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COMPENDIUM ON

ROLE OF CWPRS FOR PORT DEVELOPMENT IN INDIA

SEPTEMBER 2018

Edited by

Dr. Prabhat Chandra, Scientist E

Shri T Nagendra, Scientist E

100 years and beyond ..

Director

Dr. (Mrs.) V. V. Bhosekar

Central Water & Power Research Station

Pune 411024

Government of India
Ministry of Water Resources, River Development & Ganga Rejuvenation

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FOREWORD

The development of ports is a very ancient art. In the recent years, the ocean transport has assumed large significance due to its cost effectiveness calling for advanced trends in Port Engineering. The Central Water and Power Research Station (CWPRS), Pune, India, a premier institute in the field of applied hydraulic research, has been rendering its advice for port development and on coastal engineering aspects in a big way almost for the last seven decades. It gives me immense pleasure to release this Compendium on "*Role of CWPRS for Port Development in India*" on the occasion of 6th Indian National Conference on Coastal, Harbour and Ocean Engineering (INCHOE-2018) being held at CWPRS during September 26-28, 2018.

CWPRS had made the humble beginning to undertake the port development studies for Madras, Kandla, Kolkata and Mumbai Harbours in the year 1947. After the 3rd five year plan, there was a sudden rise in the port development schemes and CWPRS also expanded to cater to the national development. After the liberalization of economy in the year 1995, private port development started. Recently, under the flagship scheme of Government of India "Sagarmala", port led development has been initiated with modernization of exiting ports, development of six mega port under the public – private – partnership schemes and formation of coastal economic zones. CWPRS has strong imprints towards the development of all major and minor ports in India, and other coastal developments. CWPRS has marked its presence by way of offering innovative and useful solutions for coastal protection all along the Indian coast. CWPRS studied almost 125 projects and submitted more than 1500 reports in the field of Coastal Engineering and port development covering all major ports, minor ports and a number of fishing harbours. The projects in the Coastal Engineering group at CWPRS cover nearly 40% of the total works. The study for 2.0 km long Mega Container Terminal at Jawaharlal Nehru Port was completed at CWPRS and it was dedicated to nation by Hon'ble Prime Minister in February 2018. The studies for proposed International Airport at Navi Mumbai were also completed recently. In addition to providing safe, sustainable and cost effective solutions to the port development schemes, CWPRS has also contributed notably for restoration of Chilika lake in Odishha, protection of mangroves and other natural features along the sea coast for maintenance of coastal ecology, flood mitigation measures for Mithi river in Mumbai, intake and outfall studies for urban and industrial effluents, cooling water circulation for a number of Nuclear Power projects. CWPRS has been engaged in providing solutions to some of the coastal projects outside India too.

CWPRS offers the latest and most advanced hydraulic model facilities both for physical as well as mathematical modelling comparable to any International standards in addition to the latest set of equipments for laboratory and field data collection on various coastal parameters.

The serving and retired CWPRS scientists associated with these studies deserve great commendation. I am sure that the port and coastal engineering fraternity will find this Compendium very useful and take the necessary benefit of CWPRS expertise.

CWPRS, PUNE- 411 024
26th September, 2018

Dr. (Mrs.) V. V. Bhosekar
Director

EXECUTIVE SUMMARY

CWPRS is a premier research institute and has been associated with the studies for development of all major ports and most of the minor ports, fishing harbours and coastal protection works in India almost for the last seven decades. The ports along the coast are exposed to the effects of winds, waves, tides, littoral drift, upland discharges through rivers, salinity mixing in estuaries etc. The hydraulic design of the port structures viz. breakwaters, approach channel, berthing facilities, turning circle is required to be done by judiciously considering the effects of all these coastal parameters. The capital cost of port development is huge and safety concerns are of utmost importance. Hence, the optimum design of the port structures needs to be evolved in respect of operation, sustainability and maintenance. The Indian shipping industry has been registering a growth of about 6% for the last five years and is expected to grow further. The Government initiative of implementation of “Sagarmala” scheme which includes expansion of existing ports, development of mega ports and coastal economic zones poses new challenges for design of the port structures. CWPRS has contributed to more than 125 port and coastal development projects and submitted more than 1500 reports which also including studies conducted for foreign countries too.

The hydraulic model studies play a vital role for the port development in the planning stage itself. The understanding of the complex interaction of various coastal parameters like wave and tides is essential. The modelling techniques enable studying mainly the following aspects for evolving the suitable layout and design of breakwaters, berths, approach channel etc. in a port development scheme:

- Wave tranquillity conditions for predominant wave conditions
- Flow conditions and assessment of maintenance dredging
- Design of stable cross sections of breakwater
- Ship navigation and design of mooring arrangements
- Location of disposal grounds
- Littoral drift distribution and the effect of development in the adjacent regions
- Design of shore protection measures
- Location and design of intake and outfall structures for Power projects
- Coastal Ecology

The hydraulic model studies also provide solutions to protect mangroves, biological species and fish in a desired saline environment towards maintenance of coastal ecology, mitigation of coastal urban flooding, effects of oil spill etc. The model studies help in studying the different alternatives for deciding upon the final optimum layout from the considerations of wave tranquillity, navigation, flow conditions, sedimentation and other morphological aspects.

The hydraulic model studies had started with the physical models in the earlier days in large sized trays with the simulation of waves and tides, as per the modelling scales governed by Froudian law. These models were very useful in assessment of the wave tranquillity conditions and flow patterns and contributed significantly for development of major ports in India. Sediment movement was also observed qualitatively using various tracer materials in these physical models. CWPRS scientists contributed in technological advancements for major port development with the formulation of theories for assessment of sedimentation and wave attenuation along channels. The technology of physical models took a major leap with the introduction of Random Sea Wave Generation (RSWG) system wherein the actual wave spectra was reproduced truly as per the proto sea conditions using the fully computerised system. The development of Automatic Tide Generation (ATG) system enabled accurate simulation of tides in the model and advanced instrumentation system was utilized for measurement of water levels and currents in the model. The limitations of scale effects cost and time consumed for carrying out the studies are experienced sometimes in the physical models. With the advent of computers and digital technology, gradually the mathematical modelling has also emerged as a strong tool and now frequently used to solve the coastal engineering problems. These models are based on mathematical equations with certain assumptions; hence their calibration and validation are very important for using the model predictions. A well calibrated mathematical model has the advantage of carrying out simulations for longer periods, easily incorporate alternate design proposals and cover larger areas. Mathematical models can also handle transport problems better and have relatively less retaining cost. Mathematical modelling techniques are being extensively used for hydraulic model investigations in the planning and development of coastal engineering projects. The models are quite versatile in assessing the sediment movements, the dispersion of dredged material, oil spill modelling, thermal modelling, 3D effluent and salinity mixing profiles, which cannot be studied properly in physical models.

The studies for port development are often required to be done using hybrid modelling approach involving both physical as well as mathematical modelling judiciously. In general, the mathematical models provide fast results for evolving preliminary layouts. Physical models have distinct advantage and are useful to fine tune / optimize coastal projects. Modelling is an art and the experience and judgement of modeller is very important for suggesting the proper engineering solutions.

This compendium on *"Role of CWPRS in Port Development in India"* has been divided into five chapters which describe the contribution of CWPRS. In the ***Chapter 1***, the importance of the hydraulic models for port development has been presented with brief on modelling techniques; the history of development of coastal engineering branch at CWPRS, contribution of CWPRS for port development in India and abroad; major projects studied and description of the available hydraulic model facilities at CWPRS including both physical as well as mathematical. The model facilities include Random Wave Flumes, Multipurpose Wave and Tidal Basin, advanced field equipments for collection of coastal data, Remote Sensing Laboratory and the latest suites of mathematical models. CWPRS is the only Institute in the Asia Pacific region which has the privilege of having maximum facilities and the technical expertise for undertaking Coastal Engineering studies.

The ***Chapter 2*** describes the contribution of CWPRS for development of major ports. Under this chapter, studies undertaken for each major port has been presented briefly for total 12 major ports highlighting the outcome and benefits. The studies broadly cover the wave tranquillity aspects, flow conditions, sedimentation, morphological aspects, location of disposal grounds, design of breakwater sections etc. The layouts were executed as per the recommendations of CWPRS and working successfully. CWPRS has been constantly associated with all the major ports for rendering advice for their expansion plans too.

The ***Chapter 3*** describes the typical studies undertaken for development of minor ports and fishing harbours. There are total 200 notified minor ports in India and most of them have been studied at CWPRS for their successful execution and operation. A number of layouts recommended by the other institutes which faced problems after execution were re-engineered successfully at CWPRS. These layouts were revised as per the recommendations of CWPRS and found to be working satisfactorily at sites.

The ***Chapter 4*** describes the CWPRS contribution in the Shore protection measures along the Indian coast at various typical sites including the projects under Asian Development Bank (ADB). Innovative methods adopted by CWPRS for coastal protection at typical sites including some very important sites viz. sea wall at Marine Drive in Mumbai, Dwarka in Gujarat and similar projects have also been described. All the suggested coastal protection measures have been implemented and are working successfully.

The ***Chapter 5*** describes the studies undertaken for typical coastal engineering projects pertaining to the environmental effects of the coastal developments and maintenance of coastal ecology such as location of suitable disposal grounds for dredged material, restoration of Chilka lake for conserving its unique ecology, oil spill studies, mitigation of flood in coastal urban areas, location of intakes and outfalls for thermal and nuclear power projects etc. All the projects have been implemented successfully. This chapter concludes with a table of the list of type of studies conducted at CWPRS for different projects during the last five decades.

Compendium on

ROLE OF CWPRS FOR PORT DEVELOPMENT IN INDIA

CONTENTS

Chapter 1

INTRODUCTION

The Indian port and shipping industry play a vital role in sustaining growth in the country's trade and commerce. India is the sixteenth largest maritime country in the world with a coastline of about 7,517 km. According to the Ministry of Shipping, around 95 per cent of India's trade by volume and 70 per cent by value are done through maritime transport. India has 12 major and 200 notified minor and intermediate ports. During Financial Year 2017-18, cargo traffic at major ports in the country was reported at 679.36 million tonnes (MT). During 2016-17, major and non-major ports in India accomplished a total cargo throughput of 1,133.09 million tonnes, an increase of 5.7 per cent previous year 2015-16. India's cargo traffic handled by ports is expected to reach 1,695 million metric tonnes by 2021-22 according to a report of the National Transport Development Policy Committee.

The Sagarmala Programme is the flagship programme of the Ministry of Shipping to promote port-led development in the country through harnessing India's 7,500 km long coastline, 14,500 km of potentially navigable waterways and strategic locations on key international maritime trade routes. It also aims for transforming the existing ports into modern world class ports and integrate the development of the ports, the industrial clusters and hinterland and efficient evacuation systems through road, rail, inland and coastal waterways resulting in ports becoming the drivers of economic activity in coastal areas. Six Greenfield Ports are planned in Sagarmala project viz. Vadhwan (Maharashtra), Tajpur (West Bengal) Paradip Outer Harbour (Odissha), Cuddalore/Sirkazhi (Tamil Nadu), Belikeri (Karnataka), Enayam (Tamil Nadu) Transhipment Port apart from modernization and capacity expansion of existing ports. The Indian government plans to develop 10 coastal economic regions as part of plans to promote the country's Sagarmala (string of ports) project.

In 2015, a study conducted by the Space Application Centre, Ahmedabad, and the Central Water Commission found that 45% of India's more than 8,000 kilometre-long coastline is facing erosion. Experts agree that the construction of various structures along the coast that tend to protrude into the sea contribute to the erosion of the coastline by reducing natural sedimentation that allows the beach to become rejuvenated. The coastal regions where land and water meet are ecologically dynamic and sensitive regions, as marine and coastal ecosystems continuously impact on each other. These regions have rich ecosystem such as wetlands, mangroves, water bodies, seaweeds coral reefs, fisheries and other marine life, and other coastal and marine vegetation. These ecosystems protect the region from saline winds, cyclones, tsunami waves etc., promote carbon sequestration and biodiversity as well as provide raw materials for a number of manufacturing activities.

The hydraulic phenomenon in the coastal regions involves tides, waves, density currents and the movement of sediments under the influence of tides and waves. Open coasts or wide bays are exposed to wave attack and often subjected to cyclones / storm surges and Tsunami effects. In regions like estuaries, unlike open coasts and bays, generally tides and upland discharges play a dominant role. The planning and construction of various coastal protection structures, inlets, harbour basins, navigation channels, jetties / breakwaters, cooling water circulation systems e.g. for power plants, water intakes and effluent outfalls etc. extensively use hydraulic modelling techniques.

The CWPRS has been in the service of port and coastal sector in India almost for the last seven decades. CWPRS has strong imprints towards the development of all major and minor ports in India, and other coastal developments. CWPRS has marked its presence by way of offering innovative and useful solutions for coastal protection all along the coast of India. CWPRS studied almost 125 projects and submitted more than 1500 reports in the field of port development and coastal engineering.

1.1 ROLE OF HYDRAULIC MODELS IN COASTAL ENGINEERING

In general, the hydraulic modelling techniques in coastal engineering focus on finding solutions on the following aspects.

Development of Ports and Harbours

- Wave tranquility for optimisation of harbour layout including location, length and alignment of breakwaters, jetties, berths, approach channels and turning circles
- Estimation of siltation in harbours and navigation channels
- Harbour resonance and response of vessels
- Ship manoeuvering, ship motions and mooring forces
- Dredging, disposal and sand bypassing
- Stability of tidal inlets

Shoreline Changes, Coastal Erosion and Protection

- Littoral drift and shoreline changes
- Effect of harbour development on beach behaviour
- Design of shore protection works such as seawalls, groynes, revetments, offshore bunds, beach nourishment
- Innovative coastal protection methods

Design of Maritime Structures

- Design of breakwaters and coastal protection structures
- Design of intake and outfall structures
- Storm wave hindcasting for determining extreme wave conditions
- Storm surge analysis and determination of safe grade elevation

Cooling Water Systems for Power Plants

- Thermal dispersion for locating intake and outfall structures of thermal/nuclear power projects
- Flow patterns around the Intake structures
- Innovative techniques for enhanced heat dissipation and pre-cooling systems

Water Quality and Environmental Aspects

- Estimation of water quality parameters
- Density currents due to interaction between salt/sediment laden and fresh water
- Effect of reclamation on hydrodynamics and siltation
- Disposal and dispersion of dredged material, industrial and municipal waste

Advancements in science and engineering define many of the above processes in detail and with considerable accuracy. Directional Wave Spectra, a sophisticated tool that describes wave energy as a function of wave frequency and wave direction, can express the wave climate. Large and complex computer programs are available for detailed computation of wave transformation by refraction, diffraction, attenuation and reflection. Complex theories exist to compute sediment transport. Mathematical models can be used to simulate the transport of sediments and pollutants. However, the best possible representation is only simplification of reality. The complex nature of the processes involved and the large number of parameters necessitate simplification through certain assumptions and elimination or parameterization of certain processes for the formulation of a model to achieve engineering solution to a particular problem. In order to study a particular aspect, the relevant part of the prototype is simulated in the model domain. In order to decide the boundaries of the domain to be included in the model, it is essential to understand each element of the system and its physical interactions, inputs and outputs, how they affect the system and area of influence of the proposed modification to the system.

The port structures like breakwaters etc. incur huge costs and so is the recurring cost of maintenance dredging. Hence, utmost care needs to be taken to evolve safe, sustainable and economical layouts by the judicious use of modelling techniques in the planning stage itself.

1.2 MODELLING TECHNIQUES

The planning and construction of various coastal protection structures, Inlets, harbour basins, navigation channels, jetties / breakwaters, cooling water circulation systems e.g. for power plants, water intakes and effluent outfalls etc. extensively use physical and mathematical modelling techniques. The hydraulic phenomenon involves tides, waves, density currents and the movement of sediments under the influence of tides and waves. Open coasts or wide bays are exposed to wave attack and often subject to cyclones / storm surges and Tsunami effects. In regions like estuaries, unlike open coasts and bays, generally tides and upland discharges play a dominant role. The concepts of physical and mathematical modelling are briefly described in the succeeding paragraphs.

1.2.1 Physical Modelling

The physical modeling, in general, not only involves scaling physical dimensions but also the particle motion (kinematic phenomena) and the forces (dynamic phenomena). The scales can be decided based on dimensional analysis or known equations of fluid motion. A physical model simulates the prototype better than the equations. Physical models automatically include many nonlinear and complex processes and boundary conditions that are not clearly understood and therefore cannot be expressed by the equations in a numerical model.

The methods for determining the model scales are based on the assumption that the equations and the dimensionless functional relationships for fluid flow apply equally to the prototype and the model. Each equation will highlight certain aspects that can be used to derive particular scales. The basic fluid flow in a coastal problem may be described by the continuity equation and the well-known Navier-Stokes equations. In practice, however, it is not possible to satisfy all the required scaling relationships because of the model materials used and the laboratory space available. As a result, most models contain *scale effects*, defined as non-similarity between the model and prototype resulting from violation of basic scaling relationships. Since the models are also required to simulate complicated prototype conditions with relatively simple modeling tools, models will contain *laboratory effects*, non-similarity resulting from prototype forcing and boundary conditions.

Hydraulic scale models are based on the fact that in a large number of hydraulic problems, the number of important forces to be accounted for is limited to two, so that when the ratio between the two types of forces is kept the same in model and in nature (prototype), the flow pattern in the model becomes geometrically similar to that of the prototype. In hydraulic modelling of port problems, most processes are governed by gravity and inertia forces or forces similar in form to inertia forces, such as turbulent drag force, while viscous friction plays a fairly insignificant role. In such cases, the model scales may be derived from Froudian model law, which says that the Froude number '*F'* can be written as:

$$F = \frac{v}{\sqrt{gd}}$$

where *v* represents velocity, g the acceleration due to gravity and d linear dimension. If this number is the same in model and prototype, then the ratio between gravity and inertia forces is also the same. From this, it may be seen that the velocity scale of a Froude model is equal to the square root of linear scale, whereas the force scale equals the linear scale to the third power. Elastic mooring and fenders forces are reproduced by the stiffness according to the length scale in the second power. This type of hydraulic model provides a very accurate representation of most wave effects such as wave disturbance in ports and wave forces on structures, as well as many of the current related effects. Inaccuracies and indeed limitations arise when the influence of the two other types of forces, viscous friction and surface tension which are always present begin to play a significant role or when turbulent drag forces in nature go beyond the region of constant drag coefficient i.e. at very high Reynolds numbers.

In coastal areas, wave conditions interfere rigorously with the design of harbours. Most wave data are collected in deep water. In order to determine design wave conditions, the near shore wave climate has to be determined, taking into account the effect of shoaling, refraction, diffraction, reflection and breaking of the waves that propagate towards the site of the harbour. For navigation and wave penetration, the operational wave climate is important, while for the stability of breakwaters, the extreme wave conditions are decisive.

After due consideration of the scale effects, friction effects and type of studies, the suitable hydraulic model scales for wave models are generally Geometric Similar (G.S.) 1/100 to 1/150, and the breakwater sectional model scales generally range between 1/30 to 1/50. In order to reproduce turbulent flow and to facilitate measurements tidal models are generally distorted with separate scales for the horizontal and vertical dimensions and the distortion factor ranges from 5 to 7.

1.2.2 Mathematical Modelling

With the arrival of many powerful personal computers and workstations, many advanced mathematical and numerical models have been developed during the recent years. This has given engineers flexible tools for simulating tidal and wave hydrodynamics, sediment transport, advection-dispersion, oil spill, storm surge, long period oscillations etc. It is now possible to use three-dimensional models necessary in stratified water bodies and models with unstructured mesh or flexible mesh (i.e. grids varying in size and shape within the model area) is useful where more detailing is required in some areas and not in others.

The processes of fluid flow and related transport are represented by mathematical equations which are based on conservation of mass, momentum or energy. These are partial differential equations, non linear in nature and cannot be solved analytically. In the mathematical models, these are simplified based on assumptions and converted to linear form into a set of algebraic equations which can be solved using digital computers at discrete points in the computational domain.

Usually the coastal hydraulic mathematical model consists of a suite of modules, each of which is used to simulate particular coastal processes. The common modules that are widely used in assessing the impacts of a particular development are:

a) Near shore Wave Module

This module is used to transform deep sea waves to the near shore waves considering the various transformation processes such as refraction, shoaling and wave breaking.

b) Hydrodynamic Module

This module is used to simulate the water level variations and current velocities induced by a variety of forcing functions such as tides, waves and wind. This module forms the basis for carrying out other coastal processes such as advection / dispersion and mud/sand transport.

c) Advection / Dispersion and/or Water Quality Module

This module simulates the spreading of suspended material, dispersion of thermal effluent and other pollutants. This will indicate the extent and intensity of the impacts.

d) Mud/Sand Transport Module

This module simulates the erosion or sedimentation pattern in the affected areas. By comparing the ‘before’ and ‘after’ project cases it will be possible to identify areas with increased erosion or siltation.

e) Sediment Budget and Shoreline Evolution Module

This module computes the shoreline budget and simulates the shoreline evolution. This can be used to identify shoreline areas with potential erosion and simulate the potential shoreline evolution.

Data requirements differ with the type of modules used. Therefore, it is necessary to initially identify the various modules that will be utilized in a particular hydraulic study and subsequently identify all the data required in the simulations using these modules. The required data may be obtained from primary or secondary sources.

Mathematical models can also handle transport problems better and these are extensively used for the studies for the development of coastal engineering projects. The mathematical models are very useful in assessing the sediment movements, the dispersion of dredged material, oil spill modelling, thermal modelling, layered salinity profiles which cannot be studied properly in physical models. A judicious approach is always useful involving both physical as well as mathematical modelling. In general, the mathematical models provide fast results for evolving preliminary layouts. Physical models have distinct advantage and are useful to fine tune / optimize coastal projects. Modelling is an art and the experience and judgement of modeller is very important for suggesting the proper engineering solutions.

1.3 CONTRIBUTION OF CWPRS IN PORT DEVELOPMENT

1.3.1 About CWPRS

Central **W**ater and **P**ower **R**esearch **S**tation (**CWPRS**), Pune an apex Research and Development institution in the field of hydraulics and allied research in the water and power sector, has continued to serve the needs of the nation for more than **100** years by catering to the research and development needs for evolving safe and economical planning and design of Water Resources structures in River Engineering, Hydropower Generation, and Ports and Water ways projects fulfilling its motto '***Service to the Nation through Research***'. CWPRS has offered its services to a number of projects in the neighbouring countries viz., Bangladesh, Bhutan, Afghanistan, Myanmar, Nepal, Singapore, etc., as well as for some of the countries in the Middle East.

Since its inception, CWPRS has been unstintingly working and providing specialized services through physical / mathematical model studies and field / laboratory investigations. The research activities at CWPRS can be grouped into seven major disciplines viz. River Engineering, River and Reservoir Systems Modelling, Reservoir and Appurtenant Structures, Coastal and Offshore Engineering, Foundation and Structures, Applied Earth Sciences, Instrumentation, Calibration and Testing Facilities. The research station has in house capabilities to comprehensively handle projects in the allied fields as well.

1.3.2 History of Development of Coastal Engineering Group

The activities in the area of Coastal Engineering at the CWPRS had commenced as early as 1947. At that time, the studies carried out by the then Navigation Division were related to improving the navigability of ports and the training of estuaries, as well as wave tranquillity in harbours. Typical model studies were conducted for the ports of Kolkata, Kandla, Visakhapatnam, Mangalore, Madras etc. Subsequently, the other problems such as salinity intrusion in the Kuttanad area in Kerala State; development of Bombay Harbour; coastal erosion in Kerala state were taken up with establishment of Tidal Hydraulics division in the year 1958.

A spurt in the development of ports took place beginning with the 3rd Five Year Plan. This development naturally called for extensive laboratory investigations before the projects could be implemented at site. The need for undertaking studies for these new projects resulted in the creation of an additional division in

1970 called the Maritime Structures Division. A large number of studies pertaining to the development, design and layout of the new ports, design of maritime structures such as breakwaters and jetties, seawalls, evolving methods for sediment bypassing and control of littoral drift and estimation of siltation in navigation channels were then undertaken, mostly with the help of physical models.

Gradually, with the advent of new technologies in the physical modelling and advances in computer hardware/software systems, the mathematical modelling also registered a major growth over a period of time, the Coastal and Offshore Engineering group at CWPRS presently consists of four main divisions:

- Ports and Harbours (PH)
- Mathematical Modelling in Coastal Engineering (MMCE)
- Coastal Hydraulic Structures (CHS)
- Coastal Field Instrumentation (CFI)

These divisions are mainly engaged in examining different hydraulic aspects pertaining to a variety of coastal problems extending right from the deep sea to the near shore coastal areas including estuaries and creeks. These problems include not only development of major harbours, but also several minor ports and fisheries harbours and also to the stability of coastal inlets, coastal reclamation projects, coastal erosion and coastal protection measures. Basic/applied research in respect of tidal power, specialised navigation structures such as locks, dry docks and gates, inland navigation problems, salinity intrusion, hot water re-circulation between the intakes and the outfalls of cooling water used for atomic and thermal power stations, domestic and industrial effluent outfalls, design of waterways for coastal bridges etc. is also undertaken in the coastal group. Radio Active Tracer (RAT) studies are also carried out in the prototype in collaboration with the Bhabha Atomic Research Centre (BARC), Bombay to determine coastal sediment movement so as to select suitable and economical dumping grounds. Techniques of fluorescent tracers have also been used in several cases to study dispersion aspects and sediment movement.

Besides prototype and physical model studies, 1D/2D/3D advanced mathematical models have also been employed to study problems of wave tranquillity, tidal circulation, siltation, salinity intrusion, thermal diffusion and dispersion, coastal erosion, oil spill, ship navigation, ship motions and mooring forces. Necessary software for these studies are available, some of them developed at CWPRS and supplemented by those procured from outside. The Coastal Engineering group at CWPRS employs a judicious use of physical and mathematical models as per the site specific requirement utilizing a hybrid approach. The projects in the Coastal Engineering group at CWPRS cover nearly 40% of the total works.

1.3.3 Major Works Undertaken at CWPRS

The west and east coasts of India presents different challenges to port development and coastal protection. Innumerable problems connected with all the major ports of India have been solved satisfactorily, especially in respect of their expansion and development. The problems of wave tranquility and siltation at the major Ports of Kandla, Bombay, Mormugao, Mangalore and Cochin along the west coast have been under active investigation as per the requirement at various times and necessary measures have been recommended based on studies conducted both in the prototype as well as in models. Likewise, the studies for the development of suitable methods for dredging and bypassing of sand across the harbour entrances of Chennai, Visakhapatnam and Paradip along the east coast have been successfully studied. The issues related to navigation channels and dredging have dealt in detail for the ports at Kolkata and Haldia. Design of the breakwater sections have also been evolved for the major ports of Paradip, Visakhapatnam, Madras, Tuticorin, Mangalore, Kamrajar (Ennore), V. O. Chidambarnar (Tuticorin) besides other intermediate and minor ports such as Porbandar, Karanja (Bombay), Ratnagiri and others. Comprehensive studies have been made in respect of problems of coastal erosion faced at various locations along the coastline of India and necessary protective measures were recommended. Improvements in the designs of cooling water systems at the intake and outfall locations have been suggested in the case of Madras Atomic Power Station at Kalpakkam and Tarapur Atomic Power Project near Bombay. The problem of erection of offshore drilling platforms in the sea was also investigated on behalf of the Oil and Natural Gas Commission of India. Design for various navigation locks, for example lock at Haldia Dock Complex, locks at Farakka Barrage and Gandak Barrage were studied exhaustively and significant improvements suggested in their designs. Radioactive Tracer studies were conducted to determine the trajectory and movement of bed material at Bombay, Kolkata, Cochin, Karwar, Goa, Sethusamudram, Kandla, Bhavanagar and Mangalore. Fluorescent tracer studies were organised with a view to investigate the coastal bed material movement to decide upon the suitable disposal grounds. One of the major activities of the coastal group is field data collection and analysis for various coastal parameters such as waves, tides, current, salinity, temperature, bathymetry, silt charge etc. Over the years, trained group of engineers and scientists have collected field data for a number of projects in the country. Field measurements in connection with cooling water intake and outfall studies for Thermal Power Station at Tripoli (Libya) and Pasir-Gudang (Malaysia) were also undertaken by the Coastal Engineering group.

1.3.4 International Problems

Taking into account the capabilities and the role played by the CWPRS, the IXth session of the Water Transport Committee of ESCAP held in Bangkok in 1970 recognised CWPRS as the Regional Laboratory to serve the needs of ESCAP region with particular reference to water and energy resources development and water borne transport. As a result of this, CWPRS has been engaged in solving various coastal projects outside India. R&D consultancy services were rendered under a 20 year contract for the development of various schemes for Port of Singapore Authority. Also, CWPRS was called upon for advice on various problems from Burma, Iraq, Libya, South Korea, Malaysia, Indonesia, Vietnam, Zambia from time to time.

1.3.5 Facilities and Equipments

The Research Station is bestowed with more than adequate land space and Water Circulation System to meet the infrastructure needs for physical modelling and other laboratory development. A large fleet of trained manpower and active guidance and support from Government of India has helped in the progressive development of the CWPRS. The existing facilities in the coastal group include:

- **Random Sea Wave Flume and Diffraction Basin**

A New random wave flume 90 m long x 2 m wide and 1.5 m deep has been commissioned recently to cope up with the increasing number of projects as well as for basic research in the area of hydraulic stability of marine structures. Other flume 120 m long x 4 m wide and 2 m deep is available with a 12 m x 10 m diffraction basin. It is a computer controlled system capable of generating random waves upto 0.6 m height with frequencies varying from 0.3 to 3.0 Hz. The facility is used for testing of marine structures such as breakwaters, seawalls, jetties, platforms, pipelines, intake and outfall structures etc.

Random Sea Wave Flume

- **Regular Wave Flumes**

A set of three regular wave flumes having dimensions 40 m x 0.7 m x 1.2 m (depth), 50 m x 1.22 m x 1.8 m (depth) and 75 m x 3.0 m x 2.0 m (depth) are available in the Coastal Hydraulic Structures division for designing breakwater cross sections.


Regular Sea Wave Flume

- **Multipurpose Wave Basin Hangar**

A Multipurpose Wave Basin Hangar of size 60 m x 75 m has been developed equipped with Random Sea Wave Generation (RSWG) and multichannel Data Acquisition System (DAS). The operation of this facility is SCADA based and is used to study wave tranquillity conditions for design of Port layouts and fishing harbours. The time and cost of physical wave model studies taken up with this facility are comparable with that of mathematical model studies.


Multipurpose Wave Basin Hangar

- **Multipurpose Tidal Basin Hangar**

Multipurpose Tidal Basin Hangar of size 50 m x 70 m with computerized Automatic Tide generating (ATG) system to study the flow conditions for port development schemes under the effects of tides and river discharges is under construction and will be commissioned shortly.

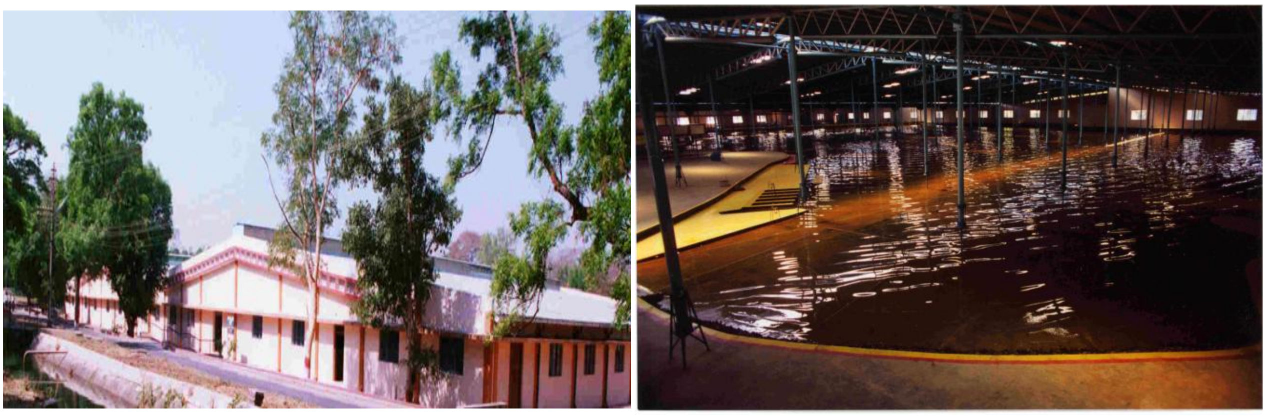
- **Thermal Basin Hangar**

Thermal Tidal Basin Hangar of size 30 m x 40 m to study the design of intake and outfalls in coastal environment for thermal and nuclear power projects is under construction and will be commissioned shortly.

- **Physical Models for Major/ Minor Ports**

At present dedicated 12 physical tidal models and 20 physical wave models and six wave cum tidal models are being maintained for specific Major/ Minor ports wherein layouts of port structures, wave tranquillity in the harbours, problems of littoral drifts and coastal sediment movement etc. could readily be studied under controlled environment using sophisticated measuring equipments connected to the computer for online data acquisition and analysis. Most of these physical model trays have been provided with hangars with random wave generators and automatic tide generating systems.

Mumbai Port Tidal Model

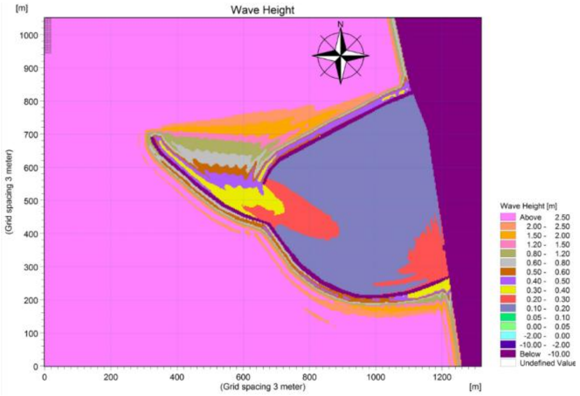


Mormugao Wave Model

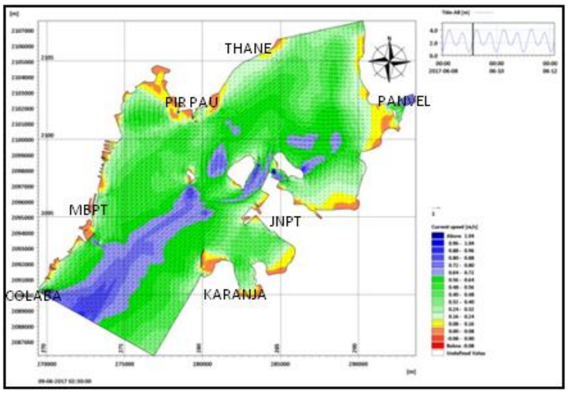
- **Mathematical Models**

A suite of mathematical models to address various aspects related to coastal hydrodynamics, sediment transport, advection-dispersion problems of thermal circulation, pollution transport are available. The established mathematical models like MIKE-21 HD, MIKE-21 SW/BW, MIKE-21 MT/ST, MIKE-3, TELEMAC, LITPACK, EVA, MIKE -21 MA, MIKE-21 OS are being used to provide solutions to specific projects of port development and power plants for wave tranquillity, hydrodynamics, sedimentation, littoral distribution, extreme wave analysis, mooring and navigation and oil spill are available.

