Appraising and Developing Your Unconventionals:

How to Avoid Squandering Billions of Dollars Next Time

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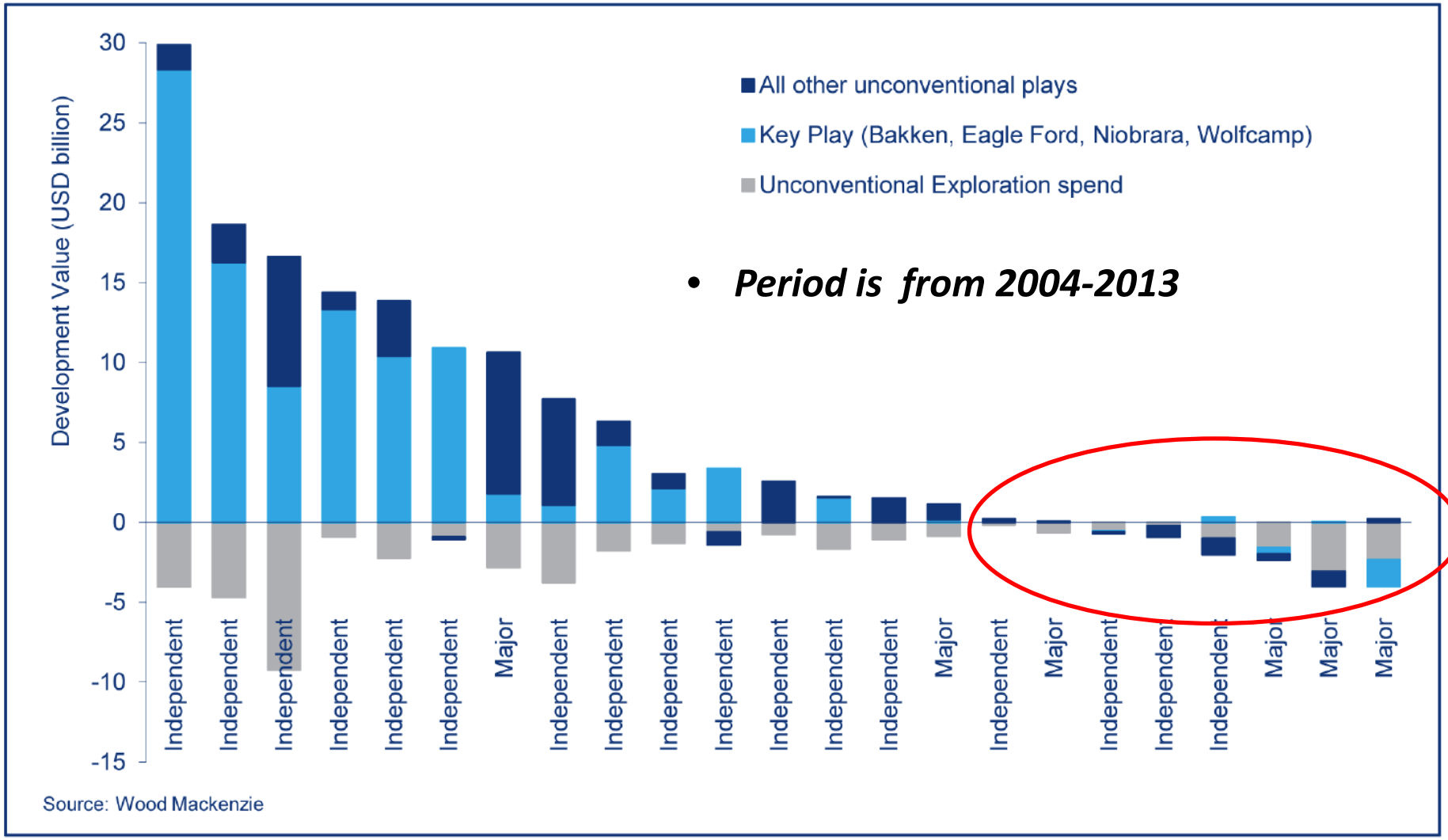
Rose and Associates

SPEE
Oklahoma City
February 22, 2018

Development Value in Unconventional Plays



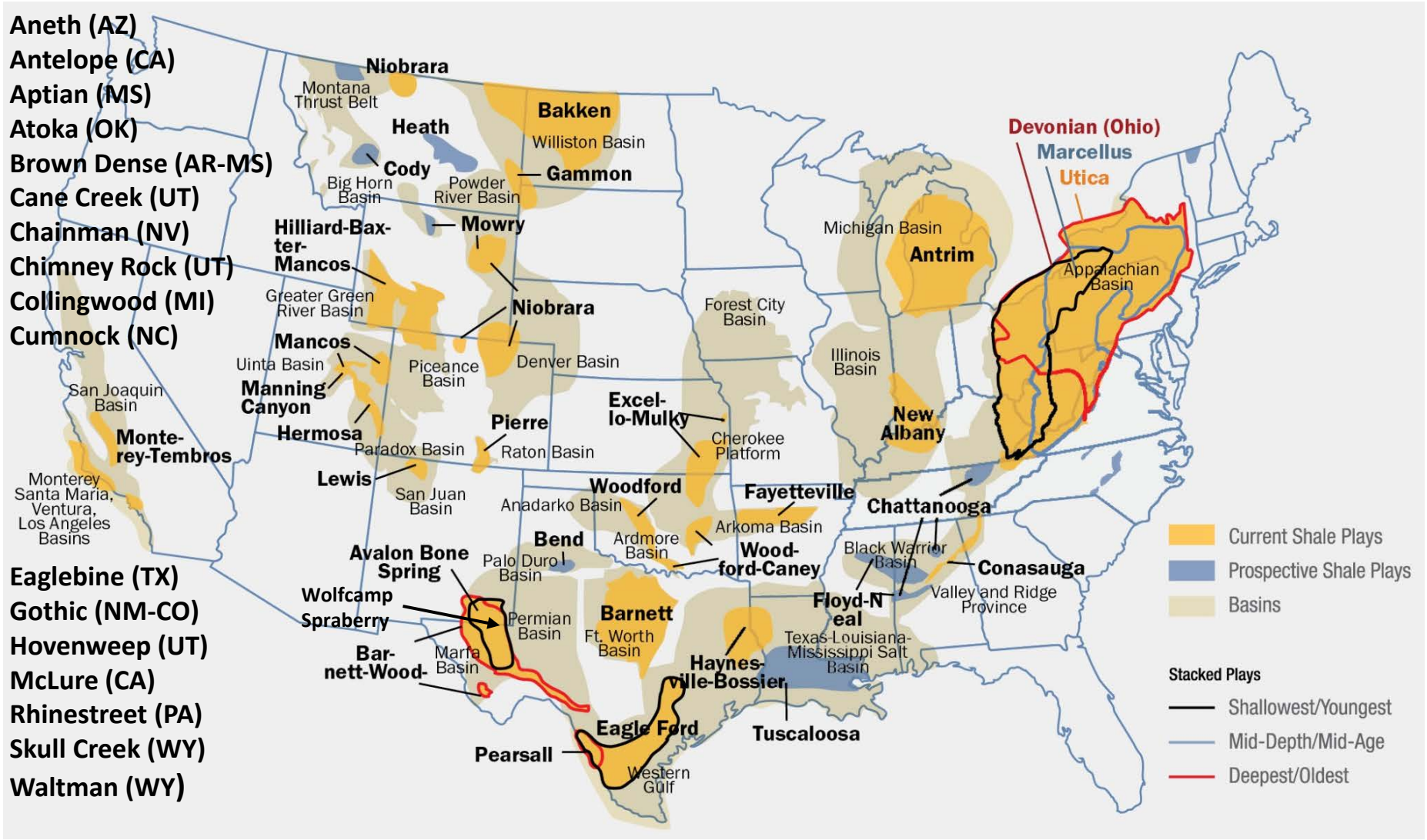
- The 23 companies shown here acquired acreage in 30+ North American plays.
- 8 of these failed to deliver positive development value

SPE 174925

A Recent Company's Experience in Unconventionals

- Evaluated 16 different low permeability reservoirs
- Drilled 1000+ wells over a 1-year period
- Only ~200 of these had a rate-of-return of greater than 12%
- Each of the 16 projects was expected to have a rate-of-return of at least 40%
- By drilling all of these wells, the company attained their production goals
- They just squandered $2-3 billion in the process
- In some of these projects, 80 or more wells were drilled with only one well being economic
- How does this happen and what can we do about it?

