

Overcoming Challenges for Drilling High-Dogleg-Severity Curves

AADE Luncheon

March 22, 2011

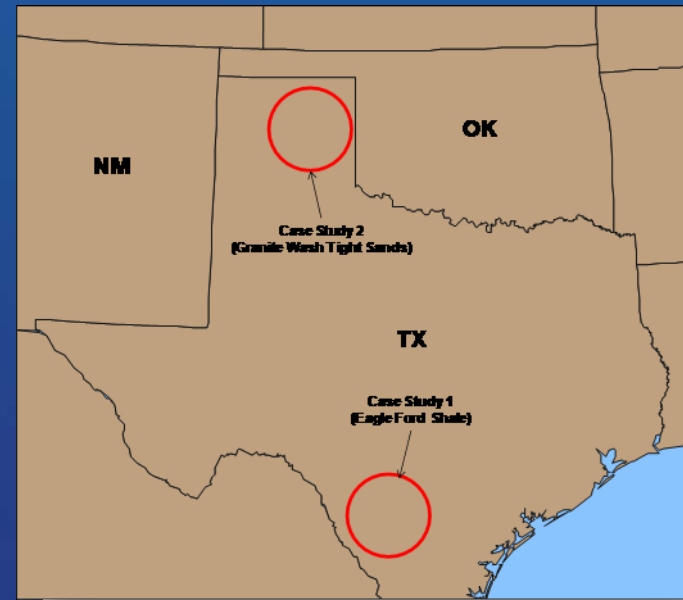
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Content

- Challenges of current drilling systems in unconventional oil & gas applications
- Technology solution:
 - High-build rate Rotary Steerable System
 - Background and principles
- Case Study – Eagle Ford Shale
- Case Study – Granite Wash Tight Sands
- Conclusion and Outlook

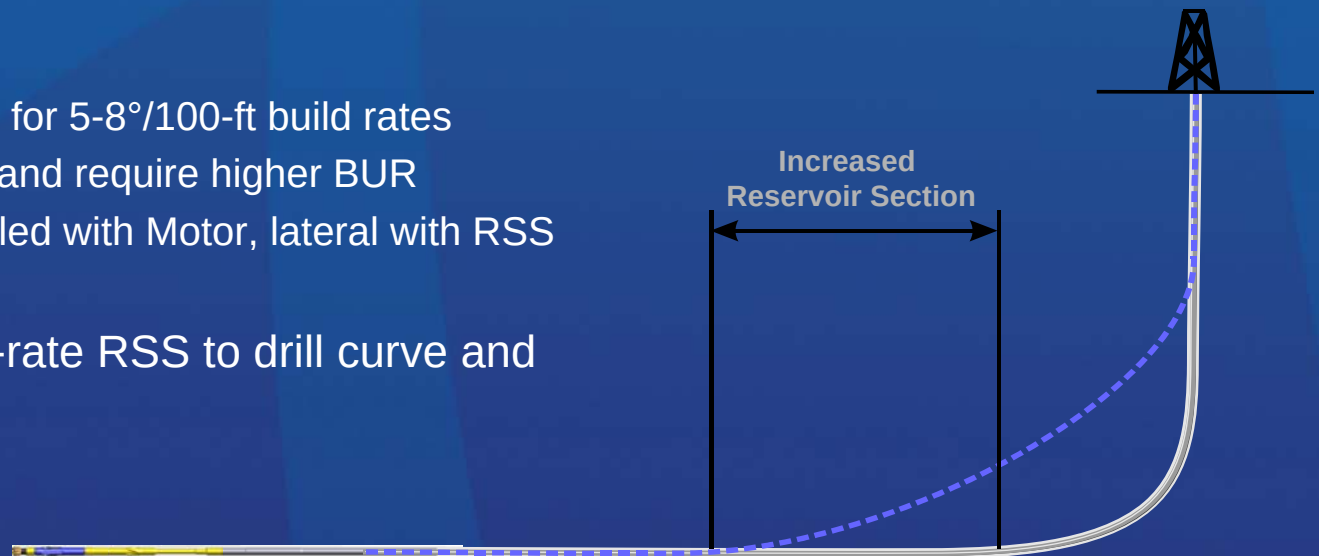
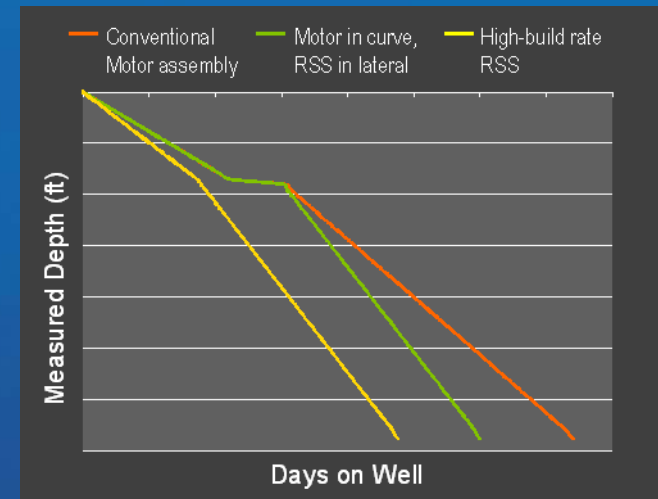


