RESMAN®

UTAH FORGE PROJECT – RESMAN TRACER STUDY

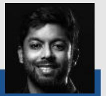
PRELIMINARY RESULT DISCUSSIONS

July 9, 2024

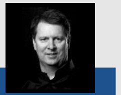
resmanenergy.com

Workflow

Chemistry



Operations



Flow

Volume

Surface Area

AGENDA – FORGE PRELIMINARY RESULT DISCUSSIONS – JULY 9TH, 2024

Chemistry Operations	**Chemistry & Operations**		Sven Kristian Hartvig *CTO / Chief Chemist*
Flow Volume	**Fluid Quantifications**		Olaf Kristoff Huseby *Chief Physicist*
Surface Area	**Fracture Characterization**		Chris Fredd *Stim Mapping Tech Director*

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Roy Greig
Senior VP – New Energy

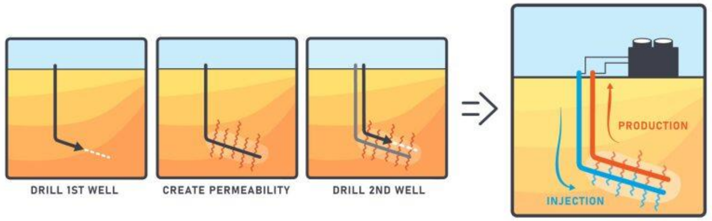
Partho Giri
Global Operations Director

Scott Lavoie
CCO

Ross Phillips
Well Technology Engineer

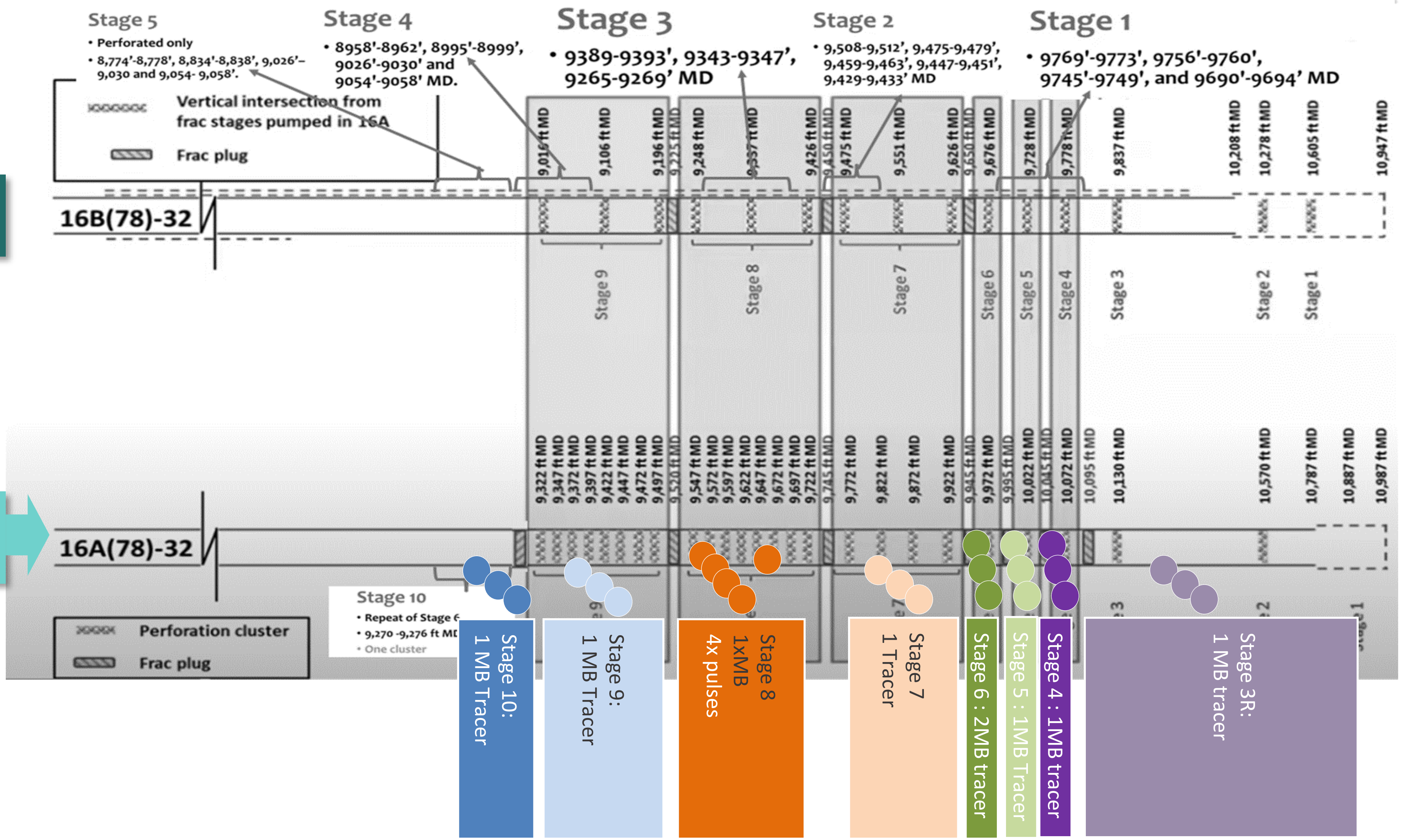
Operations

Tracer Operations: Utah FORGE



Production Well 16B: Circulation Test

Injection Well 16A: Clean up



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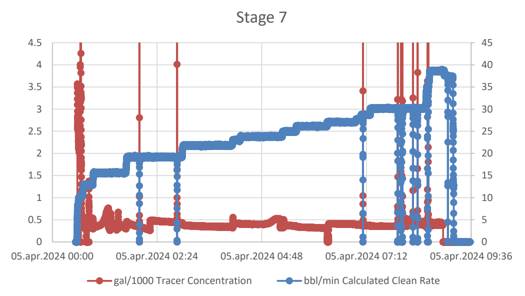
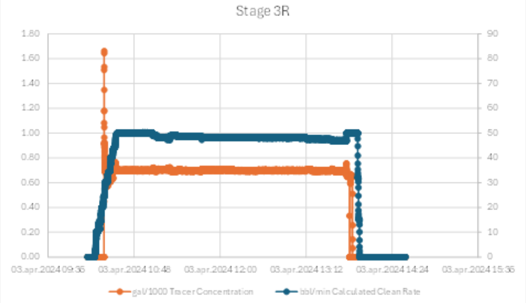
Chemistry

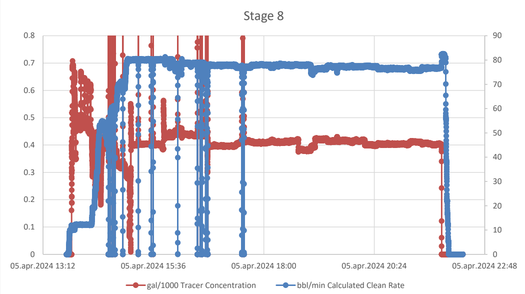
TRACER INJECTION PROFILES

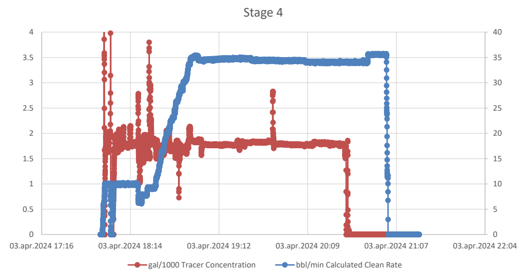
- Tracers injected continuously through Calfrac liquid additive system
- Targeting stable concentration
- Deviations:
  - Run out of tracer in stage 5 due to extension of stage
  - Stopped tracer dosage in Stage 6A and 6B when the stages did not frac
- In addition: 4 pulsed tracers in: pad, 0.5ppa, 1.25ppa & 1.5ppa stages added during ~3 minutes though blender

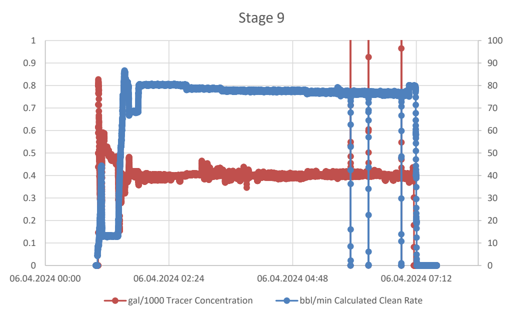
Stage	Tracer	Total amount added	Avg. dosed concentration
3R	IFE-WT-17	0.86 kg	0.70 gpt 560 ppb
4	2,6-NDS	1.0 kg	1.76 gpt 1409 ppb
5	IFE-WT-61	0.88 kg	1.77 gpt 1417 ppb
6A	IFE-WT-101 & IFE-WT-102	0.12 kg & 0.12 kg	1.27 gpt 1000 ppb
6B			1.24 gpt 1000 ppb
7	2,7-NDS	0.60 kg	0.43 gpt 344 ppb
8	IFE-WT-66	0.83 kg	0.49 gpt 196 ppb
9	IFE-WT-60	0.67 kg	0.42 gpt 168 ppb
10	IFE-WT-109	0.72 kg	1.51 gpt 1209 ppb

