TARGET 14.5. CONSERVE COASTAL AND MARINE AREAS

The coasts of the Arabian Gulf and Red Sea are witnessing rapid industrialization and urbanization that contribute to the degradation of naturally stressed marine ecosystems. Coastal and marine environments are affected by intensive dredging and reclamation activities, and several sources of pollution. Due to its unique environmental setting, the Red Sea and Arabian Gulf are increasingly receiving international scientific interest to study the effects of environmental extremes on marine organisms, and to investigate the potential impacts of future climate change on the ecological integrity of marine ecosystems. The following are the initiatives from the Center in protecting the fragile coastal and marine ecosystems in the Red Sea and Arabian Gulf.

14.5.1. Design changes for Manifa Causeway (Manifa Bay protection)

Background: Saudi Aramco proposed the construction of a Causeway to access the drilling sites at the mouth of Manifa Bay (Fig. 1). The main Causeway, which is about 20 km long, connects with drilling site islands through subsidiary routes. The total length of the lateral Causeways and coastal offshoots is about 23 km. Manifa Bay is an ecologically sensitive region and is known to be a nursery for shrimps, and various species of corals and seagrass. The modeling study was, thus, envisaged to estimate the impact of the construction activities. Likely impediments the artificial structures can cause to the local circulation can best be studied by developing computer models that simulate flow conditions when the structures are in place. KFUPM undertook modeling studies covering hydro-dynamics, sediment transport, and water quality aspects before and after the Causeway construction.

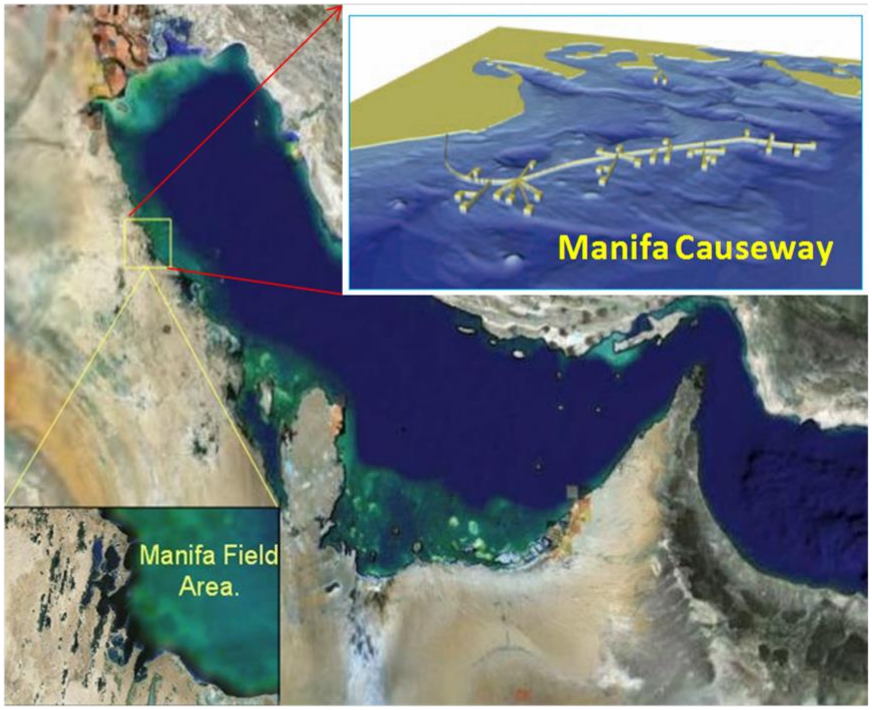

Fig. 1. Manifa Causeway site.

Model details: The DHI modeling package was utilized to investigate coastal circulation, waves and sediment transport in the Manifa Bay with a flexible grid (Fig. 2). The DHI modeling suite includes state-of-the-art modeling tools such as Mike-21 for 2D hydrodynamic and wave modeling and ECOLAB for modeling environmental conditions. Modeling and monitoring studies components were:

- Circulation (Hydrodynamics)
- Waves
- Sediment transport
- Water quality

For the Causeway design purpose, hypothetical tracer concentration initial fields (Fig. 3) were generated. Simulation for 16 days was performed as a control run to identify the distribution of the tracer concentration in the absence of the Causeway. Subsequently, simulations were performed for the same period with different Causeway designs (Table 1). Later, realistic modeling studies were carried out, for the optimal design of the Causeway using data obtained from surveys during the design phase and post-construction period.

