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BANFF

WATER RECYCLING AND DESALINATION FOR THE OIL & GAS INDUSTRY

Improved Oil Recovery through Achievement of Very Specific Water Quality

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Proceeds to Benefit Water-related Humanitarian Projects

Agenda

- Introduction
- Water-Based Improved Oil Recovery (IOR) and Enhanced Oil Recovery (EOR) Methods
 - Sulphate Removal Processes (SRP)
 - Low Salinity Waterflooding (LSF)
 - Chemical Enhanced Oil Recovery (CEOR)
- Case Studies
 - Low salinity and sulfate, medium ratio of divalent/total cations
 - Medium salinity, low hardness
 - Low salinity and hardness, high ratio divalent cations
- Conclusions

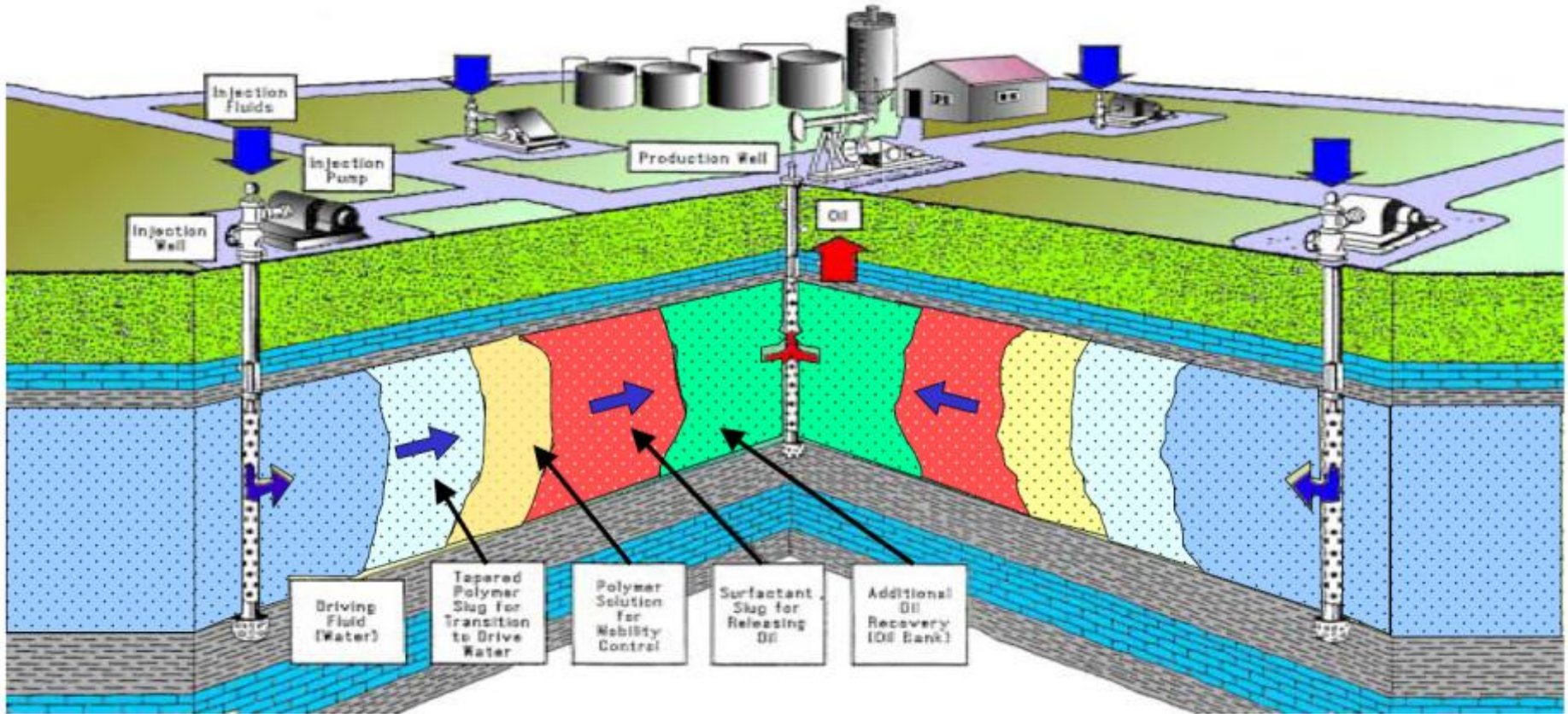


Introduction

- Water – shifting from an operations issue to a strategic issue
 - Offshore – expensive and logistically difficult
 - Onshore – limited resources in remote areas, challenging logistics
- Water treatment
 - Non-core capability for oil producers
 - “Weak link” in oil production
- Need innovative water treatment technologies to address growing demands
- Goals: minimize operating costs, maximize footprint and energy efficiency, maintain production and/or increase oil recovery rates



Reservoir Subsurface



Driving Fluid (Water)