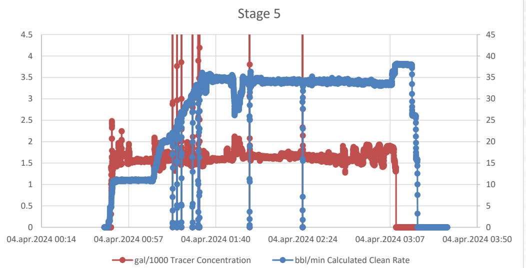


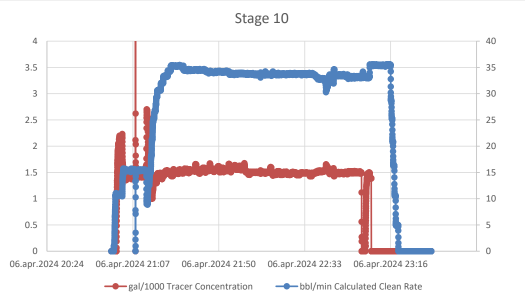


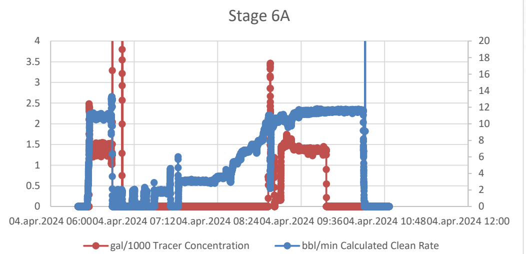


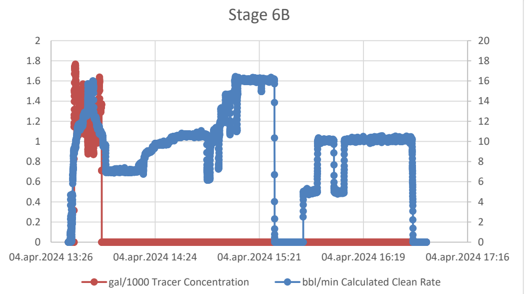












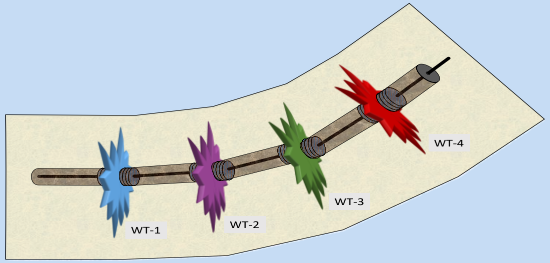
GEOTHERMAL TRACER CHEMISTRY DEVELOPMENT

- Commercial delivery consisted of 8 tracers (increased on-site from designed 7 based on addition of Stage 10)
- In addition to this **11 new geothermal** tracers were tested in different stages
  - 2 added as extra mass balance tracers in Stage 9
  - 8 added as pulses in Stage 8
  - 1 added as extra mass balance tracer in Stage 6
- In addition to this:
  - 3 tracers had previously been utilized in the project
  - 2 tracers were reserved for EGI to utilize for circulation tests
- Additional tracers pending final QA for Utah FORGE conditions: for a total of 24 tracers pumped
  - Results from circulation test in Jul/Aug will be essential to evaluate longer term stability
- RESMAN is continuing to develop new HT tracers and we have 6 new tracers that has passed lab test available for next circulation test
- This will enable zonal tracing on commercial geothermal wells with high stage count

RESMAN Energy Technology

Stage Contribution

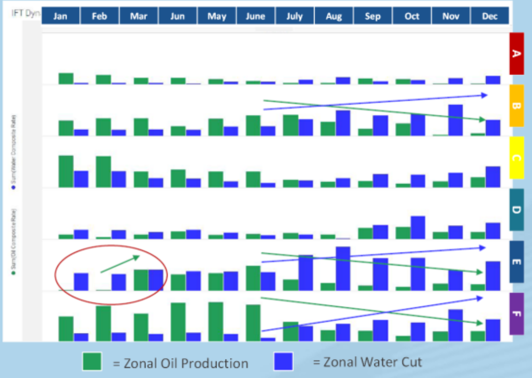
Quantify flow contributions



- Detect frac stage contribution during flowback / early production
- Tracer injected with stimulation fluid
- Quantify perf or stage efficiency

Quantitative PLT

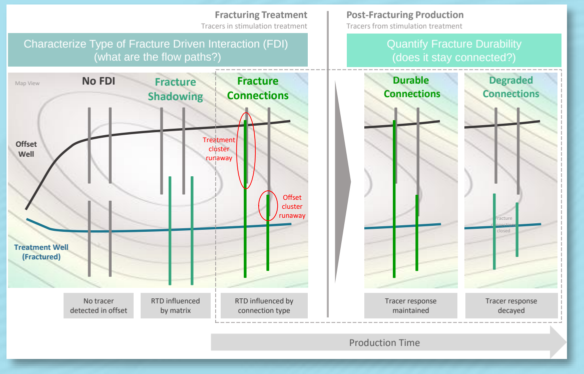
Measure while producing "PLT in a Bottle"



- Tracer-based production profile
- Undisturbed production
- No Intervention
- Monthly bottles
  = MONTHLY PLT LOG
  = 4D PLT

FDI Characterization

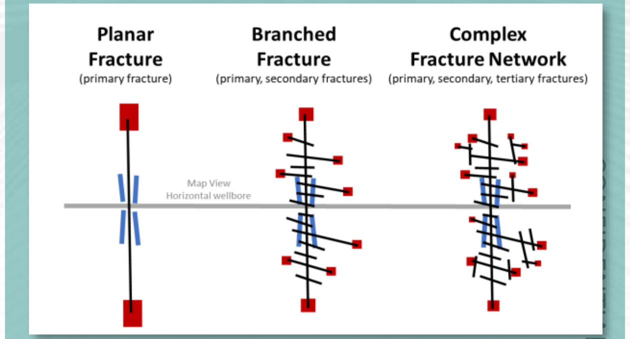
Characterize Fracture Driven Interactions (FDIs)



- Identify flow connections
- Determine FDI type
- Quantify FDI flow allocation
- Monitor connection durability
- Visualize connections across field

Frac Characterization

Characterize stimulated flow paths



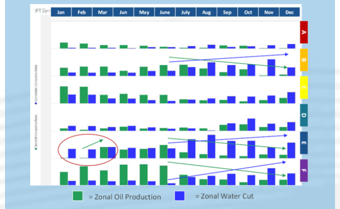
- Directly measure flow paths to enhance treatment optimization
- Fracture complexity (planar, branched, complex)
- Quantification of effective stimulated reservoir volume

Utah FORGE – Executive Summary

- Resman tracers confirm direct fracture connections between 16A and 16B from all stages
  - Spikes in cleanup data associated with 16B operations
  - All tracers being detected from during circulation test
- “PLT in a Bottle” provides stage and cluster flow contributions
- Completion and Stimulation implications:
  - Consistent results with and without 16B stimulation
  - No negative impact from no proppant in stages 6 and 7 in 16A
  - Highest flow allocation using 8 clusters per stage in 16A (since only 3 frac hits in 16B, suggests these benefited from treatment cluster runaway with more proppant)
- Fracture circulation volume estimated from initial circulation test
  - Results suggest the existence of open fractures

Quantitative PLT

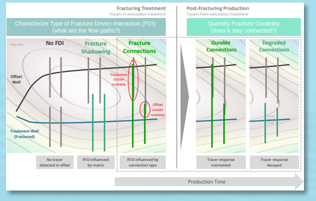
Measure while producing "PLT in a Bottle"



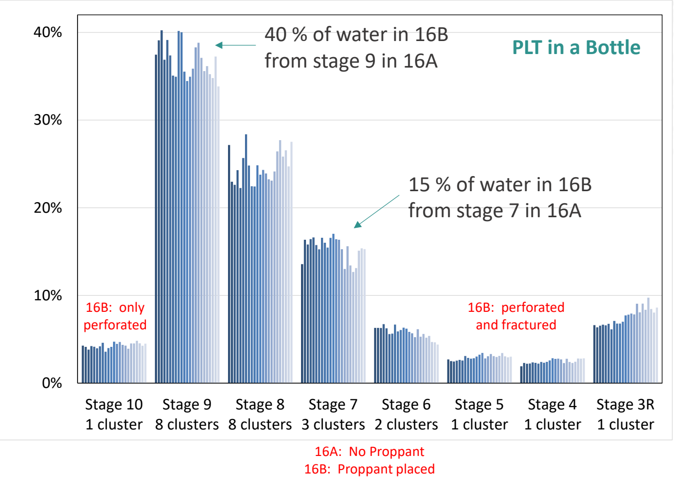
- Tracer-based production profile
- Undisturbed production
- No Intervention
- Monthly bottles
  = MONTHLY PLT LOG
  = 4D PLT

FDI Characterization

Characterize Fracture Driven Interactions (FDIs)



- Identify flow connections
- Determine FDI type
- Quantify FDI flow allocation
- Monitor connection durability
- Visualize connections across field



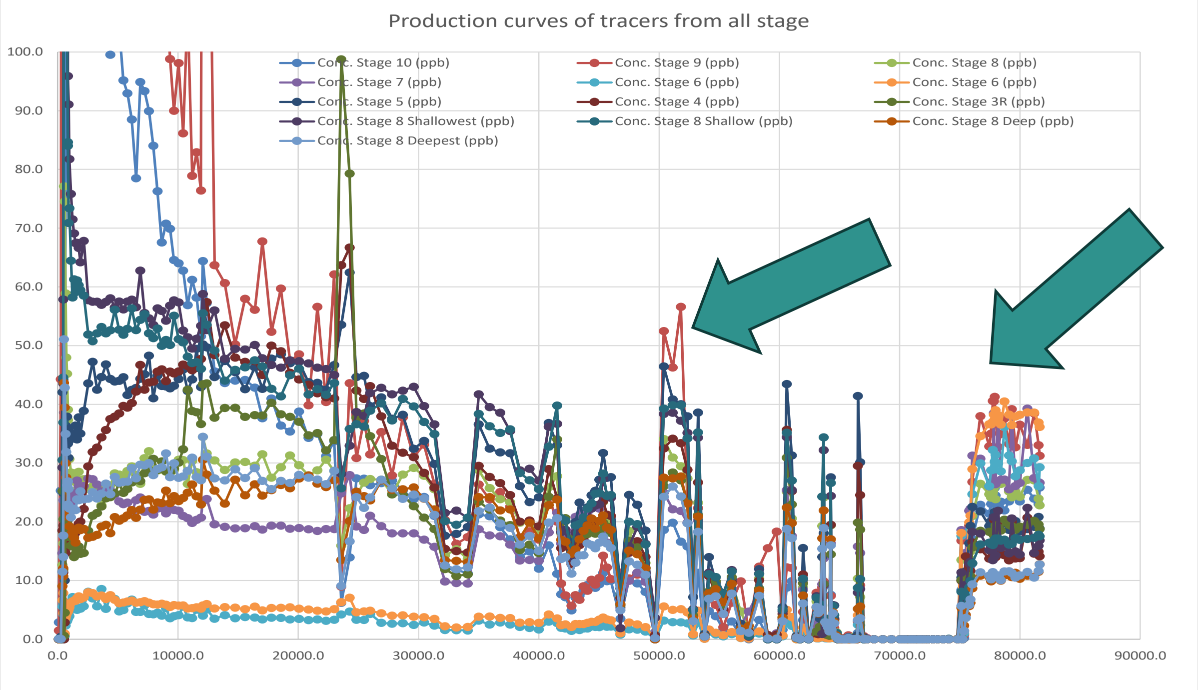
Flow

Strong Fracture Communication for All Stages

- All Resman stimulation tracers observed from injection well 16A cleanup and production well 16B circulation test
- Tracers confirm fracture connections and flow path communication

