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NORTH DAKOTA[®]



Critical Challenges. Practical Solutions.



Energy & Environmental Research Center (EERC)

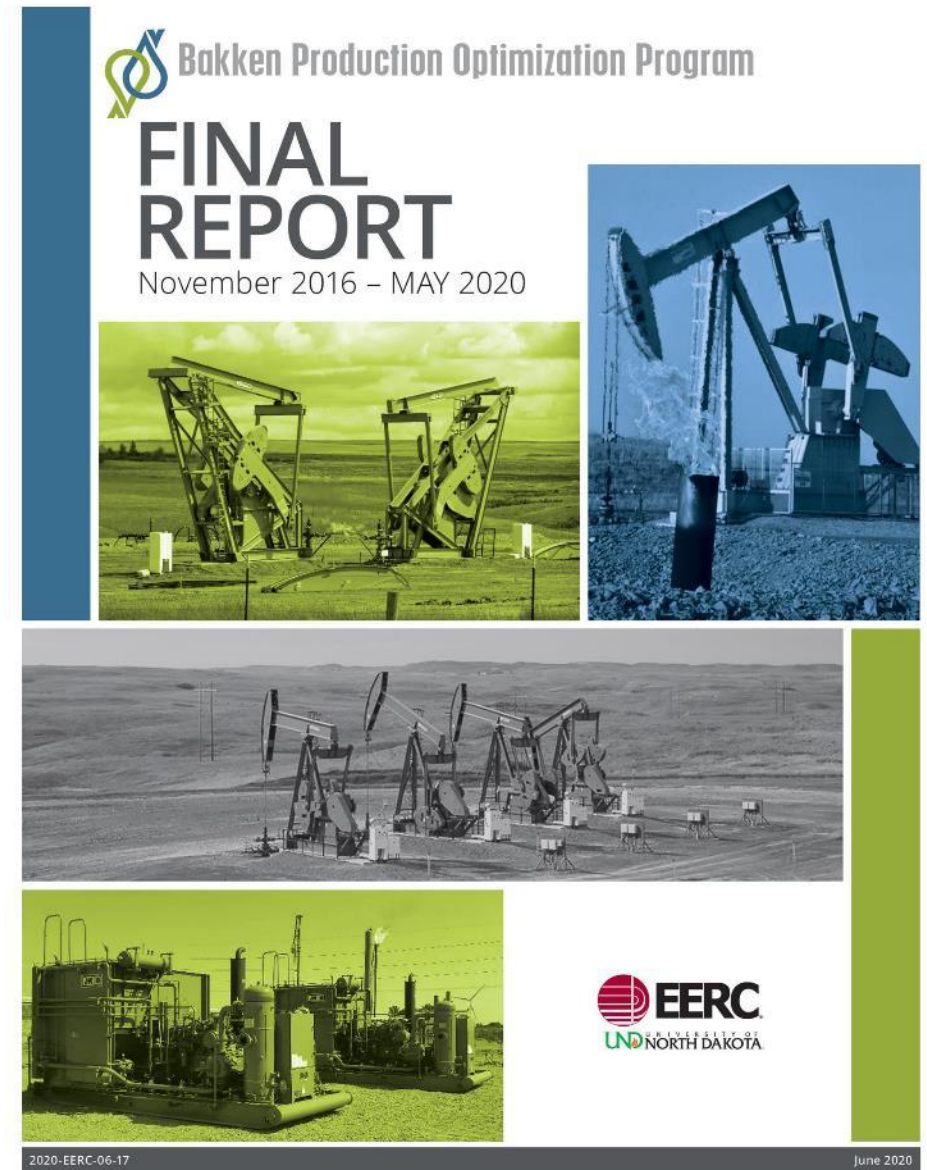
BAKKEN PRODUCTION OPTIMIZATION PROGRAM (BPOP) 2.0 FINAL PRESENTATION

Presented to Oil & Gas Research Council
Bismarck, North Dakota
August 4, 2020

Charlie Gorecki, CEO
John Harju, Vice President for Strategic Partnerships
Jim Sorensen, Director of Subsurface R&D

AGENDA

- BPOP 2.0 Highlights
 - Partners
 - Budget Evolution
 - Rich Gas Enhanced Oil Recovery (EOR) Pilot
 - Surface Facilities & Infrastructure
 - Subsurface Topics
 - Website
- BPOP 3.0 – The Next Three Years



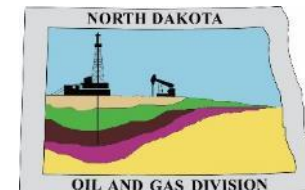
PARTNERS



U.S. DEPARTMENT OF
ENERGY



NATIONAL
ENERGY
TECHNOLOGY
LABORATORY



BPOP 2.0 BUDGET EVOLUTION

Sponsors	Original Budget	Final Budget	Actual Expenses	Balance
NDIC Share – Cash	\$6,000,000	\$6,000,000	\$5,999,645	\$355
Industry Partners – Cash	TBD	\$2,050,000	\$1,949,581	\$100,419
Marathon – In-Kind	\$7,280,000	\$12,615,401	\$12,615,401	\$0
Liberty – In-Kind		\$3,255,937	\$3,255,937	\$0
DOE – Cash		\$2,000,000	\$1,999,849	\$151
Total	\$13,280,000	\$25,921,338	\$25,820,413	\$100,925

- Program resources were nearly doubled from those originally proposed, resulting in leverage of NDIC resources > 3:1.
- A member contribution received late spring 2020 was rolled into BPOP 3.0's resources.

