Texas Desalination Association

Desal in the Offshore Oil Patch

Paul Choules

President, Texas Desalination Association

Senior Vice President, Water Standard

Texas Desal 2014

BEST PRACTICES & EMERGING TECHNOLOGY

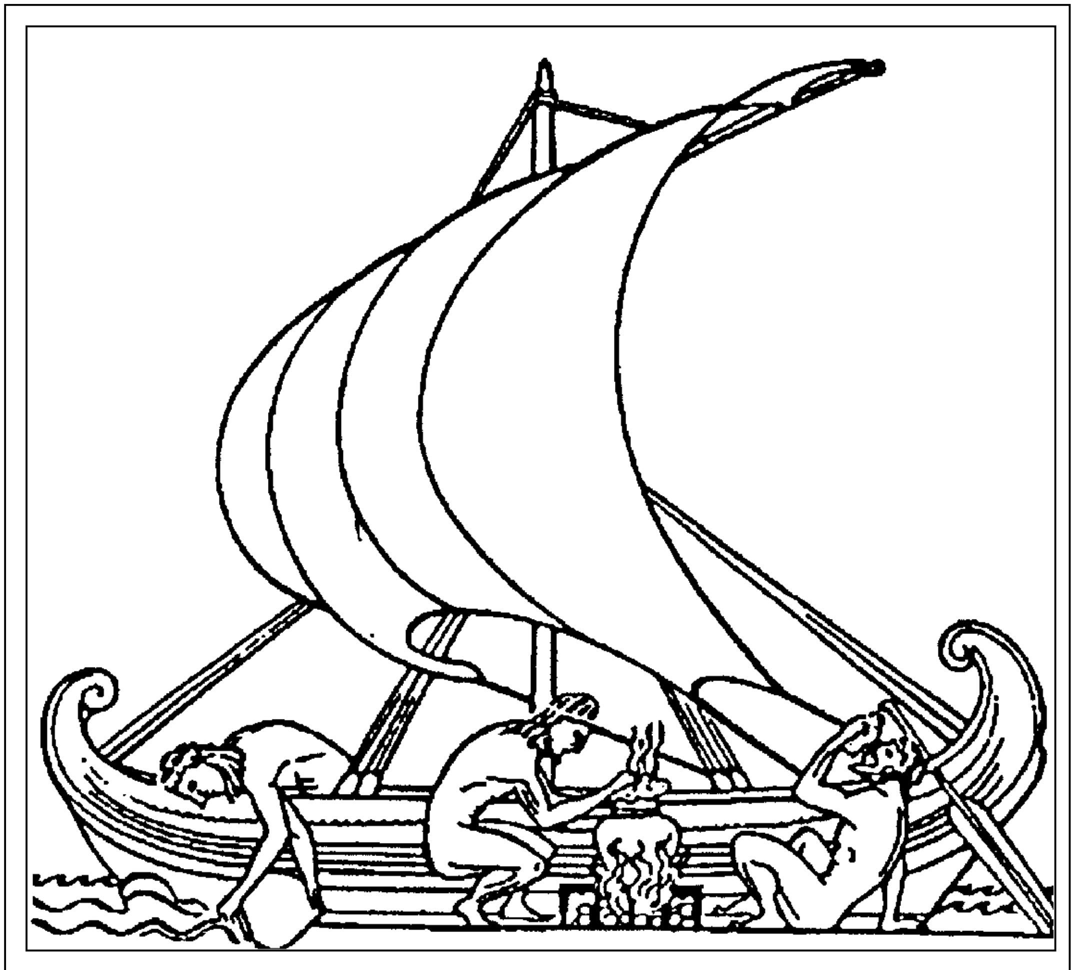
On average, one in 12 hotels or motels report a structure fire each year. Cooking equipment is the leading cause of hotel/motel fires.

- When you enter your room, review the escape plan posted in your room.
- Take the time to find the exits and count the doors between your room and the exit. Ensure that the exits are unlocked and free from obstruction. If not, notify management right away.
- Keep your room key by your bed and take it with you if there is a fire.
- If an alarm sounds, leave right away. Close all doors behind you and take the stairs.
- If you cannot escape:
    - Call the fire department and notify them of your location
    - Shut off fans and a/c
    - Stuff wet towels in gaps around the doors
    - Wait at the window and signal with a flashlight or light colored cloth.
        - Do you travel with a flashlight?

