



The Impact of Well Features on CT Reach

Presented by Patrick Kelleher

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The Impact of Well Features on CT Reach

- **CT is commonly used to mill frack plugs prior to bringing new unconventional wells online**
- **Without adequate planning CT may not reach all of the plugs in some completions**
- **This CT forces study quantifies several parameters to consider during well design and completion**

What Well Features Affect Reach and Weight on Bit?

(Tubing Forces)

- **Survey** **Less is More!**
 - Build Up Rates
 - Lateral Inclinations (Toe Up/Down)
 - Borehole Tortuosity
 - Turns in the Lateral
- **CT - Completion factors**
 - Radial Clearance
 - Friction Coefficient

Determining Feature Ranges to Compare

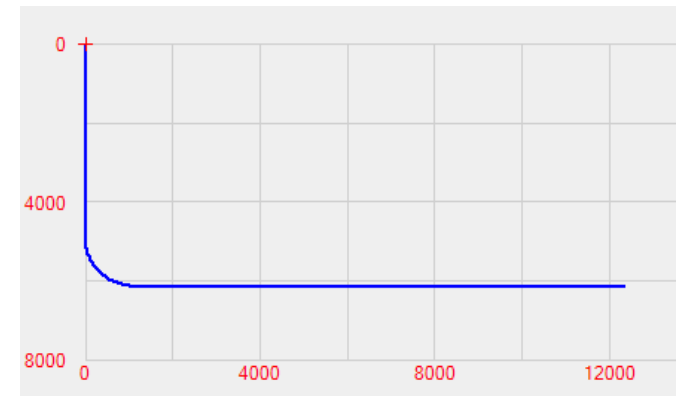
- **11 Challenging wells from North America selected for survey analysis**
 - **Extended Reach**
 - **~ 5,000 to 7,000 ft TVD**
- **Estimated survey parameters for each well and assembled them as statistics: min, max, average**

Survey Parameter Analysis

Well Feature	Units	Minimum	Average	Maximum
Build Up Rate	deg/100 ft	2.2	5.9	8.5
Tortuosity in Lateral	deg/100 ft	0.6	1.1	1.7
Turn in Lateral (3 Wells)	deg/100 ft	0.9	2.7	3.9
Highest DLS	deg/100 ft	5.6	13.4	19.1
Turn While Building	deg/100 ft	0.1	1.0	3.2
Toe Inclination	deg	89.7	90.2	91.2
Lateral Length	ft	6669	7831	9103
TVD	ft	5345	6441	7161

Theoretical Base Well for Feature Comparison

- **Simple ‘Base’ well designed using these parameters**
 - **Build Rate: 5 deg / 100 ft**
 - **Friction: 0.30**
 - **5 1/2” 17 lb/ft casing**
 - **TVD: 6150 ft**
 - **Water inside tubing and annulus**
 - **No lateral turning or tortuosity**



Comparison Wells

- **Variations applied to obtain comparison wells**
 - **Build Rates: 3 and 8 deg / 100 ft with fixed TVD**
 - **Toe Up: 91 and 92 deg Inclination**
 - **Toe Down: 89 and 88 deg Inclination**
 - **Tortuosity in lateral: 0.7 and 1.4 deg / 100 ft**
 - **Turns in lateral: 1.5 and 3 deg / 100 ft over 1500 ft**
 - **Friction Coefficients: 0.25 and 0.28**
 - **Casing sizes 5 ½ x 20 lb and 5 ½ x 23 lb**

CT String Selection

- **100 kpsi yield, 2 3/8", 0.156 to .236 Wall**
- **Custom Multi Taper Design**
 - **Optimized for extended reach and yield stress for the base well**
 - ❖ **Reduces weight along the lateral**
 - ❖ **Increases stiffness in the vertical**
 - **Commonly used in extended reach applications**

Cerberus Extended Reach CT Design Software

String Design Wizard - ICota ref design settings

Well Condition & Design Criteria:

Well Condition
 Well: ICOTA2015 Build 5
 Maximum values: TD 18000 ft, dev 90°, DLS 5 °/100ft
 Minimum wellbore: 4.892 in
 Fluid density: 8.33 lb/gal Edit...

Work zone (for tubing fatigue)

Job Requirements
 Start depth: 0
 Target depth: 14800 ft
 Set-down margin: lbf
 Pick-up margin: lbf

Tubing Selection:

Desired string length: 20000 ft
 Fluid density: 8.33 lb/gal

Job Restrictions
 Crane/road weight limitation: No
 Flow capacity: No
 Reel capacity: No
 Tubing collapse: No

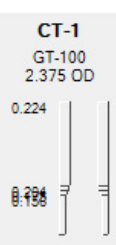
Specifications
 Manufacturer: Global Tubing
 Materials: GT-100
 Diameters: 2.375 - 2.375 in
 Wall thicknesses: 0.156 - 0.236 in Edit...

