PRODUCED WATER IN A WATER SCARCE WORLD

Emerging Models for Recycle and Reuse of Produced Water

Devesh Sharma

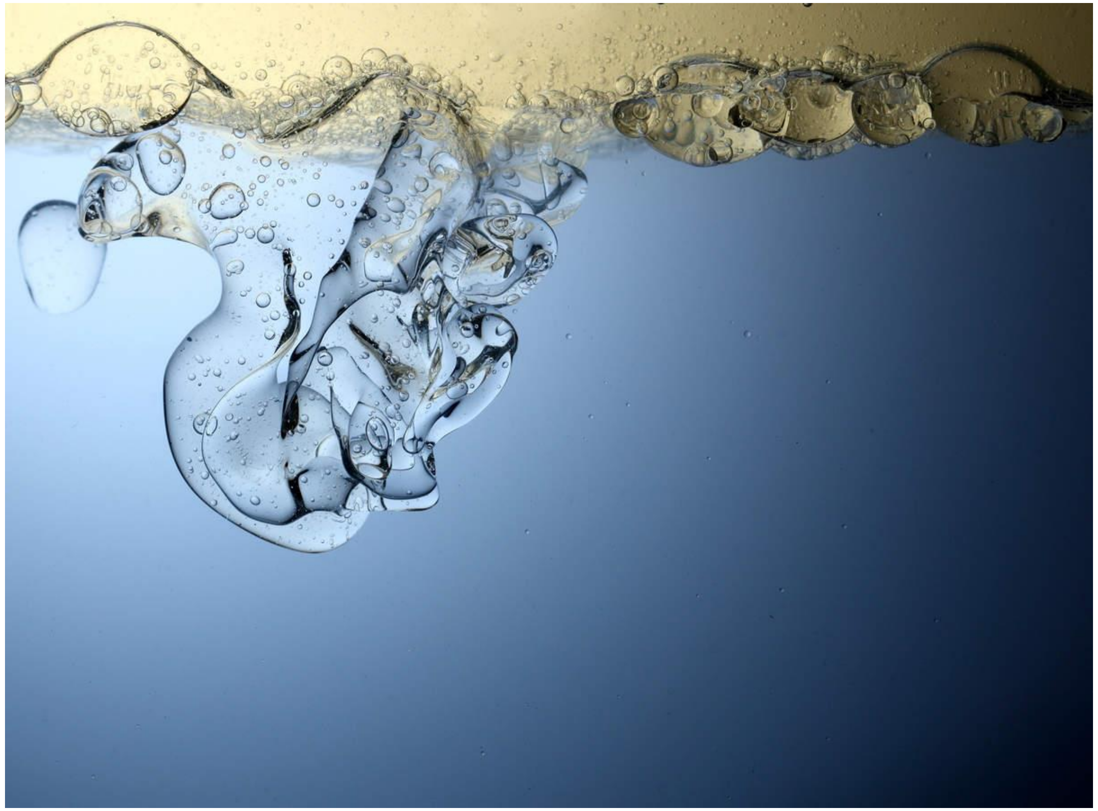
Managing Director – Aquatech International

PRODUCED WATER MANAGEMENT IN A WATER SCARCE WORLD

Water Scarcity is an increasing trend

There is an increasing "thirst" for water in oil and gas exploration

Emerging Sustainability Needs



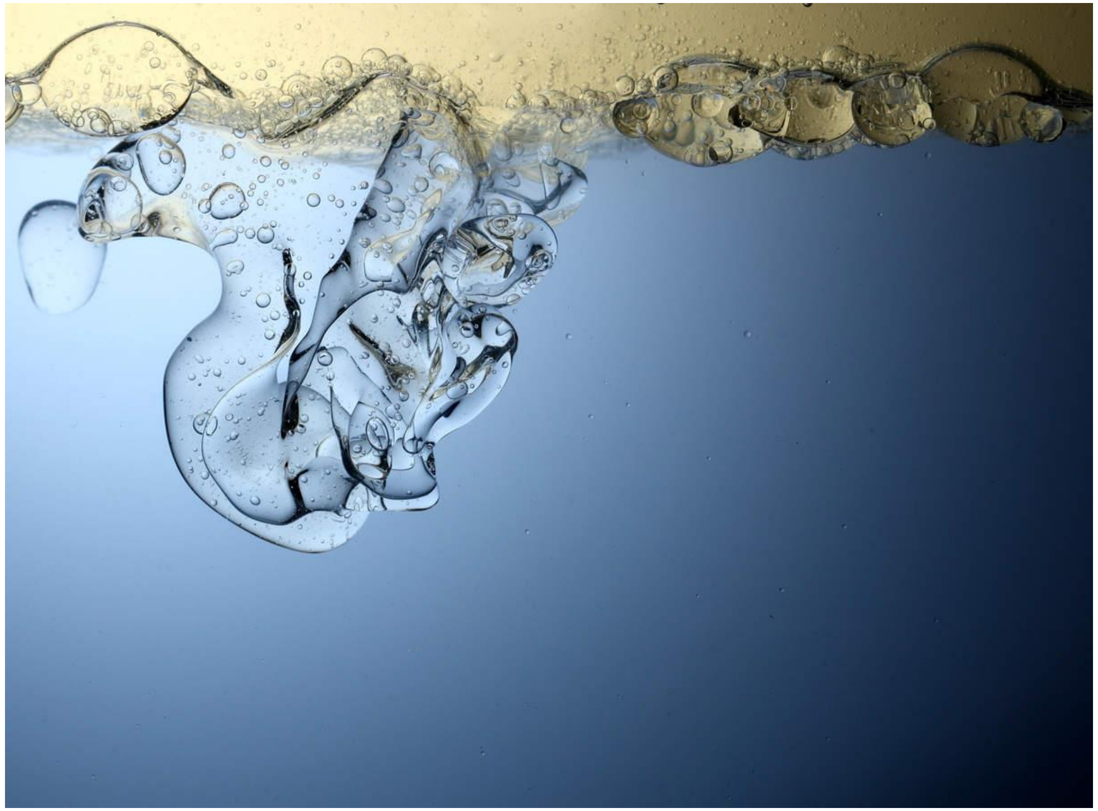
PRODUCED WATER MANAGEMENT IN A WATER SCARCE WORLD

THIRST

Pure Water / Steam EOR

"Smart Water"

