RESMAN®

WIRELESS RESERVOIR SURVEILLANCE

RESMAN Reservoir Surveillance

SPE Chapter Buenos Aires

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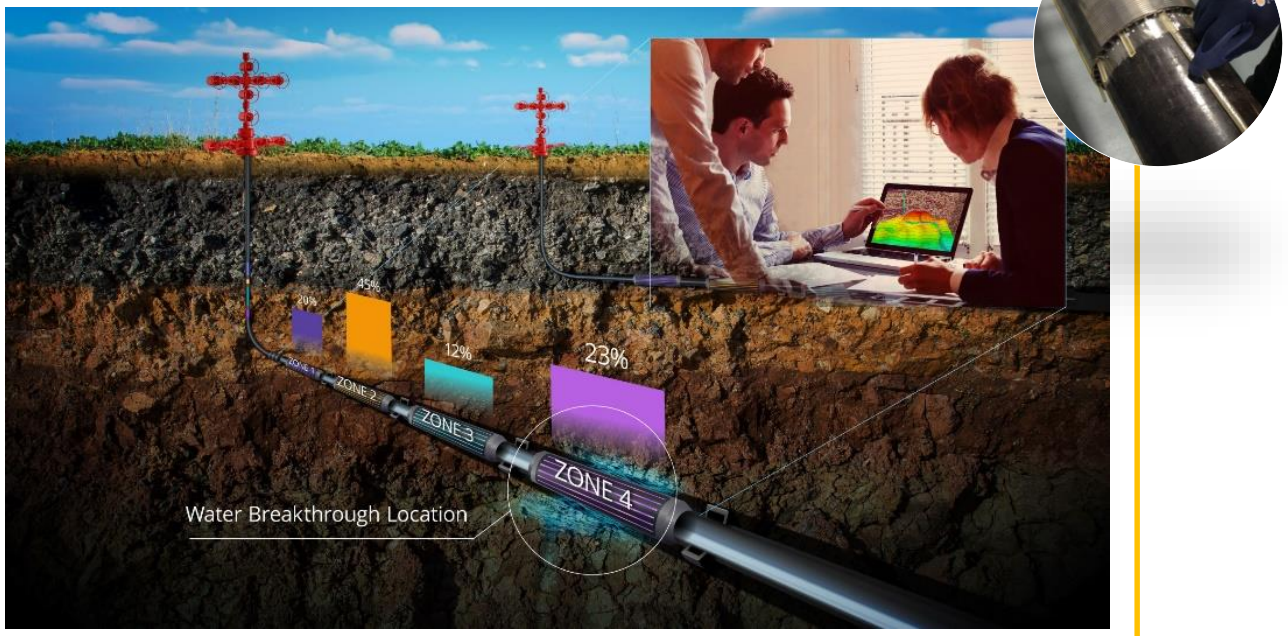
RESMAN TRACK RECORD SUMMARY

Worldwide, June 2019

- RESMAN was formed in 2005 by Statoil Technology Invest
- 576 wells = 5173 Intelligent Tracer systems
- 61 clients in 40 countries
- Max commingled flow rate to date:
200,000 BFPD
- Max pressure to date:
30,000 psi
- Max temperature to date:
400°F (200°C)
- Acquired RESTRACK (inter-well tracers) in December 2018

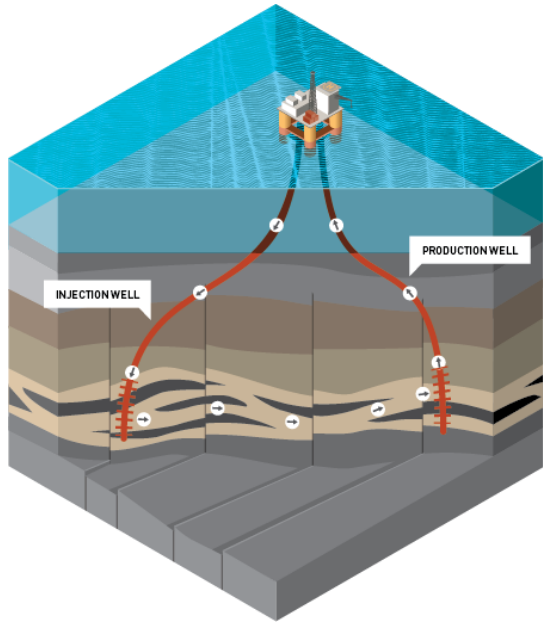
DISTINCT TRACER APPLICATIONS: INFLOW + INTERWELL

RESMAN Inflow tracers



- Quantify zonal inflow during startup
- Locate water breakthrough
- Correlate changes in PI to tracer trends
- Multiple years of monitoring life

RESTRACK Interwell tracers

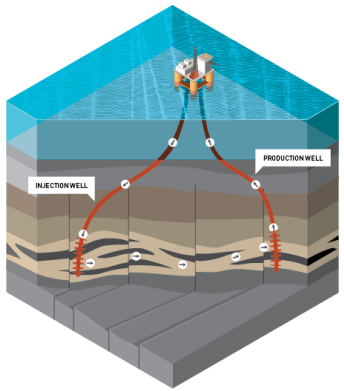


- Monitor reservoir communication and BT time between injectors and producers
- Assess sweep volume, efficiency, and heterogeneity

RESTRACK – Inter-Well Product Offering

Inter-well tracer test (IWTT)

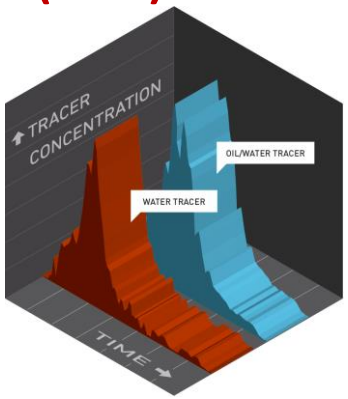
- Water injection
- Gas injection
- CO_2 injection
- WAG (Water Alternating Gas)
- EOR



- Breakthrough time
- Communication
- Allocation factor
- Sweep volume and efficiency
- Heterogeneity assessment
- Improve reservoir model

Partitioning inter-well tracer test (PITT)

- Water injection
- EOR

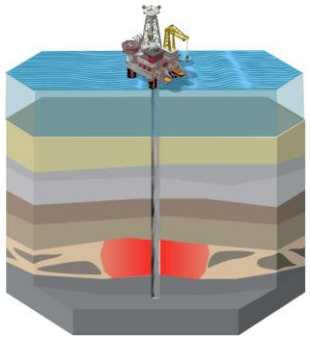


- Inter-well oil saturation
- Evaluate EOR potential
  - Larger evaluation area/volume than for SWCTT
  - Can be carried out under normal operations of wells

RESTRACK – Single Well Product Offering

Single-well chemical tracer test (SWCTT)

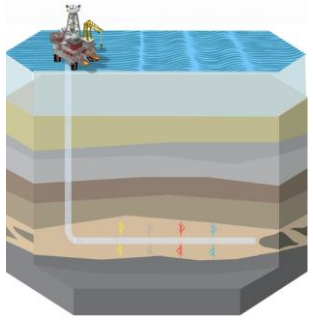
- Near well region flushed to residual oil saturation
- Tracer injected during water injection
- Onsite analysis



- Near well oil saturation measurement
- Evaluate EOR potential
  - Low salinity
  - Polymer
  - Surfactant
  - Etc.
- Connate water saturation

Fracking/Stimulation Treatments

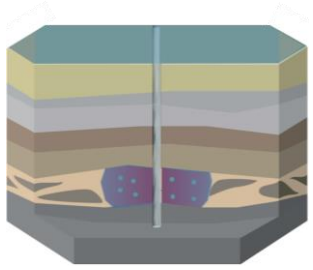
- Unique tracers used to track each stage
- Onsite or offsite analysis



- Confirm which zones are producing
- Calculated recovery during back flow
- Monitoring the back-production profile
- Assess inflow in each of the treated zones

