Multivariate Statistical Analysis of Montney Completions: Taking Aim at Design Improvements

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Data | Intelligence | Expertise

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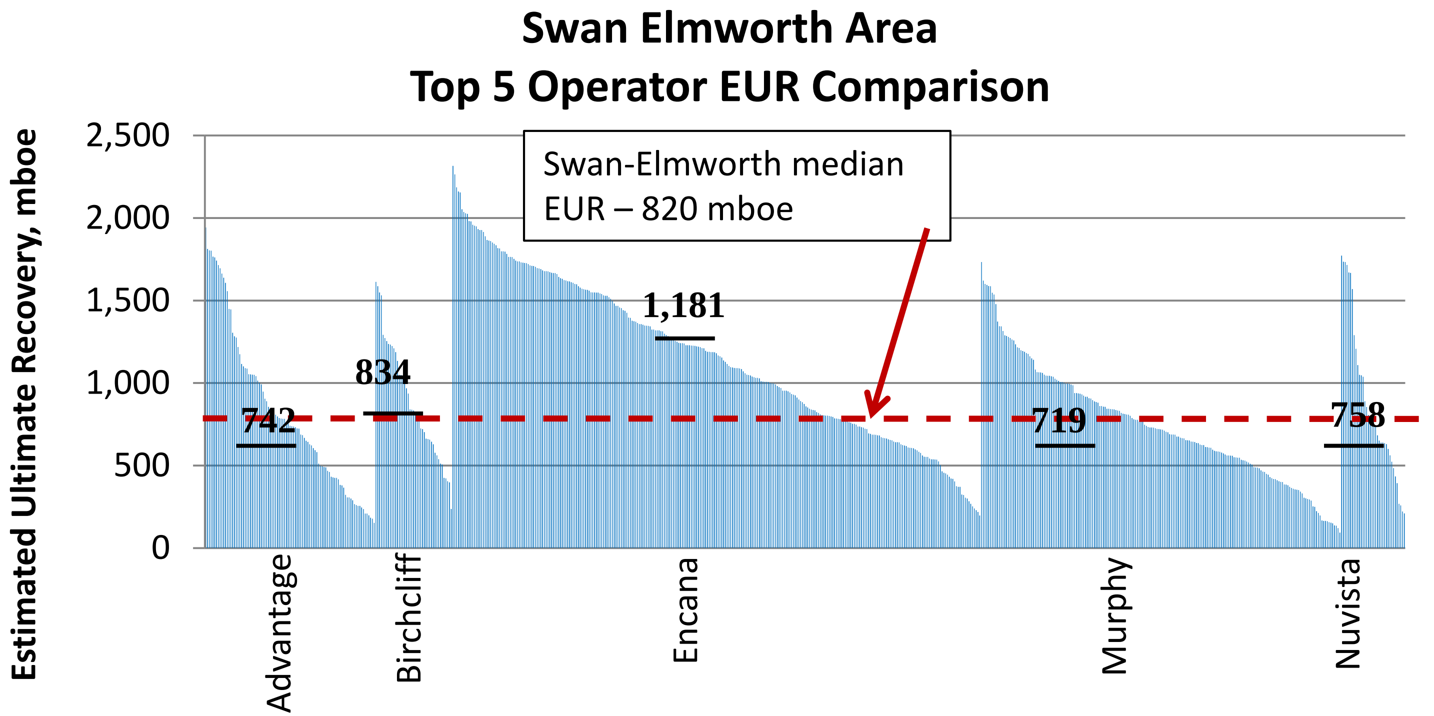
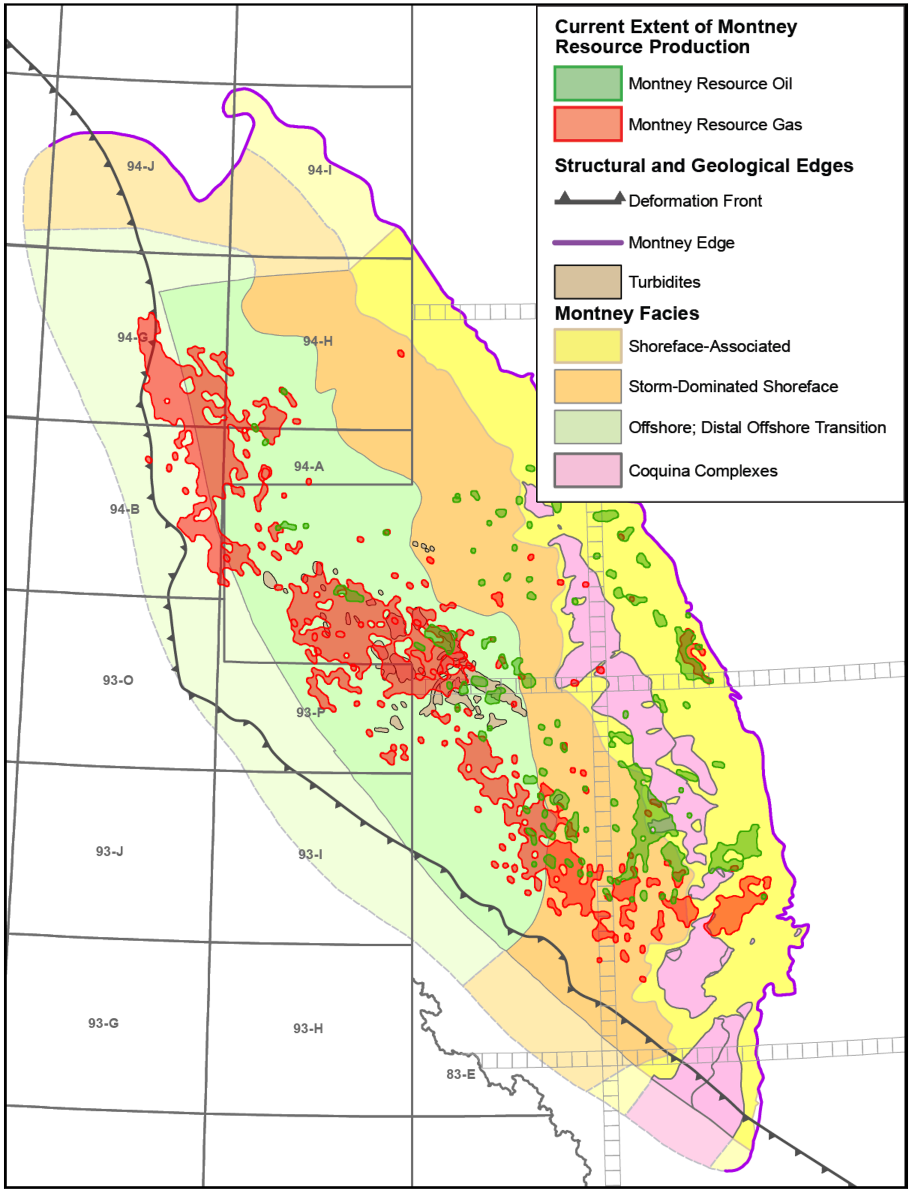
Background

CAPABLE OPERATORS WITH VARYING RESULTS



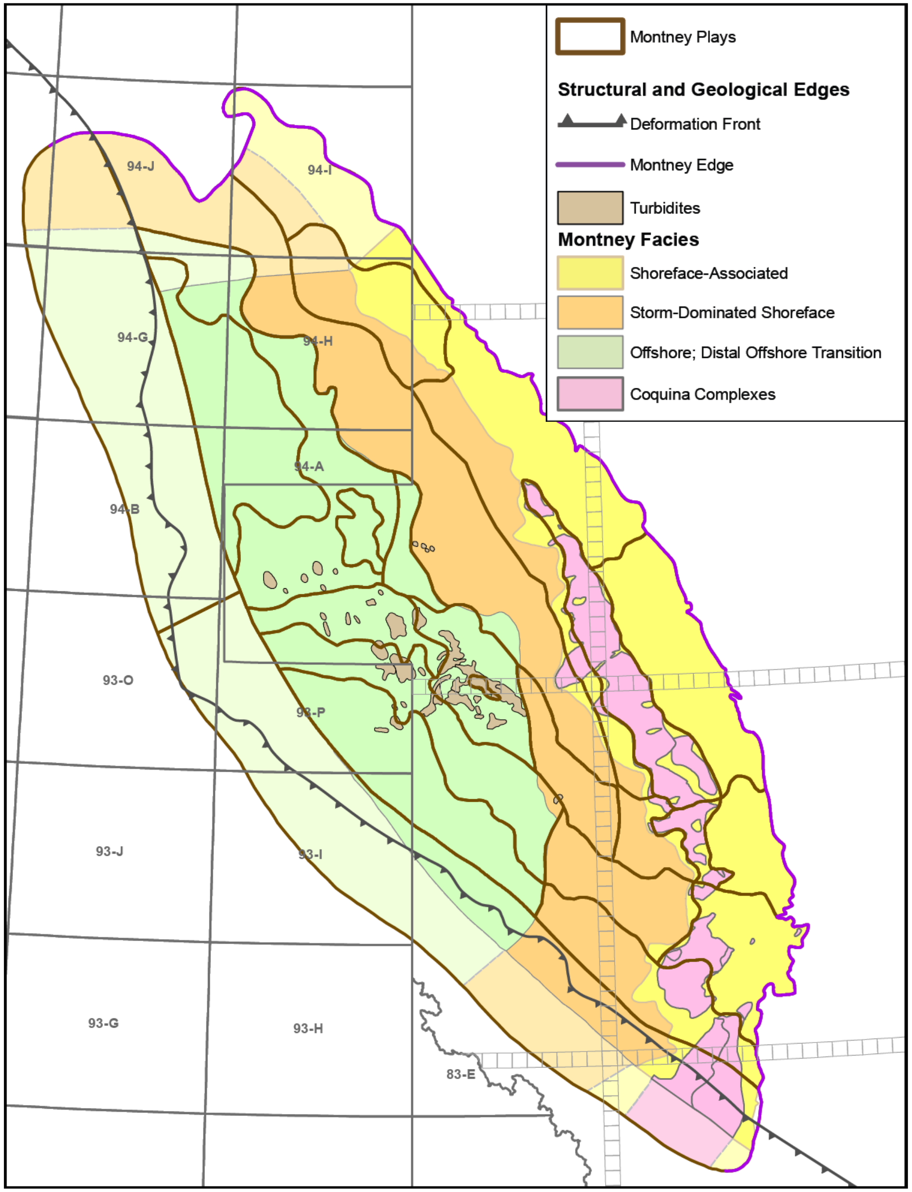
- Within Swan-Elmworth, the Estimated Ultimate Recovery (EUR) varies widely
  - 817 mboe is the median EUR
  - 15 active operators, 824 total wells
- Operators also see a range of recoveries.
  - Median EUR, mboe
    - ECA 1,181
    - BIR 834
    - NVA 758
    - AAV 742
    - MUR 719

THE MONTNEY IS MASSIVE
Considerable Variability



- Montney covers of 130,000 km^2
  - Reservoir thickness ranging from 100m to 300m
- Produces the full spectrum of hydrocarbons:
  - Oil
  - Liquid rich natural gas
  - Dry Gas
- Over 4,800 wells drilled
  - TVD 1,200m to 3,100m
  - Lateral lengths up to 2,500m