Hydraulic Fracturing



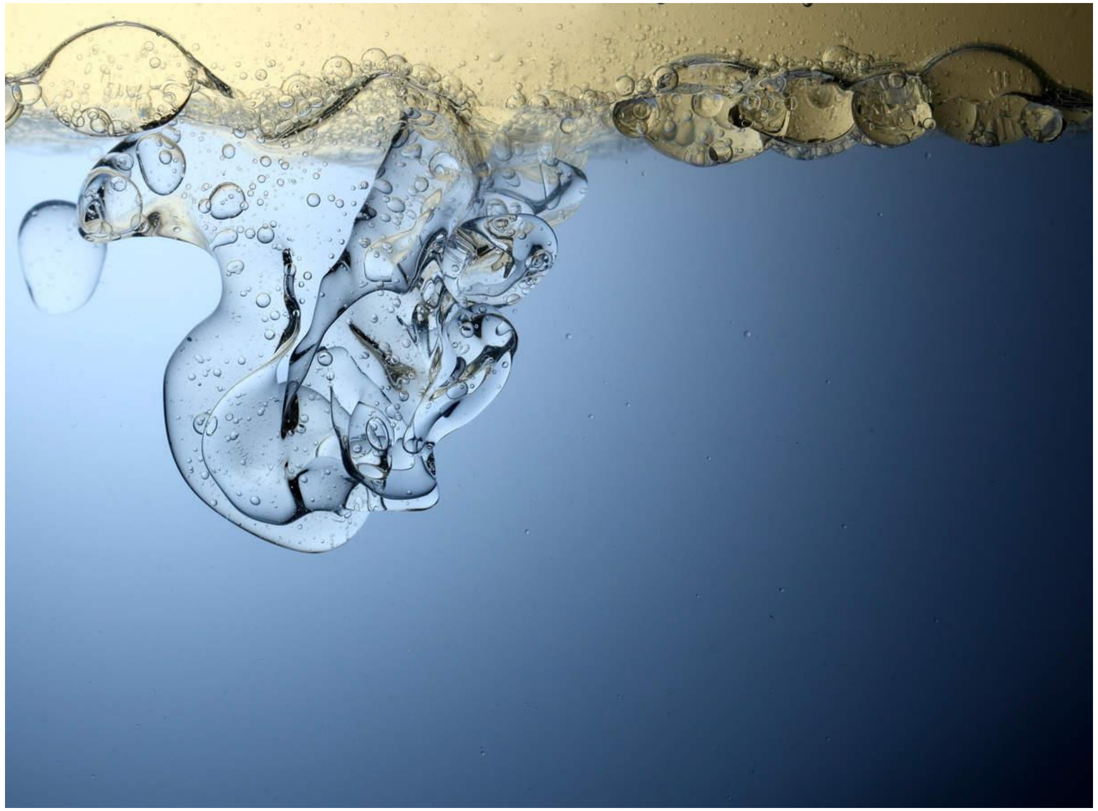
Aquatech

PRODUCED WATER MANAGEMENT IN A WATER SCARCE WORLD

SUSTAINABILITY

Increasing Generation of Produced Water

Limited Disposal Options

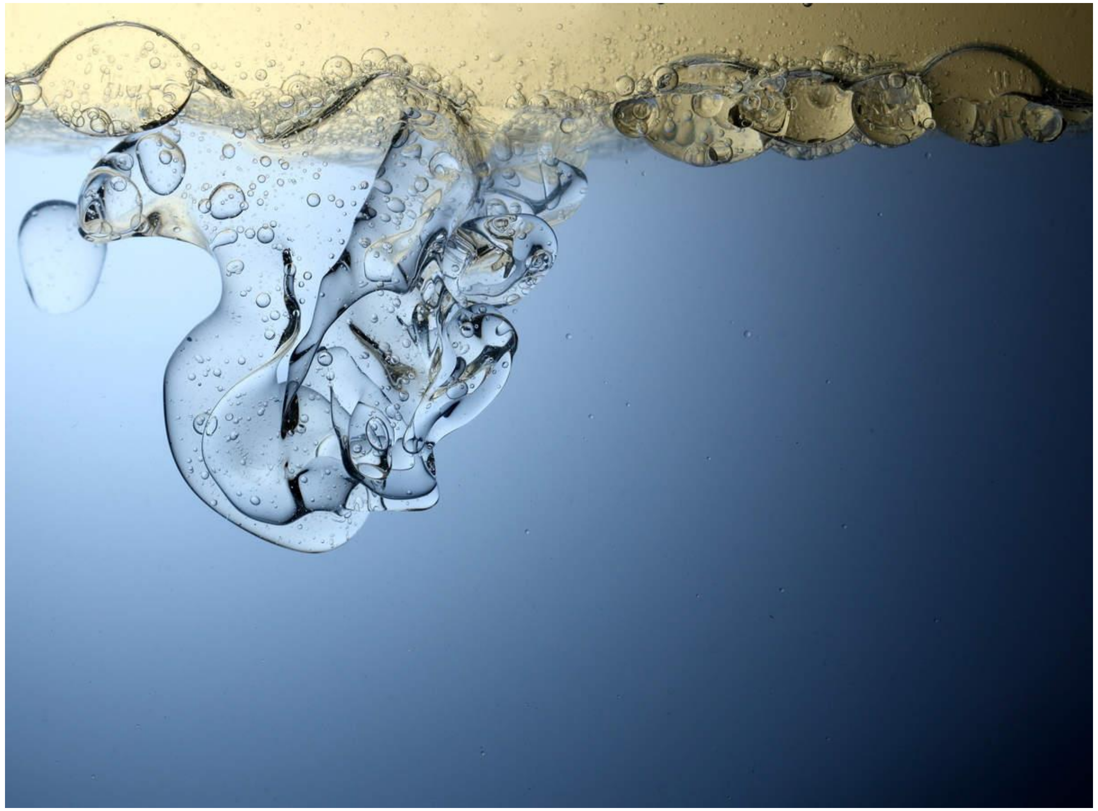


Aquatech

PRODUCED WATER MANAGEMENT IN A WATER SCARCE WORLD

IRONY

Some of the most water scarce regions of the world need an increasing amount of water for oil production



