

Primary funding is provided by

# **The SPE Foundation through member donations and a contribution from Offshore Europe**

The Society is grateful to those companies that  
allow their professionals to serve as lecturers

Additional support provided by AIME



Society of Petroleum Engineers  
Distinguished Lecturer Program  
[www.spe.org/dl](http://www.spe.org/dl)

# Active Oilfield Development While Preserving Fragile Ecosystems

James Arukhe

أرامكو السعودية  
saudi aramco



Society of Petroleum Engineers  
Distinguished Lecturer Program  
[www.spe.org/dl](http://www.spe.org/dl)

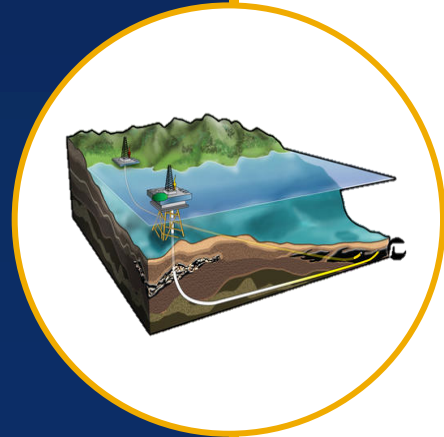


# Environmentally Sensitive Oilfields



Countries	Production (in '000 barrels per day)
Saudi Arabia	10,521
Russia	10,146
United States	9,688
China	4,273
Iran	4,252
Canada	3,483
Mexico	2,983
United Arab Emirates	2,813
Brazil	2,719
Nigeria	2,458
Kuwait	2,450
Iraq	2,408
Venezuela	2,375
Norway	2,134
Algeria	2,078

# Outline



**Key Takeaways/ Background**



**Environmental Impact Assessment**



**Problems/Challenges**



**Integrated Approaches**



**Results**



**Conclusion**

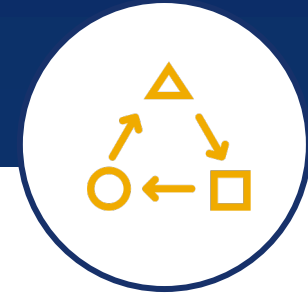
# Key Takeaways: 1 of 2



**Economic growth and environmental protection are possible**



**Collaboration, core values help achieve the impossible**



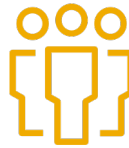
**Paradigm Shifts?**

- Time bounding
- Persevere
- Engage

# Key Takeaways: 2 of 2



Manage “**prior to**  
construction and  
huge capital spend”



**Engage  
Communities**  
(building trust)



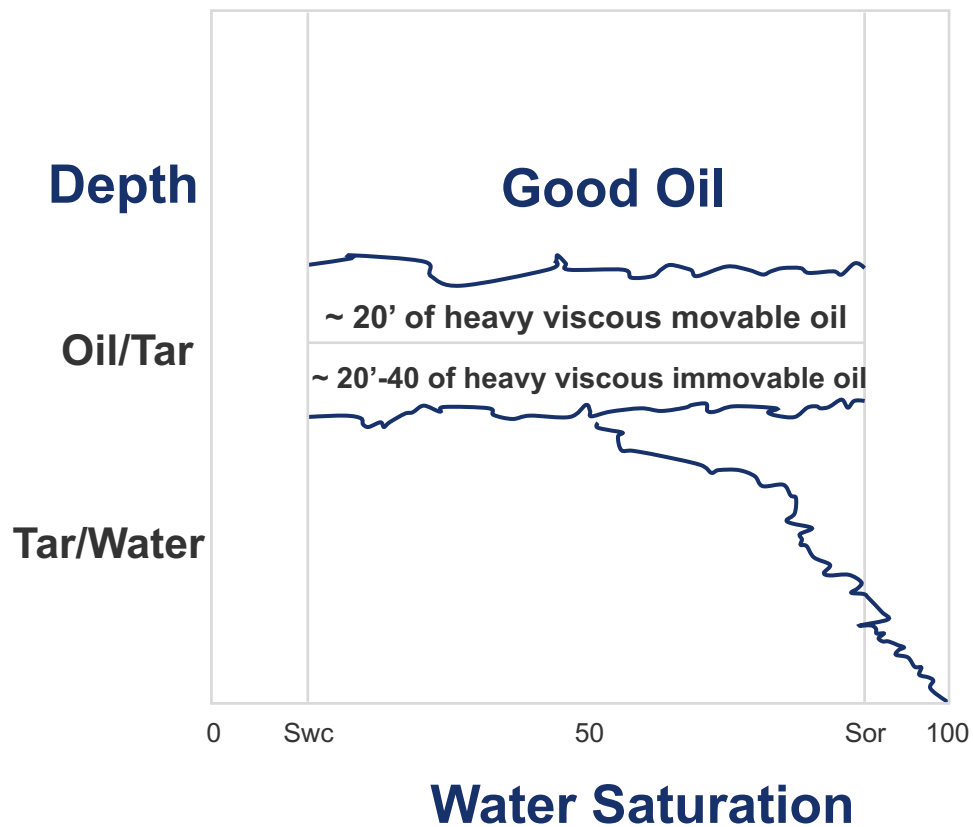
**Qualify New  
Technologies**  
Structurally

# Field Location



# Basic Reservoir Summary

## Top of Structure



The thin reservoir is underlain by heavy and immovable tar.  
The presence of tar creates challenges in:



Pressure  
support



Injector  
placement

**4223** Original Pressure, psig

**14%** H<sub>2</sub>S (gas phase)

**3,688** Present Pressure

**20%** Porosity

**2.8** Fluid viscosity at P<sub>i</sub>  
and T<sub>r</sub>, cp

**1171** Permeability, mD

**29** Stock Tank API°

# Timeline

**1957**

Oil discovery  
in Manifa,  
mainly offshore



**1964**

First sustained  
production  
from Manifa field  
40 MBPD



**1977**

17 wells drilled



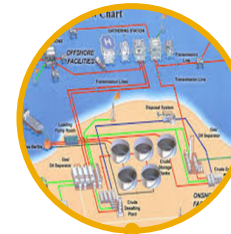
**1984**

Field mothballed  
due to low  
demand



**2006**

Grassroots Field  
Development  
Plan



**2013**

Field and CPF  
commissioning,  
500 MBPD  
Production Capacity










**2017**

900 MBPD  
Production  
Capacity



# Development Options

Method → Requirements

1	30% offshore ■■■	11	
	70% land ■■■■■■■	18	 
2	70% offshore ■■■■■■■	21	
	30% land ■■■	12	 
3	100% offshore ■■■■■■■■■	30	

## LEGEND



Offshore jackets/platforms



Rigs



ERD





# Environmental Impact Assessment (EIA) Objectives



To create an optimal causeway design that minimizes seawater impact



Predict the environmental impact of construction



Recommend measures that mitigate impacts



Tailor monitoring programs



**EIA** showed need to maintain water circulation and allow marine life to move freely from deeper to shallower water

# Environmental Factors



**Highly productive marine ecosystem**



**Oilfield's proximity to Arabian Gulf Shoreline**



**Biodiverse habitats**



**Livelihood for fishermen and their communities**



**Home to rare species**



**Susceptibility to overfishing and pollution**

# Challenges



## Technical

Heterogeneity & fluid mobilities  
Faults/fractures, light oil on tar  
SPE 164237

