Where Did the Proppant Go?*

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Abstract

Effective propped fracture half-lengths following a hydraulic fracture stimulation of a wellbore can be difficult to quantify. Therefore, different techniques for modeling proppant distributions must be applied to the same dataset for validation purposes. A proppant-filled Discrete Fracture Network (DFN) model is applied to two wells targeting the Muskwa and Evie Members of the Horn River Formation. Another technique for identifying microseismic signatures associated with the initial slickwater pad and the proppant-laden fluid was applied to both wells to obtain observed proppant distributions. The similarity of the distributions from each technique gives validation to each procedure and results can be used to optimize future completion techniques. The study objective is to compare proppant distributions using a proppant-filled DFN method to the observed proppant distributions using a technique to separate fluid-induced microseismicity from proppant-laden fluid-induced microseismicity. Proppant distributions are broken up by their perpendicular, parallel, and vertical components with respect to microseismic distances from their respective stage centers. The distributions of each component are compared in terms of their mean values +/− one standard deviation and results are within ~15% of one another. These propped fracture distributions can be used to evaluate wellbore and stage spacing intervals. This suggests that when these techniques are combined, the proppant distribution in a formation following a hydraulic fracture stimulation can be well constrained to yield good estimates. The model results are used as a completions-diagnostics tool for evaluating the effectiveness of the stimulation and make future completion techniques more efficient and economically more valuable.

Reference Cited

McGarr, A., 1976, Seismic moments and volume changes: Journal of Geophysical Research, v. 81/8, p. 1487–1494.

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Agenda

- Problem Statement:
- Background
- Workflow
- Measurements
- Example
- Conclusions

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Problem Statement

In order to predict proppant distribution in the formation, a calibrated, physically-based fracture model is required

Background

- Seismic Moment (M_0) and Moment Magnitude (M_w) Definition
- Mass balance: Relating M_0 to the change in rock volume (ΔV) due to fluid injection (V_i)

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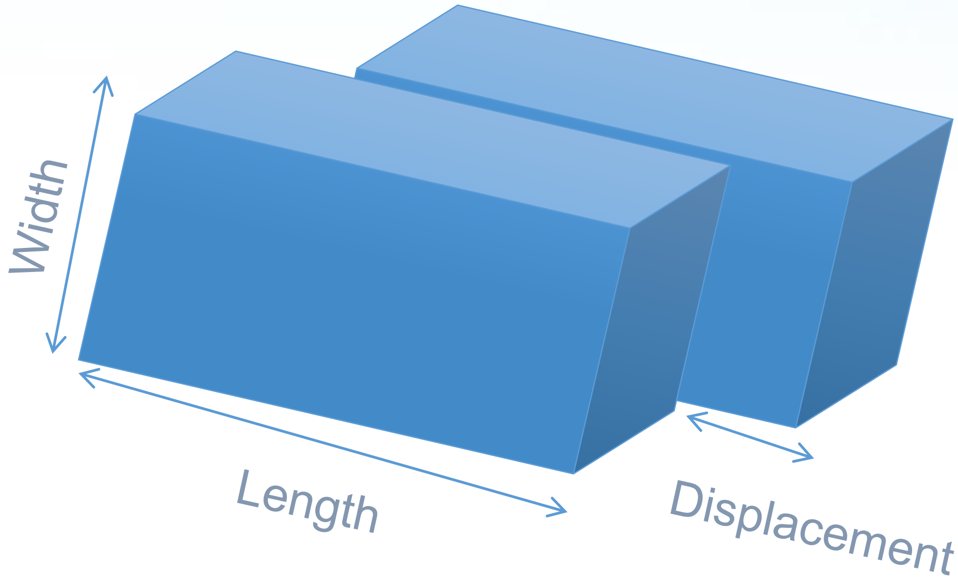
Measure of Fracture Size



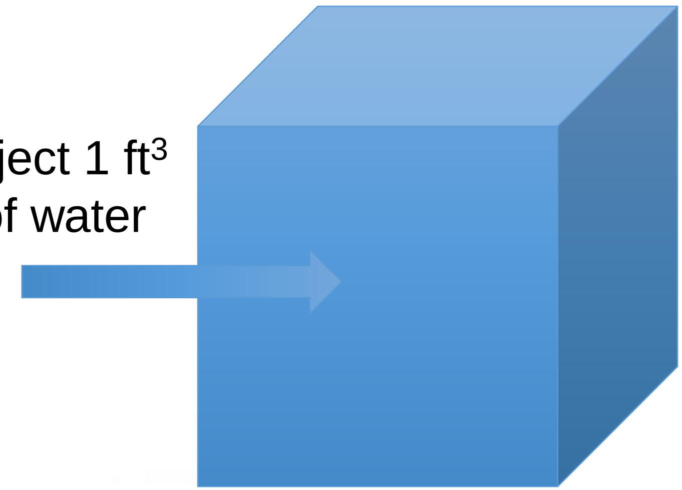
$$M_0 = A\mu\delta$$

Seismic Moment = Fracture Area * Shear Modulus * Displacement

Moment Magnitude (M_w) = 2/3 * $\log_{10}(M_0)$ + constant

Mass Balance

Inject 1 ft^3
of water



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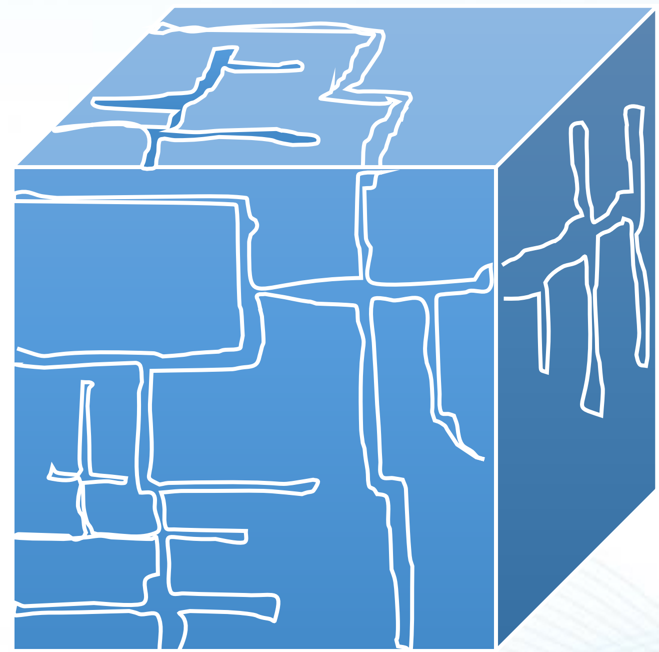

Sealed 1 ft^3 of solid
rock with no porosity

Increased volume to a total of
2 ft^3 of water-filled fractured rock

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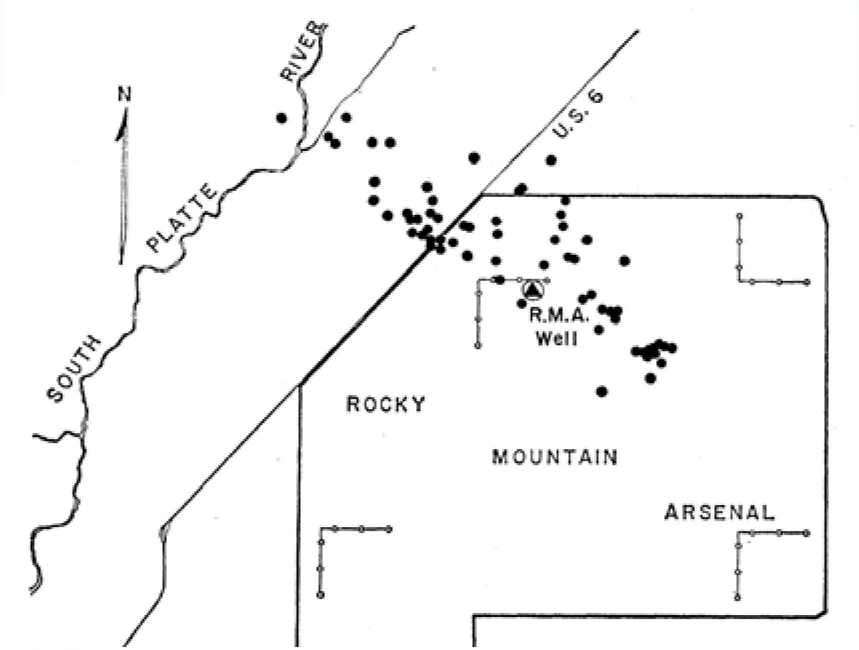
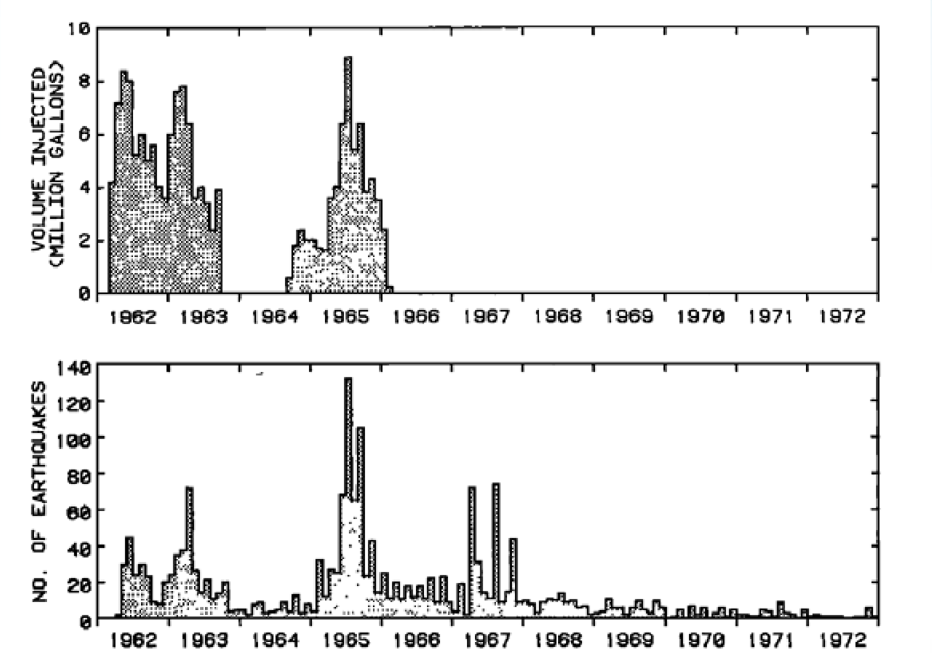
Mass Balance





ΔV is related to the volume change by $\Sigma M_0 = K\mu|\Delta V|$
ΣM_0 is the sum of the seismic moments of the seismic population,
μ is the modulus of rigidity, and K is a factor close to 1.

