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Using Geothermal Energy to Reduce Oil Production Costs

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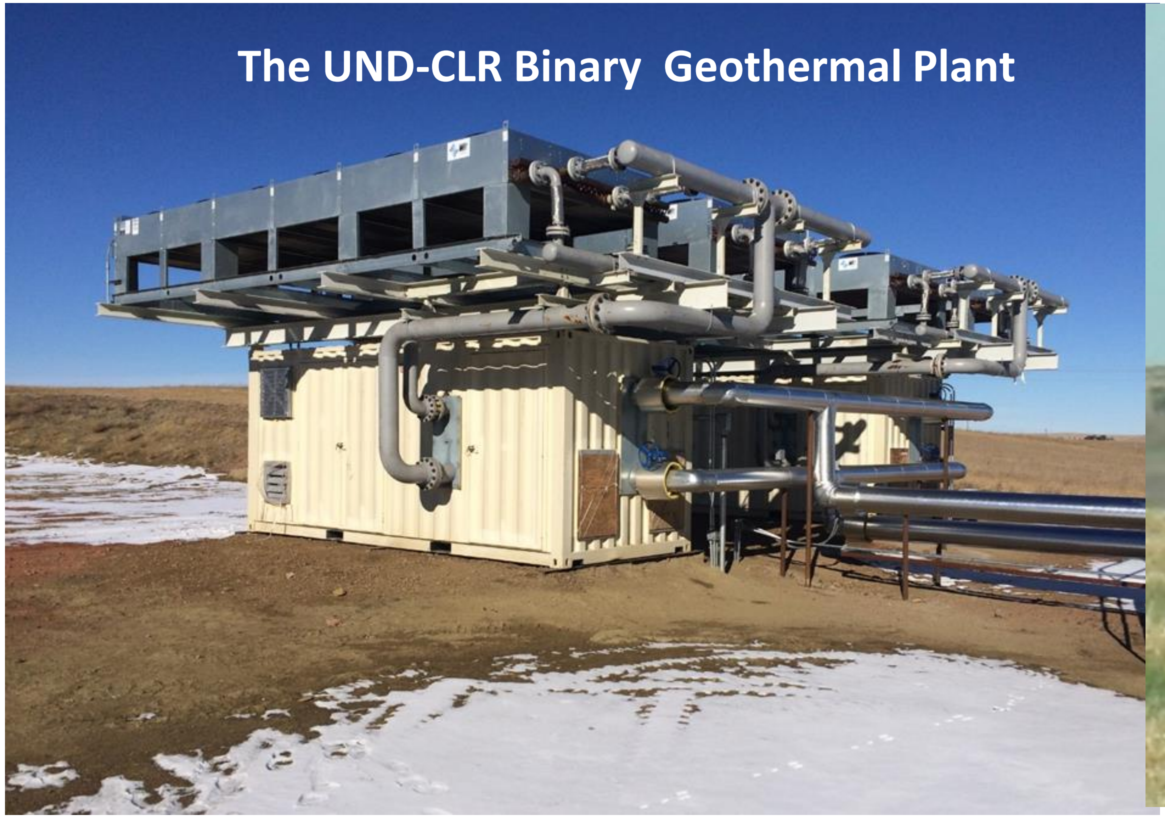
The Challenge

Decline in demand and price collapse have been particularly disruptive for shale oil extraction.

Survival and continuing operations depend on reducing operating costs, and the cost of electrical power for pumping wells increases continually.

The Bakken play in North Dakota is particularly vulnerable due to lack of an adequate electrical grid in the region.

Many Bakken fields rely on generators burning propane, gasoline or diesel fuel at costs about $0.28 per kWh - four times grid costs.



Meeting the Challenge

This 250 kW binary power plant could power six to ten 3.5 km deep Bakken wells.

