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Active Oilfield Development While Preserving Fragile Ecosystems

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saudi aramco



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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

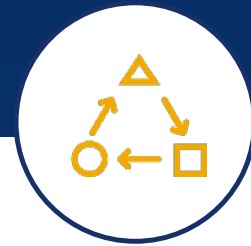
Key Takeaways: 1 of 2



**Economic
growth and
environmental
protection
are possible**



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



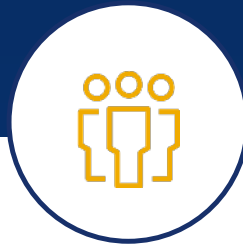
Paradigm Shifts?

- 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

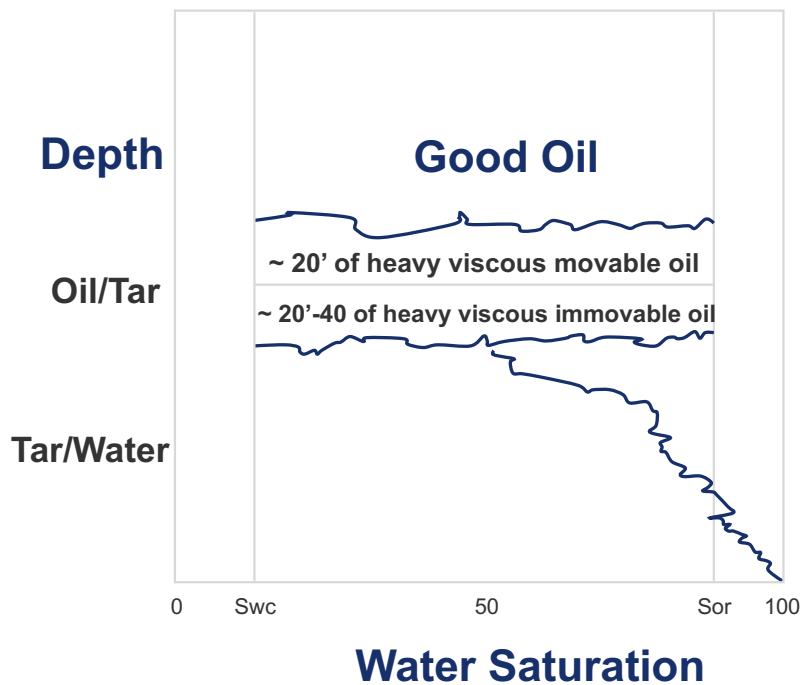
Field Location



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% H₂S (gas phase)

