

# Trenching to Micro-tunnelling: Adaptive Optioneering to Achieve Compliance Amid Design Uncertainty



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# Case Study of Reverse Osmosis Plant - Intake and Outfall Pipelines

## Presentation Agenda



Project  
background



Environmental  
Settings



Key  
Challenges



Outcome

## The Problem

“ Can ESIA function as a **decision-support tool** — rather than a compliance gateway for evaluating unresolved design? ”



# The 2030 Vision & Red Sea Global

Saudi Arabia's Vision 2030 aims to increase the economical, social and cultural diversification of the Kingdom.

Red Sea Global is contributing by developing sustainable tourism destinations along the Red Sea coast. This region has pristine and unique ecosystems, species, and natural resources that are at the core of tourism development.

Red Sea Global has developed a regenerative tourism concept, focused on People and Planet, with net gain in biodiversity conservation benefits at its core, to safeguard the delicate marine ecosystems of the Red Sea and foster sustainable development of local communities.

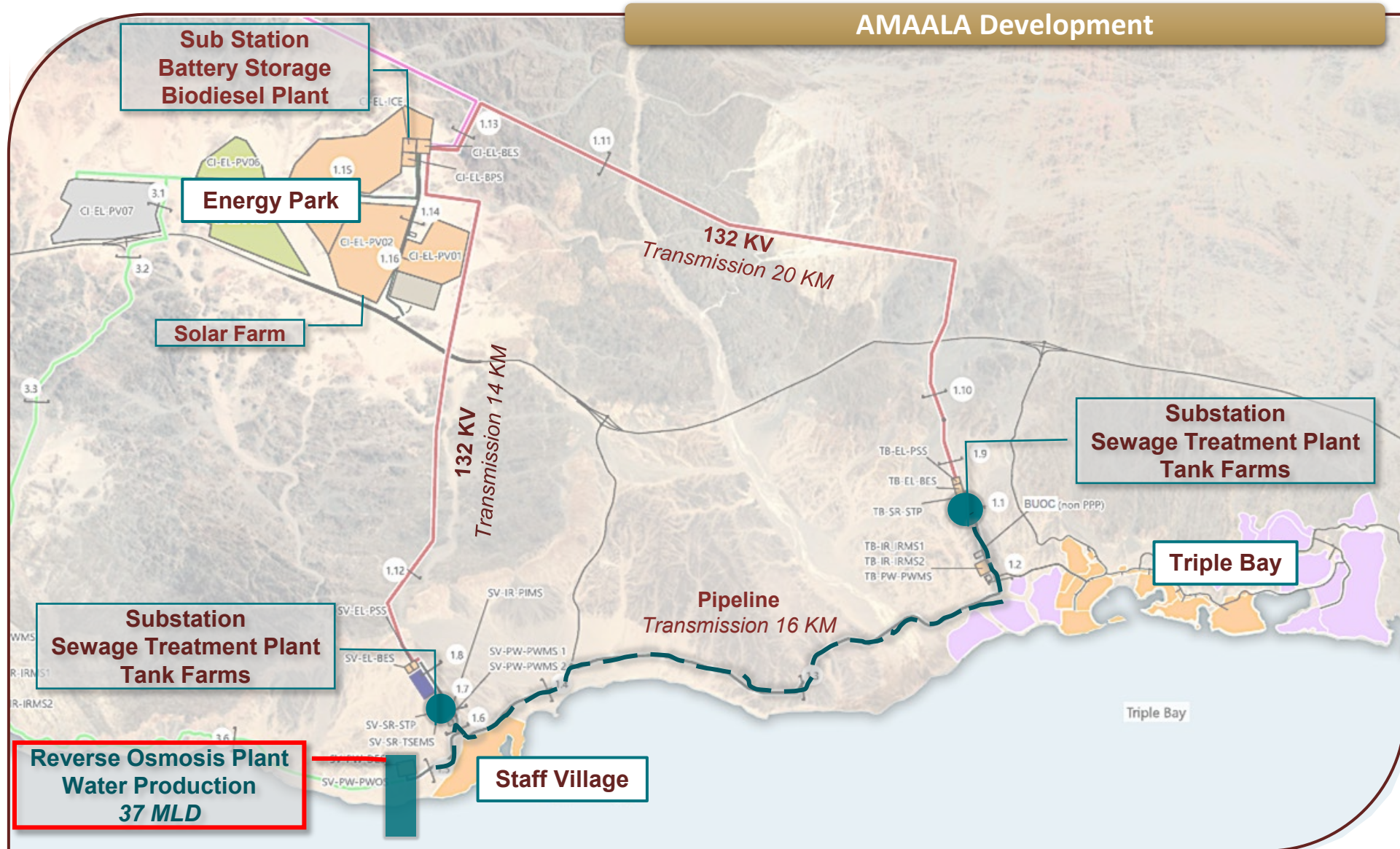
# Background

*“Regenerative Infrastructure in a Sensitive Environment - dual challenge of infrastructure delivery and ecological protection.”*

