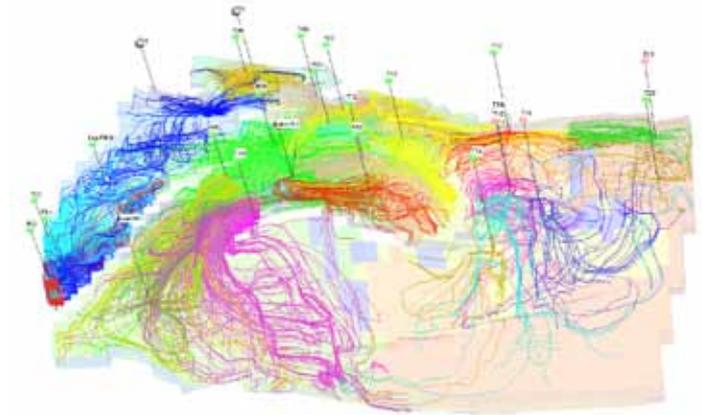


## Case Study

### Norwest Uses Tempest™ Simulator to Serve Clients Worldwide.



roxar

#### Case Study Summary

##### Customer

Norwest Corporation, Golden, Colorado, USA

##### Challenge

Norwest and its client in the U.S. needed a reliable full-field simulation model to optimize high-pressure air injection and horizontal infill drilling program for a tight reservoir in Williston Basin; however they could not afford an expensive simulator.

##### Solution

Norwest and its client chose Roxar's cost-effective, full-featured Tempest™ simulator, achieved an excellent history match, and used the model to optimize the timing and sequence of infill drilling, and to convert producers to injectors.

##### Results

Production and injection forecasts matched actuals at end of first year, even during transient operations; they more than doubled estimated recovery, and applied the lessons learned to older fields nearby.

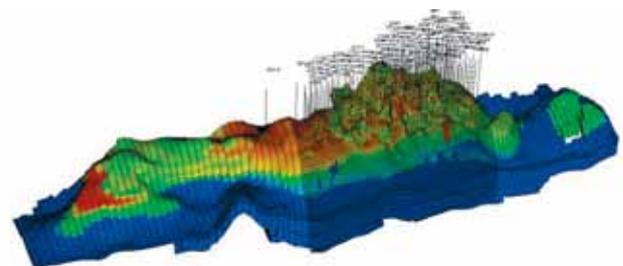
*Norwest Corporation uses Roxar's Tempest simulator for black oil, compositional and thermal simulation in projects ranging from multicomponent coalbed methane (CBM) to tight gas reservoirs and enhanced recovery operations.*

#### About Norwest

Reservoir simulation ought to be done routinely on many more oil and gas fields, according to John Campanella, Senior Reservoir Engineer with Norwest Corporation ([www.norwestcorp.com](http://www.norwestcorp.com)), an international petroleum consulting firm based in Golden, Colorado.

"Personally," he says, "I think reservoir simulation should be brought down to every engineer's desktop. We need to push simulation out of the back room and into the mainstream where people can use it on a daily basis. In addition to the big 3D projects, there are a lot of existing fields where simulation could be applied, but too often it gets skipped."

One big reason, Campanella explains, is cost. "Most simulator licenses are priced too high for everyone to get access to when they need it. And cost is a real big issue for smaller oil companies and consulting firms like Norwest. It's extremely difficult to justify a package that costs over \$200,000, like several we've evaluated. On the other hand, Roxar offers a reliable, full-featured simulator called Tempest for a much lower cost. This could be a way for companies to get simulation into the hands of more engineers."



# Case Study

At Norwest, he adds, consultants use Tempest for black oil, compositional and thermal simulation in a wide range of projects including multi-component coalbed methane (CBM), tight gas reservoirs and enhanced recovery operations. "While other simulators may have more bells and whistles, Tempest does the job efficiently and cost-effectively on almost anything—from small, conceptual models to full-field CBM models. From our perspective, it has been a great investment and provides a solid platform for the type of clients we serve."

In addition to consulting for oil and gas companies in the United States and Canada, Norwest's international project sites include Australia, Western Siberia, Kazakhstan, Italy, Southeast Asia, China, Chile and Colombia. "Some of our clients don't have the expertise to do CBM modeling or large-scale simulation on their own," says Campanella. "Others have the ability, but their people are spread too thin. They come to us to help get things moving."