NOT ALL MONTNEY IS CREATED EQUALLY
22 Distinct Play Areas



- Four primary facies
  - Facies determines the reservoir capacity and impacts productivity
- Four temperature regimes
  - Temperature determines the maturity of the hydrocarbon
- Six pressure regimes
  - Pressure determines the productivity and ultimate recovery of the wells
- 22 plays identified from 96 possible plays

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VARIABLE OUTCOMES
Uncontrollable vs. Controllable Factors

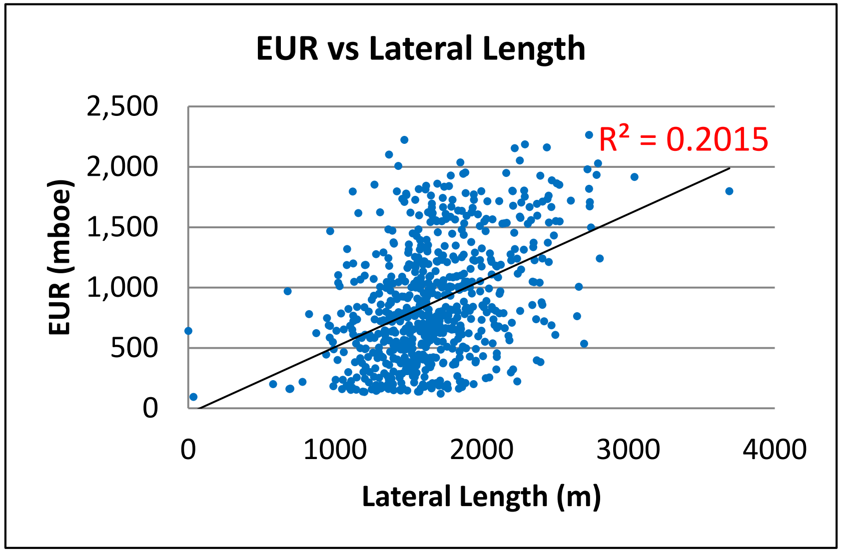
- Uncontrollable variables are beyond what operators can influence:
  - Reservoir characteristics: pressure, temperature, porosity, permeability
  - Rock properties: ductility, geochemistry, rock stress

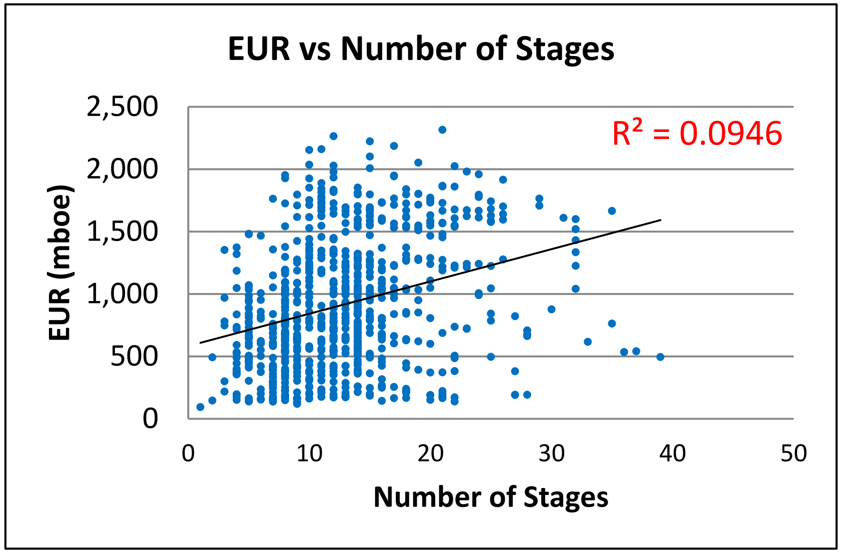
- Controllable variables are design and operational decisions that influence outcomes
  - Drilling: fluid systems, well spacing, lateral length, casing system
  - Completions: technology, fluid (type, volume), proppant (type, blend, tonnage), stages (number, spacing)

Factors in All Completions Designs

Multivariate Analysis
Influential controllable factors

What and Why



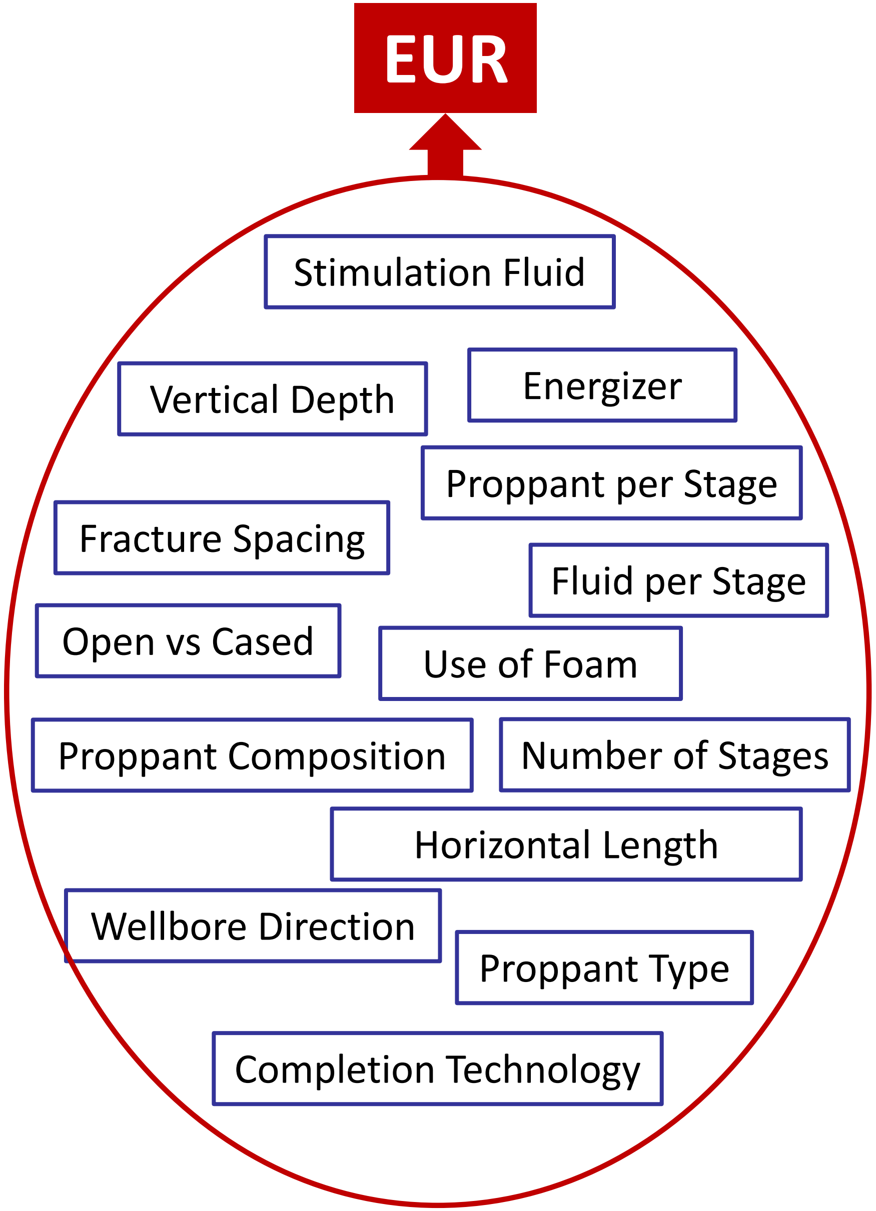


- Relationship between well performance and geologic/engineering variables is:
  - Non-linear
  - Dominated by complex interactions between variables
- Multivariate statistics aims to:
  - Identify variables that have the largest effect on outcome
  - Group wells according to similar inputs and outputs
  - Discover complex relationships in your data

AN OLD FASHIONED OPTIMIZATION PROBLEM

- Which completion variable(s) and in what amounts will most beneficially influence ultimate recovery
- Select a play area with a consistent subset of uncontrollable variables
- The analysis focuses on the impact of controllable completion variables

BUILDING A DECISION TREE
Establishing Differences



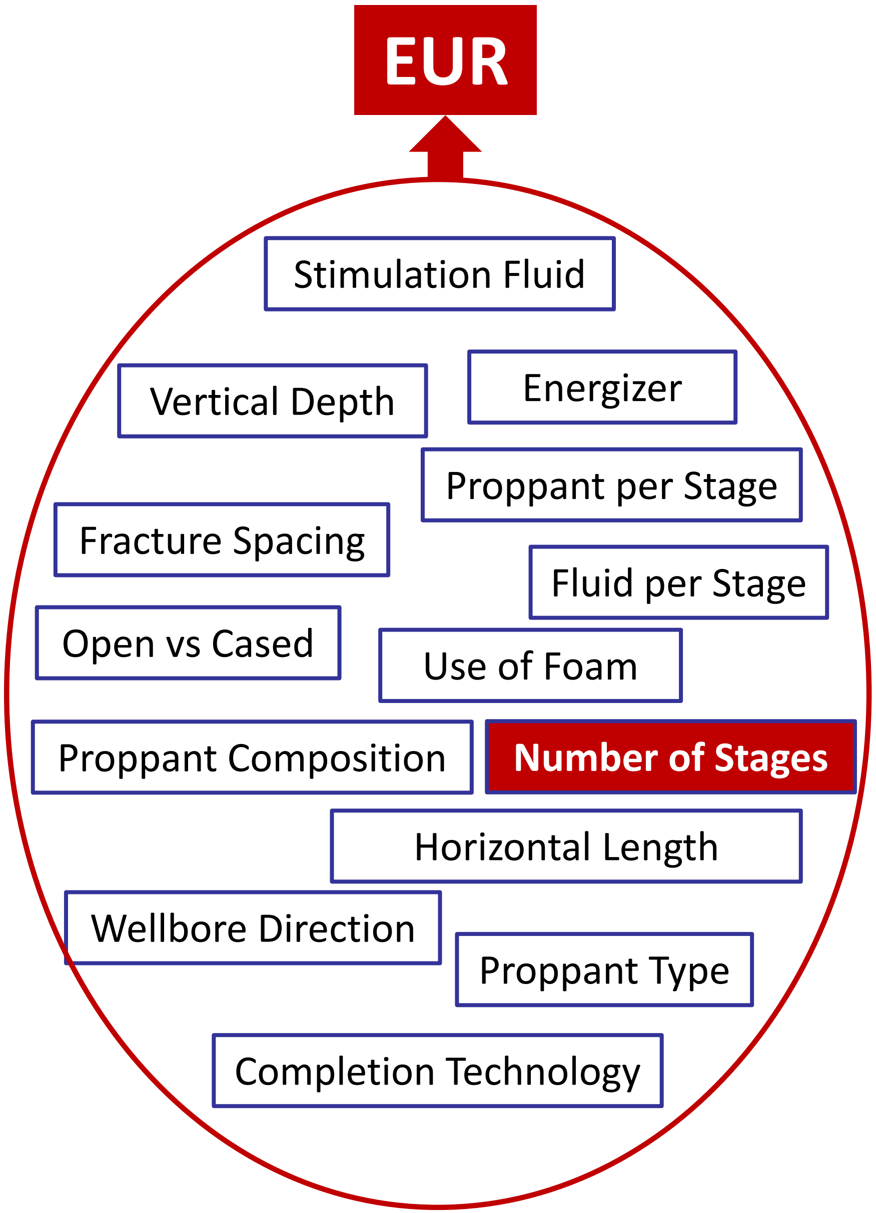
Step 1:

Is there dependence between EUR and any of the variables?