3,688 Present Pressure

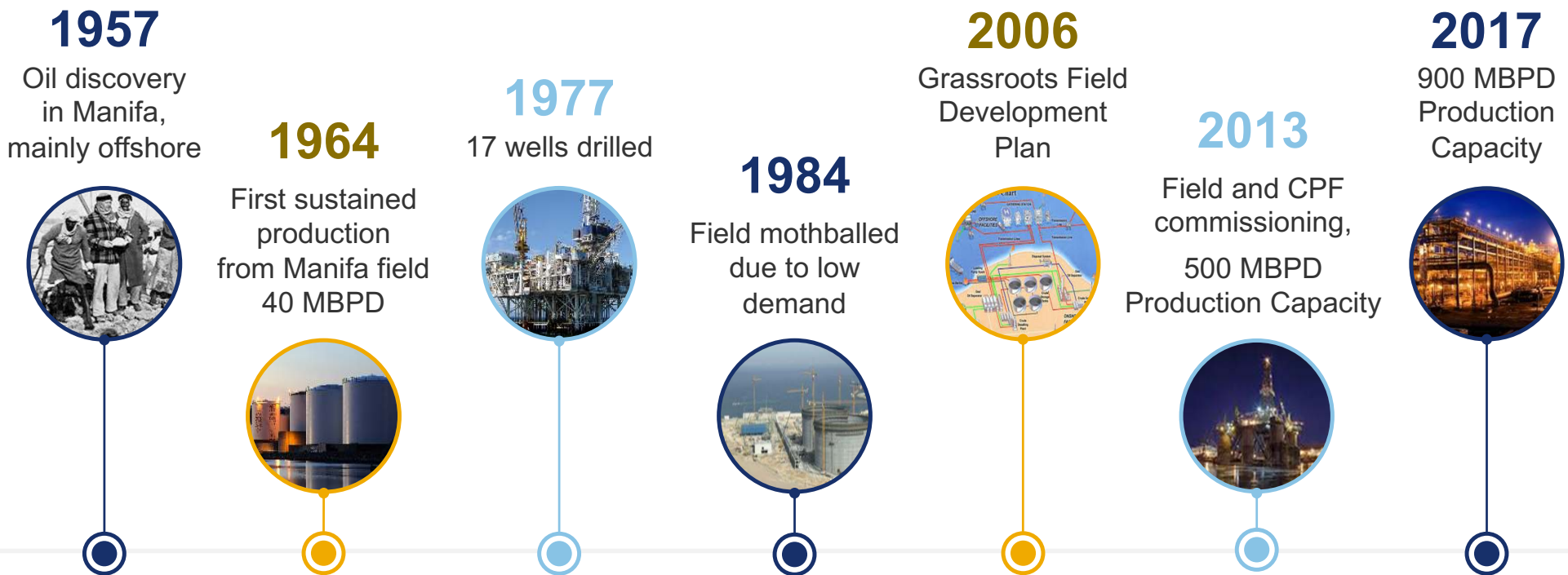
20% Porosity

2.8 Fluid viscosity at P_i and T_r, cp

1171 Permeability, mD

29 Stock Tank API°








Timeline






MBPD = thousand barrels per day; CPF = Central Processing Facilities

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



ERD = extended reach drilling

Environmental Impact Assessment (EIA) Objectives



To create an optimal causeway design that minimizes seawater impact



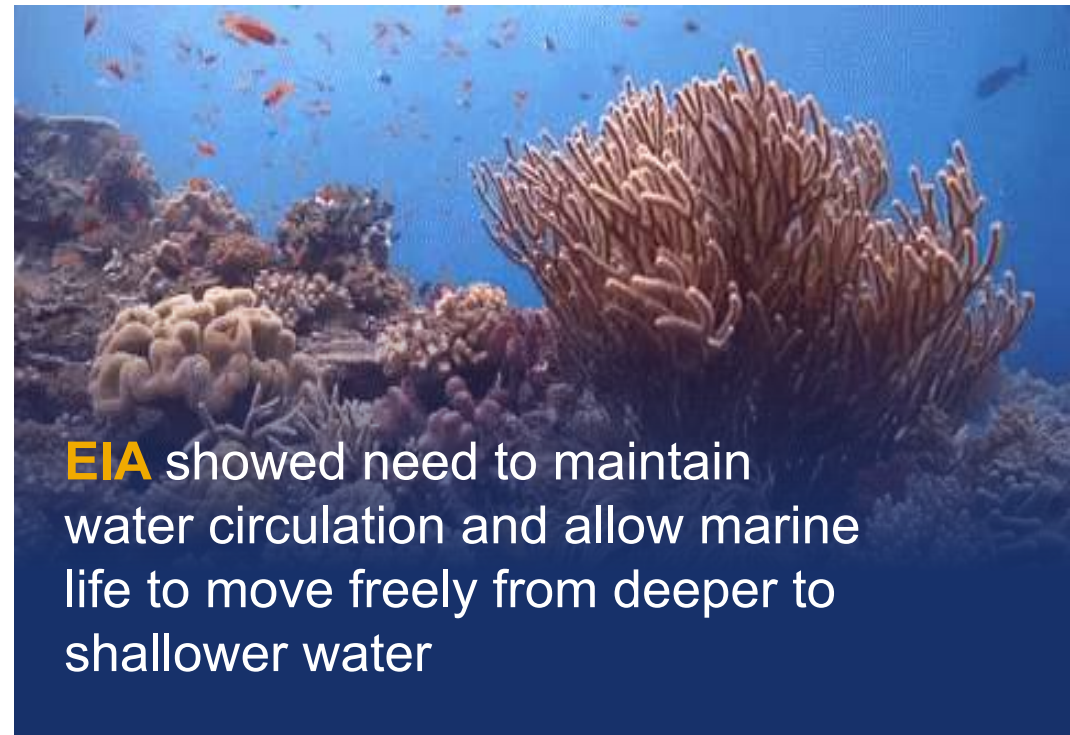
Predict the environmental impact of construction