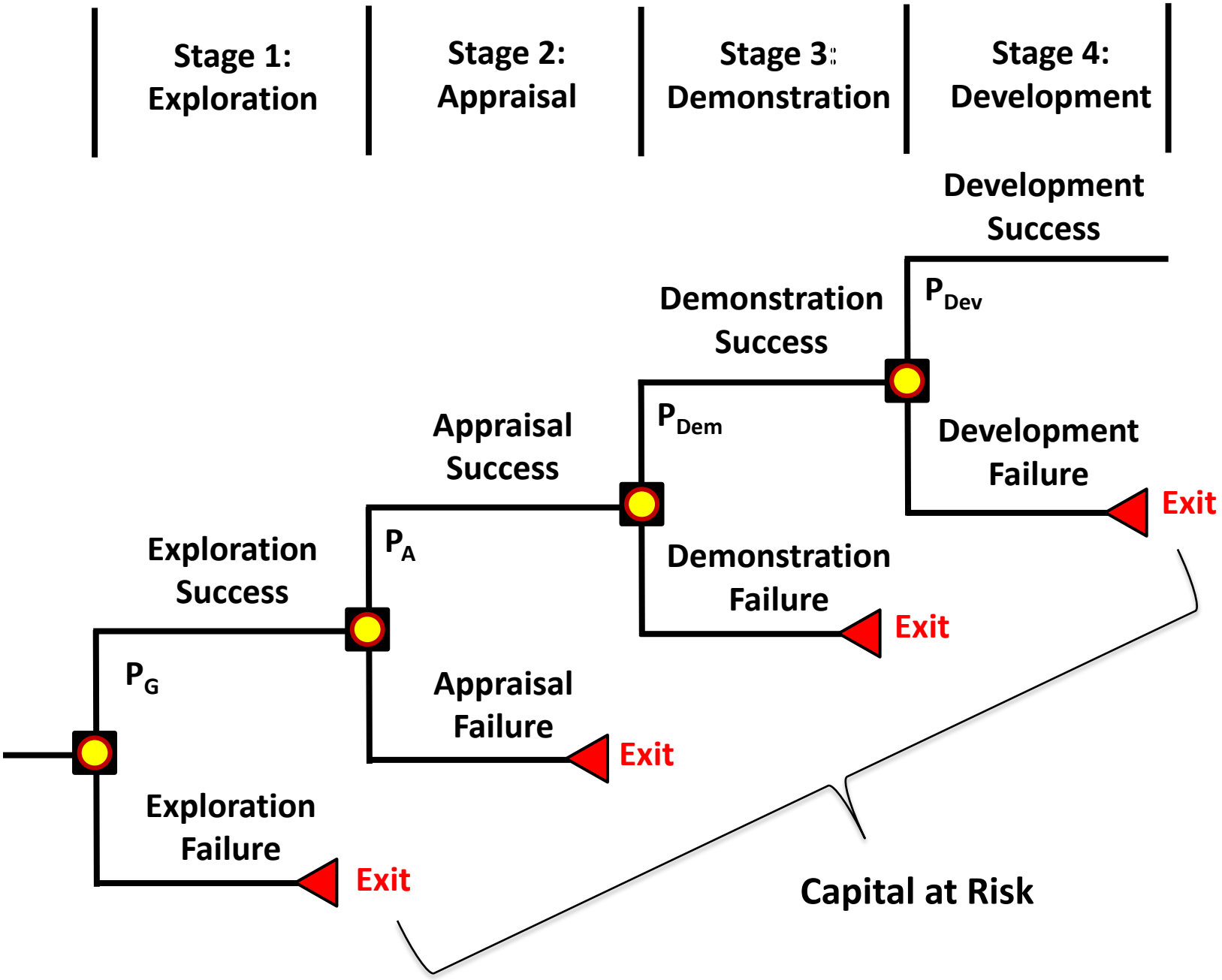
U.S. Shale Plays



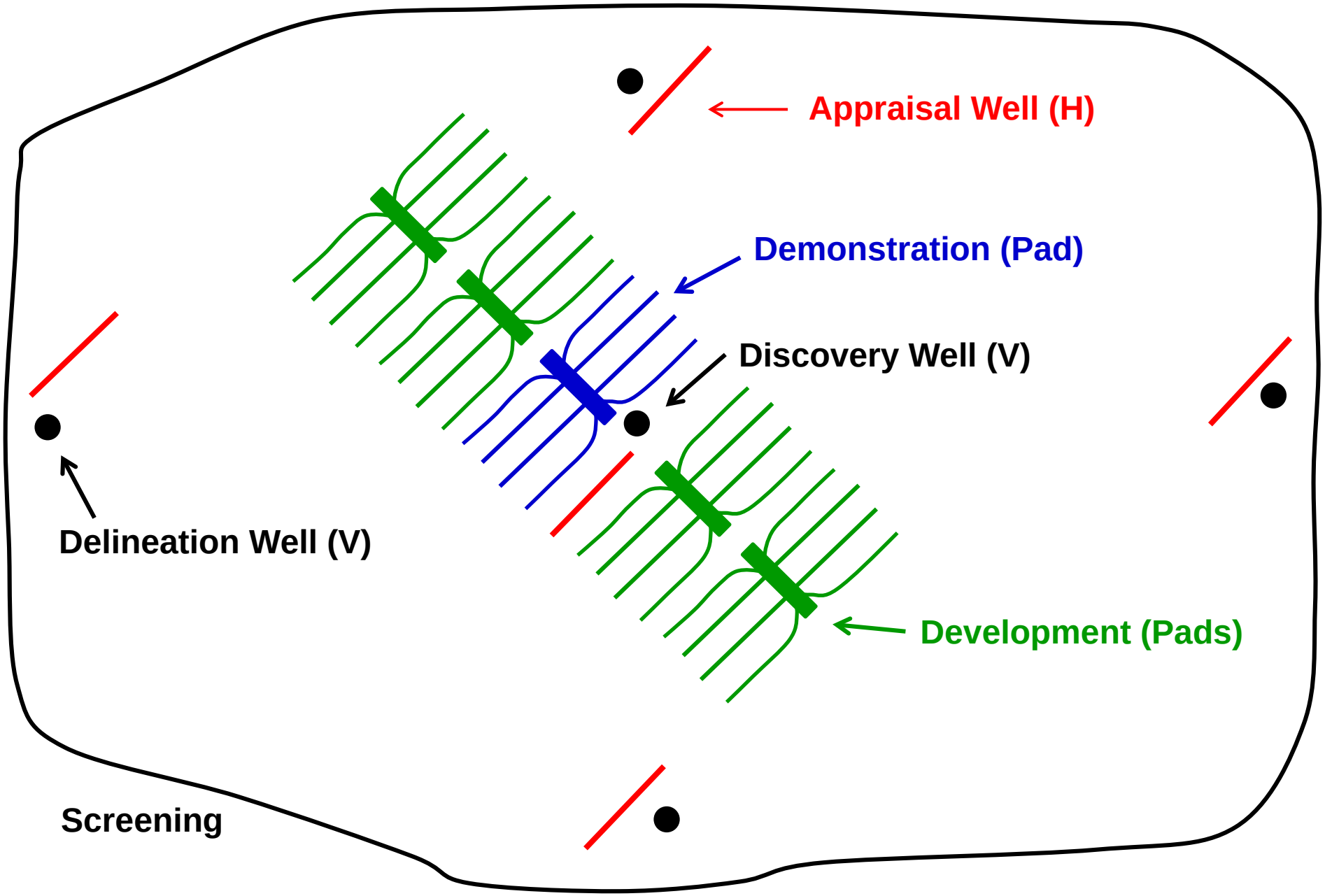
- What percentage of U.S. Shale Plays have been commercially developed?

From the American Petroleum Institute, 2014

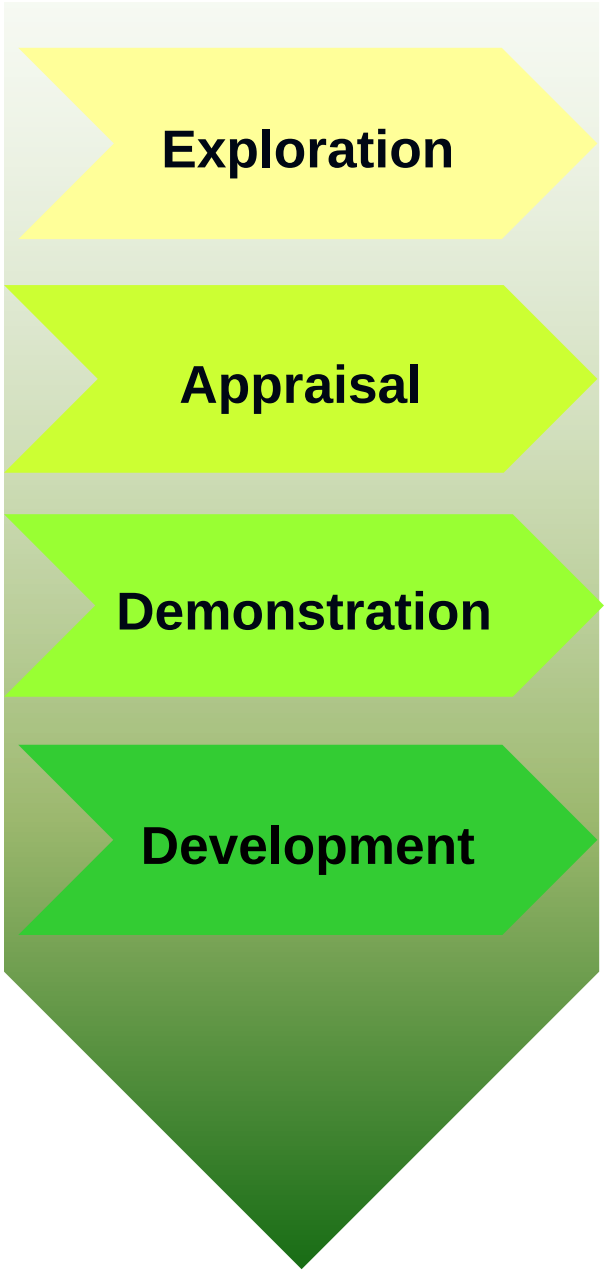
The Staged Approach



Project Stages

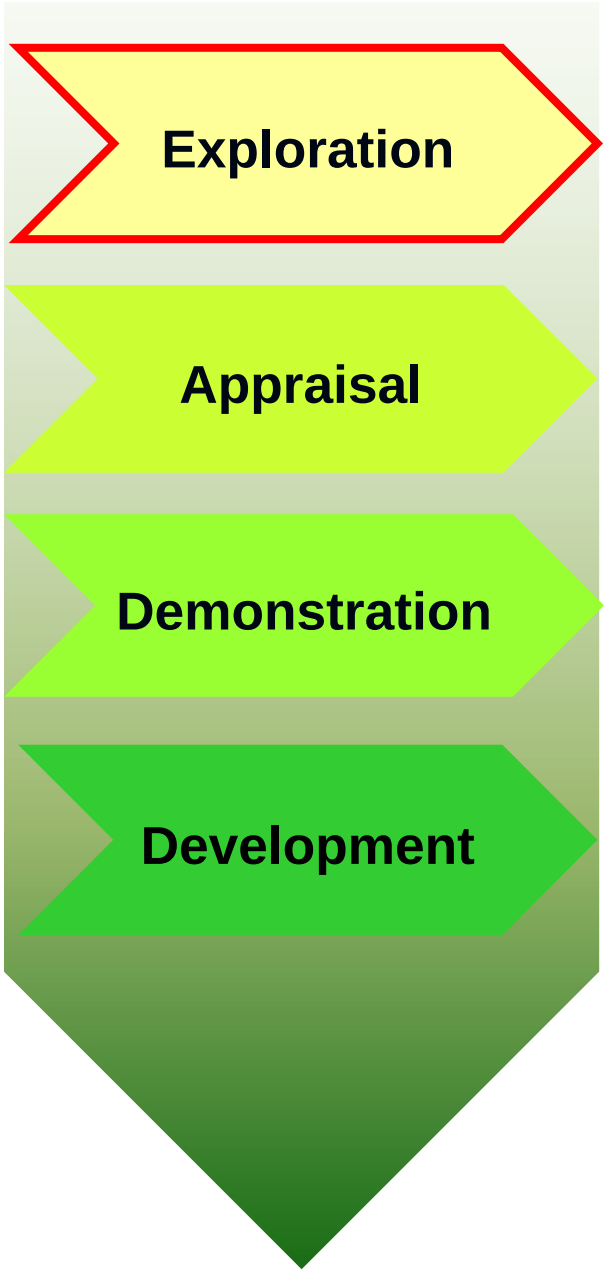


General Workflow



- Identify the stage the project is in
- Assess the key uncertainties and risks in that stage
- Define the data and analyses required to make a good decision whether to proceed to the next stage or exit
- Design a work plan, timeline and budget to acquire this information

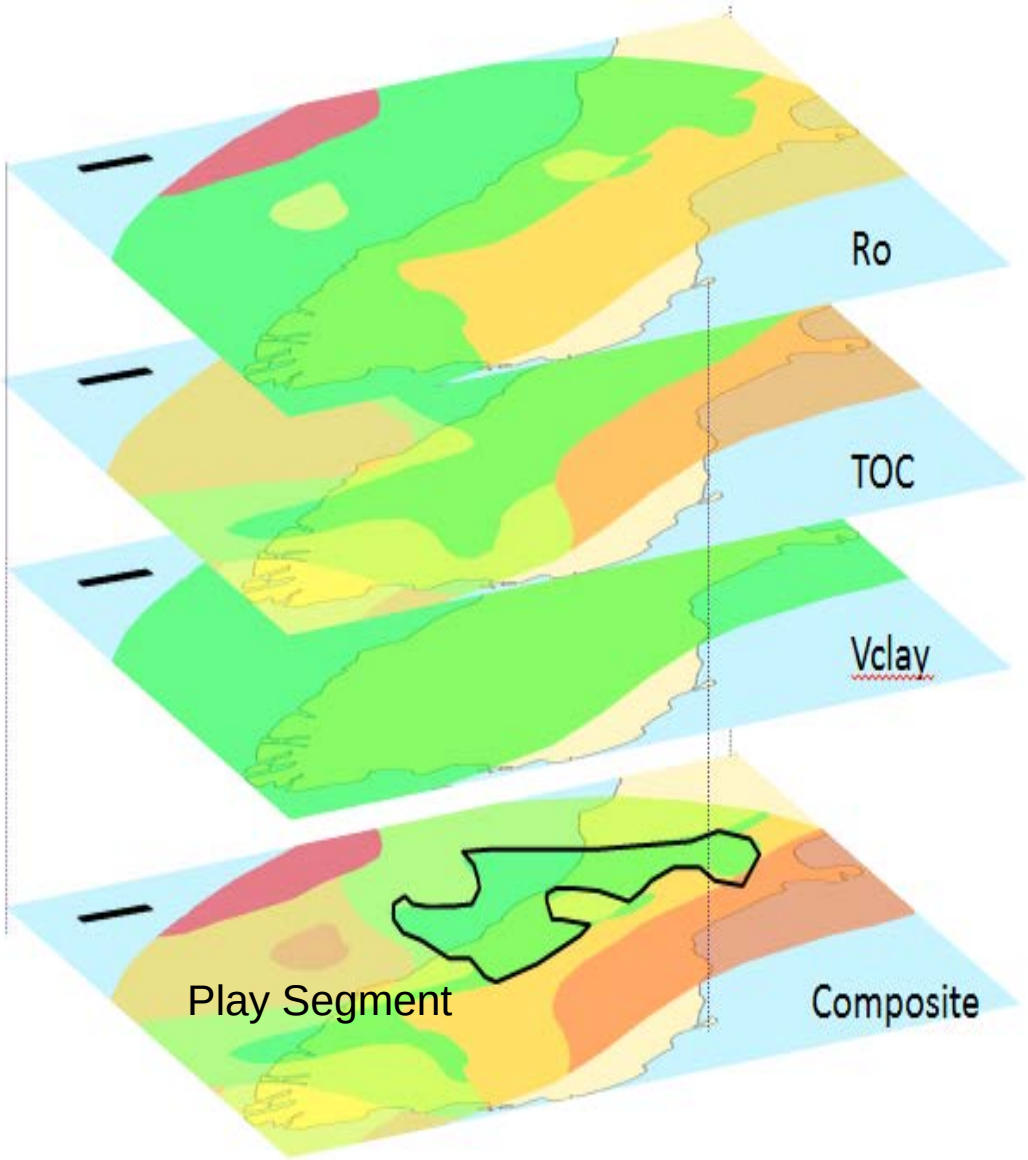
Project Stage: Exploration



Screening

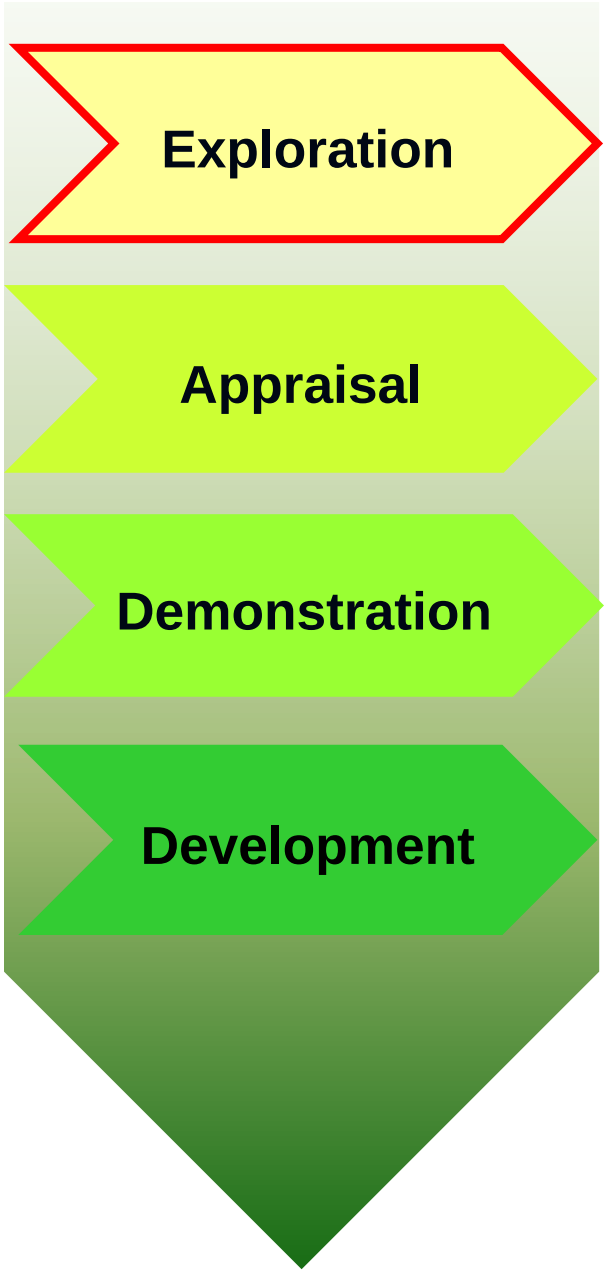
- Target basins with prospectivity and rank opportunities
- Apply criteria for identifying sweetspots
- Collect all existing relevant information
  - Cast a wide net and be resourceful
  - Look for data to fill-in the gaps
  - Evaluate the entire stratigraphic column
- Build maps and spatially composite them
- Identify potential analogs
- Determine chance of geologic success (Pg) for defined play segments