Unconventional Hydrocarbon Challenges

- Typical unconventional hydrocarbon drilling applications:
 - 10-14°/100-ft dogleg severity curve and long horizontal section
 - Drilling predominantly with steerable motor systems
- Common Challenges:
 - Toolface Control with high-performance drill bits
 - Low ROP while sliding/ steering
 - BHA trips between curve and lateral (change of motor settings)
 - Tortuous wells complicate completions
- Rotary Steerable Systems promise improvements
 - Current systems not fully fit-for purpose

Addressing Drilling Challenges with RSS

- Benefits of rotary steerable drilling proven in complex well profiles and long lateral sections:
 - Better drilling performance and lower risk with constant drill string rotation
 - Easy steering control via surface command
 - Better wellbore placement and horizontal reach
 - Improved wellbore geometry facilitates completions and production
- Constraints:
 - Commercial RSS for 5-8°/100-ft build rates
 - Small leases on land require higher BUR
 - Today: Curve drilled with Motor, lateral with RSS
- Need for high build-rate RSS to drill curve and lateral in one run



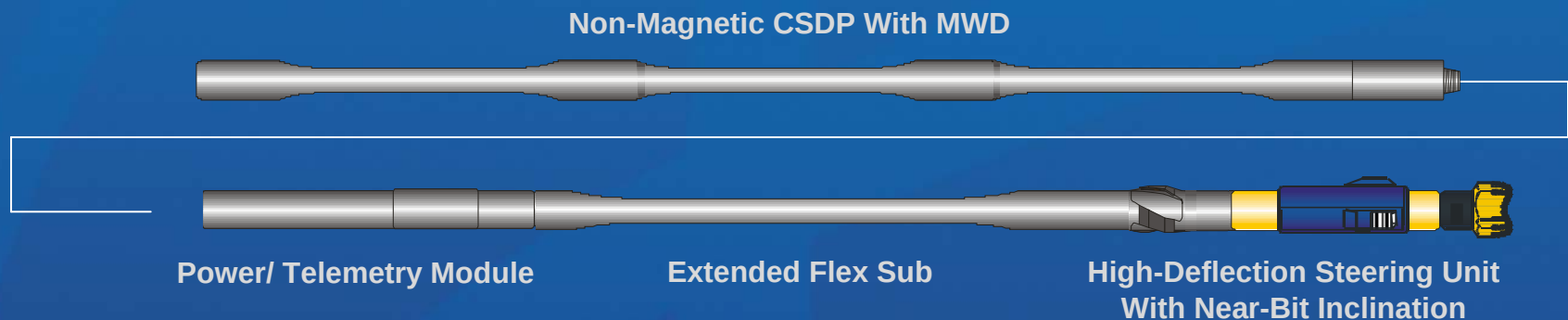
The Technology Concept

- High build-rate RSS technology requirements:
 - Increase bit deflection and BHA flexibility
 - No compromise of reliability and performance rating
 - Conserve good steering control and good hole quality
- Solution Principles:
 - Highly reliable rib-steering system with modified geometry
 - Actuators decoupled from string rotation
 - Dedicated drill bit design
 - Increased flex section in BHA



High-Build Rate RSS Components

- Bottomhole Assembly:



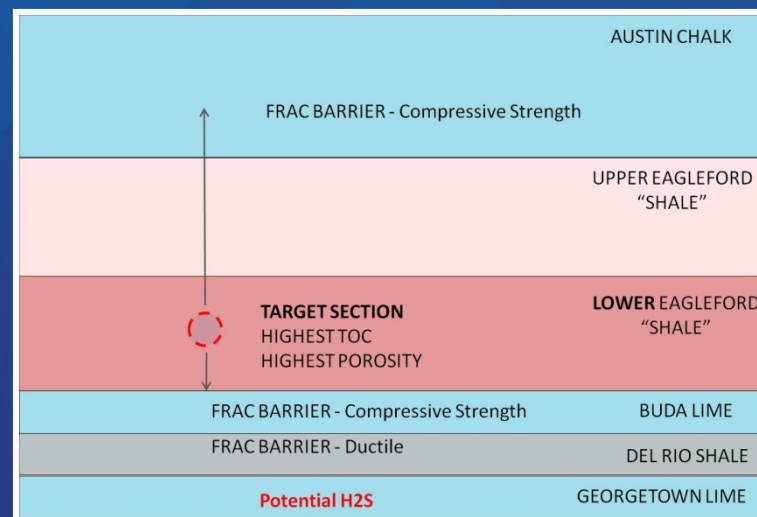
- Specific PDC Drill Bit:
 - Engineered gage geometry and side-cutting properties
 - Depth-of cut control features
 - Balance of aggressiveness and stability
 - High drilling performance and good hole quality