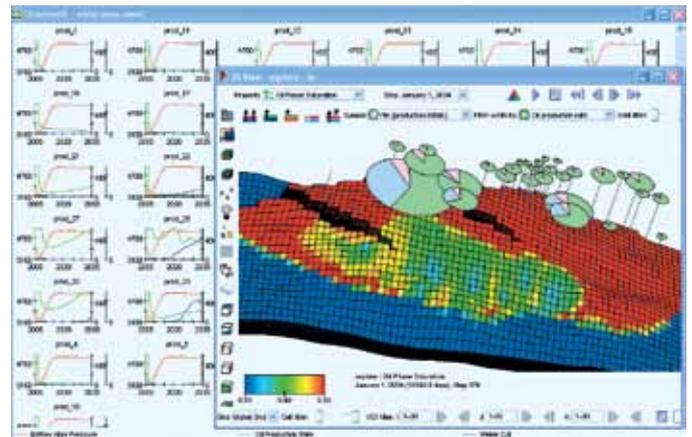
For example, Norwest was contracted to reevaluate an oil field with more than 50 years of production. After building a simple conceptual model, history matching and running the simulation, Norwest demonstrated that the water-oil contact was some 140 feet lower than previously believed and identified a deeper target capable of producing clean oil in a section thought to be completely wet. "After the simulation," says Campanella, "that well was deepened, completed and produced 100 percent oil for almost six months. This is the type of work people could do a lot more of, if they had the time and a robust tool like Tempest."

## High Pressure Air Injection Project

In the spring of 2002, Campanella began working on a full-field simulation project for an independent oil company based in the U.S. mid-continent. The client's senior reservoir engineer had previous experience with a major oil company using Tempest for a COH injection project in West Texas, and wanted to evaluate enhanced recovery options for an important field in the Williston Basin. However, as the only simulation engineer in the company, he couldn't afford to focus on a single field full time, so Norwest was engaged to work closely with him.

The field, discovered in the early 1990s, had been developed using open-hole completions in mile-long horizontal wells on 640-acre spacing. Primary recovery from a ten-foot carbonate reservoir with low oil saturation was driven by rock and fluid expansion.

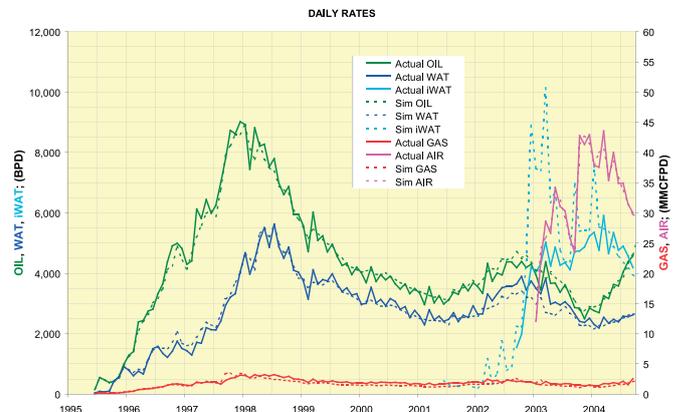
**"Most simulators are priced too high for smaller oil companies and consulting firms. Roxar offers a reliable, full featured simulator for a much lower cost. This could be a way for companies to get simulation into the hands of more engineers."** — John Campanella, Senior Reservoir Engineer, Norwest Corporation