Spatial Compositing of Maps



- Organic richness (TOC)
- Thermal maturity (%Ro)
- Structure/tectonics
- Gross/net thickness
- Lithofacies/mineralogy
- Acoustic impedance
- Geomechanical properties
- Seeps/slicks
- Surface geochemistry
- Porosity/Permeability
- Fluid saturations (Sg, So, Sw)
- Evidence of overpressure
- Overburden thickness
- Seal thickness/rheology
- Reservoir temperature
- Paleogeography
- Key wells
- Acreage held/open
- Restricted/inaccessible areas
- Pipelines, other infrastructure

Project Stage: Exploration

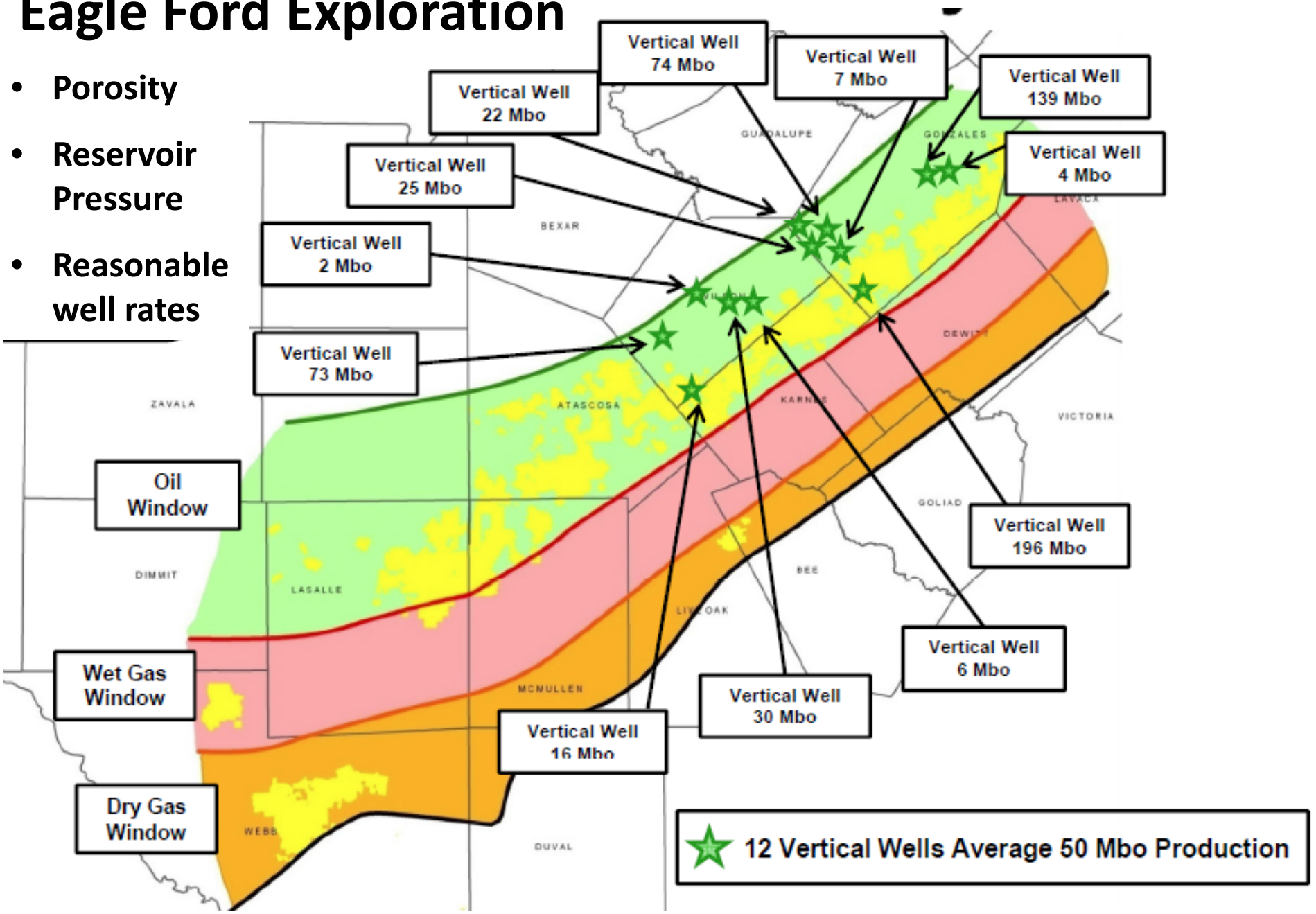


Discovery

- Locate a significant quantity of producible hydrocarbons that has the potential for commercial development
- Drill multiple wells if failure is local and not regional
- Determine how many targets to investigate
- Decide what data to gather
- Integrate newly-acquired and existing data
- Acquire open acreage, build land position
- Determine failure criteria & what outcomes trigger an exit

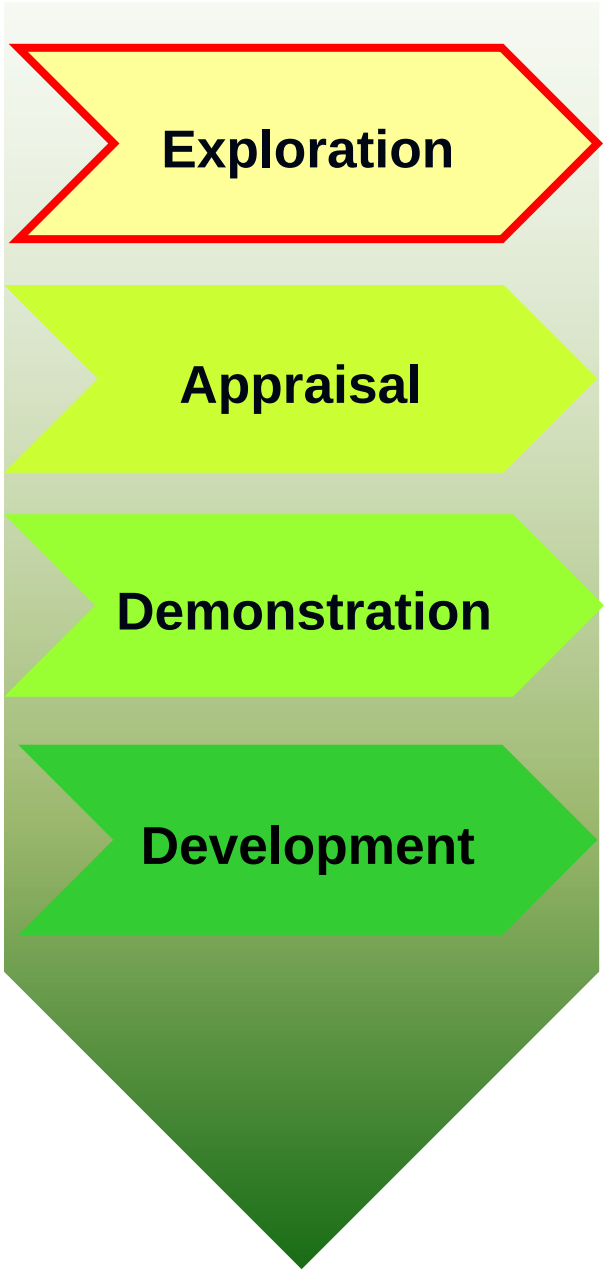
Eagle Ford Exploration

- Porosity
- Reservoir Pressure
- Reasonable well rates



From EOG Investor Presentation, 2010

Project Stage: Exploration

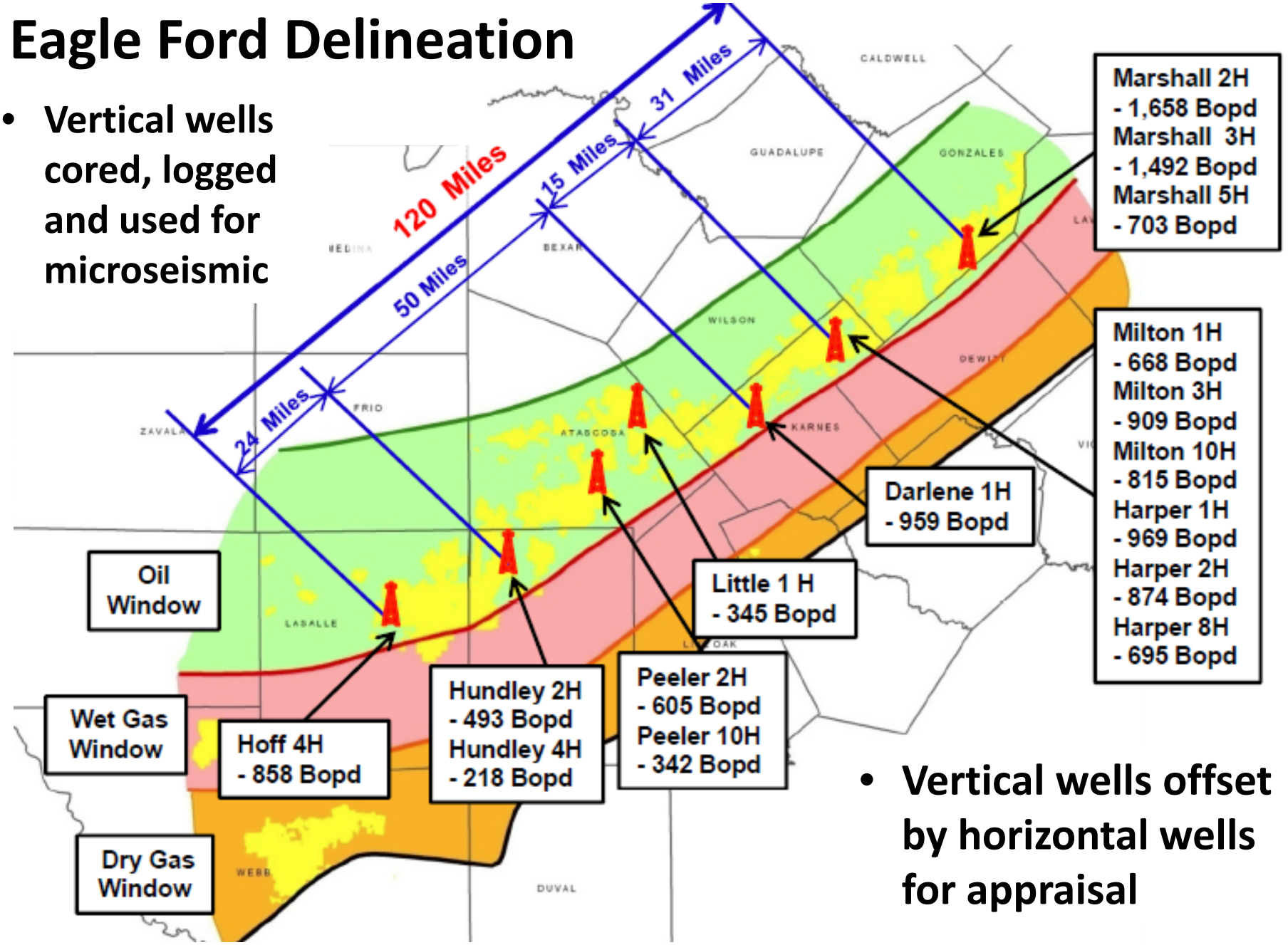


Delineation

- Validate materiality—that the potential is sufficient to justify further investment
- Show that successive wells are as good or better than the discovery well.
- Confirm thickness, lateral continuity, and internal character with 2D seismic, well data
- Demonstrate that wells can be fracced and produce fluids with desirable characteristics
- Determine well count needed to meet a defined percent confidence of achieving some minimum average well rate
- Determine failure criteria & what outcomes trigger an exit

Eagle Ford Delineation

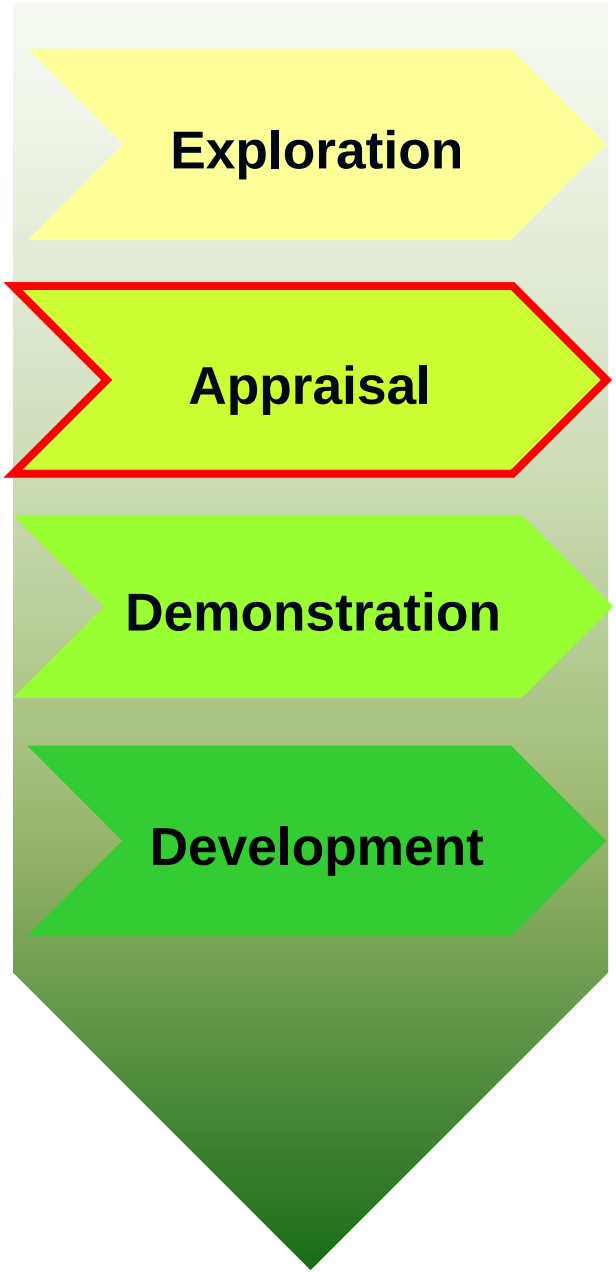
- Vertical wells cored, logged and used for microseismic