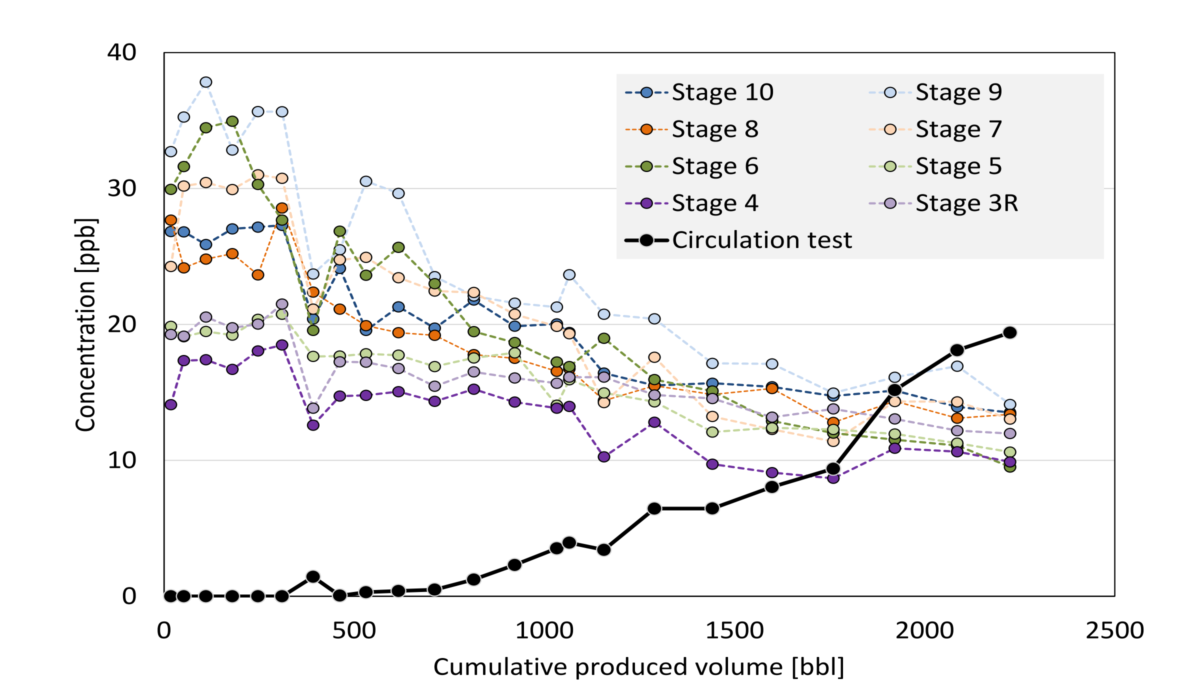
Injection Well 16A: Cleanup

- Spikes in cleanup data associated with injection well 16B operations
- Reveals direct flow path connections



Production Well 16B: Circulation Test June 2024

- Tracers detected from all production well stages during circulation test
- Short-term, fracture communication maintained



- Discussions/Request: Flowback data (rate/event/cooling water) to ensure quantitaive interpretation. Was water from pit used?

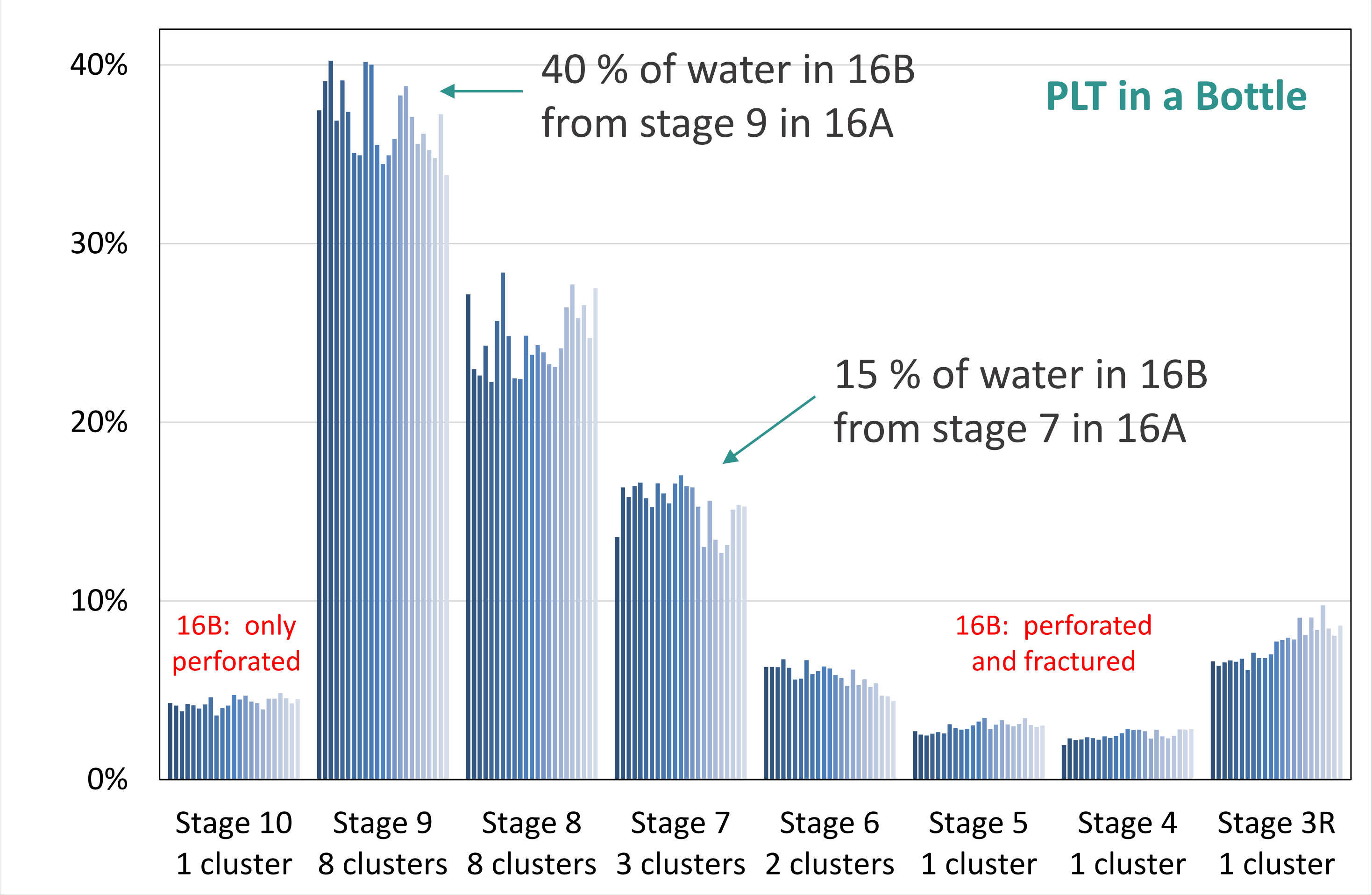
Flow - Rate

RELATIVE CONTRIBUTION TO 16B FLOW PER STAGE IN 16A

- The tracers injected continuously per stage, observed at **16B** give the proportion of fluid moving from **16A** to **16B** per stage
- A clear relation is seen between this contribution and the number of clusters per stage (larger contribution for stages with many clusters

- Consistent results with and without 16B stimulation
  - Perforated only (stage 10) consistent with clusters stimulated from 16A (stages 4, and 5); all 1 cluster cases
  - Implies good connection to 16B without stimulation from 16B
- No negative impact from 0 prop

Production Well 16B: Circulation Test June 2024



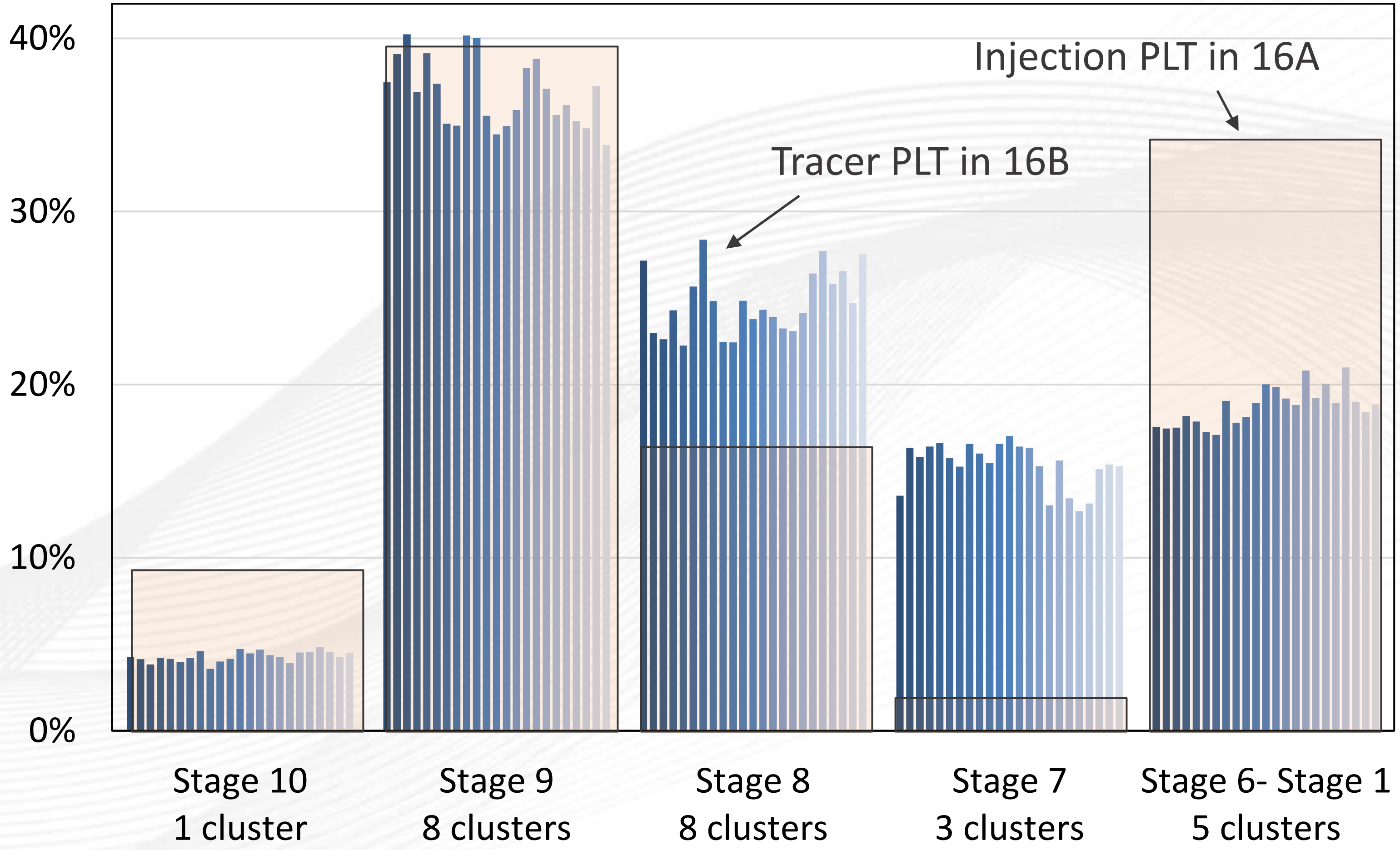
16A: No Proppant
16B: Proppant placed

Flow - Rate

PRODUCTION LOG IN 16B FROM TRACER INJECTED IN 16A

- Known, constant concentrations were added to frack stages in 16A.
- By a dilution analysis and mass balance this yields effectively a production allocation in 16B. One estimate per sample (PLT in a bottle)
- No PLT in 16B but can use the chemical tracer PLT to compare to injection PLT in 16A
- Tracer data re-organized to correspond to injection PLT in 16A

