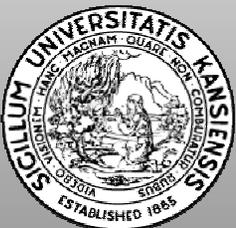


A Review of Gel Polymer Treatments in the Arbuckle Formation of Kansas

For West Coast PTTC Workshop

**Hyatt Valencia Conference Center
Valencia, California
Thursday, January 23, 2003**

**Rich Pancake
Tertiary Oil Recovery Project
University of Kansas**



Acknowledgements

Wish to thank –

TIORCO and Gel-Tec for help in collecting treatment data and with operator contacts.

Vess Oil Company and Murfin Drilling Company for help in collecting data and for permission to share that data.

Trilobite well testing for BHP surveys.

Presentation Outline

- **Background on TORP and Kansas Arbuckle Formation/Production**
- Review of Kansas Arbuckle Polymer Treatments
- TORP's Efforts in Evaluating Arbuckle Polymer Treatments
- Future TORP/PTTC Activities Related to Arbuckle Polymer Treatments

What is TORP?

- **TORP is the Tertiary Oil Recovery Project.**
- **TORP was established in 1974 to help producers apply EOR in Kansas reservoirs.**
- **TORP is affiliated with the Chemical and Petroleum Engineering Department at the University of Kansas.**
- **TORP employs 7 full-time staff and 6 to 12 graduate students/post doctorates per year.**

What is TORP?

- **TORP is guided by an advisory board of Kansas producers, petroleum consultants, service company personal, and petroleum scholars.**
- **TORP conducts laboratory and field research geared towards maximizing production from Kansas reservoirs.**
- **TORP conducts tech transfer via a biennial Oil Recovery Conference and its affiliation with the North Midcontinent Resource Center of PTTC.**

What is TORP?

● Current TORP Activities

University Research

- Laboratory research on perm modification (gel polymers)
- Computer reservoir simulation
- Crude oil minimum miscibility pressure (MMP) measurements for CO₂ flooding

Field Research/Field Demonstrations

- *Gel polymer treatments in the Arbuckle formation*
- Miscible CO₂ flooding in Central Kansas