Sour, heavy crude;  
Simultaneous Operations  
SPE-181438

Injector well placement  
OTC 25119; SPE 141101; SPE 163908



## Organizational

Qualifying technologies  
(multiple contractors)  
SPE 181438; IPTC 17859

2007/2008 Global  
economic recession  
IPTC-17666

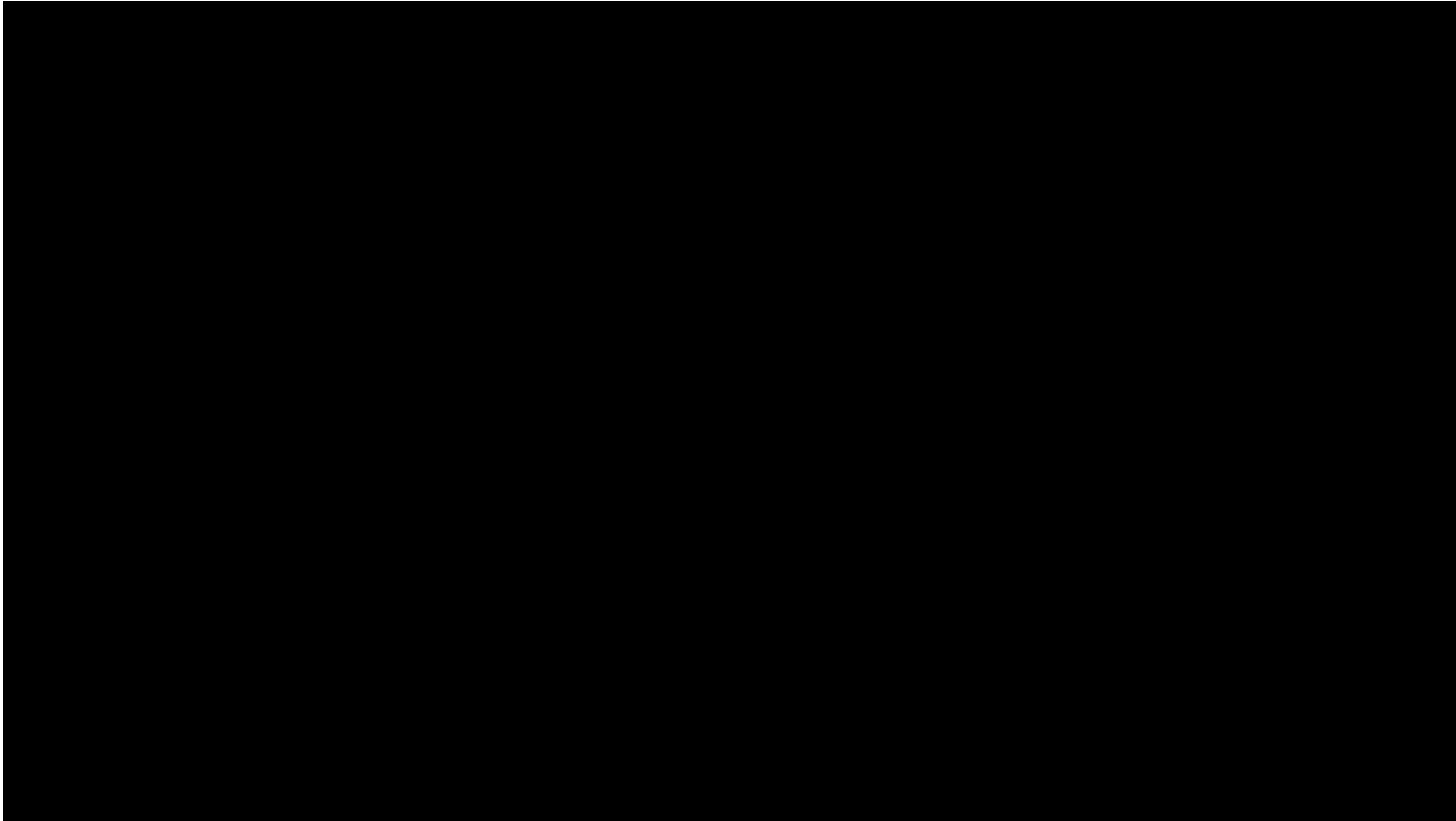


## Environment

Shallow waters  
IPTC 16665

Delicate habitat of seagrass  
and coral reefs (fragile)  
IPTC 17833

# Manifa: Energy and Nature

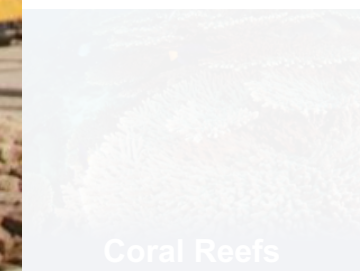


# Environmentally Friendly Oilfield

Coral reefs (artificial) and natural areas for future ge



seawater  
(11 days)  
Biodiversity



Coral Reefs



# Unavoidable Environmental Impacts

01

Loss of large  
sea floor area

02

Dredged  
areas loss

03

Alteration in  
hydrodynamics  
& water circulation

04

Reduced average  
fishery catch

05

Displaced  
fishing grounds

## Offset Mitigation



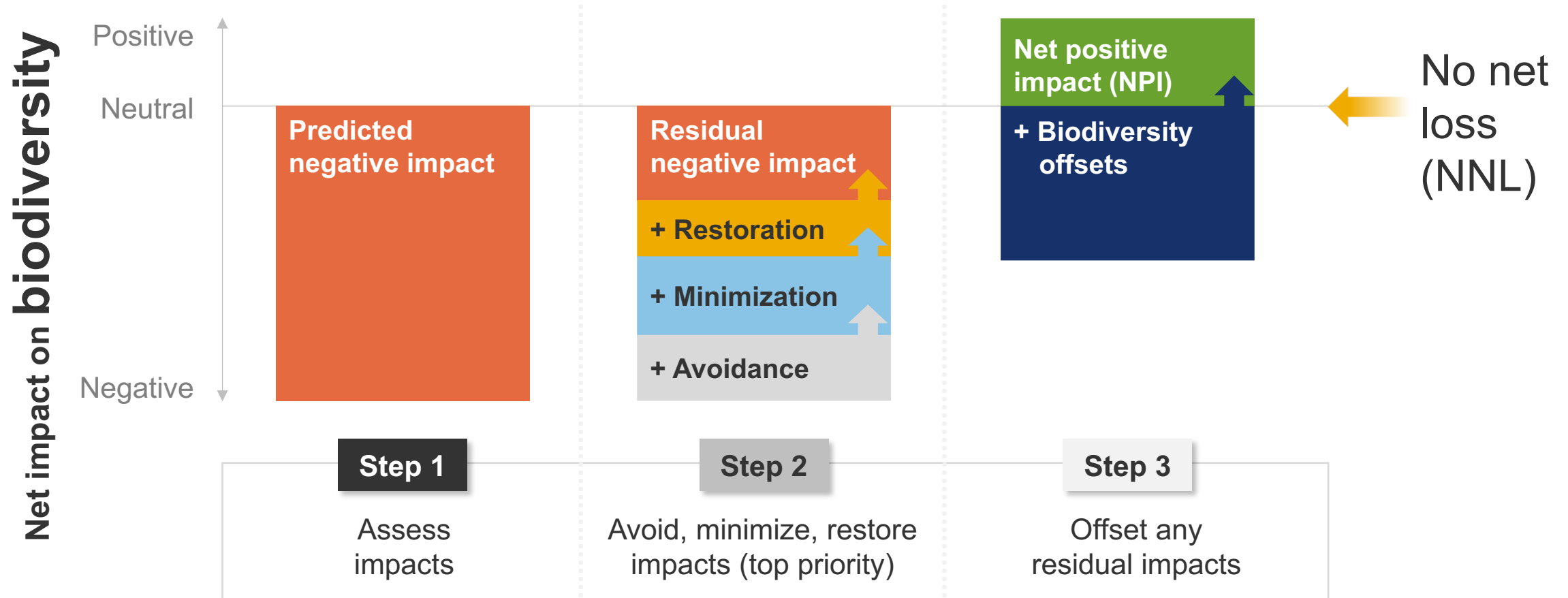
**Fish Hatchery  
for Sea  
Ranching**



**Fisheries Program**  
Arabian Gulf study to  
understand improving fisheries  
