The Oil Drum
DISCUSSIONS ABOUT ENERGY AND OUR FUTURE

A Visit to Chevron's Kern River Heavy Oil Facility

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Recently, I visited Chevron's Kern River Heavy Oil field, near Bakersfield California, as a guest of the American Petroleum Institute. Kern River is an extremely old field, discovered in 1899. The oil flows a bit on its own (API=13), but really needs to be heated to be easily extracted or to be shipped by pipeline. After more than a hundred years of pumping, most of the available oil has been extracted--a total of a little over 2 billion barrels has been extracted. The additional amount that can be extracted will depend on the price of oil and how well Chevron can minimize costs.

The site produces about 80,000 barrels a day from 8,000 producing wells, meaning that on average, each well produces about 10 barrels of oil a day. In order to make money with this type of operation, Chevron must be very efficient in everything it does--reusing equipment whenever possible, using the best techniques possible to find the remaining pockets of oil, and prioritizing the workload of the employees, based on which activities are most likely to produce a profit, and which activities are not cost effective.

In the recent past, production has been declining at 2% or 3% a year. Chevron's goal in the near future is to hold the decline rate to 1% per year. No one knows how much additional oil can profitably be produced, but rough guesses were in the 200 to 500 million barrel range. This range equates to 10% to 25% of the oil produced to date as possibly being economically available for extraction.

In this post, I will tell you a little about what I learned on my trip, and also offer some thoughts on whether heavy oil is likely to be a panacea for peak oil.

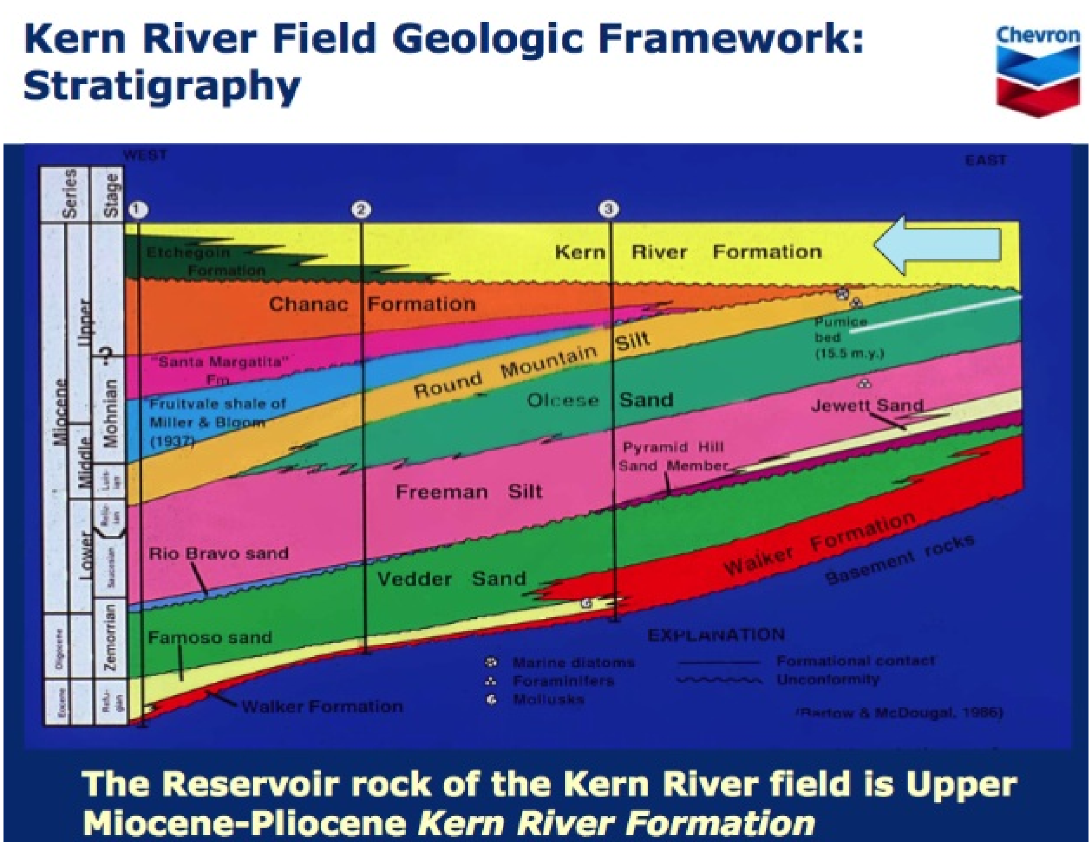
What a person sees at Kern River

I was surprised at the appearance of Kern River field. As far as one can see, there are thousands of oil producing wells bobbing up and down. Besides oil wells, one sees electric power lines and many types of pipes. The area is very arid, so there is little vegetation.

