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Impact of Well Completion on the Uncertainty in Technically Recoverable Resource Estimation in Bakken and Three Forks

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Society of Petroleum Engineers

Overview

- Uncertainty in Technically Recoverable Resource (TRR)
  - Well completion
  - Other components
- Impact of well interference on TRR estimation and recovery
- Summary and Conclusions

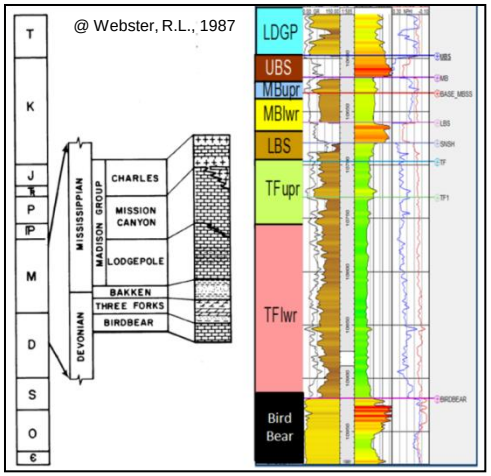
Uncertainty in Technically Recoverable Resource (TRR)

Bakken Petroleum System has multiple prolific HC producing targets stacked in a narrow vertical interval (160 ft max). MB, TF (TF1, TF2, TF3 & TF4)

Most targets need hydraulic fracture stimulation to produce at economical levels.

Hydraulic fracture propagation and growth is mainly controlled by mechanical properties of rock and in-situ stresses.

Resulting, Stimulated Reservoir Volume (SRV) may overlap more than one target, thus connect multiple reservoirs at a time.



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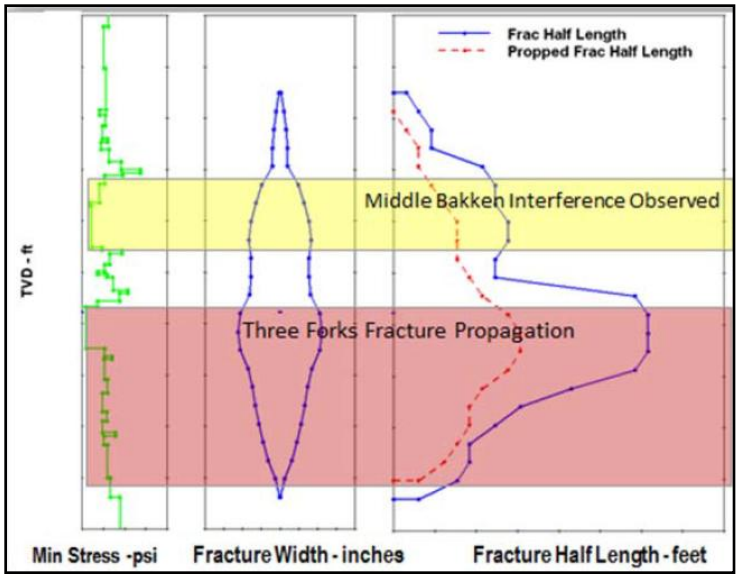

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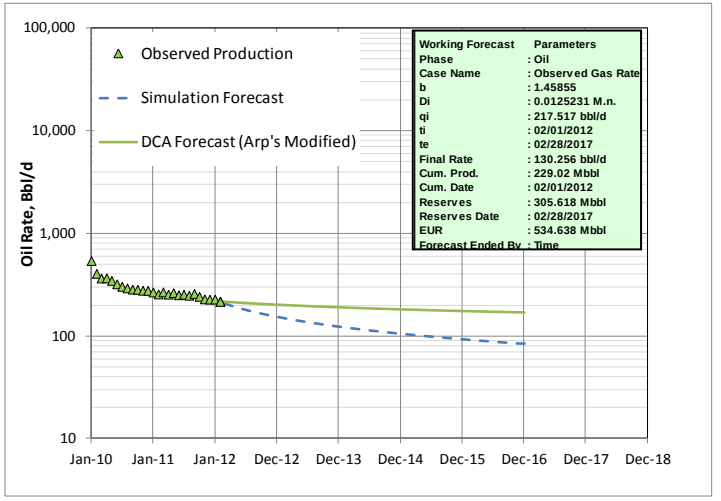
Uncertainty in Technically Recoverable Resource (TRR) (cont…)

Ignoring multiple reservoir connectivity via SRV may lead to overestimation of TRR for a given target interval.



