geoconvention
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Benchmarking Completion Strategies

Montney and Duvernay
May 8, 2018

Mark Kowaluk, Engineer
Joshua WY. Lee, Engineer

SPONSORING SOCIETIES

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Objective

- Demonstrate an investigative process for the integration of cross disciplinary data sets for the analysis of two study areas

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Introduction

- Horizontal multi-stage frac completions have been instrumental in the development of unconventional reservoirs – especially in Canada.
- The Montney and Duvernay are two of Canada's top resource plays
- Since the early 2000s, Western Canada has seen over 36,000 horizontal multi-stage frac wells – with 6,300+ and 600+ of these in the Montney and Duvernay, respectively

Montney Swan-Glacier

Montney Swan-Glacier

Basic Play Metrics

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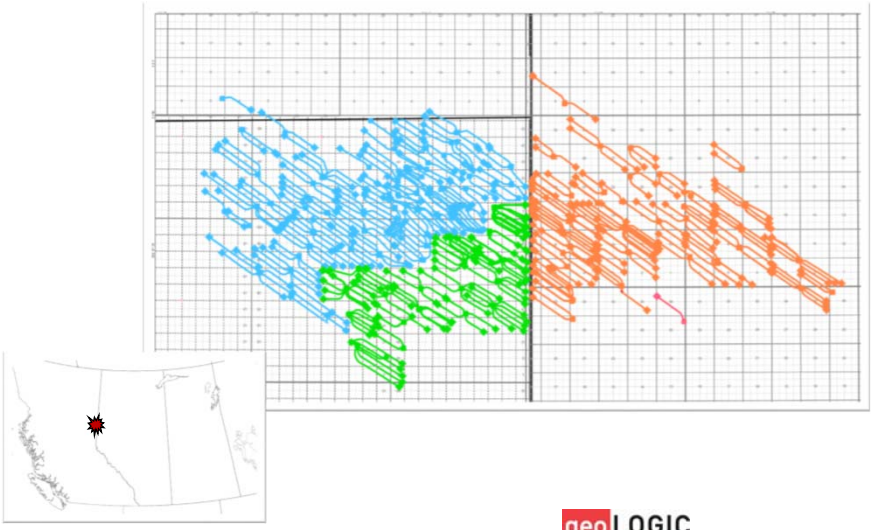
Montney Study Area



Commentary

- 481 horizontal multi-stage wells in chosen area since 2006
- Multiple targets inside the Montney as well as the Doig
- Wells drilled NW-SE

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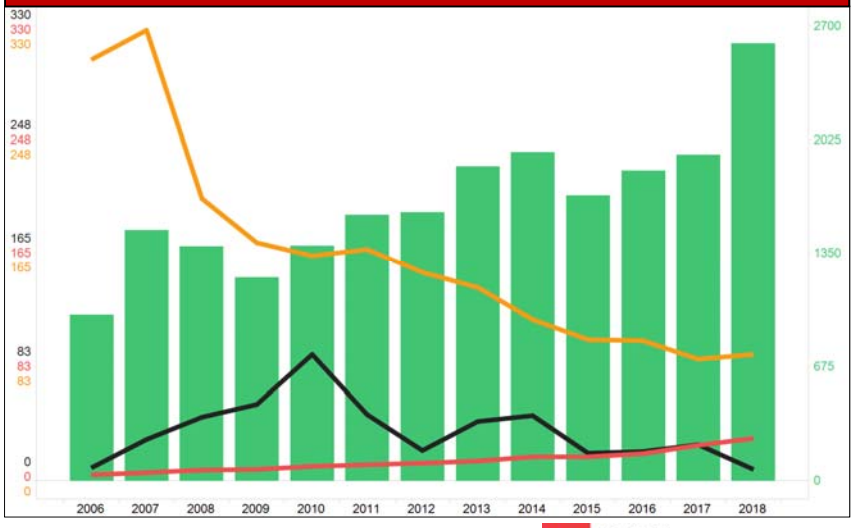
Montney Swan-Glacier