statistics and fish stock

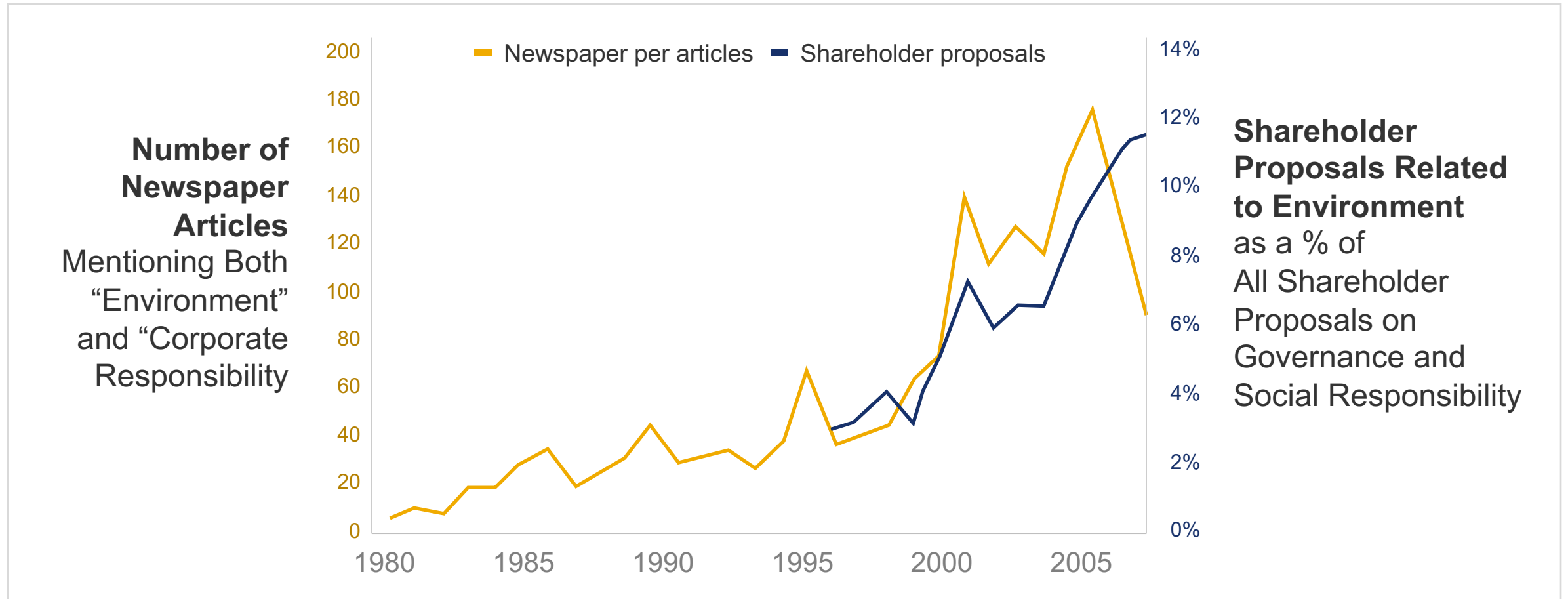
# Benefits of biodiversity offsets

## Mitigation Hierarchy and Biodiversity Impact



# Shareholders interested with environmental friendly company

## Evolution of Media Attention and Shareholder Proposals Related to Environmental CSR

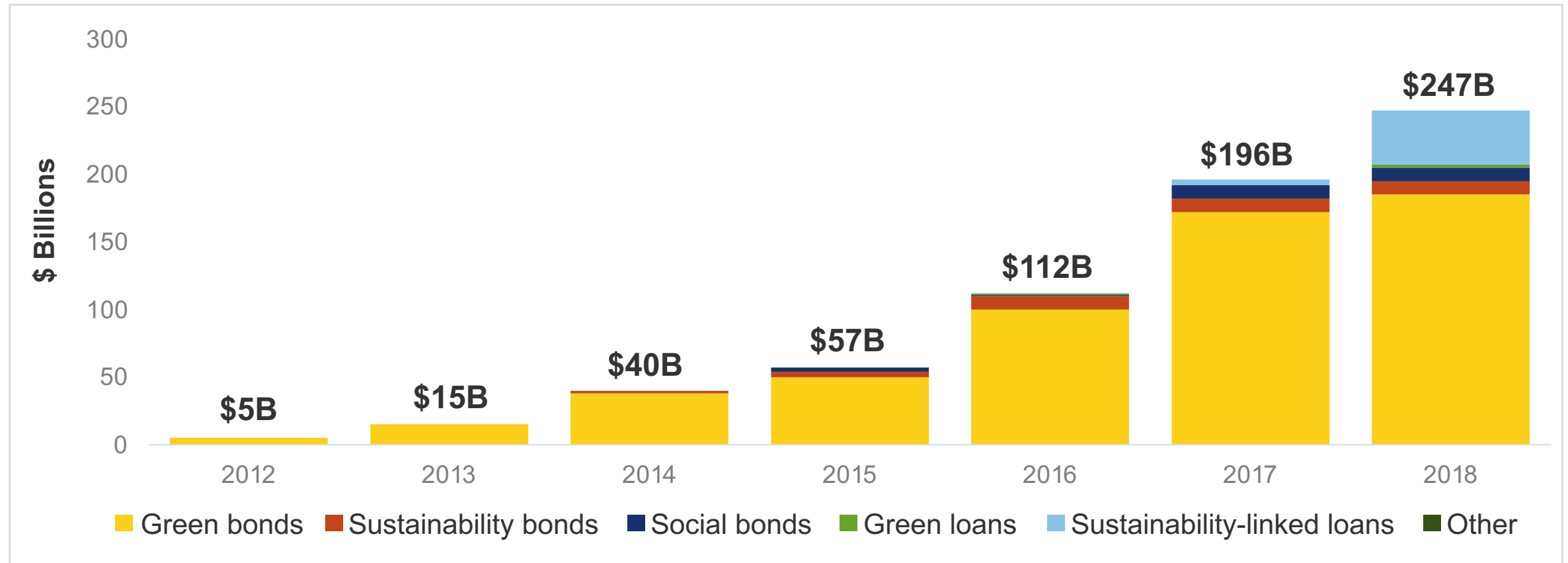




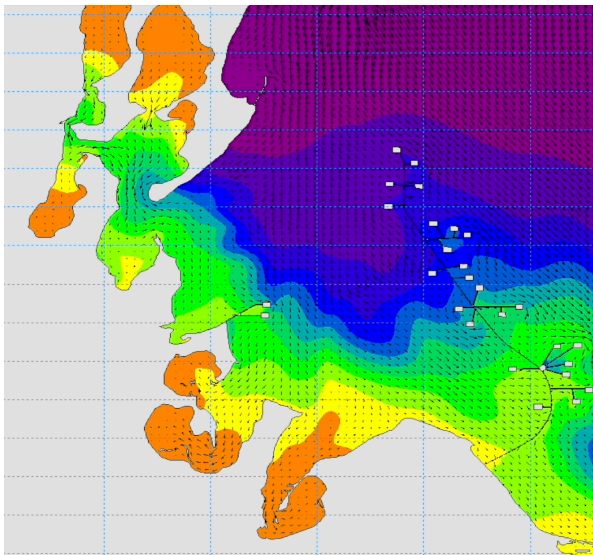
# Biodiversity projects

Increases company valuation and access to loans from financial institutions

## Global sustainable debt annual issuance, 2012-2018

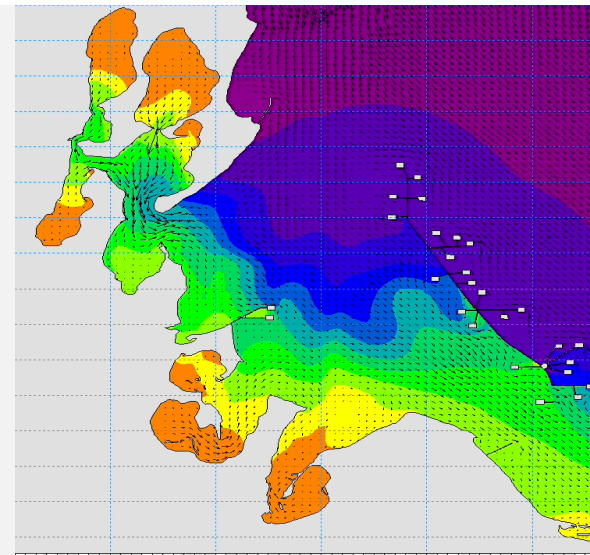


# Pre-Construction: Surveys/Modeling for Protection



**A**

**Solid Causeway:**  
water circulation  
= **71 days**



**B**

**Proposed 2.4 km bridge:**  
water circulation  
= **22 days**  
Natural water  
circulation in Manifa  
= **17 days**

**Without the project, water would take 17 days to naturally circulate**

# Improvements Made on the Causeway

- Widened causeway and coastline space
- Optimized positioning of the man-made islands and causeway