For example:
Single horizontal well landed in MB, completed with 35 fracture stages and producing for 2 years.

Since the well is landed in MB, assume oil production from MB only. 5 year TRR estimate using DCA method is 535,000 STB.

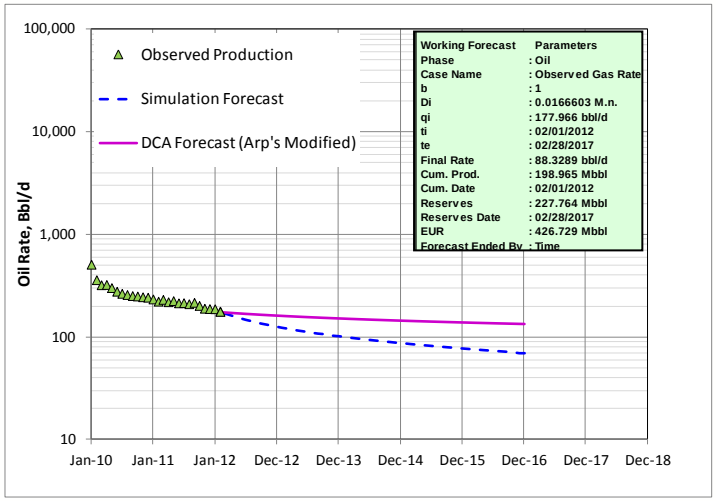
Uncertainty in Technically Recoverable Resource (TRR) (cont…)

However if technical data indicates SRV connecting MB and TF1 then both reservoirs will produce oil simultaneously.

Simulating above condition in a reservoir simulator will provide rough estimate of oil split between MB and TF1. Assuming connectivity for 5 years.

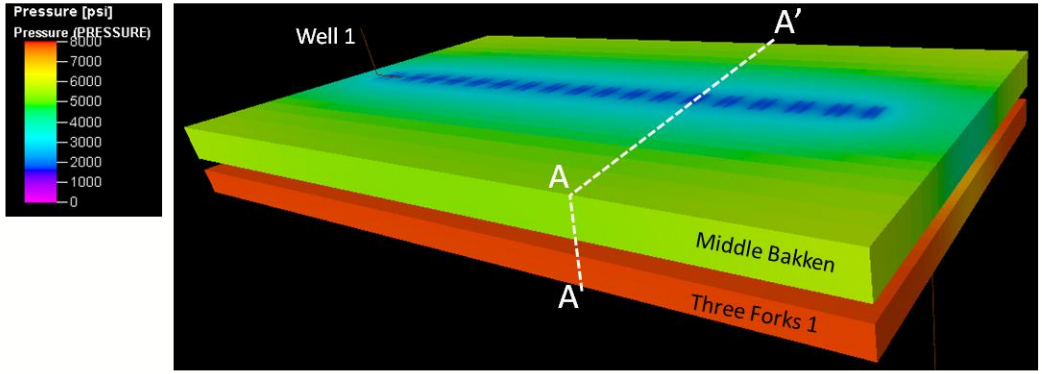
Using MB contribution only, now a 5 year TRR estimate (DCA method) will be 427,000 STB.

Δ TRR = 108,000 STB (535,000 – 427,000 STB)

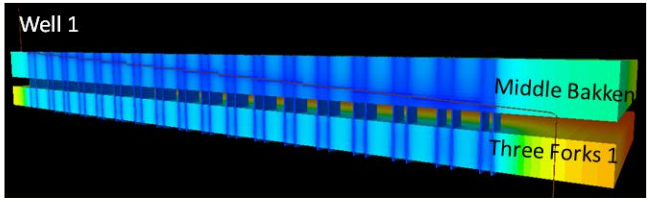


Uncertainty in Technically Recoverable Resource (TRR) (cont…)

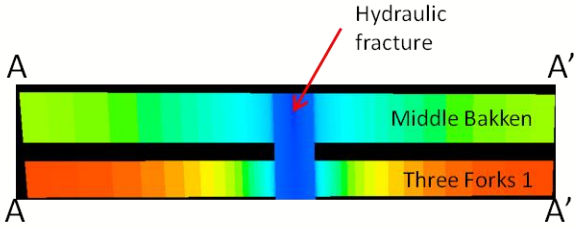
Ignoring connectivity between multiple reservoirs and allocating all production to single reservoir can lead to overestimation of TRR (>20% in this example)



