RESERVOIR SOLUTIONS

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Montney primed for higher gas prices, study shows

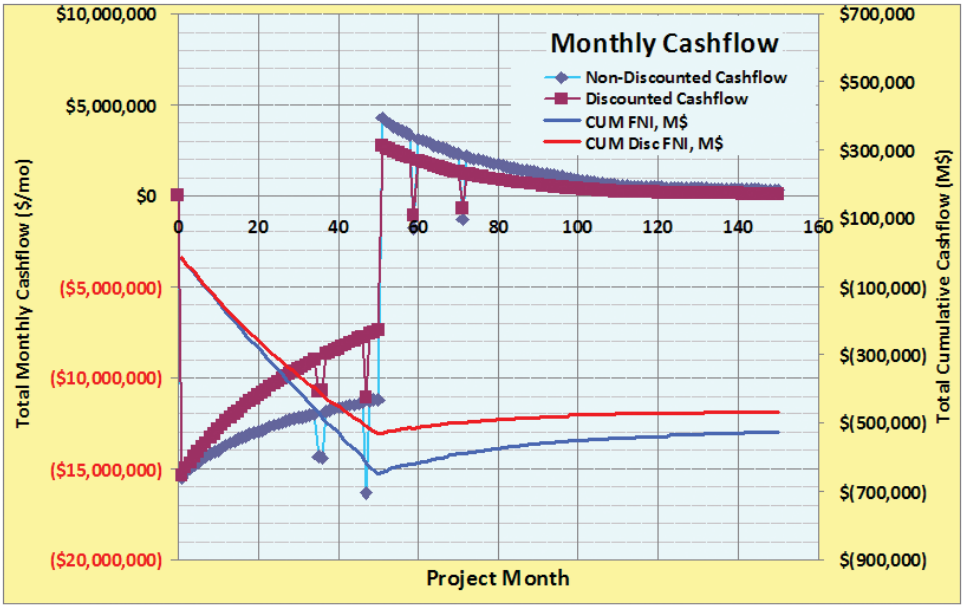
Although mired in low gas prices, the Montney unconventional shale play in northeast British Columbia is destined to be a major producer over the next 20 years.

"Some industry sources have estimated that the Montney will supply up to 40 percent of Canada's gas output by 2035. It's one of the top North American gas discoveries," said **Larry Connor**, managing senior vice president, at the Eighth Annual Ryder Scott Reserves Conference.

The kicker is the economics. The North American gas market has been battered by spot prices in the $2/Mcf to $3/Mcf range.

"With today's low gas prices and high completion costs, much of the dry gas in Montney is uneconomic," said Connor. "However, sweet spots with high liquid yields make the economics in some areas much better."

At the conference, Connor presented the results of a Montney study that he and his working group conducted, which involved geological, engineering and economic analyses of the tight-gas play.



The Ryder Scott economic analysis shows negative cash flow for a typical Montney project in which two wells are drilled each month for 50 months. Median EURs of 3,554 MMcf of gas per well were used based on type-curve analysis of more than 1,000 wells. Gas spot prices of about $2 per Mcf and condensate at $83.12 a barrel were used. The breakeven point for cash flow is $4.12 per Mcf of gas. Drilling-and-completion costs were assumed to be $7.9 million a well.

Using public and project data, Connor found that while horizontal drilling and multistage fracturing increased the estimated ultimate recoveries (EURs) per well, the economics did not significantly improve.

As background on the play, he showed it to have 1,200 Tcf gas in place, as estimated by the British Columbia Ministry of Energy and Mines. "The Montney represents a relatively consistent, geographically extensive gas play with tremendous long-term potential," said Connor.

The 2.5-million-acre Montney has three pay intervals—upper, middle and lower—with gross thicknesses of up to 350 m. Connor showed a National Energy Board comparison of the total organic carbon (TOC) in several Canadian shale plays. As a screening criterion, TOC content of 1 to 2 is good, 2 to 4 is very good and plus 4 is excellent. With a TOC range from 1 to 7, Montney generally has favorable concentrations of organic-rich kerogen.

Another characteristic of organic matter related to potential productivity is thermal maturity. The NEB chart showed Montney Ro (vitrinite reflectance) values range from 0.8 to 2.5.

