SPEE
SOCIETY OF PETROLEUM EVALUATION ENGINEERS
Houston Chapter

Meeting Notice

Chairman – Lucas Smith
Membership – Ali Porbandarwala
Secretary / Treasurer – Deji Adeyeye
Program Chairman – Jay Quinn

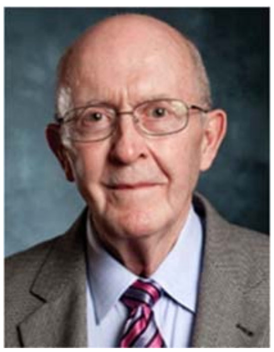
DATE: Wednesday, September 2nd, 2020 **TIME:** 12:00 pm

LOCATION: Online – Presentation conducted via Zoom **COST:** Free

Note: We will share a link to the Zoom meeting in the week before the presentation and to the email provided at registration. The meeting room will open at 11:30 am. Announcements will begin promptly at noon followed by the presentation.

SUBJECT: Well Interference in Production Forecasting for Unconventional Resources

One of the most important issues that operators in resource plays have had to deal with in recent months is forecasting the impact of well-to-well interference on ultimate recovery. Some have ignored the possibility of increased interference with decreased well spacing, and have found that forecasts of future production were too optimistic. These optimistic forecasts have in turn affected capital available for investment in resource development. This presentation will discuss one solution to this problem, use of user-friendly flow models. While not as robust as coupled geo-mechanical-reservoir models, simpler approaches have the potential to help us identify and quantify potential "parent-child" and other interference issues relatively rapidly.



SPEAKER: Dr. John Lee, PhD

John Lee is Professor of Petroleum Engineering at Texas A&M University. John holds BS, MS and PhD degrees in chemical engineering from the Georgia Institute of Technology. He worked for ExxonMobil early in his career and specialized in integrated reservoir studies. He later joined the Petroleum Engineering faculty at Texas A&M and became Regents Professor of Petroleum Engineering. While at A&M, he also served as a consultant with S.A. Holditch & Associates, where he specialized in reservoir engineering aspects of unconventional gas resources. He joined the University of Houston faculty in September 2011 and held the Cullen Distinguished University Chair until September 2015. He served as an Academic Engineering Fellow with the U.S. Securities & Exchange Commission (SEC) in Washington during 2007-8 and was a principal architect of the modernized SEC rules for reporting oil and gas reserves. John is the author of four textbooks published by SPE and has received numerous awards from SPE, including the Lucas Medal, the DeGolyer Distinguished Service Medal and Honorary Membership. He is a member of the U.S. National Academy of Engineering and the Russian Academy of Natural Sciences.

For reservations, please RSVP online using the event link. Registration will be open **until noon on September 1st.**

Menu
Online Format (BYO Lunch)

Some of our past presentations can be found here:
https://spee.org/resources/past_presentations

Past Presentations

About SPEE Houston Chapter

Recognizing that Petroleum Evaluation Engineering is a specialized field dedicated to promoting professional growth through industry related topics and presentations concerning reserves evaluations, we strive for the highest standard of ethics by promoting continuing education of our members in the area of oil and gas reserve definitions, reserve evaluations and fair market valuations. Our tightly knit group comprises of oil and gas leaders in engineering, banking and consulting. For more information about us and our upcoming events, please visit our website at https://spee.org/local-chapters/houston.

Well Interference in Production Forecasting for Unconventional Resources

John Lee, Texas A&M University

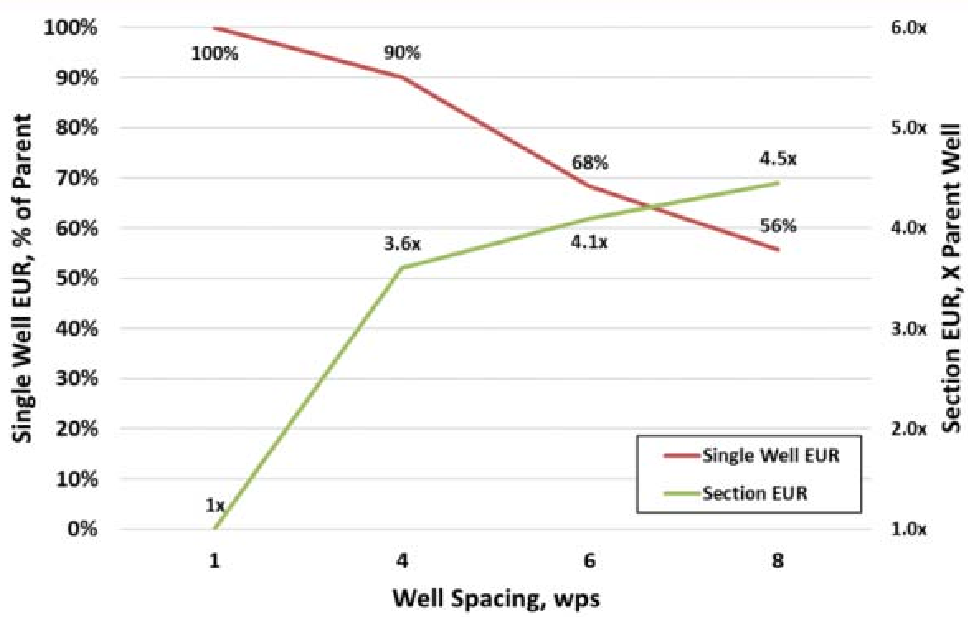
Houston Chapter SPEE

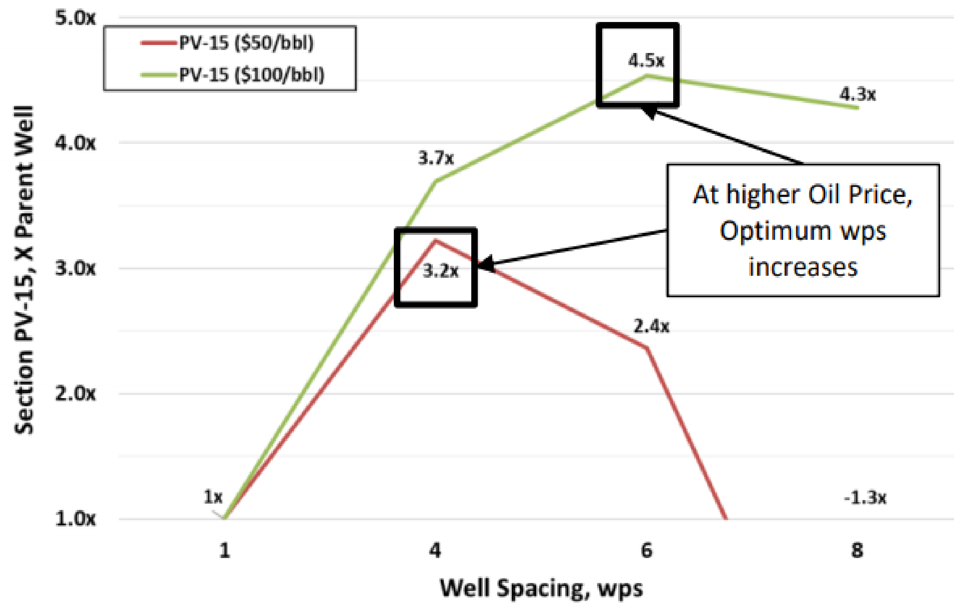
2 September 2020

Why Are We Concerned About Interference?

- Investor-oriented articles suggest EUR overestimated in infill wells because interference was ignored
  - Wall Street Journal 2019 articles
  - Wood Mackenzie 2019 study and paper
- Industry studies indicate that close well spacing for infill wells and duration of production from primary wells can decrease EUR
  - VSO 2019 analysis of Bakken well data
  - Schlumberger model study (SPE 191799)
  - Equinor model study (URTeC 2431182)

Any Supporting Evidence Available?