Photo taken on the very hazy day when we visited Kern River. (Click for larger image.)

There are much better photos in the Kern River Basin Tour video(3 minutes) taken by professional photographers the day we were there. The API website also has a page with still pictures and copies of the presentations from which I took most of the images in this post. In case you are wondering, I am wearing a blue jacket in the photos. I am not in the video.

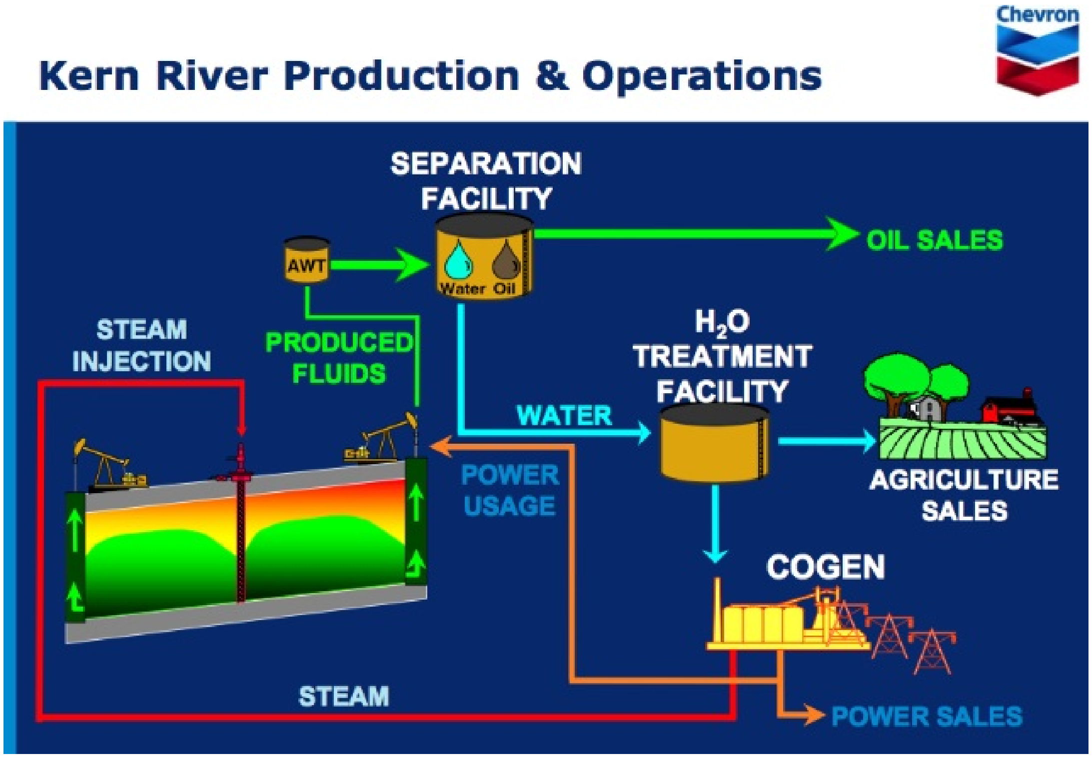
Geology



For those interested in geology, this is the slide we were shown of Kern River Stratigraphy. The oil is found in nine separate layers, the deepest of which is only 1,500 feet deep. The material that the oil is trapped in is very sandy, and one of the challenges is keeping the oil wells from becoming clogged with sand. The oil and water mixture that is extracted is about 90% water.

Extracting Oil Cheaply

This is a diagram we were shown of Chevron's operations. The technique Chevron uses to heat the earth to better extract the oil is called steam flooding. Besides the operations we would normally think of, Chevron generates electricity, most of which is sold to a local electric utility, and recycles the excess water it extracts so that it can be used for agricultural purposes.



Natural Gas

In order to generate steam for steam-flooding, Chevron purchases a large amount of natural gas. This gas represents about half of the operating costs of the facility, so it is important that it be used efficiently.