- The western half of the Williston Basin is an energy giant
- 1,000 EJ of recoverable geothermal energy
- 4.4 to 11.4 billion barrels of technically recoverable oil

Co-produced Power from Oil Field Fluids

The Pie in the Sky

- The potential power production using oil field waste waters with ORC technology is estimated to be at least 5.9 GW and could be as high as 21.9 GW (McKenna et al., 2005; MIT - 2007).
- Requirements are: 1,000 gpm (63 l/s), for a well or a group of wells in relatively close proximity
- Temperatures of at least 90 °C (192 °F)

The Initial Concept for Co-Production

- “Collecting and passing the fluid through a binary system electrical power plant is a relatively straightforward process.”
- “Piggy-backing · · · should eliminate · · · expensive drilling · · · operations, thereby reducing the risk and · · · upfront cost of geothermal electrical power production.”

Source: "The Future of Geothermal Energy," MIT Report, January 22, 2007.

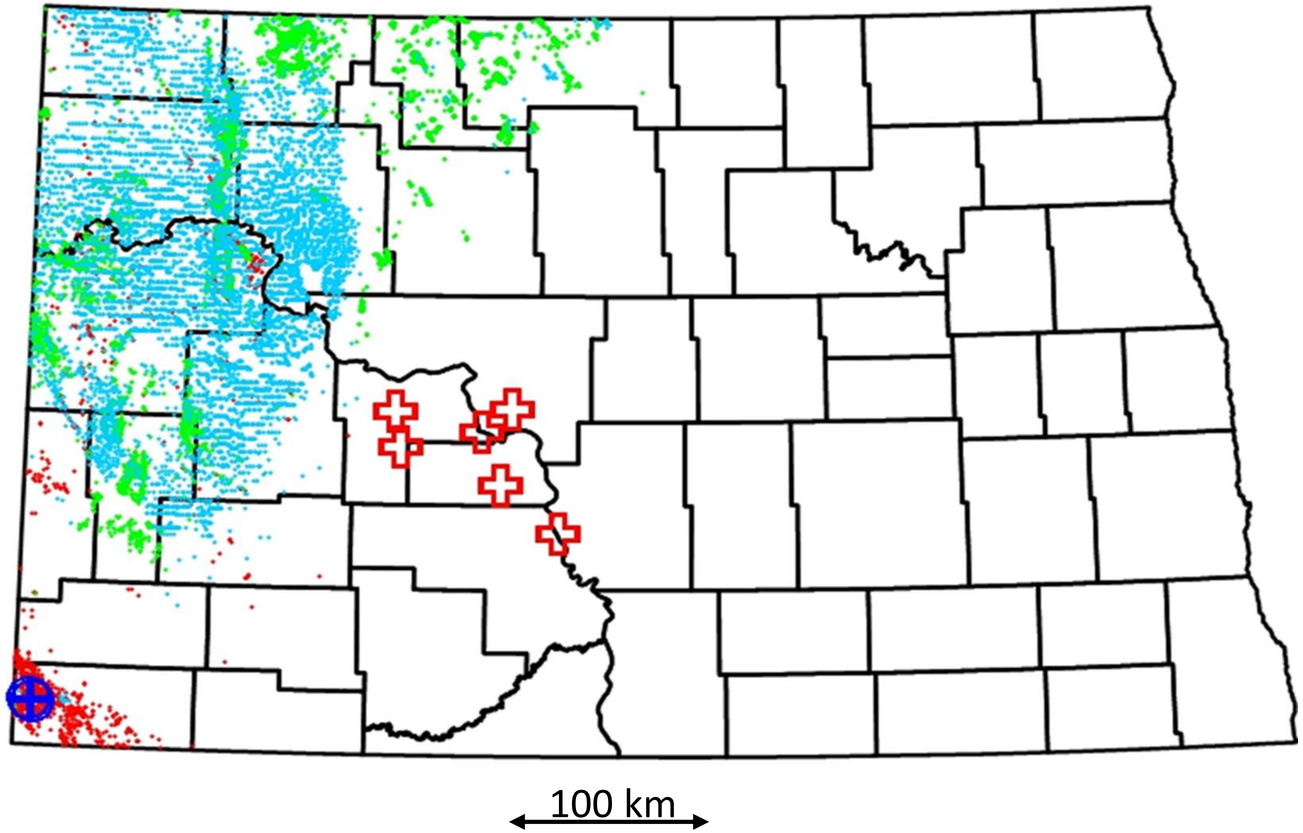
Can we move from Competitors to Partners?

