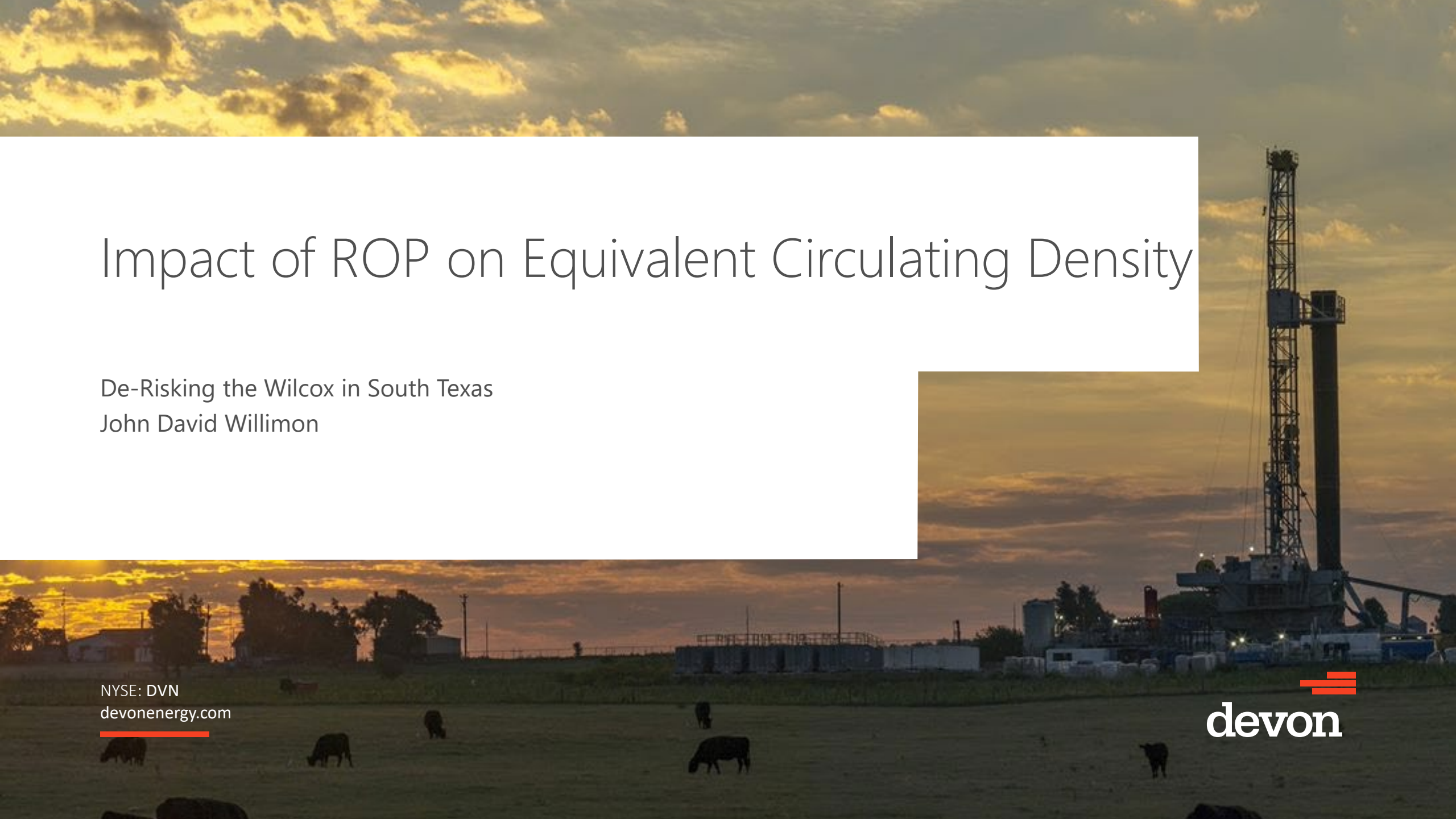

# Impact of ROP on Equivalent Circulating Density

De-Risking the Wilcox in South Texas

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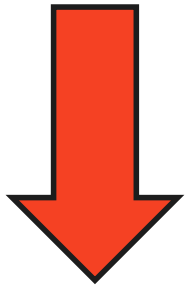
# Outline

