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Engineering a new Port at Hazira, Gujarat, India

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Background to Project

Hazira in the State of Gujarat in India was designated as a port location by the Gujarat Maritime Board (GMB). In 1997, the GMB invited applications by international competitive bidding for the development of an all-weather, multi-cargo port at Hazira. The initiative was LNG driven in response to the increasing requirement for natural gas as a fuel in North-West India. Following a rigorous evaluation process in November 1999, GMB selected Shell Gas B.V. to develop, operate and maintain the port on a BOOT (build, own, operate, transfer) basis.

Figure 1 Project Location

There then followed an intensive period of surveys, engineering and environmental studies to develop both the terminal concept and the phased master plan for development of the port facilities for LNG, containers and other cargoes. These studies and survey were managed by Shell Global Solutions International BV (Shell GSI) which awarded the engineering of the marine facilities to Delta Marine Consultants (DMC). For part of the investigations, studies and surveys DMC engaged several subcontractors: Studies on sedimentation, currents and nearshore wave-analysis (Svašek), Nautical studies (Alkyon), Cyclone modelling (HR Wallingford). Shell GSI separately awarded a contract for metocean data collection to Fugro GEOS.

This paper will give an overview of these investigations and studies with emphasis on issues of particular interest including:

- meteorological and oceanographic data gathering (currents, waves, water quality)
- coastal structures design and physical model testing
- moored ship response
- navigation studies and channel design optimisation
- marine operability (downtime) modelling
- sedimentation and coastline development studies
- quarrying and logistics issues

The implementation of Phase 1 of the port started early 2002 with design, procurement and construction of the port infrastructure undertaken through a management contract with Hazira Marine Engineering Private Limited (HME). Capital dredging works were implemented under a separate contract with Alar Infrastructure Private Limited. The port and LNG terminal became operational as of April 2005.

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Planning and Layout Overview

The development of the port comprises three phases:

- Phase 1: LNG terminal
- Phase 2: Bulk and General cargo terminal
- Phase 3: Additional LNG berth and container terminal

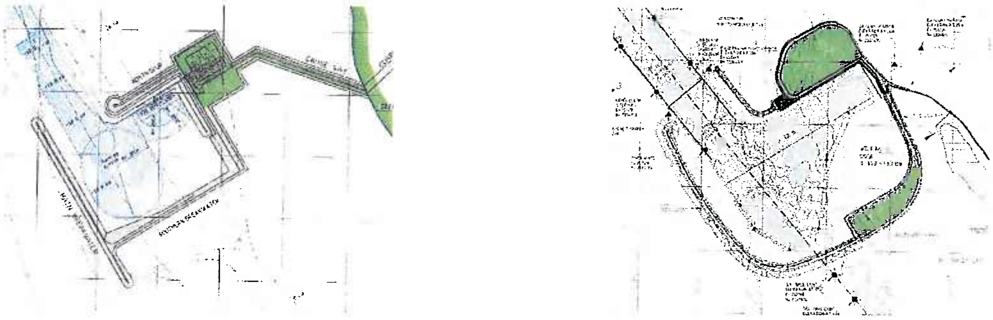

Figure 2 Early harbour development concepts

In Figure 2 the full port layouts developed in the early stages are shown. The initial concept is shown in the left picture. After the first nautical-, operability and current/wave studies the layout as shown in the right picture was developed. The breakwaters were streamlined to reduce eddies and turbulent tidal current behaviour, consequently the velocity at the harbour entrance was reduced.

Following changes in the Coastal Regulatory Zone (CRZ) legislation, the reclamation for the LNG terminal was shifted to shore, which resulted in additional studies to further optimise the layouts.
Figure 3 shows the phase 1 layout (LNG terminal), which resulted from these studies.
moved north of the northern spur. Near the southern spur the facilities for non-LNG vessels were provided. The breakwater dimensions were optimised on the basis of nautical studies (stopping length).