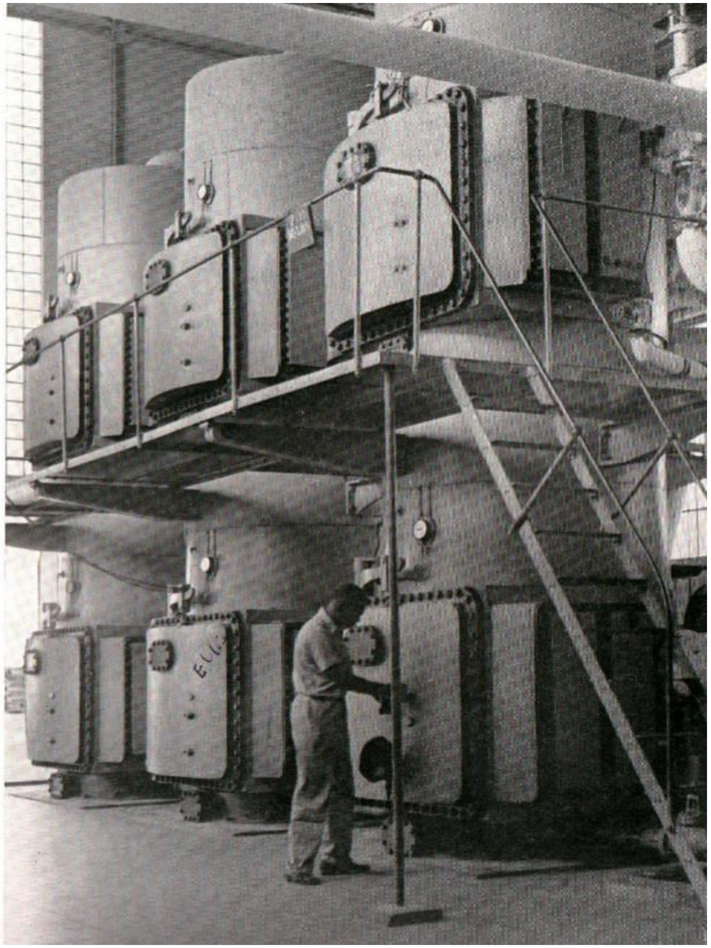
Offshore Desalination

Marine Desalination

Around 300 AD, the Greek, St. Basil made reference in his writings, to "Sailors boil seawater collecting the vapor in sponges to quench their thirst in pressing need”. Things have improved.



Desalination - Over 85 Years of Desalting



- Some of the 1st Thermal & Membrane Desal plants

Why Offshore Water Desalination

Global Water Crisis	The global water industry has entered a period of sustained, accelerated growth based on macro-economic forces that have resulted in significant supply-demand imbalances and increased shortages.
Desalination a recognized alternative to traditional sources of supply	Desalination is the only drought proof, large-scale option for solving near and long-term global water supply and quality issues. To date, the only option for desalination has been land-based plants.
Increase in development opportunities in the desalination sector	As major water infrastructure projects globally have been delayed or cancelled, there has seen a significant increase in development opportunities, where speed and mobility are seen as differentiating advantages.
Emergence of Offshore Desalination Option	A global water treatment market, offering an innovative desalination option which is offshore-based from proven desalination technologies used onshore.
More options for vessel-based than traditional land-based solutions	Desalination provides a mobile, environmentally responsible solution, produces water in an accelerated time frame, and provides cost-effective short or long-term solutions with the ability to redeploy to other locations upon expiration of a contract.

Current Desal Applications for Offshore Oil & Gas

Potable Water Maker

Water for potable consumption including drinking, cooking, showering and laundry. Both thermal and membrane processes are used. Generally small packaged plants (<10,000 gpd).

Wash Water

Water for washing salt from the crude oil before it's put in a pipeline. Usually medium sized systems up to 1.5 MGD.