McGarr, 1976

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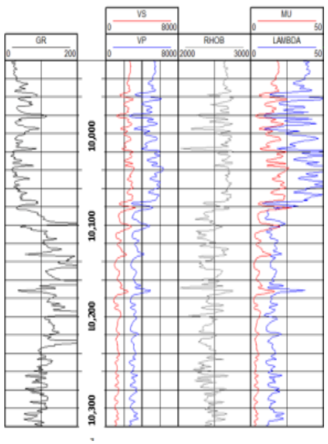
Workflow: Calibrated Discrete Fracture Network

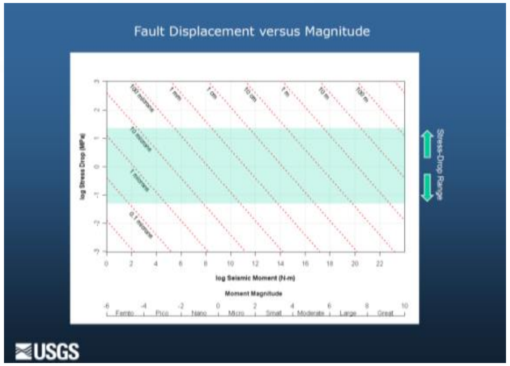
$$M_0 = A\mu\delta$$

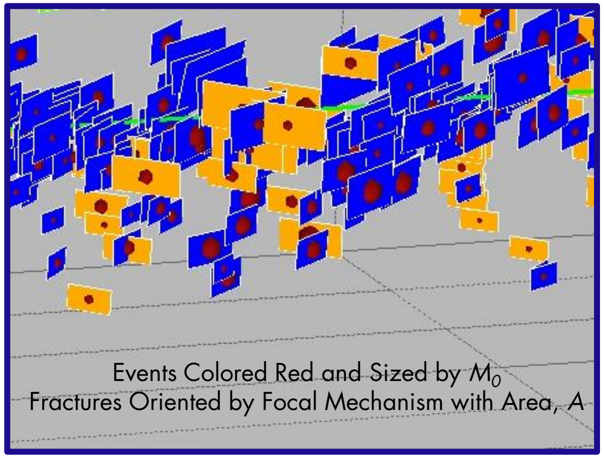
$$\Delta V_f = A * \Delta u = (\Delta V_{inj})\eta k$$

Rock Rigidity, μ

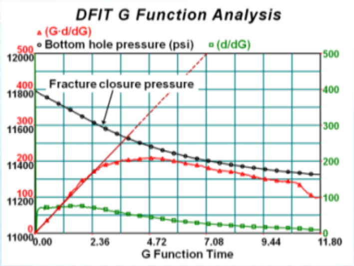


Displacement, δ





Fluid Efficiency, η



Workflow

1. Derive Fracture Area, A
   - Use magnitude from mPGV
   - Determine rigidity from logs, displacement from published tables
2. Calculate scaling factor, k
   - Compare fracture volume (ΔV_f) to product of injected volume (ΔV_i) and fluid efficiency (η)
3. Refine displacement estimate (d_{new})
   - Apply scaling factor to initial displacement estimate

Injected Volume, ΔV_{inj}

Clean Volume + Proppant Volume
Propped Volume assumes 100 lbs = 1ft^3

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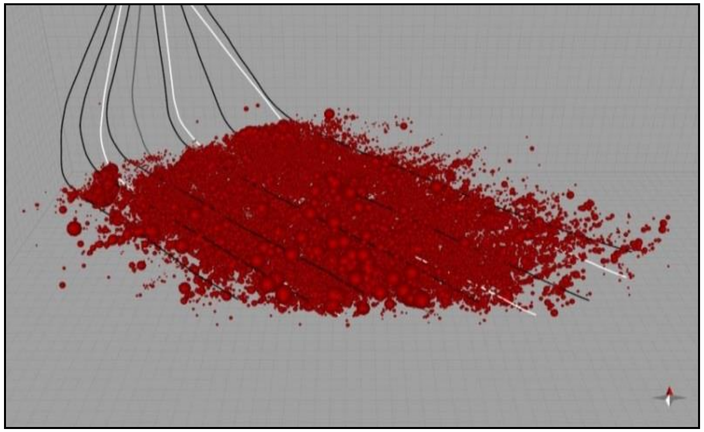
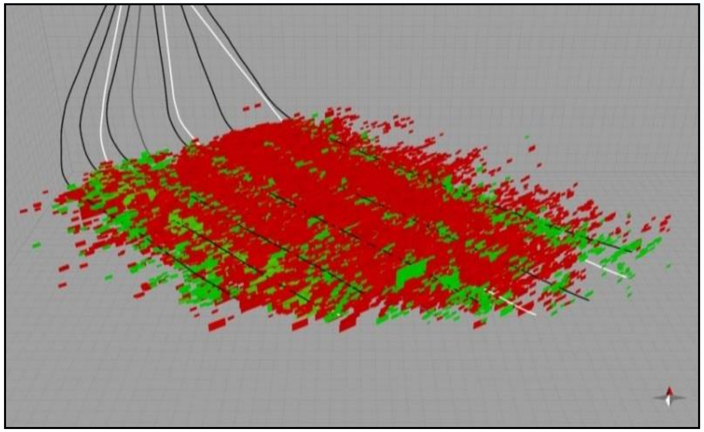
Workflow

