# Bacteria Surveillance and Management Strategy for Shell Argentina SOV Operations

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# Agenda

- Motivation
- Background
- Monitoring Techniques Description
- Workflow
  - Bioaudit
  - Kill Test
  - Production Results
  - Microbiology Control Strategy for Production
- Conclusions

# Motivation

## Before Fracking

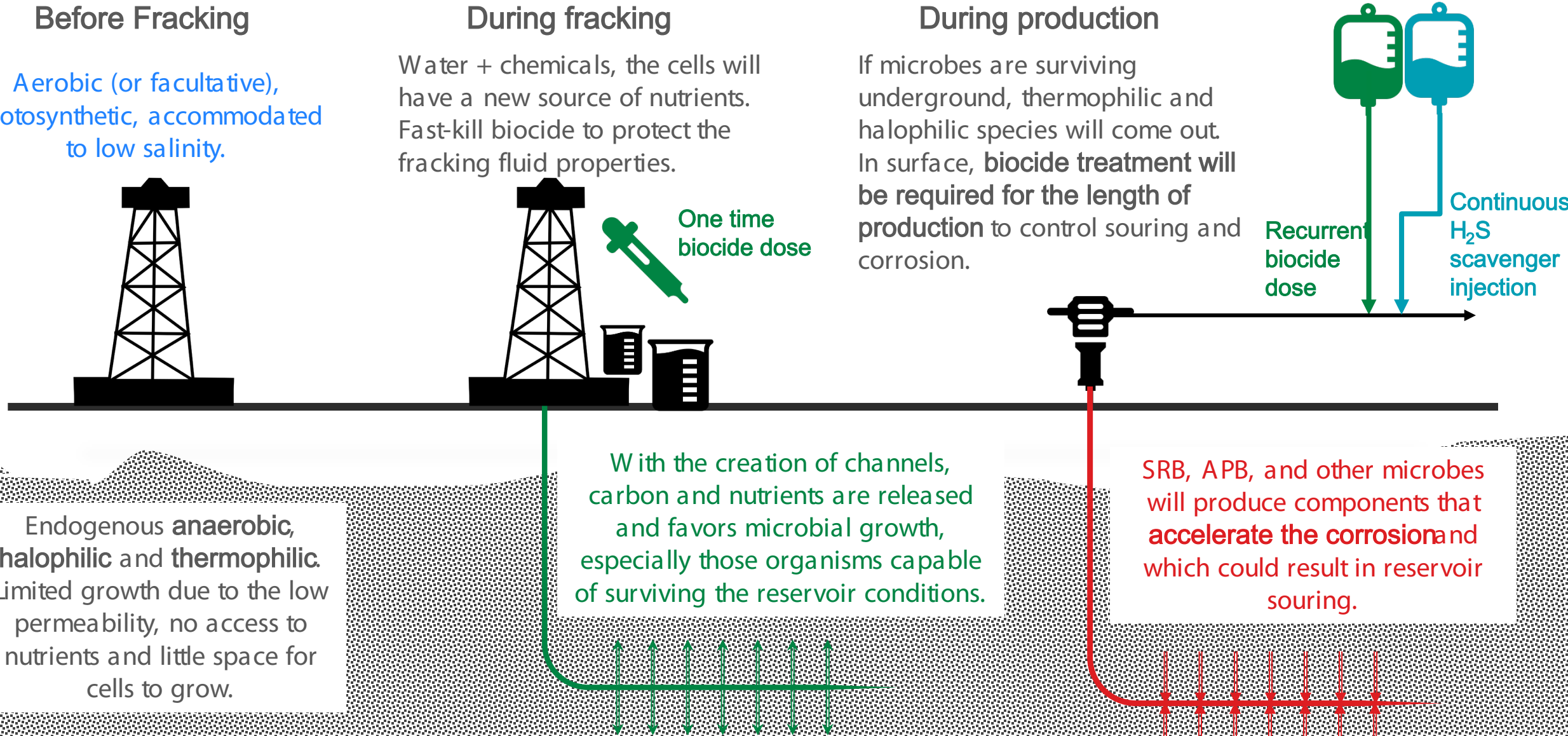
Aerobic (or facultative), photosynthetic, accommodated to low salinity.

## During fracking

Water + chemicals, the cells will have a new source of nutrients. Fast-kill biocide to protect the fracking fluid properties.

## During production

If microbes are surviving underground, thermophilic and halophilic species will come out. In surface, **biocide treatment will be required for the length of production** to control souring and corrosion.

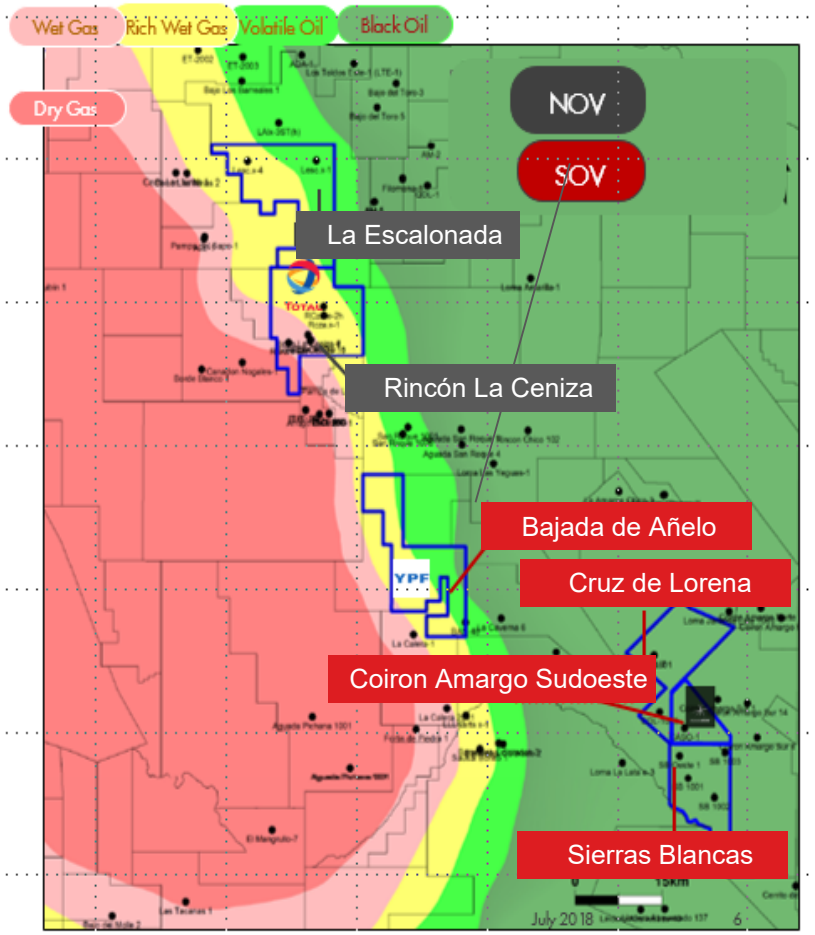



Endogenous **anaerobic**, **halophilic** and **thermophilic**. Limited growth due to the low permeability, no access to nutrients and little space for cells to grow.

With the creation of channels, carbon and nutrients are released and favors microbial growth, especially those organisms capable of surviving the reservoir conditions.

SRB, APB, and other microbes will produce components that **accelerate the corrosion** and which could result in reservoir souring.

# Background – Shell Operations in Vaca Muerta



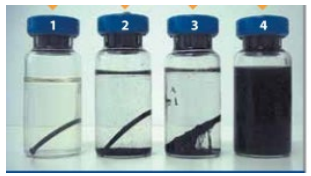

- **Harvest Areas**
  - **SB/CdL/CASO** blocks (~90% Shell)
  - Black Oil (93% Black Oil, **<10 %WC**)
  - Early Production (12,000 bbl/d Pilot Capacity)
  - **70,000 bbl/d 10+ years plateau potential**
- **Appraisal Areas**
  - **BAn** (50% Shell), **LEsCRcza** blocks (45% Shell, Total operated)
  - Wet Gas and Volatile Oil
- **Oil wells studied**
  - Data gathered in 2017, 2018 and 2019 in 3 black oil blocks and 1 volatile oil block, all operated by Shell
  - **23 wells studied**, 22 located in SB/CdL/CASO, producing hydrocarbons through Early Production Facility (EPF) in SB and 1 located in BAn

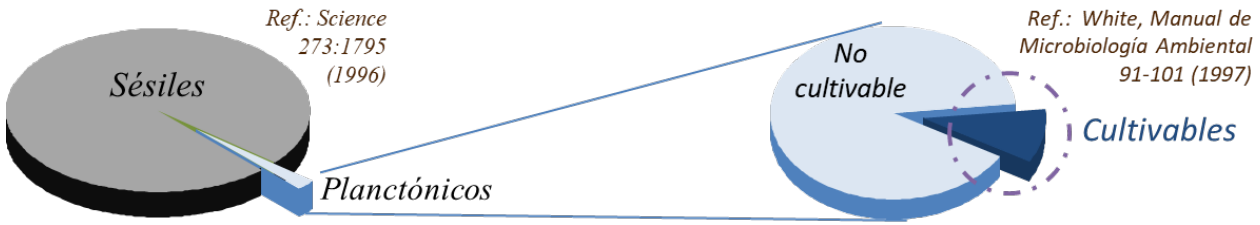
# Monitoring Techniques Description

## Serial Dilutions

APB

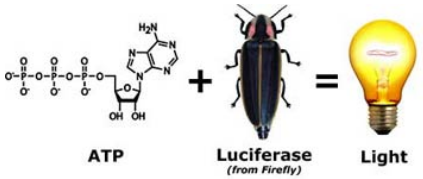
SRB






Results sensitive to different suppliers
Salinity considerations
Time consuming to get results