Proposed Designs:

Sort by:

Only show qualified strings

CT-1
 GT-100
 2.375 OD



0.224
0.193

Meet design criteria:
 Reachable depth (ft): Target
 Safe pulling depth (ft): Target
 Available setdown (lbf): -683
 Available pickup (lbf): 46235

Update Design

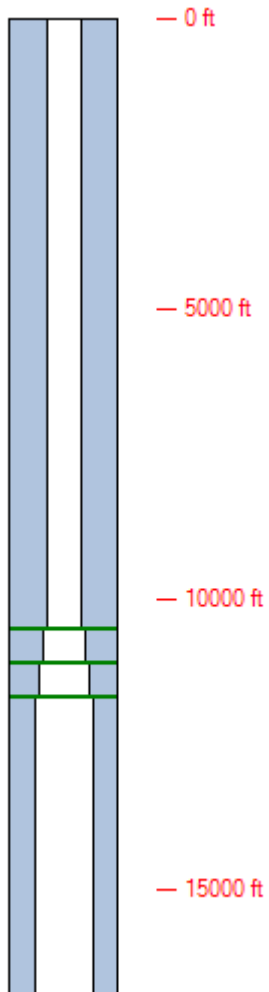
Add to Proposed

String Details...

Save String...

Options...
CTES Defaults
Load Defaults
Save Defaults
Load/Save
Exit

CT String Designed for Base Well



- 2 3/8" OD
- 0.156 to .236 Wall
- GT-100

Wall Thickness (in)	Section Length (ft)
0.156	6114
0.190	699
0.204	675
0.236	12512

