HALLIBURTON

Geomechanics & Wellbore Strengthening

Gulf of America Case Studies

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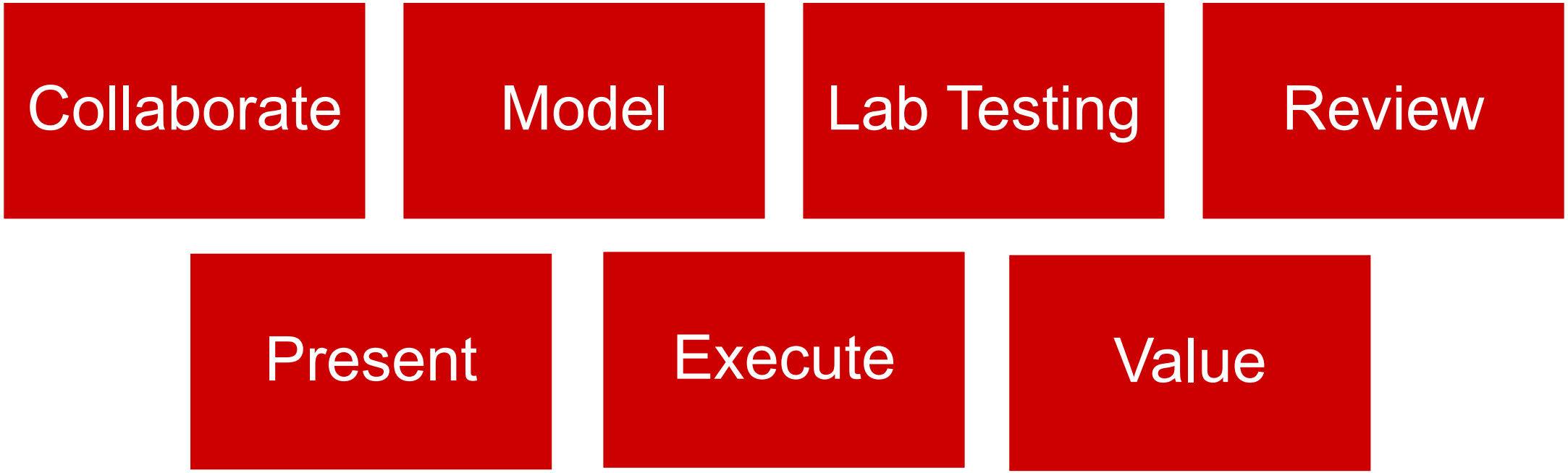
Operations Lead Drilling Fluids

Agenda

Date
Meeting details

1	Workflow & Methodology
2	Geomechanics Case Study
3	Wellbore Strengthening Case Study
4	Summary

Workflow & Methodology



Geomechanics

GoA Case Study

Sam Daugherty, Guyana (ex-GoA)

Geomechanics Model Saves Time & Money

DFG Geomechanics saves customer ~$1.2M by reducing time, and minimized whole mud losses with an accurate prediction of the formation breakdown pressure

Challenge

- Challenged to reduce losses in highly depleted basin with geomechanics modelling
- Previous wells only the LCM solution was considered
- A new approach was to use the DFG GM modelling software to identify potential areas where we could improve LCM design and identify potentially tighter drilling margins than originally predicted