Case Study I – Eagle Ford Shale

- Challenges

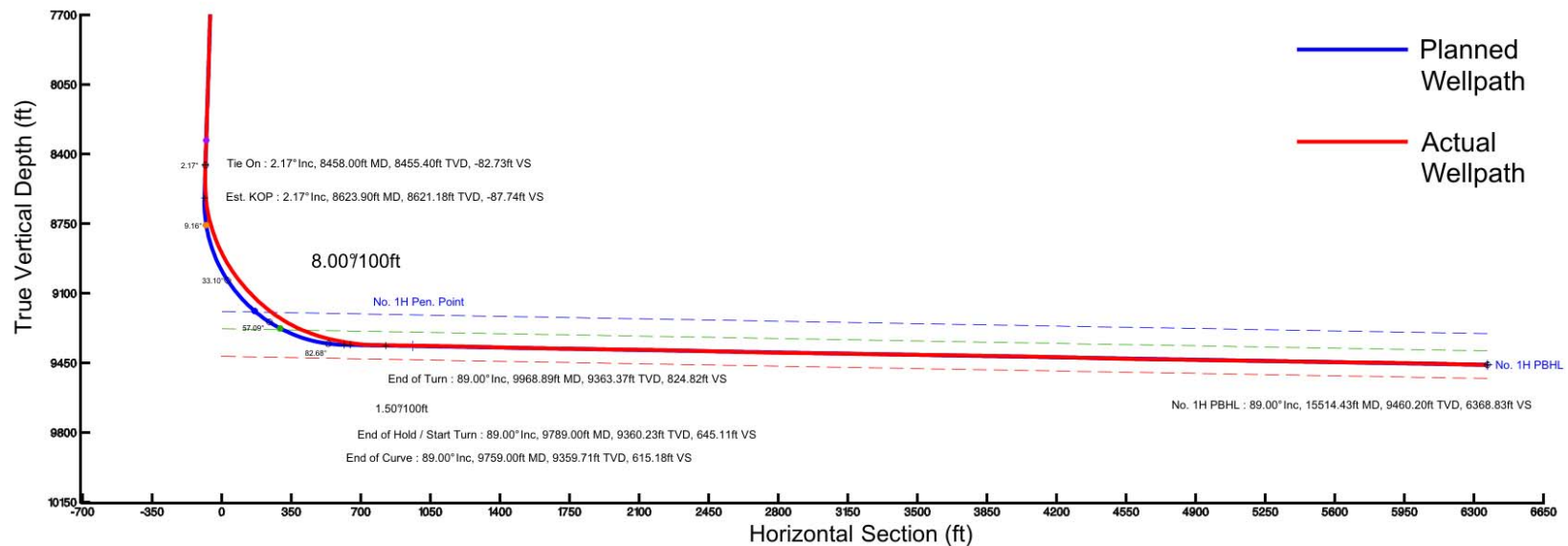
- Inconsistent BUR in curve interval
- Low ROP's in Slide
- PDC Bit Vibrations, High Stick-Slip, High Torque
- Staying in Zone while Drilling Lateral
- Hole Cleaning, Balling
- Wellbore Stability, Pack Offs, Stuck