## ATP




ATP: universal molecule for energy storage/ transport in the **living cells**
Indicates microorganisms presence/ cell activity
Not specific technique

## Molecular Biology

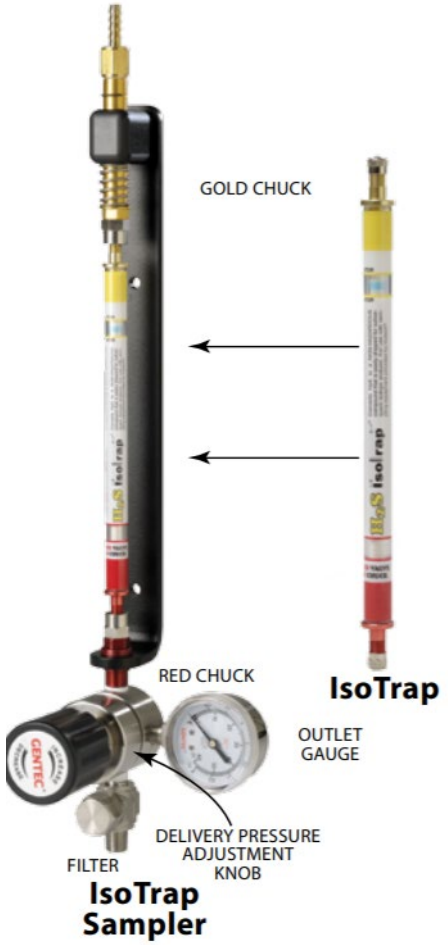
| | |
|---|---|
| Reino | Bacteria |
| Filo | Proteobacteria |
| Classe | Deltaproteobacteria |
| Ordem | Desulfobacterales |
| Familia | Desulfobacteraceae |
| Gênero | *Desulfobacter* |
| Espécies | *D. Hydrogenophilus* |

**Quantification by qPCR**– allows for total counts of living + dead cells
Specific according the primers used

**NGS – next generation sequencing:** identifies % of each Genera / Class according the taxon used

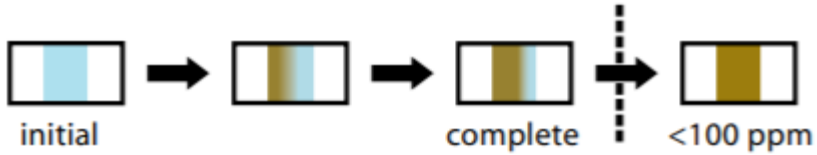
# Monitoring Techniques Description

## Sulfur Isotopic Analysis

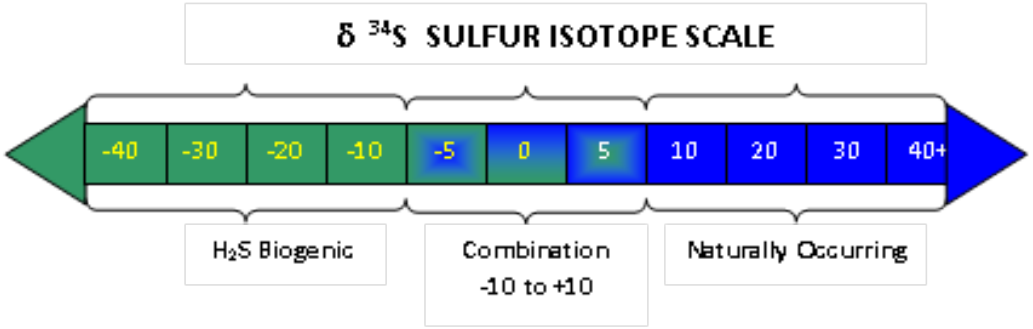



**Sulfur isotopic analyses** are designed to help identify the source of $H_2S$, determining determine whether the sulfide gas produced comes from microbiologic metabolism or from naturally occurring reactions in oil and gas reservoirs

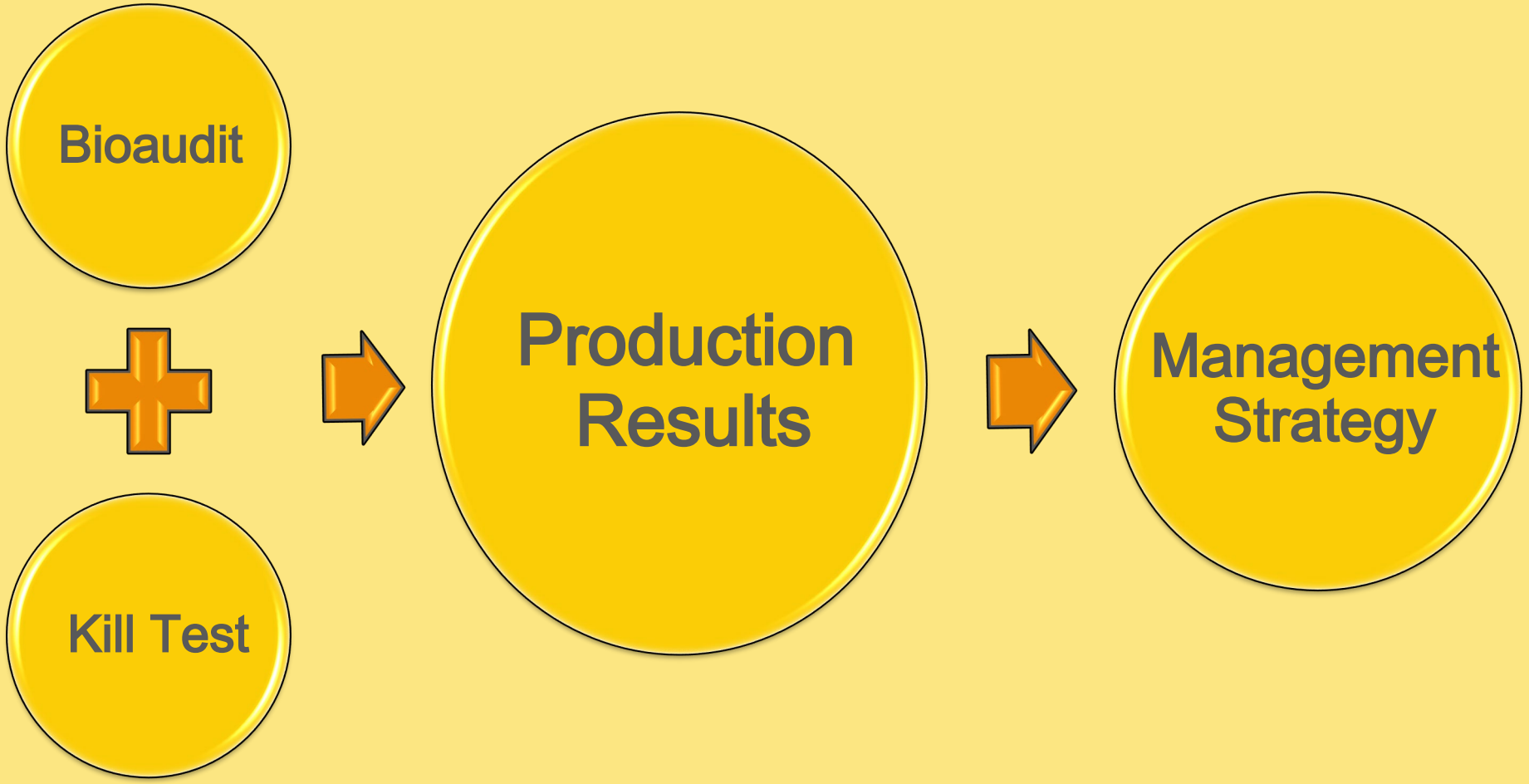
| $H_2S$ Concentration | Required Volume |
|---|---|
| 5 ppm | 500 L |
| 50 ppm | 50 L |
| 500 ppm | 5 L |
| 5000 ppm | 0.5 L |
| 5% | 0.05 L |




$$\delta\,^{34}S = \frac{(^{34}S/^{32}S)_{sample} - (^{34}S/^{32}S)_{standard}}{(^{34}S/^{32}S)_{standard}} * 1000$$