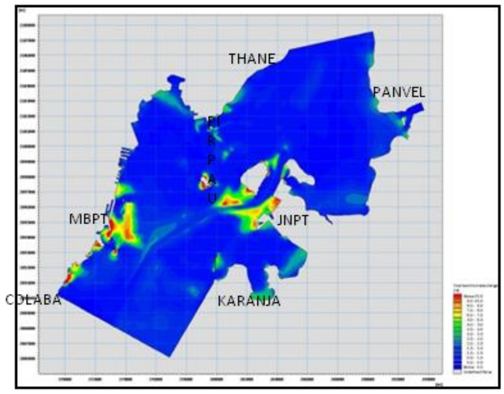
Mathematical models “NAVIGA” and “VERMO” developed at CWPRS are available for optimisation of channel layout and dimensions and MORMOT for ship motions and mooring line and fender forces on a ship at berth.



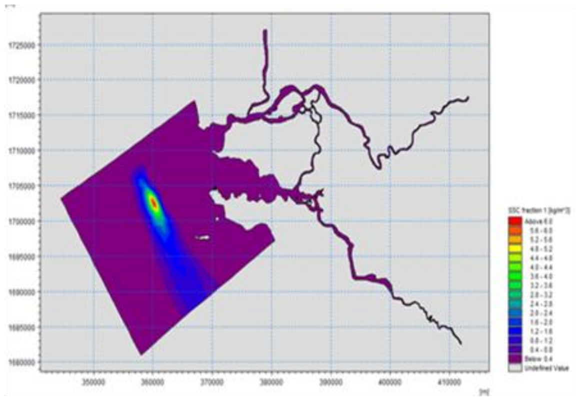
Wave Tranquility

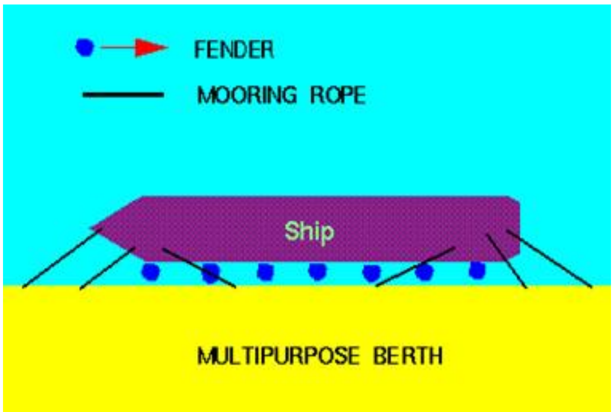


Hydrodynamics

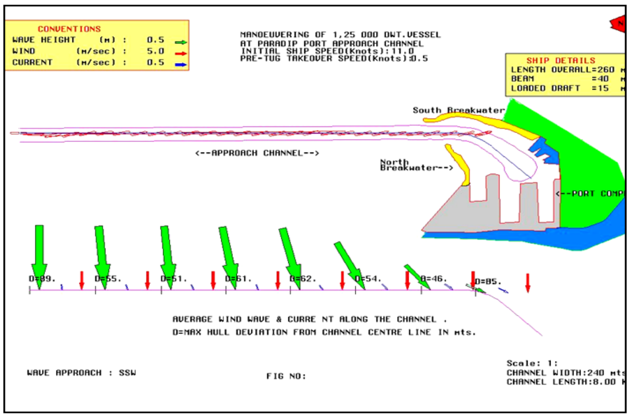


Sedimentation


Plume Movement



Mooring



Navigation

- **Field Equipments**

Sophisticated field equipments such as Dutch Wave Rider Buoys, Telemetered Type Wave Height Recorder, Insitu Tide Gauges, Propeller type and Electromagnetic type Currentmeters, Salinity-Depth-Temperature unit, Bottle Samplers, Grab Samplers as well as survey and inspection equipments like Mini Ranger, Distomat, Acoustic Release System, Underwater CCTV system etc. are available at CWPRS.

Echo-sounders, Wave cum Tide Gauges Current meters

Wave Rider Buoys installation

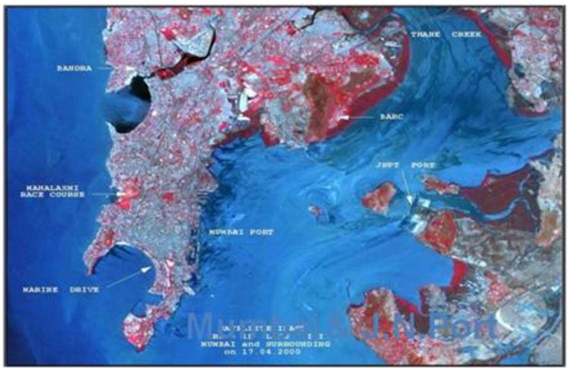
Current meters installation

Radioactive tracer studies

- **Remote Sensing Applications Laboratory**

The remote sensing laboratory at CWPRS is used for the assessment of shoreline changes by analyzing the satellite images. The facilities include; Silicon Graphics Unix based Workstations Octane (One) & O2 (Three) and A0 size Colour Scanner, Satellite Imageries, Softwares EASI/PACE, GEOMATICA and Arc GIS.

Remote Sensing Laboratory



Satellite Imagery of Munbai - JNPT

The other four chapters of this Compendium describe in more detail the specific contributions by CWPRS for the development of Major ports, Minor ports and Fishing harbours, Coastal erosion and Shore protection and other Miscellaneous Studies for maintenance of coastal ecology and assessment of environmental effects.

Chapter 2

MAJOR PORTS

2.1 INTRODUCTION

There are 12 Major Ports in India, six on the west coast and six on the east coast of India.

Locations of the Major Ports in India

The brief description of the Major Ports is given as below:

- **Kolkata Port:** Only riverine major port in India. Known for twin dock systems viz., Kolkata Dock System (KDS) on the eastern bank and Haldia Dock Complex (HDC) on the western bank of river Hooghly.
- **Paradip Port**: Located at confluence of river Mahanadi in Bay of Bengal in Odisha. It was the first major port on East Coast commissioned in independent India.
- **New Mangalore Port**: Located at a site called Panambur in Karnataka at Gurupura river confluence with Arabian Sea
- **Cochin Port**: Located on the Willington island in the Cochin backwaters on the South-West coast of India; located on the cross roads of the East-West Ocean trade. The port is called natural gateway to the vast industrial and agricultural produce markets of the South-West India.
- **Jawaharlal Nehru Port**: It is also known as Nhava Sheva and is the largest container port in India, handling around half of container traffic among of all major ports. It is located on eastern shore of Mumbai harbour off Elephanta Island and is accessed via Thane creek.
- **Mumbai Port**: One of the oldest modern ports of India. Initially the location which was in the form of group of Islands was used by navies of Shivaji.
- **Kandla Port**: This Port was built after partition as the Karachi port on western coast had gone to Pakistan. It is known for handling much of the crude oil imports of India. It is also the nearest gateway port for India from the Suez canal and the Persian Gulf.

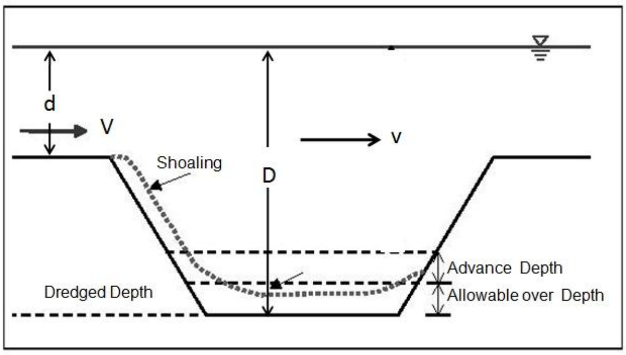
- **Vishakhapatnam Port**: Also known as Vizag port, located in Andhra Pradesh and is known for deep drafts and bulk of Cargo handling on east coast.
- **Chennai Port**: This is the largest port in the Bay of Bengal and second largest port of India after JNPT. It is largest port at east coast.
- **V.O.Chidambarnar Port**: Earlier the Tuticorin port, this port has been now renamed as V.O.Chidambaranar Port. It is located in the Gulf of Mannar. This is the only port in South India to provide a direct weekly container service to the United States.
- **Kamrajar Port**: It is first corporate port of India and is registered as a public company with 68% stake held by government.
- **Mormugao Port** : Mormugao port in Goa is leading iron ore exporting port of India.

2.2 TECHNOLOGY CONTRIBUTIONS OF CWPRS FOR MAJOR PORT DEVELOPMENT IN INDIA

The second wave of port development in India that started in the post independent era was a very challenging task and CWPRS, Pune contributed significantly by giving valuable and timely advice in the setting up and development of the major ports. The British era ports like Bombay (Mumbai) had limitations in draft with silting docks; the Calcutta (Kolkata) and Cochin ports had heavy siltation in the approach channels, the Madras (Chennai) port had large scale accretion on the updrift side of coast line and severe erosion in the downdrift side. With the remarkable increase in ship sizes and the transformation of cargo composition from break bulk to bulk, POL and containerization, complex problems like navigation to the port of Kolkata, development of new ports at Kandla, Nhava-Sheva, Mormugao, Mangalore, Tuticorin, Visakhapatnam, Cochin, Haldia and Paradeep with deeper drafts were necessary to be tackled on war footing. The west and east coasts of India presented different scenarios related to tides, waves, storms, alongshore sediment transport, slope of continental shelf and sediment transport. This presented challenges in navigation, jetty alignment, wave tranquility inside harbours, channel shoaling, dredging and disposal, breakwater design, coastline stability, etc. On the technology front, two very significant contributions were done by CWPRS in the field of shoaling of navigation channels and wave attenuation in long approach channels.

Shoaling of Navigation channels

Navigation channel performance could be limited by encroachment of the banks and rising of the channel bottom due to settlement of sediments. Maintenance dredging in the navigation channels needs to be estimated based on hydrographic surveys and observed shoaling rates. The rapidly changing trends in shipping, immediately after independence, placed tremendous pressure on expansion of existing ports and development of new deep draft ports, especially on the west coast of India. The maintenance of the channels and harbours was important component in the sustenance of the port. In the absence any reliable and accurate method for proper prediction of the probable maintenance dredging, C V Gole, Z S Tarapore and S B Brahme of CWPRS developed a method in 1971 for the estimation of likely maintenance dredging in navigation channels and harbours.

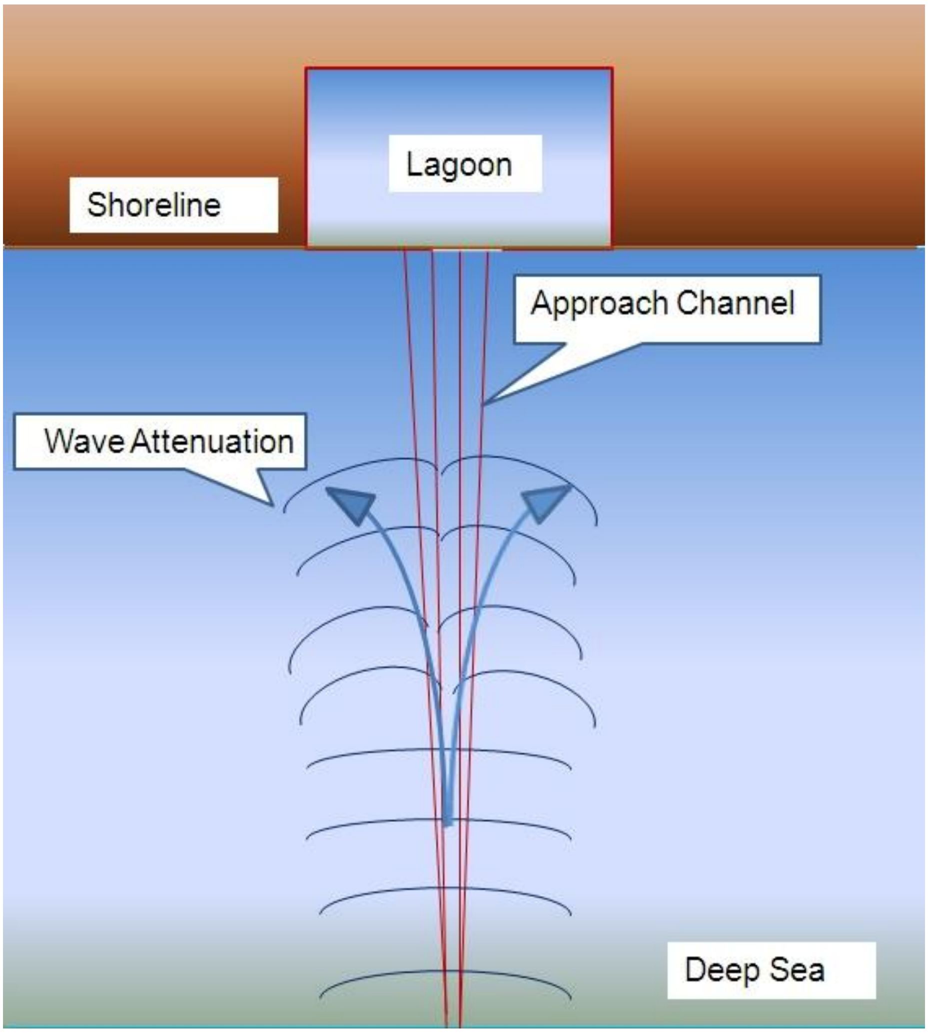


Shoaling of Navigation Channel

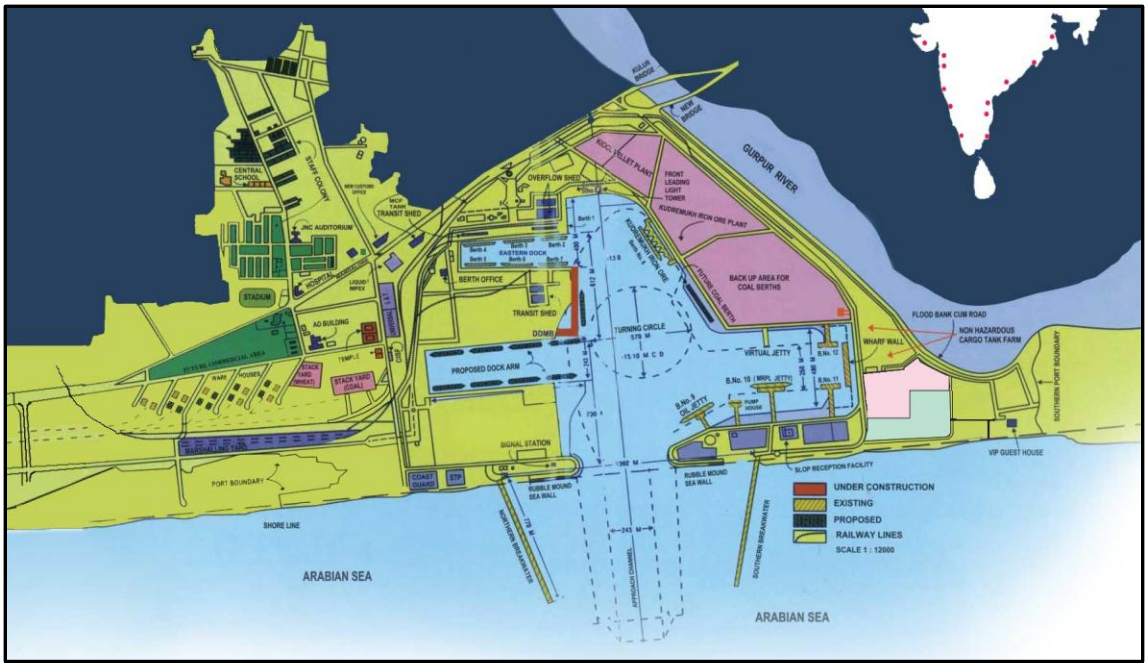
Wave attenuation in Long Channels

The foreshore or continental shelf slope on the west coast of India is flat having slopes varying from 1:300 to 1:500. For ships requiring drafts more than 12 m very long navigation channels have to be dredged from the shoreline. The project of developing an all weather artificial lagoon type port at Mangalore was referred to CWPRS for the length of breakwaters for safe berthing of ships in the lagoon. While examining various layouts in a geometrically similar wave model of 1:150, it was discovered that no matter what height of wave was generated at seaward end, the wave disturbance at the mouth of the harbor was found to drop while the wave approached along the navigation channel. Beyond a certain point in the approach channel there was recovery of wave though the recovery was never full. In the undredged areas adjacent to the approach channel, the normal shoaling pattern was observed. The effect of channel friction, refraction of waves from channel side slopes, interaction of waves within the channel and the adjacent natural bed was investigated in detail.

Much of the wave energy did not pass through the channel but got refracted out of the channel at the side slopes of the approach channel. Thus it was possible to effect considerable savings with regard to the length of the breakwaters. Thus a new phenomenon came to be known to the coastal engineers which was very useful in optimizing the breakwater lengths under similar conditions to a considerable extent. This phenomenon is also observed in the case of Mormugao port where the requirement of long breakwater was totally avoided during expansion of the port.



Wave Attenuation in Long Channels



New Mangalore Port

Mormugao Port

The contributions of CWPRS for development of Major Ports in India are briefly described in succeeding paragraphs.

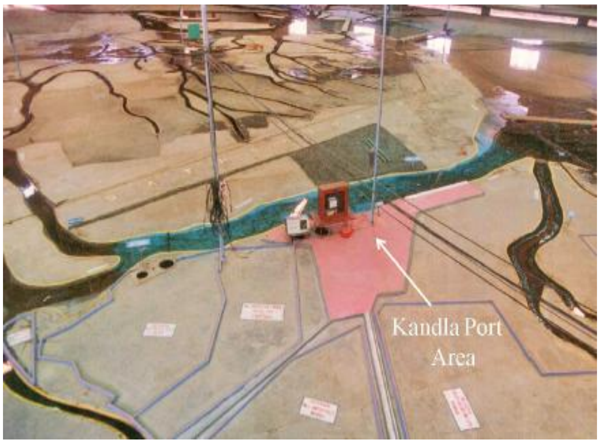
2.3 KANDLA PORT, GUJARAT

Background

The Kandla Port is located at the head of Gulf of Kutch along a tidal creek known as “Kandla creek” in the state of Gujarat. The Kandla creek is 140 km inside the gulf from the entrance. The region is dominated by high tidal range and strong tidal currents though wave disturbances in the approaches to Kandla creek are not much significant. The port is of strategic importance and is the nearest Indian port from the Middle East and Europe.

Studies Conducted

- CWPRS was approached for advice on various hydraulic related issues such as alignment of berths and jetties in Kandla creek, alignment and siltation of approach channel, dredging and disposal strategies in the approaches.
- The Physical tidal model (scale: 1/1000H and 1/100V) of Kandla estuary is used to study the flow conditions and patterns under different tidal conditions in the approaches to Kandla creek for assessment of siltation and to suggest dredging and disposal strategies.
- Additional Physical tidal model (scale: 1/300 H: 1/50 V) of Kandla creek is used to study flow conditions during flood and ebb tides to suggest suitable alignment of berths and jetties.
- Mathematical models are also setup using MIKE-21, HD/MT for studying tidal hydrodynamics, assessing the quantity of maintenance dredging and location of disposal grounds etc.



Kandla Port Model

Location of Kandla Port

Outcome and Benefits

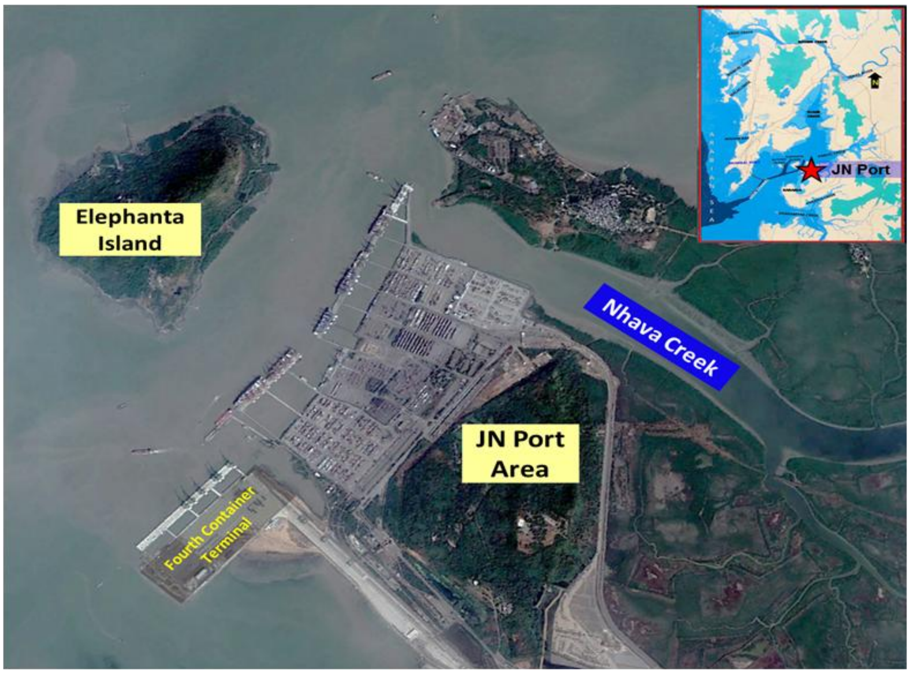
- As per the advice of CWPRS, the depth along the navigational channel at Kandla Port has improved significantly to (-) 8.5m below Chart Datum from earlier (-) 3.5m and the port now caters to ships of upto 14.m draft
- The strategy of shifting the channel and identifying the critical reach of siltation has yielded very fruitful results. The annual maintenance dredging was correctly assessed as 7.0 Million cum.
- With the help of hydraulic model studies, it was possible to align the cargo berths and the oil jetties without significantly affecting the morphodynamics of Kandla creek. The port has 12 cargo berths to accommodate vessels of 11 m draft till recently. Now 4 more berths are being added to cater to vessels of 14 m draft. Apart from these, the port also has six jetties to cater to oil and liquid cargo.

Kandla Port

2.4 JAWAHARLAL NEHRU PORT, MAHARASHTRA

Background

The Jawaharlal Nehru Port (JNP), a natural major port of India, is situated in Thane creek on the west coast of Maharashtra. The development of JNP was proposed as the port of Mumbai got congested due to significant increase in vessel traffic by mid 1970s. The location for port in front of Elephanta Island near Nhava-Sheva creek in Thane creek was identified such that the natural deeper depths in channel are available with minimum expenditure on capital dredging and no construction of breakwater was required for wave tranquility. The port facilities are being developed in stages to cater to the increasing demand of container traffic and presently it is the premier container port of India handling about 4.8 Million TEUs containers/annum. The depth of 14 m below CD is maintained by port as Phase-I deepening in main channel to allow smooth entry of 5th generation container carriers with the aid of tidal window. The Phase-II deepening of channel up to -16m is in progress. JNP has recently completed development of 2 km long mega container terminal known as Fourth Container Terminal (FCT) to increase its container handling capacity up to 10 Million TEUs.

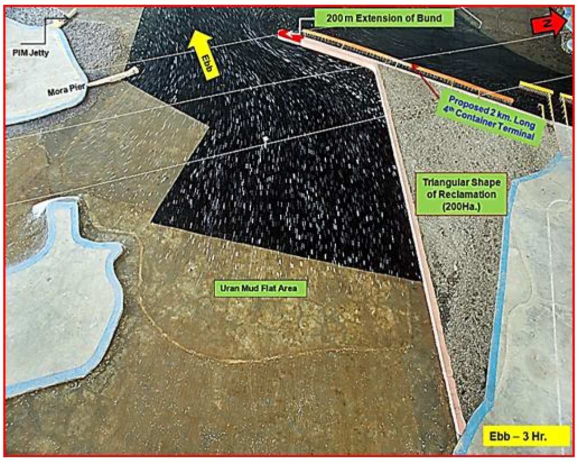


Overall View of Jawaharlal Nehru Port

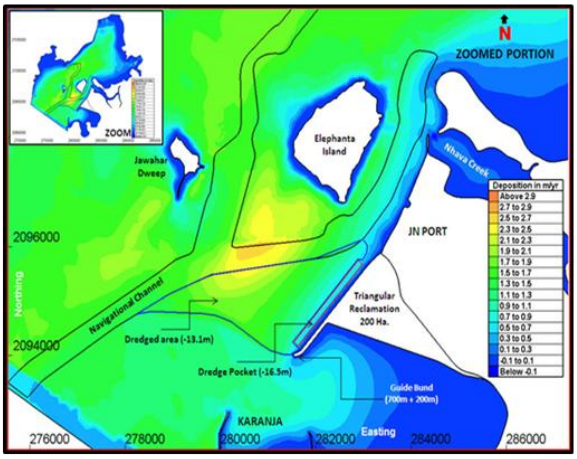
Studies Conducted

The well calibrated physical tidal model of the Mumbai Port constructed to a scale of 1:400 (H) and 1:80 (V) at CWPRS in association with mathematical model (Telemac software) are in use to study the various developments under consideration.

- More than 50 model studies including field investigations were carried out by CWPRS for JNP since its inception.
- Studies for Master plan development for the expansion of port were also carried out.
- Aspects such as alignment of jetties/berths,effect of shape of reclamation on the surroundings,alignment of navigational channel, design of channel cross sections etc, were studied and finalised to achieve safe navigation and berthing/de-berthing of shipping vessels at JN Port.
- The optimal alignment/length of guide bund to achieve desired flow conditions at container terminal proposed at the confluence of Nhava creek and Elephanta Deep was evolved considering the effect of reclamation in Nhava creek.
- The estimation of likely rate of siltation in navigational channel, berth pockets etc. to assess quantum of maintenance dredging was carried out using mathematical model.
- Since the capital dredging of main channel up to (-)16 m below CD was proposed by JNP in two phases, wherein the dredging quantity is about 85 Million m^3, the locations for disposal of dredged material were finalised based on the dispersion studies carried out using mathematical model.



Effect of Reclamation on Flow-Physical Model (FCT)



Estimation of Siltation- Mathematical model (FCT)

Outcome and Benefits

- The CWPRS studies provided optimum alignment/orientation of berths and navigational channel as well as effect of proposed developments on nearby waterfront structures.
- The dispersion studies provide environment compliant viable location of dumping grounds for the safe disposal of dredged material resulted from capital and maintenance dredging.
- The alignment & orientation of guide bund at the confluence of Nhava creek and Elephanta Deep wherein complex hydrodynamic flow conditions prevail was evolved to develop a new container terminal and it also allows safe movement of fisher folks in and out of Nhava creek.
- Recently, alignment of 2 km long mega container terminal along with suitable shape of 200 ha reclamation was evolved to have negligible impact on nearby waterfront facilities as well as to achieve smooth operability of container ships round the clock/year all along the entire berth length.
- The layout of various berths finalised through model studies carried out at CWPRS and constructed at JNP are operating smoothly without any interruption and the Port has achieved number one position in India in handling container traffic.
- No adverse impact of development is reported on surrounding area from morphological considerations.
- This has resulted in significant contribution of the Port in economic growth of the country by way of increase in export/import of goods.
- In near future the port will handle about 10 Million TEU container traffic at JNP.

Panoramic View of Jawaharlal Nehru Port

2.5 MUMBAI PORT, MAHARASHTRA

Background

Mumbai Port, one of the oldest British era ports of India, is situated in Thane creek on the west coast of India, on leeside of Salsette/Mumbai island. This is an all weather natural port and well protected from the fury of sea waves. The port has access to the Arabian sea through a navigational channel wherein tidal phenomenon is dominant with macro type of semi-diurnal tides having range of 5 m. The various marine facilities in the form of docks, jetties and oil terminals were built during pre-independence era. Since opening of Suez Canal in 1869, Mumbai Port had become the Principal Gateway to India and has played pivotal role in the development of the country's trade & commerce. The main docks viz. Indira, Princess and Victoria in use for berthing and ships, were plying towards deep waters of the Arabian sea by taking advantage of tidal window. After independence, various marine facilities like Oil berths at Jawahar Dweep, Chemical & POL berths near Pirpau, finalisation of alignment of main navigational channel with its deepening/widening etc. were planned under master plan development. The various techniques such as field data measurements, physical tidal model (scale: 1/400 H, 1/80 V) and mathematical modeling, desk studies etc. were used to finalise the layouts/alignments of waterfronts, estimation of siltation at berths/channel, identification of dumping grounds for disposal of dredged materials. The port, however, has severe restriction in ship draft due to heavy siltation of the old Docks.

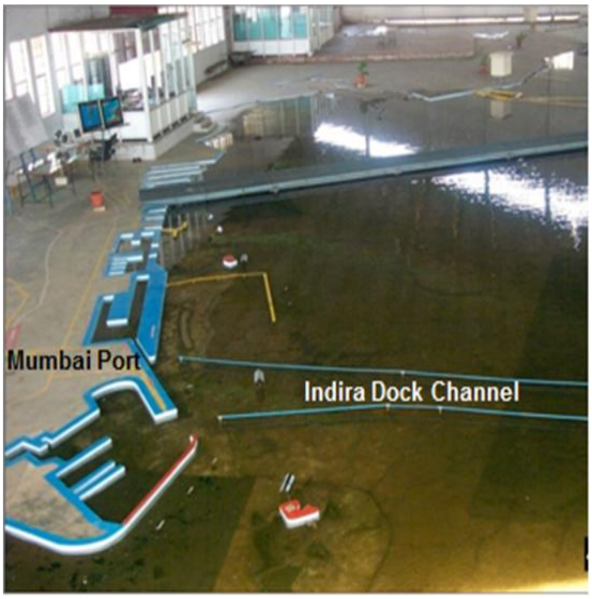
View of Mumbai Port

Physical Model of Mumbai Port at CWPRS (1953-1985)

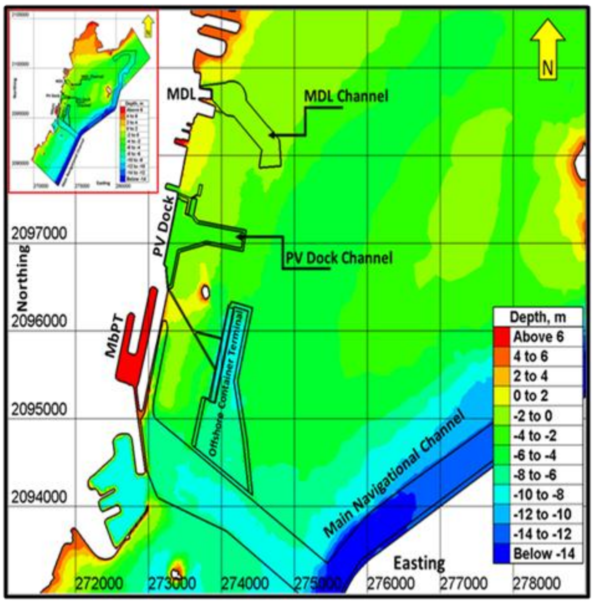
Studies Conducted

More than 150 studies were carried out since 1950s for the development of various marine infrastructures in Mumbai harbour using Physical and Mathematical modelling techniques.

- Field investigations for various oceanographic parameters were carried out to provide input data for simulation of prevailing flow phenomena in the models.
- Finalisation of alignment of main navigational channel, berths/jetties and effect of reclamations on nearby waterfront facilities.
- Estimation of maintenance dredging quantity in navigational channel and at various waterfronts.
- Identification of dumping grounds for the safe disposal of dredged material.
- Both physical & mathematical (tidal/wave) models are being used as a hybrid modeling technique to finalise alignments of berths, navigational channel etc. in complex hydrodynamic regions.



View of Mumbai Port area on Physical Model(1985- till date)



Mathematical model showing Mumbai Port area

Outcome and Benefits

- The finalisation of optimal alignment of navigational channel facilitated smooth movement of ships to and fro between port and the Arabian Sea along with significant reduction in siltation and thus appreciable decrease in maintenance dredging quantity.
- The appropriate alignment of marine facilities based on tidal/wave hydro dynamics, has simplified the herculean task of berthing/de-berthing of deep draft vessels at oil terminals near Jawahar Dweep as well as other ships at the port.
- In addition, predictions of reliable siltation in harbour by mathematical model studies provide guidance to the port authorities in planning and timely execution of maintenance dredging to enhance the operability of ships at berths.
- The shape of reclamations for various marine facilities like oil terminals, bunders etc. evolved through model studies does not have adverse impact on nearby waterfront facilities as well as on the marine environment.
- The suitable locations of disposal sites for dredged material resulted from capital/maintenance dredging are identified based on dispersion studies carried out using mathematical model studies. The material dumped at dumping/disposal site do not re-enter in to harbour area and in navigational channel.
- The comprehensive studies carried out provide the port authority a guidance to plan the future developments in the harbour area.

2.6 MORMUGAO PORT, GOA

Background

Mormugao Port is situated on the west coast of India at the entrance of Zuari estuary in Goa state. A breakwater of 525 m length and a mole of 270 m length were completed in 1930 and a total of seven berths were in operation till 1960s. The maximum draft of the vessels that could be accommodated at the berths was limited to 8.5 m. With the opportunities for large scale export of Iron ore it was considered necessary to develop the Port for big size ore carriers of 60,000 DWT size.