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

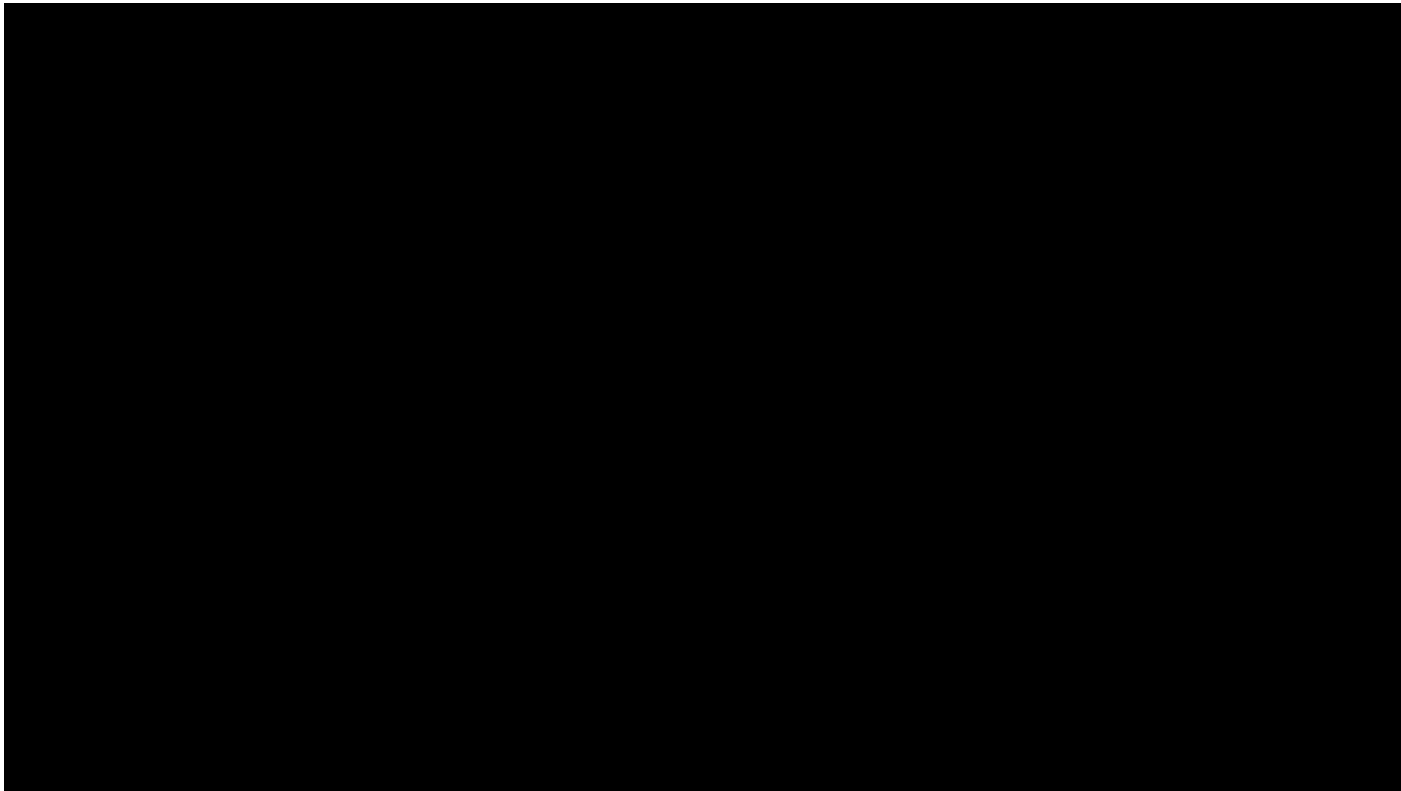


Environment

Shallow waters
IPTC 16665

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

Manifa: Energy and Nature

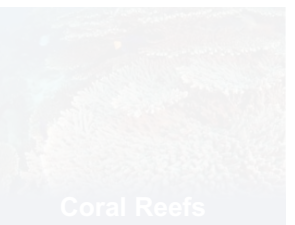


Environmentally Friendly Oilfield

Coral reefs (artificial) and natural areas for future ge



seawater
(11 days)
biodiversity



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



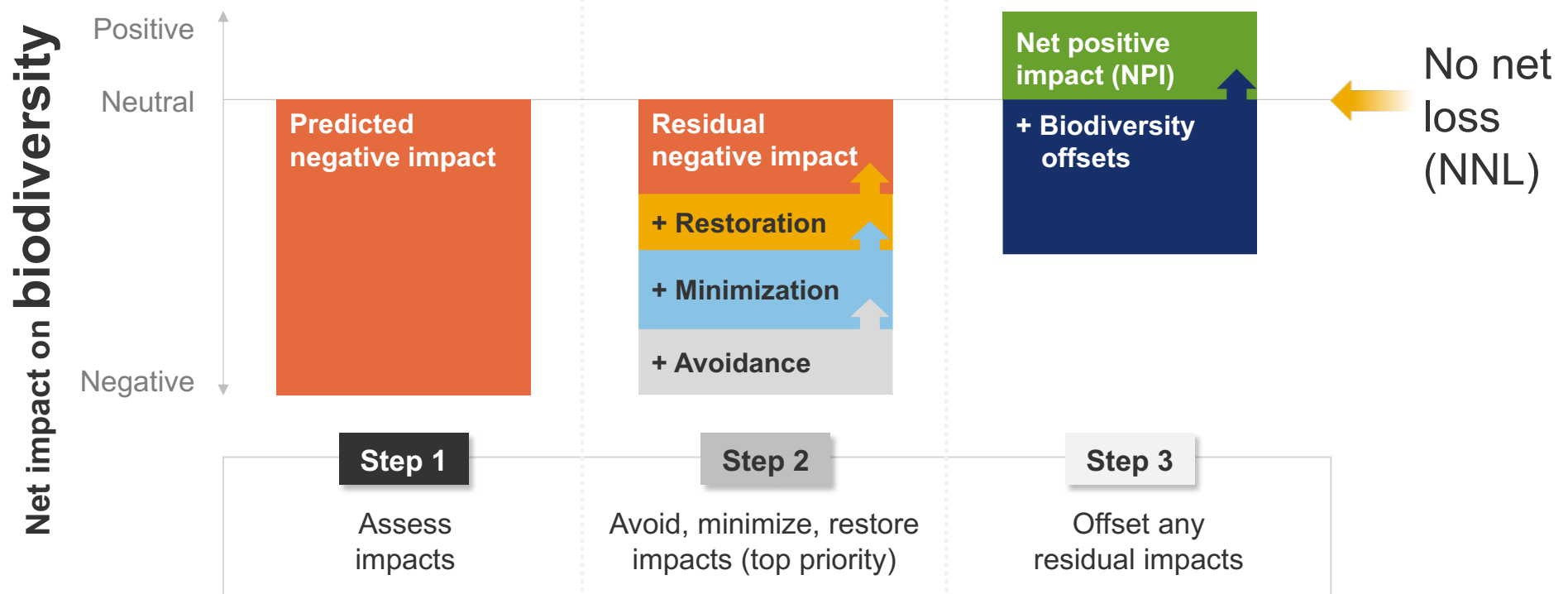
**Fish Hatchery
for Sea
Ranching**



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

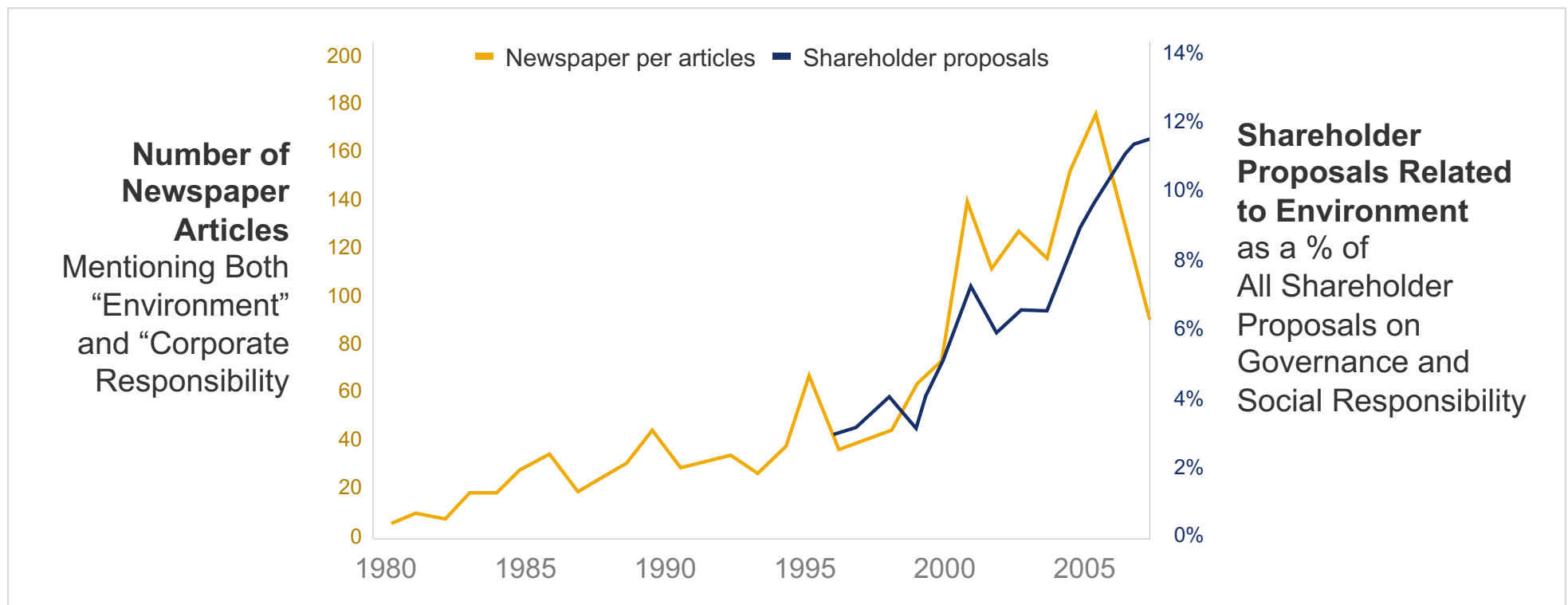
Benefits of biodiversity offsets

Mitigation Hierarchy and Biodiversity Impact



Shareholders interested with environmental friendly company

Evolution of Media Attention and Shareholder Proposals Related to Environmental CSR