3D view of pressure grid with Well 1



Cross-section view along the horizontal wellbore showing hydraulic fracture connecting Middle Bakken with Three Forks 1

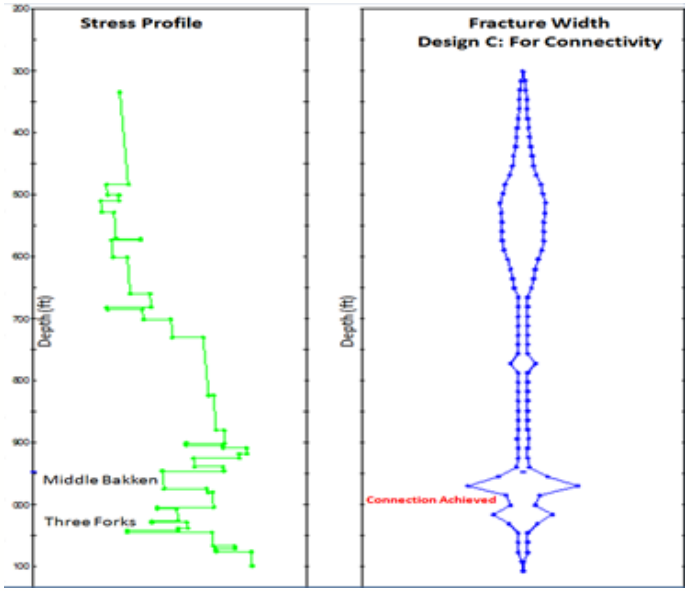


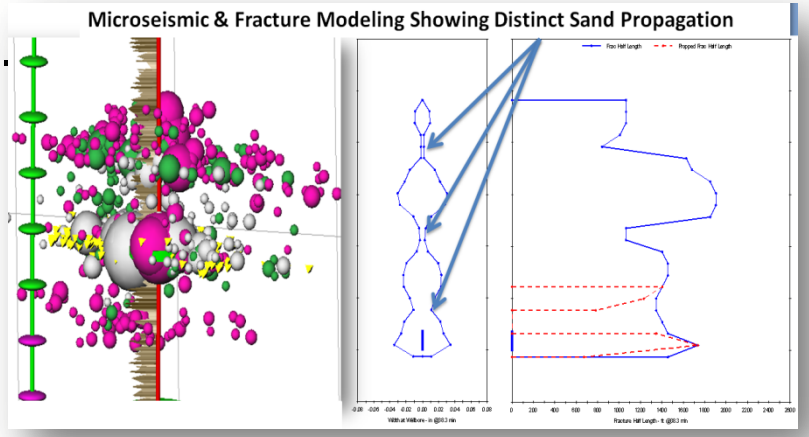
Cross-section view along AA' showing hydraulic fracture connecting Middle Bakken with Three Forks 1

Technical Basis : Multi-reservoir Connectivity via SRV

Following streams of technical data and evaluations when combined can aid in studying multiple reservoir connectivity via SRV:

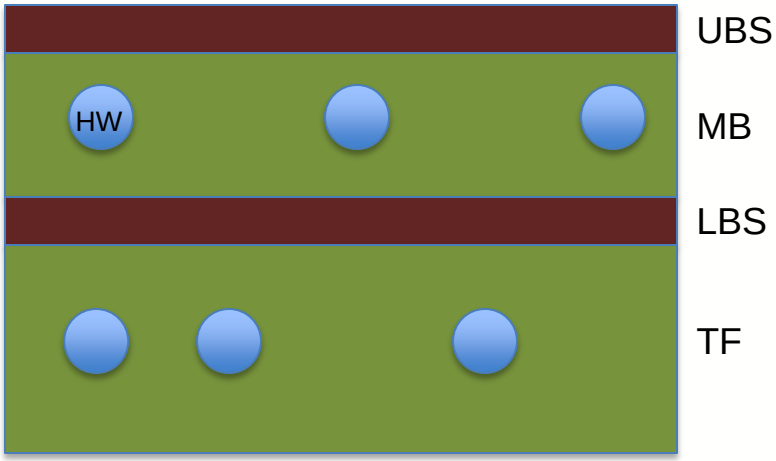
- BHP monitoring pre and post stimulation and during production life cycle
  - Well
  - Offset well(s)
- Microseismic monitoring and hydraulic fracture growth modeling by means of fracture simulators.
- Chemical tagging stimulation fluids and proppant for various stages along the lateral.
- Production characteristics THP and Water cuts.
- High tier logs including stress and image logs.





