Whiting Petroleum Corporation
and its wholly owned subsidiary
Whiting Oil and Gas Corporation

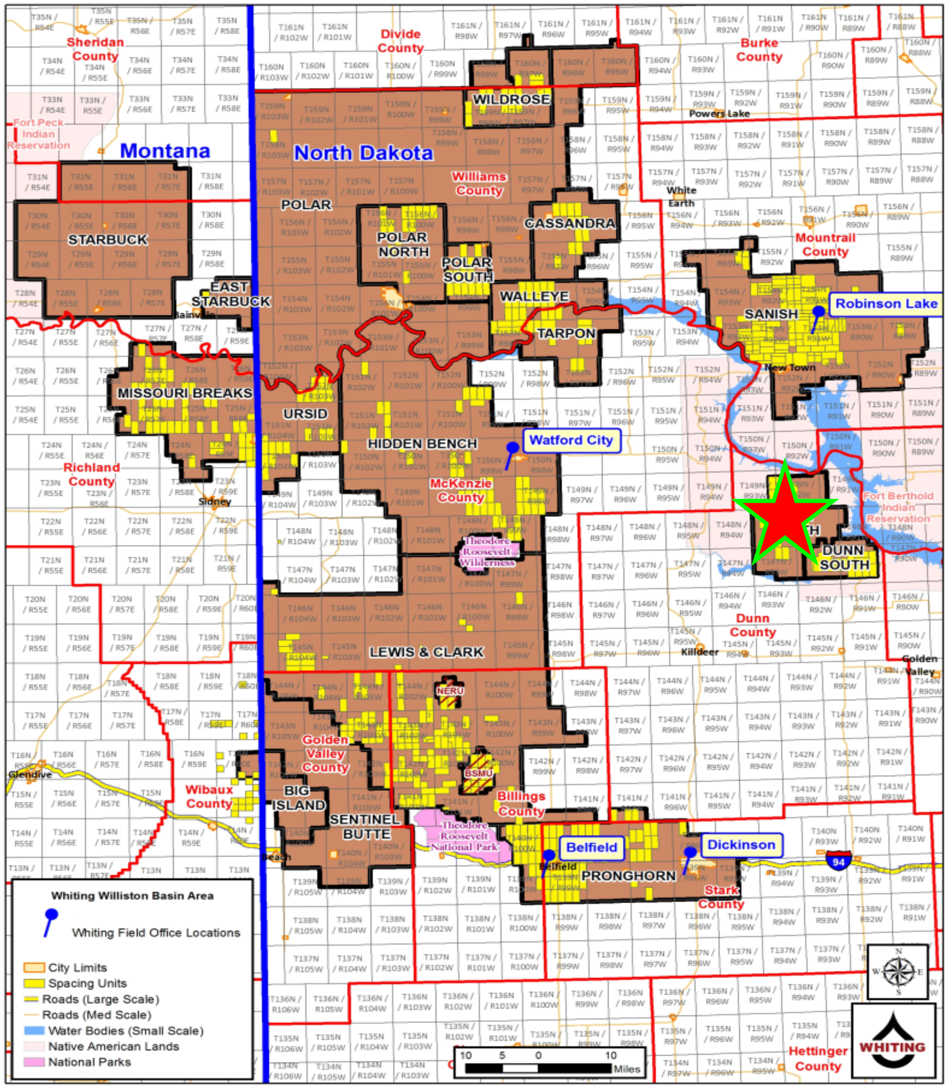
Presentation to Oil and Gas Research Council
G-040-01: Refrac Pilot

WOGC Refrac Pilot – Introduction

- Charles Ohlson, P.E. – Completions Manager at Whiting Oil & Gas
- Previous Experience:
  - Chesapeake Energy (2009-2012): Asset Manager, Production Superintendent
  - Iron Creek Energy Group (2004-2009): Sr. Petroleum Engineer
  - Marathon Oil Company (1998-2004): Completions Engineer
- Education: B.Sc. Petroleum Engineering from Montana Tech
- Registered Professional Engineer in the State of WY

WOGC Refrac Pilot – Overview

- Whiting inventory exceeds 1400 wells
- Recognized the potential for refrac'ing
- Budgeted money for refracs
- Formed multi-disciplinary teams to investigate potential
- Formulated candidate selection process
- Chose the Two Shields Butte 14-33-6H



WOGC Refrac Pilot – Candidate Selection

- **Multi-Disciplinary Teams for each area, coordinated by WOGC Refrac Steering Committee**
  - **Reservoir Engineer**
    - MOIP v Np evaluations per DSU, Performance Evaluations (Log-Log of 1/Q); Isobaric observations & analysis (remaining reservoir energy); Probability Analysis, AFE/Economic Analysis, Lookback of all Williston Basin Refracs
  - **Completions Engineer**
    - Completion Details (Liner type, annular seal), Frac Details (Stages, Prop amount, fluid type, cluster count), Cost Estimates for AFE, Procedure & job execution, Lookback of all Williston Basin Refracs
  - **Geologist**
    - Define parameters for OOIP calcs ('h', Sw, phi, core analysis), Identify potential refrac complications (map faults, areas of thin pay, water hazards), Revisit micro-seismic data (limited to certain areas)
  - **Production Engineer & Field personnel**
    - List wells w/ observed issues (scale, salt, paraffin), Estimate number of wells to frac protect, provide cost estimates
  - **Land**
    - Partners for each DSU