PLT from 16A vs. tracer "PLT in a bottle"

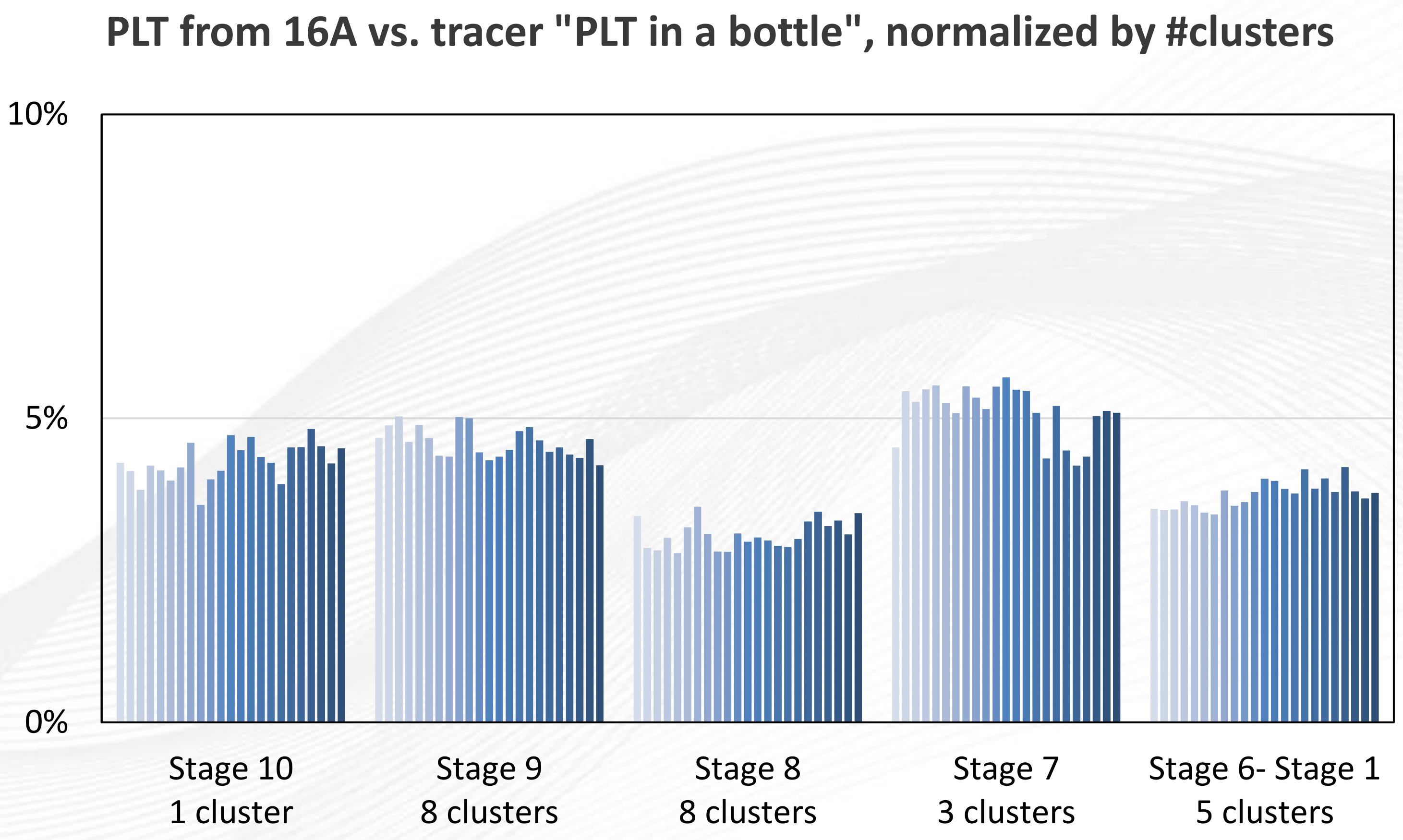


Flow - Rate

PRODUCTION LOG IN 16B PER CLUSTER IN 16A

- Contribution per 16A cluster, estimated from the tracer production assessment in 16B
- The contribution per cluster is remarkably constant, with a contribution of 3-5% per cluster

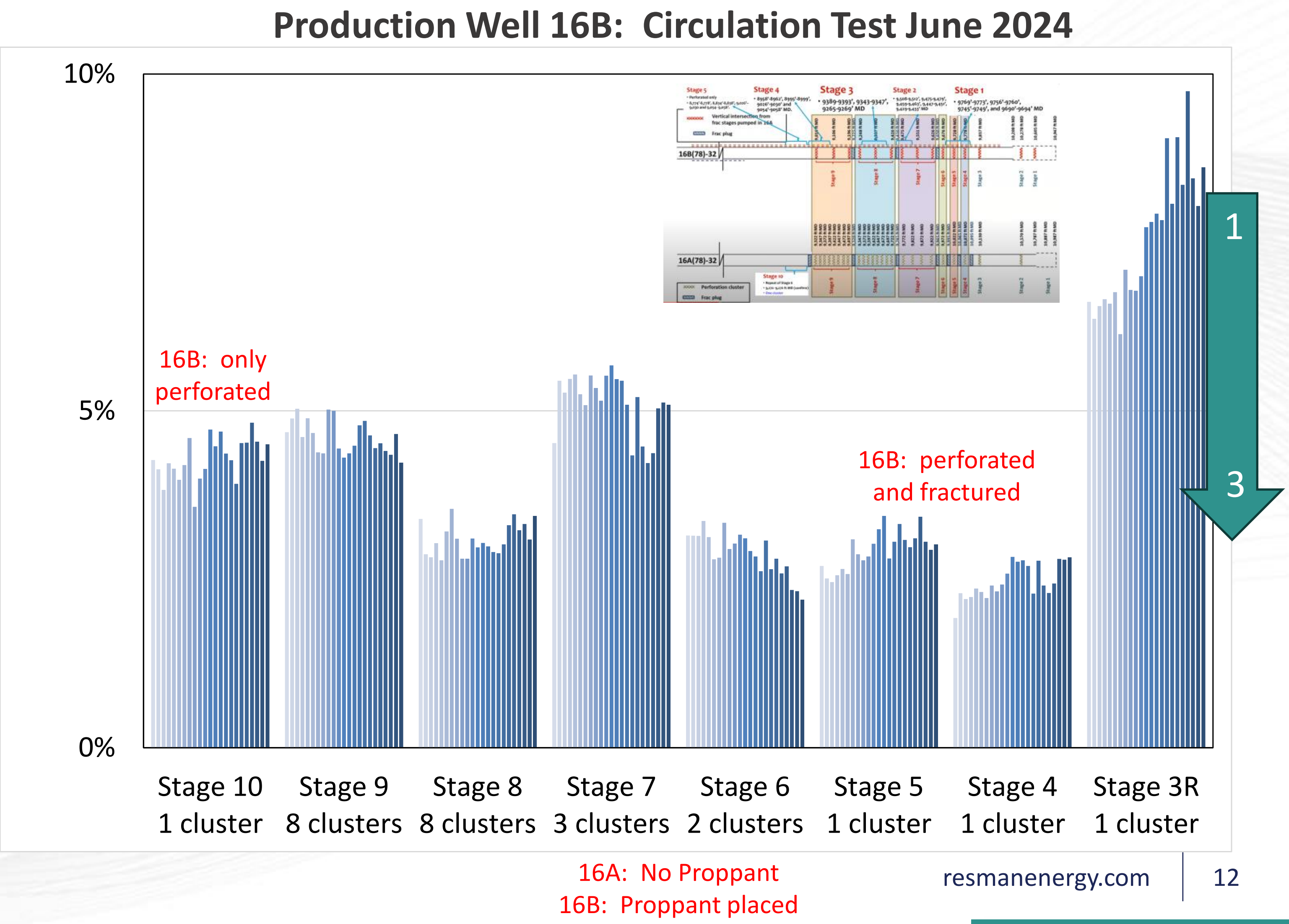
Stage	10	9	8	7	6-1
# clusters	1	8	8	3	5
Flow contribution [%]	4.3	4.6	3.1	5.1	3.7



RELATIVE CONTRIBUTION TO 16B FLOW PER CLUSTER IN 16A

- The tracers injected continuously per stage, observed at 16B give the proportion of fluid moving from 16A to 16B per stage
- A clear relation is seen between this contribution and the number of clusters per stage (larger contribution for stages with many clusters

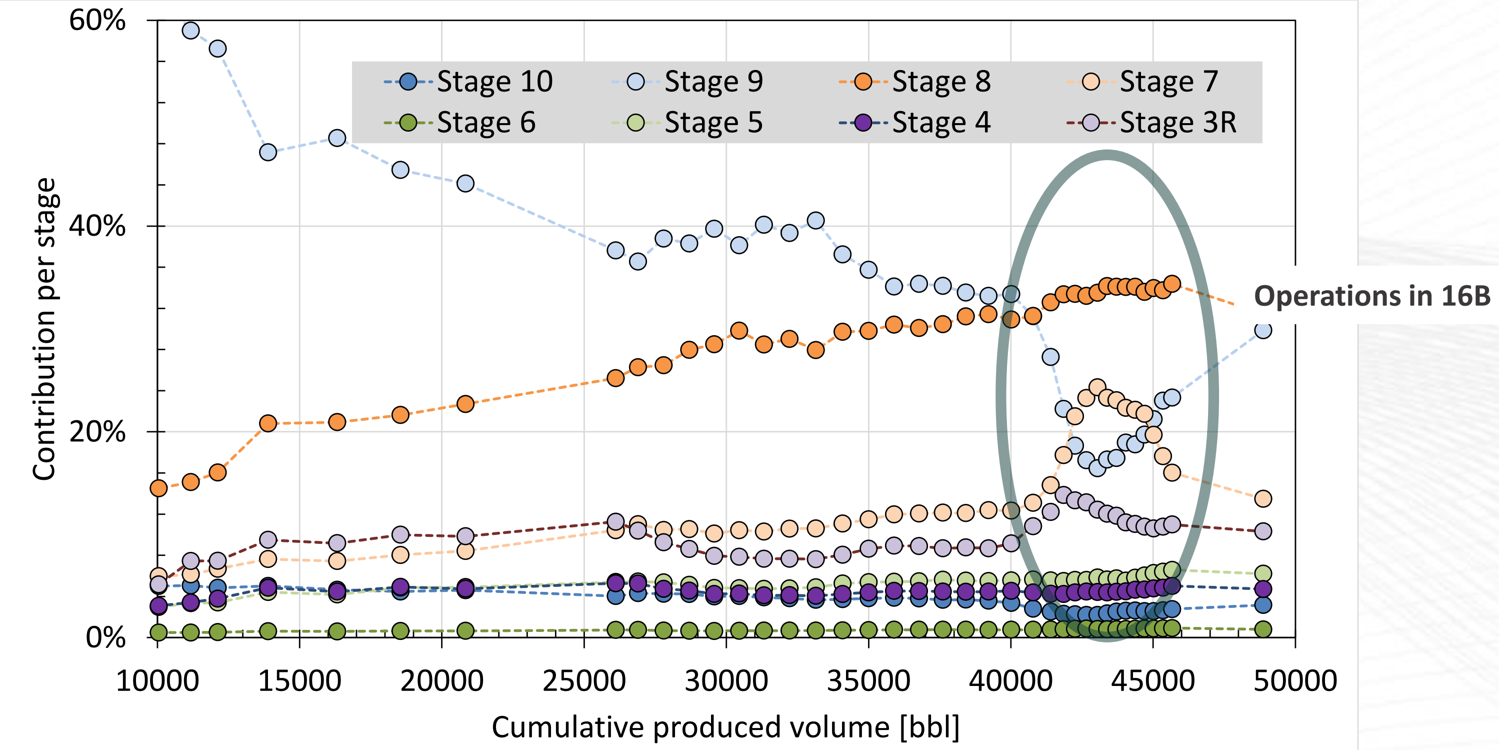
- If based on 3 clusters per stage in 16B, then Highest flow allocation from stages 8 and 9 with 8 clusters per stage in 16A
  - Each gave 3 frac hits in 16B; suggests these stages benefited from treatment cluster runaway with more proppant placed in dominant fractures

