SPE Workshop

Extended Reach and Horizontal Wells – Challenges and Solutions

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Keys to Proper Application of MSE in Horizontal/ER Wells

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Outline

- MSE Refresher
  - History
  - What it tells us
- Mechanics of Torque Generation
- Implications for Horizontal / ERD Wells
- Case Study Example

MSE Refresher

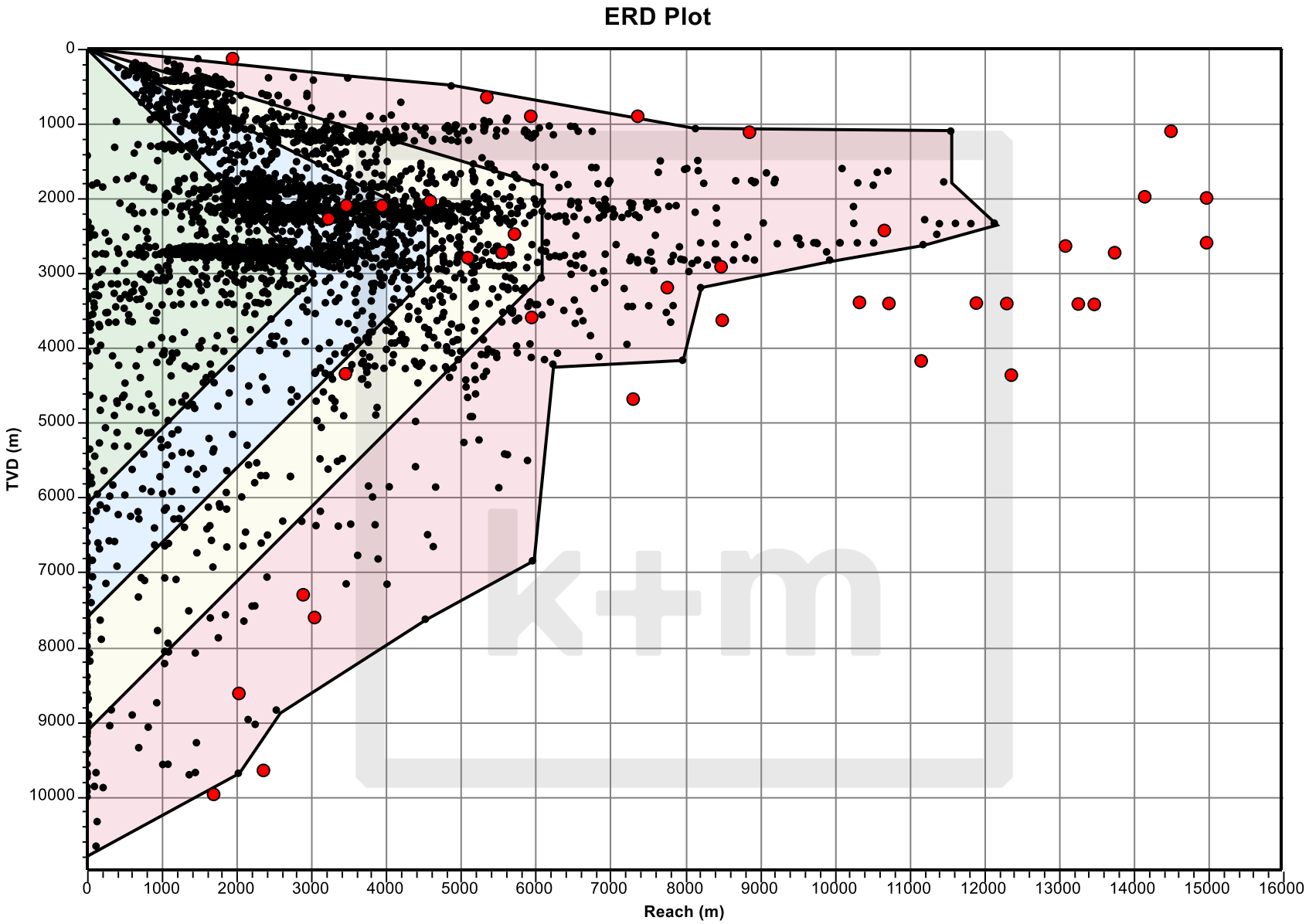
- What is Mechanical Specific Energy (MSE)?
  - Measure of energy used to destroy rock
  - For a known rock strength, efficiency can be inferred

$$MSE = \frac{\mathrm{WOB}}{\mathrm{A_B}} + \frac{120 \times \pi \times \mathrm{RPM} \times \mathrm{T}}{\mathrm{A_B} \times \mathrm{ROP}}$$

- Origins?
  - Developed by Teale in 1965 (Int. J. Rock Mech. Mining Sci. Vo.2)
  - Evolved / validated by Pessier in the 1992 (SPE 24584)
  - Applied by Waughman in 2002 (SPE 74520)
  - Popularized by Dupriest in the 2005 (SPE 92194)