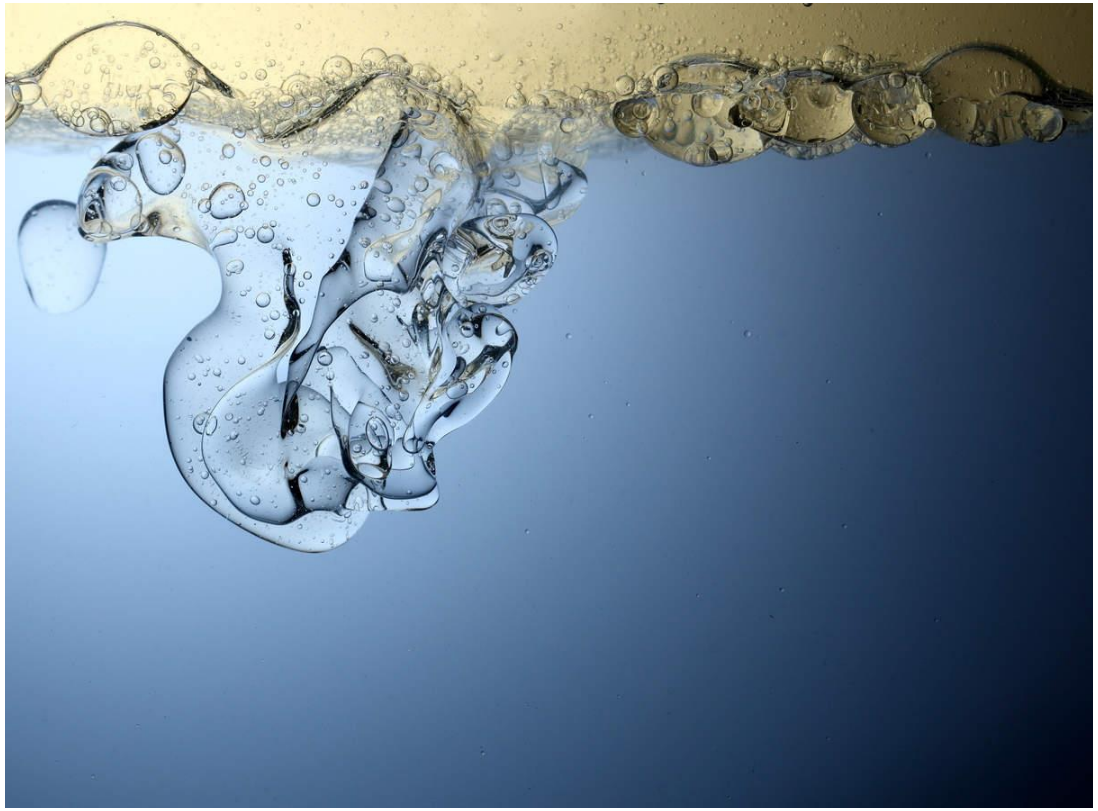
Aquatech

PRODUCED WATER MANAGEMENT IN A WATER SCARCE WORLD

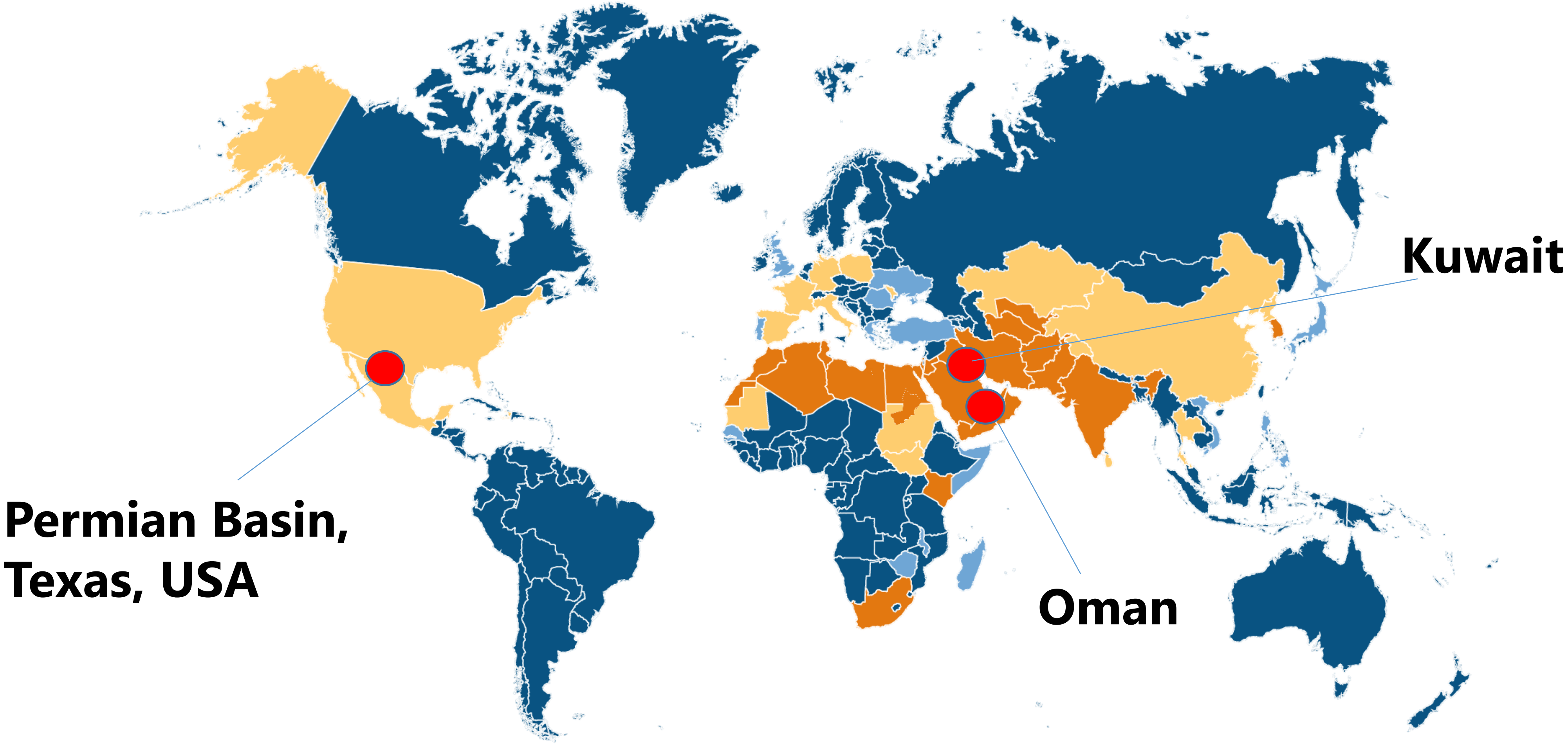
OPPURTUNITY

Reuse Water and not be inhibited by water scarcity

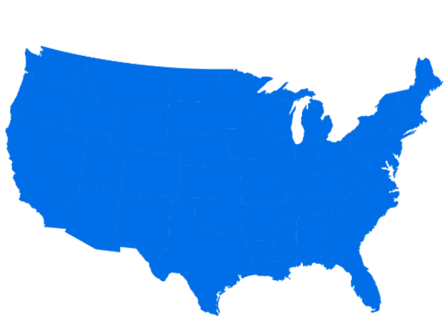
Achieve Environmental Sustainability and limit pollution



WATER SCARCITY IN O&G HOTSPOTS



3 DIVERSE AND INTERESTING CASES IN PRODUCED WATER MANAGEMENT



Permain Basin

- **Need:** Water For Fracking
- **Limitation:** Source Water Scarcity / Disposal cost of Produced Water
- **Oppurtunity:** Reuse of PW and Flowback
- **Hurdles:** Decentralized Treatment

Oman

- **Need:** Steam for Enhanced Oil Recovery
- **Limitation:** Source Water only from freshwater aquifer of Produced Water
- **Opportunity:** Reuse of PW
- **Hurdles:** Schedule / Knowledge of formation PW

Kuwait

- **Need:** Steam for Enhanced Oil Recovery
- **Limitation:** Source Water only from desalination
- **Opportunity:** Reuse of sewage effluent
- **Hurdles:** None!