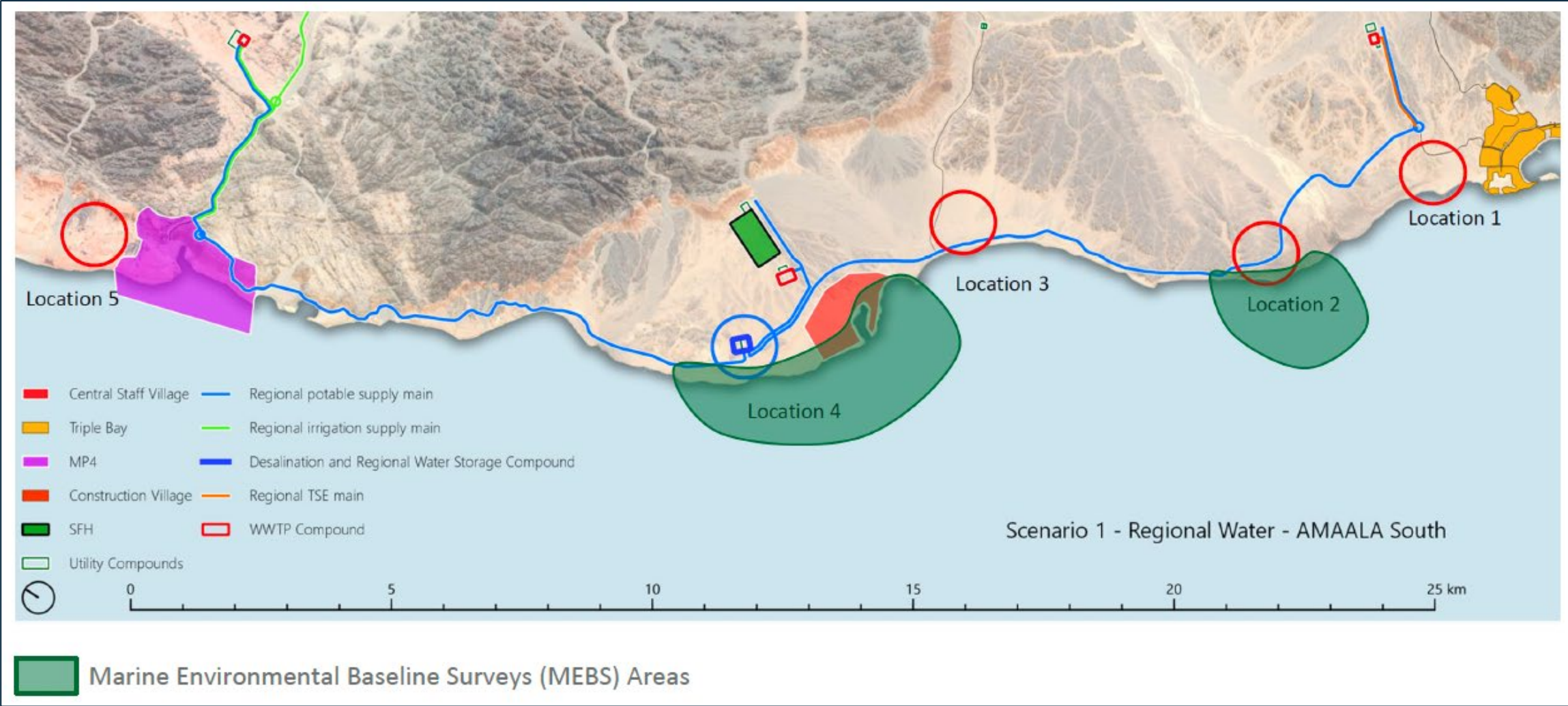
- Red Sea Global is delivering multi-utilities infrastructure for the AMAALA destination in Saudi Arabia
- Project implemented under a **25-years Public-Private Partnership (PPP)** agreement
- Includes a 37MLD reverse osmosis (RO) desalination plant along the Red Sea Coast powered by renewable energy
- Located along ecologically sensitive Red Sea coastal environments



