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Produced Water Management

A Legacy or an Opportunity for Sustainable Field Development

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Acknowledgments

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Outline

- ✓ Global energy and water challenges
- ✓ Produced water from oil fields : sources & challenges
- ✓ Water management best practices
- ✓ Examples where technology enabled integrated water management
- ✓ Key messages

The 'Global Energy Challenge'

Providing access to modern energy for all

Meeting energy growing demand while reducing environmental and social impacts

Shifting towards a low-carbon energy system

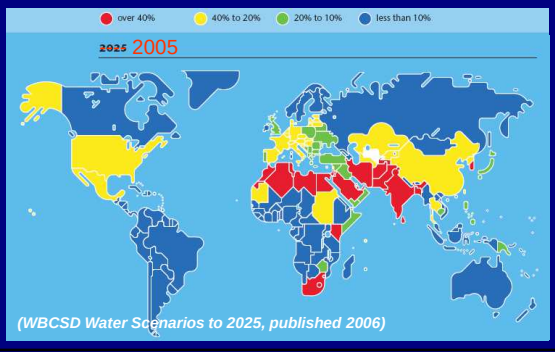
Front-page Global Country Issues

Energy diversity & security

Climate change Local air pollution

Water Scarcity

Freshwater stress is increasing faster than expected

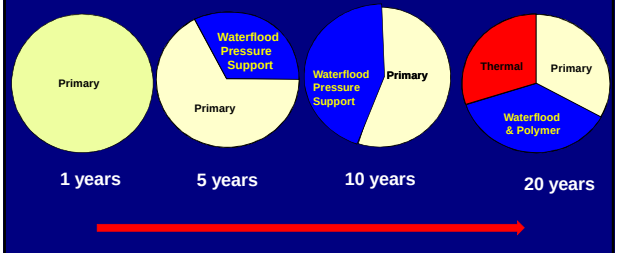


(WBCSD Water Scenarios to 2025, published 2006)

Overall Drivers for Valuing Water

- **Fresh Water Scarcity** : impacts water availability
- **Depletion of Easy Oil :** increased fresh water need for Enhanced Oil Recovery such as for Steam or Polymer processes
- **Unconventionals** : High demand for fresh water in preparing Frac fluids
- **Tightening Disposal Regulation** : Increasing needs to meet the regulations for disposal of produced water
- **Energy / CO_2 / Water :** Interdependence

High Water Footprint with IOR/EOR



- ✓ Water Footprint increases with Recovery Processes
- ✓ Water Quality requirement increases with Secondary and Tertiary Recovery processes

Unconventional Development

Fresh Water Use of Four Major Chesapeake Deep Shale Natural Gas Plays

Shale Play	Average Water Use Per Well (in gallons) *	CHK Estimated Average Natural Gas Production Over Life of Well (in cubic feet) **
Fayetteville	4,065,000	2,200,000,000
Barnett	3,400,000	2,650,000,000
Marcellus	4,100,000	3,750,000,000
Haynesville	4,000,000	6,500,000,000

*Source: *Chesapeake Energy 2009b, **Chesapeake Energy 2009c, ***USDOE 2007*

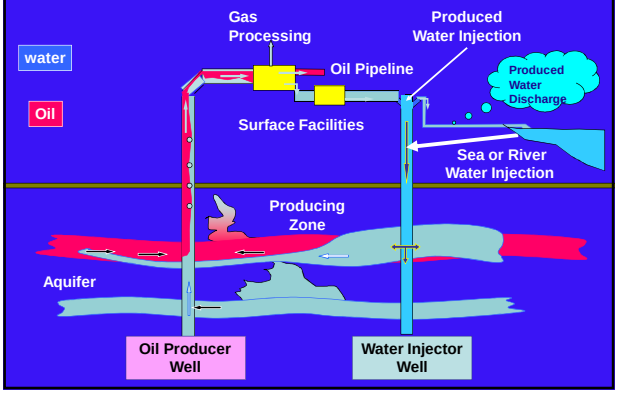
Globally and on Average

For Every Barrel of Oil Produced
> 3 Barrels of Water are Co-produced

and

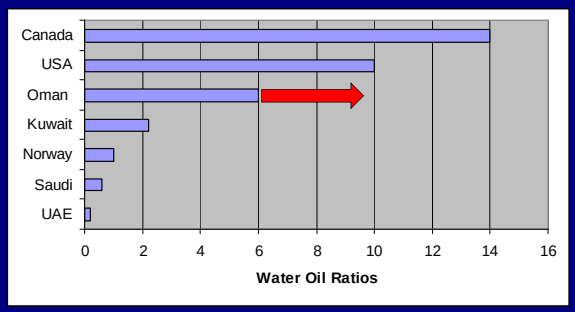
Average Global Produced Water Volumes is increasing by 10% per year