Improved Oil Recovery

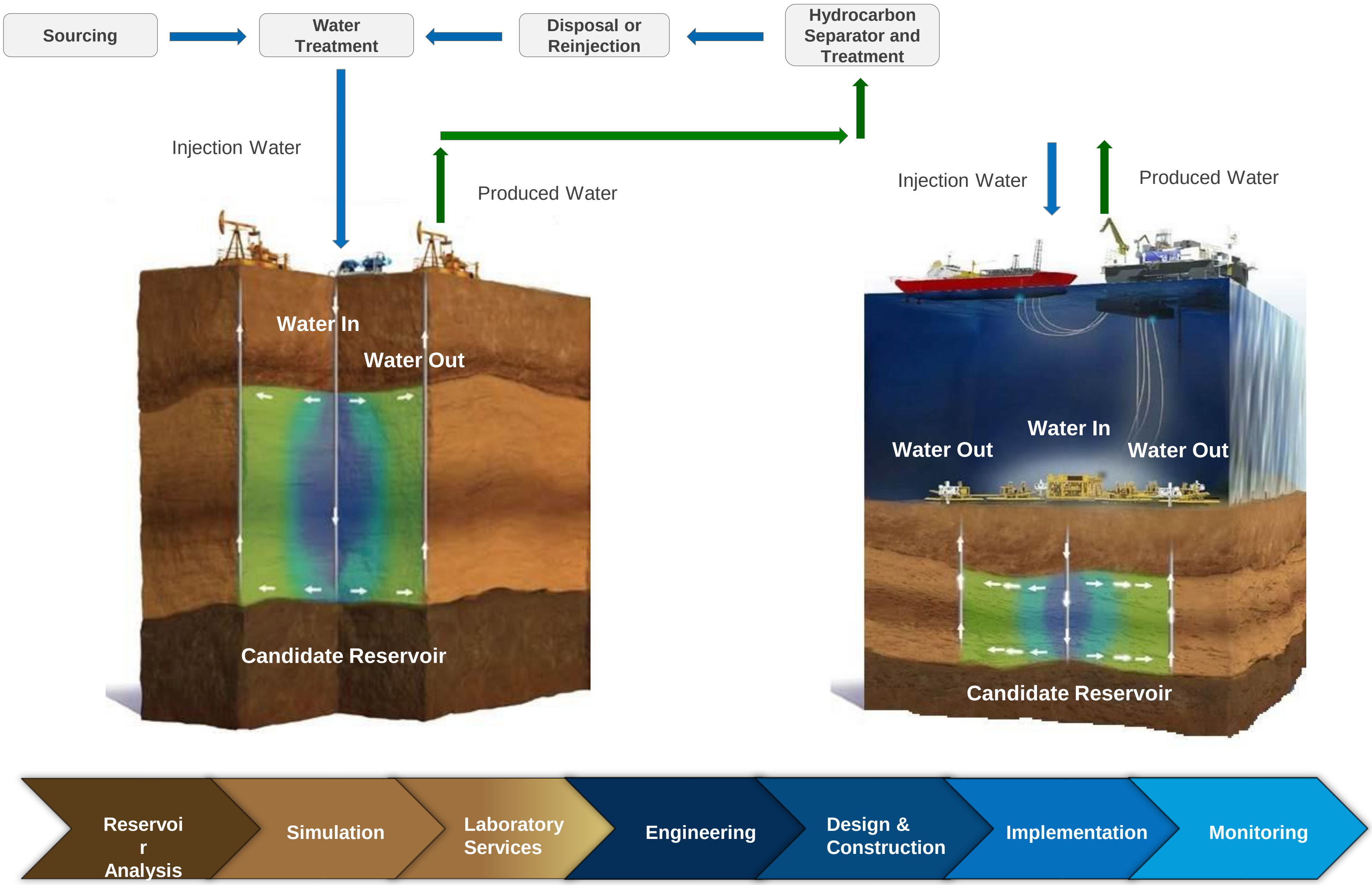
Waterflooding and water injection being incorporated into designs to maintain well pressure and to sweep displaced oil to production wells. Capacities go up to 20 MGD.

Enhanced Oil Recovery

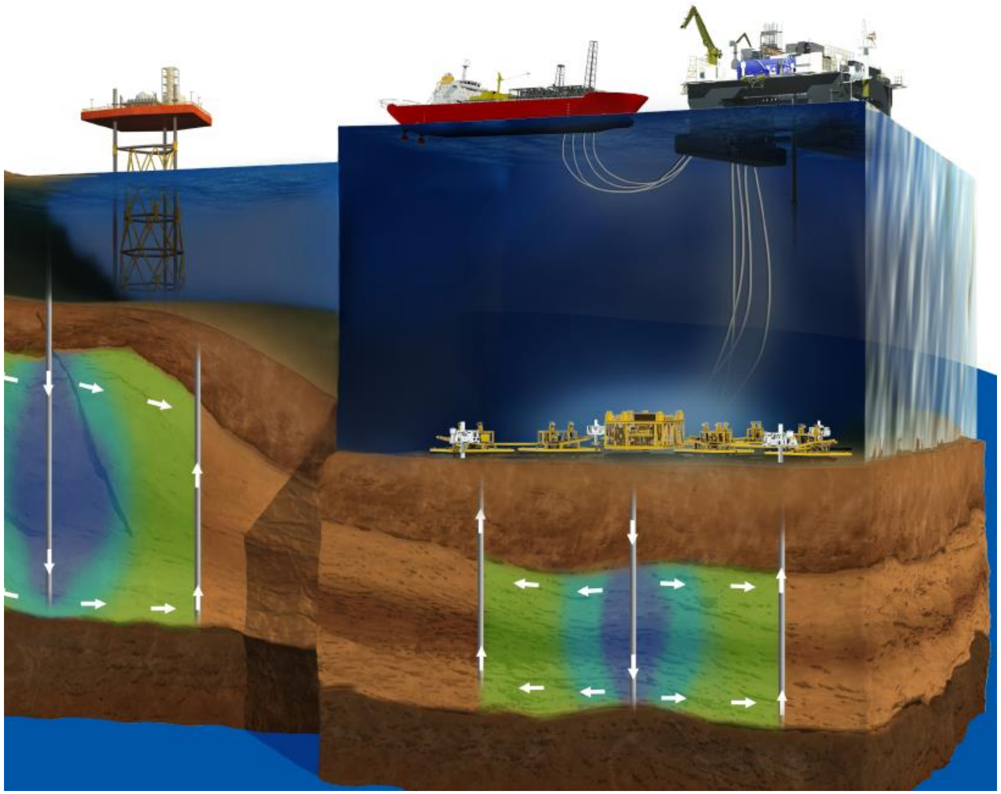
Producers aggressively looking at Secondary & Tertiary Recovery to improve recovery factors. Capacities go up to 20 MGD.