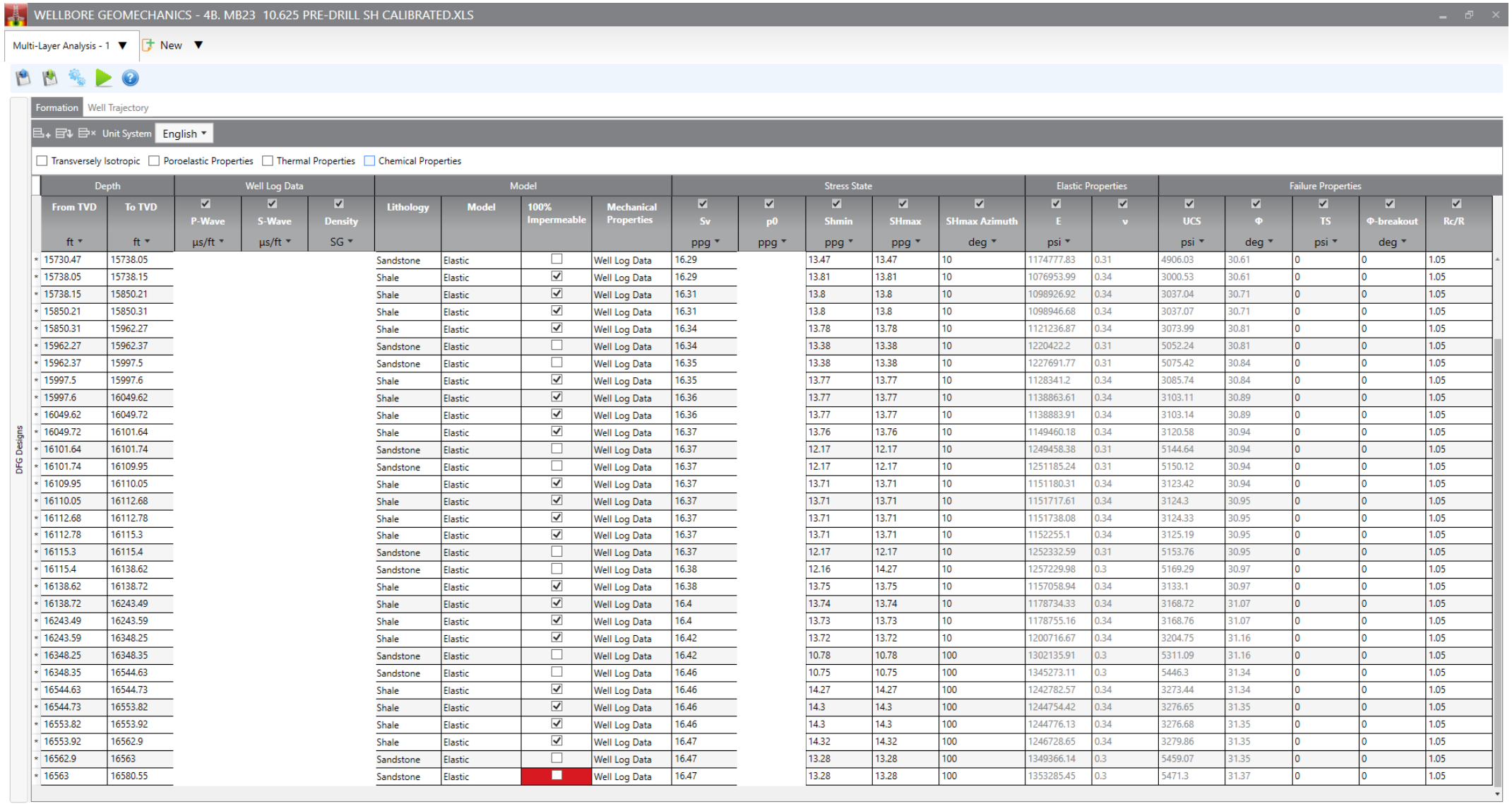
Solution

- Model the intervals with the most accurate approximation of geo pressures and present the lower limits of fracture pressure to the customer
- Provided the estimated FG to the customer, which gave them a better sense of the situation downhole
- Engage with the customer on solutions at a high level

Results

- Reduced losses, no NPT, and eliminated costs associated with a contingency liner run
- Which all equal less operational costs to the customer to the tune of $1.2M
- A new level of trust with the customer was established as a Trusted Advisor

DFG Geomechanics App Interface



Depth		Well Log Data			Model				Stress State					Elastic Properties		Failure Properties				
From TVD	To TVD	P-Wave	S-Wave	Density	Lithology	Model	100% Impermeable	Mechanical Properties	Sv	p0	Shmin	SHmax	SHmax Azimuth	E	v	UCS	Φ	TS	Φ-breakout	Rc/R
ft	ft	µs/ft	µs/ft	SG					ppg	ppg	ppg	ppg	deg	psi		psi	deg	psi	deg	
15730.47	15738.05				Sandstone	Elastic	☐	Well Log Data	16.29		13.47	13.47	10	1174777.83	0.31	4906.03	30.61	0	0	1.05
15738.05	15738.15				Shale	Elastic	☑	Well Log Data	16.29		13.81	13.81	10	1076953.99	0.34	3000.53	30.61	0	0	1.05
15738.15	15850.21				Shale	Elastic	☑	Well Log Data	16.31		13.8	13.8	10	1098926.92	0.34	3037.04	30.71	0	0	1.05
15850.21	15850.31				Shale	Elastic	☑	Well Log Data	16.31		13.8	13.8	10	1098946.68	0.34	3037.07	30.71	0	0	1.05
15850.31	15962.27				Shale	Elastic	☑	Well Log Data	16.34		13.78	13.78	10	1121236.87	0.34	3073.99	30.81	0	0	1.05
15962.27	15962.37				Sandstone	Elastic	☐	Well Log Data	16.34		13.38	13.38	10	1220422.2	0.31	5052.24	30.81	0	0	1.05
15962.37	15997.5				Sandstone	Elastic	☐	Well Log Data	16.35		13.38	13.38	10	1227691.77	0.31	5075.42	30.84	0	0	1.05
15997.5	15997.6				Shale	Elastic	☑	Well Log Data	16.35		13.77	13.77	10	1128341.2	0.34	3085.74	30.84	0	0	1.05
15997.6	16049.62				Shale	Elastic	☑	Well Log Data	16.36		13.77	13.77	10	1138863.61	0.34	3103.11	30.89	0	0	1.05
16049.62	16049.72				Shale	Elastic	☑	Well Log Data	16.36		13.77	13.77	10	1138883.91	0.34	3103.14	30.89	0	0	1.05
16049.72	16101.64				Shale	Elastic	☑	Well Log Data	16.37		13.76	13.76	10	1149460.18	0.34	3120.58	30.94	0	0	1.05
16101.64	16101.74				Sandstone	Elastic	☐	Well Log Data	16.37		12.17	12.17	10	1249458.38	0.31	5144.64	30.94	0	0	1.05
16101.74	16109.95				Sandstone	Elastic	☐	Well Log Data	16.37		12.17	12.17	10	1251185.24	0.31	5150.12	30.94	0	0	1.05
16109.95	16110.05				Shale	Elastic	☑	Well Log Data	16.37		13.71	13.71	10	1151180.31	0.34	3123.42	30.94	0	0	1.05
16110.05	16112.68				Shale	Elastic	☑	Well Log Data	16.37		13.71	13.71	10	1151717.61	0.34	3124.3	30.95	0	0	1.05
16112.68	16112.78				Shale	Elastic	☑	Well Log Data	16.37		13.71	13.71	10	1151738.08	0.34	3124.33	30.95	0	0	1.05
16112.78	16115.3				Shale	Elastic	☑	Well Log Data	16.37		13.71	13.71	10	1152255.1	0.34	3125.19	30.95	0	0	1.05
16115.3	16115.4				Sandstone	Elastic	☐	Well Log Data	16.37		12.17	12.17	10	1252332.59	0.31	5153.76	30.95	0	0	1.05
16115.4	16138.62				Sandstone	Elastic	☐	Well Log Data	16.38		12.16	14.27	10	1257229.98	0.3	5169.29	30.97	0	0	1.05
16138.62	16138.72				Shale	Elastic	☑	Well Log Data	16.38		13.75	13.75	10	1157058.94	0.34	3133.1	30.97	0	0	1.05
16138.72	16243.49				Shale	Elastic	☑	Well Log Data	16.4		13.74	13.74	10	1178734.33	0.34	3168.72	31.07	0	0	1.05
16243.49	16243.59				Shale	Elastic	☑	Well Log Data	16.4		13.73	13.73	10	1178755.16	0.34	3168.76	31.07	0	0	1.05
16243.59	16348.25				Shale	Elastic	☑	Well Log Data	16.42		13.72	13.72	10	1200716.67	0.34	3204.75	31.16	0	0	1.05
16348.25	16348.35				Sandstone	Elastic	☐	Well Log Data	16.42		10.78	10.78	100	1302135.91	0.3	5311.09	31.16	0	0	1.05
16348.35	16544.63				Sandstone	Elastic	☐	Well Log Data	16.46		10.75	10.75	100	1345273.11	0.3	5446.3	31.34	0	0	1.05
16544.63	16544.73				Shale	Elastic	☑	Well Log Data	16.46		14.27	14.27	100	1242782.57	0.34	3273.44	31.34	0	0	1.05
16544.73	16553.82				Shale	Elastic	☑	Well Log Data	16.46		14.3	14.3	100	1244754.42	0.34	3276.65	31.35	0	0	1.05
16553.82	16553.92				Shale	Elastic	☑	Well Log Data	16.46		14.3	14.3	100	1244776.13	0.34	3276.68	31.35	0	0	1.05
16553.92	16562.9				Shale	Elastic	☑	Well Log Data	16.47		14.32	14.32	100	1246728.65	0.34	3279.86	31.35	0	0	1.05
16562.9	16563				Sandstone	Elastic	☐	Well Log Data	16.47		13.28	13.28	100	1349366.14	0.3	5459.07	31.35	0	0	1.05
16563	16580.55				Sandstone	Elastic	☐	Well Log Data	16.47		13.28	13.28	100	1353285.45	0.3	5471.3	31.37	0	0	1.05