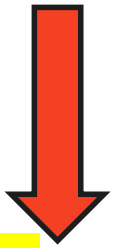
- Wellbore Diagram & Field Introduction
- Problem Statement
- Approach/Workflow
- Findings
- Plan Changes/Implementation
- Results
- Recommendations

# What is and What Effects ECD's

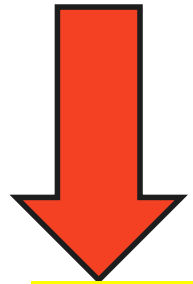
ECD, ppg = (annular pressure loss, psi) ÷ 0.052 ÷ TVD, ft + (mud weight + Cuttings Load)



(**Annular Velocity** x Mud Weight, rheology x Length of Annular )

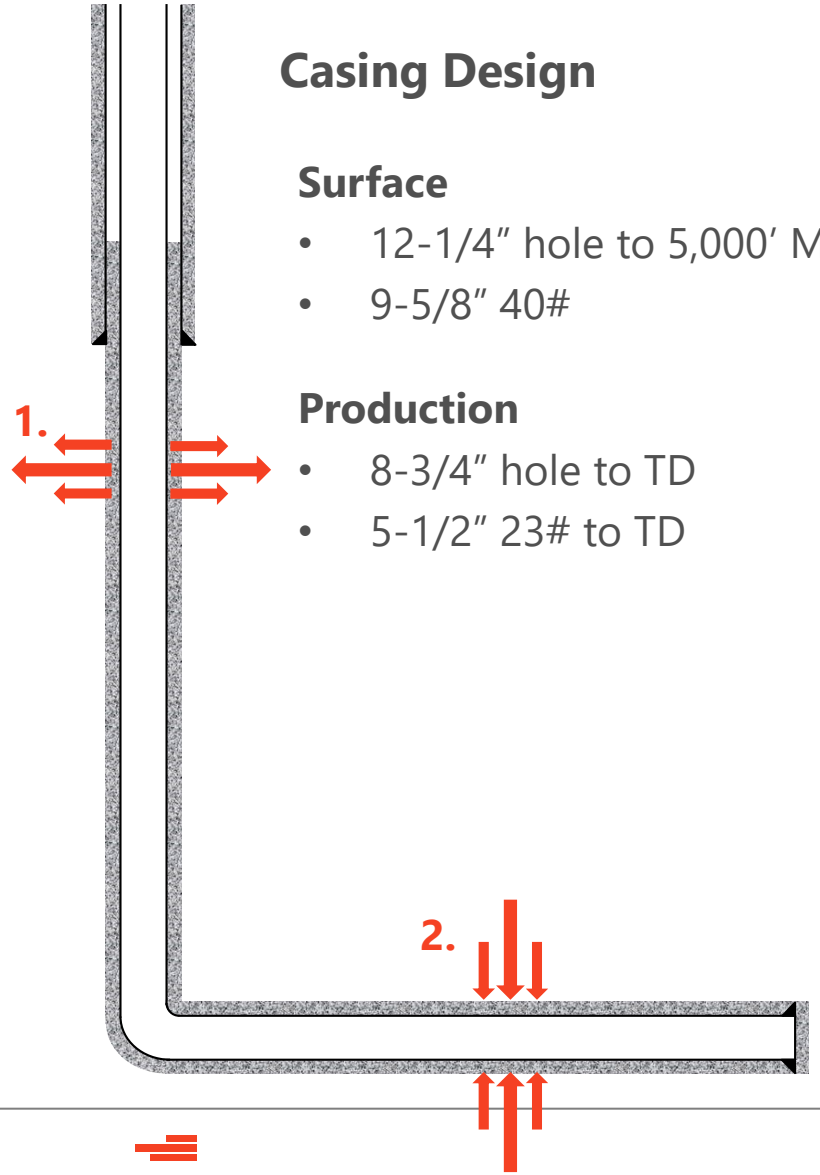


(**Flow rate** and geometry)



(11 ppg + **Function of ROP**)