Connor said wet gas ranges from 1.1 to 1.4 and dry gas is 1.4 to 3.2. Bubble maps show condensate distribution throughout the trend to be heaviest in the east.

"Identifying and mapping reservoirs and staying within sweet spots are crucial," said Connor.

Government estimates of the original gas in place (OGIP) for

Please see Montney on Page 3

Inside Reservoir Solutions

Historical price chart for oil, gas..... 2
SEC Seeker freeware released..... 2
Resource play analysis grows..... 3
Evaluation of models systematized..... 4
Book value calculations explained..... 5
Eagle Ford petrophysics examined..... 6
Rietz promoted to Exec. VP..... 7
Geologist, engineer join RS..... 7

SEC Seeker freeware program available to public


Fitzgerald

Ryder Scott has released its SEC Seeker freeware, announced **Jennifer Fitzgerald**, vice president, at the Ryder Scott reserves conference. She was instrumental in the development of the easily accessible, web-based program that is free to the public.

SEC Seeker enables a user to perform automated searches of publicly available oil and gas company filings and comment letters stored in the Edgar database of the U.S. Securities and Exchange Commission. The program has an easy interface through which a user quickly and efficiently views and retrieves multiple records and performs custom searches by filtering several relevant criteria simultaneously. Advanced text searches also are available.

Fitzgerald said that long-term functionality includes the capability to save searches for later retrieval. The database is evergreen as new, searchable documents are added regularly.

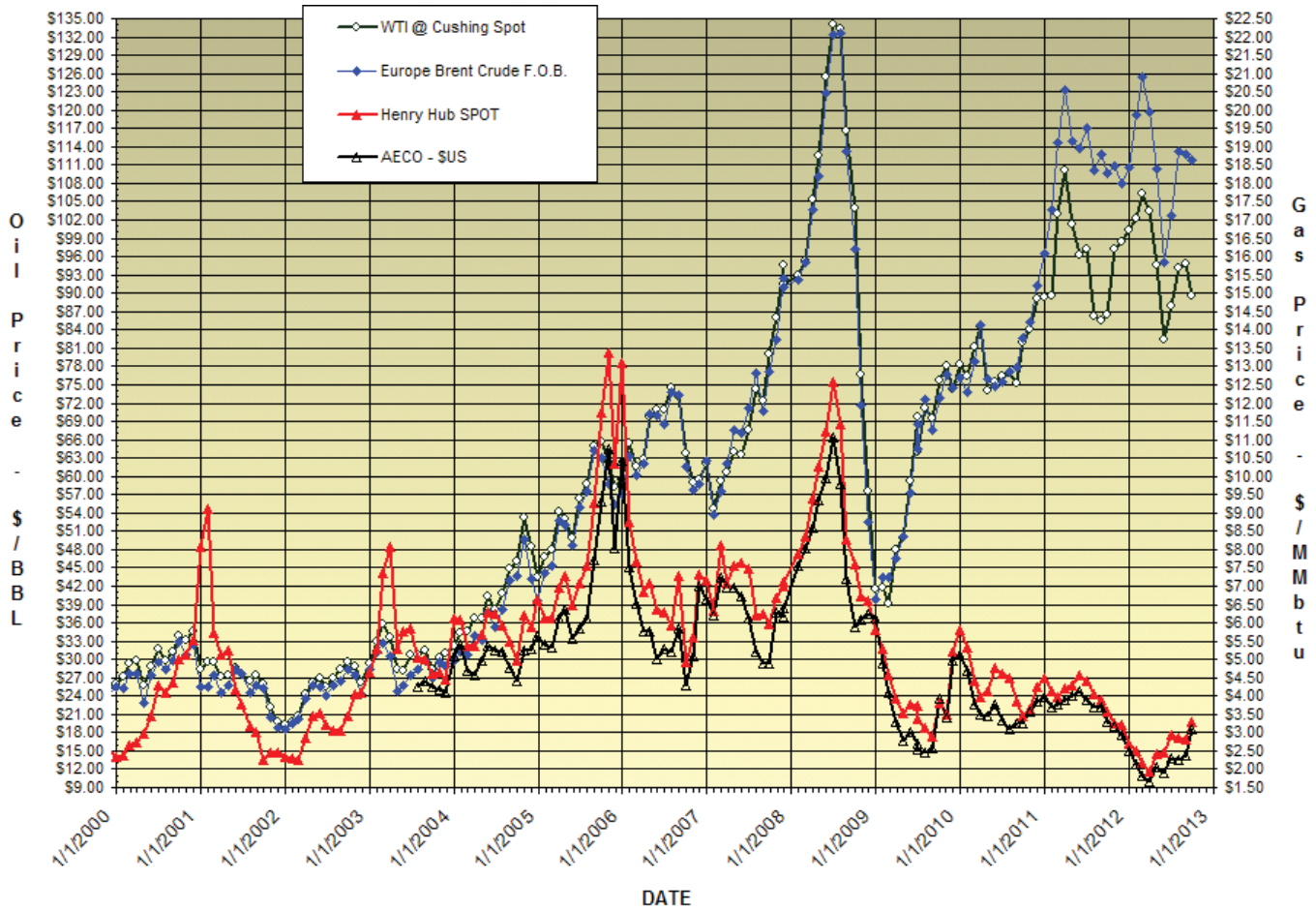
SEC Seeker searches through filings and comment letters in Edgar on or after Dec. 31, 2009. Searchable documents include 10-K, 20-F and 40-F annual filings as well as amended filings 10-Ka and 20-Fa. Comment letters that reference those filings also are searchable.