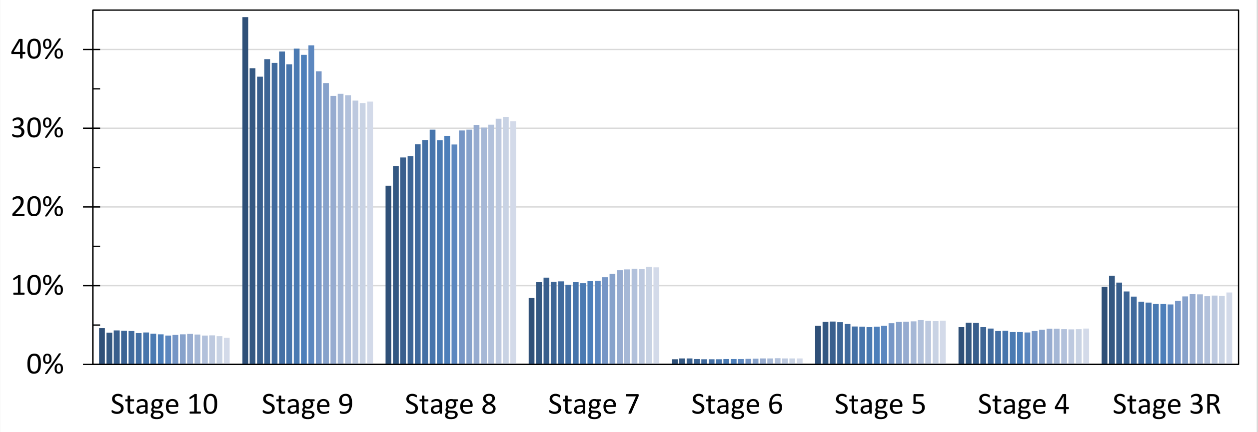


Production Well 16B

RELATIVE CONTRIBUTION TO FLOW: CLEANUP VS CIRCULATION

- The contribution **per stage** during clean-up is given from $C(t)/C_{inj}$ where C_{inj} is the constant injected concentration
- Some variability initially converges towards constant value before impact of 16B is seen
- Stages 8 and 9 contribute significantly more than the other clusters

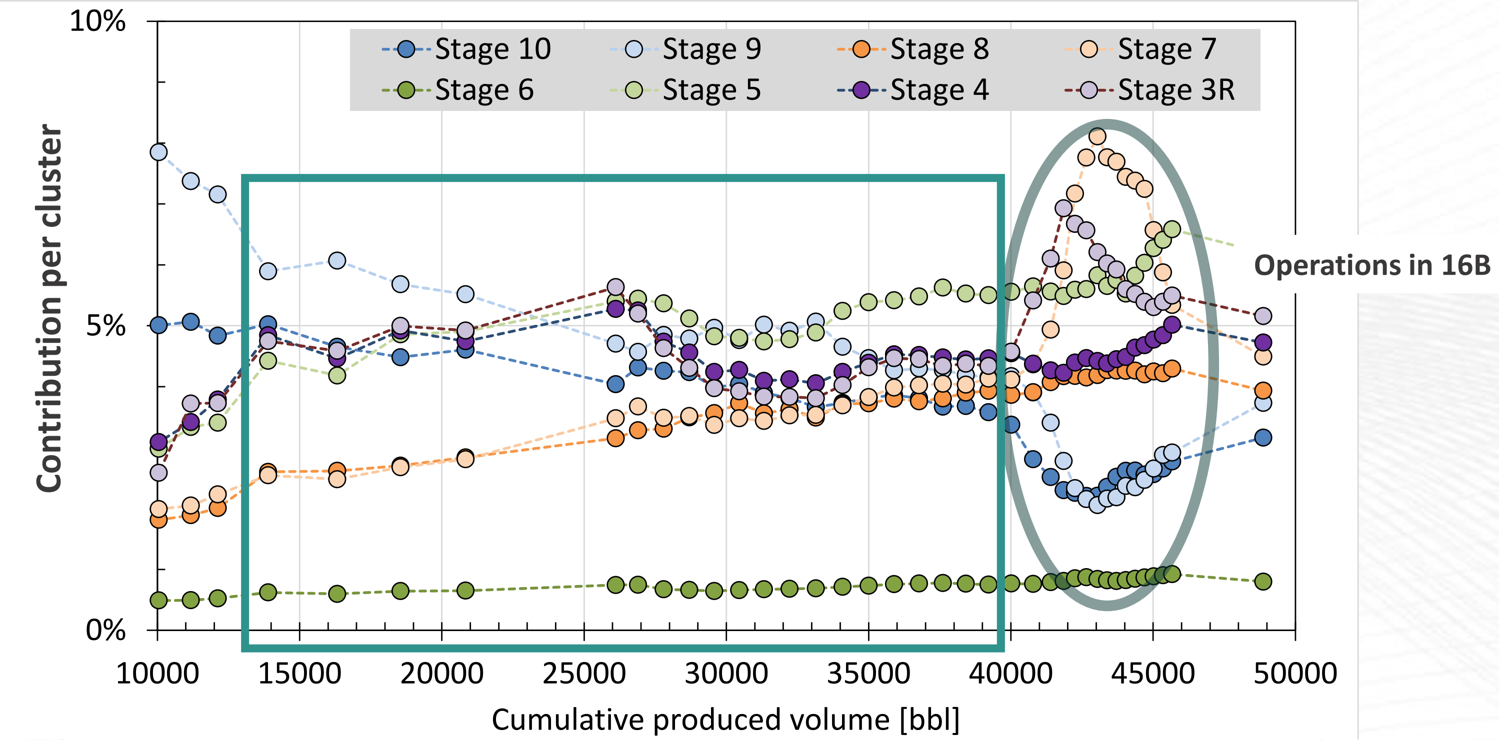


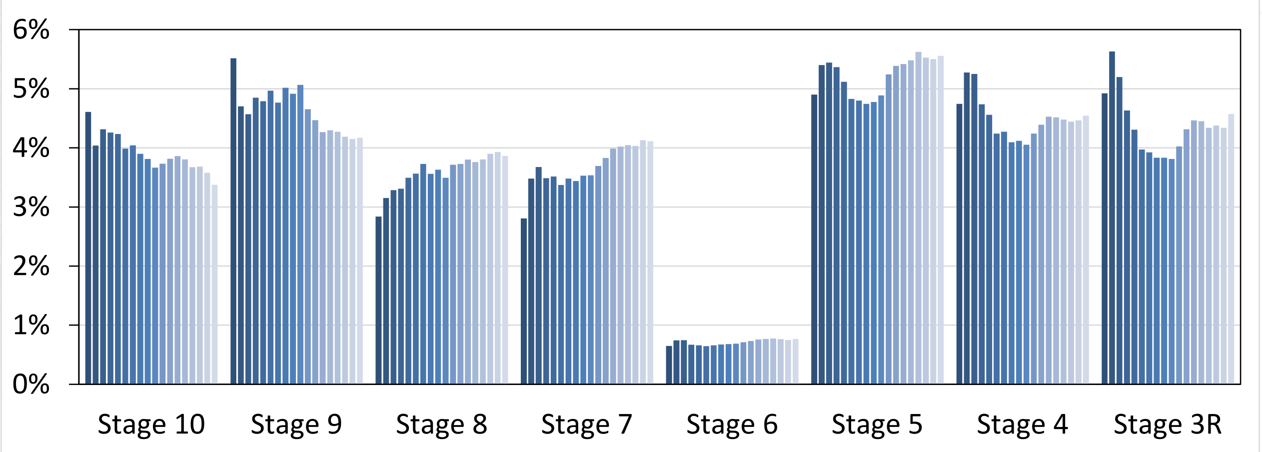


Flow - Rate

RELATIVE CONTRIBUTION TO FLOW: CLEANUP VS CIRCULATION

- The contribution **per 16A cluster** during clean-up is given from $C(t)/C_{inj}$ where C_{inj} is the constant injected concentration
- Some variability initially converges towards constant value before impact of 16B is seen
- Normalization by the number of clusters show that all stages have uniform contributions, with the exception of Stage 6