- We have known of the geothermal resource for decades, but its development has been delayed for reasons which can be summed up as economic competition from existing fossil fuel energy sources (Williams et al., 2016).

This was our incentive for analyzing co-production in the Bakken

A great opportunity for distributed power

- 2,600 MW additional power needed to produce Bakken and Three Forks by 2032
- Existing power for ND-MT is from 6 coal or gas-fired power plants on Missouri River.
- Current supply for the boom is from diesel, propane & produced gas at ≈ 4X grid cost.



Colored dots are locations of the three top producing formations: Bakken = blue, Madison = green, Red River = red. Red crosses are locations of existing power plants. The Blue circle with a cross is the site of the UND-CLR Geothermal Power Plant.

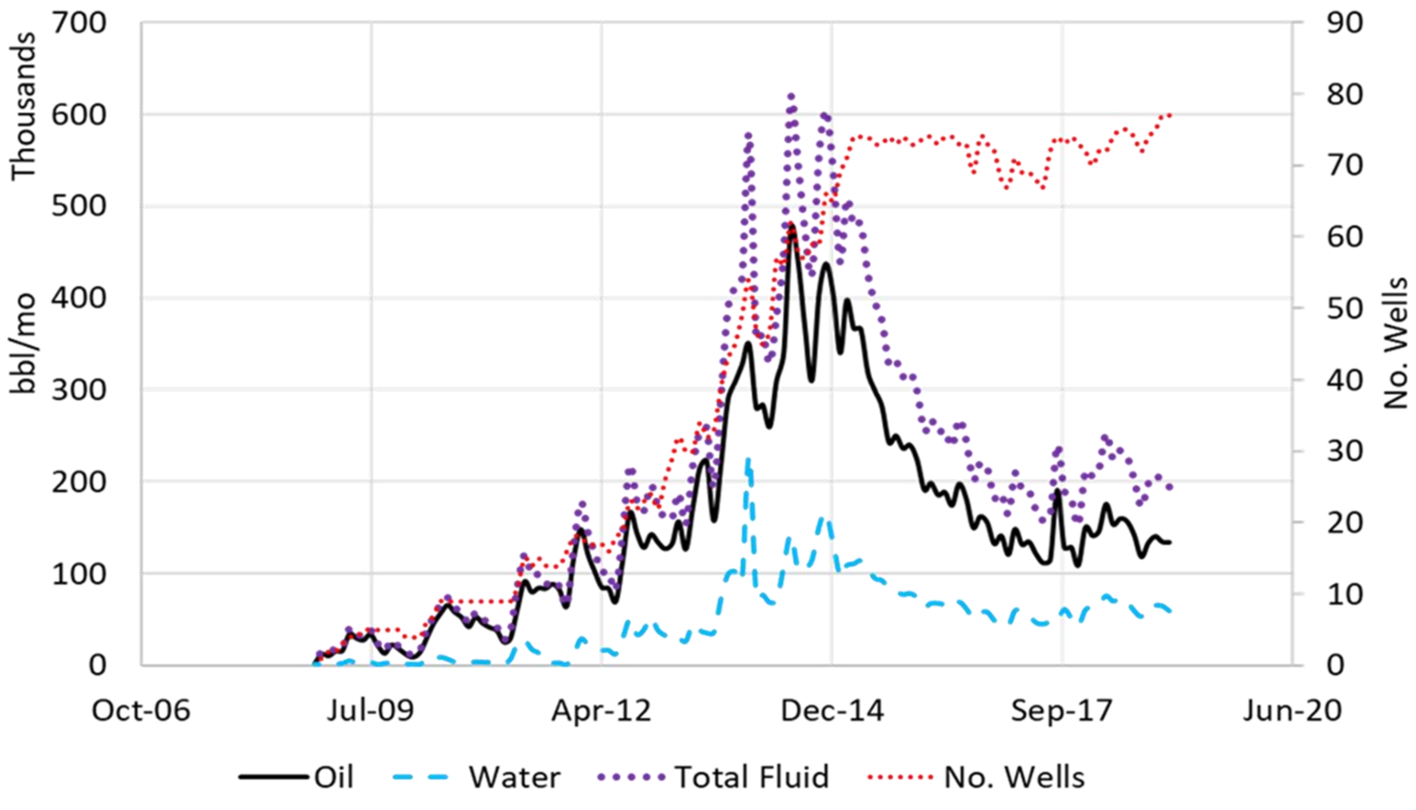
Encouraging results GRC 2019

- Our analyses indicated that Bakken oil fields could generate hundreds of kW to a few MW of electrical power (Vraa et al., 2019; Gosnold et al., 2019).
- Fluid production in the fields ranges from 100,000 bbl. per month (6 liters per second) to 1.5 million bbl. per month (91 liters per second).
- In situ temperatures range from 100 °C in the Sanish, Parshall and Heart Butte fields to 140 °C in the Banks and Siverston fields.

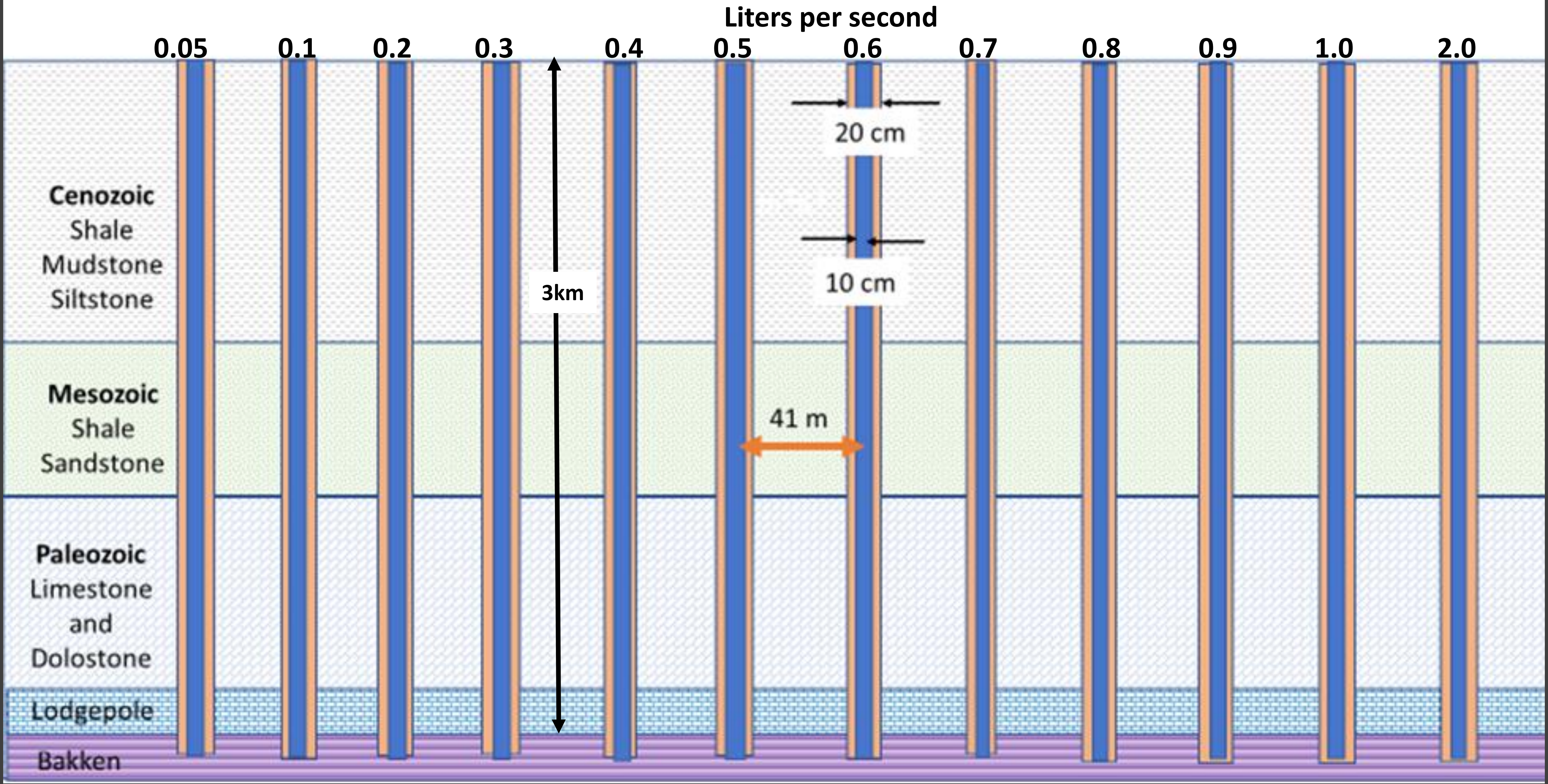
Mark Twain Quotation: *"It's not the things I don't know that cause problems, it's the things I know that aren't so."*