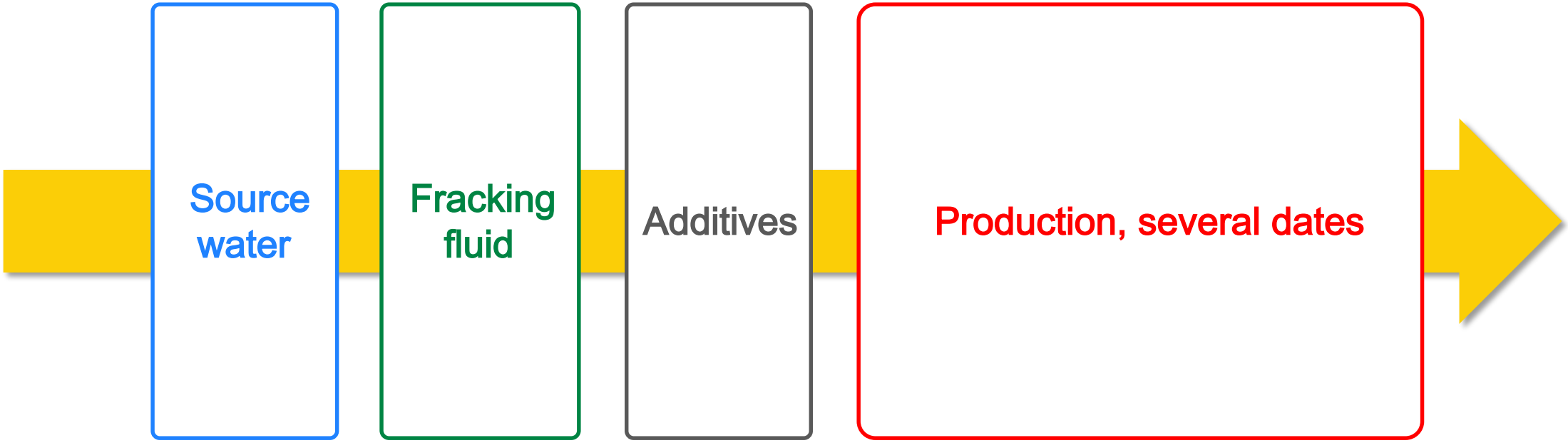


# Workflow



Bioaudit

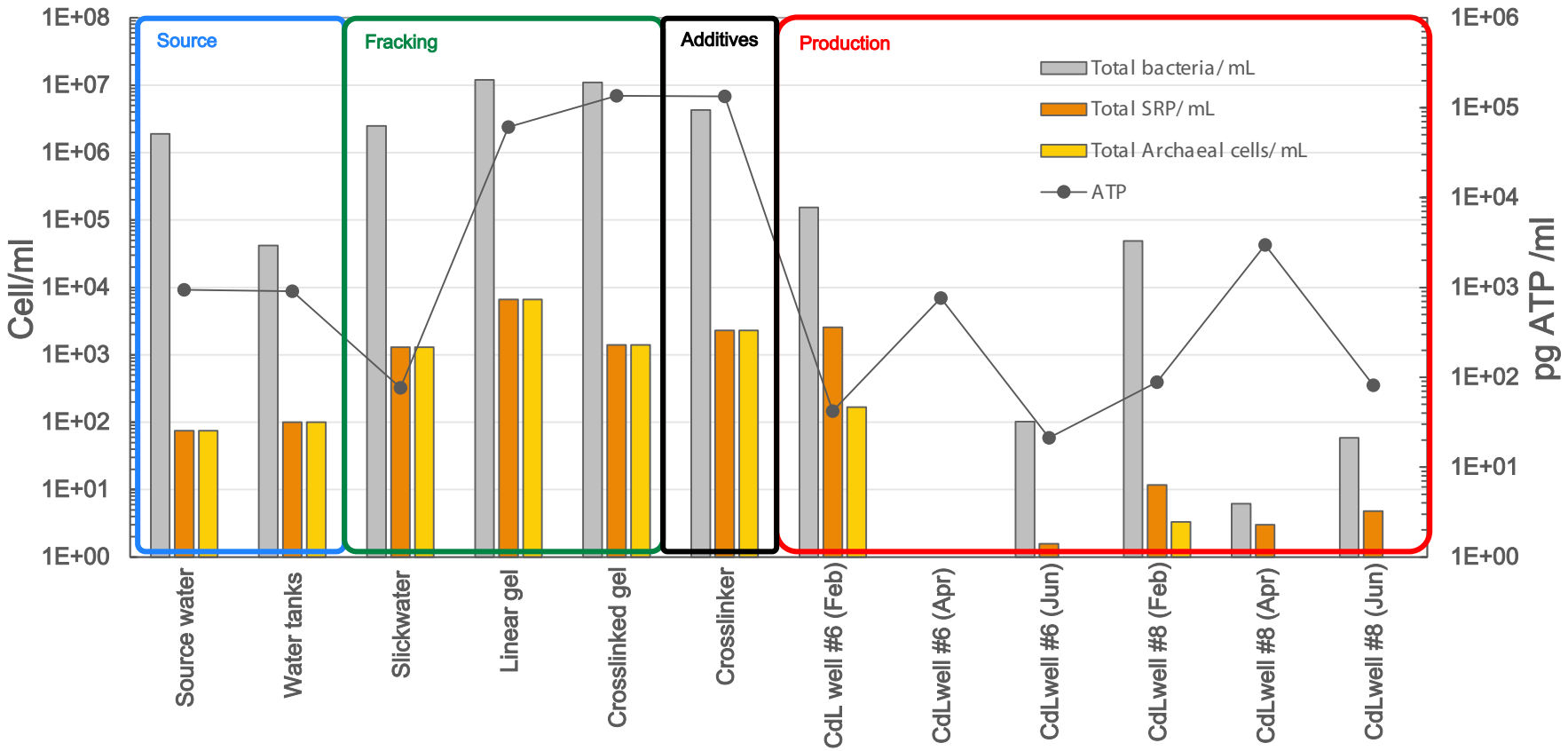
# Sampling Overview




Sampling conditions:

- Sterile flasks
- No oxygen
- Cells containing DNA filtered and preserved on the field
- ATP measured on site

# ATP & qPCR Results



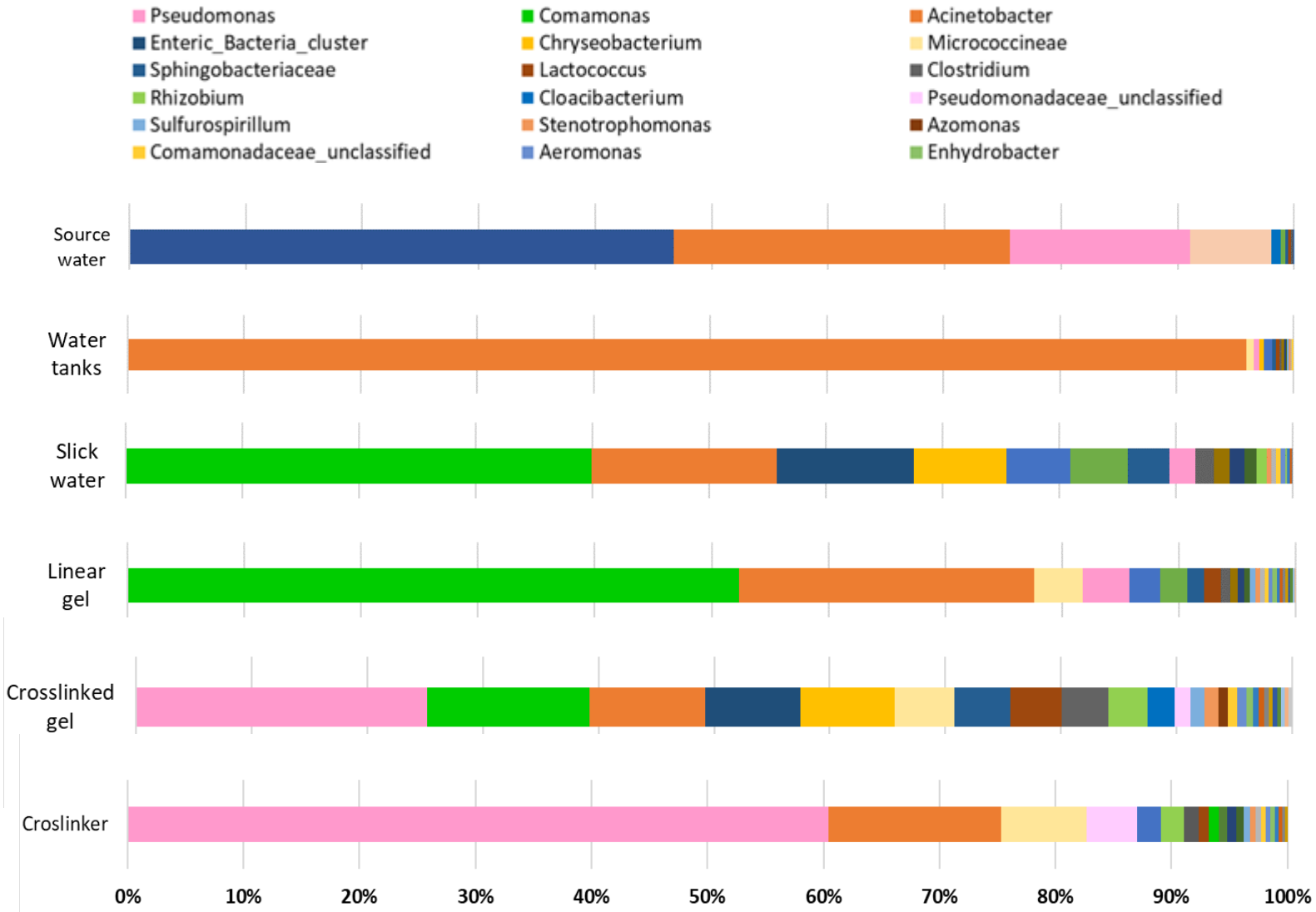

Source water: mild contamination typical for **river water**

Fracking: medium contamination, unaltered by the biocide used in this stage

**Additives:** medium contamination, unusual presence of **archaea**

Production: February to June results has a decreasing tendency, high concern for the current presence of **SRP**and **archaea** that cannot be reverted

