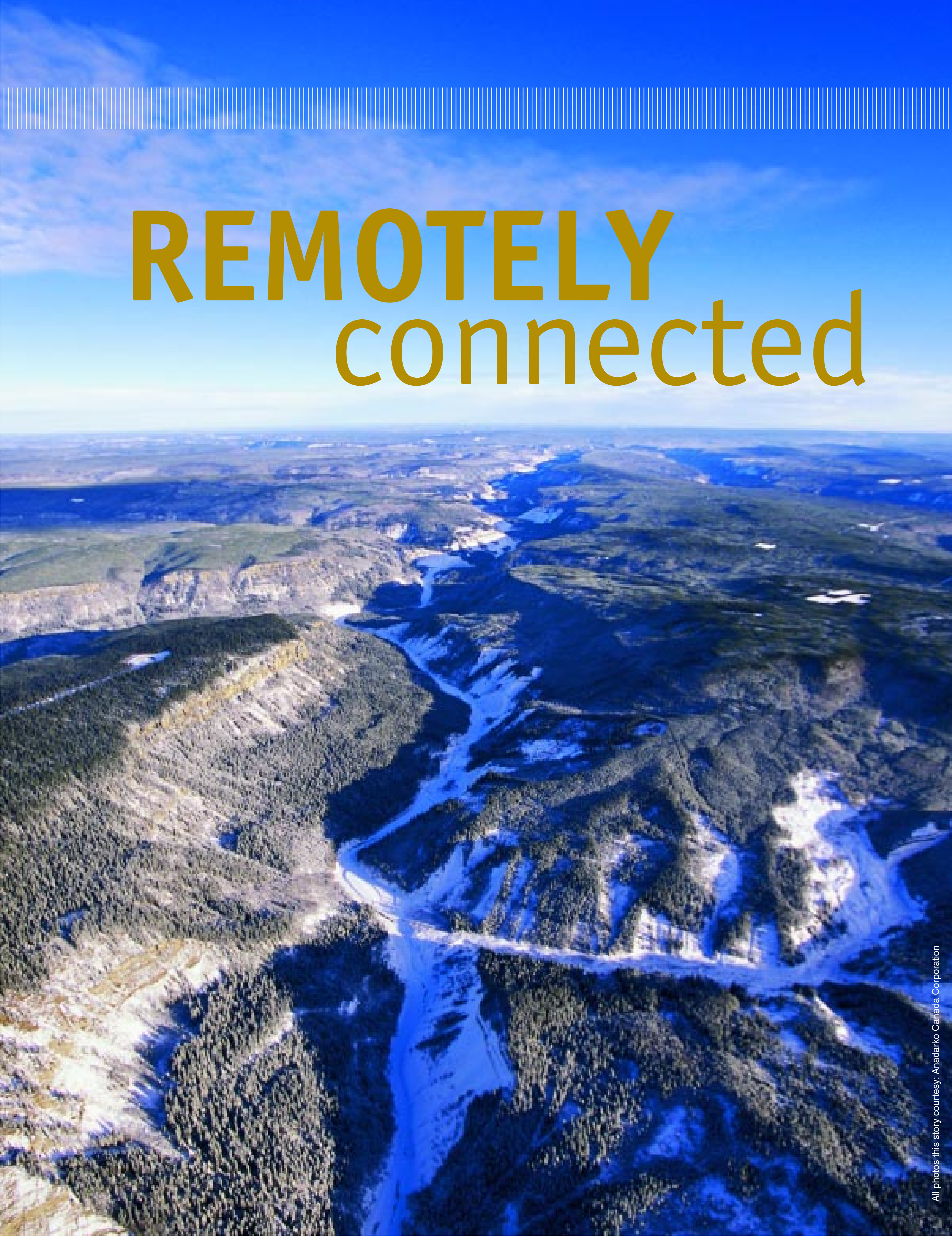
REMOTELY connected



All photos this story courtesy: Anadarko Canada Corporation

NESTLED IN THE undulating foothills where the great plains meet the Rockies in northeast British Columbia, the breathtaking Buckinghorse River gorge is a welcome relief from the hundreds of unbroken kilometres of black pine that blanket the surrounding hills. Its presence in the midst of an oil and gas rush in the region, however, was no relief for Anadarko Canada Corporation when the company found the massive gorge stranded discoveries of natural gas to its north.

