



Improving Well Performance through Multi-Variate Completion Analyses in the US Bakken Shale

C. Mark Pearson





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Dr. C. Mark Pearson is CEO & President of Liberty Resources II LLC, a Denver-based operator in the Bakken Shale of North Dakota and the Powder River Basin in Wyoming. He is a well-known industry expert in the field of well completion and stimulation and has authored over forty technical papers covering field development, "fracking", and production aspects of oil and gas operations. He has focused his career on technology advancements within the industry and is one of the pioneers of multi-stage hydraulic fracturing of horizontal wells with over thirty years of horizontal work in west Texas, Alaska, the North Sea, the US mid-Continent, North Dakota and Wyoming.



C. Mark Pearson
CEO & President Liberty
Resources II, LLC

Mark graduated with BS and PhD degrees from the Camborne School of Mines, UK and is a graduate of the Harvard Business School Advanced Management Program. He also served as a professor in the Petroleum Engineering Department of the Colorado School of Mines from 1995-1997.



Poll Question

What is your technical discipline?



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Poll Question

What is your job title?



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Poll Question

Who is your employer?



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Poll Question

How many years of experience do you have?



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Poll Question

What geographic region are you from?



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Poll Question

How experienced are you with testing different types of unconventional completions?



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Liberty Resources LLC – Denver, CO



- An independent, private-equity backed E&P company with industry leading expertise in developing tight-oil plays using advanced completion designs and fracs.
- Operates in the Williston Basin (ND) and Powder River Basin (WY) with gross and net operated production over 10,000 boepd.
- Team has been working in the Williston Basin (Bakken) since 2009 and has already sold its assets once – in mid-2013 – and then re-entered the basin in 1Q 2014 as Liberty Resources II LLC.
- The company operates a one-rig program in the Williston Basin and in 2017 is drilling a 3-well assessment program in the Powder River Basin.



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Outline



- Public E&P databases in the US:
 - Frac Focus (US Frac reporting database)
 - North Dakota Industrial Commission (NDIC) public database
- Bakken Introduction
 - Location, Geology, Development History
- Multi-Variate Analysis of Completion and Production Data
- Latest Completion Trends in the Bakken
- The end result – Well Performance



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FracFocus Introduction



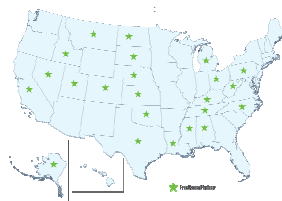
<http://fracfocus.org>

FracFocus is the national hydraulic fracturing chemical registry. FracFocus is managed by the Ground Water Protection Council and Interstate Oil and Gas Compact Commission, two organizations whose missions both revolve around conservation and environmental protection.

The primary purpose of this site is to provide factual information concerning hydraulic fracturing and groundwater protection. To help users put this information into perspective, the site also provides objective information on hydraulic fracturing, the chemicals used, the purposes they serve and the means by which groundwater is protected.

The site was created to provide the public access to reported chemicals used for hydraulic fracturing within their areas.

Currently, twenty-three states use FracFocus in this manner as shown in the map.



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FracFocus - Search for a Well

Start at the main FracFocus page www.fracfocus.org and click on Find a Well (on the green map).

Looking for information about a well site near you?



Search for nearby well sites that have been hydraulically fractured to see what chemicals were used in the process.

TOTAL WELL SITES REGISTERED **127781**

FracFocus contains many ways to search the public database for specific disclosures by:

- State
- County
- Operator Name
- Date range (on, on or before, on or after, between)
- API well number
- CAS number
- On Federal or Indian lands
- Well name
- Specific ingredients.

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FracFocus- Search for a Well

You can search using either a Standard Search or a Map Search:

Find a Well

Map Search

Search Options

Choose a State: COUNTY: WELLS IN COUNTY: OPERATOR:

DATE RANGE: DATE RANGE: RANGE START DATE: RANGE END DATE:

FEDERAL WELLS: ☐ API WELL NUMBER: WELL NAME:

CAS Number:

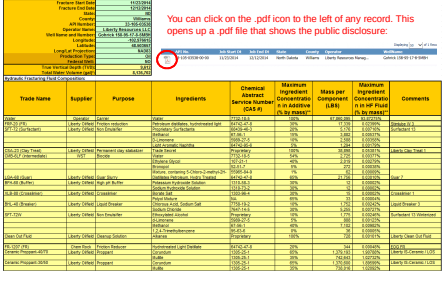
INGREDIENT LIST

Displaying 127 of 127 records

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FracFocus Completed Entry Form Example

You can click on the .pdf icon to the left of any record. This opens up a .pdf file that shows the public disclosure:



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Typical Well File

<https://www.dmr.nd.gov/oilgas/>

1 / 135

Webcam

Bookmarks

Form 6-Bakken(Revised)

Certified Surveys

Form 6-Bakken

Form 4

4-rpt-reclamation

4-rpt-reclamation

4-rpt- chng prod method

4-intent-request to waive open hole logging

4-rpt- flowing well tbq/ pkr req. waiver

Geo report

Form 1

• 100+ pages

• Form 6 – Completion Report

• Form 4 – Sundries

• Form 1 – Application for Permit to Drill (APD)

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NDIC Well File – Form 6 (Frac Data)

Webcam

CASING & TUBULARS RECORD (Report all strings set in well)

Well Bore	Type	String Size (inch)	Top Set (MD Ft)	Depth Set (MD Ft)	Hole Size (inch)	Weight (Lbs/Ft)	Anchor Set (MD Ft)	Packer Set (MD Ft)	Sacks Cement	Top of Cement
Lateral1	Conductor	16		105	16	K-65			435	0
	Surface	9 5/8	2023	13 1/2	36,465				435	0
	Intermediate	7	9023	8 3/4	30				1145	0
	Liner	4 1/2	19855	6	11.8				633	9049
	Tubing	2 7/8		9018						
									Cemented vs Uncemented	

