The Antea group, IIC technologies and Stema Systems collaborate as partners together on the detailed approach and methodology for the assignment for the Port and surroundings consists of four main parts: (1) collect field data collection to feed the simulation models (2) conduct hydrodynamic and empirical numerical model studies to research the siltation causes and remedies (3) set up and validate a nautical simulation model and (4) establish and apply an operational measurement practice to implement the nautical depth and derive dredging volumes. The study will take approximately 18 months.

Field data will be collected with respect to the tender specifications for assessment of waves, tides, currents, wind and salinity data at Cochin port. This would also include data collection for studies of flow of sediment discharge and suspended sediments. All data will be collected with the aim to (1) deduct necessary information for finding answers to the assignment topics of the TOR and (2) to give the best possible input data for the numerical model. Essential for the sedimentation processes is the monsoon period, both because there is probably a high input from the rivers entering the Port area and the ocean dynamics are high. Because the monsoon period is occurring juin-september, it is important that the measurement can start by the latest in july. We now suppose in our planning that the measurements would start in juin, and last for at least one year to capture the full hydrodynamic and morfodynamic processes of all seasons.

After 6 months, we will provide the first measuring campaign results to the hydrodynamic modelling team from Antea Group to create the possibility to start their modelling domain setup. An update of the bathymetrical map is necessary at the same time for the set-up of the hydrodynamic model, but also for the nautical model. In the first semester, a mud survey campaign will be executed as well, because these results are necessary as well to include in the hydrodynamic and nautical simulation model. We will asses in the same period the geotechnical characteristics of the mud layer with the Densitune in combination with acoustic methods analysed by Silas software. The surface bed characteristics and origin of silt material will be examined in the first semester after start of the project as well, since these data is essential for the understanding of the physical processes which is a necessary basis for the numerical model setup.

The key objective of using **numerical models** is to develop trustworthy decision support tools to study hydrodynamics of wave transformation, tidal circulation, salinity, mixing, sediment transport of the region encompassing Kochi Port, entrance channel and the Kochi backwaters. The strategy proposed for the Cochin area comprises a 2D-model with as domain the reach between Panangad (near Ramada Resort) in the south-east and Cheru Mulavukad to the north-west. A 1D approach will be employed for any additional domains that may be required. This includes simulation results for up to 2 events (one historical and one synthetic) which will be identified based on the gathered information.

In case of relevant stratification observed during measurements with ADCP's (so having detailed profiles) on the different locations C1-C6 we will developed locally a three dimensional mathematical numerical model describing the flow patterns, the fluid, density patterns and the sediment concentration pattern in that area.

For this purpose we offer developing a set of numerical models using the well know and respected platform Telemac (including modules for sediment transport, morphology and dredging) coupled to Tomawac (for taking in account the effect of waves). The proposed software is based on Finite Element Method which is very well suited for complicated geometries as it allows to discretize the domain using unstructured meshes (in contrast to MIKE-software).

With this calibrated model, in combination with field data collection results, we will be able to answer the research questions, such as the dynamics of dredge spoil, schematizing the most important physical processes of siltation in the port area, suggest methods for arresting siltation or conducting component studies on the outer harbor.

In order to investigate the nautical implications of a new nautical depth criterion in the Port of Cochin, Antea group has a technical collaboration with the FHR and University of Ghent which are worldwide the top experts in working on Nautical research with their Towing tank and ship maneuvering simulator especially equipped for maneuvering in mud conditions in shallow ports.

In navigational channels covered by fluid mud suspensions, the bottom level and, therefore the depth are not clearly defined. In those cases it is not clear which minimum Under Keel Clearance (UKC) should be selected, as contact between the ship's keel and mud would not cause any damage but on the other hand a ship's behaviour can change significantly due to the presence of a mud layer. Instead of using terms as 'bottom' and 'depth', in muddy navigation areas it is more appropriate to introduce the concepts 'nautical bottom' and 'nautical depth'. With their expertise in simulation and simulator modelling Antea Group with Flanders Hydraulics Research (FHR) and the Ghent University (UGent) will perform a real-time simulation study of the relevant inbound and outbound maneuvers to the Port of Cochin at different bottom/mud conditions. For this purpose a full mission bridge simulator located in the offices of FHR in Antwerp (Belgium) will be utilized.