# Amaala Utilities PPP (Strategic Overview)



# Amaala Utilities PPP (RO Plant Alternative Locations)



# RO Plant Intake and Outfall Pipelines

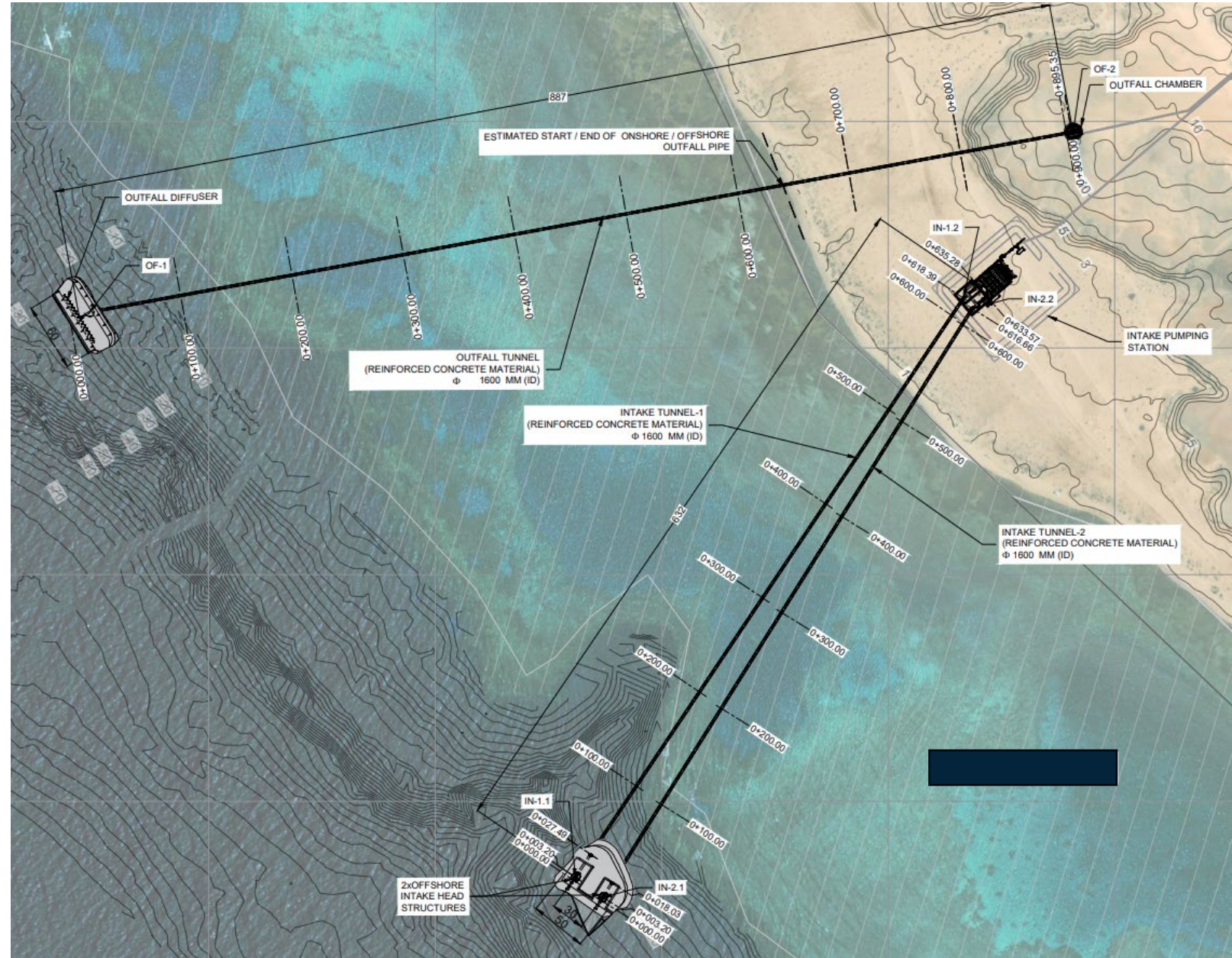
*"Reverse osmosis uses pressure to push water through a membrane, filtering out impurities"*

## Outfall Pipeline

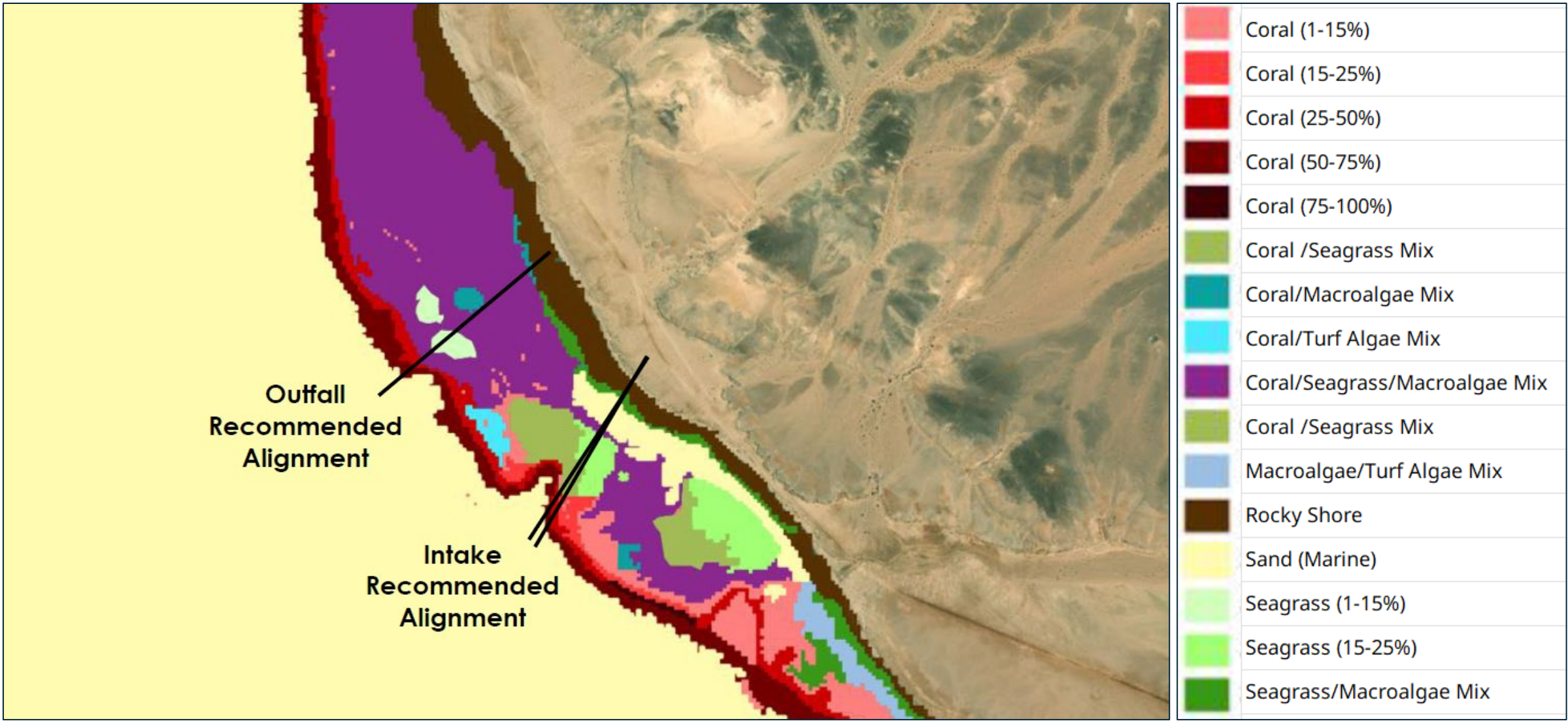
- One micro-tunnelled pipeline (815m long, 1,600 mm diameter) at seabed, depth 25m.