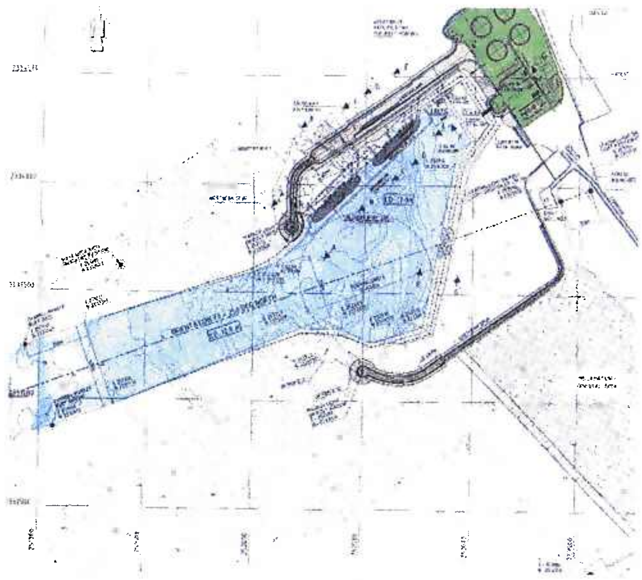

Figure 3 Phase 1 layout (LNG terminal) (final version).

The initial layouts focussed on an approach in line with the predominant current (NW) for a fully protected port layout in line with the master plan concept shown in Figure 2. It was later decided to limit the extent of the breakwater constructed at the first stage of port development. In so doing, it was also decided to adopt a revised approach and departure philosophy with an approach channel aligned closer to the prevailing SW monsoon

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winds to in the NW-SW direction. The feasibility was confirmed on the basis of ship navigation studies and metocean data monitoring campaign.

The selection of a SW approach with predominantly cross currents results in a reduction of dredging costs and navigational benefits at Phase 1.

An additional study was made on the length and orientation of the south spur in combination with a siltation and maintenance dredging study. Three alternatives of the southern spur have been envisaged. The main difference was to which extent they shelter the port. This will be described further on in this paper.

Metocean Study
The metocean study was essential for the understanding of the environmental conditions at this specific location. The Hazira project is located in a challenging physical environment with a high tidal range, significant tidal currents, exposure to the influence of the southwest monsoon weather patterns and to tropical cyclones.

In Table 1 a summary is made of the main characteristics:

Mean High Water Spring (MHWS)	MSL + 3.8 m
Mean Low Water Spring (MLWS)	MSL -4.0 m
Mean High Water (MHW)	MSL + 2.5 m
Mean Low Water (MLW)	MSL -3.5 m
1: 100 year significant wave height near shore $H_{s\ 1/100}$	5.4 m
Cross current spring tide	2 m/s

Table 1 Main metocean characteristics

Fugro (GEOS) measured the nearshore waves at a waterdepth of 20 m from June 2000 to August 2001. This period included two monsoon seasons approximately mid May to the end August). A wave buoy was used with a back up wave gauge.
Besides the wave measurements, the metocean campaign contained:

- Current measurements using an Acoustic Doppler Current Profiler (ADCP)
- Water quality sampling and testing
- a metstation to measure wind speeds, temperatures and pressures
- a tidal gauge
- Ocean Surface Current Radar (OSCR)

The results of the metocean data gathering campaign were used to validate a 10 year hindcast of the nearshore wave climate based upon offshore hindcast data and SWAN analysis by SVASEK. Comparison of the simultaneous offshore British Meteorological Office (BMO) Global wave model data and nearshore wave measurements showed that especially at low water the measured sea and swell waves were lower than the computed waves. This was explained by the presence of shallow banks relatively close to Hazira port.

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Southern spur and dredged channel optimisation

Three options have been considered for further optimisation of the southern spur namely:

- C1 A short spur with high crest height in the shallow area and a crest around MSL in the deeper areas.
- C2 A longer spur with a crest over the entire length.
- C3 A short spur with a high crest over the entire length.

