# Compound challenges in a water injector

## Client: AkerBP

### Well description

Well X is a water injector completed with sliding sleeves across 15 injection zones separated by swellable packers. The well was drilled through formation A into formation B to provide pressure support & improve sweep efficiency in formation B.

### Potential interference

Chemical tracers added to the injection water were detected in a well completed in formation A. This was indicative of crossflow thus implying fluid loss, inefficient pressure support and oil displacement.

### Well integrity

Flow dynamics during injection and distribution between formations A and B, insights on the performance of these sleeves in relation to suspected well integrity anomalies would serve useful in future workovers or remediation. If detected, compromised swellable packers/ sleeves contributing to crossflow would be isolated.

## Surveillance program

Silixa's Retrievable Wireline Deployed Fibre Optic Sensing System, Carina 100xLog was used to provide high-fidelity data, full wellbore coverage while logging and real-time analytics for injection assessment. Given its combinability, the Carina100xLog was seamlessly integrated with existing wireline equipment & workflows allowing for conveyance using the third party's downhole elecro-mechanical tractor and data acquisition on wireline logging tools in a single run-in hole.

A carefully designed logging program was used to guide the sequential acquisition of Distributed Fibre Optic Sensing (DFOS) data, Injection Logging Passes and Noise logging by the third-party Oilfield Service Provider.

Whilst distributed temperature and acoustic data were displayed in real-time to provide a global view of the wellbore during injection, flag anomalies and optimise the program, point sensors were used to home into flagged depths thus providing more granularity.

| Schedule (hrs) | 0 1 2 3 4 5 6 7 | 8 9 10 11 12 | 13 14 | 15 16 17 | 18 19 20 21 22 23 24 25 26 27 28 29 | 30 31 32 33 34 35 36 | 37 38 39 | 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 | 63 64 65 66 67 68 69 70 71 72 73 74 75 |
|---|---|---|---|---|---|---|---|---|---|
| Well status | Shut-in | | Ramp up | Stable injection @Q1 | | Ramp up | Stable injection @Q2 | | Shut-in |
| Activity | RIH & calibration passes | Baseline Measure-ments | Injection Monitoring at TD | | ILT & noise logging | Injection Monitoring at TD | | ILT & noise logging | Warm-back monitoring |
| Data type | Spinner velocity | DFOS | DFOS | | Spinner velocity & noise logs | DFOS | | Spinner velocity & noise logs | DFOS |

**Figure 1**: Well X logging program

# Discussion of results

**Figure 2** is a DFOS composite plot composed of annotations of completion components, DAS frequency spectra during the baseline & the low-rate injection condition, DTS & DAS Slow strain waterfall maps and time averaged DTS profiles before and during injection.