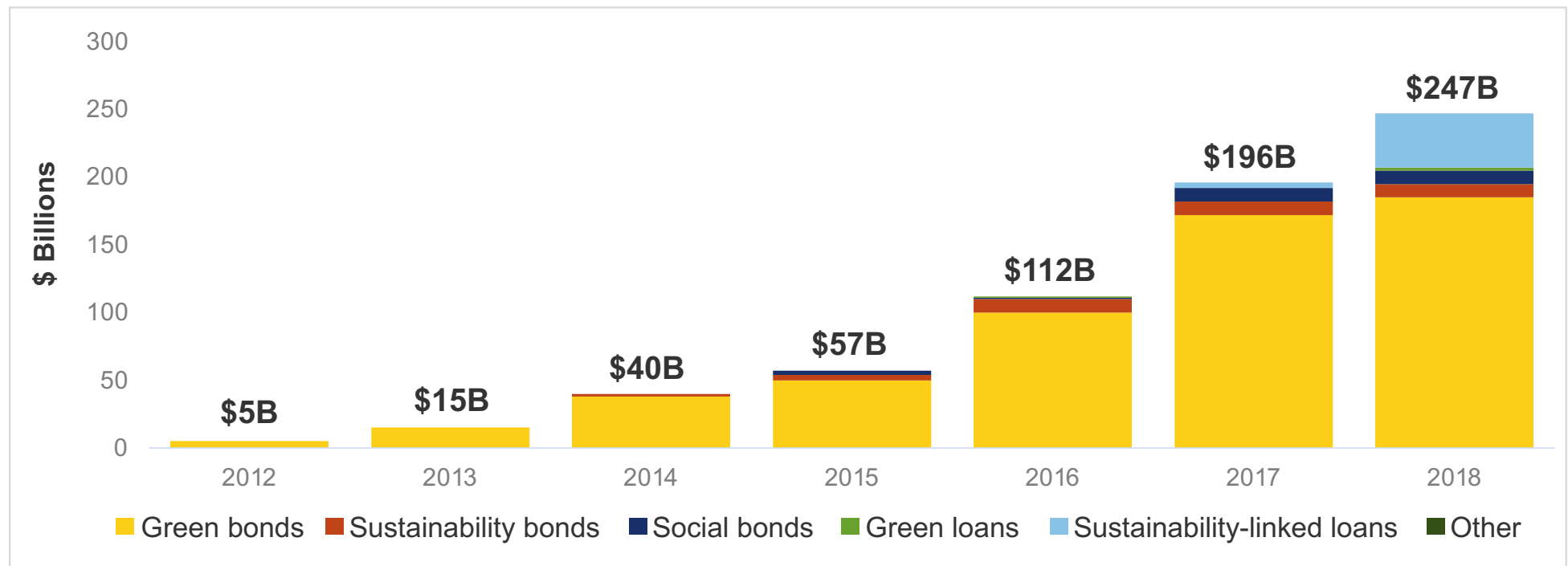


Biodiversity projects

Increases company valuation and access to loans from financial institutions

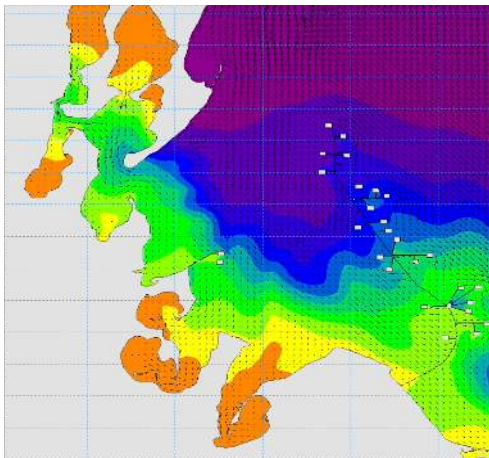


Global sustainable debt annual issuance, 2012-2018



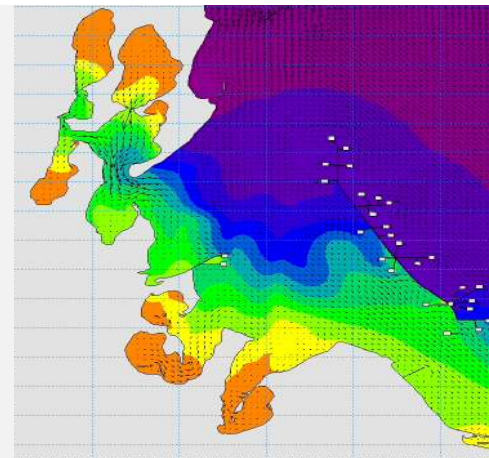
Source: BloombergNEF, Bloomberg L.P.; Note: 'Other' includes labeled blue bonds