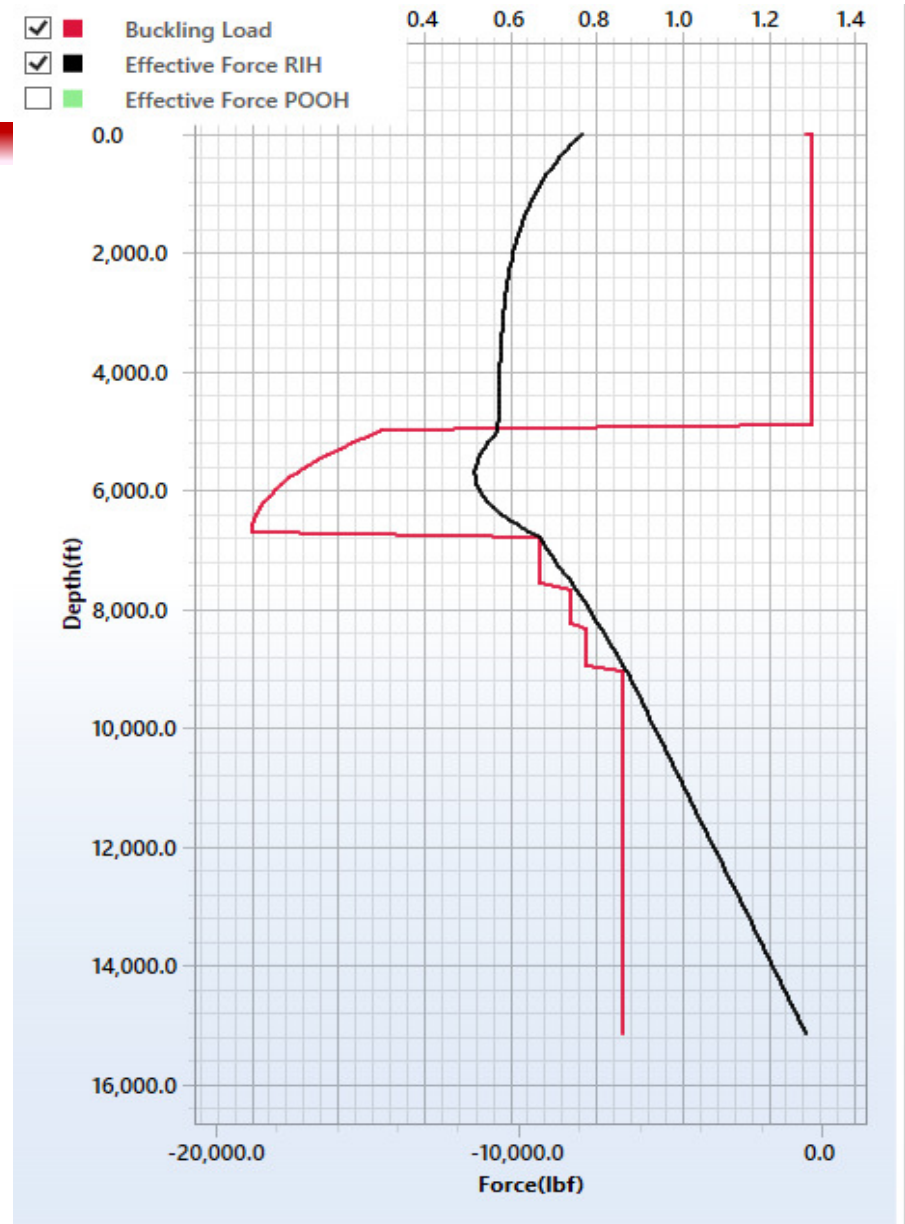
* This string used in all comparisons

Using Forces Modeling to Quantify Impacts

- **Friction Lock-Up Depth**
 - Theoretical Max CT Reach
 - Lateral Reach = $D_{\text{lockup}} - D_{\text{end of build}}$
- **Wall Contact Force (WCF)**
 - How forces are distributed
- **Force Transfer Factor (FTF):**
 - Slope of *WOB with respect to Surface Force*
 - Force Transfer Loss(section) = $\text{FTF}(\text{top to surface}) - \text{FTF}(\text{bottom to surface})$

Base Case Results

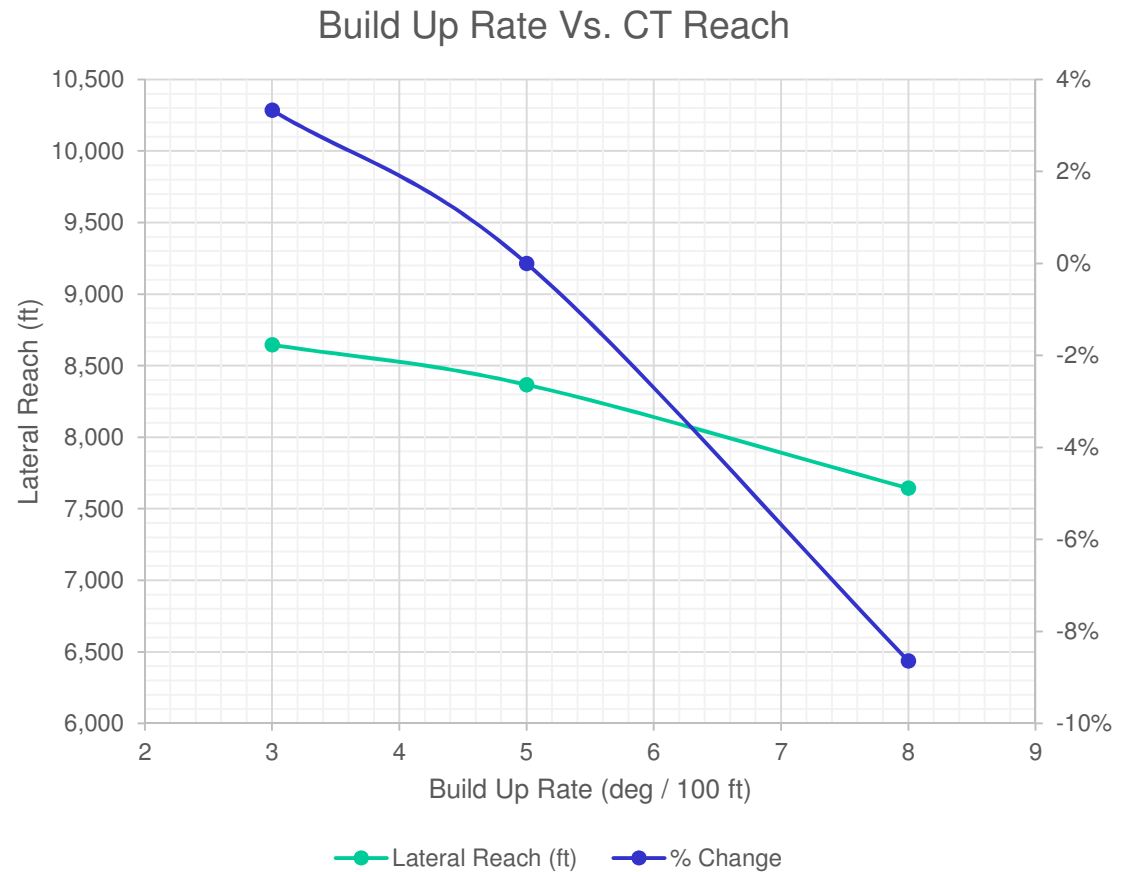
- **Lockup at 15,167 ft with 500 lbf WOB:**
 - Lateral reach of 8,367 ft
 - No buckling in the lateral due to tapered design
 - Most WCF in vertical section
 - 98% Incremental force loss in vertical section