# Wellbore Diagram & Drilling Hazards




## Casing Design

### Surface

- 12-1/4" hole to 5,000' MD
- 9-5/8" 40#

### Production

- 8-3/4" hole to TD
- 5-1/2" 23# to TD

## Drilling Hazards

### 1. Wilcox Losses

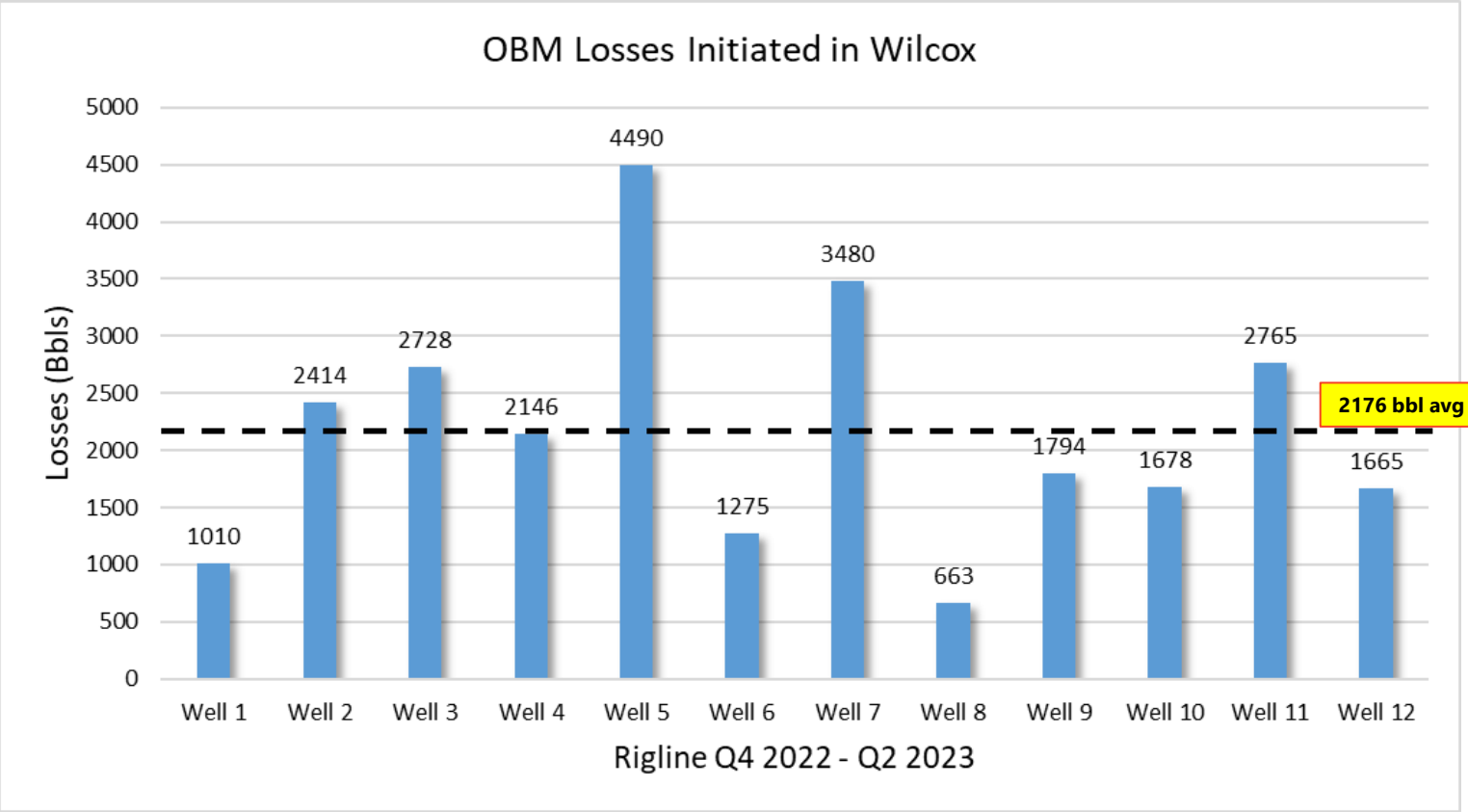
- 25% of wells had severe losses
- Inability to stop losses once initiated
- 14.5 ppg FIT (Offset control)