Starting about 1985, Chevron began to get double use of its natural gas by using the excess heat from the steam-generation process to generate electricity (co-generation). Using this approach, 300 MW of electricity is generated. The Kern River field uses 36MW of this, and the remainder is sold to a local utility. Since Kern River generates its own electricity, Chevron is assured of a constant supply of electricity for the facility, even if there are rolling black outs elsewhere. Also, the sale of this co-generated electricity is a significant source of the base electrical power for California's grid.

Through co-generation, Chevron is able to attain approximately 80% efficiency in its use of natural gas. Recently, Chevron has developed boilers for steam generation that are themselves 85% efficient, removing the incentive to add additional cogeneration capacity.

Water

Since the oil-water mixture that is extracted is approximately 90% water, the question is what to do with all of the excess water. Chevron's approach is to treat the water and reuse it, partly for its own use in generating steam, and partly to re-sell for agricultural use. A small residual portion remains, which is re-injected below the water table in regulated locations.

Other Approaches for Keeping Costs Down

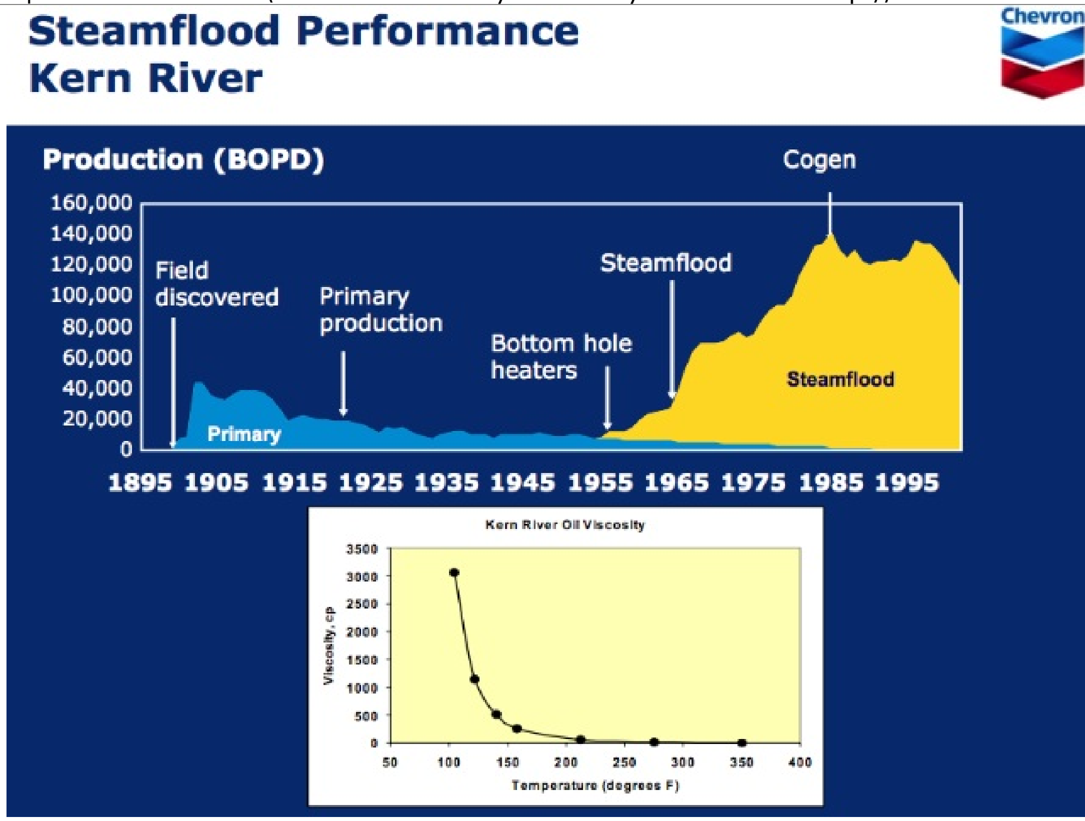
To keep costs down, Chevron reuses equipment as much as possible. If a pump jack is not needed in one location, it is moved to another location. If an oil well is no longer producing oil, the borehole can still be used for surveillance of ground temperatures (to see how the steam is heating the area) and for other measurements that will help determine whether there is still remaining oil in the area.

When new monitoring techniques are developed, Chevron adds new controls to existing equipment, rather than starting over with new equipment. For example, we were shown tanks used to measure the proportion of water and oil coming from individual wells. Some of the oil tank were set up so that a worker could use a measuring tape to measure the depth of the oil in the tank. These old tanks have been retrofitted with new electronic controls that measure the proportion of oil and water.