ERA	FORMATION	LITH
TERTIARY	Reklaw	SHALE
	Wilcox	SAND
	Midway	SHALE
	Escondido	SAND
	Olmos	SAND
	San Miguel	SAND
	Anacacho	LIME
		CHALK
		SHALE
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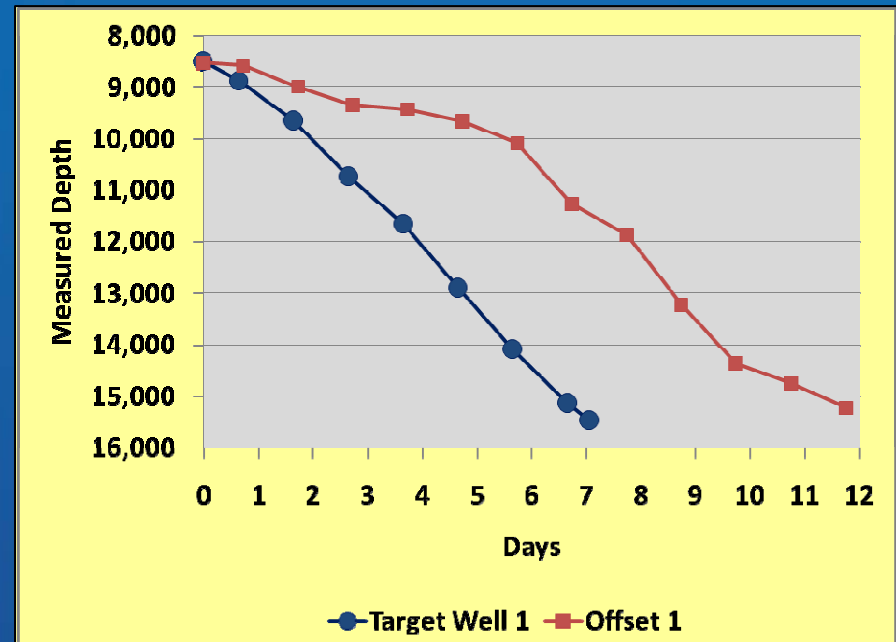
Eagle Ford Well #1 – Well Profile

- High-Build rate RSS, Well #1:
 - Kick-off at 8,500-ft MD
 - Build curve at 8°/100-ft
 - Left turn at 1.5°/100-ft turn rate
 - Target Inclination 89°, 6.370-ft lateral section
- Offset Well benchmark:
 - Steerable motor assembly in curve and part of lateral
 - Motor-powered standard RSS in majority of the lateral



Eagle Ford Well #1 – High-Build Rate RSS Results

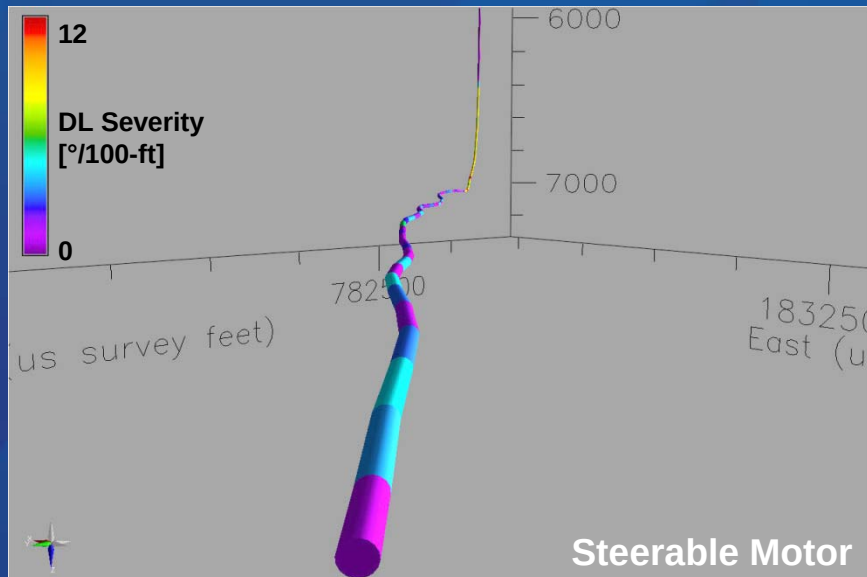
- Drilled 6,970 ft from kick-off to TD in single run
- Consistently met 8°/100-ft DLS requirement
- Saved 4.7 drilling days (40%) vs. offset
- Superior hole quality



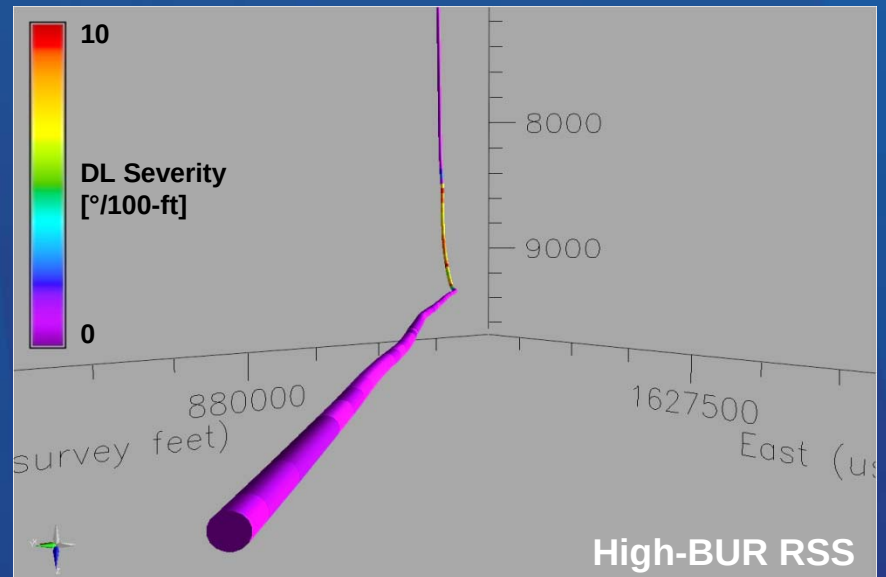
MD	Inc.	Azi	TVD	Vert Sect	DLS
[ft]	[°]	[°]	[ft]	[ft]	[°/100ft]
8647	6.2	199	8644.09	-78.24	8.13
8679	10	199.4	8675.76	-73.97	11.88
8711	12.7	196	8707.13	-67.94	8.69
8743	15	191.1	8738.2	-60.48	8.06
8775	17.2	186.2	8768.95	-51.7	8.07