### 2. Eagleford Instability

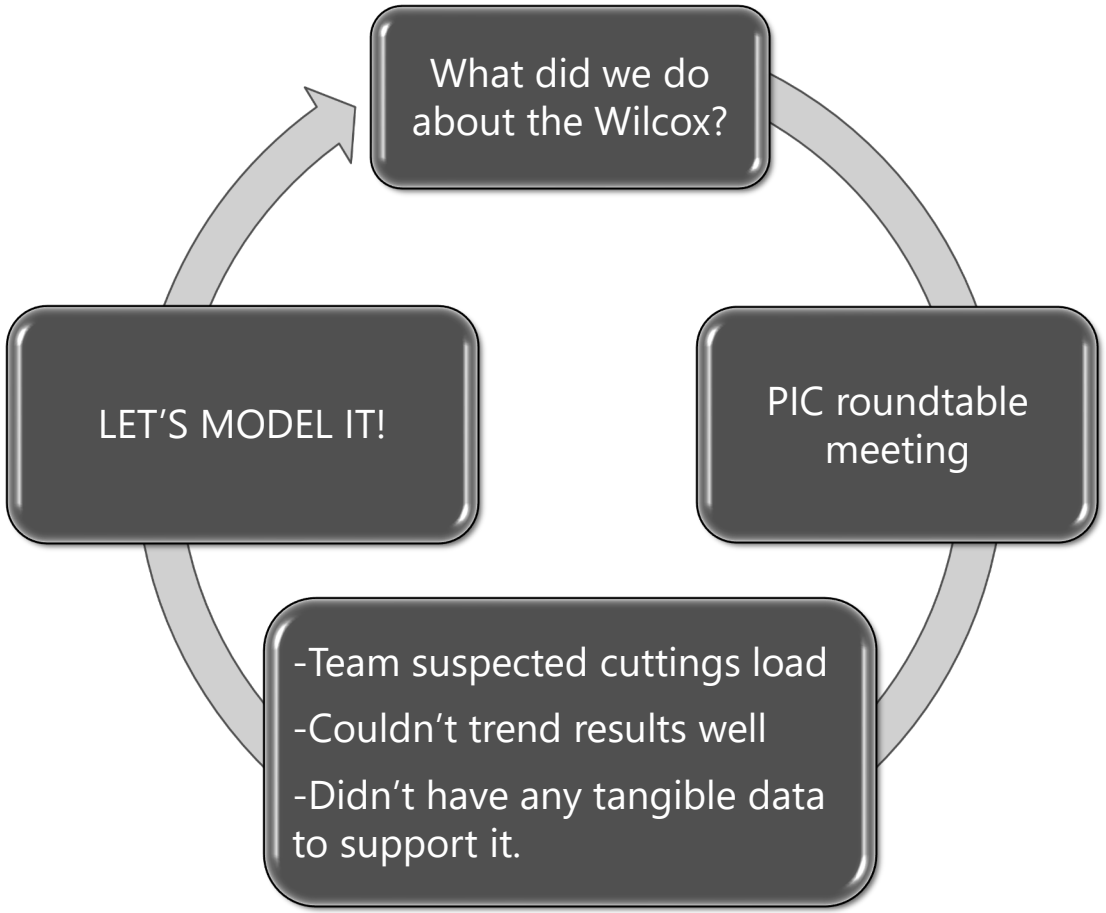
- Managing hole instability
- Significant structural complexity
- Faults encountered in multiple stratigraphic intervals
- The discipline to control drill to maintain ECD's
- 13 ppg EMW