Our methode includes development of a 3D visualization model of the Port of Cochin based on digital plans and photographs of the maneuvering environment. The 3D **nautical model** will contain the port infrastructure, signalization and the most important landmarks. A first set of hydrodynamic data (velocities, discharges, wind…) and bathymetric will be set available after 6 months, so that the FHR/UGent team can incorporate these in their model. At first the present bottom condition of the Port of Cochin will be implemented in order to achieve a reference condition. The mud layer characteristics (density, viscosity and layer thickness) will be selected based on the results of the first measurement campaign (after 6 months) and the available

maneuvering models. A recent bathymetry (available at 210 kHz) will be transformed to a bottom profile corresponding to the solid bottom and will be implemented in the simulator. In order to assess the nautical bottom several bottom/mud conditions will be simulated. A maximum number of 12 combinations of layer thickness, density, viscosity and water depth (tide) will be implemented in the simulator environment. The prevailing wind conditions may be taken into account by means of a uniform wind field. A maximum of four current vector fields resulting from numerical modelling will be implemented. During the simulation runs, a ship can be assisted by maximum six tug boats which will be controlled by the operator (FHR) by means of a control desk allowing push-pull operations of both ASD and Voith-Schneider tugs.

Starting from the mathematical maneuvering models at FHR, mathematical models for (a selection of) the four design vessels (container carrier (L=335 m); tanker (L=250 m); general cargo vessel (L=250 m); general cargo vessel (L=180 m)) will be derived. The maneuvering models for the container carrier and general cargo vessels will allow all combinations of speed and rpm, while the maneuvering model of the tanker will only allow the combination of positive rpm with forward speed.

The simulation program will consist of six simulation days divided in two sessions of three days with at least three weeks between the end of the first and the start of the second session. The simulations will be performed by minimum two pilots with experience with the design vessels in the port of Cochin. The model itself will be run in the simulation environments of the Flanders Hydraulics Lab that partners with Antea Group. Two of the most suited senior pilots from Port Cochin will calibrate the model to ensure maximum adaptation to the Port Cochin conditions to enable full commitment by the shipping community. The Port Cochin pilots will be fully assisted by 2 Belgian maritime harbour pilots, to ensure full training of the pilots. The simulations will be analysed based on both the assessment of the pilots and objective criteria such as application of rudder, propeller and tug boats.

The aim is to configure the nautical model 8 months after the start of the project. During month 8-10 there will 2 months of simulation at the simulator in the FHR. The first weeks of month 8 after the start of the project the Port Cochin pilots (together with the Flemish Pilots) will have their first simulations and be able to give comments on the model build by FHR/UGent. Their comments will be implemented in the FHR model, and the last 2 weeks of month 10 after start of the project the second part of the simulation by the Port Cochin pilots (together with the Flemish Pilots) will be executed. The FHR/UGent team will analyze & report their findings by the end of month 12 (see § planning).

With the findings of the FHR/Ugent team, it will be able to establish the criteria for **the nautical depth.** Only with these criteria it will be possible to fulfill the requirements for the other demands of the assignment, like establish acceptable frequency to navigate safely in the channel

or determining the dredging needs. These topics will be executed in the last semester of the project, after the report of the FHR/UGent will be available.

Slope stability will be assessed by frequent bathymetric surveys during the full project. After the field data collection is finished (12 months after start of project), the hydrodynamic models will be updated to take the full hydrodynamic spectrum into account of the different variables.

India Cochin Port, Highlights & future plans