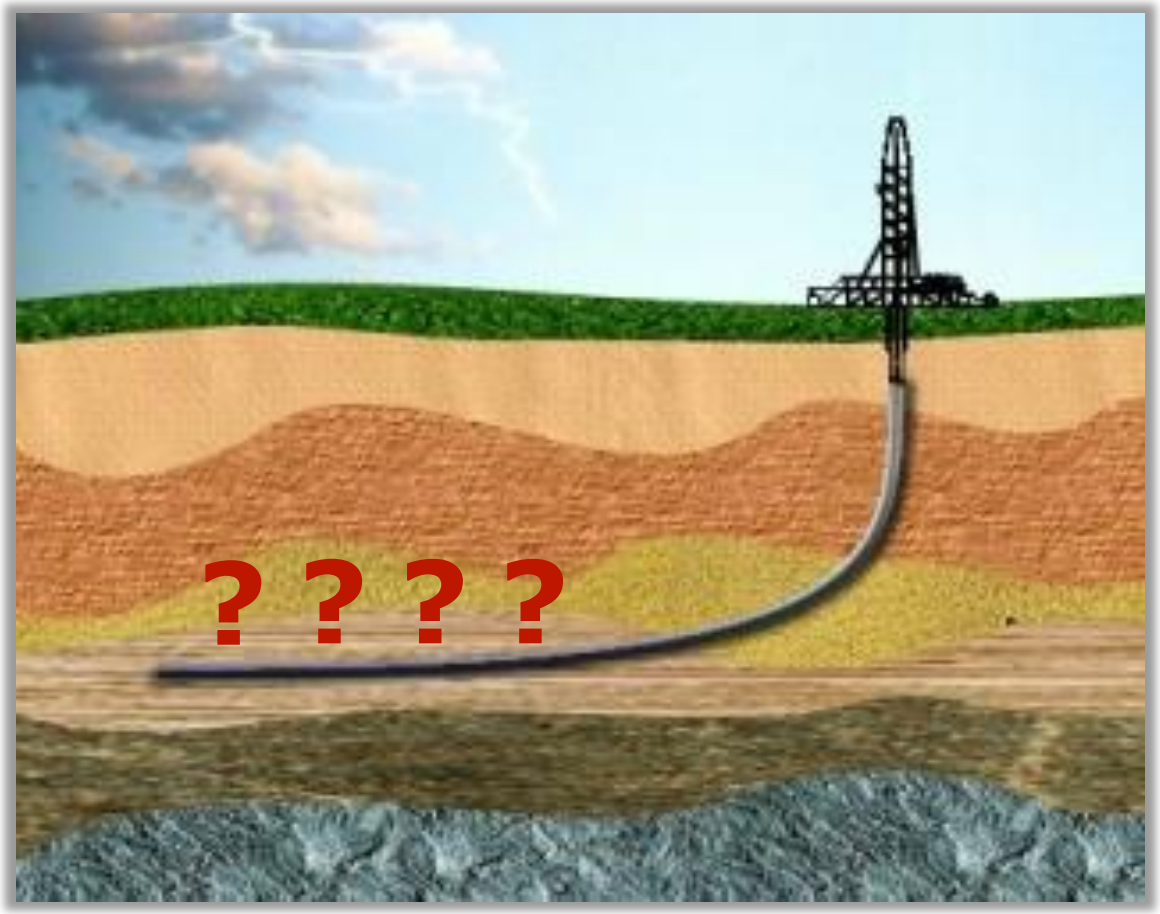
Push&Pull test

- Tracer for mass balance calculation
- Onsite or offsite analysis



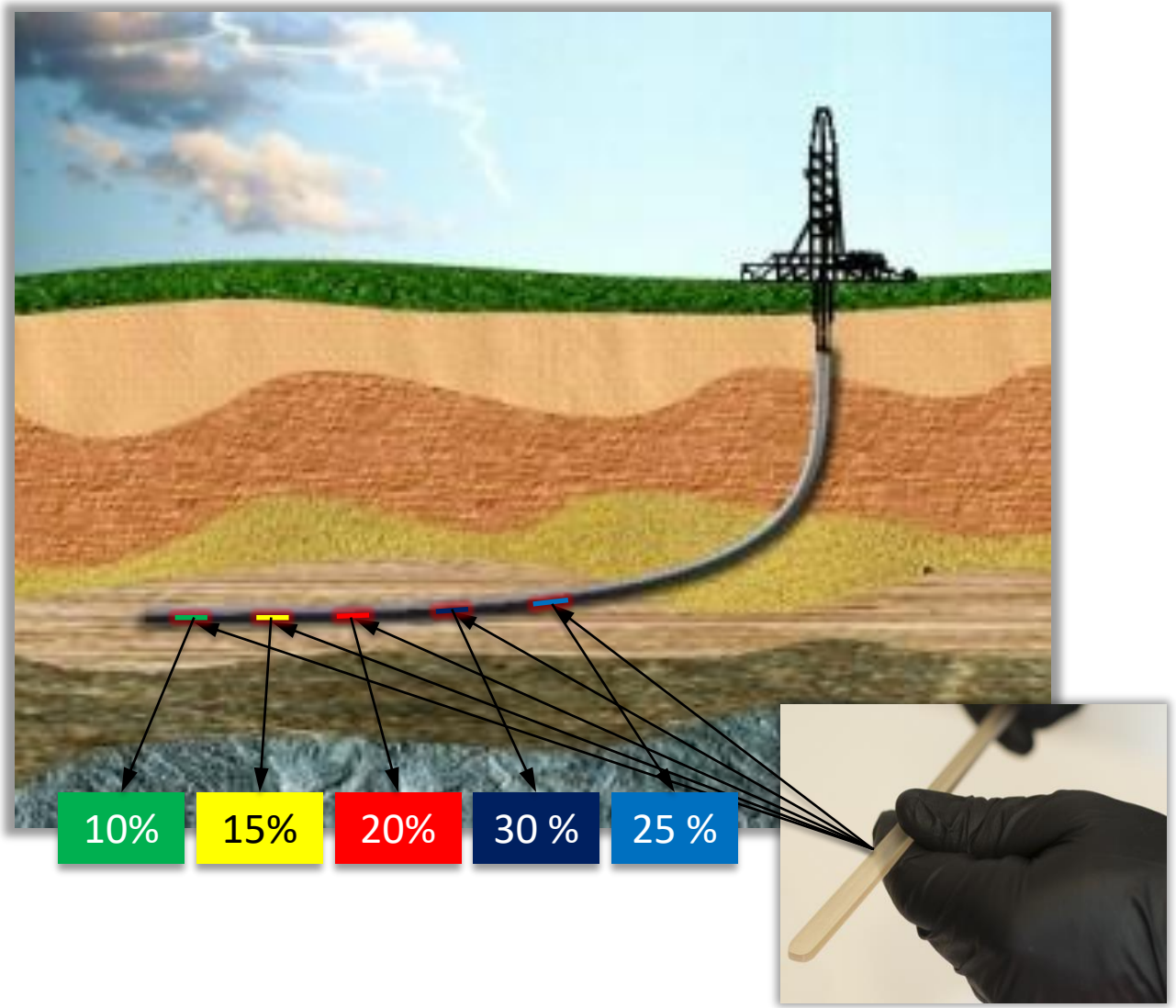
- Track mass balance of water
- Compare water behavior to that of well chemicals:
  - Polymer
  - Surfactant
  - Scale inhibitors etc.

INDUSTRY CHALLENGE: UNCERTAINTY



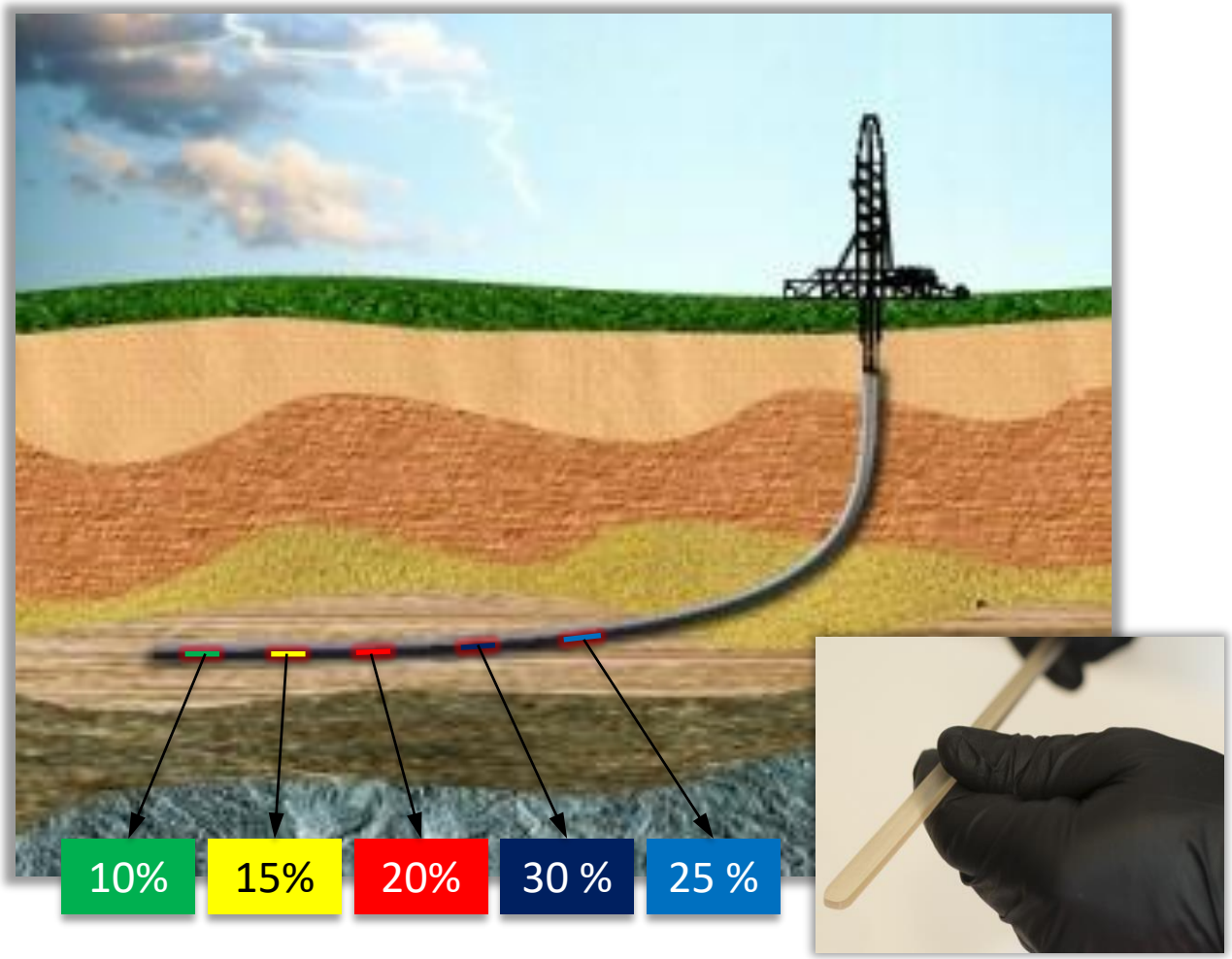
- How are my zones performing over time?
- Is my whole lateral contributing?
- Is my lateral contribution changing over time?
- Where is water influx occurring?

SOLUTION: RESMAN INTELLIGENT TRACERS



- Inflow % and zonal performance
- Confirmation of production: early & long term
- Location of water influx

SOLUTION: RESMAN INTELLIGENT TRACERS



- **Low-cost:** No added rig time.
No expensive changes to completion.
Repeated surveys with multi-year life.
- **Low-risk:** No intervention. No cables.
PPT chemicals. No radiation.
- **Reliable:** Verified inflow models with 95% accuracy. Field proven in extreme conditions: 30k psi, 16 miles of tie back. 100 000 BFPD.

APPLICABLE TRACER PATENTS FOR INFLOW MONITORING AND QUANTIFICATION

- **Reservoir Monitoring Patent:** Inflow monitoring using Intelligent Tracers - hydrocarbons and water ingress monitoring
  https://www.google.com/patents/US8949029?cl=en

- **Inflow Quantification Patent:** Zonal allocation of flow during start-ups using concentration decline functions and arrival time of tracer clouds
  https://www.google.com/patents/US8949029?cl=en

How it Works

Technology Background

HOW IT WORKS

Unique Molecule

Polymer Matrix

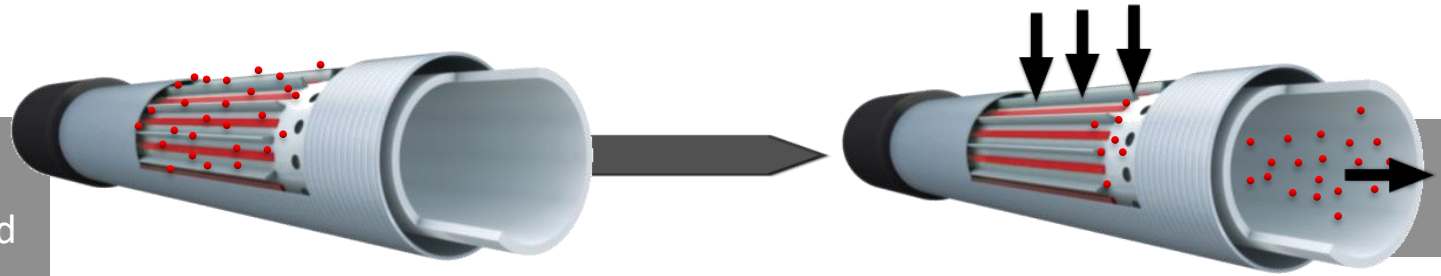
Intelligent Tracers

80 RES•OIL+ 80 RES•H2O

RIH

Downhole Fluid Contact

Molecule Release



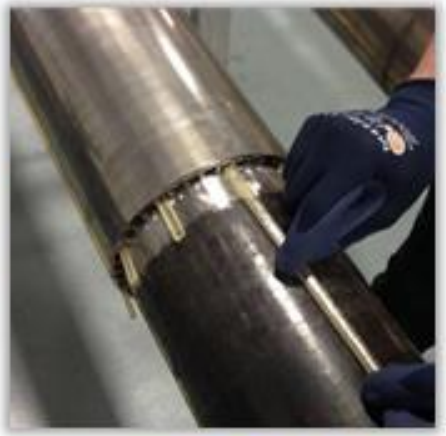
Molecules release in contact with target fluid and in static conditions

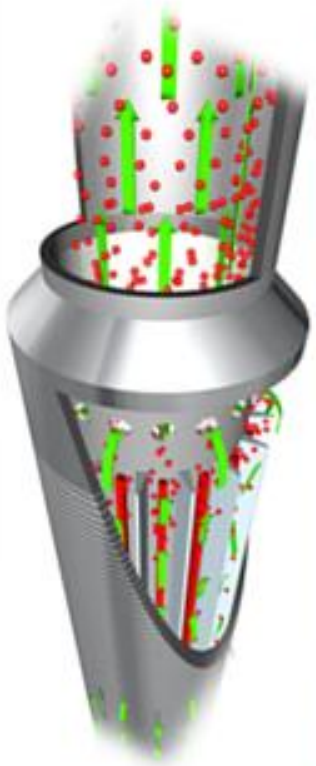
Well production carries molecules to surface

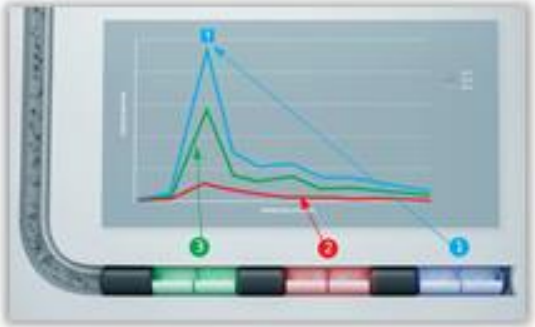
FIELD DEVELOPMENT

Manufacturing → Tracer Integration into completion → Well completion and startup → Sampling → Lab analysis & interpretation

On demand surveys, multi-year life







Up to
80 oil + 80 water
unique signatures.
PPT detection.

No changes
to completion or
RIH procedure.
No extra rig time.