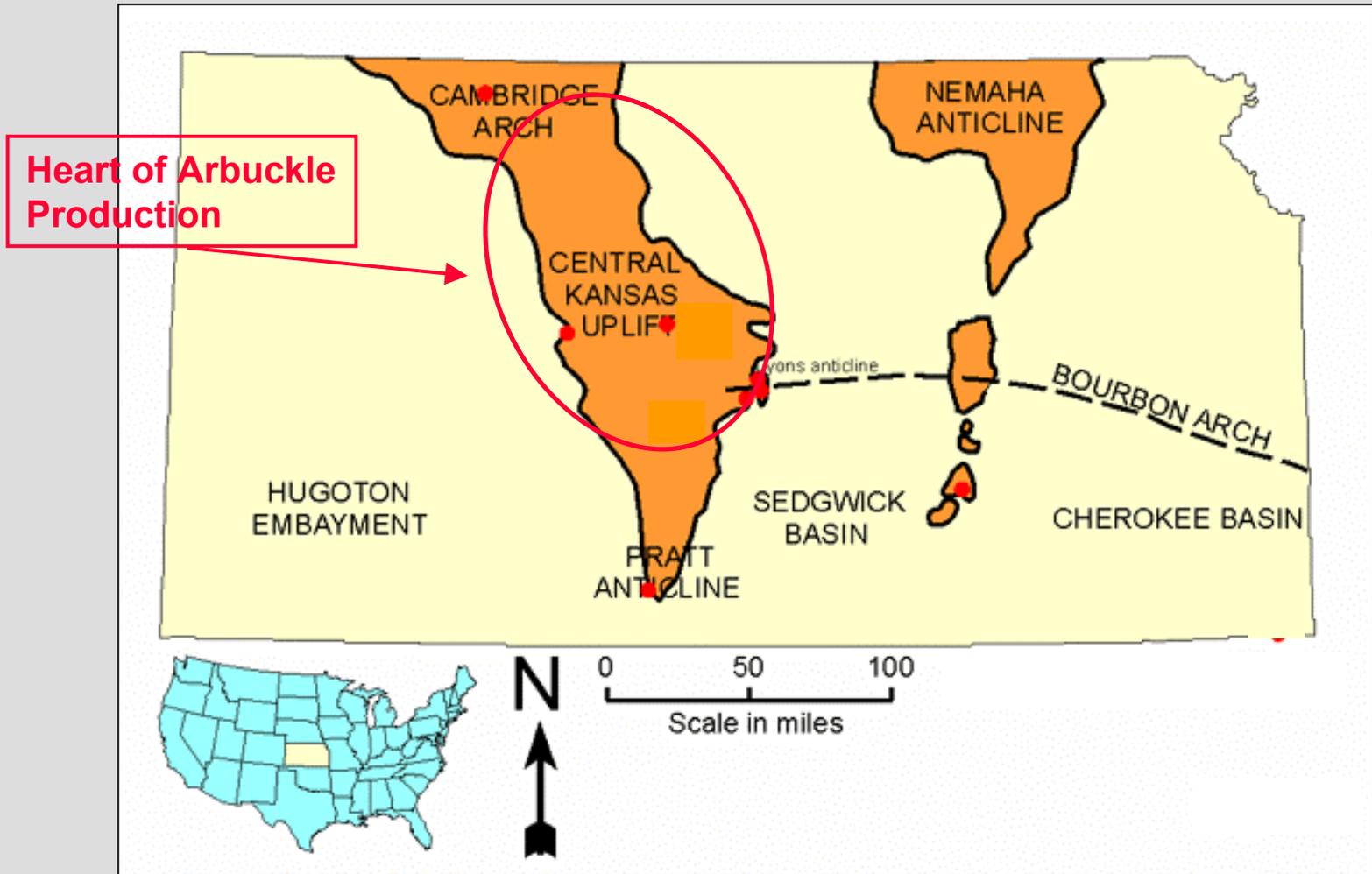
Technology Transfer

- North MidContinent Resource Center of PTTC

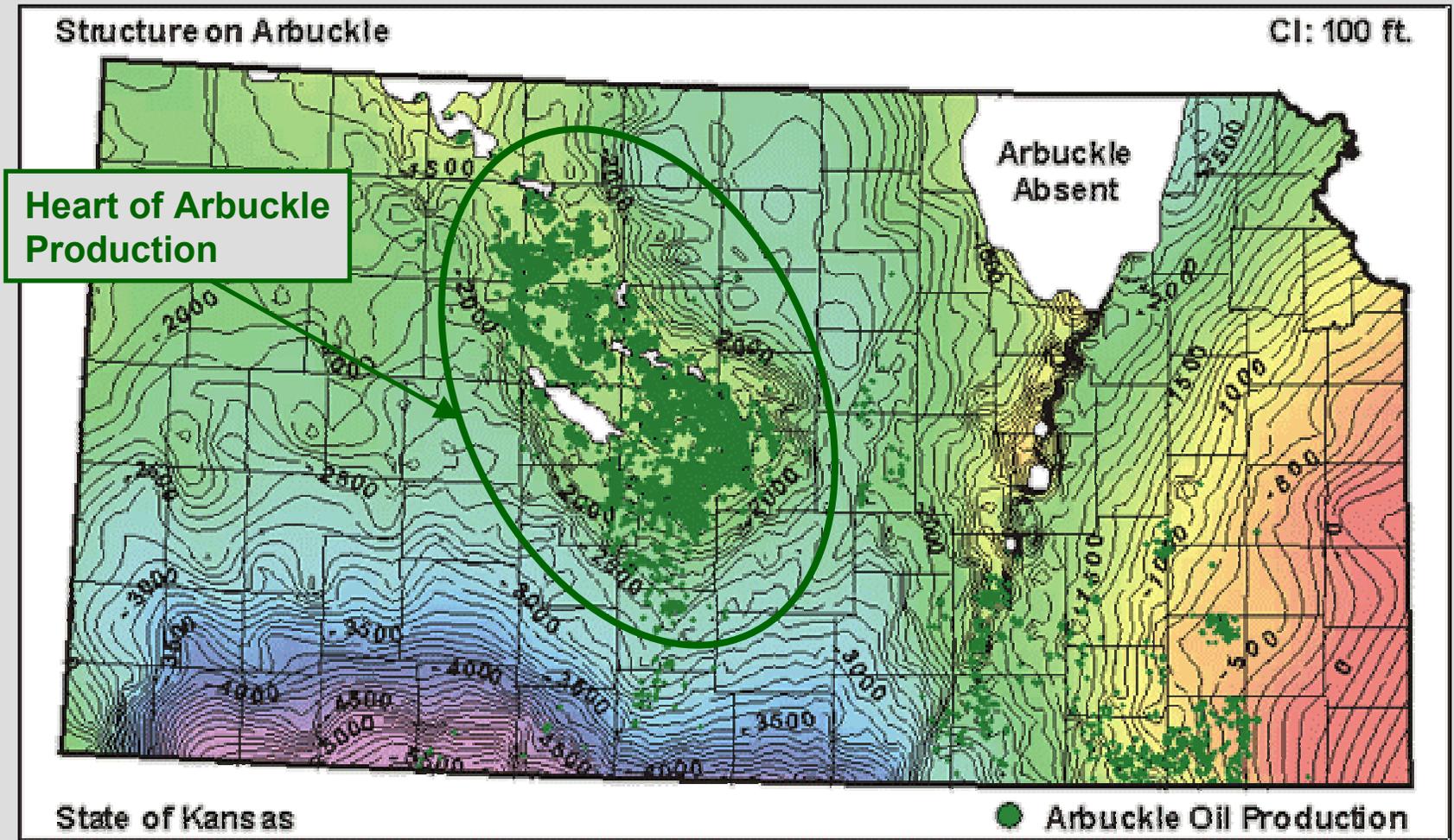
Arbuckle Formation/Production

- **Formation covers most of Kansas.**
- **Dolomite formation having Karst features.**
 - 3000 to 3500 feet deep in major producing area.
- **First oil production in +/- 1920's.**
- **Most prolific producing horizon in Kansas.**
- **Strong water-drive reservoir.**
- **Geology not well understood.**
 - Debate as to whether flow is from fracture or high-perm streaks.
- **High volume wells > 1000 BPD w/ 1% oil or less.**