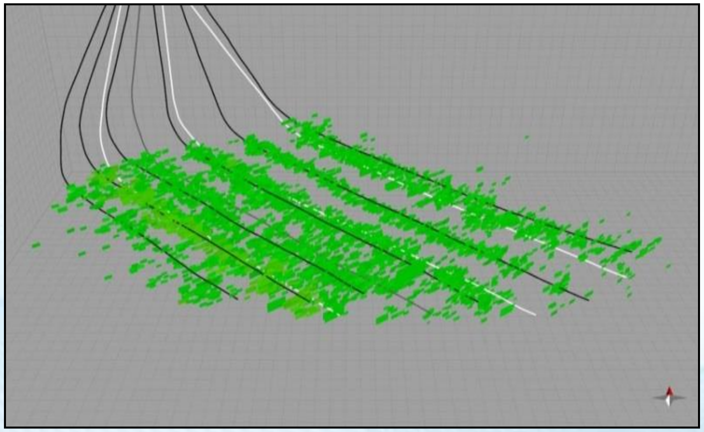
1. Events



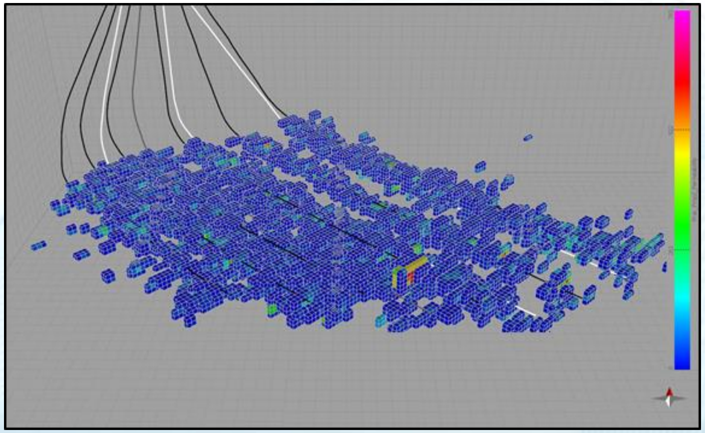
2. DFN



3. Propped DFN



4. Productive-SRV™



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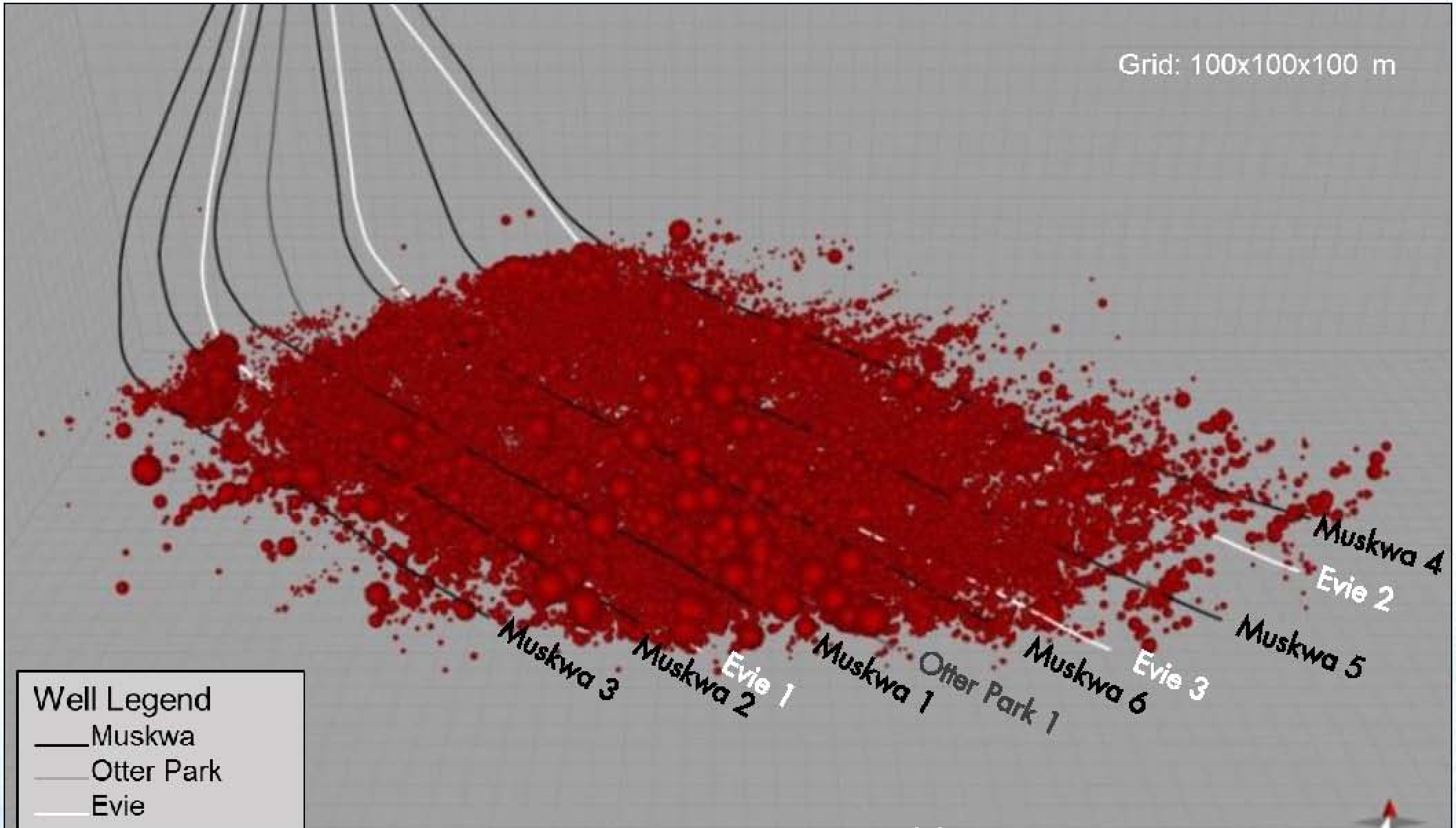
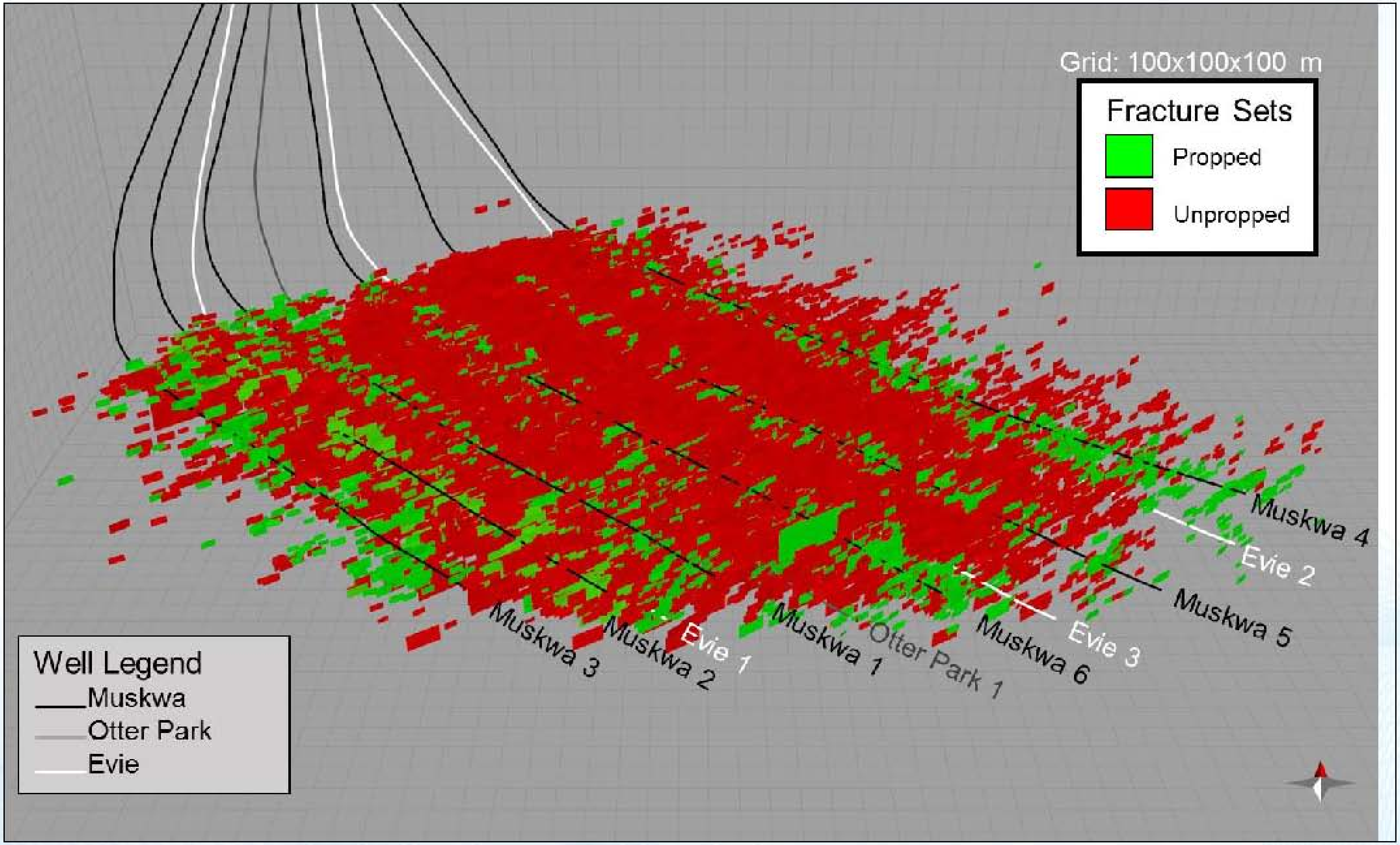
Event Set



Microseismic events are sized by seismic moment

All Fractures



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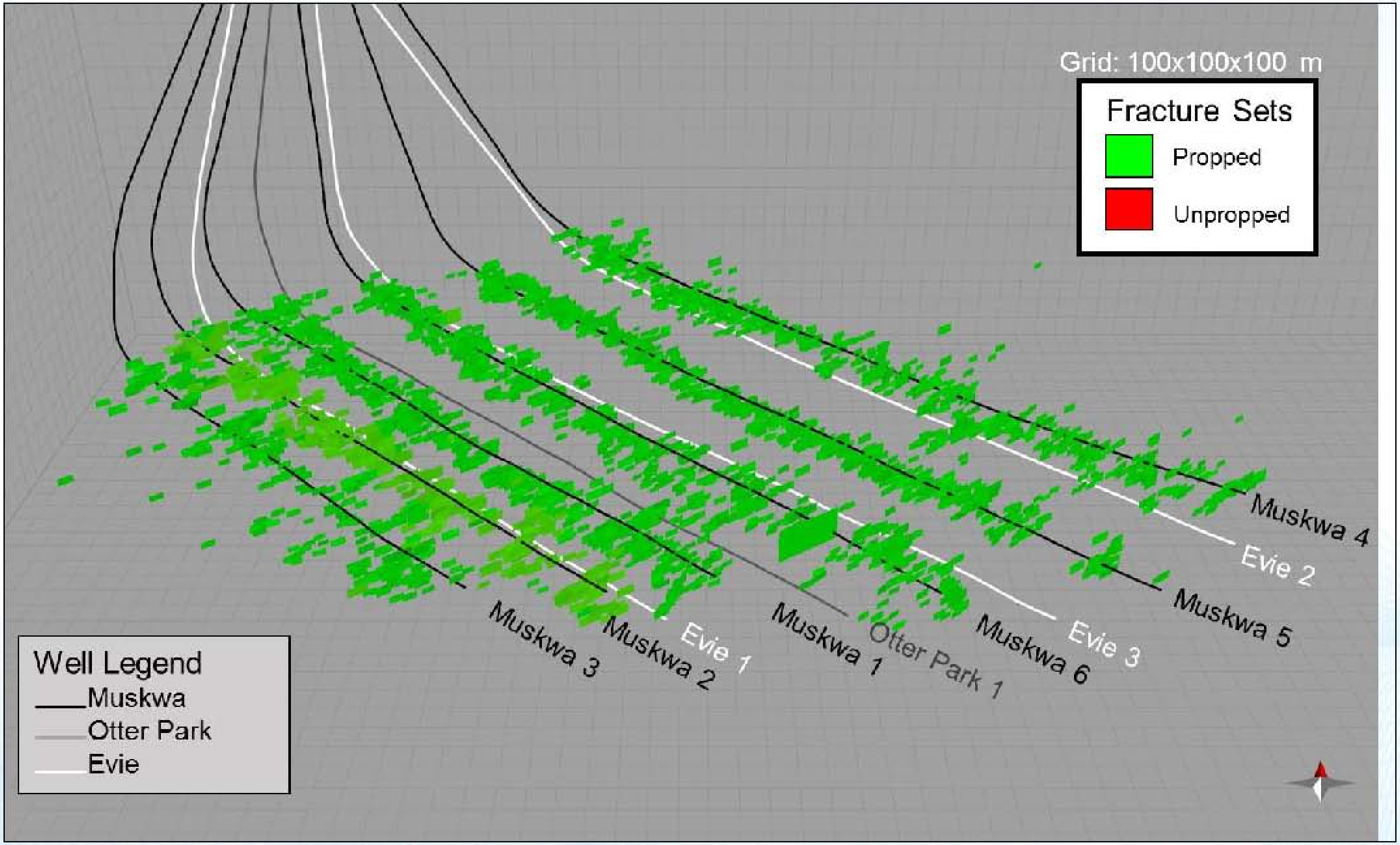
Muskwa Propped Fractures



