D2F Report

Company	**Northeast Natural Energy LLC**
Well	**Boggess 3H**
Formation	**Marcellus**
Location	**Monongalia, WV**

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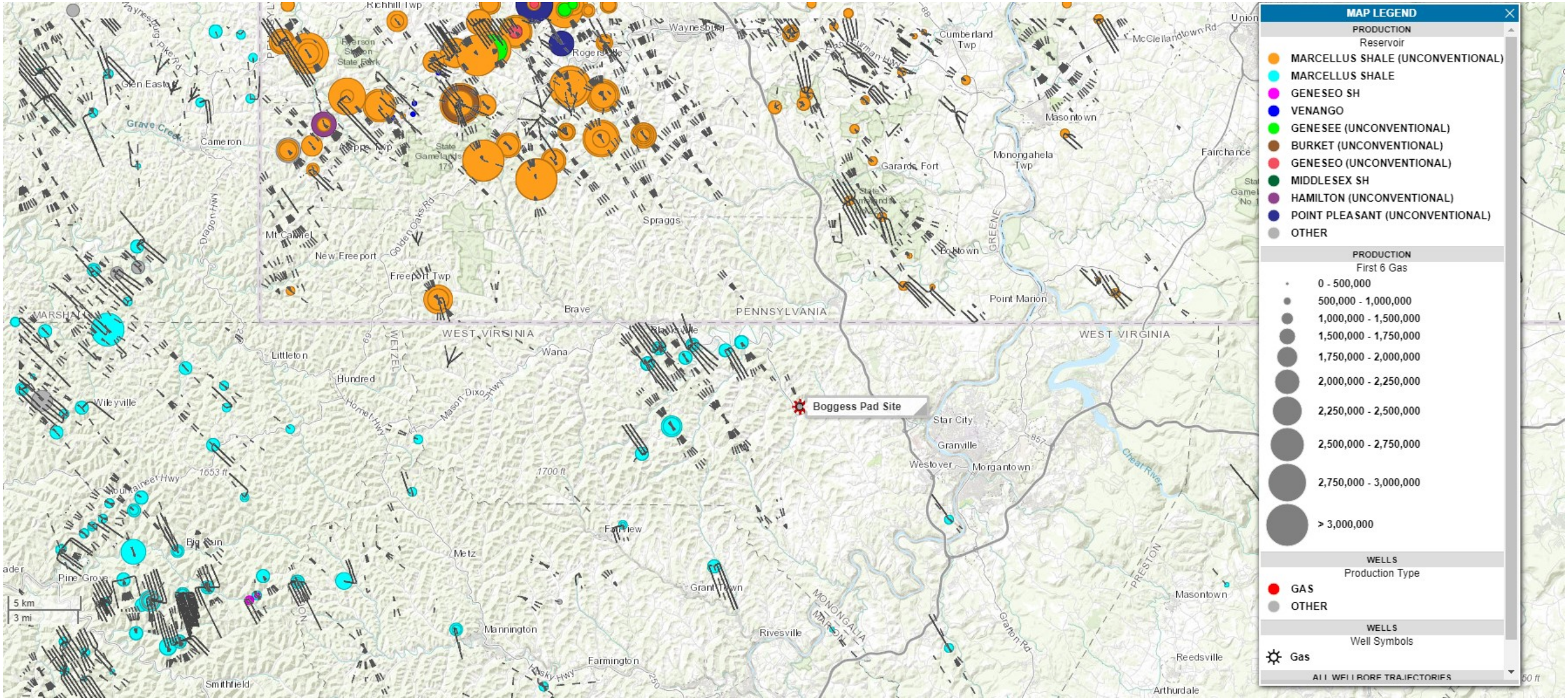
Area Map – First 6 months Gas by Reservoir



Input Data Provided

- Drilling data inclusive of standard parameters such as WOB, ROP, Torque, RPM etc.
- Directional data for well trajectory definition.
- Drilling report summary
- Mud Logs
- GR (drilling)
- Baseline Perf guidance
- Geosteering interpretation
- Natural fracture intensity channel from FracView interpretation

OmniLog Overview

Introduction

- Drilling data is used to generate a RockMSE profile.

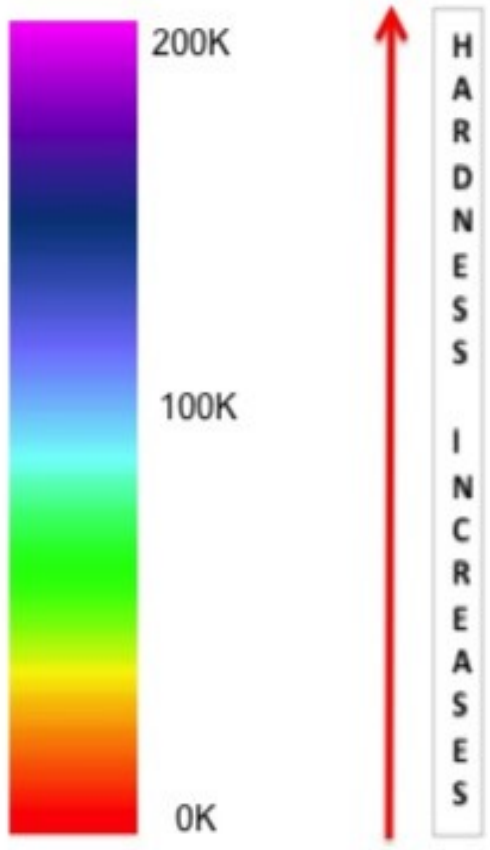
- Correction methodologies and algorithms (beyond the typical filtering, smoothing and de-spiking) are used to generate a RockMSE profile that more accurately represents the formation.

- The OmniLog comprises the final computed RockMSE along with any other available data (GR from the MWD, Mud Log Lithology, Gas shows from Mud Logs, Casing tally information etc.) and provides an insight to the geomechanical heterogeneity along the lateral.

- The OmniLog is presented on Driller's Depth.

