# 1 INTRODUCTION

## 1.1 Background

Government of India is embarking on infrastructure development through private participation. Ministry of Power, Govt. of India along with Central Electricity Authority, Power Finance Corporation Ltd. (a Govt. of India Undertaking) has taken initiative for development of a number of coastal based and pit-head coal-based Ultra Mega Power Plants (UMPP) of about 4000 MW capacity each in the various locations in the country. Coastal Gujarat Power Limited (CGPL) a wholly owned subsidiary of the Tata Power Company Limited, a body in the field of financing the power projects is developing a 4000 MW thermal power project at Mundra, Kachchh District, in Gujarat. M/s TCE Consulting Engineers Ltd., the technical consultants to CGPL, has earlier examined the feasibility of setting up a 4000 MW thermal power station at Mundra by preparing a Detailed Project Report (DPR) during July 2007.

The CGPL had obtained CRZ clearance for intake and outfall channels for their 4000 MW thermal power plant. It now proposes to draw water to the tune of $6.3 \times 10^5$ $m^3/h$ for cooling purposes from the common intake channel constructed by M/s. Adani Power Limited (APL) as suggested by the NIO. As a result, due to engineering reasons CGPL requires to change the discharge location. M/s CGPL has approached the National Institute of Oceanography (NIO) to obtain baseline data covering the new discharge location and to predict the marine environmental impacts based on the modeling reports by H.R. Wallingford that will be made available to NIO.

NIO has recently conducted studies for a similar but smaller power plant proposed by the APL in the same location and the oceanographic data collected during that study as well as data available for the Gulf of Kachchh collected over the last several years is adequate to conduct marine environment related studies like identification of discharge point for release of wastewater and assessment of impact of proposed development on the adjoining marine ecology. Also field investigations were conducted during December 2008, based on which this marine EIA report is prepared.

## 1.2 Objectives

a) To evaluate the prevailing hydrodynamics and ecological status of the coastal waters adjacent to the project site.

b) To assess the impact of effluent release and other project operations on marine ecology.

c) To assess the impact of coal conveyer system on marine ecology.

d) To recommend suitable marine environmental management plan to minimize any adverse impact on marine area due to the proposed developments.

## 1.3 Scope of work

The site of release of effluents meeting the norms of the Gujarat Pollution Control Board should be so identified that the contaminants are effectively dispersed within a reasonable distance from the release site and the effluent release system does not interfere with the operations of the nearby Mundra Port and intake facility.

In well-planned coastal developments, the probable adverse impacts are identified in advance so that the mitigation measures can be integrated within the design itself. Reliable prediction of impacts on marine ecology requires detailed information on water quality, sediment quality and biological characteristics of the area likely to be impacted and their tidal and seasonal variations. Ideally, the field data collection is required to be made in 3 seasons viz. postmonsoon, monsoon and premonsoon, since the coastal environment can change significantly from season to season. However, due to the dynamics of the Gulf it is not possible to undertake field investigations during monsoon. Moreover, due to high turbulence and wave action during monsoon, the contaminants entering the sea are dispersed at a much faster rate than during fair seasons. Hence, monsoon observations are not critical while conducting marine EIAs. The general area of the CGPL falls within the area investigated for APL power project for which data was recently acquired to study the EIA of common intake channel. It is therefore proposed to conduct field investigations during the postmonsoon season to undertake EIA studies for the discharge channel.

NIO has conducted several studies in the coastal waters of Mundra in the past several years. The studies have generated an extensive database for the region, which can be usefully utilized to establish the baseline for the present studies. Based on the information available with NIO and the project information made available by CGPL, the following scope of work was finalized.

**(a) Physical processes**

Tides will be assessed with available data in the area. The currents will be measured at the proposed release location for around one week. Drogue studies will be conducted to estimate the excursion length of the plume. Plume dilutions will be estimated using the model output generated by the H.R. Wallingford, UK.

**(b) Water quality**

Water quality would be assessed at several locations to evolve a general background for the coastal sea off the project site. The samples collected at the surface and bottom (wherever the depth exceeds 3 m) will be analyzed for salinity, suspended solids (SS), pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), phosphate, nitrate, nitrite, ammonia, Petroleum Hydrocarbons (PHc) and phenols. One critical location will be sampled temporally to assess tidal variability of selected water quality parameters.

**(c) Sediment quality**

Intertidal and subtidal sediments off the project site would be studied for texture, selected metals (chromium, iron, cobalt, nickel, copper, zinc, lead, cadmium and mercury), organic carbon ($C_{org}$), phosphorus and PHc.

**(d) Biological characteristics**

The status of flora and fauna off the project area would be established based on phytoplankton pigments, population and generic diversity; zooplankton biomass, population and group diversity, macrobenthic biomass, population and group diversity, fisheries, mangroves and intertidal corals.

**(e) Assessment**

The data would be analysed to meet the objectives as stated above. Based on the environmental results and the probable perturbations due to the proposed project, the impact of various activities on marine ecology will be assessed during construction as well as operational phases of the project. Suitable mitigation measures in terms of marine environmental management plan will be suggested to minimize the adverse impact identified.

## 1.4 Approach strategy

Severity of negative impacts of developments in the coastal zone on associated marine ecology varies widely depending on many factors such as the extent, period and type of disturbance, anthropogenic perturbations, capacity of the receiving water to assimilate contaminants and extent of its ecological sensitivity. Hence, the primary requirements for assessing such impacts are general baseline information for the Gulf as a whole and intensive site-specific data for the Tunda-Vandh area. NIO has been conducting general and site specific studies in the Gulf (Figure 1.4.1) since 1990 with more frequent investigations in recent years due to several proposed and ongoing developments bordering the Gulf, particularly along the southern coast. Thus, the site specific studies as detailed below conducted from time to time has resulted in a fairly extensive database for the Gulf.

| Area | Period |
|---|---|
| Mithapur | 1990-2004 |
| Vadinar | 1994-95, 1997, 1999, 2000, 2003, 2004,2005,2006 |
| Sikka | 1993-94, 1997, 1999, 2002, 2004,2005,2007, |
| Bedi | 1997, 2002-03 |
| Navlakhi | 1994, 2002 |
| Kandla | 1996-98, 2004 |
| Luni | 1997 |
| Mundra | 1998-99, 2000, 2002, 2003, 2005,2006,2007 |

These sets of data were found adequate to describe the general environmental setting of the Gulf and intensive field data acquisition off Tunda-Vandh was considered sufficient to meet the objectives.

The published scientific literature and available technical reports indicated that apart from the studies conducted by NIO during 1998-2007 detailed information related to the ecology off Mundra was rather scanty. This information was assessed to plan field data acquisition for the present study. Accordingly, subtidal stations covering an area of 100 $km^2$ off Tunda-Vandh were considered for sampling. Intertidal area that would be used for effluent release channel was also considered for the study and the samples at selected intertidal transects were investigated. The sampling locations are illustrated in Figure 1.4.2.

## 1.5 Studies undertaken

Subtidal sampling stations were selected based on the location of the proposed development including probable capital dredging for effluent disposal point. Bathymetry for the area is given in the Chart No. 2055 of the Naval Hydrographic Office (NHO) and local close grid mapping supplied by TCE. The locations of previous investigations were also considered to obtain comparative information for offshore and onshore areas likely to be impacted by the proposed project as well as to create general ecological database for the wider region. Intertidal macrobenthos and sediment quality particularly in the areas likely to be disturbed due to dredging were studied at two transects between the High Tide Line (HTL) and the Low Tide Line (LTL). These are also shown in Figure 1.4.2.

### 1.5.1 Period of study

The field investigations as given below were planned in such a manner so as to get a detailed picture of the aquatic environmental characteristics during December 2008 (postmonsoon).

### 1.5.2 Station locations

A total of 6 stations selected for marine environmental investigations are listed below and shown in Figure 1.4.2. Intertidal sediment was sampled along each transect in the area between the Low Water Line (LWL) and the High Water Line (HWL).

| Station/Transect | Position | |
|---|---|---|
| | Latitude (N) | Longitude (E) |
| 1 | $22^o46.285'$ | $69^o25.804'$ |
| 2 | $22^o46.239'$ | $69^o28.756'$ |
| 3 | $22^o46.258'$ | $69^o31.658'$ |
| 4 | $22^o43.532'$ | $69^o25.819'$ |
| 5 | $22^o43.532'$ | $69^o28.731'$ |
| 6 | $22^o43.532'$ | $69^o31.657'$ |
| T1 | $22^o47.235'$ | $69^o29.770'$ |
| T2 | $22^o48.291'$ | $69^o24.467'$ |

### 1.5.3 Sampling frequency

Water quality and biological characteristics were assessed at station 2 over a period of 12 h with 1 h sampling frequency for water quality and 2 h for biological characteristics. Other stations were spot sampled in duplicate at an interval of 30 min. Subtidal and intertidal sediments were collected once at each station/transect wherever possible.

### 1.5.4 Physical processes

**a) Tide**

Available information on tides for Mundra and surrounding region was assessed.

**b) Currents**

Currents were measured by deploying an Aanderaa (RCM 9) current meter at station 2 for about 6 d.

**c) Circulation**

Circulation was estimated by deploying a neutrally buoyant biplane drogue at prefixed location ( Station 2) and tracking it over the desired time. The position of the drogue was periodically fixed with a GPS (Garmin handheld GPS 12). These positions were then plotted to obtain the trajectories.

### 1.5.5 Water quality

**a) Sampling procedure**

Surface water samples for general analyses were collected using a clean polyethylene bucket while an adequately weighted Niskin sampler with a closing mechanism at a desired depth was used for obtaining subsurface water samples. Sampling at the surface and bottom (I m above the bed) was done when the station depth exceeded 3 m. A glass bottle sampler (2.5 l) was used for obtaining samples at a depth of 1 m below the surface, for the estimation of PHc.

**b) Methods of analyses**

Majority of the water quality parameters was analysed within 24 h of collection in the temporary shore laboratory established at Mundra. Colorimetric measurements were made on a Schimadzu (Model 1201) spectrophotometer. RF-5301 Schimadzu Spectrofluorometer was used for estimating PHc. The analytical methods of estimations were as follows:

**i) Temperature:**

Temperature was recorded using a mercury thermometer with an accuracy of $0.1^{o}$ C.

**ii) pH:**

pH was measured on a microprocessor controlled pH analyser. The instrument was calibrated with standard buffers just before use.

**iii) SS:**

A known volume of water was filtered through a pre-weighed 0.45 μm Millipore membrane filter paper, dried and weighed again.

**iv) Salinity:**

A suitable volume of the sample was titrated against silver nitrate (20 g/l) with potassium chromate as an indicator. The salinity was calculated using Standard Tables.

**v) DO and BOD:**

DO was determined by Winkler method. For the determination of BOD, direct unseeded method was employed. The sample was taken in a BOD bottle in the field and incubated in the laboratory for 3 d after which DO was again determined.

**vi) Phosphate:**

Acidified molybdate reagent was added to the sample to yield a phosphomolybdate complex that was then reduced with ascorbic acid to a highly coloured blue compound, which was measured at 882 nm.

**vii) Nitrite:**

Nitrite in the sample was allowed to react with sulphanilamide in acid solution. The resulting diazo compound was reacted with N-1-Naphthyl-ethylenediamine dihydrochloride to form a highly coloured azo-dye. The light absorbance was measured at 543 nm.

**viii) Nitrate:**

Nitrate was determined as nitrite as above after its reduction by passing the sample through a column packed with amalgamated cadmium.

**ix) Ammonia:**

Ammonium compounds ($NH_3^+$,$NH_4^+$) in water were reacted with phenol in presence of hypochlorite to give a blue colour of indophenol. The absorbance was measured at 630 nm.

**x) PHc:**

Water sample (2.5 l) was extracted with hexane and the organic layer was separated, dried over anhydrous sodium sulphate and reduced to 10 ml at $30^{o}$ C under low pressure. Fluorescence of the extract was measured at 360 nm (excitation at 310 nm) with Saudi Arabian crude residue as a standard. The residue was obtained by evaporating lighter fractions of the crude oil at $100^{o}$C.

**xi) Phenols:**

Phenols in water (500 ml) were converted to an orange coloured antipyrine complex by adding 4-aminoantipyrine. The complex was extracted in chloroform (25 ml) and the absorbance was measured at 460 nm using phenol as a standard.

### 1.5.6 Sediment quality

Surficial sediment for the determination of texture, heavy metals, $C_{org}$, phosphorus and PHc was collected at all water quality stations as well as intertidal transects.

**a) Sampling procedure:**

Subtidal sediment was obtained by a van Veen grab of 0.04 $m^2$ area. The samples after retrieval were transferred to polyethylene bags and preserved for further analyses. Intertidal sediment was sampled using quadrants.

**b) Methods of analyses:**

**i) Texture:** The sediment was dried at $60^{o}$ C and analysed for particle size following the procedure of Buchanan.

**ii) Metals:** Sediment was brought into solution by treatment with conc HF-$HClO_4$-$HNO_3$-HCl and the metals were estimated on a Perkin Elmer (Analyst 300/600) Atomic Absorption Spectrophotometer (AAS) by flame/graphite furnace. Mercury was estimated by flameless AAS technique after digesting the sediment with aquaregia.

**iii) $C_{org}$:**

Percentage of $C_{org}$ in the dry sediment was determined by oxidising organic matter in the sample by chromic acid and estimating excess chromic acid by titrating against ferrous ammonium sulphate with ferroin as an indicator.

**iv) Phosphorus:**

Digested sample [Section b (ii) was used for estimating phosphorus in the sediment. The method used was similar to that described under Section (V).

**v) PHc:**

Sediment after refluxing with KOH-methanol mixture was extracted with hexane. After removal of excess hexane, the residue was subjected to clean-up procedure by silica gel column chromatography. The hydrocarbon content was then estimated by measuring the fluorescence as described under Section (IX).

### 1.5.7 Flora and fauna

**a) Sampling procedure:**

Polyethylene bucket and Niskin sampler respectively, were used for sampling surface and bottom waters for the estimation of phytoplankton pigments and population. Sample for phytoplankton cell count was fixed in Lugol's iodine and a few drops of 3% buffered formaldehyde.

Zooplankton were collected by oblique hauls using a Heron Tranter net (Mesh size 0.33 mm, mouth area 0.25 $m^2$) with an attached calibrated digital flow meter (General Oceanic). All collections were of 5 min duration. Samples were preserved in 5% buffered formaldehyde.

Sediment samples for subtidal macrobenthos were collected using a van-Veen grab of 0.04 $m^2$ area. Intertidal collections between the HTL and the LTL were done with quadrants . Samples were preserved in 5% buffered formaldehyde - Rose Bengal.

**b) Methods of analyses:**

**i) Phytoplankton pigments:**

A known volume of water was filtered through a 0.45 µm Millipore membrane filter paper and the SS retained on the filter paper were extracted in 90% acetone and refrigerated overnight in dark. For the estimation of chlorophyll *a* and phaeophytin, the extinction of the acetone extract was measured at 665 and 750 nm before and after treatment with dilute acid using a fluorometer (Turner design, Trilogy).

**ii) Phytoplankton population:**

The cells in the sample preserved with Lugol's solution were allowed to settle and transferred into a Sedgwick Rafter slide. Enumeration and identification of phytoplankton were done under a microscope.

**iii) Algae, seaweeds and mangrove ecosystem:**

Algal, seaweed and mangrove flora were assessed from the upper to the lower intertidal region along predecided transects.

**iv) Zooplankton:**

Volume (biomass) was obtained by displacement method. A portion of the sample (25-50%) was analysed under a microscope for faunal composition and population count.

**v) Fish eggs, fish larvae and decapod larvae:**

These groups were sorted out from zooplankton samples and counted.

**vi) Macrobenthos:**

Sediment was sieved through a 0.5 mm mesh sieve and animals retained were preserved in 5% buffered Rose Bengal formaldehyde. Total population was estimated as number of animals in 1 $m^2$ area and biomass was determined on wet weight basis ($g/m^2$).

**vii) Fishery:**

Fish landing data were obtained from the Department of Fisheries, Government of Gujarat (Jamnagar and Kachchh Districts) for assessing fishery potential.

**viii) Corals:**

The project domain area was carefully surveyed for corals on the intertidal segment during spring low tide.

## 2 PROJECT INFORMATION

The proposed project will be located at Tunda-Vandh villages in Mundra Taluka, Kachchh district of Gujarat coastal area. The site is located in the close vicinity of Mundra Port and Special Economic Zone (MPSEZ), which is located 25 km west of Mundra Port and 1.5 km from the coast of Gulf of Kachchh. Tunda is accessible by road on NH-8A highway extension between Gandhidham and Mandavi towns and state highway SH-6 near Kandagra. The satellite imagery of the region is given in Figure 2.0.1. An approach road to the project site from the highway is under construction which will bypass two villages. The site is adjoining the first phase development of MPSEZ and adequate land for the project is totally acquired by CGPL. The proposed project consists of five power plant units totaling to 4000 MW gross capacity, utilising imported coal as fuel.

### 2.1 Need of the project

The demand for power is increasing steadily and the power shortage is felt everywhere. Mega power projects are the need of the day. With the Power grid in place it is possible to produce power at any location and feed it to the national grid. But the availability of fuel and water, the basic raw materials for power plant, are the important considerations. The site selected has both the attributes as coal can be imported through the nearest Mundra port and seawater can be used for cooling purposes. The area is under-developed and non-agricultural land availability is obvious.

#### 2.1.1 Power demand scenario

Though the demand for power in the nearby areas is relatively smaller, demand on national scale exists for the power. The beneficiaries from the proposed project include Gujarat, Maharashtra, Punjab, Haryana and Rajasthan. The existing power for evacuation and transmission network will be strengthened to enable the transfer of the power to these identified beneficiaries.