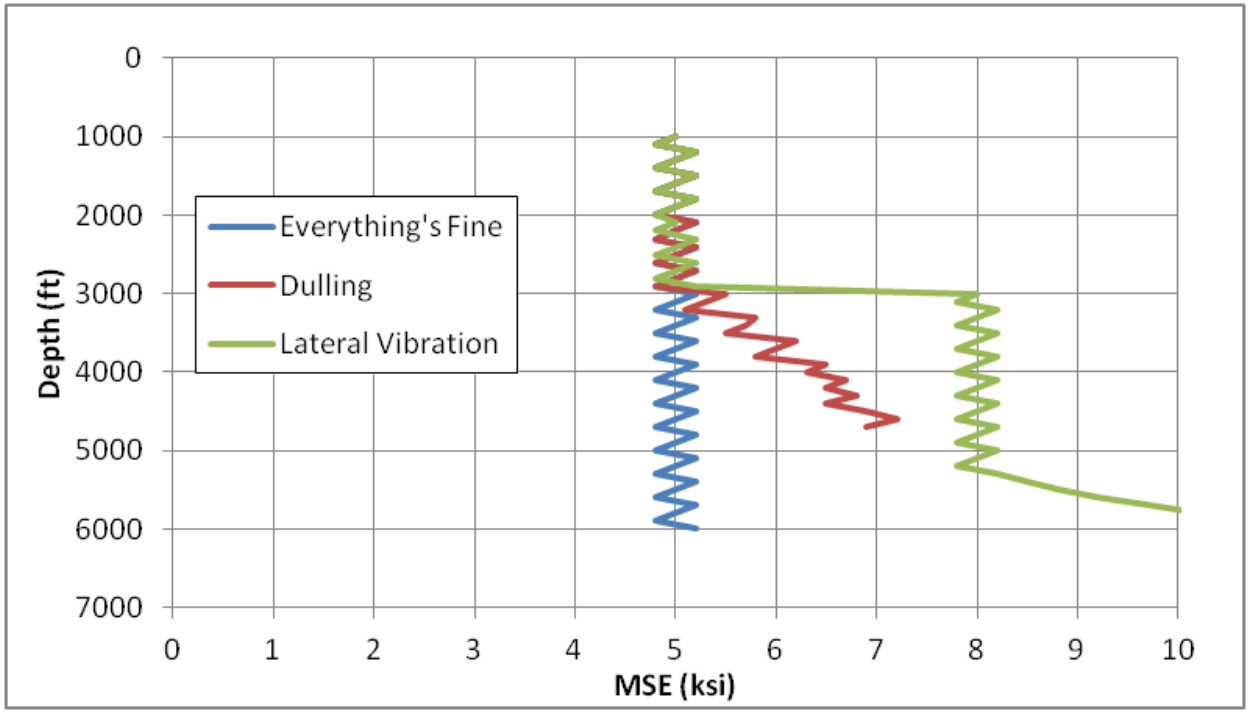
- Why use MSE?
  - **While Drilling:** Optimize parameters for maximum performance
  - **While Planning:** Identify performance bottlenecks