PERFORATION & OPEN HOLE INTERVALS

Well Bore	Well Bore TD (MD Ft)	Completion Type	Open Hole/Perforated Interval (MD Ft)	Kick-off Point (MD Ft)	Top of Casing Window (MD Ft)	Date Perforated or Drilled	Date Isolated	Isolation Method	Sacks Cement
Lateral1	19870		9038 - 19555	9128					
			Perforated Interval						
			Frac Data						
			# Stages, Total Fluid Volume, Total Lbs Proppant, Max Treating Pressure/Rate						

Well Specific Stimulations

Date Stimulated	Stimulates Formation	Top (Ft)	Bottom (Ft)	Simulation Stages	Volume (Barrels)	Volume Units
12/13/2014	Bakken	9038	19555	60	183721	
Type Treatment	Acid %	Lbs Proppant	Maximum Treatment Pressure (PSI)	Maximum Treatment Rate (BBLs/Mn)		
Stand Price	0%	4218773	9598			84.9
Details						

4,218,773 of 4070 & 3090 proppant

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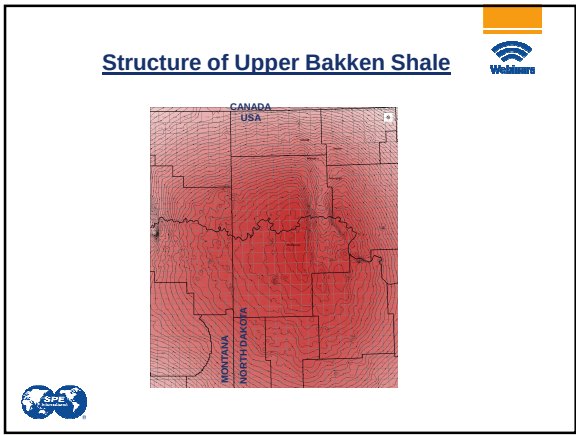
Bakken Shale – Williston Basin

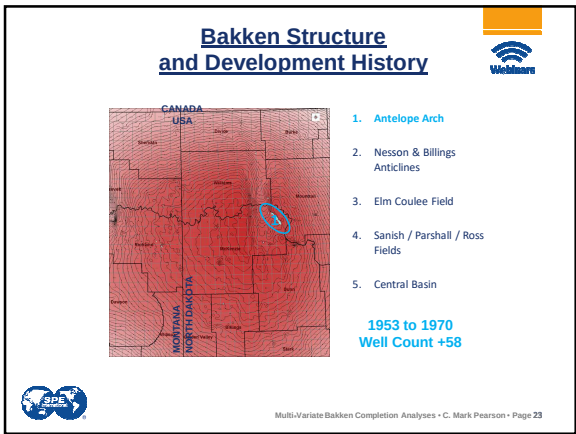
Webcam

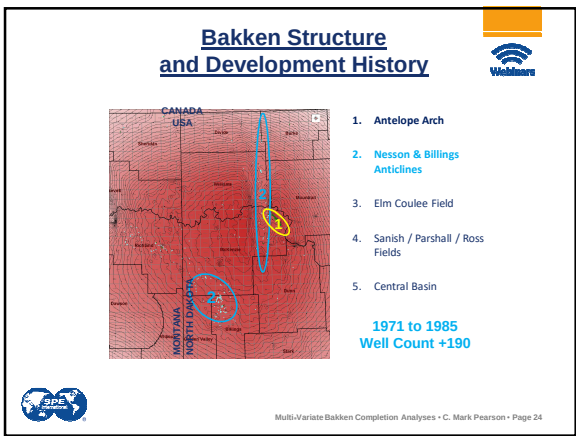
Central Basin

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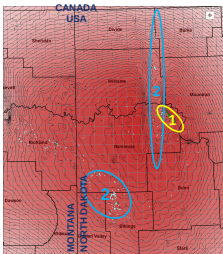
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Bakken Structure and Development History



1. Antelope Arch

2. Nesson & Billings Anticlines

3. Elm Coulee Field

4. Sanish / Parshall / Ross Fields

5. Central Basin

1986 to 2000

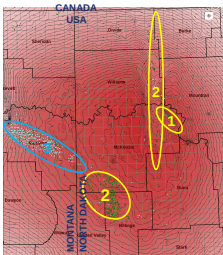
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Bakken Structure and Development History



1. Antelope Arch

2. Nesson & Billings Anticlines

3. Elm Coulee Field

4. Sanish / Parshall / Ross Fields

5. Central Basin

2001 to 2005

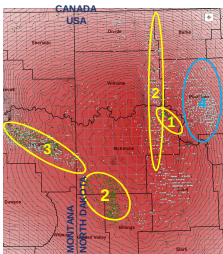
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Bakken Structure and Development History



1. Antelope Arch

2. Nesson & Billings Anticlines

3. Elm Coulee Field

4. Sanish / Parshall / Ross Fields

5. Central Basin

2006 to 2009

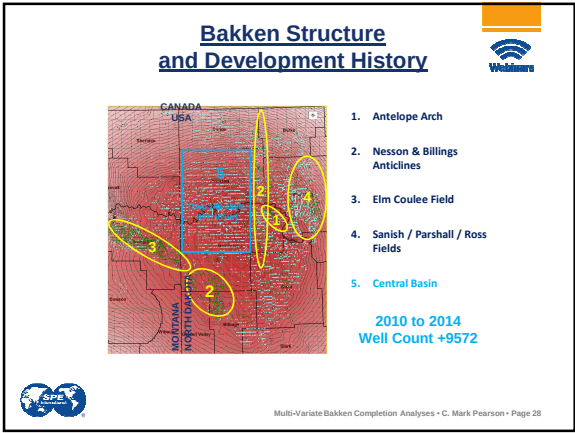
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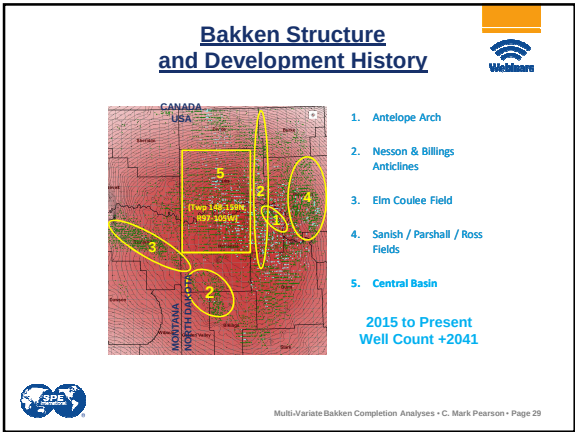