- We were confident in the formation temperatures (Gosnold et al., 2012; McDonald, 2015).
- The temperatures of the produced fluids at the surface are less than 70 °C.
- A significant amount heat must be lost during the 3.0 km trip to the surface.
- Although total field flow is high, individual well flow is very low.
- We learned that the average flow for a mature Bakken well is 0.2 l/s.

Time to Reanalyze



Model to test heat loss at different flow velocities in 3 km 4” tubing



Comparison of heat exchange surfaces in 2-D and 3-D models of fluid flow in vertical wells.
Surface area in 2-D model, A, is only half of the area represented by the cube, B, and the cylinder, C.

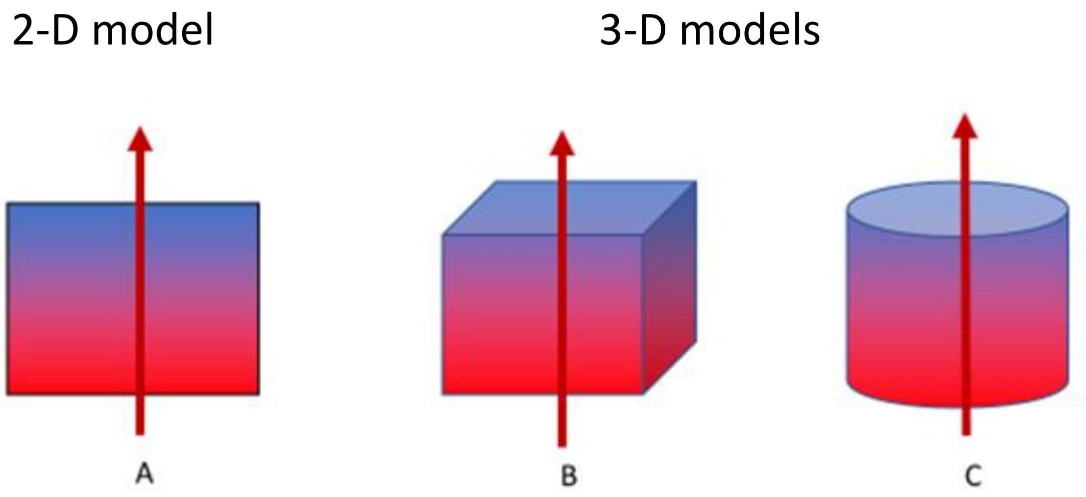
The message is that 2-D models underestimate heat loss and gain from pipes