OmniLog Color and Quality Reference

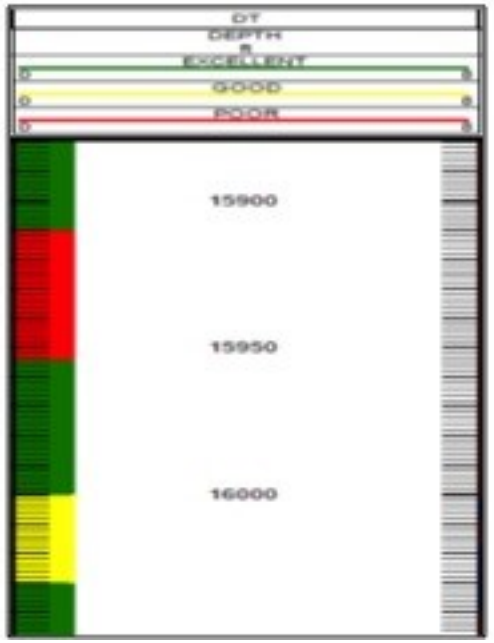
RockMSE Color Reference Index



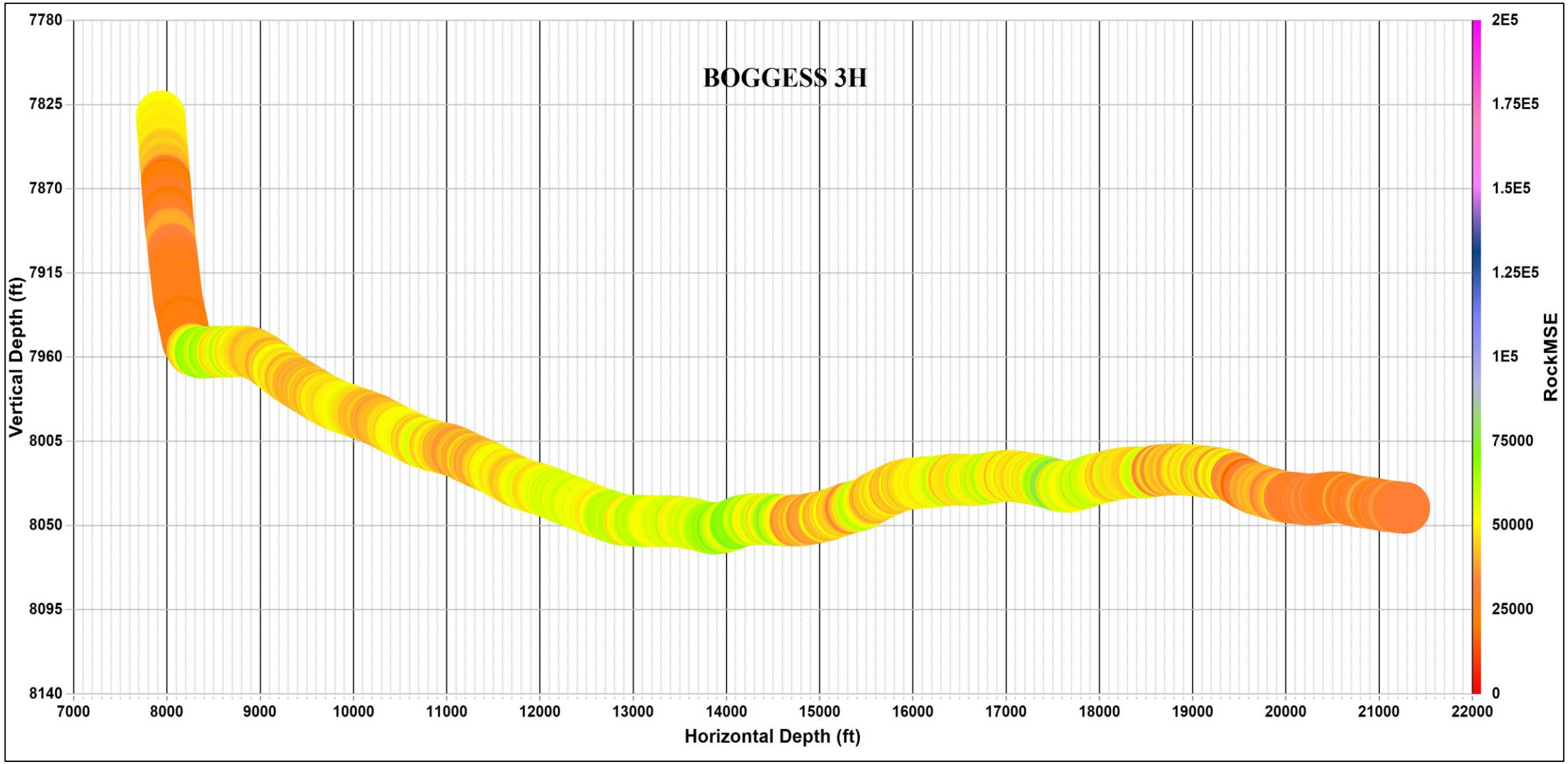
Quality Reference Table

Color Code	Quality Reference	Description
	Excellent	No Data Editing Required; High Level of Confidence in RockMSE Results
	Good	Some level of Data Editing Required; Good level of Confidence in RockMSE Results
	Poor	Quality of data is poor across large sections; Significant data editing required; Low confidence of results in RockMSE; Use with caution