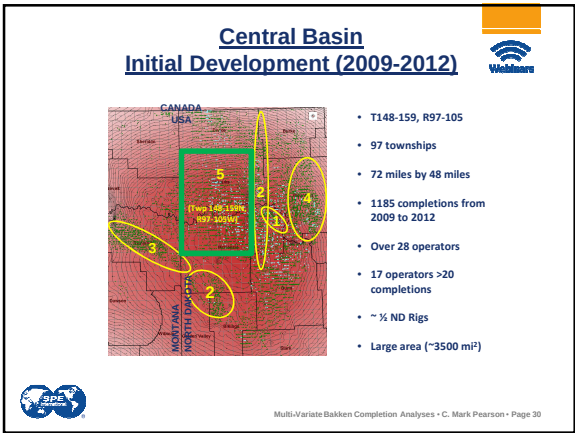
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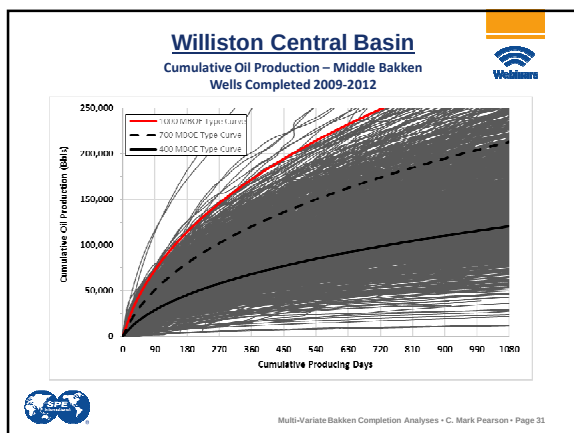


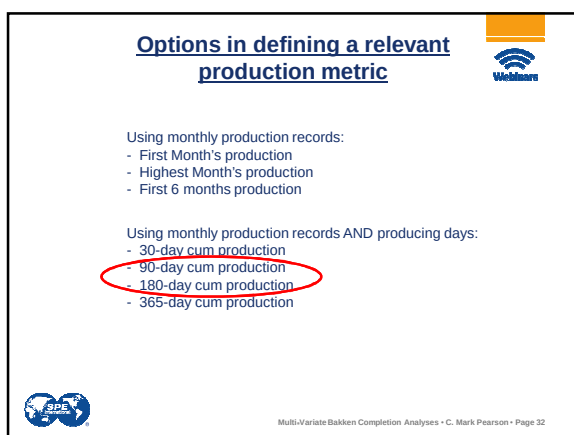
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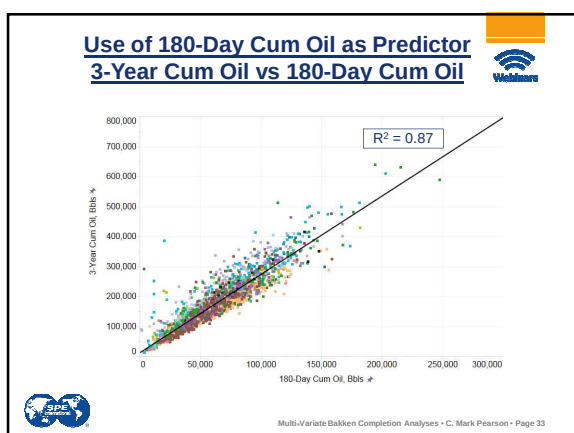












Multi-Variate Analysis

- Allows looking at multiple variables over large areas
- Includes geological variables (reservoir quality) and completion (frac) parameters
- User specified variables summed in "transformations" versus a "response" variable (180-day cum production)
- High level of correlation, no need to use a small area as is the case for bi-variate analysis
- Able to compare completions across a larger study area



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Bakken Central Basin
Multi-Variate Analysis (SPE 166479)

Model Input Parameters

- Reservoir / Geological / Production
 - Cumulative Water Cut (co-linear with pore pressure and depth); no/minimal dependence on calculated OOIP/S_gΦH or net pay
- Completion / Frac Design
 - Lateral Length, ft
 - Stage Length, ft/stage - (number stages)
 - Proppant Amount, lbs/ft
 - Fluid Volume, bbls/ft
 - Proppant Type, % sand (proxy for the amount of "premium proppant")



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Multivariate Model Predicted vs. Actual