Tapered Polymer Slug for Transition to Drive Water

Polymer Solution for Mobility Control

Surfactant Slug for Releasing Oil

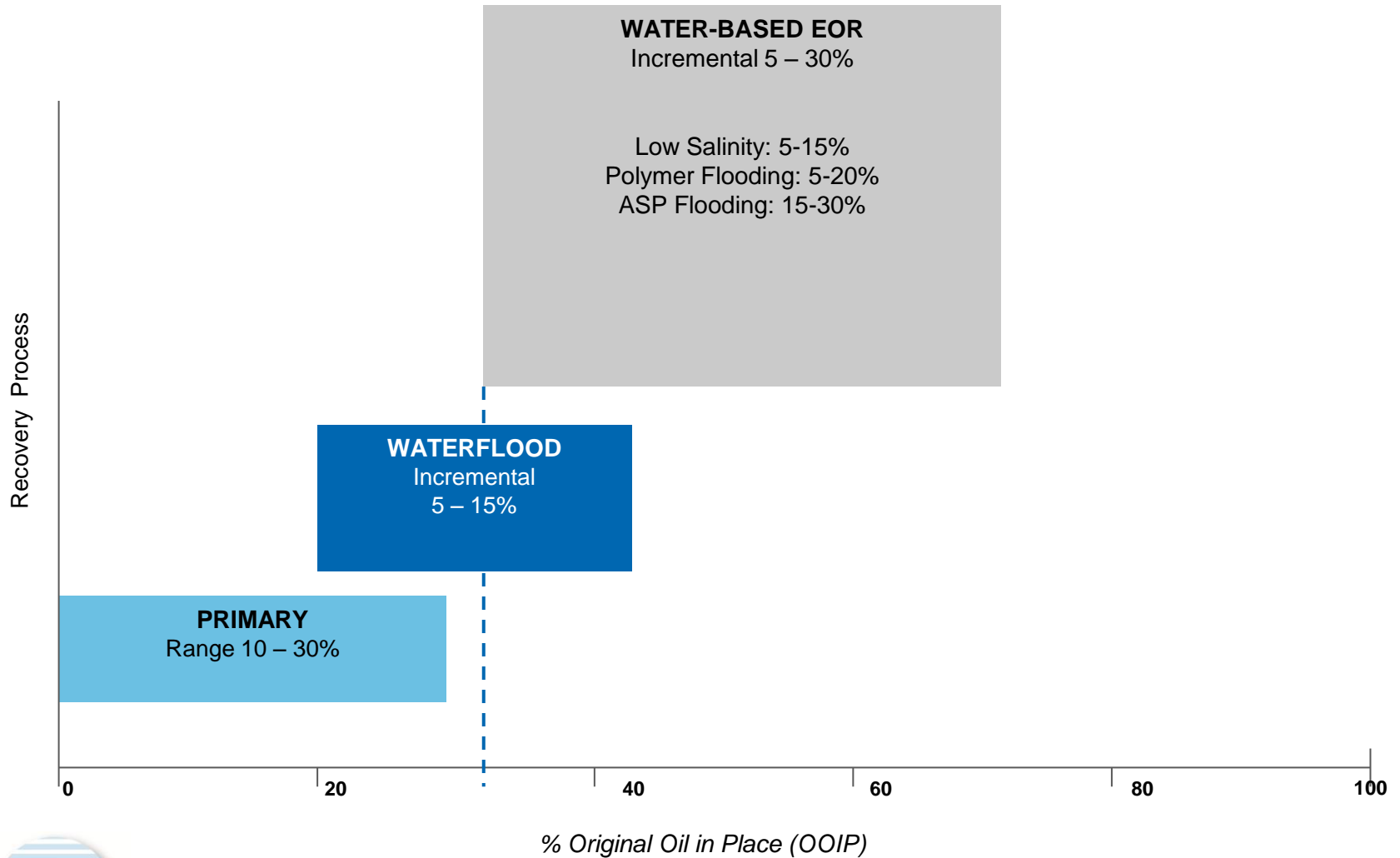
Additional Oil Recovery (Oil Bank)