### 2.1.2 Power evacuation

The feasibility study conducted by Power Grid Corporation of India Ltd. (PGCIL) revealed that the existing/planned inter state transmission network, which would be available by the year 2010 –11 may not be adequate for evacuation of 3500-3800 MW from the proposed power plant. Efforts are going on to strengthen the power evacuation and transmission network for feeding power to the various beneficiary states.

### 2.1.3 Configuration and selection of unit sizes

The selection of the configuration of the power plant/ unit size was left to the bidders with the requirement to adopt supercritical technology for boilers. The successful bidder, M/s. Tata Power Company Ltd., has offered to install 5X800 MW units to be commissioned in about 48 months period from effective date.

## 2.2 Land availability and site selection

The region around the proposed project sites is scarcely populated except in some clusters and a major part of the terrain is non-cultivated land. The site at Tunda is considered suitable for the project based on the advantages that are enumerated herein below.

Tunda site is accessible by road NH-8A extension between Gandhidham and Mandvi towns. The nearest airlink is Bhuj Airport at a distance of about 60 kms from the project site. The site is adjoining the present phase of development of Mundra SEZ and adequate land for the project is already acquired by CGPL. Mundra Port is constructing a coal jetty near to the project area to handle imported coal to the tune of 12-14 million tones/ annum.

The proposed site for discharge channel is represented by a span of sandy beach with intermittent presence of seaweed in the high tide level (Figures 2.2.1 and 2.2.2). Also seawater could be drawn through an open channel that will be more economical than an offshore pumping system and pipeline, considering the volume of water required.

## 2.3 Features of selected site

### 2.3.1 Water

The source of cooling water will be from the sea. The cooling water requirement will be met from the seawater from the common intake channel shared with APL as recommended by NIO.

### 2.3.2 Fuel

Coal from international market could be procured from countries like Indonesia, South Africa, Australia, China and other possible sources. Imported coal received at Mundra coal jetty shall be transported to the project site by conveyer belt.

### 2.3.3 Topographical and geological aspects

The area however is not prone to inundation. Pile foundation will be required for major equipment and structure foundations. The depth of piles and the related aspects will be decided appropriately based on soil investigations.

## 2.4 Plant layout configuration

In laying out the various facilities (Figure 2.4.1), consideration has been given to the following general principles.

- Power evacuation corridor for connection to grid.
- Raw water facilities
- Imported coal handling facilities at Mundra coal jetty
- Approach road to the power plant from the highway, rail link to Adipur and airport facility at Bhuj 60 kms away.
- All facilities of the 4000 MW are laid out in close proximity to each other to the extent practicable so as to accommodate all facilities efficiently within the plant boundary.
- The layout also facilitates communication of men and materials between the various facilities both during initial construction and also during subsequent operation and maintenance.

- Availability of adequate space for fabrication / construction equipment beyond the power plant boundary which can be hired temporarily for the purpose.
- Site located in plain and barren area with minimal cultivation and habitation.
- Minimal eco-sensitive spots in vicinity of project site
- R&R issues not involved in absence of requirement for displacement of any villages/ houses

## 2.5 Water requirement

The main requirement of water will be for power cycle condenser cooling and for desalination plant. The cooling water requirement will be met from the seawater from the common intake channel shared with APL as recommended by NIO. The seawater requirement will be about $6.3 \times 10^5$ $m^3/h$ of which about $6.27 \times 10^5$ $m^3/h$ will be for condenser cooling and 2796 $m^3/h$ will be used for producing fresh water. Fresh water for the plant, potable water, service water and feed water to the DM plant and other services will be met by the desalination plant.

### 2.5.1 Cooling water system

A once through cooling system with seawater is preferred for the plant. The circulating system would be so designed to attain discharge temperature of +7$^{o}$C above ambient seawater temperature. The end weir will be located at 22°47’24.65’’ N, 69° 30’1.26’’ E. The end of the outer discharge channel will be situated at 22° 46’ 14.31’’N, 69° 28’45.396’’ E.

### 2.5.2 Desalination plant

In absence of any reliable source of fresh water, desalination of abundantly available seawater is the only feasible solution to cater to the fresh water demand. A total of 25 mld desalination capacity is being planned for the power plant. Reverse Osmosis (RO) has been chosen as the technology for desalination.

The desalination plant will consist of the following systems:

1. Intake pumping system for RO plant from intake channel;
2. Clarification plant with sludge disposal systems;
3. Chlorination for disinfection;
4. Two-stage filtration consisting of pressure sand filters and dual media filters;
5. I-pass RO plant to meet service water requirement and DM plant feed requirement;
6. I-pass RO treated water storage tank;
7. II-pass RO to get DM water for SG Cycle;
8. Chemicals storage, handling, preparation and dosing;
9. Chemical laboratory;
10. Instrumentation and control and;
11. Reject disposal along with filter backwash and sludge.

Seawater (approx. 3,000 $m^3$/hr) for the 25 mld module of the desalination plant will be drawn from intake channel. The PT (pre-treatment) plant will consist of 2 x 50% capacity lamella clarifiers to remove the heavier suspended and settleable solids. The chemical treatment facility will be equipped with real-time flow-rate adjustment and adequate redundant capacity. Chlorination will be done at inlet i.e. stilling chamber and then flows into flash mixers for coagulation and flocculation chambers. The sludge will be removed and discharged into sludge sump.

The clarified water will be then stored in a clarified water storage tank and this clarified water will be pumped through 5 x 50% capacity filter feed pumps. Two stage filtration is envisaged to achieve the required SDI (Silt Density Index) for the RO plant. The first stage filtration is through dual media filters and second stage filtration will be done in horizontal pressure filters to remove suspended solids.

The backwash requirement for these filters will be met from I-pass RO reject. The filter backwash and sludge from clarifiers will be mixed in the sludge sump and disposed to CW outfall channel. After the double stage filtration, finer particles will be removed by micron cartridge filters. RO system uses a semi-permeable composite polyamide membrane to separate and remove dissolved solids, organics, pyrogens, sub-micron colloidal matter, viruses and bacteria from water to the extent of 98 to 99.5%. I-pass RO plant will have a permeate recovery of 40%. Suitable energy recovery devices will be installed for I-pass RO high pressure pumps to achieve power saving.

The desalinated water will be processed further through re-mineralization and chlorination before it is used for potable water purposes. I-pass RO permeate will be stored in a permeate water storage tank of 20,000 m3 capacity and will cater to the plant service water requirement. Part of the I-pass RO permeate will be fed to II-pass RO which will feed DM plant to produce DM water for SG feed cycle make-up.

The desalination plants will be fully automated plant with multiple PLC's and SCADA control systems.

**2.6 Effluent disposal system**

Desalination plant reject will be partly utilized for pretreatment plant backwash and the balance will be led into the discharge channel. The desalination plant reject water (1727 $m^3/h$) with high TDS will get diluted in the CW discharge channel. Pre-treatment plant filter backwash and clarifier sludge will be collected and disposed off to the discharge channel. The power plant being once through cooling type, the seawater is led back to the sea at the rate of about $6.28 \times 10^5$ $m^3/h$. The discharge channel is designed to cool the water over a length of about 1950 m and has a capacity of $6.30 \times 10^5$ $m^3/h$.

**2.7 Disposal of dredged material**

The quantity of material excavated in making the outfall channel would be of the order of 2.0 million $m^3$. This quantity will be disposed off as per the plan suggested by Mundra Port. No siltation is expected in the outer discharge channel.

## 2.8 External Coal Handling System (ECHS)

The External Coal Handling system (ECHS) proposed for the UMPP consists of coal receipt and stock pile system at the port jetty, reclaiming and conveying from the port jetty stockpile to the power plant. A brief description of the coal handling system proposed is furnished below.

### 2.8.1 Coal handling at the port

Coal will be received at the terminal point from MPSEZL. MPSEZL shall unload the coal from the ship using grab unloaders and conveyers to CGPL's conveying system, which in turn would convey this coal directly to the power plant or to their port stock pile as per requirement. The stacker cum reclaimer machine mounted on the trunk conveyer shall be used to stock the coal at the port. Rated conveying capacity from grab unloading station to port stockpile shall be 6000 TPH. The peak capacity of stacker cum reclaimer shall be 6000 TPH while stacking and 4000 TPH while reclaiming.

### 2.8.2 Conveying from port to plant stockpile

One stream of belt conveyer of 4000 TPH rated capacity shall be provided to convey the coal directly to plant stockpile. Same stream would be used to convey coal reclaimed from port stock pile.

# 3 GULF OF KACHCHH

The Tunda-Vandh and surrounding region forms an integral part of the Gulf. Hence, the knowledge of general ecology of the Gulf is necessary for comparing the site-specific environmental conditions with that of the parent body.

The Gulf (Figure 1.4.1), which occupies an area of 7300 $km^2$, has maximum depth that varies from 20 m at the head (Kandla - Navlakhi) to 60 m in the outer regions. The actual fairway however is obstructed due to the presence of several shoals, needing periodic dredging in some areas, to facilitate navigation to the Kandla Port. The tidal scour that follows the axis of the Gulf has steep slopes and rugged surfaces. A number of scraps with relative elevation of 6 to 32 m occur on the sediment-free bed of the central Gulf.

## 3.1 Land environment

The coastal configuration of the Gulf is very irregular with numerous islands, creeks and bays. The coastal area of the Gulf (within 20 km from the shoreline) falls under the Kachchh (6749.77 $km^2$), Jamnagar (4863.53 $km^2$) and Rajkot (576.71 $km^2$) Districts. Cotton is the dominant crop in the Kachchh District while it is oil seeds in the Jamnagar and Rajkot Districts. Bajra, pulses, wheat, sugarcane etc are the other common crops in the region. The general vegetation in the area is sparse and scattered and of tropical dry mixed deciduous scrub and desert thorn type belonging to the xerophytic group.

Due to extreme unreliability of rainfall in the region, ground water is a more reliable source of water for domestic as well as agricultural needs. However, uncontrolled and indiscriminate withdrawal of ground water has resulted in a sharp decline in water table in the coastal belt causing ingress of salinity. The conditions are of considerable concern in Jodia and Okhamandal Talukas of the Jamnagar District and severe in Lakhpat and Anjar Talukas of the Kachchh District.

The coastal region of the Gulf is industrially less developed and the majority of large-scale industries including the RIL refinery is located in the Jamnagar District. Kachchh District is industrially backward and except for lignite mining, thermal power plant, fertilizer plant and Mundra and Kandla Ports, there are no major industries in the district. Okha and Bedi are the two important intermediate ports in the Jamnagar District.

## 3.2 Meteorological conditions

The Gulf is a semi-arid region with weak and erratic rainfall confined largely to the June-October period. With a few rainfall days, the climate is hot and humid from April till October and pleasant during brief winter from December to February. Rainfall alone forms the ultimate source of freshwater resource to the region. The average rainfall at Mundra is 414 mm/y on the northern coast and 490 mm/y at Mithapur on the southern coast.

The wind records at Okha indicate that (a) the speed varies between 0 and 30 km/h during November-February; the predominant direction being NW - NE, (b) the speed marginally increases during March-April with the change in direction to NW-SW, (c) maximum speeds (40-50 km/h) occur during May with predominant SW-W direction and (d) maximum speeds can reach upto 70 km/h with predominant SW-W direction during depressions in June - September.

Cyclonic disturbances strike North-Gujarat, particularly the Kachchh and Saurashtra regions, periodically. These disturbances generally originate over the Arabian Sea and sometimes the Bay of Bengal. The details of number of cyclonic storms, which struck the north Gujarat region during the last 100 y, are given in Table 3.2.1. Generally during June, the storms are confined to the area north of 15$^{o}$N and east of 65$^{o}$E. In August, in the initial stages, they move along the northwest course and show a large latitudinal scatter. West of 80$^{o}$E, the tracks tend to curve towards north. During October the direction of movement of a storm is to the west in the Arabian Sea. However, east of 70$^{o}$E some of the storms moves north-northwest and later recurve northeast to strike Gujarat-north Mekran coast.

The relative humidity is generally high during June-September (60-85 %) and marginally decreases during rest of the year (30-80 %). The sky is generally clear or lightly clouded except during monsoon period. Visibility is good throughout the year. However, average visibility of less than 1 km can be expected for a few days during the winter months.

## 3.3 Marine environment

Within the Gulf, though water depths of 25 m exist in the broad central portion upto the longitude 70$^o$E, the actual fairway in the outer Gulf is obstructed by the presence of several shoals. The high tidal influx covers the low lying areas of about 1500 km$^2$ comprising a network of creeks and alluvial marshy tidal flats in the interior region. The creek system consists of 3 main creeks Nakti, Kandla and Hansthal, and the Little Gulf of Kachchh interconnecting through many other big and small creeks. All along the coast, very few rivers drain into the Gulf and they carry only a small quantity of freshwater, except during the brief monsoon. They are broad-valleyed and their riverbed is mostly composed of coarse sand and gravel. The Gulf is characterised by numerous hydrographic irregularities like pinnacles, as much as 10 m high. The southern shore has numerous islands and inlets covered with mangroves and surrounded by coral reefs. The northern shore is predominantly sandy or muddy confronted by numerous shoals.

### 3.3.1 Physical processes

Tides in the Gulf are of mixed, predominantly semidiurnal type with a large diurnal inequality. The tidal front enters the Gulf from the west and due to shallow inner regions and narrowing cross-section, the tidal amplitude increases considerably, upstream of Vadinar. The tidal elevations (m) along the Gulf are as follows:

| | MHWS | MHWN | MLWN | MLWS | MSL |
|---|---|---|---|---|---|
| Okha | 3.47 | 2.96 | 1.20 | 0.41 | 2.0 |
| Sikka | 5.38 | 4.35 | 1.74 | 0.71 | 3.0 |
| Rozi | 5.87 | 5.40 | 1.89 | 1.0 | 3.6 |
| Kandla | 6.66 | 5.17 | 1.81 | 0.78 | 3.9 |
| Navlakhi | 7.21 | 6.16 | 2.14 | 0.78 | 4.2 |
| Navinal Pt | 6.09 | 5.65 | 1.81 | 0.37 | 3.4 |

The phase lag between Okha and Kandla is 2 h to 2 h 25 min while between Okha and Navlakhi it is 3 h to 3 h 20 min. Due to high tidal ranges in the inner regions, the vast mudflats and coastal lowlands that get submerged during high tide, are fully exposed during low tide.

Circulation in the Gulf is mainly controlled by tidal flows and bathymetry, though wind effect also prevails to some extent. The maximum surface currents are moderate (0.7-1.2 m/s) but increase considerably (2.0-2.5 m/s) in the central portion of the Gulf. The spring currents are 60 to 65 % stronger than the neap currents. The bottom currents are also periodic with a velocity normally 60-70 % of the surface currents. With high tidal range, negligible land run-off and irregular topography, the waters are vertically homogeneous in terms of salinity and temperature.

### 3.3.2 Water quality

The general water quality of the Gulf is illustrated in Tables 3.3.1 and 3.3.2. The annual variation of water temperature is between 23 and 30$^{o}$ C though localised higher temperatures upto 35$^{o}$ C can result in isolated water pools formed in shallow intertidal depressions, during low tide.

SS is highly variable (5-700 mg/l), spatially as well as temporally, and largely result from the dispersion of fine sediment from the bed and the intertidal mudflats, by tidal movements. Evidently, nearshore shallow regions invariably sustain higher SS as compared to the central portions. The region between Okha and Sikka has low SS varying within a narrow range (10-50 mg/l) whereas the inner Gulf areas contain markedly higher SS, sometimes in excess of 100 mg/l.

Average pH of the Gulf water is remarkably constant (8.0-8.3) and is within the range expected for the coastal tropical seas. The evaporation exceeds precipitation leading to salinities markedly higher than that of the typical seawater. This is particularly evident in the inner Gulf where salinities as high as 40 ppt have been reported to commonly occur off Kandla and Navlakhi. Although the salinities decrease considerably for a brief period in some creeks of the Little Gulf of Kachchh under the influence of monsoonal runoff, the impact of this decrease in salinity in the Gulf proper is small and salinities exceed 36 ppt off Sikka and Mundra during normal monsoon periods.

The average DO is fairly high (3-5 ml/l) and the BOD is low (<0.1-4.0 mg/l) indicating good oxidising conditions. Hence, the organic load in the water column is considered to be effectively oxidised. The nutrients ($PO_4^{3-}$-P, $NO_3^-$-N, $NO_2^-$-N, $NH_4^+$-N) are more or less uniformly distributed in the Okha-Sikka-Mundra segment and their concentrations indicate healthy natural waters. Their levels however are marginally high in the Kandla-Navlakhi segment. The networks of creeks of the Little Gulf of Kachchh sustain high natural concentrations of nutrients perhaps due to high regeneration rates. As expected for an unpolluted coastal environment, the concentrations of PHc and phenols are low.

### 3.3.3 Sediment quality

Central portion of the Gulf extending from the mouth to upstream of Sikka is rocky with sediments confined only to the margins. The nearshore sediment that consists of light gray silt and clay and fine sand with patches of coarse sand in-between, are poorly sorted with highly variable skewness. The major source of this sediment is considered to be the shore material and the load transported by the Indus River. The portion of sediment derived from the hinterland is considered to be small because of the low run-off. Moreover, the streams discharging in the Gulf (during brief monsoon season) are short with dams constructed on many of them.

The concentrations of heavy metals such as chromium, manganese, cobalt, nickel, copper, zinc, mercury and lead though variable (Tables 3.3.3 and 3.3.4), indicate natural background levels and there is no evidence of gross sediment contamination. The concentrations of PHc are also low though large quantities of petroleum crude and its products are off-loaded at Vadinar and Kandla respectively.