WOGC Refrac Pilot – Candidate Selection

WHITING

Refrac Timeline & Workflow

TIMELINE	2/25/2016 - 3/4/2016	3/7/2016 - 4/1/2016	4/4/2016 - 4/15/2016	4/18/2016 - 4/29/2016	5/2/2016 - 5/6/2016	5/9/2016 - 5/13/2016	6/6/2016 9/30/2016
Phase	Kick-Off	Initial Screening	Root Cause Analysis	Candidate Classification	Frac Design	Economic Analysis	Job Execution
Completions Group: Denver	Hold individual team kick-off meetings	Attend individual Team meetings, coordinate Stage Gate meetings, provide assistance & guidance to groups	Attend individual Team meetings, coordinate Stage Gate meetings, provide assistance & guidance to groups	Attend individual Team meetings, coordinate Stage Gate meetings, provide assistance & guidance to groups	Attend individual Team meetings, coordinate Stage Gate meetings, provide assistance & guidance to groups	Attend individual Team meetings, coordinate Stage Gate meetings, provide assistance & guidance to groups	Attend individual Team meetings, coordinate Stage Gate meetings, provide assistance & guidance to groups
Reservoir Engineers		Identify underperforming DSU's	Understand reason for underperforming or distressed wells (e.g. infill density too high, problem with completion, etc.)	Work w/ all disciplines to categorize the candidates (small reconnect job, large job to contact new rock, etc.)		Perform analysis on potential reserve development scenarios	Process feedback
		Project EUR & DSU Recovery				Apply probability	
		Perform well performance evaluations (log-log of 1/Q v Sqrt 't', RTA, etc.)	Investigate wells & DSU's w/ frac-hit impacts - beneficial vs damaging	Consider drilling schedule w/ respect to location of possible refracs (i.e. should we still refrac, coordinate w/ new well?)		Perform AFE economics & justification based on cost & reserves criteria	
		Investigate anomalous GOR's					
Geoscience group		OOIP calcs (provide mapping, values for 'h', phi, Sw)	Revisit micro-seismic to infer original frac geometry	Work w/ all disciplines to categorize the candidates (small reconnect job, large job to contact new rock, etc.)		Perform AFE write-up & justification	Process feedback
		Identify refrac hazards (faults, areas of thin pay, water hazards, future infills)	Lab work to assist in root cause analysis	Consider drilling schedule w/ respect to location of possible refracs (i.e. should we still refrac, coordinate w/ new well?)			
Operations Engineers		Investigate Completion Details (Number stages, amount of sand, style of completion, fluid system, etc.)	Narrow-down lists - differentiate candidates based on different criteria (e.g. wells w/ too few stages, wells w/ too little amount proppant)	Work w/ all disciplines to categorize the candidates (small reconnect job, large job to contact new rock, etc.)	ReFrac Design & Cost Estimates	Perform AFE write-up & justification	Real-time diagnostics and refrac design adjustments
		Look at correlations of well performance to completion parameters (e.g. EUR vs. job size, etc.)	Investigate wells & DSU's w/ frac-hit impacts - beneficial vs damaging	Consider drilling schedule w/ respect to location of possible refracs (i.e. should we still refrac, coordinate w/ new well?)	Cost estimates & AFE		Process feedback
		Identify wells with wellbore problems or complications (e.g. wells that have not been drilled out, wells w/ csg issues, etc.)					
Engineering Techs		Support Ops team w/ data gathering, consolidation, organization & analysis	Support Ops team w/ data gathering, consolidation, organization & analysis	Support Ops team w/ data gathering, consolidation, organization & analysis		Prepare & submit regulatory paperwork (e.g. sundry)	Submit post-job sundry
Production Engineers		List wells / observed issues (scale, salt, paraffin, crushed sand, etc.)	Further study of wells with observed issues - categorize, investigate severity, causes	Work w/ all disciplines to categorize the candidates (small reconnect job, large job to contact new rock, etc.)	Cost estimates for upsized artificial lift		Pre refrac & post refrac clean-outs & artificial lift design
		Identify wells with wellbore problems or complications	Estimation of number of wells for frac protect	Estimation of number of wells for frac protect	Cost estimates for frac protect		Process feedback
		Identify wells with wellbore problems or complications (e.g. wells that have not been drilled out, wells w/ csg issues, etc.)					
Completions Group: Field Frac Supervisors		Investigate Completion Details (Number stages, amount of sand, style of completion, fluid system, etc.)		Explore service availability, early discussions with vendors	Start making loose plans with service providers	Once approval is given, start coordinating services	Refrac execution & supervision
		Identify wells with wellbore problems or complications (e.g. wells that have not been drilled out, wells w/ csg issues, etc.)		Work w/ all disciplines to categorize the candidates (small reconnect job, large job to contact new rock, etc.)	ReFrac Design & Cost Estimates		Process feedback
Landmen			Review List of candidates, Assess working interest & JOA's	Provide JOA & WI details for top candidates, start discussions with WIO's for buy-in		Circulate AFEs to partners, WO approval	
Management	Define goals, workflow and timeline	Updates, progress reports, steering team mtgs	Updates, progress reports, steering team mtgs	Updates, progress reports, steering team mtgs	Updates, progress reports, steering team mtgs	Analysis & approval of AFEs	Process feedback