- Vertical wells offset by horizontal wells for appraisal

From EOG Investor Presentation, 2010

Project Stage: Appraisal

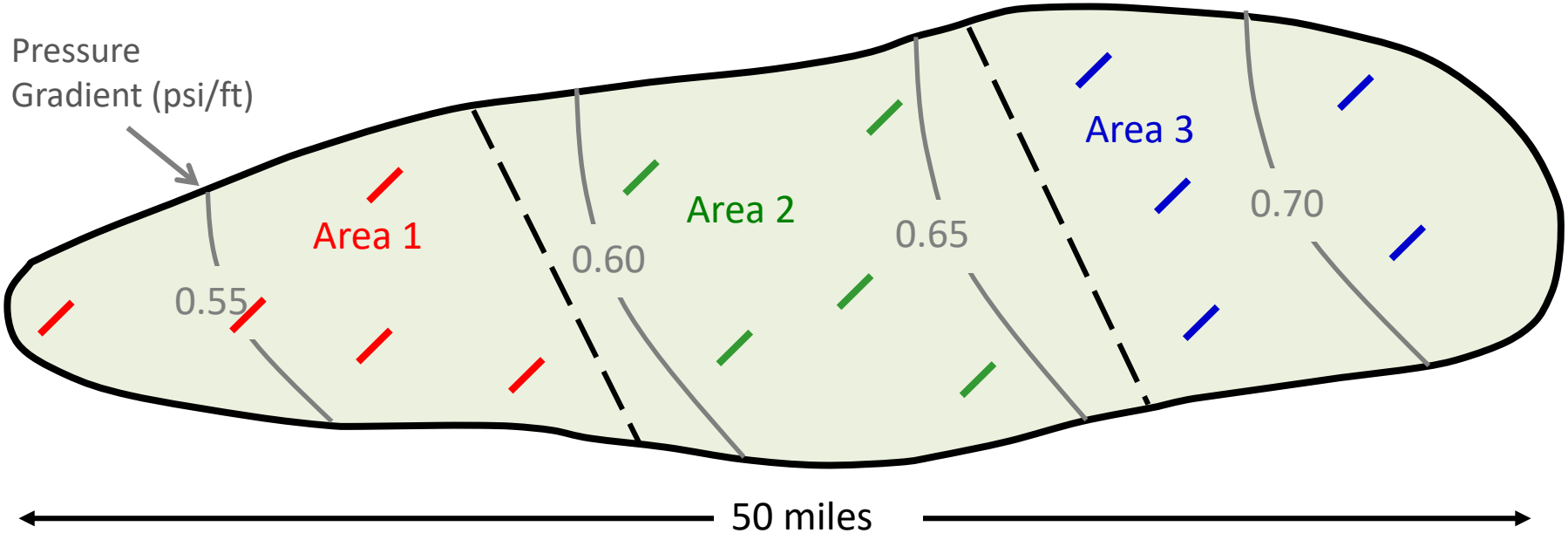


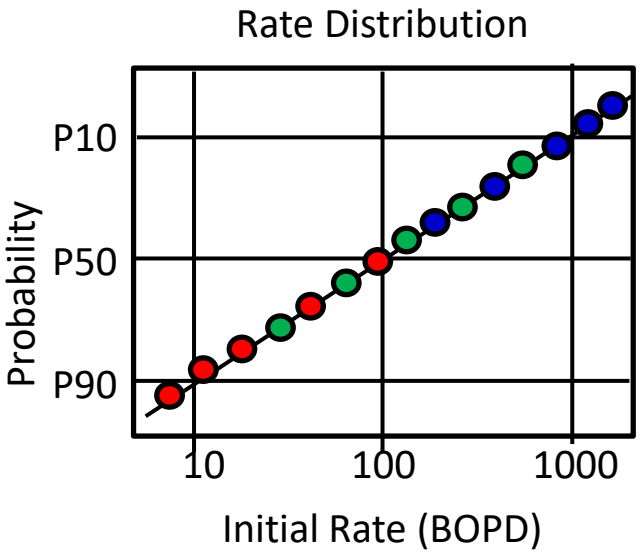
- Validate the ability to drill, complete, and produce hydrocarbons from individual horizontal wells at a rate/decline above some predetermined threshold
- Use consistent drilling/completion practices
- Identify areas of greatest productivity--will become the sites for demonstration projects
- Obtain key reservoir data (rates, pressures) to help quantify performance variability
- Determine well count needed to meet a defined percent confidence of achieving an average well rate that exceeds the threshold
- Determine failure criteria & what outcomes trigger an exit

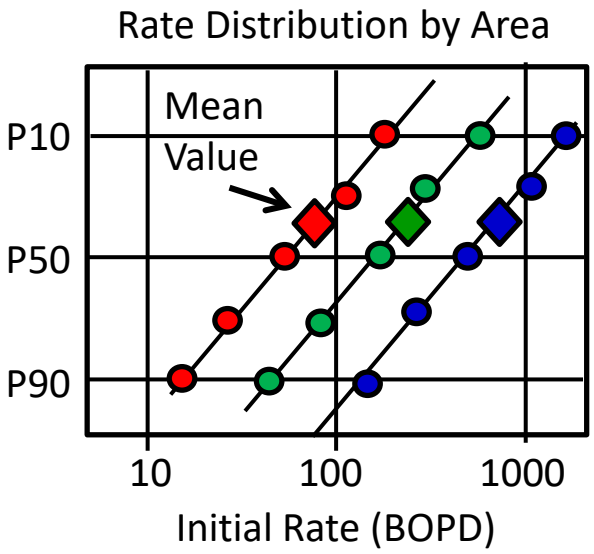
Discussion at a Recent Conference….

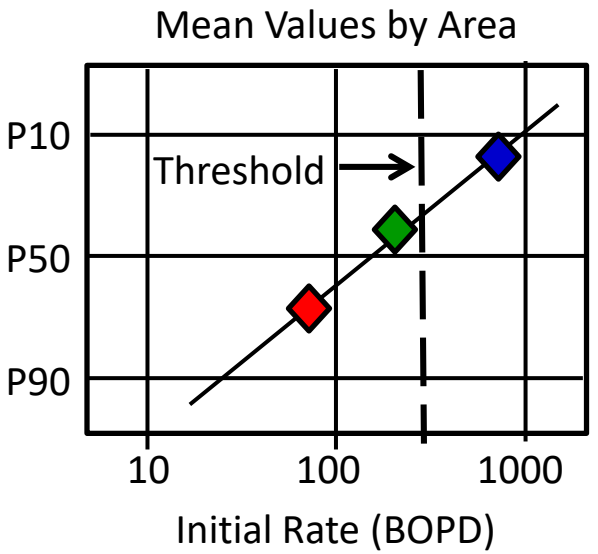
- A completions engineer presented the results of a sand size trial in a shale reservoir where they pumped a 50-50 mix of 40/70 and 100 mesh sand to see how the wells compared to their traditional 40/70 completions.
- After the presentation he was asked what *confidence do you have in the results of this trial*? "I'm very confident", he said, adding:
  - "The trial was done early when the shale was still *pristine*—we were just beginning to drill it up so there weren't other variables interfering with you"
- Variables the engineer was thinking about: changes caused by earlier wells (stresses, depletion)
- Variables the engineer was not thinking about : TOC, thermal maturity, fractures, facies changes, porosity, perm, saturation, etc.

High-Grading with Appraisal Wells





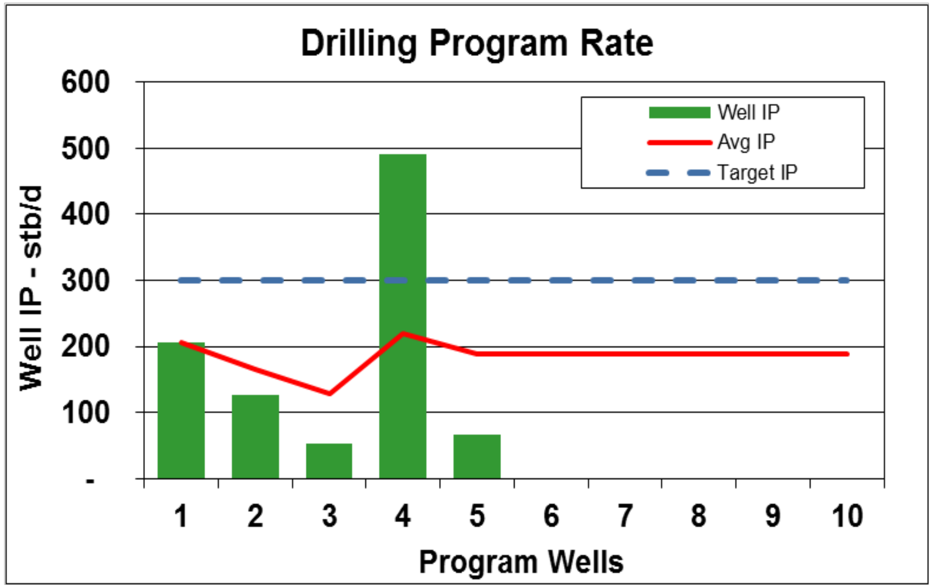


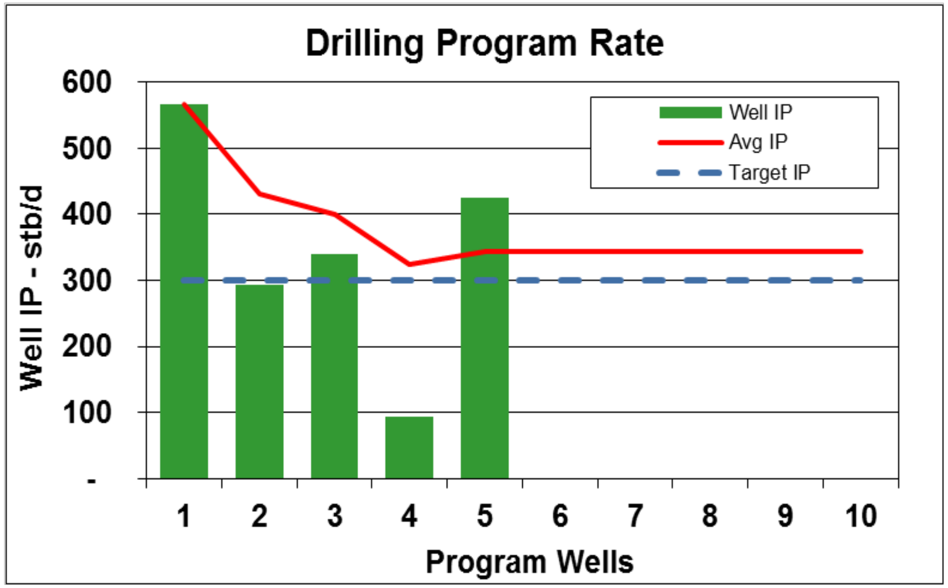


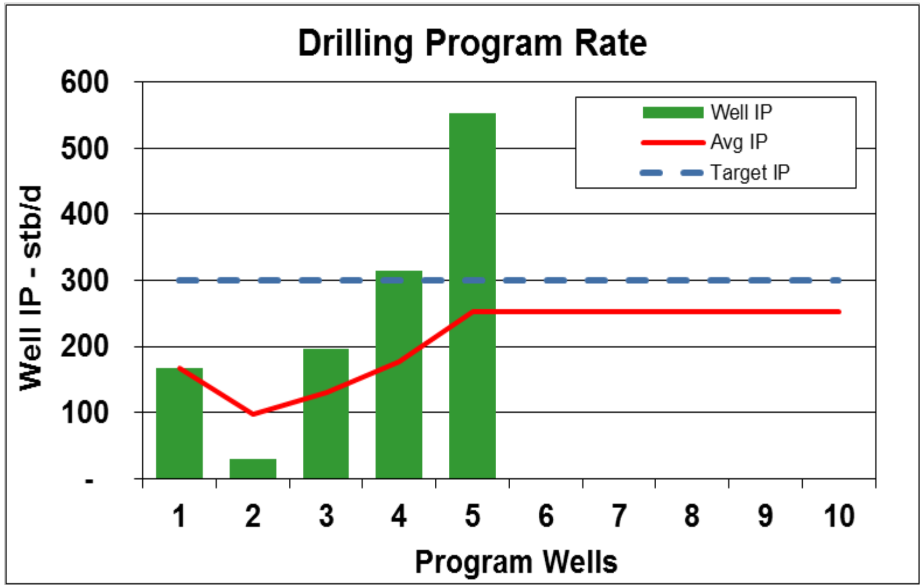
Modified from Brad Berg's 2013 SPE Distinguished Lecture Presentation