The 300-metre deep, steeply sloping gorge represented no small problem for the company, which quickly realized conventional attempts to cross it would be gigantic undertakings. Anadarko initially considered two multi-million dollar options: boring a conventional pipeline underneath the river or spanning a suspension bridge across the gorge.

But the height of the gorge walls meant the standoff distance — the distance away from the gorge required on either side to gradually angle a descending pipeline deep enough to get underneath the river — would have necessitated no less than a world-record length for such a project. Worries about slope instability, later confirmed, further mitigated against the tunneling option, as did the presence of sediment below the river bottom that was found to be unfavourable to pipelining. An early evaluation gave the scenario a dismal 50% chance of success.

Similarly, an elevated suspension crossing would also have meant a never-before accomplished distance, according to Anadarko drilling supervisor Brad Virginillo. "We looked at that [option]; it was scoped out initially and set aside fairly quickly because it is a fairly cost-intensive operation to do that, to a world-record length, not to mention the long-term implications in terms of testing and maintaining the integrity of the structure."

Stumped, the company, along with oilfield services company Halliburton Energy Services, began looking to unconventional methods to get the gas across. They looked to what the latest in new technologies could offer, and they considered applications of technologies unrelated to the pipeline industry. The solution they found, like the other two options, would also represent a world first — at an estimated half the cost.

STRANDED NO MORE
A Precision rig strikes natural gas in the Buckinghorse River area. The reserves were stranded until Anadarko completed its Buckinghorse River crossing.

FRESH APPROACH. The answer was to bring together technology developed for the drilling of relief wells — used to intersect and kill blowouts — with advanced survey and horizontal drilling technology. Rather than bore a gradually sloping pipeline with its required standoff distance, they would drill two 1 400-metre vertical wells 3.2 kilometres apart on each side of the gorge, angle them 90 degrees and horizontally drill the two to a meeting point deep under the river.

ANADARKO DIGS DEEP TO CIRCUMVENT A TREACHEROUS GORGE CROSSING BY MAURICE SMITH

WELLBORE PATH
The red line shows the path of the borehole connecting the gas line below the gorge.

The daring operation would be coordinated several hundred kilometres away, in shiny office towers in downtown Calgary. A command centre of sorts was established at Halliburton's recently opened Real Time Operations Centre (RTOC), where key personnel from the various companies involved would convene every morning to assess progress, troubleshoot when necessary, examine and reexamine plans going forward and set out direction to the drillers in real time.

It was a progression from a small pilot Halliburton had completed earlier, says Rod Schnell, directional drilling advisor for Halliburton subsidiary Sperry-Sun Drilling Services. "We took a baby step about a year and a half ago in Brazil. It was a test on a very small scale where two horizontal wells were tied together. They were only about 400 metres apart and 200 metres deep, so very shallow and relatively simple. This was the first time we have ever done anything on this scale. We brought the technology to Anadarko, said this technology is available, and they pursued it from there. Now we have proven we have enough survey accuracy and well placement capability that we can actually drill these wells successfully."