WOGC Refrac Pilot – Candidate Selection

- **Final (top 10) candidates from each team compiled into single analysis**

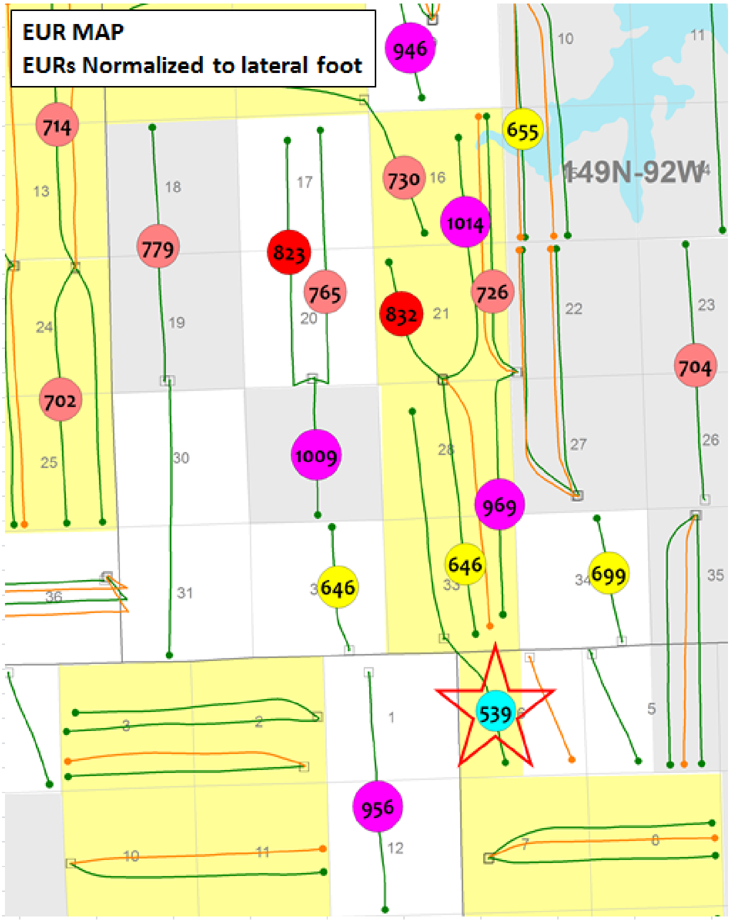
- **Peer reviews with outside experts (Halliburton & Schlumberger) with considerable refrac experience**

- **Final screening from WOGC Refrac Steering Committee**

- **Some attributes of a good candidate: Wellbore in good shape, Large recoverable OIP, Good oil cut, Modest initial completion, Immature flow regime, Possible flow assurance issue to solve, Agreeable partners**

WOGC Refrac Pilot – Objective

- **Two Shields Butte 14-33-6H**
- **Short Lateral (4200')**
- **Completed May, 2009 w/ 6 frac stages & 929Mlbs prop**
- **700' stage spacing**
- **Modest completion by today's standards**
- **Surrounded by higher performing wells with better completions**
- **Remaining recoverable reserve potential**



WOGC Refrac Pilot – Objective

- **Two Shields Butte 14-33-6H Reservoir Parameters**

RESERVOIR PARAMETER	VALUE
Formation	Middle Bakken
Max Porosity (%)	8.2%
Avg Porosity (%)	4.5%
Net Pay (ft)	46
Upper Bakken Shale Thickness (ft)	16
Lower Bakken Shale Thickness (ft)	22
Water Saturation (%)	42%
Estimated Matrix Perm (md)	0.13
Estimated BHT (deg F)	242
Oil Formation Volume Factor (rb/STB)	1.1
Oil Viscosity (cp)	1
Oil Gravity (deg API)	42
Gas Gravity (SG)	0.9938
Water Specific Gravity (SG)	1.19
Estimated Initial Reservoir Pressure (psi)	7694
Current Cumulative Oil Production (MBO)	**146**
Projected DSU Recovery (MBO)	**250**

- **Flow Regime – Transitioning from Transient to Boundary Dominated**

WOGC Refrac Pilot – Objective

WHITING

Well Name: **Two Shields Butte 14-33-6H**
Surface Loc: 530' FSL & 2340' FWL (SESW) Sect 33, T148N, R 92W
Btm Hole Loc: 553' FSL & 1869' FWL (SESW) Sect 6, T148N, R 92W
API: 33-025-00934
Elev: 2278 GL 2306 KB
Total Depth: 15919' MD 10340' TVD
Lease No: 7420A48509 (14-20-A04-8509)
Dunn County, ND
File # : 18107

Single Lateral
Field: Wildcat
Spud Date: 5/12/2009
Producing Zone: Middle Bakken

Wellbore Diagram as of : 8/12/2009 BD

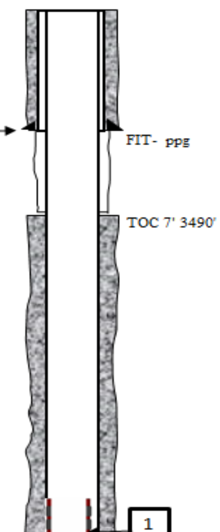
	4/12" Liner-As RUN Detail	(in)	(in)	(ft)	(ft)
Item #	Description - Service Company Name	ID	OD	Length	Depth
1	5 1/4" ID x 15' Polished Bore Receptacle (PBR)	5.250"	5.920"	14.92	9954.50
2	4 1/2" x 7" HPPK Hanger / Packer w/ 4' Seal Bore Extension	4.000"	5.875"	3.66	9958.16
	Centralizer (4 1/2" x7' HPPK Hanger/Packer w/ 4' SB ext	4.000"	5.920"	0.62	9958.78
	61 Jts. 4.5" 11.6# LTC Liner Blank	4.000"	5.000"	2396.82	12355.60
3	SwellFix Swelling Packer Water Elastomer 6 ft, 5 3/4" OD Centralizer (Top & Bottom)	4.000"	5.625"	15.50	12371.10
	6 Jts. 4.5" 11.6# LTC Liner Blank	4.000"	5.000"	670.11	13041.21
4	SwellFix Swelling Packer Water Elastomer 6 ft, 5 3/4" OD Centralizer (Top & Bottom)	4.000"	5.625"	15.50	13056.71
	7 Jts. 4.5" 11.6# LTC Liner Blank	4.000"	5.000"	710.51	13767.22
5	SwellFix Swelling Packer Water Elastomer 6 ft, 5 3/4" OD Centralizer (Top & Bottom)	4.000"	5.625"	15.50	13782.72
	7 Jts. 4.5" 11.6# LTC Liner Blank	4.000"	5.000"	676.88	14459.60
6	SwellFix Swelling Packer Water Elastomer 6 ft, 5 3/4" OD Centralizer (Top & Bottom)	4.000"	5.625"	15.50	14475.10
	7 Jts. 4.5" 11.6# LTC Liner Blank	4.000"	5.000"	708.48	15183.58
7	SwellFix Swelling Packer Water Elastomer 6 ft, 5 3/4" OD Centralizer (Top & Bottom)	4.000"	5.625"	15.50	15199.08
	7 Jts. 4.5" 11.6# LTC Liner Blank	4.000"	5.000"	357.76	15556.84
8	Divert-a-Frac Port Sub 1.5" Shifting ball	1.290"	5.375"	3.10	15559.94
	5 Jts. 4.5" 11.6# LTC Liner Blank	4.000"	5.000"	313.90	15873.84
9	Float Collar 4.5"	----	5.000"	1.35	15875.19
	1 Jts. 4.5" 11.6# LTC Liner Blank	4.000"	5.000"	38.96	15914.15
10	Float Collar 4.5"	----	5.000"	1.35	15915.50
11	4 1/2" Guide Shoe w/ Aluminum Nose and Side Ports	.750"	5.000"	3.5	15919.00
				Lateral TD	15919.00