Build Up Rate

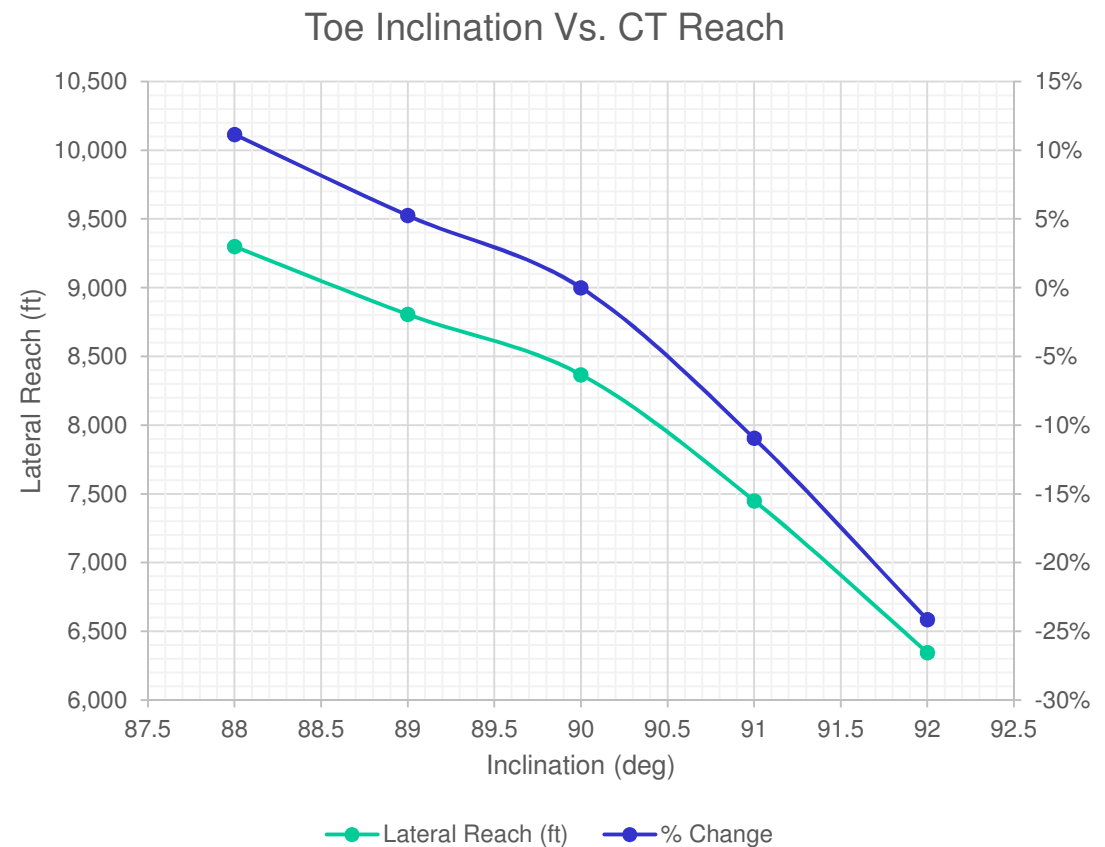
(deg / 100 ft)

- **Increasing BUR from 5 to 8 reduced lateral reach by 9%**
- **Reducing BUR from 5 to 3 increased lateral reach by 3%**