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

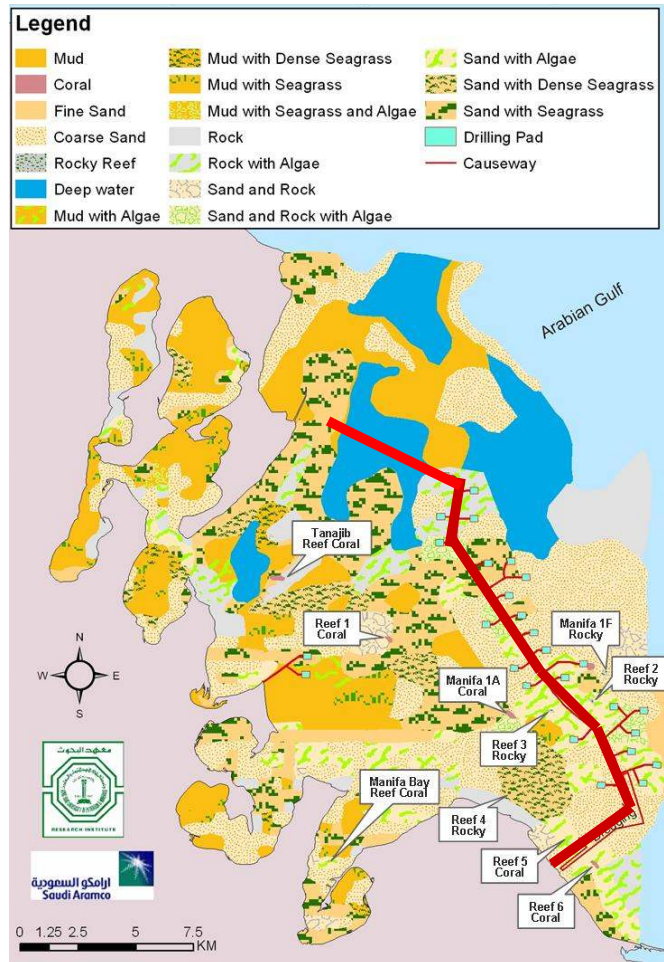


Release 10 million
juvenile fish per year

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

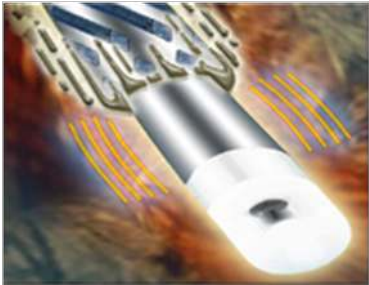
- Dissipate energy of storm waves
- Prevent recession of the backshore



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

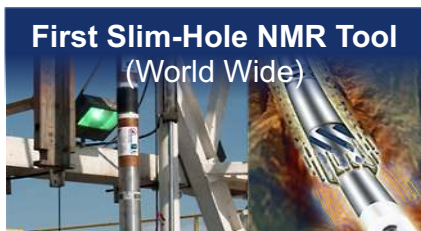


Decreased vessel activity

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

SPE 20112

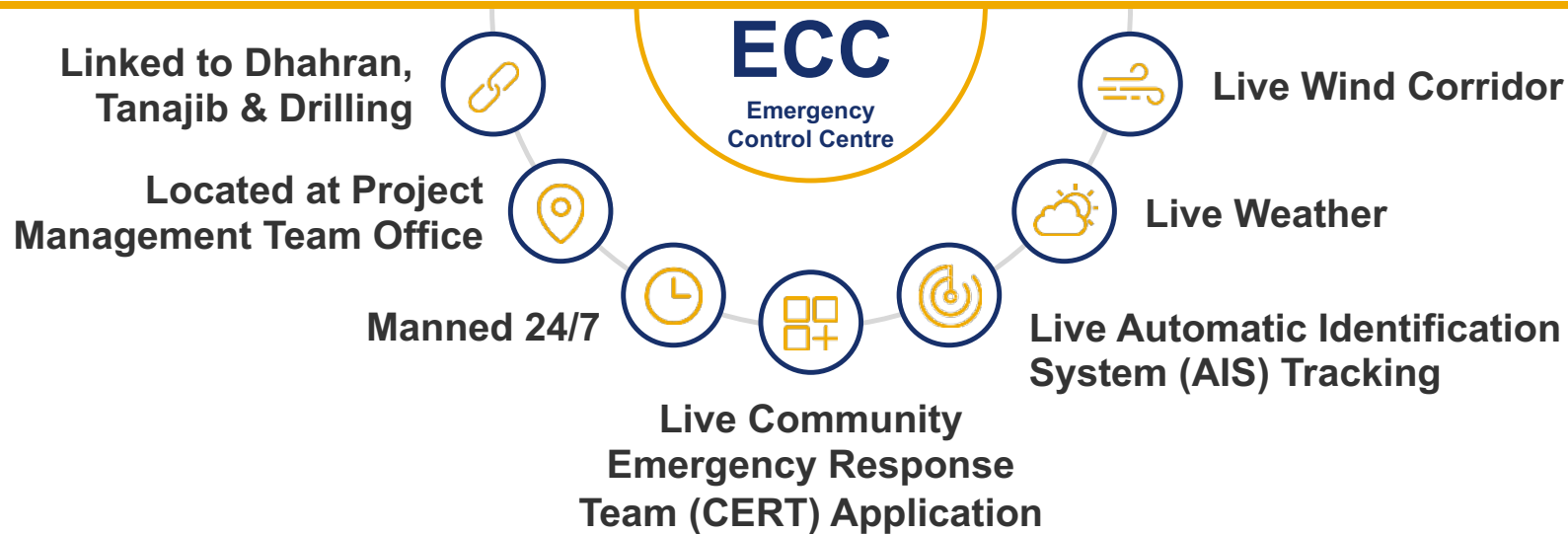
Drilling: Dry Location at Rig Site / Zero Discharge (2 of 2)