RICH GAS EOR – ACTIVITIES



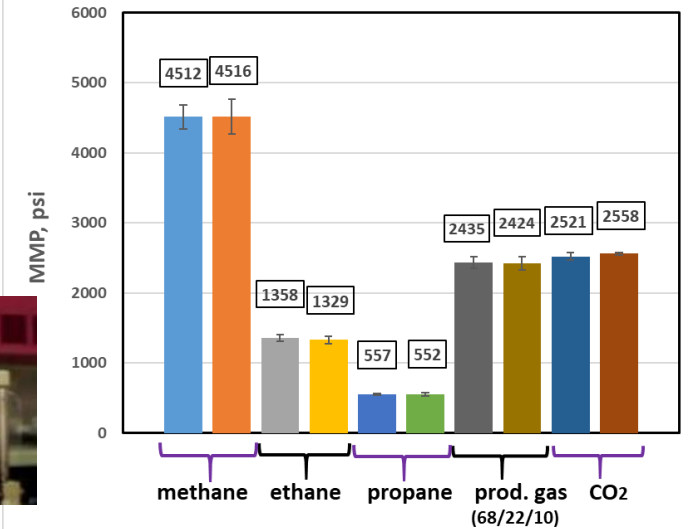
- Lab studies of rich gas interactions with fluids and rocks
- Iterative modeling of surface and subsurface components
- Pilot performance assessment



RICH GAS EOR – HIGHLIGHTS

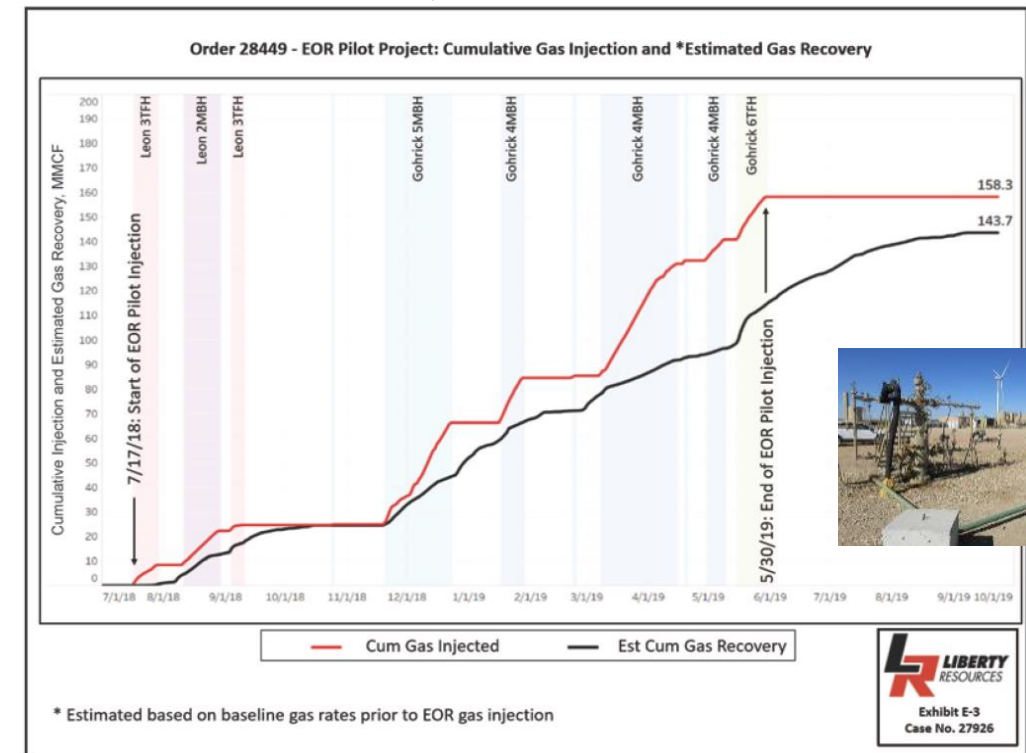
From the Lab:

- The richer the gas, the lower the MMP!!!
- Wellhead produced gas and CO₂ have similar MMP.



From the Field:

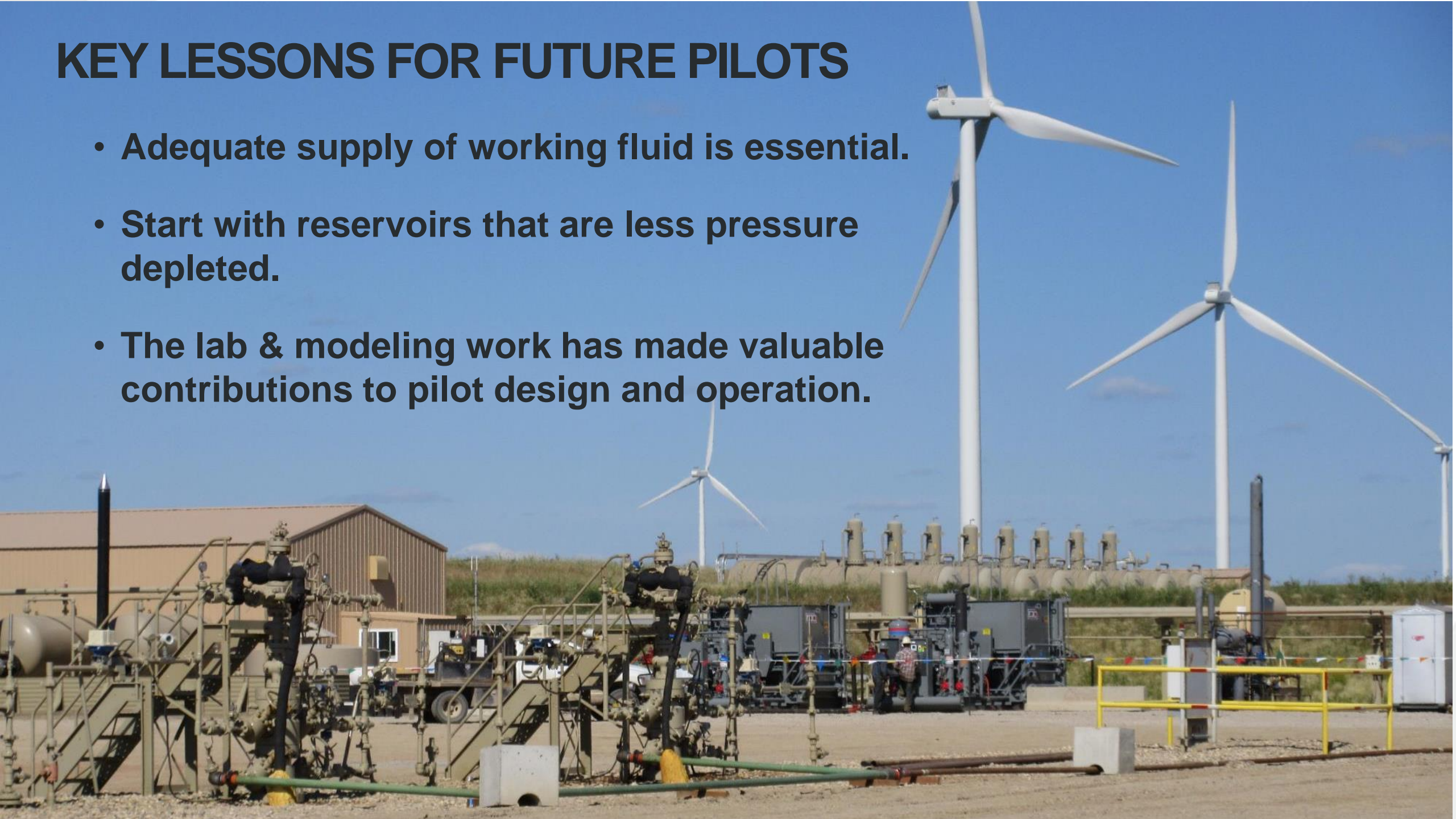
- ~160 MMscf gas injected in five wells during six different periods.
- Injected gas was controlled and contained within the DSU.
- Pressure buildup was achieved.