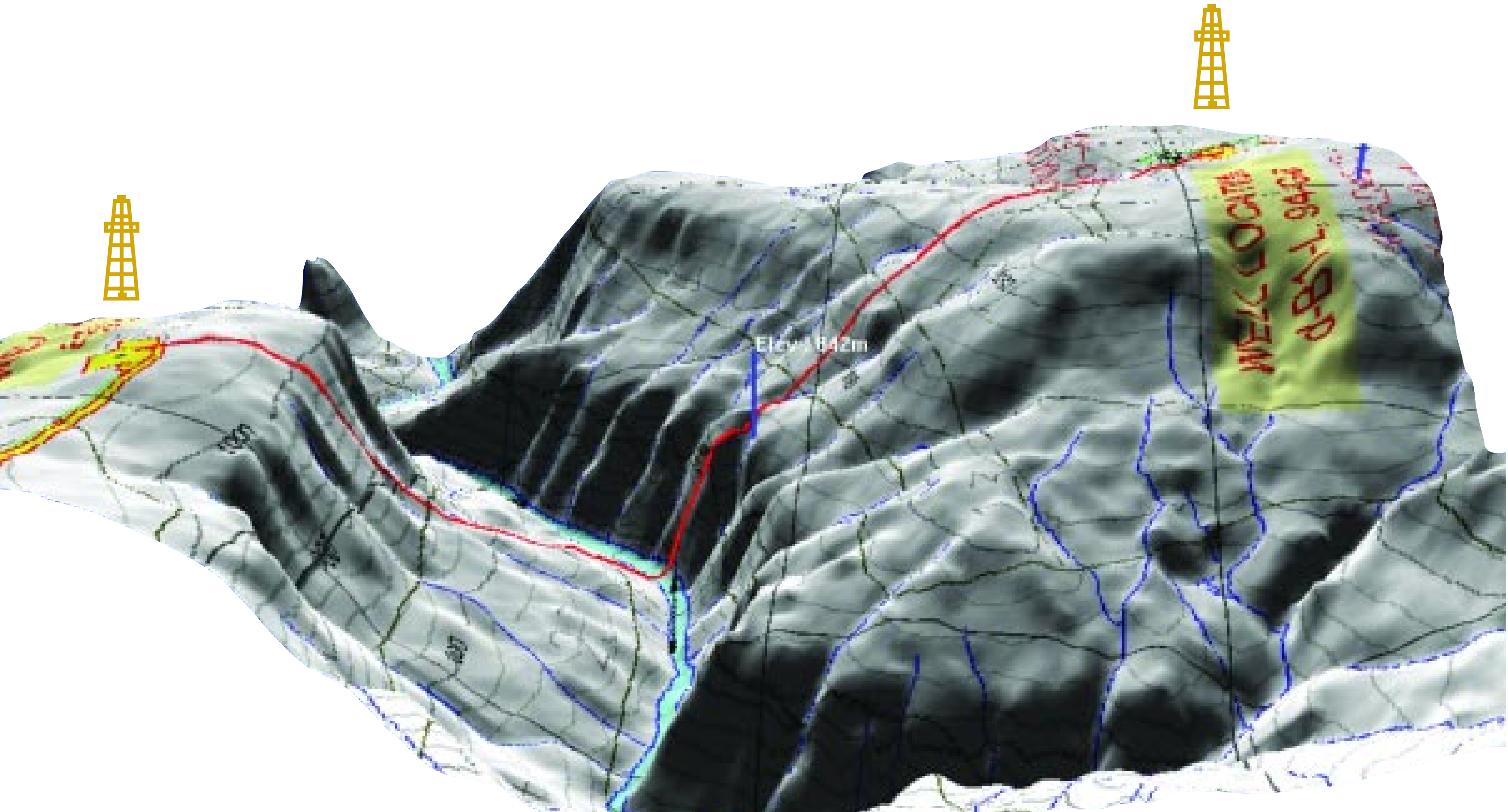
Apart from the obvious logistical challenges — the remote site is located about an hour and a half off the Alaska Highway, midway between Fort St. John and Fort Nelson — three main challenges stood out, according to company officials: the extended reach drilling itself; survey technology to place the wellbores to within "sight" of one another; and homing technology to steer the opposing drill bits on a final, intersecting trajectory.

To meet the unique horizontal drilling and pinpoint steering requirements needed for the operation, Sperry-Sun built and patented a new tool specifically for the project. Designed in-house at Sperry-Sun offices in Calgary, the tool combines the company's FullDrift directional mud motor drilling technology with its Geo-Pilot rotary steerable system. The FullDrift drilling system produces a smooth wellbore with reduced spiraling and micro-tortuosities, according to Halliburton, providing maximum wellbore drift. The Geo-Pilot system deflects a one-piece rotating driveshaft off-centre between two bearings to steer the bit.

"What we did is take the ranging technology, which is magnets in a sub, and incorporated that into our FullDrift sleeve, so we could use our rotary steerable to intersect these wells," says Schnell.

Directional drilling involves pointing the bit in the desired direction and sliding the motor to build angle and turn, Schnell explains. But with the extended wells required here, each about 1 600 metres horizontal, the buildup of friction would have caused buckling of the drillstring in the wellbore. With the ability to drill directionally with continuous rotation from the surface, a rotary steerable system removes the need to slide a steerable mud motor.

