Navigating the Bumps in the Road: The Trade-offs in Drilling the “Perfect Horizontal Well”™

Instructor

KC Oren – Horizontal Solutions International – VP, Sales and Marketing – Northern US

Lecture Agenda – Morning Session – 8:00am to 12:00pm

Introduction of Presenters – 5 minutes

Review Course Agenda – 5 minutes

Acknowledgement of Contributors – 5 minutes

Part I – Overview of the Trade-Offs – 90 minutes (8:15am – 9:45am)

Some companies are better than others in drilling horizontal wells – why?

- Company drivers
  - Find, develop, produce
  - Find, prove, sell
  - Buy, produce
  - Public vs. private
- Departmental goals – geosciences, drilling, production
  - Drivers
  - Incentives
  - Department v. entire asset team
- Individual drivers – geologist, geophysicist, petrophysicist, drilling engineer, production engineer, company management, others
  - Personas/personal motivation
  - Incentives – individual v. departmental v. asset team v. corporate
  - Is your service company totally aligned – yes or no?

The Great Train Wreck – an example of what can go wrong when the team is not pulling together

- An “Agony of Defeat” case study – quickly tell the GTW story all the way through
- Replay the GTW highlighting of key elements to be reviewed in greater detail (to be covered later in Part II)
  - Key factors
    - Well control
    - High-DLS BHAs
    - Understanding uncertainty (when landing a horizontal well and in general)
    - Introducing TSP (true stratigraphic position) modeling
    - Personas and communications
Navigating the Bumps in the Road: The Trade-offs in Drilling the “Perfect Horizontal Well”™

Break – 15 minutes

Part II – Identifying and Understanding the Trade-Offs – 90 minutes (10:00am – 11:30am)

Consider the benefits of working as a team – how to avoid the “Agony of Defeat”?

- Working towards a common end-goal using a unified team approach
  - Who, when, where and why?
  - Nomenclature and key elements across the team
  - Learn about and get to know the drilling world

Detailed review a few of key factors that influencing the “perfect” horizontal well

- “Well control” challenges
  - What is well control? (be careful: a different thing in the drilling operations world)
  - Pilot hole or no pilot hole – *that is the $1MM question?*
  - Good … or Great when it comes to “science” data
  - Seismic data or offset well information
  - the “plan” vs. reality (Murphy’s Law)
  - Introducing DWOP

- Planning a Horizontal Well
  - Basic 2D well profile
    - Key elements of a well plan
    - Up-dip or down-dip? … that is the question!
  - Alternatives including 3D designs
    - Well avoidance/Anti-collision considerations
    - Nudged for offset wells/pad drilling
    - Fish hook design
    - Formation strike and wellbore orientation

- Drilling the Well using High-Dog Leg Severity (DLS) BHAs
  - Defining Dog Leg and DLS
  - What are the components of a Bottom Hole Assembly (BHA)
  - Design and tendencies of HDLS BHAs
  - BHA response to formation heterogeneity
  - BHA selection for the curve
  - BHA’s in the lateral

- Understanding wellbore position uncertainty (when landing a horizontal well and in general)
  - Survey measurement best practices and (in)accuracies of various MWD systems
  - Survey calculation methods
    - Review of several common methods
    - Impact of course length interval
    - Testing the models: working through an example
Navigating the Bumps in the Road: The Trade-offs in Drilling the “Perfect Horizontal Well”™

- Understanding wellbore position uncertainty (continued)
  - Reviewing the importance of using the right model for a given situation
  - Precise wellbore positioning and the “Ellipse of Uncertainty”
    - systematic error
    - random error
    - quantifying magnitude of error

Part III – Geo-navigation, Geosteering and Effective Communication – 30 minutes (11:30am – noon)

Uncertainty Mitigation – managing the inevitable

- Beating “Murphy”
  - Horizontal well programming ... that plans for the unexpected
  - Every well must begin with DWOP – Drilling the Well on Paper ... FIRST!
  - Understanding the geo-prognosis for smart contingency planning
  - Pre-spud meetings – critical first step in execution of the plan

- Introducing active TSP (true stratigraphic position) modeling
  - Trumps all other methods
    - TSP modeling overcomes all noted errors for timely, accurate decision support
    - What does your targeted interval warrant for monitoring
    - Time is of the essence
    - Informed, timely decision support
  - Geo-navigation vs. Geosteering
    - Wellbore position – geologically vs. 3D space (in your subsurface model)
    - Proactive vs. Reactive – what difference does it make
    - Updating your geo-model – when ... and will it really matter?
  - Re-Introduce George Gunn for Part IV session (TSP modeling “deep dive”)