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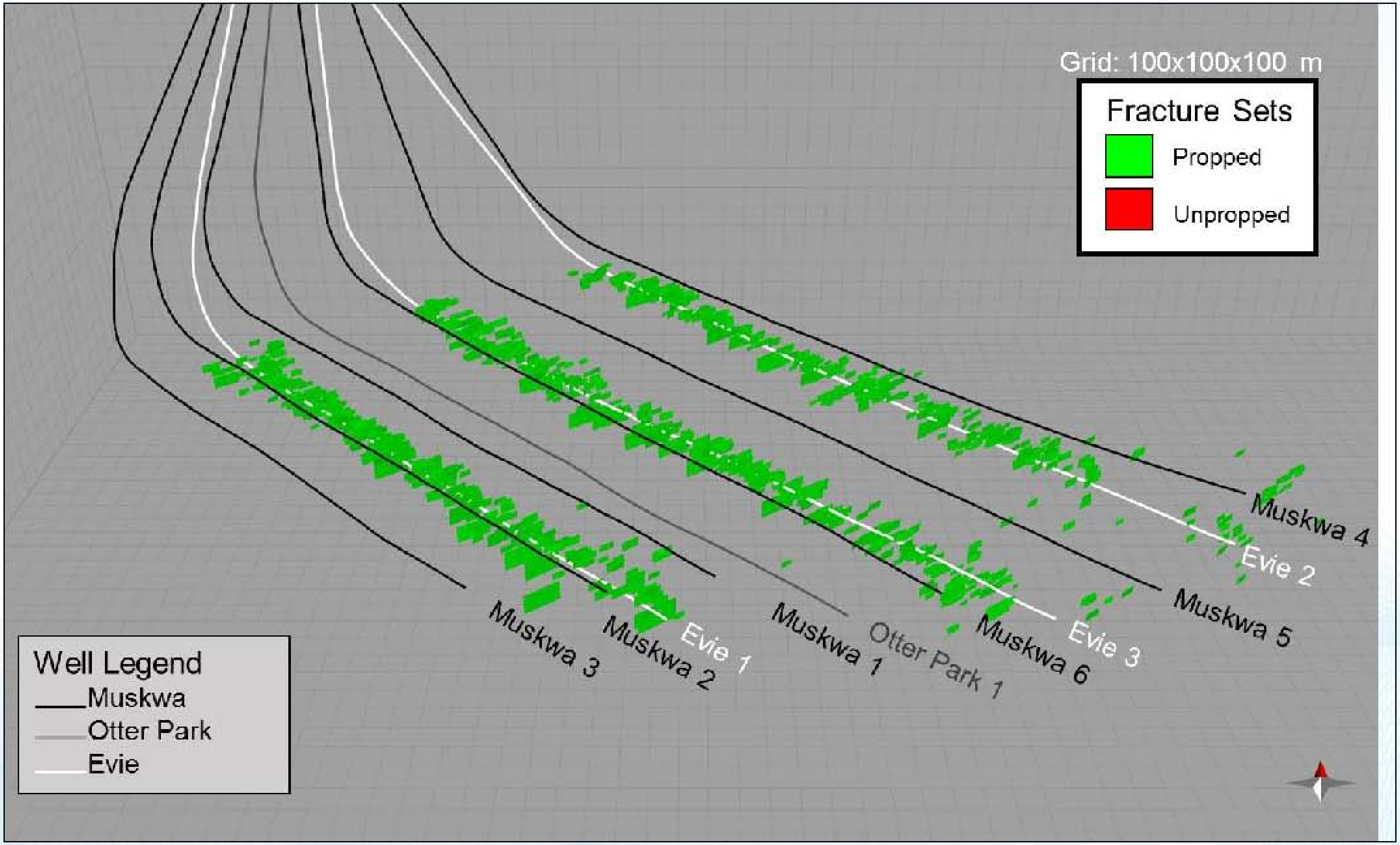
Evie Propped Fractures



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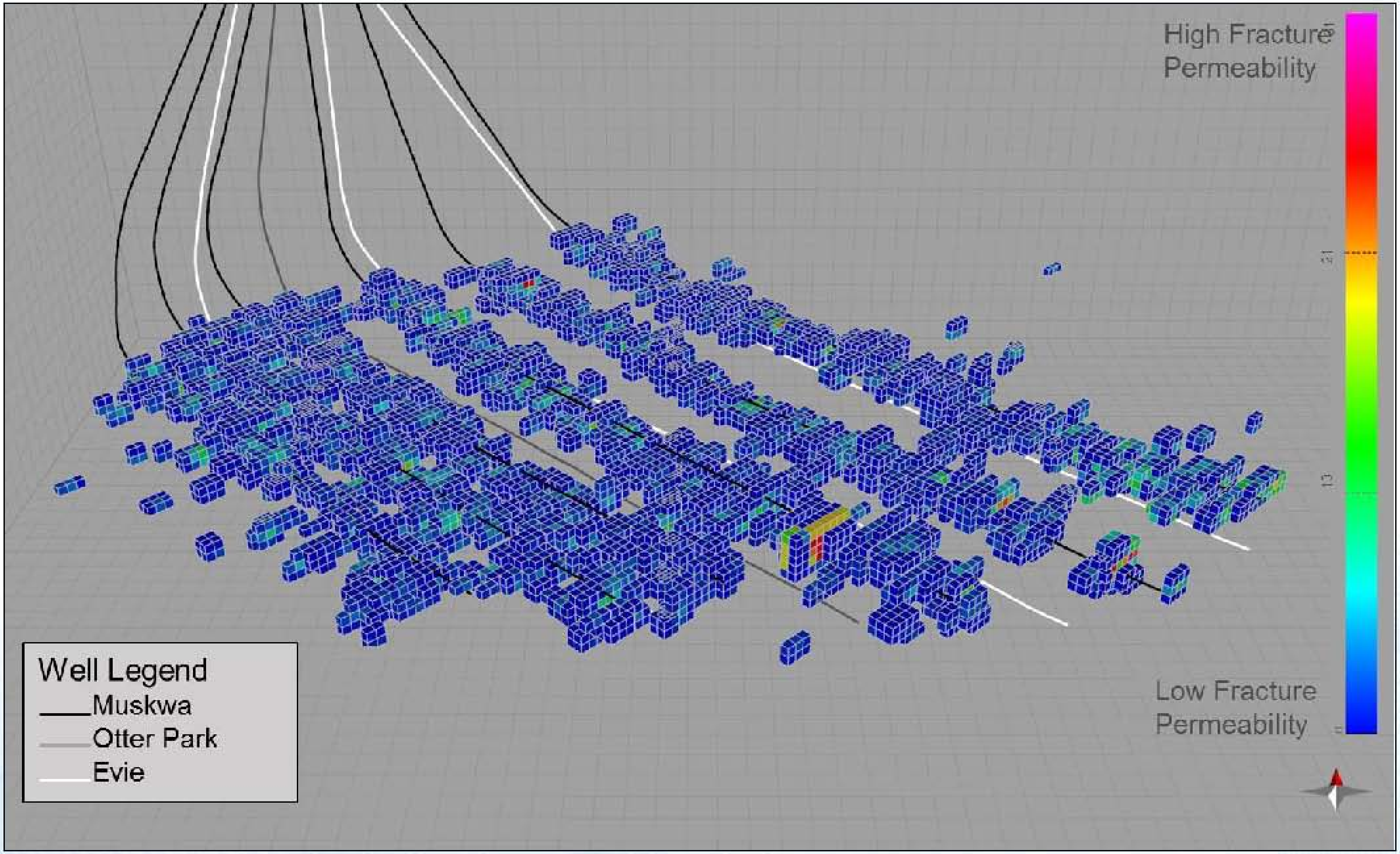
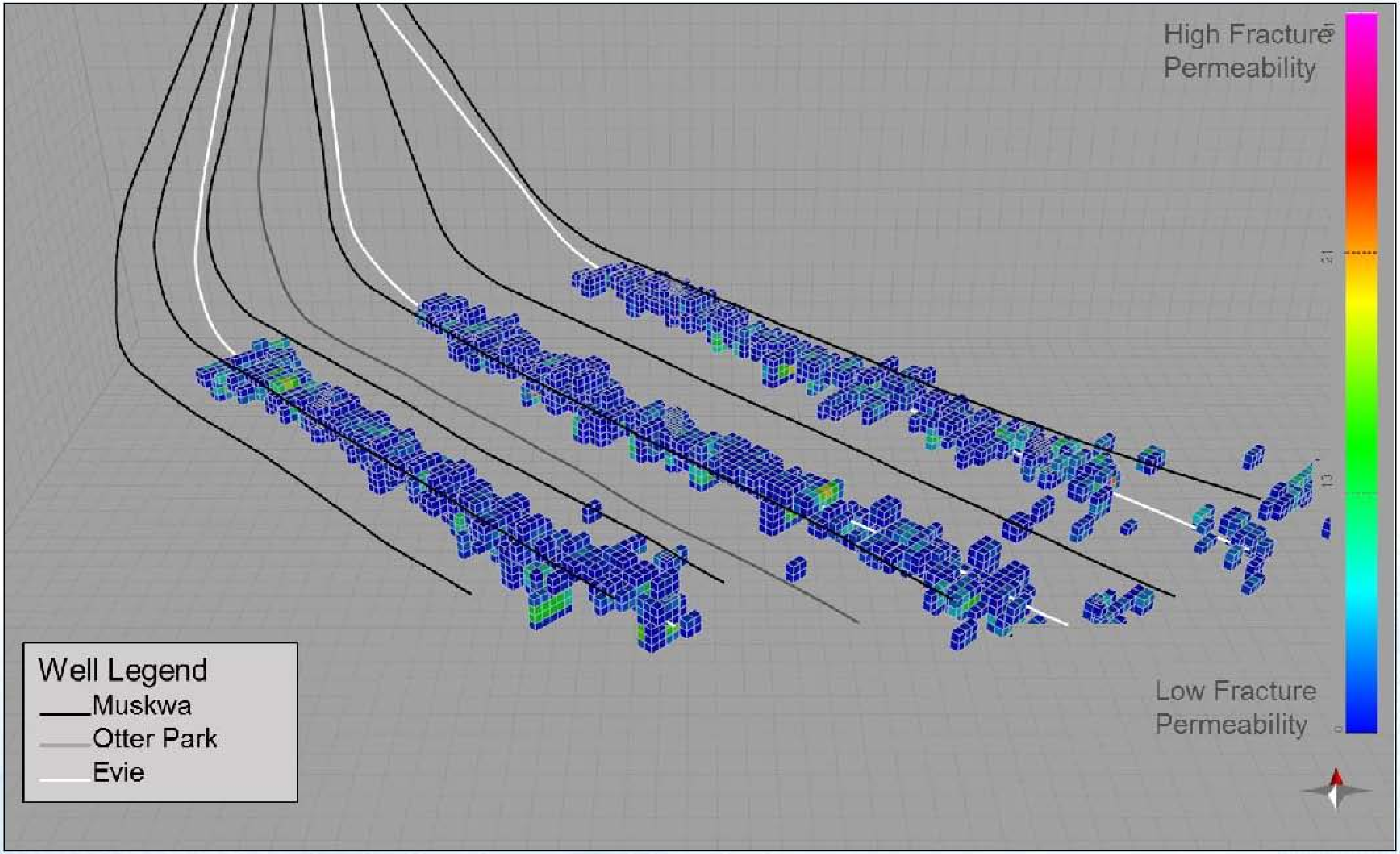
SRV: Muskwa Propped Fractures