Evolution of Completion Design

YOY Well Metric Progression



Commentary

- Well activity peaked in 2010
- Lateral lengths increasing
- Number of stages increasing
- Fracture spacing decreasing

Legend

- Wells Completed
- Average Number of Stages
- Average Frac Spacing (m)
- Lateral Length (m)

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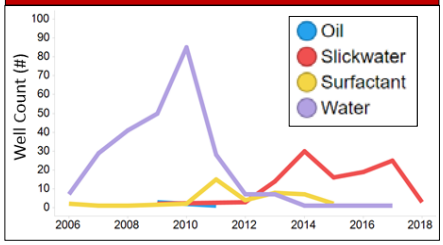
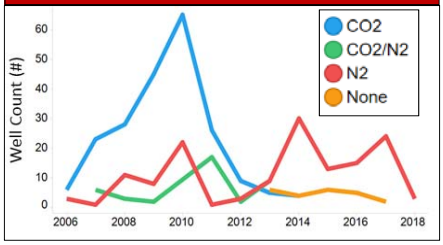
Evolution of Completion Design

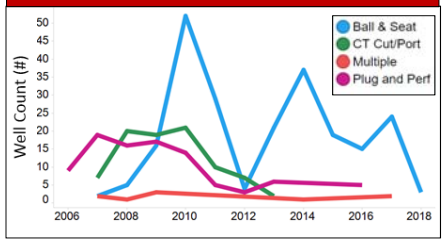
Fracture Fluid



Energizer



Technology



Commentary

- Completions shift:
  - Water to Surfactant to Slickwater
  - CO_2 and binary energized to N_2 energized and non-energized
  - CT & P&P to B&S with a few multiple technology completions

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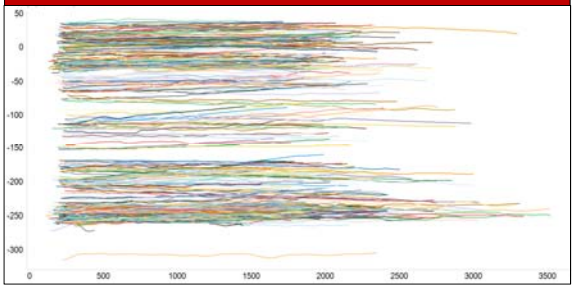
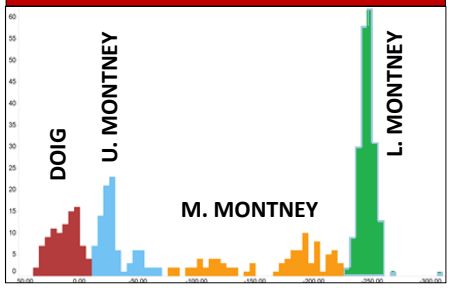
Target Landing Depth

Wellbore Diagram (w.r.t Montney Top)



Average Distance from Montney Top



Commentary

- Developed average distance from the Montney top for each well
- Visually classified the wells into four zones :
  - Doig, Upper Montney, Middle Montney and Lower Montney

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Montney Swan-Glacier

Liquids – Deep Cut

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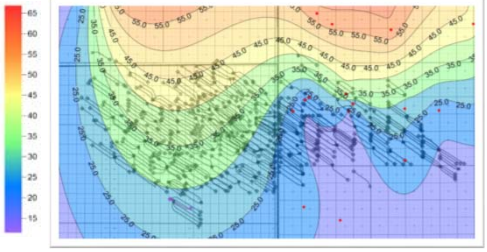
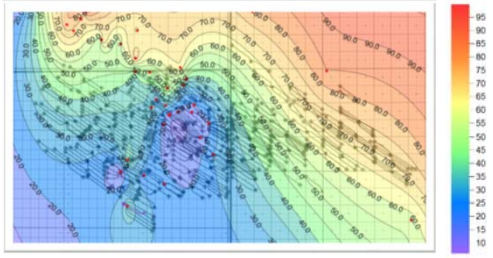
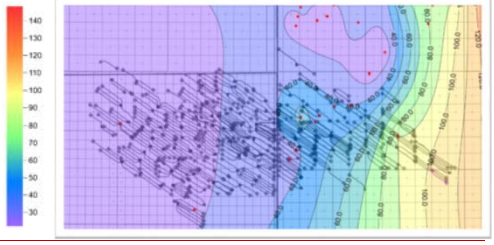
Doig