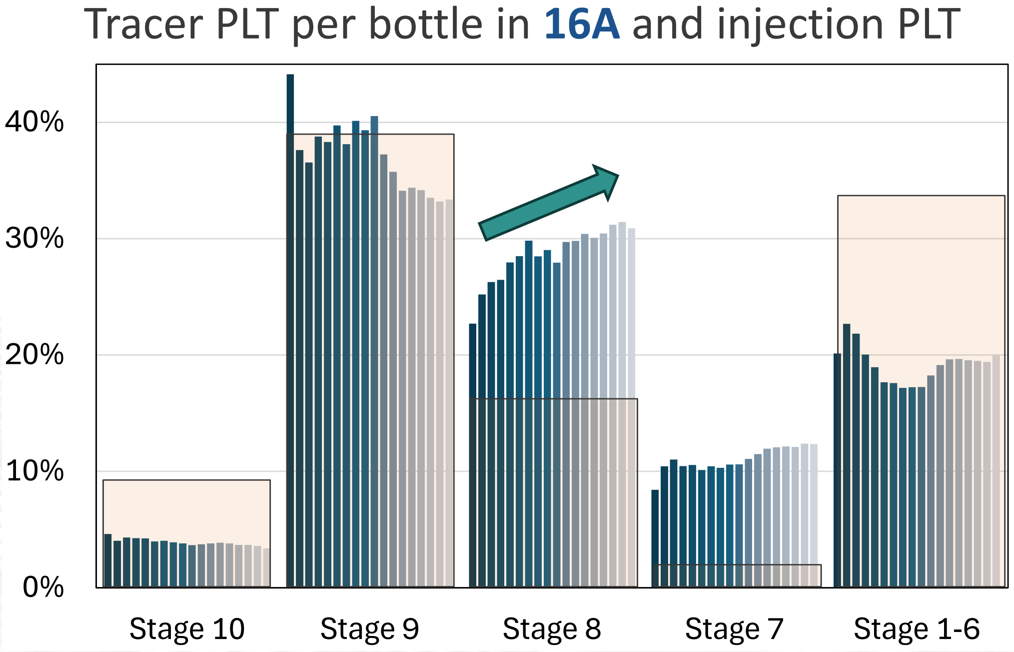


Flow - Rate

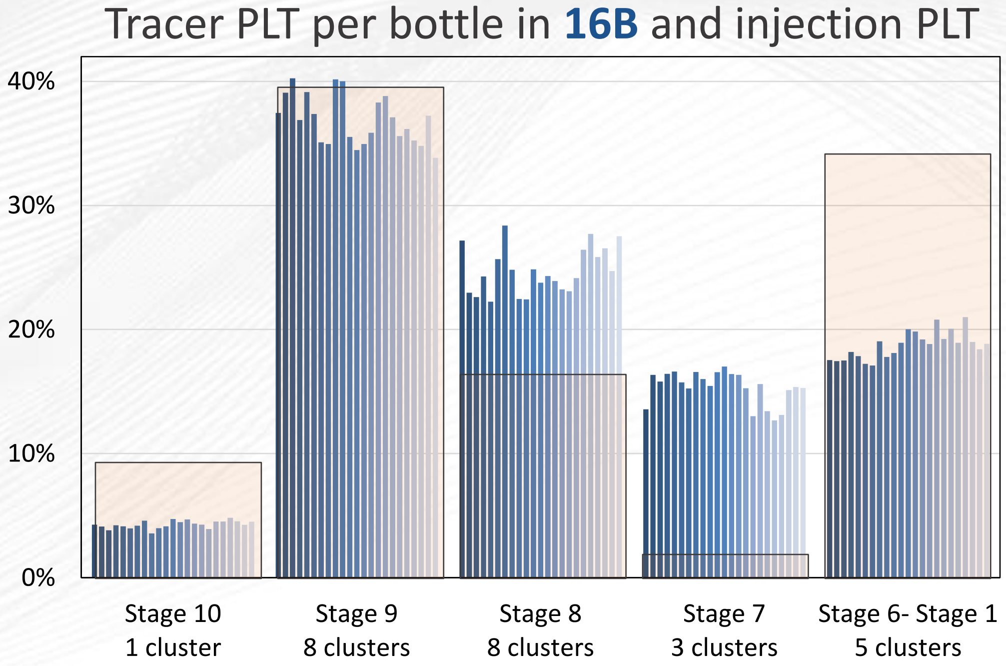
RELATIVE CONTRIBUTION TO FLOW: CLEANUP VS CIRCULATION

- **Tracer data from clean-up and from circulation test provides a chemical "PLT per bottle"**
- **Per stage contribution is remarkably consistent for circulation test and clean-up**

Injection Well 16A



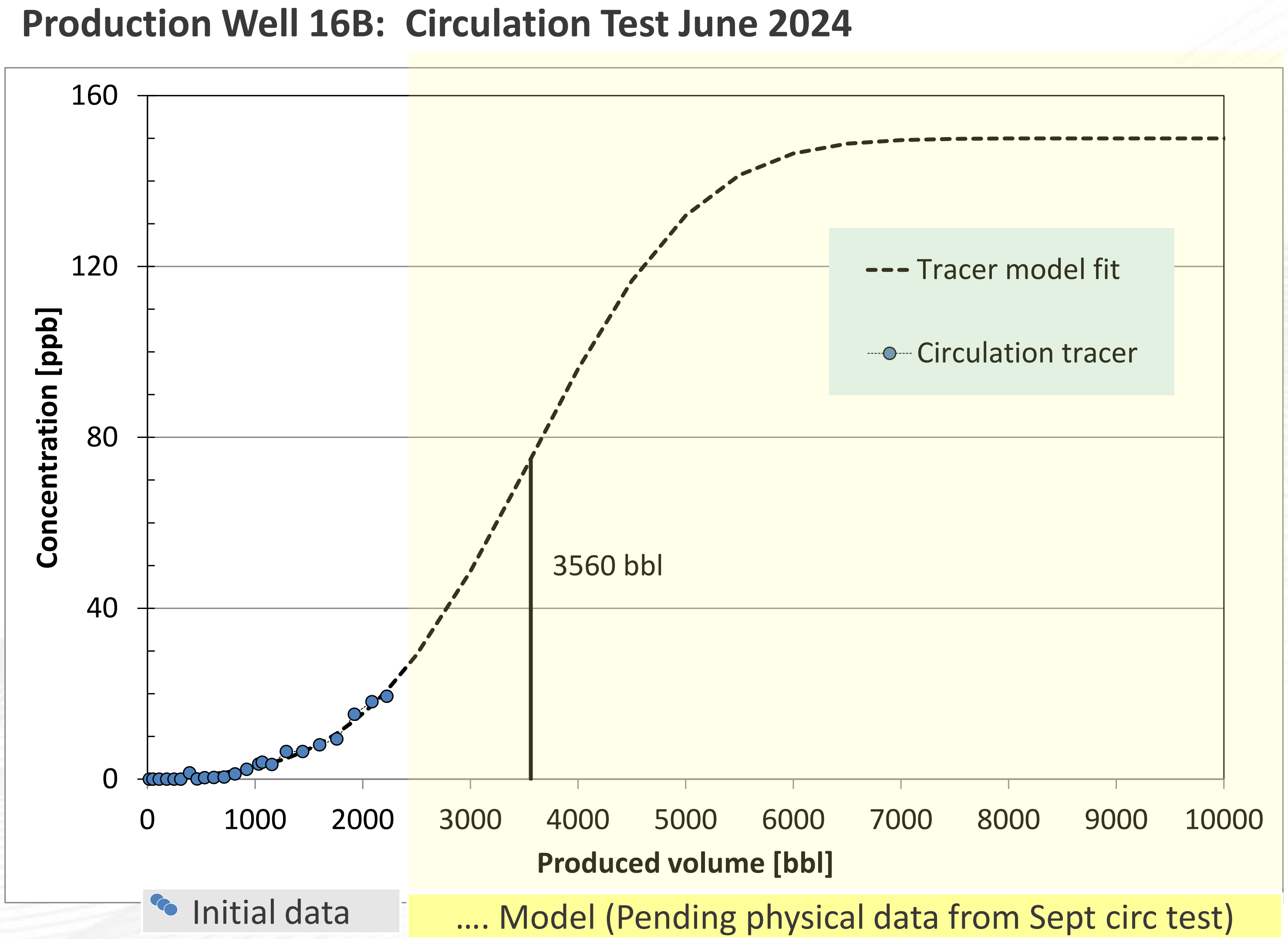
Production Well 16B



Volume

FRACTURE COMMUNICATION VOLUME

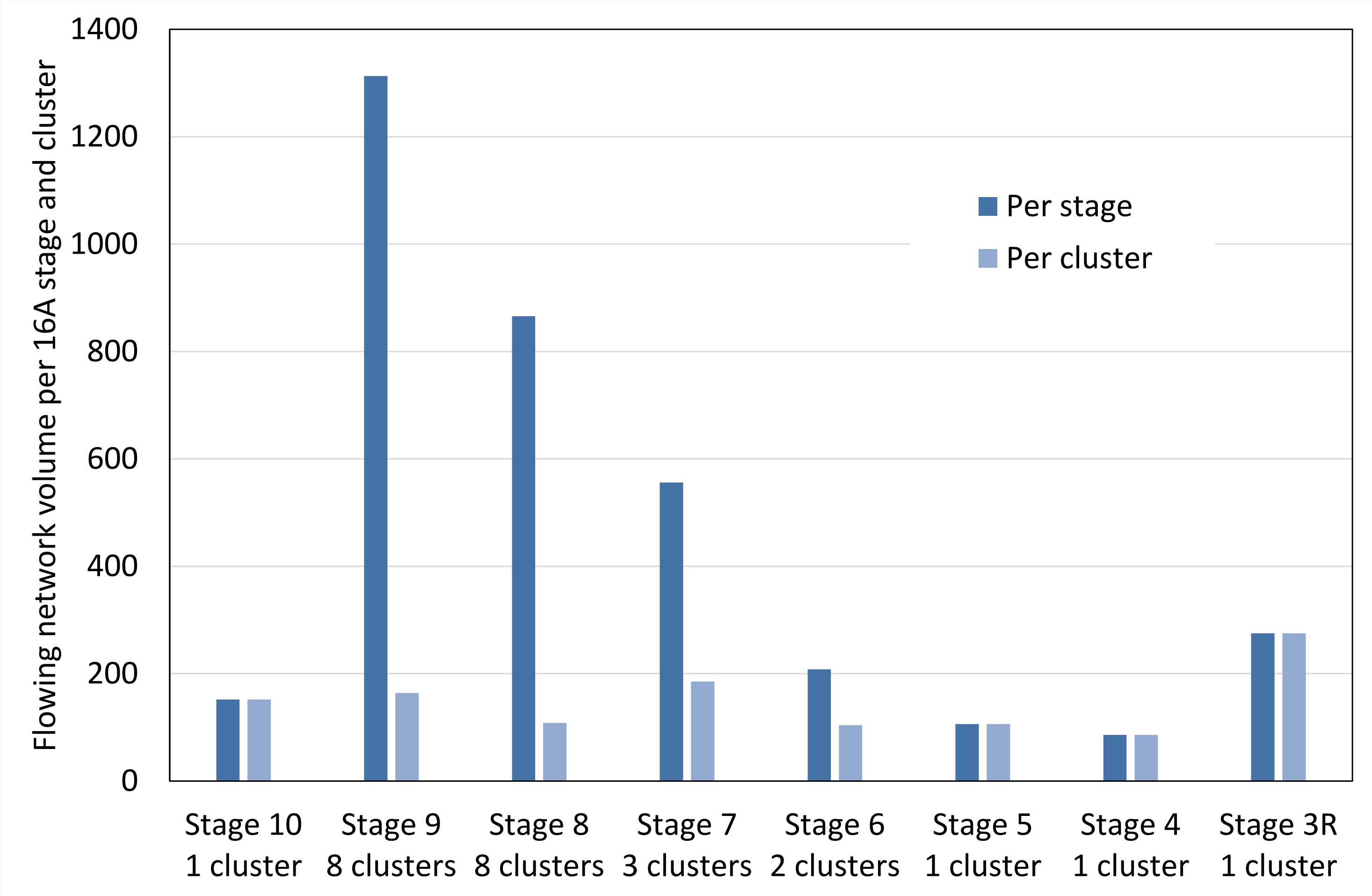
- Total connected fracture volume: From circulation tracer injected in (16A) and sampled in (16B)
- The estimated volume of 3560 bbl is the average volume explored by the tracer (and hence typical volume contacted by injected water)
- Fitted model: 1-d advection dispersion equation solution corresponding to continuous injection of tracer (Bear, 1972). Cumulative produced volume used as proxy for time
- Excellent fit of data. Final volume estimate to be updated as circulation test sampling continues