### 3.3.4 Flora and fauna

The Gulf abounds in marine wealth and is considered as one of the biologically richest marine habitat along the west coast of India. Quantitative information for selected biological characteristics of the Gulf is given in Tables 3.3.5 to 3.3.10

The marine flora is highly varied, which includes sand dune vegetation, mangroves, seagrasses, macrophytes and phytoplankton. The dominant species of sand dune flora are *Euphorbia caudicifolia, E.nerifolia, Aloevera* sp, *Ephedra foliata, Urochodra setulosa, Sporobolus maderaspatenus, Eragrostis unioloides, Calotropis procera, Fimbristylis* sp, *Indigofera* sp and *Ipomoea pescaprae*. The common seagrasses found growing on the mud flats are *Halophila ovata, H.beccarii* and *Zostrea marina*.

The most common marine algal species are *Ulva fasciata, U.reticulata, Enteromorpha intenstinalis, Dictyota* sp, *Hypnea musciformis, Sargassum tennerimum, S.ilicifolium, Gracilaria corticata, Cystocera* sp, *Padina tetrastomatica, Corallina* sp, *Laurencia* sp, *Caulerpa racemosa, C.peltata, Bryopsis* sp, *Turbinaria* sp, *Ectocarpus* sp, *Acanthophora* sp, *Chondria* sp, and *Codium* sp (Table 3.3.5).

The primary production of the water column as assessed from chlorophyll *a* concentrations is generally good in the outer Gulf but decreases in the inner regions (Tables 3.3.6 and 3.3.7). The major phytoplankton genera are *Rhizosolenia, Synedra, Chaetoceros, Navicula, Nitzschia, Pleurosigma, Thalassiothrix, Biddulphia, Stauroneis, Coscinodiscus* and *Skeletonema*.

The Gulf has a vast intertidal area with rich biota. Sheltered bays, creeks and mud flats provide ideal sites for mangrove vegetation over an estimated area of about 1036 $km^2$ (Table 3.3.8). The formations are of open scrubby type, with isolated and discontinuous distribution from Kandla-Navlakhi in the northeast to Jodia, Jamnagar, Sikka, Salaya and Okha in the southwest, as also at Pirotan, Poshitra, Dohlani and Dwarka. Vast stretches of mangroves also exist along the northern shore of the Gulf. The dominant species of mangroves are *Avicennia marina* var *acutissima, A officinalis, Bruguiera parviflora, B gymnorphiza, Rhizophora mucronata, R apiculata, Ageiceros corniculata* and *Sonneratia apetata* along with the associated species of *Salicornia brachiata, Sueda fruticosa, Artiplex stocksii* and a lichen, *Rosella montana*.

The marine fauna of the Gulf is rich, both in variety and abundance. Sponges having an array of colours are seen, both in the intertidal and subtidal biotopes. The common species of sponge is *Adocia* sp, associated with coral reef fauna. In sandy and silty mud shores, *Tetilla dactyloidea* (Carter) is common.

The most frequently encountered hydrozoans are *Sertularia* sp and *Plumularia* sp. The giant sea anemone (*Stoichactis gigantum*) is a common sight in the coral ecosystem. Sea anemones, belonging to *Anemonia, Bunodactis, Paracondylactis, Anthopleura* and *Metapeachia,* are wide spread. A zoantharian, *Gemmaria* sp, is found forming extensive hexagonal green mats in the coral pools. Another interesting actiniarian is the *Cerianthus* sp found in tubes in the soft mud.

One of the most interesting biotic features of the Gulf is the presence of living corals, thriving as patches, rather than reefs, either on the intertidal sand stones or on the surface of wave-cut, eroded shallow banks along the southern shore of the Gulf. The species diversity however is poor with identification of 44 species of Scleractinian and 12 species of soft corals (Table 3.3.9).

A number of polychaete worms, both sedentaria and errantia, with the dominant genera of *Eurythoe, Terebella, Polynoe, Iphione* and *Nereis* are rather common. Amongst a variety of sipunculid and echiuroid worms, the dominant species are *Dendrosromum* sp, *Asphidosiphon* sp and *Ikadella misakiensis* (Ikeda). The intertidal crustacean fauna is very rich and equally diverse with spider crab (*Hyas* sp) and furry crab (*Pillumnus* sp), as specialities.

Amongst the invertebrate component of the marine fauna of the Gulf, the molluscs have the highest representatives. As many as 92 species of bivalves, 55 species of gastropods, 3 species of cephalopods and 2 species each of scaphopods and amphineurans have been reported. The most notable members of the molluscan fauna are octopus, pearl oyster and a variety of chanks, including the sacred chank.

The echinoderm fauna, represented by 4 classes and 14 genera have the commonest genera of *Palmpsis, Astropecten, Asteria, Temnopleura* and *Holothuria*. The subtidal benthic fauna of the Gulf is dominated by polychaetes, crustaceans, echinoderms, gastropods and bivalves, with an average biomass of 25 g/m$^2$.

The Gulf has a variety of exploitable species of finfishes and shellfishes. Sciaenids, polynemids, perches, eels, cat-fishes, elasmobranchs and prawns are the commercially important groups with an average catch of $1.4x10^5$ t/y. Fishing grounds for Ghol, Karkara, Khaga, Dhoma, Magra and Musi exist in the Gulf.

The Gulf region offers plenty of facilities for feeding, breeding and shelter to a variety of birds (Table 3.3.10). In the mangrove forests lining the islands and along the coast, the birds find a near perfect environment. In addition, they are well placed to reach their food supply i.e. the shoals of fish, squids, mud-skippers and other animals, during low tide. All along the creeks and around islands, mangrove trees and mudflats are seen crowded with Grey Herons, Pond Herons, Painted Storks, Large and small Egrets, Reef Heron, Darters, Cormorants, Flamingos, Lesser Flamingos, etc during the periods of seasonal migration (November-March).

A large number of migratory birds pass through the Gulf and a small population of most species comprising mainly of juveniles and non-breeding adults take shelter in this area during summer. Salt works spread-out along the coast, are also important for feeding and breeding of birds. They act as alternate sites for them to roost during high tide.

Though a detailed systematic survey of biota is lacking, following number of species have been reported:

| Flora/Fauna | Species (no) |
|---|---|
| Algae | 130 |
| Sponges | 70 |
| Corals | 37 |
| Fishes | 200 |
| Sharks | 8 |
| Prawns | 27 |
| Crabs | 30 |
| Molluscs | 200 |
| Sea turtles | 3 |
| Sea mammals | 3 |
| Birds | 200 |

Because of its high biogeographical importance and rich flora and fauna, several areas along the southern Gulf are notified (Figure 1.4.1) under the Marine National Park (16289 ha) and the Marine Sanctuary (45798 ha).

# 4 SITE SPECIFIC MARINE ENVIRONMENT

## 4.1 Area description

The assessment domain of the present study involved the section of the Gulf off Tunda-Vandh. The coastal stretch of the Gulf has variegated topography with vast intertidal mudflats criss-crossed by numerous creeks, which transport seawater several kilometres inland due to high tidal ranges. In general, Bocha, Navinal, Baradi Mata and Kotdi creeks are the major tidal inlets in the vicinity of the Mundra Port area, which are broad but shallow and navigable only during flood tide. Occurrence of a large number of creeks has created a number of islets; the prominent being the Navinal and Bocha Islands. These two islands are separated by the Navinal Creek, which in the interior joins the Bocha as well as the Baradi Mata Creeks. The intertidal mudflats and many of the creeks of the surrounding area harbour mangroves and associated biota though several areas have suffered damage due to anthropogenic pressures. Large stretches of mangroves also suffered destruction during the cyclone of June 1998.

The region is semi-arid with average annual rainfall of <400 mm. The precipitation being erratic, the agricultural produce, which is dependent on rains, fluctuates considerably. As a result, the farming which has been the major occupation of the local inhabitants is gradually declining with the people shifting over to other occupations such as services, construction work etc.

May and June are generally the hottest months with a mean maximum temperature of about 37$^{o}$C. The coldest month is January with a mean minimum temperature of around 10$^{o}$C. In the winter season, the lowest temperatures can be below 5$^{o}$C under the influence of cold waves. The relative humidity is moderate (55%) most of the time though higher humidity (70-80%) occurs during monsoon months.

The wind records of Bhuj indicate that (a) during November-February the wind speed varies between 0 and 30 km/h; the predominant direction being NW-NE, (b) the wind direction changes to NW-SW during March-April with a marginal increase in wind speed, (c) during May the predominant direction is SW-W with maximum speeds between 40 and 50 km/h, and (d) during monsoon (June-September) the wind direction is predominantly SW-W and maximum speeds can reach 60 - 70 km/h.

Nagmati, Bhukhi and Phat Rivers are the major drainage streams of Mundra Taluka, which originate from the slopes of the central highland. These rivers are however dry and carry land runoff to the Gulf in brief spells only during monsoon.

The ground water is the major source for domestic use. The quality and availability however is variable depending on the rainfall, topography and hydrological setting. The level of water suitable for drinking and irrigation ranges from 5 to 35 m below the ground. The water at greater depths tends to be saline. Increased rate of extraction and scanty rainfall in recent years has not only led to groundwater depletion but seawater ingress has occurred in many areas along the coast.

The fertility of the coastal soil is affected by salinity. The vegetation mainly consists of trees, shrubs, under shrubs and climbers with stunted growth with an admixture of xerophytes and thorny species. The dominant floral species are of *Phoenix sylvestris, Achras zapota, Prosopis juliflora, Acacia senegal, Mytenus emarginatea* and *Acacia nilotica*. The shrub community is dominated by the species of *P. juliflora* and *Indigofera oblongifolia*.

The region between Mundra and Mandvi on the northern coast of the Gulf of Kachchh is interspersed with numerous creeks and islets. Some of these islets exhibit mangrove vegetation in their lower fringes where as some are made up of sand and sand dune vegetation.

The area proposed for the development of power plant of CGPL is located between two ephemeral rivulets namely Khari Nadi in the west and Wae, a contributory of Nagavati river in the east. There are two moderate size villages Tunda and Vandh in the vicinity of the project site. The intertidal area of this region is devoid of mangroves. The bottom is sandy and the inlets are partially sedimented. Tidal water enters the creek about 1-1.5 h after low water slack during spring and remains well connected, though not navigable, during neap and average low waters. Some of the sandy beaches are used by local fisher folk for beaching their shallow draft crafts and land above high water line for drying fish. The prominent vegetation is mainly composed of Babool (*Presopsis julifolia*). Mundra, the nearest major town is approximately 28 km in the E-NE direction.

## 4.2 Physical processes

### 4.2.1 Tides

Tide levels recorded at Mundra port are compared with the predicted tide at Kandla Port in the following table:

| | Mundra | Kandla |
|---|---|---|
| Spring high water (m) | 6.09 | 7.04 |
| Neap high water (m) | 5.65 | 6.84 |
| Neap low water (m) | 1.81 | 2.50 |
| Spring low water (m) | 0.37 | 0.17 |

A comparison between the data sets for the two ports indicates that the time of occurrence of flood and ebb tide at Mundra lead by 27 and 46 min respectively with respect to the Kandla tide. The tidal range ratio (Mundra : Kandla) is 0.83 and 0.88 for spring and neap tides respectively.

The mean sea level at the Mundra Port (Bocha Creek) is estimated at 3.31 m (above CD) which is comparable to that reported for Navinal Point (3.38 m) in the Admiralty Tide Tables. Tide was also measured at Kotdi Creek during January 2006 (Figure 4.2.1). The tidal ranges during this period vary from 1 to 3.5 m with the time lag of 5 to 10 min as compared to the phase of the tide at the Mundra Port. The tide recorded during April 2006 (Figure 4.2.2) at both the mouth of Kotdi creek and inside Kotdi creek indicates that the site of measurement inside the creek is about 1.8 m above CD. During this period the spring low water at Kotdi mouth is 1.0 above CD which indicates that the tidal flow is not available in the Kotdi creek for about 1.5 h during end of the spring ebb and a similar duration in the beginning of the following flood. This renders the creek partially dry and partially stagnant for about 3 h in a flood tide. The neap tide is of comparable magnitude in the creek as well as the mouth area of the creek.

### 4.2.2 Currents

The currents in the Gulf and associated creeks are largely tide induced and oscillations are mostly bimodal reversing in direction with the change in the tidal phase. Influence of wind on variations in current is minor. The current reversals are quite sharp occurring within 30 - 60 min. Currents were recorded at station 2 off Vandh (Figures 4.2.3 to 4.2.5). The U component of the currents (Northward) is stronger than the V component indicating weak lateral transport, as expected. The maximum current speed varied from 0.5 to 1.2 m/s. The predominant direction of the current is $45^o$ during flood and $220^o$ during ebb.

### 4.2.3 Circulation

The drogue studies conducted from station 2 (Figures 4.2.6 to 4.2.9) indicate that the circulation is generally elliptical with the major axis in the east-west direction. These trajectories suggest that the excursion lengths are in the range of 10 to 15 km depending on the tidal phase (neap or spring).

## 4.3 Water quality

The water quality was assessed around Tunda-Vandh at 6 subtidal stations during December 2008. Since the water quality can vary temporally in areas swept by strong tides, hourly measurements were conducted at station 2 to assess tidal variability of selected water quality parameters and other stations were monitored with spot sampling. These variations are presented in Tables 4.3.1 to 4.3.6 and Figure 4.3.1.

### 4.3.1 Temperature

Temperature of water is an important parameter and influences chemical processes in water such as dissolution – precipitation, adsorption, desorption, emulsification, flocculation, oxidation etc. For instance dissolution of gases such as ammonia and oxygen decreases with increase in temperature while some solids may precipitate out due to decrease in solubility at lower temperature. Some contaminants like PHc may absorb at high temperature and concentration of some materials may enhance due to increase in solubility at lower temperature. As a result of absorption of solar radiation, the water temperature of a well mixed water body varies in accordance with air temperature while in a water body having a restricted mixing, a thermal gradient may occur. Due to the natural changes in climatic conditions, the temperature of water fluctuates daily as well as seasonally.

The temperature of the coastal waters around Vandh varied in accordance with the air temperature. The range of temporal as well as spatial variations were small (Tables 4.3.1 to 4.3.6). The water around Vandh was vertically well mixed and comparable with earlier studies.

| Period | Temperature (ºC) |
|---|---|
| January 2006 | 19.0-23.0 (20.8) |
| April 2006 | 25.9-29.0 (27.3) |
| April 2007 | 27.5-29.1 (28.4) |
| October 2007 | 28.1-30.1 (29.2) |
| December 2008 | 24.5-27.5 (26.0) |

### 4.3.2 pH

pH is the measure of hydrogen ion activity in water. It is known as the master variable in water since many properties, processes and reactions are pH dependent. The pH of seawater is largely controlled by the $CO_3^{2-}$/ $HCO_3^-$/ $CO_2$ system. When the primary productivity is high $CO_2$ is consumed during photosynthesis, which shifts the equilibrium that favors higher pH. Comparable pH values from 2006 are given below for the area.

| Period | pH |
|---|---|
| January 2006 | 8.0-8.3 (8.1) |
| April 2006 | 7.8-8.0 (8.0) |

| Period | pH |
|---|---|
| April 2007 | 7.7-8.0 (7.9) |
| October 2007 | 8.1-8.3 (8.2) |
| December 2008 | 7.9-8.1 ( 8.0 ) |

It is evident from the above table that the pH variations in the coastal system have been negligible. Temporal variations were also minor as evident from the Figure 4.3.1.

### 4.3.3 Suspended Solids

SS is the description term used for suspended / settleable particulate matter in the water column. SS of natural origin mostly contains clay, silt and sand derived bottom and shore sediment and plankton. For nearshore, coastal areas and estuaries, clay and vegetation matter form an important component of SS. Since the major contribution to SS comes from the disturbance of bed and shore sediment, tidal currents is the vital influencing factor for the level of SS and typically lead to high values in the bottom waters. Anthropogenic discharges add a variety of SS depending upon the source. The coastal waters around Vandh sustained low suspended solids (22-54 mg/l) when compared with earlier studies as is evident below.

| Period | SS (mg/l) |
|---|---|
| January 2006 | 30-214 (57) |
| April 2006 | 16-49 (28) |
| April 2007 | 28-252 (70) |
| October 2007 | 18-209 (83) |
| December 2008 | 22-54 (34) |

SS is expected to be largely inorganic in nature and results from the dispersion of fine grained sediment from the bed as well as the banks by tidal currents. Hence the bottom water sustained marginally high SS as compared to that at the surface (Tables 4.3.1 to 4.3.6).

### 4.3.4 Salinity

Salinity is an indicator of freshwater intrusion in nearshore coastal waters as well as excursion of salinity in inland water bodies such as estuaries, creeks and bays. Normally seawater salinity is 35.5 ppt but may vary depending on evaporation, precipitation and freshwater addition. Salinity largely influences several processes such as dissolution, dispersion, dilution etc in seawater due to high dissolved salt content and high density. The range and average salinities at different stations around Vandh are presented in Tables 4.3.1 to 4.3.6. In the absence of fresh water inflow the salinity varied from 35.9 to 38.0 which compared well with earlier results as shown below.

| Period | Salinity (‰) |
|---|---|
| January 2006 | 36.5-37.8 (37.2) |
| April 2006 | 36.4-37.3 (36.9) |
| April 2007 | 35.0-36.9 (35.8) |
| October 2007 | 34.0-35.2 (34.5) |
| December 2008 | 35.9-38.0 (36.6) |

Temporal as well as spatial variations were minor (Fig 4.3.1). Minor variations in surface and bottom samples suggested that the water in the study area was vertically well mixed.