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KEY LESSONS FOR FUTURE PILOTS

- Adequate supply of working fluid is essential.
- Start with reservoirs that are less pressure depleted.
- The lab & modeling work has made valuable contributions to pilot design and operation.



PRIMER FOR PERMITTING AN EOR PILOT



BAKKEN PILOT TESTING FOR THE PURPOSE OF ENHANCED OIL RECOVERY: A NORTH DAKOTA REGULATORY PRIMER

Draft Final Report

Prepared for:

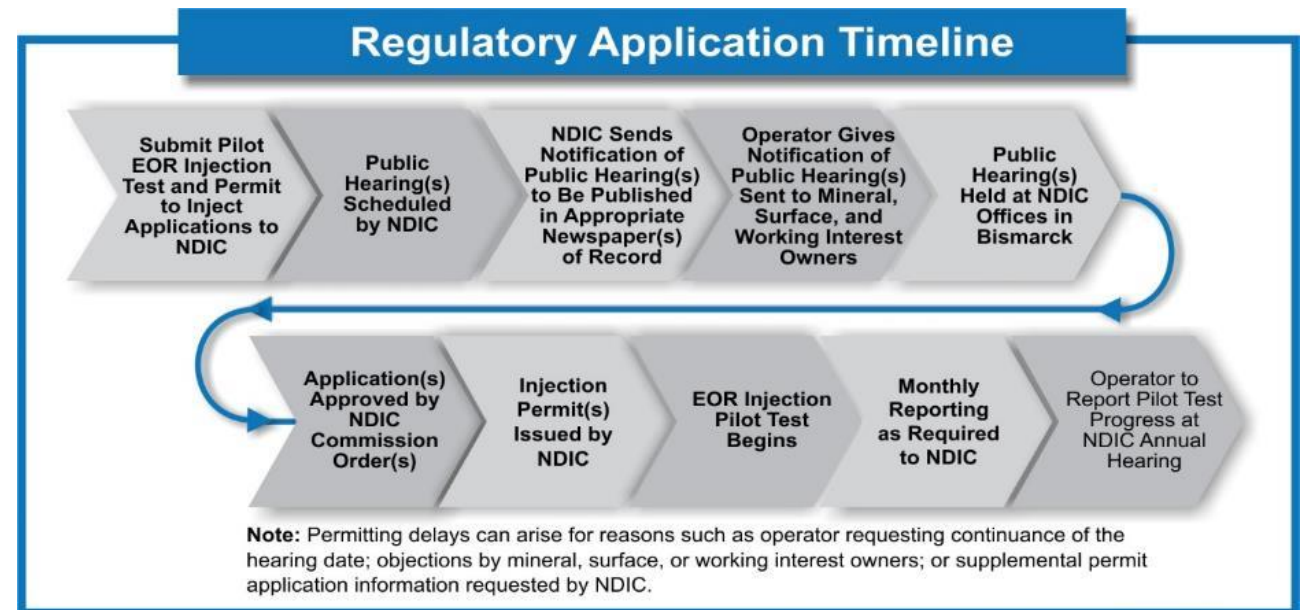
Contract No.

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May 2020



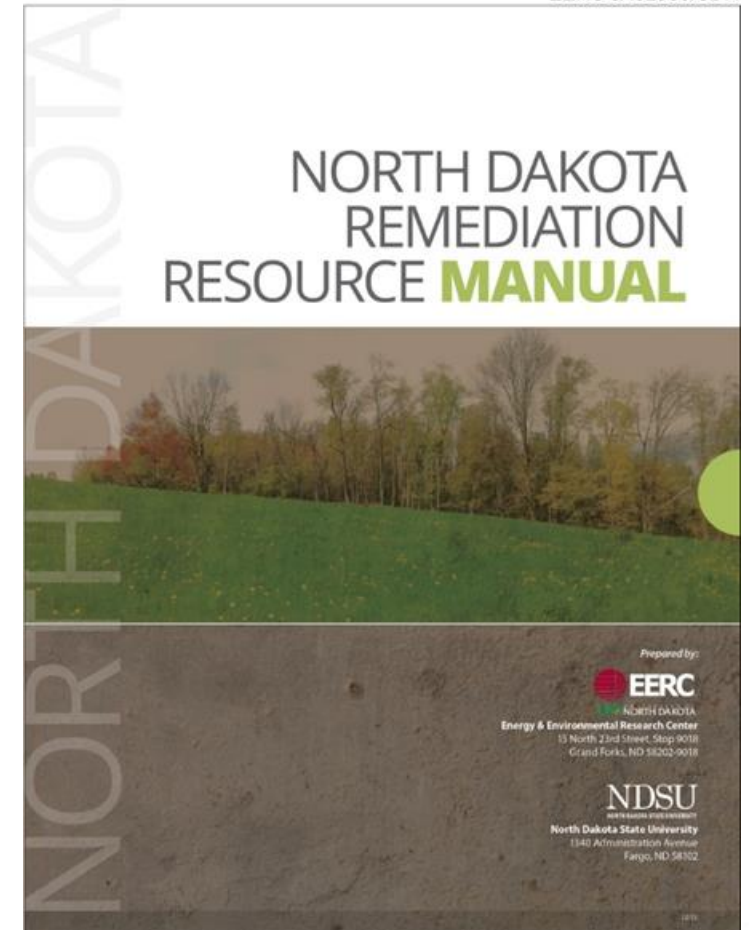
EERC JS58218.CDR

SURFACE HIGHLIGHTS

A Platform for Technical Industry Forums

- Technical support to the NDPC Hydrocarbon Remediation Task Force.
 - Co-authored the North Dakota Remediation Resource Manual.
 - ◆ Updated to include brine and hydrocarbon remediation, released March 2019.
- Supported gas capture efforts.
- Co-chaired the NDPC Technical Solutions Group, providing a forum to hear from oil field technology providers and share process optimization lessons learned.