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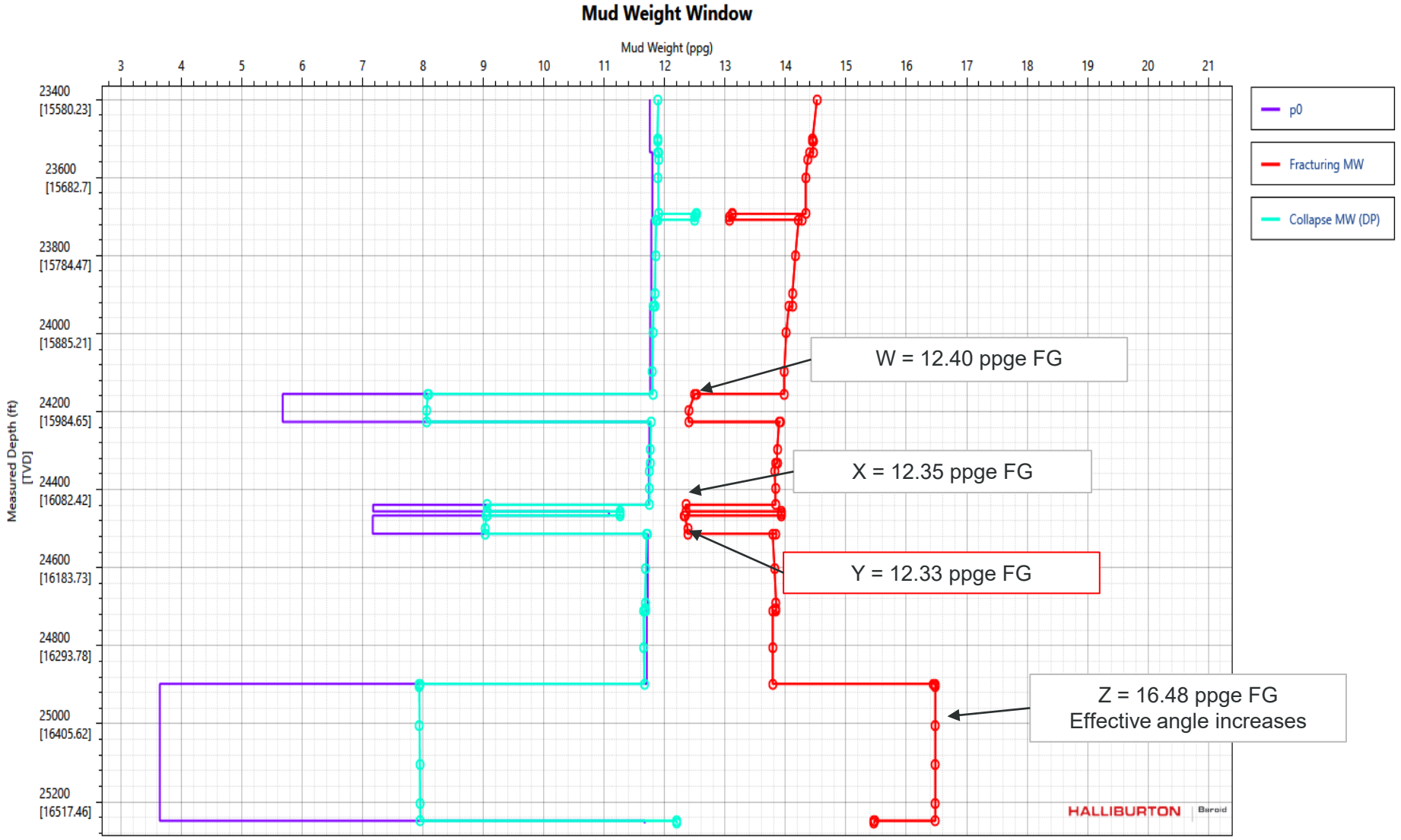
10 5/8” Drilling Window Modelling