Most of the oil in the oil-field has now been drained. The challenge now is to find the remaining pockets and drain them as efficiently as possible. Chevron has developed a 155,000,000 cell imaging model of the field that allows them to target those areas most likely to have oil remaining. Each of the 155,000,000 cells represents an area 50 feet x 50 feet by 2 feet deep. This model is based strictly on borehole data, not on seismic imaging. Besides whether or not the cell is likely to have oil, the model gives other information, such as whether the area has been heated to the optimal temperature.

In trying to minimize costs, one issue of concern is precisely how long in each 24 hours a given pump jack should be pumping. If the area is heated by steam, the area will continue to drain, whether or not the pump jack is moving. Pump jacks are put on timers and turned on and off as needed, so as to use as little electricity as possible to pump the available oil out.

Another issue is heating the ground to precisely the correct temperature. As one can see from the graph at the bottom of the figure below, viscosity does not decrease much after a temperature of approximately 230 degrees is reached. The challenge is to heat to precisely the correct temperature, and no more, so as to not waste energy needed to make heat.



Historical Production

The graph in the above figure indicates that production was quite low until steam flooding was introduced about 1965. A peak in production of 141,000 barrels a day was reached in 1985, when cogeneration was added. Since then, production has been declining.

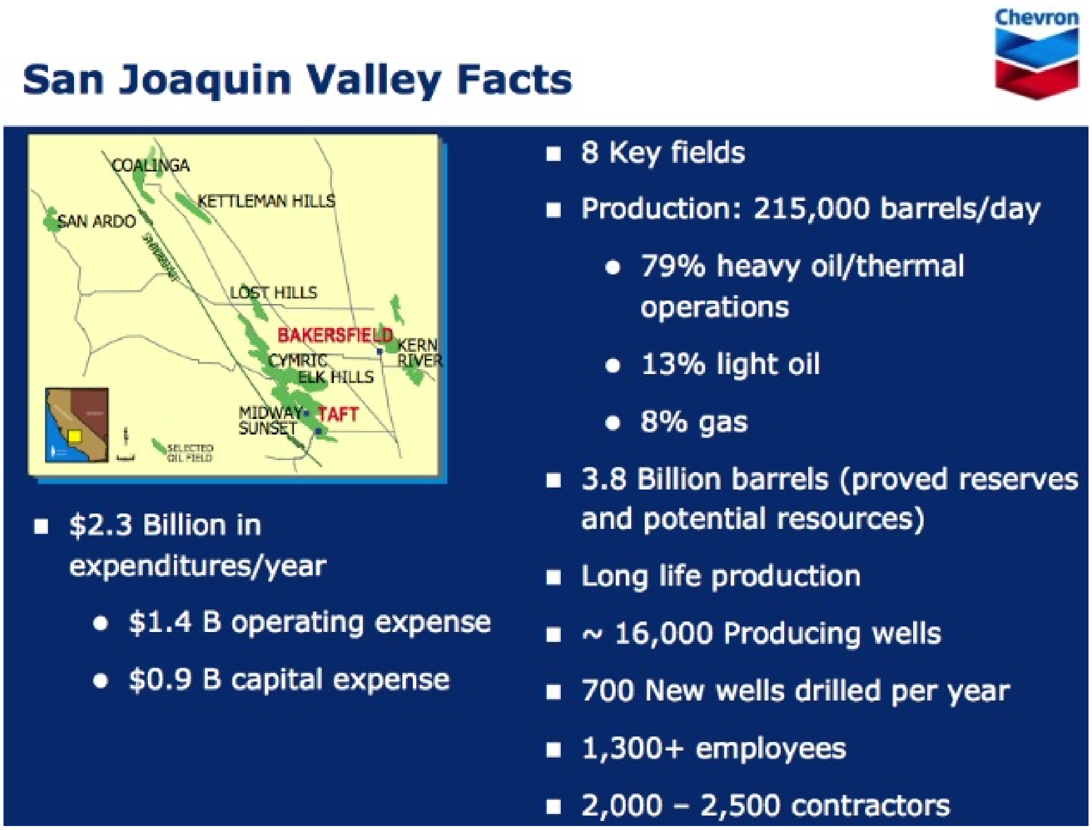
The proportion of heavy oil originally in place that can be removed varies greatly with the approach used. We were shown this table of the percentage of oil originally in place that can be extracted with various methods. Clearly, steam flooding is a major improvement over gravity drainage and hot water extraction.