Example Quality Reference Track



Trajectory Plot – Boggess 3H

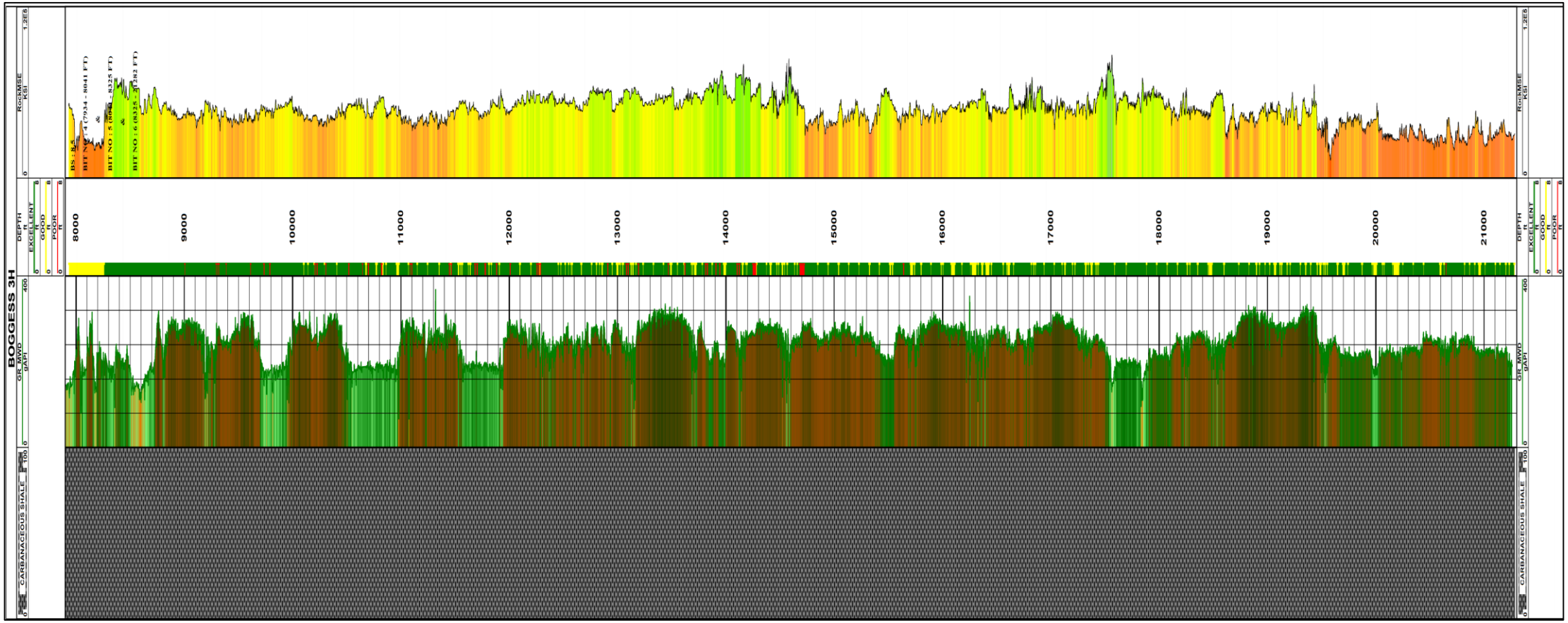


Well Overview – OmniLog/GR - Boggess 3H

OmniLog Lateral Profile

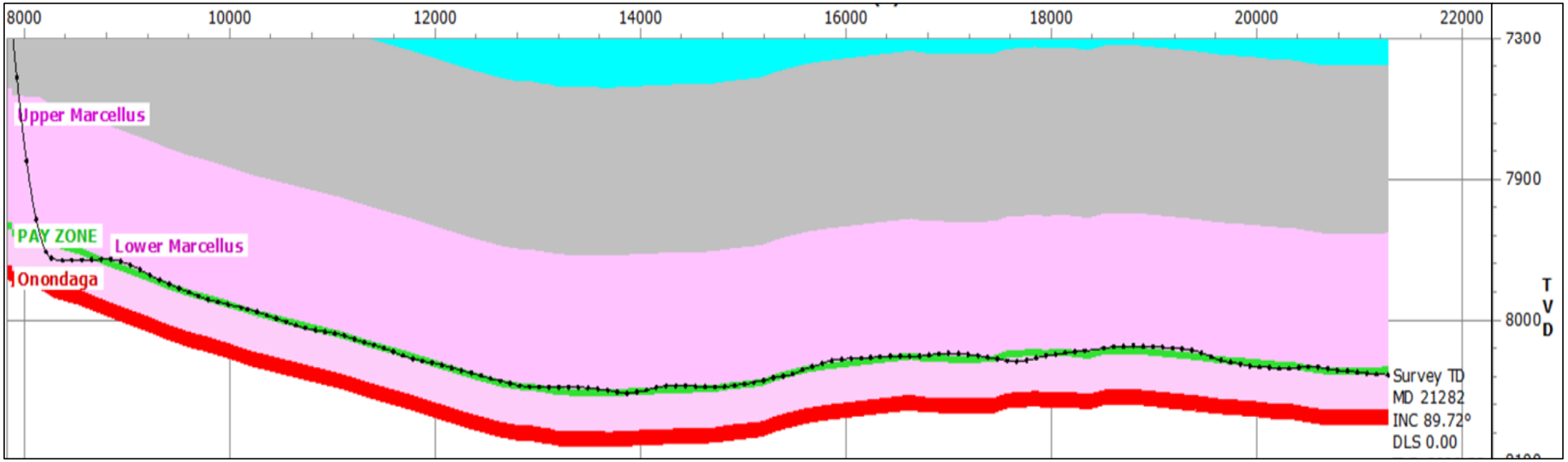
GR MWD

Mudlog Lithology



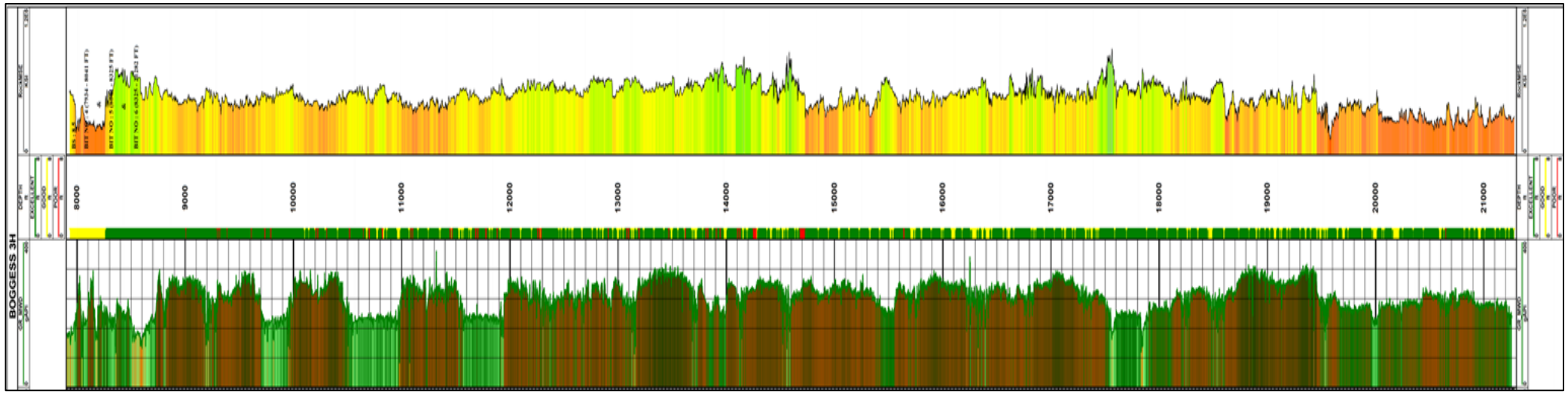
Geosteering Interpretation - Boggess 3H

Geosteering



RockMSE

GR MWD



OmniLog Observations & Summary

- Data was of reasonably good quality across both wells, though there were several sections impacted by null values, missing data and spikes.
- With our modeling workflow we were still able to generate a high quality OmniLog model for both wells
- Hardness levels and Heterogeneity are consistent with other Marcellus wells.
- There is generally good correlation with GR across most of the laterals.