Search filters consist of company name, filing year and document type. Text searches also may be performed to return records that include a specified word or phrase. In addition to basic text searches, SEC Seeker is designed to conduct advanced searches that are further explained through onscreen help.

Search results are displayed as records in a user-friendly grid detailing

Please see SEC Seeker on Page 8

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.

Knowledge base for resource play analysis grows

Analysis methods for estimating gas reserves from shale plays are proving to be adequate for evaluating oil-producing shales, but industry needs more production histories to verify that, said **John Lee**, professor of petroleum engineering at the University of Houston.

With high oil prices and low gas prices, companies are increasingly targeting and exploiting liquid-rich shale plays. Lee, a fellow at the U.S. Securities and Exchange Commission during its reserves reporting rules-change process five years ago, made his remarks at the Ryder Scott reserves conference.

"Analytical and empirical analysis methods used for gas shale are perceived as adequate, but questions remain," he said.

Lee remarked that condensate blocking in retrograde-gas reservoirs is only anecdotal now. "It is not a widespread problem now but it may be in the future," he said. Multiphase gas-oil flow also may cause problems in oil shales, said Lee, adding that industry has not experienced difficulties yet.

Industry is also gaining knowledge in what gas-oil relative permeability curves are appropriate for oil shales, he said.

Lee cited two fluid-flow regimes for shale plays—transient linear flow during a period of fracture interference followed by boundary-dominated flow (BDF). His graphs of early data from production histories in the Barnett shale indicate declines do not fall on the half-slope trend. Lee attributed that to cleanup and choke-back of wells.

John Lee (right) talks with Frank Denelle, vice president resources assurance and reporting at Royal Dutch Shell, during a break at the Ryder Scott reserves conference. Lee told almost 300 attendees that more rigorous modeling is needed to better predict well performance in shale plays.

"Bottomhole pressures drop until they level out so corrections should be made," said Lee. "However, a non-ideality is evaluators don't have time to handle pressure data, for instance, for hundreds of wells, so we should simply ignore early, off-trend data to establish a best fit."

Please see Lee on Page 8

Montney—Cont. from Page 1

Montney is 50 to 80 Tcf in the pores and fractures of two main zones—upper and lower. OGIP using a 3 percent porosity cutoff is 10 to 300 Bcf per section.

Ryder Scott study

Connor conducted type-curve analysis from a population of 1,049 Montney wells, more than 80 percent of the total, to develop ranges and probability distributions for projection parameters. He examined initial flow rate at start of decline (Qi), decline rate (Di) and curvature of the decline trend (b factor).

With a large spread in the data and minimal or no production history, Connor used a uniform distribution to generate a b factor for the hyperbolic curve fit. "There is an inherent bias in assigning b factors. That often impacts the analysis since in early-time data, there are no unique solutions to curve-fit techniques," he said.

The type-curve analysis showed a distribution of EURs with a median of 3,554 MMcf of gas per well.