Why Improved Oil Recovery/Enhanced Oil Recovery (IOR/EOR)?

Water In / Water Out



Water-Based IOR/EOR



Using Water to:

- Maintain reservoir pressure
- Provide energy to maintain drive to producing wells
- Prevent scaling that blocks pore throats and wells
- Prevent souring
- Modify injection chemistry, reducing residual oil saturation and increasing recovery

"1% increase in recovery factors for BP yields an additional 2 BBOE. Globally a 5% increase in recovery will yield an additional 300-600 BBOE"

Source: Tony Meggs, BP Group Vice President for Technology, *Tackling the Third Trillion,* 2007.

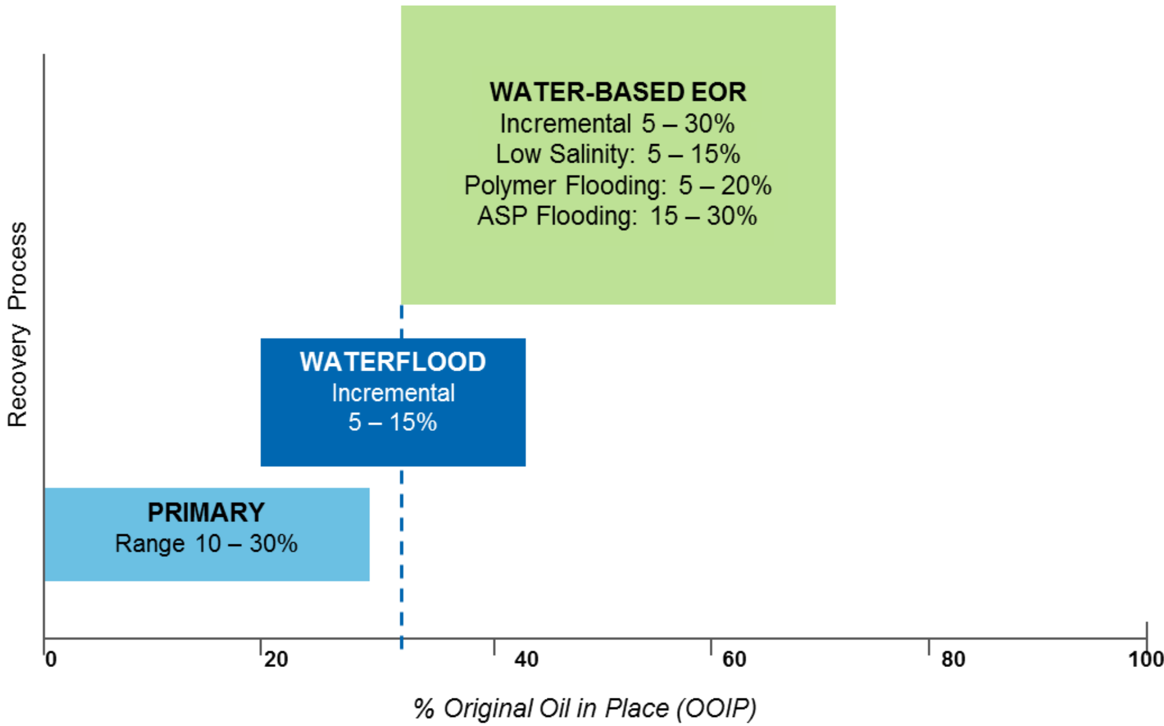
Water-based EOR Market Opportunity

"Resource holders will demand getting every barrel we can out of every reservoir, even the difficult ones, and that underpins the commitment to EOR."