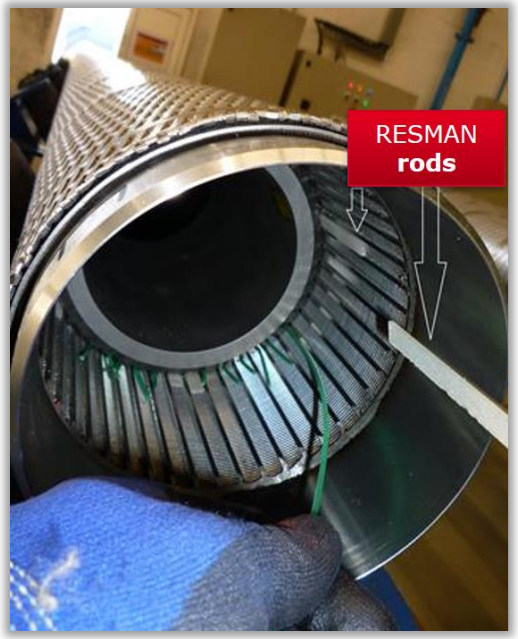
SAMPLING

How it Works

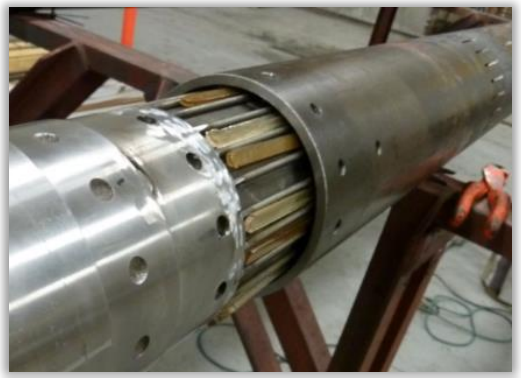
Completion Integration with RESMAN

COMPLETION INTEGRATION WITH RESMAN

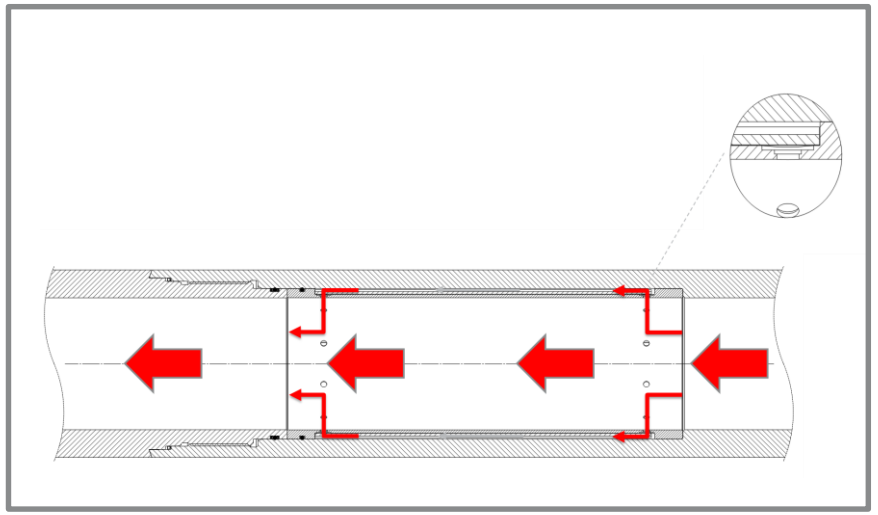
Screens



Pup joint carriers



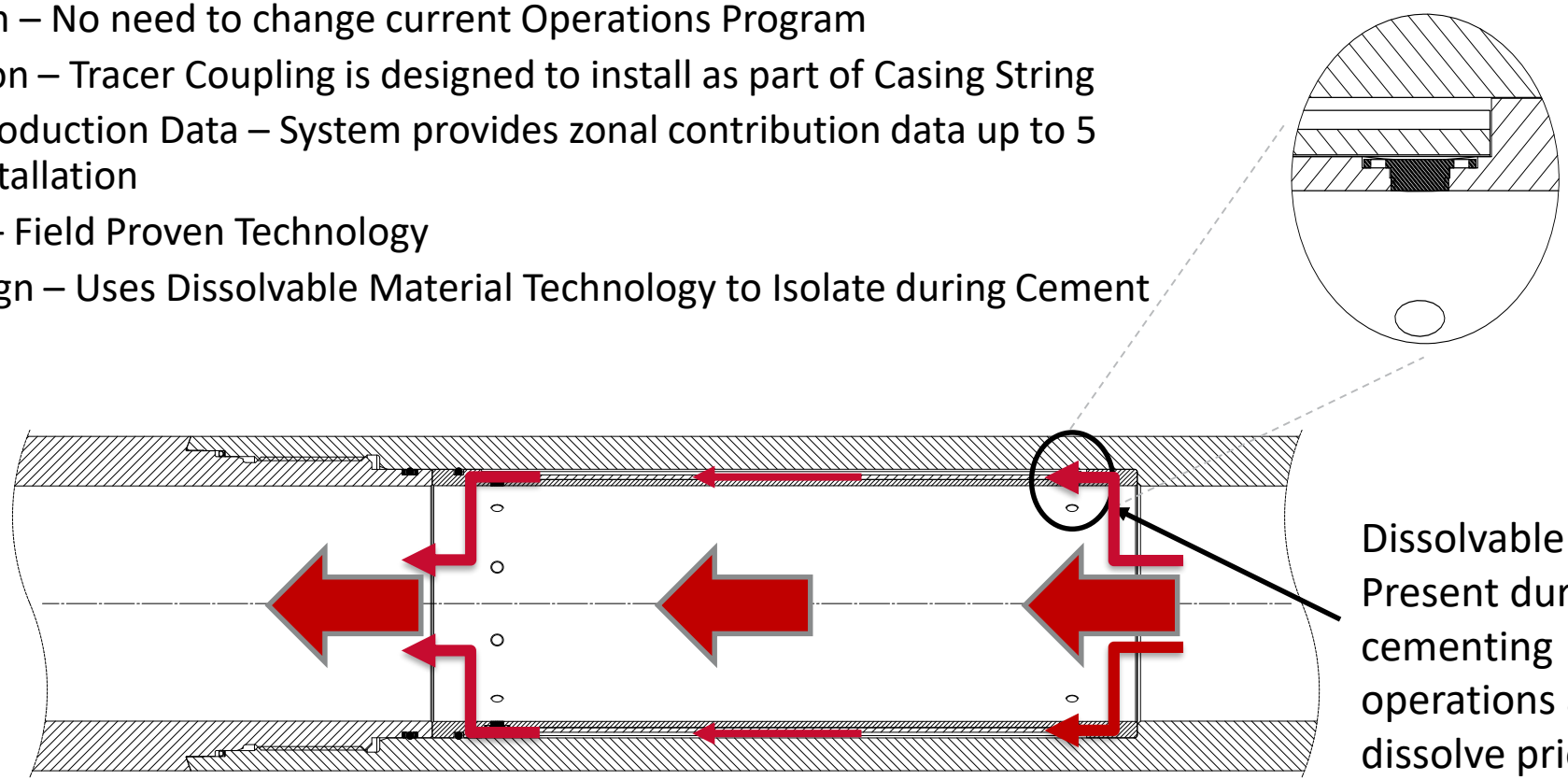
Plug and Perf - Unconventionals



Retrofit

COMPLETION INTEGRATION WITH RESMAN – Plug and Perf

- Simple and Reliable: No moving parts!
- Passive System – No need to change current Operations Program
- Easy Integration – Tracer Coupling is designed to install as part of Casing String
- Continuous Production Data – System provides zonal contribution data up to 5 years after Installation
- Track Record – Field Proven Technology
- Patented Design – Uses Dissolvable Material Technology to Isolate during Cement Job

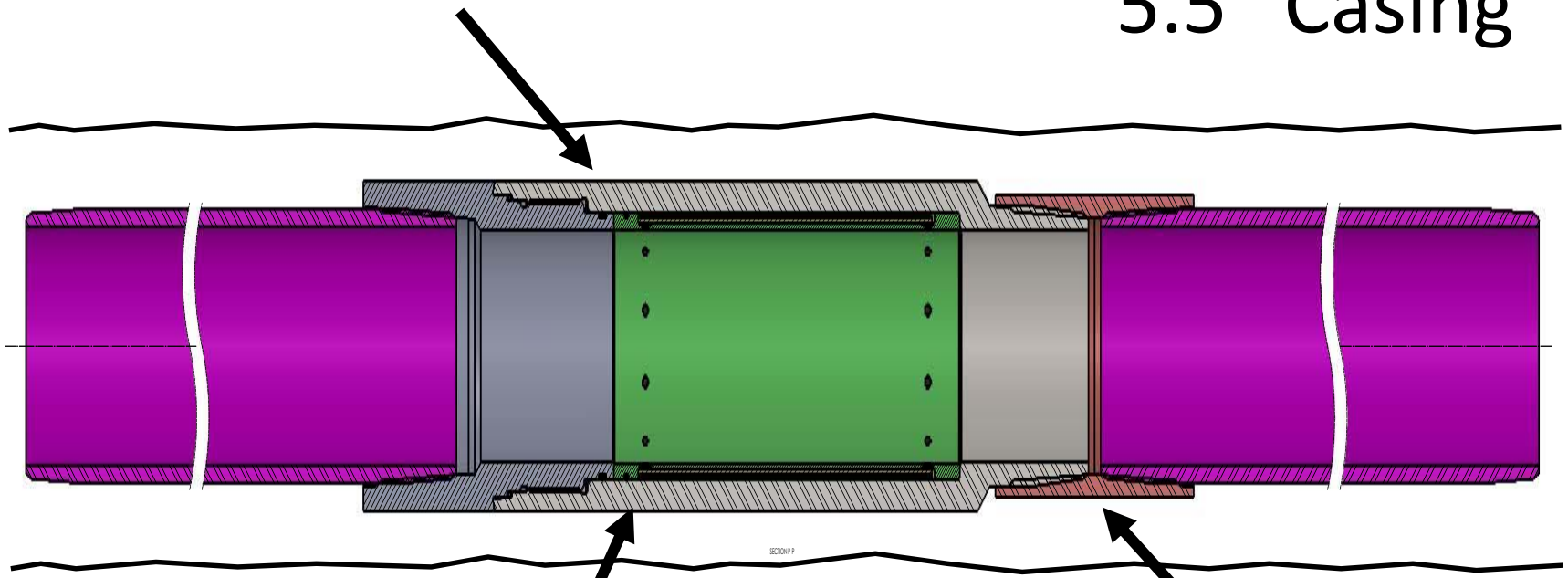


Dissolvable Plugs. Present during cementing operations and will dissolve prior to fraccing.

COMPLETION INTEGRATION WITH RESMAN – Plug and Perf

Tracer Coupling™

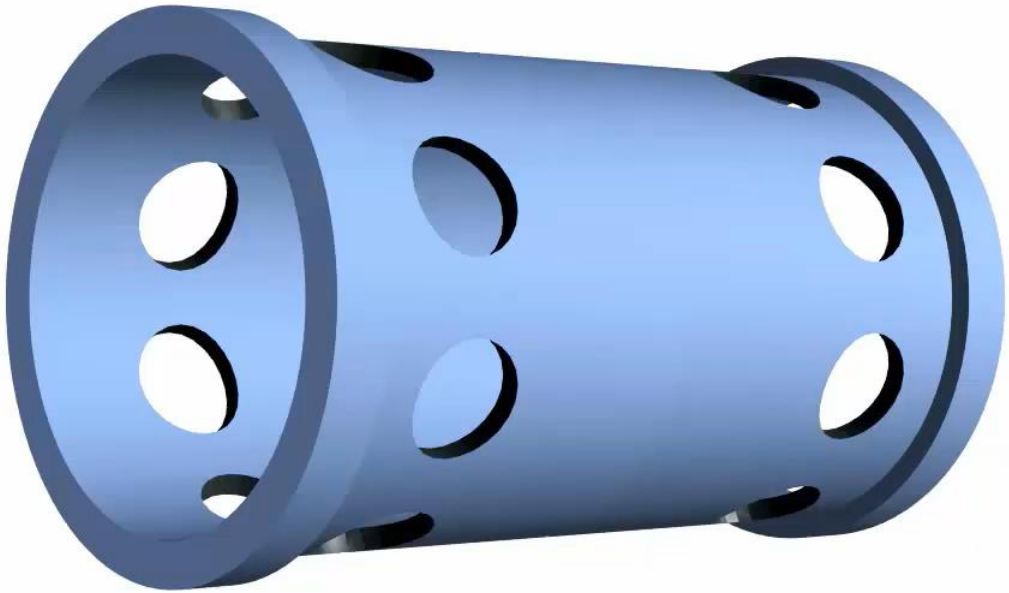
5.5” Casing



OD: 6.65”
slightly larger than
casing coupling

Casing
Coupling
OD Range : 6.30” – 6.05”