Eagle Ford Well #1 – Borehole Quality

- Offset wells (steerable motor systems):
 - High tortuosity - high friction
 - Lubricant required to drill out plugs after fracturing
 - Additional completion cost

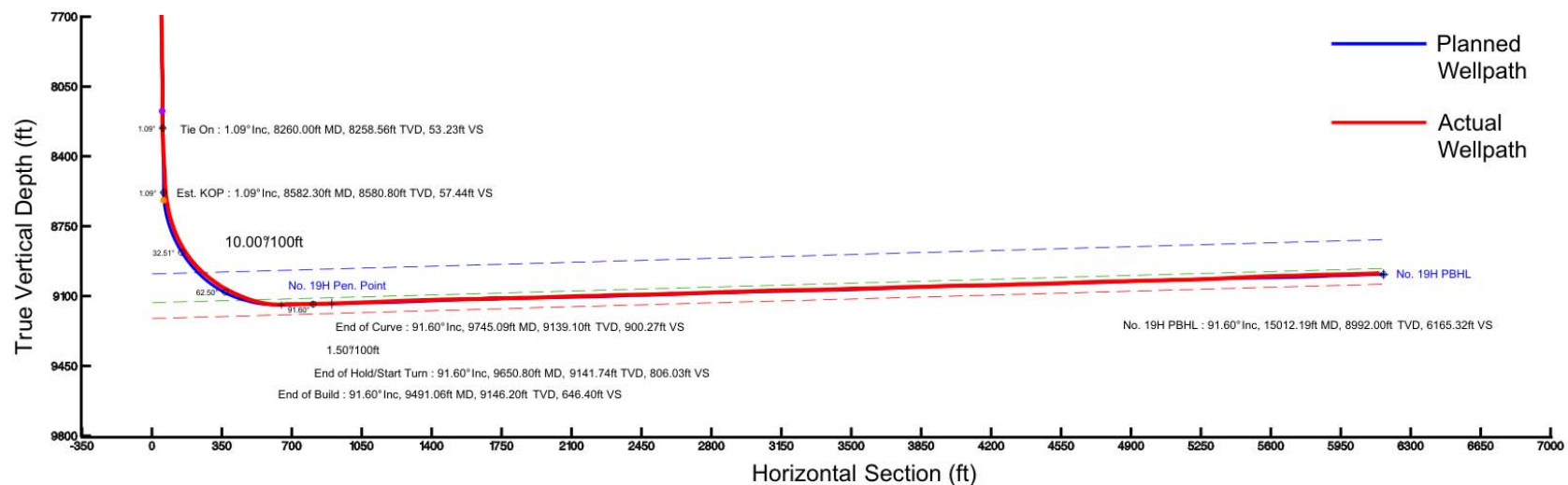


- High build-rate RSS well :
 - Smooth profile
 - No need for additional lubricant
 - Reduced time to drill out plugs
 - Significant reduction in completion cost