180-Day Cum Oil Analysis

Predicted 180-Day Cum Oil, Bbls

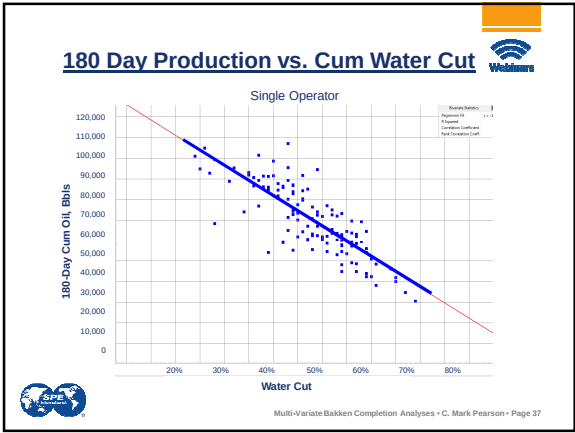
Actual 180-Day Cum Oil, Bbls

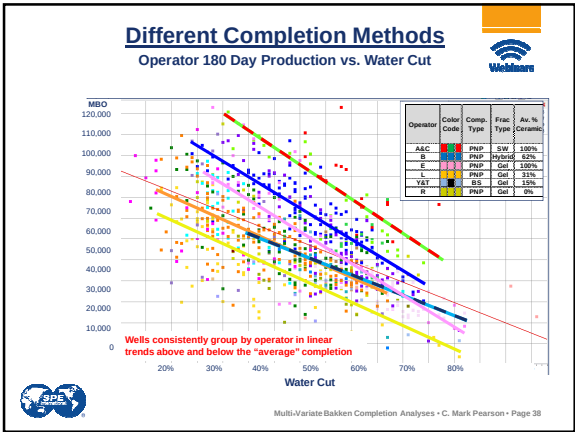
180-Day Analysis

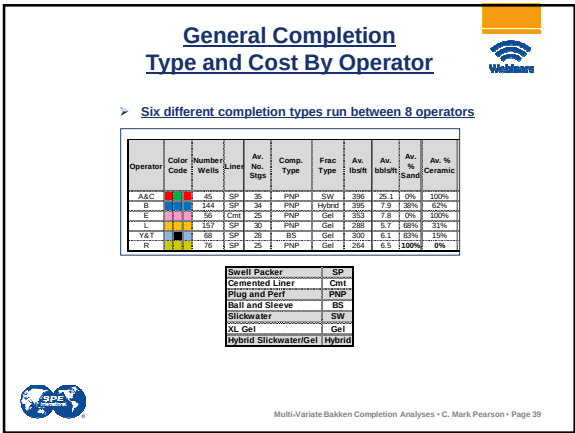
R² = 0.77

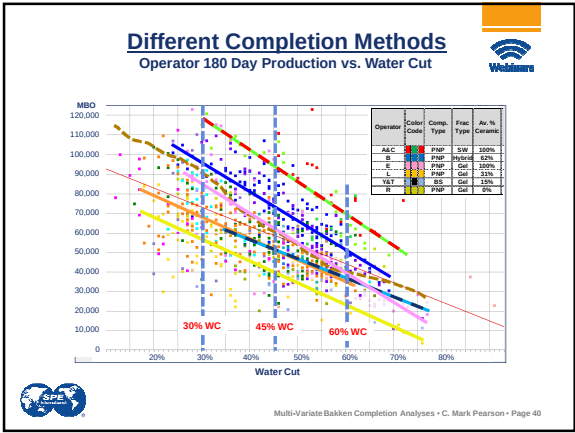


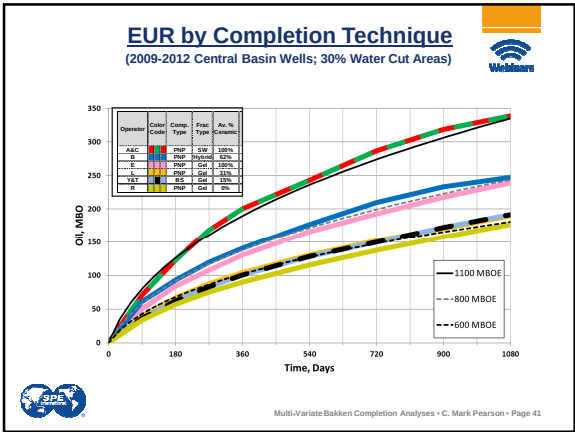
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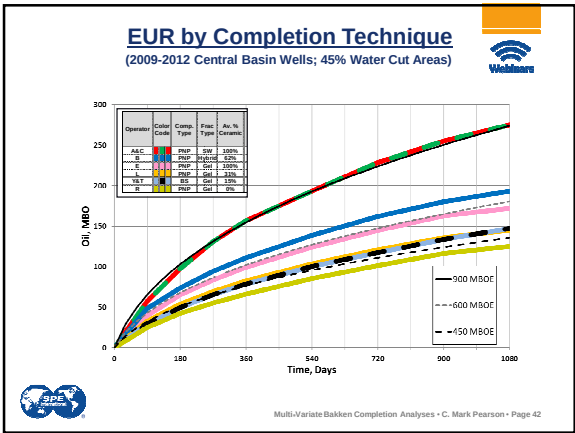