FRACTURE NETWORK VOLUME CONTRIBUTION TO FLOW PER STAGE: 16A

- The average flowing volume can be distributed per stage and per cluster
- It represents an estimated average volume experienced by water from 16A, travelling through the network per stage, eventually ending up in 16B

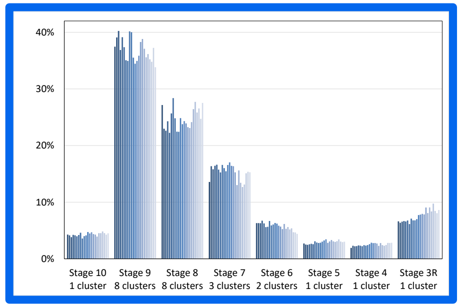
Production Well 16B: Circulation Test June 2024



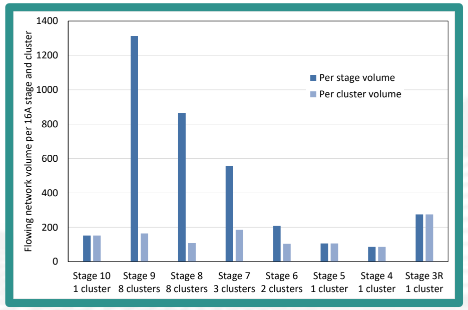
RESMAN TRACER - QUANTIFY 'EFFECTIVE' FRACTURE SURFACE AREA

Heat transfer in the fracture networks is impacted by

- Heterogeneity in flow rate per fracture (Q1, …, Qn)



- Circulated fracture surface area (*H1 L1, …, Hn Ln*); *circulation volume* from tracer response



- Heterogeneity in local flow rates and effective lengths of flow paths within fractures

$$t_D \sim \left(\frac{Q_1}{H_1 L_1}\right)^2 + \left(\frac{Q_2}{H_2 L_2}\right)^2 + \dots + \left(\frac{Q_n}{H_n L_n}\right)^2$$

Thermal Decline Type Curves

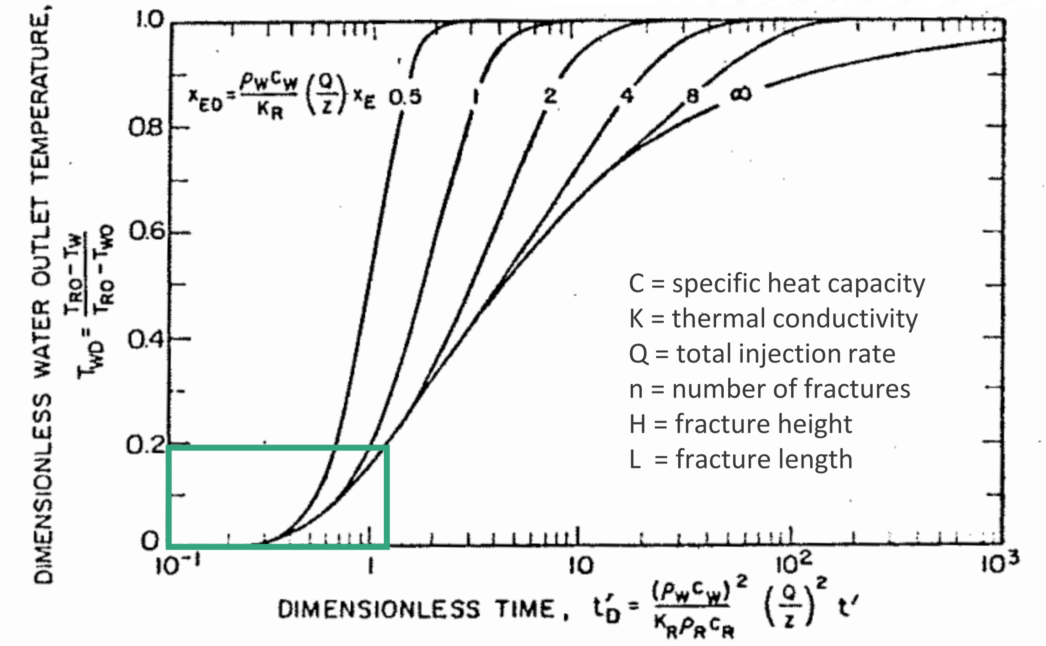


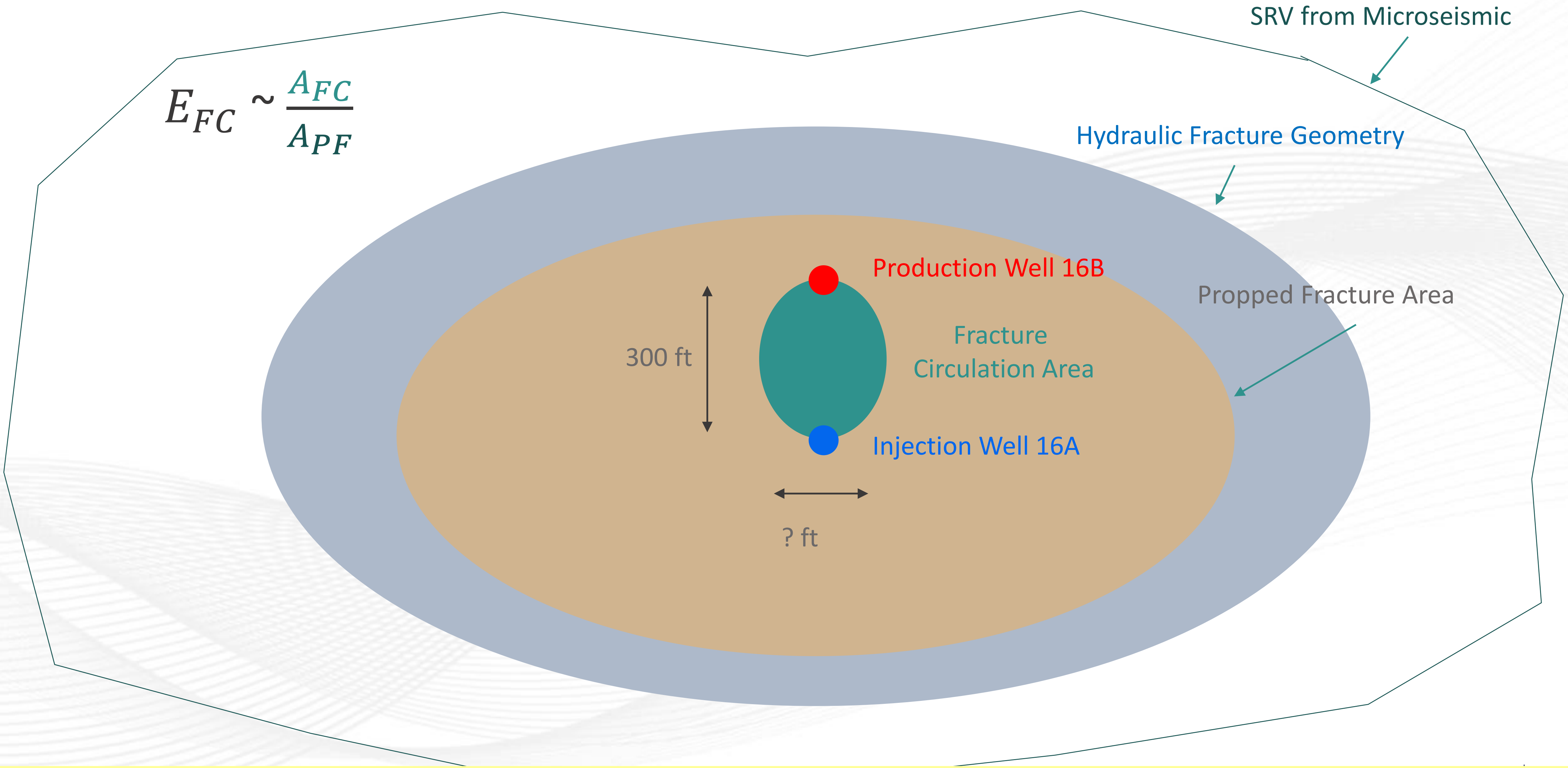
Fig. 3. Dimensionless water outlet temperature versus dimensionless time showing effect of fracture spacing.