PERMIAN BASIN WATER MANAGEMENT TRENDS

Recycling programs have matured

Produced water volumes are increasing

Problem more pronounced in oil producing areas with high water to oil ratio

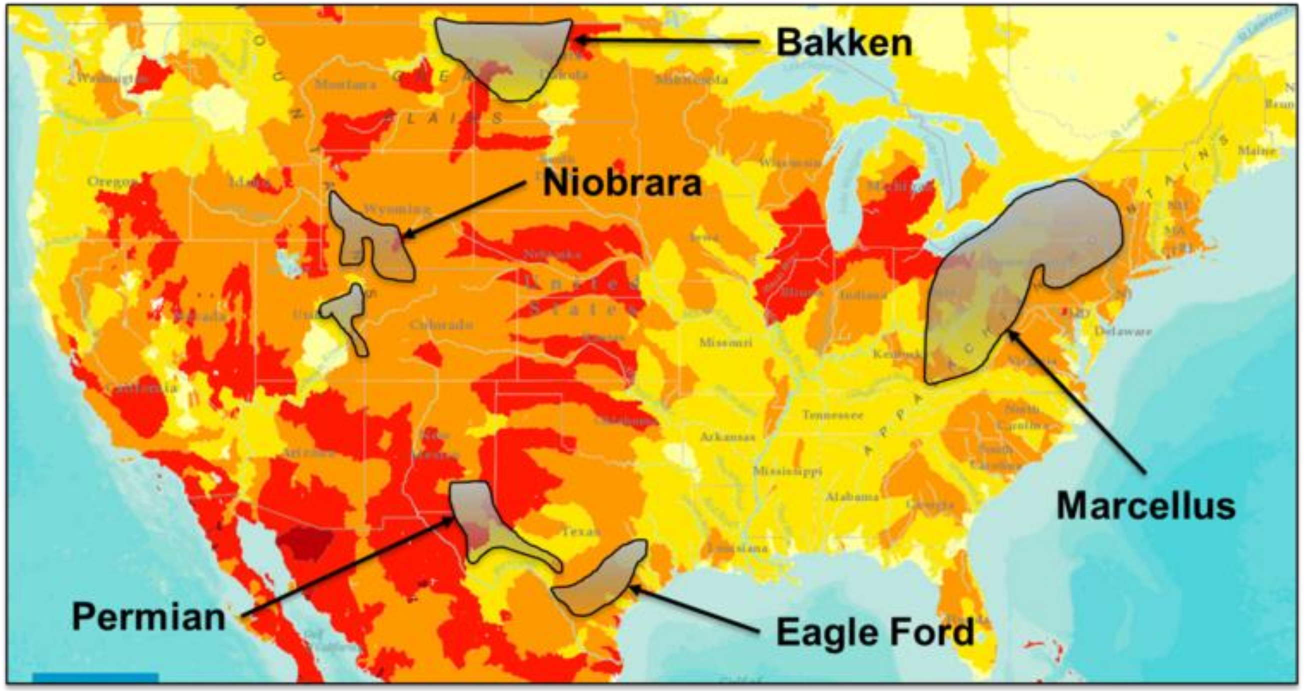
More produced water > 200,000 ppm TDS

Disposal well capacity is becoming limited

Seismic activity considerations are changing well development costs

More cost effective and sustainable disposal options are needed

Capex and operating costs need to reduce



Aquatech

MOBILE / MODULAR TREATMENT

Mobile Clarifier Equipment

Mobile Filter Press Equipment

Oil Removal / Pretreatment Equipment

Mobile Evaporator Equipment

Modular Movable Crystallizer Equipment

Aquatech

PERMIAN BASIN SOLUTION, START WITH STUDY

Client goals

Iron reduction

Maybe…hardness reduction

Determine optimal treatment level

Treatment costs

Compatibility with frac chemicals & cost

Determine treatment chemistry & chemical dosing levels

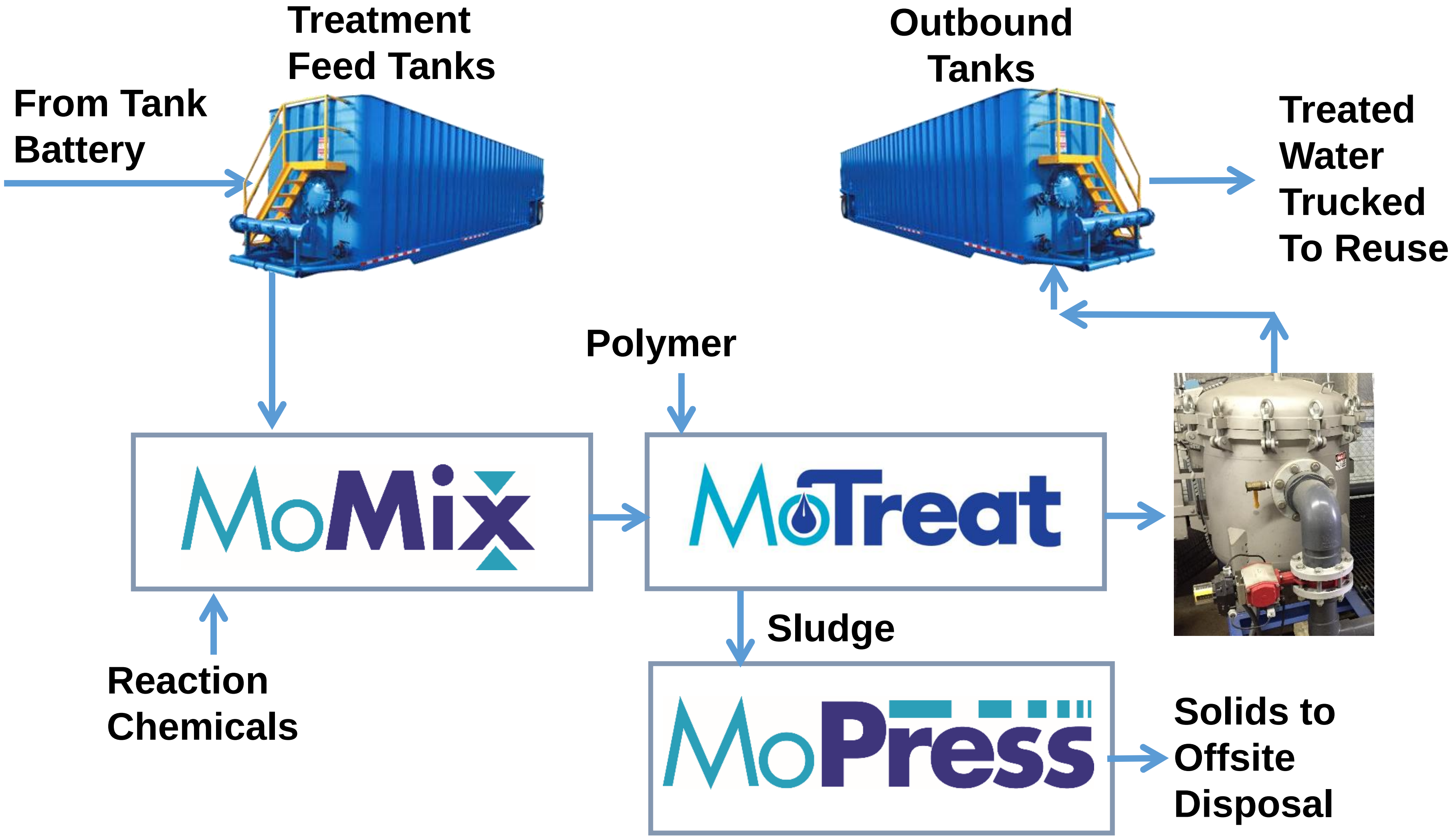
Establish safety protocols

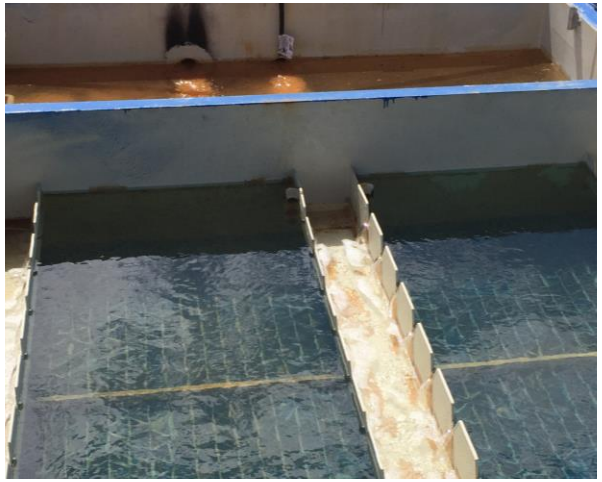
Fear of ammonia

- **Level 1 – Operating pH ≈ 7.0**
  - Hydrogen Peroxide (H_2O_2) for iron oxidation
  - Caustic (NaOH) for pH
  - Polymer (anionic) for coagulation & flocculation
  - Hydrochloric acid (HCl) for treated water pH reduction
- **Level 2 – Operating pH ≈ 9.5**
  - Caustic (NaOH) for pH and iron reduction
  - Polymer (anionic) for coagulation & flocculation
  - Hydrochloric acid (HCl) for treated water pH reduction
- **Level 3 – Operating pH ≈ 11**
  - Sodium Carbonate (Na_2CO_3) for hardness reduction
  - Caustic (NaOH) for pH
  - Polymer (anionic) for coagulation & flocculation
  - Hydrochloric acid (HCl) for treated water pH reduction

Aquatech

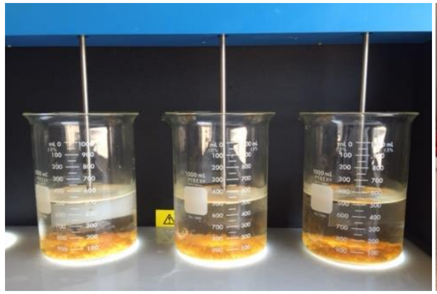
SIMPLIFIED PROCESS DIAGRAM

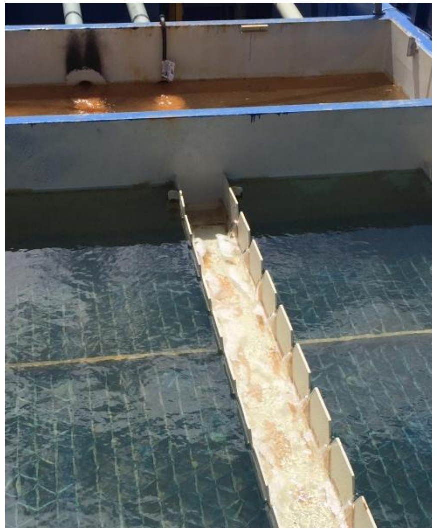




Aquatech

LAB DATA REAFFIRMATION




- Optimized chemical usage – through testing reduced chemical usage by more than 50% from previous usage
- Lab test data replicated within +/- 2% on actual equipment operation for all 3 treatment levels
- Dosing sequence, dosing rates and retention times replicated very well
- Switching between varying feed sources was easy based on lab data generated for all treatments
- Lab data also helped prepare safety protocol to deal with Ammonia in Level 2 & Level 3 treatments