Possible Scenarios for Multi-reservoir Connectivity via SRV

- Areas where Lower Bakken Shale (LBS) has natural fractures.
- Peripheral regions in the basin where Lower Bakken Shale (LBS) is thinning out.
- Stacked well configuration. Horizontal well in MB with another horizontal well in TF well right below the MB well.
- Sections with high well density in MB and TF.
- Wells stimulated with viscous fluid (X-link).



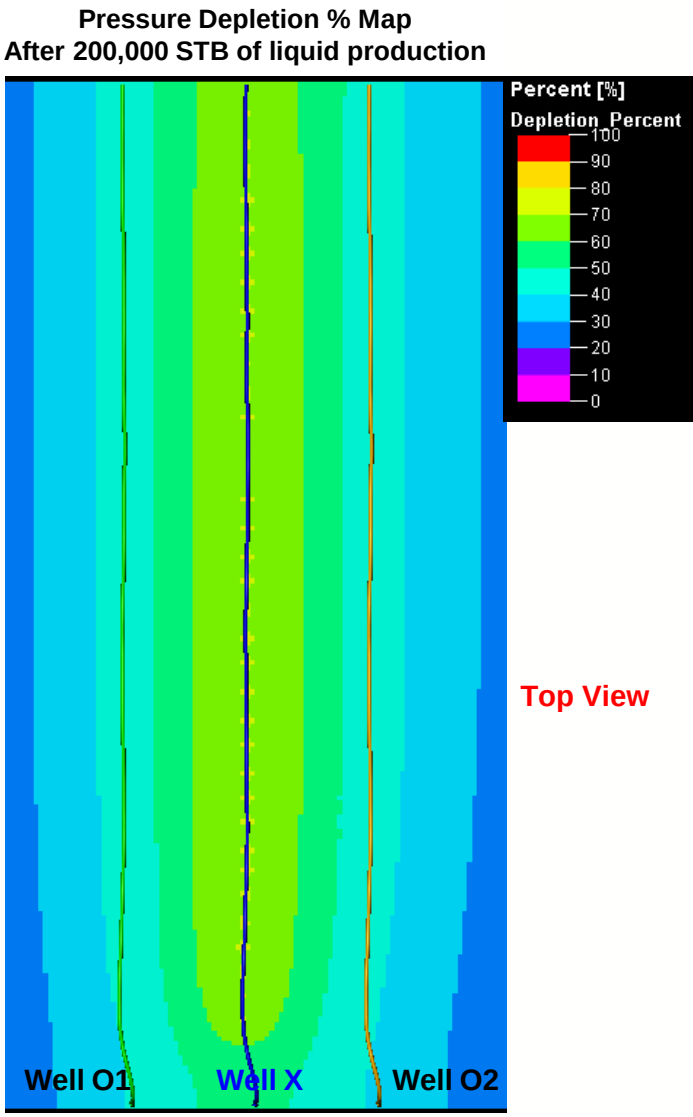
Impact of Well Interference on TRR Estimation and Recovery

Middle Siltstone Member (informally referred as Middle Bakken) is considered a tight oil play, therefore production related depletion my sound unusual initially.

However, given the petrolphysical characteristics of MB combined with limited vertical extent in a closed system, withdrawal of fluids results in pressure depletion.

Pressure depletion leads to re-distribution of in-situ stresses around the producing well.

