PRODUCED WATER
MIDDLE EAST

أدنوك
ADNOC

WATER FLOOD EXCELLENCE

Make Every Drop Of Water Count!

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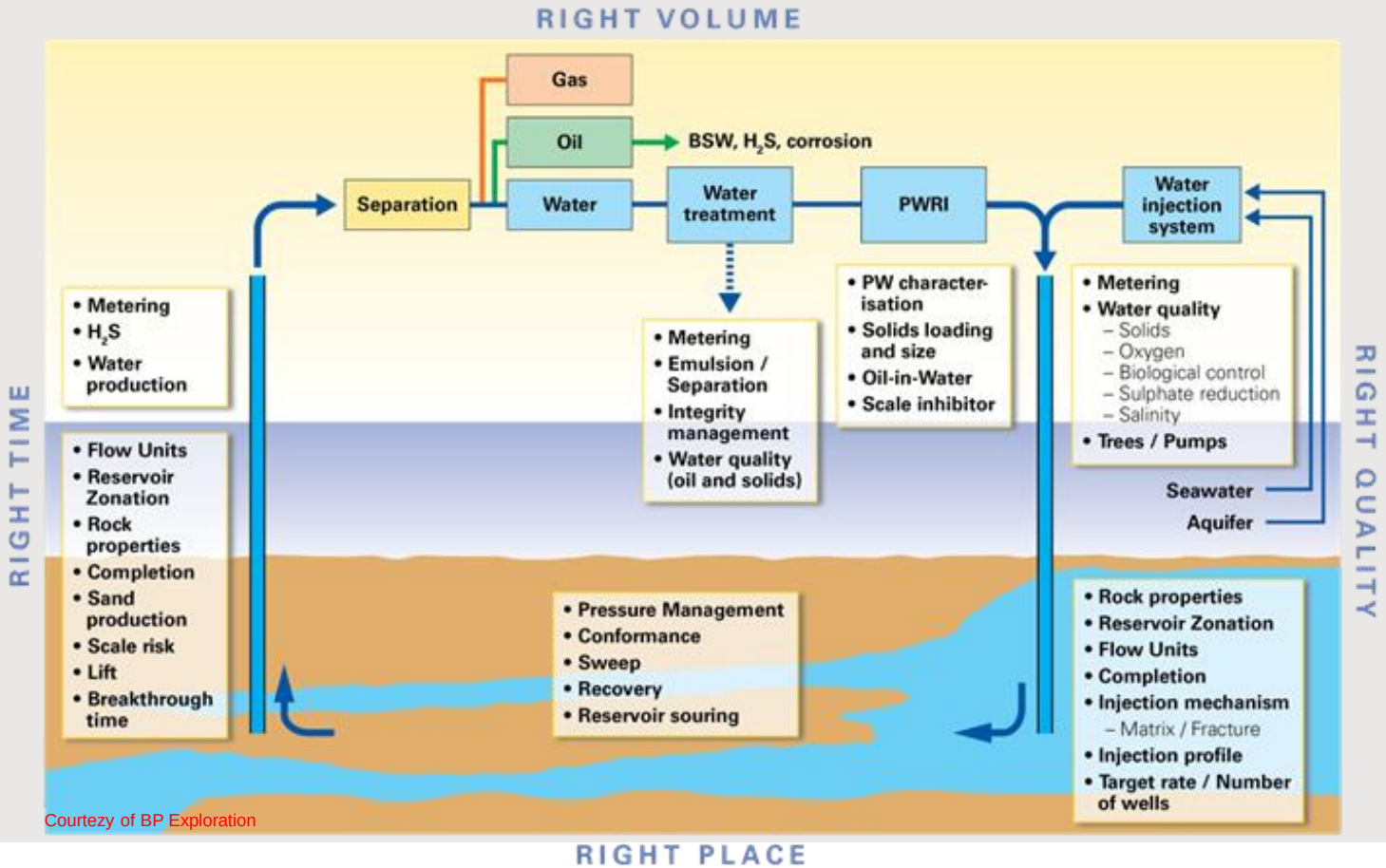
ABU DHABI NATIONAL OIL COMPANY

