MTI-004

Waterflood Surveillance: From Injection Volume to Sweep Efficiency

A practical framework for VRR, pattern response, injection profiling and reservoir decision-making

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DATA NOTE: Oman operating examples use anonymized, rounded data derived from confidential materials supplied by the client. Field, well and operator identifiers are intentionally omitted. External publication should be subject to rights-holder/confidentiality review.

Executive Summary

Waterflood performance cannot be judged by injection volume alone. A field can achieve its injection target and still deliver poor sweep if water is entering the wrong layer, cycling through high-permeability pathways, or arriving too early at producers.

The most useful surveillance hierarchy moves from field-level voidage and pressure support to pattern-level response, then to well-level injectivity and zonal intake. The objective is to determine whether injected water is creating pressure support, contacting unswept oil and generating incremental oil.

Observe	Diagnose	Act
Track VRR, pressure, water cut, GOR and PVI	Resolve pattern connectivity and zonal intake	Reallocate injection, improve conformance, then verify response

1. Why VRR Is Necessary - But Not Sufficient

Instantaneous and cumulative voidage replacement ratio (VRR) are fundamental waterflood health indicators. A value close to unity may indicate appropriate replacement of produced reservoir volume, but it says nothing about where the injected water is going. Conversely, a cumulative VRR below unity can coexist with acceptable short-term pressure support where aquifer influx, compressibility or recent injection changes contribute.

Indicator	What it tells you	What it does not tell you
Instantaneous VRR	Current replacement of produced reservoir volume	Areal/vertical sweep efficiency
Cumulative VRR	Long-term balance of injection and withdrawal	Whether water is cycling through thief zones
Reservoir pressure	Adequacy and distribution of pressure support	Exact injector-producer connectivity
Water cut / WOR	Flood maturity and breakthrough behavior	Whether water source is matrix, fracture or completion
Injection profile	Where water enters the reservoir	Whether injected water contacts movable oil

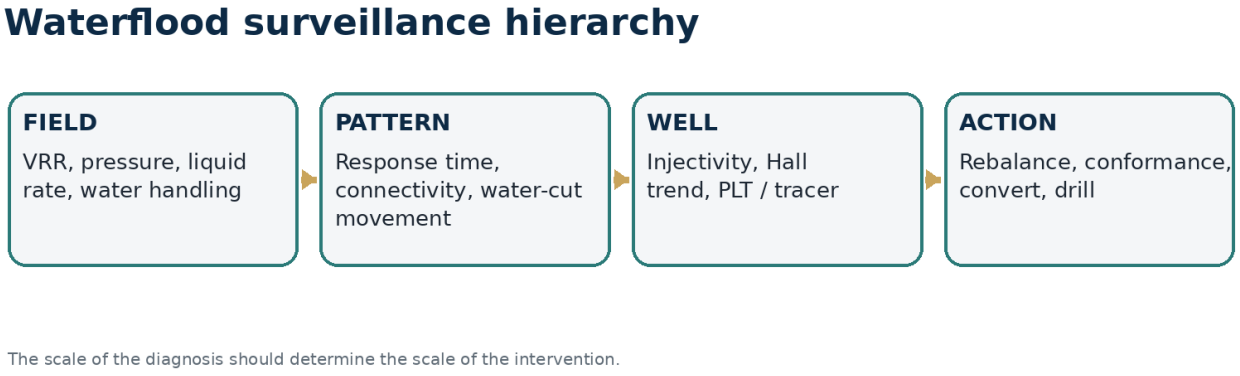


Figure 1. A surveillance workflow that moves from field balance to pattern and well diagnostics.

2. Anonymized Oman Operating Examples

Oman Field A - large mature waterflood

A large mature Oman asset was operating at roughly 570 thousand barrels of water injected per day against a plan near 600 thousand, with 18 active injectors versus 20 planned. At field scale this looked close to target. Pattern-level review, however, showed important differences: one pattern carried an instantaneous VRR around 1.2 with cumulative VRR near 1.0, while another also had instantaneous VRR around 1.2 but cumulative VRR only around 0.6. The same current injection intensity therefore represented very different flood histories.

The implication is practical: identical present-day VRR values should not lead automatically to identical actions. A mature pattern with cumulative replacement close to unity may need sweep/conformance optimization, whereas a historically under-injected pattern may still require sustained pressure restoration and careful monitoring of delayed response.

Oman Field C - pattern response and injection profiling

In another Oman pattern, instantaneous VRR was approximately 1.0 while cumulative VRR was only about 0.25 and water cut was about 84%. A new injector began supporting the pattern and a production response was observed after roughly three months. A production/injection logging survey subsequently indicated that more than half of injected water was entering through the toe section. A conformance intervention was applied to the injector, followed by producer lift remediation; the producer subsequently returned at approximately 170 BOPD.

Why this matters

The response demonstrated that “injection is working” and “injection is distributed efficiently” are different questions. Response time established connectivity; the profile log identified uneven zonal intake; the conformance action targeted the distribution problem.

3. Global Analogs

Analog	Published observation	Transferable lesson
El Trapial, Argentina	Oil rate tracked VRR closely in a field without strong aquifer support.	Pressure/voidage balance can directly control oil response.
Bangko, Indonesia	Aquifer support weakened the simple oil-rate/VRR relationship; total liquid later reached ~550,000 B/D facility capacity.	Interpret VRR in drive-mechanism context and include facilities.
Meren, Nigeria	Long-term VRR above 1 with rising liquids helped sustain oil rate in a mature offshore flood.	High injection can be effective when capacity and sweep remain aligned.
Multifield surveillance pilot	Methodical waterflood management reduced nominal decline from ~33% to ~18%/yr without infill drilling.	Surveillance itself can create material value before capital projects.

4. Diagnostic Questions Before Changing Injection

• Is reservoir pressure responding where injection is being increased?

• Does producer response timing support the assumed connectivity?

• Is water cut rising proportionally to liquid response, or disproportionately?

• Do PLT/tracer data show concentrated intake into one layer or end of a horizontal injector?

• Is the pattern limited by injection capacity, producer lift capacity, or surface water handling?

• Is the observed response consistent with the dynamic model?

5. Application to Oman

For mature Oman waterfloods, a practical surveillance dashboard should combine instantaneous and cumulative VRR, pressure support, PVI, injector uptime, injectivity, producer liquid/oil response, water-cut acceleration, GOR and zonal intake. The key is to rank patterns by value opportunity rather than by injection shortfall alone.

Madar technical principle

Do not ask only “Are we injecting enough water?” Ask “Where is the water going, what oil is it contacting, how quickly does the reservoir respond, and what is the incremental oil per barrel injected?”

References

1. Terrado, M., Yudono, S. & Thakur, G. (2007). Waterflooding Surveillance and Monitoring: Putting Principles Into Practice. SPE 102200, SPE Reservoir Evaluation & Engineering.

2. Anonymized Oman operating records supplied by the client, 2025-2026. Values rounded and identifiers removed.

3. Yibal V2V Team (2002). Maximizing Yibal's Remaining Value. SPE 77641.