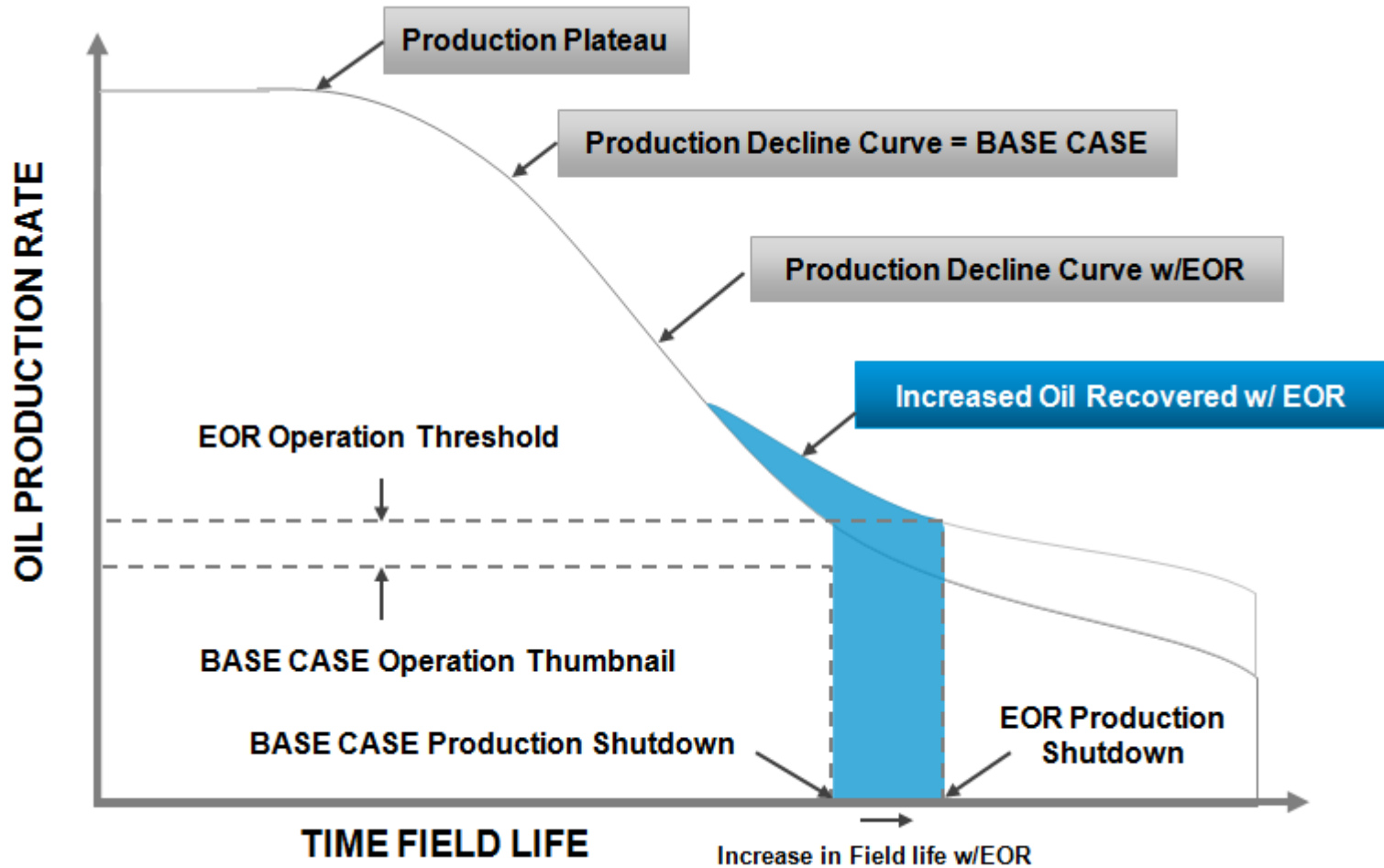
Shell Westhollow Technology Day, 10-13-2009

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Indicative Reservoir Recovery