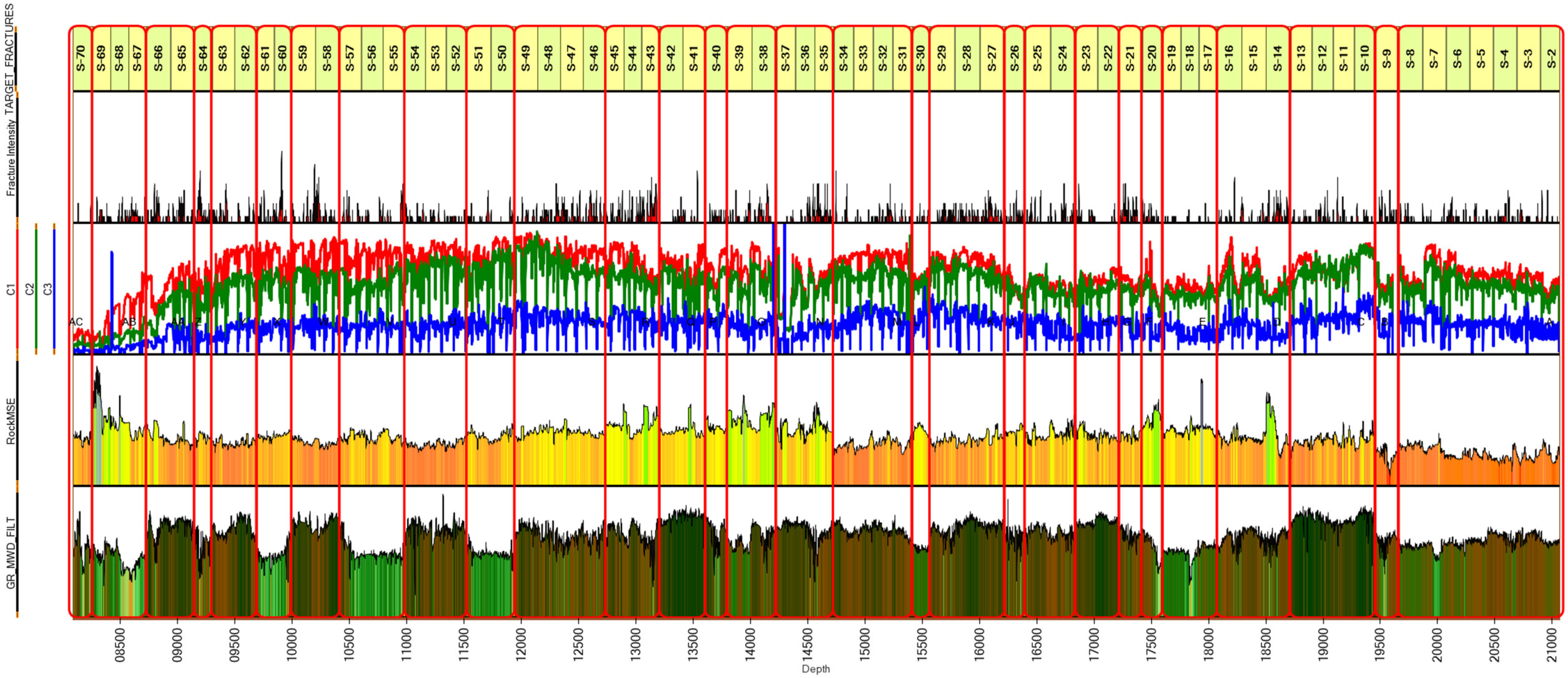
PerfAct Overview

PerfAct Summary

- PerfAct was run with the primary goals of:
  - Creating stage boundaries so each stage is in similar rock
  - Placing perforating clusters so that
    - Each cluster is in similar rock
    - Placement is biased to either avoid fractures or target fractures
  - Average stage length = 189’
  - 4-5 clusters/stage