Aquatech

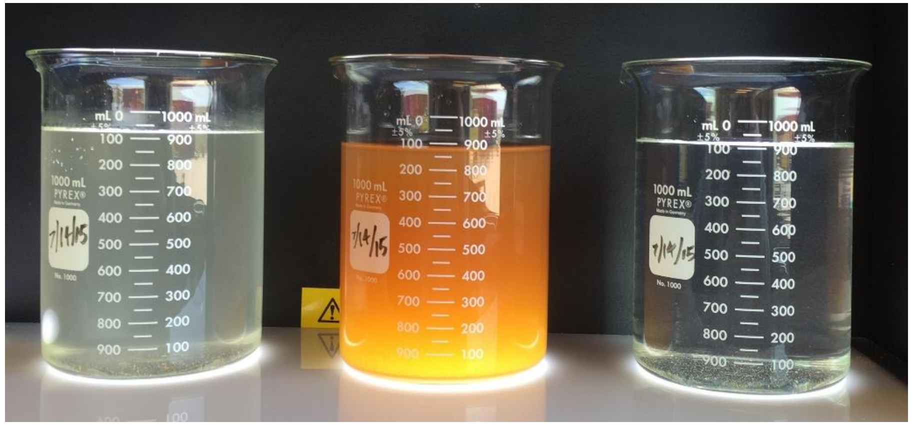
CASE STUDY – PERMIAN BASIN TANK BATTERY TREATMENT OF FLOWBACK & PRODUCED WATER FOR REUSE

Untreated Water

- Delaware Basin
- Red Hills & China Draw water
- Appearance – varying between dark gray, light greenish, blackish depending on well location
- Oil ≈ 60 to 250 ppm
- Total Fe ≈ 80 to 100 ppm
- Ferrous ≈ 50 to 80 ppm
- Hardness ≈ 50,000 ppm as $CaCO_3$
- Dissolved salts ≈ 100,000 ppm to 220,000 ppm
- Treated water from several wells connected to the Tank Battery

Achieved

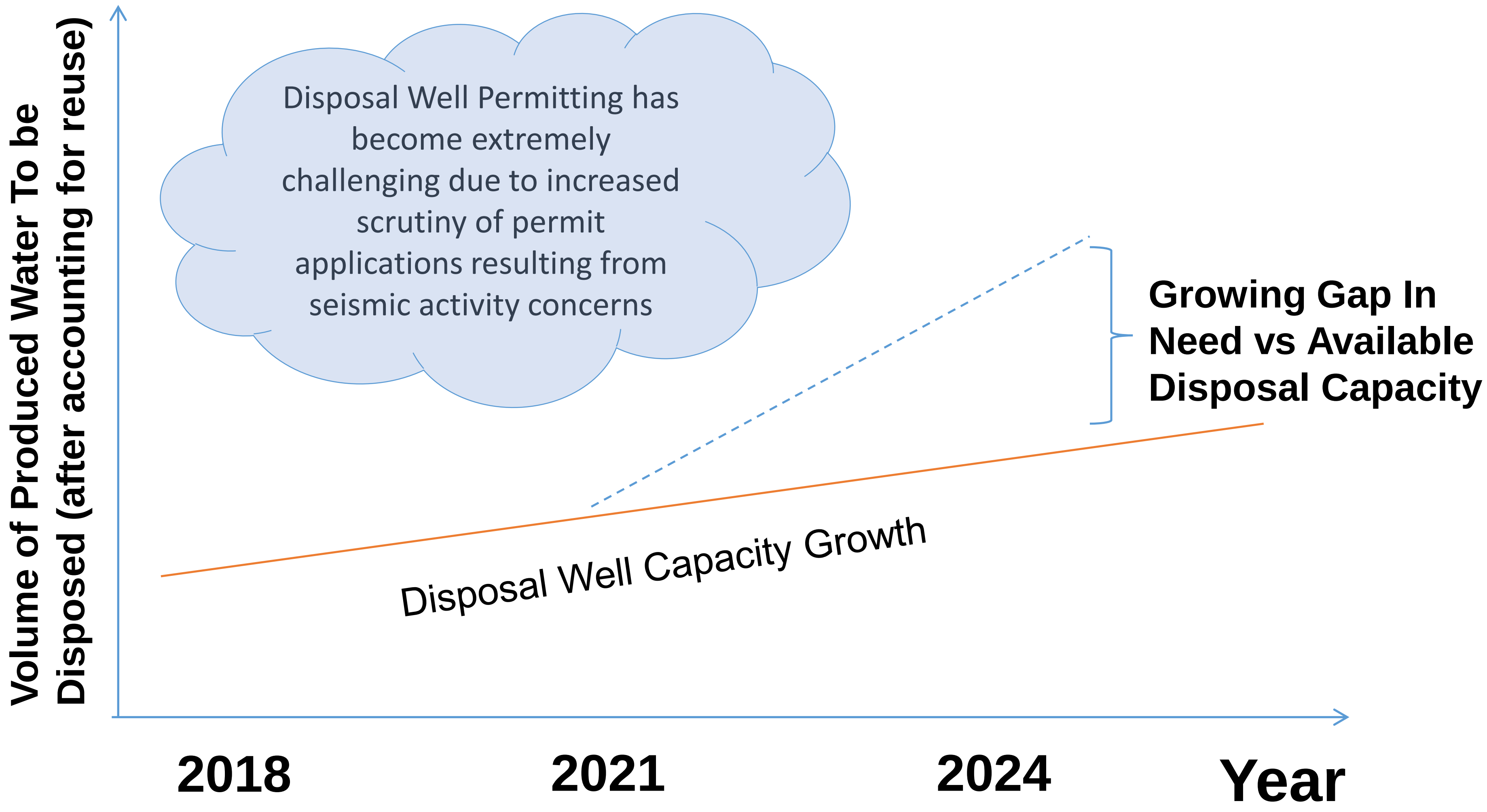
- Turbidity < 5 NTU
- Total Iron (Fe) < 0.5 ppm
- Appearance – clear
- Disinfected