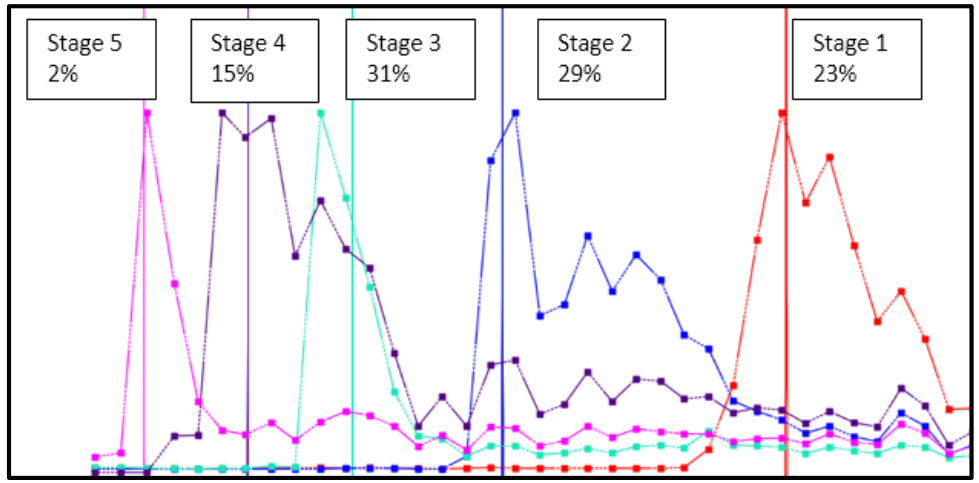
TRACER COUPLING



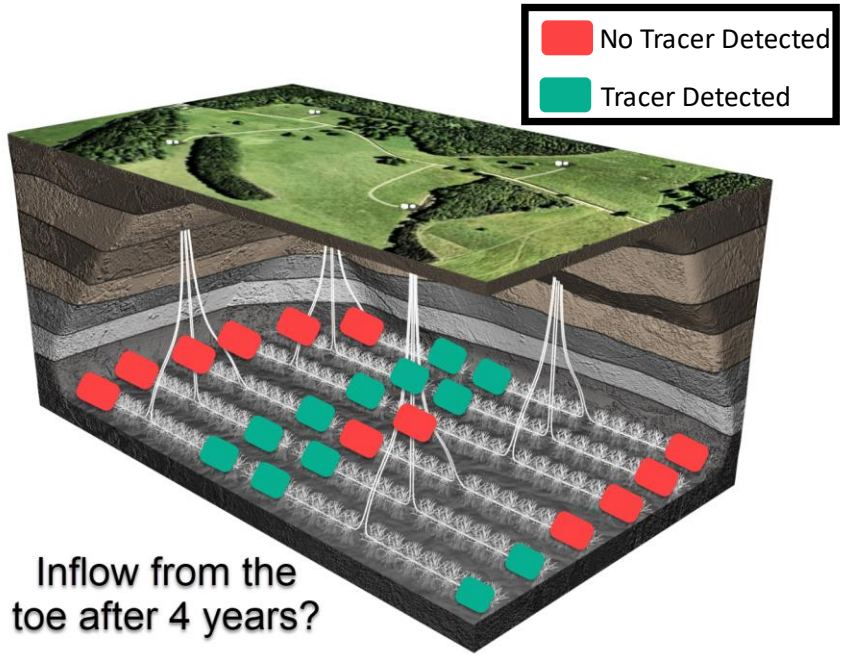
Is the whole well flowing over time? (Flow Continuity Survey)
How much is flowing from each segment? (Percent Inflow Distribution Survey)

Customizable to your data needs:

Percent Inflow Distribution from multiple segments of the lateral of a single well.



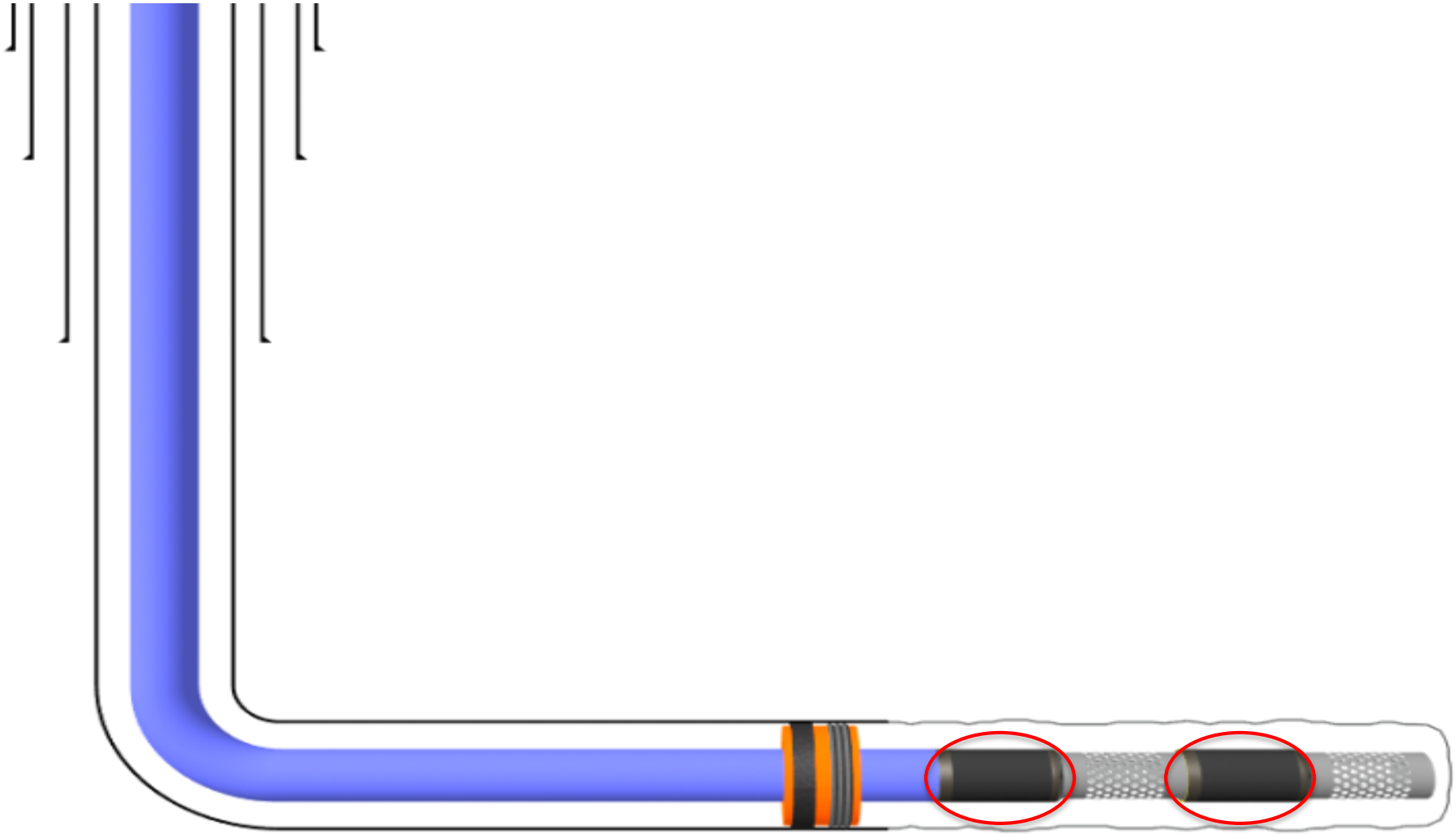
Verification of Flow Continuity via a single monitoring location across multiple wells.