PerfAct - Segmentation

Well Segmentation



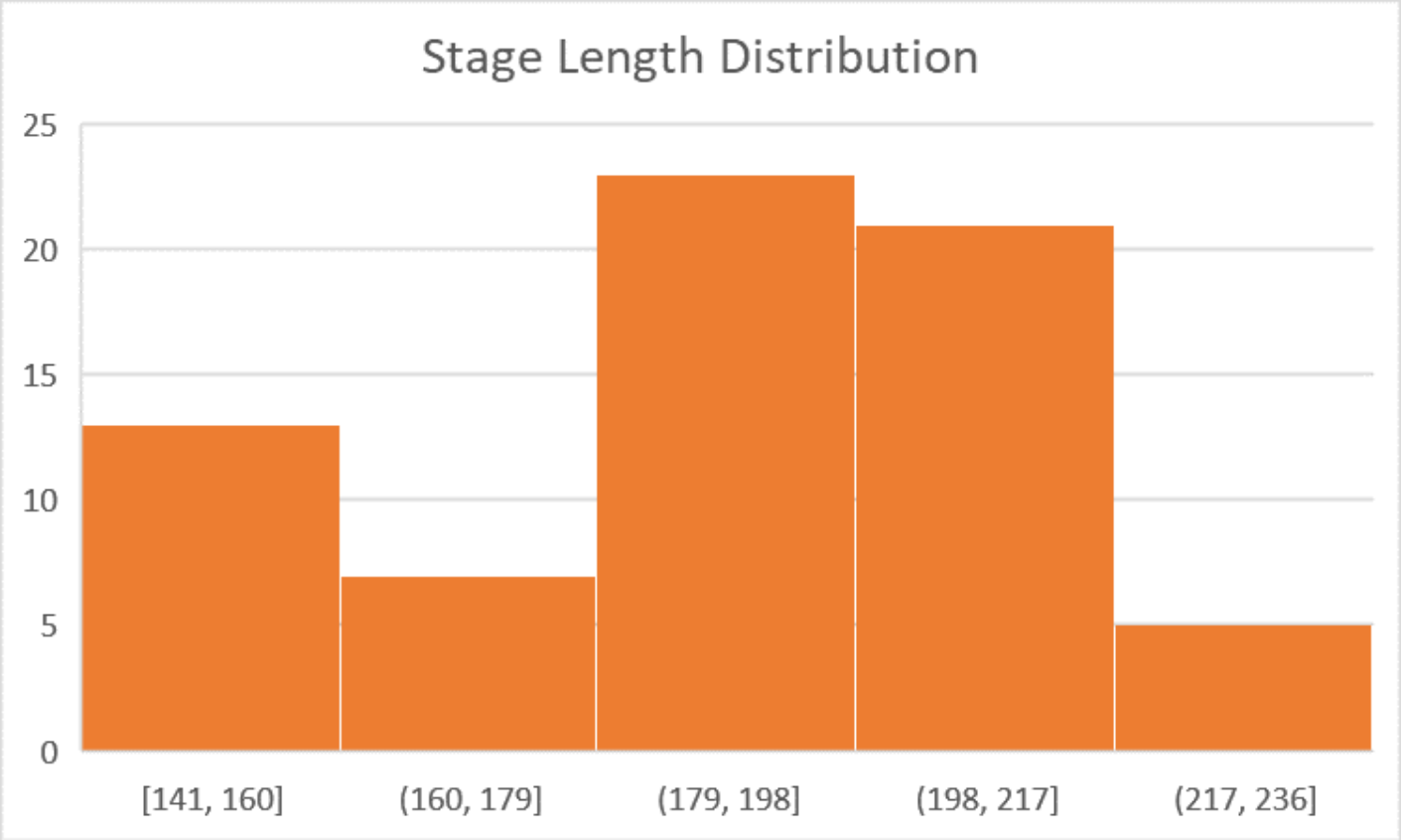
Segmentation Summary

Segment ID	Depth Start	Depth End	Segment Length	No of Stages	Stages	GR	RockMSE	Fracture Intensity	TG	C1	C2	C3
A	19660	21101	1441	7	2,3,4,5,6,7,8	225	32421	0.448	1573	74.9%	24.0%	1.0%
B	19457	19660	203	1	9	228	30222	0.760	1048	73.5%	25.3%	1.0%
C	18715	19457	742	4	10,11,12,13	293	45687	0.445	1856	72.8%	25.9%	1.1%
D	18075	18715	640	3	14,15,16	239	49899	0.764	1521	74.8%	24.2%	0.9%
E	17600	18075	475	3	17,18,19	198	56694	0.172	1329	74.6%	24.4%	0.9%
F	17420	17600	180	1	20	211	66644	0.691	1343	75.3%	23.6%	1.0%
G	17220	17420	200	1	21	248	49671	1.224	1396	74.7%	24.3%	1.0%
H	16840	17220	380	2	22,23	286	50781	0.315	1453	74.6%	24.4%	1.0%
I	16400	16840	440	2	24,25	253	51611	0.646	1370	73.6%	25.2%	1.0%
J	16220	16400	180	1	26	237	54153	0.912	1368	72.5%	25.8%	1.2%
K	15565	16220	655	3	27,28,29	269	46277	0.889	1831	74.5%	24.3%	1.1%
L	15415	15565	150	1	30	210	55570	0.424	1462	72.8%	25.5%	1.2%
M	14728	15415	687	4	31,32,33,34	261	41766	0.531	1832	75.5%	23.4%	1.0%
N	14228	14728	500	3	35,36,37	260	56363	0.758	1357	74.0%	25.0%	0.9%
O	13800	14228	428	2	38,39	236	67469	0.846	1692	75.3%	23.4%	1.0%
P	13610	13800	190	1	40	255	57925	0.607	1661	75.9%	23.0%	1.0%
Q	13210	13610	400	2	41,42	299	55387	0.411	1674	75.7%	23.1%	1.0%
R	12740	13210	470	3	43,44,45	249	61488	1.204	1754	75.7%	23.1%	1.0%
S	11945	12740	795	4	46,47,48,49	247	53719	0.866	2004	74.7%	24.3%	0.9%
T	11525	11945	420	2	50,51	191	49669	0.504	1873	74.5%	24.6%	0.8%
U	10983	11525	542	3	52,53,54	262	41545	0.471	1897	75.3%	23.9%	0.8%
V	10415	10983	568	3	55,56,57	194	49078	0.580	1811	78.1%	20.9%	0.8%
W	9995	10415	420	2	58,59	279	43248	0.831	1872	77.6%	21.5%	0.8%
X	9695	9995	300	2	60,61	185	49687	0.947	1773	77.9%	21.3%	0.8%
Y	9302	9695	393	2	62,63	267	42845	0.637	1758	78.0%	21.3%	0.7%
Z	9150	9302	152	1	64	218	49248	1.412	1210	77.1%	22.2%	0.7%
AA	8730	9150	420	2	65,66	270	47986	0.891	1250	79.1%	20.3%	0.7%
AB	8260	8730	470	3	67,68,69	176	66031	0.739	706	85.5%	14.0%	0.5%
AC	8060	8260	200	1	70	208	48913	0.244	328	83.2%	16.3%	0.5%

Top 1/5
Median
Bottom 1/5

Stage Length Distribution

- Stage lengths vary depending on well segmentation
- Average stage length = 189’