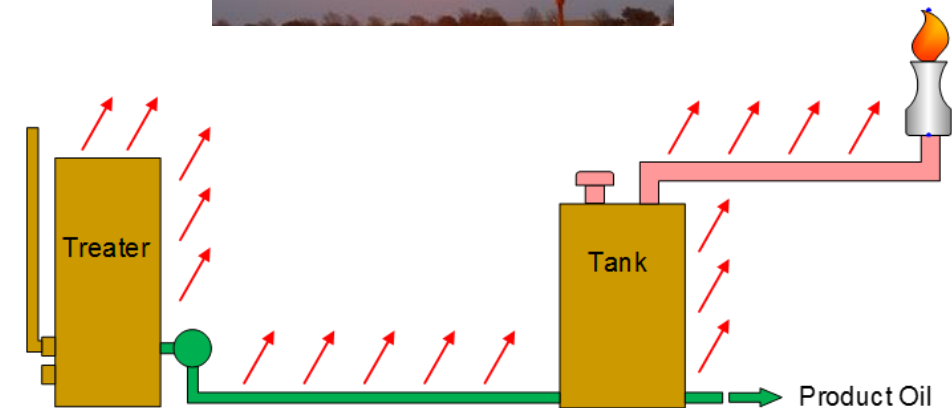
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SURFACE HIGHLIGHTS – FACILITY OPTIMIZATION

Member participation, computational modeling, and field studies addressed:

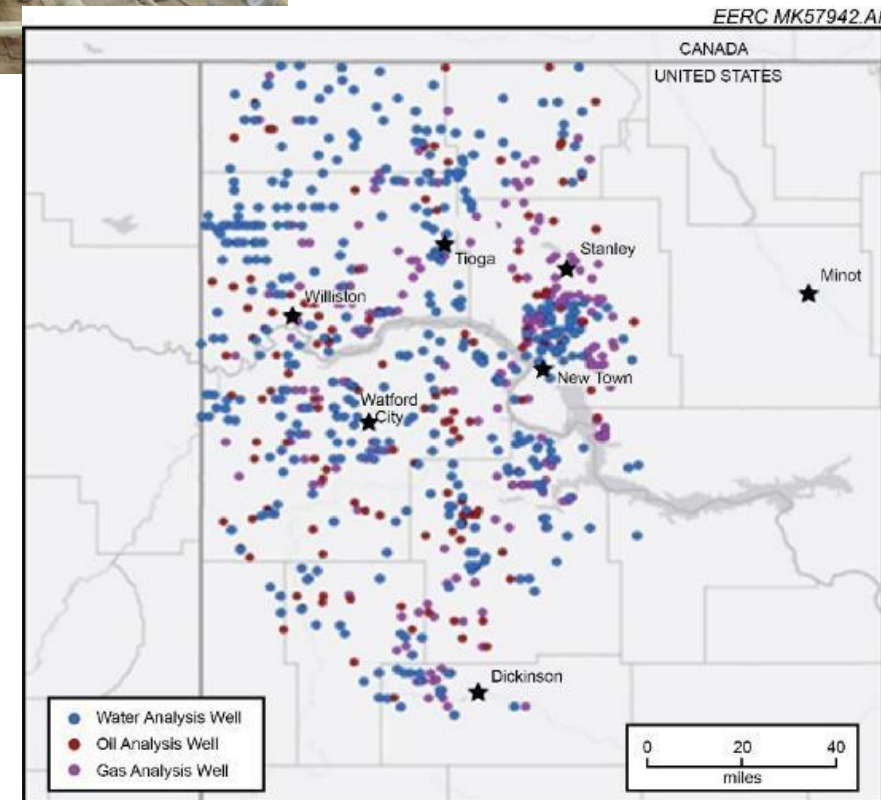
- **Emissions**
 - Impacts of production rate and tank design on tank emissions.
- **Gas Capture**
 - Technoeconomic analysis of mobile data centers as a flare mitigation strategy.
- **Crude Oil Vapor Pressure**
 - Design and operational strategies to improve vapor pressure compliance in cold weather.
- **Tank Vapor Management**
 - Identified operational conditions necessary to avoid flammable atmosphere in tank batteries.
- **Central Facilities**
 - Technoeconomic analysis of a central facility and identified advantages and challenges relative to a DSU-based facility.