# Bacteria DNA Sequencing Results | Fracture Samples



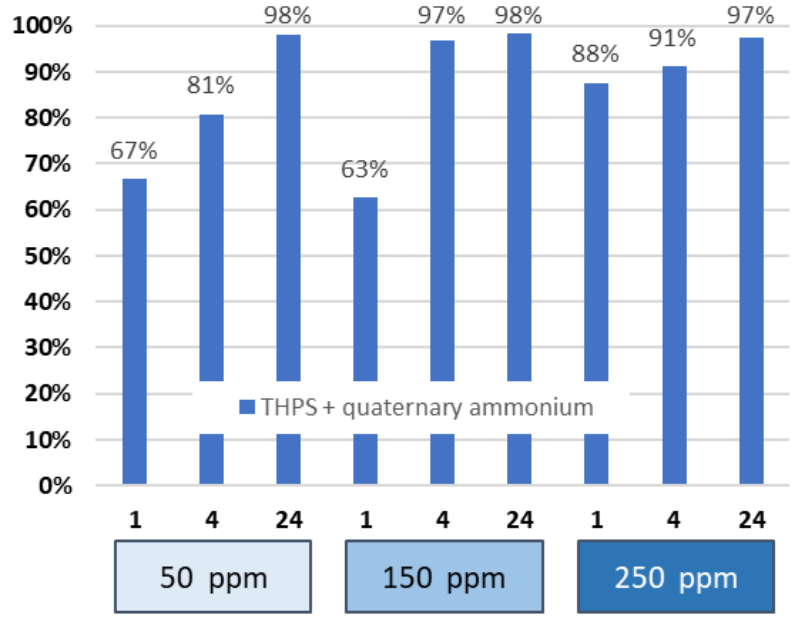

Corrosion risks

| | |
|---|---|
| ~45% | Acinetobacter, pseudomonas |
| ~94% | Acinetobacter |
| ~26% | Acinetobacter, Chryseobacterium |
| ~28% | Acinetobacter, Pseudomonas |
| ~49% | Pseudomonas, Acinetobacter, Chryseobacterium |
| ~77% | Pseudomonas, Acinetobacter, |

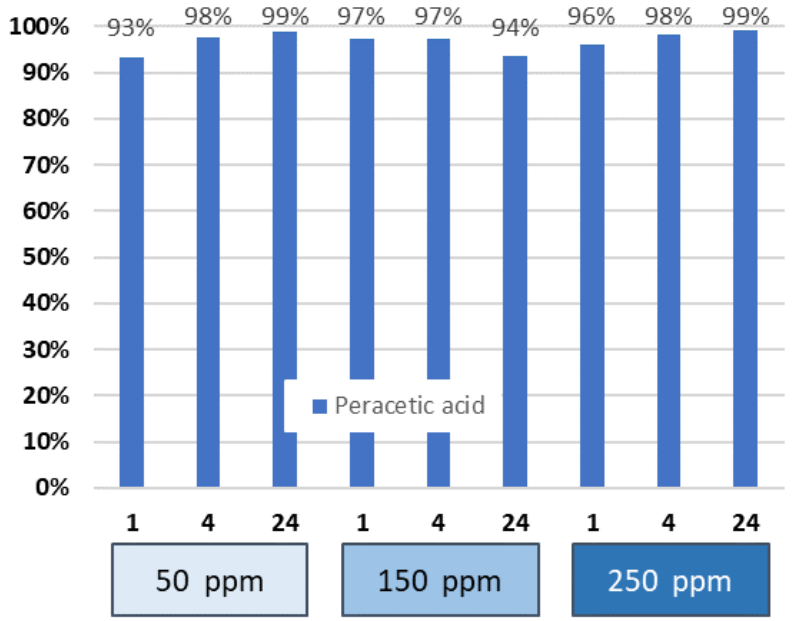
Kill Test

# Results and Biocide Selection

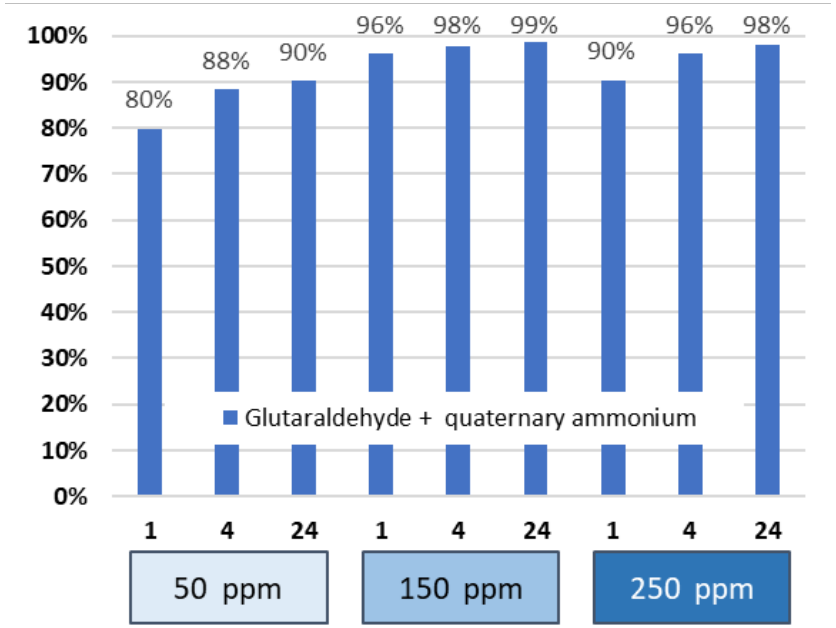
## THPS + Quaternary ammonium




## Peracetic acid




## Glut + Quateranary ammonium

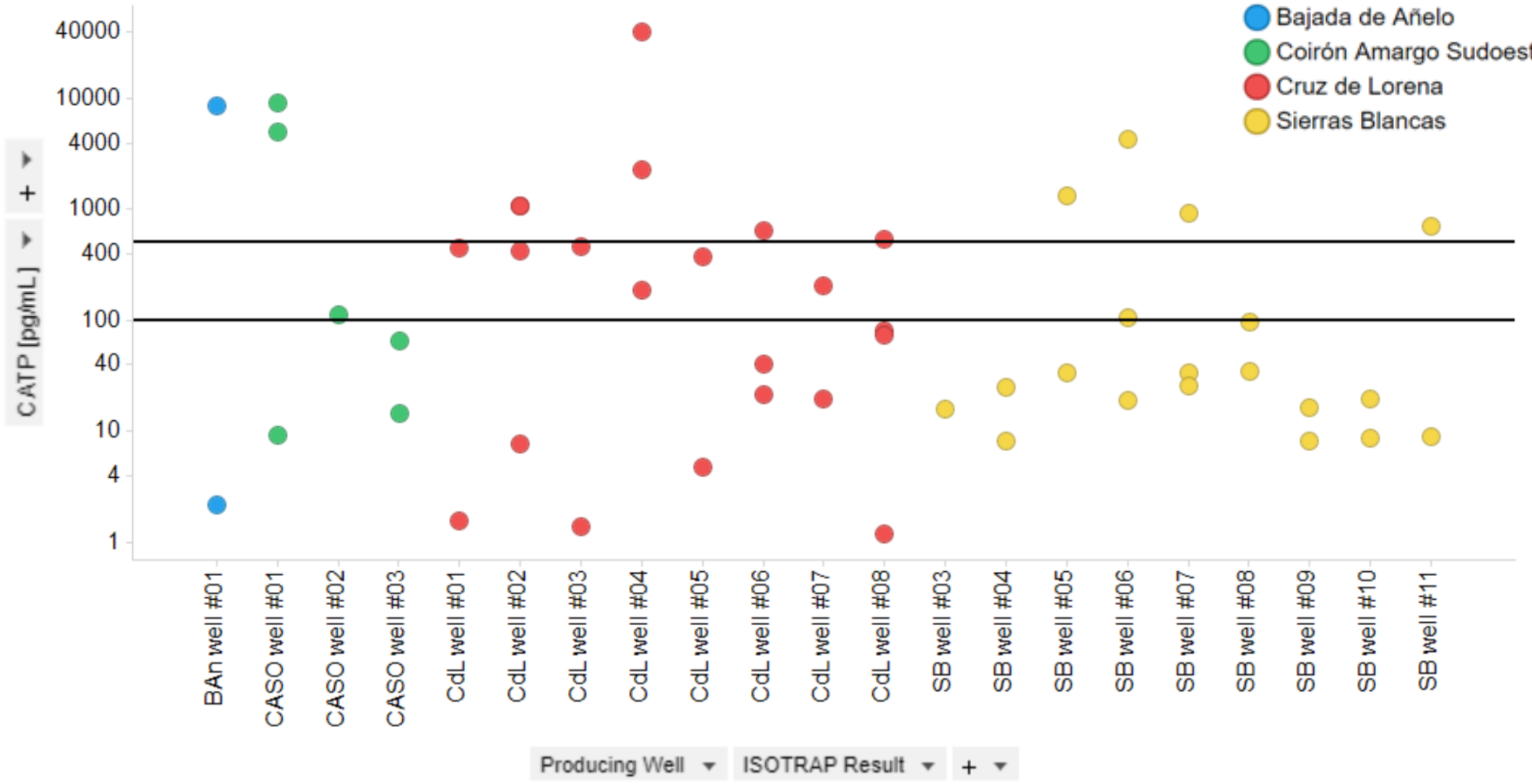



**Treatment Strategy for New Completions:**

Glut + quaternary ammonium at 250 ppm was selected considering that the same combination was used by Shell in the Permian operations