Wastewater ● During Treatment ● Treated

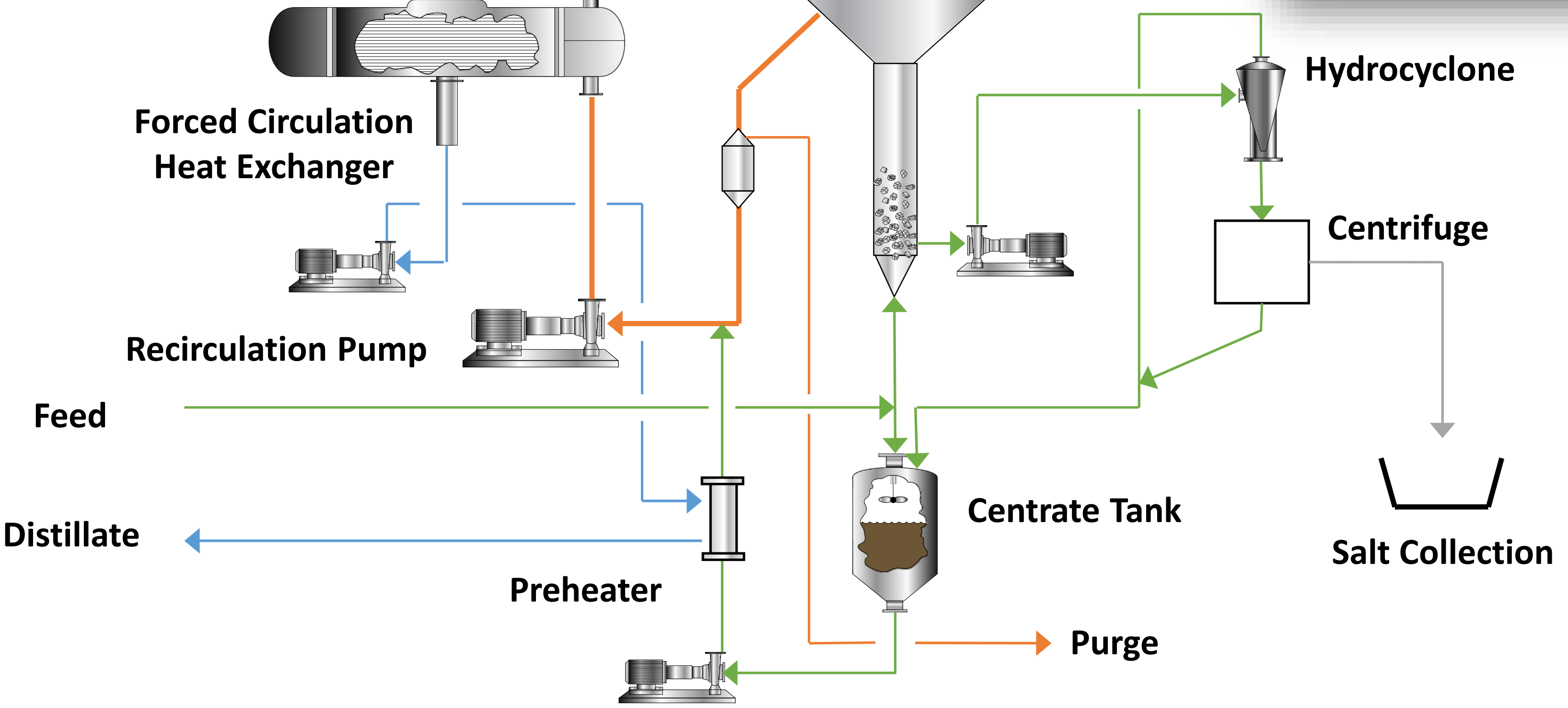
Aquatech

NEED FOR ALTERNATIVE TO DISPOSAL WELLS



This is a depiction of a emerging situation, and is based anecdotal information

CRYSTALLIZER



ENHANCED OIL RECOVERY, OMAN

Development of Mukhaizna Oil Field

Aggressive timeline for production

Not enough data on water quality

Robust solution required for recycling of produced water for OTSG's

O&G ENHANCED OIL RECOVERY – PRODUCED WATER CHARACTERISTICS

HIGHLY DEPENDENT ON THE GEOGRAPHICAL STRATA/FORMATION FROM WHERE IT IS ORIGINATED AND THE METHOD OF EXTRACTION USED.

Parameter	Typical Range - Offshore	Typical Range - Onshore
pH	6.0 – 9.0	5.0 – 9.0
Oil & Grease, mg/l	100 – >10,000	10 – >10,000
TSS, mg/l	20 - 500	20 - 1000
TDS, mg/l	10,000 – 50,000	2000 – 250,000
Total Hardness, mg/l CaCO3	2000 - 8000	200 – 50,000
Chloride, mg/l	5000 – 30,000	1000 – 125,000
Sulfide, mg/l	0 - 500	0 - 500
Silica, mg/l	0 - 10	0 - 250
COD, mg/l	-	500 - 2500
Boron, Barium, Strontium, Iron, mg/l	0 – 100	0 – 10,000

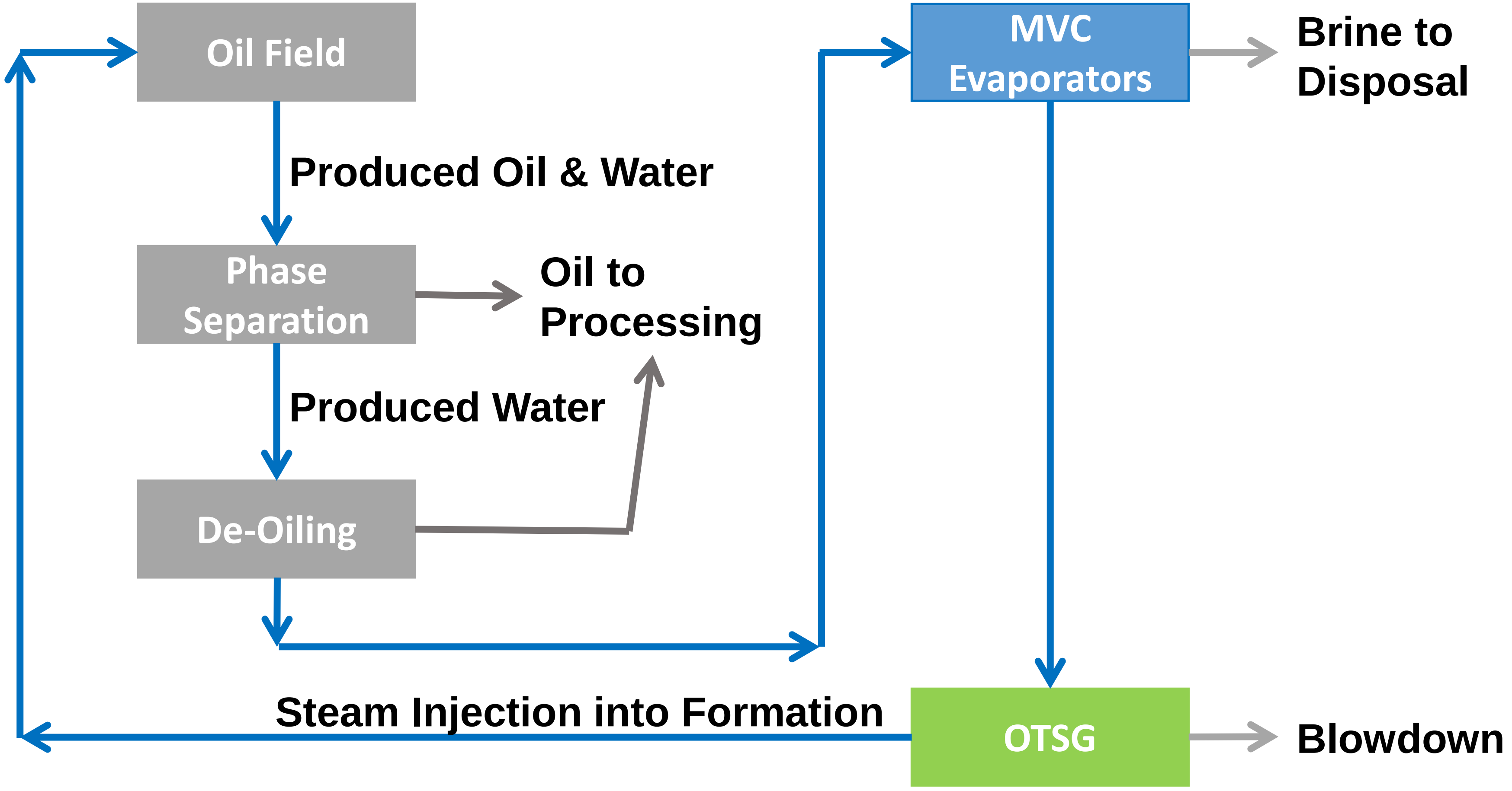
Aquatech

O&G ENHANCED OIL RECOVERY – TREATED PRODUCED WATER QUALITY

Parameter	Offshore Disposal	Onshore (Deep Well Disposal)	Onshore (Irrigation/ Surface Water)	Onshore (Recycle as OTSG Feed Water)	Onshore (Recycle as Drum Boiler Feed Water)[1]
pH	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	6.0 – 9.0	8.8 – 9.6
O&G, mg/l	15 - 40	1 - 10	<10	1 - 10	0.2
TSS, mg/l (<5 µm)	-	< 1	< 30	< 1	Nil
TH, mg/l $CaCO_3$	-	-	SAR < 10	0.5 - 1.0	< 0.3
BOD_5, mg/l	-	-	< 30	-	<0.2
DO, mg/l	-	< 0.01	2	< 0.007	<0.007
TDS, mg/l	-	-	500 – 2100	< 8,000	5 – 10
Silica, mg/l	-	-	-	< 50	0.2 – 0.4