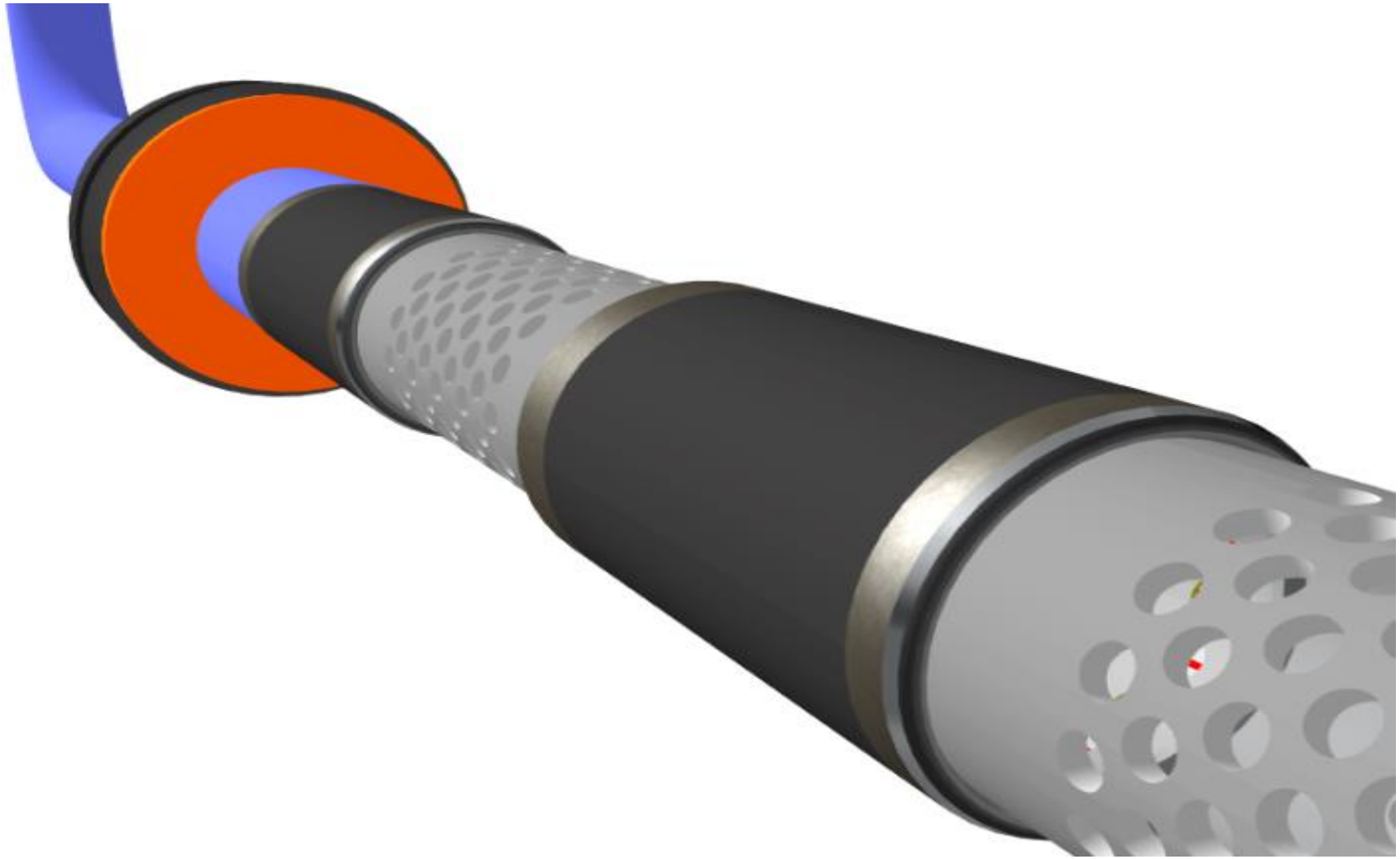
How it Works

Percent Inflow Distribution – Tracer Arrival Method

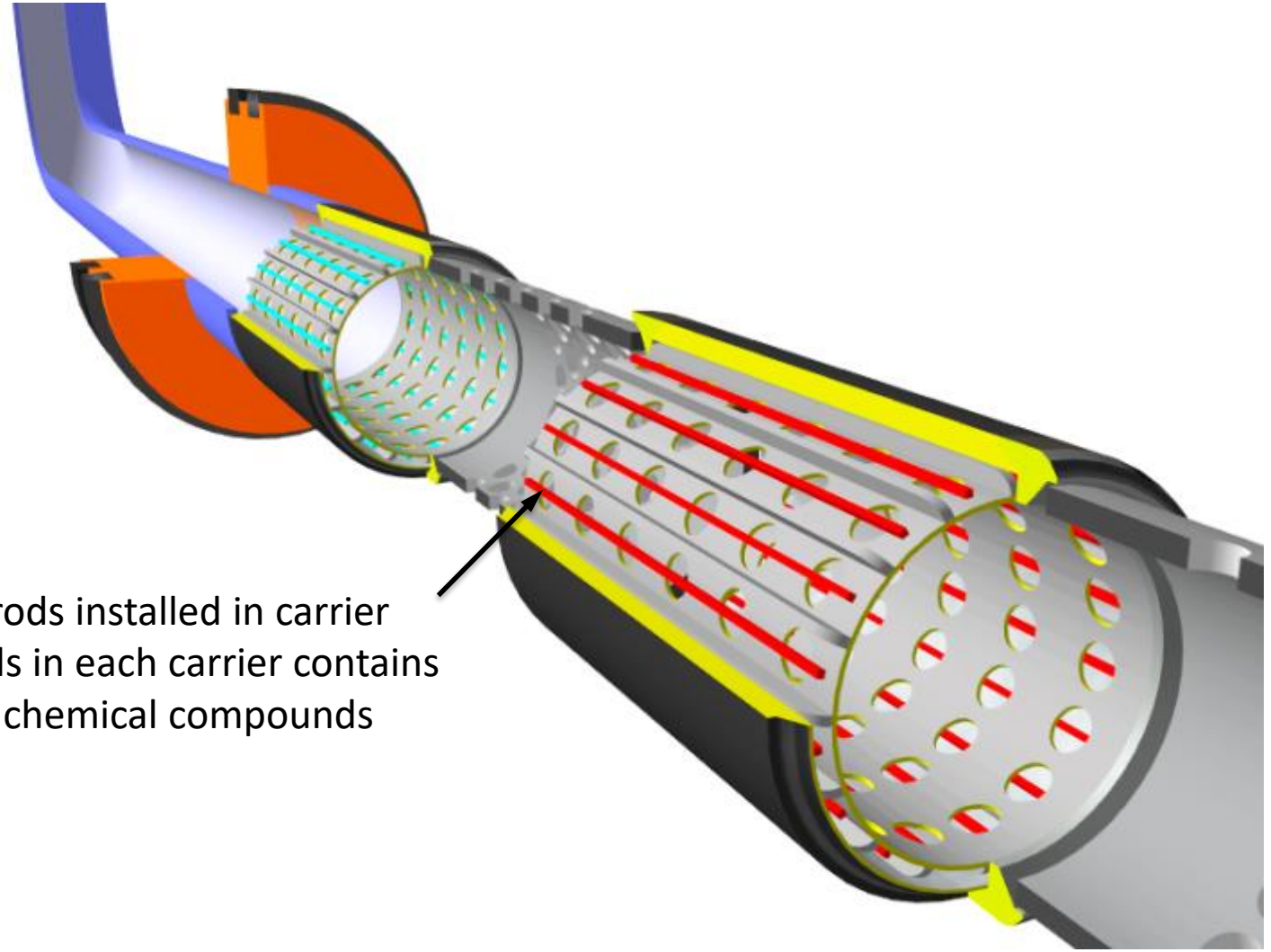
TRACER ARRIVAL METHOD



TRACER ARRIVAL METHOD – DOWNHOLE PERSPECTIVE

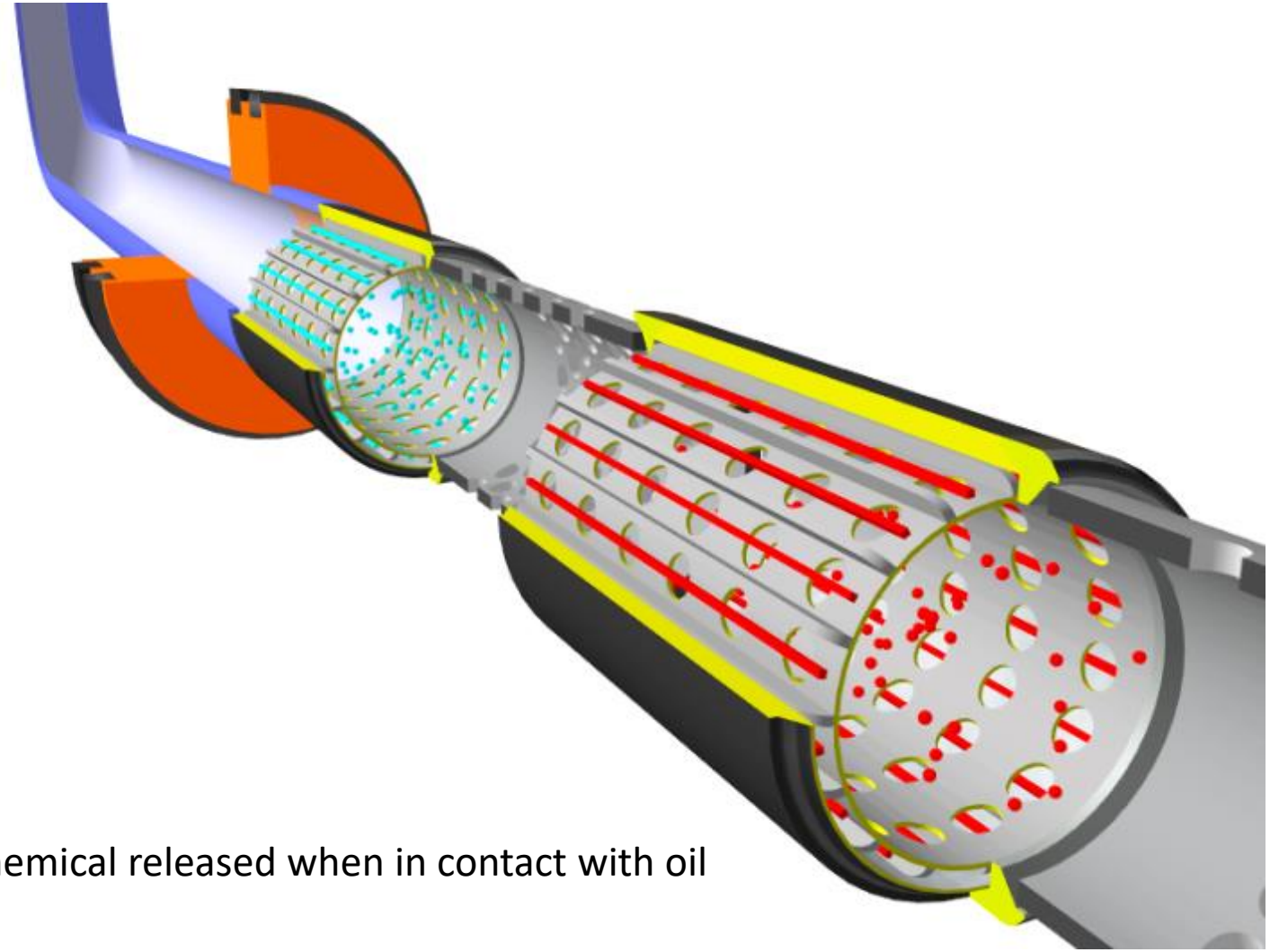


TRACER ARRIVAL METHOD – CUT AWAY OF CARRIER



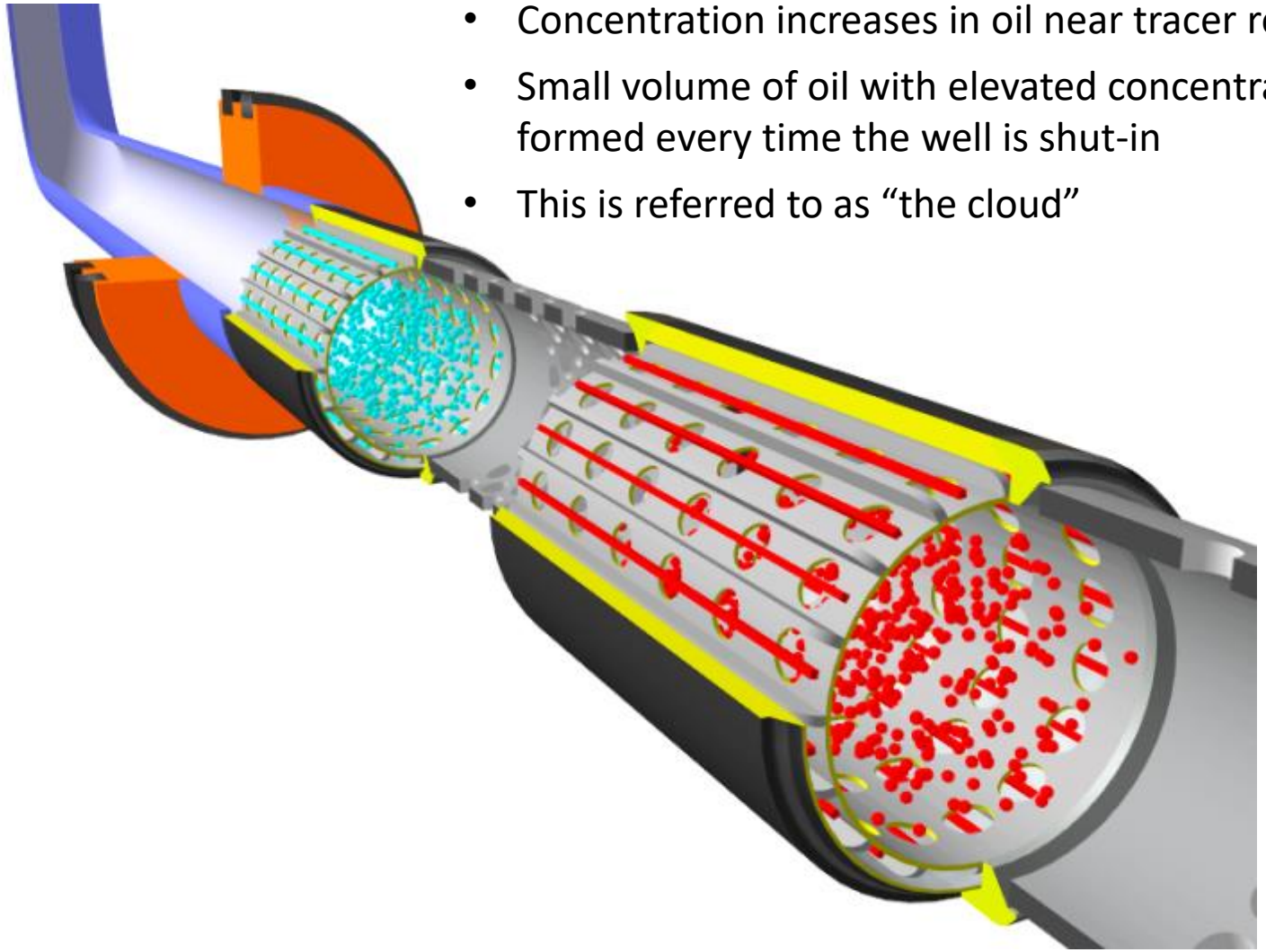
- Tracer rods installed in carrier
- The rods in each carrier contains unique chemical compounds

TRACER ARRIVAL METHOD – STATIC CONDITIONS



- Tracer chemical released when in contact with oil

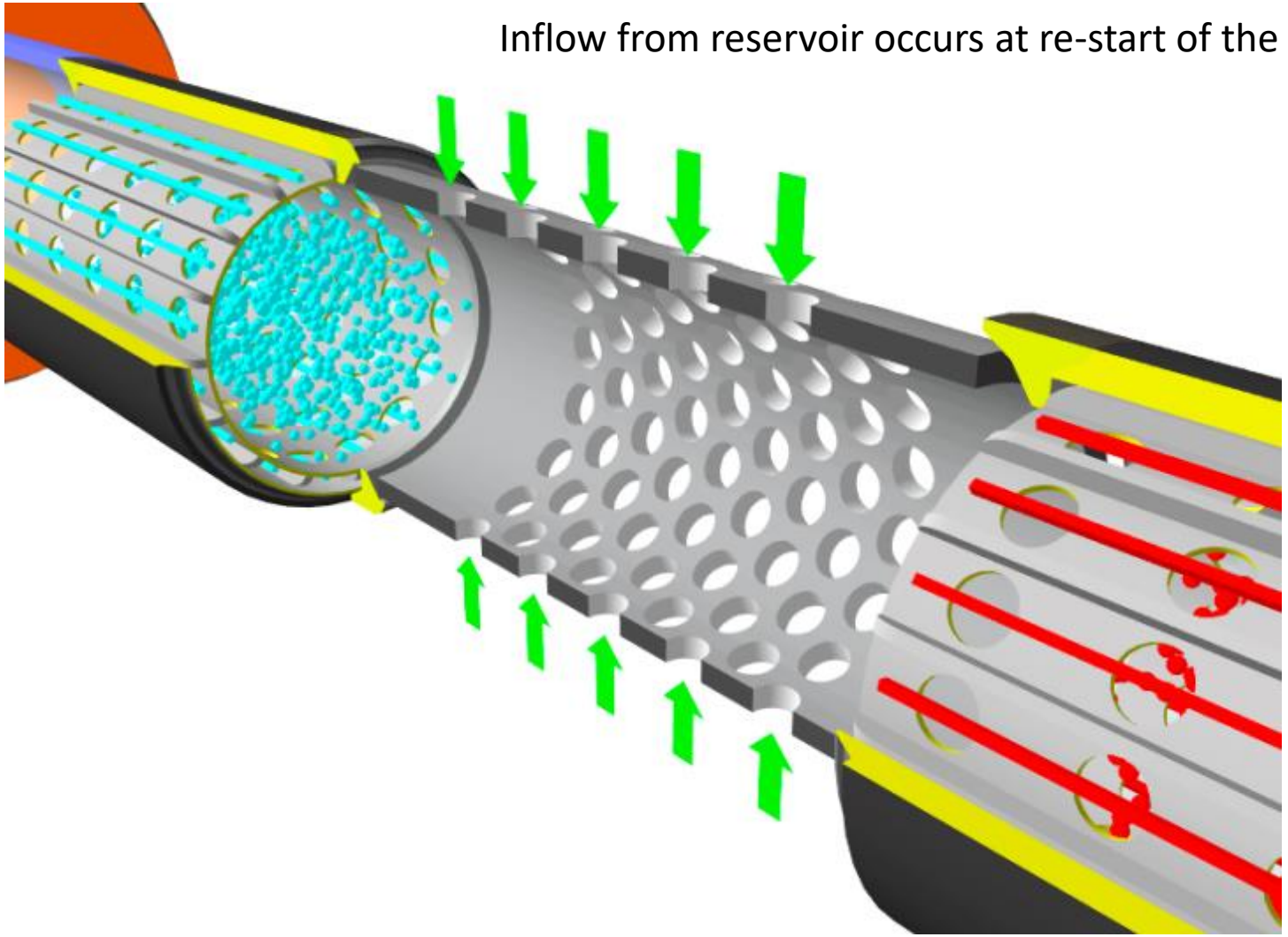
TRACER ARRIVAL METHOD – CREATING THE CLOUD



- Concentration increases in oil near tracer rods
- Small volume of oil with elevated concentration is formed every time the well is shut-in
- This is referred to as “the cloud”