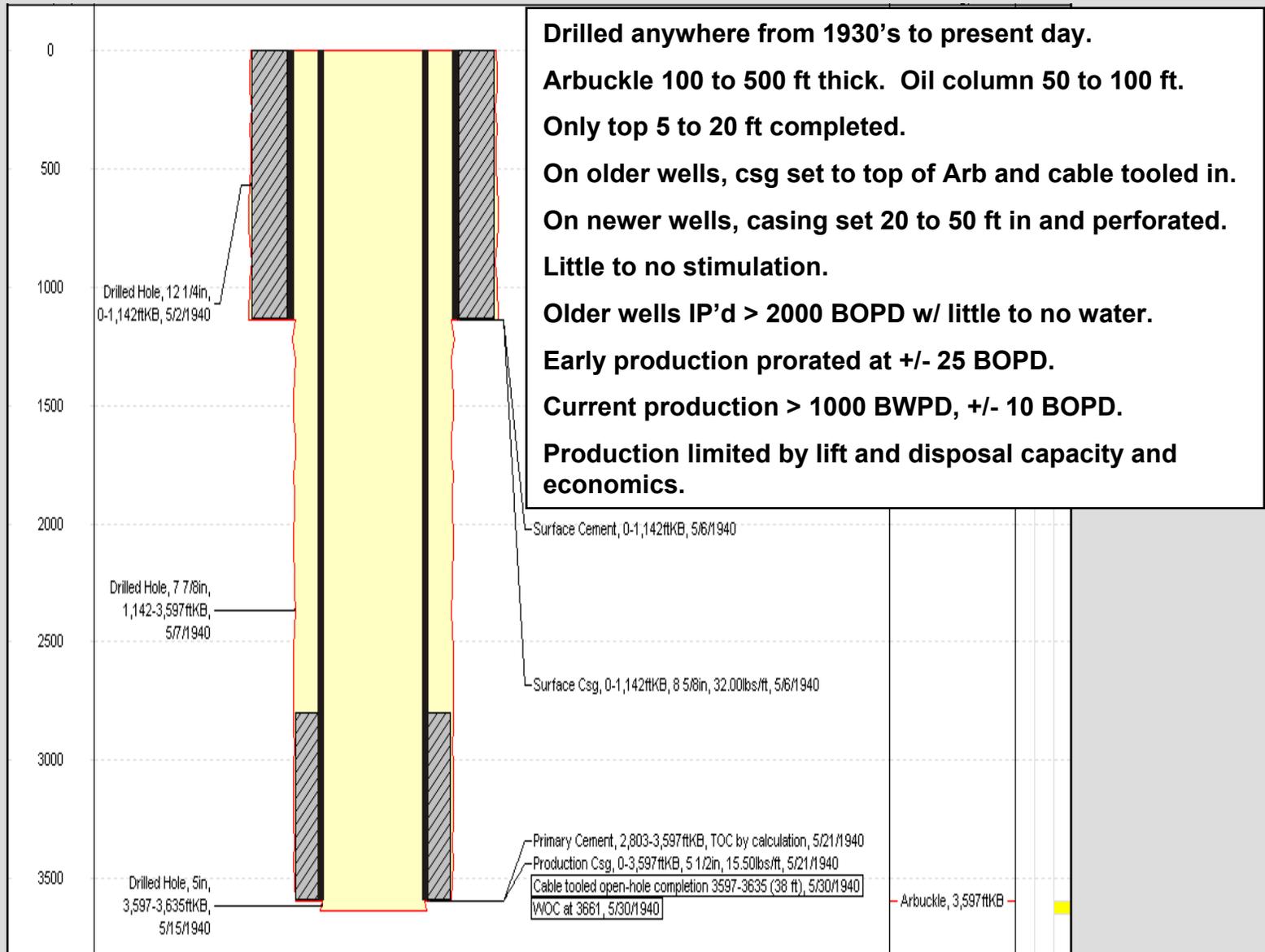
Kansas Geologic Features



Kansas Arbuckle Structure



Typical Arbuckle Well



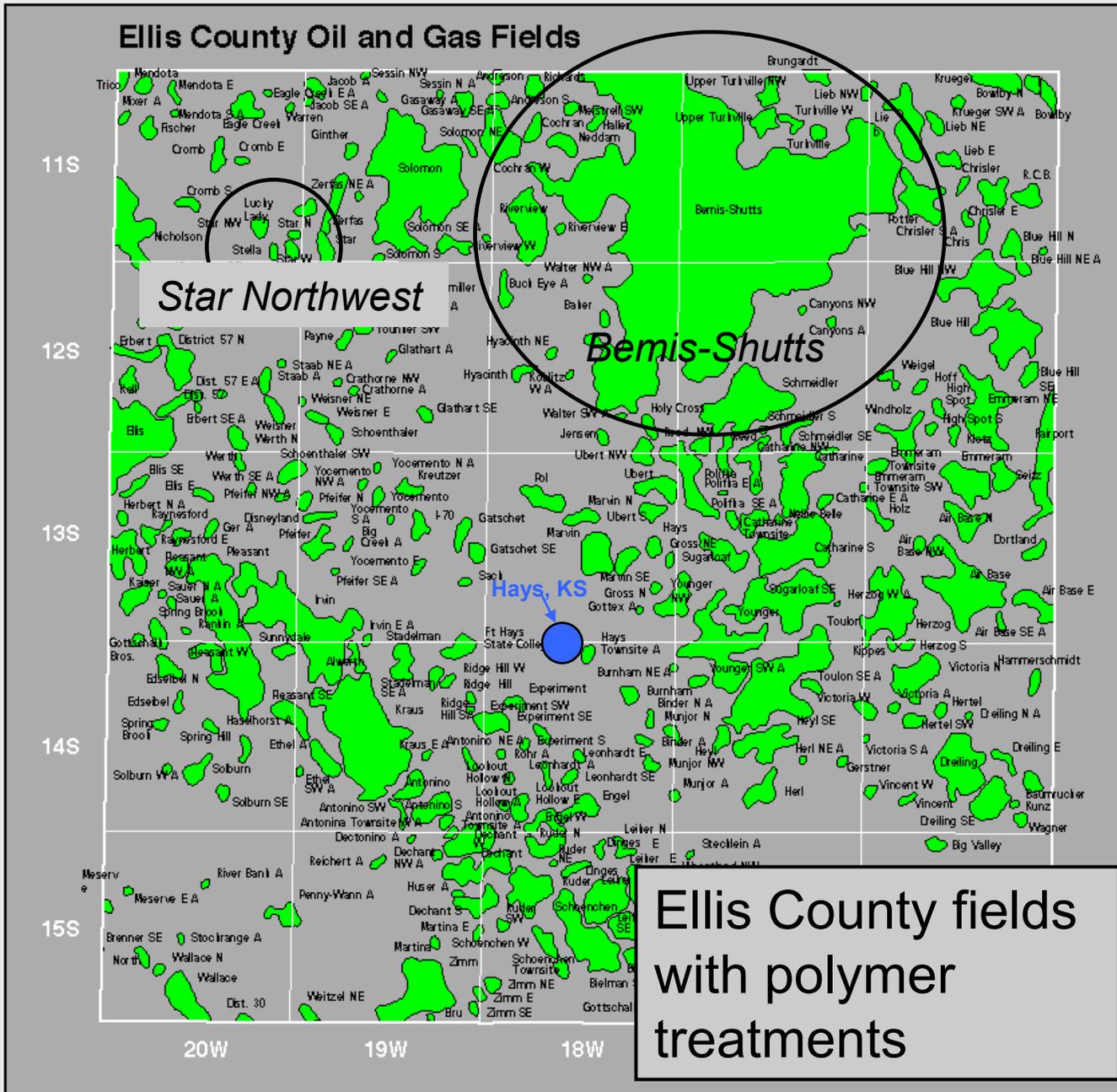
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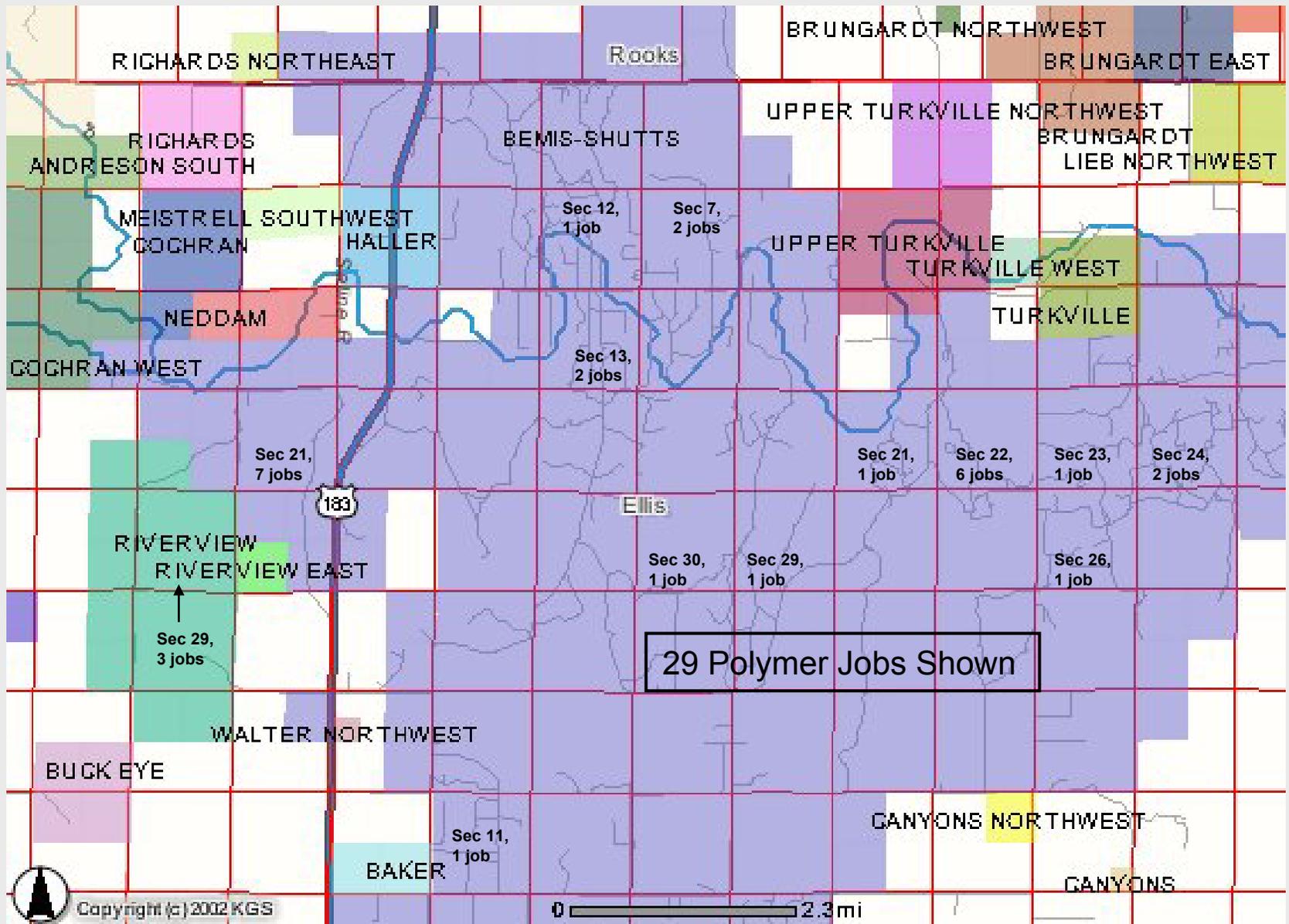
Review of Arbuckle Polymer Treatments

- **+/- 130 MARCIT technology polymer jobs pumped in the Arbuckle since 2000**
 - +/- 75 by TIORCO
 - +/- 55 by Gel-Tec
- **Treatment locations**
 - +/- 60 % of jobs pumped in Bemis-Shutts Field
 - Remainder pumped in Marcotte, Star Northwest, Northampton, Jelinek, Ogallah, Trapp, Geneseo-Edwards, and other fields

Ellis County Oil and Gas Fields



Polymer Treatments in Bemis-Shutts



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Review of Arbuckle Polymer Treatments

- **Well selection criteria**
 - **Well drilled up structure**
 - **Well originally had high, water-free IP**
 - **Well at its economic limit because of high WOR**
 - **Well has very high fluid level**
 - **Well has high calculated flow potential**

Review of Arbuckle Polymer Treatments

- **Treatment design criteria**

Vender 1

- For high fluid level wells, pump 2x well's daily production, up to 4000 bbls.
- For low fluid level wells, pump 1x well's daily production.
- Surface treating pressure not to exceed 200 psig.

Vender 2

- Gel volume pumped to be near well's calculated maximum inflow, up to 4000 bbls.
- Surface treating pressure to be between 200 and 400 psig.

Review of Arbuckle Polymer Treatments

- **Typical treatment design**

- **Pull pump & tbg. Sand pump well. RIH w/ tbg & packer. Set pkr +/- 100 ft above interval.**
- **Acidize well w/ between 250 & 1500 gals 15% HCl.**
 - **Recent trend appears to be towards the larger, 1500 gal acid jobs.**
- **Pump polymer down tbg.**
 - **Small job - 1000 to 1600 bbls.**
 - **Large job - 3000 to 4100 bbls.**
 - **Larger jobs are typically in Bemis.**
 - **Recent trend may be to pump even larger jobs.**

Review of Arbuckle Polymer Treatments

- **Typical treatment design (cont'd)**
 - **Pump polymer down tbg (cont'd).**
 - Gel loadings increase in 3 to 4 stages – 3500, 4000, 5000, and 6500 ppm.
 - Recent trend appears to be to increase gel loading at end of job to 7500 or 8500 ppm.
 - **Flush tbg w/ oil or water.**
 - Typically 100 bbl water flush.
 - Typically 50 to 100 bbl oil flush.
 - Philosophy of oil or water flush varies among operators.
 - **Shut-in well 7 to 14 days. Return well to production.**

Review of Arbuckle Polymer Treatments

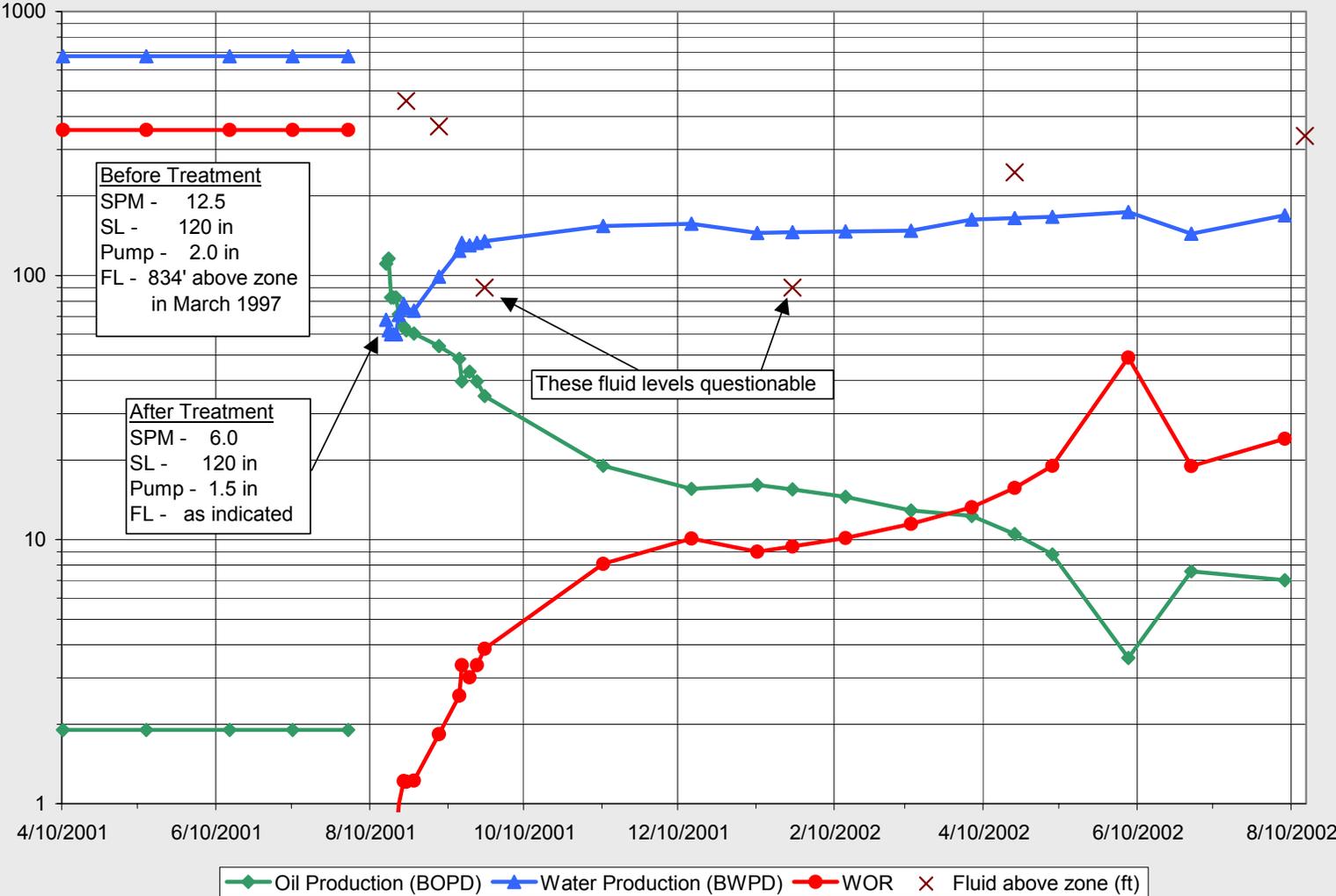
**Polymer treatment examples –
Average to below average jobs**