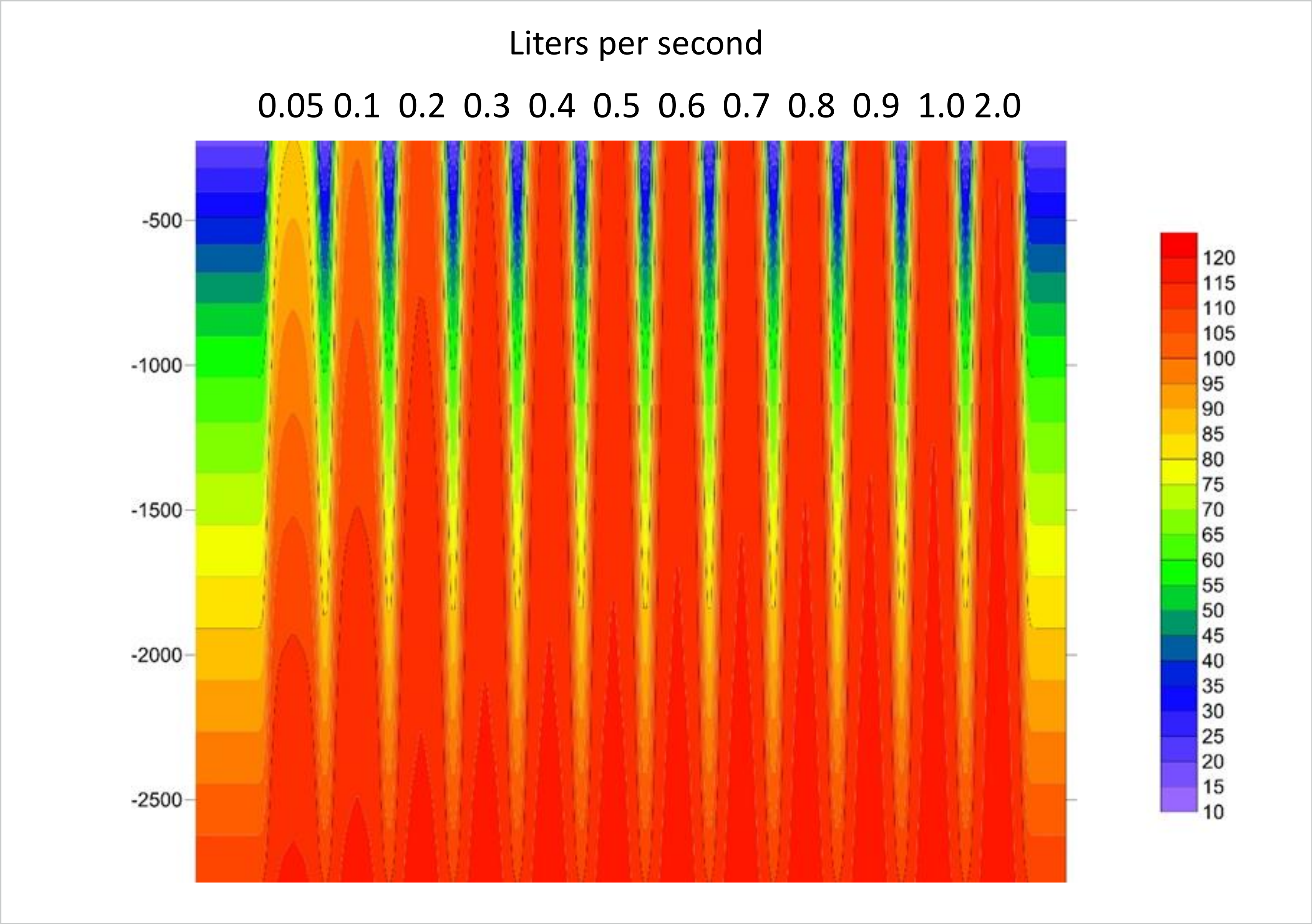
2 D model

Flow l s^{-1}	°C 1 d.	°C 1 wk.	°C 1 mo.	°C 1 y.
0.05	24.52	33.57	47.57	82.98
0.10	24.88	47.74	66.11	98.17
0.20	49.63	66.62	86.27	106.82
0.30	60.63	79.02	95.45	109.81
0.40	69.39	86.94	100.38	111.09
0.50	76.23	92.20	103.40	112.18
0.60	81.58	95.91	105.45	112.72
0.70	85.71	98.60	106.89	113.19
0.80	89.11	100.71	108.00	113.50
0.90	91.88	102.38	108.88	113.75
1.00	94.16	103.73	109.58	113.94
2.00	105.05	109.88	112.71	114.83