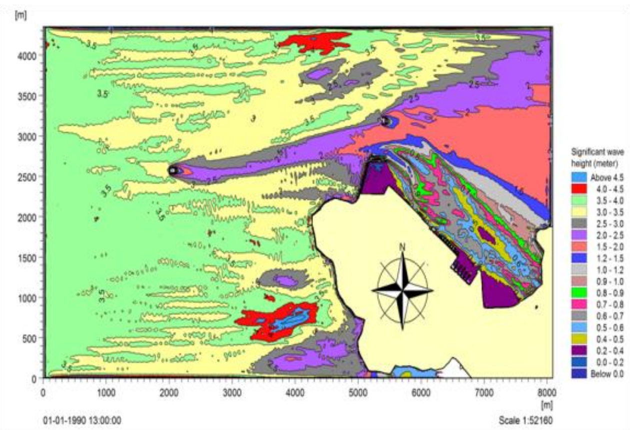
Studies Conducted

More than 80 studies were conducted since 1970 to cover the following aspects,

- Under stage-1 development in 1970s, it was proposed to dredge a 4km long approach channel to (-) 13.7 m; and construction of additional berths for iron ore export, oil berth, and a barge basin. An additional breakwater of 1000 m was proposed to provide wave protection to these berths. The CWPRS was approached to suggest suitable layout for Stage-1 development from the considerations of wave tranquility, flow conditions and siltation.
- Physical wave model (G.S.-1/100) was used to study wave tranquility conditions under the predominant incident wave conditions. Physical tidal model and mathematical models were utilized for studying hydrodynamic conditions, assessing the quantity of maintenance dredging, and location of disposal grounds.
- The challenges for the Stage-1 development were: ensuring adequate wave tranquility at the proposed berths as the port is exposed to direct waves from the Arabian Sea; assessment of the annual maintenance dredging against a capital dredging; identification of suitable locations of disposal grounds for capital as well as maintenance dredging under reversing tidal flow with prevailing wave climate.

Satellite Image Of Mormugao Port Region

View Of Mormugao Port Wave Model


Numerical Model results : Wave height distribution

Outcome and Benefits

- With the help of hydraulic studies at CWPRS, the ore, oil and barge basin were laid out in such a way that there was no need for additional breakwater for obtaining necessary wave tranquility at berths.
- The berths were laid along the existing water front and reclamation areas were created for storage of material and operation and, consequently, the hill cutting was avoided.
- The annual maintenance dredging was correctly assessed.
- Survey records show that all disposed material is transported to the deep sea in the north and no accumulation of the same is observed.
- CWPRS studies affected big savings in the project cost and eliminated recurring expenditure.

2.7 NEW MANGALORE PORT, KARNATAKA

Background

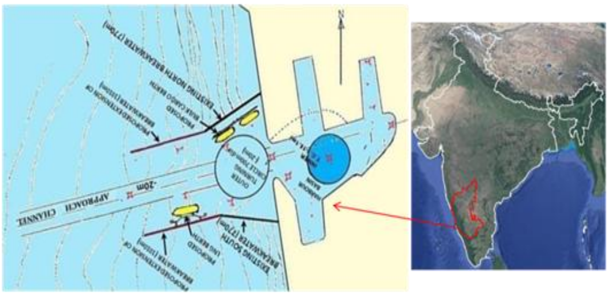
New Mangalore Port is a deep-water, all-weather man made Lagoon type port at Panambur, Mangalore in Karnataka state of India. It is located to the north of confluence of Gurupura (Phalguni) river to Arabian sea. It consists of 7.5 Km approach channel, 570 m Turning circle with draft of 15.4 m & 15.1 m, two rubble mound type South & North Breakwaters each 770 m long.

Studies Conducted

More than 45 major studies during last 50 years covering the following aspects:

- The location of the site and initial planning of the port layout is based on model studies carried out at CWPRS. Initially, a physical model to scale 1:100 (GS) was developed.
- An important decision of port entrance facing west despite the waves being critical from this direction was taken after conducting many trials on this model. This decision helped in optimising the channel length for any given depth. It was very useful for further developmental stages of the port as well.
- A physical wave model having Random Sea Wave Generation system along with computerized Data Acquisition System was developed to a scale of 1:100 (G.S.) at CWPRS during 1994.
- A number of port expansion studies were conducted for the development of Southern Dock Arm berthing structure. Later, during 2004, model was upgraded by changing the scale to 1:120(G.S.) by simulating more areas for the developmental studies of Deep Draft Multipurpose Berth and Western Dock Arm.
- CWPRS was also involved in conducting a number of field studies including Radio Active Tracer studies for identifying disposal site for the dredged material.
- Mathematical model studies were carried for assessment of wave tranquility, tidal hydrodynamics, ship manoeuvring and ship mooring.

Ship Moored at NMPT



Location of New Mangalore Port

Physical Model : Testing for outer harbour development

Outcome and Benefits

- Optimum alignment of approach channel normal to the bathymetry contours.
- Minimum length of breakwaters taking advantage of the phenomenon of wave attenuation along channel.
- Optimum alignment for various berthing structures under different stages of development.
- Identification of suitable disposal grounds for dredged material.
- Analysis and prediction of the formation of hard patches in the approach channel and suggesting preventive measures to avoid costly dredging activity

2.8 COCHIN PORT, KERALA

Background

Cochin port, an all weather port situated on the west coast of India, is located in the vast expanse of backwaters formed by confluence of two major water courses of the area viz. Vembanad Lake in the south and Periyar River in the north. Five different rivers from the south and two branches of Periyar River from the north debouch into the Arabian Sea through an opening in the shore called as Gut. Two peninsular lands Vypeen and Fort Cochin protect the harbour from waves approaching from the sea.

Studies Conducted

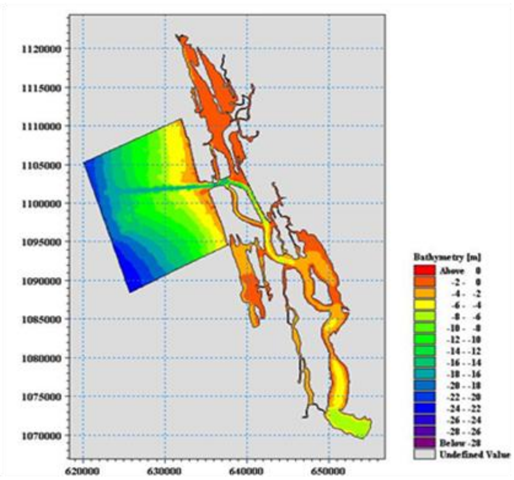
More than 50 major model studies including physical and mathematical models completed during last 70 years covering the following aspects.

- Simulation of tidal currents of semi diurnal in nature on vertically distorted physical model on a scale of horizontal 1: 800 and vertical 1: 80 in 1984.
- The model is operated by computerised Automatic Tide Generated (ATG) system for the generation of tides in the model.
- Tidal reach of the model is up to prototype distance of 80 km to the south and up to 32 km to the north of Cochin Gut.
- Two dimensional mathematical model of Cochin port area with latest MIKE 21 Software.
- Reclamation of Ernakulam foreshore, extension of Willingdon Island.
- Location of fishing harbor, location of salt water barrier at Thaneermukkam.
- Location and alignment of naval jetties, siltation and maintenance dredging for Ship Lift System for Cochin Ship Yard Ltd.
- Alignment of super Tanker oil terminal jetty, oil jetties and 10 general cargo berth, ICTT at Vellarpadam and model studies for Master Plan Outer Harbour development.
- 3 D flow simulation for inner and outer harbour to arrive at measures for prevailing siltation in the harbour.

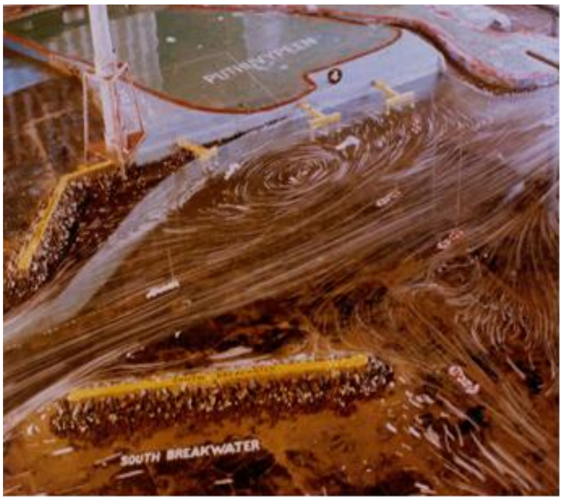
Cochin Port Layout

Outcome and Benefits

- Arresting salt water by construction of Thannermukkam salt water barrier
- Reclamation along Ernakulam shore
- Drydock facilities at Cochin Naval Base
- Berthing facilities for coastguard vessel
- Imact of ship lift system on port area
- Optimisation of outer harbour layout
- Optimization of dredging cost
- Finalising supertanker oil terminal
- Reclamation of Ship Lift System to have partly reclaimed soil and partly of RCC deck supported on piles for better flow conditions and less obstruction.



Numerical Model for Cochin



Physical Model for Cochin

2.9 V.O. CHIDAMBARNAR PORT, TAMIL NADU

Background

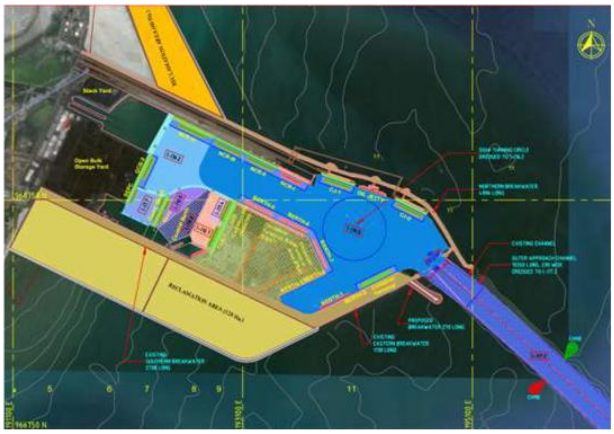
V.O.Chidambarnar Port (erstwhile Tuticorin Port) at Tuticorin in Tamilnadu state is an artificial deep-sea harbour formed with rubble mound type parallel breakwaters projecting into the sea for about 4 km. The harbour basin extends to about 400 hectares of protected water area and is served by an approach channel of 2400 m length and 183 m width.

Studies Conducted

Physical model studies for wave tranquility for the development of Outer Harbour and Mathematical model studies were undertaken at CWPRS to study,

- Wave tranquility at different berths for the development of Port and also to assess the effect of reclamation
- Tidal hydrodynamics and estimation of siltation for the development of Port
- Desk studies for safe ship navigation and optimization of channel
- Desk studies for ship mooring analysis for proposed development of Port
- Desk and wave flume studies for the design of breakwaters.
- Desk studies for storm wave hindcasting.

Location of Tuticorin Port



Layout Plan of Port

Outcome and Benefits

- Layout of port structure for desired wave tranquility conditions
- Optimization of breakwater length and alignment
- Prediction of mooring configuration and selection of optimum fenders
- Assessment of ship motions and estimation of downtime at berth

Physical Model for Tuticorin

2.10 CHENNAI PORT, TAMIL NADU

Background

Chennai Port, the third oldest major port in the country, is located on east coast of India. At Chennai, maritime trade started way back in 1639. However, an artificial modern harbor was built and began operations during 1881. Located on the open coast, the port is vulnerable to the cyclones and high littoral drift prevailing along this region. The port has expanded from time to time with modern harbor facilities for handling the increasing traffic. Space restriction is a major constraint for further developments of the port; hence a satellite port was established at Ennore during 2004 to divert some traffic from this port.

Layout of Chennai Port

Studies Conducted on following areas (Since 1950 – till Date)

- Storms in the Bay of Bengal and their effect on Chennai (Madras) Harbour.
- Layout of berths along South Quay and layout of Oil Docks etc.
- Study of embankment for protection of Chennai (Madras) Harbour.
- Model Studies for Bharati dock.
- Problems during construction of breakwaters.
- Study of development of Outer Harbour.
- Tranquility studies for breakwater layouts.
- Tranquillity studies for all berths.
- Reclamation bund for ammonia plant.
- Harbor resonance studies in Bharati Dock
- Sand trap location and design.
- Groyne field establishment.
- Design of Breakwaters, Reclamation Bund
- Wave tranquility studies for Fisheries harbor development
- Optimization of extension of Fisheries harbor breakwaters by Random wave model studies

Physical Model of Chennai Port

The physical wave model of Chennai Port is in operation at the CWPRS from 1950. The model was upgraded from time to time to accommodate development studies. The model is constructed to a scale of 1:150(G.S.) with rigid bed with regular wave generation system for waves incident from North-East and South-East. Computerized multi-Channel data acquisition system is used for wave data acquisition in the model.

Chennai Port Physical Model

Wave tranquility studies with random waves

View of Chennai Port

Outcome and Benefits

- Optimization of breakwater alignment and length
- Prediction of siltation & quantum of dredging
- Location of dumping ground.
- Wave tranquillity in harbour basin.
- Alignment of breakwaters along with safe and economical design.

2.11 KAMARAJAR PORT, TAMIL NADU

Background

Kamarajar Port (erstwhile Ennore port) is located on the Coromandel Coast in Tamil Nadu state, about 24 km north of Chennai Port.. The Port was commissioned in June, 2001 with two dedicated coal berths for handling of coal for the thermal power stations of Tamil Nadu Electricity Board (TNEB). The Port has developed terminals through private sector participation to handle liquids, coal and iron ore.

Studies Conducted

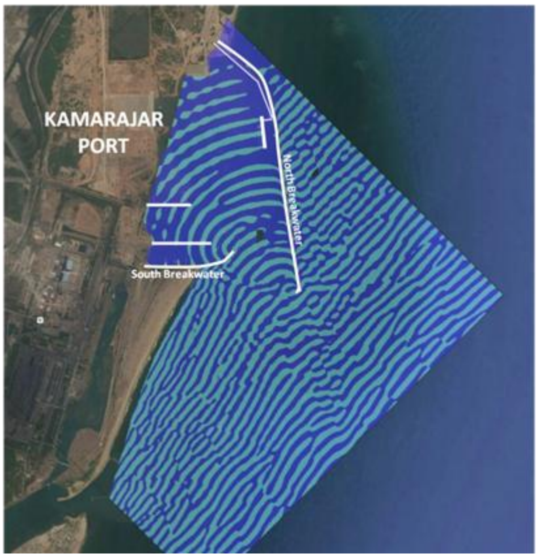
- Geometrically similar physical model on a scale of 1:120 (G.S.) to simulate random sea waves from South - East direction.
- Harbour development for LNG, VLCC berth for ships of 250,000 DWT.
- Assessment of Wave tranquility in Kamarajar Port using numerical model MIKE 21 SW and BW.
- Shoreline evolution due to development of the port.
- Ship manoeuvring studies to optimize the approach channel.
- Ship mooring studies.

Satellite Image of Kamarajar Port

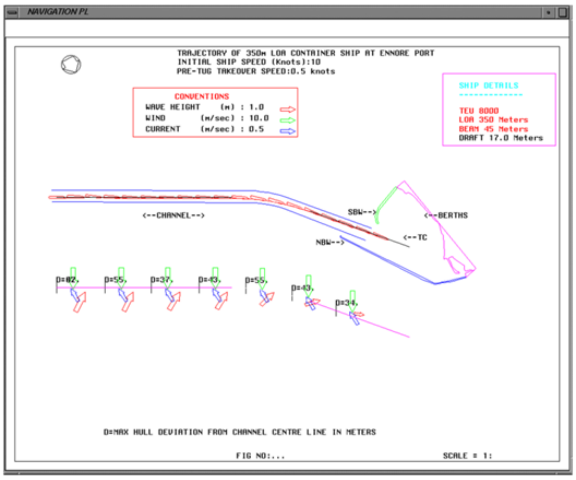
Outcome and Benefits

- Tranquility aspects at various berths and for phase wise development of port
- Navigation, Ship motions and mooring aspects of ships at berth.
- Disposal of dredged material and impact on coastal erosion
- Maintenance of breakwaters

Physical Model : Wave Propagation



Numerical Model : Wave Propagation



Numerical Model : Ship Manoeuvring

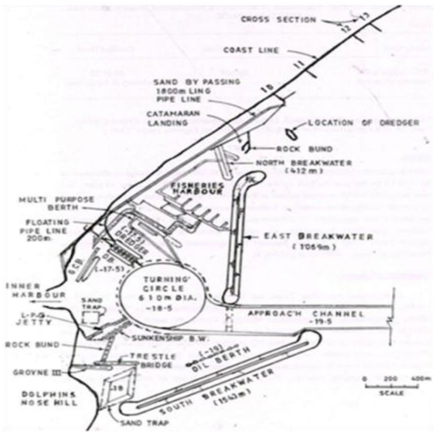
2.12 VISAKHAPATNAM PORT, ANDHRA PRADESH

Background

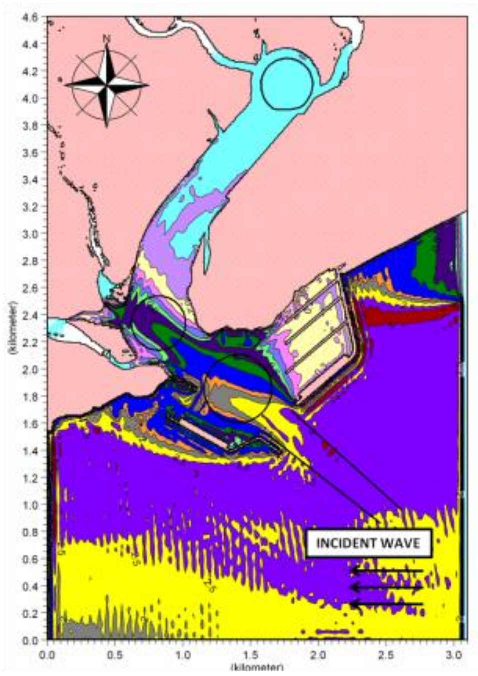
Visakhapatnam Port in Andhra Pradesh is one of the major ports on the east coast of India. Visakhapatnam port is developed in different stages as Inner Harbour and Outer harbour. River Meghadrigedda joins the harbour area on the western side at the Inner Harbour. Several Hydraulic model studies have been conducted at CWPRS right from the planning of Visakhapatnam port and for its stage-wise expansion.

Studies Conducted

- Design of optimum layout / breakwater system to achieve round-the-year tranquility at Ore Berth
- Configuration of sand trap to tackle littoral drift problem
- Sand-bypassing system evolving beach nourishment strategy to maintain dynamic equilibrium of down-drift coastline
- Design of groyne for separating Fisheries Harbour from Outer Harbour
- Studies for Off-Shore Tanker Terminal (OSTT) to achieve desired tranquility conditions with additional rubble lining to south breakwater
- Suitable extension of General Cargo Berth
- Studies for the alignment of LPG jetty
- Evolving type of structure for Multi-Purpose Berth / Container Terminal
- Reconfiguration of sand trap in view of the crude-oil pipe-line laid from Single Point Mooring system, achieving the best efficacy for trapping SW Monsoon drift
- Alignment and design of rock-bund for catamaran harbour basin
- Shifting of sand trap south of south breakwater for contemplated development by Indian Navy on southern side
- Design of suitable dredge pattern in the inner harbour to achieve suitable flow- dynamics
- Estimation of siltation in the Inner Harbour ascertaining the effect of deepening of streams debouching into the inner harbour
- Studies for the development of naval facilities evolving suitable scheme through physical and numerical models
- Radioactive tracer studies for identification of suitable dumping grounds
- Assessing impact of Hudhud Cyclone on Outer Harbour



Layout of existing outer harbour of Visakhapatnam Port



Numerical Model Wave Height Distribution

Physical Model: Wave Propagation

Outcome and Benefits

Studies covering various aspects contributed in the optimum planning, execution and maintenance of various facilities and also helped in evolving suitable sites in connection with dredging and disposal strategies.

2.13 PARADIP PORT, ODISHA

Background

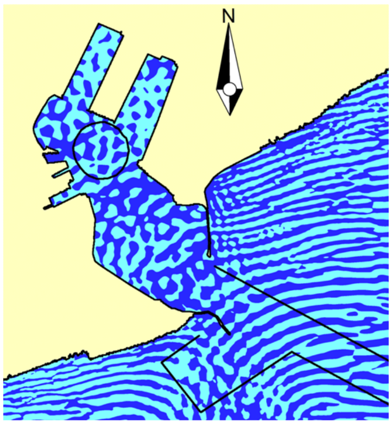
Paradip Port is situated on the East Coast in the state of Odisha, which caters to the large portion of the sea-borne trade of the eastern part of the country. This is an artificial Lagoon type protected from waves by two breakwaters viz. South breakwater with a length of 1217 m and a North breakwater with a length of 538 m commissioned in the year 1966. The wave climate during the southwest monsoon is more severe compared to the northeast monsoon season. Large wave action of about 3 to 4 m height occurs during southwest monsoon where as 2 m during northeast monsoon period, resulting in large quantum of littoral drift. The port has been developed in stages to accommodate increasingly bigger vessels of 1,25,000 DWT with 19 m draft.

Studies Conducted

More than 25 studies have been conducted on physical and mathematical models covering the following important aspects:

- Optimization of breakwater lengths and cross section for wave tranquility.
- Suitable alignment of berths
- Field studies for data collection on various coastal parameters.
- Prediction of Siltation and maintenance dredging.
- Studies for location of sand trap and nourishment of the northern shore.
- Development of fishing harbour.
- Mathematical model studies for outer harbour development, ship motion & siltation studies
- Development of Southern Dock

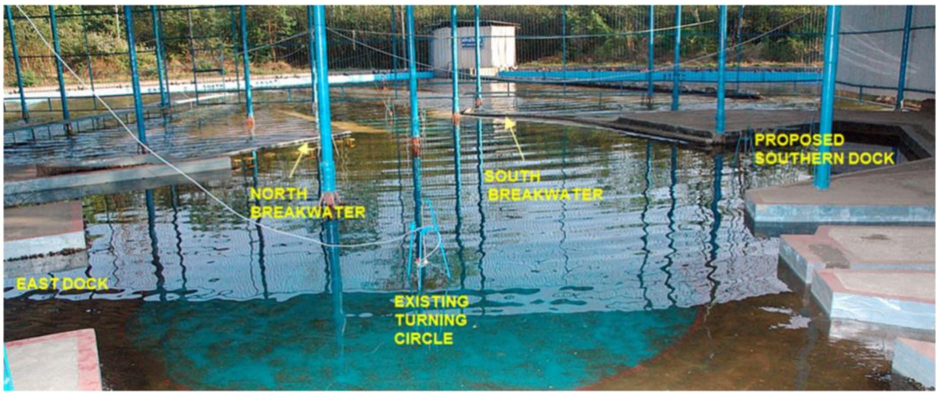
Location of Paradip Port



Numerical Model : Wave Propagation

Outcome and Benefits

- Optimising the alignment & length of breakwater to provide necessary wave tranquility in harbour area and also evolved the location of Sand trap for minimizing the siltation in the harbour and approach channel
- Hydrodynamic studies using numerical models evolved the layout of southern dock, the rate of siltation in the harbour and approaches.
- Identification of location of sand bypassing and nourishment of northern shore
- Optimization of length of breakwaters
- Optimum alignment of berthing structures
- Alignment of southern dock



Physical Model : Wave Propagation

2.14 KOLKATA PORT, WEST BENGAL

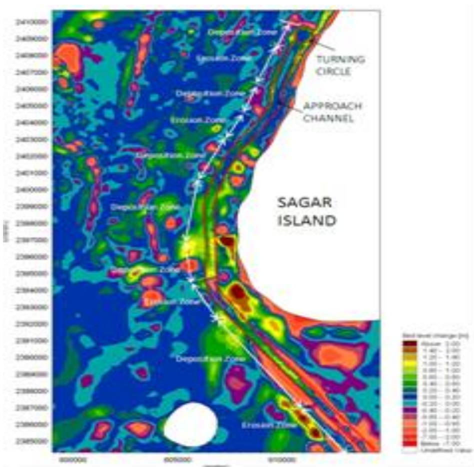
Background

The Kolkata Port (KoPT), located on the left bank of Hugli River is the first major as well as the only riverine port in India. The Haldia Dock Complex (HDC) is located on the right bank of the river at the confluence of Haldi and Hugli rivers. It has longest approach Channel of 145 km. The Bhagirathi – Hugli river system is a major distributary of River Ganga in West Bengal. The entire stretch of 280 km of river is influenced by the tides extending from Saugor downstream to Nabadwip upstream. Small rivers like Haldi, Roopnarayan, Damodar, and Churni carry large amount of sediments into Hugli River during monsoon season. This is a tidal port with severe restriction in draft and very high maintenance dredging. The dynamic nature of estuary results in frequent shifting of the navigation channels.

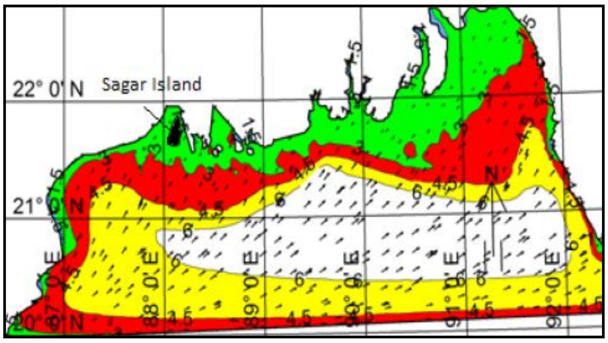
Studies Conducted

- Initially, the studies related to KoPT mainly pertained to river training and bank protection works in the upstream reaches of Hugli river and in the upstream of Kolkata.
- Subsequently, the studies were carried for development of port facilities and navigation channel from Saugor to Kolkata including few estuarine training works.
- All these studies were carried out CWPRS right from 1950's on different scale models. Afterwards the existing Hugli model (scale 1:600 H and 1: 100 V) was constructed and extensive studies were carried out. Hugli model was equipped with automatic tide generating system, and arrangement to release varying upland river discharges. Later the mathematical models were developed using MIKE 21 HD/MT for upcoming studies and all proposals were studied using mathematical models.

Hugli Estuary



Numerical Model : Bed level Change



Numerical Model :wind generated wave field

Outcome and Benefits

- Improvement in river capacities in port reach by 41 MCM
- Salinity wedge pushed down from 30 km upstream of Kolkata to 30 km downstream
- Dredging requirement in Kolkata port reach reduced to nil
- Number of occurrence of bore days reduced from 150 to 20 per year
- Increase in container traffic from 30 TEU to 1,40,000 TEU
- Stabilization of low water crossings
- Reduction in turnaround time of ships
- Declaration of Inland Waterway (IW-2)
- Suitable remedial measures in the form of bank protection work etc.
- Flow diversion measures such as guide walls, spurs and orientation of jetties.
- Sedimentation and scouring phenomena and remedial measures.
- Design of navigation channels and their behavior and impact
- Suitable reclamation techniques and measures for stability of islands
- Study of impact of upland discharges
- Development of minor ports and fishing harbours

Chapter 3

MINOR PORTS AND FISHING HARBOURS

3.1 INTRODUCTION

The problems of harbour development along the eastern and western coasts of India are completely different. The west coast of India, in general, is dominated by soft clayey material, as a result of which the sea bed is very flat. Development of harbours along the west coast would necessitate dredging of long navigation channels. As the sediment movement due to littoral drift is rather very small, the tidal inlets for minor harbours have no permanent problems throughout the year with minimum maintenance dredging. On the other hand, eastern coast is dominated by coarse/medium sand and the sea bed is comparatively steep and the approach channels are shorter. The net movement of sediments along the east coast is predominantly from south to north and is of the order of 1 to 2 Million m^3 per year. The tidal inlets along the coast tend to remain closed during the monsoon season from June to September and are required to be dredged open in order to permit the drainage of water.

The total 200 non-major ports are in the following States:- Maharashtra (48); Gujarat (42); Tamil Nadu (15); Karnataka (10); Kerala (17); Andhra Pradesh (12); Odisha (13); Goa (5); West Bengal (1); Daman and Diu (2); Lakshadweep (10); Pondicherry (2); and Andaman & Nicobar (23).

Fishing in India is a major industry in its coastal states, employing over 14 million people. In 2016-17, the country exported 11,34,948 MT of seafood worth Rs 37,870.90 Crore, frozen shrimp being the top item of export. According to the Food and Agriculture Organization (FAO) of the United Nations, fish production has increased more than tenfold since 1947 and doubled between 1990 and 2010. India has 8,129 kilometres of marine coastline, 3,827 fishing villages and 1,914 traditional fish landing centres.

The studies at CWPRS on the hydraulic aspects mainly cater to wave tranquility, flow conditions and siltation, littoral drift distribution, design of breakwater cross sections, mooring and navigational aspects, location for the disposal grounds. These studies are carried out using physical and mathematical modelling techniques in order to judiciously decide the optimum port layout which is safe, sustainable and economical from the considerations of operations and maintenance.

The typical studies for Minor ports, Singapore port and for the fishing harbours and for the port development schemes under Sagarmala conducted at CWPRS have been described briefly in the succeeding paragraphs.

Fishing Vessels At The Neendakara Harbour

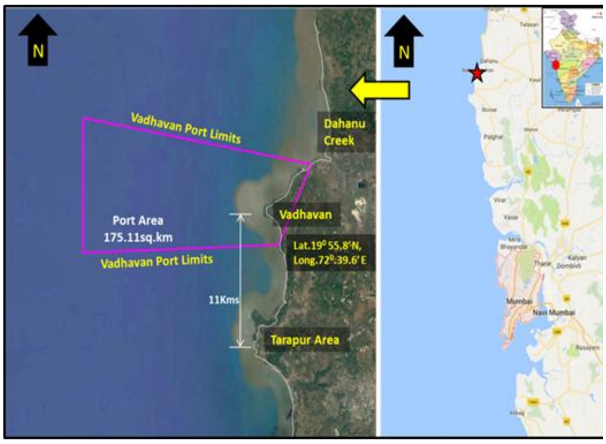
3.2 GREENFIELD PORT AT VADHAVAN, MAHARASHTRA

Background

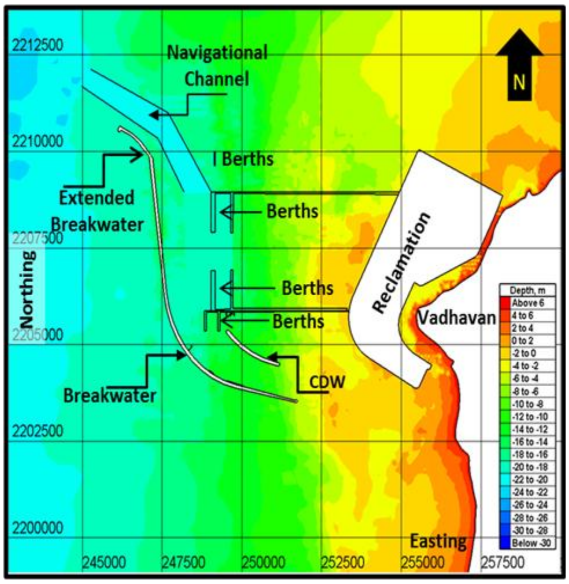
All-weather Greenfield port at Vadhavan situated in Dahanu Taluka, Palghar district of Maharashtra is proposed to be developed through a joint venture between Jawaharlal Nehru Port (JNP) and Maharashtra Maritime Board (MMB). The location of the port is about 110 km north of Mumbai and is on the open coast facing the Arabian sea. The port area is about 175 Sq km and extends up to 26 m depth in deeper part of the sea. The northern limit of the proposed Vadhavan Port is on the southern side of entrance to the Dahanu creek. The development consists of reclamation of about 1428 ha in the intertidal zone along with various berths for containers, coal, liquid cargo, harbour crafts, multipurpose terminals etc. The harbour area will be protected from fury of ocean waves by constructing an offshore breakwater with North-South orientation wherein macro type of semi-diurnal tides with tidal range of about 6 m prevails. The studies to finalise the layout of port from tidal/wave hydrodynamics as well as design of breakwater for extreme wave climate were conducted at CWPRS.

Studies Conducted

- Mathematical model studies to finalise the layout of port from tidal/wave hydrodynamics consideration and estimation of likely siltation in harbour area.
- Desk studies for prediction of extreme wave/storm surge conditions for the design of breakwater.
- Design of breakwater structure from hydraulic stability consideration.
- Assessment of shoreline changes due to the proposed port development.



Location of Proposed Port at Vadhavan



Layout of Proposed Port at Vadhavan

Outcome and Benefits

- The optimal layout of breakwater (10.3 km long) and reclamation (1428 ha.) were evolved based on tidal hydrodynamics and wave tranquility and siltation aspects.
- The layout of breakwater evolved in association with Current Deflecting Wall (CDW) of 1.9 km length provides the favourable flow conditions at berthing locations in the harbour as well as facilitate smooth movement of ships through the navigational channel at harbour entrance. It also minimises the siltation in the harbour area along with optimum utilisation of reclamation area for stacking the goods.
- The predication of extreme wave climate along with storm surge for 1 in 100-year return period provides guidance to evolve the optimal and stable cross section of breakwater for extreme storm events likely to occur during its lifetime.
- Port layout with favourable flow conditions irrespective of phase of tide along with tranquility at berth for round the year operations.
- Natural depths and reduction in maintenance dredging will ultimately increase the revenue of the port.
- The shape of the reclamation evolved provides favourable flow conditions in the harbour as well as maximal utilisation as stack yard. The area being in intertidal zone there is no need to acquire the land.

3.3 MAZGAON DOCK SHIPBUILDERS LIMITED, MUMBAI

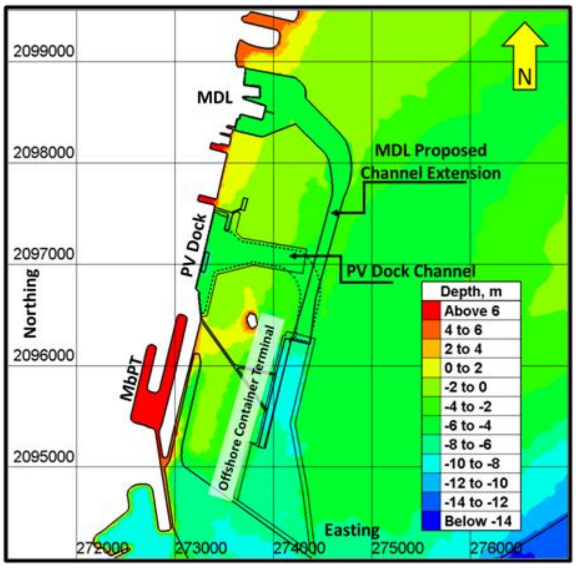
Background

Mazgaon Dock Shipbuilders Limited (MDL), Mumbai is one of the premier shipbuilding yards of India. The yard was established in the 18th century and over last 200 years, it has earned a reputation for quality of work and resourceful services to the shipping world in general and especially for the Indian Navy, ONGC & Coast Guard. After take over by Government of India in 1960, MDL has grown rapidly as a leading warship building yard of the country. The MDL is situated on the leeside of Salsette/Mumbai Island in the Mumbai harbour area on the west coast of India. MDL presently has various infrastructure facilities viz. wet basins, dry docks, slipways etc. To assess the effect of developments of these facilities on nearby waterfronts as well as smooth movements of ships back and forth from MDL, various hydraulic studies were conducted at CWPRS.