MSE, ERD, and other TLAs



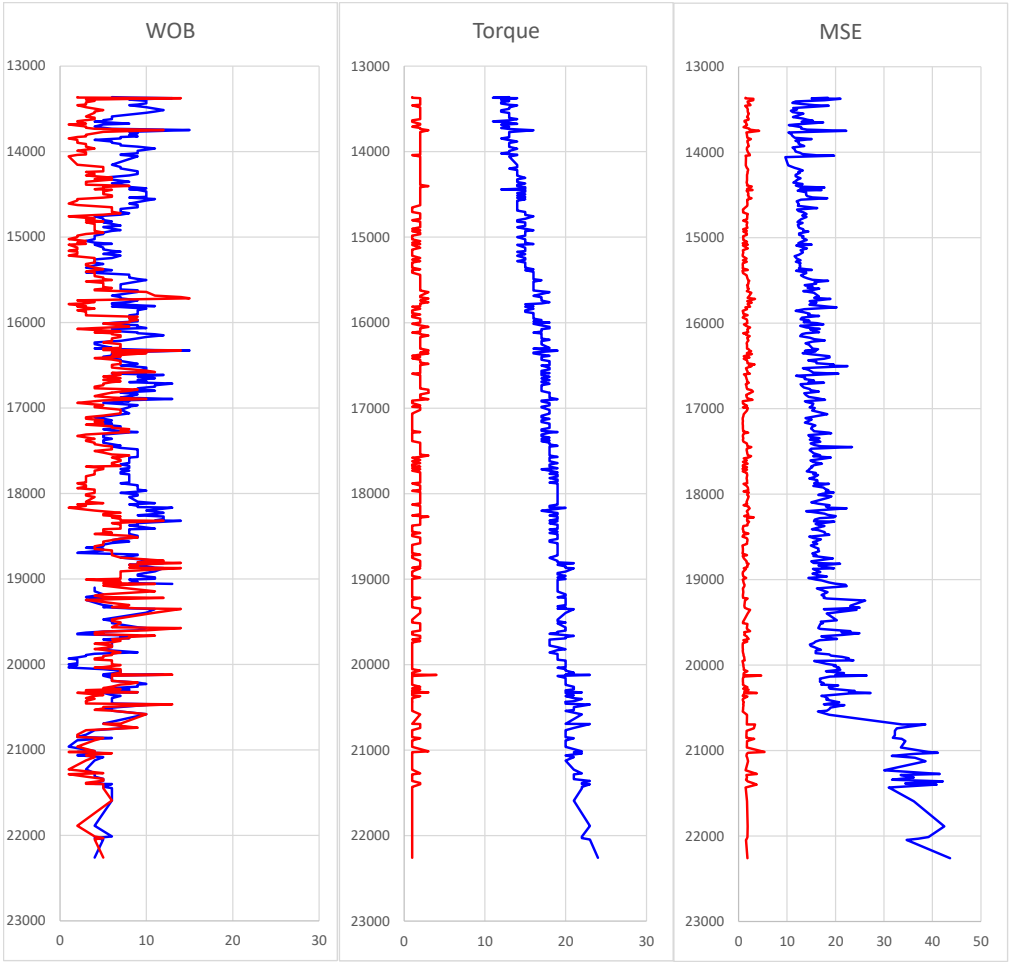
MSE Refresher

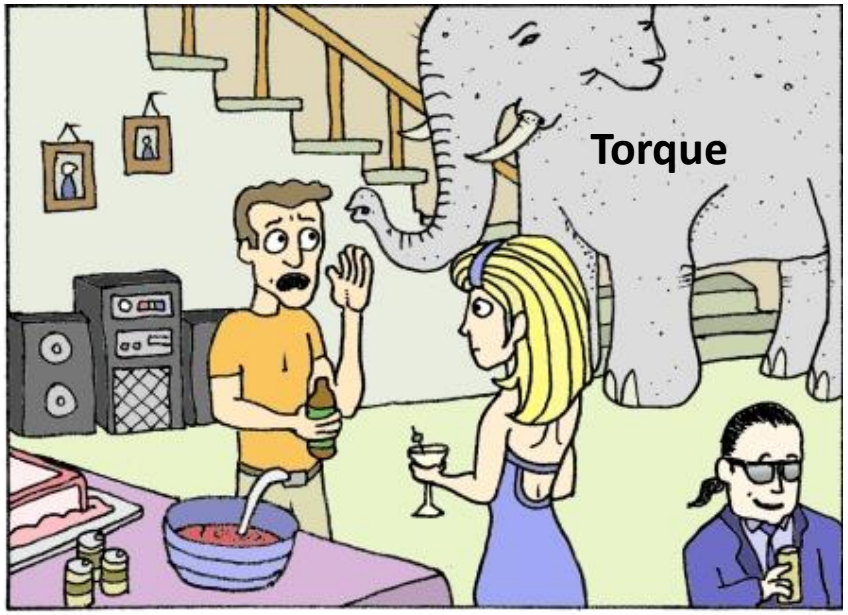
- Increasing trends may indicate a problem
  - Lateral Vibration
  - Balling
  - Bit Damage / Dulling
- Experimenting from one well to another reveals improvements
  - Better designs result in lower and/or more consistent MSE



The Problem with Surface Torque

- Torque is the most dangerous variable in the MSE equation
  - Need to know torque near bit (not at surface)
  - Surface torque is mostly due to drill string friction in ER wells





"Yeah, I see him too...But nobody wants to talk about it!"

Drill String Generated Torque

- Torque = $N \times \mu \times R_{eff}$

- Normal Force (N) can be generated in 4 ways
  1. "Low Side" – Gravity pulling pipe to the low side of the hole
  2. "Brake Drum" – Tension across a dogleg forces pipe into the side of the hole
  3. Buckling – Forces the pipe into the sides of the hole as compression increases
  4. Lateral Vibration

- Mechanisms 1-3 can be easily predicted/modeled
- Mechanism 4 can be inferred

Which torque to use?

Method	Pros	Cons
On Bottom Torque	Easy	Wrong. Leads to over-estimated MSE and apparent dulling trend. Can't compare MSE for wells with different trajectories
On Bottom – Off Bottom	Fairly Easy	Wrong, may lead to over *or* under estimation of MSE. Can't compare MSE for wells with different trajectories
Motor ΔP	Fairly easy.	Need a motor in the hole. Actual performance vs. handbook varies and degrades with time.
Down hole WOB/Torque	Can be accurate and close to the bit.	Measurements can drift if not frequently calibrated. By itself, can not differentiate between bit dysfunction and lower BHA dysfunction.
Calculate using T&D Engine	Accurate (if surface measurements are good). Can compare wells of different trajectories. Can reveal certain phenomenon* when combined with other methods	Complicated. Need special procedures, software, and resources.

