree in biological sciences from Northern Kentucky University and an MS degree in geology from the University of Missouri.

She is a member of AAPG, Geological Society of America, European Association of Organic Geochemists and Houston Organic Geochemistry Society.

Victor Abu joined Ryder Scott as a senior petroleum engineer. Previously, he was a senior reservoir engineer at Shell E&P Co. for three years where he was responsible for resources volume management. He assisted in the classification of reserves and resources of deepwater and heavy oil assets in the Americas for disclosure to the U.S. Securities and Exchange Commission and internally.

Abu also conducted a proved reserves benchmarking study using key metrics for the deepwater business unit. He also evaluated an asset in the Mississippi Lime formation for divestment purposes, preparing type curves and building a simulation model as part of his work.

He started his career at Schlumberger Ltd. in 2008 as a reservoir engineer. He worked for the company's data and consulting services division. Abu worked on reserves evaluation and audit teams and was responsible for preparing reports used in filings with the U.S. SEC and in submissions to financial institutions.

He conducted a comprehensive Marcellus shale play study involving 1,200 horizontal wells in Pennsylvania and West Virginia. Abu created type curves to generate EURs and production profiles and map out sweet spots.

He also completed reservoir-engineering studies of assets in the Woodford and Utica shale and Mississippi Lime formations. He designed well tests and completed more than 100 PTA and nodal analysis studies. Abu also has experience in the Granite Wash formation, San Jaoquin and Permian basins, Gulf of Mexico and east Texas Bossier formation.

Abu has a B. Eng. degree in chemical engineering from Federal University of Technology in Minna, Nigeria, and an MS degree in natural gas engineering from the University of Oklahoma. He is a member of SPE.

Beau Utley joined Ryder Scott as a petroleum engineer. Previously, he worked at Encino Energy LLC as a reservoir engineer where he evaluated reserves for borrowing base redeterminations and reporting to the U.S. SEC. Before that he worked at EnerVest Ltd. beginning in 2012 as a reservoir engineer responsible for assets in Oklahoma, Texas, Arkansas and Kansas. Utley prepared reserves and cashflow forecasts for PDP wells and estimated upside value. He was involved in the technical evaluation of more than $350 million in acquisitions. He also estimated reserves for filing with the U.S. SEC and for internal reporting.

Utley was a petroleum engineer at Constellation Energy Partners LLC where he provided reservoir engineering analysis and economic evaluation for all properties and potential acquisitions. That included estimating reserves under rules of the U.S. SEC and guidelines of the SPE-PRMS.

Previously, he was a production engineer at Samson Resources Co. where he performed production surveillance and project management for more than 300 oil and gas wells in northwest Oklahoma and southern Kansas. Utley also analyzed and recommended artificial lift designs and designed and implemented well stimulation treatments and recompletions.

Please see Geologists, engineers join RS on page 14

Geologists, engineers join RS – Cont. from page 13

He has a BS degree in petroleum engineering from the University of Oklahoma and an MBA degree from the University of Houston.

Utley is a member of SPE.

Board approves promotions, moves

The board of directors approved the following company promotions and lateral moves:

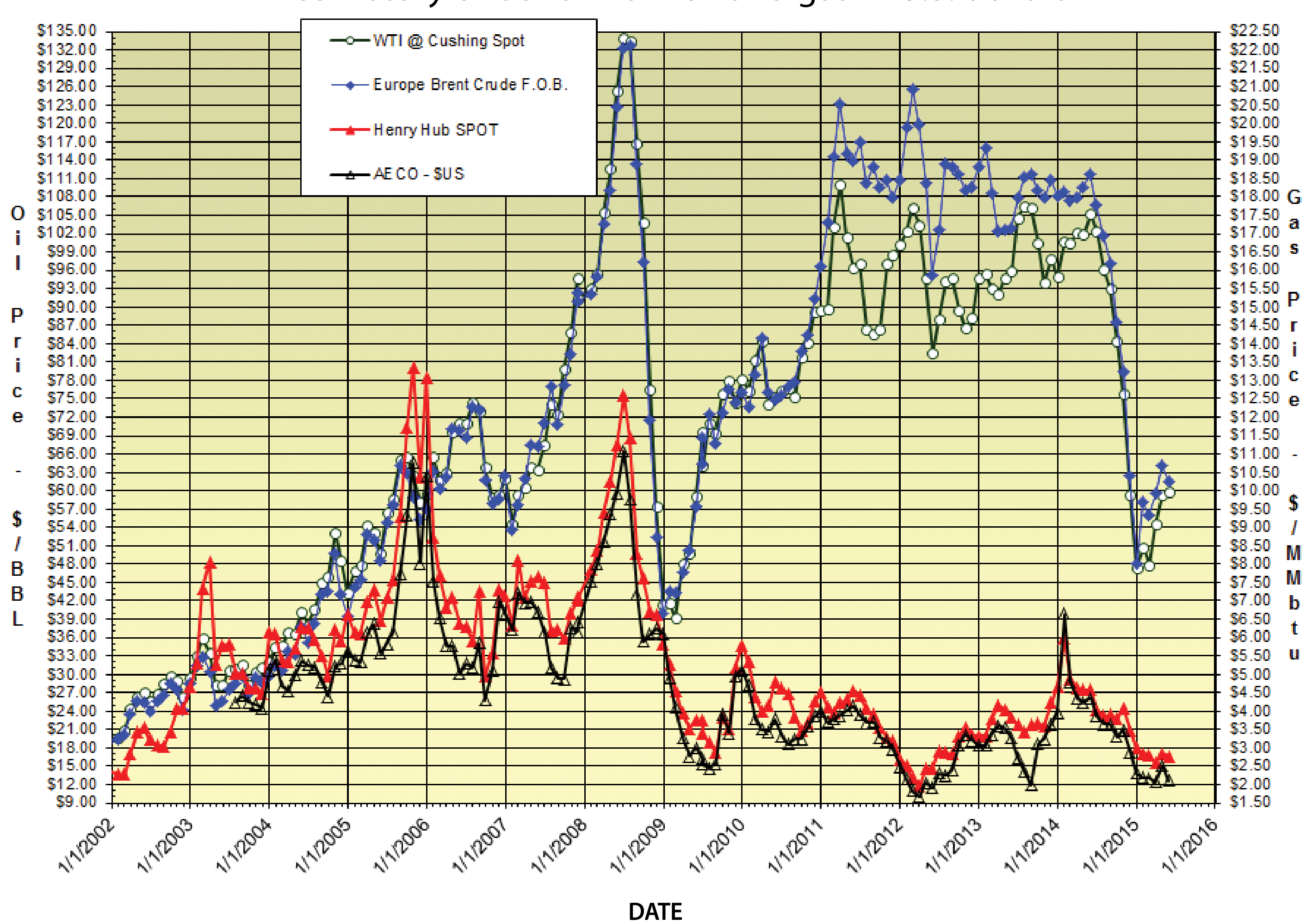
Joe Blankenship and **James Latham** were promoted from senior vice president to technical coordinator – advising senior vice president. **Steve Phillips, Mario Ballesteros** and **Eric Nelson** were promoted from senior vice president to managing senior vice president – group leader.

Ali Porbandarwala, Stuart Filler, Gabby Guerre and **Bob Paradiso** were promoted from senior petroleum engineer to vice president project coordinator.

Clark Parrott and **Marsha Wellman** were promoted from petroleum engineer to senior petroleum engineer. **Ann Maretic** was promoted from senior engineering technician to engineering analyst. **Diane Zhang** was promoted from associate engineering technician to engineering technician. **Mike Nowicki** is the new group coordinator for the geoscience group.

The following personnel have moved laterally to the position of technical coordinator – advising senior vice president: **Larry Connor, George Dames, John Hamlin, Fred Ziehe** and **Mike Stell**.

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.

Hard-to-Recover volumes require integrated evaluations

Stratigraphic reservoir characterization emphasizes an understanding of the controls that depositional processes and systems exert on reservoir performance and the extent to which an evaluator can predict stratigraphic features away from the wellbore. Combined with structural characterizations and reservoir engineering, stratigraphic analysis helps guide drilling strategies designed to unlock and maximize the flow of oil and gas from difficult-to-produce reservoirs.

For instance, stratigraphic limits to fluid flow in inter-bedded meandering river systems result because of lateral discontinuity in reservoir intervals away from the wellbore. Understanding vertical stratigraphy of the reservoir from cores analysis and modern well-log measurements improves interpretations of lateral heterogeneity. It is this heterogeneity that causes discontinuity between wells in the sedimentological environment of a meandering river system.

This type of depositional system is characterized by compartmentalization caused by mud-packed channels that cross cut sand bar deposits (point-bar sandstones). Those point-bar sands migrate toward the outer bank (cutbank) as the grain size and permeability decrease. Because of that, waterflooding higher-permeability, basal areas of the point bar, instead of the tops near the cutbank, will more efficiently sweep oil from the formation.

Other examples of complex geological characteristics in difficult-to-produce reservoirs include faulting that compartmentalizes reservoir flow units and vertical permeability barriers that minimize volumetric sweep efficiency.

"Reservoir characterization is the start to overcome complex geology," said **Larry Connor**, technical coordinator – advising senior vice president and petroleum engineer. To unravel that complexity, he analyzes logs and cores and uses reservoir analogy and static and dynamic reservoir modeling.

Developing complex reservoirs

As "common engineering solutions to complex geology," he has recommended infill drilling to reduce well spacing (downspacing) and drilling extended reach horizontals with multiple frac stages while ensuring proper orientation of horizontals to maximize recovery.

"Drilling to capture unswept areas can result in big increases in bookable reserves, but doing this may require the use of simulation or an infill pilot well," said Connor.