SRV: Evie Propped Fractures



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Propped-SRV Results

Well	% SRV Propped
Evie 1	14.5%
Evie 2	18.9%
Evie 3	12.5%
Muskwa 1	18.8%
Muskwa 2	31.2%
Muskwa 3	59.2%
Muskwa 4	27.5%
Muskwa 5	13.2%
Muskwa 6	21.6%

- Evie
  - ~15% SRV is propped
- Muskwa
  - ~29% SRV is propped
- Completions Efficiency:
  - Muskwa wells are most effectively propped
  - Difference in behavior requires investigation

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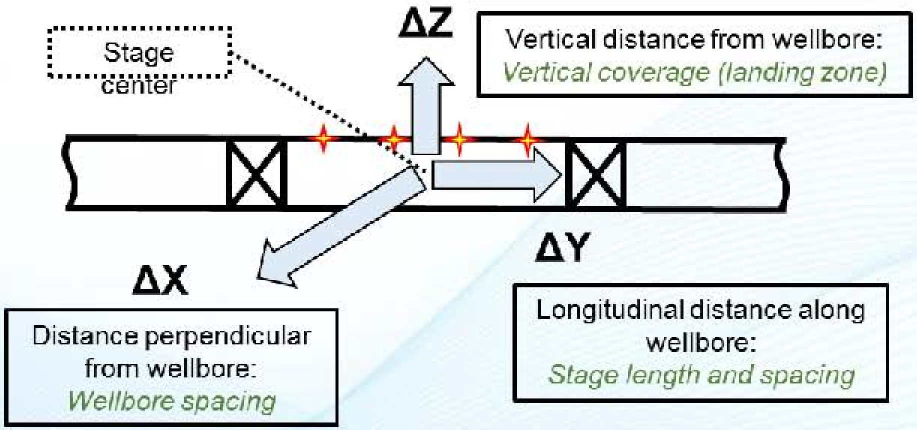
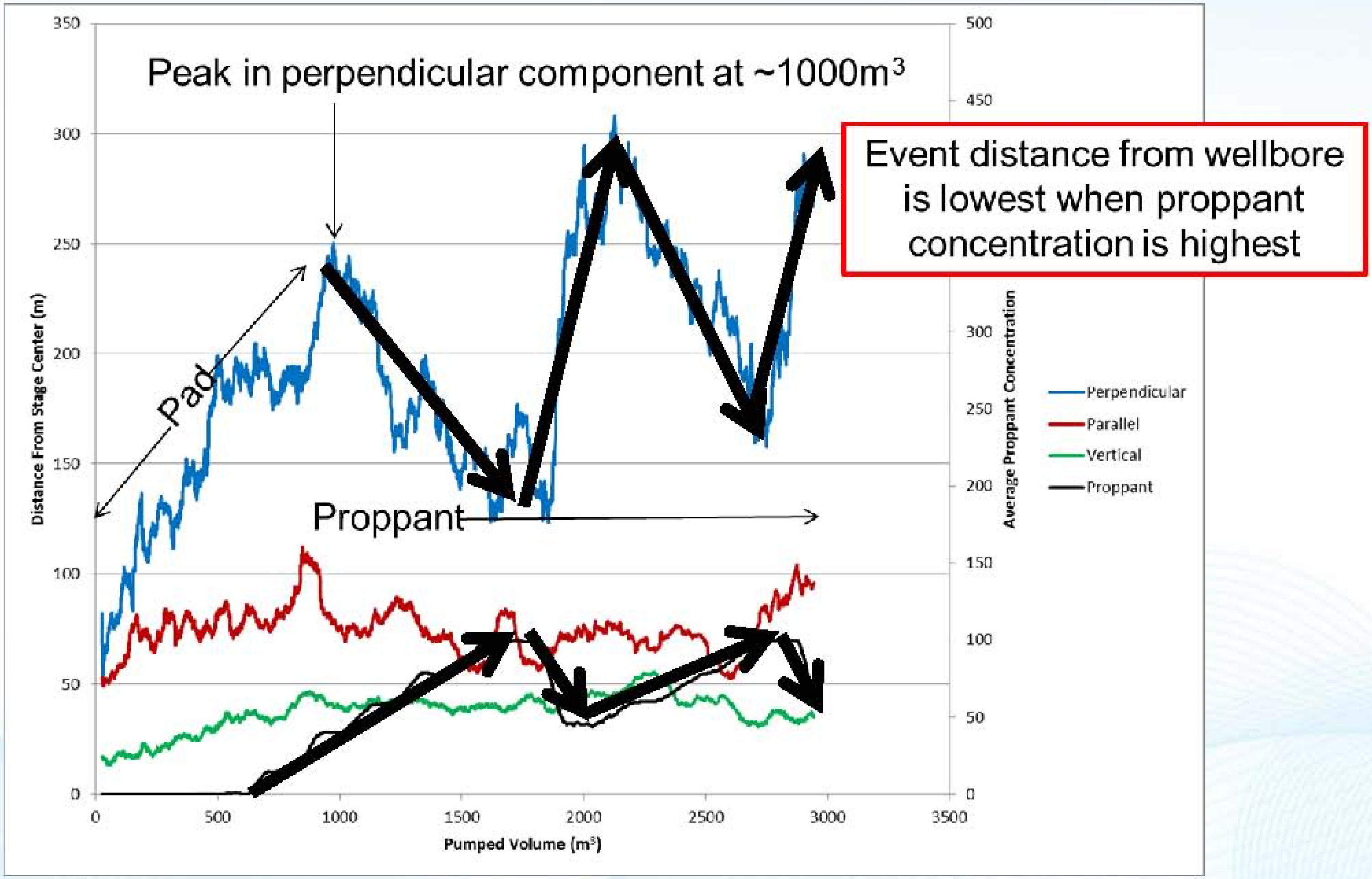
Treatment Design Analysis

- Treatment Design Analysis maps the microseismic event cloud as a function of pumped volume
- Tracking the growth of the fracture network in the horizontal, longitudinal, and vertical direction provides information for:
  - Optimum wellbore spacing
  - Optimum stage length and spacing
  - Vertical coverage and optimum landing zone