Example of Nice Initial Response

Murfin's Johnson B #3A Polymer Job

August 2-3, 2001

(1621 bbls gel, 97% of job treated on a vacuum, 51 psig max treating press)

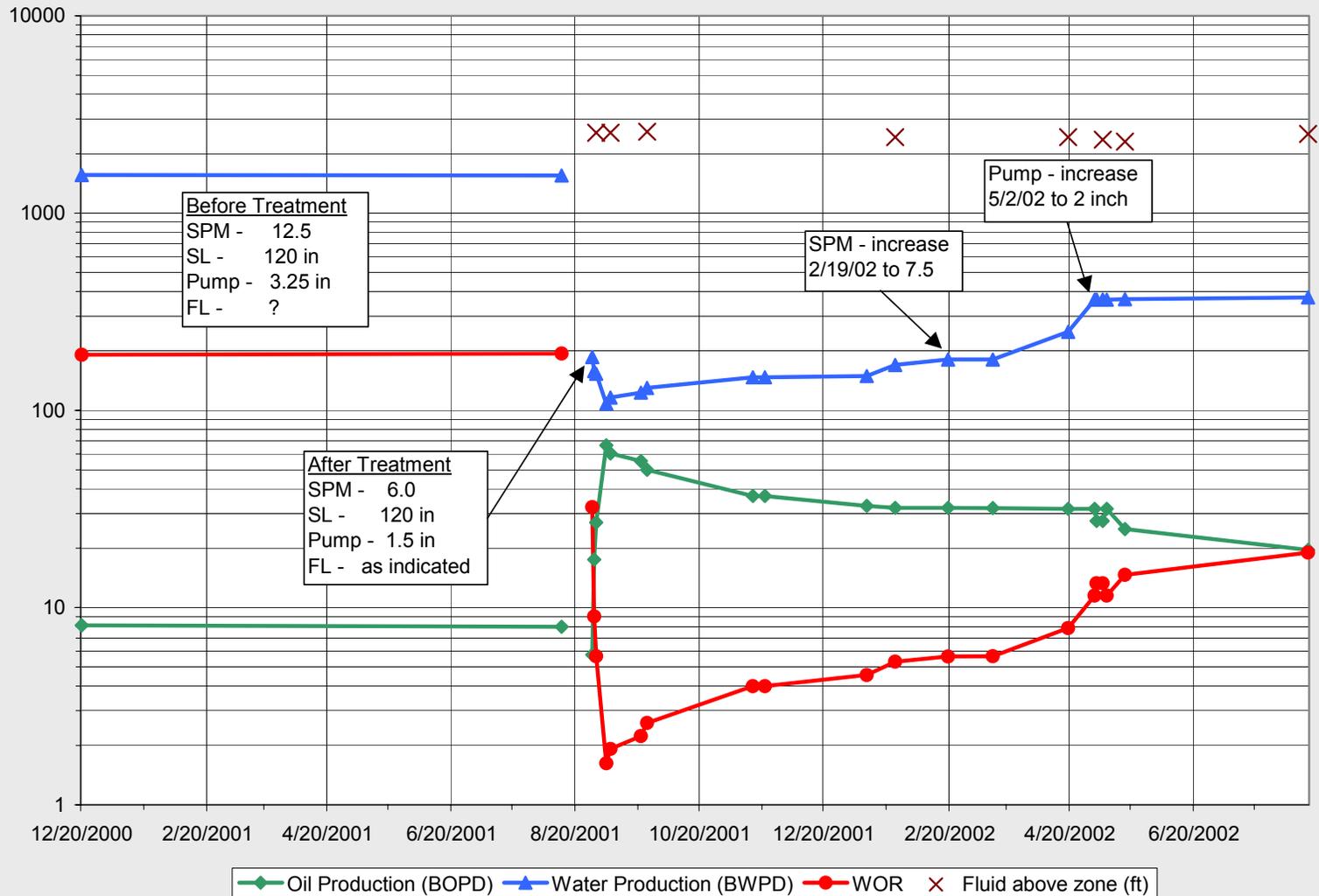


Example of Average to Good Response

Murfin's Hadley BC #10 Polymer Job

August 14-18, 2001

(3806 bbls gel, 100% of job treated on a vacuum, 0 psig max treating press)

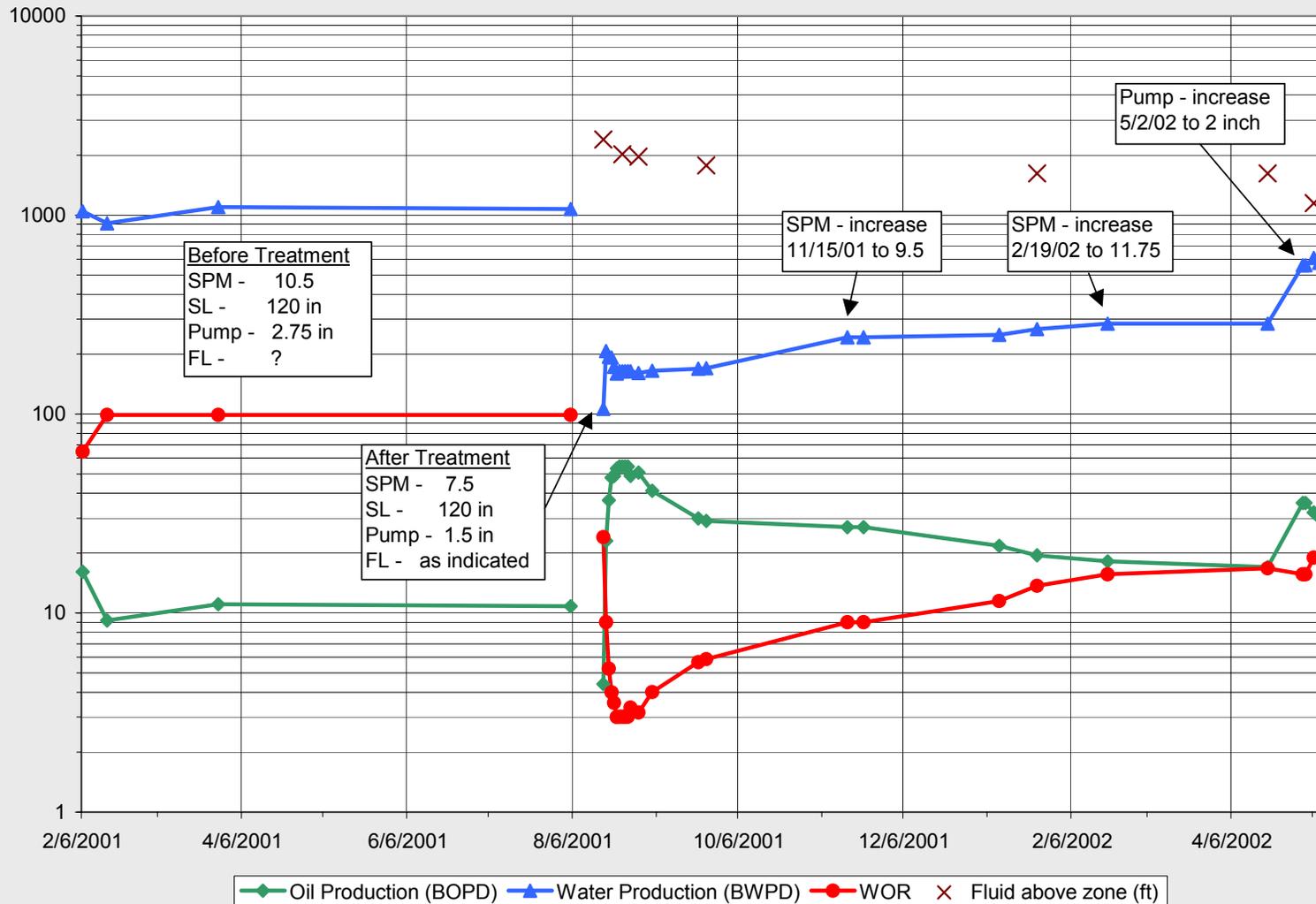


Example of Average to Good Response

Murfin's Jorgensen #4 Polymer Job

August 6-9, 2001

(3805 bbls gel, 58% of job treated on a vacuum, 102 psig max treating press)

