



**Red Sea
Global**

Abstract ID# - 578

Paper Topic – Employing Environmental Data to Inform Planning of Infrastructure Projects

Session – Ensuring Just Transformation of Infrastructure Projects

Summary Statement:

RSG applies an environmental design approach to planning, using environmental data, habitat mapping and modelling to guide infrastructure planning on offshore islands in sensitive coastal habitats.

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Abstract:

Red Sea Global (RSG) is developing regenerative tourism destinations on an archipelago in the Al Wajh Lagoon on Saudi Arabia’s Red Sea coastline. The area is characterized by complex marine and terrestrial ecosystems that support a range of high-conservation-priority species. Development islands are greenfield sites with no existing utilities or infrastructure. Several islands support critical habitats, including coral reefs, seagrass, and mangroves, that provide a range of important ecological and ecosystem services. Species of global and regional conservation importance, including Hawksbill turtle, Green turtle and Sooty falcon, periodically utilize the islands for breeding and nesting. The islands require utilities to operate including power, potable water, district cooling, sewage and wastewater treatment, and telecommunications. Some facilities will be installed on the islands, while other utilities will be supplied to the islands via corridors connected to the mainland facilities. RSG has implemented an environmental design approach, whereby environmental conditions and sensitive receptors are identified early in the design process. This information is utilized to inform the strategy for servicing the islands and the associated siting of utilities and associated infrastructure. This focus on avoidance and zoning at the visioning and planning phase aims to avoid and reduce impacts, thus minimizing the need for mitigation and/or compensatory offsets and promoting sustainable development in a sensitive coastal environment.

Employing Environmental Data to Inform Planning of Infrastructure Projects

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A draft paper submission for the International Association for Impact Assessment (IAIA)
2024. IMPACT ASSESSMENT FOR A JUST TRANSFORMATION, held in Dublin, Ireland.

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Introduction

In 2016, the Kingdom of Saudi Arabia (KSA) began implementing ambitious and far-reaching plans to diversify the economy in line with the national strategy, Vision 2030. The development of key destinations along KSA's Red Sea coastline were identified as a key driver that would allow for this objective to be realized. The Red Sea Development Company (TRSDC), now Red Sea Global (RSG), was established in 2018 by KSA's Public Investment Fund (PIF) with a remit to develop the Red Sea Project, now called The Red Sea, aiming to introduce luxury tourism and residential facilities based around an archipelago of islands within a natural lagoon referred to as the Al Wajh Bank.

RSG is one of the most ambitious tourism and hospitality projects that has set itself the objective of establishing new benchmarks in sustainable development, ensuring the preservation, protection, and enhancement of the environments surrounding its assets, while creating socio-economic benefits for the region. RSG's principles focus on enhancing habitats in ways that continually renew the environment by adopting and developing pioneering technologies to optimize operational efficiencies and using scientific research, data, and technology to make informed decisions on par with international standards and best practices.

The Red Sea Concept Masterplan (CMP) has targeted development of seven of the largest islands in the lagoon and 24 smaller islands, through a phased development approach. All the islands within the lagoon are greenfield sites with no connection to existing transport infrastructure or utilities. RSG has developed an Infrastructure Concept Masterplan (ICMP) in response to the CMP that enables provision of key aspects of the project that will be required to make its developments function. These include utilities (power and water generation/supply, waste management, communications), transportation (roads and airport), and other supporting elements. Some facilities will be installed on the islands, while other utilities will be supplied via corridors connected to new mainland networks.

Since the inception of The Red Sea, King Abdullah University of Science and Technology, Beacon Development (KAUST-BD, KBD), in partnership with expert coastal modelling partners DHI A/S, has provided RSG with specialist environmental input on a broad range of projects. RSG, with the support of KBD, has developed best practices in environmental design and impact assessment, standardizing approaches for environmental data collection and developing an environmental planning approach that is embedded within RSG's project design process.

This paper provides an overview of the data-driven environmental design process that RSG applies during the early project design phases, with a view to optimizing the design process and minimizing or avoiding potential environmental impacts associated with installing infrastructure in a highly sensitive coastal environment.