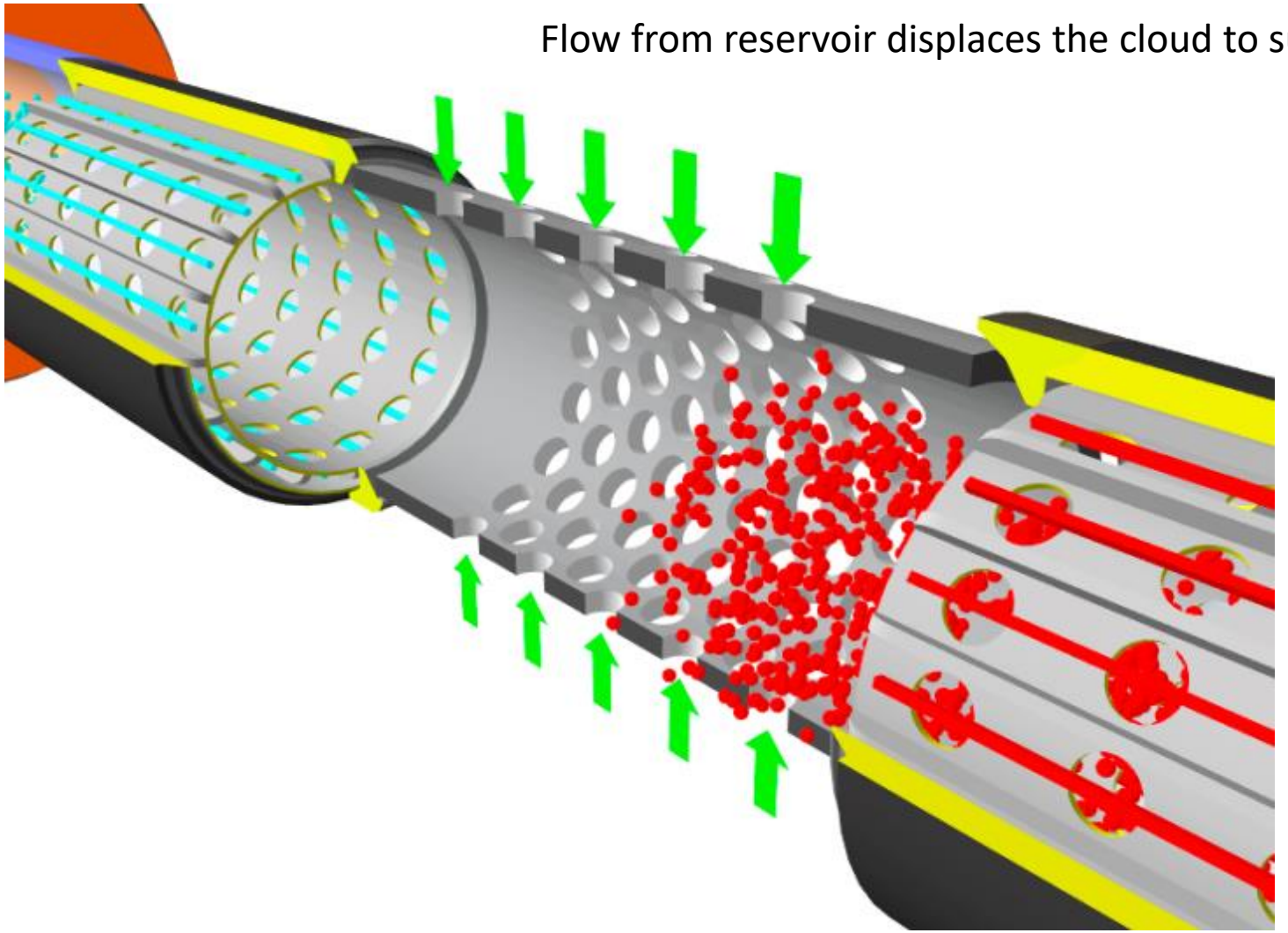
TRACER ARRIVAL METHOD – INFLOW BEGINS

Inflow from reservoir occurs at re-start of the well

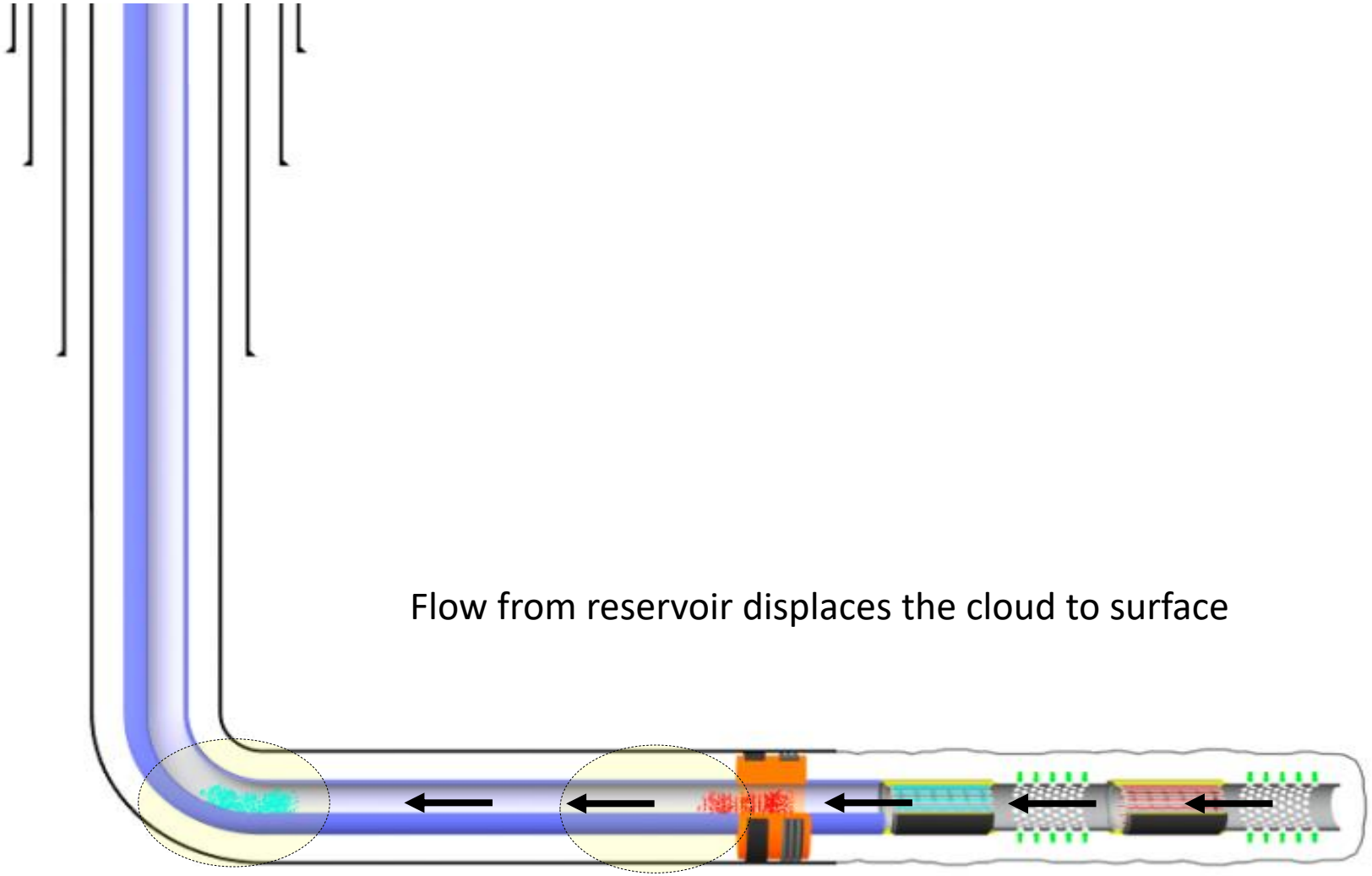


TRACER ARRIVAL METHOD – DISPLACING THE CLOUD

Flow from reservoir displaces the cloud to surface

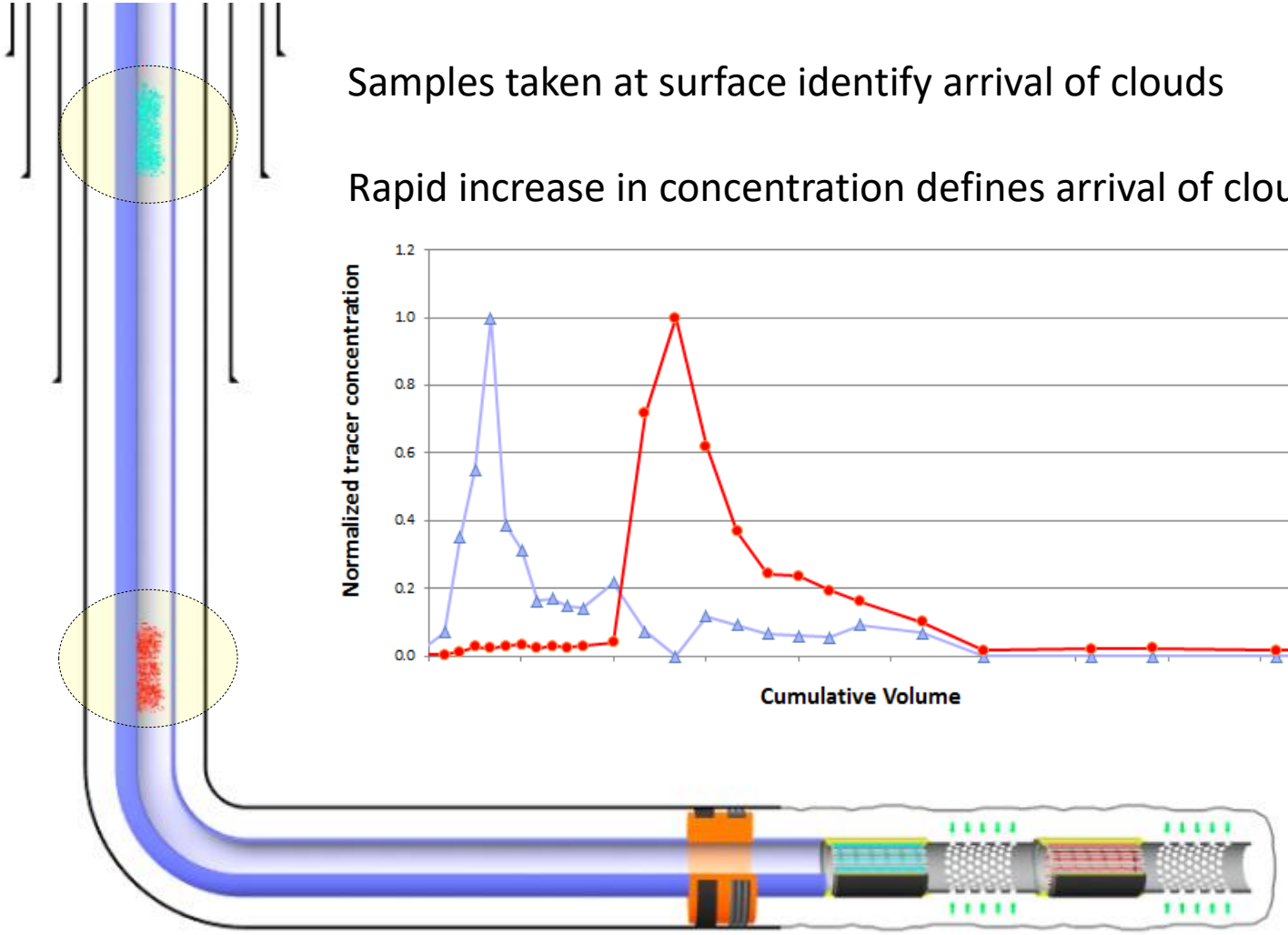


TRACER ARRIVAL METHOD – DISPLACING THE CLOUD



Flow from reservoir displaces the cloud to surface

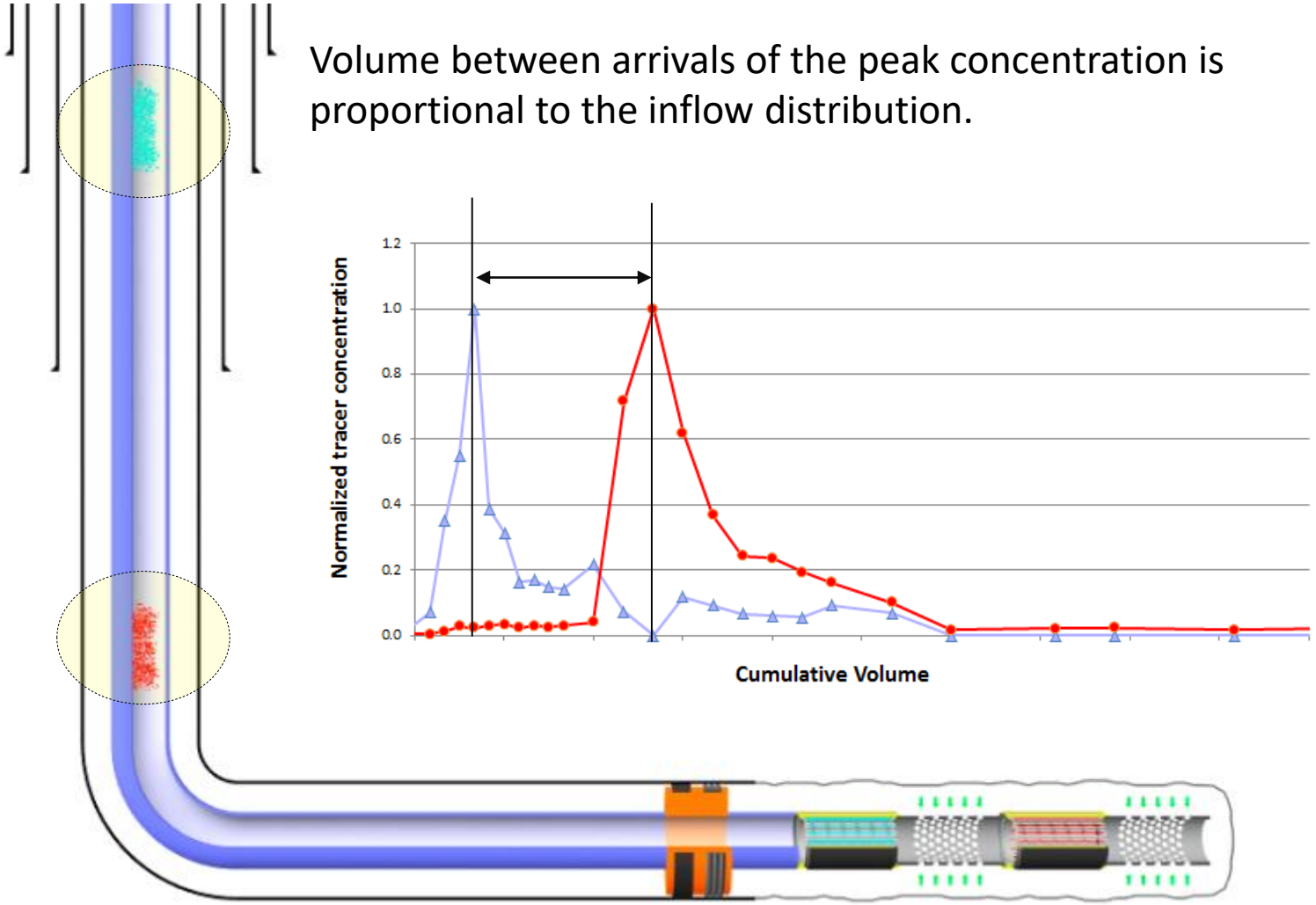
TRACER ARRIVAL METHOD – SURFACE SAMPLING



Samples taken at surface identify arrival of clouds

Rapid increase in concentration defines arrival of cloud

TRACER ARRIVAL METHOD – INFLOW DISTRIBUTION



Volume between arrivals of the peak concentration is proportional to the inflow distribution.

Field Example

Eagle Ford Shale

UNCONVENTIONAL APPLICATION: PLUG AND PERF

Challenges

- Quantify inflow along horizontal
- Low-cost and repeatable solution