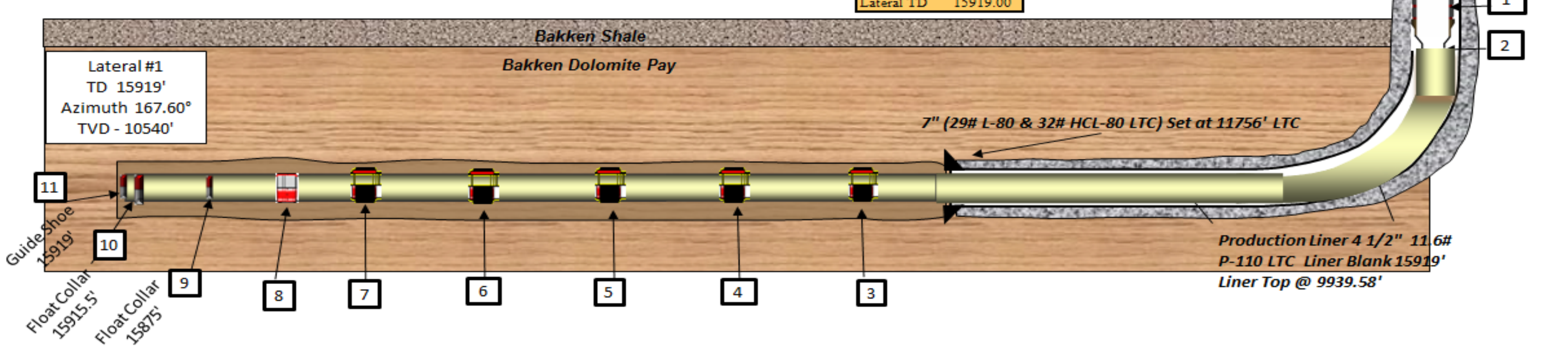
Surface Csg - Halliburton
Lead: 460 Sxs Lite cement + adds
11.5 ppg 2.97 cuft/sk
Tail: 220 Sxs Premium Cement + adds
14.2 ppg 1.49 cuft/sk
Cement to Surface (90 Bbls to pit w/ mud rings back)

9 5/8" 36# J-55 STC
Shoe Depth: 2641'
Surface Csg Hole Size 12.25"

Intermediate Csg - Halliburton
Lead: 215 Sxs Lite cement + adds
12.7 ppg 1.89 cuft/sk
Tail: 625 Sxs Premium Cement + adds
15.6 ppg 1.56 cuft/sk

Intermediate Csg Hole Size 8.75"	(Ft)
166 Jt 7.0" 29.0# L-80 LTC	6453.93
136 Jt 7.0" 32.0# HCL-80 LTC	5249.69
Landing/Marker Jts	58.83
Total String - 302 Jts. 7"	11762.45
Above (-)/Below (+) KB	-6.45
Landed 7" casing at:	**11756**





WOGC Refrac Pilot – Duration

- **Intended to start in July, now looks like September:**

1. Extract artificial lift equipment from wellbore (2 days);
2. Install a fracstring, test the casing and ensure pressure integrity (2-3 days);
3. Clean-out well to the Total Depth (3-5 days);
4. Perforate additional holes in the casing for additional access points for the refrac (1-2 days);
5. Perform the refrac - design is 2 MMlbs proppant, 20-30 cycles, each separated by diversion material (2 days);
6. Flowback well for clean-up (3-7 days);
7. Clean-out wellbore to Total Depth, ***run diagnostics*** (3-5 days);
8. Remove fracstring from well (1 day);
9. Install artificial lift equipment, return to production (2 days); and
10. Test well and report results.

WOGC Refrac Pilot – Duration

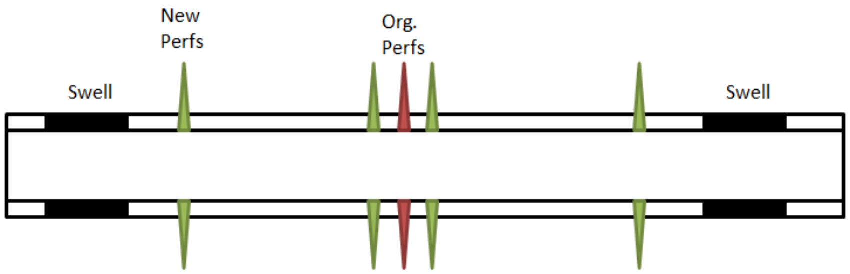
- Timeline of a ‘Best Case Scenario’
- Possible it will be extended if issues arise

DESCRIPTION OF PHASE OF WORK	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14	Day 15	Day 16	Day 17	Day 18
Remove artificial lift																		
Clean-out well																		
Test casing, install fracstring, test																		
Perforate additional holes in the liner																		
Perform refrac																		
Flowback																		
Clean-out well, run diagnostics																		
Run artificial lift back, return to production																		
Begin the testing phase																		