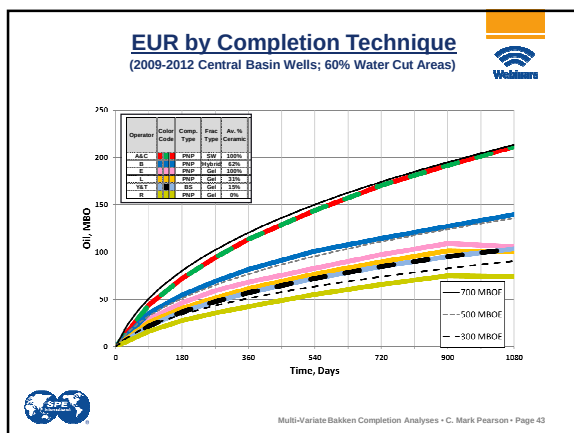


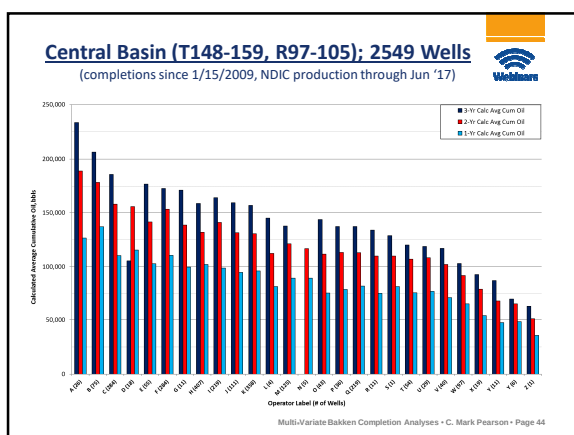








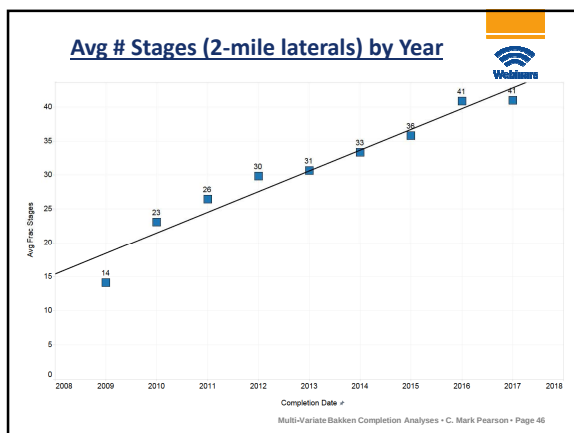


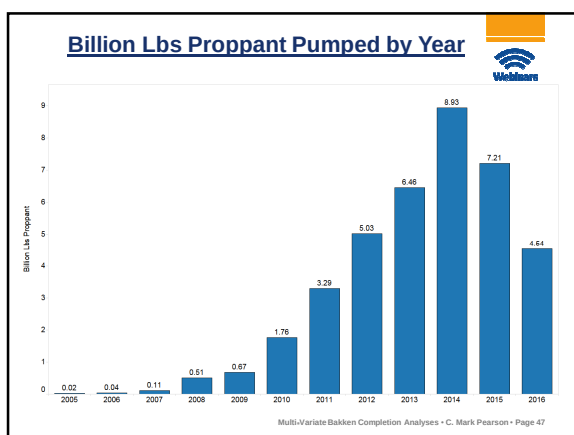


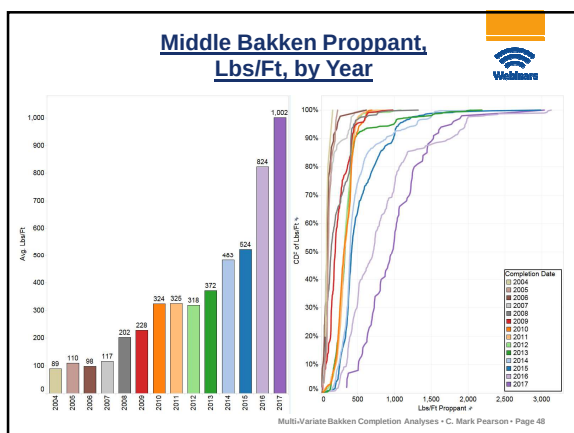
Latest Completion Trends in the Bakken

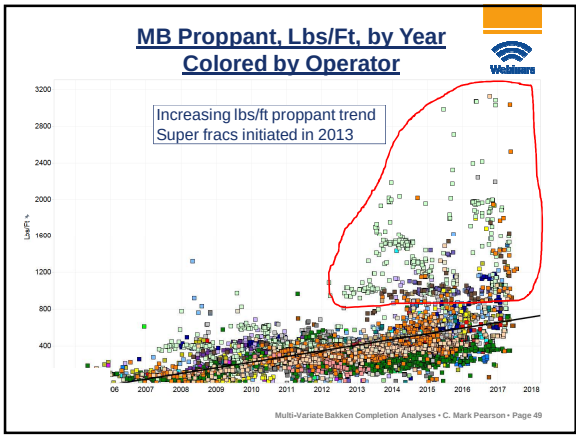
- How has Industry put these learnings to work?

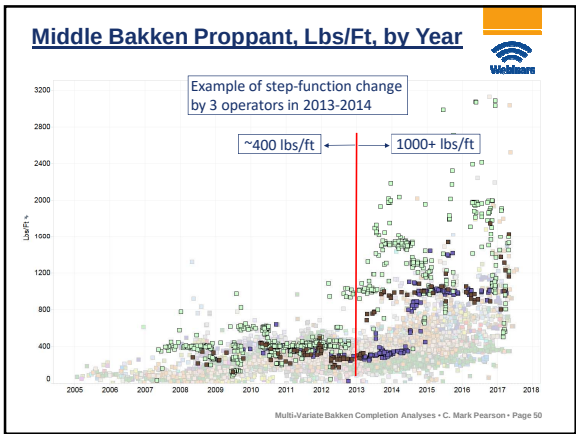
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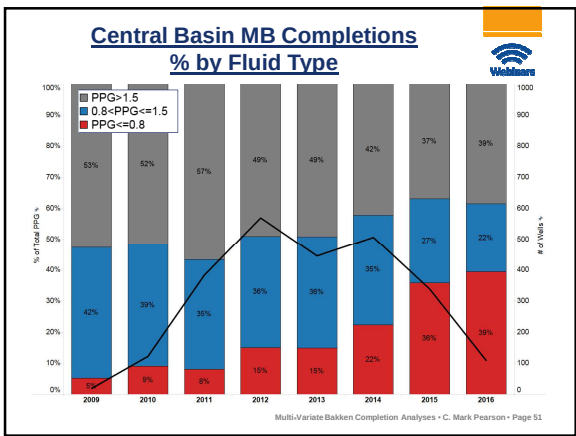