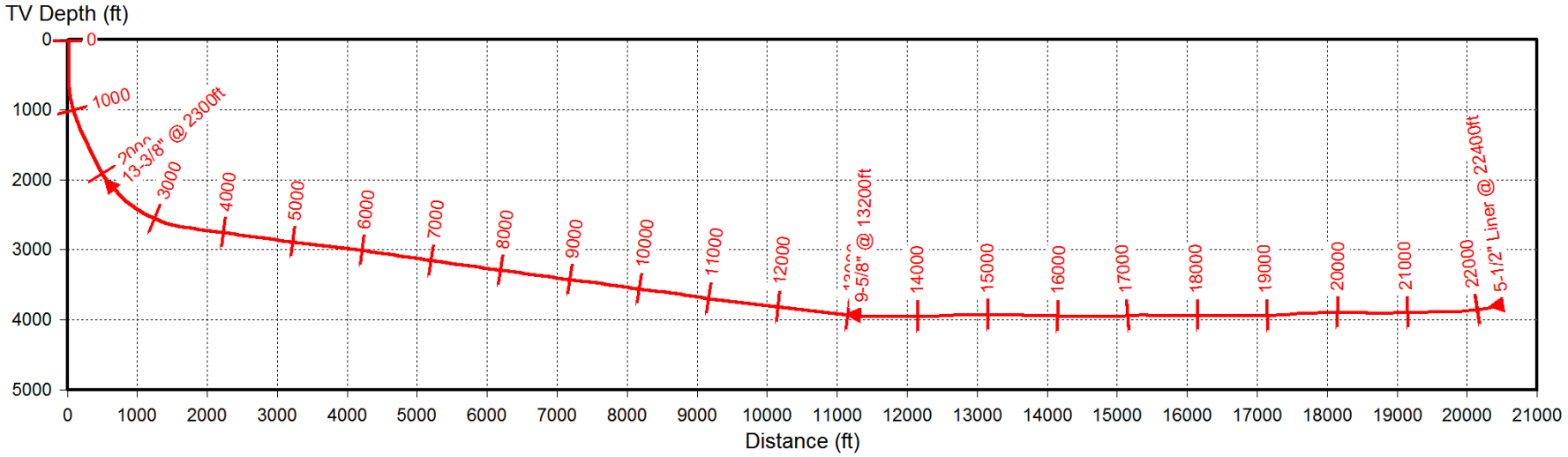
* For example, when used with ΔP can identify bit balling. When used with DWOB/DTOR placed below an under reamer can differentiate between bit/reamer dysfunction

How to Infer Bit Torque

1. Record off bottom torque each stand at drilling
2. Back-calculate the TQFF using T&D Model
3. Calculate the string-generated torque at each data point;
   - Actual surveys
   - Current WOB
   - Most recent TQFF
4. "Down hole" torque is the difference between surface torque and string-generated torque