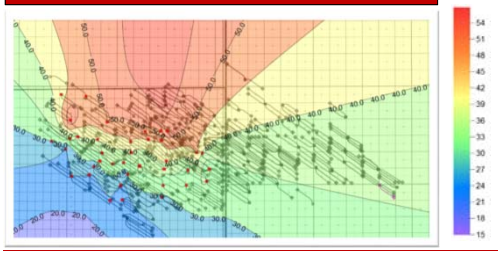
Upper Montney



Middle Montney



Lower Montney



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Montney Swan-Glacier

Calculation of Production Metric

Commentary

- 6 and 12 month production are calculated based on cumulative hours on (4,320 and 8,640 hours, respectively)
- BOE = produced gas + produced condensate + deep cut at plant (from contours)
- Normalized to completed lateral length

YOY 12 Month Cumulative Normalized Prod (boe/m)

12 month length normalized BOE (boe/m)

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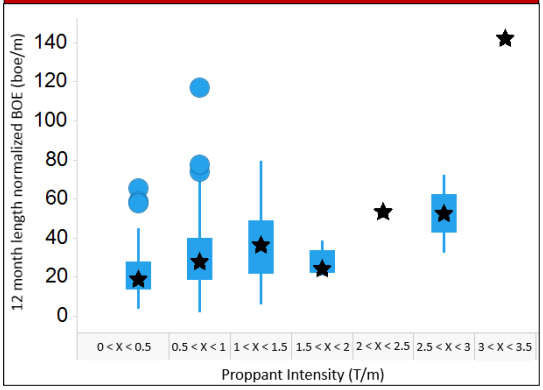
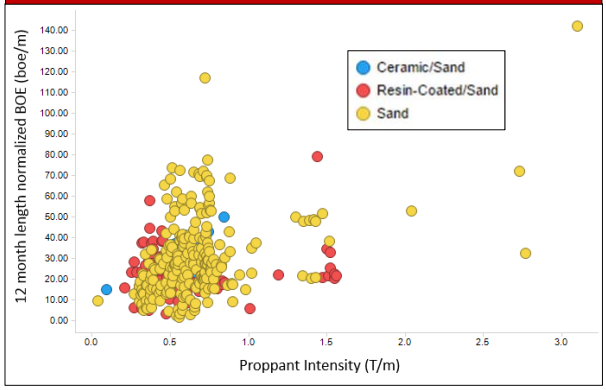
Montney Swan-Glacier

Completion Benchmarking

Proppant Intensity



Proppant Intensity and Composition



Commentary

- Indications that pumping greater than 2 T/m is beneficial to production
- Only sand fractures have been pumped at greater than T/m intensity

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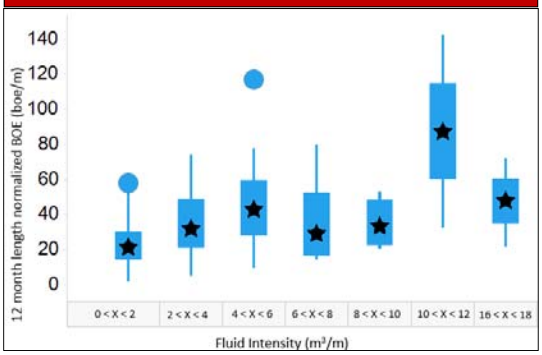
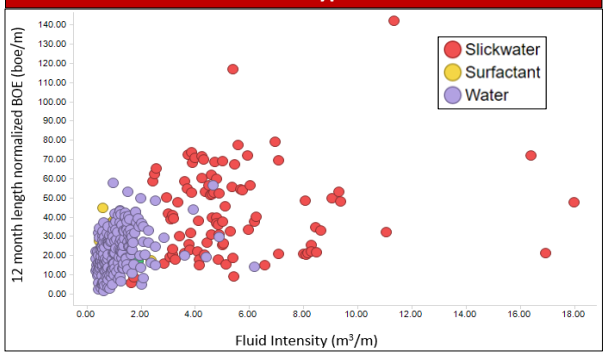
Montney Swan-Glacier