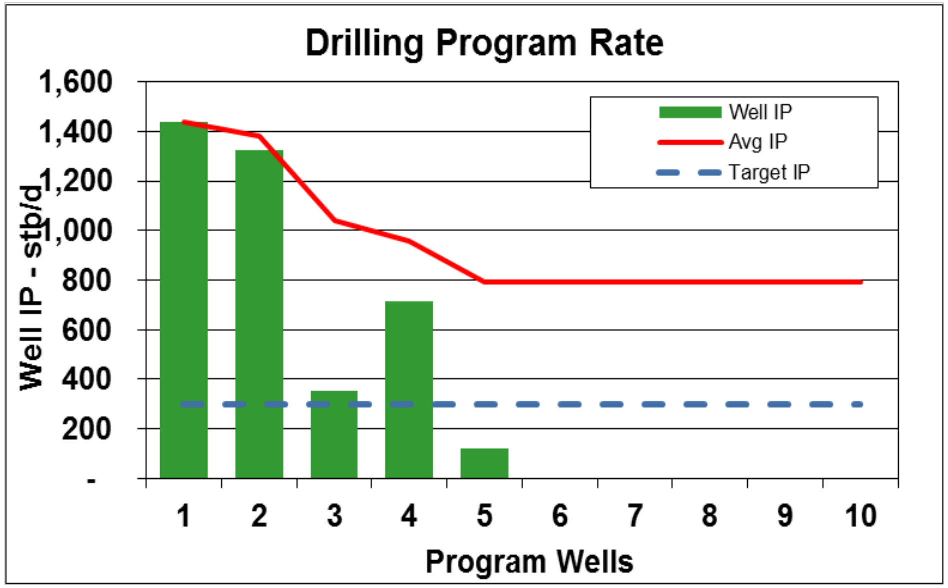
Examples of 5-Well Drilling Programs

P90 = 75, P10 = 750, Mean = 350, Threshold = 300

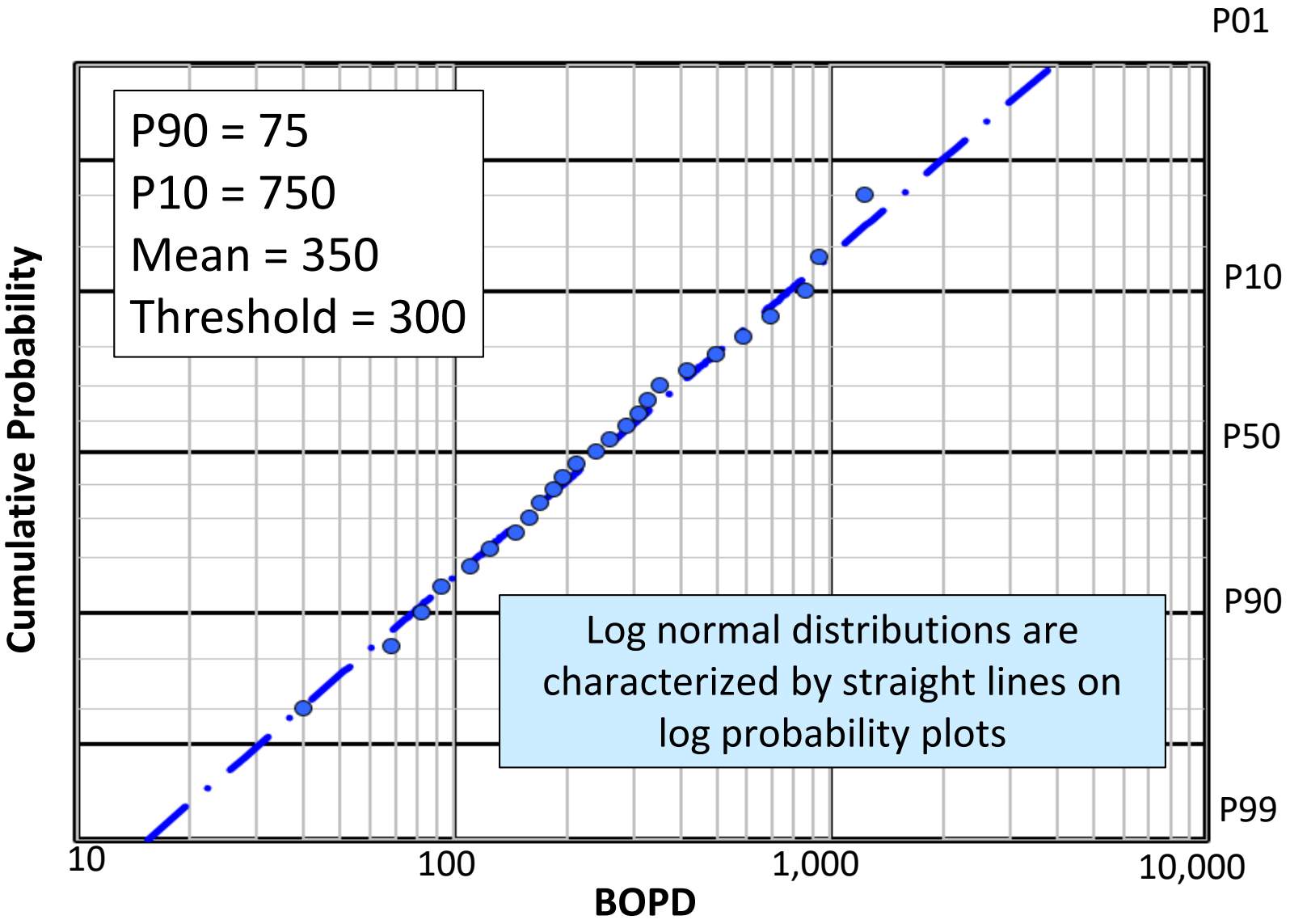






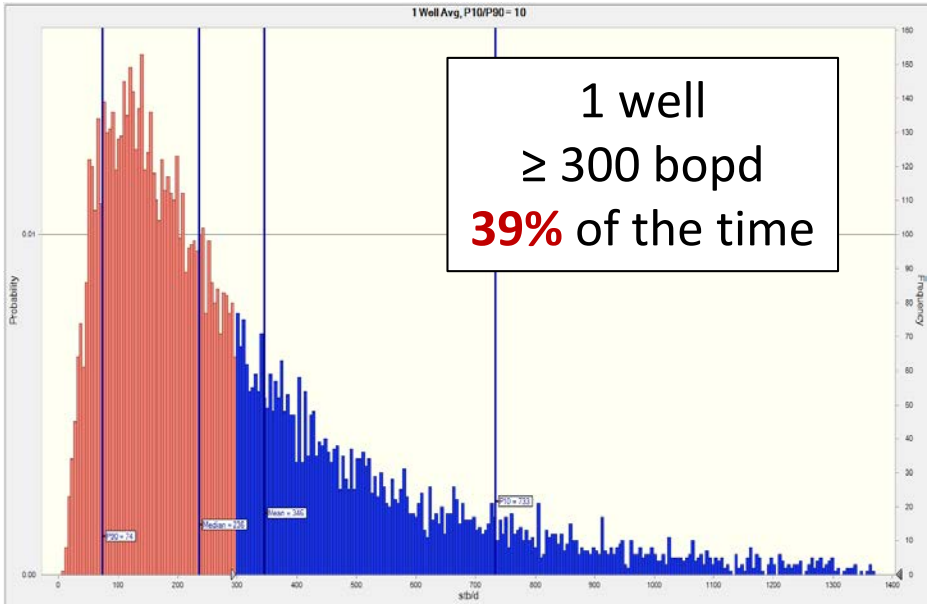


Log Probability Plot of Initial Rate

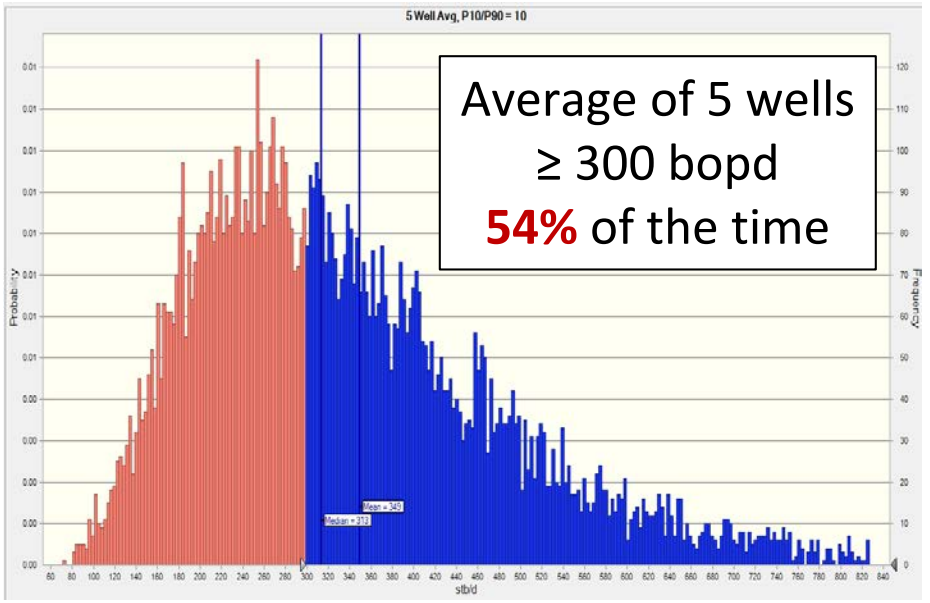


Let's randomly sample this distribution and generate frequency plots

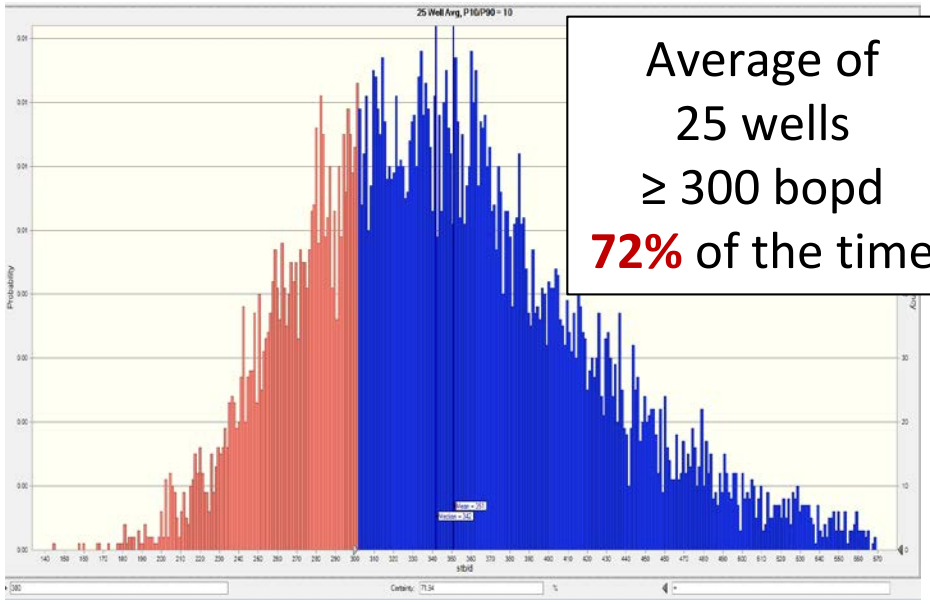
Confidence of Achieving Some Minimum



1 well
≥ 300 bopd
39% of the time



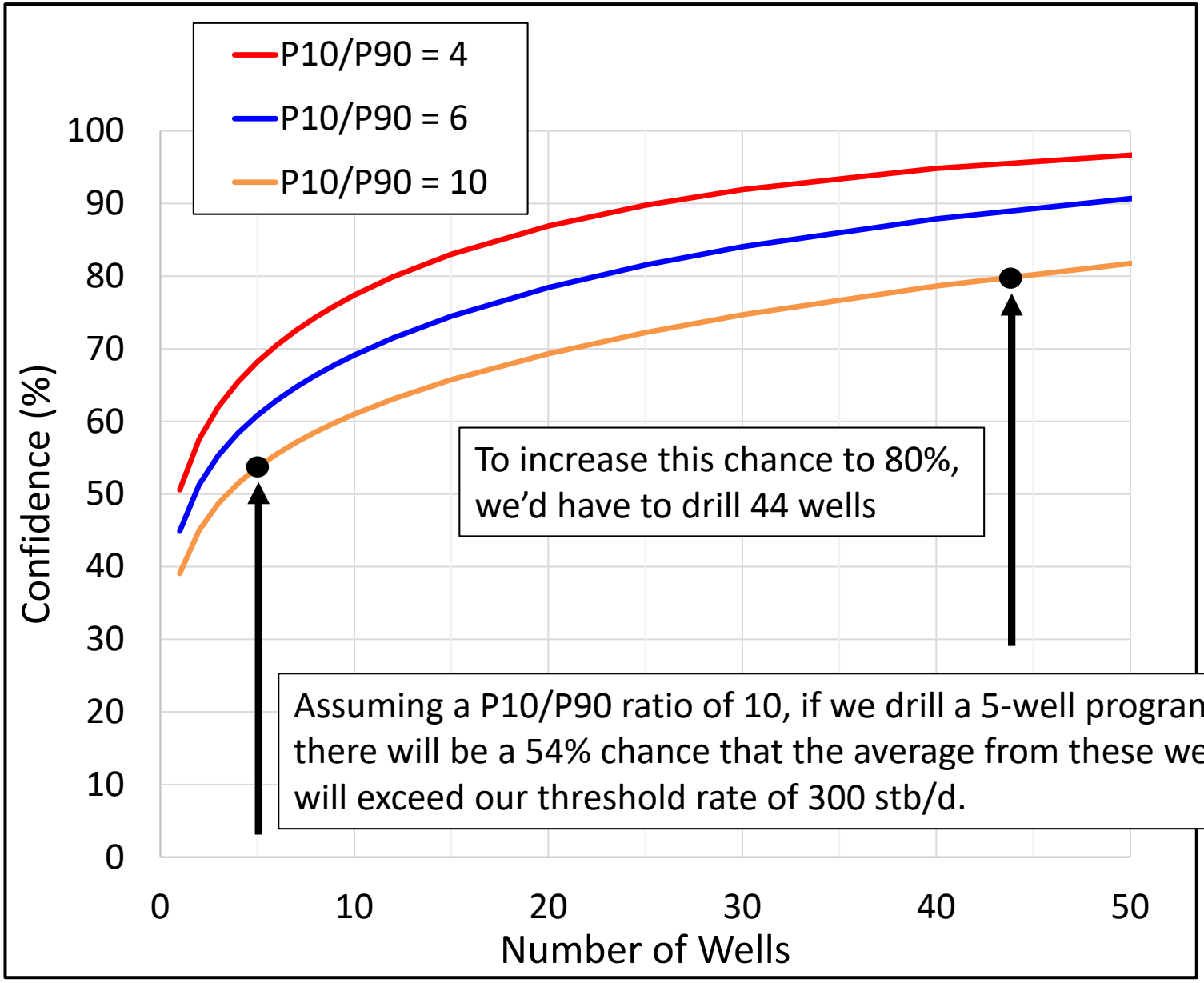
Average of 5 wells
≥ 300 bopd
54% of the time