WOGC Refrac Pilot – Project Description

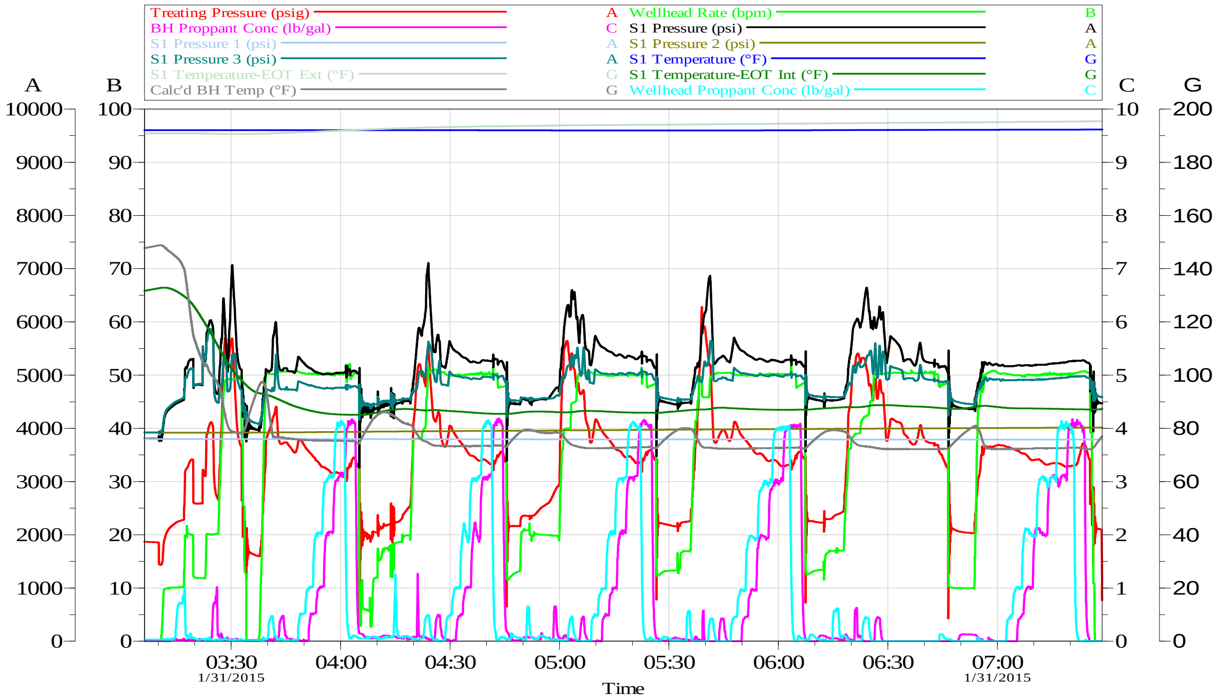
- Pull artificial lift, install fractstring, pressure test, clean-out wellbore to PBTD
- Perforate liner for access to new parts of the reservoir
  - One scenario that is being considered:

- Perf within swell packers 200’ away from original perfs approx 300’ spacing with 5 or 6 Perf clusters each
- Also add perfs within ~25’ of original perf to help plug off depleted area.
- Avoid perforating on swell packers



WOGC Refrac Pilot – Project Description

- Re-Frac the entire lateral in a single “Bullhead” style frac
- 2MM lbs proppant, utilizing 20-30 individual “cycles”, separated by 50 – 300 lb diversion drops



WOGC Refrac Pilot – Diversion Material

- Diversion Material of choice:
  - Polylactic Acid (synthetic organic polymer), which is a biodegradable thermoplastic (generally derived from things like corn starch or tapioca root)
  - Generally a mix of different shapes and/or mesh sizes
  - Pumped using a separate pump from the rest of the horsepower to keep the 'slugs' concentrated
  - The practice is evolving, some companies are seeking patents on their diversion process in addition to the material

WOGC Refrac Pilot – Diversion Material

- Diversion Material degrades thermally, over time (with temperature)