**4.3M** Mangrove  
trees planted



**3** Nesting  
Platforms built



**Established fish hatchery offset program to:**



Release 5 commercially  
relevant species



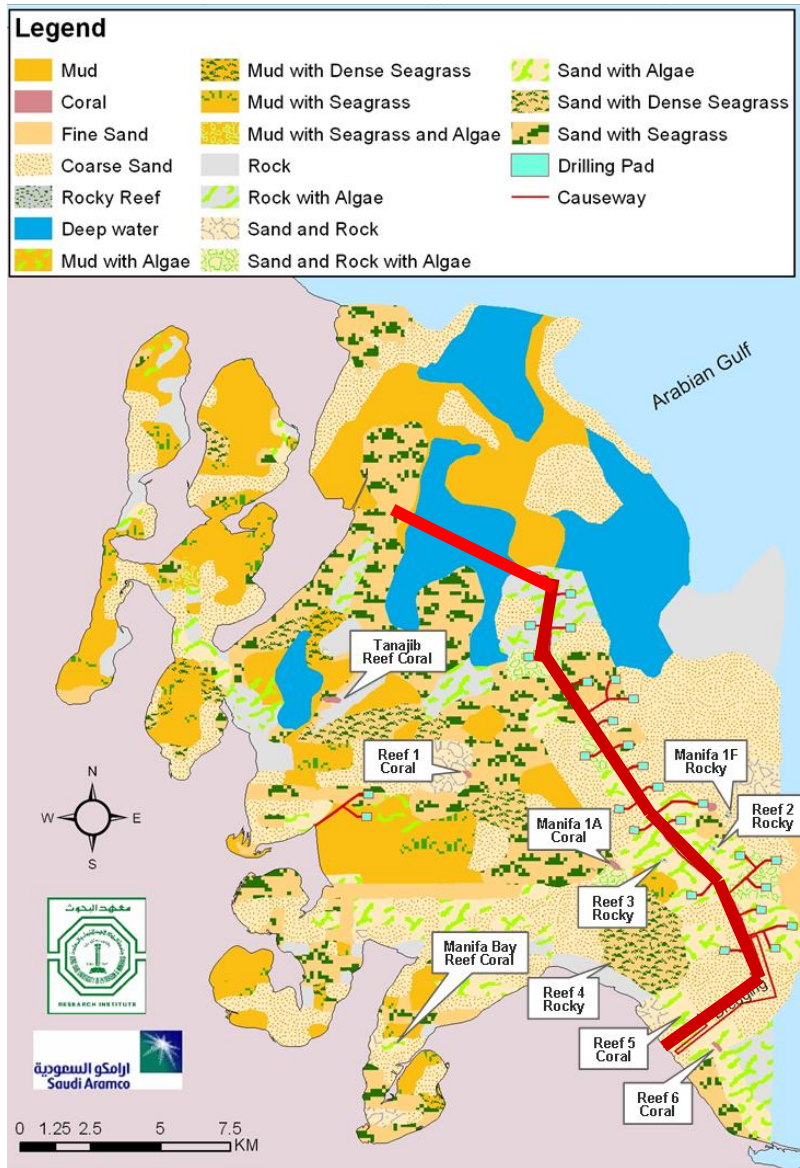
Release 10 million  
juvenile fish per year



# Early Improvements on the Initial Causeway Layout

Adjusting the causeway path to avoid sensitive habitats

Eliminating the Northern Part of the Causeway



# Construction: with Ecosystem Considerations



## Dredging & Sand Reclamation

- Remediation for contaminated sediments
- Restore health of aquatic ecosystems



## Geotextile & Rock Revetment

- Prohibit erosion of the dredged sand slopes
- Protection against wave attack



## Rock Gathering & Placement

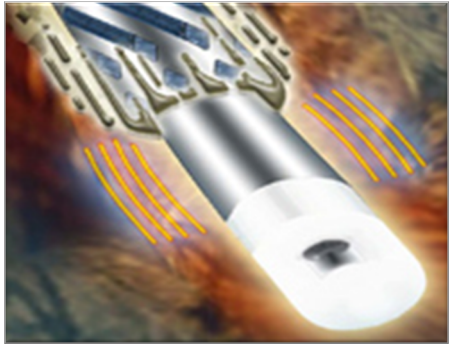
- Dissipate energy of storm waves
- Prevent recession of the backshore



## Bridges Construction

- NW Causeway Eliminated
- Maintain water circulation

# Drilling: Logging, mud use, vessel activity... (1 of 2)



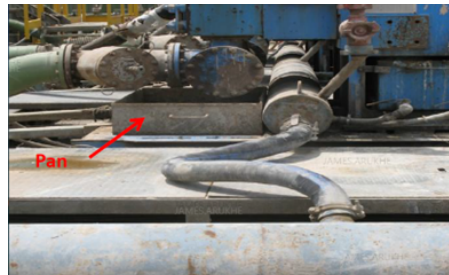
## Nuclear Magnetic Resonance (NMR) logging

- Custom designed, 1st kind
- Clean, non-radioactive
- Real time 3D profile
- Reduced operational risk
- Fewer wells, less footprint



## Recycled mud

- Recovered base fluid suitable for reuse



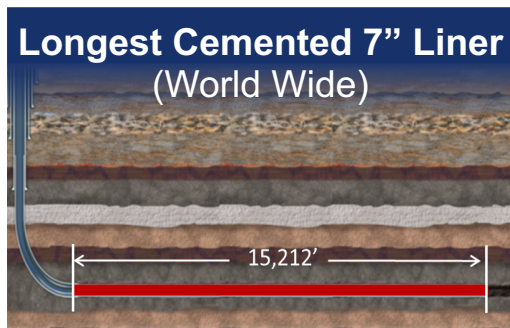
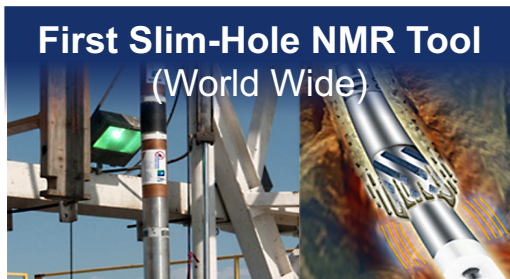
## Decreased vessel activity

- Flexible fully enclosed transfer systems
- Eliminated lifts, reduced transfer time

SPE 20112



# Drilling: Dry Location at Rig Site / Zero Discharge (2 of 2)



**EPDM**  
**Lining**  
(Ethylene  
Propylene  
Diene  
terpolymer)



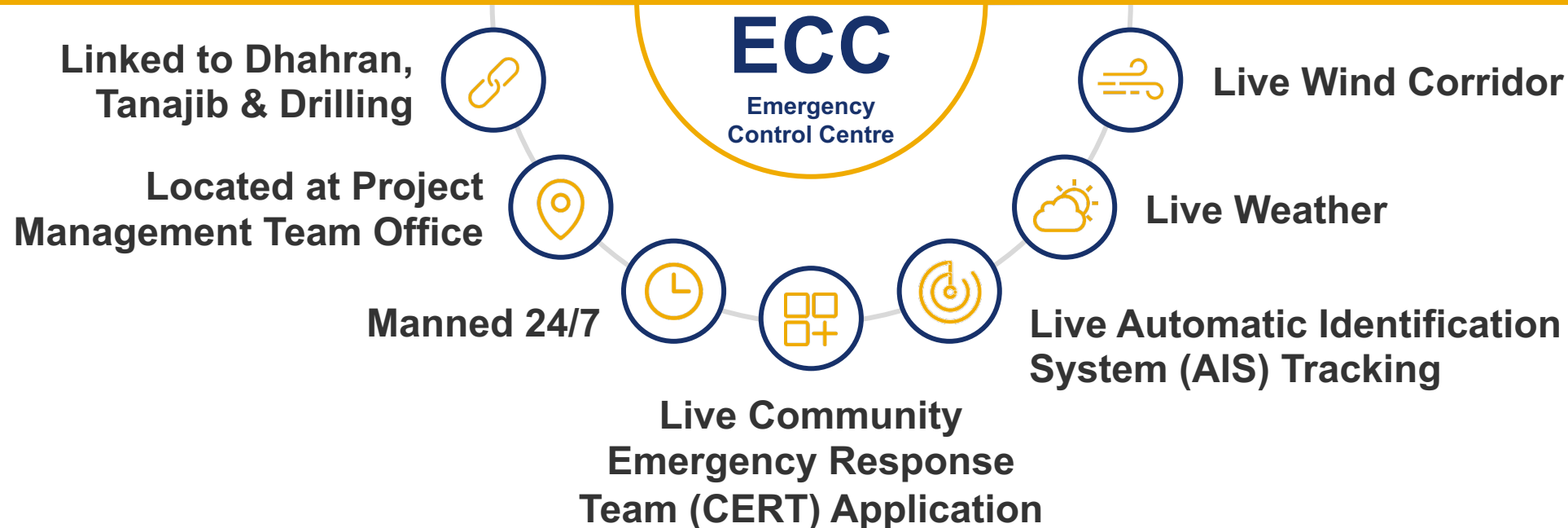
Waste pit at rig site while  
drilling in normal conditions