Oil Field Life with EOR Implementation

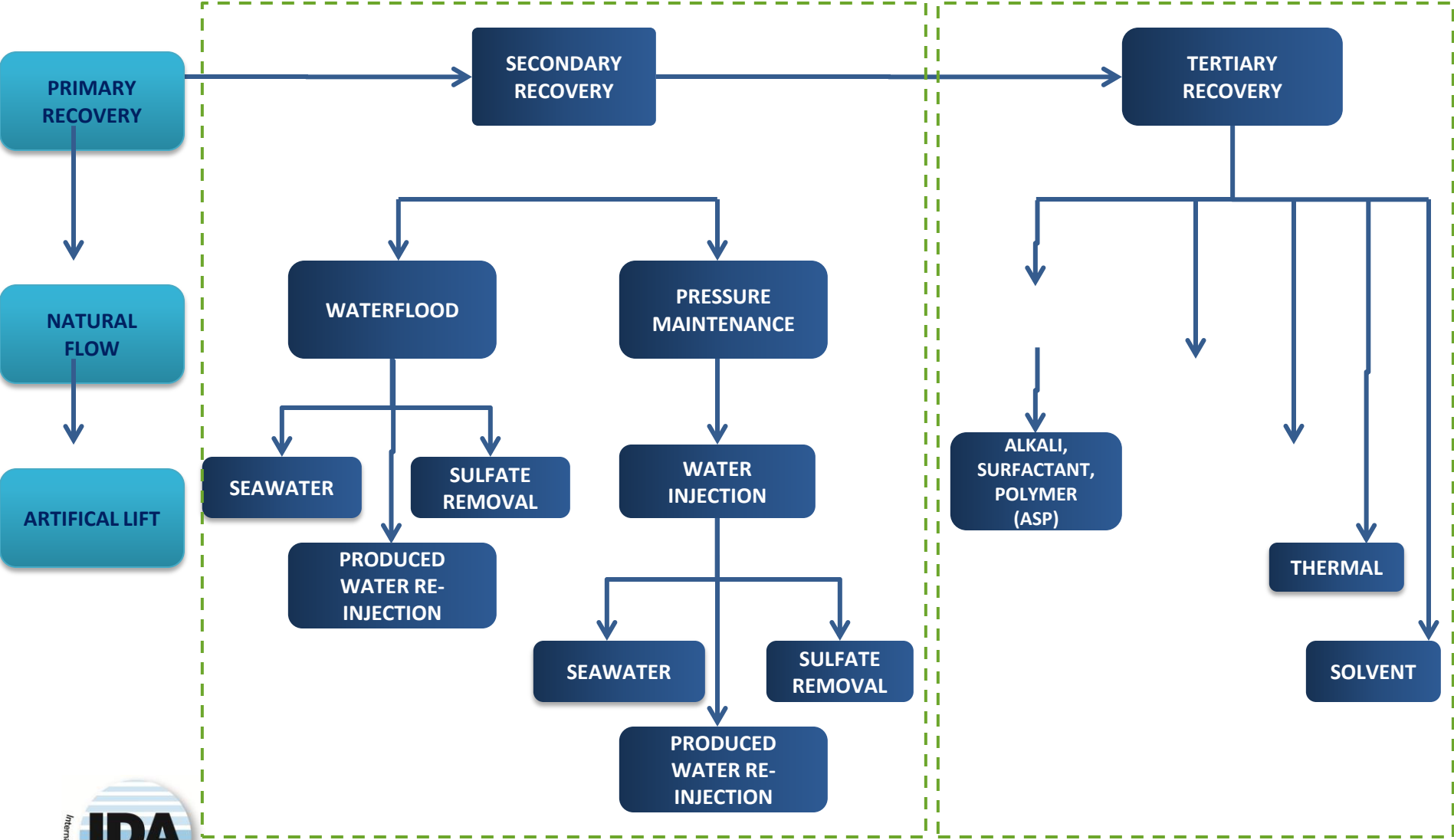


(Note: This graph is representative. Many technical, commercial and contractual variables are reservoir dependent.)

Water-Based IOR and EOR Methods

Improved Oil Recovery (IOR)

Enhanced Oil Recovery (EOR)



Sulphate Removal Processes

- Risks
 - Process: Reservoir scaling
 - Economic: Oil quality degrades
 - Safety: H₂S production
- SRP
 - Removes sulphate to prevent process, economic, and safety risks