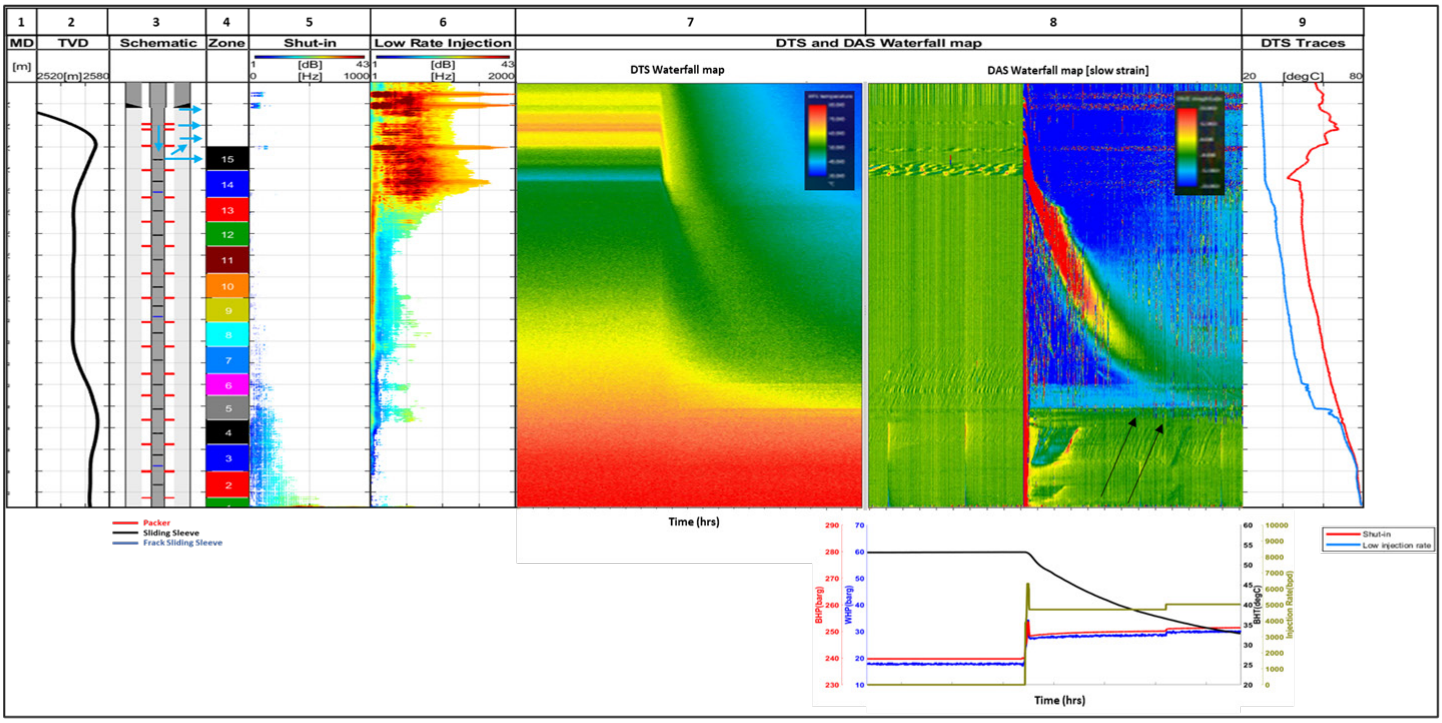



**Figure 2** - Composite plot from report

## The following were inferred from this display:

- Residual acoustics detected adjacent to heel-ward zones during the shut-in period indicative of cross flow in this well. This is visible on the frequency distance plot obtained during the shut-in period (Track 5).
- At the start of injection, warmed-up fluid in the vertical casing is pushed into the reservoir. The thermal and strain effects of this are seen on the DTS and DAS Slow Strain waterfall maps (Track 7 & 8).
- As injection progresses at this rate, upward diagonal patterns originating from depths below zone 1 were also observed. These are annotated by black lines on the slow strain DAS map in Track 8. The Speed of sound analysis, shown in Figure 4 below, identified the cross-slow to be related to inconspicuous oil production from higher pressure zones in the toe section of the well.
- Dominant fluid intake was detected across zones 14-15 with expected water intake in other zones. This conclusion was reached owing to the convergence of both DAS & DTS datasets as low acoustic signals and insignificant thermal variations were observed & the operating injection pressure.
- First indications of Out-of-Zone Injection were detected at this time with consistent acoustic signals and temperature changes observed between zone 15 and the non-perforated section above as seen in Tracks 5,6 and 7. These was further validated by data at later times.

Figure 3 compares frequency spectra from later times with key findings discussed below:

» Higher noise activity as the injection rate is increased. But acoustic signals indicative of water intake across heel-ward stages remain unchanged.

» On the contrary, these less-active zones appear active during the warm-back as seen on the spectral plots, and as informed by diagonal patterns detected on the slow strain map.

» These further confirmed active communication between this well and the zone described in point (3) above.

» The warm back effect is not only observed across the injection interval but above zone 15. These thermal effects and residual acoustic signals confirmed active Out-of-Zone injection in this well.