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SURFACE HIGHLIGHTS – FLUIDS CHARACTERIZATION

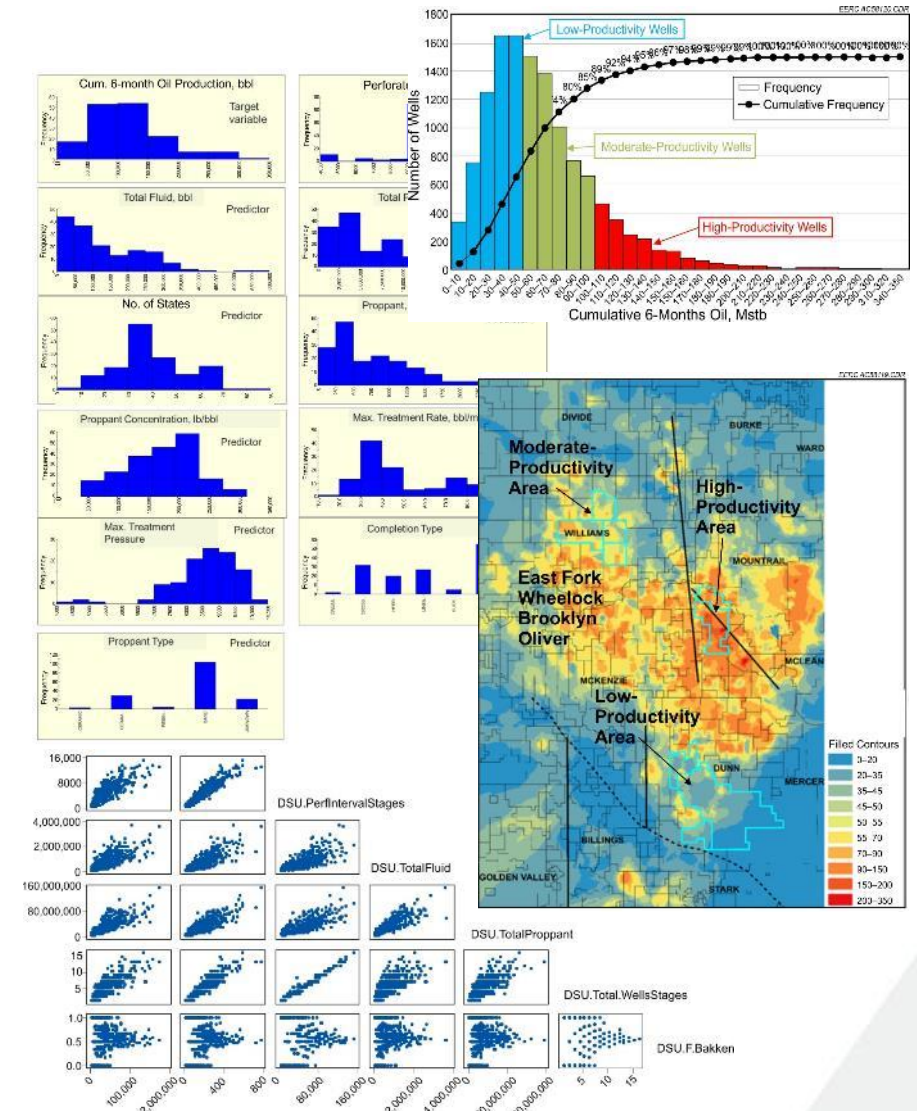
- Bakken/Three Forks produced fluids database:
 - 1000 produced water & gas samples
 - 500 crude oil samples
 - Maps were created and used to identify trends and correlations between fluid characteristics, geology, and well design & operational parameters.
- Produced gas composition observed to change over the first few years of production, with an increase in methane and a decrease in rich components.
- These findings were similar to, and used to validate, a separate basin wide gas composition forecasting effort.



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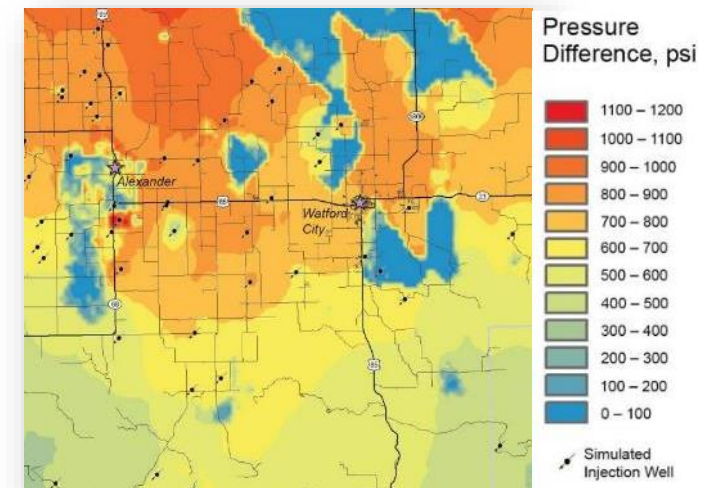
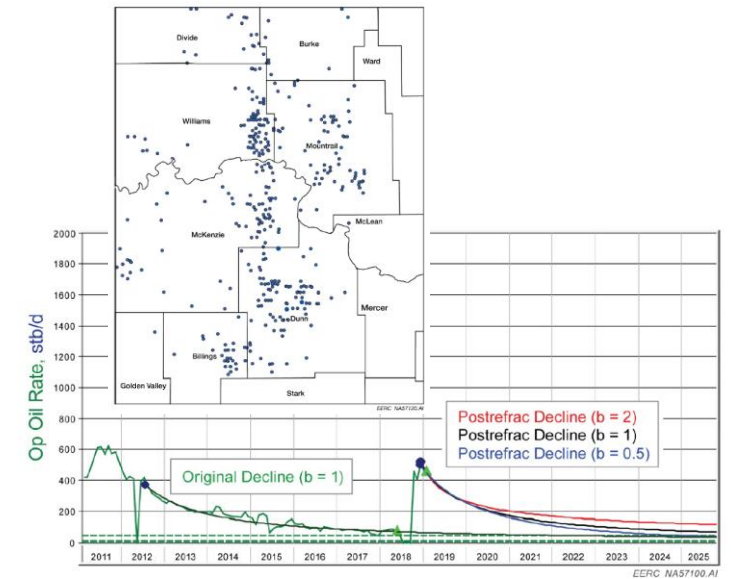
SUBSURFACE HIGHLIGHTS – WELL DATA ANALYSIS

- ML algorithms and data analytics used to determine the top factors that affect oil production.
- Example findings:
 - ◆ The top completion-related parameters that affected 6-month oil production were total proppant mass, total fracturing fluid volumes, number of wells within a DSU.
 - ◆ Sensitivity analyses showed that oil production generally increases with more intense completion practices.
 - ◆ All other inputs being equal, a well completed in the Three Forks has an 8% lower cumulative oil production in the first 6 months (on average) than an equivalent Bakken well.



SUBSURFACE HIGHLIGHTS – REFRACTS AND SWD

- **Evaluation of well refrac opportunities in the Bakken**
 - Identified ~ 400 wells that would be promising candidates for refracturing.
 - Based on 2019 economics, refracturing these wells estimated to yield a discounted net oil revenue of approximately \$2 billion, reflecting the median outcome after deducting the refrac cost, taxes, and royalties.
- **Modeling and simulation of SWD in the Inyan Kara Formation (Dakota Sandstone)**
 - Localized areas of pressurization have occurred.
 - Predictive model simulations suggest that the areas of elevated pressure could expand in size and magnitude with continued long-term injection, especially in the northern portion of McKenzie County.