Studies Conducted

- The well-calibrated physical (scales:- 1:400(H), 1:80(V)) and mathematical models of Mumbai harbour available at CWPRS were used (1981-2003) to assess the effect of construction of various wet basins, dry docks, slipways on the hydrodynamics and siltation of nearby waterfront facilities existing at Mumbai Port.
- Recently in 2016, various alignments for extension of navigational channel between existing Kasara channel and Offshore Container Terminal (OCT) of Mumbai Port in shallow waters were studied from hydro-morpho dynamic, wave and navigational considerations by calibrating the mathematical model for prevailing flow conditions/ siltation rates.

Location Plan of Mazgaon Dock in Mumbai Harbour



Recommended Layout of Navigational Channel

- The optimal alignment for extension of navigational channel between existing Kasara channel and Offshore Container Terminal (OCT) was finalized based on tidal-wave hydrodynamics along with PIANC guidelines to enable smooth plying of deep draft ships back and forth from MDL. Thus it allows MDL to build warships requiring deeper drafts to serve the nation.

Outcome and Benefits

- The physical model studies carried out for various alternatives facilitated MDL to finalise the shape and size of the wet basins/ dry docks / slipways without affecting smooth functioning of nearby waterfront facilities.
- Favourable flow conditions irrespective of phase of tide along with tranquility at berth will keep round the year port operations.
- Reduction in maintenance dredging and shape of the reclamation evolved provides favourable flow conditions in the harbour as well as maximal utilisation as stack yard. The area being in intertidal zone there is no need to acquire additional land.

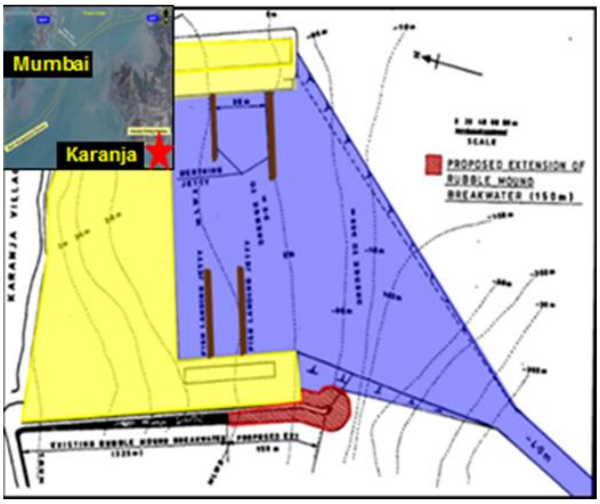
3.4 KARANJA FISHING HARBOUR, MUMBAI

Background

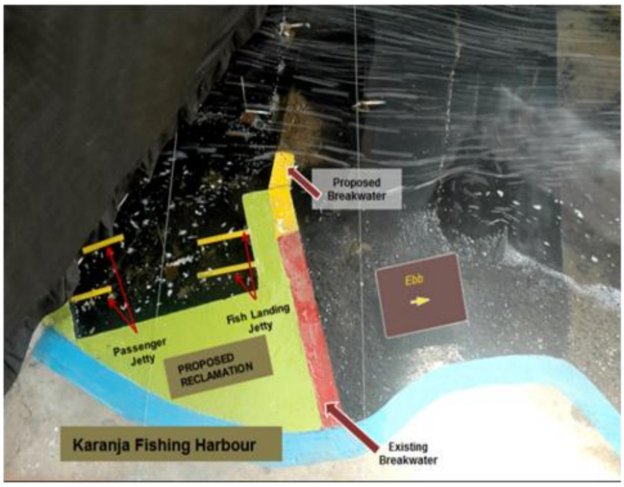
The existing marine facility used by the fishermen living in the nearby villages of Dharamtar creek, Mumbai such as Karanja, Aware and Rewas is proposed to be expanded to accommodate about 300 to 500 fishing trawlers having length 16m and 17m. The facility at Karanja in Dharamtar creek is on the east side of entrance to the Mumbai harbour. The rivers such as Amba, Patalganga, Bhogeswari along with Karanja creek meet the Dharamtar creek prior to debouching into the Arabian Sea. The Central Institute of Coastal Engineering for Fishery (CICEF), Bangalore had evolved a conceptual layout of fishing harbour where deepening of harbour basin/approach channel (up to -3 m and -4 depth w.r.t. Chart Datum respectively) and extension of existing breakwater by 350/200/150 m were proposed to accommodate fishing trawlers. The studies to optimise the length of breakwater and achieve desirable flow and wave conditions inside the harbour as well as estimation of siltation and design of breakwater were conducted at CWPRS.

Studies Conducted

- The well calibrated physical hydraulic model of Mumbai Port (scales: 1:400 (H), 1:80 (V)) was used to optimise the length of breakwater from tidal hydrodynamic consideration to achieve favourable flow conditions in harbour basin and approach channel. The siltation in harbour basin and approach channel was estimated using semi-analytical formulation.
- The wave tranquillity in harbour for predominant waves approaching from south-west quadrant was studied to achieve desirable tranquility at berths by optimising the length of breakwater.
- The hydraulic stability of breakwater was studied in wave flume, scale 1:27 (G.S.) to design the breakwater cross-sections.



Location of Karanja Fishing harbour in Dharamtar Creek



Layout Of Fishing Harbour Finalised By Hydraulic Model Study

Outcome and Benefits

- The physical hydraulic model studies conducted reveal that 150 m extension of breakwater will provide favourable flow conditions inside the harbour basin as well as in approach channel. The quantity of maintenance dredging will be of the order of 1.15 lakh m^3 per annum.
- The wave tranquillity study also indicates that with 150 m extension of breakwater wave height less than 0.3 m (permissible limit) will prevail at berth inside the basin.
- Wave flume study revealed design of different cross-sections of rubble mound breakwater that varies along its length and Tetrapod blocks of 2, 3 tonne weight in trunk and 4 tonne in roundhead in double layer for armour unit of breakwater are essential on 1:2 armour slope.
- The layout evolved optimises the length of breakwater and provides desirable wave and flow conditions for safe berthing of fishing trawlers inside the fishing harbour.
- The construction of 150 m long rubble mound breakwater along with the strengthening of existing 325 m long rubble mound breakwater achieved safe conditions for berthing of trawlers.

3.5 KARWAR SEA BIRD PROJECT, KARNATAKA

Background

INS Kadamba is an Indian Navy base located near Karwar in Karnataka. The first phase of construction of the base, code-named Project Seabird, was completed in 2005 and the base was commissioned on 31 May 2005. During Phase I development of the project, two breakwaters and a spur (total length 5.17 km) were constructed to provide sheltered harbour, along with 410 m long pier and the shiplift facility.

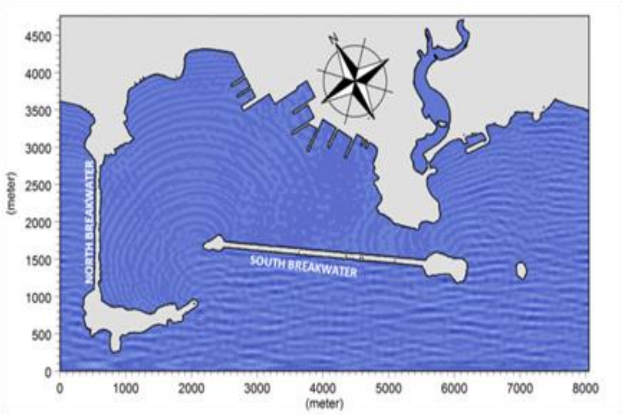
Studies Conducted

Hydraulic physical model studies and field studies were conducted by CWPRS for the Karwar Seabird project for Indian navy during 1981 to 1991.

- Studies for preliminary layout on physical model (scales- 1:250 (horizontal), 1:125 (vertical) during 1981-1982.
- Aerial reconnaissance of entire area between Kalinadi and Balekari Bay during 1983.
- 3-D hydraulic physical model studies scale G.S. 1:150 during 1984-85. Wave tranquility studies were carried out on a 3-D rigid bed model provided with computerized random sea wave generating and data acquisition system from two directions.
- Field studies for wave, tides, currents water samples during 1983.
- Random wave flume studies for breakwater design.
- Radio Active Tracer (RAT) studies in collaboration with BARC, Mumbai for suggestion of dumping ground for the capital and maintenance dredged material during 1988 and 1990.
- Assessment of wave tranquility in port using numerical model MIKE 21 SW and BW.
- Ship motion studies for Phase-II A developments of Project Seabird.

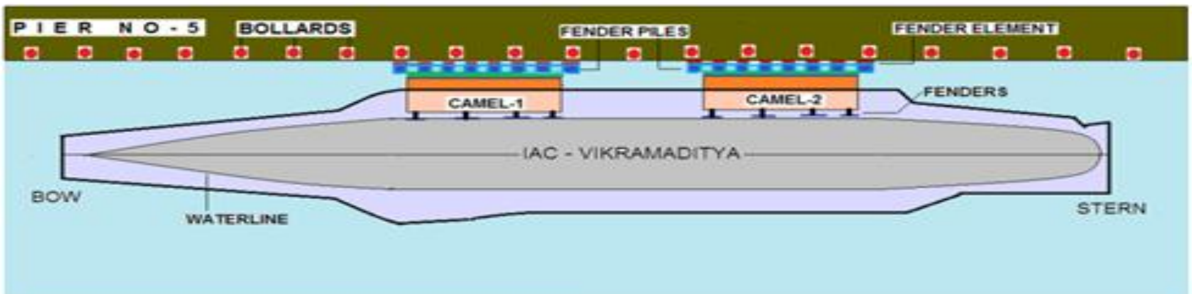
Location of Karwar Sea Bird Project

Naval Officers Visit to CWPRS



Numerical Model results : Wave Propagation

Physical Model : Wave Propagation



IAC - Vikramaditya berthing arrangement

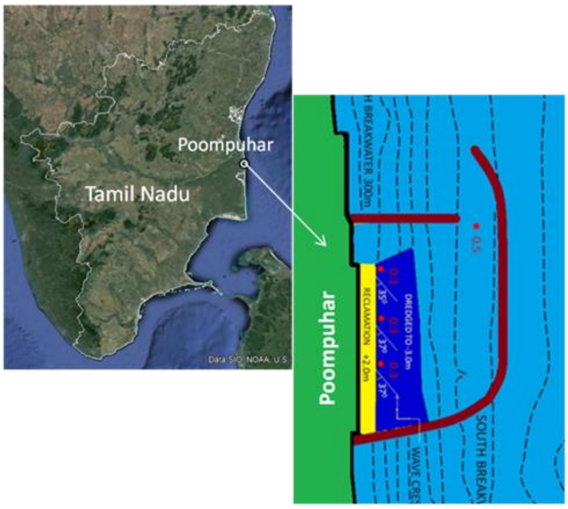
3.6 POOMPUHAR FISHING HARBOUR, TAMIL NADU

Background

Poompuhar fishing harbour is in the Nagapattinam district in the southern Indian state of Tamil Nadu. Poompuhar being near the shadow zone of the Palk Bay, the wave climate and littoral drift trend is different from the normal trend existing at other locations on the east coast of India. The Central Institute of Coastal Engineering for Fishery (CICEF), Bangalore has conducted feasibility studies for development of the fishing harbour. The harbour layout proposed by CICEF consists of a South Breakwater of 910 m length and North Breakwater of 255m length. CWPRS checked adequacy of the proposed harbour layout and modified the layout to achieve the desired wave tranquility in the harbour.

Studies Conducted

- Assessment of wave tranquility in Poompuhar fishing harbour using Numerical Model MIKE 21 SW and BW.
- Estimation of littoral drift distribution and simulation of shore line changes due to construction of the breakwaters using numerical model MIKE 21 LITPACK.
- The Physical wave model (G.S. scale: 1/100) of Poompuhar fishing harbour is used to study the wave tranquility with Random Sea Wave Generation system for the breakwater layout.
- Design of breakwater sections

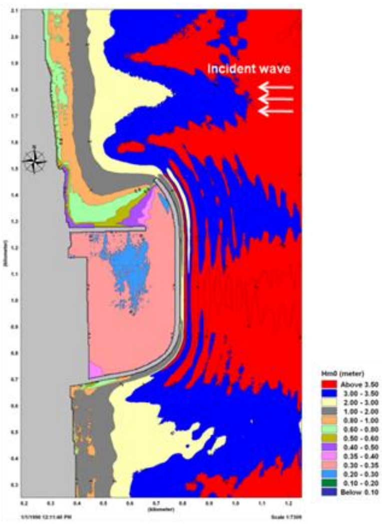


Location of Poompuhar Fishing Harbour with Recommended Layout

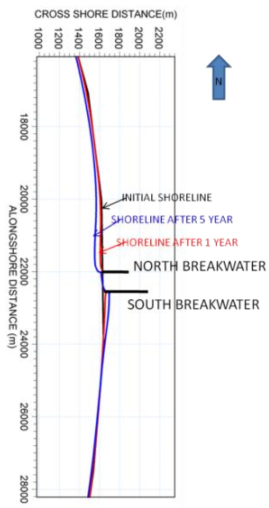
Physical Model : Wave Propagation

Outcome and Benefits

- Numerical Model studies evolved the harbour layout to provide the necessary wave tranquility for harbour with less siltation in the harbour and also optimize breakwater lengths
- Physical wave model studies obtained wave tranquility and optimization of breakwater lengths.
- Optimization of breakwater alignment and length
- Wave tranquillity in harbour basin.
- Alignment of breakwaters along with safe and economical design.



Numerical Model : Wave Height Distribution



Numerical Model : Shoreline Evolution

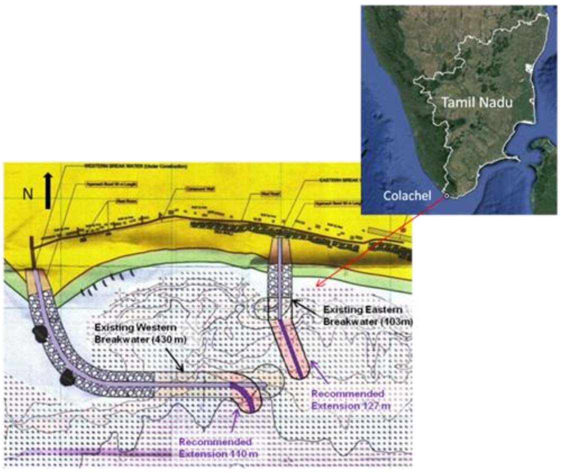
3.7 COLACHEL FISHING HARBOUR, TAMIL NADU

Background

Colachel fishing harbour is located on the west coast of Kanyakumari District, 20 km north-west of Kanya Kumari (Cape Comorin), the southernmost tip of peninsular India, which is exposed to high wave action of upto 5.0 m height. Major siltation in the harbour and subsequent advancement of the shoreline on the west of the eastern breakwater has been observed since the construction of the initial two breakwaters.

Studies Conducted

- Estimation of littoral drift distribution and simulation of shore line changes due to construction of the breakwaters using numerical model MIKE 21 LITPACK.
- Assessment of wave tranquility in Colachel fishing harbour using numerical model MIKE 21 SW and BW.
- The physical wave model (G.S. scale: 1/100) of Colachel fishing habour is used to study the wave tranquility with Random Sea Wave Generation system for the breakwater layout.
- Design of breakwater sections

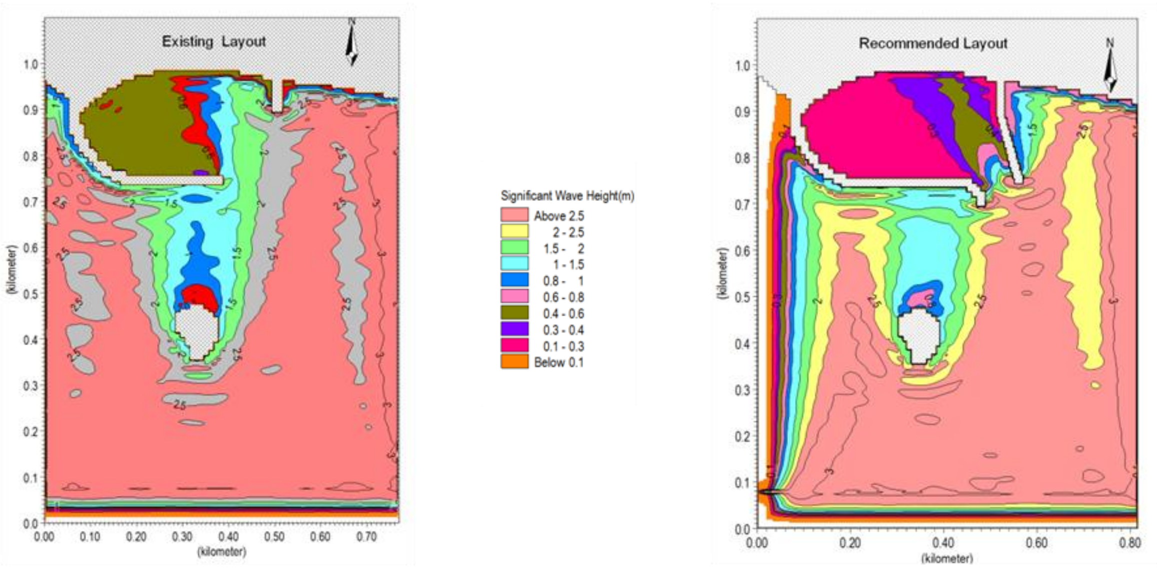


Location of Colachel Fishing Harbour with Recommended Layout

Physical Model : Wave Propagation

Outcome and Benefits

- Numerical model studies evolved the harbour layout to reduce the siltation in the harbour and also provide the necessary wave tranquility for harbour.
- Physical wave model studies obtained wave tranquility even with the vertical berthing face for modified layout and additional areas for berthing also identified.
- Minimum siltation in the harbour
- Additional berthing area
- Harbour operations throughout the year



Numerical Model Results : Wave Height Distribution

3.8 THE PORT OF SINGAPORE

Background

The Port of Singapore is the busiest container transshipment hub in the world. Located on the southern end of the Malay Peninsula, 30 km south-west of the Port of Johor in Malaysia, the Port of Singapore offers connectivity to more than 600 ports in 123 countries. It is the largest publicly owned port in the world. Since Singapore's full independence in 1965, it had to compete with other ports in the region to attract shipping and trade at its port. Hydraulic model studies were conducted at CWPRS for the development of Singapore Port during 1971 to 1976.

Studies Conducted

- Analysis of tidal data for Victoria dock, Jurong wharf, Sultan shoal and Sembawang, Pulau Bukom, cause way etc.,
- Hydraulic physical model studies were carried out for developments at Changi reclamations on the eastern tip of Singapore.
- Hydraulic physical model studies for the sea Port at Changi.
- Hydraulic physical model studies for the recreational facilities at Pu. Hantu and the sister Islands.
- Hydraulic physical model studies for development of Keppel ship yard at Tuas, Jurong.

Photo: Showing Limits Of Model

Photo: Showing Layout Changi Harbour & Flow Pattern At The Entrance Of Basin During Flood

Photo: Showing Eddy In The Basin During Westerly Ebb At Pu. Hantu Island Reclamation

Photo: Showing Flow Pattern In The Vicinity Of Taus Shipyard

Outcome and Benefits

Based on model studies suggestions were given to Singapore Port authority for layout plan of the harbour, ship yard developments for the tested projects, land reclamations for implementation at site.

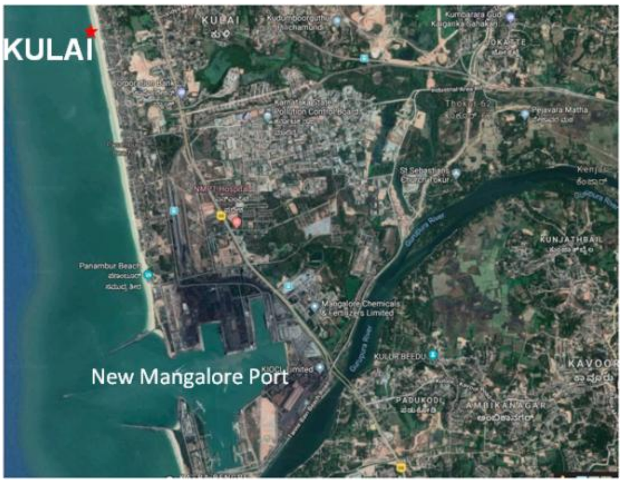
3.9 KULAI FISHERIES HARBOUR, KARNATAKA

Background

Kulai fishing harbour is located on north of New Mangalore port. As there was no sheltered area for fishermen near the New Mangalore Port, fish landing activities were carried out on the beach inside the port. To avoid risk of accidents inside the port basin, decision was taken to provide separate fisheries harbour outside port area. A site near Kulai was chosen for developing the fisheries harbour with two rubble mound type breakwaters on North and South measuring 675 m and 270 m respectively having entrance from South-West.

Studies Conducted

- Finalising the alternative breakwater alignments suggested by CICEF, Bangalore
- Wave tranquillity & sediment movement near the harbour
- Design of breakwaters against waves and Geo-technical aspects



Location Of Kulai Fisheries Harbour

Outcome and Benefits

- Optimum alignment of break waters to obtain required tranquility in the harbour basin.
- Optimisation of berthing facilities, studies for sediment movement around fisheries harbour.

Physical Model : Wave Propagation

Physical Model : Sediment Movement Studies

3.10 MUNAMBAM TIDAL INLET, KERALA

Background

Munambam fishing harbour is located in Azikode estuary where a branch of Periyar river joins the Arabian sea. Sediments eroded due to wave action from the adjacent coastal area are transported by the southerly littoral current. After construction of the breakwaters (North Breakwater of 625 m length and South Breakwater of 360 m length) in the year 1995, shoreline at the north of North Breakwater has been advanced and reached up to the tip of the breakwater due to this southward drift. Sedimentation in the harbour region as well as the sand bar formation across the entrance channel is major menace to the safe entry and berthing of the fishing boats.

Studies Conducted

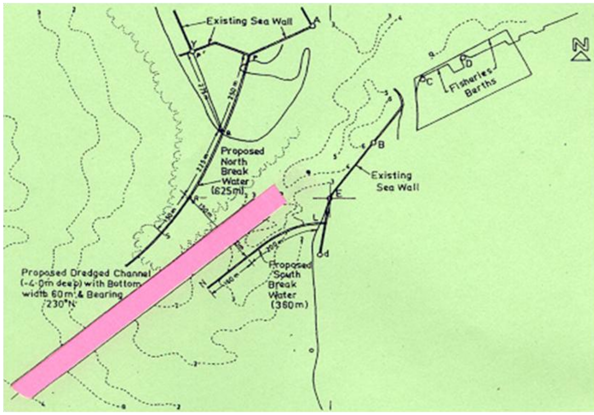
- The physical wave model used to study the wave tranquility and mathematical tidal model to study the sediment movement near the harbour.
- Estimation of littoral drift distribution and simulation of shore line changes due to construction of the breakwaters using numerical model MIKE 21 LITPACK.
- Assessment of wave tranquility using numerical model MIKE 21 SW and BW.
- Design of breakwater sections

Fig. 1 : LOCATION MAP OF MUNAMBAM

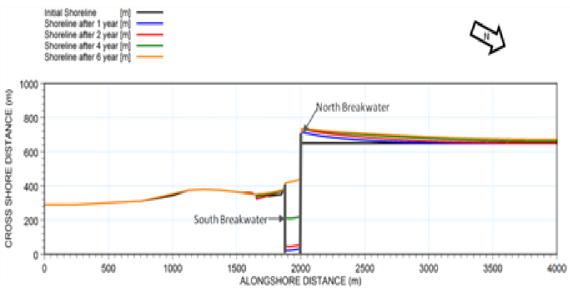
Location of Munambam Fisheries Harbour

Outcome and Benefits

- For the improvement of the inlet for fisheries development, construction of a South Breakwater of 360 m length and a North Breakwater of 625 m at the entrance was recommended. The construction of breakwaters was completed in the year 1995-96.
- Adequate depths in the navigational channel without any capital dredging, arresting of littoral drift, stabilizing the channel and inlet and providing wave tranquility with suitable approach angles in the channel and at berth.



Layout Plan Of Channel And Breakwaters



Numerical Model results Shoreline Evolution

Physical Wave Model

3.11 JSW JAIGARH PORT LIMITED, MAHARASHTRA

Background

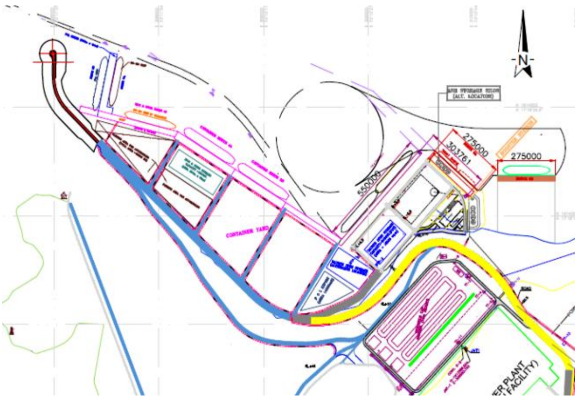
All weather Green Field Port was developed at Jaigarh, Maharashtra, on the west coast of India, situated at Damankhol Bay. The port has a 510 m long breakwater projecting from the Jaigarh Head to give protection from extreme weather conditions in South West monsoon. The site is mostly affected by the Westerly and North westerly waves during South West monsoon. During South West monsoon, severe motions of moored ships were observed at the berths which affected loading, unloading operations at the berth badly.

Studies Conducted

Mathematical model studies for wave propagation at Jaigarh Port included,

- Wave Transformation from deep waters to 15 m depth contour.
- Simulation of wave propagation in the harbour for the existing harbour layout, to compute wave heights in the harbour area.
- Simulation of wave propagation in the harbour for different alternative layouts of breakwater.

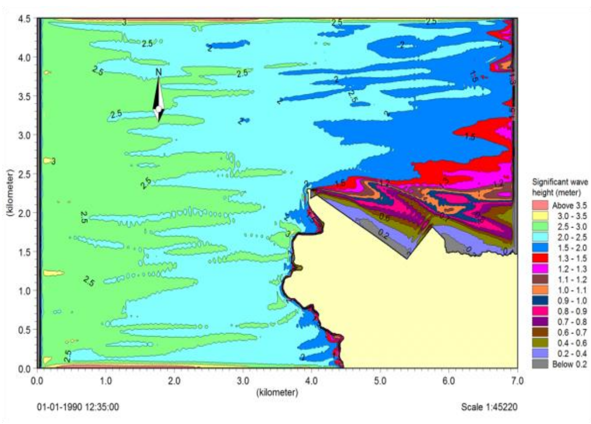
Location Of Jaigarh Port



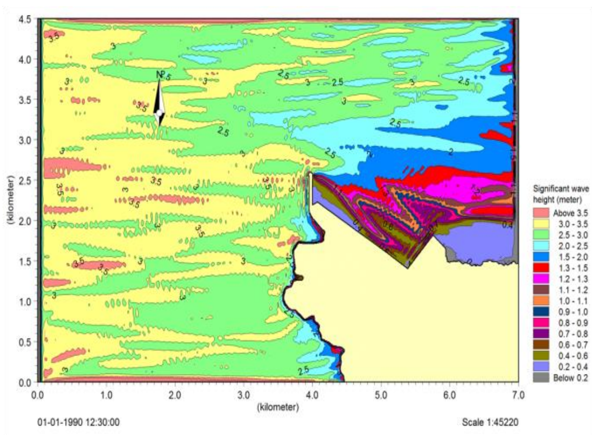
Jaigarh Port Layout

Outcome and Benefits

- Studies for existing layout indicated that wave heights at the berths were seen to be less than the permissible wave height
- Suitable layout was suggested for safe operations at the existing berths.
- Extension of the existing breakwater by 300 m would further improve tranquillity near the berths
- Port operational throughout the year.
- Optimised breakwater length.



Wave Height Distribution For Existing Layout (Incident Wave Height : 3.0 m)



Wave Height Distribution For Proposed Layout (Incident Wave Height : 3.5 m)

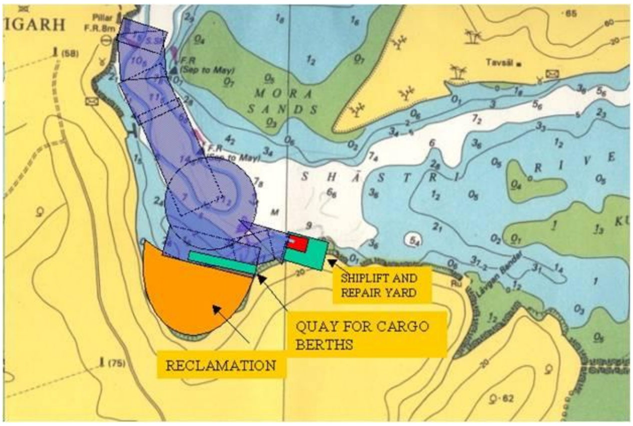
3.12 JAIGAD HARBOUR (ANGRE PORT), MAHARASHTRA

Background

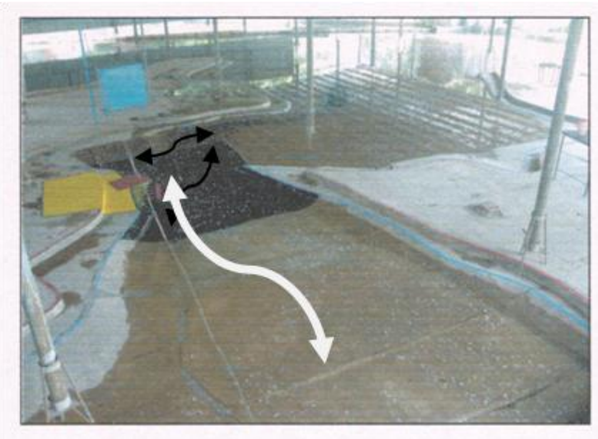
Maharastra Maritime Board (MMB) has allocated water front area to M/s Chogule Steam Ship Yard Ltd. at Lavgaon village near Jaigad, Maharastra for development of port facilities comprising ship repair yard and cargo berths. The outfall of Shastri river (estuary) at Jaigarh is located 225 km south of Mumbai. The Shastri estuary has an entrance width of 3.50 km with prevalent water depth of almost 8-9 m below chart datum. The total length of Shastri river is about 64 km. The peak freshwater flow in the river is estimated as 2850 m^3/s. The depths along longitudinal direction vary from 8 to 4 m in the upstream, where sand bar is situated.

Studies Conducted

- The studies were conducted at CWPRS for port facilities using physical tidal model for prediction of siltation in the approach channel at Jaigad port.



Location of Angre Port

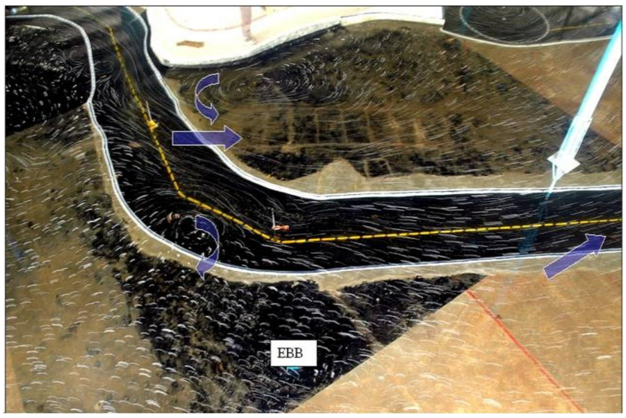


Jaigarh Tidal Model

Outcome and Benefits

- The alignment of Ship Lift facility and Cargo Berth was modified to suite the flow conditions in the Shastri River
- Navigation channel for 12 m draft across the Sand bar is aligned for safe navigation and minimum siltation
- Siltation both along the channel and the dredge pocket infront of the proposed developed jetty is estimated and a disposal location is identified at (-) 30.0m contour as per the CRZ norms.
- Port operational throughout the year

Cargo Berth In The Model



Navigational Channel In The Model

3.13 NAVAL DOCKYARD, MUMBAI

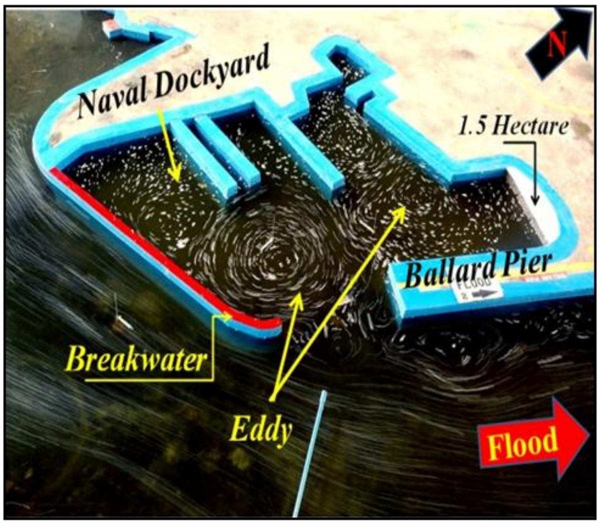
Background

Naval Dockyard, Mumbai is a premier marine facility of the Indian Navy to berth and maintain the Naval ships under the control of Western Naval Command. The major development plan for the dockyard after independence was started in 1968, wherein construction of 640 m rubble mound breakwater along with 610 m caisson breakwater and extension of Ballard Pier were proposed. The hydraulic model studies for finalising the layout and design of breakwater were entrusted to CWPRS and thereafter studies to assess the change in flow/siltation pattern due to the proposed development of dry dock and reclamation of 1.5 Hectare in the dockyard were conducted in 2005.

Studies Conducted

- The well calibrated physical model (1:1000 (H), 1:100 (V)) of Mumbai Port was used to finalise the alignment of breakwaters and to assess the impact of extension of Ballard Pier on flow field in and around Naval Dockyard.
- Wave flume studies were conducted to a scale of 1:25 (G.S) to assess the hydraulic stability of proposed rubble mound breakwater and rubble base foundation of caisson breakwater for Naval Dockyard in 1968.
- The field data on various oceanographic parameters were collected and studies using physical model (scales-1:400(H),1:80(V)) and mathematical model (Telemac software) studies were conducted to assess the change in flow/siltation pattern for the development of dry dock and reclamation in "R"-Zone (1.5 ha.) under consideration.