Thumbnail Plots & 3D Plots in Tempest

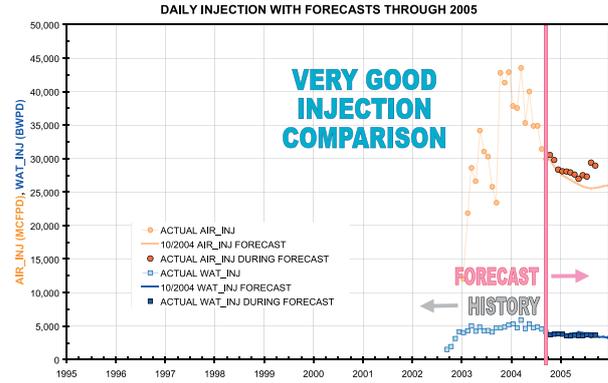
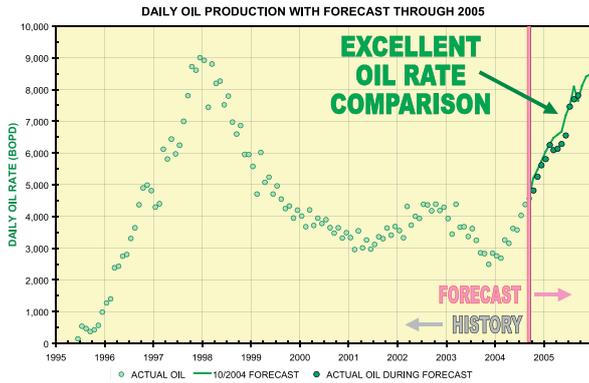
Production peaked in 1998 and began to plummet thereafter. To optimize recovery, the company decided to investigate high-pressure air injection and infill drilling using a field simulation model. Reservoir simulation was considered vital to the project's success because decline curve techniques couldn't accurately predict the oil rate response during transient periods in which new wells were drilling and selected producers were being converted to injectors. The relatively complex development and investment strategy called for numerical modeling.

Due to tight reservoir rock and low oil saturations throughout most of the field (except along the unit boundary, where water injection has been used successfully), the company felt that air would sweep the reservoir more efficiently than water and at a lower cost than COH, of which there was no local source. Campanella used nine years of available production history to calibrate the simulation model. In addition, a field just to the south had been injecting air for 20 years, so he used it as an analog to create relative permeability curves for the model. Working iteratively with the client to clarify the reservoir geology and tweaking the model to account for water lost into the formation during drilling (not otherwise factored into historical water and oil production), Campanella was able to achieve an excellent history match.



Norwest used 9 years of production history and air injection information from an analog field nearby to calibrate the simulation model and achieve an excellent history match.

# Case Study



Graph of daily oil production (left) and air injection (right) through end of 2005. Note the close match between forecast and actuals.

The simulation model was subsequently used to optimize the timing and sequence of infill drilling, as well as the conversion of existing wells to air injection. Initially, as new wells were drilled on 320-acre spacing, oil production spiked. For a period in 2003 during which some wells were converted for air injection, field production dropped off, as expected, then rapidly rose again as air began to sweep the reservoir more efficiently. The model was tuned and validated to reflect drilling and conversion activity through the fall of 2004, including 21 months of high-pressure air injection. Then, 12 months later, measured water and oil production rates were compared with the forecast. How accurate were they? "The predictions and actuals matched almost exactly," says Campanella. "We're pretty proud of that, especially because it was during a huge transient phase when things were changing rapidly. I think it shows what an engineer can accomplish by properly using an effective tool like Tempest."

"The trickiest part of the simulation," adds Norwest's client, "is getting the early response right when you're changing operations. You have to get a combination of factors correct in order to forecast production. By successfully predicting the response rates over that one year period, we're pretty confident we can predict the peak oil rate and ultimate recovery in this field."

Since 2005, three drilling rigs have been active in the field, and new infill wells are being drilled on 160-acre spacing. Field development plans, which call for more than 125 horizontal wells and extensions by 2009, are driven by the results of reservoir simulation with Tempest. Current estimates based on the simulation model indicate field recovery will more than double during that time. Estimated primary recovery was only between 8 and 10 percent of original oil in place; now the client's company is predicting recovery of 24 percent. In addition to high-pressure air injection, they are investigating the possibility of a hybrid air and water injection program to further improve recovery and reduce operating expenses. The company is also using what it learned in this project to set up simulation models for two older fields nearby, in order to evaluate proper well spacing and plan infill drilling in the next year or so.

## Benefits and Capabilities of Tempest

Both Norwest and its client have Tempest software inhouse, enabling them to exchange files easily and work together more collaboratively. For both companies, the price of the simulator was a key factor in choosing Tempest, but its ability to model reservoirs using black oil or compositional simulation also was important. "Coalbed methane is a big part of our business," says Campanella. "And one of the benefits we see in having Tempest is that Roxar is continuously increasing its functionality to handle more complex problems. They came out with a multi-component capability, so we can handle cutting-edge techniques in our CBM projects." A lot of companies involved in CBM don't use reservoir simulation, he notes, which often is a big mistake.