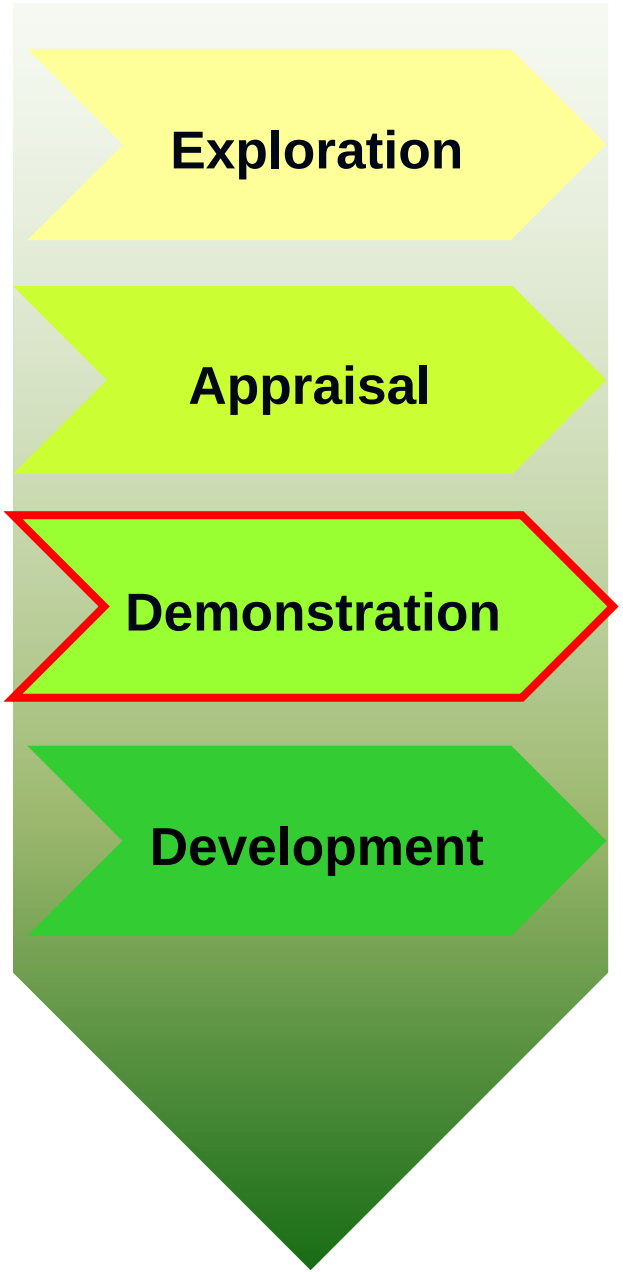
Average of
25 wells
≥ 300 bopd
72% of the time

These plots allow us to determine the percent of simulated outcomes that are ≥ 300 bopd for 1, 5, and 25-well programs

Confidence Curves



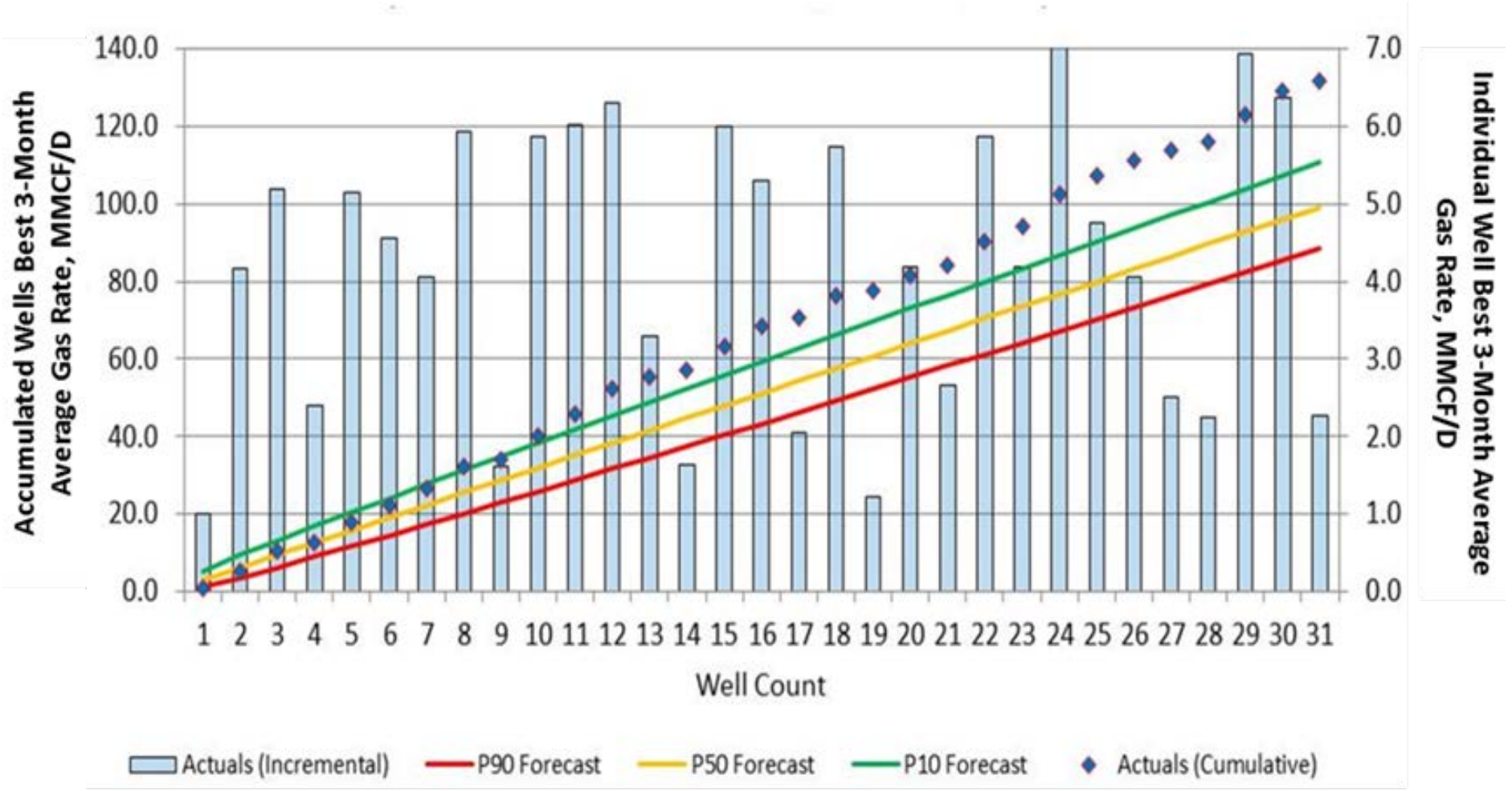
Project Stage: Demonstration



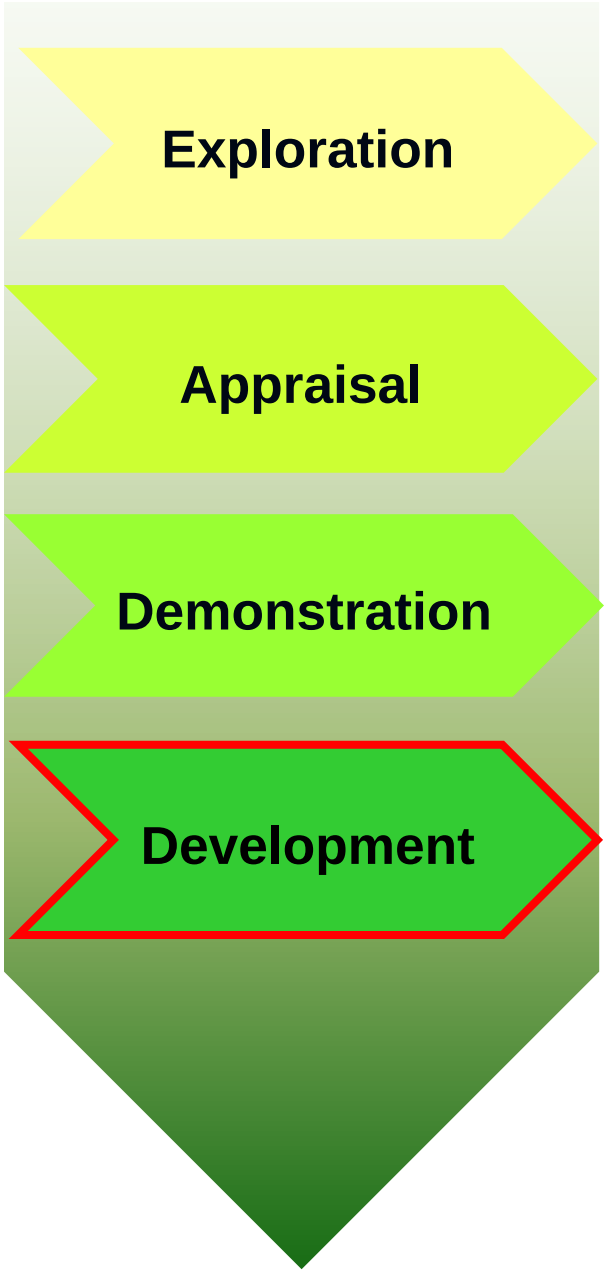
- Validate that you have a commercially viable project above a prescribed confidence level
- May need multiple demonstration projects
- Determine the well count required to meet the prescribed confidence level
- Confirm type curve(s) and ensure that expected cost improvements are achievable
- Determine the well spacing that maximizes project value
- Use sequential aggregation plots to track performance vs forecast for major elements
- Determine failure criteria & what outcomes trigger an exit

Sequential Aggregation Plot

Showing Best 3 Month Average Gas Rate for 31 Wells Compared to Forecasts



Project Stage: Development

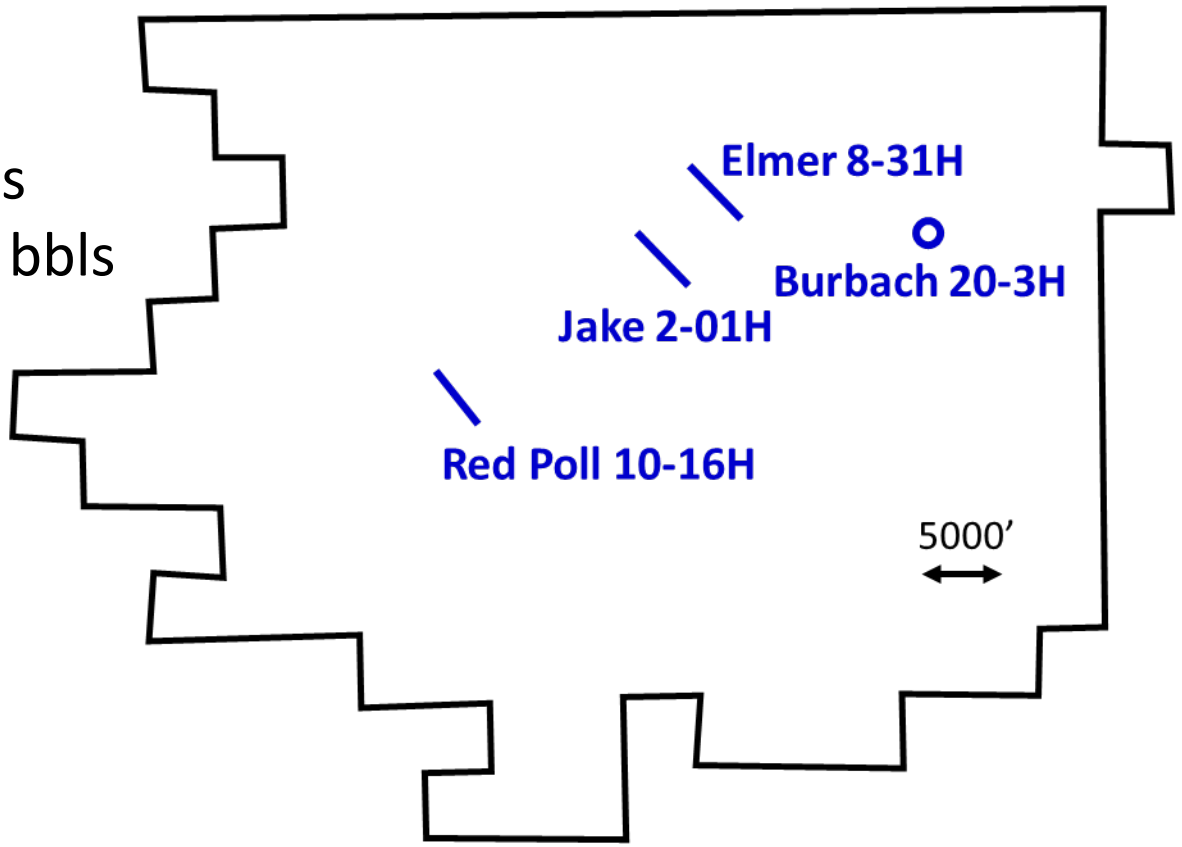


- Proceed if the expected results are competitive with other opportunities in your company's portfolio
- As development drilling expands, ensure that results from new wells continue to meet expectations
- Use continuous learning and KPIs to reduce costs, optimize well spacing and maximize production & reserves
- Synchronize pad construction, well drilling, completion, fluid gathering and processing to maximize profitability

Hereford Field Example (Niobrara Fm)