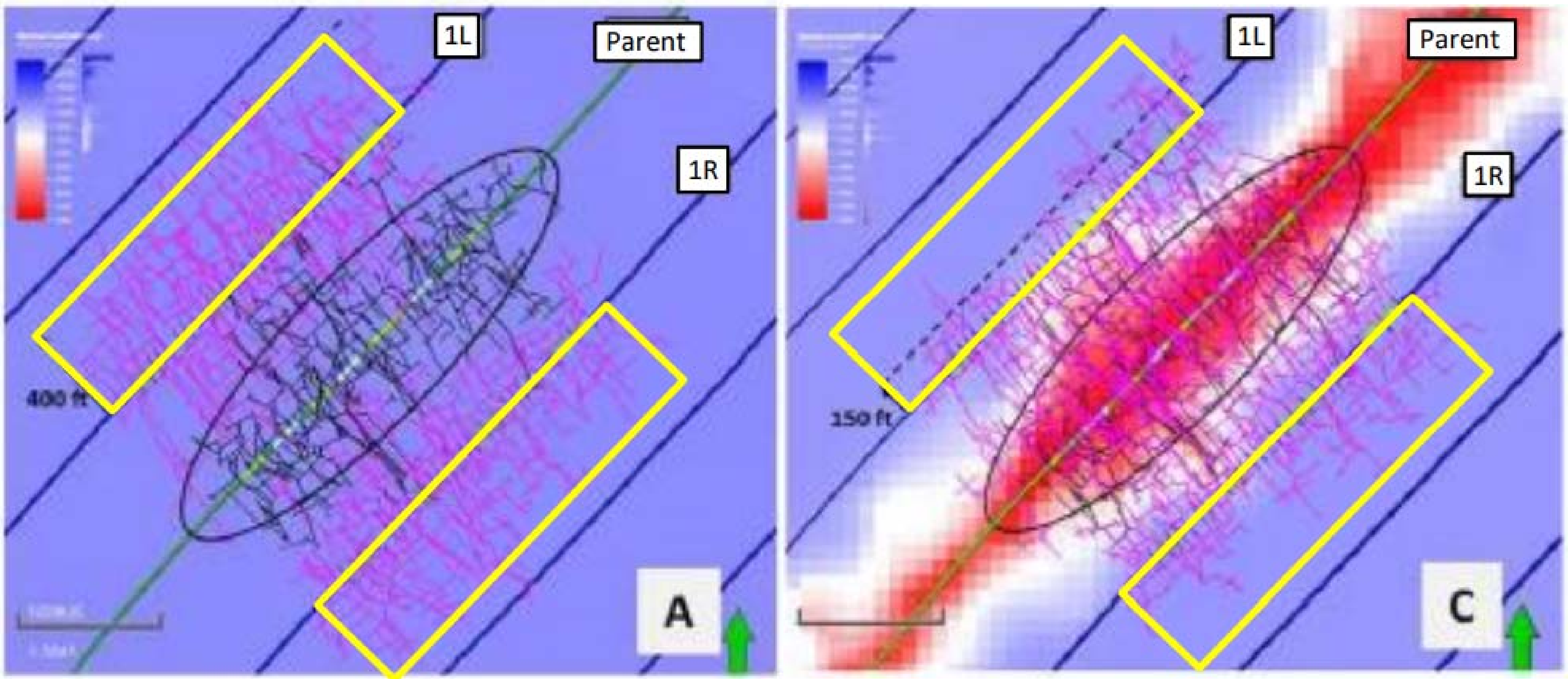




VSO 2019 study indicated substantial interference in Bakken
(based on observed field data)

After VSO (2019)
https://www.vsoinc.com/wp-content/uploads/2019/10/2019_10_14_Valdez_Well_Spacing_FtWorth_Geo_Society.pdf

Well Spacing Affects Fracture Geometry



After SPE 191799

Well Spacing Affects Fracture Geometry

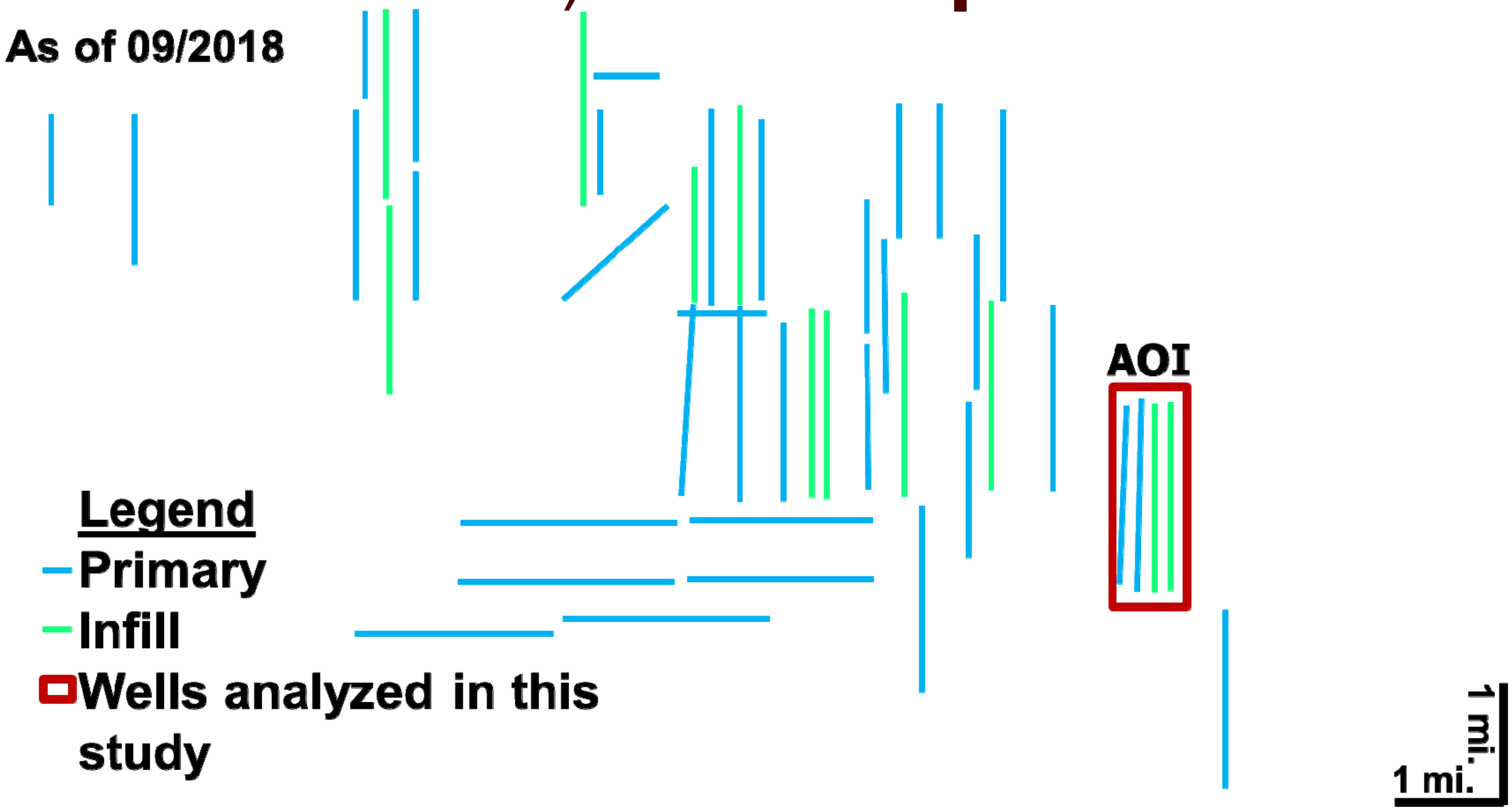
- Figure A: all three wells completed at same time
  - Yellow boxes show extent of infill well fractures on the “outbound” edge of wells
- Figure C: modeled fracture geometry when primary well produces for 12 months
  - Fracture geometry from the two offset wells (1L,1R) grow asymmetrically toward the primary well
  - Yellow boxes show significantly less fracture density, and an equivalently shorter frac half-length on one side of the wellbore