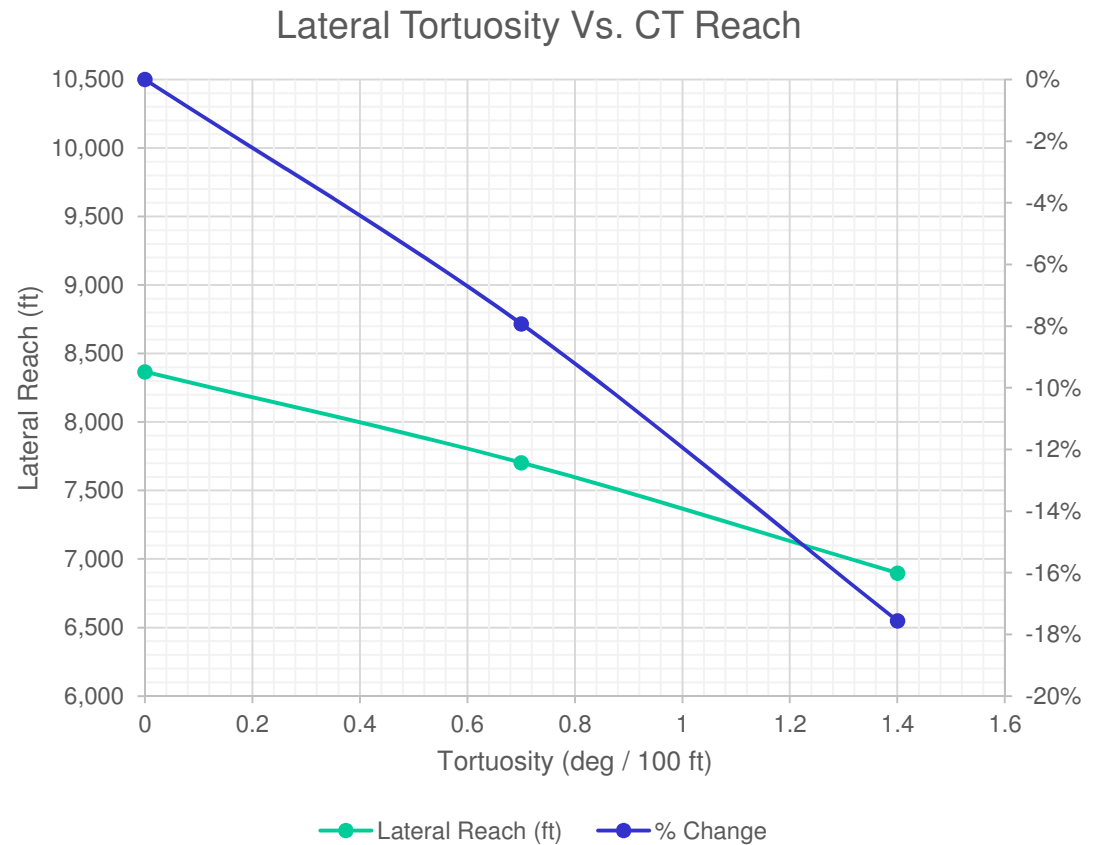
Toe Up / Down (deg)

- **1 Degree Toe Up reduced lateral reach by 11%**
 - **Onset of buckling in the lateral**
- **1 Degree Toe Down increased lateral reach by 5%**



Lateral Tortuosity (deg / 100 ft)

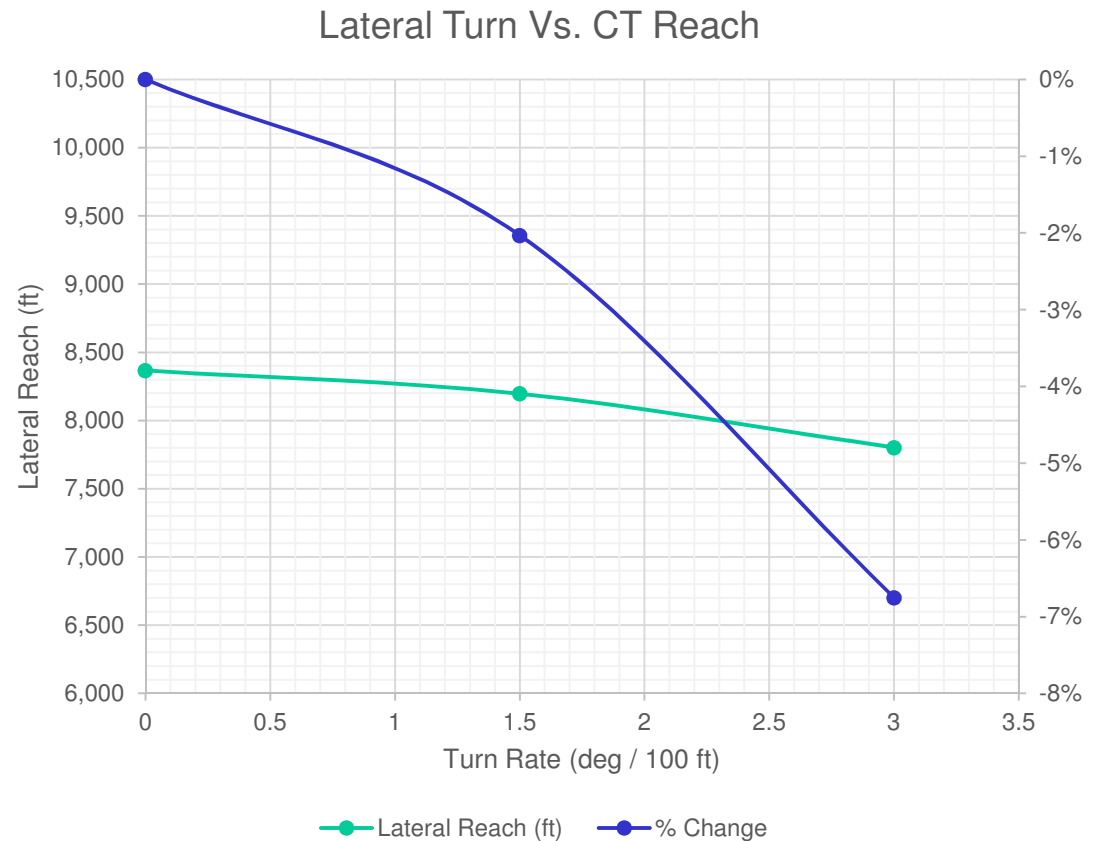
- **0.7 deg/ 100 ft** tortuosity reduced lateral reach by **8%**
- **1.4 deg/ 100 ft** tortuosity reduced lateral reach by **18%**