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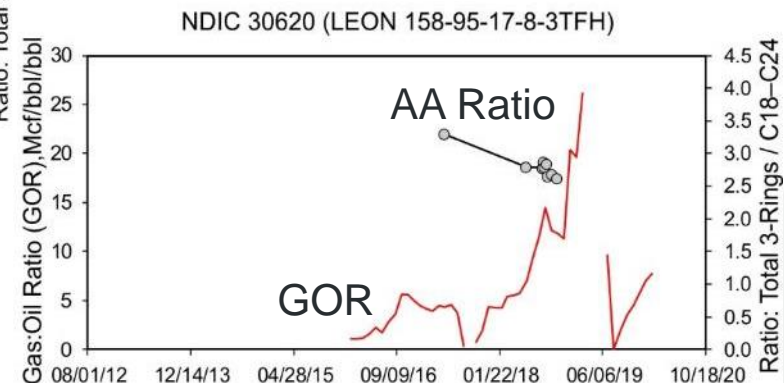
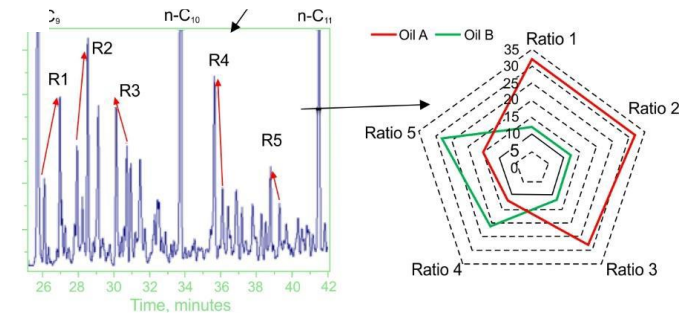
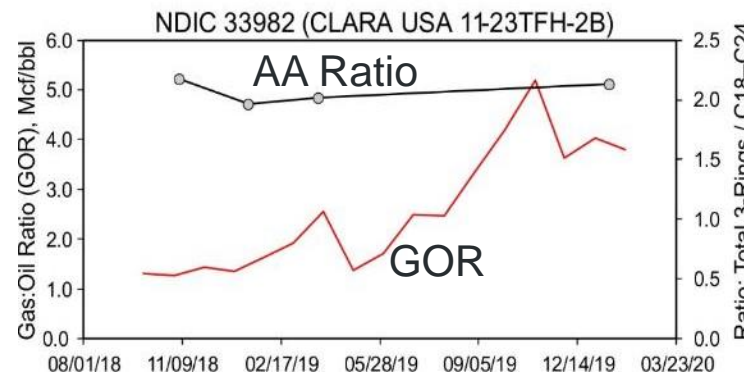
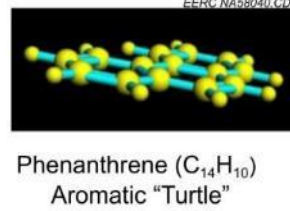
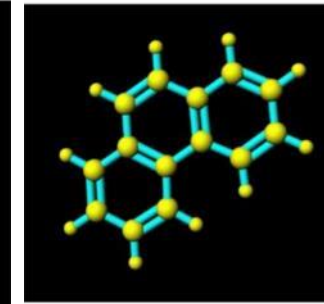
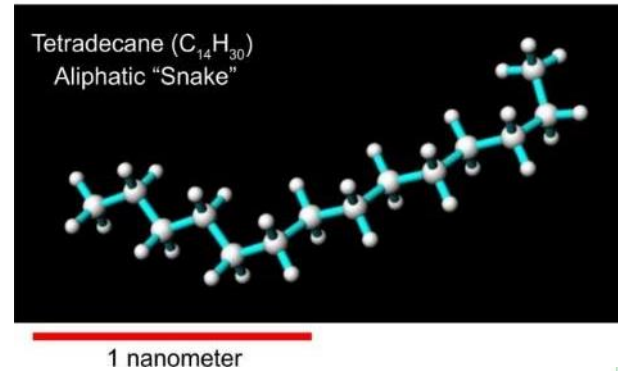
SUBSURFACE HIGHLIGHTS – OIL FINGERPRINTING

- Oil fingerprinting using aromatic/aliphatic (AA) ratios

Statistically significant differences in the AA ratio of oil from the shales vs nonshale reservoirs were identified from 105 rock samples.

Temporal AA ratios for oil from 12 Marathon & Liberty wells:

- 10 wells had no statistically significant changes in AA, suggesting no changes in the source of oil.
- 2 wells showed decreasing AA ratio, suggesting less contribution of oil from shales over time.



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PRODUCTS CAN BE ACCESSED ON THE WEBSITE