- Horizontal well targeting
  - Updating the plan (i.e. the target line)
    - Does it really matter?
    - The trade-offs in defining a new target
      - Porpoisuosity
      - Lateral extent
      - Drilling problems
        - Torque and drag
        - Fatigue
        - Hole cleaning
      - Completions and the life-time well performance
Navigating the Bumps in the Road: The Trade-offs in Drilling the “Perfect Horizontal Well”™

- Horizontal well targeting (continued)
  - Targeting best practices
    - Follow the plan – *which plan?*
    - “3D Point in space” targeting
    - Targeting best practice
      - Vector based targeting
      - VS₀/TVD @ inclination approach
      - Landing a well – using an airplane landing video to illustrate

**Introduce lunch-time assignment** – 10 minutes

- Questions to ponder during lunch hour
  - Vocabulary review using a horizontal well plan graphic
  - Survey calculation methods – when to use which
  - Systematic versus Random error and explain sources (and mitigation) of each

**Lunch** – 12:10 to 1:10pm

- Buffet Lunch and opportunity to meet classmates and network, and to discuss lunch-time assignments and morning’s lessons
Lecture Agenda – Afternoon Session – 1:10pm to 5:00pm

Morning Session recap – 15 to 20 minutes

- Review assignment
- Q&A discussions from morning session

PM Kick-Off: Re-introduce presenter(s) and review afternoon course agenda – 10 minutes

Part IV - Geosteering Horizontal Wells – 75 minutes (1:30pm – 2:45pm)

Making a case for geosteering - The questions, the goals and the benefits

- Time out! First, a reality check – questions you should be asking yourself?
  - What can be learned from a horizontal wellbore about the geology in an area that we don’t already know from vertical wells and seismic data?
  - How will geosteering a horizontal wellbore save drilling dollars?
  - Are there “sweet spots” we should be targeting?
  - How can geosteering horizontal wellbores improve the performance of the next wells?
  - How do we use the geologic interpretation of data from a horizontal well to improve our completions?

The goals of geosteering

- Increase exposure of wellbore to the pay zone
- Minimize slide times and reduce doglegs
- Learn as much as possible about your geology
- Optimize:
  - Human Resources
  - Time and Money
  - Knowledge
  - Production

The benefits of Geosteering

- More than simply staying in zone: it’s about understanding the geology
- TSP Modeling shows you all the warts:
  - Details that can be seen in no other way
  - Small faults, anomalous dips, stratigraphic variations
- Every area has its own unique characteristics that can be planned for ... if they are known
Navigating the Bumps in the Road: The Trade-offs in Drilling the “Perfect Horizontal Well”™

- Identifying karsted and faulted areas
- The only way to identify “sweet spots” is to know which section each well drilled
Navigating the Bumps in the Road: The Trade-offs in Drilling the “Perfect Horizontal Well”™

Focus on Stratigraphy – TSP modeling

- What exactly is True Stratigraphic Position (TSP) modeling
  - Relating TSP in a 2D graphical domain
  - Translating stratigraphic datum in a log correlation perspective/view
  - Type curve(s) vs. the active MWD data curve(s)
  - Defining apparent formation dip and TSP
- The four keys needed to navigate a well successfully
  1. Measured subsurface position of the drilling assembly
  2. Formation dip
  3. Fault identification
  4. Stratigraphic position of the bit

The elements for good geosteering decision support

- Log correlation is the most fundamental skill of the geologist
- Correlation is the only way to determine stratigraphic position
- Correlation must be performed in a stratigraphic setting
- Successfully applying the four keys support timely, more accurate geosteering decisions

Case Studies – detailed review of several examples

- **Woodford Example** – complex structure
  - “Believe in average dip from your well control, but ....”
- **Marcellus Shale Example #1**
  - “Don’t be trapped by preconceptions ....”
- **Montney Formation Example**
  - “Do not over-react ....”
- **Barnett Shale Example**
  - “Leverage all of your data whenever possible ...”
- **Marcellus Shale Example #2**
  - “Follow the data ... don’t force it! And ... expect to be surprised.”