"Well Recovered" Shell (2009)

MARKET DRIVERS FOR EOR

- Increased cost of finding new reserves; get more oil where you have already found it
- Increased recovery with proven cost-effective technology
- Maturing reservoirs with production decline
- High costs of decommissioning
- Environmental regulations on feed water for injection and produced water disposal/re-injection
- Current commodity price environment
- Demand for oil security



New Waterflooding Strategies

Low Salinity Flooding
(LSF)

Injection of 1,000-10,000 mg/L TDS with varying divalent cation and sulphate requirements

Water Injection
(WI)

Injection of filtered and deaerated water to maintain reservoir maintenance

Chemical Enhanced Oil Recovery
(CEOR)

Injection of 2,000-30,000 mg/L TDS with varying divalent cation and sulphate spec's (often extremely low hardness levels)

Sulphate Reduction Process
(SRP)

Injection of reduced sulphate seawater while maintaining high salinity to prevent scaling and souring

IOR/EOR & Associated Treatment Technologies

Cost $ — Weight & Footprint

Water Injection:
Inlet water to output water ratio 1: 1

Sulphate Removal:
Filtration + Sulphate removal membranes (NF) + Deaeration
Inlet water to output water ratio 1: 0.75

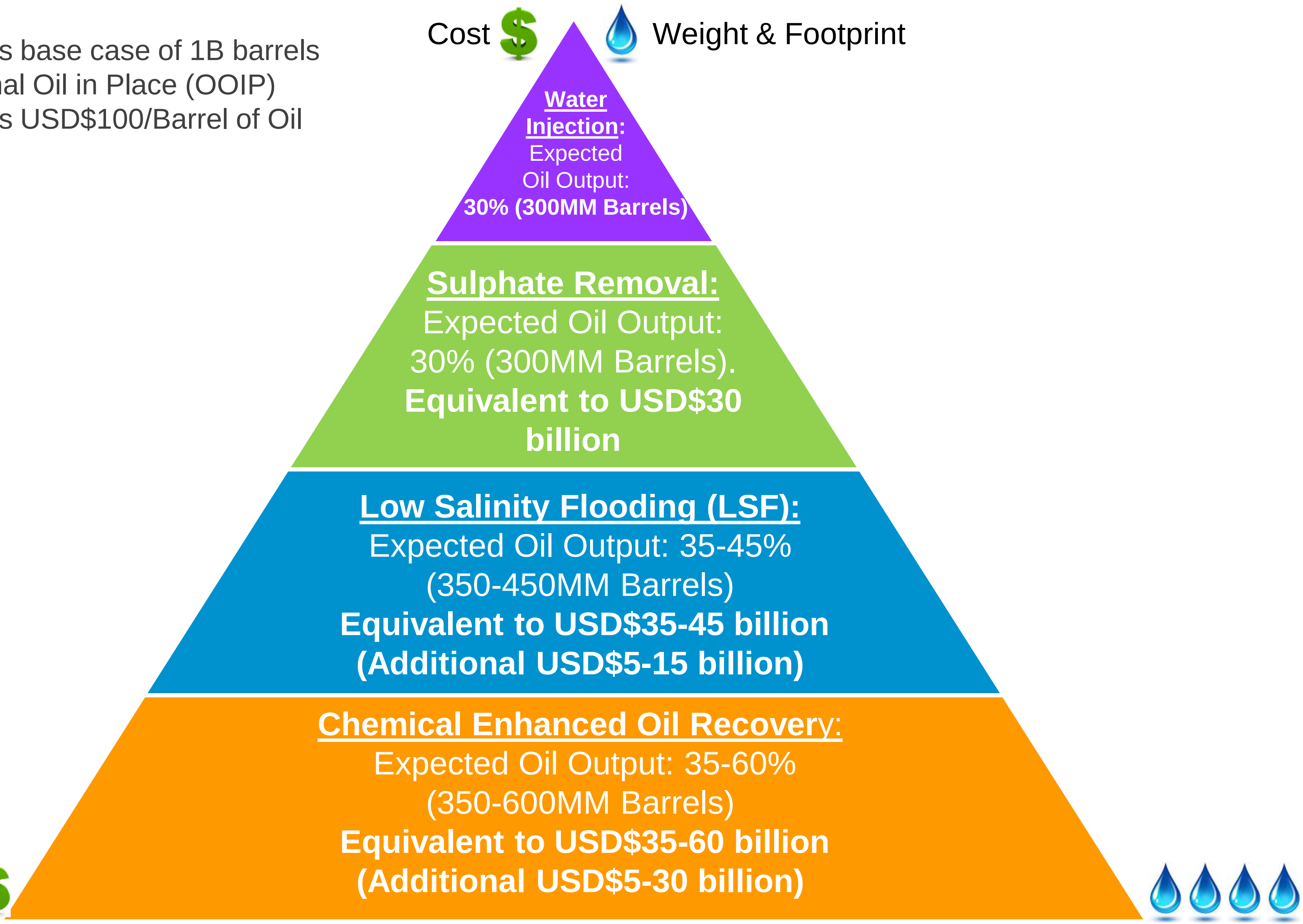
Low Salinity Flooding (LSF):
Filtration + Membrane Process (RO/NF) + Deaeration
Inlet water to output water ratio 1: 0.45