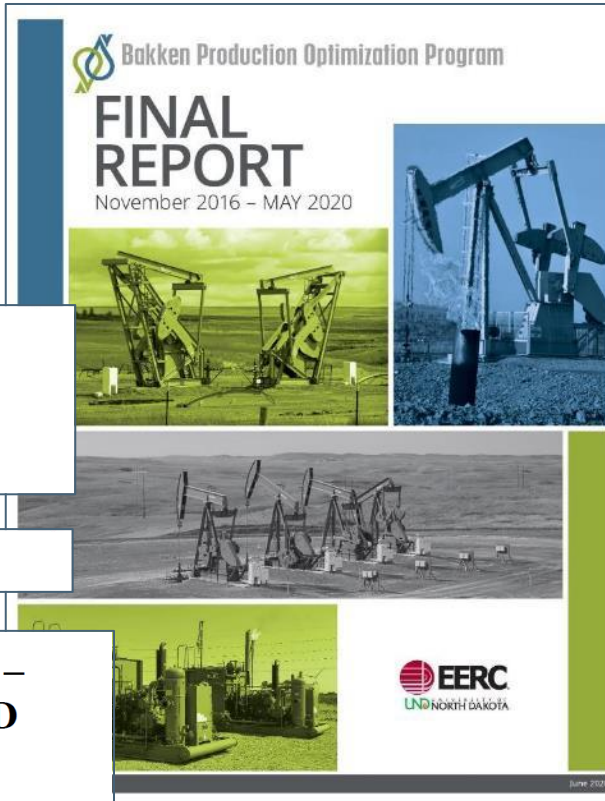
REFRACTURING IN THE BAKKEN – AN ANALYSIS OF DATA FROM ACROSS NORTH DAKOTA

OVERVIEW SUMMARY OF ADVANCED ANALYSIS OF BAKKEN DATA TO OPTIMIZE FUTURE PRODUCTION STRATEGIES

PRODUCED FLUID CHARACTERIZATION

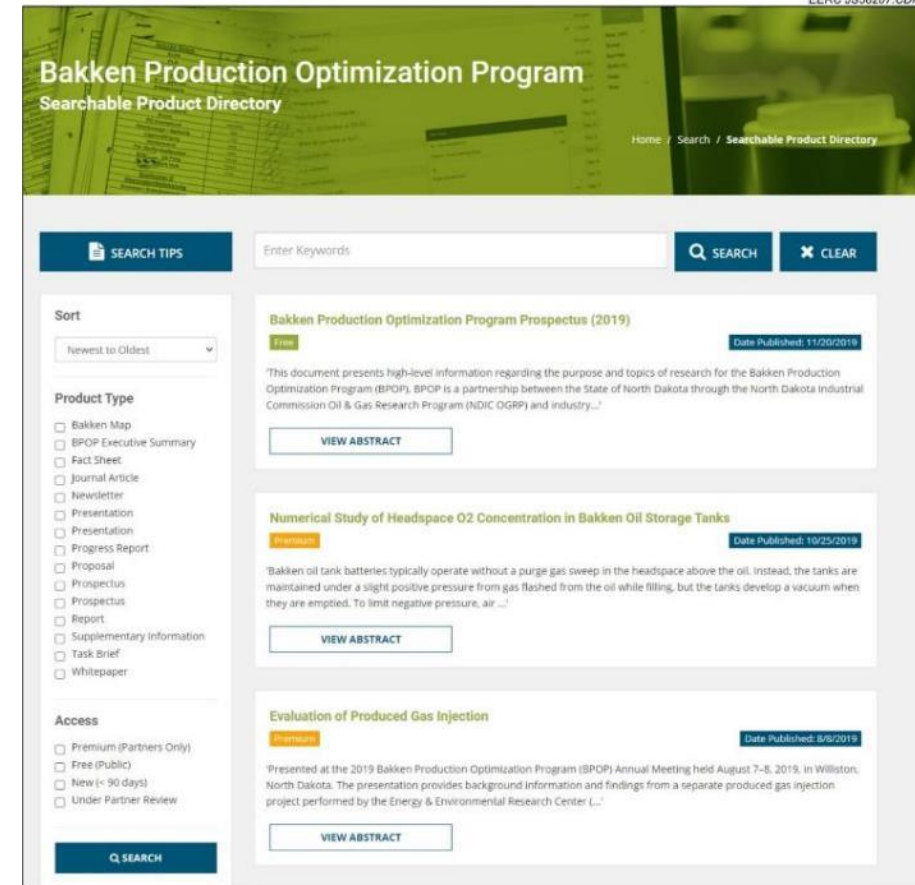
ENHANCED OIL RECOVERY IN THE BAKKEN – KEY OBSERVATIONS AND LESSONS LEARNED FROM LABORATORY STUDIES, MODELING, AND FIELD TESTING

TURTLES AND SNAKES: USING MOLECULAR SHAPE TO UNDERSTAND OIL MIGRATION AND PRODUCTION IN THE BAKKEN PETROLEUM SYSTEM



BAKKEN PILOT TESTING FOR THE PURPOSE OF ENHANCED OIL RECOVERY: A NORTH DAKOTA REGULATORY PRIMER

EXAMINATION OF PREFERENTIAL SORPTION OF RICH GAS COMPONENTS IN BAKKEN SHALE



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EERC JS58207.CDR

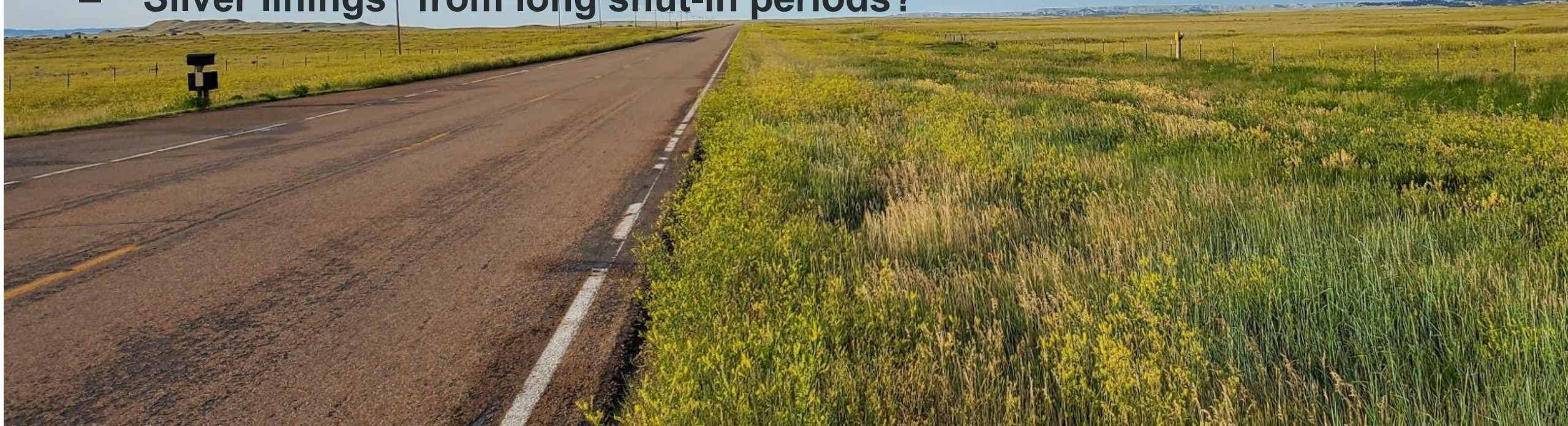
ROAD AHEAD FOR THE BAKKEN...