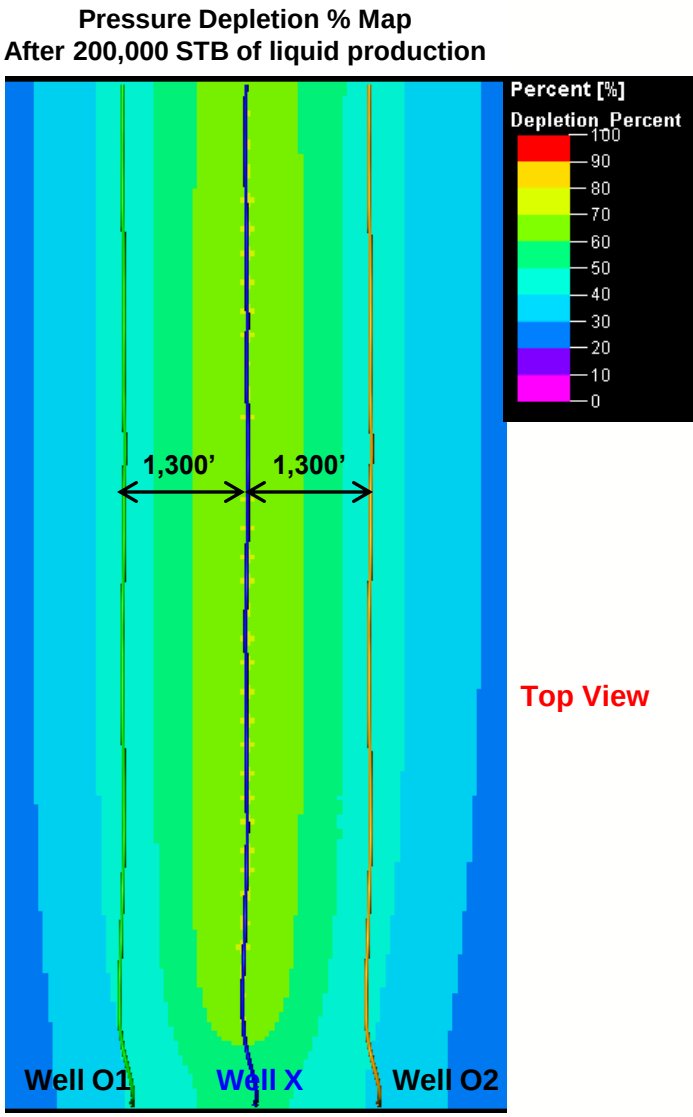
Offset well(s) completed close to old well may result into asymmetric hydraulic fracture geometries thus contacting more of depleted reservoir interval.



Impact of Well Interference on TRR Estimation and Recovery

Example:
Bakken asset with 3 HW in MB, laterals of 10,000 ft, 35 hydraulic fracture stages. Well X is in the center of 1,280 Acre (10,560 ft x 5,280 ft) acreage, completed in Jan 2010 and produced more than 200,000 STB of total liquid. Well X productive half length is150ft, bi-wing (symmetric) geometry.

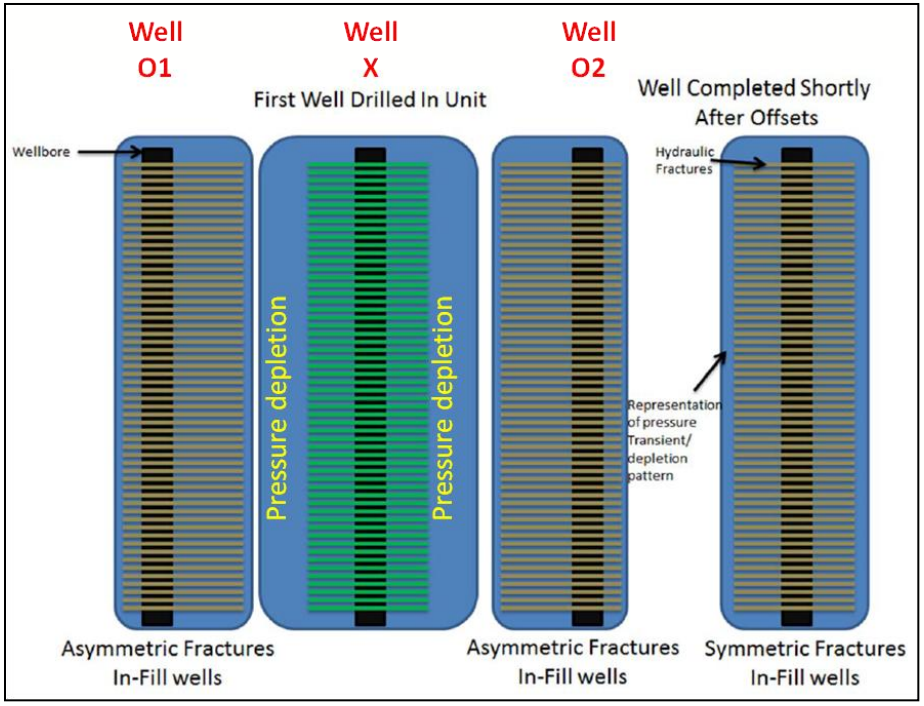
Offset wells O1 and O2 completed in Jan 2012. Distance between the wells is 1,300 ft. Asymmetric fracture growth towards old well.