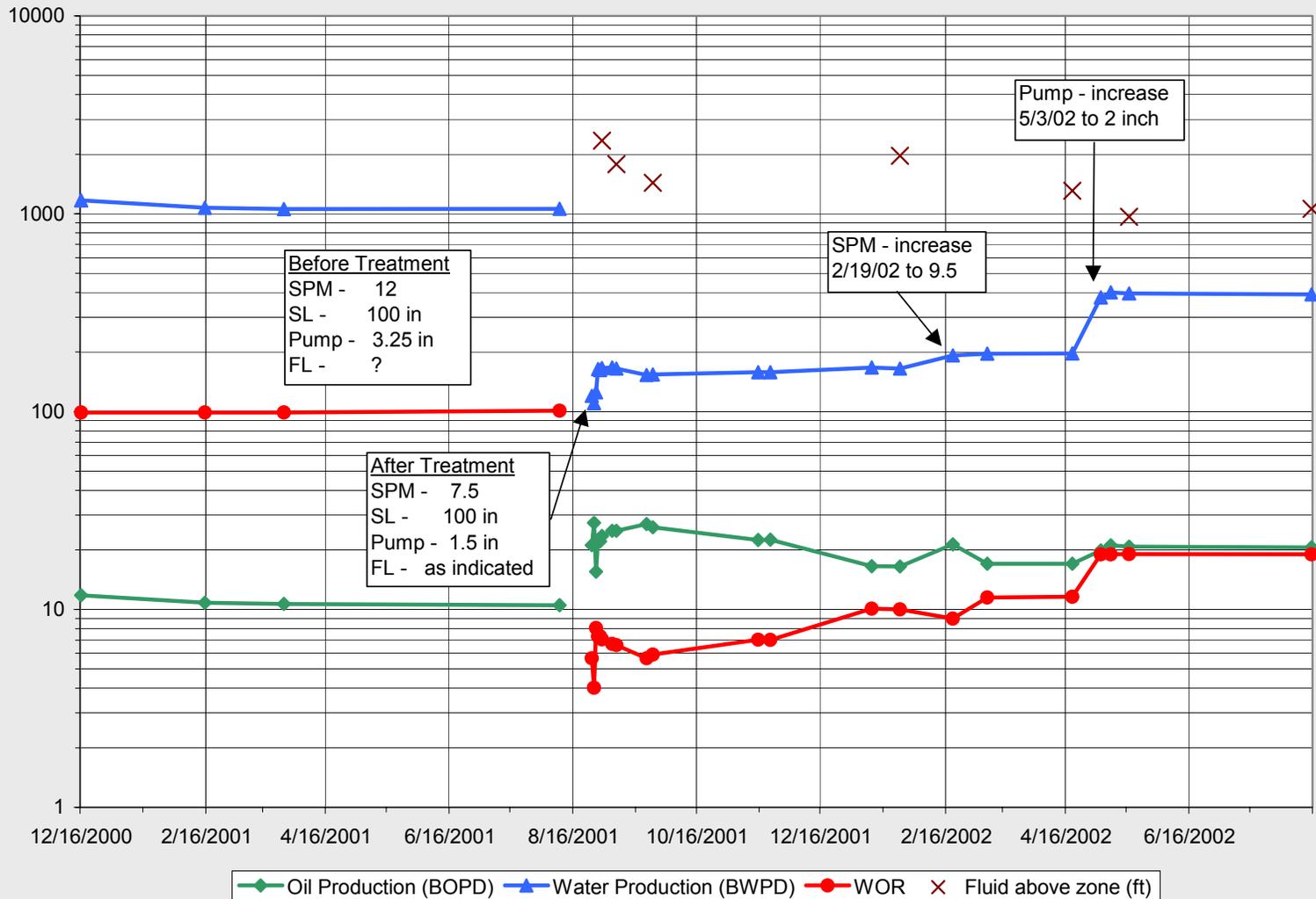


Example of Average to Good Response

Murfin's Peavey A-6 Polymer Job

August 10-13, 2001

(3806 bbls gel, 64% of job treated on a vacuum, 446 psig max treating press)

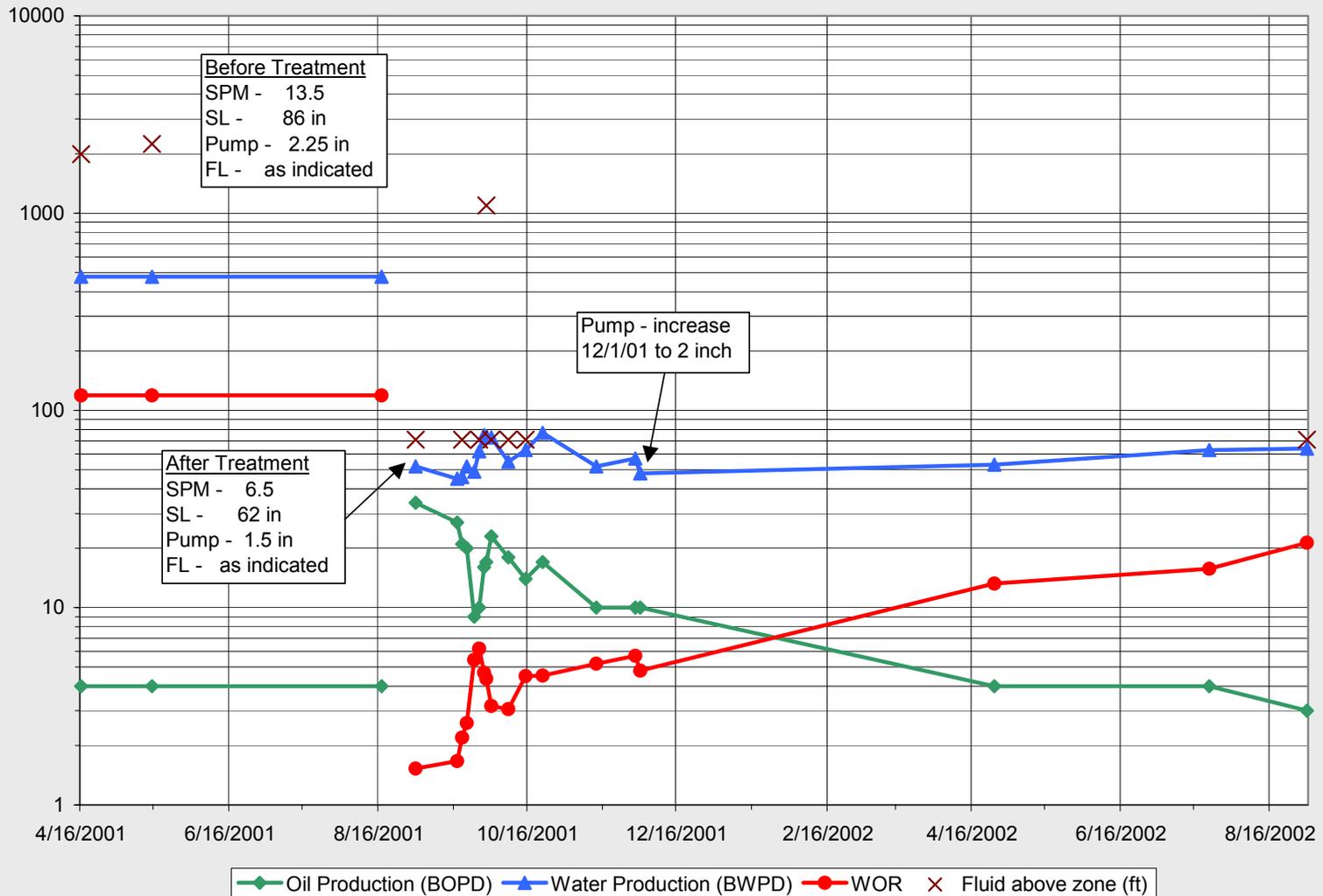


Example of Poorer Response

Vess's Colahan A #41 Polymer Job

August 18-21, 2001

(2988 bbls gel, 8.2% of job treated on a vacuum, 923 psig max treating press)