Source: Gringarten et al, 1975

Utah FORGE: Fracture Circulation Efficiency

Surface Area

$$E_{FC} \sim \frac{A_{FC}}{A_{PF}}$$



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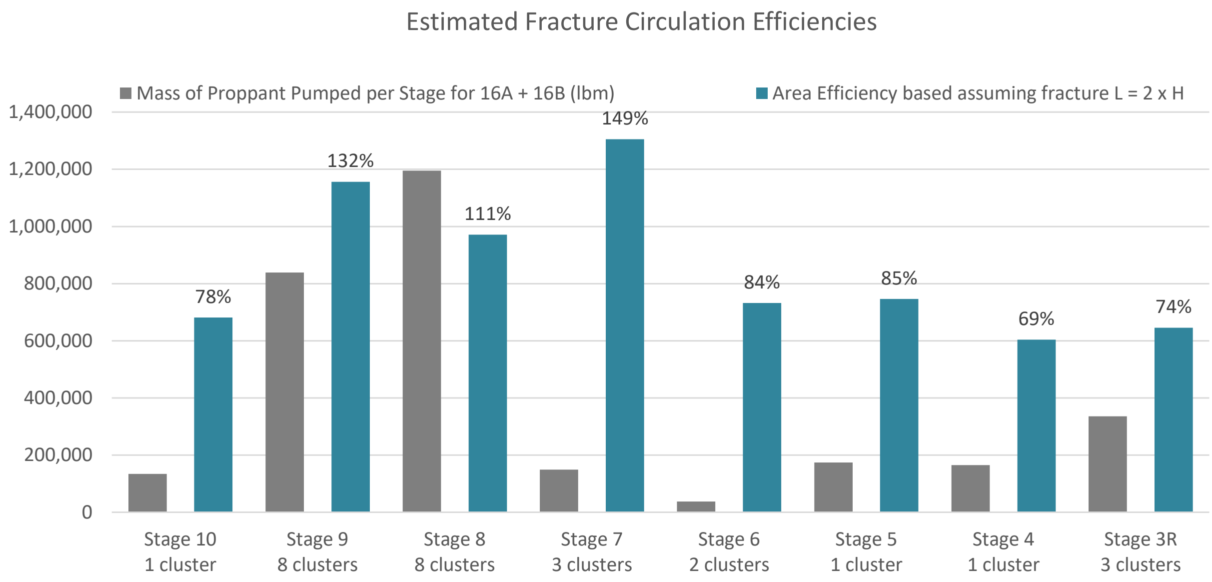
- ❑ Request: fracture geometry as reference for Efc

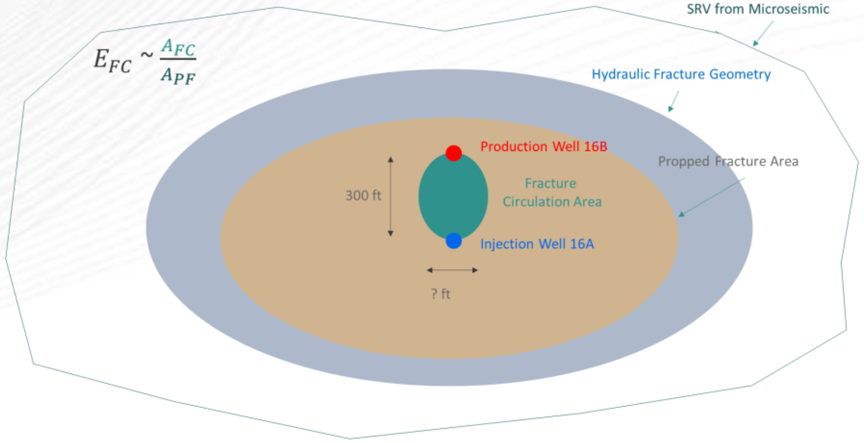
Surface Area

VOLUME AND AREA ASSESSMENT

Fracture Circulation Efficiency Estimates (Total Volume of 3560 bbl):

- % of Clean Volume of Frac Fluid: 2%~6%
- % of Proppant Porosity Volume: 130%~1200%
- % of Estimated Fracture Surface Area: 69~149%
- **Not trending with proppant mass**
- **Suggests circulation through open fractures**
  - Channeling
  - Duning
  - Multiple, Complex Fracture Networks (basement rock often exhibits different fracture planes for stimulation and production)



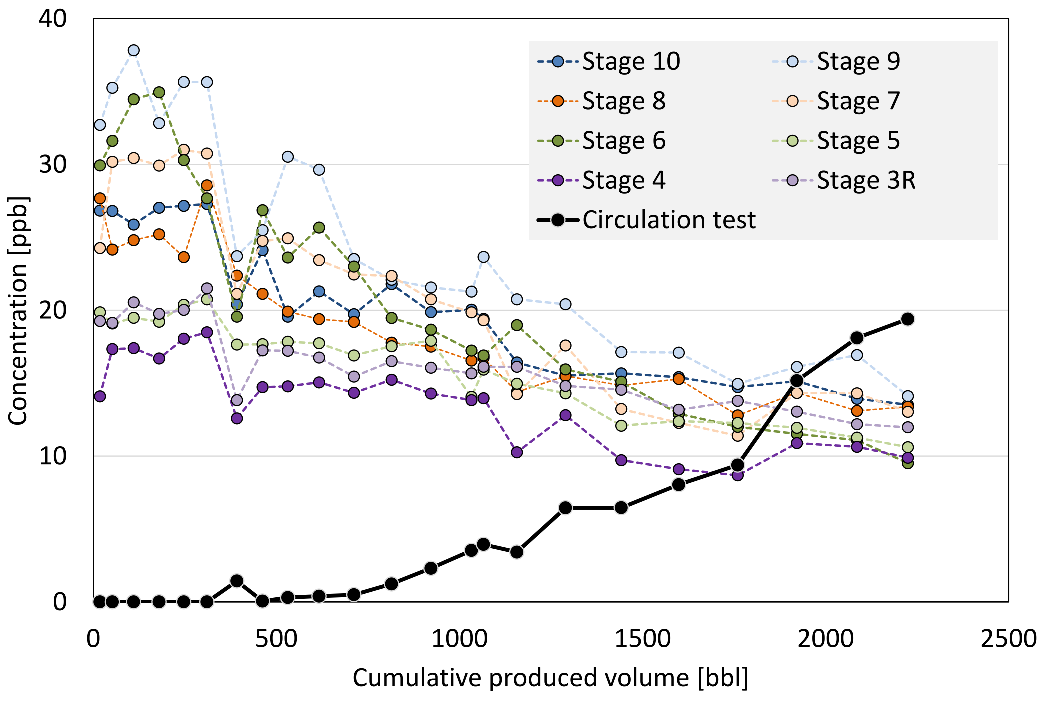


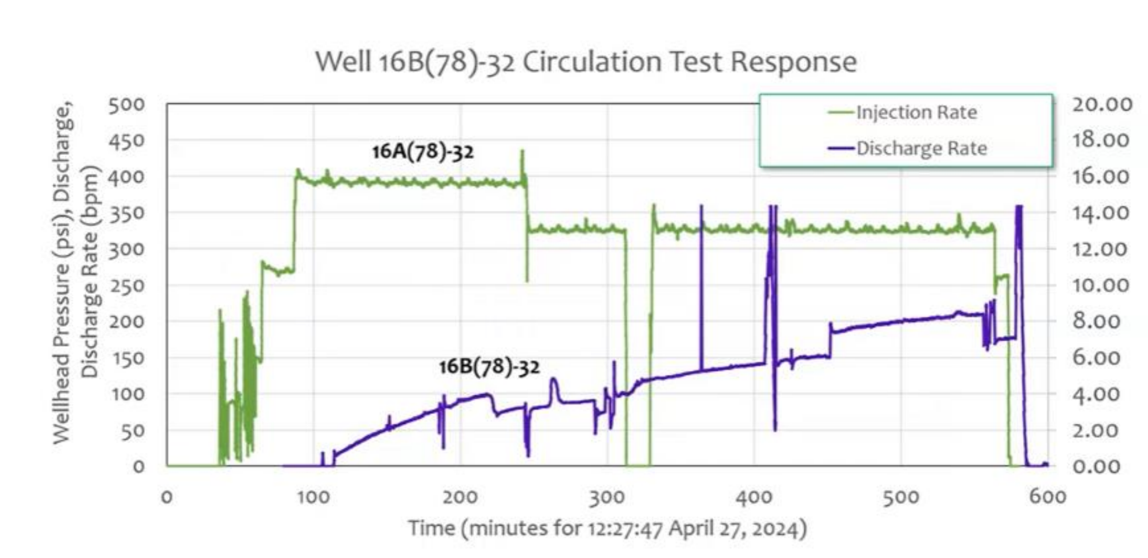
WAY FORWARD DISCUSSIONS

CIRCULATION TEST PROPOSAL AND RECOMMENDATIONS

NEXT CIRCULATION TEST

- Important to capture the rest of the response from the previous circulation test tracer
- Important to have undisturbed results from frac tracers to gain as much information as possible
- Avoid re-circulation to the furthest
- Inject new tracer pulses to increase understanding of flow system





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TENTATIVE TRACER PROGRAM

- Avoid re-circulation to the furthest
- Inject new tracer pulses to increase understanding of flow system
- Distribution of 6 tracers suggested with objective
  - Tracer 1: check of system at low rate after long shut-in
  - Tracer 2 : Check effect of rate 5 BPM on communication
  - Tracer 3 : Check effect of rate 7.5 BPM on communication
  - Tracer 4 : Check effect of rate 10 BPM on communication
  - Tracer 5 : Check durability at 10 BPM
  - Tracer 6 : Check durability at 10 BPM

Tentative pumping program (from webcast)

Step	Rate (bpm)	Volume (bbl)	Cumulative Volume (bbl)	Incremental Time (day)	Cumulative Time (day)	Well 16B(78)-32 Status
1	0	0	0	0	0	Shut-In
2	2.5	3,600	3,600	1.0	1.0	Shut-In
3	0	0	3,600	0.33	1.33	Shut-In
4	2.5	1,200	4,800	0.33	1.67	Open
5	5	3,600	8,400	0.5	2.17	Open
6	7.5	7,200	15,600	0.67	2.84	Open
7	10	391,104	406,704	27.16	30.00	Open
8	0	0	406,704	TBD	TBD	Shut-In

Step	Tracer	Injection type
2	#1	Continuous
3	None	
4	None	
5	#2	Pulse half-way through step
6	#3	Pulse half-way through step
7	#4 #5c #6	Pulse 12 hour into step (@stable prod rate) Pulse on day 4 of injection Pulse on day 20 of injection
8	None	
Continuous through all stages	EGI (1,5-NDS)	Continuous

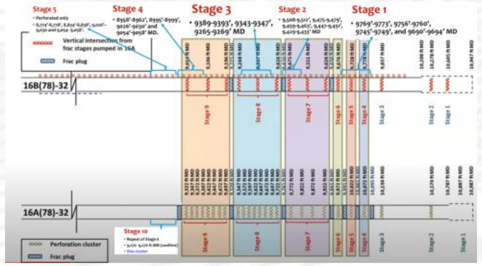
CONTINUED LEARNINGS – DISCUSSIONS

EGS TRACER INNOVATION DEVELOPMENT …

Additional information for advanced interpretation

Summary of information required

- ❑ Confirmation on 16B perforations
- ❑ Data Request: **Flowback data** (rate/event/cooling water) to ensure quantitaive interpretation. Was water from pit used?
- ❑ Request: **fracture geometry as** reference for Efc
  - Fracture geometry from simulations
    - Propped fracture width
    - Frac height
    - Fracture half-length & Propped half-length
  - Fracture closure time



Circulation test

- ❑ Plan proposed for September circulation test

Additional Tracers Development

- ❑ R&D in work for additional tracer development as required

Next Production well: INFLOW Tracers

- ❑ Consider **inflow tracer** in the next production well

DISCUSSIONS: RESMAN can start R&D to develop HT Inflow Tracer

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THANK YOU

SEEING IS BELIEVING

RESMAN®

T: +47 91 67 13 33

L: Strindfjordvegen 1
N-7053 Ranheim
Norway

resmanenergy.com