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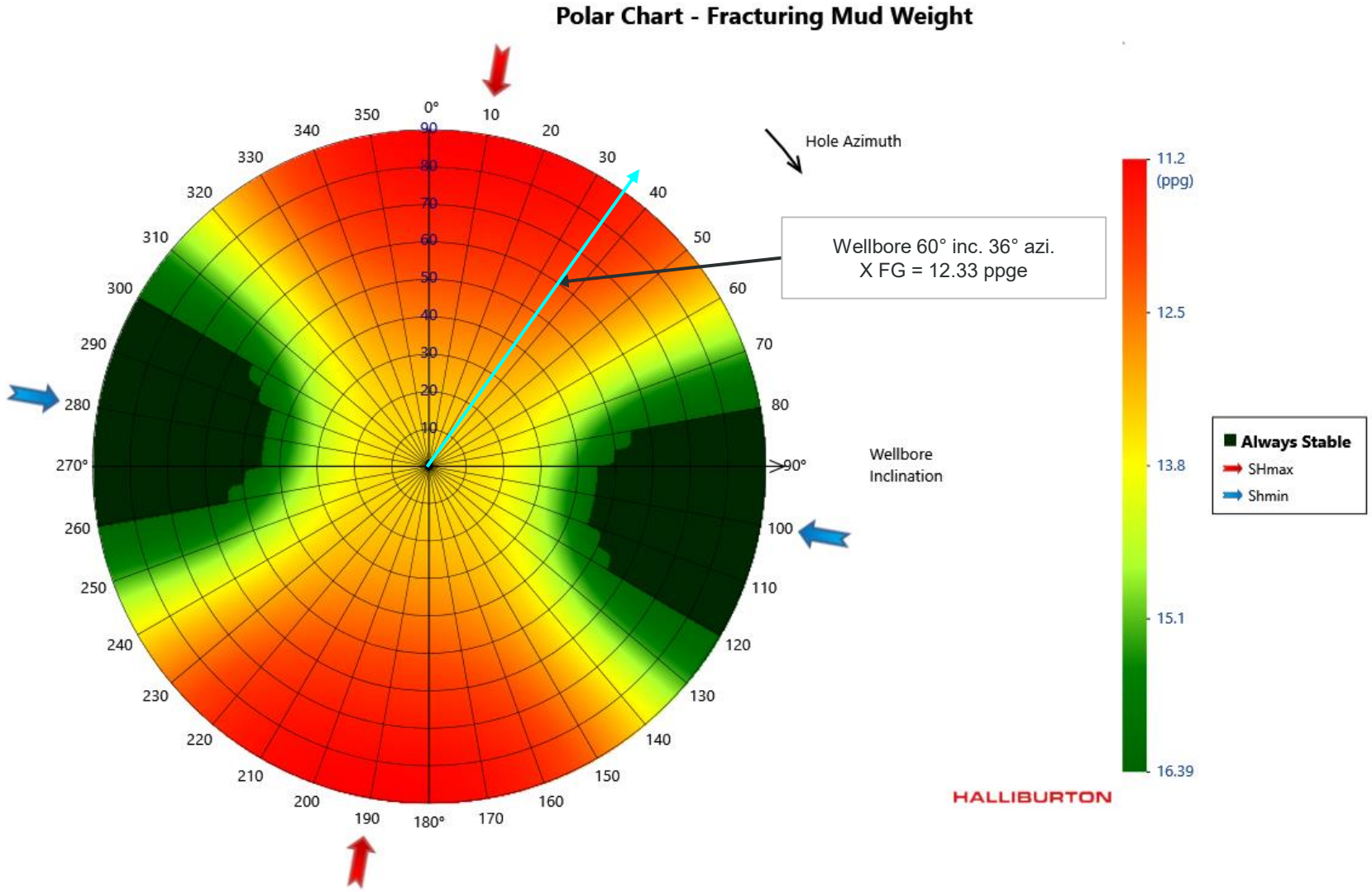
10-5/8" Wellbore Stability Modelling – X Actual



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Pre-Drill vs. Actual

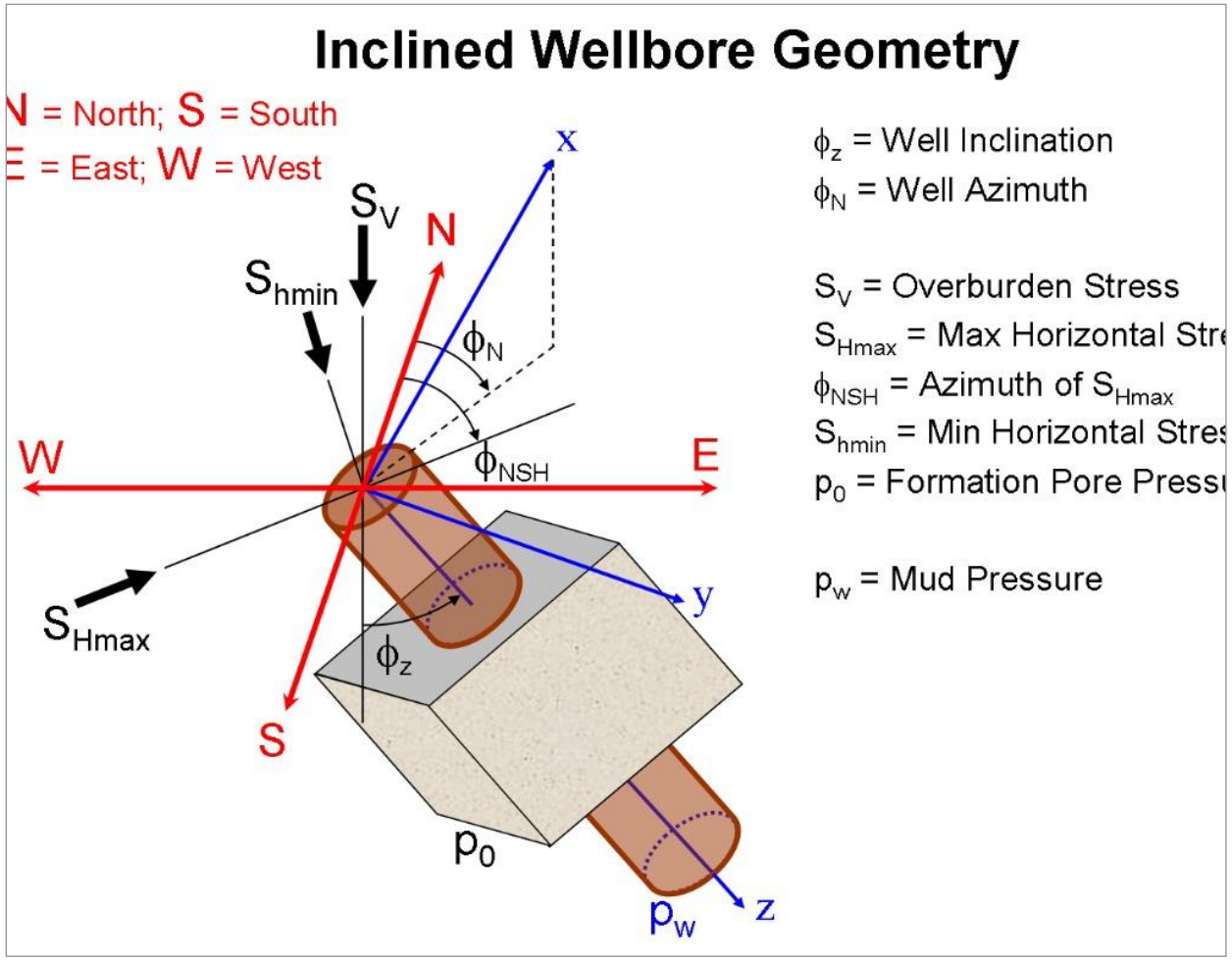
Formation	Length	FG: Customer	FG: DFG (WG/WS)	FG: LOT
W	35’	12.64 ppge	12.75 ppge	12.40 ppge
X	8’	14.04 ppge	12.71 ppge	12.35 ppge
Y	23’	14.04 ppge	12.69 ppge	12.33 ppge

- Total losses while drilling into the Y sand and immediately spot an LCM pill.
- Discussions around reducing the MW were had and ultimately stopped losses and allowed the rig to drill the well to section TD.