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



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

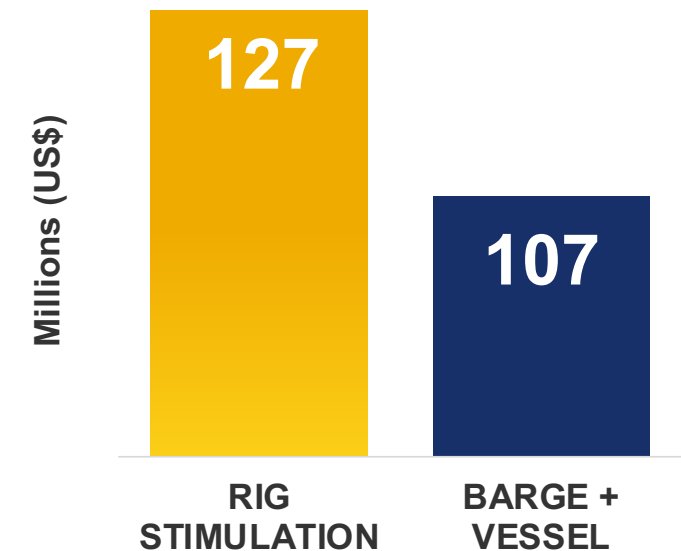


OTC 20112

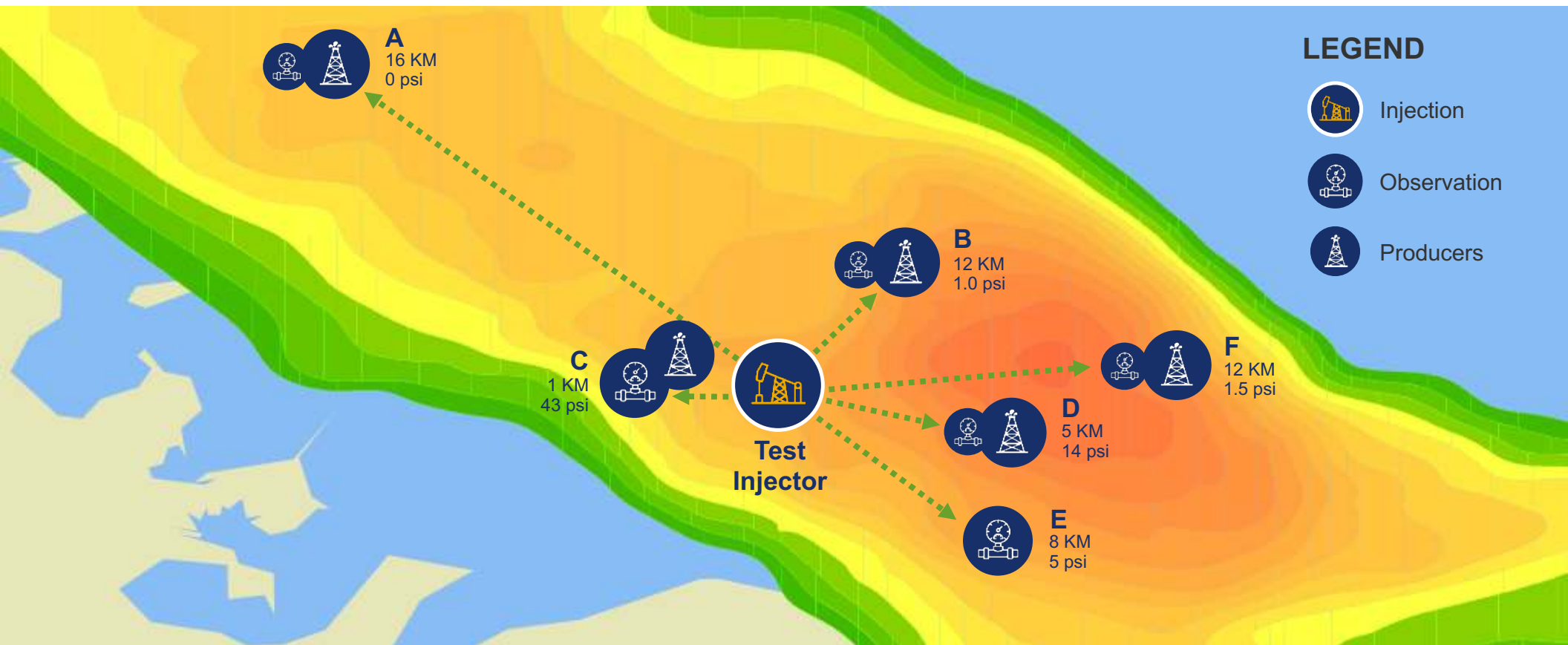
Stimulation Vessel & Barge

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

Cost Comparison

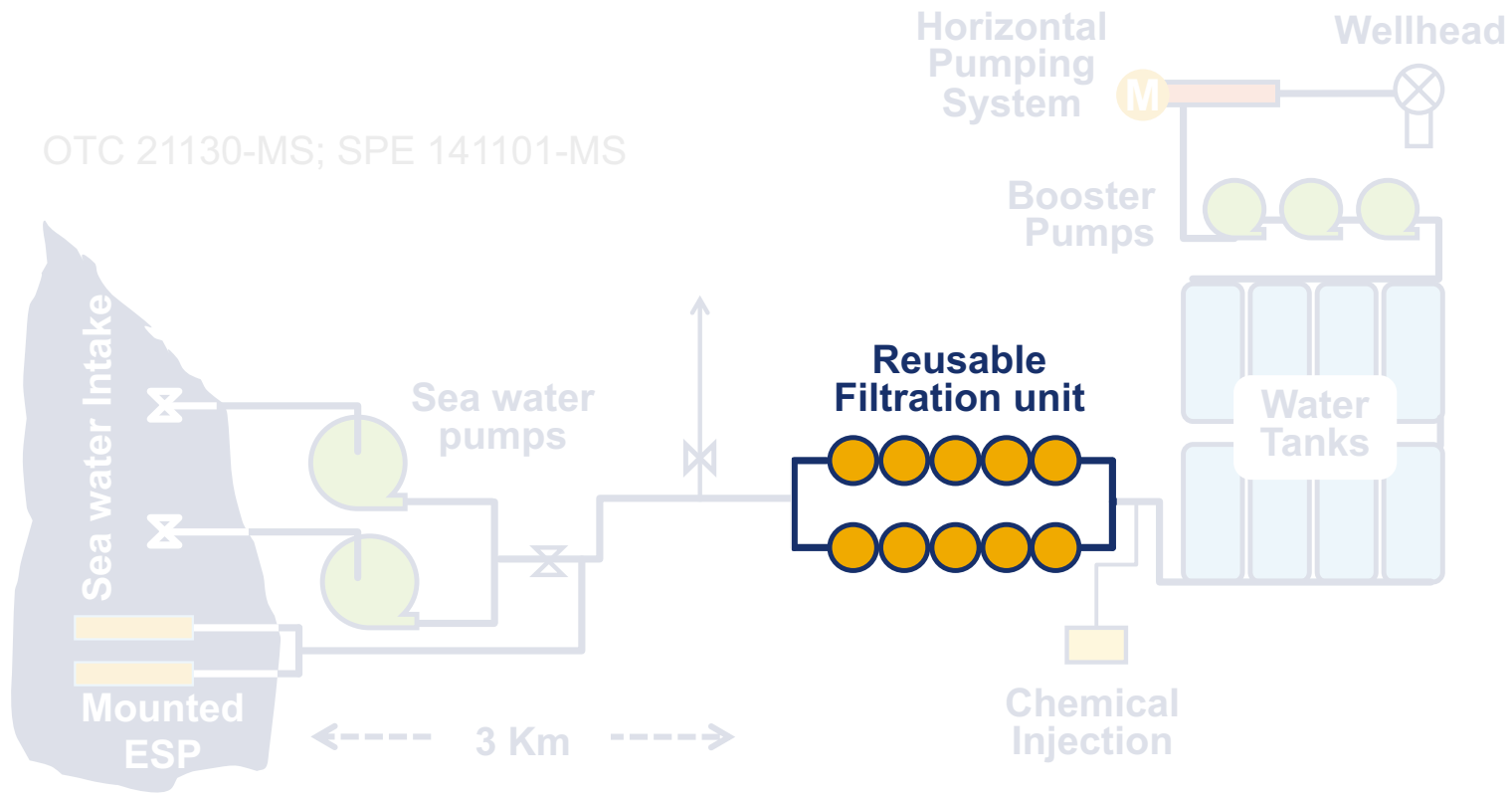


Long-Term Injection Testing



Long-Term Injection Test: Reusable Filtration

OTC 21130-MS; SPE 141101-MS

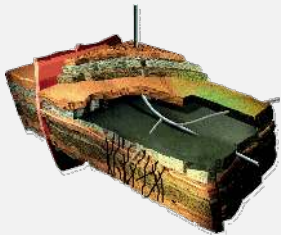


ESP = Electrical Submersible Pump