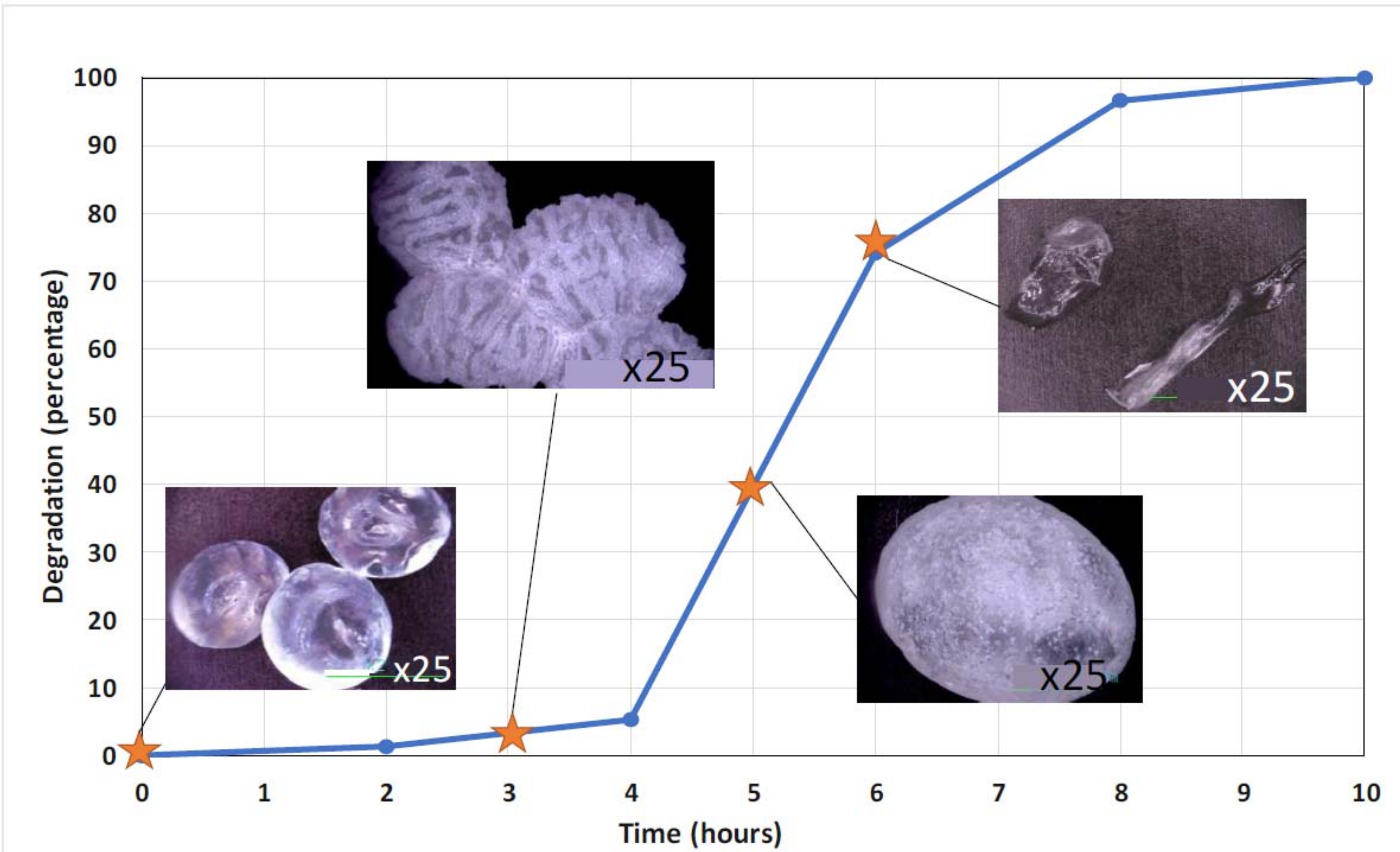


Figure 3: Degradation plot of the largest particles in water at 245 degF

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WOGC Refrac Pilot – Project Description

- Flowback well (if it will flow)
- Clean-out well to PBTD with Stick Pipe, ***run diagnostics***
  - ***Possible Fiber CT run to 'see' where refrac went***
- Pull fracstring
- Run back production equipment
- Production evaluation and optimization

DESCRIPTION OF PHASE OF WORK	Sep-2016	Oct-2016	Nov-2016	Dec-2016	Jan-2017	Feb-2017	Mar-2017	Apr-2017	May-2017	Jun-2017	Jul-2017	Aug-2017
Perform refrac, return well to production												
Post-job report to OGRC detailing the initial findings from the refrac												
Testing and monitoring of performance												
Post-job report to OGRC detailing the initial changes in production behavior												
Testing and monitoring of performance												
Post-job report to OGRC detailing the changes in production behavior & established production trend												
Testing and monitoring of performance												
Final report to OGRC summarizing project, resulting changes in EUR, application to remaining wells in Refrac Pilot												