Completion Benchmarking

Fluid Intensity



Fluid Type



Commentary

- Some advantage to running larger fluid intensities (>10 m^3/m)
- Slickwater generally outperforms older water based systems

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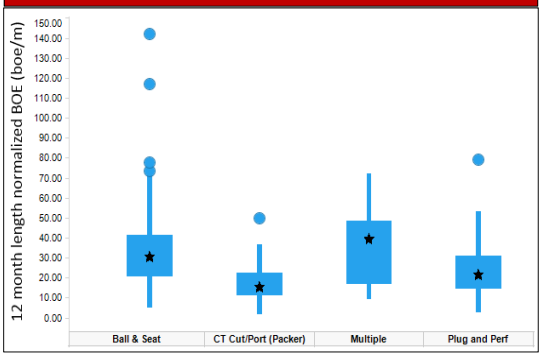
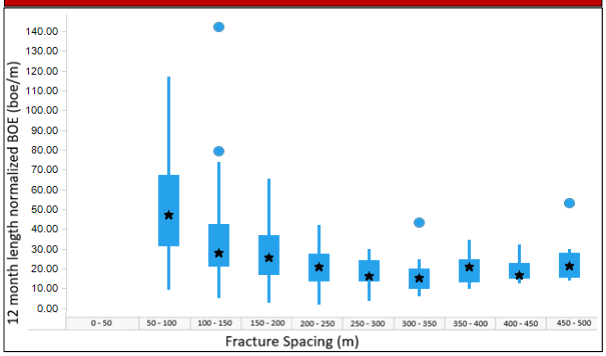
Montney Swan-Glacier

Completion Benchmarking

Completion Technology



Fracture Spacing



Commentary

- Ball and Seat technologies have been consistent performers
- Multiple technology completions show promise but there is a limited sample size
- Tighter frac spacing is advantageous

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Montney Observations

- In our study area, operators have targeted the Doig, Upper, Middle and Lower Montney.
- A normalized cumulative production variable was selected to compare the wells
- The Montney wells have been getting better production YOY, except for the lower Montney, which has seen a decrease in the recent years
- Over the course of 10+ years, many types of completions have been tried. The following are beneficial to production in the Montney:
  - Higher intensity fractures
  - Larger slickwater treatments
  - Ball and seat completions
  - Decreasing fracture spacing

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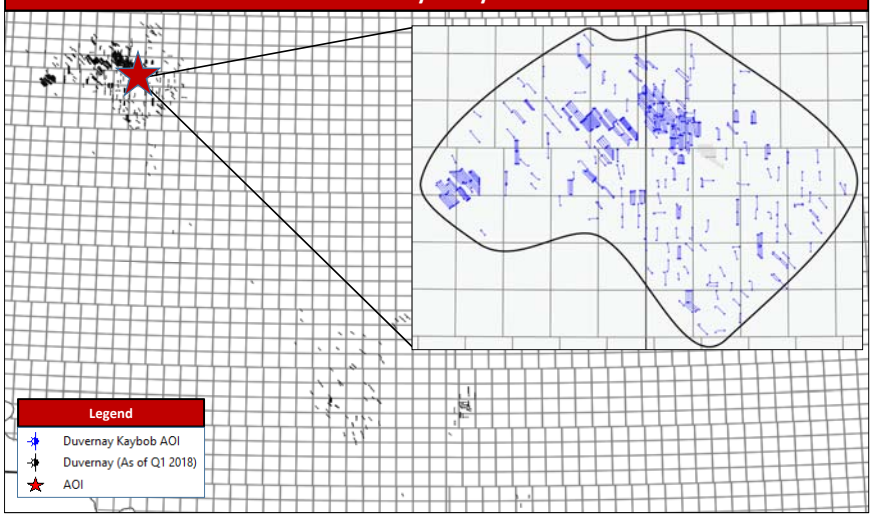
Duvernay Kaybob