Mechanism	Oil Recovery
Primary	5 - 10%
Hot Waterflood	15 - 25%
Steamflood	50 - 80%

Nearly all of the producing wells at Kern River are vertical wells. Recently, Chevron has begun using a small number of horizontal wells as well. Horizontal wells only make sense if the bypassed oil lies in a horizontal pattern and if the soil for the entire length has been adequately heated by steam. If only part of the soil has been heated, the oil does not flow sufficiently freely to make the horizontal well useful. We were told that one horizontal well started with 500 barrels a day of production--truly outstanding when the average is only 10 barrels a day.

Costs, etc

When we asked about marginal production costs, and the answer was, "We can't tell you that." We were shown a slide that does give some partial indications, however:



Kern River is part of the San Joaquin Valley. Using figures from this graph, we can calculate some averages for the valley as a whole. Kern River's costs no doubt are somewhat higher, because its oil is weighted more toward heavy oil than that of the valley as a whole, and its average production per well is lower than for the valley as a whole.

According to the slide, there is a total of 215,000 barrels a day of oil produced in the San Joaquin Valley, of which Kern River amounts to about 80,000 barrels. The exhibit indicates that operating expenses are $1.4 billion a year and capital expenditures are $0.9 billion a year. 215,000 barrels a day is equivalent to 78,475,000 barrels a year, so operating expenses amount to $17.84 a barrel and capital expenditures amount to $11.47 a barrel, for the San Joaquin Valley as a whole. The selling price for San Joaquin Valley oil is several dollars below that of West Texas Intermediate, so these costs are approaching the current price of oil, if WTI is about $40 barrel.

The costs for Kern River would be higher, so the most expensive capital expenditures are likely getting squeezed. It was clear from our discussion that any decision on drilling or allocating workers time is made only after carefully considering the implications for profitability. Some of the deeper areas of the Kern River Field which are harder to heat have been by-passed in the past. Cost considerations will determine whether it makes economic sense to drill additional wells in this area. Because of this, I would expect the price of oil to have an impact on the decline rate--the lower the price of oil, the fewer projects are economic to undertake.
One factor that keeps costs down for Chevron is lack of debt. Chevron has accumulated capital over the years, and is able to run its operations without debt. Also, the fact that it has been able to buy a huge amount of oil drilling equipment at low prices over the years is helpful. Since this equipment is fully paid for, it does not affect current costs.

Implications for Drilling Other Heavy Oil

Chevron is involved with quite a number of different heavy oil fields around the world, in areas such as Venezuela, Indonesia, and the Middle East, and the techniques it has learned are no doubt helpful in these areas as well.

It seems likely that the costs in these other oil fields will be higher, because Chevron does not have the benefit of building up a large inventory of equipment at low prices, in years past. Also, if another company is actually drilling the wells, it may not be as well capitalized as Chevron, and need to obtain debt to finance the large up-front costs. This will also tend to raise the cost. In some cases, companies may not be able to obtain financing, so new or expanded heavy oil production may not be an option.

Another consideration is natural gas. The way Chevron is currently running its operation, natural gas is needed to create the steam for steam-flooding. If natural gas is not available in adequate quantities, it may not be possible to extract the heavy oil.

A third consideration is the speed at which the oil can be extracted. There is more than 1 billion barrels of oil still in place. Something less than 3% of this can be extracted in a year (comparing production to remaining oil). If new heavy oil fields are put into production, it is unlikely they will produce a huge amount oil in a single year.

The Kern River oil field, as huge as it is, produces something like 1/1000 of total world production. If one wanted to replace lost oil production due to decline of say, 4 or 5 million barrels as day, it would take a huge amount of infrastructure. To replace a decline of 4 million barrels a day would require the equivalent of 50 additional Kern River oil fields each year. The capital expenditure, if nothing else, would be overwhelming.

Because of these considerations, I don't see heavy oil ramping up to replacing declining production of freer flowing oil. There may be some growth in heavy oil, especially if the price of oil rises, but it is hard to see it ever growing to replace lighter oil.

Can steam-flooding be used to greatly increase the recovery on other-than-heavy production? I am sure we would have heard about it if it were the case--it is not a new technique. Steam flooding "works" on very heavy oil, because the oil is too heavy to flow otherwise. The oil seems to be very loosely bound in what is close to sand in Kern River, so steam-flooding yields a very high percentage of oil in place. If the oil is deeply embedded in stone with a different structure (permeability, porosity), the results will likely be quite different.