To look at a probabilistic cash flow, Connor incorporated a range of observed values to assign a distribution with most likely values to the following economic parameters: gas spot price of $2.15/MMbtu, condensate price of $83.12/bbl drilling-and-completion cost of $7.9 million, operating cost (opex) of $0.92 per Mcf of gas and fixed cost of $3,500 per well per month.

The study assumed two wells drilled a month for a total of 100 wells. Provincial deep and marginal gas holidays were applied in the royalty calculations.

"This project is in trouble," said Connor while presenting the gross monthly production curve and undiscounted and discounted cash flows. "There is a significant gap between most likely spot prices of $2.15 and the economic (breakeven) price of $4.27 Mcf."

Despite a depressed gas market, Connor said, "I don't think the train will stop for Montney or other promising shale developments worldwide. The bottom line is that gas prices will drive future development here in Montney and elsewhere."

Recently, several integrated majors in Canada said they are contemplating constructing LNG export terminals on the west coast, which may spur future development in the Montney.

Evaluation system for reservoir models introduced

Palke

At the Ryder Scott reserves conference, **Miles Palke**, vice president project coordinator, outlined a systematic, quantitative review process to assess the reliability of a given model for a purpose at hand.

"Often a model is used in a way that the originator never intended," he said. "That can result in a mismatch."

Solving that involves an adjustment to the model or an understanding that the predictions will be subject to a wider range of uncertainty. "So first, understand the original purpose of the model," remarked Palke.

He said to be aware of model complexity caused by special features, such as dynamic surface facility modeling and reservoir management controls. Simulations have numerical issues caused by "workarounds," Palke explained.

He cautioned evaluators to understand parameter adjustments made during the history match before relying on the model. "Adjustments with minor effects on the history match may have major effects in the future," Palke said. His "rules of thumb," included the use of status-quo cases and volumetrics as checks on parameter and model validity.

The new quantitative review system measures two characteristics of reservoir models: construction and history match, each on a scale of 0 to 1. The reviewer builds the scores for each by first checking (turning on) and unchecking (turning off) parameters in an electronic evaluation template.

Whether to check or uncheck parameters depends on how important they are to the prediction. In an example showing construction parameters, Palke turned on pay-continuity, porosity and permeability distributions while turning off facies and seismic-attribute distributions and rock compressibility. Other parameters also were turned on and off.

Then the reviewer rates each switched-on parameter on a five-point scale for each of several questions—for instance, how adequate is the field-observed sampling of the parameter, how closely does it emulate field-observed data, how significant is it to depletion process, etc.

Scores for each question are added together to get a composite score for each parameter. Then parameter scores are added up to get either a model-construction or history-match score, both of which are graphed on x and y axes, respectively.

Low scores for construction and history matching result in very unreliable, very uncertain predictions. High scores on both result in high reliability and high certainty in predictions. Palke plotted several cases showing a variety of data points.

He said the approach is subjective to some degree but each reviewer follows the same process and the system forces reviewers to consistently consider available data.

Palke, **Dean Rietz**, executive vice president, and **Bruce Palmer**, vice president technical specialist, detailed the process in SPE technical paper, "A Novel Simulation Model Review Process," No. 159274. The paper is available for purchase online through OnePetro at onepetro.org.

Palke's presentation is on the Ryder Scott website at ryderscott.com/Presentations.

Olds examines reserves, book value and accounting

The effect of petroleum reserves on book-value calculations was presented by **Dan Olds**, senior vice president, at the Ryder Scott reserves conference. He discussed petroleum accounting basics for book value, which is the net capitalized costs associated with developing oil and gas properties. Accountants "equate" book value with reserves value.

Those book values are adjusted to account for additional capital spending and production of associated reserves through an annual DD&A (depreciation, depletion and amortization) process. Typically, an accountant uses a reserves report to calculate a depletion rate, and then applies it to annual production to determine book value that was lost because of production. Olds cited the formula for adjusting book values through a depletion rate calculated as follows: Depletion rate = book value/reserves; Annual DD&A = depletion rate x annual production.

He also examined how DD&A is treated under both full-cost (FC) and successful-efforts (SE) accounting methods. Under FC, all exploration and drilling costs are capitalized into a single, full-cost pool for each country. That approach dilutes the financial impact of a discovery or dry hole during the reporting period.

SE companies capitalize drilling costs for discoveries or development wells, but expense exploration dry holes. The pool concept is limited to a single well, reservoir or field. Under SE, a significant discovery or dry hole is more immediately reflected in the financial reporting period.