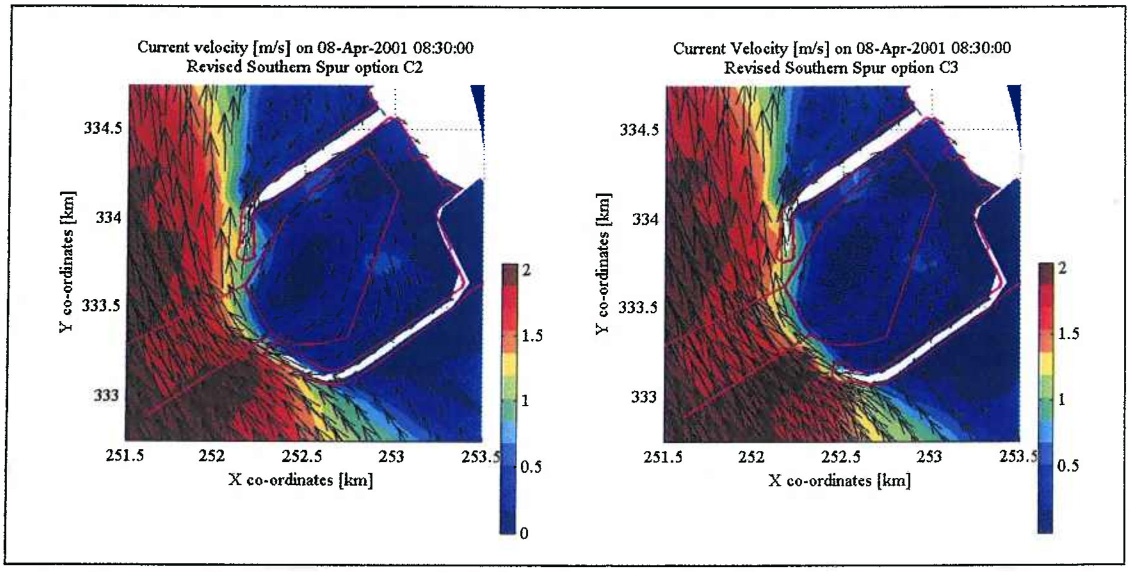

Figure 4: Calculated current patterns during strongest flood currents (Svašek)

Hydrodynamic studies have been performed by Svašek to firstly compare the current pattern around the breakwater heads (Figure 4). Subsequently the siltation rates could be determined. It was concluded that mainly sand is deposited in the approach channel, while silt is deposited in the basin. The silt is deposited in the basin by exchange through the large tidal range and the eddy current exchange. As C1 and C3 were both having the same layout the impact on sedimentation was equal. Siltation for the C2 alternative was slightly lower.

To assess the effect of the sediment changes due to the port development on the existing shoreline, a simplified coastline development study was done also using satellite images. It was concluded from this study that the effect of the port on the shoreline would be limited.

The current profile around the breakwater heads is also used to compare the situation at the moment of the arrival of the LNG carrier. Figure 5 shows that for a longer spur the current velocities in the port entrance and turning circle are higher. Outside this area, the current velocities in options C2 are higher due to the fact that the C2 spur protrudes further into the sea. This extra deflection of the tidal current results in higher velocities in the approach channel near the port.

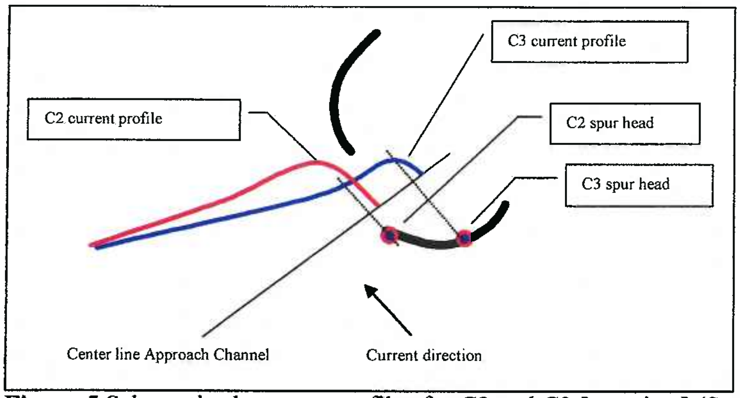

Figure 5 Schematised current profiles for C2 and C3 [top view] (Svašek)

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