After SPE 191799

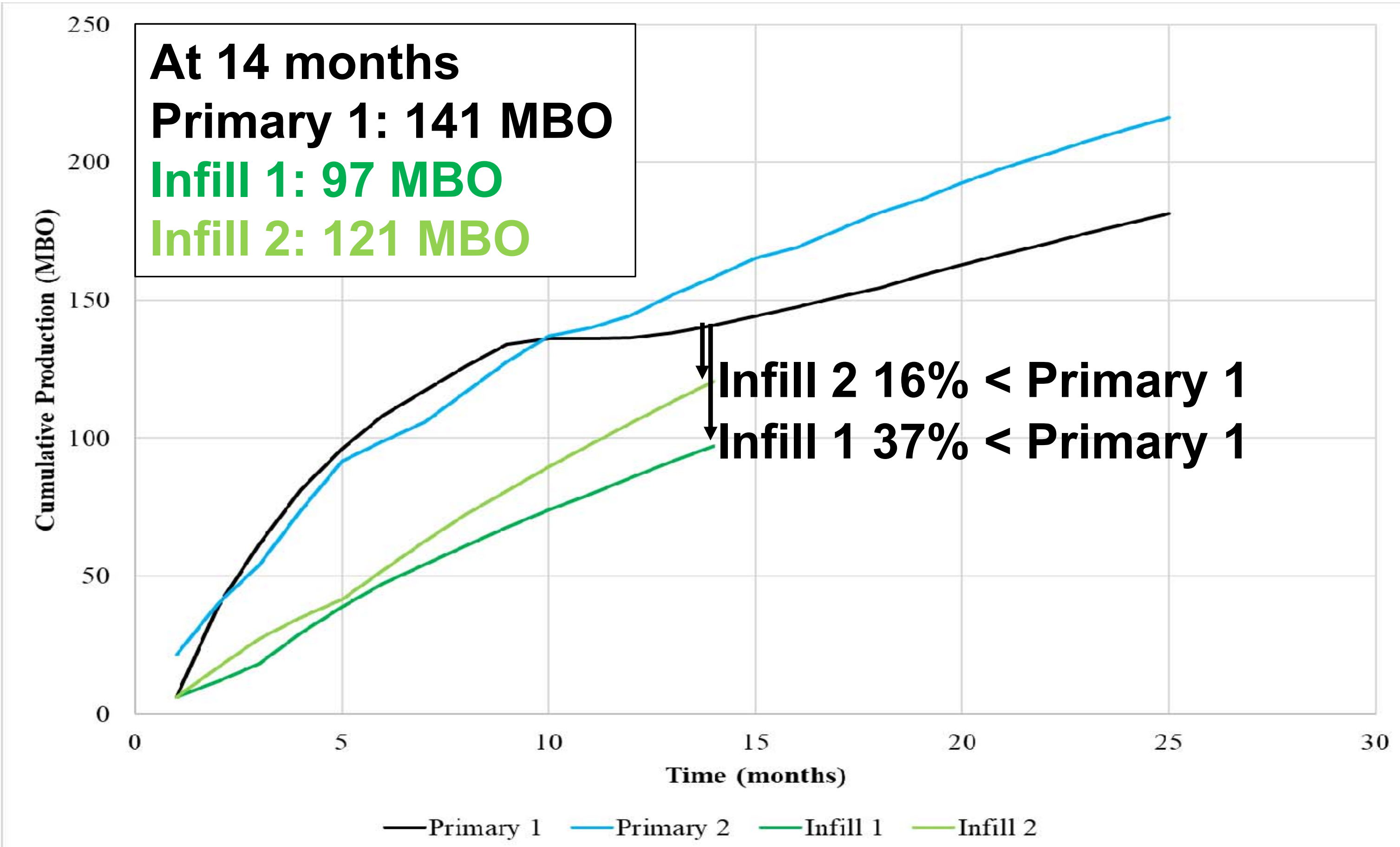
How Can We Solve the Problem of Overestimating EUR for Infill Wells?

- Fundamental consideration: model interference properly
- Possible approaches
  - Rigorous reservoir simulation with coupled geomechanical model
    - Probably most accurate approach
    - Time-consuming, expensive, extensive input data requirements
  - Analytical solutions in RTA software
    - History match early (mostly transient) data for k, x_f
    - Vary well spacing to model interference effects
  - Empirical decline curves, type wells
    - Models interference only if present in production histories
  - Rapid reservoir simulation: Science Based Forecasting (SBF)

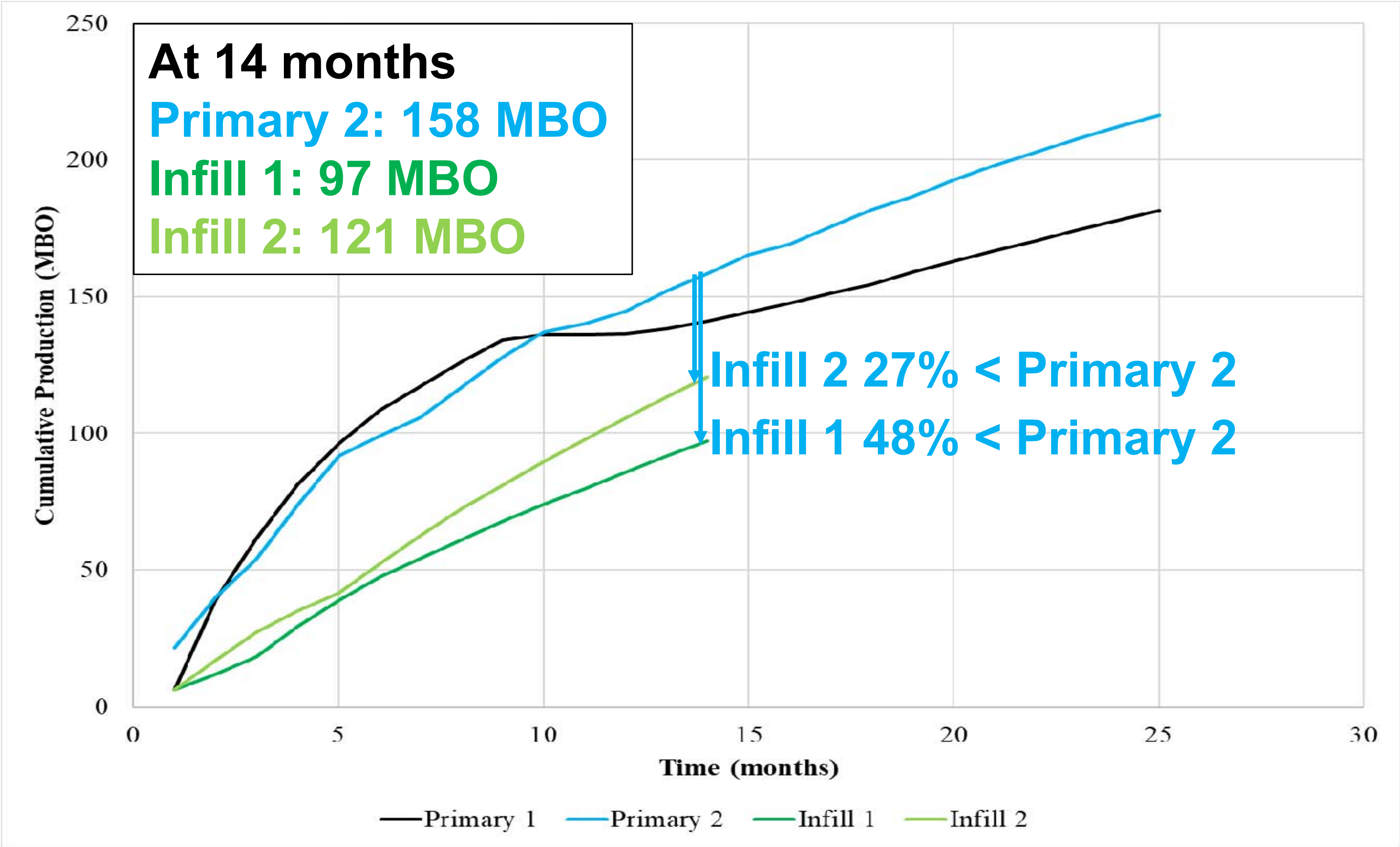
Field Data Study: West Texas, Delaware Basin, Wolfcamp A



The Fundamental Problem Illustrated: Primary Well 1 Outperforms Two Infill Wells…