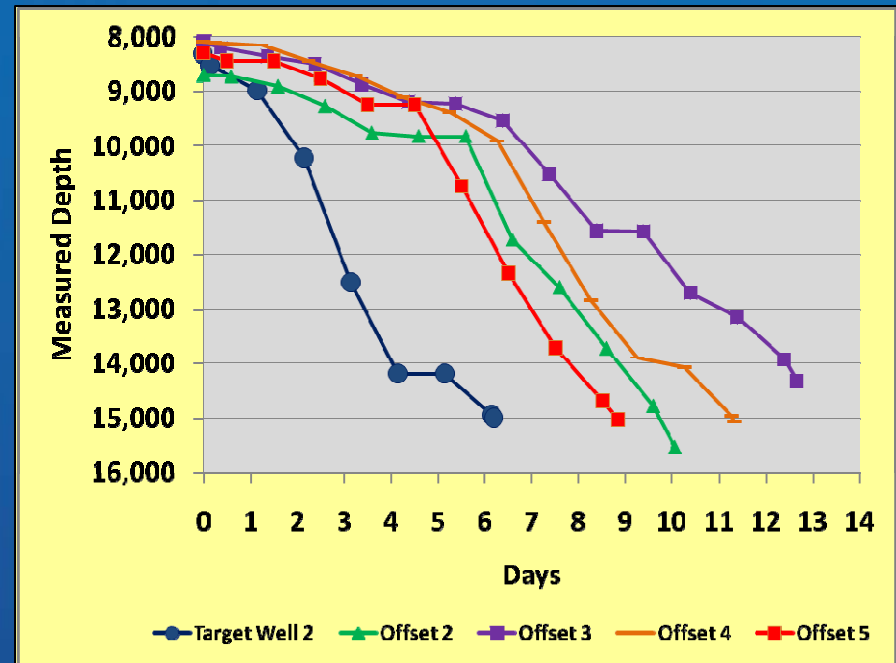
Eagle Ford Well #2 – Well Profile

- High-Build rate RSS, Well #2:
 - Kick-off at 8,582' MD
 - Combined build & left turn in curve section
 - Build rate $10^{\circ}/100'$, turn rate $1.5^{\circ}/100'$
 - Target Inclination 91.6° , 5,500-ft lateral section
- 4 Offset wells :
 - Steerable motor assemblies in all curve sections
 - Standard RSS with and without motor addition in laterals



Eagle Ford Well #2 – High-Build Rate RSS Results

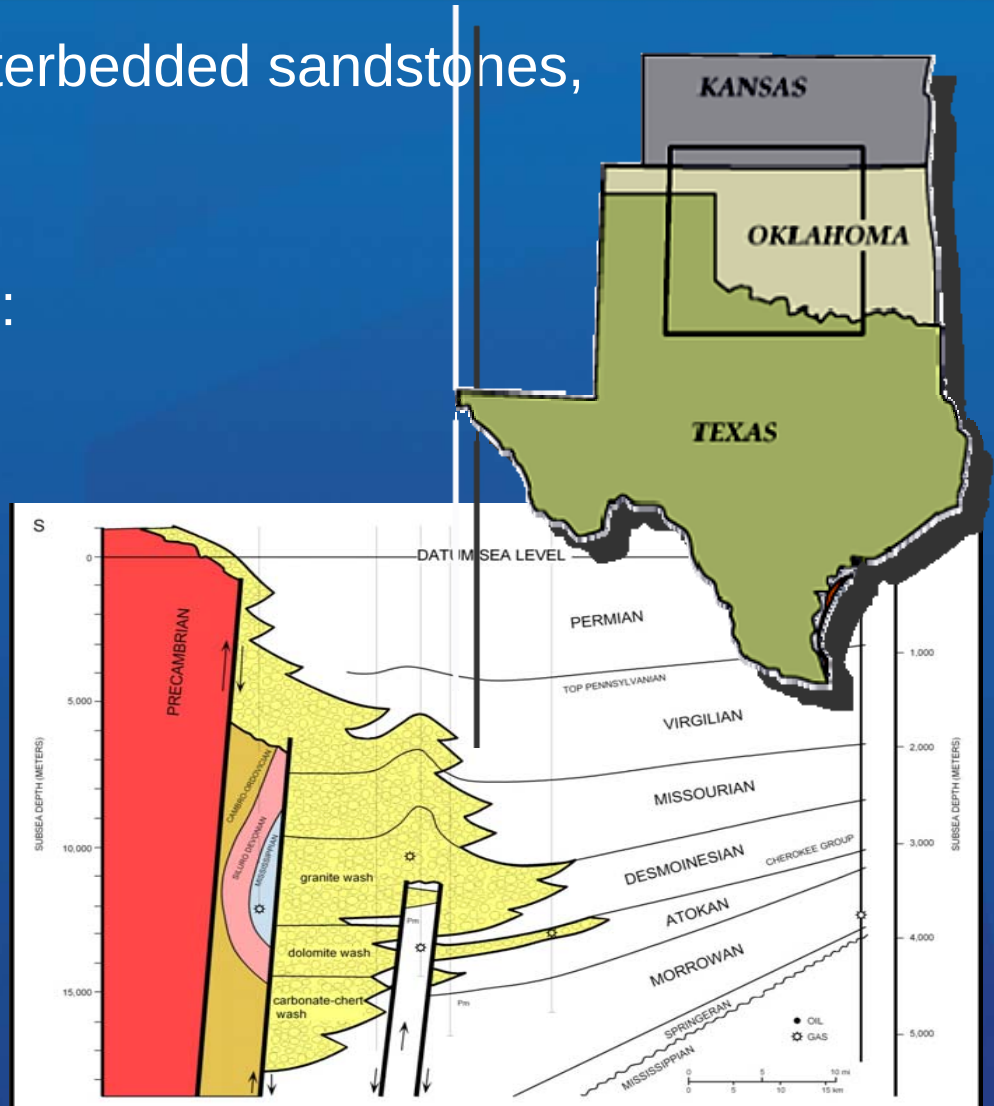
- Drilled Curve and lateral to 14,187-ft MD
- Well profile drilled to plan
- Met/ Exceeded required 10°/100-ft DLS
- Saved 2.64 days (25%) vs. best offset well, despite one trip