Chemical Enhanced Oil Recovery:
Filtration + Hardness and Salinity Removal Membrane Process (RO/NF) + Deaeration
Inlet water to output water ratio 1: 0.45

$$$$$

IOR/EOR & Associated Oil Recovery

- Assumes base case of 1B barrels of Original Oil in Place (OOIP)
- Assumes USD$100/Barrel of Oil



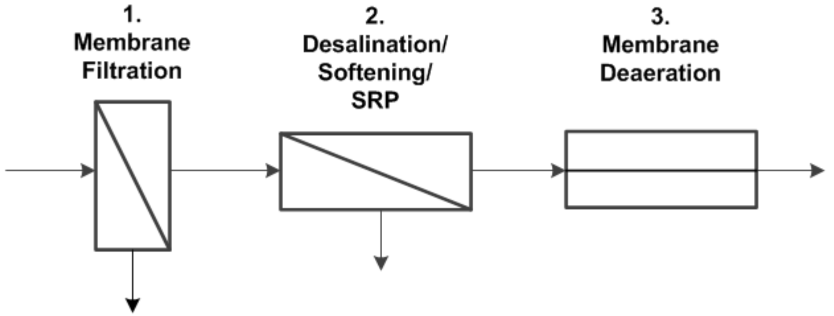
Reducing Weight & Footprint for Offshore Applications

Chevron Perspective (March 2014)

Source: Chevron

Compact Solution

Compact technologies have been developed to meet the Oil & Gas Industry’s water injection needs (IOR/EOR)



The key attributes of the compact system design include:

- **Smaller footprint**
- **Reduction in weight**
- **Oxygen content of <10 ppb**
- **Increased system recovery**
- **Reduced infrastructure**
- **Flexibility to customize**

Source: Water Standard

Weight and Footprint Savings

- The table below outlines the reductions achieved with the compact technology in inlet capacity, weight, and footprint.
- Comparison of conventional arrangements to the advanced alternatives used in compact design technologies.
- Assumes 5.25M Gallons per day (125,000 bpd) system.

System Comparison			
Parameter	Conventional	Compact Design	Δ
Outlet Capacity, gpd	5,250,000	5,250,000	-
Inlet Capacity, gpd	12,600,000	10,080,000	**20% reduction**
Waste Capacity, gpd	7,350,000	4,830,000	**33% reduction**
Dry Weight, MT	431-862	234	**46-73% reduction**
Full Footprint (single deck), ft^2	7,018	4,359	**38% reduction**
Oxygen Content	<50 ppb	<10 ppb	**80% reduction**

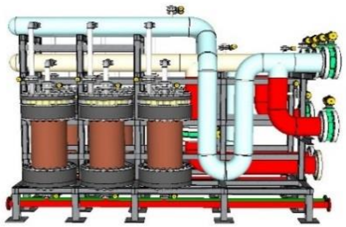
Source: Water Standard

Smaller equipment footprint due to lower water feed demand of efficient LSF design

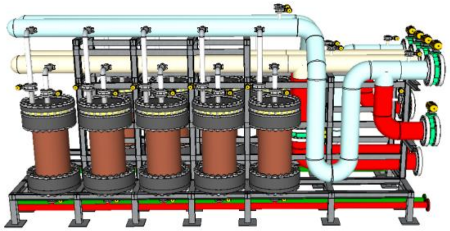
Compact MF Design
- Membranes with high flux pre-coat*
  - Significantly smaller MF to feed 55% recovery LSF system @ flux of 28 Lmh

Conventional MF Design
- Standard membranes without pre-coat
  - Larger to feed 45% recovery LSF system @ flux of 14 Lmh

* Proprietary coating to achieve high flux



X 8 skids → **Compact MF Design**



X 8 skids → **Conventional MF Design**

125,000 bpd system

Source: Water Standard

The Compact LSF Design achieves higher recovery with substantially fewer membranes

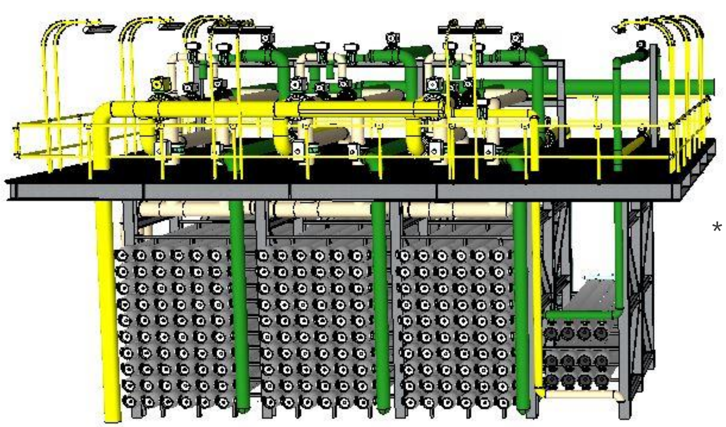
Conventional LSF Design

- Standard fiberglass vessels
  - 7 element for RO and 6 element for NF
- Standard membranes (14 Lmh flux)
  - 180 RO vessels and 1260 membranes
  - 45% recovery