 - Uses specialized Nanofiltration (NF) membranes to reduce sulphate content in seawater while maintaining high salinity
 - Over 70 systems worldwide, > 7.5M bbl/day capacity (Reyntjens 2013)
- Challenges
 - Relatively high CAPEX
 - Substantial space and weight requirements
 - Platform retrofits often prohibitively expensive

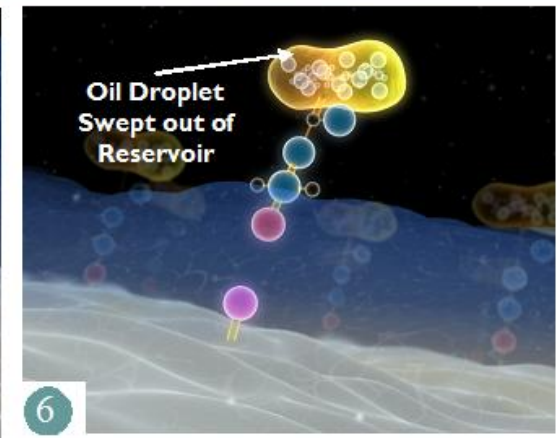
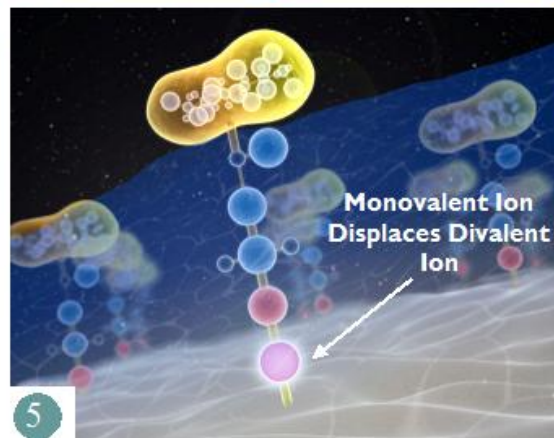
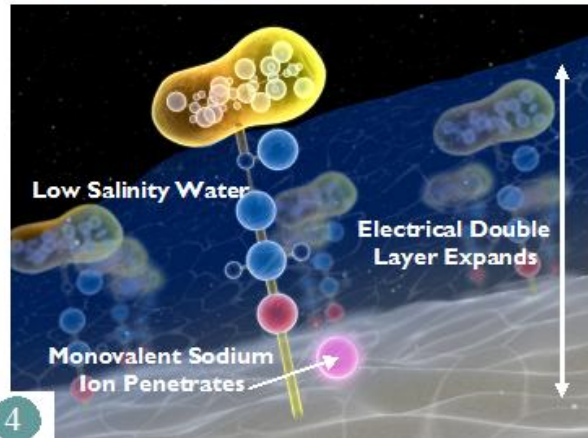
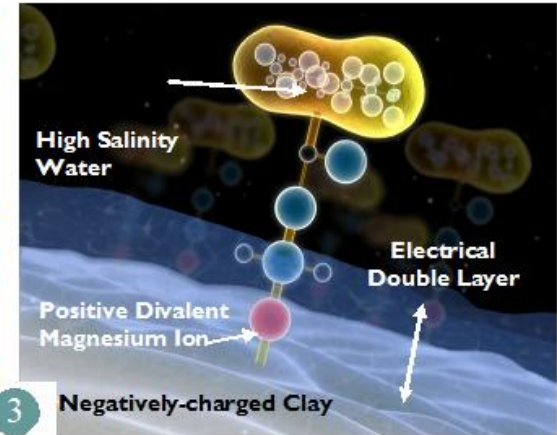
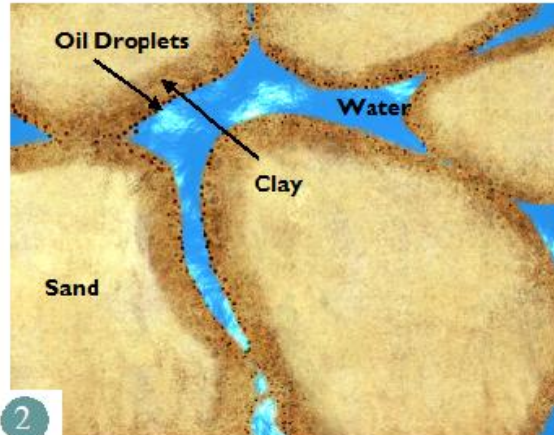
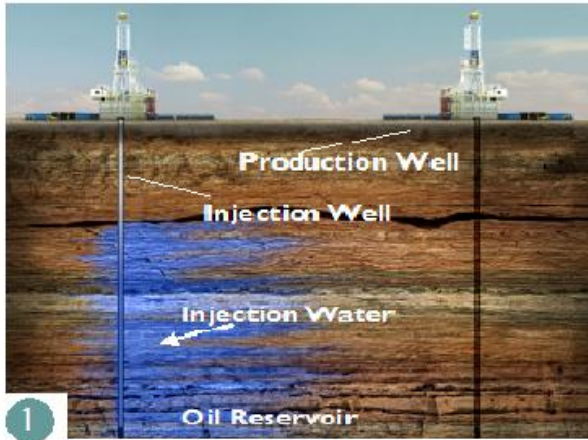