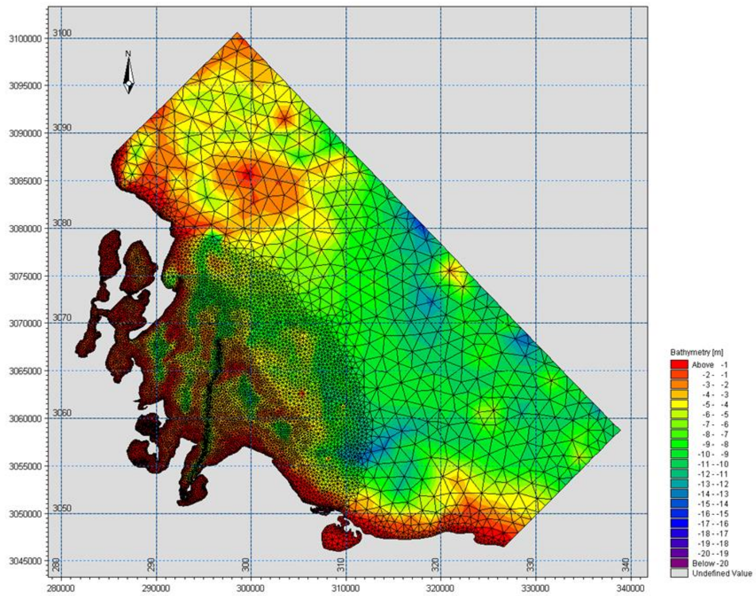

Fig. 2. Modelling domain and grid.

Table 1. Causeway design criteria.

Case	Description
A	No Causeway
B	Causeway with no openings
C	20% opening as main culverts only
D	Long bridge in the southeast (2 m contour depth (CD) to drill sites 21/22)
E	Short bridge in the southeast (3 m CD to drill site 20)
F	With 20% openings in the main Causeway as in case D
G	5% openings in the main Causeway and 1 km short bridge in southeast
H	A short bridge in the southeast (3 m CD to drill site 20) and 5% openings in the main Causeway
I	2.5 km short bridge in the southeast and openings in the form of short bridges (150 m) and culverts (50 m)

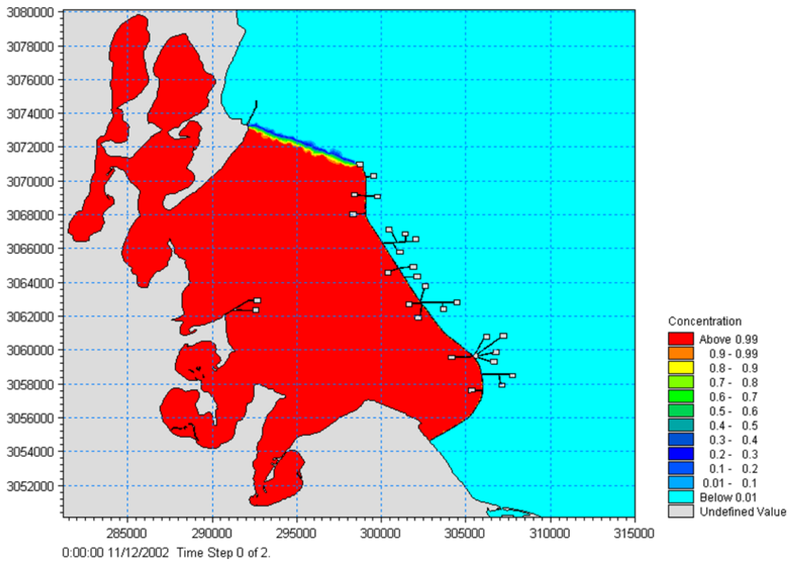

Fig. 3. Initial tracer concentration

Results: Optimization of Causeway Design:- Case A estimates the ideal tracer concentration pattern in the absence of any Causeway. Different Causeway designs alter the model circulation in the region and hence tracer concentration field and flushing time of the bay (Fig. 4). In the optimal design (case I) the concentration field closely resembles that of the control run. Furthermore, the modeling study predicts quick flushing of the bay after the construction of the Causeway (Table 2).

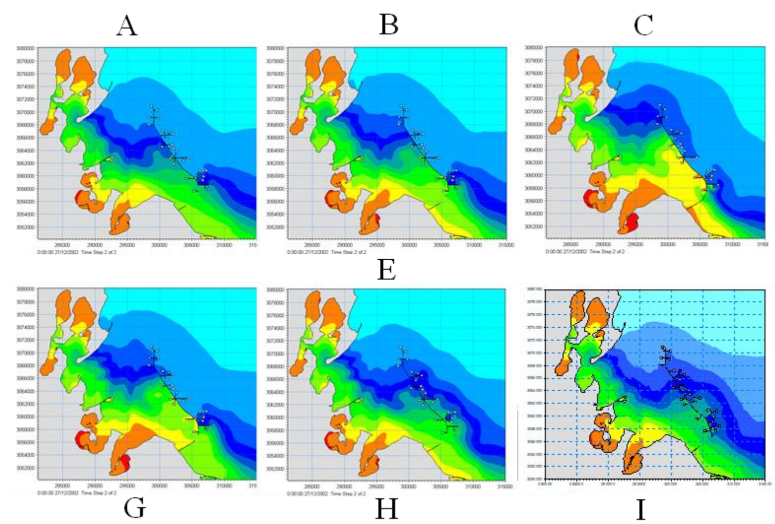

Fig. 4. Tracer concentrations after 16 days for different Causeway designs.