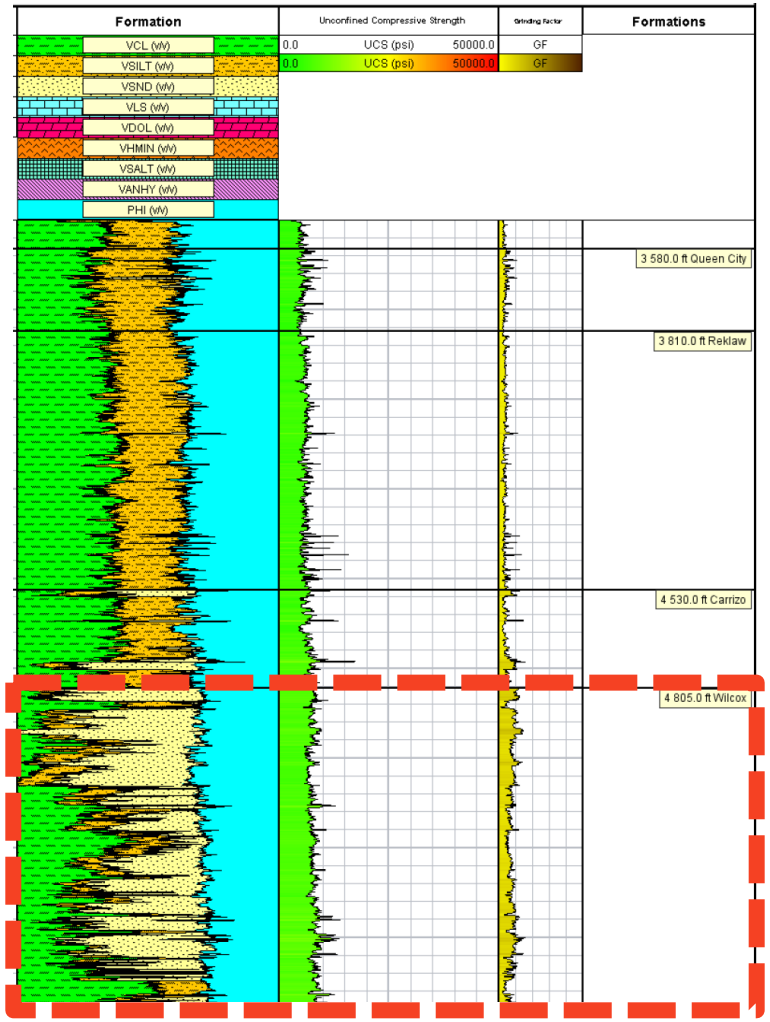
# Problem Statement

- Encountering severe losses
- Somewhat randomly
  - At least 1-well every pad
  - @≥600 ft/hr | 650 GPM
- Never regained full returns
  - LCM squeezes not significant mitigator
- Mostly in production vertical
- 6-8 PPB preventive background LCM does not work.



# Approach / Workflow



# Software & Variables

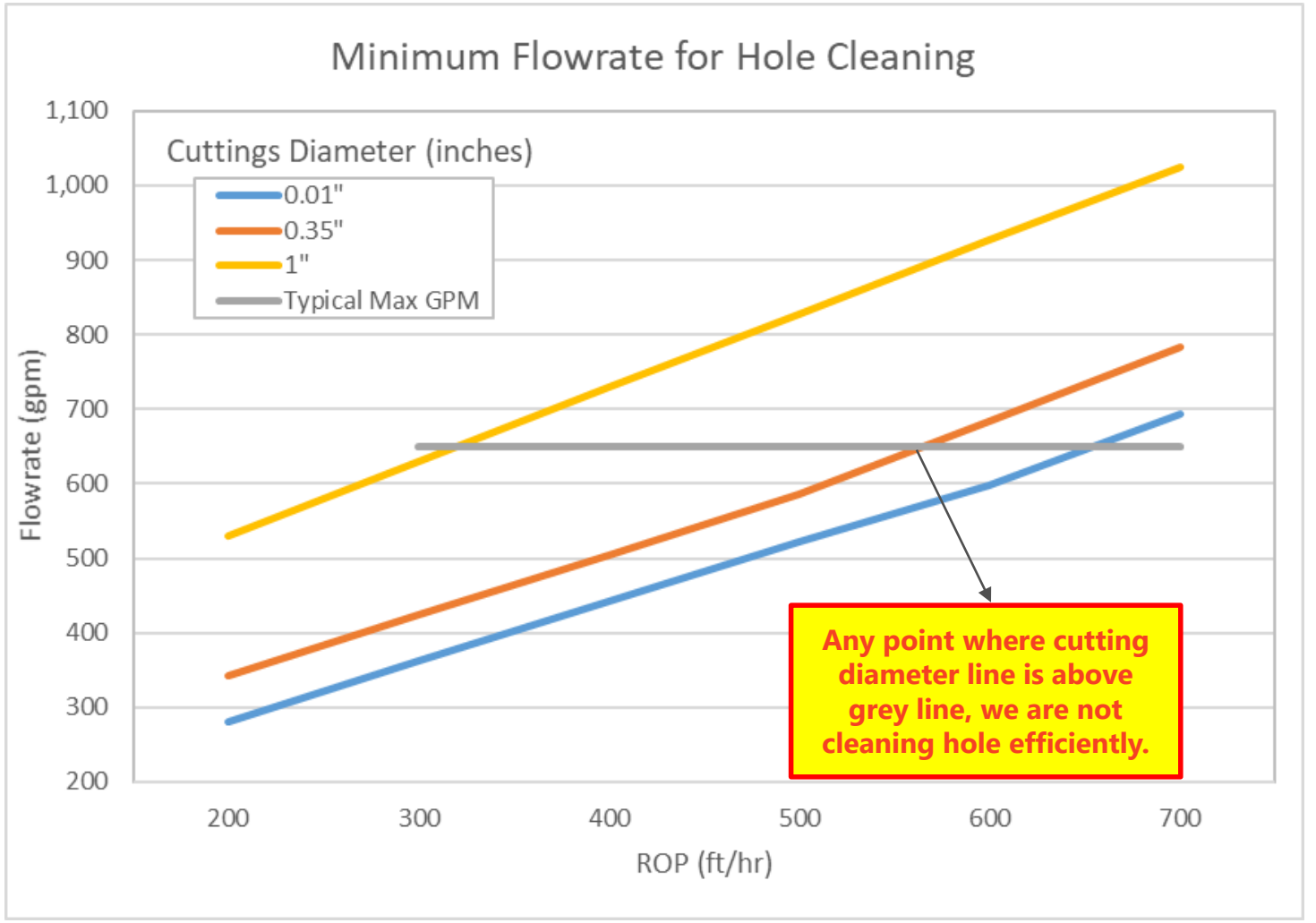
- Software - Landmark WellPlan
- Static Variables
  - Hole geometry – Casing, open hole, directional plan
  - String geometry – BHA Design
  - Mud Properties
- Dynamic Variables
  - Pump Rate
  - Cuttings Load (ROP)
  - **Cuttings diameter**