FC companies factor in all categories of proved reserves in the depletion-rate calculation while SE companies adjust the book value of producing properties using proved developed reserves only. Olds also summarized the write-down (impairment) process under both accounting methods.

He concluded the following:

- Reserves volumes directly impact the depletion rate.
- Higher reserves volumes translate to a lower depletion rate, which yields higher net income.
- Proved undeveloped reserves (PUDs) are just as important to a FC company as developed reserves.
- Since PUDs are only considered in the depletion of leasehold costs for an SE company, the impact is diluted compared to PUDs of a FC company.

Olds at the Ryder Scott reserves conference.

The 2012 Ryder Scott Reserves Conference attracted 284 attendees.

Petrophysical analysis of Eagle Ford shales outlined

Industry is rapidly gaining an understanding of the geology of unconventional shale plays and setting up knowledge bases that will be on par with what is known about conventional reservoirs, said geoscientist **Michael Michaelides**.

"We will get there," he told an audience at the Ryder Scott reserves conference. "As more information becomes available, qualitative geologic comparisons may be possible in the future as it is done in conventional reservoirs today."

To estimate in-place shale gas resource volumes, Michaelides outlined an upscaling approach that begins at the well level and extends to regional areas. "You must have core data, preferably whole core, to correlate it to log data," he said. "Whole core is expensive. We can manage to make side-wall cores work but they have less resolution."

Michaelides recommended running a full suite of conventional logs that include, at a minimum, GR, resistivity, neutron, density and sonic. "Other more specialized logs may be critical in some shale plays," he added.

Michaelides explained that a geologist can determine local trends by tying the core-to-log correlations to nearby non-cored, logged wells. The upscaling process after that involves determining whether seismic attributes can be extracted locally out to the regional level.


Michaelides at the Ryder Scott reserves conference.

> "The Passey method can result in false positive indications of total organic carbon. That's why we use cutoffs."
> — Michaelides

Michaelides cautioned that a geologist may not be able to use core-log correlations as an "analogy" beyond a local level. "There is no such thing as a homogenous isotropic reservoir," he remarked.

Michaelides discussed the geology of the Eagle Ford shale play, examined its log characters and covered details on the use and limitations of the Passey and modified Passey methods of log analysis. "The Passey method can result in false positive indications of TOC (total organic carbon)," he said. "That's why we use petrophysical cutoffs."

Michaelides also said that both methods need to be calibrated using barren shale. The modified Passey method, which requires core data and is generally used in later stages of field development, is useful for deriving total hydrocarbon-filled porosity.

"Core data in different wells should be analyzed by the same core lab," remarked Michaelides.

He summarized a petrophysical approach for estimating in-place hydrocarbon volumes of an example field in the Eagle Ford shale that involved determining cutoffs, setting up a delta-log measurement and tying the logs to cores. Dlog (or delta-log R) is the separation of acoustic and resistivity curves measured in decades.

Michaelides said that the following simple cross plots have worked well to tie logs to cores in that play: DlogR/HC-filled porosity and Density log porosity/core porosity. In a series of slides, he applied correlations and cutoffs, the latter derived from crossplots, and mapped the log results.

His comments on current limitations of petrophysical analysis of shale plays included the following:

- HC-filled porosity from well log analysis has not been successfully separated into liquid and gas.
- Petrophysical analysis is very sensitive to the type of resistivity curve available for a well.
- Some operators only log the zone of interest resulting in a poor calibration to barren shale.
- Without basic density and neutron curves to verify cutoff compliance, in-place volumes can be grossly overestimated.

His presentation is posted at ryderscott.com/presentations.

Rietz promoted to executive vice president

Dean Rietz at Ryder Scott reserves conference reception.

Dean Rietz is the new executive vice president. He replaces **Fred Richoux**, who was recently promoted to president. Rietz is a member of the board of directors and has been a petroleum engineer since 1984.

He joined Ryder Scott in 1995 as a petroleum engineer and became manager of the simulation group in 1998. Rietz has 28 years of diverse experience in oil and gas property evaluations, including more than 25 years in numerical modeling.

He has extensive experience in reservoir studies of oil and gas fields throughout the world, including in North America, Middle East, Central and South America, Central and Southeast Asia, Europe and the Former Soviet Union.