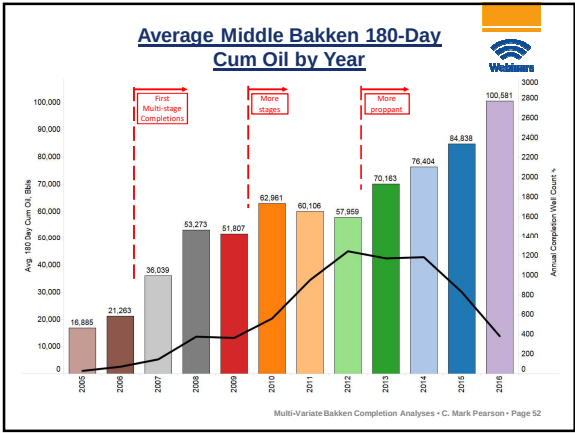


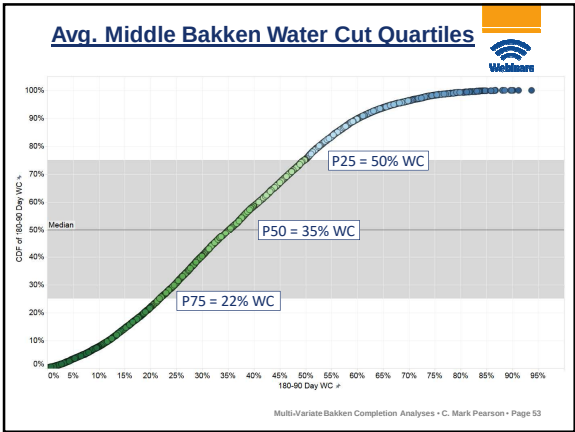


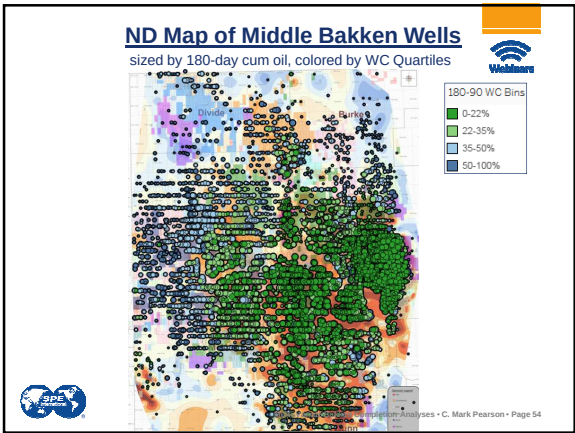


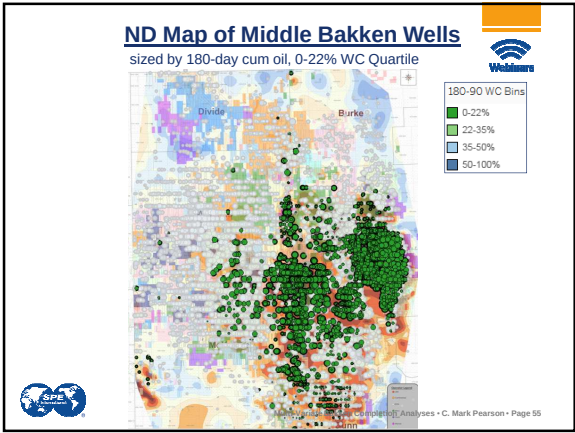


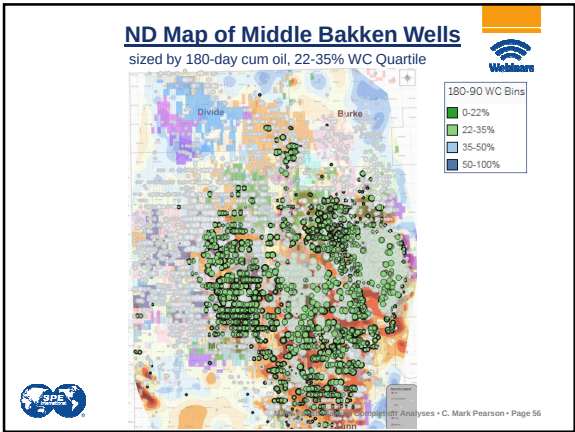


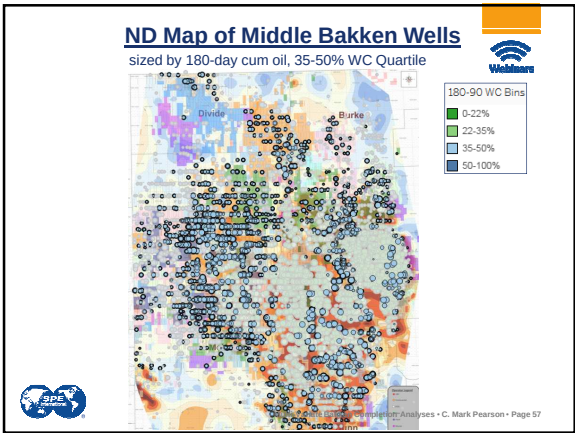


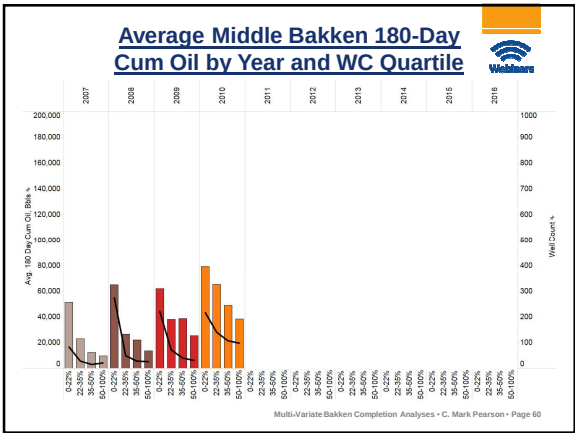