Oil & Gas Produced Water Sources



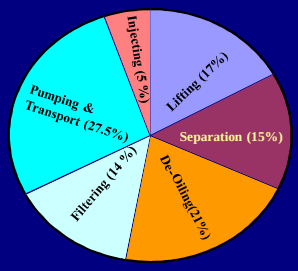
Average Produced Water Per Country

Water Oil Ratios (Bbl/bbl)



Produced Water Handling Is Costly

Estimated CAPEX & OPEX Cost worldwide is ~ $50 billions/yr



Cost ranges from $0.15 - $15/bbl of water

Many Water Challenges Composition and its Impact on Operations

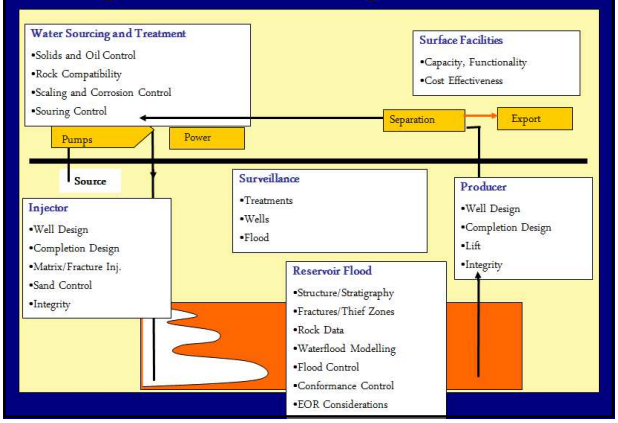
- Demulsifiers (separators, water treatment, other topside vessels)
- Scale (Wellbore, pipelines, topsides)
- Asphaltene and Wax Deposition
- Hydrate potential (pipelines and risers)
- Reservoir Souring

Intervention costs are >$$$ millions
+ loss in production due to unscheduled shut down

Water Management Best Practices

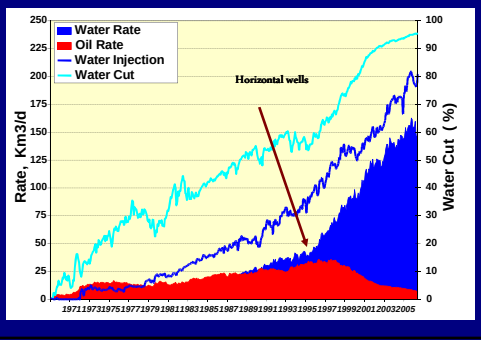
- ✓ ***Minimize*** the volumes to Surface
- ✓ ***Maximize*** re-use of water by injecting into hydrocarbon producing formation
- ✓ ***Reduce*** facilities footprint and cost
- ✓ ***Use beneficially*** all resources
- ✓ ***Safeguard*** open waters & aquifers

Is Integrated Water Management a must?

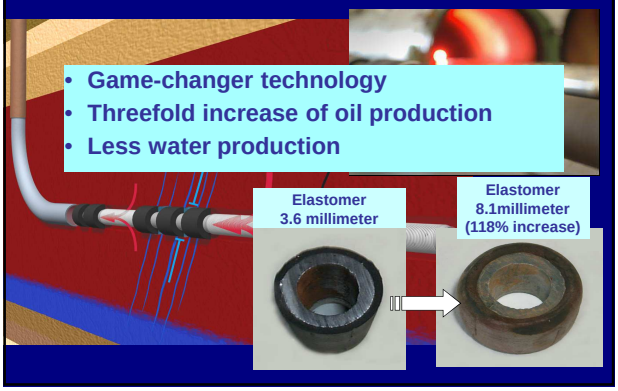


Examples Where Technology Enabled Integrated Water Management

Use of Horizontal Wells Sustained Oil Production for Decades but Increased Water Production Drastically