# Sensitivity for Cuttings Diameter and Min Flowrate

Variables:

- Cuttings size
- ROP
- MW = 11.0 ppg

| | Cuttings Diameter (in) | | |
|---|---|---|---|
| ROP (ft/hr) | 0.01" | 0.35" | 1" |
| 200 | 280 | 343 | 530 |
| 300 | 362 | 424 | 630 |
| 400 | 442 | 504 | 729 |
| 500 | 521 | 585 | 828 |
| 600 | 598 | 684 | 926 |
| 700 | 693 | 783 | 1025 |
| | Minimum Flowrates (GPM) | | |



# ECD at TD – Vertical Hole

| ROP (ft/hr) | Flowrate (GPM) | | | | |
|---|---|---|---|---|---|
| | 500 | 550 | 600 | 650 | 700 |
| 0 | 11.54 | 11.63 | 11.77 | 11.89 | 12.01 |
| 300 | 11.84 | 11.94 | 12.02 | 12.12 | 12.23 |
| 400 | 12.80 | 12.03 | 12.11 | 12.20 | 12.30 |
| 500 | 19.73 | 19.00 | 12.19 | 12.27 | 12.36 |
| 600 | 17.84 | 19.60 | 23.55 | 21.22 | 12.43 |
| 700 | 17.44 | 19.00 | 20.55 | 23.55 | 12.44 |

**Approximately +0.07 ppg per 100 ft/hr**

- ROP effect on ECD's > flow rate
- Current parameters < optimal for hole cleaning
- Offset operator control drilling well under ROP/Flow rate limit
- **Drilling at a lower P rate will solve the problem!?**