1 Year Cumulative Production for 3 Early Wells

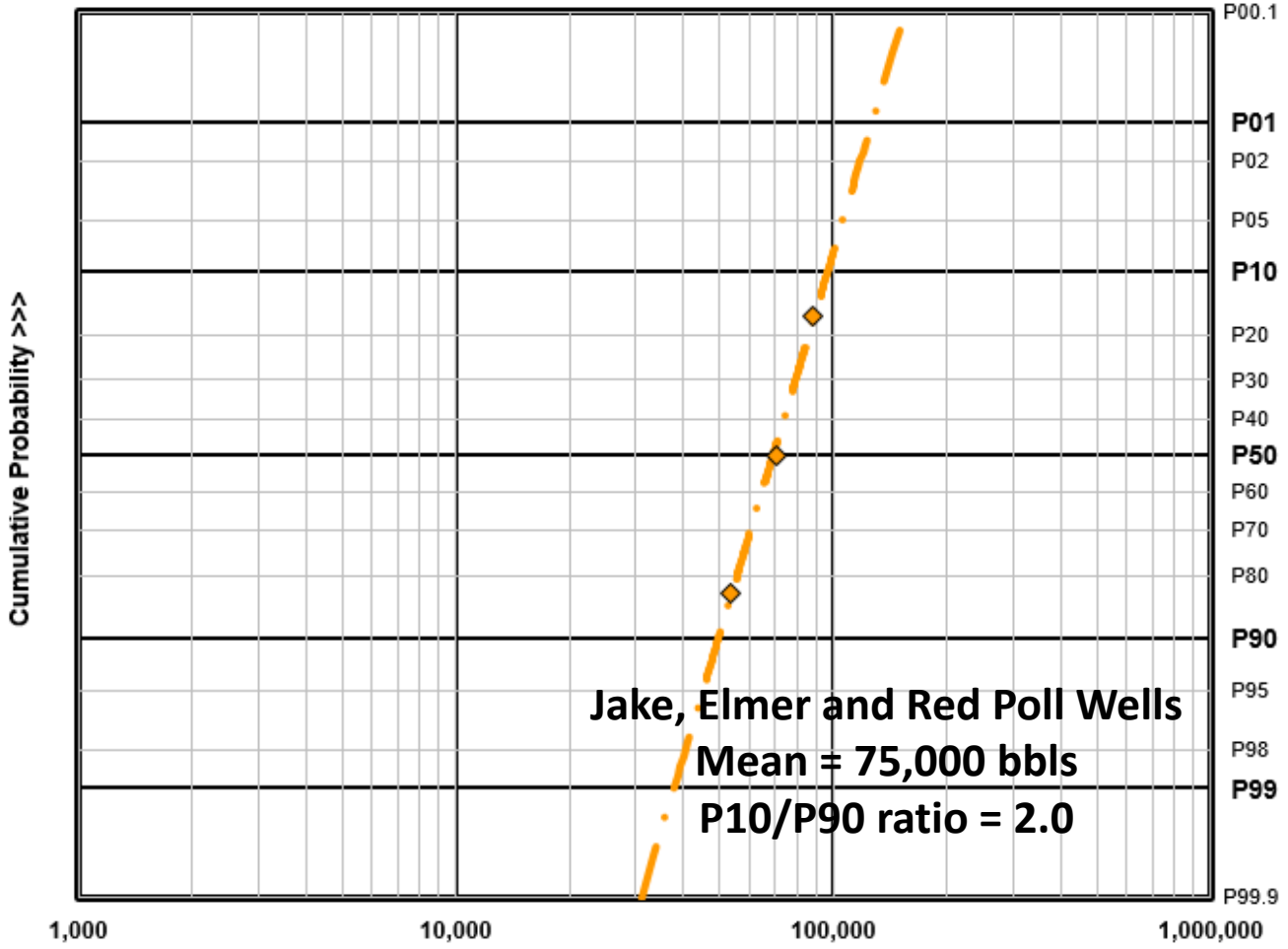
Jake 2-01H = 70,410 bbls
Elmer 8-31H = 53,413 bbls
Red Poll 10-16H = 88,157 bbls



From "A Short History of the "Jake" Niobrara Horizontal Oil Discovery…", Mountain Geologist, July 2015
Production data from the Colorado Oil and Gas Conservation Commission

Hereford Field Example (Niobrara Fm)

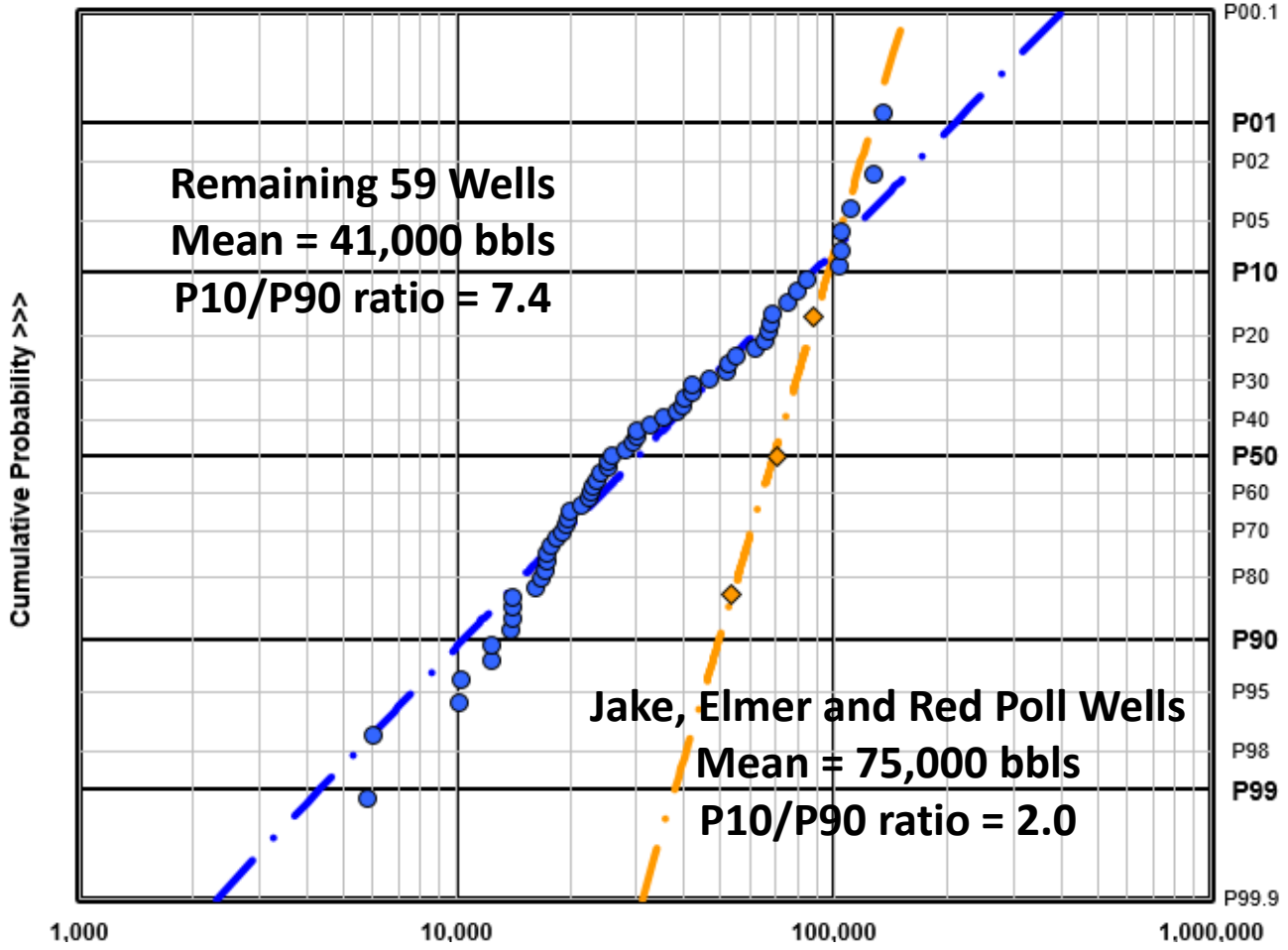
1 Year Cumulative Production for 3 Early Wells



Production data from the Colorado Oil and Gas Conservation Commission

Hereford Field Example (Niobrara Fm)

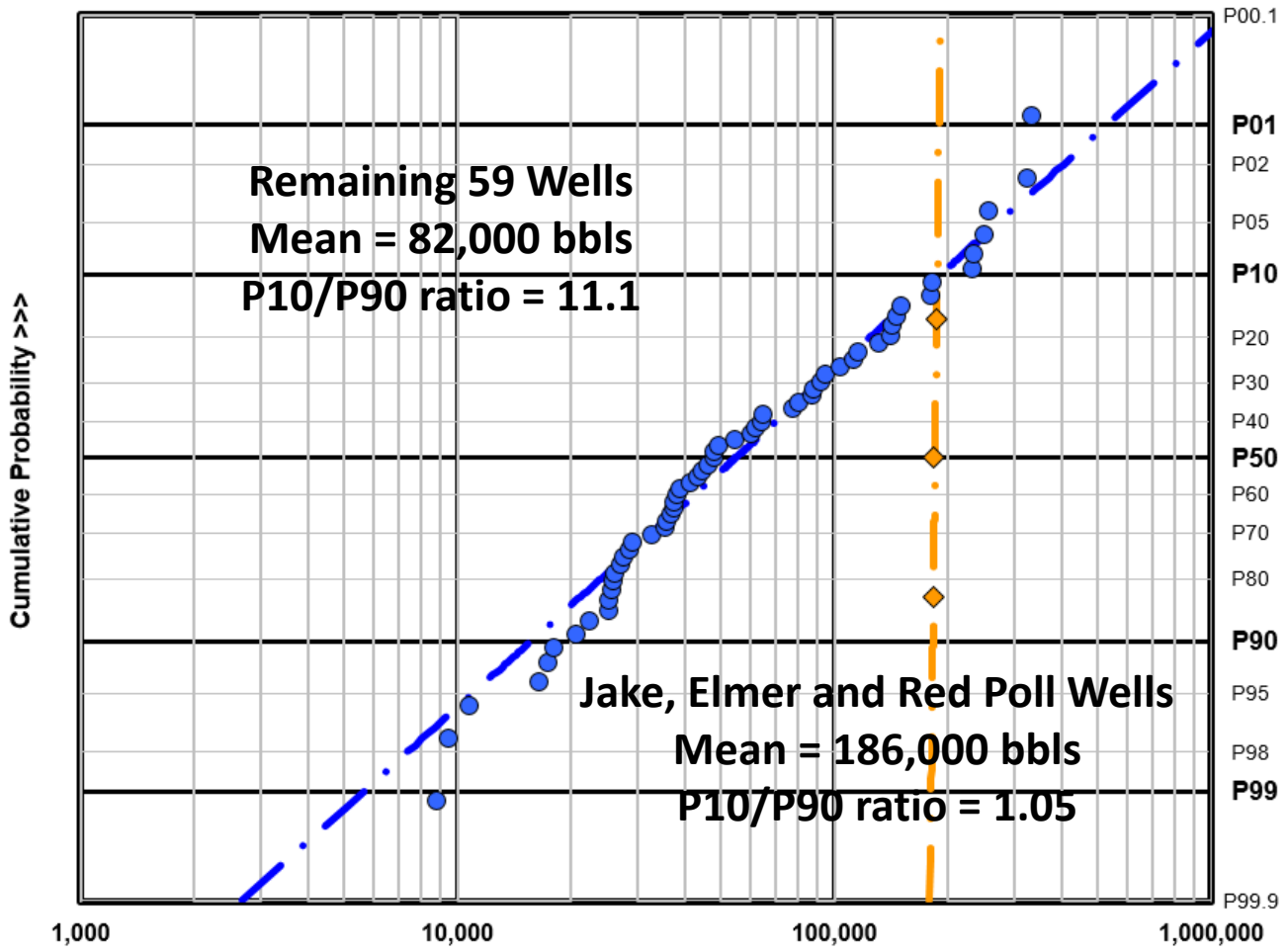
1 Year Cum. Production for 3 Early Wells + 59 Later Wells



Production data from the Colorado Oil and Gas Conservation Commission

Hereford Field Example (Niobrara Fm)

Cumulative Production Through 2016



Production data from the Colorado Oil and Gas Conservation Commission

Hereford Field Example (Niobrara Fm)