- No intervention

Solution: RESMAN iTrace

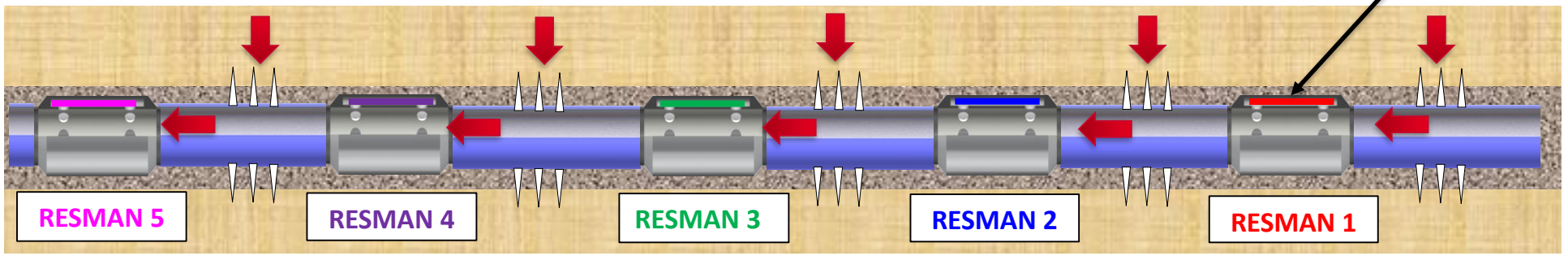
- Five (5) iTrace carriers installed along the horizontal for inflow quantification
- Thus, each iTrace monitored production from 6 stages, **multi-year life**

iTrace carriers

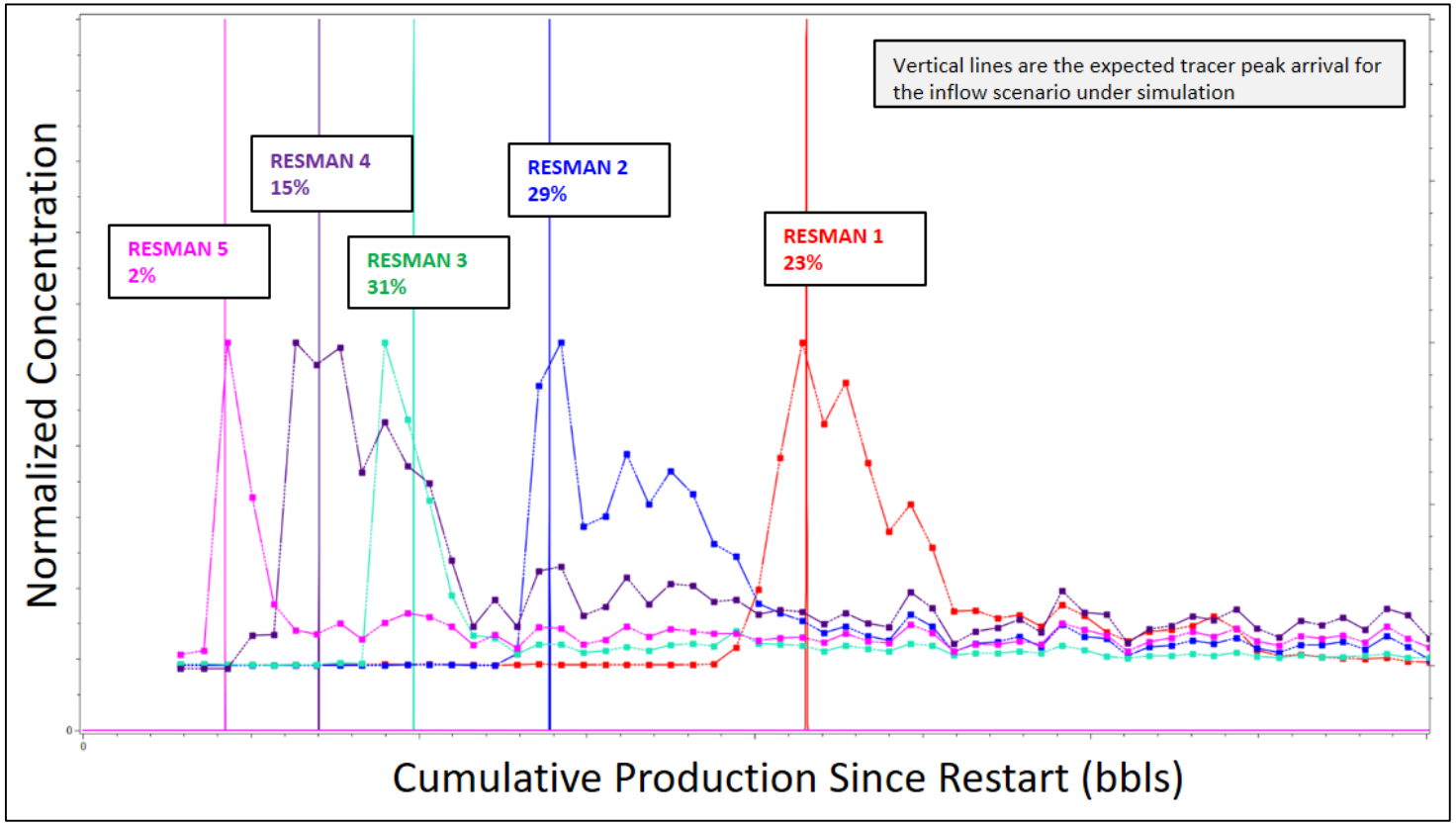
Plug & perf, 30 stages

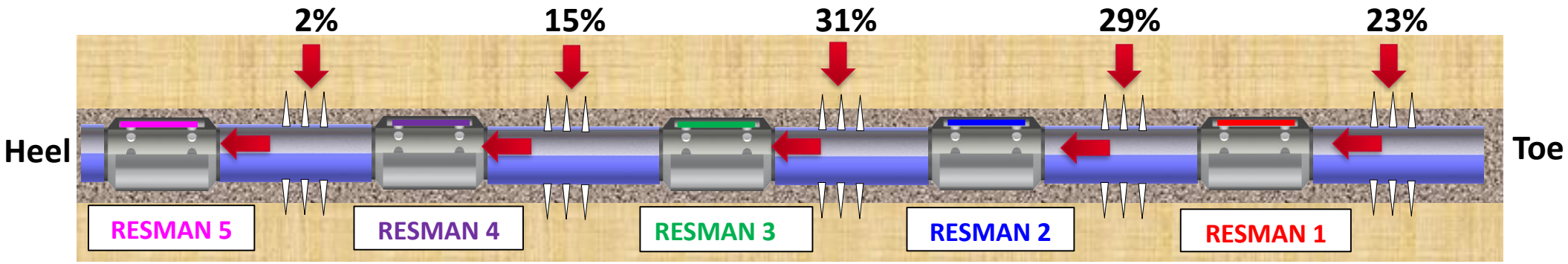
TD = approx. 17,200 ft (5243m)

Lateral length = approx. 6,000 ft (1829m)



UNCONVENTIONAL APPLICATION: PLUG AND PERF





How it Works

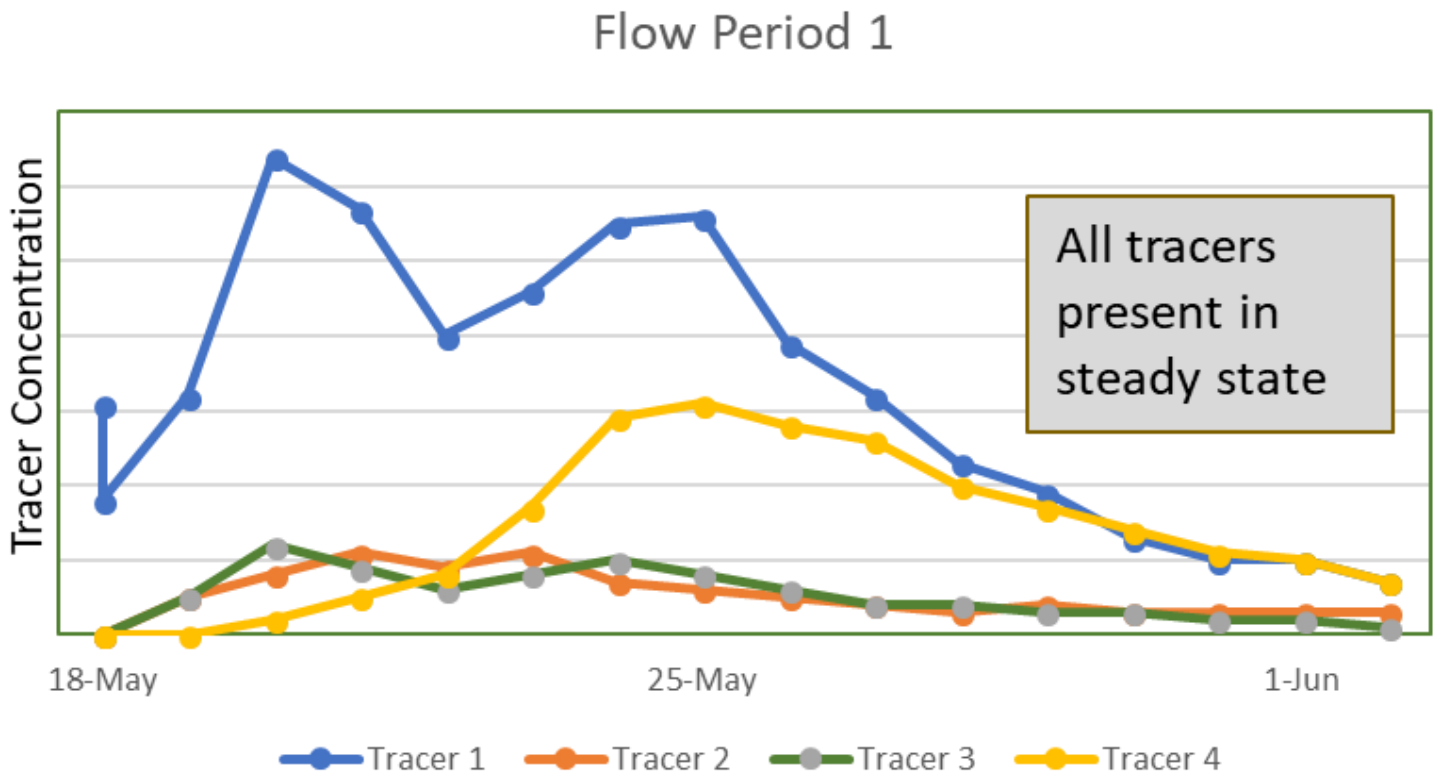
Flow Continuity

STEADY STATE ANALYSIS

- During normal well production tracers can be used to verify flow from sections of the lateral.
- Changes in tracer signal can be correlated to changes in production to identify the location of the changes downhole.
- Steady state analysis is conducted with no intervention and no well shut-in required.