Duvernay Kaybob

Basic Play Metrics

Duvernay Study Area



Commentary

- 621 horizontal multi-stage Duvernay wells since 2011
- Development focused on the Kaybob, Willesden Green and East Basin areas
- We have selected the Kaybob area for further investigation
- In this area the wells are drilled predominantly NW-SE and N-S direction

Duvernay Kaybob

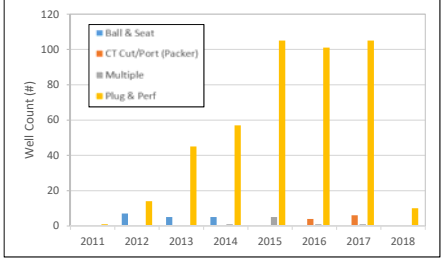
Evolution of Completion Design

YOY Well Metric Progression

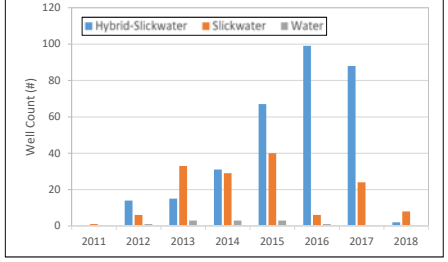
Duvernay Kaybob

Evolution of Completion Design

Technology



Fracture Fluid



Commentary

- Initial exploration saw ball drop system being used
- Completions technology has shifted to predominantly plug & perf with some CT and multiple
- Two primary fluid systems used
- There was an increase in the percentage of hybrid-slickwaters used until 2017, at which time the shift went towards slickwater fracs

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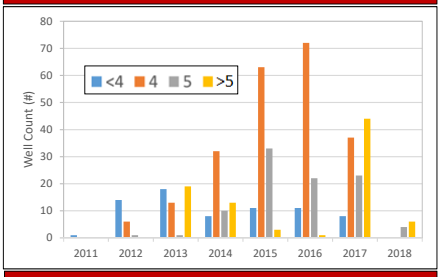
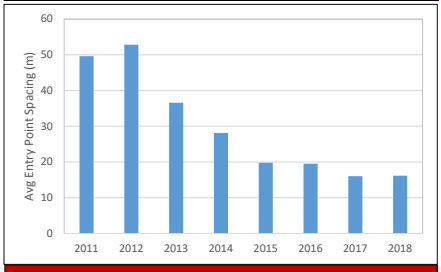
Evolution of Completion Design

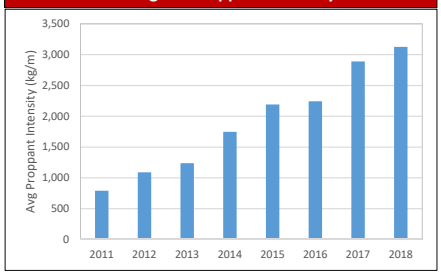
Median Number of Entry Point



Average Entry Point Spacing



Average of Proppant Intensity



Commentary

- 4 and 5 median number of entry points is the most common
- Steady decrease in average entry point spacing
- YOY increase in proppant intensity on a kg per m basis