* Can verify with DWOB/DTOR sensors or motor ΔP

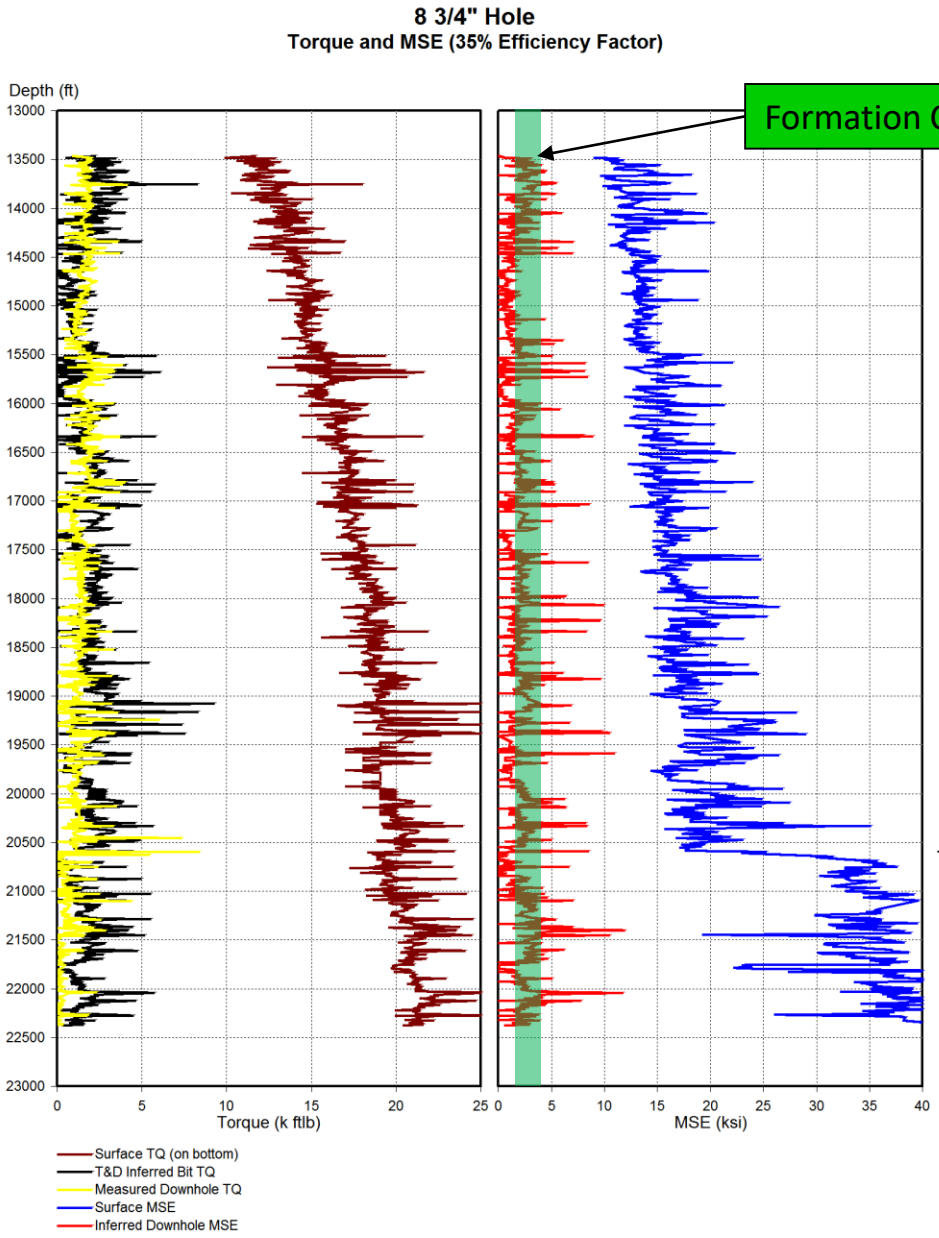
Concept Validation



Consider this ER well

- Very long (>22,000') and shallow (<4,000')
- Tapered 5"x4½" drill string
- Highly variable WOB, Torque, RPM, ROP
- T&D engine used to normalize string generated torque and attempt to estimated bit torque