Novel Zonal Isolation of Water

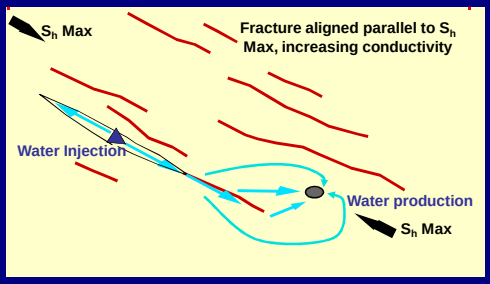


EZIP's Applications

On average Reduced Water Cut from 90% to 10% & Increased the Oil Production by a factor of 10

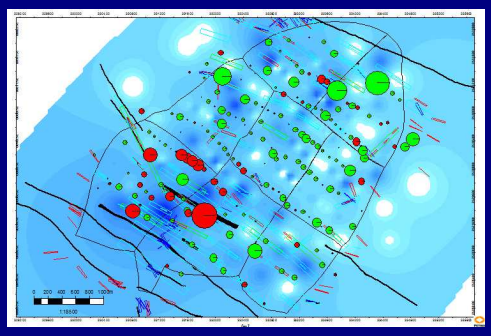
The value for a 5 year implementation plan was >> $ 45 millions

Early Water Breakthrough in Naturally Fractured Reservoirs



- Short cutting injector - producer
- Reduced sweep (near injector?)

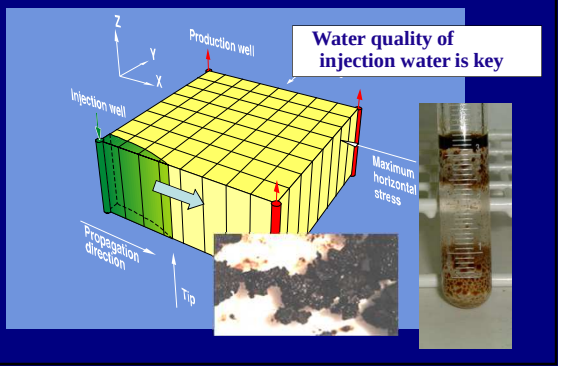
Reservoir Characterisation & Management



Good Injection — No Injection

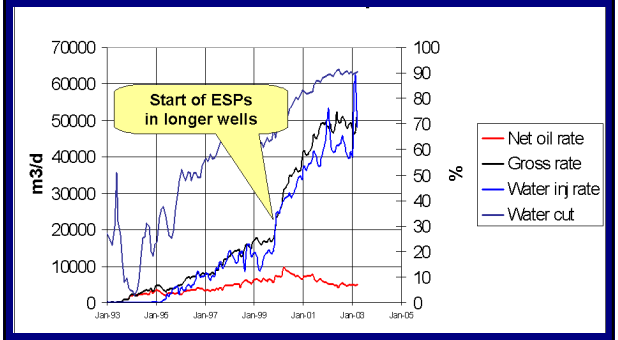
Oil Gain — Oil Loss

Control of Induced Fractures During Water Flood



Using High Rate ESP's

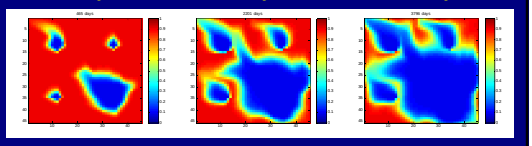
Unfavorable Mobility Ratio Increased Water Production



Control of Pressure at Injectors

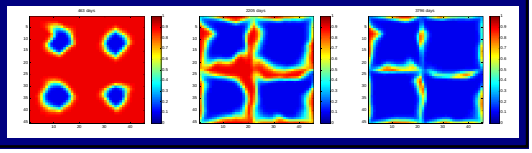
Conventional- Pressure Control at Producers

1.5 yrs **6 yrs** **10 yrs**

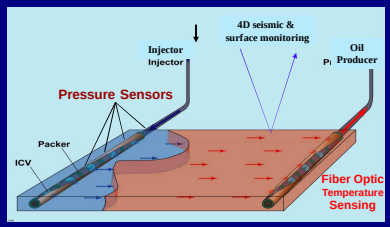


Ultimate Recovery > 15%

Optimal – Pressure Control at Injectors



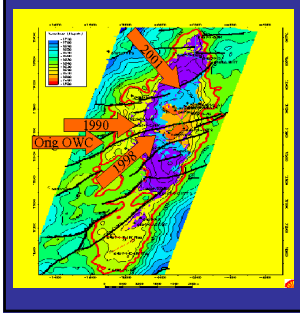
Smart Field Technologies



- **Managing breakthrough** - key to development & facility concepts
- **Managing profile** - Control of in-situ sweep & connectivity
- **Ensuring oil recovery through dynamic flood optimization** by continuous monitoring and adjustments