Site at closure while using  
the Dry Location System



# Monitoring: Operations Oversight....(1 of 2)





# Monitoring: Before, During, After ....(2 of 2)



**Quality readings:  
Sediments/Water  
(Continuous) for  
Compliance**



**Dedicated  
environmental  
monitoring  
vessel with crew**

# Stimulation/logging: Eco-friendly vessel and barge

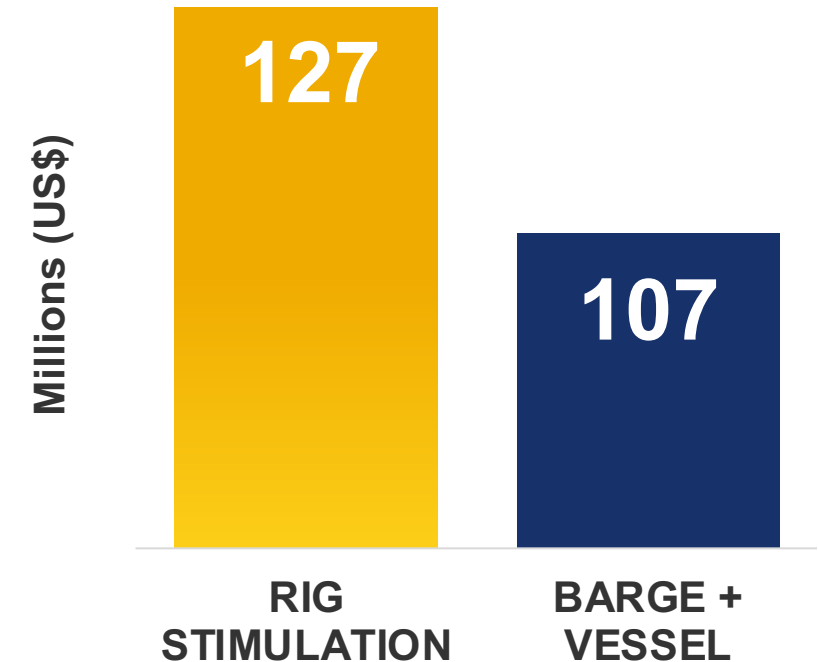


OTC 20112

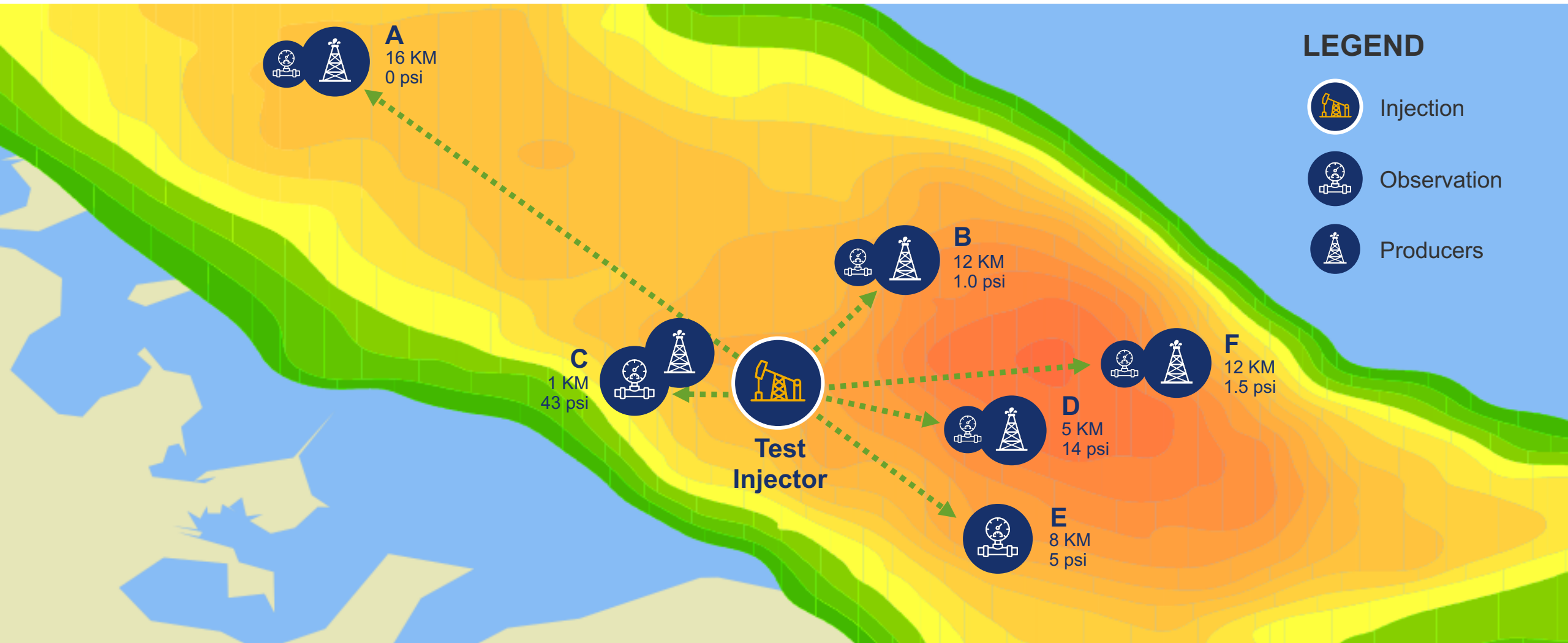
## Stimulation Vessel & Barge

- Emergency disconnection
- Spill Containment
- Water treatment
- Ozone-free refrigerants
- Low fuel consumption
- Low pollutant emissions