"At the point when we had to intercept the wells, torque and drag issues would have made it impossible for us to drill the well with a motor, with a regular assembly, because we wouldn't have been able to



CROSSING THE CHASM
A topographical image depicts the steeply sloping walls of the Buckinghorse River gorge and the location of drilling sites on either side that connect deep below the river.

overcome the friction factor to actually be able to slide the motor," Schnell says. "Because of the length of the horizontal section, without rotary steerables, we wouldn't have been able to intersect the wells."

Drilling challenges aside, bringing the wellbores together 1 100 metres below the river bottom would be akin to two needles in a haystack finding each other. Halliburton brought its most advanced survey technologies to bear to bring the wellbores to within the estimated 70 to 80 metres required for them to magnetically "see" each other.

"With the measured depth on the two wells just under 6 000 metres, your ellipse of uncertainty on either well is going to be over 100 metres if you don't have any survey management. So without survey management, we would have never been able to use the vector ranging technology, the magnetic ranging technology, to actually see the other well when we went to intercept it," says Schnell. "So survey management was critical."

Traditional measurement-while-drilling (MWD) technology was combined with gyroscopic survey technology, Virginillo says. "Knowing the ellipse of uncertainty of those two technologies, and looking at our angles of incidence, we were able to actually come up with a design that was almost failsafe in terms of getting us to a point where the magnet subs could actually see each other. We knew that once the receiver could see the magnet, it would be mechanical from there forward."

For greater accuracy, rather than rely on published declination numbers for magnetic field measurement, Halliburton took its own local declination shot, Schnell noted. "Without a local declination shot, the two wells would have been 1.3 degrees difference in azimuth, so when we went to range with the magnetic ranging tool, we might not have been able to see the other well."

Halliburton was also doing infield magnetic referencing, which is sensitive to solar storms, Schnell says. "When you have solar storms, it affects the Earth's magnetic field, which in turn will cause big swings in your magnetometers, which give you direction. So, by doing infield referencing, we can tell when we are in a very high solar storm period and shut down and stop drilling, because we are getting too much variation in our magnetic field. All this [survey] technology is out there, it was just a matter of pulling it all together and using it."

The technology proved its worth. By the time the two drill bits were within ranging distance, some 80 metres apart, one was just 14 metres off to the side of the other.

Planners turned to relief well guidance technology, which uses magnetic attraction to guide the drill bit to a damaged well, as the homing technology that would bring the wellbores the final distance. The technique has also been adapted to steam-assisted gravity drainage (SAGD) drilling, where a horizontal wellbore is shadowed by a second horizontal wellbore to create one steam injection and one producer well. With a magnetic source in one well and a magnetic receiver in the other, the SAGD wellbores can be drilled at a precise, parallel distance from each other and prevented from intersecting.

"We looked at that [technology] and said, 'Why can't we just drill two opposing wells, using the same sort of technology in a slightly different application, to intersect the two wells together,'" says Virginillo. "And that's virtually what we did."

The technology worked even better than anticipated, says Schnell. "We had some contingency plans to ream the junction open. We assumed we wouldn't actually hit it perfectly clean, that we would actually skim it, so the reaming assembly would be used to open up the junction, but after the well was finished, we were able to pass a FullDrift system completely through it. So we had actually steered right into it, basically stabbed it in the heart."

The seven-inch line was aimed through a section of Baldonnel formation and through the 30-metre Triassic dolomites of the Charlie Lake formation, extremely tight formations that "chewed up bits like crazy," according to Schnell. "The ROP [rate of penetration] in the horizontal section was one or two metres an hour — very slow."

Good formation competency with virtually no permeability was a requirement, says Virginillo. "It's very tight, very hard rock, and that was one of the initial criteria that we put on the project. We wanted to have the connections done in a competent rock from the perspective that we didn't want to have any potential for reaching the fracture gradient or having the gas fracture off into the formation."