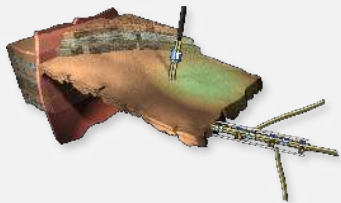
Extended Reach Well Completion

Produced water management

SPE 188732; IPTC 12145

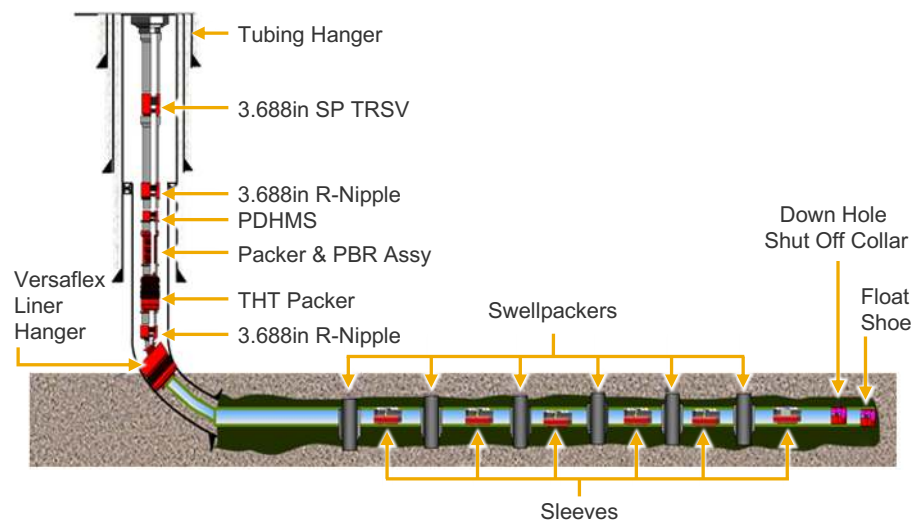


**Geosteered
Multilateral (ML)
/ MRC**



**Advanced
Completions
MRC Smart Wells**

Extreme Reservoir Contact (ERC) Wells



GOC = Gas Oil Contact; **OWC** = Oil Water Contact; **ICD** = Interval Control Devices; **MRC** = Maximum Reservoir Contact

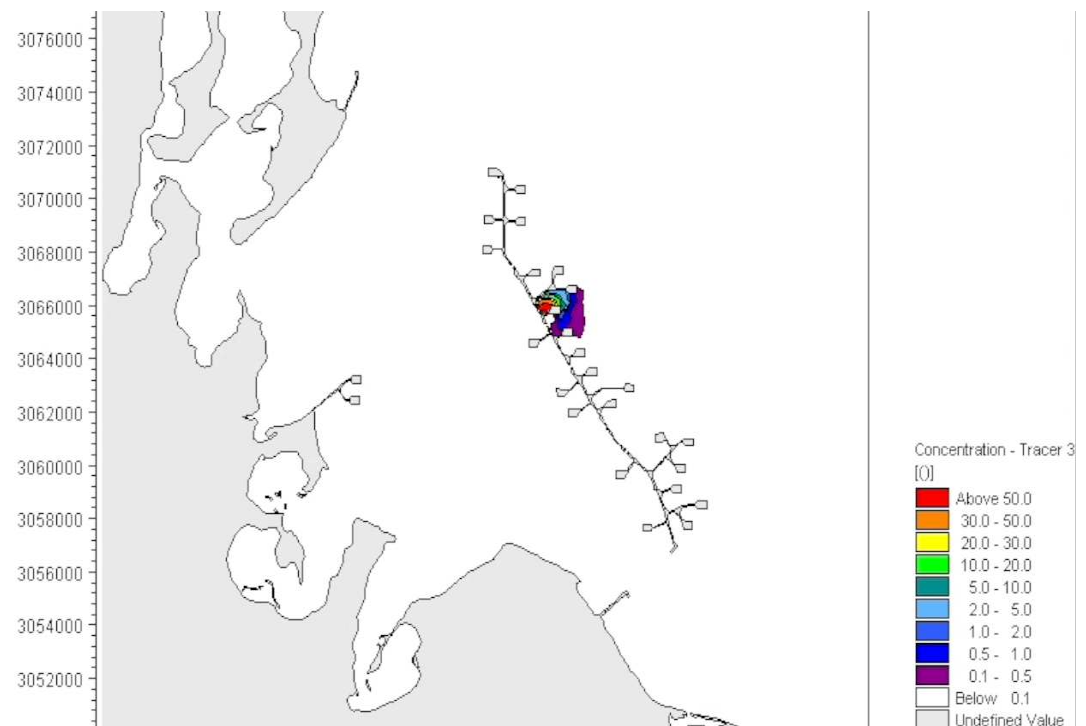
Fact: Waterflow & biodiversity enhancement