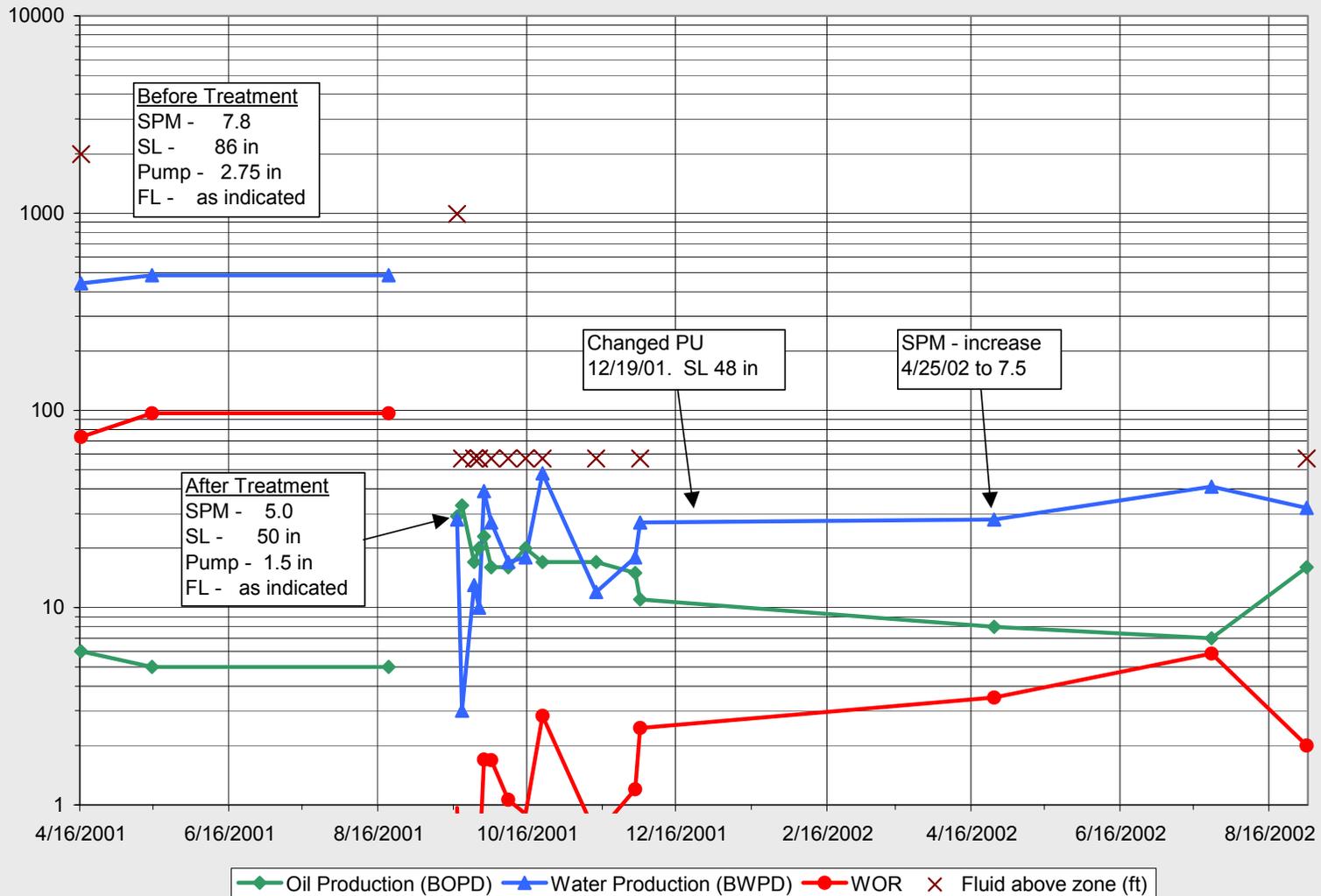


Example of Poorer Response

Vess's Colahan A #2 Polymer Job

August 26-30, 2001

(4093 bbls gel, 29% of job treated on a vacuum, 591 psig max treating press)

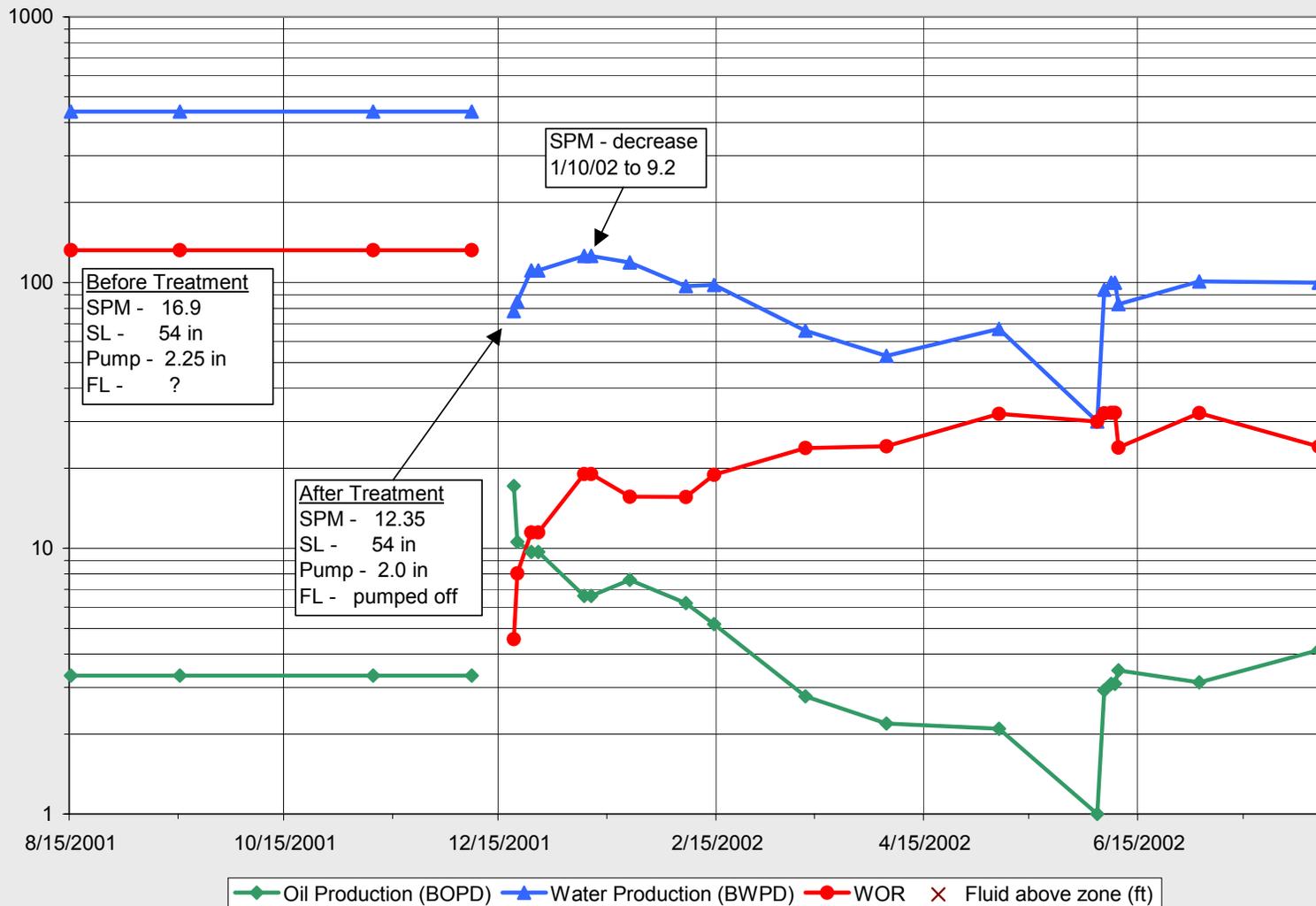


Example of Poorest Response

Murfin's Glathart #1 Polymer Job

December 8-9, 2001

(1007 bbls gel, 0% of job treated on a vacuum, 200 psig max treating press)



Review of Arbuckle Polymer Treatments

- **Job costs**

- **Gel cost**

- \$35 M to \$45 M for larger jobs (+/- 4,000 bbl)
- \$15 M to \$20 M for smaller jobs (+/- 1,500 bbl)

- **Rig & acid costs**

- \$5 M to \$10 M depending on rig time & volume acid

- **Total costs**

- \$40 to 55 M for large jobs
- \$20 to 30 M for small jobs

Review of Arbuckle Polymer Treatments

- **Pay-out** (*based only on incremental oil recovery, water reduction savings not considered*)
 - **3 to 6 month pay-out for average performing jobs**

Assumptions

- +/- 18 BOPD/well incremental oil recovery for 6 months
- \$22/bbl oil price
- \$45 M job cost

- **Three poorest performing jobs did not pay-out**

Assumptions

- +/- 6 BOPD/well incremental oil recovery for 6 months
- \$22/bbl oil price
- \$45 M job cost



Murfin's Hadley A #3 Polymer Job



TIORCO's Polymer Injection Equipment



TIORCO's Polymer Mixing Hopper



Gel-Tec Polymer Job on an Elysium Well



Pumping into well



Tri-plex pump and crosslinker storage



Computer Monitors

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- **TORP's Efforts in Evaluating Arbuckle Polymer Treatments**
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TORP's Efforts