Production Results

# Microbiologic Results – Production

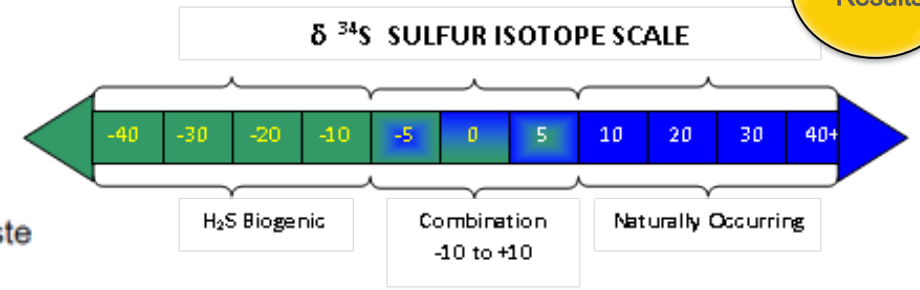


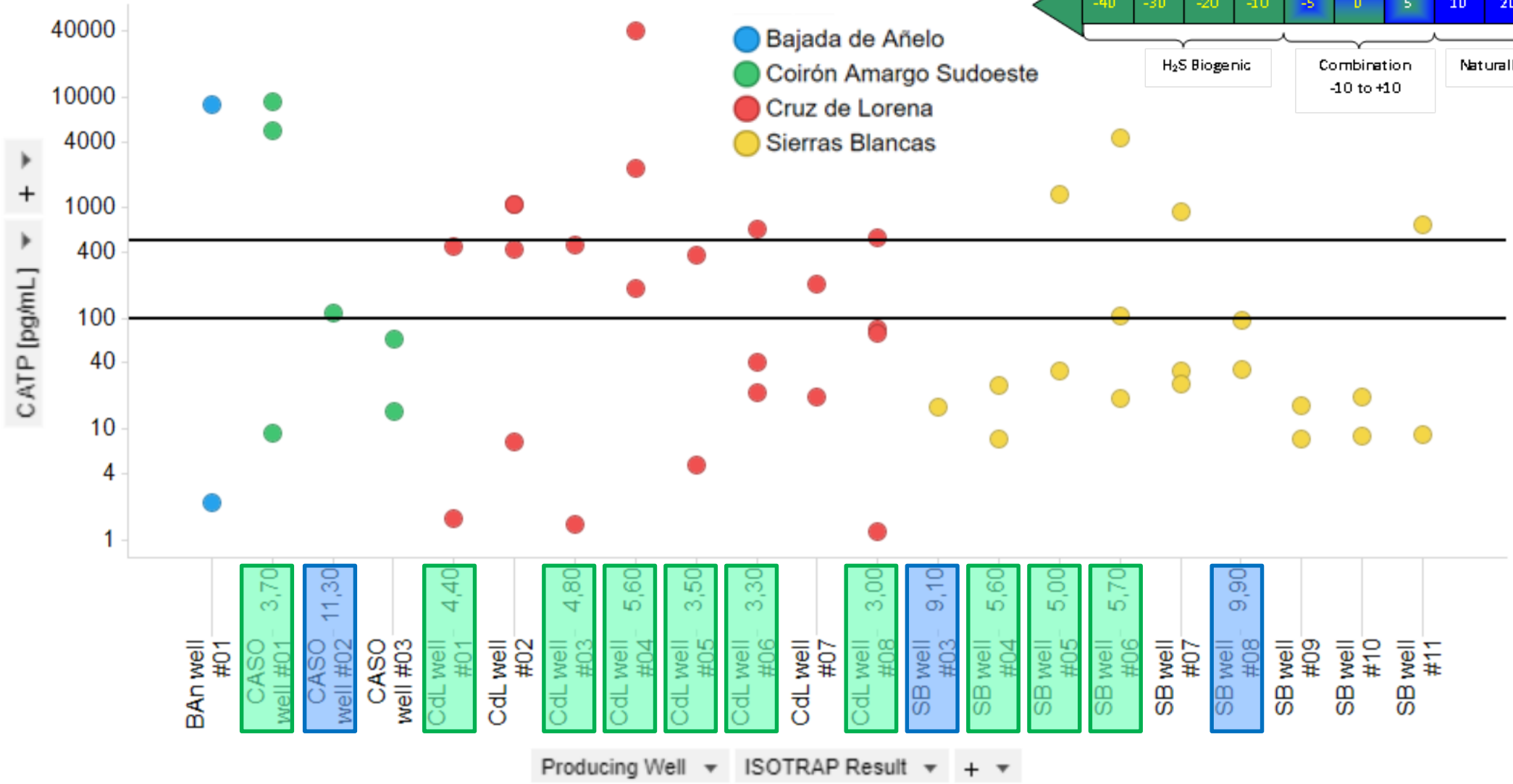

Acceptable maximum level of ATP

Industry standard KPI

# Microbiologic Results – Production

Production Results

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Production Results

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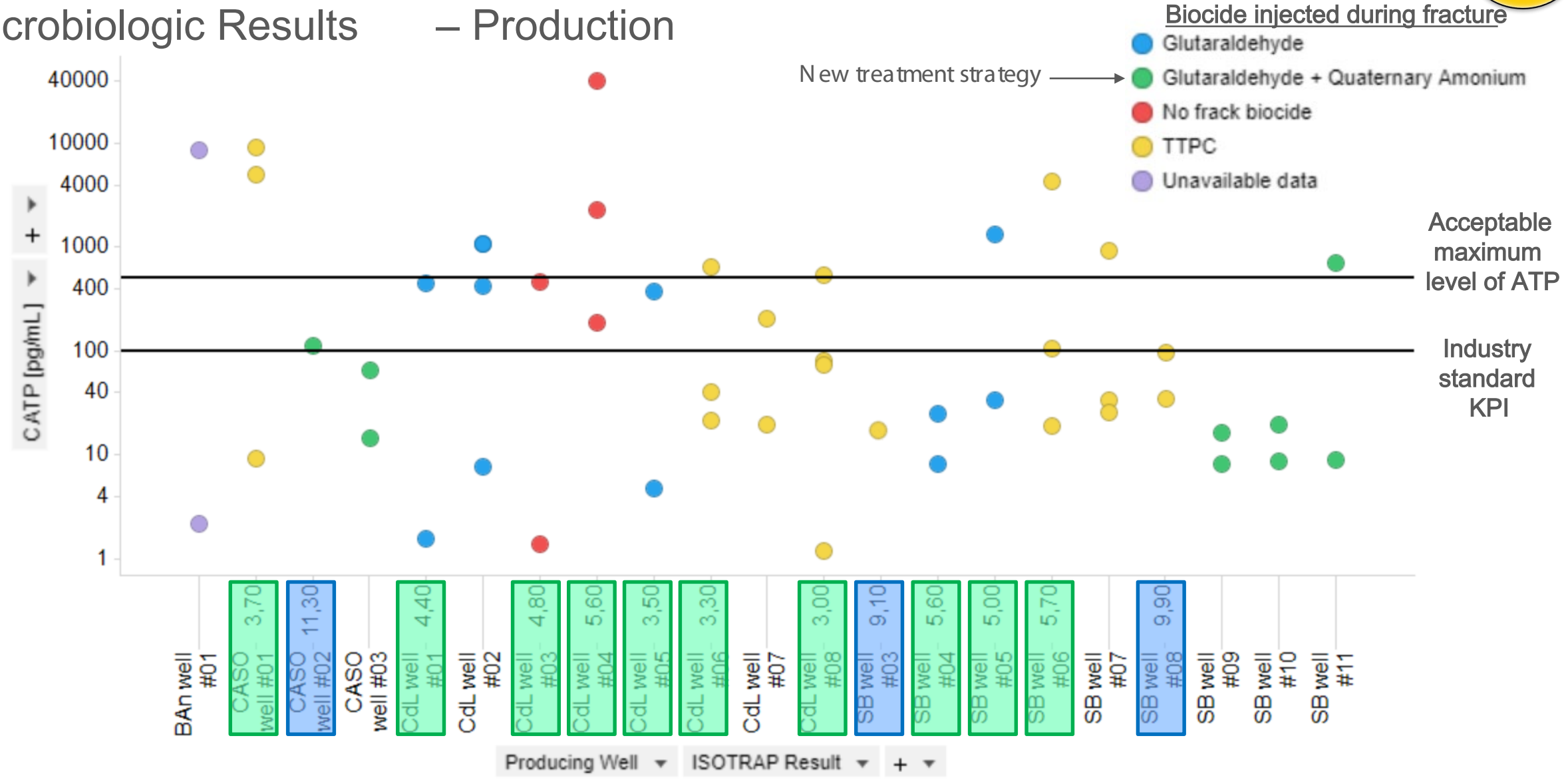