Lateral Turns

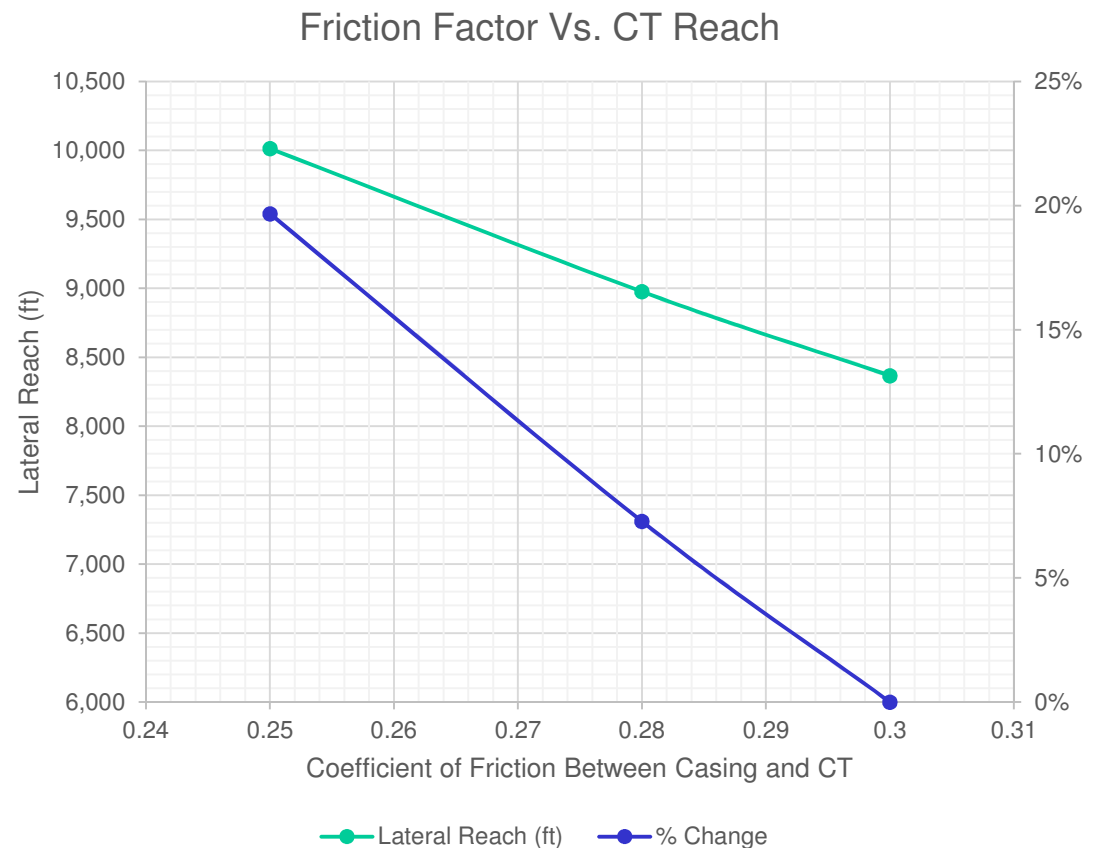
(deg / 100 ft over 1500 ft)

- 1.5 deg/100 ft turn reduced lateral reach by only 2%
- 3 deg/100 ft turn reduced lateral reach by 7%