Water Front Management and Oil Tracking

(Application of 4D Seismic improved Well Strategy)



Outcome

- ✓ Increased intensity of injection to southern wells
- ✓ Converted high water cut producers to injectors
- ✓ Used produced water injection instead of seawater in the North

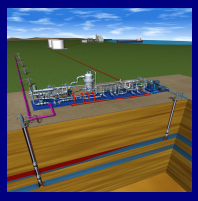
Small Foot Print Facilities

"Lower Impact on Environment"

(Modular, Compact, Fit for Purpose Facilities)

Offshore Assets

Land Assets

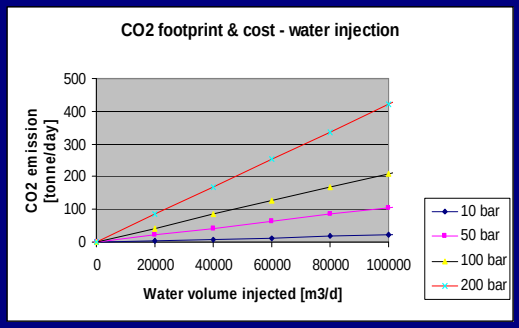


Deepwater Sub-sea

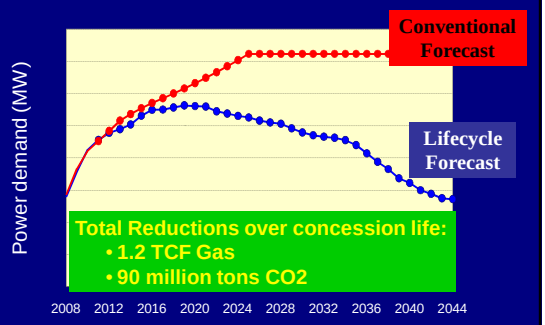
But the challenges are increasing →

Link between Energy, CO_2 and Water

" Injection in Deep Disposal Wells "

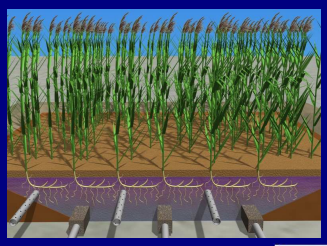


Think of a "Water Master Plan" within Energy Master Plan for Lifecycle of Fields



Reedbed/ Bio filter: removing hydrocarbon & metals

"oily & contaminated" Production water



"clean" Production water

Picture of Reedbeds in Oman

Cost Estimates for Low Salinity Produced Water

* Cost in $cents/bbl water	CAPEX	OPEX	Total
Reed Beds	2.4-3	2.4-3	4.8-6
Deep Well Disposal	7.4-8	7.4-8	14.8-16
Reverse Osmosis	4-5	4.8-6	8.8-11

* For about 300MBWPD , Low Salinity Processing Facilities , Oman

Reed Beds appear to be the Cheapest option

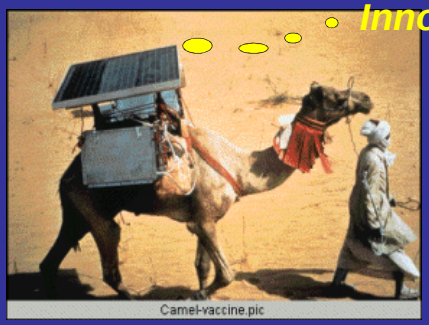
Key Messages & Conclusions

- ✓ Produced Water is > 3 times the oil production and has been increasing at about 10% per year
- ✓ Water management practices are an integral part of effective well and reservoir management
- ✓ Technology enables integrated water management but the challenge is in the implementation

Key Messages & Conclusions

- ✓ Produced water is a valuable resource particularly in an increasingly constrained fresh water world
- ✓ Integrated Water Management is good business for extending life of mature fields :
  - o Increased Recovery Factors and
  - o Improved Operational Efficiency

"We are all guardians of the future. What we do today will impact on the world that the next generations will inherit"



Innovation

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Thank You

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