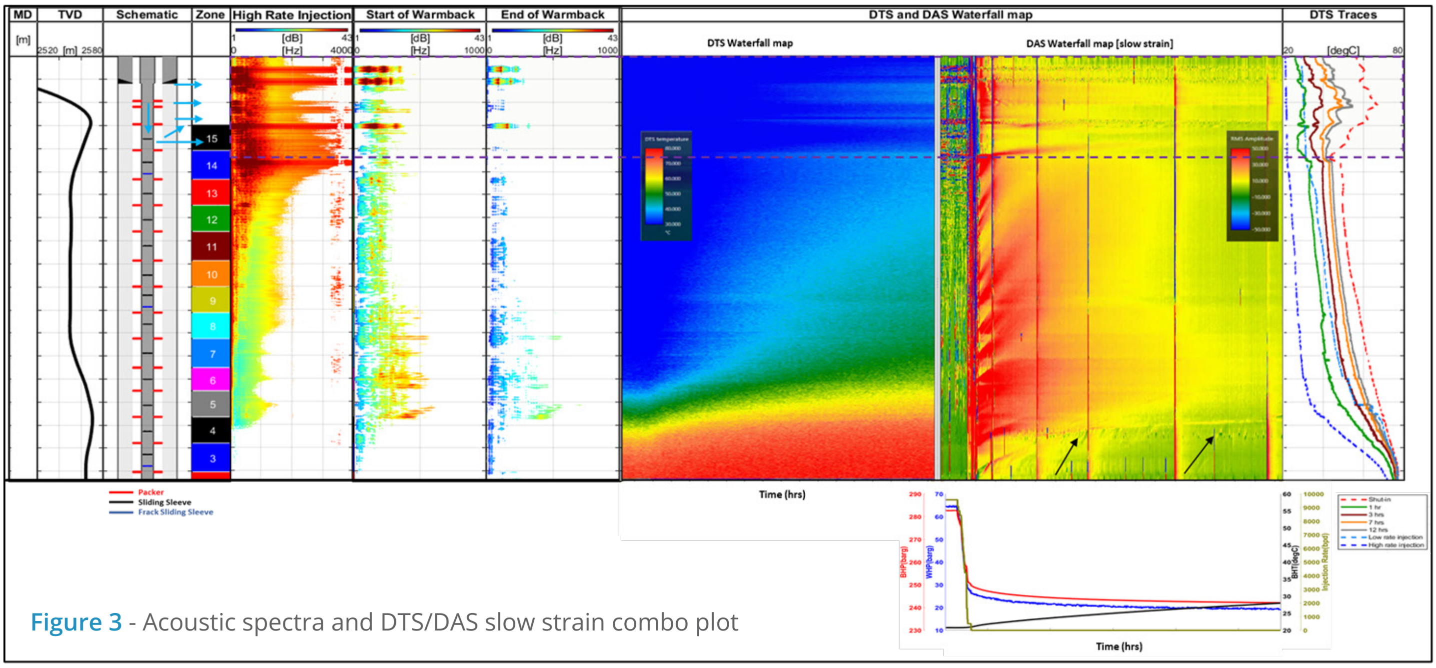
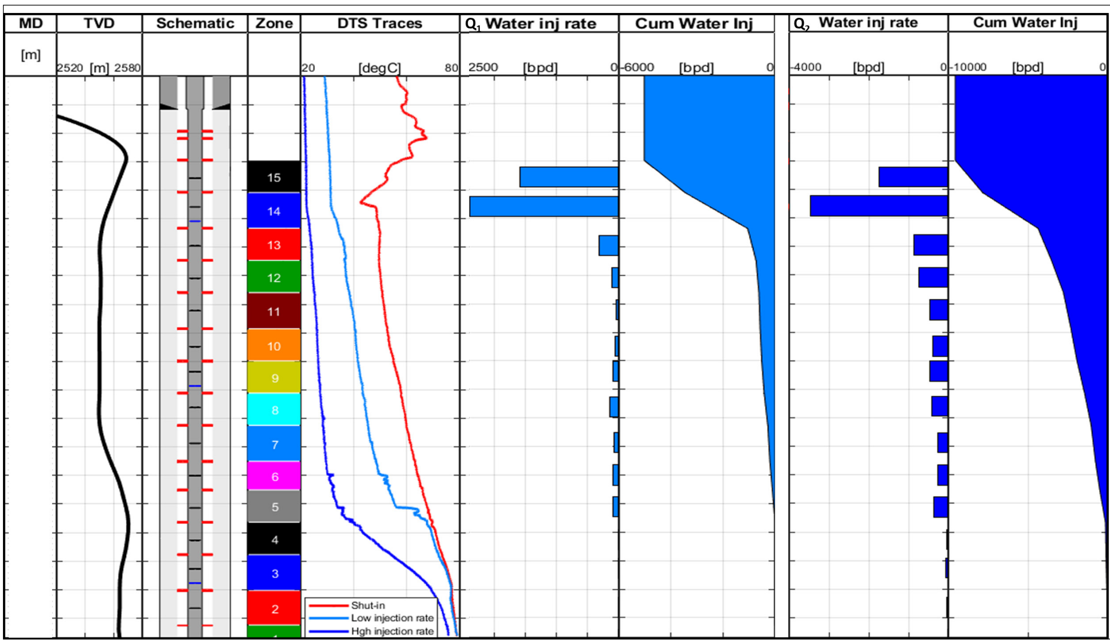



Figure 3 - Acoustic spectra and DTS/DAS slow strain combo plot

At the end of this assessment, it was established that the sliding sleeve door linked to zone 14 was compromised and remediation was to be planned for.

Figure 4 shows the estimated inflow allocation profiles using Silixa's unique DAS & DTS injection Profiling Solution




| Zone | Water Allocation during Q2 injection (%) |
|---|---|
| 15 | 18.1 |
| 14 | 36.3 |
| 13 | 8.9 |
| 12 | 7.8 |
| 11 | 4.9 |
| 10 | 4 |
| 9 | 5 |
| 8 | 4.3 |
| 7 | 2.8 |
| 6 | 2.9 |
| 5 | 3.7 |
| 4 | 0.3 |
| 3 | 0.6 |
| 2 | 0.4 |
| 1 | 0 |

Figure 4 - Inflow allocation

An in-depth cross-flow analysis was performed by computing the speed of sound (SOS) profile, indicative of the fluid composition, over the different well operating conditions, and displaying it alongside the Slow strain DAS thermals plumes, as shown in Figure 5.