Source: H2Oil & Gas 2012

Low Salinity Waterflooding

- Proposed Mechanisms
 - Multi-Component Ion Exchange (MIE)
 - Fines Migration
 - pH Variation
 - Double layer expansion
- EOR Potential
 - Global water-based EOR potential - ~750 billion barrels
 - North Sea: 6 billion barrels
- Technology
 - EOR – a 1% increase in recovery could yield 2 billion barrels of oil equivalent (*Upstream Technology* 2013)
 - LSF – strong candidate for implementation due to substantial recovery potential and “relative simplicity” when viewed as an extension of seawater injection processes (DECC 2011)

Low Salinity Waterflooding

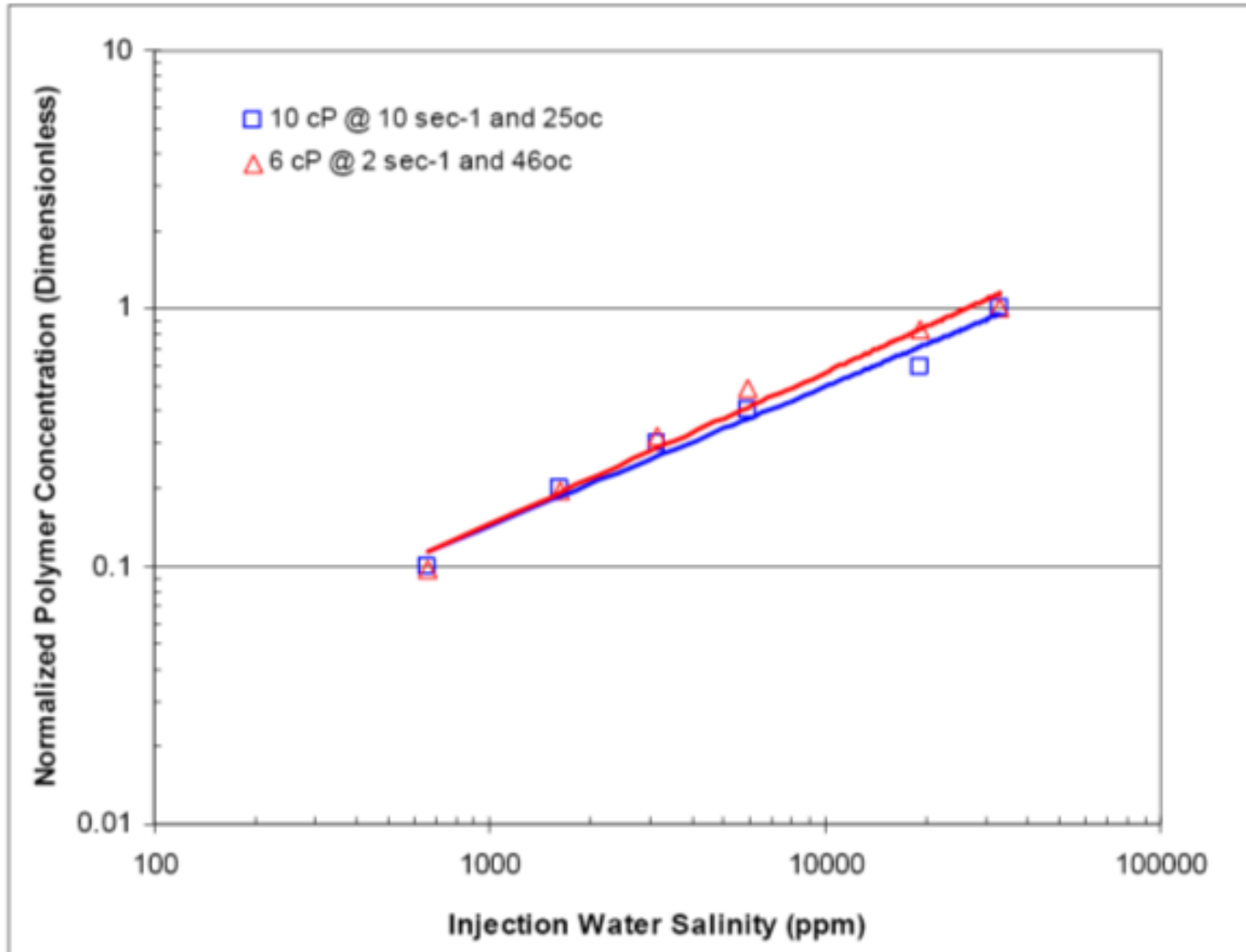


Chemical Enhanced Oil Recovery

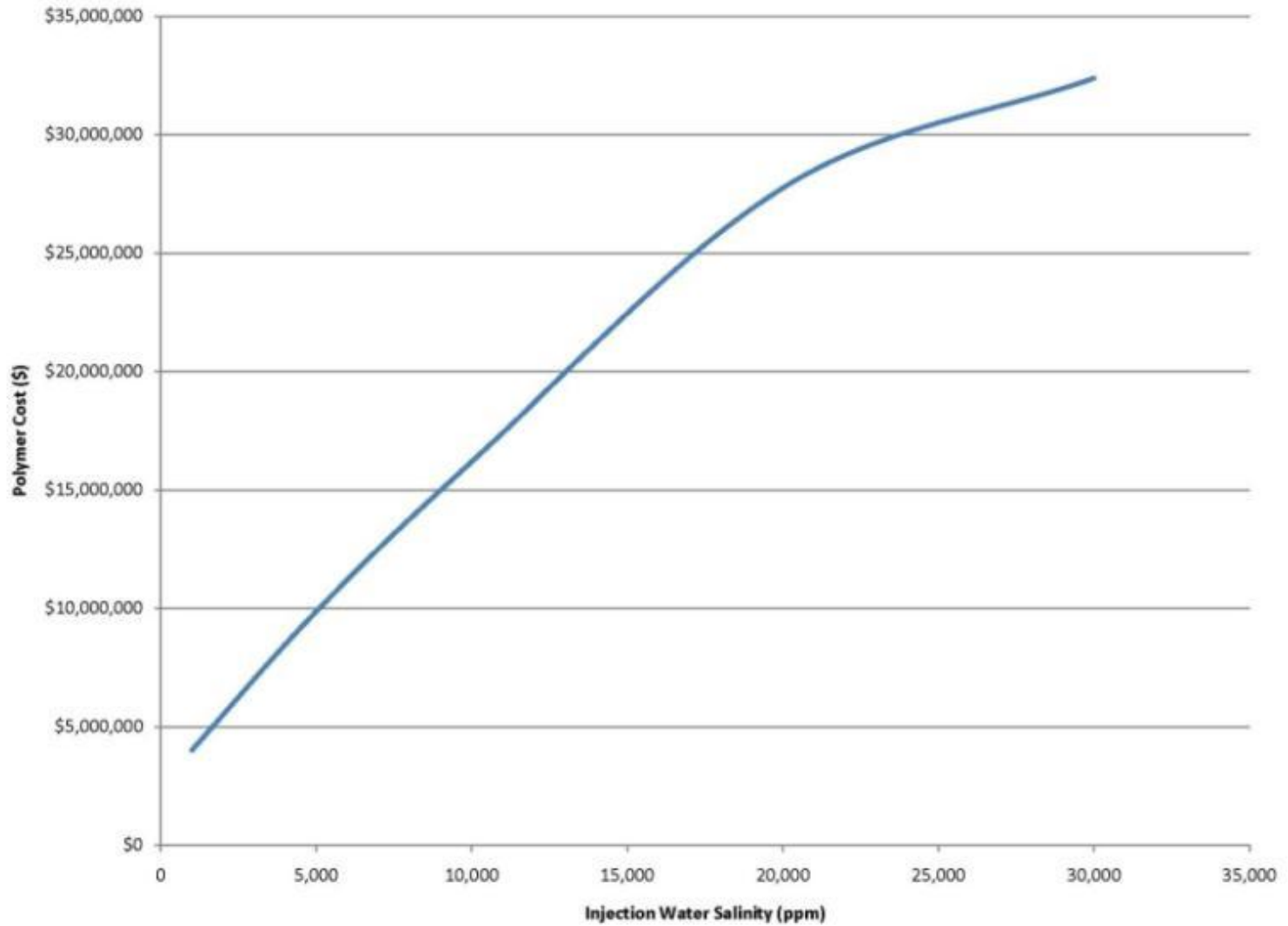
- Typical CEOR Program Chemistry
 - Alkali
 - Surfactant
 - Polymer
- Water Quality Considerations
 - Source water must be softened to prevent hardness from precipitating in the presence of alkali and damaging wells and reservoirs
 - Reducing salinity prior to adding alkali, surfactant and polymer can amplify positive impacts of each individual program
 - Customizing ionic compositions enable optimal polymer viscosities to be achieved easier and more economically