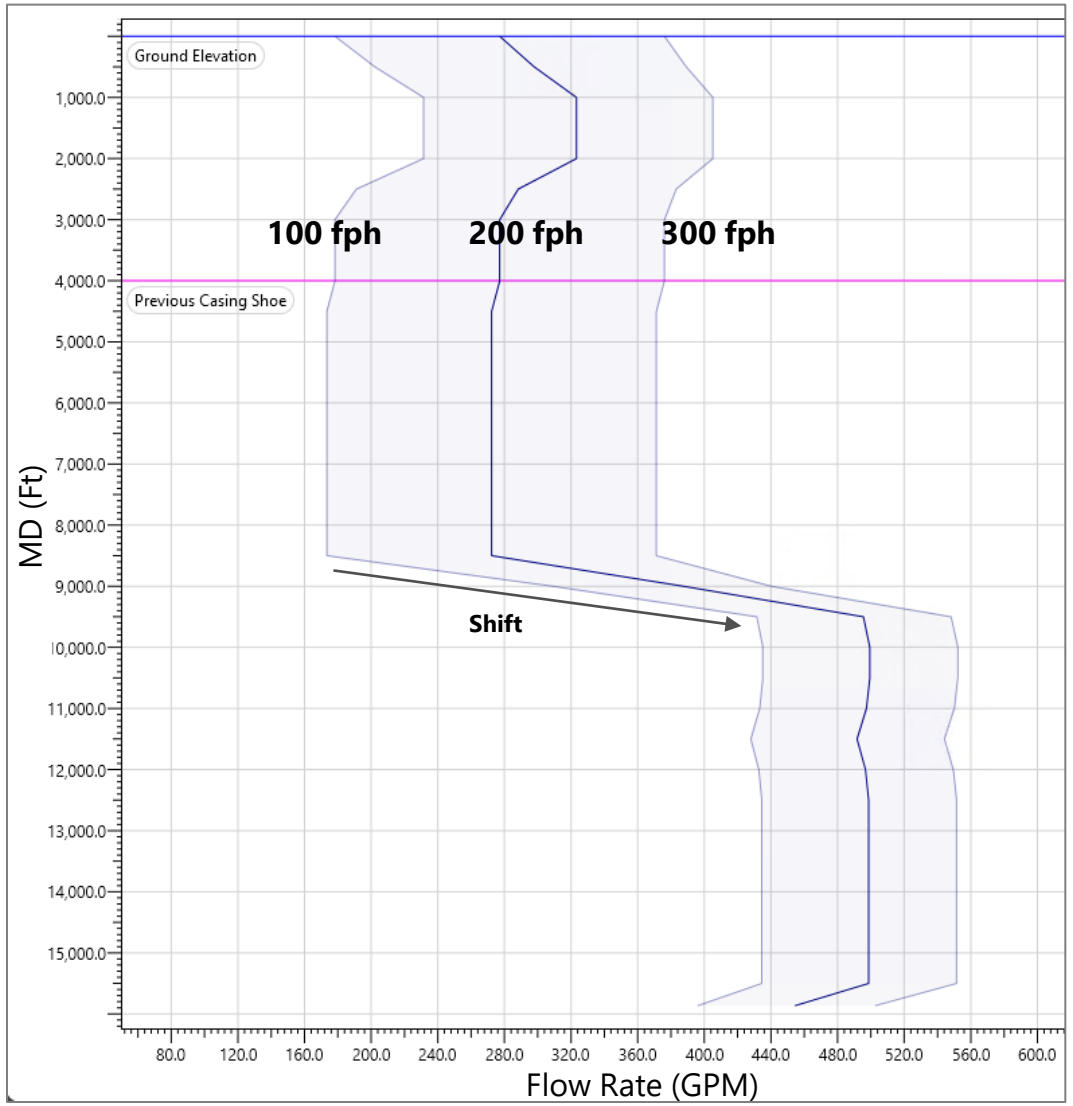
# NO!

# I WANNA ~~GO~~ FAST DRILL

# ECD at TD – Lateral Hole

- What's different in lateral?
  - Cuttings bed
  - Gravity settling
- Higher flow rates to clean hole
  - Less mechanical agitation due to motor bend

Lateral Hole 15,600' MD



# Changes: Drill-Out Schedule

**8-3/4" Drill-Out Schedule**

| MD past Shoe | ROP | Flow Rate | Min. Flow Rate | TD RPM |
|---|---|---|---|---|
| 100 | 200 | 550 | 346 | 30-50 |
| 200 | 300 | 550 | 420 | 30-50 |
| 300 | 400 | 650 | 500 | 65 |
| 700 | 500 | 650 | 580 | 65 |

- Previously drilled 600 fph/650 gpm not consistently cleaning hole
- Following schedule with good margin to min. flow rates