CASE STUDY – STEADY STATE ANALYSIS

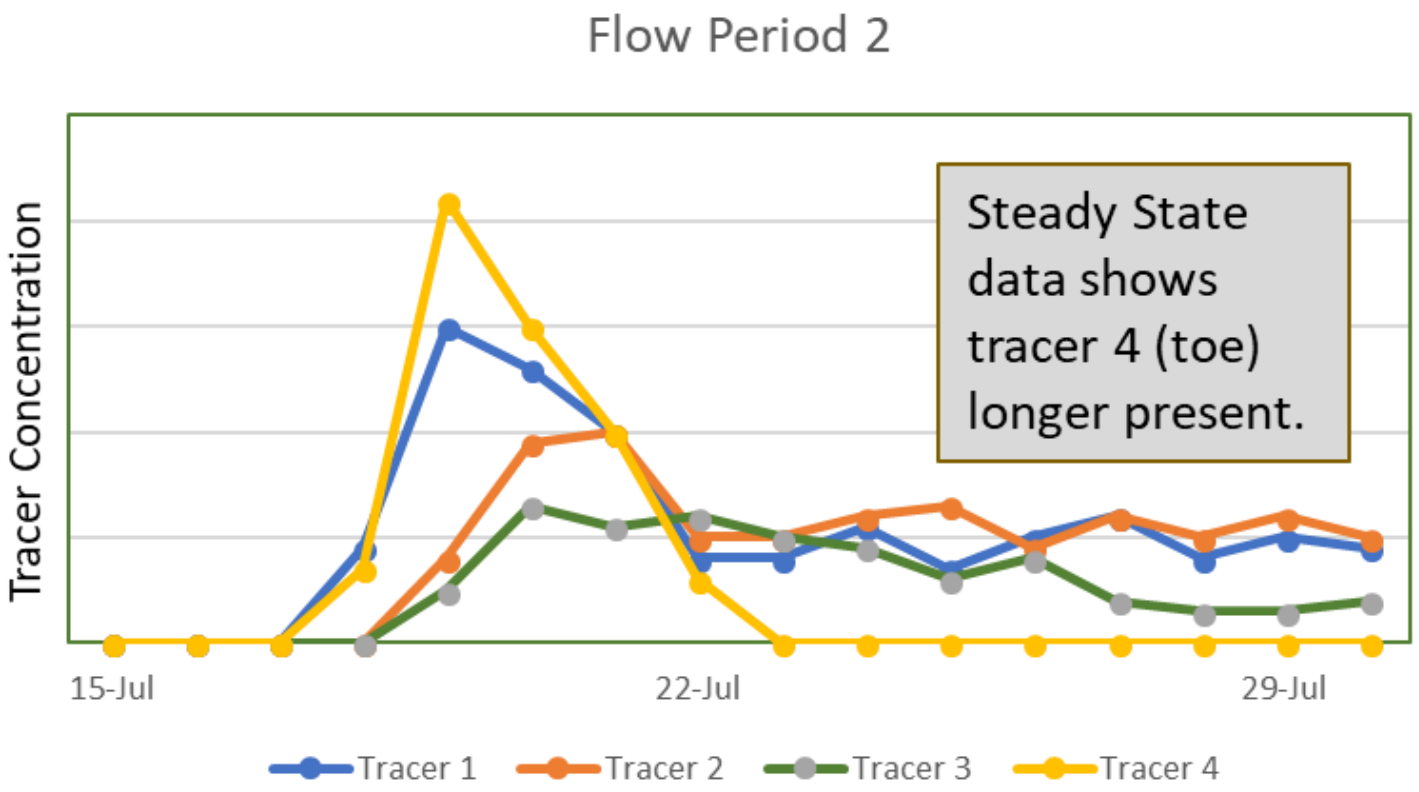
Steady State Analysis – Wellbore Connectivity



- Tracer Data from initial well production.
- Data shows oil production coming from all monitored zones.

CASE STUDY – STEADY STATE ANALYSIS

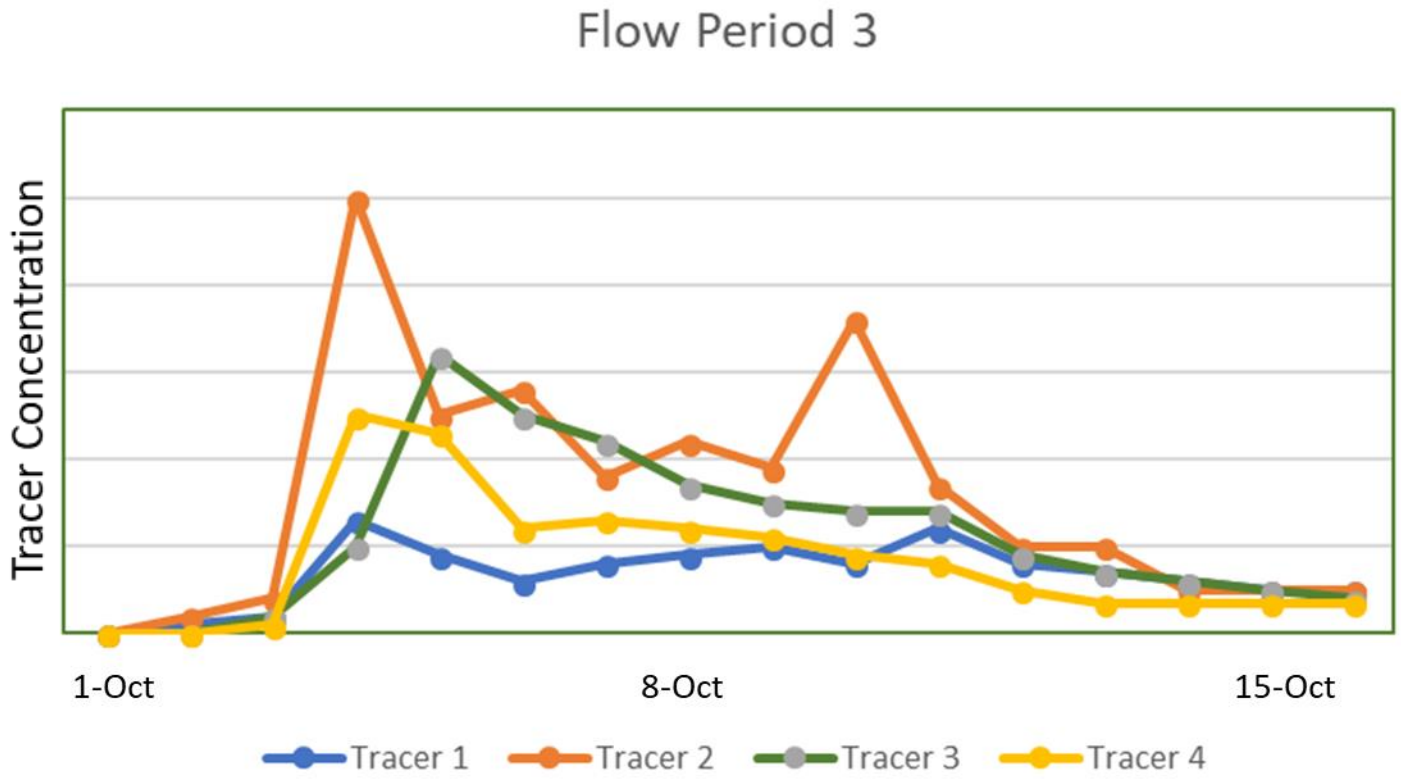
Steady State Analysis – Wellbore Connectivity



- Ongoing tracer analysis showed that oil was no longer flowing from the toe of the well (tracer 4).
- Tracer analysis supports intervention.

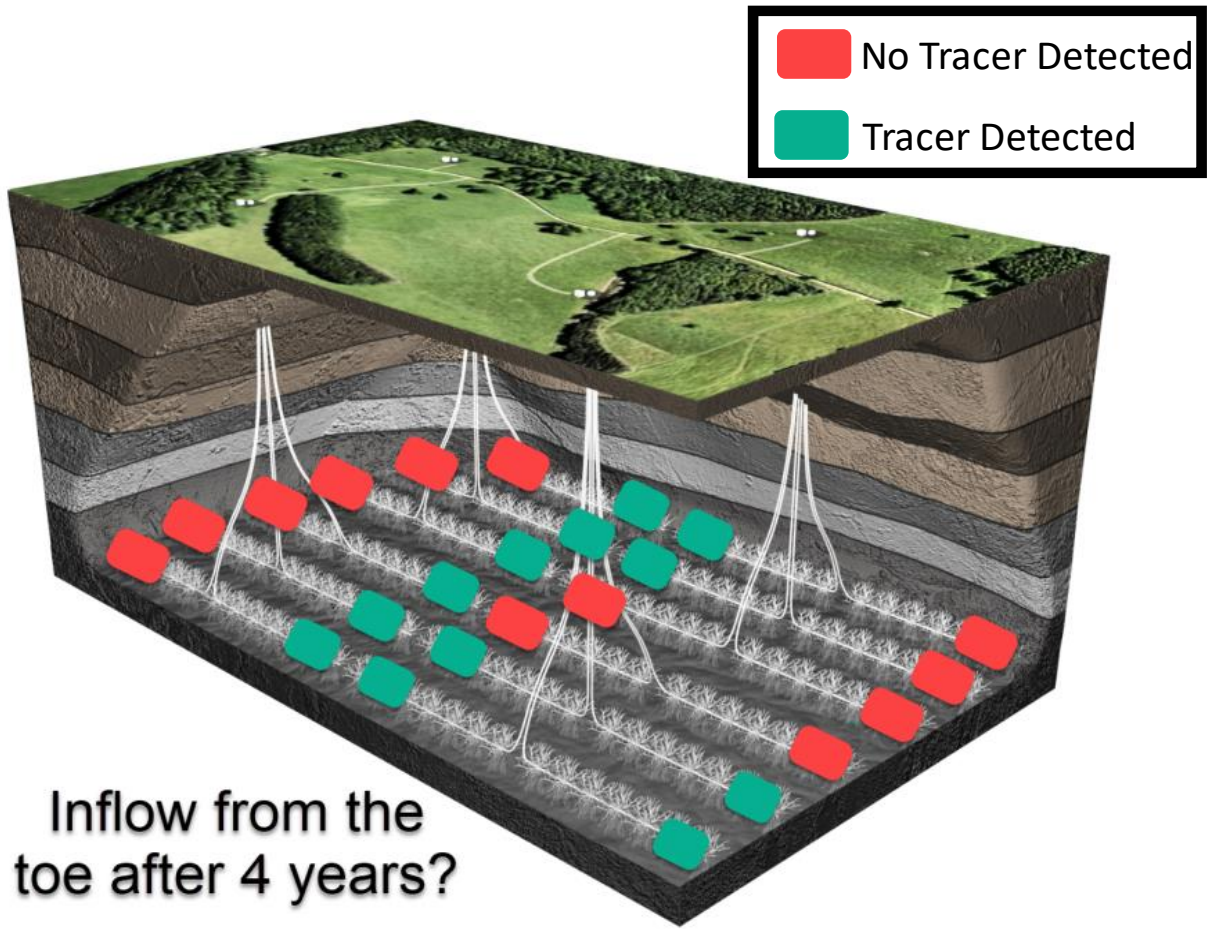
CASE STUDY – STEADY STATE ANALYSIS

Steady State Analysis – Wellbore Connectivity



- Following intervention the tracer data is analyzed again.
- Analysis shows that all 4 oil tracers are present again.

TOE INFLOW VERIFICATION – FIELDWIDE FLOW ASSURANCE



Answers the question:

"Is my whole lateral contributing?"

- Single tracer in the toe of each well.
- 2-3 samples per well a few times a year with no shut-in required.
- All wells analyzed as a single analysis run.

Contact

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Questions & Comments