Treatment Design Analysis: (Evie Well)



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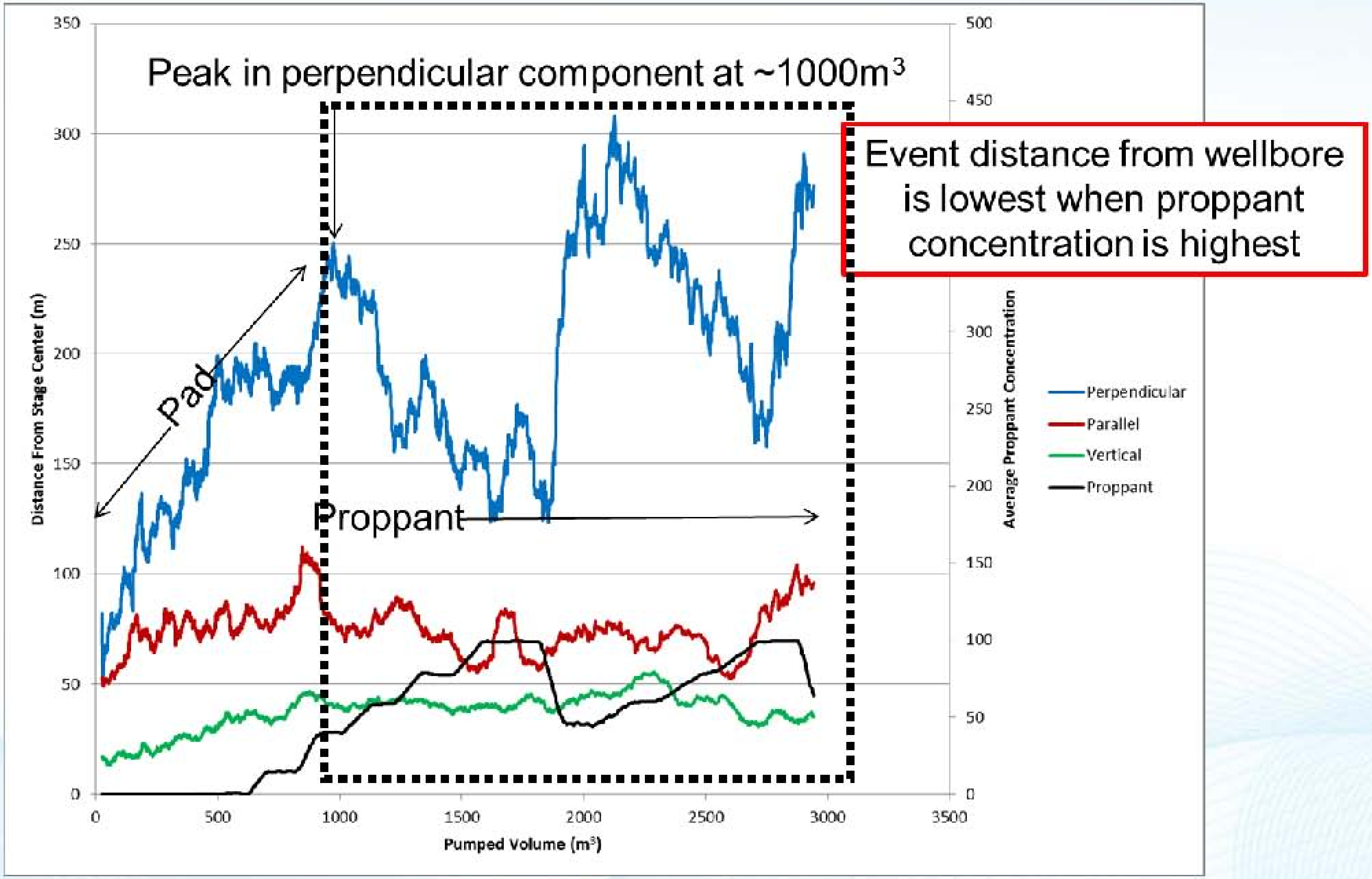
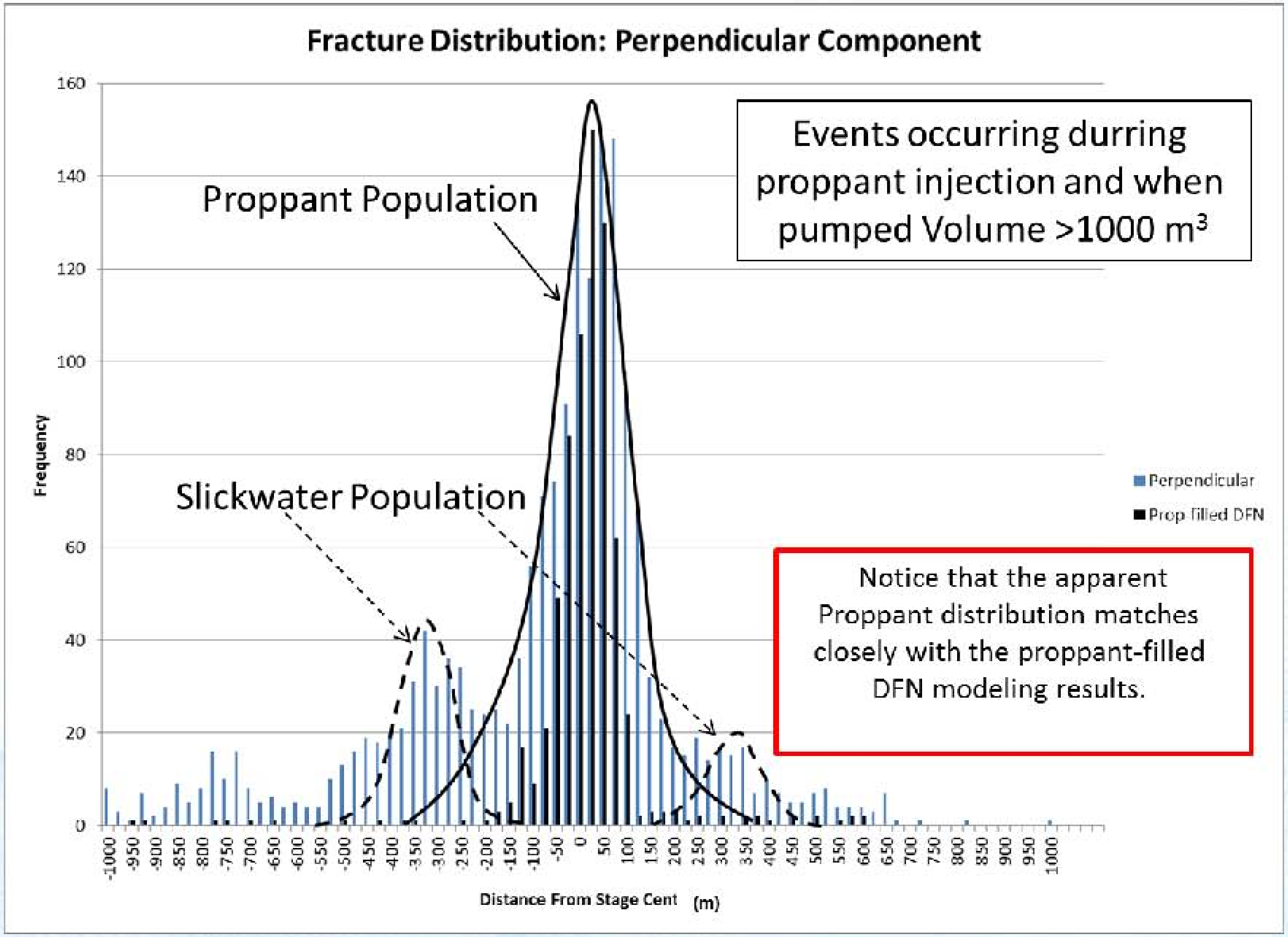
Treatment Design Analysis: (Evie Well)