## Cost Comparison



# Long-Term Injection Testing

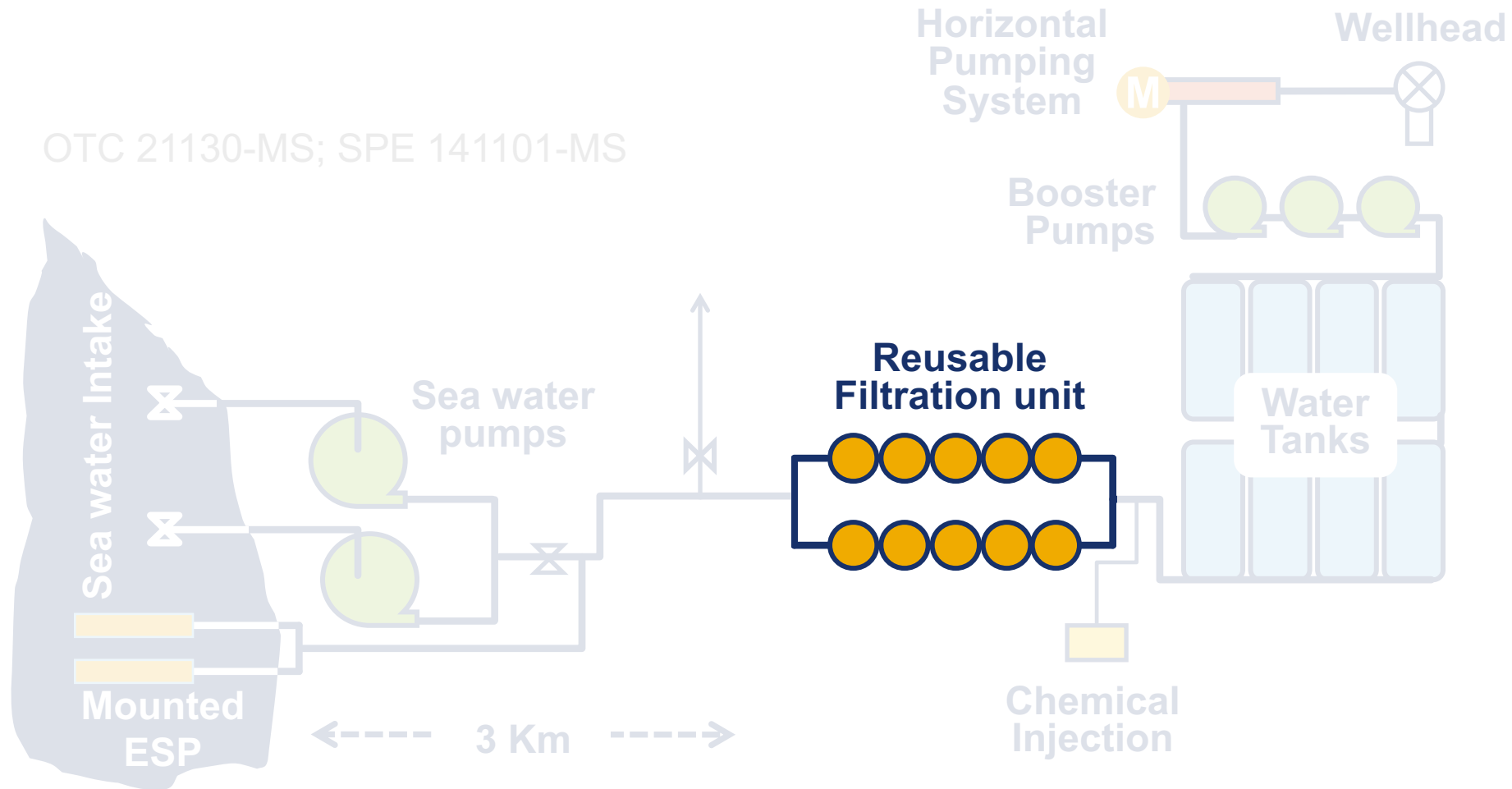


## LEGEND

-  Injection
-  Observation
-  Producers

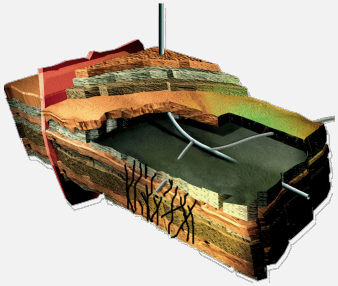
# Long-Term Injection Test: Reusable Filtration

OTC 21130-MS; SPE 141101-MS

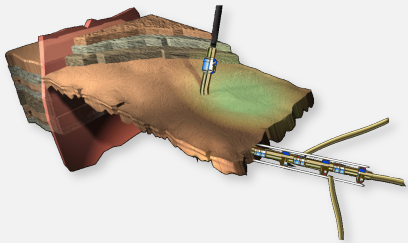




SPE 188732; IPTC 12145



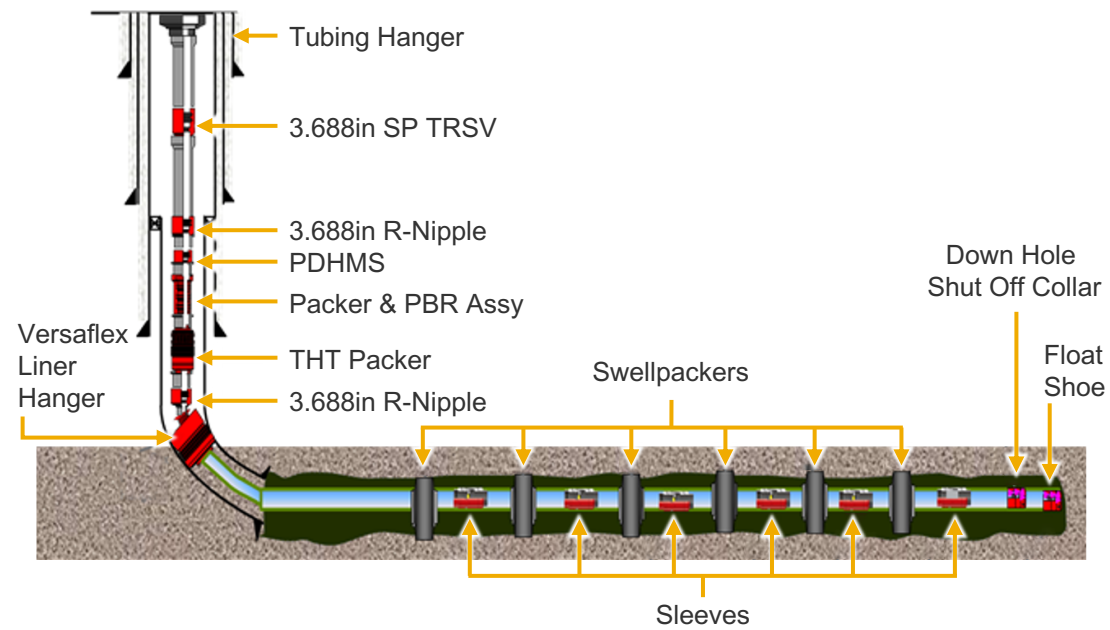
## Geosteered Multilateral (ML) / MRC



# Advanced Completions

## MRC Smart Wells

## Extreme Reservoir Contact (ERC) Wells



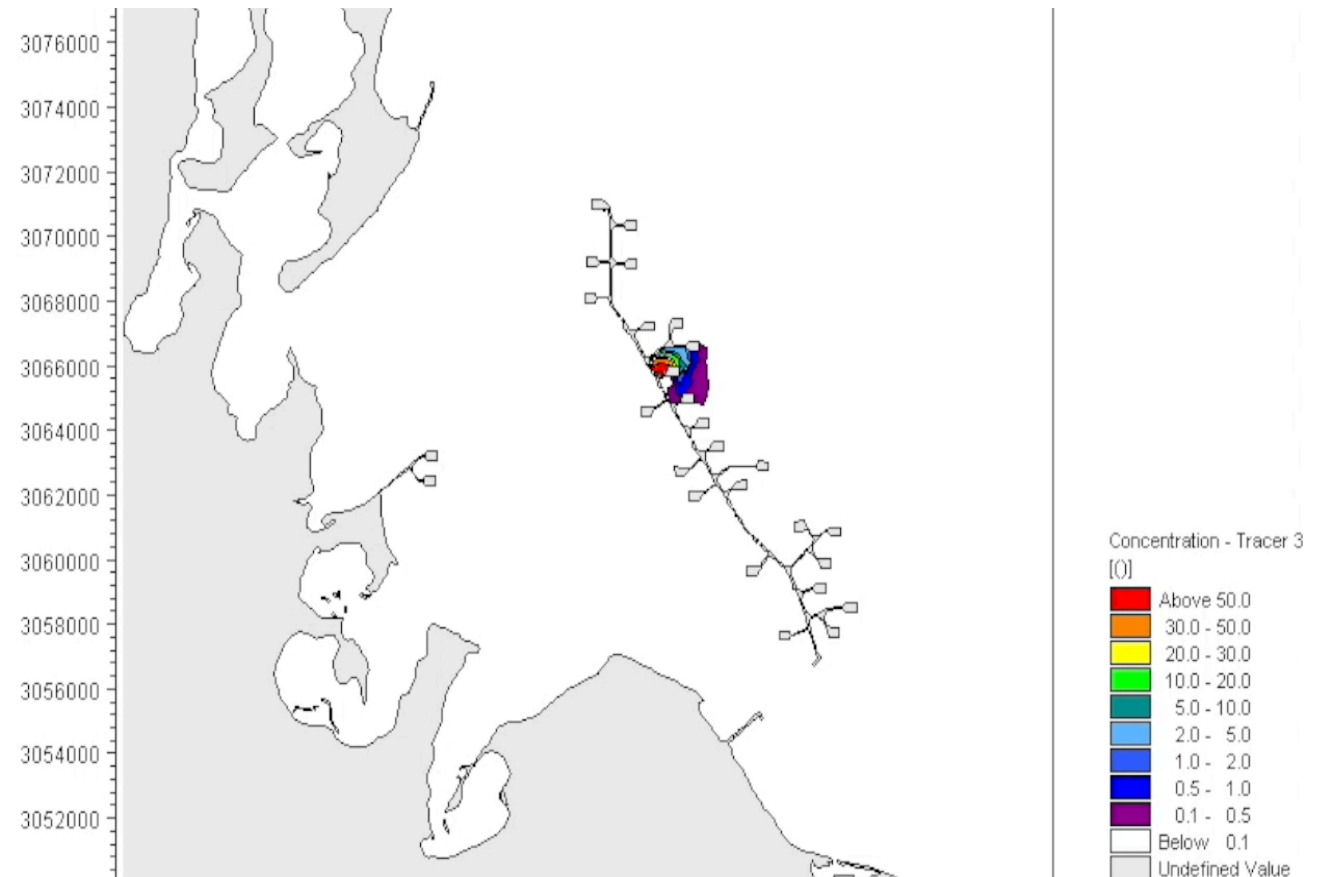
# Fact: Waterflow & biodiversity enhancement