Yes: Go to Step 2

No: Stop growing the tree

BUILDING A DECISION TREE
Strongest Associations



Step 1:

Is there dependence between EUR and any of the variables?

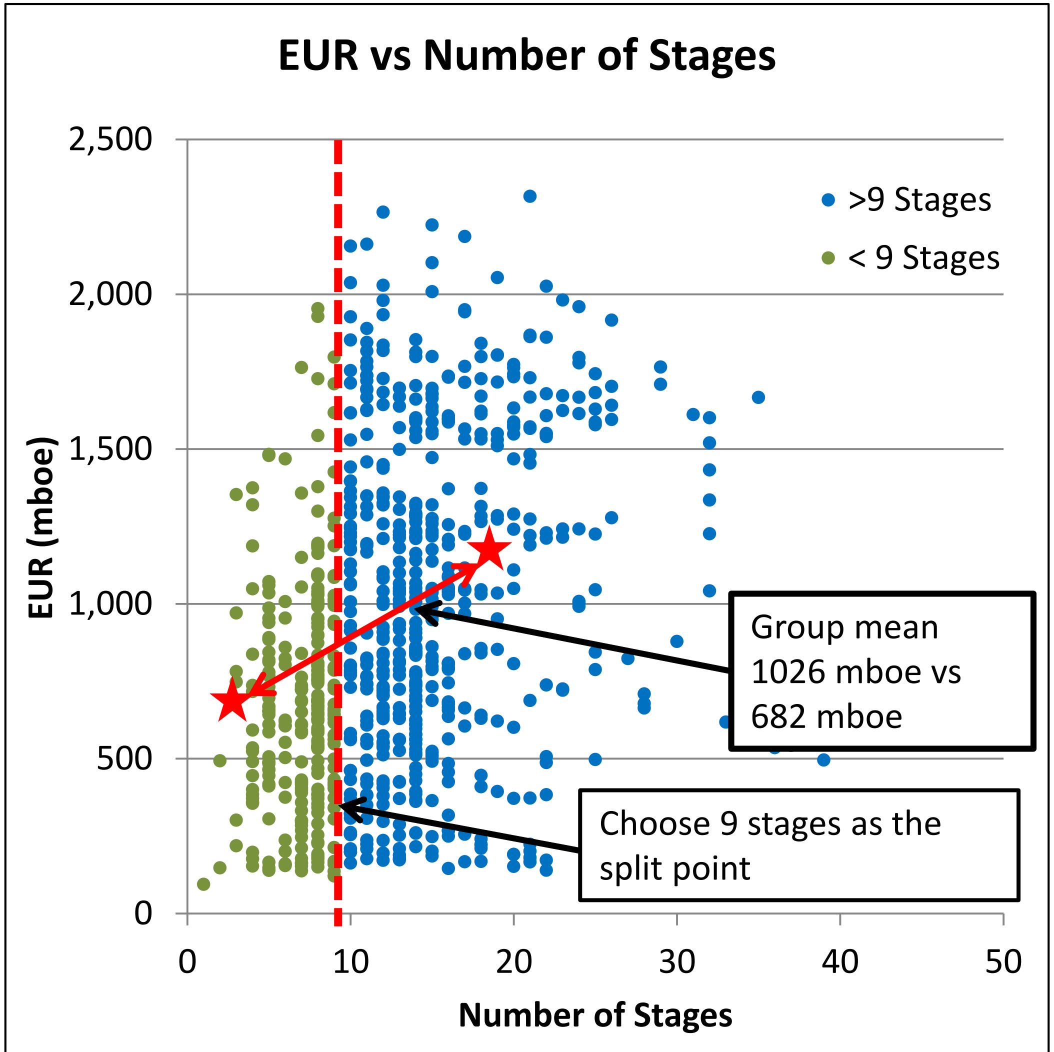
Yes: Go to Step 2

No: Stop growing the tree

Step 2:

Find the variable that has the strongest association to EUR (using a Chi squared test)

BUILDING A DECISION TREE
Identifying The Impact



Step 1:

Is there dependence between EUR and any of the variables?

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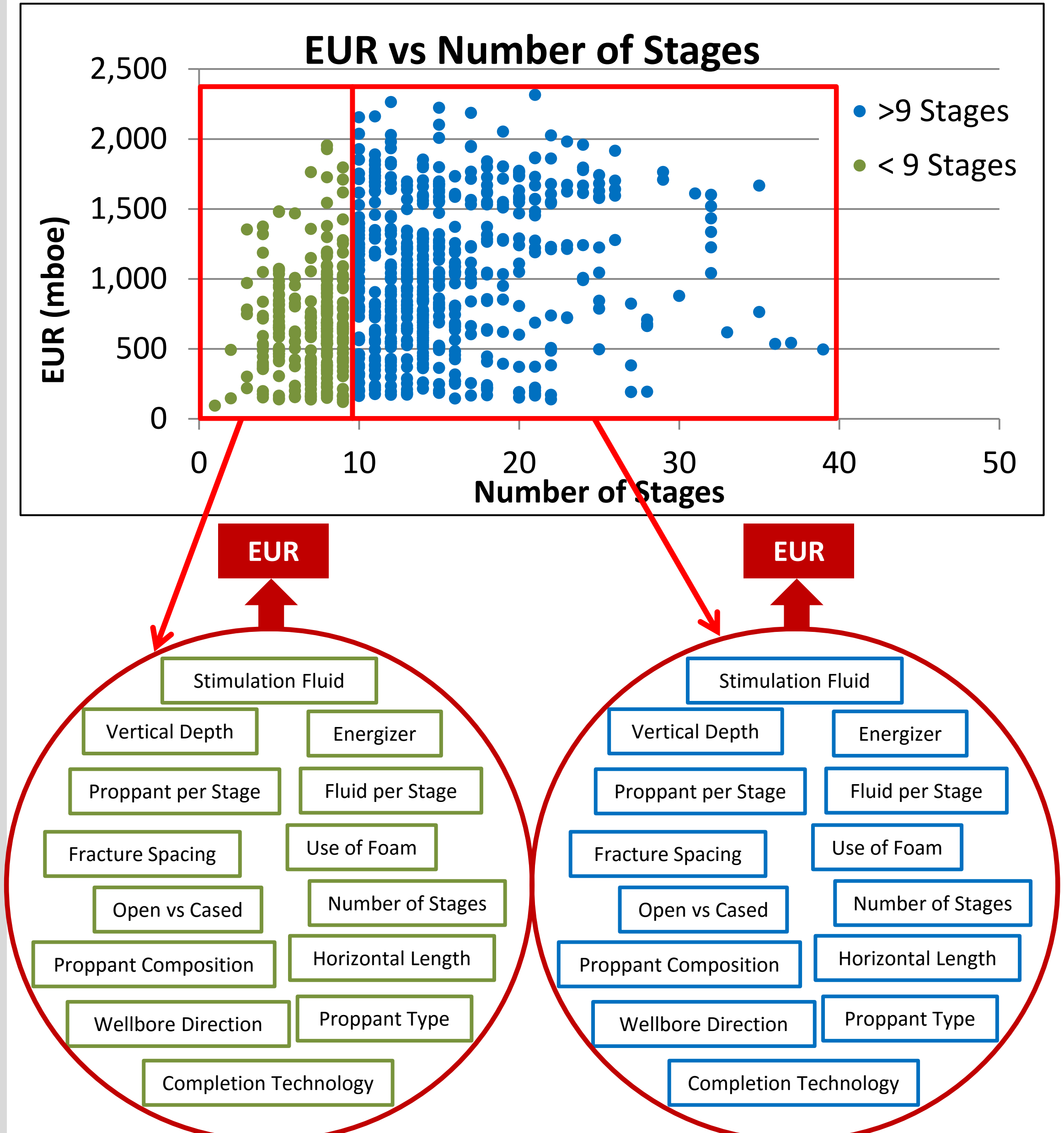
Find the variable that has the strongest association to EUR (using a Chi squared test)

Step 3:

Find the split point of the variable that results in the largest difference between the mean of two groups

BUILDING A DECISION TREE
Finding the Next Factor



Step 1:

Is there dependence between EUR and any of the variables?

Yes: Go to Step 2

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Step 2:

Find the variable that has the strongest association to EUR (using a Chi squared test)

Step 3:

Find the split point of the variable that results in the largest difference between the mean of two groups

Step 4:

Repeat steps 1-3 on each of the sub groups

RECURSIVE PARTITIONING
Resulting Decision Tree

Outcomes

Path to Optimal Design

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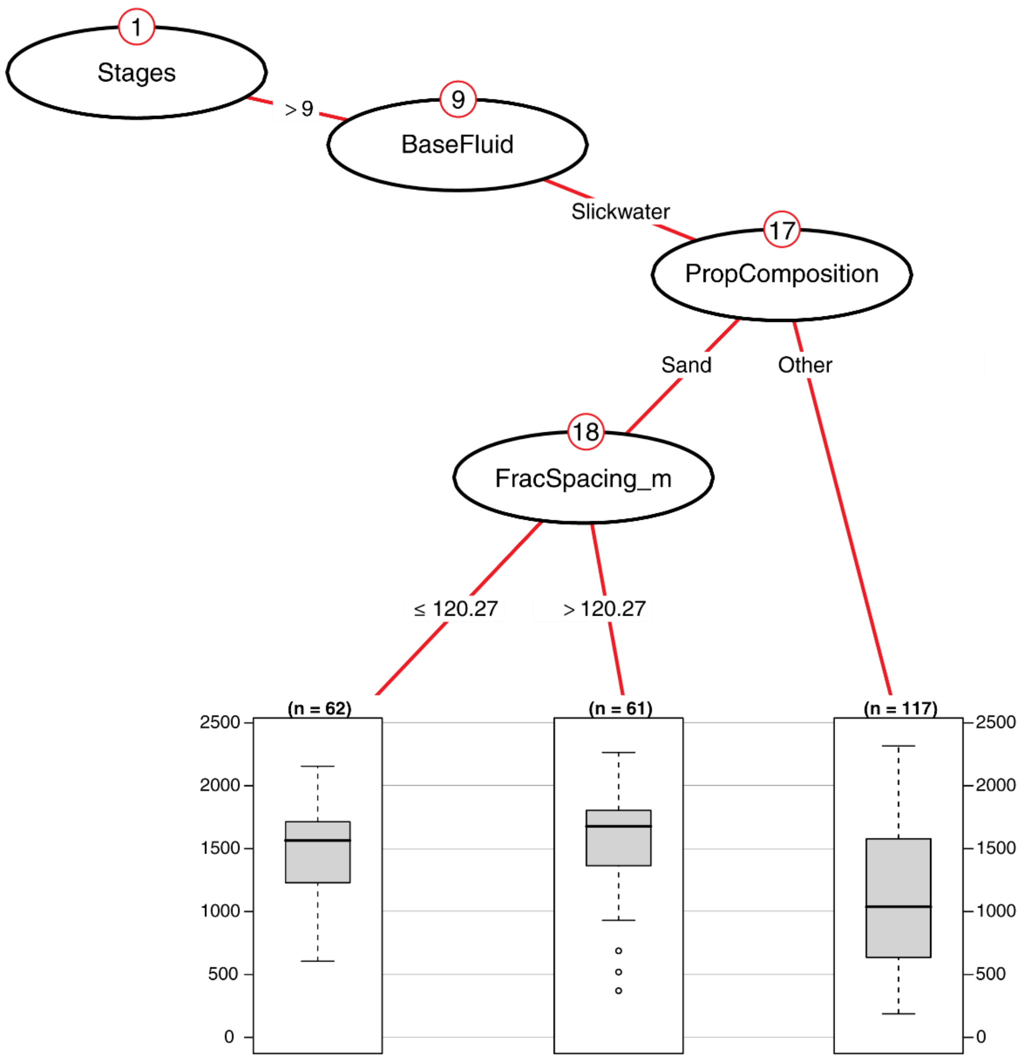
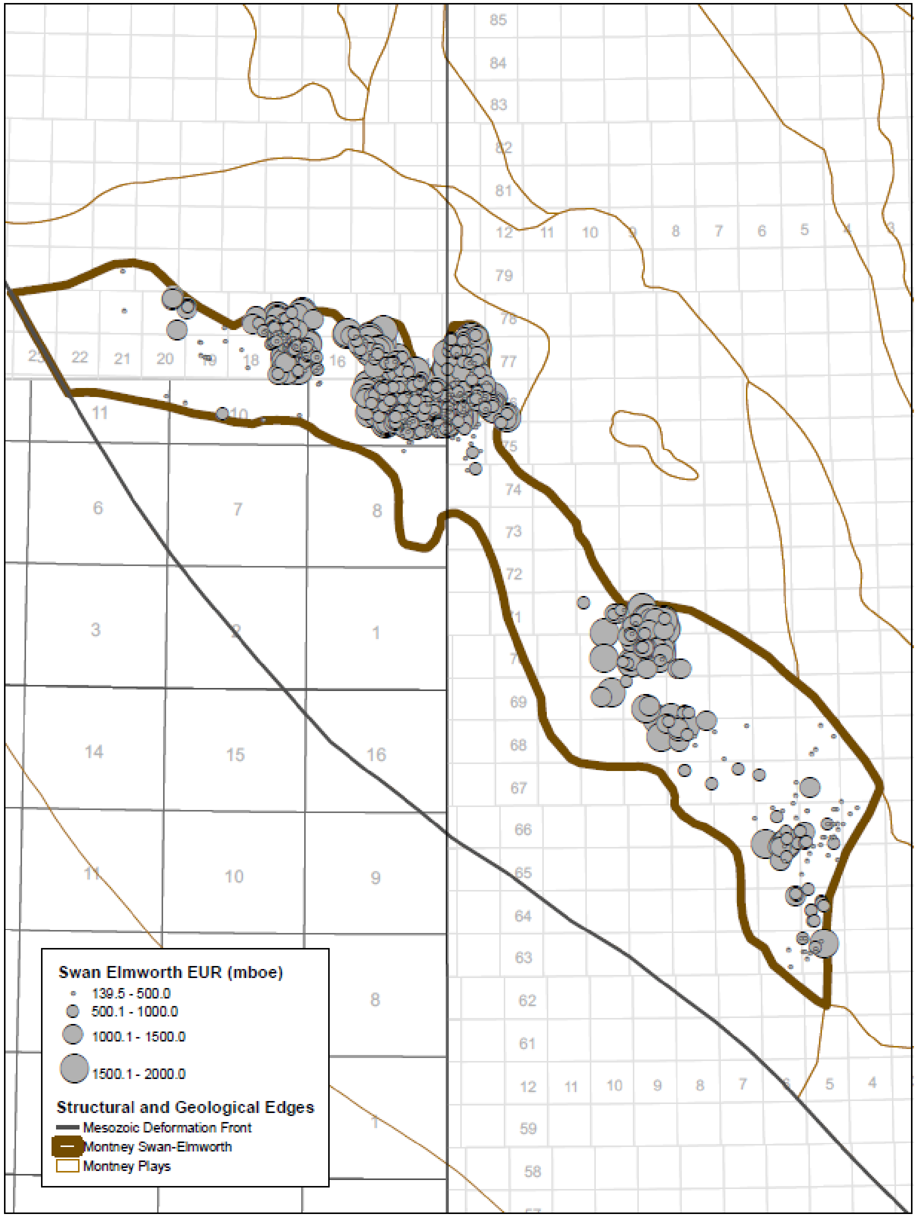
OPTIMAL PATH
Toward Maximum EUR



- The path to the group with the highest median EUR
- Four key factors to maximize EUR
  - Stages > 9
  - Frac Fluid – Slickwater
  - Proppant Composition – Sand or Combination Ceramic/Resin-Coated/Sand
  - Fracture Spacing > 120 m

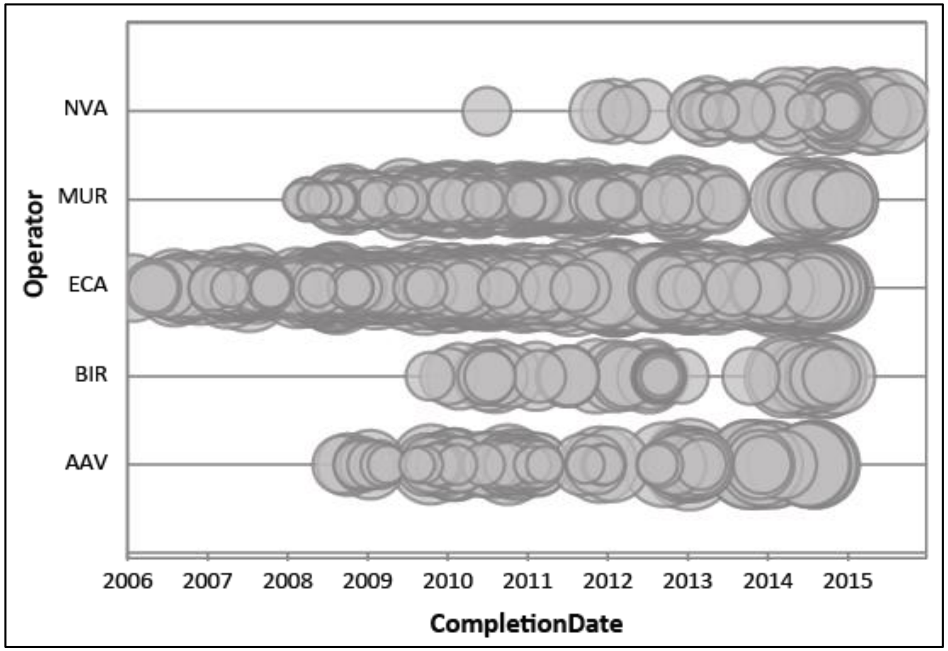
HIGH EUR EVOLUTION
Entire Swan-Elmworth Area, 824 Wells

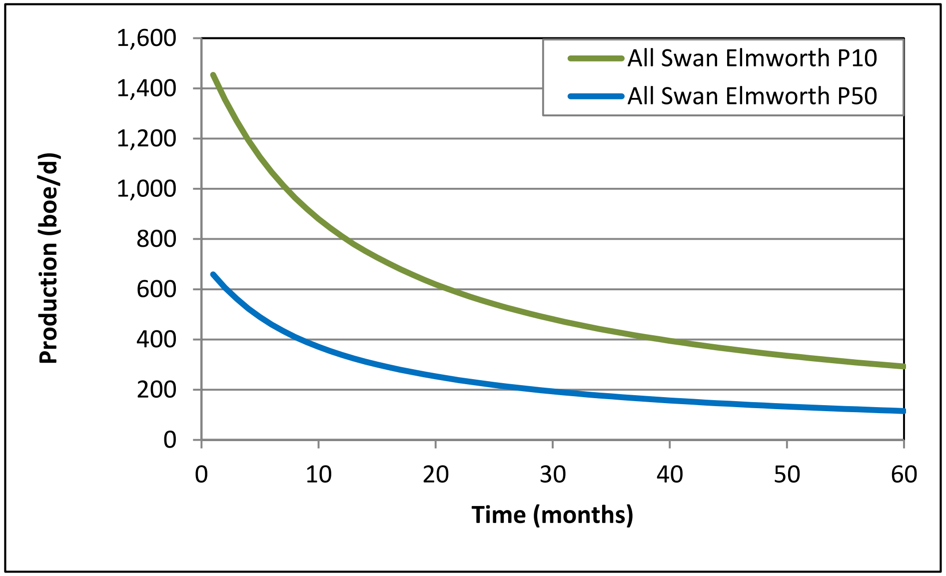


- The Swan-Elmworth Area has 824 wells
- EURs
  - P10: 1,969 mboe
  - P50: 754 mboe
  - P90: 173 mboe