Aquatech

MUKHAIZNA – PROCESS SCHEME
PHASE 1



O&G ENHANCED OIL RECOVERY





Aquatech

PHASE II

Water quality known

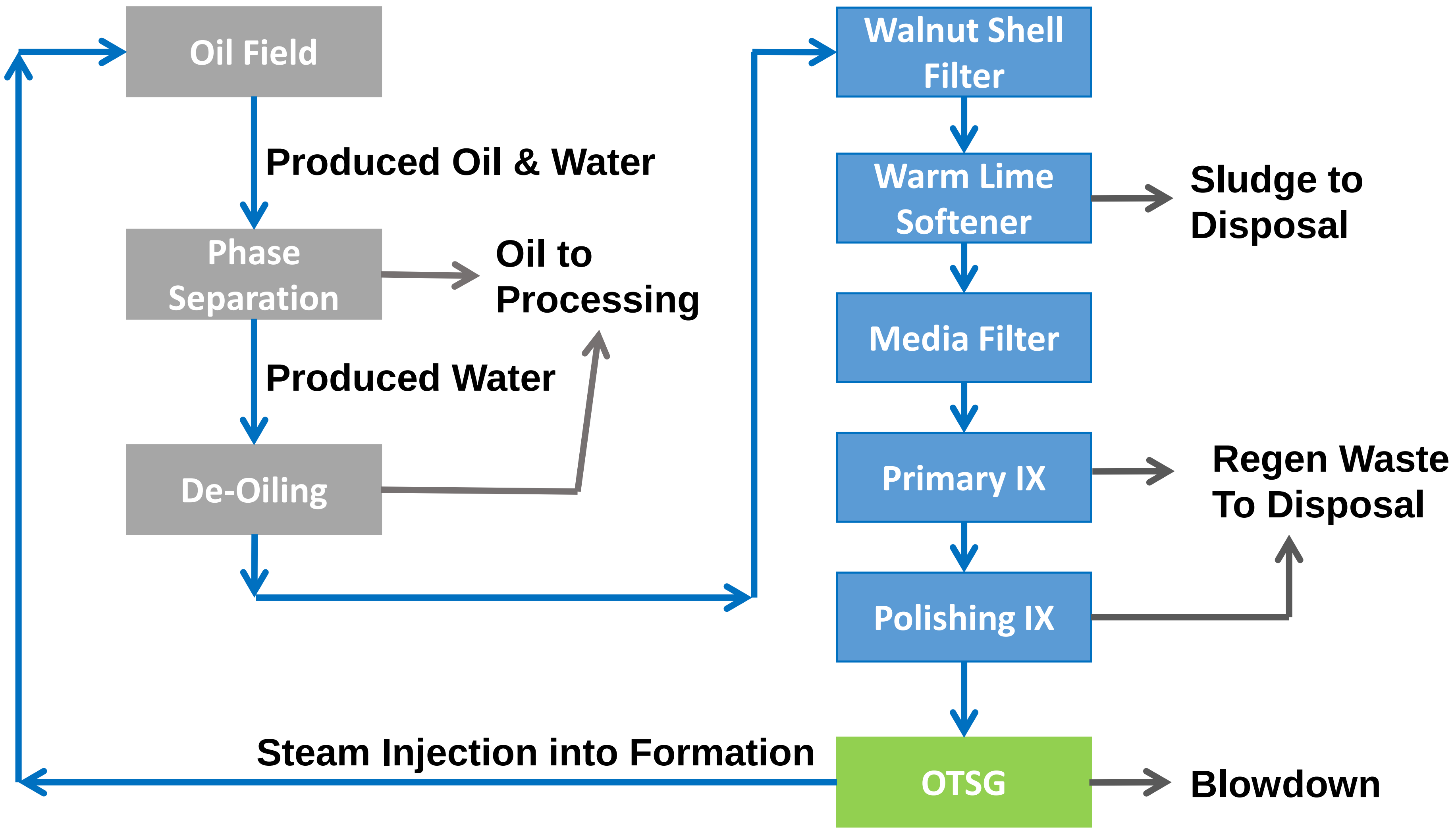
Really only need to treat to OTSG Level

Walnut Shell Filters, WLS, Afterfilters and IX

~~400,000 BWPD

Onshore (Recycle as OTSG Feed Water)	Onshore (Recycle as Drum Boiler Feed Water)[1]
6.0 – 9.0	8.8 – 9.6
1 - 10	0.2
< 1	Nil
0.5 - 1.0	< 0.3
-	<0.2
< 0.007	<0.007
< 8,000	5 – 10
< 50	0.2 – 0.4

MUKHAIZNA – PROCESS SCHEME PHASE 2



- **Phase 1**

  MVC Falling Film Evaporator

  7 x 1,250 GPM (7 x 284 m^3/hr)
- **Phase 2,3,4**

  Walnut Shell Filters, WLS,
  Afterfilters and IX
- **Over a 350 MN USD Investment**
- **Over 800,000 BPD Development**

Aquatech

MUKHAIZNA OIL FIELD

Great example of a holistic solution

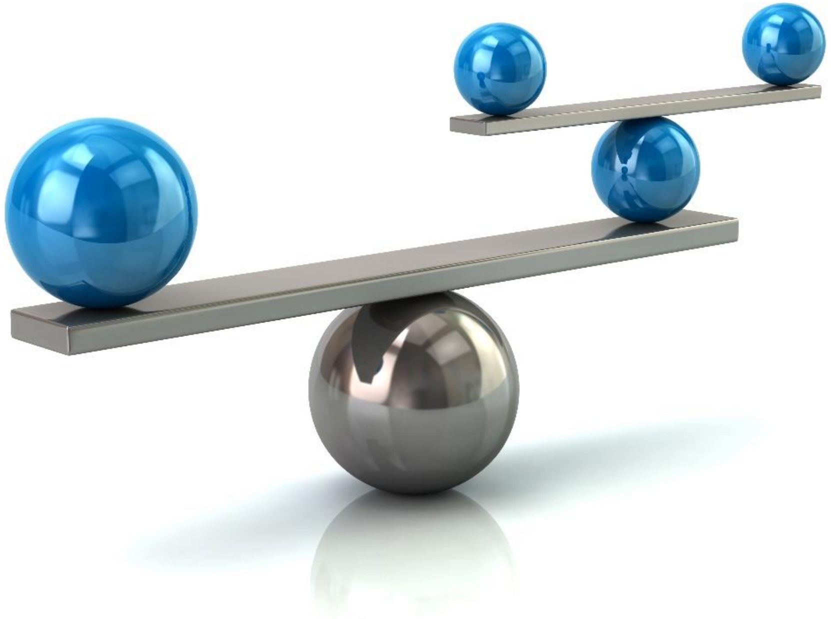
High tech to Low Tech Balance

The right solution for the right time and project phase

One of the largest complex PW treatment and reuse projects in the world

Global Water Awards – 2009

Water Reuse Project of the Year



ENHANCED OIL RECOVERY, KUWAIT

Development of Lower Fars Oil Field

First Phase requires 30,000 M3/Day of Water for OTSG

Desalinated Water?