Location Plan of Naval Dock yard in Mumbai Harbour



Physical Model showing Eddy Zones in Dockyard

Outcome and Benefits

- The orientation and alignment of both the breakwaters i.e. rubble mound and caisson along with suitable extension of Ballard Pier were finalised based on tidal and wave model studies carried out.
- The cross-sections of rubble mound breakwater and design of rubble foundation beneath the caisson were finalised from hydraulic stability consideration in a wave flume. Also a filter layer on leeward side of rubble mound breakwater was suggested to avoid transmission of waves in the dockyard as well as to prevent loss of reclamation material.
- The model studies conducted reveal that the effect of reclamation in the "R"-Zone reduces eddy formations and effect on siltation in inner tidal basin is negligible, while with dry dock in the outer tidal basin increases the existing rate of siltation by 5-10%.

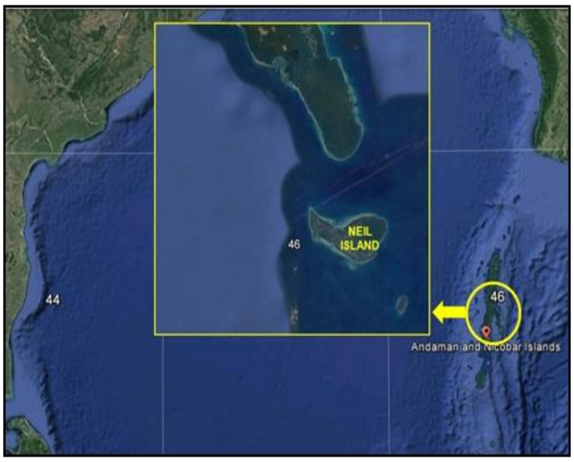
3.14 NEIL ISLAND, ANDAMAN & NICOBAR ISLANDS

Background

Neil is a tiny but beautiful island located 37 km to the North - East of Port Blair in Andaman Islands. With unexplored coral reefs, brilliant bio-diversity, white sandy beaches and tropical forest and vegetation, it is one of the popular tourist spots in the Andaman. Neil Island is known as the 'vegetable bowl' of the Andaman. ALHW proposes dredging of sea bed along the berthing face of this jetty and a turning circle of 120 m diameter and approach channel of jetty. Quantity of dredged material is likely to be of the order of 39,000 m^3. The study aims to identify the suitable dumping ground.

Studies Conducted

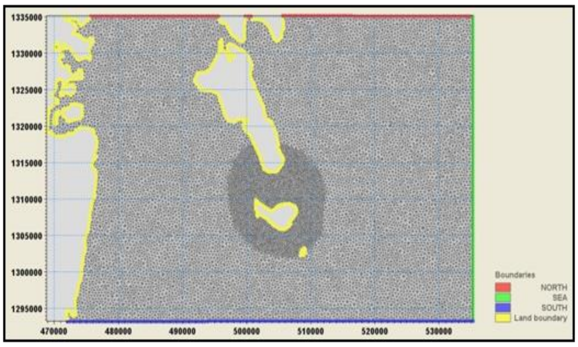
- Mathematical model studies for hydrodynamics using MIKE 21 HD (FM) model were carried out for existing conditions of the Neil Island.
- MIKE 21 HD coupled with MT was used to simulate the sediment transport.
- Sediment parameters were given as input to the model and material was disposed at few locations (one location at a time).
- Assessment of current circulations, current speed and direction was carried out and dispersion of dredged material in open sea was observed.
- The model simulations were carried out for most suitable dumping ground and the same was suggested to the project authority.



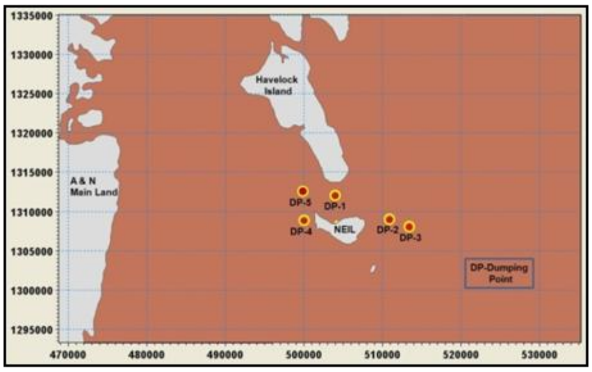
Location of Neil Island

Outcome and Benefits

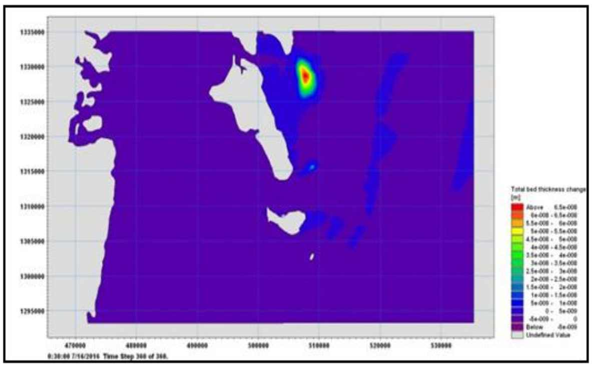
- Study indicated that the peak tidal currents in the vicinity of dumping points would be in the rage of 0.25 m/s to 2.5 m/s which may help in the dispersion of dredged material.
- From hydrodynamic results, there are strong currents prevailing in the channel between Havelock and Neil Island. After leaving this channel, it follows the northeast direction.
- Out of all locations 'Dumping Location - 5' gives the most satisfactory result and is suitable compared to other dumping Locations.



Mesh generated in Mathematical Model



Locations of 5 dumping ground that tested in HD/MT model



Results of dumping location 5

3.15 CAMPBELL BAY, ANDAMAN & NICOBAR ISLANDS

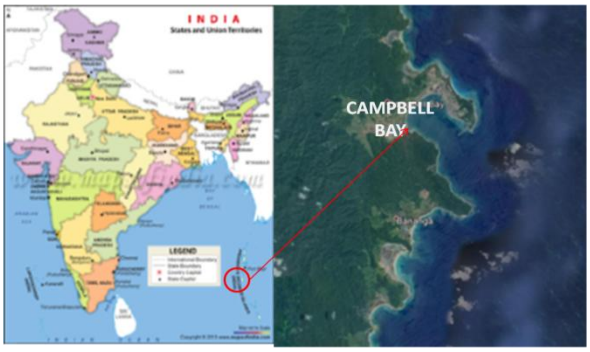
Background

Andaman Lakshadweep Harbour Works, Port Blair has a proposal to extend the existing breakwater at Campbell Bay by 300 m. The Mathematical Model Studies for wave tranquillity were referred to CWPRS for the proposed development. Wave tranquillity studies to assess wave disturbance near the Wharf, Jetty and Marine Hard locations using mathematical model were done at CWPRS, Pune.

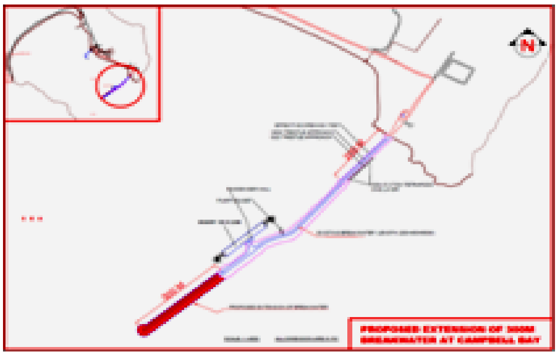
Studies Conducted

Mathematical model studies for wave propagation were carried in two stages:

- Stage 1. Transformation of wave height and wave direction from deep water to 16 m depth using MIKE 21-SW Model (Spectral Wave Model).
- Stage 2. Simulation of wave propagation from 16 m depth to the proposed extension of breakwater in harbour area to obtain wave heights and wave directions near the Wharf, Jetty and Marine Hard locations.
- Mathematical Model Studies for wave tranquillity using MIKE21 BW model were carried out for the existing layout as well as with 300 m extended breakwater



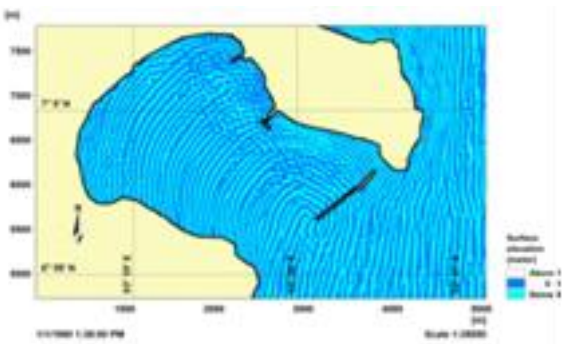
Location of Campbell Bay



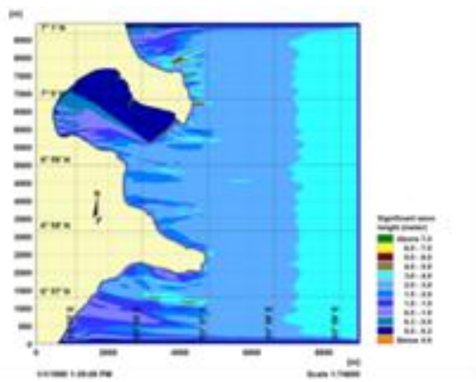
Proposed layout with extension of 300 m length of breakwater at Campbell Bay

Outcome and Benefits

- The wave propagation studies were carried out to determine the layout for safe berthing operation in all the season from wave tranquility point of view.
- The percentage improvement of wave tranquility after the extension of breakwater for incident wave direction East are 76.47%, 79.62% & 31.82% for Wharf, Jetty and Marine Hard location respectively. Similarly, the improvement of wave tranquility for incident wave direction SE are 84.14%, 47.47% & 46.33% and for SSE direction there are 79.31%, 69.29% & 13.75% near Wharf, Jetty and Marine Hard locations respectively.
- Hence extension of breakwater by 300 meter length is suitable from wave tranquility point of view for safe berthing operation.



Surface Elevation



Wave Height Distribution

Numerical Model Results

3.16 PASSENGER JETTY MANDWA PORT, MAHARASHTRA

Background

Mandwa Port is situated on the west coast of India near Rewas at the entrance of Dharamtar creek. A breakwater is constructed to reduce the effect of waves and tidal currents at jetty to improve overall berthing facilities for passenger and for RO-RO services at Mandwa port.

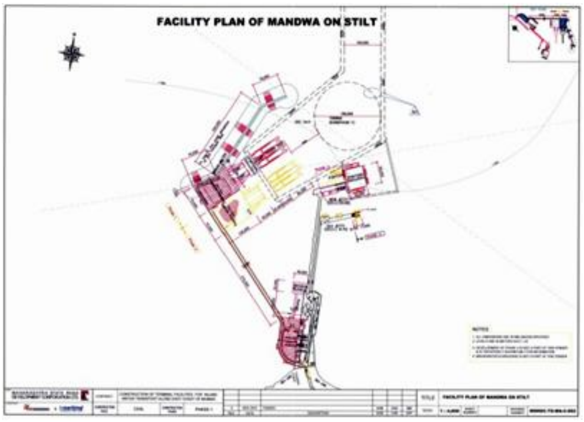
Studies Conducted

- Assessment of wave tranquility at Mandwa passenger jetty and at RO- RO berth using numerical model MIKE 21 SW and BW.
- Assessment of tidal flow conditions near the Jetty and near the breakwater using numerical model MIKE 21 HD
- Design of breakwater sections

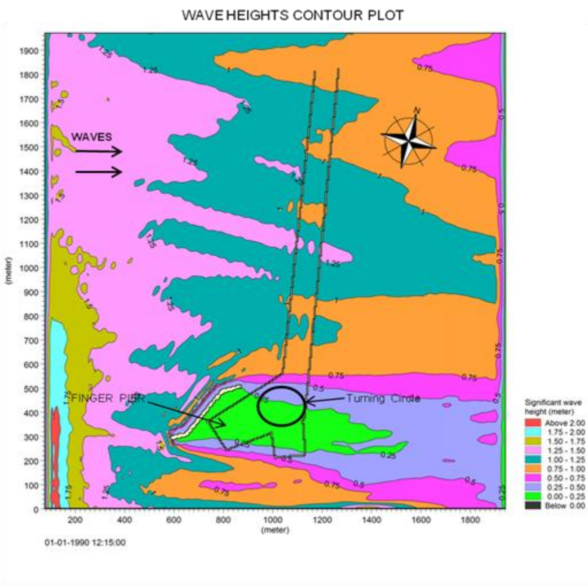
Location Of Mandwa Port

Outcome and Benefits

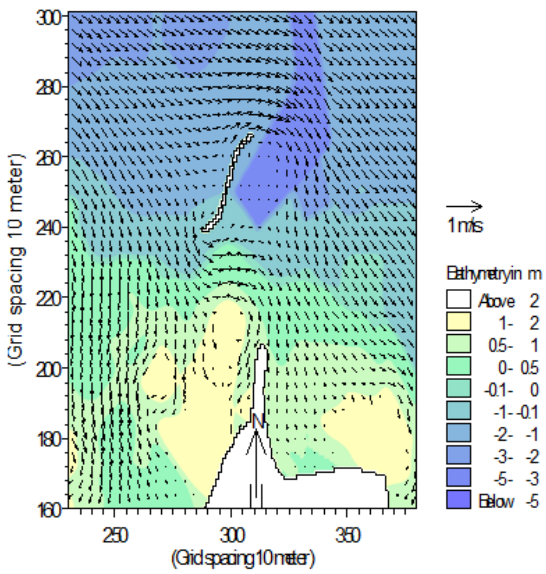
- Wave tranquility studies indicated that the wave heights at the finger piers would remain within the permissible tranquility limit of 0.5 m for all incident wave conditions.
- Tidal hydrodynamics studies indicated that there will not be any significant change in tide induced currents in the vicinity of harbor area, and circulation in the harbor area due to proposed breakwater would be very weak and it would not have any adverse effect on operations at Finger Pier.
- Passenger Jetty as well as RO-RO Services will be operational throughout the year.



General Development Plan At Mandawa



Wave Height Distribution



Flow Pattern

Numerical Model Results

3.17 MUTHALAPOZHY FISHING HARBOR, KERALA

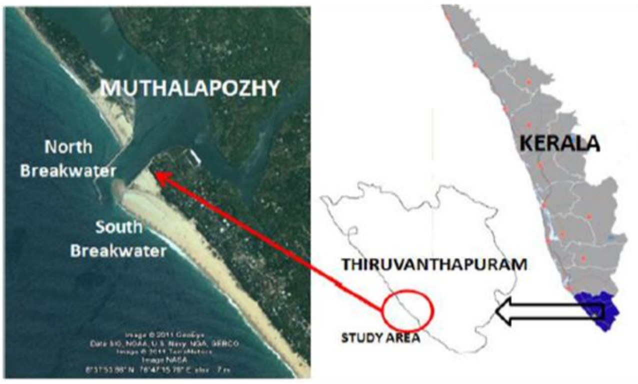
Background

Muthalapozhy fishing harbor is located at a coastal inlet on the west coast of India between Vizhinjam and Thangassery in Kerala. The Vamanapuram River falls into Arabian Sea through this inlet. A stretch of backwaters known as Kadinamkulam Kayal is situated close to this inlet. The river mouth is open only during the monsoon period from June to November. For maintaining the entrance channel, two rubble mound breakwaters were earlier proposed by project authority based on IIT, Chennai recommendations on either side of the inlet but even after implementing, the severity of the problem remained same.

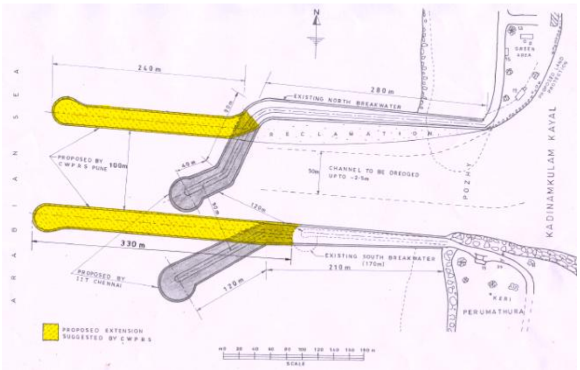
Studies Conducted

Mathematical model studies were undertaken at CWPRS

- Wave transformation from deep waters to 15 m depth contour.
- Estimation of seasonal/annual littoral drift rates and cross-shore distributions
- Shoreline evolution due to proposed extension of the breakwaters
- Simulation of wave propagation in the harbour
- Design of breakwater sections



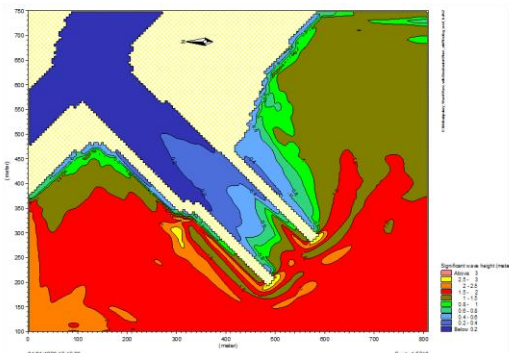
Location Of Muthalapozhy



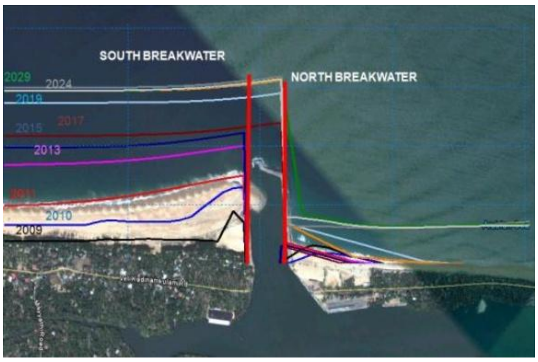
Proposed Extension of Breakwaters

Outcome and Benefits

- Extension of the South and North breakwaters by 200m will help in trapping the sediments on southern side of the south breakwater and prevent bypass and subsequent filling of the channel.
- Shoreline changes predicted that after about 6 years the cross-shore accretion on the south side would be about 220 m, and siltation into the channel towards north side will commence. Therefore regular sand bypassing from south to north is essential to prevent erosion of the northern coastline and accretion on the south.
- Wave tranquility studies indicated that the wave heights at the finger piers would remain within the permissible tranquility limit of 0.5 m for all incident wave conditions.
- Inlet is made operation throughout the year.



Wave Height Distribution



Shoreline Evolution

Numerical Model Results

3.18 THOTTAPPALLY MINI FISHING HARBOR, KERALA

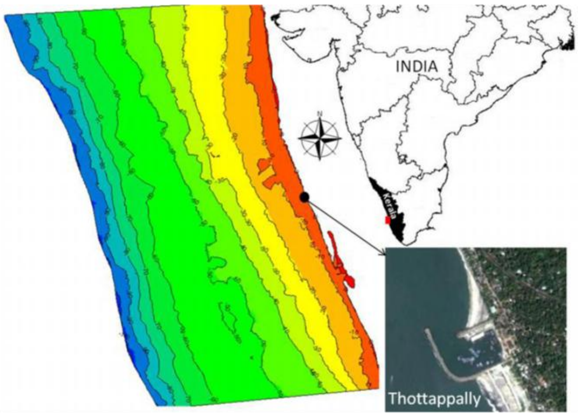
Background

The Thottappally fishing harbour is situated in Kerala state at 700 m north of Pamba River. The existing harbour layout consists of two breakwaters; North Breakwater of 145m length and South Breakwater of 476m length. Existing harbour is facing problem of sever siltation in the harbour. In this regard, the Harbour Engineering Department, Kerala referred the studies to CWPRS to suggest modifications to the existing harbour layout to minimize the problem of siltation in the harbour.

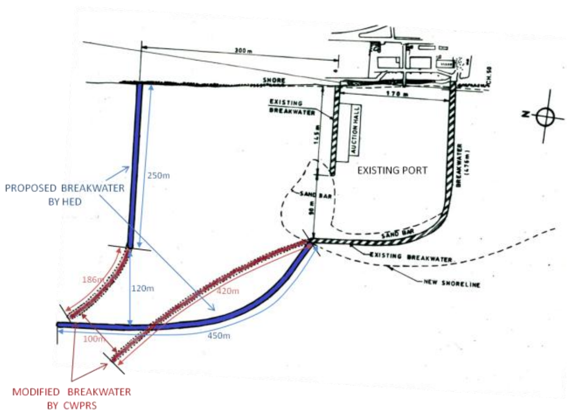
Studies Conducted

Mathematical model studies were undertaken at CWPRS

- Wave Transformation from deep waters to 10 m depth contour.
- Estimation of littoral drift rates and cross-shore distributions
- Shoreline evolution due to proposed extension of the breakwaters
- Simulation of wave propagation in the harbour to check the adequacy of the proposed harbour layout
- Hydrodynamics and probable morphological changes studies for the modified layout
- Design of breakwater sections



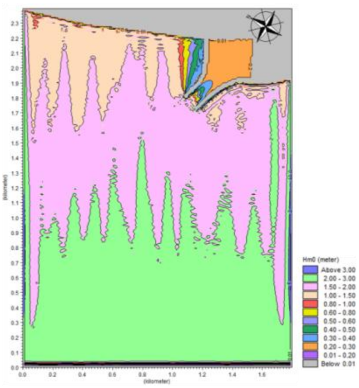
Location and Bathymetry Of Thottappally



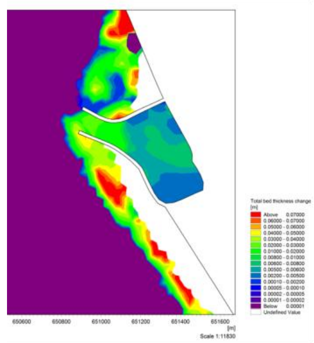
Proposed Extension of Breakwaters

Outcome and Benefits

- Thottappally harbour is subjected to siltation inside the basin due to passage of northward littoral drift through the harbour entrance.
- A modified layout was evolved from the considerations of the wave tranquility and sedimentation with North Breakwater of 436 m and South Breakwater of 896 m (476+420) length with a clear gap of 120 m for the harbour entrance.
- The annual sedimentation in the fishing harbour is estimated to be about 25 cm at initial stage of construction of modified layout. The annual sedimentation in the harbour would, however, expected to increase to about 40 cm after 6 years
- Harbour is made operational throughout the year.
- Optimum design of breakwaters



Wave Height Distribution



Sedimentation Pattern

Numerical Model Results

3.19 ESSAR JETTY, HAZIRA, GUJARAT

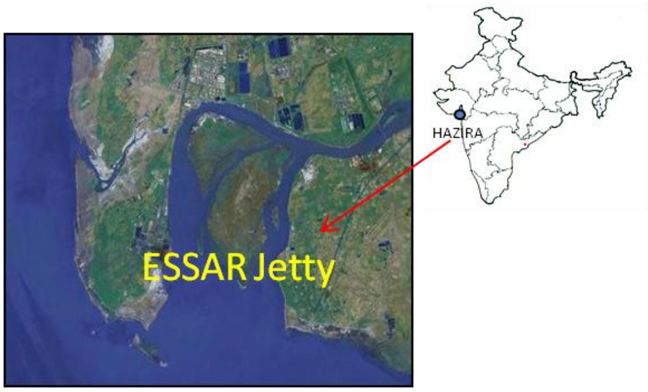
Background

M/s ESSAR Steel Ltd. (ESSAR) is located at the mouth of Tapi river near Hazira, Gujarat with sponge iron plant and a hot rolled coil plant. The proposal included extending the jetty and creating a new approach channel to cater to 75000 DWT bulk carriers.

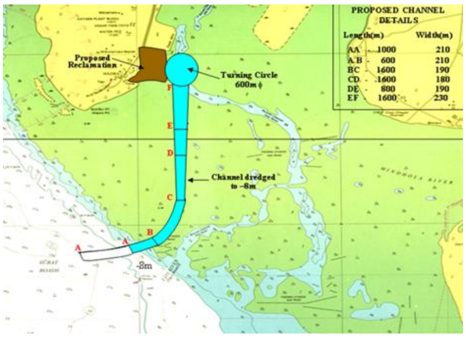
Studies Conducted

Mathematical model studies were undertaken at CWPRS for

- Hydrodynamics and morphological studies to investigate the current pattern, siltation in the channel and likely maintenance dredging in the channel due to the proposed developments.
- Wave propagation studies to enable identification of wave activity in different zones near the jetty and along the approach channel. Further, the wave field generated was used as input for the sediment transport studies and ship navigational studies.
- Ship manoeuvering studies considering stopping distance of ship under the prevailing environmental forces like wind, waves and currents.



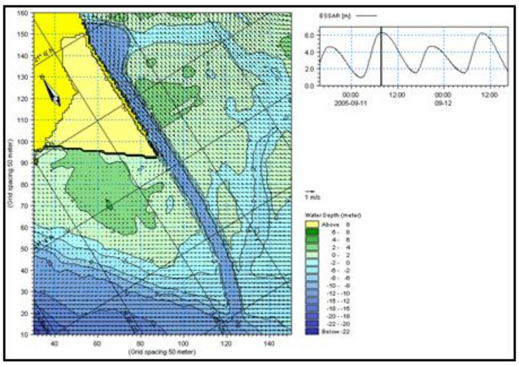
Location Of Essar Jetty



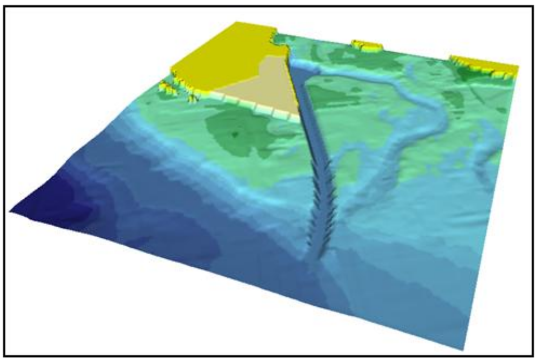
Approach Channel Evolved By Ship Manoeuvering Studies

Outcome and Benefits

- Feasible channel alignment and orientation of the proposed jetty was evolved under the tidal, wave and wind conditions prevailing at the project site.
- Safe manoeuvering of the designed ships
- Prediction of sedimentation for the maintenance dredging of the approach channel.



Flow Field During High Water



3 – Dimensional View of Computational Model

Numerical Model results

3.20 THENGAPATTINAM FISHING HARBOUR, TAMIL NADU

Background

Thengapattinam fishing harbour is located on the west coast of Kanyakumari District and the site is exposed to high wave action of upto 4.5 m height. National Institute of Ocean Technology (NIOT), Chennai suggested the fishing harbour location, alignment and design of the breakwaters. Two breakwaters were proposed for the harbour - North Breakwater 690 m of length and South Breakwater of 200 m length .The harbour was facing siltation and wave penetration, the studies were referred to CWPRS accordingly the modified layout design studies were conducted to achieve the desired wave tranquility in the harbour.

Studies Conducted

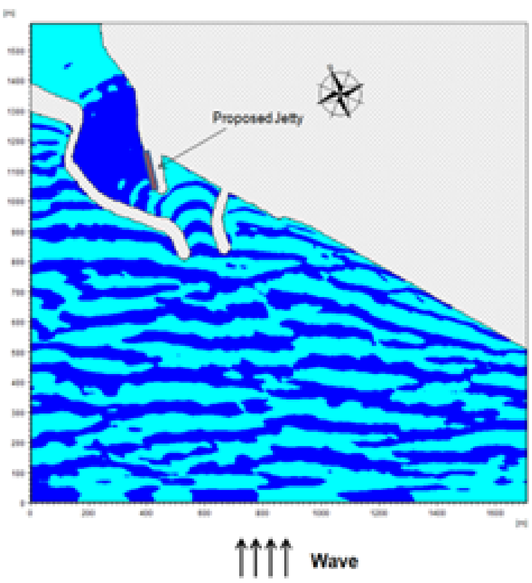
- Assessment of wave tranquility in Thengapattinam fishing harbour using numerical model MIKE 21 SW and BW.
- Design of breakwater sections for stability of breakwater.

Location Of Thengapattinam fishing harbour

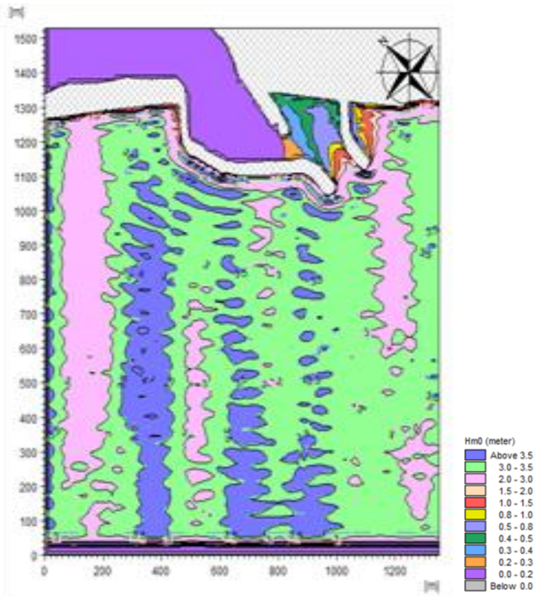
Satellite Image

Outcome and Benefits

- Numerical model studies evolved the harbour layout to provide the necessary wave tranquility for harbour and reduce the siltation in the harbour.
- Physical wave flume studies to obtain the stability of breakwaters.
- Minimum siltation in the harbour
- Harbour operational throughout the year



Wave Propagation



Wave Height Distribution

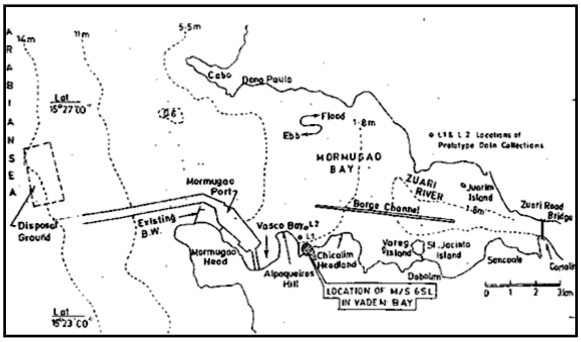
3.21 GOA SHIPYARD LTD. , GOA

Background

The Goa Shipyard Ltd. is located in Vadem bay at about 5.0 km from the entrance of the Zuari estuary on its south bank in Goa. M/s Goa Shipyard Ltd. (GSL), a Govt. of India undertaking under the administrative control of Ministry of Defence, is engaged primarily for the construction and repairs of warships for the Indian Navy and Coast Guard. The Vadem bay has considerable wave protection due to Aplarquerios hill on its west. The present facilities at Goa Shipyard Ltd. include four slipways, one fitting out jetty of size 180 m x 11 m, a basin of approx. size 235 m x 150 m maintained at -4.5 m level below CD and a approach channel of size 40 m width and 300 m length maintained at -3.0 m level. The M/s GSL has undertaken the modernization programme of augmenting the existing infrastructure facilities.

Studies Conducted

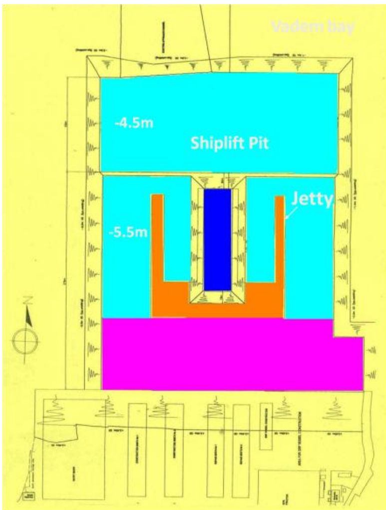
The hydraulic model studies were conducted at CWPRS in the existing tidal model (scales: 1/350 H, 1/50V) in respect of flow conditions at GSL water front area for the proposed Shiplift Pit and other developments.



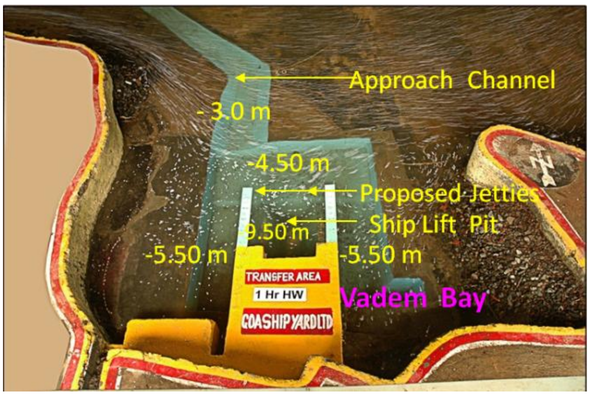
Index Plan of Vadem Bay

Outcome and Benefits

- The tidal model studies indicated that the flow conditions in the Vadem bay are marked by the eddy current patterns during flood and ebb tides. The strengths of currents are weak in the Vadem bay which are maximum 0.13 m/s near the proposed shiplift pit and 0.20 m/s at the north of proposed basin and were not expected to cause any problem in respect of navigation and berthing.
- The average annual depth of siltation in the development area (plan area of about 1,05,000 sqm) would be about 1.5 m most of which would occur during the southwest monsoon season. To maintain the level of proposed Shiplift Pit at -9.5 m on continuous basis, regular cleaning of about 1000 m^3 per month of silt would be required.
- Location of Shiplift Pit in the Vadem bay is suitable from the considerations of flow conditions, siltation, wave tranquility and other hydraulic aspects



Suggested Layout of GSL Facility



Flow Conditions in Model Studies

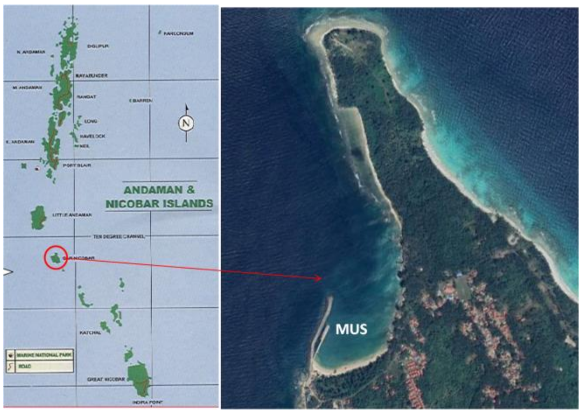
3.22 MUS, CAR NICOBAR

Background

Car Nicobar Island is the northern island in the Nicobar group of Islands situated at a distance of about 240 km from Port Blair. This is a small flat coral island of a squarish shape having a total area of 127 sq. km. This land is strategically important due to its geographical location. To provide landing facilities for the Car Nicobar Island, a harbour has been developed at Mus. The harbour consists of a breakwater of 490 m length and an approach channel of about 150 m width with turning circle of 170 m in diameter. The harbour was developed with an intention to make it an “All Weather Port”. Breakwater was damaged in some portions due to severe wave climate.