HIGH EUR EVOLUTION

Entire Swan-Elmworth Area, 824 Wells





- Focus on the top 5 operators out of 15 active in the area

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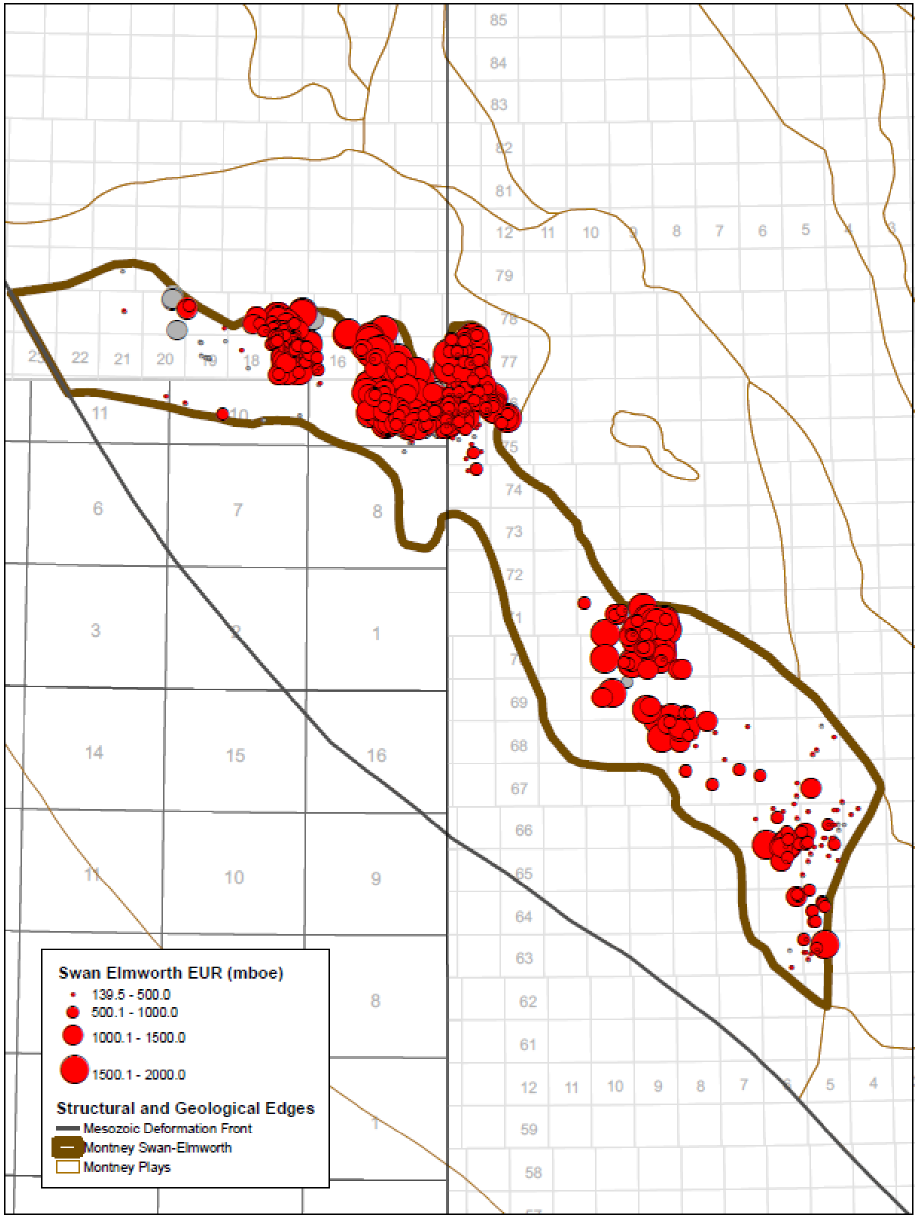
HIGH EUR EVOLUTION
1: Wells With Stages > 9

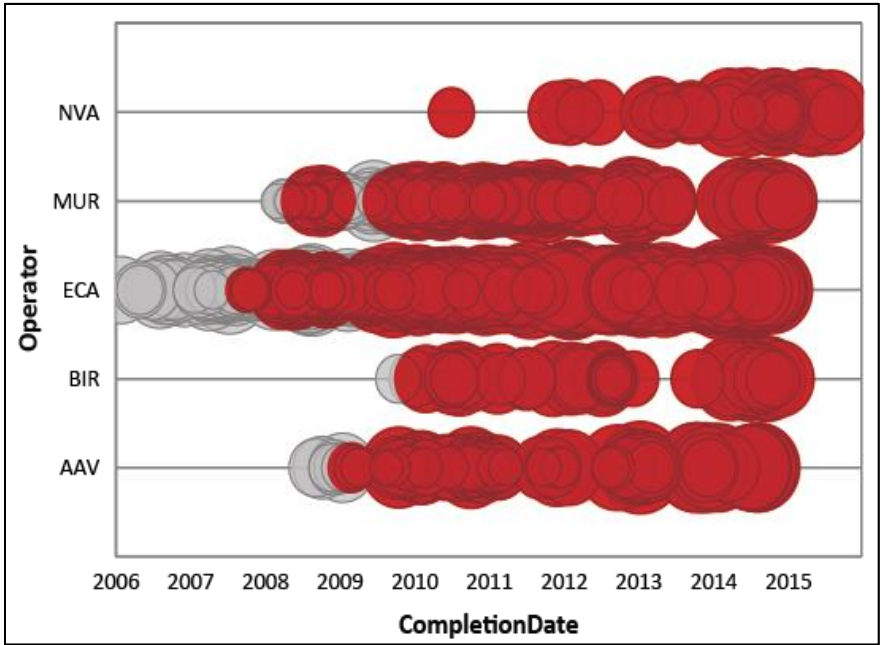


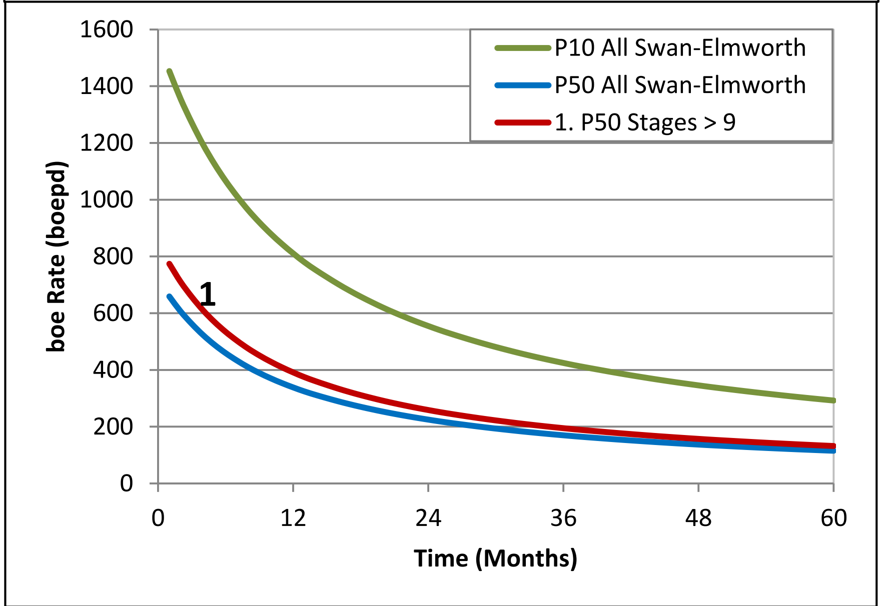
- Wells with more than 9 completed stages, 552 wells
- EURs
  - P10: 2,358 mboe
  - P50: 878 mboe
  - P90: 229 mboe

CATALYST

WELL COMPLETIONS & FRAC DATABASE

HIGH EUR EVOLUTION
1: Wells With Stages > 9





- Over time operators have universally adopted completions with more than 9 stages.
- EURs have increased

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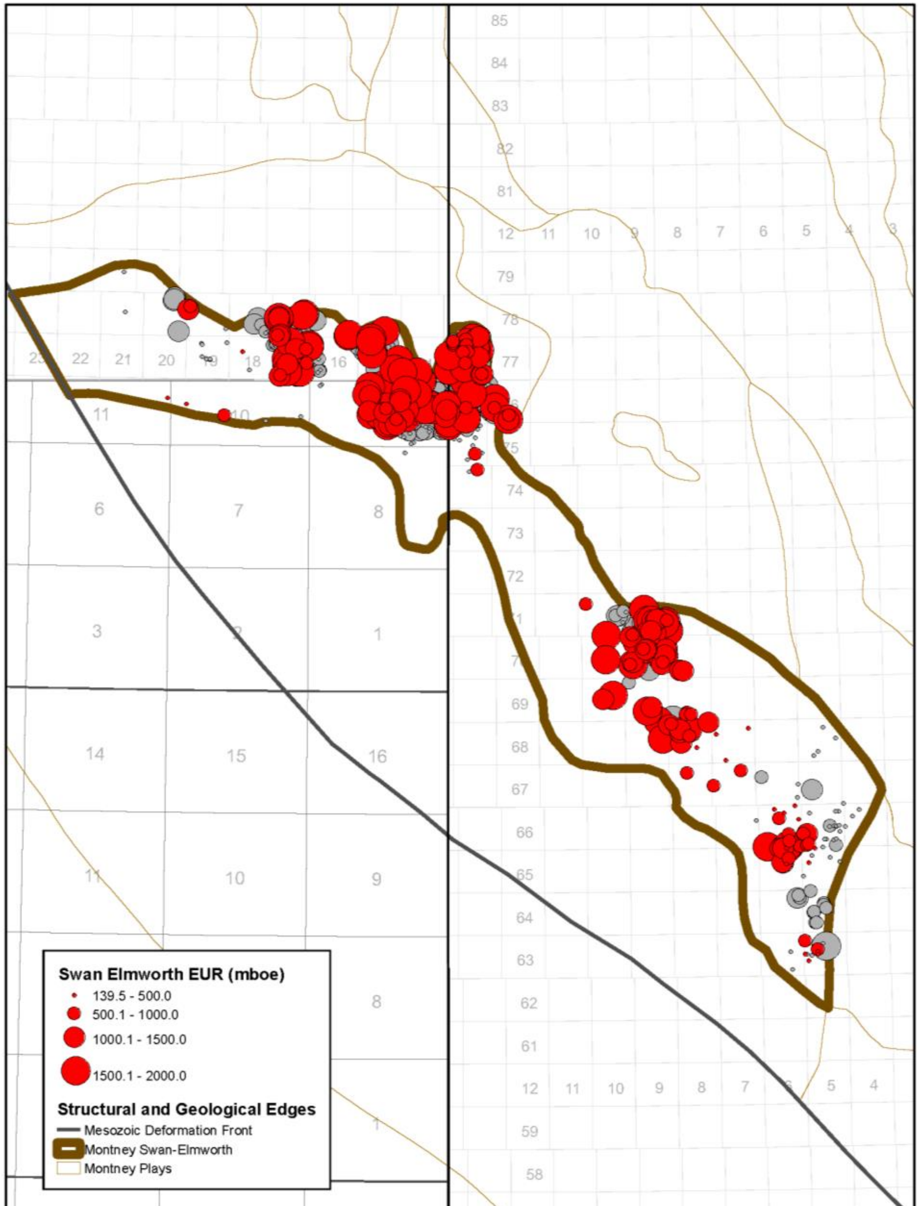
HIGH EUR EVOLUTION
2: Frac Fluid - Slickwater