## Intake Pipelines

- Two micro-tunnelled pipelines (600m long, 1,600 mm diameter) at seabed depth 16m.



# Environmental Setting



Habitat map of the project area

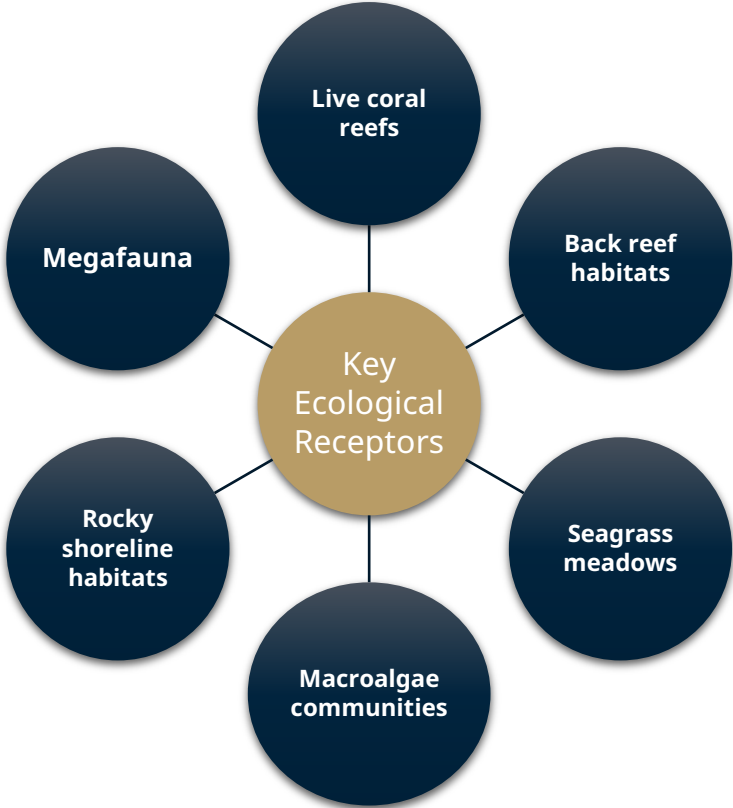
# Environmental Setting



Corals



Whale shark



Turtle footprint at nearby beach



Seagrass within backreef at lowtide



## Design Uncertainty & Regulatory Risk

**Lesson learned** from RO plant at another Red Sea Destination

Methodology **not fixed** at early design stage

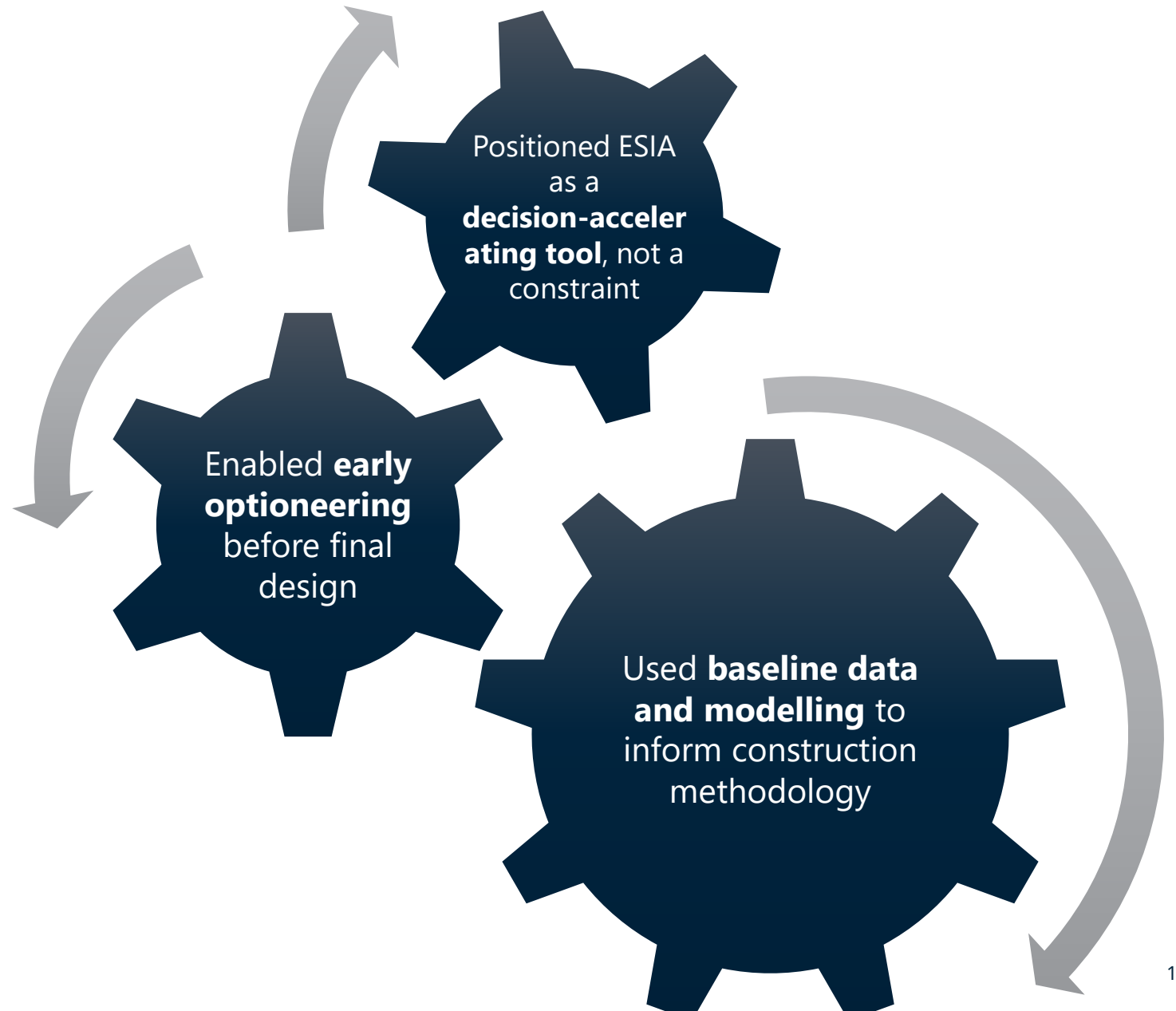
ESIA approval prerequisite for **Final Investment Decision (FID)**