INTRODUCTION

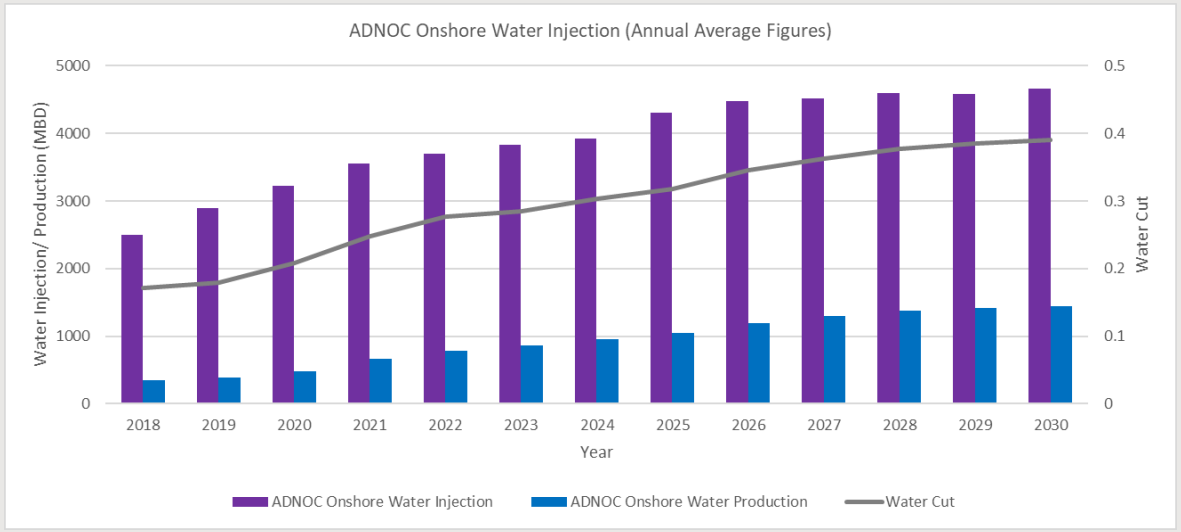
- Majority of current oil production is supported by waterflood. Waterflood management is critical to future oil production & ultimate recovery.
- Current water injection is 4300 MBWPD & water production is 600 MBWPD. Produced water is expected to increase at the rate of 50-100 MBWPD per year.
- As illustrated below, water flooding requires a multi-disciplinary team effort to get it right.