Table 2. Mean tracer concentration and residence time.

Case	Mean	$T_{50\%}$*
A	0.52	17
B	0.85	71
C	0.57	20
D	0.56	19
E	0.61	22
F	0.71	33
G	0.66	26
H	0.58	20
I	0.48	15

Environmental impact of causeway: The salinity difference predicted during the design phase was lower compared to that obtained in the post-construction modeling investigation (Fig. 5). The residual surface current intensifies at the Causeway openings. However, its impact on the flushing rate was minimal (Fig. 6). The Causeway also modifies the sedimentation rate. Modeling investigation shows that the seabed thickness could change by more than 5 mm at some locations over a year (Fig. 7).

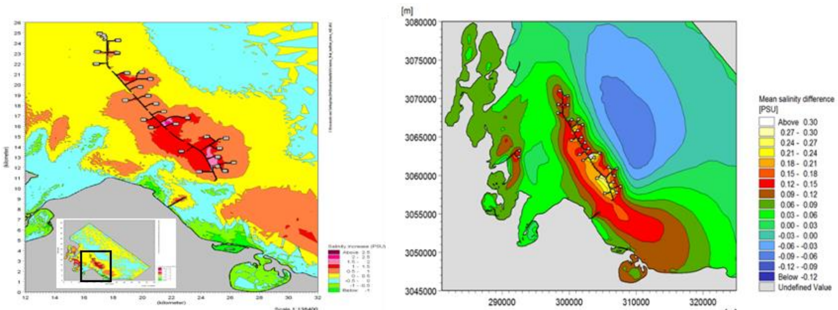

Fig. 5. Salinity difference predicted during the EIA (left) and after the construction (right).

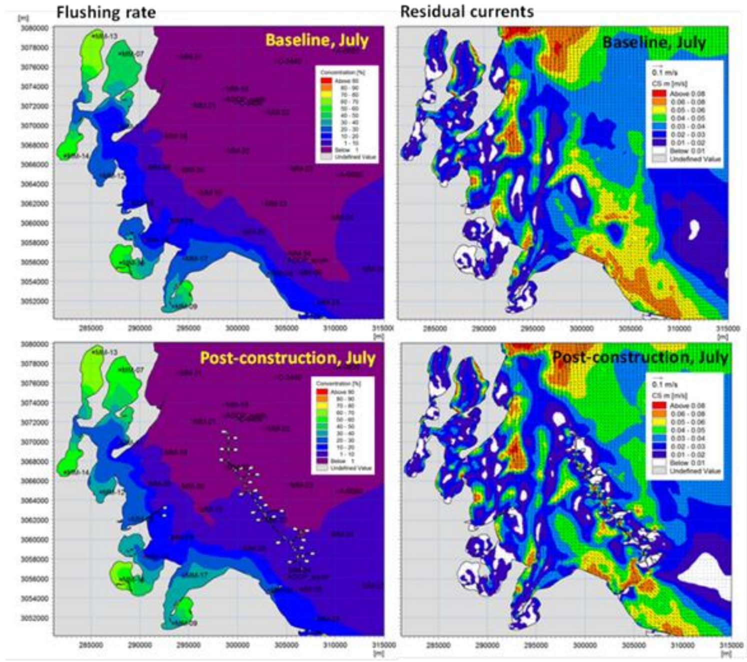

Fig. 6. Model-predicted flushing rate (left panels) and Residual current (right panels) before (top panels) and after (bottom panels) the Causeway construction.