Wellbore Strengthening

GoA Case Study

Sharath Savari, GTS
Sam Daugherty, Guyana (ex-GoA)
Jason Gibbs, GoA



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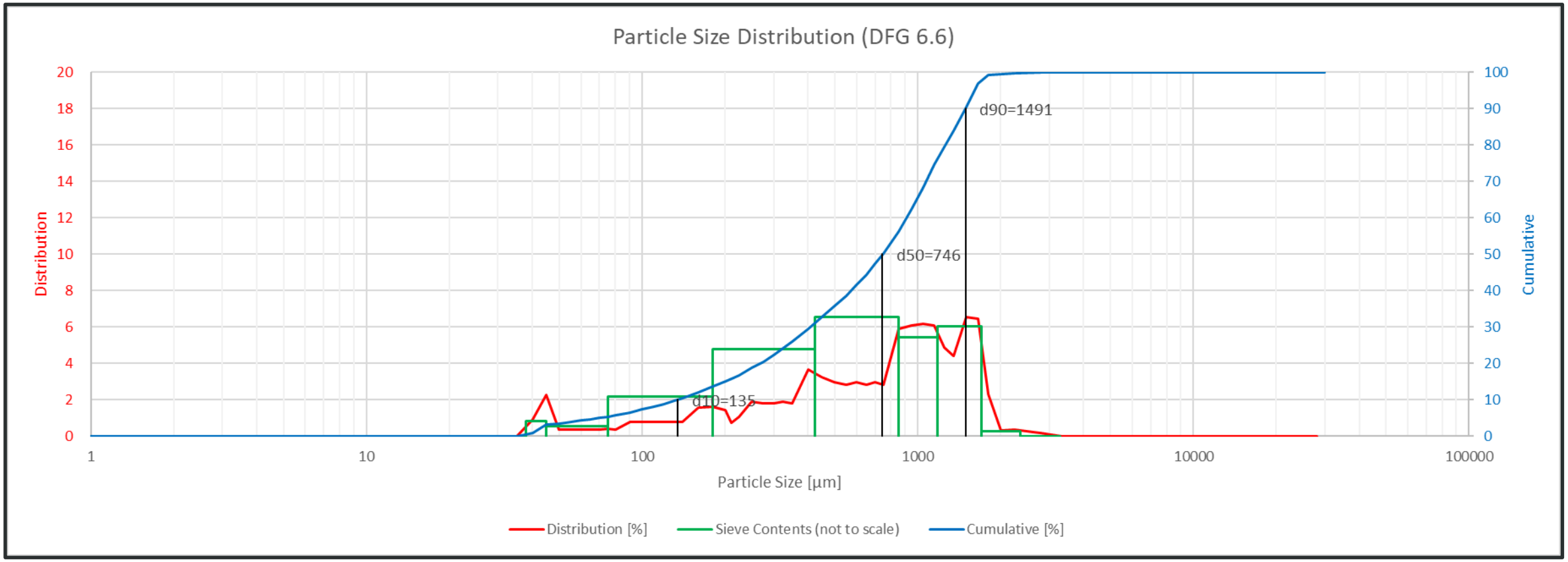
Input data – GoA wells

Information	Well A	Well B	Well B
Drilling Fluid type	SBM	SBM	SBM
Target Formation type	Sand	Sand 3	Sand 2
Hole Diameter, inch	12¼”	12¼”	12¼”
Target TVD, ft	17,397	25,435	24,992
Borehole Azimuth, deg	309	52.7	52.7
Borehole Angle, deg	56	22.4	22.4
Overburden Stress, ppg	14.1	17.3	17.3
Minimum Horizontal Stress, ppg	Client provided / calculations / assumption		
Maximum Horizontal Stress, ppg - calculated			
Pore Pressure, ppg			
Max. Horizontal stress azimuth, deg - estimated			
Pressure depletion, psi			
Static Young’s Modulus, Mpsi			
Poisson’s Ratio			
ECD used (or Maximum ECD used) eventually to drill the depleted zone, ppg			
Fracture length, inch – assumption			
Mud Weight (surface), ppg			
Biot-Willis Coefficient, α – calculated/calibrated	0.68	0.74	0.69
Mud filtercake efficiency, β – impermeable cake	0	0	0
Tensile Strength of depleted formation, psi	100	100	100
Critical Stress Intensity Factor, psi.in$^{0.5}$ – tables	3000	3000	3000
Background LCM applied	52 ppb BaraShield-1065	52 ppb BaraShield-1065	52 ppb BaraShield-1065