Environmental Overview

The Al Wajh Bank and the surrounding lagoon's ecosystem, comprising 92 islands, is a particularly sensitive natural location with high-quality marine and coastal ecosystems that support a range of high-conservation-priority species. The outer coral bank has created a protected lagoon that reduces sea surges and enables development of coral, mangroves, and seagrass beds within its waters. These foundational habitats support and provide sanctuary to a diverse array of resident and migratory ecological communities.

The area within The Red Sea does not include any nationally designated areas for biodiversity purposes. However, the site is within an Important Bird and Biodiversity Area (IBBA) as set out by Birdlife International (Birdlife International, n.d.). A few of the breeding bird species utilizing the islands are listed as Saudi National High-Conservation-Priority (HCP) species under Saudi HCP Criterion No. One. Expert opinion provided by regional specialists indicates that some of the species can be considered to be either endemic to this region or significantly range-restricted. The presence of species such as the Sooty falcon (*Falco concolor*), Crab plover (*Dromas ardeola*), White-eyed gull (*Ichthyaetos leucophthalmus*), and a number of tern species are regionally important.

The Red Sea is recognized as one of the most important zones within the Red Sea in terms of Green turtle and Hawksbill turtle nesting distribution, abundance, and rookery size (Al Ameri, et al., 2022; Shimada, et al., 2021). The Halavi guitarfish (*Glaucostegus halavi* - critically endangered) breeds in the lagoon, with the shallow reef flats around many of the islands serving as nursery sites. A variety of other elasmobranchs (sharks and rays) are reported in the range of habitats around the lagoon. Dugongs (*Dugong dugon* - vulnerable) are present, though the ecology of this species remains cryptic and comparatively poorly understood. The area also supports Indian Ocean humpback dolphin (*Sousa plumbea* - endangered), with four other species of cetacean reported, predominantly in deeper waters outside of the lagoon.

Using Environmental Data to Guide Infrastructure Planning

RSG has developed an environmental design approach through an integrated Planning and Assessment process to address the potential environmental impacts during the design progress, offering solutions and alternative approaches, seeking to design-out potential environmental impacts to avoid\minimize their effects while protecting and enhancing environmental values and benefits provided by existing ecosystems. These recommendations are embedded using a toolkit into the project design process from inception to ensure the sustainable management of environmental resources.

The approach is data-driven and adopts the mitigation hierarchy, with information and guidance recognized based on the outcomes of various surveys, studies, and modelling specific to the project site. Regular interaction and guidance is provided to the RSG key stakeholders on an on-going basis deployed in parallel to the development of the project visioning and continued throughout the pre-concept and schematic\concept masterplan design stages. It is intended to guide the placement of key assets and infrastructure, aiming to continuously improve the designs to avoid any potential

degradation of ecosystem functioning through early impacts avoidance and integration of inherent mitigation measures throughout the project delivery framework. The key components of this process are summarized in the following section.

Methodological Approach:

a. Environmental Baseline Surveys and Habitat Mapping

Following project initiation, RSG commissions a comprehensive search for available references, including but not limited to data and reports from other RSG sites, secondary information from publicly available sources, and literature reviews. A desktop review report is prepared synthesizing key data and identifying data gaps, providing a foundational understanding of environmental and social conditions in the Area of Interest (AoI) and guiding development of the scope of environmental surveys to be carried out with a view to enhancing understanding of natural systems in the AoI.

Utilizing the scope of works developed through desktop review, environmental baseline surveys are undertaken at the outset of the pre-CMP design process. They typically include components such as: marine water and sediment quality; marine and terrestrial ecology surveys, ranging from Phase One rapid site assessments to detailed community surveys; soil and groundwater intrusive investigations; deployment of Acoustic Doppler Current Profilers (ADCPs) to collect data on water flows and waves; archaeological and cultural heritage surveys; and others. These surveys are conducted based on standardized guidance notes for terrestrial and marine environmental baseline survey methodologies, which are carried out through all RSG programs and assets to ensure that data collected is meaningful and comparable.