### 4.3.5 DO and BOD

DO content of water is a vital water quality parameter influencing the aquatic biota. DO is an important constituent and is significant in the protection of aesthetic qualities of water as well as maintenance of aquatic life. Although there is considerable dispute on the minimum level of DO required for a healthy tropical marine environment, it is considered that the DO level should not fall below 3ml/l prolonged periods in creeks, estuaries and coastal waters for health of ecosystem. Hence, it is of considerable interest in water quality investigations as its concentration in water is an indicator of prevailing water quality and ability of a water body to support a well balanced aquatic life. The sources of DO in seawater are photosynthesis and dissolution from the atmosphere at air-water interface. This vital parameter is linked with the health of aquatic life including fishes. However, DO is consumed during microbial oxidation of organic substances which is measured in terms of BOD.

The DO in the waters off Vandh varied from 2.9 to 5.4 ml/l and was generally >3.0 ml/l (Tables 4.3.1 to 4.3.6). The average DO was 4.1 ml/l. The present range and average DO values around Vandh are compared with earlier studies and presented below.

| Period | DO (ml/l) | BOD (mg/l) |
|---|---|---|
| January 2006 | 1.8-5.6 (4.4) | 0.5-4.0 (1.5) |
| April 2006 | 4.6-4.9 (4.8) | 0.8-5.2 (3.0) |
| April 2007 | 2.9-5.0 (2.6) | 0.2-4.5 (2.0) |
| October 2007 | 2.6-5.9 (4.3) | 0.2-4.6 (1.8) |
| December 2008 | 2.9-5.4 (4.1) | <0.2-5.4 (2.4) |

All waters contain some oxidisable matter in low concentration, leading to BOD, which can be 2 to 5 mg/l. The BOD around Vandh varied from <0.2-5.4 mg/l during the study period (Tables 4.3.1 to 4.3.6).

### 4.3.6 Nitrogen and phosphorous compounds

Dissolved phosphorus and nitrogen compounds play a major role in primary productivity of a water body which in turn influences the fishery since they are vital nutrients for the growth of phytoplankton. Phosphorus is present as orthophosphate, while nitrogen in mainly present as nitrate with low concentration of nitrite and ammonia. Nitrite is thermodynamically unstable and ammonia is biochemically oxidized to nitrate via nitrite apart from being directly assimilated by algae. Hence, concentration of nitrite and ammonia are often very low in natural waters. The concentrations of nitrogen and phosphorus compounds in the coastal waters of Vandh are presented in Tables 4.3.1 to 4.3.6 and suggest that though the concentrations are variable but are as expected for the coastal waters of the region as evident from the data given below:

| Period | $NO_3^-$-N | $NO_2^-$-N | $NH_4^+$-N | $PO_4^{3-}$-P |
|---|---|---|---|---|
| January 2006 | 1.9-12.6 (6.5) | 0.2-0.5 (0.4) | ND-6.1 (0.4) | 0.4-2.3 (1.6) |
| April 2006 | 3.2-6.2 (4.0) | 0.3-0.5 (0.4) | 0.3-1.2 (0.7) | 0.5-1.5 (1.0) |
| April 2007 | 2.7-10.1 (5.6) | 0.2-.0.8 (0.4) | ND-0.7 (0.3) | 0.4-2.3 (1.4) |
| October 2007 | 2.2-11.4 (8.0) | 0.1-0.5 (0.3) | ND-4.3 (0.8) | 0.5-2.1 (1.2) |
| December 2008 | 5.2-10.6 (7.0 ) | 0.2-0.6 (0.4 ) | 0.1-1.3 (0.7) | 1.3-3.5 (2.1) |

### 4.3.7 Phenols and PHc

Natural water contains trace levels of PHc and phenols. However, their occurrence in high concentration is often due to external perturbations. The comparison with past levels of phenols and PHc in the coastal waters of Vandh are summarized in the table below.

| Period | PHc (ug/l) | Phenol (ug/l) |
|---|---|---|
| January 2006 | 2.4-22.6 (15.5) | 10-62 (21) |
| April 2006 | 9.8-28.1 (20.3) | 10-64 (28) |
| April 2007 | 5.4-19.2 (11.5) | 29-67 (47) |
| October 2007 | 30-79.4 (50.5) | 14-103 (58) |
| December 2008 | 0.8-3.1 (1.6) | 3.4-52.5 (14.4 ) |

These results indicate that such concentrations of PHc and phenols in the coastal waters commonly occur which are not mainly influenced by the anthropogenic release in the system.

## 4.4 Sediment quality

The concentrations of several contaminants such as trace metals, PHc etc in aquatic sediment increases in areas receiving their anthropogenic fluxes. This is because these pollutants on entering water are absorbed by the suspended particulate matter and some like heavy metals are also hydrolysed and precipitated before adsorption. The suspended load on settling enriches the bed material with these pollutants. Hence, the analysis of sediments serves as a useful indicator of pollution status with respect to these contaminants.

### 4.4.1 Texture

The sediment texture along the open shore around Vandh and the intertidal areas were found to be generally sandy (Table 4.4.1).

### 4.4.2 Heavy metals

Determination of trace pollutants such as heavy metals and organic compounds in water often reveals wide fluctuation as their concentrations depend on the location and time of sampling, nature of pollutants and chemical characteristics of water. Moreover, several trace pollutants get rapidly fixed to SS and thus get removed from the water column. It has been observed in several instances that even close to location of effluent release the metal content in water decreases to normal value making the assessment of ambient concentration through analysis of water, a difficult task.

The pollutants adsorbed on the SS are ultimately transferred to the bed sediment, on settling evidently, the concentrations of pollutants in sediment increases over a period of time in regions receiving their fluxes. Hence if the levels of the pollutants in sediment are reliably known prior and after release of industrial effluent into marine environment the impact due to pollutants can be identified and data may be used for future assessment.

The concentration of heavy metals around Vandh in subtidal as well as intertidal sediments are presented in Table 4.4.1. The range in concentration of metal content in sediment varied as follows:

| Elements | Jan 2006 | Apr 2006 | Apr 2007 | Oct 2007 | Dec 2008 |
|---|---|---|---|---|---|
| Al (%) | 1.2-9.0 | 1.0-6.8 | 1.2-6.6 | 0.6-7.6 | 0.4-1.3 |
| Cr (µg/g) | 17-69 | 5-67 | 20-115 | 2-70 | 32-45 |
| Mn (µg/g) | 296-928 | 677-1566 | 260-1244 | 296-1566 | 253-799 |
| Fe (%) | 1.4-8.9 | 1.3-5.0 | 0.4-5.0 | 0.3-1.4 | 0.4-3.1 |
| Co (µg/g) | 11-38 | 5-58 | 6-28 | - | 2-6 |
| Ni (µg/g) | 9-61 | 6-58 | 11-58 | 3-39 | 5-9 |
| Cu (µg/g) | 10-42 | 4-32 | 6-33 | 2-26 | 6-10 |
| Zn (µg/g) | 94-767 | 162-242 | 21-80 | 3-91 | 18-28 |
| Hg (µg/g) | - | ND-0.04 | 0.01-0.04 | 0.01-0.03 | - |

It is evident from the table that the concentrations of most metals are comparable with earlier studies. In the absence of any anthropogenic releases of metals to marine area the above concentrations can be considered as base line for future assessments.

### 4.4.3 Organic carbon and phosphorus

Generally organic matter in natural marine sediment originates from the terrestrial runoff. Anthropogenic organic inputs however can increase the content of organic matter to abnormal levels disturbing the equilibrium of the ecosystem. Organic matter settling on the bed is scavenged by benthic organisms to a large extent. The balance is decomposed in the presence of DO by heterotrophic microorganisms. Hence, DO in sediment-interstitial water is continuously consumed and anoxic conditions develop if the organic matter is more than that can be oxidised through oxygen as an oxidant. Such anoxic conditions are harmful to benthic fauna. The level of $C_{org}$ in the sediments around Vandh is presented in Table 4.4.1. Over all concentration of $C_{org}$ (av 0.2%) shows that concentration of organic carbon is meagre off Vandh. Comparison with available data given below also gives the conclusion that the levels are low and do not indicate any accumulation of the constituent in the sediment.

| Period | Concentration (%) |
|---|---|
| April 2006 | 0.6 |
| December 2008 | 0.2 |

### 4.4.4 Phosphorus

Lithogenic phosphorus in marine sediments is derived from the geological sources through river flows, while, the anthropogenic phosphorus is the result of sewage and industrial discharges, agricultural runoff etc. The concentration of phosphorus (µg/g; dry wt) in sediments around Vandh are presented in Table 4.4.1 and varied in the range of 381 to 724 µg/g. These concentrations though variable, are comparable to those recorded in the sediment of other areas of the Gulf and do not indicate its enrichment in the sediments. The comparison of current levels of the element with that of April 2006 does not show wide variation as depicted below.

| Period | Concentration (µg/g) |
|---|---|
| April 2006 | 188 -631 |
| December 2008 | 381 - 724 |

### 4.4.5 Petroleum hydrocarbon

Naturally occurring low PHc content is associated with vegetation decay, erosion etc. PHc entering through the spillage on water partly evaporates and the leftover residue eventually sinks to the bottom due to increase in density or its incorporation with particulate matter. Thus bed sediment serve as a sink for PHc and its high level may indicate gross sediment contamination in the region. The concentration of PHc around study area is presented in Table 4.4.1. The PHc content (µg/g wet weight) in the sediment in the surrounding region varied in the following range and suggests insignificant accumulation in the sediment.

| Period | Concentration (µg/g) |
|---|---|
| April 2006 | ND - 0.4 |
| December 2008 | 0.1-1.2 |

### 4.5 Flora and fauna

Whenever probable implications of a coastal development on marine environment are assessed, it must be remembered that despite many changes the development may cause in the physico-chemical properties of the coastal marine ecosystem including the bed sediments, the ultimate concern is inevitably the biological resource. Hence, the assessment of status of flora and fauna at the development site is very important. Floral and faunal components in the coastal zone are highly diverse inhabiting a variety of ecosystems. However, it is not practical to include all components in a monitoring programme and EIA studies because of shear complexity of ecosystem. However, areas of high ecological importance such as zones of rich biological productivity and feeding, breeding, spawning and fishing grounds of economically important organisms which can be degraded due to a coastal activity should be studied in more detail and should be included in the investigations of this nature.

The living community of an ecosystem comprises of consumers, producers and decomposers and related non-living constituents interacting together and interchanging materials as a whole system. The basic process in an aquatic ecosystem is the primary productivity. The transfer of energy from the primary source through a series of organisms is defined as the food chains, which are of two basic types; the grazing food chain and the detritus food chain. The stress may cause the communities to exhibit low biomass and high metabolism. In addition, due to depressed functions of less tolerant predators, there may be also a significant increase of dead organic matter deposited in sediments of ecosystems modified under stress. Depending upon the type, strength and extent of a stress factor, the ecosystem will react to either re-establish the previous equilibrium or establish a new one, or it may remain under prolonged disequilibrium.

The biological parameters considered for the present monitoring study are phytoplankton pigments and cell count, zooplankton standing stock and population, macrobenthic biomass and population, mangroves and fishery status. The first two reflect the productivity of water column at the primary and the secondary levels. Benthic organisms being sedentary animals associated with the seabed, provide information regarding the integrated effects of stress, if any, and hence are good indicators of early warming of potential damage. Assessment of mangroves and corals are considered as a part of overall ecological evaluation. The aggregate data presented in Tables 4.5.1 to 4.5.23 and Figures 4.5.1 and 4.5.2 is used to evaluate the status of flora and fauna in the coastal system off Vandh.

### 4.5.1 Seaweeds, seagrasses and mangrove ecosystem

Marine flora like algae and mangrove play a significant role in enriching nearshore sea, by adding dissolved organic matter, nutrients and detritus besides serving as nursery areas for the larvae and juveniles of several marine animals.

Coastal vegetation such as seaweeds, seagrasses and mangroves were studied from the subtidal to the HTL within the proposed development site where the intertidal region is largely sandy - silt. The marine alga *Enteromorpha* sp commonly occured in the intertidal area while seagrasses were dominated by *Halophila ovata* and *Halodule uninervis*.

**Mangrove ecosystem**

Mangroves are salt tolerant forest ecosystem of tropical and subtropical intertidal regions of the world. Where conditions are sheltered and suitable, the mangroves may form extensive and productive forests like around Mundra, which are the reservoirs of a large number of species of plants and animals. The role of mangrove forests in stabilizing the shoreline or coastal zone by preventing soil erosion and arresting encroachment on land by sea is well recognised thus minimising water logging and formation of saline banks.

Vegetation of mangrove ecosystem can be divided into the following broad categories.

(a) Mangroves

(b) Salt marshes

(c) Sand stands

**a) Mangroves**

Mangrove forests are extensive along the coastal belt of Kachchh District occupying an area of 1067 $km^2$ as a dense forest; dominant species being *Avicennia* with almost pure stands at place. In some localities these are associated with *Avicennia officinalis, Rhizophora mucronata, Bruguiera gymonorrhiza, Ceriops tagal, Aegiceras corniculatune* and *Sonneratia apetala*. Other associated mangrove flora includes species such as *Salicornia brachiata, Sucieda fruticoa* and *Atriplex stocksii*.

The areas around Kandla-Nakti, Hansthal, Navinal-Bocha, Baradi Mata-Kotdi Creek complex, Kori Creek etc represent the best mangrove formations along the northern shore of the Gulf. These mangrove areas are seen as red patches bordering the creeks in satellite imagery shown in Figure 2.0.1. The composition and ecological status of mangroves and obligate halophytes is given in Table 4.5.1. Mangroves are dominated by *Avicennia marina* and are of fringing type in regularly inundated zones along the water ways. Mangrove belts bordering short segments of Kotdi Creek/Baradimata Creek-2, are degraded and under pressure of camel grazing and cutting for firewood. The stray plants of *Rhizophora mucronata* also occur among *Avicennia* stands. *Salvodora persica* commonly occur in the supralittoral regions towards the HTL.

*Sesuvium portulacastrum* is common at the HTL along the creeks. Beds of *Salicornia brachiata* commonly habit the areas inland of regularly inundated zones or above the mean high tide line. The *Salicornia* stands are more dense towards waterways and become sparse in saline banks. *Sueda maritima* is sparsely distributed in the saline bank regions.

The land portion proposed for the discharge channel falls under saline bank is devoid of mangrove vegetation. Very poor leaching of salts due to low frequency of inundation and poor rainfall result in salt encrustation of saline banks rendering them unsuitable for vegetation to grow except for stray halophytes like *Sueda maritima*. It may be mentioned here that it is a common practice to utilize such saline banks or supralittoral regions of low biological productivity and diversity for salt works in the Gulf.

Overall assessment indicates that the site proposed for the development largely falls under the category of saline banks devoid of mangroves.

**b) Salt marshes**

The vegetation of this zone consists predominantly of *Aeluropes lagopoides,* supported by *Sporoblus* sp. *Cressa cretica* also occur in dried salt marshes and salt pans. Presence of species such as *Cyperus pangorei, Bergia adorata* and *Oldenlandia umbellata* is probably an indication of retrogression due to the detrimental effect of salt works.

**c) Sandy stands**

In the sandy patches between the rocks, a few species such as *Cyperus conglomerates* and *Asparagus demosus* are identified.

### 4.5.2 Phytoplankton

Phytoplankton forms the vast array of minute and microscopic plants passively drifting in natural waters and mostly confined to the illuminated zone. In an ecosystem these organisms constitute primary producers forming the first link in the food chain. Phytoplankton long has been used as indicators of water quality. Some species flourish in highly eutrophic waters while others are very sensitive to organic and/or chemical wastes. Some species develop noxious blooms, sometimes creating offensive tastes and odours or anoxic or toxic conditions resulting in animal death or human illness. Because of their short life cycles, plankton responds quickly to environmental changes. Hence their standing crop in terms of biomass, cell counts and species composition are more likely to indicate the quality of the water mass in which they are found. Generally, phytoplankton standing crop is studied in terms of biomass by estimating chlorophyll *a* and primary productivity and in terms of population by counting total number of cells and their generic composition. When under stress or at the end of their life cycle, chlorophyll *a* in phytoplankton decomposes with phaeophytin as one of the major products.

Phytoplankton biomass is estimated in terms of concentration of phytopigments. The levels of chlorophyll *a* (0.5 – 5.9 mg/$m^3$; av 1.6 mg/$m^3$) and phaeophytin (0.2 – 2.0 mg/$m^3$; av 0.7 mg/$m^3$) varied in wide range in the coastal ecosystem off Vandh (Tables 4.5.2). The variations from the surface to bottom were negligible indicating their uniform distribution throughout the water column. This homogenous nature of the water mass perhaps provided stability for the biological processes. The comparison of their distribution in the area from 2006 to 2008 (present study) is given in the table below.

| Year | Chlorophyll *a* (mg/$m^3$) | Phaeophytin (mg/$m^3$) |
|---|---|---|
| January 2006 | 0.2-14.1 (1.6) | 0.1-10.2 (2.3) |
| April 2006 | 0.2-1.5 (0.7) | 0.2-5.1 (3.5) |
| April 2007 | 0.2-2.3 (0.4) | 0.1-5.6 (2.4) |
| October 2007 | 0.9-3.0 (1.8) | 0.1-2.3 (0.4) |
| December 2008 | 0.5 – 5.9 (1.6) | 0.2-2.0 (0.7) |

It is evident from the above table that average concentrations of chlorophyll *a* and phaeophytin in the sea off Vandh have not changed significantly over the years, though high values had been occasionally observed in January 2006. The average concentration of phaeophytin was often lower or comparable with the concentration of chlorophyll *a* as commonly observed for coastal waters of the Gulf. The temporal variation in phytoplankton pigment concentrations did not show any marked variation (Figure 4.5.1).