Break – 15 minutes
Part V - Geosteering Horizontal Wells (continued) – 45 minutes (3:00pm – 3:45pm)

Basic Geosteering Principles

• Do not over react
• Believe average dip BUT don’t expect to see it!
• Do not be trapped by preconceptions
• Use all of your data whenever possible
• Drill to a target line NOT to a point in space (referencing earlier discussion in the morning)

Recommended Best Practices for geosteering

• Establish your own geosteering best practices
  o Efficiency and consistency
  o Standard software & workflows
  o Streamlined training
  o Consistent analysis and evaluations
• Continuing improvement
  o Improve geosteering decisions
  o Save money
  o Improve performance and return on investment
  o Assure safety

Communications

• Personas
• Departmental incentives
• Company drivers
• Include service company personnel

How to be successful – starts with the TEAM

• Experienced senior geologists first
• Real time personnel – 24/7 surveillance and support
• Streamlined integrated communication standards
  o Senior geologists
  o Real-time personnel
  o Customer operations staff
  o Directional drilling team
  o Other service company contractors as needed
• Collaborative geosteering software (a key enabler)
Navigating the Bumps in the Road: The Trade-offs in Drilling the “Perfect Horizontal Well”™

Geosteering software solutions

- LatNavNet Well Data Management System
  - Centralized enterprise level geosteering database
  - Integrated data hub
  - Team collaboration system
    - TrueTime interpretation sharing
- LatNavNet Geosteering Software
  - Portable for use in any location
  - Streamlined for rapid geosteering interpretation
  - High resolution reports designed for rapid and clear communication of decision critical geosteering results

Best Practices Workflows

- Real-Time Operations Center Support
  - What is “real-time” really? Introducing the concept of TrueTime™
  - Well setup, initial data formats and templates
  - LWD/MWD data QC and uploads with every survey
  - 24/7 drilling data monitoring to support geosteering decisions
  - Report anomalies as observed to the team
  - Push data out to the team
  - Build well clones for parallel interpretations, different working scenarios
- Senior Geoscientist – critical skills
  - Experience in area, with targeted formation(s)
  - Interpretation expertise, correlation skills
  - Accurate geosteering resolution history
  - Drilling/field experience
  - Communication experience
  - Team collaboration across all disciplines
  - Solid relationships with key stakeholders
  - Trust IN the team, trusted BY the team

Levels of Services required

- Fit for purpose solutions
  - Scalable services
    - Risk based
    - Complexity of play
    - Size of targeted zone
Navigating the Bumps in the Road: The Trade-offs in Drilling the “Perfect Horizontal Well”™

- Drilling rates
- Maturity of play
Navigating the Bumps in the Road: The Trade-offs in Drilling the “Perfect Horizontal Well”™

• Fit for purpose solutions (continued)
  o Leverage the right tools to fit the project
  o Err in favor of over subscribing, then scale back as experience proves out
  o Scale back slowly with contingencies in place for quick recovery
• Building on the basics – scale up as necessary
  1. Mudlogging
  2. 24/7 remote monitoring
  3. Expert QC and automatic data management
  4. FirstLook™ geosteering interpretation
  5. Tiered geosteering analysis – more eyes when required
  6. Senior interpretation
  7. Team review
  8. Active guidance by experts

Part VI – Using Geosteering Software – 60 minutes (3:45pm – 4:45pm)

Log correlation for geosteering applications

• Correlation software options
  o Sliding logs
  o Spreadsheet correlation
  o Geosteering software – commercial
  o In-house solutions
• Drilling and offset well data requirements and data management
  o Setting up a correlation
    ▪ LAS files
    ▪ Directional surveys
  o Active well data requirements
    ▪ LAS files
    ▪ Directional surveys
    ▪ Other data
  o Data management for interpretation and archival
    ▪ Locally
    ▪ Cloud-based
    ▪ Auditing
• Geosteering software results
  o Input data discussion
  o Results discussion
  o Graphical representation
  o Target description
  o Target line
Demonstration of a software for geosteering (optional)

- Working on the cloud
  - Operations center-based well set-up
  - Ops center data management and QC
  - Collaboration using a single data set
- How to correlate
  - Stretch and squeeze
  - Using apparent dip to reconcile a fit
  - Introducing faults
- The report
  - Input data review
  - Cross section views
    - Vertical Section plane view
    - Measured depth panel
  - Target lines

**Conclusions and Wrap-up** – 15 minutes (4:45pm – 5:00pm)