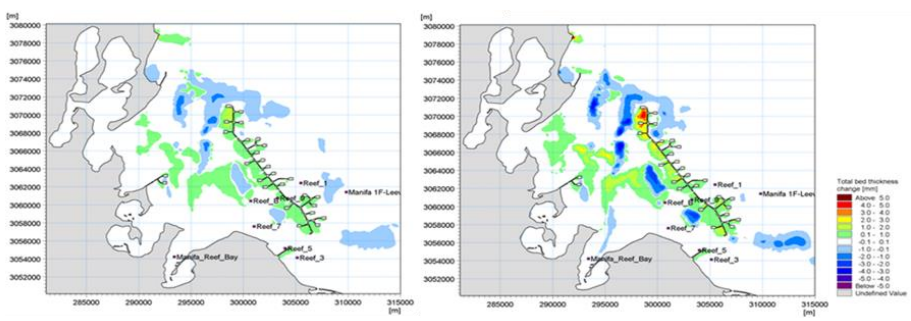

Fig. 7. Model-predicted changes in sediment deposition after 6 months (left) and 1 year (right).

Conclusion: The model simulations predicted that the maximum current speed will increase from 25 cm s-1 to about 50 cm s-1 at the 2.4-km southern bridge. The surveys conducted during 2013-2015 confirmed the same. The residual current speeds at the Causeway openings can exceed 10 cm s-1. The modeling study reveals that the Causeway has only a minor impact on the overall flushing rate. Modeling investigations suggest an increasing trend in the seabed thickness at the northern edge of the Causeway. The modelled thickness increase is approximately 5 mm a year.

14.5.2. Avoiding Biodiversity Hotspots from developmental activity (Northern Red Sea)

The Center was approached by Saudi Aramco to conduct an EIA at a site for exploratory drilling in the northern Red Sea. Upon studying the baseline of the site, the project area was notable for the presence of several ecologically sensitive coastal marine biotopes. Among them, the coral reefs are the most abundant, occurring as shallow fringing reefs near the shore and the islands and as a barrier-like formation across the mouth of the bay leading to the open sea. As is the norm, these reefs are home to a wide variety of marine life including fishes and macro-invertebrates. Next in importance, the seagrasses were found along the shallow sandy intertidal areas and reef flats. Numerous seaweed patches were found on sandy-rocky areas of the back reefs. In addition, several sea turtles and sting rays were also observed adjacent to the seagrass beds and coral reefs.

The Center proposed that the present location chosen for the drilling operations was unsuitable based on three considerations. The first is that it is located amidst a high density of sensitive marine habitats. The second is that, because of its proximity to the coast, any impact that may arise will reach the shores quickly (ex. Oil spill, favoured by tidal currents). The third is the shallow nature of the site, which requires dredging for navigational channels with attendant negative environmental and ecological consequences.

The recommendation of the Center was, therefore, a fresh location, away seaward from the present site, may be identified for the exploratory drilling, which would have to be sited as far away as possible from sensitive biotopes.

14.5.3. Optimal design of cooling water Discharge from Jizan Refinery

The Applied Research Center for Environment and Marine Studies (ARCEMS) at King Fahd University of Petroleum and Minerals (KFUPM) conducted an Environmental Impact Assessment (EIA) for the Cooling Water Discharge of Jazan Refinery and IGCC Plant, Jazan, Saudi Arabia based on the request received from Saudi Aramco. The objective of this EIA was to prepare an expert assessment of the potential environmental impacts due to the Cooling Water Discharge of Jazan Refinery and IGCC and suggest suitable mitigation measures to avoid or reduce the potential environmental impacts.

Saudi Aramco intended to construct a grassroots 400 thousand barrel per day refinery and hydrocarbon terminal facility, as well as a new power plant in its vicinity, within Jazan Economic City (JEC) premises on the south-west Red Sea coast of Saudi Arabia. The proposed facilities will generate significant amount of heat as a result of the cooling/processing of crude oil, which is intended to be moderated using seawater as the heat exchanger. The expected increase in temperature of the cooling water is about 8ºC. Continuous disposal of this warm water into the sea is expected to entrain impacts on coastal hydrography, biota, and habitats, which need to be minimized and/or mitigated. This requires the preparation of an EIA, detailing the prevailing baseline conditions and the expected impacts of construction and operation of the facilities.

As part of the EIA for the proposed development, ARCEMS collected baseline environmental, oceanographic, and biological data near the proposed refinery site. The components chosen to reflect environmental impacts were hydrodynamics of the study area, physical, chemical, and biological properties of the seawater, benthic organisms, sediment properties and contaminants therein, sensitive biotopes, and fishery. The likely dispersion of sediments associated with trenching for the installation of offshore discharge pipelines and the probable dispersion of cooling water during the operation of the refinery were assessed with the help of modeling studies. The potential impacts and environmental risks associated with the construction of the offshore discharge pipeline and the operation of the seawater intake and cooling water discharge facilities were systematically assessed and suitable mitigation measures were identified to avoid or reduce the potential environmental impacts. An environmentally suitable discharge layout option was recommended after analyzing 16 options. An EIA report was prepared based on the survey and studies conducted and as suggested in the scope of work.