MD	Inc.	Azi	TVD	Vert Sect	DLS
[ft]	[°]	[°]	[ft]	[ft]	[°/100ft]
9236	65.10	313.00	9092.85	419.53	9.68
9267	68.20	312.80	9105.13	447.99	10.02
9299	71.60	312.40	9116.13	478.03	10.69
9331	75.00	312.30	9125.32	508.67	10.63
9362	79.30	311.80	9132.22	538.89	13.96
9394	83.00	311.30	9137.14	570.50	11.67
9426	85.90	311.20	9140.23	602.35	9.07

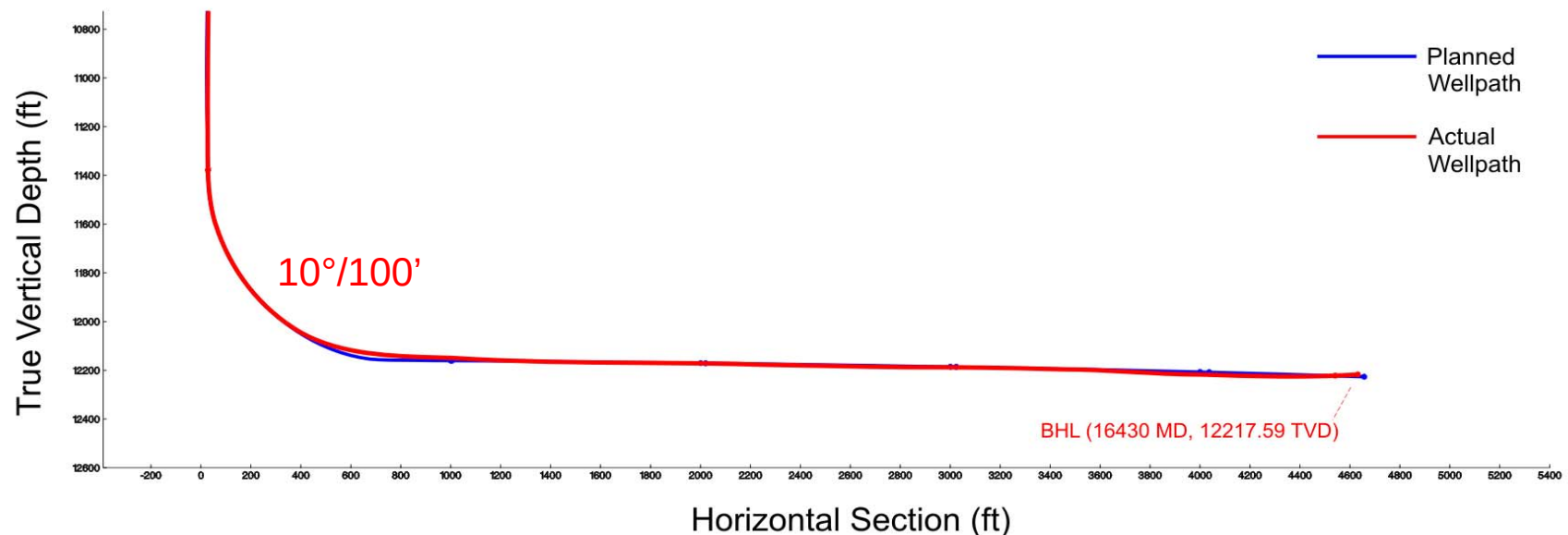
Case Study 2 – Granite Wash Tight Sands

- Challenging sequence of interbedded sandstones, silts, and shales
- Steerable Motor experience:
 - High bend settings to achieve BUR
 - Difficult toolface control
 - Limited rotary RPM
 - Unacceptable ROP
- Conventional RSS:
 - BUR limited to $\sim 4^\circ/100\text{-ft}$
 - Inconsistent directional performance