Concept Validation



<u>Conventional Interpretation:</u>

- MSE is increasing, bit may be dulling
- Shift at 20,500' – Whirl?

<u>"Inferred Downhole Torque" Interpretation:</u>

- MSE and torque are fairly constant
- MSE is similar to CCS
- Everything is normal

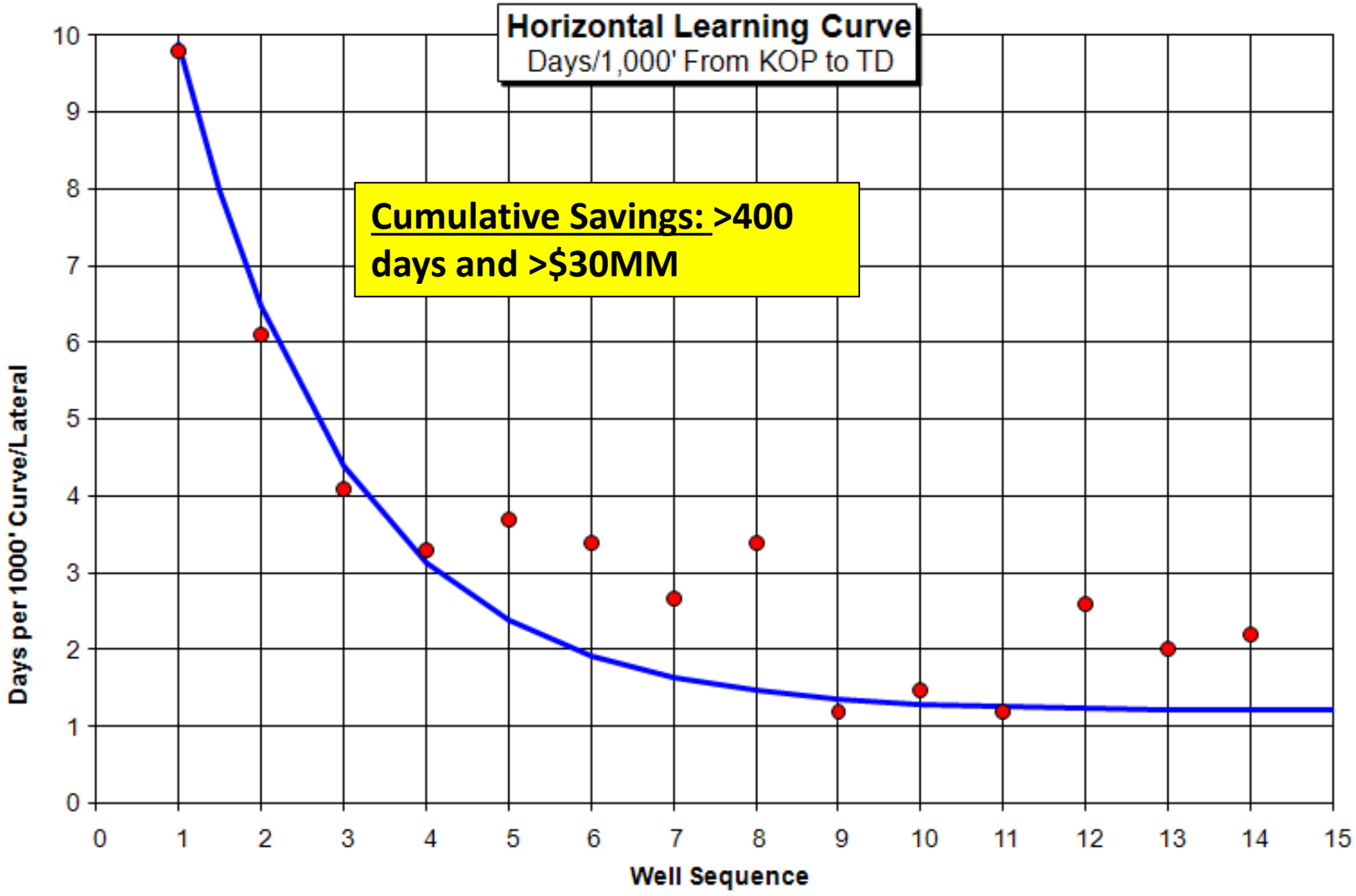
Down hole measurements agree with calculated torque