In line with the high variability of pigments, the average cell count (no x $10^3$/l) of phytoplankton also varied (Table 4.5.3) dramatically as evident from the following results.

| Year | Cell count ($nox10^3$/l) | Total genera (no) |
|---|---|---|
| January 2006 | 415.2 | 13 |
| April 2006 | 18.2 | 16 |
| April 2007 | 53.3 | 20 |
| October 2007 | 88 | 15 |
| December 2008 | 861.7 | 19 |

These results reveal variable phytoplankton cell counts and generic diversity in the region with marked increase during recent years. These results indicate no regular trend in the distribution pattern of phytoplankton. This can be due to high patchiness and uneven distribution of phytoplankton cells in the coastal waters. The above table also indicates an increase in generic diversity since January 2006. Enhanced generic diversity in association with higher cell counts indicates good conditions for phytoplankton growth.

In the present investigation the generic diversity varied between 13 to 19 (av 17) in the area (Table 4.5.4). Overall, about 31 genera of phytoplankton were recorded in the coastal waters off Vandh during December 2008. The populations were dominated by *Fragilaria, Thalassiosira, Thalassionema, Pleurosigma, Navicula, Nitzschia, Peridinium, Melosira* and *Thalassiothrix*.

### 4.5.3 Zooplankton

By virtue of sheer abundance and intermediate role between phytoplankton and fish, zooplankton is considered as the chief index of utilization of aquatic biotope at the secondary trophic level. Zooplankton includes arrays of organisms, varying in size from the microscopic protozoans of a few microns to some jelly organisms with tentacles of several metres long.

Zooplankton standing stock in terms of biomass (0.4 – 14.1 ml/100m$^3$; av 4.6 ml/100m$^3$) and population (2.3 – 86.2 x 10$^3$/100m$^3$; av 25.3 x 10$^3$/100m$^3$) revealed good secondary production in the coastal waters off Vandh (Tables 4.5.5) though the distribution indicated considerable spatial and tidal fluctuations. The temporal variations in distribution of zooplankton standing stock revealed no particular trend (Figure 4.5.2). The zooplankton standing stock in different segments of the study area recorded during the present study is comparable with the results of earlier studies as seen in the following table.

| Year | Biomass (ml/100m$^3$) | Population (nox10$^3$/100 m$^3$) | Total groups (no) |
|---|---|---|---|
| January 2006 | 1.6-13.1 (5.3) | 5.1-141 (30.2) | 13-21 (17) |
| April 2006 | 1.2-11.0 (4.5) | 9.8-64.6 (22.1) | 13-17 (15) |
| April 2007 | 0.5-17.2 (4.1) | 2.7-207.6 (37.4) | 11-18 (14) |
| October 2007 | 1.3-15.9 (9.1) | 8.0-322.5 (85.0) | 11-19 (15) |
| December 2008 | 0.4-14.1 (4.6) | 2.3-86.2 (25.3) | 9-19 (15) |

Wide spatial variation in zooplankton biomass and population off Vandh is evident from the above results. These variations in zooplankton standing stock are invariably associated with factors like tide, patchiness in their distribution, seasonal changes and grazing pressure within the food chain. Such variations are common to dynamic coastal waters. The above table reveals insignificant seasonal fluctuations in zooplankton standing stock.

The zooplankton community structure showed the dominance of copepods and decapod larvae in the study area as given Table 4.5.5. The other common groups were foraminiferans, siphonophores, medusae, ctenophores, chaetognaths, polychaetes, ostracods, mysids, *Lucifer*, gastropods, lamellibranchs, fish eggs, fish larvae and appendicularians. A total of 23 faunal groups were identified (Table 4.5.6) though all of them did not occur together at any given location. The group diversity of zooplankton varied from 9 to 19 (av 15 groups). It is also evident from the above that the faunal group diversity of zooplankton at different stations was closely comparable.

## Breeding and spawning

To identify breeding grounds of fishes and crustaceans, extensive field observations over a long duration are required. This approach was not possible during the present short term investigations. Hence, alternatively, decapod larvae, fish eggs and fish larvae were studied from zooplankton collections and taken as indices of probable existence of spawning grounds. The adults, caught during trawling, were considered for comparison. The available information on the breeding habits of the species found in the area is also included as supportive literature.

### i) Decapods

This group forms the major constituent of zooplankton and includes the larval stages of commercially important shrimps. During December 2008, the population density varied from 0.4 to 10.1 x $10^3$ no/100 $m^3$ (av 5.7 x $10^3$ no/100 $m^3$) (Table 4.5.7). The average (nox$10^3$/100$m^3$) population of this group off Vandh are summarized here which varies in accordance with the season in line with zooplankton distribution.

| Period | Population (nox$10^3$/100$m^3$) |
|---|---|
| January 2006 | 6.1 |
| April 2006 | 2.3 |
| April 2007 | 0.6 |
| October 2007 | 19.0 |
| December 2008 | 5.7 |

All commercial penaeid prawns of the Indian waters breed in the sea in relatively deeper waters in relation to the area of normal habitat of adult prawns. Penaeid prawns have high fecundity and the number of eggs produced varies from species to species and size of the prawn. *M.affinis, M.dobsoni, M.monoceros* and *P.stylifera* breed throughout the year with individually delineated peak breeding period. The eggs are released while swimming in the columnar waters or near the bottom. The early development takes place in the open sea and post larvae enter the creeks/estuaries/backwaters and attain all the adult characters including secondary sexual characters. They return to the sea where maturation of the ovary and subsequent spawning takes place.

Generally, the spawning grounds of penaeid prawns are away from the coast. The spawning ground of *M.dobsoni* is reported to be at 20 - 30 m while that of *M.affinis* is at still deeper waters. Spawning ground of *M.monoceros* is reported to be at 50 - 65 m and that of *P.stylifera* at 18 - 25 m. *M.affinis* and *P.stylifera* prefer areas of soft mud and zones of rich plankton for mating and spawning.

*Acetes indicus* are another common economically important species of shrimps. During January-April they form conspicuous aggregations near the shore and are fished on a large scale. Fishing grounds of these shrimps are mostly located in calm muddy intertidal zones or waters shallower than 5 m. The life span of *Acetes* is 3 - 10 months and the adults die soon after spawning. Breeding is continuous and surface water currents stimulate *Acetes* to swarm in shallow inshore waters when the wind blows moderately towards the coast.

The Gulf has a varied representation of prawns and so far 27 species belonging to Penaeidea and Caridea are recorded. Out of these, species like *P. penicillatus, M. brevicornis, M .kutchensis* and *Parapenaeopsis sculptilis* are commercially important. *M. brevicornis* occur in high number along the northern shore of the Gulf between Mandvi and Luni where the substratum is sandy. Higher percentage of *M. kutchensis* are generally confined to the inner Gulf area because the substratum predominantly contains clayey silt. The Gulf segment off Mundra is generally composed of sandy silt (Section 4.4) which can influence the distribution of *M.kutchensis* a very hardy, euryhaline prawn with a probable preference for clayey silt substratum. Beside the substrate preference, another possible factor, which may control the distribution of prawns along the northern coast of the Gulf can be tidal currents which during the course of their movement (prawns) into and out of the Gulf, may act as a hydraulic barrier.

**ii) Fish eggs and larvae**

Fish eggs and larvae though less in number (0 - 239 no/100 $m^3$; av 18 no/100 $m^3$) are fairly common among zooplankton (Table 4.5.7). The relative abundance of the fish eggs and fish larvae from 2006 to 2008 are summarized here.

| Period | Fish eggs (no/100 $m^3$) | Fish larvae (no/100 $m^3$) |
|---|---|---|
| January 2006 | 6 | 19 |
| April 2006 | 243 | 272 |
| April 2007 | 18 | 33 |
| October 2007 | 155 | 318 |
| December 2008 | 18 | 16 |

The above table shows inconsistent pattern in fish eggs and larvae production.

### 4.5.4 Macrobenthos

Depending upon their size, benthic animals are divided into three categories, microfauna, meiofauna and macrofauna. Benthic community responses to environmental perturbations are useful in assessing the impact of anthropogenic perturbations on environmental quality. Macrobenthic organisms which are considered for the present study are animal species with body size larger than 0.5 mm. Samples for macrobenthos were collected from intertidal segments as well as subtidal stations for the estimation of macrobenthic density, biomass and composition.

**a) Intertidal fauna**

The intertidal macrobenthic standing stock in terms of population (440-12848/$m^2$, av 3504/$m^2$) and biomass (0.27- 23.8 g/$m^2$, av 7.7 g/$m^2$ wet wt) varied widely (Table 4.5.8). The present macrobenthic values which are compared with the earlier studies are summarised here.

| Period | Population ($no/m^2$) | | Biomass ($g/m^2$; wet wt) | | Faunal groups (no) | |
|---|---|---|---|---|---|---|
| | Range | Av | Range | Av | Range | Av |
| January 2006 | 0 - 24464 | 3219 | 0 - 963.2 | 28.3 | 0 - 7 | 3 |
| April 2006 | 0 - 13024 | 1354 | 0 - 103.0 | 10.0 | 0 - 8 | 3 |
| April 2007 | 0 - 28600 | 2457 | 0 - 422.6 | 30.2 | 0 - 7 | 3 |
| October 2007 | 0 - 17116 | 2224 | 0 - 222.9 | 17.4 | 0 - 9 | 4 |
| December 2008 | 440-12848 | 3504 | 0.27-23.8 | 7.7 | 3-8 | 5 |

These results do not indicate any significant changes in the macrobenthic standing stock in terms of population though the biomass values in the current study are the lowest as compared to previous years. Though, the region in general, sustains rich intertidal benthos, significant variation in the macrobenthic standing stock as well as group diversity is clearly evident. The faunal composition of intertidal macrobenthos of the area is given in Table 4.5.9. The intertidal macrofauna was constituted mainly by amphipods, polychaetes, gastropods and cumaceans. As evident from Table 4.5.9 the total number of faunal groups in the intertidal transects varied from 3 to 8 (av 5). Overall about 15 groups of intertidal macrobenthos were recorded off Vandh during the present investigation.

**b) Subtidal macrobenthos**

During December 2008 the faunal standing stock in terms of population and biomass ranged from 25-1100/$m^2$ and from 0.1-4.23 $g/m^2$ (wet wt) respectively (Table 4.5.10). The standing stock of subtidal macrobenthos at the study area both in terms of biomass (av 0.7 $g/m^2$; wet wt) and population (315/$m^2$) was low and varied widely.

The past values of subtidal macrobenthos production is given below.

| Period | Population ($no/m^2$) | | Biomass ($g/m^2$; wet wt) | | Faunal groups (no) | |
|---|---|---|---|---|---|---|
| | Range | Av | Range | Av | Range | Av |
| January 2006 | 0 - 2900 | 400 | 0 – 3.4 | 0.5 | 0 - 10 | 3 |
| April 2006 | 0 - 1800 | 1354 | 0 – 10.6 | 1.8 | 0 - 7 | 4 |
| April 2007 | 600- 1900 | 1200 | 0.3 – 3.4 | 2.3 | 4-9 | 7 |
| October 2007 | 0-3100 | 600 | 0 – 34.11 | 3.9 | 0 -10 | 4 |
| December 2008 | 25-1100 | 315 | 0.1-4.23 | 0.7 | 1-9 | 4 |

The above table indicates wide variations in the faunal standing stock in the region and no clear seasonal trend in the distribution is discernible, suggesting high patchiness in the distribution of subtidal macrobenthos.

The faunal distribution (Table 4.5.11) revealed low diversity (av 4 groups) with a low variability (1-9 groups). In general, about 10 groups of subtidal macrobenthos were recorded off Vandh during the present investigation. The faunal composition indicated the dominance of polychaetes, brachyurans and amphipods.

### 4.5.5 Fishery

The prevailing fishery status of the region off Vandh is evaluated on the basis of data from the Department of Fisheries, Government of Gujarat and experimental fishing undertaken in Gulf segments during earlier studies. Vandh forms a part of the Kachchh District. Evidently, no large scale of commercial fishing operations prevail off Tunda-Vandh and surrounding region except for minor based hand-net and gill-net operations. However, along the northern coast of the Gulf, fishing by trawlers is common particularly off Mandvi, Modhwa, Mundra, Bhadreshwar and Tuna. Depending on the topography of the coast and type of fishing, necessary modifications are made to economise fishing operations by local operators. Small, plank built canoes and traditional crafts like the sail boat locally known as "Machuwa" are also deployed for fishing. The gear commonly used by these traditional crafts are drift nets, gill nets and large bag nets.

Gujarat is a leading state in marine fish landings and during 2005-06 the total landings were $6.6 \times 10^5$ t (Table 4.5.12). Landings at various centres of Kachchh District contributed about 10% to the total landings of the state. The total fish landing in the district was around $8.1 \times 10^4$ t during 2002-03 followed by a decrease during 2003-04, 2004-05 and 2005-06 (Table 4.5.13). Recent 6 y composition of fish catch indicated the incidence of 27 different groups (Table 4.5.13); the common groups being small sciaenids, Bombay duck, *Coilia* sp, ribbon fishes, sharks and prawns. Monthwise composition of fish landings of the district indicated that October-December period is peak season followed by January and September with March-July period as the lean season (Table 4.5.14). The landings at Mundra contributed about 0.6 to 3.9% to the total landings of the district (Table 4.5.15). The composition of fish catch at Mundra indicated incidence of 20 different groups (Table 4.5.16) with October to January as the peak landing period (Table 4.5.17).

Navinal, Jarpara, Mundra, Chenkhedia, Luni, Bhadreshwar and Kukadasar are the seven major fish landing centres in the Mundra region. However, their contribution to the district landing was meagre (Table 4.5.18). The composition of fish landings at these centres revealed the incidence of 26 different groups (Table 4.5.18); the common groups being Bombay duck, *Coilia* sp, mullet, cat fish, ribbon fish, white pomfret, small sciaenids, shrimps and prawns. During 2005-06, the total catch for Navinal, Jarpara, Mundra and Bhadreshwar was 1071, 333, 1031 and 2160 t respectively and contributed less than 10% to the landings of the Kachchh District. Higher landings occurred at Mundra during March-April-May followed by January (Table 4.5.17). This was due to heavy landings of Bombay duck and *Coilia* which formed 33% and 22.8% respectively of the landings for 2005-06. The other landing centres also followed more or less similar pattern. District-wise details of fishing activities, total number of fishermen and fishing gears are given in Table 4.5.19 whereas total number of fishermen and fishing boats of Navinal, Jarpara, Dhrab, Mundra, Chenkhedia, Luni and Bhadreshwar are given in Table 4.5.20.

During experimental fishing in April 2007 (Table 4.5.21) the fish catch rate varied between 5.0 and 14.5 kg/h (av 9.3 kg/h). This catch consisted of 27 species of fishes, 9 species of prawns and 5 species of other species which includes crabs, cephalopods and *Squilla*. *Harpadon nehereus, Johnius glaucus, Coilia dussumieri, Arius caelatus, Otolithes* sp, *Pampus argenteus, Scoliodon laticaudus, Thryssa* sp, *Otolithus* sp, *Exhippolysmata ensirostris*, *Neptunus pelagicus* and *Metapenaeus* sp were recorded as the dominant species. The other common species were *Sillago sihama, Valamugil seheli, Polynemus tetradactylus, Scomberomorus guttatus, Thryssa hamiltoni, Lepturacanthus savala, Parapenaeopsis stylifera, Thryssa vitrirostris* and *Charybdis cruciata* . During October 2007, the fish catch rate ranged between 3.0 and 18.0 kg/hr (av 10.3 kg/h). This catch comprised of 31 species of fishes, 11 species of prawn and 5 other species of crabs, cephalopods and squilla. The fish catch was dominated by *Johnius glaucus, Coilia dussumieri, Harpadon nehereus, Arius caelatus, Sillago sihama, Trichurus lepturus, Lepturocanthus savala, Pampus argenteus, Pampus chinensis, Ilisha megaloptera, Scoliodon laticaudus, Charybdis annulata, Exhippolysmata ensirostris* and *Metapenaeus* sp (Table 4.5.22).

Available long term fishing data off Tunda/Vandh is summarized here:

| Period | Total catch (kg/h) | | | Total species | | |
|---|---|---|---|---|---|---|
| | Min | Max | Av | Min | Max | Av |
| January 2006 | 8.0 | 18.5 | 13.7 | 18 | 20 | 19 |
| April 2006 | 3.0 | 15.5 | 9.3 | 13 | 22 | 18 |
| April 2007 | 5.0 | 14.5 | 9.3 | 13 | 22 | 17 |
| October 2007 | 3.0 | 18.0 | 10.3 | 11 | 23 | 18 |

The above data reveals wide fluctuation in fish catch around Tunda/Vandh which may be due to prevailing natural variation in the coastal waters in the Gulf.

### 4.5.6 Corals and associated biota

The Tunda/Vandh region also does not sustain reef building corals as the intertidal area is largely sandy or muddy. Coral growth in the subtidal region is also unlikely in view of the high suspended load in the water column, the conditions under which corals do not thrive. Reef building corals were also not sighted in the subtidal area off Tunda/Vandh.

### 4.5.7 Birds

The saltpans, islands and intertidal coastal system with mangroves off Mundra offer plenty of facilities for feeding, breeding and shelter to a variety of birds. The mangroves were often seen crowded with Grey herons, Pond herons, Painted storks, Large and small egrets, Darters, Cormorants etc. During receding tide, hectic activity of various Gulls, Avocets, Whimbrel, Curlew, Terns, Egrets, Grebes, Plovers etc is common.