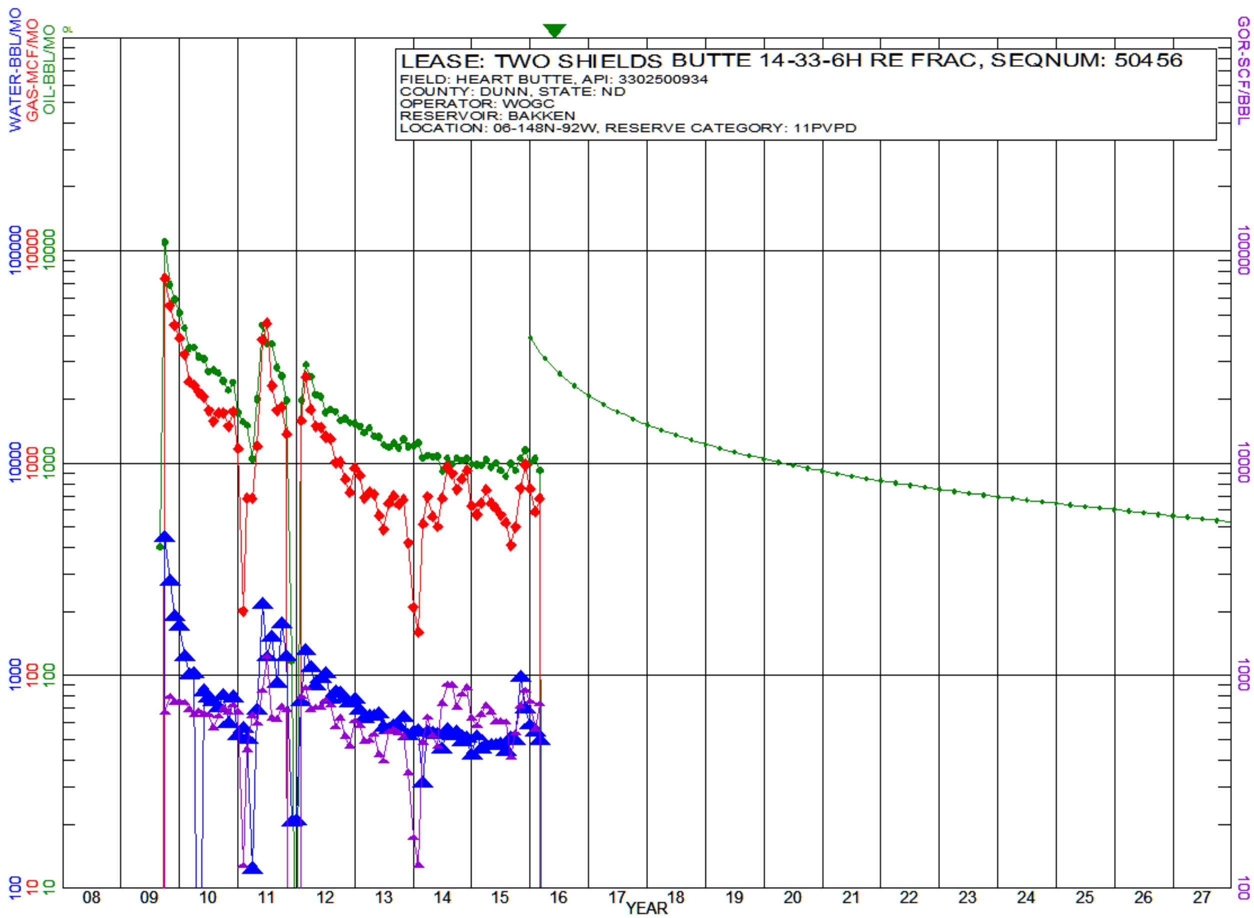
WOGC Refrac Pilot – Project Description

- **Breakdown of Estimated Costs**

BUDGET CATEGORY	GROSS	WOGC Share	ND OGRC Share
RIG - DAYWORK	$ 180,000	$ 96,923	$ 83,077
SUPERVISION	$ 28,500	$ 15,346	$ 13,154
LOCATION, ROADS, PITS	$ 5,000	$ 2,692	$ 2,308
RENTAL-DOWNHOLE TOOL/EQUIPMENT	$ 58,000	$ 31,231	$ 26,769
COMPLETION FLUIDS/WATER	$ 91,000	$ 49,000	$ 42,000
COIL TUBING EQUIP & SERVICES	$ 100,000	$ 53,846	$ 46,154
PERFORATING	$ 50,000	$ 26,923	$ 23,077
STIMULATION TREATMENT	$ 413,100	$ 222,438	$ 190,662
CONTINGENCIES	$ 150,000	$ 80,769	$ 69,231
CONTRACT SERVICES & EQUIPMENT	$ 87,000	$ 46,846	$ 40,154
RENTAL - WORKSTRING	$ 46,000	$ 24,769	$ 21,231
DISPOSAL - FLUID WASTE	$ 62,400	$ 33,600	$ 28,800
TUBING	$ 15,000	$ 8,077	$ 6,923
PUMPS AND RODS	$ 10,000	$ 5,385	$ 4,615
PACKERS & DOWNHOLE EQUIPMENT	$ 1,500	$ 808	$ 692
MATERIALS & SUPPLIES	$ 2,500	$ 1,346	$ 1,154
TOTAL AFE COST	**$ 1,300,000**	**$ 700,000**	**$ 600,000**