- Operators face challenges beyond current price environment.
 - Flaring
 - Produced water
 - Fugitive emissions
 - Takeaway capacity



BPOP 3.0 - CHALLENGES YIELD OPPORTUNITY

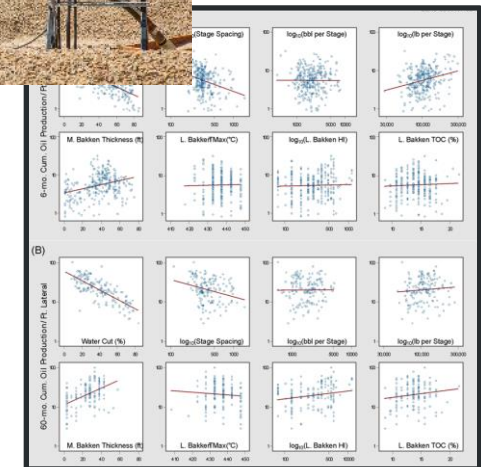
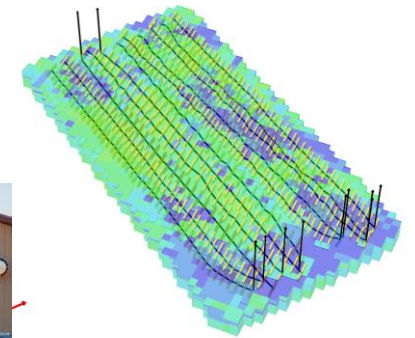
- Use Big Data Analytics & Machine Learning to identify opportunities to gain efficiency and guide a “Smart Restart.”
- Capture more gas and put it to work for EOR or store it for future beneficial use.
- Develop and deploy innovative technology to improve efficiency and increase EUR.
- “Silver linings” from long shut-in periods?



BPOP 3.0 MAY 2020 – APRIL 2023

Key questions to be addressed during the next 3 years could include:

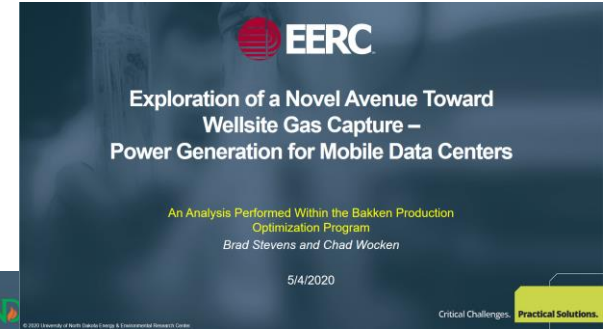
- How do we go about a “Smart Restart” for Bakken wells & infrastructure?
- How do we apply lessons to next-generation pilots and build momentum to commercial EOR?
- What is the best development strategy for Bakken and Three Forks resources over the next decade?
- How do we manage long-term, large-volume water and rich gas coproduction?
- How can recent advances in BDA and ML be applied to oil and gas resource development in North Dakota?



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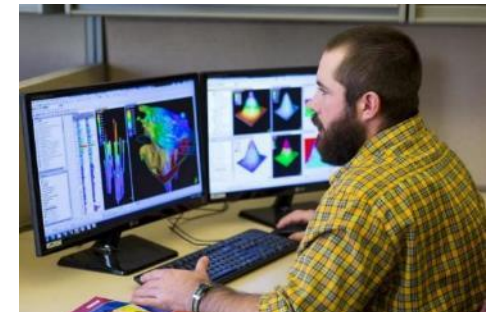
BPOP 3.0 CURRENT ACTIVITIES

- **Surface operations and infrastructure investigations**
 - Knowledge transfer through webinars
 - Planning for next round of field data collection
 - Beginning to look at impact of shut-ins on infrastructure
- **Subsurface investigations**
 - Knowledge transfer through webinars
 - Planning for next round of field data collection
 - Advanced analysis of well completions and fluids production data
 - Continuing to improve oil fingerprinting methods



BPOP 3.0 CURRENT ACTIVITIES

- **Enhanced oil recovery**
 - Rich gas–oil fluid behavior and rock extraction studies in conjunction with Oasis
 - Reservoir modeling and simulation in support of new Liberty Resources pilot concept
- **Machine learning and big data analytics applied to the Bakken**
 - U.S. Department of Energy match
 - Real-time visualization, forecasting, and control tools for improved reservoir surveillance
 - Virtual learning tools to investigate alternative injection scenarios



BPOP 3.0 TIME LINE

	BPOP 3.0 Year 1												BPOP 3.0 Year 2												BPOP 3.0 Year 3																						
	2020				2021				2022				2023																																		
	Q1			Q2			Q3			Q4			Q5			Q6			Q7			Q8			Q9			Q10			Q11			Q12													
	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
Project Management				▼ D1			▼ D1			▼ D1			▼ D1			▼ D1			▼ D1			▼ D1			▼ D1			▼ D1			▼ D1			▼ D1													
																																		D9 ▼													
Surface Operations and Infrastructure Investigations										D2 ▼												D6 ▼									D10 ▼																
Process Optimization																																															
Fluids Characterization																																															
Subsurface Investigations										D3 ▼												D7 ▼									D11 ▼																
Investigation of Improved Reservoir Drainage and Production Efficiency																																															
Well Completions and Fluids Production Trend Analysis																																															
Well Completions Optimization																																															
Produced Water Management																																															
Enhanced Oil Recovery (EOR)										D4 ▼												D8 ▼									D12 ▼																
Rich Gas–Oil Behavior and Rock Extraction Studies																																															
Modeling of EOR Reservoir Components																																															
Pilot Performance Assessment																																															
Maching Learning and Big Data Analytics Applied to the Bakken																D5 ▼																															
Real-Time Visualization, Forecasting, and Control Tools for Improved Reservoir Surveillance																																															
Virtual Learning Tools to Investigate Alternative Injection Scenarios																																															

D1 – Quarterly Report

D2–D4, D5–D8, D10–D12 – Topical Report

D9 – Final Report

BPOP 3.0 PROPOSED BUDGET

	NDIC Share	Industry Share	Federal Share	Total Project
Total Cash Requested	\$6,000,000	\$500,000	\$1,500,000	\$8,000,000
Total In-Kind Cost Share		\$4,000,000		\$4,000,000
Total Project Costs	\$6,000,000	\$4,500,000	\$1,500,000	\$12,000,000

QUESTIONS?



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A wide-angle photograph of a university campus at sunset. The sun is low on the horizon, casting a warm glow over the scene. In the foreground, there are large trees with some yellowing leaves. In the background, several multi-story brick buildings and a parking lot with many cars are visible under a clear sky.

THANK YOU

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