Need for **regulatory confidence** under uncertainty

Time pressure from financing and **construction schedules**

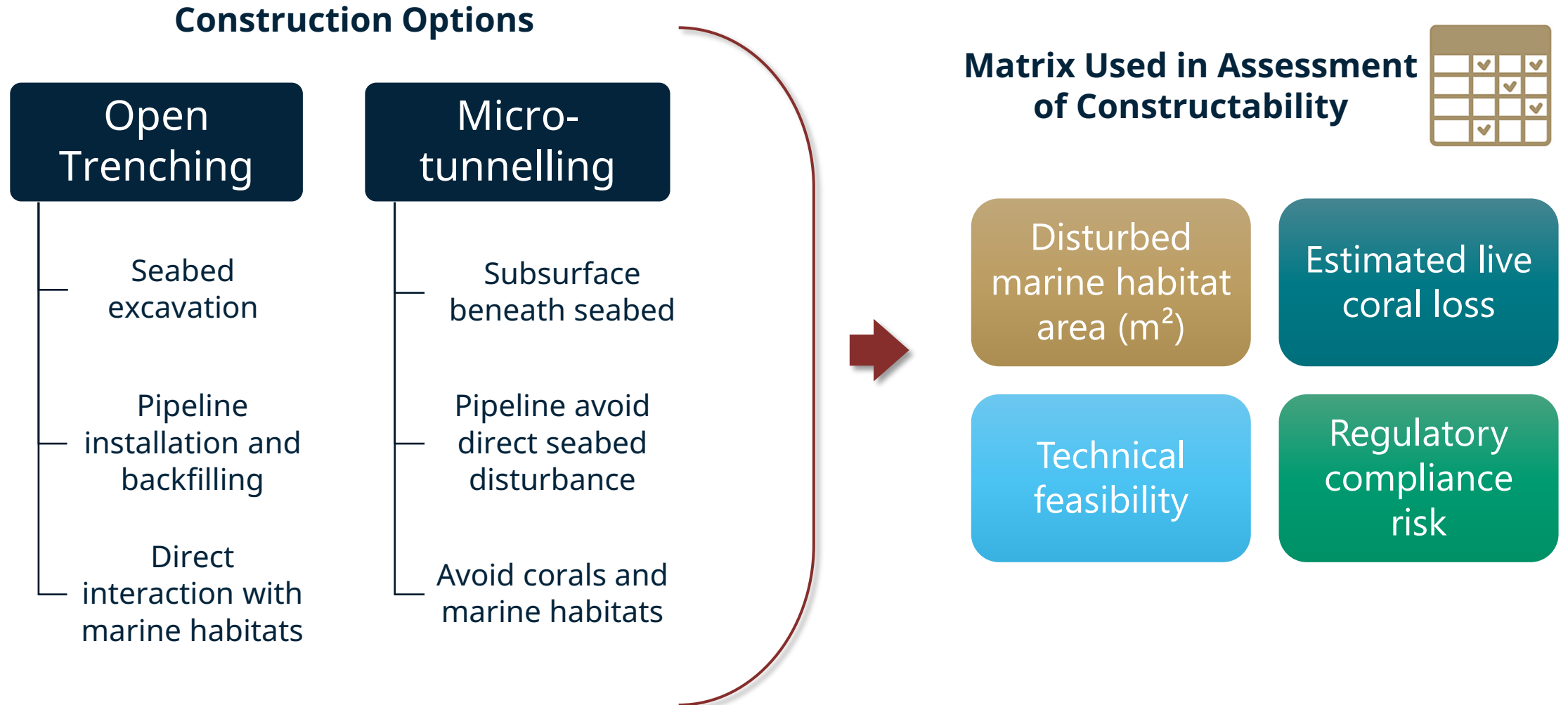
# Role of ESIA

ESIA went beyond impact identification



# Construction Options Assessed

*“How Options Were Evaluated – Use of Quantifiable, Regulator-Relevant Metrics.”*