Compact LSF Design

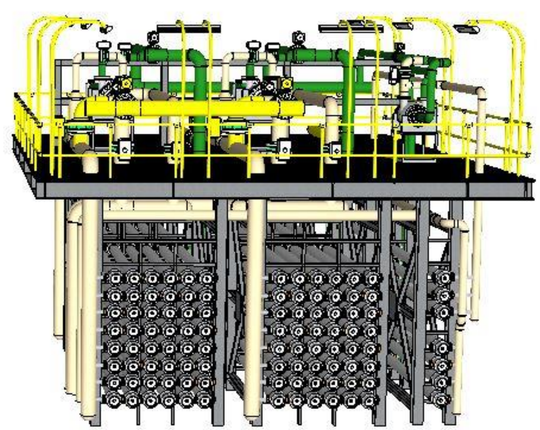
- Center-port vessel design, inter-stage boost, & ERDs
- NF with center-port vessels
- High flux & increased recovery RO membranes (28 Lmh flux)
  - 96 RO vessels and 768 membranes
  - Up to 55% recovery

Conventional LSF Design



* 125,000 bpd system

Compact Design



Source: Water Standard

Membrane Deaeration (MDA)

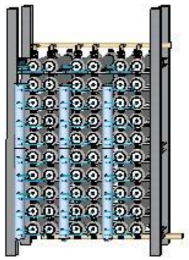
MDA is capable of required oxygen removal without chemical dosing while achieving significant weight and footprint reduction

WS MDA

- Substantial weight and footprint reduction
- Approx. 50% smaller vacuum package than tower configurations
- No chemicals required to reach < 10 ppb oxygen content

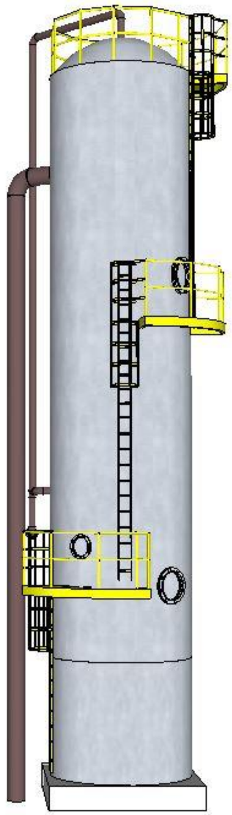
Conventional Vacuum Tower Deaerator

- Design height restrictions
- Chemical dosing required to achieve desired oxygen removal
- Up to 3x larger than comparable MDA system