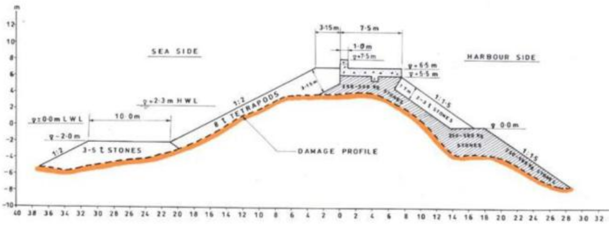
Studies Conducted

- Type of fenders and fender spacing were computed for relative berthing energy.
- The standard version of software OPTIMOOR had been used for ship mooring analysis for ballast as well as fully loaded condition.
- Desk and wave flume studies were conducted to design sections for restoration of damaged breakwater at different chainages.



Location Plan

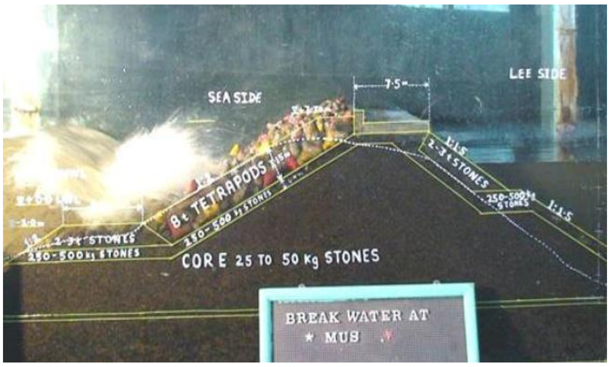
Existing Breakwater and Jetty at Mus Harbour



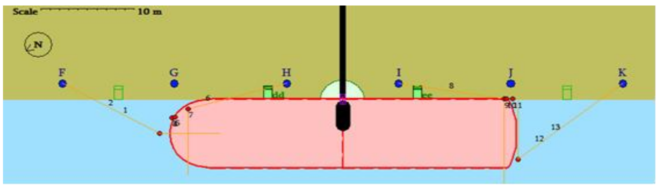
Design of Restoration of Damaged Breakwater

Outcome and Benefits

- Super cone fender i.e. SPC 900H E 0.47 were selected for abnormal berthing energy.
- Ship motion studies indicate that the ship motions and consequent mooring rope tensions, fender deflection and bollard pull are within the safe limits for all normal environmental conditions.
- The damaged trunk portion of the breakwater repaired using the 8 t Tetrapods on 1:2 slope.
- Development of port will benefit passenger as well as goods transport. Such transport facility is essential for Car Nicobar Islands.
- Helpful for development of tourism



Wave Flume



Mooring line Description for Passenger Ship

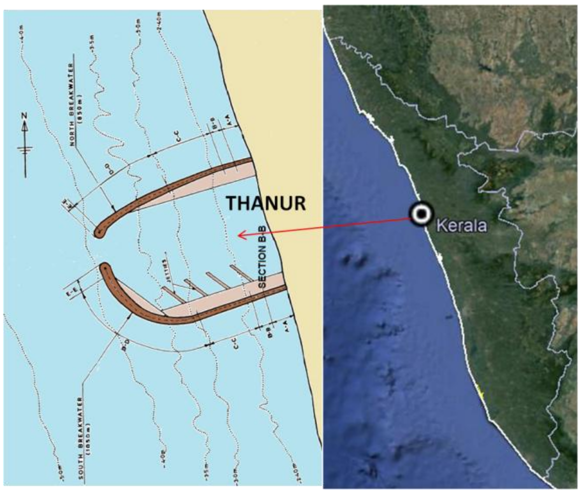
3.23 THANUR FISHERIES HARBOUR, KERALA

Background

Thanur is a small town situated at about 25 km south of Beypore, in Malappuram District of Kerala. Fishing is one of the main sources of livelihood of the people of Thanur. Since, the Thanur is situated on the open coast, the fishermen are facing difficulties in berthing operation. Harbour Engineering Division (HED), Government of Kerala has proposed development of fishery harbour at Thanur.

Studies Conducted

- Mathematical model studies for hydrodynamics and siltation aspects in and around the proposed fisheries harbour were carried out by using MIKE21 HD & MT models with the existing and the proposed conditions.
- Assessments of Wave Tranquility at fisheries harbour using numerical model MIKE 21 SW and BW.
- Design of breakwater sections for stability of breakwater.

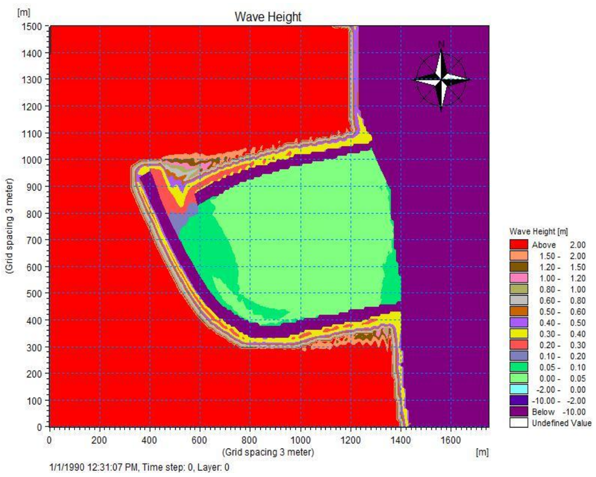


Location Plan with Layout

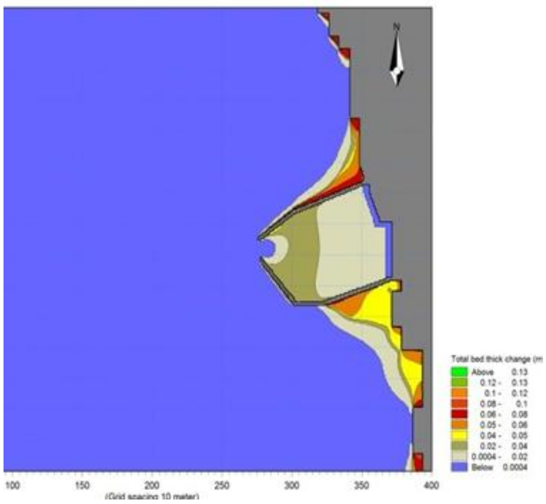
Wave Flume : Testing Breakwater Section

Outcome and Benefits

- A modified layout was evolved extending the partly constructed south and north breakwaters to 1350m and 740 lengths and an entrance width of 120m at mean sea level to facilitate suitable navigation of the fishing crafts. This modified layout would enable full tranquility inside the harbour basin throughout the year.
- Provides better berthing facility throughout the year for fishing boats



Wave Height Distribution In Modified Layout



Sedimentation Pattern in the Proposed Condition

3.24 VELLAYIL FISHERIES HARBOUR, KERALA

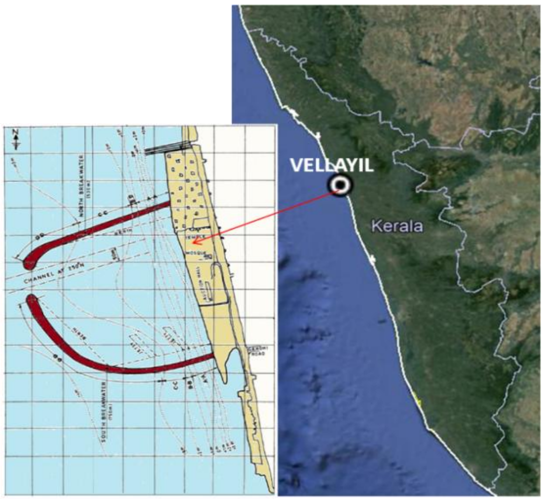
Background

Vellayil is located within the Corporation limits of Calicut in Kozhikode District of Kerala state on the west coast of India. Harbour Engineering Department (HED), Kerala state has a proposal to develop fisheries harbuor at Vellayil. The proposed layout of the harbour consisted of a shore connected North Breakwater of 880 m length and a shore connected South Breakwater of 350 m length.

Studies Conducted

- Mathematical model studies for hydrodynamics and siltation aspects in and around the proposed fisheries harbour at Vellayil were carried out by using MIKE21 HD & MT models with the existing and the proposed conditions.
- Assessments of wave tranquility at Vellayil fisheries harbour using numerical model MIKE 21 SW and BW.
- Design of breakwater cross sections.

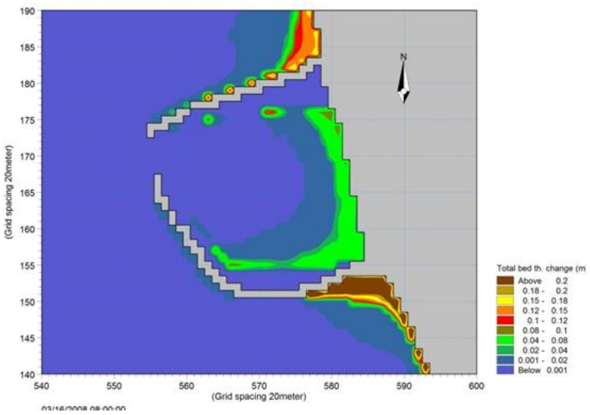
Wave Flume : Testing Breakwater Section



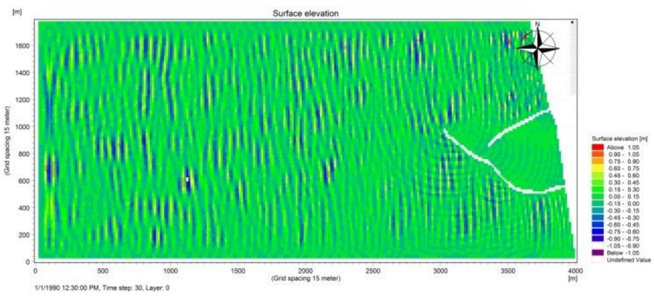
Location Plan with Layout

Outcome and Benefits

- The harbor opening was modified towards northwest direction which is exposed to much lesser wave action in comparison to the earlier westerly opening. It is seen that with modified layout, the entire harbor basin is tranquil throughout the year.
- It is observed that flow field is generally smooth and conducive with Layout – II of the breakwaters without significant circulations. The likely annual maintenance dredging with Layout – II would be of the order of 10 to 15 cm.
- Provides better and additional berthing facility along with safe navigation and shelter throughout the year for fishing boats



Sedimentation Pattern



Surface Elevations

3.25 GREENFIELD SEAPORT AT HALDIPUR, KARNATAKA

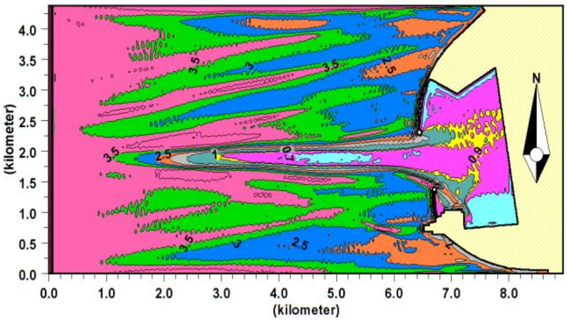
Background

M/s Mineral Enterprises Limited (MEL) proposed development of deep drafted Greenfield Seaport on the west coast of India. In this regard, M/s MEL have initiated feasibility studies for the development of all weather port at Haldipur in Karnataka. The proposal included development of port in two phases: with northern and southern breakwaters.

Studies Conducted

- The mathematical model studies for hydrodynamics and sedimentation were carried out for the proposed development of all weather port at Haldipur in Karnataka.
- The mathematical models MIKE21-HD and MIKE21-MT were used for simulation of hydrodynamics and sedimentation in and around the port area for the proposed development.
- Mathematical model studies conducted for assessment of wave tranquility for the proposed first stage development of all weather port at Haladipur.
- Assessment of shoreline changes due to development of port

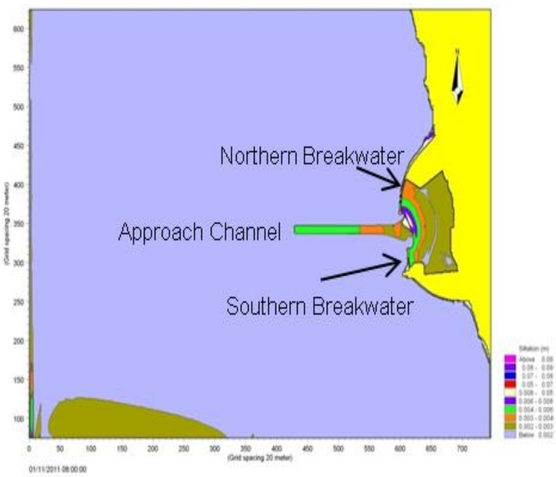
Location Plan



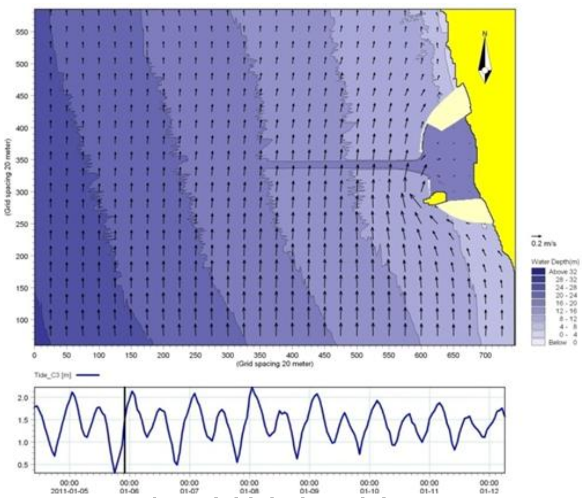
Wave Height Simulation

Outcome and Benefits

- Studies with MIKE 21-BW model indicated that wave heights near the proposed berths will remain within the permissible tranquility limit of 0.6m for about 345 days in a year.
- From the hydrodynamic studies, it is concluded that the flow field is conducive for both the stages of development and without significant circulation
- Sedimentation studies revealed that the maintenance dredging would tend to increase with phase – II development.
- The shoreline changes simulations indicated that due to the construction of the South Breakwater and North Breakwater, accretion would take place on the south of the South Breakwater and coastline north of North Breakwater will be subjected to minor erosion



Sedimentation in the Proposed Condition



Flow Field during High Water

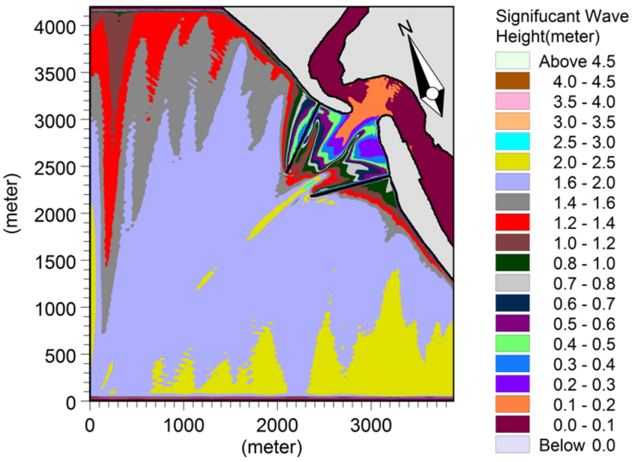
3.26 HONNAVAR FISHERIES HARBOUR, KARNATAKA

Background

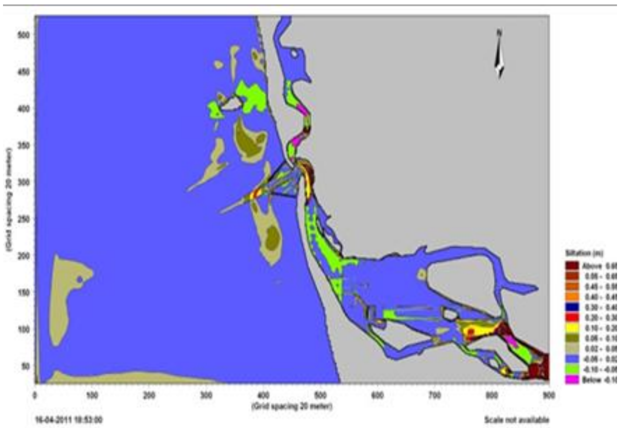
Honnavar Fisheries harbour is located on the west coast of India in Karwar District of Karnataka. The harbour was commissioned in 1986 and was designed for catering to a fleet size of 120 mechanized fishing vessels. The inlet of the harbour got shifted and sandbar has been formed at the entrance of the harbour. The fishermen are facing difficulty in navigating the vessels due to narrow entrance and shallow depths at the mouth. Honnavar Port Private Ltd (HPPL) have a proposal for development of a Port at Honnavar, for providing berthing facilities for coal and iron ore carrying vessels having northern breakwater of 820m length and southern breakwater of 865m length

Studies Conducted

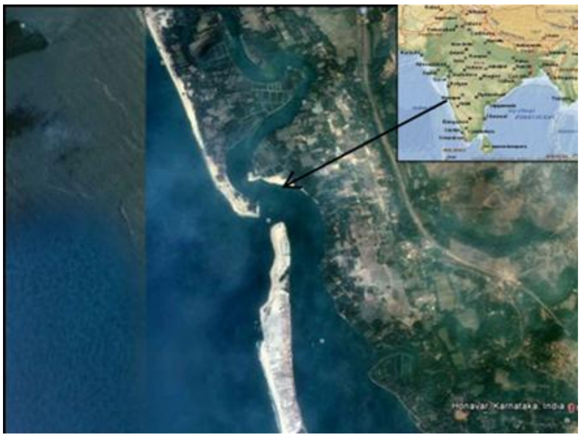
- The mathematical model studies for hydrodynamics and sedimentation were carried out
- Mathematical model studies conducted for assessment of wave tranquility for the proposed development.
- Design of breakwater sections for stability of breakwater.



Wave Height Simulation



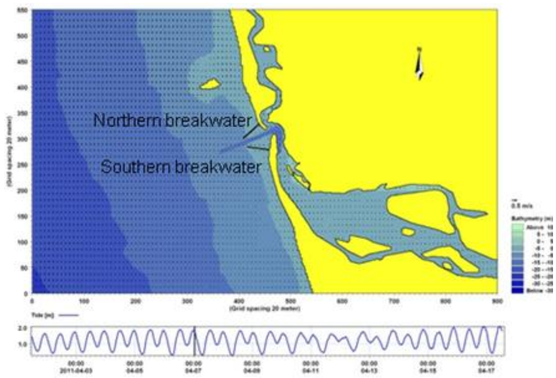
Sedimentation in the Proposed Condition



Location Plan

Outcome and Benefits

- Studies with MIKE 21-BW model indicated that with the proposed breakwater layout, wave heights are in the range 0.1 m to 0.3 m near the proposed berths and are within the permissible limit of 0.6 m. It would be possible to operate these berths safely throughout the year.
- It was found that the flow field is conducive without significant circulation. Hence the port layout is recommended for port development. The annual deposition of sediment is expected, in the approach channel. The maintenance dredging data may be recorded on seasonal basis, which could be further useful for predicting the stabilized annual maintenance dredging for port development.



Flow Field during High Water

3.27 ESSAR JETTY, VADINAR CREEK, GUJARAT

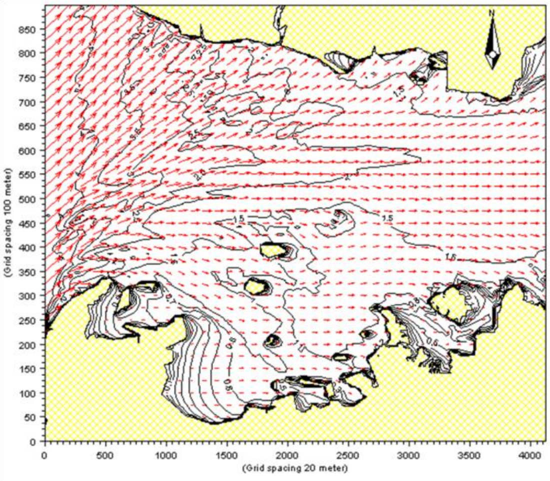
Background

Vadinar Oil Terminal Limited (VOTL) an Essar Group company has established marine facilities at Pathfinder Inlet, Vadinar Port, Jamnagar within the conservancy of Kandla Port Trust (KPT). The refinery is now undergoing expansion from 10.5 MMTPA capacity to 16 MMTPA

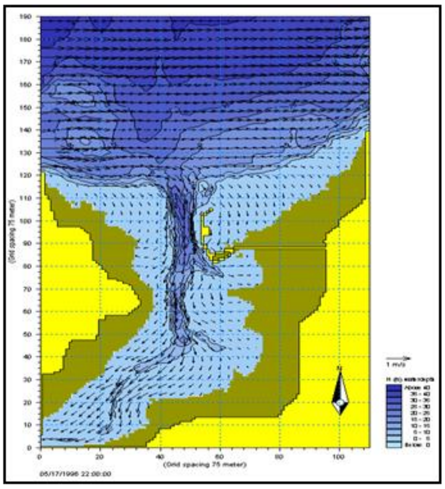
Studies Conducted

- Mathematical model studies for wave propagation were carried out to investigate the wave conditions along the proposed approach channel and at the proposed extension.
- Mathematical model NAVIGA was used for simulation of ship maneuvering along the approach channel.
- Flow simulations with proposed expansion, mathematical model studies for hydrodynamics and sedimentation were carried out.

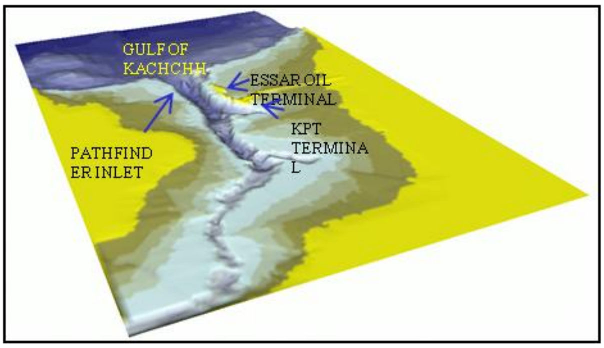
Location Plan



Wave Height Contour and Vector Plot



Tidal Flow Pattern



3-D View Of Vadinar Creek

Outcome and Benefits

- Export of refined products & a SPM buoy offshore for receiving imported crude oil. The total combined capacity of the refineries will eventually be enhanced to 34 MMTPA. Suggested alignment will facilitate in future expansion of berthing facilities.
- There would be no significant wave disturbance at the jetty throughout the year.

Chapter 4

COASTAL EROSION AND PROTECTION

4.1 INTRODUCTION

The coastal erosion is the process of wearing away of the land by the sea due to corrosion, abrasion, hydraulic action, attrition and corrosion/solution. India has long peninsular region and due to development, activities are often carried out without properly understanding the coastal dynamics, leading to long-term damage, particularly to the local communities.

Reason for Coastal Erosion

1. Wave Energy
2. Climate Change
3. Obstruction of Littoral Drift
4. Construction of breakwaters and other structures
5. Construction of dams in catchment areas
6. Sand and coral mining and dredging

Measures to deal with Coastal Erosion

1. Preventing disruption of Littoral Drift
2. Sand bypassing
3. Beach profiling and Sand Dune formation
4. Construction of saline stone-packaging and breakwater structures
5. Construction of low crest walls called groyne
6. Installing Geo-Synthetic Tubes
7. Growing more vegetation along the coastline
8. Encouraging Social Forestry
9. Encouraging conservation activities, educational and recreational opportunities (Eco-development).

In the succeeding paragraphs, the studies/solutions and the innovative methods as provided by the CWPRS for typical sites have been briefly discussed.

4.2 METHODS FOR COASTAL PROTECTION

The causes of coastal erosion are broadly classified as natural and human causes. In order to mitigate the coastal erosion, the coastal protections are broadly classified as soft and hard solutions and also combination of both. Soft solutions are vegetation, beach nourishment, sand bypassing, flood proofing, sand dune formation, zoning, retreat etc., Hard solutions are. Seawall / revetment, groynes, offshore reefs, detached seawalls etc. Innovative methods comprise sand filled Geotextile tubes/containers/bags/mats, Stone filled gabions, artificial reef balls etc.

Coastal protection with seawall is the direct protection method, constructed parallel to the coastline in between the High Tide Level & Low Tide Level. Design of seawall normally evolved for the maximum breaking wave force, which increases with the water depth available at the toe of the seawall. Reefs & groynes are the indirect protection methods to the coastline. Reefs are parallel to the coastline & built away from the coastline in the deeper portion and groynes are built normal to the coastline. Reefs & groynes are provided to trap the sediments in the leeward side, which helps in the formation of the beach. Some of the coastal protection measures implemented successfully at the suggestions of CWPRS at some of the vulnerable sites are shown as below.

Seawall (Mumbai)

Groynes (Cochin)

Offshore Reef

Design of coastal protection structures consist of armour layer with stones or artificial concrete blocks to take the brunt of the wave energy, sub layers with suitable stone sizes for fulfilling the filter criteria & smooth dissipation of wave energy & toe-berm protection for the probable sea-bed scour. The design process involves evolution of conceptual design using empirical methods with various hydraulic parameters such as, wave height, wave period, tidal level, storm surge, sea level rise, beach profile, beach materials etc. The hydraulic stability of the coastal protection measures can be assessed in the wave flumes.

Seawall With Stone Filled Gabions at Tithal

Seawall With Stones at Maravanthe

Seawall With Tetrapods at Dwarka

Seawall at Shriwardhan, Maharashtra

Seawall at Paradeep

Seawall at Lakshadweep Islands

Seawall at INS Dronacharya, Fort Kochi

Seawall at Thiruvananthapuram

Temporary Protection Work at Umbrat, Gujarat

4.3 MARINE DRIVE SEA WALL, MUMBAI

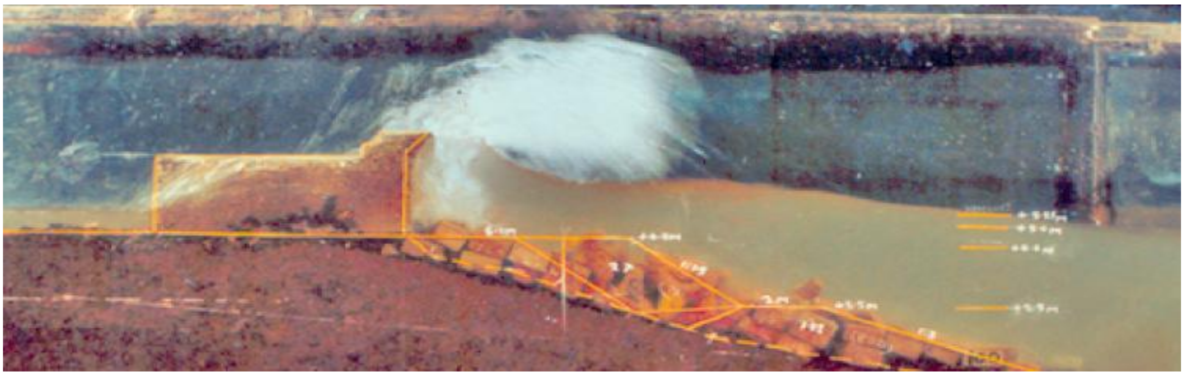
Background

A sea wall from Nariman Point to Chowpatty, Mumbai, was constructed in 1920 as a retaining wall for the reclamation as well as to protect the promonenade and a main road provided on the reclamation. The total length of the sea wall is about 3340 m and was protected by Tetrapods and stones in some reaches during 1960-61. A parapet wall is also provided to avoid overtopping. However, in early 1980's damages were noticed to the rubble protection provided on the sea side of the wall. Furthermore, the splash/spray of sea waves was causing obstruction to the vehicular traffic and the pedestrians during the monsoon. The road surface needed frequent repairs due to pooling of water.

Studies Conducted

- The Govt. of Maharashtra referred the problem to the CWPRS to conduct model studies and to suggest suitable measures for
  - a) Strengthening the existing sea wall from Nariman point to Chowpatty sea face
  - b) Reducing the splash/spray action coming on the roadway due to wave striking the seawall during high water.
- Two-Dimensional hydraulic model studies taken up in a wave flume to recommend remedial measures by providing suitable modifications in the seawall cross-section.
- Data collected like topography of the backbay, bed material, wave climate and tidal levels for deciding the appropriate design of seawall.

Marine Drive Sea Wall



Wave Flume Studies

Outcome and Benefits

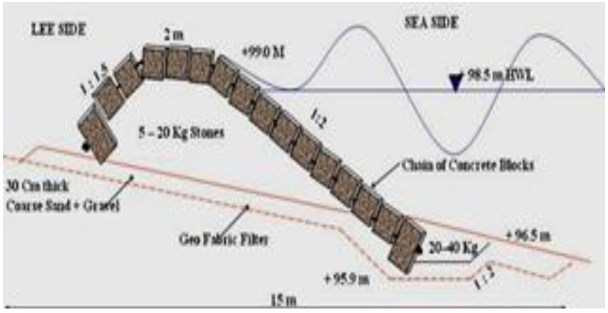
- Strengthening of seawall, armour layer with 2.0 tonne Tetrapods placed in double layer and supported by 800 kg to 1000 kg stones/concrete cubes in the toe.
- The curved parapet with its crest level raised to about +8.5 to +9.0 m to reduce the splashing of water on the road / footpath.
- Footpath level on the lee side was raised upto +7.5m so that view of the sea would not be obstructed.
- The toe berm and the layer of Tetrapods enhanced the stability of the seawall. Furthermore, the dissipative surface of the armour layer and the toe reduced the run-up and thereby the splashing of the waves. Beautification of the marine drive area and the aesthetics of the area for attracting the tourist

4.4 INNOVATIVE TECHNIQUES FOR COASTAL PROTECTION

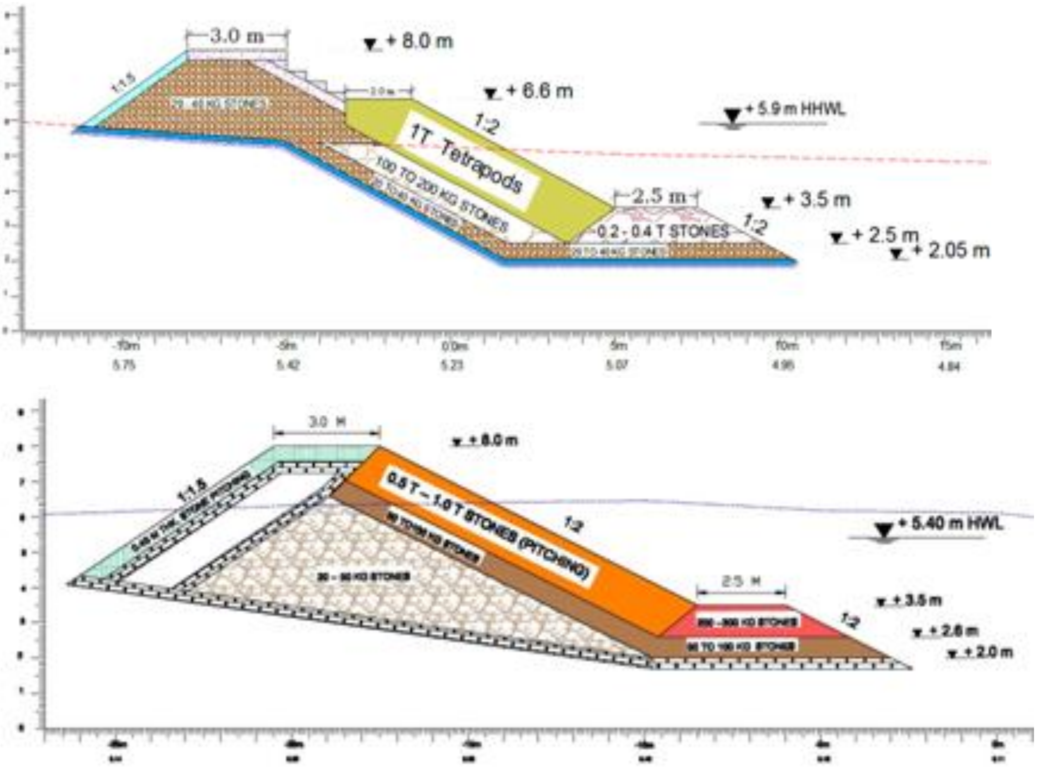
The solution to mitigate the coastal erosion involves widely used hard measures viz. construction of seawalls, groynes, offshore breakwater etc. The materials required for the conventional construction various sizes of stones, Tetrapods, etc. The coastal protections are site specific and require thorough planning of the projects. The designer tends to evolve innovative methods of coastal protection considering the project requirements and constraints of availability of materials, manpower, beach space available for construction, cost of the projects, time required for the construction etc. Few innovative methods have been evolved at CWPRS considering the specific site conditions. Use of chains of concrete blocks, seawall with embedded steps in the armour for tourists beaches, Geo-container/Geo-textile tubes for the protection works, Offshore reefs, steep slope stabilization techniques for estuarine bank etc.

Chains of Concrete Blocks

The Chain of armour blocks were used at Udwada in Valsad District, Gujarat and at Dahanu in Maharashtra.



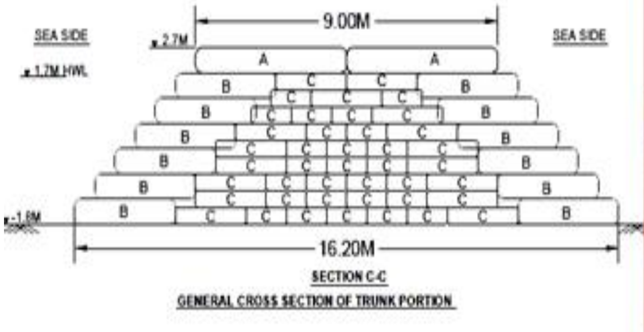
Design of Seawall:



Design of seawall with embedded steps in the armour for the protection of the tourists beaches considering the aesthetics of the site at Kelwa beach, Maharashtra.