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Liquids – Deep Cut

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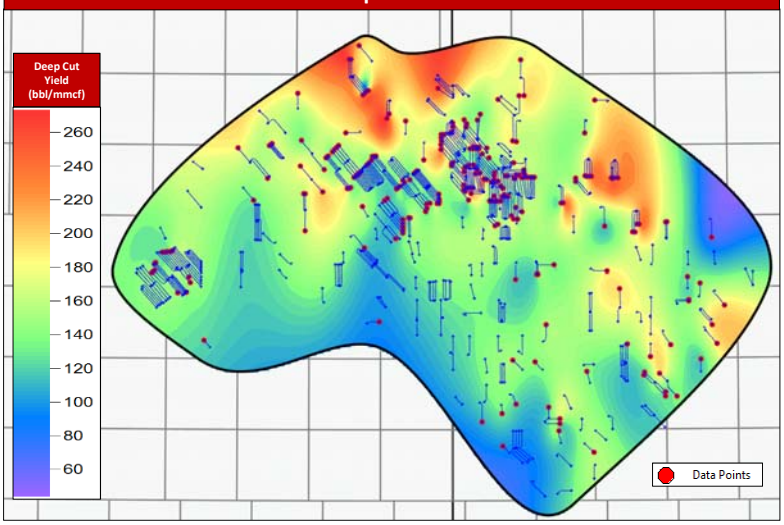
AOI Deep Cut Contour



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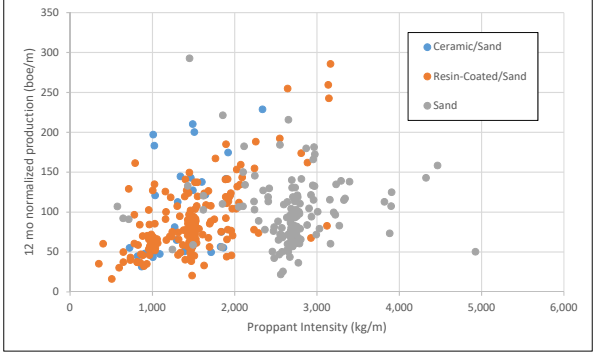
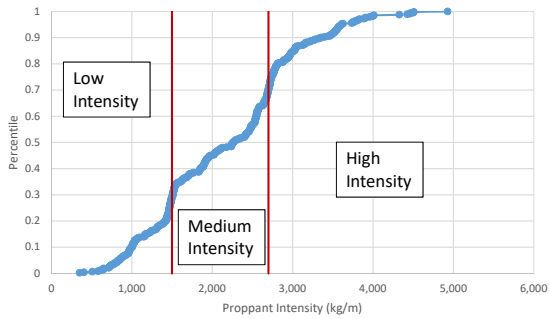
Completions Benchmarking

Proppant Intensity vs 12 Mo Norm Cum Prod



Cumulative Probability of Proppant Intensity



Commentary

- Sand only fractures generally done with a higher intensity
- Proppant intensity can be binned into 3 categories – low, medium and high intensity

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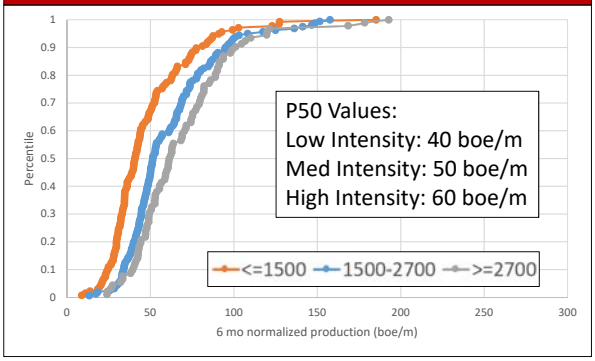
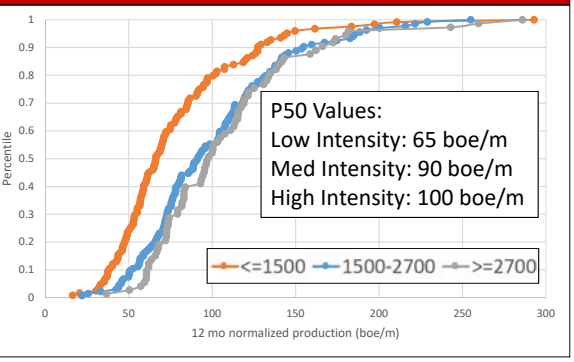
Completions Benchmarking