Production Results

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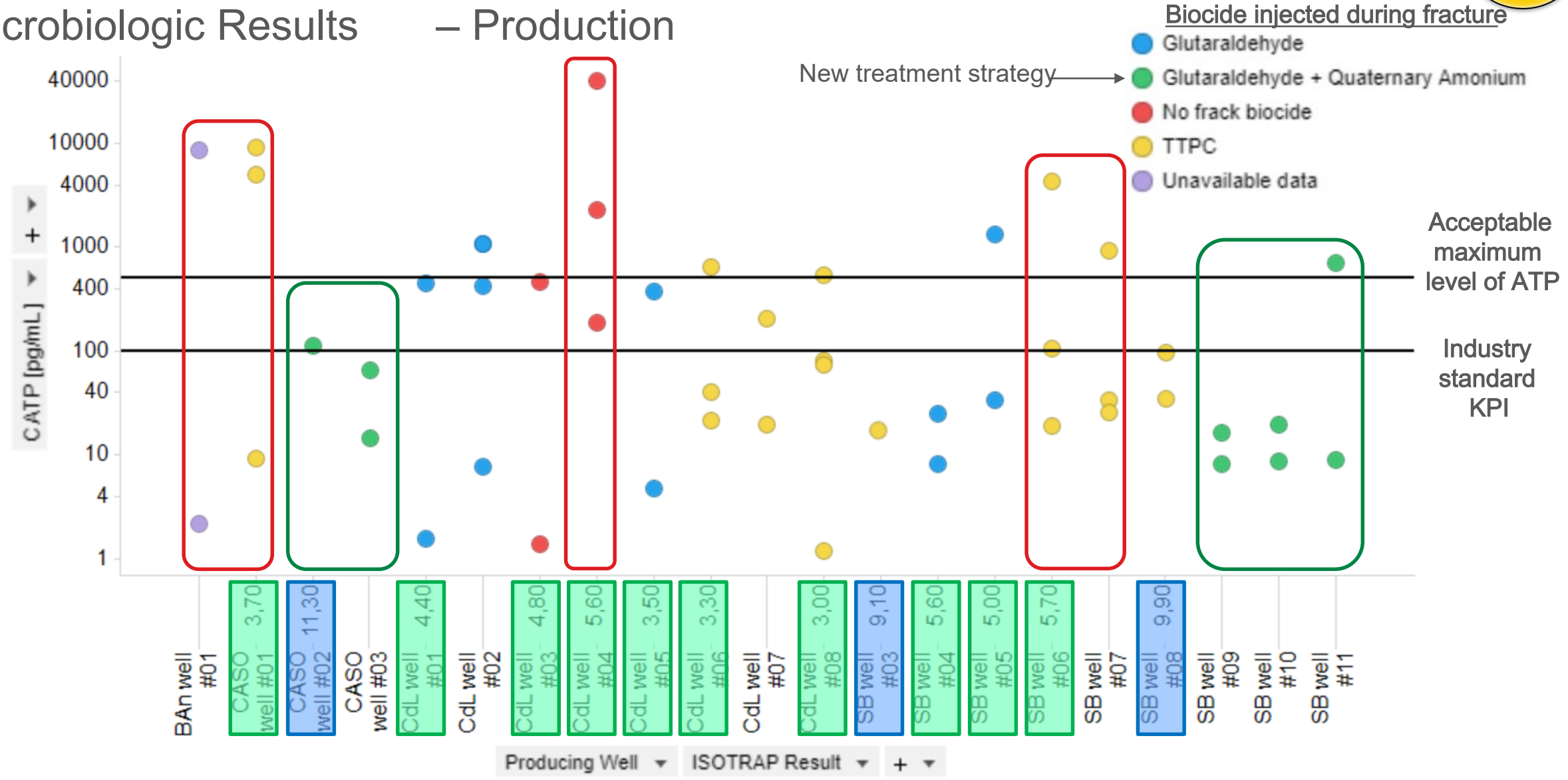
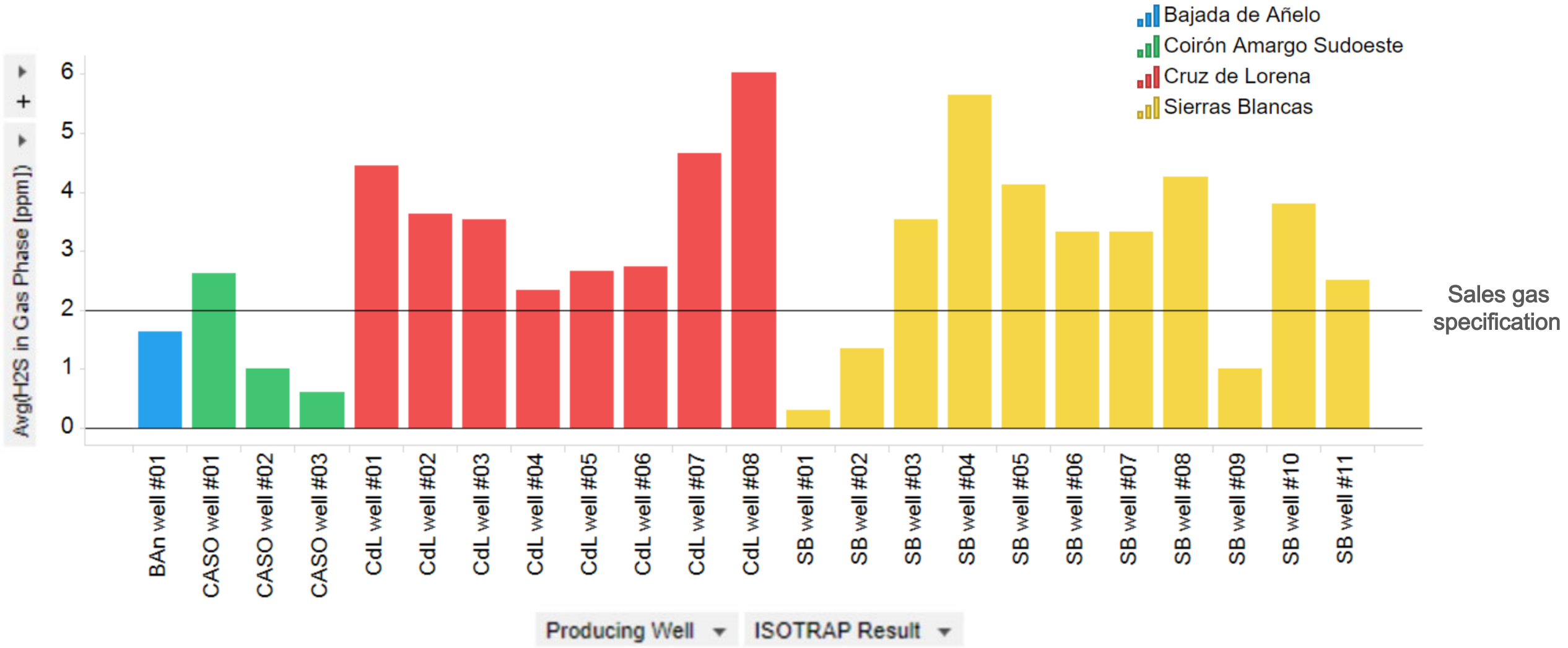