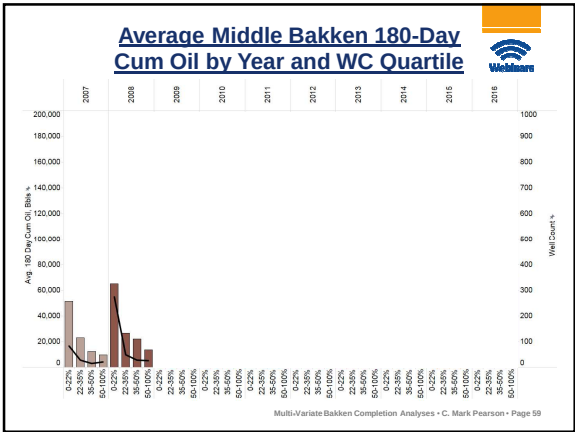
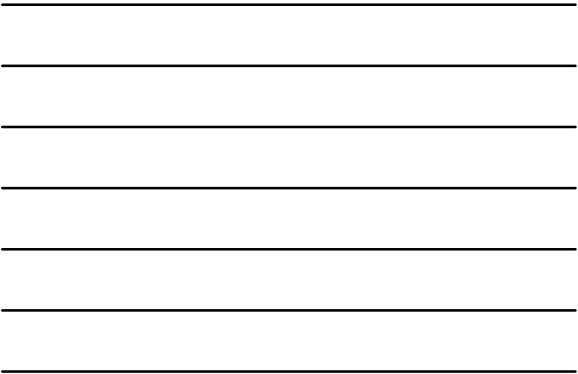
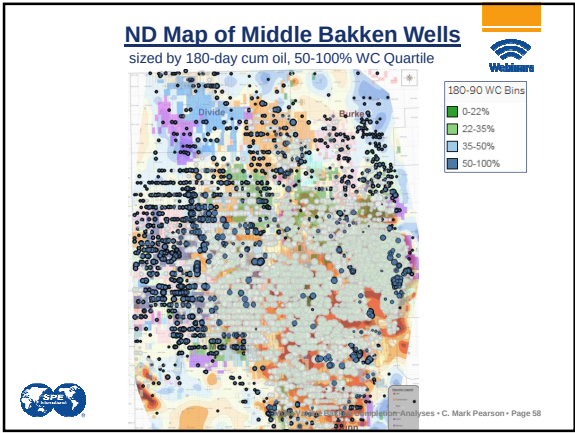


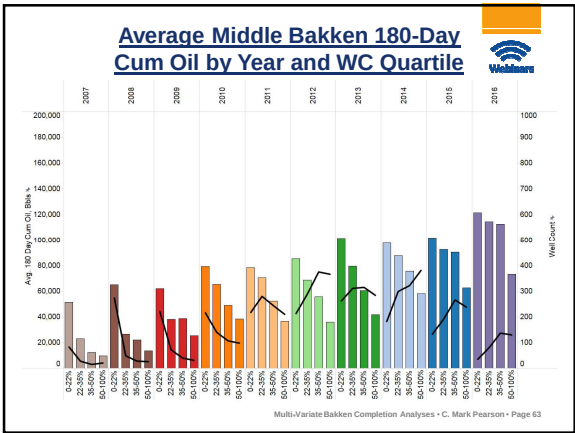
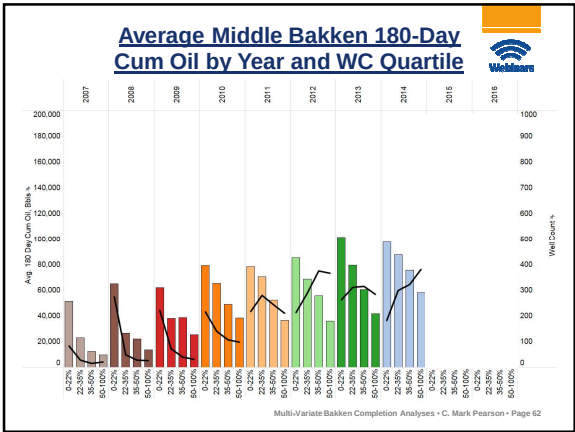
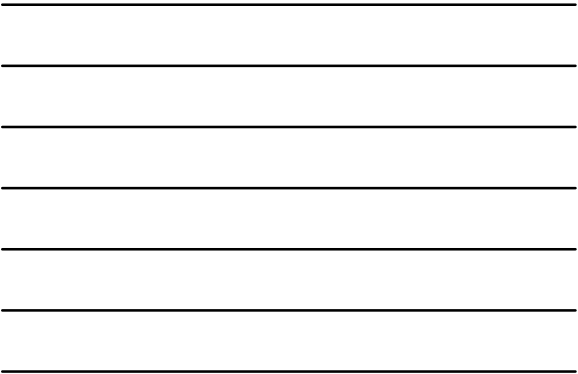
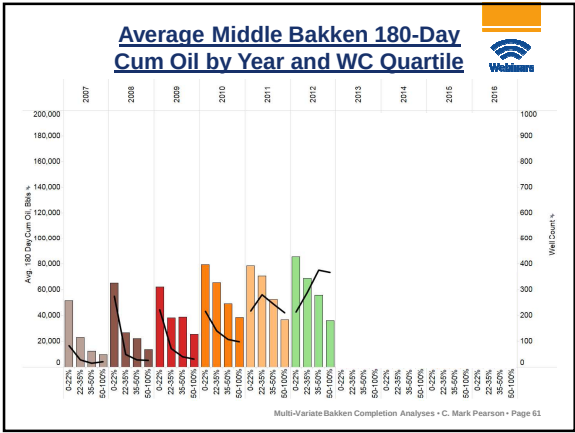