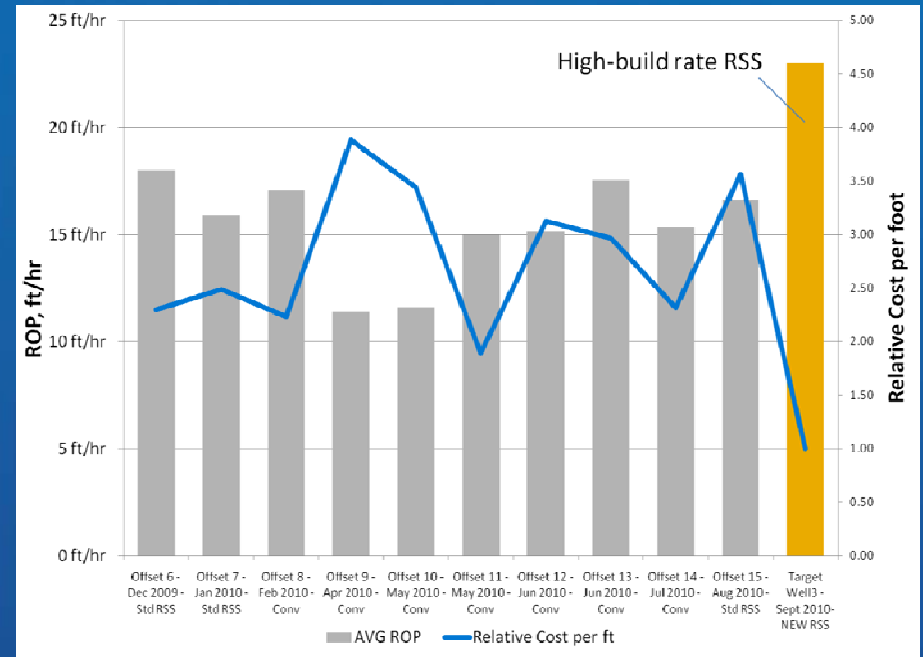
Granite Wash – Well Profile

- Drill curve and lateral with PDC bit
- Improve penetration rates
- Land curve at 89.4°, 12,158-ft TVD
- Build rate: 10°/100-ft
- 3,926-ft lateral section



Granite Wash – HBUR RSS results

- Drilled curve and part of lateral until bit trip
- Met 10°/100-ft BUR requirement
- Drilled precisely to well plan
- 28% ROP improvement vs. best offset (from 18 to 23-ft/hr)
- 47% cost per foot improvement vs. best offset



MD	Inc.	Azi.	TVD	Vert Sect	DLS
[ft]	[°]	[°]	[ft]	[ft]	[°/100ft]
11505	8.2	192.5	11503.54	35.73	10.27
11536	11.4	191.8	11534.09	40.88	10.33
11568	14.5	190.8	11565.27	47.9	9.71
11599	17.3	190	11595.08	56.23	9.06

Conclusion and Outlook

- Successful collaboration between operators and service provider to address drilling challenges
- High-Build rate RSS concept proven:
 - Dedicated component, BHA and drill-bit design
 - Consistent BUR >8-10°/100-ft
 - Curve and lateral drilled with one BHA
 - Improved drilling performance
 - Precise Steering per well plan

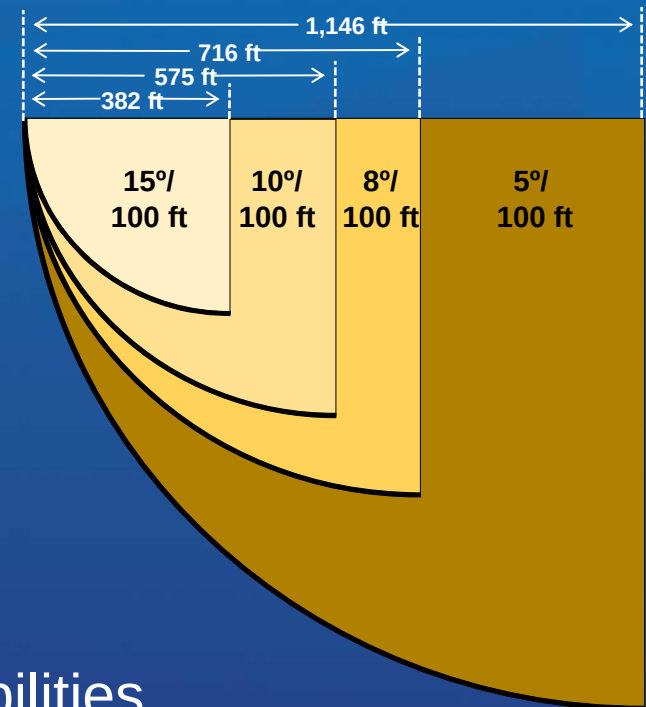
Conclusion and Outlook

- Straight tangents and smooth curves reduce completion time and cost:

- Trouble-free casing runs
- Optimized plug & perf process

- Outlook:

- Further expand RSS build-rate capabilities
- Optimize BHA and application-specific drill bit for further drilling performance increase



Thank You!

Questions?