PSD of BaraShield-1065



- Designed to seal 1500-2000 microns

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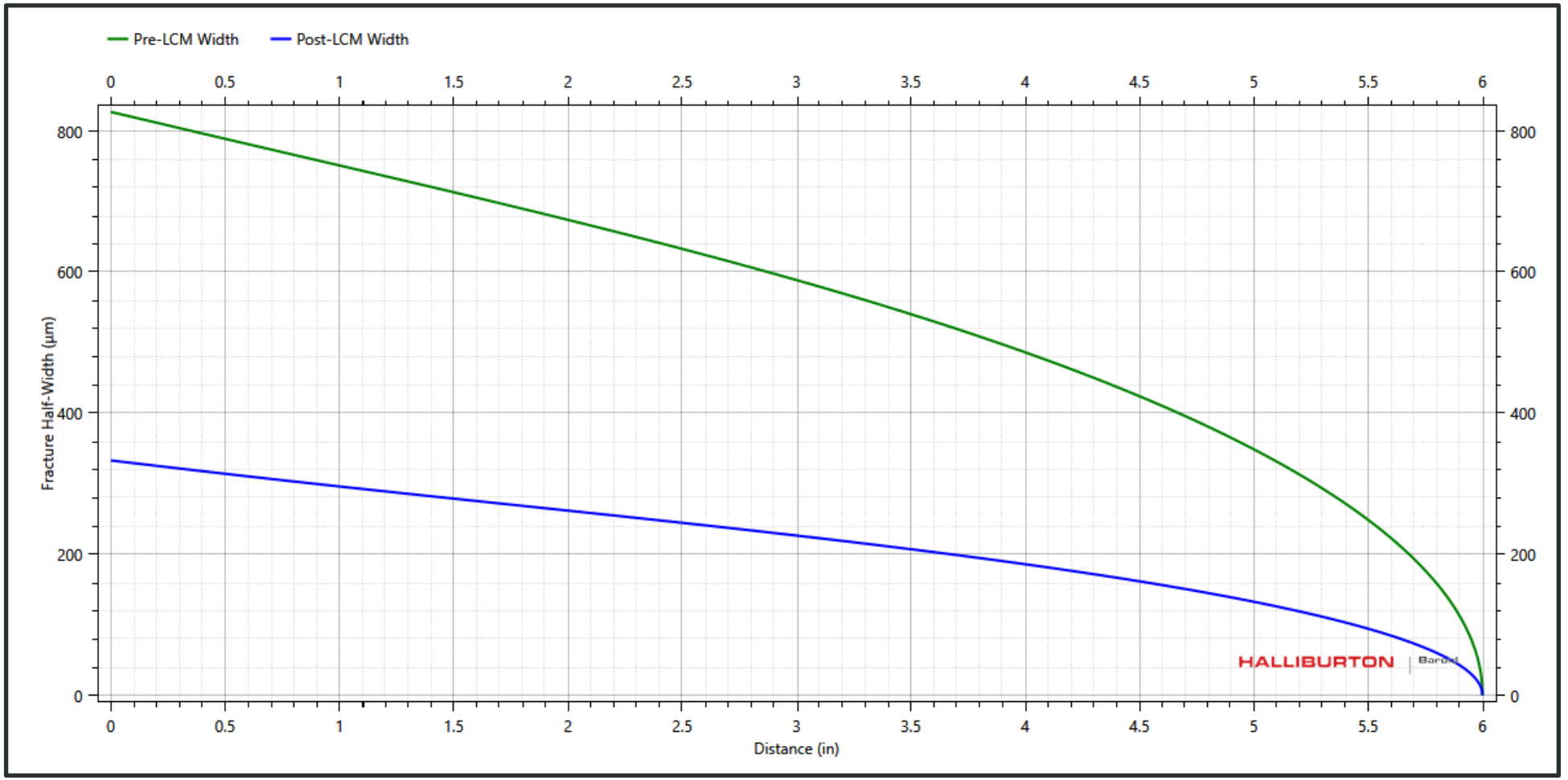
Well A: Est. Fracture width

- WG-WBS Model
  - 1650microns
- Well drilled with no losses
- Stable fracture tip



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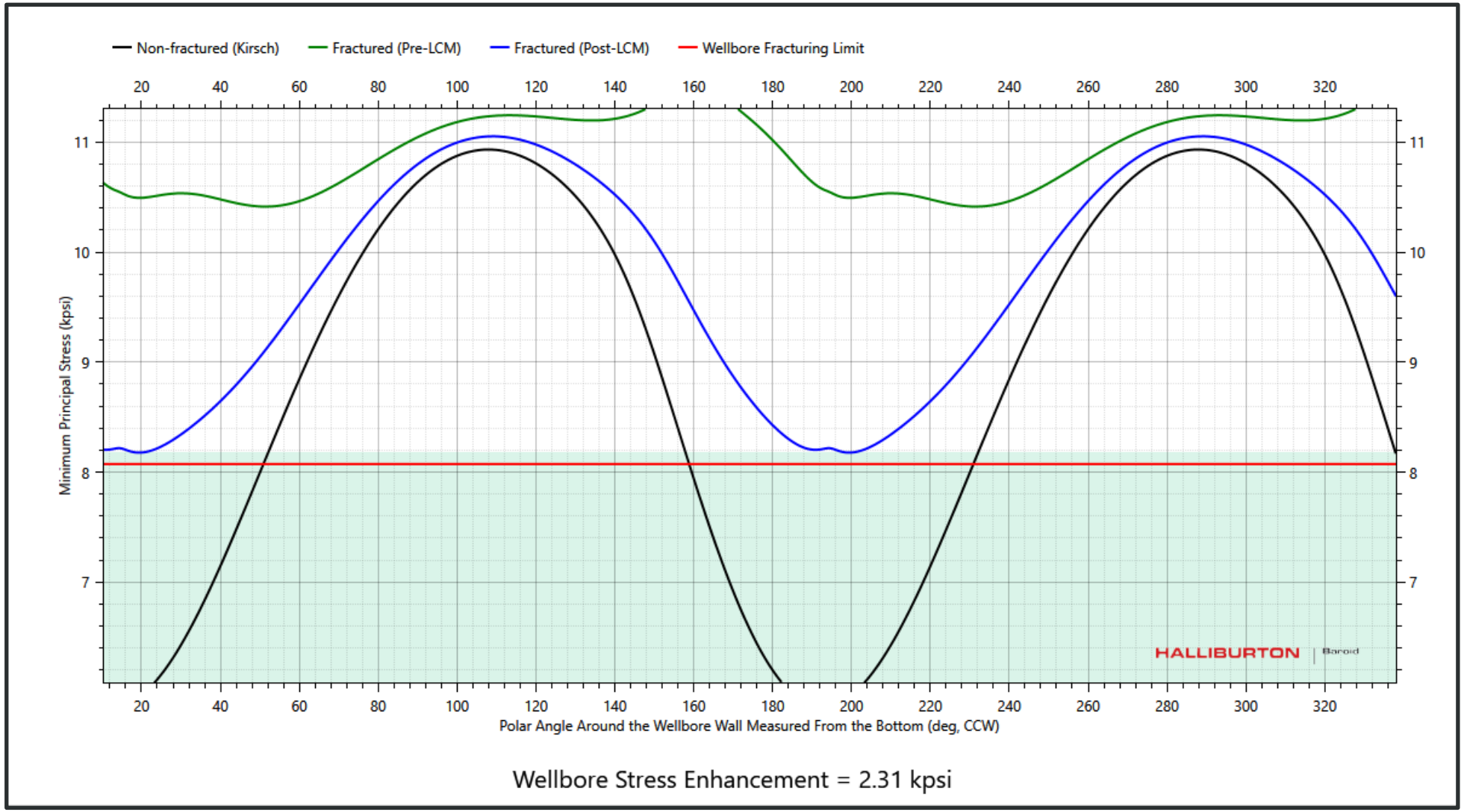
Well A: Wellbore stability

- Est. Stress Enhancement 2310psi (2.55ppg)