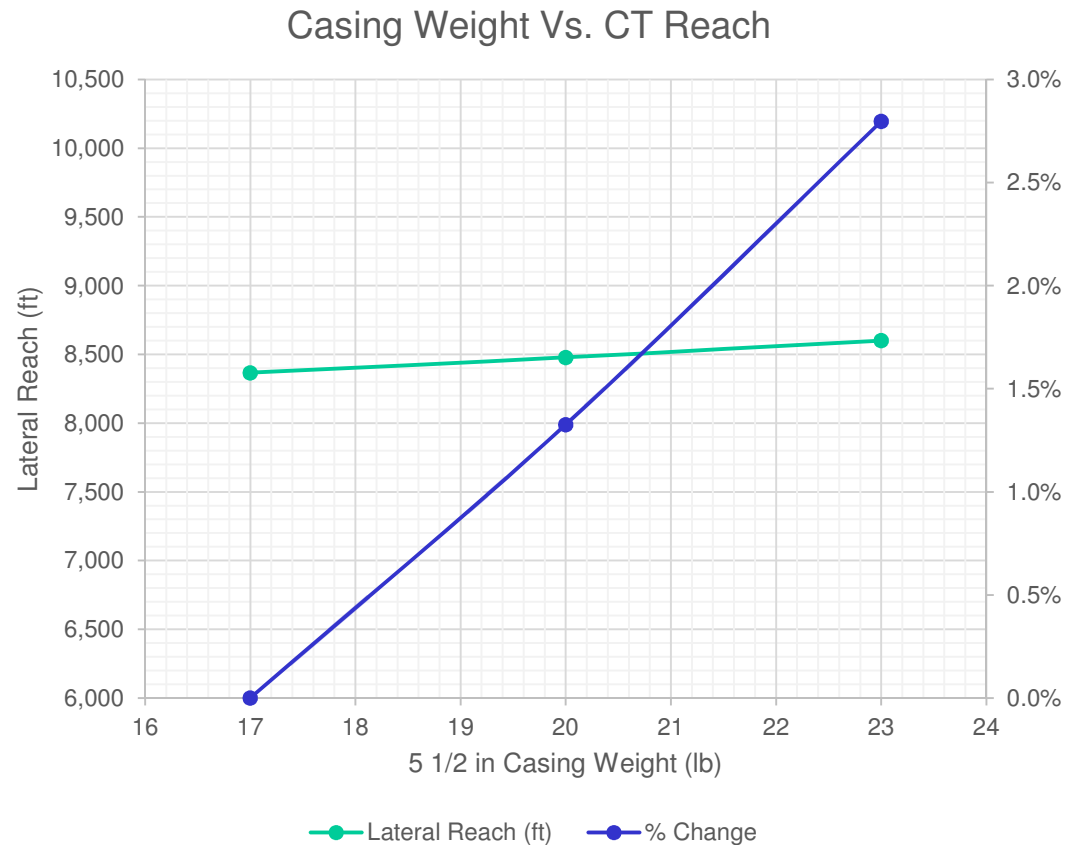
Coefficient of Friction (Cf)

- Reducing Cf from 0.30 to 0.28 increased later reach by 7%
- Lower friction significantly reduces buckling and friction in the vertical section



5 1/2 in Casing Weight (lb / ft)

- Increasing Weight from 17 lb/ft to 23 lb/ft increased lateral reach by 3%
- Same result if only the vertical section is increased in this case