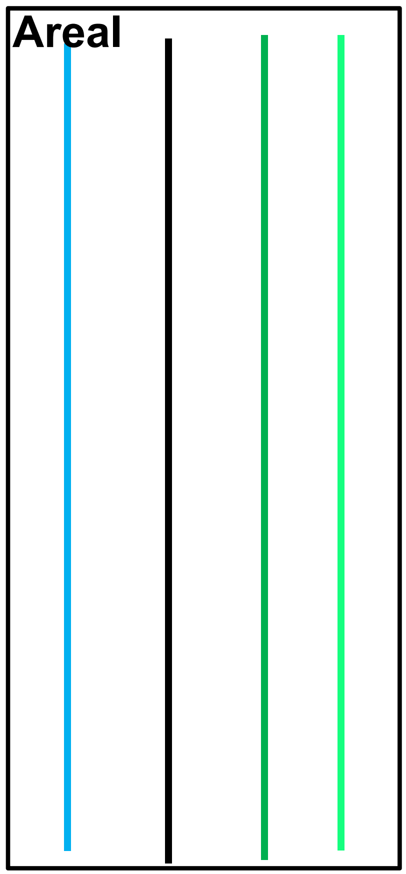


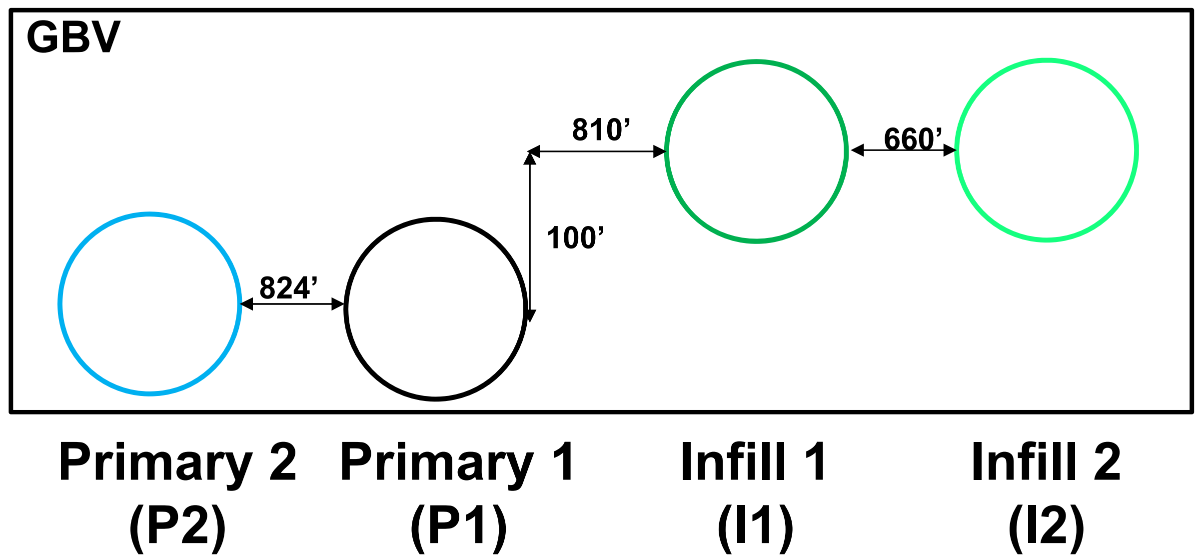
... And so Does Primary Well 2



Areal and GBV Views of Area Of Interest

Primary 1
Primary 2
Infill 1
Infill 2





How Does SBF Work?

- Provides physics-based approach to forecasting
- Uses observed reservoir, completion, production, pressure data
- Retrieves *pre-run simulations* as basis to history match primary well
  - Selects candidate simulations from stored results with parameters in range of known parameters
- Forecasts future production of primary, infill wells

So How Do We Proceed?

- Create infill well model based on best matches of history
- Forecast future production for infill well(s)
- Some parameters based on primary well history match
- Other parameters based on match of shorter history of infill well, allowing reasonable range of parameters from primary well match
- Study alternative infill well spacing, completion design with varied SRV
  - Learn how to improve results in similar situations in future

Blind Test Used to Validate SBF, Compare with DCA-Based TWP Analysis

- **Purpose**: Determine accuracy of SBF results
- **Methodology**
  - **Step 1**: Construct P50 type well using DCA profiles from wells in area
  - **Step 2**: History match primary well with simulation
    - Place ranges on primary well parameters
      - Account for uncertainty of parameters in infill wells
  - Generate simulated TWP for infill based on parametric ranges
  - Construct P50 TWP well (or other probabilities if desired)
- **Validation**: Compare cumulative production from
  - Reported production data
  - Forecast with DCA-based TWP
  - Forecast with SBF

Assumptions for SBF Blind Test

Reservoir Properties:

- Thickness: 200–350 ft
- Matrix k: 300-700 nD
- Matrix ϕ: 8%
- Matrix S_{wi}: 42%

BHP: 6,000–2,800 psi

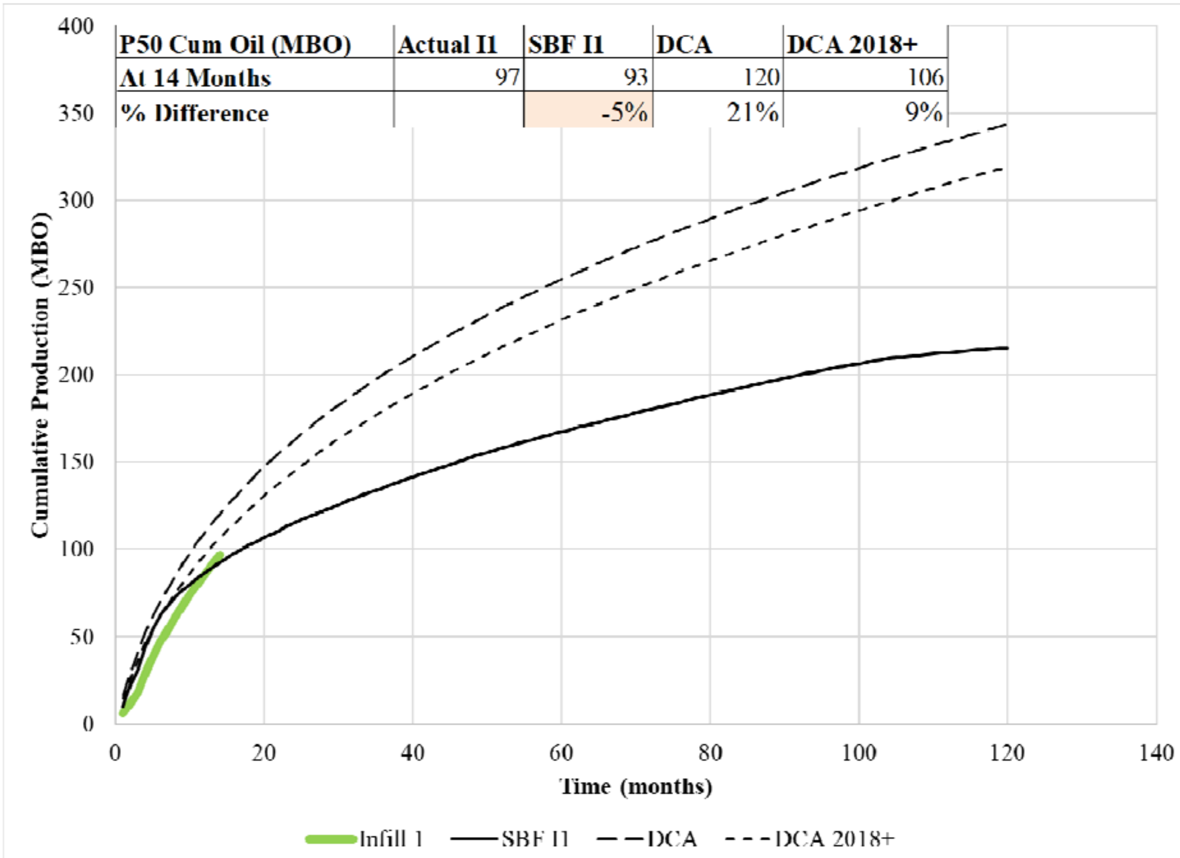
- Drawdown increases over 8 months

Ranges of SRV Parameters:

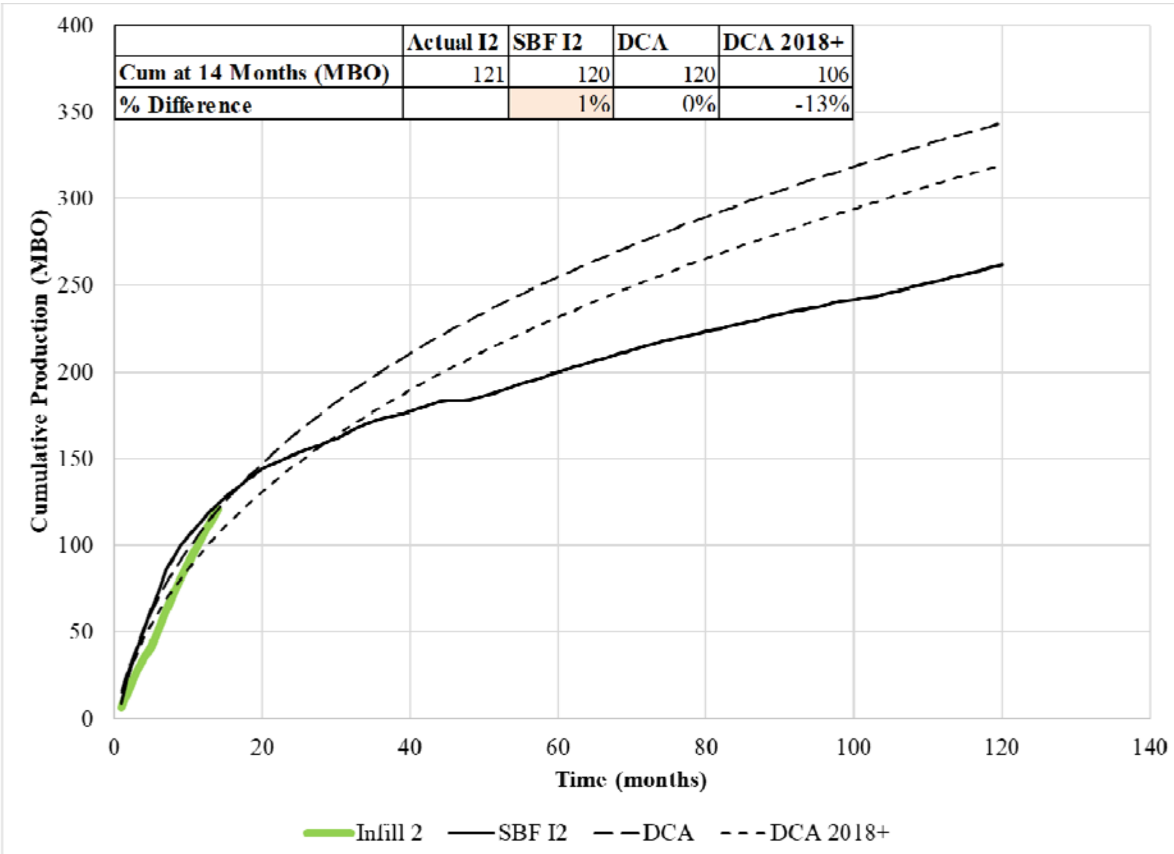
- Infill Well 1
  - x_f: 200-300 ft
  - h_f: 100-210 ft
  - HF k: 8,000-12,000 mD
- Infill Well 2
  - x_f: 200-400 ft
  - h_f: 100-260 ft
  - HF k: 8,000-13,000 mD
- HF S_{wi}: 80% – 95%

SBF TWP Compared to 14-Month History for Infill 1

P50 Cum Oil (MBO)	Actual I1	SBF I1	DCA	DCA 2018+
At 14 Months	97	93	120	106
% Difference		-5%	21%	9%



DCA-Based and SBF TWPs Compared to 14-Month History for Infill 2



	Actual I2	SBF I2	DCA	DCA 2018+
Cum at 14 Months (MBO)	121	120	120	106
% Difference		1%	0%	-13%

SBF Accurately Estimates Infill Wells P50 Cumulative Production

Infill Well 1	Actual I1	SBF I1	DCA	DCA 2018+
Cum at 14 Months (MBO)	97	93	120	106
% Difference		-5%	21%	9%

Infill Well 2	Actual I2	SBF I2	DCA	DCA 2018+
Cum at 14 Months (MBO)	121	120	120	106
% Difference		1%	0%	-13%

- SBF accurately approximates Infill 1 and 2
  - 5%, 1% difference actual vs. SBF TWP, respectively
  - 21%, 0% difference actual vs. DCA-based TWP, respectively
- Cannot quantify effect of interference with DCA alone

So Why Use SBF? What Makes it Different from the DCA-Based TWP Approach?

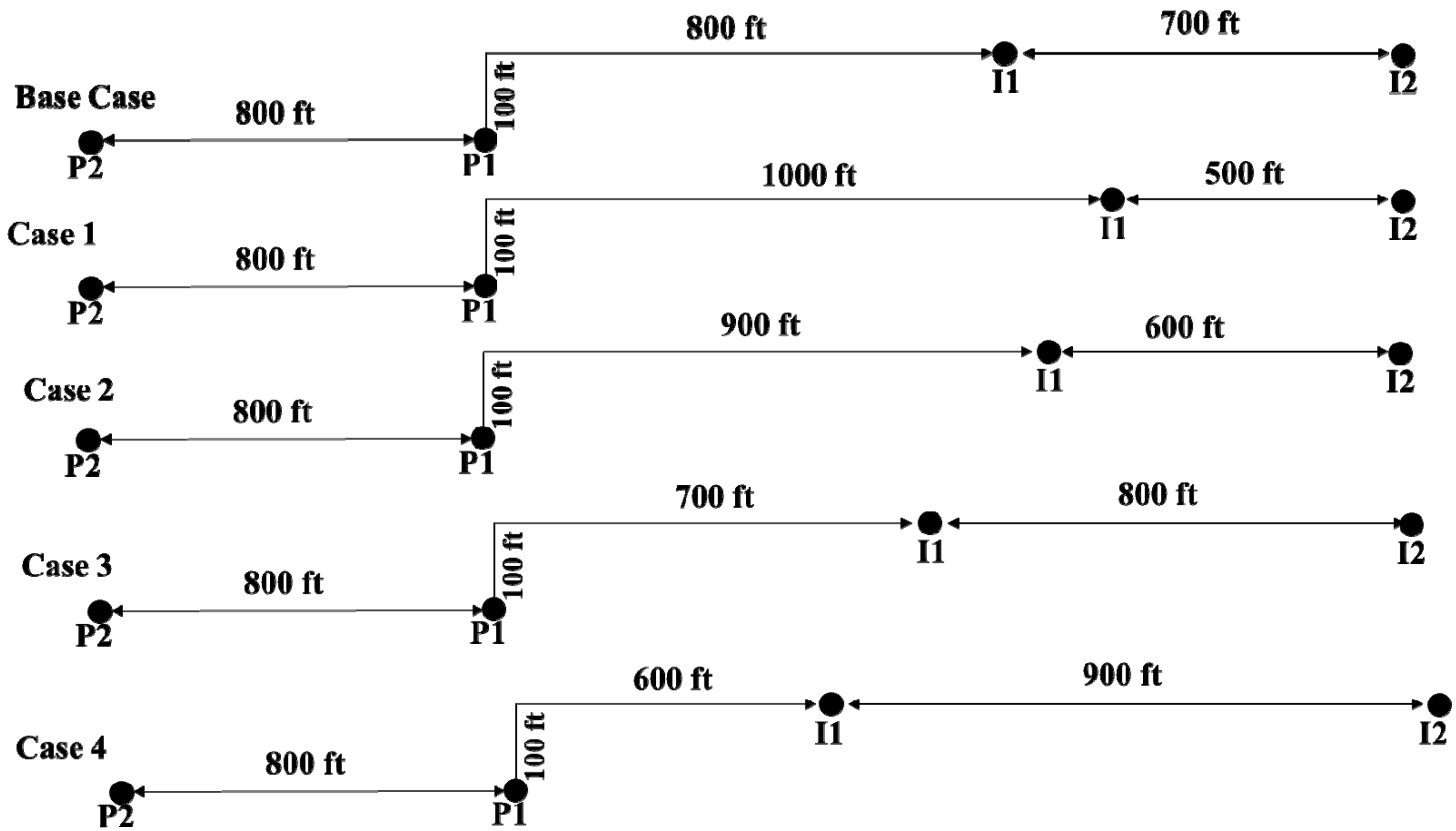
With SBF, we can answer important questions:

- Could we have planned infill well spacing better?
- Could we have forecasted infill well production more accurately?
- Can we improve future infill wells that we drill?