Effect of Salinity on Polymer Requirements



Effect of Salinity on Polymer Cost

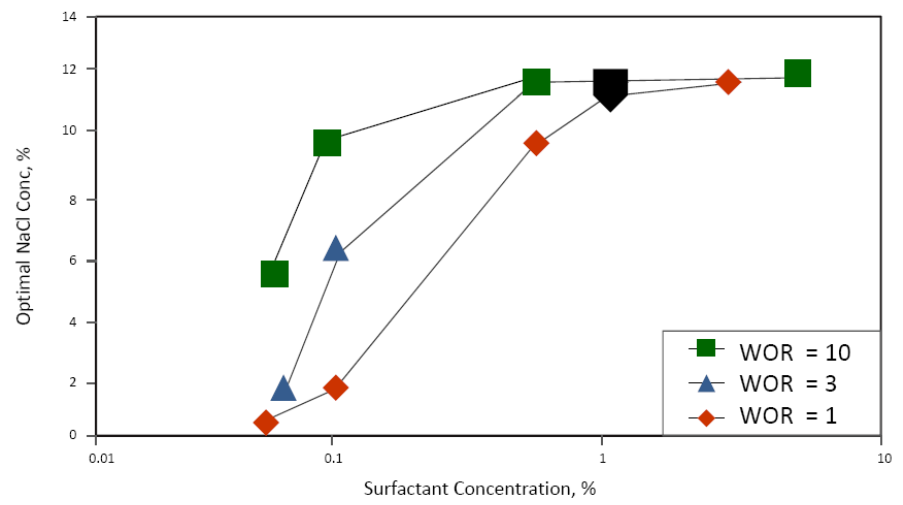
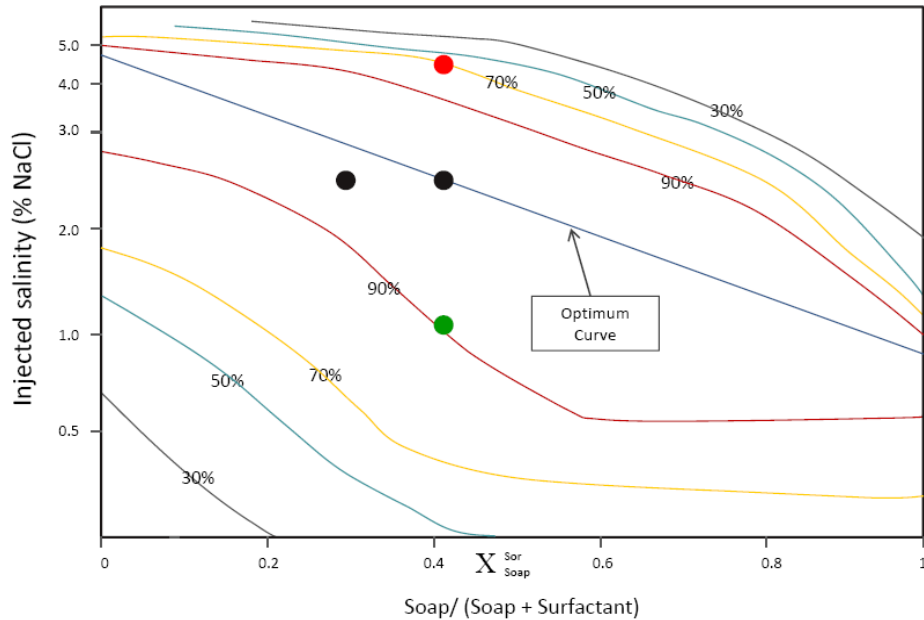


Adapted from Ayirala, S., Ernesto, U., Matzakos, A., Chin, R., Doe, P., van Den Hoek, P., 2010

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Optimal Salinity for Surfactant Floods



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Case Study

- Goal: Demonstrate the effect of salinity on EOR program costs and revenues
- Cases
 1. SRP for IOR waterflooding programs, paired with either surfactant or polymer to increase recovery
 2. LSF for water injection only, and enhanced with the addition of chemicals
 3. Water Softening using NF treatment for water injection only, and enhanced with chemical addition



Assumptions

Required Chemical Concentration by Water Treatment Process

	Resulting Salinity (TDS)	Alkali Concentration (mg/L)	Surfactant Concentration (mg/L)	Polymer Concentration (mg/L)
SRP	23,000	-	1,000	1,200
Low Salinity	1,500	14,000	1,000	250
Softening (Nanofiltration)	20,000	14,000	1,000	1,100

Indicative Incremental Oil Recovery by Treatment Process (Not Cumulative)