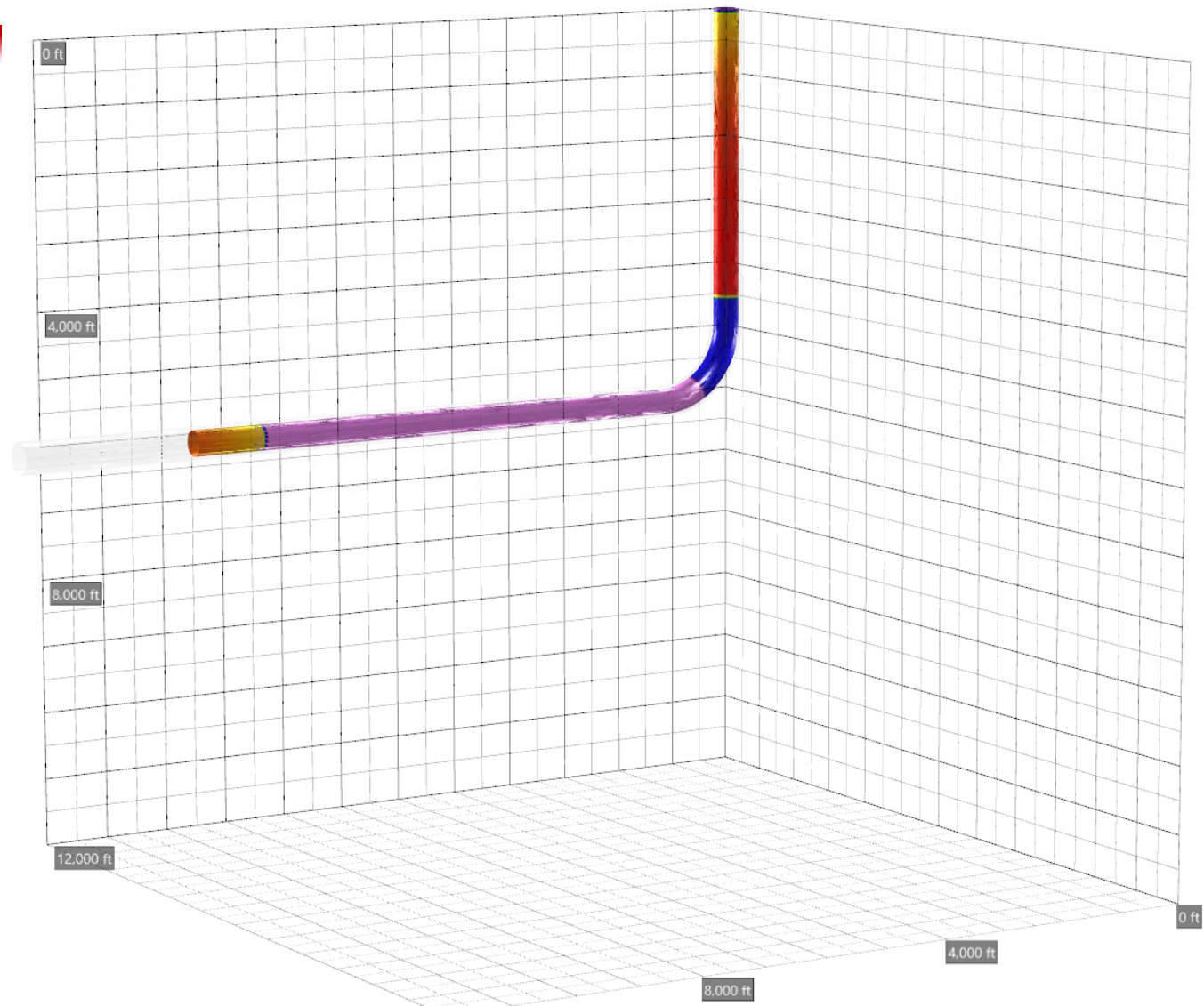
Parametric Matrix

Parameter	Lateral Reach (ft)	Vertical		Heel		Toe	
		WCF (lbf)	% FTF Loss	WCF (lbf)	% FTF Loss	WCF (lbf)	% FTF Loss
Build 5 deg / 100 ft 0.25 Friction	10,013	54,712	95.0%	22,881	1.6%	36,605	2.2%
Toe Down 88 deg inclination	9,299	62,931	98.2%	20,701	0.7%	33,792	0.0%
Build 5 deg / 100 ft 0.28 Friction	8,976	48,239	95.6%	21,698	1.6%	32,160	1.7%
Toe Down 89 deg inclination	8,806	66,696	98.4%	20,965	0.6%	31,495	0.0%
Build 3 deg / 100 ft	8,646	34,325	92.4%	23,586	4.0%	32,246	2.4%
Build 5 deg / 100 ft, 5.5 23 lb casing	8,601	73,007	98.4%	21,835	0.6%	30,548	0.0%
Build 5 deg / 100 ft, 5.5 20 lb casing	8,478	63,133	98.2%	21,182	0.7%	29,498	0.1%
Build 5 deg / 100 ft (Base Case)	8,367	66,478	98.4%	21,203	0.6%	29,361	0.0%
Turn in Lateral 1.5 deg / 100 ft for 1500 ft	8,197	63,133	98.2%	21,182	0.7%	29,498	0.1%
Turn in Lateral 3.0 deg / 100 ft for 1500 ft	7,802	60,155	98.0%	21,161	0.8%	30,958	0.3%
Lateral Tortuosity 0.7 deg / 100 ft	7,704	30,908	90.7%	20,652	3.5%	28,577	4.8%
Build 8 deg / 100 ft	7,644	59,938	98.2%	17,293	0.6%	26,007	0.0%
Toe Up 91 deg inclination	7,450	26,980	88.1%	21,448	4.7%	26,465	5.9%
Lateral Tortuosity 1.4 deg / 100 ft	6,898	27,383	88.4%	19,020	4.2%	28,912	6.3%
Toe Up 92 deg inclination	6,346	22,974	84.7%	20,104	6.0%	24,842	7.9%

- TVD at start of lateral = 6150 ft for all wells
- WOB = -500 lbf for all cases

Force Transfer Loss

- Red shown where the majority of additional set down weight is lost due to wall contact forces



What Influences these Parameters?

- **Build Rate, Turns, Final Trajectory, Tortuosity**
 - **Economics, geography, drilling equipment, and formation characteristics**
- **Radial Clearance**
 - **Casing, liner and CT Diameter selections**
- **Friction coefficient and downhole tools**
 - **Fluid Additives**
 - **BHA vibration tools**

Conclusions

- **Survey parameters that significantly reduce CT Reach in this case:**
 - **Toe Up > 0.5 deg**
 - **Cased hole tortuosity > 0.5 deg /100 ft**
 - **Build Rates > 6 deg/100 ft**
 - **Lateral turns > 3 deg/100 ft**
- **Custom CT string designs reduce buckling in the lateral**
- **Majority of forces attributed to lock up are in the vertical section (with a custom CT design)**
 - **Decrease radial clearance if possible**
 - **Liners add challenges for CT extended reach**



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NOV CTES**

Thank You

Questions?