Comparison of Methods



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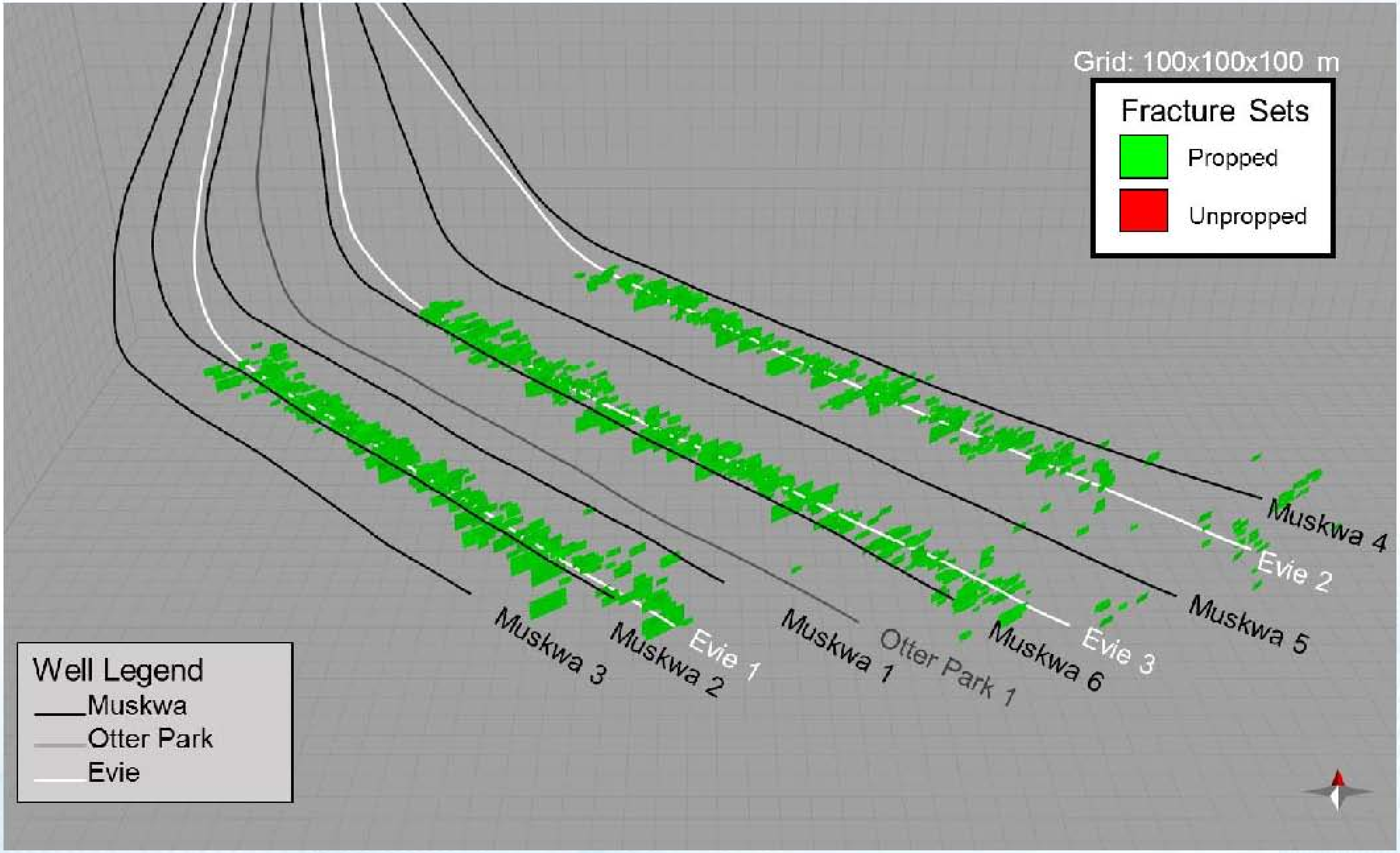
Evie Propped Fractures



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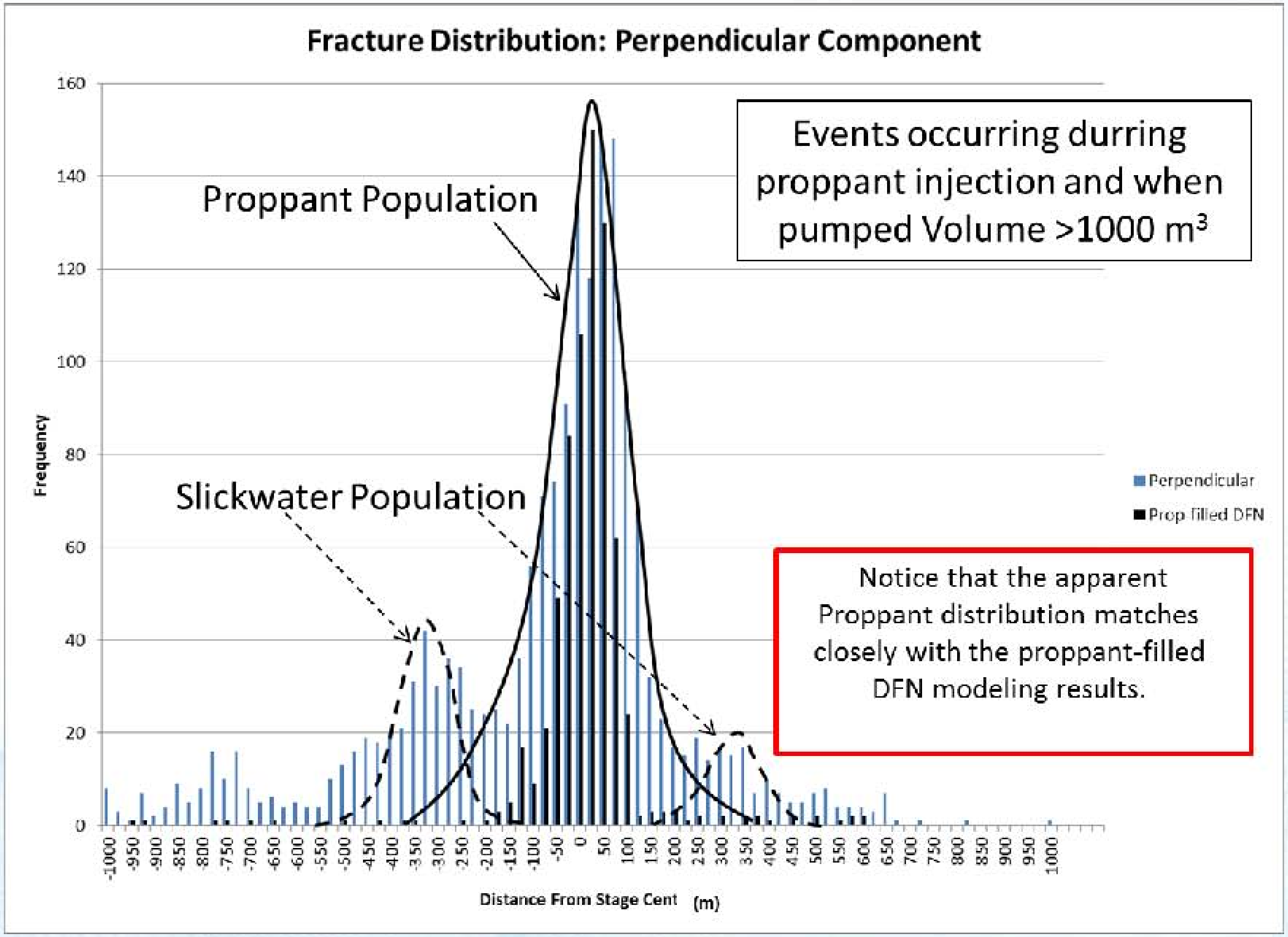
Comparison of Methods



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Conclusions

- Calibrated DFN is physically based, calibrated to real data, preserves original shape and distribution of event cloud
- Distribution can be used to analyze appropriate well and stage spacing as well as proppant containment
- Proppant distribution is consistent with other methods
- Can be used to measure Productive-SRV

Acknowledgements

Encana, Kogas

MSI CE Group

Thank You!

we listen®

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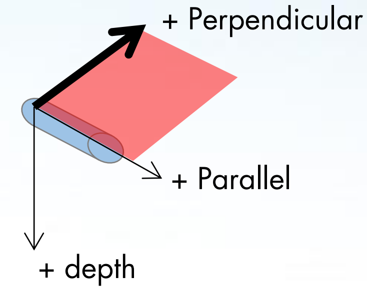
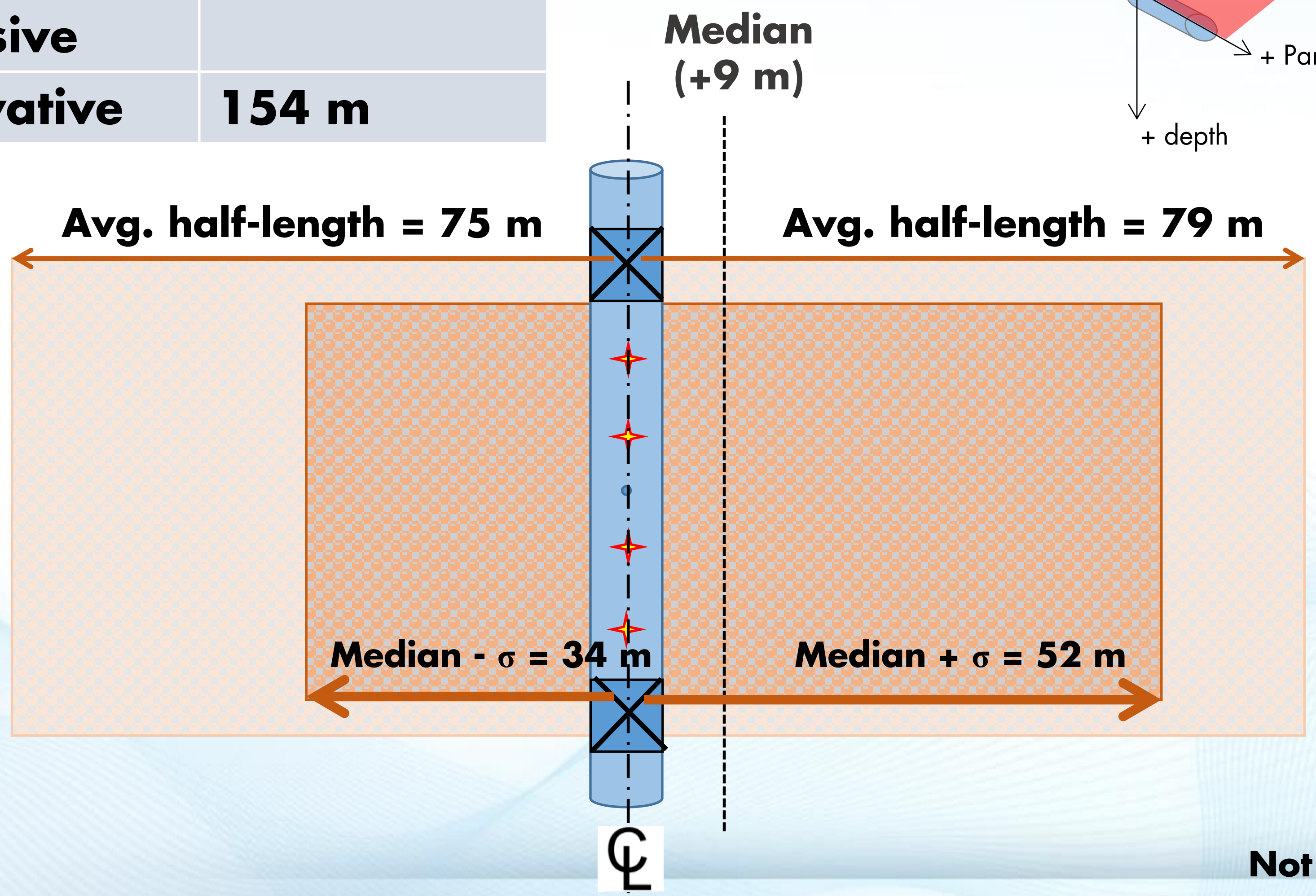
Evie: Wellbore Spacing – Propped Length