## Tracer showed

- Bridges facilitated juvenile organisms transport

## Confirms

- Causeway a hotspot of biodiversity
- Improvement in waterflow



SPE 156051; SPE 156609; SPE 172567

# Facts: Ecosystem Enhanced ...



The development **enhanced** the ecosystem



Shallow water bay for shrimp and fish still flourishing



Potential ecosystem losses offset

- Fishing port & hatchery



Nesting platforms

- Ospreys safe haven



Mangrove trees

- 4.3 million to date
- Migratory birds refuge
- Sequester CO<sub>2</sub>, filter dust



Native trees

- 1.1 million with wastewater

**Facts:** We're **Able**. Are we **Willing** and **Ready**?...

**246**

The peak number of  
cranes used during the  
construction phase

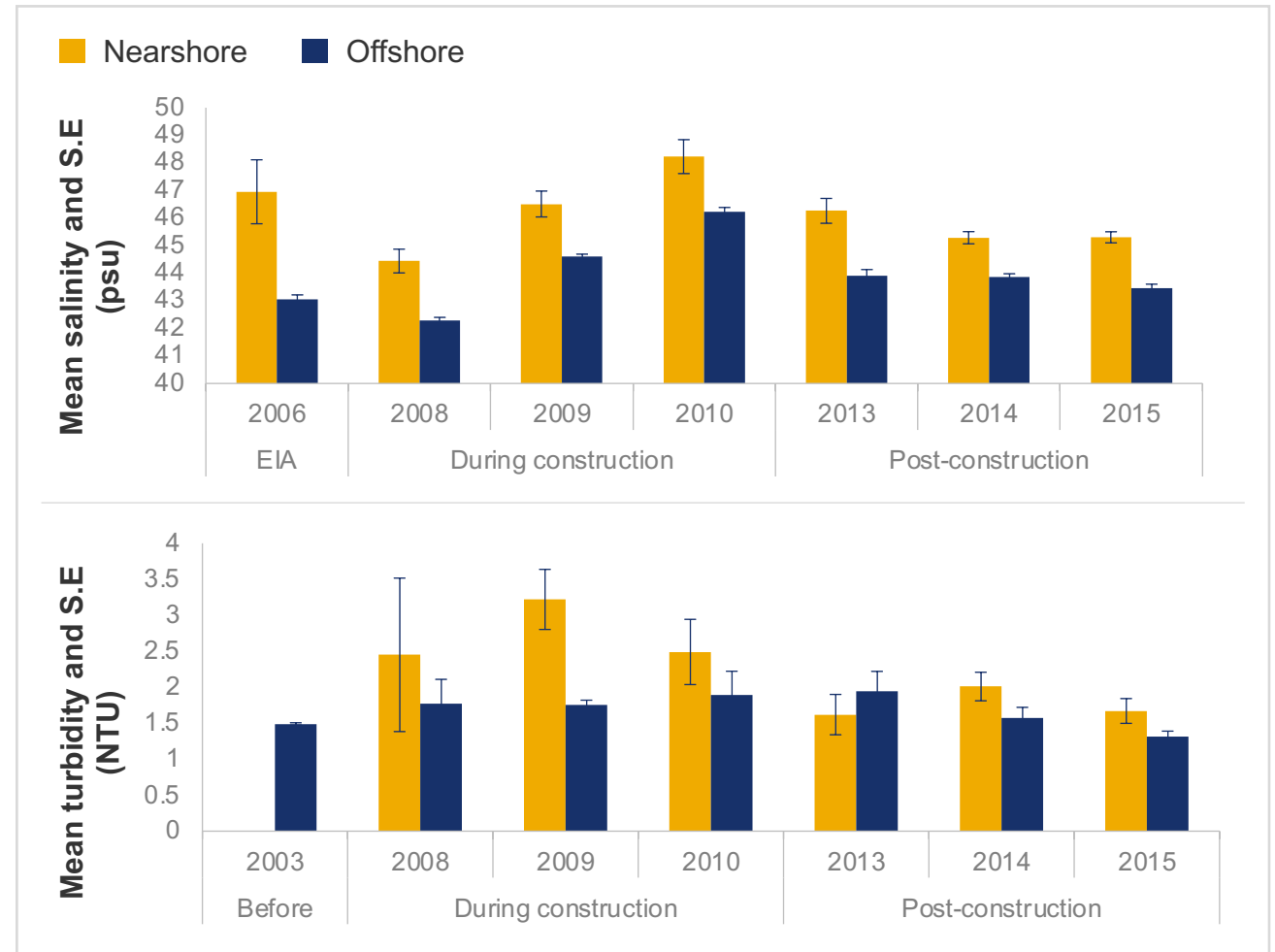
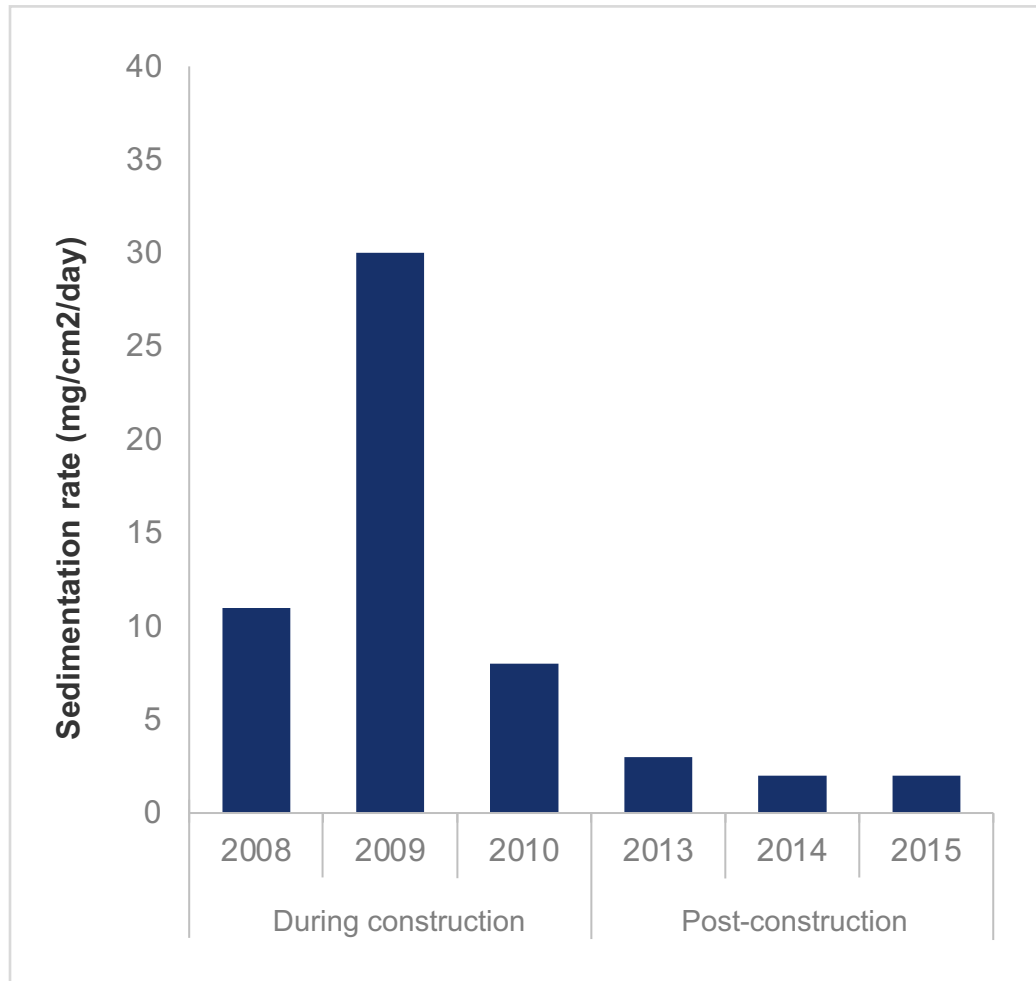


# Fact: Oil Production in a Pristine Environment...



# Results Environmental Quality Field Data ...

## Water quality status



# Results...(6 of 6)



**Seagrass increased 70%**  
(Innovative solutions for growing coral reefs)



**Electricity co-generation**  
(power surplus)



**Increased Species richness**  
(Biotope maps)



**900 MBCD milestone achieved**  
– July 2017



**Planted mangrove trees**  
(4.3 million to date)



**Designated and managed as**  
**a biodiversity protection area**



# Conclusion

Economic growth and environmental protection? Possible.