# Impact Modelling Results

## Environmental Footprint Comparison



*"~90% reduction in disturbance footprint"*

*"~75% less impact on corals"*

### Conventional open trenching

Higher footprint disturbance and habitat loss

Requires less specialized equipment and expertise

Cost-effective

Higher sediment release

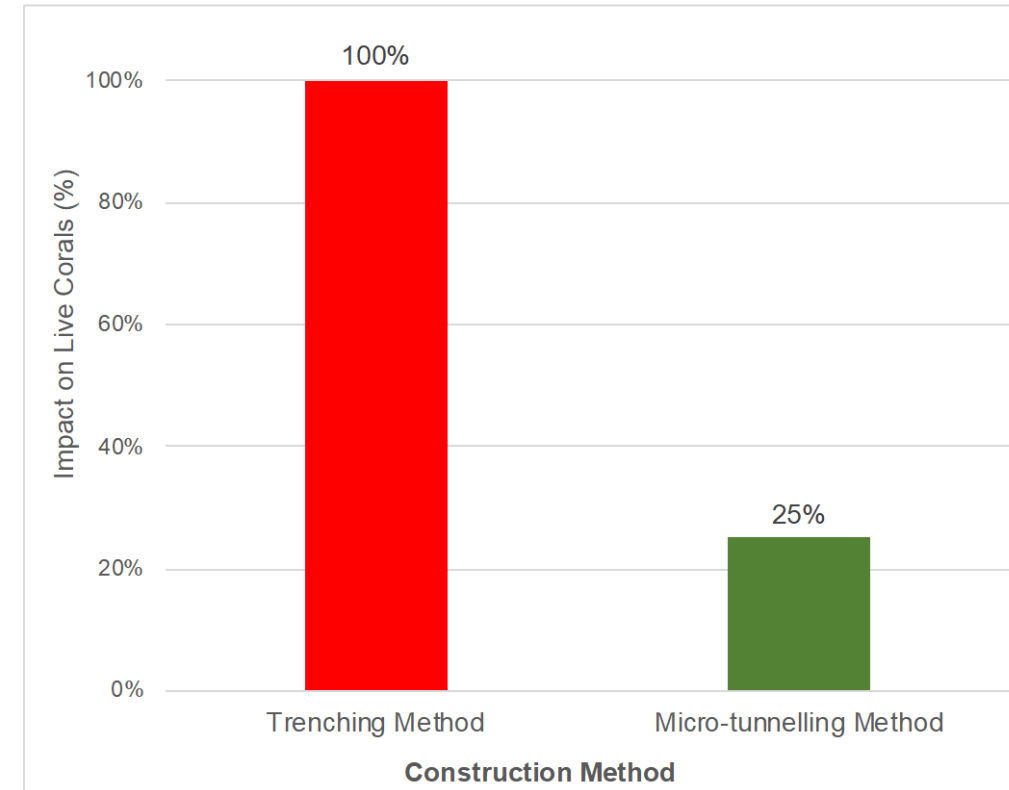
### Micro-tunnelling

Lower footprint disturbance and habitat loss

Complex equipment and precise excavation

Expensive ~2 to 4x cost of trenching

Less sediment release



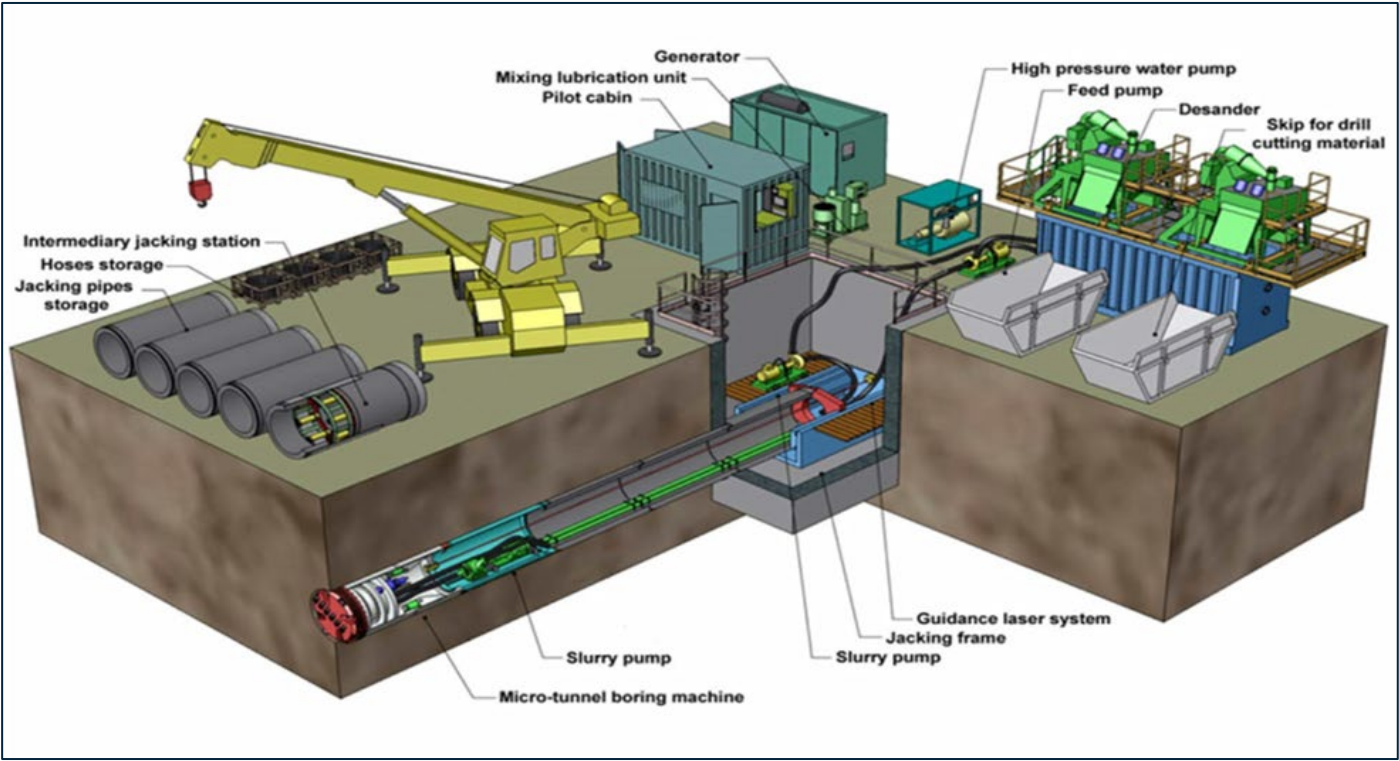
# Construction Footprint – For Context

## Cost vs Impact and Risk

*"tunneling cost is commonly cited as ~2 to 4x cost of trenching"*



**Typical pipeline trench excavation** – subsurface pipelay, backfill, continuous elevated turbidity and sedimentation



**Typical microtunnel (model)** – subsurface tunneling beneath substrate; disturbance limited launch/reception and tie-ins

# Decision Outcome

*“Why was the more complex and costly option of Micro-tunnelling selected?”*

- Significant reduction in ecological impacts
- Enhanced **regulatory confidence**
- **Adaptive compliance pathway** enabled under design uncertainty
- Supported timely ESIA approval and Final Investment Decision



Photograph of Micro-Tunnelling Machine inside the RO Plant Outfall Shaft

# Construction Environmental Compliance

- ESIA requirements are **integrated** in Construction Environmental Plans, Method Statements, and Risk Assessments
- Corals
  - Relocated, and nearby degraded areas rehabilitated
  - Biological measurements (survival rate, coral bleaching, coral cover)
- Monitoring - water quality (turbidity, pH, salinity, dissolved solids, dissolved oxygen, sediment analysis, heavy metals, hydrocarbons), and marine ecology
- Regulatory - permits, reports and site visits



# Construction Environmental Compliance



Corals for relocation to new receptor site



Coral health monitoring



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JNCC Approved Marine Mammal Observer Trainer

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**Marine mammal observer competency**