Soft Solutions

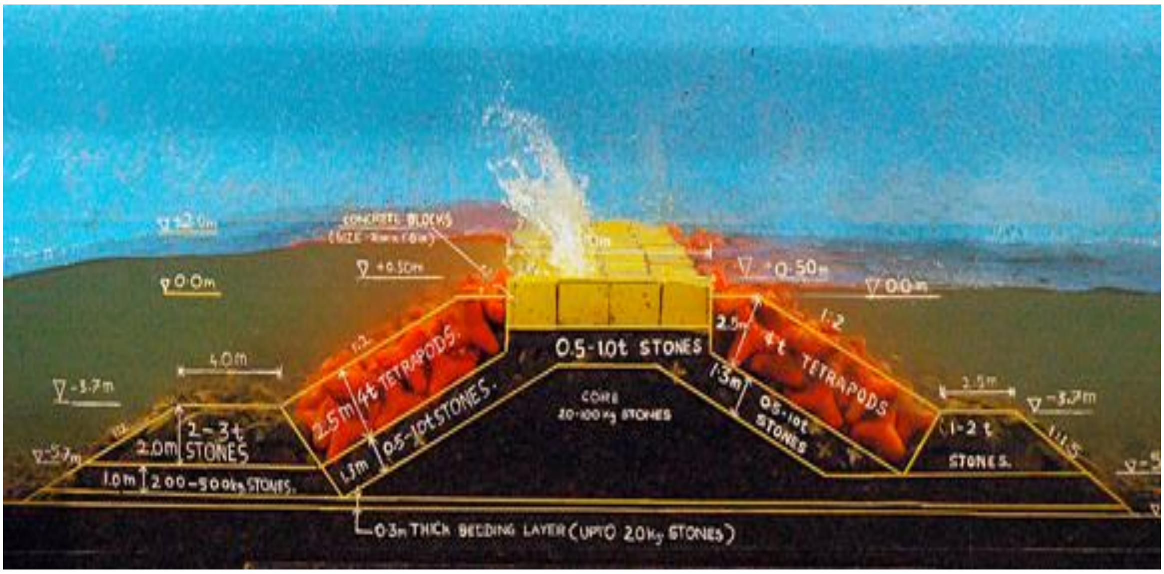
The nearshore berm with Geo-container constructed for the sustainable coastal protection works at Ullal, Mangalore under ADB project.



The groynes field with Geo-textile tubes constructed for the coastal protection works at Deobaug, Maharashtra

Offshore reef

The Offshore submerged reef constructed for the sustainable coastal protection works at Ullal, Mangalore under ADB sub-project.



Chapter 5
MISCELLANEOUS STUDIES

5.1 INTRODUCTION

In this Chapter, the studies for the different projects of Nuclear power projects, coastal urban development, restoration of Chilka Lake for maintenance of coastal ecology, mooring and navigation studies, oil spill studies etc. not covered under the conventional port development studies, have been presented in brief. The typical studies described under this chapter as below relate to the environmental effects of cooling water circulation, disposal and oil spills, protection of mangroves and marine species, coastal flooding etc.

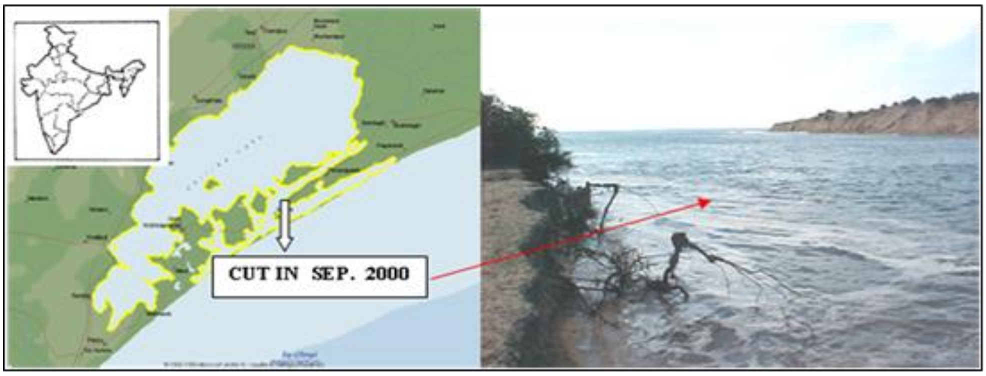
1. Chilka lake, Oddisha
2. Mumbai Trans harbour Link Project, Mumbai
3. Kalpakkam Nuclear Power Project, Tamilnadu
4. North Chennai Thermal Power Station, Tamilnadu
5. Tarapur Atomic Power Station, Maharashtra
6. Trans Thane Creek (TTC) Outfall, Mumbai
7. Cooling Water Jetty, Trombay, Mumbai
8. Studies for Ship manoeuvring using NAVIGA
9. Studies for Ship Mooring using MORMOT
10. Oil Spill Studies for Mormugao Port, Goa
11. Location of Disposal grounds for Mormugao Port, Goa
12. Flood Mitigation of Mithi River, Mumbai
13. Disposal of dredged material off the coast of Mumbai

Tarapur Nuclear Power Plant

5.2 CHILIKA LAKE, ODISHA

Background

Chilika is the largest brackish water lake in India. Despite having vast expanse of water, the lake was getting degraded due to the choking of the lake entrance by the river borne sediment and formation of long sand spit due to littoral drift prevailing in the region. Due to reduced exchange of water between the sea and the lake, the lake was gradually tending to become a fresh water lake affecting the fish yield and biodiversity of the area. Detailed mathematical model studies were carried out at CWPRS for Chilika Development Authority to examine various proposals of improvement like providing a straight cut between the lake and the sea. With these studies, the impact of the straight cut on the improvement of tidal prism as well as salinity flux to the lake were examined



Location Map and Position of Straight Cut Operated in Sep.2000

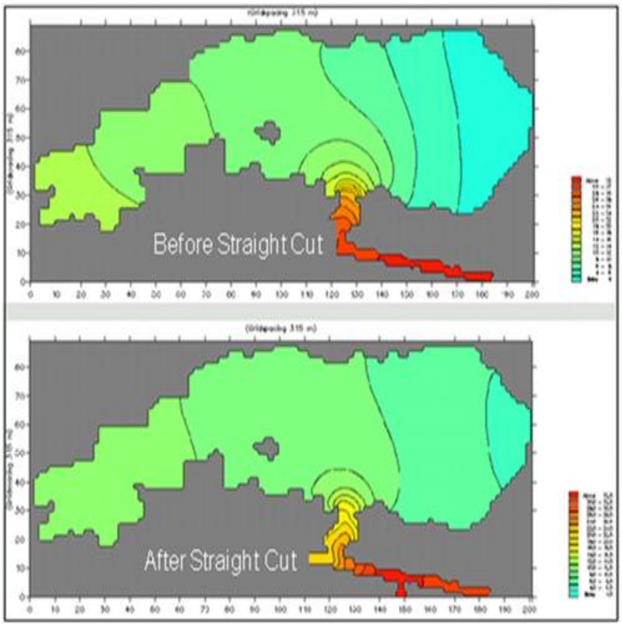
Studies Conducted

- Physical modelling for improvement of flow in the lake.
- Mathematical modelling to identify the location for straight cut and assess its effect.
- Hydrodynamics and salinity flux computation before and after proposed straight cut.
- Impact of Naraj barrage on Chilika Lake.

Benefits and Outcome

Implementation of CWPRS recommendations resulted in

- Salinity increase due to improved tidal exchange.
- Ten times increase in fish catch.
- Retarding shrinkage of lake area.
- Increase in number and varieties of migratory birds.
- Extinction of aquatic weeds.



Salinity Levels In The Lake Before And After The Straight Cut

Migratory Birds in Chilika Lake

5.3 MUMBAI TRANS- HARBOUR LINK (MTHL) PROJECT, MUMBAI

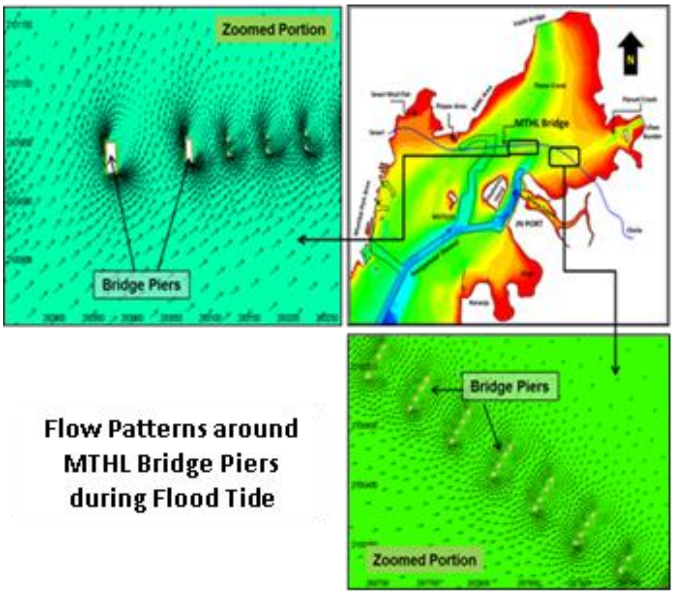
Background

The Mumbai Trans-Harbour Link (MTHL) is a Road Bridge spanning across the Thane creek which connects Sewri on Mumbai and Chirle on Navi Mumbai side. Mumbai, an island city, is facing a problem of traffic congestion over past three decades due to rapid industrialization and scarcity of land for the development of allied infrastructures. Mumbai Metropolitan Region Development Authority (MMRDA) have a proposal to provide a road link between island city and main land (Navi Mumbai) as a direct faster connectivity for the upcoming development in Navi Mumbai Region. The length of MTHL bridge is about 21.8 km and consists of six lanes, each of 3.5 m width. Since MTHL is spanning across Thane creek wherein two major ports viz. Mumbai and Jawaharlal Nehru along with number of waterfront facilities exists, the impact of MTHL on these facilities need to be studied from hydrodynamics consideration.

Studies conducted

- A well-calibrated mathematical model for Thane creek was used to assess the impact of obstructions created due to hundreds of piers/piles of MTHL on the tidal hydrodynamics of Thane creek by simulating pier geometry and prevailing flow field.

Location Plan of MTHL Bridge in Thane Creek



Flow Patterns around MTHL Bridge Piers during Flood Tide

Benefits and Outcome

- CWPRS studies reveal that effect of MTHL on the existing nearby waterfront facilities such as Intake at BARC; BPCL; NSICT berths in JNPT, Marine oil terminal (MOT) at Jawahar Dweep etc. will be negligible except on the facilities at Pir-Pau wherein reduction in velocity is about 10%.
- The overall effect of MTHL on tidal hydrodynamics of Thane creek is insignificant (less than 2% of total tidal flux entering/leaving Thane creek). Hence, it will not have any detrimental effect on the Mumbai/Jawaharlal Nehru Ports.
- Overall hydrodynamics of Thane creek remain unaltered thereby it not only allows construction of MTHL but will also maintain smooth operability at Mumbai/ Jawaharlal Nehru ports.
- The plying of barges in and out of Thane creek will remain unaffected due to construction of MTHL.
- MTHL will not impose additional burden of maintenance dredging on waterfront facilities in the creek.

5.4 KALPAKKAM NUCLEAR POWER PROJECT, TAMILNADU

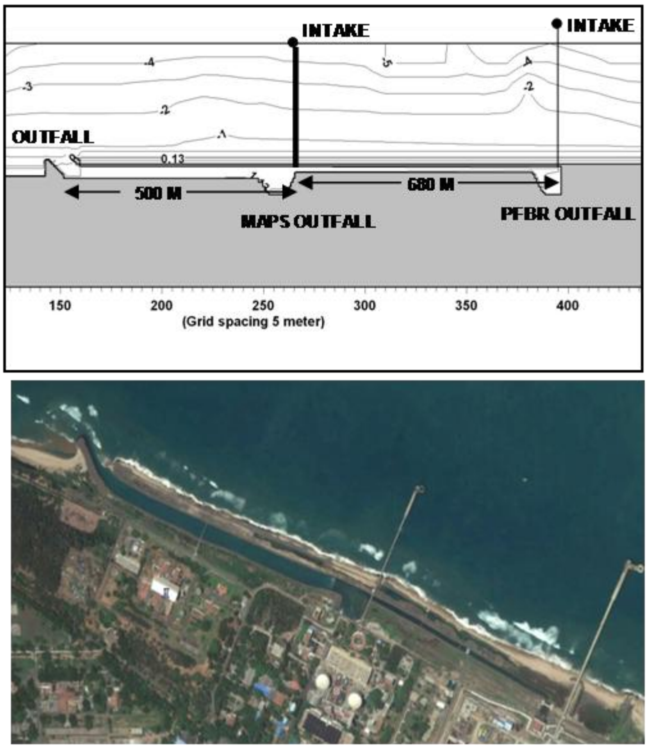
Background

Kalpakkam is located on the east coast about 70 km south of Chennai in Tamil Nadu State. The Madras Atomic Power Station (MAPS) having two units of 220 MW was established in 1983-85 by Nuclear Power Corporation of India Ltd (NPCIL). MAPS is operating on once-through cooling water system for which the cooling water (i.e. about 35 m^3/s) required for the power station is drawn from the sea through an intake well which is located at 360 m from seashore and connected to the forebay of the pump house by a submarine tunnel. Department of Atomic Energy has proposed to establish a Fast Breeder Reactor Project (PFBR) of 500 MW capacity at a location 500 m south of MAPS.

Studies conducted

- Field data collection and analysis for Condenser Cooling Water System (CCWS) of PFBR,
- Mathematical model studies for location of intake/outfall for 500 MWe Prototype Fast Breeder Reactor using Numerical Model MIKE 21
- Wave Flume studies for the design of outfall guide bund and shore protection works
- Mathematical model studies for littoral drift and thermal recirculation using Numerical Model LITPACK.

Location Map and Intakes



Recommended layout and implemented in field

Outcome and Benefits

- Field studies provided the data useful for physical as well as mathematical model studies.
- Numerical Model studies evolved the location of intakes to avoid recirculation of warm water.
- Wave Flume studies accorded the criteria for design of outfall guide wall and shore protection works Location map of Kalpakkam NPP.
- Littoral drift studies confirmed the advancement of coastline and its effect on nearby shoreline.
- Allowable recirculation to intakes
- Power plant is operational to its capacity, commercial power generation yet to start.
- Outfall channel is working properly Recommended layout and implemented in field.
- Shoreline advancement is limited.

5.5 NORTH CHENNAI THERMAL POWER STATION, TAMIL NADU

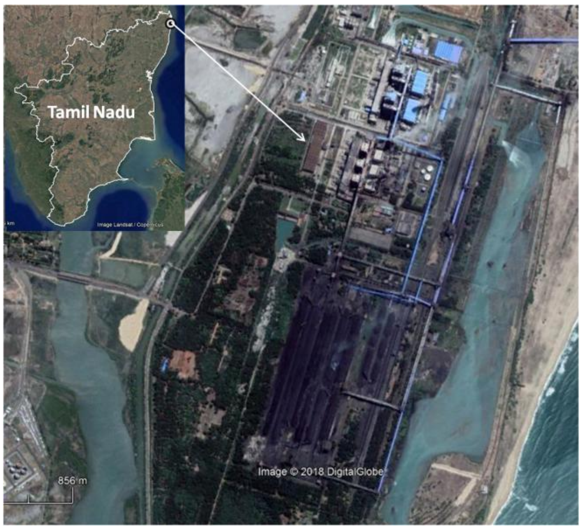
Background

Tamil Nadu Electricity Board established 630MWe (Phase-I) Power Station at 20 km North of Chennai called North Chennai Thermal Power Station in 1994. It is operating on once through cooling water system with intake located at the Ennore creek and Outfall at about 2km North of the creek mouth. Cooling water requirement of 27.5 cumecs drawn through intake channel from the creek and warm water from condensers was let out to sea through surface discharge System. However, due to frequent choking of creek mouth, Power Station was experiencing an acute shortage of the requisite coolant water. The advancement of the shoreline due to construction of southern breakwater of the Ennore Port, made the warm water outfall land locked and lots of difficulties were experienced in letting out the warm water discharge to sea.

Studies Conducted

More than 10 studies have been conducted covering the following important aspects:

- Field data collection and analysis for identification of problem and calibration of model.
- Analysis of meteorological data to determine daily and annual cycle of rate of heat-loss.
- Mathematical model for examining tidal propagation and siltation in the creek system.
- Thermal model studies to determine suitable location of intake and outfall structure for better functioning of power station and satisfy thermal stipulations of EPA, 1986.
- Studies to improve and optimize the warm water discharge system including studies for pre-cooling channel.



Location Of Chennai Thermal Power Station

Physical Model

Outcome and Benefits

- A vertically exaggerated model was constructed. The arrangement of heater system was made to reproduce hot water discharge in the model.
- Proposal of locating intake in the port basin and outfall near the creek mouth was the most suitable solution for the problem.
- A pre-cooling channel was proposed to bring down the warm water temperature rise to within the acceptable limit prescribed by the MoEF before being discharged in to the creek system.
- After incorporating suggested measures, North Chennai Thermal Power Station and also adjacent Ennore Thermal Power Station started running to full capacity.
- Pre-cooling channel technique was evolved and implemented to reduce the temperature of condenser discharge to satisfy thermal stipulations of EPA, 1986.

5.5 TARAPUR ATOMIC POWER STATION, MAHARASHTRA

Background

Tarapur Atomic Power Station is located about 140 km North of Mumbai in Palghar district of Maharashtra. This Power Station is situated on the sea shore and comprises of four units. Initially, unit 1&2 were established in 1969 with an initial generating capacity of 210 Mwe each. Subsequently, Nuclear Power Corporation of India Ltd. (NPCIL) has established two more units i.e. unit 3&4 in 2005 and 2006 respectively with a generating capacity of 540 Mwe each at a distance of about 700 m south side of the units 1&2. The cooling water requirement is drawn from the sea through an intake channel and the warm water from the condensers is discharged back into the sea through an outfall channel. Selection of location of cooling water Intake and Outfall is important at the design stage of any power plant. The locations should be selected in such a way that there should not be any recirculation of warm water discharge. The locations shall be identified by conducting Thermal dispersion studies.

Studies Conducted

- Field data collection and analysis
- Studies for Safe grade elevation
- Analysis of meteorological data
- Physical & Numerical Model studies for Hot water recirculation
- Wave resonance studies for intake and fore bay chambers of pump house
- Assessment of adequacy of Intake channels

Location Of Power Plant

Physical Model for Locating Cooling Water Intake and Outfall for the Unit 3 & 4

Outcome and Benefits

- The intake and outfall structures were designed in such a way that, no warm water recirculation takes place while both the power stations are operating to their full capacity, simultaneously.
- The Power Stations are getting their desired quantum of Cooling water and working satisfactorily.

5.6 TRANS THANE CREEK (TTC) OUTFALL, MUMBAI

Background

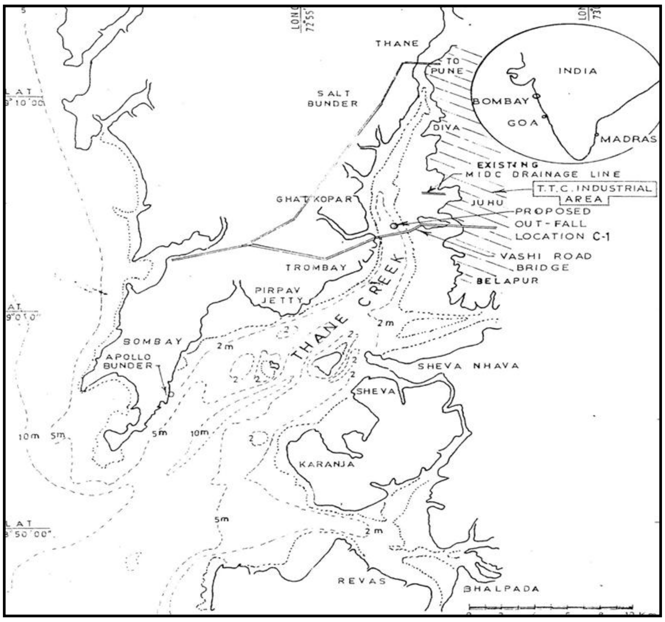
On the east bank of Thane creek in New Mumbai, an industrial area was under development which mainly consisted of chemical plants. Maharashtra Industrial Development Corporation (MIDC) was entrusted with the task of developing infrastructural facilities for the industrial development. The effluents of the industries were proposed to be disposed in the Thane creek. The existing location of outfall located in very shallow depths at about 3.2 km north of Vashi Bridge on the east bank, was not suitable due to inadequate depths available required for mixing of the effluents.

Studies Conducted

- 2-D mathematical model studies were carried out to indentify the disposal location in the Thane creek
- For designing the suitable diffuser for attaining the designed dilution characteristics in near field, hydraulic model studies were conducted at CWPRS in a model tray (G.S.1/20) and Rhodamine 'B' dye was used as tracer for estimating dilution performance.

Outcome and Benefits

- Disposal location was located in the Thane creek at 0.9 km north of Vashi bridge at 2.4 - 2.8 m depths below the Chart Datum. It was recommend that before disposing of the effluents in the Thane Creek, the effluents had undergone treatment at Common Effluent Treatment Plant
- The alignment of the diffuser was modified and suggested to be laid normal to the flow direction to attain maximum dilution.
- As per the requirement of State Pollution Control Board, the BOD/COD concentration of the effluent reduced to 5 ppm within 100 m of the diffuser.



Index Plan of Vadem Bay

Satellite Image

5.7 COOLING WATER JETTY, TROMBAY, MUMBAI

Background

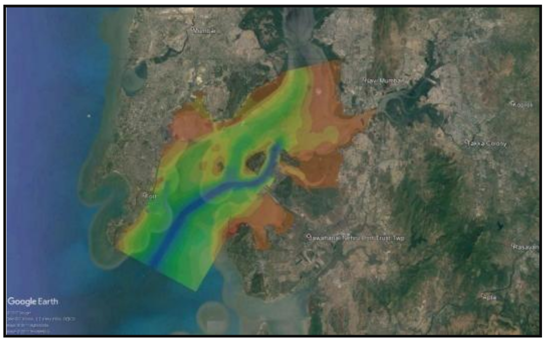
Tata Power Company has been operating their thermal power plant at Trombay, Maharashtra since 1956. The first unit of 62.5 MW generating capacity was installed for supply of power to Mumbai city. Later, a number of units were added to the system. The present generating capacity of the Trombay Thermal Power Station is 1430 MW. All the units of a power plant are operating on 'once-through' cooling system. The cooling water required for the power plant is being drawn from Thane Creek through pumps. The warm water from all the units is being discharged back to the Thane Creek through a pre-cooling channel. The water depths near the intake are shallow and as a result lot of mud/ sand also enters the pump chamber along with water affecting performance of sea water handling machinery and thus increasing the maintenance cost. It is proposed to relocate the cooling water intake further deep into the sea

Studies Conducted

- Hydrodynamics and siltation studies for the proposed new location of the cooling water intake.
- To study the effect of the proposed new intake on the other facilities in the near vicinity.
- Field investigations for extension of cooling water system.
- Hot water recirculation studies for cooling water system.
- Model studies for cooling water discharge channel.
- Physical model studies for evaluation of quantity of water re-circulated through CW system.
- Assessment of performance of cooling water channel.

Physical Model

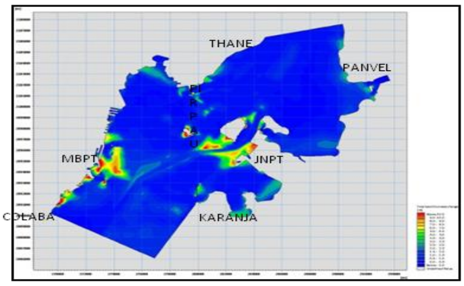
Physical Model of Pre-Cooling Channel



Location Plan

Outcome and Benefits

- The model for the existing conditions predicts an annual silt deposition rate of 3.9 m in front of CW Jetty.
- In the proposed conditions, the siltation near the cooling water jetty is found to have been increased from 4.0 m/annum to 6.5 m/ annum. However, once the bed level regains its original regime, the siltation rate is expected to stabilize.
- Based on results of the model studies the intake and outfall structures were designed in such a way that, no warm water recirculation takes place.
- A pre-cooling channel was proposed to bring down the warm water temperature rise to within the acceptable limit prescribed by the MoEF before being discharged in to the creek system.



Sedimentation in the Proposed Condition

5.8 STUDIES FOR SHIP MANOEUVERING USING NAVIGA

Description

Simulates approach and departure maneuver with the help of a mathematical auto-pilot in a waterway under the action of wind, waves & currents

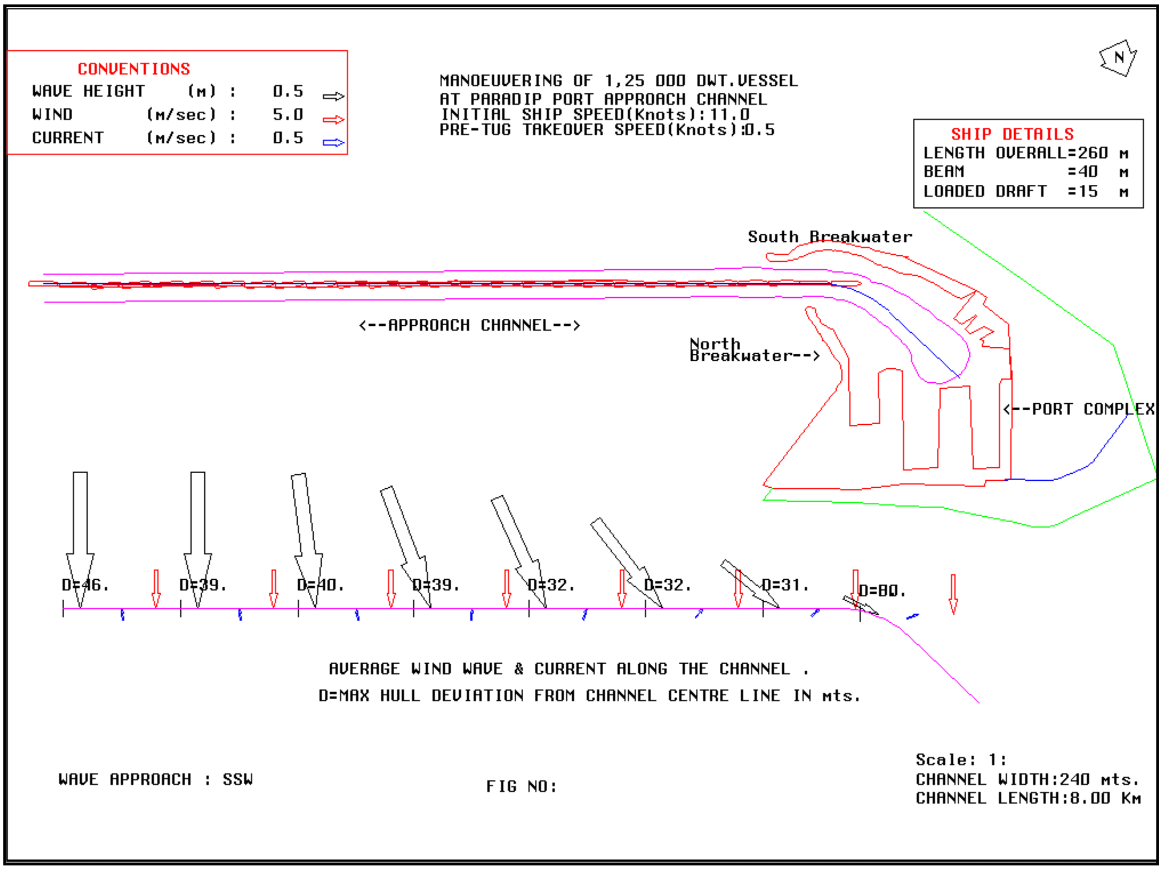
Applications

- Optimization of approach channel width
- Determination of best alignment of channel
- Ascertaining the navigability of channel
- Identification of limiting climatic conditions for safe manoeuvering
- Determination of safe manoeuvering speed

Studies Conducted

Manoeuvering studies : Car carriers at JNPT; passenger ship to direct landing facility at Kavarathi; general cargo ships at Pondicherry and Cuddalore; LPG carriers for port of Hazira; bulk carriers at M/s Sanghi Cements, Gujarat; ore carriers at Mirya bay, Ratnagiri; container ships in JNPT channel for entry point modification.

Adequacy of approach channel : Cochin port for 125000 cum LNG tankers; Paradip port; Baina bay, Goa; Ennore port.



Manoeuvering of Ore Carrier at Paradip Port

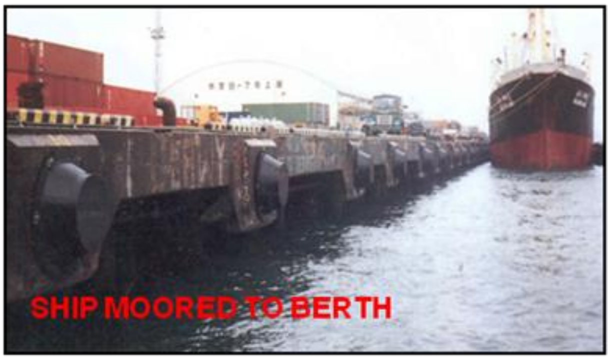
5.9 STUDIES FOR SHIP MOORING USING MORMOT

Description

A computer simulation software to predict the motions of a moored ship, consequent mooring rope tensions and fender deflections under the action of wind, waves & currents

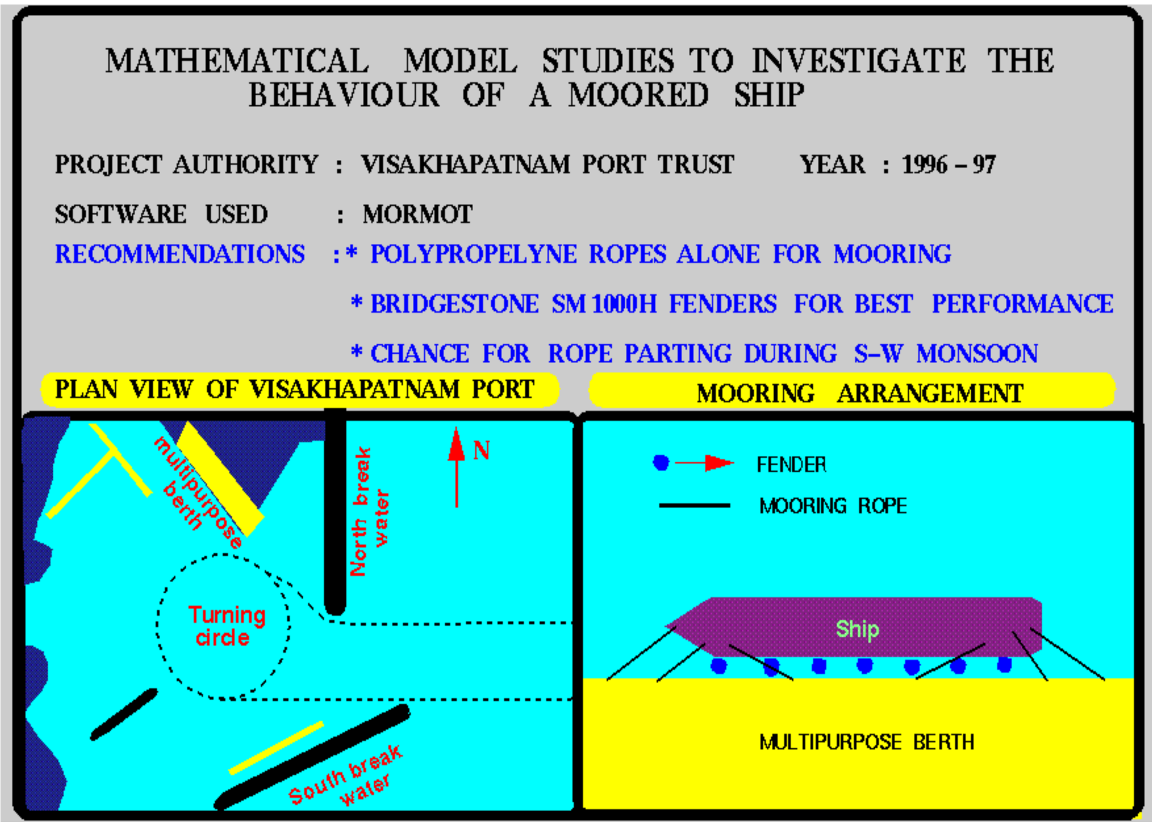
Applications

- Prediction of surge, sway, yaw, pitch, heave & roll of a moored ship
- Computation of mooring line tensions
- Identification of best mooring configuration
- Determination of fender deflections
- Optimization of berth alignment for reduction of downtime at berth



Studies Conducted

Moored ship studies for multipurpose berth, LPG berth and general cargo berth at Visakhapatnam port; bulk cargo berth, JNPT; Bharati dock, Chennai port; bulk berth, Muldwarka, Gujarat; oil berth , Suvali, Gujarat; container berths, and north cargo berth, Tuticorin port; chemical jetty for GCPTCL and IPCL jetty, Dahej; ore berth, Mirya bay, Ratnagiri; Pir Pau jetty, Gujarat.



Moored Ship Studies at Multipurpose Berth, Visakhapatnam Port

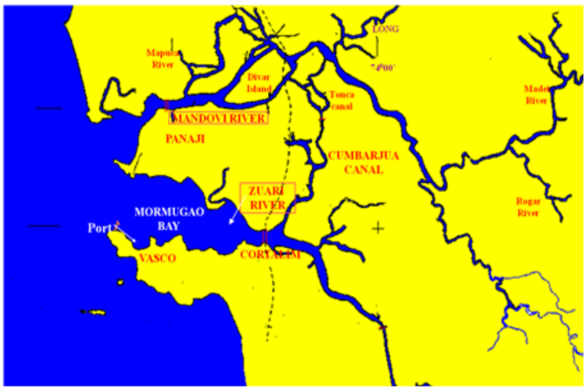
5.10 OIL SPILL STUDIES AT MORMUGAO PORT, GOA

Background

Oil spill poses a severe and ongoing threat to marine ecosystem and the invertebrate. Over 100 million Metric Tons of oil is transported by sea per day and more than 1.3 million metric tons of petroleum enters the ocean each year. When an oil spill occurs, the damage depends upon its location and prevailing weather condition. The major cause of sea pollution is oil spill due to the oil vessel collision and leakages resulting in heavy loss to living and non-living things in the sea. The accidents may occur due to human error and leakage could be due to mechanical faults in the pipes or containers. Detection and tracking of oil is essential to determine the required mitigation measures. The oil spread does not only depend on the quantity of spill but also on the location and prevailing environmental conditions. Thus, an extensive study is required to simulate oil spill under various environmental conditions at different locations. In recent times, many accidents are reported on west coast of India causing huge loss to environment.