# Changes: Hole Cleaning Paradox

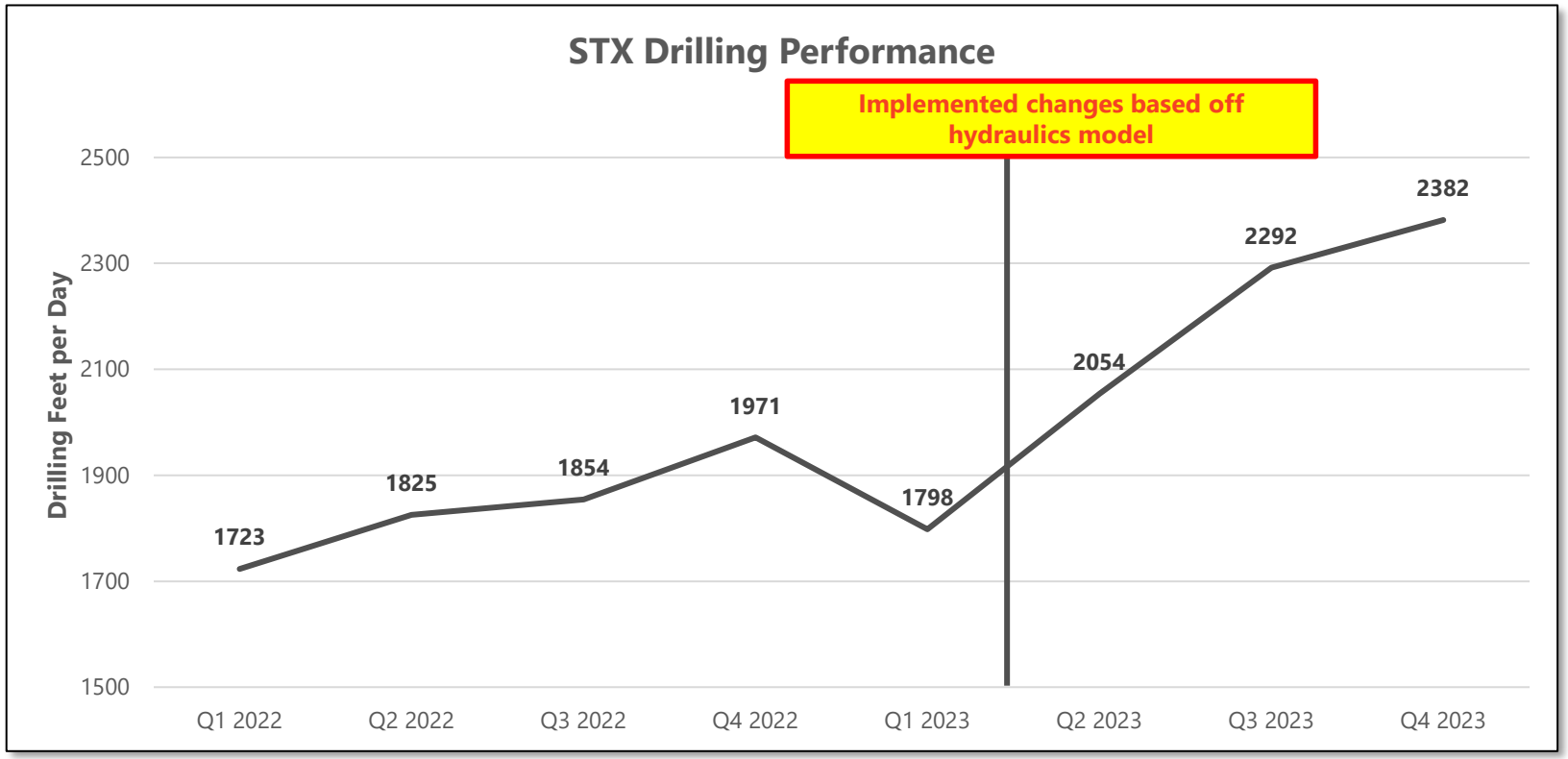
| ROP (ft/hr) | Flowrate (GPM) | | | | |
|---|---|---|---|---|---|
| | 500 | 550 | 600 | 650 | 700 |
| 0 | 11.54 | 11.63 | 11.77 | 11.89 | 12.01 |
| 300 | 11.84 | 11.94 | 12.02 | 12 | 12 |
| 400 | 12.80 | 12.03 | 12.11 | .20 | 12.3 |
| 500 | 19.73 | 19.00 | 12.19 | 2.27 | 12 |
| 600 | 17.84 | 19.60 | 23.55 | 21.22 | 12.49 |
| 700 | 17.44 | 19.00 | 20.55 | 23.55 | 12.44 |

- Raising the flowrate reduces the equivalent circulating densities at the Wilcox.

# So, drilling faster and pumping harder will reduce our ECD's?

# Results

- We've drilled 50 wells since with no losses
- We've drilled faster – 700 fph inst. Instead of 600 fph.
- Spud-RR ft/day increased 27% due to not fighting losses and seeing higher inst. ROPs



# Takeaways

- South Texas – relationship of flow rate to ROP to understand cuttings load on Wilcox is critical
- Other areas – cuttings load effect on ECD's can be very significant at high ROP's
- We've also seen this come into plan in other shale plays with low clearance annulus, large cuttings, and high ROPs (Woodford, Niobrara, etc)
- Use hydraulic models to define proper hole cleaning in all fields to understand limits