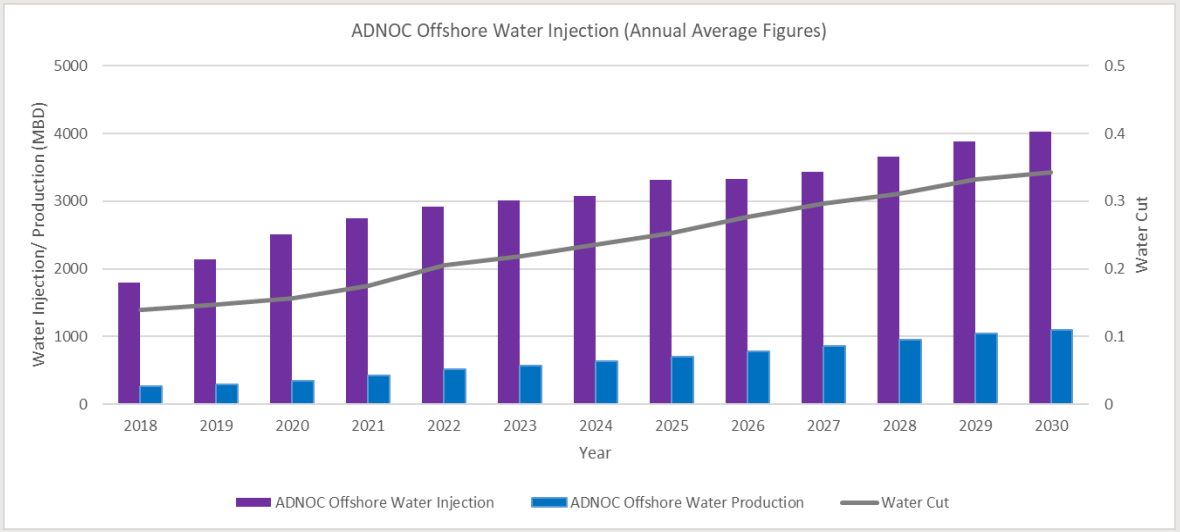


Courtezy of BP Exploration

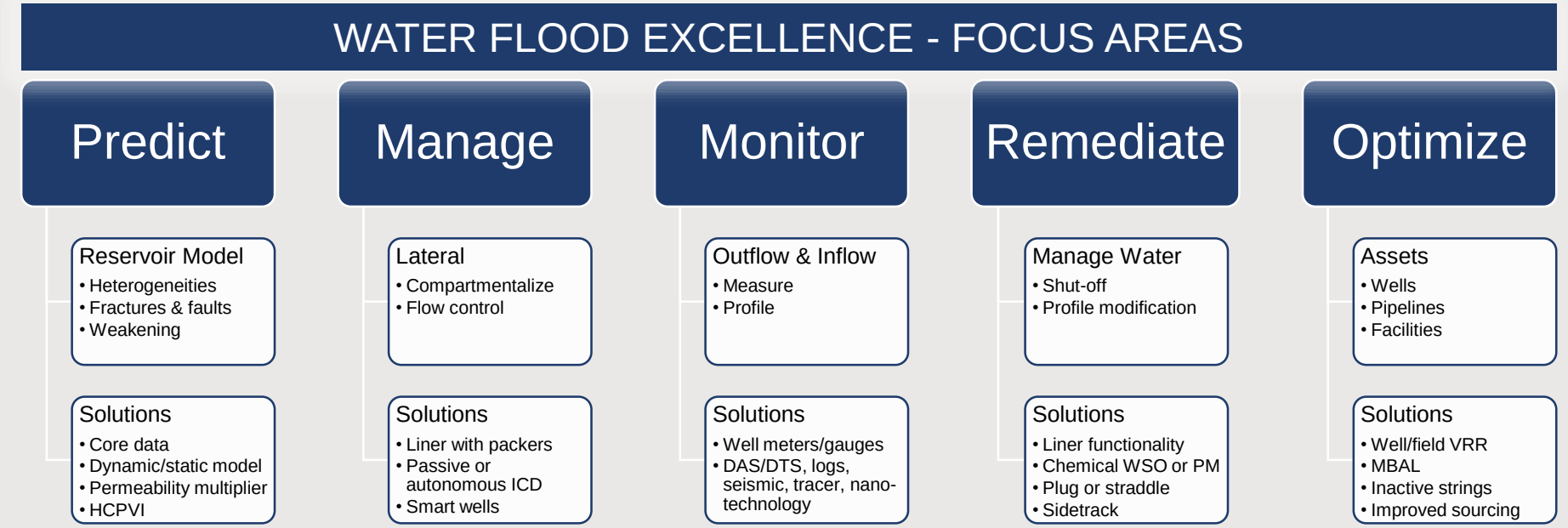
WATER INJECTION & PRODUCTION FORECAST

	TODAY (MBWPD)	2030 (MBWPD)	Fold Increase
ADNOC ONSHORE INJECTION	2500	4700	X 2
ADNOC ONSHORE PRODUCTION	350	1450	X 4
ADNOC OFFSHORE INJECTION	1800	4000	X 2
ADNOC OFFSHORE PRODUCTION	260	1100	X 4





WATER FLOOD MANAGEMENT FOCUS AREAS



The focus areas demonstrate the activities for water flood excellence, including effective water management & handling throughout the cycle, i.e.

- Maintain reservoir model prediction to account for errors or changes & perhaps modify flooding
- Manage placement of water downhole to maximize efficiency of flood
- Monitor flooding to validate outflow & model, to then make possible changes
- Alter outflow of injector or water cut in producer by remediation
- Improve asset utilization & measurement of water flooding effectiveness

Water Flood Excellence – Multi-Disciplinary Project

Context:

- Vast majority of current production is supported by water flooding. Management of water both in the reservoir & on the surface is critical to future oil production & ultimate recovery.

Strategy:

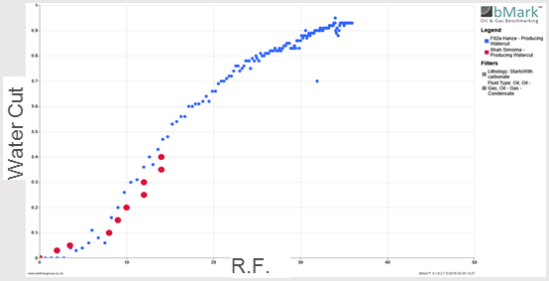
- "Make every drop of water count", by implementing effective water flooding versus just injection to improve reservoir sweep, production, recovery & water management.