Once joined, the companies relied on further innovation to complete the connection. The well casing was cemented in a reverse-circulation fashion from one side to the other, says Virginillo. "Typically when you do a cement job you pump the cement down your casing and bring it back up the annulus, but what we did in this case is we pumped the cement down the annulus from one side of the valley right to the well on the opposite side and basically pumped cement until we had good quality cement returns on the north side. In all, it was about 5 800 metres of annulus that we pumped it through.

"We were able to model the entire cementing operation before we went ahead and did it and it went off without a hitch, virtually exactly what we modelled it for pressures and pumping times and pumping rates," he adds. "It went textbook, even though there is no textbook written on it."

COMMAND CENTRE. Tying all the technology and know-how together was the recently opened Real Time Operations Centre, which allowed experts from numerous disciplines to deal in real time with drillers on site.

Halliburton's visualization room and monitoring centre were the site of daily morning get-togethers with everyone from drilling fluid and hydraulic modelling experts to specialists in bit technology, cementing, directional drilling and software, says Darcy Cuthill, Halliburton regional manager, Real Time Asset Management.

Streaming data from the well sites detailed every inch of penetration in real-time, allowing the experts to solve any technical problems as they arose, Cuthill says. "It took an incredible amount of teamwork, communication, collaboration and integration to pull off this project," she says.

"We needed to make sure we were not only doing the best we could for that current day's operations, but more importantly that we were adequately planning ahead of the bit and looking for anticipated trouble spots and anything that required some kind of alternate plan or contingency design. The crux of working in real-time mode is that as critical as the early planning and scenario modelling is, we still have to be prepared for just about anything when it comes to operations.

"But it's not all about real-time data," she adds. "It's about a different way of working, of team skills and problem solving and learning curves and continuous improvement. It was really a combination of people, process and technology that allowed us to achieve these results."

Schnell calls the RTOC "the mayonnaise in the sandwich — what we needed to pull it all together …. This is the first time we have had all these technologies put together to be run at once. There were so many product lines from Halliburton and so many other people involved in the project that we needed one place where we could meet and actually see the scope of the project and have everyone's input on everything we did on a daily basis."

The project wasn't without its setbacks. A first attempt to drill the north well last spring was abandoned when an uphole shale stability problem was encountered. It was determined the Cretaceous shales didn't have enough competency to hold a wellbore pattern and had a high tendency of sloughing and collapse.

"We originally started out with a different well design than we ultimately ended up drilling," says Virginillo. "It was basically a high angle penetration through the upper shales, and it's interesting because when you look at that [failed well], that in itself implies that a conventional pipeline crossing probably had very little chance of success, because that is what they would have been doing was a high angle penetration through the upper shales.

"It was a situation where I think we slightly underestimated some of the geological risk and as it turned out we didn't really have the technologies to bring to bear to overcome that risk, so we at that point said, 'Let's go back to something we know and understand very well,' which was a profile that we drill most of our production wells with in that area and that's ultimately where we landed. We went back to a very well known well design and just altered that design accordingly to make it work for this application."

The false start set the project back four months and increased costs above the initial $12 million estimate, though it still represented a significant savings over conventional designs, says Anadarko. First gas — from two previously stranded wells with combined output of nine mmcf per day — flowed through the line in early December, connecting to the Jedney pipeline infrastructure to the Caribou gas processing plant to the south. Anadarko has drilled five exploration wells north of the gorge since 1999 and plans to drill four more this winter.

Potential conversion to a high-pressure system in future would increase throughput under the gorge to the range of 30-plus mmcf per day, Virginillo says. Looked at as a continuation of the prolific Jedney play, which has pumped 900 bcf of gas, Anadarko says its approximately 60,000 net acres in the Buckinghorse area hold an estimated 200 bcf of potential resource.

The Buckinghorse River crossing has created a big win-win for the industry and the province, say the companies. Both Halliburton and Anadarko are eyeing more applications for the techniques they have perfected, and the province stands to benefit from production of previously stranded resources and a reduced environmental footprint.

Halliburton is already looking to export the technology to the Middle East and to Alaska, says Schnell. Some authorities in the Middle East are considering burying above-ground oil and water pipelines perceived to be vulnerable to attack, he says. In Alaska, new regulations that forbid pipelines across bays to be situated on the sea floor are expected to open a market for boring them underground for distances of two to eight miles, he says. "I think the potential for this technology is quite large."

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