A study carried out during November 1999 revealed high avifaunal diversity in the Mundra region. On the whole, 140 species were documented; 85 terrestrial and 55 aquatic. Out of these, 71 are resident species, 44 migrants and another 25 resident migrant. Based on sightings, 21 species are reported to be abundant, 42 common, 51 rare and 26 very rare. The scientific name, common name, abundance status etc of the aquatic birds are given in Table 4.5.23. Exotic species like Greater Flamingo (*Phoenica pterus ruber*), Lesser Flamingo (*P. minor*) and Dalmatian Pelican (*Pelecanus cripus*) and Eurasian Spoon Bill (*Platalea leucorodia*) were commonly recorded, thus emphasising the importance of the study site. Dalmatian Pelican, Greater Flamingo, Lesser Flamingo and Spoon Bills commonly occured in salt pans.

### 4.5.8 Reptiles

In the Gulf, the reptiles are mainly represented by marine turtles *Chelonia mydas* and *Lepidochelys olivacea* which have their breeding and spawning ground on the sandy beaches along the coast as well as on the islands particularly along the southern Gulf. No turtle however was sighted in the waters off Tunda-Vandh during the study period.

### 4.5.9 Mammals

The mammals are chiefly represented by dolphin (*Dolphinus delphis*), whale (*Balanoptera* spp) and Dugong (*Dugong dugon*) in the Gulf especially along the Jamnagar coast but not sighted during the study period.

# 5 EFFLUENT RELEASE

The total 4000 MW power project envisages water drawl of about 6.3 x $10^5$ $m^3/h$ out of which 6.28x $10^5$ $m^3/h$ will be discharged back to the sea from the condensers of the power plant. The intake channel that is developed at the site towards east to the proposed plant location will be used for the cooling water requirement. The channel is located nearly 6 km away and to the east of the proposed outfall channel.

The effluent temperature would be $7^o$ C above ambient. The salinity would insignificantly increase by 0.1 ppt. The thermal effluent should be sufficiently diluted before it reaches intake during flood tide conditions to avoid recirculation.

## 5.1 Modeling of temperature

HR Wallingford was assigned with the modeling work for this purpose. A 2D model was used to estimate the plume movement in the vicinity of the release location. Model bathymetry was selected based on the bathymetry survey conducted in April 2008. The eastern and western boundary conditions (water levels) were taken from the regional model of Gulf of Kachchh. The other inputs are as follows

Average ambient temperature of seawater = 30 C
Average ambient temperature during monsoon = 28.5 C
Maximum excess temp rise over ambient in pump house <= 0.5 C
Minimum wind speed = 1.5 m/s

Five options were considered for the intake and outfall locations and it was found that the option 5 is appropriate for the release.

The simulated currents were compared with the observed counterparts and presented in the Figures 6.1.1 and 6.1.2. The model results are in fairly agreement with the observed ones in speed as well as in direction.

The model was run giving input and outfall as specified earlier. The thermal dispersion is presented in the Figures 6.1.3 to 6.1.5. The output is presented for three scenarios, peak flood, peak ebb and low water conditions. During peak flood period the temperature rise would be around $5^{o}$ C around the effluent channel, however the rise would be only $0.5^{o}$ C ( Figure 6.1.3) at the intake channel. This shows that the recirculation is not possible in the peak flood conditions. The Figure 6.1.4 where the peak ebb conditions are considered, the temperature rise at intake channel would be $1^{o}$ C above ambient and the plume would spread around 2 km from the proposed outfall location. The results pertaining to lowest low water spring (Figure 6.1.5) denote that the area of the plume with high water temperature would be more at outfall site as compared to the other two scenarios. However the rise at intake channel would remain $1^{o}$C. From the above results it is found that near ambient conditions would be attained at the distance of 3 km from the outfall channel alignment. The time series of the modeled temperature indicate that the excess temperature of the seawater in the intake channel would vary between $0.2^{o}$ to $1.4^{o}$ C (Figure 6.1.6).

# 6 POTENTIAL MARINE ENVIRONMENTAL IMPACTS

Major potential negative marine environmental impacts due to the proposed activities would be largely associated with the (a) construction of the effluent channel and the coal conveyer belt, (b) deterioration in ecological conditions due to operation of the effluent discharge channel and (c) operational activities of the proposed coal conveyer belt. Evidently, potential negative impacts on the coastal ecology can arise during the construction as well as the operational phases of the proposed project.

## 6.1 Construction phase of the effluent channel

Adverse impacts of the proposed project on the marine environment during construction phase would be due to (a) modifications in the hydrodynamic characteristics of the area, (b) degradation in water and sediment qualities, and (c) loss of biota.

### 6.1.1 Hydrodynamic characteristics

The effluent release channel would tend to deepen as the water equivalent to the tidal prism of the channel preferentially uses the deepened channel during ebb. As a consequence the intertidal areas around the proposed effluent channel may experience slow but steady deposition. The overall impact would be morphological change confined to the intertidal area near the effluent channel.

### 6.1.2 Water quality

Excavations in the intertidal and subtidal areas for making a channel has high potential to disperse the bed sediment into the water column thereby increasing the SS in water and degrading the water quality locally.

From Section 4.4.1 it is evident that the subtidal and lower intertidal areas off Tunda-Vandh are composed of sediment with a fair percentage of sand. Hence these patches may not particularly generate fine SS when disturbed. The average SS in Tunda-Vandh region is in the range of 70 to 97 mg/l. Moreover, SS in the Gulf is inherently high and variable (Section 4.4) rendering the water turbid and muddy. The local increase in SS would be confined only to the construction phase and the baseline conditions would be re-established when the construction activity is terminated.

In areas where the bed sediment is contaminated, there is apprehension of release of pollutants entrapped in the sediment to the region when the bed is disturbed thereby mixing interstitial water rich in contaminants with the overlaying water; DO levels might be suppressed and the BOD can increase because of the release of this interstitial water which also includes oxidisable organic compounds. However, as discussed in Sections 3.3.3 and 4.4.2 the sediment off Mundra and Tunda/Vandh is uncontaminated and has markedly low levels of $C_{org}$. The levels of metals in sediment also largely represent lithogenic contribution (Sections 3.3.3 and 4.4.2). Hence, the concentrations of DO and BOD are unlikely to be altered due to the suspension of sediment particles in water. Though the entry of SS has the high potential to enhance levels of nutrients and pollutants, since the sediment are low in organic pollutants, contamination of the disturbed water column would not take place. The SS transferred to the water column is expected to be dispersed and settled fairly quickly and transient pulses will be smothered soon.

Several types of floating platforms such as barges, cranes, ships etc will be deployed in the area during construction. An accident involving such platforms may lead to the loss of onboard construction material and fuel. While material may sink to the bed the fuel spill would deteriorate the water quality of the affected area.

The discharges from ships and shore based sources would introduce pathogens, BOD, PHc etc to the coastal waters which may degrade the water quality locally.

From the foregoing discussion it is evident that the water quality off Tunda/Vandh is unlikely to be adversely influenced during the construction phase except for minor local perturbations which will level out as the constructions are completed.

The possibility of an increase in salinity ingress which is already a serious problem in the Mundra region due to seawater associated with the dredged spoil percolating into the sub-surface strata, is remote since as the sub-soil is already saline and the strata consists of compact soil.

The sufficient distance (6 km) between the intake and discharge channels minimizes the risk of effluent entering the intake channel before attaining near ambient conditions of temperature and salinity.

### 6.1.3 Sediment quality

The sediment excavated for constructing the channels would be re-distributed by tidal circulation which may change the texture of the sediment of nearby areas, particularly of the intertidal region. The impact however would be minor.

The dredging to excavate the channel would generate huge quantities of dredge spoil. This needs to be disposed off at a selected spoil ground or used for land filling of the site. However, this material should not be used in non-saline environments.

Misuse of the intertidal area by workforce employed during construction phase, can locally degrade the intertidal sediment by increasing BOD and populations of pathogens. The impact however would be minor and temporary and recovery would be quick when the source of this contamination is eliminated at the end of the construction phase.

### 6.1.4 Flora and fauna

Hectic construction activities in the intertidal and subtidal areas would influence the local biotic communities, particularly the macrobenthos along the corridors selected for seawater intake as well as release of effluent. As the sediment is not enriched in $C_{org}$ (Section 4.4.3), its suspension in the water column is unlikely to deplete DO in this dynamic marine area and DO availability would not be a constraint for the biotic processes. The danger of biota getting exposed to pollutants released from sediment porewater ,when the bed is disturbed, is minimal since the sediment of the coastal waters off Vandh is free from anthropogenic contaminants (Section 4.4).

The intertidal zone near the concerned area of activity is largely sandy and devoid of vegetation. An increase in turbidity due to enhanced levels of SS can negatively influence the photosynthesis and hence the primary productivity. However, the impact if any would be local, temporary and reversible with the phytoplankton community structure quickly reestablishing once the construction is completed.

A temporary and minor reduction in phytoplankton standing stock, if at all, and increase in turbidity is unlikely to produce any negative impact on zooplankton though a localised and marginal change in the community structure and population alternations may occur confined to the project area. Such changes are temporary and irrelevant to the overall secondary productivity of the coastal system of Tunda-Vandh.

Excavations for making the effluent channel would affect benthic habitats along the selected corridor. Based on the results presented in Section 4.5.4 and the area likely to be trenched/disturbed, the probable loss of standing stock of macrobenthos during the construction phase is estimated as given below.

| **Activity** | **Habitat** | **Area (ha)** | **Population (no x $10^6$)** | **Biomass (kg)** |
|---|---|---|---|---|
| Effluent channel | Intertidal | 45.1 | 1623 | 2841.3 |
| | Subtidal | 1.6 | 3.1 | 1.1 |
| | Total | 46.7 | 1626.1 | 2842.4 |

As evident from above the benthic habitat that would be affected during the construction phase would be around 46.7 ha depending on which the losses were computed. Actual may vary slightly depending on the final alignment of effluent channel. The loss of intertidal benthos both in terms of population and biomass would be more as compared to subtidal benthos due to better representation of faunal standing stock at the intertidal regions as compared to subtidal zone. The major components of benthos which would be affected are given below:

| Area of activity | Polychaetes (%) | Crustaceans (%) | Molluscs (%) |
|---|---|---|---|
| Intertidal | 37.8 | 37.9 | 24.2 |
| Subtidal | 77.3 | 22.7 | - |

The above results indicate that polychaete is the major group which would be affected at the subtidal zone whereas polychaetes, molluscs and crustaceans are the major intertidal components which would be affected.

However, this loss would be temporary and the benthos would recolonise in due course after the construction activities are terminated. The overall loss of benthos which would be temporary and minor compared to the benthic potential of Gulf off Tunda-Vandh, and such temporary losses are not likely to be reflected on the overall biopotential of the Gulf system.

### 6.1.5 Miscellaneous

Aesthetics of the area would deteriorate due to the presence of construction machinery and materials, make-shift huts for labour force, cabins etc. Left over solid waste generated during construction would be a source of nuisance if not cleared from the site.

The extent of impact on the beach ecology would also depend on the duration of the construction phase. If the construction is prolonged due to time - overruns or improper planning, the adverse influence would increase accordingly.

Mangrove forests around Mundra are among the best mangrove formations in the Gulf. These mangroves in association with vast mudflats around provide congenial environment for migratory as well as resident birds (Sections 3.3.4 and 4.5.1) particularly during November-March. Increase in noise level during construction can disturb these bird populations. Several species of birds use salt pan areas for feeding as well as roosting during high tide when the mudflats are submerged under seawater. The adverse impact however, would not be serious since additional intertidal areas, mudflats and slat works exist in the region.

Marine reptiles and mammals common to the area (Sections 3.3.4, 4.5.8 and 4.5.9) would not be affected due to construction activities since they tend to migrate temporarily from such sites. Moreover major activity is in shallow areas, where marine and mammals were not sighted during field visits.

As mentioned in Section 4.5.5, there are not much commercial fish trawling operations off Tunda-Vandh. However, drifts and other local nets are commonly used by local fishermen community. Also some local beaches are used by migrated fishermen temporarily for landing and sun drying. These operations would not be hampered much during the construction activities.

The area off Mundra-Tunda/Vandh does not sustain corals though fringing corals occur in patches along the southern shore of the Gulf segment off Vadinar. These corals are atleast 25-30 km away from Mundra. The nature of circulation in the Gulf with predominant transport along east-west would not permit the effect of localised perturbations along the northern shore to reach these corals.

## 6.2 Operational phase of the effluent channel

Marine environmental implications during the operational phase of the project would be essentially confined to the i) release of biocides added to the water used in the plant and ii) adverse influence of release of effluent on the water quality, sediment quality and flora and fauna of the Gulf.

### 6.2.1 Release of biocides

The return coolant will contain some residual chlorine used as biocide in the circulation system to prevent biofouling. Release of biocides and other chemicals mainly chlorine used to control biofouling on heat exchanger surface poses a potential danger to coastal marine organisms because of their toxicity. Though they are known to effectively control biofouling, they can easily kill non target organisms entrained in the cooling system.

### 6.2.2 Water quality

Probable impact of release of treated effluent at the designated site through an open channel on water quality is predicted based on probable dilution the effluent would attain and assuming conservative behaviour of constituents in the receiving water. The temperature is not a conservative property and decay due to evaporative and sensible heat losses reduces the impact outside the channel system. The temperature in a limited area comprising the discharge channel and its immediate vicinity will however have temperatures of 4-5$^{o}$C above ambient. This increase may not be lethal to the organisms but proliferation of resistive organisms may change the community structure of the biota. The intertidal area however experiences such temperatures and salinities even in the normal course.

### 6.2.3 Sediment quality

Some fraction of contaminants such as heavy metals, PHc, phenols etc if present in the effluent would be adsorbed onto the SS which is abundantly available in the proposed area of release thereby enriching the bed sediment on settling. However, due to high tidal dispersal and efficient advection by strong currents, this SS would be scattered over a large area. Hence an increase in the concentration of contaminants in the marine sediments to levels that cause harm to biota is unlikely.

### 6.2.4 Flora and fauna

The general water quality of the waters off the project domain would not be affected adversely, though limited degradation would result in a small area around the discharge channel. Hence, by and large, the biological characteristics of the surrounding segments would not be affected adversely. Although the concentrations of some contaminants may remain higher in the vicinity of release, the predicted levels are sufficiently below the threshold concentrations to cause toxicity to flora and fauna of the effluent receiving segment.

Some marine organisms are sensitive to salinity changes and large variations in salinity can cause harm to them. It is evident from Tables 4.3.1 to 4.3.3 that the salinity in the segment between stations 1 and 3 varies from 35.7 to 38.0 ppt. Hence, the marine biota in Gulf segment would have adapted to such fluctuations which are larger than the predicted increase in salinity of 0.1 ppt at the discharge channel mouth. Hence, marine biota would not be affected due to a small increase in salinity.

Increase in temperature of the receiving water due to release of warm effluent is another factor that needs evaluation. This is particularly important for the arid environment of the coastal zone off Tunda-Vandh. The high air temperatures during May and October can increase the water temperature of the waters off Tunda-Vandh upto $35^{o}C$ (Section 4.3.1) which may adversely affect the survival of several marine organisms. Hence, it should be ensured that the heat associated with the effluent dissipates rapidly on release. From the model studies it is estimated that the temperature of the water within 2 km from the seaward end of the channel would increase by about $2\text{-}3^{o}C$. Such an increase in temperature is unlikely to adversely affect the biota of the effluent release site.

The return coolant will contain some residual chlorine used as biocide in the circulation system to prevent biofouling. Free chlorine does not remain stable in seawater and decays on release. However if sufficient dilution is not attained, marine ecology will have a minor and localized impact.

### 6.3 Dumping of dredged materials

The quantity of material excavated in making the outfall channel would be of the order of 2.0 million $m^3$. This quantity will be disposed off as per the plan suggested by Mundra Port. No siltation is expected in the effluent discharge channel.

## 6.4 Construction phase of the coal conveyer belt

During construction, activities like drilling, concreting, piling and installation of support structures, erection of conveyer belt etc will be performed. Temporarily, some of the environmental parameters may get disturbed during the construction phase. The impact of each of these parameters is discussed below.

### 6.4.1 Impact on Air quality

The major source of air pollution during the construction period will be from the movement of vehicles for construction activity. The emissions will be from stationary sources like generator sets during emergency service only, and air borne dust emissions from cutting and filling of soil and vehicular movements. The exhaust emission along with the dust emissions resulting from vehicles operating at site will also add to air impact. Dust suppression by spraying of water will reduce these impacts considerably. The emission from vehicles will depend on the type and capacity of the vehicles used. The impact due to additional vehicles plying during the construction period is of temporary nature and their impact on air quality will not be significant.

### 6.4.2 Noise Impact

Major sources of the noise pollution due to construction activity will be from the earth moving, levelling and compacting, trucks for transportation of construction materials, concrete mixers, asphalt mixing and laying equipment which all add to the general noise level. The noise generated from all construction activities will be restricted to daytime working hours. Generally the noise will be limited very much within the site boundary except noise of piling work for pile foundation, the trucks entering and leaving the site. Further the noise impact during construction will be temporary in nature. The noise level will drop down to the acceptable level, once construction period will be over.

### 6.4.3 Water quality

During construction, the runoff from the construction site will be a source of water pollution. Such pollution may persist entirely during the initial phase of construction when site grading and excavation for foundation and back filling would be in progress. During this stage the rainwater runoff would carry more soil/silt than normal and this would cause siltation problem in the receiving water bodies.