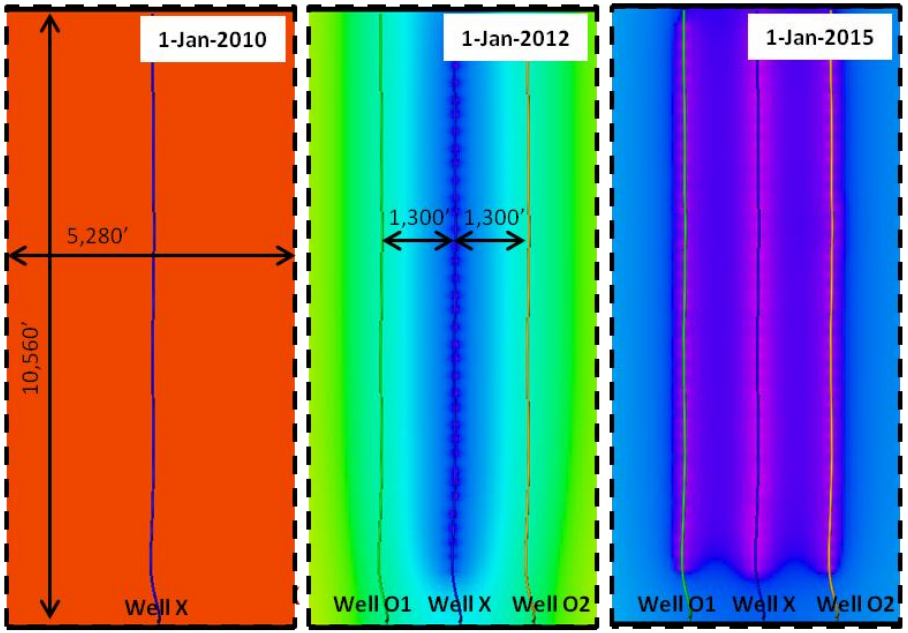


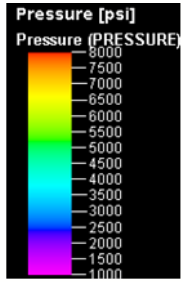
Impact of Well Interference on TRR Estimation and Recovery (cont…)

Consider two scenarios:
Depletion: Offset wells, O1 and O2, completed after depletion from Well X
No Depletion: Wells X, O1 and O2 are completed and put on production at same time

Case	Oil, STB	Water, STB	Liquid, STB	OOIP, STB	RF
Depletion	521,179	35,879	557,058	3,231,408	16%
No Depletion	588,614	46,398	635,012	3,231,408	18%







Summary

Intention of this paper is promote further technical discussion on the role that well completion plays in resource evaluation of unconventional plays such as the Bakken Shale.

The paper highlights stimulation-reservoir interactions and its overall impact on recoverable resource estimation in Bakken and Three Forks formations.

Two main concepts presented here are:

- Challenges, in estimating recoverable resources, arising from the stimulated reservoir volume (SRV) not contained within a single reservoir but straddling and draining more than one reservoir at a time.

- Effects of completion interference between a well and its infill offsets on uncertainty in estimating recoverable resource

Conclusions

Ignoring multi-reservoir connectivity via SRV can result in an overestimation in recoverable resource (> 20% for case presented here).

Production induced depletion from old wells and timing of completion of offset wells to these old wells can impact overall recovery of an asset.

Asymmetric SRV due to depletion can influence project economics as more wells per section may be needed to develop an asset in Bakken. In example cited in this paper, a “3 wells per section” development plan had to be revamped into a “4 wells per section” development plan.

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Thank You / Questions

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