Focus Areas:

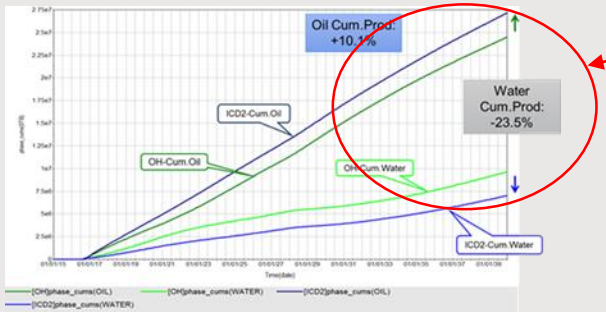
1. Predict - review accuracy of reservoir models & benchmark recovery factor performance
2. Manage - implement ERD & MRC well technology to improve production, reservoir recovery & value.
3. Monitor – implement & develop downhole & surface measuring tools.
4. Remediate – create toolbox of technologies for diagnostics & profile modification or shut-off solutions to address anomalies.
5. Optimize – review surface & sub-surface performance to improve system capability.

Value:

- Improved unit development cost
- Improved well productivity & injectivity
- Improved sweep efficiency
- Improved well management



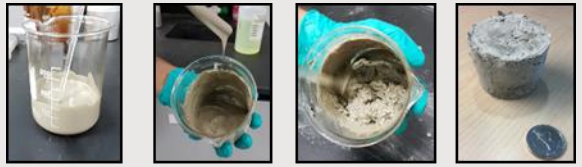
1. Benchmarking our reservoirs against world's best in class analogues to assess performance of reservoirs



2. Well optimized design with ICD liner giving >10% cumulative oil & 24% less water versus open hole

Intervention Method	15,000'	20,000'	25,000'	30,000'	35,000'	40,000'
High Strength Wireline w/ tractors						
Coiled Tubing (2-3/8") w/ CT tractors						
Coiled Tubing (2") w/ CT tractors						
Coiled Tubing (2-3/8") w/ CT tractors & splice						
Composite Carbon E-Line w/ tractor						

3. Developing World Class intervention capability to match ERD / MRC to monitor & treat wells



Without water | *Water added* | *16 mins, gelled* | *Days, hard*

4. Long horizontal wells more challenging to remediate, requiring specialist treatments to prevent slumping & ensure isolation

5. Offshore platform with multi-phase pump to address high sea-line pressure

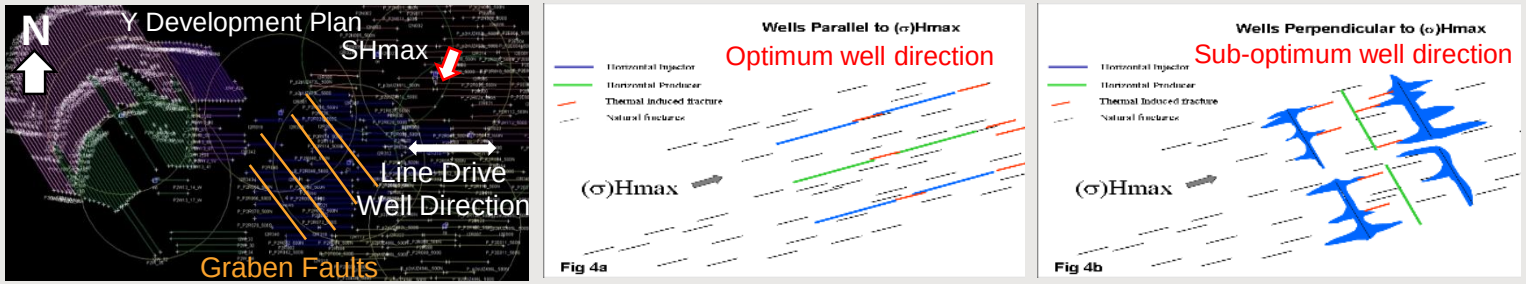
Water Flood Excellence – Multi-Disciplinary Project

Additional Focus Areas Undertakings:

A. Optimize quantity of injection wells with MLTBS technology to reduce cost & drilling complexity

Studied for synergy of reservoirs, potential cost saving of at least $10MM, reduction in slots plus avoiding potential collision issue & complexity of drilled wells