Using reservoir characterization and engineering techniques, he has tackled various oil- and gas-recovery challenges including those involved in producing high-viscosity oil with poor mobility.

Maximizing recovery from reservoirs in deepwater and harsh environments has also been challenging.

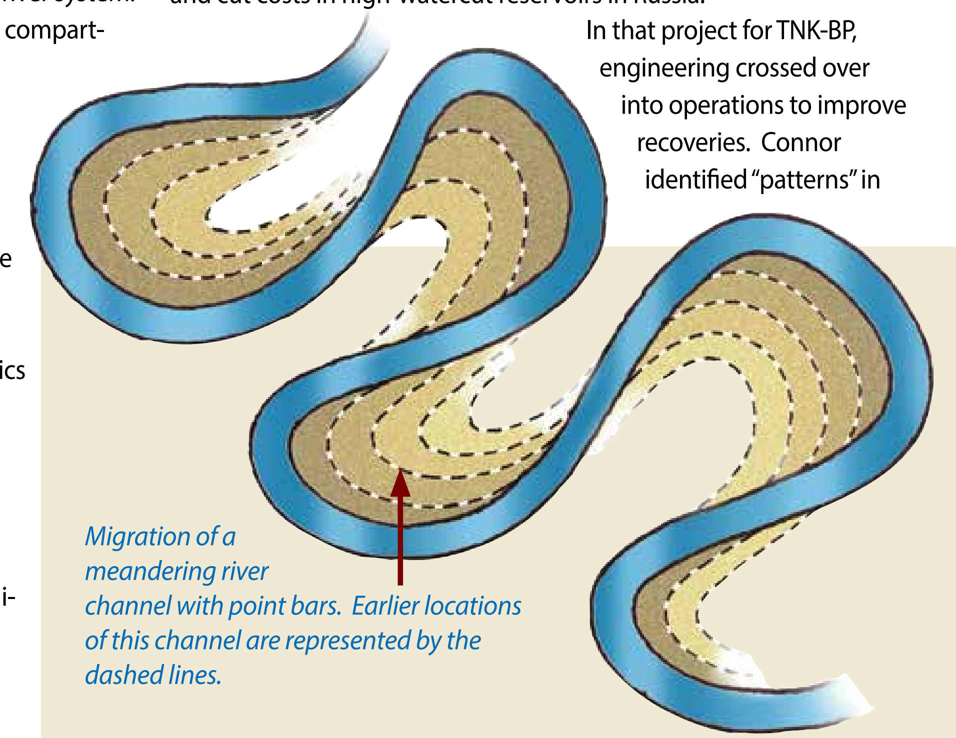
Larry Connor

Connor focuses on cost controls in evaluating the economics of redeveloping and operating hard-to-recover, capital-intensive reservoirs.

"We do detailed cost accounting that involves identifying expenses and controlling them," he said. "Don't skip this step. You can't control it if you can't find it."

Less costly, more efficient field development plans improve economic outlooks for difficult reservoirs. For instance, Connor has recommended the optimization of workovers to boost production and cut costs in high-watercut reservoirs in Russia.

In that project for TNK-BP, engineering crossed over into operations to improve recoveries. Connor identified "patterns" in planning and personnel early to recommend improvements in field operations, including shifting emphasis from ineffective projects to effective ones and increasing the roles of higher performing field supervisors.



Migration of a meandering river channel with point bars. Earlier locations of this channel are represented by the dashed lines.

Waterflood operations in hard-to-recover reservoirs provide special opportunities because engineering is in control, said Connor.

Engineering waterfloods involves reorienting flood patterns, pattern voidage balancing using injection, using wellbore utility diagrams to find maximum pay exposure and using polymers to control fluid breakthrough and sweep efficiency.

"Engineering solutions often require experience, judgment, imagination and a large dose of common sense," said Connor.

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In Memoriam

Brian Shane Everitt, a 35-year old petroleum engineer at Ryder Scott, died June 16 in Hempstead, TX.

"Brian was a great asset to our firm, but more importantly, he was my friend," said **Stuart Filler**, vice president at Ryder Scott. "Brian had extraordinary skills. His tireless energy and willingness to assist those with less experience marked him as a fine young engineer and teacher. He left a great legacy professionally, and he will live in our hearts and minds."

Everitt joined Ryder Scott in Houston in 2013 as a petroleum engineer. Before that, he was a business development reservoir engineer at J-W Midstream Co. and a lead reservoir engineer at Western Production Co. Everitt also worked at Constellation Energy Partners LLC, Snowmass Energy Partners and RJD Management Co. Inc.

He began his career at XTO Energy Inc. as a field engineer in 2005. He evaluated numerous conventional and unconventional plays and reservoirs across the United States.

Everitt earned a BS degree in petroleum engineering from Texas Tech University and was a member of the Society of Petroleum Engineers.

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.

Reservoir Solutions

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