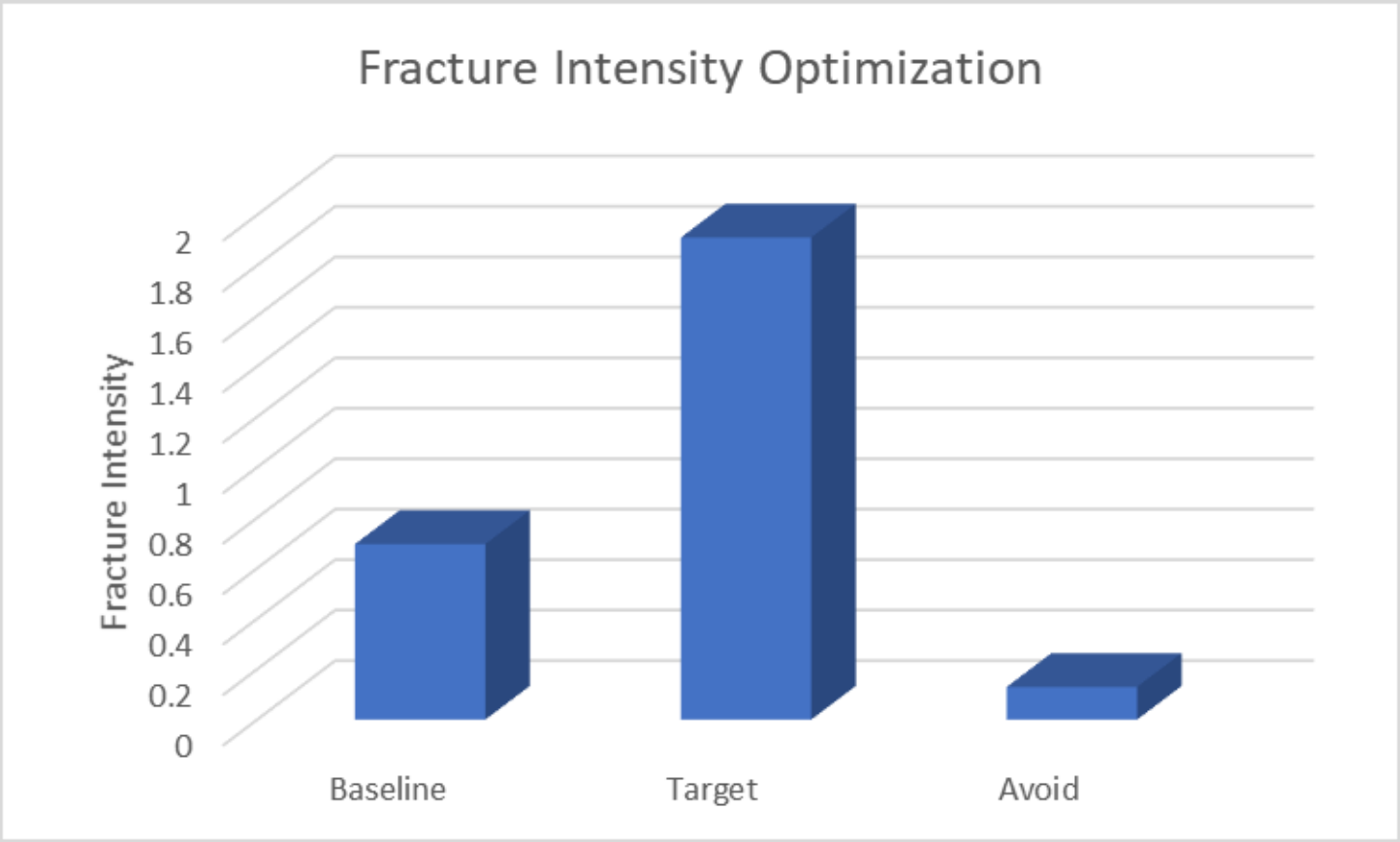


PerfAct – Optimization Parameters

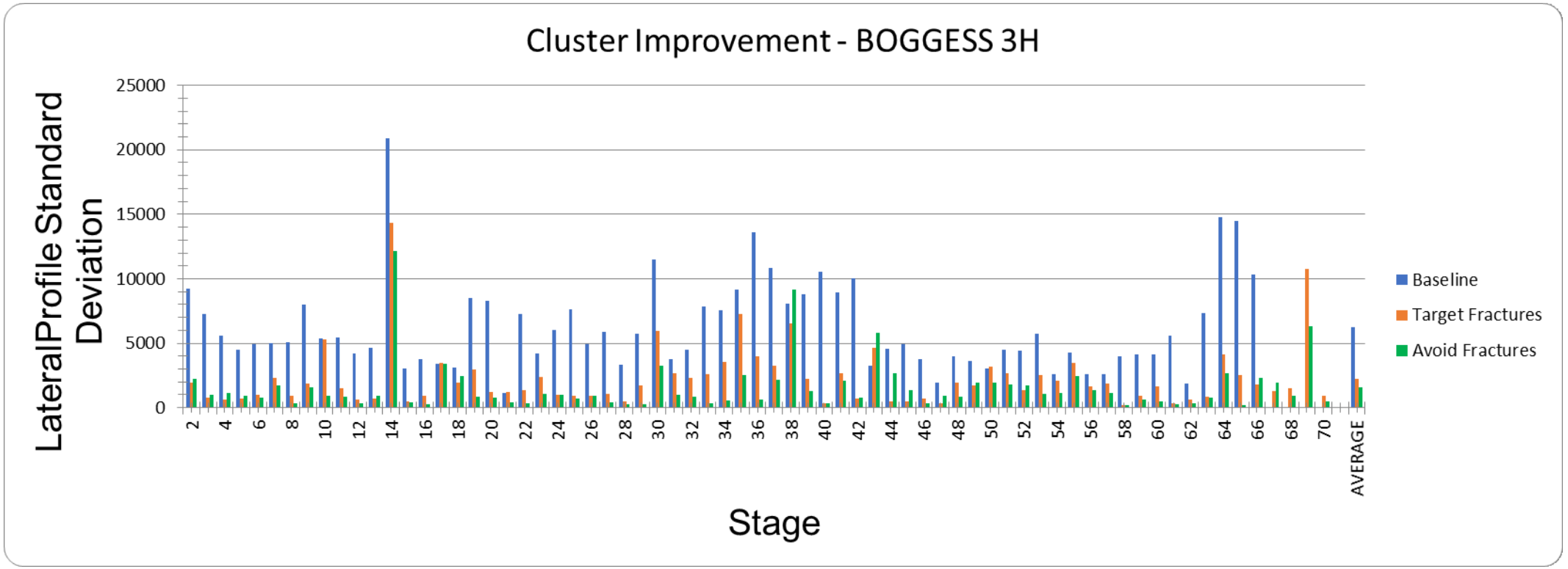
Optimization Parameters

Optimization was performed to put clusters in:

- Similar rock MSE (50%),
- Target or avoid fractures (35%)
- Avoid sudden changes (15%)



Reduction in RockMSE Standard Deviation



69% Reduction in Standard Deviation

Fluid Distribution

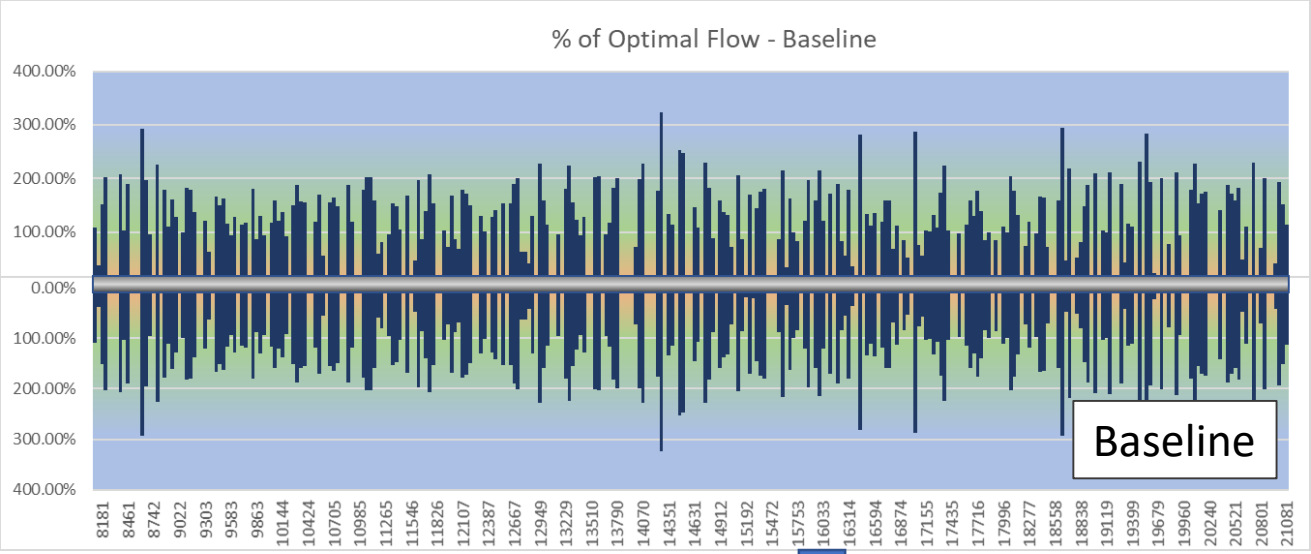
Fluid Distribution

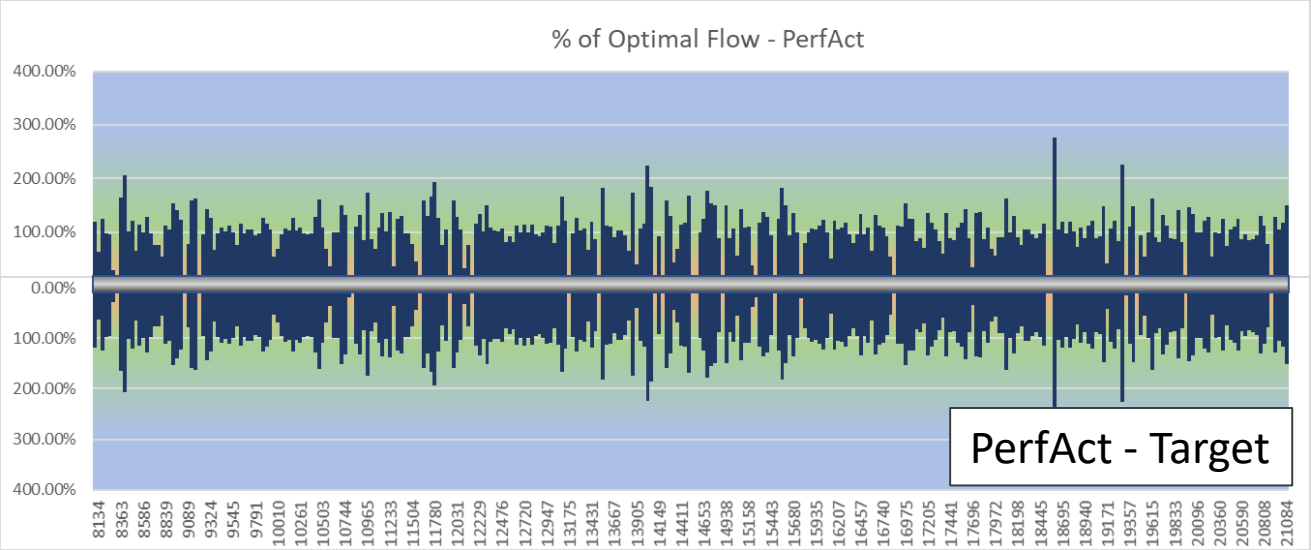
Fluid distribution is estimated at each cluster based on OmniLog and the following completion parameters

0.42” Entry hole diameter
0.7 Discharge coefficient
90 bpm pump rate

All Clusters:

- 8 shots/cluster

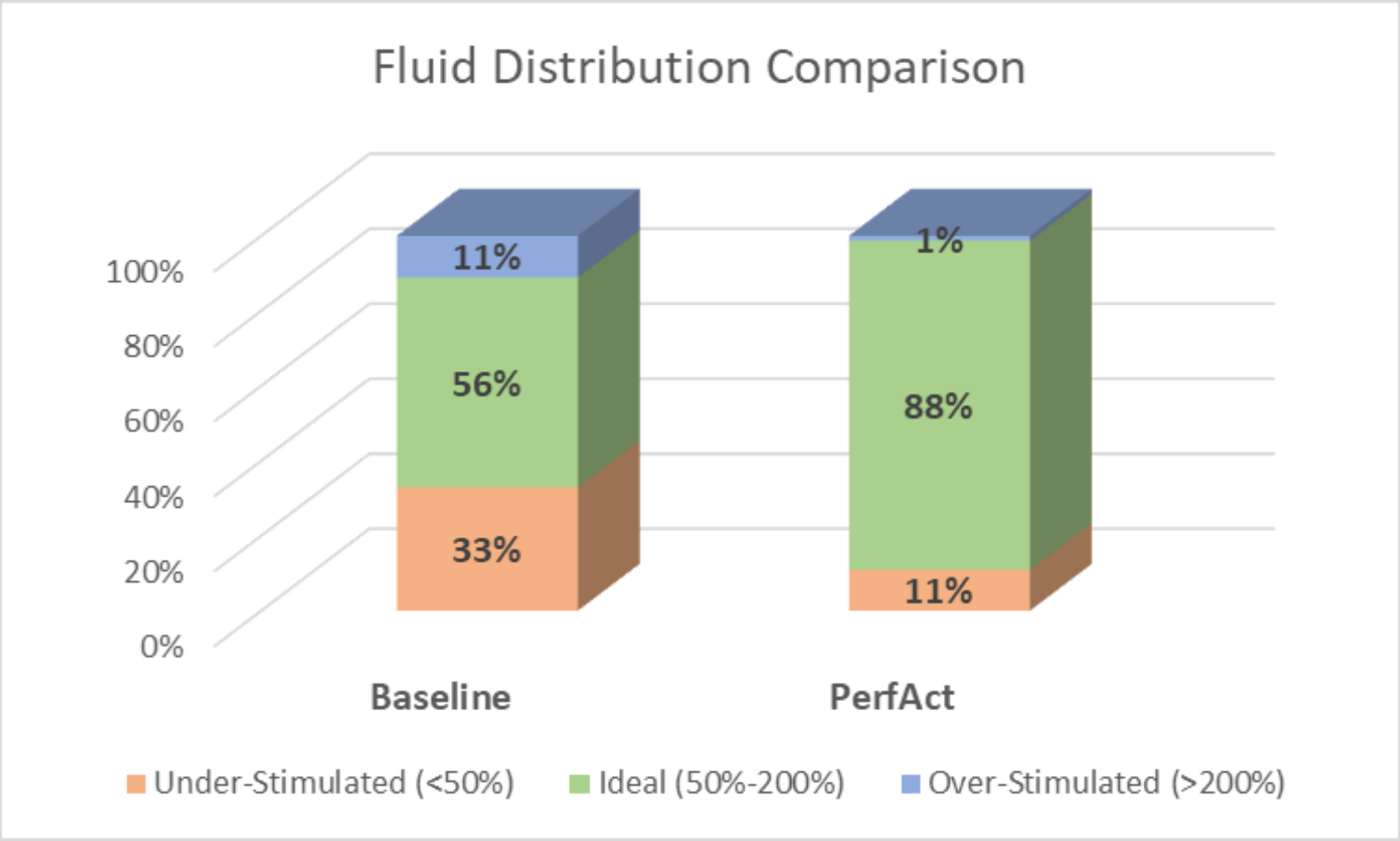




Fluid Distribution Summary

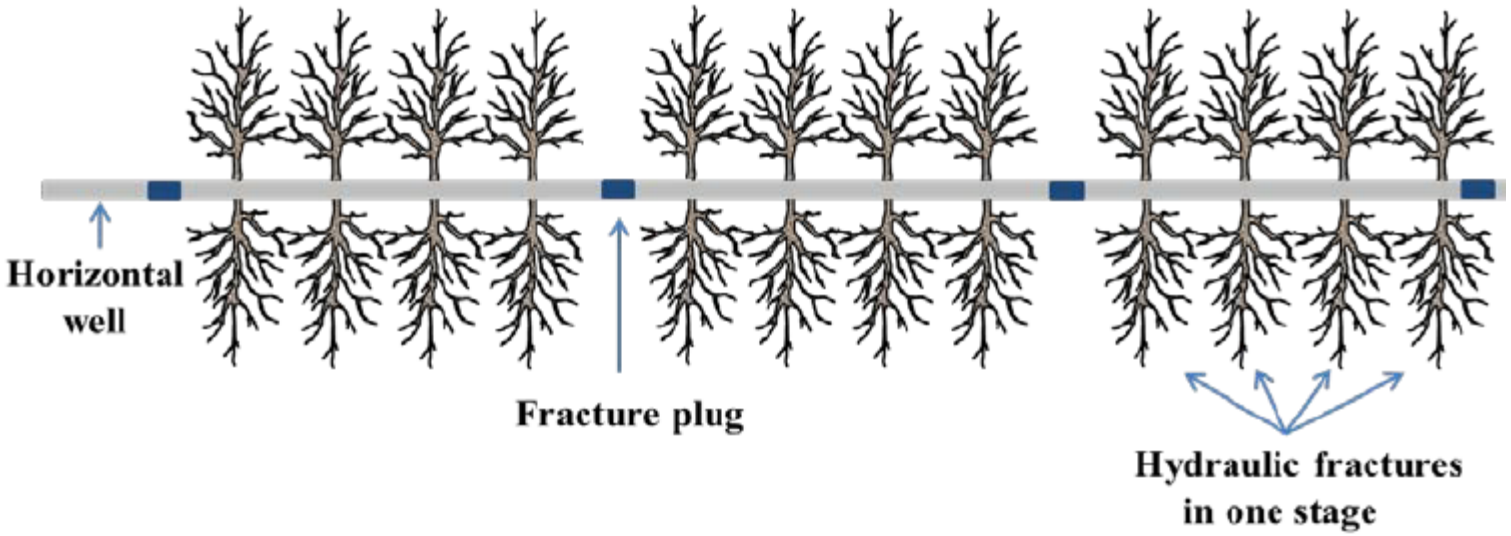
By placing perforations in like rock, we can achieve:

- 65% reduction in understimulated clusters
- 90% reduction in overstimulated clusters



Perforation Depth Control

Depth Control in Plug & Perf Completions



- Many completions designs based on geometric spacing
- Foot-by-foot data on formation characteristics not available or not utilized
- Precise placement of perforations is not critical in geometric design
- When actual rock measurements used to design completions, then accurate placement of perfs & plugs relative to those measurements is important
- The perforation design from PerfAct is provided on Driller's depth.

Casing String Design & Planning

- Use of toe sleeve impacts
  - Stage 1 initiation & space-out
  - Logistics & timing of wireline GR/CCL

- Use of adequate short “marker” casing joints recommended
  - Minimum 2-3 per lateral
  - More for longer laterals

- RA marker tags can optionally be used to aid correlation in low GR contrast

PDC Procedure – Shift Wireline to Driller's Depth

- Run wireline GR/CCL on first WL descent. Log from Toe to 200' above top perf or top marker joint & transmit LAS file to D2F ASAP. Maintain similar line speed and pump rate while logging.