During the initial shut-in, the speed of sound profile identifies oil produced from the lower toe zones moving up the well, as also displayed by the DAS slow strain waterfall map.

During the low injection rate, the water/oil interface is displaced towards the lower toe zones, however the oil production is still present, as shown by both the SOS and the Slow strain features. Only once water injection at high rate is reached, the pressure is significant enough to push the oil back into the reservoir, and effective water injection occurs.

The last SOS track in Figure 4 shows no oil detection and the slow strain DAS shows the thermal plume reach the bottom last stage of the horizontal.

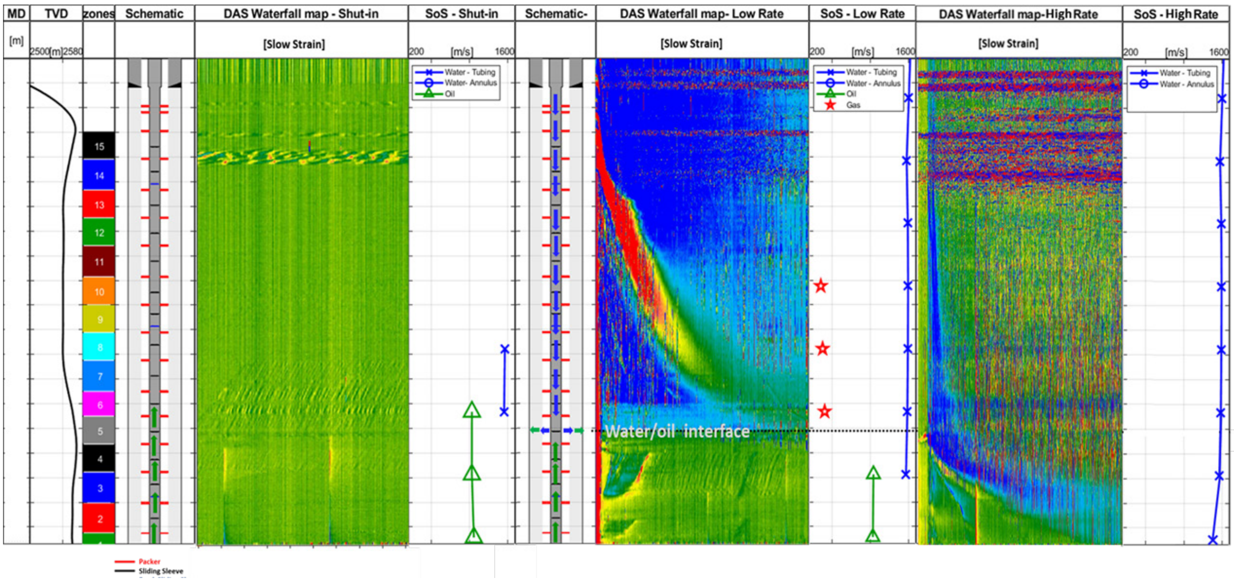



**Figure 5**
Speed of sound and DAS waterfall combo plots

# Actionable insights – efficiently obtained

## Actionable Insights

Carina 100xLog acquires data simultaneously across the entire well allowing for a holistic understanding of well dynamics, interference effects and identification of well integrity flags.

Visualising data in real time allowed a rapid analysis of Injection efficiency, the identification and flagging of zones of interest, and the commencement of advanced data analytics – live while the data was still being acquired.

Continuous engagement, dialogue and information sharing between Silixa & customer Petro-technical experts enabled the rapid progression of the analysis: from data to answers to actionable insights in a matter of days.

## Efficiency & Operational Agility

Carina100xLog integrates with existing wireline equipment & workflows allowing for seamless integration of Silixa's hybrid fibre optic cable and the third party's logging tools.

No additional runs required – all data was acquired in a single descent in combination. Deploying the complementary wireline sensors combined with the DFOS run yielded significant cost and time savings with minimal risk and exposure.

## Data Consolidation

The collation of well data of different sources i.e., DFOS and point sensors and the convergence of results broaden the client's knowledge of this well. Data files submitted in the client's preferred formats would allow for future integrated displays with other petrophysical data types.

## Predictability

Well X was successfully logged without any Lost Time Injury (LTI) or Non-Productive Time (NPT).

Risk assessments, hazard mitigation plans, and KPI-driven processes were employed to ensure zero minimal risk.

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