Cumulative Production Comparison

Cumulative Production for 3 Early Wells

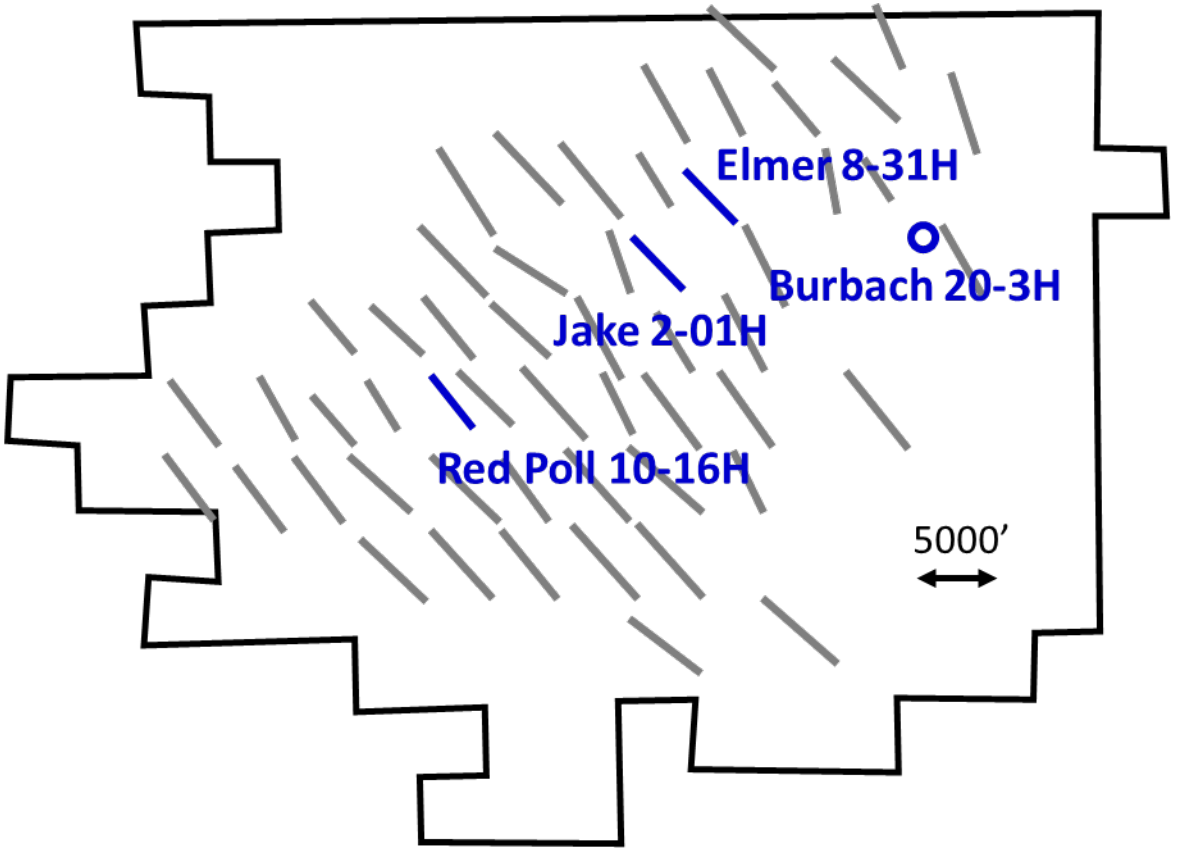
Jake 2-01H = 187 M bbls

Elmer 8-31H = 188 M bbls

Red Poll 10-16H = 182 M bbls

Cumulative Production for 59 Later Wells

- 2 wells: > 300 M bbls
- 4 wells: 200-300 M bbls
- 10 wells: 100-200 M bbls
- 11 wells: 50-100 M bbls
- 32 wells < 50 M bbls
- P10/P90 ~ 11

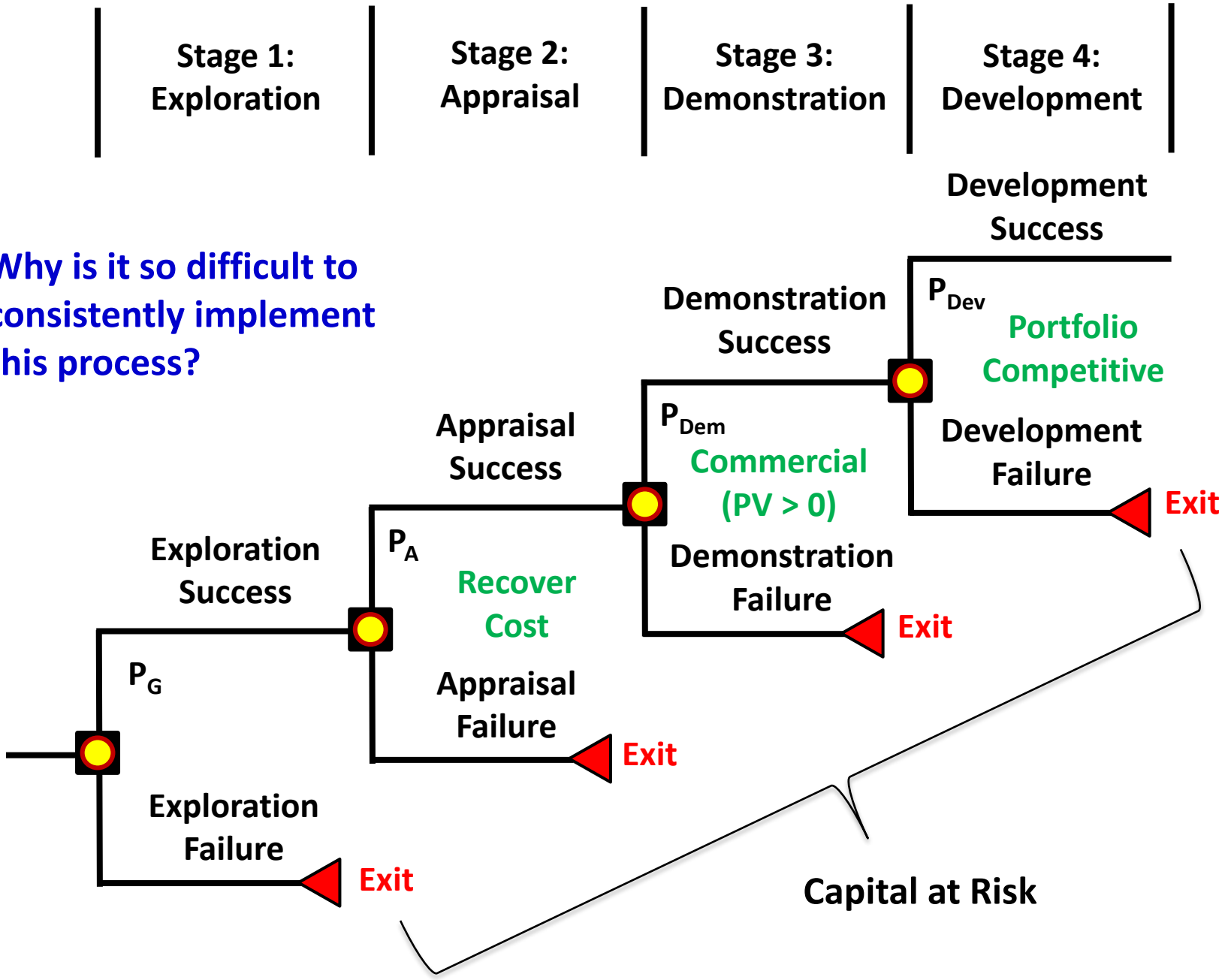


Mean Cumulative Oil Per Well ~ 87 M bbls

At $80 oil, need 42.5 M bbls to cover a well cost of $3.4 MM

Production data from the Colorado Oil and Gas Conservation Commission

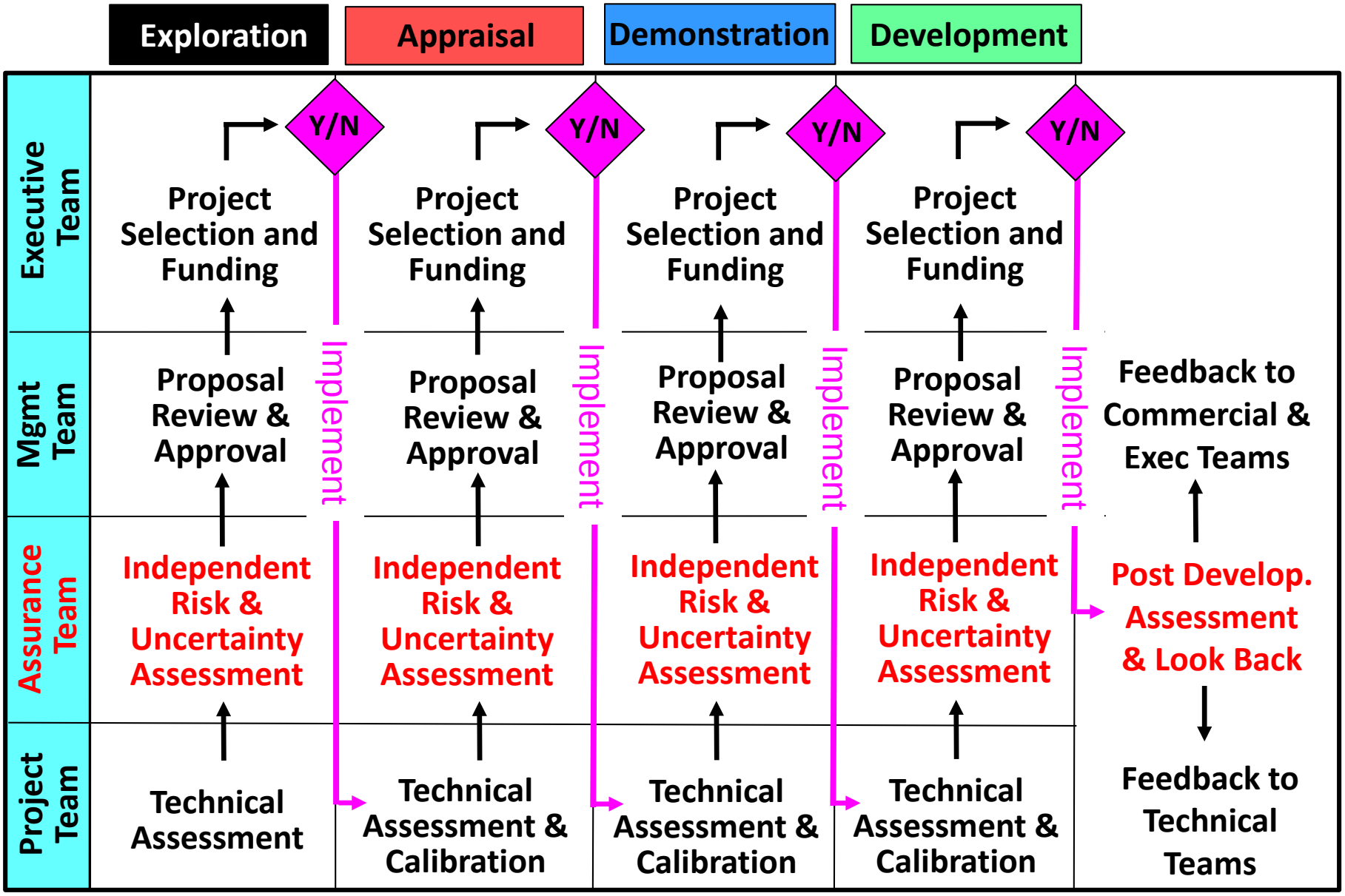
The Staged Approach



The Assurance Process

- **Standards** such as minimum economic metrics and project size
- **Guidelines** including use of the staged approach
- **Workflows** that are discipline specific and tied to the staged decision tree, sets of deliverables, and KPIs
- **Peer assists** conducted with an independent external prospective to help ensure projects are properly focused
- **Documentation** to create a record of what was planned, predicted, and actually achieved
- **Lookbacks** to calibrate the outcomes and make changes that result in closer correspondence between what's promised and delivered in the future

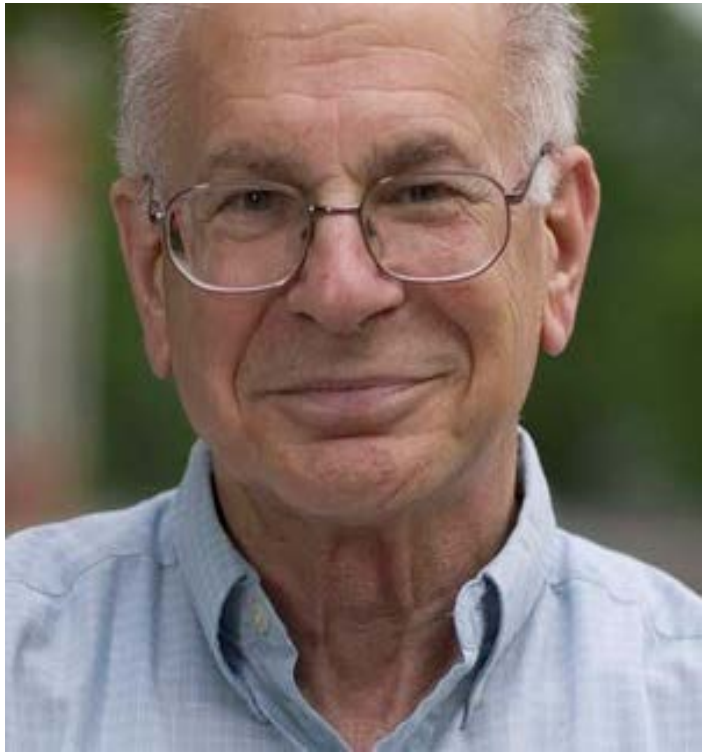
The Role of the Assurance Team in a Staged Evaluation



Key Questions for Decision Makers to Ask

- What is the source of the numbers that justify the recommendation?
- Does the recommendation assume that an approach that is successful in one area will be just as successful in another?
- Is there an over-attachment to a history of past decisions or to a rare but memorable success?
- Is the base case too optimistic? Too pessimistic?
- Were there dissenting opinions leading up to the recommendation? How was this resolved?
- If we delay a decision on this project for one year, what data would you gather in the interim and what impact could this have?

A Concluding Thought



"If I had one wish, it is to see organizations dedicating some effort to study their own decision processes and their own mistakes, and keep track so as to learn from those mistakes."

Daniel Kahneman – "Thought Leader" by Michael Scrage

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How to Avoid Squandering Billions of Dollars Next Time

Thank You! Questions?

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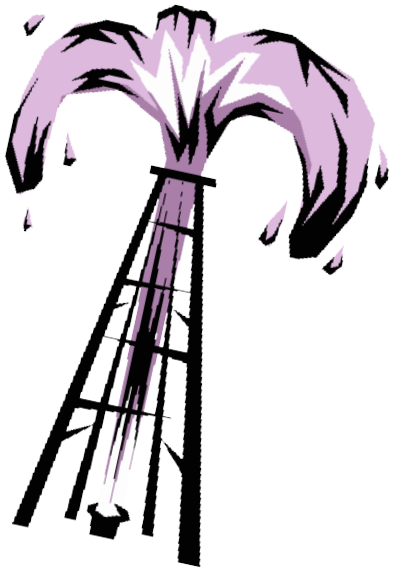

Send me an Email if you want a copy of the slides, drilling simulator, and our SPE paper