Wellbore Spacing	
Most Aggressive	**86 m**
Conservative	**154 m**

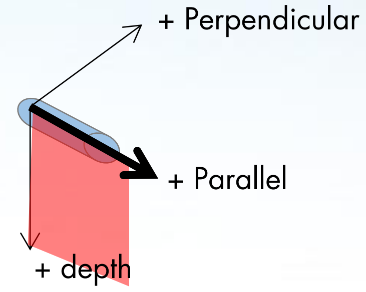


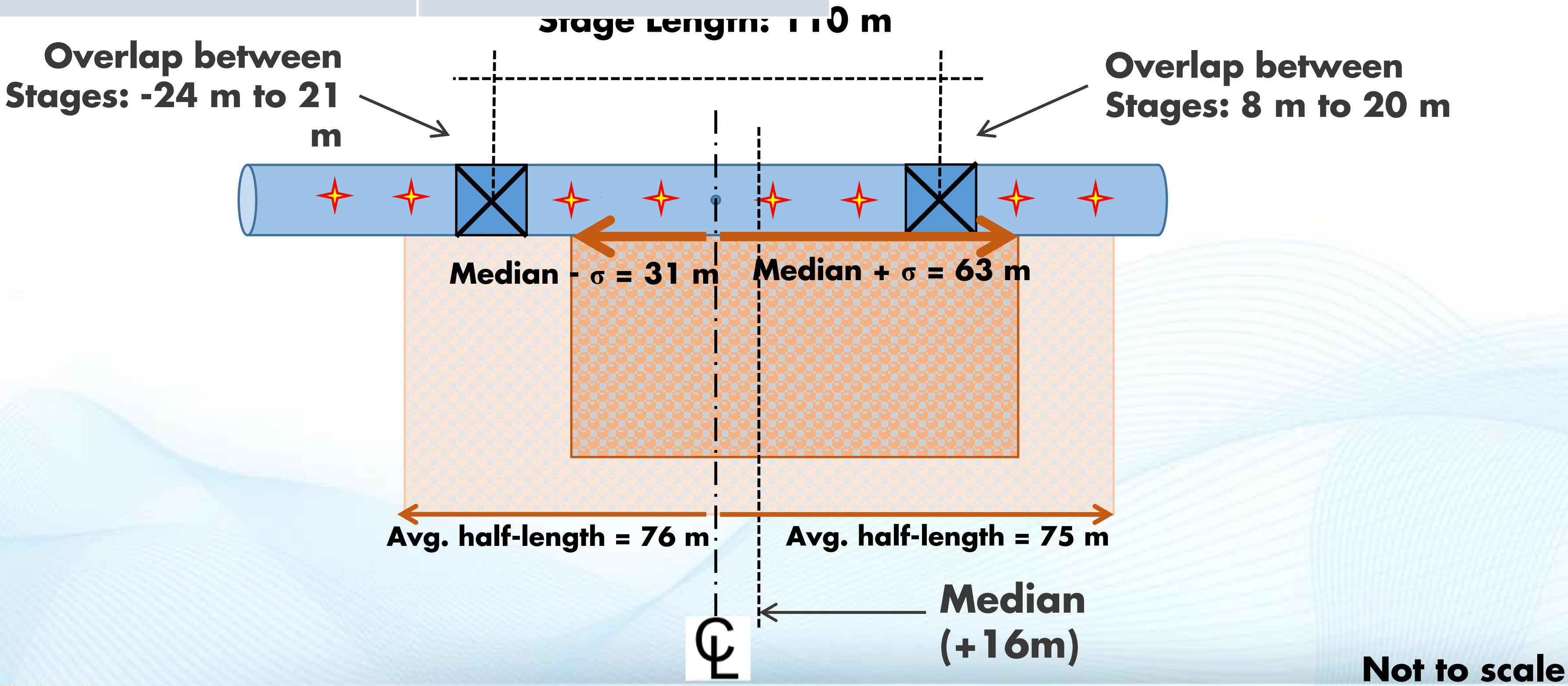


Not to scale

Evie: Stage Length and Spacing – Propped Length

Stage Length	
Most Aggressive	**Decrease up to 16 m**
Conservative	**Increase up to 41 m**





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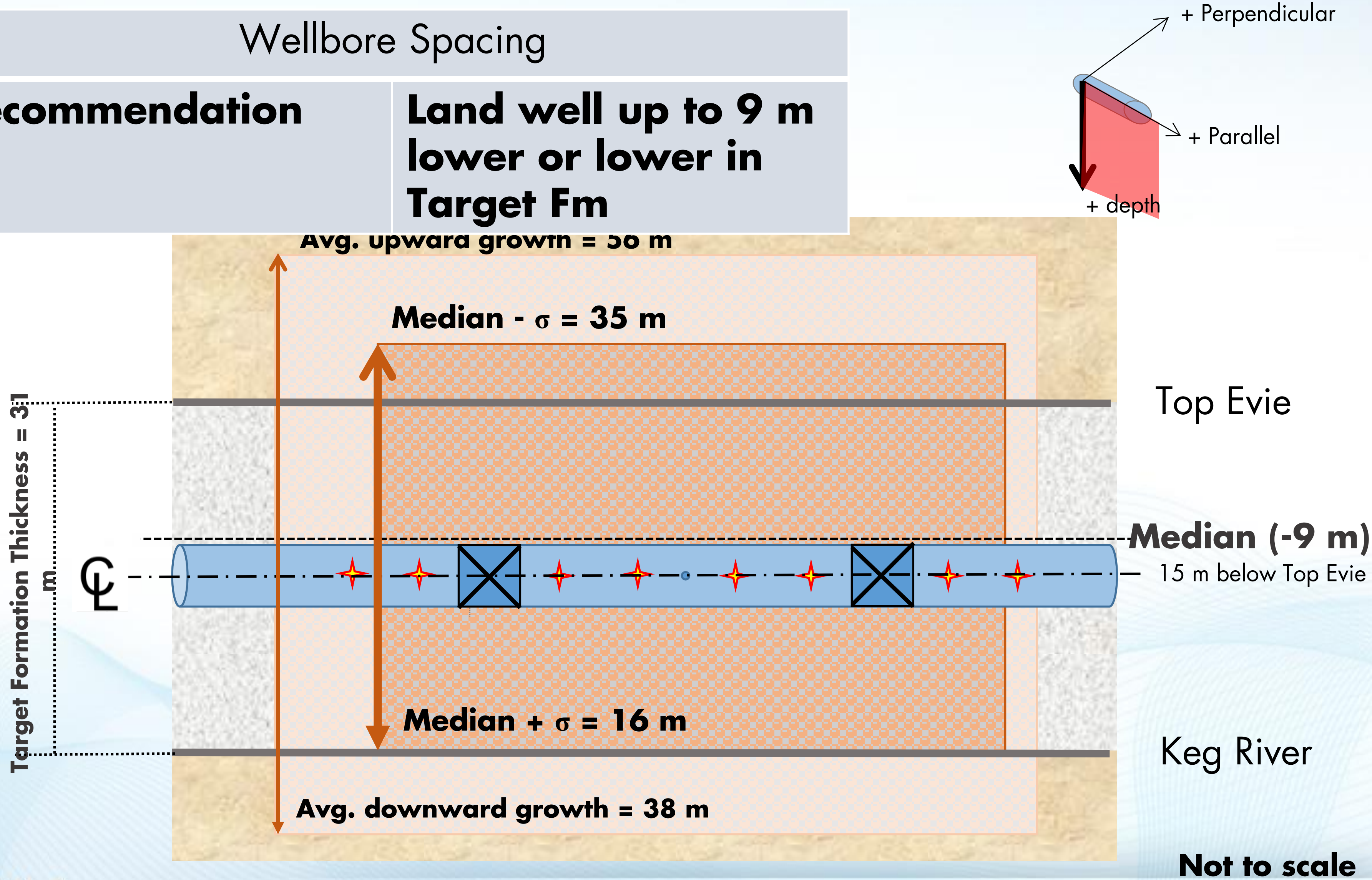
Evie: Vertical Coverage – Propped Length

Wellbore Spacing	
Recommendation	**Land well up to 9 m lower or lower in Target Fm**



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