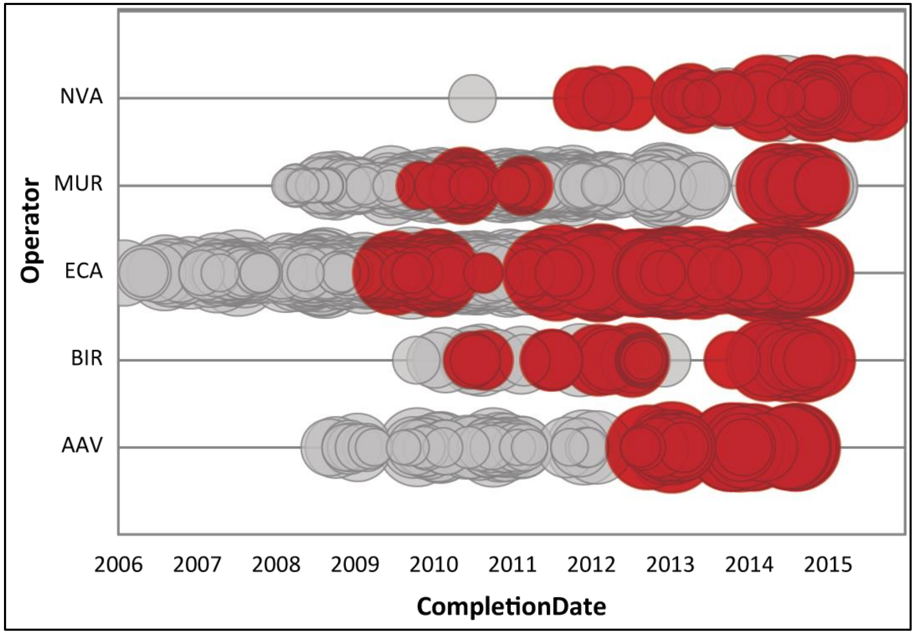


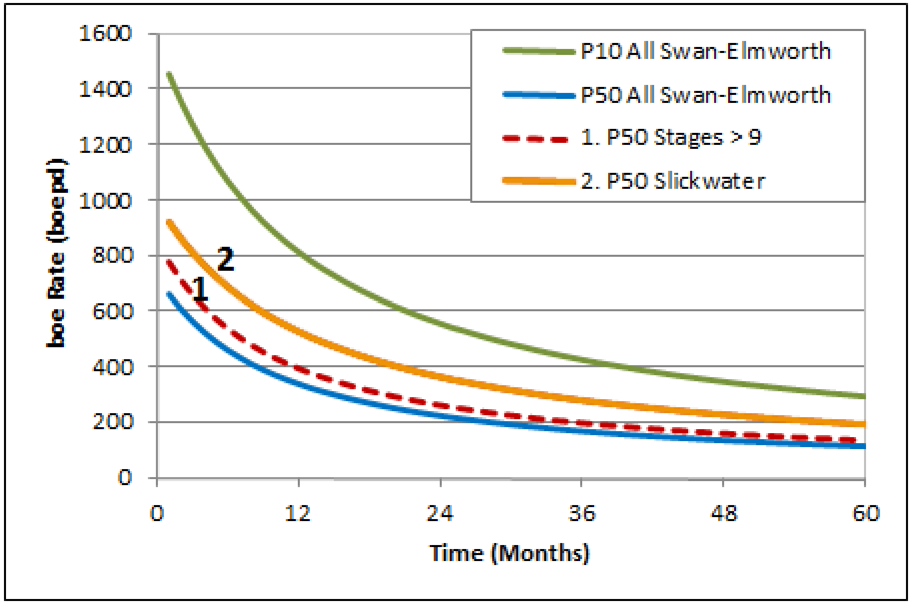
- Wells completed with Slickwater and more than 9 completed stages, 240 wells
- EURs
  - P10: 3,423 mboe
  - P50: 1,285 mboe
  - P90: 297 mboe

CATALYST

WELL COMPLETIONS & FRAC DATABASE

HIGH EUR EVOLUTION
2: Frac Fluid - Slickwater





- As operators continue operations, Slickwater becomes the dominant completion fluid system.
- Median EURs are consistently higher than the with other completion fluids

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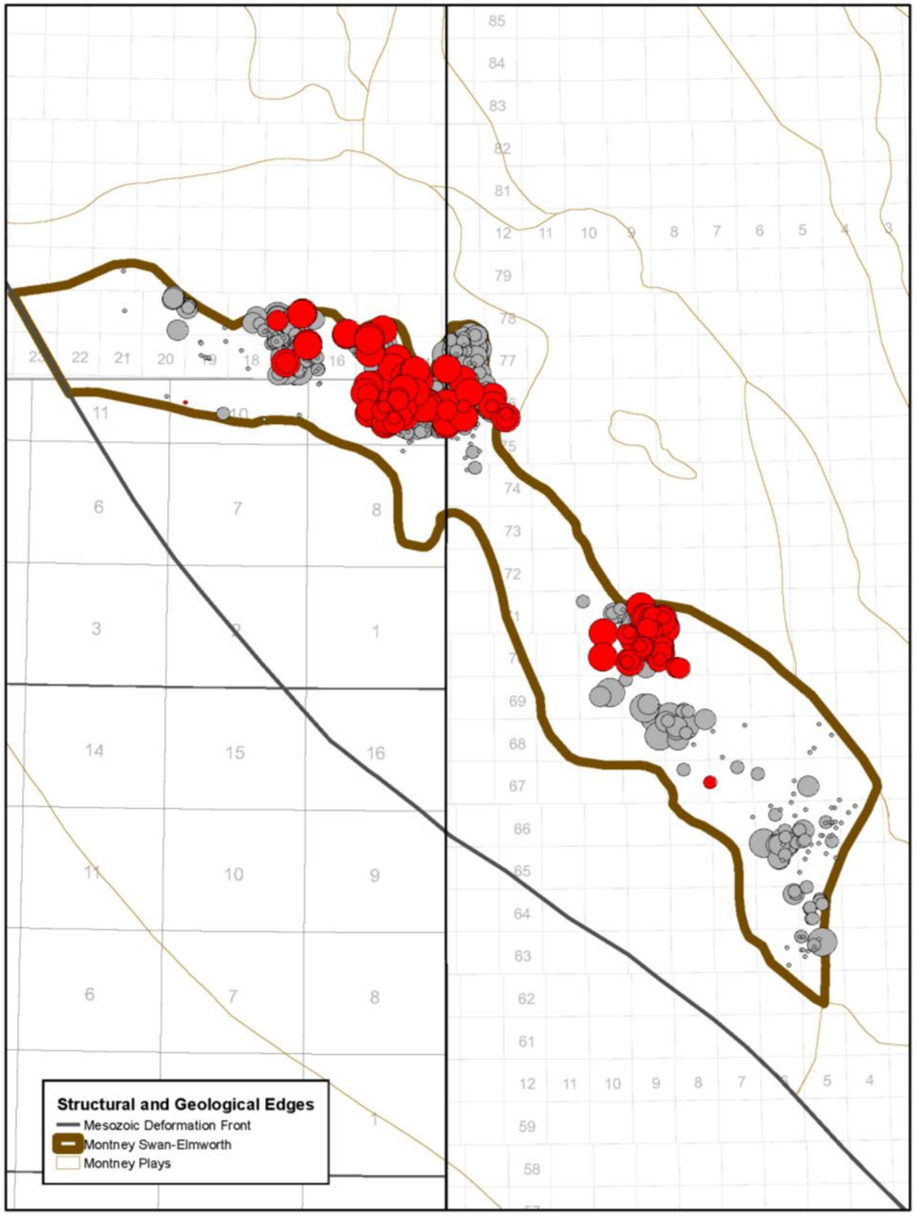
HIGH EUR EVOLUTION
3: Proppant Composition – Sand

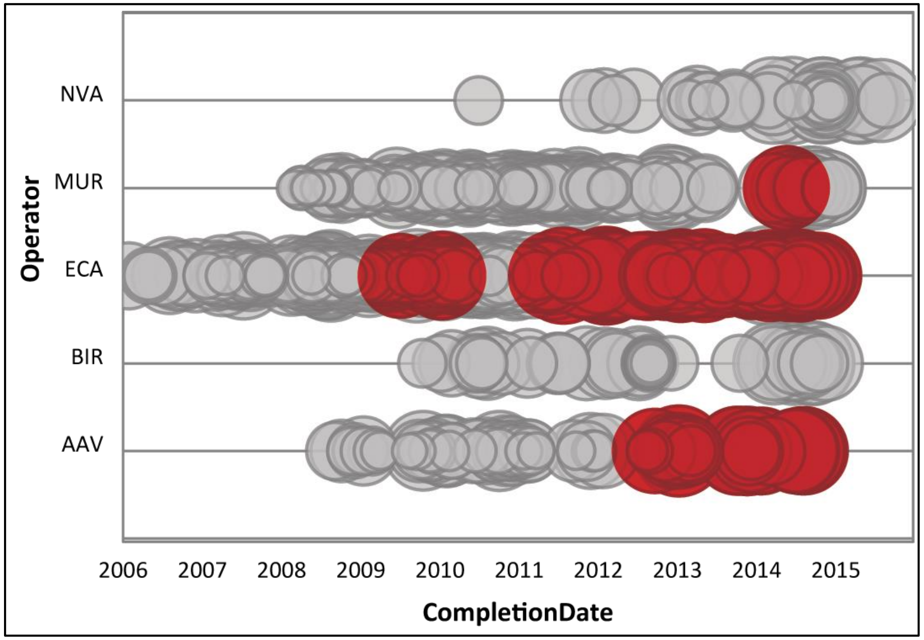


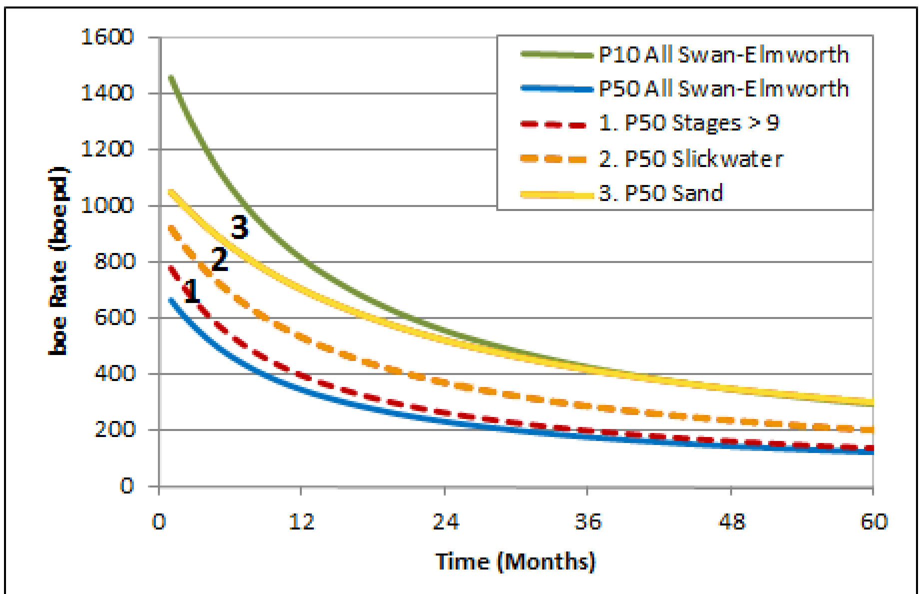
- Wells using sand proppant or a combination of proppants, Slickwater and more than 9 stages, 121 wells
- EURs
  - P10: 3,919 mboe
  - P50: 1,927 mboe
  - P90: 748 mboe