The other source of water pollution is expected from the sanitary waste coming from the temporary accommodation of the construction workers if envisaged. However, most of the construction workers will be made available from the near by villages and no separate migration of workers is envisaged for this project. The facilities presently available with the villages will continue to be used during construction activities and no sanitation problem is expected during construction period. However, on site during working hours additional sanitation will be handled by septic tank/pit if required, the arrangement will be made available during the construction phase of the project.

The main source of marine pollution during project construction phase could be the discharge of sewage into the marine water body, No other impacts are envisaged on marine ecology as all the activities of conveyer belt construction are on land and away from sea water. The construction activity for this project component is temporary in nature and not likely to have significant impact on the quality of ground water.

### 6.4.4 Land impact

The major impact of any project on land environment during project construction phase generally occurs due to the acquisition of land, construction of approach roads and dumping of construction spoils. The adverse impacts due to pre-construction activities, e.g. clearing and levelling, generation of construction waste, etc. are expected. However, considering footprint of the conveyer belt and the extent of construction activities, impacts are not expected to be significant on this account.

During construction phase, temporary land acquisition is required for storage of construction material, siting of construction equipment, storage of construction waste, etc. The land is cleared once the construction phase is over. The proposed land to be utilized during construction phase, i.e. for storage of construction equipment, construction material etc., shall be cleared, levelled, compacted, on completion of construction activities. The objective of the exercise is to obliterate to the extent possible all the visible impacts of construction activities. Thus, no impacts on this account are anticipated.

## 6.5 Operational phase of the coal conveyer belt

Conveyer belt will be used for conveying coal from Mundra jetty up to stock yard at CGPL. Conveyer belt will be operated on electromechanical system, hence no impact is envisaged during operation phase of the project. There might be minor impact on air due to wind force during high wind condition. Fugitive emission is envisaged which will be very limited in nature.

## 7 MITIGATION MEASURES AND ENVIRONMENT MANAGEMENT PLAN

The region of Tunda-Vandh identified for effluent release facilities is a typical inshore marine zone of the Kachchh District. No endangered or rare species was encountered during field studies. Further, fragile and sensitive habitats such as mangroves are absent in the vicinity of the proposed development site. Hence, conventional methods generally recommended for marine areas can be employed for setting-up the effluent release facilities and the coal conveyer belt with standard mitigation measures to minimise the adverse impacts on marine ecology. The construction and operation phase environmental management plan has been aimed to achieve the following objectives:

- To ensure that the environmental control systems are installed and are operating satisfactorily.
- To ensure that quality of pollutants discharged if any are within the stipulated standards.
- To ensure that pollutants concentration in the surrounding area does not exceed the National Ambient Air Quality Standards NAAQS.
- To monitor impacts on the surrounding environment and the effectiveness of mitigation measures during the construction and operation.

### 7.1 Construction phase of effluent channel

Construction of the return coolant discharge channel could change the pattern of littoral drift locally. This change should be minimized by suitably orienting the channel and adequately designing the side slopes based on model studies. Such a study would also aid in incorporating structural modifications if required to minimise maintenance cost.

Considering the sensitivity of the area, proper care is warranted while dredging which should be in a controlled manner. Except for the temporary destruction of macrobenthos along the corridor selected for discharge channels the impact on the marine ecology during construction phase would be largely confined to the duration over which the activities are spread. Hence, the key factor in minimising adverse impacts would be reduction in the construction period at the site and avoidance of spillage of activities beyond the specified geographical area which should be kept to a minimum.

There is a distinct advantage of reduction in time of marine construction operations by prefabricating the structures wherever possible and transporting them to the site. However, the fabrication yard should be located sufficiently away from the shore and transport of structures to the site should be through a predecided corridor. Similarly the movement of construction vessels should be restricted to the operational area only through proper supervisory controls.

Work force employed during construction often misuses the intertidal and supratidal areas. This should be avoided by establishing the temporary colonies of workers sufficiently away from the HTL and proper sanitation should be provided to them to prevent abuse of the intertidal region.

The noise level during transport and construction of marine facilities should be kept to a minimum. The intertidal and nearshore subtidal areas should be restored to their original contours once the construction activities are completed. General clean-up along the corridor areas should be undertaken and discarded materials including excavated soil should be removed from the site and the aesthetic quality of surroundings restored on completion of the construction phase.

The excavation of the channels will produce some amount of dredge spoil (approximately 2.0 million $m^3$ from discharge channel). This spoil should not be dumped in the intertidal area. A suitable spoil ground is to be found or should be used for site filling.

## 7.2 Operational phase of effluent channel

The Gulf segment off Tunda-Vandh represents an unpolluted marine environment, which should be maintained in future also. Hence, it should be ensured that the effluent released into the Gulf meets the prescribed GPCB criteria at all times. Since, the Gulf segment already sustains high salinity and water temperatures, it should be ensured that their levels in the effluent are maintained as prescribed.

It is predicted that the effluent would attain near ambient temperatures and salinities within 3-4 km when released through a channel based on the model predictions. Such calculations are based on average environmental conditions and a few assumptions which cannot be easily verified. Hence, the actual dilution attained should be measured through tracer studies after the effluent channel becomes operational. Analysis of time series of the modeled temperature by HRW indicated that the average excess temperature of the seawater in the intake channel under spring - neap cycle calm conditions would be around 0 - 4$^{o}$C (typical time series of temperature variation in intake channel under spring tide indicated in Figure 6.1.6).

Use of the biocides should be kept at the minimum and their concentration at the outlet should be regularly tested. If required the use should be regulated.

## 7.3 Construction phase of coal belt conveyer

The following construction engineering practices are recommended to minimise construction phase environment impacts:

a) Use of existing roads for transportation of material. Compaction of access road to minimise dust pollution.

b) Proper disposal of construction wastes generated during construction of coal conveyer belt.

c) Adequate erosion control plans to minimise soil erosion.

d) Minimise noise by using appropriate noise control measures.

e) Spraying of dust suppressants at regular intervals.

f) Sedimentation pond and peripheral drains for the runoff water from the construction site.

g) STP for workers colony.

h) Afforestation program.

i) Use of high quality equipments for construction.

j) Ban on use of vehicles more than 15 years of age.

## 7.4 Operational phase of the coal belt conveyer

All the equipment shall be suitable for handling wet and sticky coal during monsoon season with moisture content of 35% and fines up to 40% so that pollution due to jamming of conveyer can be avoided. All the equipments and conveyers shall be designed for handling coal of (-) 50mm to avoid dust pollution. Self aligning carrying and return idlers shall be provided at an interval of 24m to avoid unnecessary spillage of coal from belt conveyer. All the chutes shall be constructed out of 20mm Tiscral/SAIL hard material. The size of the chute shall be sufficiently bigger to avoid any build up of coal with high moisture. All conveyers shall be provided with open galleries with hood covering the belt to avoid dust nuisance. The clear width of walkway shall be 1200mm on one way and 800mm on the other side. Wind guard shall be provided to avoid flapping/lifting of the belt. Inspection and maintenance doors/poking holes at suitable location shall be provided for all chutes. Platform with ladder shall be provided to facilitate poking so that jamming and thus material spillage can be avoided.

### 7.4.1 Dust suppression (DS) System

There shall be two (2) service water pumps (1 working + 1 Standby) which supply water to (a) local water storage tanks of DS system of stock yard, junction towers etc., (b) service water tap points for plant cleaning, toilets etc. Each DS system shall be provided with two (1 working + 1 standby) pumps. The quantity of water to be sprayed for the stockyard DS systems shall be calculated for a section of 90 meter length wherein a set of sprinklers operates simultaneously. The DS system at conveyer transfer points shall be dry fog type using compressed air. Globe valves shall be provided at each sprinkler. The operation of each section of sprinklers shall be sequential.

Service water piping with tap off points (with isolating valve and quick connecting coupling) shall be provided for each floor of junction towers. Two (2) points per floor in junction tower shall be provided. Flexible hoses of 20m long each shall be provided with storage boxes. Service water piping shall be provided all along the galleries with tap off points at 30m interval with flexible hose. Each tap off point shall contain isolating valve with quick connecting coupling to enable fixing of hoses. Each water spray header in DS system shall be provided with a solenoid valve to stop water spray when the concerned pant and equipment of coal handling system do not operate.

Each DS system shall be operated from local control panel and shall be interlocked with the respective conveyer/ equipment. The pipes for stockpile dust suppression system shall be buried below ground and suitable protection like wrapping shall be provided. Pipes at road crossing shall be provided in RCC Hume pipes.

### 7.4.2 Coal Yard Drainage

Around the coal stock yard, drainage channels shall be constructed to take all the effluent from the coal stock yard which shall be ultimately led to a coal pile run off pit. Coal particles shall settle down in this sump. The overflow from the sump shall be lead to the plant drains. The coal pile run off pit shall be suitable for storing about 10 hrs rainwater falling in the stockpile area based on the climatologically data. This shall be RCC construction. Two pumps (1W+1S) shall be provided in this coal pipe run off pit to discharge the water at final disposal point

## 7.5 Environmental Management Plan (EMP)

Important features of the Environment Management Plan are the following:

a) Environment management cell
b) Ambient air and noise quality monitoring
c) Water quality monitoring

d) Meteorological data collection

e) Afforestation program

f) Periodic preventive maintenance & occupational safety and health

### 7.5.1 Environmental Management Cell

The major environmental considerations involved in the construction and operation of the thermal power station and related accessories like conveyer belt, intake outfall channel, transmission network, etc. are taken up by a full-fledged multi disciplinary Environmental Management Division (EMD) with key functions of environmental, safety and occupational health for management of the entire plant and surrounding environment. At CGPL EMD is already in place with team of environmental engineers, chemists, horticulturists, safety specialists and well-trained staff for operation and maintenance of pollution control equipment. Staff training programmes in the areas of environment, ambient air, water quality monitoring, solid waste management, noise abatement, safety and health aspects are conducted regularly.

### 7.5.2 Environmental Monitoring Programme

An environmental monitoring programme is already in place to provide scientifically defensible information for determining the status of the environmental quality of the surrounding area and to check whether the levels of critical pollutants are within the environmentally acceptable limits. This will help obtain an early warning of unacceptable environmental conditions so that control measures can be taken immediately. It also helps to determine in a timely fashion, changes in the local environmental quality. The environmental monitoring programme includes ambient air quality monitoring, meteorological data collection, water quality monitoring, soil testing and sea water monitoring.

It is necessary to monitor the marine environment periodically and identify the perturbations if any to take appropriate follow-up action.

**a) Baseline quality**

To understand seasonal variations it is necessary to conduct periodic investigations, ideally monthly, but at least seasonally at carefully selected monitoring locations. These should include subtidal as well as intertidal segments. In the present case, the station 2 should be adequate to represent the subtidal environment while intertidal transects in the vicinity of the plant utilities alongwith a transect sufficiently away from this area should be selected for evaluation of the intertidal ecology. Till a proper baseline is established, the data presented in this report can be considered for comparing the results of future monitoring. The monitoring however should be confined to the month in which the data are collected. Selected stations including the effluent disposal location should be sampled diurnally during the monitoring programme. The parameters to be monitored are listed below:

**Physical processes:** Tides, currents and circulation in the project domain should be studied. Bathymetric surveys by echo sounding in both the intake and discharge channels should be undertaken to delineate erosion and deposition.

**Water quality:** Water samples obtained from 2 levels in the vertical when the depths exceed 3 m, should be studied for temperature, pH, SS, turbidity, salinity, DO, BOD, (or total organic carbon), nitrate, nitrite, ammonia, dissolved phosphate, PHc and phenols. For shallow waters, only surface samples can be analysed.

**Sediment quality:** Sediment from subtidal and intertidal regions should be analysed for texture, $C_{org}$, phosphorus, chromium, nickel, copper, zinc, cadmium, lead, mercury, arsenic and PHc.

**Flora and fauna:** Biological characteristics should be assessed based on primary productivity, phytopigments, phytoplankton populations and their generic diversity; biomass, population and group diversity of zooplankton; biomass, population and group diversity of benthos and fish quality.

**b) Post-project monitoring**

A comprehensive marine quality monitoring programme with periodic (premonsoon and postmonsoon) investigations at predetermined locations (these should coincide with those used for the baseline quality) by a specialised agency is a practical solution to ensure quality data acquisition. This can be a continuation of the study designed for baseline quality and some parameters listed above should be included in the post-project monitoring programme.

The results of each monitoring should be carefully evaluated to identify changes if any, beyond the natural variability identified through the baseline studies. Gross deviation from the baseline may require a thorough review of the effluent disposal scheme to identify the causative factors leading to these deviations and accordingly, corrective measures to reverse the trend would be necessary.

### 7.5.3 Afforestation program

Afforestation is a key element in environment conservation and protection. At CGPL afforestation programme is already in place, The establishment of a vegetation covering will result in many direct and indirect benefits such as:

(a) Vegetation can absorb dust pollution and also attenuates the noise levels.

(b) Vegetation will be able to control the build-up of atmospheric pollutants that are emitted during construction.

(c) Afforestation will help restore the ecodynamics around the plant. It checks soil erosion.

(d) A green belt will also compensate the vegetation loss during the construction phase and will help in reclamation of land used for ash disposal.

(e) Provision of one third land of the project area will help in complying with the statutory requirements.

# 8 SUMMARY AND CONCLUSION

CGPL has embarked on developing the infrastructure for a 4000 MW thermal power project proposed to be set up at Mundra for which they had obtained CRZ clearance for intake and outfall channels. It now proposes to draw water to the tune of $6.3 \times 10^5$ $m^3/h$ for cooling and other purposes from the common intake channel constructed by APL as suggested by the NIO. As a result, due to engineering reasons CGPL requires to change the discharge location. M/s CGPL has approached the National Institute of Oceanography (NIO) to obtain baseline data covering the new discharge location and to predict the marine environmental impacts based on the modeling reports that will be made available to NIO.

The studies presented in this report have been carried out by the NIO with the objectives of evaluating the prevailing hydrodynamics and ecological status of the coastal water adjacent to the project site, assessing the impact of effluent release and coal conveyer system on marine ecology and recommending suitable marine environmental management plan to minimize any adverse impact on marine area.

## 8.1 Project information

The project site is in the vicinity of Mundra SEZ about 25 km from the Mundra Port and 1.5 km from the coast of the Gulf of Kachchh. The proposed project consists of five power plant units totaling to 4000 MW gross capacity, utilising imported coal as fuel. Fresh water for the plant, potable water, service water and feed water to the DM plant and other services will be met by the desalination plant. A once through cooling system with sea water is preferred for the plant. The circulating system will be designed to attain temperature of less than +7$^{o}$C above the ambient seawater temperature.

Desalination plant reject will be partly utilized for pretreatment plant backwash and the balance will be led into the discharge channel. The desalination plant reject water (1727 $m^3/h$) with high TDS will get diluted in the CW discharge channel. Pre-treatment plant filter backwash and clarifier sludge will be collected and disposed off to the discharge channel. The power plant being once through cooling type, the seawater is led back to the sea at the rate of about 6.28 x $10^5$ $m^3$/h. The discharge channel is designed to cool the water over a length of about 1950 m and has a capacity of 6.30 x $10^5$ $m^3$/h. The quantity of material excavated in making the outfall channel would be of the order of 2 million $m^3$. This quantity will be disposed off as per the plan suggested by Mundra Port. No siltation is expected in the discharge channel.

## 8.2 Gulf of Kachchh

The Gulf occupies an area of 7300 $km^2$, has maximum depth that varies from 20 m at the head (Kandla - Navlakhi) to 60 m in the outer regions. Kachchh District is industrially backward with a few industrial establishments.

Tides in the Gulf are of mixed, predominantly semidiurnal type with a large diurnal inequality. The tidal front enters the Gulf from the west and due to shallow inner regions and narrowing cross-section, the tidal amplitude increases considerably, upstream of Vadinar. The phase lag between Okha and Kandla is 2 h to 2 h 25 min while between Okha and Navlakhi it is 3 h to 3 h 20 min. Due to high tidal ranges in the inner regions, the vast mudflats and coastal lowlands that get submerged during high tide are fully exposed during low tide. Circulation in the Gulf is mainly controlled by tidal flows and bathymetry, though wind effect also prevails to some extent. The maximum surface currents are moderate (0.7-1.2 m/s) but increase considerably (2.0-2.5 m/s) in the central portion of the Gulf. With high tidal range, negligible land run-off and irregular topography, the waters are vertically homogeneous in terms of salinity and temperature.

The annual variation of water temperature is between 23 and 30$^{o}$C though localised higher temperatures upto 35$^{o}$ C can result in isolated water pools formed in shallow intertidal depressions, during low tide. SS is highly variable (5-700 mg/l), spatially as well as temporally, and largely result from the dispersion of fine sediment from the bed and the intertidal mudflats, by tidal movements. Average pH of the Gulf water is remarkably constant (8.0-8.3) and is within the range expected for the coastal tropical seas. The evaporation exceeds precipitation leading to salinities markedly higher than that of the typical seawater. This is particularly evident in the inner Gulf where salinities as high as 40 ppt commonly occur off Kandla and Navlakhi. The average DO is fairly high (3-5 ml/l) and the BOD is low (<0.1-4.0 mg/l) indicating good oxidising conditions. The nutrients ($PO_4^{3-}$-P, $NO_3^-$-N, $NO_2^-$-N, $NH_4^+$-N) are more or less uniformly distributed in the Okha-Sikka-Mundra segment and their concentrations indicate healthy natural waters. As expected for an unpolluted coastal environment, the concentrations of PHc and phenols are low.