Previously, he worked at Intera Technologies Inc. and H. J. Gruy and Assocs. Rietz began his career at Chevron Corp. as a petroleum engineer.

He has BS and MS degrees in petroleum engineering from the University of Oklahoma and University of Houston, respectively. Rietz is a member of the Society of Petroleum Engineers and Tau Beta Pi and Pi Epsilon Tau honorary engineering societies. He is an adjunct professor at UH and instructor in a graduate course, "Applied Reservoir Simulation."

Senior geologist, petroleum engineer join Ryder Scott

Rebecca K. Carson joined Ryder Scott as a senior geoscientist. Previously, she was an independent contractor for 15 years. During that time, Carson evaluated oil and gas reserves of properties in the United States and internationally using integrated petrophysical and geological methods. She also prepared and reviewed sales packages of producing properties for buyers and sellers.

Carson was a staff geologist at Tenneco Ventures Corp. during 1991 to 1996 where she evaluated about 100 drilling prospects and 15 producing properties a year. She developed more than 25 Miocene oil and gas fields and conducted a major integrated field study of a south Louisiana salt-dome field, which included identifying drilling prospects and recompletion opportunities.

Carson started at Tenneco in 1985 as a senior geologist. She used geologic interpretation, formation evaluation and reservoir engineering methods to calculate oil and gas reserves in U.S. gulf coast fields for a potential tie-in to a pipeline system. She also conducted gas field studies for properties in the Arkoma basin, Wyoming Overthrust region and Mackenzie Delta in Canada.

Carson

Carson began her career at Gulf Oil Corp. as a development geologist in 1981 and two years later became an exploration geologist at Kriti Exploration Inc. She has a BS degree in geology from Texas Tech University.

Amaro

Manuel A. Amaro joined Ryder Scott as a petroleum engineer. Previously, he evaluated reserves and field performance for Noble Energy Inc. as a reservoir engineer—deepwater Gulf of Mexico. He joined Noble six years ago as a drilling engineer in the U.S. mid-continent region where he supervised drilling operations.

Please see Amaro on Page 8

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Lee—Cont. from Page 3

Other non-idealities he included are that complex transitions to BDF are possibly influenced by linear flow from unstimulated matrix outside the stimulated reservoir volume (SRV) and possible transient linear flow into the SRV from unstimulated matrix takes place at late times.

"This makes the flow more complicated and harder to model," said Lee. "Evaluators should use simulation while seeking understanding."

He also discussed decline-curve analysis (DCA) methods for evaluating production from shale. Lee said that although Arps with a Dmin does not honor basic physics during the transient-flow regime that its use is still worth consideration.

He suggested options to the Arps hyperbolic decline equation, namely the stretched exponential model and the Duong transient linear flow model. Lee added that the original Fetkovich type curve for DCA has limitations in analyzing production from unconventional, hydraulically fractured reservoirs because it models transient radial flow, not transient linear flow.

He suggested that industry conduct reservoir simulation using representative reservoir properties, lateral lengths, fracture spacing and operating practices, such as choking back wells. Next, evaluators can identify expected types and durations of early transient flow, characteristics of transition flow and BDF regimes.

"We can then adopt empirical models for rapid data processing to be consistent with expectations based on more rigorous modeling," he said. Lee also discussed when to switch from the transient-flow model to the BDF model and when to switch back to linear flow (from the unstimulated matrix to the stimulated reservoir volume) from BDF, if required.

Amaro—Cont. from Page 7

Amaro became a reserves engineer two years later where he coordinated corporate reserves. After that, he was a business unit finance analyst/production liaison in the southern region for Noble.

He began his career at Cosmopolitan Investment Corp. in 2001 where he worked for five years as an operations director. He managed financial transactions, analyzed investments and executed divestitures.

He has a BS degree in finance and international business from the University of Central Florida and an MS degree in petroleum engineering from the Colorado School of Mines.

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.

SEC Seeker—Cont. from Page 2

such information as company name, filing year, filing period, document type and filing date. The user may then select a record to view the corresponding PDF file.

Quarterly filings, registration statements, miscellaneous documents, older documents, press releases, annual reports and investor presentations are not indexed for searching. Through SEC Seeker's interface, users also download documents that meet their search criteria.

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