- **Objective – help operators maximize gel polymer treatment performance.**
- **Develop comprehensive database by which to compare all Arbuckle gel polymer treatments.**
 - **Hope to spot trends that lead to improved treatments.**
 - **Have contacted several operators requesting information on gel polymer treatments.**
 - **Getting some positive feedback and information.**

TORP's Efforts

- **Conduct and analyze pre and post-treatment build-up tests using TORP's computerized Echometer.**
 - **Measure formation kh and skin.**
 - **Determine if reservoir flow is linear (through fracture) or radial (through matrix).**
 - **For pre-treatment build-ups, attempt to predict how much polymer a well will take.**
 - **Have performed pre-treatment build-ups on 7 Arbuckle wells.**
 - 5 in Bemis-Shutts
 - 2 in Geneseo-Edwards

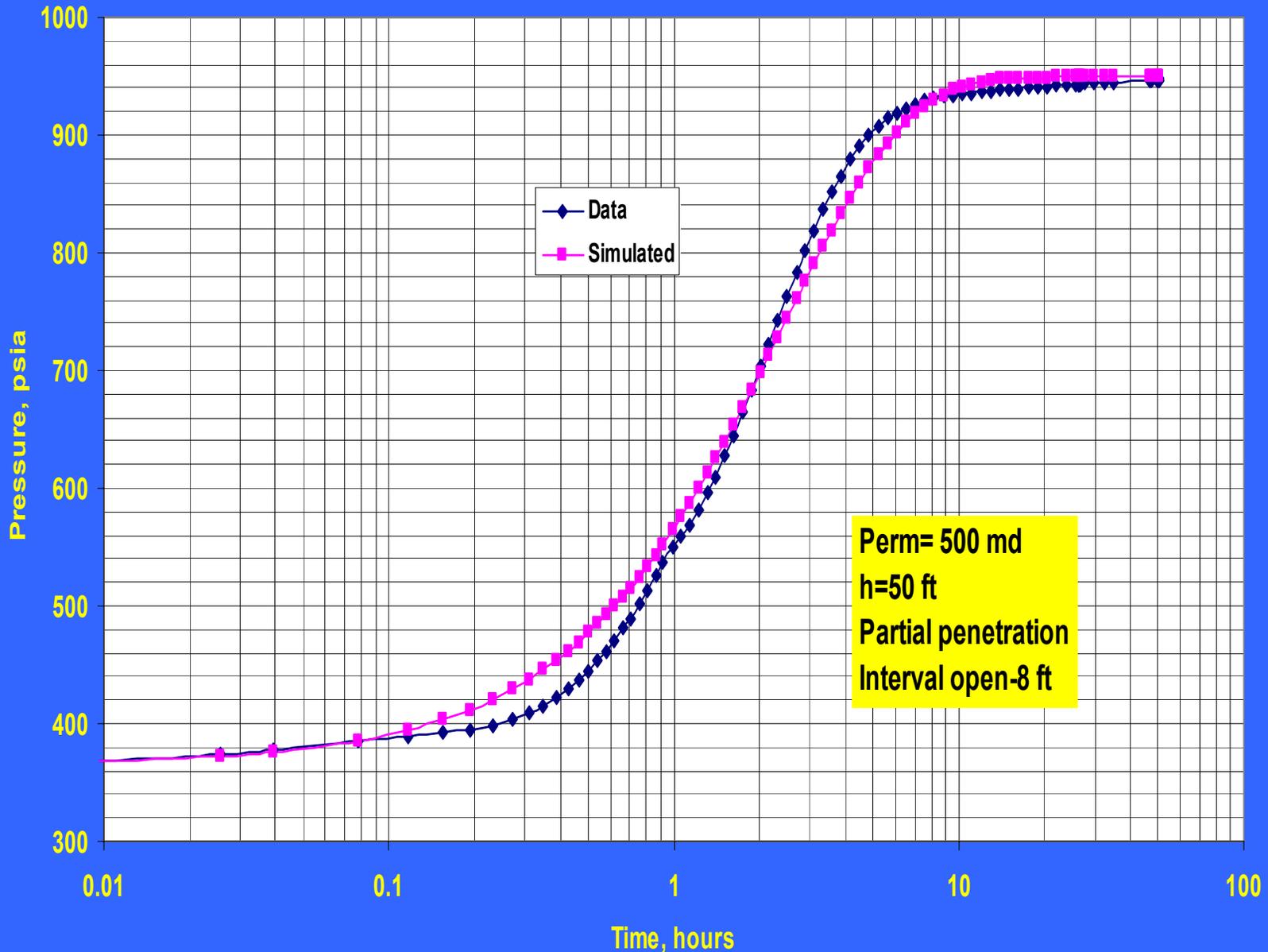


Build-up Test on Vess Oil's McCord A #4

TORP's Efforts

- **Pre-treatment build-up on Vess Oil's Hall B #4.**
 - **Bemis Shutts Field – Ellis County**
 - **Depth – 3423 ft**
 - **Net pay open – 10 ft**
 - **Water production – 611 BPD**
 - **Oil production – 6 BPD**
 - **Static BHP – 935.3 psig**
 - **Producing BHP – 501.0 psig**

Build-up Analysis – Hall B #4



TORP's Efforts *

- **Analyze bottom-hole pressure (BHP) surveys run on 6 wells.**
 - **Bottom-hole pressure measured (via pressure bomb on slickline) before, during, and after gel treatment.**
 - **Hope to gain insights into the gel/rock interface, which should help in sizing treatments and setting maximum treating pressures.**
 - **Hope to determine a friction coefficient for pumping gel down tubing.**