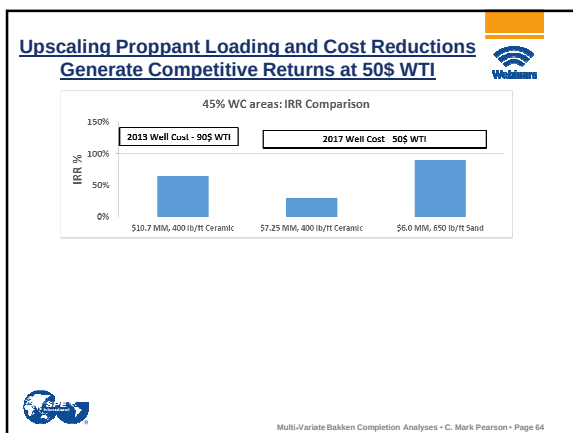


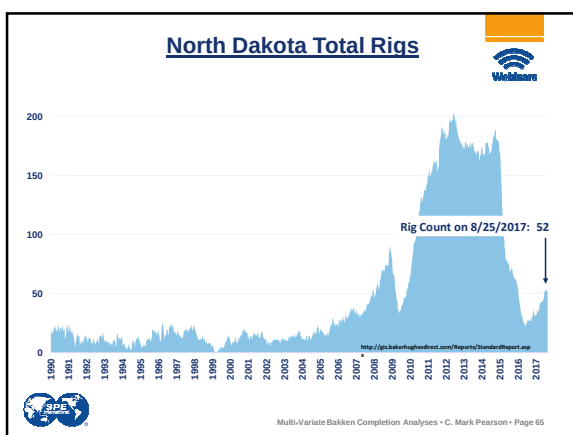


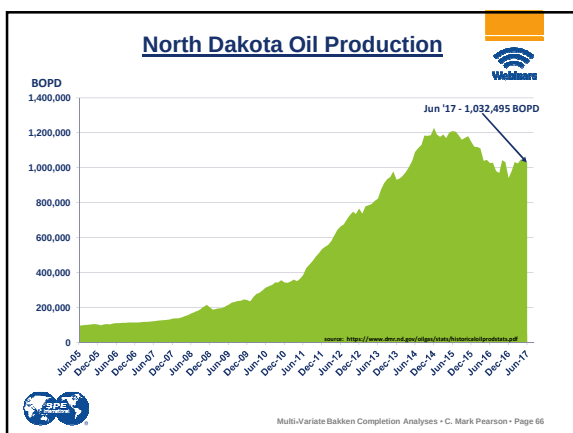












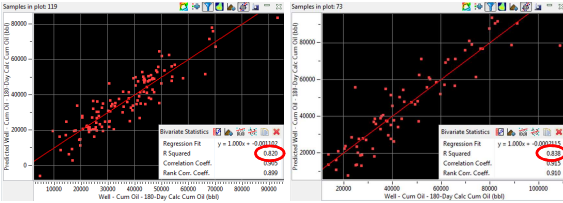
Current MultiVariate Input Parameters

- Reservoir / Geological / Production
 - Township and Range
 - Cumulative **Shifted** Water Cut
 - Cumulative GOR
- Completion / Frac Design
 - Lateral Length, ft
 - Cemented Liner
 - Well Order
 - Stage Length, ft/stage - (number stages)
 - Proppant Amount, lbs/ft
 - Average Proppant Concentration, ppg
 - Fluid Volume, bbls/ft
 - Proppant Type, % sand



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Current Multi-Variate Example Modeling Results



Left Plot Statistics:
Samples in plot: 139
Regression Fit: $y = 1.000x + 0.00043$
R Squared: 0.97843
Correlation Coeff.: 0.989
Rank Cor. Coeff.: 0.989

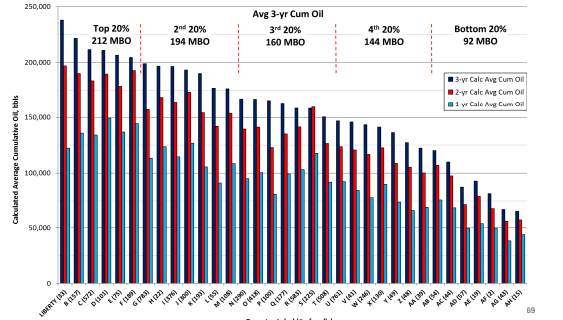
Right Plot Statistics:
Samples in plot: 73
Regression Fit: $y = 1.000x + 0.00044$
R Squared: 0.99044
Correlation Coeff.: 0.995
Rank Cor. Coeff.: 0.990



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Middle Bakken – Entire Williston Basin

(6884 Wells; completions since 1/15/2009;
all operators >15 wells, NDIC production through Jun '17



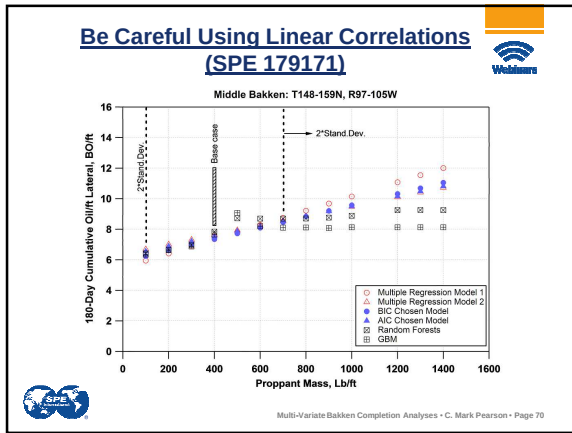
Top 20%: 212 MBO
2nd 20%: 194 MBO
Avg 3-yr Cum Oil: 160 MBO
4th 20%: 144 MBO
Bottom 20%: 92 MBO

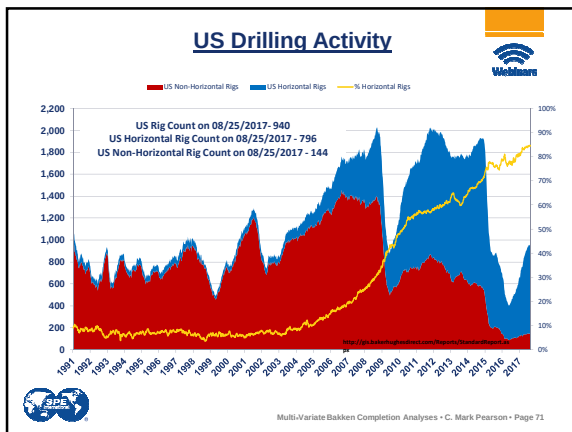
Legend:
0-yr Calc Avg Cum Oil
2-yr Calc Avg Cum Oil
3-yr Calc Avg Cum Oil



Operator Label (# of wells)

23





Acknowledgements

Co-workers at Liberty Resources
especially Stacy Strickland, Paul Weddle, Larry Griffin,
Juliana Chikaloff and Rachel Grande

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Thank You / Questions





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