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 CO₂, filter dust



Native trees

- 1.1 million with wastewater

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



246

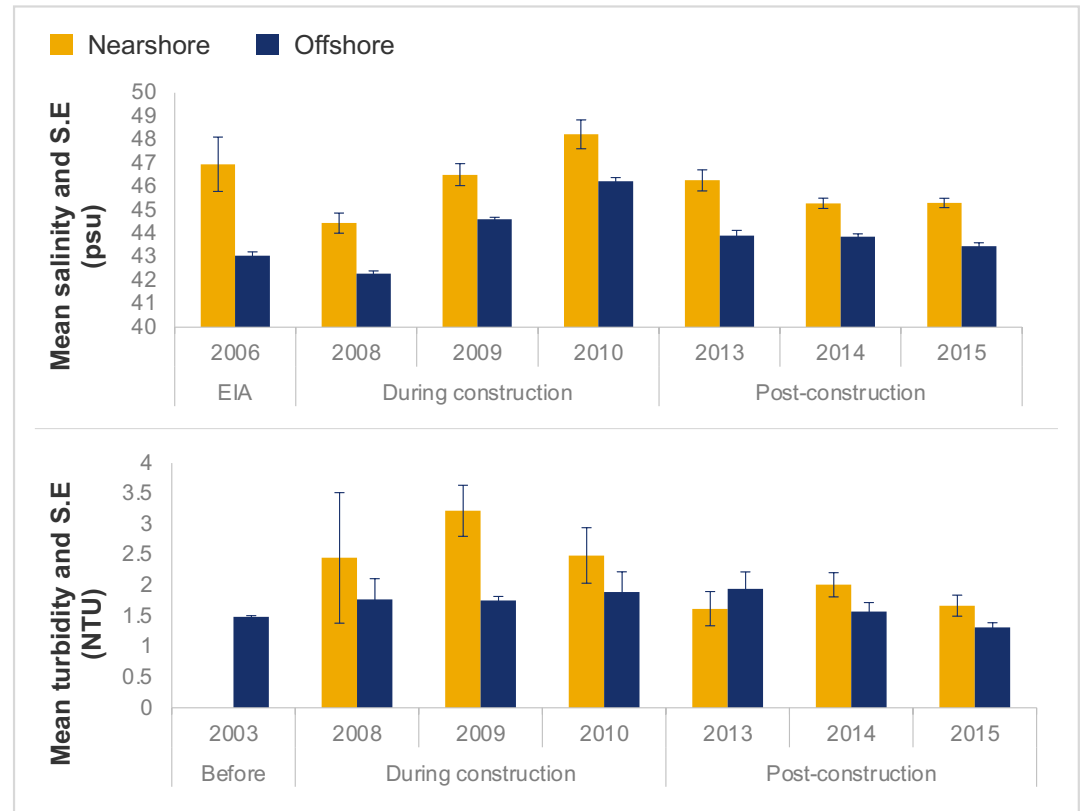
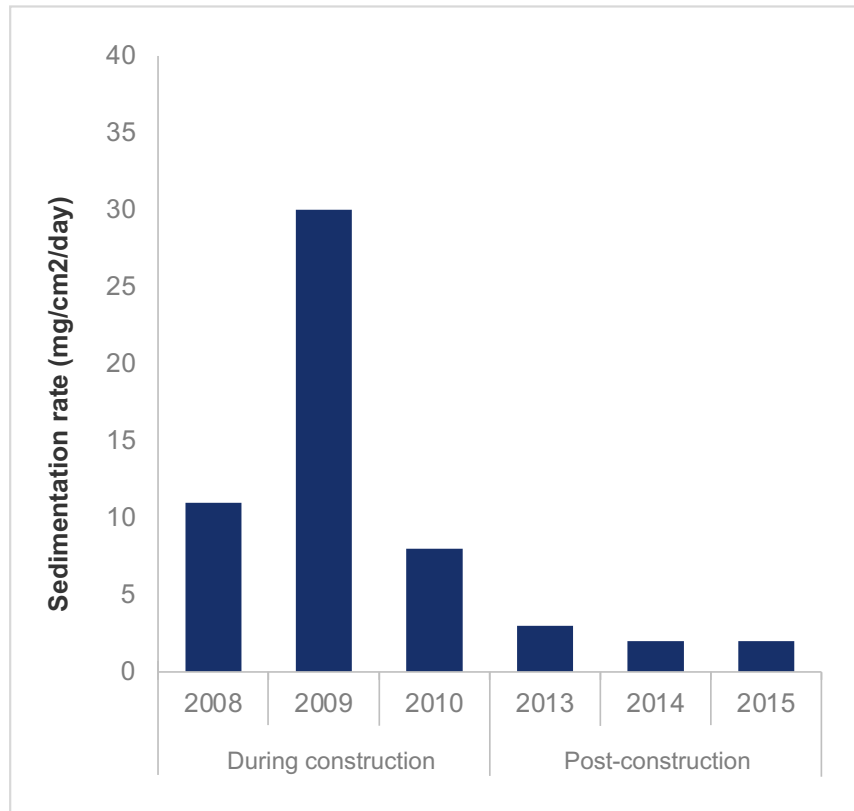
The peak number of
cranes used during the
construction phase

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**

Shaybah Wildlife Sanctuary

Rub' al-Khali



Shaybah Wildlife Sanctuary

- First protected area of the Rub' al-Khali
- One of the largest fenced nature reserves in the world
- Largest fenced nature reserve by an oil and gas company
- Aligns Aramco with several UN biodiversity conventions



637 km²
104KM FENCE

217 plant and animal species are protected within the sanctuary



Including many sensitive species



39

High Conservation Priority species

19

endemic species

92

decreasing species

40

threatened species

169

migratory species

SWS: a conservation success!

Three species previously driven out of the region have been successfully reintroduced into the sanctuary



¹ Arabian Oryx

² Arabian
Sand
Gazelle

³ Ostrich

“Operation Oryx”



CRITICALLY ENDANGERED

EXTINCT IN
THE WILD

CRITICALLY
ENDANGERED

ENDANGERED

VULNERABLE

1950s

↓
Population
dwindling from
hunting and
poaching;
50-60 wild
oryx remain

1962

↓
World conservation program
begins—oryx transported to
Phoenix Zoo (Arizona)
• Four of last wild oryx captured
(one died from stress)
• Six other oryx received from
private collections

1972

↓
Last wild
oryx hunted

1982

↓
Reintroduction
program begins

1986

2011

↓
~1000 wild
oryx and
6000-7000
captive oryx

SWS: Restored populations



31 Arabian
Oryx

- 25 adults donated by Saudi Wildlife Authority
- 5 juveniles born this year

61 Sand
Gazelles

11 Ostriches

Sand Gazelles



Saudi Aramco: biodiversity protection

Aiming for a “Net Positive Impact”



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



DEVELOPMENT

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