CATALYST

WELL COMPLETIONS & FRAC DATABASE

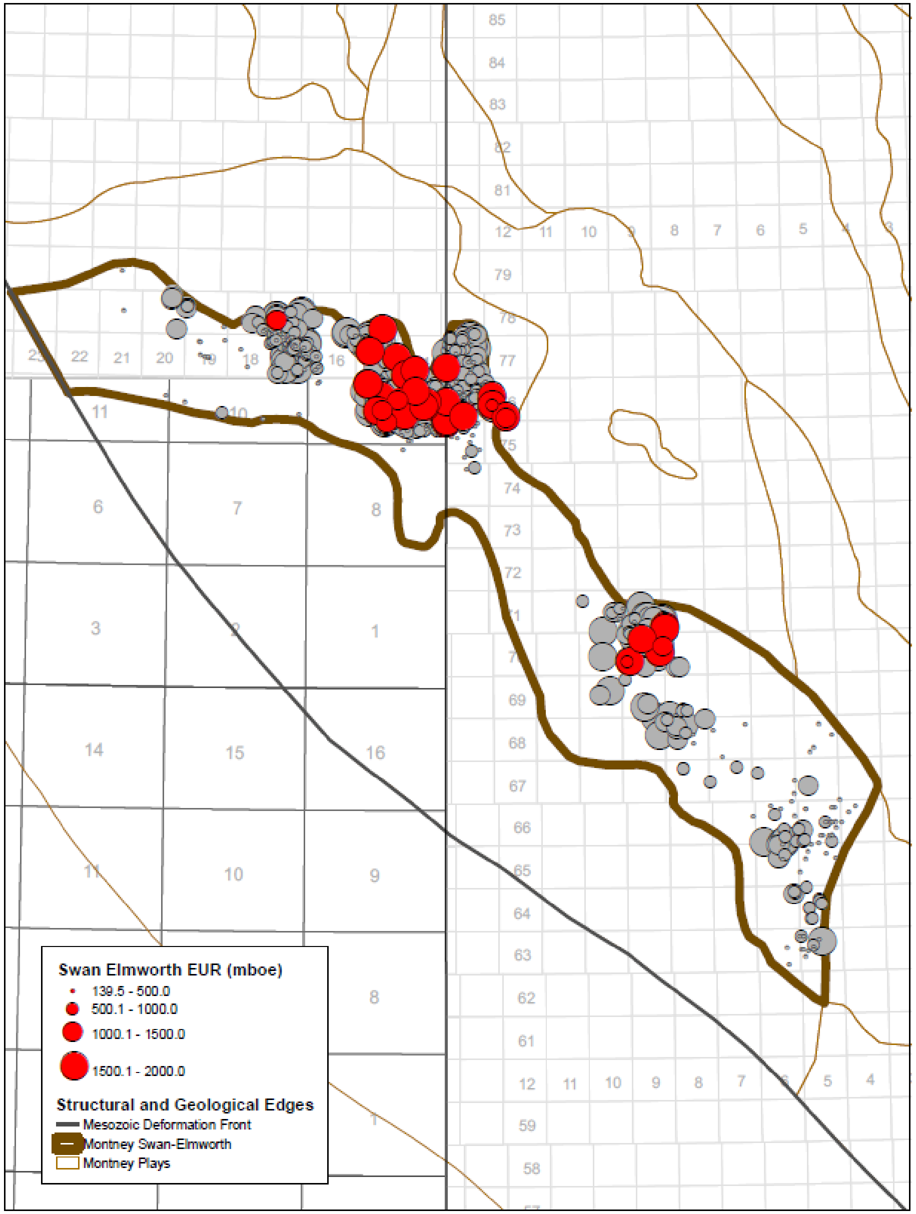
HIGH EUR EVOLUTION
3: Proppant Composition – Sand





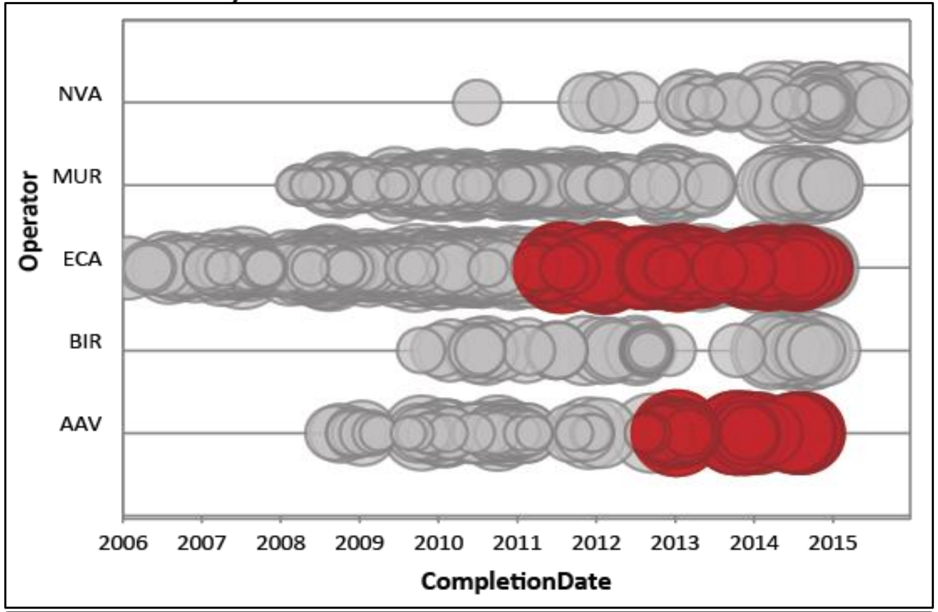
- Encana and Advantage have gravitated to this proppant blend
- This blend developed over time

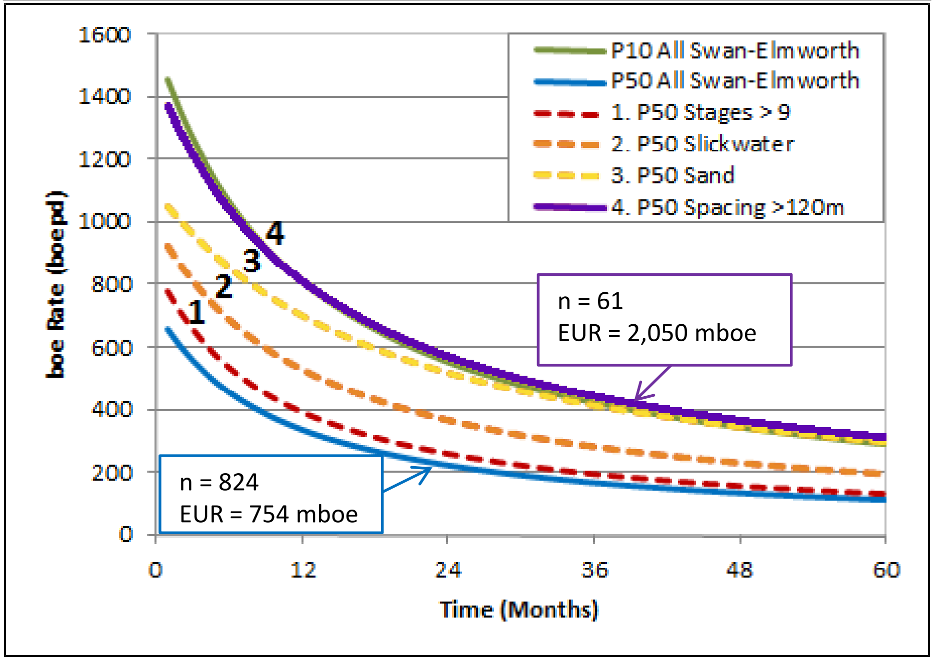
HIGH EUR EVOLUTION
4: Stage Spacing > 120m



- Wells with stages more than 120m apart, sand or combination proppant blends, Slickwater and more than 9 stages, 61 wells
- EURs
  - P10: 3,851 mboe
  - P50: 2,050 mboe
  - P90: 724 mboe

HIGH EUR EVOLUTION
4: Stage Spacing > 120m





- Two operators, Encana and Advantage, entirely dominate this group.
- The optimal completion has a P50 EUR is significantly above the overall P50 and is approaching the P10 for the entire Swan-Elmworth play

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Optimal Design
Who's putting it to use?

Operator		ECA	AAV	ARX	
Well Count		45	14	2	61
Tech	Plug & Perf		3		5%
	Ball & Seat	29	11		66%
	Plug & Perf (ball)	13		2	25%
	Multiple	3			5%
Fluid	Slickwater	45	14	2	
Stages		15	15	11	
Proppant per stage	Tonnes	135	60	193	
Fluid per stage	m^3	661	429	713	
Hztl Length	m	2,262	1,932	1,502	
Frac Spacing	m	153	127	150	
EUR	mboe	1,678	1,471	1,613	

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Optimal Design
How's it working?

Operator		ECA	AAV	ARX
Well Count		45	14	2
Median Cost, $000's	Completion	3,875	3,888	4,977
	Drilling	2,738	3,094	2,632
	Half Cycle	6,612	6,982	7,610
Efficiency, $ per boe	Completion	2.55	3.10	3.09
	Drilling	1.88	2.39	1.63
	Half Cycle	4.43	5.50	4.72
Efficiency, $000's per 100m hztl section	Completion	180	196	331
	Drilling	130	159	175
	Half Cycle	310	354	507
Efficiency, mboe per 100m hztl section		74	88	107

82% of completions costs are actuals

48% of drilling costs are actuals

What have you done lately? (Since January 2014)

Operator		ECA	AAV	BIR	NVA	MUR
Well Count		43	8	13	21	20
Tech	Plug & Perf	8				
	Ball & Seat	29	8	13	21	20
	Plug & Perf (ball)					
	Multiple	6				
Fluid	Slickwater	43	8	13	21	8
	Surfactant					12
Stages		21	17	15	18	14
Prop per stage	Tonnes	102	60	75	100	100
Fluid per stage	m^3	558	394	434	781	154
Hztl Length	m	2,240	1,855	1,872	1,891	1,689
Frac Spacing	m	117	122	136	110	129
EUR, recent (165)	mboe	1,593	1,619	1,223	1,028	1,195
EUR, overall (824)	mboe	1,181	834	758	742	719