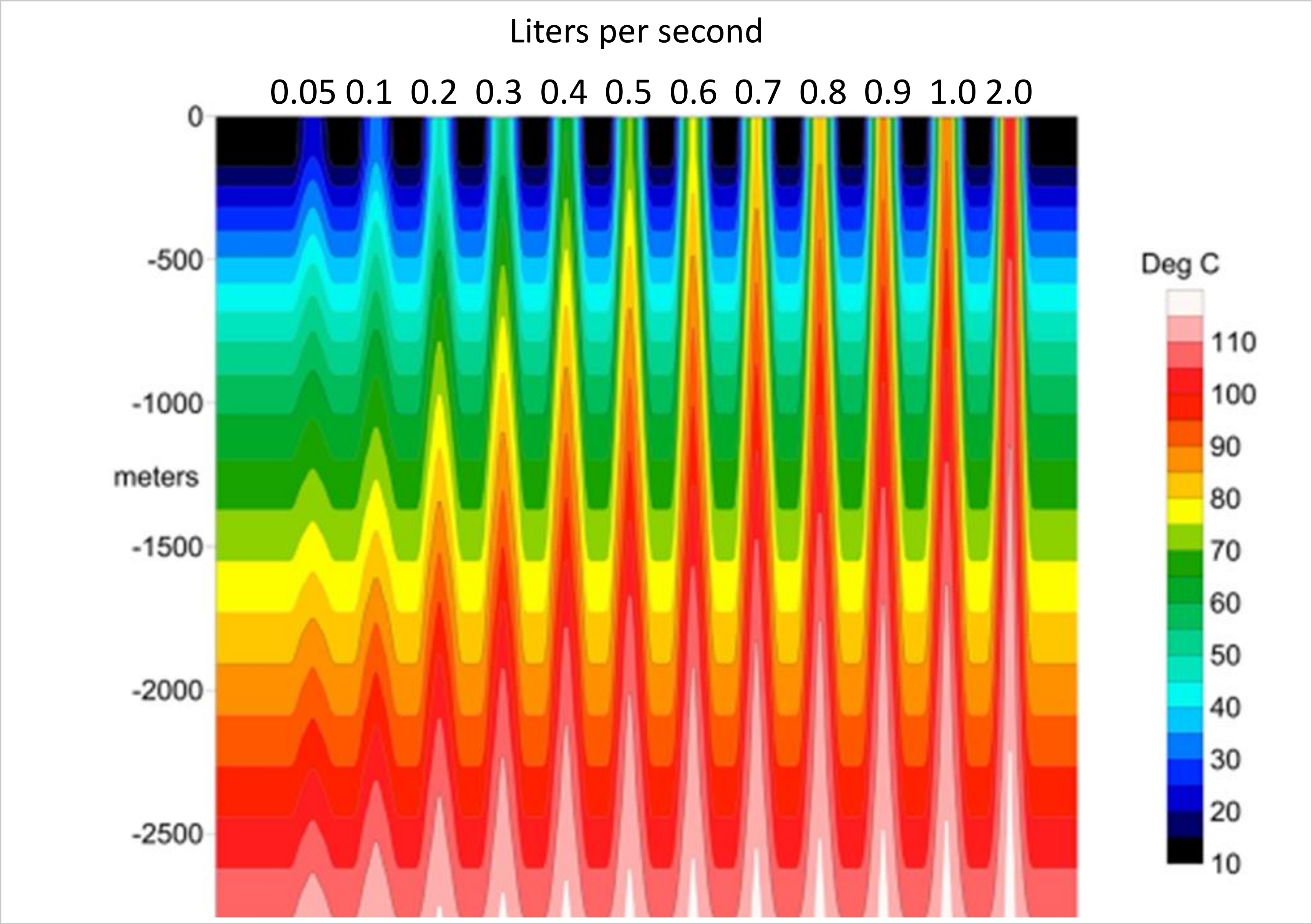
3 D model

Flow l s^{-1}	°C 2 y.
0.05	**31.01**
0.1	**44.26**
0.2	**62.53**
0.3	**74.31**
0.4	**82.15**
0.5	**87.62**
0.6	**91.66**
0.7	**94.98**
0.8	**97.12**
0.9	**99.08**
1.0	**100.7**
2.0	**104.13**





Simulated temperatures in 2-D models in 3-km vertical pipes at different velocities suggest that high formation temperatures reach the surface.