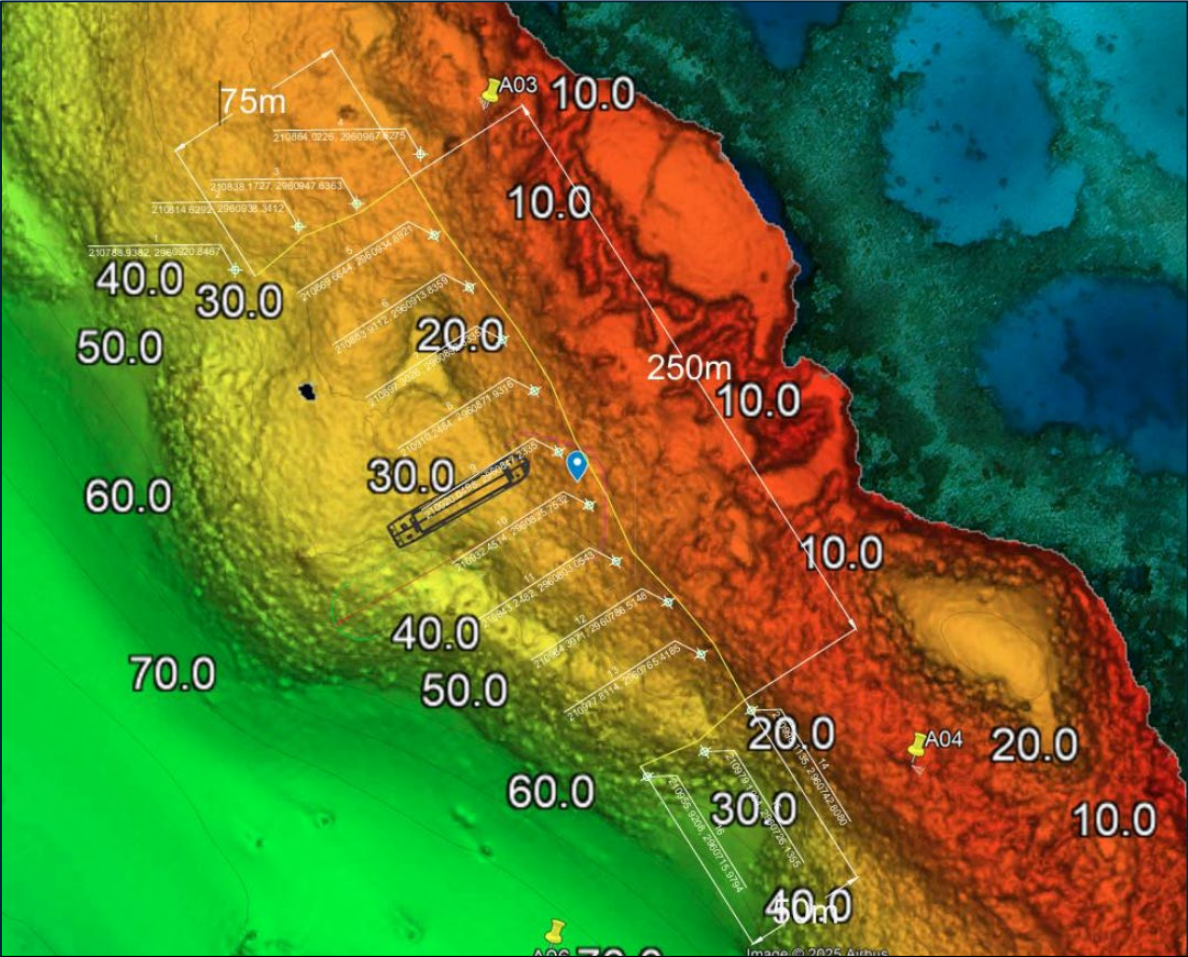


Coral health status monitoring

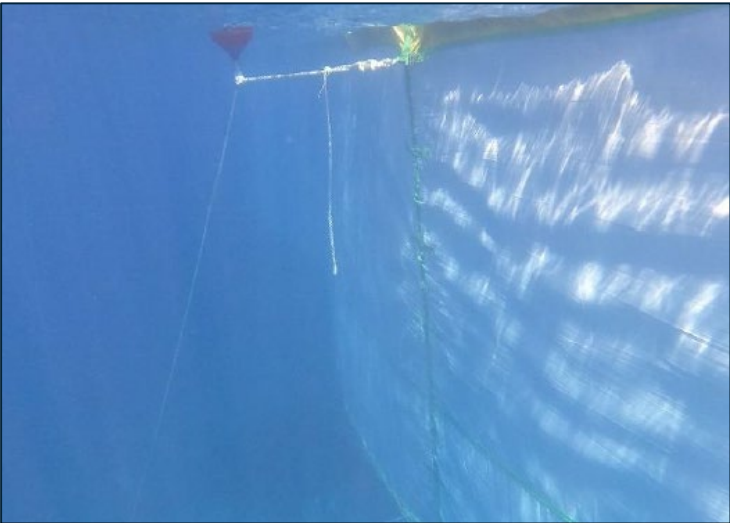


ROV for monitoring

# Construction Environmental Compliance



Outfall silt curtain Installation layout



Silt Curtain (Type 3) installation



Vertical acoustic monitoring (Hydrophone)

## Lessons Learned from Adaptive Optioneering as a Compliance Strategy



Proactive use of environmental data, can boost regulatory confidence

Optioneering bridged gaps between design, ecology and finance

Quantified metrics resonate with regulators and financiers

ESIA can reduce risks, accelerate decisions and strengthen investor confidence

Early integration of modelling improves outcomes

ESIA can function as a **strategic project enabler**

Flexible design thinking is critical in sensitive environments

# Conclusion

## From Impact Assessment to Impact Avoidance

- Project demonstrates the value of **adaptive, data-led ESIA practice to reduce risks and build** regulatory confidence.
- **Significant reduction** in marine ecological impacts
- Micro-tunnelling enabled **regulatory** and stakeholder compliance amid uncertainty.

## Regulators



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National Center for Environmental Compliance  
المملكة العربية السعودية



شمس  
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ROYAL RESERVE

# Water Systems (Site Status)



# Thank you

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# Let's continue the conversation!

Message me your questions or comments in the IAIA26 app.

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