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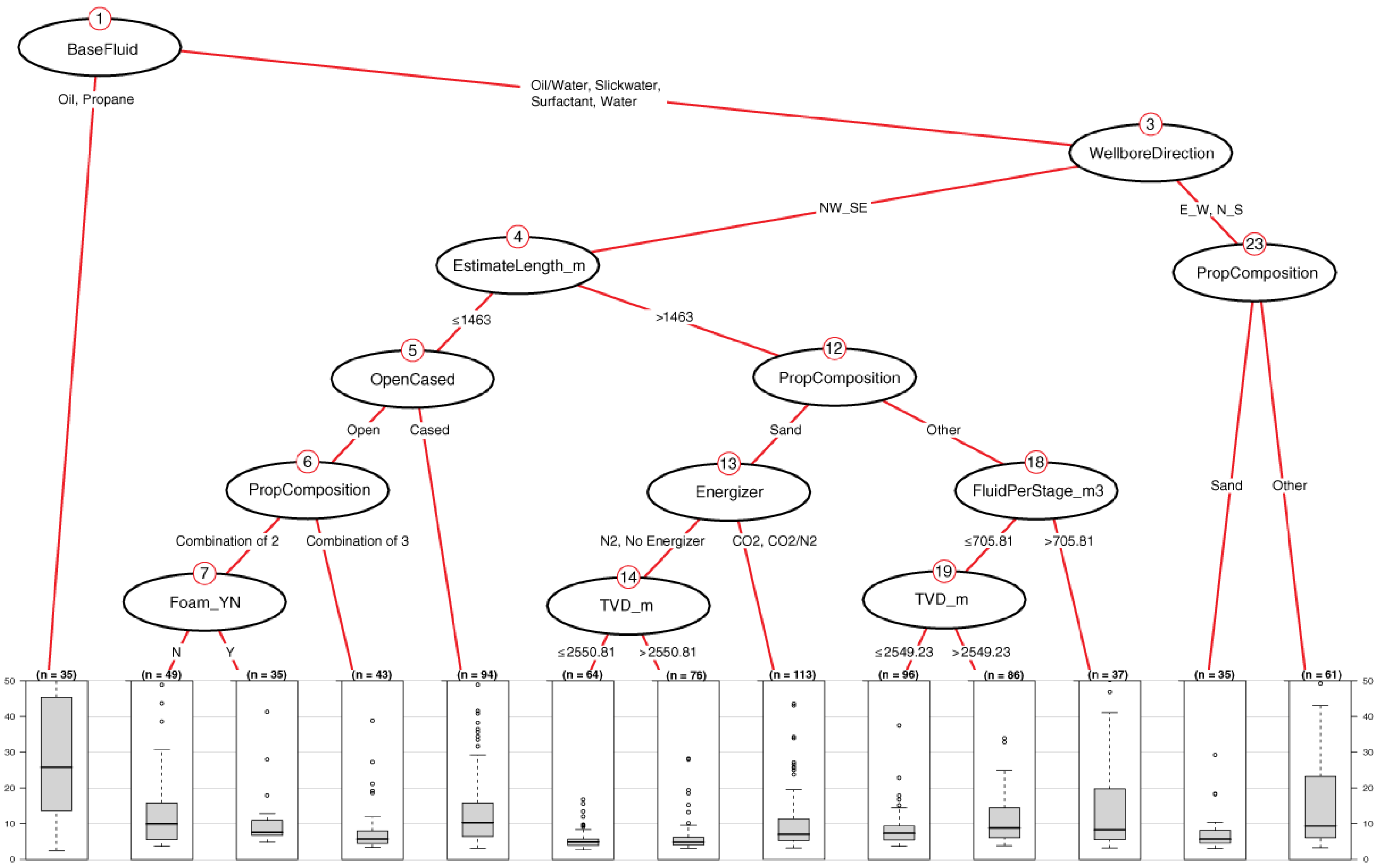
Recent Activity
How's it working? (Since January 2014)

Operator		ECA	AAV	BIR	NVA	MUR
Well Count		43	8	13	21	20
Median Cost, $000's	Completion	4,555	2,872	2,475	3,112	3,634
	Drilling	2,923	2,821	3,127	4,744	3,258
	Half Cycle	7,478	5,693	5,602	7,856	6,892
Efficiency, $/boe	Completion	2.95	1.86	2.12	4.29	3.28
	Drilling	1.94	1.82	2.76	6.40	2.87
	Half Cycle	4.89	3.69	4.88	10.70	6.15
Efficiency, $000's /100m hztl	Completion	203	150	130	171	221
	Drilling	133	150	166	253	192
	Half Cycle	336	300	297	425	413
Efficiency, mboe / 100m hztl		71	86	64	51	72

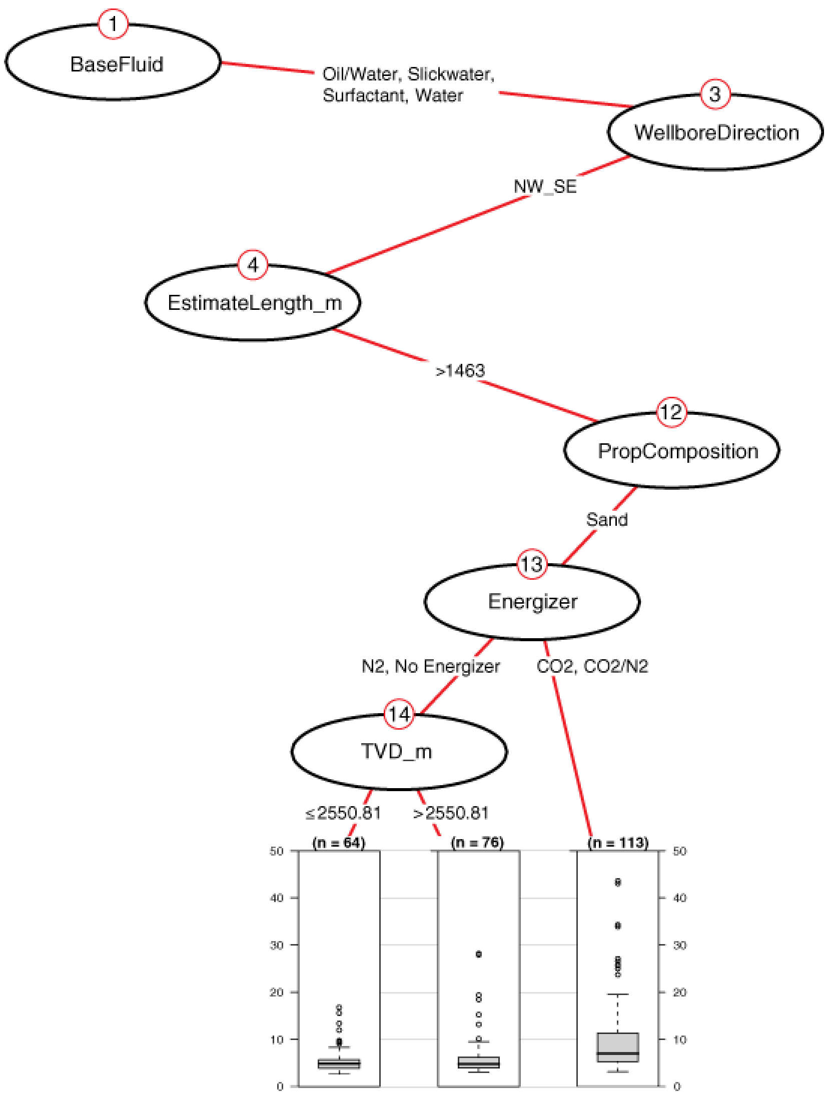
76% of completions costs are actuals

56% of drilling costs are actuals

Designing For Low Cost



LOW COST EVOLUTION



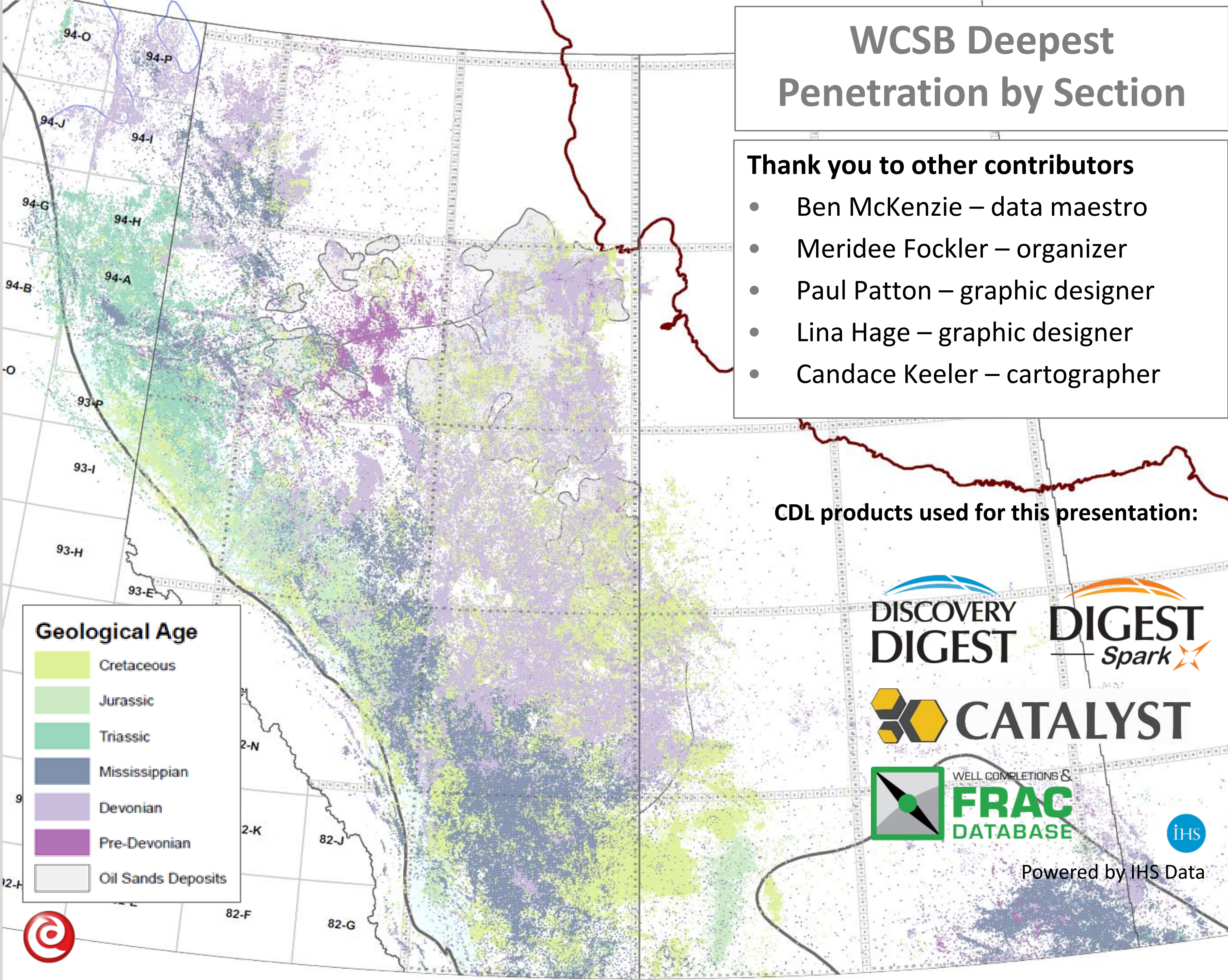
- The path to the group with the lowest median half-cycle cost per boe
- Lowest median EUR is $5.56 per boe, half-cycle
- Six key factors to maximize EUR
  - Frac Fluid – Water based (Water, Slickwater, Surfactant)
  - Orientation – NW-SE
  - Lateral Length – greater than 1,463m
  - Proppant Composition – Sand
  - Not Energized or Nitrogen
  - Depth – TVD less than 2,550m
- 64 wells in this group: operated by ECA (50 wells), AAV (11), BIR (2), and ARX (1)

Conclusions

Conclusions

- Multivariate statistical analysis can illuminate
  - Completions practices to engage and avoid to maximize EUR
  - Completion practices to engage and avoid to minimize cost per barrel
  - The value of detailed data collection
  - The variables to focus effort/money on
  - Guide technical question – ie. Why is a certain fluid or proppant performing better than others?
- CDL's MV analytics provides a method to test individual D&C design parameters against actual results.
- With tuning of design some operators have lifted their P50 results to what used to be the area P10
- Analysis can guide new entrants in an area to a higher point on the learning curve

WCSB Deepest Penetration by Section



Thank you to other contributors

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- Candace Keeler – cartographer

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DISCOVERY DIGEST

DIGEST Spark

CATALYST

WELL COMPLETIONS & FRAC DATABASE

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