WS's Membrane Deaerator

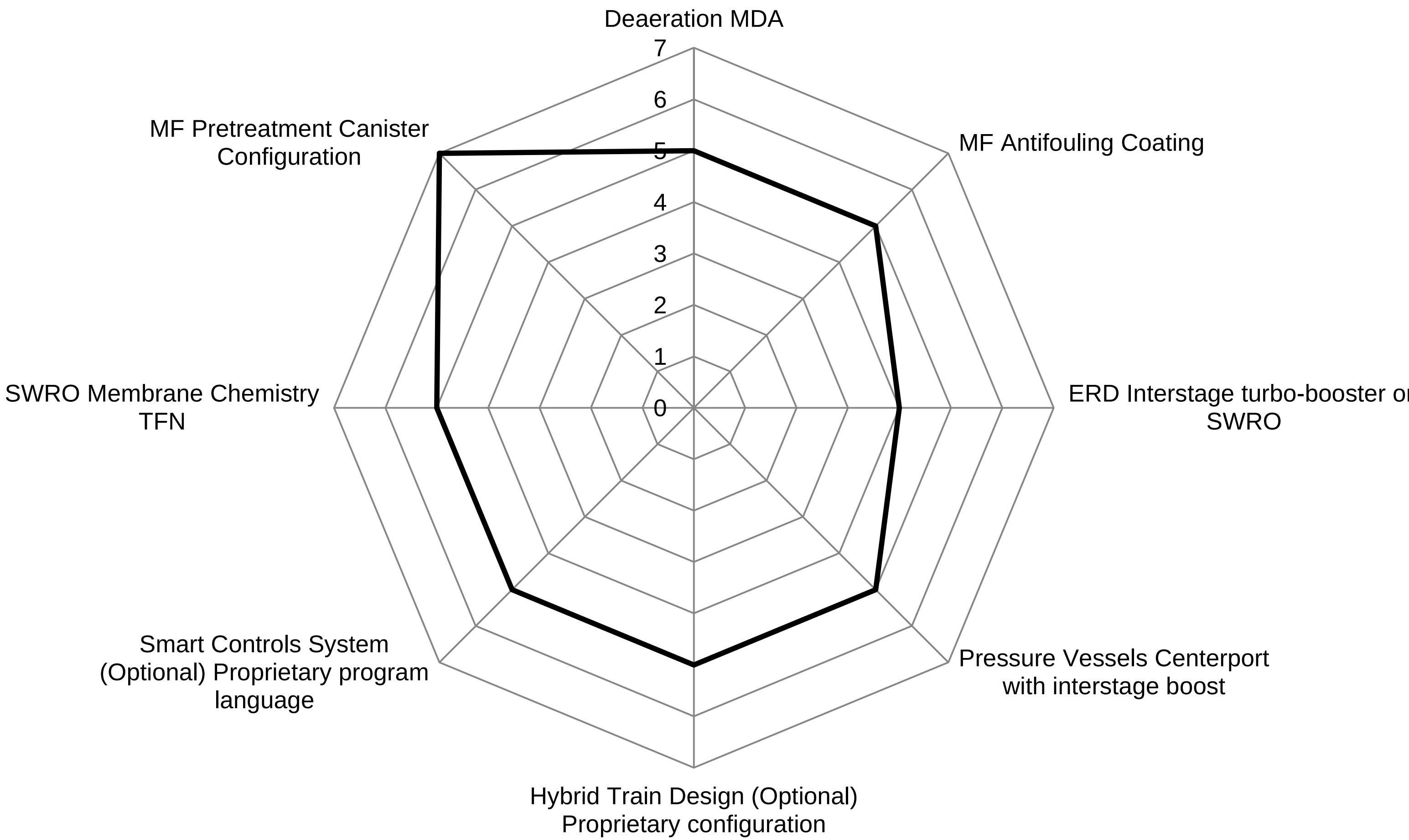
* 125,000 bpd system



Conventional Vacuum Tower Deaerator

Source: Water Standard

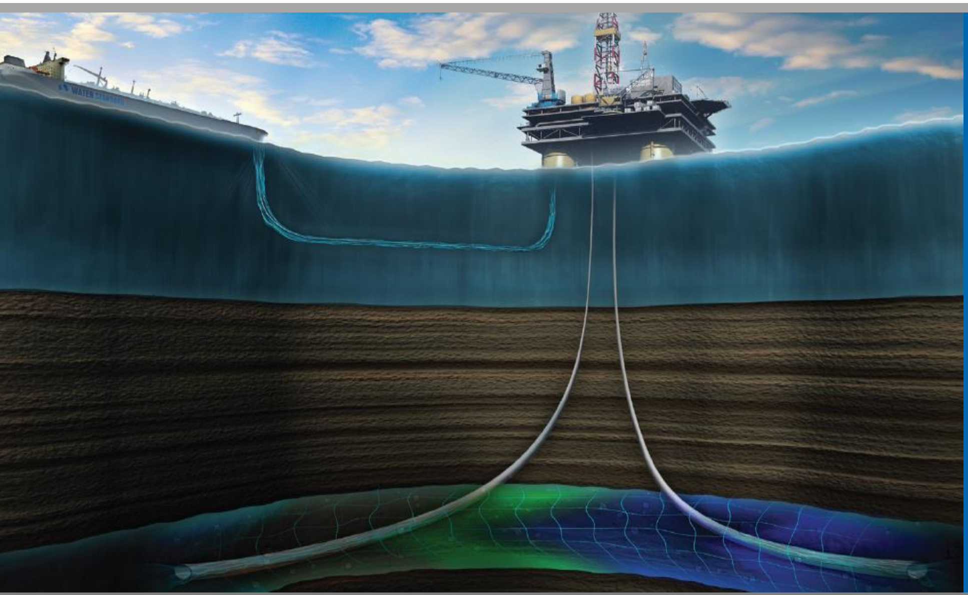
Compact System Current TRL Status



Conclusion

- As oil exploration and production activities shift into offshore environments, their technical and economic complexity dramatically increases.
- Waterflooding, which presently accounts for over half of oil production worldwide, offers an opportunity to increase the production potential of offshore reservoirs.
- The Oil & Gas industry has adapted proven desalination technologies to an offshore environment.
- The technical and economic viability of these activities is dependent on technology selection and their footprint and weight requirements;
- Minimization of each and understanding of technology API, TRL, and HSE implications are paramount to successful implementation of the technology offshore.

WATER STANDARD



FOR MORE INFORMATION CONTACT

Paul Choules
Senior Vice President, Business Development
pchoules@waterstandard.com

Executive Office:
4265 San Felipe, Suite 620
Houston, Texas USA 77027
+1-713-400-4777

www.waterstandard.com