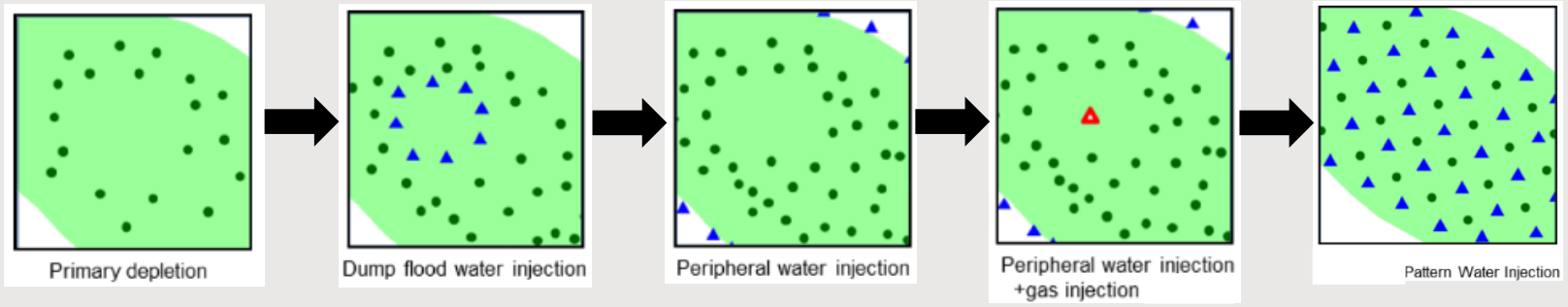
B. Optimize well direction with respect to SHmax to reduce risk of early water break-through



Water moves preferentially along fractures in direction of SHmax

(Ref.: SPE 101425, ADCO, 2006)

C. Optimize flood pattern from early field development to future field development to maximize field recovery



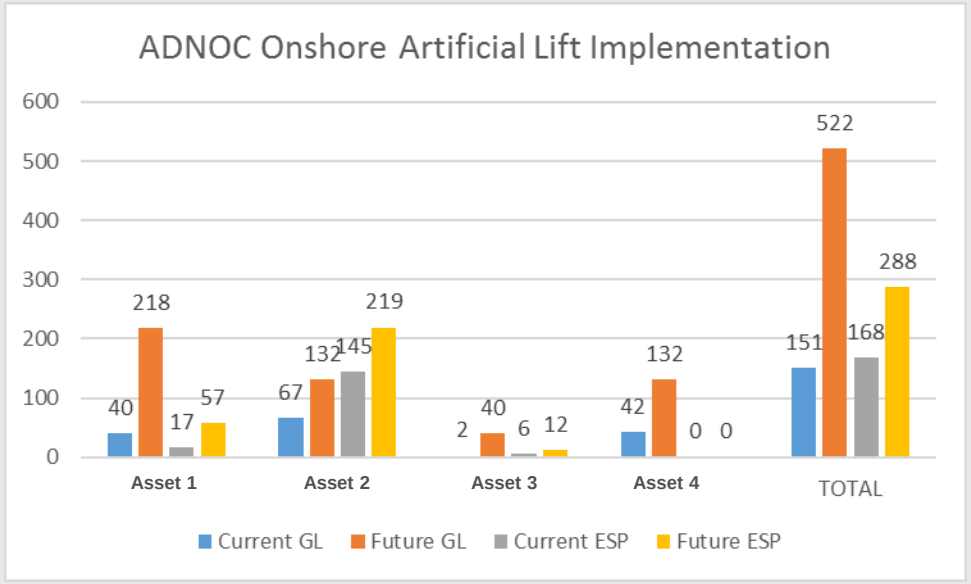
Pattern change over time in brownfield development to optimal line drive