The concentrations of heavy metals such as chromium, manganese, cobalt, nickel, copper, zinc, mercury and lead though variable, indicate natural background levels and there is no evidence of gross sediment contamination. The concentrations of PHc are also low though large quantities of petroleum crude and its products are off-loaded at Vadinar and Kandla respectively.

The Gulf abounds in marine wealth and is considered as one of the biologically richest marine habitat along the west coast of India. The marine flora is highly varied, which includes sand dune vegetation, mangroves, seagrasses, macrophytes and phytoplankton. The Gulf has a vast intertidal area with rich biota. Sheltered bays, creeks and mud flats provide ideal sites for mangrove vegetation over an estimated area of about 1036 $km^2$.

The marine fauna of the Gulf is rich, both in variety and abundance. One of the most interesting biotic features of the Gulf is the presence of living corals, thriving as patches, rather than reefs, either on the intertidal sand stones or on the surface of wave-cut, eroded shallow banks along the southern shore of the Gulf. The Gulf has a variety of exploitable species of finfishes and shellfishes. Fishing grounds for Ghol, Karkara, Khaga, Dhoma, Magra and Musi exist in the Gulf. The Gulf region offers plenty of facilities for feeding, breeding and shelter to a variety of birds.

Because of its high biogeographical importance and rich flora and fauna, several areas along the southern Gulf are notified under the Marine National Park (16289 ha) and the Marine Sanctuary (45798 ha).

## 8.3 Site specific marine environment

The assessment domain of the present study involved the section of the Gulf off Tunda-Vandh. The area proposed for the development of power plant of CGPL falls between two ephemeral rivulets namely Khari Nadi in the west and Wae a contributory of Nagavati river in the east. There are two moderate size villages Tunda (in the east) and Vandh (in the west) in the vicinity of the project site. The prominent vegetation in the area is mainly composed of Babool (*Presopsis julifolia*) and stray mangroves. Local fishing community uses the navigable creeks for their country crafts during high tide and use sandy beaches around for beaching their shallow draft crafts.

The time of occurrence of flood and ebb tide at Mundra lead by 27 and 46 min respectively with respect to the Kandla tide. The tidal range ratio (Mundra : Kandla) is 0.83 and 0.88 for spring and neap tides respectively. The tidal range in the Kotdi Creek varied from 1 to 3.5 m with the time lag of 5 to 10 min as compared to the phase of the tide at the Mundra Port. The tide off Tunda-Vandh is comparable in amplitude to that of Mundra.

The maximum current speed observed off the Kotdi Creek is 0.8 m/s. The U component of the currents (Northward) is stronger than the V component indicating weak lateral transport, as expected. The maximum current speed varies from 0.5 to 1.2 m/s in the Gulf off the project site. The predominant direction of the current is $45^o$ during flood and $220^o$ during ebb tide conditions. The circulation off the project site is generally elliptical with the major axis in the east-west direction. The excursion lengths vary in 10 to 15 km range depending on the tidal phase (neap or spring).

The water quality in the nearshore water off Tunda-Vandh was assessed during December 2008.

The water temperature varied in the range of 19 – 30.1 $^{o}C$ in the study area. Under the influence of buffering action of $CO_3^{2-}/HCO_3^{-}/CO_2$ system the pH of water was fairly constant (av 8.0). The SS was variable; the maximum value recorded being 252 mg/l. In the absence of freshwater inflow the salinity (ppt) in the waters off Vandh was markedly high (35.9 to 38.0 ppt). Surface to bottom variations were minor and the waters are well-mixed vertically. The DO varied from 2.9 to 5.4 ml/l and was generally >3.0 ml/l suggesting good ecological conditions. The nutrients such as phosphate, nitrate, nitrite and ammonia as well as PHc and phenol are low and in the range expected for the Gulf. The overall assessment indicates that the water quality off Vandh has not measurably altered over the years.

The surface 1.5 m layer of the intertidal segment typically contains around 90% sand with silt and clay in minor proportions. The concentrations of chromium, cobalt, nickel, copper, zinc, mercury, organic carbon, phosphorus and PHc were in the expected ranges for the Gulf indicating uncontaminated nature of the sediment.

The marine alga *Enteromorpha* sp commonly occured in the intertidal area off the project site while seagrasses were dominated by *Halophila ovata* and *Halodule uninervis*. The major land portion proposed for the development falls under saline bank which was devoid of mangrove vegetation. No dunes or dune vegetation occur around the proposed discharge channels.

The levels of chlorophyll *a* and phaeophytin varied in wide range in the coastal ecosystem off Vandh. The generic diversity of phytoplankton varied from 13 to 19 in the area. Overall, about 31 genera of phytoplankton are recorded with the dominance of *Fragilaria, Thalassiosira, Thalassionema, Pleurosigma, Navicula, Nitzschia, Peridinium, Melosira* and *Thalassiothrix*. The zooplankton standing stock in terms of biomass and population reveals good secondary production in the coastal waters. The zooplankton community structure reveals the dominance of copepods and decapod larvae. The other common groups are foraminiferans, siphonophores, medusae, ctenophores, chaetognaths, polychaetes, ostracods, mysids, *Lucifer*, gastropods, lamellibranches and appendicularian. The intertidal macrobenthic standing stock in terms of population (av 3504/$m^2$) and biomass (av 7.7 g/$m^2$ wet wt) varied widely. Total faunal groups are comparable both in creeks and Gulf segment. The average standing stock of subtidal macrobenthos at the study area both in terms of biomass (av 0.7 g/$m^2$; wet wt) and population (315/$m^2$) is low.

During experimental fishing in April 2007 off the project site the fish catch rate varied between 5.0 and 14.5 kg/h. This catch consisted of 27 species of fishes, 9 species of prawns and 5 species of other miscellaneous groups. *Harpadon nehereus, Johnius glaucus, Coilia dussumieri, Arius caelatus, Otolithes* sp, *Pampus argentius, Scoliodon laticaudus, Thryssa* sp, *Otolithus* sp, *Exhippolysmata ensirostris*, *Neptunus pelagicus* and *Metapenaeus* sp were recorded as the dominant species. The Vandh region does not sustain reef building corals as the intertidal area is largely sandy or muddy. Coral growth in the subtidal region is also unlikely in view of the high suspended load in the water column, the conditions under which corals do not thrive. The saltpans, islands and intertidal coastal system with mangroves off Vandh offer plenty of facilities for feeding, breeding and shelter to a variety of birds. In the Gulf, the reptiles are mainly represented by marine turtles *Chelonia mydas* and *Lepidochelys olivacea.* No turtle however was sighted off Mundra during the study period. The mammals are chiefly represented by dolphin (*Dolphinus delphis*), whale (*Balanoptera* spp) and Dugong (*Dugong dugon*) in the Gulf especially along the Jamnagar coast. These were not sighted during the study period off Vandh.

## 8.4 Effluent release

The total 4000 MW power project envisages water drawl of about 6.30 x $10^5$ $m^3$/h out of which 6.28 x $10^5$ $m^3$/h will be discharged back to the sea from the condensers of the power plant. The intake channel, that is developed at the site towards east to the proposed plant location, will be used for the cooling water requirement. The channel is nearly 6 km away from the proposed outfall channel. The effluent temperature would be 7$^o$C above ambient. The salinity would have a small increase of 0.1 ppt. The thermal effluent should be sufficiently diluted before it reaches intake during ebb tide conditions to avoid recirculation.

HR Wallingford was assigned with the modeling work for this purpose. A 2D model was used to estimate the plume movement in the vicinity of the release location. Model bathymetry was selected basing on the bathymetry survey conducted in April 2008. The eastern and western boundary conditions (water levels) were taken from the regional model of Gulf of Kachchh.

From the model results it is found that near ambient conditions would attained at the distance of 3 km from the outfall channel alignment. The time series of the modeled temperature indicate that the excess temperature of the seawater in the intake channel would vary between $0.2^{o}$ to $1.4^{o}$ C. Analysis of time series of the modeled temperature by HRW indicate that the average excess temperature of the sea water in the intake channel under spring –neap cycle calm conditions would be around $0.4^{o}$C.

## 8.5 Potential marine environmental impacts

Major potential negative marine environmental impacts due to the proposed activities would be largely associated with the (a) construction of the effluent channel and the coal conveyer belt, (b) deterioration in ecological conditions due to effluent release and operational activities of the proposed coal conveyer belt. Evidently, potential negative impacts on the coastal ecology can arise during the construction as well as the operational phases of the proposed project.

### Construction phase of the effluent channel

Adverse impacts of the proposed project on the Gulf environment during construction phase would be due to (a) modifications in the hydrodynamic characteristics of the area, (b) degradation in water and sediment qualities, and (c) loss of biota.

Excavations in the intertidal and subtidal areas for making a channel has high potential to disperse the bed sediment into the water column thereby increasing the SS in water and degrading the water quality locally. The subtidal and lower intertidal areas off Tunda-Vandh are composed of sediment with a fair percentage of sand. Hence these patches may not particularly generate fine SS when disturbed. Moreover, SS in the Gulf is inherently high and variable rendering the water turbid and muddy. The local increase in SS would be confined only to the construction phase and the baseline conditions would be re-established when the construction activity is terminated. The dredging to excavate the channel would generate substantial quantities of dredge spoil which will have to be adequately disposed and not used in non-saline environments.

Misuses of the intertidal area by workforce employed during construction phase can locally degrade the intertidal sediment by increasing BOD and populations of pathogens. The impact however would be minor and temporary and recovery would be quick when the source of this contamination is eliminated at the end of the construction phase.

Hectic construction activities in the intertidal and subtidal areas would influence the local biotic communities, particularly the macrobenthos along the corridors selected for seawater intake as well as release of effluent. As the sediment is not enriched in $C_{org}$, its suspension in the water column is unlikely to deplete DO in this dynamic marine area and DO availability would not be a constraint for the biotic processes. The danger of biota getting exposed to pollutants released from sediment porewater, when the bed is disturbed, is minimal since the sediment off Vandh is free from anthropogenic contaminants.

An increase in turbidity due to enhanced levels of SS can negatively influence the photosynthesis and hence the primary productivity. However, the impact if any would be local, temporary and reversible with the phytoplankton community structure quickly reestablishing once the construction is completed. A temporary and minor reduction in phytoplankton standing stock, if at all, and increase in turbidity is unlikely to produce any negative impact on zooplankton though a localised and marginal change in the community structure and population alternations may occur confined to the project area. Such changes are temporary and irrelevant to the overall secondary productivity of the region.

Excavation for making the channel would have significant negative impact on benthic habitats which would be destroyed along the selected corridors. A total loss of 2842 kg of macrobenthic biomass is estimated from the dredging of the effluent channel. This loss would be temporary and the benthos would recolonise in due course after the construction activities are terminated.

Aesthetics of the area would deteriorate due to the presence of construction machinery and materials, make-shift huts for labour force, cabins etc. Left over solid waste generated during construction would be a source of nuisance if not cleared from the site. The extent of impact on the marine ecology would also depend on the duration of the construction phase. If the construction is prolonged due to time - overruns or improper planning, the adverse influence would increase accordingly. Since there are no commercial fishing operations off Tunda-Vandh except shore based local fishing, the impact on fisheries would be minor and non-consequential.

**Operational phase of the effluent channel**

Marine environmental implications during the operational phase of the project would be essentially confined to the adverse influence of release of effluent on the water quality, sediment quality and flora and fauna of the Gulf.

The temperature in a limited area comprising the discharge channel and its immediate vicinity is predicted to be 4-5$^{o}$C above ambient. This increase may not be lethal to the organisms but proliferation of resistive organisms may change the community structure of the localized zone. The intertidal area however experiences such temperatures and salinities even in the normal course.

Some fraction of contaminants such as heavy metals, PHc, phenols etc if present in the effluent would be adsorbed onto the SS which is abundantly available in the proposed area of release thereby enriching the bed sediment on settling. However, due to high tidal dispersal and efficient advection by strong currents, this SS would be scattered over a large area. Hence an increase in the concentration of contaminants in the marine sediment to levels that cause harm to biota is unlikely.

The quantity of material excavated in making the outfall channel would be of the order of 2.0 million $m^3$. This quantity will be disposed off as per the plan suggested by Mundra Port. No siltation is expected in the effluent discharge channel.

**Construction phase of the coal conveyer belt**

The major source of air pollution during the construction period will be the emissions from stationary sources like generator sets during emergency service only, and air borne dust emissions from cutting and filling of soil and vehicular movements. Dust suppression by spraying of water will reduce these impacts considerably. The impact due to additional vehicles plying during the construction period is of temporary nature and their impact on air quality will not be significant.

Major sources of the noise pollution due to construction activity will be from the earth moving, levelling and compacting, trucks for transportation of construction materials, concrete mixers, asphalt mixing and laying equipment which all add to the general noise level. The noise generated from all construction activities will be restricted to daytime working hours. Noise impact during construction will be temporary in nature. The noise level will drop down to the acceptable level, once construction period will be over.

During construction, the runoff from the construction site will be a source of water pollution. The other source of water pollution is expected from the sanitary waste coming from the temporary accommodation of the construction workers if envisaged. However, most of the construction workers will be made available from the near by villages and no separate migration of workers is envisaged for this project. However, on site during working hours additional sanitation will be handled by septic tank/pit if required, the arrangement will be made available during the construction phase of the project.

**Operational phase of the coal conveyer belt**

Conveyer belt will be used for conveying coal from Mundra jetty up to stock yard at CGPL and will be operated on electromechanical system, hence no impact is envisaged during operation phase of the project.

## 8.6 Mitigation measures and EMP

The segment of Gulf off Vandh proposed for the setting-up of effluent release facilities is a typical nearshore marine zone of the Kachchh District. No endangered or rare species was encountered during field studies or reported in these creeks. Further, fragile and sensitive habitats such as mangroves are absent in the immediate vicinity of the proposed development site. Hence, conventional methods recommended for marine areas can be employed for setting-up the effluent release facilities and the coal conveyer belt with standard mitigation measures to minimise the adverse impacts on marine ecology.

**Construction phase of the effluent channel**

Except for the temporary destruction of macrobenthos along the corridors selected for discharge channels the impact on the marine ecology during construction phase would be largely confined to the duration over which the activities are spread. Hence, the key factor in minimising adverse impacts would be reduction in the construction period at the site and avoidance of spillage of activities beyond the specified geographical area which should be kept to a minimum. There is a distinct advantage of reduction in time of marine construction operations.

Work force employed during construction often misuses the intertidal and supratidal areas. This should be avoided by establishing the temporary colonies of workers sufficiently away from the HTL and proper sanitation should be provided to them to prevent abuse of the intertidal region. The noise level during transport and construction of marine facilities should be kept to a minimum.

The intertidal and nearshore subtidal areas should be restored to their original contours once the construction activities are completed. General clean-up along the corridor areas should be undertaken and discarded materials including excavated soil should be removed from the site and the aesthetic quality of surroundings restored on completion of the construction phase.

The excavation of the channel will produce substantial amounts of dredge spoil. This spoil should not be dumped in the intertidal area and a suitable strategy must be decided for disposal of the material.

**Operational phase of effluent channel**

The Gulf segment off Tunda-Vandh represents an unpolluted marine environment, which should be maintained in future also. Hence, it should be ensured that the effluent released into the Gulf meets the prescribed GPCB criteria at all times.

It is predicted that the effluent would attain near ambient temperatures and salinities within 3-4 km when released through a channel based on the model predictions. Such calculations are based on average environmental conditions and a few assumptions which cannot be easily verified. Hence, the actual dilution attained should be measured through tracer studies after the outfall becomes operational. The effluent release process can then be adequately modified to ascertain necessary dilution. Analysis of time series of the modeled temperature by HRW indicate that the average excess temperature of the seawater in the intake channel under spring-neap cycle calm conditions would be around 0.4°C. The surrounding segment of Gulf is not an important navigational route though local craft and fishing vessels operate in the region. Hence, as a navigational safeguard, the seawater effluent release location should be adequately identified with marker buoys. Use of biocides should be kept at the minimum and their concentration at the outlet should be regularly tested.

**Construction phase of coal belt conveyer**

Engineering practices such as proper disposal of construction wastes, adequate erosion control plans, noise control measures, spraying of dust suppressants, STP, afforestation program and usage of high quality equipments for construction are recommended to minimise construction phase environmental impacts.

**Operational phase of coal belt conveyer**

All the equipments and conveyers shall be designed for handling coal of (-) 50mm to avoid dust pollution. Self aligning carrying and return idlers shall be provided at an interval of 24m to avoid unnecessary spillage of coal from belt conveyer. All conveyers shall be provided with open galleries with hood covering the belt to avoid dust nuisance. Wind guard shall be provided to avoid flapping/lifting of the belt. Inspection and maintenance doors/poking holes at suitable location shall be provided for all chutes. Platform with ladder shall be provided to facilitate poking so that jamming and thus material spillage can be avoided.

An environmental monitoring programme is already in place to provide scientifically defensible information for determining status of the environmental quality of the surrounding area and to check whether the levels of critical pollutants are within the environmentally acceptable limits. The environmental monitoring programme includes ambient air quality monitoring, meteorologically data collection, water quality monitoring, soil testing and seawater monitoring.

A comprehensive marine quality monitoring programme with periodic investigations at predetermined locations must be undertaken. The results of each monitoring should be carefully evaluated to identify changes if any, beyond the natural variability identified through the baseline studies. Gross deviation from the baseline may require a thorough review of the effluent disposal scheme to identify the causative factors leading to these deviations and accordingly, corrective measures to reverse the trend would be necessary.

The change in location of discharge point is expected to have no significant impact during the operational phase of the power plant on the surrounding marine environment with the implementation of the proposed EMP.