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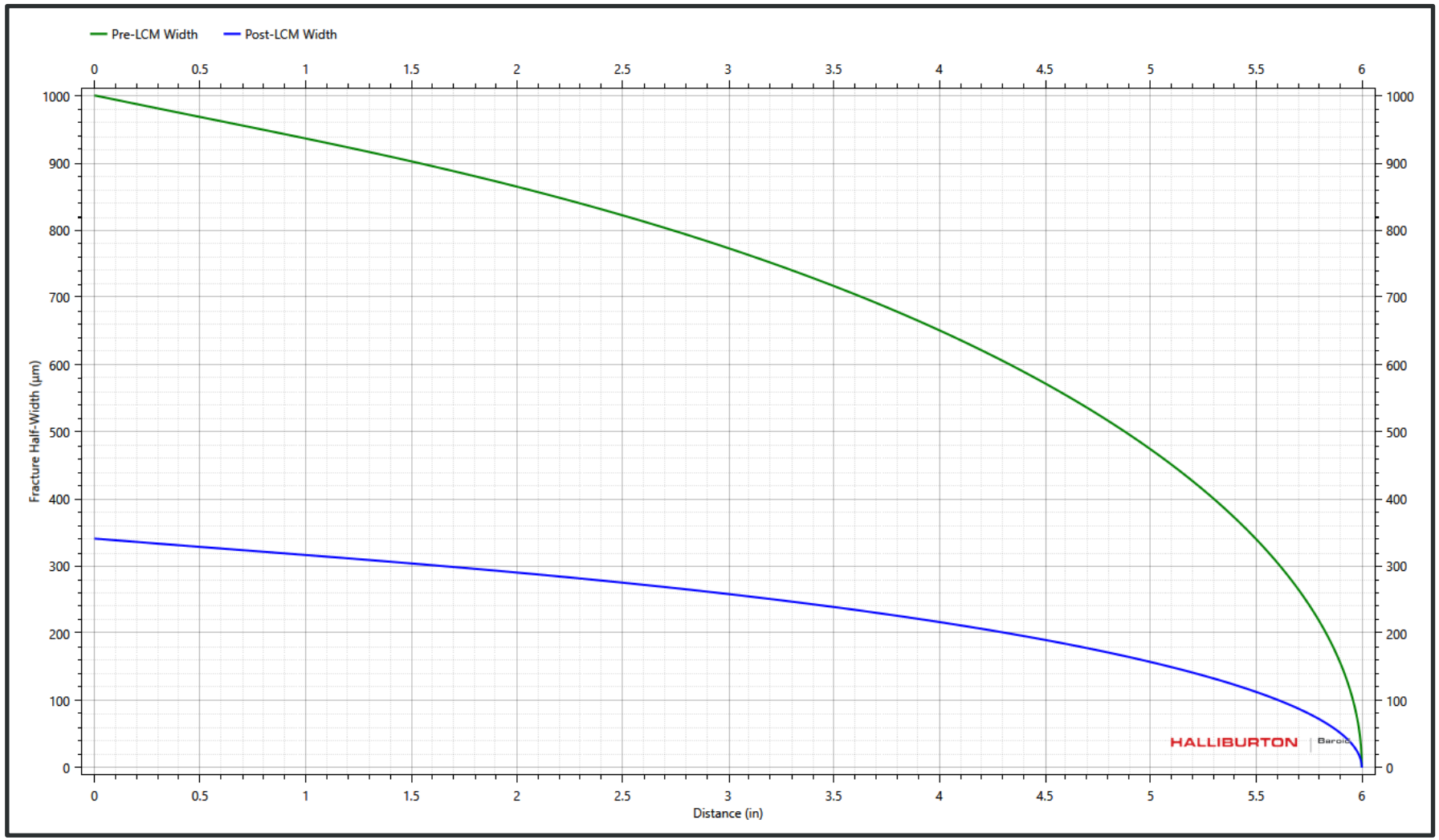
Well B: Est. Fracture width (Sand 3)

- WG-WBS Model
  - 2000microns
- Well drilled with no losses
- Stable fracture tip



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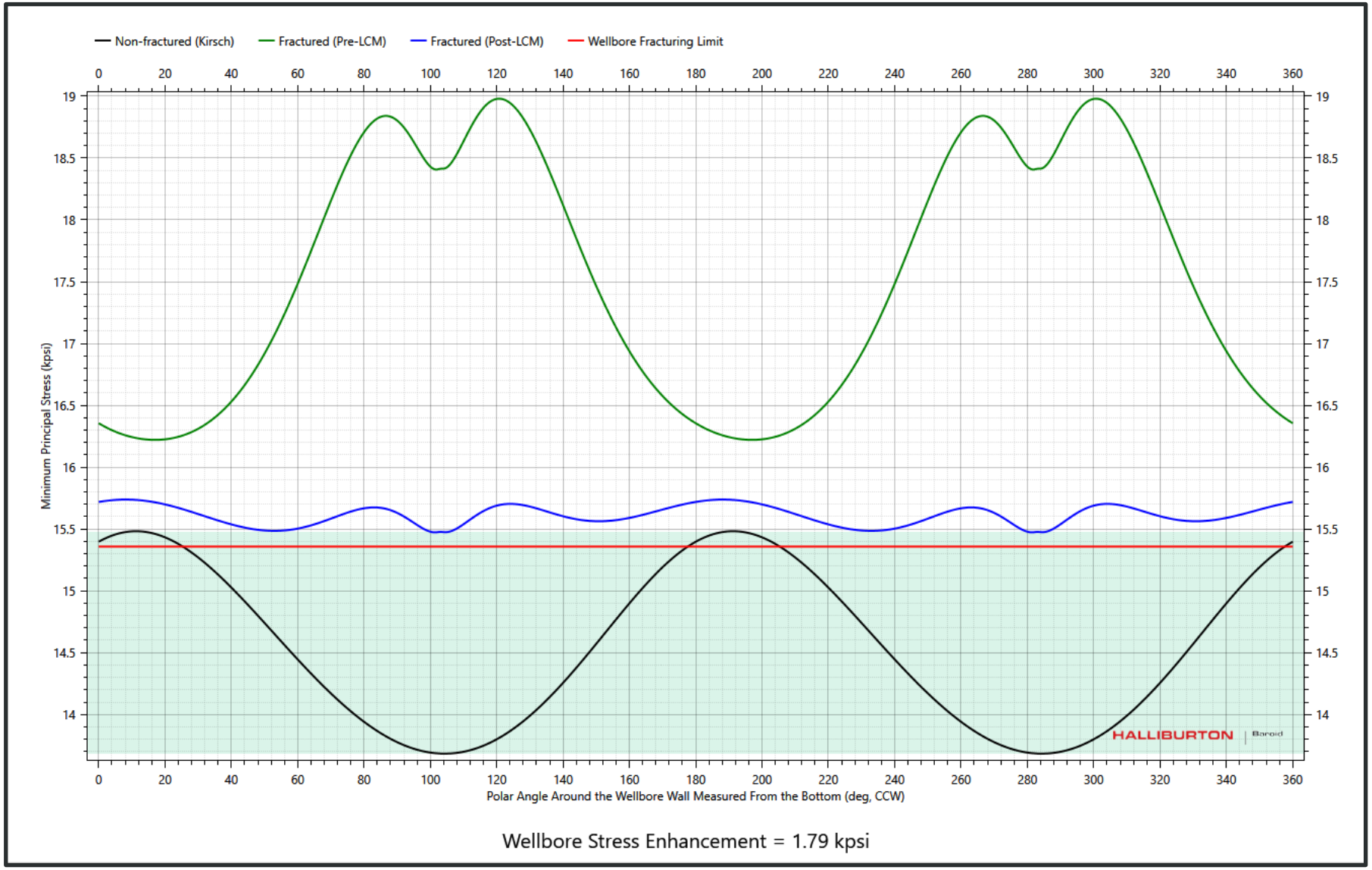
Well B: Wellbore stability (Sand 3)