Proppant Intensity vs 6 Mo Cumulative Production



Proppant Intensity vs 12 Mo Cumulative Production



Commentary

- The low intensity completions are resulting in lower 6 and 12 month cumulative production
- The regular and high intensity completions on average have a 25 and 50% higher production in the 6 month case
- In the 12 month cumulative case, the regular and high intensity case have a 40% higher production

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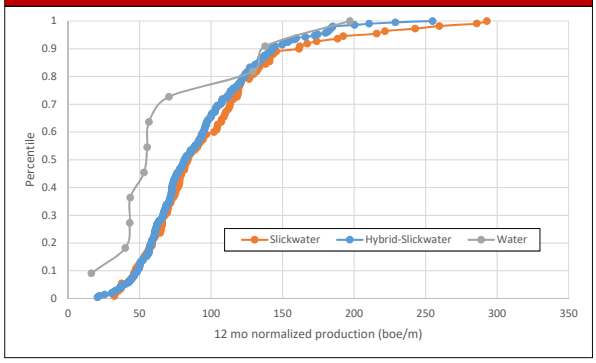
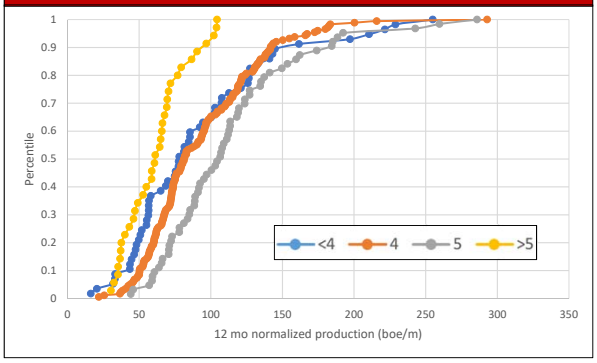
Completions Benchmarking

Frac Fluid



Median Number of Entry Points



Commentary

- There is not a significant difference in using slickwater and hybrid-slickwater
- Both slickwater and hybrid-slickwater outperform water fracs
- There appears to be a benefit of 5 median number of entry points per stage

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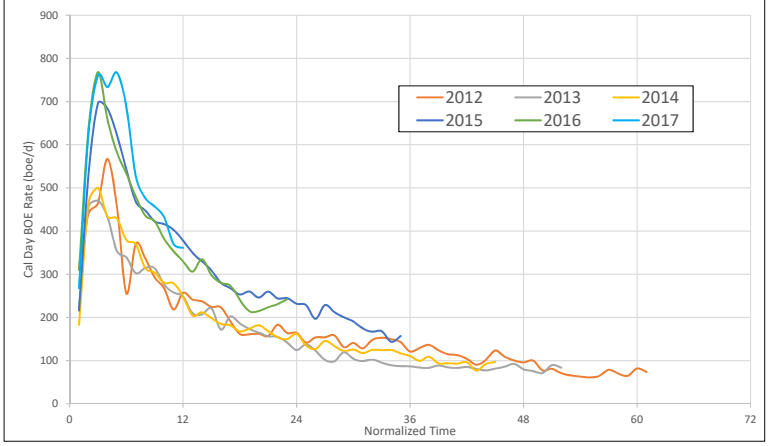
Completions Benchmarking

YOY Rate Time



Completion Metric	2012 – 2014	2015 – 2017
Lateral Length (m)	1,755	2,299
Stages (#)	16	33
Proppant Intensity (kg/m)	1,452	2,445
Avg Entry Point Spacing (m)	35	18

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Duvernay Observations

- Well completions in the Duvernay have been trending to:
  - Longer laterals
  - More stages
  - Higher frac intensity
  - Tighter entry point spacing
- It appears that slickwater and hybrid slickwater fracs are achieving similar results
- A higher median number of entry points appears to be beneficial
- An increase in production is observed with an increase in proppant intensity

Takeaway

- Demonstrate an investigative process for the integration of cross disciplinary data sets for the analysis of two study areas
- Next steps will involve machine learning and multi-variate analysis

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