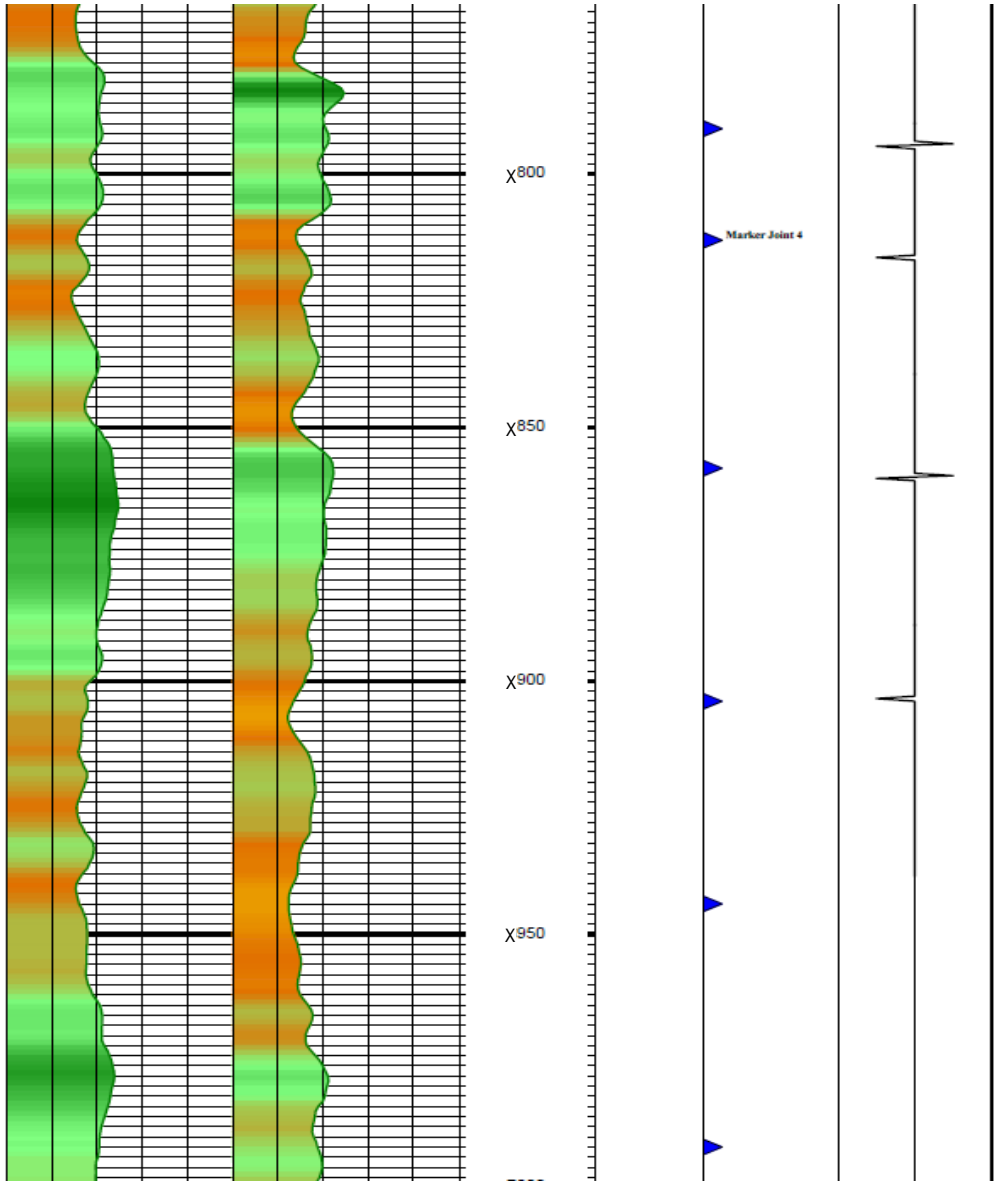
- D2F will depth match field GR/CCL to driller's depth using MWD GR and send corrected PDC log back to the field via operator.

- Perf depths and plug depths can then be used directly from this log or from perf schedule with no further adjustment.

- Procedure for subsequent descents is to tie in to adjusted PDC Log at the top marker joint, then again using 1 or 2 collars close to the perf interval for each stage.

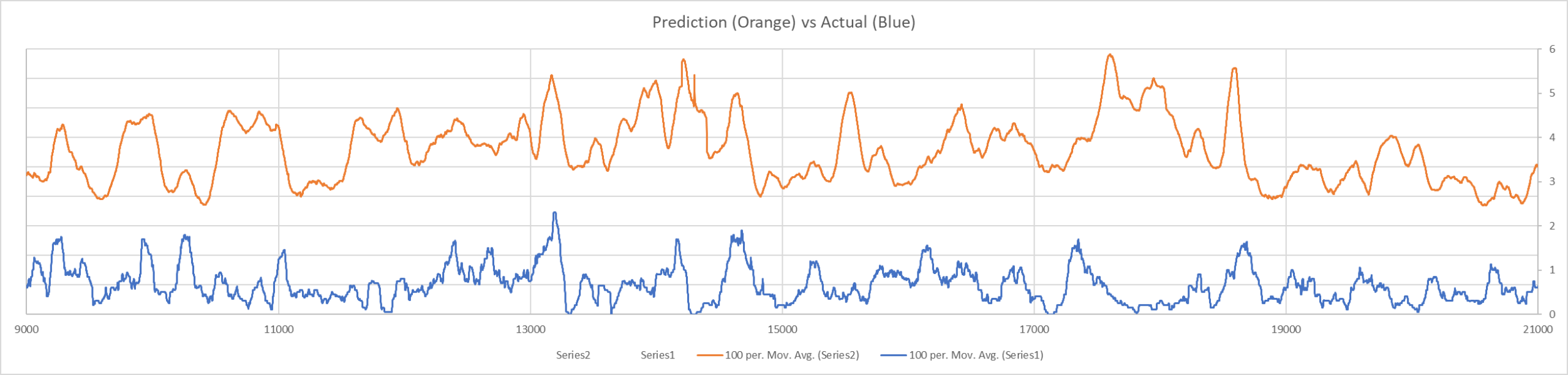
PDC Log Example 1

- Simple, fit for purpose log display for field use
- Marker joints & accessories annotated
- Low resolution LAS file may miss some collars



Fracture Prediction (Probability)

- New algorithm has recently been created that predicts fractures based on a number of factors (RockMSE, GR, Gas Shows)
- Still in early trials but results look promising



D2F Summary

- Data was of reasonably good quality across both wells, though there were several sections impacted by null values, missing data and spikes.
- Hardness levels and Heterogeneity are consistent with other Marcellus wells.
- Two designs were considered. One that targets fractures and one that avoids
- Reduction of standard deviation in RockMSE was 69% by using PerfAct.
- Stress variations amongst the perforations was significantly reduced across all stages by using PerfAct. This resulted in:
  - 33% more clusters stimulated
  - 90% fewer dominant fractures