With SBF, we can provide additional analysis techniques

- Pre- and post-drill TWP comparison:
  - Is there an optimal spacing for our project? SBF analyzes well spacing
  - How does an index called "Fracture-Driven Interaction" (FDI) impact our infill production? SBF analyzes fracture interference
  - Can we time our infills better? SBF analyzes timing of infill well drilling

Infill 1 (I1) Well Spacing Sensitivity Analysis



EUR Results for I1 – Spacing Sensitivity

Spacing from I2

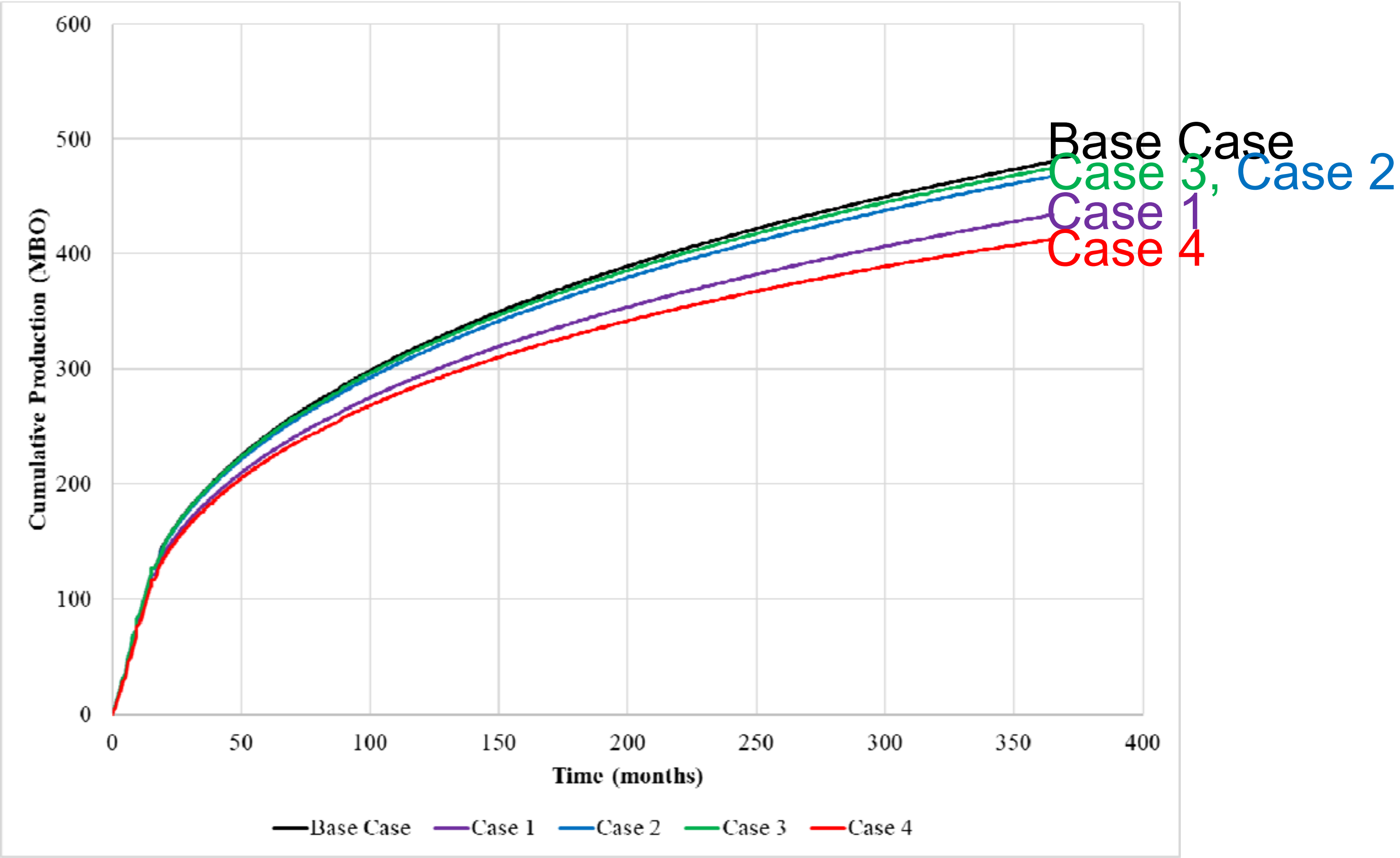
Base Case: 700 ft

Case 1: 500 ft

Case 2: 600 ft

Case 3: 800 ft

Case 4: 900 ft



EUR Results for I1 – Spacing Sensitivity

Spacing from I2

Base Case: 700 ft

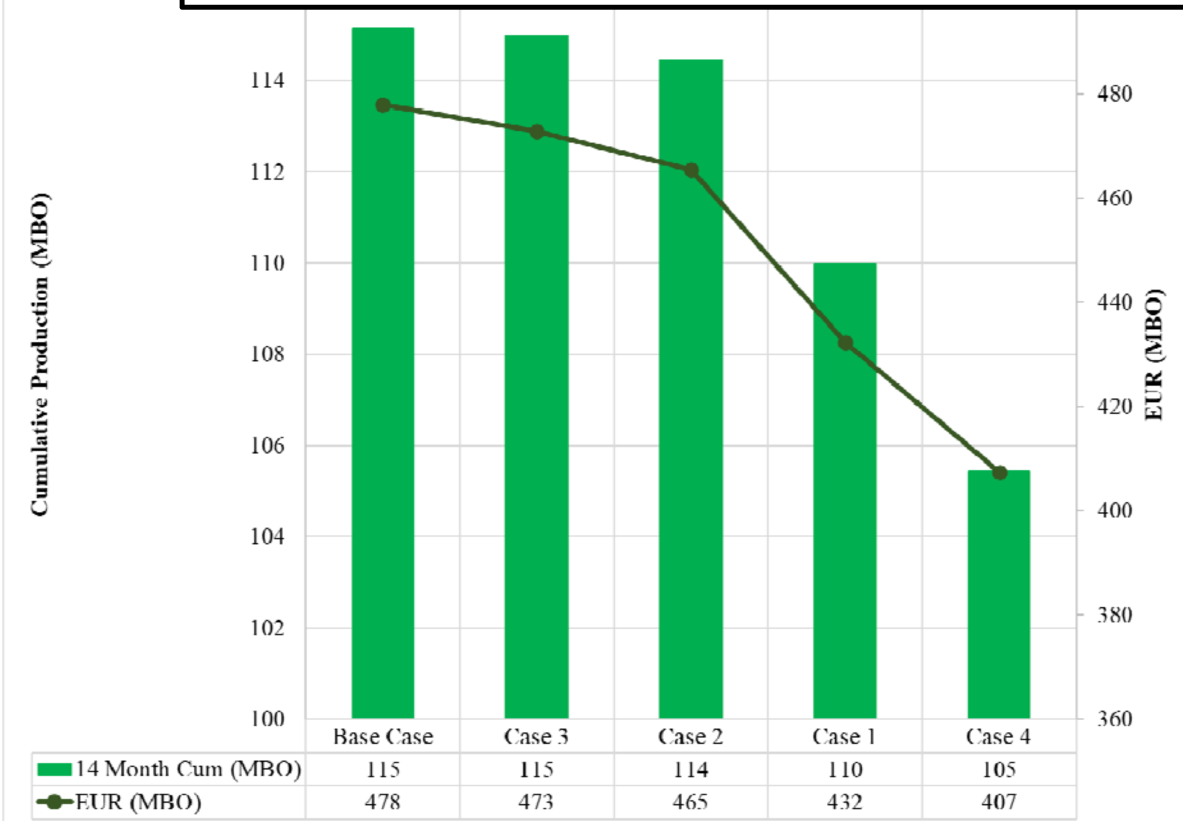
Case 1: 500 ft

Case 2: 600 ft

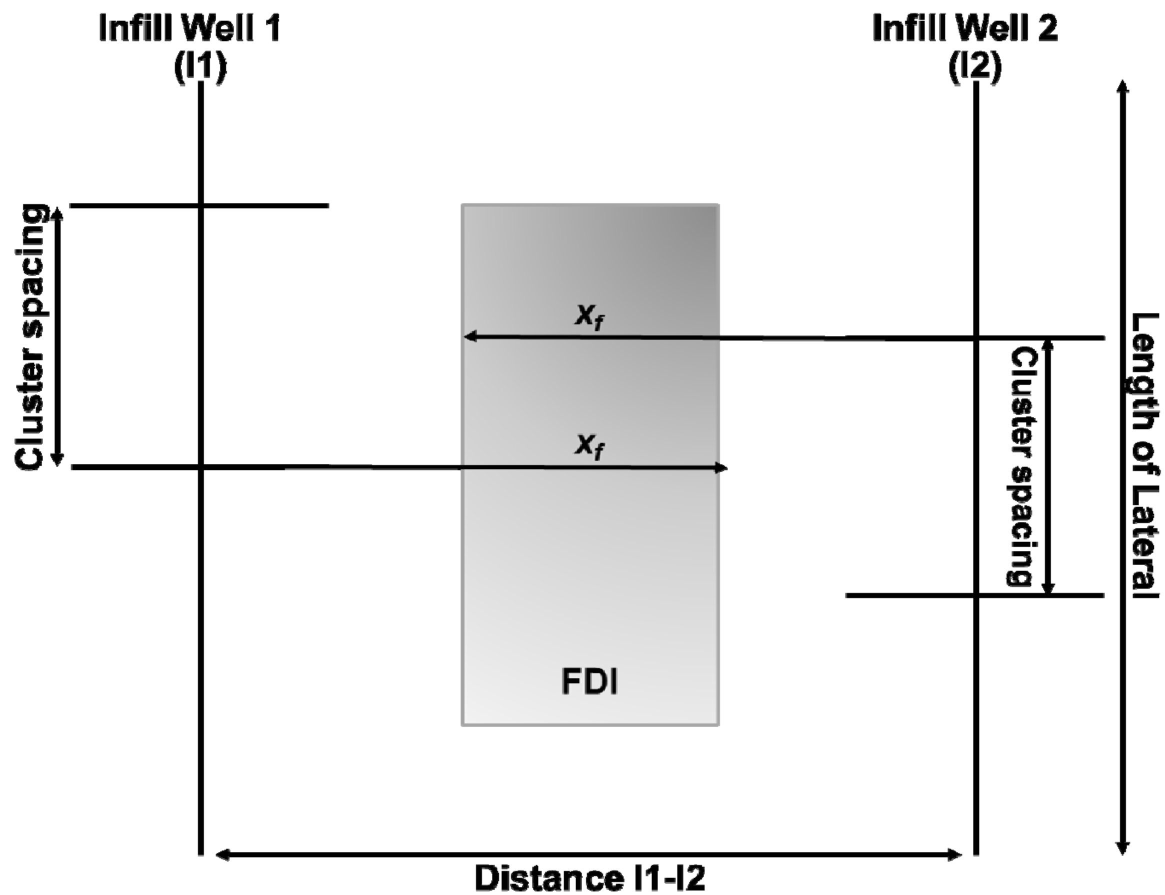
Case 3: 800 ft

Case 4: 900 ft

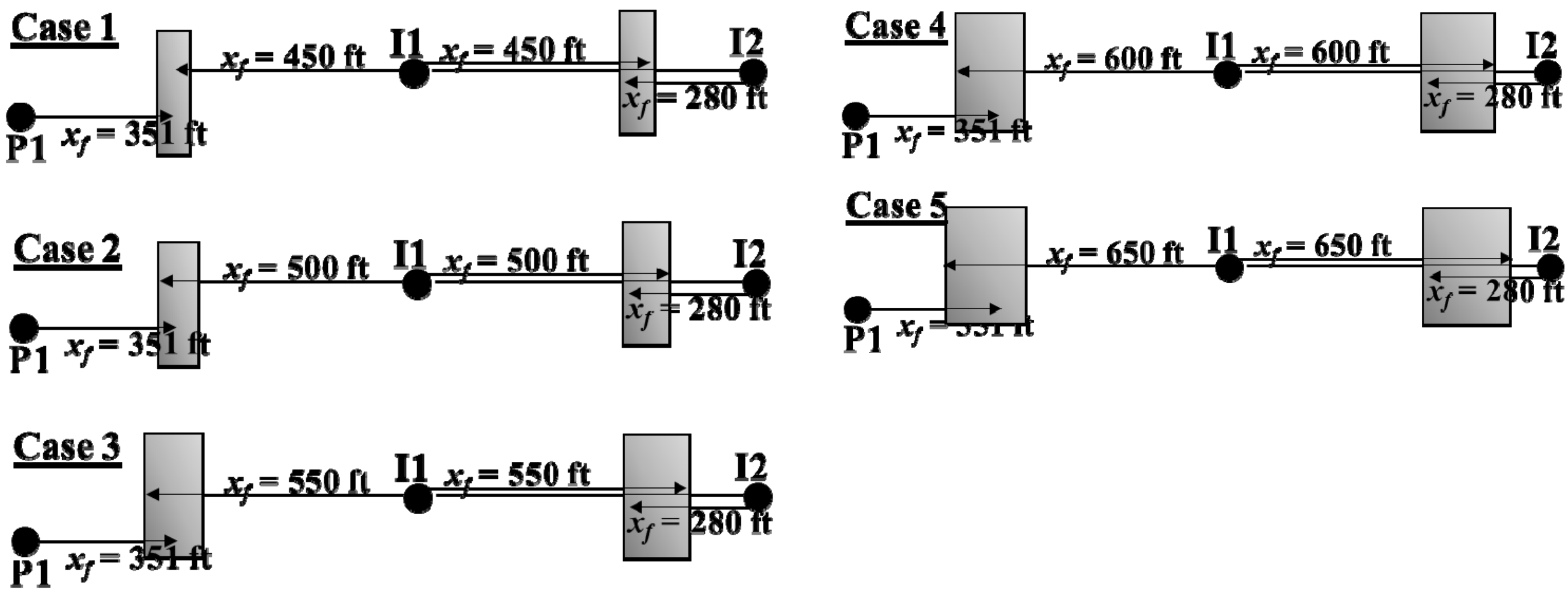
Base Case shows optimal well spacing



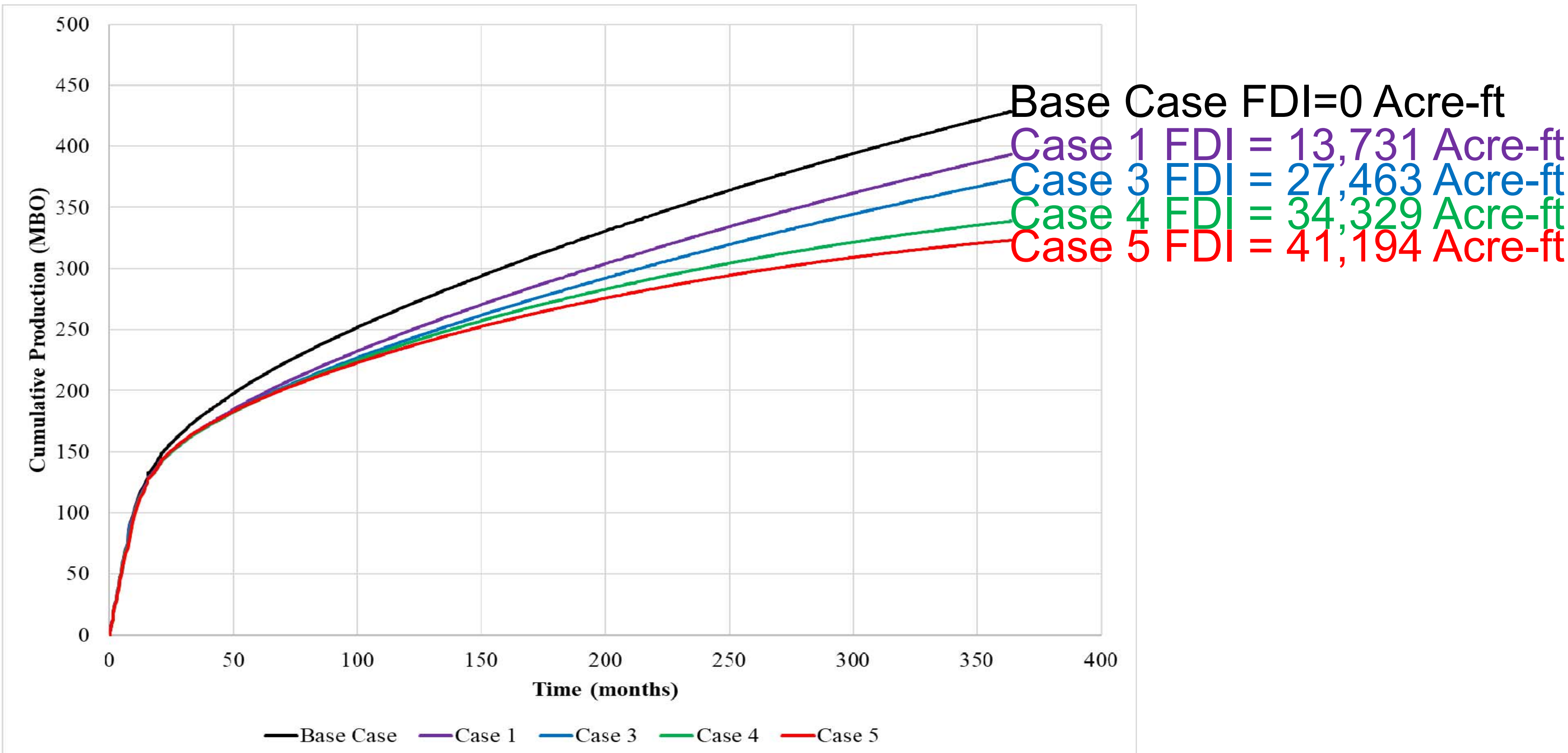
Calculating Fracture-Driven Interaction (FDI) To Quantify Fracture Interference



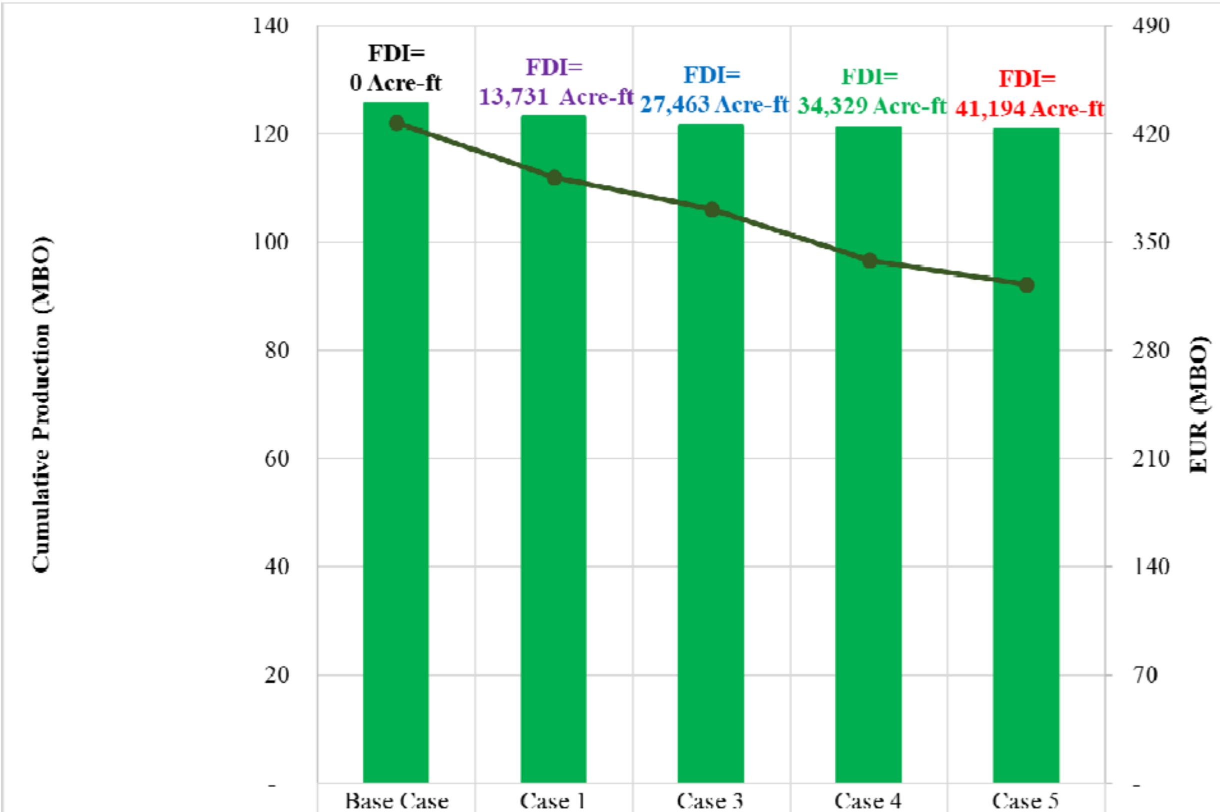