"We see tremendous losses in productivity, especially when companies drill horizontal CBM wells without simulation. Some just poke a lot of holes in the ground and hope. Often, one of two things happen. Either they drill more wells than they need to, wasting money unnecessarily, or they sit on unproductive areas pumping water for way too long because they don't understand what's going on. CBM can be a very complex play—you're lowering the water pressure so gas will desorb from the coal. If you plug the gas content and absorption isotherm into a simulator along with historical information on pressures, you can figure out exactly how to get gas out of the ground, how fast you can produce it, and what your peak will look like. Some people try to do it with Excel, but that's not very cost-effective. We do it easily with Tempest."

Campanella notes that Roxar has enhanced Tempest recently to include thermal recovery methods. "Roxar has always been extremely responsive to us when we have issues," he adds. "They always get back to us in a timely fashion, and work very hard to make sure it's a good product. Not only is Tempest a robust tool for small companies like Norwest, but because it can pretty much read and write an Eclipse deck, I think the regional offices of major oil companies could use it too, when their main licenses are all tied up. Roxar has some very big Russian clients, I know."

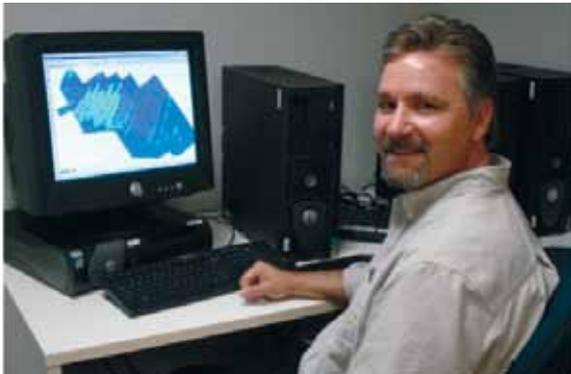
## Case Study

According to Raj Damodaran, a senior consultant with Roxar's Technical Services Group, Tempest has been widely used in Russia on very largemodels. "Tempest is the market leading simulator in Russia today," he says. "Oil companies have run models as large as 3.5 million cells with 11,500 wells in Western Siberia. Tempest is strong in postprocessing, in visualizing 3D grids and simulation results. At present, it can easily handle up to 9 million cells. But we're enhancing it to visualize up to 100 million cells in the near future."

An integrated link with RMS – Roxar's highly acclaimed GeoModeling software – makes it very efficient for users to set up the base case in Tempest, adds Damodaran. What's more, they can take advantage of the outputs of RMS FracPerm – effective permeability or individual matrix and fracture permeability arrays – and RMS Fault Seal Analysis – transmissibility modifiers across faults – which can also be incorporated in the Tempest simulation model.

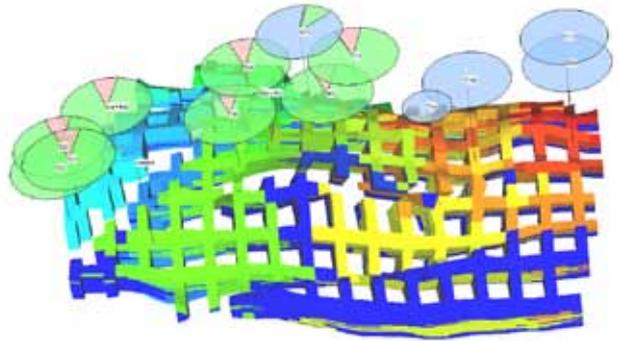
Tempest runs on all platforms, including 64-bit Linux systems. In addition, says Damodaran, Roxar is working on what he calls a "blazingly fast" version. It is also teaming up with leading third-party developers to offer uncertainty management and accelerated history matching with *EnABLE™* software from Roxar, and surface facilities and network optimization with *GAP™* software from Petroleum Experts. A new generation parallel processing engine will debut very soon.

"Basically," he concludes, "Tempest lowers the cost of owning a quality reservoir simulator with virtually all the features found in much more expensive systems."



*John Campanella explains that oil companies come to Norwest when their own staff is spread too thin, or they lack the expertise to do CBM modeling or large-scale simulation.*

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For further information please email [tempest@roxar.com](mailto:tempest@roxar.com) or go to our website [www.roxar.com](http://www.roxar.com) for regional contact information.