*** *With financial assistance from vendors and oil companies***

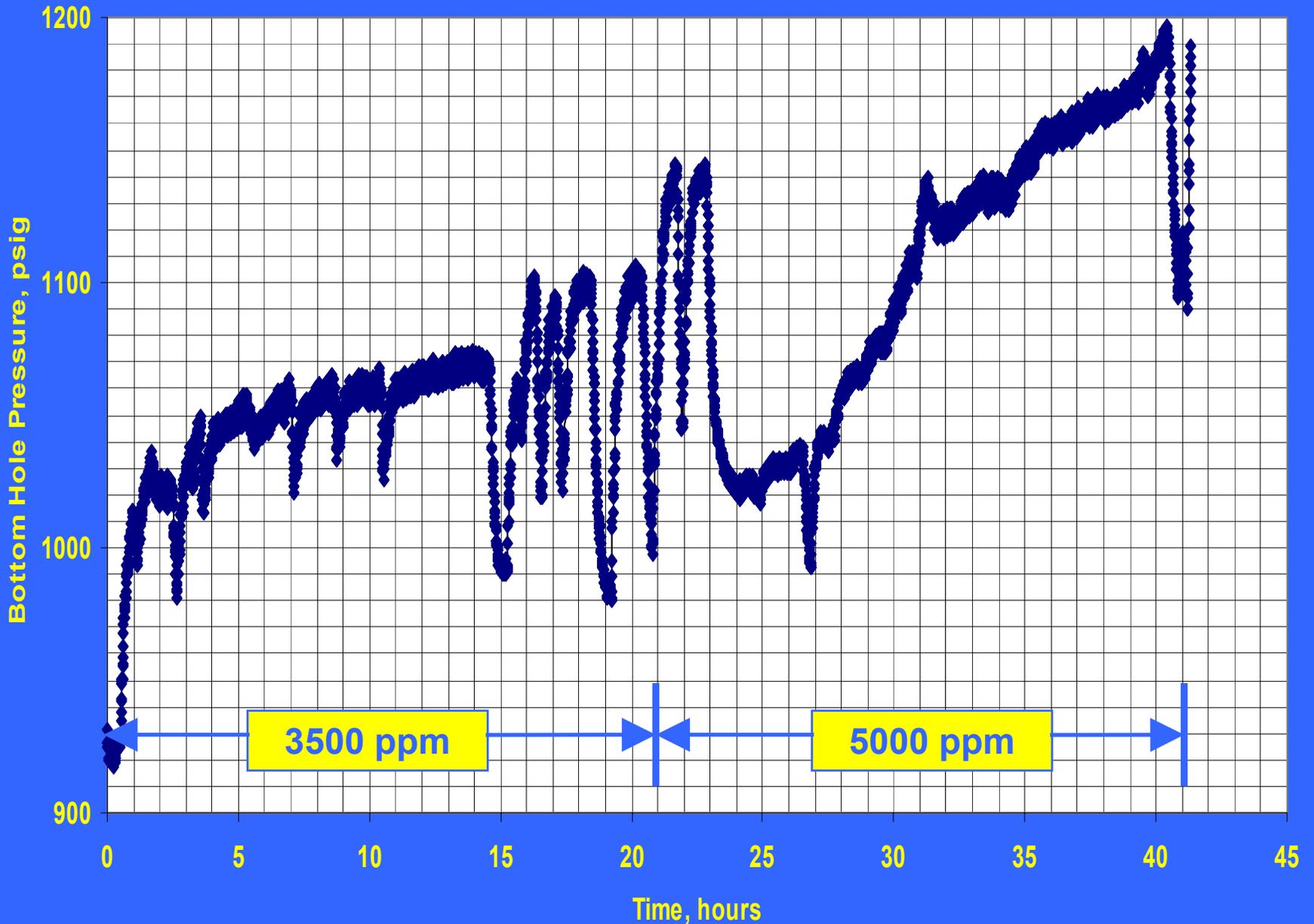


Trilobite Testing's Slickline Trailer at Vess Oil's Hall B #4

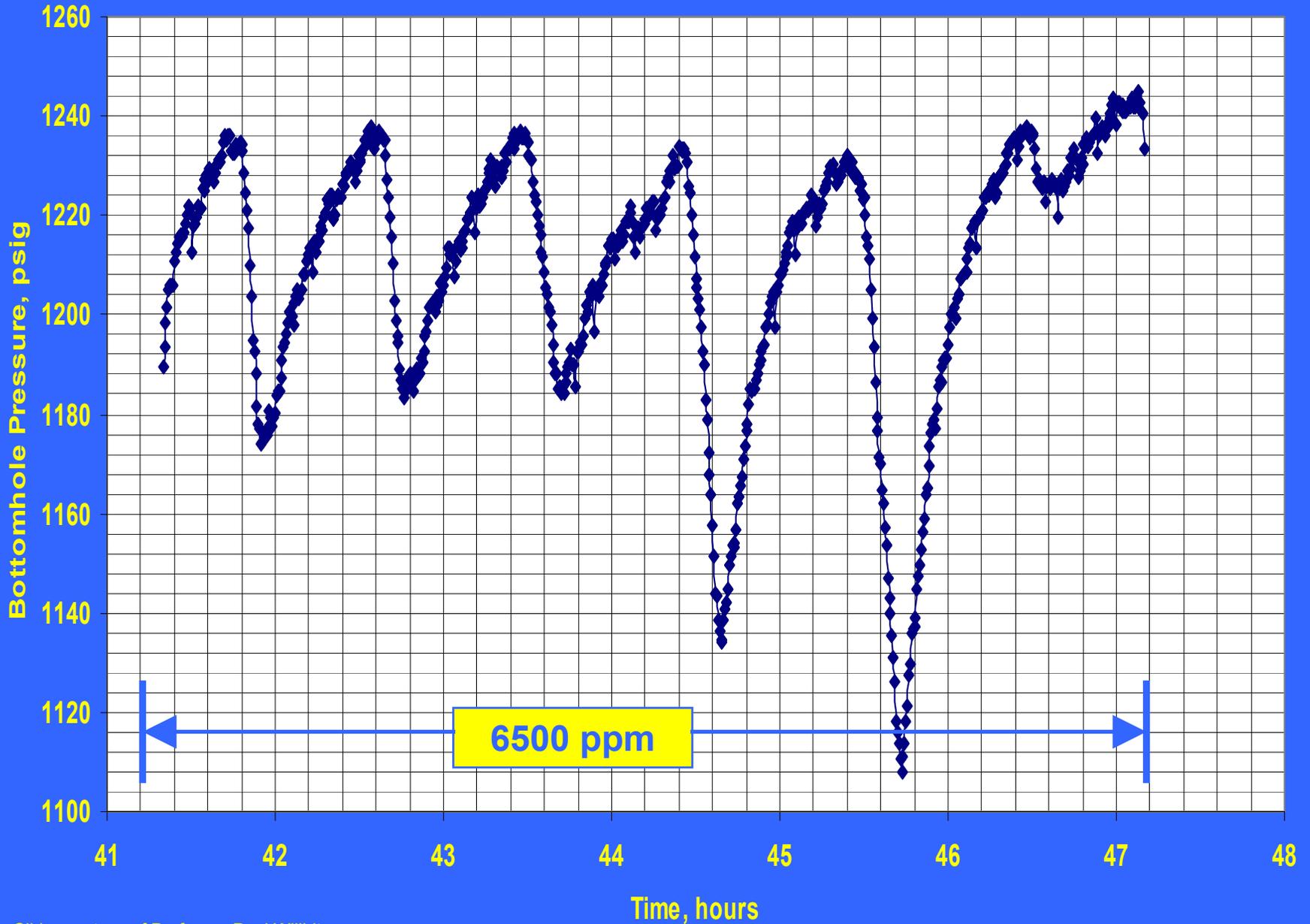
TORP's Efforts *

- **Hall B #4 Gel Treatment w/ bottom-hole pressure measurement (entire treatment went on vacuum).**
 - **0.75 BPM (1080 BPD)**
 - **Down tubing on packer**
 - **976 bbl @ 3500 ppm**
 - **988 bbl @ 5000 ppm**
 - **264 bbl @ 6500 ppm**
 - **100 bbl oil overflush**
 - **Shut in**

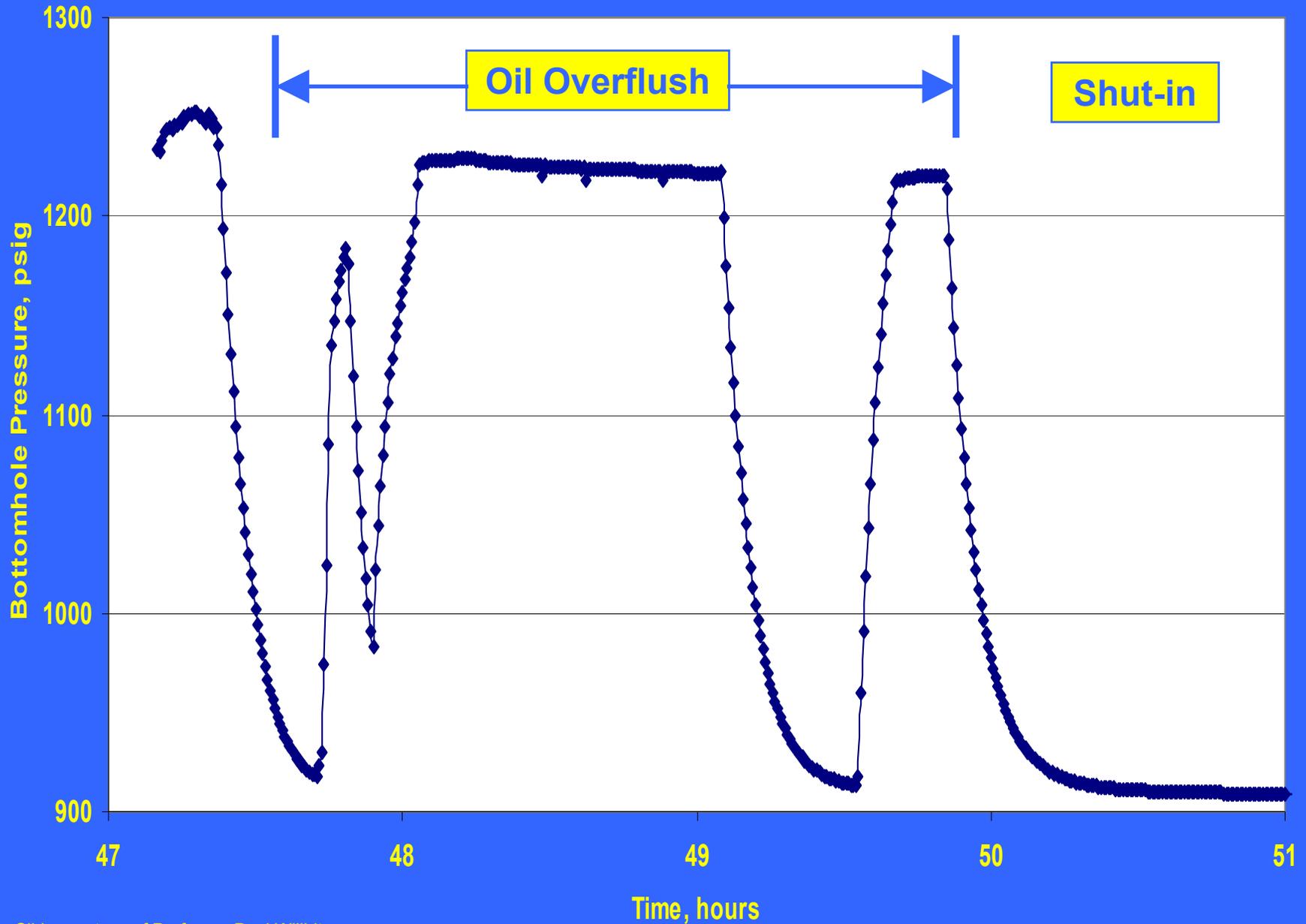
BHP Data – Hall B #4



BHP Data – Hall B #4



BHP Data – Hall B #4



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Future TORP/PTTC Activities

- **Conduct post-treatment build-ups on same 7 wells – hope to document how reservoir changes after treatment.**
- **Sponsor operator forum for those operators who have pumped jobs – February 4, 2003.**
- **PTTC to conduct gel polymer workshop – Summer 2003.**
- **Publish case studies relative to gel polymer treatments – Fall 2003.**
- **Put gel polymer database online – Fall 2003.**