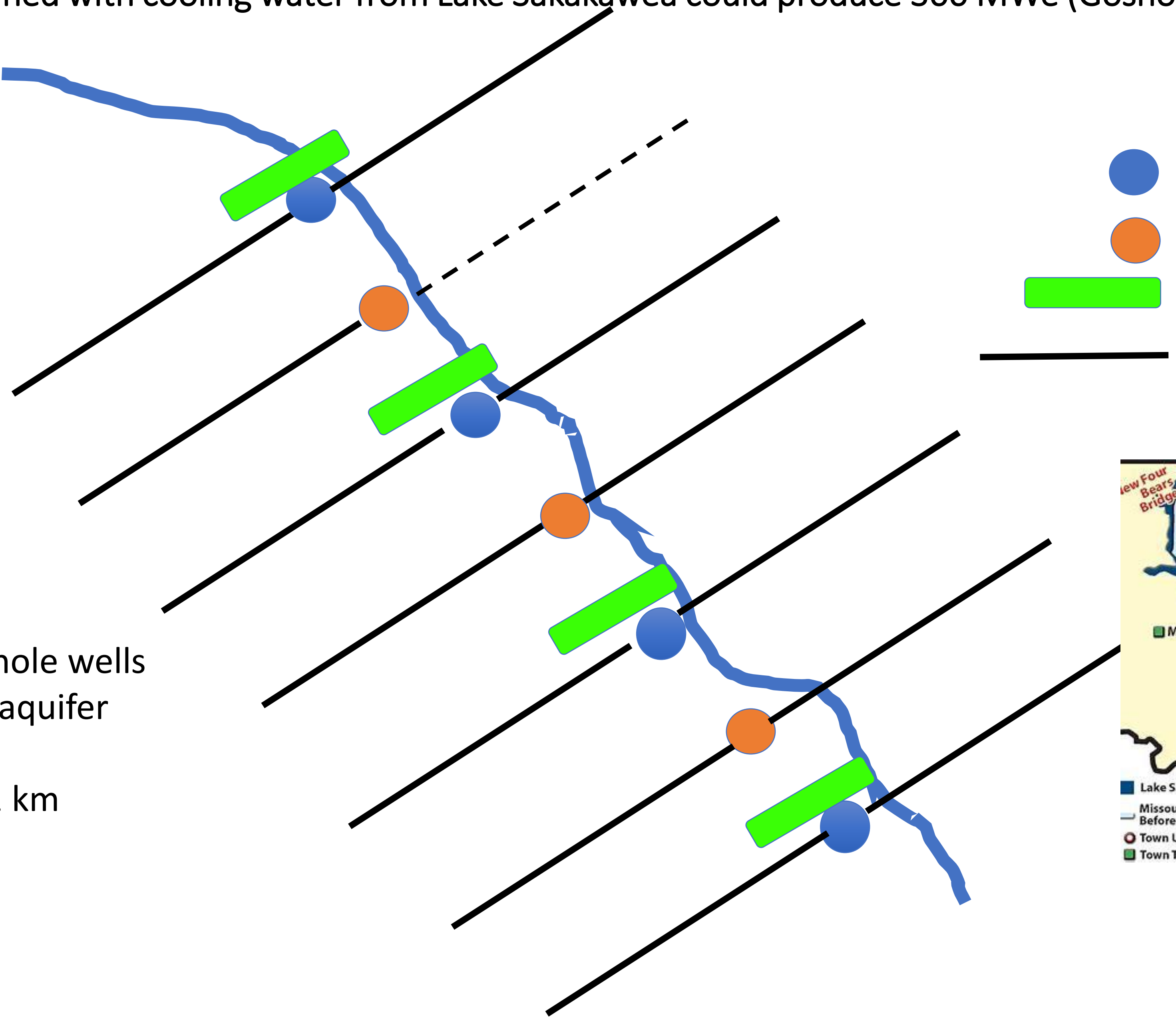


Simulated temperatures in 3-D models in 3-km vertical pipes at show that high formation temperatures do not reach the surface at average Bakken production velocities.

What would work? A distributed binary power well field.

Analysis of this arrangement using high-performance heat to power technology combined with cooling water from Lake Sakakawea could produce 300 MWe (Gosnold et al., 2017).

Lake Sakakawea



1 km lateral open hole wells in the geothermal aquifer

Well spacing 1 to 2 km
To be determined

Conclusions

- Co-production requires flow rates of 10s l/s to be profitable for oil field support.
- Bakken wells do not produce enough flow for co-production.
- 2-D models should be replaced by 3-D models.
- The promising concept is lateral wells in hot permeable formations.
- Cascading hot water for multiple use is preferred for all applications.

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