	Water Injection Only (no ASP)	Polymer (P)	Alkali-Surfactant (AS)	Alkali-Polymer (AP)	Surfactant-Polymer (SP)	Alkali-Surfactant-Polymer (ASP)
SRP	0%	3%	-	-	4%	-
Low Salinity	6%	10%	7%	12%	15%	20%
Softening (Nano-Filtration)	2%	6%	5%	8%	10%	12%

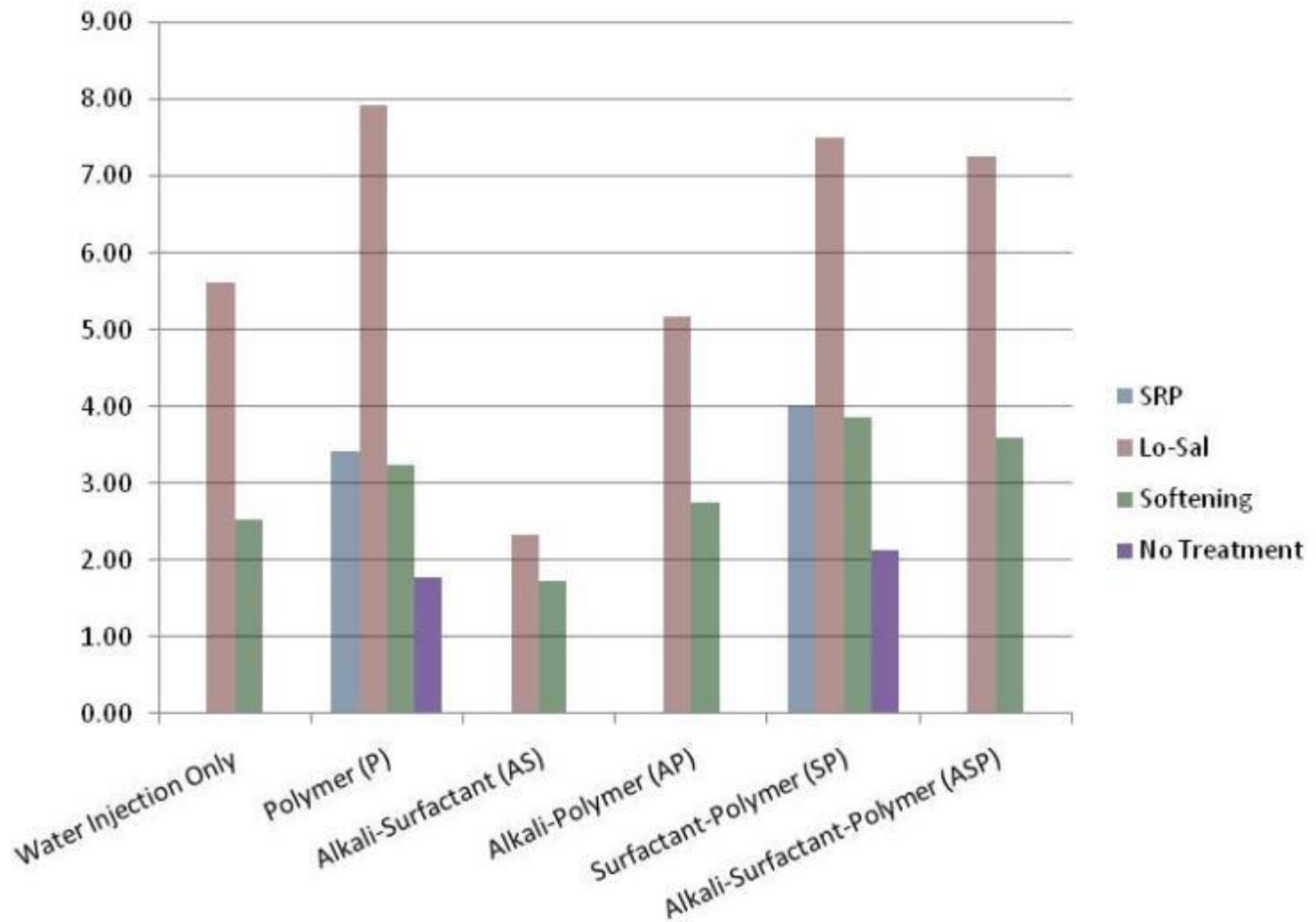


Assumptions

- CAPEX
 - Included: water treatment equipment (e.g., pre-treatment, membranes, energy-recovery devices), chemical injection system
 - Neglected: intake, discharge, electrical systems, piping, engineering, and integration
 - Assume: seawater feed, produced water does not require further treatment
- OPEX
 - Included: fuel, water treatment membrane replacement, chemicals
 - Neglected: labor, maintenance, equipment replacement
- Revenue
 - Based on projected increases in oil recovery
 - 100,000 bbl/day water injection program
 - 10 years
 - \$40/bbl for additional oil after the deduction of royalties and taxes



Case Study – Relative ROI



Conclusions

- Water poses significant challenges for the offshore oil industry
- IOR and EOR programs may reduce process, safety, and economic risks
- Specialized membrane technologies can help IOR and EOR project benefits to be fully realized
- Investment in water treatment systems can increase oil production with revenues proving the return on the initial capital investment