Studies Conducted

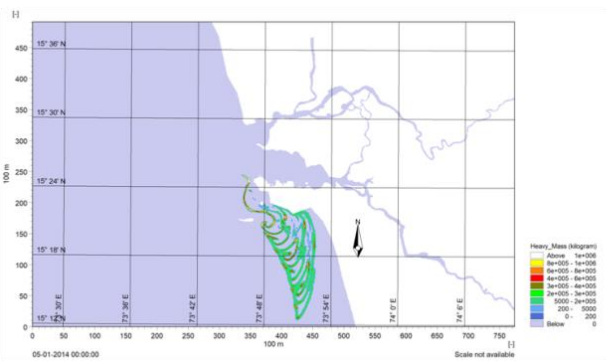
- Oil spill studies were carried out at CWPRS using numerical model MIKE-21 OS to simulate the various scenarios near Mormugao Port under various environmental conditions so that proper measures can be taken up in case of any mishap.



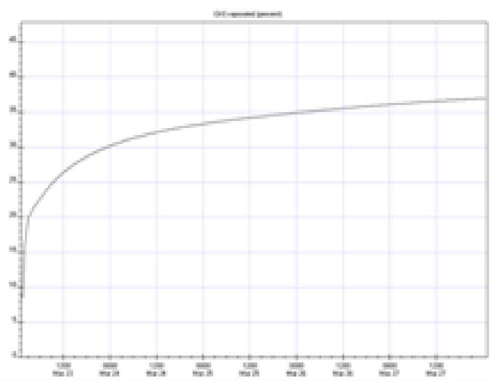
Satellite Image Of Mormugao Port Region

Outcome and Benefits

- The currents in the vicinity of Mormugao Port are of the order of 0.3 m/s and flow is unidirectional for most of the period.
- Within 12 hrs of oil spill, about 27% of oil gets evaporated while in next 12 hrs the evaporation would be of the order of 3 %.
- It was also observed that 37% Heavy Fuel Oil (HFO) evaporates during period of 5 days.
- The studies show that about 65% water in oil emulsion takes place in 24 hrs which goes upto 90% in 3 days.
- Oil spill in the harbour region would have minimum environmental impact on the other hand spill in the approach channel would cause server impact on coastline adjacent islands.
- These studies would help in taking appropriate measures to control the spread of oil in case of any mishap.
- This will help in minimising the heavy loss to living and non-living things in the sea.



Track of Volatile Mass after 4 Days of Spill



Oil Evaporation

5.11 LOCATION OF DISPOSAL GROUND FOR MORMUGAO PORT, GOA

Background

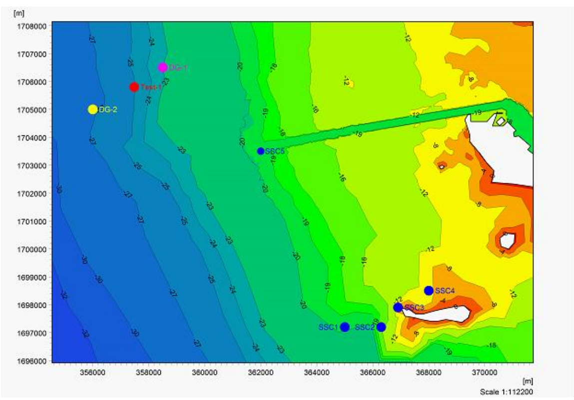
Identification of location for dumping dredged material is a very essential for any maritime development. The dredged material dumping grounds are identified to avoid recirculation of sediment, minimal impact on coastline and environmental conditions. Crossing of this sediment plume through the dredged portions will cause loss of depth in the area which should be avoided in any case. Apart from this, if the plume interacts with any island, it may have an adverse impact on flora-fauna present at the island. It was proposed to deepen the existing approach channel and port area from existing -14.4m to -19.8 m at Mormugao Port, Goa. The existing annual maintenance dredging of 3.0 Million m^3 was being dumped at -14.2m depth contour north of existing channel. The channel length would increase by 3.5 km after deepening the channel. The total capital dredging with deepening of channel was estimated to be 14 Million cum while maintenance dredging was estimated to be 6 Million m^3.

Studies Conducted

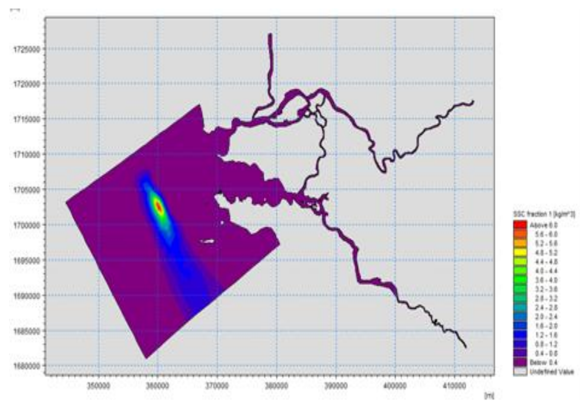
Mathematical model Studies were carried out to identify new location for dumping the dredged material from capital and maintenance dredging for the proposal of deepening of approach channel at Mormugao port to cater to bigger vessels. The studies were conducted to track the dredged plume for northerly and southerly tidal currents for a quantity of about 0.1 Million cum per trip.

Outcome and Benefits

- The location (UTM 356000 E and 1705000 N) at (-) 27 m depth contour is recommended for the dumping 60% of capital dredging while maintenance dredging of 6 Million m^3 and 40% of capital dredging can be dumped at -24m depth contour.
- The second location was optimized at -24m considering sediment concentrations at Grandy island. The MIKE-AD model was simulated for both dumping grounds.
- The dumping ground at -24m was more sensitive compared to dumping at -27m contour.
- The dredged plume tracks were studied for a period of one month. The results of dumping location at -24m indicated that there would not be any change in suspended sediment concentration in the periphery of 500m around Grandy Island.
- It was also established that in no case sediment plume will reach to the coast as the flow is almost parallel to coastline. It was also seen that sediment concentrations of the sediment plume keeps on reducing as it moves forward.



Dumping Ground Locations and Suspended Sediment Concentration Monitoring Points

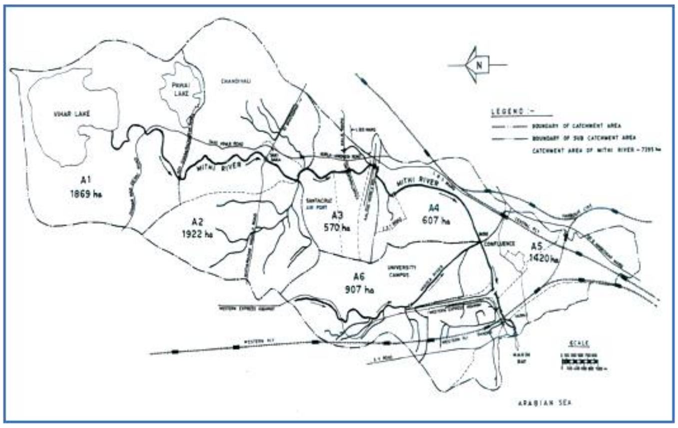


Suspended Sediment concentration Plume for Dumping ground at -27m depth contour

5.12 FLOOD MITIGATION OF MITHI RIVER, MUMBAI

Background

The Mithi River originates in the hills east of the Sanjay Gandhi National Park. It carries the overflow discharge from Tulsi-Vihar-Powai Lake system and runoff from its catchments. The river is of short length of 17.922 km, which flows from its origin at Vihar Lake and join the Arabian sea near the Mahim Bay. The tidal reach of the river is about 7 km from Mahim Bay upto Air India complex. The total catchment area of Mithi River basin is 7295 ha which also includes the 907 ha area of the major tributary, the Vakola Nalla system and 70 ha of Mahim bay.



Catchment Area of Mithi River Basin

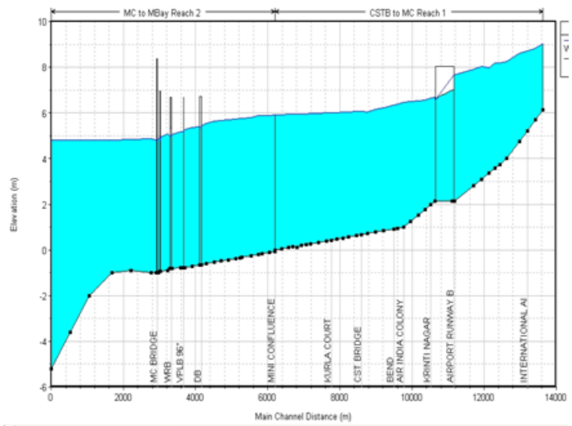
Studies Conducted

- After the deluge of 26th July 2005, the Mumbai Metropolitan Region Development Authority (MMRDA) reviewed various options for avoiding the recurrence of the floods in the Mithi River.
- CWPRS carried out 1-D mathematical model studies and recommended channelisation of the Mithi River by providing adequate depths and widths in various reaches of the River, including increasing the water way under various bridges.

Outcome and Benefits

- The work of channelization, to the extant possible, is in progress and the widening of old bridges and construction of new bridges is also being planned.
- CWPRS has also taken up the work of construction of a physical model of the Mithi River including construction of a hangar (80 m x 26.50 m) in which the entire length of Mithi River including the portion of Arabian Sea and Mahim Bay were reproduced.

Physical Model



Numerical Model result

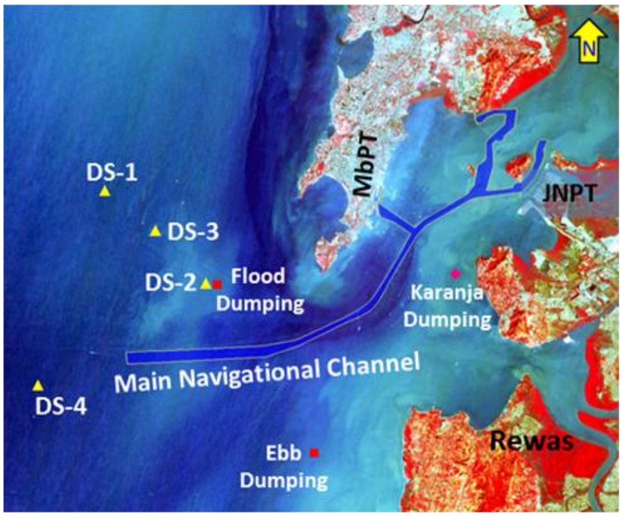
5.13 DISPOSAL OF DREDGED MATERIAL OFF THE COAST OF MUMBAI

Background

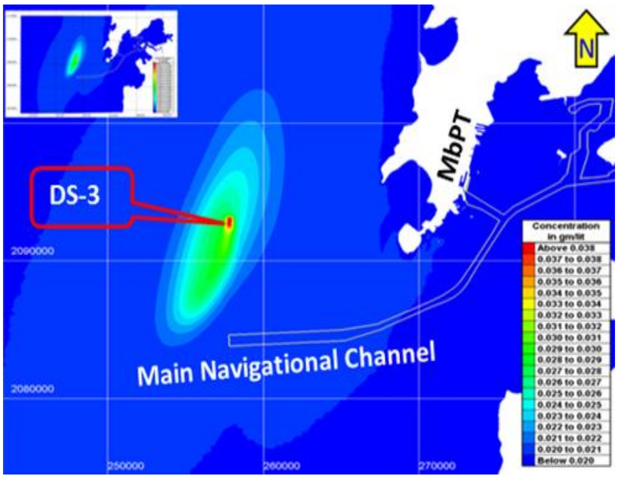
Mumbai being on the lee-side of Salsette Island and JN being well inside from wide entrance to the harbour, tidal phenomenon and associated siltation, governs the hydraulic design of waterfront structures rather than waves. The type of sediment in region being silty clay/clay, it is of cohesive nature. The ships docking in Mumbai harbour during pre-independence era. were navigating during high tides only (tidal range of 5 m) owing to less draft and material getting silted at berth pockets was dredged and dumped near Karanja dumping site on opposite coast of Mumbai port. After independence based on various field and physical model studies carried out by CWPRS (1958), alignment of main navigational channels and its hydraulic design (cross section) was recommended and dredged. The material dredged during capital/maintenance dredging (clay/silt) could not be used for reclamation owing its cohesive nature and needs to be disposed off in to the sea. The location of flood and ebb dumping sites were recommended based on field investigation (dispersion) and model studies carried out by CWPRS. After the development of JN port, siltation is increased due to increase in channel length/berths and dredging is carried out by grab/TSHD dredgers at berths and navigational channels respectively. After several decades, existing dumping grounds used are no more capable of accommodating dredged material (about 80 million cum) resulted due to deepening of main channel from 10.8 m to 14 m below (channel length of about 33 km) CD in phase-I and up to 16 m in phase-II. Model studies were conducted at CWPRS to identify new safe and suitable dumping locations in deeper sea.

Studies Conducted

- The field studies on various Oceanographic parameters viz. currents, Tides, float track observations, dye dispersion, suspended sediment concentration etc. were conducted for finalising flood / ebb dumping sites.
- The well-calibrated mathematical model of Mumbai was used to identify dumping locations for safe disposal of dredged material resulted during capital/ maintenance dredging of main channel in two phases (I & II) in association with field investigations and dumping at DS-3 was suggested after studying DS-1, DS-2, DS-3 and DS-4 sites



Locations of Dumping Grounds Off Mumbai Coast



Spread of Dredged material in model during Disposal

Outcome and Benefits

- The studies conducted reveal that the identified locations are such that the dredged material dumped at these locations during those development periods does not enter in to the navigational channel as well as it does not reach waterfront facilities/ beaches of Mumbai region. With increase in quantum of dredged material for dredging in phases, new dumping locations identified especially DS-3 is safe for the disposal of dredged material which can accommodate about 100 Million cum.

5.14 LIST OF STUDIES CONDUCTED AT CWPRS FOR PORT DEVELOPMENT

Major Ports

Project (Period of Studies)	Wave Tranquility	Tidal Hydrodynamics & Siltation	Stability of Coastal Hydraulic Structures	Dredging & Disposal	Littoral Drift & Shoreline Changes	Ship Motion & Maneuvering	Field Data Collection & Analysis	Coastal Protection Works	Hindcasting & Storm Surge Analysis
East Coast									
Chennai (TN) (1975-2012)	*		*	*		*	*	*	*
Ennore (TN) (1983-2012)	*	*	*	*	*	*		*	*
Kolkata - Haldia (WB) (1954-2012)	*	*	*	*		*	*	*	
Paradip (Orissa) (1963-2012)	*	*	*	*	*	*	*	*	*
Tuticorin (TN) (1964-2003)	*		*	*		*	*		*
Visakhapatnam (AP) (1967-2012)	*	*	*	*	*	*	*	*	*
East Coast									
Chennai (TN) (1975-2012)	*		*	*		*	*	*	*
Ennore (TN) (1983-2012)	*	*	*	*	*	*		*	*
Kolkata - Haldia (WB) (1954-2012)	*	*	*	*		*	*	*	
Paradip (Orissa) (1963-2012)	*	*	*	*	*	*	*	*	*
Tuticorin (TN) (1964-2003)	*		*	*		*	*		*
Visakhapatnam (AP) (1967-2012)	*	*	*	*	*	*	*	*	*

Minor Ports

Project (Period of Studies)	Wave Tranquility	Tidal Hydrodynamics & Siltation	Stability of Coastal Hydraulic Structures	Dredging & Disposal	Littoral Drift & Shoreline Changes	Ship Motion & Maneuvering	Field Data Collection & Analysis	Coastal Protection Works	Hindcasting & Storm Surge Analysis
Gujarat									
Alang(2001)							*	*	
Dahej-Gogha(1993-1996)						*	*		
Hazira(1980-2012)		*	*	*			*		
Jaferabad(1980-85)	*		*						
Jageshwar(IPCL)(1994)	*								
Mul Dwarka(1992-1995)	*	*	*						
Mundra(2010)	*	*							
Okha(1998-2004)	*		*				*	*	
Path Finder Creek(Essar) (1977-1998)	*								
Pipavav (1974-2001)	*	*	*			*	*	*	
Porbandar (1957-2012)	*	*	*					*	
Rozi (1993-1994)		*							
Salaya (2008)		*							
Sikka Jamnagar (1985-2009)	*	*	*	*		*	*		
Vadinar (1997-2010)		*				*			
Veraval (1958-1998)	*		*				*	*	
Maharashtra									
Dabhol (1988-2010)	*	*		*		*	*		
Dahanu (1988-2010)			*				*	*	
Dighi (2006-2008)	*	*				*			
Jaigad (1992-2012)	*	*	*					*	
Mandawa (2009-2012)	*	*	*	*	*			*	
Pawas (1990-2008)	*								
Ratnagiri (1972-1993)	*		*				*	*	
Revdanda (2007-2012)		*							
Rewas - Aware (1983-2009)	*	*		*			*		
Vengurla1977-2009)	*							*	

Minor Ports

Project (Period of Studies)	Wave Tranquility	Tidal Hydrodynamics & Siltation	Stability of Coastal Hydraulic Structures	Dredging & Disposal	Littoral Drift & Shoreline Changes	Ship Motion & Maneuvering	Field Data Collection & Analysis	Coastal Protection Works	Hindcasting & Storm Surge Analysis
Karnataka									
Haldipur (2010-2011)	*	*			*		*		
Karwar (1964-2005)	*	*	*				*	*	
Old Mangalore (1989-2012)			*		*		*	*	
Goa									
Baina Bay (1972-2010)	*	*		*	*	*			
Katem Bay (2010-2012)	*	*	*				*		
Betul, Goa (2017)	*	*			*				
Kerala									
Azikkal (1989-94)	*	*			*		*		
Beypore (1972-1998)					*		*		*
Kudankulam (1989-2012)	*	*			*		*		
Tamil Nadu									
Cuddalore (1995-2012)	*	*	*		*				*
Pondicherry (1969-2000)	*					*		*	
Tirukkadaiyur (2011)	*	*			*	*			*
Chidambarner Port (2016-2018)	*		*						
Kamarajar Port(2016)	*								
Andhra Pradesh									
Gopalpur (1968-1997)	*								*
Kakinada (1973-2012)	*		*	*			*		*
West Bengal									
Hooghly (1952-1995)		*	*	*		*	*	*	
Andaman & Lakshadweep									
Agatti, Lakshadweep (2000-2012)	*		*						
Androth, Lakshadweep (1983-2005)	*	*				*	*		
Arial Bay, Andaman (2011)				*					
Butler Bay, Little A. (2008-2010)		*					*		
Campbell Bay, Nicobar (1974-2007)	*			*		*			

Minor Ports

Project (Period of Studies)	Wave Tranquility	Tidal Hydrodynamics & Siltation	Stability of Coastal Hydraulic Structures	Dredging & Disposal	Littoral Drift & Shoreline Changes	Ship Motion & Maneuvering	Field Data Collection & Analysis	Coastal Protection Works	Hindcasting & Storm Surge Analysis
Andaman & Lakshadweep									
Flat Bay, Andaman (2001)							*		
Hut bay, Little A. (1976-2005)	*		*						
Junglighat, Port Blair (2008)				*					
Kalpeni, Lakshadweep (1988-2012)	*						*		
Kavaratti, Lakshadweep (1977-2000)	*								
Minicoy, Lakshadweep (1988-2012)	*		*						
Mus, Car Nicobar (1993-2017)	*					*	*		
Neil Island, Andaman (2010)				*					
Phoenix Bay, Port Blair (2000-2010)	*			*					

Fisheries Harbours

Project (Period of Studies)	Wave Tranquility	Tidal Hydrodynamics & Siltation	Stability of Coastal Hydraulic Structures	Dredging & Disposal	Littoral Drift & Shoreline Changes	Ship Motion & Maneuvering	Field Data Collection & Analysis	Coastal Protection Works	Hindcasting & Storm Surge Analysis
Agardanda, Maharashtra (1978-2005)	*						*		
Androth, Lakshadweep Island (1983-2005)	*	*	*						
Bhatkal, Karnataka (1962-2012)	*	*	*						
Chicalim, Mormugao Bay, Goa (1994-1997)	*								
Colachel, Tamil Nadu (2012)	*		*						
Hejamadi Kodi, Karnataka (2006-		*	*	*					
Honnavar, Karnataka (1996-2013)	*	*	*						
Kakdwip, West Bengal (2010-2011)	*	*							
Karaikal, Pondicherry (1999-20	*		*						

Fisheries Harbours

Project (Period of Studies)	Wave Tranquility	Tidal Hydrodynamics & Siltation	Stability of Coastal Hydraulic Structures	Dredging & Disposal	Littoral Drift & Shoreline Changes	Ship Motion & Maneuvering	Field Data Collection & Analysis	Coastal Protection Works	Hindcasting & Storm Surge Analysis
Karanja, Maharashtra (1969-2011)	*	*						*	
Koderi, Karnataka (2011-2012)	*	*							
Kulai , Mangalore (1973-2002)	*				*			*	
Mahim Creek, Maharashtra (1960-2006)			*	*					
Mandarmani creek, WB (2005-2009)		*	*					*	
Mangrol, Gujarat (1980)	*		*						
Manjeshwar, Kerala (2009-2010)	*	*			*				
Maravanthe, Karnataka (2012- 2017)	*		*					*	
Mirkarwada, Maharashtra (1975-2012)	*	*			*			*	
Mormugao Bay, Goa (1993-1999)	*	*		*				*	
Motidanti - Nanidanti, Gujarat (2012)								*	
Munambam, Kerala (1977-1992)	*	*	*						
Murud, Maharashtra (1998-2012)			*					*	
Nandgaon, Maharashtra (2009-2010)		*	*						
Navi Bander, Gujarat (2008)	*								
Parappanangodi, Kerla (2010)	*				*				
Poompuhar, TN (2012)	*		*		*				
Poonani, Kerala (2001)		*							
Poonthura, Kerala (2012)	*		*						
Shankarpur, WB (2004)			*					*	*
Thane Creek, Maharashtra (1979-1993)			*	*					
Vadinar, Gujarat (1997-2010)	*					*		*	
Varsoli, Maharashtra (2001-2006)		*	*					*	
Vellayil, Kerala (2010-2011)	*	*			*				
South Paravoor,Kerala(2016)	*	*	*		*				
Majali Karnataka (2016)					*				
Nayachara Island, West Bengal(2016)		*							
Thottappally, Kerala(2016)		*			*				
Thrikkunnapuzha Kerala(2016)					*				
Keni Karnataka (2016)	*		*						
Munambam Kerala (2016)					*				

Fisheries Harbours

Project (Period of Studies)	Wave Tranquility	Tidal Hydrodynamics & Siltation	Stability of Coastal Hydraulic Structures	Dredging & Disposal	Littoral Drift & Shoreline Changes	Ship Motion & Maneuvering	Field Data Collection & Analysis	Coastal Protection Works	Hindcasting & Storm Surge Analysis
Ajanur Kerala (2016)	*				*				
Thengapattinam Tamilnadu (2016)	*								
Bhatkal Karnataka (2016)			*					*	
Belambar Karnataka (2016)	*								
Thanur Kerala (2016)	*								
Vellayil Kerala (2016)	*								
Vatanabappally Kerala (2016)								*	
Belapur Karnataka (2016)			*						
Versova Maharashtra (2016)	*	*							
Chethi Alappuzha Kerala (2016)	*								
Versova Maharashtra (2016)			*						
Harihareshwar Maharashtra (2016)	*								
Raigad Maharashtra (2016)	*								
Thiruvotriyur Kuppam Tamil Nadu (2017)			*						
Tharangambadi Tamil Nadu (2017)			*						
Neendakara Kerala (2017)			*						
Vellapallam Tamil Nadu (2017)			*						
Thalai Kerala (2017)			*						
Puthiyangadi Kerala (2017)	*				*				
Juvvaladinne A.P. (2017)	*	*	*						
Alvekodi- Tenginagundi Karnataka (2017)	*								
Navabhandar Gujarat (2017)	*	*	*						
Vodarevu Andhra Pradesh (2017)			*						
Manglore Gujarat (2017)			*						
Uppada Andhra Pradesh (2017)			*						
Mangrol Gujarat (2017)	*								
Machilipatnam Andhra Pradesh (2017)			*						

Fisheries Harbours

Project (Period of Studies)	Wave Tranquility	Tidal Hydrodynamics & Siltation	Stability of Coastal Hydraulic Structures	Dredging & Disposal	Littoral Drift & Shoreline Changes	Ship Motion & Maneuvering	Field Data Collection & Analysis	Coastal Protection Works	Hindcasting & Storm Surge Analysis
Nizampathnam Andhra Pradesh (2017)			*						
Madhwad Gujarat (2017)	*		*						
Vasco Bay, Goa (2018)	*	*							
Chetty Kerala (2018)	*								
Parappanangadi Kerala (2018)	*								
Porbandar Gujarat (2018)	*								

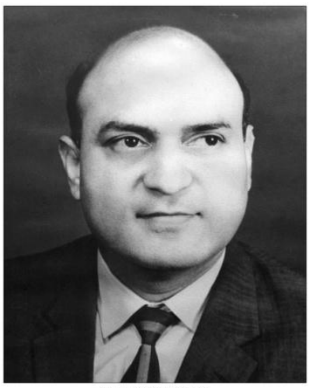
ACKNOWLEDGEMENTS

The development of coastal engineering group at CWPRS and the further growth and advancements have occurred in a phased manner as a result of tireless and progressive efforts by a number of officers since the year 1947. The contribution of CWPRS in the port development sector could happen due to the great team effort. The hydraulic model studies had started initially with the physical model studies with regular wave generation and manually operated tides. Gradually, with the advancement of technologies, the Random Sea Wave Generation (RSWG) facilities and Automatic Tide Generation (ATG) systems were developed which greatly helped in much more representative and accurate simulation of sea waves and tides in the model. There were limitations in the physical models for simulations of sediment movements, dispersion patterns and sedimentation covering large areas. To overcome these shortcomings, the mathematical modelling was initiated by the CWPRS scientists in 1990s. A number of CWPRS scientists were trained abroad to learn advanced techniques in hydraulic modelling systems under the UNDP aided schemes during 1980s and 1990s. Under UNDP schemes, the latest field equipments were procured by CWPRS for field data collection which is vital input for conducting hydraulic model studies. The port development schemes started in a big way after 3rd plan scheme and further after 1995 when liberalisation of port development by private sector was started. The hydraulic models at CWPRS, which include both physical and mathematical, always catered to the challenges posed by the port sector in India by offering safe, economical and sustainable solutions. The Instrumentation group at CWPRS also offered valuable services from time to time for simulating the waves and tides and for data acquisition in the physical models and also in setting up computer network facilities with related software and hardware to cope up with the technological advancements.

Under the dynamic leadership of ***Shri C V Gole***, former Director, the challenges of developing the coastal engineering group at CWPRS had been initiated. The foresight and charisma of ***Shri P C Saxena***, former Director facilitated creation of infrastructural facilities and training of the CWPRS officers abroad under the UNDP schemes. ***Padma Shri Dr. Z S Tarapore***, former Director had taken it further ahead with the association of foreign laboratories and basic research. ***Dr. P P Vaidyaraman***, former Director focussed on the development of mathematical modelling centre at CWPRS in the field of coastal engineering which went a long way in taking up the challenges of port development in India. ***Mrs. V M Bendre***, former Director contributed through much needed support for developing instrumentation for the RSWG, ATG, DAS systems for the physical models and advanced computing facilities for mathematical modelling.

Shri. C.V.GOLE
05/01/1963-28/8/1974

Shri C V GOLE



Shri. P.C.SAXENA
29/08/1974-22/04/1985

Shri P C SAXENA

Dr. Z.S.TARAPORE
23/04/1985-31/10/1991

Dr. Z S TARAPORE


Dr. P.P.VAIDYARAMAN
01/11/1991-31/07/1994

Dr. P P VAIDYARAMAN


Mrs. V.M.BENDRE
04/07/2000-31/07/2009

Mrs. V M BENDRE

A number of our former officers had played a vital role in the advancement of the Coastal Engineering group at CWPRS. A few of the contemporary names are cited here and a more elaborate list based on available records and recalled from memory is also given at the end. All efforts were made to include these names as accurately as possible; however, a few errors might have crept in. In respect of some of the names of officers, which may have been inadvertently missed, the editors offer their apologies and nonetheless have great regard for their contributions.

Shri U V Purandare (former Additional Director), Shri P K Khare (former Joint Director) and Shri Y D Barve, Dr. S B Brahme, Shri D P Gokhale, Shri J G Dixit, Shri J B Shaligram, Shri R Srinivasan, Dr. T M Parchure, Shri A G Phansalkar, Shri V B Joshi, Shri V V Vazhe, Shri P S Kapileshwar, Shri A P Dange, Shri V M Bapaye (former Chief Research Officers) had played a significant and vital role in the promotion of field studies and advancement of physical modelling techniques. Dr. L K Ghosh, and Shri C N Kanetkar (former Additional Directors), Shri S K Guha, Shri S C Patel, Shri Narayan Prasad, Dr B M Patil, Dr V P Shukla, Dr. S Balakrishna, (former Chief Research Officers), Dr. S K Das (former Senior Research Officer) and Dr. C B Singh (former Joint Director) contributed extensively in the field of mathematical modelling. Shri Y D Barve, Shri M R Gadre, Shri I Z Poonawalla, Shri A G Kale (former Joint Directors) and Shri M D Kudale (former Additional Director) had notable contributions in the field of shore protection and design of breakwater structures.

While preparing this Compendium on the “Role of CWPRS for Port development In India”, the services of the following CWPRS scientists (both of the retired and serving) are hereby acknowledged:

Retired Senior Officers:

Ex. Director		**Ex. Additional Director**		**Ex. Joint Director**	
1	Shri C V Gole	1	Dr. L K Ghosh	1	Shri Y D Barve
2	Shri P C Sexena	2	Shri U V Purandare	2	Shri M R Gadre
3	Dr. Z S Tarapore	3	Shri C N Kanetkar	3	Dr. S B Brahme
4	Dr. P P Vaidyaraman	4	Shri M D Kudale	4	Shri I Z Poonawalla
5	Mrs. V M Bendre			5	Dr. N Somayazi
6	Dr. B U Nayak			6	Shri A G Kale
				7	Shri P K Khare
				8	Mrs. J S Panvalkar
				9	Dr. C B Singh
				10	Mrs S V Phadke

Ex. Chief Research Officers

1	Shri J G Dixit	9	Shri V M Bapaye	17	Shri V B Joshi
2	Shri R Srinivasan	10	Shri D P Gokhale	18	Shri S L Patel

3 Shri A G Phansalkar
4 Shri P S Kapileshwar
5 Shri J B Shaligram
6 Shri V V Vazhe
7 Dr. T M Parchaure
8 Shri S C Patel
11 Dr. S Balakrishna
12 Dr. B M Patil
13 Shri S V Wadhwankar
14 Shri A P Dange
15 Dr V P Shukla
16 Shri Narayan Prasad
19 Mrs. A M Vaidya
20 Mrs. S Kulkarni
21 Mrs. A S Barve
22 Shri S Puttramaiah
23 Shri S K Guha

Ex. Senior Research Officer

1 Dr. S. K. Das
2 Shri U Ramesh
3 Shri Biju George
4 Shri C A Kambalyal

Ex. Research Officer

1 Dr. S N Das
2 Shri S Ghosh

Serving Officers:

Scientist 'E'

1. Shri T Nagendra
2. Dr. Prabhat Chandra
3. Dr. J D Agrawal
4. Shri S D Ranade

Scientist 'D'

1. Shri S S Ragte
2. Shri A A Purohit
3. Shri H B Jagadeesh
4. Shri L R ranganath
5. Shri N Ramesh
6. Dr. J Sinha
7. Shri S G Manjunatha
8. Shri A V Mahalingaiah
9. Shri Hraday Prakash
10. Mrs. A B Pardesi
11. Shri G V Ramana Rao

Scientist 'C'

1. Shri B R Tayade
2. Shri M Phanikumar
3. Shri M M Vaidya
4. Shri J A Shimpi

Scientist 'B'

1. Shri V K Shukla
2. Shri V B Sharma
3. Shri S S Chavan
4. Shri K H Barve
5. Dr. R Manivanam
6. Shri G A Rajkumar
7. Shri Animesh Basu
8. Shri H C Patil
9. Shri U B Patil
10. Shri N V Gokhale
11. Shri Parag Kashyape
12. Shri J. S. Bagwan
13. Shri K B Bobade
14. Shri Amol Jatkar
15. Shri R K Chaudhari
16. Shri Amol Borkar
17. Shri B L Meena
18. Mrs. Shivani Sahu
19. Shri B B Choudhree
20. Shri B. Gopikrishna
21. Mrs A S Erande
22. Dr. C Ramesh
23. Shri B Krishna

Assistant Research Officer

1. Dr. A K Singh
2. Shri Santosh Kori
3. Shri S P Jagtap
4. Shri A S Chalwadi
5. Shri B Girish
6. Shri Sanjay Nath Jha
7. Dr. Anil Baghwan
8. Mrs. A A Sonowane

Research Assistant

1. Shri Karthikeyan M.
2. Shri Jagtap N
3. Shri Sawant Rahul Dilip
4. Shri Ganesh N.S.
5. Shri Sawant Mahesh D.
6. Shri Konde Vaibhav P.
7. Shri Kokane Vijay D.
8. Shri Sagar Chanda
9. Shri Walke K. G.
10. Shri Chavan K.A.
11. Shri Karambelkar K.R.
12. Mrs. Roy Vaibhavi
13. Mrs. Vighe K. S.
14. Shri Pardeshi G.R.

The Coastal engineering group is thankful to all other staff members at the levels of Technicians, Lab assistants, Masons, Helpers and Draftsmen who provided their valuable services especially for the construction and operation of physical models.

VISION

To be a world-class centre of excellence in hydraulic engineering research and allied areas; which is responsive to changing global scenario, and need for sustaining and enhancing excellence in providing technological solutions for optimal and safe design of water resources structures.

MISSION

- To meet the country's need for basic & applied research in water resources, power sector and coastal engineering with world-class standards.
- To develop competence in deployment of latest technologies by networking with the top institutions globally, to meet the future needs for development of water resources projects in the country effectively.
- To disseminate information, build skills and knowledge for capacity-building and mass awareness for optimization of available water resources.

MAJOR FUNCTIONS

- Undertaking specific research studies relating to development of water resources, power and coastal projects.
- Consultancy and advisory services to Central and State Governments, private sector and other countries.
- Disseminating research findings and promoting/assisting research activities in other organizations concerned with water resources projects.
- Contributions to Bureau of Indian Standards and International Standards Organization.
- Carrying out basic and applied research to support the specific studies.
- Contribution towards advancements in technology through participation in various committees at National and State Levels.

Central Water & Power Research Station

Khadakwasla, Pune 411024
Telephone, +91 020 24103200 / 24381801
Fax +91 020 2438 1004,
Email : director@cwprs.gov.in
Web: https://cwprs.gov.in