Following completion of baseline surveys, a high-resolution habitat map is developed using 0.5 meter x 0.5 meter resolution satellite imagery of the site. Once imagery is acquired, a segmentation process is undertaken to group together pixels with similar spectral signatures into pre-defined habitat map categories. An initial unsupervised habitat classification is then validated using ground-truthing data collected during the field surveys. A final habitat map with supervised classification is then delivered to RSG and becomes a key tool informing the spatial planning process.

b. Met-ocean and Hydrodynamic Studies

In parallel with the ecological and environmental surveys, preliminary met-ocean and hydrodynamic screening studies are conducted to provide conditions at the project site. Met-ocean conditions are characterized using hindcast met-ocean data from KAUST's Red Sea hindcast database, considered the most reliable dataset of its kind for the Red Sea. A long-term time series (~40 years) of wave- and water-level conditions is extracted from KAUST's Red Sea Model database, and the long-term time series of water-level conditions are analyzed to provide seasonal water-level changes at each of the islands. An extreme value analysis is completed for each asset, using DHI's in-house extreme value analysis tool, to derive the 1:1-year, 1:10-year, and 1:100-year return period wave- and water-level conditions and the associated wind conditions on all the projects they are contracted.

DHI has developed a MIKE 3 FM hydrodynamic (HD) model and Spectral Waves (SW) model of the Al Wajh Lagoon, calibrated with data collected from over 20 sites within the lagoon since 2018. The models are run for a calendar year to establish modelled simulations of pre-development hydrodynamic baseline conditions at the site. This modelled output is utilized to inform areas that might be suited for placement of critical infrastructure as well as areas that should be avoided.

Modelling studies conducted by DHI are utilized to ascertain the suitability of locations in terms of:

- Dilution potential/flushing
- Temperature and salinity of the ambient water
- Bathymetry/tendency for pooling of disposed effluents

Following the initial screening studies, during schematic/CMP design, DHI evaluates the impact of development on hydrodynamics, wave characteristics, shoreline dynamics, sediment transport, and nutrient release modelling, informing decision-making for infrastructure development.

c. Environmental Opportunities and Constraints Workshops

Environmental and hydrodynamic consultants lead workshops with key project stakeholders during which the findings of the preceding studies and the associated implications on the pre-concept masterplan development are set out. These workshops include outputs from the marine modelling studies and highlight the key environmental and ecological constraints and opportunities specific to both the project site and the nature of the assets/infrastructure that are proposed for development. Engagement with the stakeholders ensures collaborative decision-making and alignment with RSG's environmental and social goals.

d. Design Reviews and Site Optioneering

Masterplan designs are subject to multiple reviews, with regular feedback provided to design teams at project stage gates. The design teams are provided spatial planning guidance and appropriate environmental mitigation measures that help identify viable alternatives. Site-specific opportunities and constraints guide the development of a set of design review criteria that is utilized to review and allocate a score to design options. This facilitates clear communication of infrastructure placement implications to non-technical stakeholders, ensuring alignment with our environmental objectives, and potentially reduce significant adverse impacts on both sensitive environmental receptors and the functionality of the assets and infrastructure.

The design optioneering process focuses on specific infrastructure components and includes the alignment of corridors and rights of way, routing of proposed dredge channels, siting and orientation of marinas and marine infrastructure, placement of desalination plant intake/outfall, water treatment utilities and/or designation of ecological protected areas/natural reserve zones, among others.

e. Habitat Risk Assessments

A qualitative risk assessment, based on the baseline information and expert judgement is undertaken using the InVEST Habitat Risk Assessment (HRA) Model, developed by the Natural Capital Project, Stanford University. A Risk/Opportunity Index draws on an ecological risk assessment approach, to identify risk to natural habitats by accounting for locations of specific activities (spatially delineated stressors).

Using the habitat map developed, the risk assessment evaluates direct interactions between habitats (coastal natural capital) and activities (stressors), mapping resulting risks and identifying areas where cumulative risks from multiple stressors is greatest.

Based on the results of the HRA model, risk-mitigation measures are identified for key habitats, influenced by factors like habitat loss/degradation and changes in hydrodynamic conditions. The maps help in identifying locations where the remedial measures are recommended for implementation. Similarly, the assessments highlight areas suitable for compatible development activities based on low habitat risk.

Summary

RSG is developing high-quality tourism assets and associated infrastructure in an area of high ecological sensitivity. The natural systems in the Al Wajh lagoon, and the associated biodiversity, are a key asset to the development that warrants protection. Recognizing this, RSG has proactively implemented an environmental planning approach intended to ensure that environmental considerations are embedded into the development of project designs from the outset. Site-specific data collated from secondary sources, remote sensing platforms, targeted site surveys, and mathematical modelling is a critical tool that guides spatial planning of infrastructure at both the asset and wider project level.

References

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