WOGC Refrac Pilot – Expected Results

- **Anticipated production profile**



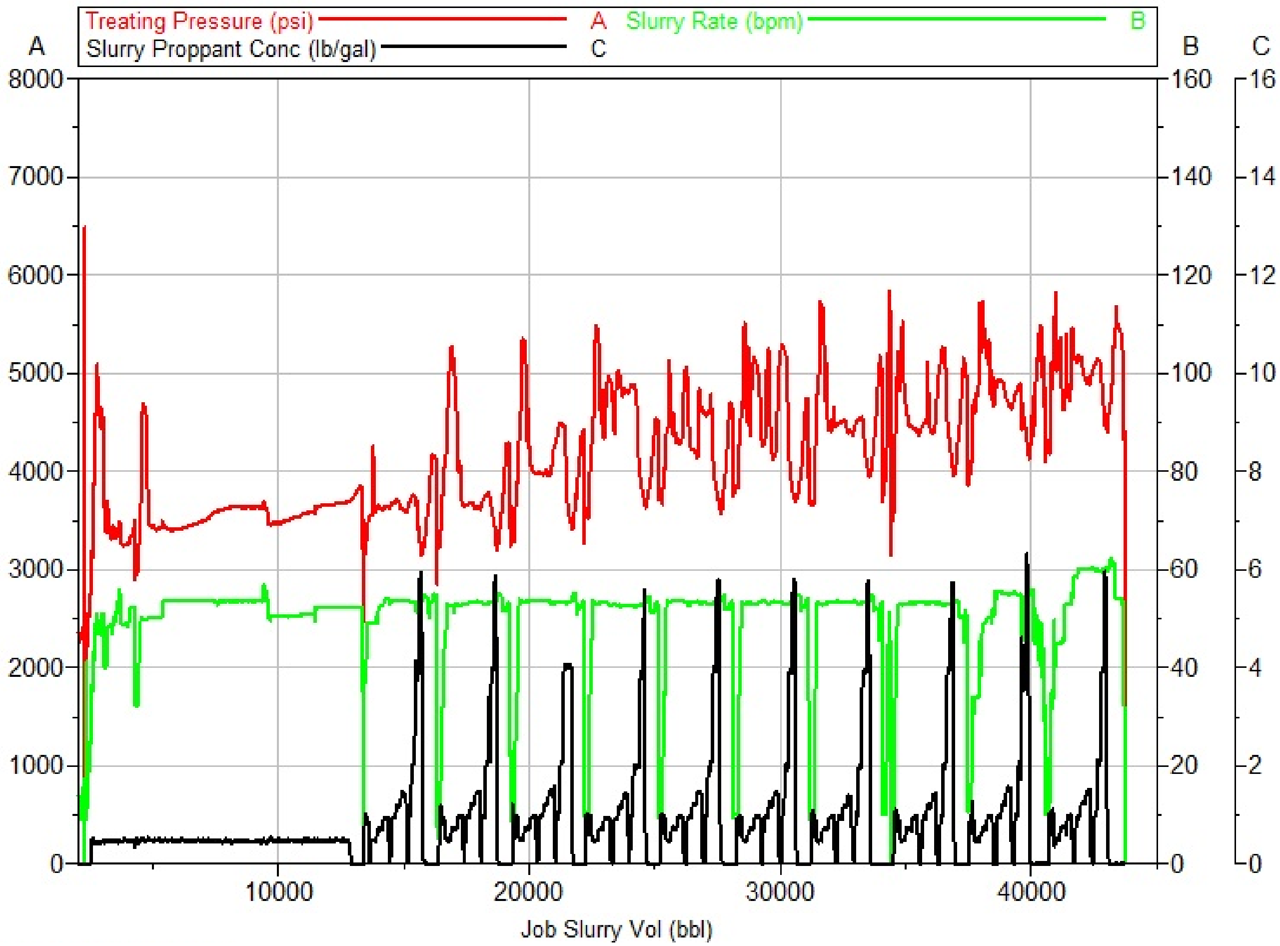
WOGC Refrac Pilot – Expected Results

- **Investment of $1.3MM, anticipated to yield:**

CATEGORY	Earlier Price Deck	Current Price Deck
Incremental Reserves	132 MBOE	132 MBOE
Incremental Initial Production	100 BOPD	100 BOPD
NPV_{10}	$199K	$354K
Undiscounted ROI	2.2	2.5
Rate of Return	19%	29%
Payout	4.0 Years	2.85 Years

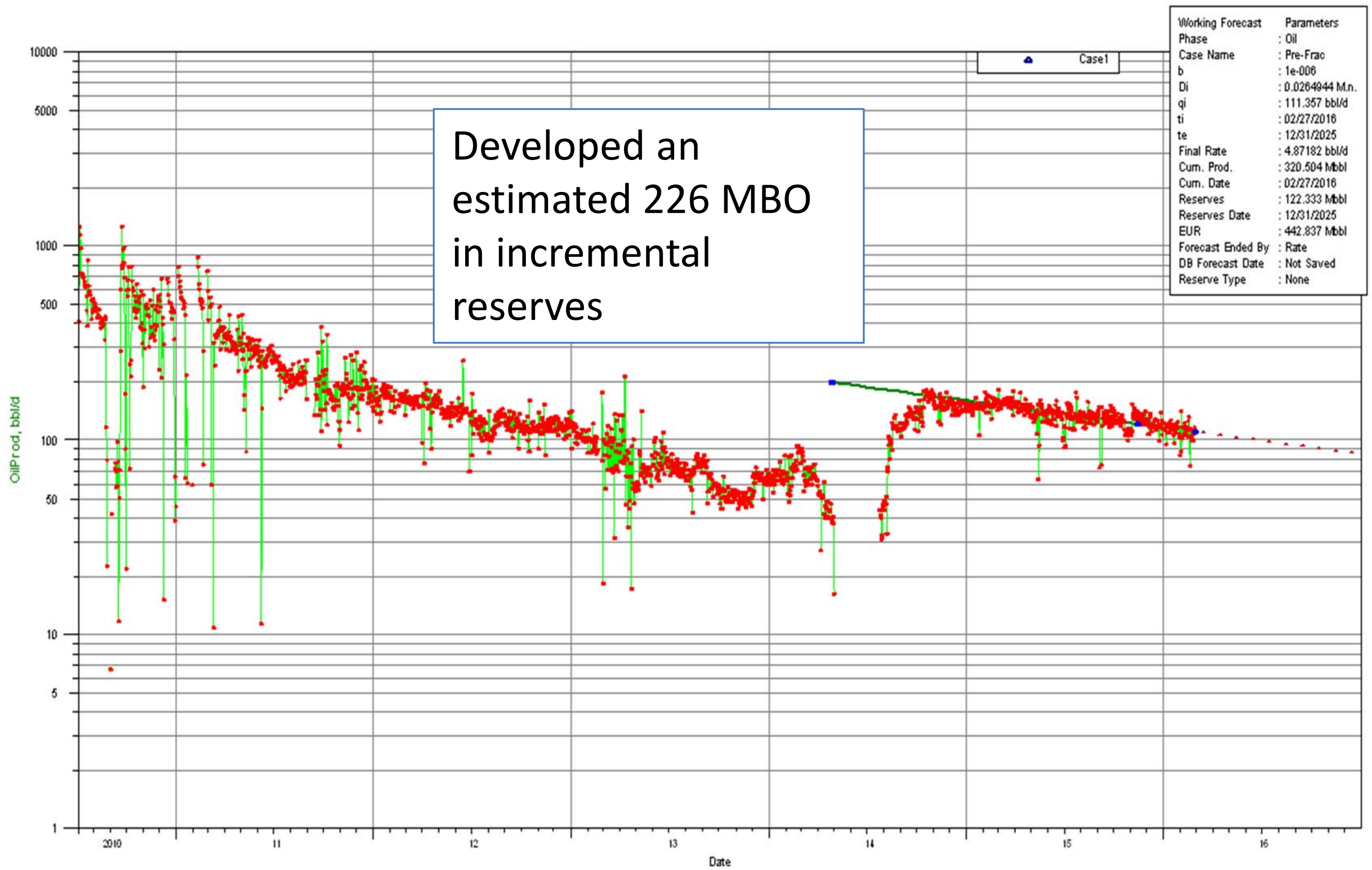
WOGC Refrac Pilot – Prior WOGC Refrac (2014)

- Utilized older style Refrac Design with fewer diversion drops & cycles



WOGC Refrac Pilot – Prior WOGC Refrac (2014)

- But it still yielded excellent results



WOGC Refrac Pilot – Conclusion

- Funding will help WOGC kick-off a successful refrac campaign
- The State of ND will benefit from WOGC's learnings
- Other ND operators will benefit from our refrac details and conclusions
- Applying new, top refrac technologies & learnings of refracs past

WOGC Refrac Pilot – Conclusion

Thank you for your time and consideration