---

Big Environmental wins for collaboration along core values

---

Revisit “stampede” of high cost-high reward projects

---

Optimize solutions generating phase

---

Engage communities (social license)

---

Qualify technologies

---

Difficult times? No problems!

# Active Oilfield Development while Preserving Fragile Ecosystems is



**IMPOSSIBLE**





# Selected References

## Active Oilfield Development and Environmental Care Handbook

- Public Relations Department, Saudi Aramco (2015). Manifa where every grain of sand and every drop of water tells a story. Retrieved from <https://www.saudiaramco.com/-/media/publications/books/manifa-book-english.pdf>

## Referenced and Accompanying Paper and Articles

- Arukhe, J. O., & Duthie, L. S. (2015, March 8). Technology Improvements in the Giant Manifa Field Maturation Project. Society of Petroleum Engineers. doi:10.2118/172523-MS
- Arukhe, J., Duthie, L., Al-Ghamdi, S., Hanbazazah, S., Almarri, H., Sidle, B., & Al-Khamees, H. (2014, January 19). World's First Tandem 2.125" Coiled Tubing Tractor for ESP Open Hole Completions. International Petroleum Technology Conference. doi:10.2523/IPTC-17386-MS
- Arukhe, J. O., Duthie, L. S., Hernandez, J. R., Ahmari, A. S., & Hanbazazah, S. M. (2016, September 26). Application of Simultaneous Operations in Saudi Arabia's Causeway Oilfields Development. Society of Petroleum Engineers. doi:10.2118/181438-MS
- Arukhe, J., Abdulelah, B., Yateem, K., & Namlah, S. (2015, March 8). Excellence in Environmental Technology and Stewardship — Manifa Mega-Project. Society of Petroleum Engineers. doi:10.2118/172567-MS
- Arukhe, J., Al Ghamdi, S., Hanbazazah, S., & Ahmari, A. (2014, January 19). Active Field Development Without Harm to Saudi Arabia. International Petroleum Technology Conference. doi:10.2523/IPTC-17389-MS
- Arukhe, J. O. I., Al-dhufairi Mubarak Audah, Al Ghamdi, S., Duthie, L., & Omairan, K. I. (2012, January 1). The First Real Time Logging with Tractor in an Extended Reach Horizontal Well With Proof of True Stimulation. Society of Petroleum Engineers. doi:10.2118/160496-MS
- Arukhe, J., Hanbazazah, S., Ahmari, A., Adesegha, R., Perez, J., Noguera, J., Nakhwa, A. (2014, April 21). CT Extended Reach Acid Stimulation in Openhole Wells, Offshore Saudi Arabia: A 23-Well Case Study. Society of Petroleum Engineers. doi:10.2118/172221-MS
- Arukhe, J. O., Khelaiwi, F., Isichei, O., & Dhubaiki, A. A. (2017, November 13). Smart Well Completion Optimization in Multilateral Wells. Society of Petroleum Engineers. doi:10.2118/188732-MS
- Arukhe, J., Balto, A., Perez, J., & Noguera, J. (2015, March 24). Rigless Optimization of CT Stimulation in Saudi Arabia's Offshore Laterals. Society of Petroleum Engineers. doi:10.2118/173677-MS
- Arukhe, J. O. I., Al-dhufairi Mubarak Audah, Ghamdi, S. A., Al-Harbi, B. M., & Docherty, P. R. (2011, January 1). Saudi Arabia's Long Term Injectivity Test in a Field Characterized by a Tar Mat Zone Strives to Unlock Higher Reservoir Potential. Offshore Technology Conference. doi:10.4043/21130-MS
- Al-Dhufairi, M. A., Arukhe, J., Al-Mutairi, S., Al Ghamdi, S., & Aborshaid, A. (2012, January 1). Responsible Oil Well Tests on Artificial Islands Close to Offshore Waters. Society of Petroleum Engineers. doi:10.2118/156051-MS
- Elsherif, T., Dhufairi, M., Bal, M., Krueger Jr., R. E., Baez, F., Kharrat, W., & Arukhe, J. (2013, March 26). Well Intervention Challenges in Mega-Reach Wells With Coiled Tubing and the Application of the Latest Technologies in Tackling These Challenges, Saudi Arabia. Society of Petroleum Engineers. doi:10.2118/163908-MS
- Arukhe, J., Harthi, M., Namlah, S., & Ahmari, A. (2014, April 21). A Saudi Arabia Giant Field Development: Lessons from Integrating Technologies. Society of Petroleum Engineers. doi:10.2118/172235-MS
- Arukhe, J., Al Ghamdi, S., Dhufairi, M., Duthie, L., Yateem, K., Almari, A., ... Othman, B. (2013, March 26). A New Solution to an Old Problem: Tractored CT Conveyed Real-Time Water Injection Profiling in Ultra Deep Wells. International Petroleum Technology Conference. doi:10.2523/IPTC-16846-MS
- Arukhe, J. O., Ghamdi, S., Dhufairi, M., Duthie, L., Omairan, K., Ahmari, A., ... Othman, B. (2013, March 10). Record Coiled Tubing Aided Reach and First Real-Time Injection Profiling with Tractor in Extended Reach Well. Society of Petroleum Engineers. doi:10.2118/164237-MS
- Al Utaibi, A. Z. (2014, January 19). Program Acceleration - CASE STUDY. International Petroleum Technology Conference. doi:10.2523/IPTC-17666-MS
- Arukhe, J. O., Ghamdi, S., Dhufairi, M., Duthie, L., & Omairan, K. (2013, March 26). The World's First Real Time Logging with Tractor in an Extended Reach Horizontal Well with Proof of True Stimulation. International Petroleum Technology Conference. doi:10.2523/IPTC-16665-MS
- Arukhe, J., Ghamdi, S., Dhufairi, M., Duthie, L., Almari, A., Elsherif, T., & Othman, B. (2013, March 26). Saudi Arabia's Value Adding, Record-Breaking Coiled Tubing Interventions Travel Farther than Mount Everest. International Petroleum Technology Conference. doi:10.2523/IPTC-16815-MS
- Arukhe, J. O. I., Al Dhufairi, M., Ghamdi, S., Duthie, L., Elsherif, T. A., & Ahmed, D. (2012, January 1). Saudi Arabia's Two World Records for Aided Coiled Tubing Reach and Real Time Logging in Extended Reach Well. Society of Petroleum Engineers. doi:10.2118/160764-MS
- Arukhe, J. O. I. (2014, December 10). Environmentally Friendly Manifa Field Development — The World's Largest. International Petroleum Technology Conference. doi:10.2523/IPTC-17833-MS
- Arukhe, J., Hanbazazah, S., Ahmari, A., Al Ghamdi, S., Yateem, K., Aramco, S., ... Baez, F. (2014, May 5). Saudi Arabia's Manifa Giant Offshore Field Development: The Role of Technology. Offshore Technology Conference. doi:10.4043/25119-MS
- Arukhe, J. O. I., & De Landro, W. (2014, December 10). Saudi Arabia's Giant Manifa Oilfield Development: Lessons from Integrating Technologies. International Petroleum Technology Conference. doi:10.2523/IPTC-17859-MS
- Duthie, L., Arukhe, J. O., & Namlah, S. (2015, March 8). The Evolution of Well Testing Practices From Conventional to Zero Flaring in a Saudi Aramco Oilfield Development. Society of Petroleum Engineers. doi:10.2118/172689-MS
- Ji, L., Guo, Q., & Wang, C. (2010, January 1). Is It Possible to Inject Larger Sizes and Higher Solids Concentrations of Drill Cuttings? Society of Petroleum Engineers. doi:10.2118/131347-MS
- Muxika, I., Borja, Á., Bald, J., (2007). Marine Pollution Bulletin 55, 16-29.
- Pauly, D. (1979). Theory and management of tropical multispecies stocks: a review, with emphasis on Southeast Asian demersal fisheries. ICLARM Stud. Rev. 1: 35 p

## Permissions

- Permissions received for all pictures, diagrams from other sources

# Your Feedback is Important

Enter your section in the DL Evaluation Contest by completing the evaluation form for this presentation

Visit <https://www.spe.org/en/dl/contest/>  
**#SPEdl**



20-21



Society of Petroleum Engineers  
Distinguished Lecturer Program  
[www.spe.org/dl](http://www.spe.org/dl)