SULABAYA WATER RECLAMATION PLANT

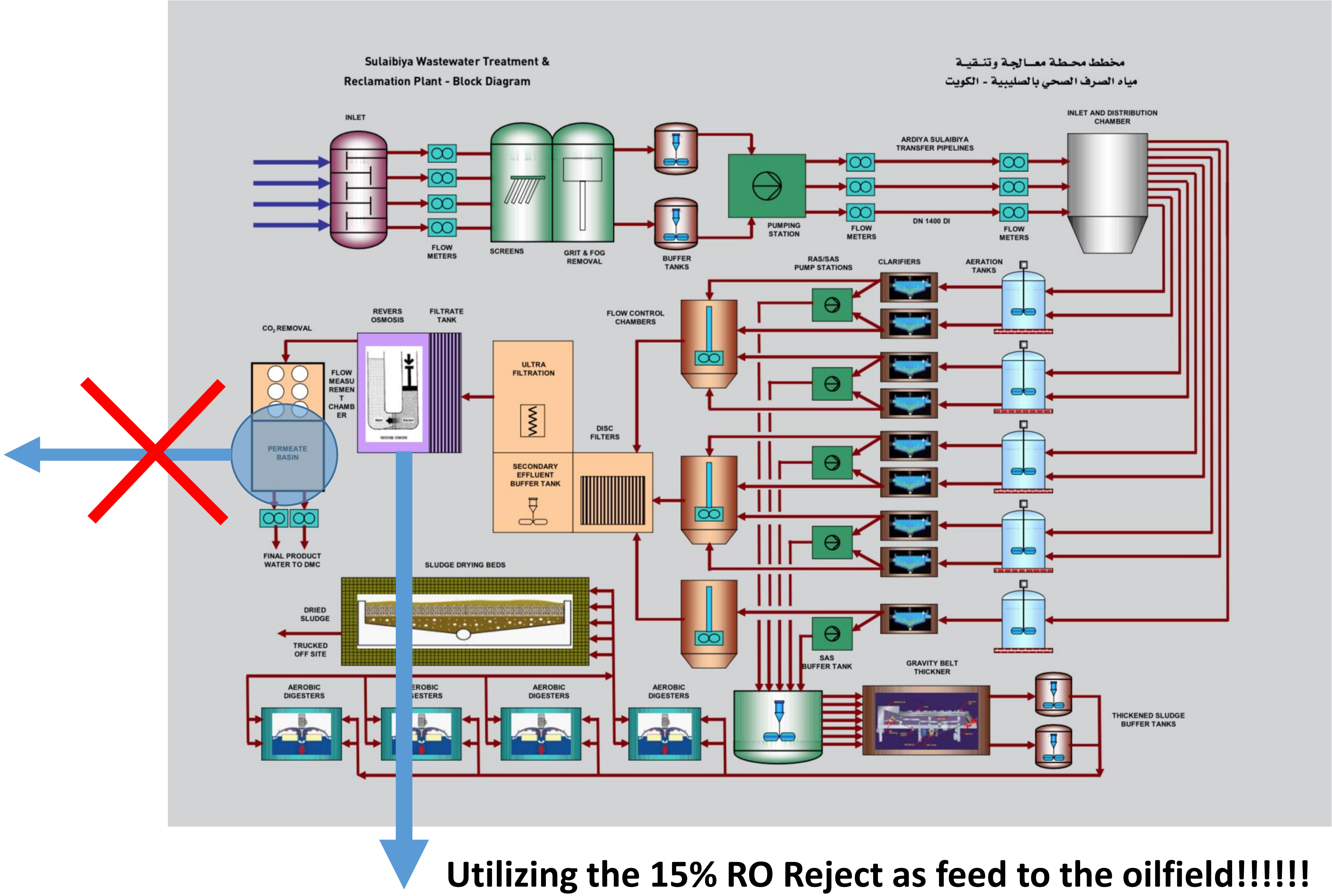
100 MGD

Groundbreaking project, at the time the largest in the world

Treated Sewage recycling 85%

Although meeting WHO drinking standards, water used mainly for agricultural and other non potable purposes

Aquatech



Utilizing the 15% RO Reject as feed to the oilfield!!!!!!

SOURCE WATER TREATMENT PACKAGE – DESIGN BASIS

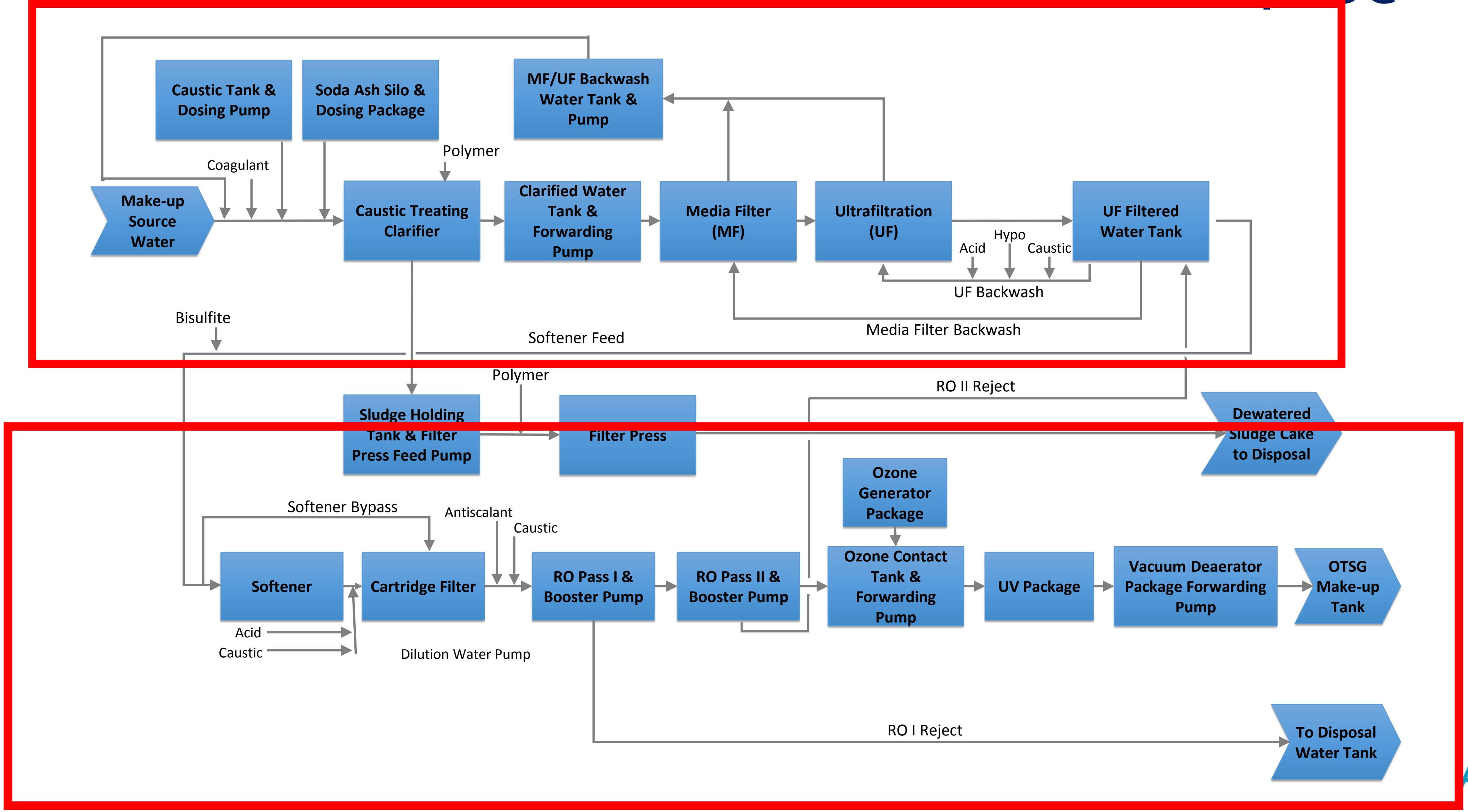
Streams	Combined Feed Water
Flow, m3/h	**1321**
pH	6.5 – 8.4
Temperature, deg C	< 40
Ca, mg/l	784.5
Mg, mg/l	157.7
Total Hardness, mg/l CaCO3	2610
Total Alkalinity, mg/l CaCO3	~600
TSS, mg/l	75
COD, mg/l	386
NH4, mg/l	~74
PO4, mg/l	~100
TDS, mg/l	11,065

Make-up Water Design

Parameter	Value
pH @ 25 ^{0}C	8.5 – 9.0
TSS, mg/l	<0.1
Total Hardness, mg/l CaCO3	< 0.5
TDS, mg/l	< 570
Chloride, mg/l	< 130
Silica, mg/l	< 0.01
DO, mg/l	< 0.1*
COD, mg/l	< 0.1

Aquatech

BLOCK FLOW DIAGRAM – SOURCE WATER TREATMENT, LOWER FARS HEAVY OIL DEVELOPMENT PROJECT, KOC



Aquatech

LOWER FARS ENHANCED OIL RECOVERY

Taking the "waste water from a waste water treatment plant" and converting it into high purity industrial water

Great demonstration of sustainability

Aquatech

In Conclusion

Recycle solutions can be big, small, “low tech”….”high tech”

Water treatment is “artful” application of “science”; same outcome can be achieved multiple ways

New & amazing treatment are rare

All treatment processes have limitations

”If its too good to be true…..”

A holistic approach is key

Customer specific needs

Understand drivers

Delivery of a complete solution to support maximum yields

Aquatech