Calculating FDI in Production Forecasting



Using FDI to Quantify Fracture Interference



Using FDI to Quantify Fracture Interference



	Base Case	Case 1	Case 3	Case 4	Case 5
14 Month Cum (MBO)	125	123	121	121	121
EUR (MBO)	427	392	371	338	323

Summary of Spacing and Interference Sensitivity Results

- Spacing significantly impacts recovery of Infill 1
  - Highest EUR increase in Base Case
  - EUR and cumulative production decrease in four other cases
  - Operator properly placed Infill 1

- Increased FDI decreases recovery
  - Cumulative production at 14 months remains constant
  - EUR decreases with increased FDI

Conclusions

- Both DCA-based TWPs and SBF can forecast future production accurately for primary wells, at least up to time of interference
  - DCA-based TWPs, SBF require comparable effort, have comparable cost
- SBF provides more accurate forecasts for infill wells, primary wells after wells interfere
- SBF provides basis for improving spacing, timing of future infill-drilling programs

Well Interference in Production Forecasting for Unconventional Resources

QUESTIONS?

John Lee, Texas A&M University

Houston Chapter SPEE

2 September 2020

References

- VSO:

https://www.vsoinc.com/wp-content/uploads/2019/10/2019_10_14_Valdez_Well_Spacing_FtWorth_Geo_Society.pdf

- USI Technology https://www.techusi.com/
  - Email: info@techusi.com

History Matching of Primary Wells

- Obtain:
  - Geological and petrophysical parameters
  - Vertical and lateral distance
  - Measured BHP
- Place in CMOST
- Get cases that match best for oil and BHP (gas and water matched secondarily)
- Large range of permeability: 30 nD – 10 μD
- Load matched HM cases into SBF

Infill Well Matching in SBF

- From HM cases loaded in SBF, remove outliers compared to infill production curve
  - Only matched cases remain
- In Future Type Well tab, place range on the primary well parameters
  - Ranges can be arbitrary (20% added, or we can take the highest and lowest values of the primary well ranges and use those as our min/max range)
- Obtain P50 type well based on the results from the above step
- Get a best matched case to actual infill production to then use in CMG to run sensitivities