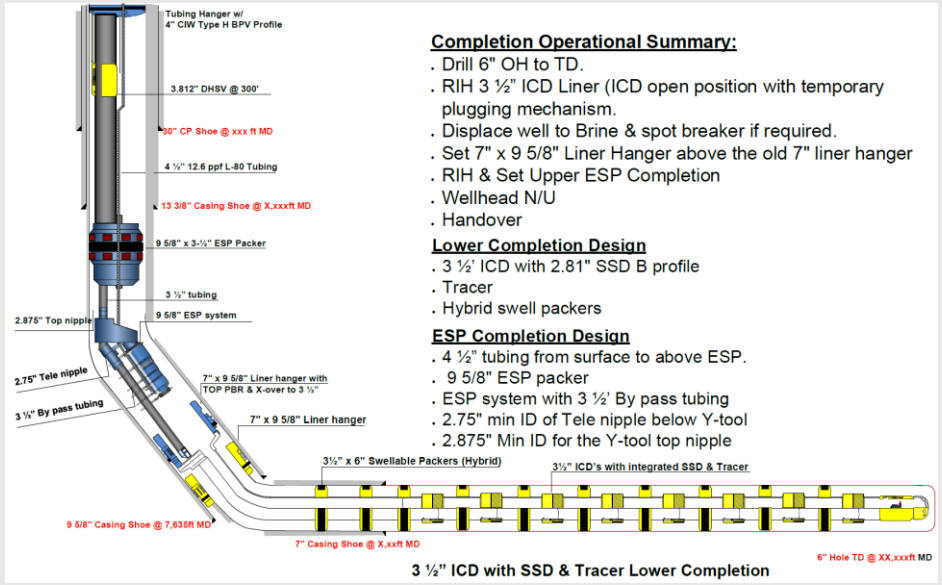
(Ref.: SPE 181598, ADMA, 2016)

Water Flood Excellence – Multi-Disciplinary Project

Additional Focus Areas Undertakings:

D. Optimize liquid production with onset of increasing water cut by implementation of artificial lift plus segmenting wells to manage reservoir section





Completion Operational Summary:

. Drill 6" OH to TD.
. RIH 3 ½" ICD Liner (ICD open position with temporary plugging mechanism.
. Displace well to Brine & spot breaker if required.
. Set 7" x 9 5/8" Liner Hanger above the old 7" liner hanger
. RIH & Set Upper ESP Completion
. Wellhead N/U
. Handover

Lower Completion Design

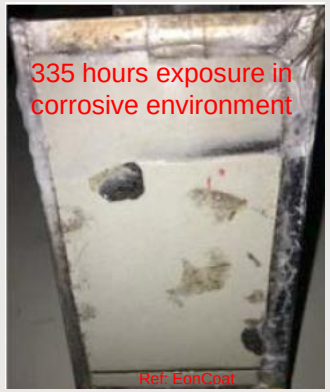
. 3 ½' ICD with 2.81" SSD B profile
. Tracer
. Hybrid swell packers

ESP Completion Design

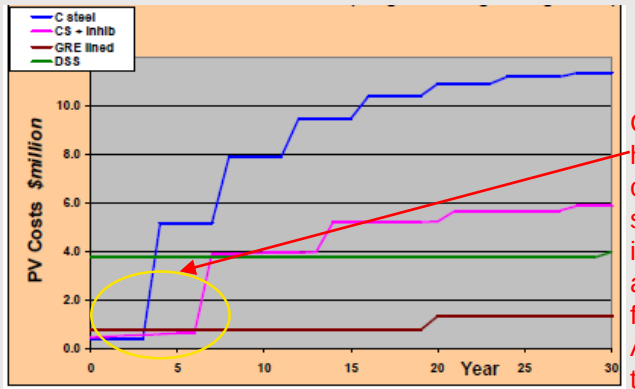
. 4 ½" tubing from surface to above ESP.
. 9 5/8" ESP packer
. ESP system with 3 ½' By pass tubing
. 2.75" min ID of Tele nipple below Y-tool
. 2.875" Min ID for the Y-tool top nipple

Maturing assets with increasing %WC require utilisation of ESP or gas lift to maintain production, dependent upon fluid properties & electric/gas source proximity. Segmenting also allows managing of heterogeneous reservoir by restricting or halting inflow

E. Optimize material selection & use for changing conditions away from dry oil & increasing water cut



Inorganic Chemically Bonded Phosphate Ceramic (CBPC) coating for application to surface & downhole equipment – product test being pursued



GRE lined tubing higher initial CAPEX vs carbon steel or carbon steel + corrosion inhibitor, but surpassed after year 3-6 plus fewer workovers – ADNOC Onshore tested in disposal well