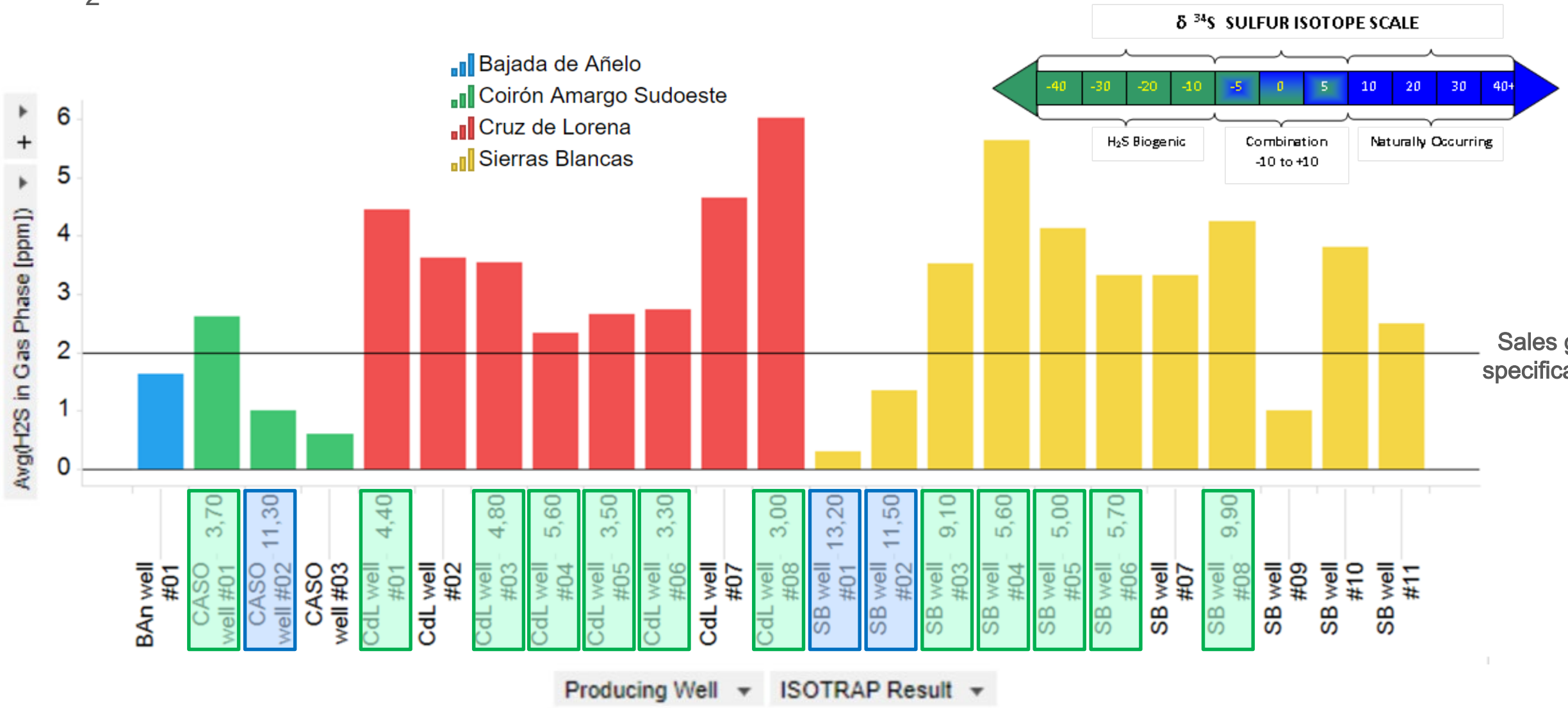
Production Results

# $H_2S$ Results



Production Results

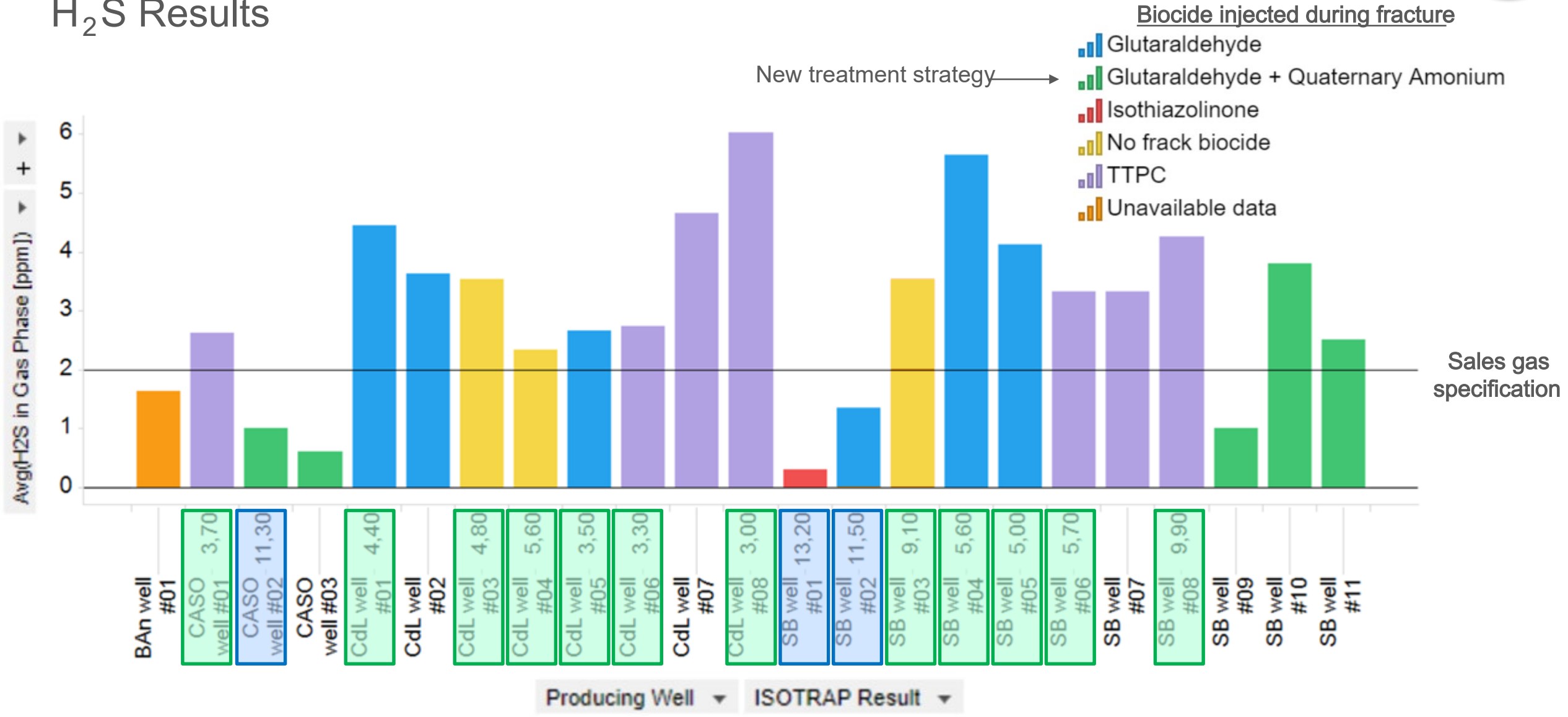
# $H_2S$ Results




Sales gas specification

Production Results

# $H_2S$ Results



Production Results

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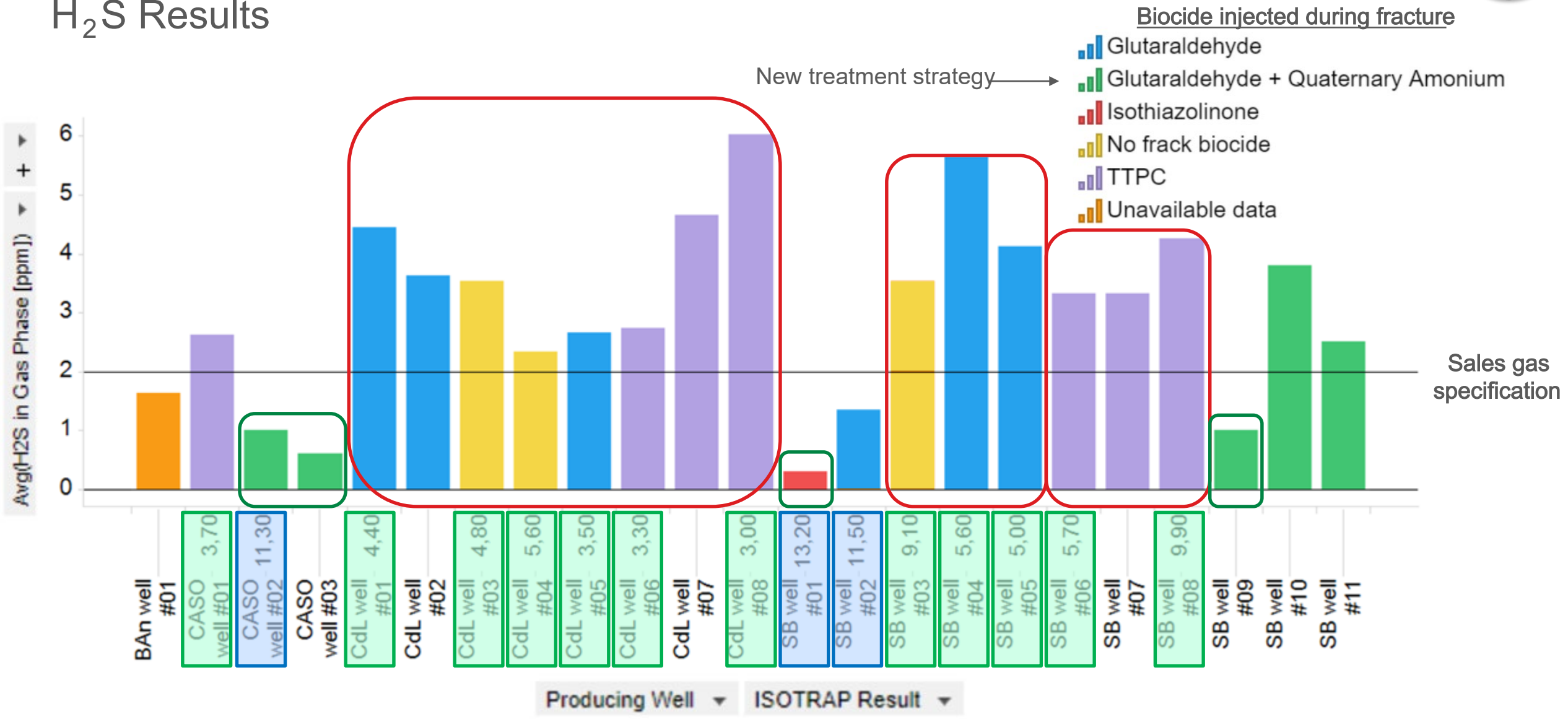
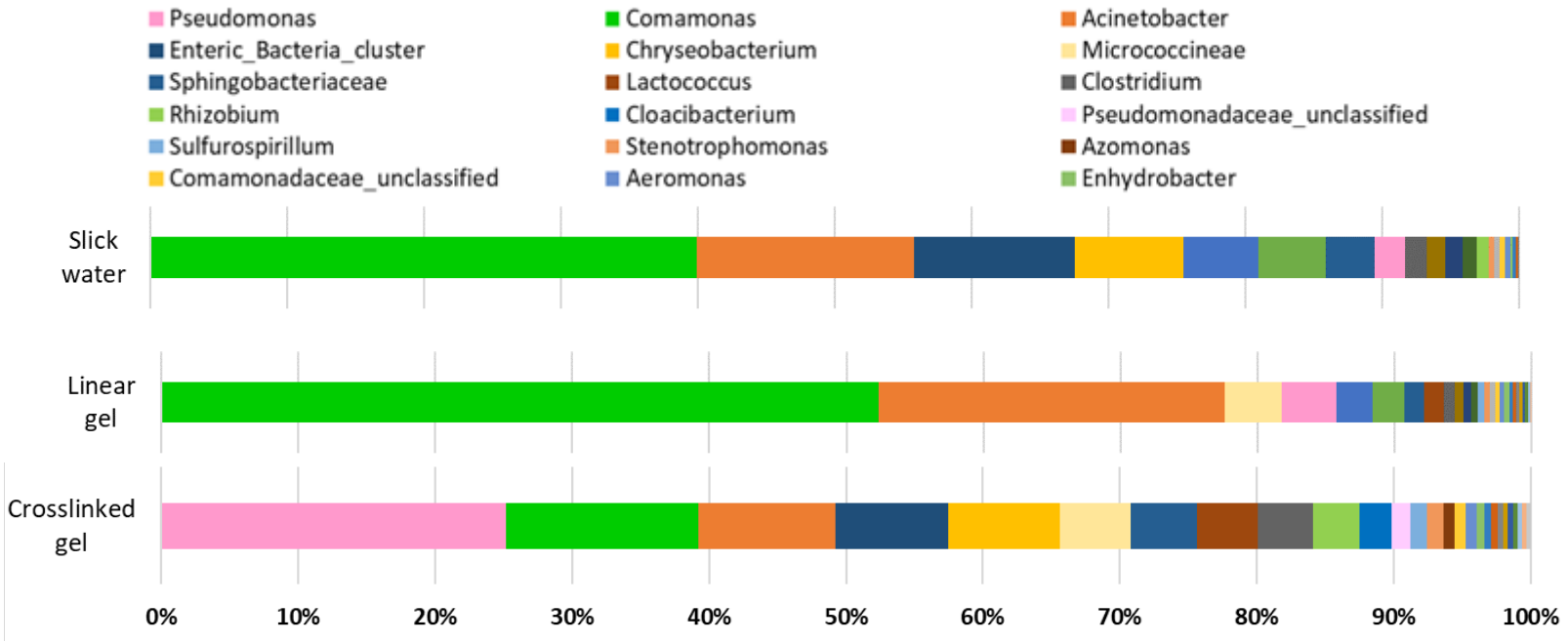