- Est. Stress Enhancement 1790psi (1.35ppg)



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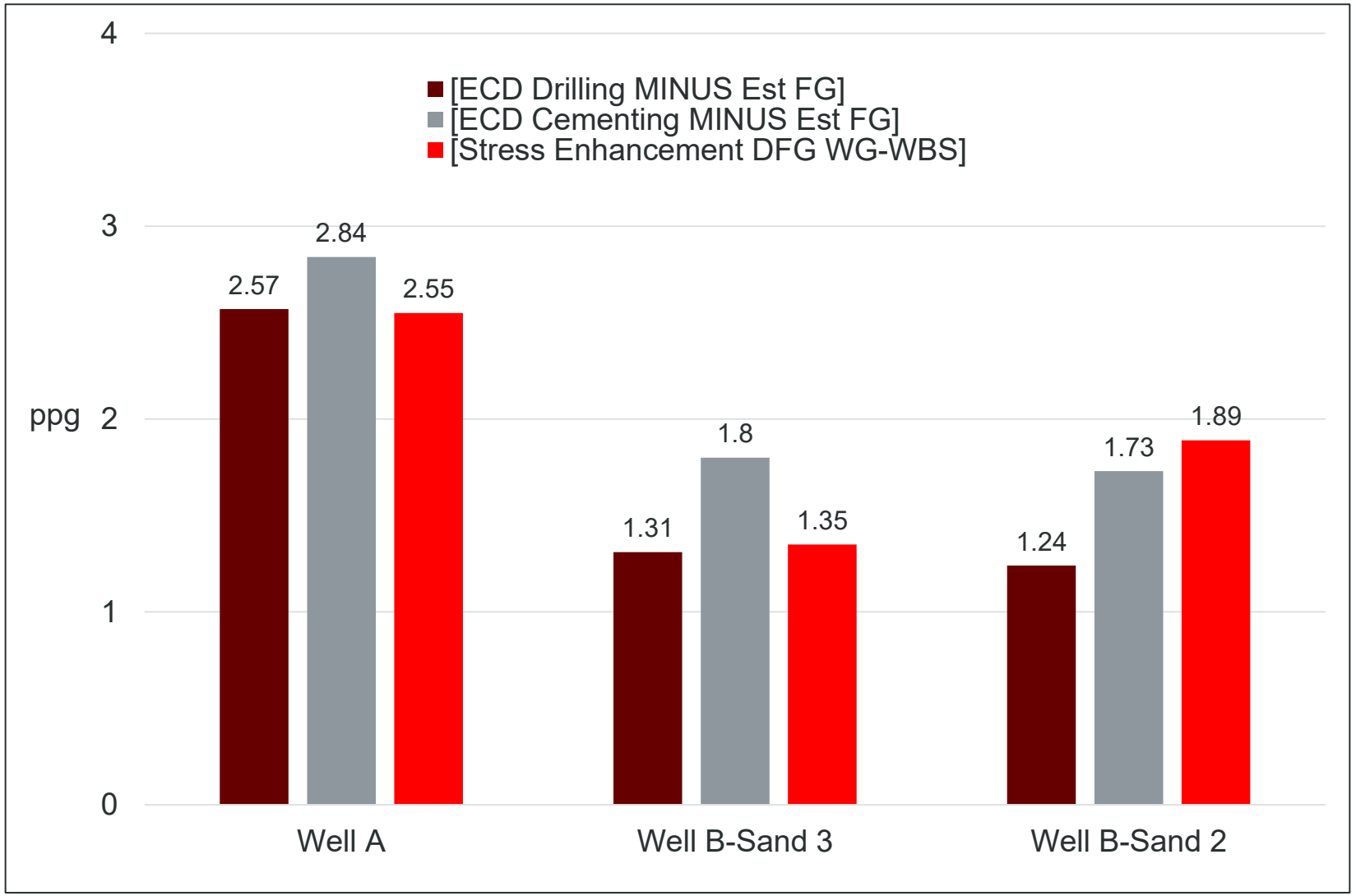
Stress Enhancement (WBS) Comparison



- Est FG – Estimated Fracture Gradient
- ECD Drilling MINUS Est FG – difference between Est FG and ECD achieved while drilling (Operator provided data)
- ECD Cementing MINUS Est FG – difference between Est FG and ECD achieved while cementing (Operator provided data)
- Stress Enhancement-DFG WG.WBS

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WG WBS Analysis Summary – GoA

- Stress enhancement modeled via DFG WG-WBS in close Compliance with reported field data (ECD Drilling MINUS Est FG & ECD Cementing MINUS Est FG)

- Limitations
  - Data requirement
  - Fracture length is assumed
  - Not All LCM combinations – ongoing project
  - PSD, LCM Conc. as inputs
  - Critical Stress Intensity factor (K_{IC}) assumption