ESP WELL PERFORMANCE MONITORING & OPTIMIZATION

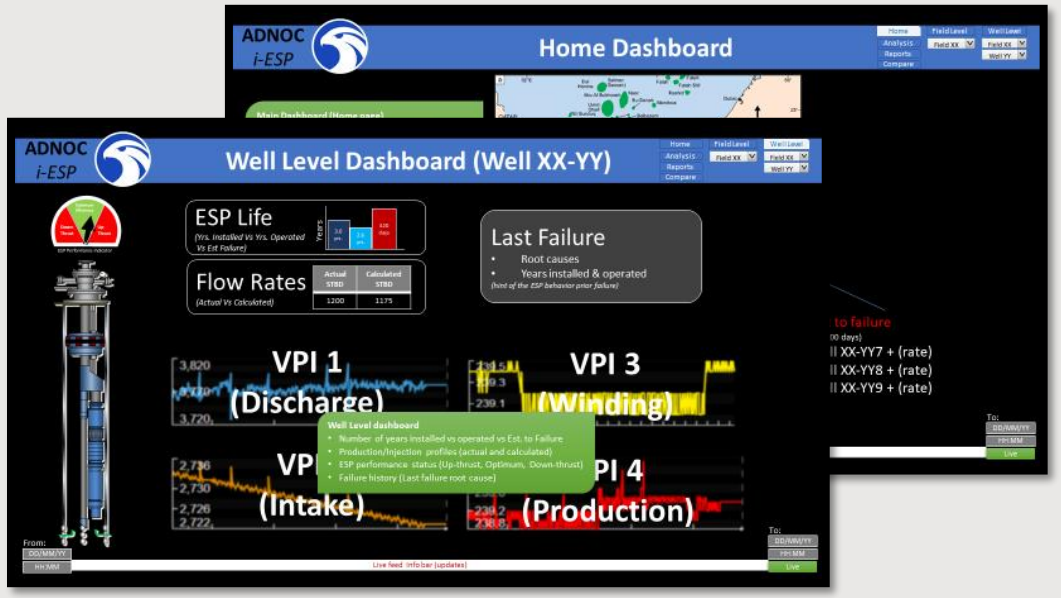
A SOLUTION TO EMPOWER OPERATORS IN MAXIMIZING VALUE FROM DATA

Project Vision

Application of data analytics and machine learning to predict ESP failure and suggest corrective actions to **prolong ESP run life** and **optimize overall well performance**.

Expected Benefits

1. Early ESP failure prediction.
2. Reducing production loss by **~30%.**
3. Extending Mean Time to Failure by **~40%.**
4. Increase people's productivity and performance by **~50%.**



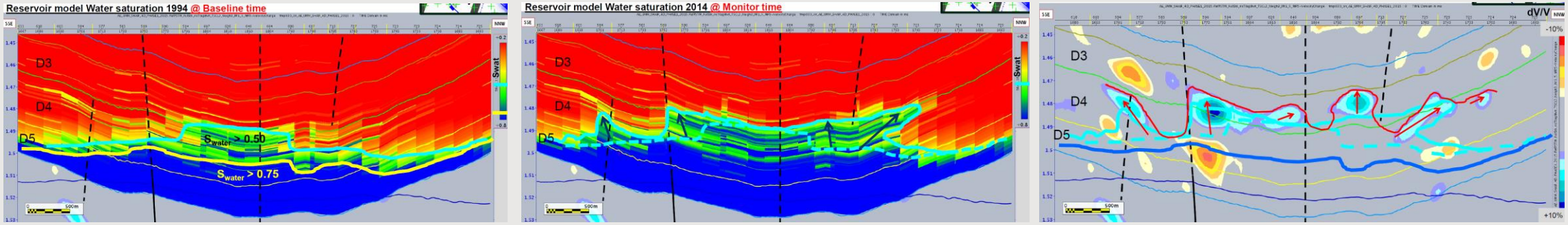
- SHs & Vendor Guidelines
- Downhole, Surface & Test Data
- Well Configuration

- Optimize Well Performance
- Predict Failures
- Diagnose Conditions
- Pump Sizing

Water Flood Excellence – Multi-Disciplinary Project

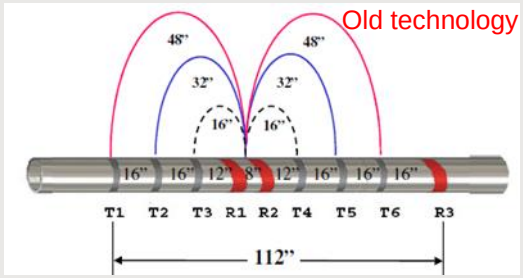
Additional Focus Areas Undertakings:

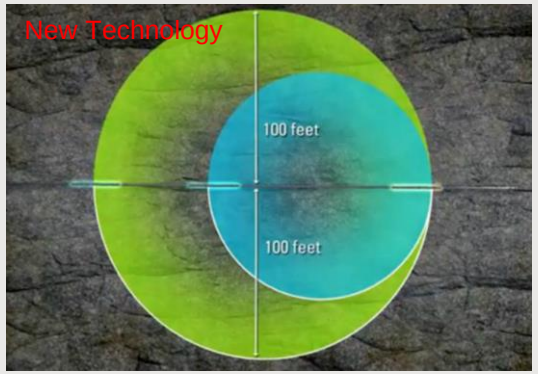
F. Monitor flood front over time with 4D seismic



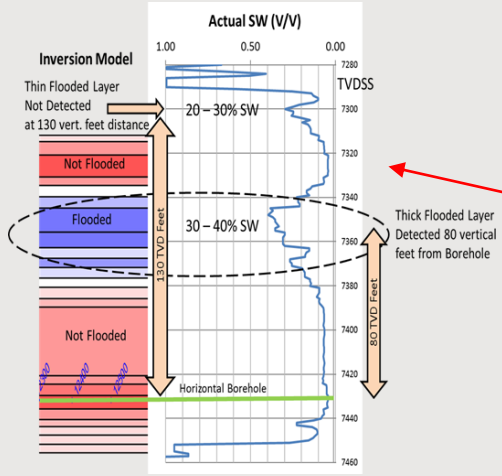
Water saturation over time monitored by 4D seismic to compare against reservoir – ADNOC Offshore example of comparison of reservoir model to seismic

G. Optimise well placement by identifying flooded or non-flooded layers during well construction to then avoid or target layer then install suitable completion





Deep directional resistivity (DDR) drilling tool to give far reaching awareness of water location by 100'-200' vs 6'



DDR drilling tool identify flooded & non-flooded layers - being reviewed by ADNOC On & Offshore

IMPLEMENTATION OF SEA WATER INJECTION FOR ONSHORE FIELDS

Motivation

- Represents a sustainable source for meeting future water injection demand
- It will help mitigate pressure decline observed in some of the regional aquifers
- It would minimize the flow to clean to desert (HSE) and significantly reduce the stimulation of the injectors damaged by the suspended solids in the aquifer water
- It would have a positive impact on future CAPEX & OPEX by reducing the number of water injection clusters, ESP's, pulling hoist, manpower, power consumption, etc.
- It would make the co-development of gas cap and oil rim more economically attractive
- Centralization of water treatment facilities and chemicals will improve operational efficiency, system reliability and unit operating cost.
- Seawater injection would be particularly attractive as most of ADNOC Onshore assets are moving towards pad based drilling.
- Seawater, due to its lower salinity than aquifer water, is better suited for IOR/EOR projects. Moreover, it can be modified to low salinity water if required.

Water Flood Excellence – Strategy & Future Work Plans

"MAKE EVERY DROP OF WATER COUNT" -

Effectively manage water as a necessary resource vs a commodity by implementing effective water flooding vs injection to improve reservoir sweep, production, recovery & water management that will deliver greatest value & performance excellence.

Focus on injecting water for both pressure support & sweep

- Review LTDPs to assess the timing & the pace of water flood expansion from peripheral to pattern floods
- Continue OPCO reviews to **optimize well direction in relation to SHmax** to reduce the risk of water short circuiting to production wells

Focus on lower completion to manage water outflow & inflow & not solely upper completion

- Progress strategy to run **segmented liner** as opposed to open hole to effectively manage & reduce water volumes to **delay the artificial lift requirements**.
- Progress strategy to justify downhole completion based on value as opposed to cost

Improve efficiency & production related to water production management

- Collaborate with OPCOs to **create an ADNOC Group MSA** for water flood **remediation solutions**
- Identify gaps in **new technologies** to be pursued under ADNOC Group R&D framework

Achieve top quartile performance in water flooding

- Develop & implement **diagnostic plots** for measuring water flood performance **through ARPR & SPR**
- Set KPI's for water injection & water flood management through IRM
- Conduct **baseline assessment** for 82 reservoirs under water flood to identify & address gaps
- Initiate an **AI project** to demonstrate the value of data driven reservoir modeling for production/injection optimization

THANK YOU

Make Every Drop Of Water Count!