- Reduce ROP from 300-150 ft/hr (for logging)

Summary

1. MSE is a great tool when used properly
2. Directional wells skew MSE results / interpretation
3. Modeling should be used to remove string torque
4. Combining inferred down hole MSE from different sources can reveal interesting phenomenon

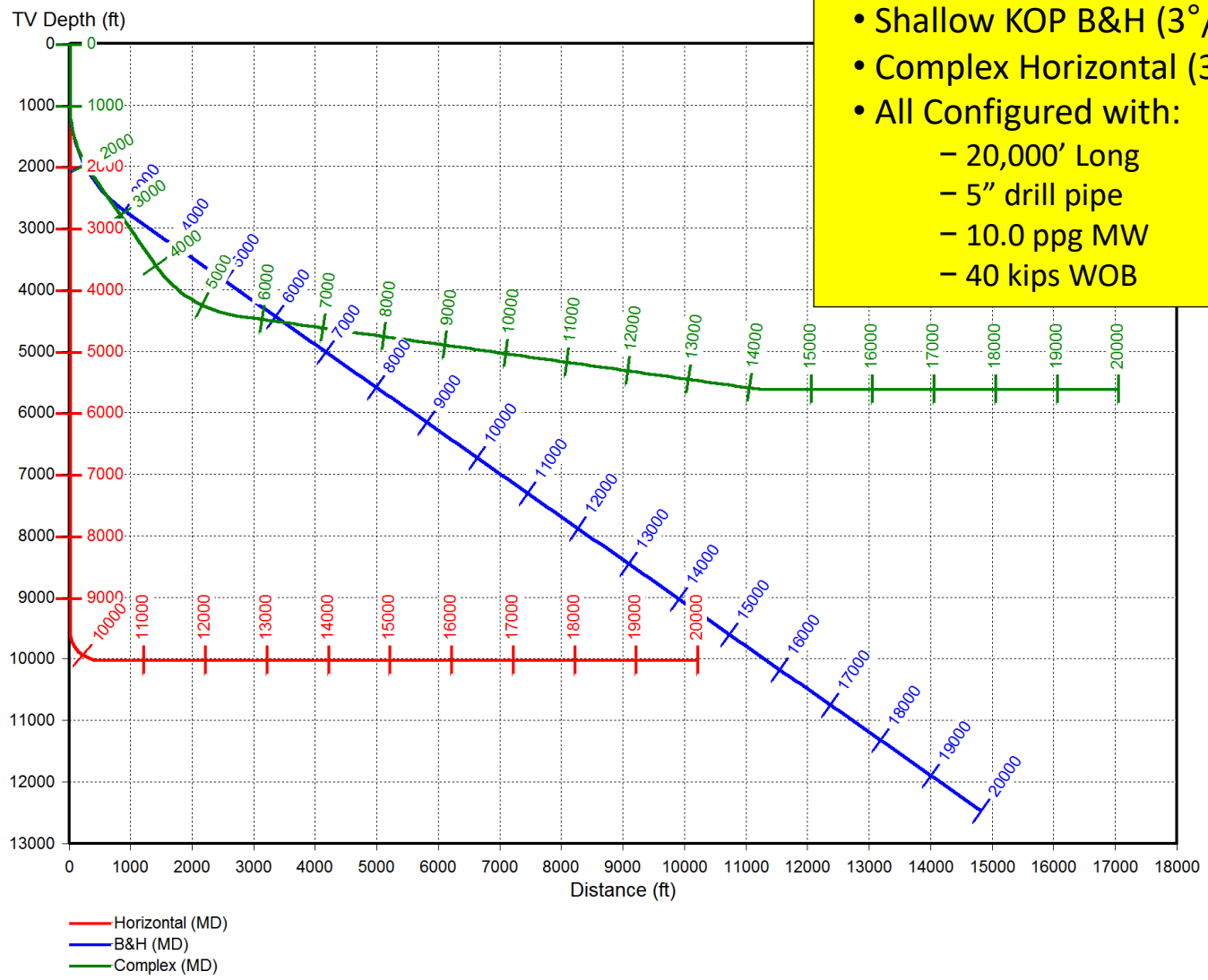
Backup Slides


Horizontal Learning Curve
Days/1,000' From KOP to TD
Cumulative Savings: >400 days and >$30MM
Days per 1000' Curve/Lateral
Well Sequence
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

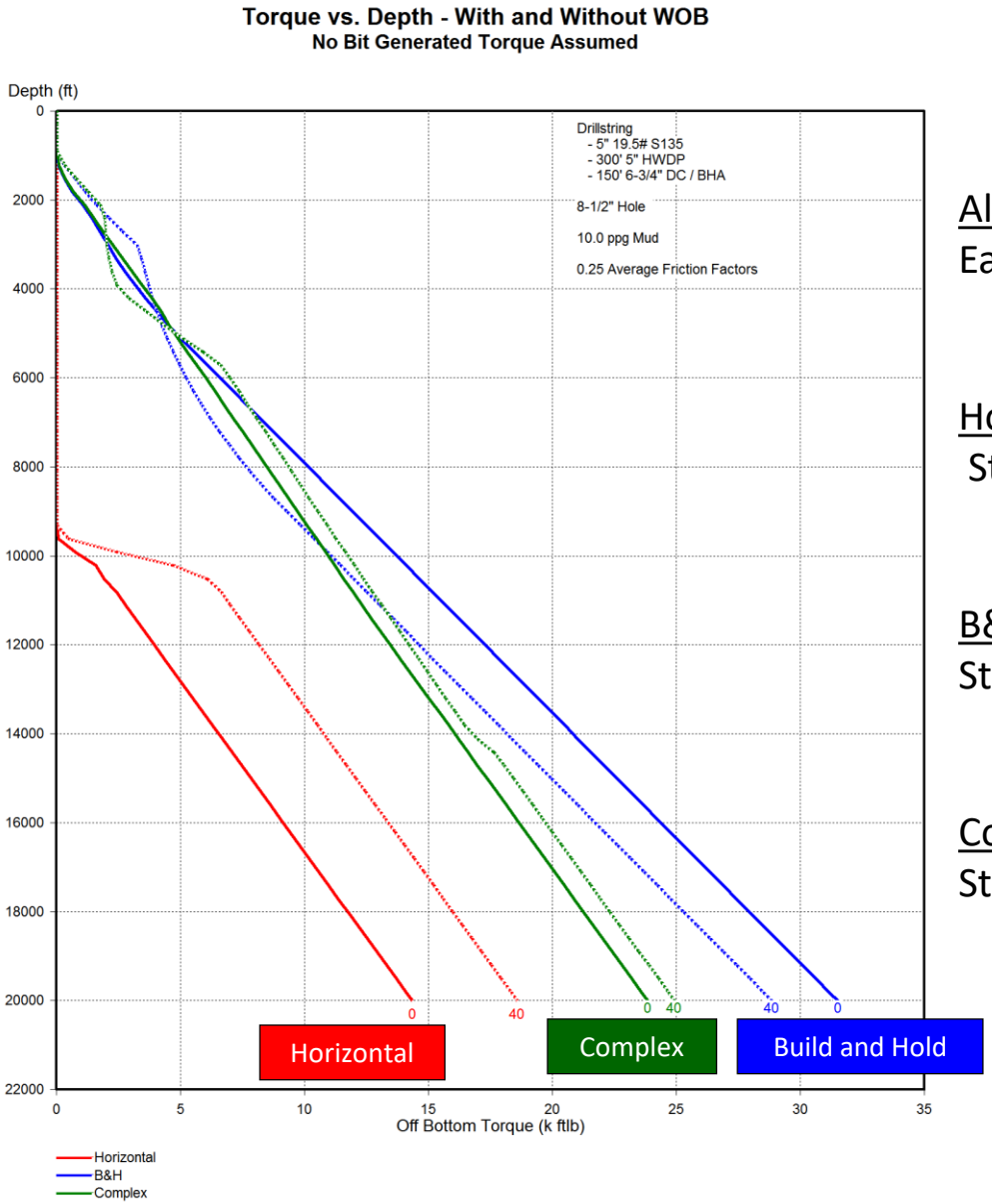
Wellpath Effects

Consider These 3 Wells:

- Deep KOP Horizontal (12°/100’ BUR)
- Shallow KOP B&H (3°/100’
- Complex Horizontal (3°/100’ BUR’s)
- All Configured with:
  - 20,000’ Long
  - 5” drill pipe
  - 10.0 ppg MW
  - 40 kips WOB



Wellpath Effects



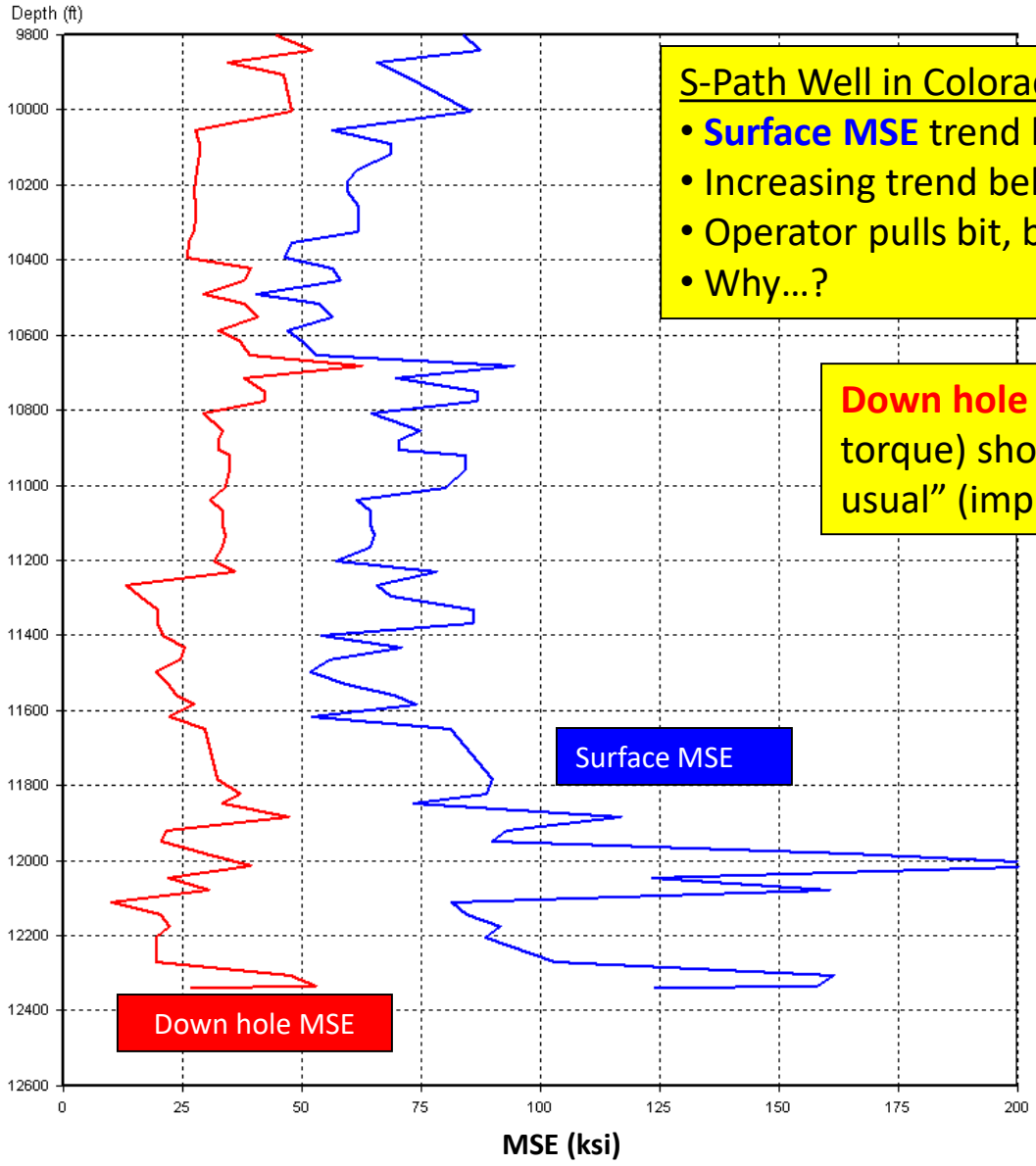
All wells with 0 WOB:
Each has a different off-bottom torque trend

Horizontal well with 40 kips WOB
String torque is 4 k ft-lbs (28%) higher

B&H well with 40 kips WOB
String torque is 3 k ft-lbs (10%) lower

Complex well with 40 kips WOB
String torque is 1 k ft-lbs (4%) higher

Wellpath Effects



S-Path Well in Colorado

- **Surface MSE** trend had been fairly constant to 11,600' MD
- Increasing trend below 11,600' suggests dulling trend
- Operator pulls bit, but is "green" at surface
- Why…?

Down hole MSE trend (accounting for string torque) shows everything was "business as usual" (improving, if anything).