# Bacteria DNA Sequencing Results | Fracture & Production Samples

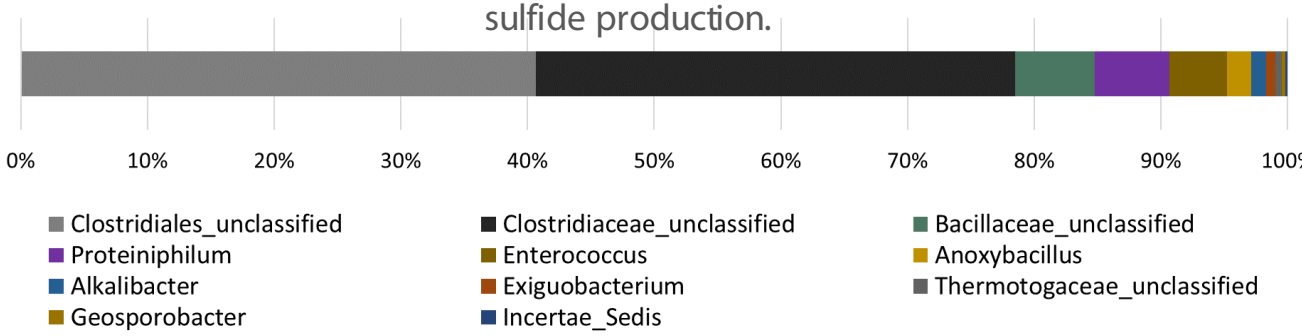
## Fracking Fluids

**$10^6$ - $10^7$ cell/ml.** Mostly aerobic genera, almost 10-27% Acinetobacter (APB), 8% BSR.



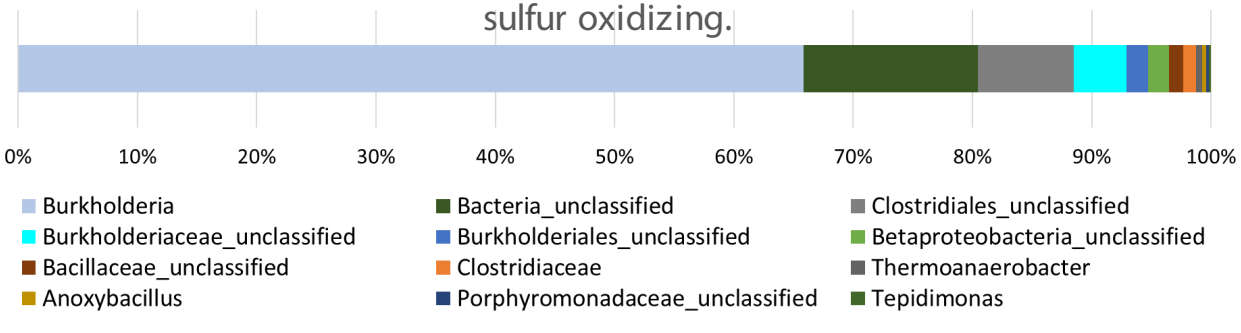

## CdL Well #06 Production

**$2x10^5$ cell/ml.** Almost 80% Clostridia. Involvement in sulfur cycling and sulfide production.



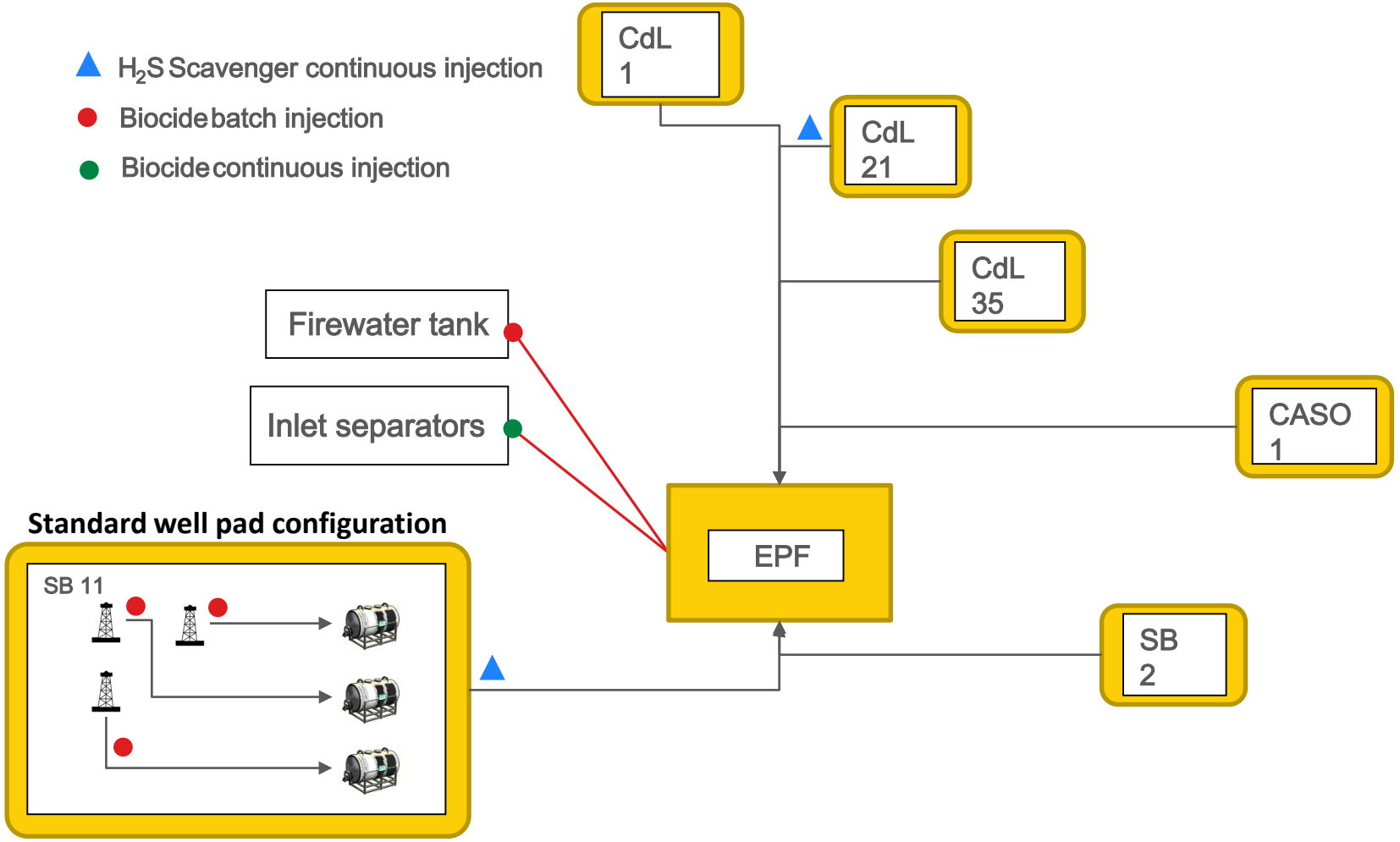

## CdL Well #08 Production

**$5x10^4$ cell/ml.** 80% Burkholderiaceae and some Clostridia. Potential to be sulfur oxidizing.



Management Strategy

# Microbiology Control Strategy – Operations




## Monitoring

- **ISOTRAP** test are done <u>once per well</u>
- **Kill tests** are done <u>once a year</u>
- **Bacteria serial dilution broths** and **$H_2S$** are measured <u>once per quarter</u> on all water storage vessels and tanks
- **ATP** measuring technology is now available at the EPF laboratory

## Control

- **$H_2S$ scavenger** injection point in well pads far apart from EPF
- **Biocide** batch and continuous injection rates are adjusted <u>based on monitoring results</u>

# Conclusions

- Full microbiological inspection, including analyses on fresh water, frack fluid and later flowback and produced water, is highly recommended for fracking sites
- Biocide treatment is recommended to prevent the early appearance of SRB, APB and $H_2S$ in the production system
- Proper surveillance program and microbial control strategy includes
  - Kill test analyses for produced water, well interventions and fracture fluids;
  - Continuous and batch injection of biocide on production operations;
  - Quarterly serial broth/ ATP monitoring
  - Isotopic analysis of $H_2S$ in produced gas
  - DNA sequencing screening
- Glut/ quat biocide treatment strategy was proven effective in controlling microbes throughout the entire process